



STANDARDS and TYPICAL SPECIFICATIONS
for
TRAY TYPE DEAERATORS

SEVENTH EDITION

HEAT EXCHANGE INSTITUTE, INC.

STANDARDS and TYPICAL SPECIFICATIONS for **TRAY TYPE DEAERATORS**

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FOREWORD

The Deaerator Section of the Heat Exchange Institute has developed the seventh edition of this standard. The material in this standard has been selected to incorporate the safest available design criteria, as well as the highest levels of deaerator performance.

This standard contains practical information on the design, construction and operation of tray type deaerators. It is intended to serve as a guide for individuals who design, purchase and specify tray type deaerators.

This standard represents the collective experience of the Deaerator Technical Committee and is continually reviewed and discussed during regularly scheduled meetings. This standard has been renamed and the content revised, to reflect the Institute's position that the tray type deaerator is the superior design type with regard to overall performance, safety and longevity.

This standard continues to be influenced by the work of other organizations, such as American National Standards Institute (ANSI), American Society of Mechanical Engineers (ASME), American Society for Testing Materials (ASTM), National Society of Corrosion Engineers (NACE), and the Technical Association of the Pulp and Paper Industry. Special consideration and credit is given to NACE and TAPPI, for their extensive research on deaerator pressure vessel cracking. Particular attention and credit is given to NACE standard RPO 590-90. Adherence to this standard is strongly recommended.

Comments and suggestions for the improvement of this standard are always welcome and should be directed in writing to the Deaerator Section at the Institute's address.

1.0 SCOPE AND PURPOSE

1.1 Scope

The Seventh Edition of the HEI Standards and Typical Specifications for Tray Type Deaerators is intended to apply only to tray type designs which use steam as a means to heat incoming water and drive the deaeration process. This process heats the incoming water, condenses the steam, and liberates non-condensable gases from the incoming water.

The HEI realizes that there are other deaerator designs in the marketplace including spray type deaerators. This standard is written for tray type deaerators. Spray deaerators are defined as all deaerators that do not contain trays, sieve plates or packing. Spray deaerators are an economical alternative to a tray deaerator where longevity and ultimate performance are not a concern. Specifically, the HEI has eliminated spray deaerators from the standard, as they do not meet the general requirements of Section 6.1, paragraphs 3 and 4. Some European spray deaerators designs utilize cladding and/or stainless steel vessels to satisfy HEI requirements.

1.2 Purpose

The Seventh Edition of the Standard has been developed by the Deaerator Section of the Heat Exchange Institute. This Standard provides practical information on nomenclature, design considerations, testing, and performance of the tray type deaerator. Use of the Standard will ensure a minimum of misunderstanding between manufacturer and purchaser and will assist in the proper selection of equipment best suited to the requirements of the application.

The equipment covered by this standard should also conform to the appropriate part, and most current edition, of the ASME Boiler and Pressure Vessel Code. Typically, ASME Section VIII, Division 1 is applicable, although other sections and divisions can be utilized. While this HEI standard is intended to apply to all tray type deaerators, some specialized types may require additional specifications. This HEI specification will be required as a minimum standard for ASME Section 1, HRSG (Heat Recovery Steam Generator) Integral Deaerators.

2.0 DEFINITIONS

2.1 Deaerator

A deaerator is defined as a thermo-mechanical device for removal of dissolved gasses, primarily oxygen and carbon dioxide, from water. For the purposes of this standard, we will consider only pressurized and vacuum types which deaerate by contacting water with steam and elevating the temperature. Vacuum degassifiers remove dissolved gasses by reducing the pressure over the liquid without heating and will not be considered in this standard. Also, in cases where the storage section is a separate vessel, the term deaerator is used to describe what might better be called the deaerator vessel or deaerator section.

2.2 Tray Deaerator

This is a common industry term for a type of deaerator also known as a spray-tray deaerator. Inlet water is sprayed into a steam atmosphere and falls onto a bank of trays through which the steam passes. Steam flow may be co-current, cross-current, or counter-current to the water flow.

2.3 Spray Deaerator

This is the common industry term for a unit which might more properly be called a spray-scrubber or a spray atomizing deaerator. Inlet

water is sprayed into a steam atmosphere and falls onto a collector pan from which it flows into the scrubber/atomizer where it is mixed with incoming steam.

2.4 Storage Section

The storage section is an area in or below a deaerator which contains a specified volume of deaerated water. This may be contained in the lower portion of an integral unit or may be a separate tank located below the deaerator tank. See Section 7.5.

2.5 Pressure Vessel

A pressure vessel is "a metal container, generally cylindrical or spheroid, capable of withstanding various loadings."¹

2.6 Vent Condenser

The vent condenser is typically an internal direct contact area in a deaerator where steam is cooled by the incoming water and caused to condense. Shell and tube heat exchangers may be used as external vent condensers, where specified by the customer on vacuum units.

¹ Pressure Vessel Handbook, Eugene F. Megyesy, 10th Edition, 1995, page 489.

2.7 Vent

A vent is an opening in the deaerator through which the noncondensable gasses and some steam are released. This release is normally to the atmosphere, although it is possible to vent to a vacuum for special applications.

2.8 Design Pressure and Temperature

The pressure and temperature for which the pressure vessel is mechanically designed. The maximum allowable working pressure (MAWP) shall be equal to the design pressure, unless otherwise specified. The minimum design metal temperature (MDMT) shall be -20°F, unless otherwise specified.

2.9 Operating Pressure and Temperature

The operating pressure is the pressure inside the deaerator when operating. This pressure is important as it determines what the temperature of the deaerator effluent will be. The deaerator effluent temperature will be within 2°F of the saturated temperature at the operating pressure.

2.10 Corrosion Allowance

An additional thickness of steel added to the pressure vessel in addition to that required to meet the structural requirements for pressure vessel design normally expressed in inches.

2.11 Rated Capacity

The total quantity of deaerator effluent including condensed inlet steam, water inlet, high pressure returns, and all other inlet flows normally expressed in pounds per hour.

2.12 High Pressure Returns

Flows which enter the deaerator or storage tank from higher pressure sources or sources such as high pressure feedwater heaters.

2.13 Low Pressure Returns

Flows which enter the deaerator at elevated, but less than saturation, temperatures.

2.14 Makeup

Undeaerated flow which enters the deaerator and is saturated with dissolved noncondensable gasses at the temperature specified.

2.15 Sentinel Partial Relief Valve

A warning device that indicates pressure exceeding normal operating conditions by exhausting steam.

2.16 Safety Relief Valve

A device that protects the vessel against pressurization above the design pressure.

2.17 Downcomer Flow

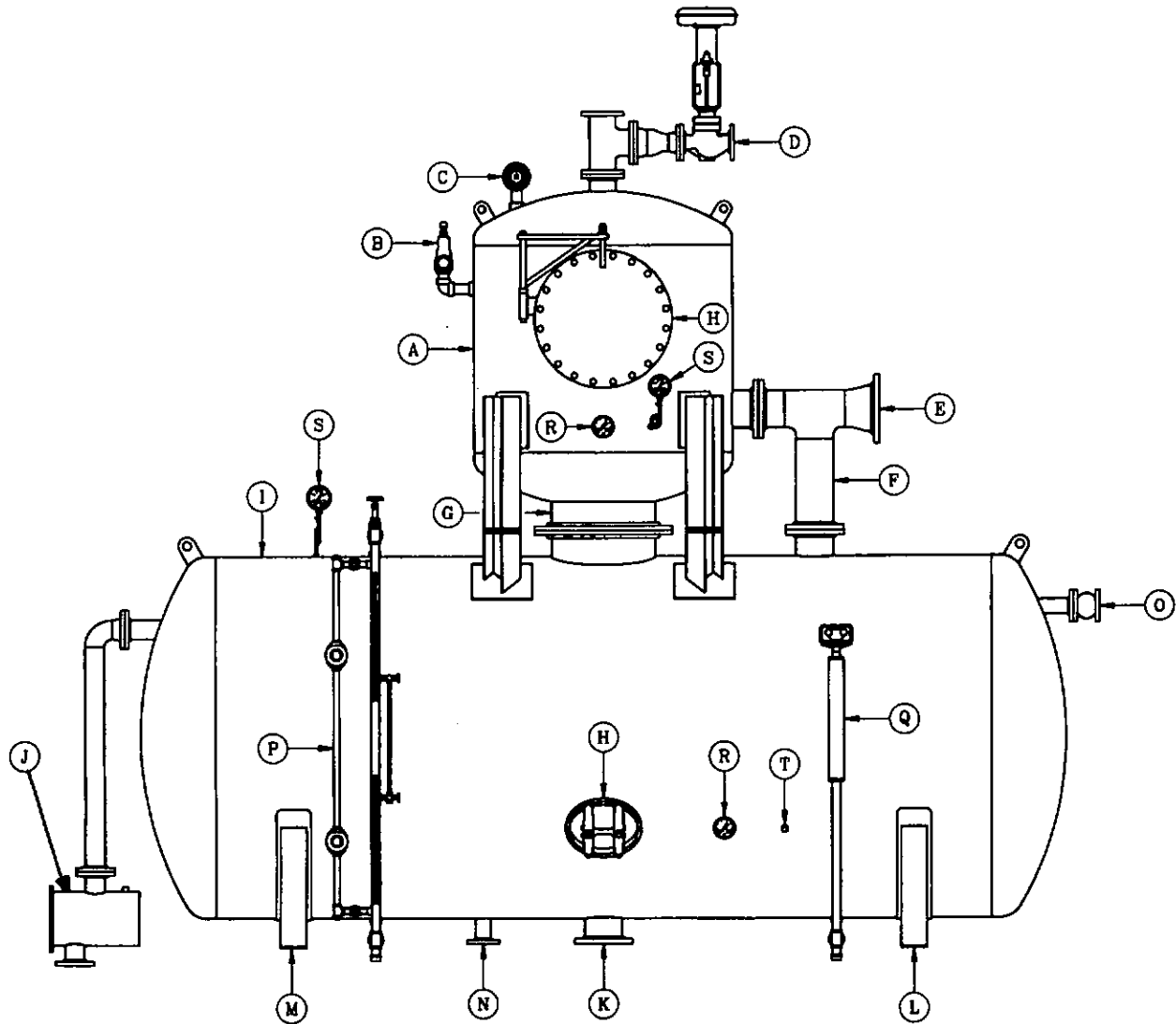
Deaerated outlet flow to the storage section.

2.18 Equalizer

A method of maintaining equal pressure between the deaerator and storage section.

3.0 TYPICAL VESSEL CONNECTIONS, ACCESSORIES, AND ORIENTATION

Please see Figure 1 for typical deaerator connections and accessories and Figure 2 for vessel orientations. The sketch itself is merely illustrative for the purpose of indicating names of parts.

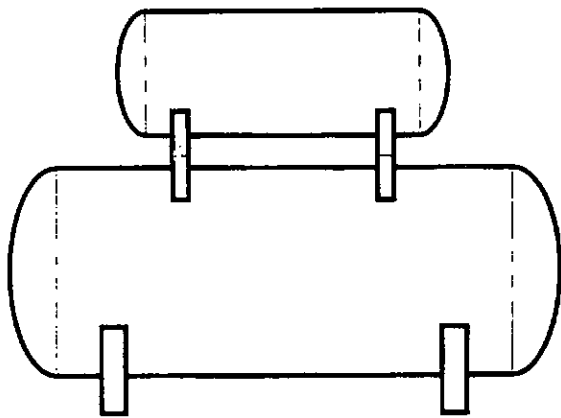


- | | |
|----------------------|-----------------------------------|
| A. Deaerator Section | K. Outlet |
| B. Relief Valve | L. Fixed Support Saddle |
| C. Vent | M. Sliding Support Saddle |
| D. Water Inlet | N. Drain |
| E. Steam Inlet | O. Vacuum Breaker |
| F. Equalizer | P. Level Gauge/Level Alarm Column |
| G. Downcomer | Q. Level Controller |
| H. Access Manway | R. Thermometer |
| I. Storage Section | S. Pressure Gauge |
| J. Overflow Control | T. Sampling Connection |

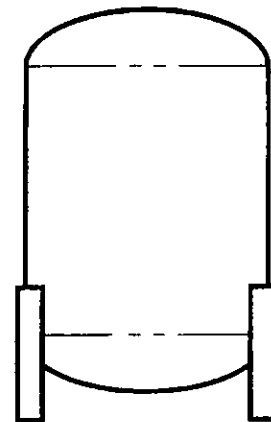
TYPICAL CONNECTIONS AND ACCESSORIES

Fig. No. 1

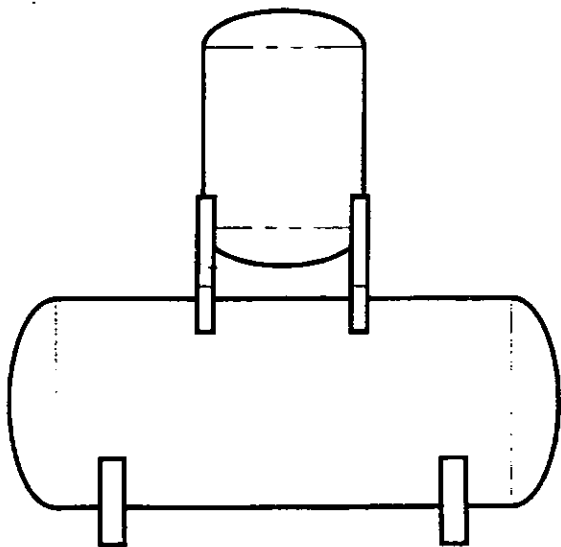
4.0 ILLUSTRATIONS OF TYPICAL TRAY DEAERATOR ORIENTATIONS



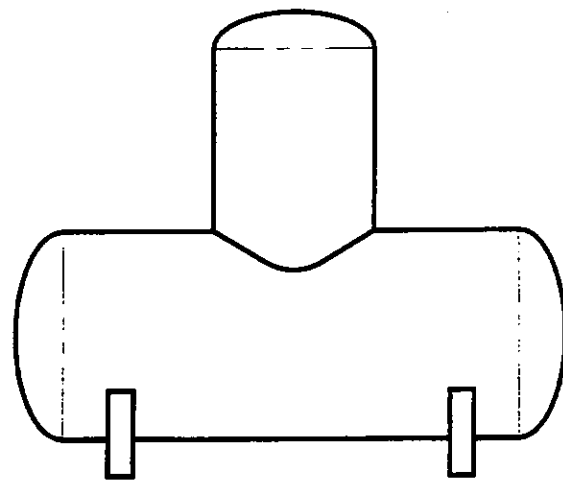
HORIZONTAL DEAERATOR ON
HORIZONTAL STORAGE TANK



VERTICAL DEAERATOR WITH
INTEGRAL STORAGE TANK



VERTICAL DEAERATOR ON
HORIZONTAL STORAGE TANK



TANK CAR DEAERATOR ON
HORIZONTAL STORAGE TANK

TYPICAL ORIENTATIONS

Fig. No. 2

5.0 STANDARDS OF CONSTRUCTION

5.1 Code Requirements

A deaerator shall be constructed and stamped in accordance with the applicable portion of the ASME Code, normally Section VIII, Division 1, and/or the appropriate state and local requirements for pressure vessel construction.

5.2 Design Requirements

The ASME Code may not be adequate for minimum deaerator pressure vessel design for all applications. Many of these units operate at conditions which require more stringent design standards. Deaerator design shall therefore incorporate the following, in addition to the ASME Code:

5.2.1 A corrosion allowance of 1/8" (3 mm) is to be included in the deaerator head and shell. A minimum corrosion allowance of 1/16" (1.5 mm) is to be included on nozzles, internal nozzle reinforcing pads, nozzle necks, and manway covers. The corrosion allowance for stainless steel nozzles shall be zero.

5.2.2 The vessels shall be Post Weld Heat Treated (PWHT). Treatment shall be in accordance with the ASME Code.

5.2.3 The following tests shall be performed on the internal nozzle to shell weld:

- a. Carbon Steel Nozzle to Carbon Steel Shell - Magnetic Particle Testing
- b. Stainless Steel Nozzle to Carbon Steel Shell - Dye Penetrant Testing
- c. Stainless Steel Nozzle to Stainless Steel Shell - Dye Penetrant Testing
- d. Carbon Steel Nozzle to Stainless Steel Shell - Dye Penetrant Testing

5.2.4 Internal and external weld seams must be sufficiently smooth to produce satisfactory NDE results. The transition between the base metal and weld metal need not have a radius.

5.2.5 Longitudinal and circumferential head and shell weld seams are to be radiographed per ASME Section VIII, Division 1 in order to obtain a 1.0 joint efficiency.

5.3 Pressure/Vacuum Design

The vessels shall be designed for the pressure and temperature as specified by user/engineer. Internal design pressure shall be a minimum of 30 psig. Design temperature shall be a minimum 400 degrees F. The vessels shall be designed for full vacuum or shall be provided with a vacuum relief device.

5.4 Pump Suction Design

The pump suction outlet nozzle shall extend a minimum of 3" into the storage section and shall be provided with a vortex breaker.

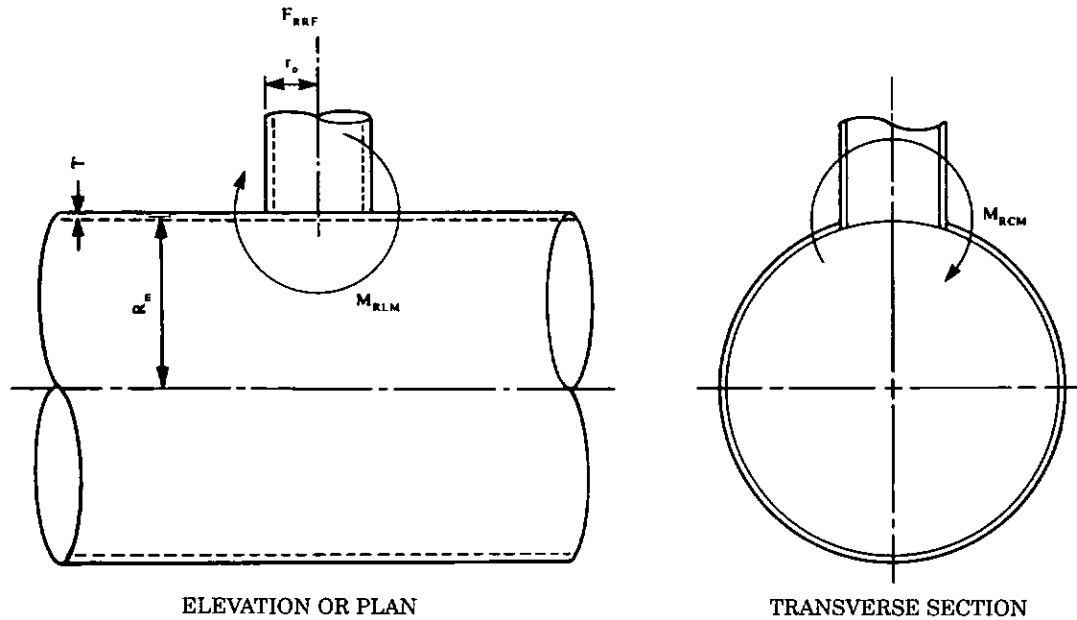
5.5 Nozzle Loads

The determination of acceptable nozzle loads is a complex problem involving the interaction of external forces and moments applied at the vessel wall. These loads are functions of the mechanical and thermal piping design. Frequently, the piping designer has a need to know the allowable loads at the nozzle in order to determine the piping configuration and generate the actual loads. The following procedure permits estimating nozzle loads for cylindrical shells. The procedure is based in part on the design data included in Welding Research Council Bulletin 107.² The allowable loads have been linearized to show the interaction between the maximum permitted external radial load and the maximum permitted applied moment vector. Once the maximum forces and moments are determined, a diagram similar to Figure 4.1 should be plotted to ensure that the maximum combined loads are not exceeded.

The procedure represents a simplification of the method of WRC 107 and users of the procedure included in this standard are cautioned that more exact analysis is required to verify the adequacy of final designs. The stresses considered in developing the procedure have been defined as secondary stresses with stress limits established according to the definition. Although the effect of internal pressure has been included in the combined stresses, the effect of pressure on nozzle thrust has not been included and requires combination with other radial loads.

Loads exceeding those calculated by this method usually require additional reinforcement. The user is cautioned that the higher allowable loads obtained through design modification may require strengthening other parts such as supports, supporting structure and floors. It should be understood by the user that the deaerators are not intended to serve as anchor points for the piping.

² Local Stresses in Spherical and Cylindrical Shells Due to External Loadings, K. R. Wichman, A. G. Hopper and J. L. Mershon - Welding Research Council. Bulletin 107/ August 1965 - Revised Printing - December 1968.



PROCEDURE FOR CALCULATING NOZZLE EXTERNAL FORCES AND MOMENTS IN CYLINDRICAL VESSELS

Figure No. 3

5.5.1 Nomenclature

P	= Design Pressure, pounds per square inch	α	= Dimensionless Numbers
r_o	= Nozzle Outside Radius, inches	Σ	= Dimensionless Numbers
R_m	= Mean Radius of Shell, inches	Δ	= Dimensionless Numbers
T	= Shell Thickness, inches	F_{RRF}	= Maximum Resultant Radial Force, pounds*
S_y	= Yield Strength of Material at Design Temperature, pounds per square inch	M_{RCM}	= Maximum Resultant Circumferential Moment, inch-pounds*
σ	= Stress Due to Design Pressure, pounds per square inch	M_{RLM}	= Maximum Resultant Longitudinal Moment, inch-pounds*
S_a	= ASME Section VIII, Division 1 Code Allowable Stress, pounds per square inch	F_{RF}	= Maximum Resultant Force, pounds*
β	= Dimensionless Numbers	M_{RM}	= Maximum Resultant Moment, inch-pounds*
γ	= Dimensionless Numbers		

*Use absolute values.

Note: All thicknesses and dimensions are in the corroded condition.

5.5.2 External Forces and Moments

To calculate the maximum force and moment, first evaluate β and γ . Then determine α , Σ and Δ from Figures 5, 6 and 7 for the specified β and γ , substitute into the equations below and calculate F_{RRF} , M_{RCM} and M_{RLM} .

$$\beta = .875 \left(\frac{r_o}{R_m} \right) \quad \gamma = \frac{R_m}{T}$$

Determine α , Σ and Δ from Figures 5, 6 and 7. Calculate Pressure Stress (σ).

$$\sigma = \frac{P}{T} \left(R_m - \frac{T}{2} \right)$$

$$F_{RRF} = \frac{R_m^2}{\alpha} (S_y - \sigma)$$

$$M_{RCM} = \frac{R_m^2 r_o}{\Sigma} (S_y - \sigma)$$

$$M_{RLM} = \frac{R_m^2 r_o}{\Delta} (S_y - \sigma)$$

Plot the value of F_{RRF} as F_{RF} and the smaller of M_{RCM} and M_{RLM} as M_{RM} . The allowable nozzle loads are bounded by the area F_{RF} , 0, M_{RM} .

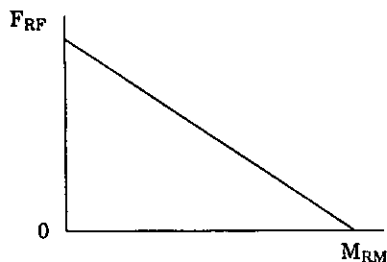


Fig. No. 4.1

5.5.3 Sample Problem

Determine Resultant Force and Moment for a vessel made from SA-516-70 with a design temperature of 650°F.

$$\begin{aligned} R_m &= 37.5 \text{ in} & S_y &= 28,200 \text{ psi @ } 650^\circ\text{F} \\ r_o &= 15 \text{ in} & S_a &= 18,800 \text{ psi @ } 650^\circ\text{F} \\ T &= 0.75 \text{ in} \\ P &= 150 \text{ psig} \end{aligned}$$

$$\beta = 0.875 \left(\frac{r_o}{R_m} \right) = 0.875 \left(\frac{15}{37.5} \right) = 0.35$$

$$\gamma = \left(\frac{R_m}{T} \right) = \frac{37.5}{0.75} = 50$$

From Figure 5, $\alpha = 440$

From Figure 6, $\Sigma = 1,085$

From Figure 7, $\Delta = 330$

Calculate Pressure Stress

$$\sigma = \frac{P}{T} \left(R_m - \frac{T}{2} \right) = \frac{(150)}{.75} \left(37.5 - \frac{.75}{2} \right) =$$

$$7,425 \text{ psi} < S_a = 18,800 \text{ psi}$$

Use $\sigma = 7,425$ psi in the equations for calculating F_{RRF} , M_{RLM} and M_{RCM} .

Calculate Allowable Forces and Moments

$$F_{RRF} = \frac{R_m^2}{\alpha} (S_y - \sigma) =$$

$$\frac{(37.5)^2}{440} (28,200 - 7,425) = 66,397 \text{ lbf}$$

$$M_{RCM} = \frac{R_m^2 r_o}{\Sigma} (S_y - \sigma) =$$

$$\frac{(37.5)^2 (15)}{1,085} (28,200 - 7,425) = 403,892 \text{ in-lbf}$$

$$M_{RLM} = \frac{R_m^2 r_o}{\Delta} (S_y - \sigma) =$$

$$\frac{(37.5)^2 (15)}{330} (28,200 - 7,425) =$$

$$1,327,947 \text{ in-lbf}$$

Plot the value of F_{RRF} as F_{RF} and the smaller of M_{RCM} and M_{RLM} as M_{RM} . The allowable nozzle loads are bounded by the area of F_{RF} , 0, M_{RM} .

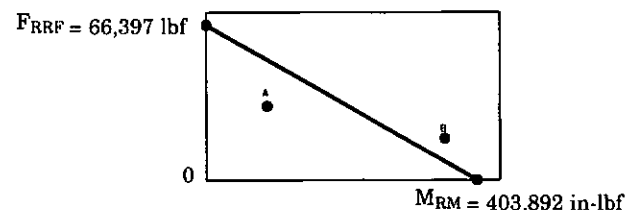
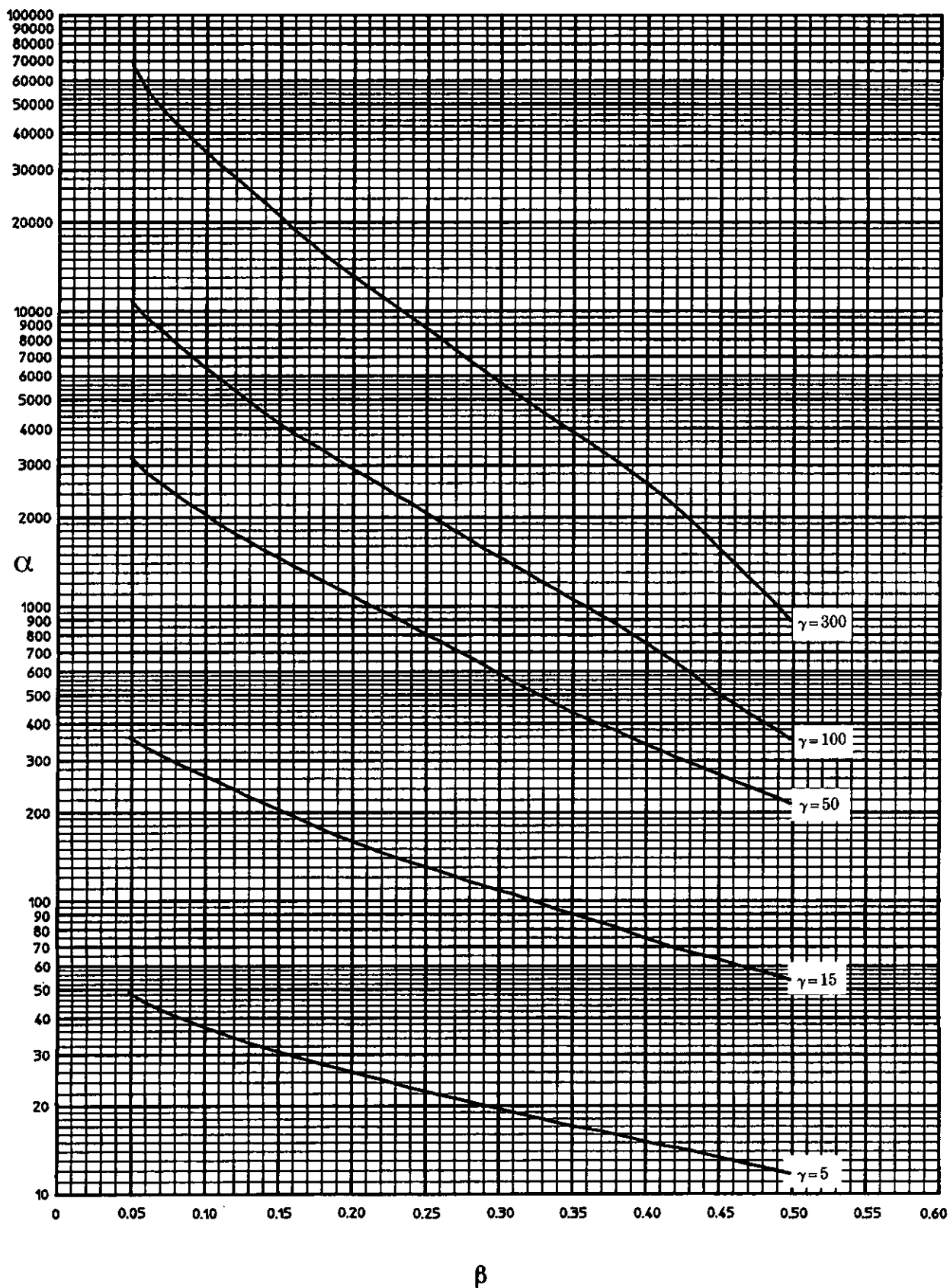


Fig. No. 4.2

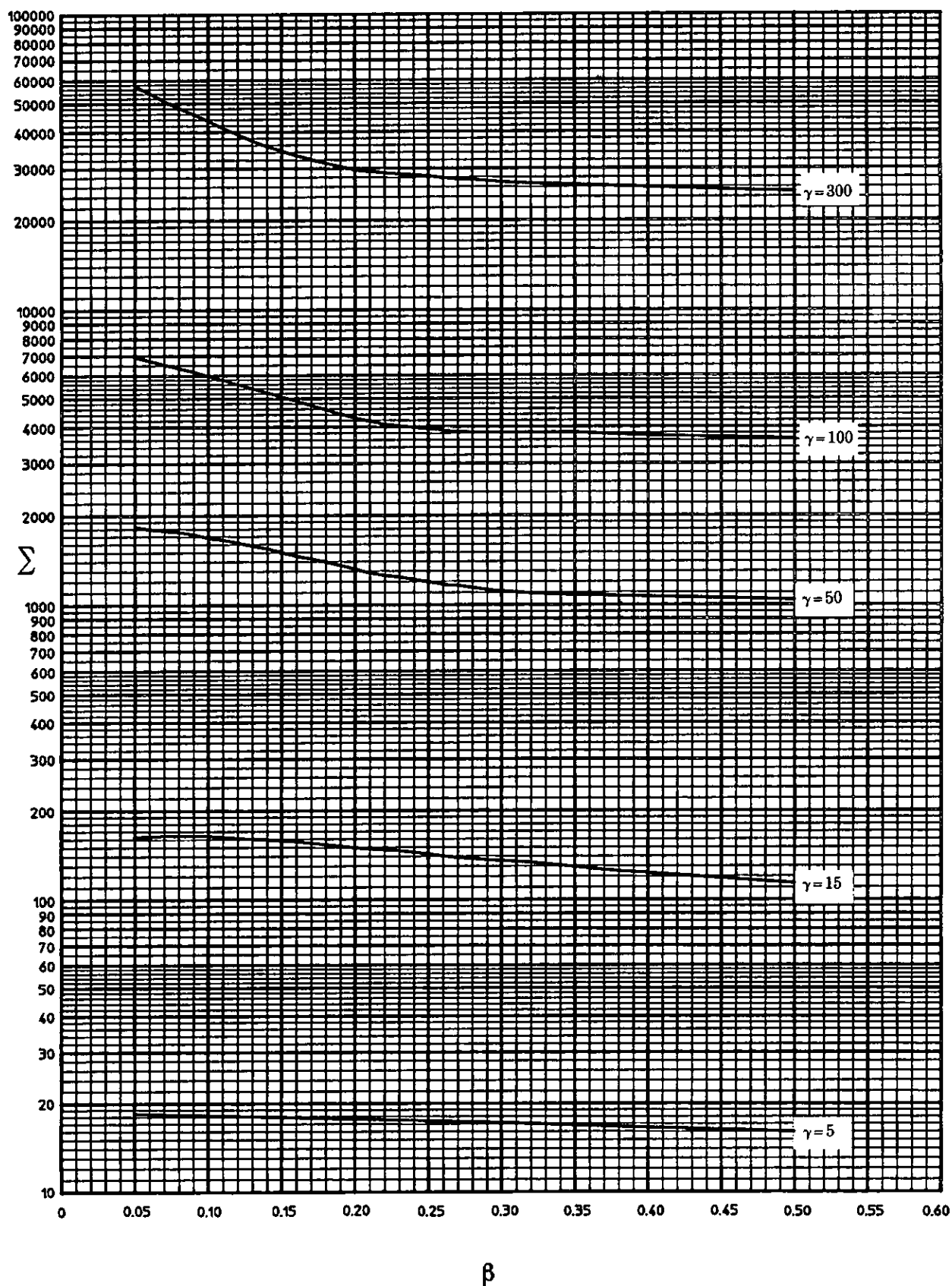
Therefore, a nozzle reaction of $F = 35,000$ lbf. and $M = 100,000$ in-lbf would be allowable (point A) but a nozzle reaction of $F = 20,000$ lbf and $M = 350,000$ in-lbf would not be allowable (point B).

*Note: Use absolute values in the graph.



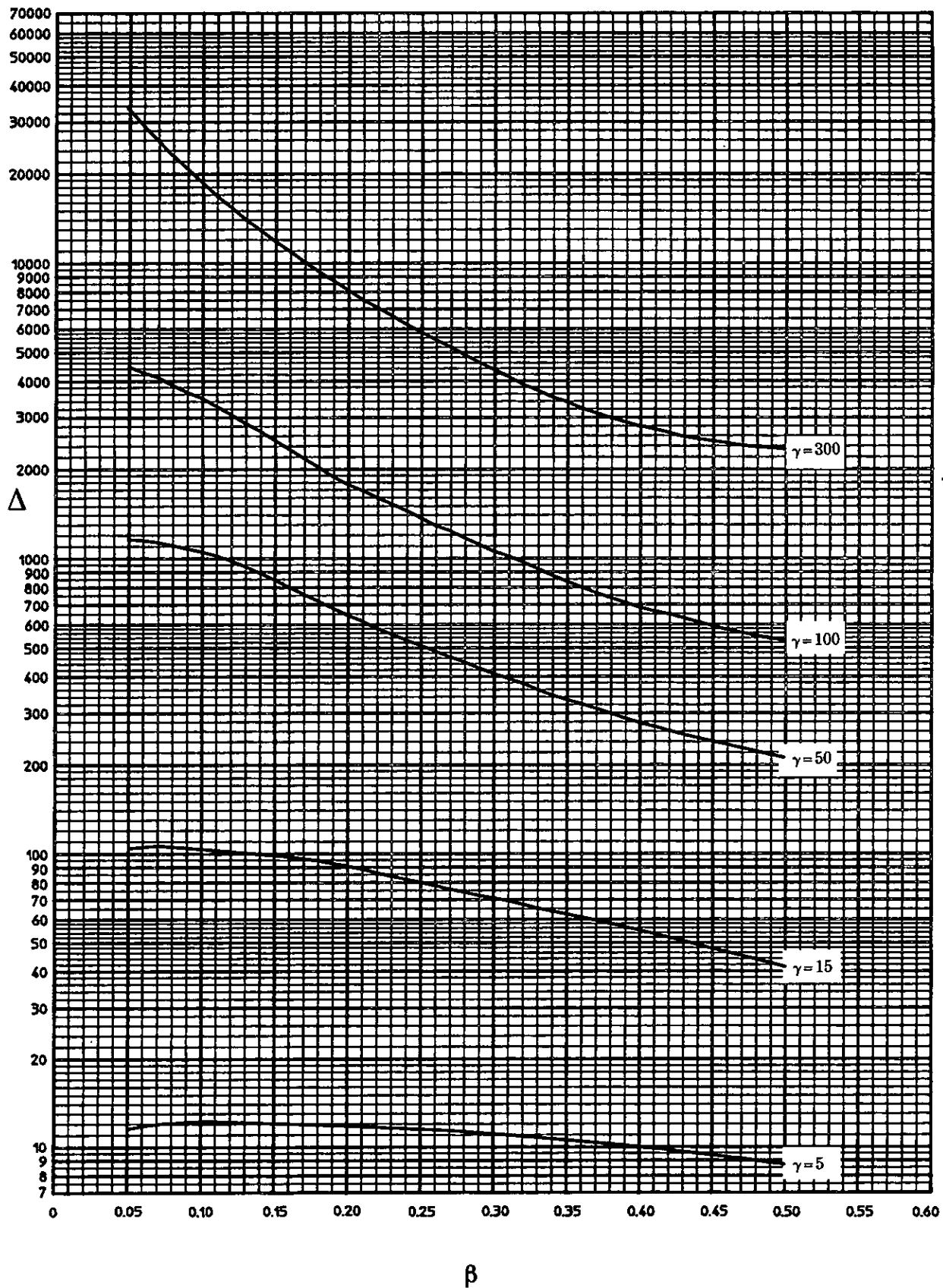
ALLOWABLE NOZZLE LOADS

Fig. No. 5



ALLOWABLE NOZZLE LOADS

Fig. No. 6



ALLOWABLE NOZZLE LOADS

Fig. No. 7

5.6 Nozzle Sizes

The deaerator shall be provided with a minimum of steam inlet, water inlet, pump suction, overflow, drain, vent, relief valve, sample, pressure gauge, and thermometer connections. Suitable openings shall be provided for inspection and removal of parts.

The following velocity ranges should be used for nozzle sizing:

Connection	Velocity
Water Inlet	6-8 fps
Steam Inlet (> 0 psig)	125-175 fps
Pump Suction (≤ 4 in)	3 fps
Pump Suction (> 4 in)	3-5 fps
Overflow –	
749,000	3-5 fps
750,000 – 1,999,999	10 fps
Above 2 million	12 fps
Inlet High Pressure Drain	10-14 fps
Downcomer	2 fps max.

For large capacity units, the overflow connection size is considered a function of individual plant design. This table serves only as a guideline to be used when no specific information is provided.

Manways - Elliptical manway size shall be a minimum 12" x 16" on the storage vessel and a minimum of 18" diameter hinged or davited manway on the deaerator section.

5.7 Accessories

Selection and sizes should be based on maximum operating conditions specified. Accessories shall be provided when specifically requested by the purchaser.

5.7.1 Relief Valves

One or more relief valves shall be provided to either protect the pressure vessel against overpressurization or act as sentinel relief. This can occur upon a failure of the steam pressure reducing valve, single or multiple trap discharges entering the deaerator, or other conditions. It is the responsibility of the purchaser to evaluate all possible conditions and determine the worst case scenario for sizing the relief valve. If sentinel relief is selected by the customer for the deaerator, safety relief must be provided elsewhere in the system.

It is the Institute's minimum recommendation that the relief valve(s) be capable of passing the fail open capacity of the steam pressure reducing valve with the relief pressure set at the vessel

design pressure. If high pressure trap discharges or heater drains are present, additional relieving capacity may be required to protect the vessel.

These valve(s) may be supplied by the deaerator manufacturer or the purchaser; however, all sizing criteria is to be determined by the purchaser and/or engineer. Table 1 indicates the minimum recommended sentinel relief valve size based on the rated capacity of the deaerator.

TABLE 1
Minimum Sentinel Relief Valve Size

Rated Capacity Lbs./Hr	Relief Valve Size - Inches
0 - 19,999	1.5
20,000 - 44,999	2
45,000 - 99,999	2.5
100,000 - 199,999	3
200,000 - 599,999	4
600,000 - 1,199,999	6 (Quantity = 1)
1,200,000 and over	6 (Quantity = 2)

5.7.2 Vacuum Breaker

If vessel is not designed for full vacuum, a vacuum breaker shall be provided with minimum sizes as shown in Table 2.

TABLE 2
Vacuum Breaker Selection

Rated Capacity Lbs./Hr	Vacuum Breaker Size - Inches
0 - 19,999	1
20,000 - 44,999	1.5
45,000 - 99,999	2
100,000 - 199,999	2.5
200,000 - 599,999	3
600,000 - 899,999	4
900,000 - 1,199,000	6 (Quantity = 1)
1,200,000 and over	6 (Quantity = 2)

5.7.3 Water Inlet Regulating Valves and Controls

It may be desirable to control the water flow from one or more sources. The valve size depends on the required flow rate, temperature, and valve inlet and outlet pressures. External control equipment shall be complete with equalizing lines and shutoff valves to connect to the storage space.

5.7.4 Overflow Control

This control is a device to protect against high water level in the storage area.

5.7.5 Level Gauges

At a minimum, level gauges shall be provided to cover from 10% to 90% of storage tank diameter.

5.7.6 Thermometers

Thermometers, properly located, give a visual indication of deaerator performance. Probable locations are the steam space of the deaerator, and under the water level in the storage area.

5.7.7 Level Switches

Switches may be desirable for warning of high or low water levels and for boiler feedpump cutoff. Audible or visible alarms may be specified if desired.

5.7.8 Pressure Gauge

A pressure gauge shall be provided for the steam space. Range shall cover the design pressure of the unit.

5.7.9 Vent Valve(s)

Properly sized vent valve(s) or vent orifice(s) shall be installed.

5.8 Other Design Considerations

In many plants today, it is necessary to save energy in every way possible. One of the ways this is done is to heat the inlet water to the deaerator, usually using a shell and tube heat exchanger. It should be recognized that this practice may be detrimental to proper deaerator operation and may also shorten deaerator life, often by many years. Preheating the cold makeup water to the deaerator reduces steam demand in the deaerator, but more importantly, if the inlet water is saturated or nearly saturated with noncondensable gasses, preheating it may cause liberation of these gasses, resulting in free air, which the deaerator may not be able to remove. This should be taken into consideration in the original design concept of the plant and in subsequent modifications.

Optimum deaerator performance is achieved at steady state operation. Events such as turbine trips, deaerator pressure loss, cold water inlet surges, etc. will degrade performance and potentially damage the deaerator.

It must be recognized that frequent cooldown and reheat of a deaerator can cause cracking and premature corrosion. It is recommended that

deaerators which are operated intermittently be maintained in a hot, standby mode. At the very least, the purchaser/engineer should consider an auxiliary means of warming the stored water prior to start-up, such as a sparger pipe, electric heaters, or other method.

Mixing high temperature and low temperature flows within the deaerator can cause thermal stresses, potentially damaging to the deaerator internals. Makeup and low pressure condensate shall be mixed at least 10 pipe diameters prior to introduction into the deaerator to eliminate possible damage to the internals. Makeup and low pressure condensate, including all flows lower than the outlet deaerator temperature shall be mixed in a tee in the external piping to the deaerator.

6.0 MATERIALS OF CONSTRUCTION

6.1 General

The materials used for pressure parts and for external supports, where applicable, shall be in accordance with the ASME Code, as necessitated by the Design Specifications.

Some materials which are permitted for use in Section VIII deaerators may not be permitted by the ASME Code for use in the construction of Section I deaerators. Furthermore, the required tests and inspections differ depending on the applicable section of the ASME Code.

All materials in contact with undeaerated or partially deaerated water shall be a minimum of 1/8" thick stainless steel, including the inlet nozzle, waterbox, waterbox lining, vent condenser, valve plate, vent, and spray valves. Tray enclosures shall be a minimum of 1/8" thick stainless steel. Trays shall be a minimum of 20 gauge stainless steel.

All materials, including heads and shells, in contact with steam which has previously been in contact with undeaerated water or partially deaerated water shall be stainless steel, stainless steel lined, or stainless steel clad.

It would be impractical to list all the materials that may be used in Code constructed units; however, some of the more commonly used materials and the parts for which they are used are given in Table 3. It is recommended that the materials in Table 3 be utilized as minimum requirements for materials of construction. It is recommended that SA-515 not be utilized.

6.2 Gaskets

The choice of suitable gasket material depends upon the condition of service and, unless otherwise specified by the Purchaser, will be in accordance with the standards of the deaerator manufacturer.

6.3 Makeup Inlet Nozzle

The makeup inlet nozzle for deaerators shall be stainless steel, or stainless steel lined.

6.4 Water Inlet Chamber (Waterbox)

The water inlet chamber shall be fully enclosed by stainless steel so as to prohibit all undeaerated water from coming in contact with any carbon steel.

6.5 Valve Plate/Vent Condenser Area

The valve plate and vent condenser area is where noncondensable gasses and steam collect. This area shall be constructed of stainless steel so as to prohibit noncondensibles and steam which

have been in contact with undeaerated or partially undeaerated water from coming in contact with any carbon steel.

6.6 Tray Enclosure

The tray enclosure contains the trays that remove the final traces of noncondensable gasses and shall be stainless steel.

6.7 Trays

Trays shall be stainless steel and shall be stamped or riveted. Welding shall not be utilized for tray construction.

6.8 Corrosion Allowance & Minimum Thicknesses

The vessel head and shells shall be fabricated in accordance with the ASME Code with 1/8" corrosion allowance³. Nozzles, reinforcing pads, nozzle necks, and manway covers shall include a minimum of 1/16" corrosion allowance. A corrosion allowance is not required for stainless steel components.

See Table 3 for additional minimum thicknesses of materials.

TABLE 3
Minimum Thickness and Material

Deaerator Component	Minimum Thickness and Material
Waterbox	1/4" S.S., L grade
Inlet Header Pipe	Schedule 10s S.S., L grade
Tray Enclosure	1/8" S.S., L grade
Vent Condenser/Hood	1/8" S.S., L grade
Trays	20 Gauge S.S.
Baffles	1/4" S.S., L grade
Drip Shields/Vortex Breakers	1/4" C.S.
Head and Shell	3/16" + corrosion allowance for C.S. or 1/4" S.S.

Note: The thickness of corrosion resisting linings and cladding shall not be included in the above minimum thicknesses.

³ 3 mm is substantially equivalent to 1/8" and 1.5 mm is substantially equivalent to 1/16" for projects using SI Units.

7.0 DEAERATOR PERFORMANCE

7.1 Operating Conditions

In order for the deaerator manufacturer to properly design the unit, the buyer must make available all known operating conditions and circumstances (heat/mass balances), including especially, start-up, minimum flow, maximum flow, and others. Simply providing a design condition may not provide sufficient information to adequately design the unit.

7.2 Thermal Capacity

The deaerator shall be guaranteed to heat the influent water to within 2°F of the saturation temperature of the steam in the deaerator at the operating pressure. Note that the potential exits for temperature indicators to give readings higher than saturation temperatures if superheat is present in the steam. Saturation temperature must be verified using the operating pressure of the unit.

The user shall provide the minimum inlet water temperature, percentage of makeup and operating pressure at each design condition. (Refer to Deaerator Specification Sheet attached).

7.3 Performance Guarantee

Tray deaerators are capable of and shall operate from 10% to 100% of design point and achieve .005ml/l (7PPB) outlet dissolved oxygen content. Oxygen/carbon dioxide removal guarantees are based on the following assumptions unless more specific data is provided by the customer.

TABLE 4
Incoming Flow Assumptions

Flow	Oxygen Inlet	Carbon Dioxide Inlet
Makeup	saturated at inlet temp. at atmospheric condition	< 10 PPM
Condensate	< 50 PPB	< 50 PPB
HP returns	< 7 PPB	None
Steam	None	None

The deaerator shall remove all carbon dioxide from loads of 10% to 100% when tested by the APHA method.

7.4 Testing

When operated properly, deaerators can and do produce water with very low levels of dissolved noncondensable gasses. In order to determine what noncondensable gas level the deaerator is producing, it is imperative that the analysis be conducted very carefully. Atmospheric gasses that enter a water sample can lead to a completely erroneous reading. The analyst must be diligent in preventing gasses from entering the sample. Gasses can be introduced into pressurized piping systems through leaking pump seals and other mechanical means.

Testing should be in accordance with a suitable colorimetric test. "On-line" testing shall not be an acceptable method of verifying.

Testing shall be performed at the storage vessel as close to the pump suction as possible, and below the water level. The sample point should never be downstream of the boiler feed pump.

BFP recirculations must be turned off or directed elsewhere prior to the performance test.

The test shall be performed at the deaerator storage section with less than 5 feet of SS tubing and a SS sample cooler with one isolation valve on the inlet and outlet. All excess fittings shall be removed.

Oxygen scavenger shall be turned off prior to the test.

The unit shall be running at a minimum of three days and at a constant load for three hours (see footnote in Section 8.0).

Testing shall be performed in accordance with the instrument manufacturer's guidelines. Run sample for 2 hours prior to test.

The test must be completed within 10 seconds of drawing the sample from the storage tank.

Additional tests shall be taken (approximately five or six). The lowest reading shall be determined as the oxygen level, as false low readings are not possible. High readings are assumed to be in error as a false high reading is possible due to a poor test. Do not average readings.

If the results of the colorimetric test are not acceptable, the customer shall conduct testing in accordance with ASME PTC 12.3. Carbon dioxide test shall be ran per the APHA method.

7.5 Storage Capacity

For deaerators with separate storage and deaerating vessels, it is recommended that a ten minute storage to overflow be supplied as a minimum unless otherwise specified. Storage of 5 to 7 minutes for central station utility units

may be adequate. The overflow level shall not be closer to the top of the vessel than 85% of the tank diameter.

For a single tank deaerator with integral storage, the storage capacity shall be 10 minutes to overflow as determined by the manufacturer's design criteria.

The storage capacity shall be calculated using the density of water at the effluent temperature.

Refer to Table 5 for approximate storage requirements for different rated capacities.

TABLE 5
Storage Tank Requirements

Flow PPH	Lbs	Cu Ft	Gallons
10,000	1,667	28	208
20,000	3,334	56	416
30,000	5,000	83	623
40,000	6,667	111	831
50,000	8,334	139	1,039
60,000	10,000	167	1,247
75,000	12,500	208	1,558
100,000	16,667	278	2,078
150,000	25,000	417	3,117
200,000	33,334	556	4,156
250,000	41,667	694	5,195
300,000	50,000	833	6,233
400,000	66,667	1,111	8,311
500,000	83,334	1,389	10,389
600,000	100,000	1,667	12,467
700,000	116,667	1,944	14,545
800,000	133,334	2,222	16,622
900,000	150,000	2,500	18,700
1,000,000	166,667	2,778	20,778

Above table is based on a water density of 60 lb/ft³, and 10 minutes of storage.

8.0 GUIDE TO TROUBLESHOOTING DEAERATORS

Symptom	Possible Causes	Comments or Possible Solutions
8.1 High O ₂	- Air in-leakage - Insufficient stabilization period* - Trays not installed properly and in place - Not steady state conditions* - O ₂ inlet not in accordance with specified design conditions - Spray valves not installed correctly - Water inlet temperature too low - Improper venting	
	- Incorrect testing	- See test procedures in section 7.4 - Loose fittings - Shut scavenger off - Remove chemical interferences
	- Operation outside of design conditions	- Verify design conditions
8.2 Excessive Pressure Fluctuation	- Steam PRV improperly sized or calibrated	- Check size and calibration
	- Improperly sized downcomer and equalizer - Inlet steam pressure too high or too low - Improper pilot installation	
	- Excessive inlet temperature variation	- Keep within design range
	- Heater flooding	- Check all valve and control settings
8.3 Low Outlet Temperature	- Incorrect thermometer reading	- Check calibration
	- Insufficient steam flow	- Check steam supply - Check for restrictions - Check pipe and valve sizing
	- Incorrect steam/water ratio	- Check heat and mass balances
	- Spray valves or internals malfunctioning	- Check spray valves, trays, etc.
	- Heater flooding	- Check all valve and control settings
	- Inlet flows piped incorrectly	- Check all inlet flows and temperatures
8.4 Water Hammer	- Inlet flows mixing just prior to deaerator inlet	- Mix flows farther upstream of deaerator
	- Improper pipe design	- Check and/or redesign
	- High inlet velocities	- Keep within HEI

*Often, high oxygen measurements can be traced to inadequate test procedures. In order to conduct a proper test, it is important that there be a sufficient stabilization period and steady state conditions. The proper length of a stabilization period is extremely dependent on system-specific conditions, particularly the size of the system. Therefore, while three days of boiler operation are typically required to reach steady state, no definitive guidelines can be given. As a general rule, if there is a downward trend in oxygen content measurements, steady state condition has not yet been attained.

**Shading is provided for the ease of reading only.

GUIDE TO TROUBLESHOOTING DEAERATORS (con't.)

Symptom	Possible Causes	Comments or Possible Solutions
8.5 High CO ₂	- High CO ₂ at inlet	- Verify CO ₂ design condition
	- High pH	- Lower pH
	- Improper venting	- Review vent system
8.6 Tray Upsets	- Tray hold down not secure	- Install correctly
	- Turbine trip	
	- Flashing	- Gradual increase/decrease of controlled flows
8.7 Unexpected Storage Tank Level Excursions		
	- Malfunctioning level control system	- Check setting and system operation
	- Malfunctioning overflow or improper boiler feed pump operation	- Check overflow level and boiler feed pump operation
	- Pressure fluctuations	- Refer to 8.2
8.8 Water Out of Vent		
	- Cracked vent welds	- Repair or redesign
	- Improper vent piping	- Should be as short and as vertical as possible
	- Water carryover	- Reset vent flow
8.9 Iron Oxide in Deaerator		
	- Condensate or system corrosion	
	- Frequent shutdowns	- Keep positive pressure on deaerator
	- High O ₂	- See 8.1

**Shading is provided for the ease of reading only.

APPENDIX A GENERAL CONVERSION FACTORS

*Indicates preferred SI system units

To convert from	To	Multiply by
acres	square feet (ft ²)	43 560
	*square meters (m ²)	4 046.9
	*hectares (ha)	0.404 69
acre-feet	cubic feet (ft ³)	43 560
	gallons (U.S.)	325 851
	*cubic meters (m ³)	1 233.5
atmospheres (standard)	bars (bar)	1.013 25
	centimeters of mercury (cmHg) at 32°F (0°C)	76.0
	feet of water (ftH ₂ O) at 68°F (20°C)	33.96
	inches of mercury at 32°F (0°C)	29.921
	kilograms-force per square centimeter (kgf/cm ²)	1.033 2
	kilograms-force per square meter (kgf/m ²)	10 332
	*kilopascals (kPa)	101.325
	pounds-force per square inch (lbf/in ²) (psi)	14.696
	tons-force (short) per square foot (tonf/ft ²)	1.058 1
	torr (torr) (= mmHg at 0°C)	760
barrels (U.S. liquid)	gallons (U.S.)	31.5
barrels (oil)	cubic meters (m ³)	0.119 24
	gallons of oil (U.S.)	42
	cubic meters (m ³)	0.158 99
bars	atmospheres (atm) (standard)	0.986 92
	feet of water (ftH ₂ O at 68°F) (20°C)	33.52
	inches of mercury (inHg) at 0°C	29.53
	kilograms-force per square centimeter (kgf/cm ²)	1.019 7
	kilograms-force per square meter (kgf/m ²)	10 197
	*kilopascals (kPa)	100
	pounds-force per square inch (lbf/in ²) (psi)	14.504
	torr (torr) (= mmHg at 0°C)	750.06
boiler horsepower	British thermal units per hour (Btu/h) (see note)	33 479
	*kilowatts (kW)	9.809 5
	pounds of water evaporated per hour at 212°F (100°C)	34.5
British thermal units (Btu) (see note)	calories (cal)	252.0
	foot-pounds (ftlb)	778.2
	horsepower hours (hp·h)	0.000 393
	*joules (J)	1 055
	kilowatt-hours (kW·h)	0.000 293
	kilo-calories (kcal)	0.252
	kilogram-force-meters (kgf·m)	107.6
British thermal units (Btu) per second (see note)	*watts (W)	1 055
British thermal units (Btu) per minute (see note)	horsepower (hp)	0.023 58
British thermal units (Btu) per hour (see note)	*watts (W)	17.58
	*watts (W)	0.293 1
calories	British thermal units (Btu)	0.003 968 3
	foot-pounds (ft·lb)	3.088
	*joules (J)	4.186 8
	kilogram-meters (kg·m)	0.426 5
	watt hours (W·h)	0.001 163
*centimeters (cm)	inches (in)	0.393 7
centimeters of mercury (cmHg at 0°C)	atmospheres (standard) (atm)	0.013 158
	bars	0.013 33
	feet of water (ftH ₂ O) at 68°F	0.446 8
	inches of water (inH ₂ O) at 68°F	5.362
	kilograms-force per square centimeter (kgf/cm ²)	0.013 595
	*kilopascals (kPa)	1.333 2
	pounds-force per square inch (lbf/in ²)(psi)	0.193 37
	pounds-force per square foot (lbf/ft ²)	27.85
	torr (= mmHg at 0°C)	10

APPENDIX A (continued) **GENERAL CONVERSION FACTORS**

*Indicates preferred SI system units

To convert from	To	Multiply by
centimeters per second (cm/s)	feet per second (ft/s)	0.032 81
	feet per minute (ft/min)	1.968 5
	miles per hour (mph)	0.022 37
	kilometers per hour (km/h)	0.036 00
	meters per minute (m/min)	0.600 00
circumference	radians (rad)	6.283
circular mils	square inches (in ²)	0.000 000 785 4
cubic centimeters (cm ³)	cubic inches (in ³)	0.061 02
	cubic feet (ft ³)	0.000 035 315
	cubic yards (yd ³)	0.000 001 308
	gallons (U.S.) (U.S. gal)	0.000 264 2
	gallons (Imperial) (imp gal)	0.000 22
	*liters (L)	0.001
cubic feet (ft ³)	cubic centimeters (cm ³)	28 317
	*cubic meters (m ³)	0.028 317
	cubic inches (in ³)	1 728
	cubic yards (yd ³)	0.037 04
	gallons — U.S. (U.S. gal)	7.480 5
	gallons — Imperial (imp gal)	6.229
	*liters (L)	28.32
cubic feet per minute (ft ³ /min)	cubic centimeters per second (cm ³ /s)	471.9
	*cubic meters per second (m ³ /s)	0.000 471 9
	cubic meters per hour (m ³ /h)	1.699
	liters per second (L/s)	0.471 9
	gallons — U.S. per second (U.S. gps)	0.124 7
	pounds of water per minute (lbH ₂ O/min) at 68°F	62.32
cubic feet per second (ft ³ /s)	*cubic meters per second (m ³ /s)	0.028 317
	cubic meters per minute (m ³ /min)	1.699
	cubic meters per hour (m ³ /h)	101.9
	gallons — U.S. per minute (U.S. gal/min)	448.8
	gallons — U.S. per 24 hours (U.S. gpd)	646 315
	liters per second (L/s)	28.32
cubic inches (in ³)	cubic centimeters (cm ³)	16.387
	cubic feet (ft ³)	0.000 578 7
	*cubic meters (m ³)	0.000 016 387
	cubic yards (yd ³)	0.000 021 43
	gallons — U.S. (U.S. gal)	0.004 329
	gallons — Imperial (imp gal)	0.003 605
	*liters (L)	0.016 387
*cubic meters (m ³)	cubic inches (in ³)	61 024
	cubic feet (ft ³)	35.315
	cubic yards (yd ³)	1.308 0
	gallons — U.S. (U.S. gal)	264.17
	gallons — Imperial (imp gal)	219.97
	liters (L)	1 000
*cubic meters per hour (m ³ /h)	cubic meters per minute (m ³ /min)	0.016 667
	*cubic meters per second (m ³ /s)	0.000 277 78
	gallons U.S. per minute (U.S. g/min)	4.403 3
	liters per second (L/s)	0.277 78
cubic meters per second (m ³ /s)	cubic meters per hour (m ³ /h)	3 600
	gallons U.S. per minute (U.S. gpm)	15 850
cubic yards (yd ³)	cubic centimeters (cm ³)	764 550
	cubic feet (ft ³)	27
	cubic inches (in ³)	46 656
	*cubic meters (m ³)	0.764 55
	gallons — Imperial (imp gal)	168.17
	gallons — U.S. (U.S. gal)	201.97
	liters (L)	764.55
degrees angular	grade (gon)	1.111
	radians (rad)	0.017 453
degrees per second (angular)	radians per second (rad/s)	0.017 453
	revolutions per minute (r/min)	0.166 67
	revolutions per second (r/s)	0.002 777 8

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APPENDIX A (continued) GENERAL CONVERSION FACTORS

*Indicates preferred SI system units

To convert from	To	Multiply by
drams-avoir	grains (gr)	27.344
	*grams (g)	1.771 8
	ounces (oz)	0.062 5
dynes	*newtons (N)	0.000 01
ergs	*joules (J)	0.000 000 1
fathoms	feet (ft)	6
	*meters (m)	1.828 8
feet (ft)	centimeters (cm)	30.480
	inches (in)	12
	*meters (m)	0.304 80
	yards (yd)	0.333 3
feet of water (ftH ₂ O) at 68°F	atmosphere (standard) (atm)	0.029 45
	bars (bar)	0.029 84
	inches of mercury at 0°C (inHg)	0.881 1
	kilograms-force per square centimeter (kgf/cm ²)	0.030 42
	*kilopascals (kPa)	2.984
	pounds-force per square inch (lbf/in ²) (psi)	0.432 8
	pounds-force per square foot (lbf/ft ²)	62.32
feet per minute (ft/min)	centimeters per second (cm/s)	0.508 0
	kilometers per hour (km/h)	0.018 29
	meters per minute (m/min)	0.304 80
	*meters per second (m/s)	0.005 08
	miles per hour (mph)	0.011 36
feet per second (ft/s)	centimeters per second (cm/s)	30.480
	kilometers per hour (km/h)	1.097
	meters per minute (m/min)	18.29
	*meters per second (m/s)	0.304 80
	miles per hour (mph)	0.681 8
feet per second squared (ft/s ²)	centimeters per second squared (cm/s ²)	30.480
	*meters per second squared (m/s ²)	0.304 80
foot-pounds-force (ft-lbf)	British thermal units (Btu) (see note)	0.001 285
	calories	0.323 8
	horsepower hours (hp-h)	0.000 000 505 0
	*joules (J)	1.355 8
	kilocalories (kcal)	0.000 323 8
	kilogram-force meters (kgf-m)	0.138 25
	kilowatt hours (kW-h)	0.000 000 376 6
foot candle	*lumen per square meter (lux)	10.764
gallons (U.S.) (gal)	cubic centimeters (cm ³)	3.785.4
	*cubic meters (m ³)	0.003 785 4
	cubic inches (in ³)	231
	cubic feet (ft ³)	0.133 68
	cubic yards (yd ³)	0.004 951 5
	pints—liquid (pt)	8
	quarts—liquid (qt)	4
	gallons—Imperial (imp gal)	0.832 7
	*liters (L)	3.785 4
	pounds of water at 60°F	8.338
gallons (Imperial)	cubic centimeters (cm ³)	4 546.1
	*cubic meters (m ³)	0.004 546 1
	cubic feet (ft ³)	0.160 54
	cubic yards (yd ³)	0.005 946
	gallons U.S. (U.S. gal)	1.200 94
	*liters (L)	4.546 1
	pounds of water at 62°F	10.000
gallons (U.S.) per minute (U.S. gpm)	*cubic meters per second (m ³ /s)	0.000 063 090
	*cubic meters per minute (m ³ /min)	0.003 785 4
	*cubic meters per hour (m ³ /h)	0.227 1
	cubic feet per second (ft ³ /s)	0.002 228
	cubic feet per hour (ft ³ /h)	8.021
	*liters per second (L/s)	0.063 09

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APPENDIX A (continued) GENERAL CONVERSION FACTORS

*Indicates preferred SI system units

To convert from	To	Multiply by
grains (gr)	*grams (g)	0.064 8
	ounces-avoir (oz)	0.002 285 7
grains per gallon (U.S.) (gr/U.S. gal)	grams per cubic meter (g/m ³)	17.118
	*kilograms per cubic meter (kg/m ³)	0.017 118
	parts per million by weight in water (ppm)	17.118
	pounds per million gallons	142.9
grains per gallon (Imperial)	grams per cubic meter (g/m ³)	14.25
	*kilograms per cubic meter (kg/m ³)	0.014 25
	parts per million by weight in water (ppm)	14.25
grams (g)	grains (gr)	15.432
	ounces-avoir (oz)	0.035 274
	pounds-avoir (lb)	0.002 204 6
grams-force (gf)	*newtons (N)	0.009 806 6
grams-force per centimeter (gf/cm)	*newtons per meter (N/m)	98.07
	pounds-force per inch (lbf/in)	0.005 600
grams per cubic centimeter (g/cm ³)	*kilograms per cubic meter (kg/m ³)	0.001
	pounds per cubic inch (lb/in ³)	0.036 13
	pounds per cubic foot (lb/ft ³)	62.427
*grams per liter (g/L)	grains per U.S. gallon (gr/U.S. gal)	58.417
	parts per million (ppm) by mass weight in water	1 000
	pounds per cubic foot (lb/ft ³)	0.062 242 7
	pounds per 1000 U.S. gallons	8.354 4
hectares (ha)	acres	2.471 0
	square feet (ft ²)	107 639
	*square meters (m ²)	10 000
horsepower (hp)	British thermal units per minute (see note) (Btu/min)	42.43
	foot-pounds force per minute (ft·lbf/min)	33 000
	foot-pounds force per minute (ft·lbf/s)	550
	kilocalories per minute (kcal/min)	10.69
	*kilowatts (kW)	0.745 7
	horsepower-metric	1.013 9
	*watts (W)	745.7
horsepower-boiler	British thermal units per hour (see note) (Btu/h)	33 479
	kilowatts (kW)	9.809 5
	pounds of water evaporated per hour at 212°F	34.5
horsepower hours (hp·h)	British thermal units (Btu)	2 545
	foot-pounds-force (ft·lbf)	1 980 000
	*joules (J)	2 684 500
	kilocalories (kcal)	641.5
	kilogram-force-meters (kgf·m)	273 200
	*kilowatt-hours (kW·h)	0.745 7
inches (in)	centimeters (cm)	2.540
	*meters (m)	0.025 40
	*millimeters (mm)	25.40
inches of mercury (inHg) at 0°C	atmospheres (standard) (atm)	0.033 42
	bars (bar)	0.033 864
	feet of water (ftH ₂ O) at 68°F	1.135
	inches of water (inH ₂ O) at 68°F	13.62
	kilograms-force per square centimeter (kgf/cm ²)	0.034 532
	kilograms-force per square meter (kgf/m ²)	345.32
	*kilopascals (kPa)	3.386 4
	millimeters of mercury (mmHg)	25.40
	pounds-force per square foot (lbf/ft ²)	70.73
	pounds-force per square inch (lbf/in ²) (psi)	0.491 2
inches of water (inH ₂ O) at 68°F	atmosphere (standard) (atm)	0.002 454
	bars (bar)	0.002 487
	inches of mercury (inHg) at 0°C	0.073 42
	kilograms-force per square centimeter (kgf/cm ²)	0.002 535
	*kilopascals (kPa)	0.248 7
	ounces-force per square inch (ozf/in ²)	0.577 0
	pounds-force per square foot (lbf/ft ²)	5.193
	pounds-force per square inch (lbf/in ²) (psi)	0.036 06

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APPENDIX A (continued) GENERAL CONVERSION FACTORS

*Indicates preferred SI system units

To convert from	To	Multiply by
*joules (J)	British thermal units (see note)	0.000 948 4
	calories (cal) (thermochemical)	0.239 0
	foot-pounds-force (ft·lbf)	0.737 56
	watt-hours (W·h)	0.000 277 78
*kilograms (kg)	pounds (lb)	2.204 6
	tons (ton) short	0.001 102 3
kilograms-force (kgf)	*newtons (N)	9.806 6
	pounds-force (lbf)	2.204 6
kilograms-force per meter (kgf/m)	*newtons per meter (N/m)	9.806 6
	pounds-force per foot (lbf/ft)	0.672 1
kilograms-force per square centimeter (kgf/cm ²)	atmospheres (standard) (atm)	0.967 8
	bars (bar)	0.980 66
	feet of water (ftH ₂ O) at 68°F	32.87
	inches of mercury (inHg) at 0°C	28.96
	*kilopascals (kPa)	98.066
	pounds-force per square foot (lbf/ft ²)	2 048
	pounds-force per square inch (lbf/in ²) (psi)	14.223
kilograms-force per square millimeter (kgf/mm ²)	kilograms-force per square meter (kgf/m ²)	1 000 000
	*megapascals (Mpa)	9.806 6
*kilometers (km)	feet (ft)	3 280.8
	miles (mi)	0.621 37
kilometers per hour (km/h)	centimeters per second (cm/s)	27.778
	feet per second (ft/s)	0.911 3
	feet per minute (ft/min)	54.68
	international knots (kn)	0.539 96
	meters per minute (m/min)	16.667
	*meters per second (m/s)	0.277 78
	miles per hour (mph)	0.621 4
kilometers per hour per second (km/h·s)	centimeters per second squared (cm/s ²)	27.778
	feet per second squared (ft/s ²)	0.911 3
	*meters per second squared (m/s ²)	0.277 78
kilometers per second (km/s)	miles per minutes (mi/min)	37.28
*kilopascals (kPa)	dynes per square centimeter (dy/cm ²)	10 000
	feet of water (ftH ₂ O) at 68°F	0.335 1
	inches of mercury (inHg) at 32°F	0.295 3
	inches of water (inH ₂ O) at 68°F	4.021
	kilograms-force per square centimeter (kgf/cm ²)	0.010 197
	pascals (Pa) (or newtons per square meter) (N/m ²)	1 000
	pounds-force per square inch (lbf/in ²) (psi)	0 145 0
kiloponds	*newtons (N)	9.807
	kilograms-force (kgf)	1
	pounds-force (lbf)	2.204 6
	poundals	70.932
	kips	0.002 205
kips (1000 lbf)	*newton (N)	4.448
	kilogram-force (kgf)	453.6
	pounds-force (lbf)	1 000
	poundal	32 174
	kilopond	453.6
kips per square inch (ksi)	*kilopascals	6 894.8
	kilograms-force per square centimeter (kgf/cm ²)	70.307
	bars (bar)	68.94
	pounds per square inch (psi)	1 000
*kilowatts (kW)	British thermal units per minute (Btu/min)	56.92
	foot-pounds-force per minute (ft·lbf/min)	44.254
	foot-pounds-force per second (ft·lb/s)	737.6
	horsepower (hp)	1.341 0
	kilocalories per minute (kcal/min)	14.34

APPENDIX A (continued) **GENERAL CONVERSION FACTORS**

*Indicates preferred SI system units

To convert from	To	Multiply by
kilowatt hours (kW·h)	British thermal units (Btu) (see note)	3 413
	foot-pounds-force (ft·lbf)	2 655 000
	horsepower hours (hp·h)	1.341 0
	*joules (J)	3.600 000
	kilocalories (kcal)	860
	kilogram-force meters (kgf·m)	367 100
knots (international)	*meters per second (m/s)	0.514 4
	miles per hour (mph)	1.151 6
*liters (L)	cubic centimeters (cm ³)	1 000
	cubic feet (ft ³)	0.035 315
	cubic inches (in ³)	61.024
	cubic meters (m ³)	0.001
	cubic yards (yd ³)	0.001 308
	gallons U.S. (U.S. gal)	0.264 18
	gallons Imperial (imp gal)	0.220 0
*liters per minute (L/min)	cubic feet per second (ft ³ /s)	0.000 588 5
	*liters per second (L/s)	0.016 67
	gallons (U.S.) per second (U.S. gal/s)	0.004 403
	gallons (U.S.) per minute (U.S. gal/min)	0.264 18
	gallons (Imperial) per min (imp gal/min)	0.003 666
*liters per second (L/s)	cubic meters per second (m ³ /s)	0.001
	cubic meters per minute (m ³ /min)	0.06
	cubic meters per hour (m ³ /h)	3.600
	*liters per minute (L/min)	60
	gallons (U.S.) per minute (U.S. gal/min)	15.85
	gallons (Imperial) per minute (imp gal)	13.20
*megapascals (MPa)	kilograms-force per square millimeter (kgf/mm ²)	0.101 97
	kilograms-force per square centimeter (kgf/cm ²)	10.197
	*kilopascals (kPa)	1 000
	*pascals (Pa)	1 000 000
	pounds-force per square inch (lbf/in ²) (psi)	145.0
*meters (m)	feet (ft)	3.280 8
	inches (in)	39.370
	yards (yd)	1.093 6
*meters per minute (m/min)	centimeters per second (cm/s)	1.666 7
	feet per minute (ft/min)	3.280 8
	feet per second (ft/s)	0.054 68
	kilometers per hour (km/h)	0.060 0
	miles per hour (mph)	0.037 28
*meters per second (m/s)	feet per minute (ft/min)	196.8
	feet per second (ft/s)	3.281
	kilometers per hour (km/h)	3.600
	kilometers per minute (km/min)	0.060 0
	miles per hour (mph)	2.237
	miles per minute (mi/min)	0.037 28
*micrometers (formerly microns)	*meters (m)	0.000 001
mills (0.001 inches)	*millimeters (mm)	0.025 4
miles	feet (ft)	5 280
	*kilometers (km)	1.609 3
	*meters (m)	1 609.3
	yards (yd)	1 760
miles per hour (mph)	centimeters per second (cm/s)	44.70
	feet per minute (ft/min)	88
	feet per second (ft/s)	1.466 7
	international knots (kn)	0.869 0
	*kilometers per hour (km/h)	1.609 3
	*meters per minute (m/min)	26.82
milligrams per liter (mg/L)	parts per million (ppm)	1.0
*millimeters (mm)	inches (in)	0.039 370

APPENDIX A (continued) **GENERAL CONVERSION FACTORS**

*Indicates preferred SI system units

To convert from	To	Multiply by
millimeters of mercury at 0°C (mmHg)	bars (bar)	0.001 333 2
	feet of water at 68°F	0.004 680
	inches of mercury (inHg)	0.039 37
	inches of water (68°F)	0.536 16
	kilograms per square centimeter (kg/cm ²)	0.001 359 5
	*pascals (Pa)	133.32
	pounds per square inch (psi)	0.019 336 8
minutes, angular (')	radians (rad)	0.000 290 9
*newtons (N)	dynes (dyn)	100 000
	kilograms-force (kgf)	0.101 97
	poundals	7.233 0
	pounds-force (lbf)	0.224 8
ounces-avoir (oz)	drams—avoir (dr)	16
	grains (gr)	437.5
	*grams (g)	28.349 5
	*kilograms (kg)	0.028 350
	pounds-avoir (lb)	0.062 50
	tons (ton) long	0.000 027 90
	*tonnes (t) metric ton	0.000 028 350
ounces-U.S. fluid	cubic inches (in ³)	1.804 6
	*liters (L)	0.029 57
ounces-force per square inch (ozf/in ²)	grams-force per square centimeter (gf/cm ²)	4.395
	*pascals (Pa)	43.1
	pounds-force per square inch (lbf/in ²) (psi)	0.062 50
parts per million by mass (ppm)	grains per U.S. gallon at 60°F (gr/U.S. gal)	0.058 3
	grains per Imperial gallon at 62°F (gr/imp gal)	0.070 0
	grams per cubic meter (g/m ³) at 15°C	0.999 1
	*milligrams per liter (mg/L)	1.0
	pounds per million U.S. gallons at 60°F	8.328
*pascals (Pa)	bars (bar)	0.000 01
	dynes per square centimeters (dyn/cm ²)	10.0
	grams-force per square centimeter (gf/cm ²)	0.010 197
	kilograms-force per square centimeter (kg/cm ²)	0.000 010 197
	kilograms-force per square meter (kg/m ²)	0.101 97
	*kilopascals (kPa)	0.001
	*newtons per square meter (N/m ²)	1.0
	pounds-force per square inch (lbf/in ²) (psi)	0.000 145 0
poise	centipoises (CP)	100
	*pascal second (Pa·s)	0.100 0
	pound-force-seconds per square foot (lbf·s/ft ²)	0.002 088 6
	pounds per foot second (lb/ft·s)	0.067 21
poundals	*newtons (N) (joules per meter)	0.138 26
pounds-force (lbf)	kilograms-force (kgf)	0.453 59
	*newtons (N)	4.448 2
pounds-avoir (lb)	drams-avoir (dr)	256
	grains (gr)	7 000
	*grams (g)	453.59
	*kilograms (kg)	0.453 59
	ounces-avoir (oz)	16
	*tonnes-metric tons (t)	0.000 453 59
	tons — long	0.000 446 43
	tons — short	0.000 5
pounds per foot (lb/ft)	*kilograms per meter (kg/m)	1.488 2
pounds per square foot (lb/ft ²)	*kilograms per square meter (kg/m ²)	4.882 4
pounds-mass of water at 60°F	cubic centimeters (cm ³)	454.00
	cubic feet (ft ³)	0.016 03
	cubic inches (in ³)	27.70
	gallons (U.S.) (U.S. gal)	0.119 93
	liters (L)	0.453 98

APPENDIX A (continued) GENERAL CONVERSION FACTORS

To convert from	To	Multiply by
pounds of water per minute at 60°F	cubic centimeters per second (cm ³ /s)	7.566 7
	cubic feet per second (ft ³ /s) (cfs)	0.000 267 5
	*cubic meters per minute (m ³ /min)	0.000 453 98
	*kilograms per second (kg/s)	0.007 559 9
pounds per cubic foot (lb/ft ³)	grams per cubic centimeter (g/cm ³)	0.016 018
	*kilograms per cubic meter (kg/m ³)	16.018
	pounds per cubic inch (lb/in ³)	0.000 578 7
pounds per cubic inch (lb/in ³)	grams per cubic centimeter (g/cm ³)	27.68
	*kilograms per cubic meter (kg/m ³)	27 680
	pounds per cubic foot (lb/ft ³)	1 728
pounds-force per foot (lbf/ft)	grams-force per centimeter (gf/cm)	14.882
	kilograms-force per meter (kgf/m)	1.488 2
	*newtons per meter (N/m)	14.594
pounds-force per square foot (lbf/ft ²)	feet of water (ftH ₂ O) at 68°F	0.016 05
	kilograms-force per square centimeter (Kgf/cm ²)	0.000 488 2
	*kilopascals (kPa)	0.004 788 0
	*pascals (Pa)	47.880
	pounds-force per square inch (lbf/in ²) (psi)	0.006 944 4
pounds-force per square inch (lbf/in ²) (psi)	atmospheres (standard) (atm)	0.068 05
	feet of water (ftH ₂ O) at 68°F	2.311
	inches of water (inH ₂ O) at 68°F	27.73
	inches of mercury (inHg) at 0°C	2.036
	kilograms-force per square centimeter (kgf/cm ²)	0.070 31
	*kilopascals (kPa)	6.894 8
quarts—dry (qt dry)	cubic centimeters (cm ³)	1 101.2
	cubic inches (in ³)	67.20
	*cubic meters (m ³)	0.001 101 2
quarts—liquid (qt liquid)	cubic centimeters (cm ³)	946.35
	cubic inches (in ³)	57.75
	*liters (L)	0.946 35
radians (rad)	degrees (°) angular	57.296
radians per second (rad/s)	degrees per second (°/s) angular	57.296
	revolutions per minute (r/min)	9.549
revolutions per minute (r/min)	degrees per second	6
square centimeters (cm ²)	radians per second (rad/s)	0.014 72
	square inches (in ²)	0.155 0
square feet (ft ²)	acres	0.000 022 956
	*square meters (m ²)	0.092 903
square inches (in ²)	square centimeters (cm ²)	6.451 6
square kilometers (km ²)	acres	247.10
	square miles	0.386 10
*square meters (m ²)	acres	0.000 247 10
	square feet (ft ²)	10.764
square miles	acres	640
	square kilometers (km ²)	2.590
square yards (yd ²)	acres	0.000 206 61
	*square meters (m ²)	0.836 13
standard cubic feet per minute (scfm) (at 14 696 psia and 60°F)	cubic meters per hour (m ³ /h) at standard conditions (15°C and 101.325 kPa)	1.695 7
	liters per second (L/s) at standard conditions (15°C and 101.325 kPa)	0.471 03
stokes	square feet per second (ft ² /s)	0.001 076
	*square meters per second (m ² /s)	0.000 1

APPENDIX A (continued) GENERAL CONVERSION FACTORS

*Indicates preferred SI system units

To convert from	To	Multiply by
temperature degrees—		
Fahrenheit (°F)	*degrees Celsius (°C); °C = 5/9 (°F – 32)	
*degrees Celsius (°C)	degrees Fahrenheit (°F); °F = 9/5°C + 32	
degrees Fahrenheit (°F)	*kelvin (K) K = 5/9 (°F + 459.67)	
*degrees Celsius (°C)	*kelvin (K) K = °C + 273.15	
degrees Rankine (°R)	*kelvin (K) K = °R/1.8	
degrees Fahrenheit (°F)	degrees Rankine (°R); °R = °F + 459.67	
for temperature conversion tables; i.e. °F to °C and vice versa refer to page 27		
tons — long	*kilograms (kg)	1 016.0
	metric tons (t)	1.016 0
	pounds-avoir (lb)	2 240
	tons — short	1.120
*tonnes-metric ton	*kilograms (kg)	1 000
	pounds (lb)	2 204.6
tons — short	*kilograms (kg)	907.18
	pounds-avoir (lb)	2 000
	tons — long	0.892 86
	tonnes (metric ton) (t)	0.907 2
tons (short) of water per 24 hours (at 60°F)	cubic feet per hour (ft ³ /h)	1.338
	cubic meters per hour (m ³ /h)	0.037 89
	gallons (U.S.) (U.S. gal/min)	0.166 8
	pounds of water per hour (lbH ₂ O/h) at 60°F	83.333
tons of refrigeration	British thermal units (Btu) (see note) per hour	12 000
	British thermal units (Btu) (see note) per 24 hours	288 000
*watts (W)	British thermal units (Btu) per minute (Btu/min)	0.056 91
	foot-pounds-force per second (ft·lbf/s)	0.737 56
	foot-pounds-force per minute (ft·lbf/min)	44.254
	horsepower (hp)	0.001 341 0
	joules per second (J/s)	1.0
	kilocalories per minute (kcal/min)	0.014 340
watt-hours (W·h)	British thermal units (Btu)	3.413
	foot-pounds-force (ft·lbf)	2 655
	horsepower hours (hp·h)	0.001 341 0
	*joules (J)	3 600
	kilocalories (kcal)	0.860 4
	kilograms-force-meters (kgf·m)	367.10
yards (yd)	*meters (m)	0.914 40

NOTE: British Thermal Units (Btu)—since there are several definitions of the Btu, the values of applicable and/or equivalent factors may vary slightly depending on the definition used. In the accompanying tables of conversion factors, the first three or four significant figures given, in most cases, are common to most definitions of the Btu; if greater accuracy is required for certain calculations then reference to the appropriate handbooks and standards should be made.

APPENDIX A (continued)

DEGREES FAHRENHEIT TO DEGREES CELSIUS CONVERSION TABLE

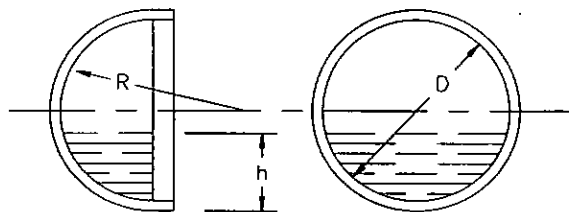
Degrees Fahrenheit Celsius		Degrees Fahrenheit Celsius		Degrees Fahrenheit Celsius		Degrees Fahrenheit Celsius		Degrees Fahrenheit Celsius		Degrees Fahrenheit Celsius	
40	4.44	94	34.44	148	64.44	202	94.44	256	124.44	310	154.44
41	5.00	95	35.00	149	65.00	203	95.00	257	125.00	311	155.00
42	5.56	96	35.56	150	65.56	204	95.56	258	125.56	312	155.56
43	6.11	97	36.11	151	66.11	205	96.11	259	126.11	313	156.11
44	6.67	98	36.67	152	66.67	206	96.67	260	126.67	314	156.67
45	7.22	99	37.22	153	67.22	207	97.22	261	127.22	315	157.22
46	7.78	100	37.78	154	67.78	208	97.78	262	127.78	316	157.78
47	8.33	101	38.33	155	68.33	209	98.33	263	128.33	317	158.33
48	8.89	102	38.89	156	68.89	210	98.89	264	128.89	318	158.89
49	9.44	103	39.44	157	69.44	211	99.44	265	129.44	319	159.44
50	10.00	104	40.00	158	70.00	212	100.00	266	130.00	320	160.00
51	10.56	105	40.56	159	70.56	213	100.56	267	130.56	321	160.56
52	11.11	106	41.11	160	71.11	214	101.11	268	131.11	322	161.11
53	11.67	107	41.67	161	71.67	215	101.67	269	131.67	323	161.67
54	12.22	108	42.22	162	72.22	216	102.22	270	132.22	324	162.22
55	12.78	109	42.78	163	72.78	217	102.78	271	132.78	325	162.78
56	13.33	110	43.33	164	73.33	218	103.33	272	133.33	326	163.33
57	13.89	111	43.89	165	73.89	219	103.89	273	133.89	327	163.89
58	14.44	112	44.44	166	74.44	220	104.44	274	134.44	328	164.44
59	15.00	113	45.00	167	75.00	221	105.00	275	135.00	329	165.00
60	15.56	114	45.56	168	75.56	222	105.56	276	135.56	330	165.56
61	16.11	115	46.11	169	76.11	223	106.11	277	136.11	331	166.11
62	16.67	116	46.67	170	76.67	224	106.67	278	136.67	332	166.67
63	17.22	117	47.22	171	77.22	225	107.22	279	137.22	333	167.22
64	17.78	118	47.78	172	77.78	226	107.78	280	137.78	334	167.78
65	18.33	119	48.33	173	78.33	227	108.33	281	138.33	335	168.33
66	18.89	120	48.89	174	78.89	228	108.89	282	138.89	336	168.89
67	19.44	121	49.44	175	79.44	229	109.44	283	139.44	337	169.44
68	20.00	122	50.00	176	80.00	230	110.00	284	140.00	338	170.00
69	20.56	123	50.56	177	80.56	231	110.56	285	140.56	339	170.56
70	21.11	124	51.11	178	81.11	232	111.11	286	141.11	340	171.11
71	21.67	125	51.67	179	81.67	233	111.67	287	141.67	341	171.67
72	22.22	126	52.22	180	82.22	234	112.22	288	142.22	342	172.22
73	22.78	127	52.78	181	82.78	235	112.78	289	142.78	343	172.78
74	23.33	128	53.33	182	83.33	236	113.33	290	143.33	344	173.33
75	23.89	129	53.89	183	83.89	237	113.89	291	143.89	345	173.89
76	24.44	130	54.44	184	84.44	238	114.44	292	144.44	346	174.44
77	25.00	131	55.00	185	85.00	239	115.00	293	145.00	347	175.00
78	25.56	132	55.56	186	85.56	240	115.56	294	145.56	348	175.56
79	26.11	133	56.11	187	86.11	241	116.11	295	146.11	349	176.11
80	26.67	134	56.67	188	86.67	242	116.67	296	146.67	350	176.67
81	27.22	135	57.22	189	87.22	243	117.22	297	147.22	351	177.22
82	27.78	136	57.78	190	87.78	244	117.78	298	147.78	352	177.78
83	28.33	137	58.33	191	88.33	245	118.33	299	148.33	353	178.33
84	28.89	138	58.89	192	88.89	246	118.89	300	148.89	354	178.89
85	29.44	139	59.44	193	89.44	247	119.44	301	149.44	355	179.44
86	30.00	140	60.00	194	90.00	248	120.00	302	150.00	356	180.00
87	30.56	141	60.56	195	90.56	249	120.56	303	150.56	357	180.56
88	31.11	142	61.11	196	91.11	250	121.11	304	151.11	358	181.11
89	31.67	143	61.67	197	91.67	251	121.67	305	151.67	359	181.67
90	32.22	144	62.22	198	92.22	252	122.22	306	152.22	360	182.22
91	32.78	145	62.78	199	92.78	253	122.78	307	152.78	361	182.78
92	33.33	146	63.33	200	93.33	254	123.33	308	153.33	362	183.33
93	33.89	147	63.89	201	93.89	255	123.89	309	153.89	363	183.89

APPENDIX B

SEMI-ELLIPTICAL HEAD CAPACITIES WHEN FILLED TO VARIOUS DEPTHS

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,
BUT CLOSE ENOUGH FOR PRACTICAL USE.

	HEAD DIAMETER (IN) FULL HEAD CAPACITIES																				
	144	132	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12
h (in)	1692.0	1303.0	979.2	839.5	713.8	601.3	501.3	413.1	335.9	268.9	211.5	162.9	122.4	89.2	62.7	42.0	26.4	15.3	7.6	3.3	1.0
141	1690.0																				
138	1683.0																				
135	1673.0																				
132	1659.0																				
129	1641.0	1301.0																			
126	1619.0	1295.0																			
123	1595.0	1285.2																			
120	1567.0	1272.6																			
117	1536.0	1256.1	977.4																		
114	1502.0	1236.3	972.1																		
111	1460.0	1213.6	963.5	837.8																	
108	1428.0	1189.2	951.8	832.8																	
105	1387.0	1161.2	937.1	824.7	712.2																
102	1344.0	1130.7	919.7	813.6	707.5																
99	1300.0	1099.4	899.7	799.8	699.8	599.8															
96	1253.0	1064.7	877.4	783.4	689.4	595.4															
93	1206.0	1028.1	852.8	764.6	676.3	588.1	499.8														
90	1157.0	989.8	826.2	743.6	661.0	578.3	495.7														
87	1107.0	951.8	797.6	720.6	643.4	566.2	488.8	411.7													
84	1056.0	910.8	767.7	694.9	623.1	551.8	479.6	407.8													
81	1004.0	868.6	735.2	669.2	602.3	535.4	468.5	401.5	334.6												
78	952.0	825.5	703.3	641.3	579.2	517.1	454.8	393.0	331.0												
75	899.0	783.6	669.4	612.0	554.6	494.3	439.9	382.5	325.1	267.7											
72	846.0	739.2	634.5	581.7	526.8	475.9	423.0	370.1	317.3	264.5											
69	793.0	694.5	596.3	550.4	501.8	453.3	404.7	356.1	307.6	259.0	210.4										
66	740.0	651.5	562.6	518.4	473.9	429.5	385.1	340.6	296.2	251.8	207.4										
63	688.0	608.5	526.3	485.8	445.3	404.8	364.4	323.9	283.4	244.9	202.4	161.9									
60	636.0	563.8	489.6	452.9	416.2	379.4	342.7	306.0	269.3	232.6	195.6	159.1									
57	585.0	519.4	452.9	419.8	386.6	353.5	320.4	287.2	254.1	220.6	187.8	154.7	121.5								
54	535.0	477.5	416.6	386.7	356.9	327.2	297.4	267.7	237.9	208.2	178.5	148.7	119.0								
51	486.0	434.4	382.9	353.7	327.2	300.7	274.1	247.5	221.1	194.5	168.0	141.1	115.0	88.4							
48	439.0	392.2	344.7	321.1	297.7	273.6	250.7	227.2	203.7	181.2	156.7	135.0	109.7	86.1							
45	392.0	351.2	309.8	289.1	268.5	247.9	227.2	206.5	185.9	165.2	144.5	123.9	103.3	82.6	62.0						
42	348.0	313.2	275.9	257.8	239.9	221.9	203.9	185.9	167.9	149.9	132.0	114.0	96.0	77.9	60.0						
39	305.0	274.9	244.0	227.5	212.0	196.5	180.9	165.6	150.0	134.5	118.9	103.4	87.9	72.4	56.9	41.4					
36	264.0	238.3	211.5	198.2	187.0	171.8	158.6	145.4	132.9	119.0	105.7	92.6	79.3	67.0	52.9	39.7					
33	232.0	203.6	181.6	170.3	159.2	148.0	136.9	125.9	114.8	103.7	92.6	81.5	70.4	59.2	48.1	37.0	25.9				
30	190.0	172.3	153.0	144.6	134.6	125.4	116.2	107.1	98.0	87.7	79.5	70.4	61.2	51.9	42.8	33.7	24.5				
27	156.0	141.8	126.4	118.9	111.5	107.0	96.6	89.2	81.8	74.4	67.0	59.4	52.0	44.5	37.2	29.7	22.3	14.8			
24	125.0	113.8	101.8	95.9	90.7	84.2	78.3	72.5	66.6	60.7	54.8	48.9	43.1	37.3	31.3	25.5	19.6	13.7			
21	97.0	89.4	79.5	74.9	70.4	65.9	61.4	57.0	52.5	48.3	43.5	39.0	34.5	30.0	25.5	21.0	16.5	12.0	7.3		
18	73.0	66.7	59.5	56.1	52.8	49.5	46.5	43.0	39.7	36.3	33.0	27.9	26.4	22.2	19.8	16.5	13.2	9.9	6.4		
15	51.0	46.9	42.1	39.7	37.5	35.1	32.8	30.6	28.3	24.0	23.7	21.8	19.1	16.9	14.5	12.2	10.0	7.7	5.2	3.1	
12	33.0	30.4	27.4	25.9	24.4	23.0	21.7	20.1	18.6	17.1	15.9	14.2	12.7	11.4	9.8	8.3	6.9	5.4	3.8	2.4	
9	19.0	17.8	15.7	14.8	14.0	13.2	12.5	11.6	10.8	9.9	9.1	8.2	7.4	6.7	5.8	4.9	4.1	3.3	2.4	1.7	0.8
6	9.0	8.0	7.1	6.7	6.3	5.9	5.6	5.3	4.9	4.4	4.1	3.8	3.4	3.1	2.7	2.3	2.0	1.6	1.2	0.9	0.5
3	2.0	2.0	1.8	1.7	1.6	1.5	1.5	1.4	1.3	1.2	1.1	1.0	0.9	0.8	0.7	0.6	0.5	0.5	0.3	0.2	0.3

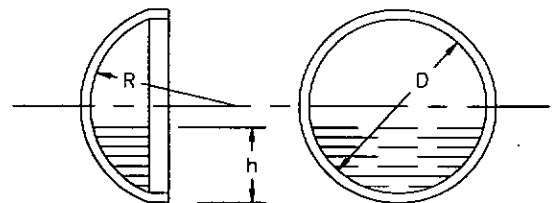


APPENDIX B (continued)

HEAD CAPACITIES DISHED (RAD. = DIAM.), WHEN FILLED TO VARIOUS DEPTHS (ONE HEAD ONLY)

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,
BUT CLOSE ENOUGH FOR PRACTICAL USE.

		HEAD DIAMETER (IN)																			
		FULL HEAD CAPACITIES																			
	144	132	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24	18	12
h(in)	1048.0	807.3	611.0	527.0	414.0	380.0	308.0	251.0	203.0	162.0	128.0	98.9	73.4	53.4	37.5	26.3	15.7	9.1	4.6	1.9	0.5
141	1045.3																				
138	1042.7																				
135	1036.2																				
132	1027.4																				
129	1016.2	805.5																			
126	1003.0	802.4																			
123	987.6	796.6																			
120	970.4	788.5																			
117	952.3	778.4	609.5																		
114	930.5	766.4	607.3																		
111	908.1	752.5	602.2	525.6																	
108	884.2	736.9	596.3	523.4																	
105	859.0	719.8	588.4	518.6	412.8																
102	832.5	701.2	579.2	512.8	410.5																
99	804.9	681.2	568.8	505.4	406.5	378.9															
96	774.3	659.9	555.4	497.0	400.7	376.6															
93	746.6	637.5	541.6	487.0	394.1	372.8	307.1														
90	716.4	614.1	525.5	474.3	386.0	367.5	304.9														
87	685.4	589.8	509.7	461.2	375.8	361.0	301.2	250.2													
84	653.8	564.7	490.0	451.1	364.7	353.0	296.6	248.0													
81	622.6	538.6	471.8	430.6	351.9	343.5	290.8	245.0	202.2												
78	589.2	512.5	449.8	412.8	339.0	332.9	283.7	240.5	200.2												
75	556.7	485.7	429.0	394.1	323.0	321.1	275.1	235.2	197.5	161.2											
72	524.0	458.6	405.5	375.2	307.7	308.2	264.9	228.2	193.3	159.6											
69	491.3	431.2	381.7	354.9	289.9	294.2	254.8	220.4	188.4	157.0	127.4										
66	458.8	403.7	359.4	332.9	274.0	278.8	242.8	211.1	181.2	153.3	125.8										
63	425.4	376.1	335.0	312.8	253.0	262.8	231.1	201.3	174.6	148.5	123.3	98.3									
60	394.2	348.7	305.5	290.0	235.0	245.2	216.4	190.7	166.6	142.7	119.9	96.9									
57	362.6	321.6	276.0	263.5	216.0	228.9	201.8	179.5	157.5	136.2	115.3	94.6	73.0								
54	331.6	294.8	251.6	237.0	192.0	210.8	187.0	166.6	147.5	129.1	110.1	91.5	71.6								
51	301.4	268.7	229.3	214.2	198.0	190.0	177.9	153.9	136.8	120.2	104.1	87.4	69.6	53.0							
48	273.7	242.6	205.5	194.1	179.0	169.2	154.0	141.0	125.8	111.5	97.2	82.7	66.7	51.9							
45	243.1	217.5	182.0	172.1	161.0	151.1	130.1	125.5	113.0	101.7	89.7	77.2	63.1	50.0	37.1						
42	215.5	193.2	161.2	151.8	140.0	134.8	121.0	110.0	101.5	92.3	81.8	70.9	58.9	47.5	36.1						
39	189.0	169.8	139.2	132.9	124.1	117.2	106.2	97.1	88.0	81.0	74.6	64.1	54.0	44.3	34.5	26.0					
36	163.8	147.4	121.0	114.2	106.3	101.2	91.6	84.4	77.2	69.7	64.0	57.5	48.8	40.7	32.3	25.1					
33	139.9	126.1	101.3	96.4	91.0	85.8	76.9	71.5	66.2	60.3	53.4	49.4	43.2	36.3	29.6	23.6	15.4				
30	117.5	106.1	85.5	75.9	75.0	71.8	65.2	60.3	55.5	50.5	46.2	41.4	36.7	32.0	26.3	21.6	14.7				
27	95.7	87.5	69.4	65.8	62.1	58.9	53.2	49.7	45.5	41.8	38.3	34.8	30.2	26.7	22.8	19.2	13.5	8.9			
24	77.6	70.4	55.6	52.7	49.3	47.1	43.1	39.9	36.4	32.9	30.8	28.0	24.6	21.4	18.7	16.3	12.0	8.3			
21	60.4	54.8	42.2	40.0	38.2	36.5	32.9	30.6	28.4	25.8	23.9	21.7	19.4	17.1	14.7	13.2	10.1	7.3	4.4		
18	45.0	40.9	31.8	30.0	28.0	27.0	24.3	22.8	21.8	19.3	17.9	16.2	14.5	12.7	11.2	10.0	7.9	6.0	3.9		
15	31.8	28.9	22.6	21.6	19.9	19.0	17.2	15.8	14.6	13.5	12.7	11.5	10.3	9.1	8.0	7.1	5.7	4.6	3.2	1.8	
12	20.6	18.8	14.7	14.2	13.3	12.5	11.4	10.5	9.8	8.8	8.1	7.4	6.7	5.9	5.3	4.7	3.7	3.1	2.3	1.4	
9	11.8	10.7	8.9	8.4	7.5	7.2	6.8	6.0	5.5	5.0	4.7	4.4	3.8	3.4	3.0	2.7	2.2	1.8	1.4	0.9	0.5
6	5.3	4.9	3.7	3.6	3.5	3.4	3.1	3.0	2.8	2.4	2.2	2.0	1.8	1.6	1.4	1.2	1.0	0.8	0.7	0.4	0.3
3	2.8	1.9	1.5	1.4	1.2	1.1	0.9	0.9	0.8	0.8	0.6	0.6	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.1	0.1

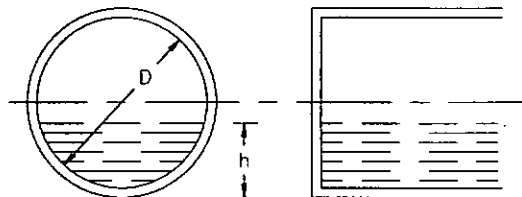


APPENDIX B (continued)

TANK CAPACITIES HORIZONTAL, CYLINDRICAL, FLAT ENDS, WHEN FILLED TO VARIOUS DEPTHS

CONTENTS IN U.S. GALLONS. THIS TABLE IS ONLY APPROXIMATE,
BUT CLOSE ENOUGH FOR PRACTICAL USE.

		TANK DIAMETER (IN)																	
		FULL TANK CAPACITIES																	
h (in)	144	132	120	114	108	102	96	90	84	78	72	66	60	54	48	42	36	30	24
141	846.0	710.9	587.5	530.3	476.1	424.5	376.0	330.5	287.9	248.2	211.5	177.7	146.9	119.0	94.0	72.0	52.9	36.7	23.5
138	841.7																		
135	833.8																		
132	823.7																		
129	812.5																		
126	801.4	706.7																	
123	785.0	699.5																	
120	769.5	689.5																	
117	753.1	678.7																	
114	735.8	666.1	583.6																
111	718.6	652.9	576.6																
108	699.9	638.1	567.5	526.5															
105	680.6	622.5	557.0	519.5															
102	660.8	606.1	545.2	510.8	472.4														
99	640.4	589.7	532.3	500.5	465.7														
96	619.6	571.9	518.5	489.0	457.2	420.9													
93	599.5	553.6	503.9	476.5	447.2	414.4													
90	578.0	535.7	488.6	463.2	436.1	406.1	372.5												
87	556.2	516.5	472.6	449.0	424.0	396.5	366.2												
84	534.2	496.9	456.2	434.2	411.0	385.5	358.2	327.1											
81	512.0	477.0	439.3	418.8	397.4	374.0	348.9	321.0											
78	489.6	457.7	422.0	402.9	383.1	361.5	338.5	313.3	284.6										
75	468.2	437.4	404.3	386.6	368.2	348.3	327.2	304.3	278.8										
72	445.6	416.8	386.3	369.9	352.9	334.6	315.2	294.3	271.3	245.1									
69	423.0	396.1	368.1	352.9	337.2	320.3	302.5	283.4	262.7	239.5									
66	400.4	376.3	349.7	335.7	321.2	305.6	289.3	271.9	253.1	232.3	208.5								
63	377.8	355.5	331.1	318.2	304.9	290.6	275.6	259.7	242.7	224.0	203.1								
60	356.4	334.6	312.5	300.6	288.4	275.3	261.6	247.1	231.6	214.8	196.3	174.8							
57	334.0	314.8	293.8	282.9	271.7	259.7	247.2	234.1	220.0	204.9	188.4	169.7							
54	311.8	294.1	275.1	265.1	255.0	244.0	232.6	220.7	208.0	194.4	179.6	163.2	144.1						
51	289.8	273.5	256.4	247.4	238.1	228.1	217.9	207.0	195.6	183.4	170.2	155.7	139.3						
48	268.0	253.2	237.9	229.7	221.1	212.3	203.0	193.2	182.9	172.0	160.2	147.4	133.1	116.4					
45	246.5	233.9	219.5	212.1	204.4	196.4	188.0	179.3	170.1	160.3	149.8	138.5	126.0	111.8					
42	226.4	214.0	201.2	194.6	187.7	180.5	173.1	165.2	157.0	148.3	139.1	129.1	118.2	105.9	91.6				
39	205.6	194.4	183.3	177.3	171.2	164.8	158.2	151.2	144.0	136.3	128.1	119.3	109.8	99.3	87.2				
36	185.3	175.2	165.6	160.3	154.9	149.3	143.4	137.3	130.9	124.1	117.0	109.3	101.1	92.0	81.8	69.7			
33	165.4	157.3	148.3	143.6	138.9	133.9	128.8	123.5	117.9	112.0	105.8	99.1	92.0	84.3	75.6	65.7			
30	146.1	139.0	131.3	127.3	123.2	118.9	114.4	109.8	105.0	99.9	94.5	88.9	82.8	76.2	68.9	60.7	50.8		
27	127.4	121.2	115.0	111.4	107.9	104.2	100.4	96.4	92.3	88.0	83.4	78.6	73.5	67.9	61.8	55.0	47.1		
24	110.2	104.9	99.0	96.1	93.0	89.9	86.7	83.4	79.9	76.3	72.5	68.4	64.1	59.5	54.5	48.9	42.5	34.8	
21	93.0	88.4	83.7	81.2	78.7	76.2	73.5	70.8	67.9	64.9	61.7	58.4	54.9	51.1	47.0	42.5	37.5	31.5	
18	76.5	72.8	69.1	67.1	65.1	63.0	60.8	58.6	56.3	53.9	51.3	48.7	45.8	42.8	39.5	36.0	32.0	27.5	21.8
15	61.0	58.0	55.3	53.7	52.1	50.5	48.8	47.1	45.2	43.3	41.4	39.3	37.1	34.7	32.2	29.5	26.4	23.0	18.9
12	44.6	44.8	42.4	41.2	40.0	39.0	37.5	36.2	34.9	33.4	31.9	30.4	28.7	27.0	25.1	23.1	20.9	18.4	15.5
9	33.5	32.2	30.6	29.8	28.9	28.0	27.1	26.2	25.2	24.2	23.2	22.1	20.9	19.7	18.4	17.0	15.4	13.7	11.8
6	22.3	21.4	20.0	19.5	18.9	18.4	17.8	17.2	16.6	15.9	15.3	14.6	13.8	13.0	12.2	11.3	10.3	9.3	8.1
3	12.2	11.4	11.0	10.7	10.4	10.1	9.8	9.5	9.1	8.8	8.4	8.0	7.6	7.2	6.8	6.3	5.8	5.2	4.6
3	4.3	4.2	3.9	3.8	3.7	3.6	3.5	3.4	3.3	3.2	3.0	2.9	2.8	2.6	2.5	2.3	2.1	1.9	1.7



APPENDIX C

PROPERTIES OF SATURATED STEAM AT PRESSURES LESS THAN THAT OF THE ATMOSPHERE

Vacuum Inches Hg. Referred to 30" Barometer (Mercury at 58.4°F.)	Absolute Pressure in Inches Mercury at 32°F	Temp. Degrees Fahrenheit	Specific Volume Cu. Ft. per Pound	Heat of the Liquid	Total Heat of Steam	Absolute Pressure in Lbs. per Sq. Inch
29.5	0.498	58.77	1259.0	26.85	1085.3	0.244
29.0	0.997	79.07	657.0	47.11	1094.3	0.488
28.5	1.495	91.70	446.2	59.70	1100.0	0.732
28.0	1.994	101.15	339.6	69.12	1104.1	0.977
27.5	2.493	108.70	275.2	76.64	1107.4	1.221
27.0	2.991	115.06	231.9	82.98	1110.2	1.465
26.5	3.490	120.55	200.2	88.46	1112.6	1.710
26.0	3.989	125.38	176.7	93.28	1114.7	1.954
25.5	4.487	129.75	158.1	97.64	1116.5	2.198
25.0	4.98	133.77	143.0	101.65	1118.3	2.44
24.0	5.98	140.64	129.0	108.51	1121.3	2.93
23.0	6.98	146.78	104.5	114.64	1123.9	3.42
22.0	7.97	152.16	92.3	120.02	1126.2	3.90
21.0	8.97	157.00	82.6	124.86	1128.2	4.39
20.0	9.97	161.42	74.8	129.28	1130.1	4.88
19.0	10.97	165.42	68.5	133.28	1131.8	5.37
18.0	11.96	169.14	63.1	137.00	1133.4	5.86
17.0	12.96	172.63	58.6	140.50	1134.8	6.35
16.0	13.96	175.93	54.6	143.80	1136.1	6.84
15.0	14.95	179.03	51.17	146.91	1137.4	7.32
14.0	15.95	181.92	49.03	149.80	1138.6	7.81
13.0	16.95	184.68	45.55	152.57	1139.7	8.30
12.0	17.95	187.31	43.18	155.21	1140.7	8.79
11.0	18.94	189.83	41.05	157.73	1141.7	9.28
10.0	19.94	192.23	39.13	160.14	1142.3	9.77
9.0	20.94	194.52	37.40	162.44	1143.6	10.26
8.0	21.94	196.73	35.79	164.68	1144.5	10.75
7.0	22.93	198.87	34.33	166.81	1145.4	11.23
6.0	23.93	200.94	33.00	168.88	1146.3	11.72
5.0	24.93	202.92	31.76	170.89	1147.0	12.21
4.0	25.92	204.85	30.62	172.81	1147.6	12.70
3.0	26.92	206.71	29.55	174.68	1148.4	13.19
2.0	27.92	208.52	28.57	176.50	1149.1	13.68
1.0	28.92	210.28	27.66	178.27	1149.7	14.17
0.0	29.92	212.00	26.79	180.00	1150.4	14.67

APPENDIX C (continued)

PROPERTIES OF SATURATED STEAM

Vacuum, Inches of Mercury	Absolute Pressure Lbs. per Sq. In.	Tempera- ture, Fahren- heit	Total Heat Above 32 °F		Latent Heat, $L=H-h$ Heat- Units	Volume, Cu. Ft. in 1 Lb. of Steam	Weight of 1 Cu. Ft. Steam, Lb.	Entropy of the Water	Entropy of Evapor- ation
			In the Water h Heat- Units	In the Steam H Heat- Units					
29.74	0.0886	32	0.00	1073.4	1073.4	3294	0.000304	0.0000	2.1832
29.67	0.1217	40	8.05	1076.9	1068.9	2438	0.000410	0.0162	2.1394
29.56	0.1780	50	18.08	1081.4	1063.3	1702	0.000587	0.0361	2.0865
29.40	0.2562	60	28.08	1085.9	1057.8	1208	0.000828	0.0555	2.0358
29.18	0.3626	70	38.06	1090.3	1052.3	871	0.001148	0.0745	1.9868
29.89	0.505	80	48.03	1094.8	1046.7	636.8	0.001570	0.0932	1.9398
28.50	0.696	90	58.00	1099.2	1041.2	469.3	0.002131	0.1114	1.8944
28.00	0.946	100	67.97	1103.6	1035.6	350.8	0.002851	0.1295	1.8505
27.88	1	101.83	69.8	1104.4	1034.6	333.0	0.00300	0.1327	1.8427
25.85	2	126.15	94.0	1115.0	1021.0	173.5	0.00576	0.1749	1.7431
23.81	3	141.52	109.4	1121.6	1012.3	118.5	0.00845	0.2008	1.6840
21.78	4	153.01	120.9	1126.5	1005.7	90.5	0.01107	0.2198	1.6416
19.74	5	162.28	130.1	1130.5	1000.3	73.33	0.01364	0.2348	1.6084
17.70	6	170.06	137.9	1133.7	995.8	61.89	0.01616	0.2471	1.5814
15.67	7	176.85	144.7	1136.5	991.8	53.56	0.01867	0.2579	1.5582
13.63	8	182.86	150.8	1139.0	988.2	47.27	0.02115	0.2673	1.5380
11.60	9	188.27	156.2	1141.1	985.0	42.36	0.02361	0.2756	1.5202
9.56	10	193.22	161.1	1143.1	982.0	38.38	0.02606	0.2832	1.5042
7.52	11	197.75	165.7	1144.9	979.2	35.10	0.02849	0.2902	1.4895
5.49	12	201.96	169.9	1146.5	976.6	32.36	0.03090	0.2967	1.4760
3.45	13	205.87	173.8	1148.0	974.2	30.03	0.03330	0.3025	1.4639
1.42	14	209.55	177.5	1149.4	971.9	28.02	0.03569	0.3081	1.4523
Gauge Pressure Lbs. per Sq. In.	Absolute Pressure	Tempera- ture	h	H	Latent Heat	Volume	Weight of 1 Cu. Ft. Steam	Entropy of the Water	Entropy of Evapor- ation
0	14.70	212	180.0	1150.4	970.4	26.79	0.03732	0.3118	1.4447
0.3	15	213.0	181.0	1150.7	969.7	26.27	0.03806	0.3133	1.4416
1.3	16	216.3	184.4	1152.0	967.6	24.79	0.04042	0.3183	1.4311
2.3	17	219.4	187.5	1153.1	965.6	23.38	0.04277	0.3229	1.4215
3.3	18	222.4	190.5	1154.2	963.7	22.16	0.04512	0.3273	1.4127
4.3	19	225.2	193.4	1155.2	961.8	21.07	0.04746	0.3315	1.4045
5.3	20	228.0	196.1	1156.2	960.0	20.08	0.04980	0.3355	1.3965
6.3	21	230.6	198.8	1157.1	958.3	19.18	0.05213	0.3393	1.3887
7.3	22	233.1	201.3	1158.0	956.7	18.37	0.05445	0.3430	1.3811
8.3	23	235.5	203.8	1158.8	955.1	17.62	0.05676	0.3465	1.3739
9.3	24	237.8	206.1	1159.6	953.5	16.93	0.05907	0.3499	1.3670
10.3	25	240.1	208.4	1160.4	952.0	16.30	0.0614	0.3532	1.3604
11.3	26	242.2	210.6	1161.2	950.6	15.72	0.0636	0.3564	1.3542
12.3	27	244.4	212.7	1161.9	949.2	15.18	0.0659	0.3594	1.3483
13.3	28	246.4	214.8	1162.6	947.8	14.67	0.0682	0.3623	1.3425
14.3	29	248.4	216.8	1163.2	946.4	14.19	0.0705	0.3652	1.3367
15.3	30	250.3	218.8	1163.9	945.1	13.74	0.0728	0.3680	1.3311
16.3	31	252.2	220.7	1164.5	943.8	13.32	0.0751	0.3707	1.3257
17.3	32	254.1	222.6	1165.1	942.5	12.93	0.0773	0.3733	1.3205
18.3	33	255.8	224.4	1165.7	941.3	12.57	0.0795	0.3759	1.3155
19.3	34	257.6	226.2	1166.3	940.1	12.22	0.0818	0.3784	1.3107
20.3	35	259.3	227.9	1166.8	938.9	11.89	0.0841	0.3808	1.3060

APPENDIX C (continued)

PROPERTIES OF SATURATED STEAM

Gauge Pressure Lbs. per Sq. In.	Absolute Pressure	Tempera- ture	<i>h</i>	<i>H</i>	Latent Heat	Volume	Weight of 1 Cu. Ft. Steam	Entropy of the Water	Entropy of Evapor- ation
21.3	36	261.0	229.6	1167.3	937.7	11.58	0.0863	0.3832	1.3014
22.3	37	262.6	231.3	1167.8	936.6	11.29	0.0886	0.3855	1.2969
23.3	38	264.2	232.9	1168.4	935.5	11.01	0.0908	0.3877	1.2925
24.3	39	265.8	234.5	1168.9	934.4	10.74	0.0931	0.3899	1.2882
25.3	40	267.3	236.1	1169.4	933.3	10.49	0.0953	0.3920	1.2841
26.3	41	268.7	237.6	1169.8	932.2	10.25	0.0976	0.3941	1.2800
27.3	42	270.2	239.1	1170.3	931.2	10.02	0.0998	0.3962	1.2759
28.3	43	271.7	240.5	1170.7	930.2	9.80	0.1020	0.3982	1.2720
29.3	44	273.1	242.0	1171.2	929.2	9.59	0.1043	0.4002	1.2681
30.3	45	274.5	243.4	1171.6	928.2	9.39	0.1065	0.4021	1.2644
31.3	46	275.8	244.8	1172.0	927.2	9.20	0.1087	0.4040	1.2607
32.3	47	277.2	246.1	1172.4	926.3	9.02	0.1109	0.4059	1.2571
33.3	48	278.5	247.5	1172.8	925.3	8.84	0.1131	0.4077	1.2536
34.3	49	279.8	248.8	1173.2	924.4	8.67	0.1153	0.4095	1.2502
35.3	50	281.0	250.1	1173.6	923.5	8.51	0.1175	0.4113	1.2468
36.3	51	282.3	251.4	1174.0	922.6	8.35	0.1197	0.4130	1.2432
37.3	52	283.5	252.6	1174.3	921.7	8.20	0.1219	0.4147	1.2405
38.3	53	284.7	253.9	1174.7	920.8	8.05	0.1241	0.4164	1.2370
39.3	54	285.9	255.1	1175.0	919.9	7.91	0.1263	0.4180	1.2339
40.3	55	287.1	256.3	1175.4	919.0	7.78	0.1285	0.4106	1.2309
41.3	56	288.2	257.5	1175.7	918.2	7.65	0.1307	0.4212	1.2278
42.3	57	289.4	258.7	1176.0	917.4	7.52	0.1329	0.4227	1.2248
43.3	58	290.5	259.8	1176.4	916.5	7.40	0.1350	0.4242	1.2218
44.3	59	291.6	261.0	1176.7	915.7	7.28	0.1372	0.4257	1.2189
45.3	60	292.7	262.1	1177.0	914.9	7.17	0.1394	0.4272	1.2160
46.3	61	293.8	263.2	1177.3	914.1	7.06	0.1416	0.4287	1.2132
47.3	62	294.9	264.3	1177.6	913.3	6.95	0.1438	0.4302	1.2104
48.3	63	295.9	265.4	1177.9	912.5	6.85	0.1460	0.4316	1.2077
49.3	64	297.0	266.4	1178.2	911.8	6.75	0.1482	0.4330	1.2050
50.3	65	298.0	267.5	1178.5	911.0	6.65	0.1503	0.4344	1.2024
51.3	66	299.0	268.5	1178.8	910.2	6.56	0.1525	0.4358	1.1998
52.3	67	300.0	269.6	1179.0	909.5	6.47	0.1547	0.4371	1.1972
53.3	68	301.0	270.6	1179.3	908.7	6.38	0.1569	0.4385	1.1946
54.3	69	302.0	271.6	1179.6	908.0	6.29	0.1590	0.4398	1.1921
55.3	70	302.9	272.6	1179.8	907.2	6.20	0.1621	0.4411	1.1896
56.3	71	303.9	273.6	1180.1	906.5	6.12	0.1634	0.4424	1.1872
57.3	72	304.8	274.5	1180.4	905.8	6.04	0.1656	0.4437	1.1848
58.3	73	305.8	275.5	1180.6	905.1	5.96	0.1678	0.4449	1.1825
59.3	74	306.7	276.5	1180.9	904.4	5.89	0.1699	0.4462	1.1801
60.3	75	307.6	277.4	1181.1	903.7	5.81	0.1721	0.4474	1.1778
61.3	76	308.5	278.3	1181.4	903.0	5.74	0.1743	0.4487	1.1755
62.3	77	309.4	279.3	1181.6	902.3	5.67	0.1764	0.4499	1.1730
63.3	78	310.3	280.2	1181.8	901.7	5.60	0.1786	0.4511	1.1712
64.3	79	311.2	281.1	1182.1	901.0	5.54	0.1808	0.4523	1.1687
65.3	80	312.0	282.0	1182.3	900.3	5.47	0.1829	0.4535	1.1665
66.3	81	312.9	282.9	1182.5	899.7	5.41	0.1851	0.4546	1.1644
67.3	82	313.8	283.8	1182.8	899.0	5.34	0.1873	0.4557	1.1623
68.3	83	314.6	284.6	1183.0	898.4	5.28	0.1894	0.4568	1.1602

APPENDIX C (continued)

PROPERTIES OF SATURATED STEAM

Gauge Pressure Lbs. per Sq. In.	Absolute Pressure	Temperature	h	H	Latent Heat	Volume	Weight of 1 Cu. Ft. Steam	Entropy of the Water	Entropy of Evapor- ation
69.3	84	315.4	285.5	1183.2	897.7	5.22	0.1915	0.4579	1.1581
70.3	85	316.3	286.3	1183.4	897.1	5.16	0.1937	0.4590	1.1561
71.3	86	317.1	287.2	1183.6	896.4	5.10	0.1959	0.4601	1.1540
72.3	87	317.9	288.0	1183.8	895.8	5.05	0.1980	0.4612	1.1520
73.3	88	318.7	288.9	1184.0	895.2	5.00	0.2001	0.4623	1.1500
74.3	89	319.5	289.7	1184.2	894.6	4.94	0.2023	0.4633	1.1481
75.3	90	320.3	290.5	1184.4	893.9	4.89	0.2044	0.4644	1.1461
76.3	91	321.1	291.3	1184.6	893.3	4.84	0.2065	0.4654	1.1442
77.3	92	321.8	292.1	1184.8	892.7	4.79	0.2087	0.4664	1.1423
78.3	93	322.6	292.9	1185.0	892.1	4.74	0.2109	0.4674	1.1404
79.3	94	323.4	293.7	1185.2	891.5	4.69	0.2130	0.4684	1.1385
80.3	95	324.1	294.5	1185.4	890.9	4.65	0.2151	0.4694	1.1367
81.3	96	324.9	295.3	1185.6	890.3	4.60	0.2172	0.4704	1.1348
82.3	97	325.6	296.1	1185.8	889.7	4.56	0.2193	0.4714	1.1330
83.3	98	326.4	296.8	1186.0	889.2	4.51	0.2215	0.4724	1.1312
84.3	99	327.1	297.6	1186.2	888.6	4.47	0.2237	0.4733	1.1295
85.3	100	327.8	298.3	1186.3	888.0	4.429	0.2258	0.4743	1.1277
87.3	102	329.3	299.8	1186.7	886.9	4.347	0.2300	0.4762	1.1242
89.3	104	330.7	301.3	1187.0	885.8	4.268	0.2343	0.4780	1.1208
91.3	106	332.0	302.7	1187.4	884.7	4.192	0.2336	0.4798	1.1174
93.3	108	333.4	304.1	1187.7	883.6	4.118	0.2429	0.4816	1.1141
95.3	110	334.8	305.5	1188.0	882.5	4.047	0.2472	0.4834	1.1108
97.3	112	336.1	306.9	1188.4	881.4	3.978	0.2514	0.4852	1.1076
99.3	114	337.4	308.3	1188.7	880.4	3.912	0.2556	0.4869	1.1045
101.3	116	338.7	309.6	1189.0	879.3	3.848	0.2599	0.4886	1.1014
103.3	118	340.0	311.0	1189.3	878.3	3.786	0.2641	0.4903	1.0984
105.3	120	341.3	312.3	1189.6	877.2	3.726	0.2683	0.4919	1.0954
107.3	122	342.5	313.6	1189.8	876.2	3.668	0.2726	0.4935	1.0924
109.3	124	343.8	314.9	1190.1	875.2	3.611	0.2769	0.4951	1.0895
111.3	126	345.0	316.2	1190.4	874.2	3.556	0.2812	0.4967	1.0865
113.3	128	346.2	317.4	1190.7	873.3	3.504	0.2854	0.4982	1.0837
115.3	130	347.4	318.6	1191.0	872.3	3.452	0.2897	0.4998	1.0809
117.3	132	348.5	319.9	1191.2	871.3	3.402	0.2939	0.5013	1.0782
119.3	134	349.7	321.1	1191.5	870.4	3.354	0.2981	0.5028	1.0755
121.3	136	350.8	322.3	1191.7	869.4	3.308	0.3023	0.5043	1.0728
123.3	138	352.0	323.4	1192.0	868.5	3.263	0.3065	0.5057	1.0702
125.3	140	353.1	324.6	1192.2	867.6	3.219	0.3107	0.5072	1.0675
127.3	142	354.2	325.8	1192.5	866.7	3.175	0.3150	0.5086	1.0649
129.3	144	355.3	326.9	1192.7	865.8	3.133	0.3192	0.5100	1.0624
131.3	146	356.3	328.0	1192.9	864.9	3.092	0.3234	0.5114	1.0599
133.3	148	357.4	329.1	1193.2	864.0	3.052	0.3276	0.5128	1.0574
135.3	150	358.5	330.2	1193.4	863.2	3.012	0.3320	0.5142	1.0550
137.3	152	359.5	331.4	1193.6	862.3	2.974	0.3362	0.5155	1.0525
139.3	154	360.5	332.4	1193.8	861.4	2.938	0.3404	0.5169	1.0501
141.3	156	361.6	333.5	1194.1	860.6	2.902	0.3446	0.5182	1.0477
143.3	158	362.6	334.6	1194.3	859.7	2.868	0.3488	0.5195	1.0454
145.3	160	363.6	335.6	1194.5	858.8	2.834	0.3529	0.5208	1.0431
147.3	162	364.6	336.7	1194.7	858.0	2.801	0.3570	0.5220	1.0409

APPENDIX C (continued)
PROPERTIES OF SATURATED STEAM

Gauge Pressure Lbs. per Sq. In.	Absolute Pressure	Temperature	<i>h</i>	<i>H</i>	Latent Heat	Volume	Weight of 1 Cu. Ft. Steam	Entropy of the Water	Entropy of Evapor- ation
149.3	164	365.6	337.7	1194.9	857.2	2.769	0.3612	0.5233	1.0387
151.3	166	366.5	338.7	1195.1	856.4	2.737	0.3654	0.5245	1.0365
153.3	168	367.5	339.7	1195.3	855.5	2.706	0.3696	0.5257	1.0343
155.3	170	368.5	340.7	1195.4	854.7	2.675	0.3738	0.5269	1.0321
157.3	172	369.4	341.7	1195.6	853.9	2.645	0.3780	0.5281	1.0300
159.3	174	370.4	342.7	1195.8	853.1	2.616	0.3822	0.5293	1.0278
161.3	176	371.3	343.7	1196.0	852.3	2.588	0.3864	0.5305	1.0257
163.3	178	372.2	344.7	1196.2	851.5	2.560	0.3906	0.5317	1.0235
165.3	180	373.1	345.6	1196.4	850.8	2.533	0.3948	0.5328	1.0215
167.3	182	374.0	346.6	1196.6	850.0	2.507	0.3989	0.5339	1.0195
169.3	184	374.9	347.6	1196.8	849.2	2.481	0.4031	0.5351	1.0174
171.3	186	375.8	348.5	1196.9	848.4	2.455	0.4073	0.5362	1.0154
173.3	188	376.7	349.4	1197.1	847.7	2.430	0.4115	0.5373	1.0134
175.3	190	377.6	350.4	1197.3	846.9	2.406	0.4157	0.5384	1.0114
177.3	192	378.5	351.3	1197.4	846.1	2.381	0.4199	0.5395	1.0095
179.3	194	379.3	352.2	1197.6	845.4	2.358	0.4241	0.5405	1.0076
181.3	196	380.2	353.1	1197.8	844.7	2.335	0.4283	0.5416	1.0056
183.3	198	381.0	354.0	1197.9	843.9	2.312	0.4325	0.5426	1.0038
185.3	200	381.9	354.9	1198.1	843.2	2.290	0.437	0.5437	1.0019
190.3	205	384.0	357.1	1198.5	841.4	2.237	0.447	0.5463	0.9973
195.3	210	386.0	359.2	1198.8	839.6	2.187	0.457	0.5488	0.9928
200.3	215	388.0	361.4	1199.2	837.9	2.138	0.468	0.5513	0.9885
205.3	220	389.9	363.4	1199.6	836.2	2.091	0.478	0.5538	0.9841
210.3	225	391.9	365.5	1199.9	834.4	2.046	0.489	0.5562	0.9799
215.3	230	393.8	367.5	1200.2	832.8	2.004	0.499	0.5586	0.9758
220.3	235	395.6	369.4	1200.6	831.1	1.964	0.509	0.5610	0.9717
225.3	240	397.4	371.4	1200.9	829.5	1.924	0.520	0.5633	0.9676
230.3	245	399.3	373.3	1201.2	827.9	1.887	0.530	0.5655	0.9638
235.3	250	401.1	375.2	1201.5	826.3	1.850	0.541	0.5676	0.9600
245.3	260	404.5	378.9	1202.1	823.1	1.782	0.561	0.5719	0.9525
255.3	270	407.9	382.5	1202.6	820.1	1.718	0.582	0.5760	0.9454
265.3	280	411.2	385.0	1203.1	817.1	1.658	0.603	0.5800	0.9385
275.3	290	414.4	389.4	1203.6	814.2	1.602	0.624	0.5840	0.9316
285.3	300	417.5	392.7	1204.1	811.3	1.551	0.645	0.5878	0.9251
295.3	310	420.5	395.9	1204.5	808.5	1.502	0.666	0.5915	0.9187
305.3	320	423.4	399.1	1204.9	805.8	1.456	0.687	0.5951	0.9125
315.3	330	426.3	402.2	1205.3	803.1	1.413	0.708	0.5986	0.9065
325.3	340	429.1	405.3	1205.7	800.4	1.372	0.729	0.6020	0.9006
335.3	350	431.9	408.2	1206.1	797.8	1.334	0.750	0.6053	0.8949
345.3	360	434.6	411.2	1206.4	795.3	1.298	0.770	0.6085	0.8894
355.3	370	437.2	414.0	1206.8	792.8	1.264	0.791	0.6116	0.8840
365.3	380	439.8	416.8	1207.1	790.3	1.231	0.812	0.6147	0.8788
375.3	390	442.3	419.5	1207.4	787.9	1.200	0.833	0.6178	0.8737
385.3	400	444.8	422	1208	786	1.17	0.86	0.621	0.868
435.3	450	456.5	435	1209	774	1.04	0.96	0.635	0.844
485.3	500	467.3	448	1210	762	0.93	1.08	0.648	0.822
535.3	550	477.3	459	1210	751	0.83	1.20	0.659	0.801
585.3	600	486.6	469	1210	741	0.76	1.32	0.670	0.783

APPENDIX D

FRICTION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

U. S. Gallons per Minute	1 in. (1.049" I. D.)		1¼ in. (1.3880" I. D.)		1½ in. (1.610" I. D.)		U. S. Gallons per Minute
	V	h _f	V	h _f	V	h _f	
4	1.48	1.29					4
5	1.86	1.93					5
6	2.23	2.68	1.29	0.70			6
7	2.60	3.56	1.50	0.93			7
8	2.97	4.54	1.72	1.18	1.26	0.56	8
9	3.34	5.65	1.93	1.46	1.42	0.69	9
10	3.71	6.86	2.15	1.77	1.58	0.83	10
12	4.45	9.62	2.57	2.48	1.89	1.16	12
14	5.20	12.8	3.00	3.28	2.21	1.53	14
16	5.94	16.5	3.43	4.20	2.52	1.96	16
18	6.68	20.6	3.86	5.22	2.84	2.42	18
20	7.42	25.1	4.29	6.34	3.15	2.94	20
25	9.29	37.4	5.37	9.66	3.94	4.50	25
30	11.1	54.6	6.44	13.6	4.73	6.26	30
35	13.0	73.3	7.52	18.5	5.52	8.38	35
40	14.8	95.0	8.58	23.5	6.30	10.8	40
45	16.7	119	9.66	29.5	7.10	13.5	45
50	18.6	146	10.7	36.0	7.88	16.4	50
60	22.3	209	12.9	51.0	9.46	23.2	60
70	26.0	283	15.0	68.8	11.0	31.3	70
80			17.2	89.2	12.6	40.5	80
90			19.3	112	14.2	51.0	90
100			21.5	138	15.8	62.2	100
120			25.7	197	18.9	88.3	120
140					22.1	119	140

*V = Velocity in ft./sec.

**h_f = Friction head loss in ft./100ft.

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APPENDIX D (continued)

FRICITION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

U. S. Gallons per Minute	2 in. (2.067" I. D.)		2½ in. (2.469" I. D.)		3 in. (3.068" I. D.)		U. S. Gallons per Minute
	V	h _f	V	h _f	V	h _f	
30	2.87	1.82	2.01	0.75			30
35	3.35	2.42	2.35	1.00			35
40	3.82	3.10	2.68	1.28			40
50	4.78	4.67	3.35	1.94	2.17	.66	50
60	5.74	6.59	4.02	2.72	2.60	0.92	60
80	7.65	11.4	5.36	4.66	3.47	1.57	80
100	9.56	17.4	6.70	7.11	4.34	2.39	100
120	11.5	24.7	8.04	10.0	5.21	3.37	120
140	13.4	33.2	9.38	13.5	6.08	4.51	140
160	15.3	43.0	10.7	17.4	6.94	5.81	160
180	17.2	54.1	12.1	21.9	7.81	7.28	180
200	19.1	66.3	13.4	26.7	8.68	8.90	200
220	21.0	80.0	14.7	32.2	9.55	10.7	220
240	22.9	95.0	16.1	38.1	10.4	12.6	240
260	24.9	111	17.4	44.5	11.3	14.7	260
280	26.8	128	18.8	51.3	12.2	16.9	280
300	28.7	146	20.1	58.5	13.0	19.2	300
350			23.5	79.2	15.2	26.3	350
400			26.8	103	17.4	33.9	400
500			33.5	160	21.7	52.5	500
600					26.0	74.8	600
700					30.4	101	700
800					34.7	131	800
1000							1000

*V = Velocity in ft./sec.

**h_f = Friction head loss in ft./100ft.

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APPENDIX D (continued)

FRICITION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

U. S. Gallons per Minute	4 in. (4.026" I. D.)		5 in. (5.047" I. D.)		6 in. (6.065" I. D.)		8 in. (7.981" I. D.)		Gallons per Minute
	V	h _f	V	h _f	V	h _f	V	h _f	
140	3.53	1.16	2.25	0.38					140
160	4.03	1.49	2.57	0.49					160
180	4.54	1.86	2.89	0.61					180
200	5.04	2.27	3.21	0.74	2.22	0.3			200
240	6.05	3.21	3.85	1.03	2.66	0.42			240
280	7.06	4.3	4.49	1.38	3.11	0.56			280
320	8.06	5.51	5.13	1.78	3.55	0.72			320
360	9.07	6.92	5.77	2.22	4	0.9			360
400	10.1	8.47	6.41	2.72	4.44	1.09	2.57	0.28	400
450	11.3	10.5	7.23	3.42	5	1.37	2.89	0.35	450
500	12.6	13	8.02	4.16	5.55	1.66	3.21	0.42	500
600	15.1	18.6	9.62	5.88	6.66	2.34	3.85	0.6	600
700	17.6	25	11.2	7.93	7.77	3.13	4.49	0.8	700
800	20.2	32.4	12.8	10.2	8.88	4.03	5.13	1.02	800
900	22.7	40.8	14.4	12.9	9.99	5.05	5.77	1.27	900
1000	25.2	50.2	16	15.8	11.1	6.17	6.41	1.56	1000
1200	30.2	72	19.2	22.5	13.3	8.76	7.7	2.2	1200
1400	35.3	97.6	22.5	30.4	15.5	11.8	8.98	2.95	1400
1600			25.7	39.5	17.8	15.4	10.3	3.82	1600
1800			28.8	49.7	20	19.4	11.5	4.79	1800
2000			32.1	61	22.2	23.8	12.8	5.86	2000
2400					26.6	34.2	15.4	8.31	2400
2800					31.1	46.1	18	11.2	2800
3200					35.5	59.9	20.5	14.5	3200
3600							23.1	18.4	3600
4000							25.7	22.6	4000

*V = Velocity in ft./sec.

**h_f = Friction head loss in ft./100ft.

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APPENDIX D (continued)

FRICTION & VELOCITY CHART FOR SCHEDULE 40 STEEL PIPE

U. S. Gallons per Minute	10 in. (10.020" I. D.)		12 in. (11.938" I. D.)		14 in. (13.124" I. D.)		16 in. (15.000" I. D.)		Gallons per Minute
	V	h _f	V	h _f	V	h _f	V	h _f	
800	3.25	0.328							800
900	3.66	0.410	2.58	0.173					900
1000	4.07	0.500	2.87	0.210	2.37	0.131			1000
1200	4.88	0.703	3.44	0.296	2.85	0.185			1200
1400	5.70	0.940	4.01	0.395	3.32	0.247			1400
1600	6.51	1.21	4.59	0.509	3.79	0.317	2.90	0.163	1600
1800	7.32	1.52	5.16	0.636	4.27	0.395	3.27	0.203	1800
2000	8.14	1.86	5.73	0.776	4.74	0.483	3.63	0.248	2000
2500	10.2	2.86	7.17	1.19	5.93	0.738	4.54	0.377	2500
3000	12.2	4.06	8.60	1.68	7.11	1.04	5.45	0.535	3000
3500	14.2	5.46	10.0	2.25	8.30	1.40	6.35	0.718	3500
4000	16.3	7.07	11.5	2.92	9.48	1.81	7.26	0.921	4000
4500	18.3	8.88	12.9	3.65	10.7	2.27	8.17	1.15	4500
5000	20.3	10.9	14.3	4.47	11.9	2.78	9.08	1.41	5000
6000	24.4	15.6	17.2	6.39	14.2	3.95	10.9	2.01	6000
7000	28.5	21.1	20.1	8.63	16.6	5.32	12.7	2.69	7000
8000	32.5	27.5	22.9	11.2	19.0	6.90	14.5	3.49	8000
9000	36.6	34.6	25.8	14.1	21.3	8.7	16.3	4.38	9000
10,000			28.7	17.4	23.7	10.7	18.2	5.38	10,000
12,000			34.4	24.8	28.5	15.2	21.8	7.69	12,000
14,000			40.1	33.5	33.2	20.7	25.4	10.4	14,000
16,000					37.9	26.8	29.0	13.5	16,000
18,000					42.7	33.9	32.7	17.2	18,000
20,000							36.3	21.2	20,000

*V = Velocity in ft./sec.

**h_f = Friction head loss in ft./100ft.

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APPENDIX E

PIPE DATA

Nominal Pipe Size Inches	Outside Diameter Inches	Identification			Wall Thickness (t) Inches	Inside Diameter (d) Inches	Transverse Internal Area (A) Square Feet	Weight Pipe Pounds per foot	Weight Water Pounds per foot of pipe
		Steel		Stainless					
		Iron Pipe Size	Sched. No.	Steel Sched. No.					
1/8	0.405	--	--	10S	0.049	0.307	0.00051	0.19	0.032
		STD	40	40S	0.068	0.269	0.00040	0.24	0.025
		XS	80	80S	0.095	0.215	0.00025	0.31	0.016
1/4	0.540	--	--	10S	0.065	0.410	0.00091	0.33	0.057
		STD	40	40S	0.088	0.364	0.00072	0.42	0.045
		XS	80	80S	0.119	0.302	0.00050	0.54	0.031
3/8	0.675	--	--	10S	0.065	0.545	0.00162	0.42	0.101
		STD	40	40S	0.091	0.493	0.00133	0.57	0.083
		XS	80	80S	0.126	0.423	0.00098	0.74	0.061
1/2	0.840	--	--	5S	0.065	0.710	0.00275	0.54	0.172
		--	--	10S	0.083	0.674	0.00248	0.67	0.155
		STD	40	40S	0.109	0.622	0.00211	0.85	0.132
		XS	80	80S	0.147	0.546	0.00163	1.09	0.102
		--	160	--	0.187	0.466	0.00118	1.31	0.074
		XXS	--	--	0.294	0.252	0.00035	1.71	0.022
3/4	1.050	--	--	5S	0.065	0.920	0.00462	0.69	0.288
		--	--	10S	0.083	0.884	0.00426	0.86	0.266
		STD	40	40S	0.113	0.824	0.00371	1.13	0.231
		XS	80	80S	0.154	0.742	0.00300	1.47	0.188
		--	160	--	0.219	0.612	0.00206	1.94	0.128
		XXS	--	--	0.308	0.434	0.00103	2.44	0.064
1	1.315	--	--	5S	0.065	1.185	0.00766	0.87	0.478
		--	--	10S	0.109	1.097	0.00656	1.40	0.409
		STD	40	40S	0.133	1.049	0.00600	1.68	0.375
		XS	80	80S	0.179	0.957	0.00499	2.17	0.312
		--	160	--	0.250	0.815	0.00362	2.84	0.230
		XXS	--	--	0.358	0.599	0.00196	3.66	0.122
1 1/4	1.660	--	--	5S	0.065	1.530	0.01277	1.11	0.797
		--	--	10S	0.109	1.442	0.01134	1.81	0.708
		STD	40	40S	0.140	1.380	0.01040	2.27	0.649
		XS	80	80S	0.191	1.278	0.00891	3.00	0.555
		--	160	--	0.250	1.160	0.00734	3.76	0.458
		XXS	--	--	0.382	0.896	0.00438	5.21	0.273
1 1/2	1.900	--	--	5S	0.065	1.770	0.01709	1.28	1.066
		--	--	10S	0.109	1.682	0.01543	2.09	0.963
		STD	40	40S	0.145	1.610	0.01414	2.72	0.882
		XS	80	80S	0.200	1.500	0.01225	3.63	0.765
		--	160	--	0.281	1.338	0.00976	4.86	0.608
		XXS	--	--	0.400	1.100	0.00660	6.41	0.42
2	2.375	--	--	5S	0.065	2.245	0.02749	1.61	1.72
		--	--	10S	0.109	2.157	0.02538	2.64	1.58
		STD	40	40S	0.154	2.067	0.02330	3.65	1.45
		XS	80	80S	0.218	1.939	0.02050	5.02	1.28
		--	160	--	0.344	1.687	0.01556	7.46	0.97
		XXS	--	--	0.436	1.503	0.01232	9.03	0.77
2 1/2	2.875	--	--	5S	0.083	2.709	0.04002	2.48	2.50
		--	--	10S	0.120	2.635	0.03787	3.53	2.36
		STD	40	40S	0.203	2.469	0.03322	5.79	2.07
		XS	80	80S	0.276	2.323	0.02942	7.66	1.87
		--	160	--	0.375	2.125	0.02463	10.01	1.54
		XXS	--	--	0.552	1.771	0.01710	13.69	1.07
3	3.500	--	--	5S	0.083	3.334	0.06063	3.03	3.78
		--	--	10S	0.120	3.260	0.05796	4.33	3.62
		STD	40	40S	0.216	3.068	0.05130	7.58	3.20
		XS	80	80S	0.300	2.900	0.04587	10.25	2.86
		--	160	--	0.438	2.624	0.03755	14.32	2.35
		XXS	--	--	0.600	2.300	0.02885	18.58	1.80

APPENDIX E (continued)

PIPE DATA

Nominal Pipe Size Inches	Outside Diameter Inches	Identification			Wall Thickness (t) Inches	Inside Diameter (d) Inches	Transverse Internal Area (A) Square Feet	Weight Pipe Pounds per foot	Weight Water Pounds per foot of pipe		
		Steel		Stainless Steel Sched. No.							
		Iron Pipe Size	Sched. No.								
3 1/2	4.000	--	--	5S	0.083	3.834	0.08017	3.48	5.00		
		--	--	10S	0.120	3.760	0.07711	4.97	4.81		
		STD	40	40S	0.226	3.548	0.06870	9.11	4.29		
		XS	80	80S	0.318	3.364	0.06170	12.50	3.84		
		--	--	--	--	--	--	--	--		
4	4.500	--	--	5S	0.083	4.334	0.10245	3.92	6.39		
		--	--	10S	0.120	4.260	0.09898	5.61	6.18		
		STD	40	40S	0.237	4.026	0.08840	10.79	5.50		
		XS	80	80S	0.337	3.826	0.07986	14.98	4.98		
		--	120	--	0.438	3.624	0.0716	19.00	4.47		
		--	160	--	0.531	3.438	0.0645	22.51	4.02		
		XXS	--	--	0.674	3.152	0.0542	27.54	3.38		
5	5.563	--	--	5S	0.109	5.345	0.1558	6.36	9.72		
		--	--	10S	0.134	5.295	0.1529	7.77	9.54		
		STD	40	40S	0.258	5.047	0.1390	14.62	8.67		
		XS	80	80S	0.375	4.813	0.1263	20.78	7.88		
		--	120	--	0.500	4.563	0.1136	27.04	7.09		
		--	160	--	0.625	4.313	0.1015	32.96	6.33		
		XXS	--	--	0.750	4.063	0.0901	38.55	5.61		
6	6.625	--	--	5S	0.109	6.407	0.2239	7.60	13.97		
		--	--	10S	0.134	6.357	0.2204	9.29	13.75		
		STD	40	40S	0.280	6.065	0.2006	18.97	12.51		
		XS	80	80S	0.432	5.761	0.1810	28.57	11.29		
		--	120	--	0.562	5.501	0.1650	36.39	10.30		
		--	160	--	0.719	5.187	0.1469	45.35	9.16		
		XXS	--	--	0.864	4.897	0.1308	53.16	8.16		
8	8.625	--	--	5S	0.109	8.407	0.3855	9.93	24.06		
		--	--	10S	0.148	8.329	0.3784	13.40	23.61		
		--	20	--	0.250	8.125	0.3601	22.36	22.47		
		--	30	--	0.277	8.071	0.3553	24.70	22.17		
		STD	40	40S	0.322	7.981	0.3474	28.55	21.70		
		--	60	--	0.406	7.813	0.3329	35.64	20.77		
		XS	80	80S	0.500	7.625	0.3171	43.39	19.78		
		--	100	--	0.594	7.437	0.3018	50.95	18.83		
		--	120	--	0.719	7.187	0.2819	60.71	17.59		
		--	140	--	0.812	7.001	0.2673	67.76	16.68		
		XXS	--	--	0.875	6.875	0.2578	72.42	16.10		
		--	160	--	0.906	6.813	0.2532	74.69	15.80		
		10	10.750	--	--	5S	0.134	10.482	0.5992	15.19	37.39
--	--			10S	0.165	10.420	0.5922	18.65	36.95		
--	20			--	0.250	10.250	0.5731	28.04	35.76		
--	30			--	0.307	10.136	0.5603	34.24	34.96		
STD	40			40S	0.365	10.020	0.5475	40.48	34.20		
XS	60			80S	0.500	9.750	0.5185	54.74	32.35		
--	80			--	0.594	9.562	0.4989	64.43	31.13		
--	100			--	0.719	9.312	0.4732	77.03	29.53		
--	120			--	0.844	9.062	0.4481	89.29	27.96		
XXS	140			--	1.000	8.750	0.4176	104.13	26.06		
--	160			--	1.125	8.500	0.3941	115.64	24.59		
12	12.75			--	--	5S	0.156	12.438	0.8438	20.98	52.65
				--	--	10S	0.180	12.390	0.8373	24.17	52.25
		--	20	--	0.250	12.250	0.8185	33.38	51.07		
		--	30	--	0.330	12.090	0.7972	43.77	49.74		
		STD	40	40S	0.375	12.000	0.7854	49.56	49.00		
		--	60	--	0.406	11.938	0.7773	53.52	48.50		
		XS	80	80S	0.500	11.750	0.7528	65.42	46.92		
		--	100	--	0.562	11.626	0.7372	73.15	46.00		
		--	120	--	0.688	11.374	0.7058	88.63	44.04		
		--	140	--	0.844	11.062	0.6677	107.32	41.66		
		XXS	160	--	1.000	10.750	0.6303	125.49	39.33		
		--	--	--	1.125	10.500	0.6013	139.67	37.52		
		--	--	--	1.312	10.126	0.5592	160.27	34.89		

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APPENDIX E (continued)

PIPE DATA

Nominal Pipe Size Inches	Outside Diameter Inches	Identification			Wall Thickness (t) Inches	Inside Diameter (d) Inches	Transverse Internal Area (A) Square Feet	Weight Pipe Pounds per foot	Weight Water Pounds per foot of pipe
		Steel		Stainless					
		Iron Pipe Size	Sched. No.	Steel Sched. No.					
14	14.00	--	--	5S	0.156	13.688	1.0219	23.07	63.77
		--	--	10S	0.188	13.624	1.0124	27.73	63.17
		--	10	--	0.250	13.500	0.9940	36.71	62.03
		--	20	--	0.312	13.376	0.9758	45.61	60.89
		STD	30	--	0.375	13.250	0.9575	54.57	59.75
		--	40	--	0.438	13.124	0.9394	63.44	58.64
		XS	--	--	0.500	13.000	0.9217	72.09	57.46
		--	60	--	0.594	12.812	0.8956	85.05	55.86
		--	80	--	0.750	12.500	0.8522	106.13	53.18
		--	100	--	0.938	12.124	0.8020	130.85	50.04
		--	120	--	1.094	11.812	0.7612	150.79	47.45
		--	140	--	1.250	11.500	0.7213	170.28	45.01
		--	160	--	1.406	11.188	0.6827	189.11	42.60
16	16.00	--	--	5S	0.165	15.670	1.3393	27.90	83.57
		--	--	10S	0.188	15.624	1.3314	31.75	83.08
		--	10	--	0.250	15.500	1.3103	42.05	81.74
		--	20	--	0.312	15.376	1.2895	52.27	80.50
		STD	30	--	0.375	15.250	1.2684	62.58	79.12
		XS	40	--	0.500	15.000	1.2272	82.77	76.58
		--	60	--	0.656	14.688	1.1766	107.50	73.42
		--	80	--	0.844	14.312	1.1175	136.61	69.73
		--	100	--	1.031	13.938	1.0596	164.82	66.12
		--	120	--	1.219	13.562	1.0035	192.43	62.62
		--	140	--	1.438	13.124	0.9394	223.64	58.64
		--	160	--	1.594	12.812	0.8956	245.25	55.83
18	18.00	--	--	5S	0.165	17.670	1.7029	31.43	106.26
		--	--	10S	0.188	17.624	1.6941	35.76	105.71
		--	10	--	0.250	17.500	1.6703	47.39	104.21
		--	20	--	0.312	17.376	1.6467	58.94	102.77
		STD	--	--	0.375	17.250	1.6230	70.59	101.18
		--	30	--	0.438	17.124	1.5990	82.15	99.84
		XS	--	--	0.500	17.000	1.5763	93.45	98.27
		--	40	--	0.562	16.876	1.5533	104.67	96.93
		--	60	--	0.750	16.500	1.4849	138.17	92.57
		--	80	--	0.938	16.124	1.4183	170.92	88.50
		--	100	--	1.156	15.688	1.3423	207.96	83.76
		--	120	--	1.375	15.250	1.2684	244.14	79.07
		--	140	--	1.562	14.876	1.2070	274.22	75.32
		--	160	--	1.781	14.438	1.1369	308.50	70.88
20	20.00	--	--	5S	0.188	19.624	2.1004	39.78	131.06
		--	--	10S	0.218	19.564	2.0876	46.06	130.27
		--	10	--	0.250	19.500	2.0740	52.73	129.42
		STD	20	--	0.375	19.250	2.0142	78.60	125.67
		XS	30	--	0.500	19.000	1.9690	104.13	122.87
		--	40	--	0.594	18.812	1.9305	123.11	120.46
		--	60	--	0.812	18.376	1.8417	166.40	114.92
		--	80	--	1.031	17.938	1.7550	208.87	109.51
		--	100	--	1.281	17.438	1.6585	256.10	103.39
		--	120	--	1.500	17.000	1.5762	296.37	98.35
		--	140	--	1.750	16.500	1.4849	341.09	92.66
		--	160	--	1.969	16.062	1.4074	379.17	87.74
22	22.00	--	--	5S	0.188	21.624	2.5503	43.80	159.14
		--	--	10S	0.218	21.564	2.5362	50.71	158.26
		--	10	--	0.250	21.500	2.5212	58.07	157.32
		STD	20	--	0.375	21.250	2.4629	86.61	153.68
		XS	30	--	0.500	21.000	2.4053	114.81	150.09
		--	60	--	0.875	20.250	2.2365	197.41	139.56
		--	80	--	1.125	19.75	2.1275	250.81	132.76
		--	100	--	1.375	19.25	2.0211	302.88	126.12
		--	120	--	1.625	18.75	1.9175	353.61	119.65
		--	140	--	1.875	18.25	1.8166	403.00	113.36
		--	160	--	2.125	17.75	1.7184	451.06	107.23

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APPENDIX E (continued)

PIPE DATA

Nominal Pipe Size Inches	Outside Diameter Inches	Identification			Wall Thickness (t) Inches	Inside Diameter (d) Inches	Transverse Internal Area (A) Square Feet	Weight Pipe Pounds per foot	Weight Water Pounds per foot of pipe
		Steel		Stainless Steel Sched. No.					
		Iron Pipe Size	Sched. No.						
		--	--	5S	0.218	23.564	3.0285	55.37	188.98
		--	10	10S	0.250	23.500	3.0121	63.41	187.95
24	24.00	STD	20	--	0.375	23.250	2.9483	94.62	183.95
		XS	--	--	0.500	23.000	2.8853	125.49	179.87
		--	30	--	0.562	22.876	2.8542	140.68	178.09
		--	40	--	0.688	22.624	2.7921	171.29	174.23
		--	60	--	0.969	22.062	2.6552	238.35	165.52
		--	80	--	1.219	21.562	2.5362	296.58	158.26
		--	100	--	1.531	20.938	2.3911	367.39	149.06
		--	120	--	1.812	20.376	2.2645	429.39	141.17
		--	140	--	2.062	19.876	2.1547	483.12	134.45
		--	160	--	2.344	19.312	2.0346	542.13	126.84
26	26.00	--	10	--	0.312	25.376	3.5122	85.60	219.16
		STD	--	--	0.375	25.250	3.4774	102.63	216.99
		XS	20	--	0.500	25.000	3.4088	136.17	212.71
28	28.00	--	10	--	0.312	25.376	4.0876	92.26	255.07
		STD	--	--	0.375	27.250	4.0501	110.64	252.73
		XS	20	--	0.500	27.000	3.9761	146.85	248.11
		--	30	--	0.625	26.750	3.9028	182.73	243.53
30	30.00	--	--	5S	0.250	29.500	4.7465	79.43	296.18
		--	10	10S	0.312	29.376	4.7067	98.93	293.70
		STD	--	--	0.375	29.250	4.6664	118.65	291.18
		XS	20	--	0.500	29.000	4.5869	157.53	286.22
		--	30	--	0.625	28.750	4.5082	196.08	281.31
32	32.00	--	10	--	0.312	31.376	5.3694	105.59	335.05
		STD	--	--	0.375	31.250	5.3263	126.66	332.36
		XS	20	--	0.500	31.000	5.2414	168.21	327.06
		--	30	--	0.625	30.750	5.1572	209.43	321.81
		--	40	--	0.688	30.624	5.1151	230.08	319.18
34	34.00	--	10	--	0.344	33.312	6.0524	123.65	377.67
		STD	--	--	0.375	33.250	6.0299	134.67	376.27
		XS	20	--	0.500	33.000	5.9396	178.89	370.63
		--	30	--	0.625	32.750	5.8499	222.78	365.03
		--	40	--	0.688	32.624	5.8050	244.07	362.23
36	36.00	--	10	--	0.312	35.376	6.8257	118.92	425.92
		STD	--	--	0.375	35.250	6.7771	142.68	422.89
		XS	20	--	0.500	35.000	6.6813	189.57	416.91
		--	30	--	0.625	34.750	6.5862	236.13	417.22
		--	40	--	0.750	34.500	6.4918	282.35	405.09

APPENDIX F

Heat Exchange Institute, Inc.
Standards and Typical Specifications for Tray Type Deaerators 7th Edition

DEAERATOR SPECIFICATION SHEET

1.	CUSTOMER	DATE	
2.	ADDRESS	CUSTOMER NO.	
3.	PLANT LOCATION	PROPOSAL NO.	
4.	SERVICE OF UNIT	JOB NO.	
5.	TYPE Spray Tray/Spray Scrubber	ITEM NO.	
6.	NO. UNITS		
7.		7a. HEATER ORIENTATION (HOR) (VERT)	7b. STORAGE ORIENTATION (HOR) (VERT)
8.	PERFORMANCE		
9.		RECOMMENDED	DESIGN POINT
10.	AVG. FLOW		
11.	MAKE-UP	#HR °F.	#HR °F.
12.	LP CONDENSATE	#HR °F.	#HR °F.
13.	HP CONDENSATE	#HR °F.	#HR °F.
14.	STEAM	#HR °F.	#HR °F.
15.	OTHER	#HR °F.	#HR °F.
16.	TOTAL OUTLET	#HR °F.	#HR °F.
17.	BFP RECIRCULATION	#HR °F.	#HR °F.
18.	OPERATING PRESSURE/TEMP	PSIG °F.	PSIG °F.
19.	OTHER SPECIAL CONDITIONS		
20.			
21.			
22.	VENT RATE (% OF STEAM INLET)	0.5%	#HR
23.	EFFLUENT PPB O ₂ /CO ₂	7 / 0	PPB PPB
24.	STORAGE TANK CAPACITY AT OVERFLOW (MIN)		
25.			
26.	CONSTRUCTION		
27.		HEATER	STORAGE
28.	DESIGN PRESSURE	PSIG	PSIG
29.	VACUUM	PSIG	PSIG
30.	TEST PRESSURE	PSIG	PSIG
31.	DESIGN TEMPERATURE	°F.	°F.
32.	SHELL THICKNESS	IN.	IN.
33.	HEAD THICKNESS	IN.	IN.
34.	TYPE HEADS F&D/2:1		
35.	CORROSION ALLOWANCE (IN.)	1/8 IN.	IN.
36.	VACUUM RINGS		
37.	WEIGHT: EMPTY/OPERATING/FLOODED	/ /	/ /
38.	RADIOGRAPHY: HEAD/SHELL	1.0 JE.	/
39.	MAGNETIC PARTICLE INSPECTION	INCL.	
40.	LIQUID DYE PENETRANT	INCL.	
41.	STRESS RELIEF: (1 STAGE/2 STAGE)	INCL.	
42.	ASME CODE SECTION (8 OR 1)		
43.	SURFACE PREP: INT/EXT	/	/
44.	INSULATION CLIPS		
45.	MATERIALS		
46.		HEATER	STORAGE
47.	SHELL	SA516-70	
48.	WATERBOX	1/4" S.S. min, L grade	
49.	INLET WATERPIPE	S.S. 10s	
50.	TRAYS	S.S., L grade	
51.	SPRAY VALVES	20 g S.S.	
52.	TRAY ENCLOSURE	S.S.	
53.	VENT CONDENSER	1/8" S.S. min, L grade	
54.	ACCESSORIES		
55.			
56.			
57.			
58.			
59.			



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