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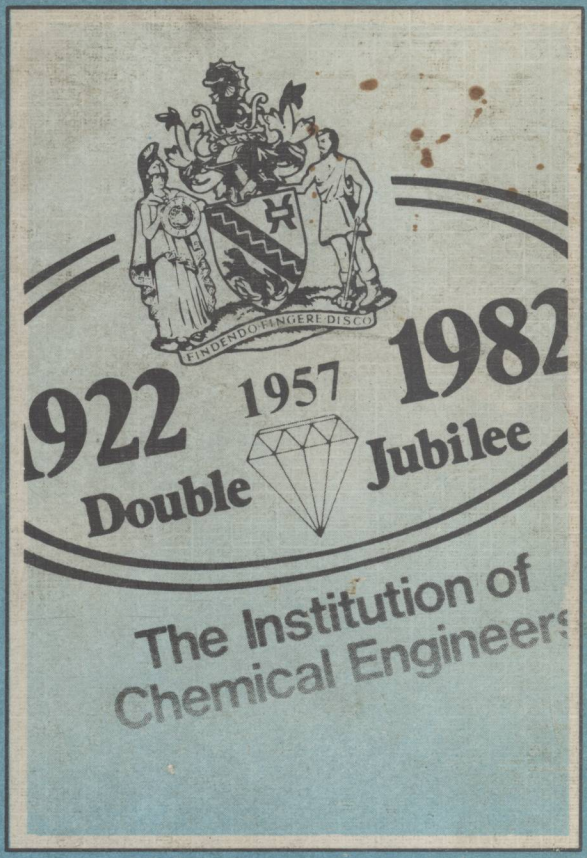

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This event marked the 60th Anniversary of the founding of the Institution and the 25th Anniversary of the granting of its Royal Charter. The organisers of some sessions elected not to give papers for permanent publication: this book contains the papers from the sessions which did elect for permanent publication.

Section A

Petroleum Production

Session Co-ordinator
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Imperial College
London

Contents

A NOVEL DEVICE FOR DEGASSING SEAWATER

R. S. SILVESTER*

INTRODUCTION

Deoxygenation of seawater is essential prior to its injection into an offshore oil reservoir. Dissolved oxygen promotes the corrosion of wellhead tubing and pipelines and corrosion products can then plug the pores of oil-bearing strata. The options generally available to the reservoir engineer are as follows:

(a) Mechanical stripping of all dissolved gas by means of a vacuum.
(b) Stripping out the oxygen with another appropriate gas.
(c) Chemical reduction of the oxygen in solution.

Generally, some form of mechanical stripping process is used to remove the bulk of the oxygen. This is followed by chemical dosing, the "polishing" stage. This sequence provides a good balance between the cost of the chemical agent and the performance limitations of mechanical stripping/gas stripping, dictated by the equilibrium concentration of oxygen at the operating vacuum or in the stripping gas.

Conventionally, vacuum stripping is achieved by spraying the feed liquor over a packed column. Most of the gas is transferred from the spray; the porous column primarily serves to allow sufficient residence time for full release. In a study of jet-impingement spray stripping, Simpson and Lynn (1) argue further that the bulk of gas transfer from the spray occurs before droplet formation. The key to efficient stripping appears to lie in the maintenance of as large a liquid surface areas at as low a pressure as possible.

BHRA have developed a degassing device based on the principle of a cavitating jet. It was invented by Mr. D. S. Miller (UK Patent No. 1461591) and operates according to the principle illustrated in Figure 1. The central component is the desorption tube, consisting first of a nozzle through which the feed is injected. The flow cross-section is broadened in a stepwise fashion in order to decelerate the jet without pressure recovery. Most of the gas release is believed to occur near the nozzle, where pressures below the vapour pressure of water have been measured. The purpose of the turning vanes at the nozzle inlet has been to ensure uniform reattachment of the jet as it enters each new section of tube. Ideally the point of reattachment should lie just upstream of the next step, to minimise pressure recovery. The purpose of the shroud tube has been to extract residual energy from the exit jet and prevent it splashing against the roof of the vacuum vessel.

HISTORY OF DEVELOPMENT

The sequence of References 2 to 5 inclusive give the history of the development of the linear tube degasser at BHRA. Bain and Darlington (2) describe the earliest tests on a 500 gph prototype with both tube and vessel made of perspex. Other units, of 1000 and 2500 gph nominal capacities, were con-

*BHRA Fluid Engineering, Cranfield

structed and tested with a view to establishing a set of scaling relationships. It was during this phase of development that the need for turning vanes and shroud tube became apparent. A suitably optimum tube geometry was determined and selected as a design basis for all future units. Following the tests at BHRA, the system underwent a more complete experimental programme at the APV Company Ltd., who now hold a licence for development of the device for the food processing industry.

For the degasser to be suited to offshore applications, two major developments were required. These were to upgrade the system capacity to the order of 10,000 gph, and to render it capable of handling seawater. The first of these objectives was readily achieved in the laboratory, as described by King and Bain (3). The new 10,000 gph device was then tested with seawater transported inland by road tanker, with considerable foaming observed during unloading of the water. Subsequent analysis revealed traces of both ethylene glycol and lubricating oil, presumably part of the tanker's previous load. The need for site tests became clear.

The site tests (King, 4) were conducted at the Admiralty Marine Technology Establishment, H.M. Naval Base, Portland. Although less severe than the laboratory test cases, foaming was still observed. This was eliminated by trace quantities of anti-foaming agent, with a resulting degassing performance as good as that observed in the earlier freshwater tests.

King and Swann (5) describe the latest phase of BHRA laboratory work, i.e. tests on a multiple tube cluster. This was designed for the same vacuum vessel and nominal throughput as the single 10,000 gph tube. Tests with both four-tube and five-tube arrays produced similar levels of dissolved oxygen as with the single tube, provided the full diameter of vacuum vessel was used. Reduction of the vessel diameter by a third resulted in poorer performance, due apparently to re-entrainment of gas bubbles through the extraction system.

Babcock-Woodall-Duckham Ltd. (6) have taken over the development of the linear tube degasser for high seawater throughput applications. They have designed two units of 35,000 and 165,000 bbd (50,000 and 250,000 gph) nominal capacity consisting respectively of circular arrays of five and twenty five 10,000 gph tubes. These are to be tested at Nigg Bay in Scotland upon completion of fabrication.

EARLY PARAMETRIC STUDIES

The rig used by Bain and Darlington (2) in the initial development phase is shown in Figure 2. The aerated feed, which could be heated, was pumped to the inlet nozzle of the 500 gph degasser tube. The released gas was removed by a liquid ring vacuum pump and the product water by a centrifugal extraction pump fitted with a liquid seal. The seal water was deaerated to prevent contamination of the product. The following operational parameters could be varied independently:

(a) Feed water temperature
(b) Nozzle inlet pressure
(c) Environmental vacuum

For an initial oxygen concentration of about 10 ppm, an increase in feedwater temperature from 10 to 50°C brought the product DOC (dissolved oxygen content) from 0.8 to 0.2 ppm, at a 3.5 bar supply pressure. At 12°C, increasing the nozzle gauge pressure from 0.7 to 3.5 bar decreased output DOC from 1.25 to 0.75 ppm. The variation of DOC with vacuum was linear at a slope of about 0.01 ppm/torr, provided the vacuum was insufficient to induce fresh vapouri-

sation.

The initial tests displayed considerable free surface motion, particularly in the presence of jet instability. Both jet and surface stability were improved by the presence of a shroud tube. However, gas release tended to inhibit reattachment of the jet to each stepped portion of the desorption tube. Alternatively the jet would preferentially attach itself to one side of the tube, similarly defeating the purpose of the steps. The only device capable of producing a uniformly attached stable jet was a set of turning vanes at the nozzle inlet. This encouraged gas release at the tube centreline, resulting in a more uniformly distributed voidage. The optimum turning angle was found to be about 30°; excessive circulation tended to pressurise the tube wall.

The rig illustrated in Figure 2 was used in a set of scaling tests. It was assumed that flow capacity was proportional to cross sectional area; thus the 1000 gph and 2500 gph units were respectively 1.4 and 2.2 times the diameter of the basic 500 gph system. Two units of each upgraded capacity were made, one based on constant geometry (length/diameter) and the other on constant length. The results are shown in Figure 3 for an initial DOC of 9 ppm, feed temperature of 12°C, vacuum of 38 torr, vane angle of 30° and a variable nozzle supply pressure. It soon became clear that increasing the total tube length much beyond the original 0.7 metres prejudiced system performance. The tube geometry shown in Figure 4 was established, with any change in flow capacity accomplished by a scaled enlargement of all internal diameters without any length change at all.

One limitation upon the foregoing system was the inability of the vacuum pump to handle a large vapour load. The rig was taken to the test laboratories of the APV Company Ltd., to establish the true performance limits on product DOC. Figure 5 shows both the test circuit and results. Due to the much greater vapour release rates possible the optimum vane angle was found to be nearer 50° than the 30° found for the BHRA tests, i.e. more swirl was required to keep the jet attached. The results were encouraging, with 0.2 ppm possible with very little heating and less than 0.03 ppm at maximum flash near 100°C. For each feed temperature the vacuum was adjusted to give the three conditions in incipient, active and maximum flash. The maximum was determined by the capacity of the surface condenser, indicating that further reductions in DOC would be within the reach of a system with a larger condenser.

DEGASSING OF SEAWATER

The first step in this programme was the upgrading of throughput to 10,000 gph (Ref. 3). A tube of the same longitudinal and twice the diametral dimensions as that shown in Figure 4 was constructed, along with a vacuum vessel as illustrated in Figure 6. The top plate was made with a single 76 mm hole for the vacuum offtake, whilst the bottom plate had a central hole for the degasser tube and an offset hole of similar diameter for product extraction. The four smaller holes at 460 pitch circle diameter were drilled for later tests with multiple 2500 gph tubes. Sealing was achieved by clamping the perspex cylinder between the two end plates by a ring of eight toggle clamps per end. No problems were found maintaining internal pressure under 40 torr. The system was run at a maximum supply pressure of 5.5 bar (80 psig) at a throughput of 15.2 litres/second (12,000 gph). Under these conditions the DOC was reduced from 9.0 to 0.4 ppm in a single pass with a 20°C freshwater feed and a 30° vane angle.

The laboratory tests with seawater were abandoned due to foaming and the first measurements made on site tests at Portland. Two meters were used to

monitor DOC: and E1L model 1500 (believed to be more accurate) and an SEA model OM2 (with a faster response). Both were calibrated against fully aerated water and a sodium sulphite solution. Without additive, foaming levels were sufficient to prevent satisfactory operation of the unit. The addition of as little as 0.1 ppm of NALFLOC was sufficient to both eliminate foaming and give the usual 0.4 ppm DOC output. The feed temperature for the foregoing tests was 12°C.

The tests with four and five tube clusters (Ref. 5) within the 10,000 gph vacuum vessel gave identical performance to that of the single tube. A 600 mm liner was fitted within the vessel to check the effect of flow cross section, with the result that product DOC was trebled. Considerable bubble carryover was observed from the liner into the extraction system, demonstrating the need for sufficient residence time to allow bubble disengagement. Further tests were conducted with the five tube cluster to investigate the possibility of using nitrogen to flush out residual oxygen. This was found to reduce outlet DOC by no more than 25% without depriming the pumping system. Typical operation of a tube within a cluster is illustrated in Figure 7.

Babcock Woodall-Duckham Ltd., have designed a degassing system around the 10,000 gph tube in a range of capacities from 50,000 gph (35,000 bbd) to 250,000 gph (165,000 bbd). Figure 8 illustrates the general arrangement for the 35,000 bbd unit, with an outer annular ring of five desorption tubes. The valves at the inlet to each tube allows tube removal without interruption of unit operation. The larger diameter of the 165,000 bbd vessel allowed a relatively shorter central section, so that the total vessel height could be kept constant at about 6 m over the entire capacity range. The "mushroom" shape allowed the use of torispherical ends, well recognised in the pressure vessel codes. Each tube can be observed in operation through the windows indicated in Figure 8. It is hoped that tube failure, if it occurs, can be detected from its bubble plume.

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6. Babcock Woodall-Duckham Ltd., 1981, "Degasser PC 6022", Drwg. No. 1/AD 13435, and 1981, "Degasser PE 6018", Drwg. No. 1/AD 13441.

ACKNOWLEDGEMENTS

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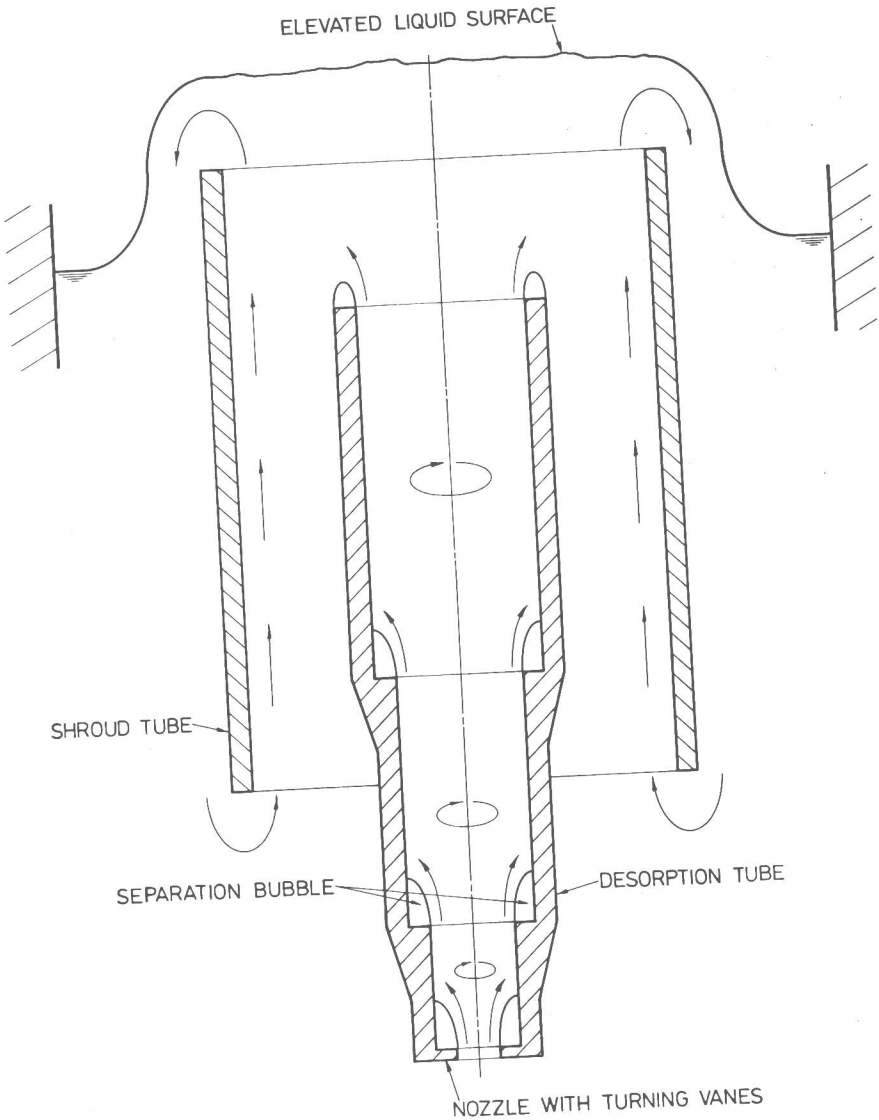


Figure 1: Principle of Operation

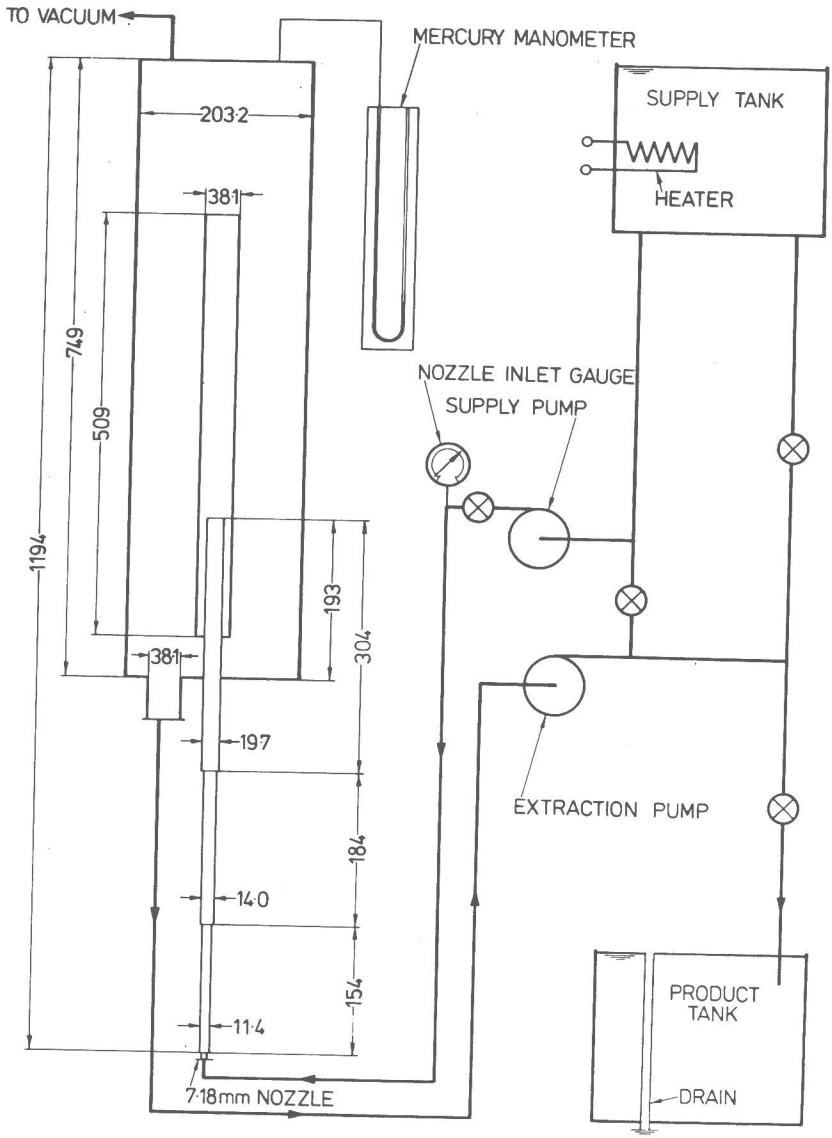
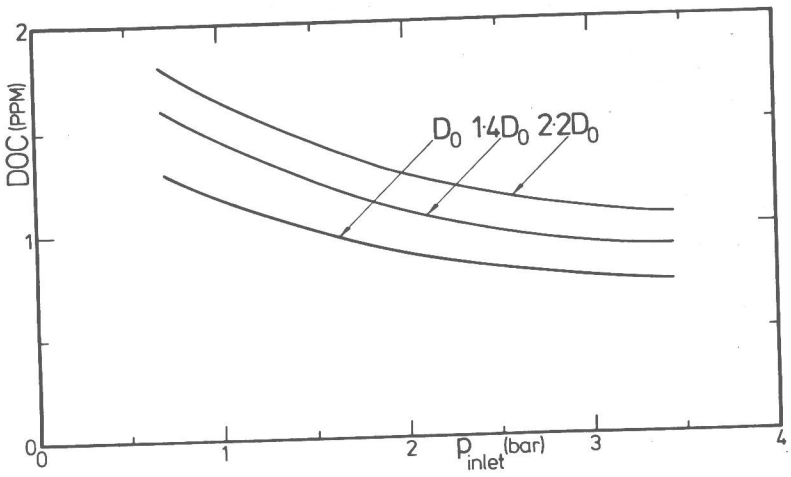
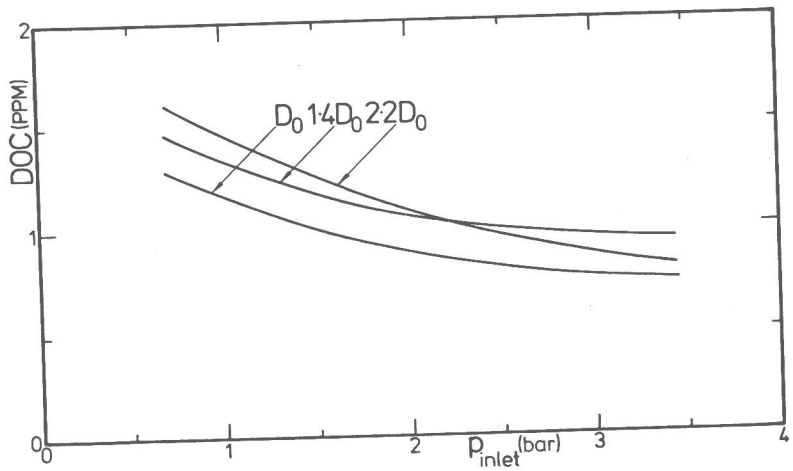


Figure 2: Initial 500 gph Scaling Test Rig

(mm dimensions)



(a) Constant geometry



(b) Constant length

Figure 3: Scaling Test Results

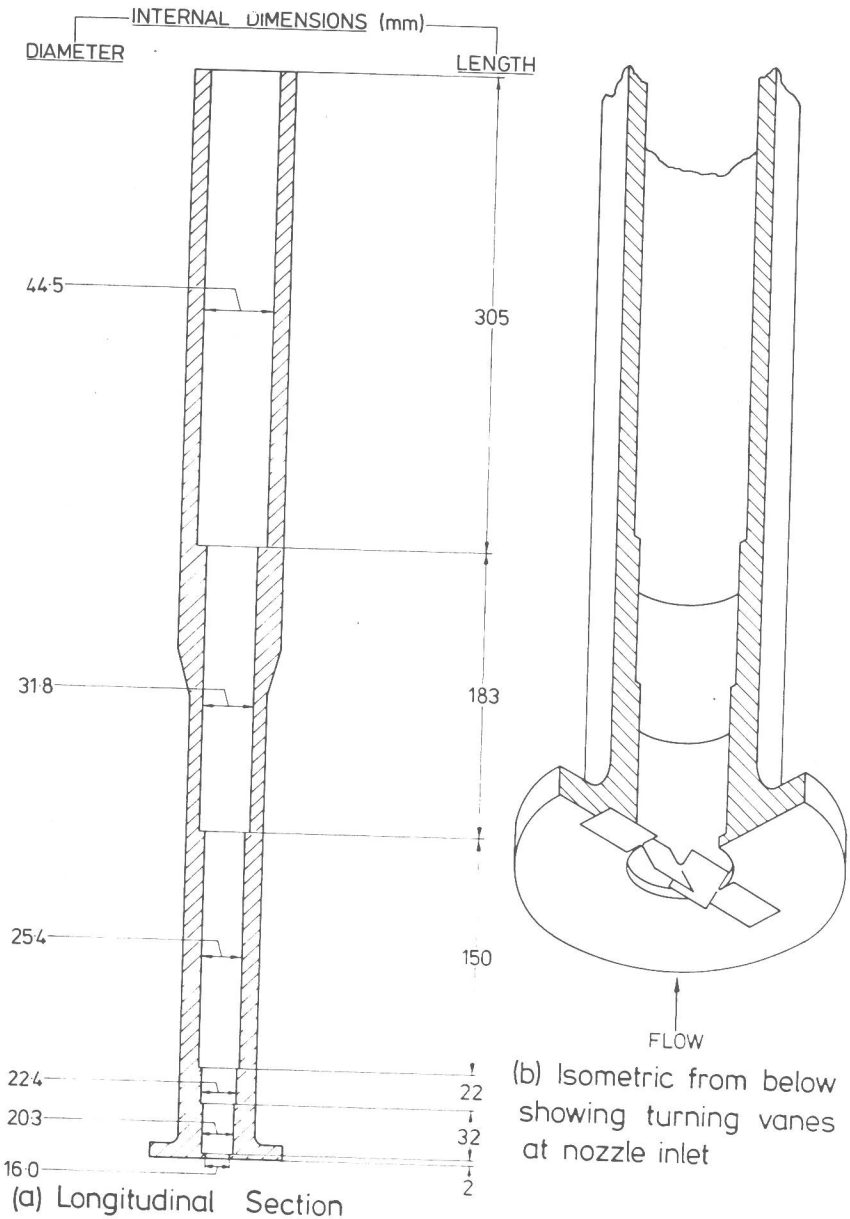
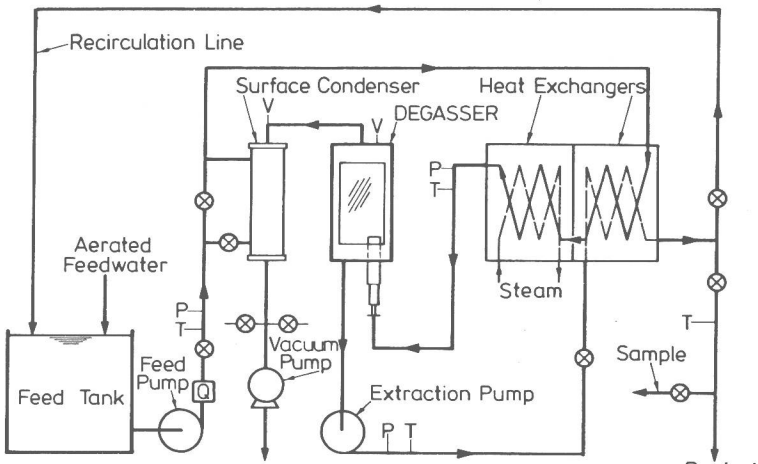
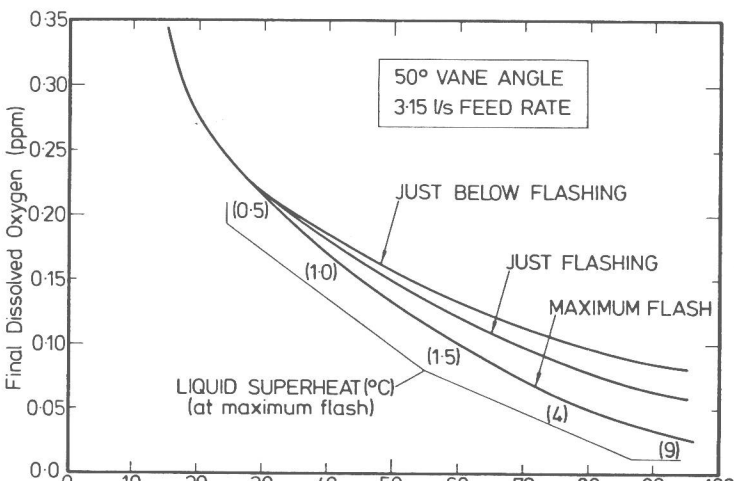


Figure 4: Current Design of 2500 gph Tube



(a) APV test circuit for 2500 gph degassing unit



(b) APV performance results (shroud tube removed)

Figure 5: Test Results with Downstream Condenser