
 NISOC	<p>نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض</p> <p>احداث ردیف تراکم گاز در ایستگاه جمع آوری بینک</p>																									
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## طرح نگهداشت و افزایش تولید ۲۷ مخزن

## PIPING CORROSION STUDY & MATERIAL SELECTION REPORT

### نگهداشت و افزایش تولید میدان نفتی بینک



D04	MAY. 2023	IFA	M.Noori	M.Fakharian	A.M.Mohseni	
D03	DEC. 2022	IFA	M.Noori	M.Fakharian	M.Mehrshad	
D02	OCT. 2022	IFA	M.Noori	M.Fakharian	M.Mehrshad	
D01	FEB. 2022	IFA	A.Khosravi	M.Fakharian	M.Mehrshad	
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Class:1

CLIENT Doc. Number: F0Z-708905

#### Status:



IDC: Inter-Discipline Check  
IFC: Issued For Comment  
IFA: Issued For Approval  
AFD: Approved For Design  
AFC: Approved For Construction  
AFP: Approved For Purchase  
AFQ: Approved For Quotation  
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AB-R: As-Built for CLIENT Review  
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## 1.0 INTRODUCTION

Binak oilfield in Bushehr province is a part of the southern oilfields of Iran, is located 20 km northwest of Genaveh city.



With the aim of increasing production of oil from Binak oilfield, an EPC/EPD Project has been defined by NIOC/NISOC and awarded to Petro Iran Development Company (PEDCO). Also PEDCO (as General Contractor) has assigned the EPC-packages of the Project to "Hirgan Energy - Design and Inspection" JV.

As a part of the Project, a New Gas Compressor Station (adjacent to existing Binak GCS) shall be constructed to gather of 15 MMSCFD (approx.) associated gases and compress & transfer them to Siahmakan GIS.

### GENERAL DEFINITION

The following terms shall be used in this document.

CLIENT:	National Iranian South Oilfields CLIENT (NISOC)
PROJECT:	Binak Oilfield Development – Surface Facilities; New Gas Compressor Station
EPD/EPC CONTRACTOR (GC):	Petro Iran Development Company (PEDCO)
EPC CONTRACTOR:	Joint Venture of : Hirgan Energy – Design & Inspection (D&I) Companies
VENDOR:	The firm or person who will fabricate the equipment or material.
EXECUTOR:	Executor is the party which carries out all or part of construction and/or commissioning for the project.
THIRD PARTY INSPECTOR (TPI):	The firm appointed by EPD/EPC CONTRACTOR (GC) and approved by CLIENT (in writing) for the inspection of goods.
SHALL:	Is used where a provision is mandatory.
SHOULD:	Is used where a provision is advisory only.
WILL:	Is normally used in connection with the action by CLIENT rather than by an EPC/EPD CONTRACTOR, supplier or VENDOR.
MAY:	Is used where a provision is completely discretionary.

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## 2.0 SCOPE

This Specification covers the report of Materials Selection for the Basic Engineering of “Preservation and Production Increase of Binak New Compressor Gas Station” project, based on the estimated internal process conditions which are discussed in detail in this document. This document presents the resultant material selection for Process Piping, Equipment and Utilities. Deviations from these criteria shall be raised and approved by “CLIENT”.

## 3.0 NORMATIVE REFERENCES

### 3.1 LOCAL CODES AND STANDARDS



- IPS-E-TP-740 Engineering Standard for Corrosion Consideration in Material Selection
- IPS-E-TP-780 Chemical Control of Corrosive Environment

### 3.2 INTERNATIONAL CODES AND STANDARDS

- NACE MR 0175/ISO 15156 Petroleum, petrochemical, and natural gas industries — Materials for use in H<sub>2</sub>S-containing environments in oil and gas production
- NACE TM 0284 Evaluation of Pipeline and Pressure Vessel Steels for Resistance to Hydrogen-Induced Cracking
- NACE TM 0177 Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H<sub>2</sub>S Environments
- DEP 39.01.10.12-Gen Selection Of Materials For Life Cycle Performance (Upstream Facilities) – Equipment
- DEP 20.04.10.10-Gen Manual Glycol-Type Gas Dehydration and Hydrate Inhibition Systems
- ISO 21457 Petroleum, petrochemical and natural gas industries — Materials selection and corrosion control for oil and gas production systems

### 3.3 THE PROJECT DOCUMENTS

- BK-GCS-PEDCO-120-PR-PF-0001 Process Flow Diagram (PFD)
- BK-GCS-PEDCO-120-PR-UF-0001 Utility Flow Diagrams (UFD)

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- BK-GNRAL-PEDCO-000-PI-SP-0006 Specification For Painting
- BK-GNRAL-PEDCO-000-PI-SP-0007 Specification For Lining (Internal Protection of Equipment by Painting)
- BK-GNRAL-PEDCO-000-PI-SP-0008 Specification For Material Requirements in Sour service

### 3.4 ENVIRONMENTAL DATA



Refer to "Process Basis of Design; Doc. No. BK-GNRAL-PEDCO-000-PR-DB-0001"

### 3.5 ORDER OF PRECEDENCE

In case of any conflict between requirements specified herein & the requirements of any other referenced document, this subject shall be reflected to CLIENT and the final decision will be made by CLIENT..

## 4.0 ABBREVIATIONS

Carbon Steel(C.S.)	An alloy of carbon and iron containing up to 2% carbon and up to 1.65% manganese and residual quantities of other elements, except those intentionally added in specific quantities for deoxidation (Usually silicon and/or aluminum). The carbon steel used in oil industry usually contains less than 0.8% carbon.
Sour Service	Exposure to oilfield environments that contains H <sub>2</sub> S and can cause cracking of materials.
Corrosion Resistant Alloy(CRA)	Alloys that are intended to be resistant to general and localized corrosion in oilfield environments that are corrosive to carbon steels.
Hydrogen Induced Cracking(HIC)	Planar cracking that occurs in carbon and low alloy steels when atomic hydrogen diffuses into the steel and then combines to form molecular hydrogen at trap sites. Steels with high impurity levels are commonly susceptible to HIC.

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Stress Corrosion  
cracking(SCC)

Cracking of metal involving anodic processes of localized corrosion and tensile stress (residual and/or applied) in the presence of water and H<sub>2</sub>S. High strength metallic materials and hard weld zones are prone to SSC.

Sulfide Stress  
Cracking(SSC)

Cracking of metal involving corrosion and tensile stress (residual and/or applied) in the presence of water and H<sub>2</sub>S.

stepwise cracking  
(SWC)

cracking that connects hydrogen-induced cracks on adjacent planes in a steel

stress-oriented  
hydrogen-induced  
cracking (SOHIC)

staggered small cracks formed approximately perpendicular to the principal stress (residual or applied) resulting in a "ladder-like" crack array linking (sometimes small) pre-existing HIC cracks

soft zone cracking  
(SZC)

form of SSC that can occur when a steel contains a local "soft zone" of low-yield-strength material

Galvanically induced  
hydrogen stress  
cracking (GHSC)

cracking that results due to the presence of hydrogen in a metal induced in the cathode of a galvanic couple and tensile stress (residual and/or applied)

H.D.P.E

High Density Poly Ethylene



## 5.0 DESIGN BASIS

### 5.1 GENERAL

Materials selection has been used as the primary means of corrosion control. Various types of short-and-long-term undesirable metallurgical changes and corrosion that may be induced during fabrication and/or services have been taken into consideration.

Where necessary the selection of materials is combined with other corrosion control measures such as corrosion allowance, metallic cladding, internal and external protective coatings, hot insulation, corrosion inhibitors, and cathodic protection, to ensure design service life.

All materials selected for wet H<sub>2</sub>S environments shall be fully in compliance with NACE MR175/ISO15156-2015 and "Specification for Material Requirements in Sour service; BK-GNRAL-PEDCO-000-PI-SP-0008

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## 5.2 DESIGN LIFE

A total design life of 25 years has been considered based on “Basic Engineering Design Data”.

## 5.3 CORROSION ALLOWANCES

Corrosion allowances have been based on achieving the design life stated in the above Section.

Unless stated otherwise the minimum corrosion allowances are as follows:

- Carbon and low alloy steels in non-corrosive service → 1.0 mm
- Carbon and low alloy steels in sour service → 3.0 mm
- CRAs and integrally clad carbon or low alloy steels → 0.0 mm

Carbon steel major equipment and piping items, taking into account also corrosion inhibition if applicable, that have calculated a corrosion allowance in excess of 6.0 mm have been upgraded to CRAs, solid or clad, or provided with a protective coating.

Minimum cladding thickness for all CRA clad carbon steels shall be 3.0 mm.

## 5.4 DESIGN DATA

The bases for process aspects and design conditions of the material selection philosophy are listed in the PFD in which the Process Heat and Material Balances are also presented. Appendix 1 contains the data which are the input data for corrosion rate calculations.

### 5.4.1 PRODUCED FLUID



The plant feed contains a significant fraction of both acid gasses CO<sub>2</sub> and H<sub>2</sub>S, the first of these two corrosive species resulting in general corrosion, the latter involving risk of sulfide stress corrosion cracking hence NACE MR0175/ISO 15156- 2015 requirements shall be considered.

On the basis of the fluid composition data coming from gas wells, a process simulation have been carried out for the process and CO<sub>2</sub> and H<sub>2</sub>S molar contents in the process streams have been estimated and reported in the Heat and Material Balances (Appendix 1).

### 5.4.2 SATURATED WATER

Binak Compressor Station Feed Composition is assumed to be water-saturated, so no presence of separate water phase is considered. The chloride levels in a stream can often be difficult to estimate. For gas streams the majority of free liquid water and hence chlorides are removed in separators, however some free water can get carried over depending on the efficiency of the separator due to foaming, splashing, misting etc. Therefore where the actually level of



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chlorides are not available, it will be assumed that a single separator (column, separator, K.O drum) will be insufficient to remove all free liquids, but downstream of two separators in series it will be assumed that free water no longer present in the gas stream and hence chlorides are below 50ppm.



## 6.0 CORROSION PHILOSOPHY

Steel structures, equipment and pipes are susceptible to various kinds of corrosion in different media, internally and externally. Some types of corrosion gradually reduce the thickness and strength of the equipment material and this may cause breakdown and failure during working period of the plant. Thus, for safe design of the plant an estimation of corrosion rate is necessary, so as to make allowance for corrosion during operation period of the plant and to foresee some controlling measures for corrosion, if necessary.

Different types of corrosion that are probable for a pipeline containing gas, hydrocarbons and common impurities are as follows:

- External Corrosion
- Internal corrosion
  - 1- Uniform attack corrosion by CO<sub>2</sub>
  - 2- Galvanic Corrosion
  - 3- Pitting and crevice
  - 4- Under deposit corrosion
  - 5- Corrosion by Oxygen
  - 6- Erosion corrosion
  - 7- Sulfide stress corrosion cracking(S.S.C)
  - 8- Stepwise cracking
  - 9- Chloride Stress Corrosion Cracking(C.S.C.C)
  - 10- M.I.C (Microbiologically induced corrosion)

Presence of H<sub>2</sub>S, CO<sub>2</sub>, water, and salt in handled gas usually increases the rate of corrosion, but the dependence of corrosion rate to each of these parameters follows complicated trends and it depends also on the other parameters, like temperature and pressure for a particular alloy. The following parts of the report investigate different aspects of the corrosion problem and provide the results of preliminary calculations of corrosion rate.

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## 6.1 EXTERNAL CORROSION

All above-ground tanks, vessels, separators, piping, piping components and structures shall be protected from external corrosion using paint schedule as per standard "IPS-E-TP-100".

Some CRAs like austenitic stainless steel are susceptible to pitting due to chlorides. Further, if piping were to be insulated, it is necessary to specify (and ensure) use of chloride-free insulation otherwise the combination of external coating of austenitic stainless steel piping and thermal insulation might protect the piping total protection against Chloride Stress Corrosion Cracking (CSCC) and make the use of 304L and 316L viable.

All buried metallic piping, pipelines and flow lines shall be externally coated and shall be protected by using cathodic protection system.

## 6.2 UNIFORM ATTACK CORROSION

Uniform attack on metal is the common form of corrosion characterized by a chemical or electrochemical reaction that proceeds uniformly over the entire exposed surface. The metal becomes thinner and eventually fails.

Uniform corrosion arises from the presence of carbon dioxide (CO<sub>2</sub>) in a wet or condensing water-saturated hydrocarbon process stream. CO<sub>2</sub> can dissolve in water to form carbonic acid.



CO<sub>2</sub> corrodes carbon steel bringing to a loss of thickness in lines and equipment. The rate of attack may be modified by dissolved salts and liquid hydrocarbons, and usually becomes more rapid with increase in pressure (partial pressure of acid gas). Temperature can lead to the formation of a stable protective layer of FeCO<sub>3</sub> on the steel surface. High fluid velocities, however, can destroy the film by erosion effects.

The rate of uniform corrosion depends primarily on the concentration of H<sub>2</sub>S, CO<sub>2</sub>, and water in handled gas. Actually, the influence of CO<sub>2</sub> on corrosion rate depends on the concentration of H<sub>2</sub>S in a complicated way. For example, corrosion rate of carbon steel resulted from CO<sub>2</sub> gas, may increase in the presence of H<sub>2</sub>S, but the relation between corrosion rate and H<sub>2</sub>S concentration follows a very complex scheme. The presence of water in the system also aggravates the effect of CO<sub>2</sub> on corrosion.

Mitigation of this form of corrosion can be achieved by inhibitor injection and/or avoiding stagnation of water. Presence of oil and temperature above 60 °C may be beneficial.

CO<sub>2</sub> corrosion is generally assumed to be eliminated when the chromium level in the material is at least 13%.

The rate of carbonic acid corrosion can be predicted for carbon steel by semi-empirical calculation models. All corrosion calculations for the Project have been based on the use of the Predict™ software.

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According to IPS-E-TP 740, the minimum corrosion allowance for uniform corrosion, to be considered for piping and equipment, depends on the required service life of the piping and equipment multiplied by the expected corrosion rate under process conditions.

$$C.A \text{ (in mm)} \geq \text{Life (year)} \times C.R \text{ (mm/y)}$$

Where:

C.A = Corrosion allowance

C.R = Corrosion rate

According to the above equation the following classes shall be considered for piping and equipment with a design life of 25 years.

Where the corrosion rate is more than 0.3 mm/y or the total corrosion over the design life exceed 6 mm then use of inhibitor injection, Corrosion resistance linings or solid corrosion resistance material shall be evaluated. For piping and equipment minimum corrosion allowance of 1.5 and 3 mm for sweet and sour services respectively shall be considered according to related IPS standard which has been mentioned in codes and standards. Vessel corrosion allowance shall be provided to all non-removable internal parts and removable parts.

All specified minimum corrosion allowance which mentioned above shall be considered when calculated corrosion allowance was less than specified minimum corrosion allowance.

### 6.2.1 PREDICT SOFTWARE



The model being utilized is the software developed by InterCorr International: PREDICT™ 6.1, now a part of Honeywell. All the corrosion assessment carried out by PREDICT™ program has been based on the environmental parameters that affect the corrosion resistance in sour and sweet environments.

The Predict™ system presents encapsulates a novel hierarchical approach to assess system corrosivity and prediction of corrosion rates in carbon steels in production environments containing CO<sub>2</sub> and/or H<sub>2</sub>S.

The primary objective of the corrosivity prediction model is to address the need of developing a predictive method that would synthesize different parametric relationships based on information from literature, lab research data and practical experience and expertise.

The main variables in corrosivity prediction in the Predict™ system are the acid gases CO<sub>2</sub> and H<sub>2</sub>S that contribute to the typically acidic pH found in production environments. The model uses the widely accepted de Waard – Milliams relationship for CO<sub>2</sub> corrosion for an initial determination of CO<sub>2</sub> based corrosion rates:

$$\log(V_{cor}) = 5.8 - \frac{1710}{273 + t} + 0.67 \cdot \log(pCO_2)$$

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Where:

$V_{cor}$  = corrosion rate in mm/y



t = operating temperature in °C

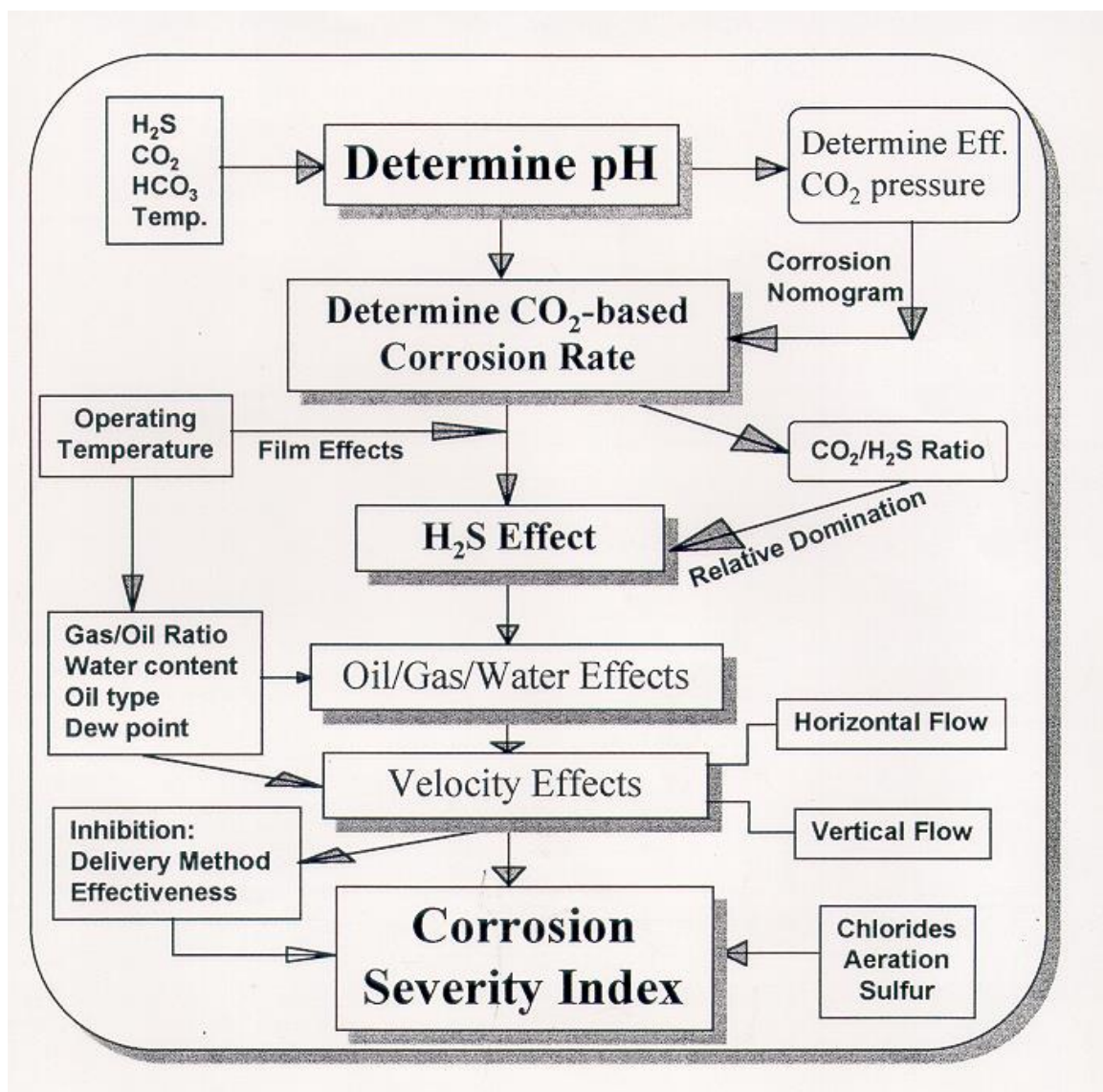
$p_{CO_2}$  = partial pressure of CO<sub>2</sub> in bar a

The corrosion rate obtained by the above equation is often seen as the maximum possible corrosion rate without accounting for iron carbonate scaling. This rate is further refined to account for the presence of H<sub>2</sub>S, corrosion products, temperature effects, etc., and the effective CO<sub>2</sub> partial pressure in the system is not based on the operating partial pressure but one obtained from the system pH.

An important concept in the Predict™ model is the role of superposition of different parameters. Such super positioning requires a clear understanding of independent parameter effects and also on how corrosion rate progresses when subjected to the effects of two or more variables.



A flow chart delineating the hierarchical reasoning structure of the Predict™ model is given in the following figure.

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The first step in corrosivity determination is computation of the system pH, since it is the hydrogen ion concentration that drives the anodic dissolution. For production environments, where it is the dissolved CO<sub>2</sub> or H<sub>2</sub>S that contribute significantly to a suppressed pH, the pH can be determined as a function of acid gas partial pressures, bicarbonates and temperature. From a practical stand point, the contribution of H<sub>2</sub>S or HCO<sub>3</sub> or temperature to pH determination is another way of representing effective levels of CO<sub>2</sub> that would have produced a given level of pH.

This type of pH determination has been found to be quite accurately applicable in other modeling efforts. While it has been documented that the CO<sub>2</sub> corrosion mechanism is dissimilar to that of strong acids like HCl (where as CO<sub>2</sub> corrosion is now understood to progress through direct reduction of H<sub>2</sub>CO<sub>3</sub> to HCO<sub>3</sub> rather than reduction of H<sup>+</sup> ions), and that carbonic acid corrosion is much more

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corrosive than that obtained from a strong acid such as HCl at the same pH, there is also significant agreement that lower pH levels obtained from higher acid gas presence leads to higher corrosion rates. Conversely, higher levels of pH obtained through buffering in simulated production formation water solutions have been shown to produce significantly lower corrosion rates even at higher levels of CO<sub>2</sub> and/or H<sub>2</sub>S. Hence, it is more meaningful to determine the effective CO<sub>2</sub> partial pressure from the system pH. A numerical computer model has also been developed to compute pH for different values of HCO<sub>3</sub> and temperature.



The effective CO<sub>2</sub> partial pressure can be used to determine an initial corrosion rate for CO<sub>2</sub> based corrosion. The corrosion rate so obtained is modified to account for the formation of a FeCO<sub>3</sub> film (Fe<sub>3</sub>O<sub>4</sub> at higher temperatures) whose stability varies as a function of the operating temperature. A scale correction factor is used to determine the initial corrosion rate from the well-known de Waard and Milliams corrosion nomogram. It is generally estimated that this corrosion rate presents a maximum corrosion rate even though it has been reported that the rate computed by the nomogram are reached or exceeded in systems with high flow rates. It is important to recognize that this corrosion rate has to be modified to account for the effect of other critical variables in the system. Further, this rate does not indicate modality (general or localized) but rather, represents the maximum rate of attack.

As mentioned above, it is necessary to superposition the effects of other critical system parameters. The flow chart previously reported provides the sequential effects that are important from a stand point of corrosivity determination. In addition to the system pH, these include:

- H<sub>2</sub>S partial pressure
- Maximum operating temperature
- Dissolved chlorides
- Gas to oil ratio
- Water to gas ratio/water cut
- Oil type and its persistence
- Elemental Sulphur/aeration
- Fluid velocity
- Type of flow
- Inhibition type and efficiency

The effects of these parameters on corrosivity are well discussed in the Predict™ User's Guide providing information as to how it is critical to examine the parameter interactions prior to capturing the synergistic effects of these parameters on corrosion.



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### 6.3 GALVANIC CORROSION

Galvanic corrosion results when dissimilar metals form a corrosion cell or couple. This cell results when metals with different electrochemical potentials are immersed in an electrolyte. If the two metals are connected electrically, electrons will flow in the metallic circuit to the cathode from the anode.

The tendency of a metal to corrode in a galvanic cell is determined by its position in the “galvanic series” (or electrochemical series) of metals and alloys. A metal tends to corrode when connected to a metal more cathodic than it (above it on the table). The farther apart the metals are in the series, the more tendencies there is for corrosion of the more anodic metal.

The rate of corrosion resulting from galvanic action depends upon the relative exposed areas of the two metals in contact. The use of corrosion at the anode to protect the cathode is the basis for cathodic protection by sacrificial galvanic anodes.

Galvanic corrosion is not limited to cells in which totally dissimilar metals are in contact while exposed to an electrolyte. Differences in the composition or surface condition of otherwise similar metals often result in galvanic corrosion cells.

The conductivity of a solution (electrolyte) in which dissimilar metals are placed will have a significant effect on the corrosion rate. For example, more galvanic corrosion problems occur in saltwater, because of its higher conductivity, than in fresh water.



In summary, galvanic attack is minimized or prevented by:

- Avoiding unfavorable metal combinations, that is, metals far apart in the galvanic series
- Avoiding combinations involving relatively small areas of the more active (anodic) metal
- Where material change from carbon steel to CRA, “ISOLATION KIT” shall be used to prevent contact (and completion of the electrical circuit) between dissimilar metals
- Avoid coating the anode of the couple. This is important because gaps in the coating will expose small areas of anode creating unfavorable anode-to-cathode areas. Coat the cathode to reduce galvanic corrosion

### 6.4 PITTING AND CREVICE

Pitting is a localized corrosion that makes holes in the metal. Often, pitting is caused by chlorides, particularly on stainless steels. Pitting usually occurs in stagnant conditions, and the pitted metals will show little general or uniform corrosion. It causes pipe to fail because of perforation with only a small percent weight loss of the entire pipeline.

The contemporary presence of H<sub>2</sub>S and chlorides in an aqueous medium can lead to pitting and crevice corrosion of CRAs. Chloride doesn't participate directly in the electrochemical corrosion

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reaction but can catalyze the breakdown of the passive film of stainless alloys or the formation of surface pits, with or without crevices.

The occurrence of pitting depends on the temperature, chloride concentration, H<sub>2</sub>S partial pressure and local flow conditions and can be avoided selecting materials having an appropriate Pitting Resistance Equivalent Number (PREN).

Crevice is less dramatic in sour environments than in oxygen-bearing environments such as sea water. It consists in a later stage of pitting thus it is usually prevented by preventing pitting itself.

#### 6.4.1 PREVENTION

The methods suggested for combating crevice corrosion generally apply also for pitting. Materials that show tendencies to pit, during corrosion tests shall not be used to build the plant under consideration.

Adding inhibitors is sometimes helpful, but this may be a dangerous procedure unless attack is stopped completely. If it is not, the pitting may be increased.

Where the corrosion problem is not uniform, and is localized such as; stress corrosion cracking, pitting, crevice, sulphide stress cracking, etc.; the material selection shall be on the basis of specific corrosion problem. As a general rule, stainless steels should be avoided in chloride-containing aqueous solutions if the fluid velocity is less than 1 m/s. Saline waters, even at ambient temperature, require the use of materials with PREN > 40, Ni-Cr-base alloys or Titanium alloys.

#### 6.5 UNDER DEPOSIT CORROSION



Deposits can not only reduce heat transfer and cause restricting flow problems, but corrosion; specifically under-deposit corrosion can lead to some significant damage. This corrosion can occur both directly and indirectly.

When the attack is direct, the deposit itself contains corrosive substances which when concentrated at a localized or generalized site can cause wastage. An example of such a deposit would include chlorides.

Indirect attack is more commonly associated with under-deposit corrosion. This wastage occurs when the accumulation of deposits shields the covered surface from the bulk water system. Corrosion occurs on a metal surface due to some inherent or environmental difference between one area on that surface and another. These differences will create anodic and cathodic areas, setting up a basic corrosion cell. The anode is the area at which the metal is lost. The electrons given up by the metal flow to the cathode to be consumed in a reduction reaction. The growth of bacteria and formation of biofilms may also result in under-deposit corrosion.

Biofilms are notorious for not only acting like a deposit and instigating corrosion and heat inefficiencies, but also for entrapping suspended debris. Biofilms are also capable of the formation of mineral scales by engulfing ions like calcium and magnesium. The trapped ions are now more readily available for a reaction with carbonate and phosphate anions.



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Whether the scale or debris accumulation or the biofilm occurred first each is most likely present in even a moderate accumulation. These accumulations inhibit full penetration of biocides and corrosion inhibitors, thus accelerating anaerobic growth underneath deposits and corrosion. Sulfate-reducing bacteria are especially active in covered, anaerobic areas. These organisms reduce sulfate compounds to sulfuric acid and hydrogen sulfide, both creating an acidic attack on the metal surface.

Scale and debris accumulation should be removed and cleaned regularly to prevent under deposit corrosion.

## 6.6 CORROSION BY OXYGEN

Oxygen is strong oxidant and reacts with the metal very quickly. The dissolved Oxygen in the formation/produced water is one of the primary causes of corrosion in the production equipment. Although Oxygen is not present in the well fluids, Oxygen ingress takes place in the well fluids through leaking pump seals, casing and process vents, open hatches.

The forms of corrosion associated with Oxygen are mainly uniform corrosion, pitting type corrosion.

Oxygen is directly involved in the corrosion reaction and promotes general corrosion of steel and localized corrosion and cracking in stainless steels.

One of the prevention provisions is to inject Oxygen scavenger in disposal water.

## 6.7 EROSION

Erosion corrosion is the acceleration or increase in rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. This kind of corrosion is induced by high flow velocities and can be avoided by keeping flow velocity at less than a critical limit.



Erosion is the physical removal of wall material by the flowing process fluids. Erosion is a complex issue; dictated by fluid phase, flow regime, density, solids content, solids hardness, solids geometry, and flow corrosivity (erosion - corrosion).

Potential mechanisms that could cause significant erosion damage are:

- Particulate erosion
- Liquid droplet erosion

It is generally accepted that particulates (sand & ...) are the most common source of erosion problems in gas and hydrocarbon systems. Because of the absence of particulate in handled gas particulate erosion cannot take place in present case.

Droplet erosion is obviously confined to wet gas and multiphase flows in which droplets can form. The erosion rate is dependent on a number of factors including the droplet size, impact velocity, impact frequency, and liquid and gas density and viscosity.

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Solids-free erosion only occurs at very high velocities. High velocities cause unacceptably high pressure losses, therefore the conditions required for droplet erosion are unlikely to occur in correctly designed production pipework systems. API RP-14E contains a simple formula for estimating the velocity beyond which accelerated corrosion due to erosion may occur. The formula is empirical and derived from field experiences and is meant to describe the velocity for the possible onset of erosion corrosion in carbon steel pipe and equipment in the absence of particulates:

$$V = C / \rho^{0.5}$$

Where

V is the maximum acceptable velocity (m/sec)

$\rho$  is the liquid density (Kg/m<sup>3</sup>)

Although this limit is known to be conservative in most cases, it provides a reliable design tolerant of design changes and unexpectedly erosive flows (e g from slugs of solids) API RP 14E is designed to be used for carbon steel in wet gas and liquid lines, but has been adapted for use in other circumstances.

Table 3. Recommended Amendments to API Erosion Limit "C" Factors



Material	Tow phase, solid free	Dry gas, solid free
Carbon Steel	100	200
Stainless Steel	150	300
Alloy 625/825	200	400

Solids-free erosion only occurs at very high velocities. High velocities cause unacceptably high pressure losses, therefore the conditions required for droplet erosion are unlikely to occur in correctly designed production pipework systems. The suggestion in DNV RP0501 that droplet erosion and liquid impingement erosion is unlikely to occur in steel components at velocities below 20 m/s is probably more realistic.

## 6.8 SULFIDE STRESS CORROSION CRACKING

The electrochemical reaction between the metal and an aqueous H<sub>2</sub>S-bearing environment leads to the formation of atomic hydrogen that can enter the steel at the corroding surface. The presence of hydrogen in the steel may cause embrittlement and cracking depending on the steel type, microstructure and residual or applied stresses.

The Sulfide Stress Cracking (SSC) occurs when the atomic hydrogen diffuses into the crystal lattice where it remains in solid solution and promotes dislocations that propagate following the stresses present into the metal structure and due to the mechanical assembling of the line/equipment or followed to a fabrication/welding process. With the reduction in ductility and deformability the embrittled metal can easily and rapidly crack leading to a catastrophic failure.

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Tendency to give SSC increases if hard phases are present in the metal structure. The phases can be inherently present, for example, in high strength low alloy steels or they can form due to incorrect heat treatment. Limiting hardness, particularly in HAZs, of metals exposed to sour environments is an effective way to control SSC or at least to reduce its likelihood. High strength metallic materials and hard weld zones are prone to SSC.

SSC can develop both in CS and in CRA but in the latter case the presence of chlorides is fundamental and has been taken into account in selecting materials. A widely accepted guideline to avoid SSC is given in the Standard ISO 15156.

## 6.9 STEPWISE CRACKING

Also known as HIC, the Stepwise Cracking (SWC) is encountered mainly in steel lamination products (plates and welded tubes) as they contain in the metal matrix planar inclusions of manganese sulfides whose particular form promote collection and recombination of atomic hydrogen to molecular hydrogen.

Where this phenomenon occur internal stresses are generated in microscopic voids at interfaces between the inclusions and the matrix and cracks may develop with first a crack initiation phase and then propagation along the metallurgical structures sensitive to this type of hydrogen embrittlement, linking each other in a characteristic stepped appearance.

HIC can be avoided using clean steels, that is steel characterized by low sulfur contents and globular-shape (instead of planar) inclusions of manganese sulfide, minimizing segregations and microstructural discontinuities, to reduce the availability of crack initiation sites.

HIC may arise without the concurrence of external or residual stresses. The most susceptible materials are rolled steels whereas the likelihood of HIC occurrence in seamless and forged pipes is lower than in welded pipes.

SOHIC is another form of HIC in which it assumes a typical ladder-like array.



## 6.10 CHLORIDE STRESS CORROSION CRACKING

CSCC is the most common form of SCC. It requires the contemporary presence of water, oxygen and chlorides in contact with a stressed material. The stresses can be due to mechanical load, pressure load or can be induced by the fabrication processes (welding, cold working, etc.).

In neutral aqueous solutions the susceptibility of a given alloy to chloride-induced corrosion depends mainly from the temperature of the system. Austenitic (AISI 300 series) and austenitic-ferritic stainless alloys are particularly prone to crack by CSCC, in fact they have been classified based on the maximum temperature at which they can be exposed in presence of chlorides and oxygen.

Limits for some alloys are reported below:

- 304/316 SS                      60 °C

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- 2205 DSS                      150 °C
- 6 Mo                              300 °C
- 2507 DSS                      > 300 °C
- Ni-base alloys                no cracking reported

All Materials for sour service shall comply fully with requirements and recommendations of the ISO 15156 Standard for resistance to all mechanisms of cracking that can be caused by H<sub>2</sub>S, including sulfide stress cracking (SSC), stress corrosion cracking (SCC), hydrogen-induced cracking (HIC) and stepwise cracking (SWC), stress-oriented hydrogen-induced cracking (SOHIC), soft zone cracking (SZC) and galvanically induced hydrogen stress cracking (GHSC).

## 6.11 MICROBIOLOGICALLY INDUCED CORROSION



Microbes commonly found in oil and gas systems are sulfate-reducing bacteria (S.R.B) and acid-producing bacteria (A.P.B). Some of the bacteria are plank tonic, free floating in the liquids; others are sessile and are attached to the surfaces in the system. Samples of the liquids indicate the presence of the plank tonic bacteria; however, their presence does not necessarily indicate that microbiologically influenced corrosion has or will occur. M.I.C is usually found in aqueous environments or services where water is always or sometimes present; especially where stagnant or low-flow conditions allow and/or promote the growth of microorganisms e.g. bottom water of storage tanks, piping with stagnant or low flow, and piping in contact with some soils. The following shall be considered to prevent M.I.C.

- Systems that contain water (cooling water, storage tanks, etc.) should be treated with biocides such as chlorine, bromine, ozone, ultraviolet light or proprietary compounds.
- Minimize low flow or stagnant zones.
- Systems that are not designed or intended for water containment should be kept clean and dry.
- Empty hydro test water as soon as possible. Blow dry and prevent moisture intrusion.
- Wrapping and cathodic protecting of underground structures have been effective in preventing M.I.C.

## 7.0 CORROSION CONTROL

### 7.1 GENERAL PHILOSOPHY

CRAs, solid or clad, or internally lined carbon steel have been selected where bare carbon steel with a high corrosion allowance cannot provide the required design life.

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In addition to material selection the following measures have been properly taken into account to combat and to control internal corrosion:

- Chemical injection
- Internal and external coating
- Cathodic protection

## 7.2 CORROSION INHIBITION

Inhibitor treatment is intended as corrosion control technique to mitigate corrosion of carbon steel (CO<sub>2</sub> corrosion in particular). For an inhibitor to work effectively it must be absorbed on to all wetted surfaces and under the system conditions it must be sufficiently effective to maintain a protective film on the surface to provide adequate protection. Areas which cannot be inhibited effectively will either be in CRA, as solid or clad, or have high corrosion allowance made for reduced inhibitor effectiveness. The efficacy of the inhibitor is affected by the temperature, inhibitor concentration, flow regime and phase behavior.

In wet gas streams corrosion inhibitor may be injected only where unexpected water condensation, even for short periods, may cause severe corrosion on carbon steel.

The Corrosion Injection selection has been prescribed as a precautionary measure for wet oil and water lines where bare carbon steel selection may not be fully adequate to provide the desired design life because of the uncertainty of formation water chemical analysis.



Monitoring points aimed at verifying the treatment efficiency shall be at least 5 meters or 10 times of O.D. (which is grater) downstream the corrosion inhibitor injection points for assuring an effective mixture. Individual distance between corrosion probe and coupons shall be 0.5 meter for each pipe. The final Corrosion Injection locations have been marked on the Material Selection Diagram. The exact location of probes and injection points will be finalized in detail design based on defining high risk locations.

### 7.2.1 CORROSION INHIBITORS

It has been common practice for many years to inject corrosion inhibitors into CO<sub>2</sub> containing production tubing and process streams carried by carbon steels.

Corrosion inhibitors are chemicals which may be divided in a few categories. Among these, the most used class in horizontal flow lines/pipelines is the film forming amine type.

The effect of film forming inhibitor is thus to establish a first layer of flat molecules just on the steel surface, a second layer of aliphatic tails and a third layer of oil/condensates. Water cannot thus reach the steel surface and promote corrosion.

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It is generally accepted to define the capacity of inhibitors to protect against corrosion using a parameter, called efficiency, defined as:

$$\text{Inh. Eff} = [R_{\text{Corr}} (\text{Without inhibitors}) - R_{\text{Corr}} (\text{With inhibitors})] / R_{\text{Corr}} (\text{Without inhibitors})$$

Often used as a percentage. To give an example, if a system would exhibit 2 mm/y corrosion rate without inhibitors and 0.2 mm/y with inhibitors injection, the calculated efficiency is 90%.

### 7.3 COATINGS

Non-metallic internal coatings have been specified to mitigate corrosion in large carbon steel equipment, like vessels and sumps, where liquid stagnant conditions could lead to corrosion rates higher than the required design life, fluid temperature allows coating application and CRA selection is not a viable alternative.

### 7.4 CATHODIC PROTECTION

Cathodic protection systems could be considered both for external and internal corrosion control of carbon steel and low alloy equipment.

## 8.0 LOW TEMPERATURE CARBON STEEL (LTCS) APPLICATION



Depressurization of equipment containing high pressure gas will result in a temperature drop. Process simulation shall be used to determine the lowest design temperature of all pressure vessels, piping, piping components and rotating equipment. For pressure vessels and piping, minimum design metal temperature shall be established and carbon steel (LTCS) material or stainless steel shall be selected. To avoid brittle fracture MDMT (minimum design metal temperature) and related requirements shall be considered in grade specification for carbon steel or stainless steel according to the code.

The material selection for vessels and piping with regard to low temperature:

Design Temperature(°C)	Steel Type
-196≤T<-101	Austenitic SS
-101≤T<-45	Austenitic SS/Nickel alloy steel
-45≤T<-29	LTCS

## 9.0 SELECTION OF MATERIALS OTHER THAN CARBON STEEL

Whenever the corrosion rate calculation for carbon steel results in a corrosion allowance greater than 6 mm, corrosion resistant alloys are the preferred material for use in environments containing CO<sub>2</sub> and H<sub>2</sub>S according to NACE MR0175/ISO 15156 part 3.

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Austenitic SS of type 304L and 316L are most commonly used in oil and gas production because of the excellent resistance to CO<sub>2</sub> corrosion and good low temperature properties in the case of very low temperatures from depressurization. These alloys are susceptible to chloride stress corrosion cracking (CSCC) in oxygenated chloride containing environments.

Selection of CRAs involves understanding and characterizing effects of the following variables in terms of mechanical, corrosion and cracking considerations:

- Mechanical characteristics such as strength, heat treatment and hardness
- H<sub>2</sub>S partial pressure
- CO<sub>2</sub> partial pressure
- Maximum operating temperature
- Bicarbonates
- Chlorides
- Hydrogen ion concentration (pH)
- Sulfur
- Gas to oil ratio
- Water to gas ratio
- Metallurgical composition
- Oxygen.

## 10.0 MATERIAL SELECTION REPORT



Corrosion rate prediction is based on the process fluid properties (Appendix 1) and PREDICT 6.1 software.

### 10.1 PIPING

To better explain the assessments carried out, the following general remarks are pointed out:

- The considered design case is the Case with the maximum expected water.
- Liquid water in gas lines is condensed from water vapor, thus the dissolved salts content is low and it contains little or no dissolved bicarbonate and chloride. Carried away salts are assumed to be very little.



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- Corrosion rates have been evaluated by PREDICT™ 6.1 software.
- In the CO<sub>2</sub> corrosion rate calculation, the CO<sub>2</sub> and H<sub>2</sub>S contents are always referred to the relevant content in gaseous phase in equilibrium with the fluid in the vessel. For liquid streams, the total pressure adopted is always equals or lower, but never higher than the value at the equilibrium conditions upstream the considered line.
- For vessel corrosion evaluation has been performed on the base of the relevant stream. Since stagnant conditions are likely, the occurrence of wetting on the bottom surfaces is evaluated on the base of the water content of the outlet streams considering high probability of pitting, specially pitting due to chloride, So 6 mm corrosion allowance + lining + sacrificial anode are considered for V-101.
- For CS piping where the uncertainty of the assumed chlorides and bicarbonates contents in the formation water could give rise to unexpected corrosions, provision of Corrosion Inhibitor Injection Systems available for future use have been prescribed to minimize the risk of corrosion and with the intention to provide addition protection.
- A Corrosion Monitoring Point has been always prescribed jointly with each provided corrosion inhibition point to control corrosion rates and inhibition treatment efficacy.
- For all the materials selected, sour service requirements have been prescribed applying NACE MR0175 / ISO 15156-2015 and "Specification For Material Requirements in Sour Service-BK-GNRL-PEDCO-000-PI-SP-0008".

According to the above explanations corrosion rate calculations is summarized in table 1.





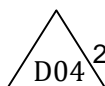
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Table1. Overview of corrosion rate calculations for flow lines and process piping for project total life (25 years)

Stream No. in PFD	Size (in)	Press. (Bara)	Temp (°C)		Dew Point (°C)		PREDICT 6.1 Results mm/year		corrosion mm/25 years (For Worst Case)	Corrosion Inhibitor Injection (Yes/No)	Corrosion mm/25 years (If CI required)	Selected Material+ Corrosion Allowance	NACE MR 0175
			S	w	S	w	S	w					
S01	6	6.50	46.11	26.67	46.11	26.67	0.72	0.08	18.0	Yes	4.50	CS+6mm	Yes
S02	14	6.50	32.0	15.50	32.0	15.50	0.29	0.05	7.25	Yes	1.75	CS+6mm	Yes
S03	10	6.30	37.17	19.23	37.17	19.23	0.39	0.04	9.75	Yes	2.50	CS+6mm	Yes
S04	10	6.10	36.92	19.02	36.92	19.02	0.39	0.06	9.75	Yes	2.50	CS+6mm	Yes
S05	8	6.10	36.92	19.02	36.92	19.02	0.45	0.07	11.25	Yes	2.75	CS+6mm	Yes
S06	8	5.90	36.78	18.88	Note 1	Note 1	Nil	Nil	Nil	No	-	CS+3mm	Yes
S07	6	20.0	129.0	117.7	36.78	18.88	Nil	Nil	Nil	No	-	CS+3mm	Yes
S08	6	19.30	60.0	60.0	60.0	60.0	0.61	0.55	104.0	No	-	SS316L	Yes
S09	6	19.10	59.88	59.89	Note 1	Note 1	Nil	Nil	Nil	No	-	CS+3mm	Yes
S10	6	52.22	140.1	147.3	59.88	59.89	Nil	Nil	Nil	No	-	CS+3mm	Yes
S11	6	51.52	60.0	60	60.0	60	8.0	0.43	200	No	-	SS316L	Yes
S12	6	51.52	60.0	60	60.0	60	7.85	0.43	196.25	No	-	SS316L	Yes
S13	6	51.32	59.89	59.90	59.89	59.90	0.48	0.43	12.0	Yes	1.75	CS+ 6 mm	Yes
S14	6	50.32	59.42	59.39	59.42	59.39	0.47	0.41	11.75	Yes	3.0	CS+3mm	Yes
S15	6	46.98	57.48	57.62	57.48	57.62	0.42	0.38	10.5	Yes	1.75	CS+3mm	Yes
S16	2	6.1	36.92	19.02	36.92	19.02	0.45	0.07	11.25	Yes	1.75	CS+6mm	Yes

Notes:

- 1- Gas shall be dry in compressor entrance, so this line shall be electrical traced to keep operating temperature above dew point.





- 2- There is no chloride in system. So, S.S 316L could be used.
- 3- S.S316L shall be used for bottom outlet piping of Suction drums, Knock Out Drum, Discharge drum, Slug Catcher up to control valve and C.S+6mm shall be used after control valve. The C.S+6mm shall be used for bottom outlet piping of Closed Drain Drum.

## 10.2 EQUIPMENT

Material selection of equipment is summarized in table 3.

Table3. Material selection of equipment

Tag Number	Description	Condition	Material	Minimum C.A. (mm)	Remark
V-2105	INLET KNOCK OUT DRUM	Sour	C.S. + Lining (P3) + +Sacrificial Anode	6	
V-2101 A/B/C	1 <sup>ST</sup> STAGE GAS COMPRESSION SUCTION DRUM	Sour	C.S. + Lining (P3)	6	
V-2104	SLUG CATCHER DRUM	Sour	C.S. + Lining (P3) + +Sacrificial Anode	6	

	<p>نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض</p> <p>احداث ردیف تراکم گاز در ایستگاه جمع آوری بینک</p>								
شماره پیمان: ۰۵۳ - ۰۷۳ - ۹۱۸۴	PIPING CORROSION STUDY & MATERIAL SELECTION REPORT							شماره صفحه : ۲۶ از ۳۰	
	پروژه	بسته کاری	صادر کننده	تسهیلات	رشته	نوع مدرک	سریال		نسخه
	BK	GCS	PEDCO	120	PI	RT	0001	D04	

Tag Number	Description	Condition	Material	Minimum C.A. (mm)	Remark
P-2101 A/B	SLUG PUMPS	Sour	API 610 / S-8	3	
C-2101 A/B/C	1 <sup>ST</sup> STAGE GAS COMPRESSOR	Sour	VTA	3	
AE-2101 A/B/C	1 <sup>ST</sup> STAGE GAS COMPRESSION AIR COOLER	Sour	Header: SS316L Tube: SS316L	0	
V-2102 A/B/C	2 <sup>ND</sup> STAGE GAS COMPRESSION SUCTION DRUM	Sour	C.S. + 3 mm Clad SS 316L	0	
C-2102 A/B/C	2 <sup>ND</sup> STAGE GAS COMPRESSOR	Sour	VTA	3	
AE-2102 A/B/C	2 <sup>ND</sup> STAGE GAS COMPRESSION AIR COOLER	Sour	Header: SS316L Tube: SS316L	0	
V-2103	2 <sup>ND</sup> STAGE GAS COMPRESSION DISCHARGE DRUM	Sour	C.S. + 3 mm Clad SS 316L	0	

Notes:

- As per depressurizing study MDT for flare header, flare drum and flare stack is -26C and for other process and utility equipment MDT is 3.4C (minimum ambient temp.)

### 10.3 UTILITY



#### 10.3.1 FLARE SYSTEM

The flare must cater to the possibility of depressurization of equipment during emergencies, for this purpose, MDMT from depressurizing calculation shall be considered. The considered MDT in this stage is -26°C. Two flare systems are considered in Binak new gas compressor station that is described as bellows:

Flare system LP consists of following items:

- Flare header
- Flare K.O. drum
- Flare K.O. drum pumps
- Flare stack
- Flare ignition package

Flare system LLP consists of following items:

	<p>نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض</p> <p>احداث ردیف تراکم گاز در ایستگاه جمع آوری بینک</p>																									
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PIPING CORROSION STUDY & MATERIAL SELECTION REPORT																										
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- Flare header
- Flare stack
- Flare ignition package

Since the MDMT for flare system is  $-26^{\circ}\text{C}$  therefore; flare LP K.O. Drum shall be NACE carbon steel with 3.2 mm corrosion allowance with lining. Both flare LP & LLP piping shall be constructed with carbon steel (6 mm C.A) NACE and from V-2201 to pump P-2201 A/B to be considered SS316L. Flare LP pump shall be class S-6 of API 610 Standard.

### 10.3.2 FUEL GAS SYSTEM

Gas separated from oil/gas separator (V-2105) is used for fuel gas. NACE carbon steel with 6 mm C.A. + internal coating and S.S. 316L internal component is foreseen for Fuel gas K.O. drum (V-2205) and NACE carbon steel with 6 mm C.A. is foreseen for Fuel gas piping system. For outlet liquid form Fuel Gas K.O. Drum the NACE carbon steel with 6 mm C.A has been chosen regarding the probability of condensed water aggregation. Corrosion inhibition and corrosion monitoring point has been prescribed as precautionary measure to cater for any unexpected corrosion that may occur.

### 10.3.3 DIESEL OIL SYSTEM

Fuel oil system including vessel (V-2206) and pump (P-2206) will be considered for this unit. The V-2206 is an above ground vessel which will be filled by diesel oil pump. Corrosivity of fuel oil is negligible; for the piping, the corrosion allowance of 1.0 mm has been chosen for any unexpected corrosion that may occur regarding any probability of water presence.

For the fuel oil vessel, carbon steel with 1.6 mm corrosion allowance is adequate. Internal lining shall be provided up to low liquid level to avoid corrosion from settled out water.

The fuel oil pump casing and impeller material shall be carbon steel and cast iron respectively, according to class S-1 of API 610 Standard.



### 10.3.4 INSTRUMENT & PLANT AIR SYSTEM

Wet air is slightly corrosive to carbon steel and equipment will need to be internally coated to prevent corrosion product in the system.

Inlet piping shall be galvanized CS (if size is larger than or equal to 4" S.S. will be used otherwise galvanized C.S. will be used.) and the Air Receiver is specified as CS internally epoxy coated over the entire surface. The corrosion allowance of 1.6 mm has been foreseen for any unexpected corrosion that may occur at coating defects.

The instrument air lines shall be galvanized CS (if size is larger than or equal to 4" S.S. will be used otherwise galvanized C.S. will be used.).

Carbon steel with 3.0 mm corrosion allowance shall be used for the plant air piping.

	<p>نگهداشت و افزایش تولید میدان نفتی بینک سطح الارض</p> <p>احداث ردیف تراکم گاز در ایستگاه جمع آوری بینک</p>																									
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BK	GCS	PEDCO	120	PI	RT	0001	D04																			

### 10.3.5 POTABLE WATER SYSTEM

Carbon steel (with 1.6 mm C.A) plus internal Epoxy painting (food grade) and Galvanized carbon steel shall be considered as material of construction for potable water elevated tanks (TK-2209) and above ground potable water piping system respectively (If pipe size is larger than or equal to 4" S.S. will be used otherwise galvanized C.S. will be used.). H.D.P.E will be used for all underground piping.

All products used internally in potable water tanks and also H.D.P.E material for underground piping shall be approved for such use by end users governing requirements/local health authorities.

The water pump (P-2209) material shall be according to class I-2 of API 610 Standard.

### 10.3.6 FIRE FIGHTING WATER SYSTEM

The firewater that is supplied from potable water source and also existing plant will be stored in two fire water storage tanks (TK-2301 A/B).

Fire water storage tank will be made of carbon steel (with 1.6 mm C.A.) plus lining.

H.D.P.E is used as material for underground fire water piping. Above ground piping shall be considered carbon steel with 3 mm C.A.

Cast Iron (with 3 mm C.A) and Al-bronze shall be used as materials of construction of casing and impeller of water pump respectively.

### 10.3.7 CLOSED DRAIN SYSTEM

The closed drain system including vessel and related pumps is considered for collecting drainage from the process equipment.



Provision is also made to route the fluid to existing burn pit at emergency condition.

The liquid from the Closed Drain Drum and Closed Drain lines may consist of mixture of water and hydrocarbon liquids in any proportion. The liquid contains H<sub>2</sub>S, CO<sub>2</sub>, chloride, chemicals and etc. The composition may vary widely from a few ppm to a few mole percent.

Carbon steel NACE plus Lining (with 6 mm C.A) is recommended for the Closed Drain vessel (V-2107) and Carbon steel NACE with 6 mm C.A burn pit pipes. Closed drain pump casing and impeller material shall be according to class S-6 of API 610 Standard.

### 10.3.8 CHEMICAL INJECTION SYSTEM

Chemicals shall be utilized for protection of the flow lines and for process aid and troubleshooting purposes. Piping, Tank/Vessel and Pumps for corrosion inhibitor package shall be SS. 316L.

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For methanol piping, carbon steel with 1.0 mm C.A. shall be considered.



The injection lines material after check valve shall be changed according to the connected process line.

### 10.3.9 DEHYDRATION GLYCOL PACKAGE

The materials for the glycol dehydration system will be submitted by vendor and shall be confirmed by client. The following table shall be used as minimum material requirements based on practice of SHELL DEP 39.01.10.12:

Component	Acceptable material	Notes
Contactora	Shell: carbon steel with a minimum corrosion allowance of 3 mm All internals shall be AISI 316L stainless steel Internal gaskets: Viton 'B' or equivalent	A 3 mm thick AISI 316L stainless steel cladding shall be applied below the bottom tray when bubble caps are used or below the chimney tray when structured packing or swirl tubes are used.
Reboiler	AISI 316L clad steel.	
Still column	AISI 316L stainless steel	Overhead vapor line piping shall be AISI 316L or duplex stainless steel
Condenser exchanger or coil	AISI 316L stainless steel	Removable for easy replacement
Glycol-glycol exchangers (plate type heat exchangers)	AISI 316L stainless steel plates Gaskets: metal reinforced flexible graphite	
Glycol-glycol exchangers (double pipe type heat exchangers)	Tube fin material shall be aluminum, except offshore or in presence of saline formation water, where marine bronze shall be used.	Only applicable in case finned tubes are applied.
Surge drum	Carbon steel with a minimum 3 mm corrosion allowance	
Glycol flash vessel	Carbon steel with a minimum 3 mm corrosion allowance	
Glycol stripping column	Carbon steel with a minimum 3 mm corrosion allowance	Only applicable if gas stripping of lean glycol applied.

Note: Instrument to measure dew point at outlet of dehydration package shall be considered by vendor.

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CS with 6 mm (1/4 in) corrosion allowance shall only be considered if a glycol pH and chemical maintenance program is in place and if the still reflux liquid is drained without reboiler CS contact.

Organic coatings (such as Epoxy and vinyl ester) shall not be used in the contactor as the high pressure (greater than about 40 barg) can induce coating failure (blistering and disbonding) during blowdown due to explosive decompression when the built up gas pressure at the coating/substrate exceeds the bonding strength. In addition, in some applications the wet gas may be so corrosive that if the organic coating is damaged, the underlying carbon steel vessel may be severely corroded before this is identified during inspections.

Column and vessel internals (e.g. demisters, dip pipes, packing, schoepentoeters, reboiler tubes) shall be AISI 316L stainless steel.

Lean Glycol Storage Tank storage tank will be made of carbon steel (with 3.2 mm C.A.) plus lining.

## 11.0 APPENDIX 1

Predict 6.1 (.prd) original files, PFD and P&ID are attached to this document to support the results.