APPENDIX F – Residual Contents of Maureen Storage Tanks

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F.1 Introduction

Throughout the operating life of Maureen, the three submerged steel tanks in the substructure provided local storage for the produced oil, pending its transfer to a tanker via the Oil Loading Pipeline and Column. During transfer operations the oil was pumped out from the top of the tanks and it was displaced by sea water entering via the bottom of the tanks. The crude oil/sea water interface inside the tanks therefore rose and fell according to the rate of production and frequency of off-loading.

Following Cessation of Production in October 1999, the final tanker load of market-quality crude oil was taken to the Immingham refinery. A further “slops” shipment (approximately 80% water and 20% oil) was subsequently taken ashore in December 1999 for treatment at the Petroplus facility at Milford Haven. During the offloading of the “slops” shipment the opportunity was taken to flush the storage tanks and the Oil Loading Pipeline with clean sea water.

Before refloat the storage tanks are mainly full of sea water, most of which will be displaced by nitrogen during the refloat operations (when it is pumped to a tanker), as described in section 7.4. There are also non-sea water components that are trapped or have settled out inside the tanks. These have accumulated over time and will remain there throughout the refloat and tow. (For safety, refloat integrity and avoidance of accidental pollution, tank entry will not be attempted prior to refloat.) These substances will therefore have to be dealt with when the tanks are opened for inspection and cleaning at the selected Deep Water Mooring location.

This Appendix summarises the Maureen Owners’ estimates of the quantities and materials other than sea water which might be contained within the Platform’s three storage tanks. These estimates, summarised below (2.8% to 5% of the total volume), are considered cautious.

Volumes	bbl	% of Total Volume
Total Volume of the Tanks (Ref. F.3, F.6.2)	645,385	100%
Volume of Oily Residues by Calculating Maximum Catchment Volume (Ref. F.6.1)	**33,500**	**5%**
Maximum Recorded Inventory of Oil in the Tanks (Ref. F.6.2)	627,000	97.2%
Volume of Oily Residues using "Maximum Recorded Inventory" (Ref. F.6.2)	**18,385**	**2.8%**

The estimates have been made in order to ensure that the regulatory authorities are advised and the relevant contractors are prepared for dealing with all such substances when the tanks are cleaned. All necessary procedures for treatment and disposal, and regulatory licensing will be in place before any tank cleaning work begins.

The estimates will also be used for the planning of waste management activities to ensure that adequate provisions are made, consented and costed before the work commences.

F.2 Overview

Sea water will be displaced from the tanks by nitrogen during the deballasting/refloat sequence and will be treated onshore as described in Section 7.4. During its transportation the floating platform will contain a small quantity of crude oil currently trapped in the top of each tank which will also be recovered (see subsection F.4) and oily residues. Previous surveys such as the DnV inventory survey undertaken in 1997 (the results of which are summarised in Section 5.1) have attempted, from reasonable assumptions, to estimate quantities of wax and other residual and oily substances (collectively known as "oily residues") which may be contained within the storage tanks.

The quantity and nature of these oily residues has here been considered in more detail because they are likely to contain small quantities of Naturally Occurring Radioactive Material (NORM)[1]. This natural material has very low activity by comparison with man-made radioactive sources but still requires regulated and licensed disposal. A sub-group of NORM is Low Specific Activity (LSA) material, which can precipitate when the formation water produced from an oil reservoir is mixed with sea water.

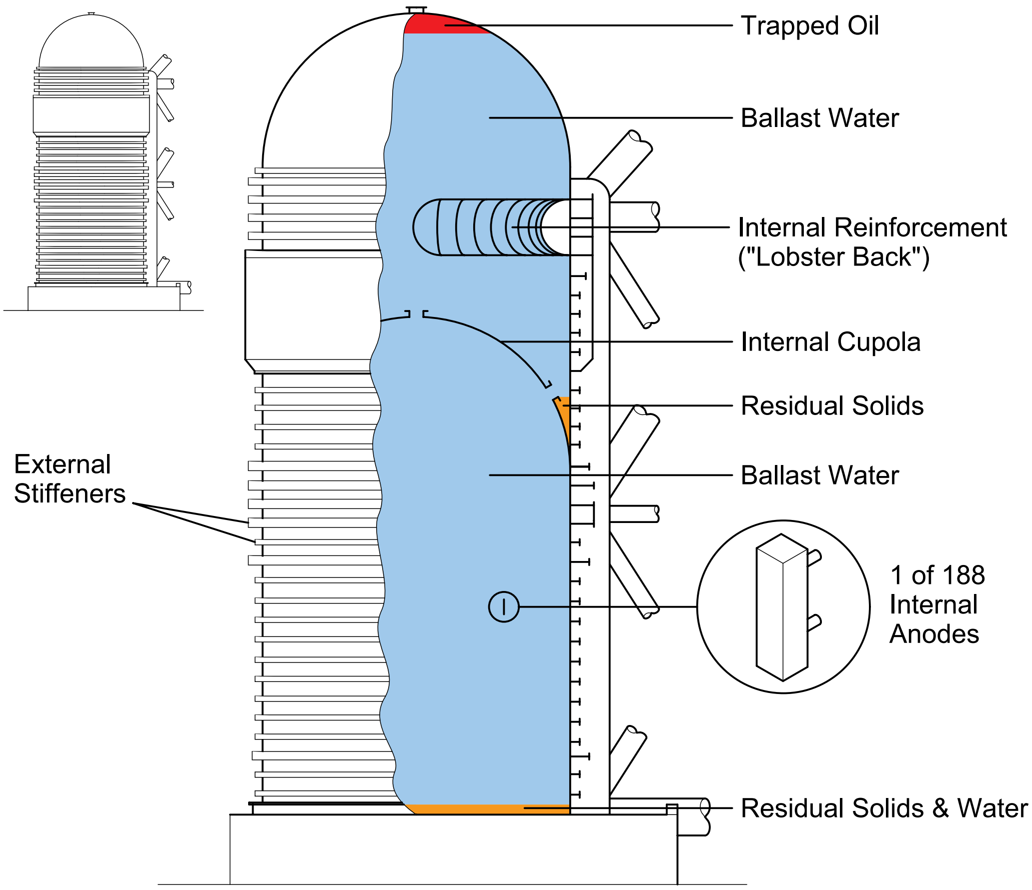
The estimates which follow for the potential maximum volumes of oily residues are based upon the known internal geometry, layout and dimensions of the Platform’s tanks and associated pipework. The assumptions used in the estimates of the potential accumulations are based on the characteristics of oily residues observed in crude oil storage tanks used elsewhere in the industry.

By design, fluids have entered and exited the storage tanks throughout their operational life by means of the 18” and 24” piping systems provided for this purpose. However, divers cannot safely be deployed to enter the submerged tanks through such systems to make inspections and/or take samples. There are no suitable remotely operated underwater vehicles available which are capable of the task because of the complexity of the piping systems and obstructions within them. As a consequence the Maureen Owners have chosen to base their estimates of the maximum volume of oily residues which could be contained within the tanks on known data and the dimensions of the tanks themselves. This has resulted in potential waste estimates that are likely to be significantly higher than those which actually will be found to be present when the tanks are unsealed, inspected and cleaned in the safety of the inshore mooring. Until that time, all the inspection hatches will remain sealed in order to maintain the established integrity of the tanks and safeguard their ability to generate the buoyancy needed for the refloat and decommissioning operations.

F.3 Tank Construction and Dimensions

The three storage tanks were built to the same general design and are of equal dimensions. As shown in Figure F-1 below, each comprises a tall cylindrical section with a flat base and a hemispherical top. The cylindrical section is 58.7 m high. The hemisphere and the cylinder have the same internal radius of 12.8 m. By adding the volume of the hemisphere to the volume of the cylinder the gross internal volume of each tank is calculated to be 34,610 m^3. The details of this calculation and all others that follow within this Appendix are found in Phillips internal report 0572/33/0567[2].

Figure F-1 Cut Away View of a Storage Tank Prior to Refloat



The majority of the structural stiffening is on the outside of the tanks, leaving the internal surfaces generally smooth. The only major structural features enclosed within the tanks are the internal cupola (which is not a barrier to the movement of fluids because of its open manways) and the "lobster back" internal bracing where the upper tank wall and substructure join together. Inside each tank there are 188 sacrificial anodes attached to the tank walls to minimise corrosion.

It is a relatively simple geometrical calculation to determine the amount by which the internal structures and fittings reduce the overall available storage space within each tank. The volume taken up is 412m^3 therefore the net useable volume of each tank is calculated to be 34,200 m^3 or 215,130 bbl.

Note: 1.0 m^3 = 6.2905 bbls.

F.4 Trapped Oil

During normal operations crude oil entered and exited each storage tank from the upper hemispherical section via an 18” diameter pipe which terminates approximately 1.5 m below the top of the tank. A pocket of oil is trapped at the top of each tank as a consequence.

Clean sea water was circulated through each tank to sweep as much oil as possible to the final “slops” tanker. However, fluid velocities are unlikely to have been sufficient to dislodge more than an estimated 0.2 m of the layer of oil trapped above the crude oil entry pipe, leaving a pocket about 1.3 m deep.

The estimated volume of oil trapped in each tank is calculated as 65.7 m^3 or 413.3 bbl. Hence the total volume of crude oil trapped in the three tanks is 197.1 m^3 or 1240 bbl, which corresponds to approximately 0.2% of the net storage capacity.

This trapped oil will be redistributed across the surface of the sea water in each tank as the water level is lowered and nitrogen introduced during the deballasting process. Once the tank top manways have been opened at the inshore mooring, the thin layer of oil will be accessible for recovery under controlled circumstances.

F.5 Nature of Oily Residues

Oily residues form within storage tanks as a result of chemical reactions and deposition. In general, these materials can be made up of some, or all of the following:

- waxes and asphaltenes
- the products of reactions between dissolved compounds in waters from different sources when they mix
- small sand or mineral particles from the reservoir which have been carried over in the flow stream from the oil process plant
- corrosion products flaking from the internal surfaces of the tanks or the pipes supplying them
- remains of marine organisms that enter with the sea water.

Whatever the source, particles of material will gravitate through the liquid column and will usually accumulate as relatively unconsolidated materials in areas of low flow and low slope. The term “oily residues” has been used to describe these accumulations. It is anticipated that these accumulations might also contain small quantities of NORM that have precipitated owing to a reaction between the produced water carried over into the tanks and the sea water ballast. However, only very low levels of produced water (<0.2%), if any, were carried over with the crude oil to the tanks, so the potential for significant quantities of NORM to precipitate out was small.

The oil produced from the reservoirs in the earliest phase of operations was water-free, but would have contained waxy components which could, whilst in storage, have deposited over the insides of the tank walls (which are at the temperature of the surrounding sea water). For the purposes of calculation, wax is presumed to have gravitated with any other particulate matter to potential catchment areas e.g. bottom of tanks, gutter around internal cupola, etc.

F.6 Estimated Quantities of Oily Residues

Estimates of the quantities of oily residues which might be contained within the sealed tanks were derived by two separate methods. In the first method, the geometrical configuration of the tanks was considered in order to assess where oily residues could have accumulated and the maximum extent to which they could have built up.

In the second method, the peak volume of stored oil measured during production operations has been subtracted from the calculated internal net volume of the tanks to generate a “Volume Unaccounted For” (VUF). This VUF represents the volume within the tank known not to have been occupied by oil. This volume must therefore have been occupied by a mixture of sea water and oily residues. The maximum would occur in the unlikely event that the entire volume was occupied by oily residues.

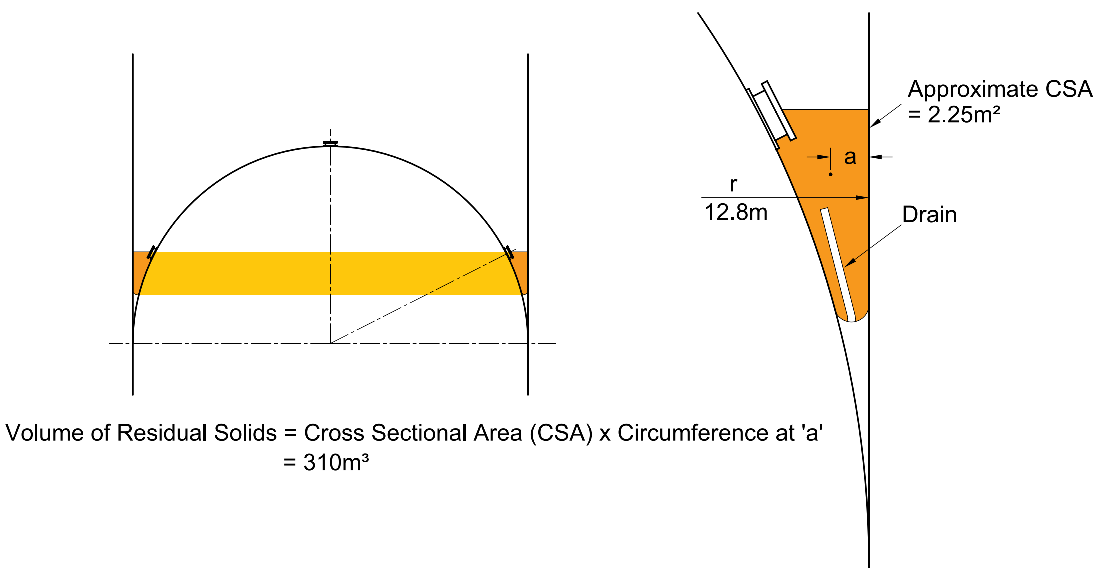
The second method – which uses measured rather than inferred data – generates the lower of the two estimates and it is this figure which has been further considered in estimating the waste content of the residues.

F.6.1 Potential Catchments for Oily Residues

Potential Catchment 1 – Gutter between the Upper Surface of the Internal Cupola and the Main Tank Walls

This potential catchment is shown (in cross section) in Figure F-2.

Figure F-2 Oily Residues Around Cupola



In order to generate a maximum theoretical estimate of potential volume of oily residues, it has been assumed that they have built up all the way to the level of the manways, as shown.

The volume of oily residue which is likely to be trapped in this section of each tank is calculated to be 173 m^3.

Potential Catchment 2 – Upper Surface of the Internal Cupola

It has also been assumed that the upper surface of the cupola is another potential catchment all the way down to the lower manways and that it has attracted and retained a layer of oily residue 250 mm thick. The volume of this layer is calculated to be 137 m^3.

Potential Catchment 3 – Bottom of the Tank

During production operations the regular monitoring programme of discharged ballast water quality did not identify any carry-over of oily residues. A detailed sampling programme undertaken in the last three months of operation during 1999 (Ref. M-Scan report 0572/33/503[3]) confirmed very low levels (<1 ppm) of hydrocarbons in the discharged water.

These two pieces of information imply that there can be no build-up of oily residues near the mouth of the ballast water outlet pipe in any of the tanks. However, in order to generate a 'worst case' estimate of oily residues in the bases of the tanks, it is assumed that materials could have built up at a significant gradient away from the mouth of the pipe to fill the bottom of the tank in the shape of an inverted, truncated cone.

The volume which, theoretically, could be trapped in the base of each tank under these assumptions would be 1465 m^3.

Maximum Possible Oily Residue Volume in all Catchments

Under the assumptions described above, the maximum possible volume of oily residue in each tank is 1775 m^3, i.e. a total, theoretical, potential for the three tanks of 5325 m^3 or 33,500 bbl.

F.6.2 'Volume Unaccounted For' from Peak Oil Inventory Measurement During Production Operations

On one occasion during the operational life of Maureen (Feb 1997), production had to be shut-in because the oil storage tanks had become full and bad weather was preventing a tanker mooring at the Oil Loading Column to off-load the cargo. They were known to be full because an oil emulsion started to be detected in the ballast water discharge treatment facility onboard after being displaced from the bottom of one of the tanks. The recorded inventory of crude oil in the tanks at that time was 627,000 bbl[4].

Given that the total available storage volume within the oil storage tanks is known to be 645,385 bbl this production information confirms that the maximum VUF which, theoretically, could be occupied by oily residues is (645,385 – 627,000) = 18,385 bbl or 2925 m^3. Note: In practice it is unrealistic to expect that oily residues would fill the entirety of the volume theoretically available.

The figure of 2925 m^3 of oily residues derived above from measured production data has, therefore, been carried forward as the basis for further assessment in the following sections of this Appendix.

F.7 Treatment of Oily Residues Recovered from Tanks

Once the Platform is safely moored inshore in Norway, the tanks will be unsealed, vented and internally inspected. The oily residues will only be removed by a specialist Contractor, working to strict procedures and using appropriate treatment plant and techniques. These residues will be subjected to controlled filtration and centrifugation to extract - as oily water - approximately 80% of the volume of the residues originally recovered. This oily water will contain no NORM and will therefore be subject to routine cleanup treatment.

The remaining 20% of the original residues will be in the form of a gel. The means by which this gel can be treated or disposed of depends principally on the extent to which it contains NORM.

The residues will be held within sealed containers. Once the radioactivity level of each container has been established it will be progressed for disposal. Several possible disposal routes for the oily residue have been identified in Norway. One, involving incineration and landfilling ash, has already been confirmed as acceptable. No repatriation of this residue is consequently required and will not require the involvement of the UK authorities. All necessary consents and authorisations for work carried out in Norway will be obtained.

F.8 Radioactivity Levels of Gel Residues

All of the oily residues recovered from the tanks will be reduced in volume by approximately 80% through controlled filtration and centrifugation. Hence the estimated maximum volume of oily residue which may be recovered (2925 m^3) will be reduced to no more than 585 m^3 of gel.

The density range of such gels has historically been found to be between 1.2 g/cc and 1.4 g/cc. In order, however, to generate a cautious estimate of the total weight of gel, a higher value of 1.5 g/cc has been used. Hence the weight of residual material to be dealt with should be no more than 880 te.

The form of the equation used to determine total activity is:

Total Activity = Weight of Material x [(6 x Ra_{226} activity) + (8 x Ac_{228} activity)]

The activity factors previously experienced in North Sea facilities are:

Ra_{226} activity = 3.5 beq/g

Ac_{228} activity = 1.7 beq/g.

Hence the cautious (High) estimate for the total activity level which may be contained within the three Maureen storage tanks is:

Total activity = 880 x 10^6 x [(6 x 3.5) + (8 x 1.7)] / 10^9 Gbeq = 30.4 Gbeq.

F.9 Notes and References

[1] NORM in the Oil and Gas Industries: National Radiological Protection Board Pamphlet

[2] Maureen Decommissioning Project – Estimate of Storage Tank Residues, Phillips Petroleum Company United Kingdom Limited, Document No. 0572/33/0567 Rev A.

[3] Analysis of Ballast Water Samples from the Maureen Platform July – September 1999: M-Scan Report 0572/33/503 Rev 1.

[4] Platform inventory records for February 1997.