International Journal of Innovative Research in Engineering & Management (IJIREM)
ISSN: 2350-0557, Volume-9, Issue-2, April 2022
https://doi.org/10.55524/ijirem.2022.9.2.47
Article ID IJIR-2250, Pages 316-323
www.ijirem.org

Flow Assurance in Petroleum Industry

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ABSTRACT: In the oil and gas business, flow assurance is a relatively recent word. Flow assurance refers to a low-cost method of producing and transporting fluids from a reservoir to a processing facility**.** The growing demand of energy has led oil companies to move towards exploration in offshore deep water sand remote places, under extreme environmental conditions. Owing to such harsh environmental conditions, oil companies have to face critical operational challenges during production and transportation of crude oil. One of such menace is flow assurance issues. Stream confirmation issues contrarily affect well consummation plan and creation working procedures. Hydrates, wax affidavit, naphthenates, asphaltenes, consumption, scales, slugging, and emulsion are all stream confirmation challenges. For stream confirmation, hydrates and wax testimony are basic difficulties that should be tended to first. This paper portrays the stream confirmation challenges that impact unrefined petroleum transportation from the repository to the retail location, both coastal and seaward, in chilly environments. The paper also represents the process mechanism and mitigation methods used for each fluid flow assurance issue. It is impossible to overstate the significance of flow assurance in the oil as well as gas business. Failure of flow assurance can result in catastrophic consequences, such as the loss of resources or even lives.

KEYWORDS: Asphaltenes, Flow assurance, Hydrates, Scales Wax deposition.

I. INTRODUCTION

Increasing population has occasioned a rise within the world energy demand. Since fossil oil is a non-renewable energy source and crude oil reserves are declining speedily, exploration in offshore regions becomes essential. In offshore fields, high pressures and cold conditions favor solid deposition and alternative flow related issues resulting into production interruption or damage to pipeline and consequently, oil companies have to bear huge financial losses. Thus, for sleek operations and economically viable production of crude oil in offshore regions and cold onshore regions, flow assurance plays eminent role in the gas and oil industries[1], [2]. Petrobras instituted the expression "Stream Assurance" in the mid 1990s, and that signifies "Stream Guarantee." Flow confirmation is a word used to portray the method involved with guaranteeing a smooth and financially savvy stream of unrefined petroleum. Since conventional philosophies neglected to clarify creation related worries in profound water creation because of high temperature and tension conditions, the expression stream Assurance was instituted. Stream affirmation is stressed over network exhibiting and transient multiphase multiplication, as well as solid stores, for instance, gas hydrates, wax, scale, and naphthenates, which could hurt establishment and, in the most ridiculously desperate result possible, cause pipeline blockage. As a result, asset hurt occurs, achieving basic money related adversities for oil firms. Figure 1 addresses the range of stream confirmation issues.

Stream Assurance is applied during all phases of framework including determination of foundation, planning and investigating. Greater part stream confirmation difficulties can be alleviated or forestalled by individual methodologies or by blend of synthetic, mechanical or warm techniques alongside satisfactory information on liquid stream properties. Though chemical methods are relatively successful for flow assurance issues in offshore regions, implementation of thermal and mechanical methods in offshore is ineffective and hence, research in the field novel approaches for mitigation of flow assurance issues in offshore becomes vital.

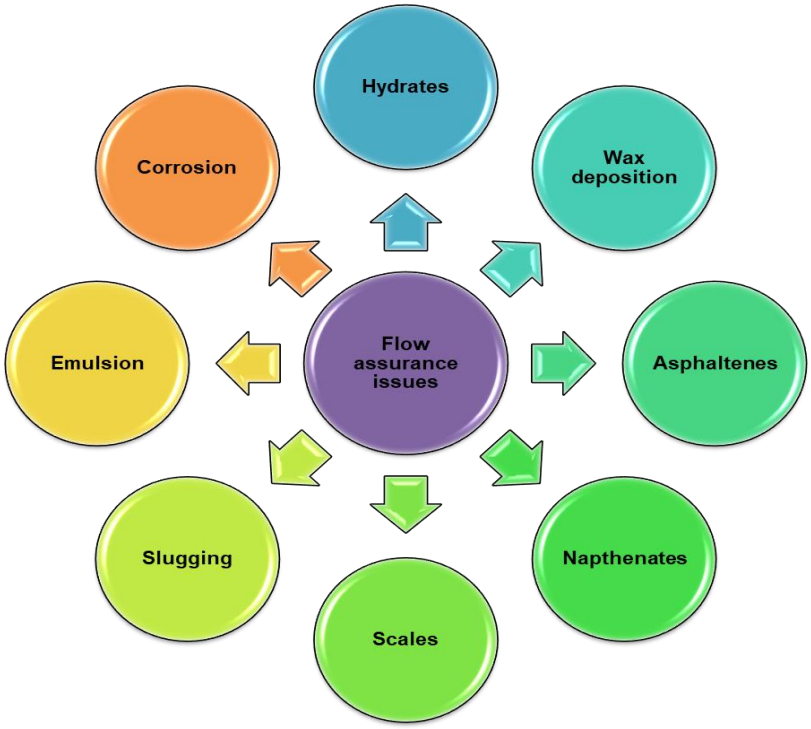

Figure 1: Illustrates the Spectrum of Flow Assurance Issues.

II. DISCUSSION

A. Problems of Fluid Flow Assurance

The main flow assurance problems in offshore and onshore oil fields are hydrates, wax deposition, asphaltenes, slugging, naphthenates, scales, corrosion and emulsions. Among above flow assurance challenges, hydrates, wax deposition, asphaltenes, naphthenates and scales cause deposition in pipeline and these issues are the most significant areas being considered today due to exorbitantly higher cost of maintenance and troubleshooting during oil productions. Figure 2 shows solid depositions in pipeline responsible for flow assurance issue[3], [4]. Other issues such as slugging, corrosion, erosion and emulsions create operational issues during production.

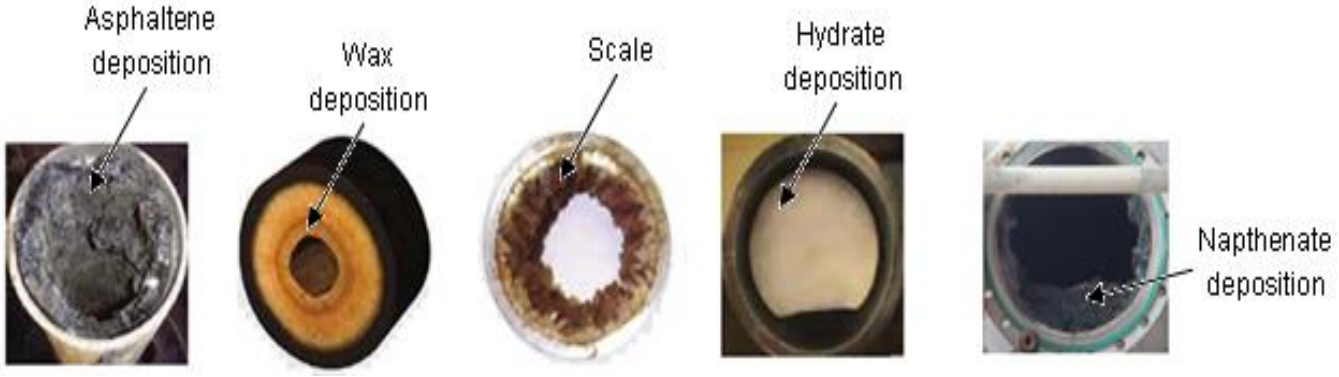

Figure 2: The above Figure Represent the Solid Deposition in Pipeline.

B. Asphaltenes

The asphalting deposition during production of crude oil is a cumbersome facing petroleum industry. Deposition of asphaltenes causes operational issues throughout the production from reservoir to transportation. Asphaltenes are considered one of the most complex polar componentspresent in the heftiest fractions of the crude oil. All the components in crude oil except asphaltenes have well defined structures. Asphaltenes have highly complex structure containingpoly condensed aromatic rings, naphthenic rings, aliphatic chains, as well as heteroatoms such as nitrogen, oxygen, sulphur due to which asphaltenes are also referred to as NSO compounds.Many models have been proposed by different researchers which describe the structural composition of asphaltenes[5], [6]. Nevertheless,

asphaltenes structure is faintly understoodand subsequently, asphaltenes can be described by their dissolvability ascribes. Asphaltenes are portrayed as the regular piece of the crude petrol that is insoluble in n-alkanes, for instance, n-hexane and n-heptane and dissolvable in normal solvents like xylene and toluene. Asphaltene articulation occurs because of high tendency of asphaltene particles to total and along these lines, it is called as Cholesterol of Petroleum. The process diagram of as phaltene deposition is portrayed in figure 3. At equilibrium, the asphaltene will remain steady in the basic oil under tank conditions. The variation in the pressure, temperature or composition of oil disturbs the equilibrium and the asphaltenes will precipitate out of the oil solution. The as phaltene precipitates remain suspended in oil solution. However, these asphaltenes precipitates will accumulate together to form larger flocculated asphaltene particleswith a higher density[6], [7]. Due to their higher density, theseparticleswill begin tosettle to the bottom and results deposition in the reservoir pores, wellbores or pipelines. Asphaltenes built up in any stage of production can deter or in worst scenario, cease the flow of the oil resulting in catastrophic problems. Asphaltene statement is influence by numerous factors such as crude oil physical properties (viscosity, type, cloud point, pour pout, API gravity), oil velocity, solvents, agitation time and temperature significantly affectthe asphaltene deposition.

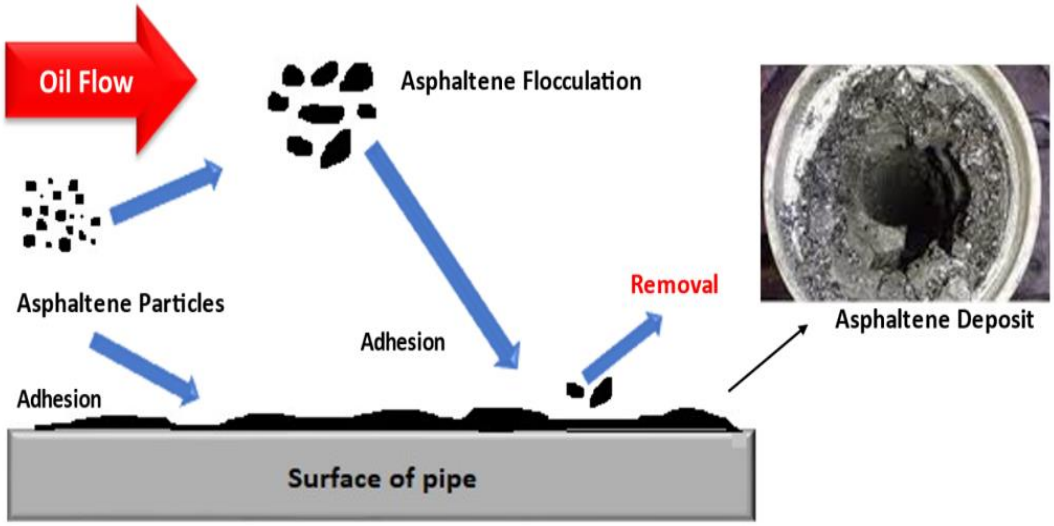

Figure 3: Illustrates the Mechanism of Asphaltene Deposition.

It is important to distinguishing working circumstances at which asphaltene affidavit happen for financial dependability and long haul creation. There is a restricted region named Asphaltene statement encompassed (ADE) district where agglomeration of asphaltenes happens. Asphaltene deposition can be prevented if the flocculated asphaltene particles are detected early and hence, recognition of ADE becomes eminent. The flocculated asphaltene particles can be dissociated back into asphaltene precipitates and homogenized into the oil solution by addition of stabilizing agent. Along these lines, expectation of stage conduct of asphaltene becomes significant for determination of appropriate solvents and inhibitors to postpone asphaltene precipitation. Asphaltenes dispersant chemicals and electro deposition methods are another means for inhibition of asphaltenes deposition used in the industry.

C. Naphthenates

In recent decades, production of acidic crude is increasing significantly. Acidic crudes are rich in naphthenic acids (NAs) which are susceptible to metal naphthenates formation, leading to two main flow assurance issues: naphthenic acid corrosion and formation of naphthenates which can either causes deposition on pipe wall or stabilizes emulsionsNaphthenic acids in unrefined petroleum are mind boggling combinations of homologous acids that respond with metal ionsin the delivered water to shape metal naphthenates. The metal ions such as alkali metals and alkaline earth metals predominantly form naphthenates. The most commonly found naphthenatesin oil fields are calcium and sodium types. The molecular structure of commonly formed calcium naphthenates is presented in Figure 4.

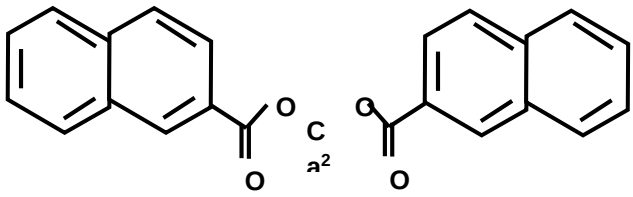

Figure 4: The above Figure Represents the Structure of calcium naphthenates

The mechanism of metal naphthenates formation is well understood. Initially, the non-ionized NAs molecules remain dispersed in crude oil. During CO_2 degassing process, pH of

the solution increase which favors formation of water-soluble interfacial active naphthenates ions. These ions rapidly react with formation water ions to form the corresponding metal naphthenates. Metal naphthenates are highly insoluble both in oil and water, and rapidly accumulate in the oil-water interface. Water cut is the most important parameter for naphthenates formation.Figure.5portrays the mechanism of metal naphthenates formation as shown in Figure 5.

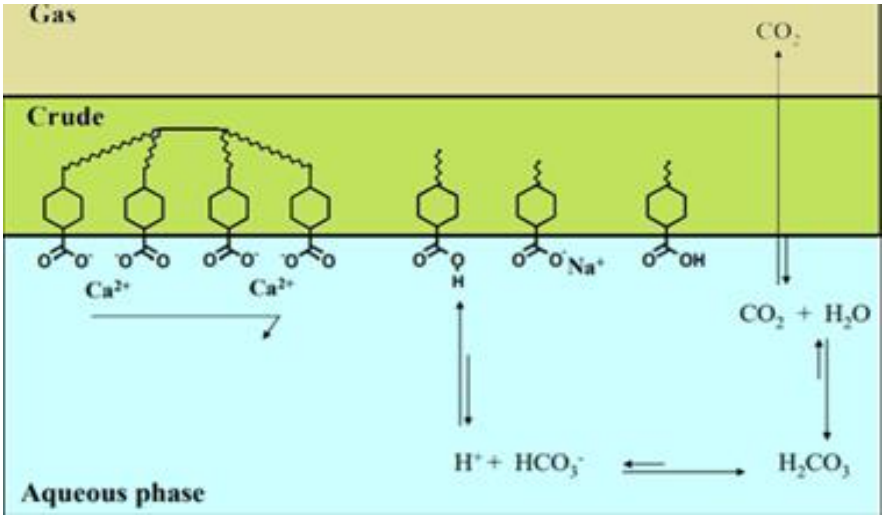

Figure 5: Illustrating Mechanism of Calcium naphthenates Formation.

Metal naphthenates adversely affect separators where the produced fluid is treated. It results severe clogging in separators and fouling of the equipment used in water treatment system. In worst case scenario, naphthenates deposition and tough emulsion potentially affect production rate and even cause shutdown of the production facilities. Thus, mitigation of naphthenates becomes eminent for smooth production of crude oil. The removal and disposal of metal naphthenates deposits is quite expensive. Manual removal of naphthenates is inappropriate due to high cost and level of difficulty. Similarly, use of common-ion effect for suppression of naphthenates ions is not plausible because it aggravates internal corrosion problems especially in topside facilities. Thus, Chemical inhibition is better option to tackle naphthenates deposition. Chemical compounds such as sulphonates, phosphate esters, aminated phosphates and sulphosuccinates work efficiently as naphthenates inhibitors. However, in chemical inhibition, complication arises due to compatibility concern. Thus, chemical inhibition along with changes in the processing parameters is the best solution to keep naphthenates problem at Bay.

D. Slugging

Slugging has been a significant functional test underway pipelines and risers. Changes in stream rates, pressures, and temperatures cause slug stream in multiphase pipelines. Slug stream is described by a course of action of liquid connections (slugs) disconnected by respectably colossal gas pockets, where gigantic frothy liquid waves produce a slug that may totally fill the line. Extreme slugs are most frequently incited in lengthy vertical pipelines, where gas is discouraged at the bend ready to go, bringing about pressure working in the gas stage, pushing the fluid slug up the riser lastly causing oil stream variety. Slugging has various adverse consequences on modern activities. Serious slugging represents various issues, including harm to handling hardware, expanded pipeline stress, lower creation, and diminished repository working life. An enormous fluid volume will be made inside in the separator that could cause flood and harm the surface hardware. There are a couple of methodology that can be used to mitigate slugging, for instance, the riser base gas lift structure, complex distinguishing proof and control systems, usage of tremendous slug catchers, and sagacious slug balance structures. Foundation of wavy lines is one such solution for mitigate genuine slugging inriser structures. Future work will consolidate carrying out the time postpone regulator in a more mind boggling non-straight slugging control model (Figure 6).

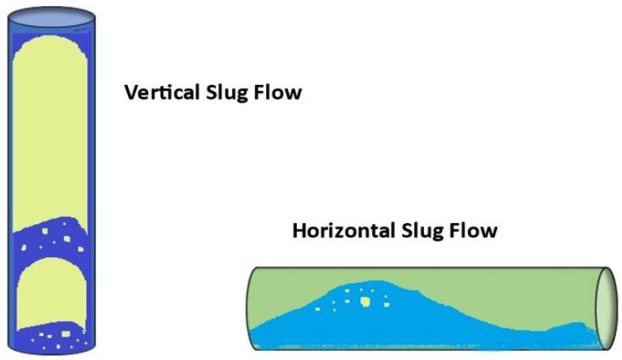

Figure 6: The above Figure Shows the Slug Flow in the Pipeline.

E. Scales

Scale arrangement is a basic issue in petrol industry coming about into low functional efficiencies and conservative misfortunes. Scale portrays strong stores comprised of natural, inorganic and precious stone water that develop after some time, obstructing and frustrating liquid course through pipelines, valves, siphons and so forth with significant decrease underway rates and hardware harms. Scales create genuine danger during unrefined petroleum creation for example obstruction in liquid stream, hardware harm and development changes. Subsequently, there could be decrease underway effectiveness or closure, and support cost of this threat is tremendous. Scale development happens because of testimony of scale accelerates. Scale precipitation happens when their water dissolvability diminishes because of supersaturation either as a result of blending of two contradictory waters (Two waters are called inconsistent on the off chance that they communicate synthetically and accelerate minerals when blended) or because of changes in tension and temperature states of viable waters during creation and handling. Most ordinarily observed scale stores during unrefined petroleum creation are calcium carbonate, calcium sulfate, barium sulfate as well as magnesium carbonate. The improvement of scale during creation is trailed by nucleation, precious stone development, and testimony. Scaling particles alongside counter particles are at first dissolvable in water. At the point when these particles arrive at supersaturation limit, they crash to frame particle sets in arrangement and total. In nucleation process, the miniature totals take shape to frame miniature precious stones as displayed in Figure 7. These miniature precious stones structure bigger gems that circuit to shape large scale gems. The agglomeration stage is set apart with the development of large scale precious stones into a scales layers on a surface and end up into a scale store. Factors, for example, temperature, the centralization of scale shaping species, water quality, pH, and hydrodynamic circumstances impact the course of scale development. Furthermore, natural parts, explicitly naphthenic acids and their salts, affect scale arrangement. Be that as it may, immersion level is an irreplaceable boundary for assessment of scale arrangement either thermodynamically or dynamically.

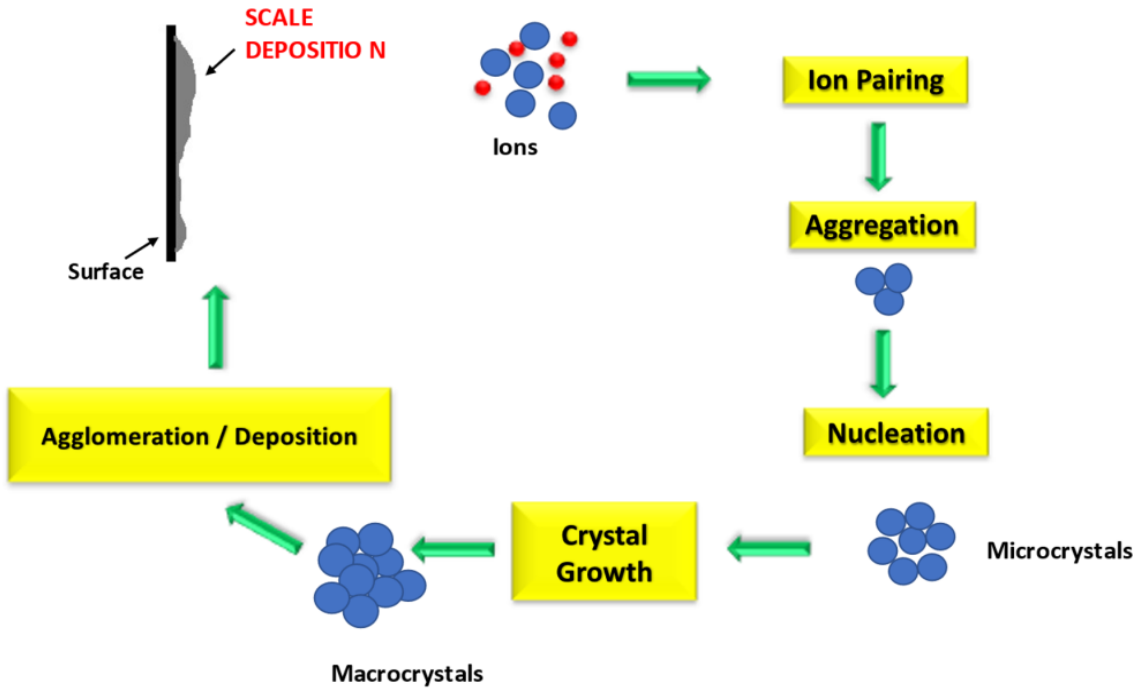

Figure 7: Illustrates the Mechanism of scale formation**.**

A better management strategy must be build up to deal scale issue. Mechanical methods and chemical methods are extensively used to remove the formed scales in oilfields. Milling and drilling are commonly used mechanical methods to remove scales in pipelines. Chemical methods include use of chelators, chemical inhibitors and acid washing. However, acid washing is inefficient for scales which are insoluble in the acid solutions. Scale inhibitor is the best option for prevention of scales. Phosphonate and polyacrylate are the foundation of majority scale inhibitors in oilfields. Injection of inhibitors assures long-term protection against scaling.

F. Erosion

Consumption is the disintegration of a material, generally a metal because of response among metal and its current circumstance [8], [9]. Corrosion causes flow assurance issue during production, refinery operations and transportation of crude oil resulting into production loss, damage to infrastructure and high maintenance and repairing costs (Figure 8).

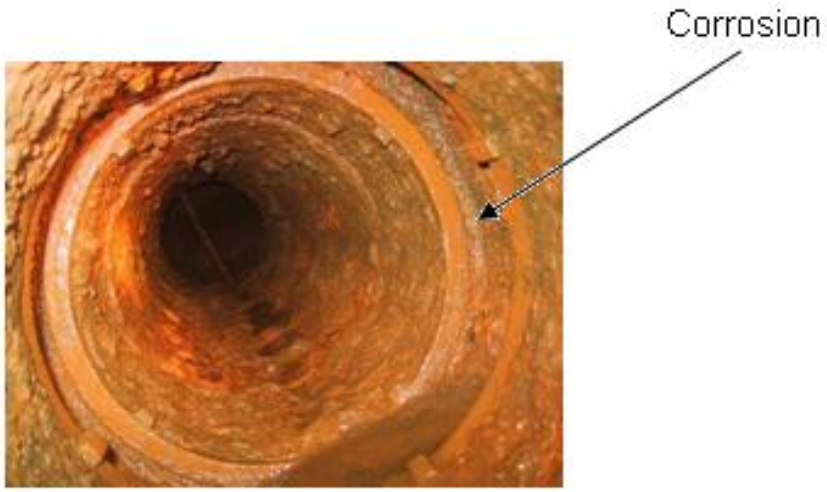

Figure 8: One of the most common causes of subsea pipeline failure is corrosion in the pipeline.

It is to be noted that carbon steel is economical viable and hence, it is widely used in petroleum industry for infrastructure. However, these pipes are prone to corrosion. Corrosion occurs through the action of the electrochemical cell in which electrochemical process involving the transfer of electrons from metal atoms to hydrogen ions or oxygen in water takes place. CO_2 and H_2S gases present in crude oil are acidic in nature and decreases pH when dissolved in water due to formations of a carbonic acids ion or bi carbonate and Sulphide ion respectively.The mechanism of corrosion in pipeline is depicted in Figure 9.

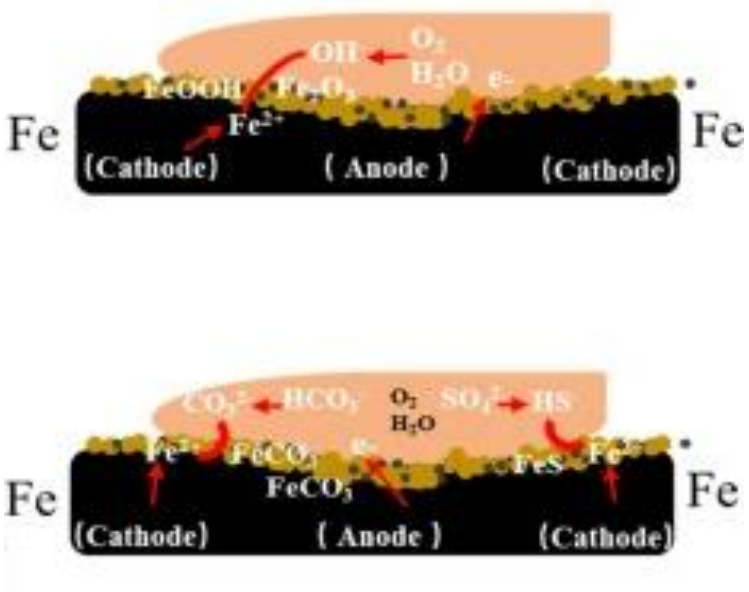

Figure 9: The above Figure Represents the Mechanism of Corrosion.

The rate of corrosion is significantly affected by metal as well as environmental conditions especially presence of water as well as gases such as -CO_2, SO_2, Cl_2, HCl.There are several types of corrosion including sweet corrosion (CO_2corrosion), sour corrosion (H_2S corrosion), oxygen corrosion, galvanic corrosion, microbiologically influenced corrosion, etc. Various techniques have been employed for successful prevention and removal of corrosion out of which chemical techniques such as corrosion inhibitor, biocide, paint, coating and cathodic protection are widely used[10], [11]. Mixtures, for example, quaternary ammonium compounds and propargyl liquor based mixtures have been effectively utilized in the business. Other preventive measures include removal of corrosion causing agents, separation of water from oil and gas, material selection, etc. Petroleum industries have now moved towards green inhibitors such as food-grade products and medicinal plants due to environmental concern. Chicory, a medicinal plant has been used as a corrosion inhibitor for high-temperature and strong-acidic conditions. Fortunately, corrosion failures in onshore and offshore pipelines have diminishes in recent

years because of successful corrosion management strategies.

G. Emulsions

Water commonly delivered with unrefined petroleum makes various creation related issues. Delivered water is additionally answerable for emulsion development. An emulsion is a combination of two immiscible fluids wherein one fluid (scattered stage) is scattered in other fluid (consistent stage). Emulsions are of three distinct sorts: oil in water (O/W), water in oil (W/O) and different or complex emulsions (O/W/O and W/O/W). During creation, unrefined petroleum and water are combined as one and transcendently structure water [12]–[14] in oil emulsion in which water droplets are dispersed in continuously flowing crude oil as shown in Figure 10.

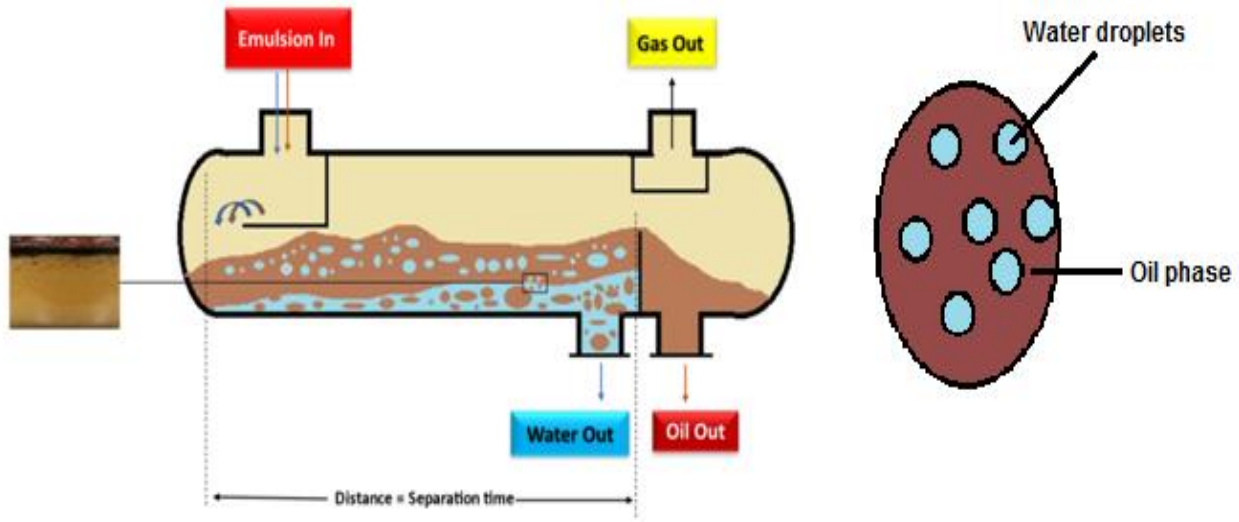

Figure 10: The above Figure Represents Emulsion in Separator.

Emulsion formation is an undesirable issue resulting into serious flow assurance problems and numerous operational issues such as reduction in crude oil quality, pressure drop and blockage in the pipeline, separation difficulties and corrosion that eventually impair pipeline and other equipment. The troubleshooting cost of these issues is immense. Thus, for economic reasons, the issue of oil emulsion needs to be tackled on priority. Crude oil contains oil and water which are immiscible liquid phases. Water present with crude oil disperses in crude oil as small droplets to form thermally unstable emulsion. However, naturally occurring emulsifiers such as asphaltenes and resins present in crude oil stabilizes emulsion. Asphaltene and other heavy components adsorb on water molecules and form films around the water droplets at the oil-water interface which acts as a barrier and stop two drops to coalesce together as shown in Figure 11. Thus, in presence of asphaltene and other heavy organic components stable emulsion is formed which is difficult to separate out by means of simple treatments. Apart from heavy components, parameters such as physical and chemical properties of the crude oil, temperature, presence of solid particles such as silica, clay, iron oxides, etc. develop stable emulsion.

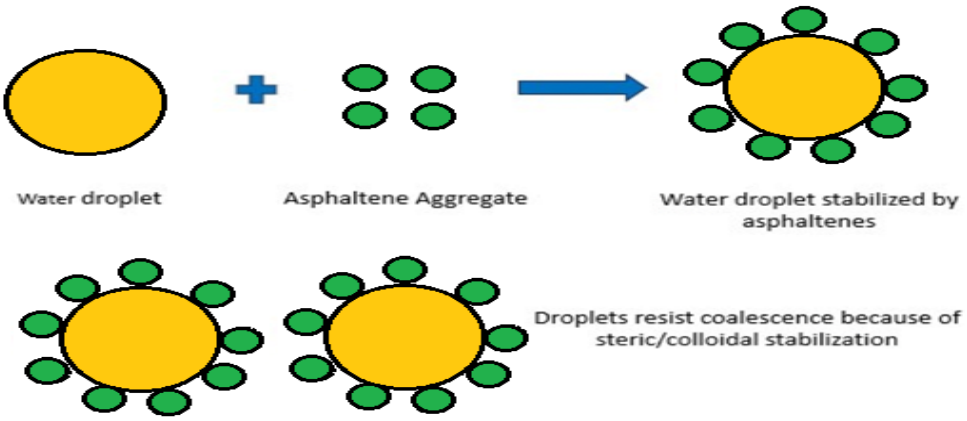

Figure 11: Illustrates the Mechanism of Emulsion Stabilization by Asphaltenes.

Emulsion contains highly toxic components such as naphthenic acids and heavy metals having negative effect on environment and hence, appropriate emulsion control management is prerequisite[15], [16]. Various techniques such as thermal, mechanical, chemical and electrical have been used for breaking of emulsion. However, chemical methods suit the best and the chemical process is known as demulsification process which is ordinarily used to break stable oil emulsion. Substance added substances included this interaction are known as demulsifiers. Demulsifiers are surface dynamic synthetic substances that relocate to the oil-water interface, bursting or debilitating the interfacial layer and improving water bead combination.

III. CONCLUSION

Flow assurance refers to the ability to regulate and profit from fluid flow from the reservoir to the point of sale. Hydrates, wax deposition, asphaltenes, naphthenates, scales, corrosion, emulsion and slugging are major flow assurance problems which adversely affect fluid flow throughout the production. Along with flow assurance issues and their mechanism, effective remedies have also been discussed in this paper. Among numerous remedial measures, chemical methods are the best suited preventive measure for solid deposits. Some chemical inhibitors include asphaltene inhibitors for asphaltenes. Moreover, demulsifies work best for emulsion breaking. Slug catchers and intelligent slug mitigation systems are widely used for slug removal. However, early detection and appropriate methods is most important to control flow assurance issues. Thus, the principle that prevention is better than cure has proven to be true for oil and gas industries.

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