



نگهداشت و افزایش تولید میدان نفتی بینک  
فعالیت های روزمینی در بسته های کاری تحت الارض  
عمومی و مشترک



شماره پیمان:

053 - 073 - 9184

PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT

| پروژه | بسته کاری | صادر کننده | تسهیلات | رشته | نوع مدرک | سریال | نسخه |
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شماره صفحه: 1 از 24

طرح نگهداشت و افزایش تولید 27 مخزن

PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT

نگهداشت و افزایش تولید میدان نفتی بینک

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شماره صفحه: 2 از 24

REVISION RECORD SHEET



| PAGE | D00 | D01 | D02 | D03 | D04 |
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| 37   |     |     |     |     |     |
| 38   |     |     |     |     |     |
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| 41   |     |     |     |     |     |
| 42   |     |     |     |     |     |
| 43   |     |     |     |     |     |
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| 45   |     |     |     |     |     |
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| 47   |     |     |     |     |     |
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| 49   |     |     |     |     |     |
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| 53   |     |     |     |     |     |
| 54   |     |     |     |     |     |
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| 62   |     |     |     |     |     |
| 63   |     |     |     |     |     |
| 64   |     |     |     |     |     |
| 65   |     |     |     |     |     |

| PAGE | D00 | D01 | D02 | D03 | D04 |
|------|-----|-----|-----|-----|-----|
| 66   |     |     |     |     |     |
| 67   |     |     |     |     |     |
| 68   |     |     |     |     |     |
| 69   |     |     |     |     |     |
| 70   |     |     |     |     |     |
| 71   |     |     |     |     |     |
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| 92   |     |     |     |     |     |
| 93   |     |     |     |     |     |
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| 97   |     |     |     |     |     |
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| 99   |     |     |     |     |     |
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| پروژه  | بسته کاری  | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                             |
| BK   | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                             |

## CONTENTS

|           |   |           |
|-----------|---|-----------|
| <b>1.</b> | <b>INTRODUCTION .....</b>                                     | <b>4</b>  |
| <b>2.</b> | <b>SCOPE .....</b>  | <b>5</b>  |
| <b>3.</b> | <b>NORMATIVE REFERENCES .....</b>                             | <b>5</b>  |
| 3.1       | LOCAL CODES AND STANDARDS .....                               | 5         |
| 3.2       | INTERNATIONAL CODES AND STANDARDS .....                       | 5         |
| 3.3       | THE PROJECT DOCUMENTS .....                                   | 6         |
| 3.4       | ENVIRONMENTAL DATA .....                                      | 6         |
| 3.5       | ORDER OF PRECEDENCE .....                                     | 6         |
| 3.6       | UNITS OF MEASUREMENTS AND ABBREVIATIONS .....                 | 6         |
| <b>4.</b> | <b>PREDICTION OF CORROSION AND DEGRADATION MODES .....</b>    | <b>7</b>  |
| 4.1       | GENERAL .....   | 7         |
| 4.2       | PRESENCE OF WATER .....                                       | 7         |
| 4.3       | CO <sub>2</sub> CORROSION .....                               | 8         |
| 4.4       | H <sub>2</sub> S CORROSION .....                              | 8         |
| 4.5       | CORROSION CALCULATION SOFTWARE .....                          | 10        |
| 4.6       | CRACKING GENERAL .....  | 10        |
| 4.7       | CHLORIDE INDUCED STRESS CORROSION CRACKING (CSCC) .....       | 12        |
| 4.8       | LOW TEMPERATURE SERVICE .....                                 | 13        |
| 4.9       | ORGANIC ACIDS .....   | 13        |
| 4.10      | UNDER DEPOSIT CORROSION .....                                 | 13        |
| 4.11      | OXYGEN CORROSION .....  | 13        |
| 4.12      | MICROBIOLOGICALLY INDUCED CORROSION (MIC) .....               | 14        |
| 4.13      | ELEMENTAL SULPHUR CORROSION .....                             | 14        |
| 4.14      | CHEMICAL CORROSION .....                                      | 14        |
| <b>5.</b> | <b>MATERIALS SELECTION PHILOSOPHY .....</b>                   | <b>15</b> |
| 5.1       | MATERIALS SELECTION OPTIONS .....                             | 15        |
| 5.2       | CANDIDATE MATERIALS .....                                     | 15        |
| <b>6.</b> | <b>CORROSION ASSESSMENT .....</b>                             | <b>17</b> |
| 6.1       | GENERAL .....   | 17        |
| 6.2       | CORROSIVE SPECIES: CO <sub>2</sub> AND H <sub>2</sub> S ..... | 17        |
| 6.3       | CORROSION ASSESSMENT – UNINHIBITED FLUID .....                | 18        |
| 6.4       | CORROSION MONITORING PHILOSOPHY .....                         | 18        |
| <b>7.</b> | <b>HYDROCARBON , WATER CHARACTERISTICS .....</b>              | <b>19</b> |
| 7.1       | OIL COMPOSITION .....   | 19        |
| 7.2       | FORMATION WATER .....   | 19        |
| <b>8.</b> | <b>RECOMMENDATION .....</b>                                   | <b>19</b> |
| 8.1       | FLOWLINES PIPELINE .....                                      | 19        |
| <b>9.</b> | <b>ATTACHMENTS .....</b>                                      | <b>24</b> |

|   |  |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                             |
|---|--|---|-----------|------------|----------|-------|----------|-------|------|----|-------|-------|-----|----|----|------|-----|-----------------------------|
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| پروژه   | بسته کاری  | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                             |
| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                             |

## 1. 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, construction of well location, access roads, wellhead facilities for 6 new wells (with electric power supply for 2 of them) and required modifications on 4 workover wells (with electric power supply) shall be done. In addition, construction of 6 new flowlines from new wells to Binak B/C unit (with extension of relevant manifold) are in the Project scope of work.

### GENERAL DEFINITION

The following terms shall be used in this document.

|                              |  |
|------------------------------|--|
| CLIENT:                      | National Iranian South Oilfields Company (NISOC)   |
| PROJECT:                     | Binak Oilfield Development – Construction of New Well Locations, Modifications on Workover Wells, Wellhead Facilities, Electrification Facilities, Flowlines and Extension of Binak B/C Manifold |
| 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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| پروژه   | بسته کاری   | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |   |
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## 2. SCOPE

This document details the procedures used to corrosion study and material selection of Binak 6 new wellhead flow lines with all necessary equipment and piping.



## 3. NORMATIVE REFERENCES

### 3.1 LOCAL CODES AND STANDARDS

- IPS G-ME-150 Iranian Petroleum Standard – Engineering & Material Standard for Towers , Reactors, Pressure vessels & Internals
- IPS-I-TP-802 Inspection standard for corrosion survey and inhibitor evaluation
- IPS-E-TP-100 Engineering Standard for Paints
- IPS-E-TP-350 Engineering Standards for Linings.
- IPS-E-TP-740 Engineering Standard for Corrosion Considerations in Material Selection
- IPS-E-TP-780 Engineering Standards for Chemical Control of Corrosion Environments

### 3.2 INTERNATIONAL CODES AND STANDARDS

- NACE MR 0175 / ISO 15156 Petroleum and Natural Gas Industries - Materials for use in H<sub>2</sub>S containing Environments in Oil and Gas Production
- API 5L Specification for Line Pipe
- DNV RP 0501 Erosive wear in piping systems
- ASME SA 578 Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications
- ISO 21547 Petroleum, petrochemical and natural gas industries  
—  
gas Materials selection and corrosion control for oil and systems

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| BK  | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                      |

### 3.3 THE PROJECT DOCUMENTS

- BK-GNRAL-PEDCO-000-PR-DB-0001 Process Basis of Design
- BK-SSGRL-PEDCO-110-PL-SP-0001 Pipeline Material Specification
- BK-GNRAL-PEDCO-000-PI-SP-0006 Specification for Painting
- BK-GNRAL-PEDCO-000-PI-SP-0008 Specification For Material Requirements in Sour service
- BK-W018S-PEDCO-110-PR-PF-0001 Process Flow Diagrams
- BK-W008N-PEDCO-110-PR-PF-0001 Process Flow Diagrams
- BK-W046S-PEDCO-110-PR-PF-0001 Process Flow Diagrams
- BK-W028-PEDCO-110-PR-PF-0001 Process Flow Diagrams
- BK-W035-PEDCO-110-PR-PF-0001 Process Flow Diagrams
- BK-W007S-PEDCO-110-PR-PF-0001 Process Flow Diagrams

### 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.

### 3.6 UNITS OF MEASUREMENTS AND ABBREVIATIONS

SI unit of measurements is used in the whole documents unless noted otherwise and the following abbreviations are used in this document:

- bbl/day Barrels of Liquid per Day
- BOPD Barrels of Oil per Day
- CA Corrosion Allowance
- CR Corrosion Rate
- MMSCFD Million Standard Cubic Feet per Day

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- PPM                                      Parts Per Million
- TOL                                        Top of Line
- BOL                                        Bottom of Line
- GOR                                        Gas Oil Ratio
- Cl    Chloride
- CRA                                        Corrosion Resistant Alloy
- SCC                                        Stress Corrosion cracking
- HIC                                        hydrogen-induced cracking
- SWC                                        Stepwise Cracking
- SLC                                        Service Life Corrosion
- CMP                                        Corrosion Management Program

#### 4. PREDICTION OF CORROSION AND DEGRADATION MODES

##### 4.1 GENERAL



Corrosion risks must consider the range of operating conditions over the field life, including start up and shutdown as well as high flow and low flow and the full range of temperatures that can be experienced either due to operating conditions, and /or environmental temperatures and blow down. Where corrosion cannot be mitigated by carbon steel with inhibition, Corrosion Resistant Alloys (CRA) may be selected. The selection of the type of CRA will be influenced by additional factors including pH, partial pressure H<sub>2</sub>S, Cl content, temperature, etc.

The following sections on CO<sub>2</sub> and H<sub>2</sub>S corrosion deal with corrosion mechanisms on carbon steels.

##### 4.2 PRESENCE OF WATER

The presence of water is the crucial factor in the assessment of corrosion risks to Hydrocarbon production systems. Hydrocarbon flows on their own are non-corrosive towards carbon steel and do not pose corrosion risk. However, if water is present in the form of liquid water it can dissolve CO<sub>2</sub> and H<sub>2</sub>S contained in the produced fluids to form acidic solutions that then lead to corrosion of the metallic materials used to retain them.

Water may be present as formation water, produced along with the hydrocarbons from the reservoir itself, or be present as water of condensation which will condense out from the water saturated Hydrocarbons as the produced fluids cool or due to pressure drop. The formation water analysis has been taken from the Process Basis of Design with document No. BK-GNRAL-PEDCO-000-PR-DB-0001. The formation water is reported as containing up to 127800 ppm. The influence of Cl is discussed below and has a major effect on the stability of the Iron Sulphide (FeS) scale leading to breakdown and pitting under certain circumstances. Chloride in combination with H<sub>2</sub>S also plays a major role in the Sulphide Stress Corrosion Cracking of

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| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |  |

#### Corrosion Resistant Alloys.

Bicarbonate is beneficial in the corrosion process and increases the pH which has been lowered by the CO<sub>2</sub> and H<sub>2</sub>S gasses. Reductions in corrosion rate associated with bicarbonate ions can only be considered where water is comprised of formation water. Water of condensation does not contain bicarbonate and therefore its effect on pH cannot be considered in these lines.

Corrosion in Oil and multiphase lines is dependent on flowing conditions and also the ability of the oil to retain water in suspension and for the pipe walls to be continually oil wetted. This in turn relies on the water cut and the density and viscosity of the oil.

#### 4.3 CO<sub>2</sub> CORROSION

CO<sub>2</sub> corrosion is a common failure mode in hydrocarbon production facilities. The corrosion is caused by CO<sub>2</sub> dissolving in the water phase to form carbonic acid, which is corrosive to carbon steel. Based on API 571 Section 4-80, increasing the level of chromium in steels offers no major improvement in resistance until a minimum of 12% is reached.

However, the presence of H<sub>2</sub>S in the fluids may strongly affect CO<sub>2</sub> corrosion. There are three different practical corrosion domains of carbon steel to consider. These are dependent on the proportions of CO<sub>2</sub> and H<sub>2</sub>S in the fluids:

| Partial Pressure Ratio                       | Corrosion Domain                                   |
|--|--|
| CO <sub>2</sub> / H <sub>2</sub> S > 500     | CO <sub>2</sub> corrosion dominates                |
| 500 ≥ CO <sub>2</sub> /H <sub>2</sub> S ≥ 20 | Mixed CO <sub>2</sub> / H <sub>2</sub> S corrosion |
| CO <sub>2</sub> / H <sub>2</sub> S < 20      | H <sub>2</sub> S corrosion dominates               |



For BINAK Production wells, the high H<sub>2</sub>S case results in an H<sub>2</sub>S dominant domain.

All of the traditional corrosion calculation models which are available are based on the well-established De Waard and Milliams equations, which were developed for evaluation of CO<sub>2</sub> corrosion. The majority of these programs are not able to consider the influence of H<sub>2</sub>S in the corrosion rate calculations and tend to overestimate general corrosion when compared to actual corrosion test data and operational experience.

#### 4.4 H<sub>2</sub>S CORROSION

The Iron Sulphide (FeS) film formed by aqueous H<sub>2</sub>S in contact with steel surfaces is a relatively hard corrosion product and is normally tightly adhere to the surface of the steel. This is in contrast to the iron carbonate scale formed under CO<sub>2</sub> dominant systems which is relatively soft and can easily be removed by erosion. This hard adherent FeS scale has been shown to prevent general corrosion and general weight loss corrosion is rarely a problem in carbon steel



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| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                             |

equipment.

The FeS scale prevents the traditional general weight loss type of CO<sub>2</sub> corrosion, in combined CO<sub>2</sub> / H<sub>2</sub>S systems, even with significant levels of CO<sub>2</sub>. The major impact of the CO<sub>2</sub> in an H<sub>2</sub>S dominant system is to combine with the H<sub>2</sub>S to further reduce the PH. As the pH is reduced, the stability of the FeS scale can be compromised and local breakdown may lead to pitting corrosion.

The complex interaction of Iron Sulphide corrosion product films and process parameters such as flow rate, flow regime, solids, and pH and chloride contents can cause large changes to the characteristics of the Iron Sulphide film, and the level of protection it provides.

Under field conditions it can be assumed that pitting corrosion may occur at locations where the surface film is stressed e.g. by locally high flow velocities or in locations with lowered pH like stagnant water phase in dead legs, or at low points in pipelines flowing at low velocities, or under deposits.

For oil wetted pipes TOL is not considered a major problem unless there is a high GOR and laminar flow with high condensation rates. However it is a consideration for the gas overhead lines. Where predicted corrosion levels are not high, carbon steel can be considered as a suitable selection provided that the wall of the pipe is maintained above the dew point by insulation and heat tracing. This option has been used on several projects to avoid the cost of more expensive CRA options.

#### ➤ **DOMAINS OF SOUR SERVICE**



Domains of sour service are defined in Figure 1, showing four Regions characterizing materials suitability for sour service applications as per NACE MR 0175/ ISO 15156. These are:

Region 0: "Sweet Service" (only negligible traces of H<sub>2</sub>S): the domain within which no specific metallurgical precautions are needed. This Region applies to all metallic components.

Region 1: "Mild Sour Service" The domain within which minor and inexpensive precautions is required. An example of materials which can be used within Region 1 includes carbon steel tubing and casing up to API 5 CT grades P110 - this Region applies to any material of similar sensitivity to SSC.

Region 2: "Intermediate Sour Service" The domain within which increasing precautions are required. An example of materials, which can be used within Region 2, includes carbon and low alloy steel tubing and casing up to the API 5CT grade N80. This Region applies to any material of similar sensitivity to SSC.

Similarly, resistance to HIC and SOHIC can be achieved by the use of moderately low sulphur, clean and micro structurally homogeneous steels.

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Region 3: "Severe Sour Service" The domain within which the most stringent precautions are necessary. Examples include materials taken from the ISO 15156 reference list. Similarly, resistance to SWC requires steels with very low sulphur and other impurity contents, and/or calcium treatment, and qualified by laboratory testing in the expected service conditions.

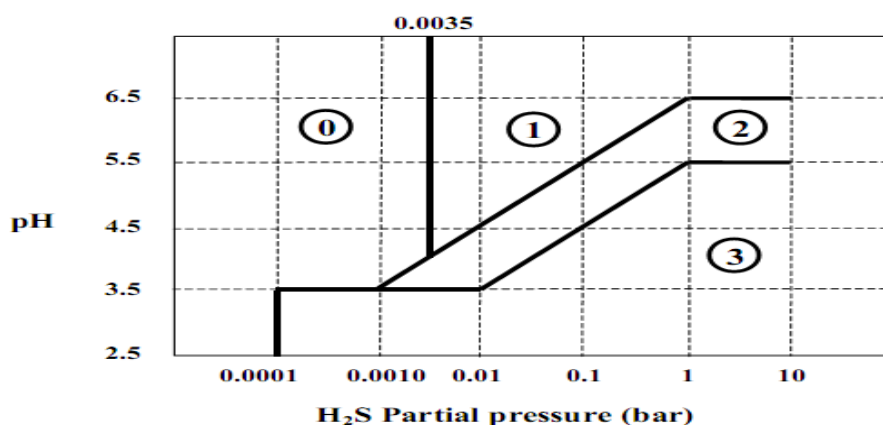


Figure 1 - Limits of sour service

The domain of crude oil services with H<sub>2</sub>S mole percentage and calculated PH have been specified region 1,2,3 as per as per section 8.

#### 4.5 CORROSION CALCULATION SOFTWARE

Electronic Corrosion Engineer (ECE) enables the quantitative estimation of corrosion rates and the selection of materials for oil and gas production systems and processing facilities. At the heart of ECE is a new and improved model for corrosion analysis and material selection, firmly based on laboratory data, and field calibration studies both with pipeline and with downhole tubing. So considering above points results of predict 6.0 been considered as the basis of material selection. The results of this software are in section 8.



#### 4.6 CRACKING GENERAL

The presence of H<sub>2</sub>S can also give rise to three principal types of cracking in steels. These are Sulphide Stress Corrosion cracking (SSCC), which may occur in carbon, low alloy, and stainless steels, and hydrogen-induced cracking (HIC), which is limited to carbon and low alloy steels, and Stepwise Cracking (SWC).

##### 4.6.1 SULPHIDE STRESS CORROSION CRACKING (SSCC)

Sulphide Stress Corrosion Cracking (SSCC) results from the joint action of corrosion and tensile stress (residual or applied) in the presence of water and H<sub>2</sub>S.

SSCC occurs when atomic hydrogen released during a corrosion process in H<sub>2</sub>S containing solutions diffuses into the metal but remains in solid solution in the crystal

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| BK  | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                      |

lattice. This reduces the ductility and deformability of the metal, particularly untempered Martensitic, which already has limited ductility. Under tensile stress, whether applied or residual from cold forming or welding, this embrittled metal readily cracks to form sulphide stress cracks. The cracking process is very rapid and has been known to take as little as a few hours for a crack to form and cause catastrophic failure.

Stress corrosion cracking not only affects carbon steel and low alloy steel but also occurs in Corrosion Resistant Alloys (CRAs). In the presence of chlorides austenitic and duplex stainless steels are also susceptible to stress corrosion cracking in H<sub>2</sub>S environments. Increasing the nickel content in CRAs improves the resistance to SSCC and in general, alloys with in excess of 40 % Ni are immune to SSC in the presence of Cl and H<sub>2</sub>S.

The limitation for the safe use of CRAs is dependent upon several contributory factors such as the partial pressure of the H<sub>2</sub>S, the level of chlorides, the partial pressure of CO<sub>2</sub>, and system PH. Guidance for use of carbon steels and CRAs in H<sub>2</sub>S containing environments are spelt out in tabular forms in NACE MR0175/ISO 15156, under H<sub>2</sub>S conditions.



#### 4.6.2 HYDROGEN INDUCED CRACKING (HIC)

Hydrogen Induced Cracking (HIC) principally affects rolled carbon and low alloy steel products, whereby any atomic hydrogen produced from the corrosion reaction diffuses into the steel and accumulates around non-metallic inclusions in the steel. The hydrogen atoms recombine as molecular hydrogen at trap sites in the steel matrix. Favorable trap sites are typically found in rolled products along elongated inclusions or segregated bands of microstructure. The high pressures generated result firstly in a crack initiation phase and then propagation along the metallurgical structure sensitive to this type of hydrogen embitterment. As more hydrogen enters the voids the pressure rises, deforming the surrounding steel so that blisters may become visible at the surface. Sulphur content in the plate material shall not exceed 0.003%, the cleanliness of the steel play an important role in the mitigation of HIC.

#### 4.6.3 STEPWISE CRACKING (SWC)

Stepwise cracking occurs following hydrogen charging. Where steel around HIC cracks becomes highly strained, can causing linking of adjacent cracks to form stepwise cracking, so called because the arrays of cracks have a stepwise appearance.

There is no lower acceptable limit. For the partial pressure of H<sub>2</sub>S that can be considered safe to prevent the onset of HIC/SWC damage, however it is rarely a problem of practical significance at partial pressures below 3.5 mbar.

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| پروژه   | بسته کاری   | صادر کننده  | تسهیلات | رشته | نوع مدرک | سریال | نسخه |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                             |
| BK  | SSGRL   | PEDCO   | 110     | PL   | RT       | 0001  | D04  |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                             |

HIC/SWC can be controlled by modification of the chemical composition of the materials. The specific requirements are spelt out in ISO 15156. Testing and acceptance criteria shall be addressed in the Project Materials Specifications.

#### 4.6.4 GALVANIC HYDROGEN STRESS CRACKING (GHSC)

Galvanic corrosion (GHSC) can be a concern when dissimilar materials are in contact in a conductive fluid such as an H<sub>2</sub>S environment.

When two different metallic materials are electrically connected and placed in a conductive solution (electrolyte), an electric potential exists. This potential difference will provide a stronger driving force for the dissolution of the less noble (more electrically negative) material.



Preventive measures that may be taken include:

1. When joining two dissimilar metals together, galvanic corrosion can be prevented by insulating the two materials from each other. For example, when bolting flanges of dissimilar metals together, plastic washers can be used to separate the two metals.
2. Do not couple metals that are far apart in the galvanic series.
3. Avoid small anode–large cathode combinations. Fasteners should be cathodic to the parts being fastened.
4. Any coating being applied should be applied to the cathodic member and not to the anodic member. This is to prevent an unfavorable anode/cathode ratio should any discontinuity in the coating occur.
5. Anodic parts may be made thicker to provide a longer life.
6. A sacrificial metal may be installed that would be anodic to both metals.

#### 4.7 CHLORIDE INDUCED STRESS CORROSION CRACKING (CSCC)

Austenitic and duplex stainless steels may suffer from external Chloride Induced Stress Corrosion Cracking (CSCC) when exposed to a combination of tensile stresses, chlorides, water, oxygen, and elevated temperature. This failure mode, typically caused by exposure to humid marine atmosphere, may represent a higher risk than the internal service and is generally manifested by a sudden fracture of pipe or equipment.

Where external CSCC is considered a possibility, susceptible materials can be coated with a high integrity organic coating system or Thermally Sprayed Aluminum (TSA). Alternatively, alloy with greater resistance to CSCC may be selected.

|   |   |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                      |
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| شماره پیمان:<br>053 - 073 - 9184  | <b>PIPELINE CORROSION STUDY &amp; MATERIAL SELECTION REPORT</b> <table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 10%;">پروژه</td> <td style="width: 10%;">بسته کاری</td> <td style="width: 10%;">صادر کننده</td> <td style="width: 10%;">تسهیلات</td> <td style="width: 10%;">رشته</td> <td style="width: 10%;">نوع مدرک</td> <td style="width: 10%;">سریال</td> <td style="width: 10%;">نسخه</td> </tr> <tr> <td>BK</td> <td>SSGRL</td> <td>PEDCO</td> <td>110</td> <td>PL</td> <td>RT</td> <td>0001</td> <td>D04</td> </tr> </table> | پروژه   | بسته کاری | صادر کننده | تسهیلات  | رشته  | نوع مدرک | سریال | نسخه | BK | SSGRL | PEDCO | 110 | PL | RT | 0001 | D04 | شماره صفحه: 13 از 24 |
| پروژه   | بسته کاری   | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                      |
| BK  | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                      |

#### 4.8 LOW TEMPERATURE SERVICE

The materials selection process shall consider the Minimum Design Material Temperature (MDMT) for all piping and equipment, determined in accordance with the applicable codes and standards. All materials shall have adequate low temperature toughness to prevent brittle fracture during normal operation and under blow down load conditions.

For carbon steel vessels actual stresses at the minimum temperature shall be taken into consideration when deciding the material test temperatures, in accordance with the design codes. Use of thermal sleeves and local use of austenitic materials for local "cold spots" shall be considered if required.

Materials shall follow the requirements of ASME VIII and B31.3 in addition to the project Equipment data sheets and piping classes, based upon the minimum anticipated metal skin temperature and wall thickness.

#### 4.9 ORGANIC ACIDS

Minor amounts of organic acids, primarily acetic acid, but also formic may also be present and can influence and complement corrosion by lowering the pH and supplying more H<sup>+</sup> ions for reaction. They can also prevent formation and interfere with the protectiveness of carbonate and iron sulphide scales. However there is no reference to these acids in the basis of design.

#### 4.10 UNDER DEPOSIT CORROSION



During periods of low flow, such as startup and shut down, it is possible for deposits to settle out of wet sour gas streams onto the bottom of piping and cause under deposit corrosion. Corrosion occurs due to a form of crevice corrosion initiated by a difference in acid water concentration under the deposit. The deposit also prevents wetting of the steel surface by corrosion inhibitor leaving localized areas unprotected.

Deposits of solids may also act as sites for sulphate reducing bacteria to accumulate, breed and cause localized corrosion. The bacteria reduce sulphate ions present in the water to sulphide ions that can then cause corrosion problems associated with H<sub>2</sub>S. Such bacteria can become very active in de-aerated water.

#### 4.11 OXYGEN CORROSION

Oxygen is not normally present in the production fluids and if detected in the process streams is an indication of an operational upset. Every effort shall be made to exclude oxygen as it has potentially serious consequences on the corrosion resistance of metallic materials.

It greatly increases the tendency towards pitting of carbon steels and CRAs in these environments and greatly increases the likelihood of stress corrosion cracking of CRAs.

|   |  |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |  |
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| شماره پیمان:<br>053 - 073 - 9184  | <b>PIPELINE CORROSION STUDY &amp; MATERIAL SELECTION REPORT</b>  | شماره صفحه: 14 از 24  |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |  |
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| پروژه   | بسته کاری  | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |  |
| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |  |

Water used for water injection can be either deaerated or aerated, which will have an impact on the corrosivity. Due to the removal of oxygen in deaerated water, the corrosion rate of carbon steel will be low, whereas in systems carrying aerated water a higher corrosion rate must be anticipated. Oxygen corrosion is a time dependent corrosion mechanism and takes principally the form of uniform corrosion, but localized attacks may also occur pitting.

#### 4.12 MICROBIOLOGICALLY INDUCED CORROSION (MIC)

Sulfate Reducing Bacteria (SRB) are the major contributors to microbiological induced corrosion for the inside of oil and gas producing facilities. As a result of the reduction of sulfates, hydrogen sulfide is created by the bacteria. Locally, under the colonies of bacteria, iron is bound to iron-sulfide. The result can be severe pitting corrosion.

SRB's are normally not present in an oil well and downstream production facilities, unless introduced by man e.g. during hydrotesting or together with injection or wash-water. Process wash water is fresh water produced by passing raw water through deaeration package. The deaerated water is treated with biocides. Because biocides are injected at 2 types (A & B), the total amount of active(live) bacteria in the system will be small.

#### 4.13 ELEMENTAL SULPHUR CORROSION



At present there is only a limited amount of information available regarding the presence of elemental sulphur in the well stream fluids. If present, contamination of the production fluids is particularly deleterious because of its influence on pitting corrosion mechanisms discussed earlier under H<sub>2</sub>S corrosion. Sulphur is naturally soluble in liquid hydrocarbons where it does not present a corrosion threat. However, when it has been encountered in hydrocarbon systems it accelerates pitting corrosion rates in carbon steels. CRAs generally suffer localized corrosion in the presence of elemental sulphur and it can be deleterious on the corrosion resistance of most CRA's.

#### 4.14 CHEMICAL CORROSION

As the chemical compositions are in accordance with vendor proficiency then following survey have been done as per vendor recommendation.

Oxygen Scavenger is an ammonium bisulfate based that used to remove dissolved oxygen from water in oil field and water injection systems. Oxygen Scavenger is water soluble which is corrosive on carbon steel material then for this case stainless steel material shall be selected for handling, storage and piping system. PH for Oxygen Scavenger is near 4.

Demulsifier is a blend of complex surface active compounds, formulated to give a product capable of improved hydrocarbon recovery from crude oil emulsion. Demulsifier gives a rapid water separation, reduces salt content of treated crude oil and minimize hydrocarbon level in dump water. Demulsifier is aromatics soluble.

|  |   |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                             |
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|  <p>NISOC</p> | <p>نگهداشت و افزایش تولید میدان نفتی بینک<br/>فعالیت های روزمینی در بسته های کاری تحت الارض<br/>عمومی و مشترک</p>   |  |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                             |
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| پروژه  | بسته کاری   | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                             |
| BK   | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                             |

Scale inhibitor is a highly effective organ phosphorous compound designed to control scale formation in water injection, salt water disposal systems and in downhole pumping equipment. Although this is effective for continuous injection in surface facilities. Scale inhibitor is soluble in fresh water and brines which is corrosive on carbon steel material then for this case stainless steel material shall be selected for handling, storage and piping system. PH for scale inhibitor is less than 2.

Corrosion Inhibitor is prevention of corrosion in oil wells and flow lines with high water content. Corrosion Inhibitor is water soluble. PH for Corrosion Inhibitor is near 4. Corrosion Inhibitor is corrosive on carbon steel material then for this case stainless steel material shall be selected for handling, storage and piping system.

Biocide is a highly effective against both aerobic and anaerobic microorganisms such as SRB. Biocide is water soluble. PH for biocide is between 2.5-4.5. Biocide is corrosive on carbon steel material then for this case stainless steel material shall be selected for handling, storage and piping system.

Liquid Reverse Demulsifier is a cationic charged. The main application for Liquid Reverse Demulsifier is for waste water treatment in oil industry. It is of low viscosity as supplied, and if required can be readily pumped. Reverse Demulsifier is water soluble. PH is near 2. Reverse Demulsifier is corrosive on carbon steel material. If there are not chloride ions in composition, then stainless steel material shall be selected for handling, storage and piping system.



## 5. MATERIALS SELECTION PHILOSOPHY

### 5.1 MATERIALS SELECTION OPTIONS

If the total calculated corrosion in the design 20 years life period is less than 1 mm, carbon steel with 1 mm corrosion allowance, if the total calculated corrosion in the design 20 years life period is selected greater than 1mm and less than 3 mm, carbon steel with 3 mm corrosion allowance is selected, if the total calculated corrosion in the design 20 years life period is greater than 3 mm and less than 6 mm then CS with 6 mm CA shall be selected and where Service Life Corrosion (SLC) greater than 6 mm CA or high pitting corrosion rate, the solid or cladding Corrosion Resistant Alloys (CRA) are selected.

### 5.2 CANDIDATE MATERIALS

The levels of H<sub>2</sub>S in the majority of streams, together with the corrosively of the associated CO<sub>2</sub> levels, mean that the H<sub>2</sub>S partial pressure has dominated material selection. Nickel based alloys have the highest tolerance to wet H<sub>2</sub>S in the presence of wet H<sub>2</sub>S, while the stainless steel have a smaller, but significant tolerance. Carbon steels can have excellent tolerance to wet H<sub>2</sub>S, but suffer badly from wet CO<sub>2</sub> corrosion, limiting their application. As tolerance to H<sub>2</sub>S increases with price, it follows that the most economical solution is to select the lowest grade of materials which will tolerate the relevant conditions.

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| پروژه   | بسته کاری  | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سرنال | نسخه     |       |      |    |       |       |     |    |    |      |     |   |
| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |   |

The material considered for selection is summarized in the following sub-sections. The materials mentioned are in contact with the mild aggressive fluid, so the selected material will be carbon steel with NACE requirements for crude oil and for chemical fluid stainless steel will be used.

### 5.2.1 CARBON STEEL

Carbon Steel is preferred for piping and equipment, as it is cheap and readily available, and its corrosion resistance in wet CO<sub>2</sub> and H<sub>2</sub>S conditions is not perceptibly dependent on the levels of chlorides ions in the solution. Low temperature carbon steel with appropriate Charpy toughness shall be used where the design temperature is below -29 °C and down to -45 °C.

Corrosion by wet CO<sub>2</sub> and H<sub>2</sub>S, both limit the application of carbon steel. As resistance to attack by H<sub>2</sub>S is dependent on the hardness and cleanliness of the steel, every precaution shall be taken to specify this, consequently SSCC and HIC resistant carbon steel has been specified in the most the applications. Carbon steel hasn't been selected for any application where the predict 6.0 predicted the corrosion rate higher than 6 mm or high pitting corrosion rate.

In non-corrosive services carbon steel is suitable material such as instrument air.

### 5.2.2 316/316L STAINLESS STEEL

This materials is an iron-based alloy with addiction of at least 16 % chromium, 10% nickel and 2% molybdenum, it is resistant to wet CO<sub>2</sub> corrosion, but it is susceptible Sulphite Stress Corrosion Cracking (SSCC) at relatively wet low H<sub>2</sub>S partial pressures. Its tolerance to wet H<sub>2</sub>S is reduced further by the presence of chlorides.



The L indicates a low carbon content to optimize weld corrosion resistance, but it tends to reduce the allowable design stresses. The disadvantage of 316L is the risk of chlorides stress corrosion cracking when it is exposed to atmospheric chlorides at temperatures exceeding 60° C.

The stainless steel materials are suitable for some chemical services such as corrosion inhibitor, demulsifier.

### 5.2.3 Glass –Reinforced Epoxy

GRE is a composite material made of an epoxy resins reinforced by fine fibers made of glass. In principle, GRE is ideal material for handing corrosive fluids, as they do not corrode and are not susceptible to stress-corrosion cracking from either chloride or sulphides. However, their performance is both time-and temperature dependent, as the binders will deteriorate slowly, and this limits their applications to lower temperature than those experienced by many of the materials listed above. The main drawbacks is



|   |   |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                      |
|---|---|---|-----------|------------|----------|-------|----------|-------|------|----|-------|-------|-----|----|----|------|-----|----------------------|
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| پروژه   | بسته کاری   | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                      |
| BK  | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                      |

vulnerability to mechanical damage (which means that they need mechanical protector) and the need for fitting which (unlike straight pipe) have to be laid up by hand, making them both slow and expensive to produce. Consequently, GRE pipe is prime candidate material for long buried pipe runs, where corrosion resistant alloy materials would be expensive and carbon steel would need inhibition and for salty waste water and water lines from 3 phase separators.

As these are relatively new materials, there are constant developments both in binder technology and jointing systems, so that the application limits in terms of operating temperatures and pressure, and the pipe sizes are regularly expanded. Confirmation of the use of GRE to any particular service will depend therefore, on the final design conditions, as the major of grades available are limited to design temperature and pressure. Now we use GRE pipe for underground and aboveground waste water system.

#### 5.2.4 Duplex Stainless Steel

Duplex stainless steels have about 21-27% chromium, 1.7-3.5% molybdenum, and 4-6.5% nickel designed for demanding applications which require exceptional strength and corrosion resistance, it has excellent resistance to chlorides stress corrosion cracking, high thermal conductivity and low coefficient of thermal expansion. The high chromium, molybdenum and nitrogen levels provide excellent resistance to pitting, crevice and general corrosion.

#### 5.2.5 Super Duplex Stainless Steel

Super duplex stainless steels have about 24-26% chromium, 3-5% molybdenum, and 6-8% nickel designed for demanding applications which require exceptional strength and corrosion resistance, it has excellent resistance to chlorides stress corrosion cracking, high thermal conductivity and low coefficient of thermal expansion. The high chromium, molybdenum and nitrogen levels provide excellent resistance to pitting, crevice and general corrosion. Super duplex stainless steels shall have PREN  $\geq 40$ .



## 6. CORROSION ASSESSMENT

### 6.1 GENERAL

The basis of temperature and pressure for corrosion calculations were taken from H&MB data in Process Flow Diagrams referred in clause 3.3.

### 6.2 CORROSIVE SPECIES: CO<sub>2</sub> AND H<sub>2</sub>S

The corrosive species for BINAK new wells are provided in ATTACHMENT 1 as Summary of Predict 6.0 corrosion results. This software considers oil gravity, water cut, flow rate, temperature, pressure and design life.

|   |  |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |                              |
|---|--|---|-----------|------------|----------|-------|----------|-------|------|----|-------|-------|-----|----|----|------|-----|------------------------------|
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| پروژه   | بسته کاری  | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |                              |
| BK  | SSGRL  | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |                              |

### 6.3 CORROSION ASSESSMENT – UNINHIBITED FLUID

The material selection for the lines first examines the suitability of carbon steel. Carbon steel in some streams will be used with inhibitor and in some streams will be used without inhibitor.

### 6.4 CORROSION MONITORING PHILOSOPHY

The reliability of both the materials selection and the corrosion assessment need to be verified at site through monitoring and careful inspection during every plant/equipment shutdown. The Risk Based Inspection plan should be developed by the plant during operation in order to know where, when and how to inspect taking into account the mutual interdependence between the various section of the plant.



The following methods of corrosion monitoring will be considered. In the direct methods the actual metal loss is being measured. With the indirect techniques except the iron count the measurement is on the test coupon.

Visual inspection is particularly desirable at equipment locations and weld joints susceptible to accelerated attack. Where visual inspection should be combined with other measurements, ultrasonic inspection and callipers can be used. Removable spool can be provided at critical vessels nozzles and inspection at the nozzles and spools will be provided valuable information concerning any corrosion related problems.

Ultrasonic inspection in conjunction with radiography is proposed as the primary means of monitoring and detection corrosion. Base line inspection should be conducted and documented. The location of these inspections should be determined based on susceptibility to corrosion and accessibility during operation and maintenance. The detailed locations will be decided during detailed stage.

Following the baseline inspection, period inspections should be performed and the maximum interval should be 5 years for carbon steel lines and 10 years for CRA lines. Subsequent inspection shall be based on comparing the actual calculated corrosion rate with the predicted the corrosion rates. The subsequent duration for inspection should not exceed half the remaining life of the line.

| Direct                | Indirect                    |
|-----------------------|-----------------------------|
| Visual inspection     | Iron counts/Coupons         |
| Ultrasonic Inspection | Linear Polarization Probe   |
| Callipers             | Electrical Resistance probe |
| Test Spools           | Galvanic Probe              |

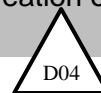
|   |  |                    |                     |                |            |                |               |   |                      |
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| شماره پیمان:<br>053 - 073 - 9184  | پروژه<br>BK  | بسته کاری<br>SSGRL | صادر کننده<br>PEDCO | تسهیلات<br>110 | رشته<br>PL | نوع مدرک<br>RT | سریال<br>0001 | نسخه<br>D04   | شماره صفحه: 19 از 24 |

|             |                |
|-------------|----------------|
| Radiography | Hydrogen Probe |
|             | Bio-Probe      |

A formal review of the corrosion monitoring requirements shall be carried out as a part of the detailed design.

Corrosion Coupon shall be considered for flow line inlet.

In this project using of pig and batch corrosion inhibitor is recommended if applicable for flowlines. Otherwise corrosion probe & coupon at inlet and outlet of flowlines and periodic measurement of pipes thickness must be considered. Also creation of low points and dead points must be avoided in pipeline design as much as possible.



## 7. HYDROCARBON , WATER CHARACTERISTICS

The following indicates the content of hydrocarbon composition & specifications in hydrocarbon fluids:

### 7.1 OIL COMPOSITION

Process condition of wellheads and flow lines such as temperature, pressure, corrosive agents, hydrocarbon and water flows and water analysis has been summarized in section 9 (Attachment).

### 7.2 FORMATION WATER

Water Analysis in Oil Specification



| ION | Na <sup>+</sup> | Ca <sup>2+</sup> | Mg <sup>2+</sup> | Cl <sup>-</sup> | SO <sub>4</sub> <sup>2-</sup> | CO <sub>3</sub> <sup>2-</sup> |
|-----|-----------------|------------------|------------------|-----------------|-------------------------------|-------------------------------|
| ppm | 65299           | 10720            | 1312             | 123185          | 300                           | 415                           |

## 8. RECOMMENDATION

### 8.1 FLOWLINES PIPELINE

Lines corrosion circuit is comprised as below table with the results ECE 5.4 software (Section 9- Attachments). So results of predict ECE 5.4 been considered as the basis of material selection. The results of this software are in this section.

The ECE 5.4 program predicts acceptable general Corrosion rate and pitting corrosion risk in wellhead and flow lines. This software specify NACE MR 0175/ISO15156 regions accurately.

|  |   |   |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |   |
|--|---|---|-----------|------------|----------|-------|----------|-------|------|----|-------|-------|-----|----|----|------|-----|---|
|  <p>NISOC</p> | <p>نگهداشت و افزایش تولید میدان نفتی بینک<br/>         فعالیت های رو زمینی در بسته های کاری تحت الارض<br/>         عمومی و مشترک</p>  |  |           |            |          |       |          |       |      |    |       |       |     |    |    |      |     |   |
| <p>شماره پیمان:<br/>053 - 073 - 9184</p>   | <p style="text-align: center;"><b>PIPELINE CORROSION STUDY &amp; MATERIAL SELECTION REPORT</b></p> <table border="1" style="width: 100%; text-align: center;"> <tr> <td>پروژه</td> <td>بسته کاری</td> <td>صادر کننده</td> <td>تسهیلات</td> <td>رشته</td> <td>نوع مدرک</td> <td>سریال</td> <td>نسخه</td> </tr> <tr> <td>BK</td> <td>SSGRL</td> <td>PEDCO</td> <td>110</td> <td>PL</td> <td>RT</td> <td>0001</td> <td>D04</td> </tr> </table> | پروژه   | بسته کاری | صادر کننده | تسهیلات  | رشته  | نوع مدرک | سریال | نسخه | BK | SSGRL | PEDCO | 110 | PL | RT | 0001 | D04 | <p style="text-align: right;">شماره صفحه : 20 از 24</p> |
| پروژه  | بسته کاری   | صادر کننده  | تسهیلات   | رشته       | نوع مدرک | سریال | نسخه     |       |      |    |       |       |     |    |    |      |     |   |
| BK   | SSGRL   | PEDCO   | 110       | PL         | RT       | 0001  | D04      |       |      |    |       |       |     |    |    |      |     |   |

Corrosion calculation has been carried out using ECE 5.4 for relevant water cuts as below tables:



نگهداشت و افزایش تولید میدان نفتی بینک  
 فعالیت های روزمینی در بسته های کاری تحت الارض  
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شماره پیمان:

053 - 073 - 9184

PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT

|       |           |            |         |      |          |       |      |
|-------|-----------|------------|---------|------|----------|-------|------|
| پروژه | بسته کاری | صادر کننده | تسهیلات | رشته | نوع مدرک | سریال | نسخه |
| BK    | SSGRL     | PEDCO      | 110     | PL   | RT       | 0001  | D04  |

شماره صفحه: 21 از 24

LINES CORROSION CIRCUIT

| Wellhead Flow line No. / WaterCut | Years        |              | Stream No. | Press. (Bara) @ Inlet S/W |      | Temp. (°C) @ Inlet S/W |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |     |  |
|-----------------------------------|--------------|--------------|------------|---------------------------|------|------------------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|-----|--|
|                                   |              |              |            |                           |      |                        |      | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |     |  |
| W008N                             | 0%           | 1401         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.38                  | 0.02                      | 0.48                 | 0.38                   | 0.02                      | 0.47                | 0.02                                   | C.S+3mm (Note 1)        | Yes |  |
|                                   | 1%           | 1402         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.38                  | 0.02                      | 0.48                 | 0.38                   | 0.02                      | 0.47                | 0.02                                   |                         |     |  |
|                                   | 2%           | 1403         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.38                  | 0.02                      | 0.48                 | 0.38                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 3%           | 1404         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.38                  | 0.02                      | 0.48                 | 0.38                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 5%           | 1405         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.39                  | 0.02                      | 0.48                 | 0.39                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 10%          | 1406         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.40                  | 0.02                      | 0.48                 | 0.40                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 12%          | 1407         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.40                  | 0.02                      | 0.49                 | 0.40                   | 0.02                      | 0.49                | 0.02                                   |                         |     |  |
|                                   | 13%          | 1408         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.40                  | 0.02                      | 0.49                 | 0.40                   | 0.02                      | 0.49                | 0.02                                   |                         |     |  |
|                                   | 14%          | 1409         | 1          | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.40                  | 0.02                      | 0.49                 | 0.40                   | 0.02                      | 0.49                | 0.02                                   |                         |     |  |
|                                   | 15%          | 1410 to 1420 | 11         | 2                         | 16.9 | 16.9                   | 74.5 | 74.1                 | 0.41                  | 0.02                      | 0.49                 | 0.41                   | 0.02                      | 0.49                | 0.22                                   |                         |     |  |
| <b>Total</b>                      | 1401 to 1420 |              | <b>20</b>  |                           |      |                        |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.40</b>             |     |  |

| Wellhead Flow line No. / WaterCut | Years        |              | Stream No. | Press. (Bara) @ Inlet S/W |      | Temp. (°C) @ Inlet S/W |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |     |  |
|-----------------------------------|--------------|--------------|------------|---------------------------|------|------------------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|-----|--|
|                                   |              |              |            |                           |      |                        |      | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |     |  |
| W018S                             | 0%           | 1401         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.36                  | 0.02                      | 0.48                 | 0.36                   | 0.02                      | 0.48                | 0.02                                   | C.S+3mm (Note 1)        | Yes |  |
|                                   | 1%           | 1402         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.36                  | 0.02                      | 0.48                 | 0.36                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 2%           | 1403         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.37                  | 0.02                      | 0.48                 | 0.36                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 3%           | 1404         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.37                  | 0.02                      | 0.48                 | 0.36                   | 0.02                      | 0.48                | 0.02                                   |                         |     |  |
|                                   | 5%           | 1405         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.37                  | 0.02                      | 0.49                 | 0.37                   | 0.02                      | 0.49                | 0.02                                   |                         |     |  |
|                                   | 10%          | 1406         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.38                  | 0.02                      | 0.49                 | 0.37                   | 0.02                      | 0.49                | 0.02                                   |                         |     |  |
|                                   | 12%          | 1407         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.38                  | 0.02                      | 0.49                 | 0.38                   | 0.02                      | 0.50                | 0.02                                   |                         |     |  |
|                                   | 13%          | 1408         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.39                  | 0.02                      | 0.49                 | 0.38                   | 0.02                      | 0.50                | 0.02                                   |                         |     |  |
|                                   | 14%          | 1409         | 1          | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.39                  | 0.02                      | 0.49                 | 0.38                   | 0.02                      | 0.50                | 0.02                                   |                         |     |  |
|                                   | 15%          | 1410 to 1420 | 11         | 2                         | 17.7 | 18.1                   | 74.1 | 73.8                 | 0.39                  | 0.02                      | 0.49                 | 0.38                   | 0.02                      | 0.50                | 0.22                                   |                         |     |  |
| <b>Total</b>                      | 1401 to 1420 |              | <b>20</b>  |                           |      |                        |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.40</b>             |     |  |



نگهداشت و افزایش تولید میدان نفتی بینک  
فعالیت های روزمینی در بسته های کاری تحت الارض  
عمومی و مشترک



شماره پیمان:

053 - 073 - 9184

PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT

شماره صفحه : 22 از 24

|       |           |           |         |      |          |       |      |
|-------|-----------|-----------|---------|------|----------|-------|------|
| پروژه | بسته کاری | صادرکننده | تسهیلات | رشته | نوع مدرک | سریال | نسخه |
| BK    | SSGRL     | PEDCO     | 110     | PL   | RT       | 0001  | D04  |

| Wellhead Flow line No. / WaterCut | Years               | Stream No.   | Press. (Bara) |      | Temp. (°C) |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |                  |     |
|-----------------------------------|---------------------|--------------|---------------|------|------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|------------------|-----|
|                                   |                     |              | @ Inlet       | S/W  | @ Inlet    | S/W  | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |                  |     |
| W007                              | 3%                  | 1401         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.59                      | 0.02                 | 0.77                   | 0.59                      | 0.02                | 0.77                                   | 0.02                    | C.S+3mm (Note 1) | Yes |
|                                   | 4%                  | 1402         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.59                      | 0.02                 | 0.77                   | 0.59                      | 0.02                | 0.77                                   | 0.02                    |                  |     |
|                                   | 5%                  | 1403         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.59                      | 0.02                 | 0.77                   | 0.57                      | 0.02                | 0.78                                   | 0.02                    |                  |     |
|                                   | 7%                  | 1404         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.59                      | 0.02                 | 0.77                   | 0.58                      | 0.02                | 0.78                                   | 0.02                    |                  |     |
|                                   | 10%                 | 1405         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.67                      | 0.02                 | 0.75                   | 0.58                      | 0.03                | 0.79                                   | 0.03                    |                  |     |
|                                   | 12%                 | 1406         | 1             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.60                      | 0.03                 | 0.78                   | 0.58                      | 0.03                | 0.79                                   | 0.03                    |                  |     |
|                                   | 15%                 | 1407 to 1411 | 5             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.61                      | 0.03                 | 0.78                   | 0.59                      | 0.03                | 0.79                                   | 0.15                    |                  |     |
|                                   | 25%                 | 1412 to 1413 | 2             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.80                      | 0.03                 | 0.95                   | 0.78                      | 0.03                | 0.96                                   | 0.06                    |                  |     |
|                                   | 30%                 | 1414 to 1415 | 2             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.64                      | 0.03                 | 0.80                   | 0.62                      | 0.03                | 0.81                                   | 0.06                    |                  |     |
|                                   | 35%                 | 1416 to 1417 | 2             | 2    | 17.5       | 17.5 | 79.5                 | 79.0                  | 0.65                      | 0.03                 | 0.81                   | 0.64                      | 0.03                | 0.82                                   | 0.06                    |                  |     |
| 40%                               | 1418 to 1420        | 3            | 2             | 17.5 | 17.5       | 79.5 | 79.0                 | 0.67                  | 0.03                      | 0.83                 | 0.65                   | 0.03                      | 0.82                | 0.09                                   |                         |                  |     |
| <b>Total</b>                      | <b>1401 to 1420</b> | <b>20</b>    |               |      |            |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.56</b>             |                  |     |

| Wellhead Flow line No. / WaterCut | Years               | Stream No.   | Press. (Bara) |      | Temp. (°C) |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |                  |     |
|-----------------------------------|---------------------|--------------|---------------|------|------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|------------------|-----|
|                                   |                     |              | @ Inlet       | S/W  | @ Inlet    | S/W  | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |                  |     |
| W028                              | 3%                  | 1401         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.31                      | 0                    | 0.05                   | 1.30                      | 0                   | 0.05                                   | 0                       | C.S+3mm (Note 1) | Yes |
|                                   | 4%                  | 1402         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.31                      | 0                    | 0.05                   | 1.30                      | 0                   | 0.05                                   | 0                       |                  |     |
|                                   | 5%                  | 1403         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.32                      | 0                    | 0.08                   | 1.31                      | 0                   | 0.07                                   | 0                       |                  |     |
|                                   | 7%                  | 1404         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.33                      | 0                    | 0.10                   | 1.31                      | 0                   | 0.10                                   | 0                       |                  |     |
|                                   | 10%                 | 1405         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.34                      | 0                    | 0.15                   | 1.33                      | 0                   | 0.15                                   | 0                       |                  |     |
|                                   | 12%                 | 1406         | 1             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.35                      | 0.01                 | 0.18                   | 1.33                      | 0.01                | 0.18                                   | 0.01                    |                  |     |
|                                   | 15%                 | 1407 to 1411 | 5             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.36                      | 0.01                 | 0.23                   | 1.35                      | 0.01                | 0.22                                   | 0.05                    |                  |     |
|                                   | 25%                 | 1412 to 1413 | 2             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.41                      | 0.01                 | 0.39                   | 1.39                      | 0.01                | 0.39                                   | 0.02                    |                  |     |
|                                   | 30%                 | 1414 to 1415 | 2             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.44                      | 0.02                 | 0.49                   | 1.42                      | 0.02                | 0.48                                   | 0.04                    |                  |     |
|                                   | 35%                 | 1416 to 1417 | 2             | 2    | 19.8       | 20   | 79.9                 | 79.6                  | 1.47                      | 0.02                 | 0.58                   | 1.46                      | 0.02                | 0.58                                   | 0.04                    |                  |     |
| 40%                               | 1418 to 1420        | 3            | 2             | 19.8 | 20         | 79.9 | 79.6                 | 1.51                  | 0.02                      | 0.69                 | 1.49                   | 0.02                      | 0.68                | 0.06                                   |                         |                  |     |
| <b>Total</b>                      | <b>1401 to 1420</b> | <b>20</b>    |               |      |            |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.22</b>             |                  |     |



نگهداشت و افزایش تولید میدان نفتی بینک  
فعالیت های رو زمینی در بسته های کاری تحت الارض  
عمومی و مشترک



شماره پیمان:

053 - 073 - 9184

PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT



شماره صفحه : 23 از 24

|       |           |            |         |      |          |       |      |
|-------|-----------|------------|---------|------|----------|-------|------|
| پروژه | بسته کاری | صادر کننده | تسهیلات | رشته | نوع مدرک | سریال | نسخه |
| BK    | SSGRL     | PEDCO      | 110     | PL   | RT       | 0001  | D04  |

| Wellhead Flow line No. / WaterCut | Years        | Stream No.   | Press. (Bara) |      | Temp. (°C) |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |                  |     |
|-----------------------------------|--------------|--------------|---------------|------|------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|------------------|-----|
|                                   |              |              | @ Inlet       | S/W  | @ Inlet    | S/W  | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |                  |     |
| W035                              | 3%           | 1401         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.21                      | 0                    | 0.04                   | 1.20                      | 0                   | 0.04                                   | 0                       | C.S+3mm (Note 1) | Yes |
|                                   | 4%           | 1402         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.21                      | 0                    | 0.04                   | 1.20                      | 0                   | 0.04                                   | 0                       |                  |     |
|                                   | 5%           | 1403         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.22                      | 0                    | 0.07                   | 1.21                      | 0                   | 0.07                                   | 0                       |                  |     |
|                                   | 7%           | 1404         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.23                      | 0                    | 0.10                   | 1.22                      | 0                   | 0.10                                   | 0                       |                  |     |
|                                   | 10%          | 1405         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.24                      | 0                    | 0.14                   | 1.22                      | 0                   | 0.14                                   | 0                       |                  |     |
|                                   | 12%          | 1406         | 1             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.25                      | 0.01                 | 0.17                   | 1.23                      | 0.01                | 0.17                                   | 0.01                    |                  |     |
|                                   | 15%          | 1407 to 1411 | 5             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.26                      | 0.01                 | 0.21                   | 1.24                      | 0.01                | 0.21                                   | 0.05                    |                  |     |
|                                   | 25%          | 1412 to 1413 | 2             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.30                      | 0.01                 | 0.37                   | 1.29                      | 0.01                | 0.37                                   | 0.02                    |                  |     |
|                                   | 30%          | 1414 to 1415 | 2             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.33                      | 0.02                 | 0.46                   | 1.32                      | 0.02                | 0.46                                   | 0.04                    |                  |     |
|                                   | 35%          | 1416 to 1417 | 2             | 2    | 21.5       | 21.7 | 79.4                 | 79.1                  | 1.36                      | 0.02                 | 0.55                   | 1.36                      | 0.02                | 0.55                                   | 0.04                    |                  |     |
| 40%                               | 1418 to 1420 | 3            | 2             | 21.5 | 21.7       | 79.4 | 79.1                 | 1.40                  | 0.02                      | 0.66                 | 1.38                   | 0.02                      | 0.65                | 0.06                                   |                         |                  |     |
| <b>Total</b>                      | 1401 to 1420 | <b>20</b>    |               |      |            |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.22</b>             |                  |     |

| Wellhead Flow line No. / WaterCut | Years        | Stream No.   | Press. (Bara) |     | Temp. (°C) |      | ECE Results (Summer) |                       |                           | ECE Results (Winter) |                        |                           | Corrosion mm/ Years | Selected Material+ Corrosion Allowance | NACE MR 0175 /ISO1 5156 |                  |     |
|-----------------------------------|--------------|--------------|---------------|-----|------------|------|----------------------|-----------------------|---------------------------|----------------------|------------------------|---------------------------|---------------------|--|-------------------------|------------------|-----|
|                                   |              |              | @ Inlet       | S/W | @ Inlet    | S/W  | Liquid Velocity m/s  | General Corr. (mm/Yr) | Sour Pitting Rate (mm/Yr) | Liquid Velocity m/s  | General Corr. (mm/Yr.) | Sour Pitting Rate (mm/Yr) |                     |  |                         |                  |     |
| W046                              | 3%           | 1401         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.71                      | 0.04                 | 1.11                   | 0.68                      | 0.04                | 1.11                                   | 0.04                    | C.S+3mm (Note 1) | Yes |
|                                   | 4%           | 1402         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.71                      | 0.04                 | 1.11                   | 0.68                      | 0.04                | 1.11                                   | 0.04                    |                  |     |
|                                   | 5%           | 1403         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.71                      | 0.04                 | 1.11                   | 0.69                      | 0.04                | 1.12                                   | 0.04                    |                  |     |
|                                   | 7%           | 1404         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.72                      | 0.04                 | 1.11                   | 0.69                      | 0.04                | 1.12                                   | 0.04                    |                  |     |
|                                   | 10%          | 1405         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.73                      | 0.04                 | 1.12                   | 0.71                      | 0.04                | 1.13                                   | 0.04                    |                  |     |
|                                   | 12%          | 1406         | 1             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.73                      | 0.04                 | 1.12                   | 0.71                      | 0.04                | 1.13                                   | 0.04                    |                  |     |
|                                   | 15%          | 1407 to 1411 | 5             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.74                      | 0.04                 | 1.13                   | 0.71                      | 0.04                | 1.14                                   | 0.20                    |                  |     |
|                                   | 25%          | 1412 to 1413 | 2             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.76                      | 0.04                 | 1.15                   | 0.74                      | 0.04                | 1.16                                   | 0.08                    |                  |     |
|                                   | 30%          | 1414 to 1415 | 2             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.78                      | 0.04                 | 1.16                   | 0.75                      | 0.04                | 1.17                                   | 0.08                    |                  |     |
|                                   | 35%          | 1416 to 1417 | 2             | 2   | 22         | 22.8 | 78.8                 | 78.2                  | 0.80                      | 0.04                 | 1.17                   | 0.77                      | 0.04                | 1.18                                   | 0.08                    |                  |     |
| 40%                               | 1418 to 1420 | 3            | 2             | 22  | 22.8       | 78.8 | 78.2                 | 0.82                  | 0.04                      | 1.18                 | 0.79                   | 0.04                      | 1.19                | 0.12                                   |                         |                  |     |
| <b>Total</b>                      | 1401 to 1420 | <b>20</b>    |               |     |            |      |                      |                       |                           |                      |                        |                           |                     |  | <b>0.80</b>             |                  |     |

Note 1: Final thickness of flowlines will be 7.9mm. So considering design pressure of 1035 psi (Approved by NISOC), the actual corrosion allowance would be 5-5.5 mm which is sufficient for the corrosion calculations.

|  <p>NISOC</p> | <p>نگهداشت و افزایش تولید میدان نفتی بینک<br/> فعالیت های روزمینی در بسته های کاری تحت الارض<br/> عمومی و مشترک</p>   |  |         |      |          |       |      |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                              |
|--|---|---|---------|------|----------|-------|------|--|--|-------|-----------|------------|---------|------|----------|-------|------|----|-------|-------|-----|----|----|------|-----|------------------------------|
| <p>شماره پیمان:<br/>053 - 073 - 9184</p>   | <table border="1" style="width: 100%; text-align: center;"> <thead> <tr> <th colspan="8">PIPELINE CORROSION STUDY &amp; MATERIAL SELECTION REPORT</th> </tr> <tr> <th>پروژه</th> <th>بسته کاری</th> <th>صادر کننده</th> <th>تسهیلات</th> <th>رشته</th> <th>نوع مدرک</th> <th>سریال</th> <th>نسخه</th> </tr> </thead> <tbody> <tr> <td>BK</td> <td>SSGRL</td> <td>PEDCO</td> <td>110</td> <td>PL</td> <td>RT</td> <td>0001</td> <td>D04</td> </tr> </tbody> </table> | PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT                                |         |      |          |       |      |  |  | پروژه | بسته کاری | صادر کننده | تسهیلات | رشته | نوع مدرک | سریال | نسخه | BK | SSGRL | PEDCO | 110 | PL | RT | 0001 | D04 | <p>شماره صفحه : 24 از 24</p> |
| PIPELINE CORROSION STUDY & MATERIAL SELECTION REPORT   |   |   |         |      |          |       |      |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                              |
| پروژه  | بسته کاری   | صادر کننده  | تسهیلات | رشته | نوع مدرک | سریال | نسخه |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                              |
| BK   | SSGRL   | PEDCO   | 110     | PL   | RT       | 0001  | D04  |  |  |       |           |            |         |      |          |       |      |    |       |       |     |    |    |      |     |                              |

## 9. TTACHMENTS

ECE 5.4 original files, PFD and PIDs and simulation report are attached to this document to support the results.