



Exploration & Production

GENERAL SPECIFICATION

PIPELINES - RISERS

GS PLR 502

Precommissioning of submarine gas pipelines

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1. Scope

This general specification for the precommissioning of submarine gas pipelines shall be considered by the CONTRACTOR as a general framework stating the technical guidelines of the COMPANY.

It must be followed by detailed, itemized procedures, produced by the CONTRACTOR, which specify, in particular, the criteria for acceptance of each of the precommissioning phases.

Neither the contents of the present specification nor the omission of essential information in the documentation provided by the COMPANY will, under any circumstances, free the CONTRACTOR from the obligation to perform and complete his contractual undertaking.

While remaining within the requirements of the specification, alternative methods and drawings, other than those specified here, may be proposed. These alternatives must be justified by their use for previous operations and will be subject to approval by the COMPANY prior to application.

This specification is a synthesis of the experience acquired directly or indirectly by the COMPANY during precommissioning of 35 identified gas pipelines, 31 of which are located in the North Sea.

It should therefore be borne in mind that the collected results of these operations reflect the evolution of working practises over the last twenty years 1967-1987.

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.

All work specified in the present document must be in conformance or in accordance with the following codes and regulations.

In addition, the CONTRACTOR must perform his work in accordance with the detailed particular specifications which may be referred to in the present document.

Standards

Reference	Title
BGC/PS/PCI	British Gas Engineering Standard

Professional Documents

Reference	Title
DOE	Submarine pipelines guidance notes - 1982
IP6	Institute of Petroleum Code of Safe Practice in the Petroleum Industry - 1982 and supplement 1986
DNV	Rules for submarine pipeline system - 1981 Edition

Regulations

Reference	Title
NPD	Regulations for design, fabrication and installation of submarine pipelines and risers

Codes

Reference	Title
BSI CP 8010-1987	British Standard Code of Practice - Pipelines - Parts 1 and 2
ANSI B 31-8-1986	Gas Transmission and Distribution Piping System
ANSI B 31-3-1980	Chemical Plant and Petroleum Refinery Piping

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS STR 101	Design of offshore jacket and subsea structures

3. Definitions

For the terms of general interest, refer to chapter 2 of the **GS STR 101**. In the present specification, and for its application, the following definitions will be used:

- **Precommissioning**

All tasks and operations performed on the pipeline subsequent to the hydrotests after line laying and prior to the introduction of production natural gas.

- **Commissioning**

All tasks and operations performed on the pipeline subsequent to precommissioning and which concern the injection of natural gas up to commercial production operations. It should be noted that precommissioning is a construction activity whereas commissioning is an operator activity.

- **Operator**

Clearly identified entity of the COMPANY who will receive the installations after precommissioning and will operate them with a view to commercial production.

- **The structure**

The system of submarine pipelines including the submarine pipelines and the connection pipelines on land, if they exist:

- Risers and their supports
- Isolating joints when they exist
- All auxiliaries.

The structure limits are specified in the particular specification. They may be a header, a manifold, an isolating joint or a riser suspension clamp.

- **General specification**

Covers the subjects in general and exists within the COMPANY.

- **Particular Specification**

Gives specific instructions for execution of the work, subject of a contract.

- **CONTRACTOR**

Party appointed by the COMPANY to perform the precommissioning work on the structure, which may include its SUB-CONTRACTORS.

4. Precommissioning philosophy

4.1 General

In all that follows, it will assumed that the pipes which are assembled on the lay barge and constitute the future submarine pipeline, have been brushed and cleaned on land before dispatching.

Indeed, the effectiveness of pigging, swabbing and drying is directly proportional to the state of the inner pipe wall surface.

This is all the more true when the pipes have been stored on land for a long period in a saline environment.

In order not to deteriorate the tightness mechanisms of isolation valves during initial dewatering or pigging operations on both pipeline ends, those valves have to be dismantled prior any pigging and replaced by dedicated spool pup pieces.

Welding on or mechanical tie ins of related valves will be carried out in completion of cleaning operations. It is essential that none debris contained in the line should not be trapped within valves sealing devices (see Appendix 1).

After successful completion of the hydrostatic tests, which sanction laying operations, the pipeline is filled with water containing a corrosion inhibitor. It will remain in this state for a certain time, though generally not more than six months.

Precommissioning work will begin from this state.

It is admitted by pipeline codes that a fully certified X-Ray inspection of the weld would be acceptable without hydrostatic tests as valves are finally installed in completion of dewatering and cleaning phases.

4.2 Precommissioning phases

The different sequential phases of precommissioning are:

- Phase 1 - Structure tightness tests
- Phase 2 - Cleaning the structure
- Phase 3 - Dewatering and swabbing
- Phase 4 - Drying and flushing the structure
- Phase 5 - Stabilization at the final dew point
- Phase 6 - Filling with nitrogen and inerting.

The first three phases will be performed in accordance with the general procedure described below, no variants being permitted.

The last three phases, which are the most important, will be performed using one of the following methods:

- Drying by circulation of dry air, nitrogen or dry gas
- Vacuum drying.

The two methods make use of the capacity for water evaporation in the pipeline at ambient temperature, in the first case by mass transfer from a dry effluent, in the second case by vacuum evaporation.

The latent vaporization heat is taken from the ambient environment in the case of vacuum drying, and from both the ambient environment and the drying gas in the first case.

In both cases, the flushing performed after drying, which removes the residual layer of water molecules remaining on the inner pipe wall may be performed either with dry air, dry gas or nitrogen.

In certain documents, line swabbing is presented as a drying operation. In fact, it leaves a considerable amount of liquid on the pipe wall in the form of a film of water.

When swabbing is performed with a chemical compound such as methanol, the residual mixture in the pipe prevents hydrate formation and, in certain cases, gas can be introduced without the need for further drying operations. However, with this type of process, it has been observed that during a certain period after dispersion of the methanol, the gas produced still contains large quantities of hydrates, rendering it unfit for consumption.

5. Phase 1 - Structure tightness tests

The pipeline will be subjected to the test pressure according to a pressurization curve and in stages specified by the COMPANY under particular conditions.

Once the test pressure has been reached, it will be maintained for a minimum of six hours or as specified in the particular specifications.

All the test parameters, pressure and temperature will be monitored and recorded at each end of the pipeline.

5.1 Test preparation

The test preparation procedure will be subject to approval by the COMPANY before operations commence.

The procedure will include, in particular, a detailed description of manpower and equipment employed.

5.2 Pressurization to 70% test pressure

This test will be performed in the presence of a COMPANY representative. The pressure increment will not exceed 0.5 bar per minute.

When 50% test pressure has been reached, a purge test will be conducted to determine the remaining quantity of air, then the pressure will be maintained for one hour.

Finally, the 70% pressure stage will be reached and the pressure maintained.

At the very least, the following parameters will be constantly recorded:

- Pump delivery rate
- Pressure in the line
- Temperature in the line
- Ambient air temperature
- Ambient air pressure
- Temperature of the filling water tank
- Subsea temperature.

The pipe will be pressurized using treated seawater from the tank (see particular specification).

5.3 Pressurization to test pressure

After the 70% pressure stage, the test is continued and the pressures corresponding to the volumes introduced are measured regularly with a manometric scale:

- Every 5 bars up to 80% test pressure
- Every 1 bar between 80% and 90%
- Every 0.2 bar between 90% and 100%.

The data will be used and correlated to estimate the quantity of air remaining in the pipe and to check the amplitude of any leaks.

The test pressure will be maintained for six hours then the line will be depressurized at the following rate:

- 100-90%: 1 bar/minute
- 90-80%: 2 bars/minute
- 80-0%: 3 bars/minute.

5.4 Equipment

All equipment used for the tightness tests must be in good operating condition, with all necessary spare parts.

The measurement instruments will have been calibrated within the last year by a recognized authority.

A large diameter Bourdon (or equivalent) pressure manometer will be mounted at each end of the pipeline (0–250 bars).

The particular specifications must give details concerning the general test layout (see skeleton diagram).

A cabin-laboratory will be exclusively and specially fitted out to receive the measurement instruments and the certified and sealed manometric scales.

5.5 Inspection and measurements

The CONTRACTOR will supply the COMPANY with a procedure for inspecting and verifying the tightness of the line, which will include at the very least:

- Theoretical and real pressure/volume curves showing the quantity of residual air remaining in the pipe at the end of testing; the maximum remaining air volume must not exceed 0.2% of the total pipeline volume.
- Purge procedure performed at the 50% test pressure stage, the theoretical air volume remaining in the line after the partial depressurization test being given as:
 - Anchored or underground pipe

$$(1) \Delta V_1 = \left[\frac{2(1-\nu)}{E} \cdot \frac{r}{s} + \chi \right] V (P_1 - P_2) \text{ en dm}^3$$

- Pipe able to expand longitudinal

$$(2) \Delta V_2 = \left[\frac{5(1-\nu)}{2E} \cdot \frac{r}{s} + \chi \right] V (P_1 - P_2) \text{ en dm}^3$$

where:

S is the pipe thickness

V the pipe volume in dm³

R the inner pipe radius in mm

P₁ the pressure at the start of the test

P₂ the pressure at the end of the test

χ seawater compressibility coefficient at the pressure and temperature considered

E elasticity module of steel

ν Poisson coefficient of steel

- The pressure will be lowered by approximately 0.5 bar and the water volume collected will be carefully measured. The test will be repeated twice.
- A theoretical temperature/pressure curve.

5.6 Final documentation

A complete report of the tightness test enclosed with the request for acceptance certificate will be provided by the CONTRACTOR.

The report will include:

- A descriptive part
- An operation journal
- A copy of all pressure/temperature sensor recordings.

6. Phase 2 - Cleaning the structure

6.1 General

After completion of the previous phase, the structure will be cleaned. The extent of the cleaning operation will depend on the quantities of debris obtained or estimated by the COMPANY when the line is filled.

As a general rule, the cleaning programme includes only one of the following combinations of processes:

- Mechanical cleaning with scraper pigs
- Hydraulic cleaning with special gels
- Mechanical cleaning and/or hydraulic cleaning using various scraper pigs and treated seawater.

Cleaning parameters must be carefully recorded or noted so that the cleanness of the structure can be demonstrated at the end of operations.

As in the previous phase, the equipment used will be thoroughly checked in conformity with the procedure submitted to the COMPANY for approval.

6.2 Mechanical cleaning

Mechanical cleaning will involve the separate passage of four pig trains, with at no time more than one train or train section simultaneously present in the line.

6.2.1 Train A

Its purpose is to remove large metallic debris or other. It will be comprised of a set of bi-directional scraper pigs separating gel plugs (at least two). A particular specification will describe the gel characteristics and its instructions for use.

6.2.2 Train B

Its purpose is to remove the small residual debris and scale adhering to the pipe wall, on the assumption that there is no more large debris.

It will be comprised of bi-directional pigs pushing sections of treated seawater. The scraper pigs will have increasingly fine brushes. Magnetic pigs will be placed in-between.

6.2.3 Train C

This train will remove the final debris left behind by train B. It will be comprised of bi-directional scraper pigs placed between small gel sections. The final section will be comprised of at least 500 m³ of treated seawater for a 24 inch pipe.

6.2.4 Train D

This train will perform the final cleaning operation, sweeping away gel residues on the pipe wall. In addition, this train will inspect the structure geometry.

It will be comprised of sprayer pigs equipped with deflectors perforated at the edge to clean the wall hydraulically by turbulent deflection.

This final pig will be an intelligent pig.

After completion of the cleaning operations, the structure will be depressurized down to atmospheric pressure.

7. Phase 3 - Dewatering and swabbing the structure

7.1 General

This phase mainly involves the drying of the structure, in the sense generally understood in emptying and drying operations.

The aim of the operations will be to extract the majority of the seawater in the pipeline.

Following this extraction, water will remain:

- In the low points of the pipeline
- On the pipe walls in the form of a film of water adhering to the rough metal surface.

Like the previous phase, dewatering will be constantly measured and quantified to provide proof of its correct execution and to demonstrate that the CONTRACTOR's performance is acceptable.

7.2 Dewatering and swabbing principles

Dewatering will be performed using highly watertight plugs propelled by super dry compressed air (dew point - 40°C).

The first two of these bi-directional plugs, at least, will be separated by a minimum of 100 m³ of fresh water.

The swab used will generally be a methanol pig preceded and followed by a nitrogen pig.

Its purpose is to complete dewatering and prepare the line for drying operations.

In view of its toxicity and operating restrictions at sea, this methanol pig will only be passed through once. **This method must not be used to dry the pipe** unless explicitly requested by the COMPANY.

Swabbing may be avoided if good results obtained during dewatering and if there are no significant low points in the structure.

Preparation for dewatering will be performed in the same spirit as that of the previous phase.

7.3 Dewatering

Dewatering will be performed by means of two separate pig trains.

The fresh water used must be treated and contain no pollutants, corrosive or foreign products. It must be filtered to 50 microns.

A specific procedure will be used to determine the composition of treatment agents such as:

- NAFLOC V933 at 100 ppm
- RHODAMINE B at 15 ppm.

7.3.1 Train A

The purpose of this train is to eliminate the majority of the sea water from the structure. It will include a part comprised of fresh water propelled by super dry air (dew point -40°C).

7.3.2 Train B

The purpose of this train is to disperse the residual water, especially in the low points, leaving only a residual film on the pipe walls:

- 50 to 80 g/m² for an unlined pipe
- 20 to 30 g/m² for an epoxy coated pipe.

It will be comprised of several bi-directional pigs propelled by super dry air.

Particular attention will be paid to the compressor delivery rate at the end of the pig run to avoid damaging the pig receiver. A progressive delivery rate reduction procedure must be implemented.

7.3.3 Depressurization

After completing the operation, the structure is depressurized to a residual pressure set by the COMPANY. Noise levels will be in conformity with the particular instructions.

7.3.4 Equipment

The CONTRACTOR must provide all equipment necessary for the correct execution of the dry air dewatering operation, and in addition:

- A covered measurement laboratory
- A compact recording and reading system
- A dew point recording system.

7.4 Swabbing

This involves the passage of a methanol plug surrounded by two 500 m³ nitrogen plugs (for a 24 inch pipe) at service pressure.

The nitrogen serves mainly to prevent all contact with the oxygen and to avoid any risk of explosion.

An acoustic transmitter or a radioactive source are inserted into the methanol plug.

Upon arrival, the methanol is collected in tanks reserved for this purpose.

The theoretical quantity of methanol in the plug is such that $Q = K D.L$, where:

- D: Internal pipe diameter in mm
- L: Length of structure in km
- Q: Litres
- K: is a sampling coefficient = $K_1 \cdot K_2 \cdot K_3$, where
 - K_1 is a function of the dilution capacity of the agent used (0.2/0.4 for methanol)
 - K_2 is a function of the surface quality of the inner pipe wall and its roughness:
 - . $K_2 = 1$: for an epoxy coating
 - . $K_2 = 1.33$: for a roughness of 50 to 100 microns
 - . $K_2 = 1.66$: for a roughness of 100 to 300 microns
 - . $K_2 = 2$: for a roughness of 300 to 1000 microns
 - K_3 is a function of the vertical profile of the pipe route:
 - . $K_3 = 1$: for a flat route
 - . $K_3 = 2$: for an undulating route.

The methanol capacity available on site is 15 times the quantity expressed above.

The quantity of nitrogen required to form the two plugs surrounding the methanol plug is around 10% of the line capacity for each.

i.e. a quantity available on site equal to 20% of the line capacity, representing approximately 1 km of the line at atmospheric pressure.

7.5 Final documentation

A complete report of dewatering operations will be submitted by the CONTRACTOR. It will be signed by the COMPANY and enclosed with the acceptance certificate of the phase under consideration.

The report, identical to that of the other phases, will include a copy of all the pressure, temperature and dew point sensor recordings.

8. Phase 4 - Pipeline drying

To avoid hydrate formation when the pipe is put into service and to attain the maximum H₂O level required by the customer, the pipeline must be dried and brought to its contractual dew point before inerting and injection of commercial gas.

The three following methods must be analysed and compared by the CONTRACTOR before a choice is made:

- Vacuum drying
- Drying by circulation of dry air
- Drying by circulation of dry natural gas.

8.1 Vacuum drying

This method will be preferred by the COMPANY. It is assumed that the film of water remaining on the walls has a thickness of the same order of magnitude as the height of the asperities. The quantity of water remaining in the pipeline can thus be estimated. For example, for an unlined steel pipe, the admissible limit for residual water is around 80 to 100 g/m².

The choice of vacuum drying is governed essentially by the two following parameters:

- Quantity of water remaining in the pipe and assessment of the effectiveness of dewatering
- Internal pipe temperature. The higher the temperature, the more effective and rapid will be the vacuum drying operation by reduction of the specific volume of the water vapour drawn out.

8.1.1 Operating procedure

Vacuum drying involves vaporization of the water at the boiling pressure corresponding to the pipe temperature. For example:

- At 5°C the boiling pressure is 8.6 mb.
- At 10°C, the boiling pressure is 12.2 mb.

There are four separate stages:

8.1.1.1 Step no. 1 - Pumping

The pressure is reduced down to the boiling pressure of the water in the pipe. Most of the air is removed. A small proportion of the water is eliminated at its vapour tension.

8.1.1.2 Step no. 2 - Vaporization

All the water in the pipe vaporizes. This occurs at the specific dew point and residual pressure, which depend on the limit conditions and the characteristics of the vacuum pump. Vaporization occurs at constant pressure, lowering slightly until most of the water has boiled and the water vapour has been removed. A pressure plateau is observed. If this is not the case, only a leak or the appearance of ice can explain the phenomenon.

8.1.1.3 Step no. 3 - Desorption from walls

All the free water has been vaporized and the dew-point pressure drops rapidly. This corresponds to the desorption of the last water molecules retained in the pipe wall pores by capillarity or osmotic forces. Pumping should be stopped as soon as the pressure reaches 5 or 6 millibars.

8.1.1.4 Step no. 4 - Flushing with super dry air

A rapid super dry air blast will be performed (dew point -40°C). The final water molecules are removed by turbulence effect, while the openings at each end of the structure are monitored symmetrically. The contractual dew point should thus been reached. The vacuum extraction continues up to the maximum capacity of the machine. The machine is disconnected and the structure is then ready for inerting.

8.1.2 Equipment

Depending on the size of the structure, two systems can be used to make the vacuum:

- Vacuum pumps
- Ejectors, generally operating by compressed air.

Vacuum pumps are particularly suited for smaller structures (width/diameter) and when the internal pipe temperature is higher than 10°C. Vacuum pumps have a constant volume rate of flow which has the disadvantage of lengthening considerably the drying time.

The limits of intervention and responsibility between the CONTRACTOR and the COMPANY (operator) are generally situated on the production platform just upstream of the temporary piping connected to the pipeline and installed by the operator for the needs of precommissioning. This interface limit is marked physically by a vacuum-tight bi-directional isolation valve (see skeleton diagram: Appendix 4).

Ejectors may be mounted in series and their efficiency can be greatly improved by using a condenser. They are supplied by compressed work-site air. They have the following advantages:

- They have no moving parts.
- They can be used to treat large volumes.
- They are compact and mounted on Skid.
- In the working zone (100 to 10 mb) they work with a mass flow rate which decreases slowly with intake pressure.
- They only require a supply of compressed air.

8.2 Drying by circulation of dry air

The water evaporates by mass transfer to a dry effluent such as air.

The latent heat of vaporization is taken from the ambient environment of the pipe and from the circulating effluent.

This method has the following advantages:

- It does not affect the safety of existing installations.
- It is not polluting.
- It requires no special equipment at each end of the structure.

However, it does require:

- A high compression capacity on site
- A bulky air drying system (dew point - 40°C)
- Time: 20 to 25% longer on average than vacuum drying.

8.3 Drying by circulation of natural gas

The method is identical to the above, but air is replaced by production natural gas.

The gas must be dry and free from all agents, which are corrosive in the presence of water vapour (H₂S, CO₂, etc.).

It requires that on-site production be potentially feasible and that all surface installations be already commissioned.

Its main advantage lies in the simplicity of the equipment to be installed.

Equipment costs are very low.

Its disadvantage is at the other end of the structure and concerns the problem of disposal of gas charged with water vapour:

- It is unfit for consumption.
- It has to be retreated and dried.
- Otherwise, it has to be flared, with all the disadvantages that this brings with it (large quantities).

9. Criteria for selecting a drying method

9.1 Key factors

Before choosing one or other line drying process, it is essential to identify all the factors and parameters influencing the choice. These include:

- Environmental and safety conditions
- Operating requirements, power and space available, existence of an available flare line, etc.
- Process requirements
- Dew point to be achieved
- Cost and time limits.

The enclosed tables B and C outline the approach to be adopted for the choice of swabbing and final drying techniques respectively.

For swabbing, we note that:

- Air is the safest method while the other methods use methanol.
- The use of methanol may have a direct impact on neighbouring activities.

For drying (table C), we note that:

- Vacuum or dry air drying are the safest methods.
- Drying with production gas must be carefully analysed with respect to adjacent construction activities.
- In the drying method involving large gas flows, the gas used and rendered unfit for consumption (H₂O content) must be flared and operation costs are far from insignificant.

9.2 Selection criteria

Each project has specific corresponding selection criteria. These include:

- Line characteristics (length, diameter, coating, geographical zone, trenching, etc.)
- Line equipment and extremities

- Commercial specification of the gas produced
- Planning restrictions
- Budget.

The enclosed table in Appendix 7 is a guide to data collection.

In all cases, the CONTRACTOR must justify his decision tree by a calculation method and by the ensuing routines.

9.3 Choice of method

9.3.1 Approach

The selection procedure for a pipe drying method is based on the following considerations:

- Choose the drying method which corresponds to the choice of criteria applicable to the pipe and which start with the gas specification
- For each drying method, choose a swabbing method
- Compare costs, results and duration of each method
- Construct a decision tree based on the one given in the table of Appendix 8.

9.3.2 Method selection procedure

One consideration is essential: that of the commercial specification of the gas to be conveyed in the pipe, mainly as regards corrosive agents, H₂O, CO₂, H₂S, etc.

In the case of a corrosive gas, the vacuum or nitrogen drying methods must be used.

When the gas is non-corrosive, the dew point to be attained is not exceptional and all drying methods are potentially feasible. In this case, a series of questions/answers are used to select the feasibility of drying with gas.

For most gas pipes, the choice tree in table E shows that at least two methods are always applicable.

9.3.3 Choice of a combined swabbing and drying method

A combined swabbing/drying method can usefully be associated with each of the separate drying methods shown to be possible in the tree in table 4.

Considerations of cost and total duration of structure precommissioning operations will resolve any remaining ambiguities.

At each step of the method, the CONTRACTOR must consider this cost/performance criterion before adopting the final adopted precommissioning procedure.

9.3.4 Decision table

The CONTRACTOR will propose a decision table to the COMPANY, which will justify the final choice of method chosen, from pipe dewatering up to inerting at the contractual dew point.

This decision table will also be used during the procedure to correct hypotheses or parameters, which prove to be incorrect. It will be based on the models given in Appendix 10 of the present document, the major characteristics of which are given here below.

9.3.4.1 Part A

All operating criteria are listed in order of priority along with their advantages and drawbacks (column 2).

Then (column 3), a value 1, 3 or 5 is attributed to them according to their relative importance. The criteria are then given a score of 1 to 10 for each alternative proposed.

9.3.4.2 Part B

Only those criteria of part A with a value of 5 are retained and their corresponding score is copied into columns (4), (5), (6) and (7).

The total score of each alternative is calculated and the best solution is thus deduced.

9.3.4.3 Part C

The same procedure as above is applied for the criteria with a value of 3.

A classification of secondary criteria is thus established.

9.3.4.4 Part D

If the choice of a solution has not been made or is not clear, third order criteria of value 1 can be processed in the same way.

Appendix 10, Appendix 11 give an example of a decision table (ALWYN 24 inch gas trunkline).

10. Calculation methods

This chapter proposes a calculation method and a formula to quantify the effectiveness and performance of precommissioning operations. All the formulae given below are tabulated with routines generally available from the CONTRACTOR.

10.1 Natural gas water content

To calculate the dew point and the gas water content, either of the two McCarthy and MacKetta nomographs can be used with the Bucacek method, which gives in percentage:

$$\left(\text{mg} / \text{Nm}^3\right) \% \text{H}_2\text{O} = \frac{A}{P} + B$$

P: absolute pressure in bars

A and B are coefficients which depend on temperature

- From -40°C to +40°C:
 - $A = 4926.5573 \exp (0.0737433 t - 0.00030673912 t^2)$
 - $B = 44.8739 \exp (0.053570327 t - 0.00019866041 t^2)$
- From 40°C to 90°C:
 - $A = 6156.9611 \exp (0.0620686 t - 0.00013096345 t^2)$
 - $B = 40.5058 \exp (0.055042799 t - 0.00016553793 t^2)$

- From 90°C to 130°C:
 - $A = 6156.9611 \exp(0.0620686 t - 0.00013096345 t^2)$
 - $B = 70.0737 \exp(0.032637894 t)$

The water content of acid gas is higher than that of inert natural gas. Nomographs exist to make the correction.

10.2 Hydrate formation

A number of calculation methods exist.

The Carson and Katz method is given below for reference. It is based on the equilibrium constants of water vapour/natural gas mixtures.

Conditions which favour hydrate formation are:

- Gas at a temperature below the water dew point, i.e. presence of free water
- Low temperature (below 4°C)
- High pressure
- High levels of agitation (turbulence, pulsations).

Conditions which inhibit hydrate formation are:

- Addition of methanol or glycol
- Gas pressure reduction
- Pipeline heating.

10.3 Quantity of liquid left after swabbing

After the methanol and gel trains have passed through, a film of liquid, comprised of a water/methanol mixture, remains on the pipeline walls.

The thickness of this film is directly proportional to the wall roughness (height of asperities).

$$L_Q = 10^{-6} \pi I_d L L_r$$

Where:

- L_Q Quantity in m^3
- I_d Diameter in mm
- L Length in km
- L_r Quantity of film in cm^3/m^2 of surface area

Type of surface	Film thickness (mm)	Quantity of film (cm^3/m^2)
Slightly oxidized bare steel	0.05 to 0.1	50 to 100
Epoxy	0.02 to 0.03	20 to 30

10.4 Pipeline dewatering

10.4.1 Flow rate of the propulsion agent

It can be calculated with the formula:

$$D = 2.791 \cdot 10^{-3} \cdot V \cdot P_d \cdot (I_D)^2$$

Where:

V is the pig propulsion velocity in m/s

P_d is the discharge pressure of the propulsion agent in bars

I_D is the inner pipe diameter.

The discharge pressure of the agent (air, gas) can be evaluated as the sum of head loss due to pig friction and difference in manometric head at the two pipe extremities.

$$P = 9.81 \cdot 10^{-5} \times RO \times H$$

RO Density of the liquid filling the pipe

H Manometric head

10.4.2 Swabbing with methanol

Indications given in documents such as the British Gas Engineering Standard [BGC/PS/PCI](#) may be consulted.

These standards give the calculation methods for the methanol and nitrogen volumes in the various trains and the discharge pressures required to move them.

10.5 Vacuum drying

10.5.1 Preliminary calculations

- Estimation of the quantity of water remaining after swabbing
- Calculation of the internal pipe volume
- Determination of Saturated Vapour Pressure (SVP) of the water (in the pipe) at ambient temperature
- Determination of the Final Pressure (FP) of the specified final dew point.

10.5.2 Vacuum extraction phase

Stage 1: the mass M₁ (kg) of air in the pipe under initial conditions is:

$$M_1 = 1.293 \cdot V_i \cdot \frac{273}{273 + t_i}$$

Stage 2: the mass M_2 of air in the pipe at the start of vaporization is:

$$M_2 = 1.293 * \frac{273}{1023} V_i * \frac{SVP}{273 + t_1}$$

Where:

$$t_1 = t_2$$

$$P_2 = SVP$$

Stage 3: the mass M_3 of the air extracted from the pipe is:

$$M_3 = M_2 - M_1$$

Stage 4: as the ejector capacity SC_1 (kg/h) and its efficiency are known, the durations D (hours) can be deduced:

$$D_1 = \frac{M_3}{4 * SC_1}$$

10.5.3 Evaporation phase

It is assumed that temperature and pressure remain constant until the end of evaporation, thus, $P_3 = SVP - t_3 = t_1$, and the duration of this phase is:

$$D_2 = \frac{LQ}{E_2 * SC_2}$$

10.5.4 Final drying

At the end of this phase, the conditions are Pressure: FP , Temperature: $t_4 = t_1$

- Stage 1: the mass M_4 of evaporated air equals M_2
- Stage 2: the mass M_5 of residual air at the pressure FP is:

$$M_5 = 1.293 * \frac{273}{1023} V_i * \frac{FP}{273 + t_1}$$

- Stage 3: the mass M_6 of air extracted from the pipeline equals $M_2 - M_5$
- Stage 4: the duration of this final phase is:

$$D_3 = \frac{M_6}{E_3 * SC_3}$$

- Stage 5: the total duration of drying is then $D_4 = D_3 + D_2 + D_1$

10.6 Air purge and gas purge

These purges are based on the same principle, i.e. the mass transfer of water molecules from the pipe wall to a jet of dry fluid injected into the pipe.

10.6.1 Required water quantities

$$W = K S C_m$$

Where:

- W is the quantity of water required to saturate the dry fluid per unit time (9/s)
- K is the mass transfer coefficient (cm/s) determined as per further formula (*)
- S is the transfer surface area
- C_m is the mean value of the water concentration gradient of the film remaining on the pipe wall.

$$(*) K = A * Re^n * Sc^m * \frac{D}{d}$$

Where:

- d Pipe diameter in cm
- D Water vapour diffusion capacity in a dry fluid (cm²/s)
- Re Reynolds number $Re = \frac{d \cdot u \cdot \rho}{\mu}$
- Sc Schmitt number $Sc = \frac{\mu}{\rho \cdot D}$

With:

- μ absolute viscosity of the dry fluid
- ρ density of dry fluid in pipe
- u dry fluid velocity in the pipe
- A, n, m are constants determined by Gilliland: A = 0.023, n = 0.83, m = 0.44

$$C_m = \frac{C_0 - C_1}{\ln \frac{C_0}{C_1}}$$

C₀ and C₁ are respectively the water concentrations of the fluid on the pipe wall and in the middle of the pipe, C₀ being the value at the start of the mass transfer process and C₁ at the end.

10.6.2 Required gas quantities

In the gas purge method, an initial estimation of the gas quantities required can be made as follows:

10.6.2.1 Stage 1

Give a value for purge pressure and determine the water content of the saturated purge gas (WS) at the pipe temperatures and pressures.

10.6.2.2 Stage 2

As the water content of the purge gas (WO) is known, the quantity of water (WE) conveyed with each N/m³ of purge gas can be determined as: $WE = WS - WO$

10.6.2.3 Stage 3

The required gas quantity (GQ) is estimated as:

$$GQ = \frac{LQ}{WE}$$

With:

LQ in grammes

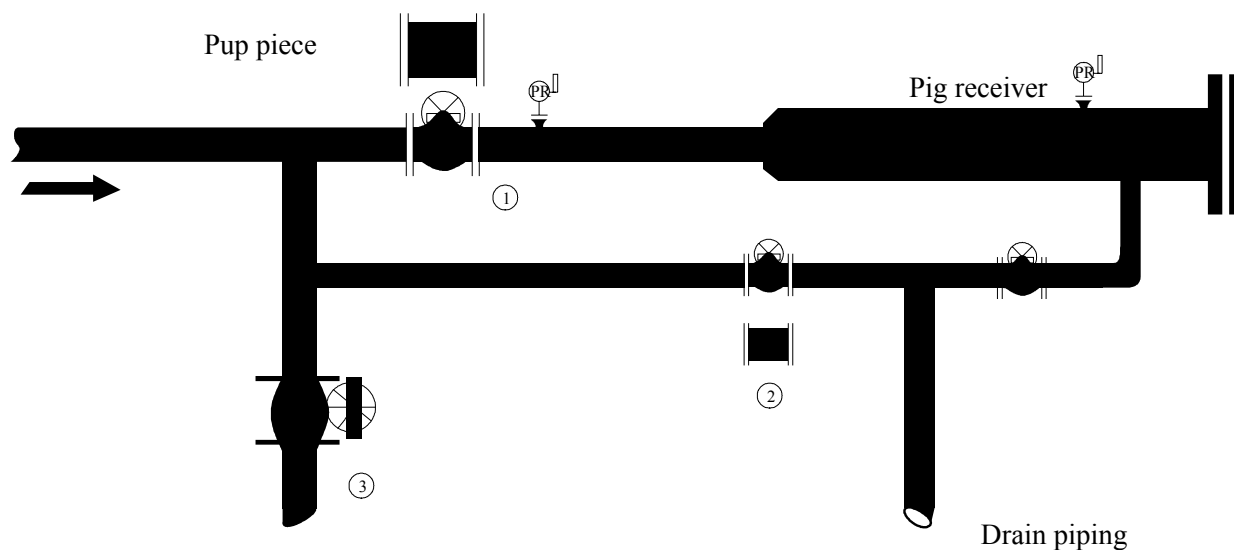
We in grammes per N/m³

10.6.2.4 Stage 4

A purge flow rate is given and a check is made, by means of head loss, to see whether the purge pressure for mean flow rate given in Stage 1 has been reached. If not, the procedure is repeated from Stage 1 with a different pressure value.

When the right pressure is reached, the purge duration is obtained.

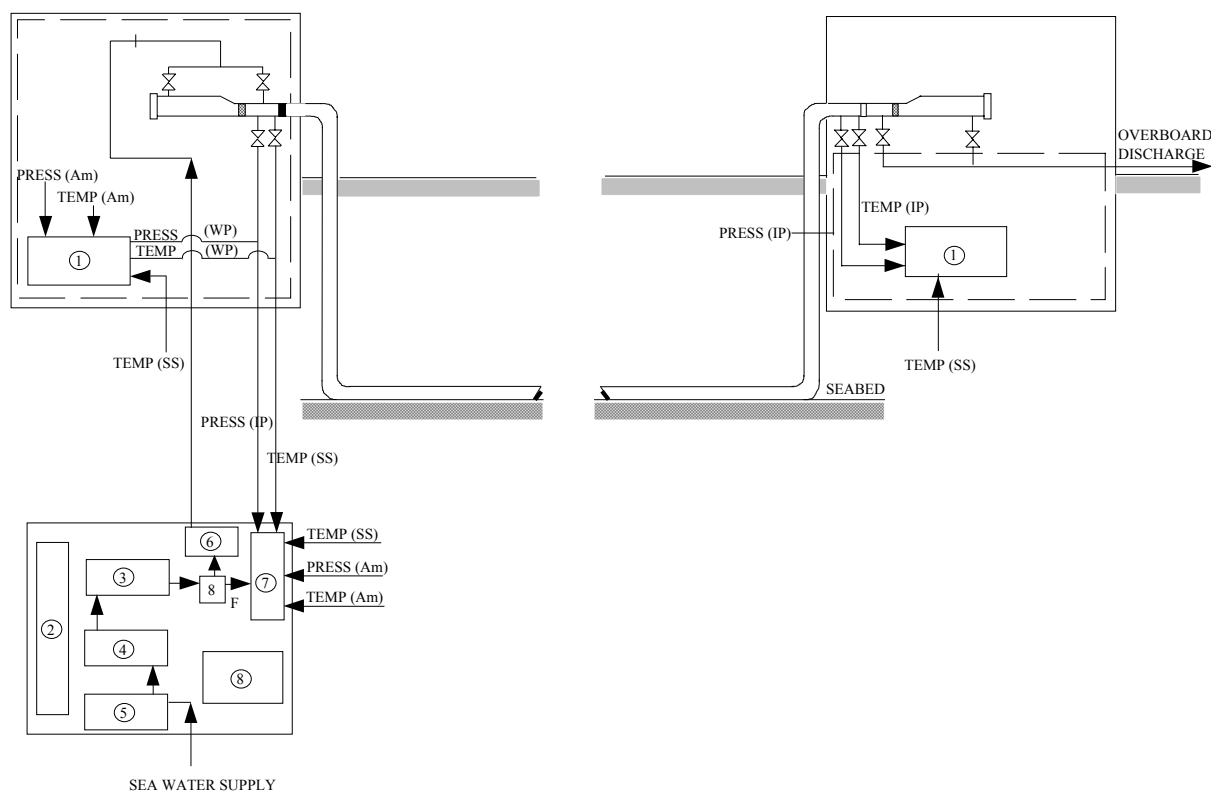
Appendix 1 Preparation of initial dewatering



- NR ② - ① Manual valves not installed or removed prior to initial pigging and replaced by a pup piece.
- NR ③ Motorised valve closed during dewatering.

Hydrostatic tests carried out with pig trap under

Appendix 2 Typical layout of instrumentation and equipment

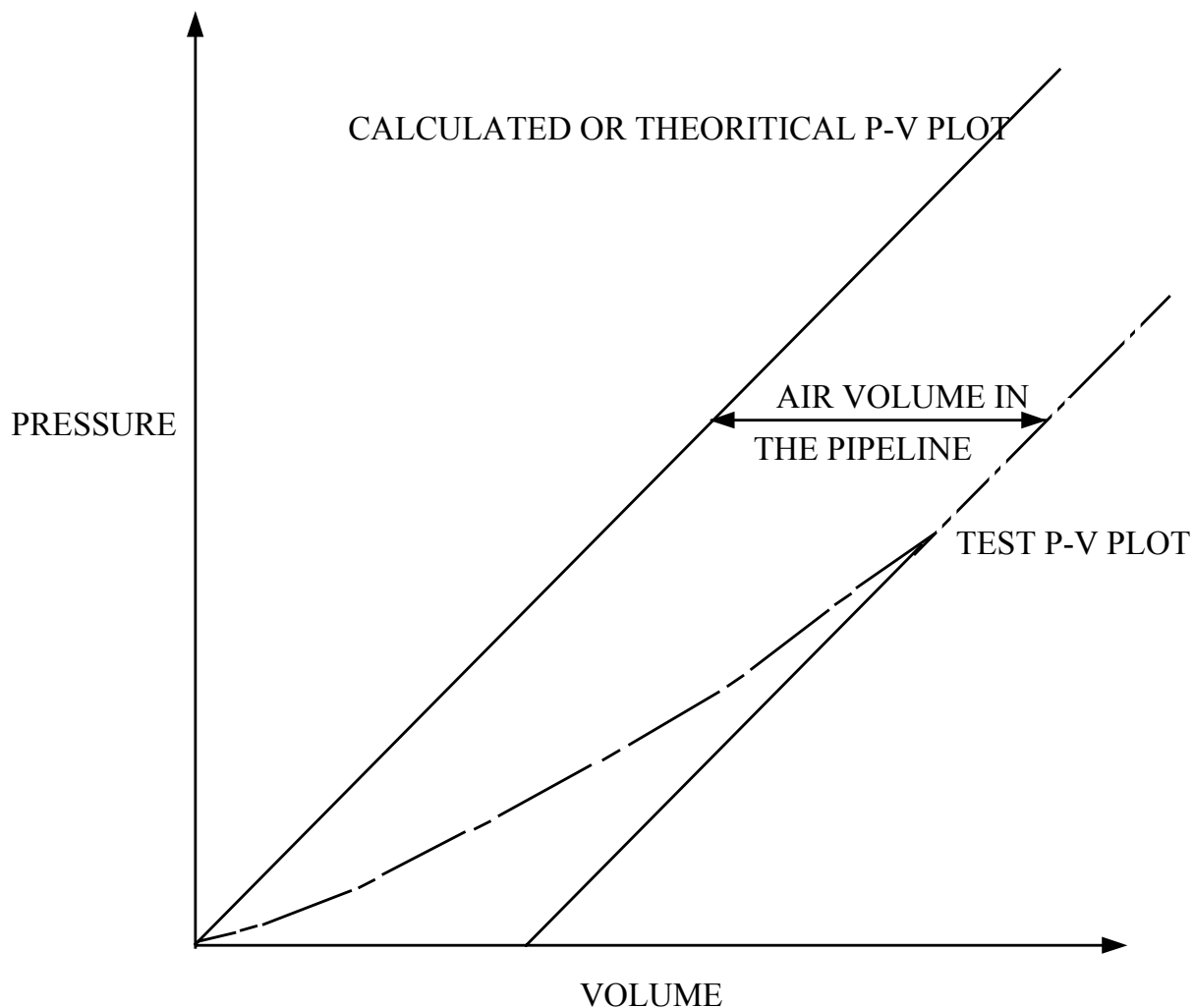


Key:

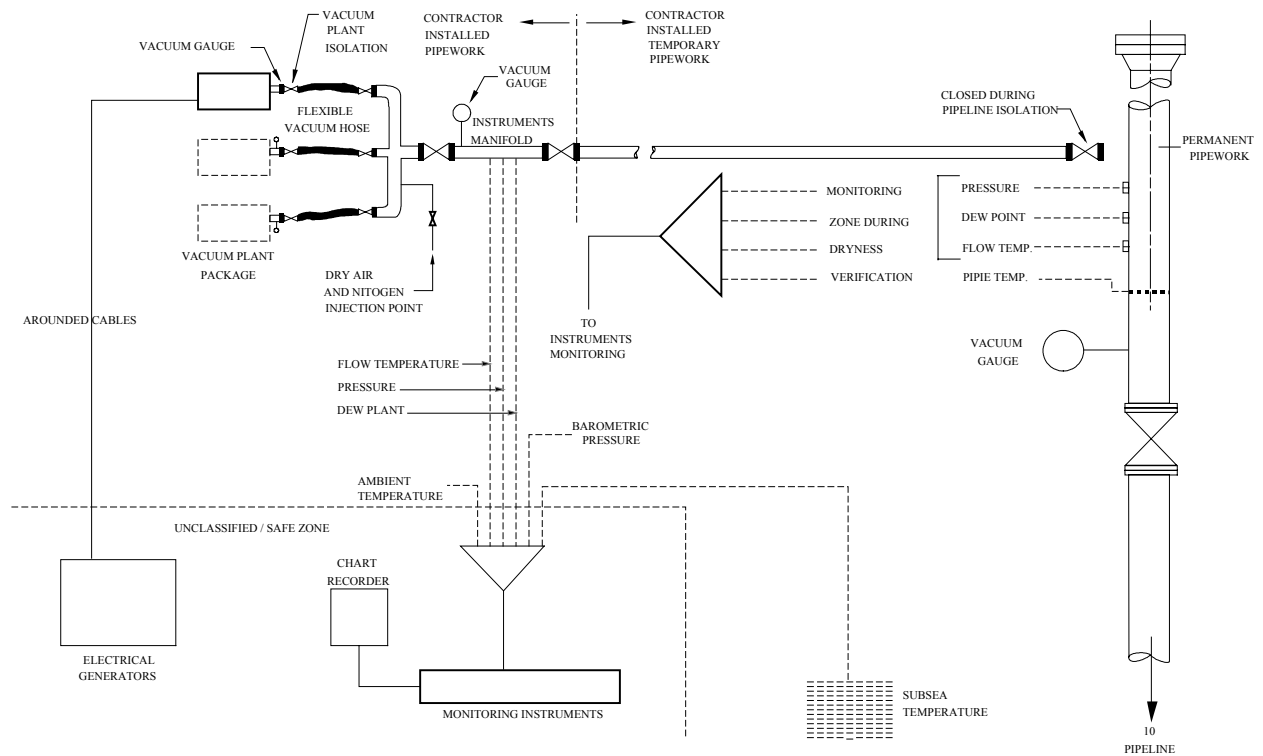
①	Data acquisition	PRESS (I.P)	= Internal pipeline pressure
②	Compressor package	TEMP (I.P)	= Internal pipeline temperature
③	Pumping package	PRESS (Am)	= Ambient pressure = barometric pressure
④	Water treatment	TEMP (Am)	= Ambient temperature
⑤	Tankage	TEMP (EP)	= External pipeline temperature
⑥	Hoses	TEMP (SS)	= Subsea temperature
⑦	Test cabin	F	= Flowrate
⑧	Gelled fluids	D	= Dew point

Tightness test

Appendix 3 Pressure/Volume plot



Appendix 4 Typical layout of vacuum plant



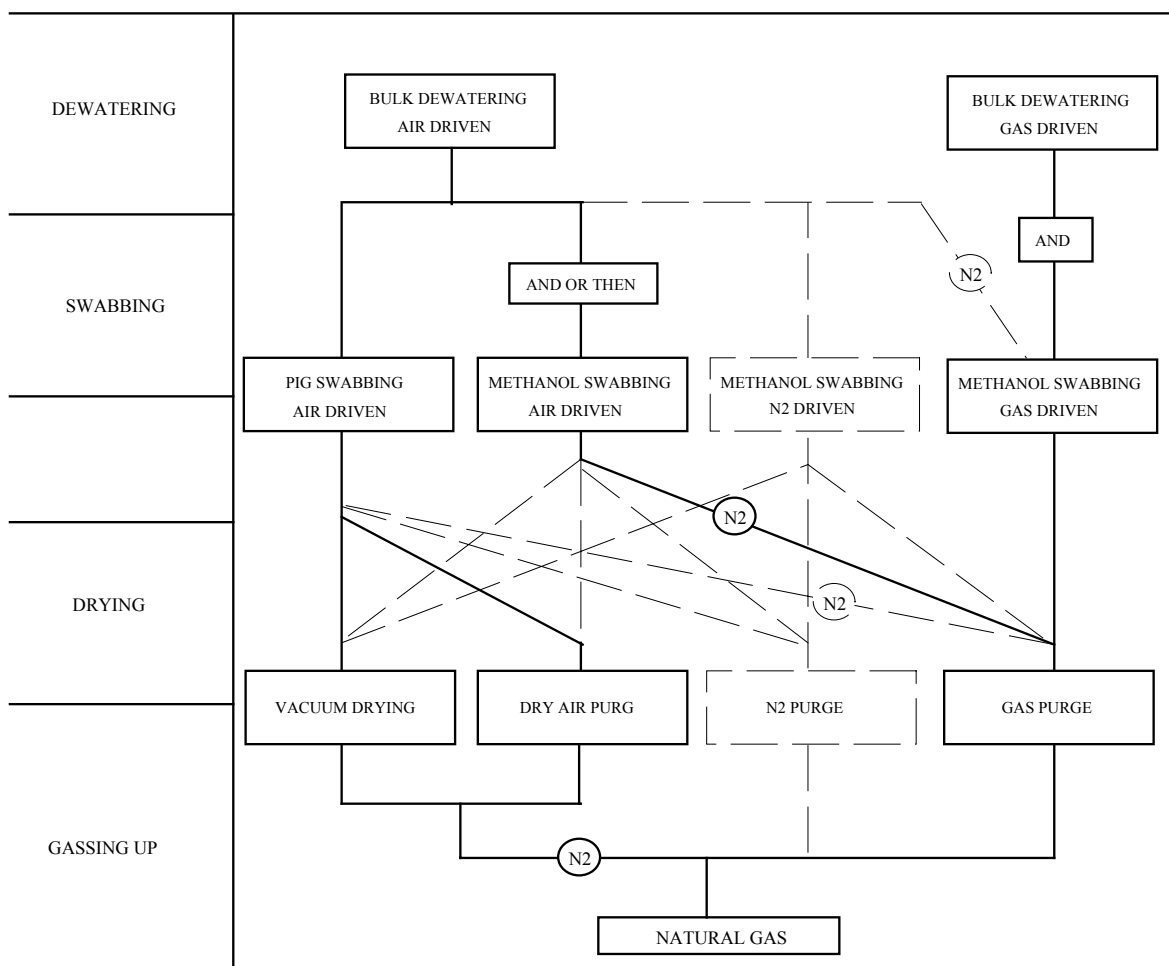
Appendix 5 Factors affecting the choice of dewatering and swabbing methods

Swabbing method	Air propelled kaliper pigs	Air propelled methanol plugs	Nitrogen propelled methanol pigs	Gas propelled methanol pigs
Nuisance		Pollution (methanol)	Pollution	Pollution and flaring
Safety		Danger of methanol	Dangers of methanol and liquid nitrogen	Dangers of methanol and gas
Operational requirements				
- Effluent	Gels	Methanol and gas	Methanol + gels + M ₂	Methanol + gels + gas
- Manpower	Limited	Moderate	Moderate	Moderate
- Equipment	Compressors and gel storage	Compressors, pumps	Effluent storage and expansion	Pumps - Flare
- Available space	Moderate	Large	Large	Moderate
Aspects of process				
- Pressure	Low	Medium, a single train	Medium	Medium, a single train
- Hydrate formation	None	None	None	Possible
- Results	Residual water film	Residual water film + methanol	Residual water film + methanol	Residual water film
- Improvement	Repeated passage of trains	High cost with a second train	Very high cost with a second train	High cost with a second train
Duration	Moderate	Short	Short	Short
Cost	Moderate	Moderate	High	Price of gas

Appendix 6 Factors affecting the choice of drying method

Methods	Vacuum	Dry air	Nitrogen	Gas
Nuisance	Ejector noise			Heat of the flare
Safety			Danger of liquid nitrogen	Danger inherent to gas
Operating constraints				
- Effluent			Nitrogen storage	Large available quantities of dry gas
- Manpower	Low manpower		High manpower	Low manpower
- Equipment	Powerful air compressors and ejectors	Large air compressors and desiccators	Vaporizer	Expansion equipment and available flare
- Space required	Moderate	Numerous pigs		
Process parameters				
- Pressure	Close to vacuum	< 8 bars Favourable	< 4 bars	As low as possible
- Ambient air: sea temperature	High temperatures favourable			
- Sea/pipe transfer coefficient	High coefficient favourable			
Pipe characteristics - Short, small diameter		Preferable for small pipe	Small pipe	
Dew point result	Excellent -35°C	Good	Very good	Fair -20°C
Duration	Medium	Long	Medium/long	Medium
Cost	Moderate	High	Very high	Price of gas

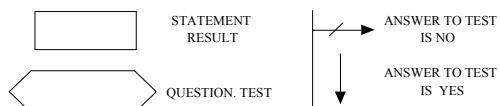
Appendix 7 Dewatering and drying available methods and possible combinations



Appendix 8 Selection chart of drying methods



LEGEND



NOTE

This chart is valid for pipelines having a normal and high range heat transfer coefficient. For pipelines with low range heat transfer coefficient (e.g. polyurethane foam insulated pipelines), the chart can be used but the vacuum drying method is not applicable.



Appendix 9 Commissioning application

Gas pipeline data

P.L. NAME:

From: _____

to : _____

Diameter (inch): _____ Length (km): _____

OWNER/operator: _____

Design pressure (bar): _____

Design flowrate: _____

Wall thickness (mm): _____

Steel grade: _____

Offshore length (km): _____

P.L. status on seabed: _____

Construction period: _____ Commiss. period: _____ ST. up date: _____

Gas dataNatural Gas ☐Other Gas ☐

Composition:

CO₂ (%) _____ H₂S (%) or (mg/Sm³): _____ Total sulfur (mg/S m³): _____Water content (mg/Sm³): _____ Water dew point (°C): _____ AT (bar): _____

Specific gravity/air: _____ Hydrocarbon dew point (°C): _____ AT (bar): _____

Flow mode: _____ When diphas, flow, liquid content (g'Sm³): _____

Other data – Comments:

Inlet facilities:

Outlet facilities:

Intermediate facilities:

Commissioning data:

- Pipeline status before commissioning:
- Pipeline status after commissioning:
- Mean ambient temperature (°C): _____ Mean temp. of surround. medium (°C): _____
- _____ S
urrounding medium of P.L.: _____

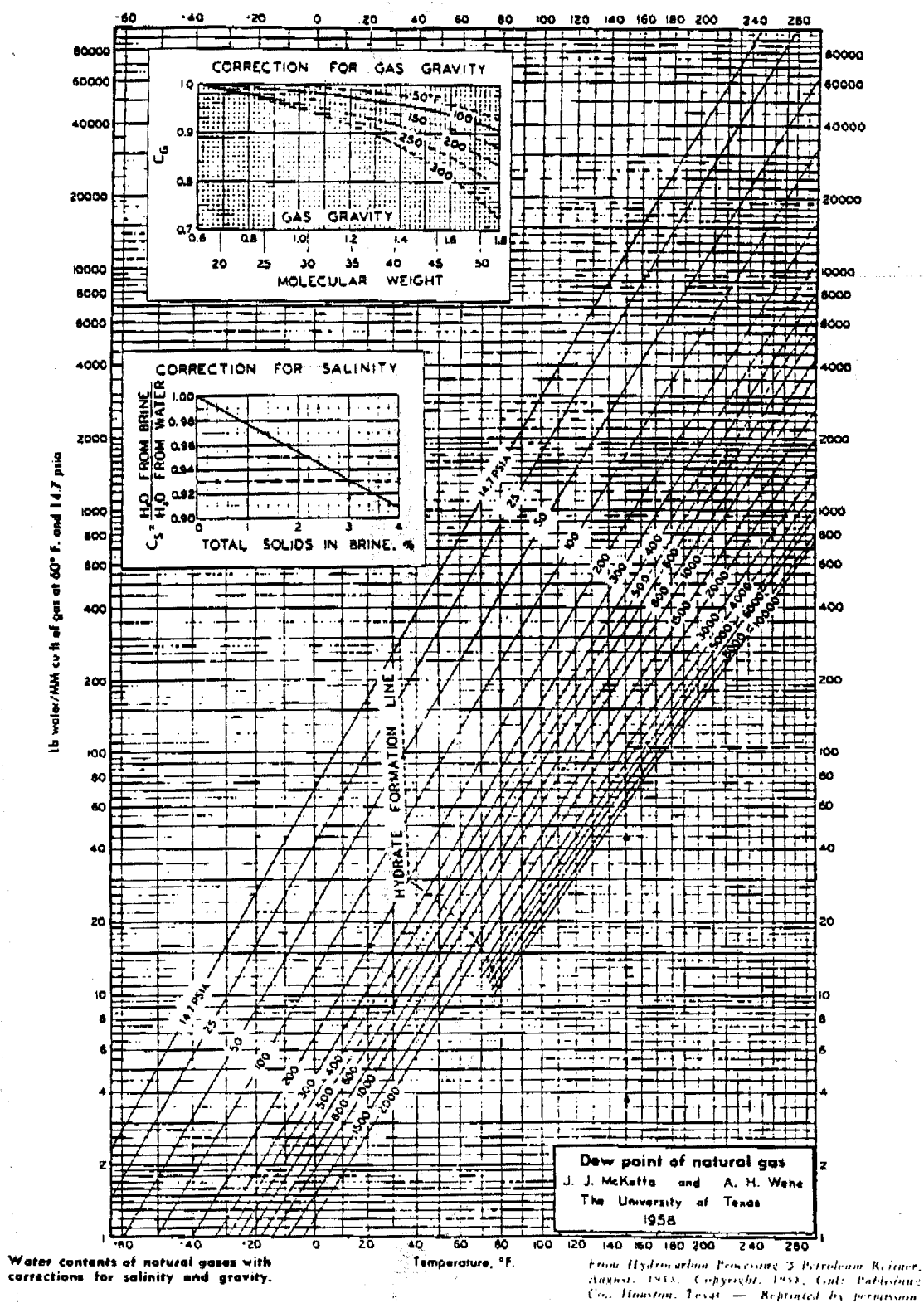
Appendix 10 Decision table

Area no	Criteria	Criteria value	Alternatives			
			No 1	No 2	No 3	No 4
A	-					
	-					
	-					
	-					
	-					
	-					
	-					
	-					
B	-	5				
	-	5				
	-	5				
	-	5				
	Total for 5 value					
C	-	3				
	-	3				
	-	3				
	-	3				
	Total for 3 value					
D	-	1				
	-	1				
	Total for 1 value					
Grand Total						

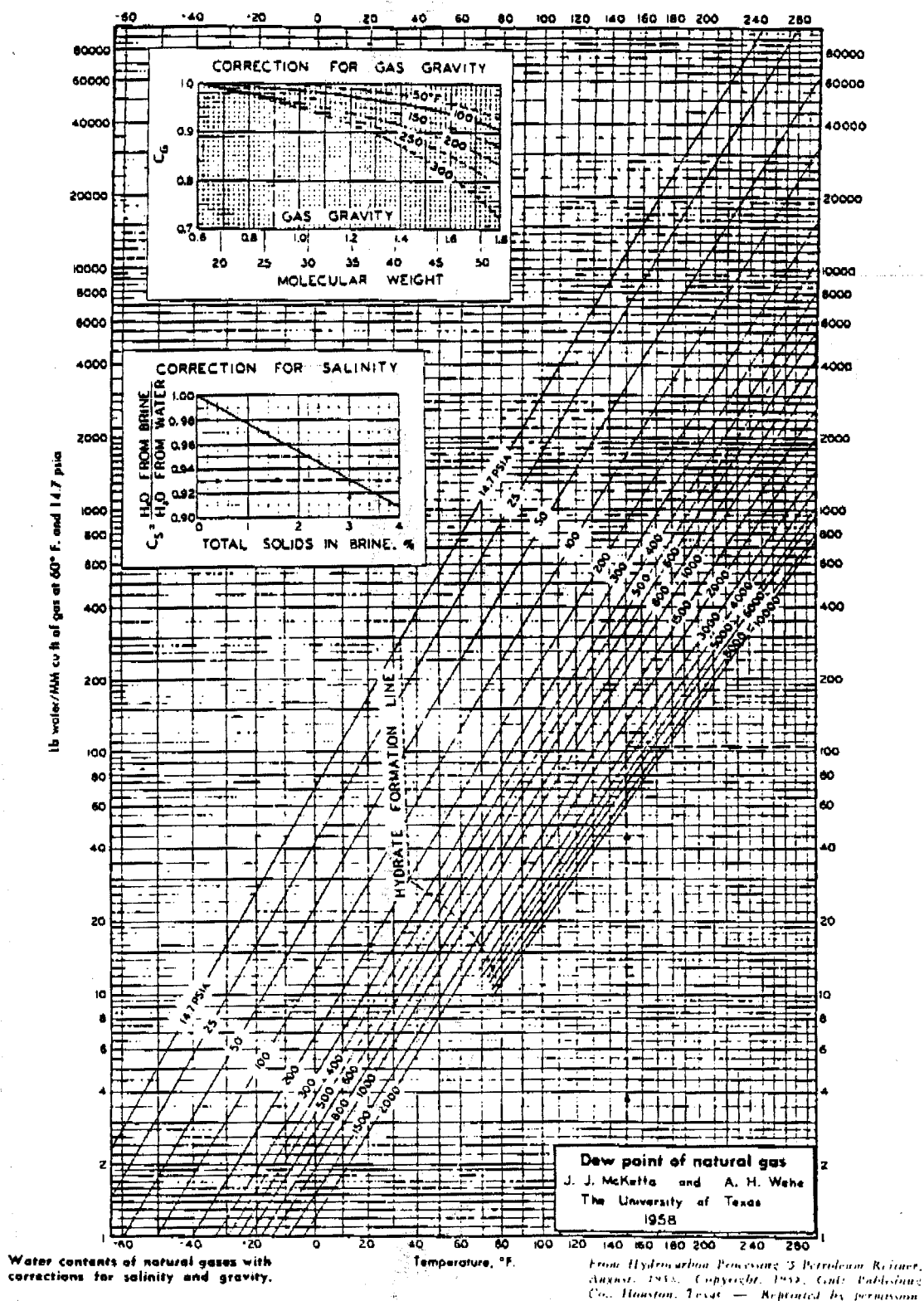
Appendix 11 Application to Alwyn - Frigg gas pipeline

Area no	Criteria	Criteria Value	Alternative 1 (Vacuum)	Alternative (Gas purge)
A	- Short duration	3	8	8
	- Low cost	5	10	6
	- Low water dew point	5	8	8
	- Reliable prediction of performance	3	8	8
	- Safety	5	10	4
	- No environment sensitivie	3	10	6
	- No danger of pig blocage	3	8	6
	- Low manpower	3	8	8
	- No interference with other platform jobs	5	10	6
	- No danger of corrosion	5	10	6
B	- Low cost	5	10	6
	- Low water dew point	5	8	8
	- Safety	5	10	4
	- No interference with jobs on platforms	5	10	6
	- No danger of corrosion	5	10	6
	Total area B		48	30
C	- Low duration	3	8	8
	- Reliable prediction of performance	3	8	8
	- No environmental sensitive	3	10	6
	- No danger of pig blocage	3	8	6
	- Low manpower	3	8	8
	Total area C		42	36
	Total B + C		90	66

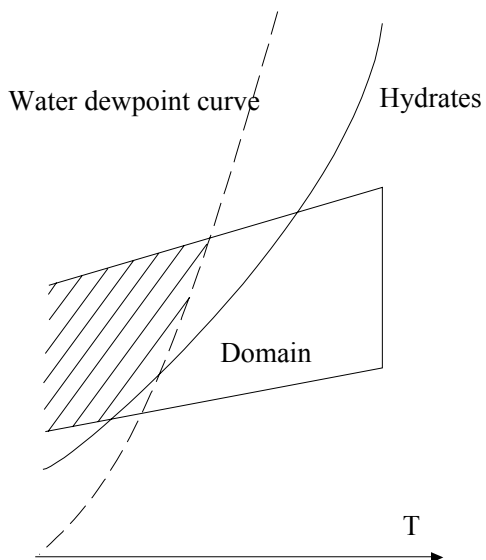
Appendix 12 Teneur en eau à saturation du gaz naturel



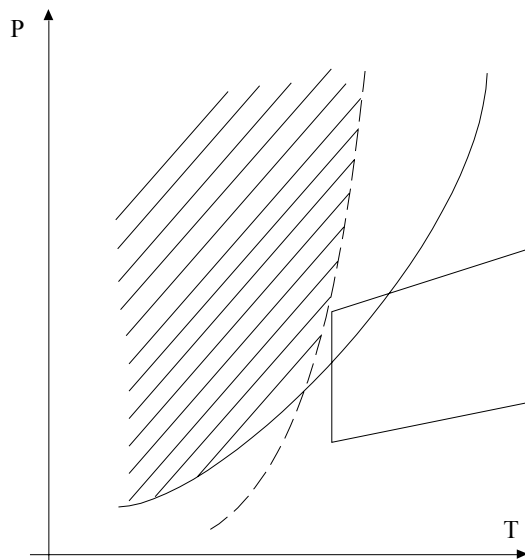
Appendix 13 Dew point of natural gas



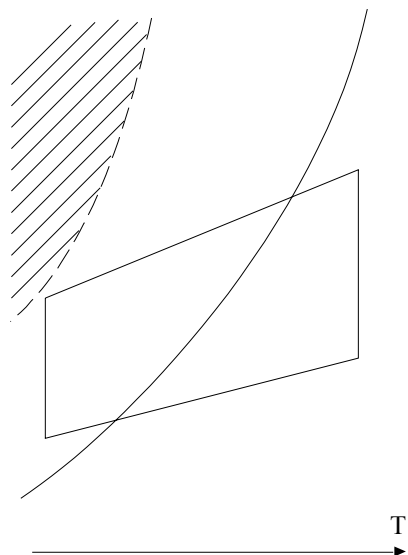
Appendix 14 Solutions for avoiding hydrate formation in a pipeline



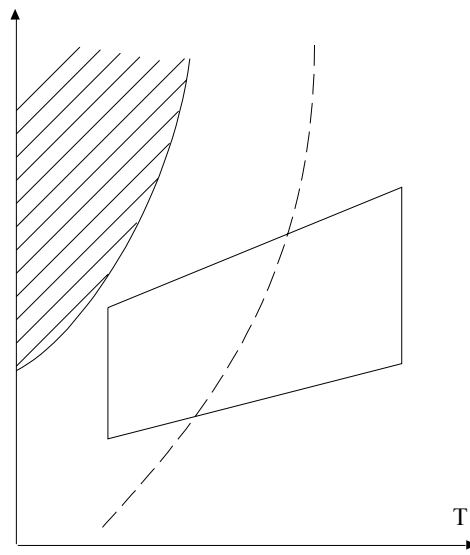
Initial diagram



Type 1 solution
(displacement of the operating domain)



Type 2 solution
(Dehydration)



Type 3 solution
(Inhibition)

Appendix 15 Hydrate formation predictive curves

