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B 120 oil spill, April 27, 2003 at Buzzards Bay. Response to Dr. Joe Costa's interim analysis of our original report issued June 14, 2003

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Independent Maritime Consulting Ltd's response to the interim analysis of our report written by Dr. Joseph E. Costa, PhD, Executive Director, Buzzards Bay Project National Estuary Program dated February 3, 2004.

Preamble

I have prepared a response to Dr. Costa's analysis of Independent Maritime Consulting Ltd's report and estimate of oil spilled from the B 120 in Buzzards Bay on April 27, 2003.

Independent Maritime Consulting respectfully disagrees with the statement by Dr. Costa that there are "technical errors and confounding factors in our analysis".

Dr. Costa characterizes our report as saying that we "first identified potential flaws in the Caleb Brett analysis". This was certainly not our intention and we point out that on page 4 of our original report where we said:

"We do note that ITS/Caleb Brett is one of the largest and most active petroleum cargo inspection companies and that their inspectors and laboratory staff are experienced in measuring the quantity and quality of cargoes such as the one delivered to Mirant, Sandwich by the B 120 and B 10. For this reason we feel that the ITS/Caleb Brett cargo figure reports are an appropriate basis for arriving at the conclusions expressed in this report."

We also note that there are factual errors in Dr. Costa's analysis. Most of Dr. Costa's factual errata are relatively un-important however one of them could be significant. He says "The vessel was likely traveling at 10 knots when the accident occurred and was continued at the [sic] speed until approaching Buoy BB, 11.5 miles Buzzards Bay".

We must state that our report was in no manner commissioned to consider where the oil was spilt but we note that the B120 and its tug are most unlikely to be capable of sustaining 10 knots through the water. On page 3 of his report Dr. Costa provides a chart indicating that the B 120 covered 11.5 miles in 2.25 hours. Using the equation "Speed equals Distance divided by Time" it may be calculated that the B 120 made an average speed of 5.1 knots.

Factual errors in Dr. Costa's analysis such as saying that the barge loaded the second parcel of oil in Staten Island are relatively unimportant but there are also a number of interpretive and conceptual errors in Dr. Costa's analysis. It is understandable that such errors are made by someone who may not be familiar with the procedures involved in measuring quantities of oil. Independent Maritime Consulting Ltd. does not see any value in making a point by point rebuttal of Dr. Costa's very lengthy analysis of our first report however we have re-examined the issues which Dr. Costa clearly has the most difficulty in finding credible.

I also note that Dr. Costa contacted me on several occasions and tried to clarify points in the report with me. At the time I did not understand exactly what Dr. Costa's purpose was in contacting me and was cautious of discussing the original report with him. In retrospect it might have avoided the confusion, caused by his lengthy analysis of our essentially simple report, if I had taken the time to be responsive and assist him in understanding our original report. I will do my best to remedy the situation in this document.

I would also like to take the opportunity to state that, like any good citizen, I both appreciate and respect the Oceans and their shores. I own a sailing boat which I keep on the Chesapeake Bay. I would be very dismayed if a similar event occurred there. I have been involved with shipping and oil transportation all my working life. I understand perfectly that heavy fuel oil, or any petroleum or chemical, is very unpleasant when it gets into the environment. My advice has been requested in this matter because of my extensive knowledge of the measurement and handling of oil, in both routine and abnormal circumstances. Because there was a real degree of uncertainty as to what amount of oil was spilled, I have done my best to estimate the amount of oil spilled fairly and accurately. I have evaluated all the available information objectively and impartially. I have no interest in developing arguments for a smaller or larger number with respect to the amount of oil spilled.

Response to Dr. Costa's analysis

There were unusually difficult circumstances in measuring the oil at all stages of the B 120's voyage for the following reasons:

1) The B 120 loaded from shore tanks at the Coastal refinery Eagle Point, New Jersey that were being filled, from refinery production units, as the barge itself was being loaded from the same shore tanks. For this reason a shore tank to shore tank comparison to determine cargo loss is not an option.

2) Oil and water were transferred from 2 stbd. to 1 stbd. on the B 120 and then both oil and oil and water mixtures were transferred from these tanks to the B 10. These mixtures were originally formed when removing oil from the B 120's 2 stbd. tank to increase the water bottom in 2 stbd. and prevent continuing leakage of oil. They were further created when decanting water from the oil so that water would not be discharged to the utility at Mirant. The oil content of the mixtures is unknown but ITS/Caleb Brett at Mirant, measured a total of 3,535 bbls of oil and water mixtures. This 3,535 bbls was reported as being carried to Caddell's yard in Staten Island on the B 10 and being discharged there.

3) Measurements of the cargo in Buzzard's bay were made when the B 120 was not on an even keel. I cannot debate with Dr. Costa what the weather conditions were at the time the ITS/Caleb Brett measurements were made because I was not there however I was informed that it was not calm. The fact that the barge was not on

even keel did not help the reliability of the any of the measurements there. Even in open water conditions that appear calm, one can expect a barge to be moving to some degree. This will inevitably impact on measurement accuracy.

4) A cargo that is normally heated was unheated after the incident occurred.

It was not until Caddell announced that they had recovered large amounts of oil that it became apparent that the figure of 98,000 gallons given as the amount of the spill was erroneous. I am sure that a large quantity of oil was recovered at Caddell's ship yard. ITS/Caleb Brett, observed by me, made a good faith effort to measure and sample it. Dr. Costa also doubts that the samples taken at Caddell were representative. The samples taken of the oil were what are termed "running samples". This technique of sampling makes the best effort to sample the entire column of oil.

The quantity of oil found at Caddell may apparently have been overstated because to use it in a reconciliation does make the spill seem smaller than is indicated by other factual information.

Dr Costa makes it clear that he doubts that such a large quantity of oil was recovered. In order that he may at least consider it, I will not reiterate my original report, which I stand by in its entirety. I will simply explain why so much oil was found at Caddell's yard when much less oil was apparently found on board the two barges after they finished discharge at Mirant.

Facts that are well established and possibly acceptable to Dr. Costa

There were 3,514.62 bbls of oil measured on board the B 120 after it discharged at Mirant, as measured by ITS/Caleb Brett.

There were 263.31 bbls of oil measured on board the B10 after it discharged at Mirant, as measured by ITS/Caleb Brett.

This is a total quantity of 3,777.93 bbls of oil measured as cargo remaining on board.

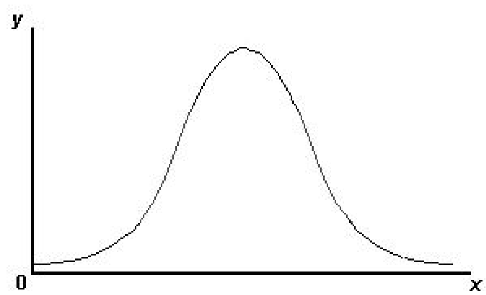
Obviously the ROB figure of 3,777.93 bbls of oil cannot account for the 6,478 bbls of oil found at Caddell.

Additional facts that must be considered to evaluate the accuracy of all measurements:

A spill figure of 98,000 gallons equates to 2.43% of the cargo carried. A spill figure of 55,000 gallons equates to 1.36% percent of the cargo carried. Cargo inspectors such as ITS/Caleb Brett might feel that they are doing well if there figures are within 0.3% for an uneventful movement of heavy fuel oil carried on a barge – shore tank to shore tank.

Due to the factors outlined in 1) through 4) on the previous page the degree of uncertainty in all the measurements, after the barge left Eagle Point, has been increased to a large degree.

Any spill figure must be therefore, by definition, an estimate, rather than a measurement. Perhaps Dr. Costa might agree that my estimate of 55,000 bbls spill lies within the middle of a "bell curve of reasonableness" in respect to all possible figures that can be derived as estimates of the spill, from the information available.



In the figure above the amount of the spill might be plotted on the X axis from zero on the left, to a number at point X on the right, of more than 100,000 gallons. The midpoint between 0 and X corresponds to an estimate of 55,000 bbls. The Y axis might be defined as a measure of probability that estimates of amounts spilled are accurate. We will consider for the purpose of illustration, that the higher on the Y axis the estimate is, the greater is the probability that it is accurate. On the left tail of the curve we have the supposition that the Caddell figures are very accurate and very little oil was spilled. Somewhere on the left slope of the curve the amount of the spill would be argued as the smaller amount as indicated by hydrostatic calculations. The right slope and tail of the curve is Dr. Costa's territory. As democracy and debate has shown us so often in the past, when there are two opposing points of view the correct answer lies somewhere in the middle or at the top of the bell curve above.

If Dr. Costa can appreciate there was a high probability that the amount of ROB measured on the B 120 and B 10 after discharging at Mirant was understated, then he might see that the amount of oil recovered at Caddell was certainly not such an unlikely amount. I will concede that it is regrettable that the oil recovered at Caddell could not be measured with a greater degree of certainty but then Caddell's business was to clean the B 120 for repairs, and also the B 10 so that it could be returned to service, rather than measure recovered oil.

Probable source of approximately 6,478 bbls of oil found at Caddell's facility after the B 120 and B 10 were cleaned

The amount of 6,478 bbls was measured by ITS/Caleb Brett at Caddell's over the period May 27 – May 28, 2003. The quantity is documented by appendices L through Q in my original report.

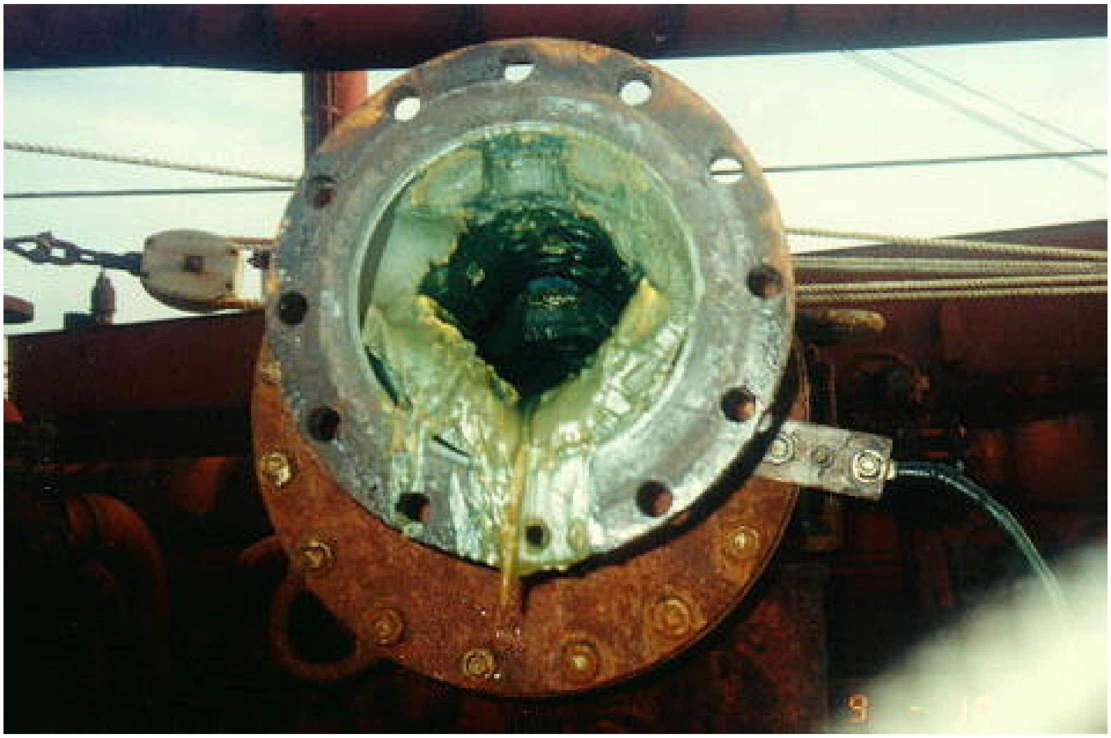
Rather than go over or justify the Caddell figures again I will explain why such an unexpectedly large amount of oil was found.

Oil+Water mix on the B 10 after leaving Mirant

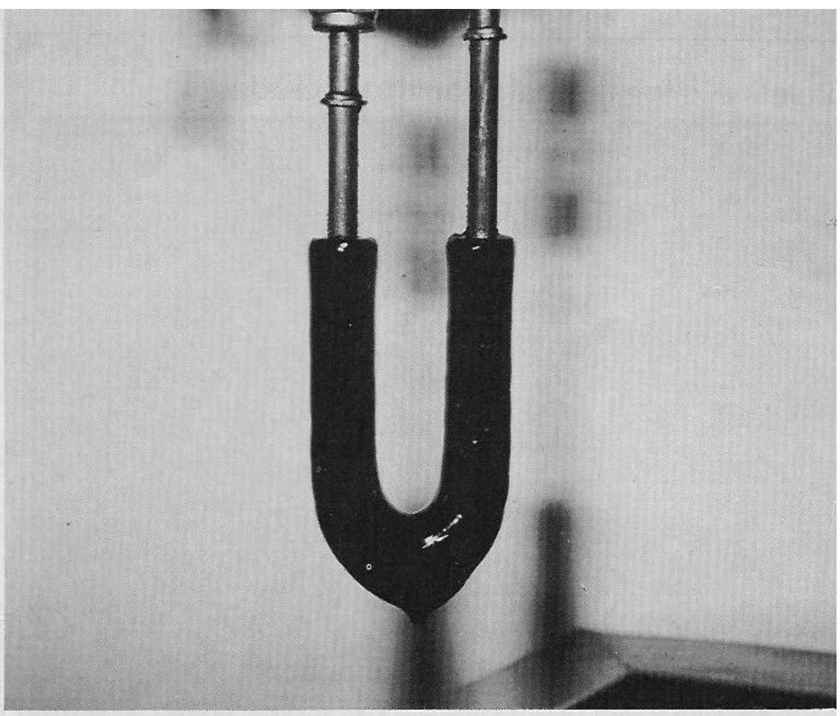
It should be noted that tanks 2 starboard and 1 starboard on the B 120 both contained water. 2 starboard as a result of the damage experienced and 1 starboard due to the fact that oil and water were pumped from 2 starboard to 1 starboard in order to increase the water bottom in 2 starboard and prevent leakage of oil. As much oily water as possible was then transferred to the B 10. Appendix K-2 in my original report, the ITS/Caleb Brett ROB report for the B 10, shows that there were 3,535.05 bbls of oil and water in 3 port and 5 starboard when she finished discharge at Mirant. The material was described on K-2 by ITS/Caleb Brett as "slops oil + water mix". I believe that ITS/Caleb Brett, if questioned, would probably confirm that the B 10 tanks holding the "slops oil + water mix" contained significant amounts of oil. A large proportion of the 3,535.05 bbls of oil/water may have been oil but unfortunately its oil content was never measured. We do not know if it was 75 percent water, 50 percent water, or 25 percent water. It was apparently not all oil so there must have been some other reason for there to be such a large amount of oil recovered at Caddell's. The cargo was unheated from the time of the incident when the thermal heating oil was lost from the B 120's cargo heating system due to damage sustained during the grounding. Because the cargo was not heated after the incident, large amounts of oil undoubtedly remained sticking to the internal structures of both the barges. ITS/Caleb Brett's measurements of ROB were of material remaining only on the bottom of the barge. They were unable to measure the clingage on the internal structure of the barges that was above the bottom of the tanks, and had been in contact with cooling heavy fuel oil. For this reason I will explain the concept of clingage.

Clingage "The residue that adheres to the inside surface of a container, such as a ship's tank or shore tank, after it has been emptied."

Measurement of cargo Remaining On Board (ROB) especially on ship's and barges carrying heavy fuel oil, or other heated cargoes, dramatically understates the amounts of cargo that really remains on board after discharge. I spent many hours, when working for Caleb Brett, and also running Quantum Marine, Inc., my own surveying company, explaining to clients the concept of clingage and why not all their heavy fuel oil cargo, or other heated cargo, had been delivered and why they were missing some of the cargo that they had paid for. Often the heavy fuel oil or other heated cargo was not delivered in its entirety, because there had been cargo heating problems on the ship or barge carrying the cargo.



The picture at top is not of heavy fuel oil but of a ship's discharge manifold that became blocked with VGO (vacuum gas oil). Like heavy fuel oil vacuum gas oil must be heated in order for it to flow. If it is not heated it sticks tenaciously to the structure containing it.

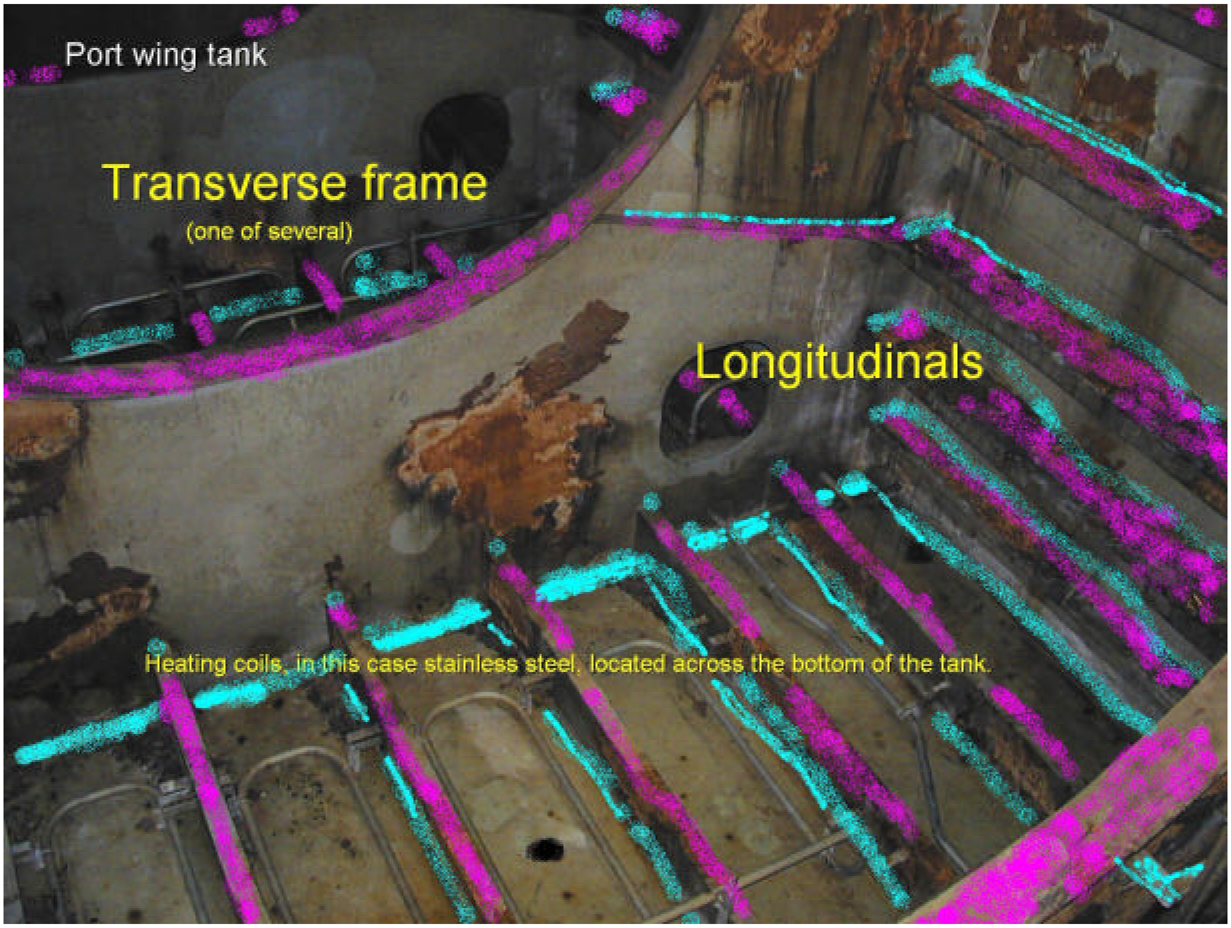


This photo illustrates the relative clingage test for Gamba crude oil (Fig. 2).

The photograph at left is crude oil clinging to a cooled pipe. A tendency to cling to cold surfaces is a well known property of some crude oils, waxy cargoes, and heavy residual fuel oil cargoes when they are not heated. I have appended the entire article of which the photograph was an illustration as the first attachment. The article is from the Oil and Gas Journal, November 1984

At left is an extreme example of clingage. The white material is paraffin wax that was heated but had splashed up into the tank hatch when the ship on which the photograph was taken had been pitching and rolling in rough weather.

Typical internal structure of a vessel's tanks. Cold heavy fuel oil can become trapped in wedges several inches, or even feet, deep behind the deep transverse frames. Similarly in the situation of an unserviceable or non-existent heating system it may sit on longitudinals in layers several inches deep. On the following page, in the same photograph, I have high lighted in light blue <u>examples of locations</u> where especially heavy accumulations of cold fuel oil may remain after all liquid cargo has been pumped out and cargo remaining on board (ROB) has been measured. It should also be understood that the cargo (ROB) measurement is often based on only one sounding of a tank as depicted above. <u>This is like trying to measure the height of all the trees in a forest by measuring the height of just one.</u>



In the picture above I have depicted a typical area that might be measured by the cargo inspector's ullage tape as a small black spot. (Analogous to measuring the height of one tree in the forest or taking one sounding in the sea to find out how deep a bay is!)

In magenta I have high lighted the many flat surfaces where additional oil can lay undetected.

At the conjunction of horizontal and vertical surfaces oil may remain adhering in wedge configurations, analogous to a snowdrift and like a snowdrift much deeper than the snow lying on adjacent flat terrain. I have highlighted these locations in light blue. In the photograph above only about 1/7 of the tank structure may be visible. Typically there are 4 or 5 of the deep transverse frames and dozens of longitudinals

Clingage of cargo on internal structures is one of the reasons for calculating the VEF (Vessel Experience Factor) as outlined in my previous report. The reason for the understatement of ROB with heavy fuel oil cargoes is their propensity to cling to structural surfaces when they become cold - even to vertical ones. The tanks of single hull ships and barges also have numerous longitudinal stiffeners, and several deep transverse frames, which tend to trap additional amounts of immeasurable cargo. This occurs to an even greater extent, when congealed oil blocks the limber or rat holes, when the cargo is draining towards the pump suction. The limber holes function both as a crack prevention feature in welded ship's structures and as drain holes that allow the petroleum cargo to flow towards the pump. ROB measurements taken by cargo inspectors measure the oil on only 1/5 or, if the vessel has been in rough weather with full tanks and a cargo that clings, 1/6 of the tank surface area that has been in contact with cargo. In addition, the measurement may only be meaningful if it can be made at a location that is unobstructed by internal structure. Further the ROB measurement is, usually on barges, based on taking just one measurement.

The construction of the tank of a single hull barge would be generally similar to that depicted in the photograph on pages 8 & 9.

It is also very significant that the oil was delivered to Mirant at temperatures well below its normal carriage temperatures. As explained, the heating system on the B 120 had been put out of commission by the grounding and the B 10 was an unheated barge. When the B 120 left Eagle Point the temperatures in the cargo tanks ranged from 136.2 to 142.0 F. At Mirant on the B 120 they ranged from 93.6 to 122.8 F and on the B 10 the temperatures were even lower. The temperatures on both barges adjacent to the water cooled shell plating were undoubtedly very low - perhaps as low as the sea water temperature itself or certainly below 50 F. The clingage (coating of oil) on the internal structures of both barges was greatly increased over that normally experienced if the cargo had continued to be properly heated. The B 10 had on board large quantities of cold water in 3 port and 5 stbd. mixed with oil. The oil in the mixture would cling and stick to 3 port and 5 stbd. On the B 120 number 2 starboard tank and possibly 1 starboard tank would certainly have had much larger quantities of oil clinging to their structures, than in the other tanks. This was due to the prolonged contact with cold water.

Calculating clingage

We will assume now that B 120 and B 10 are on hypothetical first voyages out of the ship yard and all their internal steel structures are clean. After discharging their first cargoes of heated fuel oil, that happens to have the consistency of Jell-O when its temperature falls below 95 degrees F, the cargo owner complains (and typically does) that all the oil he bought was not delivered. To explain the loss in these circumstances a clingage calculation is made as below.

B 120

The volume of the heated oil on the B 120 was approximately 100,000 bbls. It was carried in 10 tanks.

This is an average volume of 10,000 bbls per tank.

The wetted surface area of a square tank containing a liquid can be calculated by, the cube root of the volume contained, raised to the power 2, multiplied by 5. (We will assume that the under deck surface is not wetted however it may well be wetted due to the effect of oil sloshing around in the tank when a vessel is moving around in rough seas (see photograph at foot of page 6)

There are 5.6146 cubic feet per bbl so 10,000 bbls equals 56,146 cubic feet. The cube root of 56,146 raised to the power 2 multiplied by 5 gives a figure for wetted surface area of 7,331.3 square feet. There were ten tanks on the B 120 so the total wetted surface area was 73,313 square feet.

As previously explained, and can be seen in the photograph on page 7, the tanks in a single hull vessel are not smooth sided. There is extensive longitudinal stiffening and transverse framing that provides strength and stiffness to the structure of the barge. This structure probably adds about 15 percent to the total wetted surface area in each tank. It is probable that the total structural surface area in contact with cargo in the tanks on the B 120 was in the region of 84,310 square feet.

One ½ of an inch as a decimal of a foot is 0.041667. If we multiply this by 84,310 we have a coating of oil equivalent to 626 bbls. (The factor for cubic feet per bbls is 5.6146). A portion of this amount should be attributed to the ROB as measured on the tank bottom by a cargo inspector such as Caleb Brett. For this reason we will use 4/5 of 626 bbls or 500 bbls as the probable unmeasured clingage on the B 120 on her first trip out of dry-dock.

If ½ of one inch seems to be an excessive average look again at all the places in the photograph on page 9 (where oil might become trapped in depths much greater than ½ an inch).

B 10

With respect to the B 10, which is a smaller barge, the ratio of wetted surface to volume contained is higher so there will be more wetted surface area for any volume of cargo carried in her tanks and therefore more clingage for a smaller volume of cargo carried. Sometimes small unheated barges such as the B 10 are in fact used to carry hot fuel oil but only on very short trips during which the oil does not have time to cool significantly.

The volume of cargo carried to Mirant on the B 10 was 6, 966 bbls (GOV or volume at temperature). Performing similar calculations for the B 10 as for the B 120 gives, with the amount of cargo that was carried to Mirant, a clingage figure of 78 bbls for the 4 tanks. 4/5 of 78 is 62

The amount of oil lost on the first hypothetical trips out of dry dock, attributable to a uniform layer of clingage, on both barges, therefore is the sum of 500 and 62 for a total of 562 bbls.

It must be stated that a clingage calculation as performed above, for a first voyage after dry-dock or in dirty service, does not take account of additional amounts of clingage that may accumulate from cargoes carried on subsequent voyages. The clingage may accumulate to a greater extent if the barge carries subsequently heavier and more viscous cargoes in seasonal conditions that are becoming progressively colder. Conversely the amount of clingage may reduce if a barge or ship carries a light crude oil after carrying a fuel cargo. As a cargo loss control specialist I use to observe this as a larger than anticipated quantity being delivered in the shore tanks when a barge or ship discharged crude or condensate cargo after having been in fuel oil service.

The cargo on the B 120 and B 10 was required to be heated. It was not heated after the grounding and was in prolonged contact with unheated, water cooled steel tanks. I feel certain that there were far larger amounts of clingage than amounted to a uniform ½ inch. The amount of oil clinging to internal structure could have been greater, by a factor of 3 to 5 times, than the amount outlined in the clingage calculations above.

Clingage is not the only cause of immeasurable oil remaining on board. On both barges, due to the low temperature of the oil and lack of cargo heating, there would also be an immeasurable but significant amount of additional oil trapped, in non uniform but approximately wedge shaped volumes, forward of transverse frames and laying on longitudinal stiffeners, due to blocked or constricted limber holes. (As explained by and depicted in the illustration on page 9) There would also be more oil than usual remaining in the pipelines and pumps of both barges due to lack of heating on the barges. The total amount of oil, additional to the measured ROB, from these causes cannot be known with certainty. However, there would definitely be large amounts of oil trapped in or laying on the locations, as depicted in magenta and light blue in the photograph on page 9 in addition to any uniform layer of clingage caused by the lack of cargo heating.

The concept of clingage with respect to oil cargoes is further documented in the second attachment (actually titled attachment 4 – because it was originally an attachment to another party's report) which is an account of the grounding of a large tanker in South America. The fact of 2000 tons of clingage is mentioned at the end of the paragraph on the second page.

My estimations as to the amount of probable clingage are based on many years of experience, sailing on ship's carrying heavy fuel oil, cleaning ship's tanks and more years of measuring similar oil on barges and ships as a surveyor. This included situations where the cargo heating systems had failed either in part or completely. I have climbed inside cargo tanks that are dirty from heavy fuel oil and seen the volumes of residues outlined in the calculations above with my own eyes.

On one particular ship on which I sailed as chief officer, there were problems with the cargo heating system when carrying residual fuel oil. Because of the heating difficulties we had solid oil more than a foot deep remaining in each cargo tank. I remember it especially well as my job was to clean the tanks ready to carry jet fuel on the next voyage. I climbed in and out of the tanks on that ship that were dirty, to lash portable tank cleaning machines in place and wash out the residues with very hot water, more often than I would have liked. My recollection is that cargo owners claimed for the loss of some 500 tons with respect to a 30,000 ton cargo or 1.7% of the amount of the cargo. My recollection is that this was approximately equivalent to the amount of oil that we recovered in our slop tanks.

I believe it is entirely probable that the immeasurable amount of ROB, on the B 120 and B 10 as clingage and oil that was prevented from draining to the pumps, due to it being unheated, and the fact that the barges were afloat in cold seawater, was probably more than 2,000 bbls

Summary of figures explaining why so much oil was found at Caddell's yard

Actual ROB on both barges can account for an amount of oil of:	3,778 bbls
Refer to pages 5 through 12 - clingage can account for more than:	2,000 bbls

In addition we know that there was a large amount of oil water mix on the B 10. As per the ITS/Caleb Brett report for the B 10 on completion of discharge at Mirant there were 3535.05 bbls of oil and water in 3 port and 5 starboard when she finished discharge at Mirant.

If 20 percent of the 3535 bbls of "slops oil + water mix" described by ITS/Caleb Brett was oil:	707 bbls
Total	6,485 bbls
Found at Caddell's	6,477 bbls

I stress that the above is not a new reconciliation or an attempt to make another estimate of the spill but an illustration of why there are entirely plausible reasons why so much oil was found at Caddell's. It is also pointed out that the clingage that was washed out of the B 120 at Caddell included cumulative clingage from previous voyages. She was already dirty with clingage when she loaded the cargo at Hess, Delair and Coastal Eagle point on the Delaware River that was involved in the spill.

Obviously the figures are empirical. The clingage may have been more and the proportion of oil in the oil water mix may have been less – or vice versa. It is acknowledged that there are uncertainties with respect to the Caddell figures because it was not the custom there to carefully measure recovered oil. For this reason I do not propose to promote a very low figure that might be argued by the Caddell figures but to stay with my estimate of 55,000 gallons that I feel lays at the center of a bell curve of reasonable probability when all possible ways of calculating the spill amount are considered.

Hydrostatic calculation

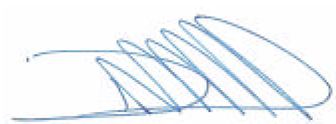
As a Master Mariner who has spent a lot of time learning about ship stability and operating ships so that they do not break in half or capsize, and spill oil, I do not see how Dr. Costa's criticism of my hydrostatic calculation is warranted. The calculation was never intended to be precise and I erred towards an overestimate as to what might have been spilled due to hydrostatic forces. Because I did not have drawings or vessel particulars to hand I did a simple and practical calculation of what might have been released. I ignored the principle of bilging by which a ship or barge will tend to sink lower in the water when a tank is holed, thereby decreasing the static head and the tendency for oil to flow out. I also did not consider the permeability of the cargo which is the space it takes up in the tank or hold which has been damaged. Simply put an empty tank or hold is 100 percent permeable and will immediately flood with seawater when the bottom is holed. One tightly packed full of closely stowed cargo in watertight containers would have a low permeability of perhaps only 10 or 20 percent and will fill slowly. The permeability of heated fuel oil coming into contact with cold seawater is uncertain because it depends on the chemical components of the oil. If the oil contains a lot of paraffin wax it may have properties that cause it to be almost self sealing when contacted by cold sea water. (See photographs on pages 6 & 7). In addition, if the cargo is highly viscous at low temperatures then it may also have self sealing properties when in contact with cold sea water. In these circumstances the permeability of a tank containing residual fuel oil may be quite low and the oil will escape slowly.

In addition, I ignored in my calculation that the density of the heated oil is actually lighter than the density of the oil which also decreases the effective static head. Arguably the amount of oil released due to the effect of static head was less than that calculated in my first report.

Additionally I doubt that the turbulence caused by the vessel moving through the water had much effect in pulling cargo out of the damaged tank especially as the barge was moving slower than Dr. Costa had thought. The forces of turbulence are governed by Bernoulli's equations and the turbulence along the underside of the B 120 would be much less at 5 knots than the 10 knots that Dr. Costa supposed the barge was making.

Sadly, as Dr. Costa has doubtless seen from looking at the material that was spilled, it was very sticky and viscous. Generally it was reluctant to leave any surface with which it was in contact. I believe that much more of it remained on the barges, adhering to the internal structure, than was measured by ITS/Caleb as cargo remaining on board (ROB).

Independent Maritime Consulting Ltd.



March 16, 2004

Reducing tanker loss of heated crude-oil cargoes

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Several years ago, Getty Refining & Marketing Co. (GRMC), a wholly owned subsidiary of Getty Oil Co., decided to give more attention to crude oil and light product losses. To control these losses, GRMC initiated an inventory and loss-control program.

The overall objective of the program is to develop, implement, and monitor cost-effective controls covering quality, inventory, and loss. The main focus of the program is on two areas:

1. Identifying excessive crude oil or light-product losses, quantifying them, determining the reasons for the losses, and devising methods to minimize them.

2. Developing and implementing systems which will alert management in a timely manner to potentially serious inventory and loss problems.

This article will explore a major part of the program: minimizing the losses of heated crude-oil cargoes on tankers and decreasing the fuel consumed to heat these cargoes during transport.

Defining the reasons for crude-oil losses on tanker shipments and developing long-term solutions often require extensive analyses. This is due to the number of causes affecting cargo losses and the number of factors which influence the control of cargo losses. Causes of cargo losses include:

- Incorrect ship gaugings
- Errors in a ship's volume-calculation tables
- Inaccurate temperature measurements for use in volume corrections
- Improper or inadequate cargo sampling
- Inaccurate testing of the sediment and water content of the samples
- Incorrect determination of the free water in the cargo tanks
- Cargo remaining in ship's lines after discharge
- Cargo clingage remaining on board a ship after discharge
- Evaporation of cargo during loading, transport, and discharge.

Over the past few years, a number of papers have been written which covered different aspects of the causes of crude oil losses. These articles have resulted in significantly increased knowledge in the loss control field and have led to considerable cost savings.

This article discusses the specific area of determining the most cost-efficient way to transport a heated crude-oil cargo. It provides an overview of the program that GRMC uses in controlling losses and minimizing the overall costs of shipping heated crude-oil cargoes, and briefly outlines the research methods used to evaluate the handling characteristics of crude-oil cargoes. Our plans are to describe these research methods in more detail and to discuss the progress in the implementation of this program in future articles. It is hoped that this work will provide additional insight into the problem of crude oil cargo losses

*At the time this article was written, the authors were employed by Getty Oil Co. subsidiaries.

and encourage further study in this area.

One of the most important factors affecting the transportation of heated crude-oil cargoes is the nature of the oil being transported. The characteristics of each crude oil influence cargo handling, cargo losses, and the overall costs of transportation.

In a recent series of articles, the Oil & Gas Journal published lists of export crude oils and their characteristics. Many of those listed were of the low gravity, high pour point, or high viscosity variety. Since many refineries have upgraded their facilities to process them, these crude oils now represent a larger share of imports than in the past.

Because of their characteristics, these crude oils often require special handling during a marine voyage, and many must be heated in transit and/or during discharge to avoid excessive clingage. If they have not been heated sufficiently during the voyage or discharge, a considerable quantity of the cargo can remain on board as unmeasurable clingage, even though a ship may be washed with heated crude oil during the discharge. Additionally, a crude oil can be heated too much, which would result in excessive costs for the fuel used to heat the cargo. Overheating also could result in cargo evaporation losses.

The following is a discussion of the transportation factors and crude-oil characteristics that should be identified and analyzed before a decision on cargo heating requirements is made.

Tanker transportation factors. The primary objective in setting crude oil cargo heating requirements is to minimize the overall transportation costs for the cargo. Some of the shipping factors which affect these overall transportation costs are:

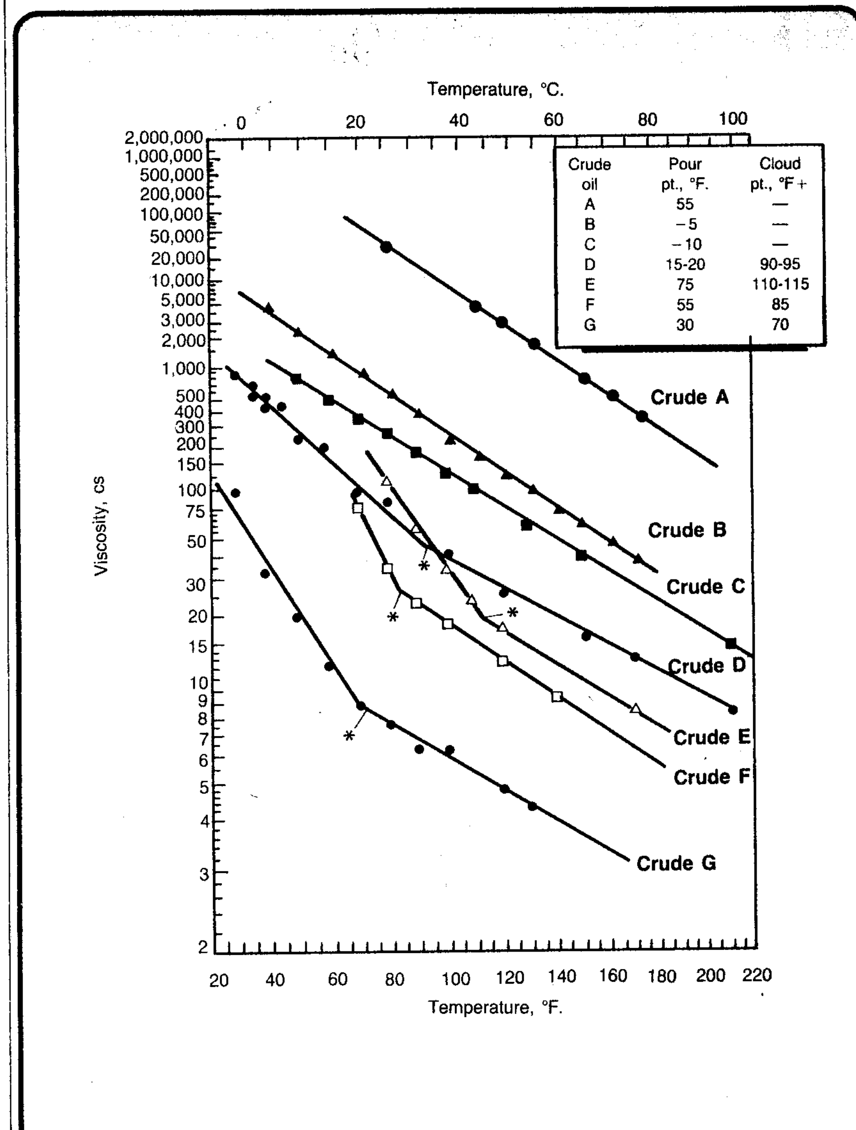
- Losses due to remaining on-board quantities
- Losses due to cargo evaporation
- Cargo heating fuel costs
- Demurrage charges resulting from delaying a ship beyond an allowable time
- Miscellaneous indirect costs related to scheduling factors.

The first two factors are monitored by the inventory and loss-control program. However, these factors are interrelated with other shipping factors, such as the last three listed, which are not monitored or controlled by the inventory and loss-control program.

All of these shipping factors can form a complex interrelationship, which must be defined to minimize the overall costs of transporting heated crude-oil cargoes. Such an effort also should include a thorough analysis of the properties of the crude oils being transported.

Fig. 1

Results of crude oil tests*



* For crude oils received at Getty's Delaware City refinery.

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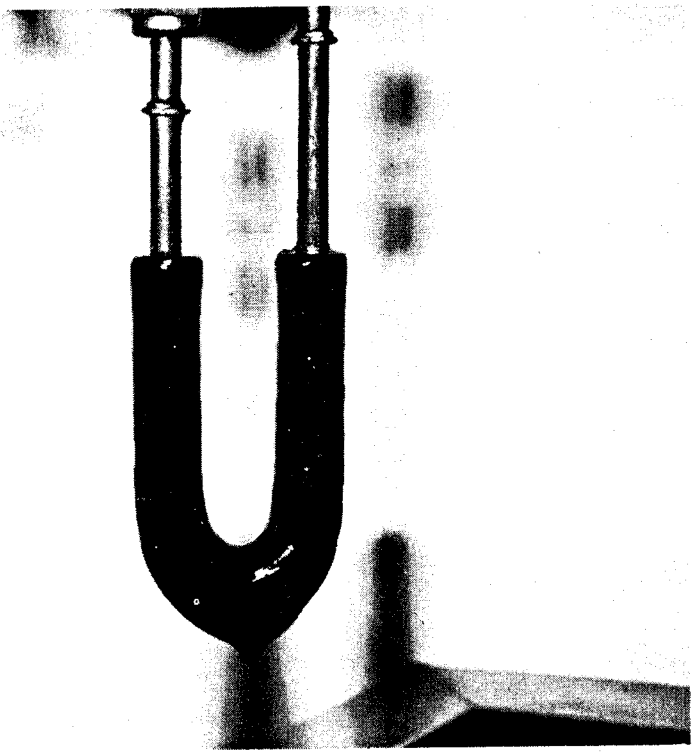
Crude oil characteristics. Historically, crude oil cargo-heating requirements have been based on viscosity data, pour points, and shipping experience. At today's costs of crude oil, and costs of fuel used for heating cargoes, a more thorough evaluation of cargo heating requirements is necessary. At the request of GRMC, the Getty Oil Exploration & Production Research Center (Getty Research) implemented a program to determine improved methods of analyzing crude-oil characteristics and their impact on cargo-heating requirements.

The objective of the research program is to establish and implement test procedures for providing the data required to control cargo losses while minimizing the overall costs of crude-oil transportation. The testing program which was developed involves determining the following characteristics of crude oils:

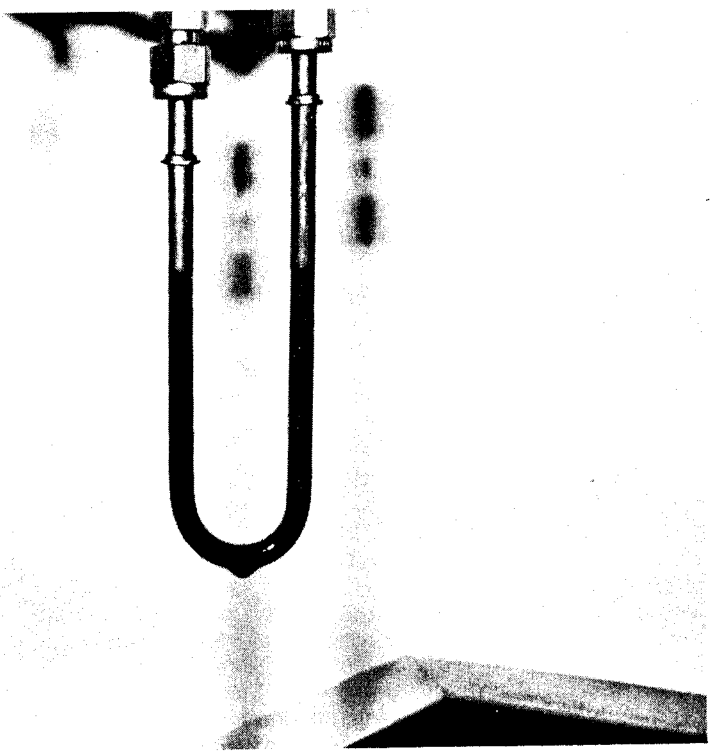
- Viscosity-vs.-temperature relationship
- Pour point
- Crude oil cloud point
- Relative clingage tendency
- Settling tendency
- Wax content
- Vapor pressure.

The viscosity-vs.-temperature relationship of a crude oil is a characteristic that affects numerous aspects of the tanker transportation of heated cargoes. It affects the pumpability of a cargo, as well as the drainage of a cargo during discharge. High-viscosity cargoes often "adhere" to tanker surfaces causing poor drainage and resulting in high remaining-on-board quantities.

The heat-transfer characteristics of a



This photo illustrates the relative clingage test for Gamba crude oil (Fig. 2).



The relative clingage test being made for Ratawi crude oil is shown here (Fig. 3).

crude oil also are a function of viscosity. If a cargo is allowed to cool too much during transit, its high viscosity and reduced heat-transfer characteristics may not enable reheating the cargo uniformly to its specified discharge temperature.

The pour point test is a standardized procedure (ASTM: D97-66). It involves heating a sample to dissolve all wax crystals and then allowing it to cool slowly under carefully controlled conditions until it just ceases to flow. Care is taken not to disturb the mass of oil that is being cooled since the spongy network of wax crystals could be broken and cause flow.

The pour point provides some understanding of crude oil cargo temperatures required. However, the crystal structures formed at the pour point do not simulate the clingage that forms on a tanker. The crude oil cloud point and relative clingage tests often provide more useful information on the behavior of crude oils and the wax deposits that may form under shipping conditions.

The crude oil cloud point can be a critical property affecting the cargo heating requirements of a crude oil. As the temperature of a crude oil is lowered, a point is reached at which wax first begins to precipitate and cause "clouding." A crude oil cloud-point test method was developed to determine that temperature.

The "cloud" is not observable in black crude oils but can be detected by changes in viscosity. The crude oil cloud-point method should not be confused with the standard test method for the cloud point of petroleum oils (ASTM: D 2500-81). This standard method is for petroleum oils which are transparent in layers 38 mm (1½ in.) thick. Crude oils are not this transparent, and no standard method exists for the measurement of the crude oil cloud point.

A high-cloud-point temperature can result in significant quantities of waxy deposits forming in a crude-oil cargo. These deposits could remain on board after discharge, thus resulting in cargo losses.

Additionally, a dramatic increase in the slope of the viscosity-vs.-temperature relationship can occur as a crude oil's temperature drops below its cloud point. Such an increase in viscosity combined with waxy deposits can result in high cargo losses. For example, during discharge, a viscous cargo with wax deposits would flow relatively slowly toward the pump suction in the bottom of a tanker. This could result in cargo (waxy, sludge-like deposits) becoming trapped along the structural members in the bottom of a tanker.

When any portion of a crude-oil cargo drops below the cloud point, waxy deposits could occur. The cloud point also can be an important factor when the seawater temperature is below the cloud-point temperature of the cargo. Seawater temperature strongly affects the temperatures of tanker's metal surfaces. When the temperatures of these metal surfaces are below the cloud-point temperature of the crude oil that they are in contact with, waxy deposits can form. These deposits can form even when bulk cargo temperatures are well above the cloud point.

The cloud points, pour points, and viscosity-vs.-temperature relationships of a number of crude oils that GRMC receives at its Delaware City refinery are shown in Fig. 1. Our observations have been that it is not practical to develop general relationships among these three factors. Each property needs to be evaluated for crude oils that may require heating.

The relative clingage tendency of a crude oil is determined using a test developed by Getty Research. This test determines the tendency of waxy deposits to precipitate from a crude oil and cling to tanker surfaces. These studies are made under a variety of seawater temperature and cargo-temperature conditions. As a result, conditions that could result in excessive crude-oil clingage are identified.

The relative clingage test provides a simulation of the conditions within a tanker. The resulting data are valid for relative comparisons between various conditions for a particular crude oil. Comparisons can also be made between various crude oils. An important aspect of this test, for waxy oils, is that it results in the formation of the type of clingage that could occur within a tanker. The isolation of this clingage allows the testing of its properties.

For example, the rheology of the clingage, the relative difficulty in removing the clingage by reheating, and the effectiveness of crude oil washing in removing clingage can be tested.

Shown in Figs. 2 and 3 are photographs of the relative clingage tests for two different oils. Relative-clingage data for several different oils are shown in Fig. 4.

Measurement of the settling tendency of a crude oil is related to the crude oil cloud-point test and the relative-clingage test. Getty Research's tests of settling tendency involve storing containers of crude oil under various cargo temperature and seawater-temperature conditions.

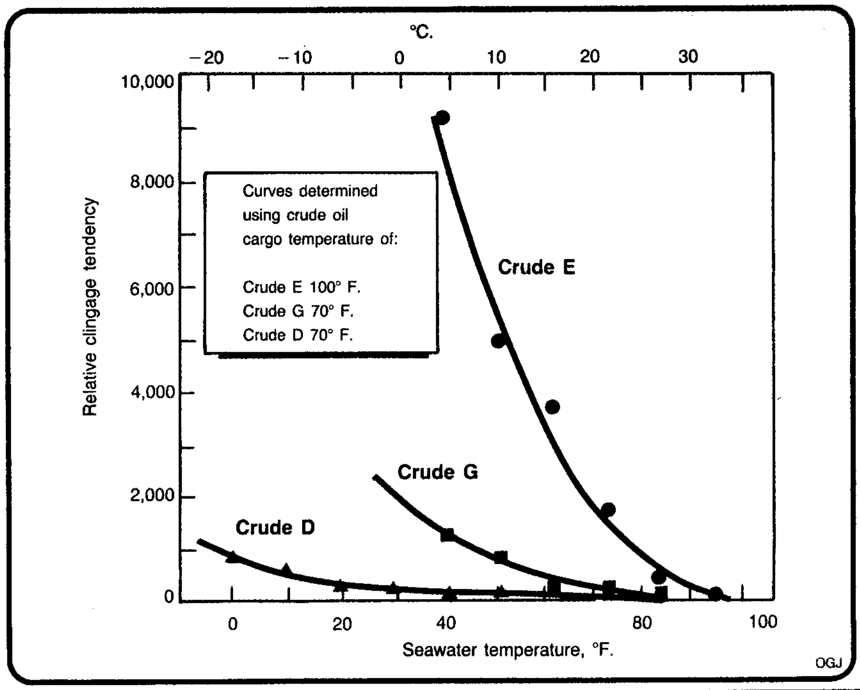
After the storage period, the viscosity and density at the top and bottom of the crude-oil sample are measured to detect any differences. If differences exist, analyses of the composition of each fraction are made in an attempt to determine the cause of settling. A significant difference would indicate that particles (wax/sand or other) could settle to the bottom of a ship and form a sludge or sediment.

An indication of the wax content of a crude oil can be estimated by measuring the concentration of $C_{20}+$ normal and branched alkanes. The concentration of these wax-forming compounds indicates the potential of a crude oil for forming a waxy clingage. However, a high concentration of these wax-forming compounds does not determine their tendency to precipitate. This is a function of the solubility of the waxy compounds in the crude oil. These solubility characteristics are evaluated by the relative clingage and crude oil cloud-point tests.

The vapor pressure of a crude oil generally is measured using the Reid vapor-pressure test (ASTM: D323-82). Vapor-pressure data are necessary to estimate the cargo losses due to evaporation at various cargo temperatures.

Fig. 4

Relative clingage data for three crudes



Determining crude oil cargo heating requirements. One purpose of GRMC's inventory and loss-control program is to reduce crude oil cargo losses. However, there are other operational factors which require consideration before a program to minimize these losses can be implemented.

For example, one aim of marine personnel is to minimize operating costs of tankers. Two ways to accomplish reduced costs are to reduce fuel consumed in heating a cargo, and to discharge a tanker as rapidly as possible. It may not be possible to achieve either objective on the same voyage and also minimize cargo losses.

Reducing the amount of fuel used to heat a cargo could result in an increase in cargo viscosity. This will decrease the rate of discharge, could increase turnaround time, and could result in demurrage charges. Conversely, heating the cargo to decrease viscosity and discharge more rapidly could increase evaporation losses and will increase the amount of fuel used to heat a cargo.

Another example of the conflict in minimizing both cargo losses and operating costs is the tanker crude oil washing (COW) process. The process involves circulating cargo back into a cargo tank through cleaning machines. The spray nozzles on the machines are directed toward the surfaces to remove waxy, sludge-like deposits and viscous crude oil.

All tanks that will receive ballast water are crude-oil washed at each discharge. Other tanks are washed on a rotational basis so that each tank is crude-oil washed at least once a year. The COW process is carried out in strict compliance with the specifications of the Intergovernmental Maritime Organization (IMO).

For many crude-oil cargoes, COW can reduce cargo losses due to remaining-on-board quantities. Therefore, each tank is usually crude-oil washed more than once a year.

However, COW also results in longer tanker-discharge times. Thus, in some cases, a decision needs to be made on whether the operating costs of COW certain tanks is offset by reductions in cargo loss.

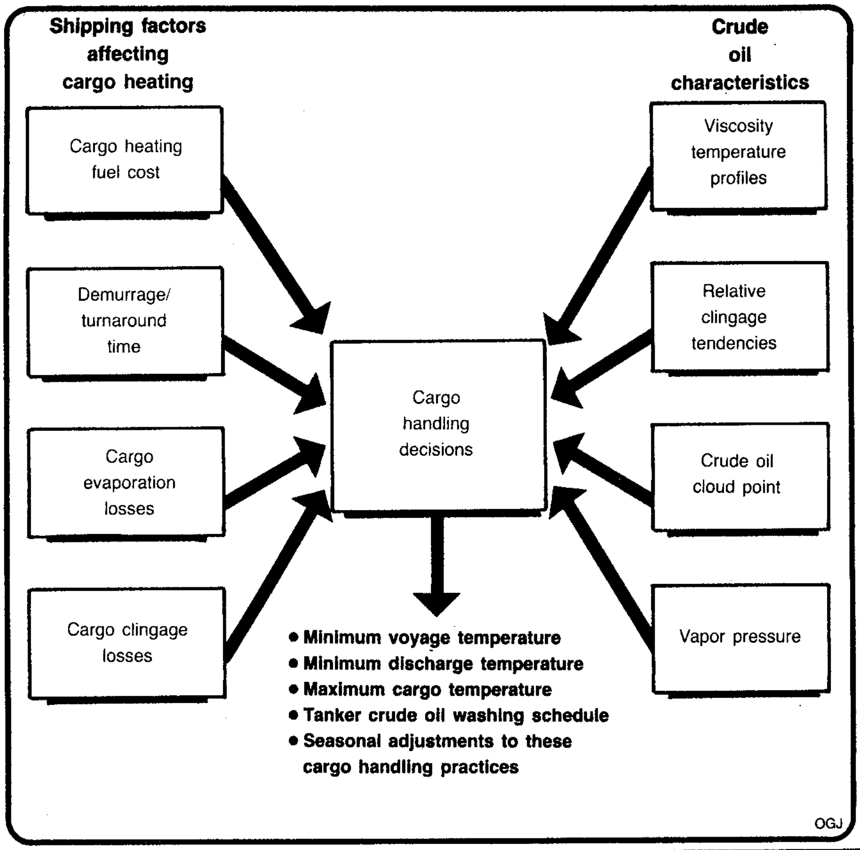
To minimize the crude oil cargo-handling costs, these various conflicting objectives must be reconciled and balanced. At present, this is being done by several groups within Getty on an informal basis.

Fig. 5 indicates that cargo-transportation factors and the crude oil characteristics that should be considered when making decisions on the handling of heated crude-oil cargoes. Arriving at a correct decision requires the coordinated effort of the various personnel involved.

The inventory and loss-control specialist of GRMC's product supply and distribution department coordinates the efforts to determine the crude oil cargo-heating requirements. Below is

Fig. 5

Determining crude cargo heating needs



The authors...


Lindner


Mihalik

Frank J. Lindner is supervisor of analysis for Texaco Inc. He previously worked in inventory and loss control for Getty Refining & Marketing Co. He developed Getty's inventory and loss-control program in 1980. Lindner has been active in the API and is a vice-chairman of the Committee on Marine Accountability. He has a BS degree in accounting from Brooklyn College—University of New York and an MBA degree in business management from Fairleigh Dickinson University, Teaneck, N.J.

Daniel R. Mihalik is in production research for Texaco in Houston. His primary involvement has been in heavy, waxy, and asphaltic crude oils. Mihalik holds a BSChE degree from the University of Toledo, an MSChE degree from the University of Michigan, and an MBA degree from the University of Houston. He is a member of AIChE and SPE.

a summary of the types of input that are provided by the participants.

Getty Oil Co.'s marine personnel monitor cargo heating-fuel usage (costs) and cargo temperatures for all voyages of Getty tankers. They also make decisions on the extent that crude oil washing should be used during the discharge of particular cargoes under various seasonal conditions.

Additionally, the marine personnel have a program for monitoring a number of cargo-handling practices. For example, they determine cargo positioning to minimize heat losses.

Personnel at GRMC's Delaware City refinery handle the receipt of heated crude-oil cargoes, which are transferred from tankers to the refinery storage through a 2-mile pipeline. They provide data on this pipeline and other facilities to determine tanker discharge rates as a function of cargo viscosity.

Based on the time available for a ship to remain at the unloading peer, they often provide input into decisions on the extent that crude oil washing should be used during the discharge of particular cargoes.

The Delaware City refinery laboratory personnel monitor the properties of the incoming crude oils.

The inventory and loss-control specialist monitors losses on crude-oil shipments and provides data on past shipments to assist in developing the overall cargo handling plan for particular cargoes. He coordinates the gathering of data and, based on the recommendations of the various groups involved, issues the heating and crude oil washing instructions.

The Getty Research staff provides input based on the specialized tests they perform. The viscosity-temperature profile, crude oil cloud point, pour point, relative clingage tendency, settling tendency, wax content, and vapor pressure are determined for crude oil which may require cargo heating. Recommendations are made which form the basis for the cargo-handling plan.

Conclusion. The efforts to determine the optimal crude oil cargo temperature to be maintained during the voyage and the discharge of a tanker have produced results. For example, we now recommend that a few Middle East crude oils imported by GRMC be heated during the discharge but not during the voyage.

Not using heat during the voyage reduces fuel costs.

Conversely, two West African crude oils which previously were heated for only several days prior to discharge are now being maintained at a specified temperature for the entire voyage.

Reduction in clingage on these West African crudes has more than offset the increased fuel usage. Also, the testing of a North Sea oil indicated that it should be heated and maintained within a very narrow range of temperatures during the voyage and discharge.

This is necessary to minimize the combined losses due to evaporation and clingage.

GRMC intends to continue its efforts in this area. We hope that sufficient interest has been generated by this article to encourage further work in similar cost saving areas.

Acknowledgments

This project evolved from the inventory and loss-control program within GRMC's product supply & distribution department. However, very quickly it became a cooperative effort with other departments. We thank the Delaware City refinery, Getty Oil Marine, and Getty Exploration & Production Research Center personnel whose expertise and assistance have been invaluable in developing and implementing a much-improved procedure to determine more precise and less costly crude oil cargo heating requirements. ▪

Attachment 4

VLCC METULA GROUNDING AND REFLOATING REPORT

EXECUTIVE SUMMARY

At **10:20 P.M. on 9 August 1974,** the VLCC METULA, **transiting westbound through the Strait of Magellan and laden with 194,000 tons of light Arabian crude oil, ran aground on Satellite Bank, at** the west end of the First Narrows. Grounding at almost her full speed of 14.5 knots, METULA came to a stop in about 260 feet, opening up five of her forward-most compartments, including two cargo tanks, to the sea, initially losing about 6,000 tons of oil, which amount increased with time due to the action of tides and current.

At first METULA held fast on her grounding heading of 235° True, but on the afternoon of 11 August, her stern swung to starboard and the after portion of the hull grounded, holing the engine room, which was flooded in about an hour. **METULA** was then stranded starboard side to a steep rocky ledge on a heading of about 185° True, and she held this position thereafter despite cross currents of up to eight knots.

Shell Tankers B.V., Rotterdam, operators of METULA, made salvage arrangements on a daily rate basis with Smit International Ocean Towage and Salvage, Rotterdam. The salvage tug ZWARTE ZEE departed Montevideo for the scene. A salvage team headed by Smit's senior salvage inspector, CAPT COLTHOFF, designated Salvage Master, was dispatched by air to Punta Arenas, along with some fourteen tons of equipment. CAPT JONGENEEL, Shell Tankers' Marine Superintendent, went along to manage the ship operator's interest in the salvage effort, as did ANDREW MARSHALL, London Salvage surveyor for the hull underwriters.

Meanwhile, Shell arranged for two tankers to proceed to the scene -- the Argentine tanker HARVELLA of 19,000 DWT, for initial lightening, and the Norwegian tanker BERGELAND of 96,000 DWT, for the HARVELLA to discharge into.

The ZWARTE ZEE arrived in Punta Arenas on 15 August and picked up the men and equipment that had been flown in. After a delay due to weather, she secured alongside METULA on 17 August. At that time damage was assessed, calculations were started, and plans for refloating began to be formulated. Meanwhile, two more salvage tugs -- the SMIT SALVOR and the NORTH SEA -- were dispatched to the scene from the Panama area.

The Coast Guard first became aware of the incident on 13 August through a message from the United States Delegation to the Law of the Sea Conference in Caracas. Two days later it was derided that a Coast Guard observer should go to Chile to learn as much as possible about the incident, in view of prospective supertanker traffic into and near the United States.

The Coast Guard observer, CDR James A. ATKINSON, arrived in Punta Arenas on 19 August, was briefed by the Chilean on-scene commander, RADM ALLEN, conferred with Shell and insurance representatives, and the next day visited METULA, There he was apprised of METULA'scondition, the severe complexities of the situation, and the salvage plans. He described to CAPT COLTHOFF the U.S. National Strike Force and ADAPTS pumping systems and told him that Chile might obtain Coast Guard assistance through a government to government request. The following day CAPT COLTHOFF sent a request to the Chilean government, which apparently contributed to Chile's decision to request U.S. assistance on a cost reimbursable basis.

Progressive damage occurred on the subsequent spring tides with four more cargo tanks opening to the sea on 19 August, a ballast tank and bunker tank on 4 September. On 24 September another cargo tank began to leak.

The tankers arrived on scene, but, were delayed awaiting the Yokohama fenders, which, due to the difficulty in finding an aircraft that could transport them, did not arrive until 26 August.

The U.S. Strike Force contingent and three ADAPTS systems arrived on 27 August. One of the systems and six men went out to METULA in time for the first offloading into HARVELLA on 28 August. After the salver's plans changed, the other two systems were ordered out and all were thereafter fully integrated into the pumping off of cargo, the injection of compensating ballast, and the deballasting during refloating.

After four offloading by HARVELLA, totalling about 50,000 tons, BERGELAND) departed the scene to deliver this cargo to Quintero Bay, Chile, (its original destination) with orders to return for the remainder of METULA's cargo.

Refloating was planned for 21 September, but was delayed by weather until the 24th. On that date an effort was made, with a combination of deballasting intact tanks and "blowing down" open tanks with air. This attempt was not successful. So on the next tide more ballast was pumped out and more air was applied, this time with success. METULA came afloat at 0235 on 25 September and was moved to anchor a few miles west of her stranded position. Here adjustments were made in list and trim, and cargo was transferred to reduce the chance of pollution. Severe winds occurred from 27 to 30 September with velocities from 90 to 100 knots. After this moderated, on 1 October, BERGELAND) went alongside METULA and offloading continued, broken by periods of high winds. Offloading was completed on 10 October. The total amount of cargo saved was about 140,500 tons; about 2,000 tons remained in the ship, mostly in clingage, and about 51,500 tons of crude oil and some Bunker C was lost into the waters of the Strait.

Pollution surveillance by air was carried on almost every day. The appearance of the polluted water and beaches from the air varied from day to day, the marked differences apparently stemming from the effects of wind and tide. The heaviest water pollution observed was on 20 August after the largest cargo release, when slicks covered about 1,000 square miles. At most other times the oil was penned against the beaches by the wind, reducing drastically the water surface coverage. A beach survey by Dr. Roy HANN of Texas A & M University, who had visited the scene on behalf of the U.S. Coast Guard, revealed massive beach deposits of oil-water emulsion, some of which was well above the highest water level, apparently carried there by the gale force winds from the breaker tops during highest tides. His rough measurements showed that most of the oil that had not either evaporated or dissolved had apparently gone ashore. At first this was confined to a strip of beach on Tierra del Fuego, on the southern shores of eastern Bahia Felipe, and the First Narrows, but it later spread farther to east and west; some ended up on the north shore eastward of Cabo Posesion, and patches were sighted west of the Second Narrows. There was an appreciable bird kill, but many migrating penguins passed the polluted area and reached their nesting islands in the Strait without damage.

The ADAPTS equipment, which was developed by the Coast Guard after a study of the TORREY CANYON disaster, gave excellent performance, fully vindicating the efforts expended in its development. The NSF contingent operating that equipment, self-supporting under primitive living and severe climatic conditions, carried out their duties with perserverence, dedication and skill confirming the best traditions of the Service and in keeping with the Strike Force concept. In so doing they played a most important part in restricting the oil pollution to a minimum, before, during and after the refloating operation.