Precommissioning Engineering as a Process Plant Approach to Configure the Philosophy that Extends the Facets of Mechanical Completion

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Abstract - *Commissioning activities are those undertaken after pre-commissioning to verify the functionality of equipment. Pre-commissioning encompasses of activities to ensure transition between the mechanical completion and commissioning/startup of process plants and pipelines. The contrast between pre-commissioning and commissioning is distinguished. The pre-commissioning phase includes three main types of activities a) conformity checks, b) static (or) de-energized tests and c) piping tests; whereas the commissioning phase comprise of activities such as a) dynamic verification, b) testing with substitute fluids for start-up, c) piping and vessels start up. In this paper it is explained further more on air blowing, steam blowing methods including mechanical & chemical methods and dewatering & drying of process plants and pipelines.*

Key Words: Pre commissioning, Commissioning, Mechanical completion, Process plant & Pipelines

1.INTRODUCTION

1.1 What is Commissioning?

Commissioning is a functional verification process used to confirm that a facility has been designed, procured, fabricated, installed, tested and prepared for operation in accordance with design drawings and specifications. Commissioning activities are those undertaken after pre-commissioning to verify the functionality of equipment i.e. system / subsystems in accordance with the specified operation.

A successful commissioning shall include the following:

a. No Loss Time Accidents
b. No Equipment Damage
c. On Test Product within a reasonable period
d. No Environmental Incidents

1.2 Mechanical Completion

Mechanical completion is a milestone that is achieved when all specified work is complete and subsequent acceptance inspection and physical testing is satisfactorily performed and documented.

Mechanical completion includes inspection and testing activities will be carried out on a single discipline basis, by construction workpacks, building to systems / subsystems. Such activities will not require equipment or systems to be energised, but may include calibration of instruments, electrical insulation tests, electrical continuity tests, hydrotesting of pipes and integrity testing of valves etc.

Mechanical completion will be documented on checksheets which will be generated and managed by the Project Commissioning Management to ensure that asset integrity can be verified and demonstrated. On achievement of mechanical completion, responsibility for the facility will transfer to those in pre-commissioning and commissioning.

1.3 Pre-Commissioning / Commissioning

Pre-commissioning is the *preparation* and *execution* of new construction activities after Mechanical Completion (MC) and those to hand over Plant or Pipeline to final Commissioning team. Mechanical Completion is the checking and testing of equipment and construction in accordance with drawings and specification and in compliance to safe project requirements.

According to API RP 1FSC, Pre-commissioning is defined as the "Group of energized and static tests that constitute verification that the equipment or component is fabricated, installed, cleaned and tested in accordance with the design and ready for commissioning".

The Software ICAPS, **I**ntegrated **C**ommissioning and **P**rogress **S**ystems, is associated to support OPERCOM Pre-commissioning / Commissioning methodology. The methodology is used by the dedicated teams responsible for *preparation* during the engineering phase and for execution at the end of the project.

The Pre-commissioning phase includes three main types of activities.

- Conformity checks
- Static (or) de-energized tests
- Piping tests

On completion of these tests, RFC (Ready for Commissioning) certificate is issued for each Sub-system and there is NO outstanding punch item category A. Commissioning is the final quality check before transfer to the start-up team.

The Commissioning phase comprise of three main types of activities.

- Dynamic verification
- Testing with substitute fluids for startup
- Piping and Vessels start up

Pre-Commissioning, also known as Static commissioning, starts when a system or sub system achieves Mechanical Completion. Whereas Commissioning is the verification process where equipment and systems that have not been operated before, or have been modified, are brought into operation safely in the correct sequence. Some of the activities are highlighted and contrasted as below.

Pre-commissioning:

1. Temporary Screens, Strainers and Blinds
2. Air and Steam Blowing
3. Flushing, Chemical and Mechanical Cleaning
4. Cleaning and Passivation
5. Electrical Energizing
6. Instrumentation Verification

Commissioning:

1. Operational Tightness Testing
2. Oil Systems Flushing
3. Loading of Desiccants and Catalysts
4. Refractory Dry out
5. Run in Rotary Equipment
6. Drying out and Inerting
7. Instrument and Electrical Function Testing
8. Function Testing of Safety Systems

1.4 Roles and Responsibilities of Plant Pre-Commissioning

The roles and responsibilities of the Project based Process Plant are not limited to the following in sequence.

1. Basic process engineering
2. Detailed engineering
3. Procurement
4. Construction
5. Operations training
6. Mechanical completion
7. Pre-commissioning
8. Commissioning
9. Ready for Start Up
10. Acceptance test run

The main aim of objective training is to instruct operators to safe commissioning and to make specification production while reducing environmental impact. This is typically include several weeks of training with a plant site visit.

The staff needs general training induction in the following fields:

a. Safety and Hazard analysis
b. Furnaces
c. Boilers and Steam Turbines
d. Pumps and Compressors
e. Distillation
f. Piping and Heat Exchangers
g. Process Control Systems
h. Electrical Systems
i. Catalyst and Molecular Sieve Systems
j. Cooling Water System and Treatment
k. Process Utilities
l. Relief Valve and Flare Systems
m. Environmental Reduction

The Plant specific training shall include but not limited to the following:

1. Pre-Commissioning Procedures
2. Commissioning Procedures
3. Plant Specific P&ID Review
4. Distillation Overview
5. Plant Specific Process Variables
6. Normal Start Up and Shut Down Procedures
7. Emergency Shut Down Procedures
8. Plant Specific Environment Procedures

1.5 Standard Operating Procedures (SOP)

SOPs are important for the safe and effective operations of industrial plants, including oil and gas facilities. A lack of a good SOPs can lead to complications, miscommunications and accidents.

1.6 Pre-Commissioning Procedures

Pre-commissioning encompasses of activities to ensure transition between the mechanical completion and commissioning/start up of process plants. The following are some types of Cleaning:

1. Cleaning by Air blowing
2. Cleaning by Flushing
3. Steam blowing
4. Chemical cleaning
5. Mechanical cleaning
6. Dewatering & Drying

2.AIR BLOWING

Air blowing is widely used in Process industry to remove construction debris, loose rust, liquids and other contaminants. A temporary piping is connected to pipework construction at entry and exit and any ancillary equipment is removed and flanged with open ends. The cleaning is achieved by Cleaning Force Ratio (CFR) defined by the Force generated within piping during cleaning operation to the force generated during normal operation.

Fig -1 (a) Decompression method

Fig -1 (b) Vessel rupture method

2.1 Cleaning Force Ratio (CFR) / Disturbance Factor (K)

The Cleaning force ratio, CFR ≥ 1.5 is achieved, further defined by following.

$$CFR = \frac{\dot{m}_c^2 Vc}{\dot{m}_o^2 Vo}$$

Where,
$\dot{m}_c^2$ = Mass flowrate of the air during cleaning (kg/s)
$\dot{m}_o^2$ = Design mass flowrate during normal operation (kg/s)
Vc = Specific Volume of the air at the pipe inlet during cleaning (m3/kg)
Vo = Specific Volume of the system fluid of the pipe inlet during normal operation (m3/kg)

There are three modes of air blowing processes as explained below.

a) Decompression (or) standard rupture blow
b) Pulse (or) vessel rupture blow
c) Continuous blow

2.2 Features of Air blowing

Air blowing is one of cheapest method that move through large piping systems to remove dust, sand, debris. Air blowing is performed as per procedures and method statement. It eliminates or reduce debris in dirty pipes and also reduce contamination to give higher purity product. It also minimizes the damages to rotating equipment, filters, strainers, valve seat etc. Air blows are pressurized air in larger volumes and cannot remove tightly adherent rust or scales, dense larger degrees, paint, oil grease or varnish.

Since air is being the lighter and abundantly available, the air blowing is connected at the entry point with large headers of pipe diameter and exits to the smaller diameter which is does not exceed 50% of larger diameter pipe.

Table -1: Air temperature, density and weight.
(Ref.EngineeringToolbox)

Temperature (deg C)	Density (Kg/m3)	Specific weight (N/m3)
0	1.293	12.67
10	1.247	12.23
20	1.204	11.81
30	1.165	11.43
40	1.127	11.05
50	1.109	10.88
60	1.06	10.4
70	1.029	10.09
80	0.9996	9.903
90	0.9721	9.533
100	0.9461	9.278

200	0.7461	7.317
300	0.6159	6.04
400	0.5243	5.142

In order to know the density/inertia trend goes down and decline as seen in Table. that might affect the cleaning results of air blowing; it is required to summarize briefly, the density of air at 0 deg C is 20% more than 50 deg C; the density of air at 100 deg C is 20% less than that is at 50 deg C; the density of air at 400 deg C is 50% less than that is at 50 deg C.

Questions:

1) Calculate job costs to air blow 17m3 piping system?
2) Compare job costs of air blowing Vs. water flushing?

2.3 Methodology

During cleaning operation, the air velocity shall be as follows.

- For gas process lines, the velocity shall be between 60 m/s and the velocity obtained at 1.3 times the max. process flow rate. The minimum velocity shall be 30 m/s.
- For liquid process lines, the velocity between 30 m/s to 60 m/s shall be used. If the quick decompression method is used, the pressure in the network is raised upto 6 bar.

2.4 Problems of Air blowing

1. If quick decompression method is used, large volumes of air are required and it may take significant time to raise the pressure in the network.
2. Air blowing is Hazardous operation. Very high forces are generated at the outlet. Therefore, specific safety procedures must be adhered to close by working area.
3. Air quality, for instrument air, oil free air and/or dry air might be needed.

3. STEAM BLOWING

Steam blowing is carried out for steam circuits for steam generating boilers, steam heat exchangers, steam turbines or other steam lines. The purpose of steam blowing is to dislodge scales and to remove any foreign matter exists in the pipework or vessels and tanks by the application of high drag forcing on the surface of piping. The principle behind blowing steam is to clean the lines, i.e. to give it a *thermal shock*, i.e. heating and cooling with high velocity gas flowing through the line will shock the pipe to break the mill scale and weld slag away from the pipe wall.

3.1 Objectives

The following are to be removed from plant critical systems steam piping prior to start-up.

- Construction Debris
- Scales
- Rust
- Loose material
- Construction leftovers
- Oil
- Weld spatter

Fig -2: Steam blowing in Process plant

3.2 Methods of Steam blowing

There are two types of steam blowing

1. Puffing method (or) Shock blow method
2. Continuous blowing method (or) Purging method

3.3 Factors to be considered during Engineering phase

- Disturbance Factor (or) CFR
- Steam blow out method

- Pipe size and Design
- Pipe routing
- Steam conditions
- Noise levels
- Thermal cycling
- Stress analysis for temporary pipework and equipment
- Water quenching

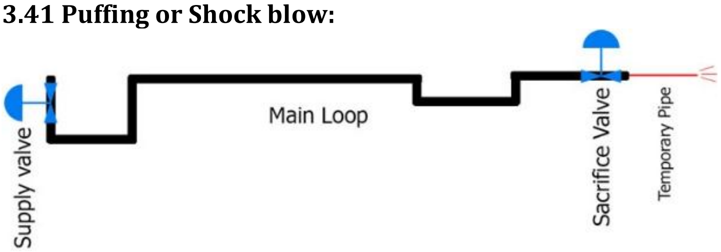
The effect of steam blowing depends on its thermal shock, removal force of steam and cleaning force of steam. The Cleaning force ratio, CFR ≥ 1.5 is achieved, further defined by following.

$$CFR = \frac{\dot{m}_c^2 V_c}{\dot{m}_o^2 V_o}$$

Where,
$\dot{m}_c^2$ = Mass flowrate of the air during cleaning (kg/s)
$\dot{m}_o^2$ = Design mass flowrate during normal operation (kg/s)
V_c = Specific Volume of the air at the pipe inlet during cleaning (m3/kg)
V_o = Specific Volume of the system fluid of the pipe inlet during normal operation (m3/kg)

3.4 Methodology

3.41 Puffing or Shock blow:



- Boiler pressure is raised to approximately 40-60 Kg/cm2 to calculated pressure
- Sacrificial valve is opened
- Steam velocity is reached for short period of time
- First few steam blows are conducted without target plate until steam color becomes clear
- Final target plate is placed once preliminary target plates are acceptable

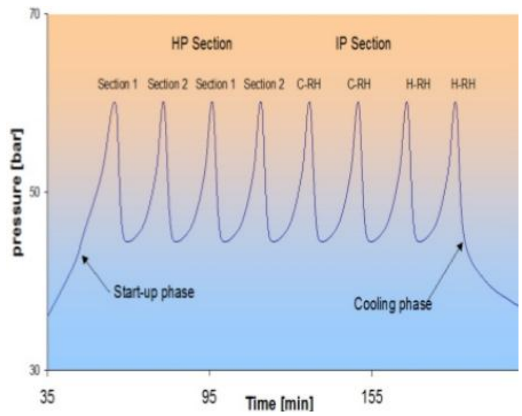
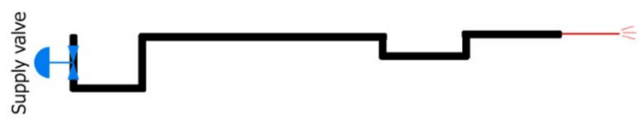


Fig -3: Shock blow, Pressure Vs Time

- High pressure drop, with time
- Completion time is incalculable
- Quick opening valve is required

3.42 Continuous blow:



- Pressure and temperature calculated for CFR to be reached and conditions are maintained for three hours including thermal cycling
- CFR ~ 1.2 -1.7
- Thermal cycling is applied to improve the cleaning process
- No pressure drop, with time
- Completion time App. 5 to 7 days
- No operating valve is required

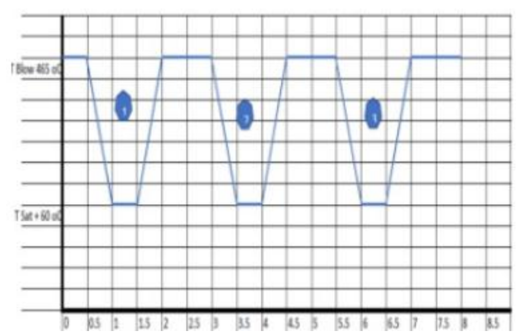


Fig -4 Continuous flow, Pressure Vs Time

3.5 Specification Job Data

The following are certain requirements of data to be collected before start of steam blowing.

1. Site & Job No.
2. Date of steam blowing
3. Circuit included
4. Steam pressure before blowing : bar (g)
5. Steam pressure after blowing : bar (g)
6. Duration of each blow : minutes
7. Time interval between two blows : hrs.
8. Total Nos. of blows : Nos.
9. Number of targets checked : Nos.
10. Material of targets plate
11. Condition of final target plate after blowing

3.6 Cleanliness Analysis

The cleanliness analysis can be done by following methods:

1. The Cleaning force ratio (CFR) is used to evaluate if satisfactory blow conditions are obtained
2. Steam line cleanliness is also determined by the condition of target plate

The number of impacts found on the Target plates gives indication of the pipe cleanliness. The highest velocity of steam is in the centre of the pipe. Hence judgment should be made for the end point of steam blowing in the central zone of the target plate. The piping shall be considered clean if number of impacts on an area of 40mmX40mm:

a) No impact with a size > 1mm
b) Less than 4 impacts with a size > 0.5mm
c) Less than 10 impacts with a size > 0.2mm

3.7 Problems of Steam blowing

The principle differences between air blowing and steam blowing are:

1. The temperature, which creates dilation stresses. Therefore steam blowing shall be performed only for steam networks.
2. The vacuum hazard created when steam condenses in a closed system. This can cause vessels and large diameter piping to collapse.
3. The main advantage of steam over air is the embrittlement of pipe wall deposits, especially millscale, caused by temperature changes between blows and subsequent contraction of the piping or equipment causing cracking effect on pipe wall deposits.
4. Steam blowing is Hazardous operation. Very high forces are generated at the steam outlet. Therefore, specific safe procedures must be adhered close by working area.

4. FLUSHING

In pre-commissioning, flushing is defined as the act of pumping water, in quantity and velocity, through a section of pipe. Oil or water is used to flush equipment and vessels for boiler, feed water and fire water systems. External pumps and filter systems are used to circulate water at a high velocity and dislodge and removes debris from piping walls and vessels.

Hydraulic and lubrication systems of rotating equipment are cleaned using oil flushing techniques. Hot oil is pumped and circulated through filtration system to remove fine welding construction material.

Retro jetting (or) hydro jetting of pipe systems is designed for cleaning of internals of pipes, process lines, sewers and tubes, tube bundles, heater coils etc. It is applied at high pressure water using line mole nozzle to move inside a pipe, dislodging and flushing mud, scale or construction debris from the internal surfaces of pipe work.

Typical types of industrial flushing are as below:

1. Cleaning piping or equipment by circulation of water (or) oil
2. Cleaning piping by retro jetting
3. Fill and dump water flushing

The choice of cleaning method is achieved with fluids available on the Site; compressed air, steam, cooling water, service water, potable water, demineralized water and so on. The volume of network determines the quantity of fluid and the time needed to fill the network.

5. CHEMICAL CLEANING

Chemical cleaning uses the most cost effective and environmentally sound means to reach the desired objective whether it is simply degreasing or removal of mill scale. The chemical mixture is formulated to remove hard deposits or soft films from virtually any type of metallurgy. Chemicals used are environmental friendly. The process injects proven chemistries into saturated steam. By not filling with liquids the chemistry is able to act directly on the surface of the pipe. Continuous monitoring of the condensate product controls pH and iron content. The vapour is condensed at the outlet point and neutralized for disposal to plant waste system. After mill scale removal a final blow for 4 hours is given at calculated flow to remove the construction debris.

Rust, grease, oil films, and scale are some of the byproducts of construction. Chemical cleaning addresses these concerns by degreasing, pickling, and passivating piping and vessels. Chemicals mixed with water are injected using a pumping unit and external filters to achieve cleaning specifications. Degreasing removes oily films and grease prior to the introduction of acid.

5.1 Chemical cleaning processes

1. Boiler front system alkaline flushing
2. Mass flushing
3. Hot water rinsing
4. Alkaline flushing
5. Hot DM water rinsing

Fig -5 Chemical Cleaning of Columns, Exchangers and Vessels

5.2 Types of cleaning chemicals

The most common types of chemicals used for cleaning of equipment are inorganic and organic acids, chelating and complexing agents, alkaline cleaners, surfactants, organic solvents and specialty additives. For removal of oxides and scales, common acid cleaning agents such as inhibited sulphuric acid and hydrochloric acid, phosphoric acid, citric acid and other weaker acid are used. By varying chemical concentration, temperature and agitation, the metal surface can be cleaned slowly or rapidly. Concentrated solutions and higher temperatures will accelerate the cleaning procedure but leads to the generation of dangerous and corrosive fumes and increased corrosion potential.

6. MECHANICAL CLEANING

Mechanical and visual methods of cleaning are not unusual for mechanical cleaning. Mechanical pigging is most commonly used cleaning method for pipe work, while visual inspections are conducted to ascertain a minimum degree of cleanliness present.

7. DEWATERING & DRYING

Pre-commissioning of oil and gas pipelines (both onshore and offshore) includes operational activities - cleaning, odometry, pigging, flooding, testing, dewatering, purging, drying and chemical cleaning. It 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.

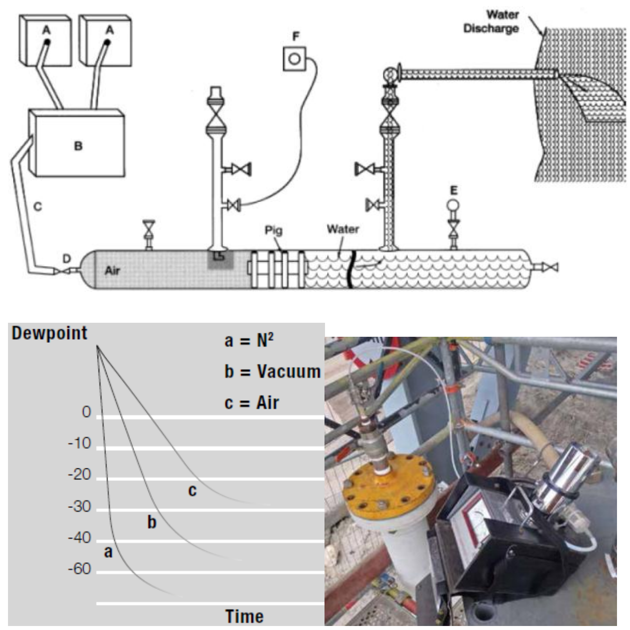


Fig -3: 1 Dewatering and Drying operation during hydrostatic testing of oil and gas pipeline

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.

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.

7.1 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.

7.2 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 -40C.

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 dust 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.

7.3 Vacuum Drying

The vacuum drying process, as with the air 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 in to three (3) main phases.

(1) Evacuation - Pump Down
(2) Evaporation - Vaporization
(3) Final drying – Dehumidification

7.3.1 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.

7.3.2 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.

7.3.3 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 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.

7.4 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 m^3

Volume per metre (Vm) = 0.7717 m^3

Pressure (P) = 1 *Bar*

Pig 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*

7.5 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 = PI/4 x ID x t X L
= PI/4 x 0.7717 x 0.0001 x 150000
= 36.3801 m^3
= 36380.143 *litres approx.*

Since Density of water is 1000 *Kg*/m^3
= 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.

8. CONCLUSION

The facts of engineering and pre-commissioning philosophy are studied. The theory has provided the concepts of transition between mechanical completion and commissioning startup. This paper shall be beneficial to graduating engineers & industry officials to enter into process plant commissioning.

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