



Exploration & Production

GENERAL SPECIFICATION

PIPELINES - RISERS

GS EP PLR 501

Hydrostatic testing of pipelines

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1. Scope

The scope of this General Specification covers the Company requirements for performing the hydrostatic testing of a pipeline.

This specification applies to hydrostatic testing of land pipelines (onshore), offshore pipelines including their risers, either 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 1110	Pressure Testing of Steel Pipelines

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	



Total General Specifications

Reference	Title
GS EP COR 560	Physical and chemical treatment of hydrostatic test water
GS EP PLR 100	Submarine pipeline systems
GS EP PLR 102	Design of submarine pipelines as per API RP 1111 and ANSI B 31.4/31.8
GS EP PLR 103	Design of submarine pipelines as per DNV-OS-F101
GS EP PLR 104	Onshore pipeline systems
GS EP PLR 105	Design of submarine pipelines as per ISO 13623
GS EP PLR 106	Design of onshore pipelines as per ISO 13623
GS EP PLR 502	Precommissioning of gas pipelines

3. Definitions

In the present specification, the following definitions will be used:

Precommissioning All tasks and operations performed on the pipeline subsequent to the pipeline construction and prior to the introduction of hydrocarbon gas.

Commissioning All tasks and operations performed on the pipeline subsequent to precommissioning and which concern the initial introduction of hydrocarbon gas in the pipeline. It should be noted that precommissioning is a construction activity whereas commissioning is an operator activity.

Operator Entity of the Company who will receive the installations after precommissioning and will operate them with a view to commercial production.

Pipeline The pipeline is a section of a system or the entire system, used for the transport of hydrocarbon gas. It can be onshore or offshore, and extends from pig trap to pig trap, including:

- Risers and their supports, when they exist
- All permanent items, such as header, piping, pig trap, valves, isolating joints, etc., when they exist.

The system limits are identified in the Particular Project Specification.

Particular Project Specification (PPS)

Gives the specific requirements for execution of the work, subject of a Contract.

Golden weld A weld which has not been hydrotested, and is therefore subject to additional non-destructive testing (NDT).

May Is used to indicate that a provision is optional.



Shall	Is used to indicate that a provision is mandatory.
Should	Is used to indicate that a provision is not mandatory, but is recommended as good practice.
Equipment	Is used for all ancillary items of the precommissioning, not part of the permanent facilities.

4. General

The land pipelines, the submarine pipelines and their risers, shall be hydrostatically tested as soon as practicable after completion of construction, installation and all anti-corrosion works. The hydrostatic pressure test shall be executed as a holding test during at least 24 hours without interruption.

The hydrotest is the first step into the precommissioning sequence, and is normally performed at the same time as the flooding, cleaning and gauging operations. The remaining precommissioning activities are described in **GS EP PLR 502**.

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

The battery limits of the test shall be from pig trap to pig trap, and include all pipeline components. The pipeline may be tested as separate sections, provided the sections are isolated from each others, but the test shall never be performed **against closed valve**.

The pipeline valves shall be kept out of the hydrotest / precommissioning sequence, to avoid damages to their internals by debris. The pipeline sectioning shall therefore take into account the valve location, either by replacing the valve by a testing spool, or by testing separately the sections on either side of the valves.

When the valves cannot be easily removed, as for subsea valves, all precautions will be taken not to damage them: pipeline cleaning to be performed before the valves are installed, valves cavities are filled with MEG and valves are not operated until the precommissioning is completed. Flushing of the seats can also be considered, if the valve was designed for it.

The different test sections may be connected by golden welds, if accepted by Company. If all the sections have been successfully hydrotested for 24h, the final hydrotest of the complete system may be waived. The number of golden welds shall be kept to the minimum and imposed by the sectioning linked to the profile of the line, or by specific requirements for keeping the pipeline valves out of the pre-commissioning activities.

The golden welds shall be 100% inspected by radiography, ultrasonic testing and magnetic particles and the connecting spool shall have been hydrotested to the design code requirements prior to be welded in place.

When different sections are connected by flange or connector, a final leak test or hydrotest shall be performed. If all the sections have been successfully hydrotested for 24h, then a leak test of 4 hours shall be performed at the hydrotest pressure. If a section has not been hydrotested for 24h, then the final hydrotest will last 24h.

The applied hydrotest pressure shall be in accordance with the design code and the Test Data Sheet in the PPS (Particular Project Specification). The test pressure shall be measured at the highest point of each section, making sure that the maximum local pressure does not cause the



hoop stress to exceed the specified minimum yield stress (SMYS) of the pipes during the pressure test.

Temporary items, such as pig traps and spools, shall be designed for the test pressure and pressure tested separately at a higher pressure, prior to being used.

No test shall be started before the hydrotest procedure and the Test Pack have been approved by Company. The tests of pipelines, risers and associated piping are to be approved and witnessed by Company, and shall appear as Hold Point in the project Quality Plan.

5. Engineering studies

5.1 Land Pipelines

The PPS shall give all the details necessary to the preparation of the hydrostatic test procedures. The PPS shall include a Test Data Sheet, indicating the name of the line, or section of line, the owner of the line, 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 thicknesses, the design pressure, the test pressure, and the battery limits. It shall define the test pressures of the various sections all along the route of the pipeline, to take into account the various elevations of the pipeline and the subsequent hydrostatic heads.

The test shall be performed with the pipeline installed inside its trench, either ready to be covered or already covered.

5.2 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, taking into account specific requirements for keeping the pipeline valves out of the pre-commissioning activities.

The PPS shall give all the necessary details for the preparation of the hydrostatic test procedures. The PPS shall include a Test Data Sheet, with the name of the line, or section of line, the owner of the line, 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 thicknesses, the design pressure, the test pressure, and the battery limits.

For offshore pipelines, the recorded pressure shall be corrected of the hydrostatic head between the mean sea level and location of the pressure measuring device.

6. Safety

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

For inland pipelines, a safety distance of 40 m (2 x 20 m) along the right of way must be observed.

For offshore pipelines, safety distances on platforms must be evaluated on a case by case basis and then approved by Company.

At the pipe ends, a restricted access area shall be materialised with warning tape and safety warning signs. Test cabin shall be located at a minimum of ten meters from the pressure head.



A Test Pack, containing all the requirements of this specification and of the PPS, shall be submitted for approval to Company. This test pack shall contain at least:

- CV of personnel involved in the testing. Only personnel having adequate testing experience shall be mobilised
- Dedicated safety procedures
- Cleaning and gauging procedure with acceptance criteria
- Hydrotest procedure, with all the calculations and acceptance criteria
- Calibration certificate for all the measuring devices to be used.

The site activities shall not start until the complete Test Pack has been approved by Company.

7. Cleaning, Gauging and Water Filling

7.1 Quality of Water

The pipelines shall be filled with water treated, as per **GS EP COR 560** requirements and sufficient quantities of chemicals shall be available onsite at all times.

For CRA pipelines, or CRA clad pipelines, seawater shall never be used and the chloride content of fresh water shall be monitored.

For land pipelines, fresh water shall be used, although in desert areas seawater may be used. For offshore pipelines, water for filling and testing can be taken from the sea on site, after proper filtration.

All water used in the test shall be filtered through 50 microns mesh screen, removing all solids in excess of 50 microns and keeping solid content below 20 mg/l. A preliminary cleaning of the line shall be performed prior to the hydrotest, preparing the final cleaning activities to be performed after the hydrotest, as defined in **GS EP PLR 502**.

Prior to filling of the pipeline, well in advance, samples of proposed test water shall be analysed by an accepted third party institute, to determine possible contaminant and presence of SRB (Sulphate Reducing Bacteria).

The analysis shall permit to determine amounts of corrosion inhibitor, oxygen scavenger and bactericide needed, but as a minimum, bactericide is to be used. The disposal of the treated water after the test must be in line with the local regulations.

7.2 Cleaning

Efficient pipe cleaning is critical at this stage and specific measures shall be considered to improve the cleaning efficiency of the pig train: increase the number of cleaning pigs, use of pigs with jetting effect, use of gel slugs etc. to help in flushing away the particles from the pipe wall, and maintain them in suspension.

Three pigs shall be used as a minimum, but for longer pipelines this number shall be increased and shall be specified in the PPS. BIDI pigs fitted with polyurethane discs are to be preferred for durability and better sealing.

The cleaning pigs shall be equipped with brushes and magnets. For flow coated pipelines, the brushes shall be soft enough, not to damage the coating.



The debris shall be collected (solid or sludge) and measured. Cleanliness acceptance criteria may be specified in the PPS.

7.3 Gauging

Gauging operation shall be performed during the filling operation, by having the last pig fitted with a calibrated aluminium plate of:

- 6-8 mm thickness, segmented and with an edge of 45° - 3 mm width for pipelines equal or smaller than 24" OD
- 10-12 mm thickness, segmented and with an edge of 45° - 3 mm width for pipelines over 24" OD.

Overall diameter of the plate shall be determined in the PPS, as well as the segment size (see also [GS EP PLR 502](#)). By default, the gauge plate shall be 95% nominal ID for pipes equal or smaller than 24" OD, and 97% nominal ID for pipes over than 24" OD. Several gauge plates can be run, to minimize the risk of spurious damage.

The gauging requirement before the hydrotest is independent from the calliper requirement to be performed during the dewatering operations (see [GS EP PLR 502](#)).

When receiving the pigs, if damages are found on the gauge plate and cannot be explained with certainty, electronic geometric pig must be run to identify the cause and location. Type of electronic geometric pig is subject to Company approval.

Recordings from the electronic geometric pig concerning size, location of diameter reductions such as dents, buckles, flat spots, construction debris, etc. over 2% nominal ID shall be analysed and subject to Company approval. Any necessary repairs shall be made to restore the structural integrity of the line, involving a repeat hydrotest. Alternatively the electronic geometric pig can be run before the hydrotest.

When the line has been gauged in sections, and, once sections have been tied-in, then the complete line shall be gauged.

7.4 Water filling

Procedure for pipeline filling shall ensure that all air is removed from the pipeline and that no air pocket is left during filling: the separation pigs shall ensure a positive sealing and a constant velocity over 1m/s maintained.

Use of intermediate water storage tanks for feeding the pumps is necessary to ensure minimum flow requirements and absence of air in flow. Only certified turbine flow meters, recently calibrated by third party, are to be used during the filling operations.

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

The volumes given below are indicative and must be adapted to the pipeline size and length.

- Pump the equivalent of 250 linear metres (minimum) of treated water into the pipeline
- Launch first pig equipped with long range locating device (such as acoustic pinger for subsea pipelines)
- Pump the equivalent of 500 linear metres (minimum) of treated water into the pipeline
- Launch second pig



- Pump the equivalent of 500 linear metres (minimum) of treated water into the pipeline. For long pipelines ($> 50,000 \text{ m}^3$), the volume of water is to be about 25% of the pipeline volume
- Launch third pig, fitted with gauging plate and short range locating device (such as magnetic or isotopic)
- Fill entire pipeline with treated water. During the filling, readings of pressure/water volume/temperature/time shall be taken every hour
- Receive pig train at the other end of the line
- Continue pumping treated water until all air is expelled. Generally a full pipeline volume is needed
- Start pressurisation.

A pig signaller shall be installed on the pig launcher and on the pig receiver to give positive indication of the departure/arrival of the first and last pigs.

PPS may specify that a second pig signaller, working on a different principle is installed on the pig launcher and on the receiver (such as non intrusive type based on magnetic or isotopic detection).

For subsea pipelines, the first pig shall be fitted with an acoustic pinger, for long range detection, and with battery life sufficient for 2 months operation. For gas pipelines, the pinger signal can be transmitted to surrounding sea by the brushes/disks. The last pig shall be fitted with short range locating device.

For onshore pipelines, pig signallers may be installed on the right of way to track the progress of the pig train. The first and last pigs shall be fitted with a location device such as magnetic or isotopic.

The pigs shall be removed from the pig receiver in the presence of the Company representative, and shall be carefully examined for possible damages, abnormal wear of cups/disks, quantity and nature of debris collected. If the gauging plate is found damaged, the cause shall be investigated (see section 8.1, above).

The pig arrival time shall be estimated based on pipeline length and flowrate. Any significant delay in pig arrival shall be investigated, and blockage suspected. Pig blockage at any point along the line shall entail suspension of filling operations and search for blocked pigs using the pig locating devices. Necessary corrective actions shall be taken to restore the line to the testing condition.

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

8. Pressure Test

8.1 Test Pack

A Test Pack shall be prepared by Contractor, containing as a minimum:

- Pipeline identification
- The battery limits of the pressure test, as defined in the PPS



- Pipe specifications and Manufacturer
- Pipeline test pressure, based on Test Data Sheet in PPS
- Test medium
- Line cleaning, gauging and filling procedures
- Pressurising procedure including location of injection points
- Water intake/discharge line locations
- Theoretical pressure volume curve for hand-plot during test and temperature volume curves
- All the necessary forms for recording the test parameters (see some examples in Appendix 3 and Appendix 4)
- Isometric drawing showing all fill and test equipment and associated piping
- Detailed description of all equipment and instrumentation
- Leak location procedure and equipment used
- Inventory of all hydrostatic fill and test equipment
- Inventory of spares
- Calibration certificates for all test equipment, to be submitted prior to the start of the testing and be included in the final test report
- List of all measuring devices to be used (pressure gauges, dead weight tester, thermometer, turbine meters, etc.) calibrated less than 6 months before the start of the testing
- Test procedures and Test Data Sheet from the PPS.

The Test Pack is to be submitted to Company for approval.

8.2 List of equipment

The following:

- Fill-pump or pumps: the pump stuffing shall be air tight to prevent air from entering. Pumps shall be fed by an intermediate storage tank. Should a single pump be used, a standby unit must be available
- The suction hose shall have a filter with 50 micron mesh screens and must be airtight at all junctions
- Variable speed positive displacement pump equipped with a stroke counter for pressurising the line with a known volume per stroke and capable of exceeding the maximum test pressure by at least 20 bar
- Two turbine meters with an accuracy of 0.3 to 0.4 per cent (of the expected total internal volume of the pipeline) 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 deadweight testers with an accuracy better than 0.1 bar (across the scale range), measuring with a sensitivity better than 0.05 bar (across the scale range) to enable an increment of 0.05 bar and with a calibration certificate not older than 6 months. To achieve the required accuracy, the dead weight tester(s) shall be corrected for local gravity. The range of accuracy for the dead weight testers must be at least 1.25 times the hydrostatic test pressures
- For small floating vessels, where dead weight tester may be difficult to use, digital pressure gauges with the same accuracy, sensitivity, and calibration requirement, may be substituted, upon Company's approval
- Two 48 hours recording pressure gauges 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 thermometers minimum to measure sea bottom temperature (offshore pipelines) with accuracy of 0.1°, with associated data logger
- 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 or a calibrated flowmeter
- 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 weeks can be a basis for accepting a pressure variation during the pressure tests.

8.3 Particular Requirements

The test pressure shall be measured with the dead weight testers, while the pressure recorder shall provide a graphical record of the pressure variation over the test duration.

The pressure recorder shall be installed in parallel with the dead weight tester at each end of the pipeline to be tested, unless otherwise stated in the PPS.

The pressure recorder accuracy shall be checked periodically through the testing period, against 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).



For offshore pipelines, seawater temperatures shall be monitored by means of thermometer with data loggers, several weeks in advance, unless otherwise stated in the PPS. The monitoring locations are to be selected, based on temperature gradients along the pipeline route and shall be recorded taking into account the tide.

From these temperature records, pressure variations while testing may be explained and stabilisation periods established.

For long pipelines (> 50 km), more measurements are to be performed, typically every 50 km, using data loggers. If significant temperature gradient has been found by the preliminary temperature monitoring, more frequent temperature measurements shall be taken.

8.4 Pressurisation

The pressurisation shall be performed at constant rates not exceeding 1 bar/min up to 70% of the pressure test, and then 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 stabilise properly.

After the stabilisation period - 1 hour as a minimum - is accepted by the Company representative, the pressure shall be gradually raised at the rate of 0.12 bar/min.

While bringing the pipeline up to pressure, the hand-plot of the pressure volume curve shall be performed until the specified test pressure is reached. At 35 bar and 95% of the pressure test, the pumping shall be stopped for 15 min, to perform a residual air content measurement.

The residual air content shall be calculated by the pressure/volume plot method (as per **API RP 1110**), and at the option of Company a pressure drop test may be requested for consistency check (see Appendix 1).

The air content shall not exceed 0.2% of the calculated capacity of the pressure tested section; pressure and volume recordings shall have the required accuracy and sensitivity to appreciate this level of air entrapment.

While pressurising, all the pipe connections and fittings on pipeline shall be periodically checked for leaks.

When the test pressure is reached and before starting the holding period, the filling valve shall be closed and the filling line disconnected from the pipeline.

8.5 Final checks before starting pressure holding period

Prior to the commencement of the test holding period, water temperature in the pipeline must be stable.

The required amount of stabilisation is to be determined and agreed with Company.

As a guide line, the stabilisation period is completed when the pipeline temperature is within 1°C of the surrounding soil/water temperature. For long pipeline, extra stabilisation time may be necessary, and pressurisation shall not start until all the temperature records are stable.

The duration of the test holding period shall be 24 hours. During the 24-hour test holding period, 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 girth welds, connections for the pressure measurement and all plugged connections are to be easily accessible for visual inspection, before, during and after the tests, by duly authorised personnel.

The residual air content measurement shall not exceed 0.2% of the total volume of the tested section.

During the stabilisation and the testing periods, care is to be taken that the maximum test pressures are not exceeded: max 0.5% above the test pressure. If necessary, water shall be drained off for this purpose. The pressure drop and the amount of water are to be measured and recorded.

8.6 Pressure holding

During the pressure test, the pressures shall be measured and recorded every half hour using the dead weight tester.

All valves and other joints where there may be leakages are to be checked carefully. Testing may begin after leakages have been repaired. Leakage repair shall only be performed after pressure is reduced to a safe level.

The 24-hour test is to commence at a time to be agreed beforehand with Company and the recording charts are to be signed by all parties, with indication of start time.

Observations must be recorded, stating clearly on the corresponding documents, such as pressure and temperature cards, the pipeline identification.

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

All drain tests, air venting or water draining events are to be recorded on the pressure charts.

During the 24-hour test period the following measurements shall be recorded every 30 minutes at both pipeline ends:

- Pressure from the dead weight testers: maximum and minimum since last measurement, as well as the average values
- Ambient temperature and pipeline temperature from the thermowells
- Atmospheric pressure
- Tide level (offshore pipelines) together with the water depths
- Seabed temperatures (offshore pipelines) or soil temperature (onshore pipeline).

At the end of the pressure test a second drain test shall be performed: this second drain test shall 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).

The recording charts are then to be signed off by all parties with clear identification of signatories, start and finish time of the test.

After all the data of the pressure test have been gathered and submitted to the Company representative, the test shall be considered acceptable if:

- The acceptance criteria for pressure variation is met
- The residual air content is below 0.2%



- All the measuring devices are performing to the required accuracy
- All the visual examination of fittings, connections, flanges etc. are acceptable.

Formal approval of the hydrostatic test can then be given by the Company Representative.

The pressure test acceptance may need to be validated by a Certifying Authority, who must be prior approved by Company.

8.7 Acceptance criteria

The pressure test shall be considered acceptable if, at the end of the 24h holding period, the pressure variation does not exceed $\pm 0.2\%$ of the initial test pressure.

If this variation is between 0.2% and 0.4%, it has to be fully explained by temperature variation. In excess of 0.4% variation, the holding period has to be repeated.

The variation of pressure with temperature can be calculated from Appendix 2 (for information)

8.8 Pressure release

During depressurisation the pressure decrease rate shall not exceed 3 bar/min.

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

Unless otherwise instructed by Company, all successfully tested pipelines and risers shall remain full of treated test water and suitably capped off.

8.9 Incidents

If, on termination of the tests, it is found that all the criteria for validating a successful test holding period have not been met, re-testing may be requested for an additional length of time entirely at the discretion of the Company representative.

If, during the tests a leakage is found in an element which does not belong directly to the pipeline system, the test can be resumed after the leakage has been repaired, but the holding pressure duration must be a new 24 hours period.

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

Following repairs, the pipeline shall be refilled and cleaned as described in Section 7 and the test repeated until a continuous 24h test holding period has been recorded.

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 during the test shall be replaced, and quarantined.

If the pressure holding period fails 3 times to meet the acceptance criteria, the pipeline has to be depressurised to 72% of the SMYS, until pressure stabilisation is achieved. The holding period can then be repeated.

9. Disposal of test media

The treated water may have to be removed from the pipelines, if so required in the PPS, as part of the precommissioning activities (see [GS EP PLR 502](#)).

This shall be performed with no harm to the surrounding environment, and comply with the local regulations. In particular, there may be a requirement to treat or segregate the test water.



10. Completion pressure test file

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

- Completed hydrostatic test forms as per Appendix 2 and Appendix 4
- Hydrostatic test diagram
- Pipeline gauging acceptance test
- Pipeline filling, log of operations
- Pressure gauges and recorders calibrations
- 24 hours hold periods, log of operations
- Hydrostatic test calculations, incl. pressure /temperature variations, air content test, etc.
- 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 signed off
- 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 calibration
- Additives specification, Supplier and amounts injected.

11. Other references

Following Total General Specifications are applicable: [GS EP PLR 100](#), [GS EP PLR 102](#), [GS EP PLR 103](#), [GS EP PLR 104](#), [GS EP PLR 105](#) and [GS EP PLR 106](#).

Appendix 1 Measurement of residual air content

Residual air content shall be determined using the P/V plot during pressurisation and, at Company option, by drain test method.

Completed during pressurisation at approx. 5 bar and at 95% of the test pressure, the drain test shall consist of drawing off enough water to decrease the pressure in the line by approximately 0.5 bar. The volume of drained water shall be measured accurately (bled volume).

This volume, V_{drain} , is compared to the theoretical calculated volume, ΔV when no air is present:

$$\Delta V = \left[2 \frac{1-\nu^2}{E} \frac{r}{s} + A \right] V \Delta P \text{ for restrained pipelines}$$

$$\Delta V = \left[\frac{5-4\nu}{2E} \frac{r}{s} + A \right] V \Delta P \text{ for unrestrained pipelines}$$

for pipeline systems containing sections with pipes of differing diameter and thickness,

$$\Delta V = \sum \Delta V_k \text{ with } \Delta V_k = \left[2 \frac{1-\nu^2}{E} \frac{r_k}{s_k} + A \right] V_k \Delta P \text{ or } \Delta V_k = \left[\frac{5-4\nu}{2E} \frac{r_k}{s_k} + A \right] V_k \Delta P \text{ for restrained or unrestrained sections respectively.}$$

where:

- s = Wall thickness
- s_k = Wall thickness of section k
- r = Internal pipe radius (same unit as s)
- r_k = Internal pipe radius of pipe in section k (same unit as s)
- V = Internal volume of line
- ΔV = Calculated volume (same unit as V)
- ΔV_k = Calculated volume for section k (same unit as V)
- ΔP = Pressure drop during drain test
- ν = Poisson ratio for the wall material
- E = Young modulus for the wall material (same unit as ΔP)
- A = $1/K$ with K = bulk modulus (in same unit as ΔP) of the test medium as per Appendix 5 for water.

An approximate value of the air volume (V_{air}) at atmospheric pressure (P_0) may be obtained by remarking that $V_{\text{drain}} - \Delta V$ is the increase in volume of the air due to the drop in pressure ΔP during the drain test at absolute pressure P .

$$\text{Hence } V_{\text{drain}} - \Delta V = V_{\text{air}} \frac{P_0}{P} \frac{\Delta P}{P}$$

From the above formula, it is clear that for high pressure test, V_{drain} at 95% of test pressure should be very close to ΔV , since the effect of air becomes negligible. However, differences may



Appendix 1

arise due to out of roundness, wall thickness and diameter tolerances, true restraint conditions versus considered restraint conditions, true characteristics of the test medium versus calculated ones, etc.

For this reason, entrapped air volume may be estimated from:

$$\frac{V_{\text{drain}}}{\Delta P_1} - \frac{V_{95}}{\Delta P_2} = V_{\text{air}} \frac{P_0}{P^2}$$

with

V_{drain} = Drain test volume at pressure P (approx. 5 bar)

ΔP_1 = Pressure drop (approx. 0.5 bar) for drain test at low pressure

V_{95} = Drain test volume at 95% of test pressure

ΔP_2 = Pressure drop (approx. 0.5 bar) for drain test at 95% of test pressure

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 Temperature corrections

The relationship between volume of test fluid added or removed, pressure change and temperature change is:

$$\frac{\Delta V}{V} = \left[2 \frac{1-\nu^2}{E} \frac{r}{s} + A \right] \Delta P - [\beta - 2\alpha(1+\nu)] \Delta T \text{ for restrained lines, or}$$

$$\frac{\Delta V}{V} = \left[\frac{5-4\nu}{2E} \frac{r}{s} + A \right] \Delta P - [\beta - 3\alpha] \Delta T \text{ for unrestrained lines.}$$

where:

s = Wall thickness

r = Internal pipe radius (same unit as s)

V = Internal volume of line

ΔV = Calculated volume (same unit as V)

ΔP = Pressure drop during test

ν = Poisson ratio for the wall material

E = Young modulus for the wall material (same unit as ΔP)

β = Thermal expansion coefficient of test medium as per Appendix 5 for water

α = Thermal expansion coefficient of pipe material

ΔT = Temperature variation of test medium during test

A = $1/K$ with K = bulk modulus (in same unit as ΔP) of the test medium as per Appendix 5 for water.

For an ideal pipeline with no leakage ($\Delta V = 0$), this provides the relation between pressure variation and temperature variation. For example, for restrained lines:

$$\frac{\Delta P}{\Delta T} = \frac{[\beta - 2\alpha(1+\nu)]}{\left[2 \frac{1-\nu^2}{E} \frac{r}{s} + A \right]}$$

For a real pipeline, the temperature variation is not accurately known and the application of the formula may indicate a release volume of test fluid over the test duration (i.e. the calculated ΔV is not zero). This unexplained ΔV shall not exceed 0.1 m³ (100 litres) per 24 hours.



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 (OD)	_____	PIPE WALL THICKNESS	_____
GRADE	_____	SMYS (Mpa)	_____
LENGTH	_____	MILL TEST PRESSURE (bar)	_____
ESTIMATED.TOTAL VOLUME OF THE LINE (Litres)	_____	HYDROTEST 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 Formulae for water characteristics (for information)

The following formulae have been reproduced from Deep Sea Research 1976 Vol. 23:

Please note that the following coefficients A and B are different from those given previously in Appendix 1 and Appendix 2.

$$A = 1/K$$

$B = \chi - 2\alpha(1+\nu)$ for fully restrained line, with α = expansion coefficient of steel and ν is Poisson coefficient of steel.

$B = \chi - 3\alpha$ for non restrained line

t = Temperature (°C)

S = Salinity (‰)

P = Pressure (bar)

β = Volumetric Expansion Coefficient (1/°C)

Bulk Modulus K (bar)

$$K = K^0 + AP + BP^2$$

Where: P = pressure (bar)

$$\begin{aligned} K^0 = & 19654.32 + 147.037 t - 2.21554 t^2 + 1.0478 \times 10^{-2} t^3 - 2.2789 \times 10^{-5} t^4 \\ & + (51.2614 - 0.45222 t + 2.6834 \times 10^{-3} t^2) S(\text{‰}) \\ & + (0.66286 + 7.281 \times 10^{-3} t) S(\text{‰})^{3/2} \end{aligned}$$

$$\begin{aligned} A = & 3.2891 - 2.3910 \times 10^{-3} t + 2.8446 \times 10^{-4} t^2 - 2.82 \times 10^{-6} t^3 + 8.477 \times 10^{-9} t^4 \\ & + (4.9305 \times 10^{-3} - 1.74067 \times 10^{-4} t + 3.7712 \times 10^{-6} t^2) S(\text{‰}) \\ & + (-2.932 \times 10^{-4}) S(\text{‰})^{3/2} \end{aligned}$$

$$\begin{aligned} B = & 6.2450 \times 10^{-5} - 3.913 \times 10^{-6} t - 3.499 \times 10^{-8} t^2 + 7.942 \times 10^{-10} t^3 \\ & - 3.299 \times 10^{-12} t^4 + (-1.17249 \times 10^{-6} + 1.40136 \times 10^{-7} t - 2.26045 \times 10^{-9} t^2) S(\text{‰}). \end{aligned}$$

Volumetric Expansion Coefficient β (1/°C)

$$\beta = \beta_w + A S(\text{‰}) + B S(\text{‰})^{3/2}$$



Appendix 5

$$\begin{aligned}\beta_w = & -6.80977 \times 10^{-5} + 1.82945 \times 10^{-5} t - 3.2519 \times 10^{-7} t^2 + 6.4062 \times 10^{-9} t^3 \\ & - 8.8997 \times 10^{-11} t^4 + 5.846 \times 10^{-13} t^5 + (3.7409 \times 10^{-7} - 1.5881 \times 10^{-8} t \\ & + 2.9713 \times 10^{-10} t^2 - 3.5431 \times 10^{-12} t^3 + 1.741 \times 10^{-14} t^4)P + (-9.6658 \times 10^{-11} \\ & + 4.8741 \times 10^{-12} t - 1.0169 \times 10^{-13} t^2 + 9.941 \times 10^{-16} t^3)P^2 + 4.75 \times 10^{-16} P^3\end{aligned}$$

$$\begin{aligned}A = & 4.04385 \times 10^{-6} - 1.399 \times 10^{-7} t + 1.727 \times 10^{-9} t^2 - 1.944 \times 10^{-11} t^3 \\ & + (-3.219 \times 10^{-9} + 1.0353 \times 10^{-10} t - 8.365 \times 10^{-13} t^2)P \\ & + (7.183 \times 10^{-13} - 1.636 \times 10^{-14} t)P^2\end{aligned}$$

$$\begin{aligned}B = & -1.058 \times 10^{-7} + 1.308 \times 10^{-9} t + 2.125 \times 10^{-11} t^2 + 1.69 \times 10^{-12} t^3 \\ & + (8.446 \times 10^{-11} - 1.88 \times 10^{-12} t)P.\end{aligned}$$