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A REVIEW ON SOLIDS SEPARATION, DISPOSAL AND HANDLING SYSTEM FOR THE PETROLEUM REFINING INDUSTRY

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Abstract

A typical reservoir fluid comprises of a mixture of hydrocarbons, salt, water and solids (sand, clay, corrosion products and gravel packs). The presence of solids triggers bacteria and hydrogen sulphide growth, which leads to intense corrosion of both pipe works and valves. The decline in the overall retention time, damages in the formation and a regular shutdown of the plant are parts of its negative impacts. This paper, therefore, reviewed all available solid cleanout systems currently being used in the industry highlighting their strength, weakness and suitability's. On a global view, case studies on four different drilling platforms (Exxon Grand Isle Block 16L /West Delta 73 A-D, South Pass Field, Albacora Deep Water and Dagang Oilfield) encountering intricate solid disposal issues were analysed. Production limits encourage drilling of wells in areas where zero amount of sand is recorded, which is rarely obtainable. Convectional exclusion approach combines various techniques (mechanical retention, gravel packs, downhole equipment and chemical consolidation) with the main aim of preventing the solids from entering the wellbore. The inclusion methodology in collaboration with a de-sander works by injecting a working fluid into the wellbore, which helps to circulate, lift and carry the solid particle to the surface for proper separation and disposal. The four different models of an integrated solid handling system used on the platforms experienced complex operational problems ranging from erosion, leakages, wears, equipment failure, sulphate reducing bacteria growth, emulsion stabilization, pluggingand an increase in pressure drop. The root cause of each issue and solutions were analysed.

Keywords: *Convectional Exclusion; De-sanders; Production Limits; Reservoir Fluid; Review; Solid Cleanout.*

1. Background study

The production of solids alongside the reservoir fluid is a phenomenon that occurs during the drilling stage of every well [1-2]. These solids are inorganic insoluble or semi- soluble deformable particles that come from a natural or artificial source [3]. Currently, research has it that roughly 90% of the world's oil and gas wells are being discovered in sandstone reservoirs, among which 25-30% of the wells experience sand production at a stage in their well life, with concentrations varying within the range of 5-250 parts per million [4]. These result in the decline of the overall rate of production; leading to the discovery and implementation of a solid separation, disposal and handling system.

Naturally, solids emerge from the reservoir material either in the form of detrital grains of sand (S_i0_2 oxide) or clay (hydrous aluminium silicates) [3]. Artificially, solids are being introduced into the well stream via the addition of foreign bodies [3]. Table 1 highlights the physical properties of both natural and artificial solids.

Asides the troubling figures listed in the table, the effects of produced sand triggers the presence of bacteria and hydrogen sulphide, which eventually leads to intense corrosion of both pipe works and valves. Other negative effects include a decline in the overall retention time, damages in formation during the process of re- injection and finally, a regular shutdown of the plant during separation processes [4-5]. The aim of this research, therefore, is to review solid cleanout systems currently being used in the industry highlighting their strengths, weaknesses and suitability's. On a global view, case studies on four different drilling platforms encountering intricate solid disposal issues were analysed. []

Table 1. Physical properties of natural and artificial solids [3]

Property	Natural		Artificial		
	Sand	Clay	Fracture sand	Corrosion products	Gravel pack
Specific gravity	2.5-2.9	2.6-2.8	2.6-3.6	5.5-6.0	2.6-3.0
Shape Factor	0.2-0.5	0.1-0.3	0.5-0.9	0.1-0.5	0.5-0.9
Size Range(μm)	50-1000	5-30	150-2000	10-10000	250-3500
Conc. (ppmv)	5-100	<1	0-10000	<2	0(unless failure)

ppmv-part per million by volume; μm-micrometre; >-Greater than and <-Less than

2. Solids separation methodologies

Generally, the three methods currently being adopted in the industry for the disposal of sands and solids generally are production limits, convectional exclusion and the inclusion approach [3]. The production limits use the conservative approach of Zero Sand Production. For this, wells are drilled in areas where there is zero amount of sand production. This is effectively done with the aid of a reservoir versus bottom hole pressure map. Although it reduces the overall capital expenditure, it has its limitations of reducing the rate of production when continuous redefining of the boundaries due to alteration in the well profile is detected [3].

The convectional exclusion approach combines various techniques with the main aim of preventing the solids from entering the wellbore. They include the use of mechanical retention systems (screen or slotted liner), gravel packs and chemical consolidation. Generally, this approach protects the production tubular's, wellhead chokes, flow lines and facilities equipment from damage. However, there will be an accumulation of solids near the well bore [3]. Downhole equipment ensures that gravel packing is positioned around the external surface of the separator screen.

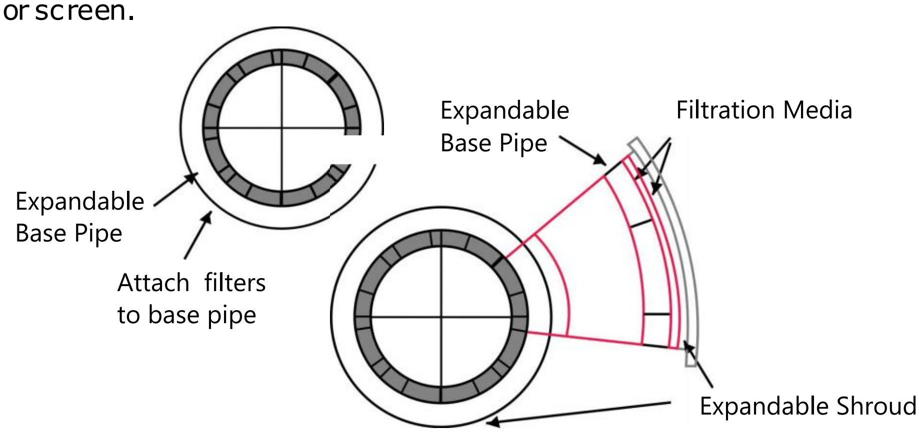

Figure 1. Expandable sand screen construction [7]

Wire wrap screen are keystone shaped designed majorly for the separation of coarse well-sorted sands. They ensure that gravel placed between the screen and the formations are maintained while trying to minimise other production constraints. It provides extra strength, eliminates the tendency of screen erosion and ensures better filtration assurance. Expandable sand screen as shown in Figure 1 is considered the strongest in the industry with a collapse strength of 2500pounds per square inch (psi), it provides better reliability via slotted base pipe structures, filter media and an outer protecting/ encapsulating layer [6-7]. The metal mesh screen, which was first adopted in 1980, comprises of a base pipe, layered filtration jacket, an outer shroud, a perforated base plate and several spacer rings. When compared to the rest, it has a high corrosion resistance and a slimmer chance of being damaged during the installation stage [8-9].

The gravel packs consist of a perforated liner placed in the well, enclosed by a mass of gravel that acts as a depth filter to prevent the sand from entering the wellbore [10]. Chemical consolidation involves the sealing of sand grains several feet down by the use of environmentally accepted chemicals. The major aim is to raise the residual strength of the formation, thereby intensifying the sand maximum free rate [3,11]. An example of such a chemical is organosilane.

The inclusion methodology works by injecting a working fluid into the wellbore, which helps to circulate, lift and carry the solid particle to the surface for proper separation and disposal. The separation of the solid is then carried out via a multiphase de-sander prior to the crude oil separating vessel [3-4]. Although it reduces skin damages due to the free flow of sand alongside the well fluid, there is always a large tendency for the working fluid to leak into the formation. It can also lead to erosion of the tubular's, choke, and flow lines that ultimately results in flooding of the production separator. The working fluid might also be in the form of energised fluid or foam that can lead to separation complications if not properly handled [3-4].

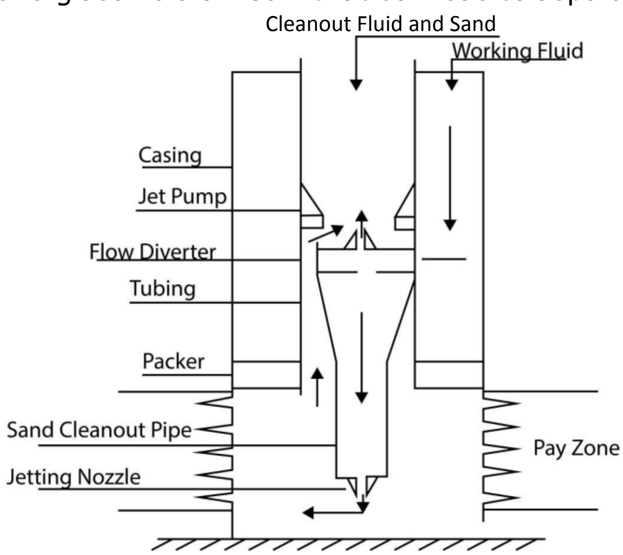

Fig. 2. Sand cleanout system [4]

As shown in Figure 2, a multistage centrifugal pump helps boost up water (working fluid) pressure, which is introduced into the well hole through the annulus. The flow diverter separates this fluid into two parts: sand carrier and power fluid for the jet pump. The sand carrier fluid flows downward through the jetting nozzle located at the sand cleanout pipe. The jetting nozzle converts the high-pressure into a high velocity head, which helps to lift the sand particle from the bottom of the wellbore to the throat of the jet pump [4]. The power fluid produces a high velocity, which helps in lowering the pressure at the bottom hole. This aids the absorbing of the carrier fluid alongside the sand particles into the fluid [4].

De- sanders are solid liquid hydro-cyclones, which are known to incur the following benefits: the ability to remove sand without necessarily shutting down the system, lesser weight, capital effective, requires little or no labour and most importantly little cost for maintenance and operations [5]. It comes in two forms: vessel and liner. The vessel type which nominal diameter is within a range of 3-30 inches, uses its vessel itself as the de-sander. Although cost effective when compared to the liner type, they are more effective in large flow rate areas with a combination of coarse separation size. The liner style is always designed to have multiple liners, each having a nominal diameter within a range of 0.5-4 inch. It can be applied to any flow rate in combination with fine separation size, making it more flexible [5].

All de-sanders have four major components: inlet, overview, cone and tailpipe. The inlet, which serves as the cylindrical feed chamber regulates the degree of turbulence that comes with the incoming flow via tangential velocity at the hydro cyclone inlet [12]. The overview houses the vortex finder also called the Core Stabilizing Shield. It protects the fluid core from any potential turbulence and decreases the available cross sectional area, thereby boosting tangential velocity.

Although the cane varies in different angles and geometrics, it increases the amount of centrifugal force needed as the fluid flows through the narrowed cross sectional area. The tailpipe increases the retention time required for the separation process. Generally, the smaller the diameter of the tail pipe, the greater the tangential velocities [12]. New generation desander introduce an internal header with an educator, which helps to handle issues of slugging of ≤ 50,000ppm. It is associated with smaller footprints, a significant reduction in weight, and lower pressure drop with zero liquid loss [13].

3. Case studies

3.1. Grand Isle Block 16L and West Delta 73 A-D Production Platform

Initially, Exxon Company faced major problems with respect to solid handling both on their offshore platforms and generally in pipelines. In addition, existing anti-pollution laws were in place that restricted improper handling and disposal of solids. A sand handling model was designed with Centrifugal force as the underlying principle. This model was first introduced and tested on the Grand Isle Block 16L and West Delta 73 A-D Production Platform, paying critical attention to the reliability of the sand discharge system [14].

3.1.1. Sand handling system

As shown in Figure 3 below, the model is divided into three sections, namely: sand removal, sand transporting and the sand cleaning/disposal system [14]. The convectional cyclone (1) separates the sand from the produced fluid; this fluid moves into a surge tank where they are transported to a shore facility via pipeline. The separated sand settles in the silt pot below each cyclone, where they are forced out by differential pressure. The centrifugal pump (2) then supplies water to the sand, which moves it to the collection trough. The two phase mixture of sand, water, and oil moves to the classifier vessel (3) where the sand and free water moves to the bottom and top of the cone respectively due to the difference in their density. The adjustable regulator (4) helps to control the vessel pressure by venting gas to the surge tank [14].

The dump valve (6) is actuated by both the water level control (5) and the oil level control (7) which maintains the level of the water in the vessel and discharges the oil to the surge tank. Both the mixture of water and sand moves to number one cyclone (9) of the sand washer at the opening of the dump valve (6).The cyclone separates the sand to the sand washer while the water and free oil go to the separation vessel (10) through the cyclone overflow line (11) [14].

Figure 4 refers to the separator where the water and the oil are allowed to separate to the bottom and top, respectively due to their difference in density. The water acts as a source for the recirculation pump (2), while the cyclone banks (1) act as both an entry and exit point for the water. It was also observed that as the sand exits the cyclone banks (1), both water and oil comes out with it. The classifier (3) removes the excess oil while water and sand go to the sand washer number one cyclone (9). The equality of both the amount of water that is being separated and discharged by the cyclone banks (1) will keep the volume of re-circulation constant; otherwise, the volume will continually fall. The high-level controller automatically opens the dump valve (15) when it senses an increase in the water level at the separator where the water is discharged into the sump tank [14].

3.1.2. Sand washer

As illustrated in Figure 5 below, the mixture of water, sand and oil moves into the number one cyclone (9) from the classifier vessel (3). The sand is separated from the mixture and moves to number one compartment (3) of the sand washer while the mixture of the oil and water flows to the separation vessel (10). The gas line prevents air from entering the cyclone as it internally spins the fluid. In the centre vortex, gas is mixed with the separated fluid where they are deposited in the separation vessel (10) [14].

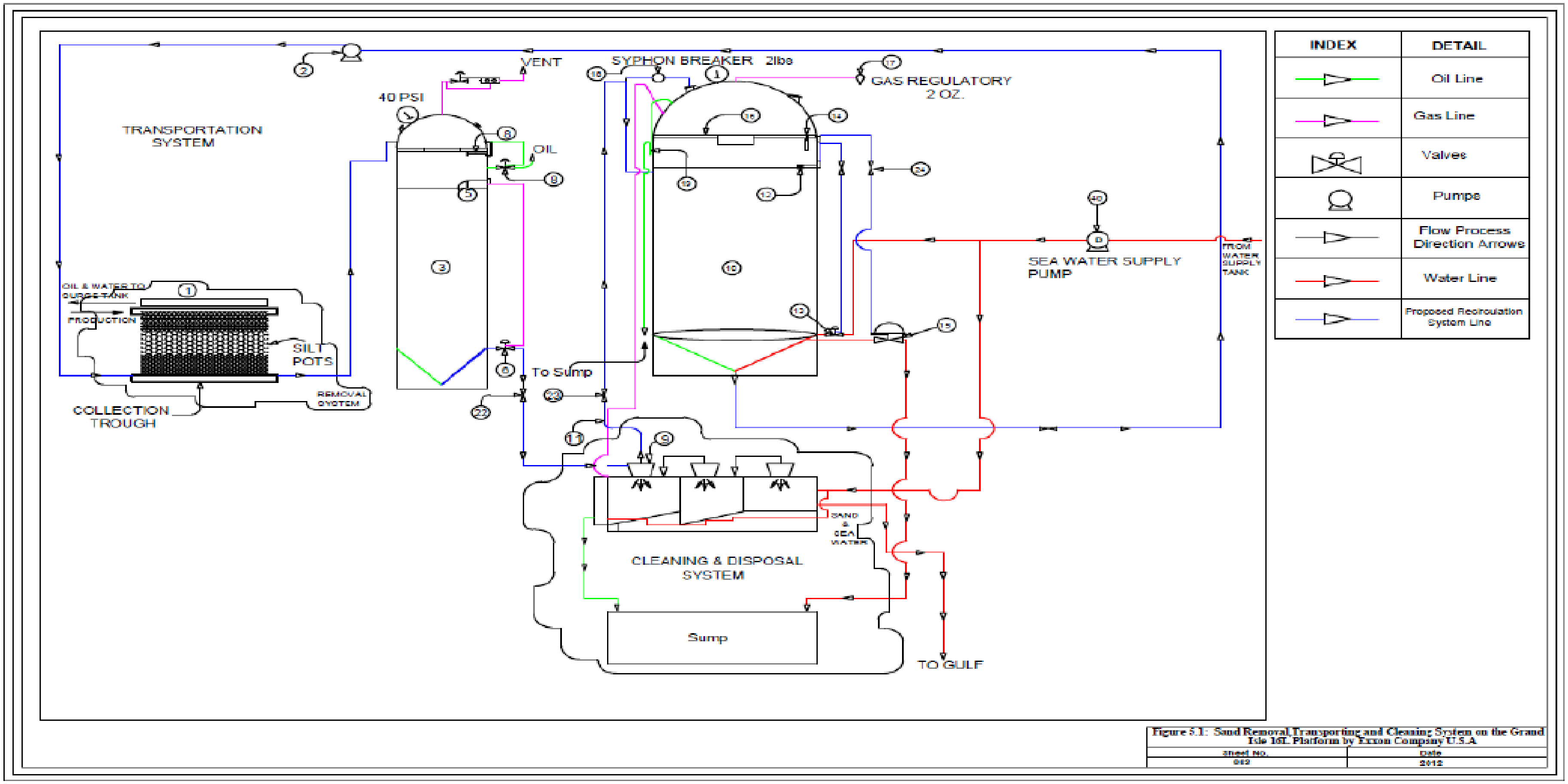

Figure 3. Sand removal, transporting and cleaning system on the Grand Isle 16L Platform by Exxon Company U.S.A [14]

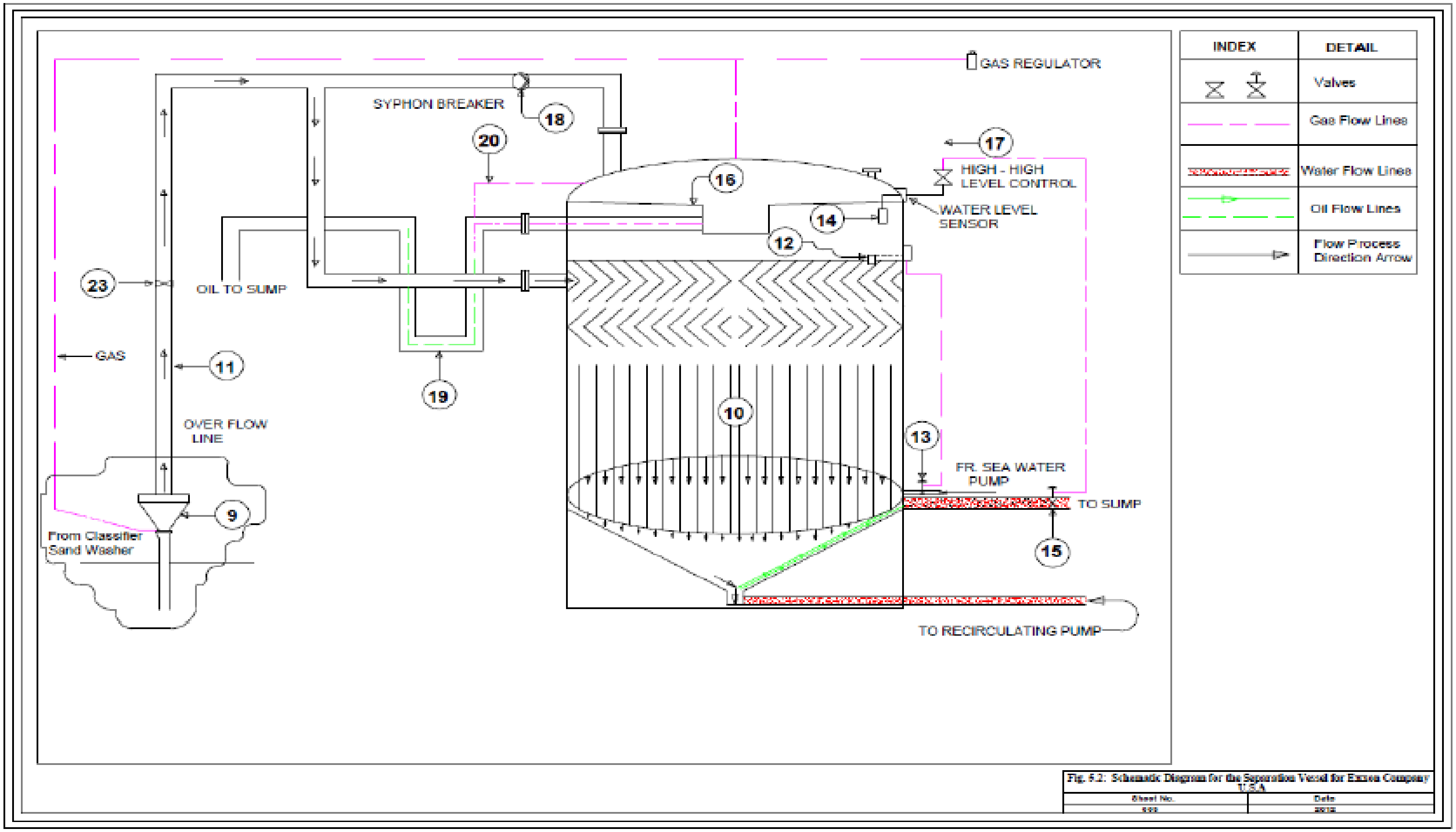

Figure 4. Schematic diagram for the Separation Vessel for Exxon Company USA [14]

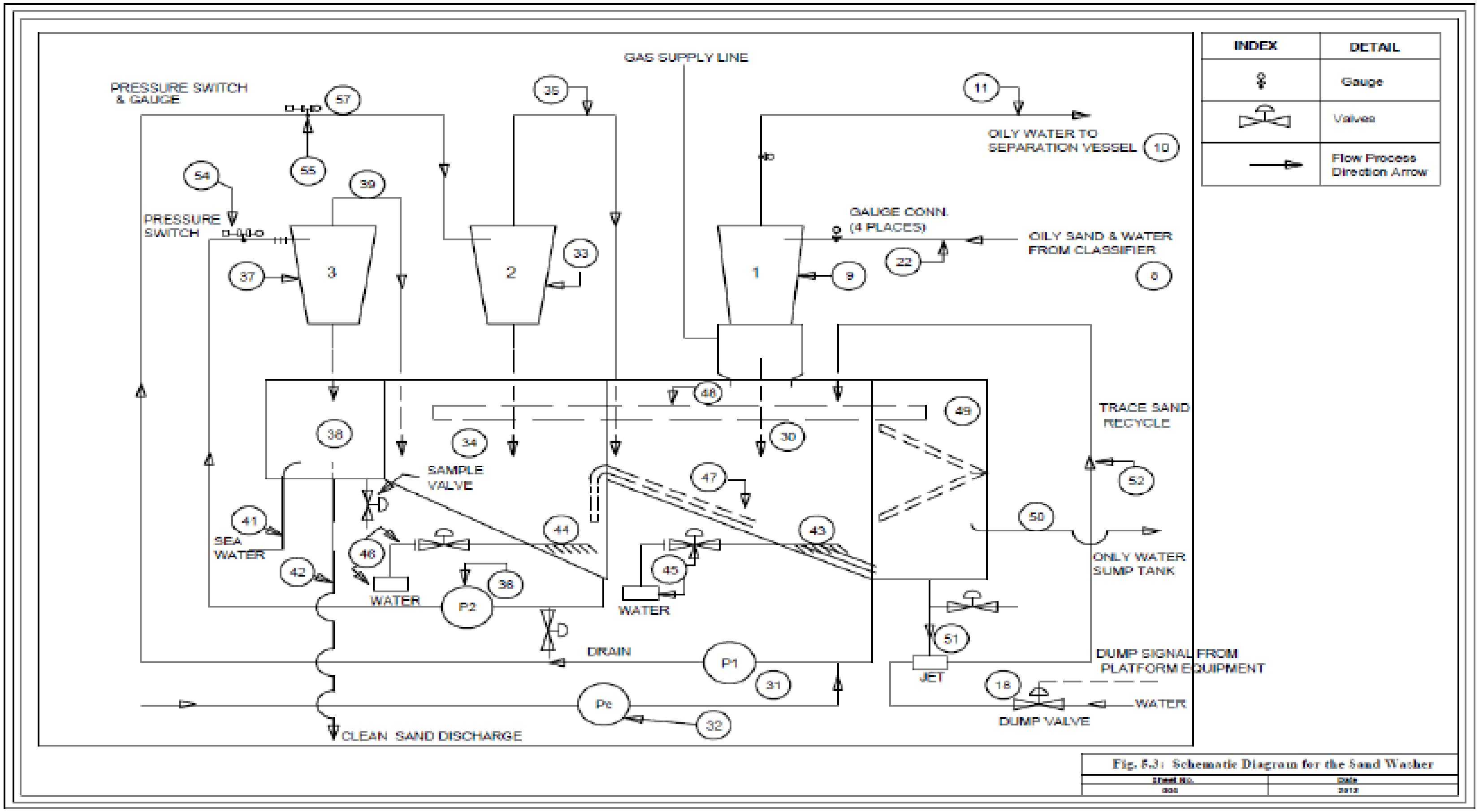

Figure 5. Schematic Diagram for the Sand Washer [14]

From the compartment, the sand moves to the suction end of the number one pump where sand cleaning chemicals are added. Sand, water and the chemicals then move to the number two cyclone (33) where the actual washing and separation takes place. Through the overflow line (35) the oil, water with the dispersed air moves to the compartment (30) while the sand is discharged into the compartment (34) that is introduced into number three cyclone (37). While the sand moves into the flush troughs (38), the water returns back to the compartment (34). Seawater then enters into the flush trough and the compartment where the sand is carried to the gulf. The valve rotameters (45 and 46) regulates the volume in each container, while the sand is collected at the bottom of the separation compartment

After several days of operation, Table 2 highlights several problems encountered and the ways they were solved [14].

Table 2. Problems and solution for Grand Isle Block and West Delta 73 A-D Platform

S/N	Problems encountered	Solution(s)
1	Erosion occurred due to leakages in the pump and wearing of the cone, which resulted in the failure of the unit within two months of operation.	Cone erosion was reduced by substituting the rubber liners with highly reliable polyurethane liners.
2	Leaking/ wearing of the shaft occurred due to the migration of sand from the pump	Regular replacement of the liners and packing's
3	A major pump failure occurred after ten months of operation which was caused by the combination of erosion and corrosion	Ceramic-coated plastic sealed housing was used to handle the issue of both corrosion and erosion. Ceramic has a high resistance to erosion but susceptible to corrosion while the plastic material, on the other hand, is not resistant to erosion but prevents the fluid from having surface contact with the coated metals thereby preventing corrosion
4	Sulphate reducing bacteria growth began to surface around the stagnant corners of the sand washer. This was due to the usage of the sea water that contained a lot of bacteria	Continuous injection of water between the gland and the seal section of the pump was done.

3.2. South Pass 98 Field

South pass 98 fields is sited in the Gulf of Mexico oil production facility and has 41 production wells. They encountered operational problems such as emulsion stabilization, erosion and equipment plugging. These occurred because of the continuous passing of produced solid through a corrugated plate interceptor, which led to a decline in the efficiency of the separator [5]. A sand handling system, as shown in Figure 6 below, was designed following the five basic steps (separation, collection, cleaning, De- watering and Haul aging) [5]. It is simple to operate, requires minimal human intervention and minimal footprint.

The de-sander starts operation once process fluid is passed through it, and the required pressure drop (40psi) has been obtained. Although the disk valve is configured to open every 10seconds to discharge its content, care has to be taken to ensure drainage of excess liquid to the collection bin does not occur. The dumped slurry is taken to the DOT (department of transport) bins, which drains the liquid via porous standpipe drains while the solid is retained. The bin continuously receives this slurry at regular interval until it reaches a gross limit of 7,700lbm and a tare weight of 1,100lbm. Table 3 highlights the problems that were encountered during operation and the ways they were tackled [5].

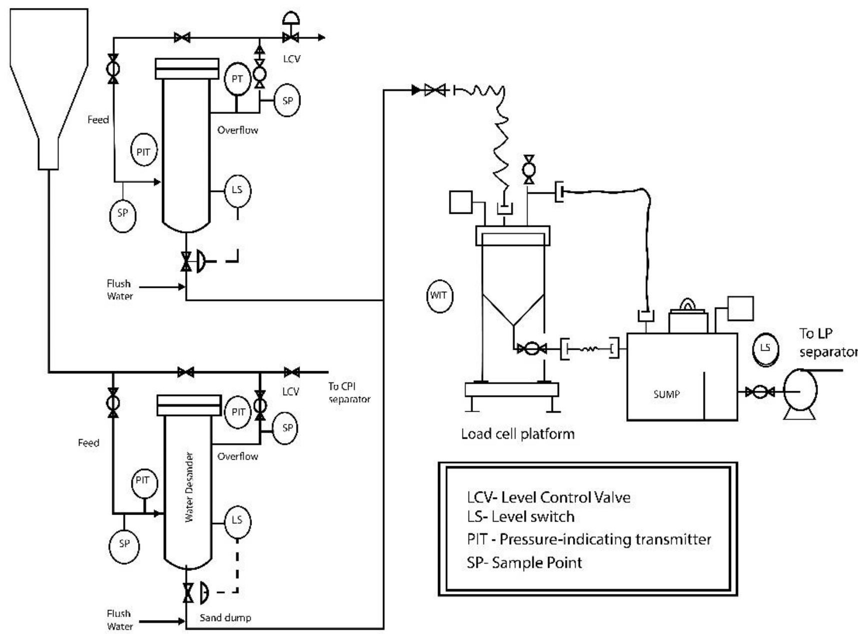

Fig. 6. South Pass 98 Field oil de-sander with integral solid dewatering and haulage system [5]

Table 3. Problems and solutions on the South Pass 78 Field

S/N	Problems encountered	Likely cause(s)	Solutions
1	An increment in the pressure drop at the initial stage of the operation when different levels of surges were experienced.	The high flow rate was suspected to be the cause, as the start- up was 13,300bpd while the measured flow rate was 16,000 bpd	Four blanks were replaced with active liners which reduced the pressure drop to 35psi
2	The dump valve refused to operate automatically, even though the sand level was found to be 3 inches above the sand probe	The probe calibration of the valve was done with tap water, and beach sand as produced solid was not available during the time of calibration	Proper calibration of the valve was done with the de-sander sample before it was put back into operation
3	After several weeks, the high pressure drop was again experienced at the water de-sander	This was solely due to the addition of more wells	An ultrasonic flowmeter was used to measure the flowrate of both the inlet and the outlet where a net flowrate was established as 20,000bpd. All blanks in the system were also replaced with active liner
4	Drainage problem surfaced at the DOT (Department of Transport) bin	Flexible drain hole was too long and badly located at the bin intervals and connections. This resulted in a 10-12ft drop below the sump level which brought back pressure to the bin	The hose was replaced and later inspected for blockage
5	Plugging of the drain screen was observed	Presence of big particles of sand	The tapping of the hard drain pipe proved as a temporary solution while the instalment of two different sized pneumatic vibrators directly below the bin proved a permanent solution
6	Dump valves open without indication of liquid flow	The drained pipe was filled with sand, caused by the insufficient slope in the drain pipe allowing the sand to accumulate in the drain line	The slight slope was added to the drain line that assisted in the flow of slurry

3.3. Installation of New Generation De-sander System at Albacora Deep Water Field

The Albacora field composed of sixty- five wells with two production units (5000bbld). The production unit includes a semi- submersible platform and a Floating Production Storage and Offloading (FPSO) platform. During the production of oil and gas, they experienced a decline in both the residence time and the rate of production [13]. Series of investigations were carried out where it was observed that the recession was caused due to the accumulation of sand in the production separator. In addition, erosions of pumps, valves, and other accessories were experienced, which led to the shutting down of the plant at regular intervals. More bills were incurred for clean out, labour, and disposal cost. The new generation de-sander system was installed on both platforms where a field test was carried out to verify the reliability of the system and to ensure that no form of an emulsion or solid entrainment will occur [13].

The separation process was recorded to be 90% efficient while the amount of solid separated by the de-sander was as much as 145 litres per shift. The amount of solid retained at the bottom of the separator after the testing period was very insignificant as compared to other conventional methods. The outcome of the test showed that both objectives were met, which confirmed it to be both a reliable and effective method [13].

3.4. Integrated Sand Cleanout System at the Dagang Oilfield in China, 2006

Excessive leakage of the working fluid into the formation, which leads to frequent stoppage of both the separation and production process were earlier recorded which led to the installation of an integrated sand cleanout system with the following attributes as highlighted in Table 4. During the cleaning operation, the amount of work fluid circulated from the wellbore equals the amount of working fluid injected, which simply means no significance leakage of the working fluid into the formation. The volume of the sand brought to the surface was 0.86 m^3 [4].

Table 4. Designed operation parameters of Dagang Oil Well [4]

Parameters	Value	Parameters	Value
Working fluid flowrate	$416.4 m^3/d$	Carrier fluid bottom hole pressure	19.80MPa
Carrier fluid flow rate	$138.6 m^3/d$	Wellhead back pressure	0.49 MPa
Power fluid flow rate	$277.8 m^3/d$	Wellhead Pressure of Working Fluid	11.42 MPa
Jet pump throat diameter	5.47mm	Power Fluid Pressure at the Jet Pump Intake (Nozzle)	34.82 MPa
Cleanout pipe jetting nozzle diameter	1.95mm	Suction Pressure at the Pump Intake (Throat)	19.01 MPa
Jet pump efficiency	29.89%	Pump discharge pressure	24.92 MPa

4. Conclusion

Technically, the different technologies currently adopted for the proper separation, disposal and handling of solids all fall under the umbrella of production limits, convectional exclusion and inclusion methodology (de-sanders). Production limits encourage drilling of wells where there is zero or insignificant amount of sand. Wire wrap screen is effective for coarse well-sorted sands. Expandable sand screen is considered the strongest due to its collapse strength of 2500psi. Metal mesh screen records a high corrosion resistance rate and has a slimmer chance of being damaged during installation. Chemical consolidation involves sealing of the sand grains several feet down by using environmental accepted chemicals. De-sanders generally have an upper edge in terms of lesser weight, capital effective, the little cost for maintenance and operation. Dagang Oilfield, Albacora Deep water, South Pass 98 Field, Grand Isle Block 16L and West Delta 73 A-D Production Platforms were cases studied that reflected their strength, weakness and general suitability.

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