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Optimization of a Horizontal Flow Electrostatic Coalescer in Offshore Gulf of Mexico Service

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Abstract

An advanced design horizontal flow oil coalescer was installed on the Marathon-operated Ewing Bank 873-A (EW-873A) platform in early 1998. The coalescer's design has enabled it to significantly exceed design capacity while simplifying operations. Design features that aid in performance include: horizontal flow to minimize water carry-over with the bulk oil phase, a cyclonic inlet device to smooth the pipe-to-vessel transition and degas oil at inlet conditions, externally adjustable louvers to distribute oil flow evenly across the vessel, multiple externally adjustable electrostatic grids to vary field density and allow improved coalescence, and directed-flow matrix packing in the oil layer to enhance the removal of the coalesced water droplets created by the electrostatic field. Operation and maintenance improvements include: internal sampling points to quickly assess performance along the length of the coalescer, externally replaceable grid entrance bushings, and an interface draw-off line to remove chemical/solids laden pads.

This unit was installed as part of a platform upgrade and operates parallel to a vertical upflow coalescer. The existing upflow coalescer is frequently unable to achieve 1.0 % BS&W in oil effluent at lower than design rates, while the horizontal flow electrostatic coalescer consistently provides <0.4% BS&W at 120% design capacity (61,000 BOPD versus 50,000 BOPD). This paper will detail horizontal flow coalescer design, with an emphasis on internal components, and provide highlights from its four-year operating history in a side-by-side comparison to a conventional upflow coalescer.

Introduction

Upgrading and debottlenecking have become common practice for Gulf of Mexico production facilities. Marathon's EW-873A platform had an existing upflow crude dehydrator that was unable to meet the required pipeline specification at the design flow rate. Furthermore, production expansion required installation of a second unit to relieve the crude loading on the first and handle the additional oil throughput. A combined electrostatic coalescer and oil storage tank (EC/OST) design was chosen based on horizontal flow technology and containing a number of significant flow path and operating improvements. The new crude dehydrator provides high operational flexibility combined with minimum operator maintenance requirements.

Ewing Bank 873A Oil Treating

The Marathon-operated EW-873A platform began production in 1994. EW-873A now serves as a production hub for the *Oyster*, *Arnold*, *Manta Ray*, and *Starfish* subsea prospects. The platform is located in the Ewing Bank area about 130 miles south of New Orleans, Louisiana. A significant contributor to the company's deepwater portfolio, the EW-873A platform stands in 775 feet of water and has handled rates in excess of 80,000 barrels of oil per day and 70 million cubic feet of natural gas per day[1].

Process Description

Oil produced from the *Manta Ray, Starfish, Arnold, Oyster*, and EW-873 fields is processed in multiple trains as shown in Figure 1. Oil from each field is heated prior to primary separation to reduce fluid viscosity, however fluid from the *Starfish* and *Arnold* fields is first degassed. All gas gathered from main (1st Stage, Primary or Test) separation is sent to compression, scrubbing, and dehydration before leaving the platform via 30" or 8" gas sales pipelines. Oil from the EW-873A and *Oyster* wells is split between the upflow coalescer and the EC/OST. Oil destined for the upflow coalescer is heated after First Stage Separators then treated with a second stage of three-phase gravity separation. Oil from the Second Stage Separator flows into the upflow coalescer and then into oil storage before leaving the platform via the LACT system. Commingled oil from the EC/OST is cooled before leaving the platform via the LACT system and into the 16" departing oil pipeline. All oil entering the EW-873 facility is considered medium-heavy with an API gravity between 20°-25°. Raw crude viscosity is in the 6-20 cP range (6 cP @ 190 °F and 20 cP @ 120 °F), which dictates the use of heating and electrostatic coalescence to meet the BS&W sales specification of 1.0%.

EC/OST Design

Commissioned in April 1998, the EC/OST is designed to accommodate increased production from the *Arnold* and *Oyster* tiebacks as well as debottleneck the existing upflow Electrostatic Coalescer. With a design capacity of 50,000 BPD the EC/OST provides mechanical and electrostatic coalescence to reduce the *design* inlet water content of 10% to a *design* BS&W specification of 0.5%. In actuality the EC/OST has handled a wide range of inlet conditions (inlet cuts in excess of 40% BS&W at rates of 40,000 BFPD to inlet cuts of 8% BS&W at rates of 66,000 BFPD) with consistent <0.4% BS&W effluent. Commingled oil at the EC/OST inlet is 22.9° API gravity at about 165 °F and 30 to 45 psig. Full design conditions are listed in Table 1. The resulting EC/OST is 13.5' OD x 45' S/S, of which 10.5' is utilized as oil storage, as shown in Figure 2. Advanced flow path technology includes a cyclonic inlet momentum breaker, externally adjustable flow distribution louvers, adjustable electrostatic grids, and matrix packing.

Several sample points were provided after baffle stations 3, 5 and 7, as shown on Figure 2. These centerline sample points allow adjustment of louvers and/or grids to maximize treating efficiency. Internal samples also allow detailed study of unit performance in order to improve sizing procedures for future projects.

Horizontal Flow

Due to the medium-heavy oil gravity, a horizontal flow path was chosen based on proven technology. Horizontal flow trajectory maximizes the separation efficiency of the lighter (gas) and heavier (water and solids) fractions by allowing separation to take place *perpendicular* to the *horizontal* process flow direction.

In vertical path electrostatic dehydrators, the flow direction of the bulk oil is upwards. As water droplets are coalesced in the electrostatic field, they are required to flow *countercurrent* to the *vertical* oil flow. In light oil applications (>25-30 °API), countercurrent flow does not create as many performance problems due to the greater density differential between the oil and water phases.

However, in heavier oil applications (<25 API), countercurrent flow of the two phases makes already difficult separation more problematic. Figure 3 illustrates the smaller critical droplet size achieved for horizontal versus countercurrent upflow patterns. Therefore, in heavy oil dehydration applications, horizontal flow is preferable to upflow–or countercurrent flow. This configuration is also beneficial in applications were the crude has foaming tendencies as well as in extra heavy oil applications where "upside down" treating is required, where oil SG is heavier than water SG at treating temperatures.

Cyclonic Inlet

The EW-873A processed crude oils often exhibit foaming tendency. Foam in a separating vessel is created by turbulent momentum reduction as fluid enters the vessel, or by allowing dispersed bubbles to rise through the liquid layer, or from pressure reduction in the separator that allows gas to flash from solution[2]. A mechanical means of preventing foam is the use of a low turbulence cyclonic inlet device to allow rapid disengagement of the gas from liquid.

A cyclonic inlet device provides a less shear intensive mechanism for gas separation, compared to impact plates or standard momentum breakers. This is due to the cyclonic action and the specific gravity differential between the gas and the liquids. The enhanced centrifugal forces also aid in collapsing any entrained foam that has formed in the inlet piping of the separator. The separated gas exits the top of the cyclone while the liquids exit the bottom. By pre-separating the gas and liquids before they enter the bulk separation zone, foaming is prevented which allows the liquid hold up volume to be used for crude-water separation only. This action allows for a more compact separator design or increased throughput on existing units.

The EC/OST contains an inlet cyclonic bundle of six tubes, each at 10" diameter. The disengaged gas is directed above the liquid layer to flow over the grids to the gas outlet. The liquids are discharged back toward the vessel's inlet head in an effort to maximize flow distribution and retention. The first louver baffle distributes the flow equally over the vessel diameter.

Adjustable Louver Baffles

A newly patented development in separator internals is the externally adjustable louvered baffle. This device consists of a series of vertically mounted louver plates that form a baffle section. As in a standard baffle section, the purpose is to distribute the bulk flow evenly over the entire cross-section of the vessel. The advantage of this design is that the open area of the baffle can be changed on-line to match the process flow conditions, by external adjustment to the plates. The louvers provide a slight pressure drop to ensure there are no dead zones or short-circuiting through the unit. The even flow distribution guarantees that the full effective residence time of the vessel is used for maximum oil-water separation performance. A detail of the louver adjustment mechanism is shown in Figure 4.

In addition, the open louver slots provide a coalescing action, as illustrated in Figure 5. The coalescing action is a function of increased droplet impact probability, and increased surface sites for droplet growth (similar to matrix packing).

The EC/OST contains seven louver stations. Station 1 is a bare louver, stations 2-4 are a louver in combination with an adjustable electrostatic grid, and stations 5-7 are a louver, adjustable electrostatic grid, and matrix packing.

Adjustable Grids

Coalescence of water droplet dispersed in the crude oil can be achieved by subjecting the emulsion to a high-voltage electrostatic field. The dispersed conductive liquid (water) in the non-conductive carrier liquid (crude) is subjected to the electrostatic field. This causes the conductive droplets to move and migrate through the non-conductive liquid at a rapid rate that increases their probability of collision and coalescence with other droplets. Once the coalesced droplets mass is great enough to overcome the buoyancy of the crude, they will settle out of the crude and collect in the water phase section of the vessel.

Occasional process upsets allow high inlet water cuts to enter the electrostatic dehydrator. The corresponding increased water droplet population results in a higher potential for grid short-circuiting. Reducing the field density strength will eliminate this short-circuiting condition. Typically, this is accomplished by reducing the electrostatic grid voltage with a step voltage transformer. Through the use of adjustable grids, the spacing between the charged grid and the ground can be adjusted to reduce the field density to eliminate short-circuiting. The adjustable spacing feature in combination with step voltage output from the transformer allows the operator to adjust the electrostatic potential on-line to provide for optimized coalescence as process conditions change.

Through the utilization of adjustable louvers and grids, electrostatic coalescers can be adjusted to meet changing inlet process conditions over a large range of flow rate and inlet water cut/emulsion levels while exceeding the process outlet specifications.

The EC/OST contains electrostatic grids at stations 2-7. These grids operate between 12,000 volts at 7.5 amps and 18,000 volts at 5 amps with a grid adjustment of 3 to 9 inches. A 90 KVA transformer provides the power for this system. The grids are designed to be removable through the vessel manway and are fabricated from 316 SS.

Additionally the electrical grid entrance bushings are externally accessible, which eliminates the need to drain and enter the vessel to replace a shorted entrance bushing, as is the case with other designs.

Matrix Packing

Matrix packing provides a high surface area “target” for the water droplets to grow on, and reduces the settling distance for removal of droplets. When using matrix packing in heavy crude, the principal factor to be considered is its resistance to plugging. The design should allow solids and asphaltenes to be removed in-situ without having to shut the unit down for maintenance. Downwardly sloped single-direction channels in the matrix packing provide self-cleaning compared to herringbone designs that trap solids in the static zones.

The EC/OST employs unidirectional matrix packing at stations 5-7, after the louvers and grids. The matrix packing provides the last polishing step in removing the coalesced water droplets from the crude oil. The matrix packs are made from corrugated stainless steel, in sections that can be removed through the vessel manway.

Interface Draw-Off

In oil treating an emulsion layer is often formed at the oil-water interface. This emulsion layer is trapped at the interface, and if not removed will continue to grow in thickness because it is heavier than the oil but lighter than the water. The horizontal flow pattern of the EC/OST continuously moves the emulsion build up in the direction of the fluid flow to the outlet end of the vessel, providing a single point of removal. These chemical and solids-rich emulsion pads are extracted from the production train via the draw-off line to an independent treatment vessel.

Oil Storage Tank

The last section in the EC/OST is the oil storage tank. The dehydrated oil flows over a weir to this section. With a 10.5’ length, the OST portion of the treater has a capacity of 250 barrels, which provides 7 minutes residence time (at design flow rates) in feeding the LACT pumps. An integrated oil storage tank minimizes process complexity and platform space. The existing oil treating facility contains separate oil dehydration and oil storage vessels, consuming more deck space, payload, instrumentation, piping, and ancillary equipment.

EC/OST Installation & Operation

Upon installation in spring 1998, the EC/OST was put through a series of tests over a six-month period where the process conditions were varied and the flow path internals tested for effectiveness[3].

The first test began in April 1998 upon completion of startup and commissioning. With a flow rate of 25,000 BPD (production limited), and the louvers set wide open (Test 0, see Table 2, an inlet cut of 6-8% was reduced to 0.1% effluent. The electrostatic grids were not energized at that time, as the outlet BS&W met process specification.

The next set of tests took place in June 1998 when the oil rate increased to 38,000 BPD at 10% inlet water cut. With the louvers still open and the grids unenergized, the outlet BS&W was <0.2% (Tests 1, 3, and 4). The flow rate was increased to 53,000 BPD; the louvers were adjusted to 21% open, with the grids energized (Test 5). An outlet BS&W of 0.25% was achieved based on 11% inlet water cut. With the grids de-energized (Test 6) the outlet BS&W increased to 0.35%, still below the 0.5% specification. Several more tests were run at the 53,000 BPD flow rate and various louvers and grids settings. In all cases the outlet BS&W met specification (Tests 7-11).

To test the EC/OST’s capacity, the flow rate was increased to 66,000 BPD, representing 120% of design conditions. The outlet BS&W was <0.3% in these tests (Test 12-14) with the grids energized and the louvers partially opened.

Comparison to Upflow Coalescer

The original upflow coalescer and the EC/OST are installed side-by-side on the EW-873A platform, as shown in Figure 6. This allows for direct physical process comparisons. Table 3 provides mechanical and performance details for both units.

Size/Weight

The EC/OST vessel is 13.5' diameter by 45' seam-to-seam length, combining both the electrostatic coalescer and oil storage duties into one vessel. The upflow coalescer is 12' diameter by 40' seam-to-seam length, however this does not include an oil storage tank. A separate oil storage tank provides residence time for LACT feed pumps. This separate tank is 8.5' diameter by 25' seam-to-seam length, and provides 250 barrels of storage. The EC/OST has a bare weight of 75,000 (568,000 full) pounds, compared to a combined weight of the upflow coalescer and separate oil storage tank of 91,000 pounds. The EC/OST requires 12% less footprint and 16% less weight with a higher effective throughput.

Throughput & Performance

Both the EC/OST and upflow coalescer are in use today on the EW-873A facility. Current rates are about 40,000 BPD at 35% watercut to the EC/OST and 15,000 BPD at 5% water cut to the upflow coalescer. The EC/OST provides <0.4% BS&W oil outlet, while the upflow coalescer struggles to operate around 1.0% BS&W effluent.

Maintenance & Operation

The EC/OST has not been shut down for maintenance since installation. Even with very high water rates at the inlet, no entrance bushings or electrodes have burned out. In comparison to the upflow coalescer, which requires isolation and drainage, and has experienced multiple short-circuit failures, EC/OST maintenance has been non-existent.

No adjustment has been made to the louvers or grids since initial stable operation was achieved. Even with high water loads, the outlet oil has maintained <0.5% BS&W.

The only challenge in EC/OST operation occurred in fall 2000. At that time a new flotation unit was installed for water treating. Shortly after the installation of the flotation unit the EC/OST experienced a thicker than normal emulsion pad. Upon investigation it was discovered that the flotation unit blanket gas valve failed, which introduced excess oxygen into the system. The high oxygen concentration created a stable iron oxide/chemical emulsion, which was skimmed off and sent to EC/OST for treating. Once the blanket gas valve was replaced, the emulsion pad went away and EC/OST operation resumed as per normal.

Chemical Cost/Usage

An estimated $100,000 per year has been saved on demulsifier cost (at maximum flow rates) as a direct result of installing the EC/OST.

Conclusions

In new construction, retrofit or debottlenecking operations, flexibility and robustness through changing conditions are key parameters in the design of process equipment. The installation of a horizontal flow coalescer (EC/OST) on the EW-873A facility using advanced flow internals has shown that this design can provide dramatically improved performance, and operating flexibility. In all conditions tested, the horizontal flow coalescer outlet BS&W was less than 0.4%. These results were obtained from 30-120% of design capacity. Significant improvements are obtainable over traditional upflow methodology, both in performance and size.

Acknowledgements

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References

1. Marathon Oil Company website. www.marathon.com/our_business/marathon_oil_company/production/gulf_of_mexico/default.htm.
2. Sabey, J.: "Designing Flexibility into a Sour Heavy Oil Treating Facility," paper SPE 74355 presented at the 2002 SPE International Petroleum Conference and Exhibition, Villahermosa, Feb. 10-12.
3. Kvaerner Process Systems Internal Report, "Marathon Ewing Bank 873-A Platform Facility, Commissioning and Test Report," June 29, 1998.

Conversion Factors

°API	x	141.5/(131.5+°API)		=g/cm^3
BBL	x	1.589 873	E-01	=m^3
cP	x	1.0	E-03	=Pa•s
ft	x	3.048	E-01	=m
ft^3	x	2.831 685	E-02	=m^3
in.	x	2.54	E+00	=cm
lbm	x	4.535 924	E-01	=kg

Table 1 – Design Conditions for EW-873A EC/OST

Crude Flow Rate (max. /min.), BOPD	50,000 / 15,000
Water Flow Rate (max. /min.), BWPD	5,000 / 500
Gas Flow Rate, MMSCFD	2.5
Crude Gravity, API	22.87
Water Specific Gravity	1.08
Gas Specific Gravity	0.8
Temperature, F	165
Pressure, psig	50
BS&W Outlet Spec. % (EW-873 P/L Spec: 1.0%)	0.5%

Table 2 – Test Results of EW-873A Sampling Program

Test No.	Flow (BOPD)	Louver / Grids	Inlet %BSW	Pt. 1 % BSW	Pt. 2 % BSW	Outlet % BSW
0	15,000	Closed / Off	6.0	--	--	0.1
1	38,000	Closed / On	10.0	0.3	0.2	0.1
3	38,000	Closed / On	10.0	0.5	0.3	0.2
4	38,000	21% Open / On	10.0	0.5	0.3	0.2
5	53,000	21% Open / On	11.0	0.4	0.25	0.25
6	53,000	21% Open / Off	10.0	4.0	1.2	0.35
7	53,000	21% Open / On	10.0	0.7	0.4	0.2
8	53,000	21% Open / Off	10.0	2.4	0.9	0.5
9	53,000	31% Open / On	10.0	0.9	0.2	0.25
10	53,000	38% Open / On	10.0	0.6	0.4	0.35
11	53,000	50% Open / On	10.0	2.0	--	0.15
12	61,000	38% Open / On	8.0	1.0	0.5	0.2
13	61,000	38%* Open / On	8.0	1.0	0.5	0.2
14	61,000	38%* Open /On	8.0	1.0	0.5	0.2

*Test 13, Louvers 2 and 3 were 100% open.

*Test 14, Louvers 2, 3, and 4 were 100% open.

Table 3 – Comparison of EC/OST and Upflow Design

Parameter	Units	EC/OST	Upflow + Oil Storage Tank
Size	ft	13.5' x 45' S/S	12' x 40' S/S + 8.5' x 25' S/S
Bare Weight	lbm	75,000	64,000 + 27,000
Full Weight	lbm	568,000	374,000 + 127,000
Throughput (design)	BPD	50,000	35,000
Outlet BS&W	%	0.5%	1.0%
Inlet Oil Viscosity	cP	9	7 (hotter)
Oil Storage Capacity	BBL	250	250
Oil Gravity	°API	22.9	22.9

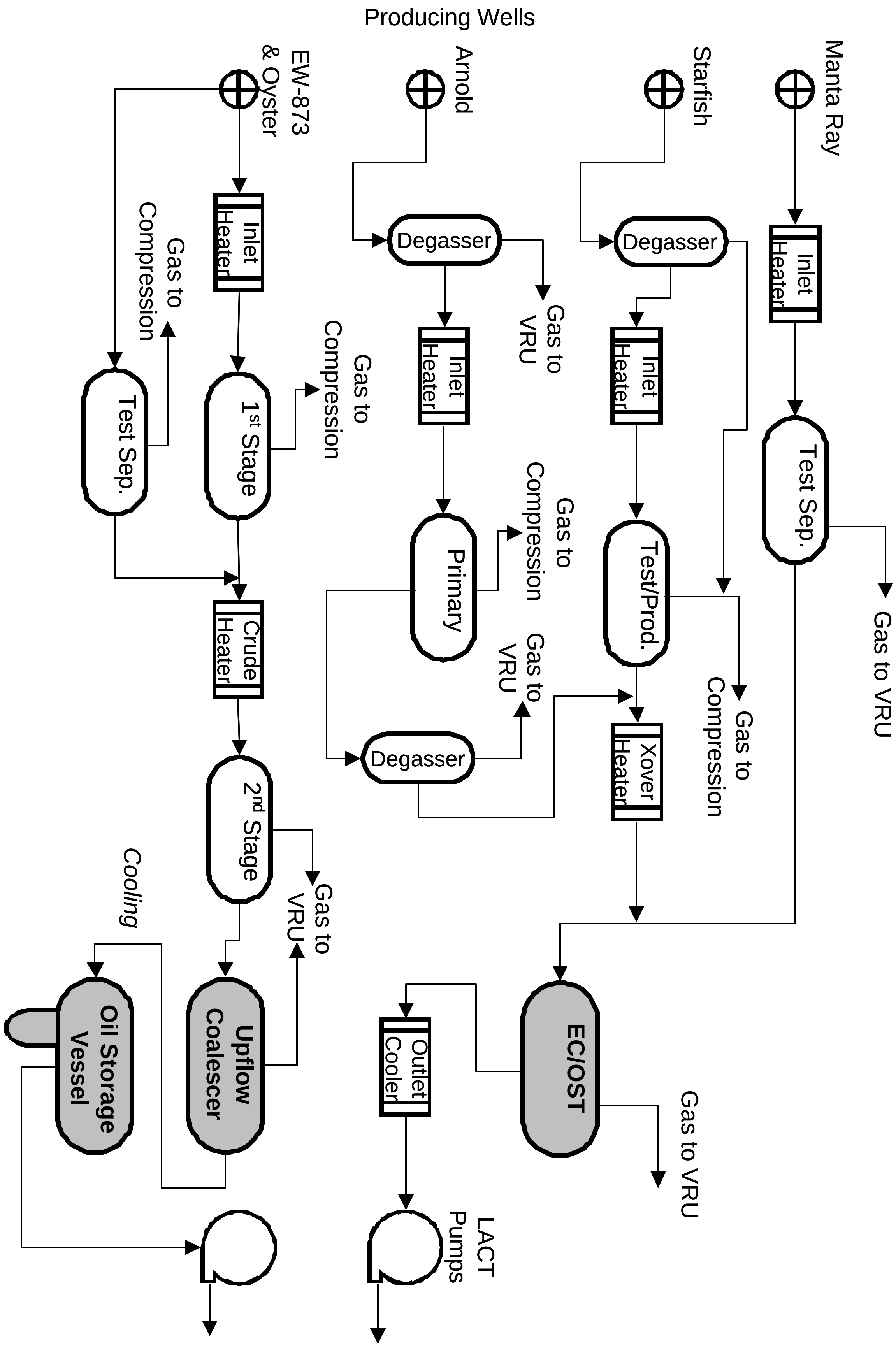

Figure 1–EW-873A flow schematic, showing oil-processing train.

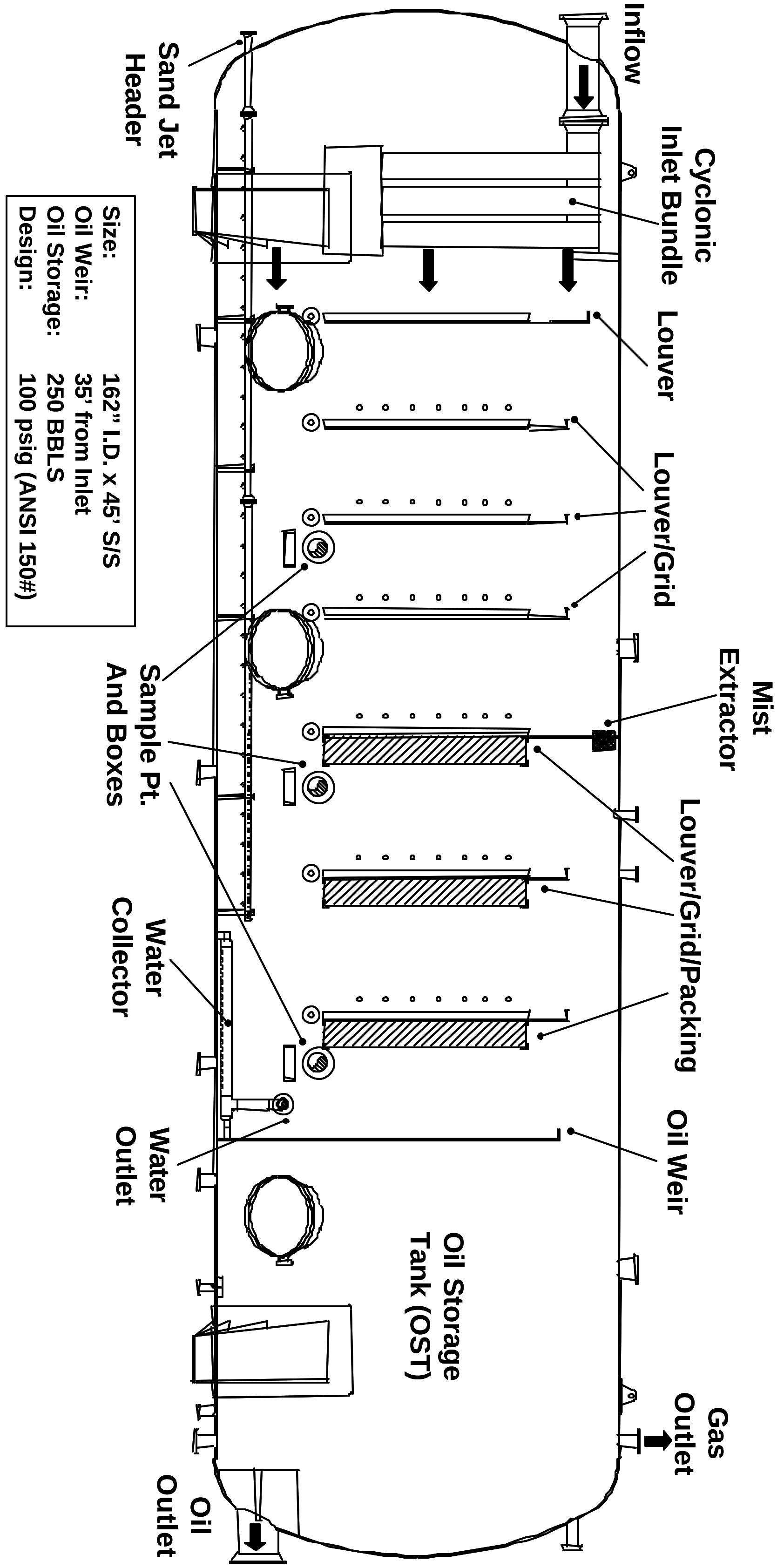

Figure 2–General arrangement of EC/OST showing key flow path components.

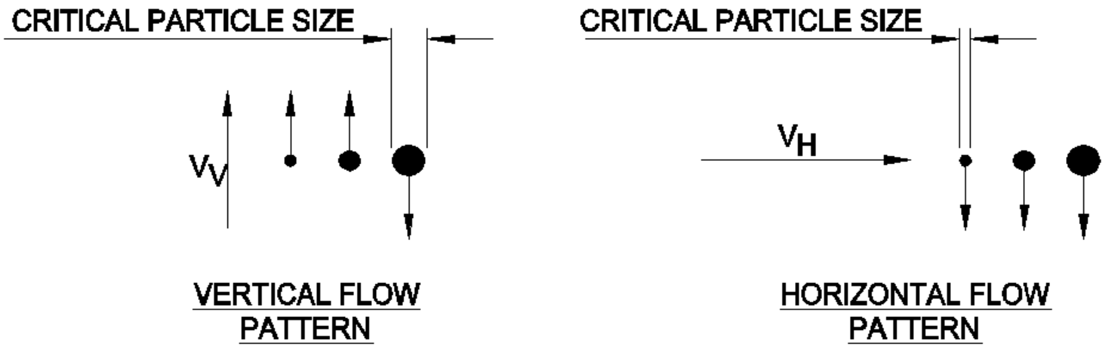

Figure 3–Vector schematic of critical droplet size for vertical upflow and horizontal flow patterns.

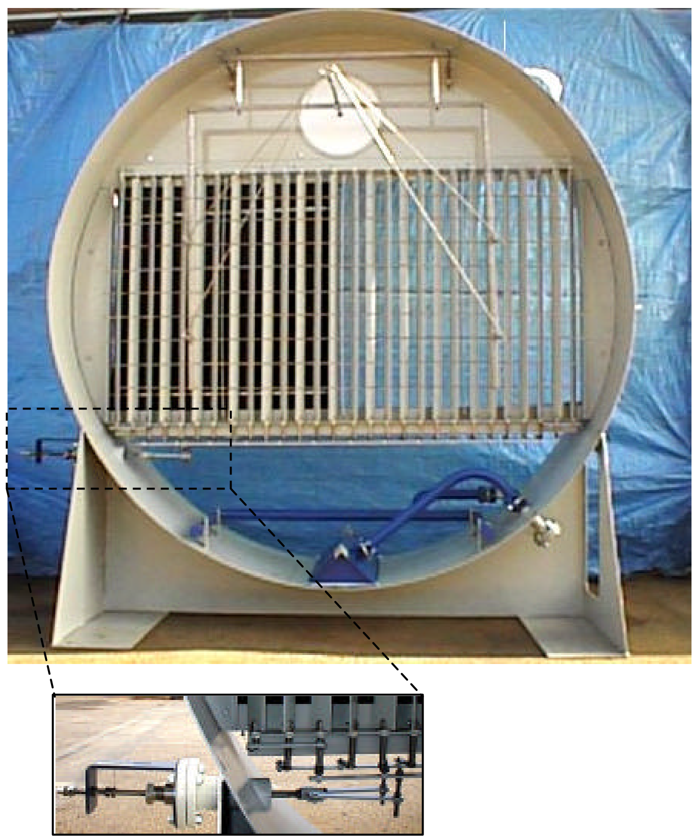

Figure 4–Vertical louver baffles shown in cross-section of vessel, including close-up of external adjustment mechanism.

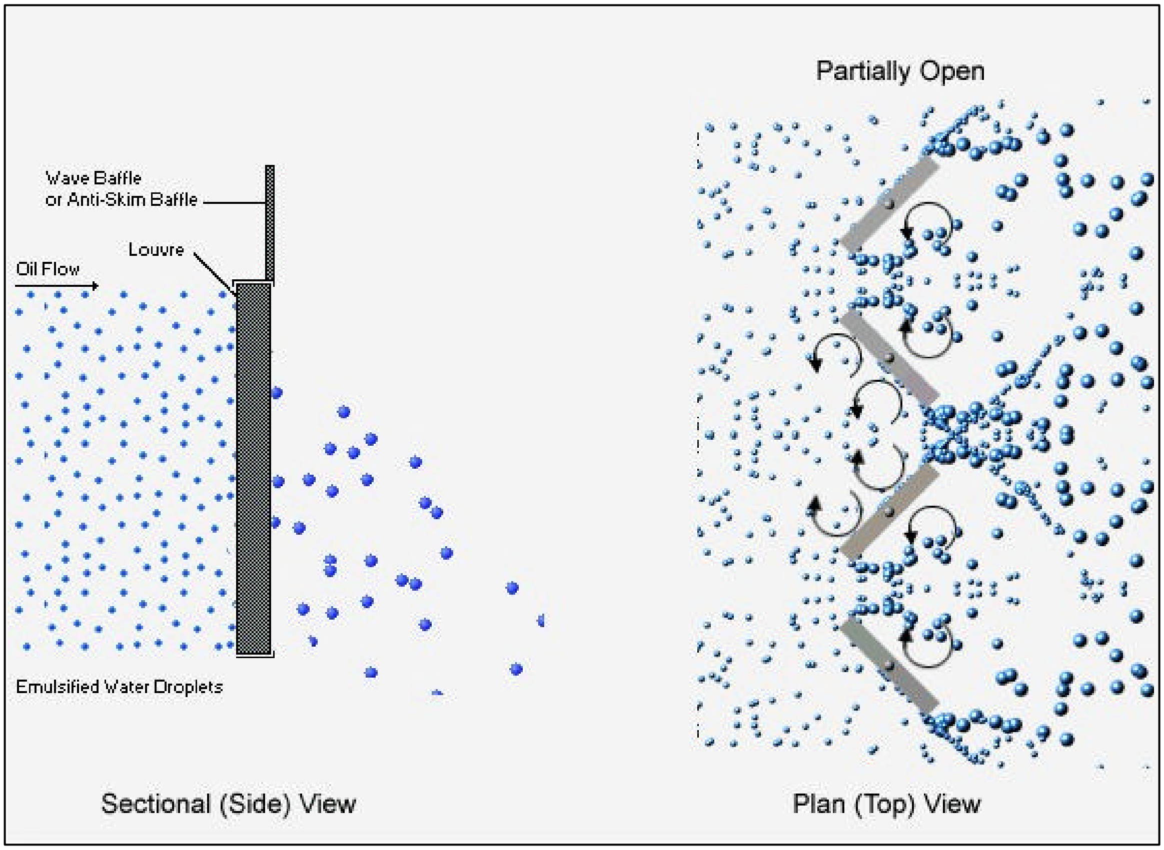

Figure 5–Schematic of coalescing mechanism exhibited by vertical louver baffles.

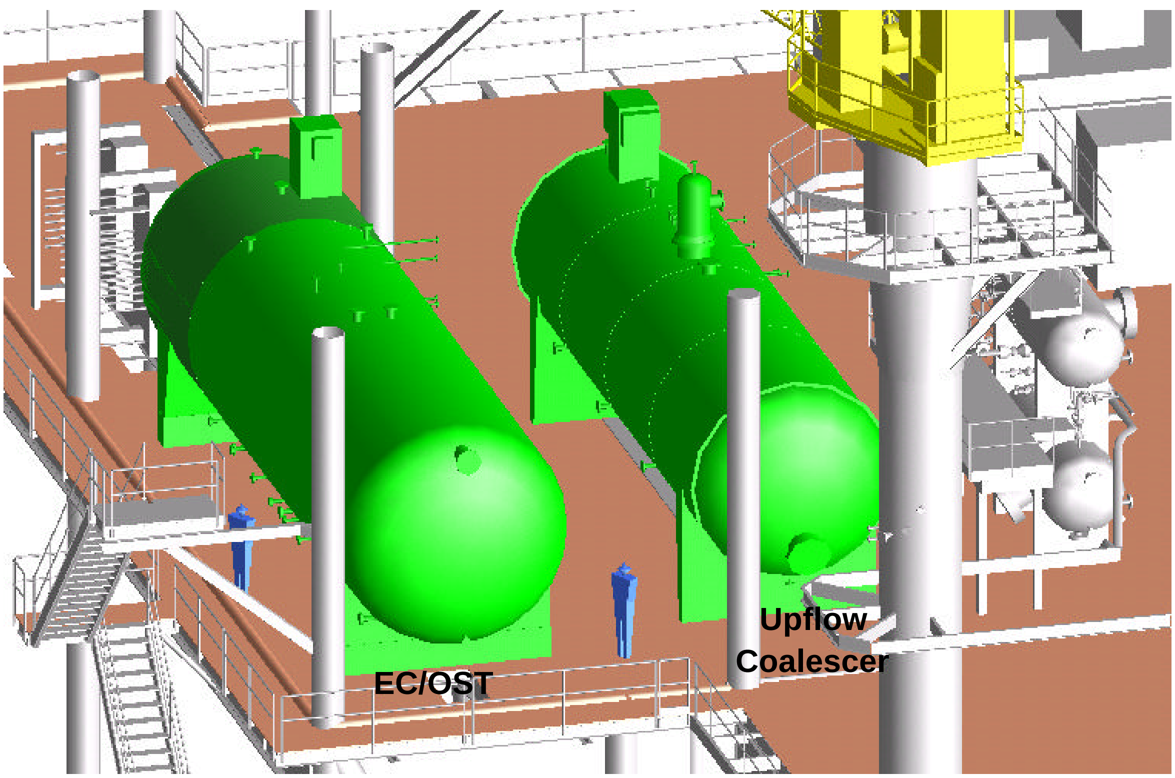

Figure 6- Platform layout of EC/OST and Original Upflow Coalescer