The Mechanical and Physical Properties of the British Standard En Steels

(B.S. 970-1955)

Volume 2

En 21 to En 39

COMPILED BY

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STEEL USER SECTION
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FOREWORD

The main object of these three volumes is to have available in one source of reference data on the most commonly used range of steels in the United Kingdom — B.S.970 En Steels. Some of the information has been published previously, some properties have been determined but not published, whilst the remaining data had not, until this work started, been investigated.

These volumes have been compiled by the Steel User Section of the British Iron and Steel Research Association which has financed the project jointly with the Department of Scientific and Industrial Research, to satisfy the many enquiries received from industry on the properties of steels and equivalent foreign specifications which could only be answered by access to the wide variety of sources in which this information was previously contained.

Today's exacting engineering designs, however, create a new demand for more detailed technical data and information in addition to mechanical properties which, in the main, are not readily available.

At all stages industry has been consulted and an advisory panel was formed to guide the work. All steelmakers consulted during the preparation have welcomed the opportunity of providing such a wealth of information, and in doing so I believe have made a very valuable contribution towards the more efficient use of steel.

E. W. SENIOR, C.M.G. J.P.
Director of the
British Iron and Steel Federation

INTRODUCTION

It is very necessary that engineers, designers, and all users of steel should have access to adequate information relating to the mechanical and physical properties of various steels, in order that they may ascertain the most suitable steel to use for a particular purpose. Hitherto the required data have not always been readily available, and in many cases extensive searching, and even special investigations, have been necessary in order to obtain it. A reference book which would provide this information in relation to all available steels is, therefore, very desirable. A start on this task has been made by the authors, in compiling data on the steels included in the En Series of British Standard 970. Volume 1 includes the most important properties of En 1 to En 20 inclusive and the present volume and volume 3 are concerned with En 21 to En 39 and En 40 to En 363 respectively.

In carrying out their task the authors have collected information from a wide variety of sources, including published literature, works brochures, and test records, both published and unpublished, from many research laboratories. In addition, several laboratories have carried out special tests to obtain properties not previously determined, and various government-sponsored organisations have granted permission to extract data from hitherto unpublished reports. A list of references to sources is given at the end of each section.

Special attention has been given to showing the nearest foreign specifications for each steel, and the most recently recognised International Standard Symbols have been used for each property in addition to the British designation.

It is recommended that all users of these volumes should read the "Notes on the Use of Tables" which follow the Introduction. These notes not only indicate the care needed when making use of the data provided, but also give some useful hints for estimation of certain properties when data is lacking.

It must be emphasized that whilst the source of all data is indicated, the properties shown should not be used to compare steels from different suppliers. The information has been taken from a vast amount of data collected by the respective steel suppliers and the values quoted might be influenced not only by the manufacturing process and the deoxidation technique used but also by such factors as whether or not the material is treated in bulk, the degree of agitation in the quenching bath and the amount of oxide on the surface. Similarly, individual values should not be used for specification purposes since they do not necessarily indicate what can readily be obtained in all cases from materials which come within a particular composition specification.

Whilst every care has been taken to ensure that the information is correct, the Steel User Section of the Association would welcome information relating to any errors or omissions.

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NOTES ON THE USE OF THE TABLES

For easy reference, the compilation is divided into sections, each devoted to one En number, and within the sections the various items of information are arranged in the following order:-

(1) Specification
  Chemical Composition
  Mechanical Properties
(2) Related Specifications
(3) Applications
(4) Welding
(5) Machinability
(6) Hot Working and Heat Treatment Temperatures
(7) Physical Properties
  Specific Gravity
  Specific Heat
  Co-efficient of Thermal Expansion
  Electrical Resistivity
  Thermal Conductivity
  Young's Modulus, Shear Modulus and Poisson's Ratio
  Magnetic Properties
(8) Isothermal and Continuous Cooling Diagrams
(9) Hardenability
(10) Mechanical Properties at Room Temperatures
(11) Mechanical Properties at Low Temperatures
(12) Mechanical Properties at High Temperatures (including Creep Properties)
(13) Torsional Properties
(14) Fatigue Properties

Some of the En specifications are sub-divided into steels of slightly different composition which, in many cases, overlap and, on account of this and other reasons. it has been found impracticable to separate the m. Where plentiful data are available, as is the case for the mechanical properties at room temperature, the steels have accordingly been arranged in order of increasing carbon content.

Apart from the tables of data, curves have been reproduced where information warrants in order to show graphically the effects of tempering temperature and of ruling section as heat treated and also to indicate the range of properties which might be expected from steels conforming to a particular En number.

The following notes may be of interest to users of the data.

Related Specifications

A list of the specification numbers for the nearest equivalent British, American and certain European Standard specifications is included in each section. This list should not only simplify the work required in dealing with enquiries concerning such specifications but it will no doubt be of value to other than British users who are more familiar with the standard steels of their own particular country.

Applications

The general characteristics and main uses of each steel are listed. Typical applications have been obtained from various works catalogues and from information supplied by a number of steel users.

Weldability

Weldability depends on a number of factors such as cooling rate of the heat-affected zone, the type of electrode used in the case of metallic arc welding as well as the composition of the steel. The cooling rate depends on the amount of metal which can conduct heat away from the weld junction (called the Thermal Severity Number) and on the degree of preheat. The effect of composition may be judged by use of the carbon equivalent (CE) formula developed by the British Welding Research Association for metal arc welding.

$$C.E. = C + \frac{Mn}{20} + \frac{Ni}{15} + \frac{Cr+Mo+V}{10}$$

The higher the carbon equivalent and the higher the Thermal Severity Number (TSN) the greater is the necessity to preheat and the higher must be the pre-heating temperature. It is not possible to state the necessary pre-heating temperature in simple terms of TSN and CE since it also depends on the type of electrode used. We would however refer readers to the pamphlet "Arc-Welding Low-alloy Steels" published by the British Welding Research Association, 29, Park Crescent, London, W.1.

The welding properties tabulated for each steel have been taken from a paper published by H.M. Stationery Office to whom we are grateful for permission to extract the details given. (Ref. 1)

The meaning of the various symbols used in the tables for describing the welding characteristics is given in the list of abbreviations following the notes on the use of the tables.

Machinability

It is not possible to give any definite quantitative measurement to machinability although many efforts have been made to find a machinability constant. This is due to the fact that the response to cutting tools depends on so many factors, e.g.

The type of machining operation (turning, drilling, sawing, screwing, etc.)
The rigidity of the machine
The tool (shape and rigidity of mounting)
The cutting condition (speed, feed, depth of cut)
The material being cut

The machinability of steel is appreciably affected by its composition (especially the sulphur content or presence of other free cutting additions), by the presence of certain hard constituents (both metallic and non-metallic), by the

grain size and by the microstructure. Generally speaking, the annealed condition is best for machinability although cases are known where other microstructures give better results for certain machining operations. In the softer steels improved machinability may be obtained by giving the steel a small degree of cold work. Machinability, therefore, can only be expressed in very approximate relative terms. An attempt has been made to give some such rough relative assessment of the various En steels which it is hoped may be of some help to the machinist and production engineer. Apart from this Wickman Wimet Ltd. have carried out comparative machinability tests using carbide tools on many of the En steels and these results are included in the appendix to Vol. III.

Hot Working and Heat Treatment Temperatures

These are affected to some extent by the carbon content. A low carbon permits somewhat higher hot working annealing and hardening temperatures than a steel with carbon at the high end of the specification range. Generally speaking, however, there is a fair degree of tolerance in the ranges of temperature which may be used for these heating operations and those quoted will be found to be reasonably satisfactory for all carbon contents within the particular specification.

The temperatures quoted for hot working are, in general, conservative. In many cases higher temperatures may be used, but in order to ensure that the overheating temperature is not exceeded the upper re-heating temperature has been limited to that which may be considered safe for all steels within the specification. The use of such lower re-heating temperatures for hot working has the added advantages of reducing the amount of decarburization and the extent of the grain growth.

Carburizing Data

The tables giving the approximate times to producea given case depth are intended as a guide only. They are based on information provided by Wild Barfield Limited, (Ref.12).

The times for "solid" carburizing are based on work carried out using "Eternite" pack carburizing compound. The times for "salt" are based on the use of I. C. I. "Rapideep" salt. The values given under "gas" are based on the use of the Wild Barfield patented P. T. G. process, the Wild Barfield "Carbo-drip" liquid method, or Endogas as a carrier gas with suitable additions of hydrocarbon gas (usually propane). These carburizing processes give identical results when carburizing at the maximum rate and given a diffusion period to arrive in every example at eutectoid composition at the surface.

Physical Properties

Specific Gravity (d)

The specific gravity of a steel is only slightly affected by composition and heat-treatment. Values have been quoted only for a temperature of 20°C, but if it is desired to know the specific gravity d_T at any other temperature T(°C) this may easily be calculated from the formula

$$d_T = d_{20}[1—3\alpha\ (T—20)]$$

where α is the mean linear coefficient of thermal expansion between 20°C and T°C.

The specific gravity at room temperature of pure iron is close to 7·880. The specific gravity of steels is affected by the state of the carbon. In the case of fully annealed steels the specific gravity is diminished by 0·026 for each 1% of carbon up to 1·6%. In a fully quenched steel (with no free carbide or austenite) the decrease is 0·122 for each 1% of carbon up to 1·2%. The following table shows the approximate effect of 1% by weight of various alloying elements.

Alloying Element		*Effect on S.G. of 1% of element*
Silicon	(up to 3%)	−0·061
Manganese	(" 2%)	−0·012
Sulphur		−0·167
Phosphorus		−0·037
Nickel	(" 6%)	+0·006
Chromium	(" 4%)	−0·009
Aluminium	(" 6%)	−0·142
Molybdenum	(" 1%)	+0·020
Copper	(" 4%)	+0·006
Cobalt	(" 7%)	+0·006
Tungsten	(" 20%)	+0·065

These figures may help to indicate by how much the actual specific gravity of a steel may differ from the quoted data. With the amount of elements normally present in the low alloy steels the actual value will not differ from the quoted value by more than 0·02.

The density of steels in pounds per cubic inch is obtained by multiplying the specific gravity by 0·0361 and in pounds per cubic foot by 62·35.

Specific Heat (c)

The specific heat of low alloy steels is not very sensitive to changes in composition and heat treatment. For example, of the 16 carbon and low alloy steels tested by the N.P.L. (Ref. 2) the values of the mean specific heat between 50° and 100°C varied only between 0·114 and 0·119. Even the 13% chromium steels had a corresponding value of 0·113. The specific heats of the austenitic steels are slightly higher, namely, between 0·120 and 0·124.

The values of the mean specific heats are naturally affected by heats of transformation of changes occurring within the temperature range considered. Thus one may expect appreciable differences between the steels in the critical regions.

The values for the mean specific heat have been adjusted to a temperature range commencing at 20°C where the published data give values for ranges beginning with a different temperature.

Coefficient of Thermal Expansion (k)

The values quoted are mean coefficients of linear expansion per °C from 20°C to the stated temperature. This physical property is again not very sensitive to composition in low alloy steels provided no transformation occurs within the temperature range in question. The coefficient of expansion in the hardened condition differs only very slightly from that in the annealed condition up to 100°C, but beyond this temperature transformations occur which alter the properties of the steel and cause contraction of the material with consequent reduction of the mean coefficient of expansion.

Electrical Resistivity (ϱ)

At room temperatures the electrical resistivity is very tensitive to composition and structure especially as regards she state of the carbon. At temperatures above about 800°C this sensitivity is much reduced. The resistivity of pure iron at 20°C is close to 9·8 microhm-cm, whilst in fully annealed pure iron-carbon alloys carbon appears to raise this value by 3·5 for each 1% of carbon. In commercially annealed steels however, the effect of carbon appears to be somewhat greater than this, namely 4·2 for each 1% of carbon. Radcliffe and Rollason (Ref. 3) give the following formula for annealed pure iron-carbon alloys at room temperature:-

Log $\varrho = 0{\cdot}90\,C_m + 0{\cdot}996$ where C_m = percentage of Fe_3C by volume. Their results agree very closely, up to 1·3 per cent of carbon, with the formula

$\varrho = 9{\cdot}94 + 3{\cdot}73C$ (where C = per cent of carbon by weight). This corresponds to a value of 9·94 for pure iron, a value which they considered rather high due possibly to a retention of 0·005% of carbon in solid solution. It could, however, be due to the combined effect of the small amounts of impurities in the iron. Thus only 0·001% of silicon could account for a rise in the resistivity of 0·013.

In hardened steels, carbon increases the resistivity appreciably more than in annealed steels. The amount of increase is not linear, the following being the resistivities at room temperature of pure iron-carbon alloys in the fully quenched condition:-

Carbon %	0	0·2	0·4	0·6	0·8	1·0	1·2	1·4
Resistivity, microhm cm	9·8	12·7	16·2	20·5	26·5	37·0	47·0	47·5

The influence on the electrical resistivity of the alloying elements in low alloy steels is approximately as follows:

Element	Effect on Electrical Resistivity of 1% by weight (microhm cm)	
Silicon	(up to 1·8%)	+13·6
Silicon	(1·8 to 6%)	+ 8·5
Manganese	(up to 6%)	+ 5·5
Phosphorus	(up to 1·2%)	+11·0
Nickel	(up to 5%)	+ 2·5
Chromium*	(up to 5 × carbon%)	+ 0·6
Molybdenum	(up to 3%)	+ 1·0
Titanium	(up to 5%)	+ 0·5
Aluminium	(up to 4%)	+11·0

* In hardened low alloy steel the effect of 1% of chromium is to increase the resistivity by about 5·5 microhm cm.

Thermal Conductivity (k)

Data on thermal conductivity are relatively scarce due, no doubt, to the difficulty of measuring this property with a high degree of accuracy.

The thermal conductivity of steels at room temperature is sensitive to composition and heat-treatment but it is much less sensitive at temperatures above 700°C.

When assessing the influence of composition on the thermal conductivity at room temperature it seems to be better to deal with the reciprocal of this property, namely with the thermal resistivity (λ), which tends to give more of a straight line relationship.

The thermal conductivity of pure iron at 20°C appears from the best results to be close to 0·175 cal/cm s deg C giving a value of the thermal resistivity of 5·72.

Information concerning the influence of composition is very scarce but we have examined what data are available and have derived the following formula:-

$$\lambda = \frac{1}{k} = 5{\cdot}80 + 1{\cdot}6C + 4{\cdot}1Si + 1{\cdot}4Mn + 5{\cdot}0P + 1{\cdot}0Ni + 0{\cdot}6Cr + 0{\cdot}6Mo$$

where λ = Thermal Resistivity at 0°C and k = Thermal Conductivity at 0°C; C, Si, Mn etc. = per cent by weight of carbon, silicon, manganese etc. This formula has been checked against the 18 low alloy steels for which thermal conductivity data have been determined by the National Physical Laboratory (Ref. 2). The values calculated for the low alloy steels agree with the determined values to within 5% for all the steels and to within 3% for 14 out of the 18 steels. The formula gives 5·8 for the thermal resistivity of pure iron (5·72) and the difference may be accounted for by the presence of trace impurities not allowed for in the formula.

The above formula does not apply to steels in the austenitic condition since the effect of carbon in solution is probably different from that in the form of cementite, and it is doubtful whether the coefficients of the formula can be applied to the large quantities of the alloying elements present in the austenitic steels. It is also probable that the thermal resistivity of face centred iron is different from that of body centred iron.

In view of the difficulty of obtaining accurate data for the thermal conductivities of steels, it may be useful to indicate two methods for obtaining reasonably reliable values where no data exist, especially for the values at elevated temperatures. The first of these methods can be used where the thermal conductivity at or near room temperature is known or can be reasonably estimated by the use of the above formula, and depends on the fact that the thermal conductivity of all steels tends to a constant value of about 0·065 at temperatures of the order of 800°C. The N.P.L. data mentioned previously give the thermal conductivity of 22 steels of a wide variety of composition. If, for any steel, the variation of thermal conductivity with temperature is required, the curve can be drawn with a reasonable degree of certainty, provided the value at or near room temperature is known or can be estimated, by reference to the curve for a similar steel drawn from the N.P.L. data.

The second method makes use of the Lorenz function $L = \frac{\varrho k}{T}$ (T = absolute temperature = 273 + °C) and applies in the case where the electrical resistivity is known for a range of temperatures. Where ϱ is measured in microhm-cm and k in Cal/cm s deg. C, L is of the order of 6 to 11×10^{-3}. Theoretically the Lorenz function would be expected to be constant for all steels at all temperatures, but for the 22 steels listed by the N.P.L. the value varies between 6·8 and $11{\cdot}5 \times 10^{-3}$ at room temperature and between 6·1 and $7{\cdot}3 \times 10^{-3}$ at 800°C. The value of the Lorenz function can be deduced without a great deal of error from the known values of steels of near composition and treatment, and from the curve giving the variation of electrical resistivity with temperature, the thermal conductivities at different

temperatures can be readily calculated, using this assumed value for L. Values for the electrical resistivity, thermal conductivity and Lorenz function for the 22 steels covered by the N.P.L. report are given in Appendix I.

Young's Modulus (E), *Shear Modulus* (G) *and Poisson's Ratio* (σ)

Young's Modulus (or Modulus in Tension) and Shear Modulus (or Modulus in Torsion) are readily determined by use of extensometers and torsionmeters respectively, but accurate values are not obtained unless very great care is taken and those obtained in normal routine testing are frequently in error by $\pm 5\%$. More accurate values appear to be obtained by vibration or pulse methods but the adiabatic values so obtained are not necessarily identical with the static values obtained with extensometers or torsionmeters on specimens under load. We have, therefore, indicated the method used for the determination where such information is known.

Most values quoted in the literature for Poisson's Ratio (σ) have been derived from separate determinations of E and G by use of the relationship $\sigma = \frac{E}{2G} - 1$. The values so derived are subject to considerable errors, since slight errors in either E or G are magnified in the subsequent estimation of σ. Thus the values of E and G of plain carbon steel are of the order of 13,500 and 5,250 tons/sq.in. respectively, giving a value of $\sigma = 0{\cdot}285$. If E were measured 2% high and G 2% low the calculated value of σ would be 0·335, giving an error of 17%. The values of σ determined by this method must, therefore, be regarded with considerable suspicion. Better values of σ from static tensile tests are obtained by simultaneous measurements of the lateral and longitudinal strains, the ratio of which gives σ directly. The maximum error by this method would be merely the sum of the errors in determining the two strains.

The values of the three elastic constants are not sensitive to structure or composition. Thus the values of E for the low alloy steels vary only between about 13,000 and 13,500 tons/sq.in., and of G from 5,000 to 5,300 tons/sq.in. The best estimates of σ are all between 0·27 and 0·30 with a general average of about 0·285. If E is known then G may be reasonably accurately estimated by using the value of 0·285 for σ since a small error in the latter produces only a negligible error in G. As an example for a steel having E = 13,500 tons/sq.in. then assuming σ to be 0·300 and 0·270 (i.e. errors of $\pm 5\%$) the calculated values for G are respectively 5,190 and 5,310 tons/sq.in. values which differ from the mean 5,250 by only 1.16%, which is an amount smaller than normal errors of measurement.

Jones and Nortcliffe (Ref. 4) suggest that for ferritic steels the ratio $\frac{E_t}{E_{20}}$ is a constant (f) at any elevated temperature. Values for f at various temperatures are:

Temperature	20°C	200°C	400°C	600°C
f	1·000	0·948	0·875	0·775

The same authors also show that steels in the hardened condition have slightly lower values of E than in the softened condition as illustrated by the following values on a sample of En 31.

Treatment °C	*Hardness* (H.V.)	*Young's Modulus* tons/sq.in. (*Vibration Method*)
O.Q. 830°C	880	13,100
" " T.400°C	600	13,600
" " T.720°C	260	13,800

Magnetic Properties

The magnetic properties of steels are highly sensitive to changes of composition and structure. This applies particularly to the permeability in low magnetic fields and to the coercivity, but not so much to the value of the saturation induction which depends almost entirely on the amount of magnetic phase present. Unfortunately, the amount of information available appears to be relatively small so that it is not possible to evaluate the effect of the alloying elements, but only to give an indication of the various trends. Silicon and aluminium and possibly nickel tend to improve the permeability in low magnetic fields and to reduce the coercivity. Carbon and chromium on the other hand reduce the permeability in low fields and increase the coercivity. The coercivity of any steel reaches its highest value when the steel is in the hardened condition and has the lowest value in the fully annealed condition.

Transformation Characteristics

Isothermal and continuous cooling diagrams have been included for each steel for which they are available. Continuous cooling diagrams may be drawn on either a time basis or a bar diameter basis, each having its own sphere of usefulness, a diagram with a time basis when considering controlled heat-treatments, e.g. for large forgings and the other for estimating the effect of different quenching rates on bars of varying diameters. Both types of diagram must be used with caution, however, since they are influenced by many factors such as melting procedure, deoxidation treatment and composition.

In some of the continuous cooling diagrams, namely those published by l'Institut de Recherches de la Sidérurgie (IRSID), lines are superimposed showing the different cooling cycles adopted to establish the different zones produced by the transformations which occurred. On each of these cooling curves is indicated the percentage of transformation of the austenite which has occurred during each transformation zone. The amount of transformation does not always add up to 100% and the deficiency gives the amount of austenite available for transformation to martensite. These curves also give the hardness at room temperature resulting from each particular cooling procedure adopted.

In these diagrams we have included, where possible, the temperatures for the AC_1 and AC_3 transformations as well as for the temperatures corresponding to the start of martensite formation on cooling (M_s) and the completion of the transformation (M_f) as well as temperatures corresponding to the formation of a stated percentage of the transformation product (M_{10}, M_{50}, M_{90}). All these transformation temperatures are affected by composition. Some of the diagrams give Ae_3 and Ae_1 instead of Ac_3 and Ac_1. The former are temperatures corresponding to true equilibrium conditions. Many attempts have been made to find formulae for calculating the transformation temperatures,

but whilst the formulae agree tolerably well with the data from which they were derived, they do not agree so well with other published data. In an attempt to find a formula more universally applicable Dr. K.W. Andrews (Ref. 5) has examined data from British and foreign sources on some 150 steels. These have been dealt with statistically using the electronic computer at the United Steel Companies Ltd. and he has put forward the following formula for calculating the Ac_3 temperature:-

$Ac_3(°C) = 910 - 203\sqrt{C} - 15{\cdot}2\,Ni + 44{\cdot}7\,Si + 104\,V + 31{\cdot}5\,Mo + 13{\cdot}1\,W$ where the composition is quoted in weight per cent of the alloying element.

Other elements were discarded by the computer, as their variations were not such as to give a significant correlation and when an attempt was made to bring them into the formula by giving values for the elements, e.g. (−30Mn −110Cr−20Cu+700P+400Al+120As+400Ti), values which were derived from Dr. Andrews' previous estimates for the effect of such elements on the true equilibrium temperature (Ae_3), the calculated results were not, in general, so good as when these elements were neglected. The above formula was based on steels containing up to 0·6% C and less than 5% of other alloying elements. The formula gave calculated values which agreed with the observed values to within ±17°C in 67% of the steels and to within ±33°C in 95% of the steels. The greatest errors occurred in steel with the higher alloy contents but the differences were not systematic. It is possible that some of the errors were due to errors of determination of the observed temperature and possibly to the effect of interaction between the various elements. It was considered that further analysis at this stage would not lead to much improvement.

Dr. Andrews has made a similar analysis for estimating the Ac_1 and M_s temperatures and has given the following relationships:- $Ac_1(°C) = 723 - 10{\cdot}7Mn + 29{\cdot}1Si - 16{\cdot}9\,Ni + + 16{\cdot}9Cr + 290As + 6{\cdot}38W$

$M_s(°C) = 512 - 410C - 14Mn - 18Ni.$

The latter formula for M_s might be compared with the following published formulae:-

$M_s = 538 - 361C - 39Mn - 19{\cdot}5Ni - 39Cr - 28Mo$ (Grange and Stewart) (Ref. 6)

$M_s = 561 - 474C - 33Mn - 17Ni - 17Cr - 21Mo$ (Stevens and Haynes) (Ref. 7)

$M_s = 500 - 317C - 33Mn - 17Ni - 28Cr - 11Si - 11Mo$ (Payson and Savage) (Ref. 8)

See Addendum on page xviii.

Formulae for calculating the temperatures for varying degrees of transformation have been proposed by Grange and Stewart and by Stevens and Haynes. These merely alter the constant in their formula for M_s as follows:-

	M_s	M_{10}	M_{50}	M_{90}	M_{99}	M_f	
Constant Term (°C)	538	513	488	452	416	—	(Ref. 6)
" "	561	551	514	458	—	346	(Ref. 7)

In the discussion of Grange and Stewart's paper, Jaffe proposed a modification to the formula as follows

$M_x = 538 - b(361C + 39Mn + 19{\cdot}5\,Ni + 39Cr + 28Mo)$

where x = percentage of martensite formed

b = 1·0 for M_s, 1·084 for M_{10}, 1·18 for M_{50}, 1·29 for M_{90} and 1·45 for M_{99}.

Hardenability

Hardenability is ascertained either from the Jominy test or from quenching tests on bars of different diameters, and both types of information are included.

The relative hardenability on quenched bars was obtained from hardness determinations across a number of diameters, and curves through the average values have been drawn neglecting any peaks of hardness resulting from segregation effects.

The Jominy test provides a ready means of assessing the relative hardenability of a particular cast of steel and, therefore, is very suitable for illustrating the range of hardenabilities to be expected from steels to a particular specification. Where they are available such ranges have been given for each specification.

It is not possible to relate accurately the Jominy hardenability with that obtained from quenched bars, but to a first approximation the relationship shown in Fig 1. (Ref. 9) may be used.

Mechanical Properties

Proof Stress, Yield Strength and Tensile Strength values are given to the nearest 0·1 ton/sq. in. (these are long tons of 2240 lbs.). Conversion Tables of tons per square inch to pounds per square inch and to kilograms per square millimetre are given in Appendix IV to Volume I.

Values of percentage elongation and percentage reduction of area have been reported to the nearest $\frac{1}{2}$ unit since the usual methods of measurement rarely improve on this accuracy. Elongation values are mainly those obtained on the former British Standard Test Pieces for which the gauge length is $4\sqrt{A}$ (=3·54d) where A and d are respectively the area of cross section and the diameter of the parallel portion of the test piece. The recently published revision of BS.18 "Method for Tensile Testing of Metals", following recommendations of the International Standards Organisation, has introduced the gauge length of $5{\cdot}65\sqrt{A}$ (=5 × d) commonly employed on the Continent as that for British Standard test pieces. We have given wherever possible the elongation values corresponding to both gauge lengths. The amount of comparative data is, however, very small and existing conversion charts or curves appear to be far from accurate. The conversion from one gauge length to the other will obviously depend on the reduction of area and few conversion charts take account of this factor. From tests carried out by the National Engineering Laboratory, however, it would appear that for ferritic and martensitic steels the elongation per cent on $l = 5d$. is approximately 0·83 x Elongation on $l = 4\sqrt{A}$ and for austenitic steels the corresponding factor is 0·90. More accurate conversions can be obtained from the table we reproduce in Appendix II. This table was initially based on a paper by Kuntze (Ref. 10), and was adjusted to give the best fit for a large number of comparisons we had available. The table has been checked against the results of careful tests carried out by the National Engineering Laboratory on 52 specimens of low alloy steels of widely differing tensile properties. All the estimations of percent elongation on $l = 5{\cdot}65\sqrt{A}$ based on the table agreed within 1 unit and in 44 cases within 0·5 units with the determined values. This table cannot be used for austenitic steels. No distinction has been made between the elongation values of British and American test pieces. These rarely differ by more than 1 unit and, in any case, the values obtained on the American test piece will be lower than those obtained

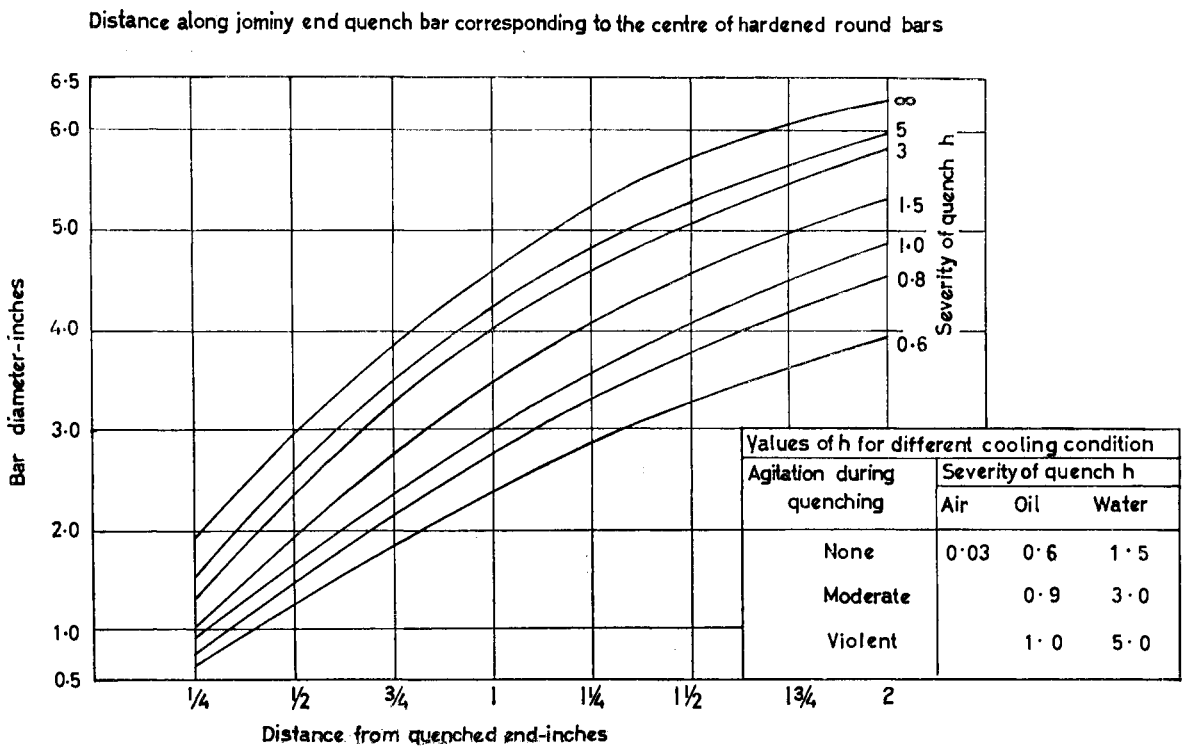


Fig 1.

on a British test piece and consequently conservative in nature so far as concerns British usage.

We have not included, except in a few cases, values of the limit of proportionality. This value is very difficult to determine with a high degree of precision and can be very much affected by the presence of internal stresses such as are produced by cold straightening operations.

Izod Impact values and Charpy type tests with an Izod V notch have been reported as foot-pounds to fracture, to the nearest unit. Unless otherwise indicated Charpy key-hole and Charpy U-notched tests (Mesnager or DVM) are reported in the manner typical of Continental practice, namely in terms of kilogram-metres per square centimetre of section behind the notch. There is no definite relationship between the various notch Impact tests. Approximate relationships are shown in the Appendix VI.

The mechanical properties of steels are affected not only by composition but also by the steelmaking process and whether grain refining additions were used. Thus within any particular specification there is, in general, a fairly wide spread of properties; we have accordingly, where possible, drawn curves showing the range of values that have been recorded for each steel. We have also included curves showing the effect of section size (the so-called mass effect) for the most frequently used hardening and tempering treatments.

Mechanical Tests at Low Temperatures and Impact Transition Temperature Data

These properties are influenced by composition and, especially in the case of notch impact value, by the presence of trace elements such as phosphorus, tin etc. and by the ferritic grain size of the material. Unfortunately for some of the data, the fullest information regarding the material is not available and such important information as steelmaking process, degree of de-oxidation or amount of aluminium added or the grain-size of the material tested cannot be stated. Such data must, therefore, be treated with extreme caution, and are only indicative of what is obtainable under certain (not necessarily stated) conditions.

Various methods have been proposed for determining the transition temperature, e.g. the temperature at which the impact value is a given percentage of the value at the lowest temperature when the fracture is 100% fibrous; the temperature at which the impact value is the average of the maximum and minimum values; the temperature for a specified impact value, or the temperature at which the fracture surface shows 50% fibrous and 50% brittle fracture. Where possible curves showing both the energy to fracture and the percentage amount of fibrous fracture have been included so that any of these methods of assessment may be determined. Where curves were not given in the original report the method of determining the transition temperature is stated.

Mechanical Properties at Elevated Temperatures

Short time tensile properties at temperatures above room temperature may be affected to a certain extent by the rate of pulling, information for which, however, is not always stated in the reports from which the data have been abstracted.

At the time of writing there is no British Standard Specification for the Short Time Tensile Test. The B.S

Specification 3082 Pt. 1 1959 has now been withdrawn and a revised version is at the moment in course of preparation. In B.S.3082 Pt. 1 the rate of testing was specified to be not greater than 2·5 tons/sq.in. min., the recommended rate for arbitration purposes being between 1·25 and 2·5 tons/sq.in. min. In the revised version* the rate of pulling will be specified in terms of strain rate which it is proposed is to be within the range 0·001 to 0·003 in./in. min. when determining the Proof Stress and Lower Yield Stress values. No limitation is envisaged on the strain rate during the major part of the elastic range but the suggestion is that it should be reduced so that the above conditions can be met before the elastic limit or yield point is reached. There are two tentative specifications issued by the American Society for Testing Materials. E21-58T recommends 0·005 or 0·05 in./in. min. up to the yield point and 0·05 to 0·10 in./in. min. beyond this point. On the other hand E151-61T specifies three rates of pulling:-

(a) Conventional 0·005 ± 0·002 in./in. min. up to 0·6% strain offset and 0·10 ± 0·002 beyond this point

(b) Rapid 0·5 ± 0·02 in./in. min. in the elastic range, and

(c) 5·0 in./in. min. in the elastic range.

The present International Standards Organisation recommended rate (I.S.O./R. 205–1961) specifies a rate not greater than 5 tons/sq.in. min. and a rate of between 1·25 and 2·5 tons/sq.in. min. for arbitration purposes. We understand, however, that this specification is also under review and that rates similar to those proposed for the revised British specification are being put forward for consideration.

We have stated the rate of loading or the speed of pulling where this information was given.

* B.S. 3688, pt. 1, 1963.

Creep and Stress Rupture Properties

Many of the En steels are not suitable for High Temperature service and for such steels there are very few data on Creep and Stress Rupture Properties. Indeed the data on steels which are used for such service are not as full as we would have liked.

In cases where creep is likely to be of importance, the usual method of obtaining the design stress limits is to plot, on a stress/temperature diagram the following:-

(a) A line representing some fraction of the tensile strength the of material at the temperature concerned.

(b) A line representing the 0·2% proof stress or 1% proof stress at temperature.

(c) A line representing the stress to cause either rupture or 1% creep strain in 100,000 hours.

Safe design stresses are considered to be those below all of these lines. There appears to be appreciable scatter (of the order of ±20%) in the stress values for times to reach specific creep strains or rupture at given temperatures for any one type of steel. Special heat treatments or fabrication may exploit the short term potentialities of the material without improving, and possibly even diminishing, the long term properties. Such treatments should be taken into account when considering the creep and rupture data quoted for any one steel.

The selection of carbon steels for high temperature service demands great care since the features which make for ease of manufacture, such as free machinability or ease of forming are those most likely to be associated with poor creep resistance.

Figure 2 shows a series of curves tentatively prepared by the National Engineering Laboratory for different steels used in steam plant.

In using creep data for a particular steel, one should take into account the characteristic shape of the creep curves for the material and the normally expected elongation at rupture. Some of the more creep resistant materials have curves with a flat secondary stage which continues for the majority of the creep test, but which accelerates rapidly into the tertiary stage to final rupture with a fairly small elongation. Such behaviour would not be satisfactory for some applications, where the normal behaviour of materials with greater creep ductility would be preferable. In these the tertiary stage is often prolonged throughout much of the test, but because of the considerable ductility, stress

TYPICAL PROPERTIES OF SOME STEELS USED IN STEAM POWER PLANT
ESTIMATED STRESS TEMPERATURE RELATIONSHIPS FOR RUPTURE IN 100,000 HOURS

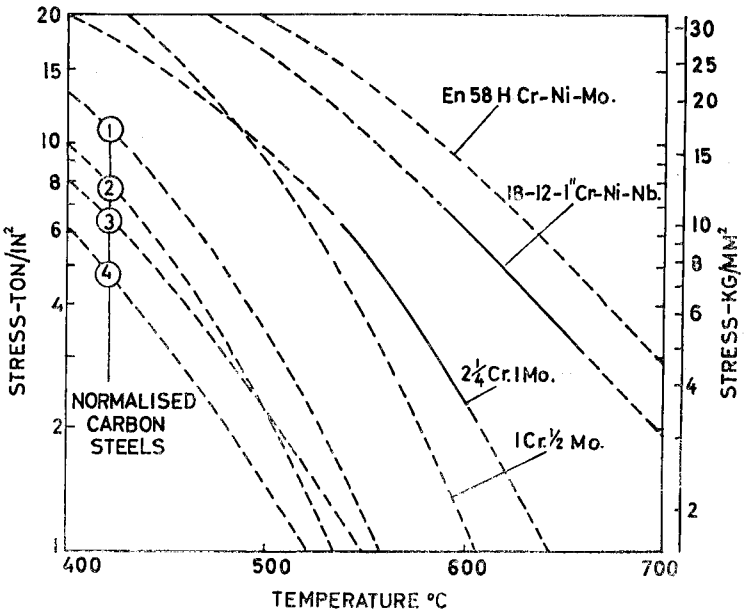


Fig 2.

(1) about 0·25% carbon steel with about 1% Manganese deoxidized by Silicon.
(2) ditto, but deoxidized by Aluminium or roughly group (1) steels subjected to prolonged stress relieving heat treatment.
(3) about 0·25% carbon steel with about 0·5% Manganese, deoxidized by Silicon.
(4) ditto, but deoxidized by Aluminium or roughly group (3) steels subjected to prolonged stress relieving heat treatment.

gradients will be reduced within the component and there is unlikely to be a sudden unexpected failure of the component.

It is strongly recommended, especially when there is any doubt in the use or interpretation of creep data, that the experience of the material manufacturer or one of the research laboratories specializing in creep testing should be invoked, so as to ensure that the design is as safe as can be achieved with the data available.

Torsion Tests

As in the case of tensile test data the strength values are reported to the nearest 0·1 tons/sq.in.

Torsional properties are usually determined on solid cylindrical specimens and may be calculated from the twisting moment in accordance with two different assumptions. According to the first of these, it is assumed that the material behaves elastically throughout the test; in other words that the shear stress at any point in the cross section of the test piece is proportional to its distance from the axis.

This gives the following formula for calculating the shear stress from the observed twisting moment.

(1) Shear Stress $= \frac{2}{\pi r^3} \times$ twisting moment (where r is the radius of the test portion)

The second method assumes that the stress is uniform from the axis to the surface of the specimen and gives the formula:-

(2) Shear Stress $= \frac{3}{2\pi r^3} \times$ twisting moment.

The formula (1) applies to all stresses up to the yield point since up to this point only a very small portion near the outer surface of the test piece suffers plastic deformation. It also applies to the maximum shear strength of materials which are very low in ductility. The formula (2) corresponds more closely to the conditions near breaking point in the case of ductile materials.

The various proof stress and yield point values have been calculated according to formula (1). As regards the torsional strength (or maximum shear strength) we have quoted the values using both these formulae. That obtained from formula (1) is sometimes called the modulus of rupture or apparent shear strength. That obtained from formula (2) is called probable shear strength for ductile materials. It will be noticed that the probable shear strength is equal to three-quarters of the apparent shear strength when testing cylindrical solid specimens.

In a few cases tests have been carried out on tubular specimens for which the above formulae do not apply. For thin walled tubes the stress can usually be considered to be uniform across the section, but we have estimated both the apparent and probable shear stress for tubular specimens used, taking into account the wall thickness and diameter in each case. The amount of data on the torsional properties of steels is comparatively small compared with that for the tensile properties. However, there appears to be a purely empirical relationship between the probable shear strength and the tensile strength of materials at or near normal atmospheric temperatures. One formula deduced by the late G. Stanfield of the Brown-Firth Research Laboratories, Sheffield, is:-

Shear Strength $= \frac{1}{2} \times$ Tensile Strength $+10$ (tons/sq. in.) This formula appears to give values within about 2 tons/sq.in. for all steels above about 25 tons/sq.in. tensile strength. A somewhat similar formula is quoted by the International Nickel Company (Mond) Ltd. in their publication "The Mechanical Properties of Nickel Alloy Steels" viz.: Shear Strength = 0·53 x Tensile Strength + 6·5 (tons/sq.in.) These two formulae agree at about 120 tons/sq.in. tensile strength whilst at a tensile strength of 25 tons/sq.in. the Brown-Firth formula indicated a shear strength of 22·5 tons/sq.in. compared with 19·7 by the International Co. (Mond) Ltd. formula. The Brown-Firth formula has the advantage of being the easier to use and to remember.

There does not appear to be such a simple relationship between the yield points in torsion and tension but the ratios of the two values appear to range themselves about a mean value of 0·58 which is the theoretical value according to the Huber-Mises-Henky criterion which deduces that the ratio should be $\frac{1}{\sqrt{3}} = 0{\cdot}577$.

Fatigue Properties

The fatigue properties of metals are usually determined on mechanically polished specimens. This method of preparation, unfortunately, not only work-hardens the surface layers but also induces compressive stresses in the surface layers, both of which tend to raise the fatigue limit of the material, and Cina has shown that the difference between the fatigue limits determined under conditions of reversed axial loading (Haigh test) and of reversed rotary bending (Wohler test) is largely removed when electrolytically polished specimens were used (Ref. 11). Since this cold work effect can be influenced appreciably by the different procedures adopted in preparing the test pieces it is clear that fatigue test data must always be treated with a good deal of caution.

Where possible we have included data on both notched and unnotched test pieces, but values for the former have only been given when either the theoretical stress concentration factor (K_t) is known, or the dimensions of the test piece and of the notch are stated from which K_t may be calculated. In all cases of notch-fatigue data we quote either the relevant details of the notch and the specimen or K_t or both.

It is, however, considered necessary to offer a word of warning concerning the possible extrapolation of these data to other cases, particularly where differences in specimen size and notch geometry are involved. Two factors may operate to render the extrapolation of data obtained on test pieces with shallow notches (such as would be used in a small rotating bending fatigue test) an unsafe procedure by which to assess the fatigue strength of a component with a deeper notch, even where different notches have the same K_t value. The first is that, for a certain notch-geometry, unbroken test pieces in a notched specimen fatigue determination may contain non-propagating cracks and their presence or absence will not, in general, have been established. The notched fatigue strength, estimated from the S – N curve using complete fracture as the criterion of failure, will, therefore, depend on the stress required to propagate a crack through the material rather than on the stress needed to initiate a fatigue crack. Recent researches have shown that the alternating stress required to propagate such cracks depends on the depth of the notch. For a given

material, non-propagating cracks are more likely to occur in shallow than in deep notches having the same K_t value, and extrapolation from the case of the shallower notch would tend to be optimistic.

The second feature which can influence such extrapolations is the unknown difference in residual surface stresses in the roots of notches of different geometry and formed by different machining processes.

The practice of deriving a "notch-sensitivity" index for a material from a series of notched fatigue test pieces, and using the index directly to deduce the probable fatigue strength of a differently notched component may, therefore, lead to serious errors.

We are indebted to Mr.D.J. Armstrong and Mr. A.J. Fenner of the National Engineering Laboratory for assistance in preparing the notes on High Temperature properties and notched fatigue tests.

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ADDENDUM

Since the publication of Volume 1 work by Dr. Andrews based on an examination of 184 steels has led him to a change in the formula given on page xiv for calculation of M_s, i.e.

$$M_s = 539—423C—30{\cdot}4\ Mn—17{\cdot}7Ni—12{\cdot}1Cr—7{\cdot}5Mo$$

A formula has also been derived to include product terms for the interaction of carbon and chromium and carbon and iron:—

$$M_s = 512—453C—16{\cdot}9Ni+15Cr—9{\cdot}5Mo—71{\cdot}4CxMn—67{\cdot}6CxCr+217(C)^2$$

This formula is most satisfactory when the chromium content lies between 2·0% and 5·0%

ERRATA (VOL. 1)

page 43, *line* 1 (0·08%C) reference number should read 8 not 7
page 80, *line* 1 0 in table should read B.O.H.
page 145, 147 page heading should read "55" Carbon Steel
page 232, *line* 17, Heat Treatment in table should read OQ880 2 hr T400 AC
page 235, *line* 7 from bottom of table, Heat Treatment column, should read N900 OQ875 T600
page 273, page heading "40" should be omitted
page 282, *Fig.* 16.5 Manganese content should read 1·48%. Sulphur content should read 0·028

LIST OF ABBREVIATIONS

General

AOH	Acid Open Hearth
BEA	Basic Electric Arc
Bess	Bessemer
BOH	Basic Open Hearth
C	Celsius (Centigrade)
cm	centimetre
deg,°	degree, degrees (temperature or angle)
dia., D	diameter
E	Electric
ft.	foot, feet
hex.	hexagon
hr	hour, hours
H.F.	high frequency
in.	inch, inches
mm	millimetre
RT	room temperature
sq.	square
°C	degrees Celsius (Centigrade)
μ	microns (10^{-4} cm)

Chemical Composition

Al	Aluminium
As	Arsenic
C	Carbon
Cr	Chromium
Mn	Manganese
Mo	Molybdenum
N	Nitrogen
Nb	Niobium (Columbium)
Ni	Nickel
O	Oxygen
P	Phosphorus
Pb	Lead
S	Sulphur
Se	Selenium
Si	Silicon
Ti	Titanium
V	Vanadium
W	Tungsten

Welding

B	Brazing and Bronze Welding by Gas
F	Flash and Resistance Welding
G	Gas Welding
IG	Inert Gas Welding
MA	Metal Arc Welding
S	Spot, Seam and Projection Welding
a	Readily welded; no special precautions are required provided the correct filler rod or wire is used when fusion welding.
b	Readily welded, but post-welding heat treatment is necessary to restore the mechanical properties of the parent metal.
c	May be welded, but special precautions may be required, e.g. pre-heating, post heating or both, or with metal arc welding the use of particular electrodes.
d	May be welded, but special precautions may be required, e.g. pre-heating and the use of particular electrodes. Post welding heat-treatment is necessary to restore the mechanical properties of the parent metal.
e	Advice should be sought before attempting to weld.
f	Welding is not recommended.
g	Sufficient information on the welding of this steel is not yet available.
h	Brazing and Bronze Welding satisfactory.
j	Brazing and Bronze Welding is possible but the mechanical properties of the parent metal are liable to modification.
k	Brazing and Bronze Welding are not recommended.
m	The process is not applicable to steel in this form.
x	With currently available filler rods, wires and electrodes, the strength of the weld metal may be less than that of the parent metal. (This symbol is always used with one of the above.)

Heat Treatment

A	Annealed
AC	Air Cooled
AH	Air Hardened
BC	Blank Carburized
CD	Cold Drawn
EQ	End Quenched
FC	Cooled in Furnace
N	Normalized
OH	Oil Hardened
OQ	Oil Quenched
SC	Slow Cooled
T	Tempered
WH	Water Hardened
WQ	Water Quenched

Physical Properties

B	Magnetic Induction
B_{rem}	Magnetic Remanence
(c)	Specific Heat
(d),S.G.	Specific Gravity
E	Young's Modulus
G	Shear Modulus
Cal	Gram calories
H	Magnetizing Field
H_c	Magnetic Coercive Force
k	Thermal Conductivity
α	Coefficient of Thermal Expansion
λ	Thermal Resistivity
ϱ	Electrical Resistivity
σ	Poisson's Ratio

Transformation Characteristics

A	Austenite
Ac	Transformation Temperature on Heating
Ae	Equilibrium Transformation Temperature
B	Bainite
C	Cementite
F	Ferrite
M	Martensite
M_s	Start of Austenite to Martensite Transformation
M_f	Temperature for 100% Austenite to Martensite Transformation
M_x	Temperature for x % Austenite to Martensite Transformation
P	Pearlite

Mechanical Properties

A	Area
(A)	Elongation per cent (International Symbol)
(C)	Centre of test piece
El	Elongation per cent
ft.lb.	Foot-pounds
HB	Brinell Hardness Number
HRC	Rockwell C Hardness Number
HV	Vickers Diamond Hardness Number
KgM	Kilogramme-force metres
K_t	Neuber's theoretical stress concentration factor
l	Gauge length
Long, (L)	Longitudinal Test
(M)	Midway between centre and outside of test piece
(O)	Outside position of test piece
PS	Proof Stress
r	Radius of bend in a bend test
RA	Reduction of Area per cent
(R_m)	Tensile Strength (International Symbol)
(xR_p)	Proof Stress in Tension for x per cent departure from the Proportionality line
RPM	Revolutions per min, Reversals per min
(R_s)	Yield Point in Tension (International Symbol)
t	Thickness of Bend test piece
Trans, (T)	Transverse Test
TS	Tensile Strength
YP	Yield Point
(Z)	Reduction of Area per cent (International Symbol)

3 PER CENT NICKEL STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

	C	Si	Mn	S	P	Ni	Cr
En 21	0·25—0·35	0·10—0·35	0·35—0·75	0·050max.	0·050max.	2·75—3·25	0·30max.
En 21A(1)	0·20—0·30	0·10—0·35	0·60max.	0·050max.	0·050max.	2·5—3·5	—

(1) When supplied in the form of plate and sheet (to BS1449)

MECHANICAL PROPERTIES

	Hardened and Tempered Condition	
	R	S
Limiting ruling section, in.	4	2½
Tensile strength, tons/sq.in, min.(Rm)	45	50
Yield stress[1] tons/sq.in., min.(Rs)	32	38
0.2% Proof stress[2] tons/sq. in., min. (0.2/Rp)	32	36
Elongation, %, min.(A)	22	20
Izod Impact, ft.lb., min.	40	40
Brinell Hardness[3] No. (HB).	201/255	223/277

(1) Not to be used as acceptance values except by special arrangement between the purchaser and the manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the specification.

APPLICATIONS

A 3% nickel steel capable of being heat treated to produce an excellent resistance to shock combined with a tensile strength of the order of 50 tons/sq.in. in small or medium-sized sections. The best combination of mechanical properties in medium-sized sections is obtained by water hardening and tempering. This steel has been replaced to a large extent by steels of lower nickel content but of the same tensile strength (e. g. En 16). Uses: automobile crankshafts, stub axles, steering levers, trackrods, valves, pinion shafts, propeller shafts, turbine shafts, pins, studs and bolts for general use.

WELDING

(See Introduction: List of Abbreviations for key to symbols used in this table)

	Welding process					
	MA	G	IG	S	F	B
En 21	d	cx	g	e	b	h
En 21A	d	cx	g	e	b	h

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MACHINABILITY

The machinability when heat treated to 45 to 55 tons/sq.in. is approximately 50 to 55% of that for mild steel (En 3). When heat treated to 55 to 65 tons/sq.in. the machinability is 45 to 50% of that for mild steel. In the softened condition the machinability is approximately 60% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1180°C.Finish above 850°C.
Annealing	830°C—850°C.Furnace cool.
Softening (sub-critical annealing)	600°C—650°C.Air or Furnace cool.
Normalizing	830°C—860°C.Air cool.
Hardening	830°C—860°C.Oil or water quench.
Tempering	550°C—650°C.Air or water quench.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)							Heat Treatment °C	Specific Gravity at 20 °C	Ref.
C	Si	Mn	S	P	Ni	Cr			
0·35	0·17	0·57	0·007	0·011	3·25	0·06	Hardened & Tempered	7·84	2
		(within specification)					—	7·85	3
		(" ")					Annealed	7·87	1

SPECIFIC HEAT (c)

Chemical Composition	Mean Specific Heat cal/g deg. C 20° to 100°C	Ref.
(within specification)	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition	10^6 x Mean Coefficient of Thermal Expansion per deg. C				Ref.
	20 to 100°C	20 to 300°C	20 to 500°C	20 to 700°C	
(within specification)	11	12	13	14	1
(" ")	12·0	12·8	13·5	14	3

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)						Heat Treatment	Electrical Resistivity microhm-cm											Ref.
C	Si	Mn	S	P	Ni	°C	0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·30	0·25	0·60	0·020	0·012	3·0	Softened	25·4	31·5	38·6	46·6	56·3	67·5	81·0	98·8	112·0	114·8	118·0	*

* Estimated values.

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)						Heat Treatment	Thermal Conductivity cal/cm s deg. C											Ref.
C	Si	Mn	S	P	Ni	°C	0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·30	0·25	0·60	0·020	0·012	3·0	Softened	0·089	0·092	0·093	0·091	0·088	0·082	0·077	0·068	0·060	0·063	0·066	*

* Estimated values.

YOUNG'S MODULUS (E); SHEAR MODULUS (G); POISSON'S RATIO (σ)

Chemical Composition (%)							Test Temp °C	Young's Modulus tons/sq. in.		Shear Modulus tons/sq. in.		Poisson's Ratio		Ref.
C	Si	Mn	S	P	Ni	Cr		Static	Dynamic	Static	Dynamic	Static	Dynamic	
0·29	0·18	0·63			3·55		20	13150						4
0·30					3·5		R.T.	13150						5
"					"		—78	13700						"
0·34	0·17	0·57	0·007	0·011	3·25	0·60	20	13050	13250	5100	5150	0·28	0·29	2

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·23	0·74	0·027	0·031	3·47	0·07	0·11

Acid Open Hearth.
McQuaid Ehn grain size 2—3 (ASTM).
As Quenched grain size 7—8 (ASTM).
Bars hot rolled to 3/8 in. dia., cold drawn to 11 SWG., with intermediate annealing at 600°C.

Austenitizing Temperature 840°C, 30 min.

(Ref. 6)

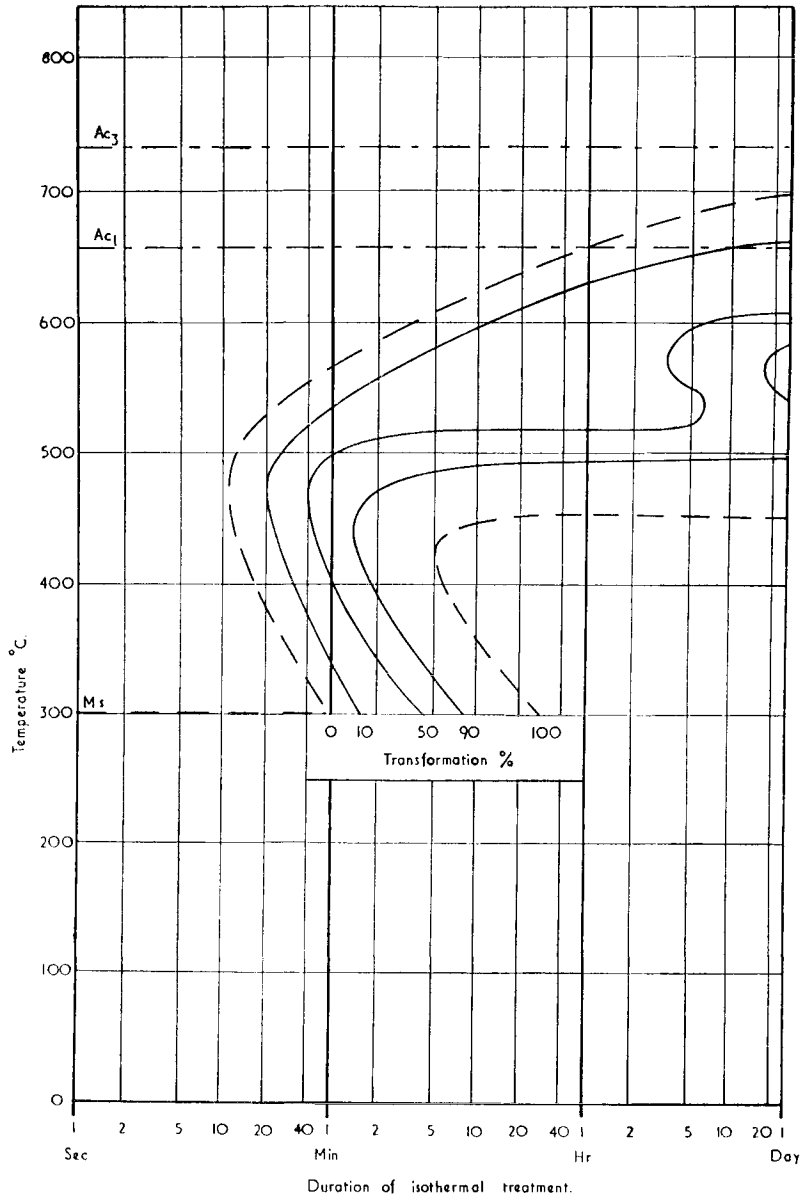


Fig. 21.1

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·23	0·74	0·027	0·031	3·47	0·07	0·11

Acid Open Hearth.
McQuaid Ehn grain size 2—3 (ASTM).
As Quenched grain size 7—8 (ASTM).
Bars End Quenched from 840°C.

(Ref. 6)

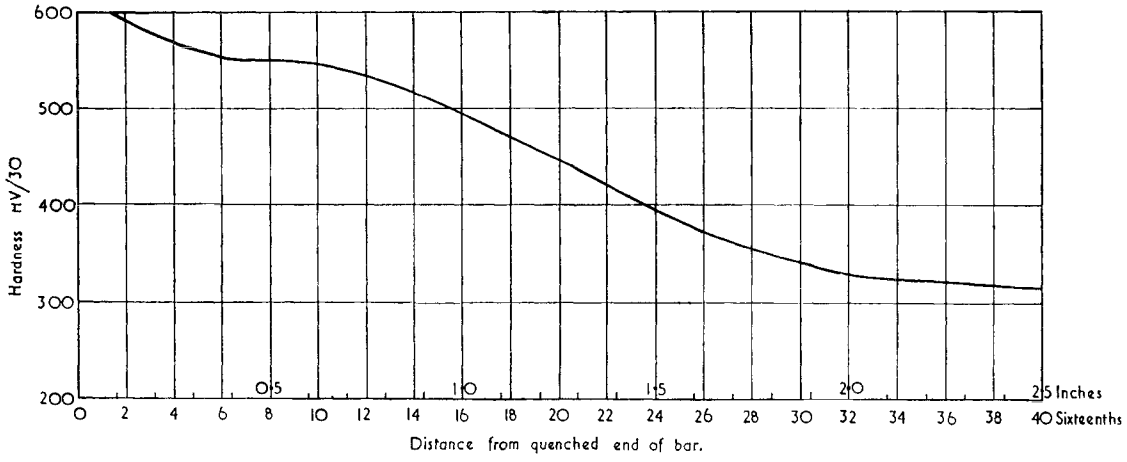


Fig. 21.2

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·34	0·28	0·51	0·014	0·005	3·26	0·15

Basic Electric Arc.
McQuaid Ehn grain size 5—6 (ASTM).
As quenched grain size 7 (ASTM).
Bars Normalized 900°C. End Quenched 840°C.
Tempered 600°C Air Cool.

(Ref. 7)

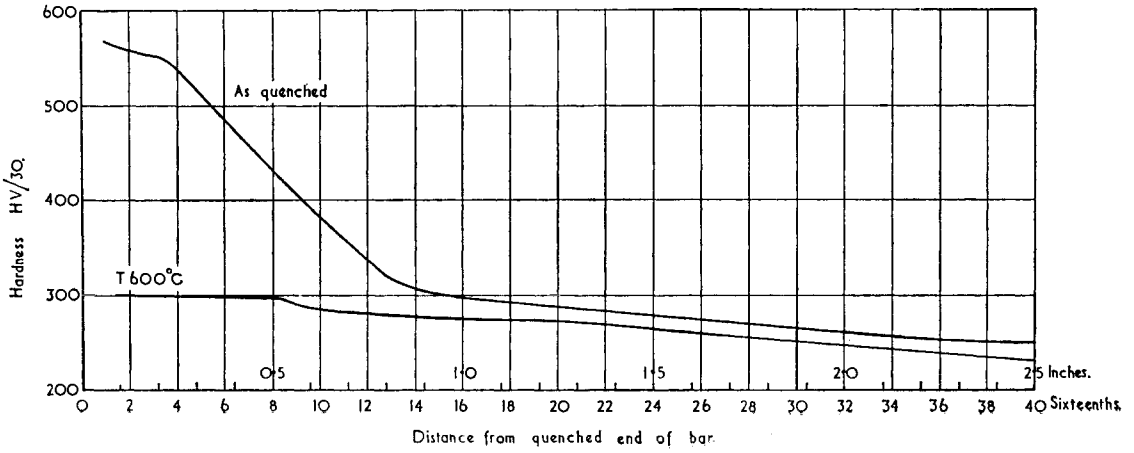


Fig. 21.3

END QUENCH HARDENABILITY DATA (Continued)

Curve No.	Method of Manufacture	Chemical Composition (%)								Grain Size		Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn	
A	E.	0·32	0·25	0·51	0·017	0·005	3·35	0·28	0·03	8	5—7	7
B	A.O.H.	0·37	0·31	0·60	0·049	0·037	2·95	0·25	0·13	6—7	6—8	"
C	A.O.H.	0·31	0·22	0·63	0·040	0·031	3·03	0·14	0·03	6—8	4—6(3)	"
D	A.O.H.	0·32	0·36	0·67	0·043	0·043	3·00	0·13	0·02	7(5—6)	5—7	"

1 in. dia. bars. Normalized 875° C. End Quenched 850° C.

As Quenched

(Ref. 7)

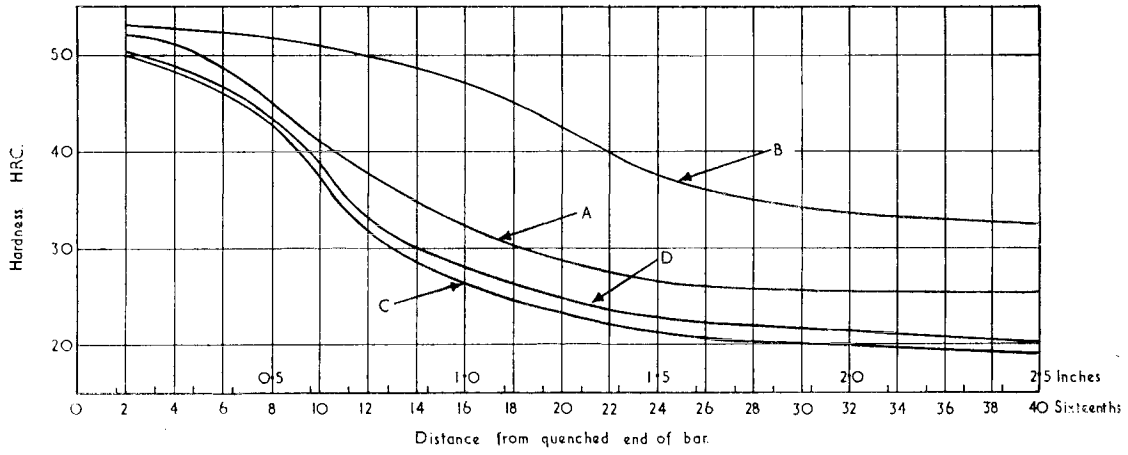


Fig. 21.4

As Quenched and Tempered

(Ref. 7)

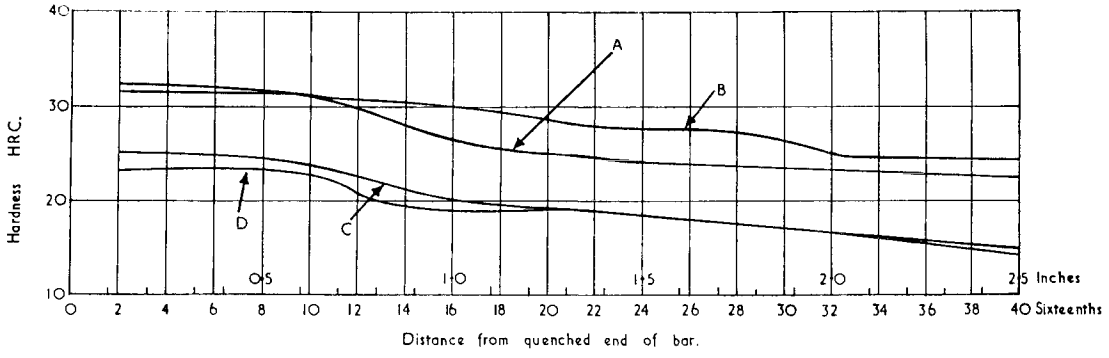


Fig. 21.5

(Ref. 3)

END QUENCH HARDENABILITY BAND

This band has been constructed from the results obtained in several casts of En 21.

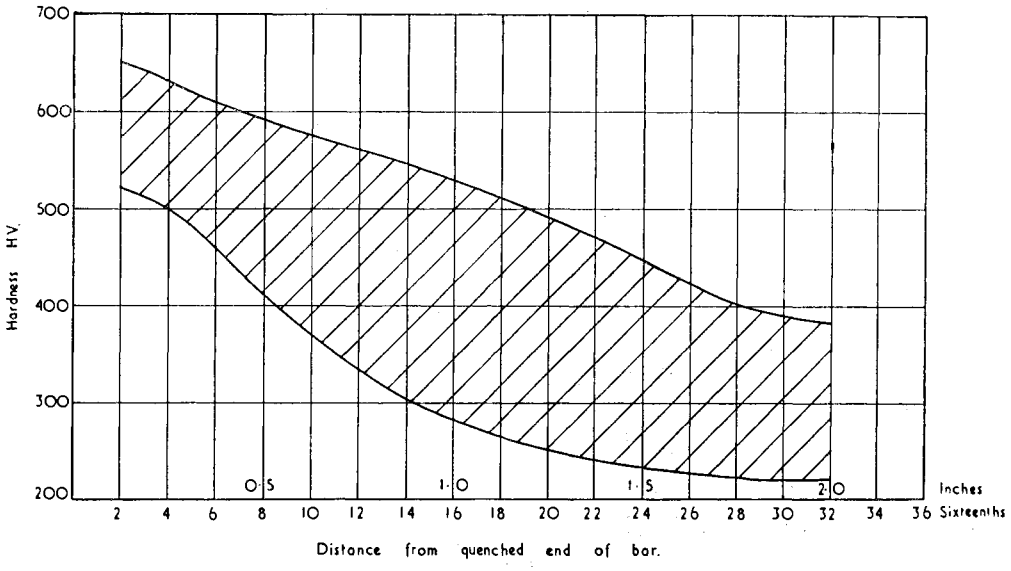


Fig. 21.6

HARDNESS TRAVERSE CURVES

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·34	0·28	0·51	0·014	0·005	3·26	0·15

Basic Electric Arc.
McQuaid Ehn grain size 5—6 (ASTM).
As quenched grain size 7 (ASTM).
Bars Normalized 900°C. Oil Quenched C840°.
Tempered 600°C.

Oil Quenched 840°C. (Ref. 7)

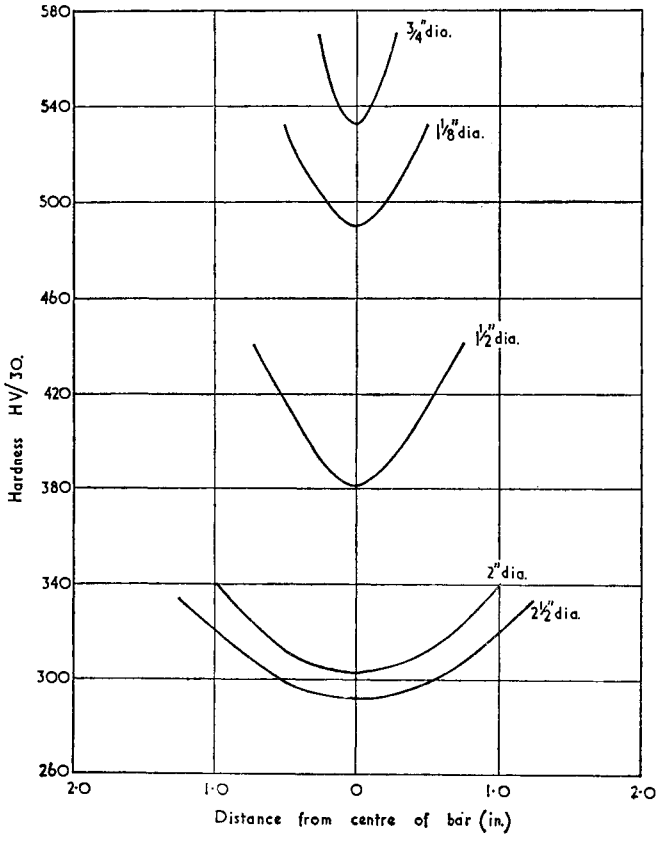


Fig. 21.7

Oil Quenched 840°C. Tempered 600°C. (Ref. 7)

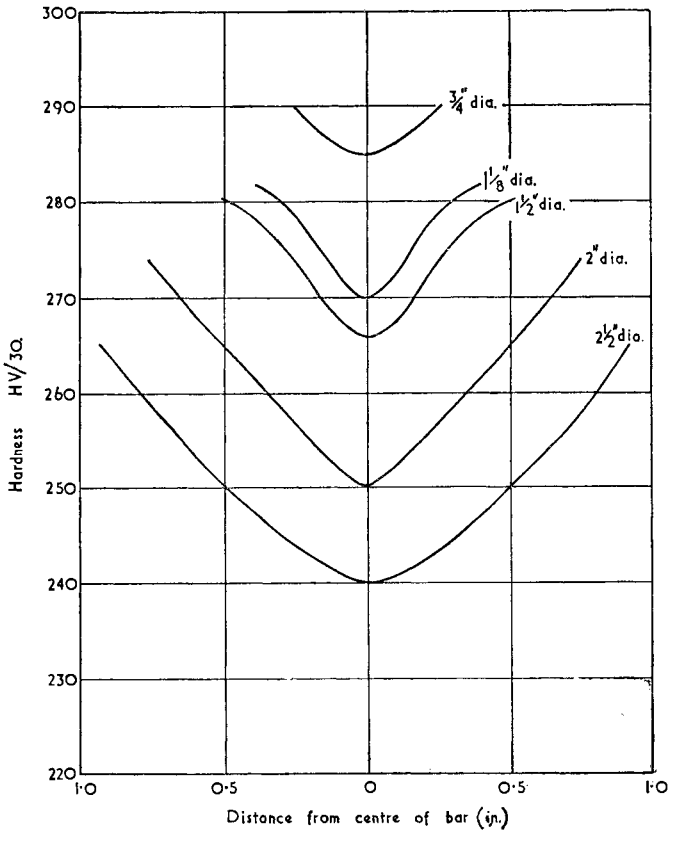


Fig. 21.8

MECHANICAL PROPRETIES AT ROOM TEMERAPTURE

Process of Manufacture	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr			0·2% P.S. (0·2Rp) tons/sq. in.	0·5% P.S. (0·5Rp) tons/sq. in.	Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El (A) % $4\sqrt{A}$	R.A. (Z) %	
B.O.H.	0·26	0·25	0·56	0·028	0·032	3·10	—	3½	OQ and tempered			34·2	45·8	25	61	45	8
B.E.A.	0·26	0·22	0·53			3·19	Tr	⅝	OQ850 T600 AC			42·8	50·0	26	69	91	1
"	"	"	"			"	"	"	" T630 "			39·6	48·0	25½	66	95	"
B.E.A.	0·28	0·16	0·65	0·025	0·028	3.25	0 22	1	OQ840 T650 WQ			40·0	52·0	25	63½	82	9
"	"	"	"	"	"	"	"	1⅜	" T660 "			39·0	52·0	22	52½	58	"
B.E.A.	0·28	0·27	0·75	0·021	0·033	3·13	0·09	3¼	" T650 "			32·0	46·0	24	59½	54	"
"	"	"	"	"	"	"	"	4½	" T640 "			34·0	46·0	25	62½	77	"
	0·28	0·24	0·60			2·90		2⅛	OQ850 T600			37	48	26	59	76	3
A.O.H.	0·28	0·23	0·44	0·036	0·029	3·26	0·09	1/16	OQ850			67	81	9	33	15	10
"	"	"	"	"	"	"	"	"	" T100 WQ			67	80	9½	36	17	"
"	"	"	"	"	"	"	"	"	" T200 "			66	78	10½	41	17	"
"	"	"	"	"	"	"	"	"	" T300 "			64	73	12½	48	16	"
"	"	"	"	"	"	"	"	"	" T400 "			58	67	15	56	37	"
"	"	"	"	"	"	"	"	"	" T500 "			51	60	18	62	64	"
"	"	"	"	"	"	"	"	"	" T600 "			42	53	22	67	80	"
"	"	"	"	"	"	"	"	"	" T650 "				48		69	87	"
"	"	"	"	"	"	"	"	1⅛	OQ850			42	57	16	45	22	"
"	"	"	"	"	"	"	"	"	" T100 "			42	57	17	46	23	"
"	"	"	"	"	"	"	"	"	" T200 "			42	56	17	47	24	"
"	"	"	"	"	"	"	"	"	" T300 "			41	55	18	49	28	"
"	"	"	"	"	"	"	"	"	" T400 "			40	54	19	52	40	"
"	"	"	"	"	"	"	"	"	" T500 "			37	51	22	58	57	"
"	"	"	"	"	"	"	"	"	" T600 "			34	48	27	63	71	"
"	"	"	"	"	"	"	"	2⅛	OQ850			31	49	23	56	43	"
"	"	"	"	"	"	"	"	"	" T100 "			32	49	23	56	43	"
"	"	"	"	"	"	"	"	"	" T200 "			32	48	24	56	41	"
"	"	"	"	"	"	"	"	"	" T300 "			32	48	24	56	40	"
"	"	"	"	"	"	"	"	"	" T400 "			32	48	24	56	44	"
"	"	"	"	"	"	"	"	"	" T500 "			32	47	25	57	51	"
"	"	"	"	"	"	"	"	"	" T600 "			30	45	26	62		"
"	"	"	"	"	"	"	"	"	" T650 "			27	43	27	64		

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El (A) % $4\sqrt{A}$	R.A. (Z) %	Izod ft.lb.	Ref.
										tons/sq. in.							
A.O.H.	0·28	0·23	0·44	0·036	0·029	3·26	0·09	3	OQ850			31	48	22	54½	38	10
"	"	"	"	"	"	"	"	"	" T100 WQ			31	48	22	44	40	"
"	"	"	"	"	"	"	"	"	" T200 "			31	48	23	55	40	"
"	"	"	"	"	"	"	"	"	" T300 "			31	48	23	55	37	"
"	"	"	"	"	"	"	"	"	" T400 "			31	48	23	55	37	"
"	"	"	"	"	"	"	"	"	" T500 "			31	47	23½	56	44	"
"	"	"	"	"	"	"	"	"	" T600 "			30	45	25	60	53	"
"	"	"	"	"	"	"	"	"	" T650 "			27	43	28	64	60	"
B.E.A.	0·29	0·35	0·57	0·023	0·019	3·07	0·12	4	OQ840 T630 WQ			39·0	49·0	25	61·5	74	9
	0·29	0·18	0·63			3·55		Forging	OQ & tempered	28·2			41·6	26	50		4
B.E.A.	0·29	0·21	0·52			3·14	0·18	1¾	OQ850 T620 AC			36·4	46·4	27	64	88	1
"	"	"	"			"	"	2¼	" " "			36·0	45·6	28½	64	86	"
	0·29		0·52			3·08		4	OQ830 T620			40·4	48·8	24	—	53	11
	0·30					3·00	0·40	1⅛	OQ840 T400			70	80	13	40	12	12
	"					"	"	"	" T500			60	65	17	48	28	"
	"					"	"	"	" T550			55	60	19	52	35	"
	"					"	"	"	" T600			50	57	21	55	46	"
	"					"	"	"	" T650			46	53	22	60	60	"
	"					"	"	2¼	" T600			47	54	21	55	45	"
	"					"	"	4½	" T600			40	49	22	60	50	"
	0·30		0·50			3·00	—	1⅛	OQ850 T500			50	60	20	58	40	"
	"		"			"	"	"	" T550			45	55	22	59	50	"
	"		"			"	"	"	" T600			40	50	24	62	60	"
	"		"			"	"	"	" T650			37	45	27	65	70	"
	"		"			"	"	2¼	" T600			36	46	24	60	60	"
	"		"			"	"	4½	" T600			32	44	25	55	55	"
	0·30	0·28	0·58			2·92		½	OQ850 T610			43·2	52·4	26	65	90	3
	0·30	0·19	0·53			3·00		2.2hex.	" T640			40·0	48·8	23½	66	100	"
	0·30	0·23	0·56			2·92		3	" T650			35·0	45·0	27	66	66	"
	0·30	0·25	0·50			3·12	0·33	3⅝	" T630 AC			39·4	48·4	27	62	79	1
B.O.H.	0·30		0·50			2·87	0·10	1⅛	OQ840 T600			37·7	46·4	25½	58	74	13
	"		"			"		2¼ sq.	" " (C)			31·8	43·8	27½	62	84	"
	"		"			"		4½ sq.	" " (O)			30·9	42·9	26	55	72	"
	"		"			"		"	" " (C)			30·8	42·4	25	47	68	"
	0·30		0·54			3·19		½	OQ830 T630			46·6	55·0	25½		84	11

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
		C	Si	Mn	S		Ni	Cr	Mo			0·2% P.S. ($0·02R_p$)	0·5% P.S. ($0·05R_p$)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.							
A.O.H.	4—6(3)	0·31	0·22	0·63	0·040	0·031	3·03	0·14	0·03	1	N875 OQ850 T600			49·5	56·9	22½	63½	60	7
		0·31	0·22	0·68			3.18			0·625×0·50	OQ850 T640			35·4	48·6	30	65	—	3
		0·31	0·19	0·53			3·10	Tr		1⅛	" T650		32·2		50·7	23½	59	60	1
B.E.A.		0·31	0·21	0·52			3·18	0·05		"	" T630 AC			41·2	48·0	23	59	81	"
B.E.A.		0·31		0·62			3·08	0·10		"	OQ840 T400			61·0	69·6	18	55	26	13
		"		"			"	"		"	" T500			54·1	60·0	21	57	50	"
		"		"			"	"		"	" T550			47·8	56·2	23½	61½	64	"
		"		"			"	"		"	" T600			43·4	52·2	25½	63½	78	"
		"		"			"	"		"	" T620			42·4	50·0	27	66	90	"
		"		"			"	"		"	" T640			39·0	48·4	27½	66	94	"
	7	0·31		0·61			3·04	0·13		5⅛	OQ850 T560			37·1	47·6	22	50	75	14
	3—5	0·31		0·62			2·90	0·10		1⅛	OQ830 T550			45·4	54·1	22½	59	66	"
	"	"		"			"	"		"	" T600			42·2	50·6	24½	66	79	"
	"	"		"			"	"		"	" T650			42·4	48·4	27½	66	94	"
	"	"		"			"	"		2¼	" T550			38·3	48·5	25	59	72	"
	"	"		"			"	"		"	" T600			36·8	47·3	25	64	79	"
	"	"		"			"	"		"	" T650			35·8	44·6	28½	66	86	"
B.E.A.	5—7 McQuaid Ehn 8 actual	0·32	0·25	0·51	0·017	0·005	3·35	0·28	0·03	1½	N875 OQ850 T600			50·7	57·3	22½	66	78	7
A.O.H.	5—7 McQuaid Ehn 7(6) actual	0·32	0·36	0·67	0·043	0·043	3·00	0·13	0·02	2 3/32	" "			46·2	54·4	22½	64½	61	"
		0·32	0·19	0·59			3·06			1	OQ850 T640			46·0	52·6	24	63½	89	3
		0·32	0·30	0·60			3·22	0·20		4	" T620 AC			36·0	46·4	25	57	81	1
		0·32		0·58			3·04			2½	" T635			39·2	49·4	24½		75	11
		"		"			"			3¾	OQ830 T640			41·6	51·2	24		72	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section 'Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
B.E.A.		0·33	0·20	0·61	0·019	0·016	3·25	0·28		$\frac{5}{8}$	OQ840 T650 WQ				41·2	53·8	23	66	75	9
		0·33	0·20	0·66			3·10	0·16		1	OQ850 T630 AC				46·8	53·8	24	64	96	1
		"	"	"			"	"		$1\frac{1}{4}$	" T610 AC				46·4	54·0	25	62	87	"
		"	"	"			"	"		$2\frac{3}{4}$	" T630 AC				40·6	49·8	$24\frac{1}{2}$	64	88	"
		0·33	0·30	0·60			3·17	Tr		$1\frac{1}{4}$	" T650 AC				36·8	47·2	27	67	87	"
		0·33	0·34	0·54			3·09	0·23		3	" T640 AC				39·2	48·0	21	56	69	"
		0·33	0·29	0·53			3·18	0·17		$3\frac{3}{4}$	" T600 WQ				40·0	49·8	23	59	63	"
		0·33		0·61			3·01			$\frac{1}{2}$	OQ830 T635				48·6	54·3	24		88	11
	4—6	0·33		0·57			3·18	0·10		$1\frac{1}{8}$	" T550				53·2	59·8	$22\frac{1}{2}$	62	66	14
	"	"		"			"	"		"	" T600				47·5	54·3	$24\frac{1}{2}$	66	82	"
	"	"		"			"	"		"	" T650				44·2	50·8	$25\frac{1}{2}$	68	91	"
	"	"		"			"	"		$2\frac{1}{4}$	" T550				42·5	52·5	$22\frac{1}{2}$	59	69	"
	"	"		"			"	"		"	" T600				41·6	50·6	25	64	82	"
	"	"		"			"	"		"	" T650				37·6	47·2	27	66	86	"
	"	"		"			"	"		3 sq	" T550(C)				38·9	50·7	22	50	61	"
	"	"		"			"	"		"	" " (O)				38·9	49·6	23	55	68	"
	"	"		"			"	"		"	" T600(C)				37·1	48·4	24	57	73	"
	"	"		"			"	"		"	" " (O)				36·4	47·8	25	64	78	"
	"	"		"			"	"		"	" T650(C)				34·5	46·0	26	62	80	"
	"	"		"			"	"		"	" " (O)				34·8	45·2	$27\frac{1}{2}$	66	83	"
B.E.A.	5–6(3–4) McQuaid Ehn																			
	7 actual	0·34	0·28	0·51	0·014	0·005	3·26	0·15		$\frac{1}{2}$	N900 OQ840 T600 $\frac{1}{2}$hr. AC	47·7	48·1	48·4		55·2	$22\frac{1}{2}$	63	84	7
	"	"	"	"	"	"	"	"	"	$1\frac{1}{8}$	" "	45·1	45·6	46·6		54·3	$24\frac{1}{2}$	65	84	"
	"	"	"	"	"	"	"	"	"	$1\frac{1}{2}$	N900 OQ840 T600 1hr. AC	43·3	43·8	45·8		52·5	24	$65\frac{1}{2}$	81	"
	"	"	"	"	"	"	"	"	"	"	" " (O)	47·2	47·8	50·6		55.0	24	$65\frac{1}{2}$	67	"
	"	"	"	"	"	"	"	"	"	2	" " (C)	38·0	38·7	41·0		49·7	$26\frac{1}{2}$	62	70	"
	"	"	"	"	"	"	"	"	"	"	" " (M)	41·3	41·7	44·1		52·1	$21\frac{1}{2}$	62	69	"
	"	"	"	"	"	"	"	"	"	"	" " (O)	41·0	41·5	43·5		51·5	24	62	63	"
	"	"	"	"	"	"	"	"	"	$2\frac{1}{2}$	N900 OQ840 T600 $1\frac{1}{4}$hr. AC(C)	37·5	38·2	41·5		49·4	$26\frac{1}{2}$	62	73	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P. S. (0·05Rp) tons/sq. in.	0·1% P.S. (0·02Rp)	0·5% P.S. (0·05Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
	5—7 (3—4) McQuaid Ehn																			
	7 actual	0·34	0·28	0·51	0·014	0·005	3·26	0·15		2½	N900 OQ840 T600 1¼hr AC(M)	39·2	39·8	42·3		51·1	23	60	73	7
	"	"	"	"	"	"	"	"		"	" " " (O)	39·6	40·2	42·0		51·5	23	60	75	"
		0·34	0·25	0·50			3·18	0·12		½	OQ850 T550 WQ				59·9	64·7	22	58	56	1
		"	"	"			"	"		1⅛	" " "				50·0	57·8	21½	53	62	"
		"	"	"			"	"		1½	" " "				46·6	54·6	20	50	62	"
		0·34	0·28	0·57			3·24	0·23		3¼	" T630 AC				37·0	47·8	25½	61	74	"
		"	"	"			"	"		5⅛	" " "				34·6	45·6	28	61	72	"
B.O.H.		0·34		0·56			3·25	0·04		1⅛	OQ840 T550				47·0	55·0	22	62	70	13
"		"		"			"	"		2¼ sq	" "				37·4	48·6	25	55	73	"
"		"		"			"	"		4½ sq	" " (O)				35·1	47·4	26½	57	59	"
"		"		"			"	"		"	" " (C)				33·9	47·4	26½	57	55	"
	7	0·34		0·70			3·04	0·13		1⅛	OQ830 T550				57·8	63·8	21	57	54	14
	"	"		"			"	"		"	" T600				49·6	56·4	24	64	78	"
	"	"		"			"	"		"	" T650				45·0	52·5	26½	66	90	"
	"	"		"			"	"		2 sq.	" T550				50·8	57·6	21½	59	65	"
	"	"		"			"	"		"	" T600				43·2	52·6	24½	64	79	"
	"	"		"			"	"		"	" T650				37·8	48·9	27½	66	88	"
B.E.A.		0·35	0·35	0·55	0·021	0·018	3·21	0·27		1⅛	OQ840 T580 AC				55·0	60·5	20	61½	53	9
"		"	"	"	"	"	"			"	" T660 "				40·0	55·5	24	55	58	"
"		0·35	0·31	0·65	0·019	0·026	3·25	0·17		3	OQ840 T650 WQ				43·0	56·0	22	57	66	"
"		"	"	"	"	"	"	"		"	" T660 "				37·0	51·0	21	56	30	"
B.O.H.	6	0·35	0·11	0·65	0·035	0·020	3·25	0·30		2⅜	OQ840 T640 "				41·0	52·0	22	61½	74	"
B.O.H.		0·35		0·70			3·10	0·18		1⅛	OQ840 T400				69·4	79·1	14½	51	14	13
"		"		"			"	"		"	" T500				60·9	65·7	19	57	42	"
"		"		"			"	"		"	" T550				54·9	61·1	21	59½	55	"
"		"		"			"	"		"	" T600				50·0	56·6	22	61½	66	"
"		"		"			"	"		"	" T620				48·0	55·0	24	61½	74	"
"		"		"			"	"		"	" T650				43·8	52·5	26	62½	83	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

1¼ in. diameter bars Oil Hardened 840°C.
Tempered as indicated.

(Ref. 3)

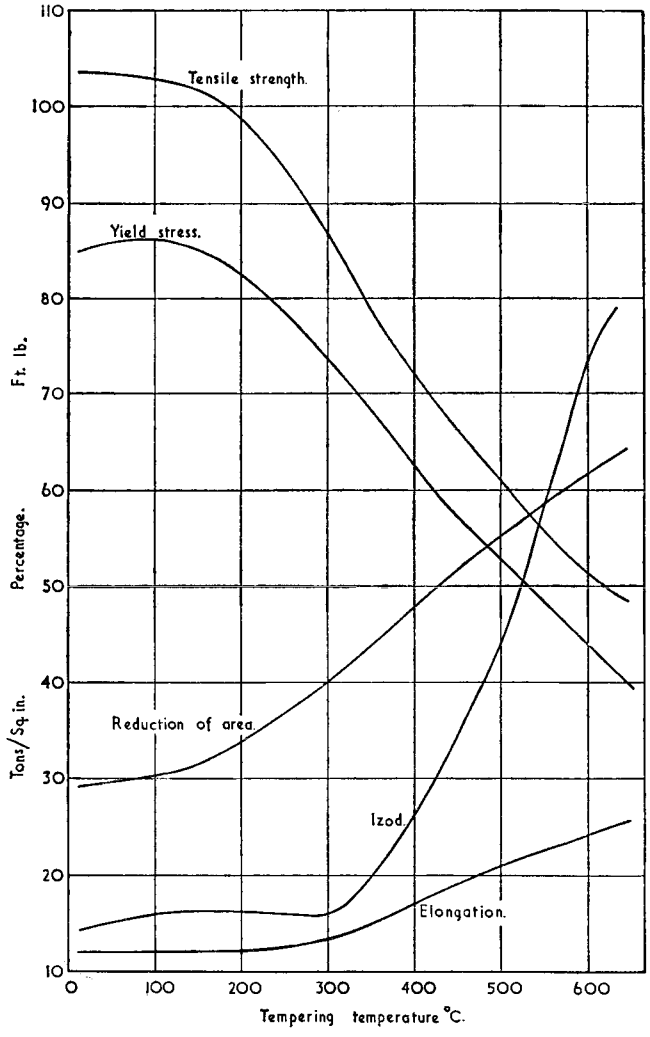


Fig. 21.9

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE

These curves have been constructed from the results obtained on several casts of En 21

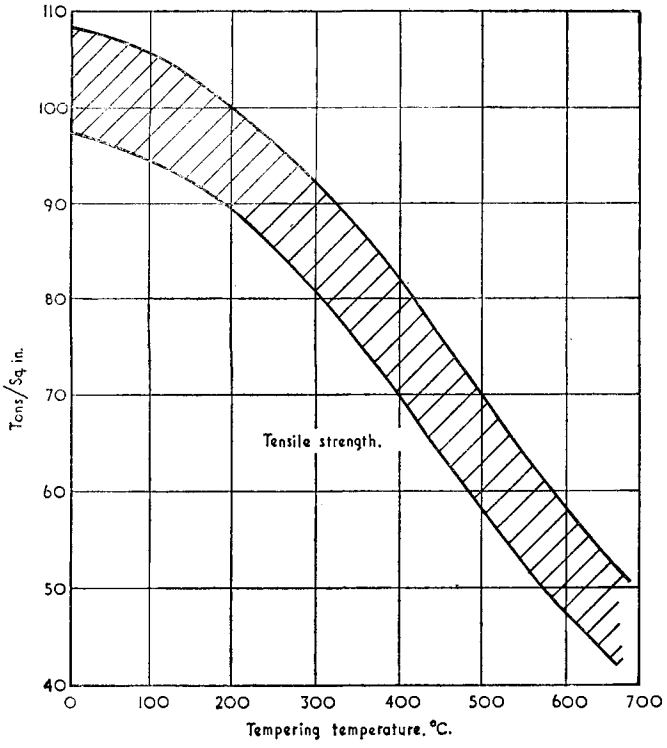


Fig. 21.10 (A)

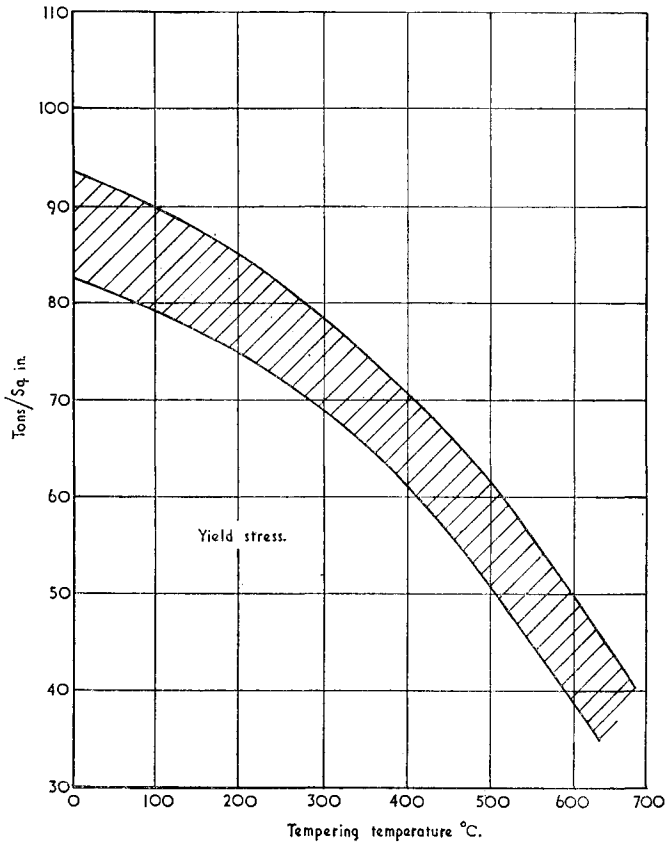


Fig. 21.10 (B)

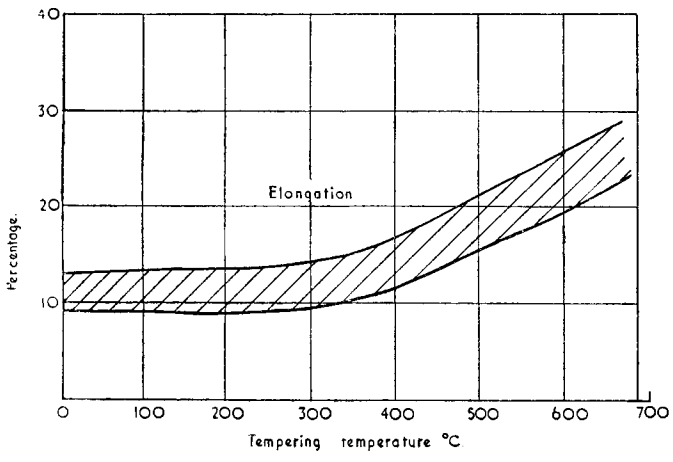


Fig. 21.10 (C)

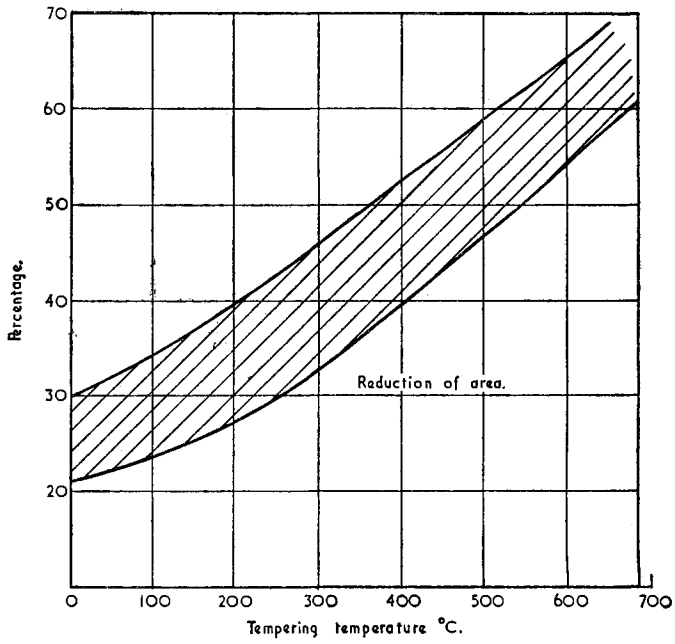


Fig. 21.10 (D)

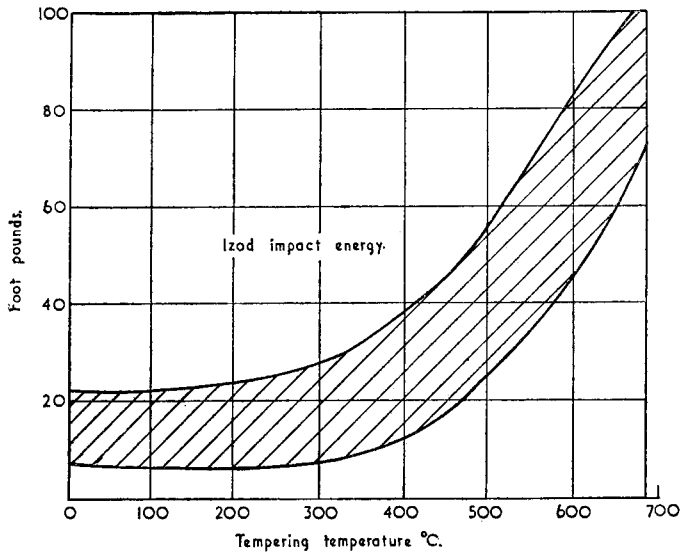


Fig. 21.10 (E)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES

Bars Oil Quenched 840°C.
Tempered 600°C. Air Cooled.

(Ref. 3)

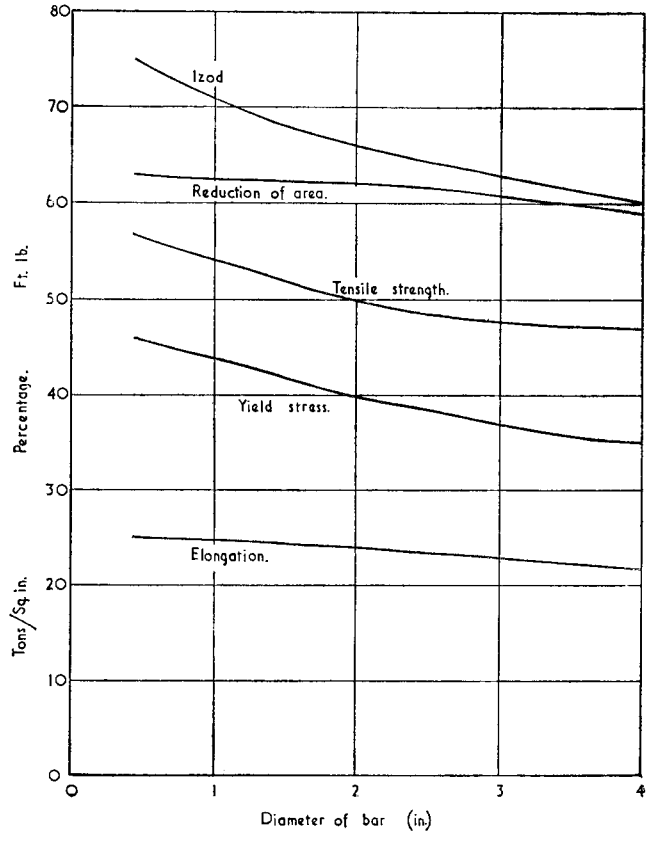


Fig. 21.11

Bars Oil Quenched 840°C.
Tempered 650°C. Air Cooled.

(Ref. 3)

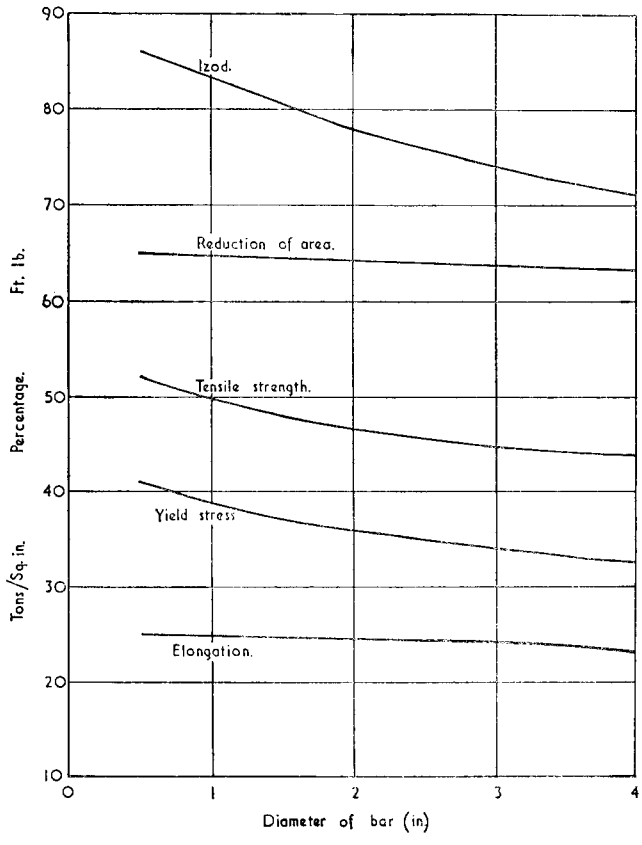


Fig. 21.12

Bars Water Quenched 840°C.
Tempered 650°C. Air Cool.

(Ref. 3)

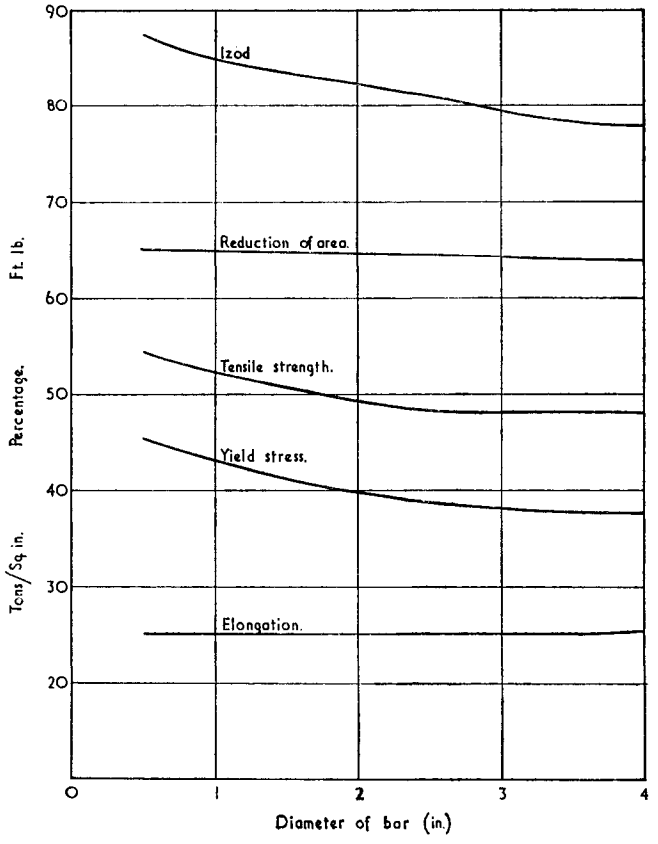


Fig. 21.13

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile				Notched Impact ft. lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr				Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)		
	0·30		0·7			3·5			Normalized	20	39·3	48·2	13	50	Charpy Keyhole 18	5
	"		"			"			"	— 78	44·6	54·5	13	47	5	"
	"		"			"			"	—196		73·1	11	35	3	"
	"		"			"			"	—253					3	"
	"		"			"			OQ815 T495	20	61·6	64·3	17	60	36	"
	"		"			"			" "	— 78	65·7	70·0	21	56	30	"
	"		"			"			" "	—196		87·9	21	44	16	"
	"		"			"			" "	—253					16	"
	0·30	0·23	0·55			3·19	0·07	$\frac{3}{4}$	OQ & Temper.	RT		49	28	29		1
		"	"			"	"	"	" "	0		50·7	31$\frac{1}{2}$	70$\frac{1}{2}$		"
	"	"	"			"	"	"	" "	— 29		52·1	29	69		"
	"	"	"			"	"	"	" "	— 90		56·8	33$\frac{1}{2}$	66$\frac{1}{2}$		"
7(4)	0·34	0·26	0·72	0·017	0·018	3·30		$\frac{3}{8}$	N925	20	33·0	51·3	16$\frac{1}{2}$	53	Charpy V 22	15 & 16
"	"	"	"	"	"	"		"	"	— 40					10	"
"	"	"	"	"	"	"		"	"	— 75	35·4	58·5	18$\frac{1}{2}$	52	7$\frac{1}{2}$	"
"	"	"	"	"	"	"		"	OQ800 T540	20	56·2	59·8	14$\frac{1}{2}$	64	80	"
"	"	"	"	"	"	"		"	" "	— 40					60	"
"	"	"	"	"	"	"		"	" "	— 75	63·8	68·8	16	60$\frac{1}{2}$	28	"

IMPACT TRANSITION TEMPERATURE DATA

Process of Manufacture	Chemical Composition (%)							Al added lb./ton	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Charpy Keyhole		Charpy V Notch ft.lb.	Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr					ft.lb.	crystalline fracture %			
A.O.H.	0·32	0·29	0·66	0·027	0·021	3·13	0·12	0	1 1/8	N850 T500	— 78	8	100			1
"	"	"	"	"	"	"	"	1	"	" "	"	16	100			"
"	"	"	"	"	"	"	"	0	"	OQ850 T600	"	27	70			"
"	"	"	"	"	"	"	"	1	"	" "	"	54	10			"
"	"	"	"	"	"	"	"	0	"	OQ850 T200	"	5	100			"
"	"	"	"	"	"	"	"	1	"	" "	"	7	100			"
B.E.A.	0·32	0·27	0·61	0·019	0·014	3·05	0·08	0	1 1/8	N850 T500	— 78	7	100			"
"	"	"	"	"	"	"	"	1/4	"	" "	"	14	100			"
"	"	"	"	"	"	"	"	0	"	OQ850 T600	"	18	100			"
"	"	"	"	"	"	"	"	1/4	"	" "	"	31	85			"
"	"	"	"	"	"	"	"	1/4	"	OQ850 T650	15	46		98	102	"
"	"	"	"	"	"	"	"	1/4	"	" "	— 40	41		66	105	"
"	"	"	"	"	"	"	"	1/4	"	" "	— 60	34		44	108	"
"	"	"	"	"	"	"	"	1/4	"	" "	— 78	33		35	94	"
"	"	"	"	"	"	"	"	1/4	"	" "	—100	24		27	—	"
"	"	"	"	"	"	"	"	1/4	"	" "	—196	6		3	—	"
								Grain Size								
	0·34	0·26	0·72	0·017	0·018	3·3		7(4)	5/8							
	"	"	"	"	"	"		"	"	N925	100			55		15
	"	"	"	"	"	"		"	"	"	20			21 1/2		"
	"	"	"	"	"	"		"	"	"	0			19 1/2		"
	"	"	"	"	"	"		"	"	"	— 20			13		"
	"	"	"	"	"	"		"	"	"	— 40			10		"
	"	"	"	"	"	"		"	"	"	— 75			7 1/2		"
	"	"	"	"	"	"		"	"	OQ800 T540	100			86		"
	"	"	"	"	"	"		"	"	" "	20			80		"
	"	"	"	"	"	"		"	"	" "	0			54 1/2		"
	"	"	"	"	"	"		"	"	" "	— 20			59		"
	"	"	"	"	"	"		"	"	" "	— 40			60		"
	"	"	"	"	"	"		"	"	" "	— 75			28		"

IMPACT TRANSITION TEMPERATURE CURVES

Chemical Composition %					
C	Si	Mn	S	P	Ni
0·34	0·26	0·72	0·017	0·018	3·3

(See Mechanical Properties at Low Temperature and Impact Transition Temperature Data.)

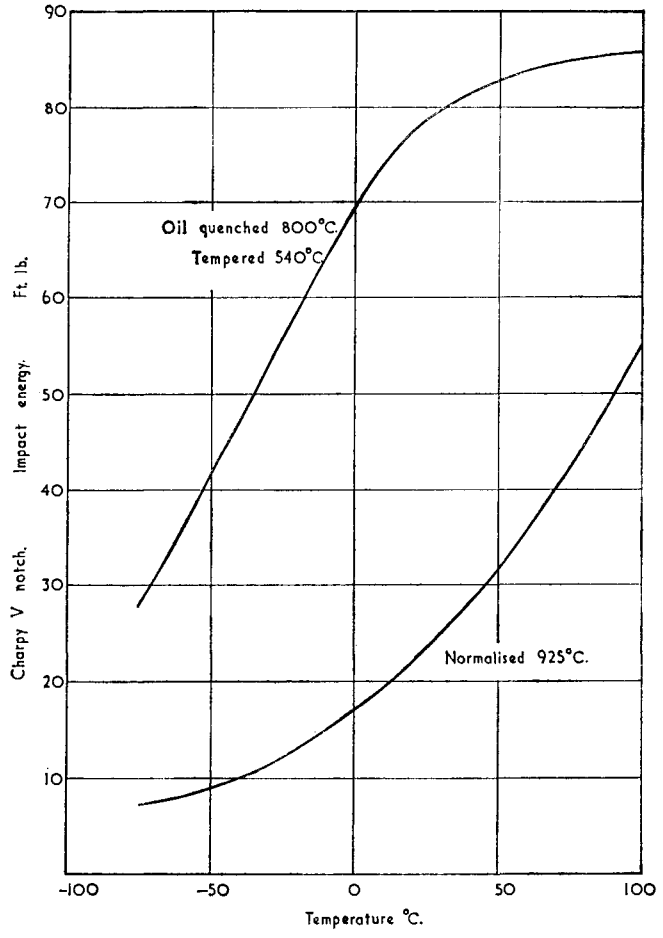


Fig. 21.14

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni				L.P.	0.1% P.S. (0.1Rp)	0.5% P.S. (0.5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A) $4\sqrt{A}$	R.A. % (Z)		
										tons/sq. in.								
B.E.A.	0·34	0·29	0·60	0·021	0·012	3·28	¾	OQ850 T640	15	29·3			32·2	50·7	23½	59		1
"	"	"	"	"	"	"	"	" "	100	28·0			34·4	48·5	25	56½		"
"	"	"	"	"	"	"	"	" "	200	26·3			34·0	48·4	25½	56		"
"	"	"	"	"	"	"	"	" "	300	25·2			33·6	47·7	21	57		"
"	"	"	"	"	"	"	"	" "	400				33·3	46·9	21¼	50½		"
"	"	"	"	"	"	"	"	" "	500				22·4	29·1	28	79½		"
"	"	"	"	"	"	"	"	" "	600				11·7	18·7	40	89		"
"	"	"	"	"	"	"	"	" "	700					11·5	48	96		"
"	"	"	"	"	"	"	"	" "	800					6·5	71	93		"
"	"	"	"	"	"	"	"	" "	900					4·0	56	83		"
"	"	"	"	"	"	"	"	" "	1000					2·4	72½	99		"
	0·34	0·20	0·57			3·06	¾	N 875	300	13·0	20·1	24·5		47·2	36	56½		1
	"	"	"			"	"	"	400	9·5	18·2	23·2		38·2	32	67½		"
	"	"	"			"	"	"	500	6·0	14·0	18·1		25·8	35½	75		"

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Tensile					Torsion				Ref.
	C	Si	Mn	S	P	Ni	Cr			L.P.	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	L.P.	Y.P. (Rs)	Apparent Max. Shear Stress	Prob. Max. Shear Stress	
										tons/sq.in.					tons/sq.in.				
B.E.A.	0·34	0·17	0·57	0·007	0·011	3·25	0·06	1⅛	OQ850 T610 AC	26·0	38·0	46·8	26½	67½	19	27·8	44·3	33·2	17

FATIGUE PROPERTIES

Chemical Composition (%) C	Mn	Ni	Heat Treatment °C	Test Temperature °C	Tensile Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Rotating Beam Fatigue Strength tons/sq. in. at cycles 10^4	10^5	10^6	10^7	Reciprocating Beam Fatigue Strength tons/sq. in. at cycles 10^4	10^5	10^6	10^7	Ref.
0·30	0·70	3·5	Normalized	25	39·3	48·2	13	50	35·7	31·3	25·9	25·0	42·8	32·1	26·3	26·3	5
"	"	"	"	— 78	44·6	54·5	13	47		35·7	30·8		52·2	41·5	31·3	28·1	"
"	"	"	"	—196		73·1	11	35					65·2	55·4	50·0	50·0	"
"	"	"	OQ815 T495	25	61·6	64·3	17	60					58·0	35·7	33·5	33·5	"
"	"	"	" "	— 78	65·7	71·4	21	56						53·6	42·4	42·4	"
"	"	"	" "	—196		87·9	21	44						71·4	55·8		"

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Bending Fatigue Limit Notched tons/sq. in.	Un-notched tons/sq. in.	Torsion Fatigue Limit Notched tons/sq. in.	Un-notched tons/sq. in.	Ref.
B.E.A.	0·34	0·17	0·57	0·007	0·011	3·25	0·06	1⅛	OQ850 T610 AC	±19·6(1)	±28·8	±11·9(2)	17·3	17

(1) Notch 55°V, 0·02 in. deep, 0·0004 in. root radius, 0·30 in. root dia.
(2) Notch 55°V, 0·02 in. deep, 0·00036 in. root radius, 0·30 in. root dia.

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11. Private correspondence with The International Nickel. Co. (Mond) Ltd.
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3½ PER CENT NICKEL STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr
0·35—0·45	0·10—0·35	0·50—0·80	0·050 max.	0·060 max.	3·25—3·75	0·30 max.

MECHANICAL PROPERTIES

	Hardened and Tempered Condition	
	S	T
Limiting ruling section, in,	4	2½
Tensile strenght, tons/sq.in., min. (Rm)	50	55
Yield stress (1) tons/sq.in., min. (Rs)	38	44
0·2% Prof Stress (2), tons/sq. in. min, (0·2 Rp)	36	41
Elengation, %, min. (A)	20	18
Izod impact value, ft. lb. min.	40	40
Brinell hardness No. (3) (HB)	223—277	248—302

(1) Not to be used as acceptance values except by special arrangement between the purchaser and the manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the speciafication.

RELATED SPECIFICATIONS

United Kingdom		America	
En No.	BS	SAE	AISI
22	102C	2340	2340

APPLICATIONS

Used for high duty parts requiring a tensile strength of 50 to 65 tons/sq. in. In the hardened and tempered condition it has excellent toughness with a low transition temperature and is suitable for sub-zero temperature service.

Uses: high tensile bolts and nuts, fork ends, pins, engine mountings and fittings, axles and connecting rods, valve rockers, gyroscope rotors, pinions and turbine shafts.

WELDING

(See Introduction: List of Abbreviations for key to symbols used In this table)

Welding Process					
MA	G	IG	S	F	B
d	cx	g	e	b	j

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MACHINABILITY

The machinability when hardened and tempered to 50—55 tons/sq. in. is approximately 50 to 55% of that for mild steel (En 3). When hardened and tempered to 55 to 65 tons/sq. in. it is approximately 45 to 50% of that for mild steel. In the softened condition the machinability is approximately 60% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1150°C. Finish above 900°C.
Annealing	830°C to 860°C. Furnace cool.
Softening (sub-critical annealing)	630°C to 650°C. Air or furnace cool.
Normalizing	830°C to 860°C. Air cool.
Hardening	830°C to 860°C. Oil quench.
Tempering	550°C to 650°C. Cool in air or water.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·32	0·18	0·55	0·034	0·032	3·47	0·17	0·04	A 860°C	7·855	1
0·38	—	0·66	—	—	3·47	0·20	—	—	7·83	2
0·40	0·25	0·65	—	—	3·50	0·25	—	OH & T	7·87	3

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cal/g deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·32	0·18	0·55	0·034	0·032	3·47	0·17	0·04	A 860°C	0·115	0·119	0·123	0·127	0·132	0·139	0·160	0·159	0·163	0·162	1
0·38	—	0·66	—	—	3·47	0·20	—	—	—	0·119	0·124	0·130	0·136	—	—	—	—	—	2
0·40	0·25	0·65	—	—	3·50	0·25	—	OH & T	0·118	—	—	—	—	—	—	—	—	—	3

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	Mean Coefficient of Thermal Expansion/deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·32	0·18	0·55	0·034	0·032	3·47	0·17	0·04	A 860°C	11·3	11·9	12·5	13·0	13·6	14·0	13·1	11·1	12·3	13·3	1
0·38	—	0·66	—	—	3·47	0·20	—	—	11·6	12·3	12·9	13·4	13·9	—	—	—	—	—	2

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm												Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·32	0·18	0·55	0·034	0·032	3·47	0·17	0·04	A 860°C	25·9	27·1	32·0	39·0	47·0	56·7	67·9	81·4	99·2	112·2	114·9	118·0	1
"	"	"	"	"	"	"	"	WQ 950°C	—	31·5	—	—	—	—	—	—	—	—	—	—	4
0·38	—	0·66	—	—	3·47	0·20	—	—	—	28·0	32·9	40·0	—	—	—	—	—	—	—	—	2

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment	Thermal Conductivity cal/cm s. deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	°C	0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·32	0·18	0·55	0·034	0·032	3·47	0·17	0·04	A 860	0·87	0·90	0·92	0·91	0·87	0·82	0·76	0·68	0·60	0·63	0·66	1
0·38	—	0·66	—	—	3·47	0·20		—	—	0·84	0·86	0·87	0·86	0·81	—	—	—	—	—	2

YOUNG'S MODULUS (E); SHEAR MODULUS (G); POISSON'S RATIO (σ)

Chemical Composition (%)							Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq. in.		Shear Modulus tons/sq. in.		Poisson's Ratio		Ref.
C	Si	Mn	S	P	Ni	Cr			Static	Dynamic*	Static	Dynamic*	Static	Dynamic*	
0·43		0·50			3·4	0·3	OQ & T	RT	13260						5
								100	13040						"
								200	12680						"
								400	11650						"
								600	10270						"
0·43	0·19	0·65	—	—	3·58	0·20	OQ850 T570	RT	13050						3
0·41	0·11	0·36	—	—	3·64	0·09	OQ & T	RT	13080						6
(within specification)							OQ & T†	RT	13050	13250	5100	5150	0·280	0·290	7

* Ultrasonic Pulse Method
† 45—50 tons/sq.in. tensile strength

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·40	0·26	0·62	0·005	0·007	3·45	0·28	0·10

Basic Electric Arc.
McQuaid Ehn grain size 5 and 6 (ASTM).
As Quenched grain size 5 (ASTM).
Austenitizing Temperature 860°C.

The hardness values shown in the diagram are those of the fully transformed steel.
(Ref. 8)

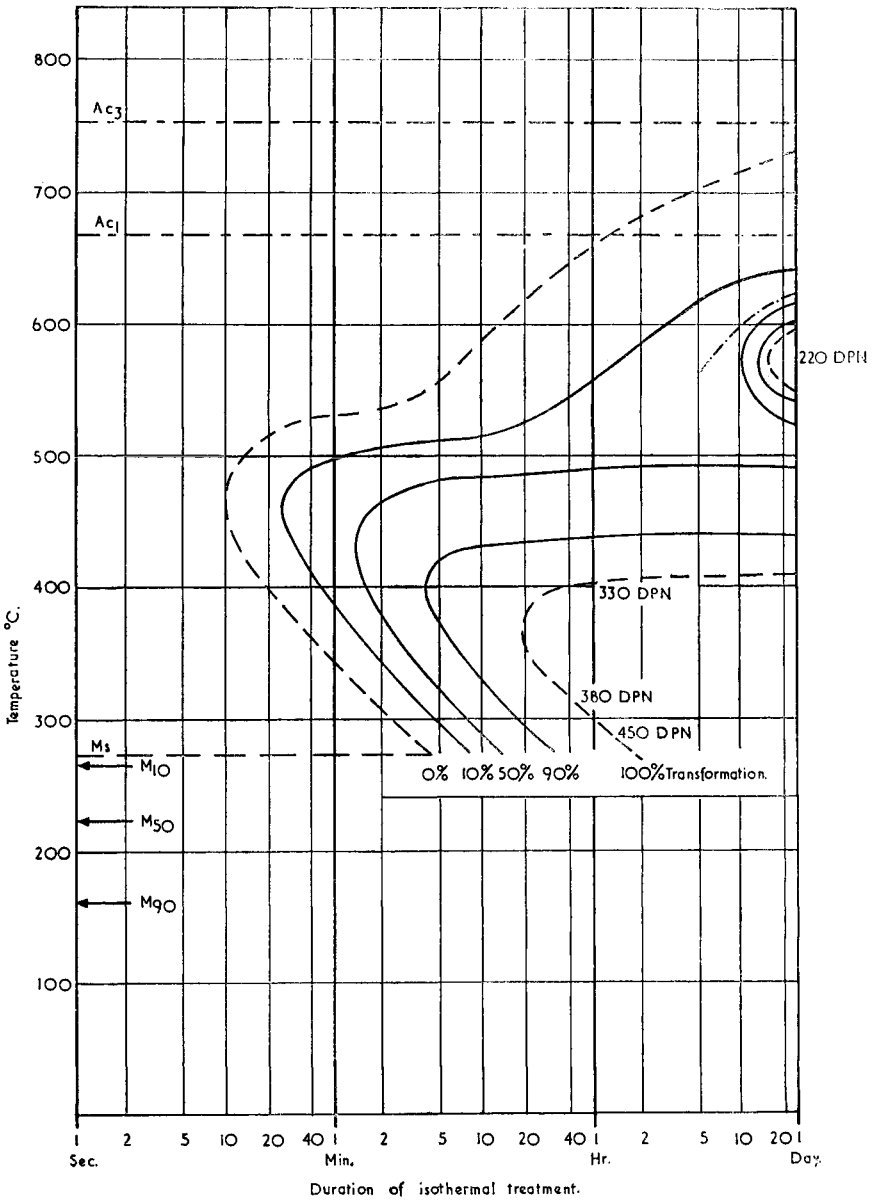


Fig. 22.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)		
C	Mn	Ni
0·37	0·68	3·41

ASTM grain size 7—8.
Austenitizing Temperature 788°C.

(Ref. 9)

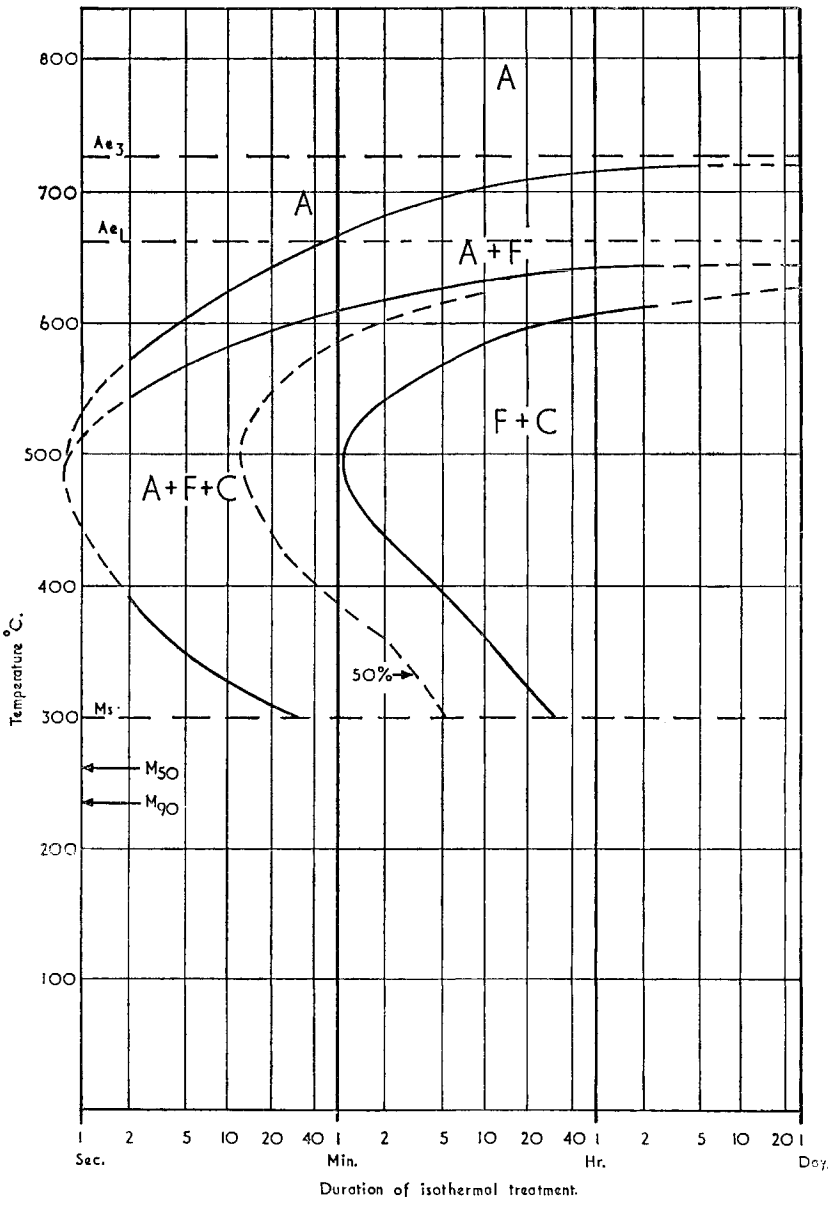


Fig. 22.2

CONTINUOUS COOLING TRANSFORMATION DIAGRAM

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·40	0·26	0·62	0·005	0·007	3·45	0·28	0·10

Basic Electric Arc.
McQuaid Ehn grain size 5 and 6 (ASTM).
As Quenched grain size 5 (ASTM).
Austenitizing Temperature 860°C.

(Ref. 8)

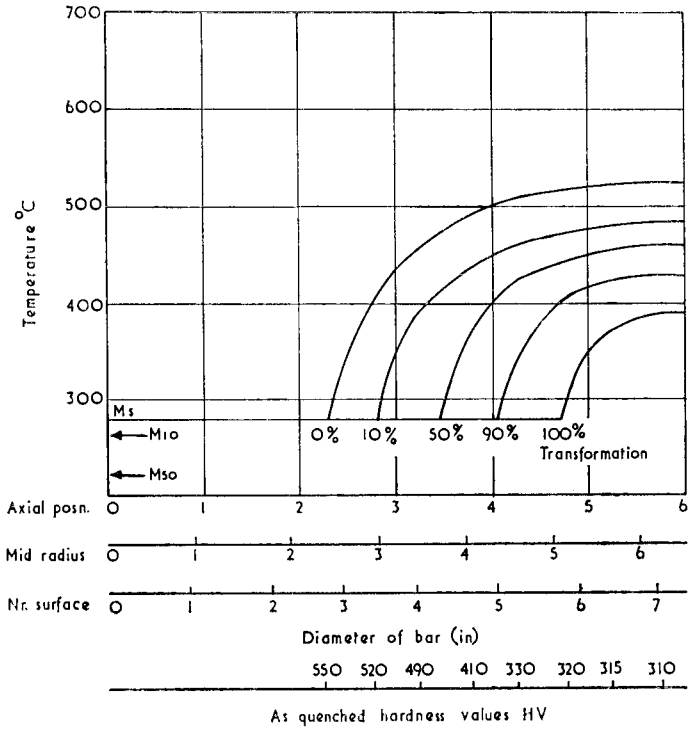


Fig. 22.3

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·40	0·26	0·62	0·005	0·007	3·45	0·28	0·10

Basic Electric Arc.
McQuaid Ehn grain size 5 and 6 (ASTM).
As Quenched grain size 5 (ASTM).
Austenitizing Temperature 860°C.

(Ref. 8)

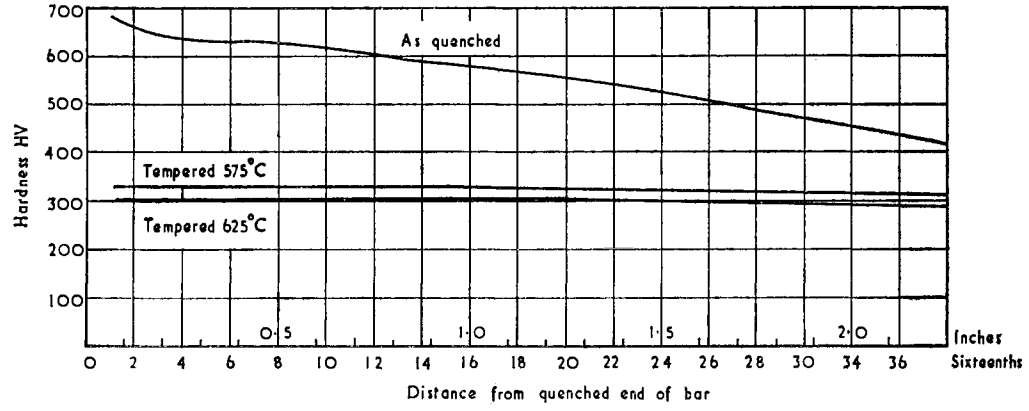


Fig. 22.4

Chemical Composition (%)		
C	Mn	Ni
0·37	0·68	3·41

ASTM grain size 7—8.
Austenitizing Temperature 788°C. (Ref. 9)

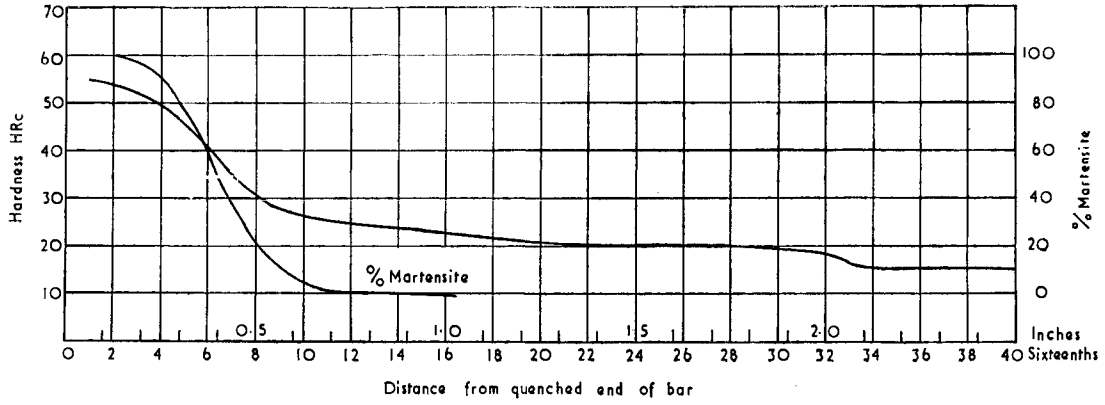


Fig. 22.5

END QUENCH HARDENABILITY (Continued)

Curve No.	Process of Manufacture	Chemical Composition (%)								Grain Size	
		C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn
A	A.O.H.	0·35	0·24	0·53	0·012	0·004	3·33	0·24	0·03	7—8	3—6 (2)
B	A.O.H.	0·39	0·25	0·60	0·020	0·007	3·50	0·28	0·07	7—9	5—6 (3—4)
C	E.	0·42	0·30	0·60	0·040	0·030	3·29	0·20	0·14	7	5—6 (4)
D	A.O.H.	0·37	0·25	0·54	0·035	0·034	3·41	0·22	0·05	6—7	3—5 (2)
E	E.	0·31	0·38	0·58	0·022	0·021	3·25	0·32	0·04	7—8	7—8 (6)
F	A.O.H.	0·38	0·32	0·64	0·044	0·041	3·45	0·16	0·05	6—7	4

1 in. dia. bars. Normalized 875°C. End quenched 850°C.

As Quenched

(Ref. 10)

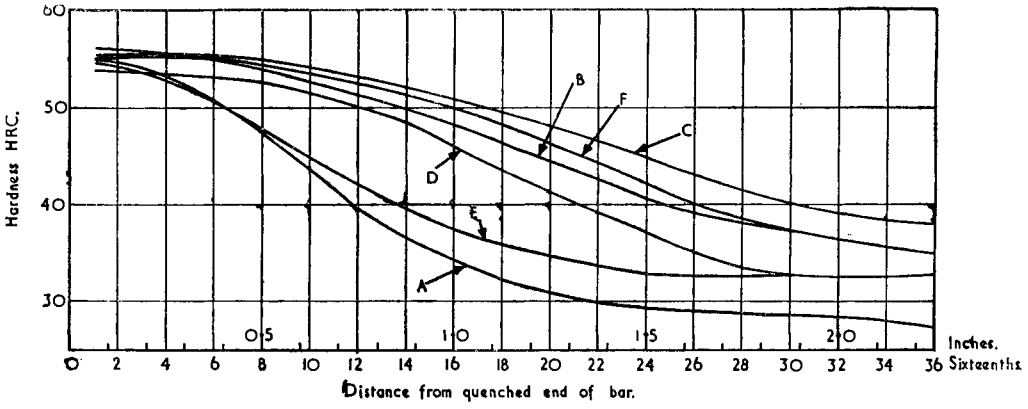


Fig. 22.6

Quenched and Tempered

(Ref. 10)

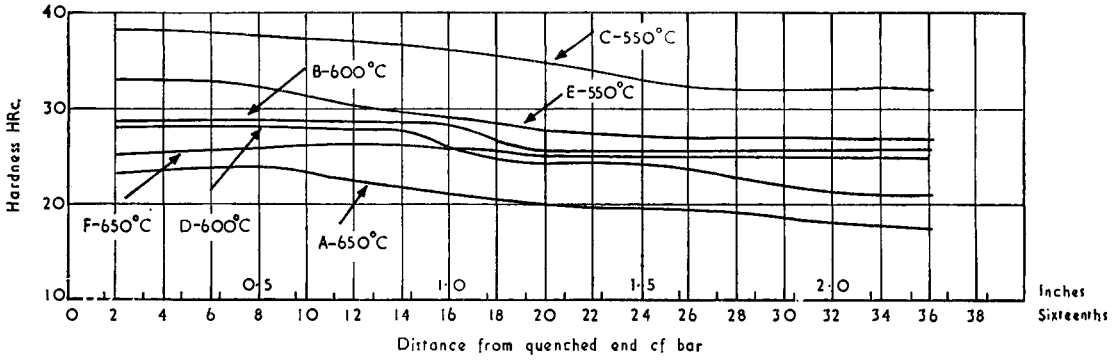


Fig. 22.7

SECTION QUENCH CURVES

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·40	0·20	0·55	0·054	0·033	3·46	0·25	0·13

Acid Open Hearth.
Bars Oil Quenched from 850°C.

Laboratory A (Ref. 10)

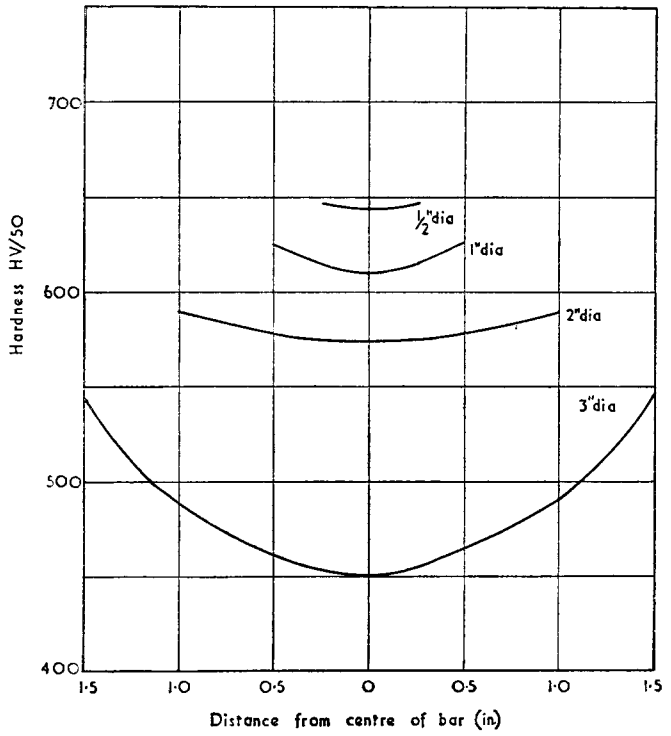


Fig. 22.8

Laboratory B (Ref. 10)

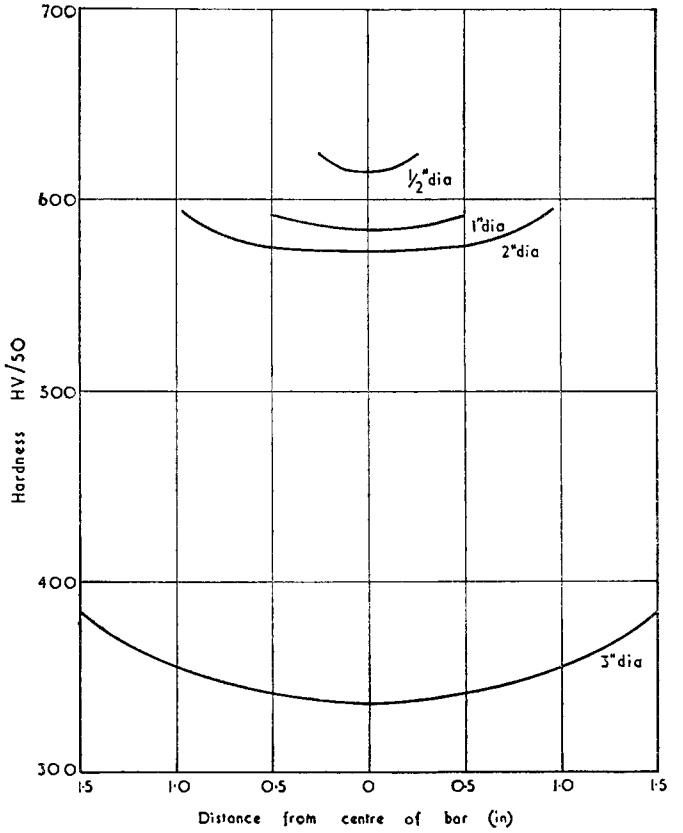


Fig. 22.9

N.B. These curves were determined by two different laboratories. The difference in results indicates a difference in the severity of quench.

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
	3—6	7—8	0·35	0·24	0·53	0·012	0·004	3·33	0·24	0·03	1⅛	N875 OQ850 T600	52·0	58·8	22½	65	70	10
B.O.H.			0·35	0·25	0·62	0·026	0·033	3·30	0·23		1·1 hex.	OQ850 T590	47·6	56·0	24	61	64	11
"			"	"	"	"	"	"	"		1⅛	" "	46·8	55·2	23	61	47	"
"			"	"	"	"	"	"	"		2⅜	" T560	47·2	56·2	22	57	40	"
"			"	"	"	"	"	"	"		2⅛	" T590	44·0	54·2	23	61	71	"
B.O.H.			0·36	0·29	0·65	0·038	0·037	3·30	0·22		½	OQ850 T630	50·3	58·1	24	51	46	11
"			"	"	"	"	"	"	"		¾	" T610	51·6	57·6	22	59	43	"
"			"	"	"	"	"	"	"		"	" T620	47·6	56·6	22	57	51	"
			0·36		0·64			3·44	0·22		1⅛	OQ830 T580 OQ	56·8	63·6	21		68	12
			"		"			"	"		3	" "	48·8	56·0	23		75	"
			0·36		0·54			3·39	0·08		1⅛	OQ840 T550	47·0	58·0	22		51	13
			"		"			"	"		"	" T600	42·0	54·0	23		57	"
			"		"			"	"		"	" T630	41·5	53·0	24		62	"
			"		"			"	"		2⅛	" T600	34·5	50·0	23		47	"
			0·36		0·54			3·39	0·06		1⅛	OQ840 T600	45·0	54·0	24		67	"
			"		"			"	"		3	" "	33·0	48·0	24		40	"
A.O.H.			0·36	0·22	0·54	0·037	0·033	3·39	0·08		1/16	OQ840	—	—	6		10	14
"			"	"	"	"	"	"	"		"	" T100 WQ	—	—	6		5	"
"			"	"	"	"	"	"	"		"	" T200 "	100	—	7	27	5	"
"			"	"	"	"	"	"	"		"	" T300 "	90	105	10	37	6	"
"			"	"	"	"	"	"	"		"	" T400 "	76	86	12	46	14	"
"			"	"	"	"	"	"	"		"	" T500 "	60	70	16	56	38	"
"			"	"	"	"	"	"	"		"	" T600 "	51	59	20	63	68	"
"			"	"	"	"	"	"	"		"	" T650 "	42	54	24	65	74	"
"			"	"	"	"	"	"	"		1⅛	QQ840	67	94	9	26	10	14
"			"	"	"	"	"	"	"		"	" T100 WQ	67	93	9	28	11	"
"			"	"	"	"	"	"	"		"	" T200 "	66	91	9	32	10	"
"			"	"	"	"	"	"	"		"	" T300 "	62	84	12	38	9	"
"			"	"	"	"	"	"	"		"	" T400 "	57	72	16	48	24	"
"			"	"	"	"	"	"	"		"	" T500 "	50	62	20	55	44	"
"			"	"	"	"	"	"	"		"	" T600 "	43	55	24	60	60	"
"			"	"	"	"	"	"	"		"	" T650 "	36	51	25	61	66	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
A.O.H.			0·36	0·22	0·54	0·037	0·033	3·39	0·08		2⅛	OQ840	37	58	18	40	22	14
"			"	"	"	"	"	"	"		"	" T100 WQ	38	58	18	40	26	"
"			"	"	"	"	"	"	"		"	" T200 "	39	58	18	40	29	"
"			"	"	"	"	"	"	"		"	" T300 "	39	57	18	42	24	"
"			"	"	"	"	"	"	"		"	" T400 "	39	56	19	46	24	"
"			"	"	"	"	"	"	"		"	" T500 "	38	54	20	54	32	"
"			"	"	"	"	"	"	"		"	" T600 "	35	50	24	58	53	"
"			"	"	"	"	"	"	"		"	" T650 "	30	48	27	60	59	"
"			"	"	"	"	"	"	"		3	"	33	54	21	46	27	"
"			"	"	"	"	"	"	"		"	" T100 WQ	34	54	21	47	28	"
"			"	"	"	"	"	"	"		"	" T200 "	35	54	21	47	26	"
"			"	"	"	"	"	"	"		"	" T300 "	26	54	21	48	22	"
"			"	"	"	"	"	"	"		"	" T400 "	36	54	21	48	24	"
"			"	"	"	"	"	"	"		"	" T500 "	36	52	22	50	32	"
"			"	"	"	"	"	"	"		"	" T600 "	34	49	24	55	40	"
"			"	"	"	"	"	"	"		"	" T650 "	—	—	—	60	—	"
A.O.H.	3—5	6—7	0·37	0·25	0·54	0·035	0·034	3·41	0·22	0·05	2	N875 OQ850 T600	50·4	62·5	20½	59½	49	10
			0·37	0·17	0·65	0·020	0·030	3·65	nil		1⅛	N860	27	44	28	56	36	15
			"	"	"	"	"	"	"		"	WQ860	110	124	9	25	4	"
			"	"	"	"	"	"	"		"	" T300	84	93	13	48	4	"
			"	"	"	"	"	"	"		"	" T400	67	75	16	56	8	"
			"	"	"	"	"	"	"		"	" T500	54	61	21	61	52	"
			"	"	"	"	"	"	"		"	" T600	45	53	35	63	72	"
			"	"	"	"	"	"	"		"	" T650	39	48	28	65	81	"
			"	"	"	"	"	"	"		"	OQ860	90	116	10	21	6	"
			"	"	"	"	"	"	"		"	" T300	83	92	12	37	5	"
			"	"	"	"	"	"	"		"	" T400	67	76	15	52	11	"
			"	"	"	"	"	"	"		"	" T500	54	63	20	60	50	"
			"	"	"	"	"	"	"		"	" T600	44	52	25	65	73	"
			"	"	"	"	"	"	"		"	" T650	40	49	27	66	82	"
			0·37		0·65	—	—	3·58	0·22		⅞	N840	44·8	67·9	17	36	—	2
			"		"			"	"		2	"	40·0	58·1	18½	39	—	"
A.O.H.	4	6—7	0·38	0·32	0·64	0·044	0·041	3·45	0·16	0·05	1⅛	N875 OQ850 T600	54·3	60·9	20	55½	42	10
B.O.H.			0·38	0·24	0·70	0·032	0·037	3·33	0·28		1½	OQ850 T600	50·0	58·4	23	59	42	11
			"	"	"	"	"	"	"		2 5/16	" T590	48·7	57·3	23	59	38	"
			0·38					3·45	0·17		5	OQ850 T650	42·0	52·0	23½		68	3

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Actual Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
	5—6(3—4) 7—9	0·39	0·25	0·60	0·020	0·007	3·50	0·28	0·07	1⅛		56·9	63·3	22½	60½	55	10
	7	0·39		0·67			3·26	0·24		"	OQ830 T600	57·6	63·7	21	57	45	16
	"	"		"			"	"		"	" T650	51·2	56·4	23½	63½	60	"
	"	"		"			"	"		2½	" T600	50·9	59·2	21	57	54	"
	"	"		"			"	"		"	" T650	48·0	55·4	22½	63½	73	"
		0·39		0·66			3·57	0·17		11/16	OQ830 T600	58·5	60·0	20½		65	13
		"		"			"	"		1⅛	" "	48·0	59·0	21		62	"
		"		"			"	"		"	" T650	46·0	58·0	23		72	"
		"		"			"	"		1½	" T640	46·0	57·0	23		74	"
				"			"	"		2⅛	" T600	47·0	58·0	21		53	"
				"			"	"		"	" T650	45·0	57·0	23		65	"
				"			"	"		4	" T640	40·0	54·0	23		57	"
		"		"			"	"		4¼	" T600	41·0	53·0	21		40	"
				"			"	"		"	" T650	38·5	52·0	22		53	"
	6—7	0·40		0·67			3·31	0·14		1⅛	OQ830 T650	41·6	52·3	28	63½		16
	"	"		"			"	"		2½	" T600	45·2	54·5	23½	61½		"
	"	"		"			"	"		"	" T650	42·7	51·6	24½	63½		"
	"	"		"			"	"		3	" T600	45·6	54·5	21½	59		"
	"	"		"			"	"		"	" T650	40·4	52·4	24	61½		"
		0·40					3·57	0·22		1⅛	OQ850 T580	59·8	65·4	21		55	3
		0·40					3·43	0·21		"	" T655	46·6	55·0	24		79	"
	3	0·40		0·66			3·47	0·22		"	OQ830 T575	61·1	65·7	19½	57	52	2
	"	"		"			"	"		"	" T600	58·2	63·7	19	57	60	"
	"	"		"			"	"		"	" T625	54·7	59·7	22	59	72	"
	"	"		"			"	"		2½ sq.	" T575	56·2	62·0	19	52	60	"
	"	"		"			"	"		"	" T600	57·1	62·0	18½	52	64	"
	"	"		"			"	"		"	" T625	55·2	58·0	20	55	74	"
	"	"		"			"	"		4 sq. (C)	" T575	48·9	56·0	19½	47	47	"
	"	"		"			"	"		" (O)	" "	49·4	57·3	20	55	55	"
	"	"		"			"	"		" (C)	" T600	49·6	58·0	18½	47	46	"
	"	"		"			"	"		" (O)	" "	49·6	59·0	20½	55	51	"
	"	"		"			"	"		" (C)	" T625	45·6	55·6	20½	47	55	"
	"	"		"			"	"		" (O)	" "	41·6	56·0	22	59	74	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Actual Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) ons/sq.in.	0·5% P.S. (0·5Rp) ons/sq.in.	Y.P. (Rs) ons/sq.in.	T.S. (Rm) ons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
		0·41					3·51	0·15		1 1/8	OQ850 T600			52·4	60·4	22		61	3
		"					"	"		2 7/8	" "			46·8	56·2	23		66	"
		"					"	"		3 1/8	" T645			42·0	52·2	20		78	"
		0·41					3·63	0·27		1 5/8	" T600			51·6	59·0	22		80	"
		"					"	"		2 1/8	" "			49·8	58·2	24		72	"
		0·41					3·65	0·19		1 1/4	" T650			46·6	55·0	24		79	"
		"					"	"		1 3/8	" "			43·2	54·8	24		86	"
		"					"	"		2	" "			40·0	53·6	28		61	"
		"					"	"		2 1/2	" "			43·2	53·0	23		84	"
		0·41					3·55	0·23		6 1/4	" T630			45·0	53·6	23		51	"
	7	0·41		0·74			3·30	0·19		1 1/8	OQ830 T550			60·7	65·8	19 1/2	59	61	2
	"	"		"			"	"		"	" T600			52·8	58·3	22 1/2	62	81	"
	"	"		"			"	"		"	" T650			47·9	54·5	25	66	86	"
	"	"		"			"	"		2 1/4	" T550			52·1	60·4	21	57	56	"
	"	"		"			"	"		"	" T600			46·9	56·5	24 1/2	62	79	"
	"	"		"			"	"		"	" T650			42·4	52·5	26	64	85	"
	"	"		"			"	"		3 sq.(C)	" T550			49·2	58·8	19	52	49	"
	"	"		"			"	"		" (O)	" "			52·0	60·8	20	57	52	"
	"	"		"			"	"		" (C)	" T600			44·3	54·8	21 1/2	55	64	"
	"	"		"			"	"		" (O)	" "			44·8	55·5	23 1/2	62	71	"
	"	"		"			"	"		" (C)	" T650			39·5	51·8	24	59	75	"
	"	"		"			"	"		" (O)	" "			42·1	52·0	25	64	79	"
B.O.H.		0·42	0·27	0·60	0·039	0·033	3·41	0·22		2	OQ850 T600			47·2	56·0	24	57	55	11
B.O.H.		0·42	0·28	0·72	0·034	0·023	3·33	0·34		2 1/2	" "			45·6	56·0	23	61	70	"
B.O.H.		0·42	0·24	0·67	0·028	0·03	3·60	0·25		3 1/4	" T580			51·2	60·1	21	56	52	"
"		"	"	"	"	"	"	"		4	" "			52·4	61·0	22	59	41	"
"		0·42	0·30	0·62	0·010	0·015	3·25	0·06		1 1/8	" T560			42·7	53·2	22	63	76	"
"		0·42	0·25	0·64	0·021	0·018	3·31	0·06		1 5/8	" "			43·6	54·0	23	61	75	"
	5—6(4) 7	0·42	0·30	0·60	0·040	0·030	3·29	0·20	0·14	1 3/8	N875 OQ850 T600			59·2	66·5	19 1/2	54 1/2	33	10
B.E.A.		0·42	0·26	0·64	0·016	0·012	3·45	0·08		1 1/8	OQ830 T600			52·0	61·2	21	57	54	17
		0·42					3·57	0·23		1	OQ850 T600			55·8	62·0	22		66	3
		"					"	"		3 5/8	" T650			46·4	55·0	22 1/2		—	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Actual Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	E l % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.O.H.		0·43	0·32	0·63	0·036	0·035	3·30	0·30		1⅛	OQ850 T650			52·0	57·2	24	57	50	11
		"	"	"	"	"	"	"		2	" T600			48·0	58·8	24	55	55	"
		0·43		0·75			3·38	0·17		1⅛	" T600			55·9	61·9	21	60	64	18
		"		"			"	"		"	" T630			49·6	56·7	23	64	75	"
		"		"			"	"		2½	" T600			51·1	57·8	20	58	58	"
		"		"			"	"		3¼	" "			44·4	54·0	19	50	59	"
B.E.A.		0·43	0·19	0·64			3·58	0·20		1⅛	" T570	53·0	56·4		63·8	22	61	55	3
B.O.H.		0·44	0·23	0·67	0·039	0·036	3·60	0·25		2⅜	OQ850 T620			48·8	58·9	19	49	49	11
		0·45		0·51			3·41	0·29		1⅛	OQ820 T640			45·0	58·0	21		59	13
		"		"			"	"		2⅛	" "			42·0	56·0	22		53	"
		"		"			"	"		3	" "			41·0	55·0	22½		43	"
		"		"			"	"		11/16	" T600			58·0	65·0	17		40	"
		"		"			"	"		1⅛	" "			53·0	63·0	18½		39	"
		"		"			"	"		2⅛	" "			45·6	58·0	20½		38	"

EFFECT OF COLD WORK

Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Heat Treatment °C	Hardness (HV) for stated % cold work (cold drawn)* 0%	10%	20%	40%	60%	80%	Ref.
0·36	0·31	0·56	0·013	0·013	3·28	0·16	Annealed	190	226	270	278	292	304	24

* Tests carried out on small diameter rods.

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)			
C	Mn	Ni	Cr
0·41	0·65	3·45	0·10

1⅛ in. dia. bars. Oil Quenched from 830°C.

(Ref. 12)

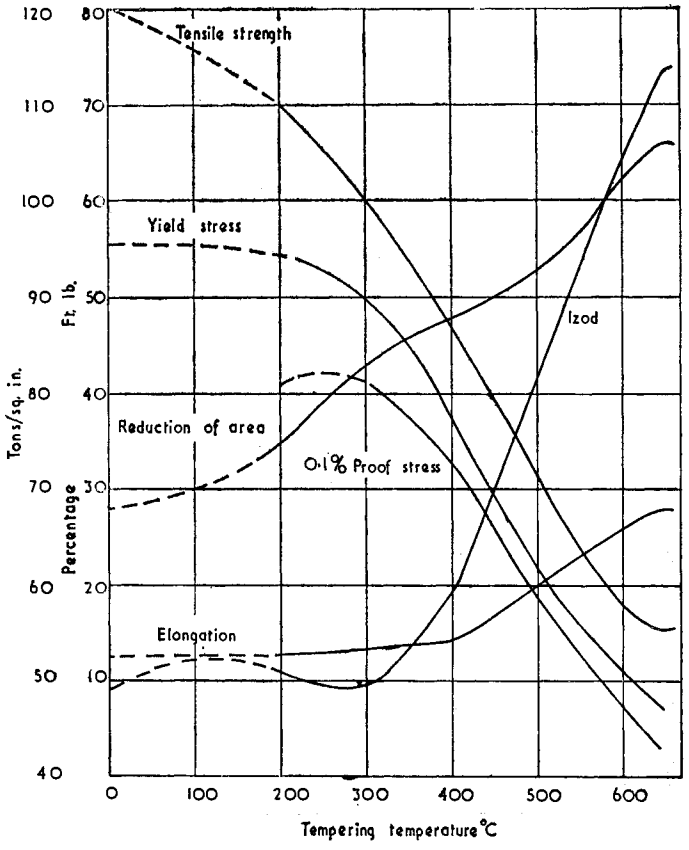


Fig. 22.10

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE

These curves have been constructed from the results obtained on several casts of En 22.

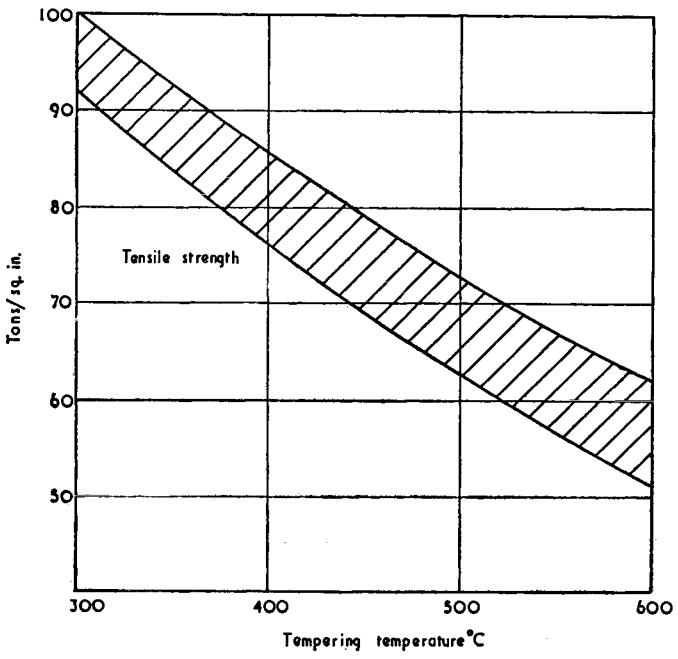


Fig. 22.11 (A)

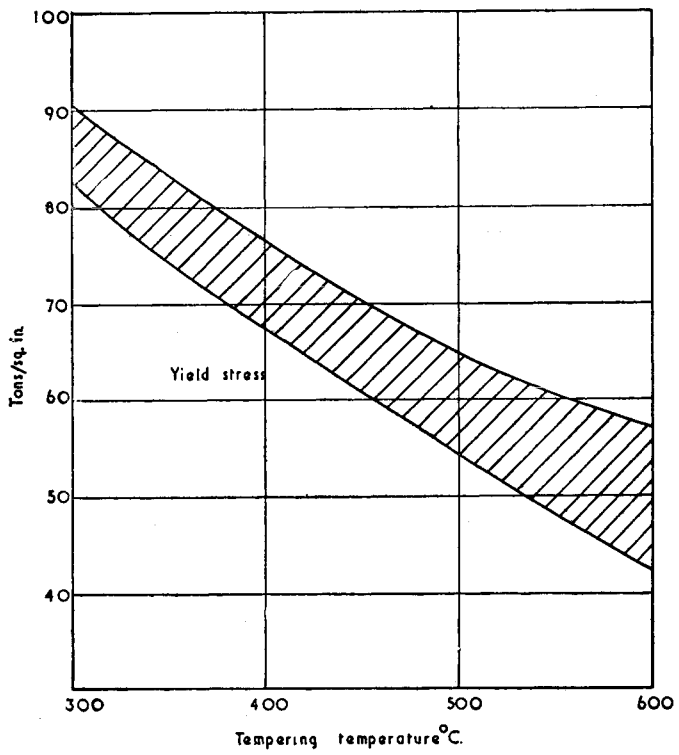


Fig. 22.11 (B)

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES (Continued)

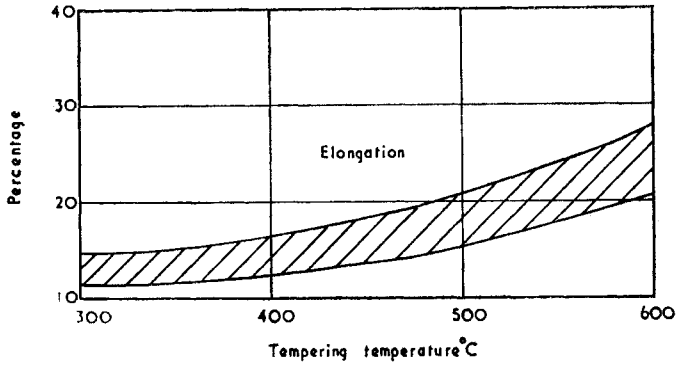


Fig. 22.11 (C)

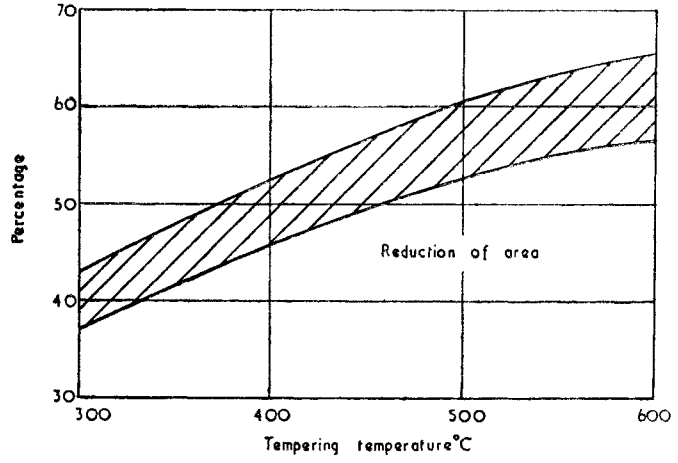


Fig. 22.11 (D)

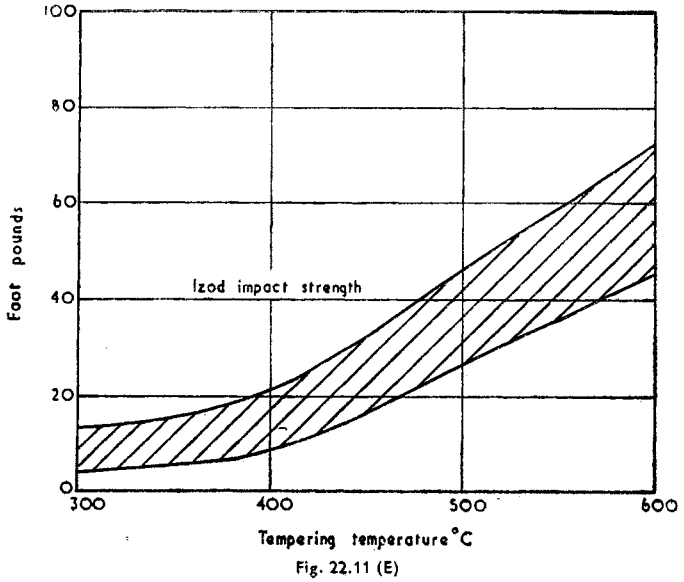


Fig. 22.11 (E)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Bars Oil Quenched and Tempered as indicated.

These curves have been constructed from the results obtained on several casts of En 22.

Tempered 550°C

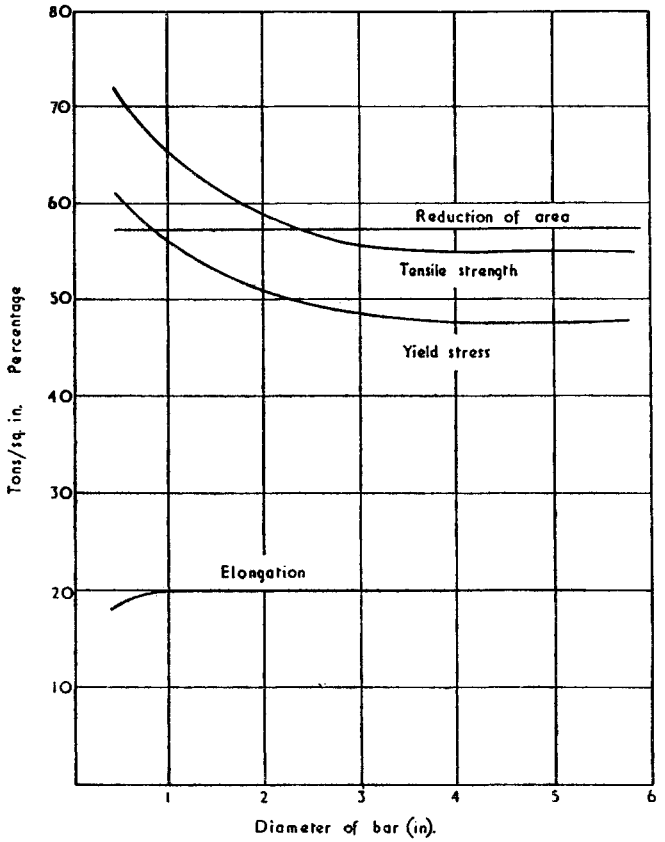


Fig. 22.12

Tempered 600°C

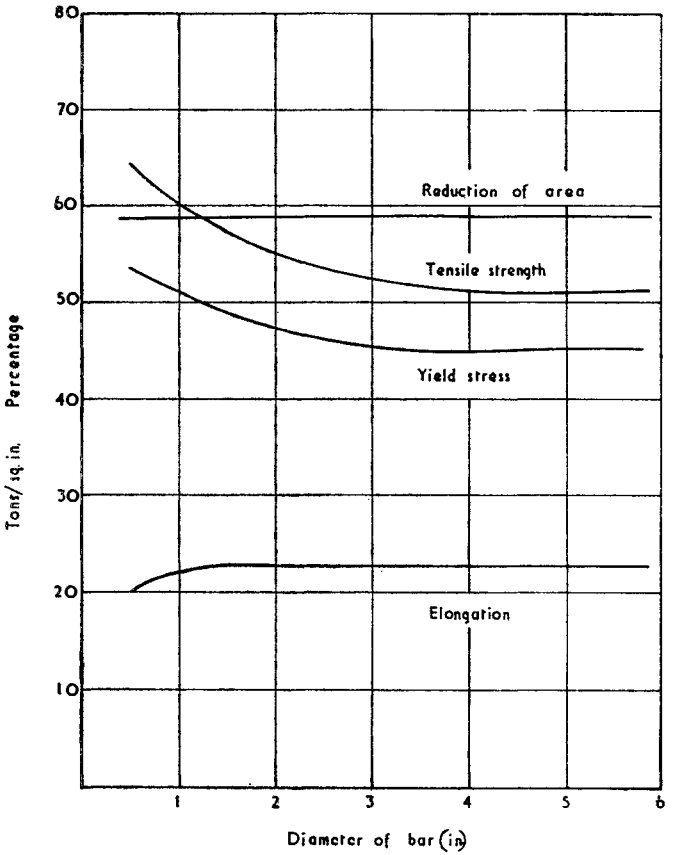


Fig. 22.13

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

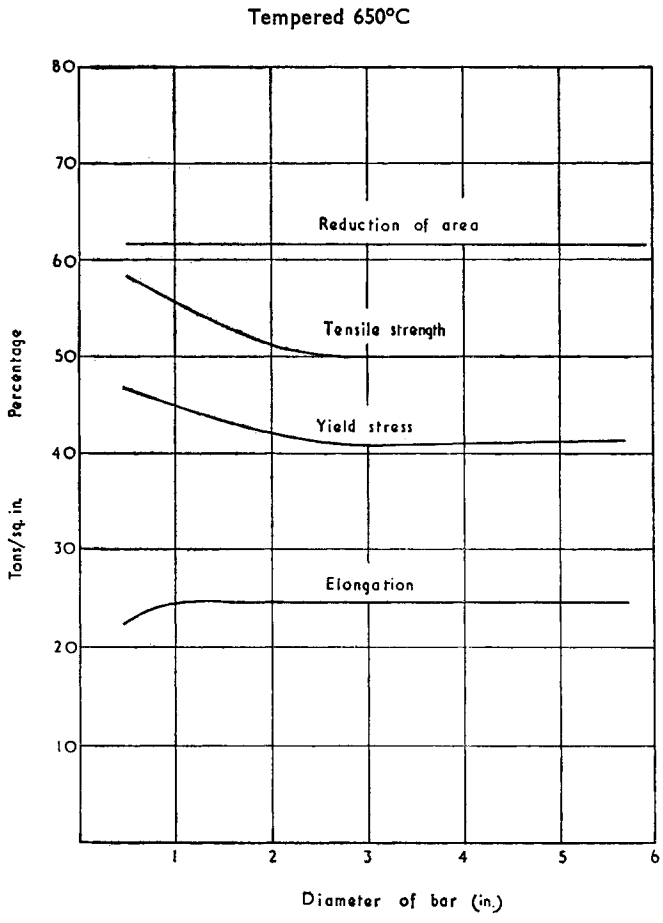


Fig. 22.14

MECHANICAL PROPERTIES AT LOW TEMPERATURE

Chemical Composition %								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Izod ft.lb.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.							
0·42	0·17	0·62	0·027	0·018	3·22	0·18	0·02		OQ820 T700	25		31·6		52·7	21	39½	60	19
"	"	"	"	"	"	"	"		" "	—120		37·2		63·8	7	6½	13	"
"	"	"	"	"	"	"	"		" "	—195		51·5		67·2	3	3	—	"
"	"	"	"	"	"	"	"		" "	0							61	"
"	"	"	"	"	"	"	"		" "	— 20							57	"
"	"	"	"	"	"	"	"		" "	— 60							36	"
"	"	"	"	"	"	"	"		" "	— 80							25	"
"	"	"	"	"	"	"	"		" "	—100							14	"
																	Charpy K ft.lb.	
0·36	0·24	0·60	0·016	0·018	3·48	0·25			OQ800 T566	R.T.				57·1	22½	63½	40	20
"	"	"	"	"	"	"			" "	— 20							37	"
"	"	"	"	"	"	"			" "	— 40				62·7	24	60½	38	"
"	"	"	"	"	"	"			" "	— 60							33	"
Not stated								1¼	O Q & T	20	51·5	53·5	56·7	62·1	21			21
								"	"	—100	56·9	57·9	61·8	71·7	25			"
								"	"	—195	75·0	75·4	76·3	87·0	25			"

IMPACT TRANSITION TEMPERATURE DATA

ASTM Grain Size McQuaid Ehn	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	80% Charpy V Maximum Energy Transition Temp °C	Ref.
	C	Si	Mn	S	P	Ni	Cr				
8—9	0·43	0·22	0·83	0·028	0·020	3·38		½×2½	OQ845 T204	10	22
"	"	"	"	"	"	"		"	" T316	27	"
"	"	"	"	"	"	"		"	" T429	7	"
"	"	"	"	"	"	"		"	" T538	—68	"
"	"	"	"	"	"	"		"	" T649	—46	"

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Rotating Bending Wöhler Fatigue Limit 10^7 rev. tons/sq.in.	Reverse Torsion Fatigue Limit tons/sq.in.	Ref.
B.E.A.	0·43	0·19	0·64	—	—	3·58	0·20	1 1/8	OQ850 T570	53·0	56·4		63·8	22	6	55	±27	—	3
	0·41	0·25	0·75	0·020	0·020	3·41	0·18	1 sq.	OQ830 T593 FC	—	—	48·6	55·0	22 1/2	59	—	±28·6	±16·6	23
	"	"	"	"	"	"	"	"	" T649 FC	—	—	40·7	49·9	23 1/2	60	—	±28·1	±16·1	"
	"	"	"	"	"	"	"	"	" T593 FC	—	—	42·0	52·4	21	60	—	±28·6	—	"
	"	"	"	"	"	"	"	"	FC785	—	—	28·8	44·9	25 1/2	52	—	±24·1	—	"
	"	"	"	"	"	"	"	"	OQ780	—	—	—	131·2	6	47 1/2	—	±53·6	—	"
	"	"	"	"	"	"	"	"	" T204	—	—	87·7	125·9	8	48 1/2	—	±50·0	—	"
	"	"	"	"	"	"	"	"	" T316	—	—	70·9	100·9	7 1/2	56 1/2	—	±43·7	—	"
	"	"	"	"	"	"	"	"	" T538	—	—	60·6	66·3	13	57 1/2	—	±34·8	—	"
	"	"	"	"	"	"	"	"	" T649	—	—	38·7	54·2	16	60 1/2	—	±29·0	—	"
																	Longi-tudinal / Trans-verse		
	(within specification)							3/8	OQ and T			(Approx.)	59				±32·5 —		21
								"	"			"	66				±35·2 —		"
								"	"			"	72				±38·0 —		"
								"	"			"	78				±39·3 —		"
								3 sq.	"			"	53				±25·8 ±23·6		"
								"	"			"	66				±34·0 ±31·7		"

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En 23

3 PER CENT NICKEL-CHROMIUM STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo*
0·25—0·35	0·10—0·35	0·45—0·70	0·050 max.	0·050 max.	2·75—3·50	0·50—1·00	0·65 max.

* Optional addition

MECHANICAL PROPERTIES

	Hardened & Tempered Condition			
	S	T	U	V
Limiting ruling section, in.	6	6	6	4½
Tensile strength, tons/sq.in., min. (Rm)	50	55	60	65
Yield stress (1) tons/sq.in., min. (Rs)	38	44	48	52
0·2% Proof stress (2) tons/sq.in., min. (0·2Rp)	36	41	46	50
Elongation, %, min. (A)	20	18	17	16
Izod impact value, ft. lb., min.	40	40	35	35
Brinell hardness No. (3) (HB)	223/277	248/302	269/321	293/341

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 269.

(1) Not to be used as acceptance tests except by special arrangement between the purchaser and manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

United Kingdom	France	Germany			Sweden	U.S.S.R.	
En No.	AFNOR	Werkstoff No.	Name	DIN	SIS	GOST	Mark
23	30 NC 11	1.5755	22NiCr14	—	14.2534	4543—61	30KhN3A

APPLICATIONS

An alloy steel of fairly high hardenability which combines a high elastic limit with good ductility and resistance to shock with tensile strengths of the order of 55 tons/sq.in. in medium section sizes. The addition of molybdenum increases the hardenability in larger section sizes and the resistance to temper brittleness. Good low temperature impact values are obtainable.

Uses: crankshafts, transmission shafts, axleshafts, connecting rods, gears and cams, high tensile studs and bolts, spindles, rocker arms, etc.

WELDING

The welding characteristics will be very similar to those for En 22 and En 24.

MACHINABILITY

The machinability in the annealed condition is approximately 55% of that for mild steel (En3). When hardened and tempered to 55/65 tons/sq.in. the machinability is approximately 40% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C. Retarded cooling is advisable for large and intricate sections.
Annealing	830°C to 850°C. Furnace cool.
Softening (sub-critical annealing)	640°C to 660°C. Air or furnace cool.
Hardening	820°C to 850°C. Oil quench.
Tempering	550°C to 660°C. Air, oil or water quench.

If an adequate molybdenum content is not present it is preferable to cool in oil or water after tempering.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·31	0·14	0·70	—	—	3·40	0·70	—	OQ850 T600	7·87	1
0·32	0·25	0·55	0·025	0·018	3·41	0·71	0·06	A860 T640	7·848	2
0·33	0·17	0·53	0·033	0·031	3·38	0·80	0·07	" "	7·847	"

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cal/g deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·32	0·25	0·55	0·025	0·018	3·41	0·71	0·06	A860 T640	0·116	0·121	0·124	0·127	0·133	0·141	0·155	0·164	0·162	0·160	2
0·33	0·17	0·53	0·033	0·031	3·38	0·80	0·07	" "	0·117	0·121	0·125	0·128	0·134	0·142	0·158	0·165	0·162	0·160	"
			(within specification)					—	—	—	0·125	—	0·136	—	—	—	—	—	3

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	10^6 x Mean Coefficient of Thermal Expansion/deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·32	0·25	0·55	0·025	0·018	3·41	0·71	0·06	A860 T640	11·6	12·3	12·8	13·3	13·7	14·0	13·8	10·8	12·2	13·2	2
0·33	0·17	0·53	0·033	0·031	3·38	0·80	0·07	" "	11·5	12·4	12·9	13·3	13·6	13·9	13·8	10·7	12·1	13·1	"
			(within specification)					—	12·3	—	12·9	—	13·8	—	—	—	—	—	3
			(within specification)					—	11·5	—	12·6	—	13·4	—	13·9(680°C)	—	—	—	4

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm												Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·32	0·25	0·55	0·025	0·018	3·41	0·71	0·06	A860 T640	26·5	28·0	32·5	39·5	47·7	57·2	68·6	82·0	99·0	111·7	115·0	118·0	2
"	"	"	"	"	"	"	"	WQ 950	—	35·7	—	—	—	—	—	—	—	—	—	—	5
0.33	0·17	0·53	0·033	0·031	3·38	0·80	0·07	A860 T640	25·6	26·8	31·7	38·7	46·9	56·7	68·1	81·7	98·1	111·5	114·8	117·8	2
"	"	"	"	"	"	"	"	WQ 950	—	34·8	—	—	—	—	—	—	—	—	—	—	5
0·39	0·21	0·64	—	—	3·55	0·85	—	OQ830 T630	—	—	31·7	—	—	55·7	—	—	98·4	—	—	—	6
			(within specification)						—	30·8	35·0	41·3	—	—	—	—	—	—	—	—	3

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Conductivity cal/cm s deg. C											Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·32	0·25	0·55	0·025	0·018	3·41	0·71	0·06	A860 T640	0·080	0·085	0·087	0·087	0·087	0·082	0·076	0·068	0·062	0·063	0·066	2
0·33	0·17	0·53	0·033	0·031	3·38	0·80	0·07	" "	0·082	0·086	0·088	0·088	0·087	0·084	0·080	0·070	0·062	0·063	0·066	"

YOUNG'S MODULUS (E); SHEAR MODULUS (G); POISSON'S RATIO (σ)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.		Shear Modulus tons/sq. in.		Poisson's Ratio		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic*	Static	Dynamic*	Static	Dynamic*	
0·31	—	0·64	—	—	3·24	0·70	0·22	OQ and T	RT	13100						6
"		"			"	"	"	(55/60								
								tons/sq.in)	100	13300						"
"		"			"	"	"		150	12900						"
"		"			"	"	"		200	12850						"
"		"			"	"	"		250	12500						"
"		"			"	"	"		300	12600						"
"		"			"	"	"		350	11500						"
			(within specification)					OQ and T (high impact condition)	RT	12,950	13,200	5100	5130	0·27	0·290	7
								OQ and T (low impact condition)	RT	12,900	13,200	5130	5130	0·26	0·290	"

* Ultrasonic Pulse Method

YOUNG'S MODULUS (E); SHEAR MODULUS (G); POISSON'S RATIO (σ) (Continued)

Chemical Composition (%)								Heat Treatment °C	Young's Modulus (static) tons/sq.in at					Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	—60°C	—120°C	—150°C	—195°C	
0·25	0·13	0·59	0·027	0·025	2·86	0·68	0·48	OQ860 T600	13200	13600	13700	13850	14100	6
0·30	0·19	0·47	0·030	0·030	2·94	0·83	0·49	" T630	13150	13450	13700	13850	14050	"
0·32	0·26	0·82	0·034	0·025	3·06	0·71	0·53	" T640	13300	13550	13750	13850	14100	"
0·35	0·24	0·57	0·030	0·021	3·08	0·67	0·50	" T640	13350	13550	13700	13750	13900	"

MAGNETIC PROPERTIES

Chemical Composition (%)								Heat Treatment °C	Magnetic Induction B (Gauss) for magnetizing field of H (Oersted)									Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		H = 10	20	40	50	60	100	150	200	250	
0·33	0·22	0·59	0·009	0·012	3·44	0·64		OQ830 T600	1000	9600	14300	15200	15900	17300	18200	19000	—	1
"	"	"	"	"	"	"		" T620	3600	13000	15600	16100	16500	17200	18000	18400	—	"
0·35	0·21	0·59	0·036	0·030	3·08	0·81		OQ840 T530	1500	4200	16200	17000	17500	18500	19100	19600	19950	3

TRANSFORMATION CHARACTERISTICS

(For steels containing molybdenum, see En 27)

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·23	0·57	0·007	0·005	3·26	0·85	0·09

Basic Electric Arc.
As quenched grain size 9 (ASTM).
McQuaid Ehn grain size 4 to 5 (ASTM).
The hardness values shown in the diagram are those of the fully transformed steel.

(Ref. 8)

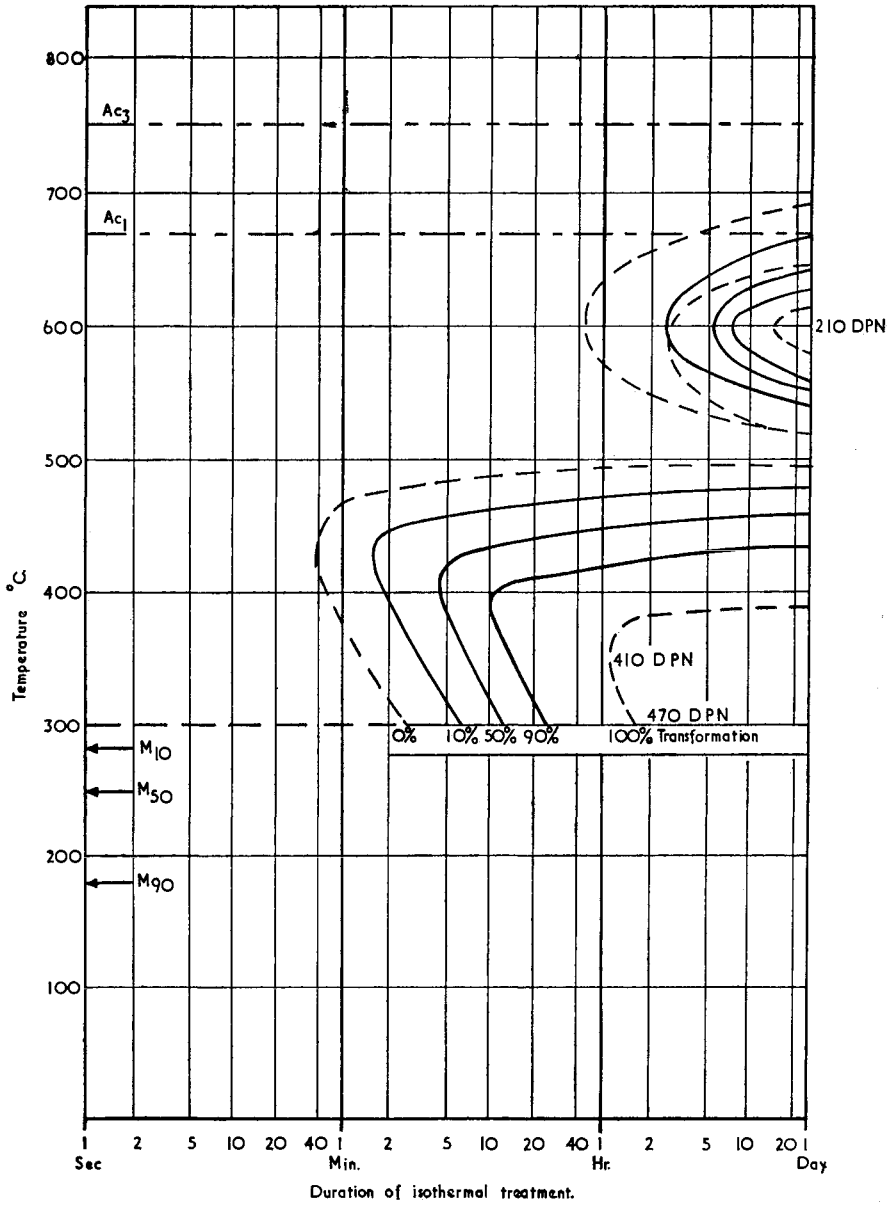


Fig. 23.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·32	0·51	0·016	0·008	3·38	0·83	0·03

Electric Arc.
Actual grain size 8.

(Ref. 9)

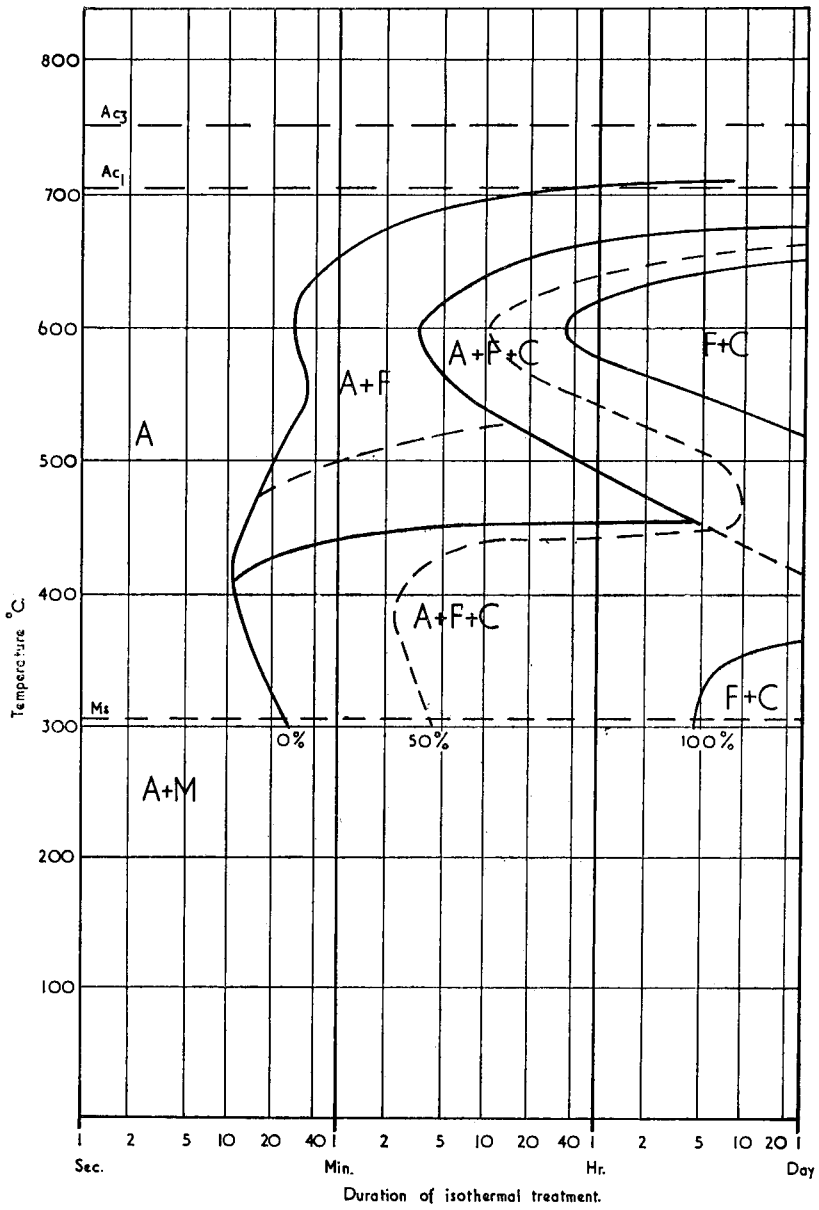


Fig. 23.2

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·23	0·57	0·007	0·005	3·26	0·85	0·09

Basic Electric Arc.
As quenched grain size 9 (ASTM).
McQuaid Ehn grain size 4 to 5 (ASTM).

(Ref. 8)

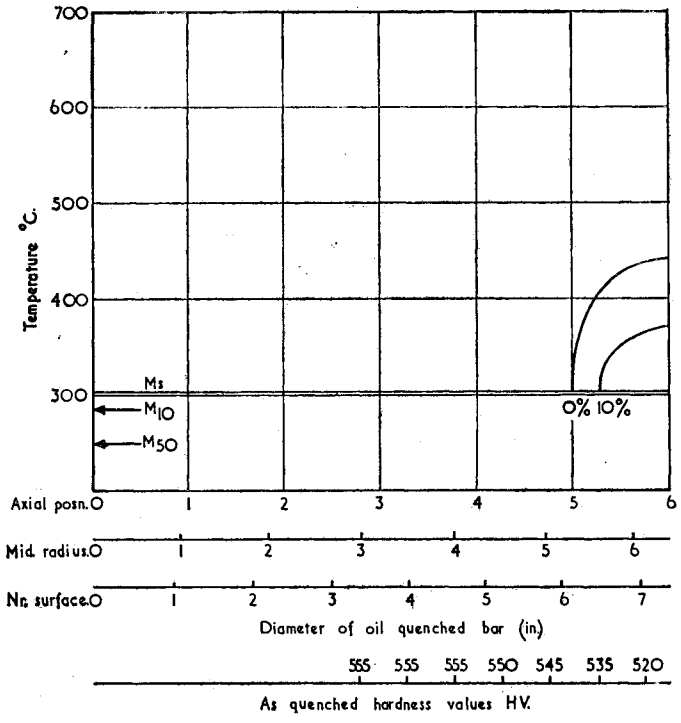


Fig. 23.3

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·23	0·57	0·007	0·005	3·26	0·85	0·09

Basic Electric Arc.
As quenched grain size 9 (ASTM).
McQuaid Ehn grain size 4—5 (ASTM).

Bars end quenched from 835 °C

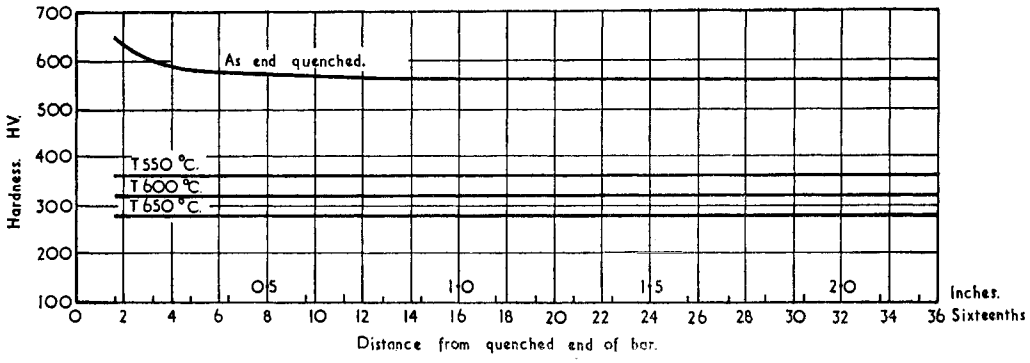


Fig. 23.4

Curve No.	Process of Manufacture	Chemical Composition (%)								Grain Size	
		C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn
A	A.O.H.	0·33	0·19	0·58	0·029	0·028	3·49	0·76	0·06	7 (6) (8)	3—4
B	E.	0·33	0·23	0·56	0·021	0·019	3·59	0·88	0·07	7—8	7—8 (6)

Bars Normalized 875 °C. End Quenched 850 °C. (Ref. 10)

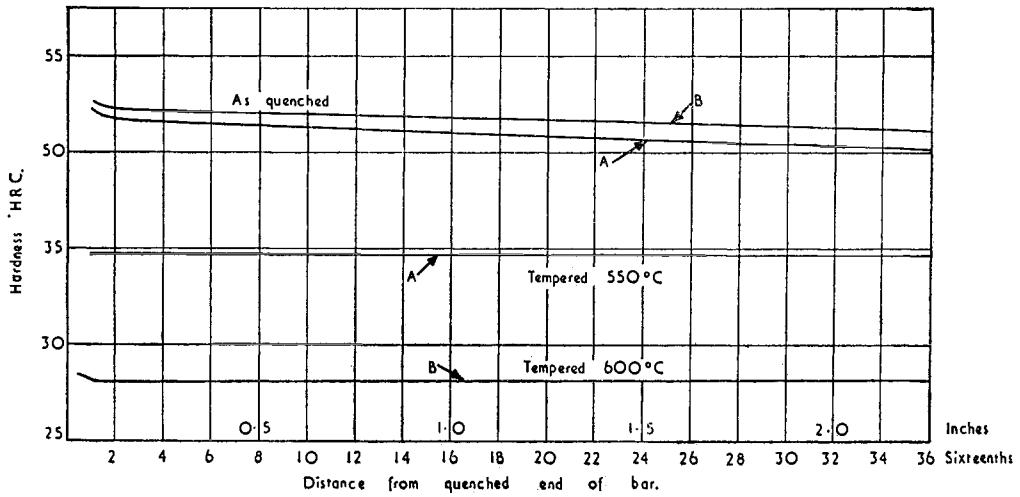


Fig. 23.5

END QUENCH HARDENABILITY BAND

These curves have been constructed from results obtained on several casts of En 23.

(Ref. 4)

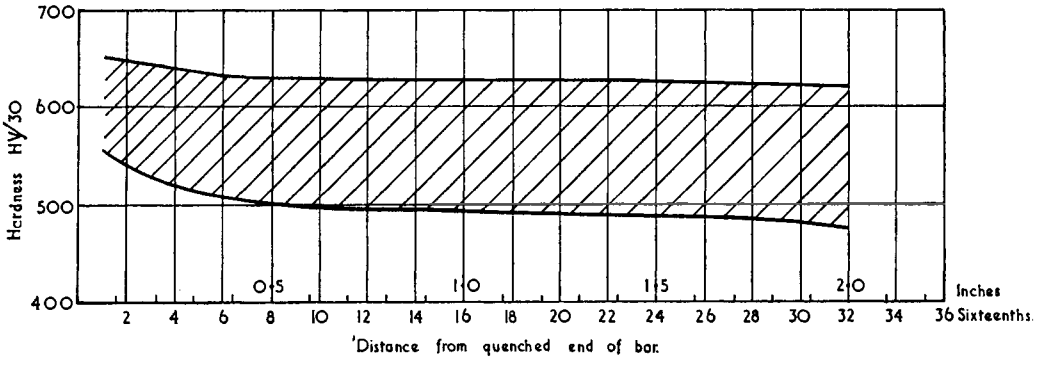


Fig. 23.6

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(For steels containing molybdenum, see En 27)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.								
	0·25		0·37			3·51	0·52		$\frac{11}{16}$	OQ830 T580				51·0	57·0	18		57	11
	"		"			"	"		$1\frac{1}{8}$	" T580				46·0	53·0	21		60	"
	0·27	0·17	0·49	0·040	0·040	3·45	0·95		$1\frac{1}{8}$	AC.850				55	72	15	41	6	12
	"	"	"	"	"	"	"		"	" T200				58	71	15	46	8	"
	"	"	"	"	"	"	"		"	" T300				60	70	15	48	3	"
	"	"	"	"	"	"	"		"	" T400				57	67	16	51	5	"
	"	"	"	"	"	"	"		"	" T500				51	60	18	54	17	"
	"	"	"	"	"	"	"		"	" T600				45	54	22	60	48	"
	"	"	"	"	"	"	"		"	" T650				43	52	23	62	64	"
	"	"	"	"	"	"	"		"	OQ820 T400				78	86	14	50	6	"
	"	"	"	"	"	"	"		"	" T500				67	73	18	54	19	"
	"	"	"	"	"	"	"		"	" T600				56	62	22	60	47	"
	0·28	0·29	0·56	—	—	3·23	0·62	0·25	$3\frac{1}{2}$	OQ840 T590				51·0	60·0	21	59	60	4
	0·29	0·19	0·64	—	—	3·32	0·68		0·66	OQ840 T600				52·0	58·4	23		89	1
	0·29	—	0·54	—	—	3·14	0·75		3 sq.	OQ830 T600				60·4	64·2	$18\frac{1}{2}$		50	11
B.E.A.	0·29	0·08	0·33	0·015	0·011	3·29	0·52		$1\frac{1}{8}$	OQ850 T500 1 hr.				64·7	68·1	15	$49\frac{1}{2}$	30	1
"	"	"	"	"	"	"	"		"	" T550 "				52·6	57·8	21	$63\frac{1}{2}$	52	"
"	"	"	"	"	"	"	"		"	" T600 "				45·0	51·5	24	67	63	"
"	"	"	"	"	"	"	"		"	" T650 "				39·6	48·0	26	69	101	"
"	"	"	"	"	"	"	"		2	" T500 "				51·3	57·3	20	$57\frac{1}{2}$	25	"
"	"	"	"	"	"	"	"		"	" T550 "				49·6	53·8	21	$61\frac{1}{2}$	43	"
"	"	"	"	"	"	"	"		"	" T600 "				42·7	50·2	24	$65\frac{1}{2}$	58	"
"	"	"	"	"	"	"	"		"	" T650 "				36·8	46·1	$26\frac{1}{2}$	68	75	"
"	"	"	"	"	"	"	"		4	" T500 "				36·6	45·1	23	$61\frac{1}{2}$	37	"
"	"	"	"	"	"	"	"		"	" T550 "				36·3	44·3	23	$61\frac{1}{2}$	34	"
"	"	"	"	"	"	"	"		"	" T600 "				34·1	43·2	25	$64\frac{1}{2}$	54	"
"	"	"	"	"	"	"	"		"	" T650 "				30·5	40·5	26	67	71	"
"	"	"	"	"	"	"	"		8	" T600 $3\frac{3}{4}$ hrs.				27·7	39·4	27	59		"
"	0·29	0·25	0·58	0·017	0·018	3·50	0·73		$1\frac{1}{8}$	" T610 1 hr. WQ	55·0		56·6		62·5	22	63	76	"
	0·29	0·16	0·51	—	—	3·12	0·63		1	OQ840 T620				47·0	56·0	23	$65\frac{1}{2}$	84	"
	0·29	0·23	0·59	—	—	3·30	0·74		$1\frac{1}{4}$	OQ850 T580				56·0	63·5	$20\frac{1}{2}$	63	76	4

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(For steels containing molybdenum, see En 27)

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.								
	0·30		0·60			3·00	0·75	—	$\frac{7}{8}$	OQ850 T580	47·3	50·7	55·5		62·3	23	62½		4
	"		"			"	"	—	"	" T650	37·0	38·0	39·4		52·6	25½	64½		"
B.E.A.	0·30		"			2·70	0·58	0·25	1	" T600	52·2	52·3	53·2		59·6	22½	61½		"
"	"		"			"	"	"	"	" T650	40·5	41·2	41·8		53·3	26	65		"
"	"		"			"	"	"	4 sq.	" T600	43·7	45·0	46·4		54·3	23½	63		"
"	"		"			"	"	"	"	" T650	39·7	40·1	46·0		50·4	26	66		"
	0·30	0·21	0·62			3·14	0·17	—	$1\frac{1}{16}$ hex	" T630				51·0	59·0	22	62½	84	"
	0·30	0·23	0·60			3·04	0·75	—	2	" T600				53·0	61·0	22	61½	70	"
	0·30	0·27	0·55			3·15	0·75	0·22	$1\frac{3}{4}$	OQ840 T650				49·0	58·0	24	66	90	"
	0·30	0·24	0·61			3·20	0·74	0·23	$4\frac{1}{2}$	" T610				59·0	65·0	23	61½	68	"
	0·30		0·59			3·19	0·70	0·28	$2\frac{1}{8}$	" "				48·0	58·0	24	71		11
	"		"			"	"	"	3	" "				48·0	58·0	23	70		"
	"		"			"	"	"	4	" "				47·0	57·0	24	74		"
	0·30		0·54			3·23	0·82	0·10	$1\frac{1}{8}$	OQ830 T620 WQ				52·0	59·6	23	92		13
	0·30		0·51			3·50	0·77	0·09	$2\frac{1}{2}$	" T630 WQ				47·2	55·2	26	95		"
	0·30	0·25	0·63			3·33	0·73	—	$1\frac{1}{8}$	OQ840 T620				49·2	57·4	24½	84		1
	0·30					3·52	0·71	—	1	OQ850 T650				47·0	55·8	24	89		"
	0·30	0·14	0·56			3·62	0·73		$1\frac{1}{8}$	OQ830 T650 WQ			48·8		57·8	19	66½	70	"
	"	"	"			"	"		"	" " AC			49·0		58·6	18	65	65	"
	0·30					3·00	0·75		$1\frac{1}{8}$	OQ830 T400				75	85	13	44	13	14
	"					"	"		"	" T500				65	70	17	50	30	"
	"					"	"		"	" T550				60	65	19	54	38	"
	"					"	"		"	" T600				55	62	21	57	49	"
	"					"	"		"	" T650				51	58	24	66	64	"
	"					"	"		$2\frac{1}{4}$	" "				50	56	23	64	62	"
	"					"	"		$4\frac{1}{2}$	" "				42	52	24	66	66	"
	0·30		0·51			3·15	0·80		3 sq.	" T600				53·8	59·6	22	57	74	3

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

ASTM Grain size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)		
	0·31	0·22	0·50	0·022	0·017	3·48	0·47	—	1 1/8	OQ830 T630 1hr WQ	48·0	53·8	23	68 1/2	93	1
	"	"	"	"	"	"	"	—	"	" 2hrs. WQ	43·1	51·9	25 1/2	69 1/2	99	"
	"	"	"	"	"	"	"	—	" "	" T630 4hrs. WQ	42·3	50·6	24 1/2	69 1/2	98	"
	"	"	"	"	"	"	"	—	"	" T630 8hrs. WQ	39·9	49·3	25 1/2	69 1/2	107	"
	"	"	"	"	"	"	"	—	"	" T630 16hrs. WQ	37·6	46·2	29	69 1/2	120	"
	0·31	0·14	0·70	0·027	0·030	3·27	0·82	—	11/16	OQ820 T500	66	72	19	58	30	12
	"	"	"	"	"	"	"	—	"	" T600	56	62	24	64	62	"
	"	"	"	"	"	"	"	—	"	" T650	50	58	25	66	77	"
	"	"	"	"	"	"	"	—	1 1/8	N.820		67	15	40	6	"
	"	"	"	"	"	"	"	—	"	OQ820		116	14	37	11	"
	"	"	"	"	"	"	"	—	"	" T100		114	14	43	17	"
	"	"	"	"	"	"	"	—	"	" T200		107	14 1/2	50	20	"
	"	"	"	"	"	"	"	—	"	" T300		97	14 1/2	53	4	"
	"	"	"	"	"	"	"	—	"	" T400	75	85	16	34	8	"
	"	"	"	"	"	"	"	—	"	" T500	65	71	19	56	28	"
	"	"	"	"	"	"	"	—	"	" T600	54	60	22 1/2	62	39	"
	"	"	"	"	"	"	"	—	"	" T650	48	57	24	65	74	"
	"	"	"	"	"	"	"	—	2 1/8	" T500	64 1/2	71	17	52	26	"
	"	"	"	"	"	"	"	—	"	" T600	53	60	22	62	57	"
	"	"	"	"	"	"	"	—	"	" T650	48	56	25	67	74	"
	0·31	0·26	0·57			3·10	0·79	—	2 1/16	OQ850 T650	47·0	56·0	23	66	91	4
	0·31	0·18	0·60			3·36	0·82	0·22	4×2	OQ840 T650	54·7	60·4	20 1/2	61	100	"
	0·31	0·21	0·62			3·33	0·70		1 1/4	" T560	66·4	70·2	20		60	1
	"	"	"			"	"		"	" T590	59·4	64·1	22		83	"
	0·31	0·27	0·57			3·24	0·87		3 3/4	" T600	53·8	60·0	22		74	"
	"	"	"			"	"		5	" T600	50·4	57·6	22		82	"
	0·31	0·66				3·32	0·76	0·18	2 1/2	OQ830 T560	62	68	17		43	11
	0·31	0·58				3·43	0·68	0·10	4 1/2	OQ830 T590 WQ	50·0	57·6	21		67	14
6—7	0·32		0·57			3·06	0·84		1 1/8	OQ830 T550	65·0	69·3	19	59	50	3
"	"		"			"	"		"	" T600	58·5	63·4	22 1/2	64	70	"
"	"		"			"	"		"	" T650	53·7	60·3	24 1/2	68	80	"
"	"		"			"	"		2 1/2	" T550	65·0	68·7	21	62	56	"
"	"		"			"	"		"	" T600	56·5	63·2	23 1/2	66	71	"
"	"		"			"	"		"	" T650	50·8	58·5	26	68	87	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El %	R.A. %	Izod ft.lb.	Ref.
			0·32		0·60			3·29	0·67	0·25	1⅛	" T640	54·0	62·0	22½		72	11
			"		"			"	"	"	2⅛	" "	53·0	61·5	22		67	"
			"		"			"	"	"	3	" "	53·0	61·5	22		63	"
			"		"			"	"	"	4¼	" "	53·0	61·0	22		60	"
			0·32	0·19	0·61			3·04	0·71	—	½	OQ850 T620	53·6	62·1	24	62½	59	4
			0·32	0·19	0·55			3·11	0·64	—	4½	OQ840 T640	49·1	56·8	20	59	78	"
			0·32	0·25	0·56			3·41	0·70	0·23	1⅞ × ⅞	" "	48·0	58·0	23	63½	83	"
			0·32	0·26	0·57			3·10	0·61	0·24	2⅜	" T630	55·0	62·0	23	63½	73	"
			0·32	0·22	0·61			3·21	0·64	0·22	5¼	" T620	54·0	60·4	20	63	72	"
			0·32	0·22	0·56			3·29	0·67	0·25	6	" T650	46·2	55·4	23	63	85	"
			0·32		0·60			3·07	0·83	0·20	5⅛	OQ830 T630	59·9	64·8	19		57	13
			0·33		0·54			3·32	0·71		1⅛	OQ T200	98·0	112·5	15	44	21	3
			0·33	0·27	0·60			3·28	0·86		2½	OQ840 T560	63·4	67·6	20		58	1
	3—4	7,6,8,	"	"	"			"	"		"	" T590	56·4	62·4	23½		75	"
A.O.H.	7—8	6,7—8	0·33	0·19	0·58	0·020	0·028	3·49	0·76	0·06	1	N875 OQ850 T550	59·2	67·0	19½	57½	37	10
B.E.A.			0·33	0·23	0·56	0·021	0·019	3·59	0·88	0·07	"	" "	62·4	69·0	19½	60	50	"
			0·34	0·17	0·55			3·41	0·77		1½	OQ840 T620	54·0	61·2	23		72	1
			"	"	"			"	"		4	" T610	50·8	59·2	23		65	"
			0·34		0·55			3·19	0·78		3	OQ830 T630	53·5	59·8	20½		64	13
			"		"			"	"		5	" T610	51·4	58·1	19½		50	"
			0·34		0·64			3·42	0·82		4 sq.	" T600	60·4	64·2	18½		50	12
			"		"			"	"		"	" T620	56·6	63·7	19		68	"
	2—4		0·34		0·60			3·18	0·62		Test piece	OQ830 T200	101·4	117·6	14½	47	17	3
	"		"		"			"	"		"	" T300	95·9	103·1	14½	47	6	"
	"		"		"			"	"		"	" T400	80·4	85·1	15	50	10	"
	"		"		"			"	"		"	" T450	74·4	77·2	16	52	20	"
	"		"		"			"	"		"	" T500	68·8	72·9	16	55	21	"
	"		"		"			"	"		"	" T550	62·4	67·0	18	50	45	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Actual Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq. in.	0·2% P.S. (0.2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
	2—4	0·34		0·60			3·18	0·62		1½	OQ830 T600 OQ				60·4	65·2	20	57	47	3
	"	"		"			"	"		"	" " FC				55·3	61·6	20½	57	10	"
	"	"		"			"	"		"	" T650				53·7	59·3	23	62	62	"
	"	"		"			"	"		2½ sq.	" T600				58·0	62·8	21	59	57	"
	"	"		"			"	"		"	" T650				49·6	56·5	24½	64	78	"
	"	"		"			"	"		3¾	" T600				57·0	62·2	20	59	57	"
		0·35		0·37			3·55	0·56		1⅛	OQ830 T600				50	60	20		58	11
		"		"			"	"		"	" T650				44	57	21		63	"
		"		"			"	"		2½	" T600				43	54	21		57	"
		0·35		0·61			3·14	0·85	0·20	4 sq.	" T630				59·4	66·6	20½		63	"
		0·35		0·53			3·10	0·57	0·20	4½	OQ840 T620				47	56·8	21		57	"
		0·35		0·62			3·12	0·78		4½ sq	" T600 M				54·9	61·2	21½	59	66	3
		0·35		0·58			3·12	0·81		7 sq.	" T600				52·8	60·9	21	55	60	"
B.E.A.		0·35	0·28	0·86	0·016	0·022	3·42	0·78		3¾	OQ850 T620WQ	46·6		47·4		56·8	23½	61		1
		0·35	0·25	0·65			3·21	0·70	0·23	7	OQ840 T640				56·0	62·5	21½	61	75	4
B.E.A.		0·35	0·25	0·53			2·90	0·90	0·46	T.P.	OQ850 T200 AC	86·6	93·0	101·0		116·5	14	45½	27	15
"		"	"	"			"	"	"	"	" T300 "	90·0	90·4	90·8		108·5	13	48	12	"
"		"	"	"			"	"	"	"	" T400 "	83·9	84·4	85·5		93·2	13½	49	19	"
"		"	"	"			"	"	"	1⅛	" T200 "	91·4	93·2	95·6		113·2	13	45½	27	"
"		"	"	"			"	"	"	"	" T300 "	87·6	88·0	89·0		104·2	14	44½	15	"
"		"	"	"			"	"	"	"	" T400 "	83·0	84·0	85·6		93·0	15	47	15	"
"		"	"	"			"	"	"	"	" T500 "	78·0	78·8	79·8		87·0	16	47	—	"
"		"	"	"			"	"	"	"	" T550 "	75·6	80·0	80·8		86·6	19	53½	38	"
"		"	"	"			"	"	"	"	" T575 "	74·8	75·8	76·4		82·8	18	53½	41	"
"		"	"	"			"	"	"	"	" T600 "	72·4	72·8	73·2		78·4	19	54½	47	"
"		"	"	"			"	"	"	"	" T625 "	65·6	65·6	65·6		71·6	21	57	62	"
"		"	"	"			"	"	"	"	" T650 "	56·4	56·4	56·4		62·0	22	59½	75	"
"		"	"	"			"	"	"	2½	" T575 " (M)	77·6	78·7	78·0		86·0	18	56	38	"
"		"	"	"			"	"	"	"	" " (C)	—	—	—		—	—	—	38	"
"		"	"	"			"	"	"	"	" T600 (M)	77·2	78·0	78·0		82·2	17½	54½	37	"
"		"	"	"			"	"	"	"	" " (C)	—	—	—		—	—	—	35	"
"		"	"	"			"	"	"	"	" T625 (M)	69·6	70·0	70·0		75·3	20	57	50	"
"		"	"	"			"	"	"	"	" " (C)	—	—	—		—	—	—	51	"
"		"	"	"			"	"	"	"	" T650(M)	64·4	64·4	64·4		67·6	21	62½	65	"
"		"	"	"			"	"	"	"	" " (C)	—	—	—		—	—	—	64	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq. in.								
B.E.A.	0·35	0·25	0·53			2·90	0·90	0·46	4	OQ850 T575 AC (M)	75·2	76·6	76·6		85·5	19½	54½	35	15
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	33	"
"	"	"	"			"	"	"	"	" T600 AC (M)	65·6	66·0	66·0		71·0	20½	60	58	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	63	"
"	"	"	"			"	"	"	"	" T625 AC (M)	63·6	64·0	64·0		70·2	22	60	62	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	68	"
"	"	"	"			"	"	"	"	" T650 AC (M)	62·0	62·0	62·0		67·4	22	61½	60	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	60	"
"	"	"	"			"	"	"	6	" T570 AC (M)	68·0	68·8	68·8		72·2	16½	52	29	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	28	"
"	"	"	"			"	"	"	"	" T600 AC (M)	64·4	65·0	65·6		71·8	20	53½	40	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	40	"
"	"	"	"			"	"	"	"	" T625 AC (M)	57·0	57·2	57·6		64·8	21	60½	54	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	49	"
"	"	"	"			"	"	"	"	" T650 AC (M)	54·4	54·4	54·4		62·8	22	61½	63	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	61	"
"	"	"	"			"	"	"	8	" 575 A C(M)	61·8	62·6	65·2		71·2	18	48½	24	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	21	"
"	"	"	"			"	"	"	"	" T600 AC (M)	57·6	58·4	59·6		66·8	18	51	35	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	33	"
"	"	"	"			"	"	"	"	" T625 AC (M)	53·0	53·4	53·6		62·0	21	56	42	"
"	"	"	"			"	"	"	"	" " AC (C)	—	—	—		—	—	—	41	"

EFFECT OF COLD WORK

Process of Manufacture	Chemical Composition (%)							Heat Treat-ment	Hardness HV for Stated % Reduction of Area by Cold Drawing*						Ref.
	C	Si	Mn	S	P	Ni	Cr		0	10%	30%	40%	60%	80%	
B.E.	0·32	0·28	0·65	0·010	0·011	3·29	0·87	OH & T	302	322	330	335	350	380	16

* Tests carried out on small diameter rods.

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Typical curve for 1¼ in. dia. bars. Oil Quenched 830°C. (Ref. 4)

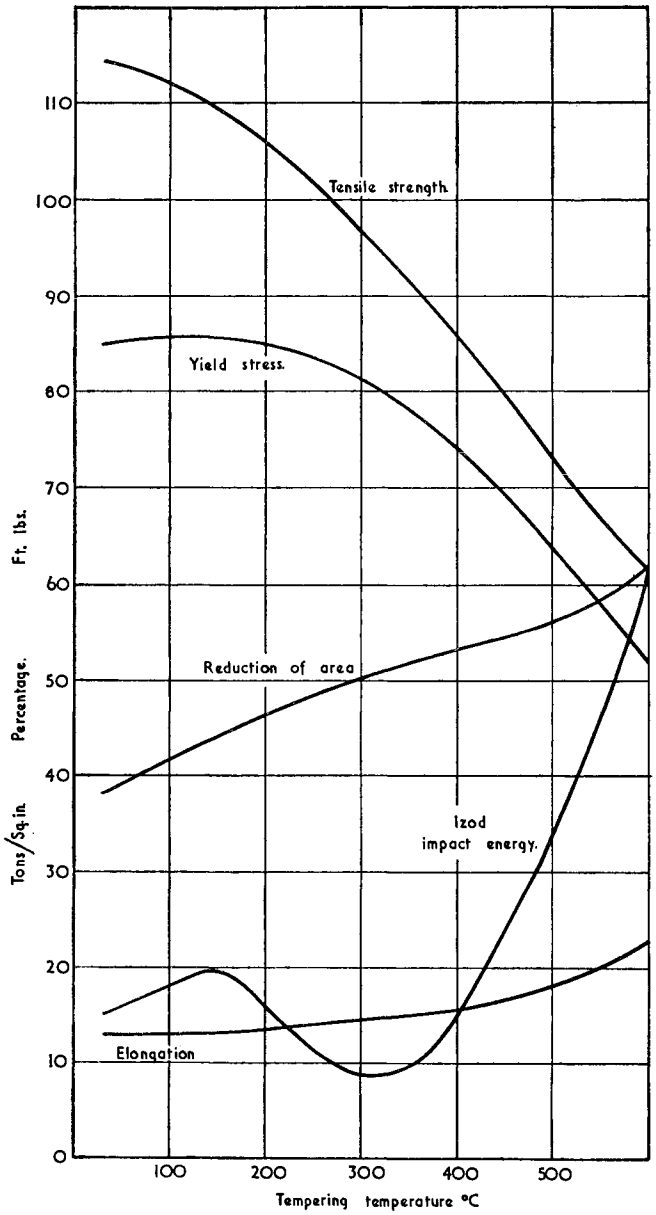
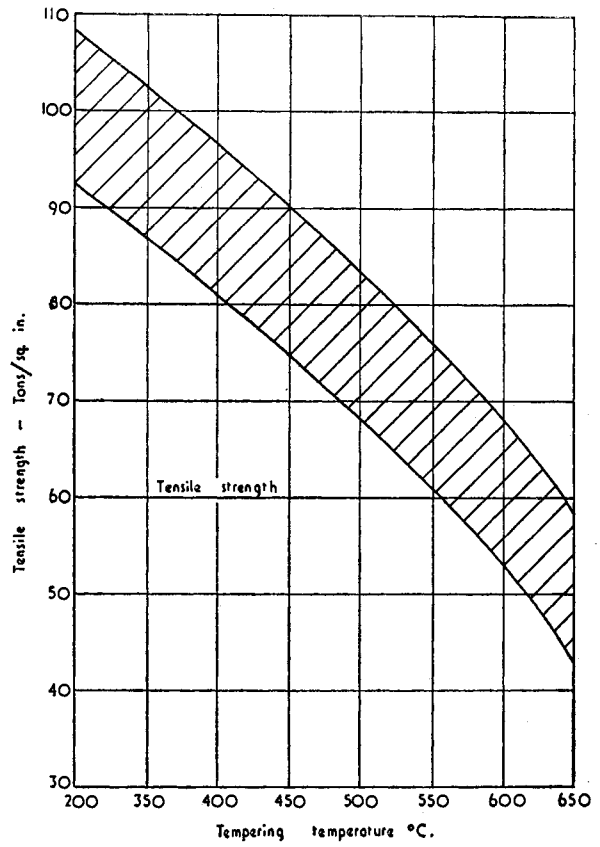
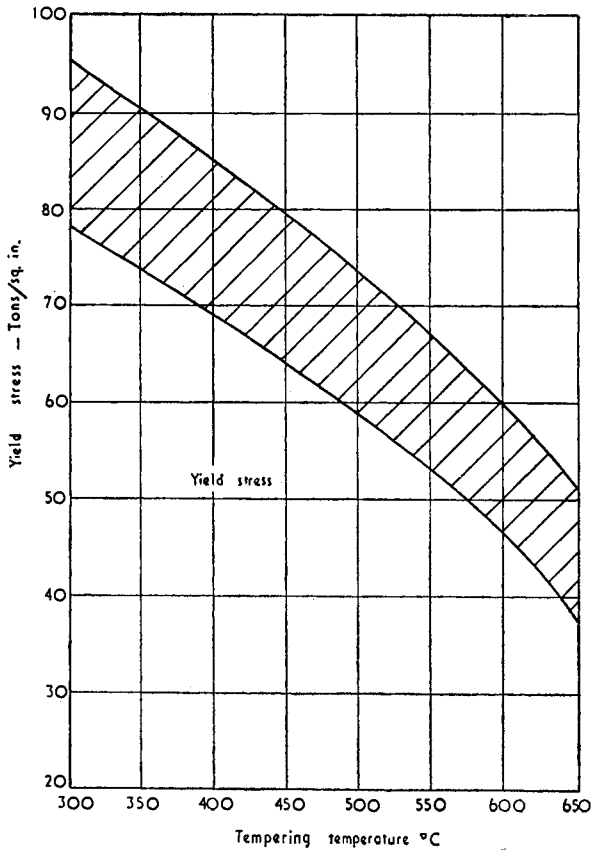


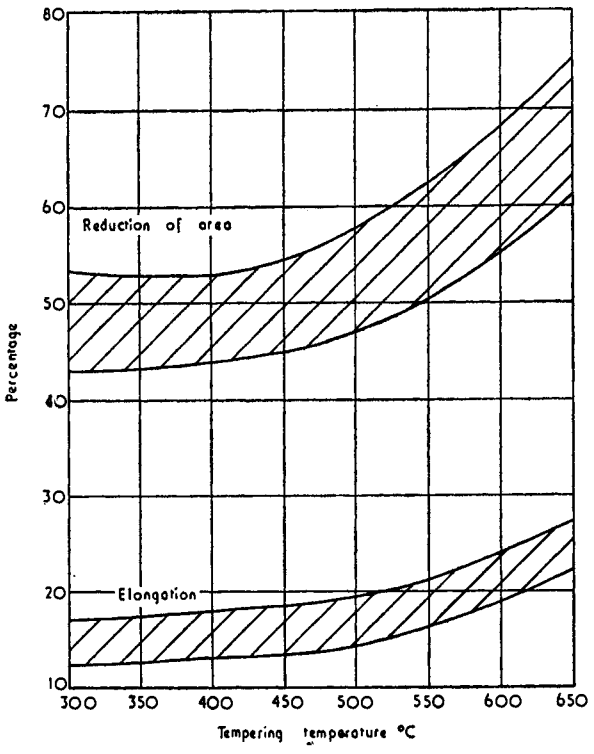
Fig. 23.7

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES

These curves have been produced from the test results obtained on several casts of En 23







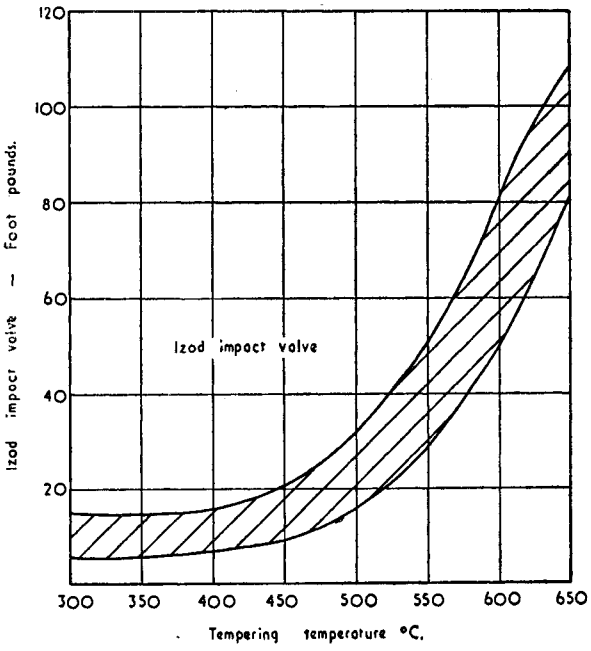


Fig. 23.8

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Oil Quenched 830°C. Temper 600°C. (Ref. 4)

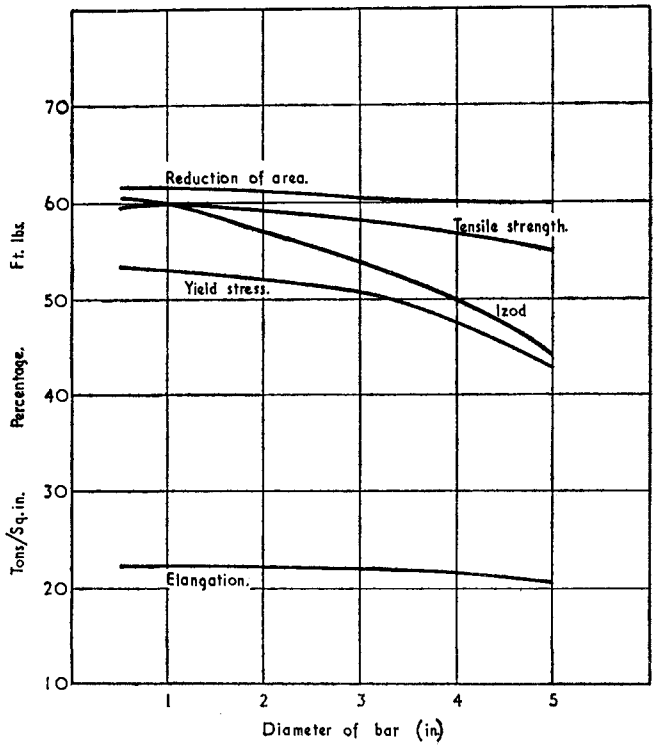


Fig. 23.9

Oil Quenched 830°C. Temper 625°C. (Ref. 4)

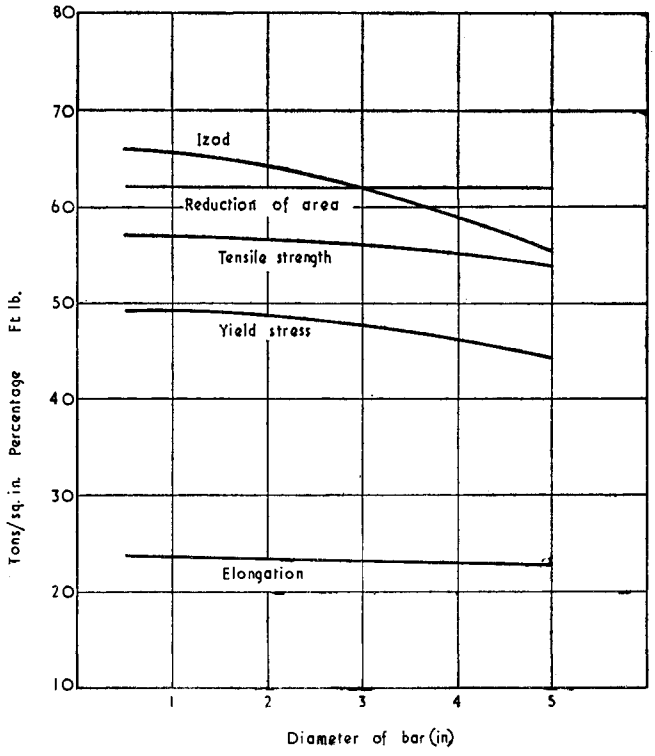


Fig. 23.10

Oil Quenched 830°C. Temper 650°C. (Ref. 4)

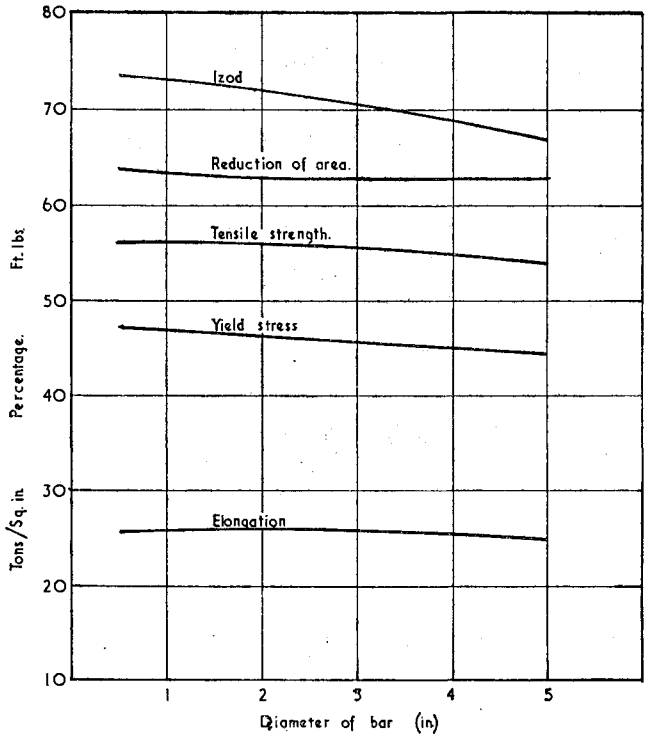


Fig. 23.11

MECHANICAL PROPERTIES AT LOW TEMPERATURE

(For steels containing molybdenum, see En 27)

As Quenched Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in							
9	0·35	0·25	0·54	0·007	0·008	3·35	0·85	0·11	$\frac{5}{8}$	OQ840 T590WQ	20	56·6	57·7	59·3		66·3	26	63	13
"	"	"	"	"	"	"	"	"	"	" " "	— 78	60·0	61·1	62·3		72·5	28	58	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	78·4	79·8	81·2		90·3	28	49	"
"	"	"	"	"	"	"	"	"	"	" T660 "	20	47·0	48·2	48·9		59·5	29	65	"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	49·1	50·3	51·3		66·2	28	63	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	66·1	68·7	70·3		85·3	30	52	"
	0·35	0·18	0·56	0·009	0·010	3·34				OQ850 T650WQ	R.T.				59·3	65·1	13½	59½	17
	"	"	"	"	"	"				" " "	—253				108·5	108·5	4½	48½	"

IMPACT PROPERTIES AT LOW TEMPERATURE

(For steels containing molybdenum, see En 27)

Process of Manufacture	As Quenched Grain Size	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Impact Values				Ref.
		C	Si	Mn	S	P	Ni	Cr				Charpy Keyhole Notch ft.lb.	Charpy V Notch ft.lb.	Izod Impact ft.lb.	%Fibrous Fracture	
B.E.A.		0·31	0·23	0·51	0·010	0·011	3·17	0·75	$1\frac{1}{8}$	N870 T500	—78	8	—	—	0	1
"		"	"	"	"	"	"	"	"	OQ870 T200	—78	11	—	—	0	"
"		"	"	"	"	"	"	"	"	" T600	—78	22	—	—	15	"
	7	0·26	0·26	0·57	0·020	0·021	3·33	0·57	$1\frac{1}{8}$	OQ840 T410	R.T.	—	—	26	—	18
	"	"	"	"	"	"	"	"	"	" T425	R.T.	—	34	31	—	"
	"	"	"	"	"	"	"	"	"	" T440	R.T.	—	—	44	—	"
	"	"	"	"	"	"	"	"	"	" T400	—40	—	—	13	—	"
	"	"	"	"	"	"	"	"	"	" T415	—40	—	—	17	—	"
	"	"	"	"	"	"	"	"	"	" T425	—40	—	23	23	—	"

IMPACT TRANSITION TEMPERATURE DATA

Curve No.	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Grain Size		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	McQuaid Ehn	As Quenched	
											tons/sq. in.									
A	0·28	0·23	0·58	0·010	0·014	3·16	0·64	0·15	1	OQ850 T600 AC	52·2	52·3	53·2		59·6	22½	62	5—3	0·015″	4
B	″	″	″	″	″	″	″	″	″	″ T650 ″	40·5	41·2	41·8		53·3	26	65	″	″	″
C	″	″	″	″	″	″	″	″	4	″ T600 ″	43·7	45·0	46·4		54·3	23½	63	″	0·003″	″
D	″	″	″	″	″	″	″	″	″	″ T650 ″	39·7	40·1	46·0		50·4	26	66	″	″	″
E	0·32	0·19	0·55	0·012	0·010	3·11	0·64	0·07	⅞	OQ850 T580	47·3	50·7	55·5		62·3	23	62½	4	0·002″	″
F	″	″	″	″	″	″	″	″	″	″ T650 AC	37·0	38·0	39·4		52·6	25½	64½	″	″	″

(Ref. 4)

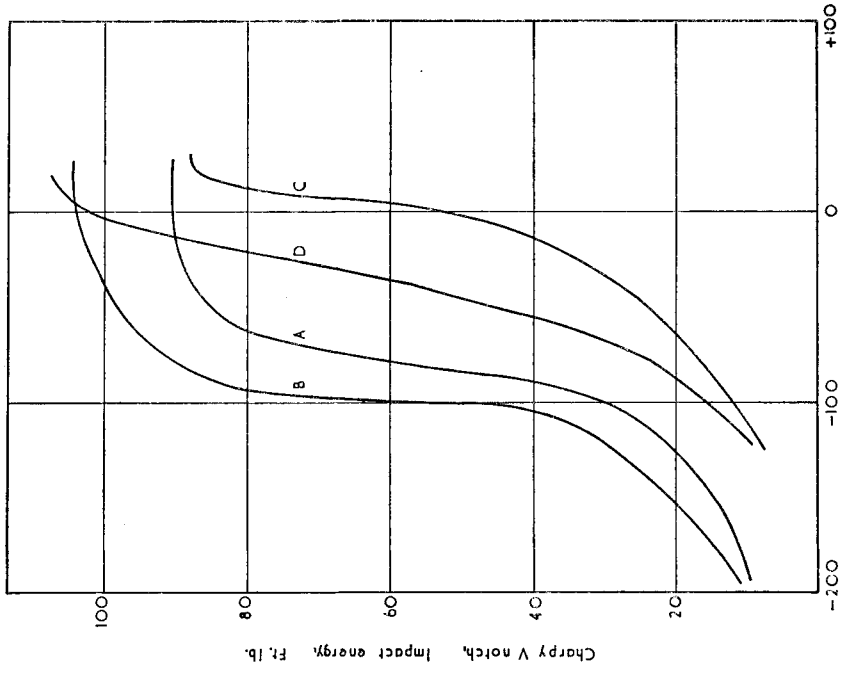


Fig. 23.12

(Ref.4)

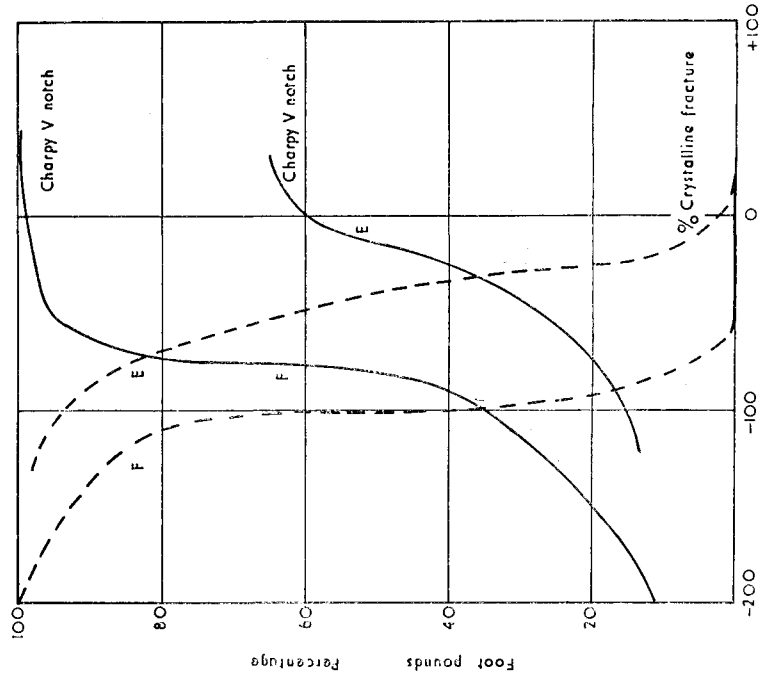


Fig. 23.13

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0.1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.							
B.E.A.	0·29	0·27	0·60	0·014	0·018	3·41	0·89		¾	OQ850 T650	R.T.	46·5		48·8	57·8	22½	63½		1
"	"	"	"	"	"	"	"		"	" "	100	34·4		47·5	56·4	23	67½		"
"	"	"	"	"	"	"	"		"	" "	200	32·6		45·6	54·8	20	64½		"
"	"	"	"	"	"	"	"		"	" "	300	37·0		48·0	55·3	20	50		"
"	"	"	"	"	"	"	"		"	" "	400	30·4		46·9	55·4	17½	44		"
"	"	"	"	"	"	"	"		"	" "	500	22·0		38·9	44·9	21½	66½		"
"	"	"	"	"	"	"	"		"	" "	600	—		—	23·6	32	88		"
"	"	"	"	"	"	"	"		"	" "	700	—		—	12·3	42½	90		"
"	"	"	"	"	"	"	"		"	" "	800	—		—	5·6	74½	92		"
"	"	"	"	"	"	"	"		"	" "	900	—		—	4·5	52	84½		"
"	"	"	"	"	"	"	"		"	" "	1000	—		—	3·0	82½	99		"
	0·31		0·64			3·24	0·70	0·22		H & T	R.T.	35·3	50·4		58·4	27		82	6
	"		"			"	"	"		"	100	27·0	49·0		57·2	22½		—	"
	"		"			"	"	"		"	150	30·1	48·1		56·3	19½		—	"
	"		"			"	"	"		"	200	37·8	45·9		56·2	22		—	"
	"		"			"	"	"		"	250	26·5	41·0		53·5	21½		82	"
	"		"			"	"	"		"	300	26·1	39·9		54·9	27		81	"
	"		"			"	"	"		"	350	26·3	37·0		49·9	24		80	"
																		Charpy V Notch	
	0·31	0·27	0·73	0·040	0·031	2·96	0·64	0·39	0·126	OH T650	R.T.			55·5	63·6			32	6
	"	"	"	"	"	"	"	"	"	" "	250			50·4	60·0			63	"
	"	"	"	"	"	"	"	"	"	" "	350			47·5	60·2			57	"
	"	"	"	"	"	"	"	"	"	" "	450			41·2	51·3			50	"
	"	"	"	"	"	"	"	"	"	" "	550			35·6	40·6			36	"
	"	"	"	"	"	"	"	"	"	" "	650			20·0	24·6			89	"
	"	"	"	"	"	"	"	"	"	" "	750			7·7	11·0			—	"
	"	"	"	"	"	"	"	"	"	" "	850			3·8	6·2			—	"
	"	"	"	"	"	"	"	"	"	" "	950			1·9	3·4			—	"

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Torsion				Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			L.P.	0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El %	R.A. %		0·1% P.S.	Y.P. (Rs)	App. Max. Shear Stress	Prob Max. Shear Stress	
											tons/sq. in.							tons/sq. in.				
B.E.A.	0·29	0·08	0·33	0·015	0·011	3·29	0·52		1½	OQ850 T500 1hr.	51·2		64·7	68·1	15	49½	30		41·3	60·1	45·1	1
"	"	"	"	"	"	"	"		"	" T550 "	43·2		52·6	57·8	21	63½	52		31·3	50·5	37·7	"
"	"	"	"	"	"	"	"		"	" T600 "	37·0		45·0	51·5	24	67	63		27·6	45·2	33·9	"
"	"	"	"	"	"	"	"		"	" T650 "	27·9		39·6	48·0	26	69	101		20·5	44·3	33·2	"
"	"	"	"	"	"	"	"		2	" T500 "	35·8		51·3	57·3	20	57½	25		34·6	52·3	39·2	"
"	"	"	"	"	"	"	"		"	" T550	25·4		47·6	53·8	21	61½	43		—	—	—	"
"	"	"	"	"	"	"	"		"	" T600	31·5		42·7	50·2	24	65½	58		26·4	46·1	34·6	"
"	"	"	"	"	"	"	"		"	" T650	29·5		36·8	46·1	26½	68	75		22·0	42·8	32·1	"
"	"	"	"	"	"	"	"		4	" T500	29·9		36·6	45·1	23	61½	37		23·1	44·0	33·0	"
"	"	"	"	"	"	"	"		"	" T550	29·9		36·3	44·3	23	61½	34		21·0	42·9	32·2	"
"	"	"	"	"	"	"	"		"	" T600	26·0		34·1	43·2	26	64½	54		21·2	42·1	31·6	"
"	"	"	"	"	"	"	"		"	" T650	27·0		30·5	40·5	26	67	71		20·5	41·2	30·9	"
	0·29	0·19	0·71	0·017	0·033	3·10	0·71	0·07		OQ and T		40·2		58·2	27½			27·5		50·9	38·2	19
	0·30	0·21	0·58	0·006	0·018	3·62	0·85			OQ830 T620WQ	38·3		49·2	58·0	25	65	76		37·8	52·3	39·2	20
	"	"	"	"	"	"	"			" " SC	13·5		48·9	58·1	24	60½	5½		—	51·2		"
A.O.H.	0·32	0·12	0·60	0·030	0·030	3·41	0·76		1⅛	OQ850 T530	57·0		66·0	73·1	18	56	45		39·0	57·3	43·0	1
"	"	"	"	"	"	"	"		"	" T600	47·0		56·0	62·0	21	62	49		37·2	52·8	39·6	"
"	"	"	"	"	"	"	"		"	" T650	40·9		49·4	56·3	24	66	65		32·5	48·7	36·5	"
B.E.A.	0·34	0·11	0·68	0·014	0·016	3·50	0·98		—	OQ845 T540			57·4	64·3	18	52½	69		39·8	50·5	37·9	"
"	"	"	"	"	"	"	"			" T600			56·0	63·1	18½	51½	64		36·7	54·5	40·7	"
"	"	"	"	"	"	"	"			" T660									24·5	47·5	35·6	"

FATIGUE PROPERTIES (Continued)

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq. in.	0·2% P.S. (0·2Rp) tons/sq. in.	0·5% P.S. (0·5Rp) tons/sq. in.	Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)	Rotating Bending Fatigue Limit tons/sq. in.	Reverse Torsion Fatigue Limit tons/sq. in.	Ref.
	0·24	0·15	0·37	0·025	0·019	3·33	0·87		2×1	OQ830 T371 OQ				57·2	61·9	18	62	±30·4	±17·0	22
	"	"	"	"	"	"	"		"	" OQ788 T649 FC				46·3	50·6	24	68½	±29·0	±14·1	"
	"	"	"	"	"	"	"		"	" OQ788 T649 FC				44·9	51·0	33	69½	±29·9	±15·2	"
	"	"	"	"	"	"	"		"	AC830 FC788				26·7	39·0	25	67	±21·9	12·7±12·7	
																			3·1±17·0	"
B.E.A.	0·29	0·25	0·58	0·017	0·018	3·50	0·73		1⅛	OQ850 T610 1hr.WQ	55·0		56·6		62·5	22	63	±33		1
	0·31	0·14	0·70	—	—	3·40	0·70	"	"	OQ820 T600	50·0		54·5		60·1	22	61	±26		"
A.O.H.	0·32	0·20	0·60	0·023	0·022	3·46	0·76		"	OQ850 T650	42·0		48·8		59·0	24	64	±30		"
A.O.H.	0·32	0·17	0·65	0·040	0·023	3·06	0·84	0·04	"	OQ830 T620 ½hr. OQ (L)	50·0	50·2			61·3	12		±33		23
"	"	"	"	"	"	"	"	"	"	" " (T)	46·3	47·8			57·1	21	47	±24·7		"
B.E.A.	0·33	0·19	0·54	0·014	0·013	2·93	0·59	0·60	"	OQ830 T535 AC				75·0	82·1	17½	55	±42(2·5×10⁶rev) ±40(10×10⁶rev)		24

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Heat Treatment °C	Fatigue Limit (tons/sq. in.) Reverse Bending (solid)	Reverse Bending (hollow)	Reverse Bending (solid)	Torsion (solid)	Torsion (hollow)	Torsion (notched)	Ref.
B.E.A.	0·30	0·21	0·58	0·006	0·018	3·62	0·85	OQ830 T620 WQ	±35·0	±33·6	±17·4(1)	±22·8	±20·5	±15·3(2)	20
	(See also Mechanical Properties in Torsion)							" " SC	±33·0	—	±16·0(3)	±21·0	—	±11·8(4)	"
									Notch (1)	55°V,	0·02″ deep,	root radius 0·0008″,	root dia 0·30″,	O.D. 0·34″	
									" (2)	"	" "	" " 0·00095″	" " "	" "	
									" (3)	"	" "	" " 0·00085″	" " "	" "	
									" (4)	"	" "	" " 0·00092″	" " "	" "	

CORROSION FATIGUE

Chemical Composition (%)							Heat Treatment and Surface Condition	Y.P. (Rs)	T.S. (Rm)	El. % (A) 5D	R.A. % (Z)	Rotating Bending Fatigue Limit tons/sq. in. (3000 r.p.m.)			Ref.
C	Si	Mn	S	P	Ni	Cr		tons/sq. in.				in air 15×10^6rev.	in tap water 15×10^6rev.	in 3% salt water 15×10^6rev.	
0·33	0·26	0·46	0·012	0·021	3·46	0·71	Oil quenched & tempered	57·1	64·7	14	55	—	—	—	25
"	"	"	"	"	"	"	" Without surface coating					±35·0	±10·6	±7·5	25
"	"	"	"	"	"	"	" Hot galvanizing 30—60μ					±20·0	±20·0	±21·2	"
"	"	"	"	"	"	"	" Elect. Zinc5—10μ					±32·5	±31·2	±29·3	"
"	"	"	"	"	"	"	" Elect.Cadmium 5—10μ					±30·0	±21·2	±11·9	"
"	"	"	"	"	"	"	" Tin coating 5—20μ					±34·4	±13·1	±10·0	"
"	"	"	"	"	"	"	" Nickel coating 20μ					±27·5	±18·4	±6·2	"
"	"	"	"	"	"	"	" 20μ Nickel +0·25—1·25μ Chromium					±26·2	±15·0	±10·0	"

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En 24

1½ PER CENT NICKEL-CHROMIUM-MOLYBDENUM STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·35—0·45	0·10—0·35	0·45—0·70	0·050 max.	0·050 max.	1·30—1·80	0·90—1·40	0·20—0·35

MECHANICAL PROPERTIES

	Hardened and Tempered Condition							
	S	T	U	V	W	X	Y	Z
Limiting ruling section, in.	6	6	4	2½	1½	1½	1½	1½
Tensile strength, tons/sq. in., min. (Rm)	50	55	60	65	70	75	80	100
Yield stress(1) tons/sq. in., min. (Rs)	38	44	48	52	58	63	68	85
0·2% proof stress (2) tons/sq. in., min. (0·2Rp)	36	41	46	50	55	59	64	80
Elongation, %, min. (A)	20	18	17	16	15	14	14	8
Izod impact value, ft. lb., min.	40	40	35	35	30	25	22	8
Brinell hardness No. (3) (HB)	223/277	248/302	269/321	293/341	311/375	341/388	363/415	444 min.

When supplied in the softened condition the material shall have a Brinell Hardness number not exceeding 277.

(1) Not to be used as acceptance tests except by special arrangement between the purchaser and manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

United Kingdom		America		France	Germany			Sweden
En No.	BS Air	AISI	SAE	AFNOR	Werkstoff No.	Name	DIN	SIS
24	S95 S119	4340	4340	35NCD6	1.6582	34CrNiMo6	17200	14.2541

APPLICATIONS

A general-purpose steel used for a wide range of engineering parts. It is capable of being heat treated to produce a wide range of tensile strengths combined with good ductility and resistance to shock. It has good hardenability, enabling it to be used for medium tensile strengths in fairly large sections, and possesses good resistance to wear. At low temperatures good impact values can also be obtained.

Typical uses are: automobile main shafts, axle shafts, connecting rod bolts, synchronizing cones, push rods, studs, differential shafts, motor cycle kick-starter ratchets, pinion sleeves, mandrel bars for tube manufacture, gun barrels, breech mechanism parts, high-duty engine connecting rods, high temperature bolts in oil refining and steam installations, various parts of machine tools such as spindle gears, compensating washers, power transmission gears, slide racks and slide cams

WELDING

(See Introduction: List of Abbreviations for key to symbols used in this table)

	Welding Process					
	MA	G	IG	S	F	B
En 24	d	bx	g	f	b	j

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MACHINABILITY

The machinability of this steel in the softened condition is approximately 53% of that for mild steel (En 3). When heat-treated to 60—70 tons/sq. in. tensile strength, the machinability is approximately 35 to 40% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 900°C. Retarded cooling is advisable for large or intricate sections.
Annealing	820°C to 850°C. Furnace cool.
Softening (sub-critical annealing)	630°C to 660°C. Air or furnace cool.
Hardening	820°C to 850°C. Oil quench.
Tempering for 100 ton condition	180°C to 250°C.
For other purposes	550°C to 660°C. } Air cool.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment	Specific Gravity	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	°C	at 20°C	
0·40	0·25	0·60	—	—	1·60	1·10	0·30	Softened	7·86	1
0·41	0·26	0·74	0·015	0·015	1·75	0·80	0·27	Q & T 200	7·81	2
0·41	0·24	0·68	0·045	0·032	1·43	1·07	0·26	OQ830 T650 1hr.WQ	7·84	3
"	"	"	"	"	"	"	"	" T2501hr.AC	7·80	"

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cal/g deg. C.										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·40	0·25	0·60	—	—	1·60	1·10	0·30	Softened	0·118										1
0·35	0·24	0·57	0·017	0·026	1·90	0·83	0·30	Annealed	0·115	0·120	0·123	0·127	0·133	0·140	0·150	0·169	0·165	0·163	*

* Estimated values

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion/deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
(within specification)									12·5		13·4		14·0		14·5				4
0·41	0·24	0·68	0·045	0·032	1·43	1·07	0·26	OQ830 T650 1hr. OQ		12·4	13·1	13·6	14·0		14·3				3
"	"	"	"	"	"	"	"	" T250 1hr. AC		11·5	12·0 (20—250°C)								"
0·35	0·24	0·57	0·017	0·026	1·90	0·83	0·30	Annealed	12·3	12·7	13·1	13·5	13·9	14·2	14·2	11·3	12·5	13·4	*

* Estimated values

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm												Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·41	0·24	0·68	0·045	0·032	1·43	1·07	0·26	OQ830 T650 1hr. OQ	—	24·8	29·8	36·7	45·1	55·2	66·7	79·7	—	—	—	—	3
"	"	"	"	"	"	"	"	" T250 1hr. AC	—	33·0	38·9	47·4(250°C)									"
0·35	0·24	0·57	0·017	0·026	1·90	0·83	0·30	Annealed	24·4	25·6	30·4	37·4	45·7	55·5	67·0	90·5	96·9	110·8	114·2	117·3	*

* Estimated values

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Conductivity cal/cm s deg. C											Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·35	0·24	0·57	0·017	0·026	1·90	0·83	0·30	Annealed	0·091	0·091	0·091	0·092	0·091	0·089	0·083	0·077	0·070	0·063	0·065	0·067	*

*Estimated values.

YOUNG'S MODULUS (E)

Chemical Composition (%)								Heat Treatment °C	Young's Modulus tons/sq. in. at stated temperature										Method of Testing	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	150°C	200°C	250°C	300°C	350°C	400°C	500°C	600°C		
0·36	0·24	0·61	0·015	0·012	1·48	0·97	0·32	Oil hardened & tempered 70/75 tons/sq.in. tensile strength	13500	13000	13050	12700	12500	12350	12100	—	—	—	Static	5
0·41	0·24	0·68	0·045	0·032	1·43	1·07	0·26	OQ830 T650 1hr. OQ	13800	13600		13200	—	12600	—	12200	11500	10700	Dynamic*	3
"	"	"	"	"	"	"	"	" T250 1hr. AC	13250	13050	—	12700	—	—	—	—	—	—	"	"
0·41	0·26	0·74	0·015	0·015	1·75	0·80	0·27	Hardened & tempered 200°C	13250	13000 (93°C)		12550 (204°C)		12200 (316°C)		11600 (427°C)		10600 (538°)	"	2
"	"	"	"	"	"	"	"	" "	13250	—	—	—	—	—	—	—	—	—	Static	"

*Vibration method.

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·20	0·69	0·010	0·017	1·58	0·95	0·26

Basic Electric Arc.
McQuaid Ehn grain size 3 to 4 (ASTM).
As quenched grain size 6 to 8 (ASTM).
Bars hot rolled to ⅞ in. dia., cold drawn to 11 S.W.G. with intermediate annealing at 600°C.

Austenitizing Temperature 835°C, 30 min.

(Ref. 6)

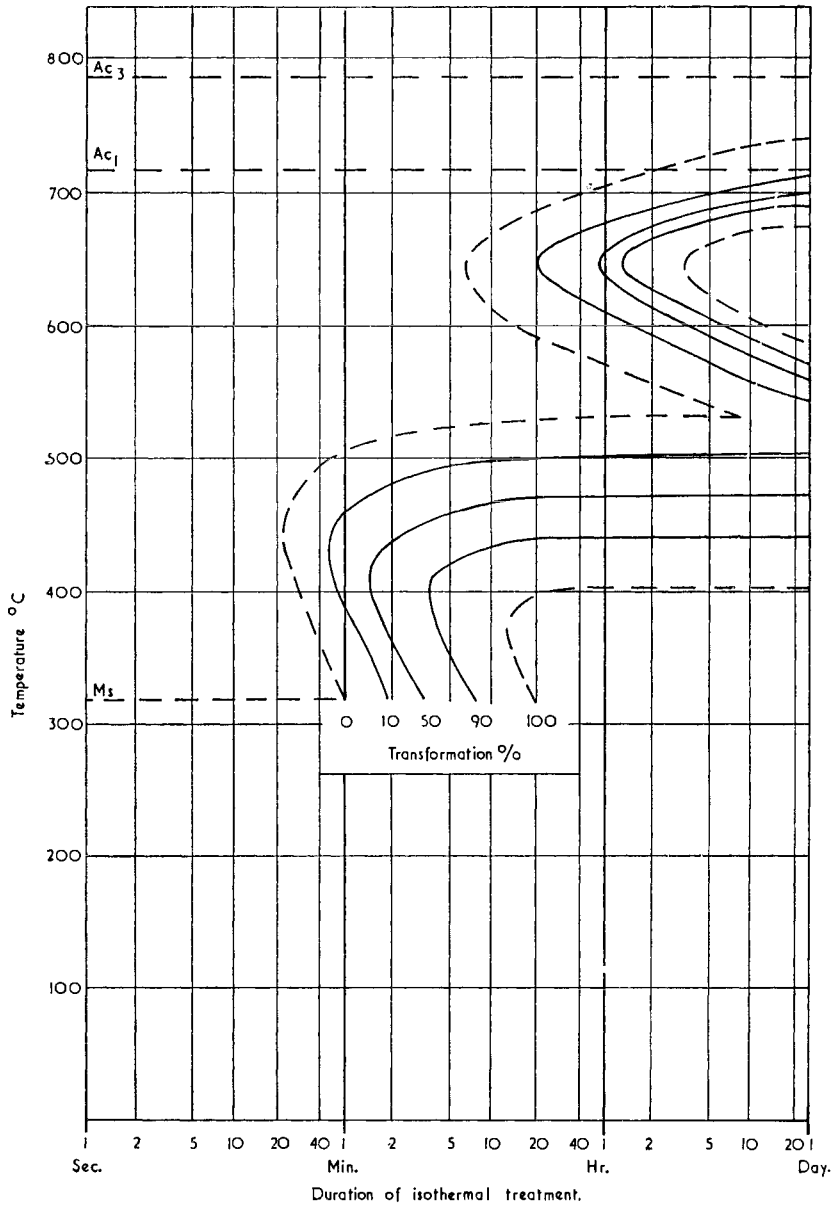


Fig. 24.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·36	0·22	0·52	0·005	0·007	1·52	1·17	0·27

Basic ElectricArc.
McQuaid Ehn grain size 4 to 5 (ASTM).
As quenched grain size 7 to 8 (ASTM).
Austenitizing Temperature 835°C.

The hardness values shown in the diagram are those of the fully transformed steel.

(Ref. 7)

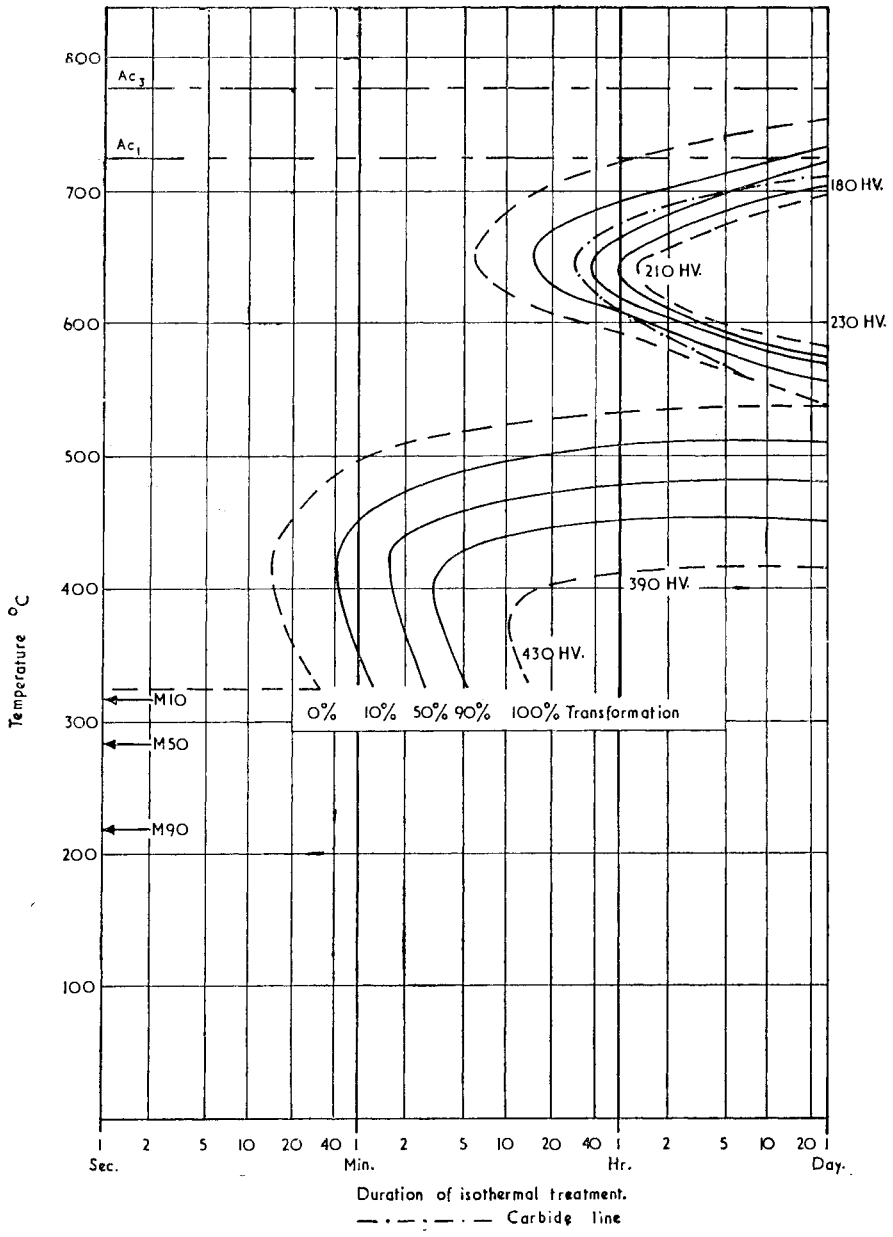


Fig. 24.2

En 24

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·36	0·22	0·52	0·005	0·007	1·52	1·17	0·27

Basic Electric Arc.
McQuaid Ehn grain size 4 to 5 (ASTM).
As quenched grain size 7 to 8 (ASTM).
Austenitizing Temperature 835°C.

(Ref. 7)

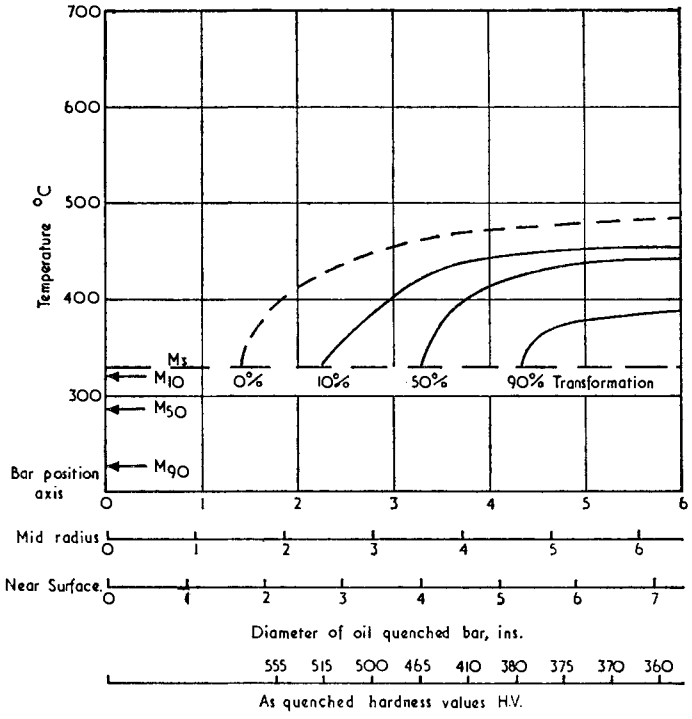


Fig. 24.3

CONTINUOUS COOLING TRANSFORMATION (Continued)

Water Quenched from 830°C.

(Ref. 3)

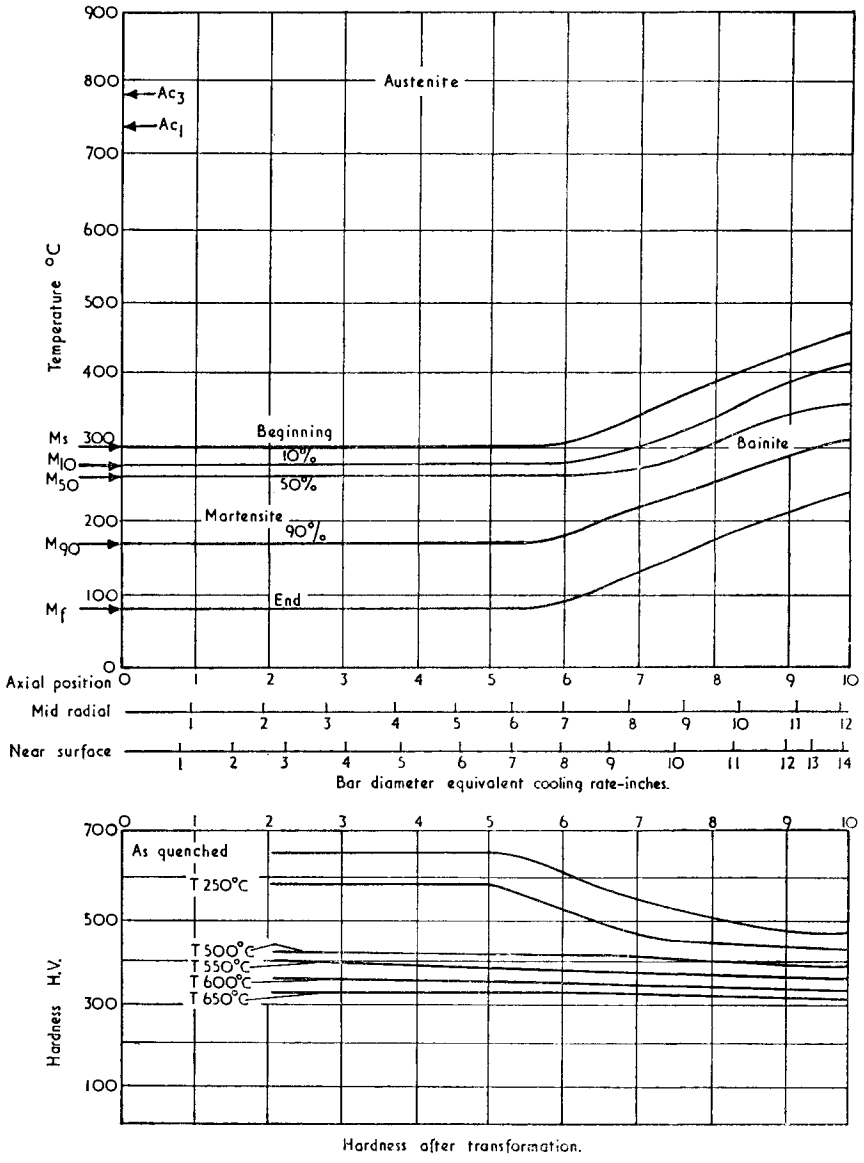
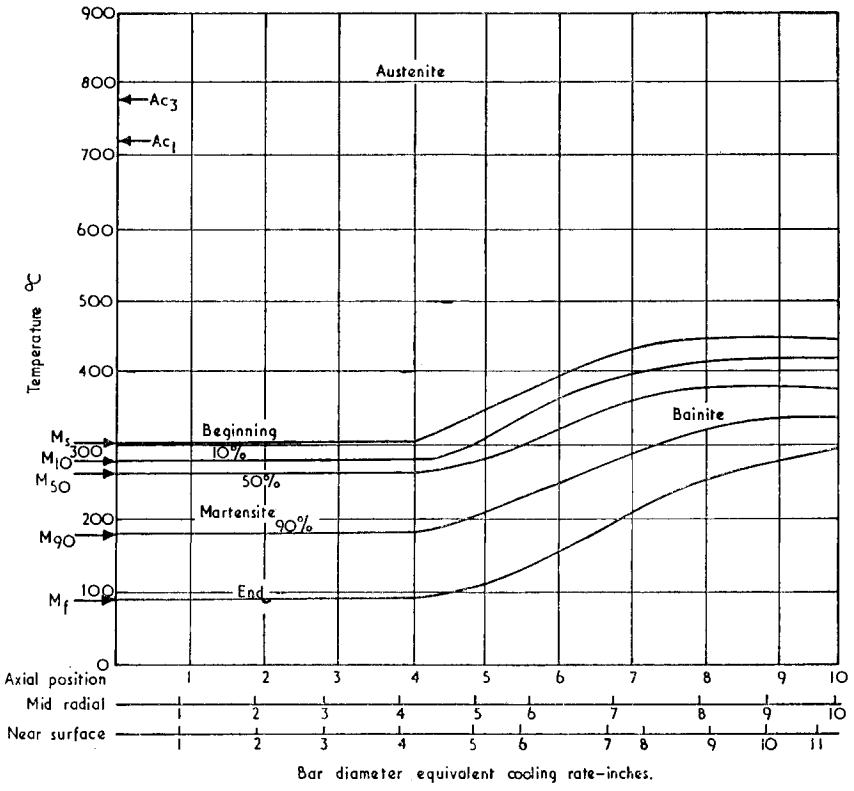


Fig. 24.4

CONTINUOUS COOLING TRANSFORMATION (Continued)

Oil Quenched from 830°C.

(Ref. 3)



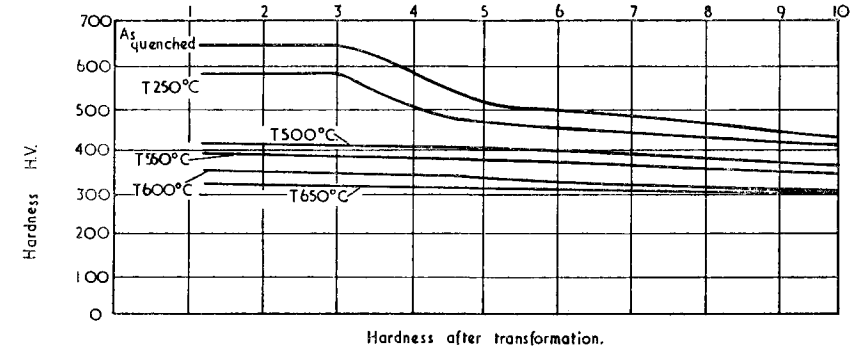
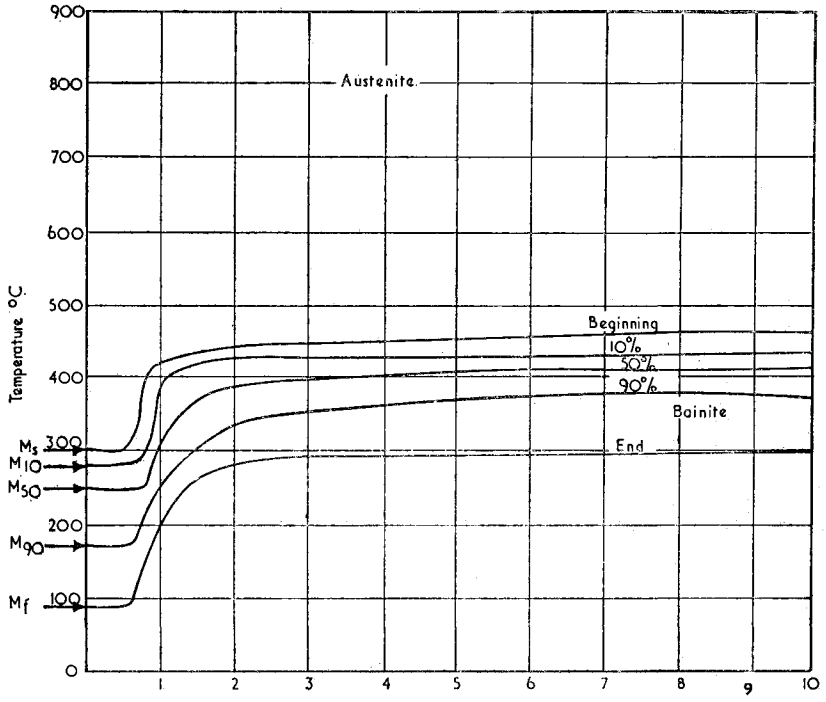


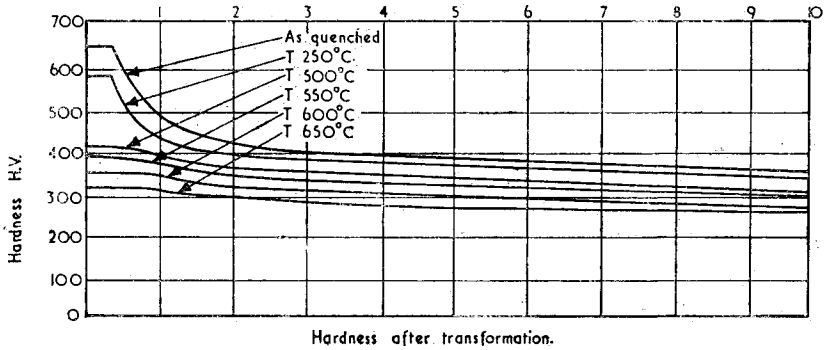
Fig. 24.5

CONTINUOUS COOLING TRANSFORMATION (Continued)

Air Cooled from 830°C. (Ref. 3)



Bar diameter equivalent cooling rate–inches



Hardness after transformation.

Fig. 24.6

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·20	0·69	0·010	0·017	1·58	0·95	0·26

Basic Electric Arc.
McQuaid Ehn grain size 3—4 (ASTM).
As Quenched grain size 6—8 (ASTM).
End Quenched from 835°C.

(Ref. 6)

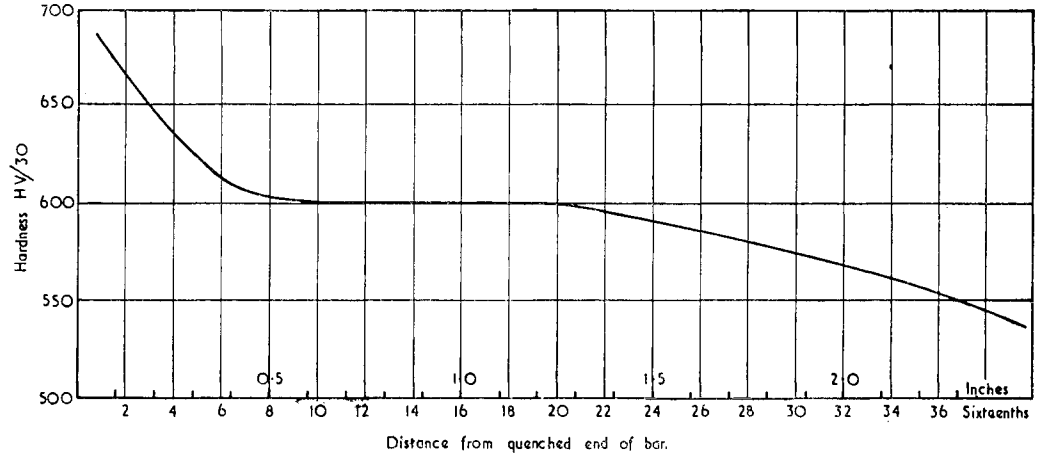


Fig. 24.7

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·30	0·22	0·52	0·005	0·007	1·52	1·17	0·27

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
As Quenched grain size 7—8 (ASTM).
End Quenched from 835°C.

(Ref. 7)

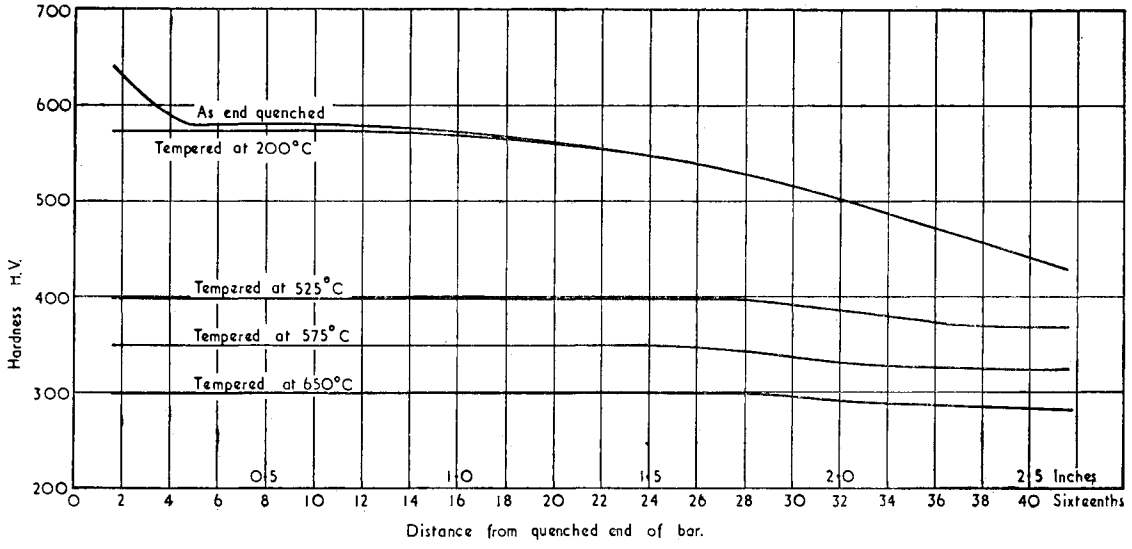


Fig. 24.8

END QUENCH HARDENABILITY DATA (Continued)

Curve No.	Chemical Composition (%)								Process of Manufacture	Grain Size (ASTM)	
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid Ehn
A	0·39	0·26	0·63	0·048	0·035	1·60	1·17	0·24	A.O.H.	6—7	5—6 (7—8)
B	0·43	0·21	0·63	0·041	0·037	1·54	1·15	0·28	A.O.H.	5—7	5—6
C	0·42	0·21	0·59	0·012	0·017	1·69	1·20	0·41	E.	6—7	6—7
D	0·38	0·24	0·62	0·032	0·032	1·43	1·00	0·29	E.	7—8	6—8
E	0·36	0·15	0·48	0·014	0·028	1·56	1·03	0·26	E.	8—9	6—8
F	0·33	0·13	0·49	0·018	0·027	1·49	1·02	0·27	E.	8(7)(9)	7—8(6)

Bars normalized 875°C. End quenched 850°C. Tempered as indicated.

As Quenched

(Ref. 8)

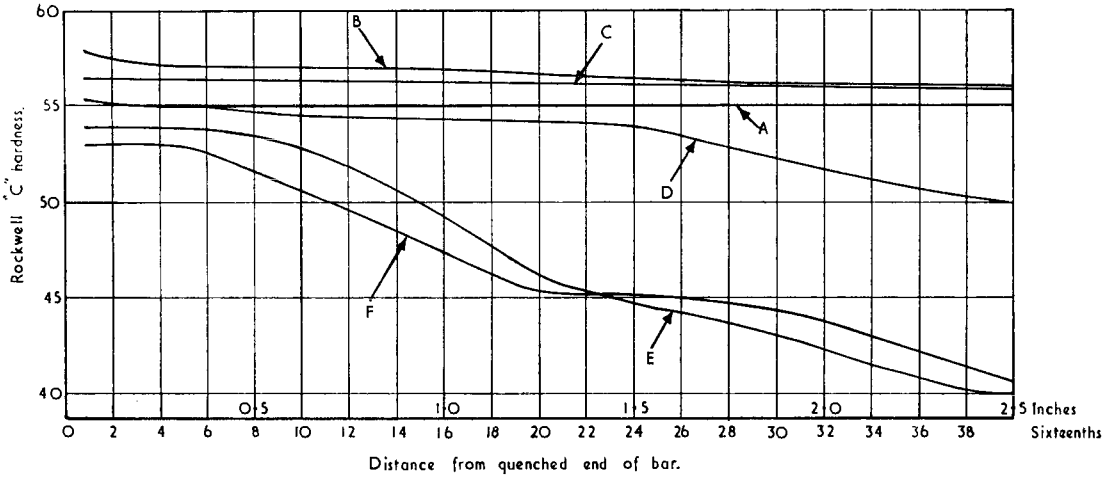


Fig. 24.9

End Quenched and Tempered

(Ref. 8)

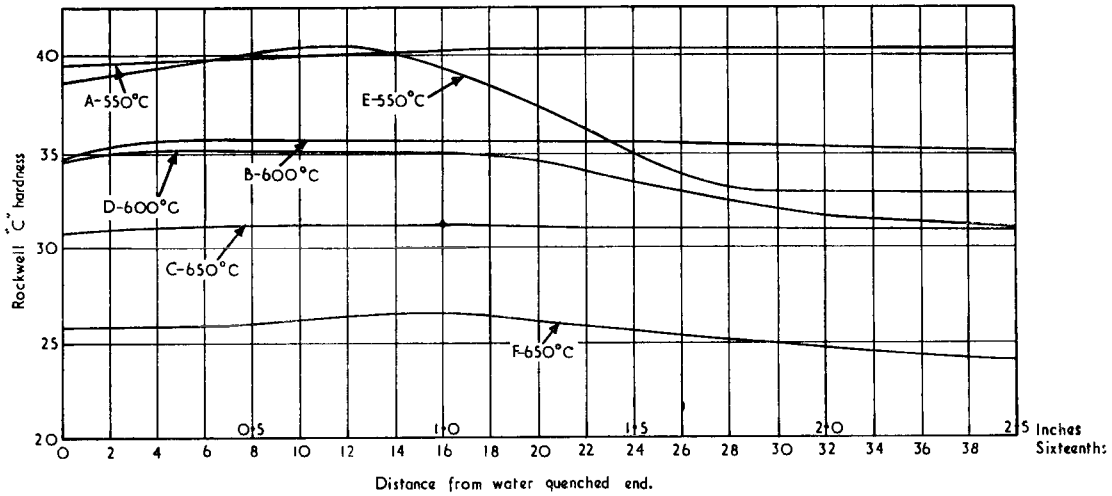


Fig. 24.10

END QUENCH HARDENABILITY BAND

These curves have been produced from the results obtained on several casts of En 24 (Ref. 4)

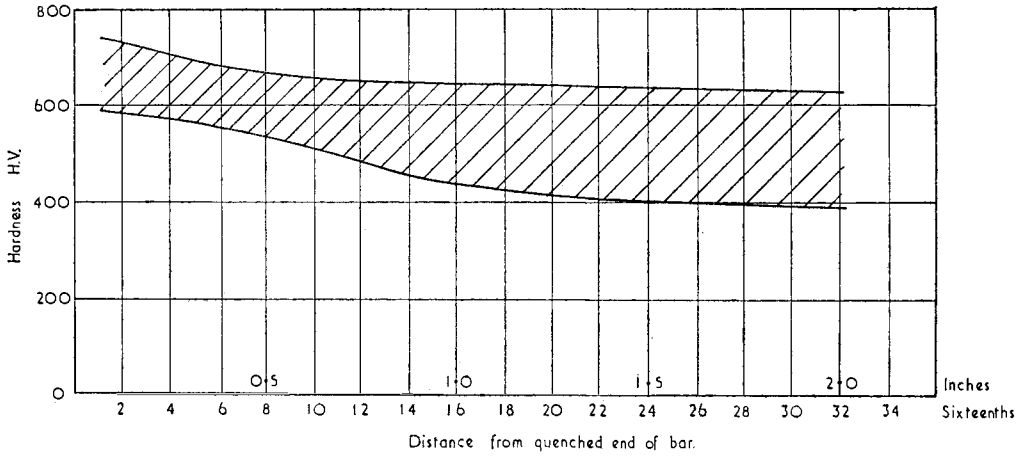


Fig. 24.11

HARDNESS TRAVERSE CURVES

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·36	0·49	0·015	0·016	1·55	1·02	0·23

Basic Electric Arc.
McQuaid Ehn grain size 6—7 (ASTM).
As quenched grain size 7 (ASTM).

Oil Quenched 840°C (Ref. 8)

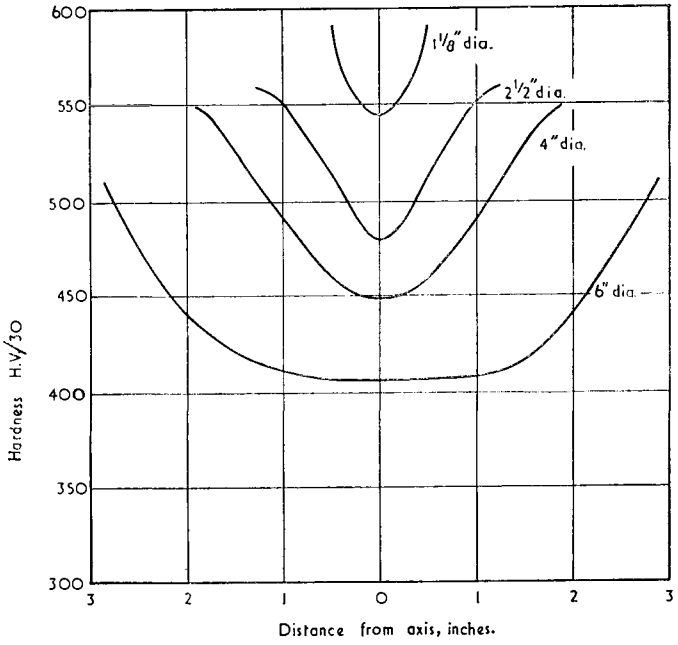


Fig. 24.12

Oil Quenched 840°C. Tempered 575°C Oil Quench. (Ref. 8)

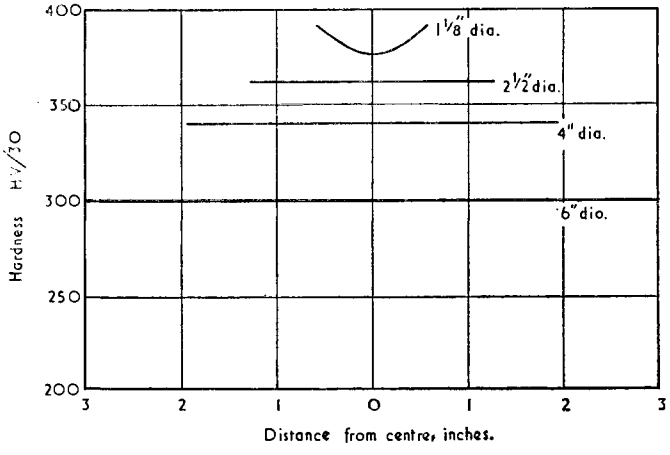


Fig. 24.13

HARDNESS TRAVERSE CURVES (Continued)

Oil Quenched 850°C (Ref. 8)

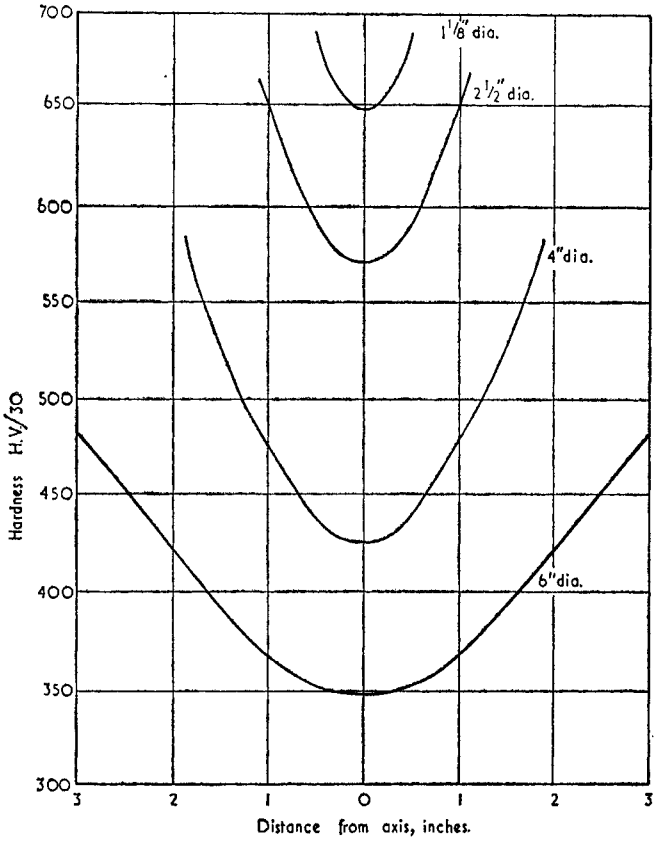


Fig. 24.14

Basic Electric Arc.

McQuaid Ehn grain size 5—7 (4) (ASTM).

As quenched grain size 6—7 (ASTM).

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·43	0·28	0·63	0·019	0·030	1·41	1·10	0·26

Oil Quenched 850°C. Tempered 600°C AC. (Ref. 8)

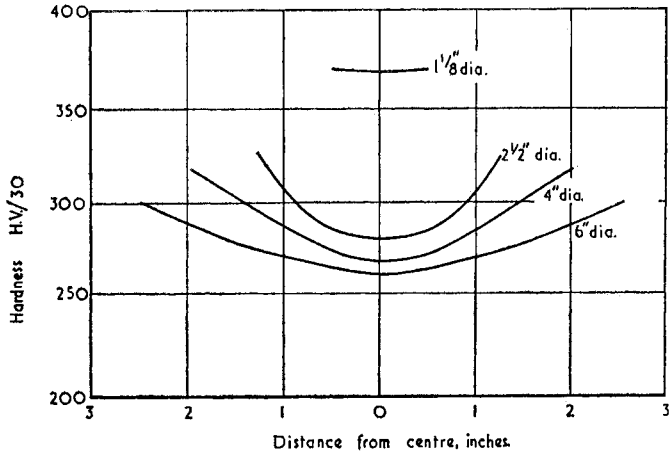


Fig. 24.15

HARDNESS TRAVERSE CURVES (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·43	0·21	0·57	0·023	0·030	1·37	1·06	0·25

Basic Electric Arc.
Bars Oil Quenched 850°C.

(Ref. 8)

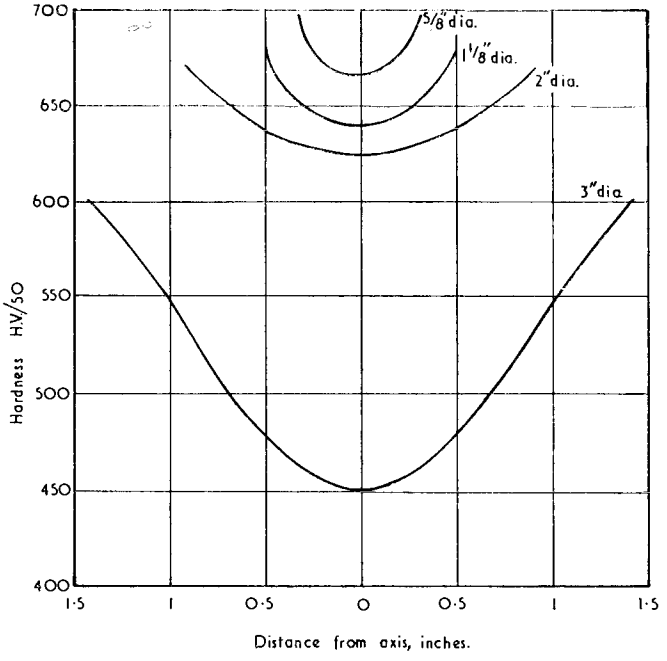


Fig. 24.16

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Treatment °C	Tensile					Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0.1% P.S. (0.1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.						
B.E.A.	4(3)	0·34	0·24	0·54	0·017	0·031	1·50	0·97	0·27	0·564	OQ850 T490 WQ	77·4		82·3	15	53	17	8
"	"	"	"	"	"	"	"	"	"	"	" T550 "	65·1		75·0	17	53	40	"
"	"	"	"	"	"	"	"	"	"	0·875	" T580 "	59·5		67·9	19½	58	63	"
"	"	"	"	"	"	"	"	"	"	1	" T250 "	82·0		120·5	13	37	9	"
"	"	"	"	"	"	"	"	"	"	1½	" T250 "	81·5		120·0	12	30	7	"
"	"	"	"	"	"	"	"	"	"	"	" T470 "	78·0		88·5	15	46	9	"
"	"	"	"	"	"	"	"	"	"	2	" T475 "	72·0		80·5	14	43	8	"
"	"	"	"	"	"	"	"	"	"	2½	" T580 "(C)	47·1		59·6	21	60	48	"
"	"	"	"	"	"	"	"	"	"	"	" T580 "(O)	52·5		63·7	19½	58	55	"
B.E.A.	6(5—7)	0·35	0·29	0·56	0·025	0·029	1·47	0·95	0·26	1	OQ850 T540 AC	75·5		82·0	16	50	19	8
"	"	"	"	"	"	"	"	"	"	"	" T560 "	71·3		76·6	17½	54	36	"
"	"	"	"	"	"	"	"	"	"	2	" T520 WQ	76·5		84·3	16	49	13	"
"	"	"	"	"	"	"	"	"	"	4¼	" T590 "	57·0		67·3	20	56	39	"
"	"	"	"	"	"	"	"	"	"	5½	" T580 AC (C)	52·4		64·4	13	—	51	"
"	"	"	"	"	"	"	"	"	"	"	" T580 AC (M)	55·1		66·6	18	52	47	"
"	"	"	"	"	"	"	"	"	"	"	" T580 AC (O)	54·6		66·4	20	57	33	"
B.E.A.	4	0·35	0·29	0·59	0·015	0·036	1·54	0·96	0·25	0·424	OQ830 T200 AC	86·6		119·0	15	47	12	8
"	"	"	"	"	"	"	"	"	"	1⅛	OQ860 T200 "	84·0		112·8	12½	45	4½	"
		0·35		0·55			1·64	1·29	0·24	0·564	OQ830 T200			119·6	13		24	9
		0·35					1·50	1·00	0·25	1⅛	OQ840 T550		66	71	18	54	33	10
		"					"	"	"	"	" T600		60	65	19½	57	55	"
		"					"	"	"	2¼	" T550		65	69	16	47	25	"
		"					"	"	"	"	" T600		59	64	19	55	36	"
		"					"	"	"	4½	" T550		59	65	17	47	25	"
		"					"	"	"	"	" T600		52	60	18½	55	39	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.		0·36	0·21	0·59			1·62	1·09	0·36	1 1/8	OQ860 T550					74·6	79·4	18 1/2	55	39	1
B.E.A.	6—8	0·36	0·15	0·48	0·014	0·028	1·56	1·03	0·26	1 5/8	N875 OQ850										
											T550					69·7	75·0	17 1/2	59 1/2	47	8
		0·36	0·27	0·57			1·75	1·02	0·23	3 3/4	OQ850 T630					49·8	58·2	23	64	82	1
B.O.H.		0·36	0·20	0·65	0·016	0·014	1·52	1·20	0·24	1 7/16	OQ840 T620					49·2	58·4	24	64	92	11
"		"	"	"	"	"	"	"	"	"	" T610					54·0	62·6	23	66	87	"
"		0·36	0·21	0·66	0·012	0·009	1·54	1·30	0·21	"	OQ840 T620					53·2	62·6	23	59	81	"
		0·36	0·25	0·61			1·49	0·96	0·31	0·9	OQ850 T530					—	80·8	17 1/2	54	36	1
		"	"	"			"	"	"	1	" T550					72·0	75·8	18 1/2	57	58	"
		0·36	0·23	0·58			1·51	1·01	0·27	0·77	" T580					68·0	71·6	19	58	55	"
		0·36	0·27	0·64			1·42	0·99	0·30	1 1/32	OQ850 T580					64·4	72·6	21	59	55	1
		0·36	0·34	0·59			1·59	1·00	0·30	2 1/4	" T610					61·6	68·2	21	60	65	"
		0·36		0·62			1·36	1·00	0·27	4 3/4	OQ830 T650					50·3	59·4	24 1/2		74	9
	6—7	0·36		0·52			1·56	1·23	0·31	1 1/8	" "					56·6	63·4	22 1/2	61 1/2	69	3
		"	"	"			"	"	"	2 1/2	" "					55·2	63·4	23 1/2	63 1/2	76	"
		"	"	"			"	"	"	3 1/4	" "					50·6	60·0	22 1/2	63 1/2	83	"
B.E.A.		0·36	0·15	0·65	0·023	0·027	1·78	1·33	0·31	5/8	OQ820 T660AC		51·2				59·6	24	63 1/2	65	12
"		"	"	"	"	"	"	"	"	1 1/8	OQ840 T660AC					49·0	58·0	22	61 1/2	67	"
	"	0·36	0·27	0·57	0·021	0·027	1·60	1·17	0·29	2 1/2	" "		48·0				58·4	22	66	75	"
	"	"	"	"	"	"			"	2 7/8	" T650AC		48·4				60·0	22	61 1/2	70	"
	"	"	"	"	"	"	"	"	"	3 1/4	" "		51·6				61·2	22	61 1/2	70	"
		0·36	0·18	0·68			1·59	1·19	0·29	2	OQ850 T660					44·7	53·3	24	65	103	4
A.O.H.	7	0·37	0·29	0·64	0·048	0·035	1·40	0·90	0·25	1 1/8	OQ860 T200AC		88·0				115·2	13 1/2	43	10	8
"	"	"	"	"	"	"	"	"	"	"	OQ850 T650		68·2				73·6	18	54	40	"
	8	0·37	0·23	0·58	0·024	0·028	1·58	1·01	0·22	1 1/8	OQ850 T640						62·7	23	58	62	"
	"	"	"	"	"	"	"	"	"	4 1/2	" T600						60·2	18 1/2	48 1/2	45	"
	7—8	0·37	0·23	0·57	0·027	0·032	1·30	1·31	0·26	1 1/8	OQ840 T640						63·1	21	58	56	"
	"	"	"	"	"	"	"	"	"	4 1/2	" T600						62·2	19 1/2	60 1/2	52	"
		0·37	0·21	0·62	0·033	0·012	1·41	1·12	0·24	1 1/8	OQ830 T620AC					55·6	60·4	18		45	3
		0·37	0·26	0·60			1·34	0·97	0·24	1 1/2	OQ850 T640					51·0	58·6	24 1/2	64	88	1
B.O.H.		0·37	0·25	0·65	0·014	0·014	1·55	1·27	0·22	1 7/16	OQ840 T620					54·0	62·0	23	64	84	11
B.O.H.		0·37	0·27	0·65	0·030	0·046	1·62	1·25	0·35	1 3/4	" "					62·4	69·3	18	45	55	"
"		"	"	"	"	"	"	"	"	4 1/2	" T625					56·0	64·4	18	42	62	"
		0·37	0·25	0·61			1·50	1·25	0·34	6 1/2	OQ850 T620					52·8	61·6	21 1/2	61	81	1
		"	"	"			"	"	"	7 1/2	" T630					48·2	57·8	20 1/2	57	75	"
		0·37		0·55			1·45	1·14	0·28	2 1/2	OQ840 T650					57·3	64·1	20 1/2		65	14
		"		"			"	"	"	4	" T620					63·1	68·6	20		54	"
		"		"			"	"	"	"	" T640					56·0	62·1	21 1/2		67	"
		0·37		0·49			1·73	1·05	0·28	1	OQ850 T580					62·4	70·1	19		56	"
		"		"			"	"	"	2 1/2	" T560					62·0	70·4	17		43	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5Rp P.S. 0·5Rp	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.									
B.E.A.		0·37	0·33	0·56	0·023	0·028	1·67	1·01	0·27	1⅛	OQ840 T660AC					47·0	55·0	24	57	74	12
B.E.A.		0·37	0·35	0·55	0·014	0·033	1·40	1·04	0·24	1¼	" T640AC					55·0	63·0	21	59½	66	"
B.E.A.		0·37	0·35	0·61	0·020	0·032	1·57	1·09	0·34	3⅜	" T650AC		46·0				57·6	22	61½	69	"
B.E.A.		0·37	0·35	0·54	0·014	0·031	1·52	1·13	0·34	3½	" T650AC					51·0	61·0	23	61½	79	"
B.E.A.		0·37	0·27	0·63	0·025	0·037	1·50	1·12	0·28	4¼	" T650AC					52·0	61·5	19	55	58	"
B.E.A.		0·37	0·26	0·58	0·017	0·031	1·56	1·18	0·29	4½	" T660AC					49·5	60·0	23	61½	77	"
B.E.A.		0·37	0·35	0·55	0·019	0·038	1·54	1·10	0·27	5½	OQ840 T640AC					48·0	61·0	16	48	41	12
"		"	"	"	"	"	"	"	"	"	" T650 "					48·0	58·0	22	57	60	"
		0·37	0·28	0·59			1·42	1·11	0·27	2½	OQ850 T660					50·8	59·3	24	63½	96	4
B.E.A.	4—5	0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31	0·424	A.C. 840	55·1	63·9	77·0	99·4		138·8	12	25½	14	4
"	"	"	"	"	"	"	"	"	"	"	" T100 2hrs. AC	56·9	65·3	77·7	98·7		136·5	12	24	15	"
"	"	"	"	"	"	"	"	"	"	"	" T200 2hrs. A	83·8	91·2	99·2	109·2		127·4	12	32½	18	"
"	"	"	"	"	"	"	"	"	"	"	" T250 2hrs. AC	91·4	95·4	110·8	111·2		122·5	12	36	10	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	92·9	96·2	100·6	109·2		116·9	11½	39	10	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	90·1	92·9	97·5	105·7		110·4	11	38½	10	"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	87·6	89·7	92·8	98·1		102·9	11½	39½	15	"
"	"	"	"	"	"	"	"	"	"	"	" T450 2hrs. AC	84·0	85·6	88·0	91·9		94·5	14	40	21	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. A	77·6	79·3	81·4	84·2		88·5	14½	42½	23	"
"	"	"	"	"	"	"	"	"	"	"	" T525 2hrs. AC	71·8	73·3	75·4	78·1		83·1	16½	50½	35	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	68·5	70·5	72·5	74·6		79·4	17	54	46	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	61·3	62·1	63·7	65·6		72·1	20	59½	57	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	58·3	59·7	61·0	62·5		69·2	18½	59½	65	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	55·2	55·8	56·5	57·7		65·7	22	62½	74	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	52·1	52·4	52·9	53·5		61·5	23½	63	85	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC				48·3		56·9	28	64	95	"
"	"	"	"	"	"	"	"	"	"	¾	" T250 2hrs. AC	89·3	94·8	101·2			123·8	11	36½	12	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	90·5	93·8	99·4	107·5		116·7	12	37	11	"
"	"	"	"	"	"	"	"	"	"	"	" T350 2hrs. AC	91·0	93·7	98·0	105·4		113·3	11	35		"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	87·8	90·3	93·7	98·8		105·4	11½	37½	11	"
"	"	"	"	"	"	"	"	"	"	"	" T450 2hrs. AC	83·8	85·8	88·4	92·4		96·4	12	40½	13	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
B.E.A.	4—5	0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31	¾	AC840 T500 2hrs. AC	77·3	79·3	81·3	84·1	89·2	14	45	16	4
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	68·6	70·2	71·7	73·5	79·2	18	53	39	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	55·4	56·1	57·3	58·8	67·5	20½	59½	62	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	53·4	53·8	54·5	55·8	65·2	22	60	67	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	49·2	49·8	50·6	52·6	61·2	24	63½	82	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	45·2	45·3	45·3	46·2	57·0	25½	66	87	"
"	"	"	"	"	"	"	"	"	"	1⅛	" T200 2hrs. AC	64·0	71·4	80·8	91·4	107·0	13	44½	19	"
"	"	"	"	"	"	"	"	"	"	"	" T250 2hrs. AC	60·8	71·0	78·0	89·6	100·0	13	47	—	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	66·8	72·8	80·4	90·2	99·4	13	45½	15	"
"	"	"	"	"	"	"	"	"	"	"	" T350 2hrs. AC	70·4	75·2	81·2	91·2	96·6	14	46½	13	"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	74·7	77·8	81·9	87·5	94·0	12½	46½	16	"
"	"	"	"	"	"	"	"	"	"	"	" T450 2hrs. AC	72·8	74·7	77·0	80·3	85·8	14½	46½	16	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	68·5	70·2	72·1	74·5	81·8	16	47	16	"
"	"	"	"	"	"	"	"	"	"	"	" T525 2hrs. AC	70·8	71·9	73·1	74·8	81·2	18	52½	20	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	63·8	64·9	65·3	67·8	75·5	18	53	36	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	56·6	57·6	58·5	59·5	69·1	20	59	68	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	51·9	52·0	52·5	53·8	64·9	21½	62½	73	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	48·9	49·1	49·2	50·8	62·4	23	64	82	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	45·9	46·1	46·4	47·2	59·1	24½	64	85	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	—	—	—	42·9	55·9	25	65½	92	"
"	"	"	"	"	"	"	"	"	"	2⅛	AC840	34·8	42·5	50·3	60·5	79·1	11½	31½	5	4
"	"	"	"	"	"	"	"	"	"	"	" T100 2hrs. AC	36·2	43·5	51·4	60·6	78·9	11½	32½	5	"
"	"	"	"	"	"	"	"	"	"	"	" T200 2hrs. AC	38·9	47·0	53·2	62·4	78·3	12	37½	6	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	42·6	49·6	57·0	66·2	77·5	12	43	4	"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	48·3	52·5	58·0	63·6	74·3	14	43½	5	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	50·9	53·6	56·9	60·4	69·2	18	46	11	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	48·6	51·1	52·8	55·1	65·3	18½	51½	17	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	48·0	48·9	50·0	51·6	61·4	20	55	17	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	45·1	46·0	46·6	47·7	59·3	20½	56½	29	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	42·6	42·9	43·4	44·8	57·2	22½	59½	39	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	39·8	39·9	40·2	40·7	53·8	23	61	83	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	37·9	37·9	38·0	38·2	51·9	24	64	90	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% (PS) (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	4—5	0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31	3	AC840	40·2	45·7	52·5	61·6	78·0	11½	35½	5	4
"	"	"	"	"	"	"	"	"	"	"	" T100 2hrs. AC	36·3	43·8	51·3	61·2	77·6	11½	32	5	"
"	"	"	"	"	"	"	"	"	"	"	" T200 2hrs. AC	39·3	45·8	52·6	62·6	77·2	12½	37½	6	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	40·2	47·2	55·0	64·5	76·4	12½	41½	4	"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	46·3	51·2	56·1	63·2	73·3	14	40½	4	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	48·8	51·5	54·5	58·3	68·2	17	46½	11	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	48·5	50·4	52·3	54·7	65·0	19	52	15	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	45·9	47·4	48·9	51·3	61·1	18½	58½	18	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	45·8	46·0	46·5	47·6	57·9	20½	56½	24	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	43·1	43·9	44·9	47·0	57·7	22	57½	41	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	39·9	40·2	40·6	41·6	54·8	23½	60	64	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	37·7	38·0	38·5	40·7	52·0	24	63	82	"
"	"	"	"	"	"	"	"	"	"	5½	AC840 (L)	36·3	43·5	51·7	63·6	80·9	13½	37	8	4
"	"	"	"	"	"	"	"	"	"	"	" T200 " 2hrs. AC	40·6	47·1	55·6	66·7	81·0	14	40½	9	"
"	"	"	"	"	"	"	"	"	"	"	" T300 " 2hrs. AC	41·4	48·5	59·3	69·2	79·8	15½	46½	8	"
"	"	"	"	"	"	"	"	"	"	"	" T400 " 2hrs. AC	49·0	54·0	59·6	65·1	76·1	14½	46½	13	"
"	"	"	"	"	"	"	"	"	"	"	" T500 " 2hrs. AC	52·6	55·6	58·8	62·5	72·2	17½	48	14	"
"	"	"	"	"	"	"	"	"	"	"	" T550 " 2hrs. AC	53·6	56·1	58·3	61·2	69·5	19	53½	16	"
"	"	"	"	"	"	"	"	"	"	"	" T575 " 2hrs. AC	51·5	52·9	54·2	62·2	64·0	21	57	19	"
"	"	"	"	"	"	"	"	"	"	"	" T600 " 2hrs. AC	46·9	49·4	50·1	51·8	60·3	22	59	36	"
"	"	"	"	"	"	"	"	"	"	"	" T625 " 2hrs. AC	44·1	44·2	45·0	47·5	57·0	23½	61	49	"
"	"	"	"	"	"	"	"	"	"	"	" T650 " 2hrs. AC	37·4	38·8	40·0	42·4	53·7	23½	61½	63	"
"	"	"	"	"	"	"	"	"	"	"	" T675 " 2hrs. AC	37·4	37·4	37·4	40·1	51·2	26	63½	62	
"	"	"	"	"	"	"	"	"	"	"	AC840 (T)	36·3	43·2	51·2	61·5	77·2	8	7	7	"
"	"	"	"	"	"	"	"	"	"	"	" T500 " 2hrs. AC	50·7	54·1	57·2	60·7	70·3	11	22½	10	"
"	"	"	"	"	"	"	"	"	"	"	" T600 " 2hrs. AC	43·7	45·1	46·5	48·6	58·2	15	29½	20	"
"	"	"	"	"	"	"	"	"	"	"	" T650 " 2hrs. AC	37·1	38·3	39·5	41·1	52·9	14	30½	29	"
"	"	"	"	"	"	"	"	"	"	¾	OQ840 T250 2hrs. AC	88·9	92·2	96·9	106·5	117·4	12	39	—	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	87·5	88·7	92·2	100·5	111·2	12	41½	7	"
"	"	"	"	"	"	"	"	"	"	"	" T350 2hrs. AC	83·4	84·4	88·0	96·0	105·8	12	38	—	"
"	"	"	"	"	"	"	"	"	"	"	" T450 2hrs. AC	79·0	80·0	82·2	87·2	92·0	12	39	13	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	75·6	76·0	77·4	80·8	87·2	15	46½	20	"
"	"	"	"	"	"	"	"	"	"	"	" T525 2hrs. AC	71·0	72·3	73·9	76·5	82·4	16	47½	26	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	68·0	69·1	70·8	72·8	78·1	17	52	37	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	62·5	63·8	65·2	66·8	72·8	19	55½	42	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	59·0	60·0	60·9	63·1	68·5	20½	58	57	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	55·3	56·0	56·9	58·7	65·6	20½	59	66	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	52·3	52·4	53·1	55·4	62·8	22	61	74	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	—	—	47·8	50·5	57·1	24½	61½	84	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·05% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.	4—5	0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31	1 1/8	OQ840	88·2	90·2	94·6	103·4		110·4	10 1/2	39	—	4
"	"	"	"	"	"	"	"	"	"	"	" T100 2hrs. AC	84·4	89·5	95·7	107·6		115·7	10 1/2	40 1/2	20	"
"	"	"	"	"	"	"	"	"	"	"	" T200 2hrs. AC	86·0	91·2	96·8	106·0		119·2	11	39 1/2	—	"
"	"	"	"	"	"	"	"	"	"	"	" T250 2hrs. AC	87·3	90·2	95·0	105·0		117·0	12 1/2	41 1/2	11	"
"	"	"	"	"	"	"	"	"	"	"	" T300 2hrs. AC	88·6	89·7	92·8	102·8		112·6	13	42	10	"
"	"	"	"	"	"	"	"	"	"	"	" T350 2hrs. AC	87·0	88·0	90·7	98·1		107·3	12	42	11	"
"	"	"	"	"	"	"	"	"	"	"	" T400 2hrs. AC	82·0	83·2	86·2	93·4		100·6	12	37	11	"
"	"	"	"	"	"	"	"	"	"	"	" T450 2hrs. AC	79·6	80·6	81·8	85·6		91·4	13 1/2	43	15	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	74·9	75·8	77·6	80·7		86·3	14 1/2	45	20	"
"	"	"	"	"	"	"	"	"	"	"	" T525 2hrs. AC	71·2	72·4	73·9	76·4		82·2	16	48 1/2	29	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	67·4	68·9	70·5	72·6		78·9	17	51	36	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	61·6	62·5	63·6	65·2		72·5	19	55	56	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	58·0	59·0	59·8	61·0		69·5	20 1/2	57	62	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	55·1	55·3	55·8	56·8		66·1	22	60 1/2	70	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	50·2	50·2	50·3	50·8		60·6	23 1/2	61 1/2	81	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	—	—	—	47·5		57·2	24	62 1/2	91	"
"	"	"	"	"	"	"	"	"	"	2 1/8	OQ840 T400 2hrs. AC	86·3	87·6	89·9	95·2		101·5	11	35 1/2	5	"
"	"	"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	74·0	74·7	76·1	78·3		83·8	15 1/2	45	12	"
"	"	"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	66·2	67·0	68·1	69·8		75·6	17	51 1/2	16	"
"	"	"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	61·5	62·0	62·4	64·2		71·7	19 1/2	55	39	"
"	"	"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	56·1	56·2	56·8	57·6		66·4	21	58 1/2	58	"
"	"	"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	53·8	53·8	54·2	54·7		64·0	23	58 1/2	68	"
"	"	"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	—	49·2	49·2	50·8		58·0	24	64 1/2	84	"
"	"	"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	—	—	—	44·2		53·7	26	64 1/2	94	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
													tons/sq.in.									
B.E.A.	4—5		0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31	3	OQ840 T400 2hrs. AC	83·2	86·2	89·0	94·0		98·1	11½	57	5	4
"	"		"	"	"	"	"	"	"	"	"	" T500 2hrs. AC	73·8	75·5	77·3	79·7		84·1	13½	45	13	"
"	"		"	"	"	"	"	"	"	"	"	" T550 2hrs. AC	66·1	67·3	68·4	70·0		76·0	18	52	16	"
"	"		"	"	"	"	"	"	"	"	"	" T575 2hrs. AC	58·0	60·7	61·9	63·6		70·5	19½	55	37	"
"	"		"	"	"	"	"	"	"	"	"	" T600 2hrs. AC	56·0	56·7	57·8	59·0		68·8	20½	60	62	"
"	"		"	"	"	"	"	"	"	"	"	" T625 2hrs. AC	52·8	53·7	54·7	56·3		64·2	23	61½	72	"
"	"		"	"	"	"	"	"	"	"	"	" T650 2hrs. AC	47·1	47·4	47·5	47·7		58·6	24	65½	86	"
"	"		"	"	"	"	"	"	"	"	"	" T675 2hrs. AC	43·6	44·0	44·1	48·5		55·1	26	65½	93	"
"	"		"	"	"	"	"	"	"	"	5¼	" T400 2hrs. AC(L)	82·8	85·7	88·5	92·8		97·5	13	46½	15	"
"	"		"	"	"	"	"	"	"	"	"	" T500 2hrs. AC "	74·8	77·4	78·7	80·4		85·7	15½	51½	17	"
"	"		"	"	"	"	"	"	"	"	"	" T550 2hrs. AC "	68·5	68·6	70·7	72·0		77·8	18	57	43	"
"	"		"	"	"	"	"	"	"	"	"	" T575 2hrs. AC "	59·4	60·1	60·8	62·0		69·5	21½	61½	59	"
"	"		"	"	"	"	"	"	"	"	"	" T600 2hrs. AC "	54·2	54·6	55·4	57·1		65·2	25	64	66	"
"	"		"	"	"	"	"	"	"	"	"	" T625 2hrs. AC "	51·5	51·7	52·2	53·6		62·9	23½	65½	76	"
"	"		"	"	"	"	"	"	"	"	"	" T650 2hrs. AC "	48·0	49·0	49·2	50·0		59·5	24½	66½	82	"
"	"		"	"	"	"	"	"	"	"	"	" T675 2hrs. AC "	—	—	—	45·5		54·4	26	68	85	"
"	"		"	"	"	"	"	"	"	"	"	" T500 2hrs. AC(T)	65·0	68·3	71·2	74·1		80·6	8½	17½	9	"
"	"		"	"	"	"	"	"	"	"	"	" T600 2hrs. AC "	48·7	50·0	51·0	52·1		62·2	16	62	36	"
"	"		"	"	"	"	"	"	"	"	"	" T650 2hrs. AC "	46·2	47·0	47·5	48·2		58·4	—	—	45	"
B.E.A.	6—7	7	0·38	0·36	0·49	0·015	0·016	1·55	1·02	0·23	1⅛	OQ840 T575 OQ(C)					62·0	68·2	21	62	52	8
"	"		"	"	"	"	"	"	"	"	"	" " (O)					62·5	69·0	20	59	45	"
"	"		"	"	"	"	"	"	"	"	2½	" " (C)					60·8	67·2	22	59½	50	"
"	"		"	"	"	"	"	"	"	"	"	" " (M)					62·0	68·9	22	60	49	"
"	"		"	"	"	"	"	"	"	"	"	" " (O)					62·4	68·8	22	62½	50	"
"	"		"	"	"	"	"	"	"	"	4	" " (C)					56·3	64·6	22	59½	55	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%) C	Si	Mn	S	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.E.A.	6—7	0·38	0·36	0·49	0·015	0·016	1·55	1·02	0·23	4	OQ840 T575 OQ (M)		58·0	66·1	23	61	52	8
"	"	"	"	"	"	"	"	"	"	"	" " (O)		61·4	67·5	22	62½	53	"
"	"	"	"	"	"	"	"	"	"	6	" " (C)		50·9	59·2	21	52	53	"
"	"	"	"	"	"	"	"	"	"	"	" " (M)		53·0	62·2	22	56½	50	"
"	"	"	"	"	"	"	"	"	"	"	" " (O)		56·0	63·2	22	60	52	"
	8	0·38	0·27	0·58	0·019	0·030	1·49	0·98	0·19	1½	" T640			61·9	21½	58	75	"
	"	"	"	"	"	"	"	"	"	4½	" T610			60·6	21	54½	40	"
B.E.A.	6—8	0·38	0·24	0·62	0·032	0·032	1·43	1·00	0·29	1⅜	N875 OQ850 T550		70·6	80·0	19	49	25	"
B.O.H.		0·38	0·26	0·72	0·020	0·039	1·50	0·80	0·45	⅞	OQ840 T650		58·9	66·2	20	59	53	11
"		"	"	"	"	"	"	"	"	1¾	OQ850 T650		54·4	62·4	19	57	62	"
B.O.H.		0·38	0·23	0·60	0·032	0·036	1·48	0·90	0·25	1⅞	OQ830 T220		—	112·0	10	40	6	"
B.O.H.		0·38	0·17	0·56	0·035	0·046	1·42	1·25	0·24	2	OQ840 T600		63·2	70·4	17	50	38	"
"		"	"	"	"	"	"	"	"	2⅛	" T610		53·6	63·4	19	47	58	"
B.O.H.		0·38	0·25	0·66	0·008	0·012	1·49	1·25	0·20	1⅛	" T620		53·2	61·6	24	64	81	"
		0·38	0·25	0·59			1·52	1·00	0·21	1⅛	OQ850 T250		—	122·6	12	33	15	1
		0·38	0·22	0·60			1·70	1·05	0·29	3⅛	" T580		66·8	71·8	19½	56	63	"
		0·38		0·62			1·44	1·12	0·31	4¾	OQ830 T650		53·1	61·4	21		82	14
		0·38		0·63			1·79	1·10	0·28	3⅜	OQ850 T650		59·2	66·0	21		89	"
		0·38		0·47			1·53	1·03	0·31	1⅛	" T510		79·5	83·6	15		28	"
		"		"			"	"	"	"	" T560		68·3	73·5	19		55	"
B.E.A.		0·38	0·32	0·38	0·015	0·015	1·61	1·09	0·25	0·564	" T250			118·4	12	39½	7	15
B.E.A.		0·38	0·33	0·60	0·020	0·033	1·70	1·00	0·27	1⅛	OQ840 T660 AC		49·0	57·0	21	57	65	12
B.E.A.		0·38	0·28	0·60	0·012	0·034	1·65	1·10	0·25	1⅜	" " "	48·0		57·2	22	66	91	"
"		"	"	"	"	"	"	"	"	1¼	" T650 "	48·8		56·8	23	59½	77	"
"		"	"	"	"	"	"	"	"	1½	" T660 "	48·4		58·0	23	63½	73	"
B.E.A.		0·38	0·19	0·69	0·028	0·032	1·46	1·24	0·28	1¾	" " "		54·0	61·5	21	61½	76	"
"		0·38	0·35	0·55	0·018	0·030	1·52	1·12	0·30	2¾	" " "	45·6		58·8	21	61½	73	"
"		0·38	0·32	0·56	0·020	0·030	1·60	1·09	0·35	3⅛	" " "		53·0	63·0	21	52½	61	"
B.E.A.		0·38	0·31	0·53	0·023	0·036	1·58	1·08	0·31	3½	" T650 "	45·6		58·8	22	61½	70	"
"		"	"	"	"	"	"	"	"	3⅝	" " "	46·8		58·0	22	63½	71	"
"		"	"	"	"	"	"	"	"	3¾	" T650 "	49·2		60·0	21	63½	64	"
		0·38	0·23	0·66			1·54	1·00	0·26	4	OQ850 T650		46·2	58·5	25		86	4

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq. in.	Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
			0·39		0·58			1·42	1·06	0·30	4¾	OQ830 T650		48·7	58·9	21		81	9
			0·39	0·23	0·55	0·021	0·025	1·77	1·01	0·25	1⅛	OQ840 T640			63·8	22	59½	63	8
			"	"	"	"	"	"	"	"	4½	" T600			61·6	17½	42	42	"
A.O.H.	5—6																		
	(7—8)	6—7	0·39	0·26	0·63	0·048	0·035	1·60	1·17	0·24	1½	N875 OQ850 T550		71·5	79·1	17½	52½	26	"
			0·39	0·27	0·62			1·67	1·10	0·22	1⅛	OQ850 T640		50·4	59·0	24	63	86	1
			0·39	0·27	0·60			1·49	1·07	0·30	"	" T250		104·0	122·4	15½	44	17	"
B.O.H.			0·39	0·24	0·73	0·030	0·027	1·46	1·00	0·35	1	OQ840 T650		59·6	67·6	20	54	54	"
			0·39		0·58			1·54	1·15	0·28	1⅛	OQ830 T550		76·0	79·5	18½		42	14
			0·39		0·53			1·69	1·15	0·30	2¼	OQ840 T600		64·4	70·8	19		58	"
			0·39		0·57			1·44	1·03	0·25	2½	OQ830 T620		54·8	64·0	22		79	"
			0·39		0·63			1·46	1·07	0·26	5¾	" T650		50·1	58·9	19½		75	"
A O.H.			0·39	0·27	0·68	0·035	0·037	1·47	1·09	0·23	8	OQ850 T630 (M)		49·5	60·6	25	52½	40	15
			0·39	0·25	0·60			1·38	1·05	0·35	8¼	" T620		48·8	59·8	20	57	45	4
B.E.A.			0·39	0·26	0·56	0·011	0·033	1·53	1·10	0·31	⅞	OQ840 T660 AC	43·0		62·8	23	57	61	12
"			"	"	"	"	"	"	"	"	¾	" T650 "	49·6		60·8	24	59½	67	"
"			"	"	"	"	"	"	"	"	1	" T660 "	50·0		59·2	21	50	74	"
"			0·39	0·35	0·54	0·028	0·026	1·55	1·09	0·27	1½	" T620 "		63·0	70·0	19	55	50	"
"			0·39	0·31	0·60	0·017	0·035	1·47	1·19	0·26	1⅝	" T650 "	51·6		61·6	22	59½	73	"
"			0·39	0·35	0·59	0·015	0·038	1·54	1·16	0·27	3¼	" T650		50·0	63·0	20	53	61	"
"			"	"	"	"	"	"	"	"	"	" T660		50·0	61·0	22	59½	65	"
			0·39		0·60			1·50	1·15	0·30	1⅛	OQ830		100	128	12	31	10	14
			"		"			"	"	"	"	" T100		103	125	12	34	18	"
			"		"			"	"	"	"	" T200	85	103	119	13	39	20	"
			"		"			"	"	"	"	" T300	87	98	110	14	44	10	"
			"		"			"	"	"	"	" T400	83	90	98	15	48	13	"
			"		"			"	"	"	"	" T500	75	77	84	17	53	27	"
			"		"			"	"	"	"	" T600	60	63	68	20	60	50	"
			"		"			"	"	"	"	" T650	51	54	60	23	68	73	"
			0·40		0·59			1·65	1·15	0·24	4½	OQ830 T650		54·3	62·0	21½		79	9
			0·40		0·55			1·50	1·10	0·19	1⅛	OQ840 T200		107·2	129·5	10½	27½	20	3
			0·40	0·25	0·51	0·018	0·012	1·38	1·29	0·26	1⅛	OQ850 T650 AC		51·7	68·9	20		82	13
B.O.H.			0·40	0·27	0·70	0·026	0·021	1·48	0·75	0·28	⅞	OQ840 T650		58·9	66·2	20	59	53	11
			0·40	0·31	0·58			1·90	1·10	0·34	0·564	OQ850 T200			128·8	15	37	16	1
			0·40		0·63			1·65	1·25	0·24	2½	OQ830 T650		59·0	65·0	21		29	9
			"		"			"	"	"	4	" "		58·6	63·8	23		68	"
			0·40		0·58			1·50	1·15	0·28	2	" T610		60·8	67·2	20		68	14

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.						
		0·40	0·20	0·60			1·55	1·11	0·30	0·564	OQ850 T200			116·0	14		27	4
		0·40	0·28	0·65			1·55	1·11	0·25	1 sq.	" T600		58·6	70·0	20		55	"
		0·40	0·22	0·59			1·44	1·09	0·26	3¼	" T620		55·0	66·0	20	37	61	"
		0·40	0·18	0·64			1·35	1·15	0·33	2½	" T600		66·0	74·0	18	50	47	"
B.O.H.		0·40	0·33	0·56	0·014	0·031	1·39	1·07	0·30	⅞	OQ820 T660 AC	50·4		59·6	28	61½	72	12
"		0·40	0·27	0·57	0·015	0·024	1·51	1·19	0·35	1¼	OQ840 T640 "		61·0	68·0	20	55	62	"
"		0·40	0·29	0·53	0·011	0·036	1·60	1·07	0·26	1⅞	" T660 "	53·2		62·8	23	59½	64	"
"		"	"	"	"	"	"	"	"	2	" " "	54·0		62·4	23	59½	63	"
"		0·40	0·31	0·61	0·034	0·034	1·60	1·02	0·35	2⅞	" " "	48·8		60·0	22	61½	70	"
"		0·40	0·35	0·55	0·014	0·026	1·60	1·14	0·28	3½	" T650 "		52·0	62·0	22	59½	68	"
	7—8	0·40		0·5			1·65	1·15	0·25	0·564	OQ830 T200 2hr.		106.0	127·5	13	36	18	3
	"	"		"			"	"	"	"	" T300 "		105·6	114·4	11	42	14	"
	"	"					"	"	"	"	" T400 "		100·3	101·6	11½	44	14	"
	"	"		"			"	"	"	"	" T450 "		90·4	94·5	13	50	18	"
	"	"		"			"	"	"	"	" T500 "		84·4	87·4	16	50	20	"
	"	"		"			"	"	"	"	" T550 "		80·5	83·6	16	52	36	"
	"	"		"	"		"	"	"	"	" T600 1hr.		65·6	70·4	20	59	62	"
	"	"		"			"	"	"	"	" T600 2hr.		66·3	71·0	17½	47	68	"
	"	"		"			"	"	"	"	" T650 "		60·3	66·0	21½	62	78	"
	"	"		"			"	"	"	2½	" T550 2½ hr.		77·9	80·8	16½	50	24	"
	"	"		"			"	"	"	"	" T600 "		65·5	71·6	20	62	59	"
	"	"		"			"	"	"	"	" T650 "		57·2	63·6	22	63	74	"
	"	"		"			"	"	"	4½	" T550 3½ hr.(C)		75·9	79·5	15½	44	25	"
	"	"		"			"	"	"	"	" 3½ hr.(O)		77·4	81·1	16½	47	26	3
	"	"		"			"	"	"	"	" T600 3½ hr.(C)		62·4	69·3	20	57	59	"
	"	"		"			"	"	"	"	" " (O)		64·0	70·6	19	59	57	"
	"	"		"			"	"	"	"	" T650 3½ hr.(C)		54·3	62·0	21½	62	79	"
	"	"		"			"	"	"	"	" " (O)		55·4	61·0	23½	64	74	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
	6—8	0·41	0·30	0·56	0·039	0·035	1·52	1·08	0·27	1⅛	OQ840 T650					64·8	21	57	44	8
	"	"	"	"	"	"	"	"	"	4½	" T600					63·2	18	47	43	"
		0·41		0·59			1·60	1·21	0·28	0·564	OQ830 T200					125·5	14½		24	9
		0·41	0·32	0·50	0·017	0·023	1·35	1·18	0·26	1⅛	OQ840 T650 AC				60·8	67·5	20		73	13
B.O.H.		0·41	0·23	0·59	0·031	0·032	1·49	0·92	0·24	1⅜	OQ830 T220					112·0	10	40	6	11
		0·41	0·19	0·53			1·55	1·16	0·25	6	OQ850 T640				50·0	60·4	21	60	73	4
B.E.A.		0·41	0·24	0·65	0·020	0·040	1·47	1·22	0·29	⅞	OQ820 T660 AC				54·0	58·0	24	61½	71	12
"		"	"	"	"	"	"	"	"	1½	OQ840 T660 "				53·0	62·0	22	61½	73	"
B.E.A.		0·41	0·20	0·70	0·026	0·032	1·59	1·24	0·34	3½	" T660 "				48·0	57·0	20	52½	70	"
B.E.A.		0·41	0·26	0·63	0·027	0·025	1·46	1·17	0·29	4½	" T630 "				51·0	62·0	19	59½	48	"
B.E.A.	5—6	0·41	0·26	0·72			1·86	1·30	0·34	T.P.	OQ850 T200 AC	92·9	99·1	106·0		127·0	14	39½	13	16
"	"	"	"	"			"	"	"	"	" T300 "	93·4	94·0	95·2		107·0	13½	42½	8	"
"	"	"	"	"			"	"	"	"	" T400 "	87·2	88·8	90·0		100·4	12	35	10	"
"	"	"	"	"			"	"	"	1⅛	" T200 "	93·2	99·0	102·0		121·6	9	21½	15	"
"	"	"	"	"			"	"	"	"	" T300 "	94·4	96·4	98·0		111·8	11	39	9	"
"	"	"	"	"			"	"	"	"	" T400 "	89·0	90·0	91·0		100·0	11½	33½	13	"
"	"	"	"	"			"	"	"	"	" T500 "	83·0	84·5	87·0		93·8	15	38	11	"
"	"	"	"	"			"	"	"	"	" T550 "	79·5	80·8	84·8		88·8	18	48½	15	"
"	"	"	"	"			"	"	"	"	" T575 "	75·2	76·0	77·6		83·3	16	49½	27	"
"	"	"	"	"			"	"	"	"	" T600 "	71·6	72·4	73·2		78·4	18	52	46	"
"	"	"	"	"			"	"	"	"	" T626 "	66·7	66·7	66·7		72·4	21½	52½	64	"
"	"	"	"	"			"	"	"	"	" T650 "	56·4	56·4	56·4		62·8	21½	59½	75	"
"	"	"	"	"			"	"	"	2½	" T575(M)	76·4	78·0	78·0		85·2	16	48½	21(21C)	"
"	"	"	"	"			"	"	"	"	" T600 "	70·4	71·6	72·0		82·4	18½	51	26(26C)	"
"	"	"	"	"			"	"	"	"	" T625 "	64·0	66·0	66·0		72·8	18½	58	48(51C)	"
"	"	"	"	"			"	"	"	"	" T650 "	62·0	62·0	62·0		68·4	21	58	50(53C)	"
"	"	"	"	"			"	"	"	4	" T575 "	75·2	77·6	78·0		84·8	16	46	16(16C)	"
"	"	"	"	"			"	"	"	"	" T600 "	66·0	66·0	66·0		74·8	16	50	43(46C)	"
"	"	"	"	"			"	"	"	"	" T625 "	64·0	64·0	64·0		71·6	19	54½	48(54C)	"
"	"	"	"	"			"	"	"	"	" T650 "	60·0	60·0	60·0		68·4	19	57	47(51C)	"
"	"	"	"	"			"	"	"	6	" T575 "	74·6	76·2	77·0		84·4	17	48½	17(15C)	"
"	"	"	"	"			"	"	"	"	" T600 "	69·6	71·1	71·1		77·9	17	52	23(23C)	"
"	"	"	"	"			"	"	"	"	" T625 "	61·2	62·4	62·4		67·3	19	57	51(51C)	"
"	"	"	"	"			"	"	"	"	" T650 "	58·2	59·0	59·0		66·4	19½	57	53(55C)	"
"	"	"	"	"			"	"	"	8	" T575 "	62·4	62·8	63·4		71·8	18½	53½	—	"
"	"	"	"	"			"	"	"	"	" T600 "	59·6	60·0	60·0		67·6	20	53½	49(46C)	"
"	"	"	"	"			"	"	"	"	" T625 "	54·0	54·0	54·0		63·6	22	59½	50(50C)	"
"	"	"	"	"			"	"	"	"	" T650 "	50·0	50·0	50·0		60·4	23½	61½	51(49C)	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.E.A.	6—7	6—7	0·42	0·21	0·59	0·012	0·017	1·69	1·20	0·41	1½	N875 OQ850 T550				71·5	79·1	17½	52½	26	8
B.E.A.			0·42	0·26	0·60	0·023	0·031	1·49	1·04	0·24	1⅞	OQ850 T650 AC				57·6	66·0	21	54	59	11
"			"	"	"	"	"	"	"	"	"	" T660 "				54·6	63·2	22	59	64	"
"			"	"	"	"	"	"	"	"	2 7/16	" T650 "				51·2	61·0	22	57	67	"
"			0·42	0·30	0·56	0·012	0·035	1·57	1·21	0·27	5×1¾	" " "	52·0				63·6	20	61½	57	"
	5—7	6—7	0·43	0·28	0·63	0·019	0·030	1·41	1·10	0·26	1⅛	OQ850 T600 AC									
												(C)				58·8	72·8	18½	53½	49	8
	"	"	"	"	"	"	"	"	"	"	2½	" " (O)				54·4	66·0	22½	59½	62	"
	"	"	"	"	"	"	"	"	"	"	"	" " (C)				54·4	62·4	22	56	71	"
	"	"	"	"	"	"	"	"	"	"	4	" " (O)				53·8	64·0	20	46	65	"
	"	"	"	"	"	"	"	"	"	"	"	" " (M)				52·0	64·0	18½	46	51	"
	"	"	"	"	"	"	"	"	"	"	"	" " (C)				50·4	61·2	15	26	39	"
	"	"	"	"	"	"	"	"	"	"	6	" " (O)				53·6	64·0	18	39	39	"
	"	"	"	"	"	"	"	"	"	"	"	" " (M)				54·4	63·2	15½	32	26	"
	"	"	"	"	"	"	"	"	"	"	"	" " (C)				50·4	56·4	5½	10	29	"
	6—8		0·43	0·24	0·64	0·019	0·030	1·66	1·15	0·25	1⅛	OQ840 T650					65·4	20½	54½	48	"
	"		"	"	"	"	"	"	"	"	4½	" T610					63·6	21½	53½	42	"
A.O.H.	5—6	5—7	0·43	0·21	0·63	0·041	0·037	1·54	1·15	0·28	1½	N875 OQ850 T550				71·5	79·7	19	50½	20	"
			0·43	0·23	0·58	0·019	0·020	1·53	1·20	0·20	T.P.	OQ840 T350 4hr.	95·0	96·4	101·1		107·9	13			1
			"	"	"	"	"	"	"	"	"	" 8hr.	95·4	96·4	100·1		106·1	13			"
			"	"	"	"	"	"	"	"	"	" 16hr.	97·5	99·0	101·3		105·2	13			"
			0·44		0·64			1·69	1·13	0·25	3½	OQ850 T650				63·6	70·4	18½		56	9
			0·44	0·27	0·63			1·76	1·09	0·23	4	" T640				53·0	61·6	23	60	75	1
B.O.H.			0·45	0·25	0·78	0·023	0·032	1·58	0·77	0·39	1 5/16	OQ850 T650				50·0	59·2	22	57	65	11

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Ref. 4)

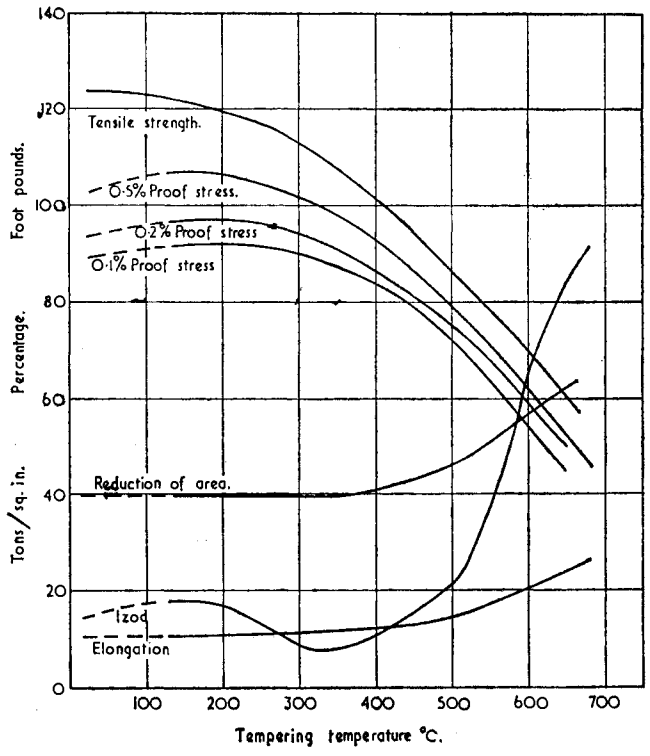


Fig. 24.17

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·37	0·24	0·66	0·009	0·007	1·68	1·23	0·31

Basic Electric Arc.
McQuaid Ehn grain size 4—5.
$1\frac{1}{4}$ in. dia. bars Oil Quenched 840°C.
Tempered as indicated.

(Ref. 16)

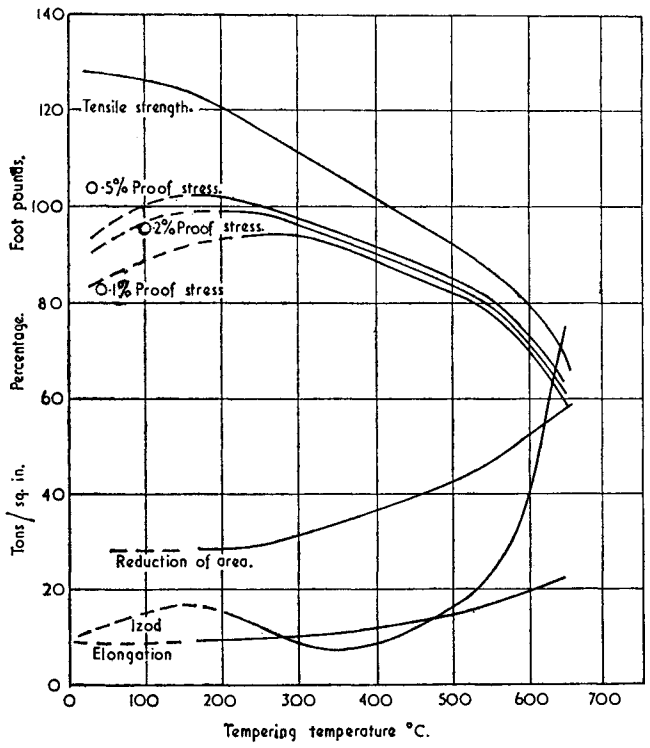


Fig. 24.18

Chemical Composition (%)					
C	Si	Mn	Ni	Cr	Mo
0·41	0·26	0·72	1·86	1·30	0·34

Basic Electric Arc.
McQuaid Ehn grain size 5—6.
$1\frac{1}{4}$ in. dia. bars Oil Quenched 850°C.
Tempered as indicated.

En 24

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE

These curves have been produced from the results obtained on several casts of En 24

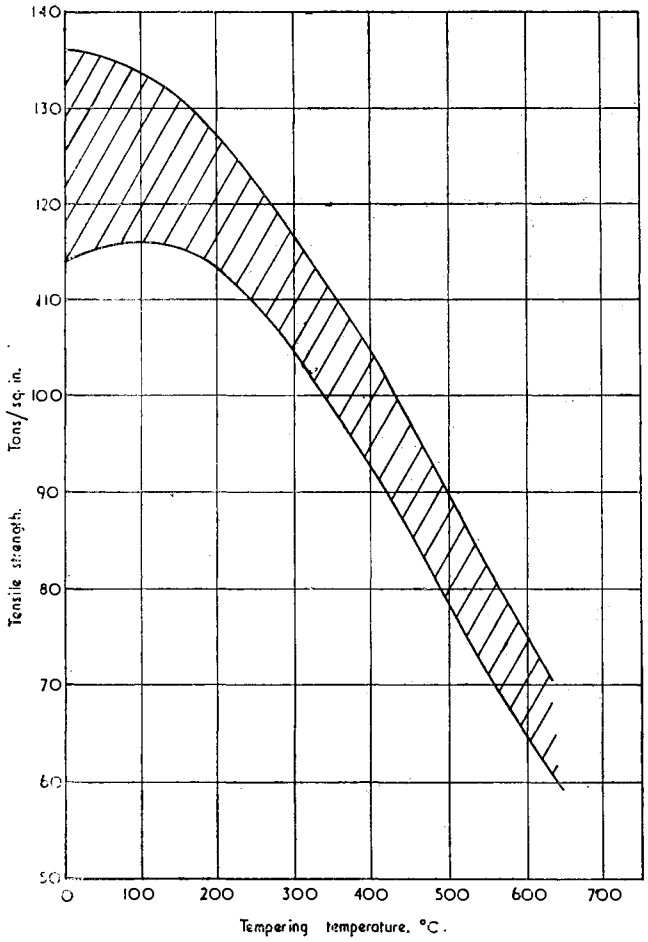


Fig. 24.19(A)

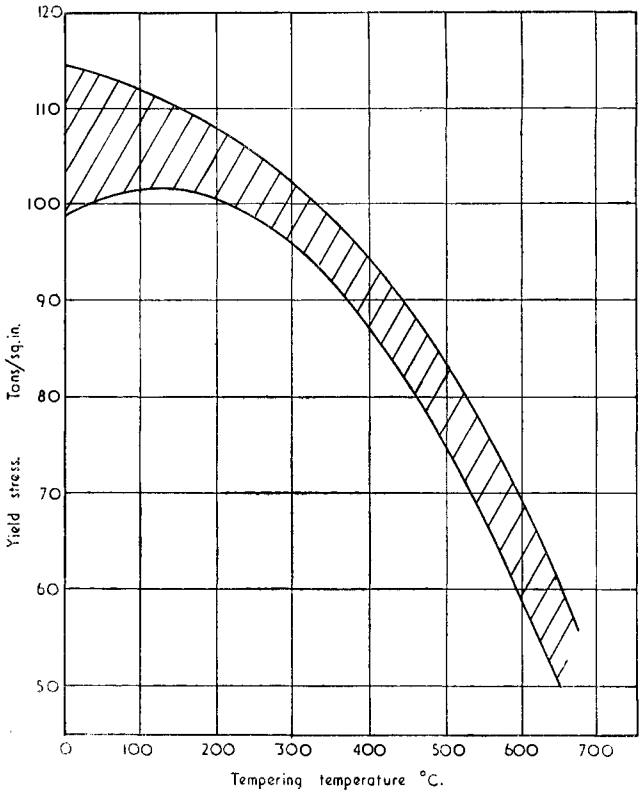


Fig. 24.19(B)

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

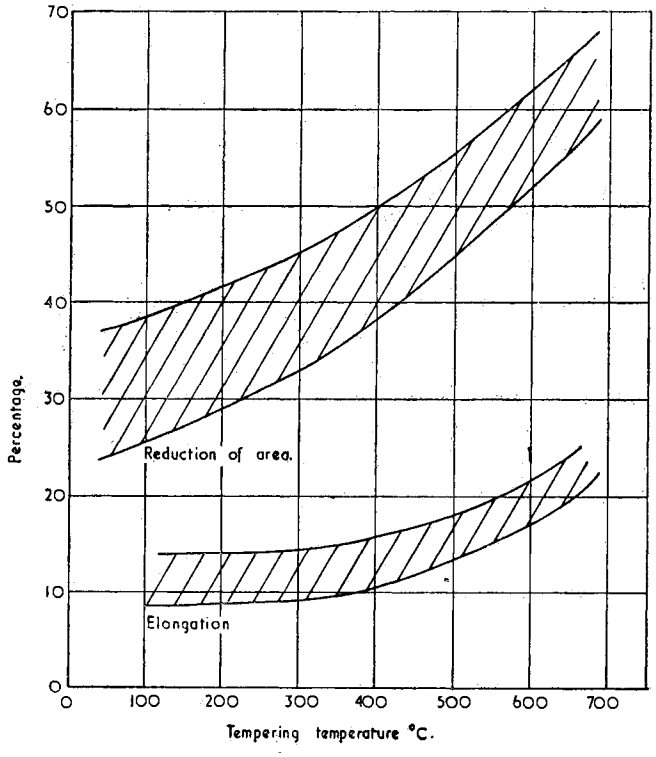


Fig. 24.19(C)

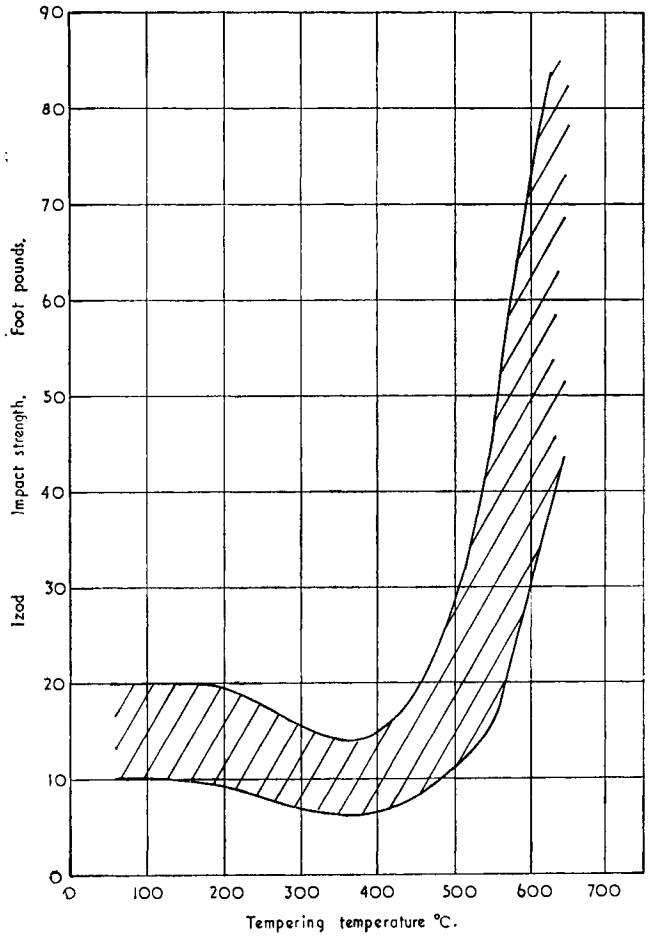


Fig. 24.19(D)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Oil Quenched. Tempered 500°C.

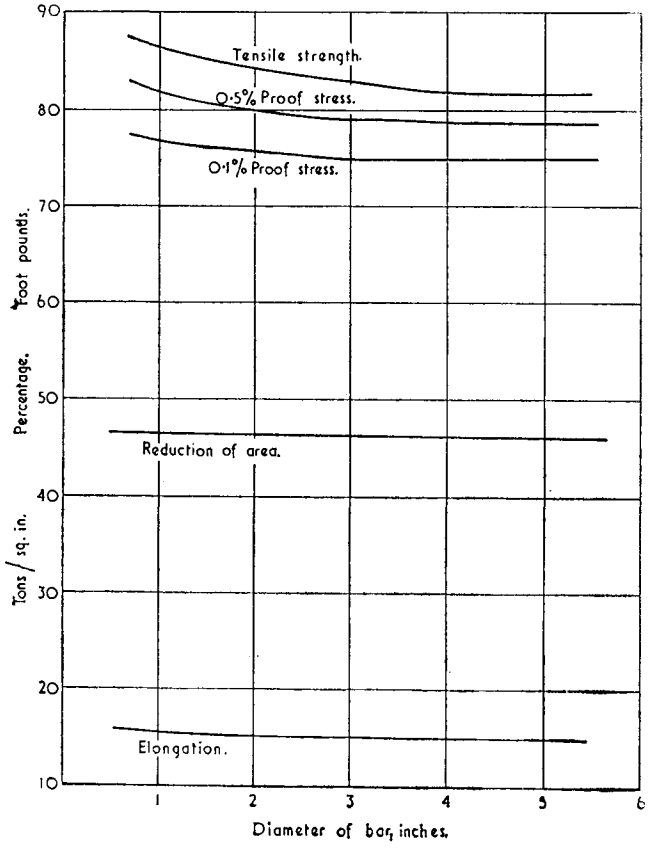


Fig. 24.20

Oil Quenched. Tempered 550°C.

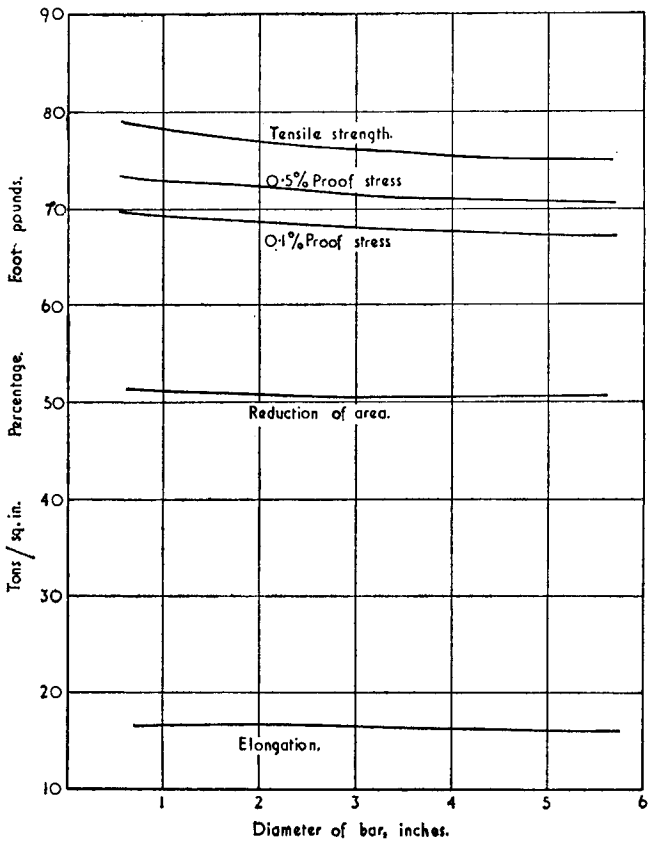


Fig. 24.21

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Oil Quenched. Tempered 600°C.

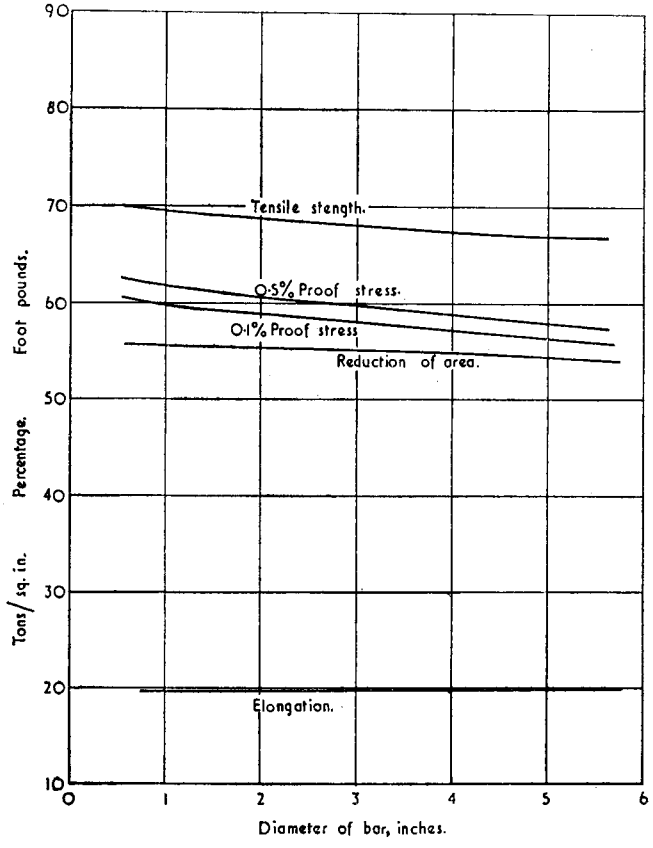


Fig. 24.22

Oil Quenched. Tempered 650°C.

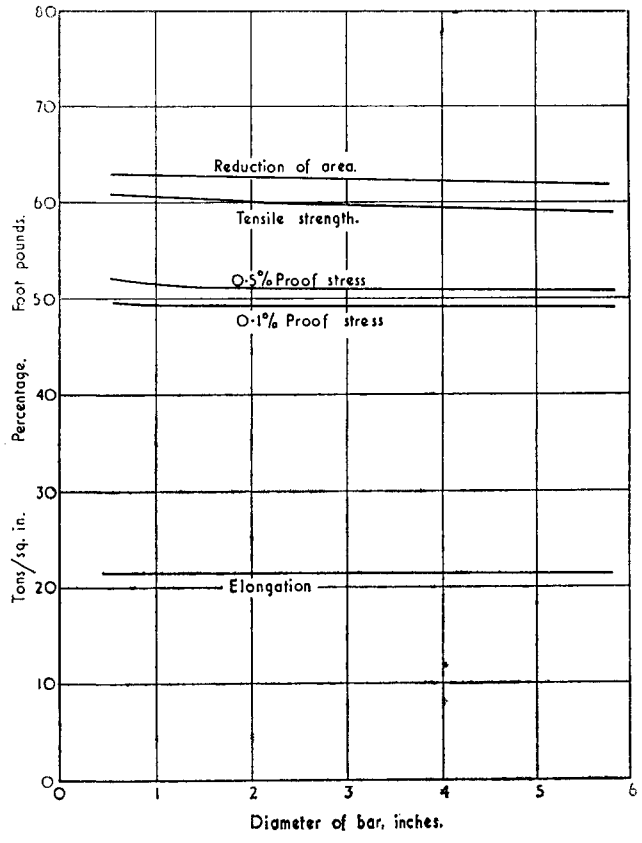


Fig. 24.23

MECHANICAL PROPERTIES AT LOW TEMPERATURE

As Quenched Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in.						
7	0·35	0·22	0·56	0·003	0·023	1·63	1·07	0·21	$\frac{5}{8}$	OQ840 T200 AC	20	88·2	94·6	102·5	120·6	18	52	14
"	"	"	"	"	"	"	"	"	"	" " "	— 78	86·1	93·1	102·4	126·0	19	57	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	100·3	106·9	115·7	138·5	18	44	"
"	"	"	"	"	"	"	"	"	"	" T520 WQ	20	73·3	74·9	77·5	80·0	19	56	"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	76·7	77·7	78·9	86·7	18	52	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	93·2	94·2	96·0	102·2	18	22	"
"	"	"	"	"	"	"	"	"	"	" T590 "	20	64·9	65·8	66·6	72·6	22	60	"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	66·6	67·7	68·7	78·2	23	58	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	86·5	88·0	90·0	96·9	17	24	"
"	"	"	"	"	"	"	"	"	"	" T650 "	20	53·0	53·2	53·6	60·7	27	68	"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	54·3	54·6	55·3	67·2	30	64	"
"	"	"	"	"	"	"	"	"	"	" " "	—196	76·0	77·0	78·0	87·1	24	37	"
	0·42	0·31	0·63	0·030	0·026	1·07	1·16	0·20	0·179	WQ850 T150 1hr.	R.T.				154	$5\frac{1}{2}$	4	17
	"	"	"	"	"	"	"	"	"	" "	— 60				138	2	2	"
	"	"	"	"	"	"	"	"	"	" T175 1hr.	R.T.				141	10	48	"
	"	"	"	"	"	"	"	"	"	" "	— 60				149	17	45	"
	"	"	"	"	"	"	"	"	"	" "	—120				151	17	49	"
	"	"	"	"	"	"	"	"	"	" "	—145				153	13	30	"
	"	"	"	"	"	"	"	"	"	" "	—196				166	8	8	"
	"	"	"	"	"	"	"	"	"	" T200	R.T.				140	10	48	"
	"	"	"	"	"	"	"	"	"	" "	— 60				143	13	40	"
	"	"	"	"	"	"	"	"	"	" "	—120				143	16	48	"
	"	"	"	"	"	"	"	"	"	" "	—145				142	16	48	"
	"	"	"	"	"	"	"	"	"	" "	—196				158	9	8	"
	"	"	"	"	"	"	"	"	"	" T225	R.T.				125	10	52	"
	"	"	"	"	"	"	"	"	"	" "	— 60				137	18	51	"
	"	"	"	"	"	"	"	"	"	" "	—145				140	17	48	"
	"	"	"	"	"	"	"	"	"	" "	—196				150	9	12	"
	"	"	"	"	"	"	"	"	"	" T250	R.T.				116	11	46	"
	"	"	"	"	"	"	"	"	"	" "	— 60				113	17	48	"
	"	"	"	"	"	"	"	"	"	" "	—145				136	15	47	"
	"	"	"	"	"	"	"	"	"	" "	—196				143	17	45	"
	(within specification)								$1\frac{1}{4}$	OQ and T	20	50·8	50·9	51·3	59·5	26		18
											—100	60·5	60·7	61·1	72·5	28		"
											—195	78·1	79·0	81·2	88·4	28		"

IMPACT TRANSITION TEMPERATURE DATA

McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Charpy V Notch	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			80% Maximum Energy Transition Temperature °C	
8—9	0·38	0·25	0·77	0·035	0·020	1·65	0·95	0·21	$\frac{1}{2}\times 2\frac{1}{2}$	OQ845 T177	—140	19
"	"	"	"	"	"	"	"	"	"	" T204	—134	"
"	"	"	"	"	"	"	"	"	"	" T316	— 79	"
"	"	"	"	"	"	"	"	"	"	" T427	— 20	"
"	"	"	"	"	"	"	"	"	"	" T538	— 73	"
"	"	"	"	"	"	"	"	"	"	" T649	—107	"

IMPACT TRANSITION TEMPERATURE CURVES

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·35	0·22	0·56	0·003	0·023	1·63	1·07	0·21

As quenched Grain Size 7 ASTM.

$\frac{5}{8}$in. dia. bars Oil Quenched 840°C. Tempered as indicated

(*See also* Mechanical Properties at Low Temperature.)

(Ref. 14)

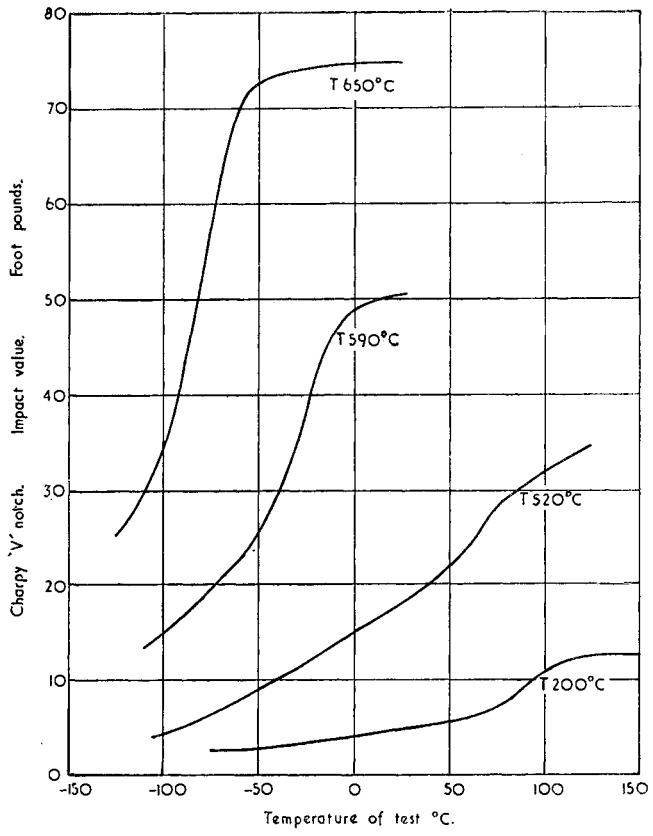


Fig. 24.24

(Ref. 14)

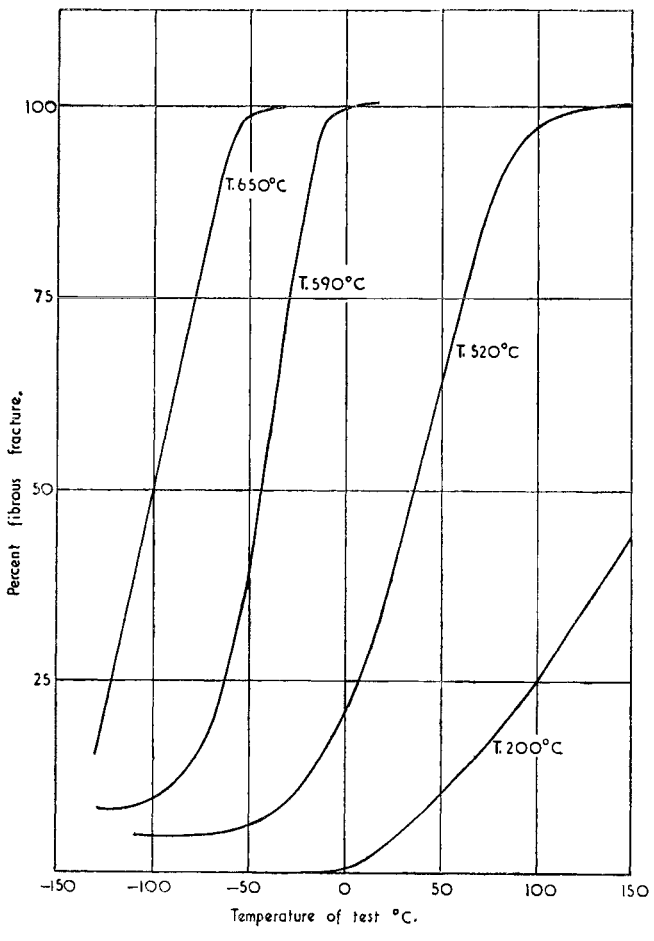


Fig. 24.25

Curve No.	Chemical Composition (%) C	Mn	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	Ref.
A	0·40	0·60	1·55	1·10	0·28	$\frac{3}{8}$	OQ850 T600	62·3	62·9	64·2	70·8	21½	58½	4
B	"	"	"	"	"	"	" T650	45·0	47·2	49·7	58·8	25	66	"
C	"	"	"	"	"	$\frac{3}{4}$	" T600	56·5	57·2	58·4	65·8	22	65	"
D	"	"	"	"	"	"	" T650	38·6	41·7	45·7	57·9	25½	22	"
E	"	"	"	"	"	1	" T600	62·9	63·4	64·7	70·1	21½	59½	"
F	"	"	"	"	"	"	" T650		53·2	(Y.P.)	61·5	23½	63½	"
G	"	"	"	"	"	4 sq.	" T600	56·5	57·7	58·8	67·3	20½	57	"
H	"	"	"	"	"	"	" T650	50·5	50·7	51·1	61·2	22½	62	"

(Ref. 4)

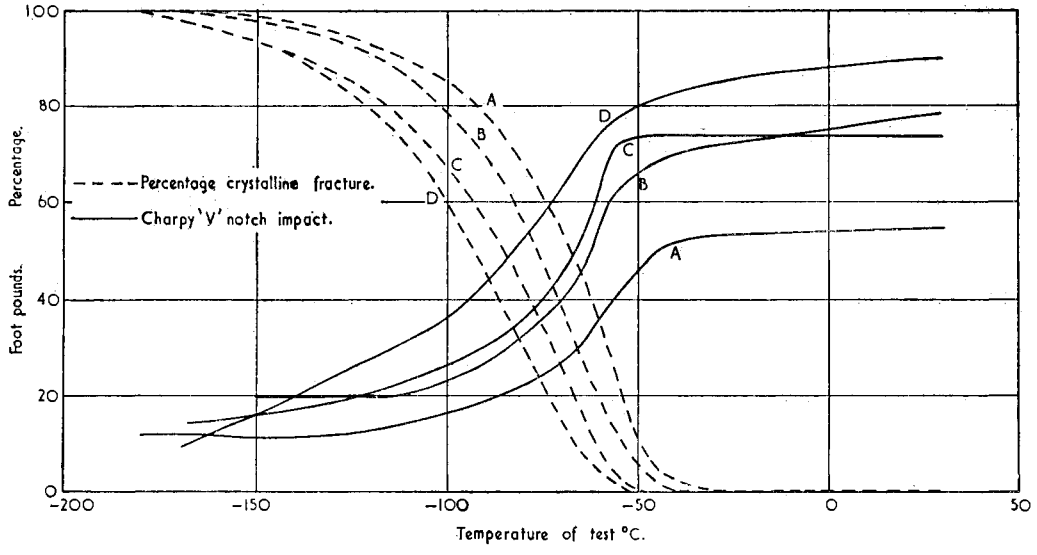


Fig. 24.26

(Ref. 4)

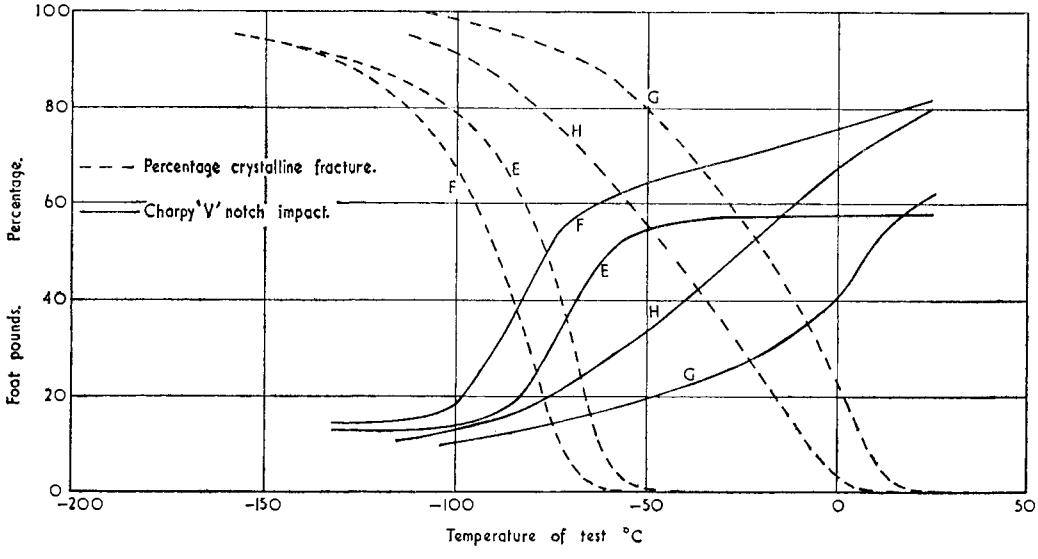


Fig. 24.27

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Heating Time hrs.	Tensile				Izod ft.lb.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·1% P.S. (0·1Rp)	T.S. (Rm)	El % (A)		
											tons/sq.in.					
0·36	0·24	0·61	0·015	0·012	1·48	0·97	0·32	H & T	R.T.	—	58·8	68·0	74·6	20	—	20
"	"	"	"	"	"	"	"	"	100	20	49·7	63·0	71·7	17½*	—	"
"	"	"	"	"	"	"	"	"	150	"	48·0	60·8	69·8	19	—	"
"	"	"	"	"	"	"	"	"	200	"	39·8	57·5	69·1	17½*	—	"
"	"	"	"	"	"	"	"	"	250	1	32·0	52·0	64·6	21	53	"
"	"	"	"	"	"	"	"	"	"	20	32·0	53·0	65·9	19½	57	"
"	"	"	"	"	"	"	"	"	"	200	34·0	53·0	65·7	16*		"
"	"	"	"	"	"	"	"	"	"	1000	39·8	52·6	64·2	15*		"
"	"	"	"	"	"	"	"	"	300	1	30·0	48·6	62·7	18*		"
"	"	"	"	"	"	"	"	"	"	20	29·9	50·6	63·8	25		"
"	"	"	"	"	"	"	"	"	"	200	28·0	50·6	64·2	22½		"
"	"	"	"	"	"	"	"	"	"	1000	30·0	50·8	64·0	23*		"
"	"	"	"	"	"	"	"	"	350	1	25·9	47·2	60·2	25		"
"	"	"	"	"	"	"	"	"	"	20	28·0	48·0	60·7	24		"
"	"	"	"	"	"	"	"	"	"	200	25·9	48·4	61·0	21½		"
"	"	"	"	"	"	"	"	"	"	1000	25·9	50·4	63·1	24½		"

* Broke at gauge points.

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile					Torsion				Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. (%) (Z)	0·1% P.S. (0·1Rp)	Y.P. (Rs)	Apparent max Shear Stress	Probable max Shear Stress	
												tons/sq.in.					tons/sq. in.				
B.E.A.	0·36	0·25	0·49	0·023	0·013	1·49	1·07	0·29	11/16		RT	40·8		56·8	25½		28·0		50·8	38·1	21
B.E.A.	0·37	0·25	0·63	0·017	0·014	1·43	1·01	0·22	¾		RT	45·5		60·0	26		31·8		52·0	39·0	"
	0·42	0·31	0·63	0·030	0·026	1·07	1·16	0·27	0·179	WQ835 T100, 1 hr.	150			152	3	3					17
	"	"	"	"	"	"	"	"	"	" "	90			79*	0	0					"
	"	"	"	"	"	"	"	"	"	" "	RT			130*	0	0					"
	"	"	"	"	"	"	"	"	"	" T150, 1 hr.	150			147	3	3					"
	"	"	"	"	"	"	"	"	"	" "	90			145	3	3					"
	"	"	"	"	"	"	"	"	"	" "	RT			154	5½	4					"
	"	"	"	"	"	"	"	"	"	" "	— 60			138	3	2					"
	"	"	"	"	"	"	"	"	"	" "	—150							87·3	133	99	"
	"	"	"	"	"	"	"	"	"	" "	—196							95·2	143	107	"
	"	"	"	"	"	"	"	"	"	" T175, 1 hr.	RT			141	10	48		67	116	87	"
	"	"	"	"	"	"	"	"	"	" "	— 60			149	17	45		71	115	86	"
	"	"	"	"	"	"	"	"	"	" "	—120			151	17	49		75	120	90	"
	"	"	"	"	"	"	"	"	"	" "	—145			153	13	30		79	123	91	"
	"	"	"	"	"	"	"	"	"	" "	—196			166	8	8		93	138	103	"

* Premature failure.

FATIGUE PROPERTIES

Process of Manufacture	ASTM Grain Size Mc Quaid Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile L.P.	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	No.of Stress Reversals	Rotating Bending Fatigue Limit tons/sq. in. Plain	Notched	Ref.
	3—4																							
	(2—6)	0·37	0·22	0·64	0·030	0·025	1·53	1·06	0·21	¾	OQ840 T300					103·7	109·3	15½	49	3		±51·2	±21·1(1)	22
	"	"	"	"	"	"	"	"	"	"	" T600						68·3	21	58	52		±39·5	±14·7(1)	"
	"	"	"	"	"	"	"	"	"	"	" T700					50·0	56·0	24½	63½	59		±31·7	±13·2(1)	"
B.E.A.		0·37	0·21	0·60	0·015	0·014	1·51	1·06	0·24	"	" T200			95·4			118·1	18	49½			±45·7	±23·6(1)	3
		0·38	0·21	0·57	0·012	0·010	1·60	1·12	0·27	"	" "			98·2			130·0	16½	47			±53·7	±21·5(1)	"
		0·40	0·24	0·60	0·032	0·016	1·46	1·10	0·35	"	" "			105·2			129·7	14	43½			±53·5	±27·0(1)	"
		0·41	0·24	0·70	0·045	0·029	1·42	1·15	0·24	"	" "			112·5			133·5	14½	47			±60·0	±23·5(1)	"
		0·38	0·24	0·69	0·012	0·016	1·48	1·04	0·29	2½	OQ850 T580 (L)	42·0	61·8		66·1		72·5	18	55	48		—	—	1
		"	"	"	"	"	"	"	"	"	" "(T)					64·0	70·5	8	17	14		±31	—	"
		"	"	"	"	"	"	"	"	1⅛	" "(L)					62·3	69·4	20	56			±34·9	±17·8(2)	"
B.E.A.		0·41	0·30	0·62	0·005	0·009	1·37	1·01	0·32	"	OQ820 T250	86·0	98·8	101·8	105·8		117·5	13½	45	8½		±48	±28	"
B.E.A.		0·41	0·22	0·58	0·009	0·020	1·73	1·17	0·25	"	OQ850 T520 3 hrs.	62·9	75·9		80·2		85·9	15½	48			±41·5		"
		0·38	0·25	0·64	0·010	0·013	1·44	1·07	0·30	⅜	OQ830 Tempered	41·4	70·6	74·4	78·6		84·0	16½			10^5	±53·0	±26·0(3)	
		"	"	"	"	"	"	"	"	"	" "												±25·8(4)	20
																					5×10^5	±46·7	±24·4(3)	
																							±23·0(4)	"
																					10^6	±44·4	±24·0(3)	
																							±23·0(4)	"
																					5×10^6	±44·4	±24·0(3)	
																							±23·0(4)	"

Details of notches

	Type of Notch	Root Radius	Depth of Notch	Diameter at Root	Diameter of bar	Neuber Stress Concentration Factor
(1)	55°V	0·0086″	0·02″	0·295″	0·335″	2·85
(2)	55°V	0·023″	0·10″	0·280″	0·300″	2·2
(3)	60°V	0·004″	0·008″	0·250″	0·266″	3·06
(4)	Semicircular	0·020″	0·020″	0·250″	0·290″	2·0

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2½ PER CENT NICKEL-CHROMIUM-MOLYBDENUM STEEL (MEDIUM CARBON)

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·27—0·35	0·10—0·35	0·50—0·70	0·050max	0·050max	2·30—2·80	0·50—0·80	0·40—0·70

MECHANICAL PROPERTIES

	Hardened & Tempered Condition							
	T	U	V	V	W	X	Y	Z
Limiting ruling section,in.	6	6	6	4	4	2½	2½	2½
Tensile strength, tons/sq.in., min. (Rm)	55	60	65	65	70	75	80	100
Yield Stress (1) tons/sq.in., min. (Rs)	44	48	52	52	58	63	68	85
0·2% Proof Stress (2)tons/sq.in.min. (0·2Rp)	41	46	50	50	55	59	64	80
Elongation, %, min. (A)	18	17	14	16	15	14	14	10
Izod Impact value ft.lb., min.	40	35	35	35	30	25	25	10
Brinell Hardness No. (3) (HB).	248/ 302	269/ 321	293/ 341	293/ 341	311/ 375	314/ 388	363/ 415	444 min.

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 277.

(1) Not to be used as acceptance values except by special arrangement between the the purchaser and manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only, not contractual part of the specification.

RELATED SPECIFICATIONS

	United Kingdom		U.S.S.R.	
En No.	BS Air	DTD	GOST	Mark
25	S96 S97 S120	713	4542-48	38KhN3MA

En 25

APPLICATIONS

Has high hardenability and may be heat treated in relatively large section sizes to produce tensile strengths ranging from 55 to over 100 tons/sq.in. combined with good ductility and resistance to shock. Due to its high molybdenum content the steel may normally be tempered in the range 300—550°C without serious loss of impact values. Good mechanical properties at low temperature can also be obtained.

Typical uses are: Undercarriages, aero-engine and air frame parts, heavy duty gears, pinions, connecting rods, crank and differential shafts and other transmission parts, high strength bolts, and studs, gudgeon pins, electric motor shafts, turbine discs, gas bottles, mandrel bars for tube manufacture, gun barrels and ordnance parts.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table).

	Welding Process					
	MA	G	IG	S	F	B
En 25	e	dx	g	f	b	j

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MACHINABILITY

The machinability in the annealed condition is approximately 50% of that for mild steel. In the hardened and tempered condition (60—70 tons/sq.in.) the machinability is approximately 40% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Max. finish above 850°C. Retarded cooling is advisable for large or intricate sections.
Annealing	820°C to 850°C. Furnace cool.
Softening (Sub-critical annealing)	630°C to 650°C. Air or furnace cool.
Hardening	820°C to 850°C. Oil quench.
Tempering	Up to 660°C according to mechanical properties required.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·30	0·25	0·60	—	—	2·40	0·60	0·45	Softened	7·86	1
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51	OQ830 T650	7·85	2
(within specification)								Softened	7·89	3

SPECIFIC HEAT (c)

(see also En 27)

Chemical Composition (%)						Heat Treatment °C	Mean Specific Heat cal/g deg. C	Ref.
C	Si	Mn	Ni	Cr	Mo		20 to 100°C	
0·30	0·25	0·60	2·40	0·60	0·45	Softened	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C									Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51	—		11·5	12·4	13·1	13·5	13·8	—	—	—	2
0·31	0·22	0·63	0·032	0·027	2·62	0·57	0·55	OQ and T	12·0	12·2	12·5	12·7	12·9	13·1	13·1	11·0	10·2	4
(within specification)								Softened	12·4	—	13·2	—	13·9	—	14·3(650°C)	—	—	3

En 25

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity michrom-cm								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	650°C	
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51	—	27·7	32·1	38·5	47·1	57·2	68·9	82·3	90·5	2

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Conductivity cal/cm s deg. C								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	650°C	
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51	—	0·083	0·085	0·087	0·086	0·086	0·081	0·073	0·069	*

* Estimated values.

YOUNG'S MODULUS (E); SHEAR MODULUS (G); POISSON'S RATIO (σ)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.		Shear Modulus tons/sq.in.	Poisson's Ratio	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic*	Static	Static	
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51		20		13,400			2
"	"	"	"	"	"	"	"		100		13,100			"
"	"	"	"	"	"	"	"		200		12,700			"
"	"	"	"	"	"	"	"		300		12,300			"
"	"	"	"	"	"	"	"		400		11,800			"
"	"	"	"	"	"	"	"		500		11,200			"
"	"	"	"	"	"	"	"		600		10,400			"
"	"	"	"	"	"	"	"		650		9,950			"
0·32		0·74			2·20	0·77	0·49	OQ & T	RT	13,200				5
"		"			"	"	"	(75tons/sq. in.)	100	12,850				"
"		"			"	"	"		200	12,550				"
"		"			"	"	"		300	12,550				"
"		"			"	"	"		350	12,200				"
0·32	0·22	0·66	0·019	0·024	2·50	0·78	0·45	OQ860 T615	17	13,200				4
"	"	"	"	"	"	"	"	" "	—60	13,550				"
"	"	"	"	"	"	"	"	" "	—110	13,750				"
"	"	"	"	"	"	"	"	" "	—146	14,000				"
"	"	"	"	"	"	"	"	" "	—196	14,100				"
0·32	0·21	0·47	0·036	0·025	2·62	0·75	0·45	OQ850 T640	— 25	13,350				"
"	"	"	"	"	"	"	"	" "	— 60	13,500				"
"	"	"	"	"	"	"	"	" "	—120	13,700				"
"	"	"	"	"	"	"	"	" "	—150	13,800				"
"	"	"	"	"	"	"	"	" "	—194	14,050				"
0·33	0·27	0·55	0·009	0·017	2·52	0·67	0·59	OQ840 T550	RT	13,450		5,200	0·293	6
"	"	"	"	"	"	"	"	" T625	"	13,500		5,220	0·292	"
"	"	"	"	"	"	"	"	" T650	"	13,500		5,230	0·290	"
"	"	"	"	"	"	"	"	" T665	"	13,600		5,270	0·290	"
0·31	0·16	0·55	—	—	2·48	0·62	0·58	OQ & T	RT	13,250				7
0·34	0·13	0·50	—	—	2·50	0·60	0·46	" "	"	13,250				"

* Vibration method.

MAGNETIC PROPERTIES

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Magnetic Induction B (Gauss) for magnetizing field H (Oersted)									Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			H=10	20	40	50	60	100	150	200	250	
0·32	0·22	0·63	0·044	0·032	2·60	0·67	0·51	¾	OQ830 T650	1700	11,850	15,900	16,600	17,200	18,050	18,350	18,400	18,450	2

For the above steel $H_{max.}$=250 Öersted.
$B_{max.}$=18,450 Gauss.
Coercive Force H_c=12·3 Öersted.
Remanence $B_{rem.}$ =14,350 Gauss.

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·31	0·20	0·62	0·012	0·018	2·63	0·64	0·58

Basic Electric Arc.
McQuaid Ehn grain size 2—3 (ASTM).
As quenched grain size 6—7 (ASTM).
Bars hot rolled to ⅜ in. dia., cold drawn to 11 S.W.G., with intermediate annealing at 600°C.
Austenitizing Temperature 835°C, 30 min.

(Ref. 8)

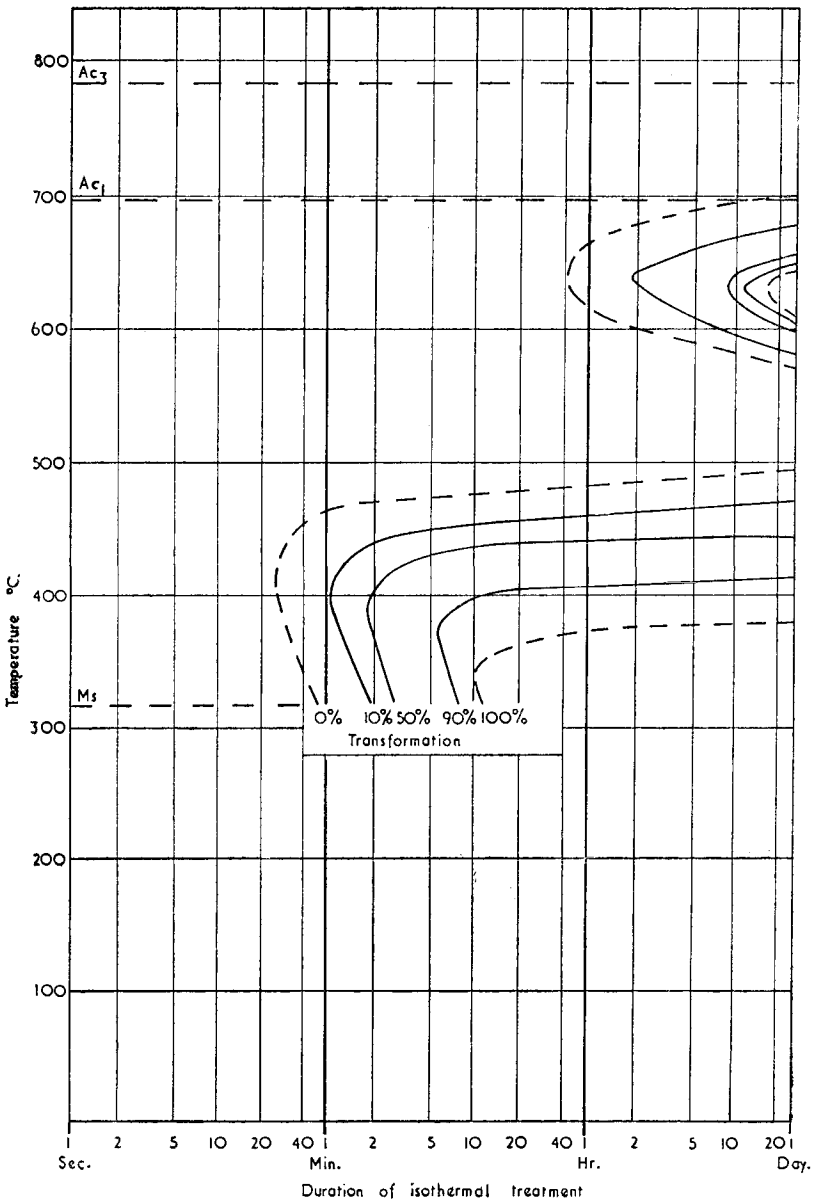


Fig. 25.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·32	0·27	0·56	0·021	0·018	2·37	0·74	0·51

Basic Electric Arc.
McQuaid Ehn grain size 3—4 (ASTM).
As quenched grain size 7—8 (ASTM).
Austenitizing Temperature 835°C.

The hardness values shown in the diagram are those of the fully transformed steel.

(Ref. 9)

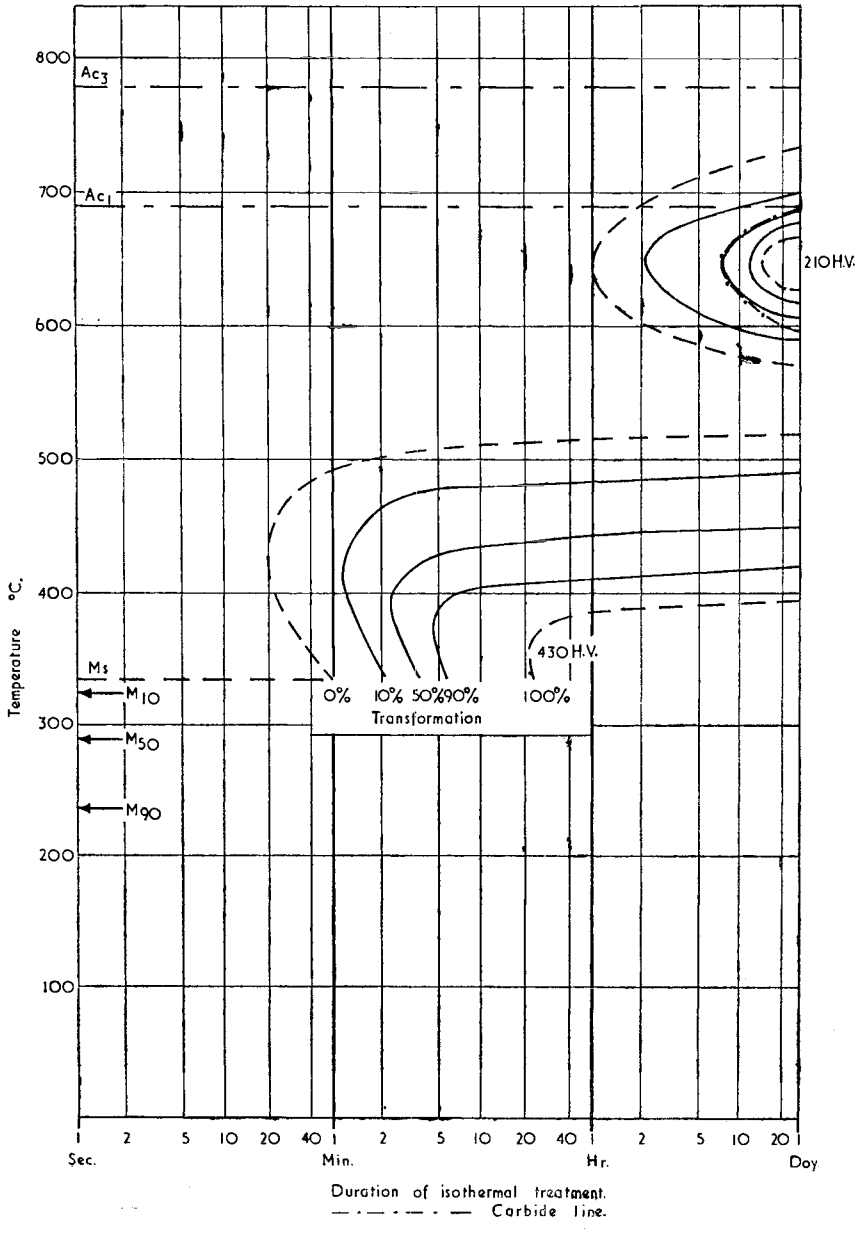


Fig. 25.2

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·32	0·27	0·56	0·012	0·018	2·37	0·74	0·51

Basic Electric Arc.
McQuaid Ehn grain size 3—4 (ASTM).
As quenched grain size 7—8 (ASTM).
Austenitizing Temperature 835°C.

(Ref. 9)

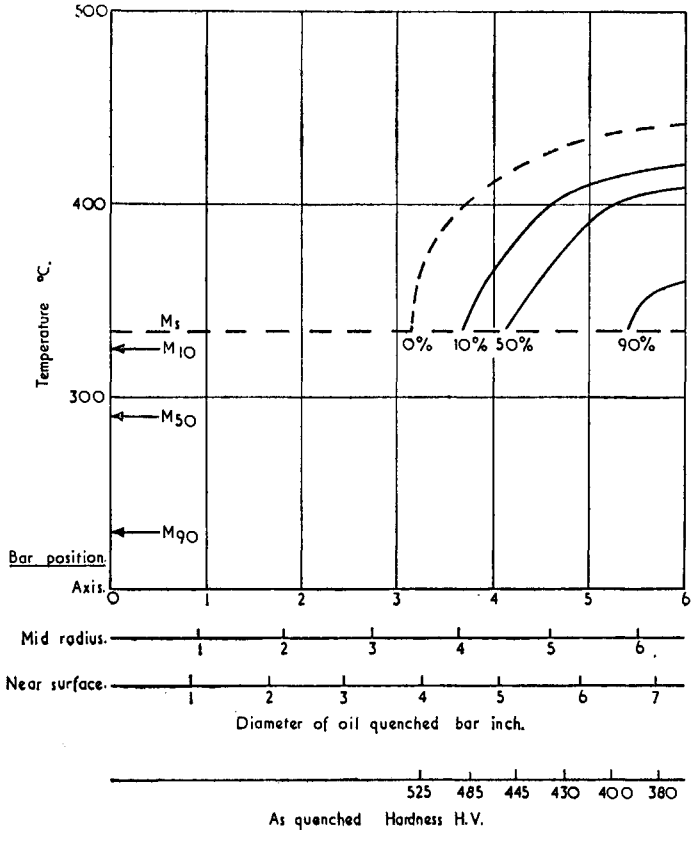
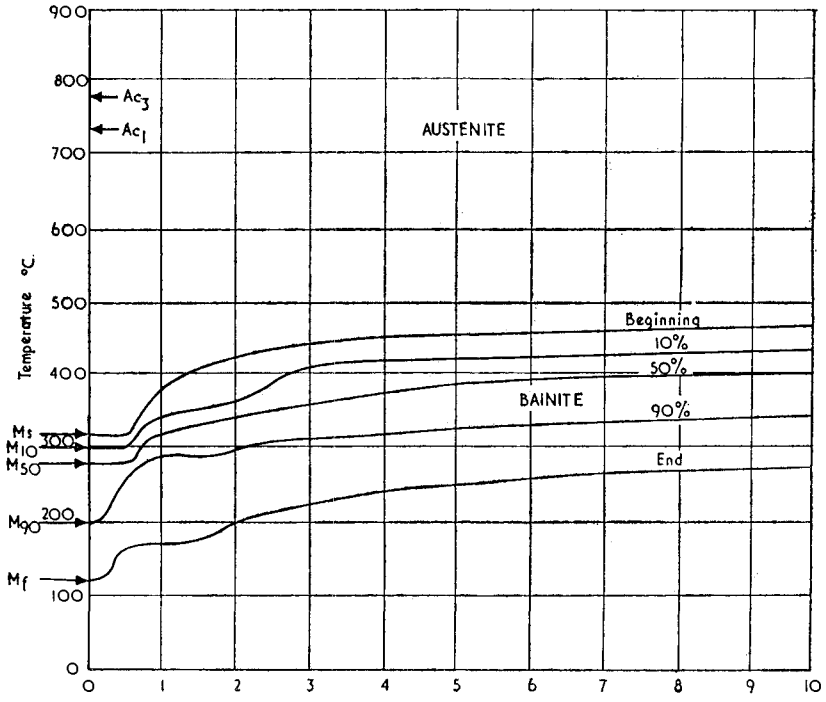


Fig. 25.3

CONTINUOUS COOLING TRANSFORMATION (Continued)

Air Cooled from 830°C. (Ref. 2)



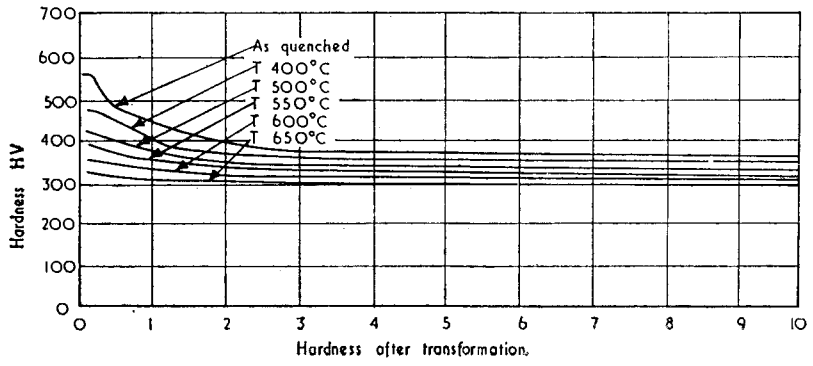


Fig. 25·4

CONTINUOUS COOLING TRANSFORMATION (Continued)

Oil Quenched from 830°C. (Ref. 2)

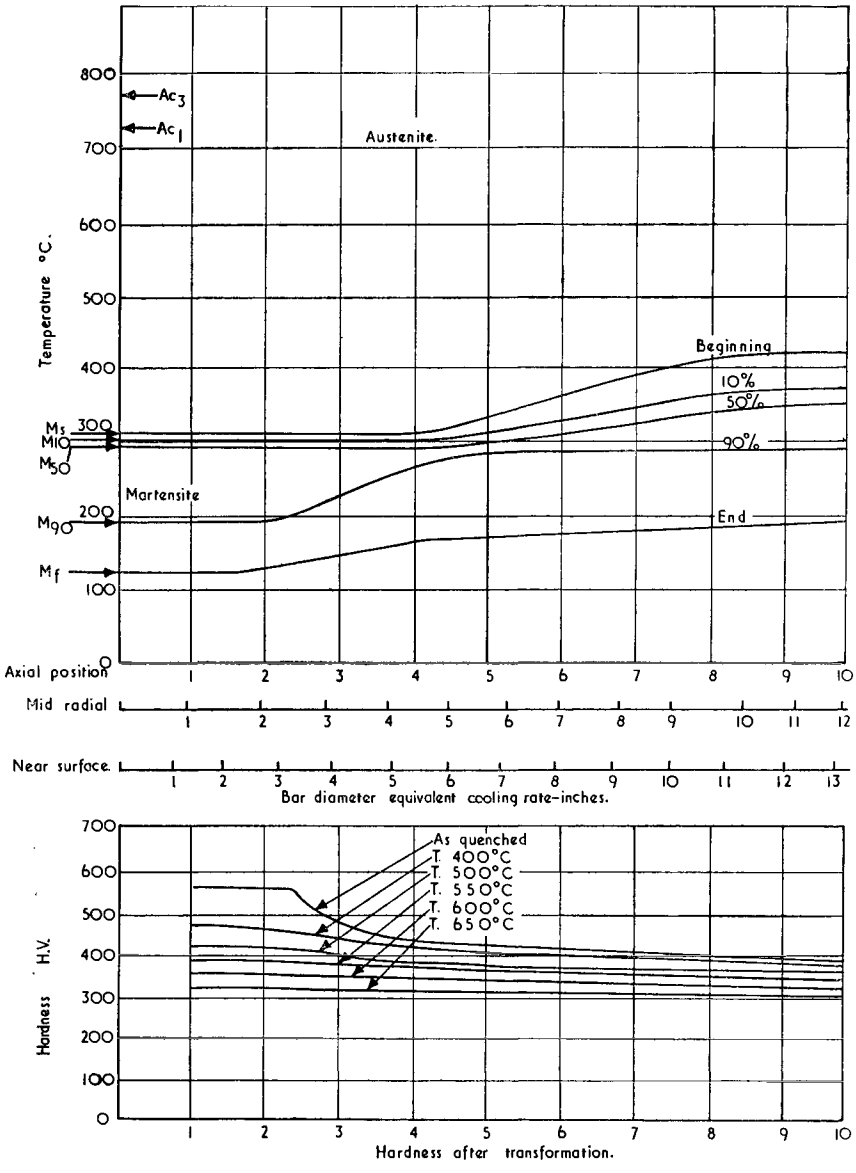
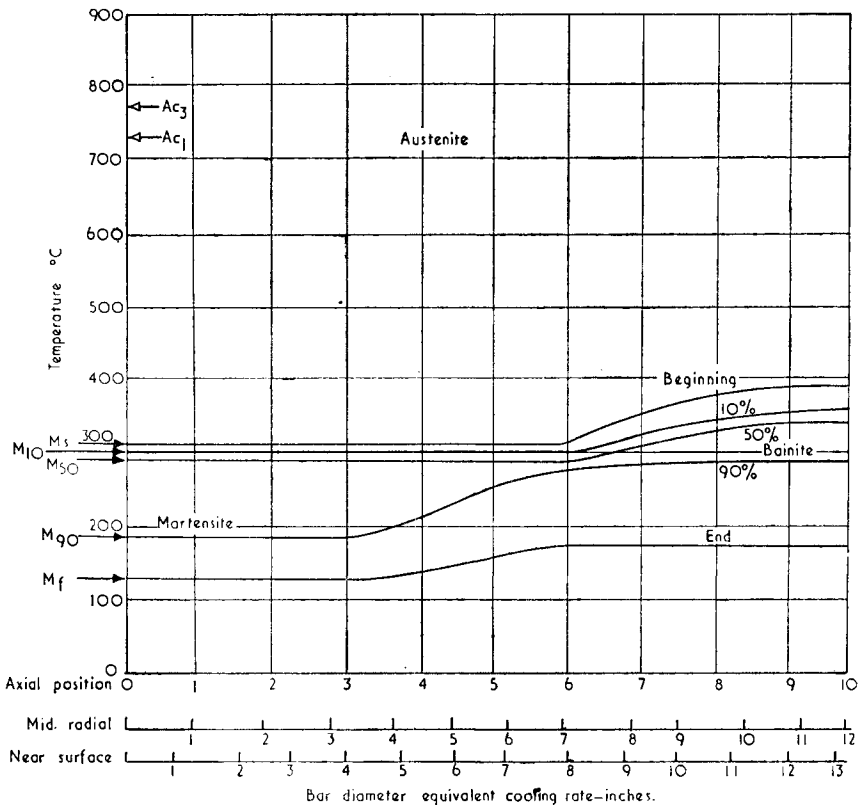


Fig. 25.5

CONTINUOUS COOLING TRANSFORMATION (Continued)

Water Quenched from 830°C.

(Ref. 2)



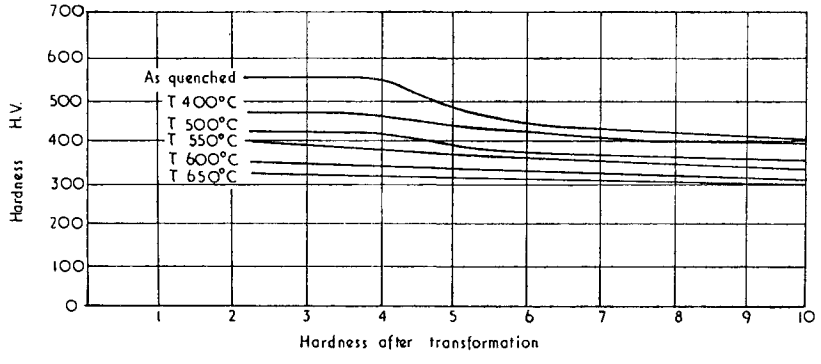


Fig. 25.6

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·31	0·20	0·62	0·012	0·018	2·63	0·64	0·58

Basic Electric Arc.
McQuaid Ehn grain size 2—3 (ASTM).
As quenched grain size 6—7 (ASTM).
End Quenched from 835°C.

(Ref. 8)

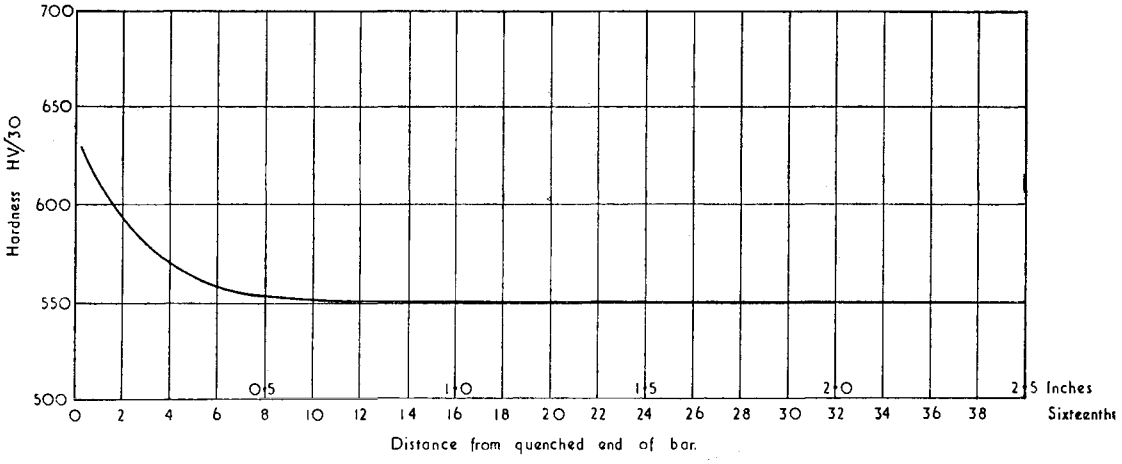


Fig. 25.7

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·32	0·27	0·56	0·012	0·018	2·37	0·74	0·51

Basic Electric Arc.
McQuaid Ehn grain size 3—4 (ASTM).
As quenched grain size 7—8 (ASTM).
End Quenched from 835°C.

(Ref. 9)

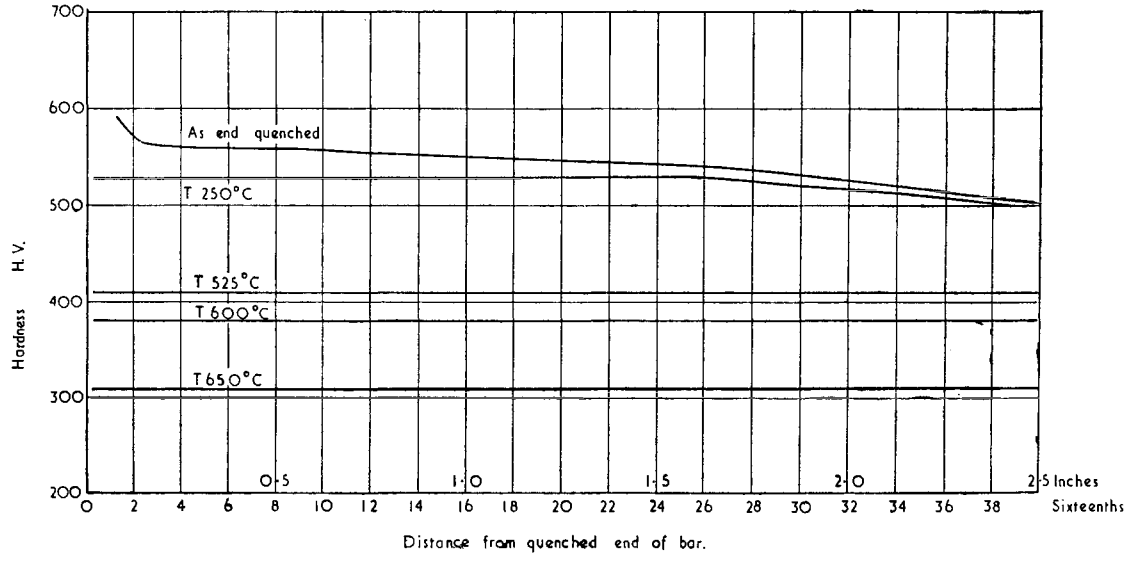


Fig. 25.8

En 25

END QUENCH HARDENABILITY (Continued)

Chemical Composition (%)								ASTM McQuaid Ehn Grain Size	Heat Treatment °C	Curve No.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·29	0·30	0·67	0·018	0·030	2·29	0·85	0·39	6	EQ 830	1
0·31	0·24	0·63	0·022	0·026	2·89	0·91	0·37	7	" "	2
0·31	0·26	0·58	0·021	0·025	2·42	0·86	0·37	7	" "	3
0·37	0·26	0·64	0·023	0·033	2·71	0·84	0·38	7	" "	4

(Ref. 10)

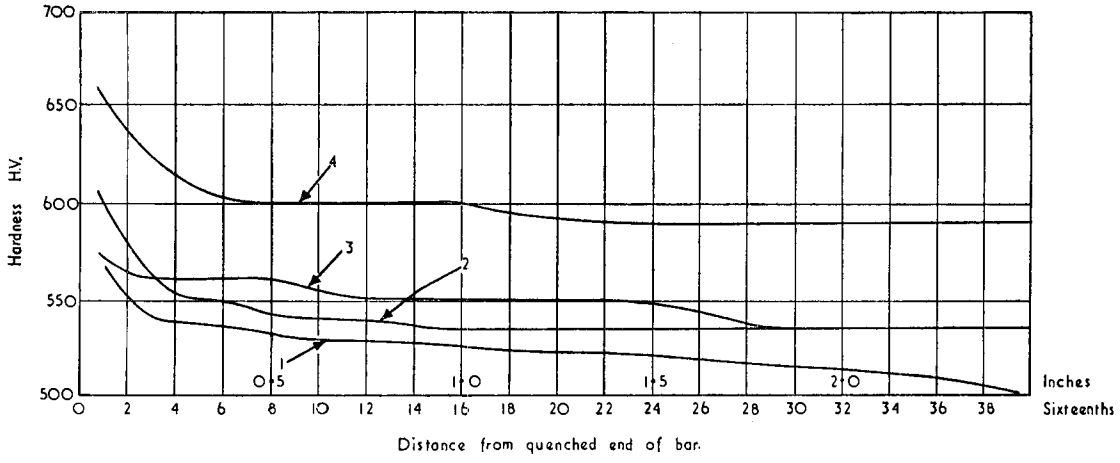


Fig. 25.9

END QUENCH HARDENABILITY BAND

These curves have been constructed from the results obtained on several casts of En 25.

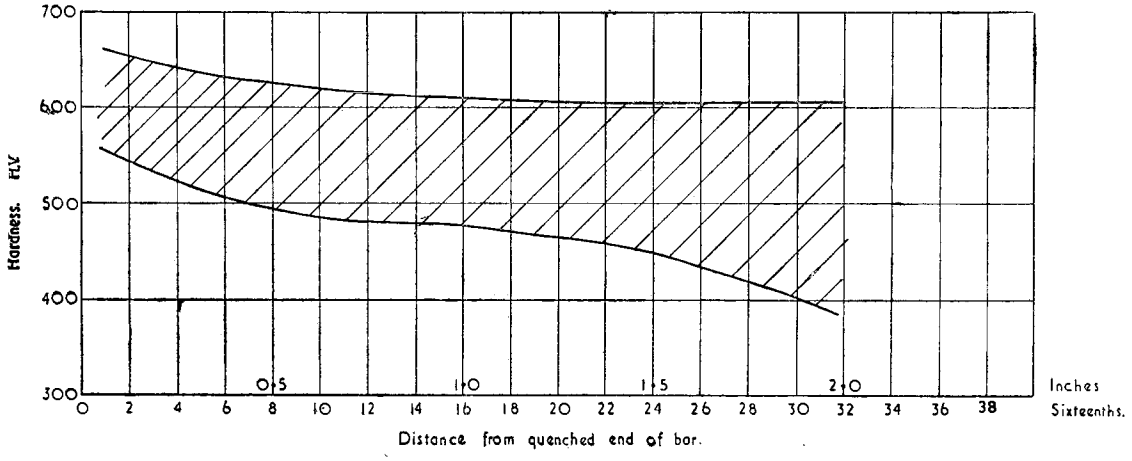


Fig. 25.10

SECTION QUENCH CURVES

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·31	0·19	0·70	0·013	0·015	2·35	0·68	0·51

Basic Electric Arc.
McQuaid Ehn grain size 3—4 (ASTM).

Oil Quenched 850°C.

(Ref. 10)

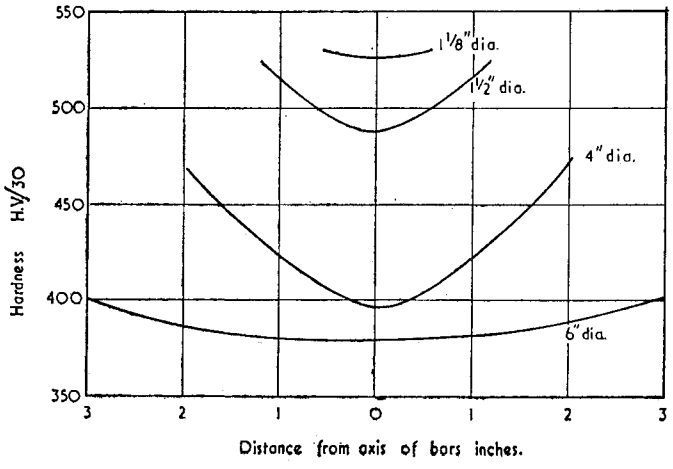


Fig. 25.11

Oil Quenched 850°C. Tempered 650°C.

(Ref. 10)

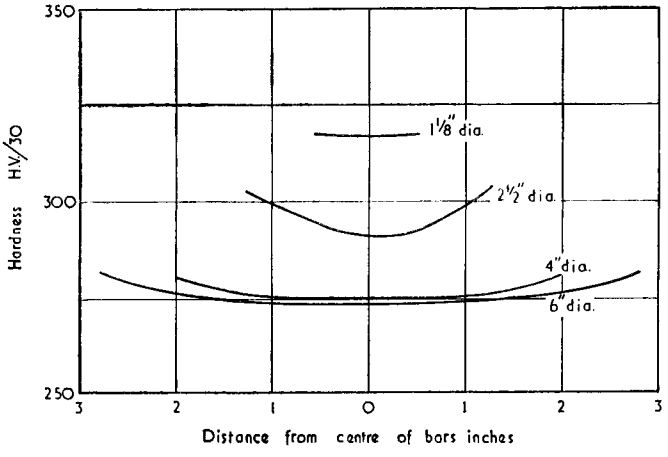


Fig. 25.12

SECTION QUENCH CURVES (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·33	0·28	0·57	0·013	0·021	2·73	0·93	0·42

Basic Electric Arc.
Bars Oil Quenched from 850°C.

(Ref. 10)

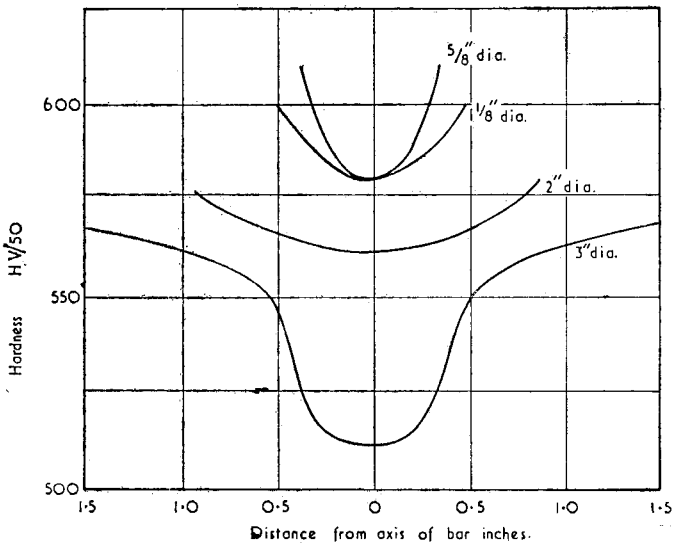


Fig. 25.13

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
		0·27	0·31	0·67			2·35	0·67	0·53	1·1 hex.	OQ850 T640					52·5	58·5	24		86	3
B.O.H.		0·27	0·27	0·60	0·019	0·035	2·89	0·72	0·40	3	" T600					53·2	62·4	20	52	68	11
B.O.H.		0·27	0·30	0·59	0·028	0·017	2·87	0·78	0·45	5	OQ840 T620					50·0	58·4	19	45	66	"
B.O.H.		0·27	0·24	0·57	0·031	0·026	2·75	0·50	0·42	3	" T560					59·0	65·9	18	54	45	"
B.E.A.		0·27	0·27	0·62	0·016	0·011	2·62	0·60	0·45	1⅛	A850 Cooled 25°/hr. to 300°C	28·1	34·0	40·8	49·5		68·1	16½	37	13	3
"		"	"	"	"	"	"	"	"	"	A850 Cooled 10°/hr. to 300°C	28·2	32·6	38·2	45·2		58·8	19	48½	14	"
"		"	"	"	"	"	"	"	"	"	A850 Cooled 10°/hr. to 300°C T630 2 hr. AC	35·1	36·0	36·7	37·7		49·9	25	58	67	"
		0·27					2·78	0·80	0·59	5	OQ850 T630					51·4	60·6	24½		77	1
		"					"	"	"	5¾	" "					49·6	58·4	23½		80	"
		0·27	0·23	0·59			2·75	0·73	0·61	5						57·6	64·0	22	61	74	"
B.E.A.	3—4	0·27	0·21	0·61	0·017	0·031	2·54	0·64	0·43	2½	OQ850 T520WQ (C)		64·0				74·4	19	56	53	10
"	"	"	"	"	"	"	"	"	"	"	" " (O)		72·9				80·3	18	56	37	"
"	"	"	"	"	"	"	"	"	"	1½	" T470WQ		74·5				83·0	17	58	31	"
"	"	"	"	"	"	"	"	"	"	1	" T490 "		72·0				80·2	17½	57	38	"
"	"	"	"	"	"	"	"	"	"	¾	" T200 "		71·5				110·0	16	51	29	"
B.O.H.		0·28	0·27	0·62	0·024	0·033	2·77	0·65	0·48	2⅛	OQ840 T585					54·8	65·2	21	61	62	11
B.O.H.		0·28	0·25	0·57	0·023	0·021	2·80	0·70	0·40	2⅛	" T555					65·2	72·4	20	59	48	"
B.O.H.		0·28	0·26	0·57	0·040	0·023	2·83	0·66	0·51	2½	OQ850 T570					68·0	74·4	18	54	39	"
B.O.H.		0·28	0·26	0·56	0·024	0·021	2·76	0·55	0·35	3¼	OQ840 T545					59·2	65·2	16	36	46	"
B.O.H.		0·28	0·25	0·60	0·022	0·029	2·72	0·69	0·40	3⅛	" T575					60·4	66·4	19	52	52	"
B.O.H.		0·28	0·23	0·72	0·020	0·038	2·85	0·62	0·40	3	" T620					49·4	61·3	23	59	69	"
		0·28					2·75	0·75	0·58	2¼	OQ850 T550					75·6	80·0	19		51	1
		"					"	"	"	3¼	" T590					65·2	68·6	23		68	"
		0·28					2·64	0·65	0·48	1½	OQ850 T600					63·0	68·6	19		65	"
		0·28					2·70	0·69	0·62	4½	" T640					54·6	61·6	22½		74	"
		0·28	0·23	0·63			2·30	0·56	0·51	1⅛	" T600					59·2	64·8	20	57	80	"
		"	"	"			"	"	"	"	" T640					50·4	57·2	23	65	91	"
		0·28	0·22	0·62			2·74	0·80	0·57	4½	" T630					52·0	60·2	23	64	84	"
B.E.A.		0·28	0·40	0·57	0·017	0·032	2·64	0·65	0·45	⅞	OQ820 T650AC		52·4				60·8	24	61½	80	12
"		"	"	"	"	"	"	"	"	⅞	" T660 "		49·6				57·6	25	61½	89	"
B.E.A.		0·28	0·30	0·59	0·015	0·034	2·46	0·69	0·56	3	OQ840 T650 "					49·0	58·0	23	64½	83	"
B.E.A.		0·28	0·29	0·60	0·023	0·032	2·52	0·69	0·53	3⅛	" T660 "		49·6				58·0	22	61½	70	"
"		"	"	"	"	"	"	"	"	3½	" T650 "		46·4				55·6	21	66	72	"
B.E.A.		0·28	0·27	0·60	0·012	0·024	2·50	0·71	0·46	4½	" T650 "					45·0	55·0	25	64½	82	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (% C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
			0·29	0·24	0·56			2·59	0·68	0·55	7	OQ850 T550		64·0	70·0	19		29	3
			0·29	0·22	0·62			2·56	0·64	0·55	4½	" T640		54·0	62·0	23	58	85	"
			0·29					2·74	0·76	0·56	1¼	" T580		74·2	77·4	19½		59	1
			"					"	"	"	3⅜	" T635		55·4	62·2	23½		84	"
			0·29	0·23	0·61			2·66	0·76	0·63	3½	" T580		72·4	76·0	19	59	61	"
			0·29	0·25	0·66			2·68	0·78	0·53	3⅜	" T630		59·1	64·6	21	64	80	"
			"	"	"			"	"	"	2⅛	" T530		81·6	84·6	18	55	36	"
B.E.A.	7—8	8(3)	0·29	0·30	0·62	0·029	0·035	2·97	0·66	0·38	1⅜	N875 OQ850 T550		69·9	76·3	17½	57½	32	10
B.E.A.			0·29	0·35	0·62	0·020	0·034	2·60	0·70	0·48	2¼	OQ840 T660AC	50·8		60·0	23	66	81	12
B.E.A.			0·29	0·26	0·55	0·023	0·027	2·57	0·72	0·50	2⅞	" "	48·0		56·8	23	67½	75	"
B.E.A.			0·29	0·28	0·63	0·020	0·028	2·59	0·69	0·49	3	" T620AC		65·0	70·0	19	59	50	"
"			"	"	"	"	"	"	"	"	"	" T630AC		60·0	65·0	19	61½	55	"
B.E.A.			0·29	0·26	0·55	0·023	0·027	2·57	0·72	0·50	3⅛	" T660AC	43·0		55·2	23	63½	75	"
B.E.A.			0·29	0·20	0·51	0·018	0·024	2·64	0·62	0·49	3⅛	" "		46·0	56·0	23	61½	84	"
"			"	"	"	"	"	"	"	"	3½	" T650AC		55·0	62·0	22	61½	67	"
B.E.A.			0·29	0·26	0·55	0·023	0·027	2·57	0·72	0·50	3½	" T660AC	49·6		58·0	21	61½	72	"
"			"	"	"	"	"	"	"	"	3⅞	" T650AC	50·0		61·2	21	61½	61	"
B.E.A.			0·29	0·28	0·54	0·026	0·033	2·56	0·74	0·52	4½	" "		53·0	61·0	19	52½	60	"
B E.A.			0·29	0·35	0·54	0·022	0·034	2·68	0·68	0·48	4½	" T660AC	49·2		61·2	21	63½	62	"
B.E.A.			0·29	0·16	0·68	0·023	0·031	2·67	0·69	0·52	5	" T650AC		54·0	62·0	23	58	64	"
B.E.A.			0·29	0·26	0·65	0·021	0·027	2·63	0·72	0·40	5¼	" "		58·0	64·0	21	57	59	"
"			"	"	"	"	"	"	"	"	5¾	WQ780(TQ) T650AC		49·0	60·0	21	55	68	"
B.E.A.			0·29	0·28	0·54	0·026	0·033	2·56	0·74	0·52	6	" "	46·0		55·6	20	52½	65	"
			0·29	0·49				2·53	0·55	0·63	2	OQ850 T570		73·5	78·0	18		48	13
			"	"				"	"	"	4	" T520		65·0	73·0	17½		35	"
			"	"				"	"	"	"	" T560		62·0	70·0	19		52	"
	6		0·29	0·30	0·67	0·018	0·030	2·29	0·85	0·39	1⅛	OQ830 T620			67·0	21	56	57	10
	"		"	"	"	"	"	"	"	"	3⅜	" T600			72·0	20	60½	54	"
A.O.H.			0·29	0·15	0·63	0·032	0·032	2·58	0·62	0·68	1⅛	" T680WQ		43·8	56·0	24	64½	78	14
			"	"	"	"	"	"	"	"	"	" T640WQ		58·0	63·9	22	65½	72	"

(TQ) = time quenched

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rm)	T.S. (Rs)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
		0·30	0·23	0·65			2·51	0·64	0·59	5¾	OQ850 T550					71·2	76·4	18	54	47	3
B.O.H.		0·30	0·26	0·70	0·028	0·043	2·78	0·65	0·40	3	OQ840 T630					50·0	58·5	22	56½	72	11
		0·30					2·73	0·79	0·62	4	OQ850 T570					68·8	72·6	21		54	1
		0·30					2·67	0·76	0·67	2	" T580					71·8	76·4	20		52	"
		0·30					2·77	0·77	0·59	1¼	" T590					64·6	71·8	21		69	"
		0·30					2·72	0·76	0·64	5¼	" "					58·8	67·2	20		71	"
		0·30					2·76	0·74	0·59	1⅛	" T600					68·6	72·6	20½		62	"
		0·30					2·72	0·76	0·64	"	" T610					65·4	70·6	21		59	"
		0·30					2·62	0·72	0·59	1¼	" T630					57·0	64·4	21½		60	"
		0·30					2·76	0·76	0·64	3¾	" T640					53·2	61·8	24		80	"
		0·30	0·20	0·64			2·41	0·69	0·52	1$\frac{13}{32}$	" T620					58·4	64·4	23	66	83	"
		0·30	0·23	0·64			2·52	0·65	0·52	0·52	" T450					80·7	85·9	16	46½	30	"
		"	"	"			"	"	"	2¼	" "					—	84·8	14	40	24	"
		"	"	"			"	"	"	1$\frac{9}{32}$	" T620					58·4	64·8	23	64	84	"
B.E.A.		0·30	0·34	0·67	0·028	0·040	2·61	0·80	0·47	½	OQ820 T660AC			48·6			57·5	25	61½	66	12
B.E.A.		0·30	0·29	0·60	0·024	0·032	2·65	0·69	0·43	¾	" T670AC			48·8			58·0	23	61½	74	"
B.E.A.		0·30	0·27	0·62	0·020	0·030	2·59	0·77	0·52	2½	OQ840 T660AC					56·0	63·0	21	61½	72	"
B.E.A.		0·30	0·35	0·55	0·024	0·024	2·53	0·68	0·53	2⅜	" T600AC					65·0	71·0	20	61½	58	"
B.E.A.		0·30	0·16	0·57	0·022	0·039	2·69	0·73	0·54	4½	" T650AC					51·0	59·0	21	59½	62	"
		0·30		0·58			2·58	0·67	0·54	2½	OQ830 T590					75·2	78·8	17		44	13
		"		"			"	"	"	6	" T620					58·5	66·2	19		56	"
		"		"			"	"	"	2½	" T650					58·8	63·6	21½		68	"
		"		"			"	"	"	4	" "					56·2	61·8	21		69	"
		"		"			"	"	"	6	" "					55·4	61·5	22		63	"
		0·30		0·50			2·50	0·60	0·45	0·042	OQ850 T250					100·0	119·0	12		30	"
B.E.A.		0·30	0·23	0·68	0·013	0·012	2·58	0·63	0·56	4¾	" T590					60·8	68·0	20	59½	65	15
		"	"	"	"	"	"	"	"	"	" T610					56·0	63·2	21	66	69	"
		0·30		0·60			2·55	0·71	0·51	2¼	OQ830 T600					72·4	75·4	18	59	48	2
		"		"			"	"	"	"	" T650					59·2	64·8	21¼	62	65	"
		"		"			"	"	"	3¼	" T600					72·4	75·7	18	59	45	"
		"		"			"	"	"	3	" T650					59·6	65·0	20½	64	56	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0.2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rm)	T.S. (Rs)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
		0·31	0·23	0·64			2·41	0·68	0·53	4¼	OQ850 T650					50·0	60·0	24	62	85	3
		0·31	0·22	0·59			2·58	0·62	0·55	11	" T610					50·0	60·0	23	59	59	"
		0·31					2·75	0·77	0·63	1¼	" T550					76·8	81·8	19½		46	1
B.E.A.	3—4	0·31	0·19	0·70	0·013	0·015	2·35	0·68	0·51	1⅛	" T650										
											(C)	47·9	49·0	50·0	50·4		58·0	24½	66	96	10
"	"	"	"	"	"	"	"	"	"	2½	" " (C)	44·6	46·4	47·5	48·3		57·0	24	64	92	"
"	"	"	"	"	"	"	"	"	"	"	" " (M)	45·7	47·1	47·7	48·3		56·8	24½	66	96	"
"	"	"	"	"	"	"	"	"	"	4	" " (C)	42·6	43·5	44·0	44·6		55·0	24	65	94	"
"	"	"	"	"	"	"	"	"	"	"	" " (M)	44·5	45·1	45·8	46·8		56·4	24½	66	92	"
"	"	"	"	"	"	"	"	"	"	"	" " (O)	43·9	45·5	46·7	47·6		56·7	24	62½	96	"
"	"	"	"	"	"	"	"	"	"	6	" " (C)	41·2	42·6	43·0	43·5		53·6	—	—	86	"
"	"	"	"	"	"	"	"	"	"	"	" " (M)	40·6	42·1	43·0	44·2		54·4	23½	61½	87	"
"	"	"	"	"	"	"	"	"	"	"	" " (O)	42·3	44·0	45·0	45·5		56·0	23½	58	90	"
		0·31					2·55	0·71	0·60	7	OQ850 T650					48·2	58·6	23		65	1
		0·31	0·25	0·58	0·019	0·025	2·38	0·69	0·44	1⅛	OQ840 T620					61·2	66·0	19		78	17
	7	0·31	0·26	0·58	0·021	0·025	2·42	0·86	0·37	"	OQ830 T600						68·0	21½	57	56	10
	"	"	"	"	"	"	"	"	"	3 13/16	" "						69·0	20	61½	56	"
	"	0·31	0·24	0·63	0·022		2·89	0·91	0·37	1⅛	" T600						67·8	20	60	57	"
	"	0·31	0·17	0·56	0·027	0·031	2·43	0·62	0·61	0·584											
										T.P.	OQ830	56·8		77·8	97·0		119·4	14	43½	22	14
		"	"	"	"	"	"	"	"	"	" T200AC	74·6		88·2	98·0		114·5	15½	48	22	"
		"	"	"	"	"	"	"	"	"	" T250 "	80·5		89·3	98·8		109·7	14	50½	20	"
		"	"	"	"	"	"	"	"	"	" T300 "	81·6		87·2	94·7		106·4	14	52½	16	"
		"	"	"	"	"	"	"	"	"	" T350 "	81·3		86·9	92·0		101·0	13	51	18	"
		"	"	"	"	"	"	"	"	"	" T400 "	82·5		85·8	88·2		94·6	14	51	21	"
		"	"	"	"	"	"	"	"	"	" T450 "	79·6		80·5	82·6		88·0	15	54	26	"
		"	"	"	"	"	"	"	"	"	" T500 "	75·1		76·2	78·2		83·6	17	54	34	"
		"	"	"	"	"	"	"	"	"	" T650WQ	57·0		57·4	57·4		63·2	24½	66	67	"
		"	"	"	"	"	"	"	"	1⅛	" T650AC			48·5			57·1	24	64½		"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size Mc Quaid Ehn	Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
													tons/sq.in.									
B.E.A.	5—7	7—8	0·31	0·23	0·53	0·012	0·015	2·40	0·56	0·48	1½	N875 OQ850 T550					71·9	80·0	17½	56	42	10
B.E.A.			0·31	0·33	0·60	0·021	0·030	2·57	0·65	0·48	2¾	OQ840 T660AC		48·4				60·8	23	66	67	12
B.E.A.			0·31	0·13	0·60	0·020	0·036	2·50	0·68	0·53	3¼	" "		52·8				58·8	22	64½	71	"
			0·31		0·45			2·60	0·64	0·54	6	OQ850 T545					62·0	69·5	17		42	13
B.E.A.			0·31	0·28	0·62	0·009	0·017	2·41	0·61	0·53	2¼	" T560 (M)					72·8	78·4	19	64	44	15
"			"	"	"	"	"	"	"	"	"	" T540 (M)					74·2	82·0	18	59½	38	"
B.E.A.			0·31	0·31	0·56	0·010	0·012	2·61	0·67	0·60	9×6	" T600 (M)					67·0	74·4	18	52½	45	"
B.E.A.			0·31	0·23	0·60			2·55	0·65	0·55	¾	OQ860 T200		83·1				123·8	11		15½	1
"			"	"	"			"	"	"	"	" T250		87·9				115·5	15½		18½	"
"			"	"	"			"	"	"	"	" T300		90·0				107·8	14½		7	"
"			"	"	"			"	"	"	"	" T350		89·6				105·8	14½		7½	"
"			"	"	"			"	"	"	"	" T400		84·7				97·5	14		9½	"
"			"	"	"			"	"	"	"	" T450		81·7				91·0	13½		15	"
"			"	"	"			"	"	"	"	" T500		79·5				87·6	13½		25	"
"			"	"	"			"	"	"	"	" T550		75·1				82·3	16		34½	"
"			"	"	"			"	"	"	"	" T600		68·4				73·7	19		49½	"
B.O.H.			0·32	0·23	0·57	0·024	0·021	2·72	0·77	0·49	4⅜	OQ840 T570					62·0	68·0	19	47	61	11
			0·32	0·21	0·67			2·60	0·62	0·58	5¼	OQ850 T600					64·0	68·9	19	57	61	3
			0·32					2·71	0·80	0·62	4½	" "					58·4	65·6	20		68	1
			0·32					2·60	0·71	0·59	1¾	" T635					55·2	63·6	24		80	"
			0·32					2·79	0·74	0·64	4	" T650					55·2	61·4	25		74	"
B.E.A.	6		0·32	0·27	0·61	0·027	0·036	2·54	0·67	0·53	2¾	" T250WQ (C)		81·5				115·0	13	39	14	10
"	"		"	"	"	"	"	"	"	"	"	" T560AC (O)		74·5				80·8	18	54	39	"
"	"		"	"	"	"	"	"	"	"	"	" " (C)		75·8				81·3	19	55	36	"
B.E.A.	4 (3—5)	6—8	0·32	0·20	0·54	0·026	0·025	2·66	0·61	0·58	1¼	N875 OQ850 T550					72·1	82·0	16½	52½	22	"
B.E.A.			0·32	0·31	0·56	0·028	0·034	2·54	0·74	0·53	1⅛	OQ840 T660AC		52·0				60·8	21	59½	70	12
B.E.A.			0·32	0·36	0·59	0·017	0·034	2·79	0·65	0·54	3	" "		46·8				58·4	22	55	73	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
B.E.A.		0·32	0·31	0·55	0·013	0·032	2·58	0·69	0·50	5¼	OQ840 T650AC	55·0	64·0	19	52½	57	12
"		"	"	"	"	"	"	"	"	5⅜	WQ780(TQ) T650AC	52·0	62·0	20	50	62	"
B.E.A.		0·32	0·15	0·51	0·015	0·027	2·58	0·72	0·51	5½	" " "	51·0	60·0	21	55	61	"
"		"	"	"	"	"	"	"	"	6	" " "	51·0	60·0	21	55	61	"
A.O.H.		0·32	0·30	0·65	0·033	0·036	2·51	0·63	0·49	4⅜	OQ850 T590(M)	64·0	70·4	18	59½	42	15
B.E.A.		0·32	0·30	0·60	0·012	0·030	2·65	0·76	0·53	3½sq	" T640(M)	58·4	64·8	22	64	77	"
		0·32		0·58			2·60	0·66	0·58	0·564T.P.	OQ830 T220	95·6	116·4	13	44	20	2
		0·32		0·54			2·63	0·74	0·45	"	" T200	100·7	116·7	16½	47	28	"
	7	0·32	0·26	0·61	0·028	0·031	2·67	0·84	0·37	1⅛	" T600		67·7	19	58	54	10
	"	"	"	"	"	"	"	"	"	3sq	" "		69·6	20½	61½	49	"
	7	0·32		0·54			2·63	0·74	0·45	1⅛	" T650	60·6	64·2	21½	61½	57	2
	"	"		"			"	"	"	2½	" "	57·6	63·6	22	63½	64	"
	"	"		"			"	"	"	3½	" "	57·7	64·8	22	61½	67	"
	7—8	0·32		0·53			2·70	0·75	0·46	1⅛	" T550	78·8	81·2	18	57	50	"
	"	"		"			"	"	"	"	" T600	68·0	71·8	21	61½	67	"
	"	"		"			"	"	"	"	" T650	58·0	61·8	23	63½	87	"
	"	"		"			"	"	"	3½	" T550(C)	79·3	82·2	17	52½	42	"
	"	"		"			"	"	"	"	" " (O)	82·4	85·4	16½	52½	43	"
	"	"		"			"	"	"	"	" T600(C)	62·2	70·0	21½	61½	60	"
	"	"		"			"	"	"	"	" " (O)	69·2	74·1	19	59	59	"
	"	"		"			"	"	"	"	" T650(C)	53·6	59·2	22	63½	84	"
	"	"		"			"	"	"	"	" " (O)	56·4	61·2	22	66	83	"
	"	"		"			"	"	"	6¼	" T600 (C) Long	58·8	65·0	17	47	62	"
	"	"		"			"	"	"	"	" T600 (M) Long	59·6	66·6	18	52½	61	"
	"	"		"			"	"	"	"	" T600 (O) Long	62·9	68·5	19½	59	60	"
	"	"		"			"	"	"	"	" T650 (C) Long	49·6	58·9	20	57	71	"
	"	"		"			"	"	"	"	" T650 (M) Long	52·5	60·0	21	59	71	"
	"	"		"			"	"	"	"	" T650 (O) Long	54·0	60·8	20½	61½	66	"
	"	"		"			"	"	"	"	" T600 (C) Trans.	58·6	65·2	12	24½	25	"
	"	"		"			"	"	"	"	" T600 (M) Trans	61·6	67·3	12½	27½	24	"
	"	"		"			"	"	"	"	" T600 (O) Trans.	66·0	70·6	15½	42	25	"
	"	"		"			"	"	"	"	" T650 (C) Trans.	52·8	59·8	17	39	38	"
	"	"		"			"	"	"	"	" T650 (M) Trans.	54·8	61·6	19	47	39	"
	"	"		"			"	"	"	"	" T650 (O) Trans.	54·0	60·2	19	49½	45	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod. ft.lb.	Ref.
			0·33	0·19	0·62			2·47	0·61	0·53	0·564								
											T.P.	OQ850 T250			115·6	14	43	25	3
			0·33	0·23	0·61			2·52	0·65	0·58	2	" T560		72·0	81·0	17	52	36	"
			0·33	0·27	0·68			2·60	0·62	0·56	$4\frac{1}{2}$	" T610			69·0	22		62	"
			0·33	0·24	0·66			2·63	0·63	0·56	$8\frac{3}{4}$	" "		58·6	65·0	$19\frac{1}{2}$	58	72	"
			0·33	0·24	0·59			2·41	0·61	0·47	0·564								
											T.P.	" T250			113·6	14	44	27	1
			"	"	"			"	"	"	$1\frac{1}{8}$	" "			114·0	$13\frac{1}{2}$	42	18	"
			"	"	"			"	"	"	$2\frac{1}{2}$	" T530			82·2	18	59	37	"
			"	"	"			"	"	"	"	" T600		60·0	67·4	22	57	67	"
			"	"	"			"	"	"	6	" "		50·4	59·7	21	57	59	"
			0·33					2·51	0·65	0·48	$3\frac{1}{4}$	" "		63·0	68·6	20		64	"
B.E.A.			0·33	0·31	0·57	0·023	0·026	2·52	0·67	0·49	$1\frac{1}{2}$	OQ840 T660AC	46·8		56·4	23	66	77	12
B.E.A.			0·33	0·27	0·55	0·018	0·031	2·57	0·77	0·55	$3\frac{1}{4}$	" " "	51·2		59·2	21	$61\frac{1}{2}$	73	"
B.E.A.			0·33	0·25	0·65	0·024	0·028	2·58	0·71	0·54	$4\frac{1}{4}$	" T650AC		51·0	60·0	20	57	65	"
B.E.A.			0·33	0·33	0·60	0·022	0·028	2·53	0·77	0·48	6	WQ780(TQ)							
												T650AC		46·0	56·5	22	50	50	"
"			"	"	"	"	"	"	"	"	$6\frac{1}{2}$	" " "		52·0	59·0	21	$59\frac{1}{2}$	68	"
			0·33		0·56			2·80	0·59	0·59	$2\frac{1}{8}$	OQ830 T640		59·5	68·5	21		65	13
			"		"			"	"	"	3	" "		57·0	67·0	$21\frac{1}{2}$		62	"
			"		"			"	"	"	$4\frac{1}{2}$	" "		57·0	66·5	21		60	"
			0·33		0·52			2·70	0·65	0·45	$2\frac{1}{2}$	" T550		79·2	81·6	16		41	"
			0·33		0·52			2·70	0·65	0·45	0·564								
											T.P.	" T200		98·4	112·0	$13\frac{1}{2}$	$44\frac{1}{2}$	26	2
	7		0·33	0·28	0·63	0·019	0·019	2·76	0·92	0·40	$1\frac{1}{8}$	" T600			71·0	$18\frac{1}{2}$	53	44	10
	"		"	"	"	"	"	"	"	"	3 sq.	" "			74·4	18	$53\frac{1}{2}$	51	"
B.E.A.	7—8	7—8	0·34	0·20	0·54	0·030	0·033	2·70	0·62	0·58	$2\frac{1}{4}$	N875 OQ850							
												T550		71·5	82·0	$16\frac{1}{2}$	54	26	10
B.E.A.			0·34	0·17	0·61	0·030	0·050	2·70	0·68	0·50	$3\frac{3}{8}$	OQ840 T660AC	50·8		59·2	20	$52\frac{1}{2}$	64	12
	7		0·35	0·24	0·66	0·023	0·023	2·53	0·90	0·38	$1\frac{1}{8}$	OQ830 T600			72·8	$17\frac{1}{2}$	57	43	10
	"		"	"	"	"	"	"	"	"	3 sq.	" "			76·8	16	46	45	"
			0·35	0·27	0·58	0·026	0·019	2·64	0·81	0·54	$4\frac{5}{8}$	OQ840 T585		60·4	68·0	16	42	57	11
B.E.A.			0·35	0·09	0·73	0·023	0·039	2·51	0·85	0·54	$\frac{1}{2}$	OQ820 T660AC	49·2		56·0	26	$64\frac{1}{2}$	77	12
"			"	"	"	"	"	"	"	"	$\frac{5}{8}$	" " "	53·2		60·0	23	$63\frac{1}{2}$	66	"
"			"	"	"	"	"	"	"	"	$\frac{3}{4}$	" " "	48·8		58·0	23	$61\frac{1}{2}$	74	"
B.E.A.			0·35	0·23	0·66	0·028	0·028	2·60	0·70	0·54	1	OQ820 T660AC		55·0	61·0	21	$59\frac{1}{2}$	61	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·30	0·60	2·60	0·65	0·55

1¼ in. dia. bars Oil Hardened from 830°C.

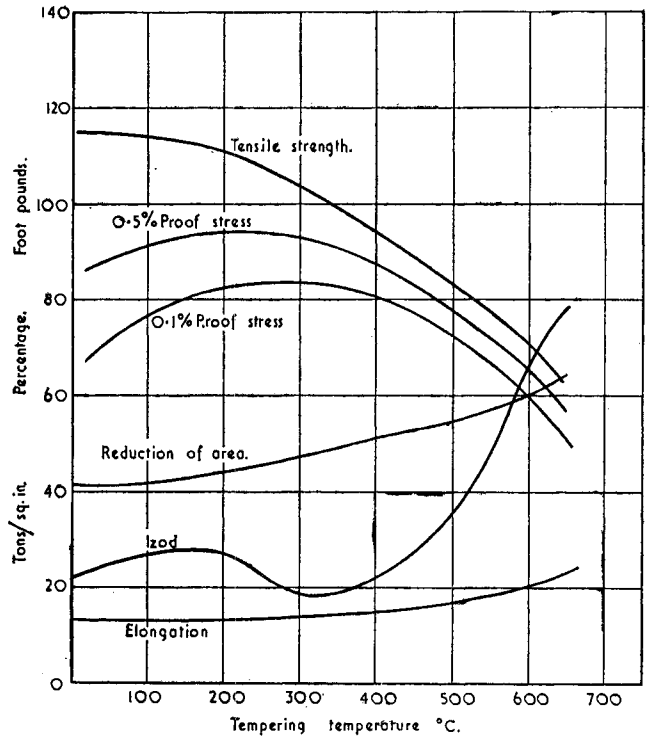


Fig. 25.14

EFFECT OF TEMPERING ON THE RANGE OF MECHANICAL PROPERTIES AT ROOM TEMPERATURE

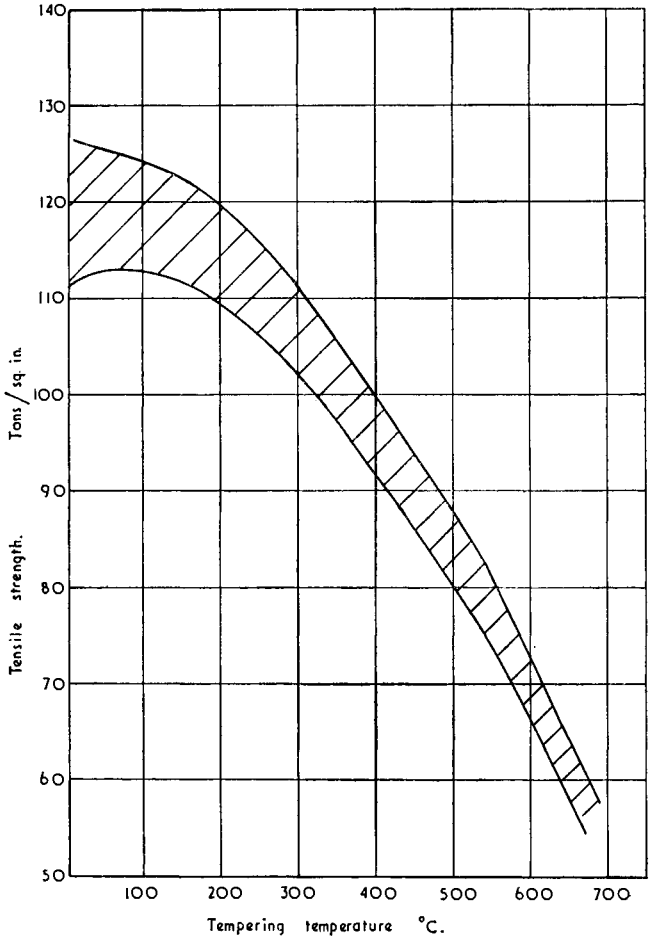


Fig. 25.15 (A)

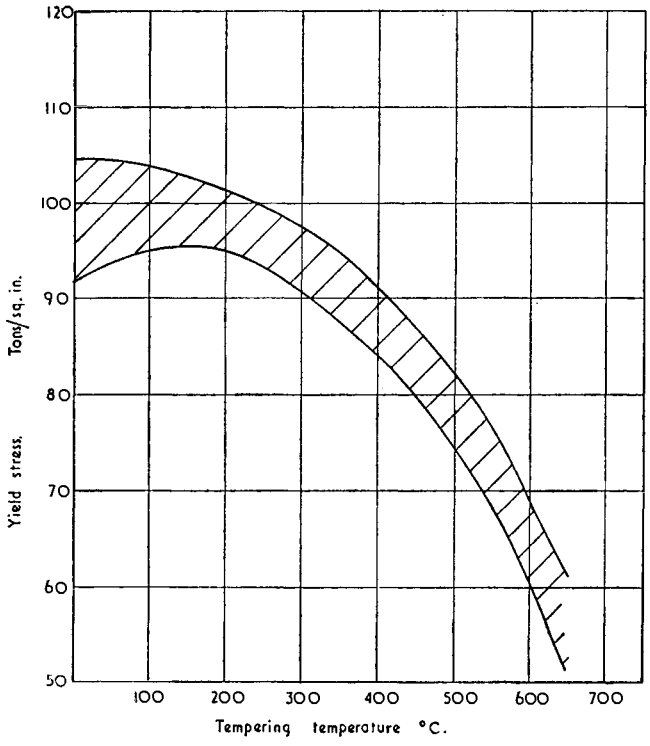


Fig. 25.15 (B)

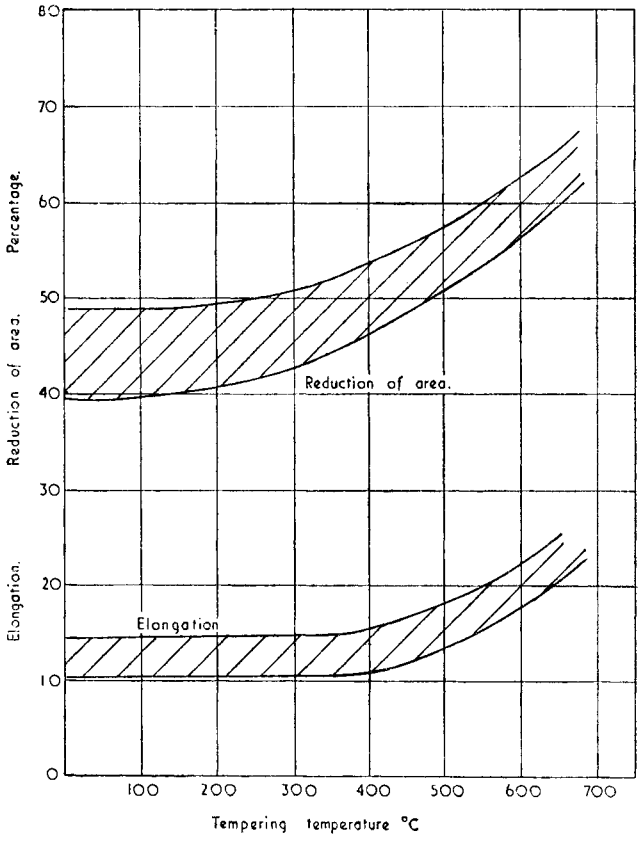


Fig. 25.15 (C)

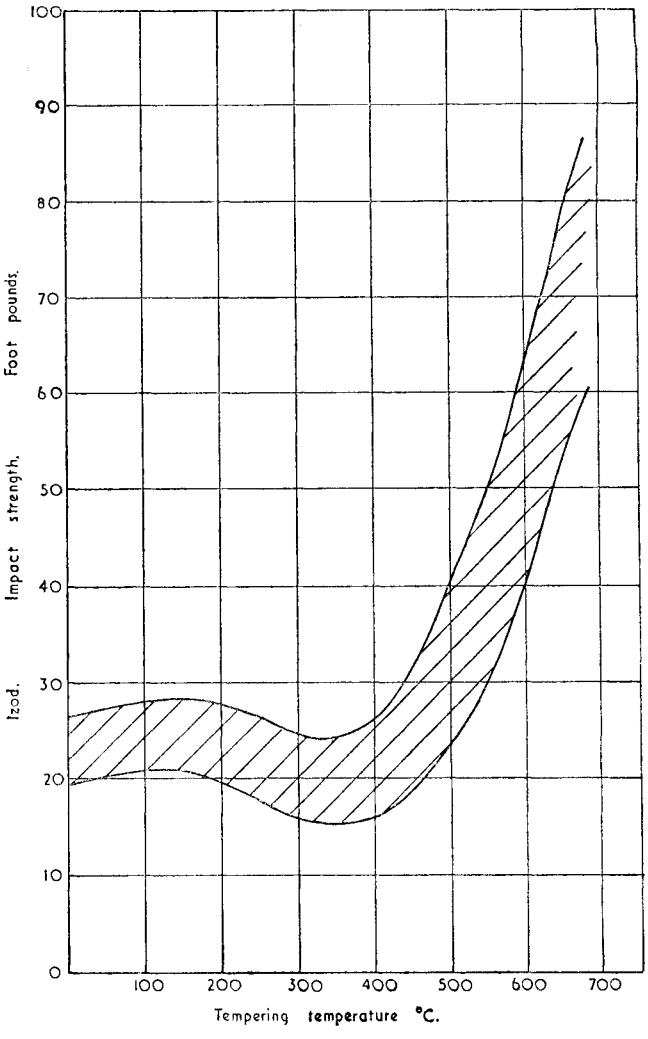


Fig. 25.15 (D)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Oil Quench 830°C. Tempered 550°C. Air Cool.

(Ref. 3)

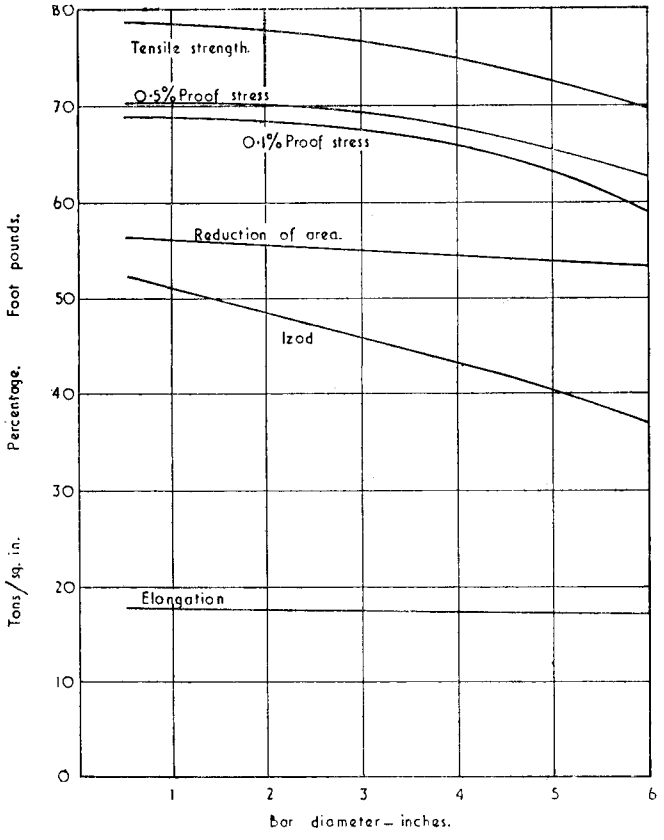


Fig. 25.16

Oil Quench 830°C. Tempered 600°C. Air Cool.

(Ref. 3)

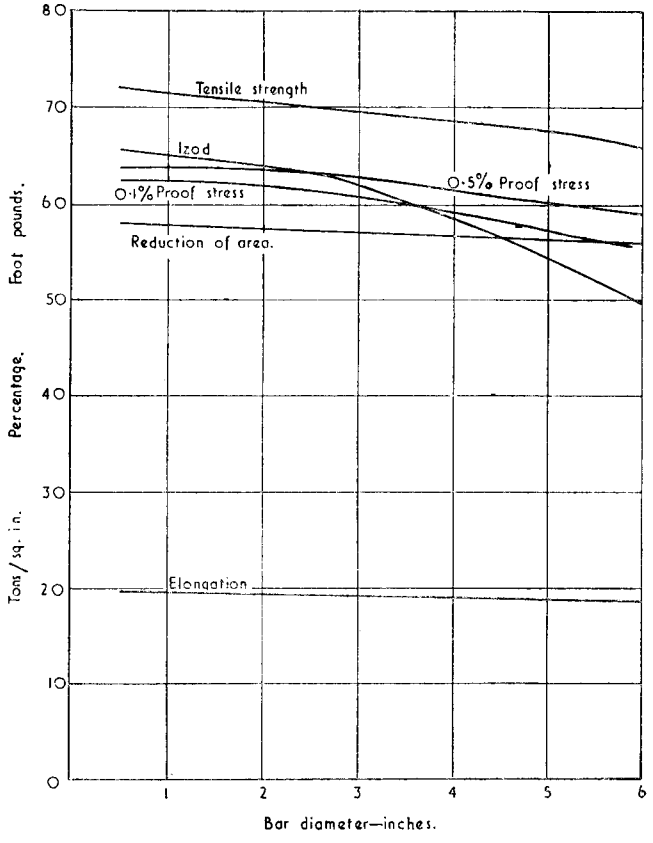


Fig. 25.17

Oil Quench 830°C. Tempered 650°C. Air Cool.

(Ref. 3)

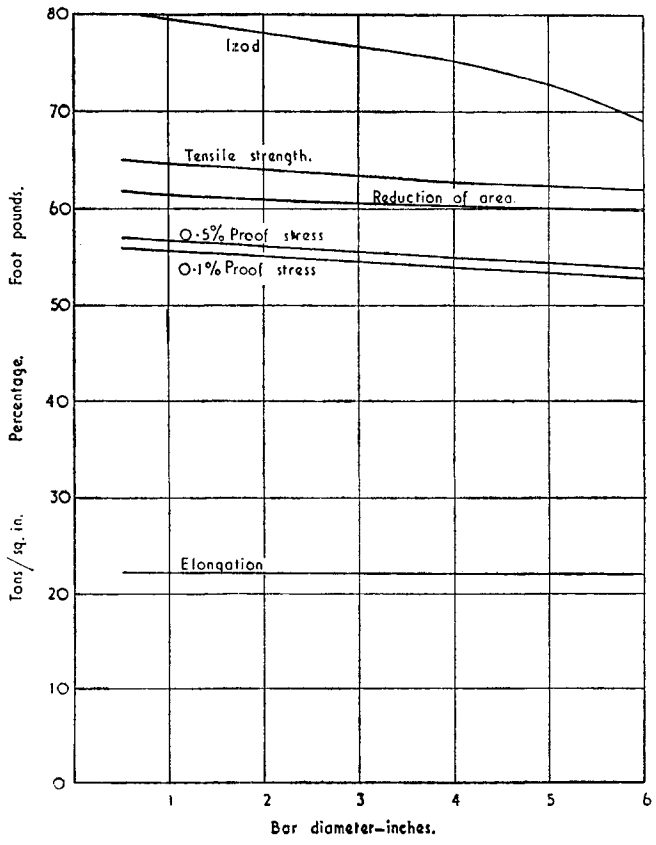


Fig. 25.18

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile								Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·01% P.S. (0·01Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
	0·29	0·26	0·61	0·016	0·020	2·70	0·70	0·45	¾	OQ860 T625	18	48·6					62·6	16	38		4
	"	"	"	"	"	"	"	"	"	" "	— 70	53·9					69·5	17½	37½		"
	"	"	"	"	"	"	"	"	"	" "	—196	69·5					84·2	7	6½		"
	0·32	0·24	0·66			2·34	0·64	0·56	¾	OQ850 T600	RT						70·5	24	65		1
	"	"	"			"	"	"	"	" "	0·5						71·1	23½	66		"
	"	"	"			"	"	"	"	" "	— 28						74·0	22½	60		"
	"	"	"			"	"	"	"	" "	— 61						75·7	26½	60½		"
	"	"	"			"	"	"	"	" "	— 92						76·8	22½	60½		"
	0·33					2·54	0·67	0·64		OQ850 T640	20					61·7	68·0	14	65	58	17
	"					"	"	"		" "	— 67					65·2	72·9	16	62		"
	"					"	"	"		" "	—100					66·6	76·0	16	61		"
	"					"	"	"		" "	—120									50	"
	"					"	"	"		" "	—180					82·2	90·0	17	63	22	"
6	0·32	0·22	0·66	0·019	0·024	2·50	0·78	0·50		OQ860 T615	17	46·4	50·9	51·7	52·1		60·0	14	33½		4
"	"	"	"	"	"	"	"	"		" "	— 60	50·6	53·8	54·4	55·0		64·9	18	32		"
"	"	"	"	"	"	"	"	"		" "	—110	54·7	58·7	59·0	59·3		69·1	18½	34½		"
"	"	"	"	"	"	"	"	"		" "	—146	58·2	62·0	62·9	63·2		74·0	18½	33½		"
"	"	"	"	"	"	"	"	"		" "	—196	69·1	73·9	74·3	74·5		82·5	9½	9½		"
5—6	0·32	0·21	0·47	0·036	0·025	2·62	0·75	0·45		OQ850 T640	25	45·9	50·0	50·5	51·7		58·5	13	30		"
"	"	"	"	"	"	"	"	"		" "	— 60	47·1	51·3	52·1	53·0		62·1	15½	27½		"
"	"	"	"	"	"	"	"	"		" "	—120	54·8	59·3	59·9	60·2		69·9	14½	21½		"
"	"	"	"	"	"	"	"	"		" "	—150	57·9	61·4	62·1	62·8		72·5	16·7	22		"
"	"	"	"	"	"	"	"	"		" "	—194	65·5	73·2	73·9	74·4		76·2	3½	3½		"

MECHANICAL PROPERTIES AT LOW TEMPERATURE

(Continued)

ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile								Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·01% P.S. (0·01Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
	0·31	0·29	0·61	0·023	0·029	2·69	0·78	0·47		OQ850 T600	25			71·9			79·5	20	58½	40	4
	"	"	"	"	"	"	"	"		" "	—120			82·0			90·1	21	51½	13	"
	"	"	"	"	"	"	"	"		" "	—145			85·3			93·2	19½	52½		"
	"	"	"	"	"	"	"	"		" "	—196			96·3			103·5	23	46½		"
7—8	0·31	0·27	0·56	0·012	0·018	2·37	0·74	0·51	⅝	OQ840 T200AC	20		80·5	86·9	95·8		110·0	21	57		13
"	"	"	"	"	"	"	"	"	"	" "	— 78		81·4	87·6	96·7		115·8	19	62		"
"	"	"	"	"	"	"	"	"	"	" "	—196		92·9	100·1	109·5		132·0	20	56		"
"	"	"	"	"	"	"	"	"	"	OQ840 T550WQ	20		72·4	73·6	74·8		80·5	20	59		"
"	"	"	"	"	"	"	"	"	"	" "	— 78		76·4	77·5	79·3		85·9	23	59		"
"	"	"	"	"	"	"	"	"	"	" "	—196		93·6	94·5	96·1		102·2	21	48		"
"	"	"	"	"	"	"	"	"	"	OQ840 T620WQ	20		65·8	66·5	67·8		72·1	23	64		"
"	"	"	"	"	"	"	"	"	"	" "	— 78		69·4	70·8	71·2		78·0	25	61		"
"	"	"	"	"	"	"	"	"	"	" "	—196		85·7	87·5	88·0		95·2	24	53		"
"	"	"	"	"	"	"	"	"	"	OQ840 T650WQ	20		56·8	56·8	56·8		63·0	27	67		"
"	"	"	"	"	"	"	"	"	"	" "	— 78		58·8	59·6	60·2		69·0	29	64		"
"	"	"	"	"	"	"	"	"	"	" "	—196		77·9	78·5	79·6		86·0	28	56		"
	0·29	0·27	0·59	0·049	0·034	2·44	0·74	0·52	1¾	OQ850 T670	RT			51·6			59·2	28½	70		4
	"	"	"	"	"	"	"	"	"	" "	— 60			54·8			64·2	27	60		"
	"	"	"	"	"	"	"	"	"	" "	—120			60·0			70·0	28½	56		"
	"	"	"	"	"	"	"	"	"	" "	196			76·8			84·0	27½	51		"

IMPACT TRANSITION TEMPERATURE DATA

Curve No.	Chemical Composition (%)									Section Size dia. (in.)	Heat Treatment °C	ASTM Grain Size McQuaid Ehn	Charpy V Notch Impact Energy ft.lb. Test Temperature °C															Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	Al				150	100	80	60	40	20	0	—20	—40	—60	—80	—100	—120	—140	—160	—180	
A	0·28	0·22	0·67	0·012	0·012	2·63	0·71	0·30		1	OQ850 T600 AC	4—3	—	—	—	—	—	88	88	88	87	82	58	34	24	19	17	16	3
B	"	"	"	"	"	"	"	"		"	" T650 AC	"	—	—	—	—	—	114	113	110	106	102	94	70	38	28	24	21	"
C	"	"	"	"	"	"	"	"		4	" T600 AC	"	—	—	—	—	86	78	57	34	17	12	9	8	8	—	—	—	"
D	"	"	"	"	"	"	"	"		"	" T650 AC	"	—	—	—	—	100	100	97	90	68	50	33	20	10	4	—	—	"
	0·29	0·27	0·59	0·049	0·034	2·44	0·74	0·52		1¾	" T670		—	57	57	55	55	55	55	55	52	47	42	22	20	15	10	5	18
E	0·31	0·27	0·56	0·012	0·018	2·37	0·74	0·51		⅝	OQ840 T200 AC	As quenched 7—8	25	25	23	21	20	18	15	13	12	8	5	—	—	—	—	—	13
F	"	"	"	"	"	"	"	"		"	" T550 WQ	"	—	—	—	—	—	50	43	35	30	25	20	17	15	12	12	10	"
G	"	"	"	"	"	"	"	"		"	" T620 WQ	"	—	—	—	—	—	68	67	65	60	50	40	25	20	17	15	12	"
H	"	"	"	"	"	"	"	"		"	" T650 WQ	"	—	—	—	—	—	87	87	85	83	75	60	40	30	23	20	17	"
	0·32	0·22	0·66	0·019	0·024	2·50	0·78	0·45	<0·005		OQ860 T615	6	—	36	—	37	—	29	21	16	12	14	7	—	6	—	3	—	4
	0·32	0·21	0·47	0·036	0·025	2·62	0·75	0·45	<0·005		OQ850 T640	5—6	31	35	32	24	24	19	16	14	13	11	8	6	4	—	—	—	"

(See also Mechanical Properties at Low Temperature for tensile data on these steels.)

Chemical Composition (%)								Heat Treatment °C	Izod Impact Energy ft.lb. Test Temperature								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20	0	—20	—40	—60	—80	—100	—120	
0·31	0·29	0·61	0·023	0·029	2·69	0·78	0·47	OQ850 T600	40	38	34	30	24	18	15	13	4

IMPACT TRANSITION TEMPERATURE DATA (Continued)

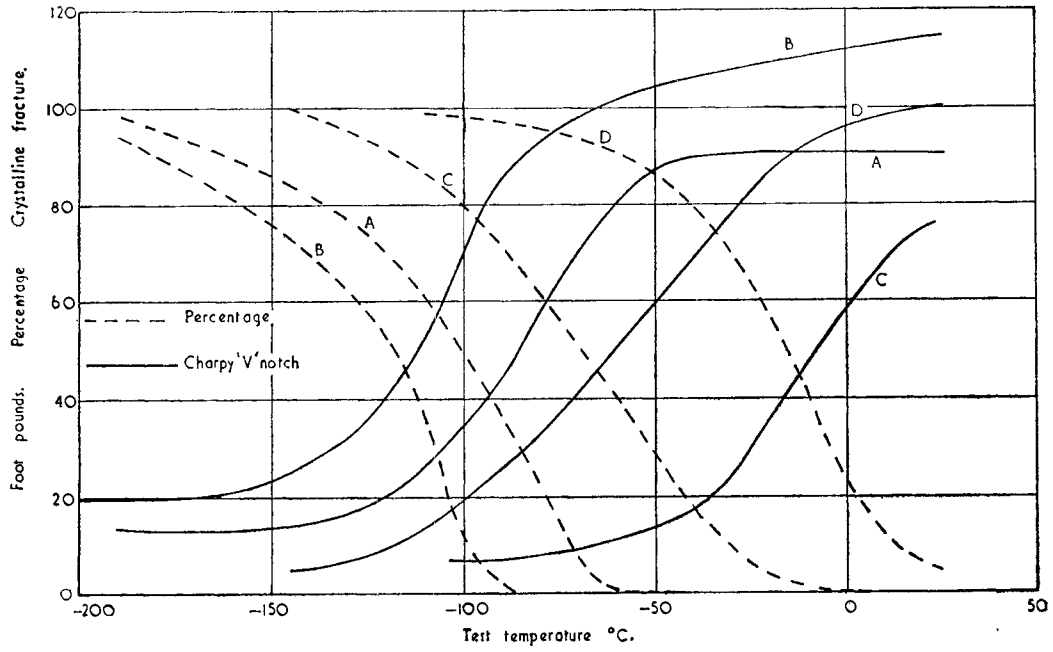


Fig. 25.19

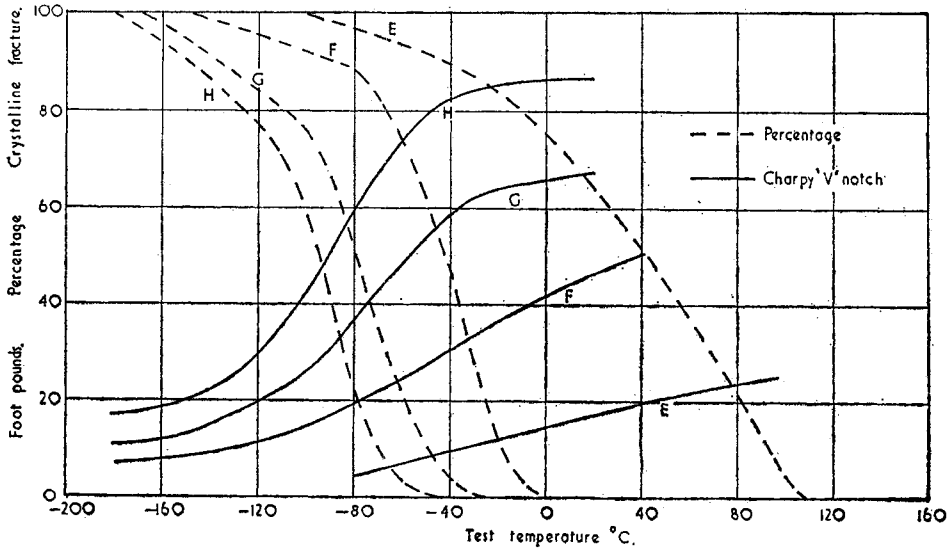


Fig.25.20

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Charpy V ft.lb.	Ref.
	0·31	0·22	0·63	0·032	0·027	2·62	0·57	0·55	—	OH & T L	20	49·2	60·4	23	66	58	4
	"	"	"	"	"	"	"	"		" T	"	53·0	61·0	16	43	22	"
	"	"	"	"	"	"	"	"		" L	250	46·2	56·8	22	62	64	"
	"	"	"	"	"	"	"	"		" T	"	46·5	57·6	15	38	27	"
	"	"	"	"	"	"	"	"		" L	350	46·7	57·0	21	59	65	"
	"	"	"	"	"	"	"	"		" T	"	46·5	58·8	15	39	23	"
	"	"	"	"	"	"	"	"		" L	450	42·7	52·5	23	68	55	"
	"	"	"	"	"	"	"	"		" T	"	41·7	50·4	17	45	23	"
	"	"	"	"	"	"	"	"		" L	550	38·5	43·4	23	74	37	"
	"	"	"	"	"	"	"	"		" T	"	38·5	44·8	16	48	16	"
	"	"	"	"	"	"	"	"		" L	650	29·0	32·2	29	85	52	"
	"	"	"	"	"	"	"	"		" T	"	25·9	28·8	22	70	16	"
	"	"	"	"	"	"	"	"		" L	750	6·0	9·7	69	92	166	"
	"	"	"	"	"	"	"	"		" T	"	6·7	9·9	51	71	63	"
	"	"	"	"	"	"	"	"		" L	850	3·2	5·3	72	93	154	"
	"	"	"	"	"	"	"	"		" T	"	2·5	5·2	50	80	76	"
										Tensile tests were carried out on Hounsfield test pieces No. 12. L = Longitudinal T = Transverse							
B.E.A.	0·30	0·24	0·59	0·010	0·015	2·38	0·61	0·59	¾	OH850 T625 3 hrs. AC	15	56·4	63·7	24	66		1
"	"	"	"	"	"	"	"	"	"	" "	100	57·3	61·9	20	63½		"
"	"	"	"	"	"	"	"	"	"	" "	200	54·2	61·0	20	65½		"
"	"	"	"	"	"	"	"	"	"	" "	300	54·0	60·6	17½	47		"
"	"	"	"	"	"	"	"	"	"	" "	400	53·8	58·5	20	58½		"
"	"	"	"	"	"	"	"	"	"	" "	500	42·7	48·2	21½	71½		"
"	"	"	"	"	"	"	"	"	"	" "	537	36·0	42·5	22	70		"
"	"	"	"	"	"	"	"	"	"	" "	600		32·7	27	89		"
"	"	"	"	"	"	"	"	"	"	" "	700		15·3	42½	94		"
"	"	"	"	"	"	"	"	"	"	" "	800		7·7	70½	90		"
"	"	"	"	"	"	"	"	"	"	" "	900		5·2	60	85½		"
"	"	"	"	"	"	"	"	"	"	" "	1000		3·2	87	96		"
										Loading rate 1 ton/sq.in. per minute.							

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Heating Time hrs.	Tensile						Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo					L.P.	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
													tons/sq.in.						
A.O.H.	0·30	0·146	0·63	0·032	0·032	2·58	0·62	0·68	1⅛	OQ860 T630WQ	20		51·2		56·0	63·8	22½	65	14
"	"	"	"	"	"	"	"	"	"	" "	300		41·0		48·0	63·5	22½	58½	"
"	"	"	"	"	"	"	"	"	"	" "	350		38·5		45·6	59·7	25	64	"
"	"	"	"	"	"	"	"	"	"	" "	400		35·5		42·5	54·7	22	66½	"
"	"	"	"	"	"	"	"	"	"	" "	450		31·5		38·0	49·3	21	68½	"
"	"	"	"	"	"	"	"	"	"	" "	500		25·8		31·2	43·3	22	75½	"
A.O.H.	0·31	0·17	0·56	0·027	0·031	2·43	0·62	0·61	1⅛	OQ830 T650AC	20		45·0		48·5	57·1	24	64½	14
"	"	"	"	"	"	"	"	"	"	" "	300		37·8		43·3	57·8	22	57½	"
"	"	"	"	"	"	"	"	"	"	" "	350		34·0		40·0	55·0	25	63	"
"	"	"	"	"	"	"	"	"	"	" "	400		33·0		39·5	51·3	23½	66½	"
"	"	"	"	"	"	"	"	"	"	" "	450		31·0		37·8	46·7	22	68½	"
"	"	"	"	"	"	"	"	"	"	" "	500		26·0		34·2	40·3	23	71½	"
"	"	"	"	"	"	"	"	"	"	" "	550		18·0		27·6	32·2	27½	77½	"
	0·32		0·74			2·20	0·77	0·49		OQ and T	R.T.	20	58·0	69·7		77·5	20	41	5
	"		"			"	"	"		"	100	20	55·7	68·3		76·4	20	—	"
	"		"			"	"	"		"	150	20	55·7	65·3		75·5	18	—	"
	"		"			"	"	"		"	200	20	23·9	60·1		75·2	19	—	"
	"		"			"	"	"		"	250	1	16·0	56·8		70·9	15½	43	"
	"		"			"	"	"		"	"	20	18·1	56·7		71·6	18	41	"
	"		"			"	"	"		"	"	200	17·9	58·1		74·7	19½	43	"
	"		"			"	"	"		"	"	1000	16·0	56·2		69·8	—	44	"
	"		"			"	"	"		"	300	1	14·0	54·0		70·0	23½	36	"
	"		"			"	"	"		"	"	20	16·0	55·2		72·7	24	41	"
	"		"			"	"	"		"	"	200	16·1	55·5		70·4	22	44	"
	"		"			"	"	"		"	"	1000	18·0	53·8		69·8	21	40	"
	"		"			"	"	"		"	350	1	14·0	53·0		69·3	23½	42	"
	"		"			"	"	"		"	"	20	14·0	53·2		67·0	22½	41	"
	"		"			"	"	"		"	"	200	12·0	53·4		67·3	22½	35	"
	"		"			"	"	"		"	"	1000	14·0	54·0		67·5	21	43	"

CREEP PROPERTIES

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Stress (tons/sq.in.) to produce creep rate of 10^{-6} per hour between 24 and 72 hours	Ref.
B.E.A.	0·32	0·24	0·57	0·010	0·025	2·38	0·61	0·59	$\frac{3}{4}$	OQ850 T625 AC	400	14·0	1
"	"	"	"	"	"	"	"	"	"	" "	500	7·0	"
"	"	"	"	"	"	"	"	"	"	" "	550	2·0	"

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Stress (tons/sq.in.) to produce creep rate 10^{-6} per hour	Stress (tons/sq.in.) to produce creep rate 10^{-7} per hour	Ref.
A.O.H.	0·29	0·15	0·63	0·032	0·032	2·58	0·62	0·68	—	OQ830 T630 WQ	400	—	15·0	14
"	"	"	"	"	"	"	"	"	—	" "	450	17·5	11·0	"
"	"	"	"	"	"	"	"	"	—	" "	500	8·0	3·3	"
"	"	"	"	"	"	"	"	"	—	" "	550	2·1	0·8	"

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Heat Treatment	Test Temperature °C	Applied Stress tons/sq.in.	Duration of test hours	Rate of creep per hour	Ref.
B.E.A.	0·31	0·21	0·58	0·017	0·020	2·42	0·52	0·46	OQ and T	482	11	24 to 72	$2·8 \times 10^{-6}$	1
"	"	"	"	"	"	"	"	"	"	"	"	250	$0·75 \times 10^{-6}$	"
"	"	"	"	"	"	"	"	"	"	"	"	500	$0·50 \times 10^{-6}$	"
"	"	"	"	"	"	"	"	"	"	"	"	750	$0·47 \times 10^{-6}$	"

FATIGUE PROPERTIES

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	Condition	Rotating Bending Fatigue Limit tons/sq.in. 10^{-7} rev.		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			tons/sq.in.						Un-notched	Notched	
0·33	0·22	0·58	0·012	0·017	2·65	0·67	0·52	$\frac{3}{4}$	OQ and T200		92·6	118·9	15½	55		±45·2	±22·6(1)	2
0·32	0·26	0·65	0·018	0·026	2·72	0·79	0·52	$\frac{13}{16}$	OQ850 T560 AC	71·3		80·4	18	56½	Machined	±34·5	±23·1(2)	19
"	"	"	"	"	"	"	"	"	" "						Machined & grit-blasted	±39·3	±23·8(2)	"
"	"	"	"	"	"	"	"	"	" "						Machined & grit-blasted + Cd plate (0·003/4") + stress relieve at 175°C ½ hr.	±39·7	±23·5(2)	"
"	"	"	"	"	"	"	"	"	" "						Machined & grit-blasted + Cd plate (0·01)" + stress relieve at 175°C ½ hr.	±39·3	—	"
"	"	"	"	"	"	"	"	"	" "						Machined + stress relieved + anodise pickle + Cd plate	—	21·5(2)	"
"	"	"	"	"	"	"	"	"	" "						Machined + stress relieve + anodise pickle + Cd plate + bake at 175°C ½ hr.	—	21·3(2)	"
0·31	0·30	0·63	0·024	0·039	2·37	0·84	0·45	1⅛ sq.	OQ830 T575 1 hr. OQ	72·7	73·9	79·0	15	68	Longitudinal test	±41·2	—	20
"	"	"	"	"	"	"	"	"	" "	74·9	76·2	82·0	11	26½	Transverse test	±29·2	—	"

(1) Neuber stress concentration factor 2·85. 55°V notch, 0·008" root radius, 0·020" deep, 0·295 root dia., 0·335 OD.
(2) " " " " 2·63. " " 0·013" " " 0·03" " 0·240 " " 0·300 OD.

Chemical Composition (%)								Heat Treatment °C	Tensile Strength tons/sq.in.	Rotating Bending Fatigue Limit, tons/sq.in.*			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			$\frac{1}{16}$" fillet radius	$\frac{1}{8}$" fillet radius	$\frac{3}{16}$" fillet radius	
0·32	0·17	0·56	0·050	0·039	2·53	0·64	0·52	OQ and T	74	±19·5	±24·5	±27·0	21

* Tests carried out on 1 in. dia. test pieces, with $1\frac{7}{16}$ dia. heads.

FATIGUE PROPERTIES

(Continued)

Chemical Composition (%)								Test Temperature °C	Endurance limit for reversed axial stresses (zero mean stress) 1500 c.p.m. tons/sq.in.						Ref.
									Un-notched			Notched (3)			
	Si	Mn	S	P	Ni	Cr	Mo		10^5 cycles	10^6 cycles	$>10^7$ cycles	10^5 cycles	10^6 cycles	$>10^7$ cycles	
0·29	0·27	0·59	0·049	0·034	2·44	0·74	0·52	20	±32	±30	±28	±12	±9	±6·7	4
								— 60	±32	±30	±28	±12	±9	±6.7	"
								—180	±46	±44½	±43	±15·7	±12·7	±12	"
(see also Mechanical Properties at Low Temperature.)									Endurance limit for fluctuating axial stress (zero minimum stress) 1500 c.p.m. tons/sq.in.						
									Un-notched			Notched			
									10^5 cycles	10^6 cycles	$> 10^7$ cycles	10^5 cycles	$10^6 >$ cycles	$> 10^7$ cycles	
								20	25±25	23·5±23·5	22·7±22·7	8·8±8·8	6·8±6·8	6·2±6,2	"
								— 60	26±26	24·5±24·5	23·7±23·7	8·8± 8·8	6·8±6·8	6·2±6·2	"
								—180	35±35	33·5±33·5	33 ±33	11·3±11·3	9·3±9·3	9±9	"

(3) 45°V notch, 0·25 mm root radius, 3 mm deep, 15 mm OD, Neuber stress concentration factor 4·3.

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2½ PER CENT NICKEL–CHROMIUM–MOLYBDENUM STEEL (HIGH CARBON)

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·36—0·44	0·10—0·35	0·50—0·70	0·050max.	0·050max.	2·30—2·80	0·50—0·80	0·40—0·70

MECHANICAL PROPERTIES

Property	Hardened and Tempered Condition									
	U	V		W		X		Y		Z
Limiting rulingsection, in.	6	6	4	6	4	6	4	6	4	4
Tensile strength, tons/sq.in., min. (Rm)	60	65	65	70	70	75	75	80	80	100
Yield stress, tons/sq.in., min. (1) (Rs)	48	52	52	58	58	63	63	68	68	85
0·2% proof stress, tons/sq.in., min. (0·2Rp) (2)	46	50	50	55	55	59	59	64	64	80
Elongation, %, min. (A)	17	14	16	13	15	12	14	12	14	10
Izod impact value, ft.lb., min.	35	35	35	30	30	25	25	25	25	10
Brinell hardness No. (3) (HB)	269/321	293/341	293/341	311/375	311/375	341/388	341/388	363/415	363/415	444 min.

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 277.

(1) Not to be used as acceptance tests except by special arrangement between purchaser and manufacturer.

(2) When specifically requested in the enquiry or order.

(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

	United Kingdom	
En No.	BS Air	
26	S.98	2S 99

En 26

APPLICATIONS

Used for similar applications to those of En25, where increased strength is required for a given ruling section or where the same strength is required in larger ruling sections. The wear resistance of En 26 is greater than that for En 25 at the same tensile strength owing to its higher carbon content.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table)

	Welding Process					
	MA	G	IG	S	F	B
En 26	e	dx	g	f	b	j

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MACHINABILITY

In the annealed condition the steel has a machinability of the order of 50% of that for mild steel. When hardened and tempered to approximately 70 tons/sq. in. tensile strength the machinability is approximately 35% of that for mild steel and when hardened to about 80 tons/sq.in. the tensile strength is about 20% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C. Retarded cooling is advisable for large or intricate sections.
Annealing	820°C—850°C. Furnace cool.
Softening	630°C—650°C. Air or furnace cool.
Hardening	820°C—850°C. Oil quench.
Tempering: (for 100 ton/sq.in. condition)	180°C—250°C. Air cool.
(for other conditions) up to	660°C. Air cool or oil quench.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·39	0·25	0·61	0·013	0·011	2·54	0·67	0·56	OQ830 T650	7·83	1
"	"	"	"	"	"	"	"	" T250	7·86	"
0·40	0·25	0·60			2·40	0·65	0·45	Softened	7·86	2

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cal/g deg.C 20 to 100°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·40	0·25	0·60	—	—	2·40	0·65	0·45	Softened	0·118	2

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 250°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 650°C	
0·39	0·25	0·61	0·013	0·011	2·54	0·67	0·56	OQ830 T250	11·4	11·8	11·9						1
"	"	"	"	"	"	"	"	" T650	11·5	12·3	—	13·0	13·6	14·1	14·3	14·5	"
(within Specification)								Softened	12·3	—	—	13·2	—	13·8	—	14·3	3

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	
0·39	0·25	0·61	0·013	0·011	2·54	0·67	0·56	OQ850 T650 1 hr.	27·1	30·6	35·3	41·7	49·0	56·5	65·8	76·4	1

THERMAL CONDUCTIVITY (k)

(See data given for En 25 and En 27)

YOUNG'S MODULUS (E)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic (vibration method)	
0·36	0·14	0·64	—	—	2·43	0·64	0·69	OQ and T	20	13,240		4
0·37	0·12	0·49	—	—	2·44	0·74	0·66	" "	20	13,240		"
0·39	0·61	0·25	0·013	0·011	2·54	0·67	0·56	OQ830 T250	20		13,100	1
"	"	"	"	"	"	"	"	" "	100		12,900	"
"	"	"	"	"	"	"	"	" "	200		12,500	"
"	"	"	"	"	"	"	"	" T650	20		13,400	"
"	"	"	"	"	"	"	"	" "	100		13,200	"
"	"	"	"	"	"	"	"	" "	200		12,800	"
"	"	"	"	"	"	"	"	" "	300		12,400	"
"	"	"	"	"	"	"	"	" "	400		11,900	"
"	"	"	"	"	"	"	"	" "	500		11,100	"
"	"	"	"	"	"	"	"	" "	600		10,500	"
"	"	"	"	"	"	"	"	" "	650		10,100	"

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·42	0·31	0·67	0·022	0·029	2·53	0·72	0·48

Acid Open Hearth.
McQuaid Ehn grain size 2 (ASTM).
As quenched grain size 6—7 (ASTM).
Bars hot rolled to $\frac{3}{4}$ in. dia., cold drawn to 11 S.W.G., with intermediate annealing at 600°C.

Austenitizing Temperature 830°C, 30 min.
(Ref. 5)

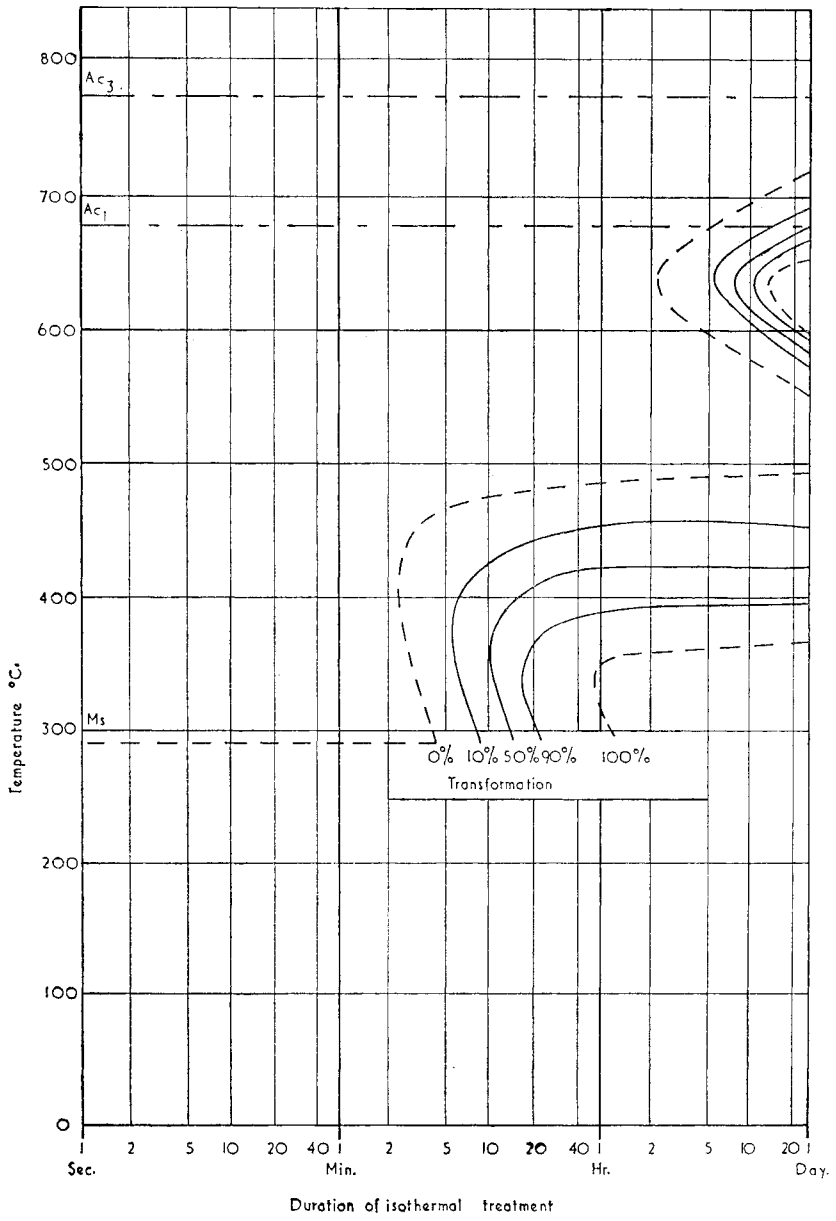


Fig. 26.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46

Basic Electric Arc.
McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).
Austenitizing Temperature 835°C.

The hardness values shown on the diagram are those of the fully transformed steel.

(Ref. 6)

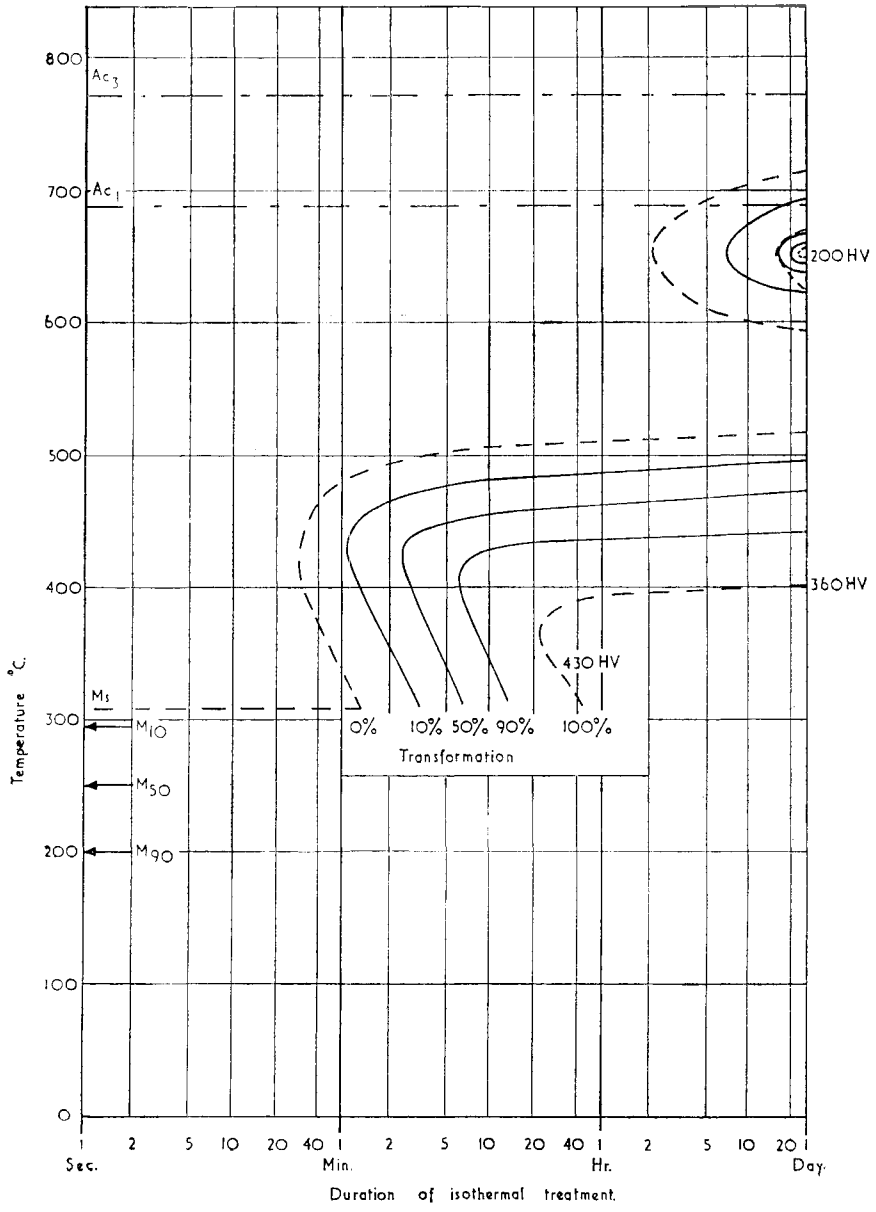


Fig. 26.2

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46

Basic Electric Arc.
McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).
Austenitizing Temperature 835°C.

(Ref. 6)

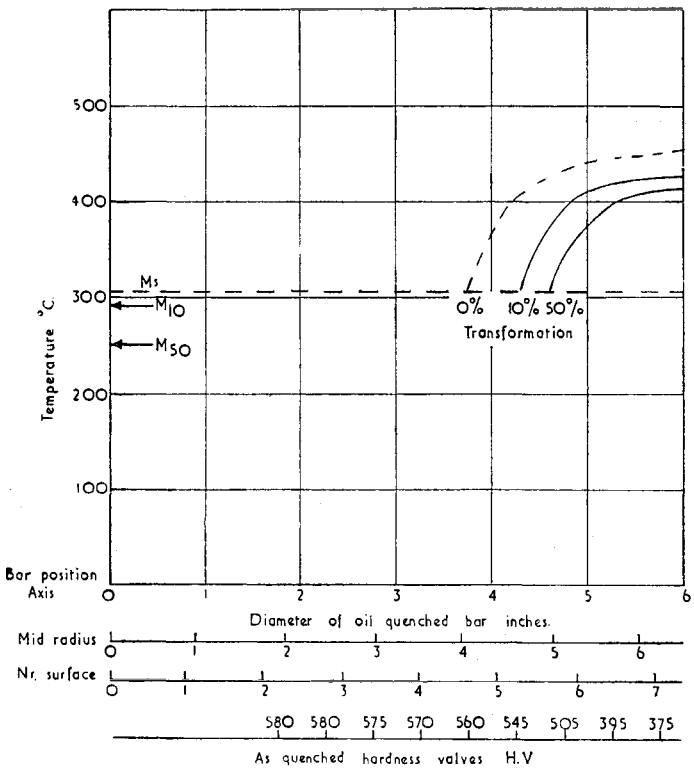
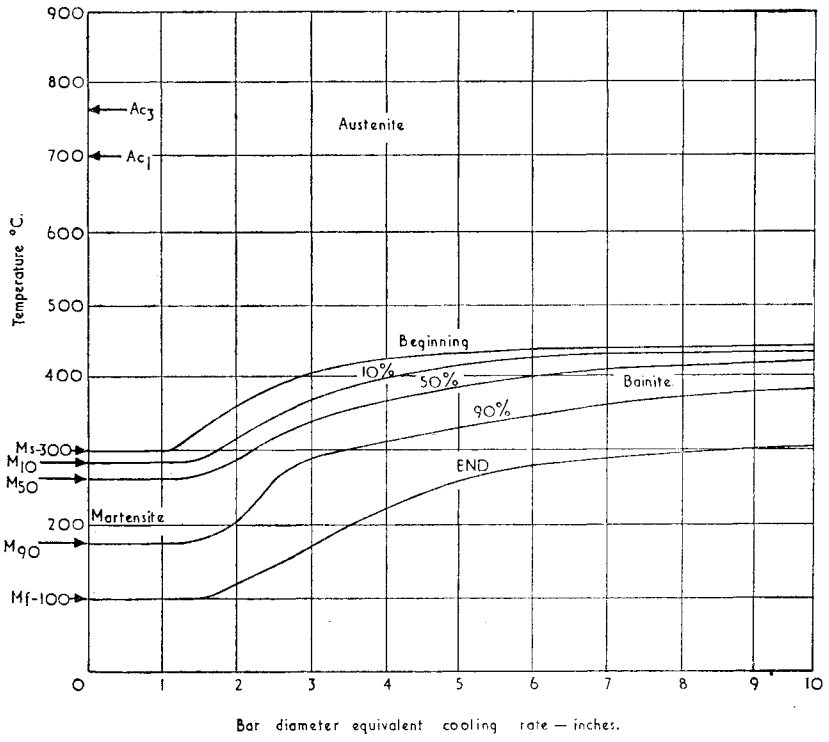


Fig. 26.3

CONTINUOUS COOLING TRANSFORMATION (Continued)

Air Cooled from 830°C.

(Ref. 1)



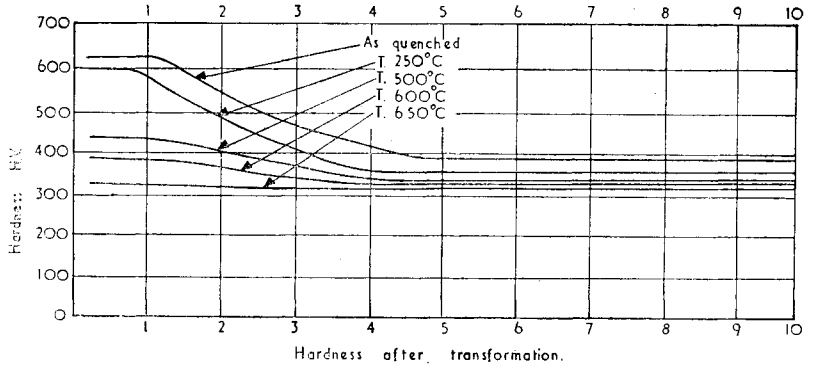
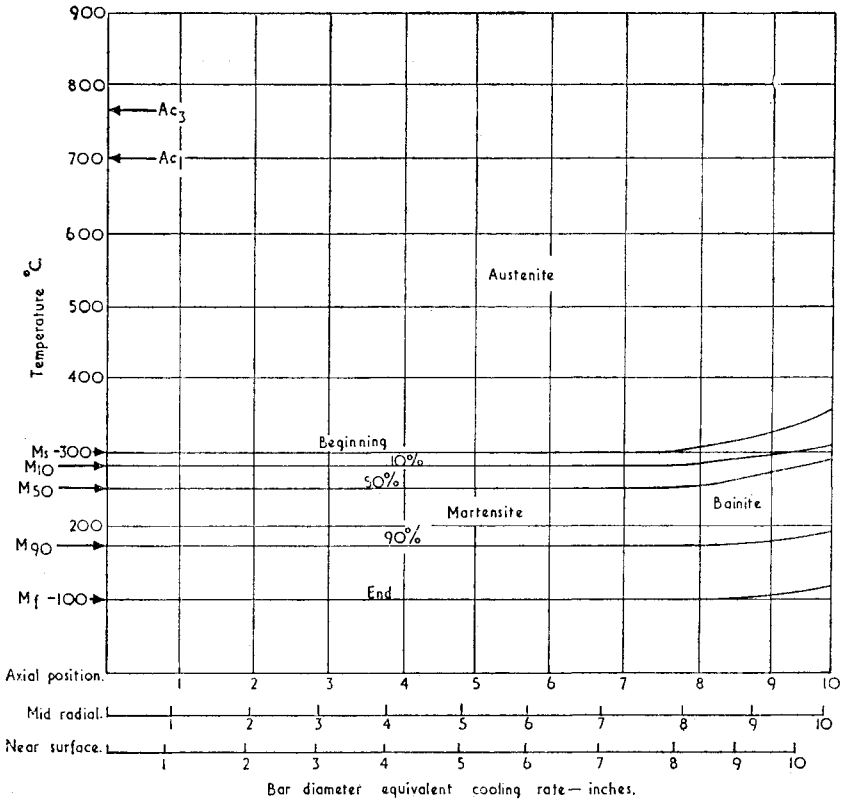


Fig. 26.4

CONTINUOUS COOLING TRANSFORMATION (Continued)

Oil Quenched 830°C.

(Ref. 1)



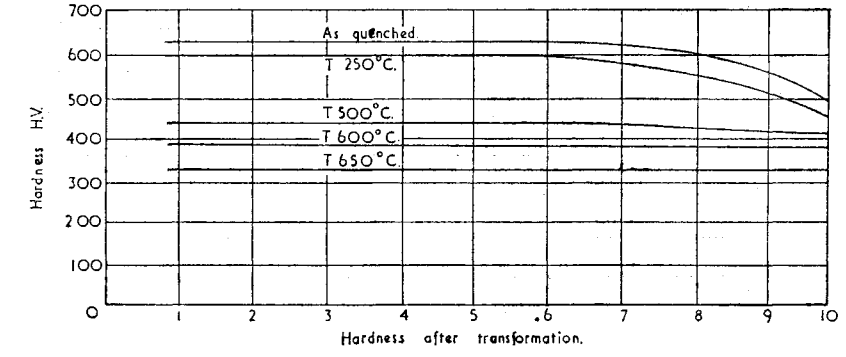


Fig. 26.5

CONTINUOUS COOLING TRANSFORMATION (Continued)

Water Quenched 830°C.

(Ref. 1)

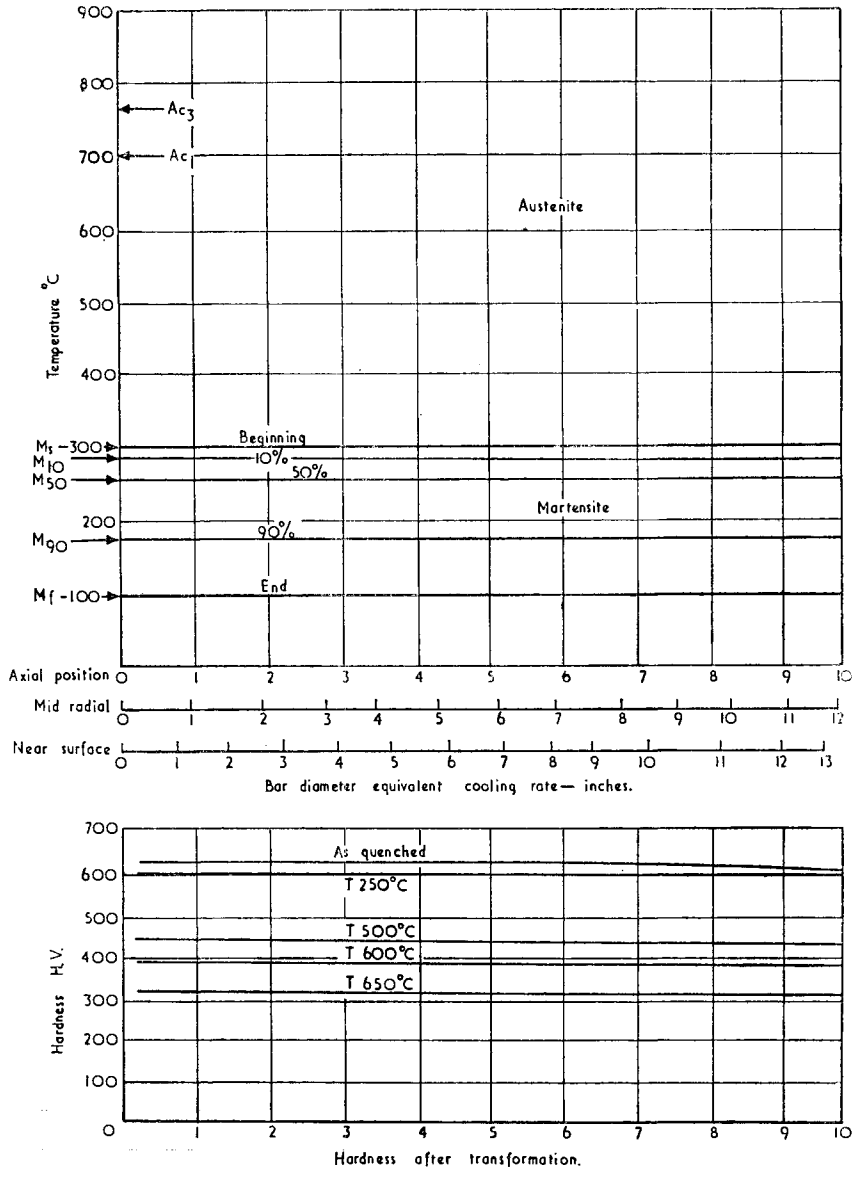


Fig. 26.6

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·42	0·31	0·67	0·022	0·029	2·53	0·73	0·48

McQuaid Ehn grain size 2 (ASTM).
As quenched grain size 6—7 (ASTM).
End Quenched from 830°C.

(Ref. 5)

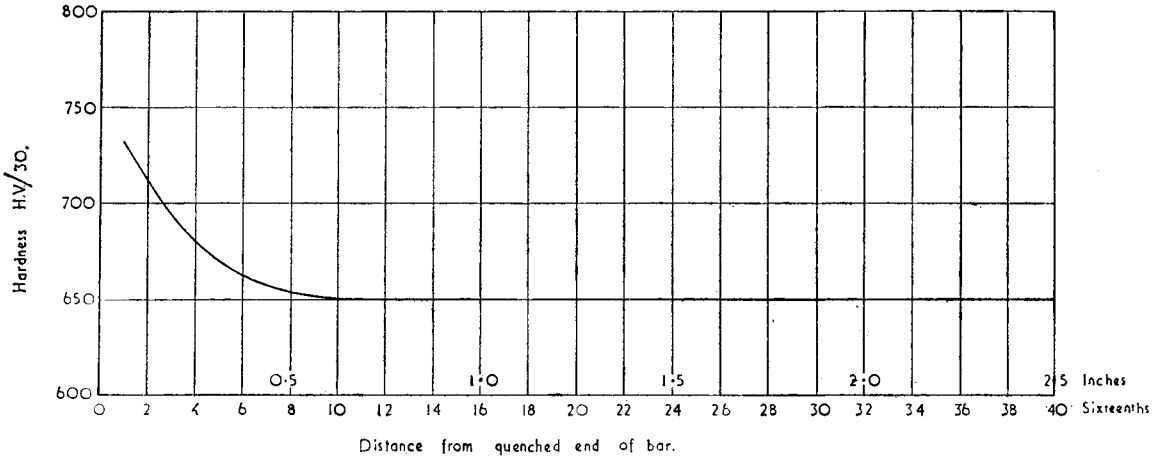


Fig. 26.7

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46

McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).
End Quenched from 835°C.

(Ref. 6)

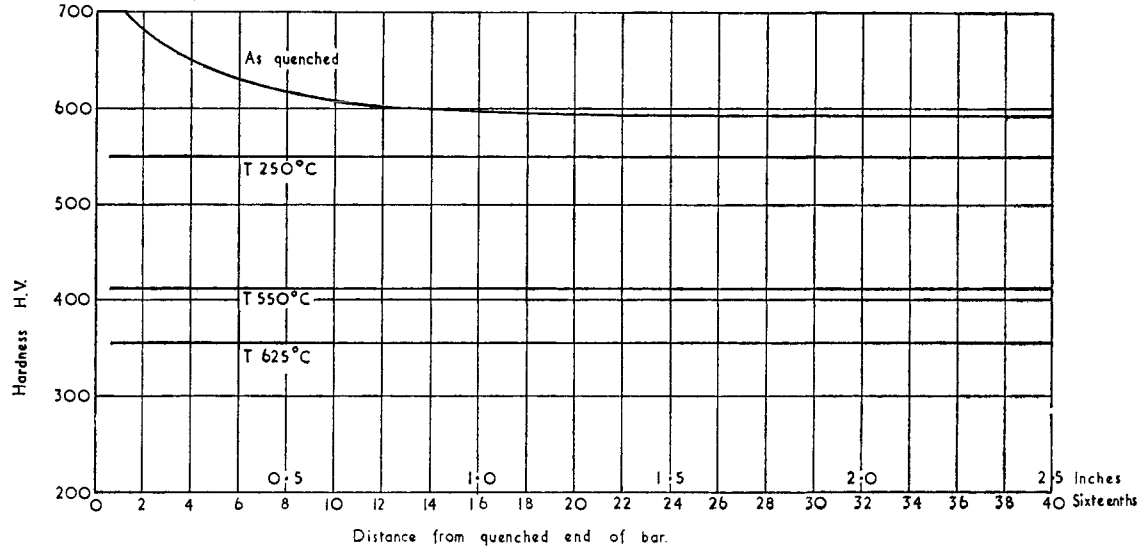


Fig. 26.8

END QUENCH HARDENABILITY DATA

Curve No.	Chemical composition (%)								Pre-treatment °C	End Quenching Temperature °C	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			
1	0·42	0·29	0·64	0·030	0·029	2·50	0·78	0·60	N850 T650	830	7
2	0·40	0·26	0·66	0·010	0·025	2·47	0·66	0·45	N900	"	"
3	0·38	0·21	0·58	0·013	0·021	2·47	0·59	0·47	"	"	"
4	0·38	0·24	0·53	0·014	0·016	2·35	0·69	0·49	"	"	"

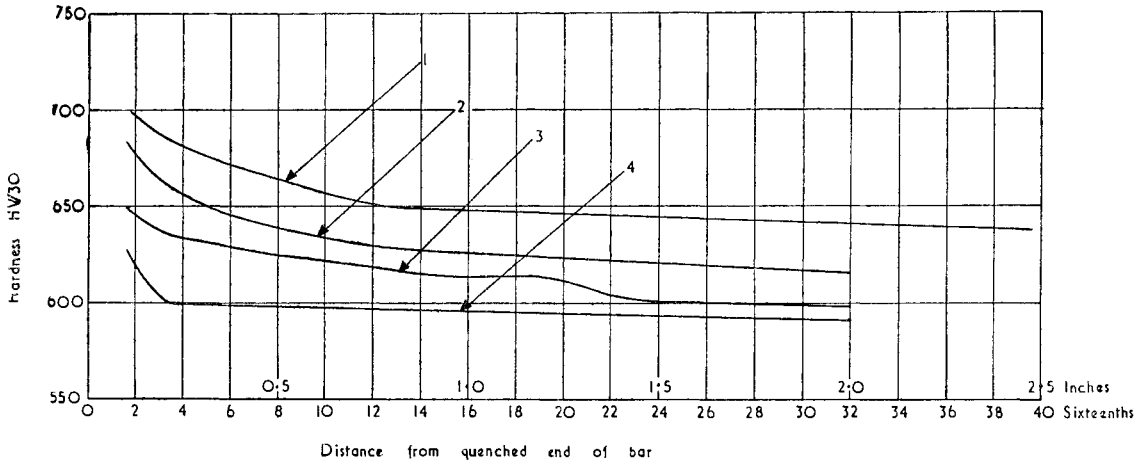


Fig. 26.9

END QUENCH HARDENABILITY BAND

(Ref. 3)

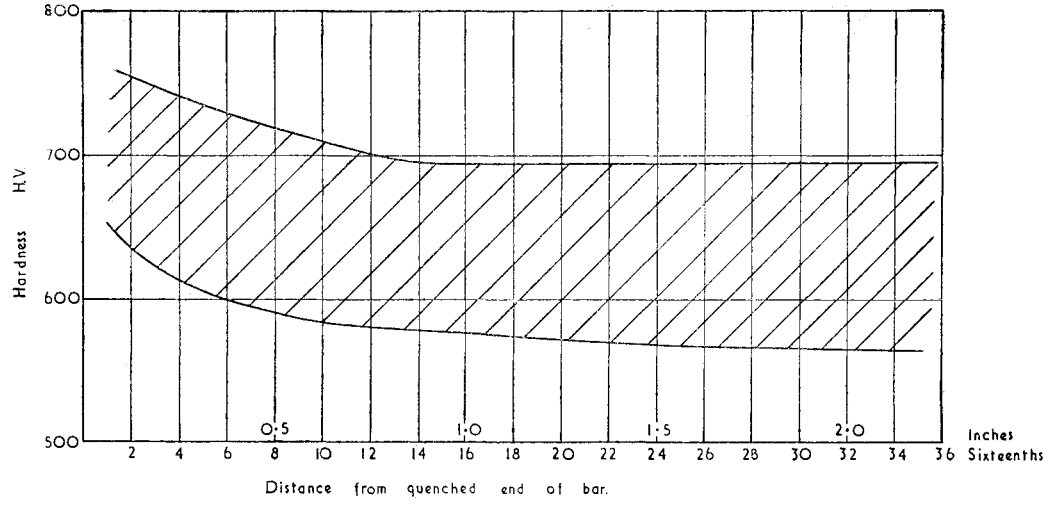


Fig. 26.10

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.		0·36	0·34	0·59	0·036	0·028	2·60	0·61	0·64	$\frac{3}{4}$	OQ820 T560AC					78·0	83·2	16	55	29	8
B.E.A.		0·36	0·14	0·57	0·026	0·032	2·50	0·75	0·48	"	" T650AC					58·4	63·6	20	59½	55	"
B.E.A.		0·36	0·30	0·56	0·019	0·030	2·51	0·69	0·54	1⅛	OQ840 T660AC					53·0	62·0	21	59½	70	"
B.E.A.		0·36	0·26	0·52	0·013	0·025	2·71	0·70	0·53	"	" T540AC		72·0				81·6	17	52½	34	"
"		"	"	"	"	"	"	"	"	"	" T590AC		67·6				75·2	19	59½	40	"
B.E.A.		0·36	0·29	0·59	0·020	0·030	2·51	0·79	0·48	2¼	" T530AC		76·0				85·0	16	53½	26	"
"		"	"	"	"	"	"	"	"	"	" T550AC		67·5				77·5	18	56½	41	"
"		"	"	"	"	"	"	"	"	2⅝	" T520AC		73·6				83·2	17	50	29	"
"		"	"	"	"	"	"	"	"	2¾	" T590AC		60·4				69·6	18	55	49	"
B.E.A.		0·36	0·40	0·59	0·020	0·033	2·56	0·70	0·56	2	" T590AC		67·6				76·4	17	53	38	"
"		"	"	"	"	"	"	"	"	2⅛	" " "		70·6				80·8	16	47	34	"
"		"	"	"	"	"	"	"	"	2¼	" T570AC		72·8				80·8	16	47	31	"
"		"	"	"	"	"	"	"	"	"	" T590AC		73·2				82·0	16	52½	34	"
"		"	"	"	"	"	"	"	"	2⅜	" T580AC		65·6				79·6	15	50	33	"
"		"	"	"	"	"	"	"	"	2½	" " "		70·0				79·2	17	52½	33	"
B.E.A.		0·36	0·27	0·60	0·020	0·026	2·57	0·78	0·49	2¾	" T540AC					78·5	86·0	16	50	20	"
"		"	"	"	"	"	"	"	"	"	" T550AC					73·0	77·0	16	52½	45	"
B.E.A.		0·36	0·26	0·51	0·012	0·038	2·66	0·65	0·52	3⅛	" T570AC		65·2				82·0	15	47	30	"
"		"	"	"	"	"	"	"	"	3¼	" " "		70·0				79·2	16	50	31	"
B.E.A.		0·36	0·31	0·60	0·021	0·039	2·57	0·63	0·50	4¼	" " "		56·8				84·4	14	45	23	"
"		"	"	"	"	"	"	"	"	"	" T600AC		76·8				85·6	13	39	18	"
B.E.A.		0·36	0·26	0·67	0·025	0·028	2·47	0·70	0·46	5¼	" T640AC					50·0	60·0	21	59	64	"
"		"	"	"	"	"	"	"	"	6⅞	" T580WQ					63·0	72·0	18	57	49	"
"		"	"	"	"	"	"	"	"	10½	" T620WQ					52·0	63·0	18	50	44	"
B.E.A.		0·37	0·33	0·56	0·024	0·032	2·68	0·73	0·52	½	OQ820 T560AC					80·5	84·0	17	51½	28	8
"		"	"	"	"	"	"	"	"	1	" T540AC					79·0	84·0	17	54	28	"
B.E.A.		0·37	0·17	0·67	0·027	0·032	2·61	0·81	0·42	1⅜	OQ840 T540AC		72·8				82·8	16	47	16	"
"		"	"	"	"	"	"	"	"	"	" " WQ		72·0				85·2	15	50	30	"
B.E.A.		0·37	0·30	0·53	0·008	0·026	2·65	0·66	0·51	2⅛	" T550AC		74·0				86·0	17	47	31	"
B.E.A.		0·37	0·32	0·59	0·021	0·029	2·79	0·79	0·53	2¾	" " "					80·0	85·0	16	50	33	"
B.E.A.	4	0·37	0·18	0·60	0·010	0·014	2·61	0·73	0·55	1¼	OQ850 T610AC	63·0	63·5	64·1	65·2		71·1	21	60	65	3
"	"	"	"	"	"	"	"	"	"	"	" T660AC	51·4	51·5	51·7	52·0		61·2	25¼	59	80	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.		0·38	0·21	0·60	0·026	0·038	2·64	0·68	0·50	$\frac{5}{8}$	OQ820 T580AC		71·2				76·8	19	57	35	8
"		"	"	"	"	"	"	"	"	$\frac{3}{4}$	" T550AC		79·2				88·8	15	42	14	"
"		"	"	"	"	"	"	"	"	$\frac{7}{8}$	" T590AC		68·0				80·4	16	55	31	"
"		"	"	"	"	"	"	"	"	$1\frac{1}{2}$	OQ840 T550AC		76·4				84·8	14	42	21	"
B.E.A.		0·38	0·28	0·63	0·022	0·031	2·67	0·60	0·52	$2\frac{1}{8}$	" T590AC		76·4				82·4	17	50	36	"
B.E.A.		0·38	0·19	0·55	0·022	0·046	2·60	0·73	0·51	$2\frac{1}{4}$	" T580AC		74·6				82·0	16	57	26	"
B.E.A.		0·38	0·25	0·61	0·027	0·024	2·70	0·77	0·45	$2\frac{3}{8}$	" T530AC		81·6				90·0	14	50	23	"
"		"	"	"	"	"	"	"	"	"	" T540AC		82·8				89·2	14	$52\frac{1}{2}$	29	"
B.E.A.		0·38	0·33	0·51	0·022	0·036	2·58	0·63	0·55	$3\frac{3}{4}$	" T600AC		66·2				75·2	17	$52\frac{1}{2}$	33	"
"		"	"	"	"	"	"	"	"	"	" T570AC		77·6				86·0	15	45	18	"
"		"	"	"	"	"	"	"	"	4	" T600AC		68·0				80·8	14	45	24	"
B.E.A.	4—3	0·38	0·25	0·61	0·016	0·011	2·66	0·66	0·55	1	OQ850 T600AC	65·0	65·5	66·2	67·5		73·7	19	57	56	3
"	"	"	"	"	"	"	"	"	"	"	" T650AC	54·8	54·8	54·9	55·1		63·6	$22\frac{1}{2}$	$61\frac{1}{2}$	75	"
"	"	"	"	"	"	"	"	"	"	4	" T600AC	62·5	63·0	63·8	64·6		71·1	22	61	60	"
"	"	"	"	"	"	"	"	"	"	"	" T650AC	55·6	55·8	56·1	56·7		64·5	23	$62\frac{1}{2}$	70	"
		0·38	0·18	0·60			2·72	0·69	0·58	$2\frac{3}{4}\times2\frac{1}{2}$	" T590		67·2				78·2	18	—	38	"
B.E.A.		0·38	0·23	0·68	0·007	0·012	2·50	0·65	0·53	$4\frac{1}{4}$(M)	" T560						86·4	18	55	22	9
B.E.A.		0·38	0·24	0·55	0·013	0·010	2·80	0·80	0·56	$1\frac{3}{4}$(C)	T570					76·0	84·8	18	57	49	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
		0·38					2·35	0·69	0·49	2½	OQ850 T600		66·0	72·0	21		57	2
		0·38					2·64	0·67	0·46	3⅛	" T650		57·8	64·4	22		70	"
		0·38					2·47	0·59	0·47	0·423	" T250			121·8	14		16	"
B.E.A.		0·39	0·25	0·54	0·011	0·029	2·66	0·74	0·49	¾	OQ820 T540AC	78·0		85·2	16	50	28	8
"		"	"	"	"	"	"	"	"	"	" T550AC	76·4		83·2	18	52½	35	"
		0·39	0·22	0·51			2·72	0·69	0·58	2¾	OQ850 T590	67·1		77·0	19		40	3
		0·39					2·44	0·68	0·42	1⅜	" T560		79·6	83·6	17½		38	2
		0·39					2·47	0·58	0·47	2½	" T550		78·0	82·8	17		35	"
		0·39					2·43	0·64	0·39	5⅜	" T650		56·6	64·8	20½		58	"
		0·39		0·61			2·54	0·67	0·56	3⅜ sq.	OQ830 T590		77·3	84·0	18	55	35	1
B.E.A.		0·40	0·16	0·50	0·013	0·031	2·52	0·71	0·43	2⅛	OQ840 T580AC	72·4		78·4	18	55	37	8
"		"	"	"	"	"	"	"	"	2½	" T590AC	72·8		80·4	18	53	36	"
"		"	"	"	"	"	"	"	"	3	" T610AC	68·4		75·2	19	56	45	"
		0·40	0·20	0·70			2·59	0·68	0·56	7	OQ850 T550	75·3		86·5	17	44½	28	3
		0·40	0·26	0·63			2·56	0·65	0·57	11	" T620		56·0	66·0	22	52	40	"
		"	"	"			"	"	"	12	" "		56·0	66·0	23	52	53	"
		"	"	"			"	"	"	12	" T605		62·0	71·0	19	49½	36	"
		0·40		0·63			2·44	0·75	0·52	4	OQ830 T620		73·6	76·9	17½		36	10
		"		"			"	"	"	6	" "		70·2	75·9	18		43	"
		0·40		0·62			2·46	0·62	0·55	0·564	OQ830 T200		114·0	133·1	13		15	"
		0·40		0·60			2·50	0·65	0·45	0·423	OQ850 T250		99·0	117·0	14		20	"
	6	0·40		0·63			2·44	0·75	0·52	1⅛	OQ830 T590		74·5	79·7	17	52	30	1
	"	"		"			"	"	"	"	" T620		74·2	77·4	17½	52	34	"
	"	"		"			"	"	"	"	" T650		59·6	67·3	21½	59	47	"
	"	"		"			"	"	"	2½ sq.	" T590		73·2	79·1	17	55	55	"
	"	"		"			"	"	"	"	" T620		72·7	76·7	17	54	39	"
	"	"		"			"	"	"	"	" T650		62·9	69·0	18	57	52	"
	"	"		"			"	"	"	4 sq.(C)	" T590		71·4	76·8	18	55	48	"
	"	"		"			"	"	"	" (O)	" "		73·3	78·2	15	57	36	"
	"	"		"			"	"	"	" (C)	" T620		73·1	77·0	17	55	43	"
	"	"		"			"	"	"	" (O)	" "		73·6	76·9	17½	54	36	"
	"	"		"			"	"	"	" (C)	" T650		59·4	67·0	21	57	54	"
	"	"		"			"	"	"	" (O)	" "		61·1	68·9	21½	59	48	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.						
	McQuaid Ehn Actual																	
		0·41					2·60	0·73	0·54	5 ¼(C)	OQ850 T570WQ	78·0		87·0	14	40	24	7
A.O.H.	5—6 7—8																	
	(7) (6)	0·41	0·24	0·67	0·031	0·043	2·59	0·98	0·68	1 3/16	N875 OQ850 T550		77·0	87·1	16 ½	49	25	"
		0·41	0·22	0·66			2·58	0·66	0·59	4	OQ850 T640		60·0	68·0	27	52	50	3
		0·41	0·19	0·65			2·63	0·70	0·55	5	" T600		71·5	76·4	16	47	53	"
		0·41	0·34	0·67			2·69	0·67	0·56	6	OQ850 T560		77·5	87·2	16 ½	48	26	"
		0·41	0·19	0·65			2·62	0·65	0·57	7	" "	75·2		85·0	17	44 ½	31	"
		0·41	0·23	0·71			2·47	0·68	0·58	11 ¾	" T580		70·8	77·5	15	43	43	"
		0·41					2·62	0·67	0·46	4	" T550		74·0	79·0	20		46	2
		0·41					2·56	0·63	0·49	3 ⅛	" T630		62·4	68·8	21 ½		60	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp) tons/sq.in.	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.E.A.		0·42	0·25	0·66	0·005	0·013	2·50	0·66	0·56	$3\frac{1}{8}$	OQ850 T250		91·0	97·6	100·0		127·2	$11\frac{1}{2}$	34	10	2
		0·42	0·27	0·64			2·58	0·68	0·57	$4\frac{3}{4}$	" T570		75·0				83·5	20		39	3
		0·42					2·64	0·60	0·46	$3\frac{1}{8}$	" T620					63·0	69·2	21		56	2
		0·42		0·53			2·52	0·64	0·65	2	OQ830 T630					60·0	70·0	20		53	10
		"		"			"	"	"	4	" T640					61·0	71·0	20		52	"
		"		"			"	"	"	4	" T630					63·0	73·0	20		52	"
		"		"			"	"	"	6	" T570					63·0	72·0	17		40	"
		"		"			"	"	"	6	" T590					62·0	71·0	18		39	"
	McQuaid Ehn Actual																				
B.E.A.	5—7 7—8																				
	(4) (6)	0·43	0·23	0·63	0·018	0·013	2·74	0·64	0·58	$1\frac{1}{4}$	N875 OQ850 T550					78·8	88·3	16	52	25	7
		0·43	0·23	0·66			2·58	0·70	0·57	$4\frac{1}{2}$	OQ850 T570		74·1				85·0	17		32	3
		"	"	"			"	"	"	$4\frac{3}{4}$	" T200					85·0	126·0	12	$36\frac{1}{2}$	20	"
B.E.A.		0·43	0·29	0·62	0·009	0·019	2·63	0·70	0·70	$4\frac{1}{4}$(M)	" T580					78·0	86·8	16	47	21	9
		0·43		0·60			2·66	0·71	0·56	0·564	OQ830 T590					77·3	84·0	18	55	35	1
		"		"			"	"	"	$1\frac{1}{8}$	" "					77·4	81·3	$17\frac{1}{2}$	52	37	"
		"		"			"	"	"	"	" T620					73·9	77·4	18	52	38	"
		"		"			"	"	"	"	" T650					64·6	71·0	$19\frac{1}{2}$	55	47	"
		"		"			"	"	"	$2\frac{1}{2}$	" T590					78·4	84·0	17	50	35	"
		"		"			"	"	"	"	" T620					74·4	79·1	$17\frac{1}{2}$	55	40	"
		"		"			"	"	"	"	" T650					63·5	70·6	20	57	53	"
		"		"			"	"	"	4sq.(C)	" T590					76·8	82·0	17	52	37	"
		"		"			"	"	"	" (O)	" "					78·9	82·3	17	52	35	"
		"		"			"	"	"	" (C)	" T620					72·6	79·3	$17\frac{1}{2}$	55	41	"
		"		"			"	"	"	" (O)	" "					75·2	78·9	18	55	42	"
		"		"			"	"	"	" (C)	" T650					63·9	69·3	20	57	52	"
		"		"			"	"	"	" (O)	" "					66·0	71·0	$20\frac{1}{2}$	57	48	"
		"		"			"	"	"	6sq.(M)	" T590					80·8	84·4	$15\frac{1}{2}$	44	32	"
		"		"			"	"	"	" (O)	" "					81·9	85·4	16	50	33	"
		"		"			"	"	"	" (C)	" T620					73·0	77·9	$16\frac{1}{2}$	50	44	"
		"		"			"	"	"	" (M)	" "					73·0	77·3	17	55	43	"
		"		"			"	"	"	" (O)	" "					74·9	79·0	$17\frac{1}{2}$	55	39	"
		"		"			"	"	"	" (C)	" T650					56·3	63·0	22	59	56	"
		"		"			"	"	"	" (M)	" "					56·0	63·6	22	57	59	"
		"		"			"	"	"	" (O)	" "					55·8	63·6	$22\frac{1}{2}$	59	54	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·2% P.S. (0·2Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
										tons/sq.in.							
0·44		0·56			2·53	0·71	0·55	0·564	OQ830 T200			118·4	133·4	12	24	14	1
"		"			"	"	"	"	" T570			80·5	84·0	16½	50	33	"
0·44	0·16	0·56	0·027	0·028	2·56	0·62	0·63	"	OQ830	47·0				*	*	5	11
"	"	"	"	"	"	"	"	"	" T200	93·4	104·3	112·7	132·0	*	*	13	"
"	"	"	"	"	"	"	"	"	" T300	93·2	98·5	105·5	115·1	12	42½	9	"
"	"	"	"	"	"	"	"	"	" T350	91·2	96·5	102·9	110·0	12	42	11	"
"	"	"	"	"	"	"	"	"	" T400	88·7	91·8	97·4	102·8	10	38½	12	"
"	"	"	"	"	"	"	"	"	" T450	84·4	85·5	89·2	95·5	11½	43	14	"
"	"	"	"	"	"	"	"	"	" T550	78·7	80·3	83·1	89·2	16	49	28	"
"	"	"	"	"	"	"	"	"	" T650	63·0	63·0	63·0	70·0	19	57	53	"

*Broke at shoulder.

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Oil Quenched 830°C. Tempered 550°C. (Ref. 3)

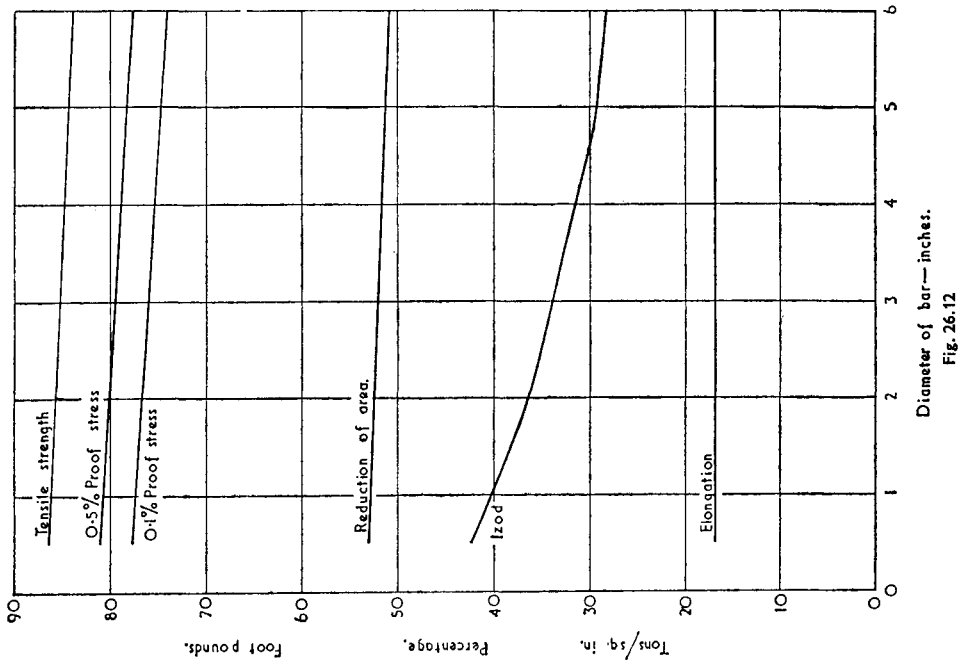


Fig. 26.12

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Typical curves for 1 in. dia. bars Oil Quenched from 830/850°C.

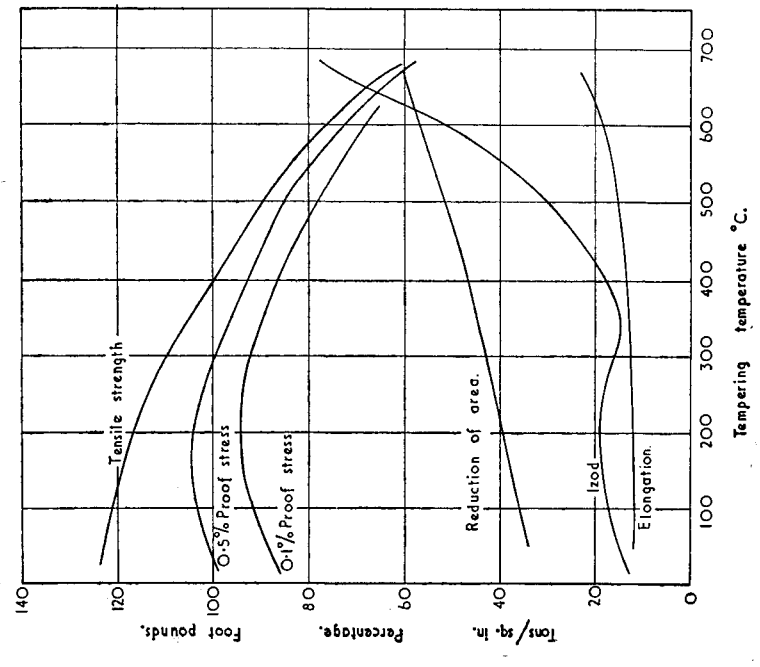


Fig. 26.11

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Oil Quenched 830°C. Tempered 600°C.

(Ref. 3)

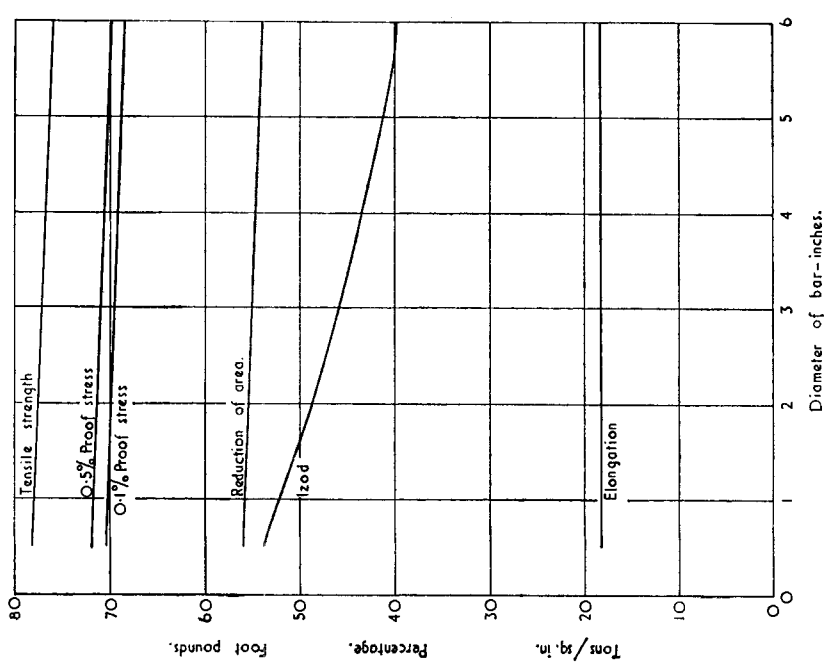


Fig. 26.13

Oil Quenched 830°C. Tempered 650°C.

(Ref. 3)

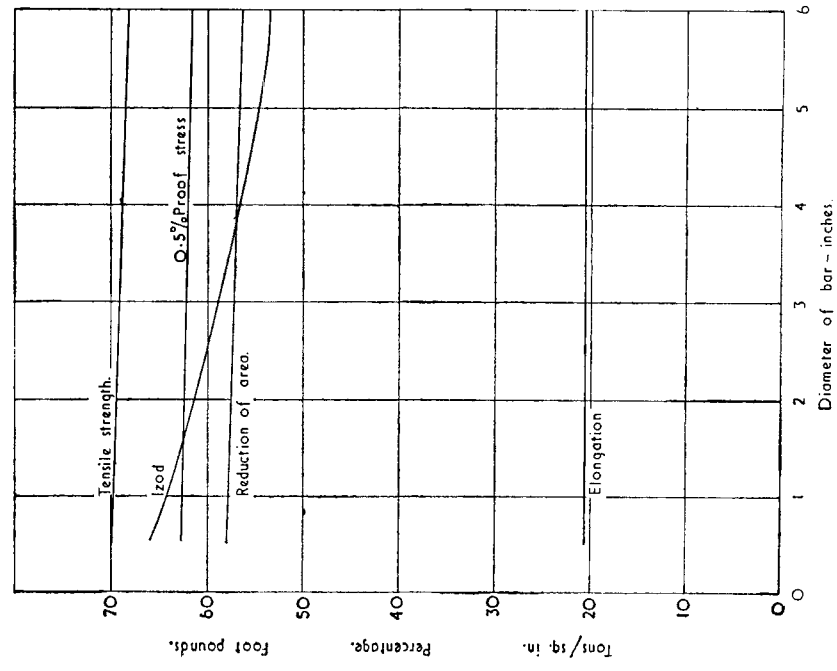


Fig. 26.14

MECHANICAL PROPERTIES AT LOW TEMPERATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Charpy V ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo				0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0.2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
													tons/sq.in.								
B.E.A.		0·39	0·28	0·58	0·010	0·013	2·56	0·63	0·45	$1\frac{3}{8}$	OQ850 T520	R.T.		78·2	79·3	81·4	86·6	$17\frac{1}{2}$	50	27	2
"		"	"	"	"	"	"	"	"	"	" "	— 70		81·5	82·7	82·7	91·2	20	$48\frac{1}{2}$	15	"
B.E.A.		0·38	0·23	0·60	0·018	0·016	2·58	0·64	0·50	$7 \times 1\frac{3}{4}$	OQ850 T515	R.T.	76·3	77·1		78·6	84·1	21	55	38	"
"		"	"	"	"	"	"	"	"	"	" "	— 78	78·7	80·2		82·2	88·5	20	$52\frac{1}{2}$	13	"
	8	0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46	$\frac{3}{8}$	OQ840 T200AC	20		84·2	90·3	98·6	120·6	16	49		10
	"	"	"	"	"	"	"	"	"	"	" " "	— 78		82·3	88·6	100·1	126·6	19	56		"
	"	"	"	"	"	"	"	"	"	"	" " "	—196		95·8	103·8	115·5	143·8	18	48		"
	"	"	"	"	"	"	"	"	"	"	" T550WQ	20		74·5	74·8	75·9	81·8	20	59		"
	"	"	"	"	"	"	"	"	"	"	" " "	— 78		78·0	78·8	81·0	87·0	20	54		"
	"	"	"	"	"	"	"	"	"	"	" " "	—196		95·8	96·8	98·8	102·7	22	47		"
	"	"	"	"	"	"	"	"	"	"	" T600WQ	20		67·9	68·1	69·1	75·0	20	62		"
	"	"	"	"	"	"	"	"	"	"	" " "	— 78		72·2	72·8	73·8	80·0	24	59		"
	"	"	"	"	"	"	"	"	"	"	" " "	—196		90·5	91·6	93·7	98·6	25	49		"
	"	"	"	"	"	"	"	"	"	"	" T660WQ	20		56·0	56·2	56·4	63·2	26	66		"
	"	"	"	"	"	"	"	"	"	"	" " "	— 78		59·4	59·8	61·1	69·6	29	61		"
	"	"	"	"	"	"	"	"	"	"	" " "	—196		81·0	81·4	82·8	88·0	27	52		"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs)	T.S. (Rm)	El %	
0·43	0·32	0·65	0·012	0·012	2·64	0·75	0·58	3	OQ850 T650	54	63	24	12

Test Temperature	Longitudinal Tests						Transverse Tests with Transverse Notch				Transverse Test with Longitudinal Notch			
	Izod		Charpy Mesnager		Charpy V		Izod		Charpy Mesnager		Izod		Charpy Mesnager	
°C	ft. lb.	% Crystalline	ft.lb.	% Crystalline	ft.lb.	% Crystalline	ft.lb.	% Crystalline	ft.lb.	% Crystalline	ft.lb.	% Crystalline	ft.lb.	% Crystalline
—196	12	100	30	91	13	100	3	100	6	100	3	100	7	100
—120	20	80	39	90	20	90	10	80	19	90	7	85	17	—
— 90	—	—	47	43	24	60	—	—	22	75	—	—	17	75
— 60	59	0	79	20	51	22	20	(50)	23	30	23	20	27	40
0	64	0	98	0	70	0	25	0	33	3	27	0	34	0
60	68	0	—	—	71	0	27	0	—	—	28	0	—	—
80	—	—	—	—	—	—	—	—	—	—	28	0	—	—

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·38	0·15	0·56	0·005	0·011	2·42	0·74	0·46

Impact properties of $\frac{3}{4}$ in. dia. bars. Oil Quenched 840°C and tempered as indicated. (See also 'Mechanical Properties at Low Temperature' for tensile test data on this steel).

(Ref. 10)

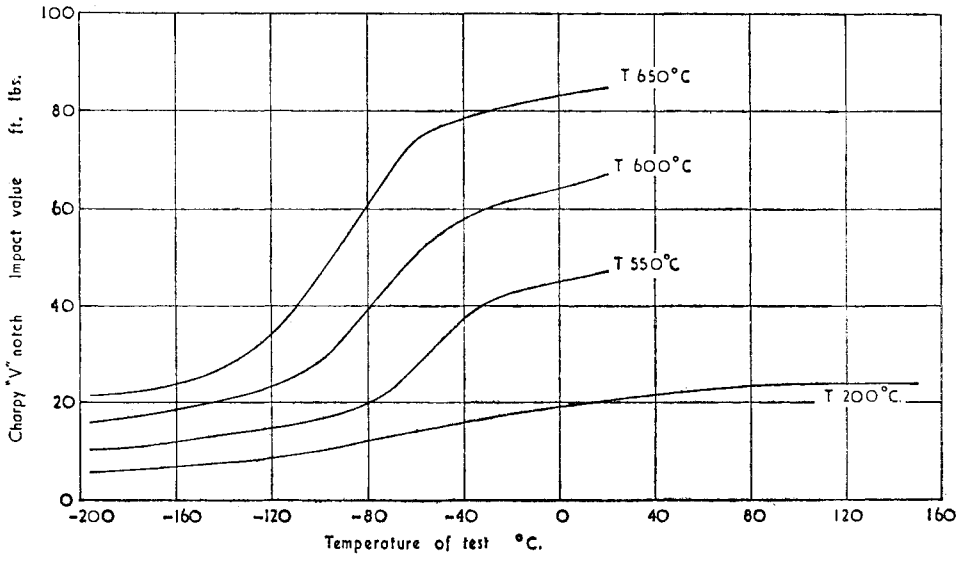


Fig. 26.15

(Ref. 10)

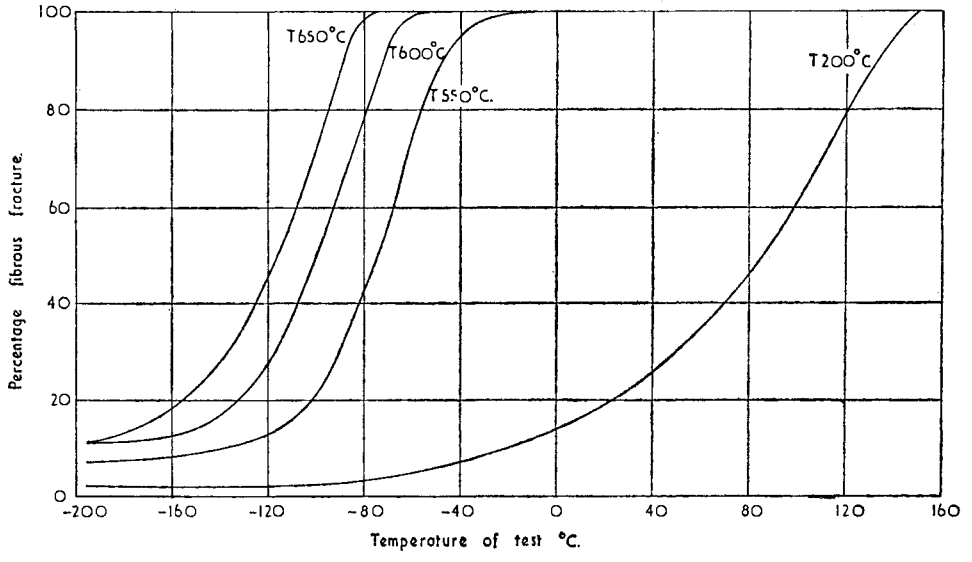


Fig. 26.16

IMPACT TRANSITION TEMPERATURE DATA

(Continued)

Curve No.	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo				0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rs)	El %	R.A. %	
													tons/sq.in.							
A	4—3	0·38	0·25	0·61	0·016	0·011	2·66	0·66	0·55	1	OQ850 T600 AC		65·0	65·5	66·2	67·5	73·7	19	57	3
B	"	"	"	"	"	"	"	"	"	"	" T650 "	20	54·8	54·8	54·9	55·1	63·5	22½	62	"
C	4	0·37	0·18	0·60	0·010	0·014	2·61	0·73	0·55	1¼	" T610 "	20	63·0	63·5	64·1	65·2	71·1	21	60	"
D	"	"	"	"	"	"	"	"	"	"	" T660 "	20	51·4	51·5	51·7	52·0	61·2	25½	59	"
E	4—3	0·38	0·25	0·61	0·016	0·011	2·66	0·66	0·55	4	" T600 "	20	62·5	63·0	63·8	64·6	71·1	22	61	"
F	"	"	"	"	"	"	"	"	"	"	" T650 "	20	55·6	55·8	56·1	56·7	64·5	23	62½	"

(See page 173)

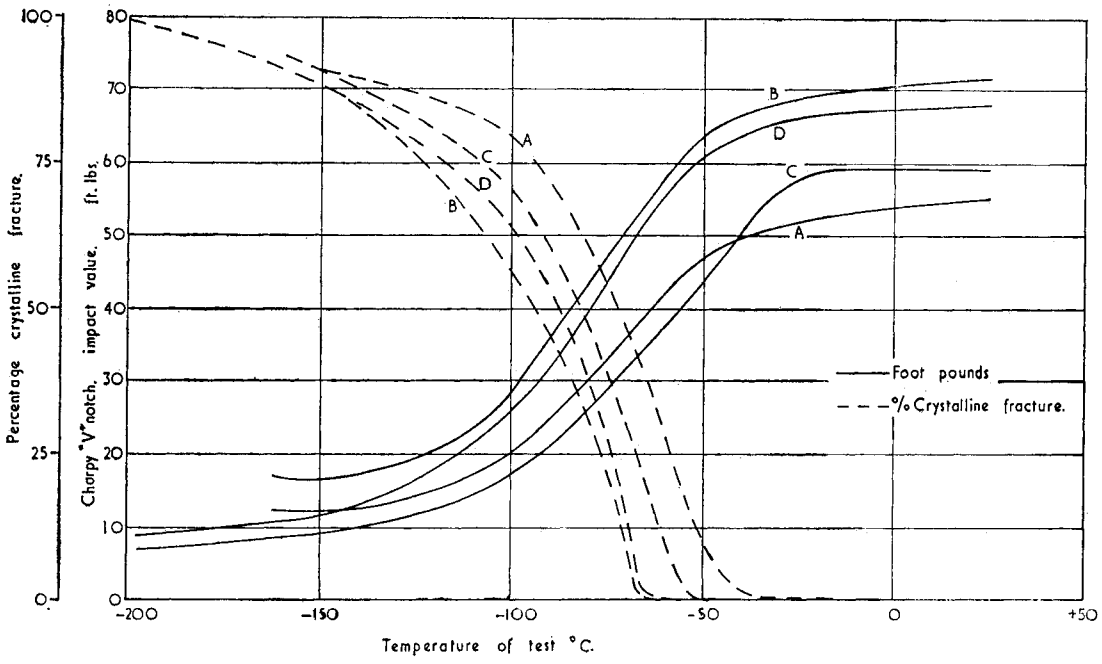


Fig. 26.17

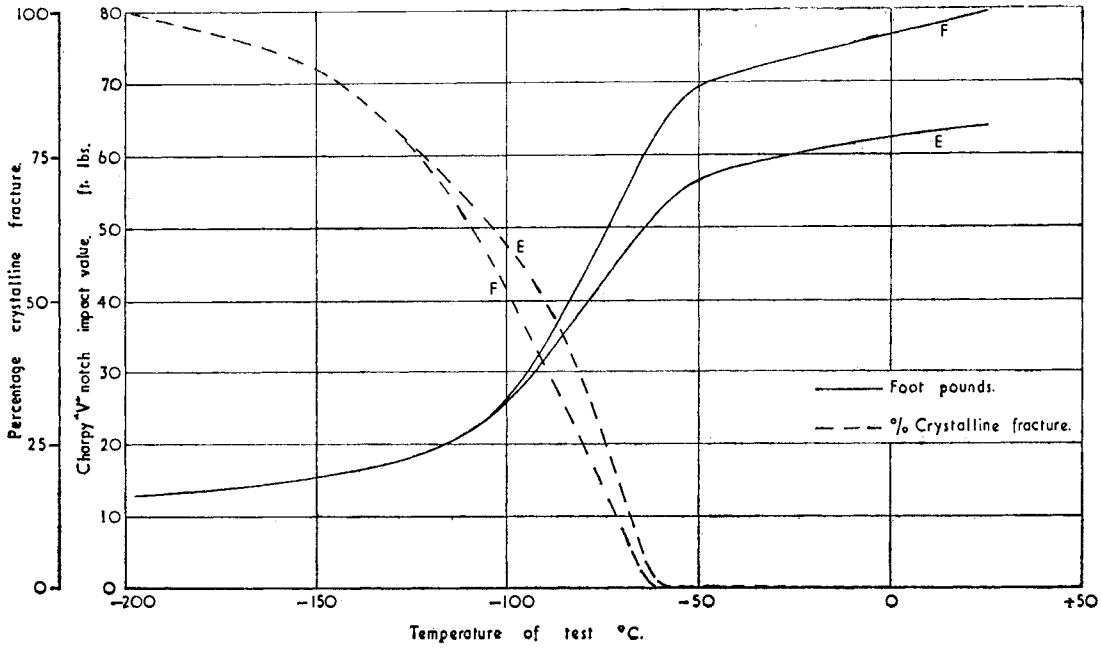


Fig 26.18

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Izod	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	0·36	0·17	0·58	0·012	0·013	2·43	0·62	0·49	1⅛	OQ850 T650	RT	52·0	56·8	58·8	59·2	65·0	21½	60		2
”	”	”	”	”	”	”	”	”	”	” ”	100	47·1	56·8	57·6	58·8	65·6	20	59		”
”	”	”	”	”	”	”	”	”	”	” ”	300	39·0	49·8	52·2	56·0	66·2	24	45		”
”	”	”	”	”	”	”	”	”	”	” ”	400	31·0	44·7	47·3	51·4	57·9	23½	56½		”
”	”	”	”	”	”	”	”	”	”	” ”	500	21·5	38·8	41·2	43·4	48·7	24	73		”
”	”	”	”	”	”	”	”	”	”	” ”	600	6·0	15·2	19·1	22·7	32·7	44	86½		”
B.E.A.	0·39	0·28	0·58	0·010	0·013	2·56	0·63	0·45	1⅜	OQ850 T520	RT	71·7	78·2	79·3	81·4	86·6	17½	50	27	”
”	”	”	”	”	”	”	”	”	”	” ”	260	44·8	65·7	70·0	76·0	82·5	16½	33	31	”

FATIGUE PROPERTIES

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Rotating Bending Fatigue Limit tons/sq. in.		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Plain	Notched*	
											tons/sq.in.								
0·38	0·23	0·60	0·018	0·016	2·58	0·64	0·50	7×1¾	OQ850 T515	RT			78·6	84·1	21	55	±41·5	±14·2	2
”	”	”	”	”	”	”	”	”	” ”	—78			82·2	88·5	20	52½	±49·0	±14·4	”
0·40	0·19	0·65	0·035	0·036	2·62	0·81	0·55	0·275	OQ830 T200 —250 1hr. (L)		92·6	99·2		120·7	9	45	±47·0		13
”	”	”	”	”	”	”	”	”	” ” ” (T)		88·1	96·5		120	3	9	±27·5		”
”	”	”	”	”	”	”	”	1⅛sq.	OQ830 T590 1hr. OQ(L)		69·8	71·0		79·1	21	67	±42·0		”
”	”	”	”	”	”	”	”	”	” ” ” (T)		68·7	69·8		74·5	7	23	±29·0		”

* Details of notch: 55°V, 0·010 in. root radius, 0·320 in., dia. at root, 0·400 in. dia. of bar, Neuber stress concentration factor 3.

EFFECT OF COLD WORK ON THE FATIGUE STRENGTH

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	% Cold Work in Compression	Tensile			Hardness HV	Rotating Bending Fatigue Limit tons/sq. in.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El %			
0·43	—	0·65	0·012	0·012	2·64	0·75	0·58	$1\frac{1}{4}$	OQ850 T650	0	54	63	24	320/335	±35	14
"		"	"	"	"	"	"	"	"	16	—	—	—	335/345	±35	"
"		"	"	"	"	"	"	"	"	23	—	—	—	325/345	±39	"
"		"	"	"	"	"	"	"	"	55	—	—	—	330/365	±38	"

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3 PER CENT NICKEL–CHROMIUM–MOLYBDENUM STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·25—0·35	0·10—0·35	0·70 max.	0·050 max.	0·050 max.	3·00—3·75	0·50—1·30	0·20—0·65

MECHANICAL PROPERTIES

	Hardened and Tempered Condition				
	T	U	V		W
Limiting ruling section, in.	6	6	6	4	4
Tensile strength, tons/sq.in., min.(Rm)	55	60	65	65	70
Yield stress, tons/sq.in., min.(1) (Rs)	44	48	52	52	58
0·2% proof stress, tons/sq.in., min. (2) (0·2Rp)	41	46	50	50	55
Elongation, %, min. (A)	18	17	14	16	15
Izod impact value, ft.lb., min.	40	35	35	35	30
Brinell hardness No.(3) (HB).	248/302	269/321	293/341	293/341	311/375

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 277.

(1) Not to be used as acceptance tests except by special arrangement between purchaser and manufacturer.

(2) When specifically requested in the enquiry or order.

(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

En No.	France	Sweden
		SIS
27	30 NCD 12 30 NCD 15	14.253

En 27

APPLICATIONS

Has a similar composition to En 23 but with higher hardenability due to the addition of Molybdenum. It may be heat treated in fairly large sections to give tensile strengths of the order of 55 tons/sq. in. combined with good ductility and resistance to shock. Good low temperature impact values are also obtainable.

Used for a wide range of highly stressed components for automobiles, aircraft and general engineering industries.

Typical uses are: Crankshafts, transmission shafts, axles, connecting rods, inlet valves, bolts, valve rockers, rams, aircraft engine components, mandrel bars for tube manufacture, gun barrels, gear and turbine parts.

WELDING

The welding characteristics are very similar to those for En 25,26 and 30B.

MACHINABILITY

In the annealed condition the machinability is about 50% of that for mild steel. When hardened and tempered to 65 tons/sq.in. tensile strength the machinability is about 35% of mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C. Retarded cooling is advisable for large or intricate sections
Annealing	820°C—850°C. Furnace cool.
Softening	630°C—660°C. Air or furnace cool.
Hardening	820°C—850°C. Oil quench.
Tempering	550°C—660°C. Air cool or oil quench.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·30	0·25	0·60			3·25	0·80	0·30	Softened	7·86	1
0·34	0·27	0·55	0·003	0·024	3·53	0·78	0·39	A860 T640 FC	7·859	2

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cal/g deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·34	0·27	0·55	0·003	0·024	3·53	0·78	0·39	A860 T640 FC	0·116	0·110	0·124	0·129	0·134	0·142	0·154	0·170	0·167	0·166	2
0·30	0·25	0·60	—	—	3·25	0·86	0·30	Softened	0·118										1
(within specification)								—			0·126		0·136						3

MEAN COEFFICIENT OF THERMAL EXPANSION(α)

Chemical Composition (%)								Heat Treatment °C	10^6xMean Coefficient of Thermal Expansion per deg.C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900C	20to 1000°C	
0·34	0·27	0·55	0·003	0·024	3·53	0·78	0·39	A860 T640 FC	11·7	12·2	12·7	13·2	13·6	13·9	13·5	10·7	12·0	13·0	2
0·30	0·11	0·66	0·005	0·025	3·05	0·86	0·53	—	11·7		12·6 (20 to 275°C)								1
(within specification)								—	11·6		13·5								3
			"	"				—	12·3		13·0		13·5			14·0(20 to 680°C)			4

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm												Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·34	0·27	0·55	0·003	0·024	3·53	0·78	0·39	A860 T 640FC	27·7	28·9	33·7	40·6	48·7	58·2	69·4	82·5	99·4	111·4	114·6	117·6	2
(within specification)										30·8	35·5	41·9									3

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Conductivity cal/cm s deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·34	0·27	0·55	0·003 (within specification)	0·024	3·53	0·78	0·39	A860 T 640FC	0·079	0·081 0·081	0·084	0·085 0·085	0·085	0·080 0·081	0·073	0·067	0·064	0·066	0·068	2 3

YOUNG'S MODULUS (E)

(See also En 23)

Chemical Composition (%)					Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in. (static)	Ref.
C	Mn	Ni	Cr	Mo				
0·31	0·65	3·24	0·70	0·22	OQ and T (55/60 tons/sq.in.)	RT	13,100	5
"	"	"	"	"		100	13,300	"
"	"	"	"	"		150	12,900	"
"	"	"	"	"		200	12,850	"
"	"	"	"	"		250	12,500	"
"	"	"	"	"		300	12,600	"
"	"	"	"	"		350	11,500	"

Chemical Composition (%)								Heat Treatment	Young's Modulus (static) tons/sq.in. at					Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	°C	20°C	—60°C	—120°C	—150°C	—195°C	
0·25	0·13	0·59	0·027	0·025	2·86	0·68	0·48	OQ860 T600	13,200	13,600	13,700	13,850	14,100	5
0·30	0·19	0·47	0·030	0·030	2·94	0·83	0·49	" T630	13,150	13,450	13,700	13,850	14,050	"
0·32	0·26	0·82	0·034	0·025	3·06	0·71	0·53	" T640	13,300	13,550	13,750	13,850	14,100	"
0·35	0·24	0·57	0·030	0·021	3·08	0·67	0·50	" T640	13,350	13,550	13,700	13,750	13,900	"

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·32	0·28	0·61	0·013	0·018	3·22	0·63	0·22

Electric arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to 4 S.W.G., cold drawn to 11 S.W.G., with intermediate annealing at 600°C.
Austenitizing Temperature 830°C, 30 min.

(Ref. 6)

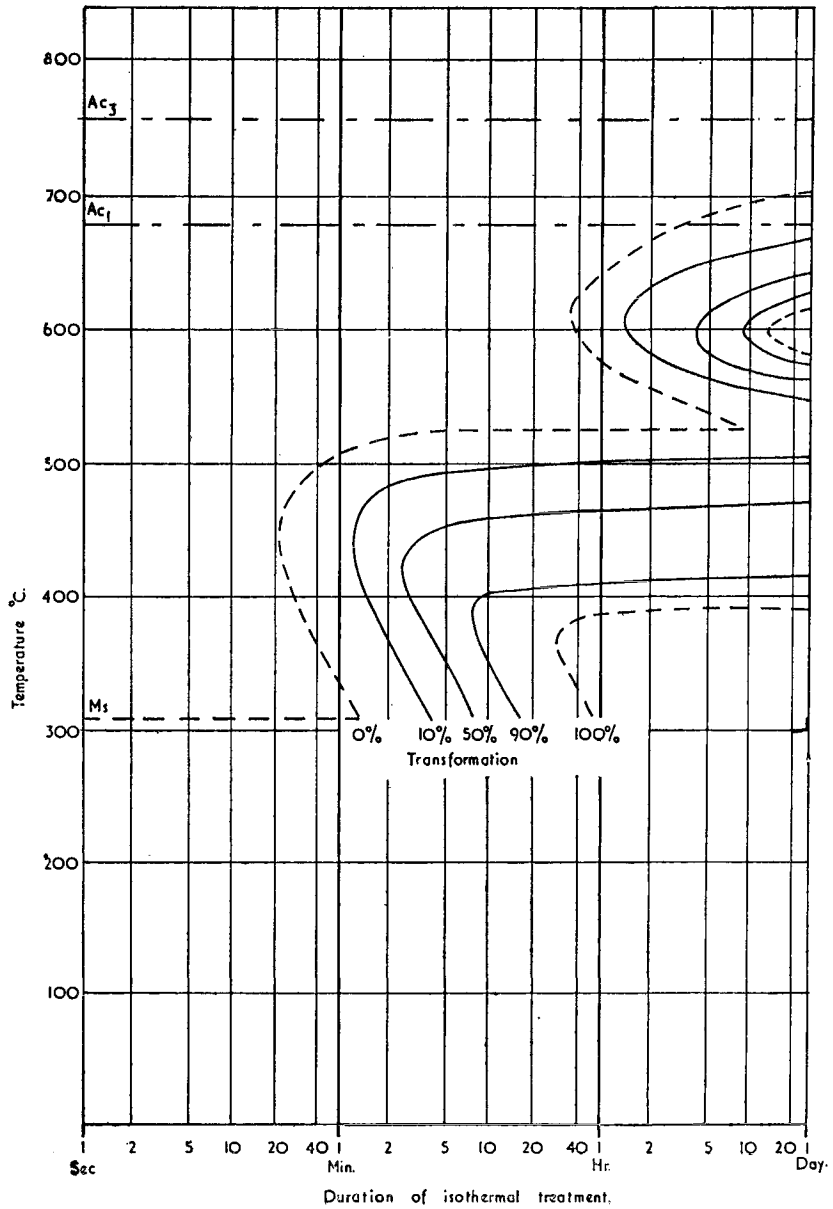


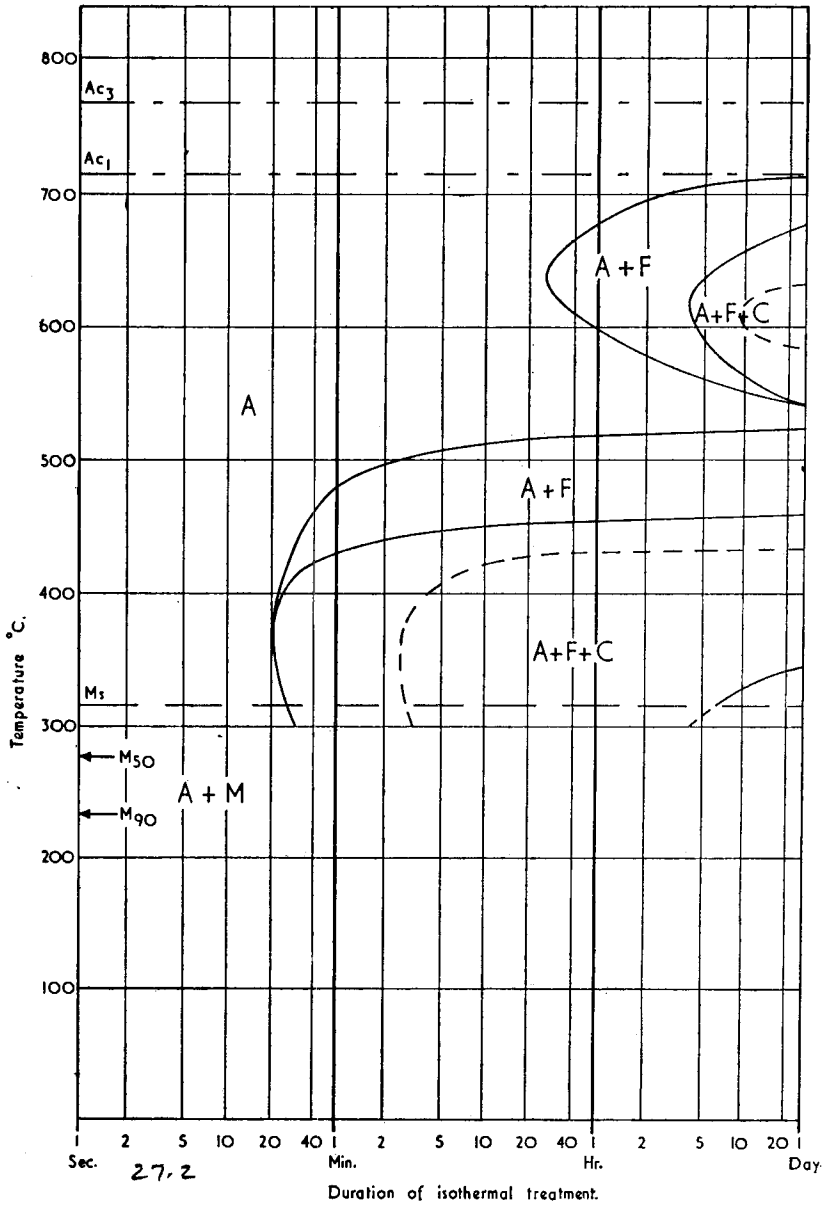
Fig. 27.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·30	0·30	0·40	0·016	0·015	3·20	0·86	0·40

Electric arc.
McQuaid Ehn grain size 8—9 (ASTM).
Actual grain size 12—13 (ASTM).
Austenitizing Temperature 850°C, 30 min.

(Ref. 7)



Fig· 27·2

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·31	0·28	0·50	0·005	0·010	3·33	1·20	0·50

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
Actual grain size 11 (ASTM).
Austenitizing Temperature 850°C, 30 min.

(Ref. 7)

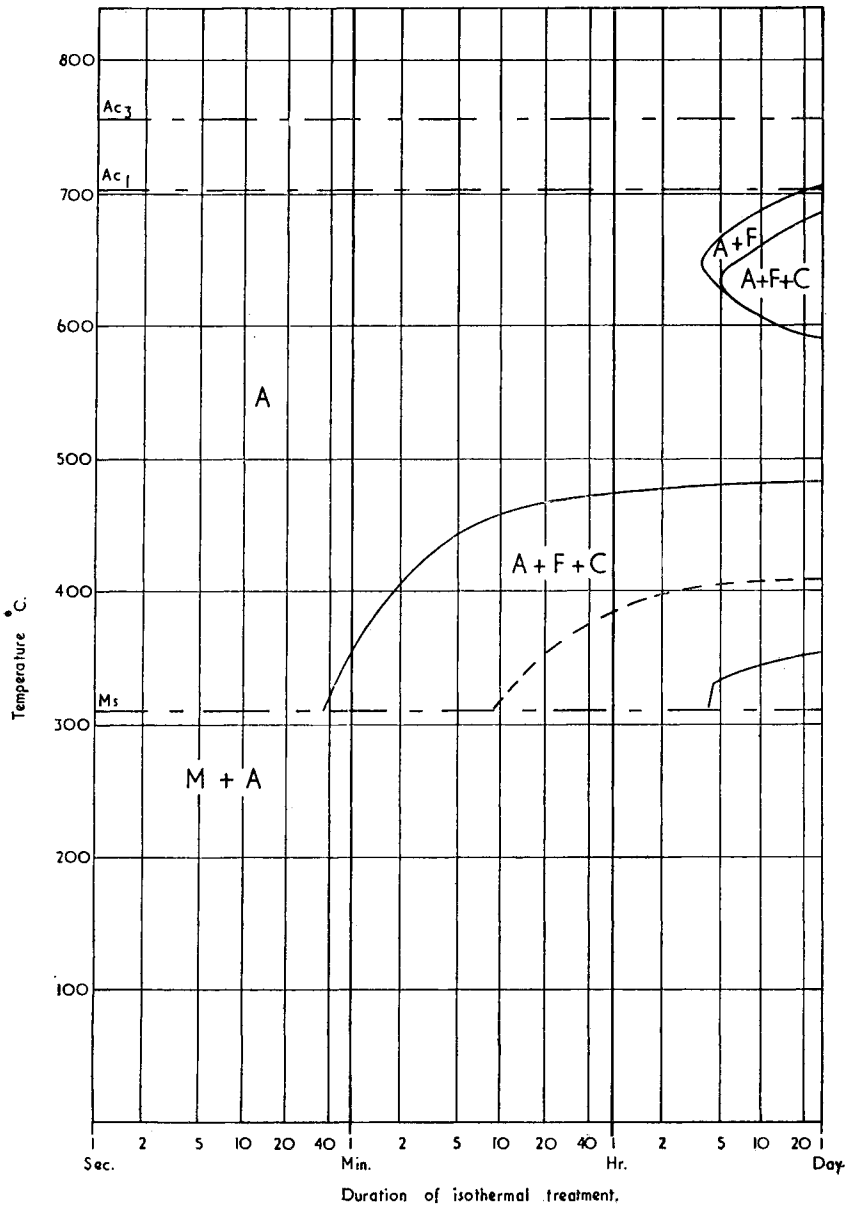


Fig. 27.3

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·30	0·30	0·40	0·016	0·015	3·20	0·86	0·40

Electric Arc.
McQuaid Ehn grain size 8—9 (ASTM).
Actual grain size 12—13 (ASTM).
Austenitizing Temperature 850°C, 30 min.

(Ref. 7)

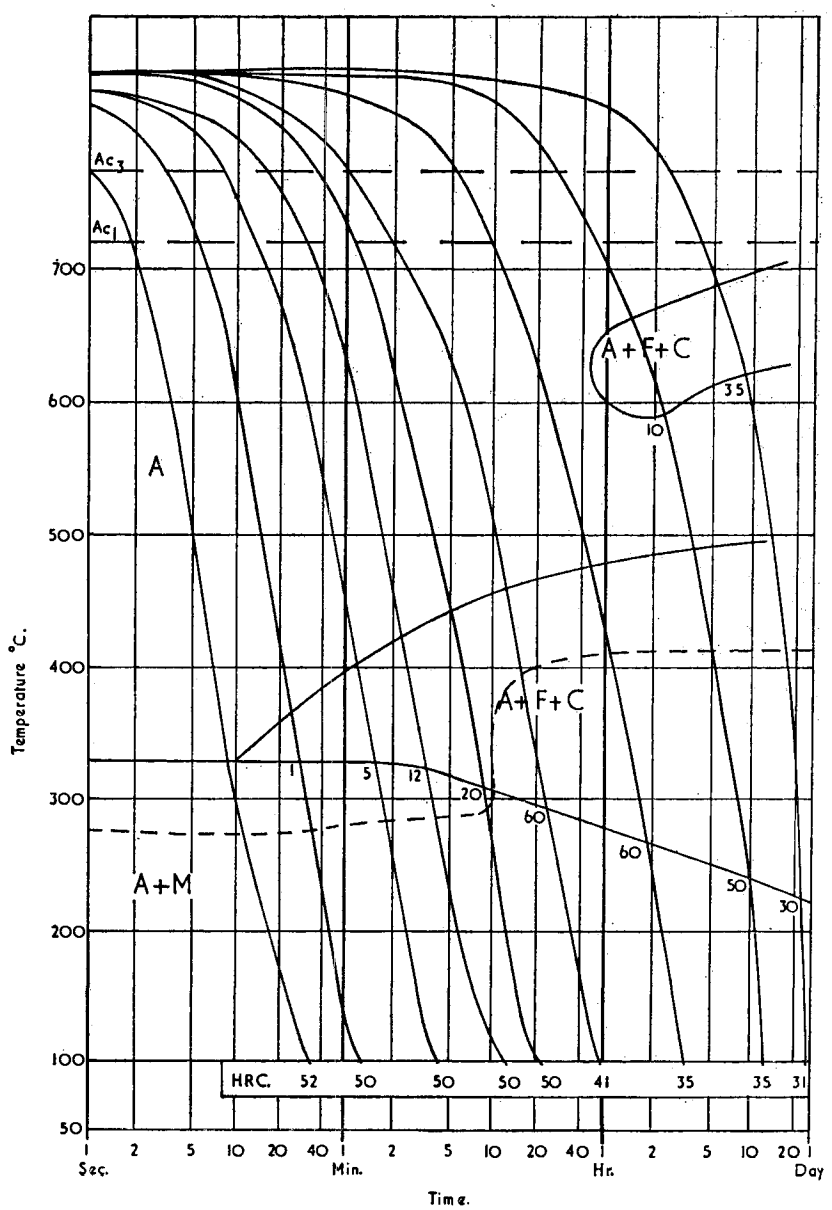


Fig. 27.4

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·32	0·28	0·61	0·013	0·018	3·22	0·63	0·22

Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size 7 (ASTM).
End Quenched from 830°C.

(Ref. 6)

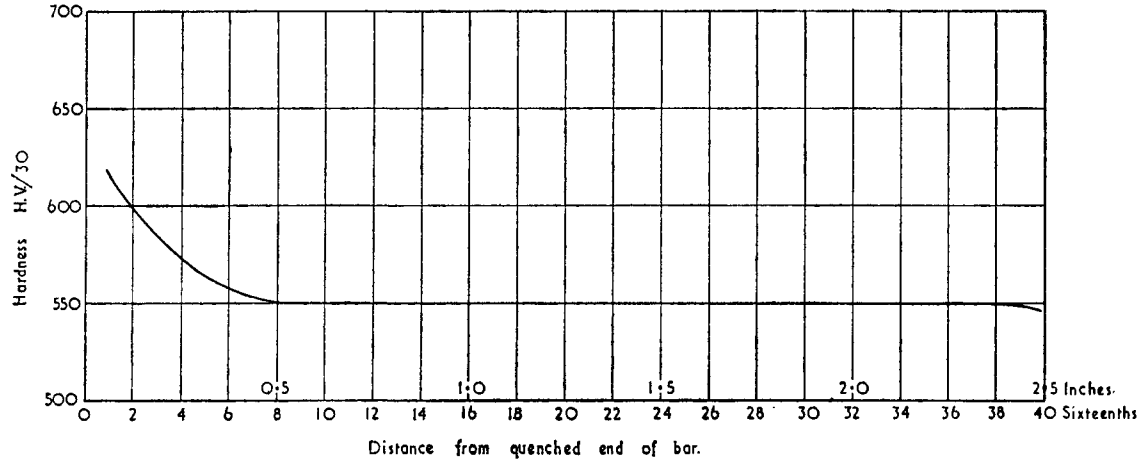


Fig. 27.5

En 27

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								Grain Size (ASTM)		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn	
A	0·29	0·25	0·56	0·032	0·032	3·24	0·99	0·33	7 (6) (8)	7—8	8
B	0·32	0·28	0·60	0·028	0·016	3·28	0·64	0·34	7—8	7—8	"
C	0·32	0·27	0·59	0·033	0·021	3·26	0·81	0·31	7—8	7—8	"

Electric Arc.
Original bar dia. 1⅜ in.
Test Bars Normalized 875°C. End Quenched 850°C.

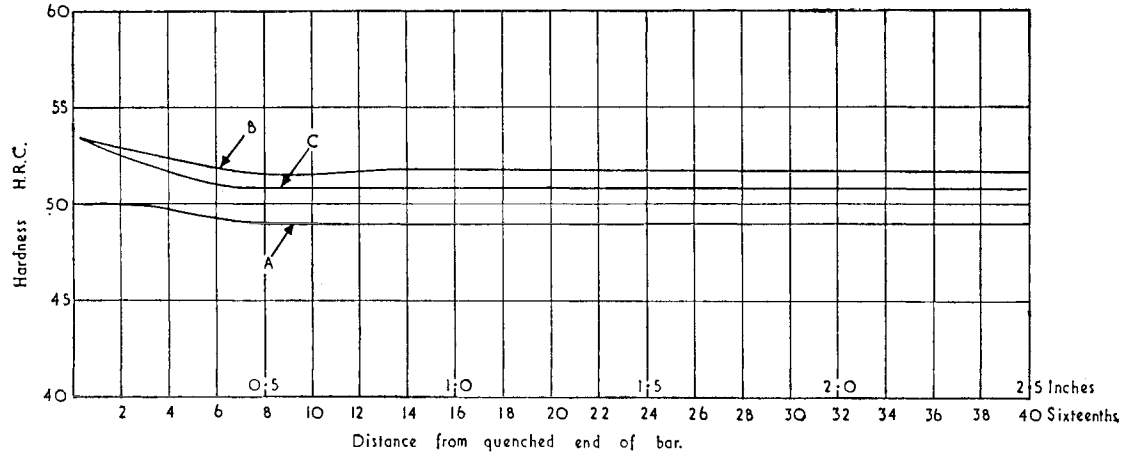


Fig. 27.6 (as quenched)

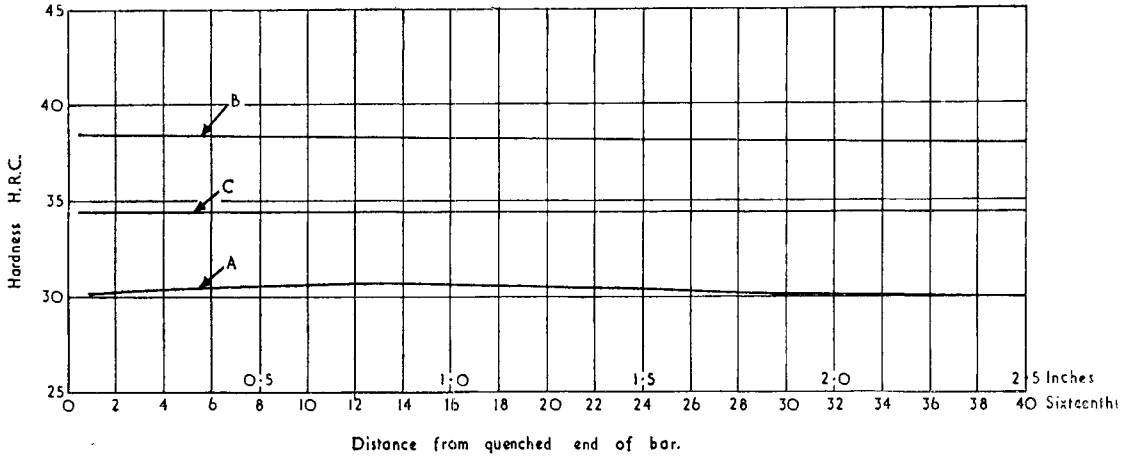


Fig. 27.7 (tempered)

END QUENCH HARDENABILITY BAND

(Ref. 4.)

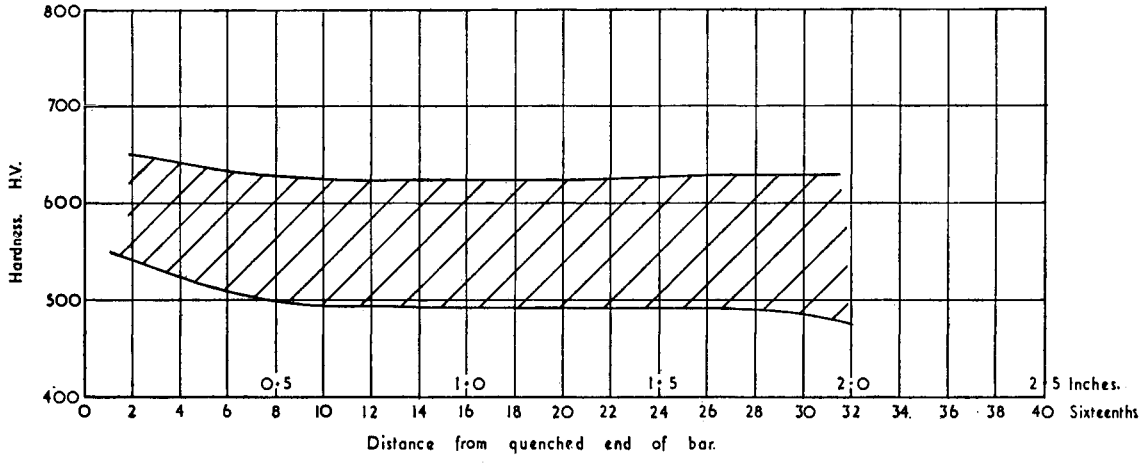


Fig. 27.8

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
B.E.A.	0·25	0·29	0·51	0·021	0·027	3·06	1·10	0·22	1 1/2 sq.	OQ840 T660 AC	46·0	58·5	22	61 1/2	66	9
	0·25		0·57			3·10	1·12	0·22	2 1/4	OQ830 T630	50·5	60	23		92	10
	"		"			"	"	"	3	" "	49	59	23		90	"
	"		"			"	"	"	4 1/2	" "	47·5	57	23		85	"
	"		"			"	"	"	2 1/4	" T580	55	65	20		80	"
	"		"			"	"	"	3	" "	53·5	63	21		76	"
	"		"			"	"	"	4 1/2	" "	51	61	21		75	"
	0·25		0·46			2·90	1·15	0·27	1 1/8	" T550	72·0	75·2	18 1/2	59	58	3
	"		"			"	"	"	"	" T600	57·5	63·0	22	66	79	"
	"		"			"	"	"	2 1/2 (M)	" T550	71·5	74·4	20	61 1/2	57	"
	"		"			"	"	"	" (M)	" T600	56·0	61·8	22 1/2	68	85	"
	"		"			"	"	"	3 1/4 (C)	" T550	67·9	71·0	19 1/2	61 1/2	63	"
	"		"			"	"	"	" (O)	" "	68·8	71·9	19 1/2	63 1/2	61	"
	"		"			"	"	"	" (C)	" T600	55·4	61·1	23 1/2	68	87	"
	"		"			"	"	"	" (O)	" "	56·6	61·4	23 1/2	70	85	"
	0·25					3·71	0·64	0·34	11/16	OQ830 T400	76	86	15	53	25	11
	"					"	"	"	"	" T500	71	78	16	60	42	"
	"					"	"	"	"	" T600	63	68	19	66	68	"
	"					"	"	"	"	" T650		63	21	67	78	"
	"					"	"	"	"	" T670	46	65	20	63	71	"
	"					"	"	"	1 1/8	OQ830		106	14	40		"
	"					"	"	"	"	" T100		105	14	41	30	"
	"					"	"	"	"	" T200	78	102	14	42	30	"
	"					"	"	"	"	" T300	77	95	15	44	20	"
	"					"	"	"	"	" T400	73	87	15	47	20	"
	"					"	"	"	"	" T500	68	78	16	51	40	"
	"					"	"	"	"	" T600	59	67	20	60	70	"
	"					"	"	"	"	" T650		61	22	64	80	"
	"					"	"	"	"	" T670		64	21	60	80	"
	"					"	"	"	2 1/8	OQ830		101	14	44	29	"
	"					"	"	"	"	" T100		100	14	45	29	"
	"					"	"	"	"	" T200		97	15	48	27	"
	"					"	"	"	"	" T300	79	91	15	50	17	"
	"					"	"	"	"	" T400	74	84	16	53	24	"
	"					"	"	"	"	" T500	68	74	19	58	45	"
	"					"	"	"	"	" T600	57	64	22	62	70	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
			0·25					3·71	0·64	0·24	3	OQ830 T400			72	80	14	51	23	11
			"					"	"	"	"	" T500			66	73	17	54	40	"
			"					"	"	"	"	" T600			55	63	21	60	66	"
			"					"	"	"	"	" T650				56	23	67	84	"
			"					"	"	"	"	" T680			40	57	22	65	82	"
B.E.A.			0·26	0·16	0·61	0·029	0·033	3·17	0·96	0·25	1⅛	OQ840 T610AC			57·0	63·0	19	52½	44	9
			0·27	0·29	0·57			3·27	1·12	0·49		OQ843 T496			79·5	86·1	10			12
			"	"	"			"	"	"		" T649			57·1	64·3	15			"
			"	"	"			"		"		N871 T496			83·5	91·	10			"
			"	"	"			"		"		" T649			66·5	50·9	15			"
B.E.A.			0·28	0·30	0·67	0·025	0·035	3·17	0·83	0·21	2	OQ840 T560WQ			68·0	73·0	19	59½	31	9
"			"	"	"	"	"	"	"	"	2½	" T630AC			57·0	63·0	22	63½	61	"
"			"	"	"	"	"	"	"	"	3½	" T580AC			60·0	65·5	18	57	40	"
B.E.A.	7—8	7 (6,8)	0·29	0·25	0·56	0·032	0·032	3·24	0·99	0·33	1	N875 OQ850 T550			69·8	77·9	17½	55	32	8
B.E.A.			0·30	0·15	0·50	0·019	0·021	3·07	0·99	0·44	2	OQ840 T560AC			63·0	70·0	22	63½	62	9
"			"	"	"	"	"	"	"	"	2⅛	" T660WQ			50·0	58·0	23	63½	75	"
B.E.A.			0·30	0·22	0·44	0·021	0·030	3·19	0·78	0·23	2¼	OQ840 T550AC			67·0	72·0	17	55	50	"
"			"	"	"	"	"	"	"	"	"	" T570AC			60·0	65·0	19	61½	56	"
			0·30		0·52			3·23	0·59	0·42	4	OQ830 T530			61·5	73·6	18		44	13
			0·30					3·66	0·86	0·25	⅞	OQ850 T650			52·8	60·2	23½		96	1
			"					"	"	"	3½	" "			50·0	58·6	24		97	"
			"					"	"	"	"	" T630			54·4	61·6	23		92	"
B.E.A.			0·30	0·21	0·60	0·008	0·016	3·69	0·85	0·20	1¼	OQ850 T580WQ	66·6	63·7		70·8	21	60		"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn		Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
			C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	
													tons/sq.in.							
B.E.A.			0·31	0·15	0·60	0·023	0·040	3·11	0·90	0·21	1¾	OQ840 T630WC				51·0	60·0	24	61½	74	9
B.E.A.			0·31	0·17	0·67	0·034	0·035	3·17	0·90	0·36	2½	" " AC				57·0	63·0	22	63½	61	"
"			"	"	"	"	"	"	"	"	3	" T620AC				53·0	61·0	23	61½	64	"
			0·31		0·50			3·16	0·75	0·43	6	OQ850 T570				59·6	68·0	18		40	13
			0·31					3·39	0·85	0·30	6¼	OQ850 T640				47·6	57·2	23		83	1
			"					"	"	"	6	" T580					67·0	19		52	"
			0·31					3·48	0·80	0·41	6	" T570				59·6	68·0	18		40	"
			"					"	"	"	3½	" T590				62·0	68·8	21½		70	"
			"					"	"	"	½	" T600				67·0	72·2	20		56	"
B.E.A.			0·31	0·20	0·58	0·009	0·010	3·50	0·84	0·28	5¼(O)	" T560(L)				67·6	71·0	17½	54½	51	"
"			"	"	"	"	"	"	"	"	" (C)	" " "				65·5	70·9	5½	6	50	"
"			"	"	"	"	"	"	"	"	" (C)	" " (T)					58·0	—	—	22	"
"			"	"	"	"	"	"	"	"	" (M)	" " "				67·6	71·4	8	16	23	"
B.E.A.	7—8	7—8	0·32	0·34	0·50	0·024	0·030	3·20	1·40	0·20	1⅛	OQ840 T620AC				57·0	66·0	22	59½	45	9
B.E.A.	7—8	7—8	0·32	0·28	0·59	0·024	0·037	3·21	0·80	0·26	3⅛	" T650 "				52·0	60·0	21	61½	64	"
			0·32		0·55			3·07	0·65	0·38	2½	OQ830 T580				66·4	70·4	18		53	13
B.E.A.			0·32	0·28	0·60	0·028	0·016	3·28	0·64	0·34	1	N875 OQ850 T550				69·9	77·5	16	55	33	8
B.E.A.			0·32	0·27	0·59	0·033	0·021	3·26	0·81	0·31	1	" "				70·6	79·1	16	54	28	"
			0·32					3·50	0·90	0·35	1	OQ850 T620				60·0	67·0	21½		68	1
			"					"	"	"	1½	" "				59·0	66·2	20½		76	"
			0·32					3·36	0·88	0·41	2½	" T590				65·2	70·6	19		61	"
	8		0·32		0·57			3·34	0·86	0·32	1⅛	OQ830 T600				65·0	70·2	20½	63½	69	3
	"		"		"			"	"	"	3½	" "				63·2	68·4	20½	59	71	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp) tons/sq.in.	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.E.A.			0·33	0·14	0·55	0·040	0·037	3·28	0·82	0·40	1⅛	OQ840 T630AC				58·0	66·0	18	57	44	9
"			"	"	"	"	"	"	"	"	3¼	" T550				68·0	72·0	18	57	40	"
			0·33		0·47			3·24	0·63	0·41	3½	OQ830 T580				63·2	70·0	18		46	13
			0·33	0·20	0·60	0·029	0·031	3·29	0·70	0·26	1⅛	A850	31·8	44·3	52·3		65·5	16	46		11
			"	"	"	"	"	"	"	"	"	N830			54·4		79·5	14	51		"
			"	"	"	"	"	"	"	"	"	OQ830 T650WQ			52·4		60·8	23	66		"
			"	"	"	"	"	"	"	"	"	" T630 "			59·9		66·0	22	62½	64	"
			0·33					3·42	0·87	0·32	3	OQ850 T585				64·8	69·0	21½		74	1
			"					"	"	"	1⅛	" T600				66·0	70·6	22		67	"
			0·33					3·57	0·82	0·36	1½	" "				62·0	68·8	21½		60	"
B.E.A.			0·33	0·23	0·55	0·009	0·014	3·11	1·23	0·54	4¼(O)	OQ850 T600AC (L)				65·8	71·6	19	53½	47	"
"			"	"	"	"	"	"	"	"	" (C)	" " "				67·0	73·7	16½	49	42	"
"			"	"	"	"	"	"	"	"	" (C)	" " (T)				63·3	72·3	12½	17½	21	"
"			"	"	"	"	"	"	"	"	" (M)	" " "				65·4	71·3	14½	39	22	"
			0·33		0·56			3·06	0·82	0·22	1⅛	OQ830 T400OQ				90·6	91·4	14	52	21	3
			"		"			"	"	"	"	" T450 "				81·1	84·9	17	55	29	"
			"		"			"	"	"	"	" T500 "				76·4	79·1	19½	57	42	"
			"		"			"	"	"	"	" T550 "				69·4	72·1	20	62	54	"
			"		"			"	"	"	"	" T600 "				61·8	66·4	21½	64	67	"
			"		"			"	"	"	"	" " AC				62·0	66·8	22½	64	61	"
			"		"			"	"	"	"	" T650OQ				58·3	62·6	22½	64	79	"
			"		"			"	"	"	"	" " AC				57·6	62·1	24	64	70	"
			"		"			"	"	"	2½sq.	" T550OQ				66·8	74·6	18½	59	50	"
			"		"			"	"	"	"	" T600 "				61·0	66·2	20½	64	64	"
			"		"			"	"	"	"	" T650 "				54·0	60·0	23	66	78	"
			"		"			"	"	"	3¼	" T550 "				71·6	74·8	18½	59	45	"
			"		"			"	"	"	"	" T600 "				56·8	63·2	23½	66	69	"
			"		"			"	"	"	"	" T650 "				51·7	58·8	25	66	81	"
B.E.A.			0·34	0·28	0·44	0·019	0·030	3·01	1·02	0·45	2¼	OQ840 T550AC				74·0	80·0	17	52½	36	9
"			"	"	"	"	"	"	"	"	"	" T660 "				51·0	62·0	22	57	60	"
"			"	"	"	"	"	"	"	"	2½	" T580 "				65·0	71·0	20	59½	52	"
"			"	"	"	"	"	"	"	"	2⅝	" T620 "				62·0	68·0	19	59½	54	"
"			"	"	"	"	"	"	"	"	3¼	" T560 "				65·0	72·0	18	58	49	"
			0·34		0·49			3·23	0·66	0·43	4½	OQ830 T540				59·8	68·0	19		50	13
			0·34		0·59			3·31	0·74	0·40	2	" T570				68·0	74·6	17		49	"
			0·34					3·46	0·93	0·34	6¼	OQ850 T600				60·6	63·7	22½		51	1
			"					"	"	"	"	" T630				54·0	62·8	24½		77	"
			0·35		0·53			3·64	0·75	0·24	1⅛	OH T220				94·0	120·8	15	44	19	3

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·33	0·50	3·40	1·10	0·37

1¼ in. dia. bars.
Oil Quenched 830°C. Tempered as indicated.

(Ref. 14)

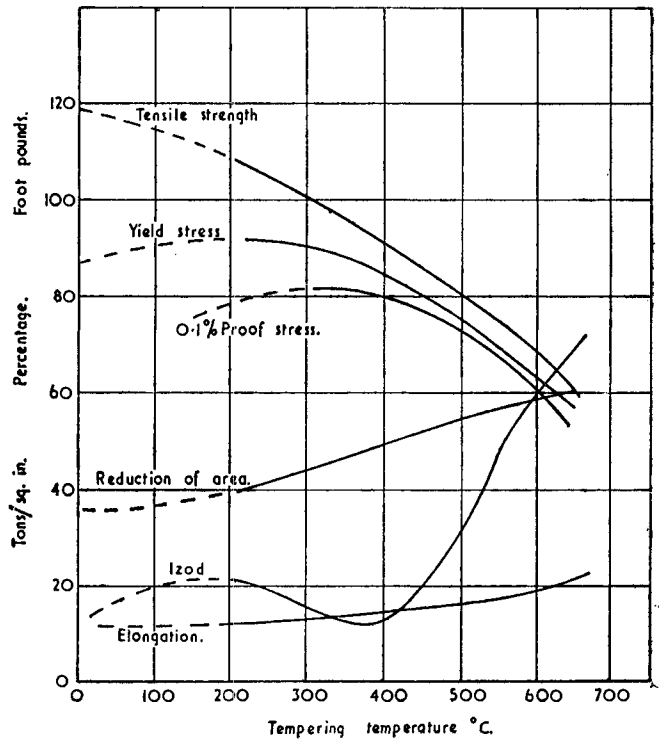


Fig. 27.9

EFFECT OF TEMPERING ON THE RANGE OF PROPERTIES AT ROOM TEMPERATURE

These curves have been constructed from the results obtained on several casts of En 27.

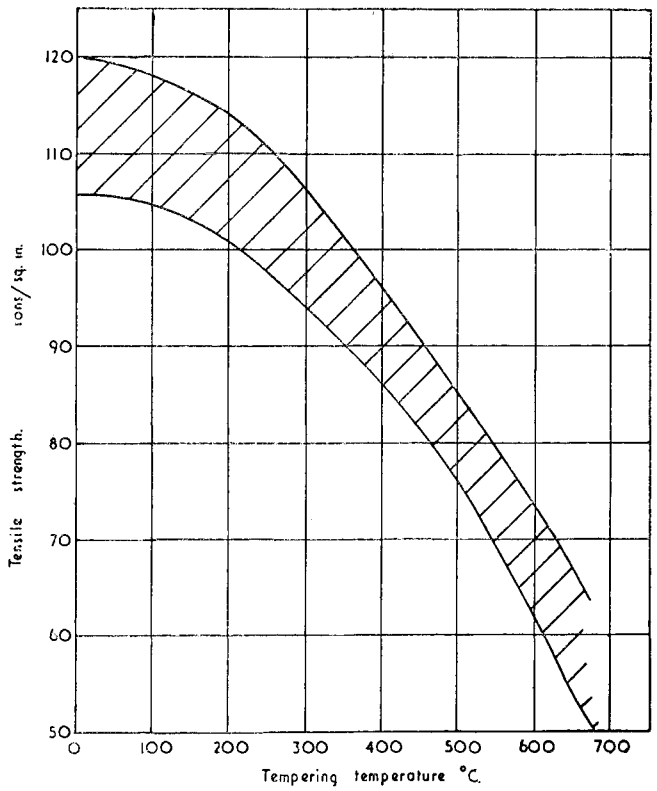


Fig. 27.10 (A)

EFFECT OF TEMPERING ON THE RANGE OF PROPERTIES AT ROOM TEMPERATURE (Continued)

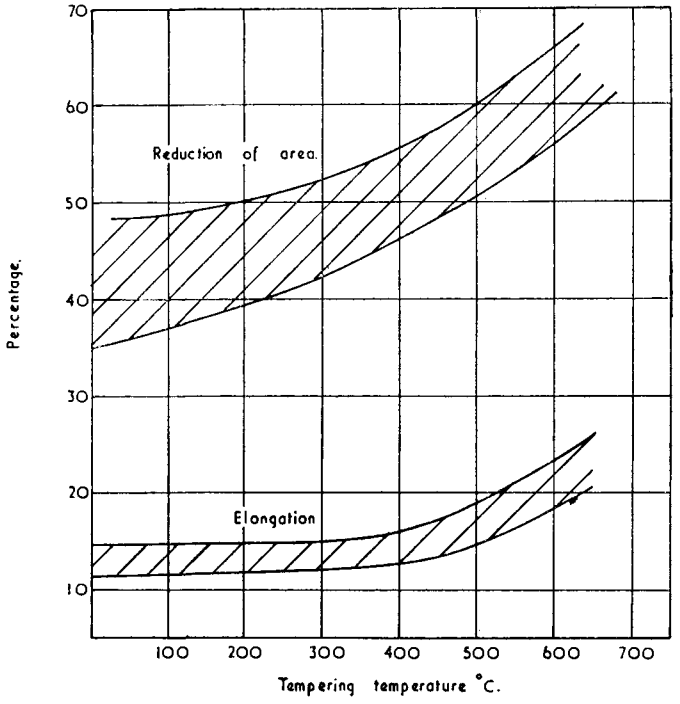


Fig. 27.10 (B)

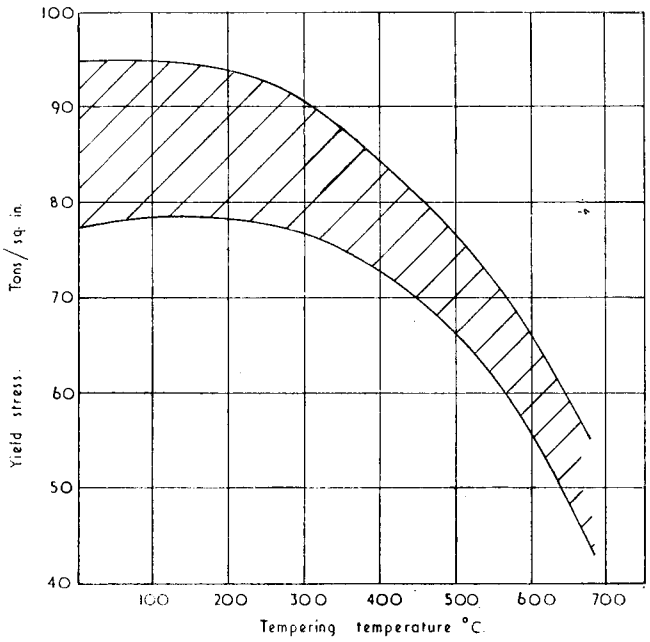


Fig. 27.10 (C)

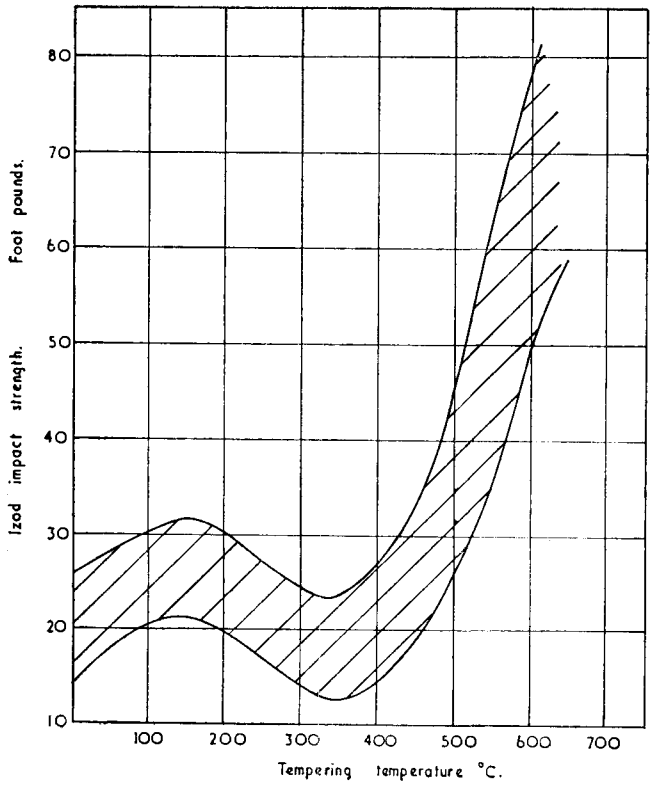


Fig. 27.10 (D)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Oil Quenched 830°C.
Tempered 600°C.
Air Cooled.

(Ref. 4)

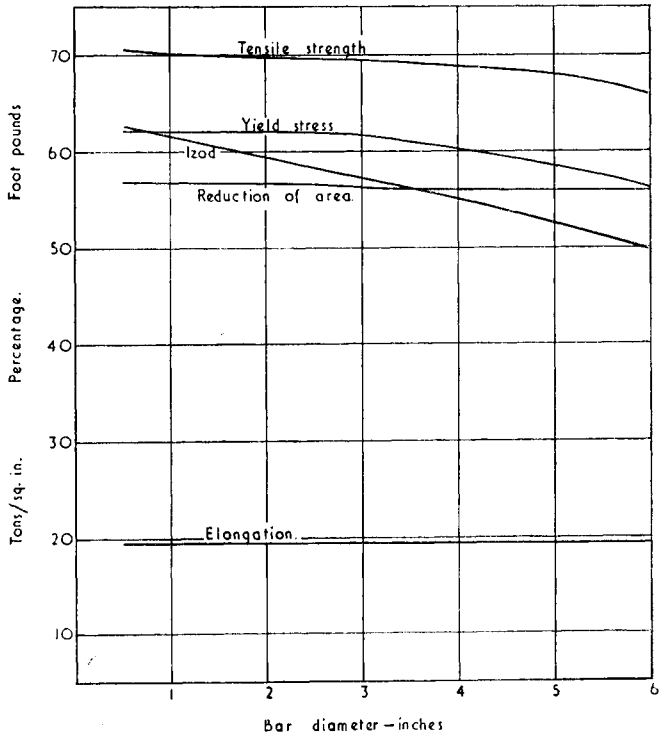


Fig. 27.11

Oil Quenched 830°C.
Tempered 625°C.
Air Cooled.

(Ref. 4)

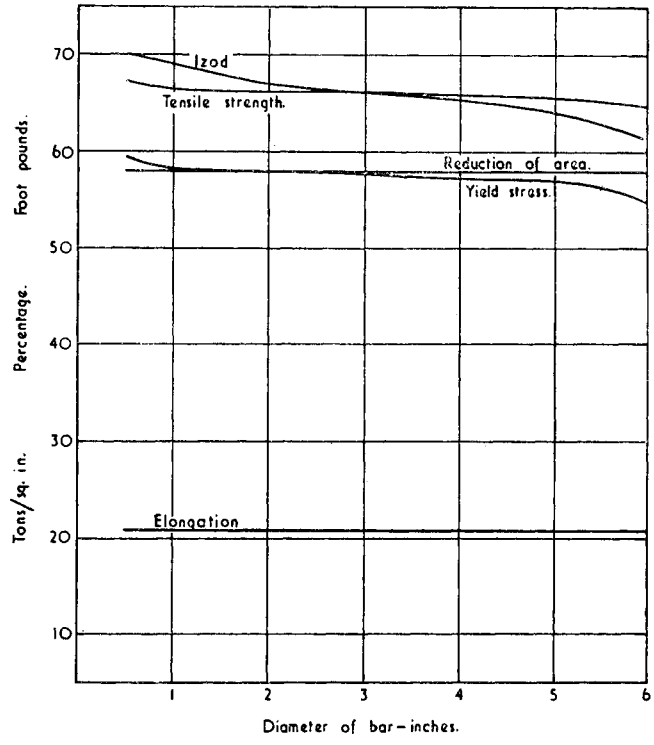


Fig. 27.12

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES (Continued)

Oil Quenched 830°C.
Tempered 650°C.
Air Cooled.

(Ref. 4)

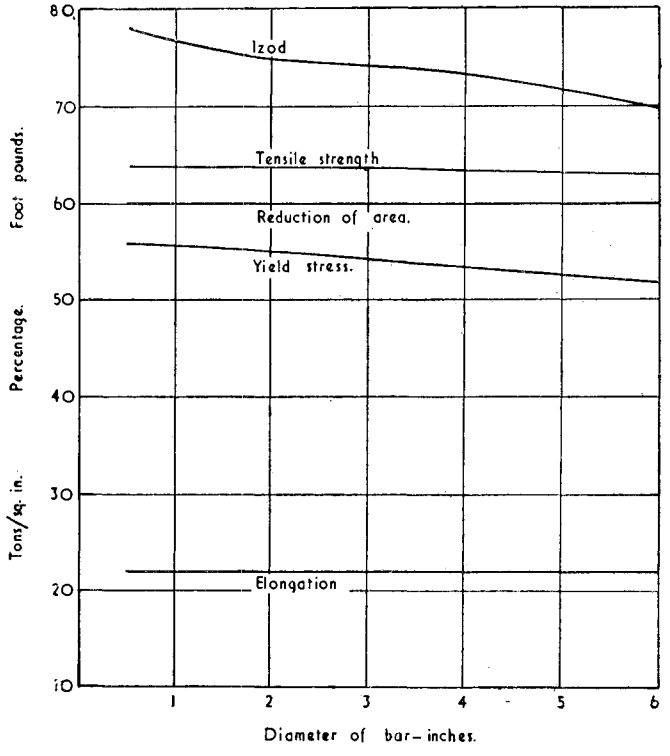


Fig. 27.13

MECHANICAL PROPERTIES AT LOW TEMPERATURE

McQuaid Ehn Grain Size	Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Tensile					El % (A)	R.A. % (Z)	Impact ft.lb.		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·01% P.S. (0·01Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)			Izod	Charpy V	
											tons/sq.in.									
4—6	0·25	0·13	0·59	0·027	0·025	(2·86)*	0·68	0·48	OQ860 T600	20	47·8	53·3	53·9	55·3	60·2	14	34½	26	13	5
"	"	"	"	"	"	"	"	"	" "	— 60	51·0	56·1	56·9	57·6	64·1	19	39		6	"
"	"	"	"	"	"	"	"	"	" "	—120	53·8	60·6	61·9	62·7	70·2	15½	28		2	"
"	"	"	"	"	"	"	"	"	" "	—150	55·8	61·7	63·0	63·8	71·3	13	18½			"
"	"	"	"	"	"	"	"	"	" "	—194	68·2	73·8	74·9	75·6	76·3	2	3½			"
3—5	0·30	0·19	0·47	0·030	0·039	(2·94)*	0·83	0·49	OQ860 T630	25	49·7	52·6	53·8	54·4	60·9	16	41	22	15	"
"	"	"	"	"	"	"	"	"	" "	— 60	51·8	55·8	56·7	57·5	64·3	15½	36		6	"
"	"	"	"	"	"	"	"	"	" "	—120	56·8	62·2	62·8	63·2	71·2	16½	34		3	"
"	"	"	"	"	"	"	"	"	" "	—146	62·8	67·0	67·2	67·3	75·5	15	28½			"
"	"	"	"	"	"	"	"	"	" "	—196	71·8	75·7	76·6	77·1	79·8	4½	6			"
3—4	0·33	0·26	(0·82)*	0·034	0·025	3·06	0·71	0·53	OQ860 T640	25	48·3	51·5	52·2	52·5	61·1	17½	36½	23	14	"
"	"	"	"	"	"	"	"	"	" "	— 60	49·4	53·9	54·5	55·2	65·4	20½	37½		7	"
"	"	"	"	"	"	"	"	"	" "	—110	52·0	57·3	58·0	58·5	70·1	19½	31½			"
"	"	"	"	"	"	"	"	"	" "	—120	54·8	61·3	62·0	62·1	73·5	17½	17½		3	"
"	"	"	"	"	"	"	"	"	" "	—150	59·0	64·6	64·9	65·2	76·8	12	12			"
"	"	"	"	"	"	"	"	"	" "	—195	68·8	73·4	74·7	74·8	74·8	1½	2			"
4—6	0·35	0·24	0·57	0·030	0·031	3·08	0·67	0·50	OQ860 T640	20	47·6	50·8	51·3	51·7	60·3	18	43	30	31	"
"	"	"	"	"	"	"	"	"	" "	— 60	50·7	54·2	54·5	54·9	65·5	20	39		8	"
"	"	"	"	"	"	"	"	"	" "	—120	54·4	62·0	62·6	63·2	72·3	19½	36		5	"
"	"	"	"	"	"	"	"	"	" "	—149	58·5	61·4	62·1	62·4	75·3	21½	33		2	"
"	"	"	"	"	"	"	"	"	" "	—196	67·2	73·0	74·1	75·0	85·0	9	9			"

* Figures in brackets are slightly out of specification.

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)								Heat Treatment °C	Transition Temperature*			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		Mean Energy °C	50% Crystalline Fracture °C	20 ft.lb. Charpy V °C	
0·25	0·13	0·59	0·027	0·025	2·86	0·68	0·48	OQ860 T600	40	65	60	5
0·30	0·19	0·47	0·030	0·030	2·94	0·83	0·49	" T630	14	35	37	"
0·32	0·26	0·82	0·034	0·025	3·06	0·71	0·53	" T640	19	45	47	"
0·35	0·24	0·57	0·030	0·021	3·08	0·67	0·50	" T640	—21	—15	—18	"

*Test pieces taken from forgings 10 in. O.D., 3 in. I.D.

IMPACT TRANSITION TEMPERATURE CURVES

Curve No.	Chemical Composition (%)									Heat Treatment °C	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	Al		
A	0·35	0·24	0·57	0·030	0·021	3·08	0·67	0·50	0·005	OQ860 T640	5
B	0·32	0·26	0·82	0·034	0·025	3·06	0·71	0·53	0·005	" "	"
C	0·30	0·19	0·47	0·030	0·030	2·94	0·83	0·49	0·004	" T630	"
D	0·25	0·13	0·59	0·027	0·025	2·86	0·63	0·48	0·005	" T600	"

Test Pieces taken from forgings 10 in. O.D., 3 in. I.D.

(Ref. 5)

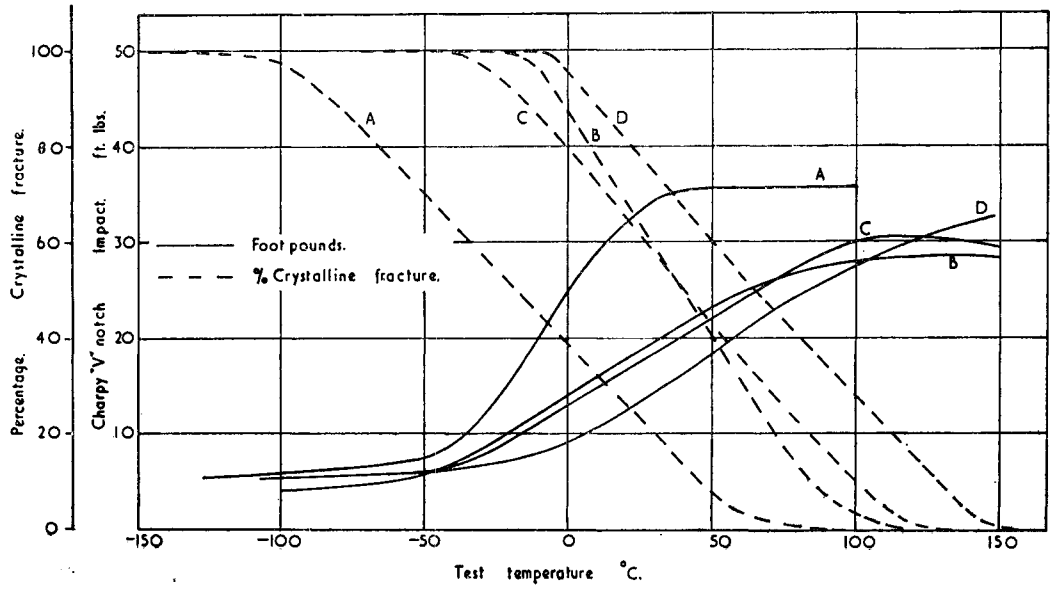


Fig. 27.14

IMPACT TRANSITION TEMPERATURE CURVES (Continued)

Nominal Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·30	0·60	3·00	0·75	0·27

Curve No.	Bar Size	Heat Treatment °C	Tensile Properties at Room Temperature					
			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0.5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)
			tons/sq.in.					
E	1″dia.	OQ850 T600	52·2	52·3	53·2	59·6	22½	62
F	″	″ T650	40·5	41·2	41·8	53·3	26	65
G	4″sq.	″ T600	43·7	45·0	46·4	54·3	24	63
H	″	″ T650	39·7	40·1	46·0	50·4	26	66

(Ref. 4.)

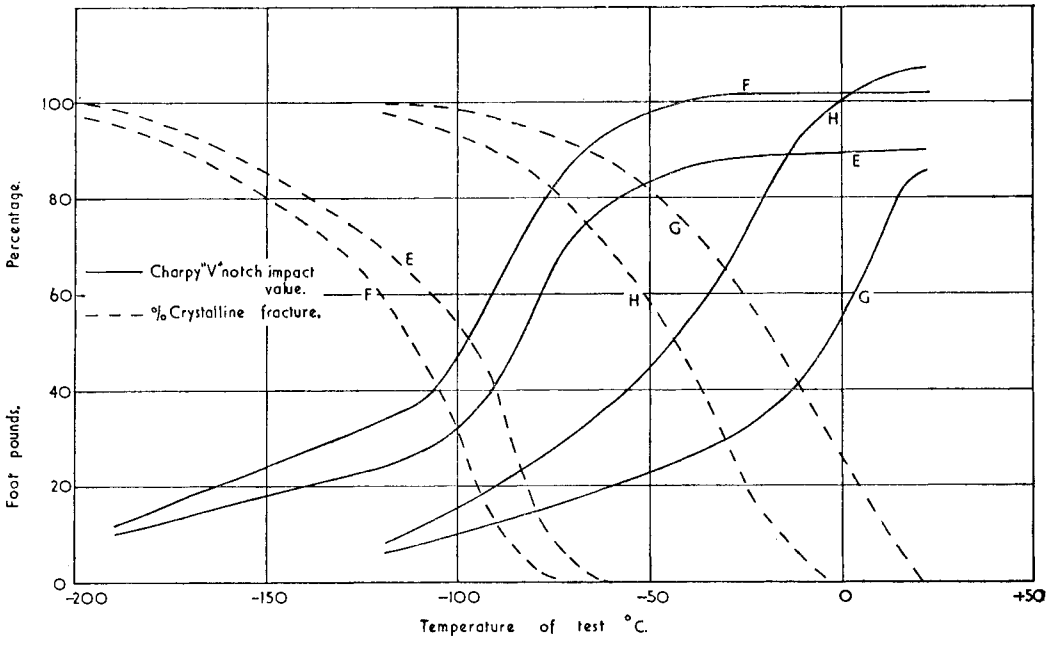


Fig. 27.15

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile								Charpy Impact ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in.									
A.O.H.	0·33	0·20	0·60	0·029	0·031	3·29	0·70	0·26	1 1/8	A850	20	18	31·8		44·3	52·3		65·5	16	46		11
											300	30	36·0		45·0			68·9	20 1/2	48 1/2		"
											350	35	41·2		48·4			65·7	21	61		"
											400	36	41·0		46·6			58·5	18	61		"
											450	29	37·2		41·8			50·4	17	61		"
											500	22	30·3		36·3			44·0	17	61 1/2		"
												Test pieces broken in 2 hr									
A.O.H.	0·28	0·16	0·46	0·026	0·030	3·32	0·77	0·24	1 1/8	OQ820 T650WQ	20	40·5			45·5			55·5	23	64		11
											300	34·2			40·6			56·5	25	60 1/2		"
											350	31·5			39·0			53·8	25	61 1/2		"
											400	28·5			37·6			49·2	23	65		"
											450	24·0			33·3			43·5	24	68 1/2		"
											500	18·5			24·5			36·5	24	77 1/2		"
												Test pieces broken in 2 hr									
A.O.H.	0·28	0·16	0·46	0·026	0·030	3·32	0·77	0·24	1 1/8	OQ820 T600WQ	20	47·7			55·0			62·0	22			11
											300	37·0			47·0			60·0	22			"
											350	35·0			46·0			57·7	24			"
											400	32·0			43·5			54·3	21			"
											450	28·0			38·0			50·0	20			"
											500	21·0			28·0			43·7	21			"
											550	8·0			13·0			35·0	25			"
	Loading rate Q·054 in./min.											Test pieces broken in 2 hr									
	0·31	0·27	0·73	0·040	0·031	2·96	0·64	0·39	0·127	OH T650	RT						55·1	63·6			32	5
	"	"	"	"	"	"	"	"	"	" "	250						50·4	60·0			63	"
	"	"	"	"	"	"	"	"	"	" "	350						47·5	60·2			57	"
	"	"	"	"	"	"	"	"	"	" "	450						41·2	51·3			50	"
	"	"	"	"	"	"	"	"	"	" "	550						35·6	40·6			36	"
	"	"	"	"	"	"	"	"	"	" "	650						20·0	24·6			89	"
	"	"	"	"	"	"	"	"	"	" "	750						7·7	11·0			183*	"
	"	"	"	"	"	"	"	"	"	" "	850						3·8	6·2			146*	"
	"	"	"	"	"	"	"	"	"	" "	950	Loading rate 0·054 in./min.					1·9	3·4			115*	"

*Unbroken

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile								Charpy Impact ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons./sq.in.									
	0·31	0·27	0·73	0·040	0·031	2·96	0·64	0·39	0·127	OH 950	RT						105·2	121·2			3	5
	"	"	"	"	"	"	"	"	"	" "	250						91·0	107·0			25	"
	"	"	"	"	"	"	"	"	"	" "	350						71·0	84·0			19	"
	"	"	"	"	"	"	"	"	"	" "	450						62·0	67·1			16	"
	"	"	"	"	"	"	"	"	"	" "	550						48·5	52·0			19	"
	"	"	"	"	"	"	"	"	"	" "	650						32·5	35·7			51	"
	"	"	"	"	"	"	"	"	"	" "	750						8·1	10·6			198*	"
	"	"	"	"	"	"	"	"	"	" "	850						2·7	4·7			153*	"
	"	"	"	"	"	"	"	"	"	" "	950						1·7	3·1			116*	"
												Speed of pulling in tension test 0·054" per min.									*Unbroken.	
																					Izod Impact ft.lbs.	
	0·31	0·25	0·65			2·96	1·11	0·42	1	OQ and T	20						55	64·5	24	69	94	5
	"	"	"			"	"	"	"	"	100						53	63	24	68	91	"
	"	"	"			"	"	"	"	"	200						50	60	25	66	88	"
	"	"	"			"	"	"	"	"	300						47	56	25	64	82	"
	"	"	"			"	"	"	"	"	400						42	52	25	63	75	"
	"	"	"			"	"	"	"	"	500						31	45	28	70	64	"
	"	"	"			"	"	"	"	"	550						20	36	33	87	57	"

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile Test			Torsion Test			Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	0·1% P.S. (0·1Rp) tons/sq.in.	Apparent Max. Shear Strength tons/sq.in.	Probable Max. Shear Strength tons/sq.in.	
B.E.A.	0·25	0·20	0·56	0·009	0·017	3·10	1·29	0·47	1	OH and T	55·2	63·4	24	35·1	55·6	41·7	15
"	"	"	"	"	"	"	"	"	"	"	54·7	67·8	21½	35·1	60·0	45·1	"

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile Test					Rotating Bending Fatigue tons/sq.in.		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Plain	Notched	
B.E.A.	0·29	0·16	0·54	0·026	0·013	2·96	0·93	0·25	1⅛ sq.	OQ830 T585 ½ hr. OQ(L)	53·2	54·7	61·3	21	68	±33·5		16
"	"	"	"	"	"	"	"	"	"	" " " " (T)	56·4	57·3	63·8	15	42	±27·0		"
B.E.A.	0·27	0·29	0·60	0·013	0·028	3·32	0·82	0·16	"	OQ830 T607 1 hr. OQ(L)	53·4	53·7	60·3	18	70½	±31·5		"
"	"	"	"	"	"	"	"	"	"	" " " " (T)	51·5	52·5	62·4	17	47	±25·2		"
"	0·29	0·29	0·55	0·011	0·033	3·37	0·75	0·23	"	" T610 1 hr. OQ(L)	53·0	53·5	61·0	17	66	±32·0		"
"	"	"	"	"	"	"	"	"	"	" " " " (T)	52·4	53·4	61·9	16	60	±24·0		"
A.O.H.	0·32	0·23	0·54	0·031	0·032	3·56	0·94	0·25	1 sq.	" T655 1 hr. OQ(L)	54·2	55·1	61·0	17	72	±33·5		"
"	"	"	"	"	"	"	"	"	"	" " " " (T)	51·7	52·5	61·1	13	42	±25·5		"
ASTM Grain Size 6	0·32		0·63			3·16	0·79	0·21	1⅛	OQ830 T650			58·9			±33·0	±14·0*	3

* Notch 55°V, 0·008 in. root radius, 0·020 in. deep. Test piece dia. 0·335 in., root dia., 0·295 in., Neuber stress concentration factor 2·85.

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En 28

3½ PER CENT NICKEL–CHROMIUM–MOLYBDENUM STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·25—0·40	0·10—0·35	0·70 max.	0·050 max.	0·050 max.	3·00—4·50	0·75—1·50	0·20—0·65

MECHANICAL PROPERTIES

	Hardened and Tempered Condition				
	U	V		W	Y
Limiting ruling section, in.	6	6	4	4	2½
Tensile strength, tons/sq.in., min. (Rm)	60	65	65	70	80
Yield stress, tons/sq.in., min.(Rs)(1)	48	52	52	58	68
0·2% proof stress tons/sq.in., min. (2) (0·2Rp)	46	50	50	55	64
Elongation, %, min. (A)	17	14	16	15	14
Izod impact value, ft.lb., min.	35	35	35	30	25
Brinell hardness No. (3) (HB)	269/321	293/341	293/341	311/375	363/415

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 277.

(1) Not to be used as acceptance tests except by special arrangement between the purchaser and manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

United Kingdom	France	Sweden
En No.	AFNOR	SIS
28	35 NCD 14 35 NCD 16	14.2534

APPLICATIONS

This steel has a composition akin to that of En 27. It is used for similar applications where higher strength or larger section sizes are required.

WELDING

The welding characteristics are very similar to those for En 25, En 26 and En 30.

MACHINABILITY

In the annealed condition the machinability is about 40% that of mild steel (En 3). When oil hardened and tempered to about 70 tons/sq. in. tensile strength the machinability is about 30% of that for mild steel.

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1180°C. Finish above 850°C. Slow cooling is necessary after hot working.
Annealing	820°C to 850°C. Furnace cool.
Softening	620°C to 650°C. Cool in air.
Hardening	820°C to 850°C. Oil quench.
Tempering	500°C to 660°C. Cool in air or oil.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·33	0·23	0·57	0·024	0·012	3·42	0·86	0·33	Softened	7·83	1
0·25	0·27	0·57	0·007	0·011	3·10	1·33	0·41	OH & T (75/80 t.s.i.)	7·820	2

SPECIFIC HEAT (c)

Chemical Composition (%)								Heat Treatment °C	Mean Specific Heat cals/g deg. C						Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 550°C	
0·33	0·23	0·57	0·024	0·012	3·42	0·86	0·33	Softened	(0·117)*	0·121	0·125	0·131	0·137	0·139	1

* Estimated.

COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	10^6 × Mean Coefficient of Thermal Expansion per deg. C						Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 550°C	
0·33	0·23	0·57	0·024	0·012	3·42	0·86	0·33	Softened	11·6	12·0	12·5	13·1	13·5	13·7	1

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	
0·33	0·23	0·57	0·024	0·012	3·42	0·86	0·33	Softened	30·8	35·0	38·2	1

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Conductivity cal/cm s deg. C							Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	550°C	
0·33	0·23	0·57	0·024	0·012	3·42	0·86	0·33	Softened	—	0·084	0·085	0·087	0·086	0·082	0·079	1

YOUNG'S MODULUS (E), SHEAR MODULUS (G), POISSON'S RATIO (σ)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus		Shear Modulus		Poisson's Ratio	Ref.
										Static	Dynamic	Static	Dynamic		
C	Si	Mn	S	P	Ni	Cr	Mo			tons/sq.in.					
0·25	0·27	0·57	0·007	0·011	3·10	1·33	0·41	OH & T (75/80 t.s.i.)	20	13,050	13,300*	5,180	5,150*	0·290	3

* Ultrasonic Pulse Method.

TRANSFORMATION CHARACTERISTICS

(see also En 30B)

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)								
C	Si	Mn	S	P	Ni	Cr	Mo	V
0·25	0·15	0·52	0·024	0·010	3·33	1·14	0·65	0·16*

Basic Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia. cold drawn to 11 S.W.G. with intermediate annealing at 600°C.

* Note the high Vanadium content.

Austenitizing Temperature 830°C, 30 min. (Ref. 4)

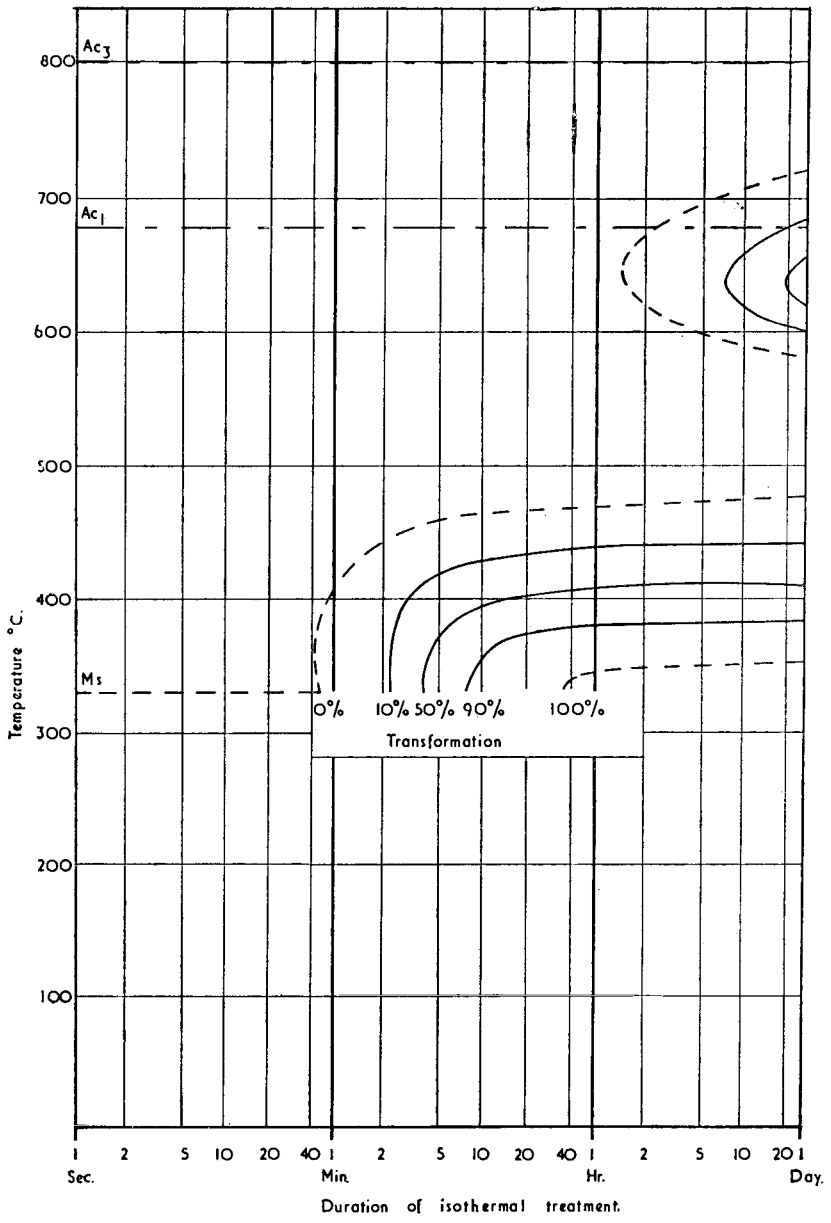


Fig.28.1

En 28

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)								
C	Si	Mn	S	P	Ni	Cr	Mo	V
0·32	0·19	0·51	0·009	0·013	3·02	1·37	0·48	0·18*

Basic Electric Arc.
McQuaid Ehn grain size 6 (ASTM).
As quenched grain size 9 (ASTM).

* Note the high Vanadium content.

Austenitizing Temperature 835°C. (Ref. 5)

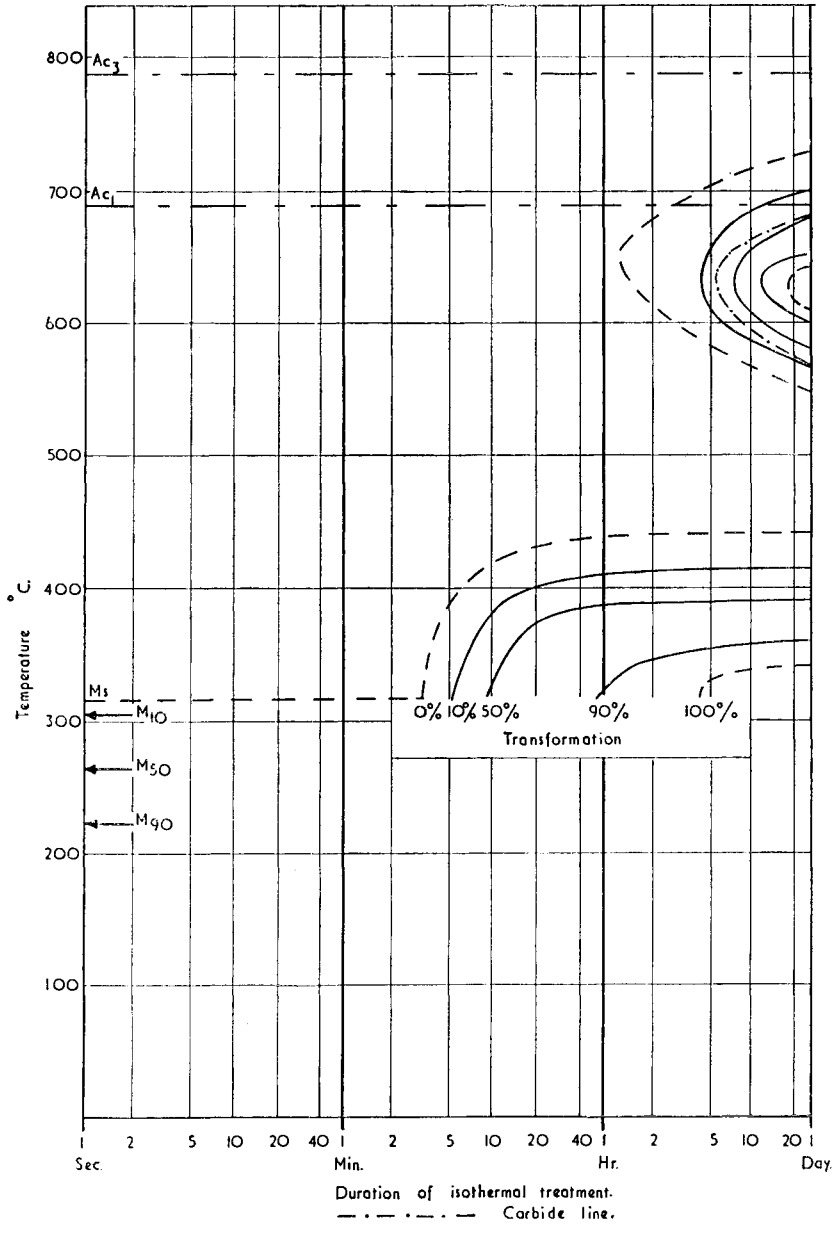


Fig.28.2

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·37	0·28	0·37	0·010	0·009	3·79	1·49	0·38

Electric Arc.
McQuaid Ehn grain size 8 (ASTM).
As Quenched grain size 7—8 (ASTM).

Austenitizing Temperature 850°C, 30 min. (Ref. 6)

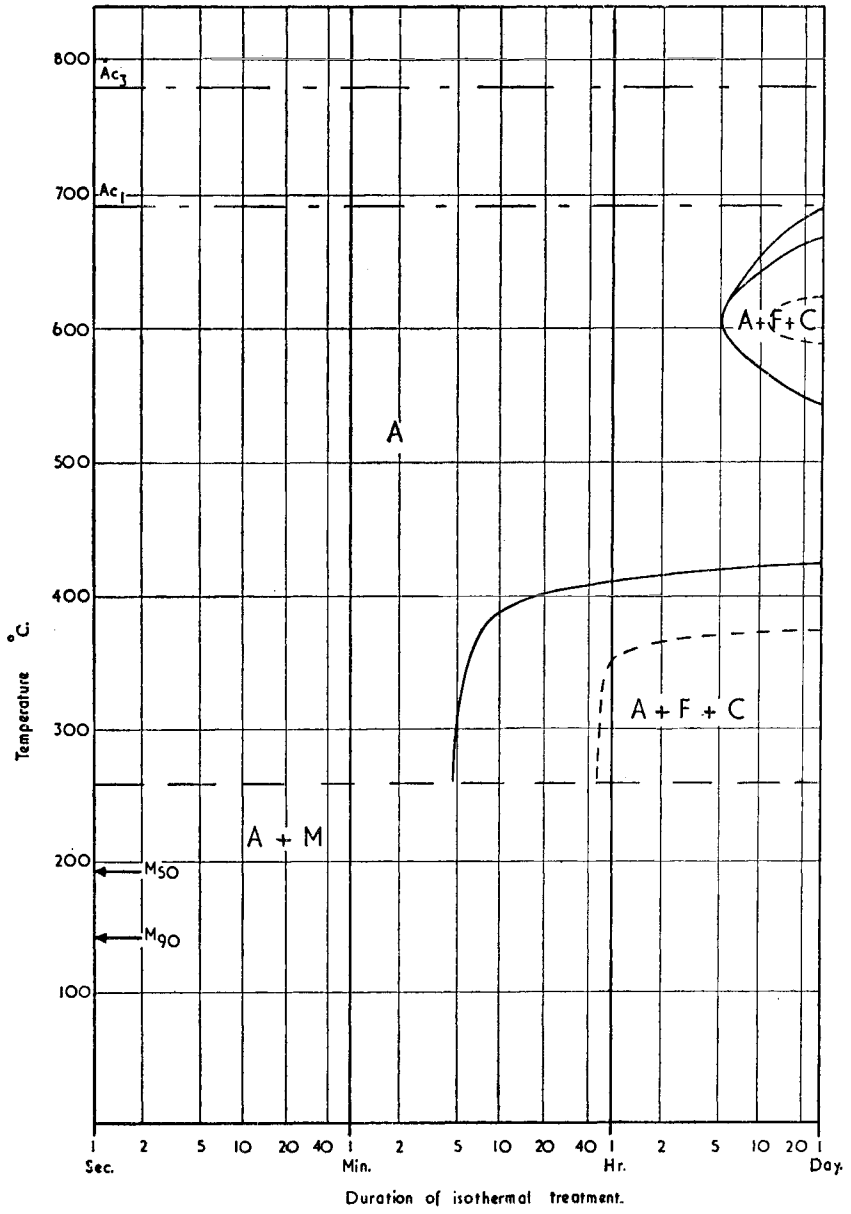


Fig. 28.3

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)								
C	Si	Mn	S	P	Ni	Cr	Mo	V
0·25	0·15	0·52	0·024	0·010	3·33	1·14	0·65	0·16*

* Note the high Vanadium content.

Basic Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size Finer than 8 (ASTM).

End Quenched from 830°C.

(Ref. 4)

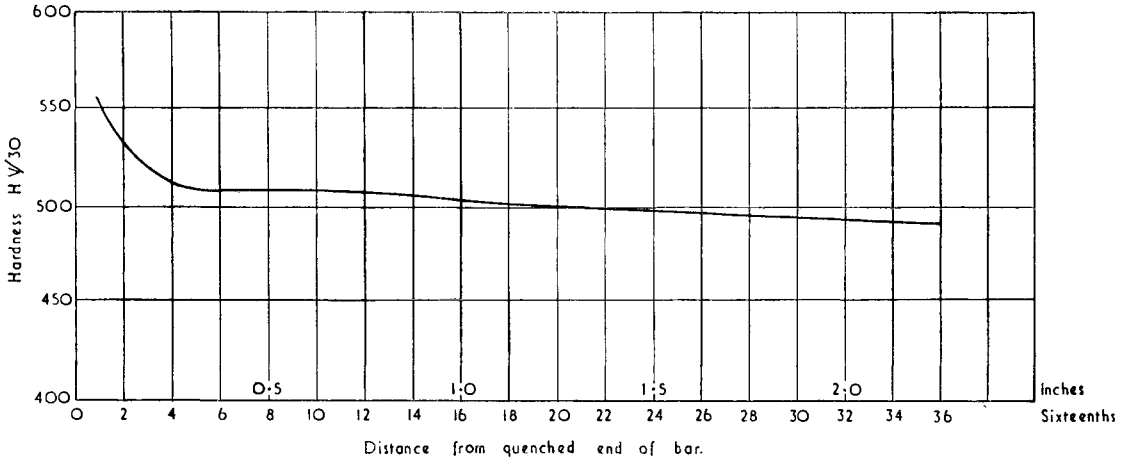


Fig. 28.4

Chemical Composition (%)								
C	Si	Mn	S	P	Ni	Cr	Mo	V
0·32	0·19	0·51	0·009	0·013	3·02	1·37	0·48	0·18

Basic Electric Arc.
McQuaid Ehn grain size 6 (ASTM).
As quenched grain size 9 (ASTM).

End Quenched from 835°C and tempered as indicated.

(Ref. 5)

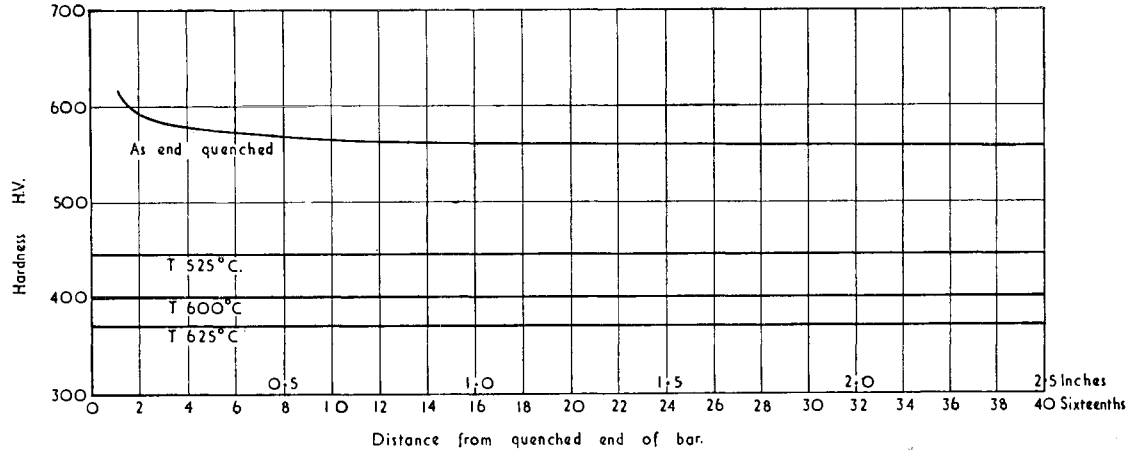


Fig. 28.5

END QUENCH HARDENABILITY DATA (Continued)

Curve No.	Chemical Composition (%)									Grain Size (ASTM)		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	V	Actual	McQuaid Ehn	
A	0·25	0·21	0·56	0·012	0·008	3·32	1·35	0·45		6—7	5—6 (7)	7
B	0·28	0·28	0·54	0·019	0·031	3·02	1·34	0·45	0·20	6—7	5—6	"

Test Bars Air Cooled from 875°C. End Quenched from 850°C.

End Quenched.

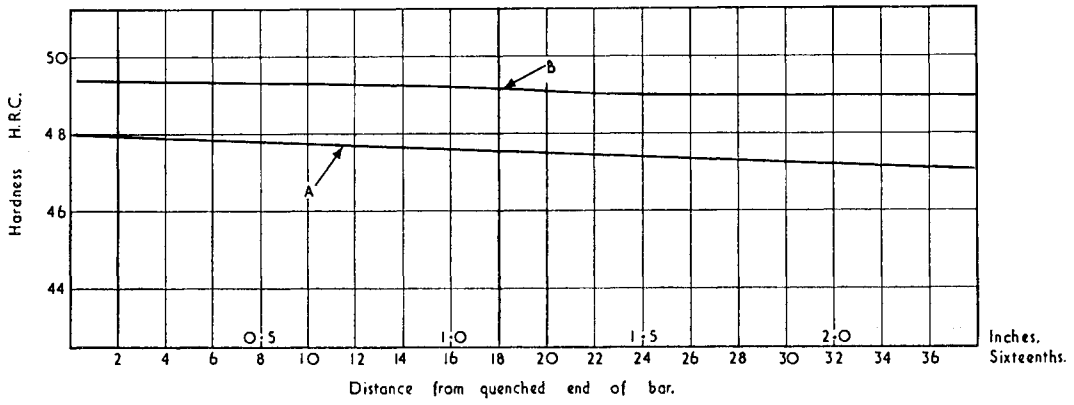


Fig.28.6

End Quenched and Tempered 550°C.

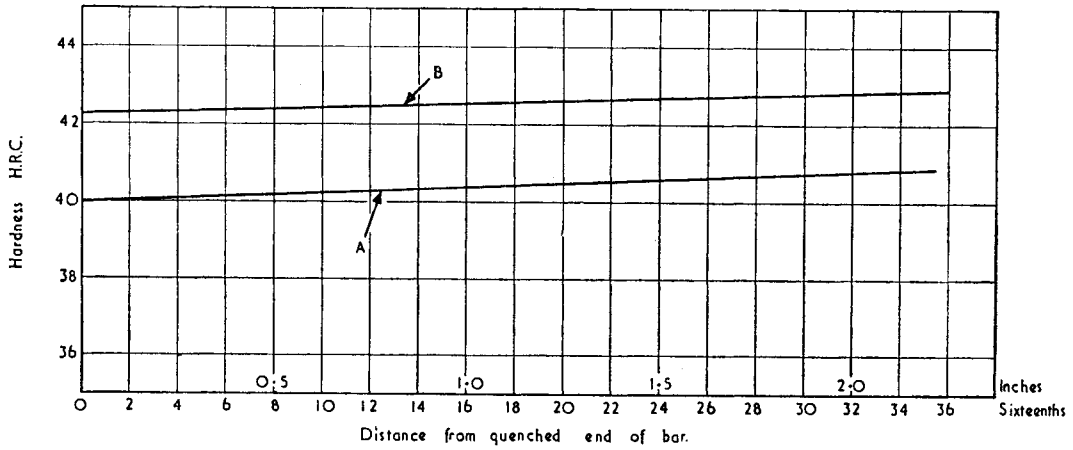


Fig.28.7

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Grain Size McQuaid Ehn	Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.E.A.	5—6(7)	6—7	0·25	0·21	0·56	0·012	0·008	3·32	1·35	0·45	1	AC875 OQ850 T550		66·5	75·5	18½	64½	60	7
B.E.A.	5—6	6—7	0·28	0·28	0·54	0·019	0·031	3·02	1·34	0·45	1	AC875 OQ850 T550		75·5	84·0	17½	57½	32	7
			0·28		0·34			3·52	1·30	0·29	2⅛	OQ830 T600		59	67	20		65	8
			”		”			”	”	”	3	” ”		58·5	67	20		61	”
			”		”			”	”	”	4	” ”		58	66·5	20		53	”
			0·28		0·42			3·04	1·10	0·33	2½	OQ830 T550		69·6	74·4	19		62	”
			0·29	0·13	0·35	0·015	0·021	4·07	1·15	0·37	1⅛	AH 820		92	113	12	30	35	9
			”	”	”	”	”	”	”	”	”	” T100 WQ		90	111	13	38	38	”
			”	”	”	”	”	”	”	”	”	” T200 ”		88	108	13½	40	38	”
			”	”	”	”	”	”	”	”	”	” T300 ”		85	103	14	46	30	”
			”	”	”	”	”	”	”	”	”	” T400 ”		82	95	15	51	22	”
			”	”	”	”	”	”	”	”	”	” T500 ”		75	84	16	56	40	”
			”	”	”	”	”	”	”	”	”	” T600 ”		63	70	19	60	65	”
			”	”	”	”	”	”	”	”	”	” T625 ”			65	20	61	70	”
			”	”	”	”	”	”	”	”	”	” T650 ”		50	66	20	60	75	”
			0·30		0·50			3·21	1·08	0·60	4	OQ830 T520		68·0	76·6	19		52	8
			0·31		0·50			3·16	0·75	0·43	6	OQ830 T570		59·6	68·0	18		40	8
			0·32		0·55			3·07	0·65	0·38	2½	OQ830 T580		66·4	70·4	18		53	8
A.O.H.			0·32	0·23	0·66	0·044	0·013	3·73	0·88	0·37	1⅛	OQ820 T620 WQ		62·8	69·3	20½	57	50	10
B.E.A.			0·33	0·24	0·65	0·013	0·012	3·71	0·88	0·26	1⅛	OQ820 T620 WQ		61·9	69·4	21	58	58	10
			0·33		0·47			3·24	0·63	0·41	3½	OQ830 T580		63·2	70·0	18		46	8
			0·33		0·51			3·36	1·00	0·35	2	OQ830 T540		77·8	80·3	17½		31	”
			0·33	0·23	0·54	0·008	0·017	4·12	1·23	0·21	1⅛	AH 820		100	127	7	22	15	9
			”	”	”	”	”	”	”	”	”	” T100 WQ		98	126	8	25	22	”
			”	”	”	”	”	”	”	”	”	” T200 ”		94	121	9	30	26	”
			”	”	”	”	”	”	”	”	”	” T300 ”		90	110	10	36	21	”
			”	”	”	”	”	”	”	”	”	” T400 ”		83	98	12½	43	13	”
			”	”	”	”	”	”	”	”	”	” T500 ”		74	84	16	52	22	”
			”	”	”	”	”	”	”	”	”	” T600 ”		62	71	20	60	52	”
			”	”	”	”	”	”	”	”	”	” T650 ”		52	65	22	58	60	”

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.						
	0·34		0·19			3·23	0·66	0·43	4½	OQ830 T540		59·8	68·0	19		50	8
	0·35					3·50	1·00	0·50	1⅛	OQ850 T200		98	105	12	32	22	9
	"					"	"	"	"	" T400		85	90	13	36	25	"
	"					"	"	"	"	" T500		77	82	14	40	35	"
	"					"	"	"	"	" T600		65	72	18	52	48	"
B.E.A.	0·38	0·30	0·51	0·020	0·016	3·85	1·13	0·45	T.P.S.	OQ830			127			10	15
"	"	"	"	"	"	"	"	"	"	" T100			125			15	"
"	"	"	"	"	"	"	"	"	"	" T250			120	9	30	23	"
"	"	"	"	"	"	"	"	"	"	" T350			114	9	34	15	"
"	"	"	"	"	"	"	"	"	"	" T450			105	10	37½	17	"
"	"	"	"	"	"	"	"	"	"	" T550			95	13	42	23	"
"	"	"	"	"	"	"	"	"	"	" T600	74		90	15	44	28	"
"	"	"	"	"	"	"	"	"	"	" T650	59		76	17	47½	44	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

1½ in. dia. bars. Oil Quenched from 830°C. (Ref. 8)

Nominal Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·33	0·50	3·40	1·10	0·37

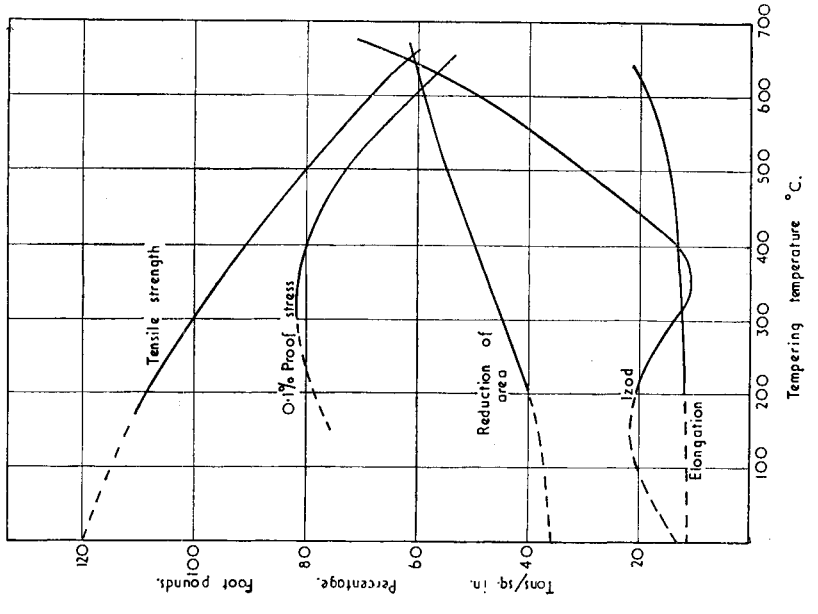


Fig.28.8

1½ in. dia. bars. Air Hardened from 820°C. (Ref. 9)

Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·29	0·35	4·07	1·15	0·37

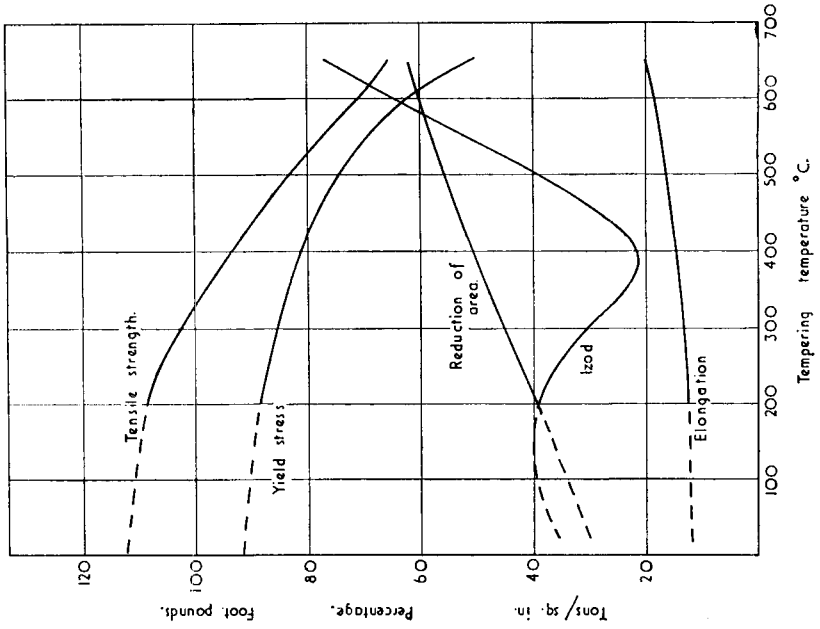


Fig.28.9

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size As Quenched	Chemical Composition (%)									Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	V				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
													tons/sq.in.						
9	0·32	0·19	0·51	0·009	0·013	3·02	1·37	0·48	0·18	5/8	OQ840 TS90 WQ	20	76·4	78·7	81·1	85·8	21	62	8
"	"	"	"	"	"	"	"	"	"	"	" " "	— 78	80·2	82·8	84·8	91·8	25	59	"
"	"	"	"	"	"	"	"	"	"	"	" " "	—196	96·7	99·5	101·8	107·9	23	58	"
"	"	"	"	"	"	"	"	"	"	"	" T630 "	20	71·5	72·7	73·0	79·3	23	65	"
"	"	"	"	"	"	"	"	"	"	"	" " "	— 78	74·6	76·2	77·2	84·1	23	62	"
"	"	"	"	"	"	"	"	"	"	"	" " "	—196	92·2	94·4	95·7	102·2	25	52	"
"	"	"	"	"	"	"	"	"	"	"	" T660 "	20	63·8	64·7	65·0	71·6	24	66	"
"	"	"	"	"	"	"	"	"	"	"	" " "	— 78	66·9	68·1	69·4	76·5	26	64	"
"	"	"	"	"	"	"	"	"	"	"	" " "	—196	83·8	86·1	88·1	95·8	27	53	"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)									Section Size dia. (in.)	Heat Treatment °C	Tensile			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	V			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El %	
0·28	0·23	0·56	0·008	0·008	3·33	1·30	0·36	0·20	2¾	OQ850 T600	60	69	19	12

Test Temperature °C	Longitudinal Tests						Transverse test with transverse notch				Transverse tests with longitudinal notch			
	Izod		Charpy Mesnager		Charpy V		Izod		Charpy Mesnager		Izod		Charpy Mesnager	
	ft.lb.	%Crystalline	ft.lb.	%Crystalline	ft.lb.	%Crystalline	ft.lb.	%Crystalline	ft.lb.	%Crystalline	ft.lb.	%Crystalline	ft.lb.	%Crystalline
—140			17	100	7	100								
—100			39	80	12	100								
— 60	20	100	38	90	20	90			5	100	5	100	7	100
— 30	22	90					3	100	6	100			9	100
0	22	90	45	80	27	77	8	100	9	100	6	100	8	100
30	22	90	64	30	31	50	6	100	17	90	8	100	15	90
60	44	25	82	10	82	0	—	—	19	80	—	—		9
80	58	0					15	58	24	50	14	58	17	50
100	62	0					17	30			18	45	21	60
							22	0						

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Chemical Composition (%)								
C	Si	Mn	S	P	Ni	Cr	Mo	V
0·32	0·19	0·51	0·009	0·013	3·02	1·37	0·48	0·18

$\frac{3}{4}$ in. dia. bars Oil Quenched 840°C and tempered as indicated.
(For tensile test results see also Mechanical Properties at Low Temperature.)

(Ref. 8)

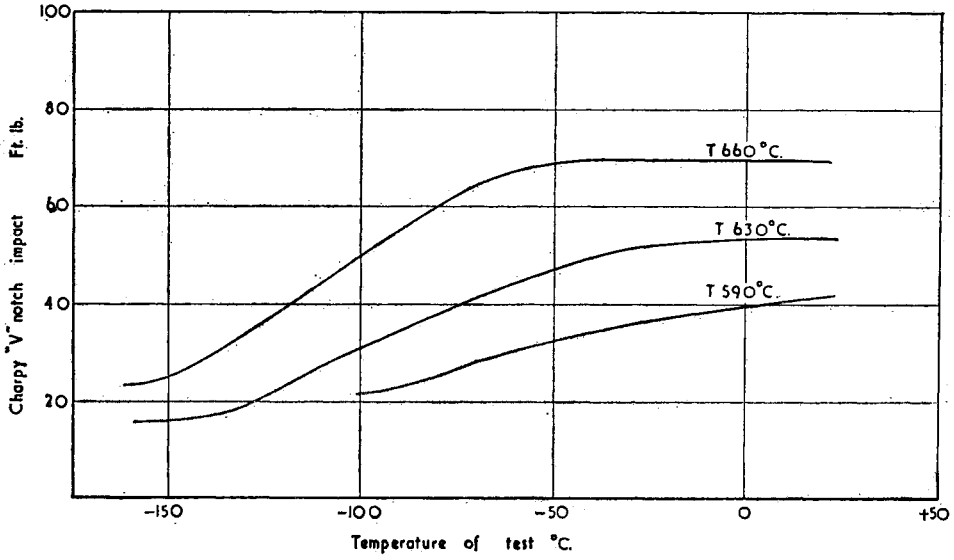


Fig.28.10

(Ref. 8)

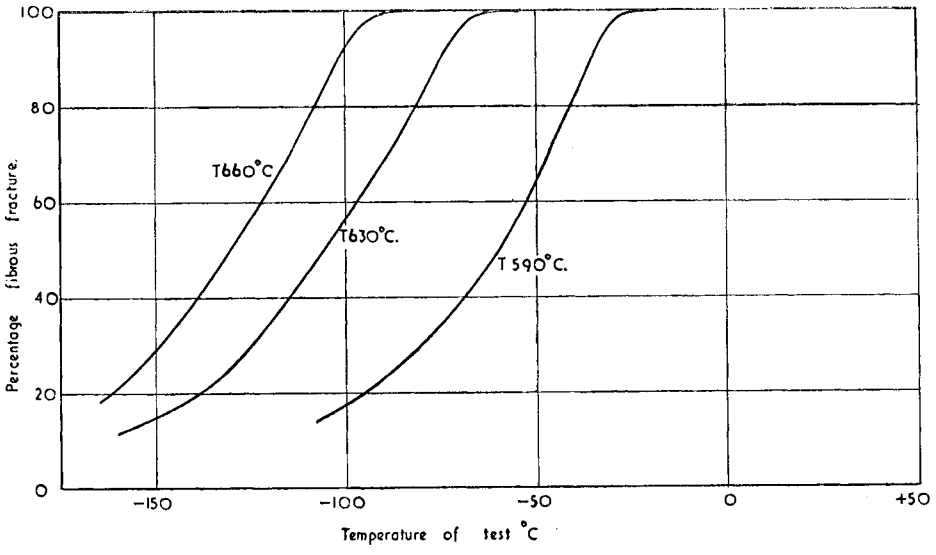


Fig.28.11

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·05% P.S. (0·05Rp)	0·2% P.S. (0·2Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
											tons/sq.in.						
0·28	0·16	0·46	0·026	0·030	3·32	0·77	0·24	1 1/8	OQ820 T650 WQ	20	40·5	43·5	45·4	55·6	23 1/2	64	9
"	"	"	"	"	"	"	"	"	" " "	300	34·6	36·4	40·6	56·6	25	60 1/2	"
"	"	"	"	"	"	"	"	"	" " "	350	30·8	36·0	38·6	53·4	25 1/2	61 1/2	"
"	"	"	"	"	"	"	"	"	" " "	400	28·6	32·0	38·0	49·9	23	65 1/2	"
"	"	"	"	"	"	"	"	"	" " "	450	23·5	30·0	33·2	43·1	24	69	"
"	"	"	"	"	"	"	"	"	" " "	500	19·1	21·2	24·6	37·0	24	77 1/2	"
"	"	"	"	"	"	"	"	"	OQ820 T600 WQ	20	47·8	53·5	55·1	62·4	22	62 1/2	"
"	"	"	"	"	"	"	"	"	" " "	300	37·4	42·8	47·4	60·7	22	61	"
"	"	"	"	"	"	"	"	"	" " "	350	35·2	39·4	46·2	58·0	23	67 1/2	"
"	"	"	"	"	"	"	"	"	" " "	425	30·2	36·0	41·4	52·2	20 1/2	66	"
"	"	"	"	"	"	"	"	"	" " "	500	21·0	25·0	28·2	43·9	21	77	"
"	"	"	"	"	"	"	"	"	" " "	550	8·0	10·6	13·0	35·6	25	82 1/2	"

MECHANICAL PROPERTIES IN TORSION

Chemical Composition (%)									Test Temperature °C	Tensile				Torsion			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	V		0·1% P.S. (0·1Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	0·1% P.S. (0·1Rp)	Apparent Shear Strength	Probable Shear Strength	
										tons/sq.in.					tons/sq.in.		
0·27	0·26	0·55	0·008	0·004	3·02	1·32	0·41	0·20	RT	76·8	84·9	18	54 1/2	51·3	70·1	52·6	13

FATIGUE PROPERTIES

Process of Manufacture	Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Izod ft.lb.	Rotating Bending Fatigue Limit tons/sq.in.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)			
													tons/sq.in.								
	0·0007″	0·25	0·17	0·45	0·027	0·028	3·53	0·65	0·29	⅞	OQ825 T600 AC	RT			55·6	62·2	24	66	57	±33·6	13
	0·0015″	″	″	″	″	″	″	″	″	″	Soaked 950°C										
											OQ825 T600	″			53·2	60·2	23½	64	55	±32·4	″
	0·002″	″	″	″	″	″	″	″	″	″	Soaked										
											2 hr. OQ825										
											T600	″			58·8	64·0	20	61	55	±34·1	″
	0·0025″	″	″	″	″	″	″	″	″	″	Soaked 1000										
											24 hr. OQ825										
											T600	″			53·8	59·0	22½	64	58	±31·2	″
	0·003″	″	″	″	″	″	″	″	″	″	Soaked 1100										
											4 hr. OQ825										
											T600	″			54·8	60·0	21½	60	60	±31·5	″
	0·006″	″	″	″	″	″	″	″	″	″	Soaked 1200°C										
											4 hr. OQ825										
											T600	″			57·6	62·9	21	58	48	±32·0	″
B.E.A.		0·31	0·17	0·62	0·007	0·008	3·76	0·91	0·24	1⅛ sq. (L)	OQ830 T650										
											½ hr. OQ	RT	42·9	45·3		62·6	26	64		±32·5	14
″		″	″	″	″	″	″	″	″	″ (T)	″ ″	″	46·6	48·7		62·6	21	60		±29·0	″
″		″	″	″	″	″	″	″	″	·275 (L)	″ T200										
											1 hr. AC	″	75·0	82·5		113·9	16	59½		±38·0	″
″		″	″	″	″	″	″	″	″	″ (T)	″ ″	″	73·9	80·6		119·0	11½	32½		±30·0	″
″		″	″	″	″	″	″	″	″	″ (L)	″ T200										
											1 hr.+250 1 hr. AC	″	81·1	86·8		108·1	15½	47		±40·0	″
B.E.A.		0·30	0·29	0·55	0·023	0·021	3·80	1·33	0·35	″ (L)	OQ820 AC T200										
											1 hr. AC	″	72·7	78·5		127·1	12½	49		±40·5	″
″		″	″	″	″	″	″	″	″	″ (T)	″ ″	″	75·8	83·4		109·1	9	45½		±27·0	″
A.O.H.		0·32	0·27	0·56	0·042	0·034	3·82	1·31	0·32	″ (L)	″ ″	″	73·0			113·0	14	38		±45·5	″
″		″	″	″	″	″	″	″	″	″ (T)	″ ″	″	83·1			111·8	4	nil		±29·3	″

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3 PER CENT CHROMIUM–MOLYBDENUM STEEL
(See also En 40)

SPECIFICATION

CHEMICAL COMPOSITION (%)

	C	Si	Mn	S	P	Ni	Cr	Mo
En29A	0·15—0·25	0·10—0·35	0·65 max.	0·050 max.	0·050 max.	0·40 max.	2·50—3·50	0·30—0·70
En29B	0·25—0·35	0·10—0·35	0·65 max.	0·050 max.	0·050 max.	0·40 max.	2·50—3·50	0·30—0·70

MECHANICAL PROPERTIES

	Hardened and Tempered Condition						
	R	S	T	U	V	W	Z
Limiting ruling section in.	6	6	6	6	4	4	2½
Tensile strength, tons/sq.in., min.(Rm)	45	50	55	60	65	70	100
Yield stress, tons/sq.in., min.(Rs) (1)	34	38	44	48	52	58	85
0.2% Proof stress, tons/sq.in., min.(0.2Rp) (2)	32	36	41	46	50	55	80
Elongation, %, min.(A)	22	20	18	17	16	15	10
Izod impact value, ft.lb., min.	40	40	40	35	35	30	10
Brinell hardness No.(3) (HB)	201/255	223/277	248/302	269/321	293/341	311/375	444

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 269.

(1) Not to be used as acceptance values except by special arrangement between the purchaser and manufacturer.

(2) When specifically requested in the enquiry or order.

(3) For information purposes only, not contractual part of the specification.

RELATED SPECIFICATIONS

En No.	United Kingdom			France	Germany	
	BS	BS Air	DTD	AFNOR	Werkstoffe No.	Name
En 29A	1503—623	S106 S123	317A			
En 29B		S106 S123	317A	30 CD 12	1.7361	32 CrMo12

En 29

APPLICATIONS

This is a nickel-free steel possessing good hardenability and capable of being heat treated to develop a wide range of tensile strengths combined with good ductility and resistance to shock. The steel may be nitrided although En 40, which is of similar composition to En 29, is specifically designated for this purpose. Good low temperature impact values are obtainable and the steel possesses a good resistance to embrittlement at elevated temperatures.

It is used for constructional applications requiring from 40 to 100 tons/sq.in. tensile strength.

Typical uses are: axles, crankshafts, gear pinions, cylinder liners, moulds for plastics, high tensile bolts and other parts for steam temperature services.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table)

	Welding Process					
	MA	G	IG	S	F	B
En 29A	d	bx	g	e	b	j
29B	d	cx	g	f	b	j

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MACHINABILITY

In the softened condition the machinability of this steel is approximately 33% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 900°C. Retarded cooling is advisable for large or intricate sections
Softening	700°C—750°C. Air or furnace cool.
Annealing	880°C—910°C. Furnace cool.
Hardening	880°C—910°C. Oil quench or in special cases air cool.
Tempering	up to 750°C. Air cool or oil quench.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)							Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Cr	Mo			
0·30	0·25	0·45			3·0	0·50	Softened	7·86	1
0·29	0·23	0·50	0·025	0·011	3·32	0·55	OQ900 T620	7·81	2
		(within specification)						7·85	3

SPECIFIC HEAT (c)

Chemical Composition (%)							Heat Treatment °C	Mean Specific Heat cals/g						Ref.
C	Si	Mn	S	P	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	
0·30	0·25	0·45			3·0	0·50	Softened	0·118						1
0·29	0·23	0·50	0·025	0·011	3·32	0·55	OQ900 T620	—	0·119	0·124	0·130	0·136	0·142	2

COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)							Heat Treatment °C	$10^6 \times$Mean Coefficient of Expansion per deg. C							Ref.
C	Si	Mn	S	P	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	
0·29	0·23	0·50	0·025	0·011	3·32	0·55	OQ900 T620	12·2	12·5	12·8	13·4	13·8	14·1	—	2
0·30	0·25	0·45			3·0	0·50	Softened	12·5		13·0		13·5		14·0	1
(within specification)							—	12·2		12·9		13·6		14·0 (to 680°C)	3
	"	"					—		12·0		12·8				4

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)							Heat Treatment °C	Electrical Resistivity microhm-cm								Ref.
C	Si	Mn	S	P	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	
0·29	0·23	0·50	0·025	0·011	3·32	0·55	OQ900 T620	34·0	38·9	46·2	—	—	—	—	—	2
0·26	0·22	0·53	0·020	0·012	3·24	0·57	AC900 T600	33·4	39·0	46·4	55·3	65·5	76·8	89·0	95·5	"

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)							Heat Treatment °C	Thermal Conductivity cal/cm s deg. C							Ref.
C	Si	Mn	S	P	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	
0·29	0·23	0·50	0·025	0·011	3·32	0·55	OQ900 T620		0·080	0·081	0·081	0·080	0·077	0·072	2

En 29

YOUNG'S MODULUS (E), SHEAR MODULUS (G)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq. in.		Shear Modulus tons/sq. in.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic*		
0·25	0·29	0·55	0·011	0·018	0·30	3·09	0·58		20	13,100			2
"	"	"	"	"	"	"	"		200	12,400			"
"	"	"	"	"	"	"	"		400	11,350			"
"	"	"	"	"	"	"	"		450	10,450			"
"	"	"	"	"	"	"	"		500	9290			"
"	"	"	"	"	"	"	"		650	5250			"
"	"	"	"	"	"	"	"		800	500			"
0·26	0·22	0·29	0·020	0·012	0·30	3·24	0·57	AC900 T600 1 hr.	20		13,800		2
"	"	"	"	"	"	"	"	" " "	100		13,500		"
"	"	"	"	"	"	"	"	" " "	200		13,100		"
"	"	"	"	"	"	"	"	" " "	300		12,700		"
"	"	"	"	"	"	"	"	" " "	400		12,150		"
"	"	"	"	"	"	"	"	" " "	500		11,550		"
"	"	"	"	"	"	"	"	" " "	600		10,850		"
"	"	"	"	"	"	"	"	" " "	650		10,450		"
within specification									20	13,400†		5350	4
									200	12,500			"
									400	11,800			"
									450	11,150			"
									500	10,500			"
									600	7700			"

* Vibration method.

† Method of determination not stated.

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·26	0·21	0·55	0·022	0·010	0·25	3·34	0·54

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
As quenched grain size 7—8 (ASTM).
Bars hot rolled to ⅞ in. dia., cold drawn to 11 S.W.G. with intermediate annealing at 600°C.

Austenitizing Temperature 900°C, 30 min. (Ref. 5)

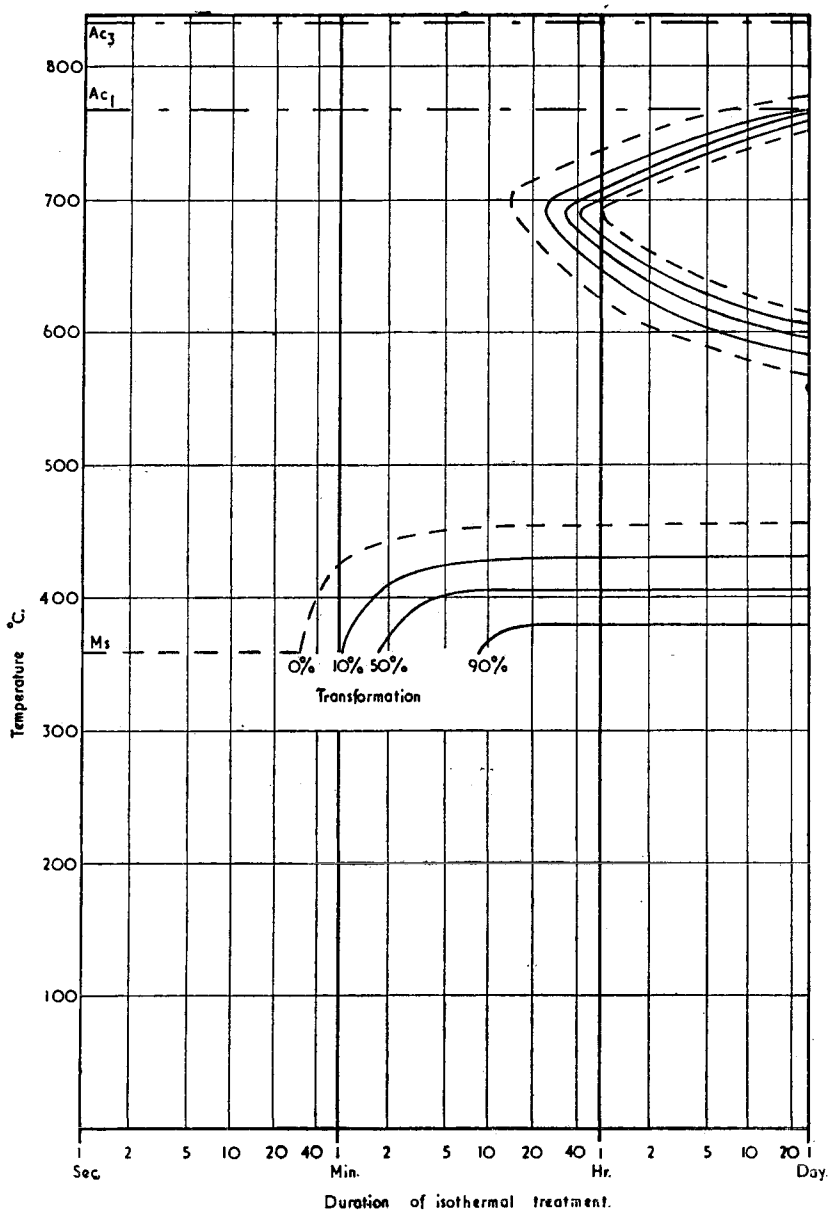


Fig. 29.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·28	0·28	0·68	0·026	0·019	0·17	3·32	0·55

Bars previously normalized and tempered.
Austenitizing Temperature 890°C, 25 min. (Ref. 1)

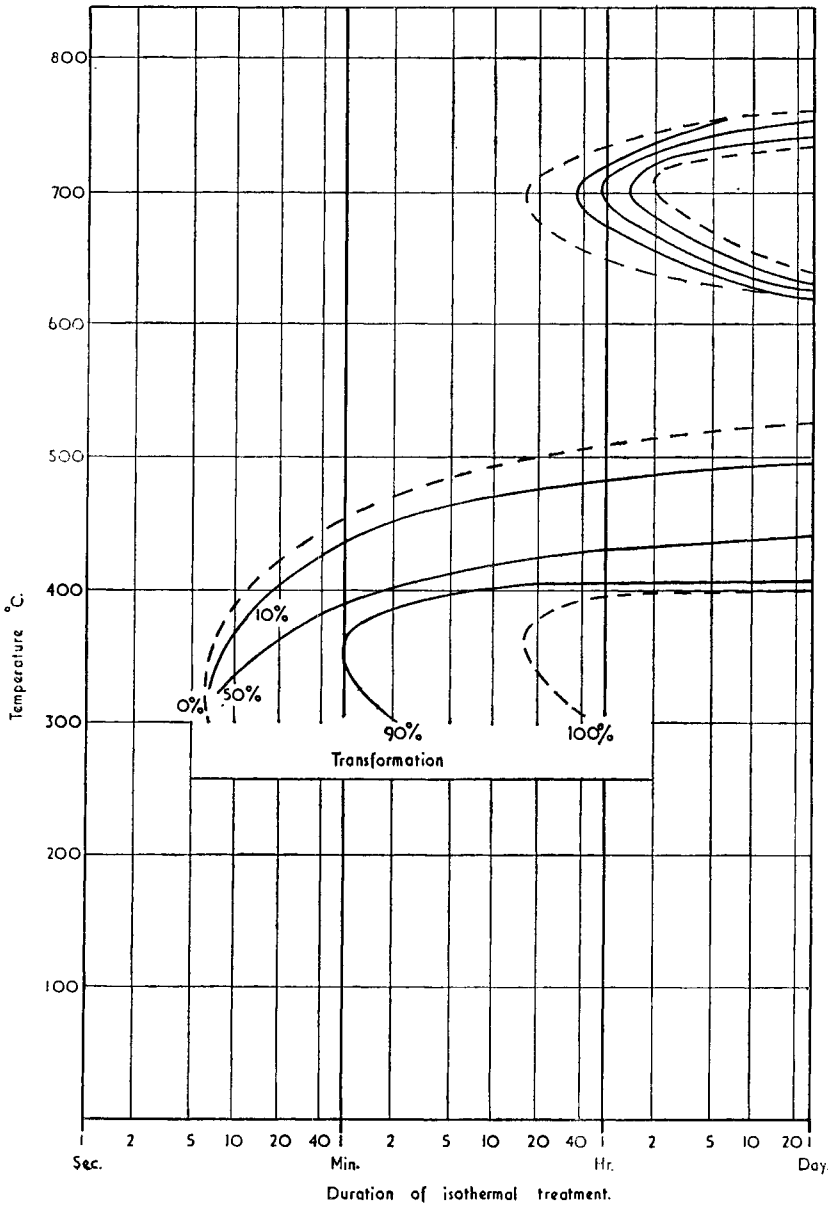


Fig. 29.2

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·26	0·21	0·55	0·022	0·010	0·25	3·34	0·54

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
As quenched grain size 7—8 (ASTM).

End Quenched 900°C, soak 30 min.

(Ref. 5)

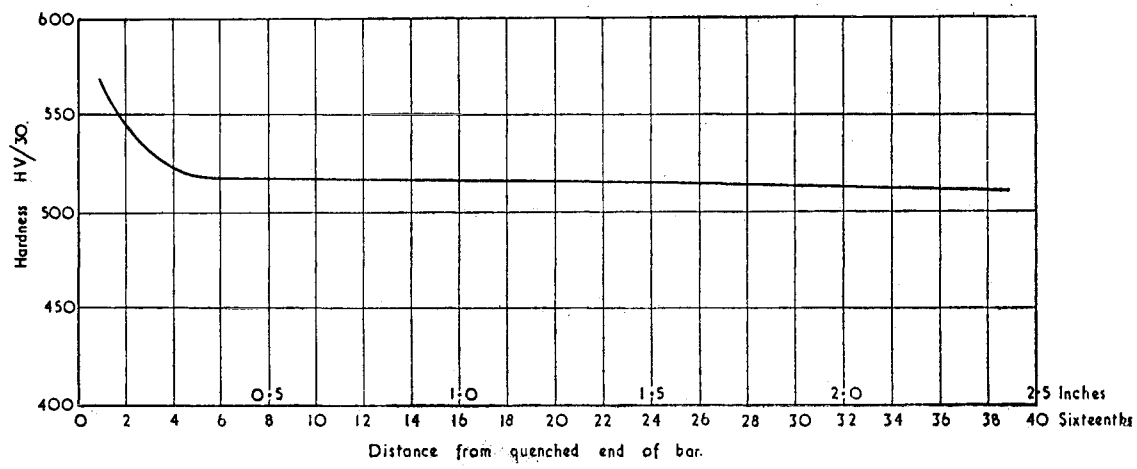


Fig. 29.3

Curve No.	Chemical Composition (%)								ASTM Grain Size		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn	
A	0·25	0·22	0·49	0·013	0·036	0·29	2·96	0·41	7—8 (6)	6—7 (8)	6
B	0·39	0·35	0·59	0·022	0·025	0·24	3·16	0·44	7	—	"

(See Figs. 29.4 and 29.5)

Bars Normalized 925°C. End Quenched 900°C.
As End Quenched

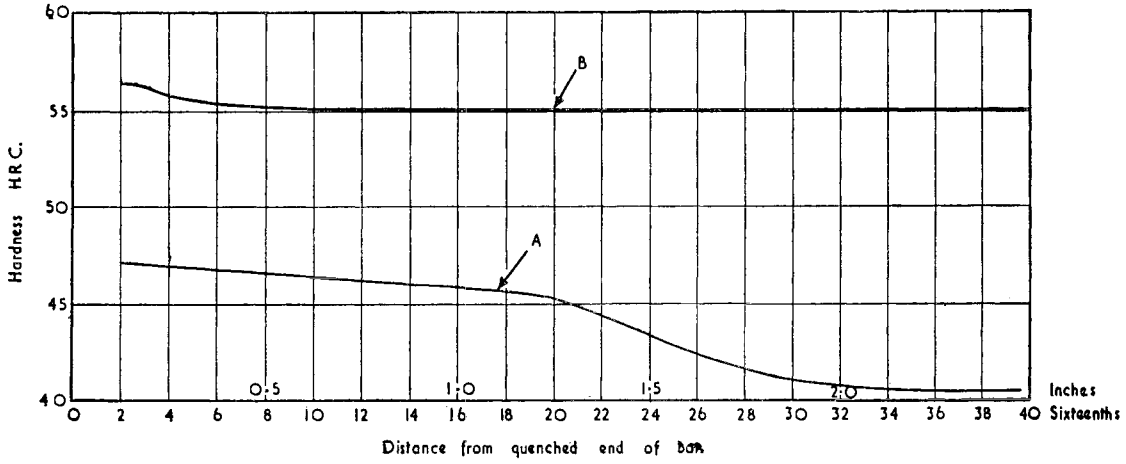


Fig. 29.4

End Quenched and Tempered

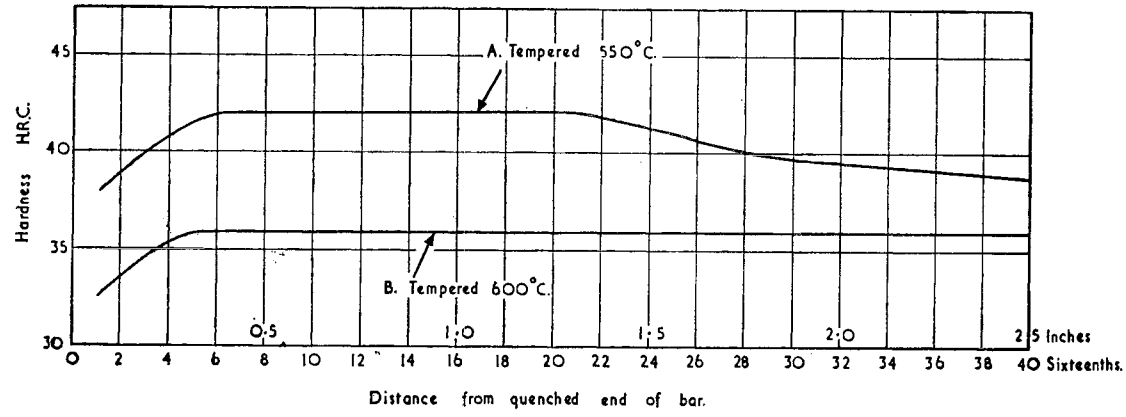


Fig. 29.5

END QUENCH HARDENABILITY BAND (Ref. 3)

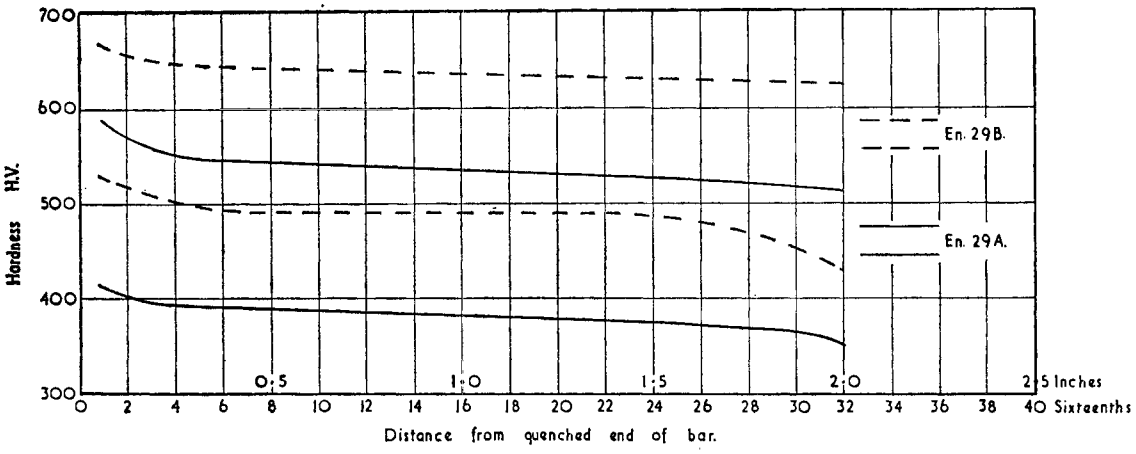


Fig. 29.6

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	0·424	AH 910	35·5	42·7	50·9	62·3	79·1	19	57	38	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	35·2	42·7	50·9	63·5	80·0	20	55½	37	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	41·5	48·7	56·5	67·7	79·1	20	59	48	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	42·0	53·2	60·7	72·1	78·6	19	63½	40	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	50·2	55·5	62·5	71·4	78·9	17	59½	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	49·0	55·2	61·5	68·8	77·3	18½	61	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	49·5	54·7	60·0	66·0	77·3	21	59½	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	48·8	52·0	57·2	64·5	78·2	20	55	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	45·7	51·0	56·9	64·8	80·0	20	59½	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	47·7	53·7	60·5	69·6	81·7	21½	61	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	48·4	54·9	61·5	68·7	79·5	21	61	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	52·3	56·7	60·8	65·4	71·3	20½	65	93	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	47·1	48·8	49·9	51·1	57·1	23½	72½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	43·4	44·5	45·5	46·0	53·6	24½	74½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	38·2	38·9	39·4	40·3	48·0	27	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	34·8	35·2	35·5	36·1	45·5	30	77	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	32·9	33·1	33·3	33·4	43·8	30	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·5	30·6	30·6	30·6	41·0	32½	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "				29·4	40·1	32½	78½	119	"
"	"	"	"	"	"	"	"	"	"	¾	AH 910	37·0	44·0	52·8	63·5	79·5	19½	55	30	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	41·7	45·5	55·5	67·0	78·7	21	56½	36	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	45·0	50·6	57·5	67·0	78·2	20	58½	39	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	51·0	56·6	64·2	74·4	78·8	18	61½	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	51·4	57·0	63·6	72·5	79·6	18½	60	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	51·2	57·4	64·5	72·5	78·0	19½	60	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	50·4	55·5	61·2	68·0	77·3	20	57½	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	49·6	54·6	59·9	66·5	78·0	21	58½	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	48·7	54·3	59·9	67·0	81·6	20	56½	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	50·7	56·0	61·5	68·2	82·6	19½	58	—	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	51·7	58·4	63·3	69·3	79·3	20	61½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	53·4	57·9	61·1	66·1	74·2	20	63	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	47·2	50·1	51·5	53·0	63·0	22	70½	110	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	44·7	45·5	46·7	47·7	54·7	23½	71½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·5	41·5	42·0	43·0	50·7	26	75	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·8	36·5	37·0	38·6	46·3	27	75½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	32·5	33·1	33·4	35·2	43·5	28	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·9	31·0	31·0	32·3	41·5	31	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	29·1	29·1	29·2	31·0	40·5	32	76½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T. S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	1⅛	AH 910	42·7	48·6	56·2	67·8	78·1	20	53	33	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	43·5	50·0	58·0	69·5	79·0	21½	55½	37	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	48·6	54·5	60·5	68·0	78·5	19	59½	36	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	49·3	54·9	61·5	69·4	78·4	19	51	32	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	53·8	59·0	65·0	72·0	78·9	18	59½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	52·1	57·0	62·6	69·0	76·8	19½	60	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	50·5	55·4	61·0	66·5	79·6	19½	56½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	44·6	48·5	52·9	54·7	77·2	22	59	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	47·4	52·8	58·6	66·4	79·0	19½	57½	19	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	52·5	58·6	63·8	70·6	78·1	19½	61	13	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	52·4	57·8	63·5	71·0	78·4	20	61	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	53·3	57·9	62·5	67·0	77·5	20½	60½	24	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	48·5	50·2	52·0	54·0	59·5	21½	69	112	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·2	40·9	41·6	44·5	49·7	26	73	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	36·1	36·5	37·6	41·0	46·1	26	75½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	33·3	33·6	34·1	36·1	44·0	27	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·8	31·0	31·5	33·2	41·4	30	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "				29·6	40·5	31	77½	119	"
"	"	"	"	"	"	"	"	"	"	2⅛	AH 910	41·0	46·5	53·4	62·4	78·7	19½	52½	22	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	40·0	45·7	52·8	62·4	78·7	19	53	24	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	42·6	47·8	53·6	63·1	78·0	20	55½	32	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	48·3	54·0	60·8	69·3	77·0	19	61½	27	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	50·1	55·2	60·4	66·5	77·3	19	56	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	47·7	51·7	56·0	61·5	77·5	20½	56	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	48·7	54·1	59·6	66·6	82·9	19	54	14	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	52·2	56·7	61·6	68·2	82·5	18½	56	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	51·6	57·2	62·3	68·4	78·4	19½	60½	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	48·9	50·5	51·8	52·8	59·0	21	69	103	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	45·0	46·0	46·7	47·5	54·5	24	73	116	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·2	41·0	41·7	42·4	50·7	24½	73½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	34·7	35·2	35·5	36·0	45·8	28	75	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	31·9	32·5	32·9	33·8	44·0	29½	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	29·6	29·7	29·9	30·0	41·4	30½	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	28·6	28·7	28·7	28·8	40·6	32	75½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	3	AH 910	38·2	44·8	52·0	61·5	79·2	19	53	23	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	40·5	47·0	53·7	63·0	79·5	20	52½	27	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	40·4	45·6	53·3	61·9	79·3	20	56	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	49·8	55·3	62·4	71·6	77·9	19½	61	30	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	49·4	54·5	59·5	65·3	77·2	20	57	19	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	50·7	55·6	60·3	65·5	77·6	20	57	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	44·4	49·9	55·7	64·3	82·2	20	54	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	49·7	55·0	60·8	67·9	82·4	20½	57	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	49·8	56·1	62·4	69·3	81·6	20	59½	14	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	57·8	61·3	64·8	69·1	76·1	19½	63	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	51·6	53·6	55·4	57·2	63·0	21½	67	96	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	44·6	46·0	46·8	47·7	54·0	25½	74½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	39·1	40·0	40·5	41·2	49·4	26½	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·2	36·1	36·7	38·2	45·8	29	78	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	32·7	33·1	33·6	34·4	43·4	30	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·8	31·4	31·5	31·9	41·8	31	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	29·5	29·5	30·1	32·6	40·7	33½	77	119	"
"	"	"	"	"	"	"	"	"	"	5½	AH 910	38·5	43·7	50·4	59·6	77·1	19	50½	22	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	40·4	46·0	52·1	61·2	78·4	19½	52½	20	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	41·1	46·9	53·0	61·8	78·3	20	53	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	47·5	52·9	59·4	67·7	73·8	19½	61	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	48·2	53·7	60·0	66·5	76·1	20	57	20	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	49·4	54·1	59·9	65·9	77·0	20	55	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	42·6	47·3	52·8	61·0	79·6	20½	54½	12	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	49·1	54·0	59·3	66·0	81·6	19	57	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	55·7	60·3	64·9	70·2	79·4	19	58½	6	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	53·7	58·1	65·6	69·2	76·1	20½	61	12	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	47·6	49·6	51·2	52·7	58·6	22½	69	84	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	45·8	46·8	47·8	49·0	54·7	22	69	112	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	41·4	42·0	42·9	46·1	49·6	24½	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·4	36·0	36·7	39·3	45·3	28½	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	31·0	31·8	32·4	33·5	41·8	30½	77	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	28·6	29·9	30·0	31·4	40·2	32½	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "		29·2	29·4	32·2	39·5	32½	76½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE
(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	0·424	OQ 910	42·4	49·9	59·5	73·0	89·1	16½	55	45	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	41·1	49·4	59·2	72·5	89·3	18½	55½	47	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	52·2	59·2	67·2	77·4	89·8	18	56½	46	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	56·0	62·0	69·5	80·0	89·6	18	59	33	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	57·6	63·0	69·4	79·3	87·5	17½	59½	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	52·7	62·1	68·4	77·0	85·2	18	58	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	59·1	64·3	69·5	76·1	84·8	17½	56	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	59·5	63·7	67·9	73·7	83·7	18	58	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	57·8	63·0	68·1	74·4	82·6	19½	62	24	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	56·2	62·0	67·2	73·2	80·3	20	63½	32	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	58·1	62·8	66·7	71·1	76·7	20	67	47	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	54·1	57·0	59·2	61·6	66·7	21	69½	113	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	46·7	48·7	50·1	52·5	57·7	24½	73½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	42·0	43·6	44·8	46·4	53·2	26	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	38·5	39·7	40·3	41·1	49·4	26	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·2	35·7	36·1	36·8	45·7	28	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	33·1	33·3	33·4	35·2	42·7	32	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "				29·9	40·1	32½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "				28·9	38·5	36	79½	119	"
"	"	"	"	"	"	"	"	"	"	¾	OQ 910	47·2	55·5	64·8	77·3	90·7	18	53	49	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100AC	47·0	54·5	63·8	75·7	90·5	16½	55	46	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	53·8	60·5	68·6	79·8	89·8	16½	57½	47	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	54·6	61·5	70·0	80·6	89·2	16	57	35	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	58·9	64·2	71·4	81·0	89·0	16	58½	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	60·2	65·1	71·3	79·1	87·9	16	58	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	62·4	67·0	72·5	79·4	86·6	16	56	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	64·1	67·9	72·5	78·0	84·9	16	55½	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	61·5	65·8	70·4	76·0	83·9	18	57½	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	62·0	66·0	70·5	75·3	81·4	18	61	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	62·5	66·5	70·0	73·5	78·2	19	63½	34	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	53·2	55·5	57·5	59·5	64·2	21	69½	96	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	46·6	48·3	49·8	51·3	57·7	23½	73	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	43·2	45·3	46·7	49·3	54·3	23	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·8	42·0	43·1	44·7	51·5	25	75	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	36·2	37·1	37·5	39·1	46·4	28½	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	33·9	34·4	34·6	36·0	43·8	28½	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·5	30·5	31·0	33·6	40·5	33	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	28·5	28·5	28·5	30·5	38·9	34	78½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. in.	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	1⅛	OQ 910	49·8	56·0	65·4	77·0	89·2	16½	55½	49	3
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, T2hr. 100 AC	50·4	57·4	65·4	77·0	89·0	18	56½	48	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 200 ,,	52·9	60·2	68·4	78·1	88·9	17½	57	44	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 250 ,,	56·4	63·0	71·1	80·5	88·8	16½	56	29	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 300 ,,	57·0	63·2	71·0	80·1	88·2	17	58	29	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 350 ,,	56·6	62·0	68·8	77·4	86·4	18	59	24	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 400 ,,	58·5	64·0	70·9	78·2	86·3	16	56	25	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 450 ,,	61·7	66·0	71·2	76·9	84·1	17	59½	23	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 500 ,,	55·8	61·5	66·6	73·0	82·8	19	60½	24	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 525 ,,	58·2	63·0	68·0	73·3	79·9	19	61½	27	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 550 ,,	60·7	64·9	68·7	73·1	78·5	20½	64	32	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 575 ,,	53·2	55·0	56·8	58·2	63·6	21	70	87	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 600 ,,	47·1	48·6	50·1	51·7	57·9	23½	73½	107	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 625 ,,	43·2	44·9	46·1	48·0	54·6	23½	72½	112	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 650 ,,	38·3	39·4	40·2	41·9	49·4	27	76½	118	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 675 ,,	34·4	35·7	35·8	37·0	46·0	28½	77½	116	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 700 ,,	32·0	32·5	33·0	35·2	43·2	28	76½	118	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 725 ,,	28·5	28·7	29·0	30·0	40·6	33	78½	118	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 750 ,,	26·5	26·5	26·6	28·0	38·6	35	77½	118	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	2⅛	OQ 910	41·3	49·8	59·0	70·4	83·8	18	55½	58	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, T2hr. 100 AC	44·8	52·0	60·2	70·9	83·7	17½	57½	40	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 200 ,,	47·6	54·0	63·1	73·7	85·3	17½	56½	41	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 300 ,,	53·9	57·3	65·7	76·4	85·6	16½	58½	27	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 400 ,,	55·4	60·5	65·9	72·4	81·4	17½	57	23	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 500 ,,	53·8	59·5	65·4	72·1	82·8	19½	57½	21	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 550 ,,	58·2	62·3	67·0	71·6	76·5	19½	63	30	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 600 ,,	45·4	48·0	49·4	50·9	56·5	20	73	118	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 625 ,,	42·7	44·0	44·9	46·0	53·8	24½	73	119	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 650 ,,	38·6	39·7	40·6	41·6	50·3	26	75½	119	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 675 ,,	35·1	35·6	36·1	36·8	46·4	29½	76	119	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 700 ,,	31·2	31·9	32·8	33·0	43·4	30½	76	119	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 725 ,,	28·4	28·4	28·7	30·0	39·9	35	77½	119	,,
,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,,	,, ,, 750 ,,	27·0	27·0	27·2	29·3	38·8	35½	78½	119	,,

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A % (Z)		
												tons/sq. in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	3	OQ 910	45·0	52·0	59·8	69·9	81·9	18	56½	36	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	41·3	48·8	57·7	69·5	83·5	18	55½	42	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	41·0	49·0	57·5	68·6	81·2	19	58½	46	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	52·0	57·6	65·0	74·4	82·6	16½	60	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	53·0	58·1	64·1	71·0	86·3	18½	58½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	51·3	57·9	65·4	72·2	81·6	20	58	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	52·7	59·2	64·3	70·0	77·5	21½	63½	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	47·9	49·8	51·1	52·3	58·2	22½	72	111	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	42·5	43·8	45·0	46·4	52·7	25	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	37·9	38·9	39·6	40·5	48·7	28½	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·1	35·8	36·4	36·9	45·7	30	77	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	31·4	31·9	32·4	33·1	42·5	32½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	29·7	30·1	30·3	30·7	41·0	32	78	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	27·2	27·4	27·6	27·7	38·9	36	78½	119	"
"	"	"	"	"	"	"	"	"	"	5½	OQ 910	44·3	50·0	56·5	65·6	77·6	18	54	32	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	43·6	49·5	56·7	67·9	78·4	19	55	36	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	48·0	53·7	61·5	72·0	78·6	19½	59	36	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	47·2	52·3	63·0	69·0	79·0	18½	58½	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	53·0	57·7	64·1	72·0	77·4	18	57½	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	55·1	60·0	67·6	75·1	77·5	17½	54	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	49·6	54·4	60·2	68·2	77·8	20½	55	16	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	55·7	60·7	65·2	70·2	77·2	20½	60½	17	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	47·0	49·0	50·3	51·8	56·2	23	71½	105	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	44·7	46·3	47·1	49·5	53·6	25	71½	114	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	39·6	40·6	41·3	43·5	48·9	27	77	113	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·3	35·8	36·4	39·2	45·0	29	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	30·7	31·6	32·3	35·0	41·4	30½	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "			29·2	30·7	39·7	33½	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "			28·0	29·0	38·6	34½	77½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	0·424	WQ 910	52·7	59·7	68·8	79·6	91·9	17½	54	39	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	50·8	57·9	67·6	79·5	91·4	17½	54	46	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	61·6	65·1	70·5	79·6	89·3	18	59½	49	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	62·1	65·1	70·2	78·9	87·7	16½	60	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	62·1	64·5	69·7	77·9	85·9	16½	59½	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	62·1	64·8	69·8	76·8	84·2	18	62	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	61·0	62·8	68·3	74·6	81·8	18	65½	20	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	60·9	63·4	67·0	72·8	79·8	18	65	30	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	57·7	61·9	66·0	71·6	79·2	19	64½	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	56·7	61·4	65·6	70·4	76·5	21	62½	32	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	56·9	60·4	63·5	67·2	72·8	21	66½	81	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	49·4	51·5	53·5	55·5	61·8	24½	73	108	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·7	47·4	49·3	51·4	56·4	23½	73½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	43·2	44·6	46·0	47·6	55·1	24	73½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	39·4	40·1	41·0	42·0	49·9	27½	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	36·6	37·1	37·6	38·2	46·9	28	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	32·6	32·6	32·7	32·9	42·4	32	79½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	30·1	30·3	30·5	30·6	40·4	32	79½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "				29·2	39·4	32½	80½	119	"
"	"	"	"	"	"	"	"	"	"	¾	WQ 910	57·0	64·0	71·2	80·8	91·8	16	52½	44	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	57·9	60·6	69·0	79·5	91·5	16	52½	45	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	61·4	65·8	71·5	80·6	90·1	16	55½	53	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	63·8	67·2	73·3	81·5	89·5	16½	57½	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	63·8	67·0	72·4	80·2	88·4	15	54	27	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	63·0	66·2	72·0	78·5	84·8	12	59	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	62·5	65·2	69·6	76·4	83·7	15	59	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	63·8	65·6	69·3	75·2	82·7	18	59	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	62·2	65·9	69·9	74·9	80·7	19	67½	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	57·5	62·2	67·7	73·0	79·4	20	64	31	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	57·5	61·2	65·1	68·4	73·6	19½	65½	43	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	50·8	53·2	55·8	58·3	63·8	21½	70½	99	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·6	47·7	49·4	51·7	58·5	23½	74½	117	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	43·0	44·5	45·6	47·1	55·1	24½	72½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·0	41·2	42·4	43·8	51·9	25½	73	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	36·0	36·9	37·4	38·2	47·1	27½	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	33·0	33·4	33·6	34·8	43·3	29½	77	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	29·8	29·9	29·9	30·5	40·6	31	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	28·7	28·7	28·7	28·9	39·3	33	78½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	1⅛	WQ 910	61·0	66·5	73·5	82·1	90·2	16	54½	45	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	59·8	66·0	73·5	83·7	90·2	16	53	42	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	62·3	66·1	74·3	82·3	90·0	16½	57	41	"
"	"	"	"	"	"	"	"	"	"	"	" " 250 "	65·5	70·5	78·1	86·1	88·0	18	57½	26	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	63·0	67·2	73·7	84·0	88·2	15½	57	27	"
"	"	"	"	"	"	"	"	"	"	"	" " 350 "	63·4	66·5	71·6	80·4	86·2	15½	55	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	62·7	65·7	70·2	77·2	84·5	17½	58	27	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	64·4	67·4	73·0	79·4	82·0	18½	59	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	57·6	63·0	68·0	74·5	80·8	18½	60½	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 525 "	59·5	64·0	68·2	73·5	79·0	19	62	28	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	58·5	62·1	65·8	69·7	73·5	20	65	70	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	50·7	52·8	54·1	57·7	63·4	21½	70	106	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·4	47·2	48·6	50·2	58·4	23	73½	113	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	42·5	44·5	46·3	48·9	55·3	23½	73	119	"
"	"	"	"	"	"	"	"			"	" " 650 "	40·0	41·6	43·0	45·0	51·9	25	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	31·4	35·4	36·2	37·6	45·6	28	76	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	33·2	33·7	34·9	35·1	42·0	29	78	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	29·5	29·8	30·5	33·0	38·9	32½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	28·0	28·0	28·7	31·7	38·5	31½	78½	119	"
"	"	"	"	"	"	"	"	"	"	2⅛	WQ 910	48·0	56·7	65·8	76·9	91·0	16	50½	42	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	44·6	52·8	66·6	77·7	92·4	16½	51½	39	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	59·5	65·3	72·6	82·0	91·6	16	50½	35	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	63·4	67·0	72·9	81·6	90·2	15½	52½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	63·3	66·0	71·5	79·0	86·1	17½	56½	19	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	58·8	64·0	69·3	75·0	82·6	19	58½	20	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	59·0	62·5	66·4	70·5	74·5	19	64½	42	"
"	"	"	"	"	"	"	"	"	"	"	" " 575 "	56·0	58·9	61·6	63·6	68·3	19½	69	95	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·9	47·5	49·2	51·1	58·5	23	71½	115	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	42·0	43·3	44·7	46·1	52·3	23½	72	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·9	42·2	43·3	44·6	52·5	25¼	74½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	34·4	35·2	35·9	36·5	45·6	29	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	31·6	32·4	32·9	34·8	42·1	29	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	28·8	28·8	28·8	29·0	39·7	32½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "				28·5	38·8	34	78½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	5—6	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64	3	WQ 910	51·8	58·9	67·0	78·2	92·6	15½	52½	34	3
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	48·7	57·0	66·3	78·0	92·7	15½	50	35	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	58·7	64·5	71·7	82·0	92·8	17	54	37	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	64·5	68·7	74·7	83·6	91·8	16½	56½	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	62·5	67·3	72·7	80·4	87·2	16½	55½	22	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	60·9	65·8	71·0	76·9	84·7	19	56½	24	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	58·9	63·9	68·1	72·2	78·0	20	63	40	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·7	48·1	50·0	51·9	58·7	23½	73½	115	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	42·6	44·3	45·6	47·3	54·4	24½	74	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	37·0	39·0	40·3	41·8	49·5	27½	74½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	34·4	35·5	36·2	37·0	45·7	29	76½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	30·8	31·5	32·1	33·2	41·5	31	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "	28·7	28·9	29·2	30·0	39·5	31	77½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	27·7	28·0	28·1	29·8	38·8	35	79	119	"
"	"	"	"	"	"	"	"	"	"	5½	WQ 910	50·2	56·5	64·1	74·2	89·6	16	56½	40	"
"	"	"	"	"	"	"	"	"	"	"	" T2hr. 100 AC	48·5	56·9	67·0	82·1	88·6	18	57½	38	"
"	"	"	"	"	"	"	"	"	"	"	" " 200 "	52·5	58·7	63·5	77·5	90·1	18	52	36	"
"	"	"	"	"	"	"	"	"	"	"	" " 300 "	57·1	61·9	68·2	77·1	85·0	16	59½	23	"
"	"	"	"	"	"	"	"	"	"	"	" " 400 "	62·4	65·8	70·9	79·2	86·1	16	56	21	"
"	"	"	"	"	"	"	"	"	"	"	" " 450 "	63·2	66·0	70·6	77·3	84·7	17	58	18	"
"	"	"	"	"	"	"	"	"	"	"	" " 500 "	57·4	62·3	67·7	74·1	80·6	18½	58½	25	"
"	"	"	"	"	"	"	"	"	"	"	" " 550 "	61·4	65·3	69·0	72·8	78·1	20½	64½	29	"
"	"	"	"	"	"	"	"	"	"	"	" " 600 "	45·3	47·0	48·6	50·5	56·3	23½	72½	113	"
"	"	"	"	"	"	"	"	"	"	"	" " 625 "	43·1	44·5	45·9	47·7	54·0	24½	75½	113	"
"	"	"	"	"	"	"	"	"	"	"	" " 650 "	40·1	41·8	43·0	45·4	51·1	25½	73	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 675 "	35·6	36·4	37·0	38·4	45·2	29½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 700 "	30·7	31·6	32·3	34·3	41·1	30½	78½	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 725 "			29·2	30·8	39·2	32	79	119	"
"	"	"	"	"	"	"	"	"	"	"	" " 750 "	26·9	27·4	27·4	29·5	38·2	35	79½	119	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
		0·18	0·22	0·52			0·25	3·19	0·63	2	OQ900 T600				54·0	61·5	25	68	91	3
		0·19	0·17	0·41			0·07	3·14	0·55	1	" T630				49·0	56·0	25	70½	110	"
		0·19	0·15	0·53			0·23	2·95	0·44	1 13/16	" T660				37·0	46·5	28	71½	119	"
		0·19	0·19	0·50			0·14	3·20	0·63	3¼	" T610				49·0	56·0	25	71½	105	"
		0·20		0·57			0·10	3·50	0·53	3 sq	OQ900 T650				45·8	50·6	24		99	7
		"		"			"	"	"	"	" T700				41·2	47·1	26½		104	"
B.E.A.		0·20	0·21	0·50	0·012	0·012	0·08	3·16	0·45	6¾	AH900 T700 AC		27·7			38·5	30	71		8
"		"	"	"	"	"	"	"	"	"	OQ900 T610/615 OQ		52·0			59·5	18			"
		0·21		0·45			0·28	2·65	0·44	1⅛	OQ900 T585				62·0	70·0	20½		75	7
		"		"			"	"	"	3	" T570				60·0	71·0	19		30	"
		0·22		0·53				3·28	0·51	4½	OQ900 T725				34·5	44·2	30		119	7
	8	0·22		0·50				3·16	0·55	0·564	" T200				92·8	99·1	15	47	36	2
	"	"		"				"	"	"	" T300				93·5	98·6	15	54	23	"
	"	"		"				"	"	"	" T450				86·4	91·0	16	55	23	"
	"	"		"				"	"	1 1/16	" T500				81·5	90·0	16	55	22	"
	"	"		"				"	"	"	" T550				76·4	84·4	19	59	36	"
	"	"		"				"	"	"	" T600				64·7	69·8	20	61½	66	"
	"	"		"				"	"	"	" T650				56·0	60·6	21½	68	81	"
	"	"		"				"	"	"	" T675				50·1	56·6	23	68	82	"
	"	"		"				"	"	"	" T700				41·0	48·3	25	71½	90	"
	"	"		"				"	"	"	" T725				38·2	44·8	26½	71½	99	"
	"	"		"				"	"	3 (C)	" T550				77·0	81·1	17	59	24	"
	"	"		"				"	"	" (O)	" "				82·4	84·9	17½	59	24	"
	"	"		"				"	"	" (C)	" T600				57·4	61·5	20	68	75	"
	"	"		"				"	"	" (O)	" "				59·1	64·0	20	68	72	"
	"	"		"				"	"	" (C)	" T650				47·8	55·8	22	70	87	"
	"	"		"				"	"	" (O)	" "				48·2	56·1	21½	70	83	"
	"	"		"				"	"	" (C)	" T675				44·4	53·0	23½	71½	93	"
	"	"		"				"	"	" (O)	" "				46·0	52·5	23½	71½	88	"
		0·23		0·62			0·09	3·50	0·46	2⅛	OQ900 T600				54·5	62·5	22		90	7
		"		"			"	"	"	"	" T630				46·5	55·5	24		105	"
		"		"			"	"	"	5½	" T600				54·0	62·0	21½		87	"
		"		"			"	"	"	"	" T630				46·0	55·0	24		100	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size McQuaid Ehn	ASTM Grain Size Actual	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
													tons/sq.in.								
					0·48																
			0·42		0·25 0·55			0·26	3·15	0·54	4½	OQ900 T600	51·5				63·0	20		95	3
			0·24					0·25	3·21	0·53	4	" "				52·0	61·0	21		90	7
			0·24						3·21	0·42	3	" T690				39·2	48·2	27		102	1
			0·24		0·55			0·38	2·84	0·60	4 sq	" T630FC				53·6	61·6	20	64	80	2
			"					"	"	"	"	" " AC				—	—	—	—	90	"
			0·25	0·19	0·53			0·20	3·14	0·54	1½	OQ900 T610	48·8				60·0	22		101	3
			0·25	0·20	0·52			0·21	3·29	0·55	3½	" T600	50·4				62·5	24		86	"
			0·25	0·22	0·51			0·14	3·40	0·51	4	" T640				50·0	56·8	23	71	115	"
			0·25	0·24	0·50			0·27	3·16	0·52	5	" T610				49·6	61·4	22½	69	100	"
B.E.A.	6—7(8)	7—8(6)	0·25	0·22	0·49	0·013	0·036	0·29	2·96	0·41	1	N925 OQ900 T550				73·1	80·9	16	61½	17	6
			0·25						3·08	0·43	2½	OQ900 T660				45·4	52·6	24		93	1
			0·25		0·54			0·19	2·89	0·54	1½	" T650 FC				55·4	61·2	22½	70	86	2
			"		"			"	"	"	"	" " AC				—	—	—	—	89	"
			0·26						3·16	0·42	1½	OQ900 T570				60·4	67·2	20½		75	1
			0·26						2·99	0·42	6	" T580				60·8	65·4	23½		75	"
			0·26						3·22	0·40	1½	" T700				38·4	45·8	30		103	"
			0·27	0·24	0·52			0·20	3·32	0·52	3¾	OQ900 T610	52·0				64·5	22		84	3
			0·27	0·30	0·62			0·28	3·40	0·53	6¾	" T600				54·0	62·0	20½	65	75	"
			0·28						2·99	0·42	2⅛	OQ900 T650				47·0	55·0	26		94	1
			0·28		0·52			0·08	3·10	0·53	3½	" T610				50·5	58·7	23½		87	7
			0·28		0·55			0·20	3·20	0·51	4	" T600				58·0	66·8	21½		81	"
	8		0·29		0·55				3·14	0·62	0·564	OQ900 T200				105·7	117·5	16	47	26	2
	"		"		"				"	"	"	" T300				105·7	109·4	14½	47	21	"
	"		"		"				"	"	"	" T400				98·6	103·3	16½	47	20	"
	"		"		"				"	"	"	" T450				95·8	99·3	15½	47	20	"
	"		"		"				"	"	1⅛	" T500				90·0	95·0	15	49½	23	"
	"		"		"				"	"	"	" T550				91·0	93·6	16	57	24	"
	"		"		"				"	"	"	" T600				65·7	71·0	19	63½	73	"
	"		"		"				"	"	"	" T650				56·0	64·0	21	68	91	"
	"		"		"				"	"	"	" T675				48·8	56·4	24½	70	94	"
	"		"		"				"	"	"	" T700				46·7	54·7	25½	90	111	"
	"		"		"				"	"	3½ sq. (C)	" T600				65·2	72·1	20	63½	66	"
	"		"		"				"	"	" (O)	" "				65·6	71·7	19½	66	76	"
	"		"		"				"	"	" (C)	" T650				54·6	61·5	21½	68	81	"
	"		"		"				"	"	" (O)	" "				57·4	61·4	21½	68	87	"
	"		"		"				"	"	" (C)	" T675				50·1	57·3	23	68	94	"
	"		"		"				"	"	" (O)	" "				45·6	53·9	25½	71½	101	"
	"		"		"				"	"	6 sq. (C)	" T650				49·2	58·2	20½	57	68	"
	"		"		"				"	"	" (M)	" "				51·2	59·0	21½	59	59	"
	"		"		"				"	"	" (O)	" "				51·2	59·6	22	68	71	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P (Rs.)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
	8	0·29		0·51				3·22	0·58	1 1/8	OQ900 T550				89·6	92·2	15 1/2	52 1/2	34	2
	"	"		"				"	"	"	" T600				68·0	73·2	19	63 1/2	70	"
	"	"		"				"	"	"	" T650				52·6	63·3	23	68	87	"
	"	"		"				"	"	"	" T675				50·1	57·3	23	68	94	"
	"	"		"				"	"	3 1/2 (C)	" T550				89·0	92·6	15	49 1/2	28	"
	"	"		"				"	"	" (O)	" "				86·2	93·0	16	55	26	"
	"	"		"				"	"	" (C)	" T600				66·3	72·1	19	63 1/2	66	"
	"	"		"				"	"	" (O)	" "				65·6	72·4	20	66	64	"
	"	"		"				"	"	" (C)	" T650				51·1	59·2	23	70	92	"
	"	"		"				"	"	" (O)	" "				51·9	59·6	23	70	92	"
	"	"		"				"	"	" (C)	" T675				52·0	58·6	22	59	87	"
	"	"		"				"	"	" (O)	" "				53·2	58·0	23 1/2	61 1/2	88	"
	"	"		"				"	"	6 1/2 sq.(C)	" T600 (L)				59·6	66·2	17 1/2	52 1/2	62	"
	"	"		"				"	"	" (M)	" " "				60·0	67·6	20	59	59	"
	"	"		"				"	"	" (O)	" " "				62·6	68·0	18	61 1/2	52	"
	"	"		"				"	"	" (C)	" T650 "				46·4	55·0	23	63 1/2	83	"
	"	"		"				"	"	" (M)	" " "				46·6	55·0	21 1/2	63 1/2	84	"
	"	"		"				"	"	" (O)	" " "				47·0	56·6	22 1/2	70	83	"
	"	"		"				"	"	" (C)	" T600 (T)				61·4	67·4	9	21 1/2	24	"
	"	"		"				"	"	" (M)	" " "				63·0	69·1	9 1/2	21 1/2	29	"
	"	"		"				"	"	" (O)	" " "				63·6	69·5	16 1/2	44 1/2	28	"
	"	"		"				"	"	" (C)	" T650 "				48·4	59·8	13	24 1/2	35	"
	"	"		"				"	"	" (M)	" " "				51·0	59·7	15	33 1/2	35	"
	"	"		"				"	"	" (O)	" " "				53·7	60·6	16	39	40	"
	0·29							3·24	0·35	1 1/4	OQ900 T585				66·4	70·8	21		70	1
	0·29							3·26	0·44	1 1/8	" T600				58·8	65·9	23		82	"
	0·29							2·92	0·42	3	" "				58·6	64·4	21		86	"
	0·29							3·16	0·52	1 1/8	" T620				56·8	64·4	22		79	"
	"							"	"	1 3/4	" "				55·8	62·8	21		81	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
		0·30						3·12	0·46	1¼	OQ900 T620				55·6	64·0	24		89	1
B.E.A.		0·30	0·24	0·56	0·055	0·023	0·35	2·92	0·45	T.P.S.	" T100					112	12	36	18	9
"		"	"	"	"	"	"	"	"	"	" T250					108	13	44	19	"
"		"	"	"	"	"	"	"	"	"	" T350					103	13	47	20	"
"		"	"	"	"	"	"	"	"	"	" T450					96	13	50	22	"
"		"	"	"	"	"	"	"	"	"	" T550	76	79	81		84	17	55	26	"
"		"	"	"	"	"	"	"	"	"	" T600	57	60	62		72	20	61	72	"
"		"	"	"	"	"	"	"	"	"	" T650	51	53	55		61	22	66	90	"
"		"	"	"	"	"	"	"	"	"	" T700	45	47	49		52	22	70	103	"
		0·31						2·89	0·43	1⅜	OQ900 T600				58·4	67·2	23		86	1
		"						"	"	2¼	" "				55·8	65·8	22½		72	"
		"						"	"	6¼	" "				51·4	61·2	22½		67	"
		0·31						3·50	0·42	2½	" "				59·2	66·0	21		73	"
		"						"	"	4	" "				54·4	63·4	22		74	"
	8	0·31		0·62				3·16	0·60	0·564	" T200				107·2	121·6	14	42	20	2
	"	"		"				"	"	"	" T300				100·4	111·4	14	47	21	"
	"	"		"				"	"	"	" T400				94·4	106·4	15	47	17	"
	"	"		"				"	"	"	" T500				95·0	101·4	15	50	19	"
	"	"		"				"	"	"	" T550				83·6	91·3	17	55	26	"
	"	"		"				"	"	"	" T575				79·6	83·5	17½	59	44	"
	"	"		"				"	"	"	" T600				64·8	74·6	20	62	60	"
	"	"		"				"	"	"	" T625				60·2	69·0	20½	64	65	"
	"	"		"				"	"	"	" T650				52·4	60·1	22	66	81	"
	"	"		"				"	"	"	" T680				47·8	56·7	24	68	90	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
8	0·31		0·62				3·16	0·60	¾	OQ900 T610	58·6	67·9	25	68	81	2
"	"		"				"	"	2½ sq	" T550	84·4	95·8	18½	52	19	"
"	"		"				"	"	"	" T600	67·2	74·6	19½	62	52	"
"	"		"				"	"	"	" T650	55·4	64·0	22½	64	69	"
"	"		"				"	"	3½ sq (C)	" T550	90·8	98·8	15½	50	15	"
"	"		"	"			"	"	" (O)	" "	92·8	97·1	15½	50	19	"
"	"		"				"	"	" (C)	" T600	67·2	75·3	19½	60	43	"
"	"		"				"	"	" (O)	" "	70·4	74·4	19	62	58	"
"	"		"				"	"	" (M)	" T625	55·0	63·5	21	64	72	"
"	"		"				"	"	" (C)	" T650	54·0	62·6	23	64	68	"
"	"		"				"	"	" (O)	" "	53·6	62·0	22	68	77	"
	0·33		0·51				3·14	0·35	0·564	OQ900 T200		122·5	12½		22	7
	0·34						3·48	0·53	1¾	OQ900 T620	55·6	64·0	24		89	1
	"						"	"	2½	" "	56·0	64·4	22		83	"
	"						"	"	3¾	" "	55·0	62·0	22		82	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 29A	0·17	0·21	0·49	0·010	0·016	0·25	3·23	0·64

Basic Electric Arc.

McQuaid Ehn grain size 5—6.

1⅛ in. dia. bars. Tempered as indicated.

Air Hardened 910°C.

(Ref. 3)

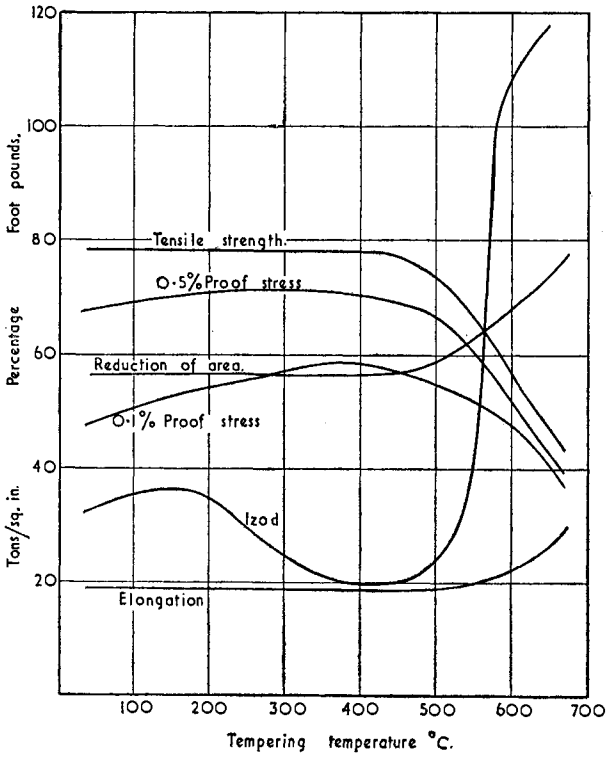


Fig. 29.7

Oil Hardened 910°C.

(Ref. 3)

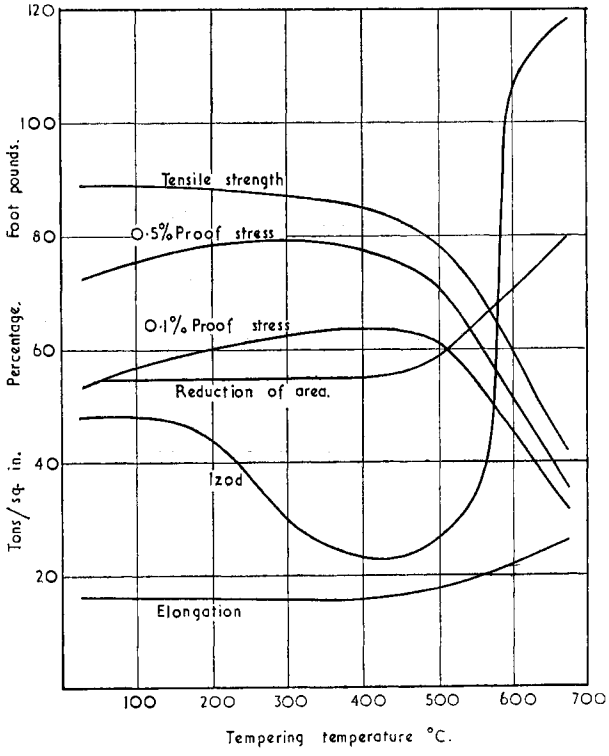


Fig. 29.8

Water Hardened 910°C.

(Ref. 3)

EFFECT OF TEMPERING ON MECHANICAL PROPERTIES AT ROOM TEMPERATURE
(Continued)

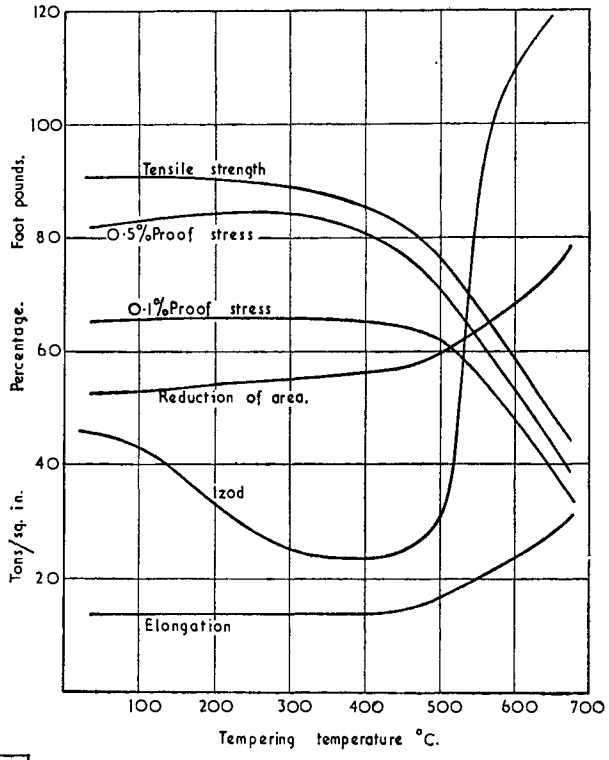


Fig. 29.9

(Ref. 3)

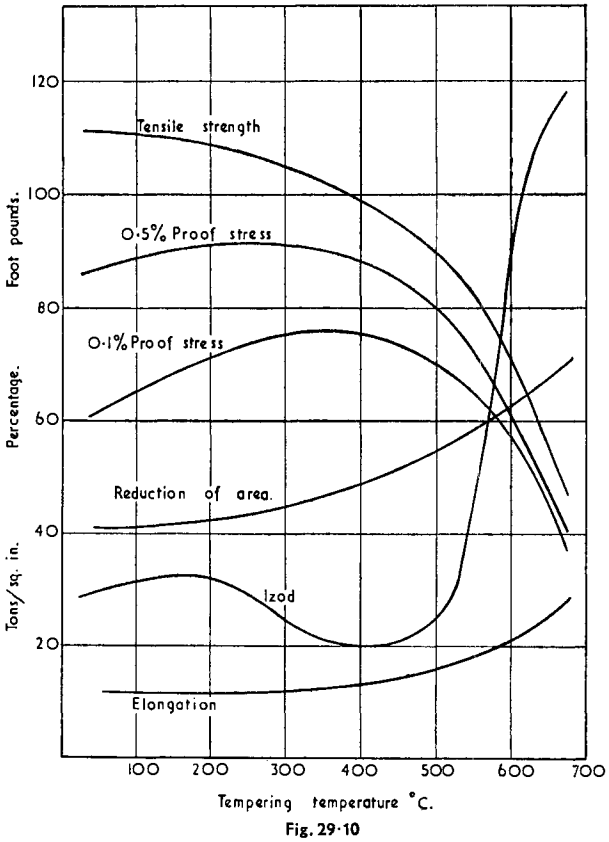


Fig. 29·10

Typical curves for En 29B.

1 ¼ in. dia. bars. Oil Hardened 900°C. Tempered as indicated

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Typical curves for En 29A.

Oil Quenched 910°C. Tempered 600°C A. C. (Ref. 3)

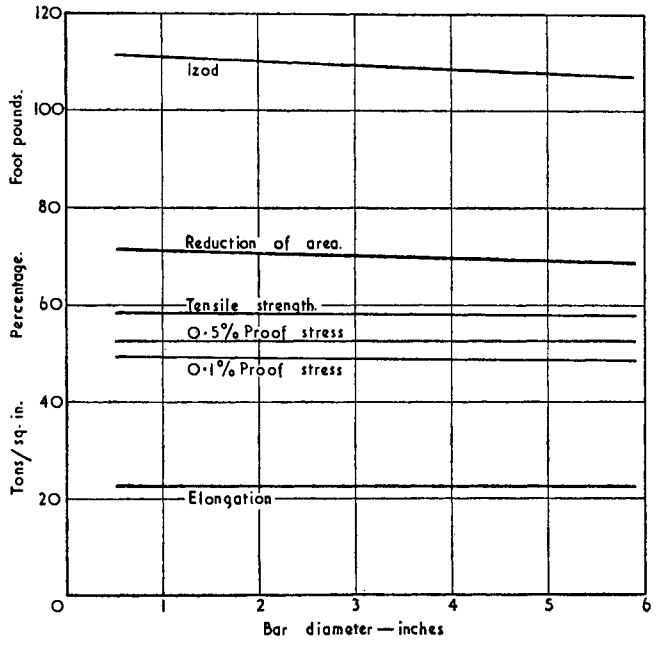


Fig. 29.11

Oil Quenched 910°C. Tempered 650°C A. C. (Ref. 3)

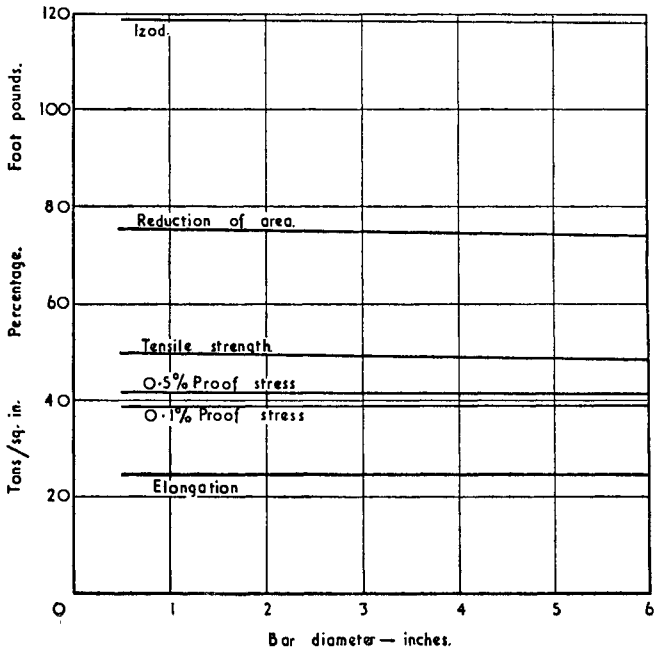


Fig. 29.12

Oil Quenched 910°C Tempered 700°C A. C. (Ref. 3)

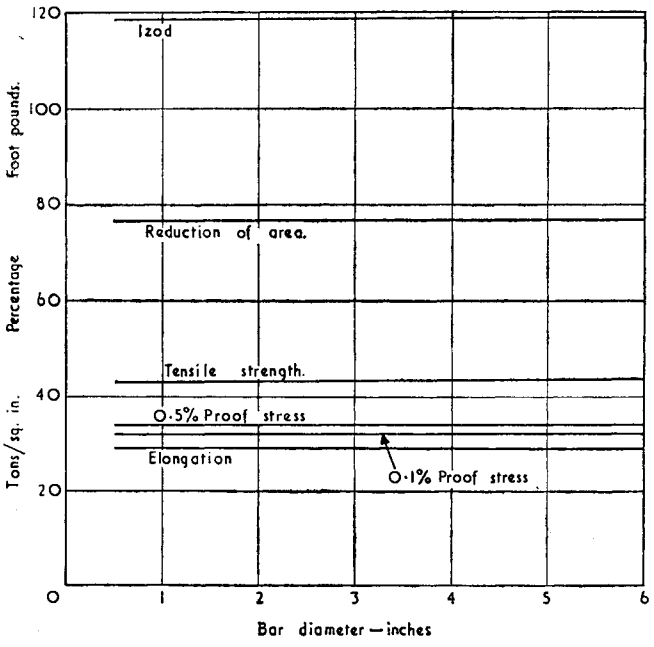


Fig. 29.13

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Typical Curves for En 29B

Oil Quenched 900°C. Tempered 600°C A.C. (Ref. 3)

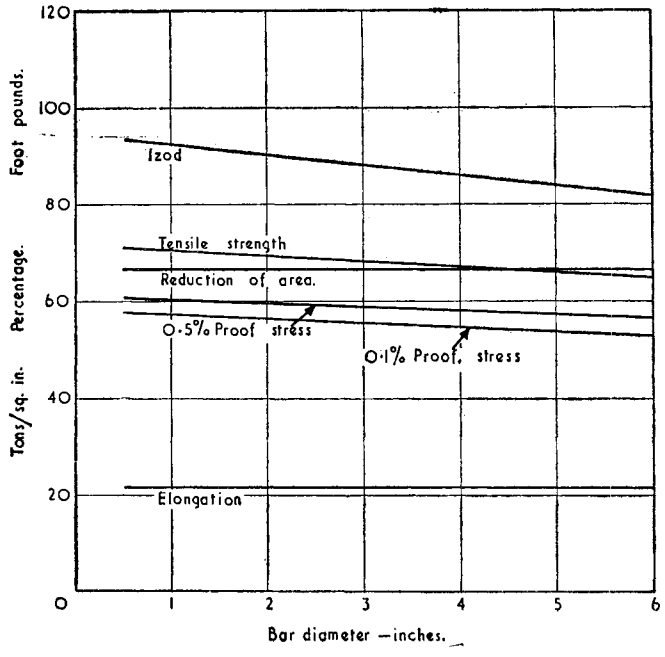


Fig. 29.14

Oil Quenched 900°C. Tempered 650°C. (Ref. 3)

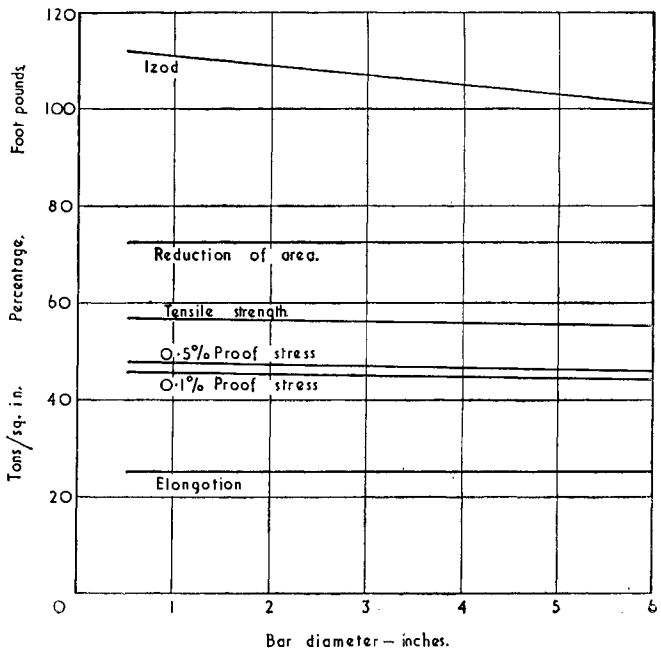


Fig. 29.15

Oil Quenched 900°C. Tempered 700°C. (Ref. 3)

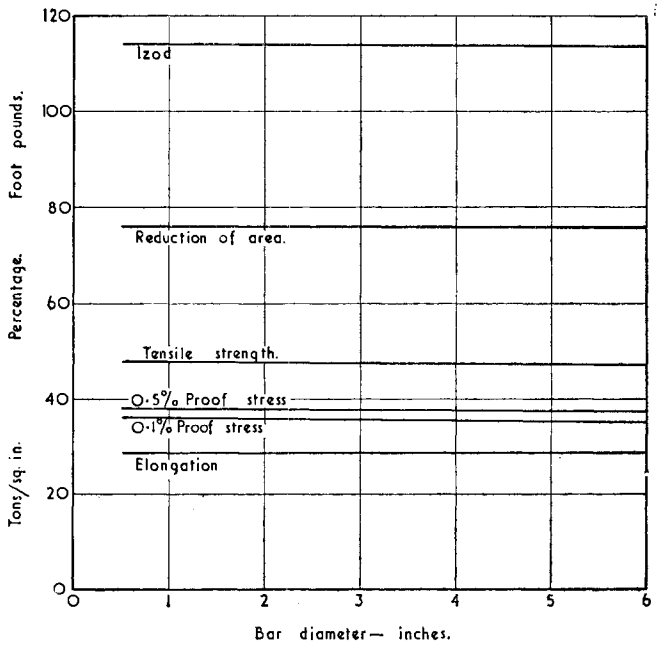


Fig. 29.16

IMPACT TRANSITION TEMPERATURE DATA

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 29A	0·20	0·22	0·51	0·015	0·019	0·15	2·81	0·44

Curve No.	Heat Treatment °C	Bar Size (in.)	ASTM Grain Size McQuaid Ehn	Tensile						
				0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)
				tons/sq.in.						
A	OQ900 T600	1 dia.	3—4	45·6	47·0	48·3	49·7	56·3	24	72½
B	" T650	1 dia.	"	39·4	40·1	40·7	41·5	49·6	27	73½
C	" T600	4 sq.	"	45·3	46·7	48·0	50·5	55·3	22½	67
D	" T650	4 sq.	"	42·1	43·5	44·4	47·1	52·4	24½	69

(Ref. 3)

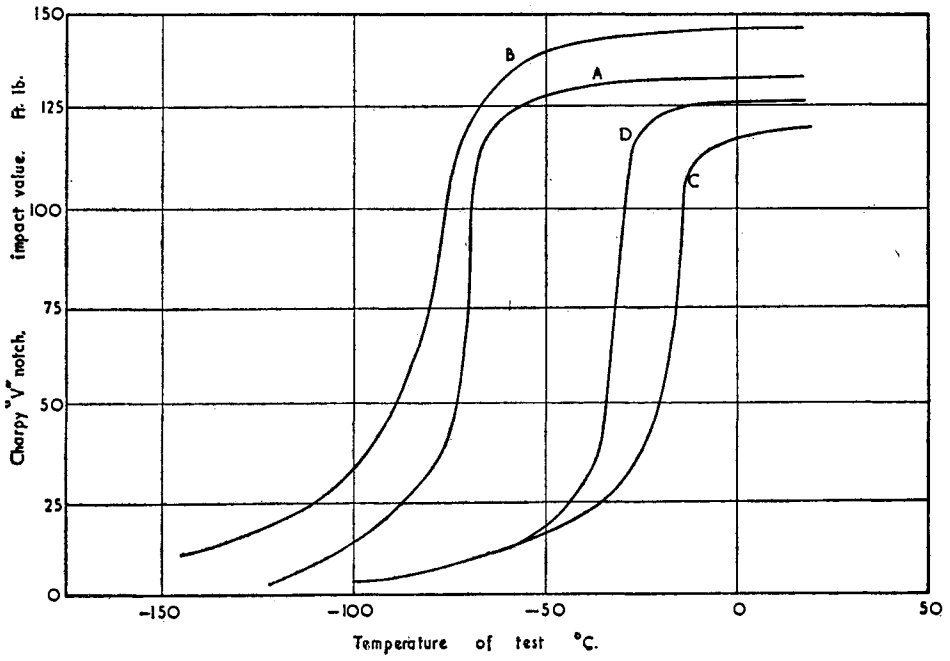


Fig. 29.17

IMPACT TRANSITION TEMPERATURE DATA (Continued)

(Ref. 3)

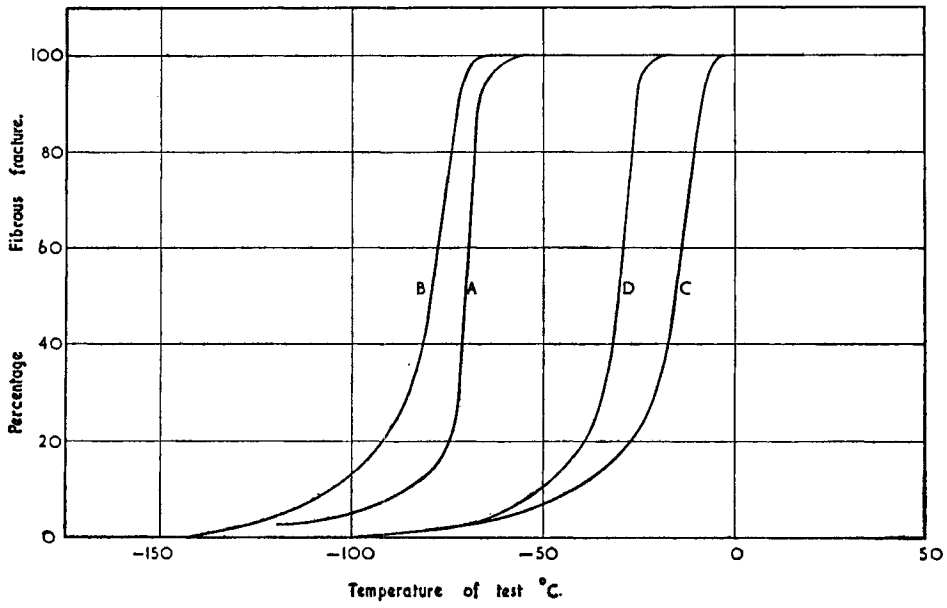


Fig. 29.18

	Curve No.	Section Size	Heat Treatment °C	Tensile					
				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)
				tons/sq.in.					
En 29B	E	1 dia.	OQ900 T600	54·5	56·2	58·3	64·4	20½	69
"	F	1 dia.	" T650	46·1	47·0	48·0	56·0	24	71
"	G	4 sq.	" T600	50·9	52·3	53·8	61·3	20	67
"	H	4 sq.	" T650	44·8	46·1	48·0	55·3	23	69½

(Ref. 3)

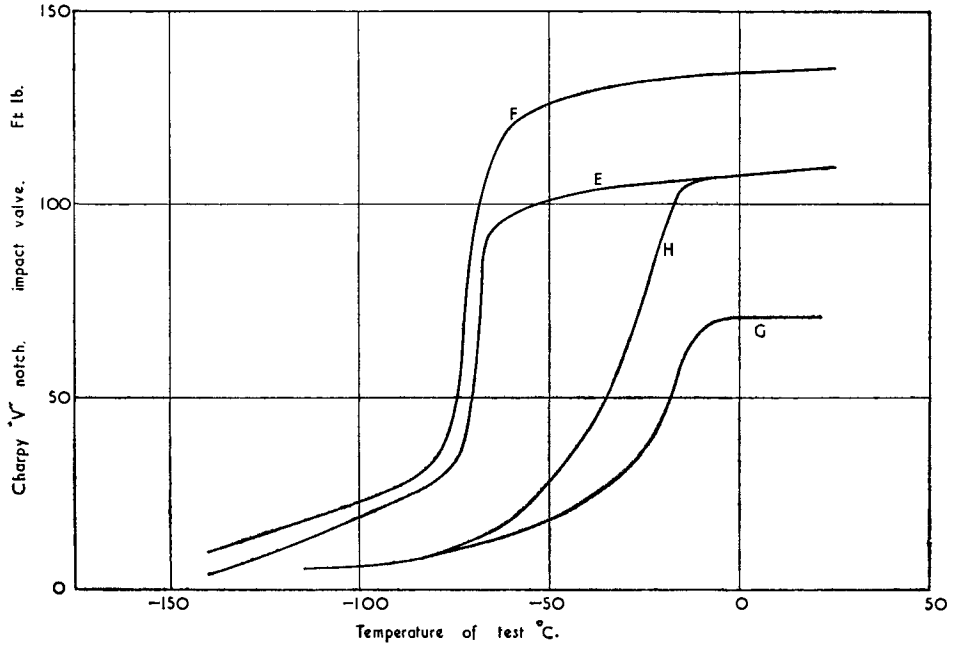


Fig. 29.19 (Ref. 3)

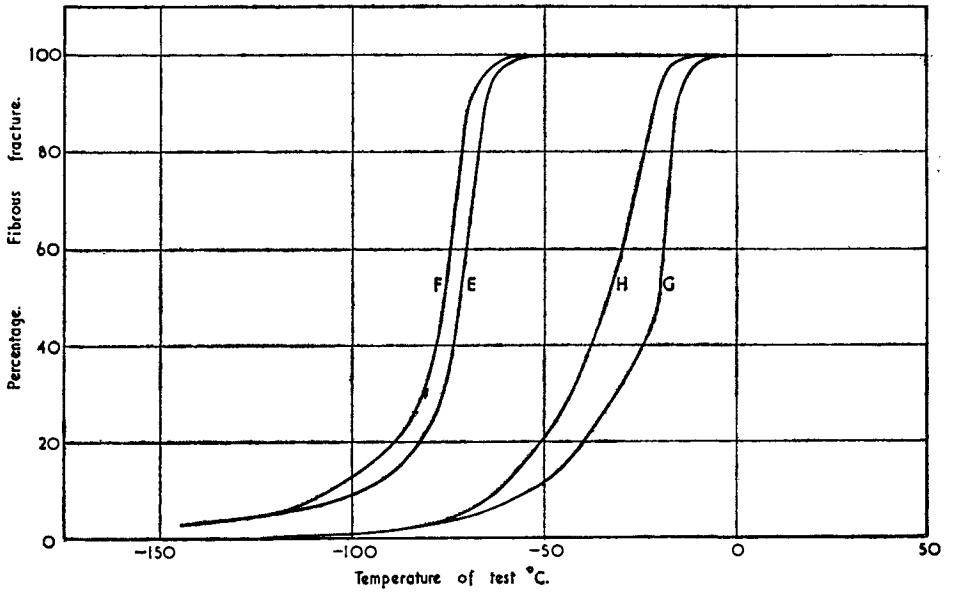


Fig. 29.20

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile L.P.	0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (tons/sq.in.)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
	0·17	0·21	0·46	0·030	0·020	0·14	2·60	0·47	1 1/16	OQ860 T650 2hr. AC	20	29	35·0	37·0	38·5	39·5	47·8	28	77	93	10
	"	"	"	"	"	"	"	"	"	" "	100	28	36·5	37·5	38	39	47	22	74		"
	"	"	"	"	"	"	"	"	"	" "	200	27	35·5	37	37·5	38·5	46	18	22		"
	"	"	"	"	"	"	"	"	"	" "	300	25	33	35	36	37·0	44	16	70		"
	"	"	"	"	"	"	"	"	"	" "	400	22	30	32	33·5	35	41	17	71		"
	"	"	"	"	"	"	"	"	"	" "	500	17	26	28	29.5	32	36	23	75		"
	0·19	0·20	0·45	0·029	0·032	0·09	3·19	0·38	12×9×9(C)	OQ900 T700OQ	20	30·0	35·2		36·2		44·6	20½	59½	74	8
	"	"	"	"	"	"	"	"	" "	" "	300	28·0	31·8		33·0		41·6	21½	64½		"
	"	"	"	"	"	"	"	"	" "	" "	350	26·0	30·0		32·6		41·9	20	61½		"
	"	"	"	"	"	"	"	"	" "	" "	400	23·6	28·8		31·1		39·9	20	61½		"
	"	"	"	"	"	"	"	"	" "	" "	450	22·0	26·0		30·7		38·8	22½	63		"
	"	"	"	"	"	"	"	"	" "	" "	500	20·0	24·8		28·3		33·3	25	71½		"
	"	"	"	"	"	"	"	"	" "	" "	550	17·6	23·0		25·9		29·9	25½	78		"
	"	"	"	"	"	"	"	"	"	(O) " "	20	29·4	35·4		36·8		45·9	27	68	74	"
	"	"	"	"	"	"	"	"	" "	" "	300	29·0	33·3		35·0		42·8	19	62½		"
	"	"	"	"	"	"	"	"	" "	" "	350	27·0	32·4		35·0		42·8	18	57		"
	"	"	"	"	"	"	"	"	" "	" "	400	24·8	30·9		33·2		41·4	20	61½		"
	"	"	"	"	"	"	"	"	" "	" "	450	22·6	28·2		30·7		38·2	23	67		"
	"	"	"	"	"	"	"	"	" "	" "	500	20·5	26·0		28·5		35·3	25	71½		"
	"	"	"	"	"	"	"	"	" "	" "	550	18·6	21·9		24·5		28·6	27	76		"
												(Rate of loading 1 ton/sq.in./min.)									
	0·20	0·23	0·43			0·17	3·12	0·44	Forging	OQ900 T685 FC	R.T.			29·3		30·8	40·6	25	62½		1
	"	"	"			"	"	"	"	" " "	100			28·4		30·0	38·0	22½	62		"
	"	"	"			"	"	"	"	" " "	200			26·3		28·0	35·6	26½	69		"
	"	"	"			"	"	"	"	" " "	250			25·7		27·9	34·7	21½	66		"
	"	"	"			"	"	"	"	" " "	300			25·5		28·0	34·4	23	67		"
	"	"	"			"	"	"	"	" " "	350			26·1		28·1	33·3	21½	60		"
	"	"	"			"	"	"	"	" " "	400			22·5		26·8	33·2	21	59		"
	"	"	"			"	"	"	"	" " "	500			23·2		25·9	30·0	26½	62		"
B.E.A.	0·20	0·21	0·50	0·012	0·012	0·08	3·16	0·45	6¾ (O)	AC900 T700 AC	20	26·0			29·0		39·2	21½	76		8
"	"	"	"	"	"	"	"	"	" "	" " "	300	21·0			24·5		33·0	15	74		"
"	"	"	"	"	"	"	"	"	" "	" " "	350	21·0			24·9		34·2	14½	72		"
"	"	"	"	"	"	"	"	"	" "	" " "	400	20·4			24·7		33·6	14½	71½		"
"	"	"	"	"	"	"	"	"	" "	" " "	450	19·0			24·0		32·0	15½	72½		"

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.	0·20	0·21	0·50	0·012	0·012	0·08	3·16	0·45	6¾ (O)	AC900 T700 AC	500	17·2			22·5		29·0	17½	76½		8
"	"	"	"	"	"	"	"	"	" "	" " "	550	15·2			21·5		25·5	18½	81½		"
"	"	"	"	"	"	"	"	"	" (C)	" " "	20	20·0			27·7		38·5	30	71		"
"	"	"	"	"	"	"	"	"	" "	" " "	300	21·0			24·7		33·6	26	73		"
"	"	"	"	"	"	"	"	"	" "	" " "	350	20·0			24·5		33·5	23	70		"
"	"	"	"	"	"	"	"	"	" "	" " "	400	19·0			24·0		33·4	22½	66		"
"	"	"	"	"	"	"	"	"	" "	" " "	450	18·0			23·5		31·2	23	70½		"
"	"	"	"	"	"	"	"	"	" "	" " "	500	17·5			22·2		28·5	27	75		"
"	"	"	"	"	"	"	"	"	6¾ (O)	OQ900 T610 OQ	20	48·0			53·4		60·3	21	68		"
"	"	"	"	"	"	"	"	"	" "	" " "	300	46·0			54·0		62·2	17½	53		"
"	"	"	"	"	"	"	"	"	" "	" " "	350	44·2			53·1		61·4	17½	54		"
"	"	"	"	"	"	"	"	"	" "	" " "	400	42·2			51·2		59·4	18½	57½		"
"	"	"	"	"	"	"	"	"	" "	" " "	450	40·2			48·4		57·9	20	66		"
"	"	"	"	"	"	"	"	"	" "	" " "	500	38·2			46·0		51·4	21½	70		"
"	"	"	"	"	"	"	"	"	" (C)	" " "	20	45·0			52·0		59·5	18	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	300	40·0			49·5		56·8	15½	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	350	38·5			48·5		56·0	15½	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	400	37·0			47·3		54·5	15½	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	450	35·5			45·7		52·0	17½	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	500	33·5			43·5		48·5	20½	—		"
"	"	"	"	"	"	"	"	"	" "	" " "	550	28·0			38·0		43·5	22	—		"
												(Rate of pulling 1 ton/sq. in./min.)									
	0·25	0·55	0·29	0·011	0·018	0·30	3·09	0·58	—	—	20		47·5	49·3			61·5	22½	72		2
	"	"	"	"	"	"	"	"	—	—	200		41·8	43·6			55·7	21½	71		"
	"	"	"	"	"	"	"	"	—	—	350		39·0	41·2			54·0	21½	63½		"
	"	"	"	"	"	"	"	"	—	—	400		36·9	39·3			52·0	23½	68		"
	"	"	"	"	"	"	"	"	—	—	450		33·0	35·9			47·9	27½	73		"
	"	"	"	"	"	"	"	"	—	—	500		26·4	30·1			41·2	28½	76½		"
	"	"	"	"	"	"	"	"	—	—	550		19·2	21·6			35·1	30½	82½		"
	"	"	"	"	"	"	"	"	—	—	650		6·2	7·3			17·7	46	92		"
	"	"	"	"	"	"	"	"	—	—	800		1·4	1·6			5·5	85½	94½		"

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

(Continued)

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment C°	Test Temperature °C	Y.P. (Rs)	T.S. (Rm)	Charpy ft.lb.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				tons/sq.in.			
0·31	0·18	0·58	0·012	0·023	0·35	3·30	0·53	0·1265	OH T60	RT	58·6	72·5	54	11
"	"	"	"	"	"	"	"	"	" "	250	52·9	66·0	81	"
"	"	"	"	"	"	"	"	"	" "	350	52·8	64·8	76	"
"	"	"	"	"	"	"	"	"	" "	450	45·8	63·1	73	"
"	"	"	"	"	"	"	"	"	" "	550	39·7	55·3	65	"
"	"	"	"	"	"	"	"	"	" "	650	33·6	38·7	85	"
"	"	"	"	"	"	"	"	"	" "	750	8·1	10·6	203*	"
"	"	"	"	"	"	"	"	"	" "	850	4·3	6·0	153*	"
			"	"	"	"	"	"	" "	950	2·2	3·9	127*	"
"	"	"												
"	"	"	"	"	"	"	"	"	OH 950	RT	100·5	114·5	4	"
"	"	"	"	"	"	"	"	"	" "	250	90·0	110·3	28	"
"	"	"	"	"	"	"	"	"	" "	350	80·7	95·0	24	"
"	"	"	"	"	"	"	"	"	" "	450	71·5	83·7	19	"
"	"	"	"	"	"	"	"	"	" "	550	60·0	66·5	27	"
"	"	"	"	"	"	"	"	"	" "	650	37·0	39·5	68	"
"	"	"	"	"	"	"	"	"	" "	750	6·25	8·7	207*	"
"	"	"	"	"	"	"	"	"	" "	850	4·5	6·2	144*	"
"	"	"	"	"	"	"	"	"	" "	950	1·9	3·4	127*	"
											Rate of straining on tensile tests 0·054/min.		* Unbroken	

CREEP PROPERTIES

Chemical Composition (%)	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Stress tons/sq. in. to produce stated percentage creep deformation in						Ref.
				100 hr			300 hr	1000 hr		
				0·1%	0·5	1·0%	0·1%	0·1%	0·2%	
(within specification)	1¼	OH & T (TS 70 tons/sq.in)	350	48·0						4
	"	" "	400	38·0			27·0	20·0	—	"
	"	" "	450	25·0			16·0	11·6	18·4	"
	"	" "	500	12·0			8·9	6·0	9·2	"
	"	" "	550	5·9	7·5	10·0	4·6	3·4	4·8	"

MECHANICAL PROPERTIES AT HIGH TEMPERATURE: CREEP PROPERTIES (Continued)

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Stress tons/sq. in. to produce stated creep rate		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				10^{-6}	10^{-7}	
0·19	0·20	0·45	0·029	0·032	0·09	3·19	0·38	12×9×9 (0)	OQ900 T700OQ	400	26·0	20	8
"	"	"	"	"	"	"	"	"	" " "	450	15·3	11	"
"	"	"	"	"	"	"	"	"	" " "	500	9·0	6	"
"	"	"	"	"	"	"	"	"	" " "	550	4·7	2·8	"

STRESS/RUPTURE, TOTAL CREEP AND CREEP RATE PROPERTIES OF EN 29A

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·17	0·21	0·46	0·030	0·020	0·14	2·6	0·47

$1\frac{1}{16}$ in. dia. bars Oil Quenched 860°C. Tempered 650°C 2 hr. A.C.

Temperature 500°C. (Ref. 10)

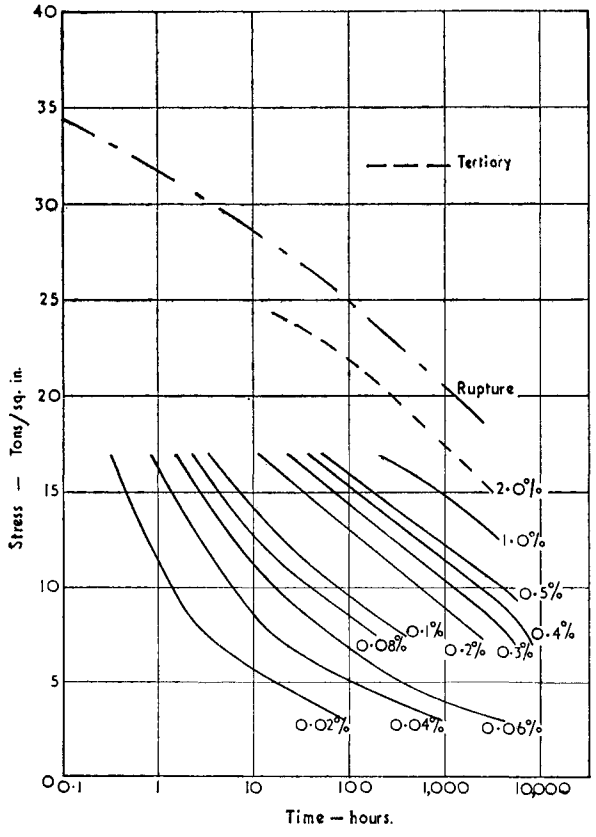


Fig. 29.21

Temperature 550°C. (Ref. 10)

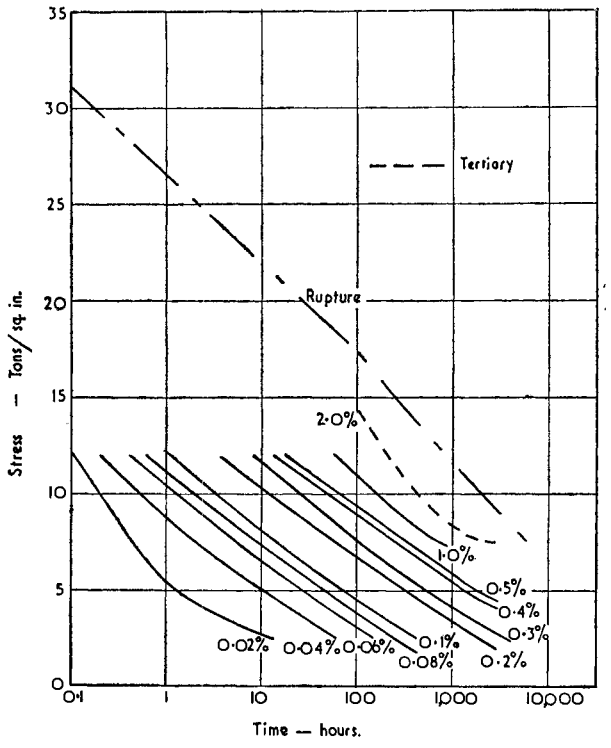


Fig. 29.22

Creep Rate at 500°C and 550°C. (Ref. 10)

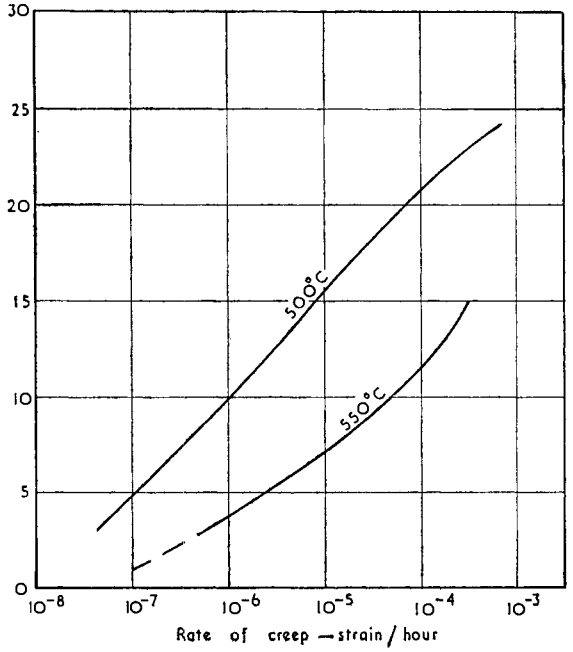


Fig. 29.23

MECHANICAL PROPERTIES IN TORSION

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Tensile Test				Torsion Test			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	0·1% P.S (0·1Rp) tons/sq. in.	Apparent Max. Shear Strength tons/sq. in.	Probable Max. Shear Strength tons/sq. in.	
0·28	0·24	0·48	0·008	0·008	0·33	2·96	0·35	OH and T	RT	56·0	69·2	21	65	37·0	57·6	43·2	12

FATIGUE PROPERTIES

ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Izod ft.lb.	Rotating Bend Fatigue Limit tons/sq. in.		Reversed Bend Fatigue Limit tons/sq. in.		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				L.P. tons/sq.in.	0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		Unnotched	Notched*	Unnotched	Notched*	
7—8	0·29	0·23	0·50	0·025	0·011		3·32	0·55	¾	OQ900 T620	RT		48·6		53·0	63·6	24½	70	81	±32	±14			2
	0·31		0·55				3·16	0·54	”	” ”	”					61·7				±35·1	±14·8	±29	±8·5	”
8	0·31		0·62				3·16	0·60	”	” T610	”				58·6	67·9	25	68	81	±38	±12·5			”
	0·31	0·18	0·58	0·012	0·023	0·35	3·30	0·53	1¾	OQ870	RT	34		83·3		125·1	11	34						11
	”	”	”	”	”	”	”	”	”	” T165	”	62		90·0		121·2	11	35					±38	”
	”	”	”	”	”	”	”	”	”	” T223	”	60		88·0		111·4	14½	41					±40	”
	”	”	”	”	”	”	”	”	”	” T416	”	66		83·7		99·8	15	45					±39	”
	”	”	”	”	”	”	”	”	”	” T700	”	30		40·5		50·7	28	74½					±22¼	”
	not stated									OH & T	20		49·3			62·5	22	72		±36·5				4
										” ”	200		46·5			59·5	23	70		±34·5				”
										” ”	400		39·3			52·0	23	68		±31·5				”
										” ”	450		35·9			47·9	27	73		—				”
										” ”	500		30·1			41·2	28	76		±28·0				”
										” ”	600		12·5			24·0	46	92		—				”

* Notches: — 56°V, 0·008 in. root radius, 0·020 in. deep. Test dia. 0·335, dia. at root 0·295.
K = 2·85 for rotary bending.
K = 3·3 for axial loading.

LIST OF REFERENCES

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3. Private correspondence with The English Steel Corporation Ltd.
4. Private correspondence with Rolls-Royce Ltd.
5. Atlas of Isothermal Transformation diagrams of B.S. En Steels, Second Edition. Special Report No. 56 of The Iron & Steel Institute, 1956.
6. Symposium on the Hardenability of Steel. Organized by the Technical Advisory Committee of the Special and Alloy Steels Committee (Ministry of Supply), and the Iron & Steel Institute. Special Report No. 36 of The Iron & Steel Institute. 1946.
7. B.S. 971: Commentary on The British Standard Wrought Steels En Series. British Standards Institution, London, 1950.
8. Private correspondence with Edgar Allen and Co. Ltd.
9. Private correspondence with Jessop-Saville Ltd.
10. B. I. Connolly and G. Boyd. The High Temperature Properties of Four Wrought Steels Used in the Chemical Industry. *Proceedings of the Institution of Mechanical Engineers*, 1958, Vol. 172, No. 31 .
11. War Office, unpublished report.
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4¼ PER CENT NICKEL–CHROMIUM STEEL
(WITH OR WITHOUT MOLYBDENUM)

SPECIFICATION

CHEMICAL COMPOSITION (%)

En No.	C	Si	Mn	S	P	Ni	Cr	Mo
30A	0·26—0·34	0·10—0·35	0·40—0·60	0·050max.	0·050max.	3·90—4·30	1·10—1·40	—
30B	0·26—0·34	0·10—0·35	0·40—0·60	0·050max.	0·050max.	3·90—4·30	1·10—1·40	0·20—0·40

MECHANICAL PROPERTIES

	En 30A	En 30B
Tensile strength, tons/sq.in., min. (Rm)	100	100
Yield stress(1) tons/sq.in., min. (Rs)	85	85
0·2% proof stress(2) tons/sq.in., min. (0·2Rp)	80	80
Elongation, % min. (A)	10	10
Izod impact value, ft. lb., min.	10	15
Brinell hardness No.(3) min. (HB)	444	444

When supplied in the softened condition the material shall have a Brinell hardness number not exceeding 285.

(1) Not to be used as acceptance tests except by special arrangement between the purchaser and manufacturer.
(2) When specifically requested in the enquiry or order.
(3) For information purposes only. Not contractual part of the specification.

RELATED SPECIFICATIONS

En No.	United Kingdom	France	Germany		Sweden
	BS Air	AFNOR	Werkstoff No.	Name	SIS
30 A	4T2 T57	35NC15	1·5864	35NiCr18	14·2536
30 B	3S28	35NCD16	1·2766	35NiCrMo16	

En 30

APPLICATIONS

These steels have the ability to harden in fairly large sections when cooled in air from the hardening temperature. Both will air harden in ruling sections up to 2½ in. dia. giving tensile strengths over 100 tons/sq.in. Over 2½ in. dia. the 100 ton/sq.in. tensile strength conditions may not be obtained by air hardening but can be obtained up to 6 in. dia. by oil quenching. If air hardening is required in sections over 2½ in. dia. En 30B should be used, as this has higher hardenability due to its molybdenum content. En 30B also has better impact properties.

These steels are used for applications requiring high tensile strengths where more drastic quenches would produce distortion or cracking, especially in parts of intricate design.

TYPICAL APPLICATIONS

High duty gears, pinions, aero engine connecting rods, differential shafts and other transmission components, gudgeon pins, air frame forgings, heavy roller bearings, breech mechanisms and small arms components, moulds for plastics.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table)

	Welding Process					
	MA	G	IG	S	F	B
En 30 B	e	dx	g	f	b	j

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MACHINABILITY

In the fully softened condition the machinability is approximately 40% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C. Retarded cooling is advisable for large or intricate sections.
Annealing	810°C—830°C. Furnace cool.
Softening	610°C—630°C. Air or furnace cool.
Hardening	810°C—830°C. Air cool. For full hardening in sizes above 2½ in. oil quenching is necessary.
Tempering	Up to 250°C.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·30	0·25	0·45			4·25	1·25	—	Softened 650	7·87	1
0·28	0·23	0·48	0·004	0·018	4·42	1·36	—	AH & T(100t.s.i)	7·82	2
0·29	0·42	0·26	0·014	0·021	4·23	1·26	—	AH820 T250	7·83	3
0·30	0·50	0·22	0·046	0·032	4·09	1·23	0·21	" "	7·83	"

SPECIFIC HEAT (c)

Chemical Composition (%)						Heat Treatment °C	Specific Heat cal/g deg. C 20° to 100°	Ref.
C	Si	Mn	Ni	Cr	Mo			
0·30	0·25	0·45	4·25	1·25	—	Softened 650	0·120	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	10^6 × Mean Coefficient of Thermal Expansion/ deg. C					Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 500°C	20to 700°C	
0·30	0·25	0·45			4·25	1·25	—	Softened 650	11		13	14	15	1
	not stated							—	11·9		12·9	13·5	13·7(680°C)	4
0·29	0·26	0·42	0·014	0·021	4·23	1·26	—	AH820 T250	10·6	12·0	12·3 (250°C)			3
0·30	0·22	0·50	0·046	0·032	4·09	1·23	0·21	" "	11·4	12·3				"

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm							Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	300°C	400°C	500°C	600°C	
0·30	0·25	0·45			4·25	1·25	—	Softened 650	25							1
0·29	0·26	0·42	0·014	0·021	4·23	1·26	—	AH820 T250	37·0	41·6	49·3					3
0·30	0·22	0·50	0·046	0·032	4·09	1·23	0·21	" "	38·5	44·0	52·3	62·1	72·8	86·5	101·0	"

YOUNG'S MODULUS (E), SHEAR MODULUS (G), POISSON'S RATION (σ)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.		Shear Modulus tons/sq.in.		Poisson's Ratio		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic	Static	Dynamic	Static	Dynamic	
0·35	0·20	0·41			4·21	1·22	—	Softened 650	20		13,200(1)					1
"	"	"			"	"		"	200		12,800					"
"	"	"			"	"		"	400		11,500					"
"	"	"			"	"		"	600		10,200					"
0·28	0·23	0·48	0·004	0·018	4·42	1·36	—	AH820 T200 AC	20	13,400	13,200(2)	5,140	5,120(2)	0·30(3)	0·29(3)	2
0·29	0·26	0·42	0·014	0·021	4·23	1·26	—	AH820 T250	20		13,000(1)					3
"	"	"	"	"	"	"		" "	100		12,700					"
"	"	"	"	"	"	"		" "	200		12,400					"
0·30	0·22	0·50	0·046	0·032	4·09	1·23	0·21	AH820 T250	20		12,900(1)					3
"	"	"	"	"	"	"	"	" "	100		12,700					"
"	"	"	"	"	"	"	"	" "	200		12,300					"
"	"	"	"	"	"	"	"	" "	300		11,900					"
"	"	"	"	"	"	"	"	" "	400		11,400					"
"	"	"	"	"	"	"	"	" "	500		10,800					"
"	"	"	"	"	"	"	"	" "	600		10,200					"
0·31	0·19	0·44	0·013	0·018	4·29	1·47	—	AH820	RT	12,800		4,950		0·29(3)		1
"	"	"	"	"	"	"		" T200	"	12,800		4,950		0·29(3)		"
"	"	"	"	"	"	"		" T400	"	12,800		—		—		"
"	"	"	"	"	"	"		" T600	"	12,800		5,000		0·28(3)		"
																"

(1) Vibration method.
(2) Ultrasonic Pulse Method.
(3) Calculated

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 30A	0·35	0·14	0·44	0·008	0·016	4·23	1·43	0·13

Basic Electric Arc.

McQuaid Ehn grain size 4 to 5 (ASTM).

As quenched grain size 9 (ASTM).

Austenitizing Temperature 820°C.

(Ref. 5)

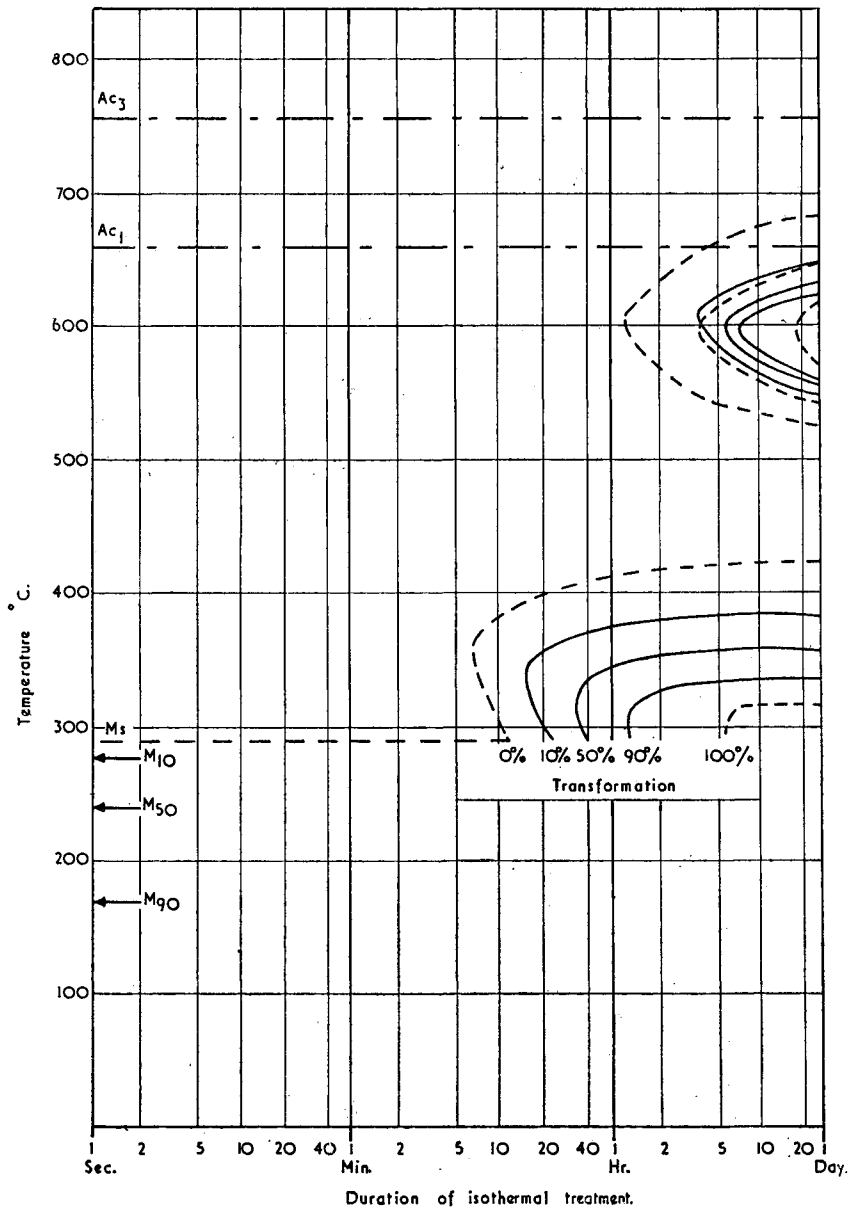


Fig. 30.1

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 30B	0·33	0·17	0·51	0·009	0·013	4·16	1·44	0·31

Basic Electric Arc.
McQuaid Ehn grain size 4 to 5 (ASTM).
As quenched grain size 9 (ASTM).
Austenitizing Temperature 820°C.

(Ref. 5)

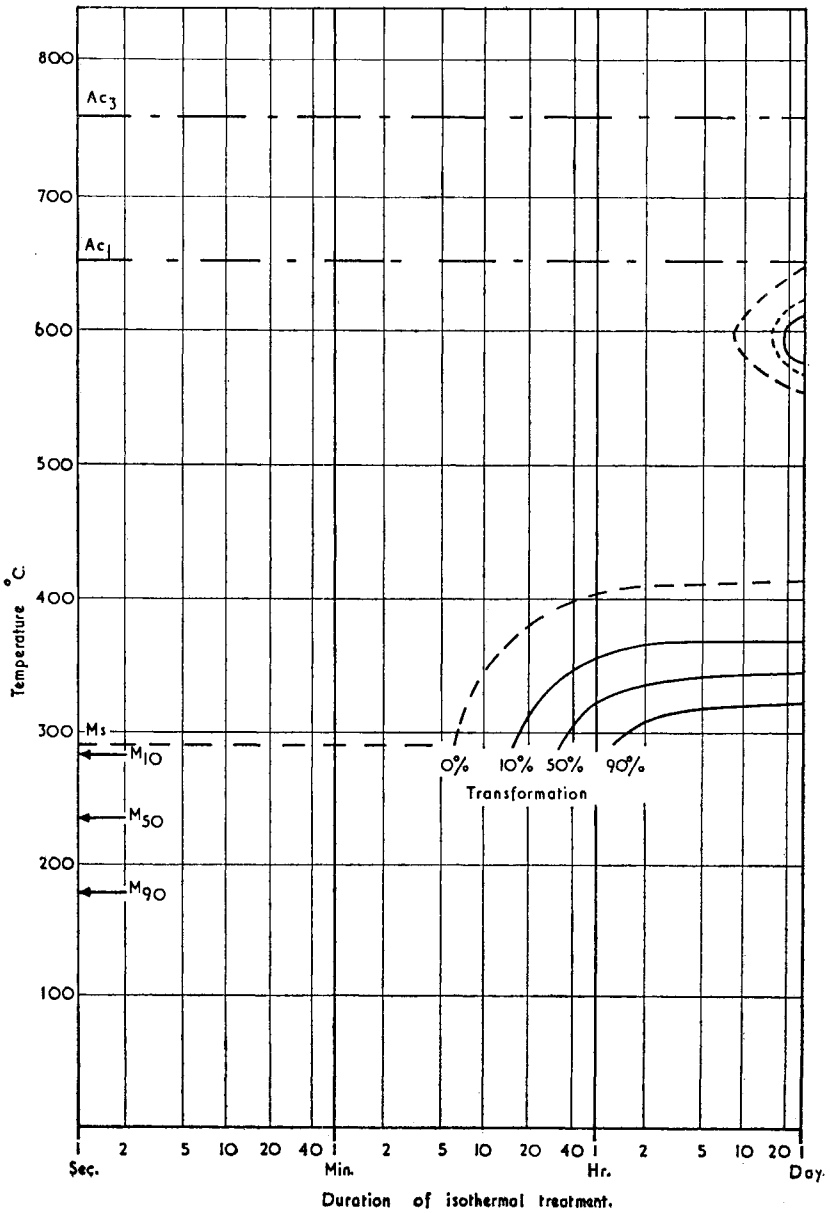


Fig. 30.2

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 30B	0·32	0·29	0·47	0·020	0·022	4·13	1·21	0·30

Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to 4 S.W.G., cold drawn to 11 S.W.G. with intermediate annealing at 600°C.
Austenitizing Temperature 820°C, 30 min. (Ref. 6)

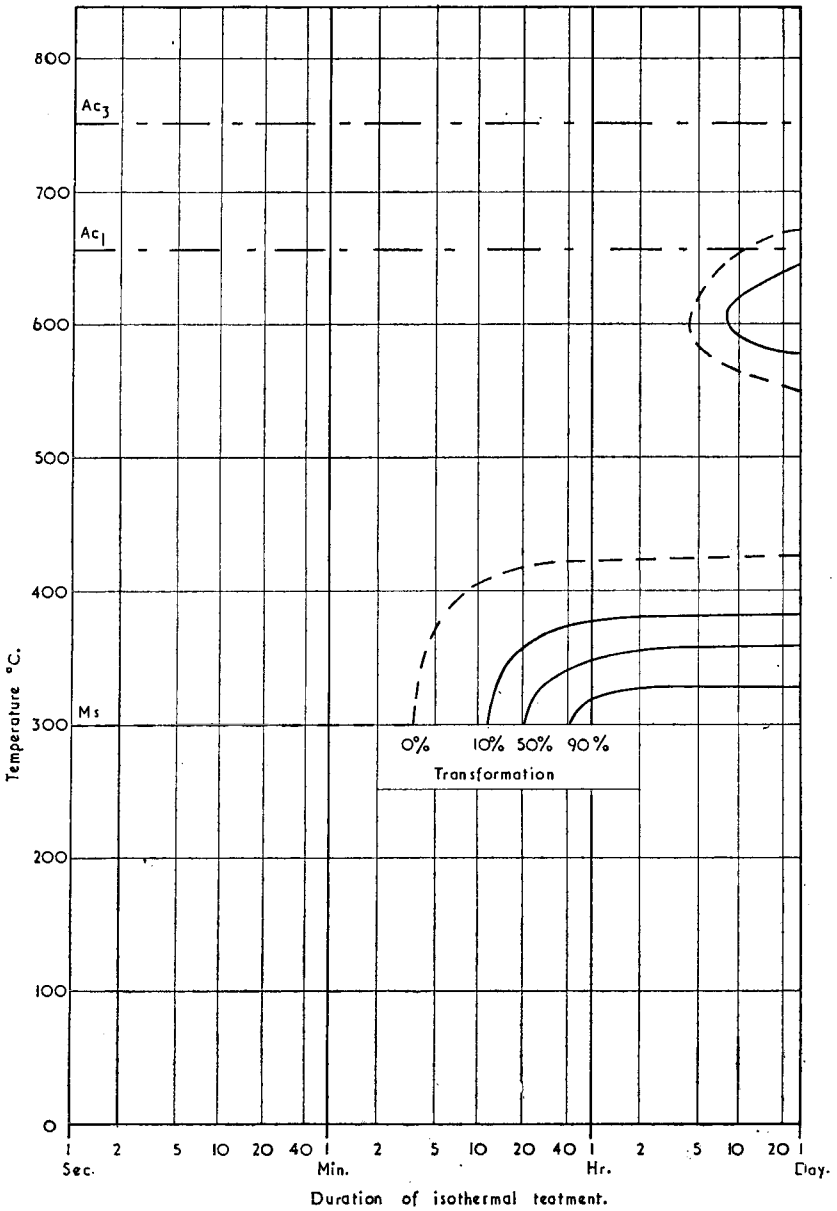


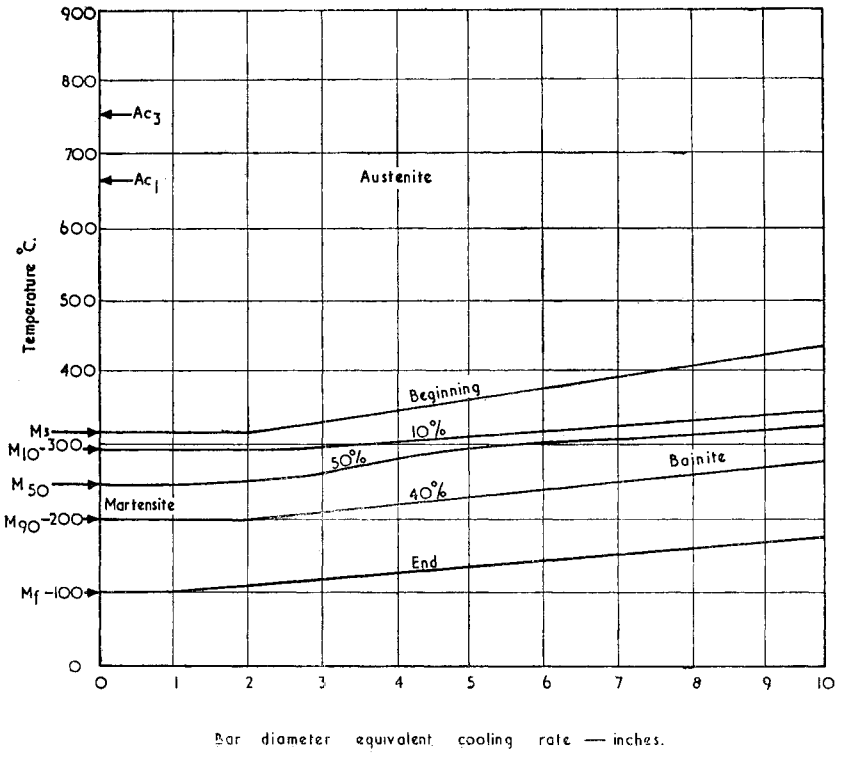
Fig. 30.3

CONTINUOUS COOLING TRANSFORMATION

Typical curves for En 30A and En 30B

En 30A-Air Cooled from 820°C.

(Ref. 3)



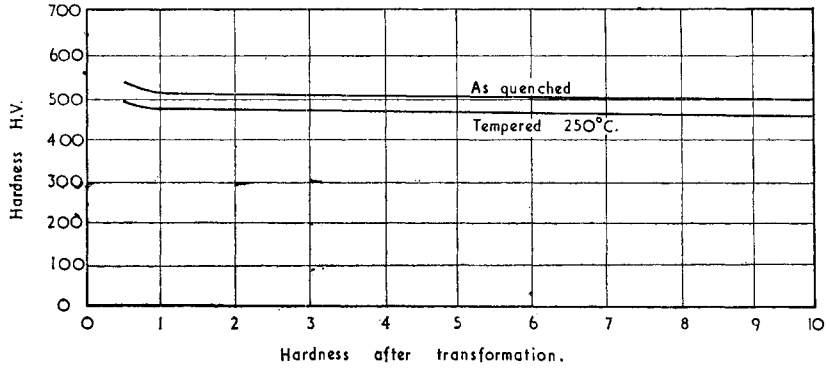
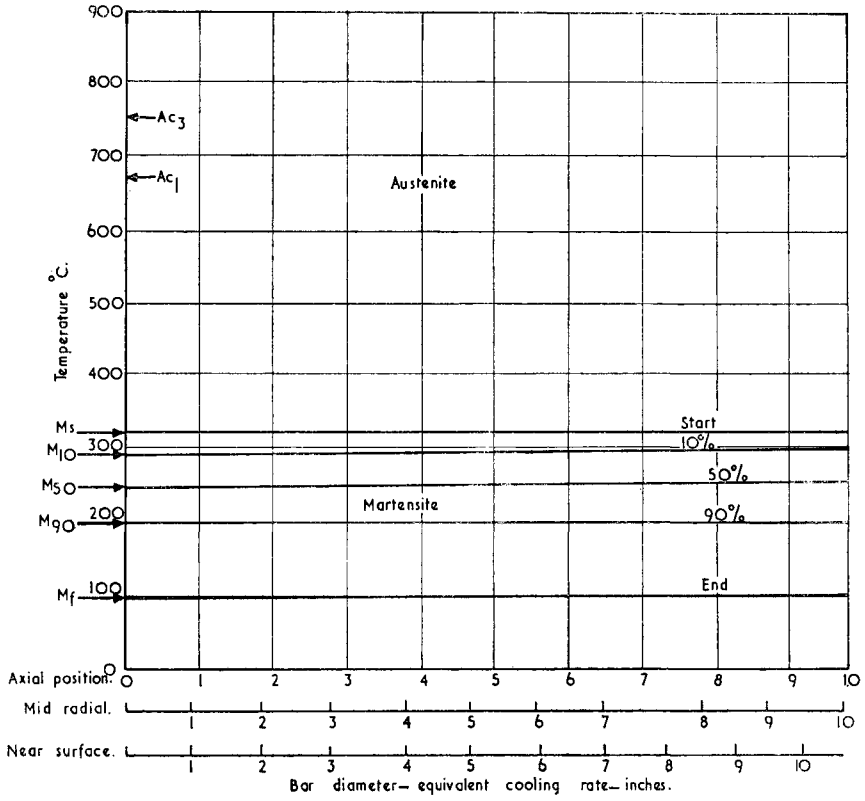


Fig. 30.4

CONTINUOUS COOLING TRANSFORMATION (Continued)

En 30A-Oil Quenched from 820°C.

(Ref. 3)



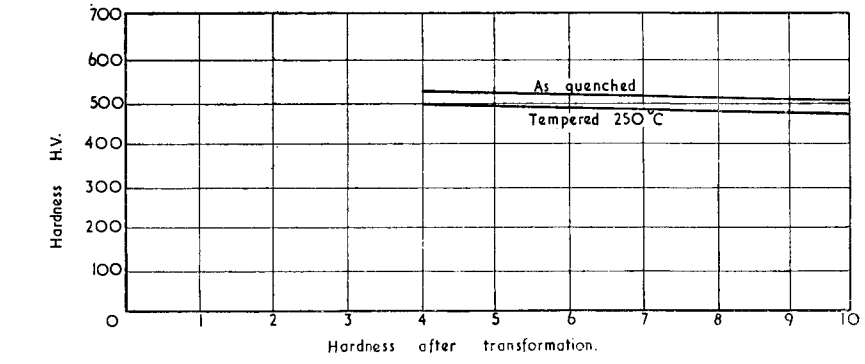
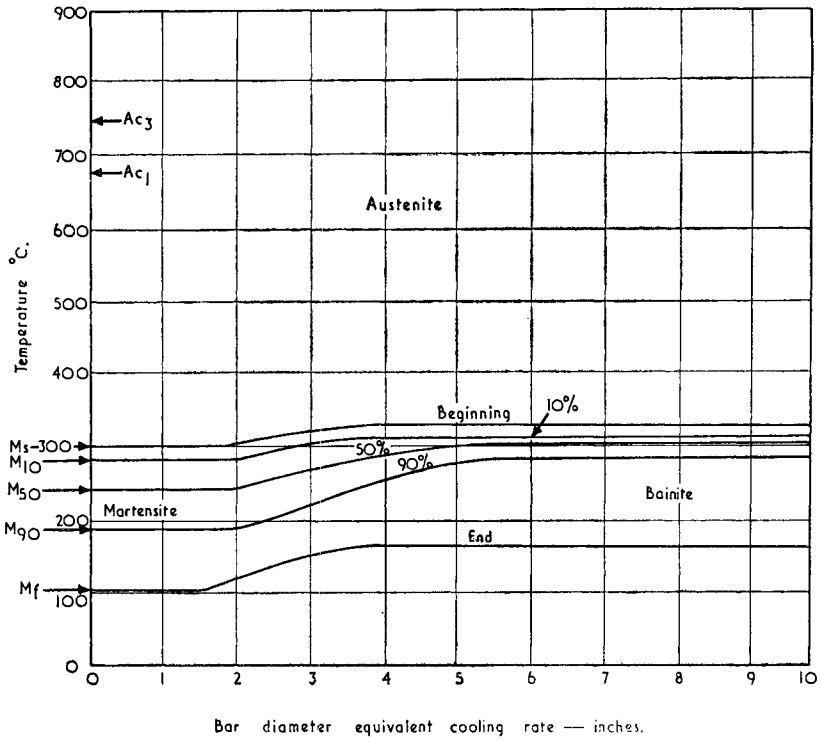


Fig. 30.5

CONTINUOUS COOLING TRANSFORMATION (Continued)

En 30B-Air Cooled from 820°C.

(Ref. 3)



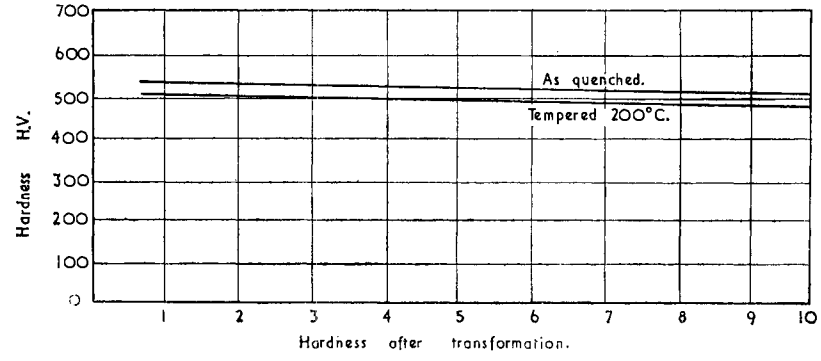


Fig. 30.6

CONTINUOUS COOLING TRANSFORMATION (Continued)

En 30B-Oil Quenched from 820°C.

(Ref. 3)

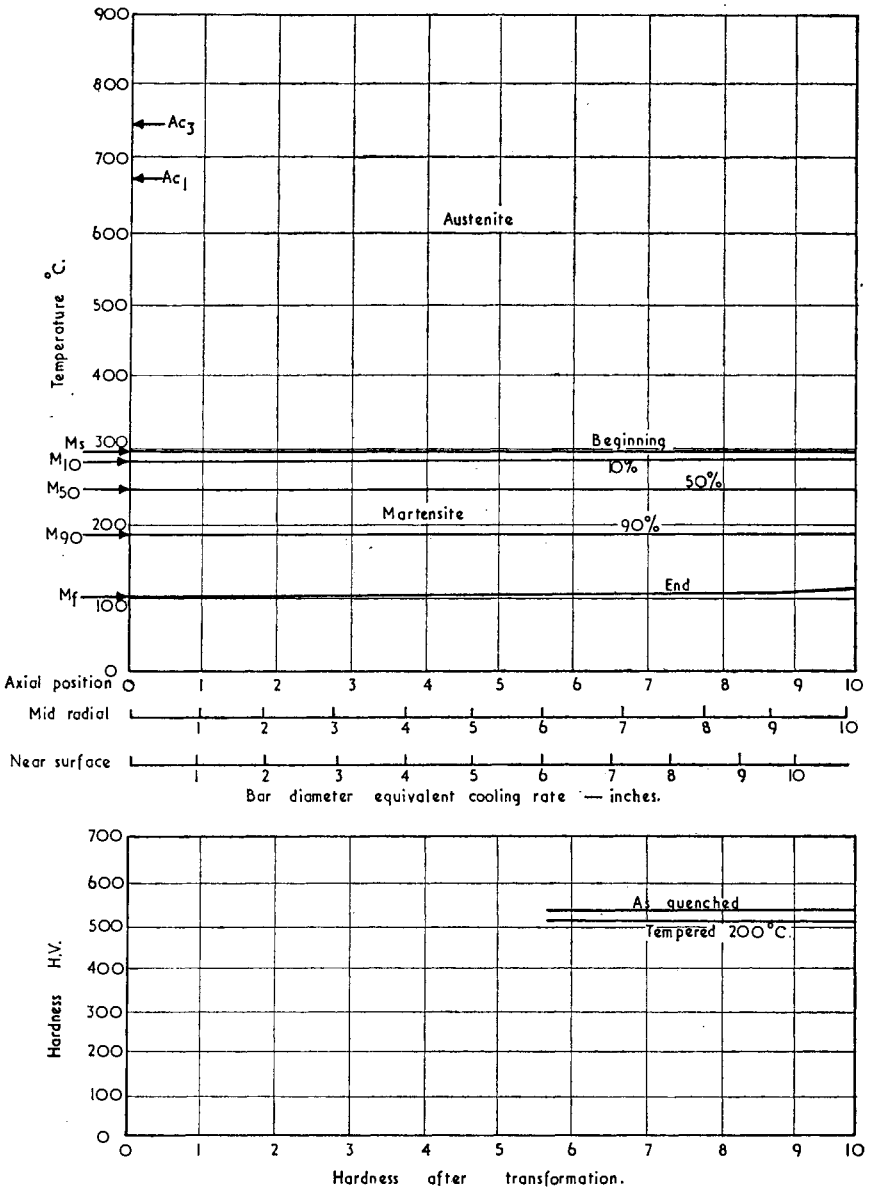


Fig. 30.7

HARDENABILITY

END QUENCH HARDENABILITY DATA

	Chemical Composition (%)								Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	
En 30A	0·29	0·22	0·45	0·015	0·022	4·15	1·17	0·12	7

Basic Electric Arc.
End Quenched 830°C.

(Ref. 7)

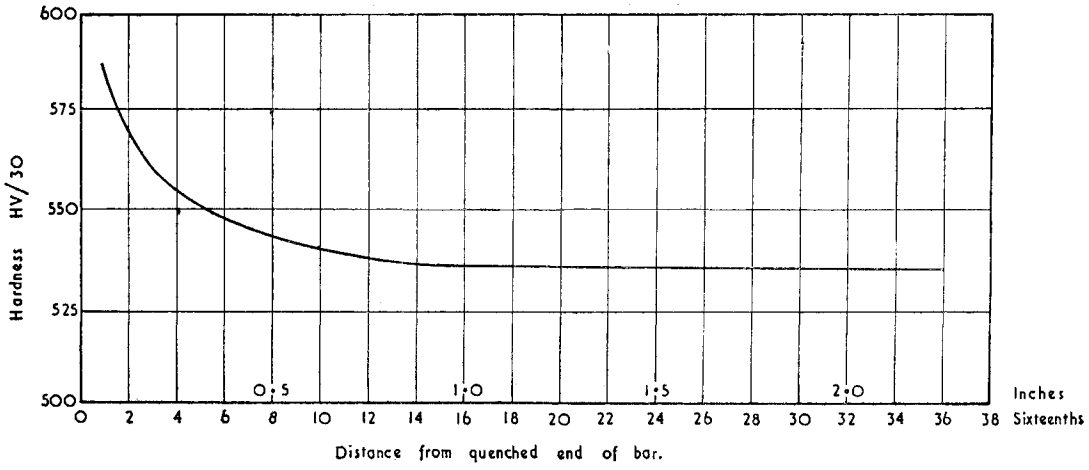


Fig. 30.8

	Chemical Composition (%)								Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	
En 30B	0·32	0·29	0·47	0·020	0·022	4·13	1·21	0·30	6

Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size 7 (ASTM).
End Quenched from 820°C.

(Ref. 6)

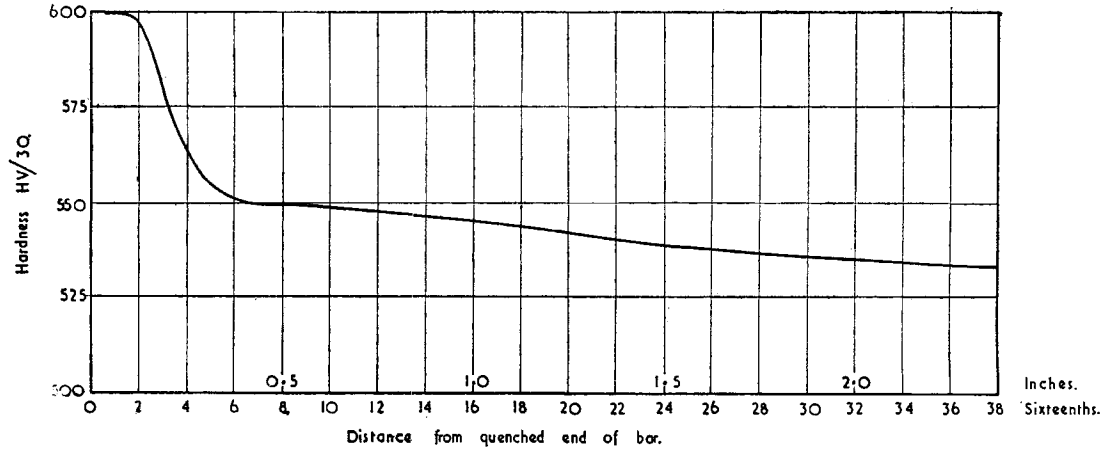


Fig. 30.9

END QUENCH HARDENABILITY DATA (Continued)

	Curve No.	Chemical Composition (%)								Grain Size (ASTM)		Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid	
En 30A	A	0·30	0·27	0·45	0·014	0·009	4·40	1·37	0·09	6—7	6	7
" "	B	0·29	0·20	0·49	0·036	0·016	4·18	1·27	0·09	7—8	7—8	"

Test bars Air Cooled 875°C. End Quenched from 850°C.

End Quenched (Ref. 7)

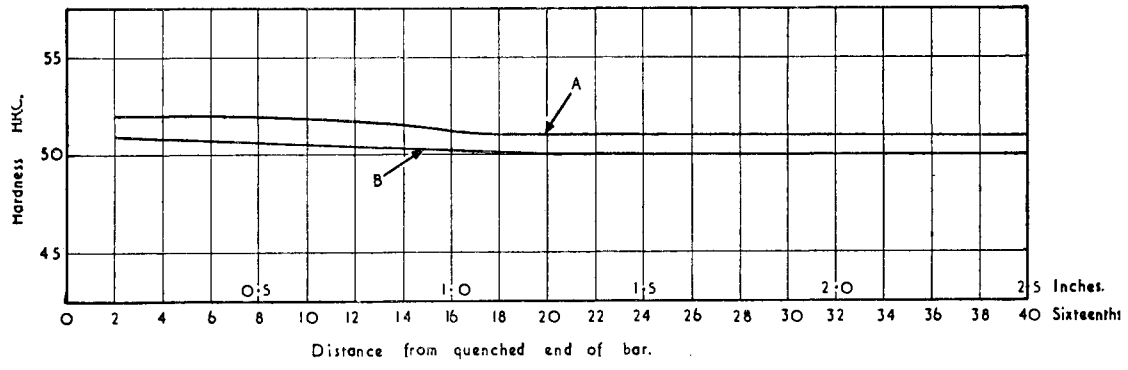


Fig. 30.10

End Quenched & Tempered (Ref. 7)

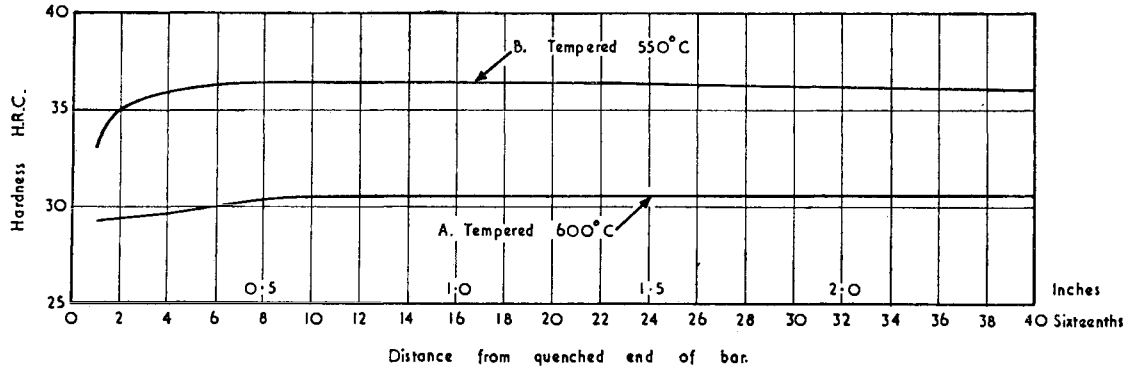


Fig. 30.11

END QUENCH HARDENABILITY DATA (Continued)

	Chemical Composition (%)								Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	
En 30B	0·33	0·17	0·51	0·009	0·013	4·16	1·44	0·31	5

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
As quenched grain size 9 (ASTM).
End Quenched from 820°C.

(Ref. 5)

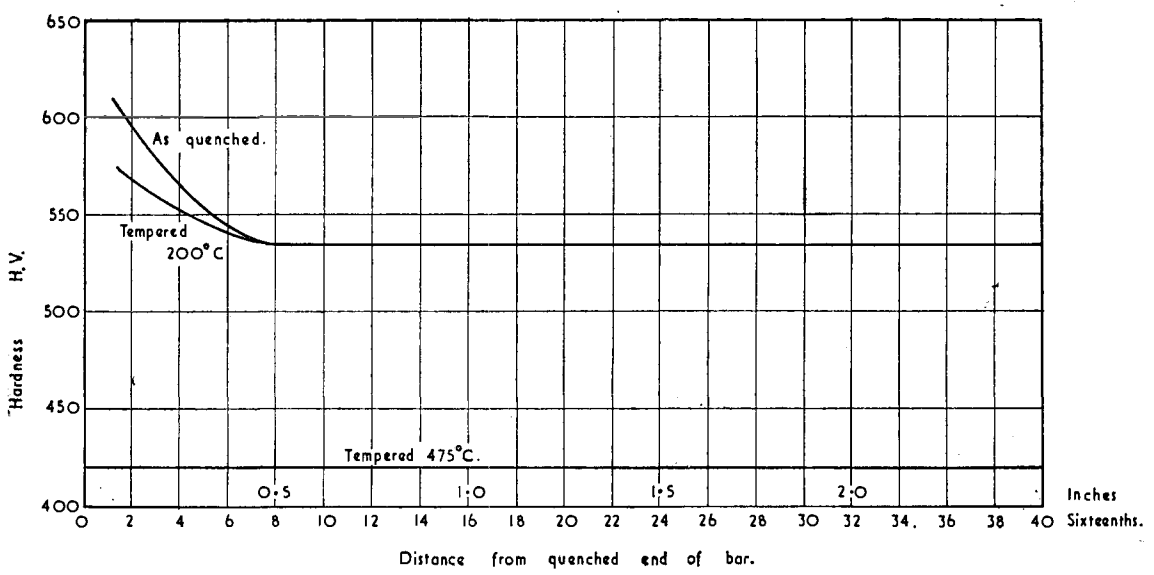


Fig. 30.12

END QUENCH HARDENABILITY BAND

These curves have been constructed from the results obtained on several casts of En 30A and En 30B.

(Ref. 4.)

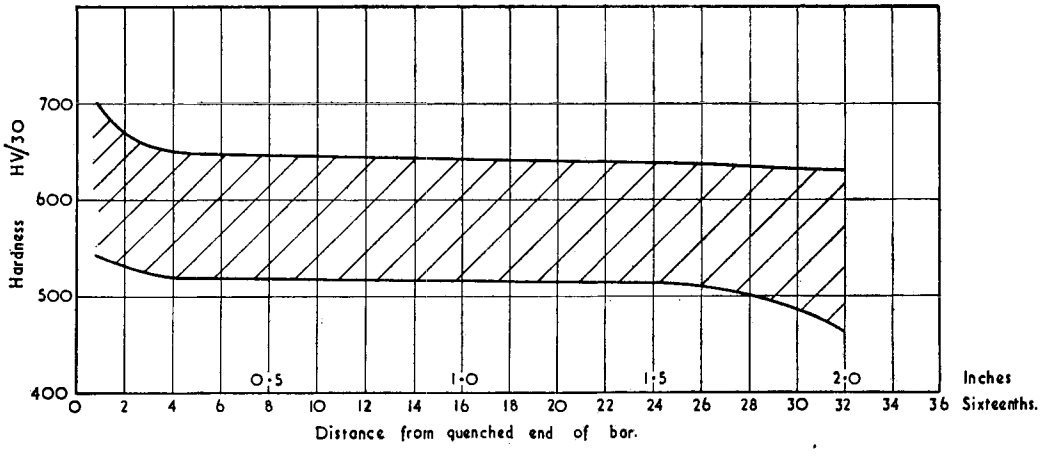


Fig. 30.13

HARDNESS TRAVERSE CURVES

	Chemical Composition (%)								Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	
En 30A	0·29	0·22	0·45	0·015	0·022	4·15	1·17	0·12	7

Bars quenched in oil from 830°C. Tests were carried out at two laboratories.

Laboratory A. (Ref. 7)

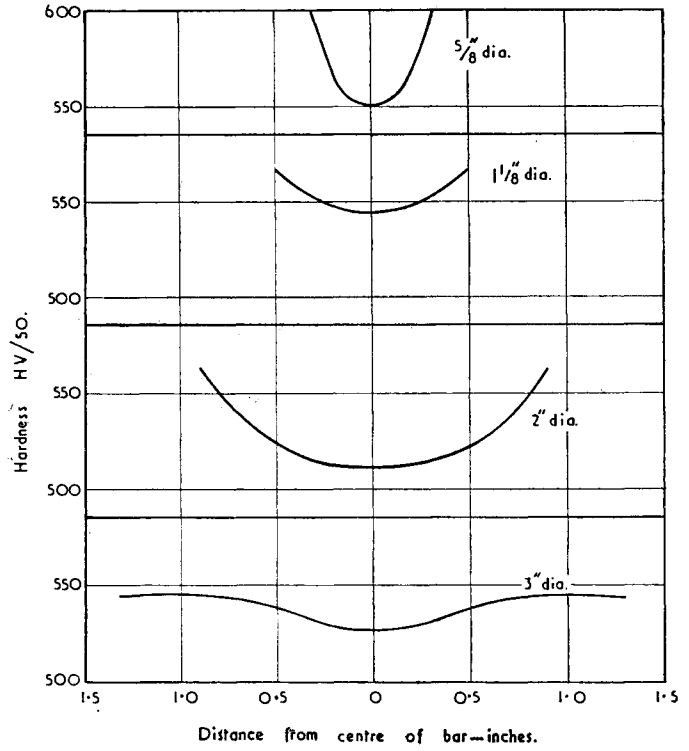


Fig. 30.14

Laboratory B. (Ref. 7)

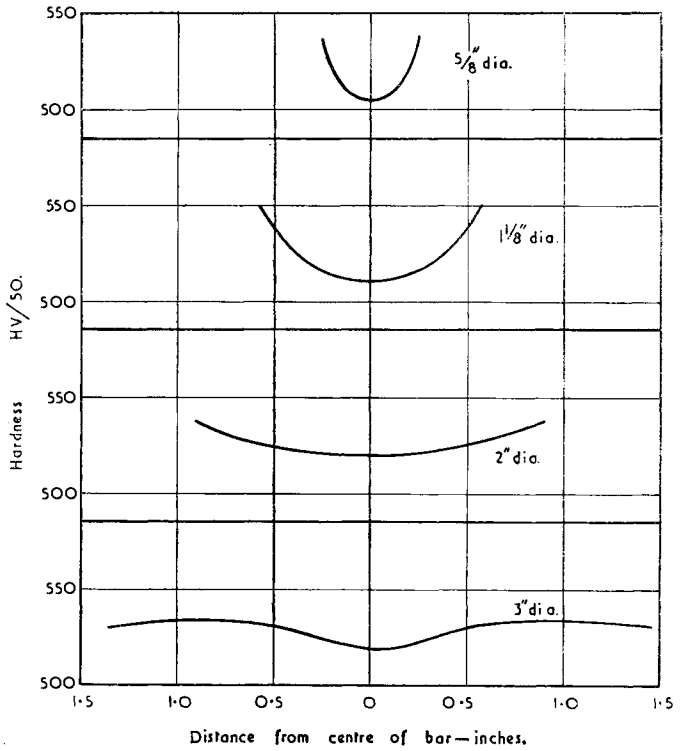


Fig. 30.15

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.							
	0·26		0·42			4·32	1·37	—	0·564	AH820		64·2		106·9	14½	44	26	3
	"		"			"	"	—	"	" T150		70·8		105·5	14	44	28	"
	"		"			"	"	—	"	" T200		74·8		104·6	14½	44	28	"
	"		"			"	"	—	"	" T250		80·8		102·1	15	50	26	"
	"		"			"	"	—	"	" T300		84·0		98·9	15	52	21	"
	"		"			"	"	—	"	" T350		81·8		95·5	15	50	18	"
	"		"			"	"	—	"	" T400		82·0		92·2	14½	50	16	"
	"		"			"	"	—	"	" T450		77·2		85·6	14½	52	19	"
	"		"			"	"	—	"	" T500		71·4		78·1	16½	55	23	"
B.E.A.	0·26	0·23	0·45	0·029	0·029	4·03	1·17	0·29	"	AH820 T180 AC	59·5			107·0	13	44½	23	8
	0·26		0·49			4·38	1·38	0·20	"	" T200			92·0	106·3	15	50	33	3
	0·26		0·57			4·17	1·25	0·17	"	AH820 T200			81·0	103·0	15			9
	0·26		0·46			4·10	1·20	0·33	"	AH820 T200			86·0	102·5	16			"
	0·26		0·45			4·24	1·25	0·23	"	OQ820 T250			90·1	102·6	15½	52	28	3
	0·27		0·40			4·30	1·35	—	0·564	AH 820		70·8		111·8	14	43	28	3
	"		"			"	"	—	"	" T150		70·4		111·0	15	50	29	"
	"		"			"	"	—	"	" T200		77·6		107·4	15½	50	29	"
	"		"			"	"	—	"	" T250		84·2		106·3	15	50	27	"
	"		"			"	"	—	"	" T300		84·4		100·8	13	50	22	"
	"		"			"	"	—	"	" T350		83·0		98·2	14½	50	21	"
	"		"			"	"	—	"	" T400		82·4		94·2	13	50	19	"
	"		"			"	"	—	"	" T450		76·8		85·5	14½	47	21	"
	"		"			"	"	—	"	" T500		73·4		81·4	17	52	25	"
	0·27		0·49			4·06	1·24	—	"	" T200				110·8	13½		20	9
	0·27		0·47			4·27	1·17	—	1¼	AH820 T210			90·0	108·8	15	47	19	1
B.E.A.	0·27	0·23	0·54	0·034	0·022	4·03	1·13	0·23	0·564	" T180 AC	78·0			111·0	13	37	17	8
B.E.A.	0·27	0·23	0·48	0·013	0·026	3·81	1·19	0·36	"	" "	76·5			115·0	13	42½	27	"
B.E.A.	0·27	0·27	0·44	0·028	0·032	4·05	1·32	0·24	"	" T200	72·4			111·2	20	47	19	"
	0·27	0·21	0·48	0·035	0·028	3·99	1·21	0·22	¾	OQ820 T200		81·3		101·5	16½	55		3
	0·28		0·46			4·35	1·25	—	0·564	AH820 T200				111·3	14		24	9
	0·28	0·23	0·48	0·004	0·018	4·42	1·36	—	"	" T200 AC				108	16	52	24	10
	0·28	0·28	0·55			4·24	1·25	—	"	WQ820 T400			84·8	86·3	15	56½	22	1
	"	"	"			"	"	—	1⅛	" T500			70·1	73·9	17	58½	40	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size		Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
			C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
													tons/sq.in.								
			0·28	0·28	0·55			4·24	1·25	—	1⅛	WQ820 T600				52·6	58·6	22	66	92	1
			"	"	"			"	"	—	"	" T700				61·6	79·6	14	43½	38	"
B.E.A.			0·28	0·27	0·42	0·010	0·009	4·40	1·32	0·13	2¾ (C)	AH820 T200				86·0	103·2	16½	50		"
B.E.A.			0·28	0·21	0·39	0·005	0·016	4·22	1·36	0·14	6 (C)	AH830 T125				72·0	92·6	11	32	22	"
B.E.A.			0·28	0·26	0·52	0·024	0·030	4·10	1·19	0·26	0·564	AH820 T180 AC	81·0				108·0	15	50	22	8
B.E.A.			0·28	0·31	0·50	0·012	0·028	4·16	1·10	0·24	"	" "	72·0				113·0	13	42½	22	"
B.E.A.			0·28	0·09	0·54	0·030	0·036	3·97	1·20	0·27	"	" "	75·5				117·0	13	42½	15	"
B.E.A.			0·28	0·25	0·54	0·023	0·026	4·15	1·22	0·27	"	" "	82·5				111·6	13	47	23	"
B.E.A.			0·28	0·13	0·54	0·030	0·023	4·01	1·31	0·47	"	" T200 AC	83·7	85·0			117·0	13	40½	23	"
			0·28		0·45			4·21	1·37	0·27	"	" T200				102·0	111·0	14	44½	26	3
B.E.A.			0·28					4·13	1·41	0·26	"	" "					112·8	14½		37	1
			0·28	0·34	0·43			4·31	1·20	0·22	"	" "	76·8				111·0	16		36	4
			0·28	0·17	0·54			4·13	1·24	0·34	"	" "				90·0	110·0	15	43	33	"
	McQuaid Ehn	Actual																			
B.E.A.	7—8	7—8	0·29	0·20	0·49	0·036	0·016	4·18	1·27	0·09	1	N875 OQ850 T550				60·9	69·4	17½	56	18	7
B.E.A.			0·29		0·43			4·29	1·31	—	0·564	AH820 T220				104·0	111·4	14½	43	20	3
"			"		"			"	"	—	"	" T300				98·6	106·4	14	47	19	"
"			"		"			"	"	—	"	" T400				93·3	94·3	14	50	19	"
"			"		"			"	"	—	1⅛	" T500				70·9	72·8	18½	59	28	"
"			"		"			"	"	—	"	" T550				59·0	63·0	21	64	55	"
"			"		"			"	"	—	"	" T600				55·0	60·9	25	66	75	"
			0·29					4·22	1·37	—	0·564	AH820 T200					111·2	18		25	1
			0·29	0·24	0·50			4·24	1·32	0·11	"	" "				98·0	114·0	16	42	29	4
			0·29	0·22	0·52			4·00	1·32	0·12	"	" "				96·0	114·0	17	43	27	"
			0·29		0·48			4·18	1·30	—	1⅛	" "				92·0	110·3	12½	31	20	1
B.E.A.			0·29	0·25	0·47	0·017	0·027	4·05	1·25	0·24	0·564	AH820 T180 AC	69·0				114·5	12	32	20	8
B.E.A.			0·29	0·25	0·47	0·017	0·027	4·05	1·25	0·24	"	" "	74·3				110·0	13	58	29	"
B.E.A.			0·29	0·30	0·49	0·026	0·022	4·06	1·16	0·21	"	" "	74·0				105·2	15	45	20	"
			0·29		0·50			4·48	1·34	0·27	"	" "					115·6	14½			9
B.E.A.			0·29	0·22	0·46	0·007	0·015	4·19	1·17	0·27	"	" T120 24 hr.	70·5	77·4	85·7		115·0	16	45	22	1
"			"	"	"	"	"	"	"	"	"	OQ820 T120 24 hr.	83·6	85·6	98·0		120·0	15	51	—	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq. in.								
B.E.A.		0·29	0·20	0·49	0·013	0·010	4·18	1·22	0·28	0·564	AH820 T200	71·6	78·0	85·4		105·0	16	50		1
"		"	"	"	"	"	"	"	"	"	" T250	72·8	84·3	92·3		102·5	16	54		"
"		"	"	"	"	"	"	"	"	1⅜	" T200	71·7	80·0	87·6		103·5	15	53		"
B.E.A.		0·29	0·21	0·52	0·009	0·021	4·04	1·25	0·25	0·564	AH830 T200	71·5				109·8				11
		0·29	0·19	0·46			4·21	1·26	0·23	"	AH820 T200	73·8				112·0	16		38	4
	McQuaid Ehn / Actual																			
B.E.A.	6 / 6—7	0·30	0·27	0·45	0·014	0·009	4·40	1·37	0·09	1	N875 AH850 T550				64·7	73·5	18¼	58½	19	7
		0·30					4·38	1·33	—	0·564	AH820 T200					112·4	16		26	1
A.O.H.		0·30		0·56			4·49	1·33	—	"	AH830 T200				90·0	115·0	15½	42	22	3
		0·30	0·18	0·48			4·01	1·36	0·22	"	AH820 T200	73·9				112·0	16¼		32	4
		0·30		0·50			4·48	1·34	0·27	"	" "					115·6	14½			9
		0·30		0·45			3·90	1·22	0·41						102·4	112·4	15			"
A.O.H.		0·30	0·18	0·58	0·025	0·031	4·20	1·31	0·26	T.P.S.	AH820					112	11	31	29	13
"		"	"	"	"	"	"	"	"	"	" T100					112	12	42	32	"
"		"	"	"	"	"	"	"	"	"	" T250					107	13	47	44	"
"		"	"	"	"	"	"	"	"	"	" T350					100	13½	47½	15	"
"		"	"	"	"	"	"	"	"	"	" T450					92	14	49	14	"
"		"	"	"	"	"	"	"	"	"	" T550	67				81	15	52	17	"
"		"	"	"	"	"	"	"	"	"	" T600	62				74	18	57	22	"
"		"	"	"	"	"	"	"	"	"	" T650	53				65	23½	62	62	"
"		"	"	"	"	"	"	"	"	"	OQ820					114	11½	27	23	"
"		"	"	"	"	"	"	"	"	"	" T100					113	12	32	29	"
"		"	"	"	"	"	"	"	"	"	" T250					106	13	45	42	"
"		"	"	"	"	"	"	"	"	"	" T350					99	14	50	20	"
"		"	"	"	"	"	"	"	"	"	" T450					90	14½	51	18	"
"		"	"	"	"	"	"	"	"	"	" T550	66				79	16½	53	31	"
"		"	"	"	"	"	"	"	"	"	" T600	61				72	19	57	43	"
"		"	"	"	"	"	"	"	"	"	" T650	53				65	22	60	60	"
		0·30		0·45			3·95	1·25	0·25	1⅛	AH820					112	10	30	20	"
		"		"			"	"	"	"	" T100					107	10½	37	21	"
		"		"			"	"	"	"	" T200	74				106	11	43	21	"
		"		"			"	"	"	"	" T300	74				100	12	46	16	"
		"		"			"	"	"	"	" T400	69				88	14	50	17	"
		"		"			"	"	"	"	" T500	61				73	16½	55	35	"
		"		"			"	"	"	"	" T600	50				59	21	62	70	"
		"		"			"	"	"	"	" T650	44				56	24	67	81	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.							
	0·30	0·14	0·35	0·015	0·021	4·07	1·15	0·37	1⅛	AH820			92	113	12	30	35	14
	"	"	"	"	"	"	"	"	"	" T100WQ			90	111	13	35	38	"
	"	"	"	"	"	"	"	"	"	" T200"			88	108	13½	40	38	"
	"	"	"	"	"	"	"	"	"	" T300"			85	103	14	46	30	"
	"	"	"	"	"	"	"	"	"	" T400"			82	95	15	51	22	"
	"	"	"	"	"	"	"	"	"	" T500"			75	84	16	56	40	"
	"	"	"	"	"	"	"	"	"	" T600"			63	70	19	60	65	"
	"	"	"	"	"	"	"	"	"	" T650"			50	66	20	60	75	"
	0·31	0·18	0·49			4·17	1·10	0·12	0·564	AH920 T200			98·0	112·0	16	46	32	4
	0·31		0·41			3·90	1·37	—	1	AH820				115	12		15	12
	"		"			"	"		"	" T200				111	13		15	
	"		"			"	"		"	" T300				107	13		11	"
			"			"	"		"	" T400				93	15		14	"
	"		"			"	"		"	" T500				79	16		32	"
	"		"			"	"		"	" T600				62	23		63	"
	"		"			"	"		"	" T650				59	26		72	"
	0·31					4·28	1·28	—	0·564	AH820 T200			96·8	110·6	14	46	—	1
B.E.A.	0·31	0·19	0·50	0·026	0·028	4·25	1·14	0·27	0·564	AH820 T200 AC	77·6			110·4	14	47	23	8
	0·31					4·15	1·22	0·28	0·564	AH820 T200				114·2	16		30	1
B.E.A.	0·32	0·26	0·44	0·009	0·011	4·40	1·31	0·15	1¾	AH820 T200	82·0	96·8		117·6	14	44	34	1
"	"	"	"	"	"	"	"	"	"	" T500	66·9	73·7		79·6	17	53½	30	"
"	"	"	"	"	"	"	"	"	"	" T550	60·4	65·9		72·8	18	57	55	"
"	"	"	"	"	"	"	"	"	"	" T600	52·4	58·0		65·8	21	61½	75	"
"	"	"	"	"	"	"	"	"	"	" T650	40·3	49·3		65·0	20½	53	68	"
"	"	"	"	"	"	"	"	"	"	" T700	36·4	46·8		69·4	21	48	54	"
"	"	"	"	"	"	"	"	"	2¼ (L)	A650	46·4	48·2		59·0	24	64	74	"
"	"	"	"	"	"	"	"	"	" (T)				48·0	58·0	16	36	22	"
"	"	"	"	"	"	"	"	"	" (L)	AH820 T200	79·1	95·0		114·7	15½	47	34	"
"	"	"	"	"	"	"	"	"	" (T)				101·0	114·0	6	12	10	"
"	"	"	"	"	"	"	"	"	5 sq (L)	A650	37·8	43·2		59·0	20	45	34	"
"	"	"	"	"	"	"	"	"	" (T)	" "	38·8	42·8		57·0	7	10½	24	"
"	"	"	"	"	"	"	"	"	" (L)	AH820 T200	81·0	97·1		118·0	15	41	30	"
"	"	"	"	"	"	"	"	"	" (T)	" "	79·1	95·8		115·2	11½	24	15	"
B.E.A.	0·32	0·31	0·55	0·013	0·019	3·98	1·35	0·29	0·564	AH820 T250	80·4			112·4	14	39	19	"
"	0·32	0·25	0·50	0·009	0·016	4·02	1·40	0·22	"	" "	80·0			110·8	14	42	25	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.							
B.E.A.	0·33	0·31	0·46	0·012	0·013	4·01	1·37	0·29	0·564	AH820 T250	80·0			113·2	14	39	21	13
A.O.H.	0·34		0·55			4·23	1·20	—	0·564	AH830 T200			93	117·2	12½	34	13	3
"	"		"			"	"		"	" T300			90	106·1	13	44	5	"
"	"		"			"	"		"	" T400			78	89·2	15	45	10	"
"	"		"			"	"		"	" T500			67	76·5	17½	47	10	"
"	"		"			"	"		"	" T550			61	69·0	19	52	12	"
"	"		"			"	"		"	" T600			55	64·6	20	56	42	"
"	"		"			"	"		"	" T630			53	62·8	21½	57	47	"
"	0·34		0·43			4·34	1·20	0·22	0·564	AH820 T200			92·0	120·0	17		32	4
	0·34	0·24	0·54	0·008	0·017	4·12	1·23	0·21	1⅛	AH820			100	127	7	22	15	14
	"	"	"	"	"	"	"	"	"	" T100 WQ			98	126	8	25	22	"
	"	"	"	"	"	"	"	"	"	" T200 "			94	121	9	30	26	"
	"	"	"	"	"	"	"	"	"	" T300 "			90	110	10	36	21	"
	"	"	"	"	"	"	"	"	"	" T400 "			83	98	12½	43	13	"
	"	"	"	"	"	"	"	"	"	" T500 "			74	84	16	52	22	"
	"	"	"	"	"	"	"	"	"	" T600 "			62	71	20	60	52	"
	"	"	"	"	"	"	"	"	"	" T650 "			52	65	22	58	60	"
	"	"	"	"	"	"	"	"	¾	AH820 T600			65	73	18	60	54	"
	"	"	"	"	"	"	"	"	1	" "			63	72	18	60	56	"
	"	"	"	"	"	"	"	"	2	" "			61	71	18	58	60	"
	"	"	"	"	"	"	"	"	3	" "			60	70	18	56	60	"
	"	"	"	"	"	"	"	"	4	" "			60	70	18	53	59	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

	Chemical Composition (%)				Ref.
	C	Mn	Ni	Cr	
En 30A	0·27	0·40	4·30	1·35	3

Test pieces Air Hardened 820°C. Tempered as indicated.

(Ref. 3)

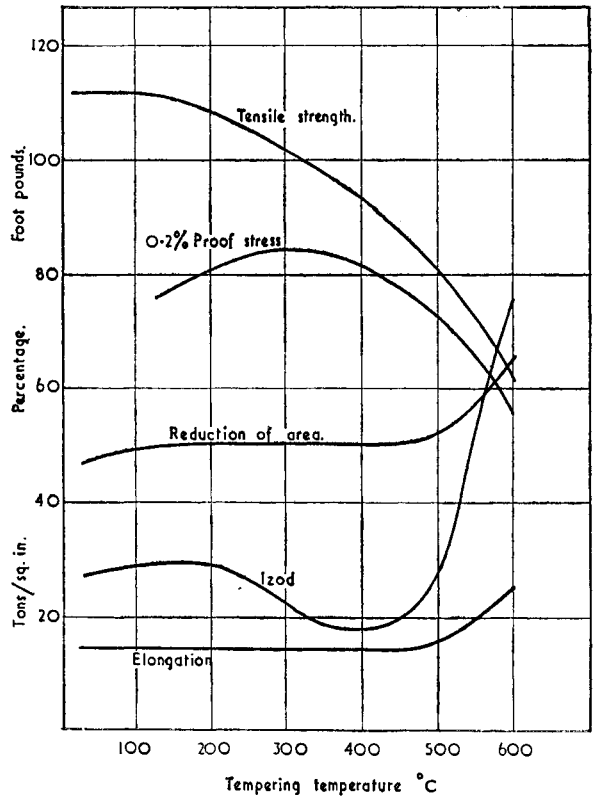


Fig. 30.16

	Chemical Composition (%)					Ref.
	C	Mn	Ni	Cr	Mo	
En 30B	0·30	0·58	4·20	1·31	0·26	13

Test pieces Air Hardened 820°C. Tempered as indicated.

(Ref. 13)

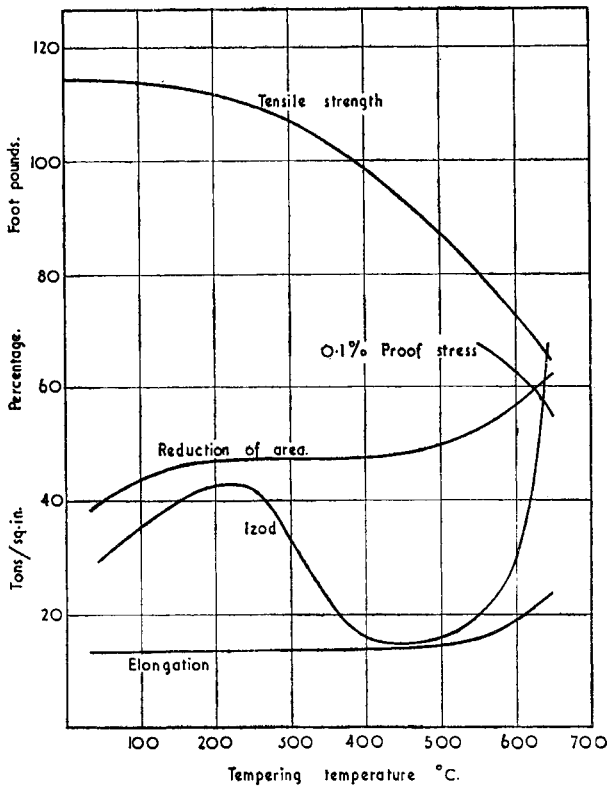


Fig. 30.17

EFFECT OF TEMPERING ON THE RANGE OF PROPERTIES AT ROOM TEMPERATURE OF EN 30A AND EN 30B

These curves have been constructed from the results obtained on several casts of En 30A and En 30B.

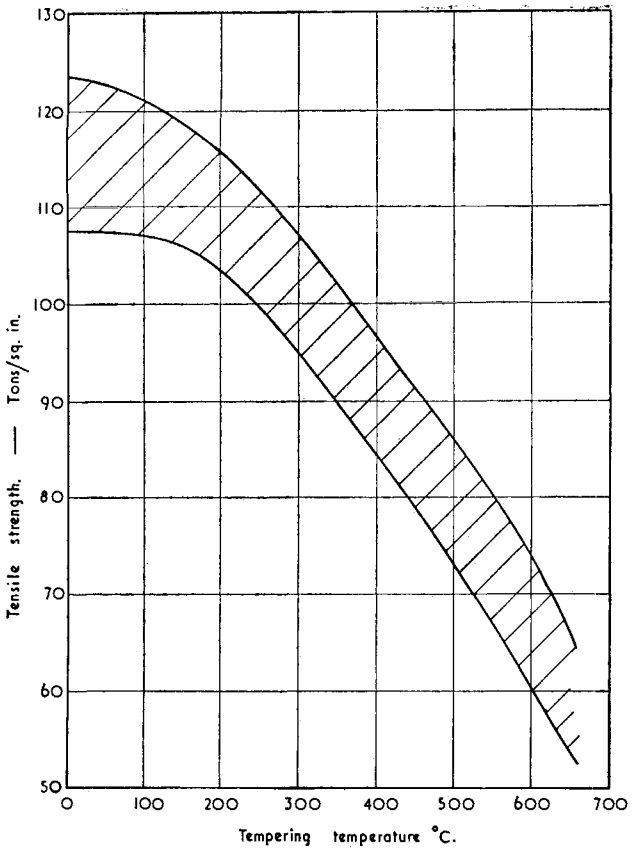


Fig. 30.18 (A)

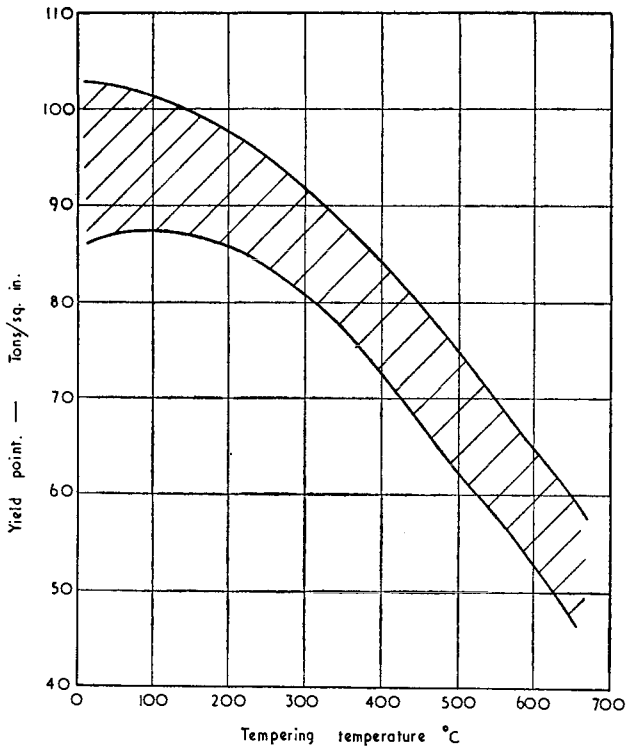


Fig. 30.18 (B)

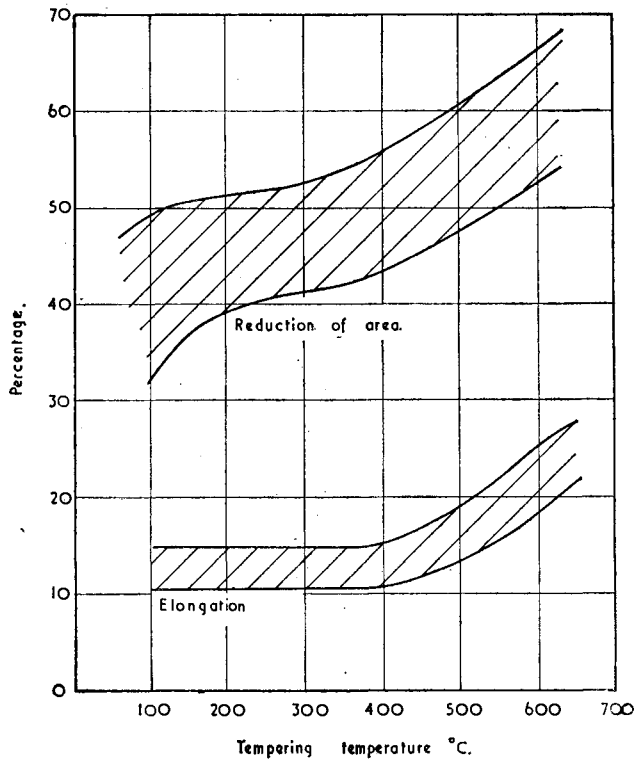


Fig. 30.18 (C)

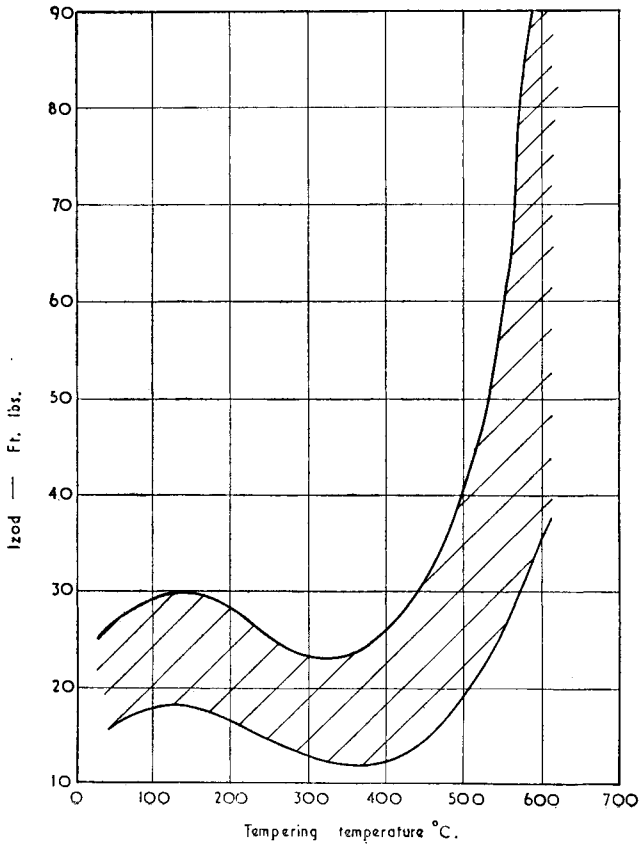


Fig. 30.18 (D)

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

En 30B-Air Hardened 820°C. Tempered 200°C A.C.

(Ref. 4)

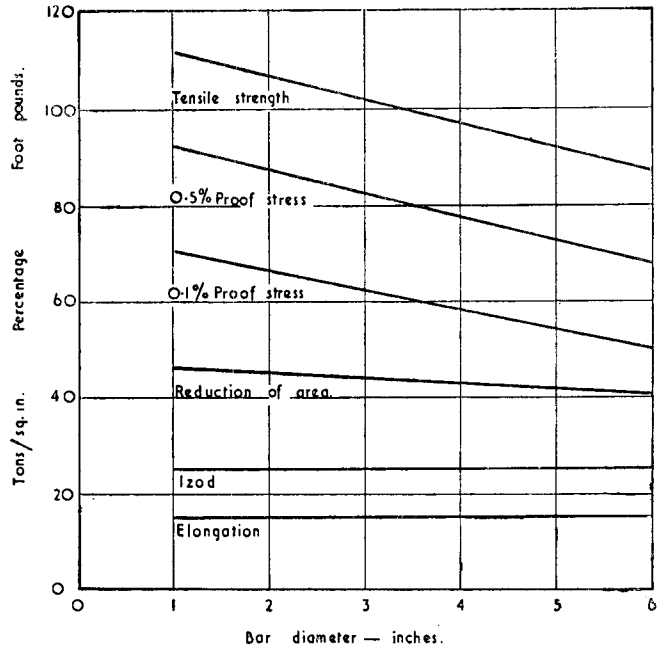


Fig. 30.19

En 30B-Oil Hardened 820°C. Tempered 200°C A.C.

(Ref. 4)

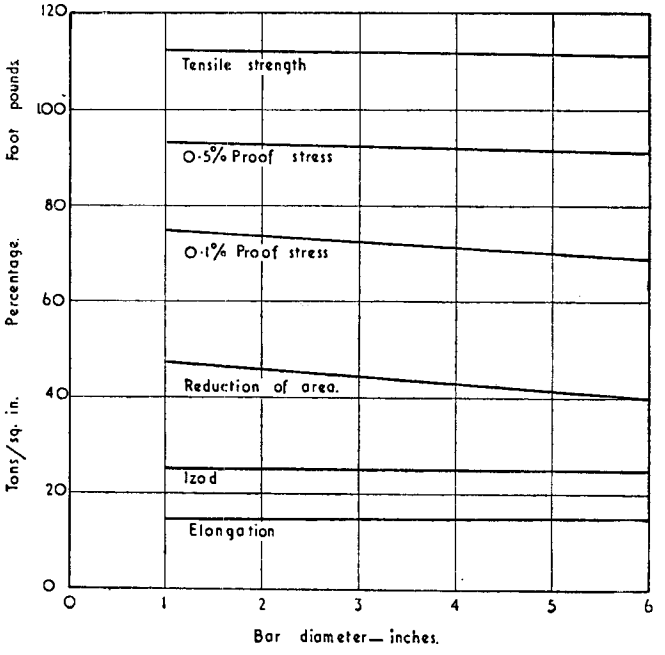


Fig. 30.20

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile							Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in.							
	0·30		0·50			4·4	1·4	—		Hardened & Tempered	RT					56	28		15
	"		"			"	"			" "	0·5					62	29		"
	"		"			"	"			" "	—30					66	30		"
	"		"			"	"			" "	—60					64	30		"
	"		"			"	"			" "	—92					68	27		"
	0·29	0·28	0·58	0·028	0·027	4·19	1·33	0·30	0·354	OQ820 T200	25		78·0			110·0	16	49½	16
	"	"	"	"	"	"	"	"	"	" "	— 50		75·4			112·3	16	51½	"
	"	"	"	"	"	"	"	"	"	" "	—120		78·7			119·8	17½	52	"
	"	"	"	"	"	"	"	"	"	" "	—150		81·0			121·0	17½	51	"
	"	"	"	"	"	"	"	"	"	" "	—195		89·3			132·0	19	42	"
9	0·33	0·17	0·51	0·009	0·013	4·16	1·44	0·31	⅜	AC820 T200	20	77·8	83·9	92·5		109·6	20	54	9
"	"	"	"	"	"	"	"	"	"	" "	— 78	74·4	81·6	91·3		114·9	20	58	"
"	"	"	"	"	"	"	"	"	"	" "	—196	88·3	100·0	107·9		132·2	20	50	"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Izod Impact Strength (ft.lb.) at									Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			20	0	—20	—40	—60	—80	—100	—120	—140	
0·29	0·28	0·58	0·028	0·027	4·19	1·33	0·30	T.P.S.	OQ820 T200	27	25	24	22	20½	19	15	13	13	16

CHARPY V NOTCH TRANSITION CURVES

Chemical Composition (%)								Ref.
C	Si	Mn	S	P	Ni	Cr	Mo	
0·33	0·17	0·51	0·009	0·013	4·16	1·44	0·31	9

⅛ in. dia. bars Air Hardened 820°C. Tempered 200°C A.C.
As quenched grain size 9 (ASTM).
(For tensile test data see also Mechanical Properties at Low Temperature)

(Ref. 9)

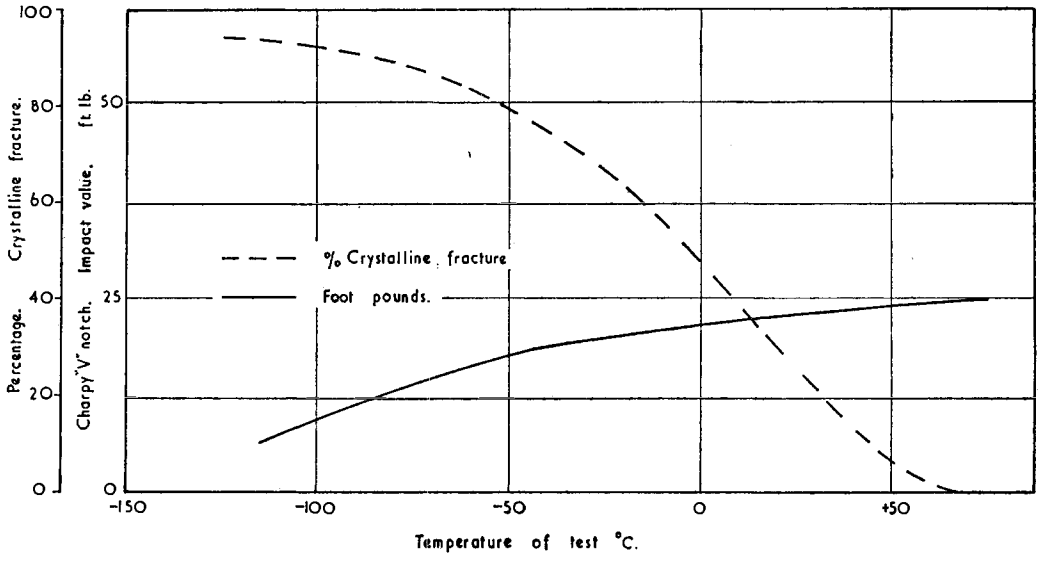


Fig. 30.21

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						El % (A)	R.A. % (Z)	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				L.P.	0.05% P.S. (0.05Rp)	0.1% P.S. (0.1Rp)	0.2% P.S. (0.2Rp)	0.5% P.S. (0.5Rp)	T.S. (Rm)			
											tons/sq.in								
0·30	0·29	0·47	0·010	0·015	4·38	1·39	—	¾	AH820	300		43·4	53·3	63·6	76·5	96·3	18½	49	1
"	"	"	"	"	"	"		"	"	400		37·9	45·0	52·9	64·1	76·0	20	57	"
"	"	"	"	"	"	"		"	"	500		17·0	21·3	26·7	29·2	51·2	28	62	"
"	"	"	"	"	"	"		"	"	600		7·2	8·8	10·5	12·6	23·4	59	89	"
"	"	"	"	"	"	"		"	"	700	—	—	—	—	—	10·5	126	95	"
"	"	"	"	"	"	"		"	"	800						5·7	81	82	"
											Loading rate 2 tons/sq.in./min.								
0·27	0·19	0·39	0·010	0·015	4·15	1·22	0·26	2 (M)	AH820 T250 AC	20	50·0			83·4		105·2	16	52½	14
"	"	"	"	"	"	"	"	" "	" "	300	63·6			92·8		120·0	16	39	"
"	"	"	"	"	"	"	"	" "	" "	375	50·4			68·5		84·0	9	36½	"
"	"	"	"	"	"	"	"	" "	" "	450	33·2			53·2		68·2	13½	55	"
"	"	"	"	"	"	"	"	" "	" "	500	12·6			31·0		58·5	15½	62	"
"	"	"	"	"	"	"	"	" "	" "	550	7·6			20·7		35·5	21½	78½	"
"	"	"	"	"	"	"	"	" "	AH820 T450 AC	20	66·0			78·5		85·2	15½	56½	"
"	"	"	"	"	"	"	"	" "	" "	300	54·5			70·0		81·6	15	47½	"
"	"	"	"	"	"	"	"	" "	" "	350	51·0			67·8		77·8	11	31½	"
"	"	"	"	"	"	"	"	" "	" "	400	47·4			64·0		73·5	10½	32	"
"	"	"	"	"	"	"	"	" "	" "	450	41·8			57·0		68·8	12½	46	"
"	"	"	"	"	"	"	"	" "	" "	500	25·4			41·0		58·0	18	61	"
"	"	"	"	"	"	"	"	" "	" "	550	19·0			30·5		44·5	22	71½	"
"	"	"	"	"	"	"	"	" "	AH820 T650 AC	20	55·2			72·2		77·2	19	59½	"
"	"	"	"	"	"	"	"	" "	" "	300	50·6			62·0		69·8	16½	50	"
"	"	"	"	"	"	"	"	" "	" "	375	47·8			59·8		68·0	14	39	"
"	"	"	"	"	"	"	"	" "	" "	450	43·2			54·5		61·0	16	60½	"
"	"	"	"	"	"	"	"	" "	" "	500	32·0			45·0		54·5	19	70	"
"	"	"	"	"	"	"	"	" "	" "	550	20·0			30·4		42·0	24	79	"
											Loading rate 1 ton/sq.in./min.								

MECHANICAL PROPERTIES IN TORSION

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Torsion				Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	0·1% P.S.	Y.P.	App. max. Shear Stress	Probable Max. Shear Stress	
										tons/sq.in.					tons/sq.in.				
0·28	0·23	0·48	0·004	0·018	4·42	1·36			AH820 T200 AC			108	16	52			89·2	66·9	10
0·30	0·10	0·40	0·027	0·033	4·07	1·38			OQ830 T620		46·9	60·0	21	54		32·8	52·3	39·2	1
"	"	"	"	"	"	"			AH820		90·5	109·6	9	21		55·8	89·7	67·3	"
0·30	0·17	0·44	0·055	0·009	4·23	1·35	0·13		—	66·4		109·5	15	42	43·5		92·4	69·3	17
0·31	0·19	0·44	0·013	0·018	4·29	1·47		T.P.S.	AH820			113·2	15	43		43·8	96·5	72·4	1
"	"	"	"	"	"	"		"	" " T200			106·0	17	57		36·3	87·3	65·5	"
"	"	"	"	"	"	"		"	" " T600		47·7	59·1	26	69		37·8	53·3	40·0	"
0·31	0·16	0·43	0·003	0·009	4·24	1·28	0·14	T.P.S.	—	66·8		111·2	15	42	45·7		93·7	70·3	17

FATIGUE PROPERTIES

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile Test						Rotary Bending Fatigue Limit tons/sq.in.		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Unnotched	Notched	
											tons/sq.in.								
not stated (En 30A)									820 AC, 780 AC, T150	RT				115.0			±52.8	±8.2(1)	3
0·27	0·21	0·48	0·035	0·028	3·99	1·21	0·22	¾	OH T200	RT		81·3		101·5	16½	55	±47·5	±22·5(1)	3
0·29	0·34	0·50	0·025	0·025	4·05	1·20	0·25	"	" "	"		96·4		129·6	14½	43½	±52·0	±21·7(1)	"
0·31	0·43	0·21	0·013	0·023	4·39	1·28	0·26	⅜	AH820 T250	"			97·1	107·5	20	56½	±51·5	±20·5(1)	"
0·32	0·26	0·44	0·009	0·011	4·40	1·31	0·15	1¾	AH820 T200	RT	82·0		96·8	117·6	14	44		±27·8(2)	1
"	"	"	"	"	"	"	"	5 sq. (L)	A 650	"	37·8		43·2	59·0	20	45	±29·8		"
"	"	"	"	"	"	"	"	" "	AH820 T200	"	81·0		97·1	118·0	15	41	±48·8		"
"	"	"	"	"	"	"	"	" (T)	A 650	"	38·8		42·8	57·0	7	10½	±24·8		"
"	"	"	"	"	"	"	"	" "	AH820 T200	"	79·1		95·8	115·2	11½	24	±35·8		"
0·29	0·22	0·46	0·007	0·015	4·19	1·17	0·27	T.P.S.	AH820 T200		80·5	86·3	94·0	110·0	16	49	±45·0	±27·0(3)	1
"	"	"	"	"	"	"	"	"	OQ820 T200		81·0	87·7	96·2	108·5	16	55	±47·0	±23½(3)	"

DETAILS OF NOTCHES

(1) 55°V, 0·008 in. root radius, 0·020 in. deep. Dia. at root, 0·295 in. Neuber stress concentration factor 2·85.
(2) U, 0·029 in. " " 0·061 in. " " " " 0·300 in. " " " " 1·9.
(3) 55°V, 0·029 in. " " 0·10 in. " " " " 0·400 in. " " " " 2·2.

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1 PER CENT CARBON–CHROMIUM STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Cr
0·90—1·20	0·10—0·35	0·30—0·75	0·050 max.	0·050 max.	1·00—1·60

MECHANICAL PROPERTIES

When supplied in the softened condition the material shall have a Brinell hardness not exceeding 229. No other mechanical properties are specified.

RELATED SPECIFICATIONS

United Kingdom		America		France	Germany		U.S.S.R.	
EN	DTD	SAE	AISI	AFNOR	Werkstoff No.	Name	GOST	Mark
31	5022	51100 52100	E51100 E52100	10006	1.3505	100 Cr6	5950—51 801—60	Kh. ShKh15

APPLICATIONS

Used mainly in the hardened and lightly tempered condition for parts requiring a high surface hardness with a deeper hardened zone than can be obtained with case-hardened steels. It can be oil quenched in sections up to 1 in. dia. and water hardened in larger sections to produce a very hard wear resistant surface.

Typical uses: ball and roller bearings, bearing rings, connecting rod big end bushes, lathe centres, collets, cams and pawls. It is used also for small hardened steel cold work rolls, blanking and forming tools, punches, knurling tools, gauges, fuel nozzles, shear blades, bullet cores, instrument pivots and spindles.

En 31

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table)

En No.	Welding Process						Note
	MA	G	IG	S	F	B	
31	f	f	f	f	f	j	B: Advice should be sought

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MACHINABILITY

En 31 is machinable only in the softened condition when its machinability is about 40% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1050°C. Finish above 850°C.
Annealing	780°C to 820°C. Cool at a maximum of 10° per hour to 600°C then air cool.
Softening	650°C to 680°C. Air or furnace cool.
Hardening	800°C to 840°C. Oil or water quench.
Tempering (for maximum hardness)	130°to 180°C;
(where maximum hardness is not necessary)	Up to 300°C.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)					Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	Ni	Cr			
0·99	0·21	0·48	0·12	1·41	WQ810	7·81	1
1·03		0·35		1·45	not stated	7·82	2

SPECIFIC HEAT (c)

Chemical Composition (%)							Heat Treatment °C	Specific Heat cal/g deg. C		Ref.
C	Si	Mn	S	P	Ni	Cr		0 to 100°C	0 to 200°C	
1·06	0·24	0·50	0·013	0·017	0·31	1·46	Annealed or hardened	0·115	0·121	3

COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)					Heat Treatment °C	$10^6 \times$ Coefficient of Thermal Expansion per deg. C							Ref.
C	Si	Mn	Ni	Cr		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	
0·99	0·21	0·48	0·21	1·41	WQ810	12·2							1
1·03		0·35	—	1·45	not stated	11·8	—	13·4	—	14·1	—	14·6(680°C)	2
1·00		—	—	1·48	softened	12·5	13·1	13·6	14·0	14·4	14·8	15·1	1

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Hard-ness HV	Electrical Resistivity microhm-cm											Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	
1·05	0·23	0·73	0·028	0·030	0·23	1·50	0·21	OQ830 T140 (6 hr.)	820	37·5	39·0	44·8									4
"	"	"	"	"	"	"	"	" T350 (3 hr.)	625	28·7	29·5	35·2	42·7	51·2							
"	"	"	"	"	"	"	"	" T550 (4 hr.)	440	24·6	25·6	30·7	38·3	47·5	57·2	68·7	82·0	97·0	114·8	118·7	"
"	"	"	"	"	"	"	"	" T720 (2 hr.)	240	23·6	24·4	30·0	38·0	47·2	57·2						
"	"	"	"	"	"	"	"	" T350 (20 hr.)	—		29·5			56·3(350°C)							
																					"
"	"	"	"	"	"	"	"	" T560 (16 hr.)	403		23·7				56·0						"
"	"	"	"	"	"	"	"	" T602 (3 hr).	332		22·8					74·9(554°C)	81·5(602°C)				
																					"
"	"	"	"	"	"	"	"	" T655 (3 hr.)	287		23·0						89·5(655°C)				
																					"
"	"	"	"	"	"	"	"	" T700 (3 hr.)	255		23·3							97·9			"
"	"	"	"	"	"	"	"	" T750 (2 hr.)	227		23·9							113·0(750°C)			
																					"
1·06	0·24	0·45	0·013	0·017	0·31	1·46	—	Annealed			24·9 (50°C)	28·1	35·6	44·0	54·6	66·5	80·0	95·5	113·5	—	4

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Hardness HV	Thermal Conductivity cal/cm s deg. C										Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	
1·05	0·23	0·73	0·028	0·030	0·23	1·50	0·21	OQ830 T140 (6 hr.)	820	0·054	0·061									4
"	"	"	"	"	"	"	"	" T350 (3 hr.)	625	0·076	0·081	0·082	0·081							"
"	"	"	"	"	"	"	"	" T550 (4 hr.)	440	0·080	0·093	0·092	0·088	0·085						"
"	"	"	"	"	"	"	"	" T750 (2 hr.)	240	0·089	0·097	0·096	0·091	0·087	0·082	0·076	0·068	0·058	0·061	"

YOUNG'S MODULUS (E)

Chemical Composition (%)							Heat Treatment °C	Test Temperature °C	Hardness HV	Young's Modulus tons/sq.in.	Ref.
C	Si	Mn	S	P	Ni	Cr				Vibration Method	
0·97	0·16	0·38			0·26	1·37	OQ825 T720	20	260	13,800	1
"	"	"			"	"	" "	200		13,100	"
"	"	"			"	"	" "	400		12,200	"
"	"	"			"	"	" "	600		10,800	"
"	"	"			"	"	" T400	20	600	13,600	"
"	"	"			"	"	" "	200		12,800	"
"	"	"			"	"	" "	400		11,800	"
"	"	"			"	"	OQ825	20	880	13,100	"
1·05	0·24	0·61	0·040	0·033		1·26	OQ830 T50 (½ hr)	20		13,280	5
"	"	"	"	"		"	" " "	50		13,180	"
"	"	"	"	"		"	" T100 "	20		13,260	"
"	"	"	"	"		"	" " "	50		13,160	"
"	"	"	"	"		"	" T200 "	20		13,390	"
"	"	"	"	"		"	" " "	50		13,250	"
"	"	"	"	"		"	" T300 "	20		13,510	"
"	"	"	"	"		"	" " "	50		13,400	"
"	"	"	"	"		"	" T400 "	20		13,610	"
"	"	"	"	"		"	" " "	50		13,520	"
"	"	"	"	"		"	" T500 "	20		13,720	"
"	"	"	"	"		"	" " "	50		13,600	"
"	"	"	"	"		"	" T600 "	20		13,780	"
"	"	"	"	"		"	" " "	50		13,670	"

MAGNETIC PROPERTIES

Chemical Composition (%)					Section Size dia. (in.)	Heat Treatment °C	Magnetic Properties for H max.=200		Ref.
C	Si	Mn	Ni	Cr			Coercive Force (Hc)	Remanence (Brem)	
0·94	0·21	0·50	0·22	1·43	$\frac{3}{8}$	WQ800	50·0	10,850	1
"	"	"	"	"	"	" 820	57·0	10,100	"
0·97	0·29	0·70		1·33	"	WQ780	61·6	9,950	"
"	"	"		"	"	" 820	65·7	9,090	"
"	"	"		"		" 860	64·6	8,000	"
0·95	0·19	0·56	0·26	1·59	"	WQ800	52·5	10,480	"
"	"	"	"	"	"	" 820	56·0	10,850	"
1·01	0·28	0·70	0·11	1·37	"	WQ780	61·0	10,310	"
"	"	"	"	"	"	" 820	64·6	9,850	"
"	"	"	"	"	"	" 860	64·8	9,020	"
1·12	0·24	0·40	0·37	1·50	"	WQ800	56·0	10,060	"
"	"	"	"	"	"	" 820	58·0	10,060	"

En 31

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
1·08	0·25	0·53	0·015	0·022	0·33	1·46	0·06

Electric Arc.
McQuaid Ehn grain size 7 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to 4 S.W.G. Cold drawn to 11 S.W.G. with intermediate annealing at 800°C.
Austenitizing Temperature 820°C, 30 min.

(Ref. 6)

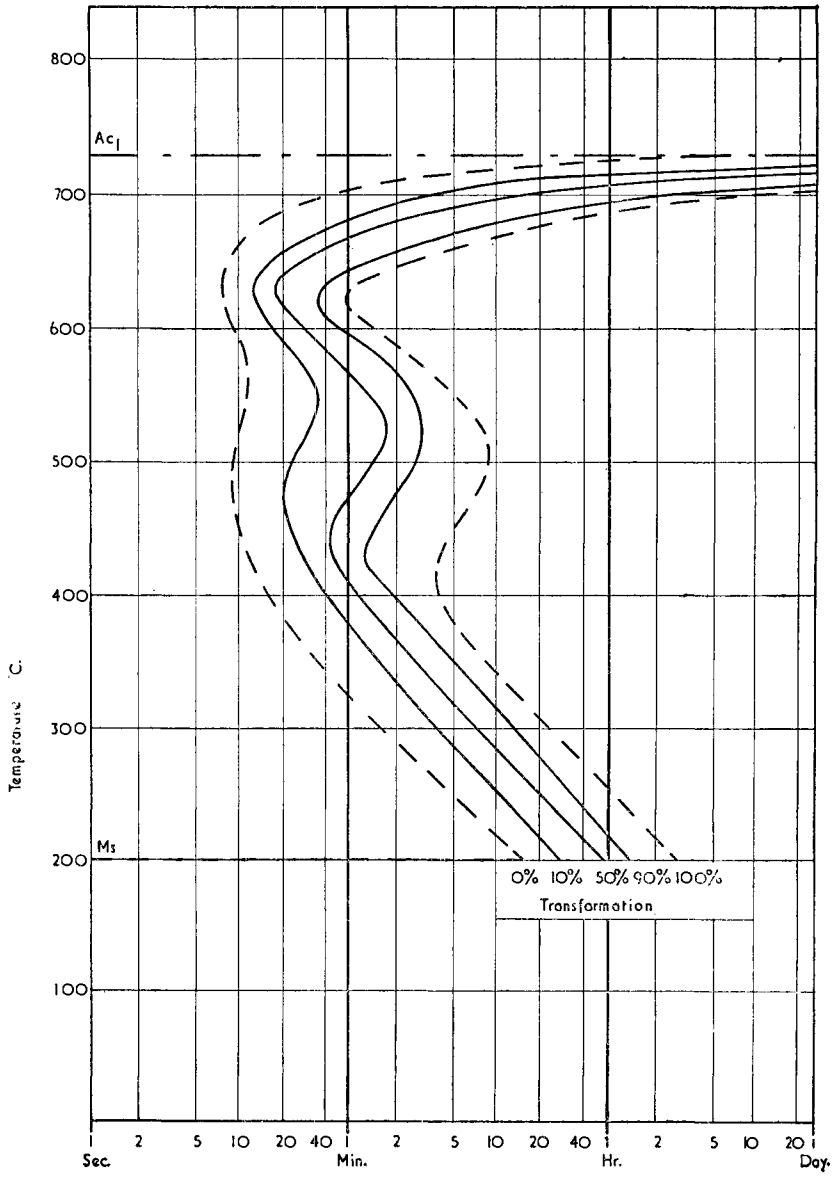


Fig. 31.1

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)			
C	Mn	Ni	Cr
1·02	0·36	0·20	1·41

(See also Fig. 31.3)

McQuaid Ehn grain size 9.
Austenitizing Temperature 843°C.

(Ref. 7)

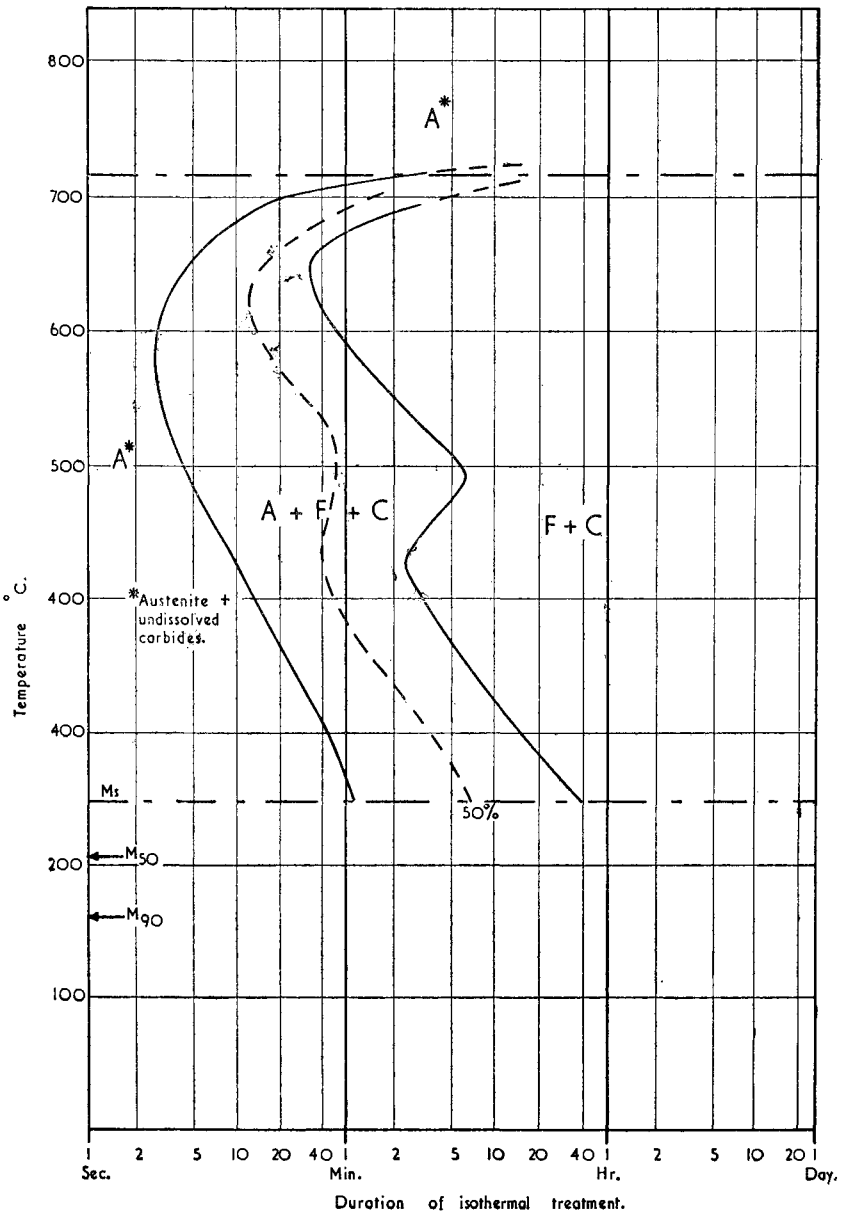


Fig. 31.2

En 31

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)			
C	Mn	Ni	Cr
1·02	0·36	0·20	1·41

McQuaid Ehn grain size 3.
Austenitizing Temperature 1066°C.

(Ref. 7)

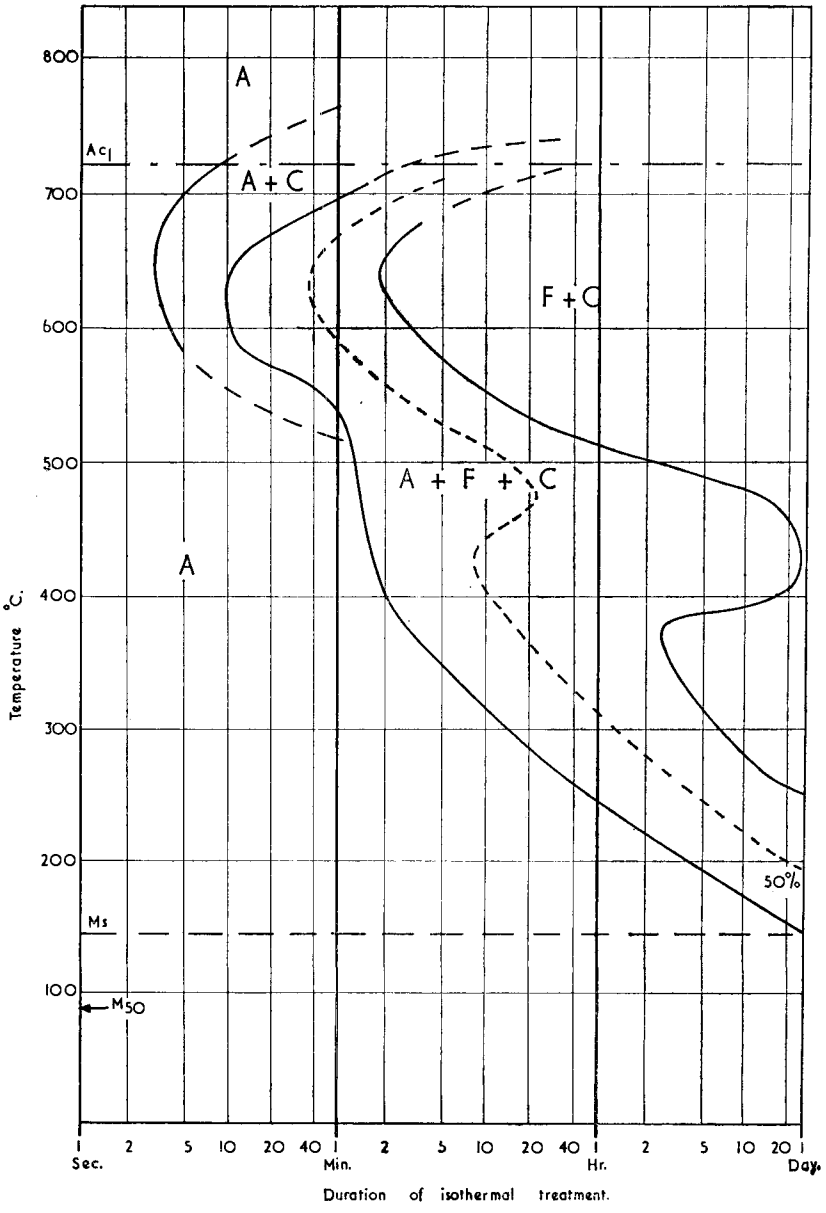


Fig. 31.3

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
1·00	0·28	0·31	0·003	0·013	0·21	1·71

(See also Fig. 31.5)

Electric Arc.
Actual grain size 7—8.
Austenitizing Temperature 850°C, 30 min. (Ref. 8)

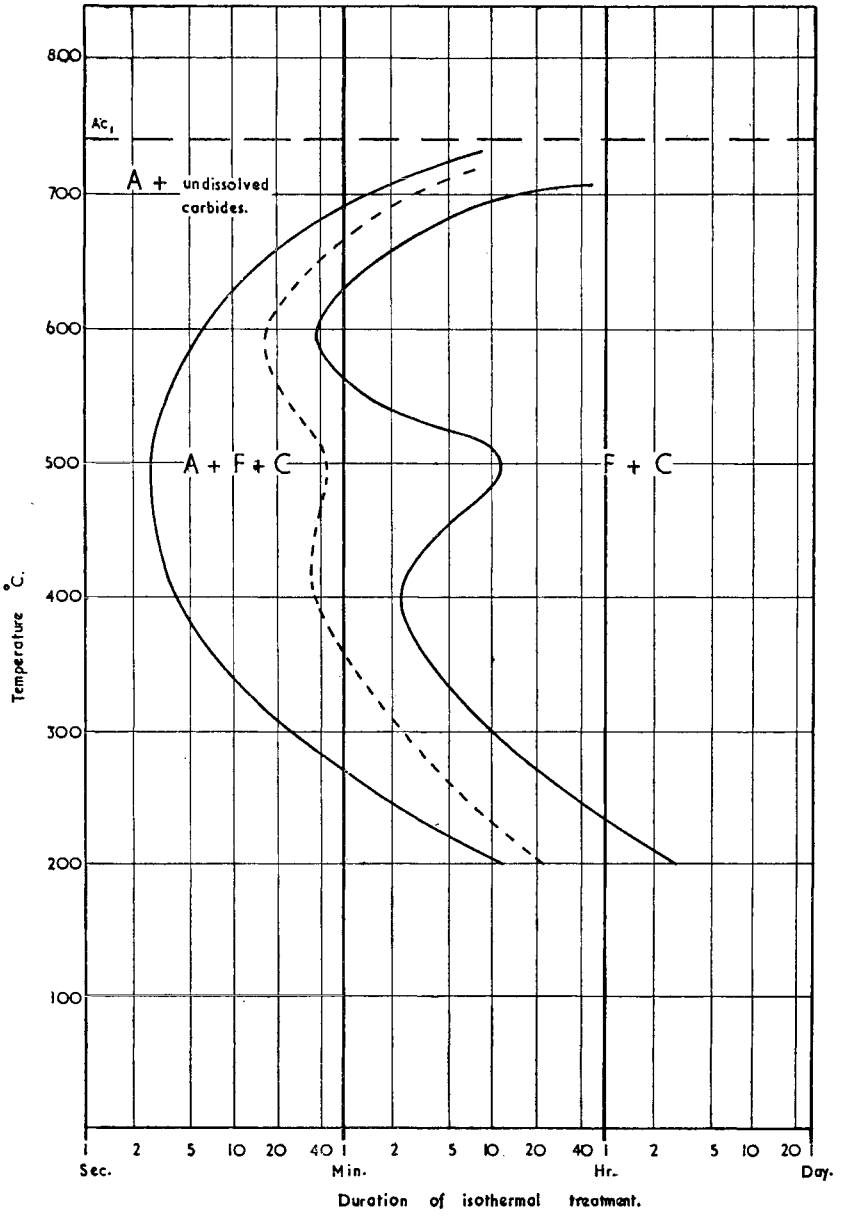


Fig. 31.4

ISOTHERMAL TRANSFORMATION (Continued)

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
1·00	0·28	0·31	0·003	0·013	0·21	1·71

Electric Arc.
Actual grain size 8—6.
Austenitizing Temperature 1000°C, 30 min.

(Ref. 8)

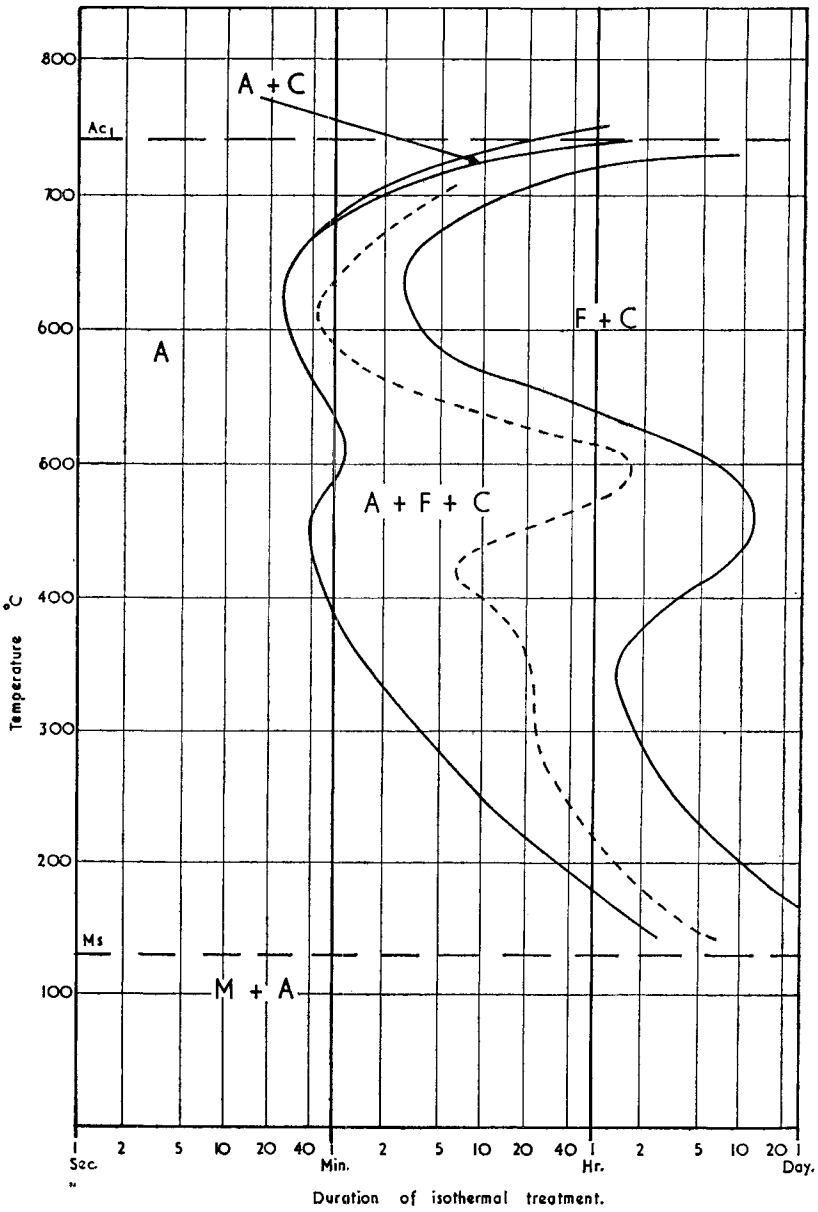


Fig. 31.5

CONTINUOUS COOLING TRANSFORMATION

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
1·00	0·28	0·31	0·003	0·013	0·21	1·71

Electric Arc.
Actual grain size 7—8.
Austenitizing Temperature 850°C, 30 min. (Ref. 8)

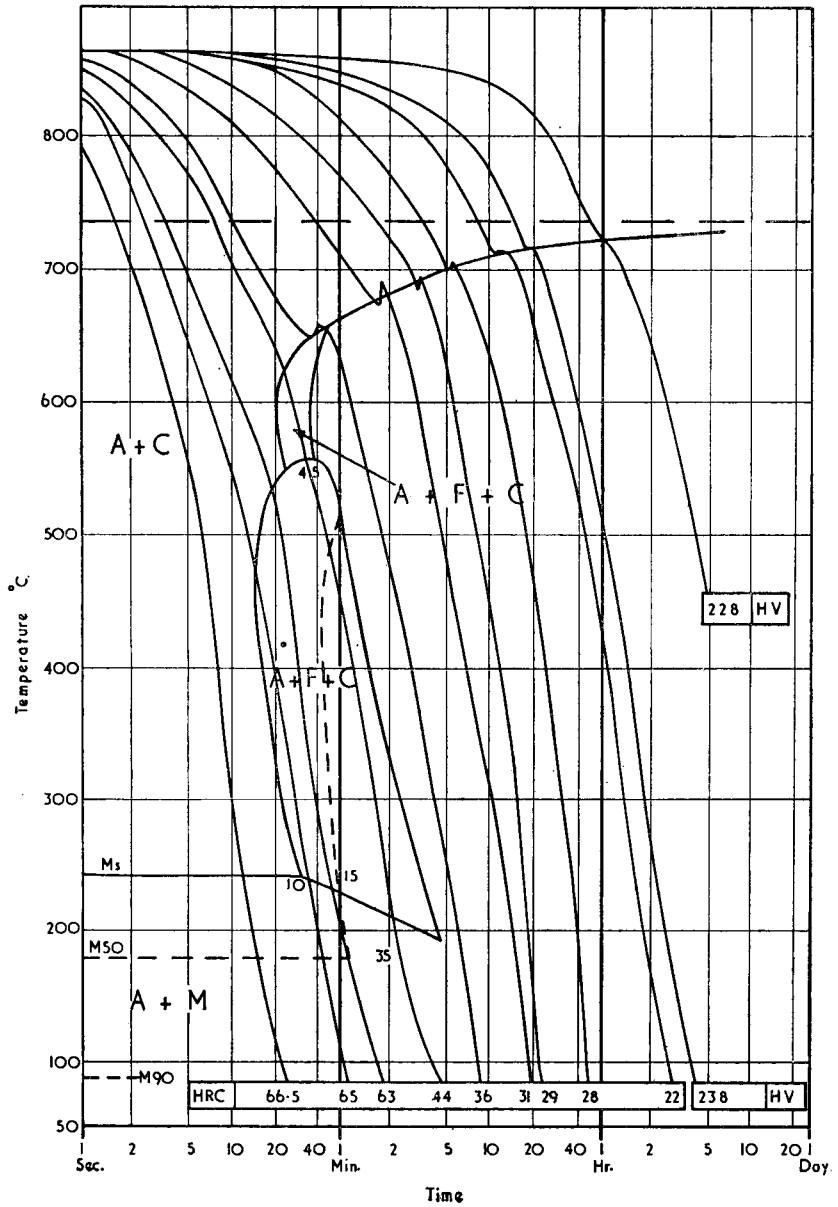


Fig. 31.6

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
1·08	0·25	0·53	0·015	0·022	0·33	1·46	0·06

Electric Arc.
McQuaid Ehn grain size 7.
As quenched grain size 7.
End Quenched from 820°C.

(Ref. 6)

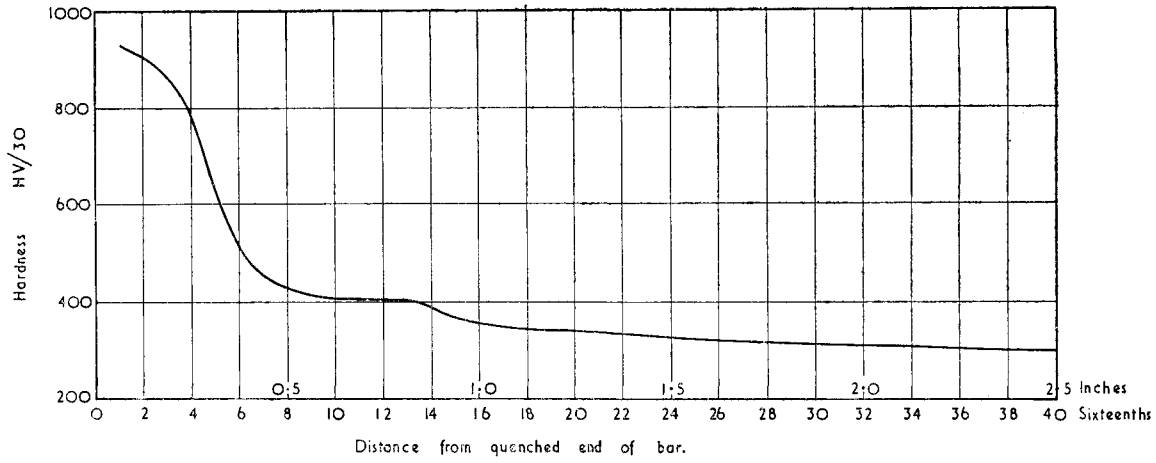


Fig. 31.7

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·98	0·22	0·47	0·011	0·013	0·25	1·36	0·07

McQuaid Ehn grain size 4—6 (7) (ASTM).
Actual grain size 6—8 (ASTM).
End Quenched from 925°C. Tempered 600°C.

(Ref. 9)

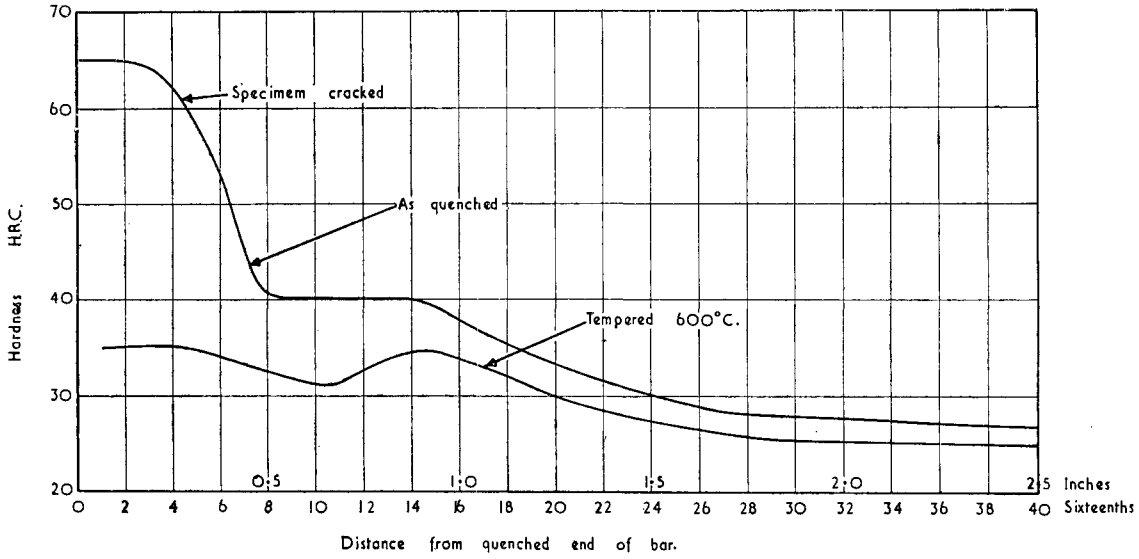


Fig. 31.8

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
											tons/sq.in.									
B.E.A.	0·96	0·21	0·32	0·018	0·014	0·31	1·29	0·04	2½ (L)	Spheroidize anneal	19·7	21·5		24·2		43·8	34	62	16	1
"	"	"	"	"	"	"	"	"	" (T)	" "					29·0	44·5	25	43	9	"
B.E.A.	0·95	0·28	0·45	0·017	0·037	0·36	1·35		⅞	As rolled					22·4	42·6	22½	56½		"
		not stated							1	OQ840 T540					77·0	82·5	9	34		10
B.E.A.	0·96	0·56	1·20	0·015	0·020	0·15	1·15		1⅛	Annealed					29·6	45·6	30	57	15	11
B.E.A.	1·00	0·25	0·36	0·010	0·011	0·18	1·32		½	OQ850 T450	89·8	92·0	94·5	96·0		102·5	9½	17		1
B.E.A.	1·01	0·17	0·42	0·004	0·015	0·14	1·56		½ sq.	" T430	101·2	103·8	106·2	108·0		114·2	9½	20		"
"	"	"	"	"	"	"	"	"	"	" T450	94·6	98·5	101·3	103·0		108·0	8	14⅓		"
"	"	"	"	"	"	"	"	"	"	" T475					93·2	98·2	8½	16	7	"

EFFECT OF TEMPERING ON THE HARDNESS OF QUENCHED BARS

Chemical Composition (%) C	Si	Mn	Ni	Cr	Heat Treatment °C	Hardness HV	Ref.
1·05	0·30	0·50	0·30	1·50	Hardened	823 to 890	12
"	"	"	"	"	" T120	823 to 890	"
"	"	"	"	"	" T150	792 to 856	"
"	"	"	"	"	" T200	749 to 792	"
"	"	"	"	"	" T250	679 to 698	"
"	"	"	"	"	" T300	644 to 661	"
"	"	"	"	"	" T350	596 to 644	"
"	"	"	"	"	" T400	541 to 570	"

En 31

EFFECT OF TEMPERING ON THE HARDNESS OF EN 31

This tempering graph shows a band which has been compiled from a large number of test results obtained from various sized bars between 1 in. and 4 in. dia. and of varying analysis.

(Ref. 2)

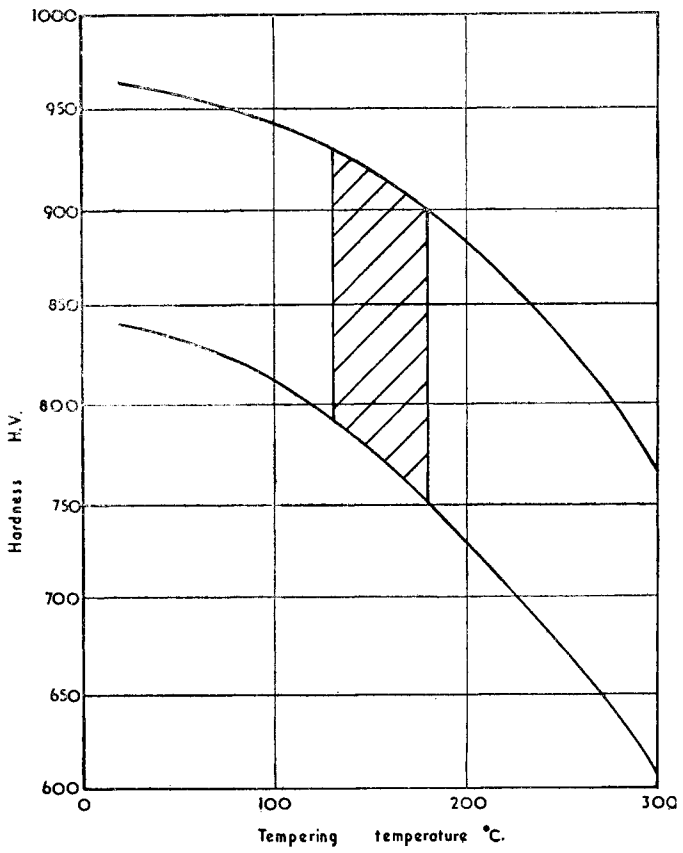


Fig. 31.9

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment*	Hardness HV	Rotary Bending Fatigue Limit tons/sq.in.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo					
B.E.A.	1·00	0·29	0·40	0·014	0·019	0·10	1·50	0·09	0·275	q	819	±37·5	13
"	"	"	"	"	"	"	"	"	"	q+t	816	±38·5	"
"	"	"	"	"	"	"	"	"	"	q+u	748	±38 approx.	"
"	"	"	"	"	"	"	"	"	"	r+v	741	±37·5	"
H.F.	0·94	0·28	0·46	0·011	0·021	0·10	1·40		"	s	760	±45·0	"
"	"	"	"	"	"	"	"	"	"	r+v	665	±42·0	"
A.O.H.	0·95	0·17	0·36	0·011	0·009	Tr	1·55		"	q	866	±43·5	"
"	"	"	"	"	"	"	"	"	"	r+v	728	±41·0	"
N.O.H.	1·00	0·20	0·41	0·025	0·025	0·30	1·29		"	q	831	±51·0	"

* Details of Heat Treatments on page 301.

FATIGUE PROPERTIES: DETAILS OF HEAT TREATMENTS

on the rough machined test pieces	on finish machined test pieces
q 850°C ½ hr. OQ (50—60°C), stood 2 days, immersed in Solid CO_2 ¼ hr. stood 2 days, T185°C, 1 hr. A C.	t immersed in liquid oxygen 4 hr.
r 800°C ½ hr. OQ (50—60°C) removed from oil after 10 min., immersed in liquid oxygen for ½ hr., T250 °C, 1 hr., A.C.	u " " " " 2¼ hr. + T250°C, 1hr. A.C
s 850°C ½ hr. OQ (50—60°C), stood 2 days, immersed in solid CO_2 ¼ hr., stood 2 days, T250°C, 1hr., A.C	v " " " " ½ hr.

N.O.H = Neutral Open Hearth, i.e basic hearth with an acid slag.

(The original report should be consulted for much further information of the fatigue properties of this steel.)

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9. Symposium on the Hardenability of Steel. Organized by the Technical Advisory Committee of the Special Alloy Steels Committee (Ministry of Supply) and The Iron & Steel Institute. Special Report No. 36 of The Iron and Steel Institute 1946.
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En 32

CARBON CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

	C	Si	Mn	S	P
En 32A	0·15 max	0·05—0·35	0·40—0·70	0·050 max.	0·050 max.
En 32B	0·10—0·18	0·05—0·35	0·60—1·00	0·070 max.(1)	0·050 max.
En 32C	0·10—0·18	0·05—0·35	0·60—1·00	0·050 max.	0·050 max.
En 32M	0·10—0·18	0·05—0·35	0·90—1·20(1)	0·10—0·15(1)	0·050 max.

(1) The higher sulphur and manganese contents are for increased machinability.

MECHANICAL PROPERTIES

	En 32A	En 32B	En 32C	En 32M
Limiting ruling section, in.	Less than ½"	Greater than ½"	Greater than ½"	
Tensile strength, tons/sq.in., min.(Rm)	32	32	32	32
Elongation, %, min.(A)	20	20	20	20
Izod impact value, ft. lbs.	40	40	40	40

The heat treatment given to 1⅛ in. dia. test bars shall be:
Blank carburize at a temperature between 880°C and 930°C (1), (2).
Refine at a temperature of 870°C—900°C, cool in air oil or water.
Harden in water from 760°C—780°C.

(1) By arrangement with the purchaser, the test may be carried out on samples from which the blank carburizing treatment has been omitted, or modified to a short heating period.
(2) A single quench from 800°C—820°C may be used in certain cases when the refining treatment after carburizing is omitted by special arrangement between the purchaser and manufacturer.

RELATED SPECIFICATIONS

United Kingdom		America		France	Germany			Sweden	U.S.S.R.	
En No.	BS Air	SAE	AISI	AFNOR	Werkstoff No.	Name	DIN	SIS	GOST	Mark
32A		1009 1010 1012	C1009 C1010 C1012	XC10f C10d C12d	1.0305 1.0345	St35.8 HI	17175 17155	14.1331 14.1332	1050—60	10
32B		1115	C1115							
32C	3S14	1015 1016	C1015 C1016	XC12f	1.0419	MRSt44	17110	14.1370 14.2101	5058—57 1050—60	14G 15G
32M		1114 1115	C1114 C1115	12Mf4	1.0723	15S20	1651	14.1922		

APPLICATIONS

A non-alloy case hardening steel which can be carburized and water hardened to produce an extremely hard and wear resistant case, with a core strength of the order of 32 tons/sq.in. and with a good resistance to shock.

Typical applications are: camshafts, light duty gears, gudgeon pins, worms, collets, selector forks, pawls, ratchets, tappets, rollers, bushes, spindles and lightly stressed small arms components subjected to wear.

WELDING

See Introduction (List of Abbreviations) for key to symbols used in this table.

	Welding Process					
	MA	G	IG	S	F	B
En 32A	a	a	a	a	a	h
32B	a	a	a	a	a	h
32C	a	a	a	a	a	h
32M*	c	f	f	f	f	h

* MA Basic low H electrodes are required.

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Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

This steel is readily machinable, especially with the high sulphur addition of En 32M (compare with En 2 and En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 900°C.
Normalizing	880°C—930°C. Air cool.
Carburizing	880°C—930°C.
Refining*	870°C—900°C. Cool in air, oil or water.
Hardening*	760°C—780°C. Quench in water.
Tempering (for stress relief and maximum case toughness)	150°C—200°C.

* A single water quench from 800°C—820°C may be adopted, but if so it is preferable for the steel to be of fine grain size.

CARBURIZING DATA

See notes given in the Introduction.

Case Depth in.	Time in hours at the stated carburizing temperature to produce the stated case depth.								
	900°C			925°C			950°C		
	Solid	Salt	Gas	Solid	Salt	Gas	Solid	Salt	Gas
0·01	0·7	0·37	0·3	0·5	—	0·25	0·3	0·26	—
0·02	1·6	1·2	1·0	1·2	—	0·75	0·7	0·75	0·40
0·03	3·7	2·4	2·3	2·5	—	1·5	1·5	1·5	0·9
0·04	6·6	4·8	4·0	4·5	—	2·75	2·7	3·0	1·6
0·06	14·8	9·6	9·25	10·0	—	6·0	6·0	6·0	3·6
0·08	26·5	—	16·0	18·0	—	11·0	10·8	—	6·4
0·10	41·0	—	28·0	28·0	—	16·0	17·0	—	10·0

PHYSICAL PROPERTIES

(See also En 2 and En 3)

SPECIFIC GRAVITY (d)

Chemical Composition (%)			Heat Treatment	Specific Gravity at 20°C	Ref.
C	Si	Mn			
0·14	0·25	0·60	Normalized	7·87	1
0·14		0·70		7·87	2

SPECIFIC HEAT (c)

Chemical Composition (%)					Heat Treatment	Mean Specific Heat cal/g deg. C										Ref.
C	Si	Mn	Ni	Cr		20to 100°C	20to 200°C	20to 300°C	20to 400°C	20to 500°C	20to 600°C	20to 700°C	20to 800°C	20to 900°C	20to 1000°C	
0·14	0·25	0·60			Normalized	0·114										1
0·13	0·20	0·61	0·12	0·01		0·110	0·116	0·121	0·125	0·130	0·136	0·144	0·156	0·159	0·159	3

COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)			Heat Treatment	10^6 × Mean Coefficient of Expansion per deg. C				Ref.
C	Si	Mn		20to 100°C	20to 300°C	20to 500°C	20to 700°C	
0·14	0·25	0·60	Normalized	12	13	14	15	1
0·14		0·70	—	12·3	13·7	14·6	15·1	2

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)					Heat Treatment	Electrical Resistivity microhm-cm											Ref.
C	Si	Mn	Ni	Cr		0°C	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	
0·12	0·18	0·65	0·10	—	Normalized		15											1
0·13	0·20	0·61	0·12	0·01	—	16·3	17·3	22·6	29·6	38·2	48·2	60·3	74·2	91·0	110·0	115·9	119·4	3

YOUNG'S MODULUS (E)

Chemical Composition (%)				Heat Treatment °C	Young's Modulus tons/sq.in.	Ref.
C	Si	Mn	Ni		Static	
0·12	0·18	0·65	0·10	Normalized	13,400	1

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)				Heat Treatment	Thermal Conductivity cal/cm s deg. C	Ref.
C	Si	Mn	Ni		20°C	
0·12	0·18	0·65	0·10	Normalized	0·12	1

MAGNETIC PROPERTIES

Chemical Composition (%)			Section Size dia. (in.)	Heat Treatment °C	H max. (Oersted)	B max. (Gauss)	Coercive Force (Oersted) Hc	Remanence (Gauss) Brem	Ref.
C	Si	Mn							
0·16	0·14	0·62	$\frac{3}{16}$	N900 T230	250	19,480	3·7	11,250	4

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

Chemical Composition (%)	
C	Mn
0·17	0·92

Austenite grain size 0—2.
Austenitizing Temperature 1316°C. (Ref. 5)

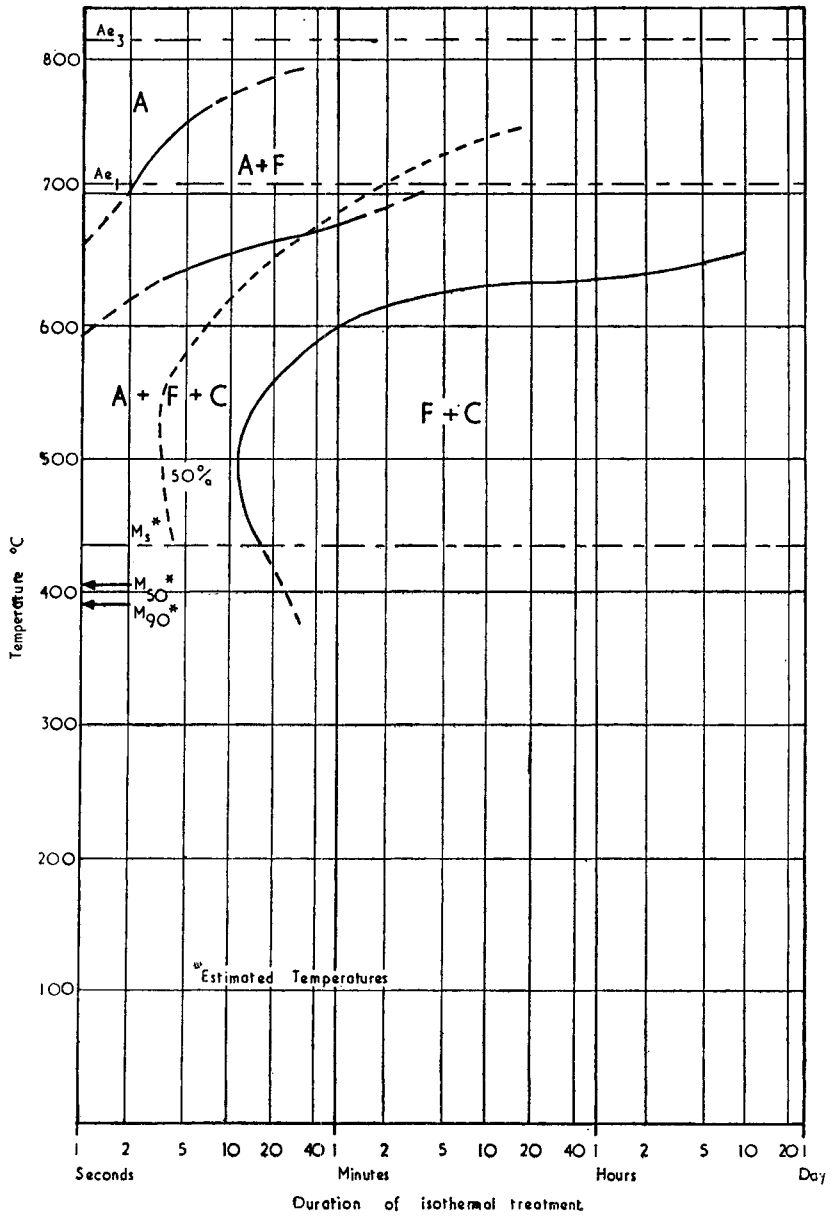


Fig. 32.1

HARDENABILITY

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								Grain Size (ASTM)	
	C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn
A	0·14	0·18	0·52	0·015	0·019	0·13	0·05	0·06	5—7(3—4)	1—3(4)
B	0·11	0·24	0·62	0·052	0·012	0·39	0·23	0·03	7—8	1—4

Bars Normalized 925°C.

End Quenched from 900°C. (Ref. 6)

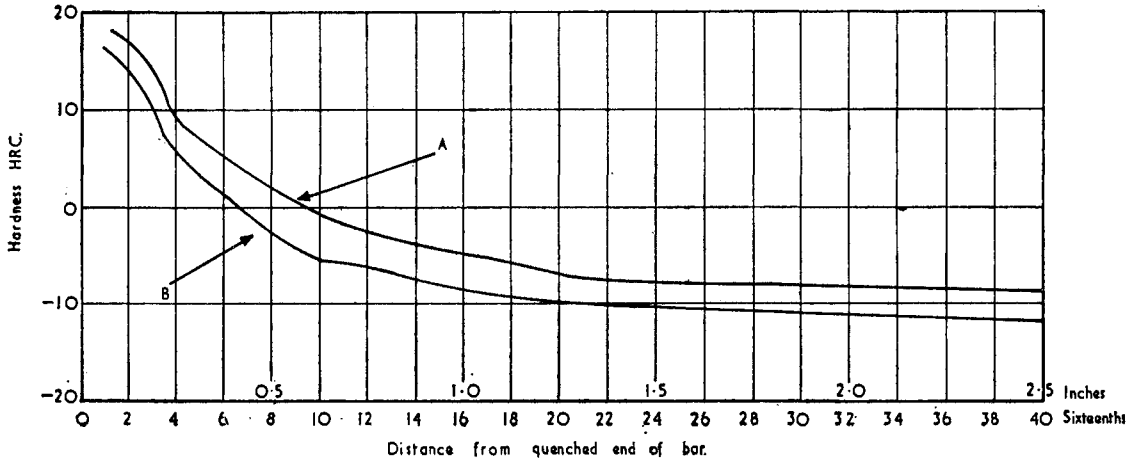


Fig. 32.2

Re-quenched from 770°C. (Ref. 6)

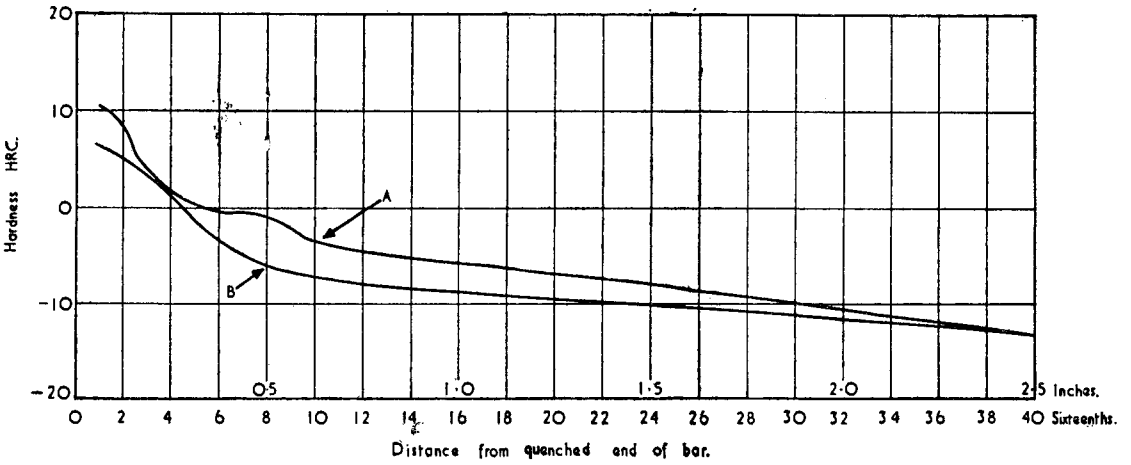


Fig. 32.3

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(See also En 2 and En 3)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			L.P.	0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.							
B.O.H.		0·08	0·19	0·50	0·047	0·025	0·18			1 1/8	WQ900 WQ770				32·0	34		93	7
B.O.H.	Al added	0·09	0·13	0·48	0·033	0·019	0·23			1 1/8	" "				30·4	39		103	"
B.O.H.		0·09	0·11	0·50	0·035	0·027	0·16			1 1/8	" "				40·0	32		65	"
B.O.H.	Al added	0·10	0·22	0·44	0·039	0·019	0·21			1 1/8	WQ900 WQ770				33·7	36 1/2		93	7
B.O.H.	Al added	0·10	0·15	0·48	0·036	0·021	0·16			1 1/8	" "				32·4	37		112	"
B.O.H.	Al added	0·10	0·08	0·45	0·039	0·026	0·20			1 1/8	" "				34·0	37		109	"
		0·10	0·23	0·55			0·32	0·05		5/8	WQ900 WQ770			26·4	36·4	30	59 1/2	100	1
		"	"	"			"	"		1 1/8	" "			20·0	32·8	34	58	99	"
		0·10	0·20	0·73	0·027	0·015	0·27	0·23	0·04	1 5/8	As rolled	13·4	17·2	18·7	29·8	40 1/2	69	119	"
		"	"	"	"	"	"	"	"	"	WQ890 WQ770	5·6	16·5	19·7	35·2	39	68	80	"
B.O.H.		0·10	0·15	1·18	0·130	0·024	0·18			7/8 hex.	WQ900 WQ760				40·0	32		75	7
"		"	"	"	"	"	"			1 1/8	WQ900 WQ770				37·2	32		75	"
"		"	"	"	"	"	"			1 9/32 hex.	WQ900 WQ760				42·9	31		55	"
"		"	"	"	"	"	"			1 1/8	WQ900 WQ770				38·2	13		59	"
B.O.H.		0·11	0·23	0·60	0·043	0·021	0·25			5/8	WQ900 WQ770				44·0	31		69	7
B.O.H.	Al added	0·11	0·16	0·44	0·033	0·019	0·21			1 1/8	" "				35·0	35		102	"
B.O.H.	Al added	0·11	0·08	0·45	0·033	0·031	0·16			1 1/8	" "				34·4	35		80	"
B.O.H.	Al added	0·11	0·12	0·50	0·038	0·039	0·19			1 1/8	" "				38·0	32		60	1
	McQuaid Ehn Actual	0·11	0·19	0·54			0·21	0·21		1 1/8	WQ900 WQ770			25·0	36·8	35	70	98	1
B.O.H.	1—4 7—8	0·11	0·24	0·62	0·052	0·012	0·39	0·23	0·03	1	N925 WQ900 T150			22·7	38·9	28	68 1/2	60 1/2	6
B.O.H.		0·11	0·15	1·02	0·144	0·027	0·22			1 1/8	WQ900 WQ760				38·2	31		70	7
"		"	"	"	"	"	"			"	" WQ770				36·0	36		77	"
B.O.H.		0·12	0·22	0·60	0·042	0·023	0·15			1 1/8	WQ900 WQ770				36·6	32		94	7
B.O.H.		0·12	0·21	0·61	0·038	0·023	0·19			31/32	" "				35·4	36		82	"
"		"	"	"	"	"	"			1 1/8	" WQ760				33·2	34		98	"
B.O.H.		0·12	0·24	0·80	0·059	0·039	0·22			7/8	" WQ770				42·0	33		84	"
"		"	"	"	"	"	"			1 1/8	" "				39·6	33		82	"
B.O.H.	Al added	0·12	0·25	0·78	0·037	0·046	0·22			1 1/8	" "				42·0	32		63	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
											tons/sq.in.							
B.O.H.		0·12	0·22	0·71	0·061	0·026	0·17		1 5/16	WQ900 WQ770				37·4	32		60	7
		0·12	0·19	0·54			0·16	0·08	1 1/8	WQ900 WQ770			24·4	35·8	37 1/2	72	110	1
		0·12	0·22	0·75					1 1/8	BC900 WQ900 WQ760				34·5	29	57	100	2
		0·12	0·19	0·57					1 1/8	" " "				32·5	29 1/2	66	92	"
		0·12	0·22	0·76	0·039	0·010			1 1/8	BC900 WQ890 WQ770			23·2	36·8	31		87	8
		0·12	0·18	0·65			0·10		1 1/8	N900	16·2	17·5		28·5	37	64 1/2	65	1
		"	"	"			"		"	WQ900 WQ760	14·1	17·2		31·3	33	61	85	"
															4√A 5D			
B.E.		0·12	0·21	0·69	0·014	0·010	0·10	0·06	1 1/8	BC925 WQ900 WQ770		19·6		36·1	39 34	72		"
B.O.H.		0·12	0·19	0·80	0·043	0·022	0·17		1 1/8	WQ900 WQ770				36·0	32		90	7
B.O.H.		0·12	0·15	1·17	0·140	0·021	0·17		7/8 hex.	WQ900 WQ770				40·2	30		67	7
B.O.H.		0·12	0·13	1·14	0·136	0·016	0·20		1 1/8	" "				40·0	30		86	"
B.O.H.		0·12	0·15	1·23	0·150	0·025	0·27		1 1/16	" "				45·6	30		69	"
B.O.H.		0·12	0·17	1·03	0·125	0·026	0·20		1 1/8	" "				38·6	31		87	"
B.O.H.		0·12	0·19	1·17	0·148	0·028	0·22		1 1/8	" "				39·0	30		66	"
B.O.H.		0·13	0·28	0·61	0·040	0·031	0·22		1 1/8	WQ900 WQ770				33·2	36		93	7
B.O.H.		0·13	0·23	0·62	0·038	0·024	0·26		"	" "				39·8	31		50	"
B.O.H.		0·13	0·23	0·62	0·034	0·022	0·20		1 3/32	" "				39·4	24		84	"
B.O.H.		0·13	0·24	0·68	0·030	0·017	0·20		1 1/8	" "				38·0	34		74	"
B.O.H.		0·13	0·24	0·73	0·032	0·019	0·19			As rolled				28·6	35		—	"
"		"	"	"	"	"	"		1 1/8	WQ900 WQ770				38·0	33		89	"
B.O.H.		0·13	0·21	0·74	0·032	0·42	0·15		1 1/8	" "				44·0	32		56	"
B.O.H.	6 to 7	0·13	0·21	0·75	0·039	0·039	0·20		"	" "				41·6	34		62	"
		0·13	0·13	0·71			0·25	Tr	1 1/8	WQ900 WQ770			24·0	36·0	30	53 1/2	85	1
A.O.H.		0·13	0·06	0·41	0·025	0·036	0·20	0·08	1 1/8	N900			18·1	28·3	42	67	92	"
"		"	"	"	"	"	"	"	"	WQ900			25·3	34·1	32 1/2	70 1/2	103	"
"		"	"	"	"	"	"	"	"	" T300			25·3	33·6	36	71	106	"
"		"	"	"	"	"	"	"	"	" T400			26·3	33·9	37 1/2	71 1/2	104	"
"		"	"	"	"	"	"	"	"	" T500			26·9	33·4	36 1/2	71	107	"
"		"	"	"	"	"	"	"	"	" T600			24·3	32·4	39 1/2	74	104	"
"		"	"	"	"	"	"	"	"	OQ900			23·3	32·5	36	69	97	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size		Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Tensile Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.O.H.			0·13	0·15	1·15	0·126	0·018	0·20		1 1/8	WQ900 WQ760		39·6	31		71	7
B.O.H.			0·13	0·06	1·08	0·144	0·019	0·16		15/16	" "		40·0	32		61	"
B.O.H.			0·13	0·07	1·20	0·134	0·021	0·23		1 1/8	" "		42·4	26		49	"
"			"	"	"	"	"	"		"	" WQ770		43·4	30		70	"
B.O.H.			0·14	0·26	0·61	0·038	0·021	0·20		1 1/8	WQ900 WQ770		37·4	32		85	7
B.O.H.			0·14	0·21	0·61	0·030	0·018	0·15		"	" "		32·0	34		93	"
B.O.H.			0·14	0·25	0·69	0·035	0·014	0·18		"	" "		37·0	33		99	"
B.O.H.			0·14	0·17	0·56	0·045	0·022	0·16		"	" WQ760		39·6	32		55	"
B.O.H.			0·14	0·22	0·75	0·038	0·031			1	" WQ770		40·0	35		74	"
B.O.H.			0·14	0·24	0·77	0·051	0·024	0·18		1 1/8	" "		39·8	32		73	"
			0·14	0·29	0·58			0·11	0·15	1 1/2	WQ900 WQ770	21·4	34·4	36 1/2	70	110	1
			0·14	0·16	0·71					1 1/8	BC900 WQ900 WQ760		37·2	30 1/2	66	89	2
	McQuaid	Actual	0·14	0·23	0·76					"	" " "		43·0	31	57	47	"
	Ehn		0·14	0·15	0·59					"	" " "		33·9	33	66	95	"
B.E.A.	1—3(4)	5—7(3—4)	0·14	0·18	0·52	0·015	0·019	0·05	0·06	1	N925 WQ900 T150	26·0	42·5	28	65	39	6
	3		0·14		0·46					1 1/8	BC920 WQ780	28·9	38·0	28	55	17	4
	"		"		"					"	" WQ900	31·6	40·2	26 1/2	68	66	"
	6—7		0·14	0·14	0·71					5/8	BC920 WQ900 WQ780	28·3	47·1	27	55	59	"
	"		"	"	"					1 1/8	" " "	23·2	39·4	34 1/2	64	85	"
B.O.H.			0·14	0·15	1·11	0·146	0·019	0·16		1 1/8	WQ900 WQ770		38·8	32		76	7
B.O.H.			0·14	0·19	1·19	0·147	0·019	0·20		"	" "		40·0	33		69	"
B.O.H.			0·14	0·14	1·19	0·132	0·022	0·21		1	" "		42·4	29		58	"
B.O.H.			0·14	0·16	1·20	0·130	0·029	0·14		1 1/8	" "		45·4	30		58	"
B.O.H.			0·15	0·23	0·64	0·022	0·023	0·15		1 1/8	WQ900 WQ770		42·0	30		53	7
B.O.H.			0·15	0·25	0·62	0·033	0·017	0·26		"	" "		40·2	32		65	"
B.O.H.			0·15	0·22	0·84	0·034	0·036	0·25		1	" "		43·4	28		68	"
B.O.H			0·15	0·23	0·72	0·038	0·024	0·19		1 1/8	" "		40·0	35		74	"
			0·15	0·19	0·65					1 1/8	BC900 WQ900 WQ760		35·0	27 1/2	56	89	2
			0·15	0·16	0·81	0·031	0·024			1 1/8	BC900 WQ890 WQ770	24·0	37·2	39		88	8

MECHANICAL PROPERTIES AT ROOM TEMPERATURE
(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (% C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Tensile L.P.	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
A.O.H.		0·15	0·16	0·90	0·033	0·034	0·39	0·08	1 1/8	N900	16·0	19·6		30·0	39 1/2	69		9
"		"	"	"	"	"	"	"	3/4	"		17·9		30·3	39	69		"
"		"	"	"	"	"	"	"	1 1/8	WQ900 WQ780	18·0	25·2		39·4	33 1/2	70 1/2		"
		0·15		0·75	0·033	0·027			1	BC WQ900 WQ780			22·4	35·8	35	"	88	10
		"		"	"	"			2	" " "			21·5	31·9	35		85	"
		"		"	"	"			3	" " "			19·0	31·4	37		84	"
		"		"	"	"			4	" " "			19·2	30·1	40		80	"
	6 to 8	0·15	0·17	0·53	0·031	0·018			—	A870			18·4	25·0	37	69 1/2	83	11
	"	"	"	"	"	"			1/2	N927			21·4	28·2	38 1/2	71	85	"
	"	"	"	"	"	"			1	"			21·0	27·4	37	69 1/2	85	"
	"	"	"	"	"	"			2	"			19·8	26·8	37 1/2	69	86	"
	"	"	"	"	"	"			4	"			18·7	26·4	36 1/2	68	83	"
	"	"	"	"	"	"			1/2	BC912 WQ775 T177			26·8	47·5	15	33	50	"
	"	"	"	"	"	"			1	" " "			19·6	33·7	30	69	85	"
	"	"	"	"	"	"			2	" " "			19·0	31·6	32	70 1/2	94	"
	"	"	"	"	"	"			4	" " "			17·4	30·0	30 1/2	69 1/2	96	"
B.O.H.		0·15	0·16	1·16	0·125	0·027	0·27		13/16	WQ900 WQ770				50·0	25		46	7
B.O.H.		0·15	0·08	1·15	0·130	0·020	0·17		1 1/8	" WQ760				38·2	29		73	"
B.O.H.		0·15	0·07	1·20	0·134	0·021	0·23		"	" "				42·4	26		49	"
"		"	"	"	"	"	"		"	" WQ770				43·4	30		70	"
B.O.H.		0·16	0·23	0·78	0·032	0·028	0·18		1 1/8	WQ900 WQ770				44·4	30		54	7
	7	0·16	0·14	0·62					1 1/8	BC920 WQ900 WQ980			26·0	36·6	32	70	102	4
	"	"	"	"					"	" WQ780			21·1	35·2	33	66	100	"
	"	"	"	"					"	" WQ820			24·2	35·4	32 1/2	74	89	"
	"	"	"	"					"	" WQ860			26·0	35·8	27	72	101	"
	"	"	"	"					"	" WQ900			27·6	34·7	33 1/2	70	99	"
	7	0·16	0·16	0·70					1 1/8	As Rolled			20·7	30·2	32 1/2	64		"
	"	"	"	"					"	N920			20·6	29·6	27	65		"
	"	"	"	"					"	FC750			17·8	28·0	34	69		"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
									Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
	C	Si	Mn	S	P	Ni			tons/sq.in.					
B.O.H.	0·16	0·14	1·16	0·126	0·020	0·18	$\frac{7}{8}$ hex.	WQ900 WQ760		46·4	29		59	7
"	"	"	"	"	"	"	$1\frac{1}{8}$	" WQ770		40·4	31		70	"
B.O.H.	0·16	0·16	1·10	0·140	0·025	0·16	$1\frac{1}{8}$	" "		39·6	31		68	"
B.O.H.	0·16	0·15	1·40	0·135	0·018	0·21	$\frac{29}{32}$	" "		44·8	28		54	"
"	"	"	"	"	"	"	$1\frac{1}{8}$	" WQ760		43·0	27		57	"
	0·17	0·24	0·72	0·041	0·047		$1\frac{1}{8}$	N920	20	31	38	64	80	12
	"	"	"	"	"		"	WQ920	34	46	22	51	24	"
	"	"	"	"	"		"	OQ920	$23\frac{1}{2}$	36	31	65	92	"
	"	"	"	"	"		"	WQ920 WQ760	24	40	32	64	43	"
B.O.H.	0·18	0·20	0·64	0·063	0·034	0·21	$1\frac{1}{8}$	WQ900 WQ770		41·0	32		68	7

EFFECT OF SECTION SIZE ON THE CORE PROPERTIES

Chemical Composition (%)			
C	Mn	S	P
0·15	0·75	0·033	0·027

Bars Blank Carburized.
Water Refined 900°C.
Water Hardened 780°C.

(Ref. 10)

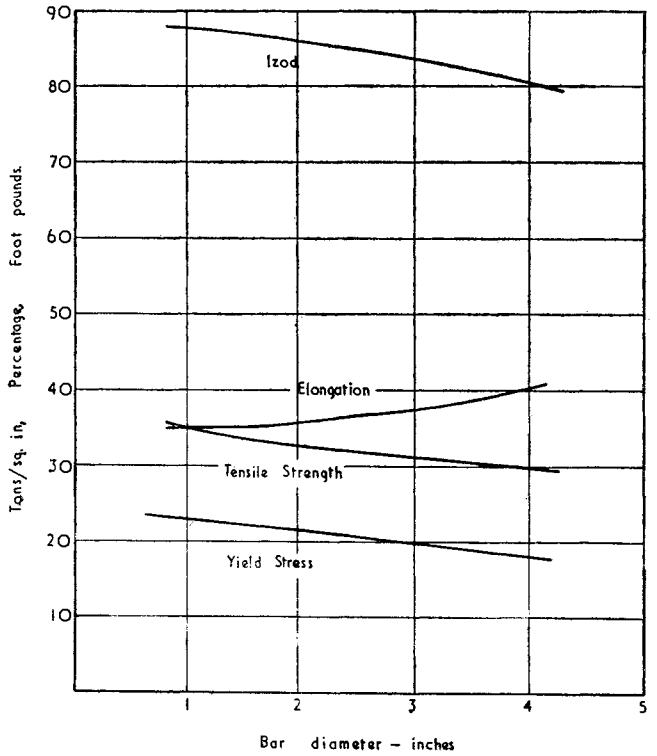


Fig. 32.4

Chemical Composition (%)				
C	Si	Mn	S	P
0·15	0·17	0·53	0·031	0·018

ASTM grain size 6 to 8.
Bars Blank Carburized 912°C.
Water Quenched 775°C.
Tempered 177°C

(Ref. 11)

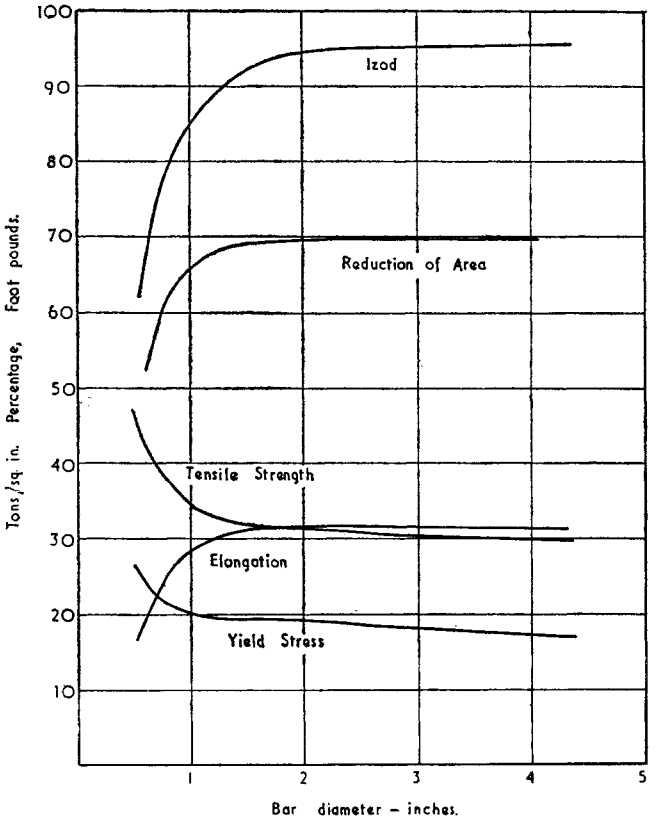


Fig. 32.5

En 32

EFFECT OF TEMPERING TEMPERATURE ON CASE HARDNESS

Typical curve for steel.
Carburized 900°C.
Water Refined 900°C.
Water Hardened 760°C.

(Ref. 2)

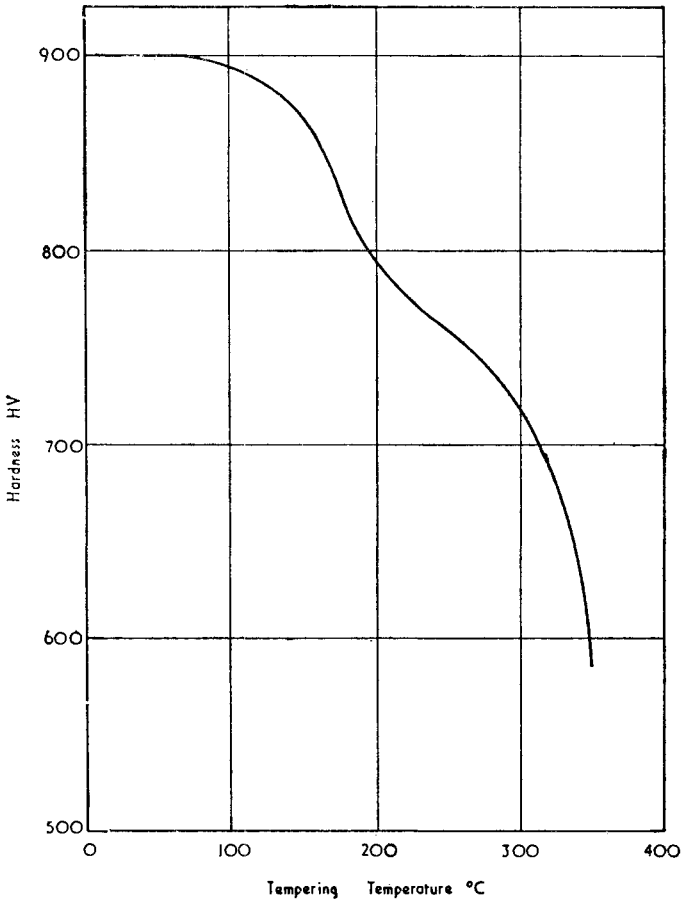


Fig. 32.6

MECHANICAL PROPERTIES IN TORSION

(See also En 2 and En 3)

Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Torsion			Ref.
C	Si	Mn	S	P	Ni			Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		Y.P.	Apparent Shear Strength	Probable max. Shear Strength	
								tons/sq.in.					tons/sq.in.			
0·11	0·10	0·73	0·018	0·020	0·12	1⅛	N900	16·6	26·3	37	62	83	11·1	30·4	22·8	1
"	"	"	"	"	"	"	" WQ700	19·1	28·1	38	69	93	11·9	33·1	24·8	"
"	"	"	"	"	"	"	" WQ760	17·0	30·1	33	63½	90	9·9	34·5	25·9	"
"	"	"	"	"	"	"	" WQ820	18·2	31·3	32	62	80	9·9	36·3	27·2	"

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temp. °C	Tensile					Rotating Bending Fatigue Limit		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·5% P S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	Plain	Notched	
												tons/sq.in.					tons/sq.in.		
	0·10	0·20	0·73	0·027	0·015	0·27	0·23	0·04	1⅛	WQ890 WQ770	RT	16·5	19·7	35·2	39	68	±21·7		1
B.E.A.	0·11	0·16	0·53	0·009	0·009	0·10	0·09		1⅛/16	N900	RT	20·0	20·0	28·5	43	71½	±17·2	± 7·9*	"
"	"	"	"	"	"	"	"		"	"	—78	26·0	26·0	34·6	44	68½	±22·0	±14·5*	"
	0·12	0·16	0·33	0·048	0·060					A925			16·5	25·1	35	—	±14·7		13
	"	"	"	"	"					WQ925			24·8	38·4	20	72	±19·2		"
	0·17	0·10	0·50	0·009	0·015					N900			18·4	25·4	33	70	±14·6		"
	0·19	0·26	0·92	0·006	0·040					N900			16·5	28·7	30	—	±14·6		"

* Notch 55°V, 0·04 in. deep, root radius 0·010 in., dia. at notch 0·320 in., test dia.0·400 in. Neuber stress concentration factor 3.

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3 PER CENT NICKEL CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr
0·10—0·15	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	2·75—3·50	0·30 max.

MECHANICAL PROPERTIES

Tensile strength, tons/sq.in., min. (Rm)	45
Elongation, %, min. (A)	18
Izod impact value ft.lb., min.	40

The heat treatment given to 1⅛ in. dia. test bars shall be:
Blank carburize at a temperature between 880°C and 930°C. (1), (2).
Refine at a temperature of 850—880°C. Cool in air, oil or water.
Harden in water from a temperature of 760°C/780°C.

(1) By arrangement with the purchaser the test may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.

(2) A single quench from 820°C may be used in certain cases when the refining treatment after carburizing is omitted by special arrangement between the purchaser and the manufacturer.

RELATED SPECIFICATIONS

United Kingdom	
En	BS Air
En 33	4S15

En 33

APPLICATIONS

A nickel case hardening steel which may be carburized and hardened to produce a hard wear resistant case, and developing a core strength of the order of 45 tons/sq.in. with very good resistance to shock.

Typical applications are gears, crown wheels, pinions, pinion shafts, camshafts, and transmission components, gudgeon pins, collets, clutch plates, levers, magneto drive wheels, push rod heads, worms, valve gear parts, breech mechanisms, and rifle components.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table.)

	Welding Process					
	MA	G	IG	S	F	B
En 33	a	ax	g	e	a	h

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Parts may be welded or high temperature brazed before carburizing, but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

In the normalized condition the machinability is about 75% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C.
Normalizing	850°C—880°C. Air cool.
Softening	630°C—650°C. Air or furnace cool.
Carburizing	880°C—930°C.
Refining*	850°C—880°C. Cool in air, oil or water.
Hardening*	760°C—780°C. Water quench (oil quenching may be used for small sections).
Tempering: for stress relief	150°C—200°C.
for maximum case toughness	200°C—250°C.

* A single water quench from 820°C may be adopted, but it is preferable that with this treatment the steel should be of fine grain size.

CARBURIZING DATA

See notes given in the Introduction

Case Depth (in.)	Time in hours at the stated carburizing temperature to produce the given case depth							
	900°C			925°C		950°C		
	Solid	Salt	Gas	Solid	Gas	Solid	Salt	Gas
0·01	0·8	0·41	0·35	0·6	0·3	0·3	0·3	—
0·02	1·7	1·50	1·1	1·3	0·9	0·8	0·8	0·5
0·03	4·0	3·4	2·45	2·7	1·85	1·8	1·7	1·1
0·04	7·2	6·0	4·2	4·8	3·2	3·2	3·0	2·0
0·06	16·0	13·6	9·8	10·8	7·25	7·2	6·5	4·5
0·08	28·8	—	17·5	19·2	13·0	12·8	—	8·0
0·10	44·0	—	29·0	30·0	20·0	20·0	—	13·0

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)						Heat Treatment °C	Specific Gravity 20°C	Ref.
C	Si	Mn	S	P	Ni			
0·14	0·25	0·40			3·10	Normalized	7·88	1
0·12	0·15	0·50			3·10	—	7·88	"
0·13		0·45			3·15	—	7·87	2
0·11	0·22	0·42	0·011	0·011	3·18	—	7·837	3

SPECIFIC HEAT (c)

Chemical Composition (%)				Heat Treatment °C	Specific Heat cal/g deg. C	Ref.
C	Si	Mn	Ni		20°C	
0·14	0·25	0·40	3·10	Normalized	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)				Heat Treatment °C	10^6 × Mean Coefficient of Expansion per deg. C				Ref.
C	Si	Mn	Ni		20to 100°C	20to 300°C	20to 500°C	20to 700°C	
0·14	0·25	0·40	3·10	Normalized	11	12·5	14	14·5	1
0·13		0·45	3·15	—	11·6	13·1	13·9	14·5	2

En 33

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)				Heat Treatment °C	Electrical Resistivity microhm-cm	Ref.
C	Si	Mn	Ni		20°C	
0·12	0·15	0·50	3·10	Softened	21·5	1

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)				Heat Treatment °C	Thermal Conductivity cal/cm s deg. C	Ref.
C	Si	Mn	Ni		20°C	
0·12	0·15	0·50	3·10	Softened	0·095	1

YOUNG'S MODULUS (E), SHEAR MODULUS (G), AND POISSON'S RATIO (σ)

Chemical Composition (%)						Young's Modulus tons/sq.in.		Shear Modulus tons/sq.in.		Poisson's Ratio (2)		Ref.
C	Si	Mn	S	P	Ni	Static	Dynamic (1)	Static	Dynamic (2)	Static	Dynamic	
0·11	0·22	0·42	0·011	0·011	3·18	13,100	13,350	5,120	5,170	0·27	0·289	3

(1) Ultrasonic Pulse Method. (2) Calculated.

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

CORE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·11	0·21	0·36	0·028	0·010	2·89	0·28	0·09

Basic Open Hearth.
McQuaid Ehn grain size 3—6 (ASTM).
As quenched grain size: Finer than 8.
Bars hot rolled to ½ in. dia., annealed and cold drawn to 11 S.W.G., followed by 900°C (1 hr.) air cool, then 865°C (½ hr.) oil quench.
Austenitizing Temperature 770°C, 30 min. (20% ferrite present at austenitizing temperature).

(Ref. 4)

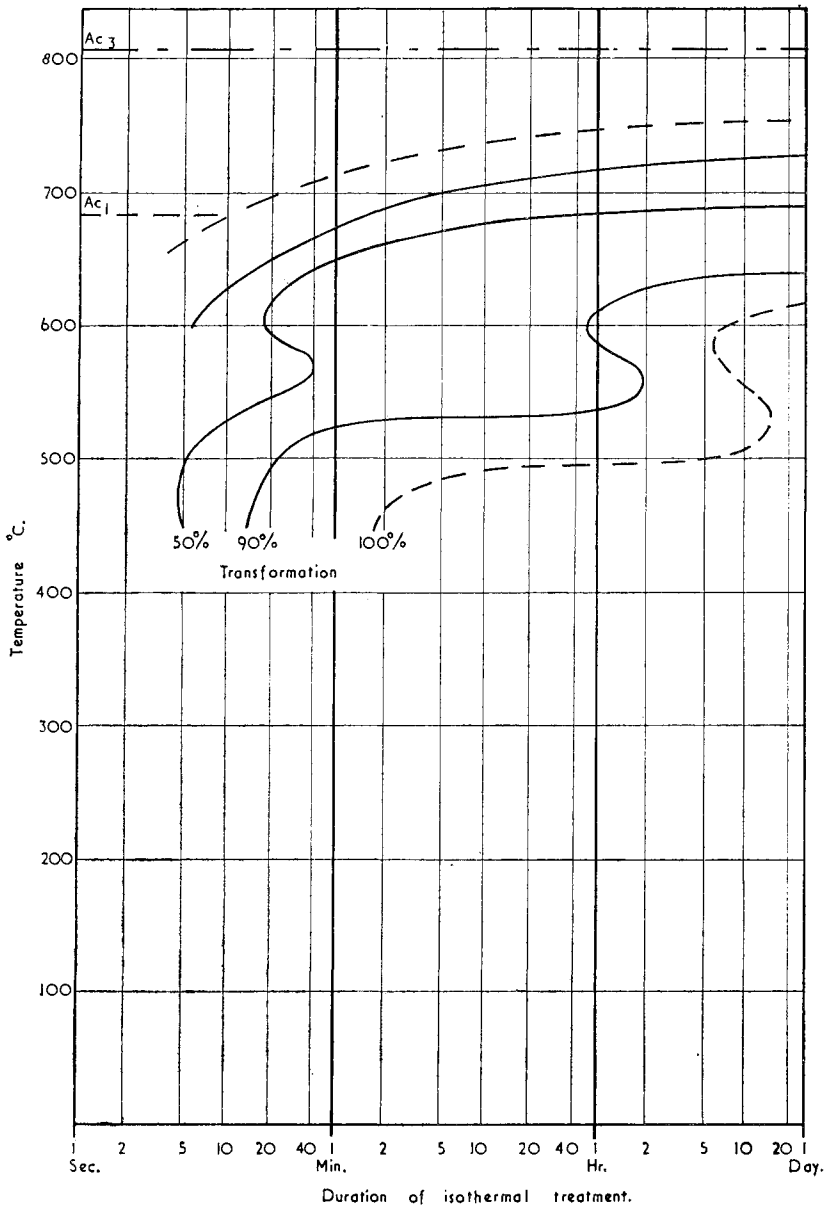


Fig. 33.1

En 33

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·95	0·26	0·40	0·015	0·028	2·95	0·36	0·08

Basic Electric Arc.
McQuaid Ehn grain size 7—8 (ASTM).
As quenched grain size Finer than 8.
Hot rolled to ⅞ in. dia., followed by 900°C (1 hr.) air cool.
Austenitizing Temperature 865°C, 30 min. (1% carbide present at austenitizing temperature).

(Ref. 4)

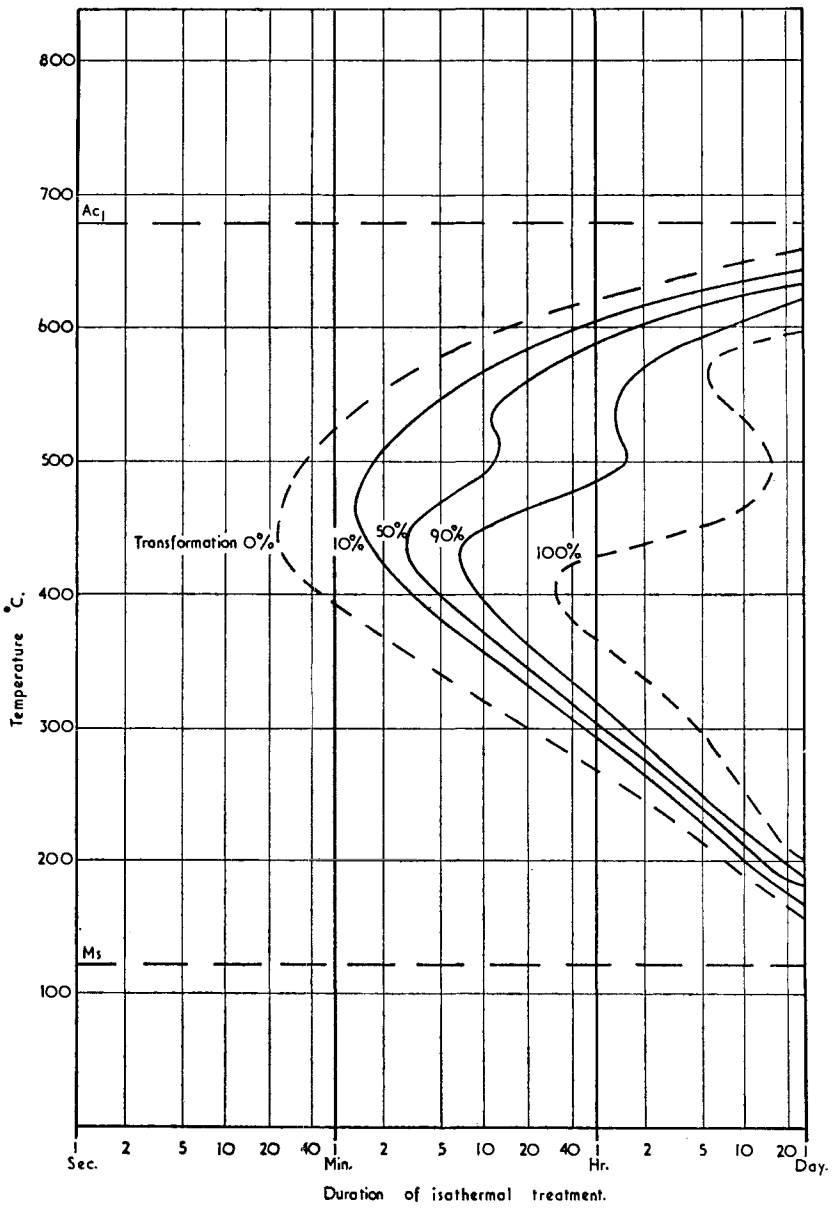


Fig. 33.2

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)					
C	Si	Mn	Ni	Cr	Mo
0·13	0·24	0·47	3·06	0·19	0·05

End Quenched from 760°C.

(Ref. 4)

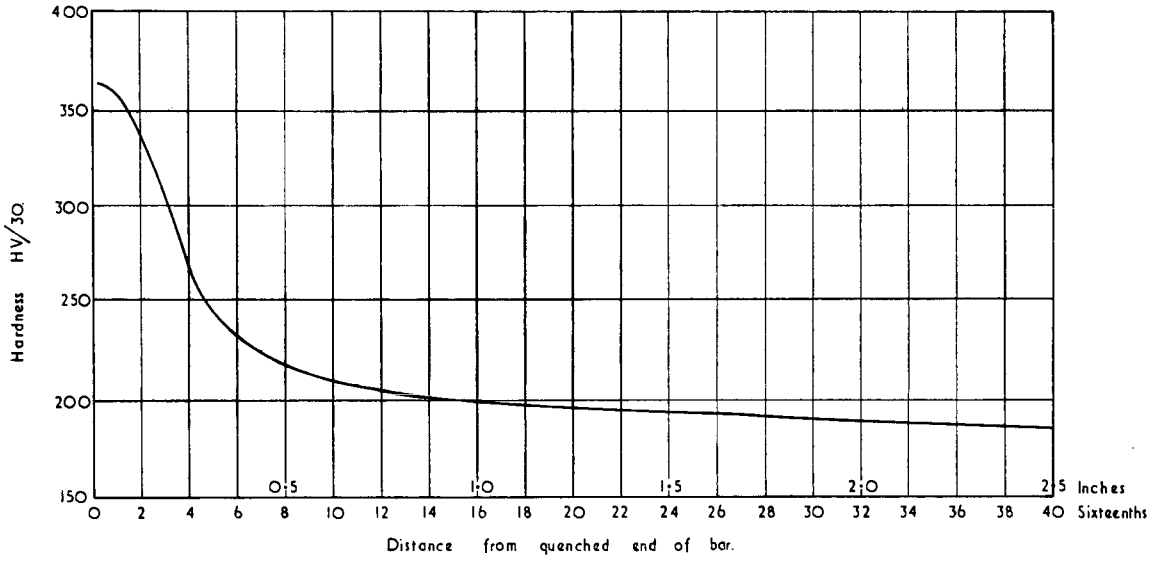


Fig. 33.3

En 33

END QUENCH HARDENABILITY DATA (Continued)

Curve No.	Chemical Composition (%)								Bar Size dia. (in.)	Grain Size (ASTM)	
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid Ehn
A	0·16	0·25	0·46	0·013	0·015	2·88	0·09	0·07	1·66	7—8(6)	2—4(1) (5)
B	0·17	0·29	0·41	0·042	0·025	2·97	0·12	0·17	1⅜	8—9	8—(7)
C	0·11	0·26	0·47	0·042	0·040	3·14	0·12	0·07	2	6(7) (5)	4—5(3)
D	0·15	0·31	0·53	0·040	0·040	3·09	0·21	0·05	1	6—7	4—6(3)
E	0·14	0·25	0·61	0·035	0·010	3·01	0·13	0·02	1¼	7—9	7—8

Test Bars Normalized 900°C and End Quenched 850°C.

As quenched from 850°C

(Ref. 5)

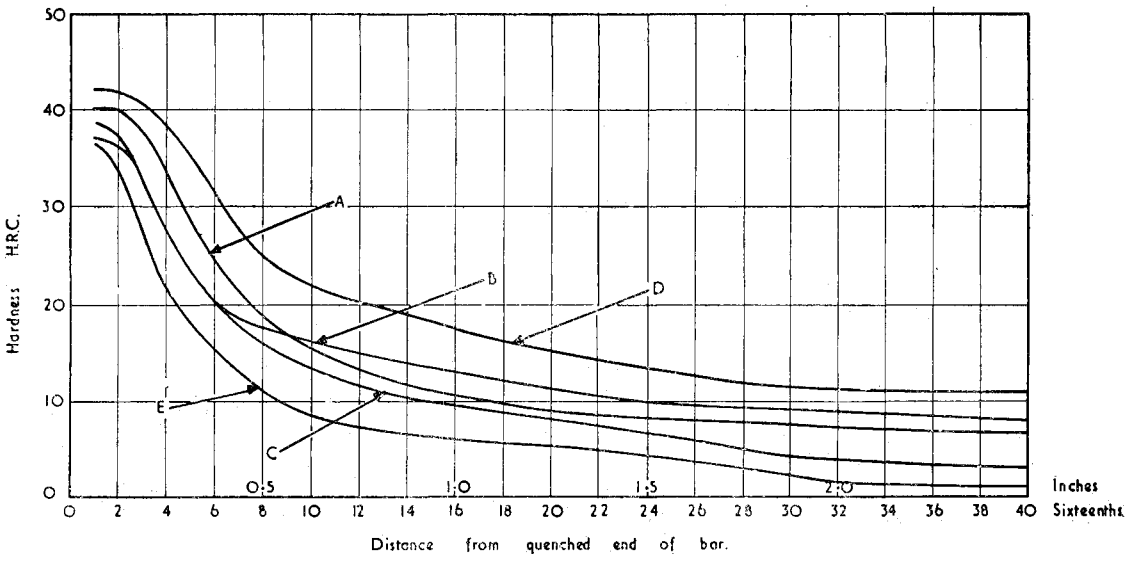


Fig. 33.4

Re-quenched 770°C.

(Ref. 5)

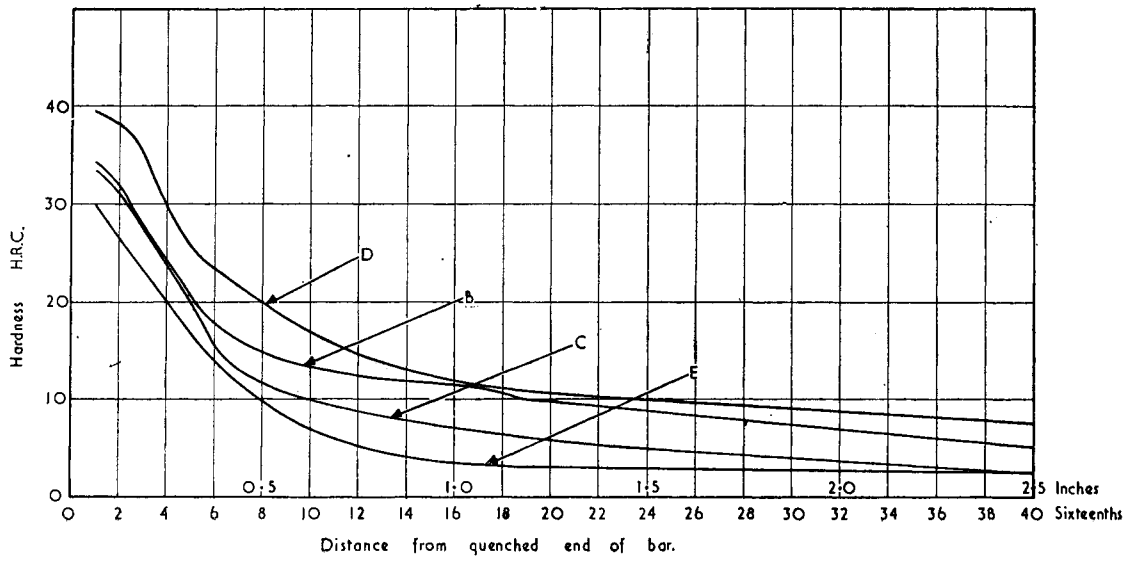


Fig. 33.5

END QUENCH HARDENABILITY BAND

These curves have been produced from the results obtained on several casts of En 33.

(Ref. 2)

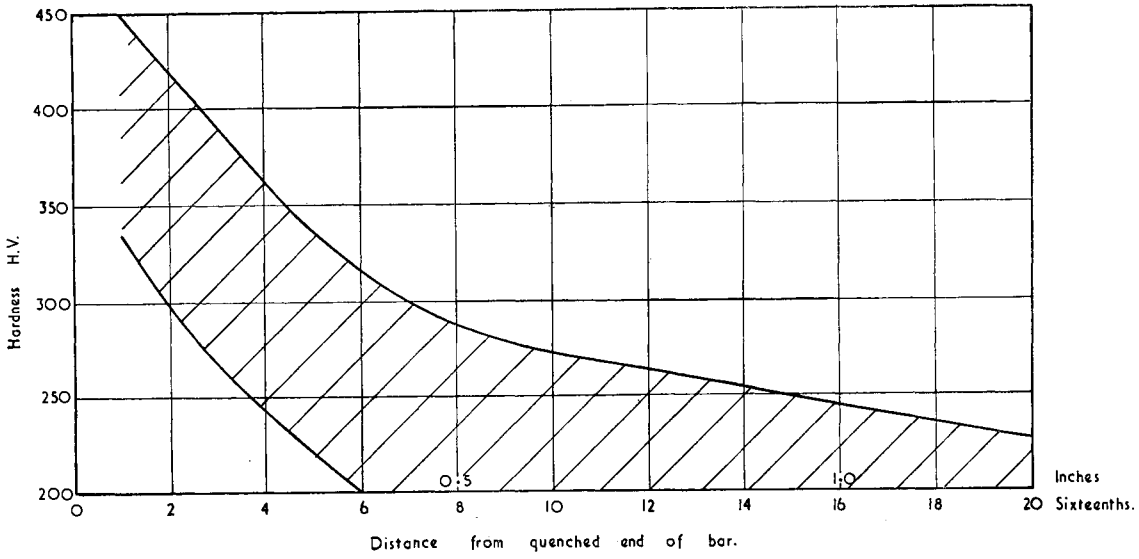


Fig. 33.6

En 33

SECTION QUENCH DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·13	0·23	0·48	0·022	0·010	3·08	0·24	0·11

Basic Electric Arc.

McQuaid Ehn grain size 2—4 (1—5) ASTM.

As quenched grain size 5—6 ASTM.

Test Bars Normalized 950°C, 1 hr. Air Cool.

Bars forged to size.

Oil Quenched 870°C.

(Ref. 5)

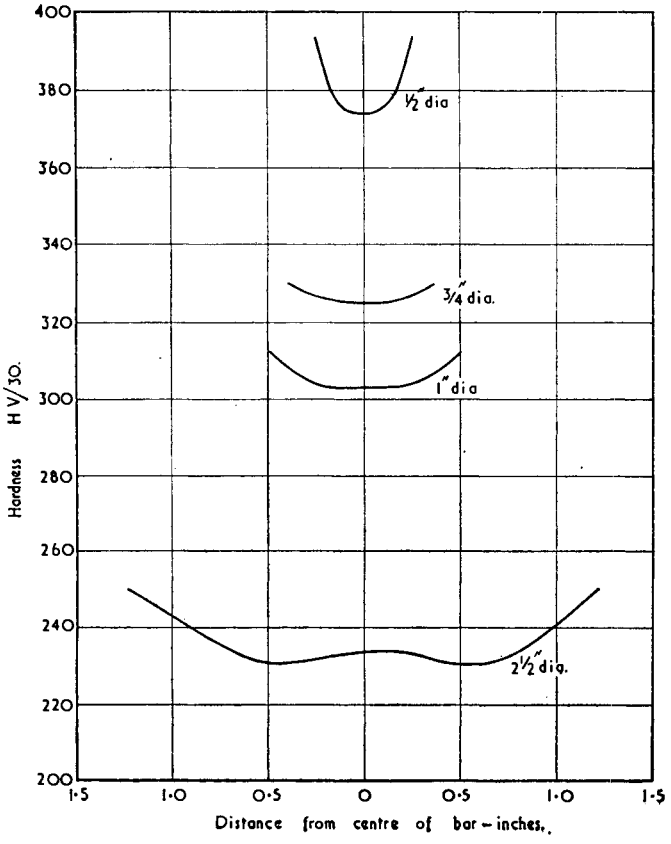


Fig. 33.7

Oil Quenched 870°C. Tempered 150°C A.C.

(Ref. 5)

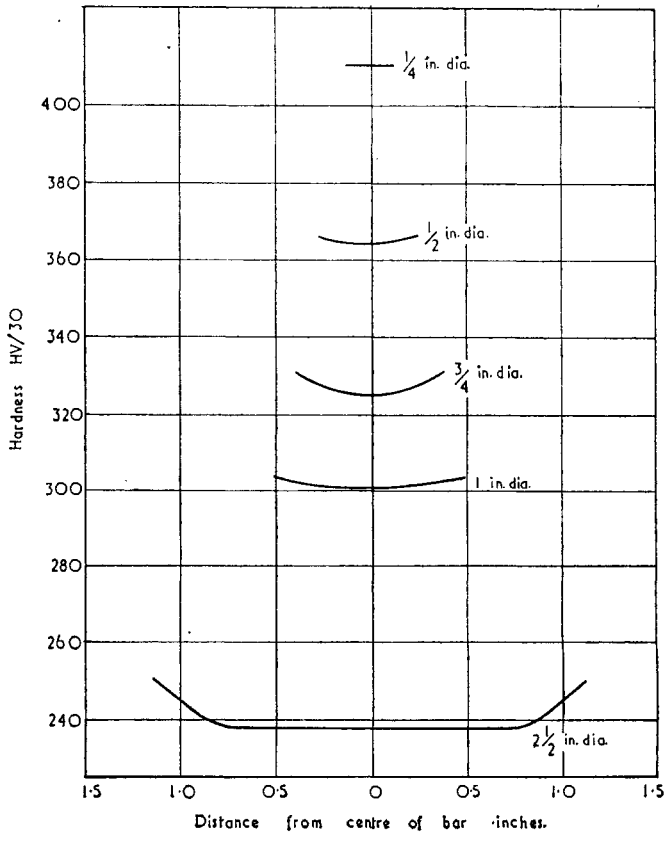


Fig. 33.8

Bars machined from 2¼ in. forged bar.

Oil Quenched 870°C. (Ref. 5)

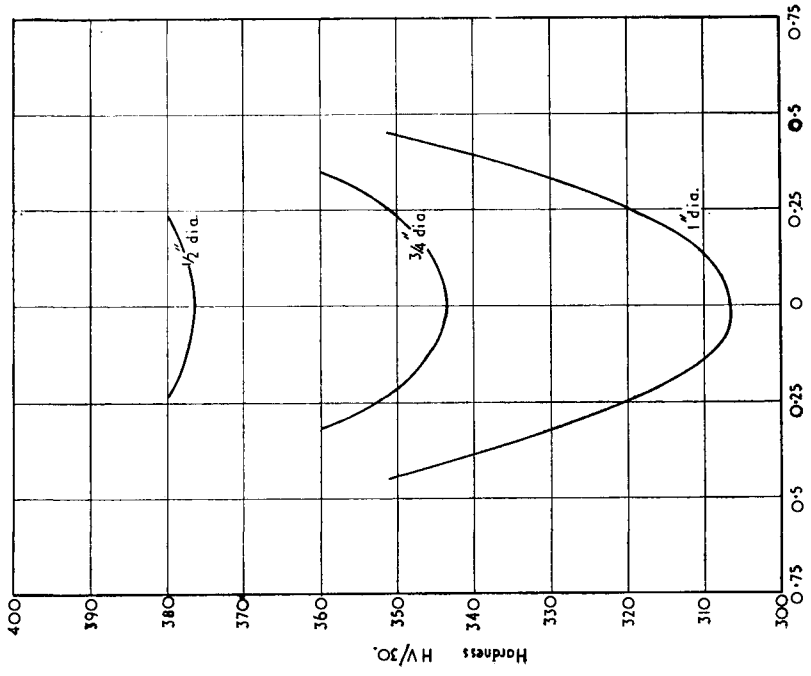


Fig. 33.9

Oil Quenched 870°C. Tempered 150°C A.C. (Ref. 5)

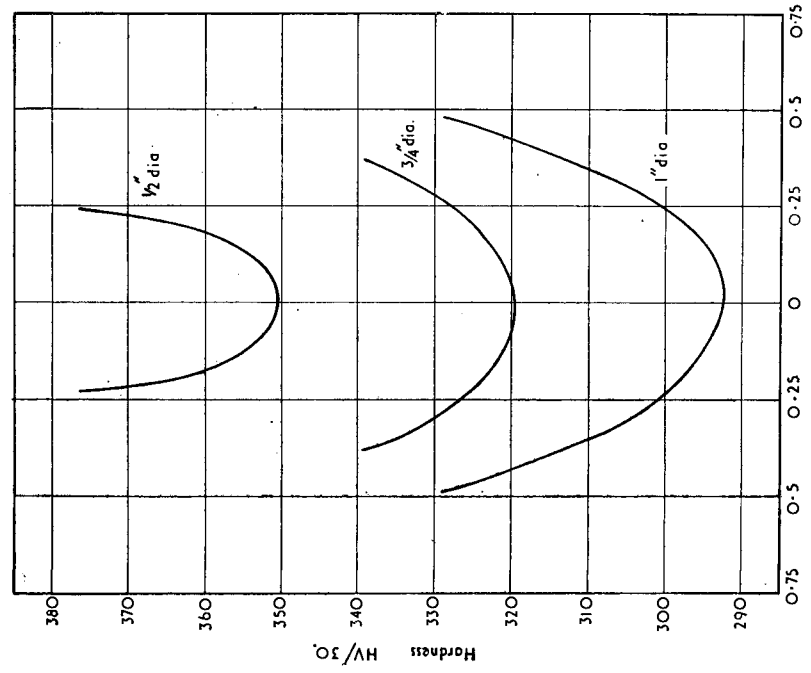


Fig. 33.10

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
B.E.A.	0·10	0·30	0·57	0·012	0·012	2·93	0·20	0·02	$\frac{1}{4}$	BC AC860 OQ770 T140		71	15			6
"	"	"	"	"	"	"	"	"	$\frac{1}{2}$	" " " "		68	17		35	6
"	"	"	"	"	"	"	"	"	$\frac{3}{4}$	" OQ860 OQ770 "		60	20		39	6
"	"	"	"	"	"	"	"	"	$1\frac{1}{8}$	" " " "		53·5	25		46	"
	0·10	0·12	0·51			2·95	0·12		$1\frac{1}{8}$	BC900 WQ860 WQ780		48·0	28	55	76	2
A.O.H.	0·10	0·52				3·24	0·04		$\frac{15}{16}$	WQ860 WQ770 T150	42	49·6	$24\frac{1}{2}$	62	73	7
"	"	"				"	"		$1\frac{1}{8}$	" " "	33	43·2	$28\frac{1}{2}$	52	88	"
"	"	"				"	"		$2\frac{3}{4}$	" " "	28	37·5	35	72	117	"
B.E.A.	0·10	0·18	0·23			3·16	0·06		$\frac{1}{2}$	N900 OQ850 WQ770	40·0	48·8	24	$68\frac{1}{2}$	94	2
"	"	"	"			"	"		$\frac{11}{16}$	" " "	27·0	46·0	$23\frac{1}{2}$	$68\frac{1}{2}$	92	"
"	"	"	"			"	"		$1\frac{1}{8}$	" " "	24·5	41·6	$25\frac{1}{2}$	66	88	"
"	"	"	"			"	"		$2\frac{1}{8}$	" " "	24·0	37·0	$35\frac{1}{2}$	68	105	"
"	"	"	"			"	"		3	" " "	23·5	37·1	35	$72\frac{1}{2}$	105	"
"	"	"	"			"	"		$\frac{1}{2}$	N900 OQ850 OQ770	29·6	38.4	32	75	113	"
"	"	"	"			"	"		$\frac{11}{16}$	" " "	24·0	36·0	$32\frac{1}{2}$	$73\frac{1}{2}$	107	"
"	"	"	"			"	"		$1\frac{1}{8}$	" " "	23·5	36·0	36	$73\frac{1}{2}$	106	"
"	"	"	"			"	"		$2\frac{1}{8}$	" " "	24·0	34·8	$37\frac{1}{2}$	$73\frac{1}{2}$	105	"
"	"	"	"			"	"		3	" " "	24·5	35·4	35	$71\frac{1}{2}$	102	"
"	"	"	"			"	"		$\frac{1}{2}$	N900 WQ850 WQ770	29·2	52·0	24	64	86	"
"	"	"	"			"	"		$\frac{11}{16}$	" " "	28·0	45·6	$27\frac{1}{2}$	$68\frac{1}{2}$	96	"
"	"	"	"			"	"		$1\frac{1}{8}$	" " "	27·0	44·2	32	67	85	"
"	"	"	"			"	"		$2\frac{1}{8}$	" " "	25·5	38·2	$36\frac{1}{2}$	$72\frac{1}{2}$	107	"
"	"	"	"			"	"		3	" " "	25·0	37·0	35	$73\frac{1}{2}$	106	"
"	"	"	"			"	"		$\frac{1}{2}$	N900 AC850 WQ770	38·4	51·6	22	$65\frac{1}{2}$	87	"
"	"	"	"			"	"		$\frac{11}{16}$	" " "	27·0	44·0	26	$69\frac{1}{2}$	92	"
"	"	"	"			"	"		$1\frac{1}{8}$	" " "	28·5	42·2	29	67	85	"
"	"	"	"			"	"		$2\frac{1}{8}$	" " "	24·0	37·0	34	$72\frac{1}{2}$	105	"
"	"	"	"			"	"		3	" " "	23·0	36·8	34	69	96	"
"	"	"	"			"	"		$\frac{1}{2}$	N900 AC850	24·8	33·4	36	$69\frac{1}{2}$	99	"
"	"	"	"			"	"		$\frac{11}{16}$	" "	23·0	32·4	33	71	95	"
"	"	"	"			"	"		$1\frac{1}{8}$	" "	24·5	32·6	35	66	91	"
"	"	"	"			"	"		$2\frac{1}{8}$	" "	22·5	32·5	$37\frac{1}{2}$	68	92	"
"	"	"	"			"	"		3	" "	24·0	32·6	$36\frac{1}{2}$	67	92	"

MECHANICAL PROPERTIES AT RO OM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0.1% P.S. (0.1Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
B.O.H.		0·11	0·21	0·51	0·030	0·024	3·10			59/64				51·2	22		75	8
"		"	"	"	"	"	"			"				48·6	32		82	"
B.O.H.	5	0·11		0·45	0·040	0·018	2·95	0·16	0·01	1	BC OQ870 OQ810 T140	24·6	34·8	47·0	29	63½	73	6
		0·11	0·22	0·48			3·10	0·10		1⅛	BC900 WQ860 WQ780			49·6	26	60	83	2
B.E.A.		0·11	0·21	0·45	0·015	0·021	3·20	0·12		1⅛	BC900 OQ860 WQ760			47·6	32	57	81	9
		0·11	0·19	0·39			3·13	0·13		2	OQ860 OQ770		37·6	46·8	27	60	95	1
		0·11	0·17	0·43			3·14	0·10		1⅛	" "		36·0	47·6	27	65	82	"
		0·11		0·33			3·08	0·12		1⅛	Normalized		25·0	31·6	35	59	91	7
		0·11		0·46			3·00	0·24		"	"		23·0	33·1	32½	66	97	"
		0·11		0·33			3·08	0·12		"	WQ770		28·0	39·6	32	64	105	"
		0·11		0·46			3·00	0·24		"	"		34·0	45·6	29	57	98	"
		0·11		0·50			3·20	0·20		⅛	WQ860 WQ775 T150		54·0	63·3	25	65	77	"
		"		"			"	"		⅞	" " "		39·0	55·1	23	59	88	"
		"		"			"	"		1⅛	" " "		43·0	52·8	25	59	92	"
		0·11		0·56			3·16	0·02		⅝	" " "		35·0	50·1	27½	55	81	"
		"			"		"	"		1⅛	" " "		30·0	42·5	32	68	102	"
		0·11		0·30			3·16	0·06		1⅛	WQ860 WQ770		24·0	34·0	35½	72	113	"
		"		"			"	"		"	WQ770		24·0	33·7	34½	70	107	"
		0·11		0·40			3·41	0·30		1	BC OQ860 WQ770		49·2	60·3	19		75	10
		"		"			"	"		1⅛	" " "		40·1	56·3	21½		83	"
		"		"			"	"		2	" " "		35·8	50·4	20		80	"
	McQuaid Ehn Actual																	
		"		"			"	"		3	" " "		36·2	47·2	20		92	"
A.O.H.	4—5(3) 6(7,5)	0·11	0·26	0·47	0·042	0·040	3·14	0·12	0·07	1	N900 OQ850 T150		34·9	47·2	22½	64	57	5
B.O.H.		0·12	0·24	0·53	0·032	0·016	3·10	0·03		⅝	WQ860 WQ760			68·0	16		34	8
B.O.H.		0·12	0·21	0·48	0·042	0·016	3·14	0·07		1⅛	" "			55·2	20		52	"
"		"	"	"	"	"	"	"		59/64	OQ860 WQ760			48·4	29		53	"
		0·12	0·23	0·50	0·034	0·019	3·12	0·07		59/64	WQ860 WQ760			52·4	27		56	"
		"	"	"	"	"	"	"		1⅛	" "			48·1	26		66	"
		0·12	0·23	0·41	0·036	0·012	2·98			1⅛	BC900 WQ880 WQ770		41·6	49·6	25		60	11
		0·12	0·25	0·50	0·018	0·023	2·94			1⅛	" " "		34·8	46·4	31		91	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.							
		0·12	0·15	0·56			3·25	0·06		1 1/8	BC900 WQ860 WQ780				48·0	28	55	76	2
		0·12	0·30	0·50			3·23	0·07		1 1/8	" " "				50·0	23	55	63	"
		0·12	0·20	0·46			3·08	0·15		3	OQ860 OQ770			34·2	43·4	27	60	107	1
		"	"	"			"	"		3 3/4	" "			30·8	41·0	28	60	109	"
B.E.A.		0·12	0·15	0·50			3·10			1 1/8	Refined WQ760	26·0	35·1		49·3	20	49	70	"
		0·12		0·58			3·30	0·05		1 1/8	OQ860 OQ770			29·0	39·6	36	71	103	7
		"		"			"	"		"	OQ770			29·0	39·6	32 1/2	66	97	"
		"		"			"	"		"	WQ770			38·0	48·1	25 1/2	61	71	"
		0·12		0·50			3·43	0·07		1	BC OQ860 WQ760			36·0	54·8	21		57	10
		"		"			"	"		1 1/4	" " "			33·2	51·6	20		63	"
		"		"			"	"		1 3/4	" " "			33·6	48·4	23		64	"
		"		"			"	"		3	" " "			26·8	42·0	24		88	"
		"		"			"	"		3 3/4	" " "			31·2	46·0	26		56	"
B.O.H.		0·13	0·18	0·51	0·045	0·021	2·92	0·04		1 3/16	WQ860 WQ760				61·2	15		41	8
"		"	"	"	"	"	"	"		1 1/4	" "				62·8	12		25	"
B.O.H.		0·13	0·19	0·58	0·029	0·019	3·20	0·10		5 9/64	" "				54·6	22		66	"
		0·13	0·18	0·46			3·15	0·07		1 1/8	BC900 WQ860 WQ780				50·2	30	62	73	2
																4√A 5D			
A.O.H.		0·13	0·20	0·47	0·033	0·023	3·04	0·18		1 1/8	BC925 WQ900 WQ770			29·4	45·0	32 26	67		1
		0·13		0·53			3·15	0·14		1 1/8	Normalized			28·0	35·0	34	66	92	7
		0·13		0·47			3·16	0·06		5/8	WQ860 WQ775 T150			38·0	55·4	25 1/2	52	80	"
		"		"			"	"		3/4	" " "			31·0	51·0	27 1/2	50	100	"
		"		"			"	"		1	" " "			32·0	45·6	30 1/2	55	113	"
	McQuaid Ehn 2—4(1—5)	0·13	0·23	0·48	0·022	0·010	3·08	0·24	0·11	1/4	N950 OQ870 T150				83·0	24	57 1/2		5
	"	"	"	"	"	"	"	"	"	1/2	" " "			64·1	77·3	16 1/2	51 1/2	39	"
	"	"	"	"	"	"	"	"	"	3/4	" " "			56·7	67·2	17	49 1/2	42	"
	"	"	"	"	"	"	"	"	"	1	" " "			45·4	61·6	20	54	50	"
	"	"	"	"	"	"	"	"	"	2 1/2(C)	" " "			33·6	49·4	24 1/2	59	77	"
	"	"	"	"	"	"	"	"	"	" (M)	" " "			36·0	47·6	25 1/2	62	76	"
	"	"	"	"	"	"	"	"	"	" (O)	" " "			39·1	47·4	25	66	87	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
		0·14	0·18	0·60			3·00	0·39	0·05	0·173	BC AC870 OQ770 T140	26·4				63·0	17	40		12
		"	"	"			"	"	"	0·236	" " " "	29·6				65·7	16	35		"
		"	"	"			"	"	"	0·367	" " " "	28·2				62·8	18	40		"
		"	"	"			"	"	"	0·574	" " " "	24·6				59·5	18	50	32	"
		"	"	"			"	"	"	⅞	" " " "	23·4				53·6	21	50		"
		"	"	"			"	"	"	1¼	" " " "	21·2				47·6	26	55	47	"
		0·14	0·25	0·42	0·024	0·010	2·91			1⅛	BC900 WQ860 WQ770				38·0	47·2	40		95	11
		0·14	0·17	0·47			3·02	0·16		1⅛	BC900 WQ860 WQ780					55·1	25	52	49	2
B.E.A.		0·14	0·34	0·37	0·012	0·019	3·04	0·15		1⅛	BC900 OQ860 WQ760					50·6	27½	53½	58	9
O.H.		0·14		0·49			2·98	0·12		1⅛	WQ770				35·0	48·5	27½	55	71	7
"		"		"			"	"		1⅛	OQ770				30·0	42·2	32½	62	91	"
O.H.		0·14		0·47			3·00	0·04		⅞	WQ860 WQ775 T150				35·0	49·8	30	61	69	"
"		"		"			"	"		1⅛	" " "				32·0	47·0	30½	57	75	"
"		"		"			"	"		2¼	" " "				28·0	40·0	29½	64	105	"
O.H.		0·14		0·54			2·98	0·11		½	" " "				56·0	65·0	23	60	69	"
"		"		"			"	"		⅞	" " "				32·0	53·1	24	59	86	"
"		"		"			"	"		1⅛	" " "				39·0	53·3	24½	57	83	"
		0·14		0·50			3·30	0·10		1⅛	OQ770				38·0	51·3	21½		60	10
		"		"			"	"		1⅛	OQ860 OQ770				40·3	53·0	22		62	"
		"		"			"	"		1⅛	" WQ770				45·2	61·2	17½		45	"
O.H.	McQuaid Ehn 7 to 8	Actual 7 to 9																		
		0·14	0·25	0·61	0·035	0·010	3·01	0·13	0·02	1	N900 OQ850 T150				29·2	45·9	26	63½	63	5
A.O.H.	4—6(3)	6—7	0·15	0·31	0·53	0·040	0·040	3·09	0·21	0·05	1	N900 OQ850 T150				45·4	58·7	20	56½	40	5
B.O.H.			0·15	0·19	0·48	0·023	0·021	2·76	0·06		1⅛	WQ860 WQ760					49·8	23		71	8
B.O.H.			0·15	0·21	0·55	0·028	0·016	3·12	0·04		59/64	" "					52·4	29		74	"
O.H.			0·15		0·49			3·07	0·15		1⅛	Normalized				24·0	36·2	33	62	62	7
"			"		"			"	"		1⅛	WQ770				38·0	55·0	25	52	45	"
"			"		"			"	"		1⅛	OQ770				32.0	47.4	28	51	69	"
O.H.			0·15		0·47			3·18	0·08		21/32	WQ860 WQ770 T150				67·0	73·9	16½	44	36	"
"			"		"			"	"		1⅛	" " "				42·0	56·4	21	47	47	"
"			"		"			"	"		3 sq.	" " "				30·0	40·2	33½	64	101	"
			0·15		0·37			3·00	0·13		1⅛	WQ860 WQ770				37·2	49·8	28½	52	74	"
			0·15		0·56			2·96	0·04		1⅛	" "				30·8	47·0	33½	68	101	"
			0·15		0·62			3·34	0·10		1⅛	" "	26·7	29·5	33·2		55·1	30	57	75	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·14	0·29	0·64	0·033	0·032	3·12	0·11	0·07

1½ in. dia. bars, Oil Quenched 860°C. Tempered as indicated. (Ref. 9)

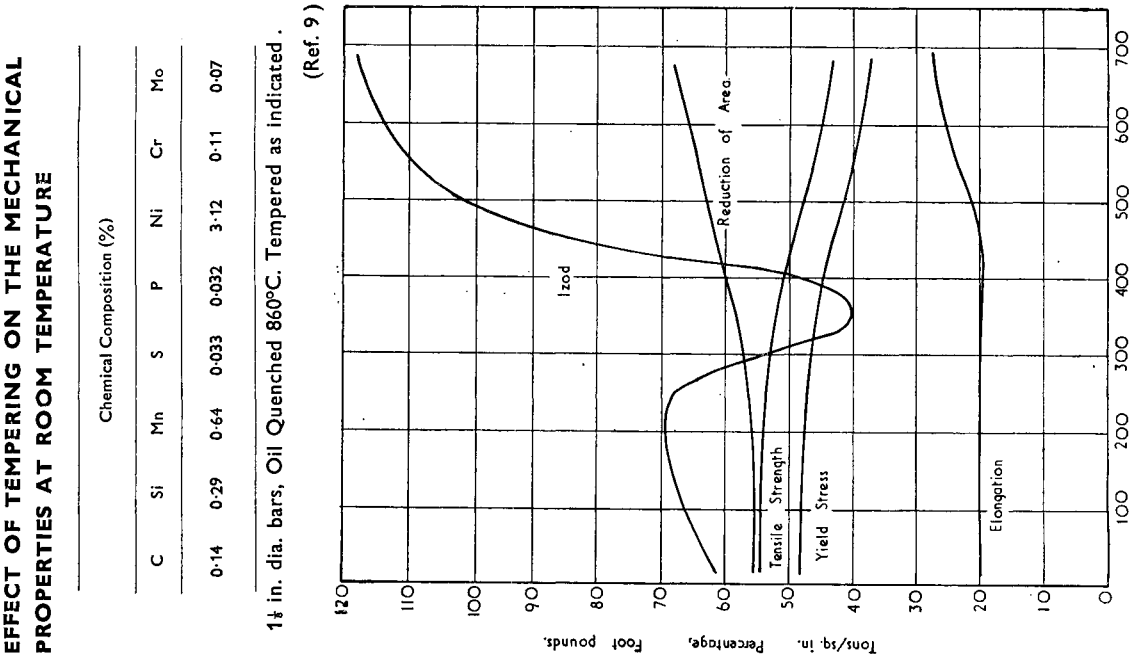


Fig. 33.11

TYPICAL CURVE SHOWING EFFECT OF TEMPERING ON CASE HARDNESS

Bars Carburized 900°C.
Water Refined 850°C.
Water Hardened 770°C.

(Ref. 2)

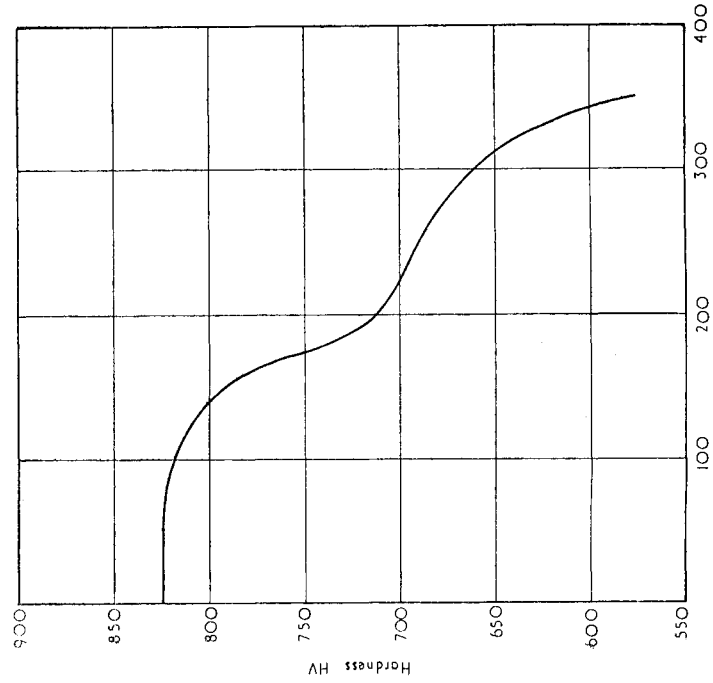


Fig. 33.12

TYPICAL CURVES SHOWING THE EFFECT OF MASS ON THE CORE PROPERTIES

Blank Carburized 900°C.
Water Refined 860°C.
Water Hardened 770°C.

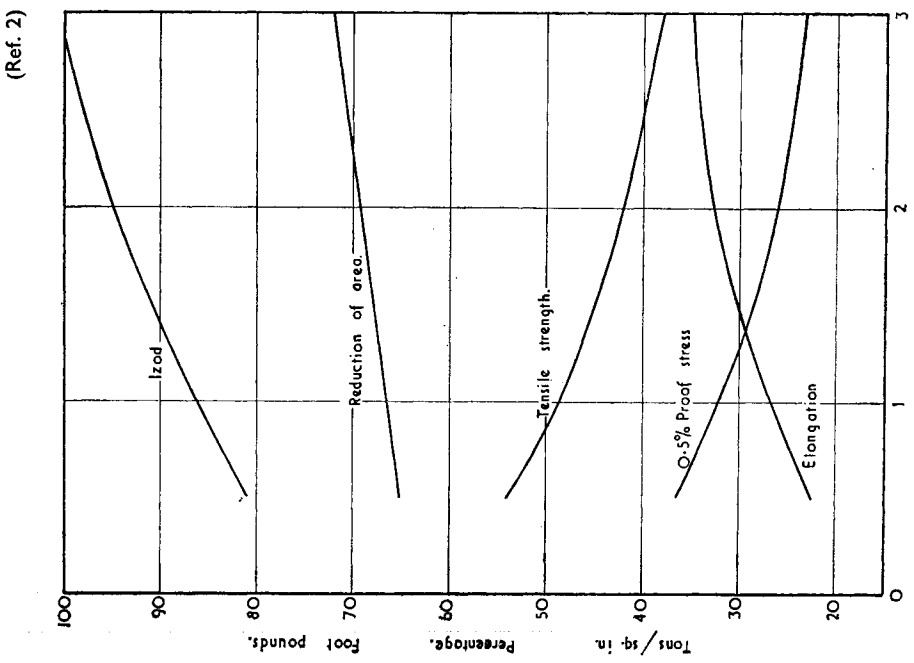


Fig. 33.13

Blank Carburized 900°C.
Water Hardened 820°C.
(Single quench quality).

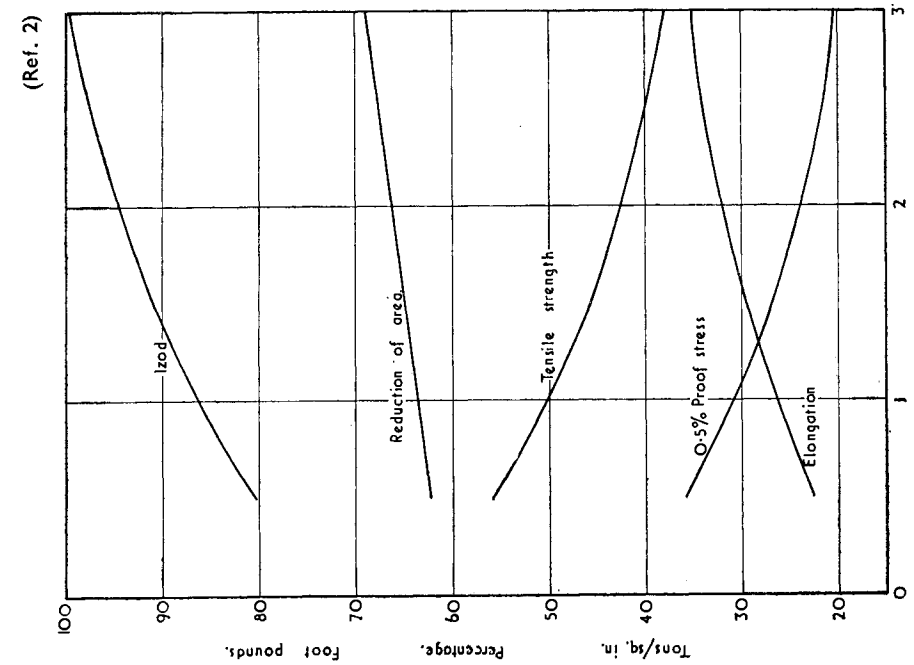


Fig. 33.14

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size As Quenched	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.							
7	0·13	0·16	0·47	0·020	0·030	3·04	0·23	nil	⅝	OQ840 T500 WQ	20	36·4	37·0	38·4	45·6	28	68		10
"	"	"	"	"	"	"	"	"	"	" " "	— 78	38·7	39·5	40·3	50·7	35	67		"
"	"	"	"	"	"	"	"	"	"	" " "	—196	57·9	59·0	60·3	67·7	32	56		"
8	0·11	0·11	0·39	0·028	0·031	3·19	0·18	nil	½ plate	N 900	20	23·3	23·5	23·7	35·6	40	66		10
"	"	"	"	"	"	"	"	"	"	"	— 78	25·4	25·7	25·9	42·0	43	61		"
"	"	"	"	"	"	"	"	"	"	"	—196	48·4	49·8	50·0	58·7	36	50		"
"	"	"	"	"	"	"	"	"	1¼ plate	"	20	17·8	18·7	20·0	33·6	42	65		"
"	"	"	"	"	"	"	"	"	"	"	— 78	20·2	21·9	23·5	39·9	43	64		"
"	"	"	"	"	"	"	"	"	"	"	—196	43·2	44·9	46·5	55·1	—	30		"
"	"	"	"	"	"	"	"	"	2 plate	"	20	18·1	18·9	20·1	33·3	35	66		"
"	"	"	"	"	"	"	"	"	"	"	— 78	20·8	22·2	23·8	39·1	40	63		"
"	"	"	"	"	"	"	"	"	"	"	—196	43·0	44·1	45·1	55·1	—	25		"
"	"	"	"	"	"	"	"	"	½ plate	N900 T600 AC	20	24·3	24·5	25·1	33·9	41	68		"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	27·6	27·8	28·3	40·3	44	65		"
"	"	"	"	"	"	"	"	"	"	" " "	—196	49·5	50·1	50·8	57·4	38	53		"
"	"	"	"	"	"	"	"	"	1¼ plate	" " "	20	23·0	23·2	23·2	32·8	41	70		"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	26·1	26·4	27·0	38·2	44	70		"
"	"	"	"	"	"	"	"	"	"	" " "	—196	46·7	46·8	47·3	54·7	35	70		"
"	"	"	"	"	"	"	"	"	2 plate	" " "	20	22·0	22·1	22·5	32·3	35	29		"
"	"	"	"	"	"	"	"	"	"	" " "	— 78	25·5	25·8	26·8	38·6	39	67		"
"	"	"	"	"	"	"	"	"	"	" " "	—196	46·7	46·8	47·5	53·8	42	67		"
	0·12	0·17	0·35	0·026	0·021	2·88	0·12	0·01		OQ870 WQ770 T150	25	23·5			31·8	42½	69½		6
	"	"	"	"	"	"	"	"		" " "	— 50	26·1			35·8	38½	68½		"
	"	"	"	"	"	"	"	"		" " "	—120	32·1			41·3	49½	65½		"
	"	"	"	"	"	"	"	"		" " "	—196	49·9			53·0	38½	49½		"

IMPACT TRANSITION TEMPERATURE DATA

Process of Manufacture	ASTM Grain Size McQuaid Ehn	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Heat Treatment °C	Tensile Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Charpy Keyhole Notch ft.lb. Test Temperature °C +21	—19	—32	—46	—60	—65	—73	—77	—87	—101	—184	Ref.
										tons/sq. in.															
H.F.		0·10	0·19	0·45			3·41		FC788	25·2	40·0	33	68	57	43				35					1	14
"		"	"	"			"		" T649	23·0	30·6	32½	66	55	59				48					1	"
O.H.		0·14		0·46	0·020	0·018	3·43		WQ843T593	35·7	49·1	25	67										39		14
O.H.		0·14	0·25	0·55	0·030	0·024	3·18		OQ816 T649	(Hardness		170 HB)		58	66				54		58				"
	6—8	0·15	0·19	0·44	0·029	0·021	3·39		AC816					57			51	48		44		44	44		13
	5—8	0·15	0·18	0·50	0·024	0·023	3·42	0·14	As rolled	(Hardness		183 HB)		46	35	33	32	24		24					14
	"	"	"	"	"	"	"	"	" "	"		" "		109*	27*	19*	19*	8*		5*					"
	5—8	"	"	"	"	"	"	"	N927																
									WQ927 T677	"		156 HB		59	57	52	52	43		43					"
		"	"	"	"	"	"	"	"	"		" "		120*	113*	74	74*	50*		35*					"
	"																								

*Charpy Vee notch ft.lb.

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·13	0·16	0·47	0·020	0·020	3·04	0·23

(See also Mechanical Properties at Low Temperature for tensile test results).
As quenched grain size 7 (ASTM).
$\frac{3}{4}$ in. dia bars. Oil Quenched 840°C. Tempered 500°C Water Quench.

(Ref. 10)

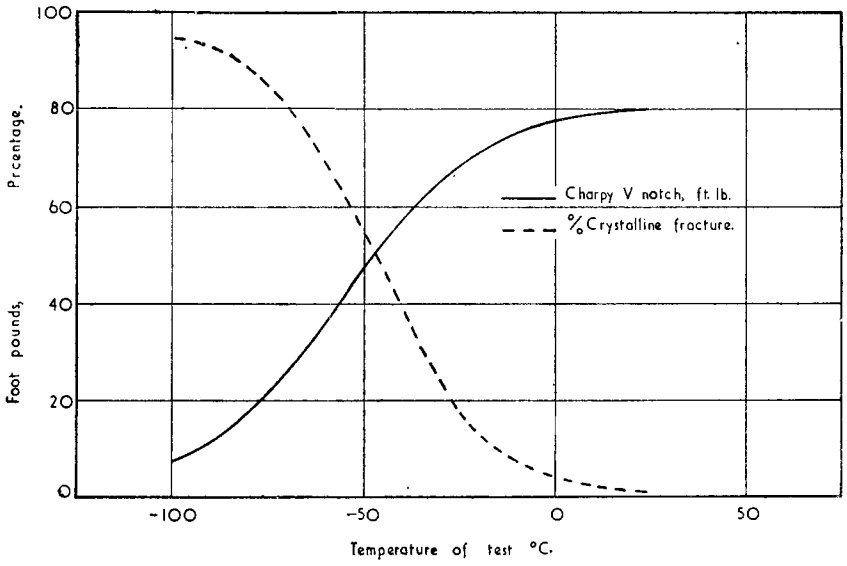


Fig. 33.15

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·11	0·11	0·39	0·028	0·031	3·19	0·18

(See also Mechanical Properties at Low Temperature for tensile test results.)
As quenched grain size 8 (ASTM).
½in., 1¼ in., and 2 in. thick plate. Air Cooled from 900°C.

(Ref. 10)

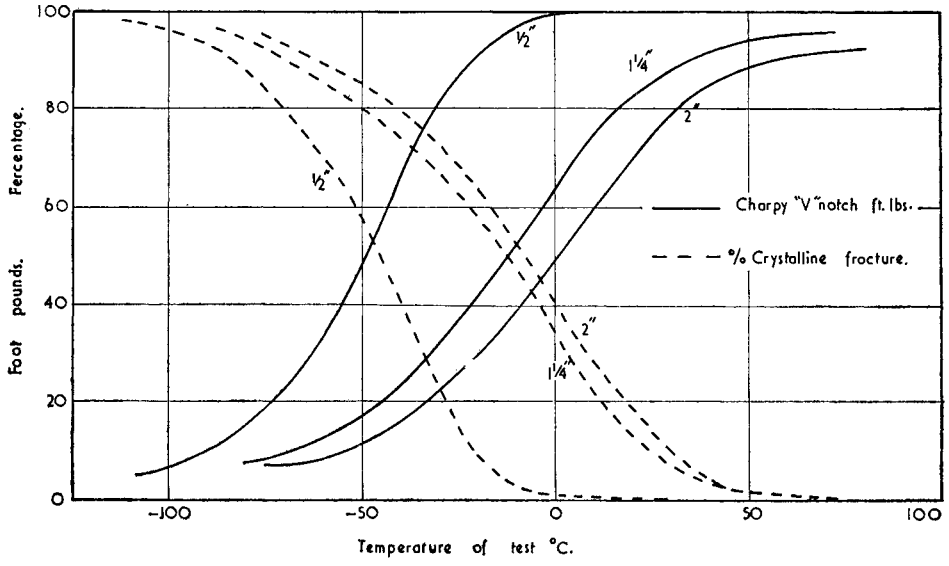


Fig. 33.16

(Ref. 10)

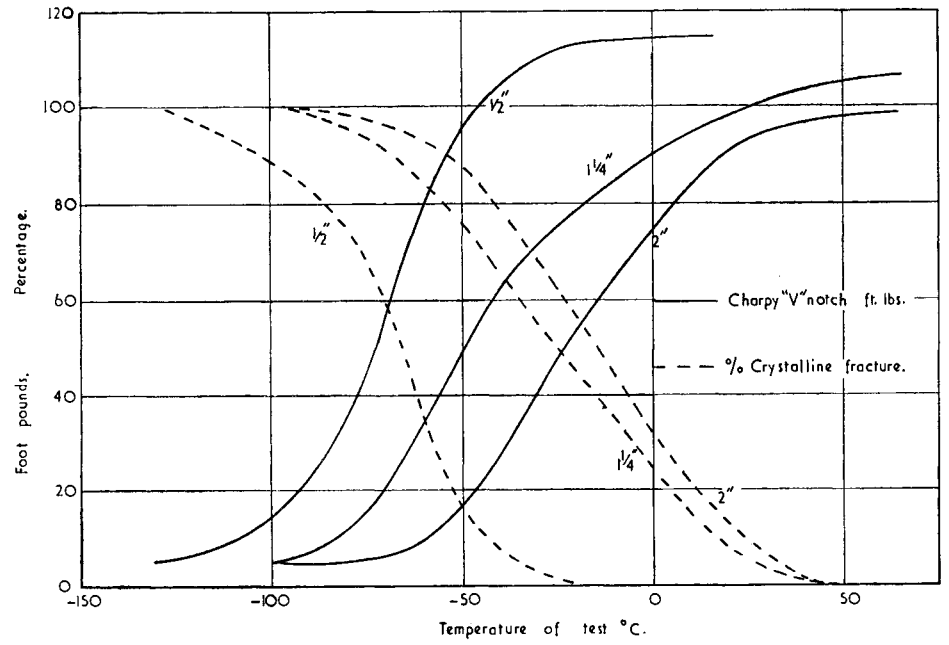


Fig. 33.17

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)							Heat Treatment °C	Tensile				Torsion			Ref.
	C	Si	Mn	S	P	Ni	Cr		L.P.	T.S.	El %	R.A. %	L.P.	Apparent max. Shear Strength	Probable max. Shear Strength	
									tons/sq.in.				tons/sq.in.			
B.E.A.	0·11	0·22	0·42	0·011	0·011	3·18	Tr	OQ850 T700	15·8	34·1	40½	72½	9·0	38·0	28·5	15

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)							Section Size dia. (in.)	Heat Treatment °C	Tensile					Fatigue Limit, tons/sq.in.			Ref.
	C	Si	Mn	S	P	Ni	Cr			0·1% P.S.	0·5% P.S.	T.S.	El %	R.A. %	Rotating Bending	Reversed Bending	Torsional (2)	
										tons/sq.in.					plain	plain notched (1)	plain notched (1)	
B.E.A.	0·12	—	0·50			3·10		1⅛	Refined WQ760	26·0	35·1	49·3	20	49	±17·5			1
B.E.A.	0·11	0·22	0·42	0·01	0·011	3·18	Tr		OQ850 T700			34·1	40½	72½		±22·2 ±13·6	±13·3 ±9·8	15

(1) Notch 55°V, 0·020 in. deep, 0·34 in. O.D., 0·30 in. root dia., root radius 0·0002 in.
(2) See also Mechanical Properties in Torsion.

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En 34

2 PER CENT NICKEL–MOLYBDENUM CASE-HARDENING STEEL (LOWER CARBON)

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Mo
0·14—0·20	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	1·50—2·00	0·20—0·30

MECHANICAL PROPERTIES

Tensile strength, tons/sq.in., min. (Rm)	45
Elongation, %, min. (A)	18
Izod impact value ft.lb., min.	40

The heat treatment given to 1¼ in. dia. test bars shall be:
Blank carburize at a temperature between 880°C and 930°C (1),
Refine at a temperature of 850°C—880°C. Cool in air, oil or water (2),
Harden in oil from a temperature of 760—780°C.

(1) By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.
(2) The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted by special agreement between the purchaser and the manufacturer.

RELATED SPECIFICATIONS

United Kingdom	America			France	Sweden	U.S.S.R.	
En No.	SAE	AISI	AMS	AFNOR	SIS	GOST	Mark
34	4615 4617	4615 4617	6290C 6292C	15ND8 20ND8	14.2520	4543—48	15NMA

APPLICATIONS

A medium alloy case-hardening steel which may be carburized and hardened to produce a hard wear resistant case and developing a core strength of the order of 45 tons/sq.in. with very good resistance to shock.

Typical uses are similar to those for En 33 and include gears, shafts, pinions, tappets, gudgeon pins, valve rockers, collets, track pins, steering balls and worms, transmission components, breech mechanisms and small arms parts.

WELDING

(See Introduction (List of Abb reviations) for key to symbols used in this table.)

	Welding Process					
	MA	G	IG	S	F	B
En 34	a	ax	a	e	a	h

* Reproduced by kind permission of H.M.S.O.

Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

The machinability of this steel in the normalized condition is approximately 75% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURE

Forging, rolling and stamping	1200°C. Finish above 900°C.
Normalizing	850°C—880°C. Air cool.
Softening	630°C—650°C. Air cool.
Carburize	880°C—930°C.
Refining*	850°C—880°C. Cool in air, oil or water.
Hardening*	760°C—780°C. Oil or water quench.
Tempering: for stress relief	150°C.
for maximum case toughness	200°C to 250°C.

* A single oil quench from 820°C may be used in certain cases when the refining treatment after carburizing is omitted by special arrangement between the purchaser and manufacturer.

CARBURIZING DATA

The times for carburizing to different case depths at various temperatures are similar to those given for En 33.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·17	0·25	0·50	—	—	1·80	—	0·25	Softened	7·87	1
0·18	0·22	0·48	0·036	0·024	1·76	0·12	0·20	AC920 OQ800	7·85	2

SPECIFIC HEAT (c)

Chemical Composition (%)					Heat Treatment °C	Specific Heat cal/g deg. C 20 to 100°C	Ref.
C	Si	Mn	Ni	Mo			
0·17	0·25	0·50	1·80	0·25	Softened	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C				Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 300°C	20to 500°C	20to 700°C	
0·17	0·25	0·50			1·80		0·25	Softened	11·0	12·5	14·0	14·5	1
0·18	0·22	0·48	0·036	0·024	1·76	0·12	0·20	AC900 OQ850	12·5				2
0·17		0·45			1·80		0·25	Softened	11·6	13·1	13·9	14·5	3

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	
0·18	0·22	0·48	0·036	0·024	1·76	0·12	0·20	BC920 OQ800	24·9	29·6	37·1	2
"	"	"	"	"	"	"	"	Softened	21			

THERMAL CONDUCTIVITY (k)

Estimated value at 20°C is 0·10 cal/cm s deg. C for steel in the softened condition.

YOUNG'S MODULUS (E)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Dynamic (Vibration method)	
0·18	0·22	0·48	0·036	0·024	1·76	0·12	0·20	AC900 OQ800	20	13,450	2
"	"	"	"	"	"	"	"	" "	100	13,100	"
"	"	"	"	"	"	"	"	" "	200	12,700	"

En 34

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

CORE CHARACTERISTICS (1)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·16	0·18	0·53	0·011	0·022	1·56	0·26	0·25

Basic Electric Arc.
McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia., annealed cold drawn and rolled to 0·030 in. thick tape, followed by 920°C (2 hr.) air cool.
Austenitizing Temperature 865°C, 30 min.

(Ref. 4)

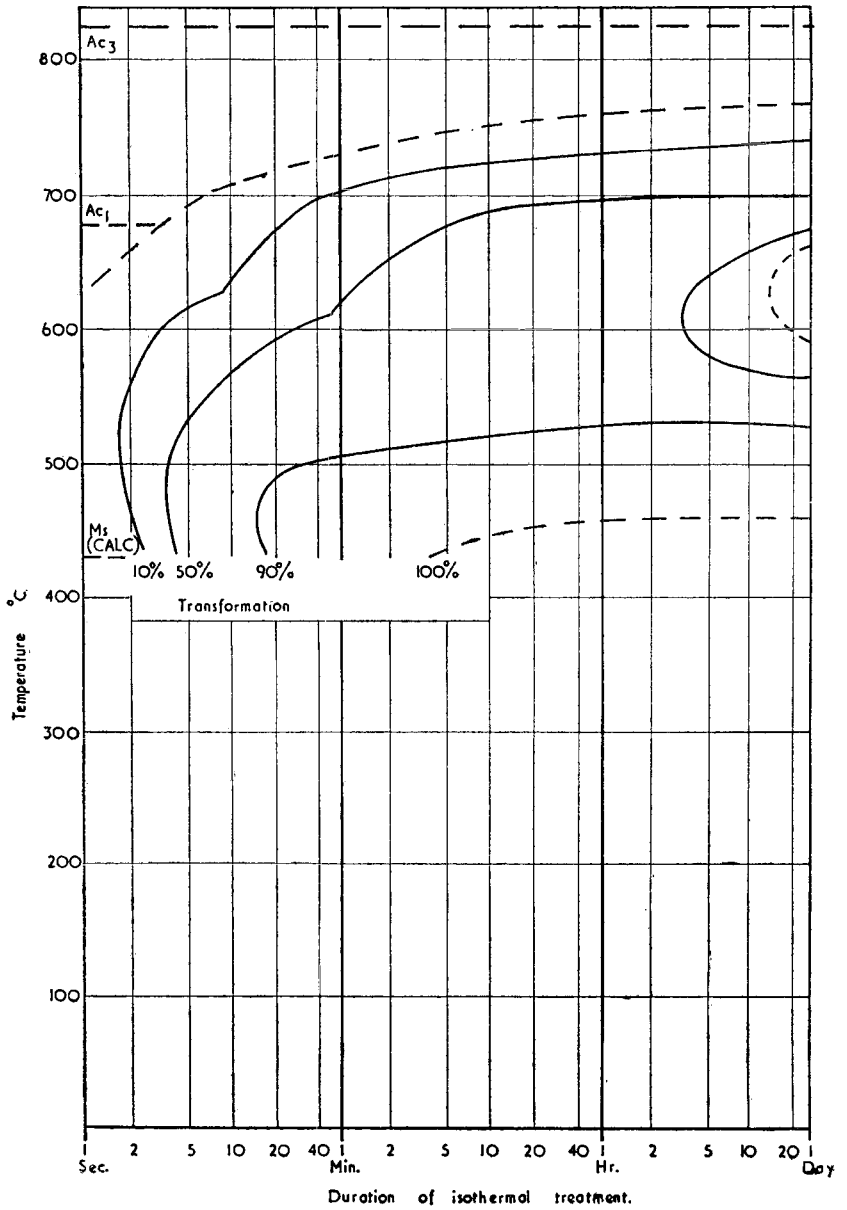


Fig. 34.1

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS (2)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·16	0·18	0·53	0·011	0·022	1·56	0·26	0·25

Basic Electric Arc.
McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia., annealed and cold drawn, rolled to 0·030 in. thick tape, followed by water quenching from 865°C (1 hr.) sealed in a 1 in. dia. steel tube.
Austenitizing Temperature 770°C, 30 min.

(Ref. 4)

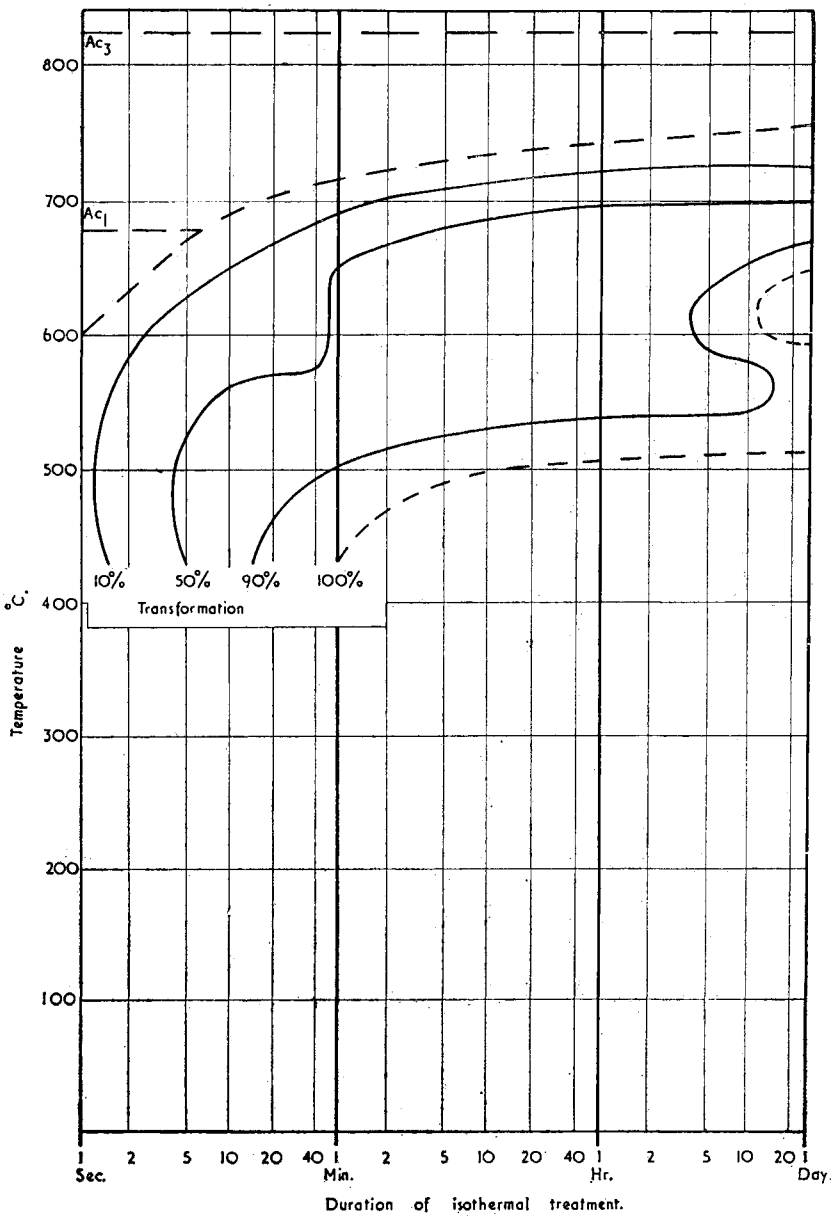


Fig. 34.2

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS (1)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·99	0·29	0·56	0·015	0·025	1·61	0·32	0·29

High Frequency Melting.
McQuaid Ehn grain size 6—8 (ASTM).
As quenched grain size 8 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia., followed by 900°C furnace cool.
Austenitizing Temperature 865°C, 30 min.

(Ref. 4)

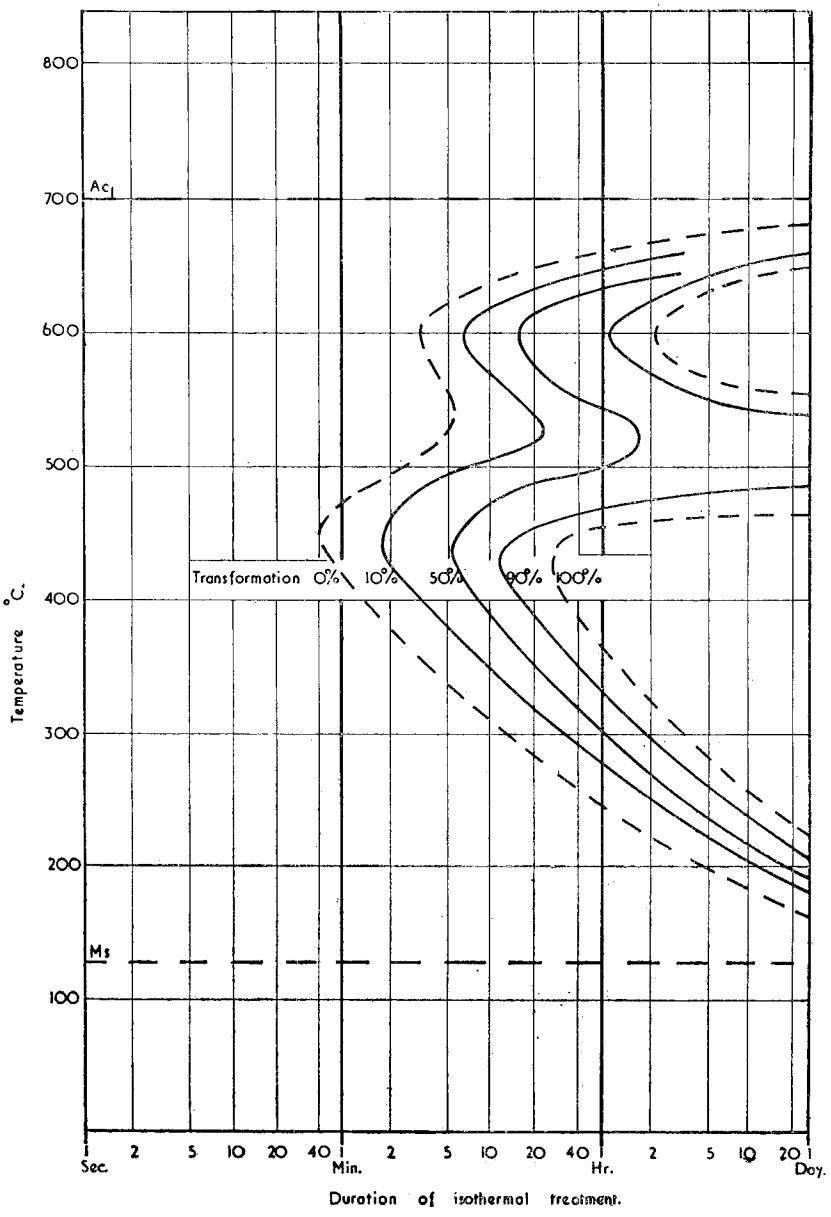


Fig. 34.3

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS (2)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·99	0·29	0·56	0·015	0·025	1·61	0·32	0·29

High Frequency Melting.
McQuaid Ehn grain size 6—8 (ASTM).
As quenched grain size finer than 8 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia., followed by 900°C (2 hr.) furnace cool.
865°C ($\frac{1}{2}$ hr.) oil quench.
Austenitizing Temperature 770°C, 30 min.

(Ref. 4)

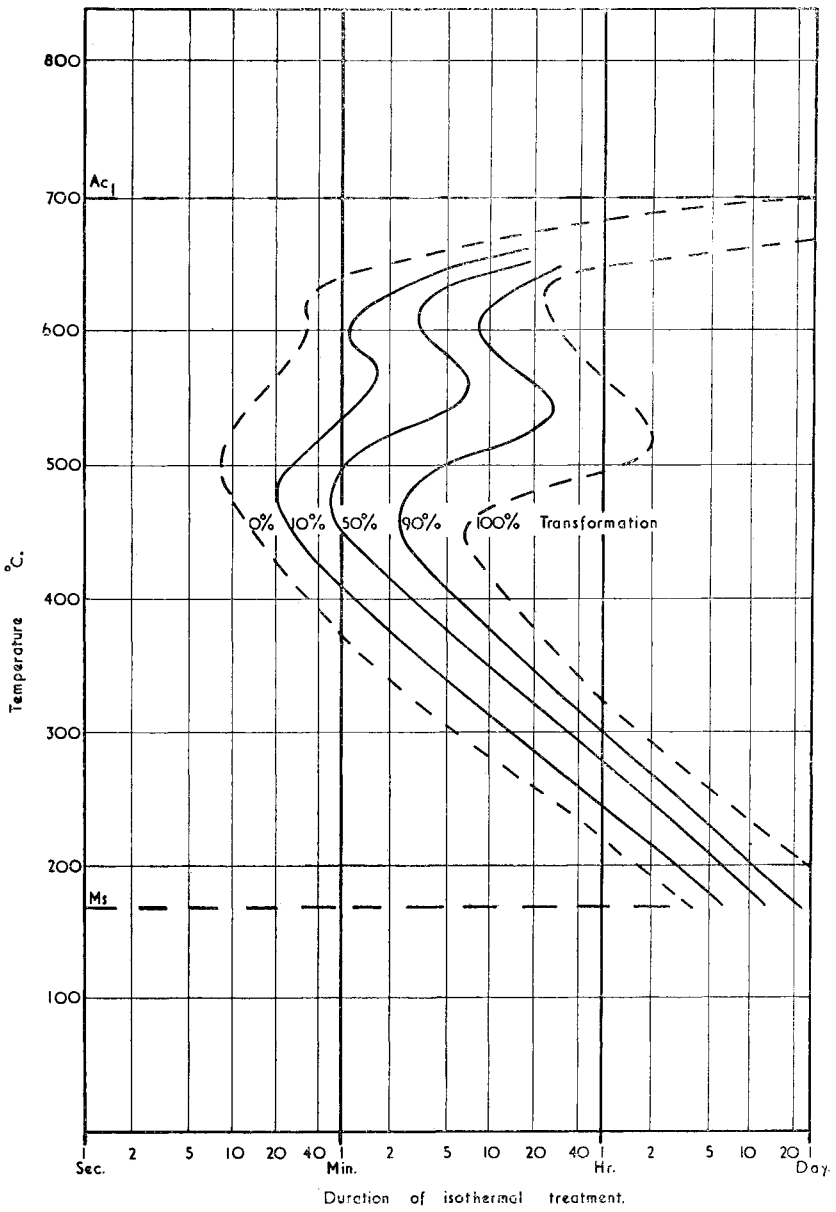
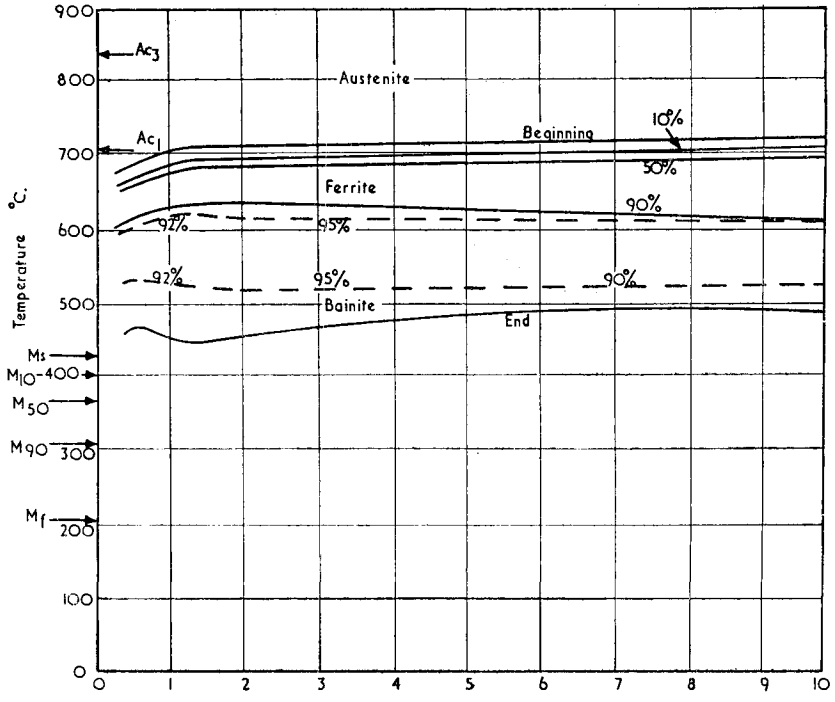


Fig. 34.4

CONTINUOUS COOLING TRANSFORMATION

Air Cooled from 865°C.

(Ref. 2)



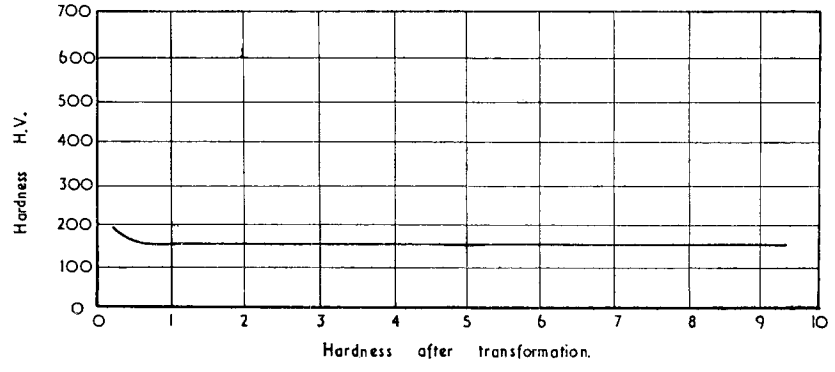


Fig. 34.5

Oil Quenched from 865°C.

(Ref. 2)

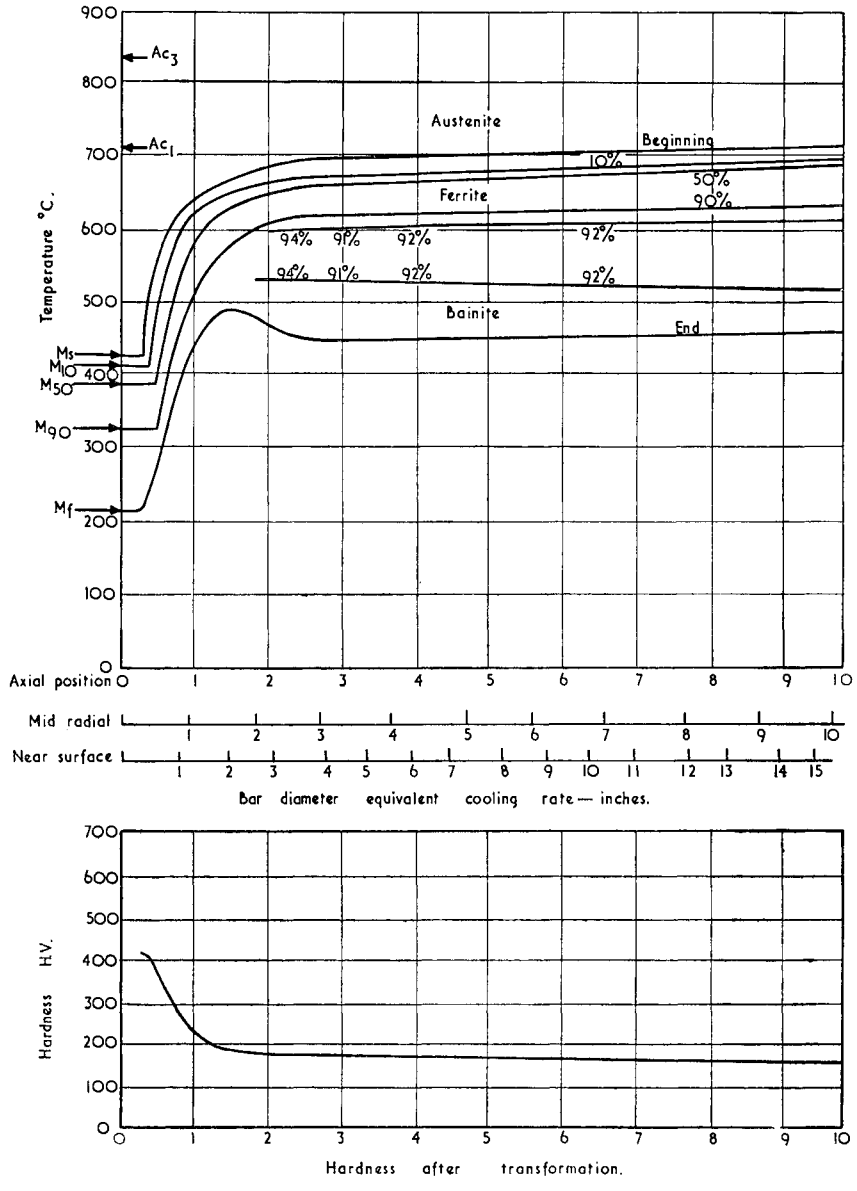


Fig. 34.6

Water Quenched from 865°C.

(Ref. 2)

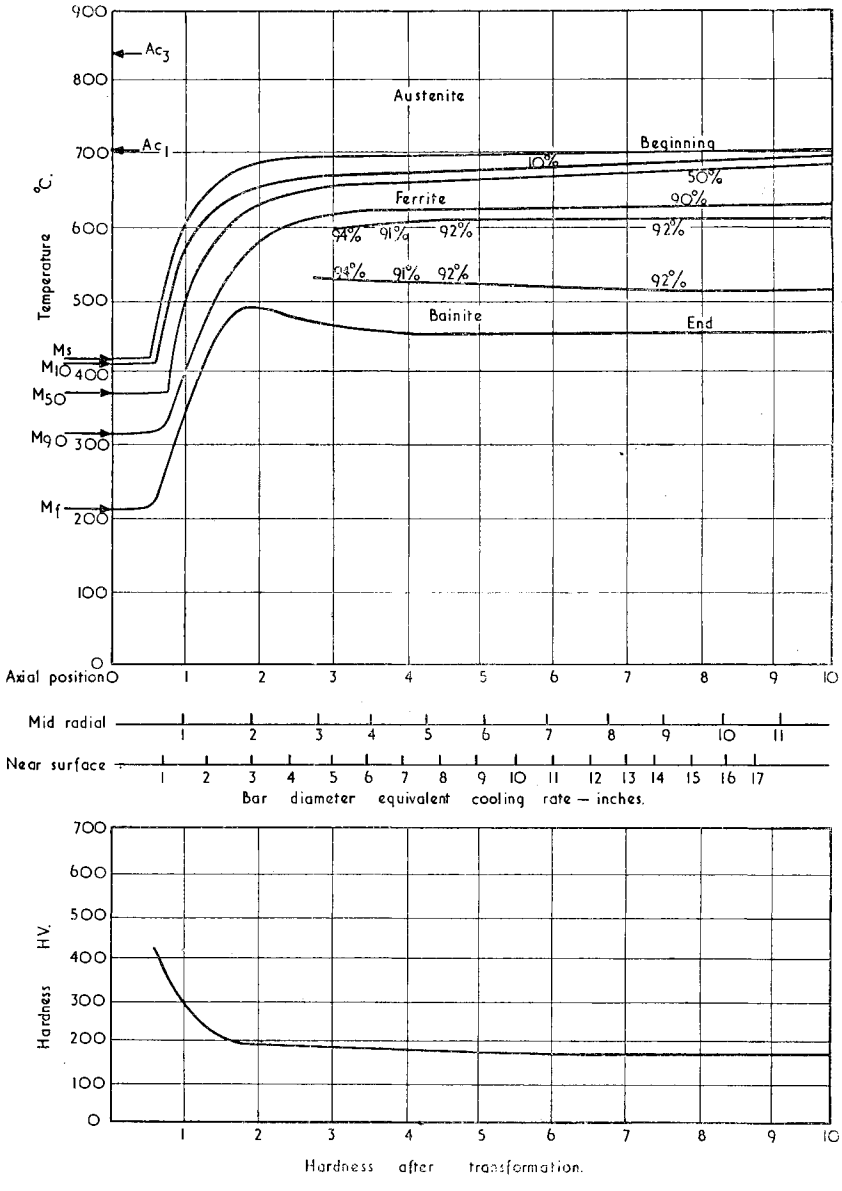


Fig. 34.7

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·16	0·18	0·53	0·011	0·022	1·56	0·26	0·25

Basic Electric Arc.
McQuaid Ehn grain size 5 (ASTM).
As quenched grain size 8 (ASTM).

End Quenched from 865°C. (Ref. 4)

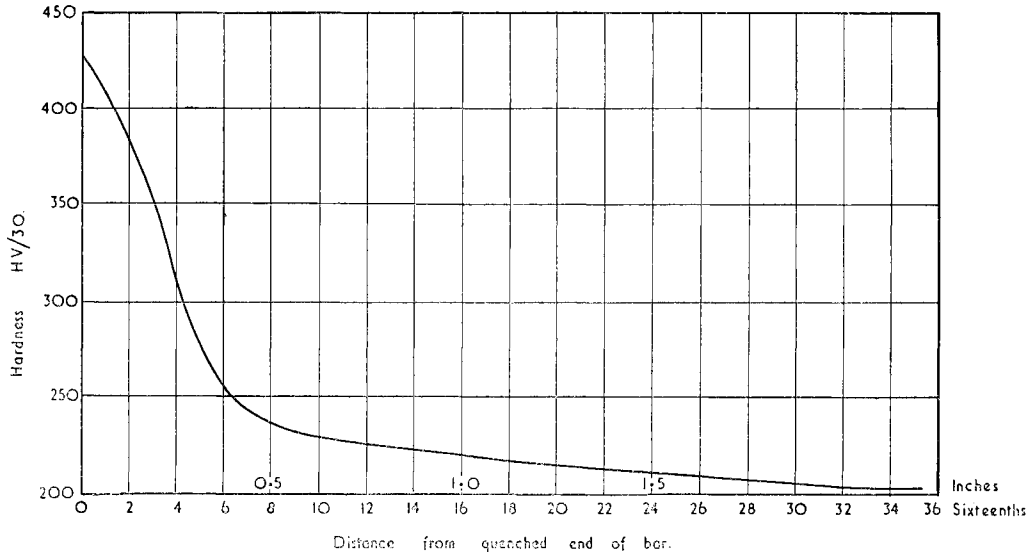


Fig. 34.8

End Quenched from 770°C. (Ref. 4)

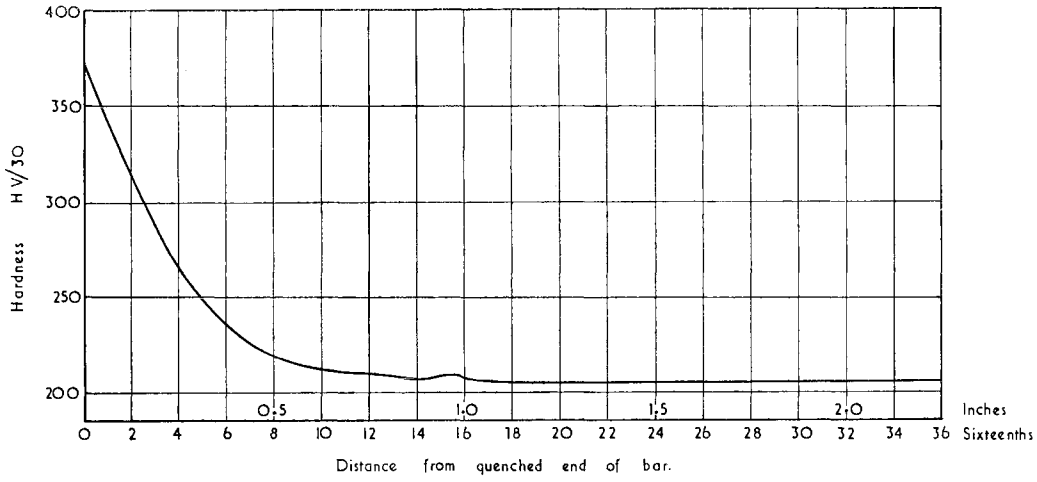


Fig. 34.9

Curve No.	Chemical Composition (%)								Original Bar dia. (in.)	Grain Size (ASTM)	
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid Ehn
A	0·14	0·24	0·46	0·017	0·013	1·94	0·08	0·28	1	7—8(6)	3—5
B	0·14	0·25	0·45	0·039	0·032	1·63	0·34	0·26	$1\frac{3}{8}$	7—8	6—8
C	0·19	0·22	0·56	0·013	0·043	1·79	0·13	0·21	$1\frac{3}{16}$	7—8	6—8(5)

Bars Normalized 900°C.

End Quenched 850°C.

(Ref. 5)

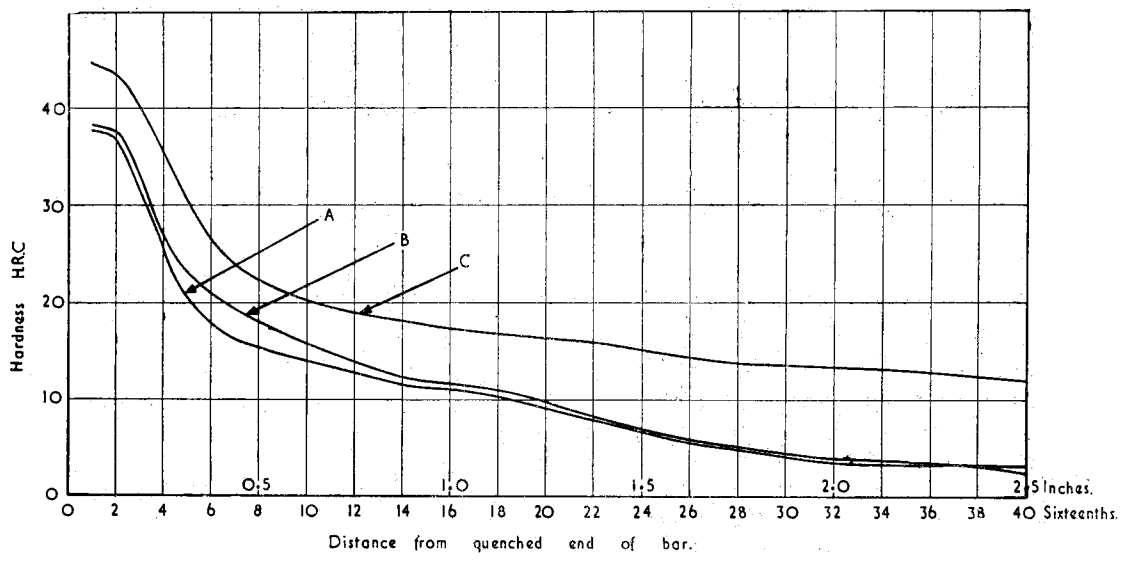


Fig. 34.10

Re-quenched 770°C.

(Ref. 5)

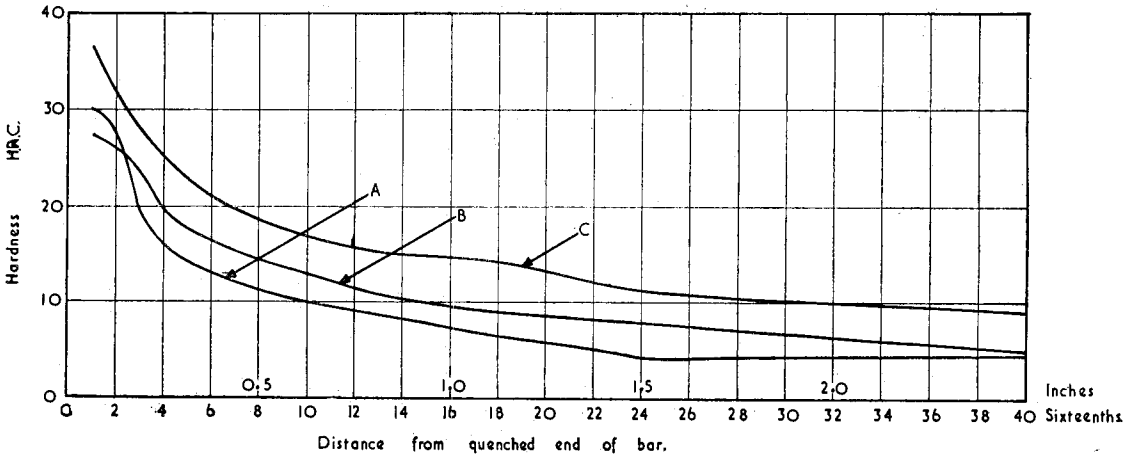


Fig. 34.11

END QUENCH HARDENABILITY BAND

These curves have been constructed from the results obtained on several casts of En 34.

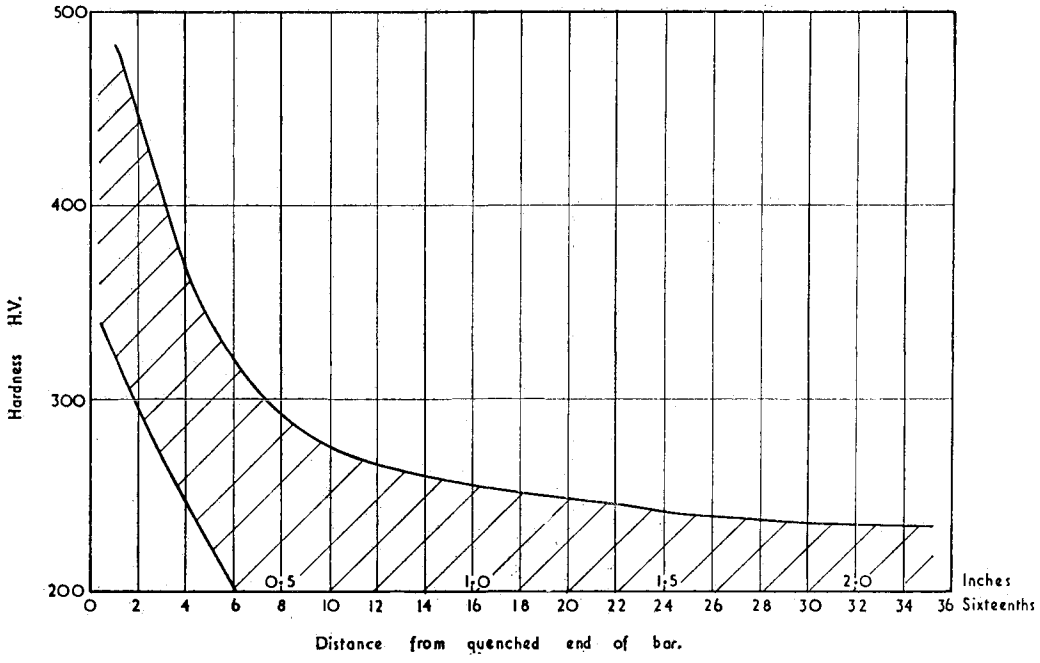


Fig. 34.12

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size		Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Ref.
	McQuaid Ehn	Actual	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
													tons/sq.in.							
B.E.A.			0·14	0·23	0·47			1·90	0·11	0·22	1⅛	OQ870 OQ770				45·6	28½	54	74	1
B.E.A.			0·14	0·23	0·53			1·90	0·14	0·23	1⅛	" "				47·8	27½	64	97	"
B.E.A.			0·14	0·20	0·49			1·90	0·21	0·25	1⅛	" "			35·6	49·4	24	52	82	"
B.E.A.	3—5	7—8(6)	0·14	0·24	0·46	0·017	0·013	1·94	0·08	0·28	1	N900 OQ850 T150			38·0	50·6	24	67½	71	5
B.O.H.	6—8	7—8	0·14	0·25	0·45	0·039	0·032	1·63	0·34	0·26	1	" " "			37·3	52·6	24	63	52	"
B.O.H.	5—8		0·15	0·15	0·47	0·035	0·027	1·28		0·27	1⅛	WQ880 OQ780				43·0	32		82	6
"	"		"	"	"	"	"	"		"	"	" "				46·4	23		53	"
"	"		"	"	"	"	"	"		"	"	" OQ770				45·2	31		69	"
"	"		"	"	"	"	"	"		"	"	" "				41·4	31		86	"
A.O.H.			0·15	0·25	0·51	0·030	0·032	1·88	0·26	0·26	1⅛	BC925 OQ870 OQ770			33·2	47·6	$4\sqrt{A}$ 31 $5{\cdot}65\sqrt{A}$ 25½	61		1
B.E.A.			0·15	0·16	0·51			1·82	0·30	0·24	1⅛	OQ870 OQ770				52·8	23	49	57	"
B.E.A.			0·15	0·23	0·53			1·88	0·16	0·24	1⅛	" "				55·0	22	51	62	"
B.E.A.			0·15	0·24	0·46			1·92	0·23	0·21	1⅛	" "			40·0	50·4	24½	54	63	"
			"	"	"			"	"	"	2	" "			35·6	45·4	29	59	75	"
			"	"	"			"	"	"	3	" "			32·8	43·0	30	60	76	"
			0·15	0·12	0·48			1·65	0·25	0·23	0·236		33·0			70·6	19	48		7
			"	"	"			"	"	"	0·367		27·8			67·0	17	48		"
			"	"	"			"	"	"	0·574		38·8			70·8	19	54	22	"
			"	"	"			"	"	"	⅞		28·6			46·4	25	70		"
			"	"	"			"	"	"	1¼		24·6			41·6	30	70	50	8
			0·15		0·56			1·69	0·05	0·25	1⅛	OQ880 OQ760				46·0	28		63	1
B.E.A.			0·15	0·20	0·51	0·016	0·014	1·90	0·19	0·23	2½ (L)	Normalized	18·8	22·9		35·7	32	63½	82	"
"			"	"	"	"	"	"	"	"	" (T)	"			25·3	35·1	26	46½	54	"
"			"	"	"	"	"	"	"	"	" (L)	OQ870 OQ770	21·5	28·4		44·2	28½	55	76	"
"			"	"	"	"	"	"	"	"	" (T)	" "			35·8	46·7	26	45½	47	"
			0·15		0·40			1·85	0·19	0·21	0·564	OQ860°C OQ780°C			50·1	52·4	29	55	57	2
			"		"			"	"	"	⅞	" "			37·0	48·9	30	57	60	"
			"		"			"	"	"	1⅛	" "			34·5	47·7	31	57	66	"
			"		"			"	"	"	2½	" "			32·8	41·1	33	70	90	"
			"		"			"	"	"	3	" "			31·2	40·8	30	64	92	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq. in.	T.S. (Rm) tons/sq. in.	El % (A)	R.A. % (Z)		
B.E.A.		0·16	0·21	0·47			1·85	0·16	0·23	1 1/8	OQ870 OQ770		48·8	25 1/2	55	68	1
		0·16	0·22	0·50			1·82	0·22	0·25	1/2	OQ850 OQ770	52·5	71·0	17	45	50	"
		"	"	"			"	"	"	7/8	" "	39·8	58·4	20	49	34	"
		"	"	"			"	"	"	1 1/8	" "	35·2	54·4	23	46	36	"
		"	"	"			"	"	"	2 1/2	" "	29·6	46·6	27	53	43	"
		"	"	"			"	"	"	4	" "	28·4	42·0	30	63	53	"
		0·16	0·23	0·60			1·81	0·17	0·20	1/2	OQ850 OQ770	54·8	66·2	17	43	45	"
		"	"	"			"	"	"	7/8	" "	40·0	57·0	24	49	38	"
		"	"	"			"	"	"	1 1/8	" "	31·5	49·6	24	43	35	"
		"	"	"			"	"	"	2 1/2	" "	28·0	44·6	32	60	58	"
		"	"	"			"	"	"	4	" "	27·3	41·2	32	64	68	"
B.O.H.	5 to 8	0·16	0·22	0·50	0·040	0·020	1·68	—	0·26	1 1/8	WQ880 OQ780		52·2	21		46	6
		0·16		0·67			1·78	0·09	0·26	1 1/8	OQ870 OQ770		50·4	26		63	8
B.E.A.		0·16	0·20	0·59	0·018	0·015	1·73	0·14	0·26	1 1/8	BC OQ870 OQ760		48·0	27	52 1/2	60	9
"		"	"	"	"	"	"	"	"	"	" " OQ780		48·0	25	55	59	"
"		"	"	"	"	"	"	"	"	2	" " OQ760		42·8	27	55	49	"
"		"	"	"	"	"	"	"	"	"	" " OQ780		43·6	27	55	58	"
"		"	"	"	"	"	"	"	"	3	" " OQ760		42·8	27	61 1/2	57	"
"		"	"	"	"	"	"	"	"	"	" " OQ780		42·0	28	64	61	"
B.E.A.		0·17	0·24	0·50			1·87	0·15	0·24	1 1/8	OQ870 OQ770		48·8	29	54	72	1
B.E.A.		0·17	0·27	0·52			1·78	0·25	0·23	1 1/8	" "		51·0	24	52	54	"
B.E.A.		0·17	0·28	0·45			1·88	0·13	0·20	1 1/8	" "	34·2	46·6	28	53	71	"
B.O.H.		0·17	0·20	0·47	0·034	0·029	1·60	—	0·26	1 1/8	WQ880 OQ780		48·6	25		51	6
"		"	"	"	"	"	"		"	"	" "		47·4	24		60	"
		0·17		0·60			1·85		0·24		AC871	25·0	39·4	28	67		10
		"		"			"		"		WQ843 T593	40·2	49·4	23	73		"
		0·17	0·23	0·55			1·77	0·25	0·22	1 1/8	BC900 OQ860 OQ780		48·0	26 1/2	57	92	3
		0·17	0·20	0·51			1·81	0·25	0·22	1 1/8	" " "		48·4	26	50	82	"
		0·17	0·22	0·52			1·80	0·20	0·22	1 1/8	" " "		52·7	22 1/2	51	73	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
												tons/sq.in.									
B.E.A.	6 to 8	0·17	0·26	0·52	0·016	0·017	1·81	0·10	0·21	1	A857					24·1	33·1	31½	60½	69	11
"	"	"	"	"	"	"	"	"	"	½	N900					24·4	39·0	30½	68	92	"
"	"	"	"	"	"	"	"	"	"	1	"					23·8	37·2	29	60½	98	"
"	"	"	"	"	"	"	"	"	"	2	"					23·7	35·9	29½	67	99	"
"	"	"	"	"	"	"	"	"	"	4	"					23·1	34·4	30½	65	92	"
"	"	"	"	"	"	"	"	"	"	½	Bc OQ816 T150					40·0	56·7	20	60	43	"
"	"	"	"	"	"	"	"	"	"	1	" " "					29·9	43·7	26	70	98	"
"	"	"	"	"	"	"	"	"	"	2	" " "					29·1	43·1	27	69½	102	"
"	"	"	"	"	"	"	"	"	"	4	" " "					23·4	37·8	28½	69	100	"
"	"	"	"	"	"	"	"	"	"	½	" " T230					36·2	52·5	21½	65½	74	"
"	"	"	"	"	"	"	"	"	"	1	" " "					29·6	43·7	27½	69	95	"
"	"	"	"	"	"	"	"	"	"	2	" " "					27·7	42·7	27	69	100	"
"	"	"	"	"	"	"	"	"	"	4	" " "					23·6	37·7	30	70½	104	"
		0·18	0·17	0·51			1·88	0·26	0·21	1⅛	OQ870 OQ770						56·2	22	50	55	1
B.O.H.	7 to 8	0·18	0·23	0·50	0·035	0·016	1·67	—	0·26	1⅛							47·4	27		64	6
	3 to 7	0·18	0·22	0·59	0·009	0·009	1·73	0·32	0·28	1⅛	N900 OQ700	23·9	25·7	27·4	29·7		45·8	26½	56	48	3
	"	"	"	"	"	"	"	"	"	"	" OQ720	21·8	24·9	28·0	32·7		54·0	24	45½	28	"
	"	"	"	"	"	"	"	"	"	"	" OQ740	20·7	24·0	27·9	33·0		52·7	27	44	37	"
	"	"	"	"	"	"	"	"	"	"	" OQ760	23·6	27·4	31·5	36·6		53·3	25	47	39	"
	"	"	"	"	"	"	"	"	"	"	" OQ780	27·2	32·1	37·4	43·7		57·5	23	53½	44	"
	"	"	"	"	"	"	"	"	"	"	" OQ800	26·6	31·9	37·6	44·5		57·7	21½	54	39	"
	"	"	"	"	"	"	"	"	"	"	" OQ820	29·0	34·0	39·2	45·6		58·4	21	51	37	"
	"	"	"	"	"	"	"	"	"	"	" OQ840	28·8	33·1	38·2	44·6		57·0	22	52	36	"
	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ780	39·7	48·1	57·4	70·9		80·2	17½	52	43	"
	"	"	"	"	"	"	"	"	"	¾	" " "	31·8	36·7	42·5	50·0		61·9	18	53½	51	"
	"	"	"	"	"	"	"	"	"	1	" " "	28·4	33·5	38·8	45·3		58·1	20½	52½	44	"
	"	"	"	"	"	"	"	"	"	1⅛	" " "	28·5	33·5	38·5	45·0		58·2	21	52½	38	"
	"	"	"	"	"	"	"	"	"	2⅛	" " "	27·1	30·4	34·1	38·8		50·4	25	60½	76	"
	"	"	"	"	"	"	"	"	"	3	" " "	24·5	27·7	31·2	35·5		47·2	28½	63	86	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
	3 to 7	0·18	0·22	0·59	0·009	0·009	1·73	0·32	0·28	0·424	N900 OQ820	35·2	43·2	51·6	62·8		75·8	15	51½	44	3
	"	"	"	"	"	"	"	"	"	¾	" "	33·0	38·1	43·9	51·2		62·0	18	54	41	"
	"	"	"	"	"	"	"	"	"	1	" "	29·0	34·0	39·2	45·9		58·2	21½	53½	37	"
	"	"	"	"	"	"	"	"	"	1⅛	" "	27·7	33·0	38·5	45·3		58·2	20½	50½	38	"
	"	"	"	"	"	"	"	"	"	2⅛	" "	24·8	28·7	33·0	38·4		49·7	25½	63½	55	"
	"	"	"	"	"	"	"	"	"	3	" "	24·4	28·4	33·2	38·8		47·6	25	62	54	"
	"	"	"	"	"	"	"	"	"	0·424	N900	22·6	25·9	29·4	54·1		46·7	25½	57	66	"
	"	"	"	"	"	"	"	"	"	¾	"	25·2	28·6	31·6	36·6		46·3	26	57½	46	"
	"	"	"	"	"	"	"	"	"	1	"	23·5	26·6	29·9	34·2		46·5	26½	56	45	"
	"	"	"	"	"	"	"	"	"	1⅛	"	23·8	26·7	29·8	34·0		46·0	23	59	37	"
	"	"	"	"	"	"	"	"	"	2⅛	"	22·2	24·3	27·2	30·9		43·0	27	60	37	"
	"	"	"	"	"	"	"	"	"	3	"	22·0	23·0	26·4	30·3		42·7	25½	59	36	"
		0·18	0·24	0·53			1·82	0·23	0·23	1⅛	BC900 OQ860 OQ780						48·0	26½	57	92	"
B.O.H.		0·18	0·24	0·51	0·035	0·010	1·62	0·25	0·26	⅜	BC OQ850 OQ760					—	56·6	25	52	—	
"		"	"	"	"	"	"	"	"	¾	" " "					31·8	50·9	27	54½	63	
"		"	"	"	"	"	"	"	"	1⅛	" " "					28·4	50·0	27	55	74	"
"		"	"	"	"	"	"	"	"	1¾	" " "					22·8	45·2	31	61½	82	
"		"	"	"	"	"	"	"	"	2½	" " "					25·6	44·0	30	63½	89	
	5 to 7	0·18		0·59			1·83		0·22	⅜	4 hrs. 920FC OQ860										
											OQ780					37·6	51·0	28½	57	48	2
	"	"		"			"		"	"	" " OQ800					55·0	63·5	18	40	15	"
	"	"		"			"		"	"	" " OQ860					63·5	64·5	18½	53	46	"
	"	"		"			"		"	1⅛	" " OQ860										
											OQ780					35·2	47·8	31½	62	65	"
	"	"		"			"		"	"	" " OQ800					36·0	51·8	20½	44	21	"
	"	"		"			"		"	"	" " OQ860					41·6	53·8	23	55	46	"
	McQuaid Actual Ehn																				
B.E.A.	6—8(5) 7—8	0·19	0·22	0·56	0·013	0·043	1·79	0·13	0·21	1	N900 OQ850 T150					37·3	53·5	22½	58½	57	5
		0·19		0·49			1·74	0·30	0·25	1	OQ850 OQ760					40·0	55·4	20		51	12
		"		"			"	"	"	2	" "					34·8	47·6	24		63	"
		"		"			"	"	"	3	" "					30·8	46·0	25½		80	"
		"		"			"	"	"	4	" "					25·0	45·1	22½		66	"
		0·19	0·24	0·54			1·82	0·25	0·26	1⅛	BC900 OQ860 OQ780						54·4	20½	42	56	3

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Tensile			Izod ft.lb.	Ref.
C	Si	Mn	Ni	Cr	Mo			T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
0·19		0·51	1·78	0·26	0·26	0·424	OQ820	70·7	14½	—	48	3
"		"	"	"	"	¾	"	55·9	22		59	"
"		"	"	"	"	1⅛	OQ760	55·4	24½		38	"
"		"	"	"	"	"	OQ780	54·1	22		67	"
"		"	"	"	"	"	OQ800	54·7	22½		74	"
"		"	"	"	"	"	OQ820	54·0	20½		71	"
0·20	0·26	0·56	1·83	0·19	0·21	1⅛	BC900 OQ860 OQ780	54.3	20½	39	73	3

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Ref. 9)

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Mo
0·15	0·29	0·52	0·027	0·031	1·82	0·22

Acid Open Hearth.
1⅛ dia. bars. Blank Carburized 900°C. Refined 860°C. Oil Quenched, hardened 760°C. Oil Quenched. Tempered as indicated.

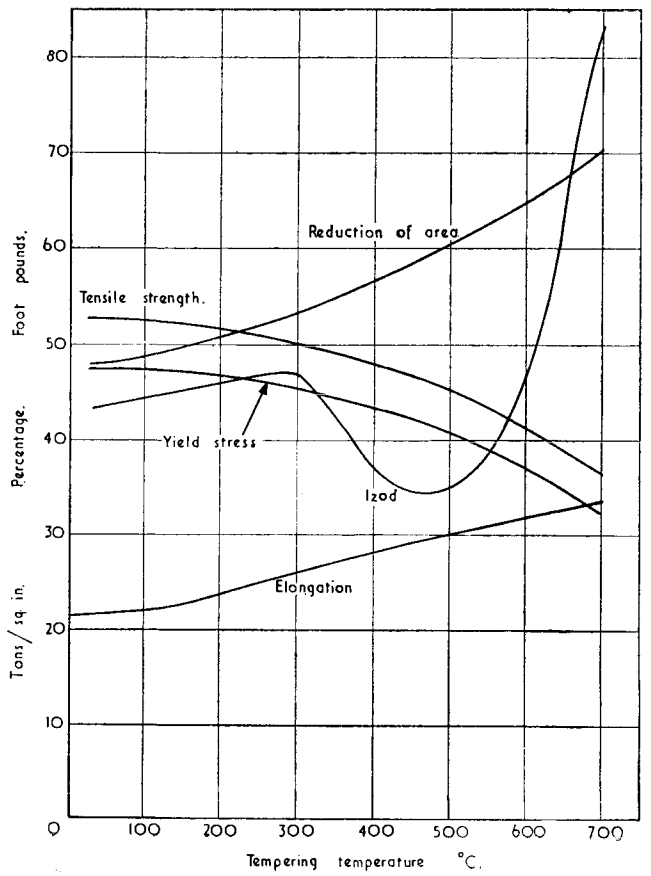


Fig. 34.13

EFFECT OF TEMPERING TEMPERATURE ON CASE HARDNESS (TYPICAL CURVE)

Bars Carburized 900°C.
Refined 860°C.
Oil Quenched, hardened 780°C.
Oil Quenched. Tempered as indicated.

(Ref. 3)

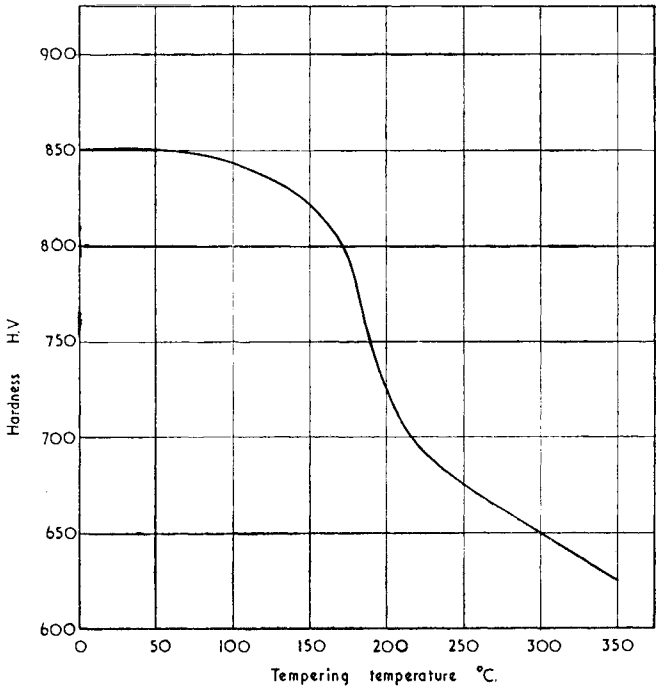


Fig. 34.14

EFFECT OF SECTION SIZE ON CORE PROPERTIES (TYPICAL CURVES)

Bars Blank Carburized 900°C. Refined 860°C. Oil Quenched.
Hardened 780°C. Oil Quenched.
(Ref. 3)

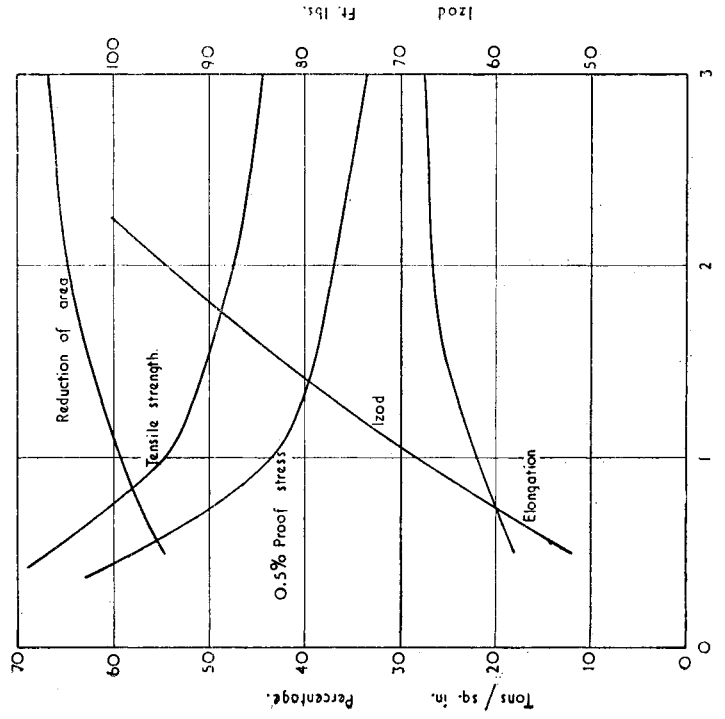


Fig. 34.15

Bars Blank Carburized 900°C. Hardened 820°C.
Oil Quench. (Single quench quality)
(Ref. 3)

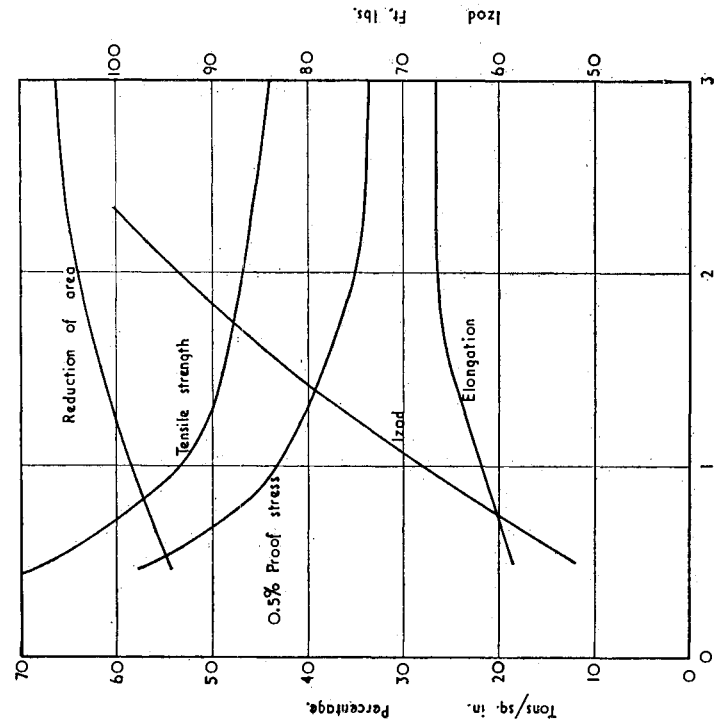


Fig. 34.16

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size As Quenched	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in.						
7	0·16	0·18	0·57	0·014	0·022	1·94	0·18	0·26	⅜	OQ860 OQ550	20	45·3	45·8	47·6	54·7	27	67	8
"	"	"	"	"	"	"	"	"	"	" "	— 78	47·8	48·3	50·0	59·4	29	65	"
"	"	"	"	"	"	"	"	"	"	" "	—196	65·4	66·1	68·1	72·8	29	49	"
7—8	0·18	0·13	0·38	0·026	0·028	1·85	0·18	0·27	½ plate	N950	20	20·1	21·4	22·3	36·9	41	65	"
"	"	"	"	"	"	"	"	"	"	"	— 78	21·7	23·5	25·2	42·9	43	64	"
"	"	"	"	"	"	"	"	"	"	"	—196	46·8	48·6	50·0	60·1	35	38	"
7	"	"	"	"	"	"	"	"	1½ plate	"	20	21·0	21·1	21·2	35·4	42	64	"
"	"	"	"	"	"	"	"	"	"	"	— 78	22·7	23·3	24·1	41·1	37	62	"
"	"	"	"	"	"	"	"	"	"	"	—196	47·6	48·6	49·5	58·1	35	46	"
7	"	"	"	"	"	"	"	"	2 plate	"	20	20·9	21·1	21·5	33·8	35	63	"
"	"	"	"	"	"	"	"	"	"	"	— 78	23·5	24·0	24·6	39·9	42	62	"
"	"	"	"	"	"	"	"	"	"	"	—196	47·6	48·2	49·2	57·2	30	26	"
7—8	"	"	"	"	"	"	"	"	½ plate	N950 T600 AC	20	25·2	25·3	25·8	34·3	42	67	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	28·6	28·8	29·2	40·9	45	65	"
"	"	"	"	"	"	"	"	"	"	" "	—196	52·6	52·8	53·2	58·0	34	53	"
7	"	"	"	"	"	"	"	"	1½ plate	" "	20	20·6	21·0	21·3	35·1	44	64	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	23·3	23·8	24·2	40·9	43	63	"
"	"	"	"	"	"	"	"	"	"	" "	—196	47·9	48·2	48·2	57·1	36	43	"
7	"	"	"	"	"	"	"	"	2 plate	" "	20	23·9	24·0	24·0	34·2	40	65	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	29·9	30·5	31·0	42·4	41	63	"
"	"	"	"	"	"	"	"	"	"	" "	—196	47·4	48·6	49·9	61·1	37	54	"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Izod ft.lb. at			Ref.
C	Si	Mn	Ni	Cr	Mo			—20°C	0°C	18°C	
0·16	0·22	0·50	1·82	0·22	0·25	1 1/8	OQ850 OQ770	23	29	42	1
"	"	"	"	"	"	"	" OQ800	35	46	72	"
0·16	0·23	0·60	1·81	0·17	0·20		OQ850 OQ770	26	31	48	"
"	"	"	"	"	"		" OQ800	37	48	74	"

IMPACT TRANSITION TEMPERATURE CURVES

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·16	0·18	0·57	0·014	0·022	1·94	0·18	0·26

(See also Mechanical Properties at Low Temperature for tensile data on this steel.)
As quenched grain size 7 (ASTM).
⅜ in. dia. bars Oil Quenched 860°C. Tempered 550°C. OQ.

(Ref. 8)

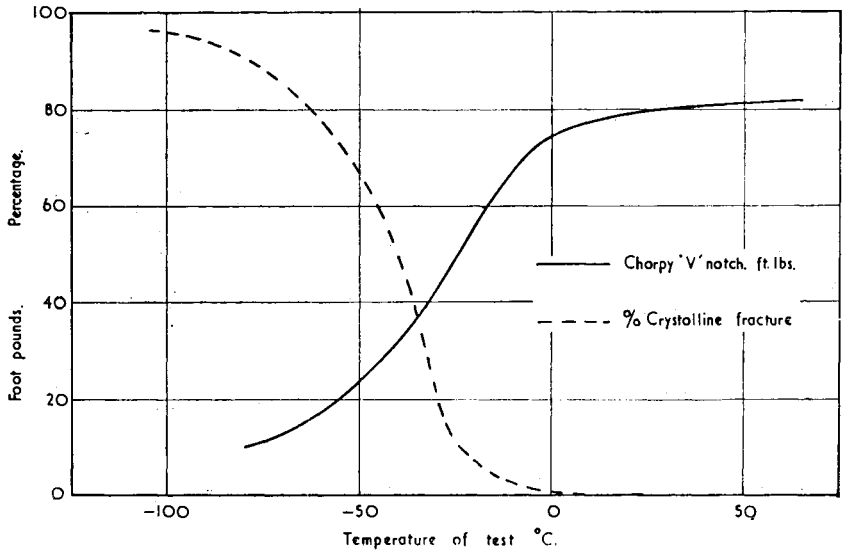


Fig. 34.17

IMPACT TRANSITION TEMPERATURE CURVES (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·18	0·13	0·38	0·026	0·028	1·85	0·18	0·27

(See also Mechanical Properties at Low Temperature for tensile data on this steel.)
As quenched grain size.
½ in. plate 7—8 ASTM.
1¼ in. and 2 in. plates 7 ASTM.
½ in; 1¼ in., and 2 in. thick plates. Normalized 900°C. A.C. (Ref. 8)

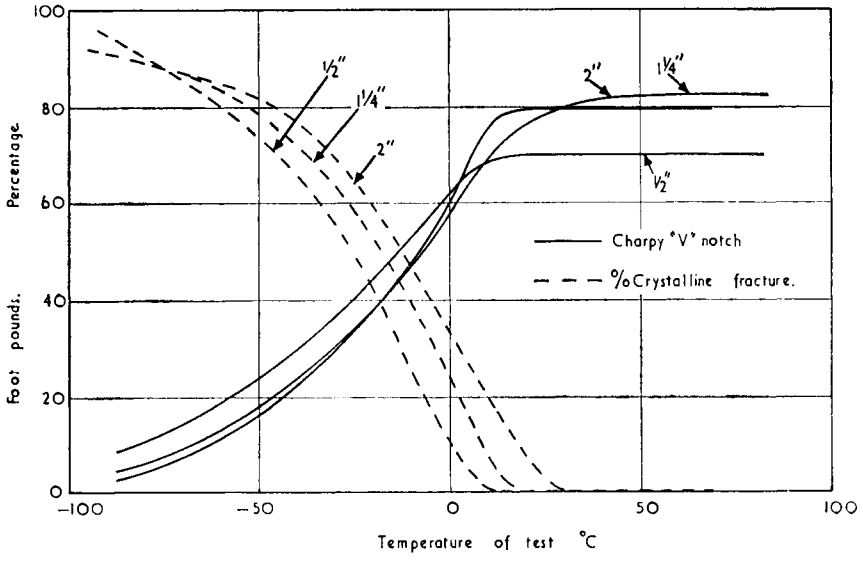


Fig. 34.18

½in.; 1¼ in., and 2 in. thick plates. Normalized 900°C. Tempered 600°C. A.C. (Ref. 8)

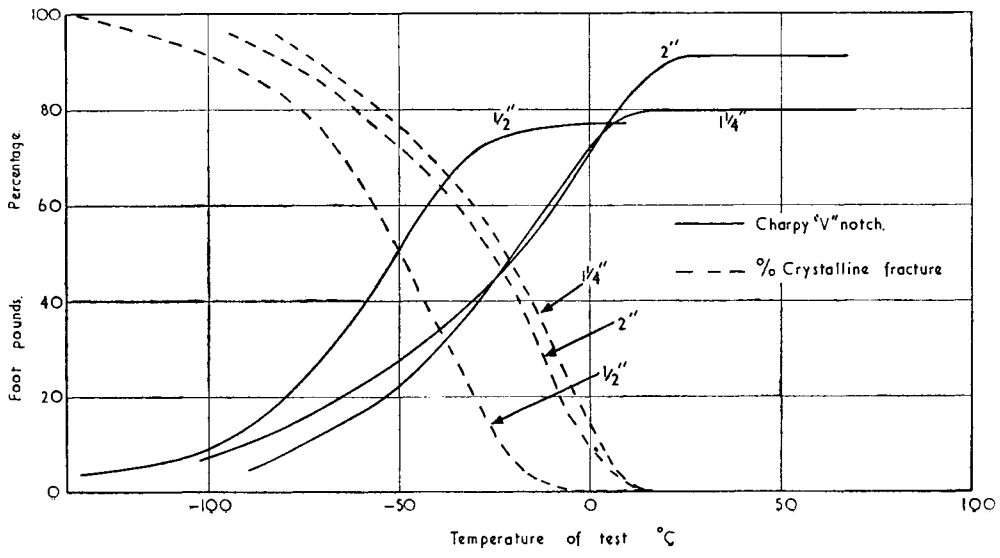


Fig. 34.19

En 34

MECHANICAL PROPERTIES AT HIGH TEMPERATURE

ASTM Grain Size	Chemical Composition (%)					Heat Treatment °C	Test Temperature °C	Tensile					Ref.
	C	Si	Mn	Ni	Mo			L.P.	0·2% P.S. (0·2Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
								tons/sq.in.					
5	0·14	0·28	0·53	1·85	0·25	N945 T645	RT	21·1	23·4	32·2	37½	70	13
"	"	"	"	"	"		395	10·9	14·6	29·1	29	69½	"
"	"	"	"	"	"		485	6·4	13·6	23·2	26	77½	"
"	"	"	"	"	"		525	3·6	11·4	19·4	25	81½	"
"	"	"	"	"	"		595	2·9	8·4	14·9	30½	80	"
"	"	"	"	"	"		645	1·9	5·3	11·2	59	80	"

HIGH TEMPERATURE IMPACT PROPERTIES

ASTM Grain Size	Chemical Composition (%)					Conditions of test	Charpy Impact ft.lb.								Ref.
	C	Si	Mn	Ni	Mo		25°C	260°C	315°C	395°C	485°C	535°C	595°C	645°C	
5	0·14	0·28	0·53	1·85	0·25	1 hr. at temperature	62	59	62	48	32	24	55	70	13
"	"	"	"	"	"	1000 hr. at temperature	—	65	64	50	37	40	52	—	"

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Rotary Bending Fatigue Limit tons./sq.in.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)			
											tons/sq.in.							
B.E.A.	0·15	0·20	0·51	0·016	0·014	1·90	0·19	0·23	2½	OQ870 OQ770 Carburized OQ870 OQ770	21·5	28·4	44·2	28½	55	76	±24·2 ±42·2	1 "

LIST OF REFERENCES

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12. B.S. 971: Commentary on the British Standard Wrought Steels En Series. British Standards Institution, London, 1950.
13. Digest of Steels for High Temperature Service. The Timken Roller Bearing Co., U.S.A.

2 PER CENT NICKEL–MOLYBDENUM CASE-HARDENING STEEL (HIGHER CARBON)

SPECIFICATION

CHEMICAL COMPOSITION (%)

	C	Si	Mn	S	P	Ni	Mo
En 35	0·20—0·28	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	1·50—2·00	0·20—0·30
En 35A*	0·20—0·25	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	1·50—2·00	0·20—0·30
En 35B*	0·23—0·38	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	1·50—2·00	0·20—0·30

* Supplied to composition only. Mechanical properties are not part of the contractual obligations.

MECHANICAL PROPERTIES

En 35	Tensile strength, tons/sq.in., min. (Rm)	55
	Elongation, %, min. (A)	15
	Izod impact value, ft.lb., min.	22

The heat treatment given to 1¼ in. dia. test bars shall be:
Blank carburize at a temperature between 880°C and 930°C (1), (2).
Refine at a temperature of 850°C—880°C; cool in air, oil or water.
Harden in oil from a temperature of 760°C—780°C.

(1) By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted, or modified to a short heating period.
(2) The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted by special agreement between the purchaser and the manufacturer.

RELATED SPECIFICATIONS

United Kingdom	America			France	U.S.S.R.	
En No.	AMS	SAE	AISI	AFNOR	GOST	Mark
En 35	6294C	4620	4620	20ND8	4543-61	20NM
En 35A		4620	4620	20ND8	4543-61	20NM
En 35B					4543-61	20NM

APPLICATIONS

A medium alloy case hardening steel which may be carburized and hardened to produce a hard wear resistant case and a core strength of the order of 55 tons/sq.in. with moderate resistance to shock.

Typical uses: Transmission gears, crown wheels, synchronizing cones, clutch plates and weights, rocker arms, gudgeon pins, camshafts, steering mechanisms, rocker shafts, and rifle components.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table)

	Welding Process					
	MA	G	IG	S	F	B
En 35	c	ax	g	e	a	h

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Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

In the softened condition the machinability of this steel is approximately 75% of that of mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1200°C. Finish above 850°C.
Softening	630°C—650°C. Air or furnace cool.
Normalizing	850°C—880°C. Cool in air.
Carburizing	880°C—930°C.
Refining	850°C—880°C. Air, oil or water quench.
Hardening*	760°C—780°C. Oil quench.
Tempering	150°C—200°C.

* A single quench (800°C/820°C oil quench) may be used when steel is specifically requested for this treatment.

En 35

CARBURIZING DATA

See notes given in the Introduction.

Case Depth (in.)	Time in hours at the stated carburizing temperature to produce the given case depth							
	900°C			925°C		950°C		
	Solid	Salt	Gas	Solid	Gas	Solid	Salt	Gas
0·01	1·0	0·5	0·37	0·7	0·33	0·4	0·35	—
0·02	1·9	1·6	1·3	1·4	0·85	0·9	0·7	0·55
0·03	4·2	4·0	2·7	2·8	1·9	1·9	1·75	1·2
0·04	7·5	6·4	4·8	4·8	3·2	3·4	2·8	2·2
0·06	16·8	16·0	10·8	10·8	7·25	7·8	7·0	4·8
0·08	30·0	—	19·2	19·2	13·0	13·6	—	8·8
0·10	47·0	—	30·5	30·0	20·0	21·5	—	14·0

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·17	0·25	0·50	—	—	1·80	—	0·25	Softened	7·87	1
0·22		0·45			1·80	—	0·25	Softened	7·87	2
0·23	0·23	0·42	0·025	0·023	1·78	0·23	0·26	BC900/920 4 hr. OQ800	7·82	3
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21	" "	7·82	"

SPECIFIC HEAT (c)

Chemical Composition (%)					Heat Treatment °C	Mean Specific Heat cal/g deg. C. 20 to 100°C	Ref.
C	Si	Mn	Ni	Mo			
0·17	0·25	0·50	1·80	0·25	Softened	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C					Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20to 100°C	20to 200°C	20to 300°C	20to 500°C	20to 700°C	
0·22		0·45			1·80		0·25	Softened	12·4		13·4	14·1	14·6	2
0·23	0·23	0·42	0·025	0·023	1·78	0·23	0·26	BC900/920 4 hr. OQ800	12·8	12·5				3
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21	" "	12·2	13·2				"

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	
0·23	0·23	0·42	0·025	0·023	1·78	0·23	0·26	BC900/920 4 hr. OQ800	26·5	31·5	37·4	3
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21	" "	28·5	33·1	40·3	"
"	"	"	"	"	"	"	"	Softened	22			*

* Estimated value.

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)								Heat Treatment °C	Thermal Cond uctivity cal/cm s deg. C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21	Softened	0·10	*

* Estimated value.

YOUNG'S MODULUS (E)

Chemical Composition (%)								Heat Treatment °C	Young's Modulus tons/sq.in. Vibration Method			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	
0·23	0·23	0·42	0·025	0·023	1·78	0·23	0·26	BC900/920 4 hr. OQ800	13,300	13,000	12,600	3
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21	" "	13,300	12,900	12,000	"

En 35

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

CORE CHARACTERISTICS (1)

Chemical Composition (%)					
C	Si	Mn	Ni	Cr	Mo
0·23	0·20	0·40	1·78	0·18	0·27

McQuaid Ehn grain size 8 (ASTM).

Austenitizing Temperature 820°C ,30 min.

(Ref. 2)

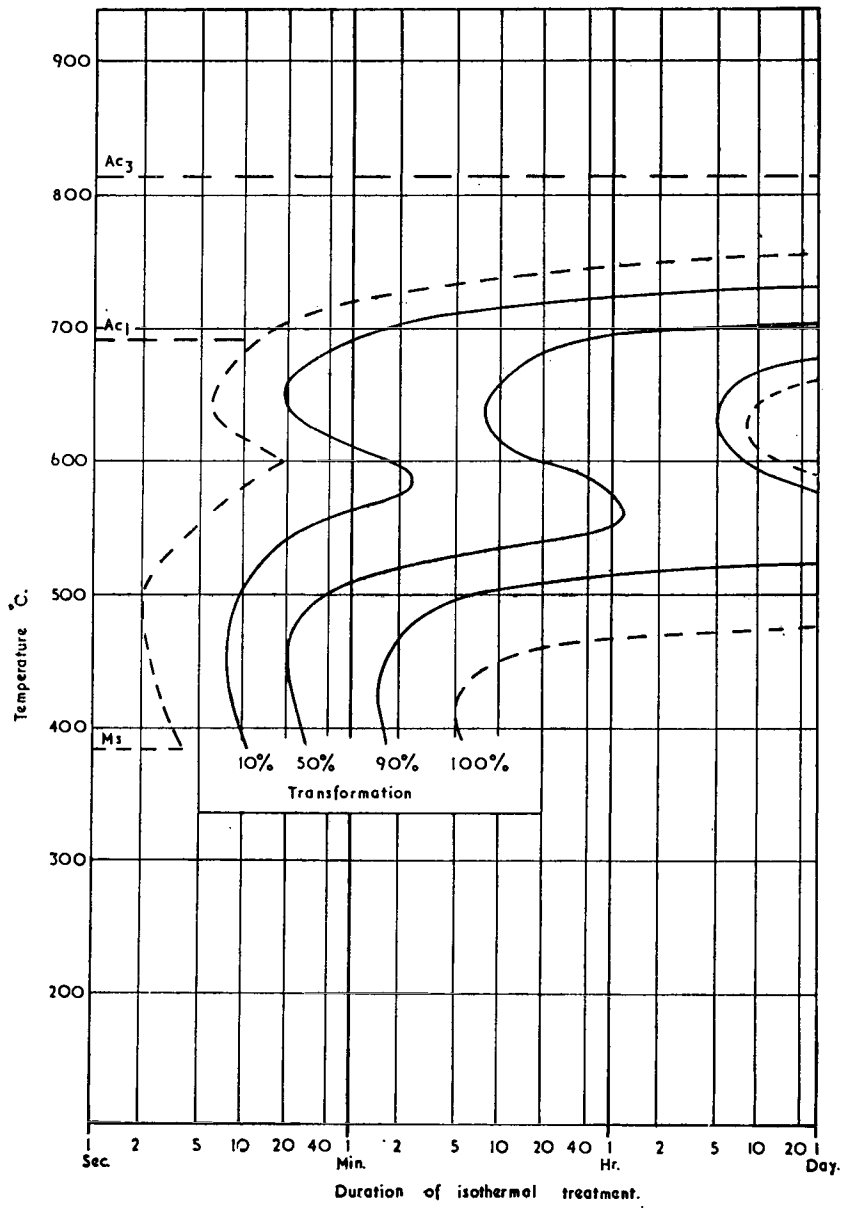


Fig. 35.1

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS (1)

Chemical Composition (%)					
C	Si	Mn	Ni	Cr	Mo
0·97	0·20	0·40	1·78	0·18	0·27

McQuaid Ehn grain size 8 (ASTM).
Bars Carburized 925°C for 16 hr., homogenized 1000°C 6 hr.

Austenitizing Temperature 820°C, 30 min.

(Ref. 2)

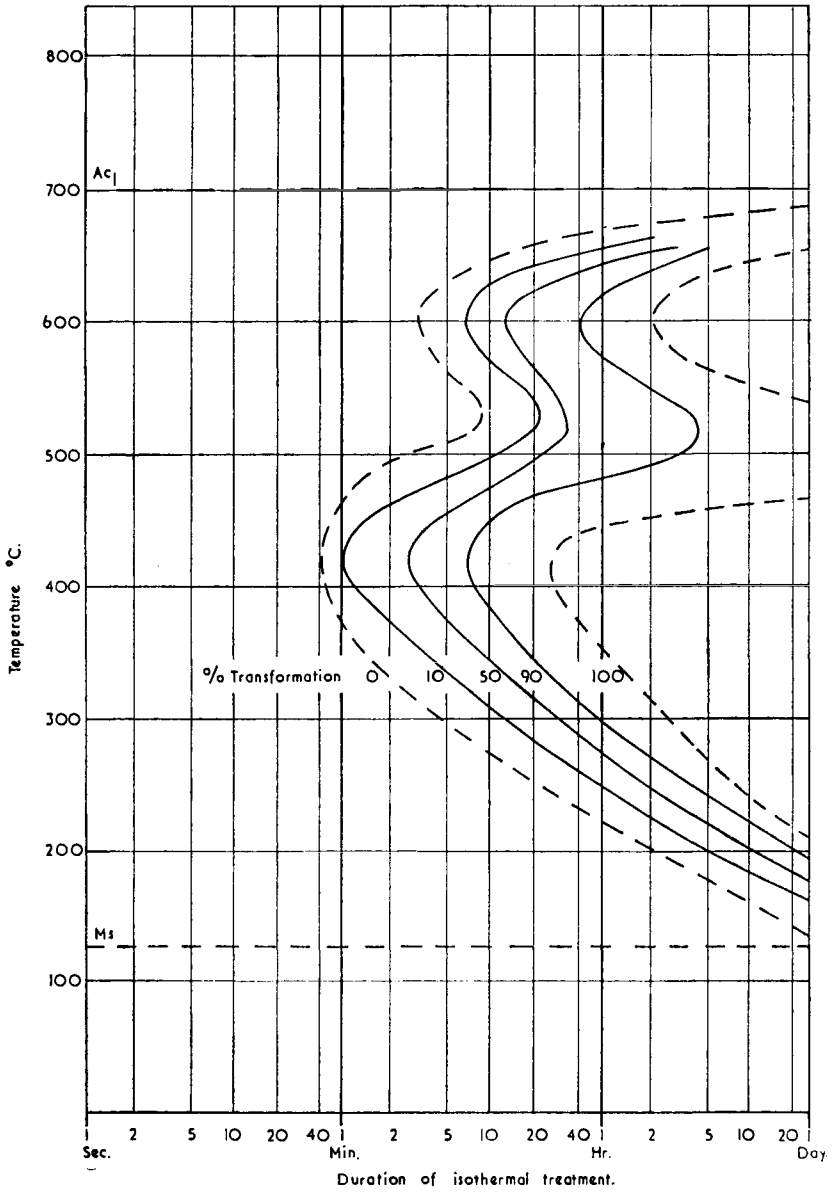


Fig. 35.2

En 35

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS (2)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·21	0·29	0·55	0·010	0·008	1·84	0·07	0·20

McQuaid Ehn grain size 3.
Actual grain size 10.

Austenitizing Temperature 875°C, 30 min.
(Ref. 4)

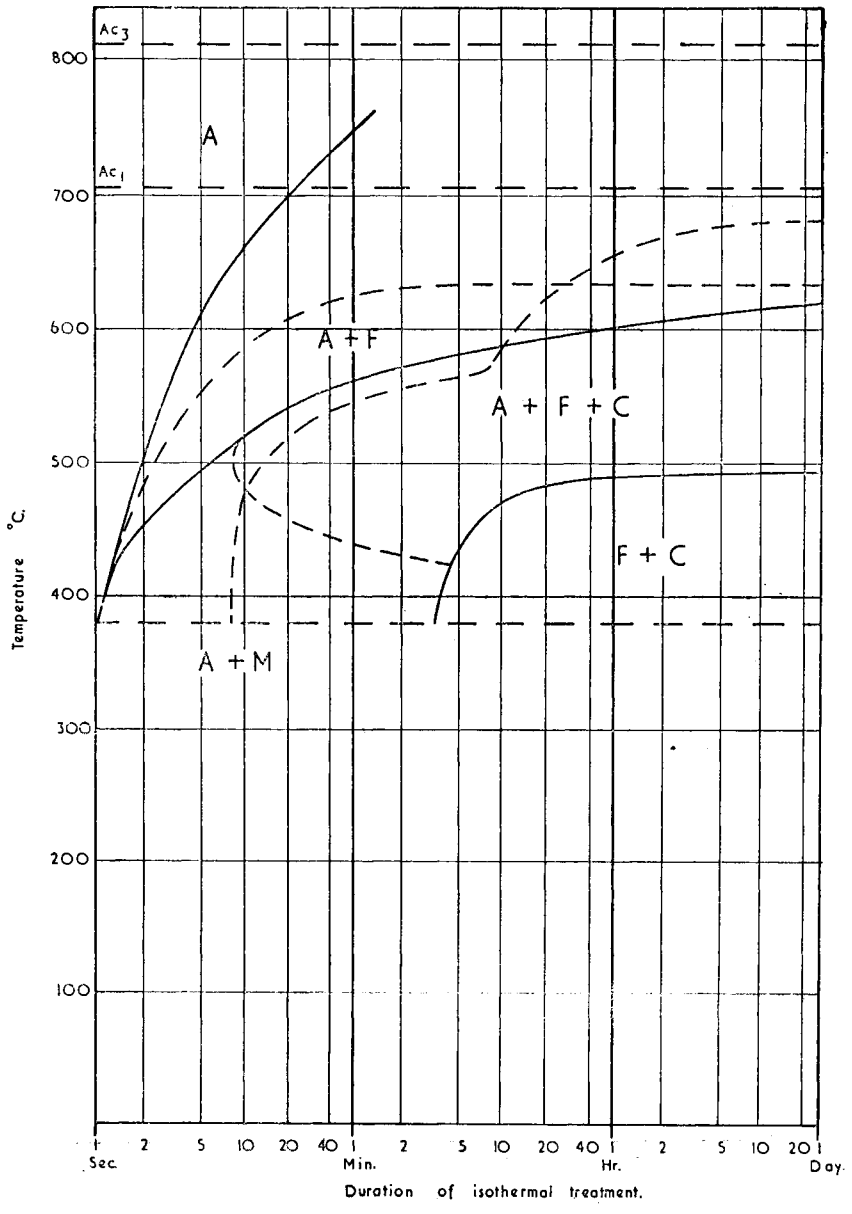


Fig. 35.3

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS (3)

En 35A

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·23	0·23	0·42	0·025	0·023	1·78	0·23	0·26

McQuaid Ehn grain size 8 (ASTM).
Test bars Blank Carburized 900—920°C for 4 hr.
Furnace Cooled.

Austenitizing Temperature 800°C, 30 min.

(Ref. 3)

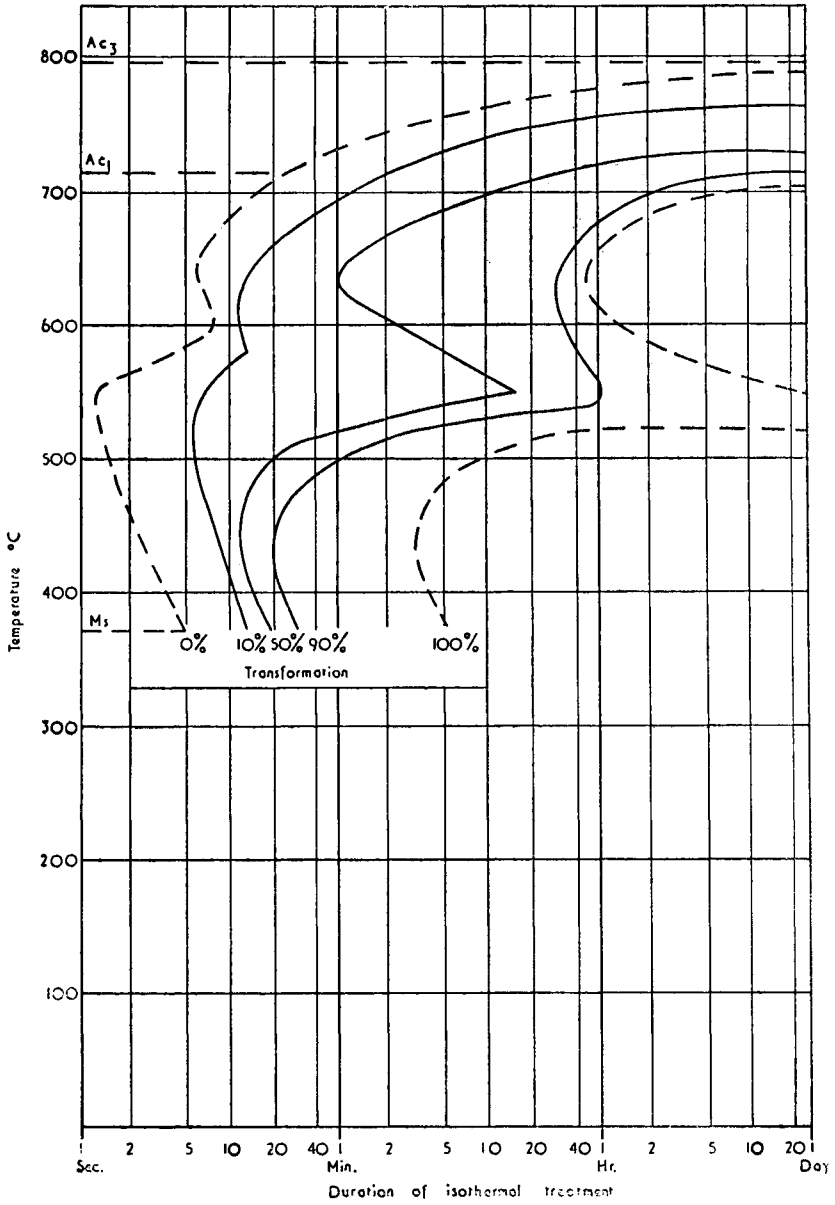


Fig. 35.4

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS (4)

En 35B

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·25	0·24	0·57	0·029	0·028	1·78	0·26	0·21

McQuaid Ehn grain size 8 (ASTM).
Test Bars Blank Carburized 900—920°C for 4 hr. Furnace Cooled.

Austenitizing Temperature 800°C, 30 min.

(Ref. 3)

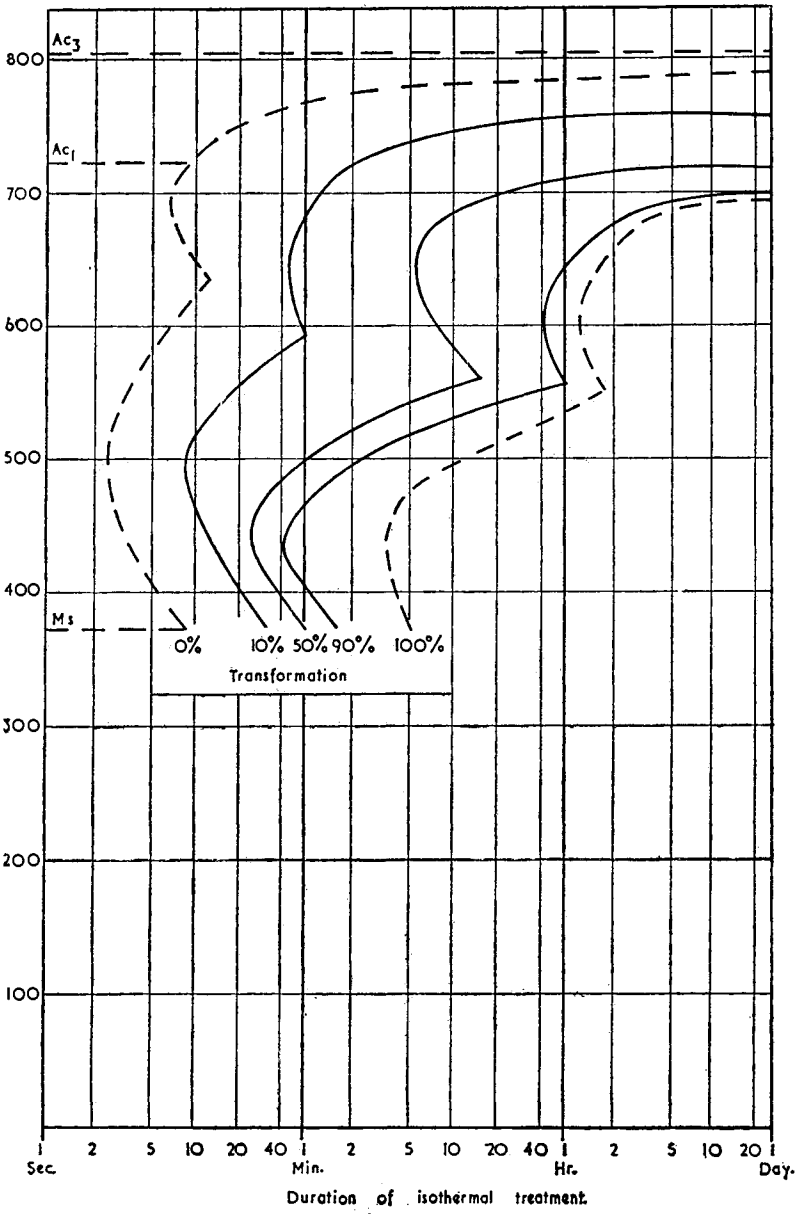


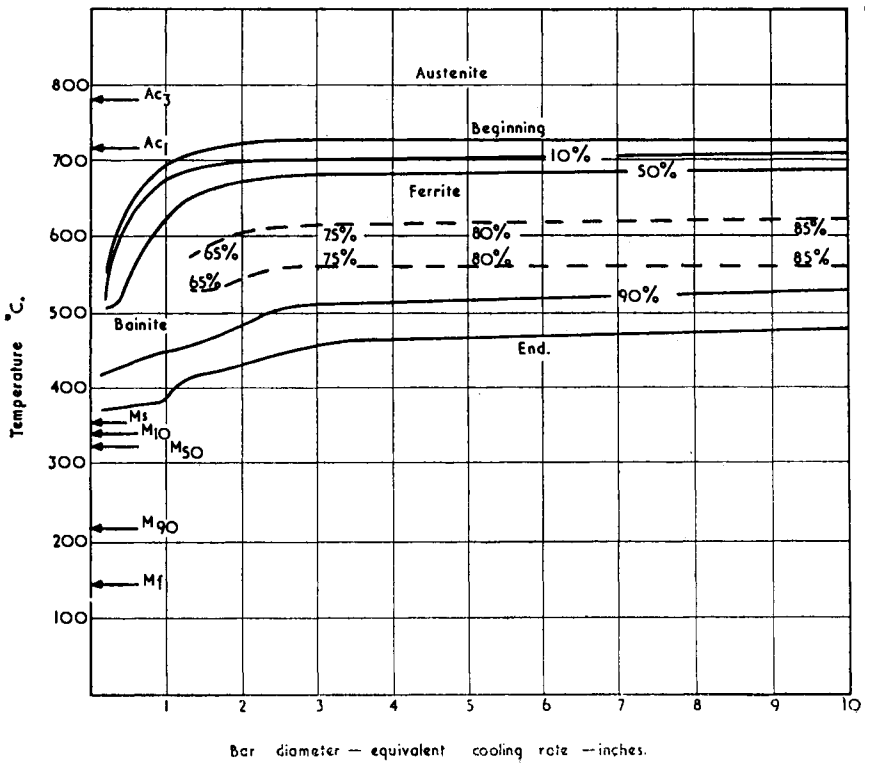
Fig. 35.5

CONTINUOUS COOLING TRANSFORMATION

En 35A

Air Cooled from 800°C.

(Ref. 3)



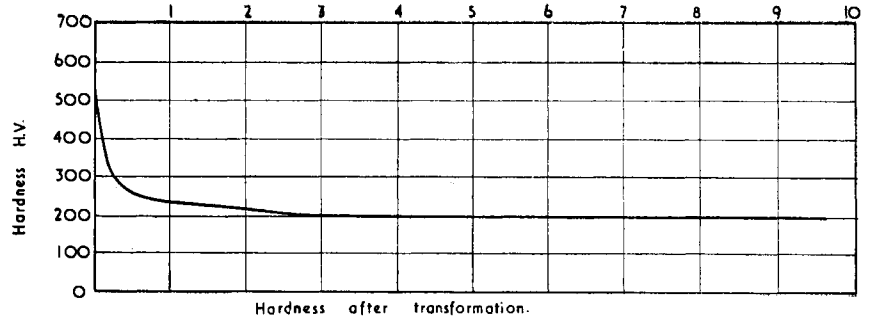


Fig. 35.6

En 35A

Oil Quenched from 800°C.

(Ref. 3)

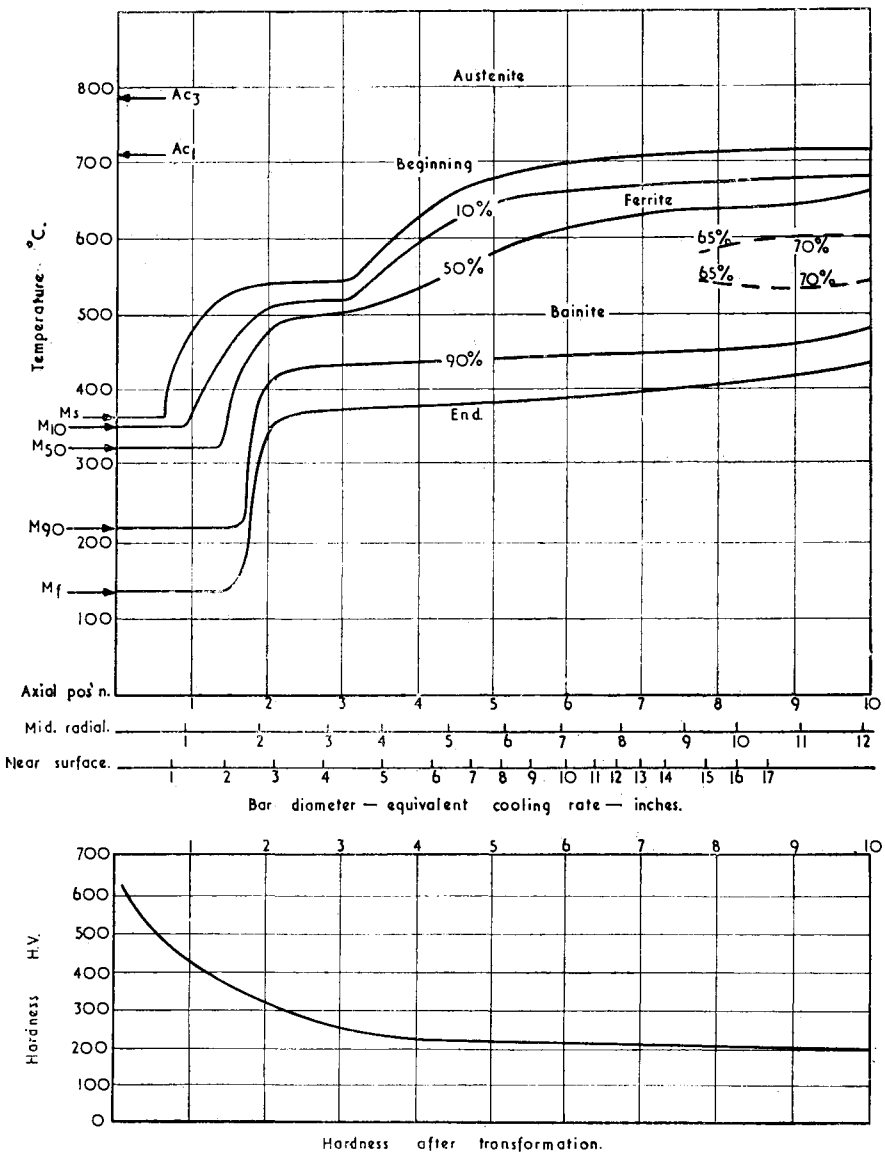


Fig. 35.7

En 35A

Water Quenched from 800°C.

(Ref. 3)

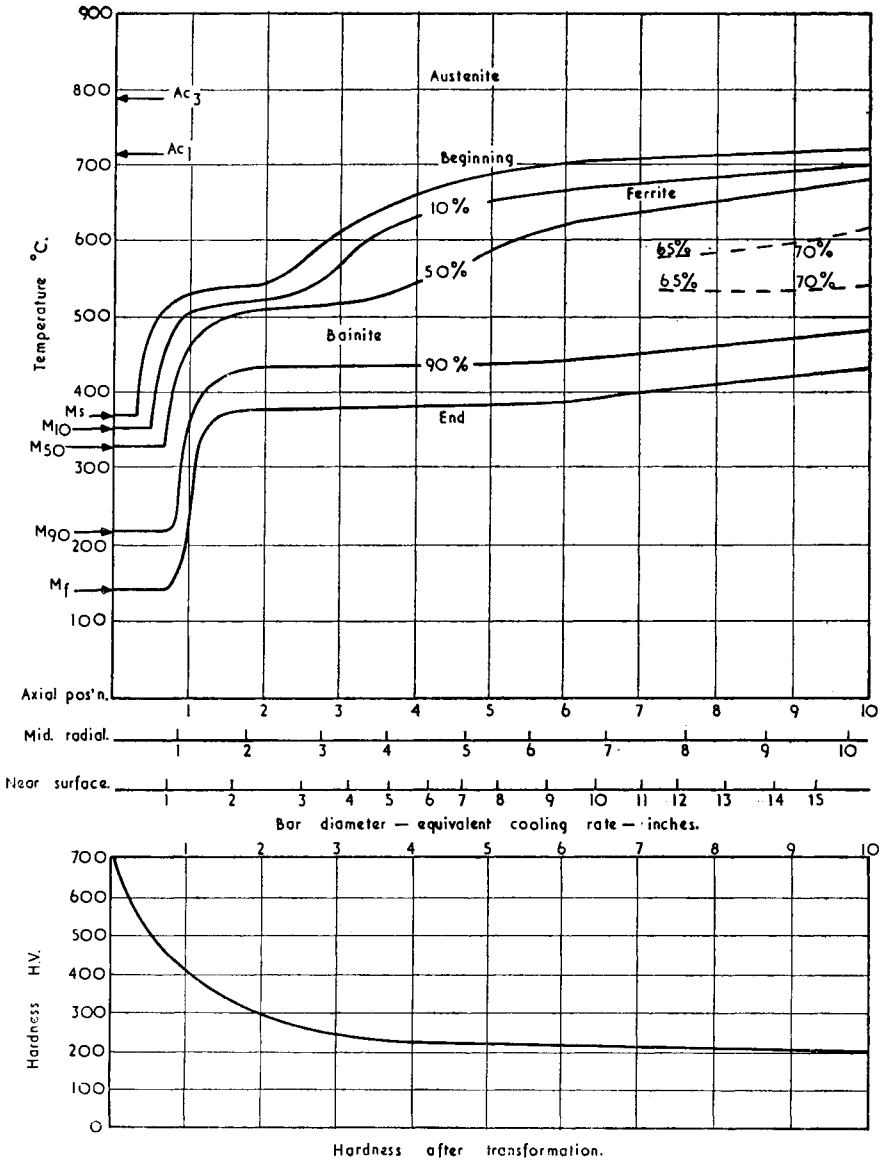


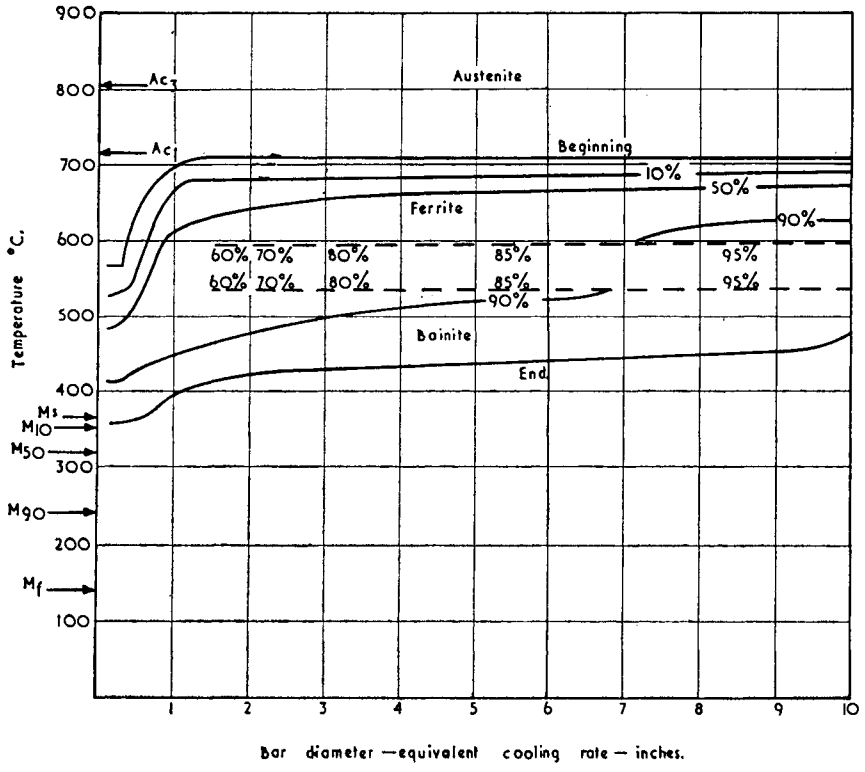
Fig. 35.8

CONTINUOUS COOLING TRANSFORMATION

En 35B

Air Cooled from 800°C.

(Ref. 3)



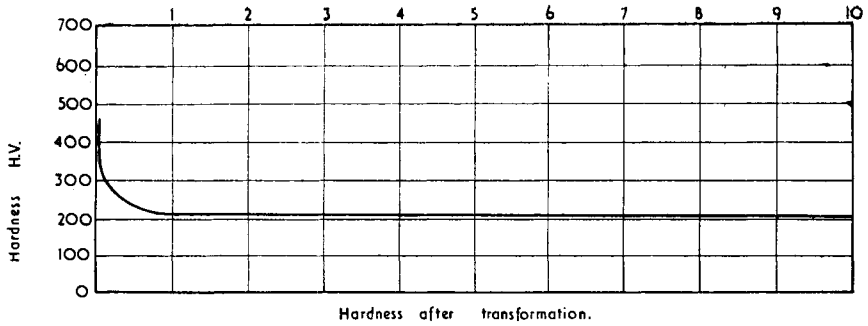


Fig. 35.9

En 35B

Oil Quenched from 800°C. (Ref. 3)

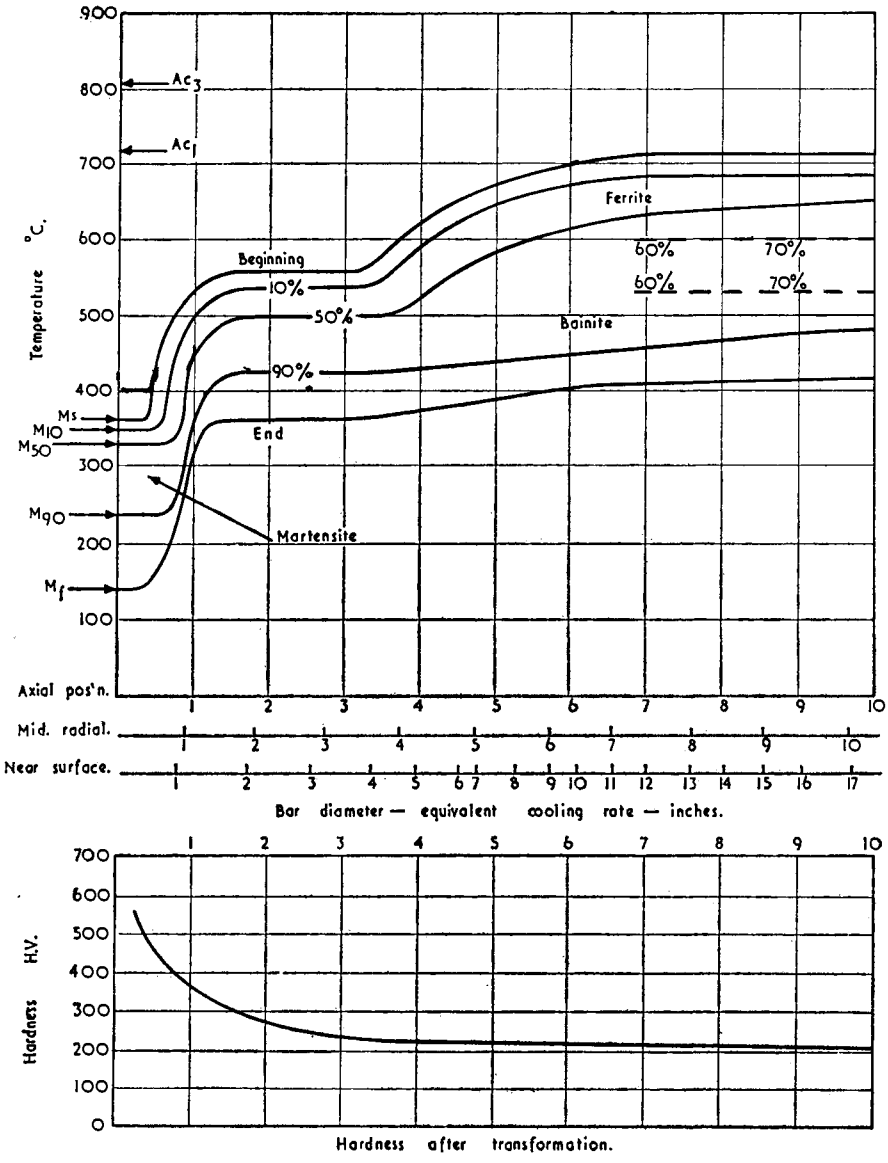


Fig. 35.10

En 35 B

Water Quenched from 800°C. (Ref. 3)

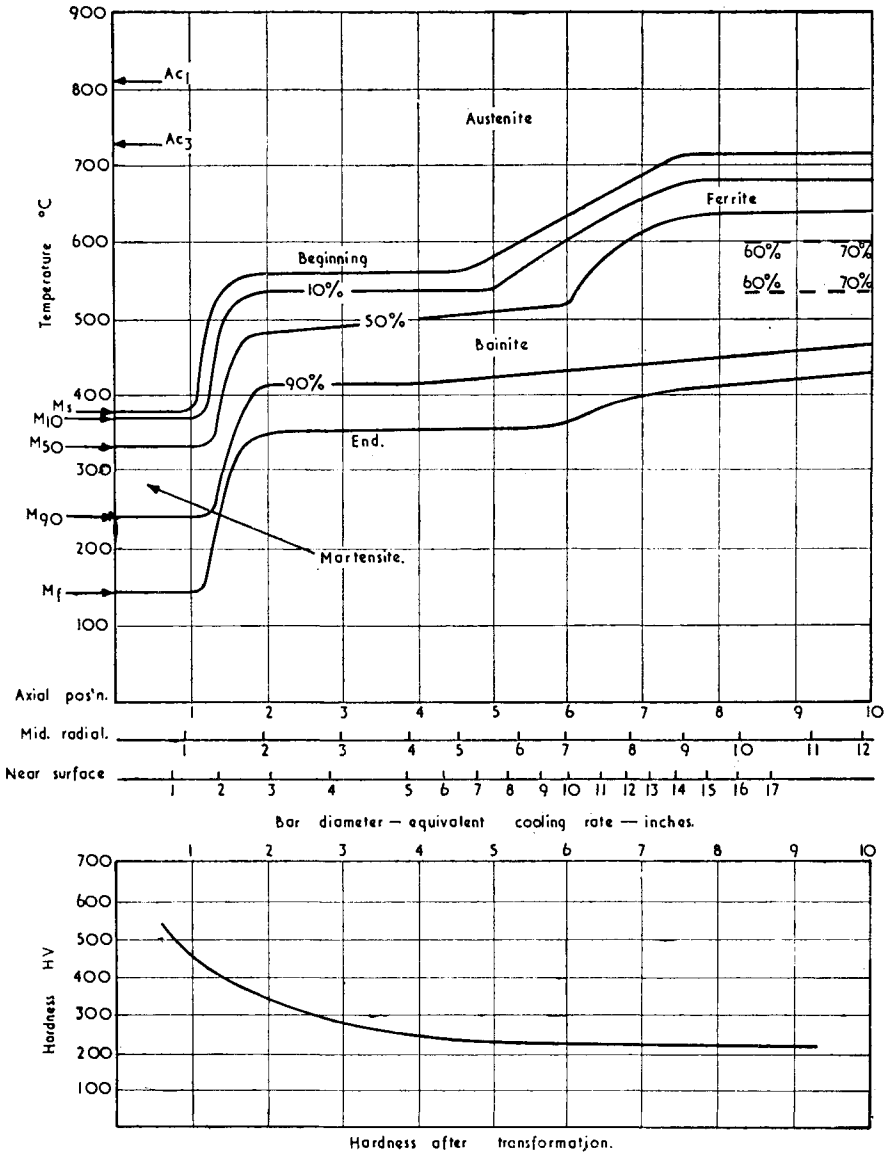


Fig. 35.11

HARDENABILITY

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								McQuaid Ehn Grain Size (ASTM)
	C	Si	Mn	S	P	Ni	Cr	Mo	
A	0·20	0·19	0·51	0·009	0·014	1·90	0·22	0·27	6/7
B	0·21	0·18	0·55	0·011	0·021	1·85	0·28	0·27	5/6
C	0·23	0·21	0·54	0·010	0·011	2·0	0·21	0·25	6

Test bars End Quenched from 850°C.

(Ref. 5)

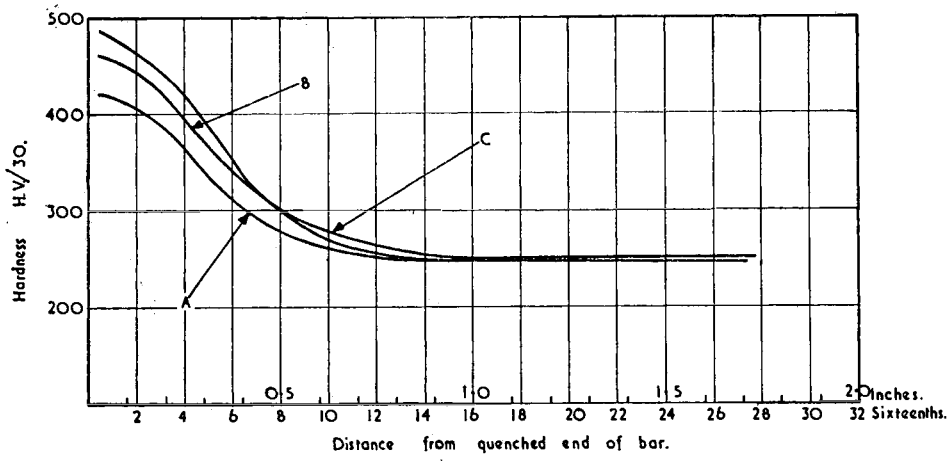


Fig. 35.12

Curve No.	Chemical Composition (%)								Grain Size ASTM	
	C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn
D	0·27	0·27	0·56	0·047	0·026	1·85	0·31	0·19	8 (7)	6—8
E	0·23	0·13	0·53	0·017	0·010	1·89	0·19	0·22	8	7—8 (6)

Test Bars Normalized 900°C. End Quenched from 850°C. Requenched 770°C.

End Quenched 850°C.

(Ref. 6)

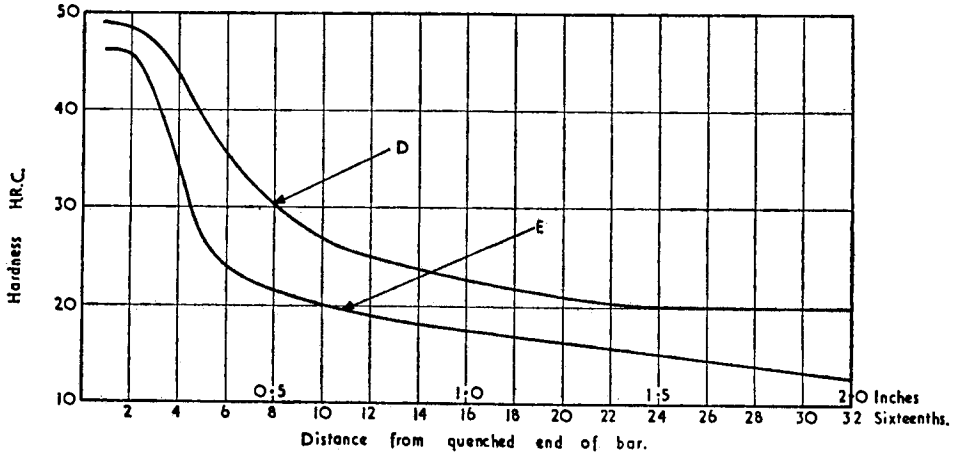


Fig. 35.13

Requenched 770°C. (Ref. 6)

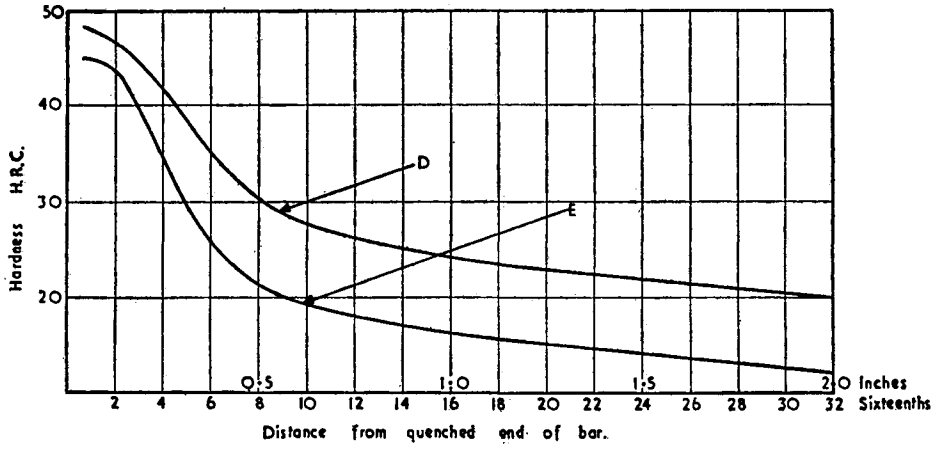


Fig. 35.14

END QUENCH HARDENABILITY BANDS

En 35A

These curves have been constructed from the results obtained on several casts of En 35A covering the analysis range.

0·20—0·25% C
0·35—0·59% Mn
1·63—1·97% Ni
0·20—0·26% Mo

(Ref. 3)

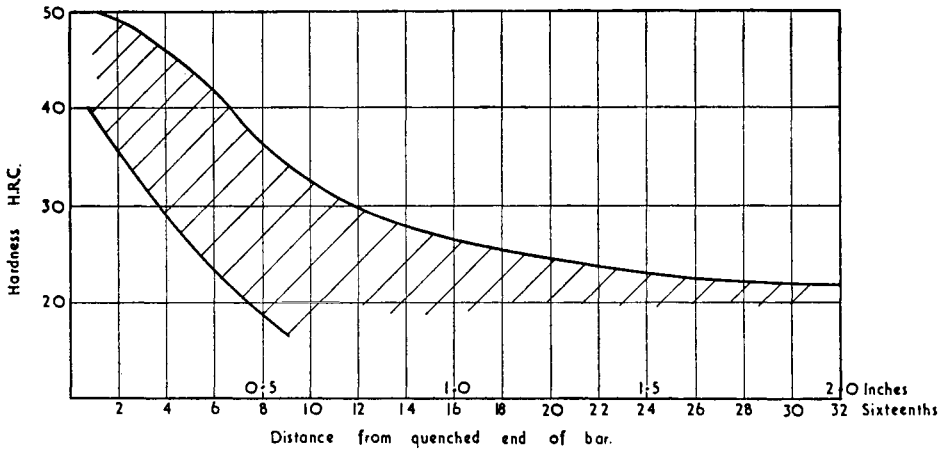


Fig. 35.15

En 35B

These curves have been constructed from the results obtained on several casts of En 35B covering the analysis range.

0·23—0·28% C
0·35—0·59% Mn
1·63—1·97% Ni
0·20—0·26% Mo

(Ref. 3)

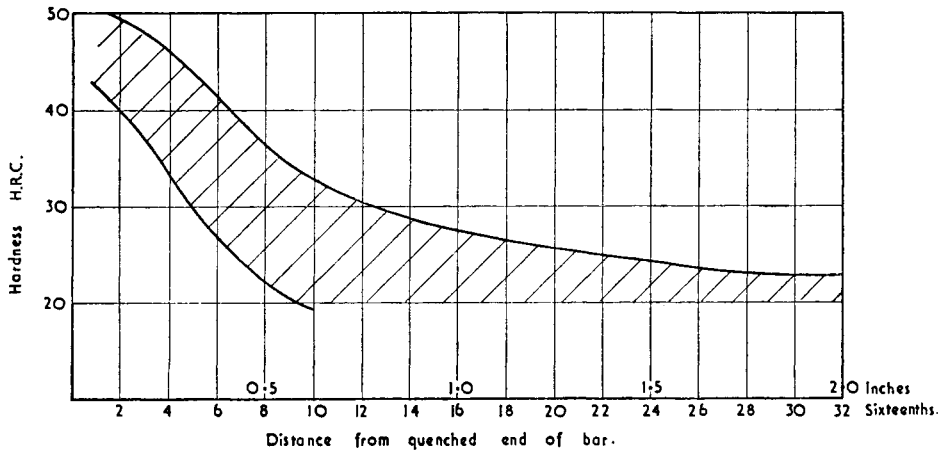


Fig. 35.16

MECHANICAL PROPERTIES AT ROOM TEMPERATURES

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
B.O.H.	4 to 5	0·20	0·24	0·50	0·040	0·031	1·66		0·25	1	WQ880 OQ780		59·2	15		21	7
		0·20	0·19	0·55			1·85	0·24	0·22	1	BC900 OQ860 OQ780		55·2	17½	36½	60	2
		0·20		0·51			1·79	0·17	0·25	⅝	BC920 FCOQ860 OQ780	43·9	59·2	23	47	34	3
		"		"			"	"	"	"	" OQ800	59·7	66·8	13½	36	12	"
		"		"			"	"	"	"	" OQ860	66·0	75·5	13	47	28	"
		"		"			"	"	"	"	BC920 OQ	57·6	63·1	17	52	29	"
		"		"			"	"	"	1	BC920 FCOQ860 OQ780	38·4	55·0	24½	47	36	"
		"		"			"	"	"	"	" OQ800	54·0	61·0	20½	42	19	"
		"		"			"	"	"	"	" OQ860	54·0	59·3	21	55	32	"
		"		"			"	"	"	"	BC920 OQ	47·0	53·4	22	55	35	"
B.O.H.	5 to 6	0·21	0·14	0·44	0·037	0·021	1·67	0·26	0·26	1	OQ880 OQ780		54·4	19		38	7
		0·21		0·52			1·84	0·18	0·29	1	OQ800		56·4	21		34	8
		0·22		0·51			1·85	0·10	0·27	⅝	BC OQ860 OQ780	51·0	63·8	17		18	9
		"		"			"	"	"	1	" " "	44·0	56·6	21½		27	"
		0·22	0·22	0·50			1·77	0·18	0·22	1	BC900 OQ860 OQ780		55·0	21	42	45	2
		0·22	0·28	0·48			1·87	0·30	0·23	1	" " "		55·6	24½	50	60	"
		0·22	0·27	0·46			1·81	0·30	0·23	1	" " "		57·2	20½	42	46	"
		0·22	0·23	0·50			1·85	0·29	0·25	1	" " "		58·0	20½	42	53	"
		0·22		0·62			1·78	0·12	0·28	1	OQ880 OQ870		57·6	20		50	8
		"		"			"	"	"	"	OQ800		61·6	22		39	"
	McQuaid Actual Ehn 7—8(6) 8	0·23	0·13	0·53	0·017	0·010	1·89	0·19	0·22	1	N900 OQ850 T150	47·1	75·1	13½	37	12	6
		0·24		0·57			1·72	0·20	0·24	⅝	OQ860 OQ780	44·4	60·8	22½		25	9
		"		"			"	"	"	1	" "	48·4	59·4	20		35	"
		0·24	0·21	0·51			1·78	0·23	0·22	1	BC900 OQ860 OQ780		61·0	19	42	40	"
		0·24		0·55			1·87	0·25	0·25	1	OQ850 OQ760		60·4	18		40	"
		0·24		0·57			1·72	0·20	0·24	⅝	BC920 FC OQ860 OQ780	44·4	60·8	22½	44	25	3
		"		"			"	"	"	"	" OQ800	62·9	76·6	17½	36	12	"
		"		"			"	"	"	"	" OQ860	55·2	76·8	14½	42	30	"
		"		"			"	"	"	"	BC920 OQ	58·4	65·6	15½	42	36	"
		"		"			"	"	"	1	BC920 FC OQ860	48·4	59·4	20	39	35	"
		"		"			"	"	"	"	" OQ800	50·4	61·7	20	42	21	"
		"		"			"	"	"	"	" OQ860	52·0	59·3	20½	50	46	"
		"		"			"	"	"	"	BC920 OQ	47·6	56·4	19½	42	50	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
		0·25		0·60			1·84	0·15	0·25	1	OQ880 OQ770		65·6	15		28	8
		0·26		0·57			1·83	0·17	0·28	1	OQ800		66·0	18½		35	8
	McQuaid Ehn Actual 6—8 8 (7)	0·27	0·27	0·56	0·047	0·026	1·85	0·31	0·19	1	N900 OQ850 T150	47·1	75·1	13½	37	12	6

EFFECT OF TEMPERING ON CASE HARDNESS (TYPICAL CURVE)

(Ref. 2)

Bars Carburized 900°C. Refined 860°C.
Oil Quenched.
Hardened 780°C. Oil Quenched.
Tempered as indicated.

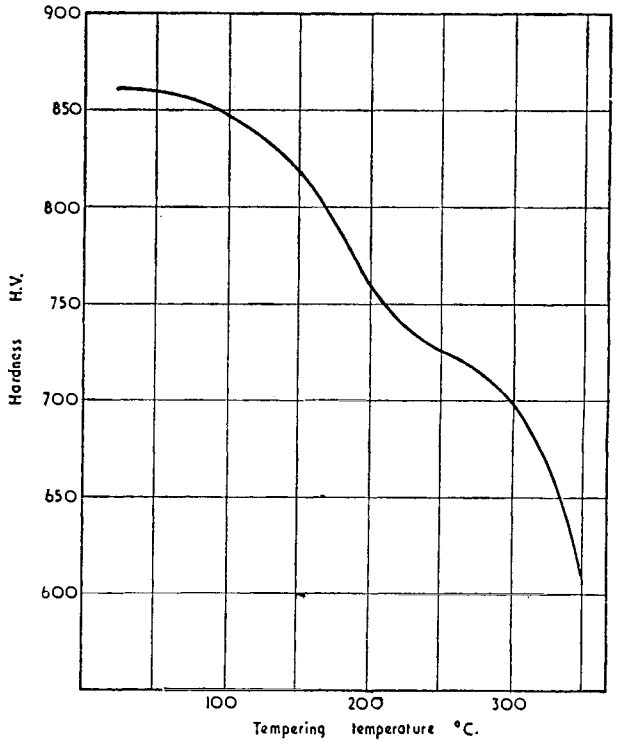


Fig. 35.17

(Ref. 2)

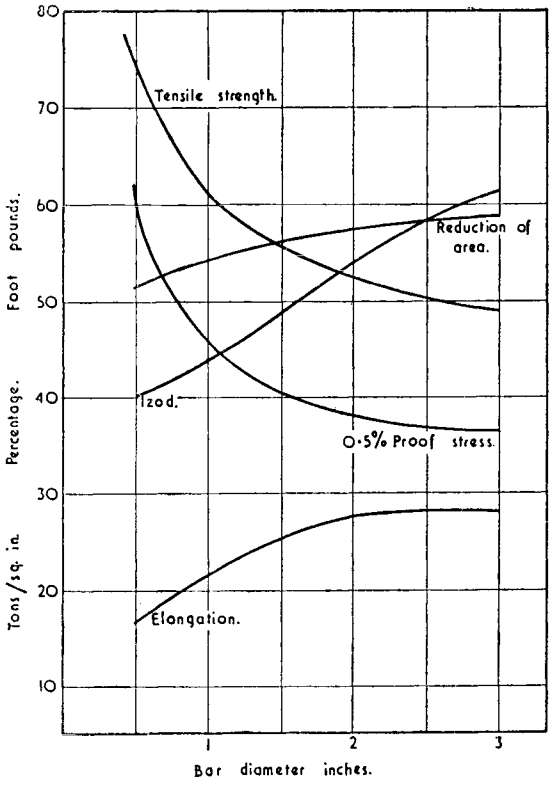


Fig. 35.18

EFFECT OF SECTION SIZE ON CORE PROPERTIES (TYPICAL CURVES)

Bars Blank Carburized 900°C. Refined 860°C.
Oil Quenched.
Hardened 780°C. Oil Quenched.

EFFECT OF SECTION SIZE ON CORE PROPERTIES (Continued)

Bars Blank Carburized 900°C. Hardened 820°C. Oil Quenched.
(Single quench quality).

(Ref. 2)

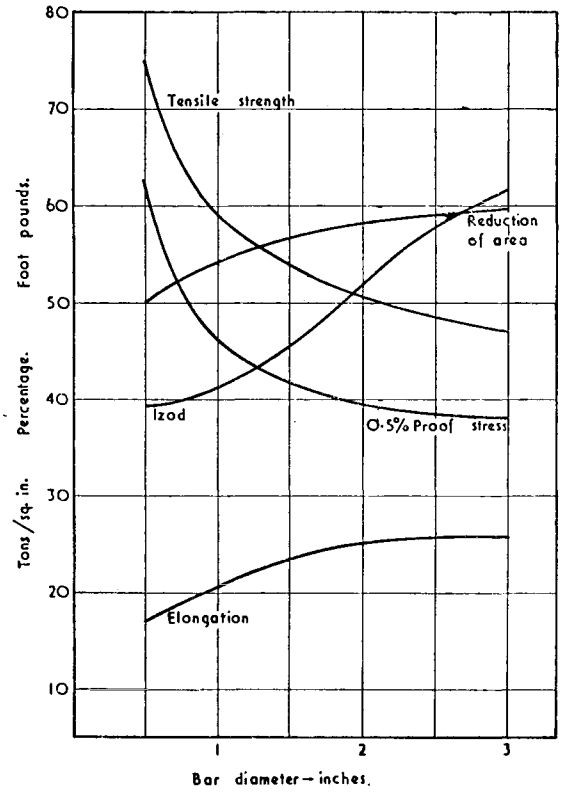


Fig. 35.19

LIST OF REFERENCES

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En 36

3 PER CENT NICKEL–CHROMIUM AND NICKEL–CHROMIUM–MOLYBDENUM CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

En No.	C	Si	Mn	S	P	Ni	Cr	Mo
36A	0·15 max.	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	3·00—3·75	0·60—1·10	—
36B	0·12—0·18	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	3·00—3·75	0·60—1·10	—
36C	0·12—0·18	0·10—0·35	0·30—0·60	0·050 max.	0·050 max.	3·00—3·75	0·60—1·10	0·10—0·25

MECHANICAL PROPERTIES

	En 36A	En 36B	En 36C
Tensile strength, tons/sq.in., min. (Rm)	55	65	65
Elongation, %, min. (A)	15	13	13
Izod impact value, ft.lb., min.	35	30	30

The heat treatment given to 1¼ in. dia. test bars shall be:
Blank carburize at a temperature between 880—930°C (1).
Refine at a temperature 850°C—880°C; cool in air, oil or water (2).
Harden in oil from a temperature of 760°C—780°C.

1. By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.
2. The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted by special agreement between the purchaser and the manufacturer.

RELATED SPECIFICATIONS

United Kingdom		America	France	Germany			Sweden	U.S.S.R.	
En No.	BS Air	AMS	AFNOR	Werkstoff No.	Name	DIN	SIS	GOST	Mark
36A			10NC12 12NC15	5752	14NiCr14	1662		4543—61	12KhN3A
36B			14NC12	5752	14NiCr14	1662	14.2515	4543—61	12KhN3A
36C	S107	6260E							

APPLICATIONS

An alloy case-hardening steel capable of producing a core strength of 55 to 80 tons/sq.in. tensile strength combined with good resistance to shock.

Typical uses: high duty gears for aircraft, heavy vehicle and automobile transmission components, steering worms, track rod pins, gudgeon pins, timing wheels, breech mechanisms and small arms parts.

WELDING

(See Introduction (List of Abbreviations) for key to symbols used in this table.)

En No.	Welding Process					
	MA	G	IG	S	F	B
36A	bx	bx	g	e	a	h
36B	bx	bx	g	e	a	h
36C	bx	bx	g	e	a	h

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Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

The machinability of this steel in the softened condition is approximately 65% of that for mild steel (En 3.).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1150°C. Finish above 850°C.
Softening	630°C—650°C. Air or furnace cool.
Carburizing	880°C—930°C.
Refining	850°C—880°C. Air, oil or water cool.
Hardening	760°C—780°C. Oil quench.
" (for single quench quality)	800°C—820°C. Oil quench.
Tempering	150°C—200°C.

CARBURIZING DATA

The times for carburizing to different case depths at various temperatures are similar to those given for En 35.

En 36

PHYSICAL PROPERTIES

(See also data for En 23)

SPECIFIC GRAVITY (d)

Chemical Composition (%)						Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	Ni	Cr	Mo			
0·12	0·25	0·40	3·30	0·80	—	Softened	7·87	1
Typical composition						"	7·87	2

SPECIFIC HEAT (c)

Chemical Composition (%)						Heat Treatment °C	Mean Specific Heat cal/g deg. C	Ref.
C	Si	Mn	Ni	Cr	Mo		20 to 100°C	
0·12	0·25	0·40	3·30	0·80	—	Softened	0·118	1

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)						Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C				Ref.
C	Si	Mn	Ni	Cr	Mo		20 to 100°C	20 to 300°C	20 to 500°C	20 to 700°C	
0·12	0·25	0·40	3·30	0·80	—	Softened	12	13	14	15	1
Typical composition						"	11·8	12·7	13·4	13·9	2

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)							Heat Treatment °C	Electrical Resistivity microhm-cm			Ref.
C	Si	Mn	S	P	Ni	Cr		20°C	100°C	200°C	
0·13	0·22	0·52	0·022	0·034	3·12	0·80	BC910 OQ860 OQ780	31·8	36·2	42·3	3
"	"	"	"	"	"	"	Softened	25·0	—	—	*

* Estimated

THERMAL CONDUCTIVITY (k)

Estimated value at 20°C in the softened condition = 0·09 cal/cm s deg. C.

YOUNG'S MODULUS (E)

Chemical Composition (%)							Heat Treatment °C			Test Temperature °C	Young's Modulus tons/sq.in.	Ref.
C	Si	Mn	S	P	Ni	Cr					Vibration Method	
0·13	0·22	0·52	0·022	0·034	3·12	0·80	BC910	OQ860	OQ780	20	13,200	3
"	"	"	"	"	"	"	"	"	"	100	12,900	"
"	"	"	"	"	"	"	"	"	"	200	12,500	"
"	"	"	"	"	"	"	"	"	"	250	12,250	"

En 36

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

CORE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·11	0·13	0·38	0·016	0·023	3·26	0·87	0·08

High Frequency Melt.
McQuaid Ehn grain size 6—8 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 860°C, 30 min. (Ref. 4)

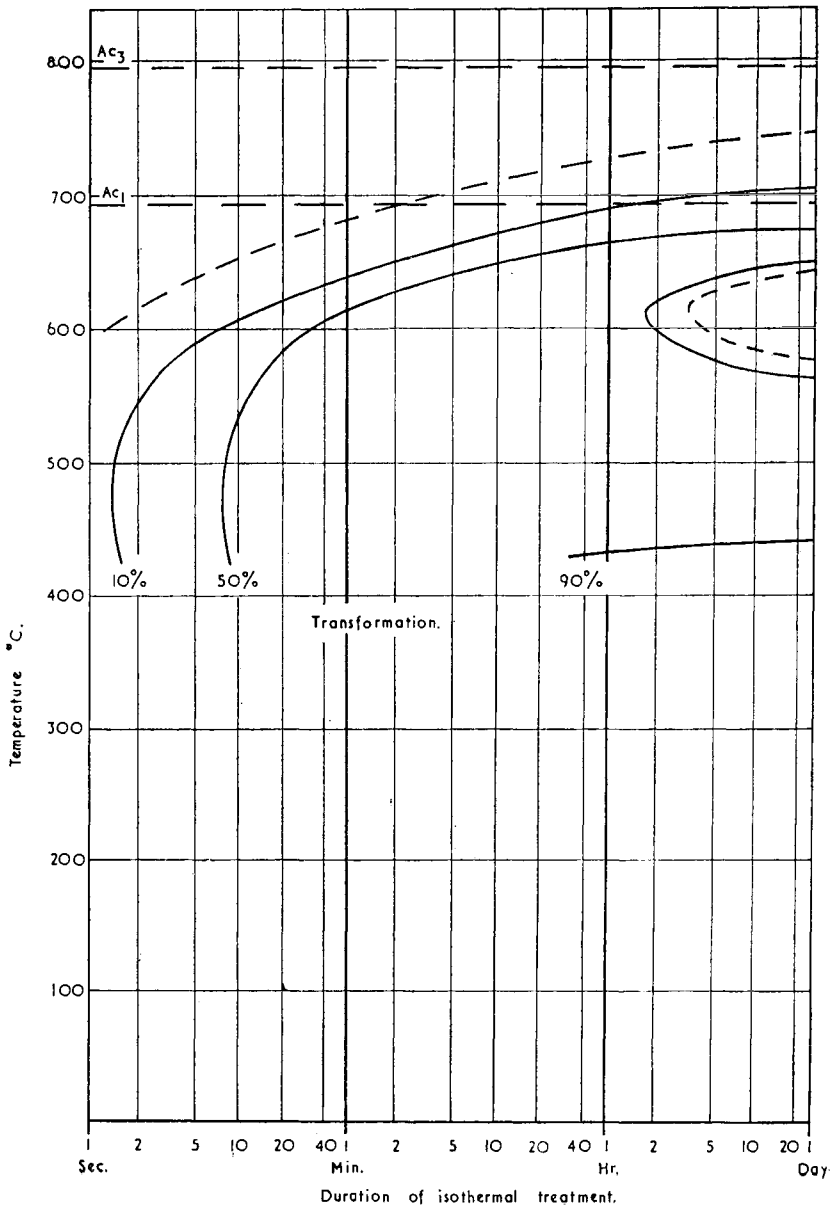


Fig. 36.1

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·11	0·13	0·38	0·016	0·023	3·26	0·87	0·08

High Frequency Melt.
McQuaid Ehn grain size 6—8 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool, then 865°C (1 hr.) oil quench.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

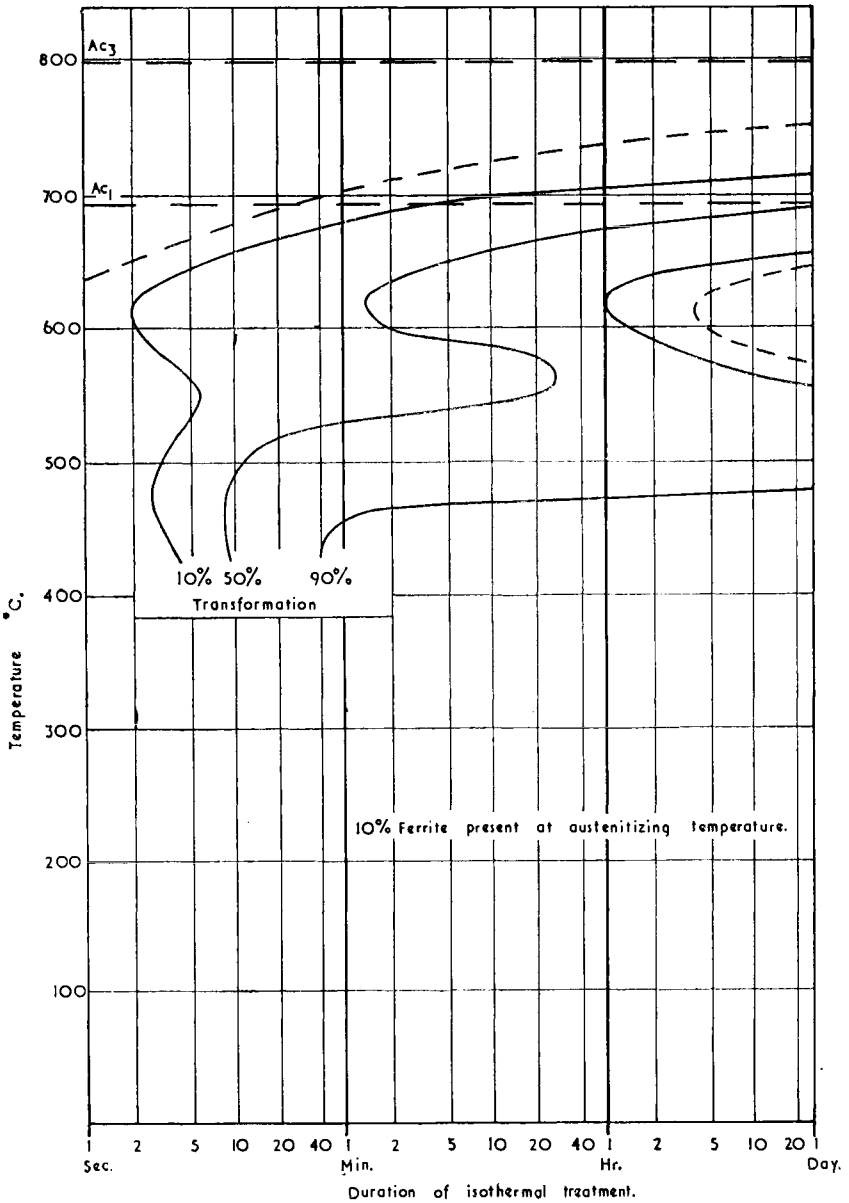


Fig. 36.2

En 36

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·14	0·19	0·46	0·009	0·006	3·55	1·11	0·12

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
As quenched grain size 6—7 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 860°C, 30 min. (Ref. 4)

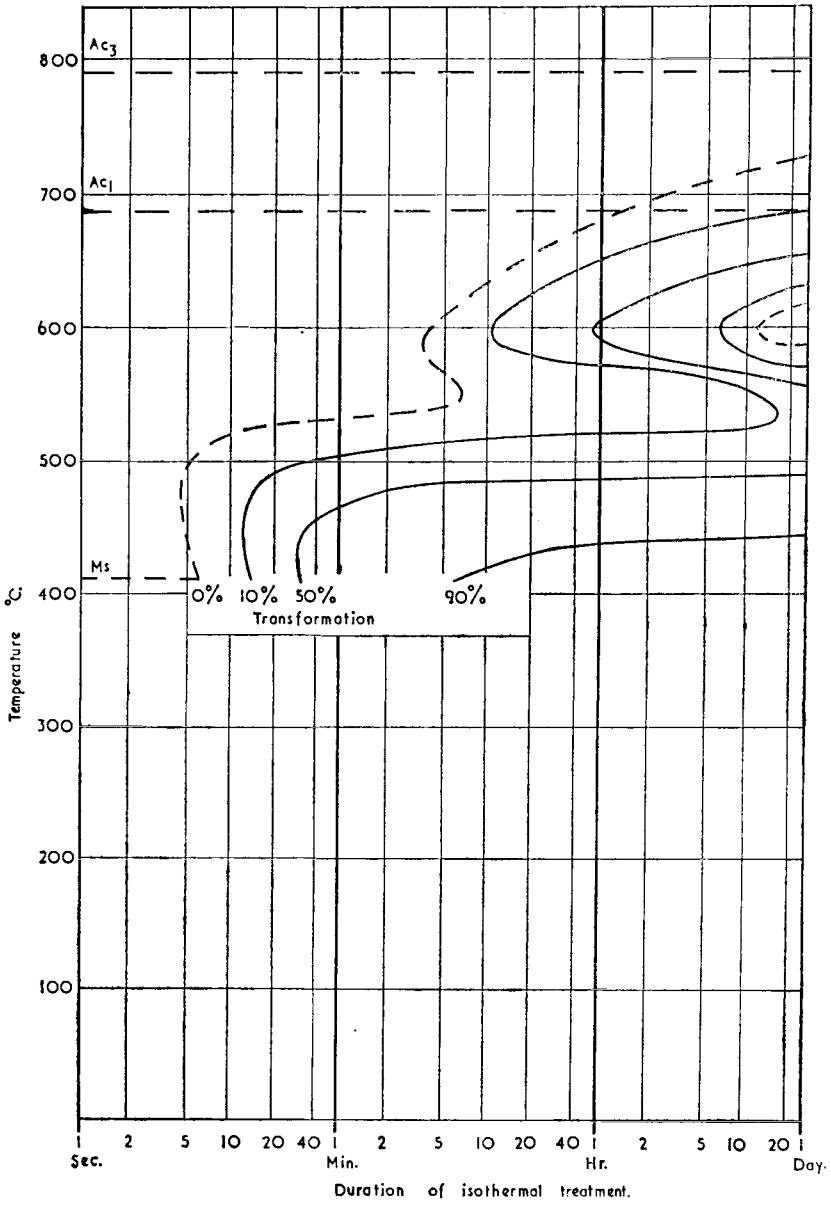


Fig. 36.3

ISOTHERMAL TRANSFORMATION (Continued)

CORE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·14	0·19	0·46	0·009	0·006	3·55	1·11	0·12

Basic Electric Arc.
McQuaid Ehn grain size4—5 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn ot 11 S.W.G. wire, followed by water quenching from 860°C (1 hr.) sealed in a 1 in. dia. steel tube.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

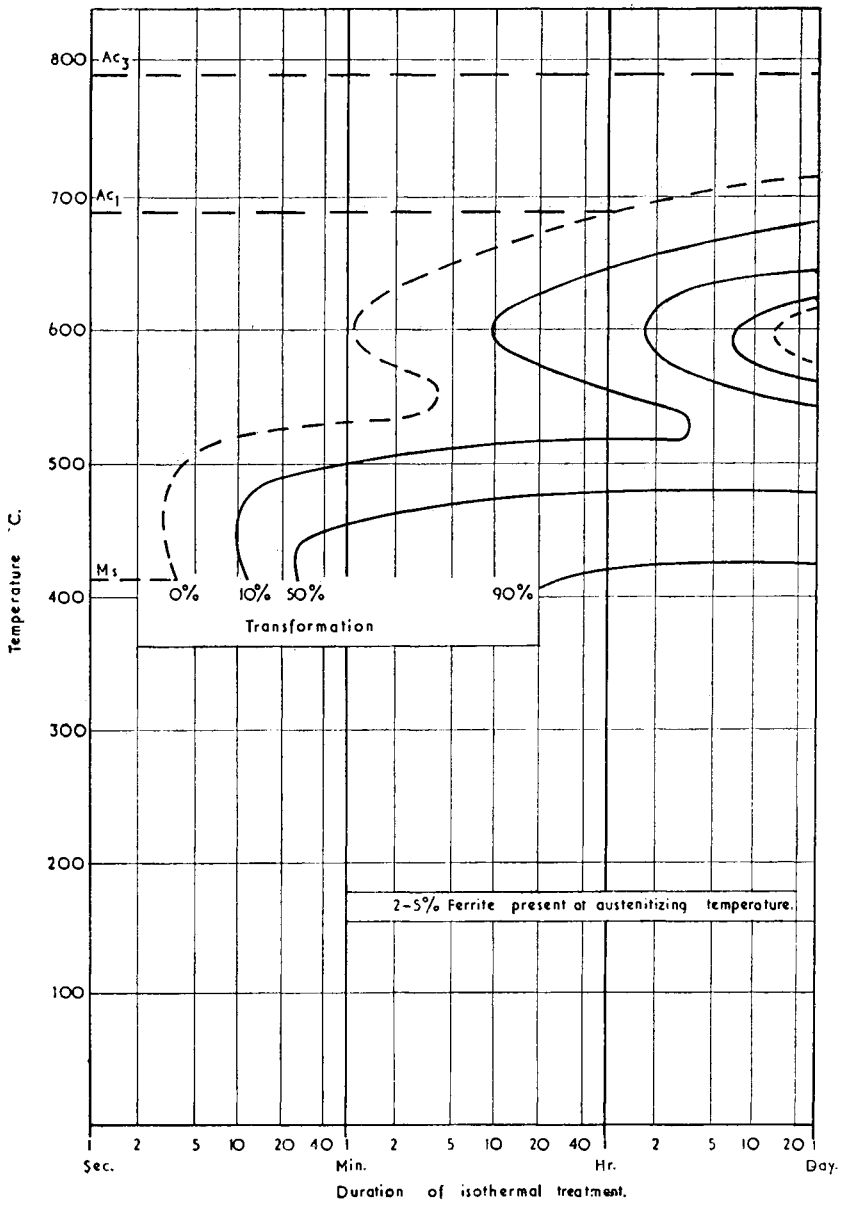


Fig.36.4

En 36

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·70	0·16	0·35	0·018	0·025	3·24	0·96	0·06

High Frequency Melt.
McQuaid Ehn grain size 7 (ASTM).
Actual grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 860°C, 30 min. (Ref. 4)

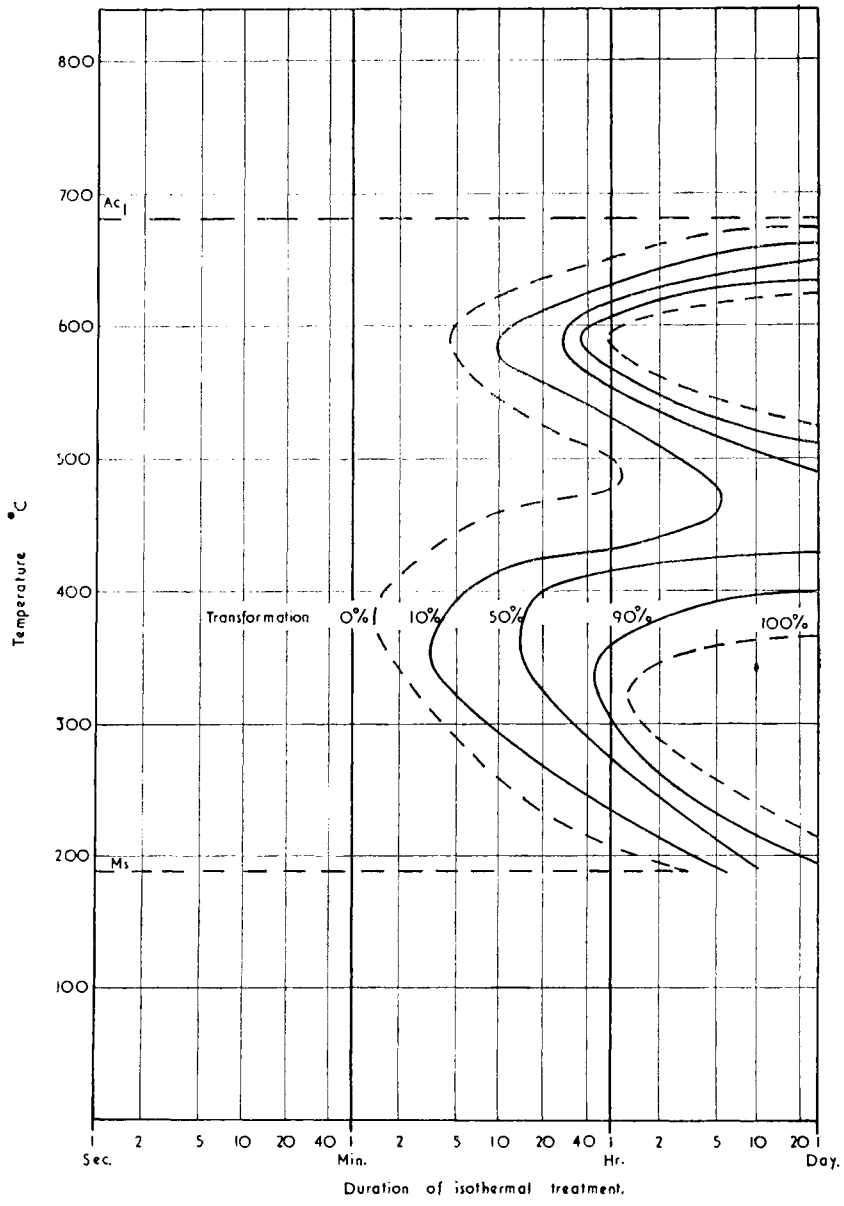


Fig. 36.5

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·70	0·16	0·35	0·018	0·025	3·24	0·96	0·06

High Frequency Melt.
McQuaid Ehn grain size 7 (ASTM).
Actual grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire followed by 900°C (2 hr.) furnace cool, then 865°C (½ hr.) oil quench.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

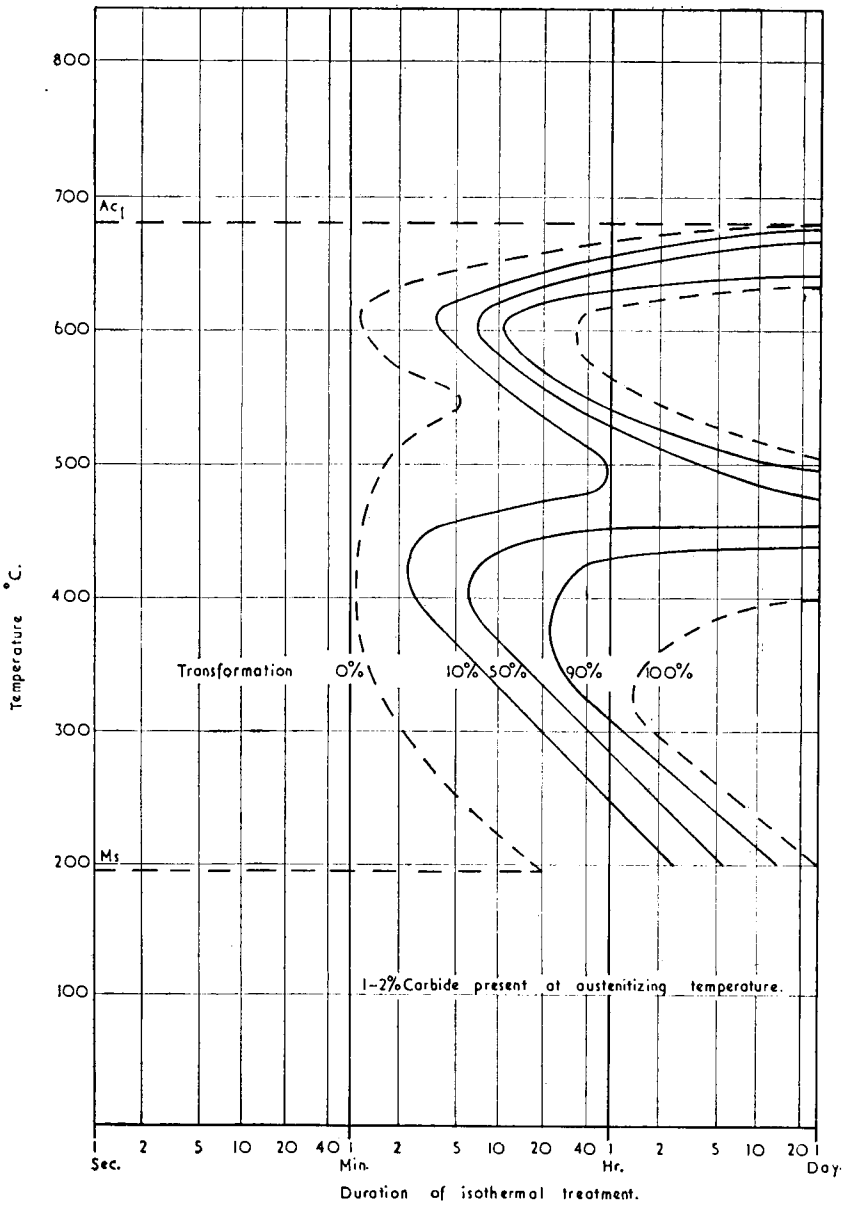


Fig. 36.6

En 36

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
1·00	0·12	0·30	0·016	0·028	3·27	0·90	0·07

High Frequency Melt.
McQuaid Ehn grain size 6—7 (ASTM).
Actual grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 860°C, 30 min. (Ref. 4)

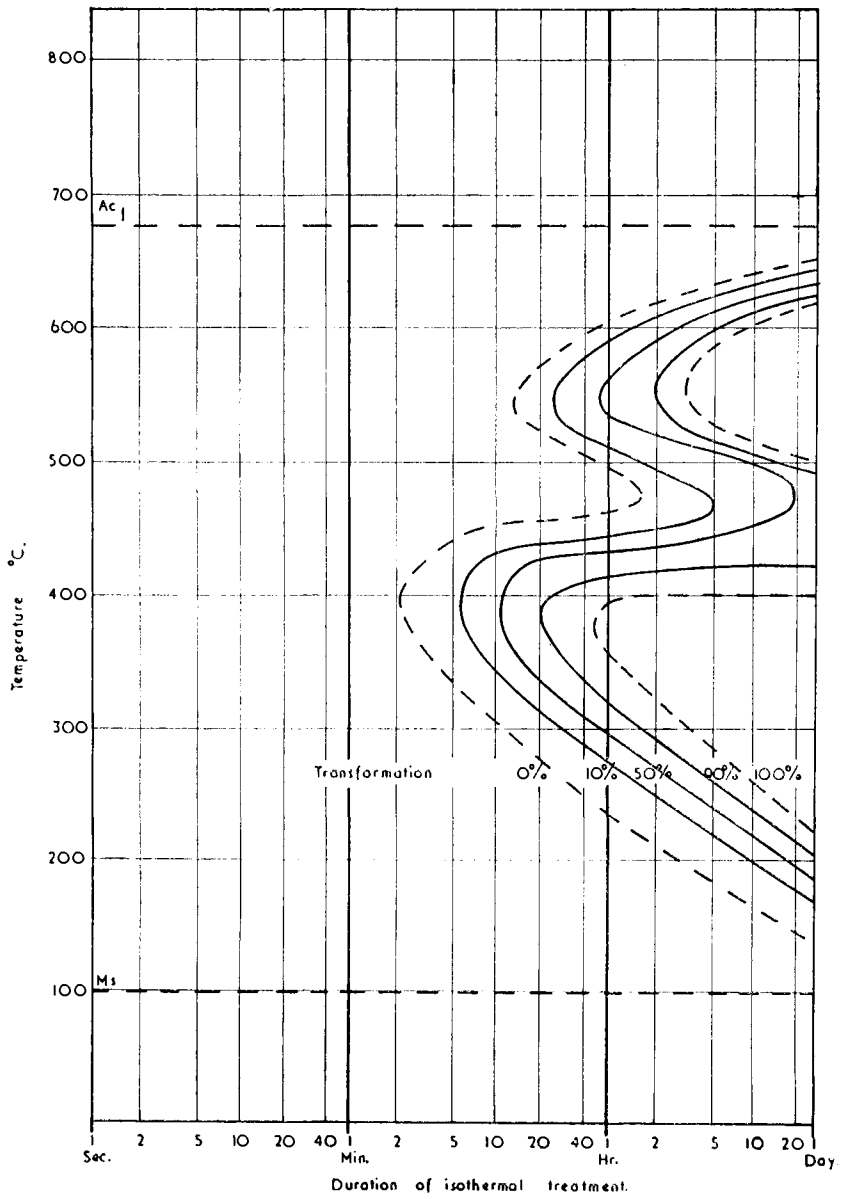


Fig. 36.7

ISOTHERMAL TRANSFORMATION (Continued)

CASE CHARACTERISTICS

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
1·00	0·12	0·30	0·016	0·028	3·27	0·90	0·07

High Frequency Melt.
McQuaid Ehn grain size 6—7 (ASTM).
Actual grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire followed by 900°C (2 hr.) furnace cool, then 865°C (½ hr.) oil quench.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

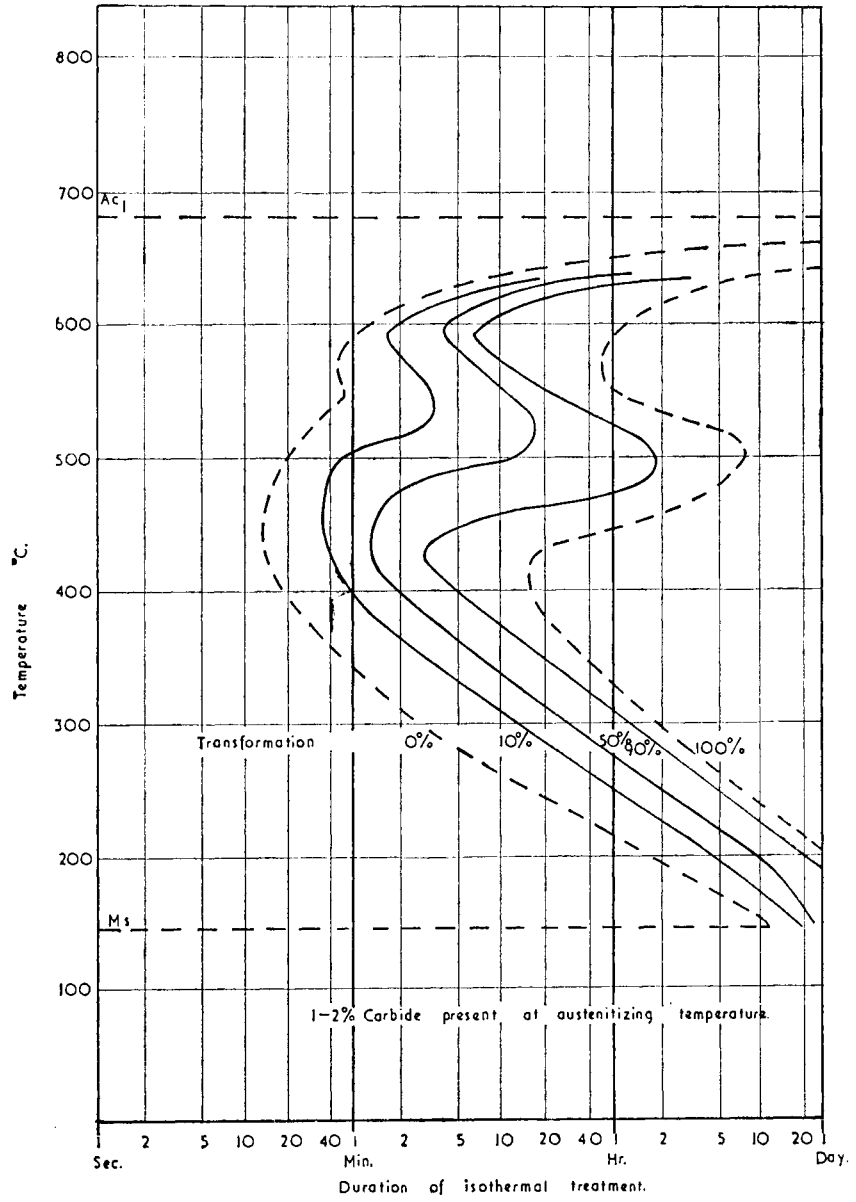


Fig. 36.8

HARDENABILITY

END QUENCH HARDENABILITY DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·14	0·19	0·46	0·009	0·006	3·55	1·11	0·12

Basic Electric Arc.
McQuaid Ehn grain size 4—5 (ASTM).
Actual grain size Finer than 8 (ASTM).
Curve A End Quenched from 860°C.
Curve B " " " 770°C.

(Ref. 4)

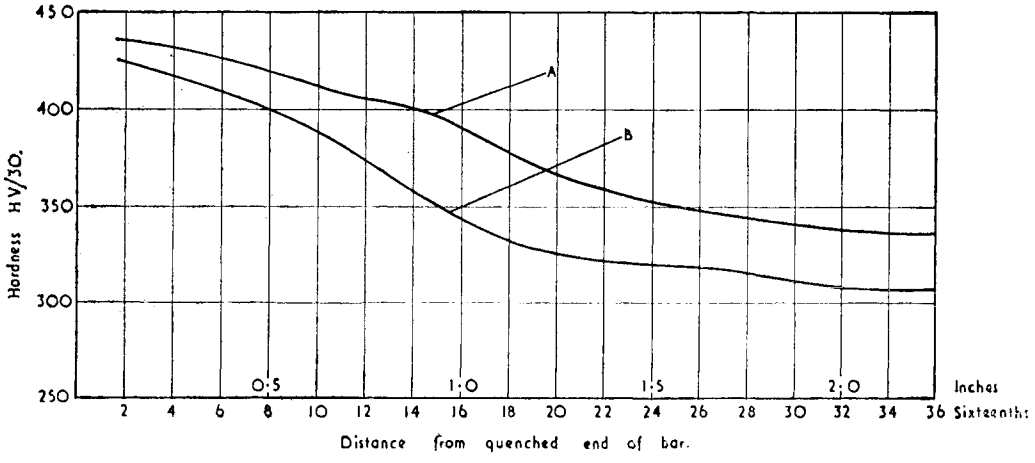


Fig. 36.9

END QUENCH HARDENABILITY DATA (Continued)

Curve No.	Chemical Composition (%)								Bar dia. (in.)	Grain Size ASTM		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid Ehn	
C	0·14	0·20	0·37	0·020	0·018	3·40	0·94	0·10	1 3/8	7—8(9)	2—4 (5—6)	5
D	0·13	0·21	0·42	0·032	0·031	3·06	1·01	0·31	1 3/8	7—8(9)	7—8	"
E	0·15	0·10	0·49	0·015	0·020	3·25	1·22	0·05	1 3/8	6—7(8)	7(6)	"
F	0·15	0·24	0·57	0·010	0·016	3·44	1·00	0·04	1 1/8	7	6—7	"

Test Bars Normalized 875°C. End Quenched 825°C. (Ref. 5)

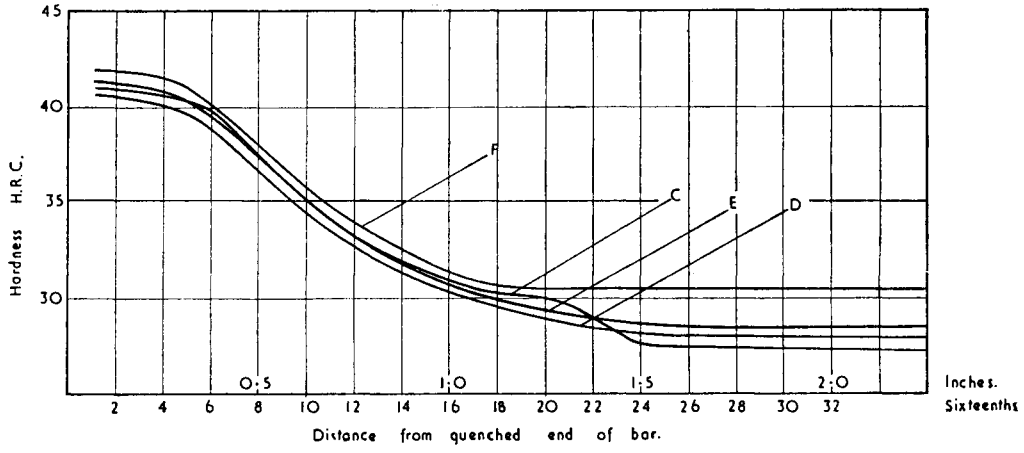


Fig. 36.10

End Quenched from 825°C. Re-quenched 770°C. (Ref. 5)

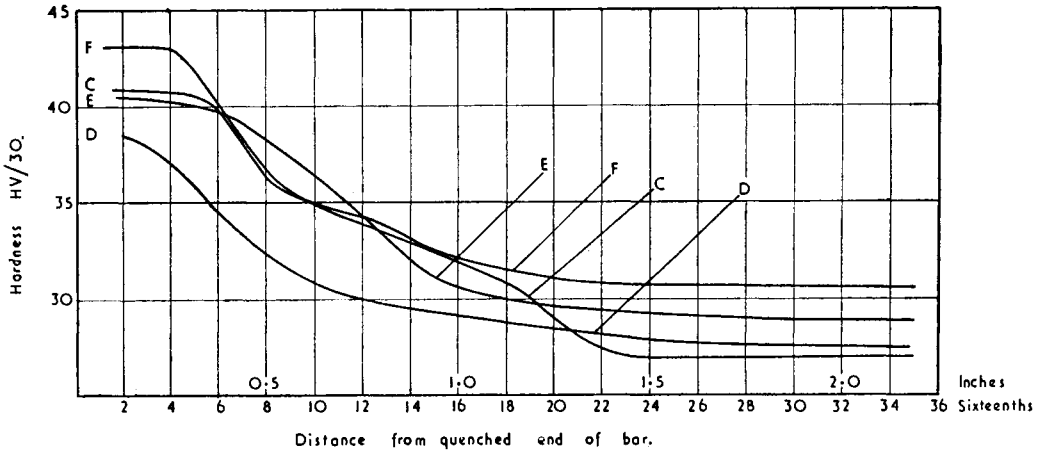


Fig. 36.11

En 36

END QUENCH HARDENABILITY BAND

This band has been compiled from a large number of results from casts meeting the physical property requirements of En 36.

(Ref. 2)

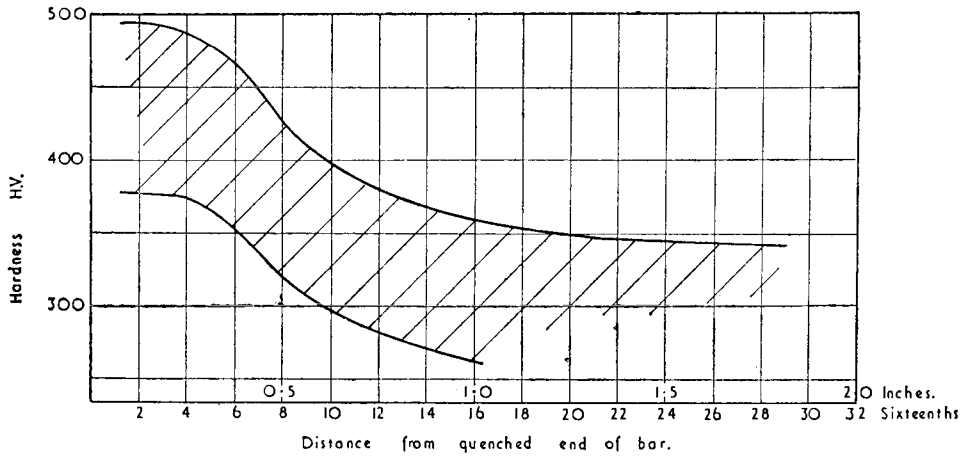


Fig. 36.12

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
											tons/sq.in.									
	0·08		0·45			3·13	1·03		0·57	OQ800					68·0	73·2	16½	57	41	3
	"		"			"	"		1⅛	OQ870 OQ780					56·8	63·2	19½	57	53	"
7	0·08		0·48			3·27	0·79		½	920 4hr. FC OQ760					49·7	60·4	21½	58	52	"
"	"		"			"	"		"	" OQ780					58·5	66·1	20	58	50	"
"	"		"			"	"		"	" OQ800					61·7	66·3	20	61	49	"
"	"		"			"	"		⅞	" OQ760					43·8	54·1	23	55	59	"
"	"		"			"	"		"	" OQ780					44·6	55·2	24½	57	62	"
"	"		"			"	"		"	" OQ800					52·8	58·1	23	59	63	"
"	"		"			"	"		1⅛	" OQ760					36·8	53·2	23½	55	59	"
"	"		"			"	"		"	" OQ780					46·3	55·8	25	57	60	"
"	"		"			"	"		"	" OQ800					46·9	56·0	23	59	63	"
"	"		"			"	"		2	" OQ760					38·9	49·0	25½	55	68	"
"	"		"			"	"		"	" OQ780					38·8	50·3	25	57	69	"
"	"		"			"	"		"	" OQ800					41·1	50·0	25	59	72	"
3	0·10		0·49			3·10	0·78		⅝	N870 T600	28·1	28·4			29·6	38·4	34½	73	90	3
6—3	0·10	0·22	0·42	0·010	0·012	3·26	0·89	0·09	1⅛	OQ700	26·5	29·5	33·0	39·0		53·5	24	57	78	2
"	"	"	"	"	"	"	"	"	"	OQ720	26·0	29·5	34·0	40·5		58·5	26	57½	70	"
"	"	"	"	"	"	"	"	"	"	OQ740	27·5	30·4	34·1	41·1		57·9	26	60½	86	"
"	"	"	"	"	"	"	"	"	"	OQ760	33·9	37·9	43·2	49·9		60·5	22½	64½	85	"
"	"	"	"	"	"	"	"	"	"	OQ780	30·0	35·8	41·9	51·4		61·3	22	63½	82	"
"	"	"	"	"	"	"	"	"	"	OQ800	29·3	34·8	41·3	49·8		60·3	22	64½	85	"
"	"	"	"	"	"	"	"	"	"	OQ820	32·5	38·0	44·5	54·0		61·6	22	64½	87	"
"	"	"	"	"	"	"	"	"	"	OQ840	32·5	38·0	44·5	53·6		62·0	20½	62½	81	"
"	"	"	"	"	"	"	"	"	0·424	OQ860 OQ760	32·2	39·4	47·3	60·6		71·8	19	62	59	"
"	"	"	"	"	"	"	"	"	¾	" "	33·6	39·0	45·6	54·0		67·1	21	60	74	"
"	"	"	"	"	"	"	"	"	1	" "	30·4	36·1	42·5	50·5		62·3	20	61½	88	"
"	"	"	"	"	"	"	"	"	1⅛	" "	29·0	35·6	42·0	51·5		61·5	22	62½	82	"
"	"	"	"	"	"	"	"	"	2⅛	" "	26·2	31·1	37·1	44·8		55·0	24½	63	102	"
"	"	"	"	"	"	"	"	"	3	" "	25·5	28·2	31·8	36·5		51·5	29	66	115	"
"	"	"	"	"	"	"	"	"	4 (O)	" "	26·7	28·6	30·8	34·0		50·6	29½	67	111	"
"	"	"	"	"	"	"	"	"	" (C)	" "	23·9	26·6	29·5	33·7		50·0	29½	66	113	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El %	R.A. %		
												tons/sq.in.									
	6—3	0·10	0·22	0·42	0·010	0·012	3·26	0·89	0·09	0·424	OQ860 OQ780	39·2	46·4	57·9	70·9		75·1	20	64	66	2
		"	"	"	"	"	"	"	"	¾	" "	39·5	45·6	52·0	60·6		66·9	20	61½	81	"
		"	"	"	"	"	"	"	"	1	" "	30·5	36·3	42·2	49·9		62·4	23½	64	91	"
		"	"	"	"	"	"	"	"	1⅛	" "	30·0	35·8	41·9	51·4		61·3	22	63½	82	"
		"	"	"	"	"	"	"	"	2⅛	" "	26·1	30·1	35·7	42·5		55·3	25	64	91	"
		"	"	"	"	"	"	"	"	3	" "	27·9	31·3	34·9	40·2		54·3	25	62	107	"
		"	"	"	"	"	"	"	"	4 (O)	" "	26·8	29·9	33·5	38·2		52·7	26	64½	106	"
		"	"	"	"	"	"	"	"	" (C)	" "	28·8	31·6	34·7	39·4		54·6	25	61	107	"
		"	"	"	"	"	"	"	"	0·424	OQ820	43·8	55·1	63·9	74·4		75·3	18	62½	67	"
		"	"	"	"	"	"	"	"	¾	"	34·6	41·5	48·8	57·8		69·6	19	61	72	"
		"	"	"	"	"	"	"	"	1	"	30·5	36·6	43·4	51·9		61·6	20	63	84	"
		"	"	"	"	"	"	"	"	1⅛	"	31·5	36·5	43·5	52·0		62·7	21	61½	81	"
		"	"	"	"	"	"	"	"	2⅛	"	28·0	32·5	38·0	45·3		54·7	23	67½	104	"
		"	"	"	"	"	"	"	"	3	"	29·9	32·0	36·5	41·5		54·2	25½	63½	107	"
		"	"	"	"	"	"	"	"	4 (O)	"	29·0	32·4	35·8	40·2		51·5	25	67	111	"
		"	"	"	"	"	"	"	"	" (C)	"	28·7	32·0	35·6	40·5		53·6	28	64	100	"
		"	"	"	"	"	"	"	"	0·424	N900	31·5	35·9	40·3	46·0		51·6	17	62½	94	"
		"	"	"	"	"	"	"	"	¾	"	23·0	28·0	32·5	38·5		52·8	24	59½	84	"
		"	"	"	"	"	"	"	"	1	"	24·0	28·5	33·0	38·6		51·9	27	59	79	"
		"	"	"	"	"	"	"	"	1⅛	"	25·2	29·5	33·5	39·0		52·0	25	61	72	"
		"	"	"	"	"	"	"	"	2⅛	"	25·1	29·1	33·5	39·3		50·6	24	60½	61	"
		"	"	"	"	"	"	"	"	3	"	25·8	28·6	32·5	37·1		50·2	24½	59½	74	"
		"	"	"	"	"	"	"	"	4(O)	"	23·1	27·5	31·4	36·5		49·4	26	58½	63	"
		"	"	"	"	"	"	"	"	"(C)	"	23·4	27·4	31·1	37·2		48·4	25	59½	73	"
B.E.A.		0·10	0·27	0·54			3·32	1·05		1⅛	OQ870 OQ770					57·2	66·4	21	64	85	1
B.E.A.		0·10		0·50			3·30	1·01	0·12	1⅛	OQ870 OQ770						63·5	20	60½	72	"
		0·10	0·15	0·58			3·14	0·95	—	1¼	OQ870 OQ770					51·0	59·4	21	57	84	"
B.E.A.		0·10		0·45			3·10	0·94		⅞	OQ860 OQ770					50·5	57·6	22		57	6
		"		"			"	"		1⅛	" "					48·5	56·2	23		57	"
		"		"			"	"		2	" "					44·3	52·3	24½		63	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
	0·11	0·15	0·43			3·15	0·93	0·10	1	BC900 OQ860 OQ780		61·0	23	63	80	2
	0·11	0·23	0·45			3·35	0·87	0·10	1	" " "		62·0	21	54	61	"
B.E.A.	0·11	0·19	0·49			3·36	1·04		½	OQ870 OQ770	68·0	82·0	18	63	84	1
"	"	"	"			"	"		⅞	" "	64·0	77·5	19	65	82	"
"	"	"	"			"	"		1	" "	40·0	66·8	26	59	88	"
"	"	"	"			"	"		2	" "	35·6	56·4	27	58	87	"
"	"	"	"			"	"		4	" "	40·8	57·6	24	60	78	"
A.O.H.	0·11	0·24	0·40			3·23	0·87		½	" "	76·7	81·6	17	57	42	"
"	"	"	"			"	"		⅞	" "	61·2	74·0	18	57	47	"
"	"	"	"			"	"		1	" "	62·2	72·0	19	57	53	"
"	"	"	"			"	"		2	" "	43·5	58·4	23	58	65	"
"	"	"	"			"	"		4	" "	38·4	54·4	24	54	56	"
B.E.A.	0·11	0·13	0·51			3·15	0·64		1	OQ870 OQ770	60·4	65·0	21	59	57	"
	0·11	0·21	0·29			3·34	0·81		3	OQ870 OQ770	41·4	49·4	27	59	100	"
	0·11					3·22	0·90	0·16	1	" "		68·0	18½		61	"
	0·12	0·27	0·40			3·38	0·92	0·15	1	BC900 OQ860 OQ780		65·0	23	59	63	2
	0·12	0·24	0·48			3·09	0·83		1	OQ870 OQ770	54·8	66·4	21	60	79	1
	0·12	0·15	0·41			3·13	0·81		1	" "		63·0	21	54	84	1
B.E.A.	0·12	0·18	0·49	0·027	0·027	3·18	1·13		1	BC OQ860 OQ760		70·0	17	45	47	7
"	"	"	"	"	"	"	"		"	" " OQ780		76·0	14	45	44	"
"	"	"	"	"	"	"	"		2	" " OQ760		66·8	16	45	37	"
"	"	"	"	"	"	"	"		"	" " OQ780		69·2	17	42	38	"
	0·12					3·28	0·93	0·15	1	OQ870 OQ770		68·0	18½		61	1
	0·12		0·35			3·45	0·80		1	OQ830 OQ770	48·2	60·5	19		50	6
	0·13	0·28	0·45			3·28	0·86	0·10	1	BC900 OQ860 OQ780		64·0	21	59	90	2
	0·13	0·26	0·42			3·31	0·97	0·07	"	" " "		64·0	22	59	80	"
	0·13	0·27	0·45			3·39	0·89	0·12	"	" " "		68·0	21	59	71	"
	0·13	0·25	0·45			3·49	0·96		1	OQ870 OQ770	69·2	73·6	15	56	70	1
	0·13	0·20	0·36			3·26	0·92		"	" "	56·8	68·0	23½	61	70	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·5% P.S.	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.			$4\sqrt{A}$ 5·65	$\sqrt{A}$		
B.E.A.		0·13	0·30	0·43	0·021	0·025	3·28	0·99		3	BCOQ860 OQ760			65·2	20	33½	32	7
"		"	"	"	"	"	"	"		"	" " OQ780			65·2	19	50	37	"
		0·13	0·21	0·36			3·29	0·81		1⅛	OQ870 OQ770		55·0	62·6	20	57	75	1
		0·13		0·56			3·20	1·05		⅞	OQ860 OQ770		73·4	76·4	17½		48	6
		"		"			"			1⅛	" "		63·8	71·3	18½		54	"
		"		"			"			2	" "		55·8	638	21½		67	"
		0·13	0·24	0·56	0·026	0·023	3·15	0·82	0·12	1⅛	BC925 OQ870 OQ770	51·2		645	21·5 18	60		1
	3—4	0·13		0·50			3·48	0·94		½	BC920 OQ840 OQ800		85·8	906	15½	53	32	3
	"	"		"			"	"		"	" OQ800		78·0	894	16	53	34	"
	"	"		"			"	"		⅞	" OQ840 OQ800		80·4	876	16	52	33	"
	"	"		"			"	"		"	" OQ800		81·9	898	15½	52	32	"
	"	"		"			"	"		1⅛	" OQ840 OQ800		75·6	846	16½	52	34	"
	"	"		"			"	"		"	" OQ800		79·8	848	16	50	31	"
	"	"		"			"	"		2	" OQ840 OQ800		67·2	71·5	18	55	46	"
	"	"		"			"	"		"	" OQ800		60·8	70·0	19½	55	43	"
		0·13		0·54			3·12	0·88		1⅛	OQ760		64·7	67·7	12½	34	41	"
		"		"			"	"		"	OQ780		62·6	67·8	14½	39	46	"
		"		"			"	"		"	OQ800		61·7	690	14	39	44	"
		0·14		0·37			3·15	0·86	0·04	1⅛	OQ870 OQ770			63·5	20	60½	72	1
		0·14	0·15	0·35			3·25	0·82		3	OQ870 OQ770		48·0	54·4	23½	58	94	"
		0·14	0·21	0·51			3·15	1·01		1⅛	OQ830 OQ770		78·4	81·8	16	55	40	"
		0·14	0·24	0·50			3·12	0·94		"	" "			66·6	20	58	67	"
B.E.A.		0·14		0·36			3·12	0·92	0·13	1⅛	OQ830 OQ770			70·0	17	57	43	"
B.E.A.		0·14		0·33			3·20	1·00	0·10	"	" "			72·5	17	57	36	"
B.E.A.		0·14	0·27	0·37	0·020	0·018	3·28	0·94	0·10	1⅛	BC900 OQ880 OQ780			67·2	18	50	60	7
"		"	"	"	"	"	"	"	"	"	" " 760			63·2	22	52½	62	"
"		0·14	0·24	0·48	0·022	0·016	3·28	0·73		1⅛	BC900 WQ870 OQ770		49·6	65·6	21		38	8

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.	2—4	0·14	0·21	0·42	0·017	0·015	3·27	0·86	0·18	1⅛	N900 OQ700	25·0	28·6	33·8	41·5	54·5	20	49	41	2
"	"	"	"	"	"	"	"	"	"	"	" OQ720	27·5	32·0	38·0	48·1	62·7	28½	52	58	"
"	"	"	"	"	"	"	"	"	"	"	" OQ740	27·5	31·6	38·0	48·4	60·1	22½	57½	69	"
"	"	"	"	"	"	"	"	"	"	"	" OQ760	31·0	38·5	46·7	58·0	68·7	19½	58	58	"
"	"	"	"	"	"	"	"	"	"	"	" OQ780	35·0	41·2	49·1	59·1	70·6	17	58	53	"
"	"	"	"	"	"	"	"	"	"	"	" OQ800	35·4	42·5	56·9	61·1	72·3	17½	60½	50	"
"	"	"	"	"	"	"	"	"	"	"	" OQ820	37·4	45·0	52·5	62·6	74·0	18	59½	52	"
"	"	"	"	"	"	"	"	"	"	"	" OQ840	36·0	44·0	51·6	62·5	74·1	18	59	51	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ760	41·8	49·0	57·8	70·7	82·3	20	59½	41	"
"	"	"	"	"	"	"	"	"	"	¾	" " "	31·5	48·0	56·0	66·8	79·6	17	57½	44	"
"	"	"	"	"	"	"	"	"	"	1	" " "	35·1	42·4	50·3	60·3	73·0	20	60	52	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	35·5	42·3	49·8	60·0	72·0	18	59	63	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " "	32·2	42·7	52·9	60·7	62·6	20	64	69	"
"	"	"	"	"	"	"	"	"	"	3	" " "	30·6	35·3	40·4	48·1	61·0	21½	59½	77	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " "	30·0	34·6	39·8	46·6	59·9	22½	59	67	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " "	27·0	31·1	36·3	43·6	54·4	23	57½	65	"
"	"	"	"	"	"	"	"	"	"	0·424	" " OQ780	42·0	48·5	56·7	70·9	82·3	20	66½	48	"
"	"	"	"	"	"	"	"	"	"	¾	" " "	39·5	47·0	55·8	67·5	80·6	17	59	46	"
"	"	"	"	"	"	"	"	"	"	1	" " "	38·4	45·1	52·7	62·9	75·6	18	59½	57	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	30·8	42·1	50·0	60·0	72·2	19	59	66	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " "	32·0	37·9	44·1	54·2	62·7	19	63	67	"
"	"	"	"	"	"	"	"	"	"	3	" " "	30·0	34·3	41·0	50·4	59·7	22½	61	72	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " "	30·1	35·1	40·1	46·2	59·7	24	58½	67	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " "	29·2	33·6	39·2	47·7	61·7	21½	57½	55	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ820	41·1	49·9	60·7	73·7	82·1	16	58	46	2
"	"	"	"	"	"	"	"	"	"	¾	" "	35·3	44·6	54·4	68·6	79·6	19	58	41	"
"	"	"	"	"	"	"	"	"	"	1	" "	35·0	42·9	51·6	62·9	76·0	17	59	51	"
"	"	"	"	"	"	"	"	"	"	1⅛	" "	37·3	44·0	51·5	61·8	73·3	16	50	51	"
"	"	"	"	"	"	"	"	"	"	2⅛	" "	31·3	37·5	44·7	53·4	63·3	19	63	62	"
"	"	"	"	"	"	"	"	"	"	3	" "	29·7	35·0	41·6	50·5	60·8	21½	60	56	"
"	"	"	"	"	"	"	"	"	"	4(C)	" "	33·2	38·5	45·6	54·3	60·4	21½	62	49	"
"	"	"	"	"	"	"	"	"	"	"(O)	" "	26·8	31·9	38·9	47·5	60·7	21½	55½	44	"
"	"	"	"	"	"	"	"	"	"	0·424	N900	31·5	36·2	42·2	49·0	56·0	22½	59½	59	"
"	"	"	"	"	"	"	"	"	"	¾	"	26·4	31·9	38·3	47·5	57·9	22	55½	34	"
"	"	"	"	"	"	"	"	"	"	1	"	27·0	32·1	37·6	44·6	56·6	21	55½	33	"
"	"	"	"	"	"	"	"	"	"	1⅛	"	28·2	33·0	38·5	45·6	55·9	22	57	31	"
"	"	"	"	"	"	"	"	"	"	2⅛	"	27·7	32·5	37·7	44·9	55·7	23	56½	32	"
"	"	"	"	"	"	"	"	"	"	3	"	27·2	35·4	36·4	42·6	54·9	21	56	30	"
"	"	"	"	"	"	"	"	"	"	4(O)	"	30·7	34·3	38·5	43·9	56·9	21½	53½	23	"
"	"	"	"	"	"	"	"	"	"	"(C)	"	29·3	33·2	37·3	43·6	56·1	22½	53	24	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp) tons/sq.in.	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
		0·15	0·14	0·43			3·20	0·89	0·15	1 1/8	BC OQ860 OQ780						77·0	18	54 1/2	39	2
		0·15	0·29	0·44			3·38	0·98	0·11	"	" " "						80·0	18	57	58	"
		0·15	0·22	0·41			3·44	0·86	0·15	"	" " "						80·0	17	54 1/2	42	"
		0·15	0·21	0·52			3·14	1·02		1 1/8						68·8	77·8	19	55	48	1
B.E.A.	McQuaid Ehn. Actual 6—7(8) 7(6)	0·15	0·10	0·49	0·015	0·020	3·25	1·22	0·05	1	N875 OQ825 T150					69·0	77·9	16 1/2	63 1/2	52	4
		0·15		0·58			3·23	1·00		1 1/8	OQ780					52·0	72·0	19		69	6
		0·16	0·28	0·50			3·45	1·08		1 1/8	OQ870 OQ770					74·8	81·6	17	59	66	1
		0·16	0·18	0·54			3·15	0·99		1 1/8	OQ870 OQ770						85·2	18	52	32	"
		0·16	0·38				3·28	0·92		0·564	BC920 OQ840 OQ800					62·9	85·2	16	57	32	3
		"	"				"	"		"	" " T180					71·6	84·7	18	57	25	"
	4—6	0·16		0·38			2·98	0·91		1/2	BC920 OQ850 OQ760					55·7	68·2	22 1/2	53	33	3
	"	"		"			"	"		"	" OQ790					84·9	90·4	16	53	19	"
	"	"		"			"	"		3/8	" OQ850 OQ760					42·1	60·8	24	52	27	"
	"	"		"			"	"		"	" OQ790					80·4	84·0	15	47	13	"
	"	"		"			"	"		1 1/8	" OQ850 OQ760					44·6	60·1	25 1/2	55	48	"
	"	"		"			"	"		"	" OQ790					75·9	76·5	16	47	15	"
	"	"		"			"	"		2	" OQ850 OQ760					45·4	57·5	24 1/2	52	44	"
	"	"		"			"	"		"	" OQ790					61·4	66·2	18	50	18	"
A.O.H.	6—3	0·16	0·34	0·45	0·017	0·015	3·19	0·92	0·10	1 1/8	N900 OQ700	25·0	29·4	35·2	46·0		60·5	18	45 1/2	31	2
"	"	"	"	"	"	"	"	"	"	"	" OQ720	27·3	31·6	37·4	47·0		68·5	21	48	43	"
"	"	"	"	"	"	"	"	"	"	"	" OQ740	24·7	30·6	37·4	48·0		62·2	24 1/2	56 1/2	55	"
"	"	"	"	"	"	"	"	"	"	"	" OQ760	36·5	43·2	50·9	62·6		75·5	18	54	36	"
"	"	"	"	"	"	"	"	"	"	"	" OQ780	47·6	49·5	56·7	66·2		79·7	18 1/2	56	38	"
"	"	"	"	"	"	"	"	"	"	"	" OQ800	39·1	46·2	55·0	66·4		80·5	17	54	31	"
"	"	"	"	"	"	"	"	"	"	"	" OQ820	42·8	50·8	58·6	69·8		2·2	17	51	30	"
"	"	"	"	"	"	"	"	"	"	"	" OQ840	41·7	50·2	55·6	69·5		82·6	17 1/2	52	32	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ760	45·5	52·5	60·9	72·6		88·7	18	56	42	"
"	"	"	"	"	"	"	"	"	"	3/4	" " "	41·3	49·7	58·6	70·3		83·9	17 1/2	53	36	"
"	"	"	"	"	"	"	"	"	"	1	" " "	42·1	48·1	55·5	65·2		78·9	19	55 1/2	38	"
"	"	"	"	"	"	"	"	"	"	1 1/8	" " "	40·6	47·0	54·3	63·4		77·2	19	54	36	"
"	"	"	"	"	"	"	"	"	"	2 1/8	" " "	38·7	42·4	46·8	52·4		65·7	22 1/2	56	65	"
"	"	"	"	"	"	"	"	"	"	3	" " "	37·6	41·4	45·2	50·0		62·4	24	58	67	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " "	29·2	33·2	38·4	49·0		59·3	25	61	68	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " "	27·4	31·9	37·0	43·8		62·3	24	54	47	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ780	39·9	49·9	58·6	70·9		87·0	20	57	44	"
"	"	"	"	"	"	"	"	"	"	3/4	" " "	50·1	56·2	63·2	73·4		84·1	16	55	33	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
A.O.H.	6—3	0·16	0·34	0·45	0·017	0·015	3·19	0·92	0·10	1	N900 OQ860 OQ780	41·2	43·4	56·0	66·6		80·8	20	55½	38	2
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	42·6	49·5	56·7	66·2		79·7	18½	56	40	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " "	36·0	40·1	45·2	51·4		63·8	22	60½	63	"
"	"	"	"	"	"	"	"	"	"	3	" " "	34·5	38·1	42·3	48·1		62·8	24	56	70	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " "	30·9	34·8	39·0	44·4		59·5	26	60½	75	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " "	31·1	35·4	40·2	47·0		64·7	20	51½	56	"
"	"	"	"	"	"	"	"	"	"	0·424	N820 OQ820	44·6	52·3	60·4	71·9		87·5	19	56½	38	2
"	"	"	"	"	"	"	"	"	"	¾	" "	47·1	56·4	64·4	74·9		87·9	17½	51½	33	"
"	"	"	"	"	"	"	"	"	"	1	" "	47·0	54·0	61·3	70·4		82·7	18	53	33	"
"	"	"	"	"	"	"	"	"	"	1⅛	" "	42·8	50·8	58·6	69·8		82·2	17	51	30	"
"	"	"	"	"	"	"	"	"	"	2⅛	" "	33·5	39·8	46·5	54·4		66·7	21	53½	53	"
"	"	"	"	"	"	"	"	"	"	3	" "	32·2	37·4	43·0	50·4		63·3	20½	52½	63	"
"	"	"	"	"	"	"	"	"	"	4(O)	" "	30·5	35·0	39·9	46·2		59·1	23	59	68	"
"	"	"	"	"	"	"	"	"	"	"(C)	" "	32·3	36·7	42·2	49·7		64·9	22	53	51	"
"	"	"	"	"	"	"	"	"	"	0·424	N900	28·2	33·3	39·0	46·7		60·0	21	63½	42	"
"	"	"	"	"	"	"	"	"	"	¾	"	29·8	34·6	39·9	46·7		61·3	23	49½	35	"
"	"	"	"	"	"	"	"	"	"	1	"	29·6	34·4	39·2	45·4		60·4	21½	52	31	"
"	"	"	"	"	"	"	"	"	"	1⅛	"	30·1	35·1	40·0	46·0		61·4	21	50	31	"
"	"	"	"	"	"	"	"	"	"	2⅛	"	28·3	32·8	37·5	48·6		58·8	21	50½	31	"
"	"	"	"	"	"	"	"	"	"	3	"	29·9	34·1	38·6	44·4		58·9	22½	49½	39	"
"	"	"	"	"	"	"	"	"	"	4(O)	"	27·6	31·8	38·7	42·3		57·1	22½	50½	34	"
"	"	"	"	"	"	"	"	"	"	"(C)	"	28·5	32·6	37·1	43·5		58·5	21½	49	33	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·11	0·27	0·40	0·011	0·023	3·08	0·96	0·12

Basic Electric.
1¼ in. dia. bars.
Oil Quenched 830°C.
Tempered as indicated

(Ref. 7)

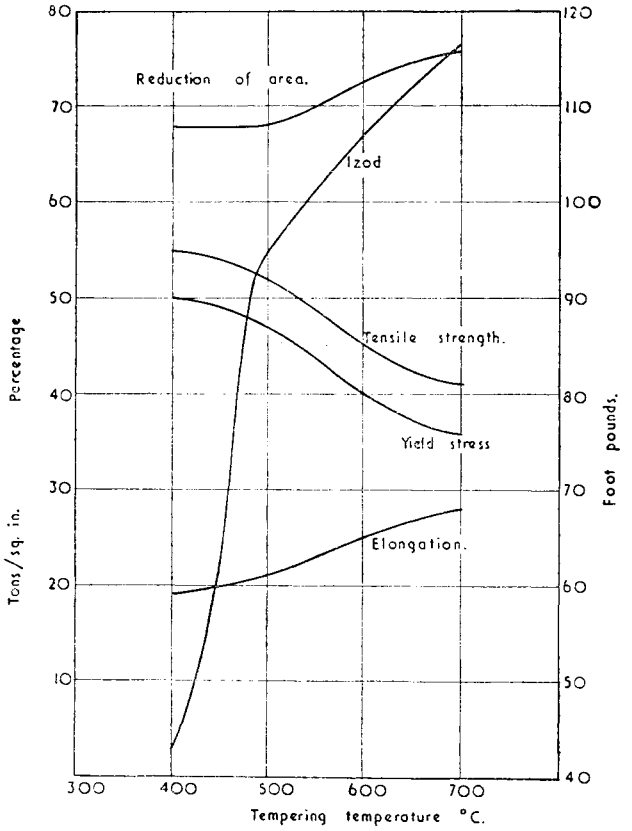


Fig. 36.13

EFFECT OF TEMPERING ON CASE HARDNESS (TYPICAL CURVE)

Bars Carburized 900°C. Refined 860°C. Oil Quench.
Hardened 760°C, Oil Quench.

(Ref. 2)

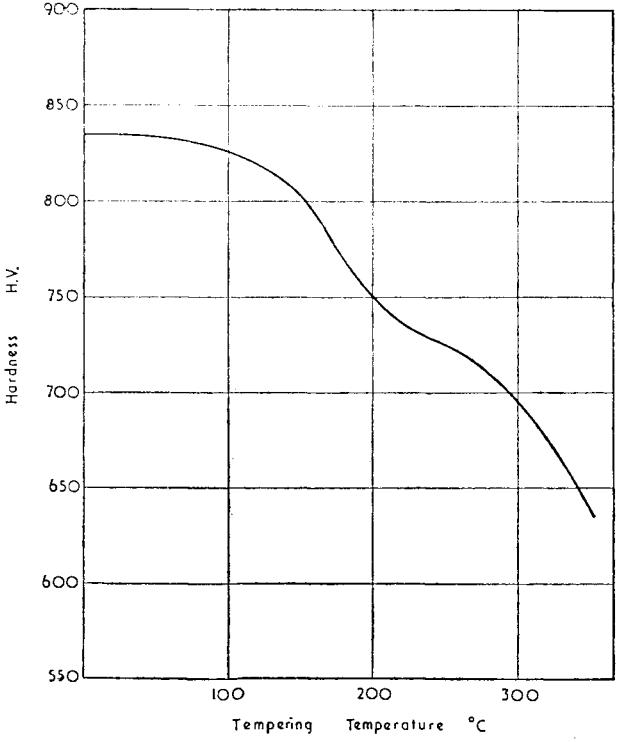


Fig. 36.14

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

En 36A

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·10	0·22	0·42	0·010	0·012	3·26	0·89	0·09

Basic Electric Arc.
McQuaid Ehn grain size 6—3 (ASTM).

Blank Carburize 900°C.
Refined 860°C. Hardened 760°C. Oil Quench.

(Ref. 2)

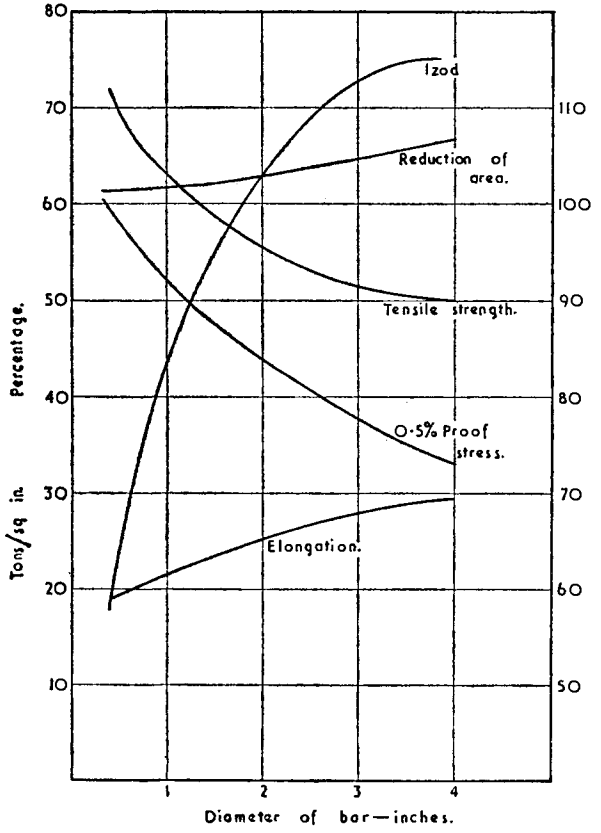


Fig. 36.15

Blank Carburize 900°C.
Refined 860°C. Oil Quench. Hardened 780°C.
Oil Quench.

(Ref. 2)

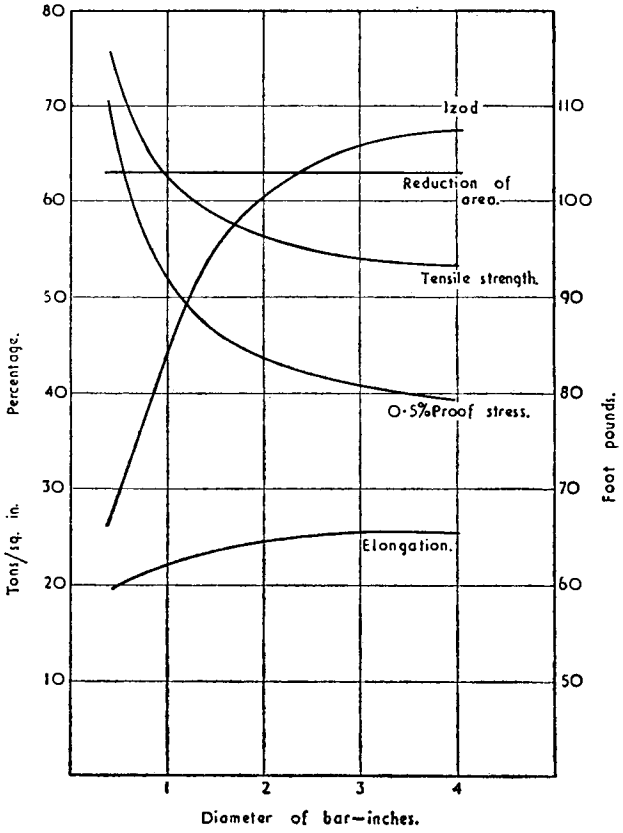


Fig. 36.16

Blank Carburize 900°C.
Hardened 820°C. Oil Quench (single quench).

(Ref.2)

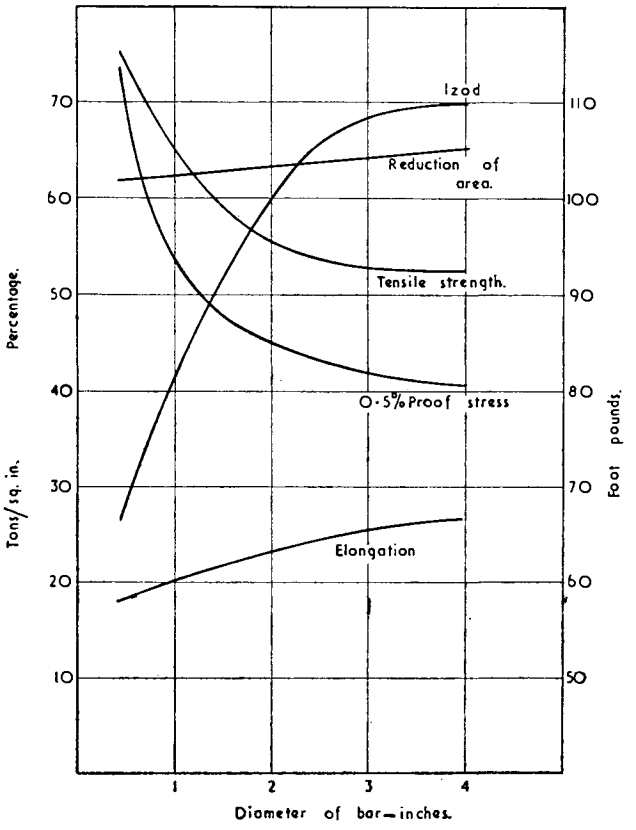


Fig. 36.17

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Chemical Composition (%)							
C	Si	Mn		P	Ni	Cr	Mo
0·16	0·34	0·45	0·017	0·015	3·19	0·92	0·10

Acid Open Hearth.

McQuaid Ehn grain size 6—3 (ASTM).

En 36

Blank Carburize 900°C.
Refine 860°C. Oil Quench. Harden 760°C. Oil Quench.

(Ref. 2)

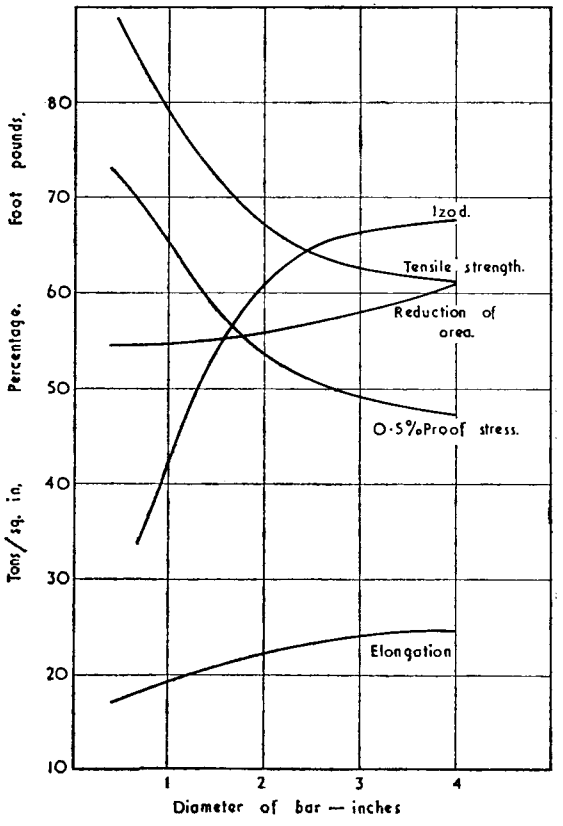


Fig. 36.18

Blank Carburize 900°C.
Refine 850°C. Oil Quench. Harden 780°C. Oil Quench.

(Ref. 2)

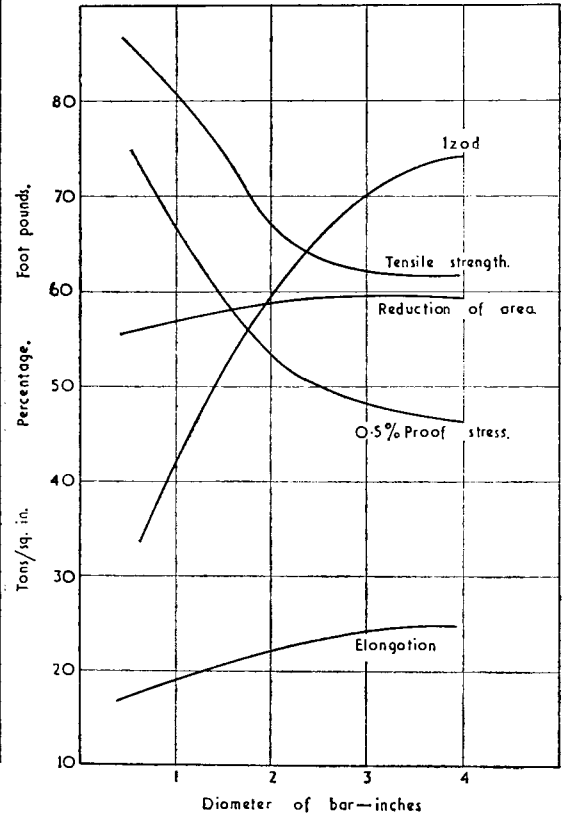


Fig. 36.19

Blank Carburize 900°C.
Harden 820°C. Oil Quench (single quench).

(Ref. 2)

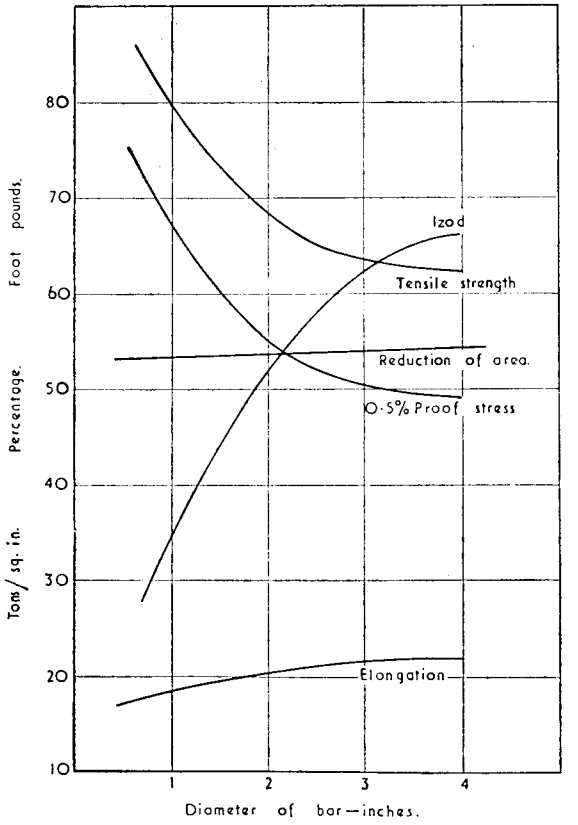


Fig. 36.20

EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

En 36C

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·14	0·21	0·42	0·017	0·015	3·27	0·86	0·18

Basic Electric Arc.

McQuaid Ehn grain size 2—4 (ASTM).

Blank Carburize 900°C.
Refine 860°C. Oil Quench. Harden 760°C. Oil Quench.

(Ref. 2)

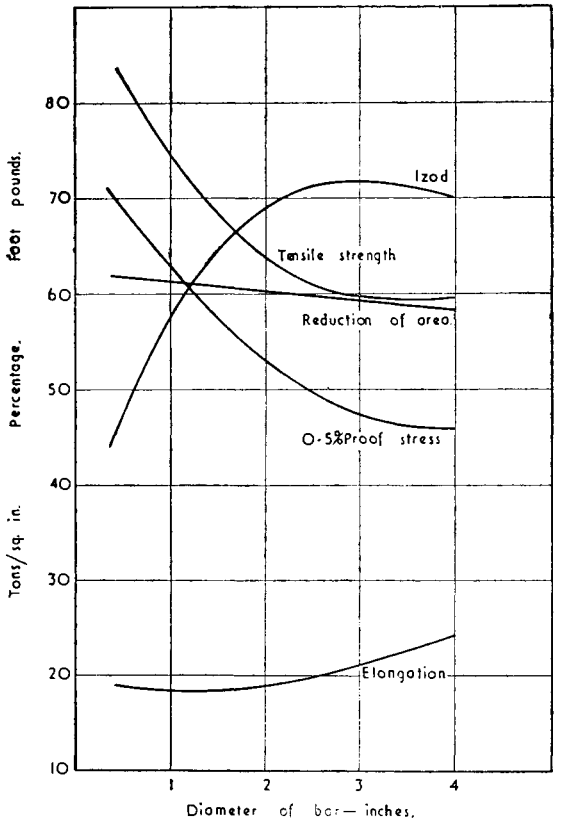


Fig. 36.21

Blank Carburize 900°C.
Refine 860°C. Oil Quench. Harden 780°C. Oil Quench.

(Ref. 2)

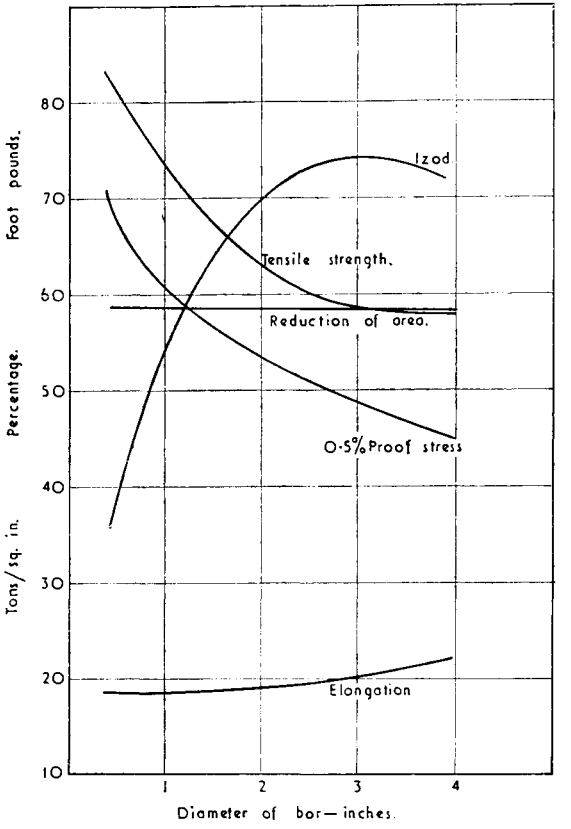


Fig. 36.22

Blank Carburize 900°C.
Harden 820°C. Oil Quench (single quench).

(Ref. 2)

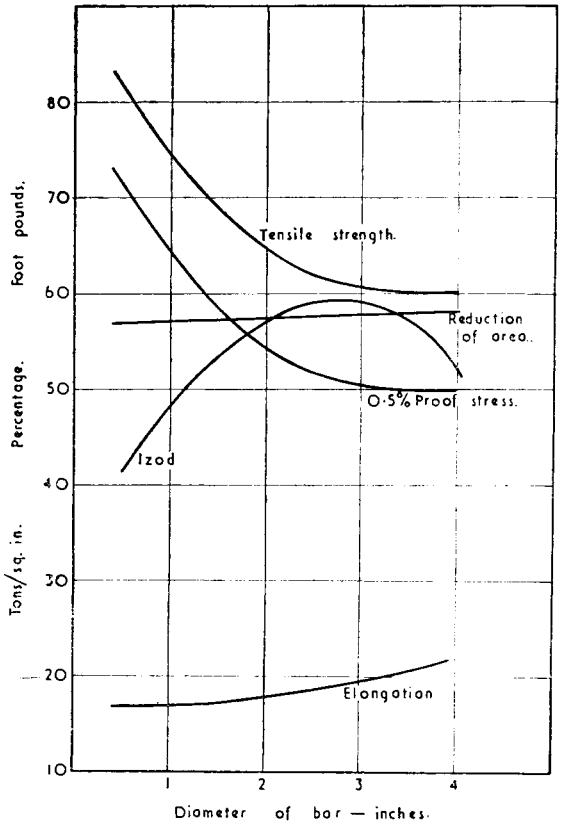


Fig. 36.23

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size As Quenched	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile						Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	
												tons/sq.in.						
7	0·13	0·17	0·43	0·017	0·017	3·36	0·90	0·07	$\frac{5}{8}$	OQ860 T525 OQ	20	55·9	56·3	57·3	59·9	25	69	6
"	"	"	"	"	"	"	"	"	"	" "	— 78	59·3	60·0	60·8	64·5	29	68	"
"	"	"	"	"	"	"	"	"	"	" "	—196	76·3	77·1	78·8	80·9	30	55	"
7—8	0·11	0·33	0·40	0·020	0·026	3·14	0·88	0·13	$\frac{1}{2}$ plate	OQ850 T600 AC	20	33·4	36·0	38·1	48·6	28	63	6
"	"	"	"	"	"	"	"	"	" "	" "	— 78	37·1	39·5	42·6	55·5	30	63	"
"	"	"	"	"	"	"	"	"	" "	" "	—196	53·0	56·0	58·8	72·2	27	50	"
"	"	"	"	"	"	"	"	"	$1\frac{1}{4}$ plate	" "	20	33·9	35·4	28·1	46·3	29	65	"
"	"	"	"	"	"	"	"	"	" "	" "	— 78	36·4	38·1	40·1	52·6	30	62	"
"	"	"	"	"	"	"	"	"	" "	" "	—196	54·4	56·7	58·7	69·8	30	46	"
"	"	"	"	"	"	"	"	"	2 plate	" "	20	34·8	35·7	37·5	46·6	30	64	"
"	"	"	"	"	"	"	"	"	" "	" "	— 78	38·2	39·8	40·9	54·7	30	60	"
"	"	"	"	"	"	"	"	"	" "	" "	—196	55·7	57·6	59·5	69·0	23	26	"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·13	0·17	0·43	0·017	0·017	3·36	0·90	0·07

As quenched grain size 7 (ASTM).
$\frac{1}{2}$ in. dia. bar. Oil Quenched 860°C. Tempered 525°C. Oil Quench.

(See also Mechanical Properties at Low Temperature for tensile test data.) (Ref. 6.)

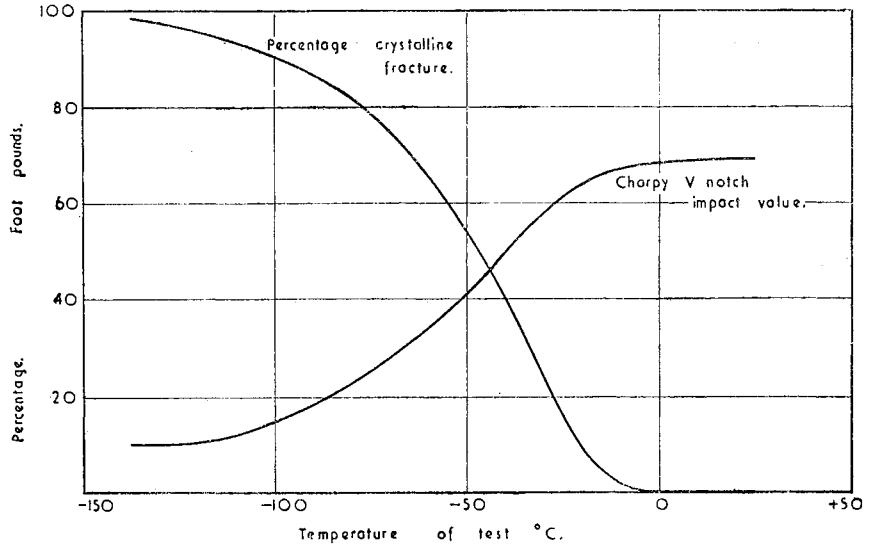


Fig. 36.24

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·11	0·33	0·40	0·020	0·026	3·14	0·88	0·13

As quenched grain size 7—8 (ASTM).
$\frac{1}{2}$ in., 1$\frac{1}{4}$ in., 2 in., plate. Air Cooled 850°C. Tempered 600°C. Air cool.

(See also Mechanical Properties at Low Temperature for tensile test data.) (Ref. 6.)

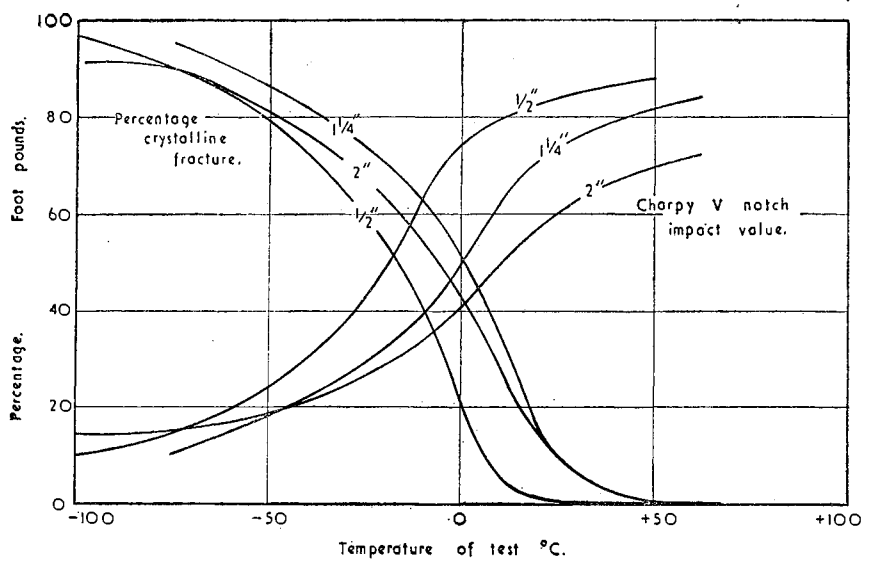


Fig. 36.25

En 36

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Curve No.	ASTM McQuaid Ehn Grain Size	Chemical Composition (%)				Section Size dia. (in.)	Heat Treatment °C	
		C	Mn	Ni	Cr			
A	3	0·10	0·49	3·10	0·78	$\frac{3}{8}$	N.870	T600
B	6—7	0·14	0·44	3·24	0·89	$\frac{3}{8}$	N.870	T600

Tensile test results at room temperature.

Curve No.	0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.
	tons/sq.in.						
A	28·1	28·4	29·6	38·4	34½	73	90
B	33·6	34·3	36·7	44·8	31½	71	91

(Ref. 3)

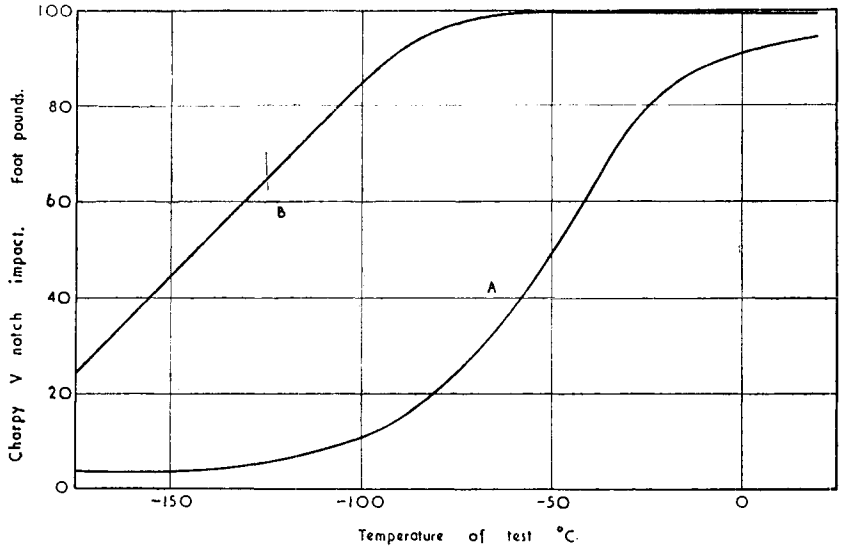


Fig. 36.26

MECHANICAL PROPERTIES IN TORSION

Chemical Composition (%)								Heat Treatment	Test Temperature	Tensile				Torsion			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)	0·1% P.S.	Apparent Shear Strength	Probable max. Shear Strength	
										tons/sq.in.				tons/sq.in.			
0·13	0·28	0·45	0·010	0·014	3·46	0·95	0·12	Hardened	RT	51·8	82·4	18	58½	37·2	69·9	52·4	9

FATIGUE PROPERTIES

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile						Izod ft.lb.	Rotary Bending Fatigue Limit		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		tons/sq.in.		
											tons/sq.in.							Plain	Notched	
B.E.A.	0·14	0·22	0·49	0·029	0·009	3·46	0·98	0·13	2½	OQ870 OQ770 (L)	30·2	47·0		64·2	24½	57½	53	±31·5		1
"	"	"	"	"	"	"	"	"	"	" " (T)			60·0	71·5	8	22	13	±27		"
"	"	"	"	"	"	"	"	"	"	Case hardened OQ870 OQ770 (L)								±49		"
	0·11	0·21	0·45	0·031	0·020	3·08	0·76		¾	OQ780 T400			49·7	54·9	24	64½	56	±28	±13·5*	10
	0·14	0·25	0·48	0·028	0·020	3·16	0·88		"	" "			71·1	74·3	16	60	17	±35·5	±14·75*	"
			(within specification)						0·3					54·9				±28		3
			"	"					"					74·3				±35·5		"

* Notches 55°V, 0·0086 in. root radius, 0·02 in. deep, test dia. 0·335 in. Neuber stress concentration factor 2·85.

LIST OF REFERENCES

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5. Symposium on the Hardenability of Steel. Organized by the Technical Advisory Committee of the Special and Alloy Steels Committee (Ministry of Supply) and The Iron & Steel Institute. Special Report No. 36 of The Iron & Steel Institute, 1946.
6. Private correspondence with International Nickel Ltd.
7. Private correspondence with Jessop-Saville Ltd.
8. Private correspondence with Round Oak Steel Works Ltd.
9. Private correspondence with Dowty Rotol Ltd.
10. W. E. Bardgett. Effect on the Fatigue Properties of En 24 and En 36 Steels. *Iron and Steel*, 1956, Vol. 29, Aug.

5 PER CENT NICKEL CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr
0·16 max.	0·10—0·35	0·45 max.	0·050 max.	0·050 max.	4·50—5·20	0·30 max.

MECHANICAL PROPERTIES

Tensile strength, tons/sq.in, min. (Rm)	40
Elongation, % min. (A)	20
Izod Impact Value, ft. lb., min.	50

The heat treatment given to 1 ½ in. dia. test bars shall be:
Blank carburize at a temperature between 880°C and 930°C 1).
Refine at a temperature of 850°C—880°C, cool in air, oil or water (2).
Harden in oil from a temperature of 750°C to 780°C.

(1) By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.
(2) The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted, by special agreement between the purchaser and manufacturer.

RELATED SPECIFICATIONS

United Kingdom	Germany	
En No.	Werkstoff No.	Name
En 37	1.5680	12Ni19

En 37

APPLICATIONS

En 37 steel is used for applications similar to those for En 33 when a tougher core is desired. Typical uses are for gears, gudgeon pins, pinions, camshafts, pushrod heads, clutch plates, levers, collets, differential spiders, oil pump wheels, worm shafts, and rifle components.

WELDING

The weldability is similar to that of En 33.

Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

In the softened condition the machinability is approximately 75% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1150°C. Finish above 850°C.
Softening	600°C—630°C. Air or furnace cool.
Carburizing	880°C—930°C.
Refining	850°C—880°C. Cool in air, oil or water.
Hardening*	760°C—780°C. Oil quench.
Tempering	150°C—200°C.

*A single oil quench from 780°C to 800°C may be used when steel is specifically requested for this treatment.

CARBURIZING DATA

See notes given in the Introduction.

Case Depth (in.)	Time in hours at the stated carburizing temperature to produce the given case-depth						
	880°C		900°C			925°C	
	Solid	Gas	Solid	Salt	Gas	Solid	Gas
0·01	1·5	0·65	1·2	0·6	0·45	0·8	0·35
0·02	2·4	2·0	2·1	1·8	1·5	1·7	1·0
0·03	6·0	4·5	4·4	4·0	3·2	2·7	2·25
0.04	10.7	8.0	7.8	7.2	5·25	4·8	4·0
0·06	24·0	18·0	17·6	16·0	12·0	10·8	9·0
0·08	43·0	32·0	31·2	—	21·0	19·2	16·0
0·10	67·0	50·0	52·0	—	33·0	30·0	25·0

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)				Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	Ni			
0·10	0·25	0·30	5·00	Softened	7·88	1
0·12	0·14	0·30	4·9	OQ840 WQ760	7·87	"
(within specification)				Softened	7·87	"

SPECIFIC HEAT (c)

Chemical Composition (%)				Heat Treatment °C	Mean Specific Heat cal/g deg. C	Ref.
C	Si	Mn	Ni		20 to 100°C	
0·10	0·25	0·30	5·00	Softened	0·118	1
(within specification)				Softened	0·117	2

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)				Heat Treatment °C	10^6 × Mean Coefficient of Thermal Expansion per deg.C				Ref.
C	Si	Mn	Ni		20to 100°C	20to 300°C	20to 500°C	20to 600°C	
0·12	0·14	0·30	4·9	OQ840 WQ760	12·4				1
(within specification)				Softened	11·9	13·0	13·7	14·0	2

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)				Heat Treatment °C	Electrical Resistivity microhm-cm	Ref.
C	Si	Mn	Ni		20°C	
0·12	0·14	0·30	4·9	OQ840 WQ760	25·5	1
(within specification)				Softened	24	"

En 37

THERMAL CONDUCTIVITY (k)

Chemical Composition (%)				Heat Treatment °C	Thermal Conductivity cal/cm s deg. C	Ref.
C	Si	Mn	Ni		20°C	
0·12	0·14	0·30	4·9	OQ840 WQ760	0·075	1
(within specification)				Softened	0·10	2

YOUNG'S MODULUS (E)

Chemical Composition (%)				Heat Treatment °C	Young's Modulus tons/sq. in.	Ref.
C	Si	Mn	Ni			
0·12	0·14	0·30	4·9	OQ840 WQ760	13,000	1

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

CORE CHARACTERISTICS

Chemical Composition (%)				
C	Si	Mn	Ni	Cr
0·13	0·39	0·40	4·55	0·08

Austenitizing Temperature 860°C, 30 min. (Ref. 3)

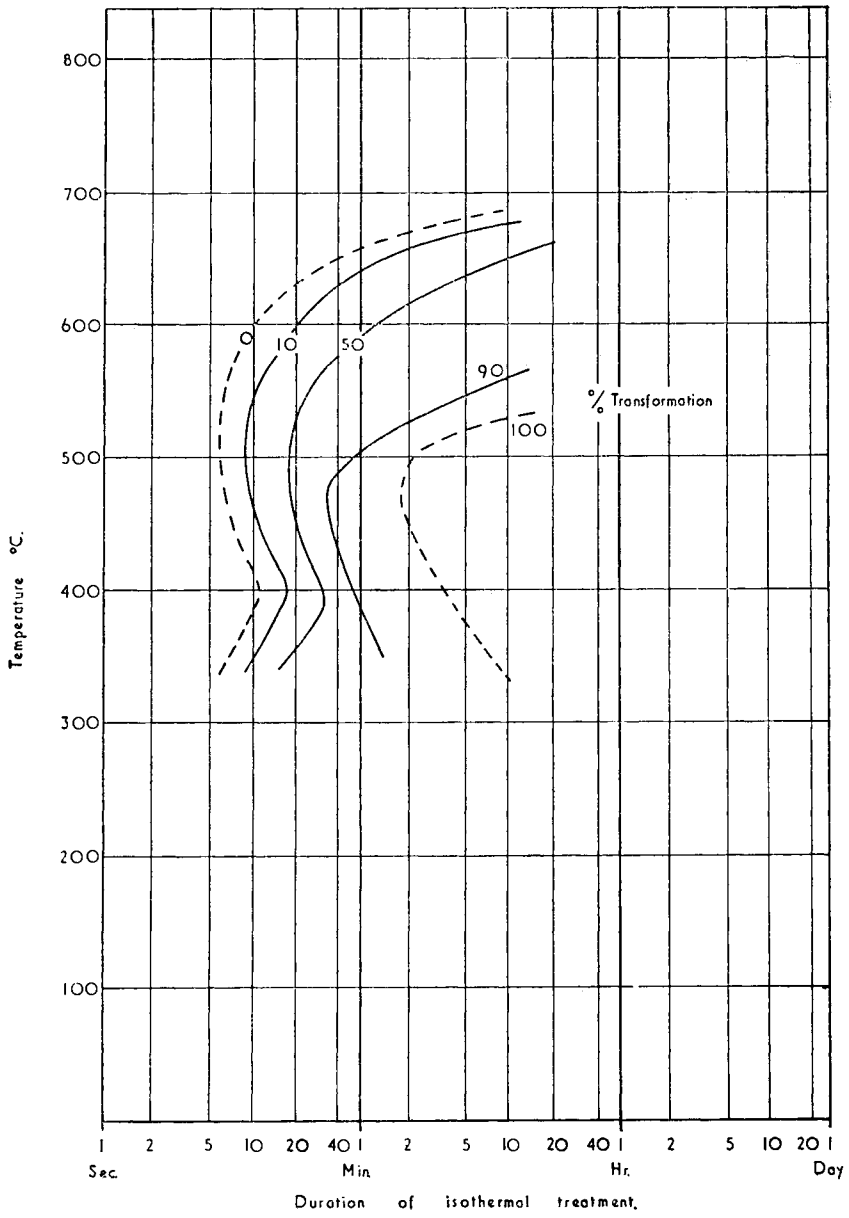


Fig. 37.1

En 37

HARDENABILITY

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								Section Size dia. (in.)	Grain Size (ASTM)	
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid Ehn
A	0·10	0·27	0·27	0·016	0·017	4·82	0·09	0·03	1 1/8	7(6,8)	6—8
B	0·13	0·17	0·30	0·036	0·024	4·95	0·07	0·03	1 3/8	7—8	5—6
C	0·14	0·21	0·36	0·041	0·030	4·65	0·13	0·05	1 1/8	6—8	6—7(8)
D	0·14	0·25	0·37	0·008	0·012	5·32	0·12	0·02	1	8	8

Test Bars Normalized 900°C and End Quenched 825°C.

As quenched 825°C. (Ref.4)

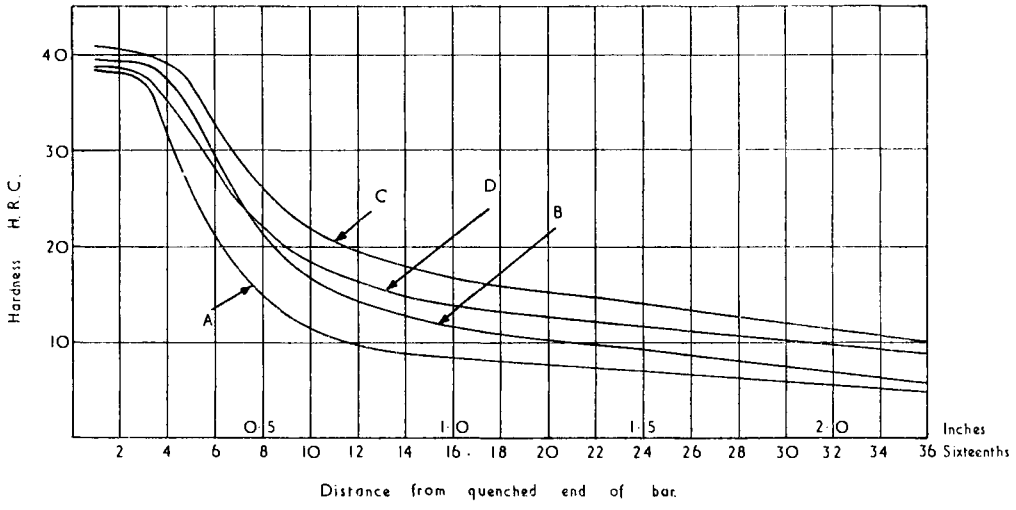


Fig. 37.2

Re-quenched 770°C. (Ref.4)

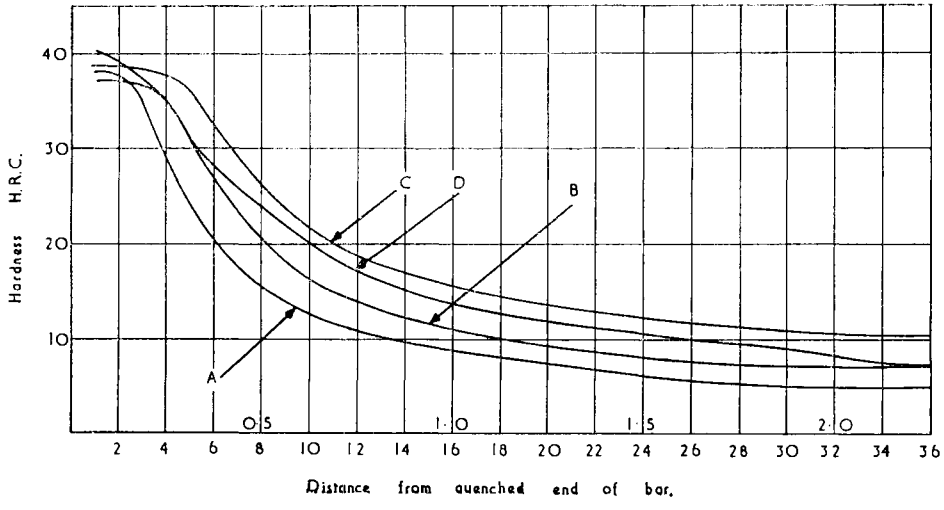


Fig. 37.3

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·5% P.S.	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.						
		0·06	0·19	0·35	0·017	0·018	5·25	0·09	0·03	1 1/8	BC900 OQ850 OQ750			44·4	33	68	112	3
		0·07	0·06	0·18	0·020	0·008	5·10			1 1/8	N860		26	31	39	72	104	5
		"	"	"	"	"	"			"	WQ860		30	42	25	70	87	"
		"	"	"	"	"	"			"	WQ860 T600		29	34	36	77	114	"
		"	"	"	"	"	"			"	OQ860		23	35	34	75	112	"
		"	"	"	"	"	"			"	OQ860 T600		28	32	38	77	116	"
		"	"	"	"	"	"			1 1/16	WQ860 WQ750		35	46	31	68	84	"
		"	"	"	"	"	"			7/8	" "		32	42	33	69	99	"
		"	"	"	"	"	"			1 1/8	" "		29	39	36	71	110	"
		"	"	"	"	"	"			1 1/4	" "		27	36	37	73	111	"
		"	"	"	"	"	"			2 1/8	" "		27	36	34	72	98	"
		0·07	0·17	0·17	0·016	0·013	5·18	0·04		1 1/8	N830		24·0	33·4	35 1/2	70 1/2		6
		"	"	"	"	"	"	"		"	OQ830 WQ770		35·1	47·0	27	67 1/2		"
A.O.H.		0·08	0·20	0·36	0·042	0·039	5·05	0·13		1 1/8	A850 SC	25·2		37·8	35	63 1/2	90	1
B.O.H.		0·09	0·37	0·36	0·010	0·019	4·76	0·15	0·05	1 1/8	BC900 OQ850 OQ750			44·4	33	68	113	3
"		"	"	"	"	"	"	"	"	"	" OQ830 OQ740			44·0	36	72 1/2	113	"
		0·09		0·25			5·15	0·10		1 1/8	OQ830 OQ740		29·0	42·0	32·0		113	7
		0·09	0·21	0·16			5·00	Tr		1/2	OQ850 OQ740		42·0	49·0	25 1/2	65 1/2	104	"
		0·10		0·33			4·66	0·10		3/4	OQ830 OQ740		43·3	52·5	25		99	7
		0·10		0·34			5·14	0·23		3/4	" "			72·8	17		38	"
		0·10		0·35			4·70	0·10		1 1/8	OQ860 OQ750		32·0	48·0	26		72	"
		"		"			"	"		"	OQ770		32·5	49·0	25		70	"
		0·10		0·32			4·80	0·06		7/8	OQ850 OQ760		37·1	49·7	26		68	8
	McQuaid Ehn Actual	"		"			"	"		1 1/8	" "		39·2	47·3	30		83	"
		"		"			"	"		2	" "		31·5	40·9	32		92	"
E.	6—8 7(6,8)	0·10	0·27	0·27	0·016	0·017	4·82	0·09	0·03	1	N900 OQ825 T150		37·8	54·7	22 1/4	61 1/2	55	4
		0·10	0·16	0·31			4·79	—		1 1/8	OQ850 OQ740		35·6	46·6	31	66	102	1

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·1% P.S (0·1Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
												tons/sq.in.							
		0·11		0·41			4·77	0·30		1	OQ850 OQ760			58·0	70·0	18		50	7
		"		"			"	"		2	" "			48·3	59·7	21½		66	"
		"		"			"	"		3	" "			43·8	57·2	23		81	"
		"		"			"	"		4	" "			46·0	56·8	18		67	"
		0·11		0·15			4·97	0·03		1⅛	WQ760				69·3	15	38	49	9
		"		"			"	"		"	OQ760				48·0	22	49½	80	"
		0·11		0·08			4·68	0·05		"	WQ760				41·4	32	67	93	"
		"		"			"	"		"	OQ760				38·2	33	71	101	"
		0·11		0·15			4·90	0·03		"	WQ760				45·3	20½	46	87	"
		"		"			"	"		"	OQ760				37·6	29	56	96	"
		0·12		0·31			4·96	0·10		1⅛	OQ830 OQ740			29·0	42·0	32		113	7
		0·12	0·34	0·35			4·96			1⅛	OQ850 OQ740			46·0	54·4	21	50	91	1
		0·12	0·14	0·30			4·90			1⅛	OQ840 WQ760	25·9	40·1		58·8	18	48	28	1
B.O.H.		0·12	0·19	0·27	0·035	0·032	4·62			⅞	OQ830 OQ740			36·8	51·6	25	53	51	10
"		"	"	"	"	"	"			1 1/16	" "			30·0	43·2	28	57	76	"
"		"	"	"	"	"	"			2	WQ830 OQ740			32·8	48·0	23	50	65	"
		0·12		0·13			4·90	0·05		1⅛	WQ760				49·4	19½	38	61	9
	McQuaid Ehn	"		"			"	"		"	OQ760				40·0	27	52	93	"
	6	0·12		0·37			4·90	0·06	0·02	½	BC920 OQ850 OQ800			68·3	81·7	16½	57	27	11
	"	"		"			"	"	"	"	" OQ800			77·9	81·3	18½	55	28	"
	"	"		"			"	"	"	⅞	" OQ850 OQ800			58·8	70·2	18½	55	33	"
	"	"		"			"	"	"	"	" OQ800			60·8	70·0	17½	55	31	"
	"	"		"			"	"	"	1⅛	" OQ850 OQ800			47·9	60·1	21	55	40	"
	"	"		"			"	"	"	"	" OQ800			54·9	62·9	19	55	32	"
B.E.A.		0·13	0·35	0·33	0·010	0·029	4·97	0·07		1⅛	BC900 OQ850 OQ760				50·0	30	57	82	3
B.E.A.		0·13	0·29	0·35	0·012	0·024	4·94	0·07		1⅛	" " "				46·4	31	61	77	"
		0·13	0·39				4·74	0·13		¾	OQ830 OQ740			48·0	66·0	18		75	7
		0·13	0·36				5·18	0·30		¾	" "				79·2	18		51	"
A.O.H.	McQuaid Actual Ehn																		
	5—6 7—8	0·13	0·17	0·30	0·036	0·024	4·95	0·07	0·03	1	N900 OQ825 T150			42·2	54·4	20	57	43	4
		0·13	0·24	0·29			4·97	0·08		1⅛	OQ850 OQ740			49·6	57·2	23	53	84	1
A.O.H.	6—7 6—8	0·14	0·21	0·36	0·041	0·030	4·65	0·13	0·05	1	N900 OQ825 T150			46·2	63·3	18	55½	26	4
E.	8 8	0·14	0·25	0·37	0·008	0·012	5·32	0·12	0·02	1	" " "			47·9	64·1	20	54½	45	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
B.O.H.	0·14	0·13	0·36	0·037	0·030	4·60			1 1/16	OQ830 OQ740	42·4	54·0	25	55	52	10
B.O.H.	0·14	0·23	0·40	0·038	0·032	4·85			1 1/16	" "	42·0	52·8	22	52 1/2	55	"
B.O.H.	0·14	0·16	0·35	0·037	0·031	4·70			1 3/16	" "	37·6	51·0	24	56	55	"
	0·14	0·15	0·28	0·014	0·013	5·17	0·13		1 1/8	N830	25·4	38·8	32	64		6
	"	"	"	"	"	"	"		"	OQ830 WQ770	66·6	77·2	18 1/2	55		"
	0·14	0·19				4·82	0·10		1 1/8	WQ760		64·8	12 1/2	36 1/2	41	9
	"	"				"	"		"	OQ760		47·3	25	47	70	"
	0·15		0·34			4·82	0·10		1 1/8	OQ830 OQ740	38·0	49·6	30		64	7
	0·16	0·28	0·18	0·010	0·011	4·80	0·07		1 1/8	N830	27·0	38·3	32		64 1/2	6
	"	"	"	"	"	"	"		"	OQ830 WQ770	57·1	70·8	16		44	"

EFFECT OF COLD WORK

Process of Manufacture	Chemical Composition (%)						Heat Treatment °C	Hardness HV for stated % reduction by cold drawing						Ref.
	C	Si	Mn	S	P	Ni		0%	10%	30%	40%	60%	80%	
B.E.A.	0·12	0·30	0·55	0·013	0·011	5·20	Annealed	190	228	270	276	292	318	12

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·13	0·10	0·31	0·018	0·010	5·30	0·03

Basic Electric.

1¼ in. dia. bars Oil Quenched 830°C. Tempered as indicated. (Ref. 6)

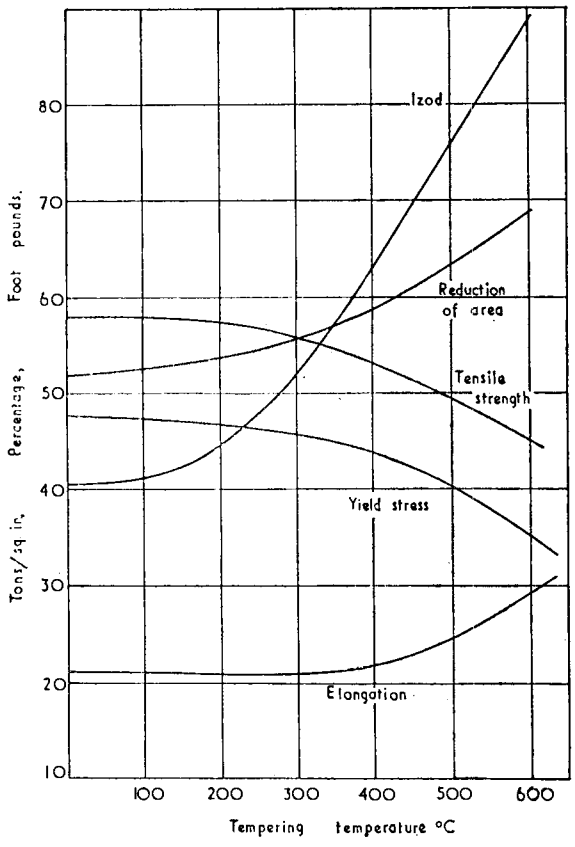


Fig. 37.4

1¼ in. bars Water Quenched 830°C. Tempered as indicated (Ref. 6.)

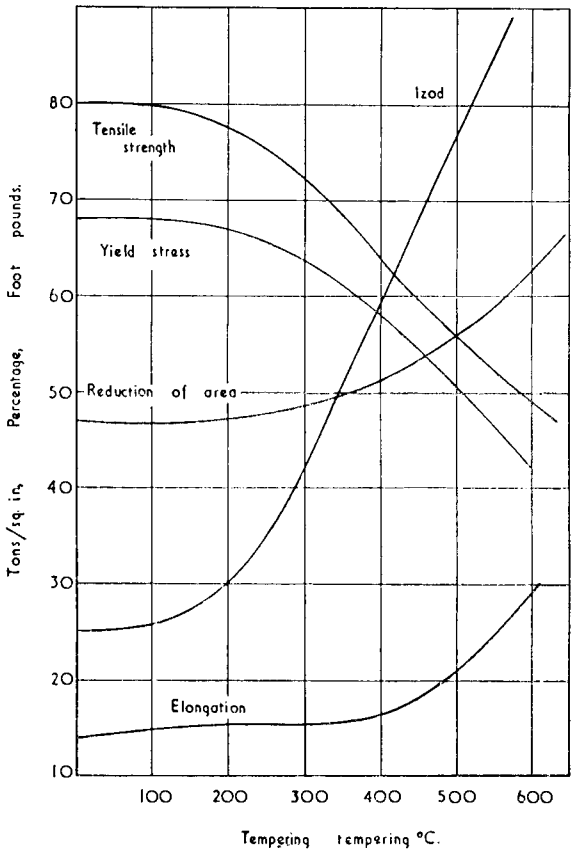


Fig. 37.5

EFFECT OF TEMPERING ON HARDNESS OF CASE

1¼ in. dia. bars, Case Hardened.
Oil Quenched 840—860°C.
Oil Quenched 750—770°C.
Tempered as indicated.

(Ref. 11)

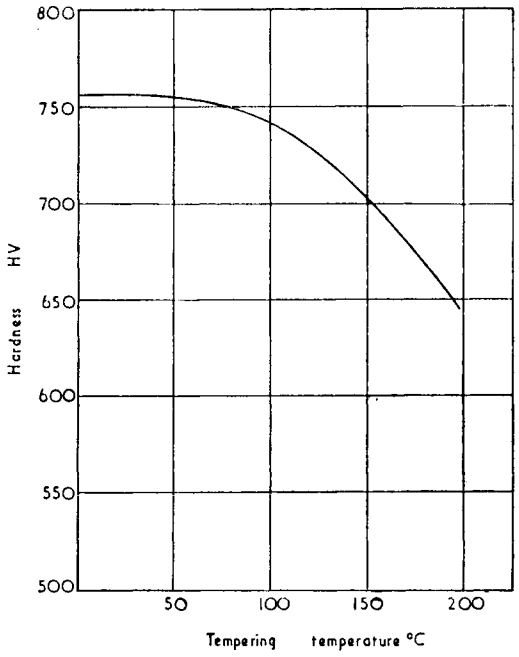


Fig. 37.6

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EFFECT OF SECTION SIZE ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)						
C	Si	Mn	S	P	Ni	Cr
0·13	0·19	0·31	0·018	0·010	5·30	0·03

Air Cooled 900°C.
Oil Quenched 830°C.
Oil Quenched 770°C.

(Ref. 6)

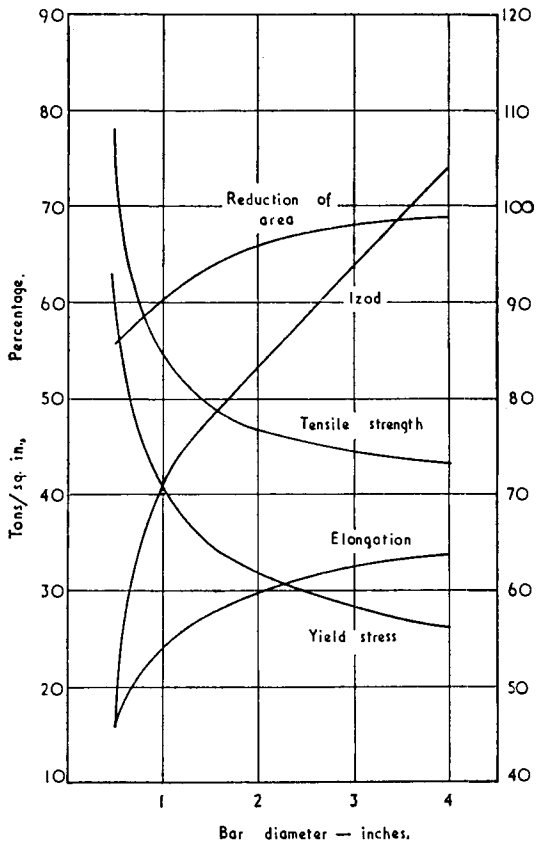


Fig. 37.7

Air Cooled 900°C.
Oil Quenched 830°C.
Water Quenched 770°C.

(Ref. 6)

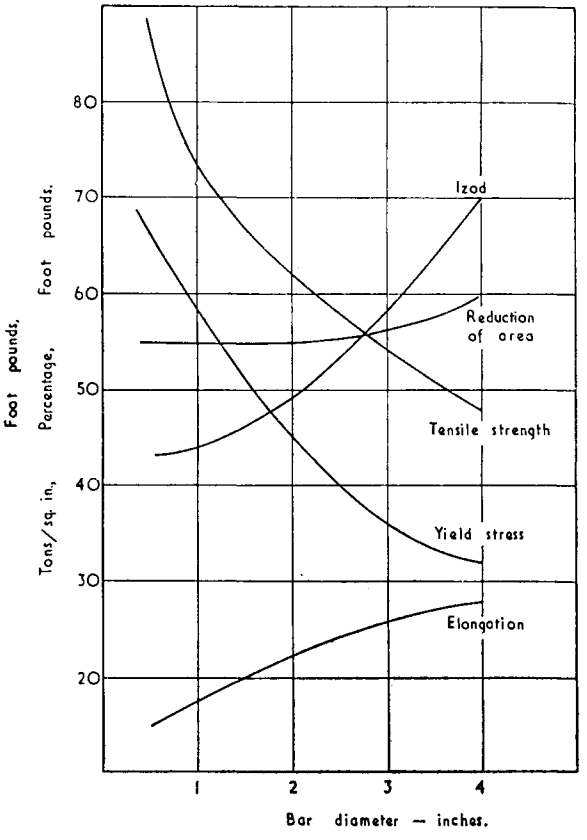


Fig 37.8

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Rm)	Izod ft.lb.	Ref.
7—8	0·09	0·33	0·33	0·031	0·018	4·87	0·13	0·08	⅝	OQ800 T550 OQ	20	46·5	46·6	46·7		49·6	27	71		7
"	"	"	"	"	"	"	"	"	"	" "	— 78	54·0	54·1	54·4		58·6	29	67		"
"	"	"	"	"	"	"	"	"	"	" "	—196	72·4	73·5	73·8		74·4	34	60		"
8	0·13	0·25	0·35	0·022	0·027	4·85	0·18	0·04	½	N900	20	24·2	27·1	30·2		45·9	35	60		"
"	"	"	"	"	"	"	"	"	"	"	— 78	22·6	27·3	33·4		54·4	34	59		"
"	"	"	"	"	"	"	"	"	"	"	—196	38·7	43·2	48·7		72·3	28	27		"
7—8	"	"	"	"	"	"	"	"	1¼ plate	"	20	28·4	28·7	29·1		39·1	39	65		"
"	"	"	"	"	"	"	"	"	"	"	— 78	31·3	32·3	33·0		46·1	36	64		"
"	"	"	"	"	"	"	"	"	"	"	—196	48·5	49·6	50·9		62·0	40	55		"
"	"	"	"	"	"	"	"	"	2 plate	"	20	22·8	25·7	29·1		43·5	32	58		"
"	"	"	"	"	"	"	"	"	"	"	— 78	22·8	27·0	32·5		52·1	34	55		"
"	"	"	"	"	"	"	"	"	"	"	—196	39·1	43·6	49·0		69·2	17	12		"
8	"	"	"	"	"	"	"	"	½ plate	N900 T600 AC	20	28·2	28·5	29·2		40·0	37	70		"
"	"	"	"	"	"	"	"	"	"	" "	— 78	31·0	32·0	32·9		46·7	42	68		"
"	"	"	"	"	"	"	"	"	"	" "	—196	48·5	49·7	51·2		63·0	42	58		"
7—8	"	"	"	"	"	"	"	"	1¼ plate	" "	20	28·6	29·0	29·6		39·8	36	66		"
"	"	"	"	"	"	"	"	"	"	" "	— 78	32·0	32·4	33·8		46·8	38	64		"
"	"	"	"	"	"	"	"	"	"	" "	—196	49·1	50·2	51·4		62·6	37	53		"
"	"	"	"	"	"	"	"	"	2 plate	" "	20	28·1	28·5	29·3		39·2	35	67		"
"	"	"	"	"	"	"	"	"	"	" "	— 78	28·5	29·2	29·2		42·8	40	65		"
"	"	"	"	"	"	"	"	"	"	" "	—196	50·4	50·6	51·1		56·9	34	44		"
	0·13					4·88	0·37			OH T600	20				38·6	44·9	24	74	21	13
	"					"	"			" "	— 75								21	"
	"					"	"			" "	—180				57·3	64·7	31	62	4	"

IMPACT TRANSITION TEMPERATURE DATA

Process of Manufacture	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	No Aluminium added to ladle Charpy Keyhole ft.lb.	%Crystalline fracture	Hardness HB	¾ lb. Aluminium added to ladle Charpy Keyhole ft.lb.	%Crystalline fracture	Hardness HB	Ref.
B.E.A.	0·11	0·27	0·34	0·010	0·012	4·89	0·09	1⅛	N840	—78	2·5	100	166	57	60	170	1
"	"	"	"	"	"	"	"	"	OQ840 T200	"	44	90	241	67	50	222	"
"	"	"	"	"	"	"	"	"	" T600	"	72	80	198	146	0	187	"
"	"	"	"	"	"	"	"	"	N840 T500	"	40	85	172	74	50	167	"

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·09	0·33	0·33	0·031	0·018	4·87	0·13	0·08

(See Mechanical Properties at Low Temperature for tensile test data.)

As quenched grain size 7—8 (ASTM).
$\frac{1}{2}$ in. dia. bars Oil Quenched 800°C. Tempered 550°C.
Oil Quenched.

(Ref. 7)

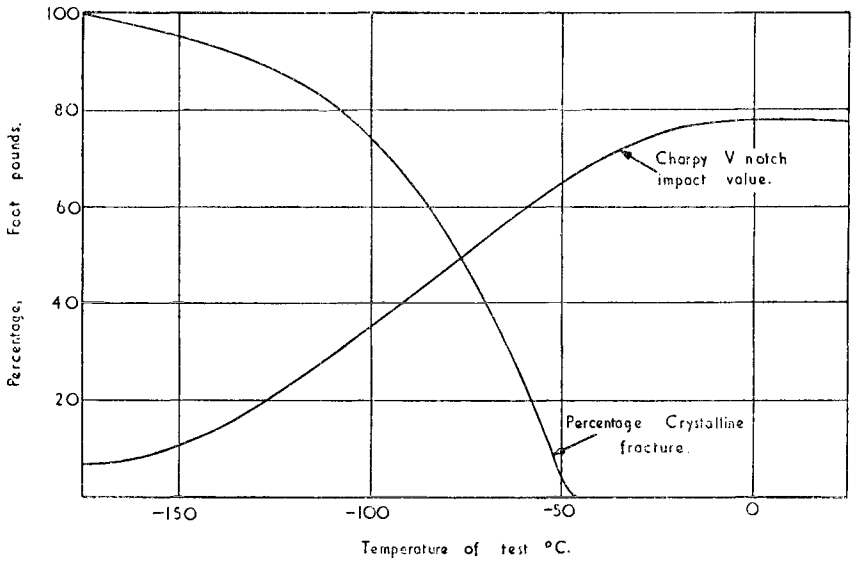


Fig. 37.9

IMPACT TRANSITION TEMPERATURE DATA (Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·13	0·25	0·35	0·022	0·027	4·85	0·18	0·04

Plate thickness (in.)	As quenched grain size ASTM
½	8
1¼	7—8
2	7—8

(See Mechanical Properties at Low Temperature for tensile test data.)

Plates Normalized 900°C.

(Ref. 7)

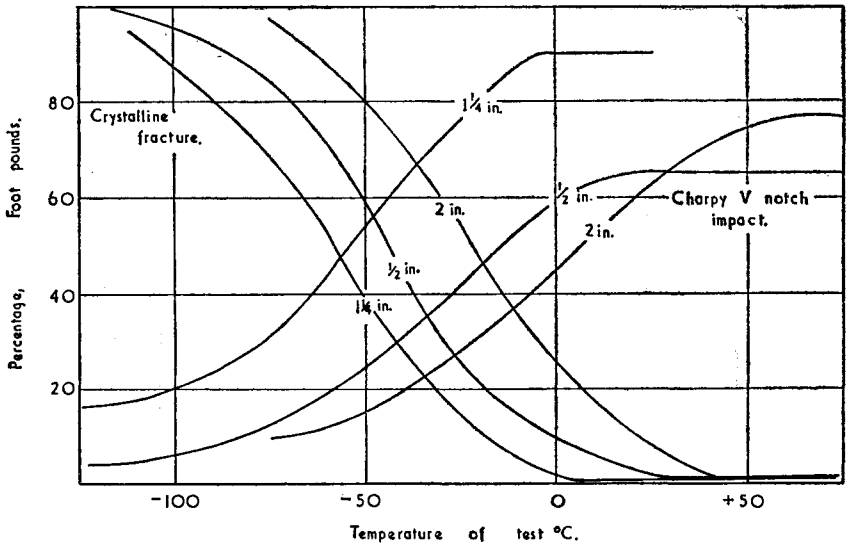


Fig. 37.10

Plates Normalized 900°C. Tempered 600°C AC.

(Ref. 7)

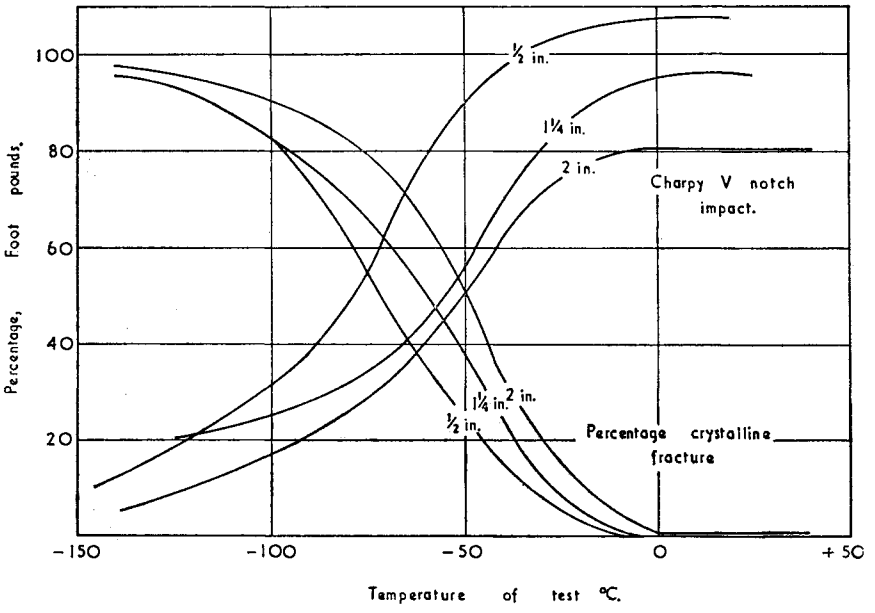


Fig. 37.11

MECHANICAL PROPERTIES IN TORSION

Process of Manufacture	Chemical Composition (%)						Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile				Izod ft.lb.	Torsion			Ref.
	C	Si	Mn	S	P	Ni				Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		Yield Stress	Apparent Shear Strength	Probable max. Shear Strength	
										tons/sq.in.					tons/sq.in.			
B.E.A.	0·14	0·16	0·29	0·018	0·009	4·84	1⅛	N860	RT	24·7	34·8	31	62	85	16·8	34·7	26·0	1
"	"	"	"	"	"	"	"	N860 WQ760	RT	41·9	60·6	17½	47	23	21·2	55·7	41·8	"

FATIGUE PROPERTIES

Chemical Composition (%)				Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile					Izod ft.lb.	Rotating Bending Fatigue Limit tons/sq.in.	Ref.
C	Si	Mn	Ni				0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)			
							tons/sq.in.							
0·12	0·14	0·30	4·90	1⅛	OQ840 WQ760	RT	25·9	40·1	58·8	18	48	28	±26·0	1

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En 38

5 PER CENT NICKEL–MOLYBDENUM CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

C	Si	Mn	S	P	Ni	Cr	Mo
0·16 max.	0·10—0·35	0·60 max.	0·050 max.	0·050 max.	4·50—5·50	0·30 max.	0·15—0·30

MECHANICAL PROPERTIES

Tensile strength, tons/sq. in. min. (Rm)	65
Elongation, %, min. (A)	13
Izod impact value, ft. lb., min.	30

The heat treatment given to 1½ in. test bars shall be:
Blank carburize between 880°C and 930°C (1).
Refine at a temperature of 850°C—880°C. Cool in air or oil (2).
Harden in oil from a temperature of 750°C—780°C.

(1) By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.
(2) The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted by special agreement between the purchaser and manufacturer.

APPLICATIONS

En 38 is used where a case-hardening steel having a tough core and a higher core strength than that of En 37 is required. Typical applications are similar to those for En 37.

WELDABILITY

Similar to En 34. Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

In the softened condition the machinability is approximately 75% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging rolling, and stamping	1150°C. Finish above 850°C.
Softening	610°C to 640°C. Cool in air or furnace.
Carburizing	880°C to 930°C.
Refining	850°C to 880°C. Cool in air or oil.
Hardening*	750°C to 780°C. Oil quench.
Tempering	150°C to 200°C.

* A single oil quench from 770°C to 800°C may be used when steel is specifically requested for this treatment.

CARBURIZING DATA

The times for carburizing to different case depths at various temperatures are similar to those for En 37.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)					Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	Ni	Mo			
0·12	0·25	0·40	5·10	0·20	Softened	7·88	1
(within specification)					"	7·89	2

SPECIFIC HEAT (c)

Chemical Composition (%)					Heat Treatment °C	Mean Specific Heat cal/g deg. C	Ref.
C	Si	Mn	Ni	Mo		20 to 100°C	
0·12	0·25	0·40	5·10	0·20	Softened	0·118	1

COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition	Heat Treatment °C	$10^6 \times$ Mean Coefficient of Thermal Expansion per deg. C				Ref.
		20to 100°C	20to 300°C	20to 500°C	20to 680°C	
(within specification)	Softened	11·4	13·2	13·4	13·7	2

ELECTRICAL RESISTIVITY AND THERMAL CONDUCTIVITY

Values will be similar to those for En 37.

HARDENABILITY

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								Original Bar dia. (in.)	ASTM Grain Size	
	C	Si	Mn	S	P	Ni	Cr	Mo		Actual	McQuaid-Ehn
A	0·14	0·18	0·41	0·018	0·015	5·13	0·24	0·17	1⅜	7—8	7—8
B	0·12	0·18	0·32	0·012	0·014	5·41	0·12	0·27	1·19	7—8	5—6
C	0·12	0·28	0·29	0·020	0·013	4·76	0·19	0·25	1⅜	8(7)	7—8(6)

Bars Normalized 875°C. End Quenched from 850°C.

End Quenched 850°C. (Ref. 4)

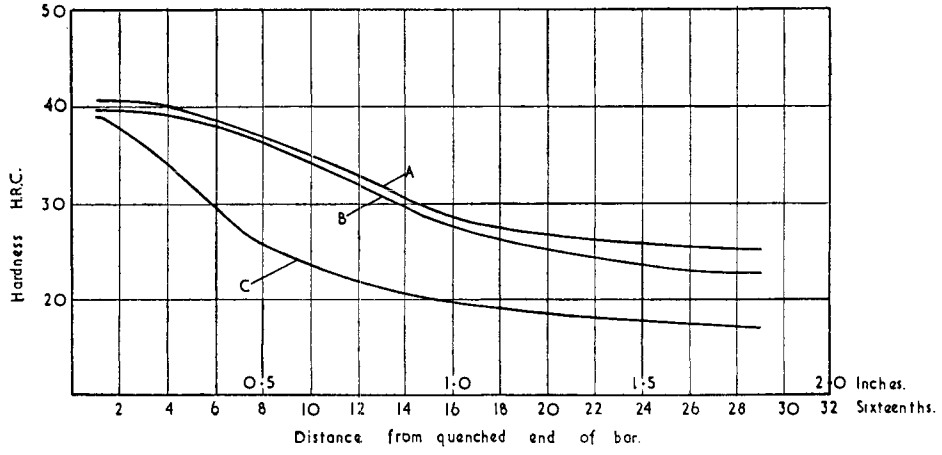


Fig.38.1

Re-quenched 770°C. (Ref. 4)

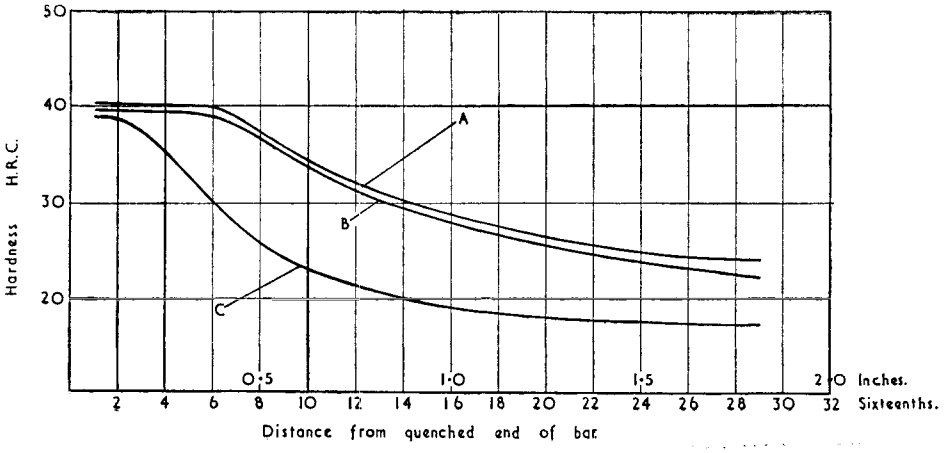


Fig.38.2

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
		0·10	0·17	0·36			5·24	0·16	0·24	1⅛	OQ850 OQ760	57·0	66·8	18	63½	71	1
		0·11		0·36			4·89	0·26	0·30	1⅛	OQ850 OQ760		66·0	20		72	3
		0·12		0·40			5·10		0·20	1⅛	OQ860 OQ770	70·0	80·0	15		45	3
		0·12	0·17	0·37			5·30	0·08	0·23	1⅛	OQ850 OQ760	61·6	70·0	19	57	66	1
		0·12	0·26	0·37			5·32	0·15	0·25	3	" "	56·0	61·4	20	58	76	"
	McQuaid Ehn Actual																
B.E.A.	5—6 7—8	0·12	0·18	0·32	0·012	0·014	5·41	0·12	0·27	1	N875 OQ850 T150	61·6	78·8	17½	60½	46	4
B.E.A.	7—8(6) 8(7)	0·12	0·28	0·29	0·020	0·013	4·76	0·19	0·25	"	" " "	47·1	62·5	18	60	46	"
		0·12		0·36			5·10	0·15	0·16	1⅛	OQ850 OQ760	62·4	73·8	16	50	53	5
		0·13		0·34			5·45	0·20	0·23	2½	OQ850 OQ760		66·4	18½	53	63	1
		0·13		0·40			5·34	0·23	0·30	1⅛	OQ850 OQ760		76·0	14		55	3
		0·13		0·37			5·20	0·21	0·19	1⅛	OQ850 OQ760	67·6	84·7	15½	50	36	5
		0·13		0·35			5·06	0·18	0·15	1⅛	BC920 OQ850 OQ760	52·8	65·1	21	57	40	"
		"		"			"	"	"	"	" OQ780	77·6	85·1	16½	52	31	"
		0·14	0·19	0·34			5·27	0·10	0·22	1⅛	OQ850 OQ760	72·4	81·6	16	54½	52	1
	McQuaid Ehn Actual																
B.E.A.	7—8 7—8	0·14	0·18	0·41	0·018	0·015	5·13	0·24	0·17	1	N875 OQ850 T150	68·1	80·0	16	58½	32	4
	8	0·15		0·35			4·80	0·19	0·15	½	BC920 OQ850 OQ760	84·8	91·3	16½	57	33	5
	"	"		"			"	"	"	"	" " WQ760	90·1	91·6	16½	57	36	"
	"	"		"			"	"	"	"	" OQ800	86·9	91·6	16	57	37	"
	"	"		"			"	"	"	"	" WQ800	88·3	93·2	16	57	33	"
	"	"		"			"	"	"	⅞	" OQ850 OQ760	68·6	79·7	16½	52	32	"
	"	"		"			"	"	"	"	" " WQ760	90·3	91·6	17	55	30	"
	"	"		"			"	"	"	"	" OQ800	74·0	89·7	15	55	29	"
	"	"		"			"	"	"	"	" WQ800	71·8	91·0	16½	55	30	"
	"	"		"			"	"	"	1⅛	BC920 OQ850 OQ760	62·3	75·4	17	55	30	"
	"	"		"			"	"	"	"	" " WQ760	68·4	91·0	16½	57	26	"
	"	"		"			"	"	"	"	" OQ800	82·4	88·5	17	55	26	"
	"	"		"			"	"	"	"	" WQ800	72·0	90·4	17	57	32	"
	"	"		"			"	"	"	2	" OQ850 OQ760	47·4	56·0	25	62	57	"
	"	"		"			"	"	"	"	" " WQ760	52·6	62·0	22½	57	46	"
	"	"		"			"	"	"	"	" OQ800	65·6	71·6	18½	57	61	"
	"	"		"			"	"	"	"	" WQ800	71·2	80·4	18	55	48	"

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4¼ PER CENT NICKEL–CHROMIUM AND NICKEL–CHROMIUM–MOLYBDENUM CASE-HARDENING STEEL

SPECIFICATION

CHEMICAL COMPOSITION (%)

	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·12—0·18	0·10—0·35	0·50 max.	0·050 max.	0·050 max.	3·80—4·50	1·00—1·40	—
En 39B	0·12—0·18	0·10—0·35	0·50 max.	0·050 max.	0·050 max.	3·80—4·50	1·00—1·40	0·15—0·35

MECHANICAL PROPERTIES

Tensile strength, tons/sq.in., min. (Rm)	85
Elongation, %, min. (A)	12
Izod impact value, ft. lb. min.	25

In the softened condition the material shall have a Brinell hardness number not exceeding 277.

The heat treatment given to 1 in. test bars shall be:

Blank carburize at a temperature between 880°C and 930°C (1).
Refine at a temperature of 850°C—880°C, cool in air or oil (2).
Harden in oil from a temperature of 760°C—780°C.
Temper at a temperature not exceeding 200°C.

(1) By arrangement with the purchaser the tests may be carried out on samples from which the blank carburizing treatment has been omitted or modified to a short heating period.
(2) The single quench treatment may be used in certain cases when the refining treatment after carburizing is omitted by special agreement between the purchaser and manufacturer.

RELATED SPECIFICATIONS

United Kingdom		France	Germany		
En	BS Air	AFNOR	Werkstoff No.	Name	DIN
39A 39B	2S82	12 NC 15	1.5860	14NiCr18	1662

En 39

APPLICATIONS

These steels may be carburized and hardened to produce a hard wear resistant case, and developing a core strength of the order of 85 tons/sq.in. with good resistance to shock.

Typical uses are high duty gears, heavy duty worms, crown wheels and pinions, heavy roller bearings, breech mechanisms and small arms components, camshafts, clutch plates, valve rockers, gudgeon pins, and tappets.

En 39B containing additions of molybdenum is recommended for components of large section size.

WELDING

See Introduction (List of Abbreviations) for key to symbols used in this table.

	Welding Process					
	MA	G	IG	S	F	B
En 39A	cx	cx	g	e	a	h
En 39B	cx	cx	g	e	a	h

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Parts may be welded or high temperature brazed before carburizing but the weld metal may not have satisfactory carburizing characteristics; the brazed region will not carburize. Welding or brazing after carburizing should be carried out in a region free from case, and before the final heat treatment.

MACHINABILITY

The machinability of this steel in the softened condition is about 60% of that for mild steel (En 3).

HOT WORKING AND HEAT TREATMENT TEMPERATURES

Forging, rolling and stamping	1150°C. Finish above 850°C. Retarded cooling is advisable for large sections.
Softening	630°C—650°C. Cool in air or furnace.
Carburizing	880°C—930°C.
Refining	850°C—880°C. Air cool or oil quench.
Hardening	760°C—780°C. Oil quench.
Tempering	150°C—200°C.

CARBURIZING DATA

The times for carburizing to different case depths at various temperatures are similar to those given for En 37.

PHYSICAL PROPERTIES

SPECIFIC GRAVITY (d)

Chemical Composition (%)								Heat Treatment °C	Specific Gravity at 20°C	Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			
		(within En 39A specification)						Softened	7·88	1
		" " "						"	7·87	2
0·14	0·26	0·40	0·012	0·007	4·33	1·15	—	BC OQ850 OQ770 T140	7·85	1
0·14	0·21	0·40			4·49	1·20	—	BC OQ850 OQ760	7·87	1
		(within En 39B specification)						Softened	7·88	1
		" " "						"	7·87	2
0·15	0·27	0·35	0·017	0·016	4·25	1·18	0·20	BC 900—920 OQ800	78·5	3

SPECIFIC HEAT (c)

Chemical Composition	Heat Treatment °C	Specific Heat cal/g deg. C. 20°C to 100°C	Ref.
(within En 39A specification)	Softened	0·118	1
" "	"	0·117	2
(within En 39B specification)	"	0·118	1
" "	"	0·117	2

MEAN COEFFICIENT OF THERMAL EXPANSION (α)

Chemical Composition (%)								Heat Treatment	10^6 × Mean Coefficient of Thermal Expansion per deg. C.					Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20 to 100°C	20 to 200°C	20 to 300°C	20 to 500°C	20 to 700°C	
			(within En 39A or B specification)					Softened	12·0	—	13·2	13·7	14·1	2
			" " "					"	12	—	13	14	15	1
0·14	0·26	0·40	0·012	0·007	4·33	1·15	—	BC OQ850 OQ770 T140	11·0	11·6	12·0	—	—	"
			(within En 39A specification)					—	11·8	—	12·8	13·4	—	3
0·15	0·27	0·35	0·017	0·016	4·25	1·18	0·20	BC900 OQ800	11·3	12·5	—	—	—	"

ELECTRICAL RESISTIVITY (ϱ)

Chemical Composition (%)								Heat Treatment °C	Electrical Resistivity microhm-cm			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo		20°C	100°C	200°C	
0·15	0·27	0·35	0·017	0·016	4·25	1·18	0·20	BC900 OQ800	36·3	40·7	46·7	3

THERMAL CONDUCTIVITY (k)

Estimated value for steel in the softened condition at 20°C is 0·08 cal/cm s deg. C.

YOUNG'S MODULUS (E)

Chemical Composition (%)								Heat Treatment °C	Test Temperature °C	Young's Modulus tons/sq.in.		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			Static	Dynamic*	
0·14	0·26	0·40	0·012	0·007	4·33	1·15	—	BC OQ850 OQ770 T140	RT	12,800		1
0·15	0·27	0·35	0·017	0·016	4·25	1·18	0·20	BC 900 OQ800	20		12,900	3
"	"	"	"	"	"	"	"	" "	100		12,700	"
"	"	"	"	"	"	"	"	" "	200		12,300	"

Vibration method.

TRANSFORMATION CHARACTERISTICS

ISOTHERMAL TRANSFORMATION

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·11	0·09	0·38	0·010	0·026	4·15	1·33	0·07

High Frequency Melt.
McQuaid Ehn grain size. Finer than 8 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to $\frac{3}{8}$ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 865°C, 30 min.

(Ref. 4)

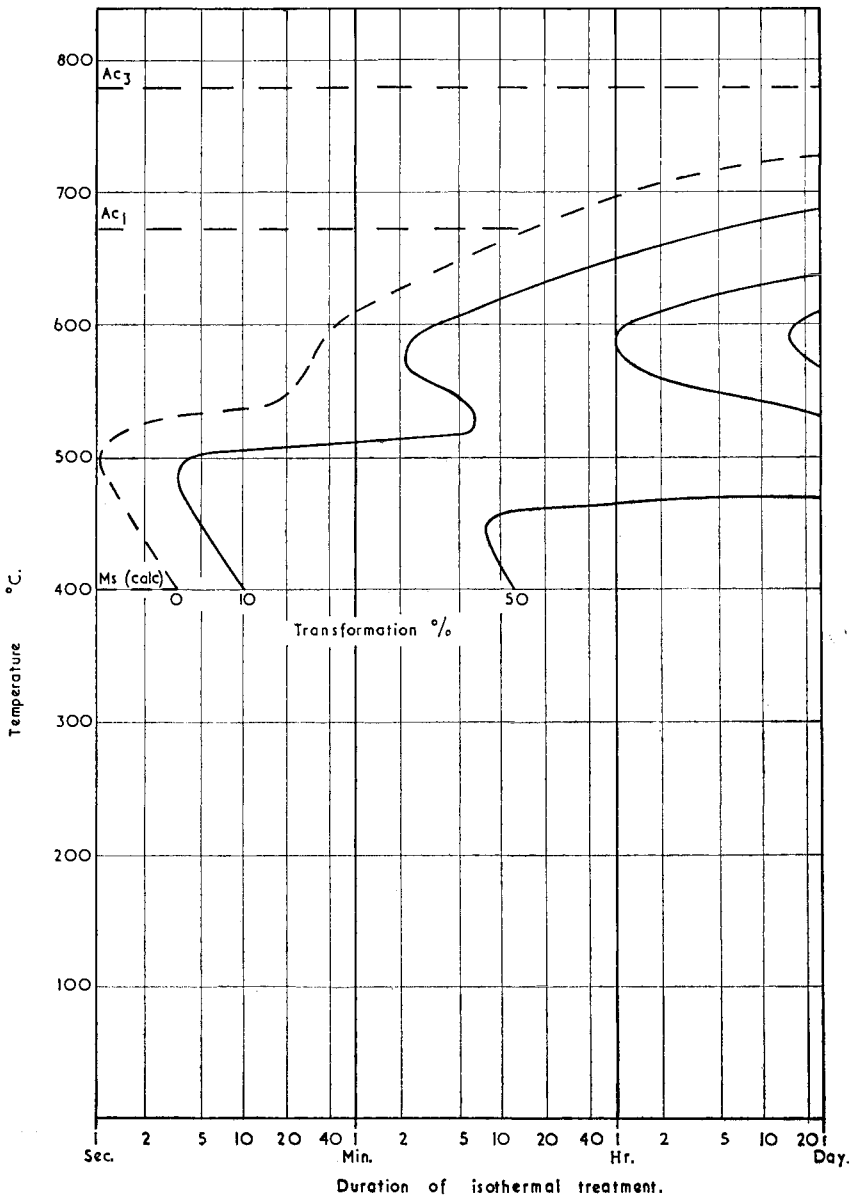


Fig. 39.1

En 39

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·11	0·09	0·38	0·010	0·026	4·15	1·33	0·07

High Frequency Melt.
McQuaid Ehn grain size Finer than 8 (ASTM).
As quenched grain size. Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by water-quenching from 865°C (½hr.) sealed in 1 in. dia. steel tube.

Austenitizing Temperature 865°C, 30 min.

(Ref. 4)

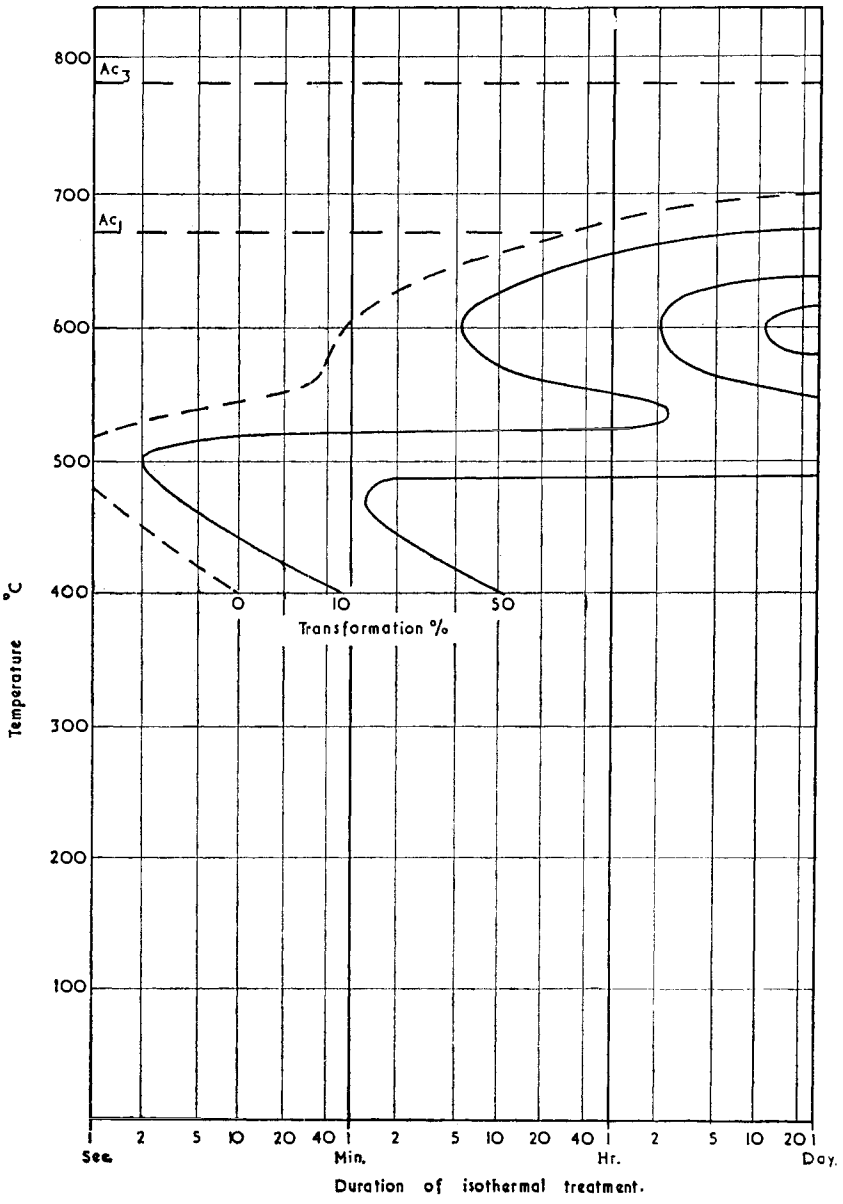


Fig. 39.2

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·54	0·26	0·34	0·019	0·024	3·92	1·28	0·07

High Frequency Melt.
McQuaid Ehn grain size Finer than 8 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to $\frac{3}{4}$ in. dia., annealed and cold drawn to 11 S.W.G wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 865°C, 30 min. (Ref. 4)

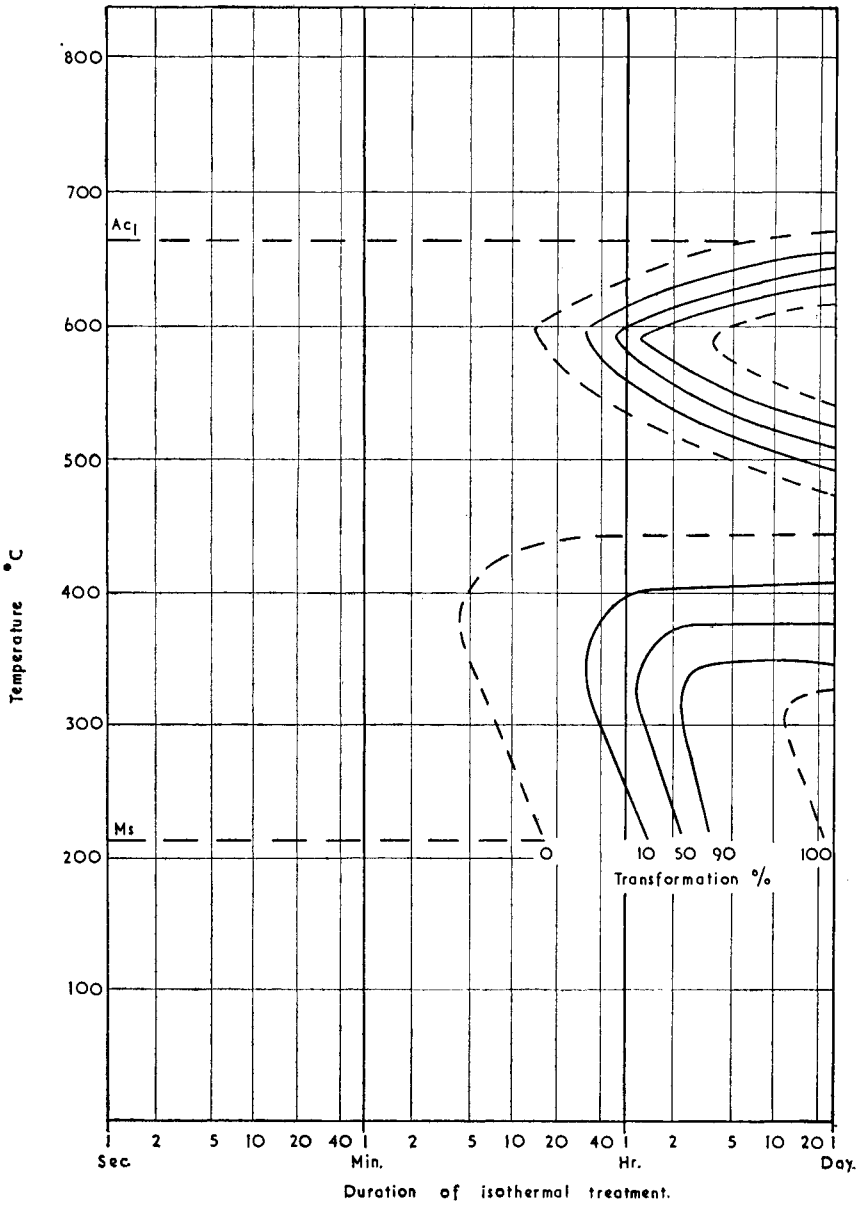


Fig. 39.3

En 39

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·54	0·26	0·34	0·019	0·024	3·92	1·28	0·07

High Frequency Melt.
McQuaid Ehn grain size Finer than 8 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to in. ⅜ dia., annealed and cold drawn to 11 S.W.G. wire, followed by water quenching from 865°C (½hr.) sealed in 1 in. dia. steel tube.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

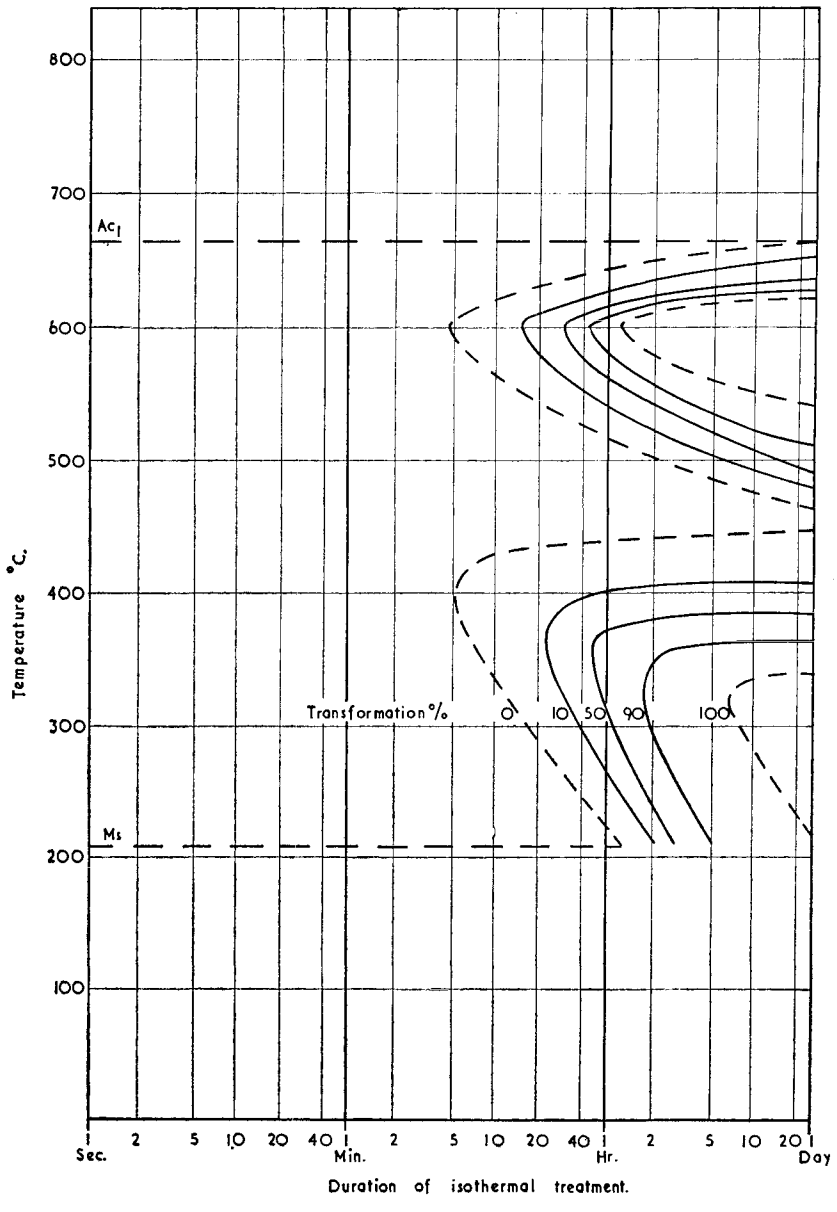


Fig. 39.4

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	1·02	0·27	0·47	0·018	0·029	4·15	1·22	0·05

High Frequency Melt.
McQuaid Ehn grain size Finer than 8 (ASTM).
As quenched grain size 7 (ASTM).
Bars hot rolled to $\frac{3}{4}$ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 865°C, 30 min. (Ref. 4)

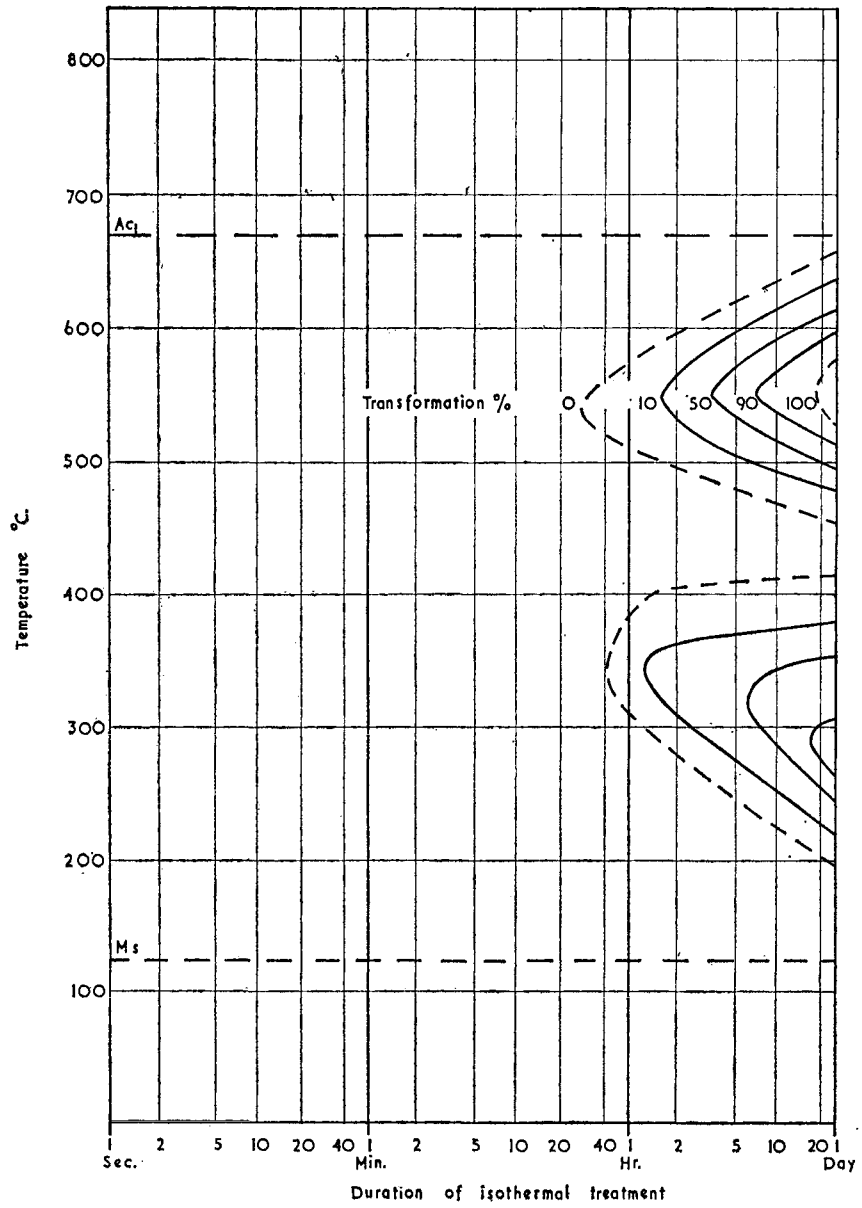


Fig. 39.5

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	1·02	0·27	0·47	0·018	0·029	4·15	1·22	0·05

High Frequency Melt.
McQuaid Ehn grain size Finer than 8 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia., annealed and cold drawn to 11 S.W.G. wire, followed by water-quenching from 865°C (½ hr.) sealed in 1 in. dia. steel tube.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

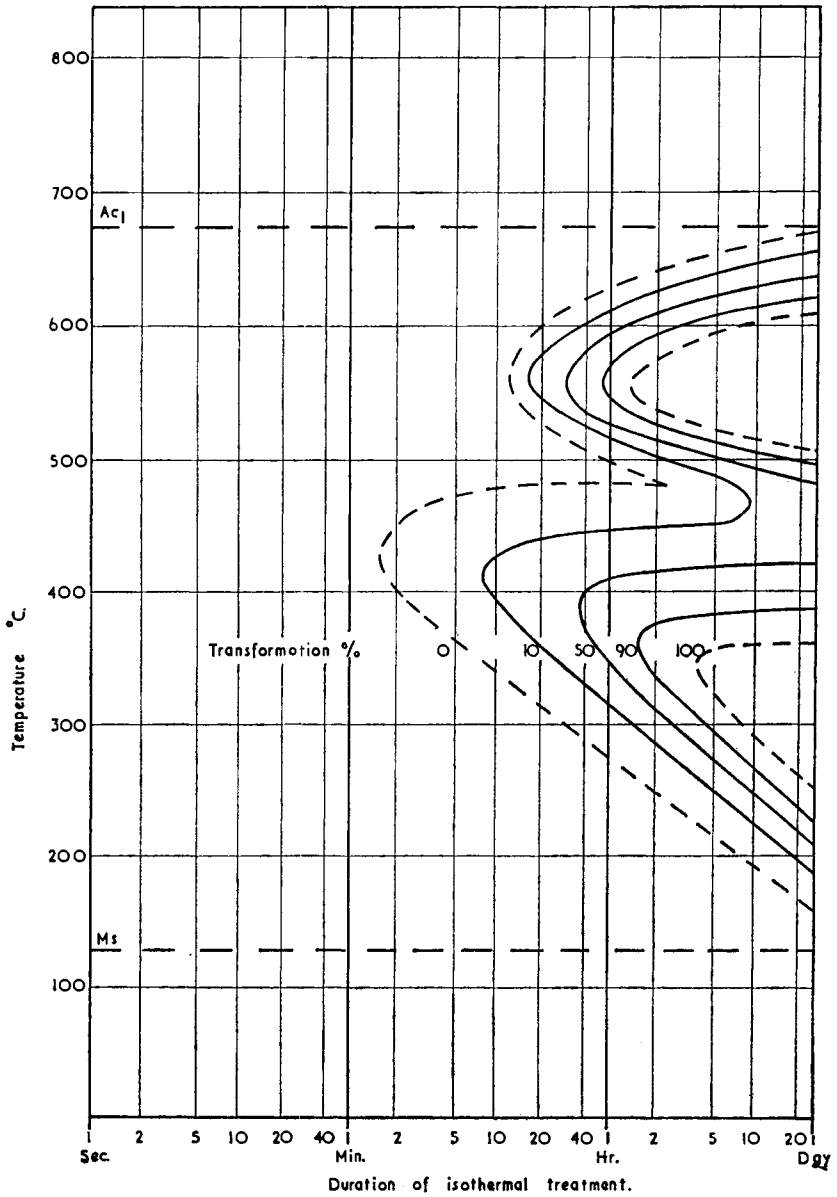


Fig. 39.6

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·15	0·20	0·38	0·018	0·027	4·33	1·16	0·17

Basic Electric Arc.
McQuaid Ehn grain size 2—4 (ASTM).
As quenched grain size 7 (ASTM).
Hot rolled to $\frac{3}{4}$ in. dia. rod, annealed, cold drawn to 9 S.W.G. wire.

Austenitizing Temperature 865°C, 30 min. (Ref. 4)

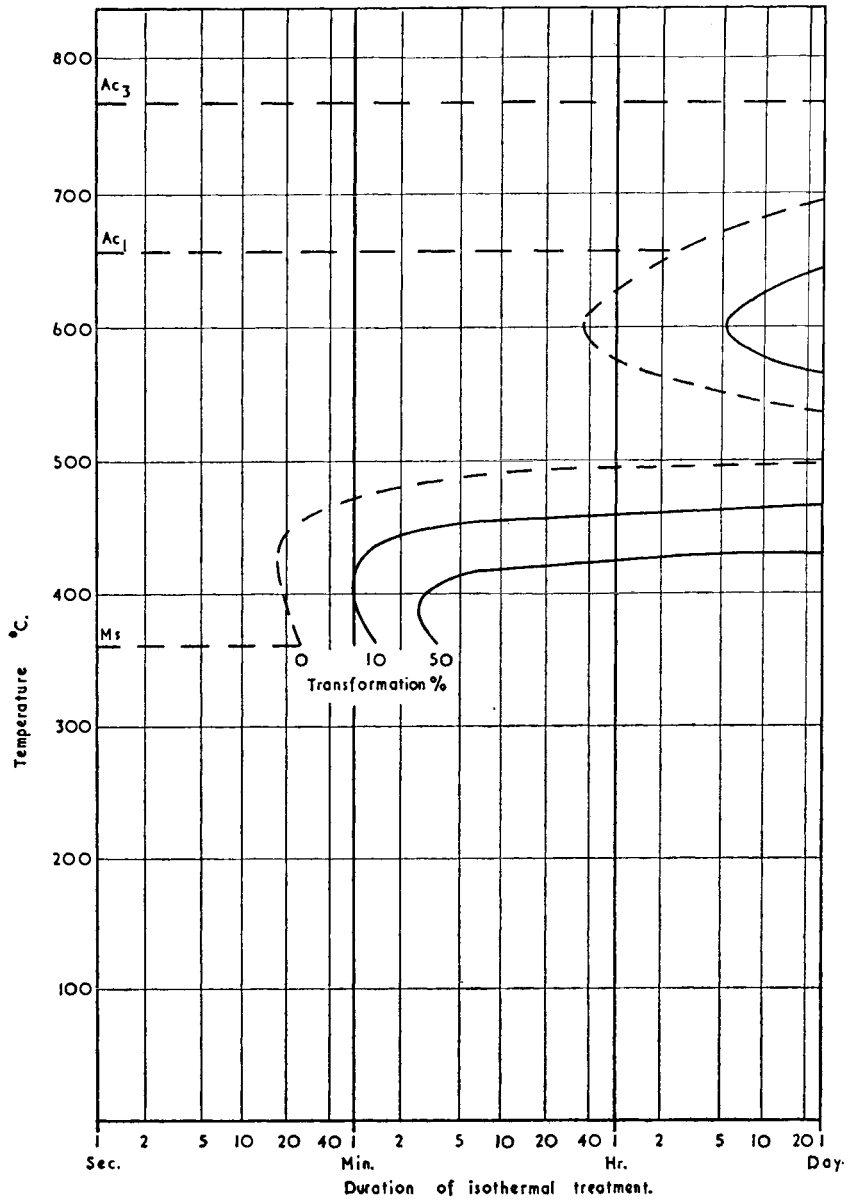


Fig. 39.7

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·15	0·20	0·38	0·018	0·027	4·33	1·16	0·17

Basic Electric Arc.
McQuaid Ehn grain size 2—4 (ASTM).
As quenched grain size Finer than 8 (ASTM).
Bars hot rolled to ⅞ in. dia. rod, annealed, cold drawn to 9 S.W.G. wire, followed by water quenching from 850°C (½ hr.) sealed in 1 in. dia. steel tube.

Austenitizing Temperature 770°C, 30 min.

(Ref. 4)

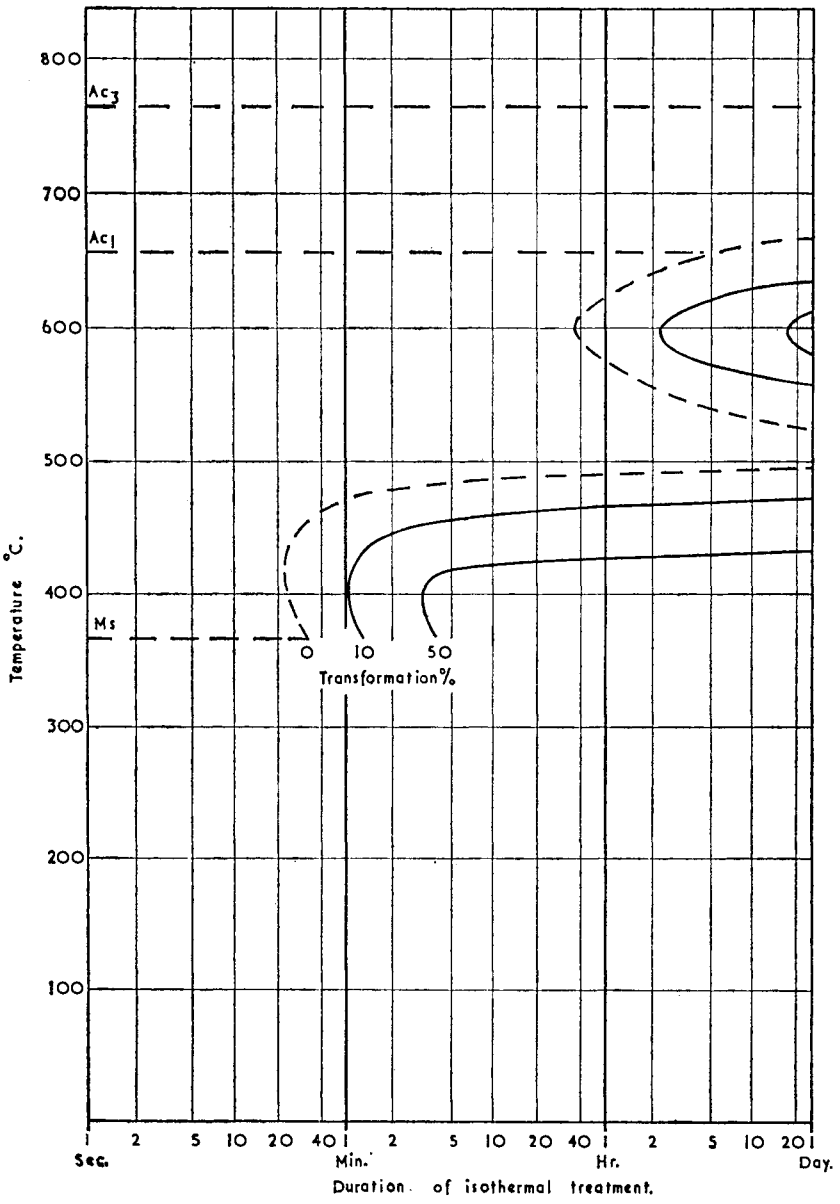


Fig. 39.8

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·56	0·18	0·47	0·028	0·020	4·25	1·16	0·18

High Frequency Melt.
McQuaid Ehn grain size 7—8 (ASTM).
As quenched grain size Mixed 7 and finer.
Hot rolled to ⅞ in. dia. rod, annealed, cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 865°C, 30 min.

(Ref. 4)

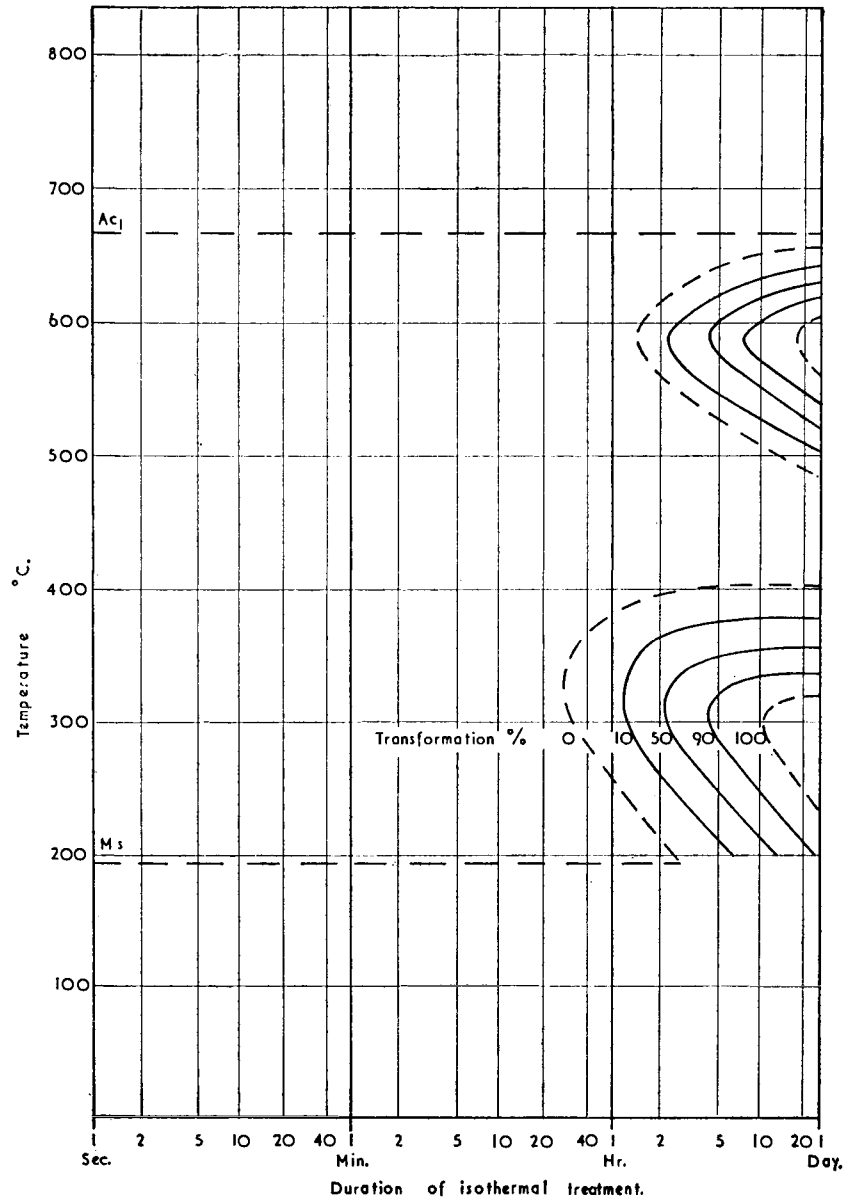


Fig. 39.9

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·56	0·18	0·47	0·028	0·020	4·25	1·16	0·18

High Frequency Melt.
McQuaid Ehn grain size 7—8 (ASTM).
As quenched grain size Mixed finer than 8 (ASTM).
Bars hot rolled to ⅜ in. dia. rod, annealed, cold drawn to 11 S.W.G. wire, followed by water quenching from 865°C (½ hr.) sealed in 1 in. dia. steel tube.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

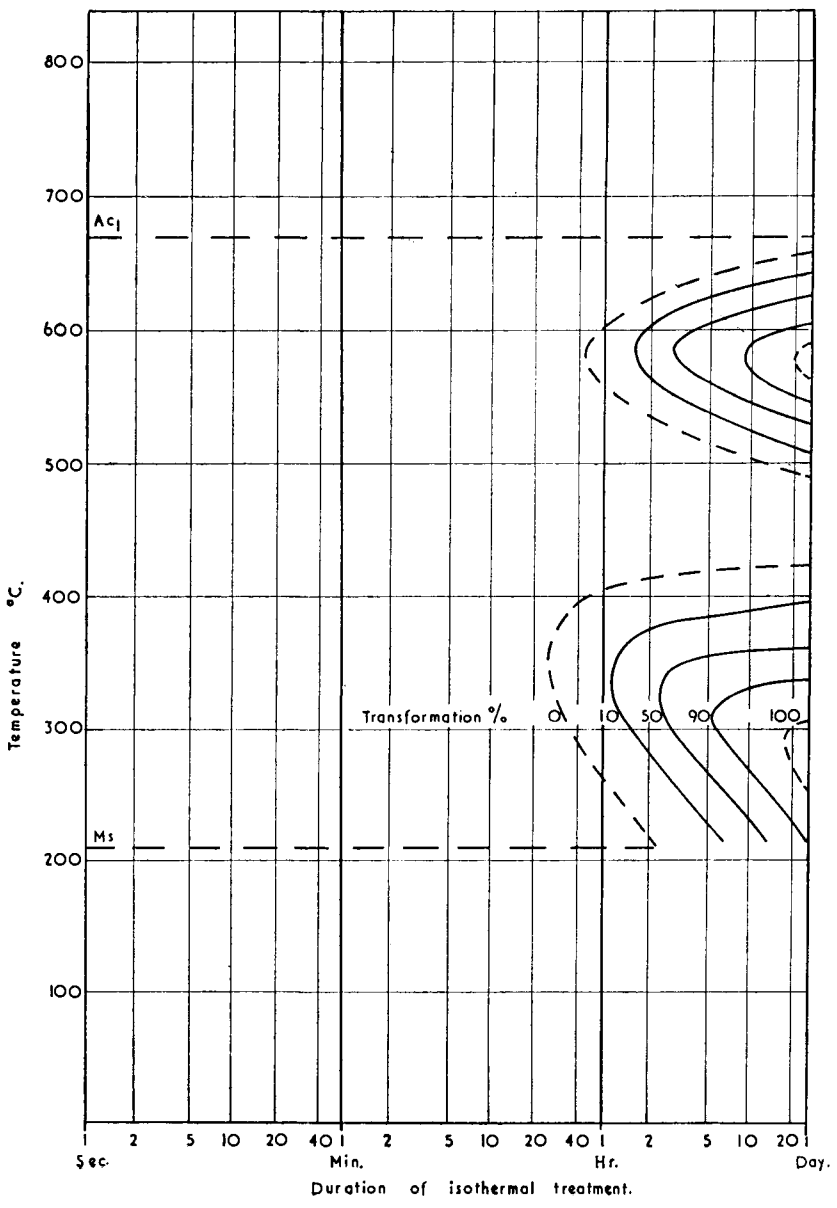


Fig 39.10

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·93	0·30	0·50	0·017	0·026	4·25	1·18	0·16

High Frequency Melt.
McQuaid Ehn grain size 7 and finer (ASTM).
As quenched grain size 8 and finer (ASTM).
Bars hot rolled to $\frac{3}{4}$ in. dia. rod, annealed, cold drawn to 11 S.W.G. wire, followed by 900°C (2 hr.) furnace cool.

Austenitizing Temperature 865°C, 30 min. (Ref. 4)

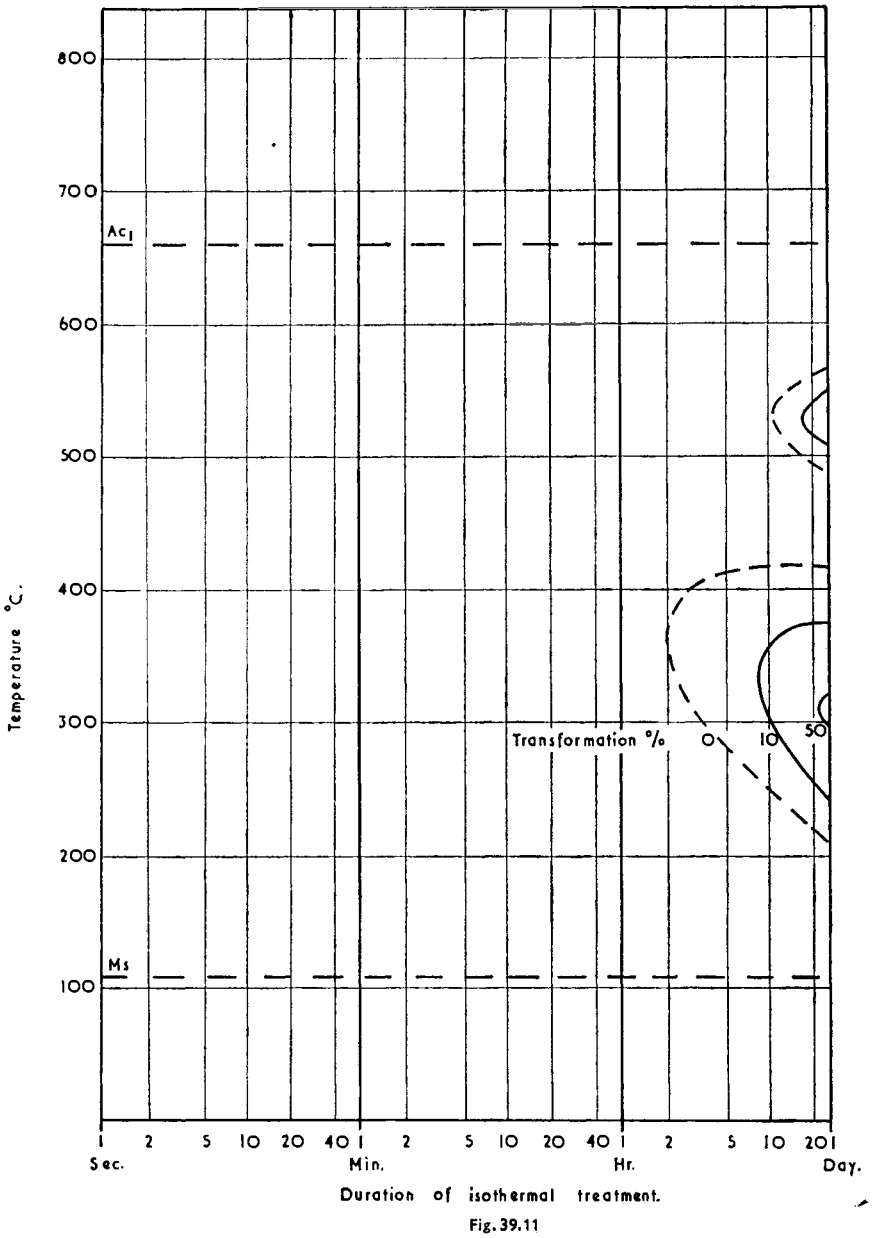


Fig. 39.11

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·93	0·30	0·50	0·017	0·026	4·25	1·18	0·16

High Frequency Melt.
McQuaid Ehn grain size 7 and finer (ASTM).
As quenched grain size Finer than 8 (ASTM).
Hot rolled to ⅜ in. dia. rod, annealed, cold drawn to 11 S.W.G. wire, followed by water quenching from 865°C (½ hr.) sealed in 1 in. dia steel tube.

Austenitizing Temperature 770°C, 30 min. (Ref. 4)

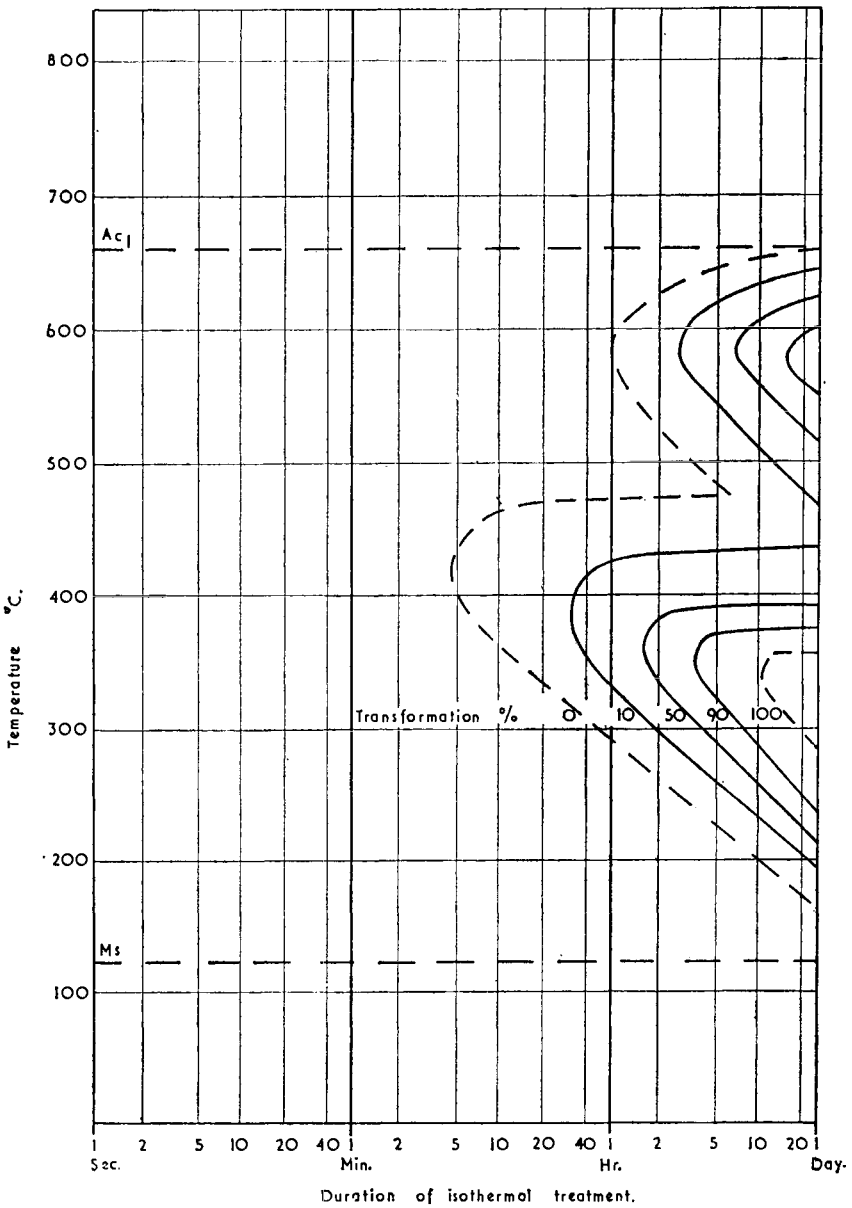


Fig. 39.12

ISOTHERMAL TRANSFORMATION (Continued)

	Chemical Composition (%)					
	C	Si	Mn	Ni	Cr	Mo
En 39B	0·14	0·21	0·34	4·39	1·29	0·34

Austenitizing Temperature 825°C, 30 min.

(Ref. 1)

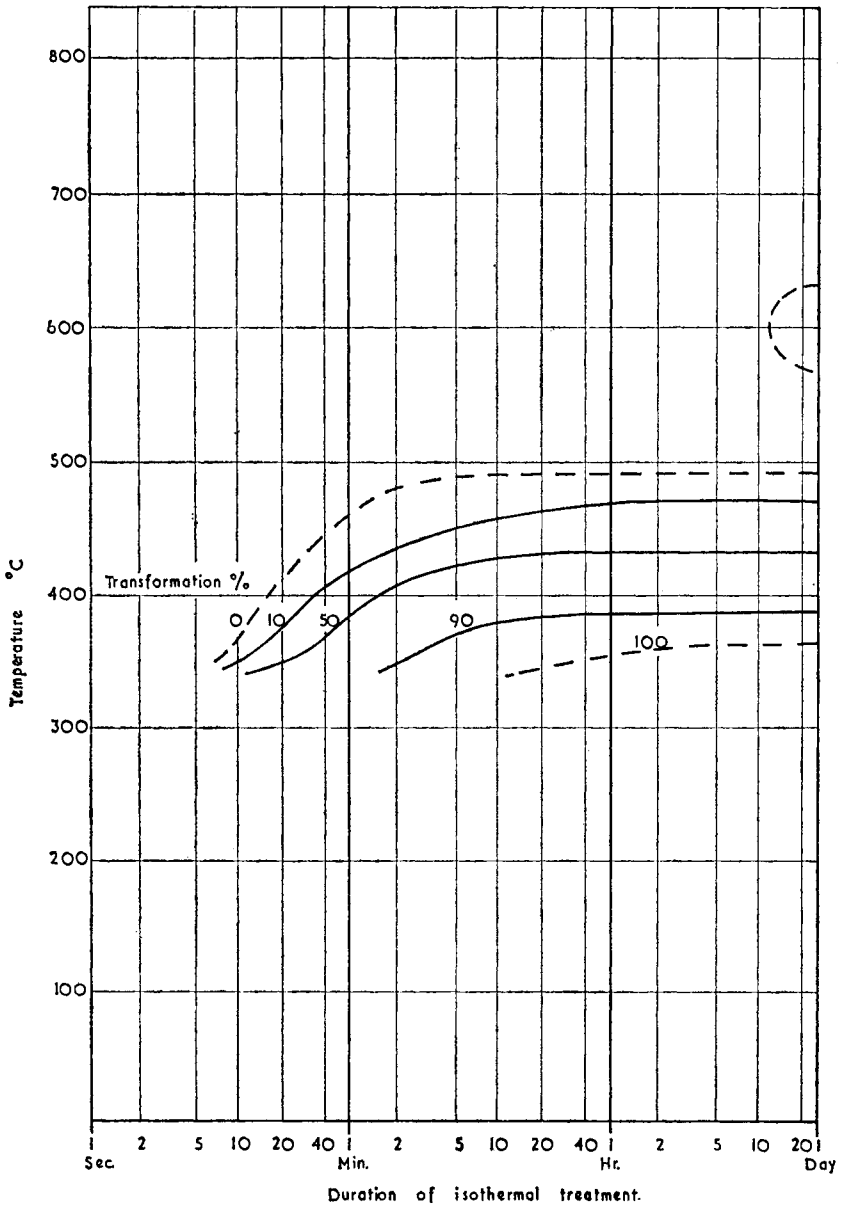


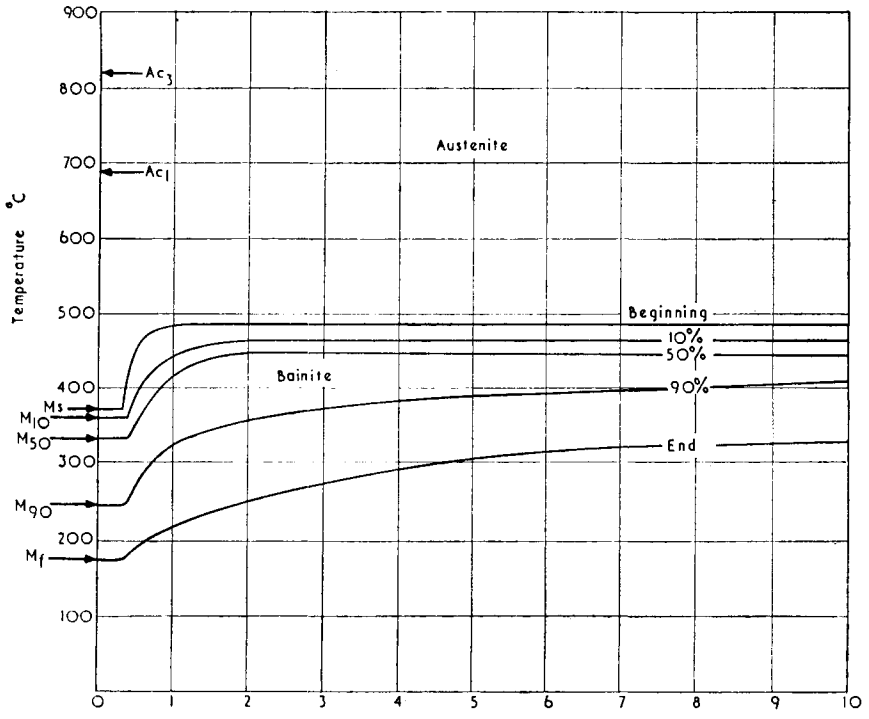
Fig. 39.13

CONTINUOUS COOLING TRANSFORMATION

En 39B

Air Cooled from 800°C.

(Ref. 3)



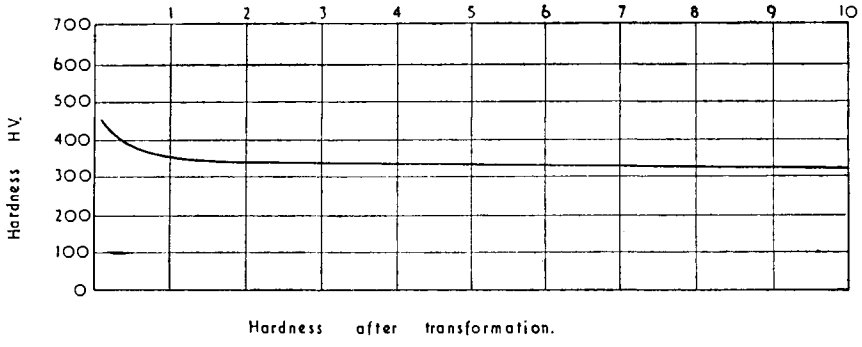


Fig. 39.14

Oil Quenched from 800°C. (Ref. 3)

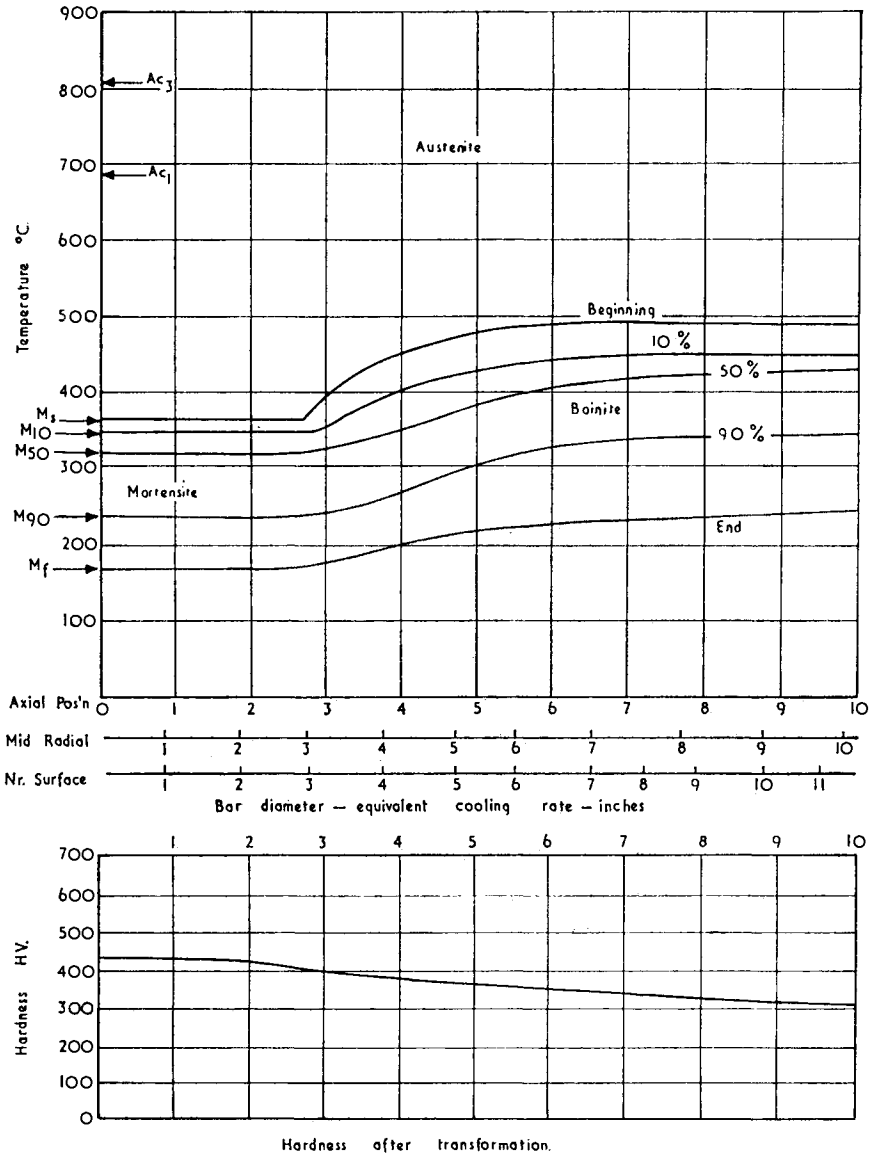


Fig. 39.15

Water Quenched from 800°C. (Ref. 3)

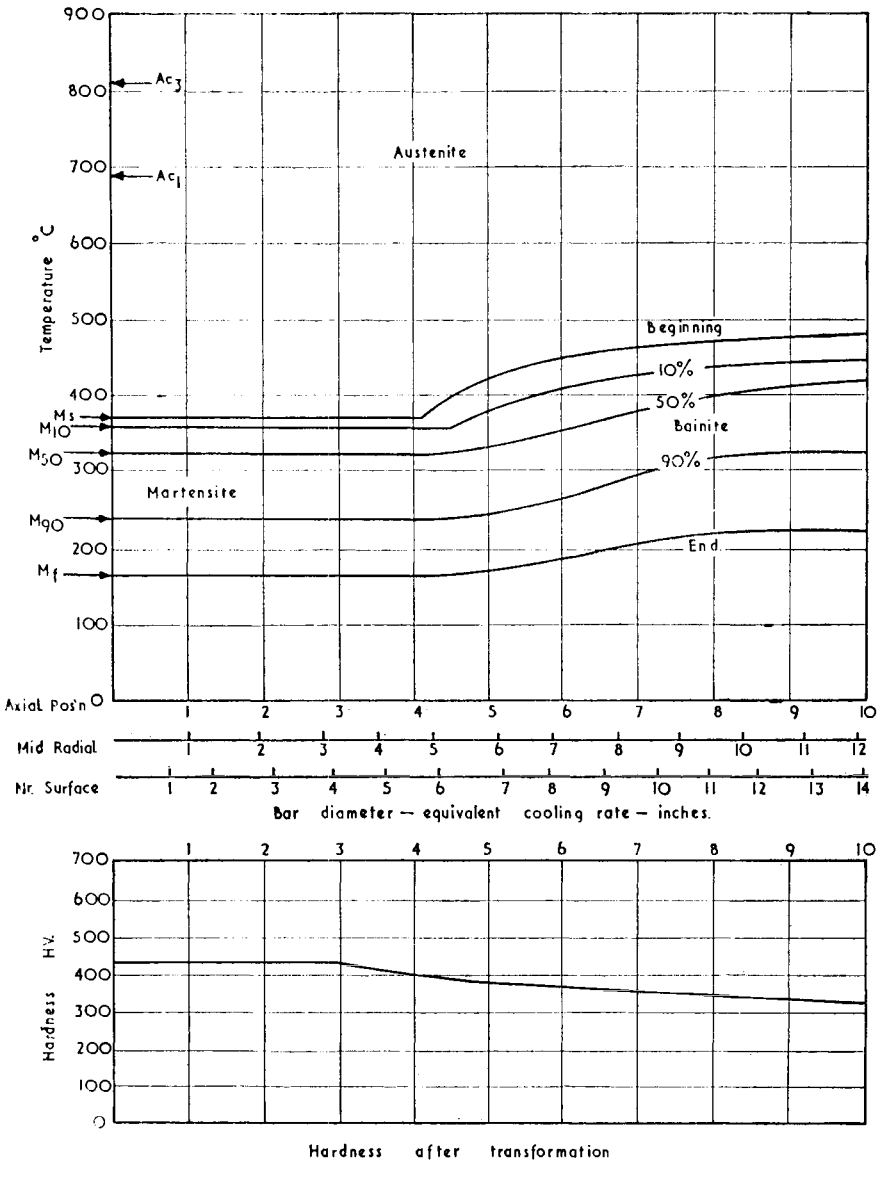


Fig. 39.16

HARDENABILITY

END QUENCH HARDENABILITY DATA

Curve No.	Chemical Composition (%)								Grain Size (ASTM)		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo	Actual	McQuaid Ehn	
A	0·17	0·24	0·47	0·016	0·013	4·30	1·28	0·03	8(7)	6—7(S)(8)	5
B	0·16	0·19	0·43	0·032	0·025	4·05	0·86	0·34	8(7)	8(7)	"

Test Bars Normalized 875°C. End Quenched 825°C.

As quenched from 825°C. (Ref. 5)

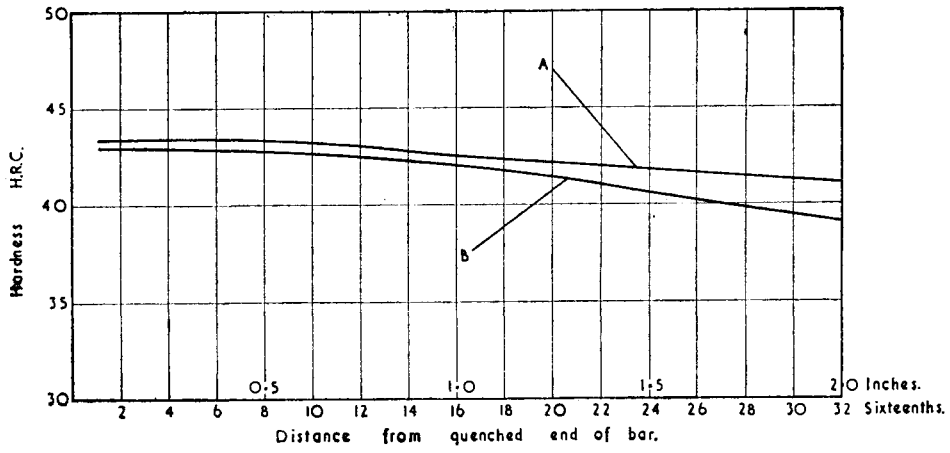


Fig. 39.17

Re-quenched 770°C. (Ref. 5)

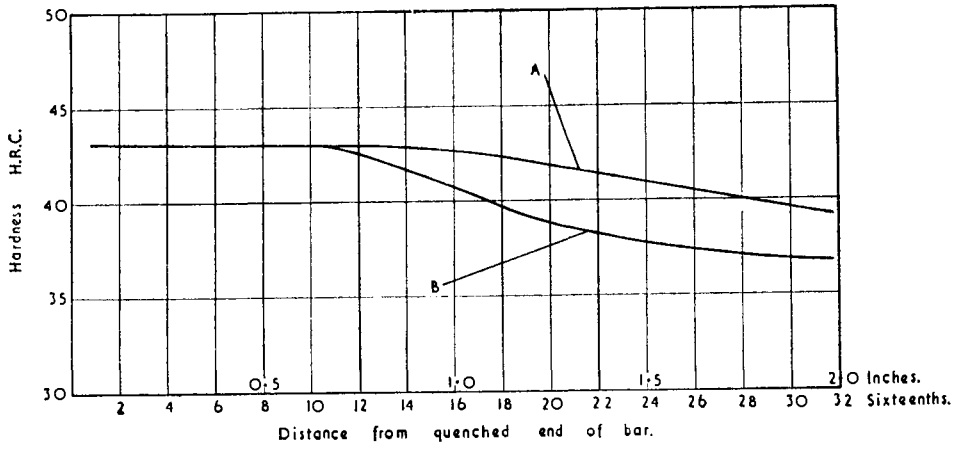


Fig. 39.18

Curve No.	Chemical Composition (%)								End Quenched from	Grain Size (ASTM)		Ref.
	C	Si	Mn	S	P	Ni	Cr	Mo		McQuaid Ehn	As Quenched	
C	0·15	0·20	0·38	0·018	0·027	4·33	1·16	0·17	865°C	2—4	7	4
D	"	"	"	"	"	"	"	"	770°C	"	Finer than 8	"

(Ref. 4)

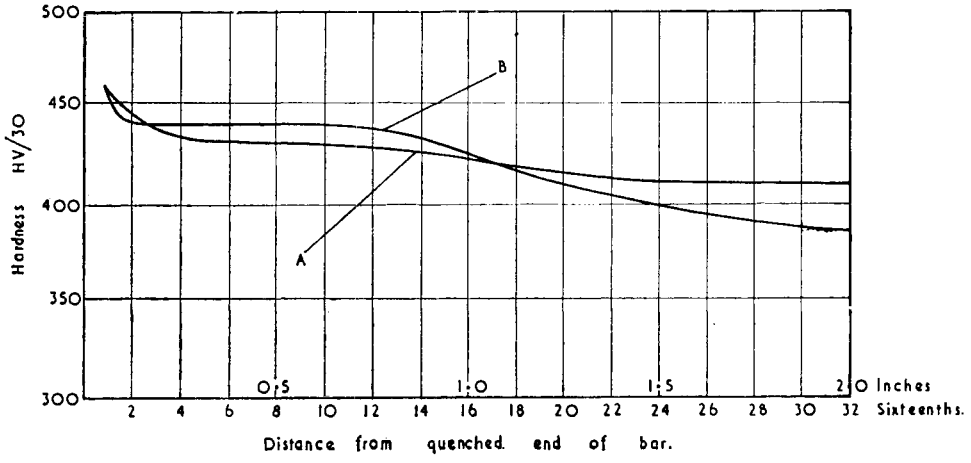


Fig. 39.19

END QUENCH HARDENABILITY BAND

These curves have been constructed from the results obtained on several casts of En 39A and 39B.

(Ref. 2 and 3)

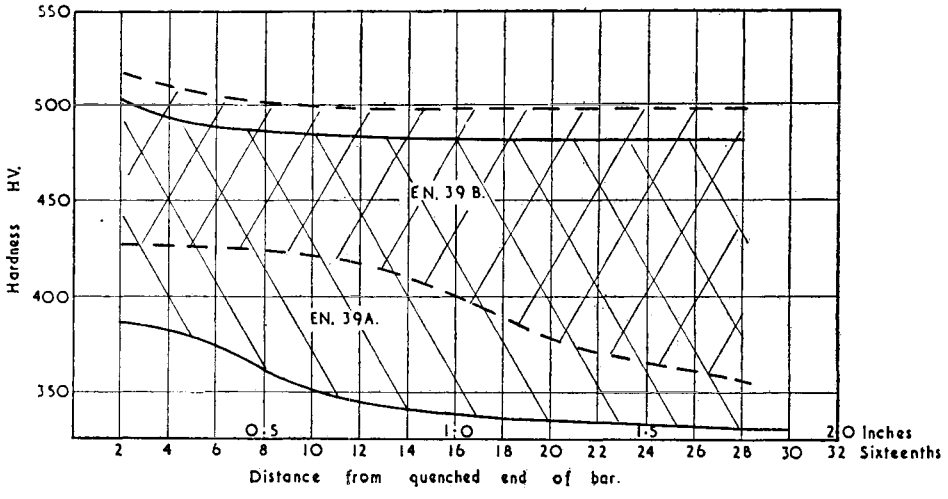


Fig. 39.20

MECHANICAL PROPERTIES AT ROOM TEMPRATURE

Process of Manufacture	ASTM Grain Size	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Tensile 0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)	Izod ft.lb.	Ref.
												tons/sq.in.									
B.E.A.		0·12	0·25	0·46			4·29	1·33	0·35	0·564	OQ850 OQ760					79·6	90·0	16	53½	50	1
B.E.A.		0·12	0·24	0·42			4·02	1·45	0·16	½	" "						86·2	18½	57	46	"
		0·12		0·39			4·27	1·37	0·31	1	OQ830 OQ760 T180					77·3	86·8	16½		42	6
		"		"			"	"	"	2	" " "					74·1	82·1	17½		61	"
		"		"			"	"	"	3	" " "					66·2	78·4	16½		62	"
		"		"			"	"	"	4	" " "					67·1	77·7	16½		62	"
		0·13		0·35			4·26	1·13	—	0·564	OQ830 OQ760 T180						85·2	16		39	7
		0·13	0·27	0·52	0·018	0·021	4·14	1·25	0·08	1⅛	BC OQ860 OQ770						86·0	15	42	24	8
		"	"	"	"	"	"	"	"	"	" " " T200						84·0	15	47	36	"
		"	"	"	"	"	"	"	"	2	" " "						79·2	15	42	28	"
		"	"	"	"	"	"	"	"	"	" " " T200						79·6	15	42	36	"
		"	"	"	"	"	"	"	"	3	" " "						73·6	12	47	24	"
		"	"	"	"	"	"	"	"	"	" " " T200						73·2	16	50	41	"
A.O.H.	7—4	0·13	0·19	0·37	0·024	0·013	4·13	1·42	0·12	1⅛	OQ700	26·7	31·3	37·0	45·2		64·3	19½	52½	49	2
"	"	"	"	"	"	"	"	"	"	"	OQ720	27·7	32·8	38·3	45·8		65·8	23	56	49	"
"	"	"	"	"	"	"	"	"	"	"	OQ740	33·2	41·2	49·2	60·4		74·8	17½	56½	47	"
"	"	"	"	"	"	"	"	"	"	"	OQ760	35·5	43·0	51·0	61·8		74·7	17	57	45	"
"	"	"	"	"	"	"	"	"	"	"	OQ780	37·5	45·0	53·0	64·2		77·2	17	58	39	"
"	"	"	"	"	"	"	"	"	"	"	OQ800	38·9	46·7	54·9	65·9		78·4	17	56	43	"
"	"	"	"	"	"	"	"	"	"	"	OQ820	40·0	46·5	54·2	65·2		77·5	18	56½	41	"
"	"	"	"	"	"	"	"	"	"	"	OQ840	39·0	46·5	54·4	65·3		77·4	16	55	42	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ760	41·3	49·9	57·4	67·6		80·7	16½	57	37	"
"	"	"	"	"	"	"	"	"	"	¾	" " "	47·9	52·3	60·5	69·7		80·5	17	57	41	"
"	"	"	"	"	"	"	"	"	"	1	" " "	43·2	49·1	56·0	65·7		77·8	17	56	41	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	40·8	47·5	54·7	64·0		75·9	18	59	49	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " "	34·0	41·3	49·1	60·7		68·9	19½	60	63	"
"	"	"	"	"	"	"	"	"	"	3	" " "	30·0	37·2	44·1	52·8		66·8	20	60½	67	"
"	"	"	"	"	"	"	"	"	"	4 (O)	" " "	35·6	40·1	45·0	51·7		65·2	23	60½	66	"
"	"	"	"	"	"	"	"	"	"	" (C)	" " "	36·8	41·4	46·9	54·1		68·3	19	59	60	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ760 T200	53·6	59·3	65·1	71·8		80·8	18	58	38	"
"	"	"	"	"	"	"	"	"	"	¾	" " " "	53·2	58·4	64·5	72·4		80·2	16½	55½	40	"
"	"	"	"	"	"	"	"	"	"	1	" " " "	48·6	54·1	60·1	68·0		76·5	18	58	42	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " " "	46·0	52·2	58·9	67·0		75·9	18	58½	44	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " " "	42·6	48·5	53·6	60·7		68·2	20	61	66	"
"	"	"	"	"	"	"	"	"	"	3	" " " "	42·2	46·3	50·9	56·5		66·9	20	60½	66	"
"	"	"	"	"	"	"	"	"	"	4 (O)	" " " "	38·1	42·6	47·3	53·5		65·1	21	61½	67	"
"	"	"	"	"	"	"	"	"	"	" (C)	" " " "	42·5	46·3	50·4	56·5		67·7	18½	60	59	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
A.O.H.	7—4	0·13	0·19	0·37	0·024	0·013	4·13	1·42	0·12	0·424	N900 OQ860 OQ780	38·5	47·3	55·1	66·2	80·0	18	56½	40	2
"	"	"	"	"	"	"	"	"	"	¾	" " "	43·7	50·9	58·6	69·2	80·4	17	55	40	"
"	"	"	"	"	"	"	"	"	"	1	" " "	42·5	49·3	57·0	68·0	77·9	18	59	40	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	37·5	45·5	53·6	64·6	77·1	17	57	41	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " "	36·0	42·0	48·5	58·5	68·5	21	61½	67	"
"	"	"	"	"	"	"	"	"	"	3	" " "	33·2	39·5	46·7	57·4	67·7	20½	59	64	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " "	32·5	38·0	43·9	51·5	65·0	21	61	67	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " "	30·6	37·0	43·8	52·5	67·0	19	60	59	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ860 OQ780 T200	53·0	58·6	64·1	71·8	79·3	16½	56	39	"
"	"	"	"	"	"	"	"	"	"	¾	" " "	52·0	57·2	63·1	72·0	80·5	16	56	38	"
"	"	"	"	"	"	"	"	"	"	1	" " " "	50·0	55·5	61·5	69·5	78·1	17	56½	38	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " " "	48·2	54·0	60·5	68·5	77·1	19	57½	42	"
"	"	"	"	"	"	"	"	"	"	2⅛	" " " "	40·5	46·5	52·0	58·8	68·3	19	59½	64	"
"	"	"	"	"	"	"	"	"	"	3	" " " "	42·0	46·0	50·7	57·0	66·6	19½	62	69	"
"	"	"	"	"	"	"	"	"	"	4(O)	" " " "	38·7	43·4	48·0	54·2	65·2	22	59½	68	"
"	"	"	"	"	"	"	"	"	"	"(C)	" " " "	42·4	46·4	51·2	57·4	68·2	18½	59	58	"
"	"	"	"	"	"	"	"	"	"	0·424	N900 OQ820	40·3	47·3	56·0	68·6	78·9	18	54	40	"
"	"	"	"	"	"	"	"	"	"	¾	" "	43·5	50·6	58·5	68·4	80·4	16	54½	39	"
"	"	"	"	"	"	"	"	"	"	1	" "	44·2	50·6	58·5	67·8	79·4	17	56	42	"
"	"	"	"	"	"	"	"	"	"	1⅛	" "	40·0	46·5	54·2	65·2	77·5	18	57	41	"
"	"	"	"	"	"	"	"	"	"	2⅛	" "	38·8	46·0	52·5	60·5	70·3	18½	59½	59	"
"	"	"	"	"	"	"	"	"	"	3	" "	35·0	42·4	49·6	58·0	67·8	18	61	61	"
"	"	"	"	"	"	"	"	"	"	4(O)	" "	30·9	38·2	45·2	54·0	65·0	20½	60½	68	"
"	"	"	"	"	"	"	"	"	"	"(C)	" "	35·8	41·9	48·5	57·7	68·4	19	59	58	"
"	"	"	"	"	"	"	"	"	"	0·424	N900	28·9	35·4	42·9	51·6	63·9	18½	57	57	"
"	"	"	"	"	"	"	"	"	"	¾	"	31·2	38·0	44·7	52·6	65·5	19	54½	56	"
"	"	"	"	"	"	"	"	"	"	1	"	31·5	37·6	44·3	52·2	64·4	19	57½	59	"
"	"	"	"	"	"	"	"	"	"	1⅛	"	31·2	37·0	44·1	51·7	64·3	20½	54½	57	"
"	"	"	"	"	"	"	"	"	"	2⅛	"	30·0	35·8	41·8	50·3	62·2	20½	57½	54	"
"	"	"	"	"	"	"	"	"	"	3	"	30·9	36·2	42·0	48·9	61·0	20	58	46	"
"	"	"	"	"	"	"	"	"	"	4 (O)	"	30·4	35·6	42·0	50·5	61·1	20½	56½	45	"
"	"	"	"	"	"	"	"	"	"	" (C)	"	32·4	37·8	43·5	51·6	61·0	21	55½	43	"
		0·13		0·38			4·00	1·18	0·24	0·564	OQ870 OQ760 T180					85·2	16		41	7

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile							Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Tm)	El % (A)	R.A. % (Z)		
												tons/sq.in.								
B.E.A.		0·13	0·31	0·41			4·19	1·44	0·19	½	OQ850 OQ750					86·6	1	55	42	1
		0·14	0·26	0·40	0·012	0·007	4·33	1·15		0·219	BC OQ850 OQ780 T140	61·3	67·6	75·5		88·8		66	—	1
		"	"	"	"	"	"	"		0·344	" " " "	59·8	66·8	76·4		90·2	10½	61	—	"
		"	"	"	"	"	"	"		0·562	" " " "	58·1	64·8	77·0		89·8	13	61	50	"
		"	"	"	"	"	"	"		0·875	" " " "	57·2	64·8	75·4		90·9	17	61	45	"
		"	"	"	"	"	"	"		1·25	" " " "	55·0	62·3	73·0		88·4	18½	62	51	"
		"	"	"	"	"	"	"		0·219	BC OQ880 OQ780 T140	62·5	69·5	77·0		89·6		66	—	"
		"	"	"	"	"	"	"		0·344	" " " "	60·1	67·0	75·8		89·3	10½	62	—	"
		"	"	"	"	"	"	"		0·562	" " " "	57·6	64·9	77·1		89·5	17	59	49	"
		"	"	"	"	"	"	"		0·875	" " " "	58·4	65·7	75·7		91·3	17	62	47	"
		"	"	"	"	"	"	"		1·25	" " " "	54·4	62·2	72·9		88·7	18	62	51	"
		"	"	"	"	"	"	"		1·25	BC OQ870 T140	49·0	57·4	66·8		86·3	18	61	50	"
		0·14	0·24	0·39			4·40	1·26		0·564	OQ850 OQ760				80·4	88·4	16	49½	44	"
		0·14		0·40			3·93	1·16		0·564	OQ860 OQ760 T150				81·8	89·0	16½		43	6
		0·14	0·17	0·40			4·19	1·30	0·14	½	OQ850 OQ760					89·6	17½	56	47	1
		0·14	0·21	0·38	0·014	0·010	4·20	1·23	0·26	¼	BC870 OQ810 T140	63·4				87·2	20		—	1
		"	"	"	"	"	"	"	"	¾	" " "	59·8				90·0	18		35	"
		"	"	"	"	"	"	"	"	1¼	" " "	57·3				87·2	16		49	"
		"	"	"	"	"	"	"	"	½	" " "	57·5				89·5	17		32	"
		"	"	"	"	"	"	"	"	¾	" " "	48·3				87·7	16		33	"
		"	"	"	"	"	"	"	"	1	" " "	48·2				86·5	16		32	"
		0·14	0·22	0·43			4·34	1·31	0·35	2	OQ850 OQ760				70·0	78·6	15	43	45	"
		"	"	"			"	"	"	4	" "				70·5	78·8	17	53	60	"
		0·14		0·44			4·36	1·23	0·26	0·564	OQ860 OQ760 T150				79·2	89·5	17½		48	6
	McQuaid	0·15		0·37			4·38	1·25		0·564	OQ830 OQ760 T150	63·6	68·8	76·8		89·0	18½	59	57	3
	4	0·15		0·42			4·34	1·16		0·564	" " "				88·0	90·8	17	57	44	"
		0·15		0·45			4·00	1·22		0·564	OQ830 OQ760 T180					90·4	16		41	7
		0·15		0·46			4·36	1·09	0·03	1¼	BC OQ870 OQ780 T140	61·0	73·2			86·8	17	55½	43	1
		0·15	0·27	0·48			4·29	1·24		½	OQ850 OQ770				80·4	92·4	15	51	56	"
		"	"	"			"	"		2½	" "				68·4	78·0	19	57	50	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile				Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			Y.P. (Rs) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)		
		0·15	0·23	0·42			4·25	1·28		½	OQ850 OQ770	77·3	94·2	17	53	40	1
		"	"	"			"	"		⅞	" "	75·1	95·2	18	53	32	"
		"	"	"	"		"	"		1⅛	" "	78·8	95·6	16	52	30	"
		"	"	"			"	"		2½	" "	71·1	89·5	17	54	38	"
		"	"	"			"	"		4	" "	57·2	74·8	22	55	60	"
		0·15	0·27	0·48			4·29	1·24		0·564	OQ850 OQ760	80·4	92·4	15	51	56	"
		"	"	"			"	"		2½	" "	68·4	78·0	19	57	50	"
B.E.A.		0·15	0·26	0·43	0·010	0·017	4·35	1·25		1⅛	OQ830 T610WQ	48·0	53·2	26½	73½	100	"
		0·15	0·27	0·42			4·30	1·16	0·14	0·564	BC900 OQ860 OQ760 T200		89·0	14	52½	49	2
		0·15	0·23	0·41			4·26	1·18	0·15	0·564	" " " "		87·0	14	52½	57	"
		0·15	0·22	0·41			4·16	1·18	0·23	½	OQ850 OQ760		91·4	16½	54	42	1
B.E.A.		0·16	0·21	0·46			4·37	1·29		1⅛	OQ850 OQ760	81·2	93·2	15	51	41	1
"		"	"	"			"	"		3	" "	70·4	78·0	13½	36	54	"
B.E.A.		0·16	0·20	0·38	0·011	0·017	4·28	1·33		1⅛	OQ830 T610 WQ	46·6	53·0	27½	73½	101	"
"		"	"	"	"	"	"	"		"	" T450 "	66·0	70·4	20	62½	19	"
"		"	"	"	"	"	"			"	" T250 "	72·8	84·8	17	61½	55	"
		0·16		0·40			4·25	1·25		1⅛	OQ830 OQ760 T160	76·0	88·2	13		38	7
		"		"			"	"		"	OQ760 T160	74·2	87·8	12½		32	"
		0·16	0·25	0·39			4·39	1·11	0·30	0·564	BC900 OQ860 OQ760 T200		89·0	16	55	40	2
	McQuaid Ehn Accual																
B.E.A.	8(7) 8(7)	0·16	0·19	0·43	0·032	0·025	4·05	0·86	0·34	1	N875 OQ825 T150	71·5	89·3	16	54½	24	5
														$4\sqrt{A}$ 5D			
B.E.A.		0·16	0·22	0·38	0·007	0·013	4·19	1·27	0·25	1⅛	BC925 OQ850 OQ760	65·0	83·7	18 15	61		1
		0·16		0·43			4·27	1·33	0·24	0·564	OQ770 T180		91·6	16		34	7
		0·16	0·19	0·43			4·17	1·25	0·24	½	OQ850 OQ760		95·8	16	49	37	1
	3—4	0·16		0·42			4·22	1·42	0·20	0·564	OQ850 OQ760 T180	72·3	91·8	15	53½	34	3
	2—4	0·16		0·47			4·16	1·45	0·14	0·564	OQ830 OQ760 T150	82·8	92·6	15½	52	30	"
	3—4	0·16		0·47			4·18	1·43	0·15	0·564	" " "	81·2	91·2	16½	57	34	"

MECHANICAL PROPERTIES AT ROOM TEMPERATURE (Continued)

Process of Manufacture	ASTM Grain Size	Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile								Izod ft.lb.	Ref.
		C	Si	Mn	S	P	Ni	Cr	Mo			0·05% P.S. (0·05Rp)	0·1% P.S. (0·1Rp)	0·2% P.S. (0·2Rp)	0·5% P.S. (0·5Rp)	Y.P. (Rs)	T.S. (Rm)	El % (A)	R.A. % (Z)		
												tons/sq.in.									
B.E.A.	7—6	0·16	0·22	0·38	0·014	0·018	4·28	1·41	0·23	0·564	N900 OQ860 OQ780	43·0	50·5	59·2	72·0		89·4	17½	54½	36	2
"	"	"	"	"	"	"	"	"	"	¾	" " "						88·0	15½	56	36	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " "	49·4	55·8	62·6	71·9		85·7	18	58½	38	"
"	"	"	"	"	"	"	"	"	"	2½	" " "	42·8	48·6	55·4	64·2		78·2	17½	60	51	"
"	"	"	"	"	"	"	"	"	"	3½	" " "	35·5	41·3	48·0	57·4		74·6	19½	60	59	"
"	"	"	"	"	"	"	"	"	"	0·564	" " " T200	62·6	67·0	72·4	79·9		87·6	16	56½	32	"
"	"	"	"	"	"	"	"	"	"	¾	" " " "						87·3	15½	56	35	"
"	"	"	"	"	"	"	"	"	"	1⅛	" " " "	57·0	62·0	67·7	74·5		84·4	17	56½	39	"
"	"	"	"	"	"	"	"	"	"	2½	" " " "	43·3	48·7	55·3	63·5		76·7	19	60½	54	"
"	"	"	"	"	"	"	"	"	"	3¼	" " " "	38·8	45·3	52·1	59·6		73·8	19½	60½	64	"
B.E.A.	McQuaid Actual Ehn 6—7(5,8) 8(7)	0·17	0·24	0·47	0·016	0·013	4·30	1·28	0·03	1	N875 OQ825 T150					78·9	90·8	17½	55	40	5
		0·17		0·37			4·40	1·20		0·564	OQ860 OQ760 T150					81·6	89·0	16½		43	6
		0·17	0·18	0·43			4·27	1·13	0·12	0·564	BC900 OQ860 OQ760 T200						91·0	14½	52½	52	2
		0·17	0·18	0·42			4·25	1·14	0·15	0·564	" " " "						89·8	12½	50	55	"
		0·17	0·38	0·52	0·009	0·012	4·35	1·25	0·25	0·564	BC900 OQ870 OQ770 T200						96·0	17	52½	40	8
		"	"	"	"	"	"	"	"	"	BC900 OQ770						100·0	15	47	44	"
		0·17	0·24	0·41			4·28	1·36	0·27	½	OQ850 OQ760						96·2	17	50	42	1
		0·18		0·40			4·25	1·24		0·564	OQ830 OQ760 T180						97·2	16		30	7
B.E.A.		0·18	0·23	0·42			4·28	1·41		½	OQ850 OQ760					88·0	98·4	15	44½	57	1
		"	"	"			"	"		2½	" "					83·6	93·2	17	57	44	"
"		0·18	0·26	0·45			4·31	1·28	0·12	0·564	BC900 OQ860 OQ760 T200						90 6	13	50	46	2
		0·18		0·36			4·11	1·12	0·25	0·564	OQ860 OQ770 T180						95·2	15		31	7
B.E.A.		0·18	0·20	0·43			4·13	1·23	0·26	½	OQ850 OQ760					87·2	98·5	17	56	50	1
"		"	"	"			"	"	"	⅞	" "					82·2	99·4	18	54	40	"
"		"	"	"			"	"	"	1⅛	" "					82·8	98·4	17	54	40	"
"		"	"	"			"	"	"	4	" "					60·5	78·8	20	55	69	"
B.E.A.		0·18	0·23	0·52			4·25	1·35	0·28	0·564	OQ850 OQ760					82·4	98·4	14½	42	41	"
		0·18		0·42			4·28	1·12	0·24	0·564	OQ850 OQ760 T150					90·0	96·0	16½		50	6
		0·18		0·44			4·02	1·44	0·15	0·564	OQ860 T200					87·2	92·1	14½	47	31	3
		"		"			"	"	"	"	" T300					86·2	88·1	14½	52	27	"
		"		"			"	"	"	"	" T400					80·5	82·2	15	52	17	"
		"		"			"	"	"	"	" T450					75·7	77·5	17	55	20	"
		"		"			"	"	"	"	" T500					70·0	73·2	17½	57	19	"
		"		"			"	"	"	"	" T550					59·2	62·7	19½	62	33	"
		"		"			"	"	"	"	" T600					52·5	58·0	22½	64	66	"
		"		"			"	"	"	"	" T650					47·2	4·3	24	66	81	"

EFFECT OF TEMPERING ON CASE HARDNESS (TYPICAL VALUES)

Chemical Composition (%)	Heat Treatment °C	Hardness HV				Ref.
		Tempering Temperature				
		RT	100°C	150°C	200°C	
(within specification range)	Air hardened	769		707	666	3
" " "	Oil hardened	804	786	725	690	"
" " "	OQ860 OQ750	802	786	729	694	"

EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES AT ROOM TEMPERATURE

Chemical Composition (%)				
C	Mn	Ni	Cr	Mo
0·18	0·44	4·02	1·44	0·15

Heat treatment at 0.564 in. dia. (test piece size).
Bars oil quenched 860°C. Tempered as indicated.

(Single quench)

(Ref. 3)

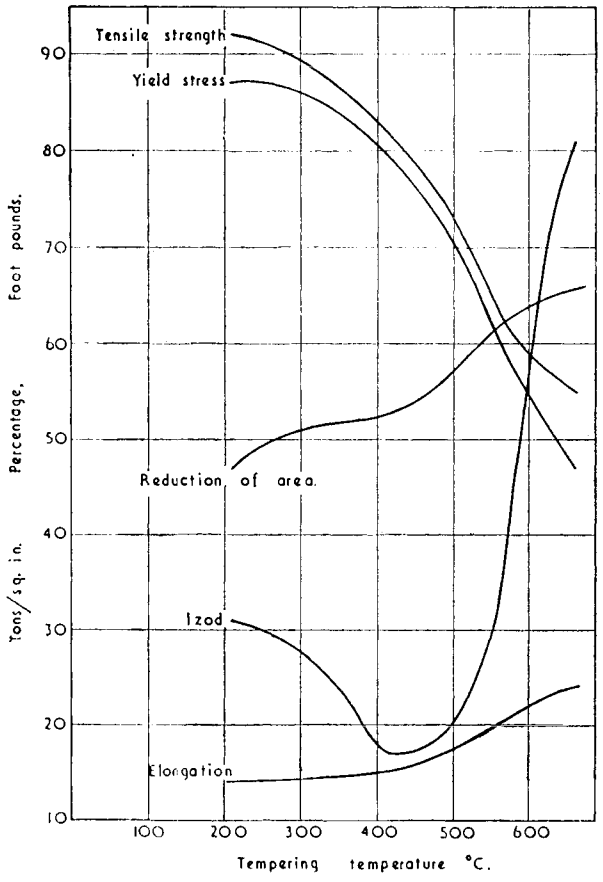


Fig. 39.21

EFFECT OF TEMPERING ON MECHANICAL PROPERTIES AT ROOM TEMPERATURE

(Continued)

Chemical Composition (%)							
C	Si	Mn	S	P	Ni	Cr	Mo
0·16	0·22	0·44	0·010	0·015	4·00	1·29	0·22

Heat Treatment at test piece size.
Bars Oil Quenched 850°C as indicated.
Oil Quenched 770°C tempered (double quench).

(Ref. 8)

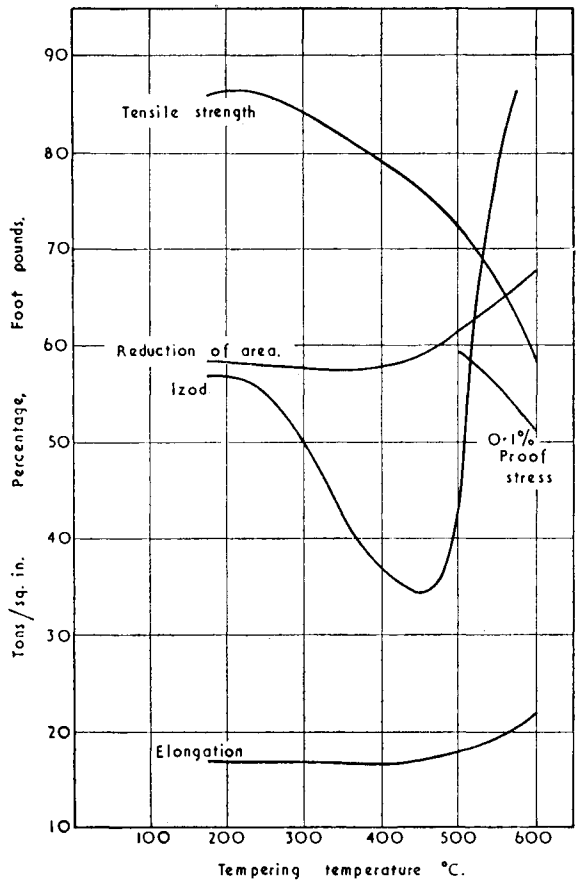


Fig. 39.22

EFFECT OF TEMPERING TEMPERATURE ON CASE HARDNESS

Curve No.	En No.	Heat Treatment °C
A	En 39A	Carburized 900 Refined 860 OQ Harden 780 OQ
B	En 39B	Carburized 900 Refined 800 OQ Harden 760 OQ

(Ref. 2)

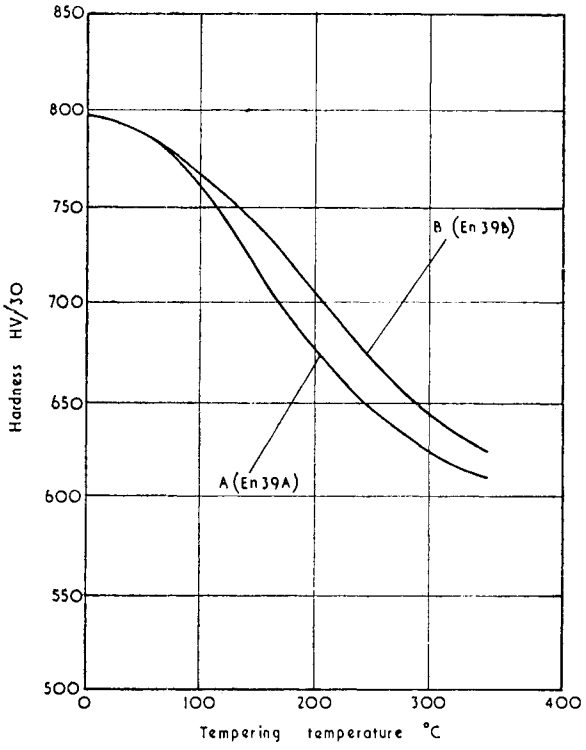


Fig. 39.23

EFFECT OF SECTION SIZE ON CORE PROPERTIES

	Chemical Composition (%)							
En 39A	C	Si	Mn	S	P	Ni	Cr	Mo
	0·13	0·19	0·37	0·024	0·013	4·13	1·42	0·12

McQuaid Ehn grain size 7—4 (ASTM).

Blank Carburize 900°C.
Refined 860°C OQ.
Harden 780°C OQ.

(Ref. 2)

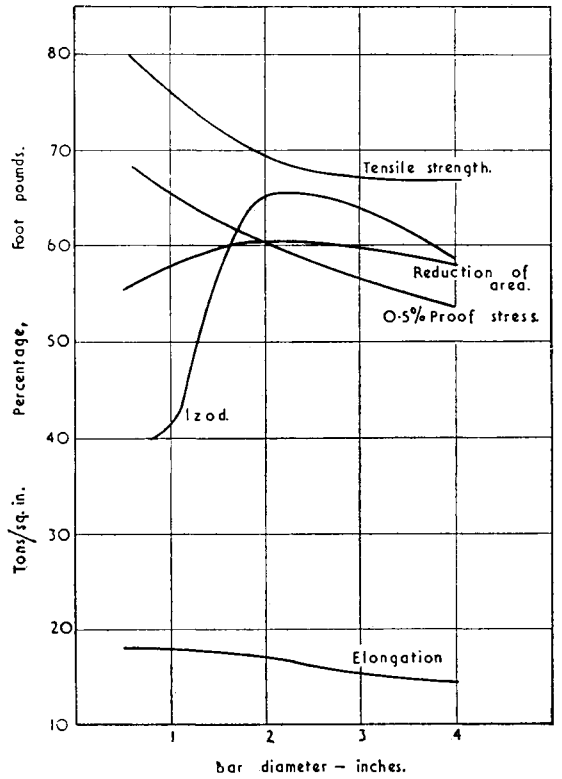


Fig. 39.24

Blank Carburize 900°C.
Harden 820°C OQ.
(Single quench).

(Ref. 2)

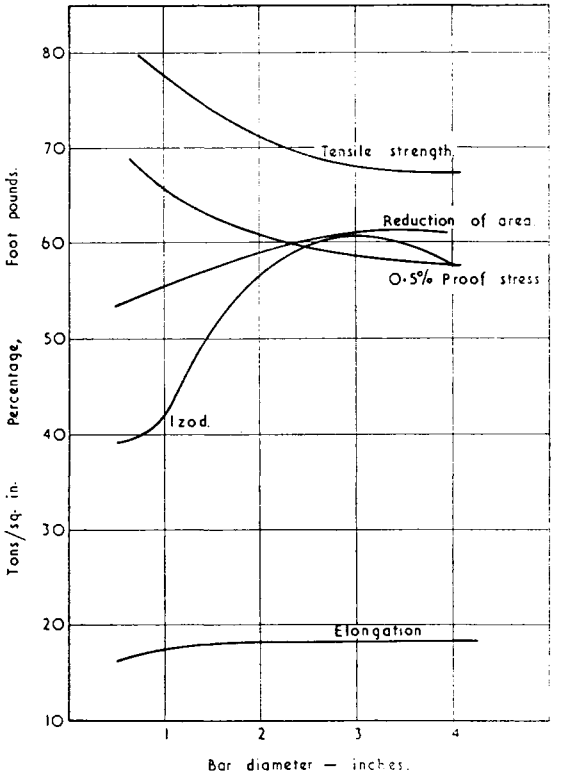


Fig. 39.25

EFFECT OF SECTION SIZE ON CORE PROPERTIES (Continued)

	Chemical Composition (%)							
En 39B	C	Si	Mn	S	P	Ni	Cr	Mo
	0·16	0·22	0·38	0·014	0·018	4·28	1·41	0·23

McQuaid Ehn grain size 7—6 (ASTM).

Blank Carburize 900°C.
Refine 860°C. Oil Quenched.
Harden 780°C. Oil Quenched.

(Ref.2)

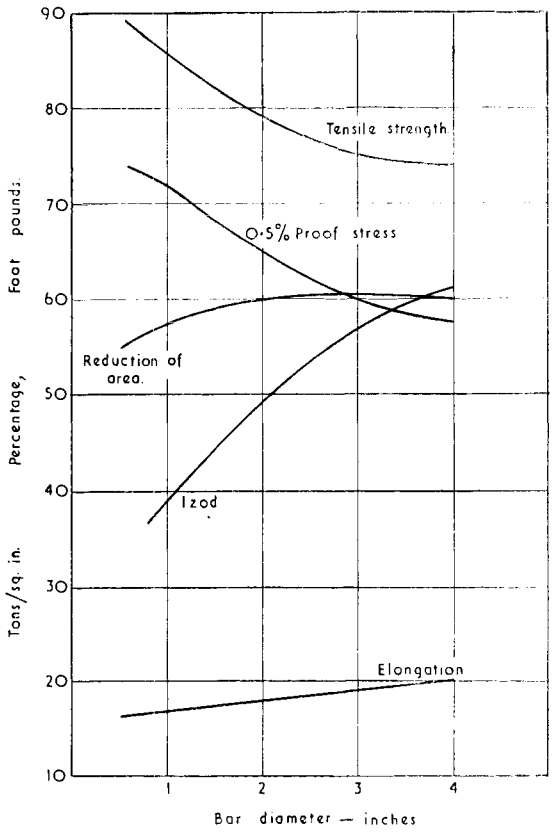


Fig. 39.26

MECHANICAL PROPERTIES AT LOW TEMPERATURE

ASTM Grain Size As Quenched	Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Mo	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Tensile 0·1% P.S. (0·1Rp) tons/sq.in.	0·2% P.S. (0·2Rp) tons/sq.in.	0·5% P.S. (0·5Rp) tons/sq.in.	T.S. (Rm) tons/sq.in.	El % (A)	R.A. % (Z)	Ref.
7	0·16	0·24	0·37	0·014	0·009	4·23	1·26	0·05	⅝	OQ800 T575 OQ	20	55·3	56·3	56·8	62·0	26	68	7
"	"	"	"	"	"	"	"	"	"	" "	— 78	57·4	59·0	60·2	68·3	29	68	"
"	"	"	"	"	"	"	"	"	"	" "	—196	70·7	76·2	78·0	85·1	31	58	"
8	0·18	0·28	0·42	0·014	0·029	4·11	1·08	0·14	½ plate	N850 T600 AC	20	43·9	45·8	47·7	56·7	26	66	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	46·9	49·2	51·6	64·7	28	63	"
"	"	"	"	"	"	"	"	"	"	"	—196	63·1	65·9	68·9	81·1	27	51	"
7—8	"	"	"	"	"	"	"	"	1½ plate	" "	20	43·4	45·7	47·9	56·9	25	61	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	46·1	48·7	51·7	64·0	29	58	"
"	"	"	"	"	"	"	"	"	"	" "	—196	61·7	65·0	68·9	81·3	25	38	"
"	"	"	"	"	"	"	"	"	2 plate	" "	20	42·0	44·0	46·1	55·2	25	61	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	45·4	47·7	50·0	62·0	28	57	"
"	"	"	"	"	"	"	"	"	"	" "	—196	61·1	63·8	65·7	79·1	23	36	"
7—8	0·14	0·28	0·45	0·017	0·016	4·11	1·11	0·24	⅝	OQ800 T575 OQ	20	53·5	55·5	56·8	59·5	27	71	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	55·6	57·1	58·8	65·0	29	70	"
"	"	"	"	"	"	"	"	"	"	" "	—196	73·0	74·5	76·2	81·4	32	63	"
7—8	0·17	0·21	0·37	0·014	0·019	4·17	1·11	0·22	½ plate	N850 T600 AC	20	44·1	46·1	48·2	56·4	24	62	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	47·0	49·6	52·2	63·2	26	59	"
"	"	"	"	"	"	"	"	"	"	" "	—196	63·6	65·2	69·2	80·0	27	46	"
7—8	"	"	"	"	"	"	"	"	1¼ plate	N850 T600 AC	20	39·8	41·9	44·4	53·2	28	63	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	42·0	44·8	57·7	60·2	29	63	"
"	"	"	"	"	"	"	"	"	"	" "	—196	58·5	61·8	65·1	77·4	29	48	"
7	"	"	"	"	"	"	"	"	2 plate	N850 T600 AC	20	40·2	42·5	44·8	54·0	25	62	"
"	"	"	"	"	"	"	"	"	"	" "	— 78	43·4	45·6	48·4	59·9	28	61	"
"	"	"	"	"	"	"	"	"	"	" "	—196	58·3	60·7	63·9	75·1	29	45	"

IMPACT TRANSITION TEMPERATURE DATA

Chemical Composition (%) C	Si	Mn	S	P	Ni	Cr	Section Size dia. (in.)	Heat Treatment °C	Test Temperature °C	Charpy Keyhole notch ft.lb.	% Crystalline Fracture	Ref.
0·14	0·21	0·37	0·010	0·011	4·18	1·25	1⅛	OQ850 T200	—78	34	50	1
"	"	"	"	"	"	"	6	" "	—78	10	100	"

IMPACT TRANSITION TEMPERATURE DATA (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39A	0·16	0·24	0·37	0·014	0·009	4·23	1·26	0·05

(See also Mechanical Properties at Low Temperatures for tensile test data.)
As quenched grain size 7 (ASTM). ⅜ in. dia. bars. Oil Quenched 800°C. Tempered 575°C OQ.

(Ref. 7)

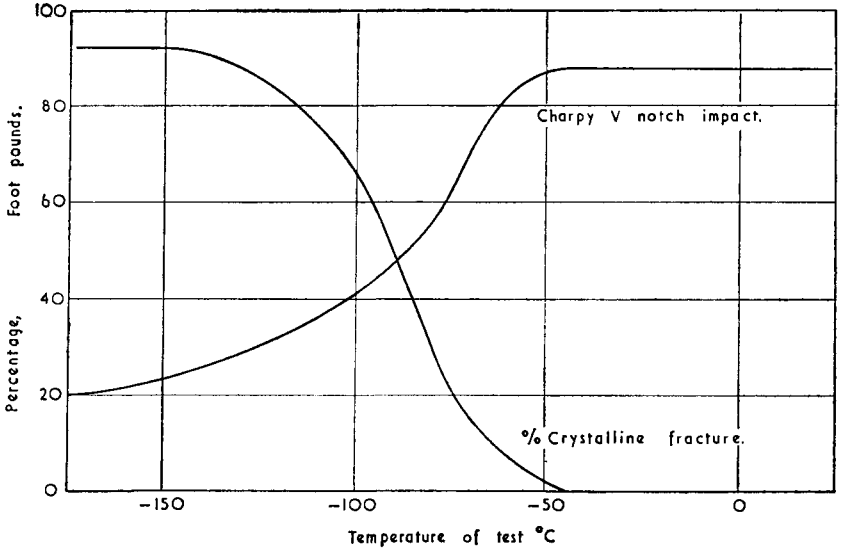


Fig. 39.27

	Chemical Composition (%)								Section Size dia. (in.)	As Quenched grain size	
	C	Si	Mn	S	P	Ni	Cr	Mo			
En 39A	0·18	0·28	0·42	0·014	0·029	4·11	1·08	0·14	½ plate	8	(ASTM
"	"	"	"	"	"	"	"	"	1¼ plate	7—8	—
"	"	"	"	"	"	"	"	"	2 plate	7—8	—

(See also Mechanical Properties at Low Temperatures for tensile test data.)
½ in., 1¼ in., 2 in. thick plates. Normalized 850°C. Tempered 600°C. Air Cool.

(Ref. 7)

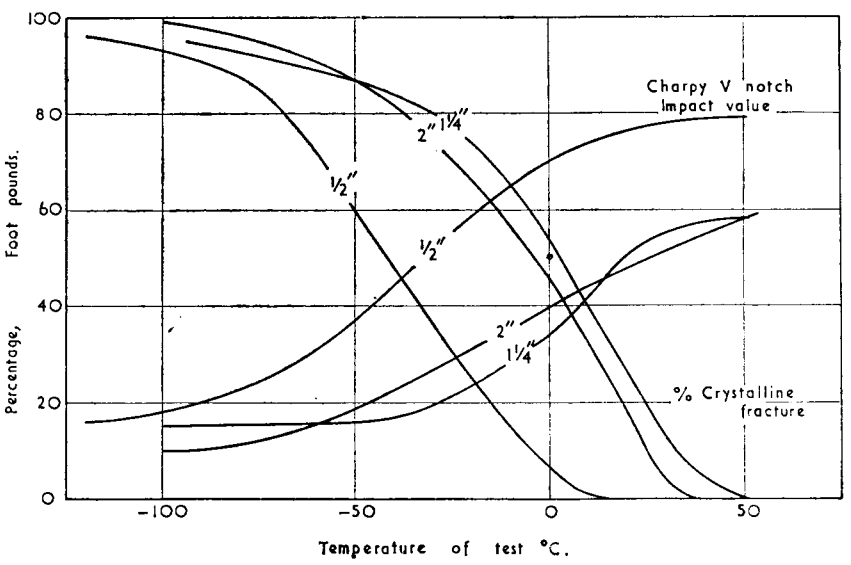


Fig. 39.28

IMPACT TRANSITION TEMPERATURE DATA (Continued)

	Chemical Composition (%)							
	C	Si	Mn	S	P	Ni	Cr	Mo
En 39B	0·14	0·28	0·45	0·017	0·016	4·11	1·11	0·24

(See also Mechanical Properties at Low Temperature for tensile data.)
As quenched grain size 7—8 ASTM.
⅜in. dia. bars. Oil Quenched 800°C. Tempered 575°C. Oil Quench.

(Ref. 7)

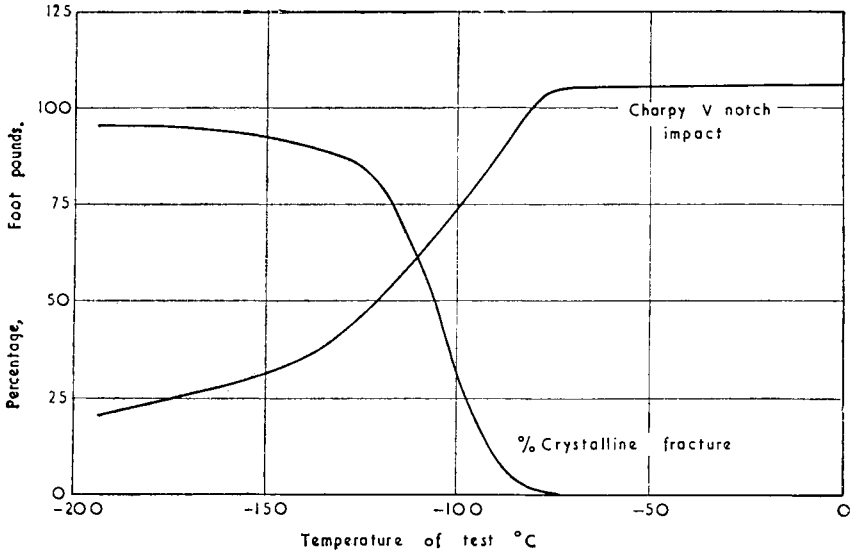


Fig. 39.29

	Chemical Composition (%)								Section Size dia. (in.)	As Quenched Grain Size
	C	Si	Mn	S	P	Ni	Cr	Mo		
En39B	0·17	0·21	0·37	0·014	0·019	4·17	1·11	0·22	½ plate	7—8 (ASTM)
"	"	"	"	"	"	"	"	"	1¼ plate	7—8 "
"	"	"	"	"	"	"	"	"	2 plate	8 "

(See also Mechanical Properties at Low Temperature for tensile test data.)
½ in., 1¼ in., 2 in. plates. Normalized 850°C. Tempered 600°C. Air Cool.

(Ref. 7)

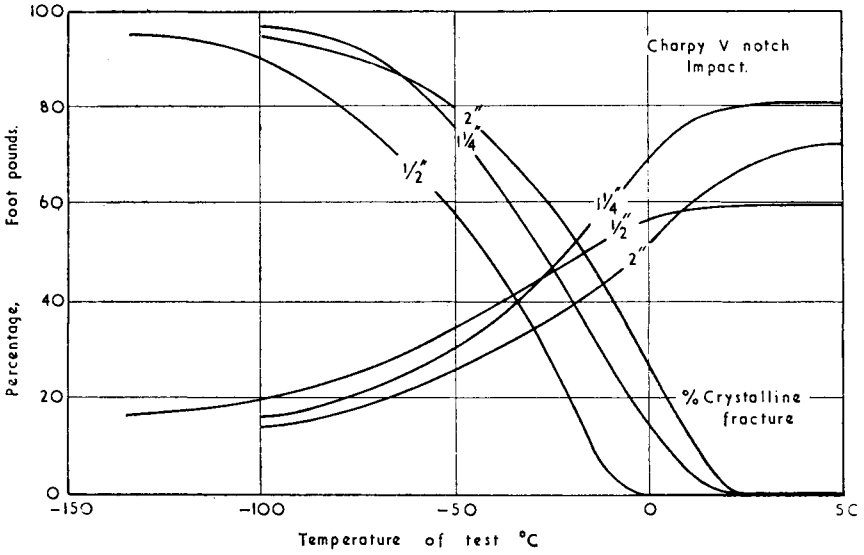


Fig. 39.30

MECHANICAL PROPERTIES IN TORSION

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C		Tensile				Torsion			Ref.
C	Si	Mn	S	P	Ni	Cr	Mo				0·1% P.S. (0·1Rp)	T.S. (Rm)	E % (A)	R.A. % (Z)	0·1% P.S.	Apparent max. Shear Stress	Probable max. Shear Stress	
											tons/sq.in.				tons/sq.in.			
0·14	0·18	0·40	0·009	0·011	4·27	1·35	0·13	—	—		46·6	86·6	17	56	32·1	71·5	53·6	9
0·15	0·12	0·44	0·019	0·018	4·41	0·94	0·20	—	—		52·8	84·4	17	58	35·2	70·5	52·9	"

FATIGUE PROPERTIES

Chemical Composition (%)								Section Size dia. (in.)	Heat Treatment °C	Tensile					Izod ft.lb.	Rotary Bending Fatigue Limit 10^7 cycles		Ref.
C	Si	Mn	S	P	Ni	Cr	Mo			0·1% P.S. (0·1Rp)	0·5% P.S. (0·5Rp)	T.S. (Rm)	El % (A)	R.A. % (Z)		Unnotched	Notched	
										tons/sq.in.						tons/sq.in.		
0·14	0·21	0·40			4·49	1·20			OQ850 OQ760	48·3	73·0	89·0	18	63½	30	±39·0		1
0·15	0·18	0·40	0·020	0·013	4·38	1·30	0·17	2½(L)	OQ870 OQ770 T175	67·5	80·5	89·6	18	58	39	±44·0		"
"	"	"	"	"	"	"	"	"(T)	" " "		(Y.P)							
											84·0	84·0	13	31½	13	±36·8		"
"	"	"	"	"	"	"	"	"(L)	OQ870 OQ770 T175							±44·5		"
0·15	0·13	0·43	0·020	0·020	4·36	1·50	0·27		OQ860 T500		68·3	73·2	19	59	43	±37·0	±15·0*	3
En 39B composition								Test dia. 0·15	C.H. 0·0075 in. deep	(HV = 420)						±63		10
									" 0·013 in. deep	(")						±68		"
									" 0·018 in. deep.	(")						±71		"

C.H. = Case Hardened

* Notch: 55°V, 0·008 in. root radius, 0·020 in deep. Test piece diameter 0·335 in. Diameter at root 0·295 in. Neuber stress concentration factor = 2·85.

LIST OF REFERENCES

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ELECTRICAL RESISTIVITY (ϱ), THERMAL CONDUCTIVITY (k) AND LORENZ FUNCTION (L) OF 22 STEELS (N.P.L. DATA)

En No.	C	Si	Mn	Ni	Cr	Mo	W	Property	0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900C°	1000°C
2 Rimming	0·06	0·01	0·38	0·05	0·02	0·03	—	ϱ	12·0	17·8	25·2	34·1	44·8	57·5	72·5	89·8	107·3	112·4	116·0
								k	0·156	0·144	0·133	0·122	0·111	0·098	0·090	0·081	0·072	0·065	0·066
								$10^8 \times L$	6·84	6·88	7·08	7·26	7·39	7·30	7·47	7·48	7·20	6·24	6·02
2 BOH	0·08	0·08	0·31	0·04	0·07	0·02	—	ϱ	13·2	19·0	26·3	35·2	45·8	58·4	73·4	90·5	108·1	113·0	116·5
								k	0·142	0·138	0·128	0·118	0·107	0·096	0·086	0·076	0·068	0·064	0·066
								$10^8 \times L$	6·85	7·03	7·11	7·26	7·29	7·25	7·22	7·06	6·85	6·17	6·04
3 BOH	0·23	0·11	0·63	0·07	Trace	—	—	ϱ	15·9	21·9	29·2	38·1	48·7	60·1	75·8	92·5	109·4	113·68	116·7
								k	0·124	0·122	0·116	0·106	0·102	0·094	0·085	0·076	0·062	0·063	0·065
								$10^8 \times L$	7·22	7·16	7·15	7·04	7·38	7·31	7·47	7·22	6·33	6·09	5·95
8 BOH	0·41	0·11	0·64	0·06	Trace	—	—	ϱ	16·0	22·1	29·6	38·7	49·3	61·9	76·6	93·2	111·1	114·9	117·9
								k	0·124	0·121	0·115	0·109	0·100	0·091	0·091	0·072	0·059	0·061	0·064
								$10^8 \times L$	7·26	7·17	7·20	7·35	7·32	7·29	7·11	6·90	6·11	5·97	5·93
8 AOH	0·43	0·20	0·69	0·04	0·03	0·01	—	ϱ	17·7	23·8	31·2	39·9	50·4	62·6	77·0	93·6	111·3	114·9	118·0
								k	0·115	0·115	0·111	0·105	0·098	0·092	0·086	0·075	0·064	0·062	0·064
								$10^8 \times L$	7·46	7·33	7·32	7·30	7·34	7·45	7·58	7·22	6·64	6·07	5·93
42G BEA	0·80	0·13	0·32	0·13	Trace	—	—	ϱ	17·0	23·2	30·8	39·8	50·5	62·8	77·2	93·5	112·9	116·4	119·1
								k	0·119	0·115	0·108	0·099	0·091	0·084	0·078	0·072	0·058	0·061	0·064
								$10^8 \times L$	7·40	7·15	7·03	6·89	6·83	6·82	6·90	6·93	6·10	6·05	5·99
42G BOH	0·84	0·13	0·24	Trace	Trace	—	—	ϱ	16·5	22·8	30·3	39·2	49·8	62·2	76·7	92·7	112·9	116·6	119·7
								k	0·122	0·117	0·110	0·100	0·092	0·085	0·079	0·073	0·058	0·060	0·064
								$10^8 \times L$	7·37	7·15	7·05	6·84	6·80	6·84	6·95	6·95	6·10	5·95	6·01
44E BOH	1·22	0·16	0·35	0·13	0·11	0·01	—	ϱ	18·4	25·2	33·3	43·0	54·0	66·5	80·2	96·4	115·2	119·6	122·6
								k	0·108	0·107	0·102	0·096	0·089	0·083	0·076	0·068	0·057	0·059	0·062
								$10^8 \times L$	7·28	7·23	7·18	7·20	7·14	7·15	6·98	6·73	6·12	6·02	5·96
14 BOH	0·23	0·12	1·51	0·04	0·05	0·025	—	ϱ	19·7	25·9	33·3	42·1	52·3	64·5	78·6	94·6	110·3	114·3	117·4
								k	0·110	0·111	0·107	0·103	0·096	0·089	0·032	0·075	0·071	0·064	0·065
								$10^8 \times L$	7·93	7·70	7·53	7·56	7·45	7·43	7·38	7·29	7·29	6·24	5·99
18A AOH	0·31	0·20	0·69	0·07	1·09	0·01	—	ϱ	20·0	25·9	33·0	41·7	51·7	63·6	77·8	93·4	110·6	114·5	117·7
								k	0·116	0·111	0.106	0·101	0·092	0·085	0·076	0·069	0·062	0·064	0·067
								$10^8 \times L$	8·50	7·70	7·40	7·35	7·07	7·00	6·76	6·62	6·39	6·24	6·20
19 AOH	0·35	0·21	0·59	0·26	0·88	0·20	—	ϱ	21·1	27·1	34·2	42·8	52·9	64·6	78·6	94·4	110·3	113·8	117·1
								k	0·103	0·102	0·100	0·097	0·093	0·087	0·081	0·074	0·063	0·065	0·067
								$10^8 \times L$	7·95	7·42	7·24	7·25	7·30	7·28	7·29	7·17	6·47	6·30	6·17
22 AOH	0·32	0·18	0·55	3·47	0·17	0·04	—	ϱ	25·9	32·0	39·0	47·0	56·7	67·9	81·4	99·2	112·2	114·9	118·0
								k	0·037	0·090	0·092	0·091	0·087	0·082	0·076	0·068	0·060	0·063	0·066
								$10^8 \times L$	8·25	7·72	7·59	7·45	7·34	7·20	7·08	6·93	6·28	6·17	6·12
23 AOH	0·33	0·17	0·53	3·38	0·80	0·07	—	ϱ	25·6	31·7	38·7	46·9	56·7	68·1	81·7	98·1	111·5	114·8	117·8
								k	0·082	0·036	0·088	0·088	0·087	0·084	0·080	0·070	0·062	0·063	0·066
								$10^8 \times L$	7·69	7·31	7·20	7·20	7·34	7·41	7·48	7·06	6·45	6·16	6·11

(continued)

En No.	C	Si	Mn	Ni	Cr	Mo	W	V	Property	0°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C
23 BEA	0·32	0·25	0·55	3·41	0·71	0·06	—		ϱ	26·5	32·5	39·5	47·7	57·2	68·6	82·0	99·0	111·7	115·0	118·0
									k	0·080	0·085	0·087	0·087	0·087	0·082	0·078	0·068	0·062	0·063	0·66
									$10^3 \times L$	7·76	7·40	7·26	7·25	7·40	7·29	7·15	6·93	6·46	6·18	6·12
27 BEA	0·34	0·27	0·55	3·53	0·78	0·39	—	—	ϱ	27·7	33·7	40·6	48·7	58·2	69·4	82·5	99·4	111·4	114·6	117·6
									k	0·079	0·081	0·084	0·085	0·085	0·080	0·073	0·67	0·064	0·066	0·068
									$10^3 \times L$	8·01	7·32	7·21	7·23	7·35	7·19	6·90	6·84	6·65	6·44	6·27
46 AOH	0·48	1·98	0·90	0·16	0·04	—	—	—	ϱ	41·9	47·0	52·9	60·1	68·5	78·8	91·1	105·7	117·3	119·7	122·3
									k	0·060	0·068	0·072	0·074	0·074	0·074	0·072	0·067	0·060	0·061	0·063
									$10^3 \times L$	9·21	8·57	8·06	7·77	7·53	7·55	7·52	7·28	6·57	6·23	6·05
56B BEA	0·13	0·17	0·25	0·14	12·95	—	—	—	ϱ	48·6	58·4	67·9	76·9	85·4	93·8	102·1	110·3	116·0	115·0	117·0
									k	0·064	0·066	0·066	0·067	0·066	0·065	0·063	0·061	0·060	0·064	0·066
									$10^3 \times L$	11·4	10·33	9·47	8·98	8·38	7·89	7·38	6·92	6·49	6·27	6·06
56D BEA	0·27	0·18	0·28	0·20	13·69	0·01	0·25		ϱ	50·3	59·5	68·4	76·9	85·3	93·5	101·5	109·9	115·7	114·6	117·9
									k	0·060	0·063	0·065	0·066	0·066	0·065	0·064	0·061	0·060	0·064	0·066
									$10^3 \times L$	11·1	10·05	9·39	8·85	8·37	7·87	7·44	6·88	6·47	6·24	6·11
58E BEA	0·08	0·68	0·37	8·14	19·11	—	0·60		ϱ	69·4	77·6	85·0	91·6	97·6	102·6	107·2	111·1	114·1	117·1	119·6
									k	0·038	0·039	0·041	0·044	0·048	0·052	0·057	0·061	0·064	0·064	0·067
									$10^3 \times L$	9·64	8·11	7·37	7·04	6·96	6·90	7·00	6·97	6·80	6·39	6·30
BEA	1·22	0·22	13·00	0·07	0·03	—	—		ϱ	66·5	75·7	84·7	93·1	100·4	105·9	110·0	115·6	120·4	124·5	127·5
									k	0·031	0·035	0·039	0·043	0·046	0·049	0·052	0·054	0·056	0·058	0·061
									$10^3 \times L$	7·55	7·09	6·98	6·93	6·87	6·72	6·54	6·42	6·28	6·15	6·11
BEA	0·28	0·15	0·89	29·37	Trace	—	—		ϱ	82·9	89·1	94 7	99·6	103·9	107·7	111.2	114·2	116·5	118·4	120·6
									k	0·030	0·035	0·039	0·042	0·045	0·049	0·053	0·056	0·060	0·063	0·066
									$10^3 \times L$	9·13	8·36	7·80	7·30	6·94	6·83	6·80	6·58	6·51	6·35	6·25
BHF	0·71	0·30	0·25	0·07	4·26	Trace	18·45	1·075	ϱ	40·6	47·2	54·4	62·7	71·8	81·5	92·2	103·7	115·2	117·3	120·9
									k	0·058	0·062	0·065	0·067	0·068	0·067	0·065	0·064	0·062	0·064	0·066
									$10^3 \times L$	8·63	7·84	7·48	7·34	7·25	7·06	6·87	6·83	6·65	6·40	6·28

Appendix II

COMPARISON OF ELONGATION ON $L=4\sqrt{A}$ AND $L=5{\cdot}65\sqrt{A}$

El % on $l=4\sqrt{A}$	Elongation Per Cent on $l=5{\cdot}65\sqrt{A}$ For Reduction of Area =																
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
5	4·3	3·9	3·5	3·2	2·9												
6	5·3	4·9	4·5	4·2	3·9												
7	6·4	6·0	5·6	5·3	5·0												
8	7·5	7·1	6·7	6·4	6·1	5·9											
9	8·5	8·1	7·7	7·3	7·0	6·8											
10	9·5	9·1	8·7	8·3	8·0	7·7	7·4	7·0	6·7								
11		10·2	9·8	9·4	9·0	8·6	8·3	8·0	7·7								
12		11·3	10·8	10·4	10·0	9·6	9·3	9·0	8·7								
13		12·4	11·8	11·3	10·9	10·5	10·2	9·9	9·6								
14		13·6	12·9	12·2	11·8	11·5	11·2	10·2	10·6	10·3							
15		14·7	14·0	13·2	12·8	12·4	12·0	11·7	11·4	11·1							
16			15·0	14·3	13·7	13·2	12·8	12·5	12·2	11·9							
17			16·1	15·4	14·7	14·1	13·8	13·5	13·2	12·9							
18			17·1	16·4	15·7	15·1	14·8	14·5	14·3	14·0	13·8						
19			18·2	17·5	16·8	16·2	15·8	15·5	15·2	14·9	14·6	14·4					
20			19·3	18·6	17·9	17·3	16·8	16·4	16·1	15·8	15·5	15·2	15·0	14·8			
21				19·7	19·0	18·4	17·8	17·3	17·0	16·7	16·5	16·2	15·9	15·7			
22				20·8	20·0	19·4	18·8	18·3	17·9	17·6	17·4	17·1	16·9	16·7			
23				21·9	21·0	20·4	19·8	19·3	18·9	18·5	18·2	18·0	17·8	17·6			
24				23·0	22·0	21·4	20·8	20·3	19·9	19·5	19·2	19·0	18·8	18·6			
25				24·2	23·0	22·4	21·8	21·3	20·9	20·6	20·3	20·0	19·8	19·6	19·5	19·4	19·3
26				25·3	24·2	23·6	22·9	22·4	22·0	21·7	21·4	21·1	20·9	20·7	20·5	20·4	20·4
27				26·4	25·3	24·6	23·9	23·3	22·9	22·6	22·3	22·0	21·8	21·7	21·6	21·5	21·4
28				27·6	26·4	25·6	24·8	24·3	23·9	23·5	23·2	22·9	22·7	22·6	22·5	22·4	22·3
29				28·7	27·4	26·6	25·8	25·3	24·9	24·6	24·3	23·8	23·6	23·5	23·4	23·3	23·2
30				29·8	28·5	27·6	26·7	26·2	25·9	25·6	25·3	24·9	24·6	24·4	24·3	24·2	24·1
31					29·5	28·6	27·7	27·2	26·9	26·6	26·3	26·0	25·7	25·4	25·2	25·1	25·0
32					30·6	29·7	28·8	28·1	27·8	27·5	27·2	27·0	26·7	26·4	26·2	26·1	26.0
33					31·7	30·7	29·8	29·1	28·8	28·5	28·1	27·9	27·7	27·5	27·2	27·1	27·0
34					32·8	31·7	30·8	30·0	29·7	29·4	29·1	28·8	28·5	28·3	28·1	28·0	27.9
35					33·8	32·7	31·8	31·0	30·6	30·3	30·0	29·7	29·4	29·2	29.0	28·9	28.8
36					34·9	33·8	32·9	32·0	31·6	31·2	30·9	30·6	30·3	30·1	29.9	29·8	29.7
37					36·0	34·8	33·9	33·0	32·5	32·2	31·9	31·5	31·2	31·0	30·8	30·7	30.6
38					37·1	35·8	34·9	34·1	33·5	33·1	32·8	32·4	32·1	31·9	31·7	31·5	31.4
39					38·3	36·9	36·0	35·2	34·5	34·0	33·7	33·3	33·0	32·8	32·6	32·4	32.3
40					39·4	38·0	37·0	36·2	35·5	35·0	34·6	34·2	33·9	32·7	33·5	33·2	33·1
41						39·4	38·1	37·2	36·5	35·9	35·5	35·1	35·8	34·5	34·3	34·1	34·0
42						40·5	39·3	38·3	37·4	36·9	36·4	36·0	35·7	35·4	35·2	35·0	34·8
43						41·6	40·5	39·3	38·4	37·9	37·4	37·0	36·6	36·3	36·1	35·9	35·7
44						42·7	41·6	40·4	39·5	39·0	38·5	38·0	37·5	37·1	36·9	36·7	36·5
45						43·9	42·7	41·5	40·7	40·1	39·5	38·9	38·5	38·2	37·9	37·6	37·4
46							43·9	42·7	41·8	41·1	40·5	40·0	39·6	29·2	38·8	38·5	38.3
47							45·1	43·8	42·9	42·1	41·5	41·0	40·6	40·2	39·8	39·4	39.2
48							46·2	44·9	44·0	43·2	42·6	42·1	41·7	41·3	40·9	40·5	40.2
49							47·3	46·0	45·1	44·3	43·7	43·2	42·8	42·4	42·0	41·7	41.4
50							48·5	47·1	46·2	45·3	44·7	44·2	43·8	43·5	43·2	42·9	42·6

Note this table does not apply for Austenitic Steels

Appendix III

APPROXIMATE RELATIONSHIP BETWEEN VARIOUS HARDNESS NUMBERS

This table has been compiled from the average of a number of published conversions.

Vickers Diamond Hardness HV	Brinell Hardness HB	Rockwell C Hardness HRC	Rockwell B Hardness HRB	Tensile Strength		
				Tons/sq. in	1000 lbs/sq. in.	Kgm/sq. mm
1200	–	70½	–	–	–	–
1150	–	70	–	–	–	–
1100	–	69½	–	–	–	–
1050	–	68½	–	–	–	–
1000	–	68	–	–	–	–
980	–	67½	–	–	–	–
960	–	67	–	–	–	–
940	–	66½	–	–	–	–
920	–	66	–	–	–	–
900	–	65½	–	–	–	–
880	–	64½	–	–	–	–
860	–	64	–	–	–	–
840	–	63½	–	–	–	–
820	–	63	–	–	–	–
800	–	62	–	–	–	–
780	–	61½	–	–	–	–
760	–	60½	–	–	–	–
740	–	60	–	–	–	–
720	612	59	–	–	–	–
700	600	58½	–	131	293	206
680	587	57½	–	128	286	202
660	572	56½	–	125	280	197
640	558	55½	–	122	273	192
620	543	54½	–	119	266	187
600	530	53½	–	116	259	183
580	516	52½	–	113	253	178
560	502	51½	–	110	246	173
540	488	50½	–	107	239	169
520	475	49½	–	104	232	164
500	461	48	–	101	226	159
480	444	47	–	98	219	154
460	428	45½	–	95	212	149
440	412	44	–	92	206	144
420	397	42	–	90	201	141
400	380	40	111	88	197	138
380	363	38	110	84	188	132
360	345	36	109	79	176	124
340	328	34	108	76	170	119
320	312	32	107	72	161	113
300	294	30	106	68	152	107
280	275	27	104	64	143	100
260	255	24	102	57	132	93
240	235	20	99	51	114	80
220	215	16	96	46	103	72
200	195	11	92	42	94	65
180	175	6	87	38	85	60
160	155	–	82	34	76	53
140	135	–	76	30	67	74
120	115	–	67	26	58	41
100	96	–	56	22	49	35
80	77	–	35	18	40	28

Appendix IV

TONS PER SQUARE INCH TO KILOGRAMMES PER SQUARE MILLIMETRE

BASED ON 1 INCH = 25·4 MILLIMETRES; 1 POUND = 0·45359243 KILOGRAMMES

Tons/ sq. in.	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	—	0·157	0·315	0·472	0·630	0·787	0·945	1·10	1·26	1·42
1	1·57	1·73	1·89	2·05	2·20	2·36	2·52	2·68	2·83	2·99
2	3·15	3·31	3·46	3·62	3·78	3·94	4·09	4·25	4·41	4·57
3	4·72	4·88	5·04	5·20	5·35	5·51	5·67	5·83	5·98	6·14
4	6·30	6·46	6·61	6·77	6·93	7·09	7·24	7·40	7·56	7·72
5	7·87	8·03	8·19	8·35	8·50	8·66	8·82	8·98	9·13	9·29
6	9·45	9·61	9·76	9·92	10·1	10·2	10·4	10·6	10·7	10·9
7	11·0	11·2	11·3	11·5	11·7	11·8	12·0	12·1	12·3	12·4
8	12·6	12·8	12·9	13·1	13·2	13·4	13·5	13·7	13·9	14·0
9	14·2	14·3	14·5	14·6	14·8	15·0	15·1	15·3	15·4	15·6
10	15·7	15·9	16·1	16·2	16·4	16·5	16·7	16·9	17·0	17·2
11	17·3	17·5	17·6	17·8	18·0	18·1	18·3	18·4	18·6	18·7
12	18·9	19·1	19·2	19·4	19·5	19·7	19·8	20·0	20·2	20·3
13	20·5	20·6	20·8	20·9	21·1	21·3	21·4	21·6	21·7	21·9
14	22·0	22·2	22·4	22·5	22·7	22·8	23·0	23·2	23·3	23·5
15	23·6	23·8	23·9	24·1	24·3	24·4	24·6	24·7	24·9	25·0
16	25·2	25·4	25·5	25·7	25·8	26·0	26·1	26·3	26·5	26·6
17	26·8	26·9	27·1	27·2	27·4	27·6	27·7	27·9	28·0	28·2
18	28·3	28·5	28·7	28·8	29·0	29·1	29·3	29·5	29·6	29·8
19	29·9	30·1	30·2	30·4	30·6	30·7	30·9	31·0	31·2	31·3
20	31·5	31·7	31·8	32·0	32·1	32·3	32·4	32·6	32·8	32·9
21	33·1	33·2	33·4	33·5	33·7	33·9	34·0	34·2	34·3	34·5
22	34·6	34·8	35·0	35·1	35·3	35·4	35·6	35·7	35·9	36·1
23	36·2	36·4	36·5	36·7	36·9	37·0	37·2	37·3	37·5	37·6
24	37·8	38·0	38·1	38·3	38·4	38·6	38·7	38·9	39·1	39·2
25	39·4	39·5	39·7	39·8	40·0	40·2	40·3	40·5	40·6	40·8
26	40·9	41·1	41·3	41·4	41·6	41·7	41·9	42·0	42·2	42·4
27	42·5	42·7	42·8	43·0	43·2	43·3	43·5	43·6	43·8	43·9
28	44·1	44·3	44·4	44·6	44·7	44·9	45·0	45·2	45·4	45·5
29	45·7	45·8	46·0	46·1	46·3	46·5	46·6	46·8	46·9	47·1
30	47·2	47·4	47·6	47·7	47·9	48·0	48·2	48·3	48·5	48·7
31	48·8	49·0	49·1	49·3	49·5	49·6	49·8	49·9	50·1	50·2
32	50·4	50·6	50·7	50·9	51·0	51·2	51·3	51·5	51·7	51·8
33	52·0	52·1	52·3	52·4	52·6	52·8	52·9	53·1	53·2	53·4
34	53·5	53·7	53·9	54·0	54·2	54·3	54·5	54·6	54·8	55·0
35	55·1	55·3	55·4	55·6	55·8	55·9	56·1	56·2	56·4	56·5
36	56·7	56·9	57·0	57·2	57·3	57·5	57·6	57·8	58·0	58·1
37	58·3	58·4	58·6	58·7	58·9	59·1	59·2	59·4	59·5	59·7
38	59·8	60·0	60·2	60·3	60·5	60·6	60·8	60·9	61·1	61·3
39	61·4	61·6	61·7	61·9	62·1	62·2	62·4	62·5	62·7	62·8
40	63·0	63·2	63·3	63·5	63·6	63·8	63·9	64·1	64·3	64·4
41	64·6	64·7	64·9	65·0	65·2	65·4	65·5	65·7	65·8	66·0
42	66·1	66·3	66·5	66·6	66·8	66·9	67·1	67·2	67·4	67·6
43	67·7	67·9	68·0	68·2	68·4	68·5	68·7	68·8	69·0	69·1
44	69·3	69·5	69·6	69·8	69·9	70·1	70·2	70·4	70·6	70·7
45	70·9	71·0	71·2	71·3	71·5	71·7	71·8	72·0	72·1	72·3
46	72·4	72·6	72·8	72·9	73·1	73·2	73·4	73·5	73·7	73·9
47	74·0	74·2	74·3	74·5	74·6	74·8	75·0	75·1	75·3	75·4
48	75·6	75·8	75·9	76·1	76·2	76·4	76·5	76·7	76·9	77·0
49	77·2	77·3	77·5	77·6	77·8	78·0	78·1	78·3	78·4	78·6
50	78·7	78·9	79·1	79·2	79·4	79·5	79·7	79·8	80·0	80·2

TONS PER SQUARE INCH TO KILOGRAMMES PER SQUARE MILLIMETRE

(continued)

BASED ON 1 INCH = 25·4 MILLIMETRES; 1 POUND = 0·45359243 KILOGRAMMES

Tons/ sq. in.	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
51	80·3	80·5	80·6	80·8	80·9	81·1	81·3	81·4	81·6	81·7
52	81·9	82·1	82·2	82·4	82·5	82·7	82·8	83·0	83·2	83·3
53	83·5	83·6	83·8	83·9	84·1	84·3	84·4	84·6	84·7	84·9
54	85·0	85·2	85·4	85·5	85·7	85·8	86·0	86·1	86·3	86·5
55	86·6	86·8	86·9	87·1	87·2	87·4	87·6	87·7	87·9	88·0
56	88·2	88·4	88·5	88·7	88·8	89·0	89·1	89·3	89·5	89·6
57	89·8	89·9	90·1	90·2	90·4	90·6	90·7	90·9	91·0	91·2
58	91·3	91·5	91·7	91·8	92·0	92·1	92·3	92·4	92·6	92·8
59	92·9	93·1	93·2	93·4	93·5	93·7	93·9	94·0	94·2	94·3
60	94·5	94·7	94·8	95·0	95·1	95·3	95·4	95·6	95·8	95·9
61	96·1	96·2	96·4	96 5	96·7	96·9	97·0	97·2	97·3	97·5
62	97·6	97·8	98·0	98·1	98·3	98·4	98·6	98·7	98·9	99·1
63	99·2	99·4	99·5	99·7	99·8	100·0	100·2	100·3	100·5	100·6
64	100·8	101·0	101·1	101·3	101·4	101·6	101·7	101·9	102·1	102·2
65	102·4	102·5	102·7	102·8	103·0	103·2	103·3	103·5	103·5	103·8
66	103·9	104·1	104·3	104·4	104·6	104·7	104·9	105·0	105·2	105·4
67	105·5	105·7	105·8	106·0	106·1	106·3	106·5	106·6	106·8	106·9
68	107·1	107·2	107·4	107·6	107·7	107·9	108·9	108·2	108·4	108·5
69	108·7	108·8	109·0	109·1	109·3	109·5	109·6	109·8	109·9	110·1
70	110·2	110·4	110·6	110·7	110·9	111·0	111·2	111·3	111·5	111·7
71	111·8	112·0	112·1	112·3	112·4	112·6	112·8	112·9	113·1	113·2
72	113·4	113·5	113·7	113·9	114·0	114·2	114·3	114·5	114·7	114·8
73	115·0	115·1	115·3	115·4	115·6	115·8	115·9	116·1	116·2	116·4
74	116·5	116·7	116·9	117·0	117·2	117·3	117·5	117·6	117·8	118·0
75	118·1	118·3	118·4	118·6	118·7	118·9	119·1	119·2	119·4	119·5
76	119·7	119·8	120·0	120·2	120·3	120·5	120·6	120·8	121·0	121·1
77	121·3	121·4	121·6	121·7	121·9	122·1	122·2	122·4	122·5	122·7
78	122·8	123·0	123·2	123·3	123·5	123·6	123·8	123·9	124·1	124·3
79	124·4	124·6	124·7	124·9	125·0	125·2	125·4	125·5	125·7	125·8
80	126·0	126·1	126·3	126·5	126·6	126·8	126·9	127·1	127·3	127·4
81	127·6	127·7	127·9	128·0	128·2	128·4	128·5	128·7	128·8	129·0
82	129·1	129·3	129·5	129·6	129·8	129·9	130·1	130·2	130·4	130·6
83	130·7	130·9	131·0	131·2	131·3	131·5	131·7	131·8	132·0	132·1
84	132·3	132·4	132·6	132·8	132·9	133·1	133·2	133·4	133·5	133·7
85	133·9	134·0	134·2	134·3	134·5	134·7	134·8	135·0	135·1	135·3
86	135·4	135·6	135·8	135·9	136·1	136·2	136·4	136·5	136·7	136·9
87	137·0	137·2	137·3	137·5	137·6	137·8	138·0	138·1	138·3	138·4
88	138·6	138·7	138·9	139·1	139·2	139·4	139·5	139·7	139·8	140·0
89	140·2	140·3	140·5	140·6	140·8	141·0	141·1	141·3	141·4	141·6
90	141·7	141·9	142·1	142·2	142·4	142·5	142·7	142·8	143·0	143·2
91	143·3	143·5	143·6	143·8	143·9	144·1	144·3	144·4	144·6	144·7
92	144·9	145·0	145·2	145·4	145·5	145·7	145·8	146·0	146·1	146·3
93	146·5	146·6	146·8	146·9	147·1	147·3	147·4	147·6	147·7	147·9
94	148·0	148·2	148·4	148·5	148·7	148·8	149·0	149·1	149·3	149·5
95	149·6	149·8	149·9	150·1	150·2	150·4	150·6	150·7	150·9	151·0
96	151·2	151·3	151·5	151·7	151·8	152·0	152·1	152·3	152·4	152·6
97	152·8	152·9	153·1	153·2	153·4	153·6	153·7	153·9	154·0	154·2
98	154·3	154·5	154·7	154·8	155·0	155·1	155·3	155·4	155·6	155·8
99	155·9	156·1	156·2	156·4	156·5	156·7	156·9	157·0	157·2	157·3
100	157·5	157·6	157·8	158·0	158·1	158·3	158·4	158·6	158·7	158·9

Appendix IV

TONS PER SQUARE INCH TO POUNDS PER SQUARE INCH

Tons	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
—	—	224	448	672	896	1120	1344	1568	1792	2016
1	2240	2464	2688	2912	3136	3360	3584	3808	4032	4256
2	4480	4704	4928	5152	5376	5600	5824	6048	6272	6496
3	6720	6944	7168	7392	7616	7840	8064	8288	8512	8736
4	8960	9184	9408	9632	9856	10080	10304	10528	10752	10976
5	11200	11424	11648	11872	12096	12320	12544	12768	12992	13216
6	13440	13664	13888	14112	14336	14560	14784	15008	15232	15456
7	15680	15904	16128	16352	16576	16800	17024	17248	17472	17696
8	17920	18144	18368	18592	18816	19040	19264	19488	19712	19936
9	20160	20384	20608	20832	21056	21280	21504	21728	21952	22176
10	22400	22624	22848	23072	23296	23520	23744	23968	24192	24416
11	24640	24864	25088	25312	25536	25760	25984	26208	26432	26656
12	26880	27104	27328	27552	27776	28000	28224	28448	28672	28896
13	29120	29344	29568	29792	30016	30240	30464	30688	30912	31136
14	31360	31584	31808	32032	32256	32480	32704	32928	33152	33376
15	33600	33824	34048	34272	34496	34720	34944	35168	35392	35616
16	35840	36064	36288	36512	36736	36960	37184	37408	37632	37856
17	38080	38304	38528	38752	38976	39200	39424	39648	39872	40096
18	40320	40544	40768	40992	41216	41440	41664	41888	42112	42336
19	42560	42784	43008	43232	43456	43680	43904	44128	44352	44576
20	44800	45024	45248	45472	45696	45920	46144	46368	46592	46816
21	47040	47264	47488	47712	47936	48160	48384	48608	48832	49056
22	49280	49504	49728	49952	50176	50400	50624	50848	51072	51296
23	51520	51744	51968	52192	52416	52640	52864	53088	53312	53536
24	53760	53984	54208	54432	54656	54880	55104	55328	55552	55776
25	56000	56224	56448	56672	56896	57120	57344	57568	57792	58016
26	58240	58464	58688	58912	59136	59360	59584	59808	60032	60256
27	60480	60704	60928	61152	61376	61600	61824	62048	62272	62496
28	62720	62944	63168	63392	63616	63840	64064	64288	64512	64736
29	64960	65184	65408	65632	65856	66080	66304	66528	66752	66976
30	67200	67424	67648	67872	68096	68320	68544	68768	68992	69216
31	69440	69664	69888	70112	70336	70560	70784	71008	71232	71456
32	71680	71904	72128	72352	72576	72800	73024	73248	73472	73696
33	73920	74144	74368	74592	74816	75040	75264	75488	75712	75936
34	76160	76384	76608	76832	77056	77280	77504	77728	77952	78176
35	78400	78624	78848	79072	79296	79520	79744	79968	80192	80416
36	80640	80864	81088	81312	81536	81760	81984	82208	82432	82656
37	82880	83104	83328	83552	83776	84000	84224	84448	84672	84896
38	85120	85344	85568	85792	86016	86240	86464	86688	86912	87136
39	87360	87584	87808	88032	88256	88480	88704	88928	89152	89376
40	89600	89824	90048	90272	90496	90720	90944	91168	91392	91616
41	91840	92064	92288	92512	92736	92960	93184	93408	93632	93856
42	94080	94304	94528	94752	94976	95200	95424	95648	95872	96096
43	96320	96544	96768	96992	97216	97440	97664	97888	98112	98336
44	98560	98784	99008	99232	99456	99680	99904	100128	100352	100576
45	100800	101024	101248	101472	101696	101920	102144	102368	102592	102816
46	103040	103264	103488	103712	103936	104160	104384	104608	104832	105056
47	105280	105504	105728	105952	106176	106400	106624	106848	107072	107296
48	107520	107744	107968	108192	108416	108640	108864	109088	109312	109536
49	109760	109984	110208	110432	110656	110880	111104	111328	111552	111776
50	112000	112224	112448	112672	112896	113120	113344	113568	113792	114016

TONS PER SQUARE INCH TO POUNDS PER SQUARE INCH

(continued)

Tons	0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.	lb.
51	114240	114464	114688	114912	115136	115360	115584	115808	116032	116256
52	116480	116704	116928	117152	117376	117600	117824	118048	118272	118496
53	118720	118944	119168	119392	119616	119840	120064	120288	120512	120736
54	120960	121184	121408	121632	121856	122080	122304	122528	122752	122976
55	123200	123424	123648	123872	124096	124320	124544	124768	124992	125216
56	125440	125664	125888	126112	126336	126560	126784	127008	127232	127456
57	127680	127904	128128	128352	128576	128800	129024	129248	129472	129696
58	129920	130144	130368	130592	130816	131040	131264	131488	131712	131936
59	132160	132384	132608	132832	133056	133280	133504	133728	133952	134176
60	134400	134642	134848	135072	135296	135520	135744	135968	136192	136416
61	136640	136864	137088	137312	137536	137760	137984	138208	138432	138656
62	138880	139104	139328	139552	139776	140000	140224	140448	140672	140896
63	141120	141344	141568	141792	142016	142240	142464	142688	142912	143136
64	143360	143584	143808	144032	144256	144480	144704	144928	145152	145376
65	145600	145824	146048	146272	146496	146720	146944	147168	147392	147616
66	147840	148064	148288	148512	148736	148960	149184	149408	149632	149856
67	150080	150304	150528	150752	150976	151200	151424	151648	151872	152096
68	152320	152544	152768	152992	153216	153440	153664	153888	154112	154336
69	154560	154784	155008	155232	155456	155680	155904	156128	156352	156576
70	156800	157024	157248	157472	157696	157920	158144	158368	158592	158816
71	159040	159264	159488	159712	159936	160160	160384	160608	160832	161056
72	161280	161504	161728	161952	162176	162400	162624	162848	163072	163296
73	163520	163744	163968	164192	164416	164640	164864	165088	165312	165536
74	165760	165984	166208	166432	166656	166880	167104	167328	167552	167776
75	168000	168224	168448	168672	168896	169120	169344	169568	169792	170016
76	170240	170464	170688	170912	171136	171360	171584	171808	172032	172256
77	172480	172704	172928	173152	173376	173600	173824	174048	174272	174496
78	174720	174944	175168	175392	175616	175840	176064	176288	176512	176736
79	176960	177184	177408	177632	177856	178080	178304	178528	178752	178976
80	179200	179424	179648	179872	180096	180320	180544	180768	180992	181216
81	181440	181664	181888	182112	182336	182560	182784	183008	183232	183456
82	183680	183904	184128	184352	184576	184800	185024	185248	185472	185696
83	185920	186144	186368	186592	186816	187040	187264	187488	187712	187936
84	188160	188384	188608	188832	189056	189280	189504	189728	189952	190176
85	190400	190624	190848	191072	191296	191520	191744	191968	192192	192416
86	192640	192864	193088	193312	193536	193760	193984	194208	194432	194656
87	194880	195104	195328	195552	195776	196000	196224	196448	196672	196896
88	197120	197344	197568	197792	198016	198240	198464	198688	198912	199136
89	199360	199584	199808	200032	200256	200480	200704	200928	201152	201376
90	201600	201824	202048	202272	202496	202720	202944	203168	203392	203616
91	203840	204064	204288	204512	204736	204960	205184	205408	205632	205856
92	206080	206304	206528	206752	206976	207200	207424	207648	207872	208096
93	208320	208544	208768	208992	209216	209440	209664	209888	210112	210336
94	210560	210784	211008	211232	211456	211680	211904	212128	212352	212576
95	212800	213024	213248	213472	213696	213920	214144	214368	214592	214816
96	215040	215264	215488	215712	215936	216160	216384	216608	216832	217056
97	217280	217504	217728	217952	218176	218400	218624	218848	219072	219296
98	219520	219744	219968	220192	220416	220640	220864	221088	221312	221536
99	221760	221984	222208	222432	222656	222880	223104	223328	223552	223776
100	224000									

Appendix V

TEMPERATURE CONVERSION TABLE

459·4 to 0			0 to 99						100 to 1000					
C	C / F	F	C	C / F	F	C	C / F	F	C	C / F	F	C	C / F	F
−273	−459·4		−17·8	0	32	10·0	50	122·0	38	100	212	260	500	932
−268	−450		−17·2	1	33·8	10·6	51	123·8	43	110	230	266	510	950
−262	−440		−16·7	2	35·6	11·1	52	125·6	49	120	248	271	520	968
−257	−430		−16·1	3	37·4	11·7	53	127·4	54	130	266	277	530	986
−251	−420		−15·6	4	39·2	12·2	54	129·2	60	140	284	282	540	1004
−246	−410		−15·0	5	41·0	12·8	55	131·0	66	150	302	288	550	1022
−240	−400		−14·4	6	42·8	13·3	56	132·8	71	160	320	293	560	1040
−234	−390		−13·9	7	44·6	13·9	57	134·6	77	170	338	299	570	1058
−229	−380		−13·3	8	46·4	14·4	58	136·4	82	180	356	304	580	1076
−223	−370		−12·8	9	48·2	15·0	59	138·2	88	190	374	310	590	1094
−218	−360		−12·2	10	50·0	15·6	60	140·0	93	200	392	316	600	1112
−212	−350		−11·7	11	51·8	16·1	61	141·8	99	210	410	321	610	1130
−207	−340		−11·1	12	53·6	16·7	62	143·6	100	212	413·6	327	620	1148
−201	−330		−10·6	13	55·4	17·2	63	145·4	104	220	428	332	630	1166
−196	−320		−10·0	14	57·2	17·8	64	147·2	110	230	446	338	640	1184
−190	−310		− 9·4	15	59·0	18·3	65	149·0	116	240	464	343	650	1202
−184	−300		− 8·9	16	60·8	18·9	66	150·8	121	250	482	349	660	1220
−179	−290		− 8·3	17	62·6	19·4	67	152·6	127	260	500	354	670	1238
−173	−280		− 7·8	18	64·4	20·0	68	154·4	132	270	518	360	680	1256
−169	−273	−459·4	− 7·2	19	66·2	20·6	69	156·2	138	280	536	366	690	1274
−168	−270	−454	− 6·7	20	68·0	21·1	70	158·0	143	290	554	371	700	1292
−162	−260	−436	− 6·1	21	69·8	21·7	71	159·8	149	300	572	377	710	1310
−157	−250	−418	− 5·6	22	71·6	22·2	72	161·6	154	310	590	382	720	1328
−151	−240	−400	− 5·0	23	73·4	22·8	73	163·4	160	320	608	388	730	1346
−146	−230	−382	− 4·4	24	75·2	23·3	74	165·2	166	330	626	393	740	1364
−140	−220	−364	− 3·9	25	77·0	23·9	75	167·0	171	340	644	399	750	1382
−134	−210	−346	− 3·3	26	78·8	24·4	76	168·8	177	350	662	404	760	1400
−129	−200	−328	− 2·8	27	80·6	25·0	77	170·6	182	360	680	410	770	1418
−123	−190	−310	− 2·2	28	82·4	25·6	78	172·4	188	370	698	416	780	1436
−118	−180	−292	− 1·7	29	84·2	26·1	79	174·2	193	380	716	421	790	1454
−112	−170	−274	− 1·1	30	86·0	26·7	80	176·0	199	390	734	427	800	1472
−107	−160	−256	− 0·6	31	87·8	27·2	81	177·8	204	400	752	432	810	1490
−101	−150	−238	0	32	89·6	27·8	82	179·6	210	410	770	438	820	1508
− 96	−140	−220	0·6	33	91·4	28·3	83	181·4	216	420	788	443	830	1526
− 90	−130	−202	1·1	34	93·2	28·9	84	183·2	221	430	806	449	840	1544
− 84	−120	−184	1·7	35	−95·0	29·4	85	185·0	227	440	824	454	850	1562
− 79	−110	−166	2·2	36	96·8	30·0	86	186·8	232	450	842	460	860	1580
− 73	−100	−148	2·8	37	98·6	30·6	87	188·6	238	460	860	466	870	1598
− 68	− 90	−130	2·2	38	100·4	31·1	88	190·4	243	470	878	471	880	1616
− 62	− 80	−112	3·9	39	102·2	31·7	89	192·2	249	480	896	477	890	1634
− 57	− 70	− 94	4·4	40	104·0	32·2	90	194·0	254	490	914	482	900	1652
− 51	− 60	− 76	5·0	41	105·8	32·8	91	195·8				488	910	1670
− 46	− 50	− 58	5·6	42	107·6	33·3	92	197·6				493	920	1688
− 40	− 40	− 40	6·1	43	109·4	33·9	93	199·4				499	930	1706
− 34	− 30	− 22	6·7	44	111·2	34·4	94	201·2				504	940	1724
− 29	− 20	− 4	7·2	45	113·0	35·0	95	203·0				510	950	1742
− 23	− 10	14	7·8	46	114·8	35·6	96	204·8				516	960	1760
− 17·8	0	32	8·3	47	116·6	36·1	97	205·6				521	970	1778
			8·9	48	118·4	36·7	98	208·4				527	980	1796
			9·4	49	120·2	37·2	99	210·2				532	990	1814

Look up reading in middle column. If in degrees Centigrade, read Fahrenheit equivalent in right hand column; if in Fahrenheit degrees, read Centigrade equivalent in left hand column.

TEMPERATURE CONVERSION TABLE

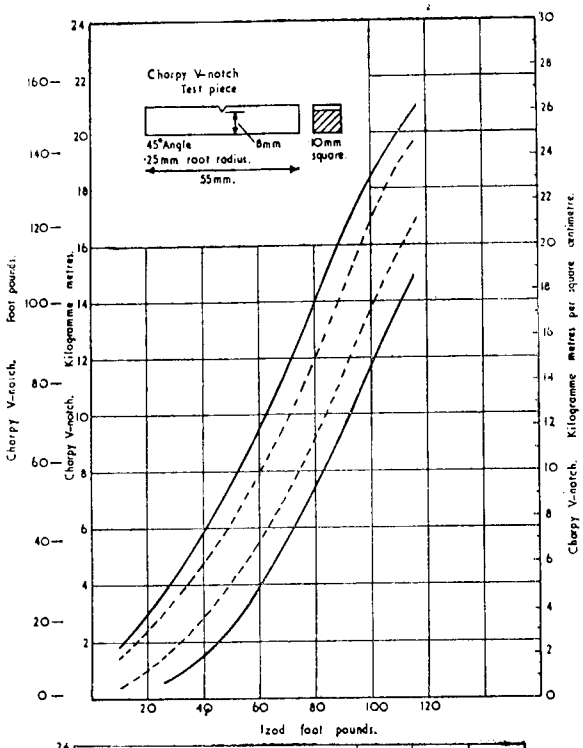
1000 to 1990						2000 to 3000					
C	C / F	F	C	C / F	F	C	C / F	F	C	C / F	F
538	1000	1832	816	1500	2732	1093	2000	3632	1371	2500	4532
543	1010	1850	821	1510	2750	1099	2010	3650	1377	2510	4550
549	1020	1868	827	1520	2768	1104	2020	3668	1382	2520	4568
554	1030	1886	832	1530	2786	1110	2030	3686	1388	2530	4586
560	1040	1904	838	1540	2804	1116	2040	3704	1393	2540	4604
566	1050	1922	843	1550	2822	1121	2050	3722	1399	2550	4622
571	1060	1940	849	1560	2840	1127	2060	3740	1404	2560	4640
577	1070	1958	854	1570	2858	1132	2070	3758	1410	2570	4658
582	1080	1976	860	1580	2876	1138	2080	3776	1416	2580	4676
588	1090	1994	866	1590	2894	1143	2090	3794	1421	2590	4694
593	1100	2012	871	1600	2912	1149	2100	3812	1427	2600	4712
599	1110	2030	877	1610	2930	1154	2110	3830	1432	2610	4730
604	1120	2048	882	1620	2948	1160	2120	3848	1438	2620	4748
610	1130	2066	888	1630	2966	1166	2130	3866	1443	2630	4766
616	1140	2084	893	1640	2984	1171	2140	3884	1449	2640	4784
621	1150	2102	899	1650	3002	1177	2150	3902	1454	2650	4802
627	1160	2120	904	1660	3020	1182	2160	3920	1460	2660	4820
632	1170	2138	910	1670	3038	1188	2170	3938	1466	2670	4838
638	1180	2156	916	1680	3056	1193	2180	3956	1471	2680	4856
643	1190	2174	921	1690	3074	1199	2190	3974	1477	2690	4874
649	1200	2192	927	1700	3092	1204	2200	3992	1482	2700	4892
654	1210	2210	932	1710	3110	1210	2210	4010	1488	2710	4910
660	1220	2228	938	1720	3128	1216	2220	4028	1493	2720	4928
666	1230	2246	943	1730	3146	1221	2230	4046	1499	2730	4946
671	1240	2264	949	1740	3164	1227	2240	4064	1504	2740	4964
677	1250	2282	954	1750	3182	1232	2250	4082	1510	2750	4982
682	1260	2300	960	1760	3200	1238	2260	4100	1516	2760	5000
688	1270	2318	966	1770	3218	1243	2270	4118	1521	2770	5018
693	1280	2336	971	1780	3236	1249	2280	4136	1527	2780	5036
699	1290	2354	977	1790	3254	1254	2290	4154	1532	2790	5054
704	1300	2372	982	1800	3272	1260	2300	4172	1538	2800	5072
710	1310	2390	988	1810	3290	1266	2310	4190	1543	2810	5090
716	1320	2408	993	1820	3308	1271	2320	4208	1549	2820	5108
721	1330	2426	999	1830	3326	1277	2330	4226	1554	2830	5126
727	1340	2444	1004	1840	3344	1282	2340	4244	1560	2840	5144
732	1350	2462	1010	1850	3362	1288	2350	4262	1566	2850	5162
738	1360	2480	1016	1860	3380	1293	2360	4280	1571	2860	5180
743	1370	2498	1021	1870	3398	1299	2370	4298	1577	2870	5198
749	1380	2516	1027	1880	3416	1304	2380	4316	1582	2880	5216
754	1390	2534	1032	1890	3434	1310	2390	4334	1588	2890	5234
760	1400	2552	1038	1900	3452	1316	2400	4352	1593	2900	5252
766	1410	2570	1043	1910	3470	1321	2410	4370	1599	2910	5270
771	1420	2588	1049	1920	3488	1327	2420	4388	1604	2920	5288
777	1430	2606	1054	1930	3506	1332	2430	4406	1610	2930	5306
782	1440	2624	1060	1940	3524	1338	2440	4424	1616	2940	5324
788	1450	2642	1066	1950	3542	1343	2450	4442	1621	2950	5342
793	1460	2660	1071	1960	3560	1349	2460	4460	1627	2960	5360
799	1470	2678	1077	1970	3578	1354	2470	4478	1632	2970	5378
804	1480	2696	1082	1980	3596	1360	2480	4496	1638	2980	5396
810	1490	2714	1088	1990	3614	1366	2490	4514	1643	2990	5414
									1649	3000	5432

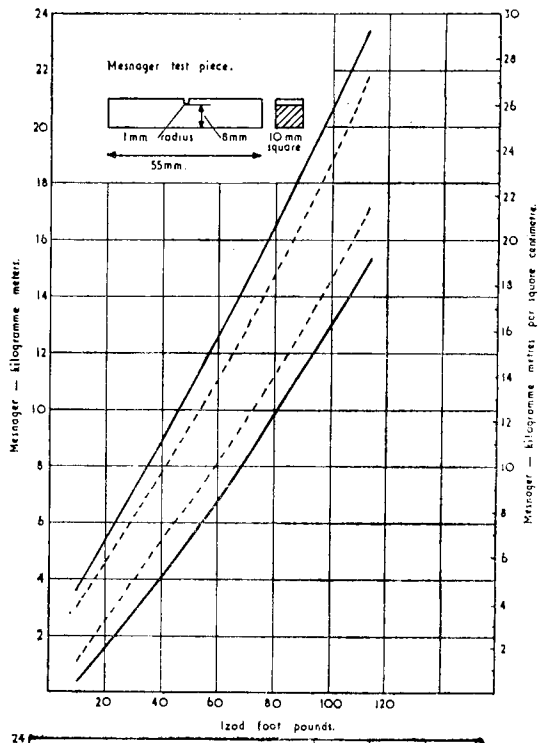
Appendix VI

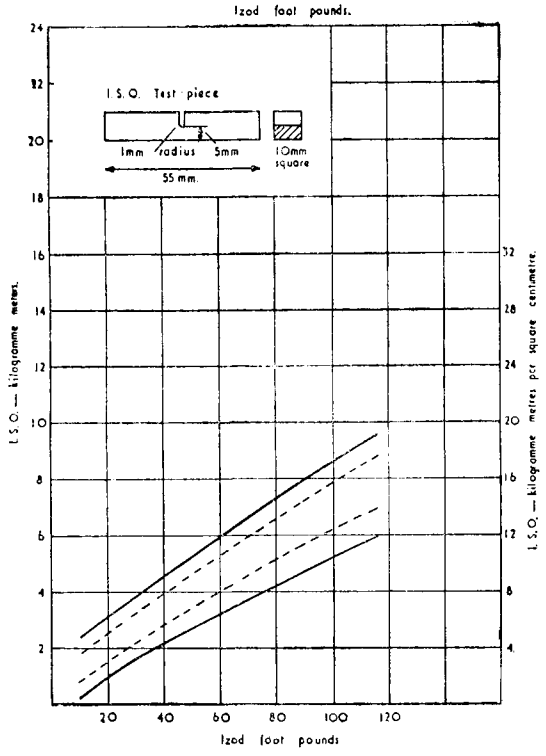
COMPARISON OF IMPACT VALUES OBTAINED WITH THE BRITISH STANDARD IZOD TEST AND VARIOUS ALTERNATIVE METHODS OF TESTING

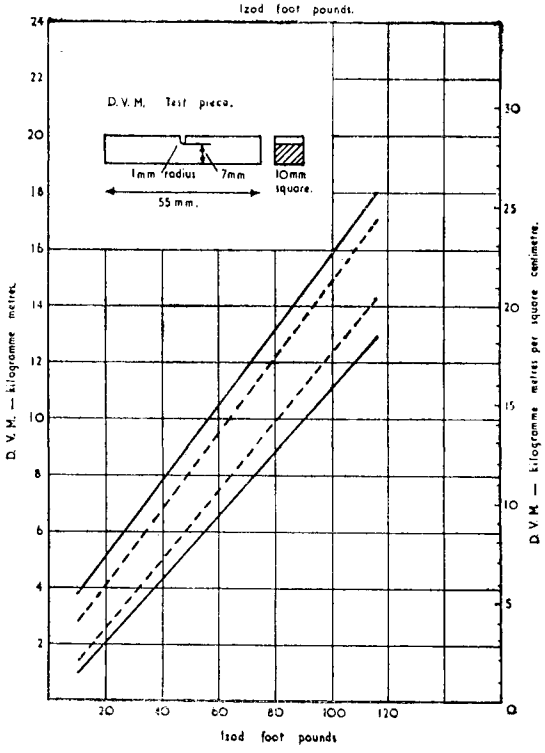
These graphs have been derived from a large number of results, each show two bands. The inner dotted band represents the area within which 50 per cent of the results may be expected to fall, whilst the wider full band covers approximately 80 per cent of results.

These curves should not be used for comparing or compiling specifications.









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