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FIVE YEARS EXPERIENCE WITH THE FIRST DEEPWATER SALM

by Robert H. Gruy, William L. Kiely, Kris I. Pederson; Sofec, W.R. Wolfram; Exxon Production Research Co. and Richard D. Swan; Esso Production Malasia Inc.

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ABSTRACT

This paper describes the performance of the Tembungo Single Anchor Leg Mooring (SALM) tanker loading terminal during its first five years of operation. This facility, located in 300 ft (91 m) of water, 50 miles (93 km) offshore Sabah, East Malaysia, was the first SALM designed and constructed under commercial license agreement from Exxon Research and Engineering. The Tembungo SALM is one of the first "early production systems" and has been in continuous service since October 1974. It was designed to permanently moor a 94,000 DWT storage tanker in maximum wave heights of 39 ft (12 m), winds of 65 mph (29 m/s) and 2 kt (1 m/s) currents.[1]

The Tembungo SALM has performed very effectively since start-up. Operational efficiency rates of up to 98.6 percent on an annual basis have been achieved. A major factor in the high utilization of this terminal has been the absence of maintenance requirements on the SALM components. No maintenance has been required on the fluid swivel, chain swivel, universal joints or the anchor chain leg. Items such as pre-planning the annual inspection and maintenance program with the diving contractor and developing detailed procedures for tanker change-out and for hose and hawser replacement were also important contributors towards maximizing operational efficiency.

The primary and most important lesson vividly illustrated by the experience at Tembungo is that a simple, hawser-type SALM terminal can indeed provide very acceptable operational performance for permanent tanker mooring in offshore environments such as those encountered in East Malaysia.

INTRODUCTION

The decade of the 1970's found wide industry acceptance of the concept of employing a Single Point Mooring (SPM) as an integral part of an offshore production facility. In this application, the SPM, which provides direct offshore tanker loading, may allow a field to be brought on-stream at an earlier date than would be possible with a pipeline and it may allow the development of marginal fields which have insufficient recoverable reserves to justify a pipeline.

Use of an offshore loading terminal in conjunction with a floating or fixed production facility constitutes one version of what is popularly called an "early production system".[2,3] The Tembungo SALM, described herein, is a good example of such an early production application.

The SALM is located 7,000 ft (2,134 m) from a fixed platform and is connected to the platform via a single 10 in. (254 mm) pipeline. Oil and gas separation is performed on the platform and oil is loaded directly into the storage tanker. While the SALM was designed to permanently moor a storage tanker, which would be periodically offloaded by shuttle tankers moored alongside, it has only been used for shuttle service to date in an operation which employs two dedicated 50,000 DWT tankers which each load for periods of 30 - 60 days.[4] While one tanker is loading, the other tanker departs to discharge its cargo. In this service, with prolonged periods of berth occupancy, the two shuttle tankers effectively become temporary storage facilities. Since no fixed storage exists, this filling station type of operation requires periodic production shut-in while the loaded tanker departs SALM and the empty tanker comes on. These operational procedures have proven to be very effective for producing this particular field and should be equally as effective in the production of other fields of similar nature throughout the World.

This paper describes the system's operational performance since inception and the various methods which have been employed to minimize downtime due to weather, equipment failures and tanker changeouts, in order to satisfy the marginal field economics.

SYSTEM DESIGN CRITERIA

The Tembungo SALM has been designed to permanently moor a 94,000 DWT vessel in the 100-year design environment. This environment and other pertinent design criteria are presented in the following table:

Design Criteria for the Tembungo SALM

Water Depth	296 ft (90 m)
Tanker Size	94,000 DWT
Significant Wave Height	21.0 ft (6.4 m)
Maximum Wave Height	39.0 ft (11.9 m)
Maximum Wind Velocity	65 mi/hr (29.5 m/s)
Max. Current Velocity	2.0 kt (1.0 m/s) (perpendicular to waves)
Product Transfer Piping	10 in. (254 mm)
Max. Operating Pressure	200 psig (1.38 MPa)
Max. Surge Pressure	400 psig (2.76 MPa)

The governing parameters for the structural design of an SPM terminal are the prediction of the statistically most probable peak mooring force and, for hawser-type systems, the selection of the bow hawser. The breaking strength of the hawser assembly will dictate the required structural capacity of the entire mooring facility. Peak mooring forces for the Tembungo SALM facility were determined by means of an empirical technique which has been developed over the past fifteen years through a continuing series of model test programs conducted by Exxon Research and Engineering and Exxon Production Research Company. The procedures used have been discussed in the literature by Flory, Poranski[5] and Maddox.[6]

Based on the given environmental conditions, the following peak design forces were predicted:

Maximum Bow Hawser Load	840 kip (3,736 kN)
Maximum Anchor Leg (axial) Load	1,200 kip (5,338 kN)
Maximum Anchor Leg Deflection (with vertical)	37½°

SYSTEM COMPONENT DESCRIPTION[1,7]

The SALM mooring buoy is anchored through a single pretensioned anchor leg to a gravity type mooring base at the seafloor (Fig. 1). The system is designed to remain constantly in tension during all operational and maximum storm conditions. The entire system was designed to be installed in three operations; set and ballast the base, attach the riser, attach the buoy. This procedure allowed the use of a small and inexpensive offshore construction spread. To minimize diver time and underwater work, the universal joint attachments between riser and base (Fig. 5) and buoy and riser (Fig. 6) were designed to be hydraulically latched (or unlatched) from the surface.

Basic characteristics of the major SALM components:

Item	Description
Mooring Buoy (Fig. 2)	22 ft (6.7 m) dia. x 36 ft (11 m) high. Internally divided into 8 water-tight chambers
Riser Shaft (Fig. 3)	8.5 ft (2.6 m) dia. x 185 ft (56 m) long
Mooring Base (Fig. 4)	Gravity-type, self-floating design. In place weight 4600 kip (20,400 kN)
Anchor Leg Assembly (Fig. 6)	6 in. (152 mm) Gr.ORQ stud-link chain including permanently lubricated underwater ball bearing swivel and universal joint
Loading Hose System	10 in. (254 mm) hose string made up of four specially reinforced submarine hoses (from hose arm to surface #1,2,3 and 4), two surface floating hoses (#5 and 6) and one tanker rail hose. All hoses are 35 ft (11 m) long
Mooring Hawsers	Two 15 in. (370 mm) circumference nylon hawsers x 150 ft (46 m) long with 3 in. (76 mm) dia. chafing chain at buoy and tanker ends
Pipeline End Manifold (PLEM)	Gravity-type connected to SALM riser via two 10 in. (254 mm) i.d. x 35 ft (11 m) long hoses in series

OPERATIONAL EXPERIENCE

The Tembungo Field has produced continuously since October 1974 at average quarterly rates which have varied from 2,000 BOPD to 16,000 BOPD, with a total production through 1979 of approximately 13.5 million bbls. To date, the average overall operational efficiency. i.e. total days minus total downtime days divided by total days, has been 93%. Operational efficiency is categorized below on a yearly basis. The five year operating profile for the Tembungo SALM is shown graphically in Fig. 8.

1979: 14 days total system downtime which consisted of 4 days for tanker changeouts (11 tankers), 6 days for maintenance and 4 days waiting on weather for maintenance. (96.2 % efficiency)

1978: 5 days total system downtime which consisted of 4 days for tanker changeouts (12 tankers) and 1 day for maintenance. (98.6% efficiency)

1977: 32 days total system downtime which consisted of 6 days for tanker change-outs (13 tankers), 8 days for maintenance and 18 days waiting on weather (and/or equipment) to do maintenance. (91.2% efficiency)

1976: 45 days total system downtime which consisted of 1 day for tanker change-outs (4 tankers), 4 days for maintenance, 20 days waiting on weather to do maintenance and 20 days waiting on tankers to arrive.(87.7% efficiency)

1975: 26 days total system downtime which consisted of 2 days for tanker change-outs (4 tankers), 15 days for maintenance, 4 days waiting on tankers to arrive and 5 days with tanker standing by due to rough seas. (92.8% efficiency)

1974: Last quarter of 1974 (operation started October 14) 18 days total system downtime which consisted of 1 day for tanker changeouts (2 tankers), 4 days for maintenance and 13 days waiting for tankers to arrive. (77% efficiency)

Total downtime October 14, 1974 - December, 1979 was 140 days, which included 37 days "waiting for tanker to arrive". Actual overall efficiency (discounting early logistics problems) is then about 95%.

Downtime Summary

	Total Days	%
Tanker Changeouts	18	.95
Maintenance Activities	38	2.00
Waiting on Weather to do Maintenance	42	2.20
Waiting on Tankers*	42	2.20
	140	7.35%

*includes 5 days tanker standing by due to rough weather

OPERATIONAL HISTORY

A complete operational history of the SALM terminal from 1976 - 1979 is provided on a year by year basis in Tables 1 - 4. Performance records and details of inspections carried out are summarized below:

1979 (Table 1)

Fourteen (14) days total downtime (96.2% operational efficiency). The annual SALM inspection and maintenance program was conducted 13 August - 20 August during which time the following activities were performed:

1. Inspect seabed around SALM base for scouring.
2. Inspect seabed around PLEM for scouring.
3. Check PLEM-SALM hose configuration and hose body floats, quick connect couplings and bracelet anodes.
4. Inspect pins, hydraulic jacks and measure bushings for wear in base universal joints.
5. Check riser shaft from bottom to top for damage, anode deterioration and general coating condition.
6. Replace submarine hose string.
7. Conduct hydrostatic and rotation test of the fluid swivel.

As a result of a careful pre-planning, production was only shut-in for 13 hours while the new hose string was connected. With the exception of this downtime, the tanker was loading continuously from the SALM during the entire inspection and maintenance program.

The used hoses were not pressure tested but were visually inspected. Inspection showed that liners and covers were in good condition with only slight signs of fatigue and some wrinkling in covers, except the #5 hose which had sustained damage by chafing against the tanker's bulbous bow. The tanker rail hose was in good condition and was warehoused for re-use. Inspection results indicated no evidence of scouring around mooring base or PLEM. The base hose profile was correct and all 10 bead floats were still in position. It should be noted that the original base hoses are still in service through 1979. Bracelet anodes at ends of PLEM-SALM hose were approximately 30 to 50% consumed.

The base universal joint was in good condition with no evidence of wear on pins or bushings. The riser shaft was in good condition. Other maintenance during 1979 was routine and is given in Table 1.

1978 (Table 2)

Five (5) days total downtime (98.6% operational efficiency). The annual SALM inspection and maintenance program was carried out April 20 - 24, during which time the entire SALM was inspected by divers utilizing an underwater video camera. All SALM components were found to be in good condition and the only maintenance performed was replacement of the navigation lantern and batteries. Other maintenance performed during 1978 is outlined in Table 2.

1977 (Table 3)

Thirty-two (32) days total downtime (91.2% operational efficiency). The SALM was shut-in for 23 days for annual inspection and maintenance. During this time 9½ days were lost waiting on weather and 6 days were lost due to equipment breakdowns on the maintenance vessel. A major part of the weather and equipment downtime could have been avoided by proper pre-planning and the establishment of definitive maintenance procedures. The major task was the replacement of 42 cathodic protection anodes which had been consumed at a much faster rate than expected. Additionally, the buoy was sandblasted and coated above the water line and navigation lantern and battery pack were replaced. The loading hoses were replaced during this shut-down.

Inspection of the U-joints, anchor chain and chain swivel was not performed due to bad weather and excessive downtime replacing anodes.

Inspection of mooring base and PLEM showed no evidence of scour and PLEM-SALM hoses had a good profile. However, the CAMLOCK clamps, which connect the base hoses at PLEM and SALM riser piping, were badly deteriorated as an apparent result of cathodic action. Bracelet anodes were installed and these clamps are still in service through 1979.

Three days were lost during shut-down in February in an attempt to replace the #5 floating hose which was chafing against the tanker's bulbous bow. Replacement was prevented because of bad weather.

A total of six shut-down days were spent during tanker turnarounds during 1977.

1976 (Table 4)

Forty-five (45) days total downtime (87.7% operational efficiency). The annual maintenance and inspection survey was conducted June 28 - July 4, 1976. It is noted that the twenty days waiting on weather to do maintenance was incurred waiting to re-connect the submarine hoses which had been removed to conduct a fluid swivel rotational torque test. The test showed that hose kinking was not due to swivel torque but to the excessive length of the hose string. An important modification was made to the tankers, ESSO CHILE and ESSO CRISTOBAL, during the second and third quarters of 1976 to allow bow loading in lieu of mid-ship loading which had been employed since start-up in 1974.

Maintenance consisted of installing a new loading hose string, replacing mooring hawser assemblies and sandblasting and painting the mooring buoy above the water line. Additionally, the navigation lantern and batteries were replaced. A "Y" piece was installed on the hose arm to facilitate future hose replacements by allowing the old hose to be used as support while installing the new hose.

Inspection revealed the SALM to be in good condition. The mooring base and PLEM were level and evidenced no scouring. The riser shaft was sound and the buoyancy chamber was water-tight. The mooring buoy had lost two wing fender units but the shell plating was undamaged and the compartments were watertight. All three universal joints were securely seated and showed no wear. Both the chain swivel and the fluid swivel rotated freely with nominal pull during the turning tests. The PLEM-SALM hoses, riser to swivel spool and surface hoses did not leak during the hydrostatic pressure test.

Inspection revealed that the anodes had disintegrated more rapidly than anticipated, with those on the mooring base completely consumed, those on the riser shaft three-quarters consumed and those on the mooring buoy half consumed. Steel construction debris, especially wire rope, left on the bottom and uncoated ballast bars in the hose arm counterweight were suspected of contributing to the rapid anode consumption.

1975 (Table 4)

Twenty-six (26) days total SALM downtime (92.9% operational efficiency). The first annual maintenance and inspection was conducted from April 14 - April 24. Maintenance consisted of changing out the submarine and floating hoses and the buoyancy tanks. Two underbuoy hoses and all but one of the floating hoses were retained for future use.

No scour was evident around mooring base base and PLEM and the curvature of the PLEM-SALM hoses was smooth and uniform. All three universal joints were in good condition with no evidence of wear and the chain swivel was also in good condition. The anchor chain showed only very minor evidence of wear. The fluid swivel showed no leaks and the protective coating system on the swivel and hose arm was in good condition.

The mooring buoy fenders were in good condition. All chambers of the buoy were dry and its protective coating was in good condition.

EARLY OPERATING PROBLEMS/SOLUTIONS

Initially, there were certain operational problems which resulted in some system/production downtime. These initial operating problems were two-fold:

(1) The tanker had a tendency to ride-up on the buoy in calm weather causing kinking of the cargo hose directly off the hose arm.
(2) The chafing chain at the tanker fairlead experienced accelerated wear.

It should be noted that the SALM design avoids secondary problems caused by the tanker "kissing" the buoy, typical to other SPM designs, i.e. damage to cargo piping, turntable and swivels or entanglement of the tanker's bow with the radially extending anchor chains.

One of the tankers which initially used the SALM facility, the ESSO ORION, was able to keep her engines astern for long periods of time and prevent tanker override if the tanker movement was discovered in time. The tankers ESSO CHILE and ESSO CRISTOBAL, which were subsequenty used for most of the operating period covered by this paper, were unable to run their engines astern for extended periods without over-heating their condensers, which made it difficult for them to maintain the necessary hose tension in calm weather.

Remedial actions which were considered included:

1. Rotation of the hose system with line tied to the hose arm and pulled by the workboat "Beauregard". In addition to the workboat, this method required the services of the Exxon Marine Advisor and two divers. It was considered impractical to keep the men and equipment available on a 24 hour basis.

2. Periodic reversal of tanker engines to tension hawser and hose string. This required that movement of the tanker toward the buoy be detected in time to take remedial action. Unfortunately, a 24 hour watch is difficult to maintain in practice.

3. Keep a tug boat secured to the stern of the tanker to assure that it does not drift toward the buoy. This was not considered as a long term solution due to the expense involved.

4. Equip the tankers with stern thrusters. This solution was ruled out due to excessive costs.

5. Installation of 24 in. (610 mm) surplus marine hoses over 10 in. (254 mm) cargo hoses #1 and #2 to increase hose rigidity and protect from kinking.

6. Installation of a "backstop" on the hose arm to limit vertical excursion. This would provide a more effective moment arm and encourage swivel rotation.

7. Modification of the tankers to accept bow loading, thereby reducing the length of hose in the water.

8. Modify the tankers to run continuously astern.

In the end, consultation with the manufacturers of the ship's turbines revealed that a simple, inexpensive modification could be effected which would allow low speed (10 - 24 rpm) astern power to be maintained over an extended period. Basically, this modification involved the installation of a 5 in. (127 mm) line from the de-superheated (saturated) steam line, which powers the cargo pumps, to the steam inlet on the low pressure astern turbine.

The operating philosophy for engine reverse running was to run continuously at 10 rpm whenever windspeeds fell below 10 - 15 mph (4 - 7 m/s).

For the 50,000 DWT class tankers, ESSO CHILE and ESSO CRISTOBAL, this procedure resulted in incremental fuel (diesel) consumption of 3 long tons per full day of continuous astern running. Additionally, the tankers were modified to allow the cargo hose to come over the forecastle rail at a point about 20 ft (6 m) abaft the stem. These modifications included hard piping from the mid-ship manifold under the forecastle deck to a bow manifold, an A-frame for lifting the hose, a hose landing saddle and modification of the fairlead rollers. This modification reduced hose maintenance by helping to prevent kinking of the long hose string and by eliminating chafing against the ship's bow.

The use of astern power susbstantially eliminated operating problems at the Tembungo SALM, as evidenced by the average 5 year terminal efficiency of 95% and the last two years (1978 and 1979) of 98.6% and 96.2% respectively.

The problem with excessive chafing chain wear was greatly reduced by the application of power astern and frequent lubrication of the chain where it enters the tanker bow chock. The average frequency of chain replacement has been approximately every 3 - 4 months and is generally coincident with tanker change-outs.

COSTS

Of particular interest to potential operators of offshore loading systems are the overall costs involved. For the Tembungo SALM in 1980 dollars, typical costs are:

Complete SALM hardware and hose system for bow loading ex-works Singapore.	$4,000,000 U.S.
Transportation, Installation and Commissioning	$2,000,000 U.S.
Total Cost to provide SALM terminal, not including pipeline to production platform.	$6,000,000 U.S.
Convert tankers to allow continuous slow astern power	$10,000 U.S
Convert tankers to bow cargo loading	$15,000 U.S.
Incremental diesel fuel cost @ $1.00 per gallon assuming 80% astern running annually	$270,000/year
Maintenance Vessel and crew chargeable to SALM (annual)	$500,000/year*
Maintenace Costs (annual) including all routine maintenance, diving services and annual inspection survey	$250,000/year
Replacement costs of hoses, hawsers and chafing chain (average annual)	$80,000/year

*This represents 50% of annual vessel cost. This vessel also serves as supply boat for the production platform and as the mooring launch (line and hose handling launch) for the tankers.

The low maintenance costs and high efficiency of the system are partially attributable to the inherent features of the SALM design, which requires minimal maintenance and minimizes the exposure of critical components (hoses, chains, swivels, etc.) to adverse environmental effects. None of the major dynamic components, e.g. universal joints, chain swivel and fluid swivels, have required any maintenance to date.

CONCLUSIONS

This paper has described the actual five year operational history of a hawser type SALM storage tanker terminal located offshore East Malaysia.

Pertinent conclusions offered by this history are:

1. The importance of prudent tanker selection to match the tanker's performance characteristics to the application and to minimize the modifications necessary to provide safe, low maintenance operation.

2. The importance of pre-planning maintenance and inspection activities and of developing practical, offshore procedures for the replacement of hoses and hawsers.

3. The necessity of having capability to apply slow astern power for extended periods of time.

4. The inherent low maintenance features of the mooring system.

It is possible that the use of astern power could be minimized by employing either simple radar-type position sensing equipment or load measuring devices in the mooring hawsers. Feedback of this data would provide a warning that the tanker was approaching the buoy or that the mooring load had fallen below a predetermined minimum level. Astern power could then by engaged manually by the crew or automatically by the feedback signal.

It is important to re-emphasize that the vital components of the Tembungo SALM have required no maintenance of any significance since start-up in 1974. This total lack of maintenance requirements on SALM components may be attributed to the inherent advantages of the SALM system and to novel design features which completely eliminate the necessity for periodic lubrication of the fluid swivel, chain swivel and universal joints.

With a properly modified tanker and careful attention to planning and training functions, a competently designed hawser-type SALM mooring system can provide an efficient, low-cost offshore storage/loading facility.

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TABLE 1

1979 OPERATIONAL HISTORY

MONTH & DAY	VESSEL	% OF TIME ASTERN POWER USED	SALM DOWNTIME (DAYS)	COMMENT
Jan. 01-11	Esso Chile	82.0	0.33	Replace #1 submarine hose 18 Jan. and install one additional floating hose. Replace both tanker end chafe chain assemblies 25 Jan. with set of used 3" chains.
Jan. 12-31	Esso Cristobal	95.0		
Feb. 01-26	Esso Cristobal	98.0	0.46	
Feb. 27-28	Esso Chile	100.0		No Maintenance
Mar. 01-16	Esso Chile	91.0	0.54	No Maintenance
Mar. 17-31	Esso Cristobal	99.0		
Apr. 01-30	Esso Chile	99.4	0.20	No Maintenance
May 01-21	Esso Chile	97.0	0.80	
May 22-31	Ms. Esso Port Dickson	87.0		No Maintenance
June 01-03	Ms. Esso Port Dickson	62.0	0.25	
June 03-30	Esso Chile	98.8		No Maintenance
July 01-24	Esso Chile	99.0	0.30	
July 24-31	Ms. Esso Port Dickson	52.0		No Maintenance
Aug. 01-31	Ms. Esso Port Dickson	47.0	0.44	
Aug. 04-31	Esso Chile	97.5	0.54	Annual Inspection August 13 - 20
Sep. 01-29	Esso Chile	100.0	0.30	
Sep. 30	Ms. Esso Port Dickson	0.0		No Maintenance
Oct.)				
Nov.)	Data Not Available			
Dec.)			10.0	Replace #1 submarine hose. Weather very rough

TABLE 2

1978 OPERATING HISTORY

MONTH & DAY	VESSEL	% OF TIME ASTERN POWER USED	SALM DOWNTIME (DAYS)	COMMENT
Jan. 01-03	Esso Cristobal	100.0	0.75	Replace tanker rail hose 30 January
Jan. 04-29	Esso Panama	99.2		
Jan. 30-31	Esso Chile	81.3	0.80	
Feb. 01-25	Esso Chile	98.0	0.35	No Maintenance
Feb. 26-28	Esso Cristobal	100.0		
Mar. 01-21	Esso Cristobal	98.0	0.31	No Maintenance
Mar. 22-31	Esso Chile	95.0		
Apr. 01-18	Esso Chile	97.7	0.44	Install new mooring hawsers 4 - 3" chafe chain assemblies 18 April. Annual Inspection April 20-24.
Apr. 19-30	Esso Cristobal	100.0		
May 01-14	Esso Cristobal	98.5	0.34	No Maintenance
May 15-31	Esso Chile	100.0		
June 01-14	Esso Chile	95.8	0.43	No Maintenance
June 15-30	Esso Cristobal	100.0		
July 01-17	Esso Cristobal	98.0	0.42	Replace all submarine hoses on 3 July
July 18-31	Esso Chile	100.0		
Aug. 01-23	Esso Chile	99.0	0.20	No Maintenance
Aug. 24-31	Esso Cristobal	100.0		
Sep. 01-11	Esso Cristobal	93.0	0.21	No Maintenance
Sep. 12-30	Esso Chile	99.0		
Oct. 01-21	Esso Chile	86.0	0.40	No Maintenance
Oct. 22-31	Esso Cristobal	96.0		
Nov. 01-28	Esso Cristobal	85.0	0.30	Install one body float on cargo hose #5 and one body body float + one end float on cargo hose #6 during tanker change on 28 Nov. Very rough weather Nov. 1-28.
	Esso Chile	92.0		
Dec. 01-31	Esso Chile	90.0	0.00	Replace chafe chain on tanker end of one mooring assembly and chain support buoy 13 Dec.

T A B L E 3

1 9 7 7 O P E R A T I O N A L H I S T O R Y

MONTH & DAY	VESSEL	% OF TIME ASTERN POWER USED	SALM DOWNTIME (DAYS)	COMMENT
Jan. 01-04	Esso Chile	100.0	0.40	Install tanker rail hose to replace ordinary floating hose which had been used while awaiting delivery of rail hose
Jan. 04-31	Esso Cristobal	45.0		
Feb. 01-25	Esso Cristobal	22.0		Utility boat M/V Service accidentally cut #5 floating hose during tanker change 2/25. Esso Chile stood by 3 days while weather delayed replacement.
Feb. 26-28	Esso Chile Standing By		3.00	
Mar. 01-31	Esso Chile	89.0	0.25	#5 hose finally replaced 1 Mar.
Apr. 01-18	Esso Chile	100.0	0.60	Replace 12" Grommet-type hawsers with 15" single leg assemblies and replace 3" tanker end chafe chain with 2½" 19 April.
Apr. 19-30	Esso Cristobal	97.0		
May 01-18	Esso Cristobal	99.5	0.26	Replace #6 floating hose due to wrinkling/kinking at the point where it breaks water 19 May
	Esso Chile	96.0		
June 01-18	Esso Chile	98.0	0.90	Replace #6 floating hose due to wrinkling 19 June
June 19-30	Esso Cristobal	85.0		
July 01-21	Esso Cristobal	58.0	1.10	No Maintenance
July 22-31	Esso Chile	83.0		
Aug. 01-19	Esso Chile	88.5	13.00	Annual Inspection finally 19 August
Aug. 19-31	No Tanker on Station			
Sep. 01-10	No Tanker on Station		10.00	Annual Inspection finally completed 10 September
Sep. 11-30	Esso Cristobal	84.0		
Oct. 01-03	Esso Cristobal	86.8	0.60	Replace hawsers with new type of braided material on 4 Oct.
Oct. 04-25	Esso Chile	95.0	0.80	Replace #6 cargo hose 25 Oct.
Oct. 26-31	Esso Cristobal	87.5		
Nov. 01-18	Esso Cristobal	95.6	0.80	
Nov. 19-30	Esso Chile	100.0		No Maintenance
Dec. 01-11	Esso Chile	81.3	0.60	Replace #6 cargo hose 11 Dec. Modify hose profile to prevent overstressing #6 in future.
Dec. 12-31	Esso Cristobal	100.0		

TABLE 4

1976 OPERATIONS HISTORY

MONTH & DAY	VESSEL	% OF TIME ASTERN POWER USED	SALM DOWNTIME (DAYS)	COMMENT
Jan. 01-08	Waiting on Tanker		8.0	
Jan. 09-28			19.5	Waiting on weather to connect underbuoy hose.
Feb.)	Esso Cristobal		0.0	No Maintenance
)	on Station during			
Mar.)	this period		0.0	No Maintenance
Apr. 11-12	Waiting on Tanker		1.5	No Maintenance
May 01-31	Esso Panama	99.8	0.0	No Maintenance
June 18			0.1	Shut-in due to rough weather No Maintenance
July 01-04	No Tanker on Station		3.7	
July 04-31	Esso Cristobal	25.0	3.7	Annual Maintenance and Inspection completed 4 July
Aug. 01-31	Esso Cristobal	86.0	0.8	Replace #5 cargo hose due to chafing on tanker's bulbous bow 13 August
Sep. 01-26	Esso Cristobal	62.0		
Sep. 27-30	Waiting for Esso Chile to arrive		4.4	Install new 12" Grommet-type hawsers with 3" chafe chain to replace 2½" previously used.
Oct. 01-05	Waiting for Esso Chile to arrive		6.0	
Oct. 06-31	Esso Chile	96.3		Install spool piece at bow loading connection point.
Nov. 01-30	Esso Chile	63.0	0.0	
Dec. 01-31	Esso Chile	60.0	0.0	Inspection of hose profile

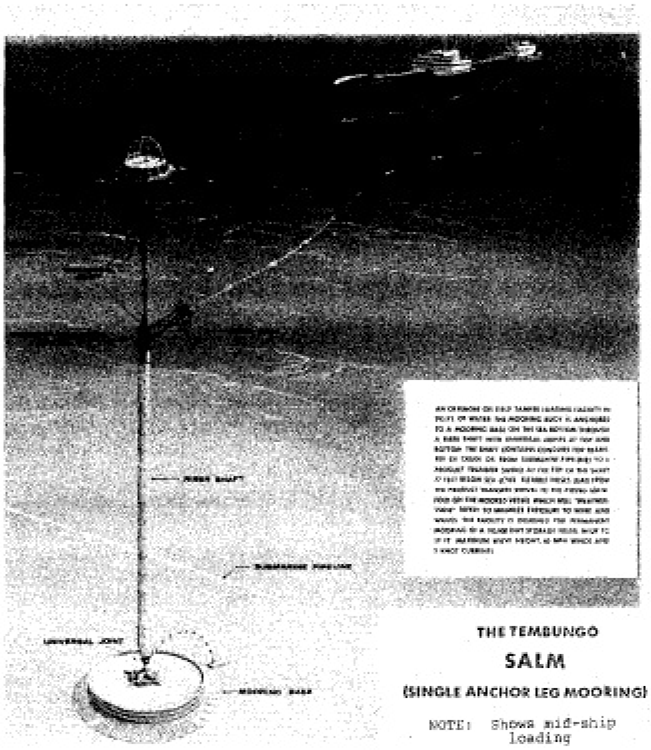

Fig. 1 - Salm perspective illustration including tanker, shows mid-shop only.

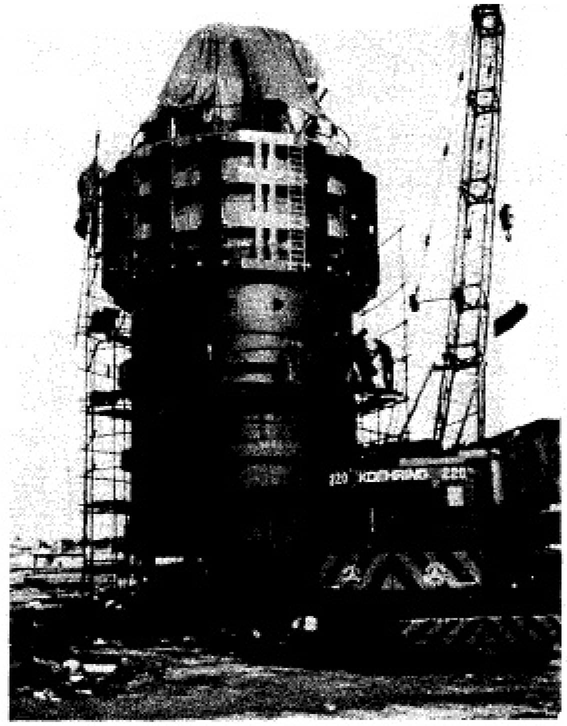

Fig. 2 - Photo - mooring buoy.

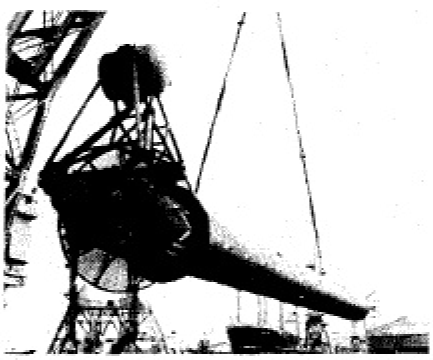

Fig. 3 - Photo - riser shaft.

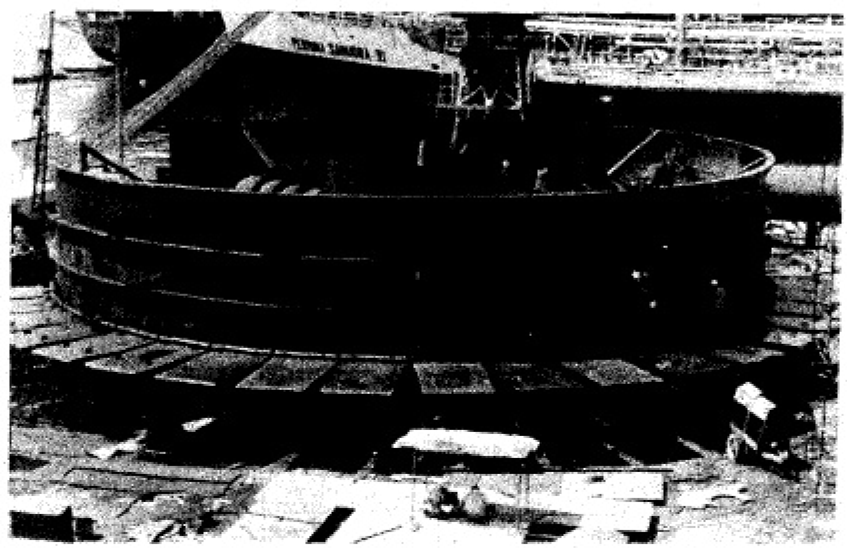

Fig. 4 - Photo - mooring base.

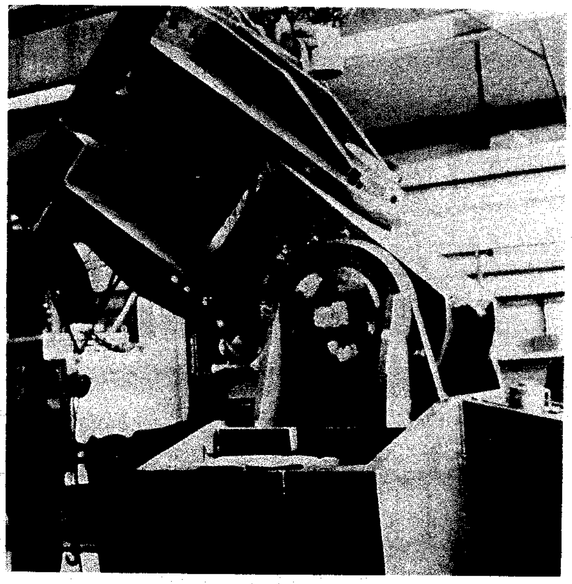

Fig. 5 - Photo - base u-joint.

Fig. 6 - Photo - riser u-joint and anchor leg assembly.

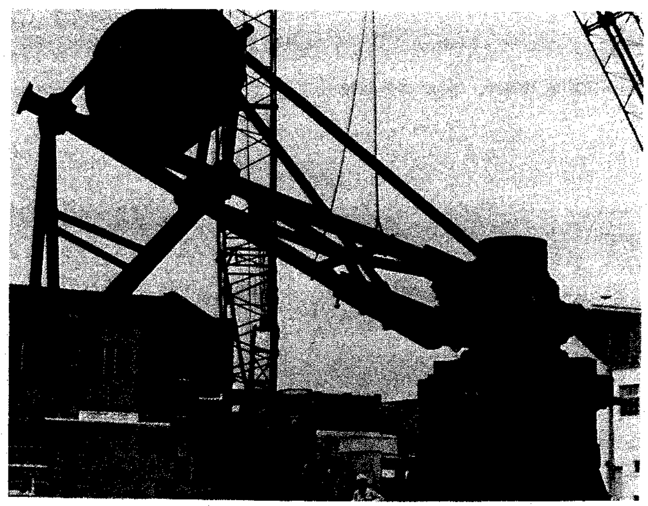

Fig. 7 - Photo - fluid swivel with hose arm.

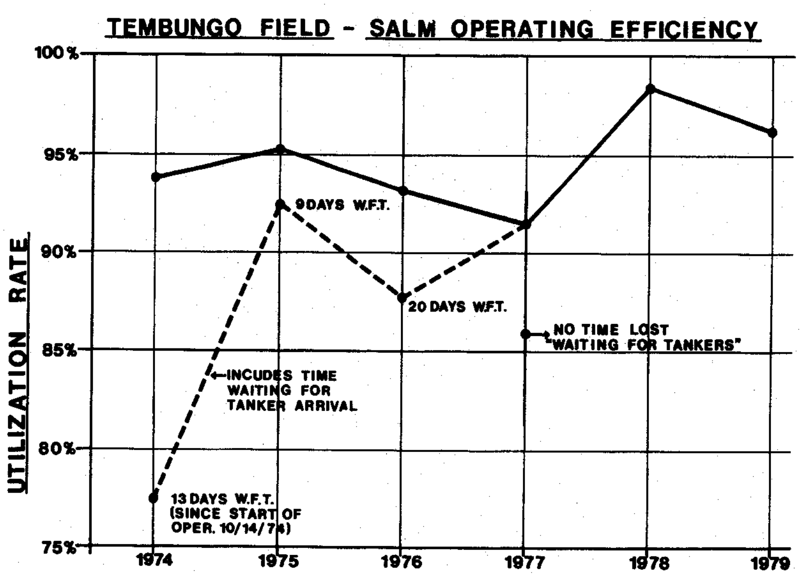

Fig. 8 - Salm operational efficiency.