Dewatering and drying operational problems associated with residual water in oil and gas onshore and offshore pipelines

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INTRODUCTION

Pipeline pre-commissioning is the process of proving the ability of a pipeline and piping systems to contain product without leaking. This product may be liquid, gaseous or multiphase hydrocarbons, water, steam, CO2, N2 etc. Pre-commissioning is the series of processes carried out on the pipeline before the final product is introduced. The process during which the pipeline is made "live" i.e. the product is put in the pipeline, is called pipeline commissioning and start-up.

The newly constructed pipelines are typically hydrostatically tested, using water as the test medium, to demonstrate that the pipeline has the strength required to meet the design conditions, and to verify that the pipeline is leak free. (See Fig.1)

It is necessary that pipelines used to transport hazardous or highly volatile liquids be tested at a pressure equal to 125% of the maximum allowable operating pressure (MAOP) for at least four continuous hours. The requirement to test to 125% of the MAOP will therefore cause the pipe to be tested to a pressure equal to 90% of the SMYS of the pipe.

If after dewatering, residual moisture in the pipeline poses a problem, it will be necessary to clean and dry the pipeline. Pipelines used to transport crude oil and/or refined products will probably only require removal of the test water before the line is placed in service.
If the pipeline will be used to transport materials which must meet a specified dryness requirement, the pipeline will need to be dewatered, cleaned, and dried. Pipelines used to transport natural gas will need some drying, depending on the operating pressure and the location of the line, to prevent the formation of hydrates. Other pipelines may require drying to protect the pipe from internal corrosion caused by the formation of corrosive acids, such as carbonic acid in the case of carbon dioxide pipelines.

**DEWATERING**

Horizontal dewatering is an activity by which water is extracted through drains. The horizontal closed drainage system is applied primarily for large areas and long stretches of trench typically found in construction. Dewatering is considered to commence with the running of the first pig after hydrostatic testing is completed and begins with the insertion of a displacer, commonly referred to as a pig, in the pipeline. The dewatering pig may be pushed through the pipeline with crude oil or other petroleum product if no drying is required. If the pipeline is to be cleaned and/or dried, the pig will be pushed by either compressed air or gas. In both case, proper precautions must be taken to be sure the test water is properly disposed of and that any required water discharge permits are obtained ahead of the dewatering operation. However there are many operational problems during dewatering to develop, causing the pig to stick or even disintegrate. Air locks are more likely to occur in hilly country than in flat land. Air locks occur when the accumulated static heads are greater than the available displacing pressure. When an air lock condition occurs, it is necessary to either increase the displacing pressure, or remove air/gas through existing vents or other connections at high points in front of the pig.

**DRYING**

Natural gas pipelines are usually dried to a lesser extent to prevent the formation of hydrates. It is not unusual for a petrochemical line to be dried to a dew point of -40°C. Dew point, by definition, is the temperature at which water vapor begins to condense out of a gas at atmospheric pressure. For example, at atmospheric pressure, water vapor begins to condense out of a gas that has a moisture content of seven pounds of water per million standard cubic feet at -39°F.

The most common methods for drying pipelines are as follows:

1. Drying with super dry air
2. Drying with methanol
3. Drying with inert gas such as nitrogen
4. Drying with the medium to be transported
5. Vacuum drying

Often a combination of two or more methods will be used to achieve a dry pipeline at the least cost. The first three methods are probably the most economical and technically feasible for most pipeline drying applications.

Dew-point readings will need to be made to determine when the line has been dried to the specified dew point. Drying with super dry air provides internal corrosion protection if the line is to remain out of service for some period of time before it is placed in service.

In *drying with super dry air*, soft foam pigs pushed by dry air are used to absorb any free water remaining in the pipeline after dewatering. After the line is dry, wire brush pigs are run to remove any water bearing debris from the pipe wall.

*Methanol drying* relies on the hygroscopic effect of the methanol. Any remaining moisture in the line will be absorbed by batches of methanol pushed through the line with either gas or dry air. Pigs are used to separate the methanol batches from the displacing medium. Pure methanol is expensive and sometimes a 96% methanol/water mix is used. Since the methanol mix contains water, some water will be left in the pipeline. Some of the methanol will vaporize in the pipeline and will be absorbed by the displacing medium. Towards the end of the line, the moisture content of the methanol will increase, which in turn reduces the amount of water that it can absorb. If the pressure used in the drying operation is too high, hydrate formation can occur, usually at the far end of the line. Methanol run with a dry gas will absorb most of the water and facilitate the vaporization of the remaining water. Soft swabs run through a line with a dry purge gas will accelerate the evaporation of remaining methanol/water solution.
**Vacuum drying** is a slow process and all free water should be removed from the pipeline before drying begins. This method appears to be used infrequently, and perhaps only offshore. If the pipeline has been properly cleaned by the water slug method using brush pigs run with liquid, drying can be accomplished by running soft foam pigs with dry air or gas to remove any free water left in the pipeline. This will usually produce a pipeline dry enough for natural gas operations. If additional drying is desired, it can be accomplished by using methanol or super dry air.

**VACUUM DRYING**

The vacuum drying process, as with the air-drying process, physically removes all the water from the pipeline. In air-drying, it is blown out and in vacuum drying it is evacuated out. The vacuum drying process relies on the fact that the boiling point of water varies with pressure, so that while water boils at 100ºC at atmospheric pressure (1013 mbara) at 8.72 mbara it will boil at 5º C. Therefore, by reducing the pressure in the pipeline down to the saturated vapour pressure (SVP) for the ambient temperature we can cause the water to boil and remove it from the pipeline as a gas with a vacuum pump.

The vacuum drying process can be split into three (3) main phases (see Fig.2):

1. **Evacuation - Pump Down**
2. **Evaporation - Vaporization**
3. **Final drying – Dehumidification**

**Evacuation**

In the first phase, the pipeline pressure is drawn down from atmospheric to the saturated vapour pressure (SVP), which will vary according to the ambient pipeline temperature. During this phase, it is mostly air that is being removed from the pipeline. A leak test is usually undertaken during this first phase to check for leaks that should be repaired or if small and untraceable quantified for later use in the soak test.

**Evaporation**

As the pressure approaches the SVP, water will start to evaporate and maintain the pressure equilibrium. Thus as the pressure tries to fall further water evaporates and as such the pressure stays constant. This vapour is sucked out of the line by the vacuum pump and more water evaporates to take its place. This process continues until all free water in the pipeline has evaporated.

**Final Drying**

Once all the free water in the pipeline has evaporated, the pressure will start to fall as there is no more water to evaporate and maintain the equilibrium. All the air in the pipeline has, essentially, long since been evacuated and the pressure in the line can be assumed to be made up of only the vapour pressure of the water. Consequently, the pressure in the pipeline can be directly correlated to the dew point. A pressure of 1.032 mbara is equivalent to a dew point of -20ºC; therefore, once this pressure has been obtained throughout the pipeline it is clear that the pipeline is dry. On some long pipelines where friction plays an important part and slows down the drying process, this phase can be modified by purging through a dry gas under vacuum. This can speed up the water removal rate for this final drying process.

A further check can be carried out in the form of a soak test. Here the pressure is shut in and monitored for a period of time, typically 24 hours. If any free water is present, then it will evaporate and the pressure will rise back to the SVP for the ambient pipeline temperature. It is at this point that the leak test carried out earlier becomes important so that it can be taken into account in evaluating whether water is present. At the end of drying, it is possible to introduce product straight into the vacuum that contains no oxygen.
Dewatering Calculations

Pipeline Outside Diameter (OD) = 32” = 812.8 mm (Assumed)
Wall thickness of Pipeline (Wt) = 20.6 mm (Assumed)
Pipeline Internal Diameter (ID) = OD – 2 X Wt = 771.7 mm

Displacing medium = Water
Water depth at offshore = 90 m (Assumed)
Pressure due to static column of Water = 9 Bar
Pig train Differential Pressure = 0.5 Bar
Total Head = 9.5 Bar
Assuming maximum driving Pressure(P) = 10 Bar
Air volume flow rate (Qa) = 6000 CFM = 171.42 m³
Volume per metre (Vm) = 0.7717 m³
Pressure (P) = 1 Bar

Velocity = Qa / (Vm x (P+1)) x 60
= 171.42 / (0.7717 x (10+1)) x 60
= 0.336 m/s

Total Dewatering time = 20.16 Hours

Drying Time Calculations

Pipeline Outside Diameter (OD) = 32” = 812.8 mm (Assumed)
Wall thickness of Pipeline (Wt) = 20.6 mm (Assumed)
Pipeline Internal Diameter (ID) = OD – 2 X Wt = 771.7 mm
Pipeline Length (L) = 150 Km (Assumed)

Thickness of Residual water film left in Pipeline after Swabbing (t) = 0.1 mm
Total quantity of Residual water left in Pipeline
= π/4 x ID x t X L
= π/4 x 0.7717 x 0.0001 x 150000
= 36.380143 litres approx.

Since Density of water is 1000 Kg/m³
= 36380.143 Kg
= 80181.85 Lbs

Average Flowrate of Dry air = 6000 SCFM
Dew point of Air at Drying Unit discharge = - 20 deg C
Moisture content of Air at – 20 deg C = 51.0 Lbs/MMSCF
Ambient Temperature of Pipeline = 25 deg C
Amount of moisture content that Air at -20 deg C can absorb = 2130 – 51
= 2079 Lbs/MMSCF
= 0.002079 Lbs/SCF

Water absorption at 6000 CFM = 12.47 Lbs/min
Assuming 80% Efficiency = 9.976 Lbs/min

Time required to Dry the Pipeline
= 80181.85 Lbs / 9.976 Lbs/min.
= 8037.5 Minutes
= 134 Hours

The above calculation is based on the following assumptions.

1) There is only a film of 0.1 mm left in the Pipeline after Swabbing operation. There is not much corrosion on the internal surface of the Pipeline.

2) The Dew point of the inlet Air is – 20 deg C (as this will depend on the relative humidity and temperature of air passing through dryer at site)

3) There is no still water present in any of the connections of the Launcher and Receiver branches.

CONCLUSION

Pre-commissioning and Commissioning of Pipelines stand long decades of experience in Oil & Gas industry that undermine problems associated with Dewatering and Drying operational problems which root cause operational research with field validation experiments. A strong epidemic on ‘Vacuum Drying’ is prognosised for Subsea and Onland Pipeline Operations and Transmission Pipelines.

REFERENCES


APPENDIX-A

Sample Field Log Plots of Vacuum Drying recorded from PT, TT of Launcher/Receiver end.

Log Plot-A, Pressure = 0-1000 mbar

Log Plot-B, Pressure = 0-5 mbar