



Exploration & Production

GENERAL SPECIFICATION

PIPELINES - RISERS

GS PLR 501

Hydrostatic Testing of Pipelines

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Appendix 6 Volume-Temperature factor B20



1. Scope

The scope of the present General Specification shall cover, as per the Project requirements, the supplies of test heads and fittings as necessary for the hydrostatic testing of the pipelines, the hydrostatic testing, the analysis of the results, and the reinstatement of the test sites.

This specification applies both for hydrostatic testing of land pipelines (onshore), offshore pipelines including their risers.

This specification applies for liquid or gas pipelines.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Standards

Reference	Title
Not applicable	

Professional Documents

Reference	Title
API RP 1100	Pressure Testing of Liquid Petroleum Pipelines

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	



Total General Specifications

Reference	Title
GS PLR 100	Submarine pipeline systems
GS PLR 104	Design of onshore pipelines
GS COR 560	Physical and chemical treatment of hydrostatic test water

3. General

The land pipelines, the submarine pipelines and their risers shall be hydrostatically tested as soon as practicable after being advised by the Project that the pipelines and risers are approved for testing.

The limits of the test section shall be from pig trap to pig trap.

Prior to be hydrostatic test, the as-built route survey of offshore pipeline shall have been performed to verify that the pipeline has been laid within the specifications for alignment, pipeline crossings, length of free spans, etc.

For land buried pipelines, the pipeline must be installed inside its trench either ready to be covered or already covered.

As per COMPANY rule, the hydrostatic pressure test shall be executed as a holding test during at least 24 hours without interruption.

Derogation to this duration may be granted for water pipelines.

For offshore pipelines, since the pressure measuring device is normally located on the platform above mean sea level, a reduction in recorded pressure equivalent to the hydrostatic head between the mean sea level and location of the pressure measuring device is required.

The applied hydrotest pressure shall be in accordance with the **GS PLR 100** and/or **GS PLR 104** requirements.

For each tests, a Test Data Sheet will be prepared indicating the name of the line, the owner of the line, the main contractor, the overall length of the pipeline, the detailed description of the part of the line to be tested, the outside diameter(s), the steel grades, the various thickness(es), the design pressure and the test pressure.

This data sheet will be attached to the hydrostatic test procedure.

There is no limitation of pipeline section length for offshore pipeline.

For onshore pipeline, as dictated by the profile of the route of the pipeline, there is no standard length.

The tests of pipelines and risers and associated pipings are to be approved and witnessed by COMPANY. **No test shall be started before approval of the procedure is obtained.**

4. Engineering study for Land Pipelines

A comprehensive engineering study will be prepared to define the various test pressures all along the route of the pipeline to take into account the various elevations of the pipeline and the subsequent hydrostatic heads.



Maximum local pressure must not exceed the specified minimum yield stress (SMYS) of the pipes.

However, with formal approval from COMPANY, depending on the type of pipe (UOE, SAW, etc.) and of their steel grades, 102 per cent of the SMYS may be locally reached.

Ideally the pipeline will be tested from pig trap to pig trap. However golden welds may be accepted by COMPANY. Their number will be limited and imposed by the profile of the line.

5. Engineering study for Offshore Pipelines

For offshore pipelines demonstrating important variations of the elevation profile - typical cases being export lines from deepwater fields, or deepwater systems connecting subsea units to floating supports - the Engineering Study shall aim at reducing the amount of separate testing of sections.

It is outlined here that the Design Studies of such a type of pipeline system shall have these issues already completely resolved, in the light of the most recent progresses made in the area of hydrotesting techniques in combination with subsea tie-in techniques and leak tests thereof.

6. Safety

During the hydrostatic test no work will be performed on or near the pipeline or on or near the risers at both ends of the pipeline.

A safety distance within 40 m along the right of way for inland pipelines must be observed.

Test cabin shall be located at ten meters from the pressure head.

Dedicated approved by COMPANY safety procedures must be prepared for the test.

Only personnel having adequate offshore testing experience shall be mobilised.

7. Quality of Water

Unless specified in the particular specification, internal cleaning with chemical pickling is not required. The pipelines will be filled with water in accordance with **GS COR 560**.

For CRA pipelines, seawater shall never be used.

For land pipelines, fresh water will be used. In some particular circumstances (desert areas) seawater may be used.

For offshore pipelines, water for filling and testing will be taken from the sea on site.

Furthermore, seawater temperatures shall be taken in advance at locations indicated by the Project.

From these temperature records, pressure variations while testing may be explained and stabilisation periods be established; these temperatures shall be noted one hour prior to or after high tide for four tidal periods.

Prior to filling of the pipeline, well in advance, samples of proposed test water shall be analysed by an accepted third party institute to further determine amounts of inhibitors, oxygen scavenger and bactericide required to neutralise the water.

8. Cleaning, Gauging and Filling

The pipelines will be filled with water that has been treated according to **GS COR 560** and sufficient quantities of chemicals shall be available at all times.

All water used in the test shall be filtered through 100 mesh screen, removing all solids in excess of 250 microns.

Extreme care in filling the pipelines shall be taken to ensure that all air is removed and that no air is introduced during filling. Gauging operation may be optionally performed during the filling operation.

Unless otherwise specified in the particular specification the following sequence shall be followed during the filling and cleaning operations.

- Pump the equivalent of 250 linear metres of pipeline (minimum) of treated water into the pipeline (mini 400 m³/hour and maxi 1000 m³/hour)
- Launch brush pig (2 polyethylene cups + 2 brushes) equipped with an acoustic pinger with a minimum 2-month life. The average speed of the pigs must be between 3 to 4 km per hour
- Pump the equivalent of 500 linear metres of pipeline (minimum) of treated water into the pipeline
- Launch batching pig (4 polyethylene cups)
- Pump the equivalent of 500 linear metres of pipeline (minimum) of treated water into the pipeline
- Launch a gauge pig equipped with a calibrated aluminium plate (optional) of 10 mm thickness and an edge of 45° - 3 mm width. Overall diameter of the plate will be determined in the particular specification.
- Fill entire pipeline with treated water. During the filling of the line readings of pressure/water input/time will be taken every 1 hour
- Receive filling pig, brush pig, and gauge pig at the other end of the line
- Continue pumping until all air is expelled
- Start pressure test.

Unless otherwise specified in the particular specification during the filling operation, the filling rate shall be kept never below 2.0 km per hour.

It is mandatory that a certified calibrated turbine flow meter be used during the filling operations. Certifying authority must be one approved by COMPANY.

It is also mandatory that a scraper passage indicator be installed on the pig receiver to give positive indication of the arrival of the pigs.

The pigs shall be removed from the pig receiver in the presence of the Project representative. Recovered pigs shall be carefully examined in order to ascertain the degree and regularity of the wear of cups.

If damages are found on the gauge pig and are not straight forward explained, electronic geometric pig must be used to give details on the defects.



Recordings made by electronic geometric pig concerning size, location of diameter reductions such as dents, buckles, flat spots, construction debris, etc. shall be analysed. Any necessary substitutes and repairs shall be made to restore the structural integrity of the line.

Blocking of brush or batching pigs at any point along the line shall entail suspension of filling operations. In such cases, the blocked pig shall be located, recovered, and causes for blockage shall be ascertained and carry out work performed to restore the line to the testing condition.

On completion of work the line shall be refilled and cleaned, as described above.

Special attention must be paid to the in line valves during the pigging cleaning operation because passage of pigs with the subsequent pushed debris will badly damage the internal of the valves.

In line valves shall be replaced by temporary spools.

9. Pressure test

The battery limits of the pressure test shall be as per the Project Requirements.

Design and supply all hydrostatic fill and testing equipment with all necessary spares needed in case of breakdown are within the scope of the present General Specification.

A complete inventory of equipment or spares shall be available prior to start of testing.

The equipment, which affects the accuracy of the measurements upon which the validity of the hydrostatic tests depends, must conform the range to be measured.

Certified proof of accuracy of gauges and test equipment shall be submitted prior to the start of the testing and be included in the final test report.

Maximum validity of certificates is six months.

The following equipment and materials shall be provided as a minimum:

- Fill-pump or pumps: the stuffing shall be water sealed to prevent air from entering. Should a single pump be furnished, a standby unit must be available
- The suction hose shall have a filter with 100 mesh screens and must be airtight at junctions
- Typical size for centrifugal volume pump is 10 inches x 8 inches - 100 psi.
- Variable speed positive displacement pump equipped with a stroke counter for pressurizing the line with a known volume per stroke and capable of exceeding the maximum test pressure by at least 20 bar (280 psi)
- Two turbine metres with an accuracy of 0.3 to 0.4 per cent to measure the water volume filling the line
- A continuous supply of treated water to the pump during the filling and the final pressure adjustments. Water is not normally supplied by COMPANY
- Six Bourdon pressure gauges of suitable pressure ranges and increment divisions
- Two dead weight testers with an accuracy of 0.01 per cent bar measuring in increments of 0.05 bar provided with a calibration certificate not older than six months
- The range of accuracy for the dead weight testers must be 1.5 times the hydrostatic test pressures



- Two recording pressure gauges for 48 hours with charts, pens and ink. These gauges shall be dead weight tested prior to use
- Barograph
- Two temperature recorders for fill water
- Two temperature recorders for air ambient temperature
- Two invertible thermometers to measure sea bottom temperature (offshore pipelines)
- Two laboratory thermometers -1° to 55°C range, accuracy 0.1° to be used in thermowells
- Means to measure the volume of water necessary to drop the line pressure by 0.5 bar. Container on scales or graduated cylinder may be chosen
- Means to display total water volume and part volume added
- Injection pump(s) to inject corrosion inhibitors, oxygen scavenger and bactericide into the test medium in the required proportions
- Test heads with all associated valves, fittings and connections, also suitable for use as pig launcher and receiver during filling, cleaning, gauging, testing, and dewatering (if required) of the line
- Necessary communication equipment

Note: The temperature recording during the 24-hour pressure tests and the information obtained during the previous week can be a basis for accepting a pressure drop during the pressure tests.

10. Procedures for Hydrostatic Tests

Testing operations shall be carefully performed according to a "Test Procedure Diagram", showing (with explanatory notes and date):

- Pipe specifications and manufacturer
- Proof test pressures
- Test medium
- Line cleaning and filling procedures
- Pressurizing procedure including location of injection points
- Water intake, discharge lines
- Theoretical pressure volume curve for hand-plot during test and temperature volume curves.

The procedure shall include an isometric drawing showing all fill and testing equipment and associated piping.

This procedure shall be accompanied with a detailed description of all equipment and instrumentation.

Important note: the disposal of the testing medium must be harmless to the environment as per Local Regulations and must be approved by COMPANY.

11. Particular Requirements for Pressure Test

The pressure recording gauge shall be installed in parallel with the dead weight tester.

The recording gauge shall be checked periodically through the testing period by the dead weight tester.

The Bourdon pressure gauge is for approximation only, and its indication shall not be recorded.

The thermowell in the test head is to be fitted with a thermometer readable with an accuracy of at least 0.1°C (graduation).

11.1 Presurisation

The pressurising shall be performed at constant rates not exceeding 1 bar/mn ending to 0.5 bar/min from 70% to 80% of the pressure test.

When approximately 80 per cent of the specified test pressure is reached, this pressure shall be maintained for a period of time sufficient to stabilize properly.

After the stabilization period - being of 1 hour as a minimum - is accepted by the COMPANY representative, the pressure shall be gradually raised to prevent surging of the water in the pipeline at the 0.12 bar/min.

While bringing the pipeline up to pressure, the hand-plot of the pressure volume curve shall be started and continued until the specified test pressure is reached.

The pressure and volume recordings will be taken, such that an adequate plot is obtained allowing to appreciate 0.2% of air entrapment.

While pressurizing, the pipe connections shall be periodically checked for leaks

When the test pressure is reached, the filling valve shall be closed and the filling line disconnected from the valve.

11.2 Final checks before pressure holding

Prior to the commencement of the hydrostatic tests, water temperature differences will be equalized. A sufficient levelling is considered as having been reached when the temperature of the testing water stabilizes.

The required amount of stabilization is to be determined and agreed by COMPANY.

As a guide line the stabilisation period is completed when the pipeline temperature is within 1°C of the surrounding soil/water temperature; request to this last requirement must be properly documented.

During the 24-hour tests, the test heads, as well as any instruments used in connection with the test, must be properly protected against sun radiation, rain and wind.

All circular welds, connections for the pressure measurement and all plugged openings are to be easily accessible and uncovered for visual inspection, before and after the tests.

Prior to the commencement of the pressure test, a drain test to test for air entrapment shall be conducted as per Appendix 1.

The test is allowed to start when the air entrapment test is successfully completed i.e. the percent of trapped air does not exceed 0.2% of the total volume of the tested line.



During the levelling and the testing periods, care is to be taken that the fixed maximum test pressures are not exceeded (max 0.5%).

If it is necessary to drain off water for this purpose, the pressure drop and the amount of water are to be measured accurately.

Care must be taken that no greater quantity of water is drained than is necessary to reach the setting pressure.

11.3 Pressure holding

During the pressure test, the test pressures determined with the help of dead weight tester are to be measured and recorded every half hour.

After the pressure in the pipelines has been raised to test pressure, all connecting pipes -except those for the pressure measurement- are to be disconnected.

All stop valves and other points where there may be leakages are to be checked carefully.

Testing may begin after possible leakages have been repaired.

The 24-hour test is to commence at a time to be agreed beforehand.

Observations must be recorded on the appropriate forms, stating clearly on the corresponding documents, such as pressure and temperature cards, to which pipeline these documents refer.

Incomplete forms and absence of other documents may be the cause of a complete retesting.

After all the data of the test have been gathered and submitted to the COMPANY representative, the test will be terminated after definite approval has been given.

All drain tests and air or water venting are to be recorded on the charts.

During the 24-hour test period the following measurements shall be taken:

- Every half hour, pressure measurements from the dead weight testers are to be recorded
- Also those pressures shall be recorded which have occurred as maximum and minimum during the last half hour as well as the average pressure value
- Every half hour, the ambient temperature, the seawater temperature (offshore pipelines) at surface and at mid-depth, and the pipe temperature from the thermowells must be recorded
- Every half hour the barometric pressure must be recorded
- Every half hour the tide level must be recorded (offshore pipelines) together with the water depths
- Seabed temperatures are recorded one hour before or after high tide (offshore pipelines).

At the end of the pressure test a second drain test shall be performed: this second drain test will reproduce the first drain test as close as possible (i.e. if 0.5 bar drop was measured for first test then 0.5 bar drop should be the pressure drop for the second test).

11.4 Pressure release

Pressure will be carefully released and the depressurisation will be regulated to ensure a moderate and constant reduction pressure at a rate not exceeding 3 bar/min.

Care will be taken to ensure line pressure not being reduced below the static head.



The lines will be left full of treated water.

Unless otherwise instructed by the COMPANY, all successfully tested pipelines and risers will remain full of test water and suitably capped off.

11.5 Incidents

If, on termination of the tests, it is found that the pipeline does not hold the pressure or if there is reason to assume this, re-testing may be carried out or the tests may be continued for an additional length of time entirely at the discretion of the COMPANY representative.

Rejection may also follow if it is found that the measuring accuracy is considered to be insufficient.

If, during the tests a leakage is found in an element which does not belong directly to the pipeline, the test is to be resumed after the leakage has been repaired.

The holding pressure duration must thus be a new 24 hours period.

Failures in the pipeline disclosed by loss of pressure shall be located and repaired.

Air shall be used for displacement of water.

The compressors are to be supplied in the frame of the testing works.

Following repairs, the pipeline shall be refilled and cleaned as described in Section 8 and the test repeated until a continuous test period has been satisfactorily attained.

Complete records of failures occurring during the test with their exact locations, description/type and cause of failure, and method of repair shall be maintained.

Pipe, fittings and valves which failed and were replaced shall be marked with their locations (KP) and pressure at which they failed; such materials shall be held for disposal by the Project.

12. Disposal of test media

The Project might be requested to remove the treated water from the pipelines; this shall be performed such that no harm is done to the surrounding environment.

Displacement of the test media shall be performed by gas or air; if dewatering of the line cannot be performed by gas, air compressors shall be provided.

After displacement of the test media, two slugs of fresh water of sufficient length shall be run to minimize salt deposition from seawater; each of the slugs shall be treated with the same corrosion inhibitor used in the hydrostatic test.

The pipelines shall then be dried by running a slug of methanol.

If gas is used for dewatering the pipelines, a pig train shall be run between the test media and the gas, consisting of two slugs of methanol with 500 metres of nitrogen in between them.

Supplies of sufficient quantities of nitrogen and methanol shall be within the scope of the testing works.



13. Completion file

Upon successful completion of the hydrostatic test, the following records shall be provided for each pipeline:

- Completed hydrostatic test forms as per Appendix 4 and Appendix 3.
- Hydrostatic test diagram
- Pipeline gauging acceptance test
- Pipeline filling, log of operations
- Pressure recording calibrations
- 24 hours hold periods, log of operations
- Hydrostatic test calculations
- Hydrostatic test evaluation
- Records of failures
- Testing procedure
- Pipeline profile showing the evaluations and test sites over the entire length of the test section noting all instrument and injection connections
- Pressure recording charts with appropriate information spelled out
- Temperature data
- Dead-weight tester log
- Theoretical and hand plot pressure-volume curve
- Theoretical and hand plot temperature-volume curve
- Tide data
- Barometric data
- Instrument certificates of accuracy
- Additives specification, supplier and amounts injected.

Appendix 1 Drain test for air entrapment

A drain test may be conducted to determine if air has been trapped in the line. The drain test consists of drawing off enough water to decrease the pressure in the line by approximately 0.5 bar. The drain water is measured accurately for its volume. This volume, VAB, is compared to the calculated volume, ΔVA, as shown below:

$$\Delta VA \text{ (litres)} = (0.87 \frac{r_i}{s} + A) \times \frac{V_{ri}}{1,000,000} (P_1 - P_2)$$

for various wall thicknesses replace

$$\frac{r_i}{s} \text{ by } \left(\frac{r_{ix}}{s_x} \times \frac{l_x}{l_t} \right) + \left(\frac{r_{iv}}{s_y} \times \frac{l_v}{l_t} \right)$$

where:

lt =	total line length in metres
lx =	segment line length in metres with wall thickness sx in millimetres
sx =	wall thickness in millimetres
sy =	wall thickness in millimetres
s =	wall thickness in millimetres
rix =	internal pipe radius in millimetres of pipe length with wall thickness sx
riy =	internal pipe radius in millimetres of pipe length with wall thickness sy
ri =	internal pipe radius in millimetres
Vri =	volume of line using ri in litres
ΔVA =	calculated volume in litres
P ₁ =	initial pressure in kg/cm ² at draining-off stage
P ₂ =	final pressure in kg/cm ² at draining-off stage
A =	volume-pressure factor as per Appendix 5

Note: The factor of 0.87 in the above equation has the units of cm²/kgf.

Difference up to 6 per cent between the actual and calculated volumes are considered acceptable (due to out of roundness, wall thickness tolerances, measuring inaccuracies, axial movement of pipe, etc.).

This calculation may be corroborated by the **API RP 1110** test pressure plot curve (pressure/volume).

Test for air entrapment is considered as successful when the volume of entrapped air does not exceed 0.2% of the whole volume of the tested line.

Appendix 2 Prediction of volume change

Pressures may vary with temperature changes induced by currents, tides, etc. from the recorded values. These changes may be calculated from temperature records using the formula below:

$$\Delta V \text{ (litres)} = \left[\left(0.87 \frac{r_i}{s} + A \right) \Delta \Delta - (B \times \Delta x) \right] \times \frac{V_{ri}}{1,000,000}$$

Experience shows the following is acceptable:

$$\Delta V_h \text{ (litres)} = \pm 4 \frac{V_{ri} \text{ (litres)}}{1,000,000}$$

where:

- $\Delta P =$ line pressure change in kgf/cm²
- $\Delta V =$ volume change in litres
- $A =$ volume-pressure factor as per Appendix 5
- $B =$ volume-temperature factor as per Appendix 6
- $\Delta V_h =$ hourly volume change in litres
- $\Delta t =$ testing water temperature change in degrees Centigrade.



Appendix 3 Certification form

CERTIFICATION OF PIPELINE HYDROSTATIC PRESSURE TEST					
PRESSURE RECORDER CALIBRATION					
Calibration before test		Calibration during test		Calibration after test	
Pressure Recorder	Deadweight Tester	Pressure Recorder	Deadweight Tester	Pressure Recorder	Deadweight Tester

Calibrated by _____ Checked by _____ Checked by _____

DEADWEIGHT TESTER MAKE AND SERIAL NUMBER _____

INJECTION AND WITHDRAWAL DATA			
Fluid Injection, Litres	Time	Fluid Withdrawn, Litres	Time

Total injection _____ Litres

Total withdrawn _____ Litres

NOT CHANGE IN VOLUME OF THE TEST SECTION



Appendix 4 Log of operation

CONTRACTOR_____	DATE_____
OWNER_____	
JOB LOCATION_____	FIELD_____
PIPE SIZE_____PIPE WALL THICKNESS_____	LENGTH_____
ESTIMATED.TOTAL VOLUME OF THE LINE (Litres)_____	TEST PRESSURE (bar)_____
Volume per km_____Volume per metre_____	WEATHER_____
REMARKS OR SPECIAL INSTRUCTIONS_____	

Date	Time	Water Meter Reading	Cumulative Litres Pumped	Observed LPM	Sump Suction Press.	Pump Disch Press.	Atmos Temp.	Baro-metric Press	Water loas Temp.	H ₂ O Cu M Per min.	Dead weight Press

ACCEPTED BY_____OPERATOR

NOTE: OPERATOR TO RECORD ALL ACTIVITIES AND SHUTDOWNS WITH COMPLETE

Appendix 5 Volume-Pressure factor A

A = Reduction of water volume due to pressure from 2°C to 20°C

Pressure range	Mean pressure	Average testing water temperature - Centigrade									
		2°	4°	6°	9°	10°	12°	14°	16°	18°	20°
1-10	5,5	48,55	47,9	47,35	46,9	46,35	45,9	45,55	45,25	44,95	44,65
10-20	15	48,4	47,8	47,2	46,7	46,2	45,8	44,4	45,1	44,8	44,5
20-30	25	48,2	47,6	47,1	46,6	46,1	45,7	44,3	45,0	44,7	44,4
30-40	35	48,1	47,5	47,0	46,5	46,0	45,6	44,2	44,9	44,6	44,3
40-50	45	48,0	47,4	46,8	46,3	45,9	45,5	44,1	44,7	44,4	44,1
50-60	55	47,9	47,3	46,7	46,2	45,7	45,3	44,9	44,6	44,3	44,0
60-70	65	47,7	47,1	46,6	46,1	45,6	45,2	44,8	44,5	44,2	43,9
70-80	75	47,6	47,0	46,5	46,0	45,5	45,1	44,7	44,3	44,0	43,7
80-90	85	47,5	46,9	46,3	45,8	45,4	45,0	44,6	44,2	43,9	43,6
90-100	95	47,4	46,8	46,2	45,7	45,3	44,9	44,5	44,1	43,8	43,5
100-110	105	47,3	46,6	46,0	45,6	45,2	44,7	44,4	44,0	43,7	43,4
110-120	115	47,2	46,5	45,9	45,4	45,1	44,6	44,3	43,9	43,5	43,3
120-130	125	47,0	46,3	45,7	45,3	45,0	44,5	44,1	43,8	43,4	43,2
130-140	135	46,9	46,2	45,6	45,2	44,8	44,4	44,0	43,7	43,3	43,1
140-150	145	46,8	46,1	45,5	45,0	44,7	44,2	43,9	43,6	43,1	43,0
150-160	155	46,7	46,0	45,4	44,9	44,6	44,0	43,8	43,5	43,0	42,9
160-170	165	46,5	45,8	45,2	44,8	44,4	43,9	43,6	43,3	42,9	42,7
170-180	175	46,4	45,7	45,1	44,7	44,3	43,8	43,5	43,2	42,8	42,6
180-190	185	46,3	45,6	45,0	44,5	44,2	43,7	43,3	43,1	42,6	42,5
190-200	195	46,1	45,4	44,8	44,4	44,1	43,6	43,2	43,0	42,5	42,4
200-210	205	46,0	45,3	44,7	44,3	43,9	43,5	43,1	42,8	42,4	42,3
210-220	215	45,9	45,2	44,6	44,1	43,8	43,3	43,0	42,7	42,3	42,1
220-230	225	45,7	45,1	44,5	44,0	43,7	43,2	42,9	42,6	42,2	42,0
230-240	235	45,6	44,9	44,3	43,9	43,5	43,1	42,7	42,5	42,1	41,9
240-250	245	45,5	44,8	44,2	43,8	43,4	43,0	42,6	42,4	42,0	41,7
250-260	255	45,4	44,7	44,0	43,7	43,3	42,9	42,5	42,2	41,9	41,6
260-270	265	45,2	44,5	43,9	43,5	43,1	42,7	42,4	42,1	41,8	41,5
270-280	275	45,1	44,4	43,8	43,4	43,0	42,6	42,3	42,0	41,7	41,4
280-290	285	45,0	44,3	43,7	43,2	42,9	42,5	42,2	41,9	41,6	41,3
290-300	295	44,9	44,2	43,6	43,1	42,8	42,4	42,1	41,8	41,5	41,2
300-310	305	44,7	44,0	43,4	42,0	42,7	42,2	42,0	41,7	41,4	41,0
310-320	315	44,6	43,9	43,3	42,9	42,5	42,1	41,9	41,5	41,2	40,9
320-330	325	44,5	43,7	43,2	42,8	42,4	42,0	41,7	41,4	41,1	40,8

A = Reduction of water volume due to pressure from 22°C to 40°C

Pressure range	Mean pressure	Average testing water temperature - Centigrade									
kgf/cm ²	kgf/cm ²	22°	24°	26°	28°	30°	32°	34°	36°	38°	40°
1-10	5,5	44,3	44,1	43,7	43,5	43,3	43,0	42,8	42,6	42,4	42,2
10-20	15	44,2	44,0	43,6	43,4	43,2	42,9	42,7	42,5	42,3	42,1
20-30	25	44,1	43,9	43,5	43,3	43,1	42,8	42,5	42,3	42,2	42,0
30-40	35	44,0	43,7	43,4	43,1	43,0	42,7	42,4	42,2	42,0	41,9
40-50	45	43,8	43,6	43,3	43,0	42,9	42,6	42,3	42,1	41,9	41,7
50-60	55	43,7	43,4	43,2	42,9	42,7	42,4	42,2	42,0	41,8	41,6
60-70	65	43,6	43,3	43,1	42,8	42,6	42,3	42,1	41,9	41,7	41,5
70-80	75	43,4	43,1	43,0	42,7	42,4	42,1	41,9	41,7	41,6	41,3
80-90	85	43,3	43,0	42,8	42,5	42,3	42,0	41,8	41,6	41,4	41,2
90-100	95	43,2	42,9	42,7	42,4	42,2	41,9	41,7	41,5	41,3	41,1
100-110	105	43,1	42,8	42,5	42,3	42,0	41,8	41,6	41,4	41,2	40,9
110-120	115	43,0	42,7	42,4	42,1	41,9	41,7	41,5	41,2	41,1	40,7
120-130	125	42,9	42,6	42,2	42,0	41,7	41,6	41,4	41,1	40,9	40,6
130-140	135	42,8	42,5	42,1	41,8	41,6	41,4	41,2	41,0	40,8	40,5
140-150	145	42,7	42,4	42,0	41,7	41,5	41,2	41,1	40,9	40,7	40,4
150-160	155	42,6	42,3	41,9	41,6	41,4	41,1	41,0	40,8	40,6	40,3
160-170	165	42,4	42,1	41,8	41,5	41,3	41,0	40,8	40,7	40,5	40,2
170-180	175	42,3	42,0	41,7	41,4	41,2	40,9	40,7	40,6	40,4	40,1
180-190	185	42,1	41,9	41,6	41,2	41,1	40,8	40,6	40,4	40,2	40,0
190-200	195	42,0	41,8	41,5	41,1	41,0	40,7	40,5	40,3	40,1	39,9
200-210	205	41,9	41,7	41,4	41,0	40,8	40,6	40,4	40,2	40,0	39,8
210-220	215	41,8	41,5	41,2	40,9	40,7	40,5	40,3	40,1	39,9	39,7
220-230	225	41,7	41,4	41,1	40,8	40,6	40,4	40,2	40,0	39,8	39,5
230-240	235	41,6	41,3	41,0	40,7	40,4	40,3	40,0	39,9	39,7	39,4
240-250	245	41,5	41,2	40,9	40,5	40,2	40,2	39,9	39,7	39,5	39,2
250-260	255	41,3	41,0	40,8	40,4	40,1	40,0	39,8	39,5	39,4	39,0
260-270	265	41,2	40,9	40,6	40,3	40,0	39,9	39,6	39,4	39,2	38,9
270-280	275	41,1	40,8	40,5	40,2	39,9	39,7	39,5	39,3	39,0	38,8
280-290	285	41,0	40,7	40,3	40,1	39,7	39,6	39,4	39,1	38,9	38,7
290-300	295	40,9	40,6	40,2	40,0	39,6	39,5	39,3	39,0	38,8	38,6
300-310	305	40,7	40,5	40,1	39,8	39,5	39,4	39,1	38,9	38,7	38,5
310-320	315	40,6	40,4	40,0	39,7	39,4	39,3	39,0	38,8	38,6	38,3
320-330	325	40,5	40,3	39,9	39,6	39,3	39,1	38,9	38,7	38,5	38,2

Appendix 6 Volume-Temperature factor B

B = Thermal expansion of water less than for steel from 3.5°C to 19.5°C

Pressure range kgf/cm ²	Average testing water temperature - Centigrade								
	3,5°	5,5	7,5°	9,5°	11,5°	13,5°	15,5°	17,5°	19,5°
1	-49	-15	+17	+46	+74	+101	+126	+150	+172
10	-46	-12	+19	+48	+76	+102	+127	+151	+174
20	-43	-10	+21	+50	+78	+104	+129	+153	+175
30	-40	-7	+23	+53	+80	+106	+130	+154	+176
40	-37	-5	+26	+55	+82	+108	+132	+155	+177
50	-34	-2	+26	+57	+84	+110	+134	+157	+179
60	-31	+1	+31	+59	+86	+112	+136	+159	+180
70	-25	+6	+36	+64	+91	+115	+139	+161	+182
90	-22	+9	+39	+67	+93	+117	+141	+163	+184
100	-19	+11	+41	+69	+95	+119	+142	+164	+186
110	-16	+14	+43	+71	+97	+121	+144	+165	+187
120	-13	+16	+46	+73	+99	+123	+145	+167	+189
130	-10	+19	+48	+75	+101	+124	+147	+168	+190
140	-7	+22	+51	+77	+103	+126	+148	+170	+192
150	-4	+24	+53	+79	+105	+127	+150	+171	+193
160	-1	+27	+56	+81	+107	+129	+152	+172	+194
170	+2	+29	+58	+83	+109	+130	+153	+174	+196
180	+5	+32	+60	+85	+111	+131	+155	+175	+197
190	+8	+35	+63	+87	+113	+133	+157	+177	+199
200	+11	+37	+65	+91	+115	+134	+158	+178	+200
210	+14	+40	+68	+93	+116	+136	+160	+180	+202
220	+17	+43	+70	+95	+118	+138	+161	+181	+204
230	+20	+45	+73	+97	+120	+139	+163	+182	+206
240	+23	+48	+75	+99	+122	+141	+165	+184	+206
250	+26	+50	+77	+101	+124	+142	+166	+185	+207
260	+29	+53	+90	+103	+126	+143	+168	+187	+209
270	+33	+56	+82	+105	+128	+145	+169	+188	+210
280	+36	+58	+85	+107	+129	+147	+170	+189	+211
290	+39	+61	+87	+109	+131	+149	+171	+190	+212
300	+42	+64	+89	+111	+133	+151	+173	+191	+213
310	+45	+66	+92	+113	+135	+153	+174	+193	+214
320	+48	+69	+94	+115	+137	+155	+176	+195	+215
330	+51	+73	+95	+117	+139	+157	+177	+197	+217

B = Thermal expansion of water less than for steel from 21.5°C to 39.5°C

Pressure range	Average testing water temperature - Centigrade									
kgf/cm ²	21,5°	23,5°	25,5°	27,5°	29,5°	31,5°	33,5°	35,5°	37,5°	39,5°
1	+194	+215	+236	+254	+271	+287	+302	+316	+330	+343
10	+196	+217	+237	+256	+273	+289	+304	+318	+331	+344
20	+197	+218	+238	+257	+274	+290	+305	+319	+332	+345
30	+198	+219	+239	+258	+275	+291	+306	+320	+333	+346
40	+199	+220	+240	+259	+276	+292	+307	+321	+334	+347
50	+204	+221	+241	+260	+277	+293	+308	+322	+335	+348
60	+202	+222	+242	+261	+278	+294	+309	+323	+336	+349
70	+205	+224	+244	+263	+280	+296	+311	+325	+338	+351
90	+206	+225	+245	+264	+281	+297	+312	+326	+339	+351
100	+208	+227	+246	+265	+282	+298	+313	+327	+340	+352
110	+209	+228	+247	+266	+283	+299	+314	+328	+341	+353
120	+211	+229	+248	+267	+284	+300	+315	+329	+342	+354
130	+212	+231	+249	+268	+285	+301	+316	+330	+343	+355
140	+214	+232	+250	+269	+286	+302	+317	+331	+344	+356
150	+215	+233	+251	+271	+288	+304	+319	+333	+345	+357
160	+216	+234	+252	+272	+289	+305	+320	+334	+346	+357
170	+218	+235	+253	+273	+290	+306	+321	+335	+347	+358
180	+219	+237	+254	+274	+291	+307	+322	+336	+348	+359
190	+220	+238	+256	+275	+292	+308	+323	+337	+349	+360
200	+221	+239	+257	+276	+293	+309	+324	+338	+350	+361
210	+222	+240	+258	+277	+294	+310	+325	+339	+351	+362
220	+223	+242	+259	+278	+295	+311	+326	+340	+352	+363
230	+224	+243	+261	+279	+296	+312	+327	+341	+353	+364
240	+225	+244	+262	+281	+298	+314	+329	+343	+354	+365
250	+227	+245	+263	+282	+299	+315	+330	+344	+355	+366
260	+228	+246	+264	+283	+300	+316	+331	+345	+356	+367
270	+229	+248	+266	+284	+301	+317	+332	+346	+357	+367
280	+231	+249	+267	+285	+302	+318	+333	+347	+358	+368
290	+232	+250	+268	+286	+303	+319	+334	+348	+359	+369
300	+233	+251	+269	+287	+304	+320	+335	+349	+360	+370
310	+234	+252	+271	+288	+305	+321	+336	+350	+361	+371
320	+236	+254	+272	+289	+306	+322	+337	+351	+362	+372
330	+237	+255	+273	+291	+308	+324	+339	+353	+363	+373