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SOURCES OF OIL AND WATER IN BILGES OF GREAT LAKES SHIPS

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SOURCES OF OIL AND WATER IN BILGES OF GREAT LAKES SHIPS

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

This report discusses the sources of oily bilge water pollution from Great Lakes ships, and therefore is intended to be a contribution to the prevention of contamination of water resources.

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ABSTRACT

Sources of bilge water and of oil in bilge water were surveyed aboard five ships of the Cleveland Cliffs Iron Company. The ships included two powered by steam turbines, one by a uniflow steam engine, one by a conventional reciprocating steam engine, and one by a diesel engine.

It is found that many sources of bilge water are clean sources. Although no accurate estimate of the water thus contributed to the bilges can be offered, it is concluded that diverting these sources from the bilges could ease the task of separating, storing, and disposing of oil wastes.

Several samples of water were taken from each ship, and analyzed for total, fixed and volatile non-filterable residue, color, pH, turbidity, total organic carbon, and oil and grease concentration.

This report was submitted in fulfillment of EPA Grant R802475 by The University of Michigan under the sponsorship of the Environmental Protection Agency. Work was completed as of October 1, 1973.

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ACKNOWLEDGEMENTS

The work reported here was carried out aboard ships of the Cleveland Cliffs Iron Company, and hence is entirely dependent upon its sincere cooperation. John L. Horton, assistant manager of the marine department, and John C. Culbertson, fleet engineer, were the principal liaison. Shipboard personnel were uniformly cooperative and helpful. The support of all is acknowledged with sincere thanks.

SECTION I

CONCLUSIONS

1. A typical Great Lakes machinery space contains roughly 150 potential sources of bilge water. About one third of these are open ended pipe drains that discharge only clean water. These could therefore be piped to a clean drain tank for disposal overboard without contribution to external pollution. The remaining bilge water, which presumably would remain oily, would require separation before overboard disposal, or could be held for shore disposal. The benefit of diverting the clean drains would therefore be in greatly reducing the volume of oil waste to be handled. It may be possible to so reduce the water volume that methods of disposal otherwise impractical, such as incineration, become feasible. Any method of oil-water separation is likely to be reduced in cost by a reduction in water throughput. The cost of additional piping to divert clean water from the bilges is unknown.

2. Bilge water sources are numerous, diverse, intermittent, and often in the nature of leakages; in consequence, it does not appear feasible to measure their flow rates. Some flow estimates, strictly from visual observation, are quoted in this report, but the conclusions of the first paragraph are based on the sum of these observations, and not on hard data.

3. No oil is deliberately discharged to the bilges, except in the oil-water mixtures to be mentioned in 6.

4. Drips of lubricating oil from reciprocating machinery are a potential source of oil in the bilge that can be eliminated by careful housekeeping (Cleveland Cliffs is doing well in this respect).

5. Accidental spills of oil are a possible source of bilge contamination that can be reduced by care in design, building, and operation, but which doubtless cannot be eliminated. If the bilges are kept dry, however, it should be feasible to clean many spills by wiping or absorption, rather than flushing to the bilge sump.

6. Several sources from which oil and water enter the bilge together exist, these being (1) residue for centrifugal purifiers, (2) contaminated heating coil drains (casualty situation only), (3) stern tube in-leakage, and (4) drainage of condensation and oil from reciprocating propulsion engines. Of these, only (3) seems to be subject to ready elimination, so that keeping oil and water totally separate before they enter the bilge does not appear to be feasible. But if (3) is eliminated, the remaining sources on non-reciprocating ships are small enough that it may be feasible to drain the oil-water to a slop tank, rather than dumping to bilge.

7. The conventional (i.e., non-uniflow) reciprocating steam propulsion engine is a special problem. Separating oil and water before it reaches the bilge does not appear feasible, but further investigation may show that the leakages of oil and water can be significantly reduced. This, however, is a statement of hope, rather than a conclusion.

SECTION II

RECOMMENDATIONS

The following three items are recommendations to Great Lakes ship operators:

1. Housekeeping recommendations

   Operating personnel should be instructed to avoid flushing of oily wastes into bilges; spills to be wiped up rather than washed away. Drips and leaks to be caught by portable receptacles. Running of water into bilges via vents and drains to be kept to a minimum. In general, a "dry bilge is a good bilge" attitude should be promoted.

2. Maintenance recommendations

   Vigilance should be exercised to keep all pump and valve packings in good condition.

3. Added gravity separation

   Even casual visual inspection shows that the bilge well acts as a gravity separator to remove gross oil contamination. However, the small size and awkward location of the well result in all or part (if the crew takes the trouble to skim the surface) of the oil being entrained by the bilge pump suction. It is therefore recommended that a simple gravity separator be placed in the bilge pump discharge line, this being basically a tank of (say) 100-gallon capacity from which surface oil can be drained to a slop container. Although such a device will not produce a sheen-free effluent, it should nonetheless reduce the amount of oil escaping overboard.

The following measures can be beneficial, but may require expense on the part of the ship owners. Since the magnitude of this expense has not been estimated, the measures are offered as suggestions for consideration, rather than as firm recommendations for action.

4. All piping drains to bilge, unless known to be potential sources of oil contamination, should be piped to a clean drain tank, for disposal overboard without passing through the bilges.

5. Reduction of bearing oil flow to the reciprocating steam engines should be investigated. This might be done by addition of a bearing temperature monitoring system, which would allow careful trial reductions in oil flow with low risk of bearing damage.

The following steps are recommended for the Environmental Protection Agency:

6. Since the generation of oil bilge water cannot be eliminated, EPA should support efforts to develop separation processes.

7. Since the water samples taken under this program give only a glimpse of the bilge water problem presented by the several hundred ships active on the Great Lakes at any one time, EPA should continue to collect such samples.

8. The concept of effecting a major reduction in flow of water to the bilges should be pursued through a more detailed study of a single ship. This would consist of preparation of piping arrangement sketches and job specifications for implementation of a clean drain system. This to be done by, or in cooperation with, a marine design firm or shipyard so that a cost estimate could be prepared.

9. A program similar to the one reported here should be attempted aboard the new Great Lakes ships (i.e., entering service since the 1955-1970 building hiatus). These ships are diesel-propelled, have oil-lubricated stern tubes, and generally are not well typified by the old ships studied here.

SECTION III

INTRODUCTION

THE PROBLEM

Bilge water is that water which collects from almost innumerable sources into the lowest internal part of a vessel--its "bilges." The principal accumulations of bilge water are found in the machinery spaces; cargo holds, tanks, and void spaces usually collect only trifling amounts of such water unless a casualty lets in sea or weather. Within machinery spaces there are many sources of leakage (e.g., pump glands, stern tube), and the bilge is used as a sump to receive wastewater from many sources. Typically these sources offer low flow rates, and are intermittent, so that piping to recover the water is not justified. The water leaking or draining to the bilges flows across the tanktop (Figure 1) to a sump, where it is picked up by a bilge pump for disoharge overboard. Oil, and possibly other contaminants, have also drained to the bilges. Although there will be some gravity separation of oil and water in the bilge well, and the water will therefore not be badly contaminated with oil *if* the engineering crew takes the trouble to manually skim the well surface, some oily contamination of bilge-water remains.

Oil draining to the bilges is mostly lubricating oil, but fuel oil may also be found.

It should be noted that bilgewater serves a useful function in that it tends to flush oil off the tanktop, thereby preventing the buildup of a hazardous combustible layer.

On ships powered by steam turbines or by diesel engines, there is usually an almost negligible deliberate discharge of oil to the bilges in normal operation. However, the reciprocating steam engine uses once-through lubrication for many of its rotating and sliding bearings. In the conventional (i.e., non-uniflow) engine, this oil drains to the tank top below the engine, whence it flows to the bilge well. Cylinder lubrication is accomplished by injection of oil into the cylinder, whence it ultimately appears in the exhaust steam. With the jet-type condensers used on the Great Lakes, the condensed steam, with oil entrained, is discharged overboard. This practice is followed by both conventional and uniflow engines

Figure 2 illustrates a typical Great Lakes bilge piping system.

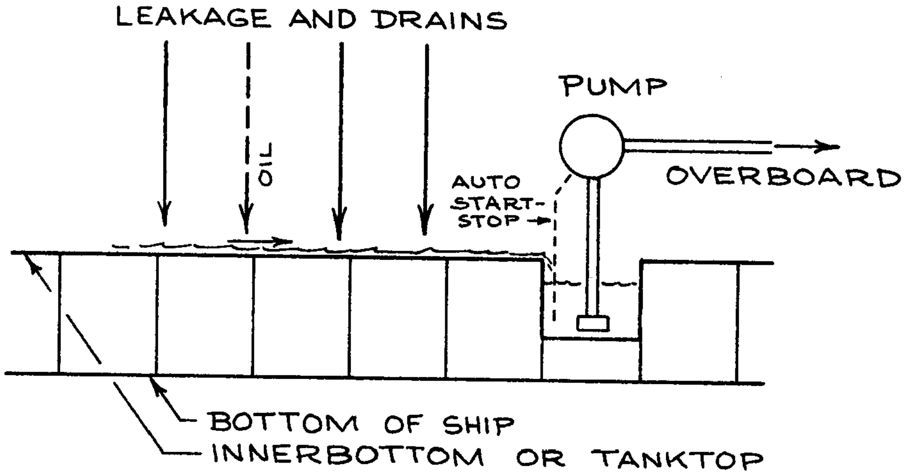

Figure 1. Typical Bilge Arrangement.

THE INVESTIGATION HERE REPORTED

This investigation was carried out aboard vessels of the Cleveland Cliffs Iron Company. The purpose was to locate all sources of water and oil flowing to the bilges, and to determine if it were possible to eliminate such sources, i.e., provide some means of disposal, other than discharge to bilge. This was intended to contribute to solution of the oily bilge water problem by keeping oil and water separate before they come in contact at the bilge well. A second purpose was to collect samples of bilge water for subsequent laboratory analysis.

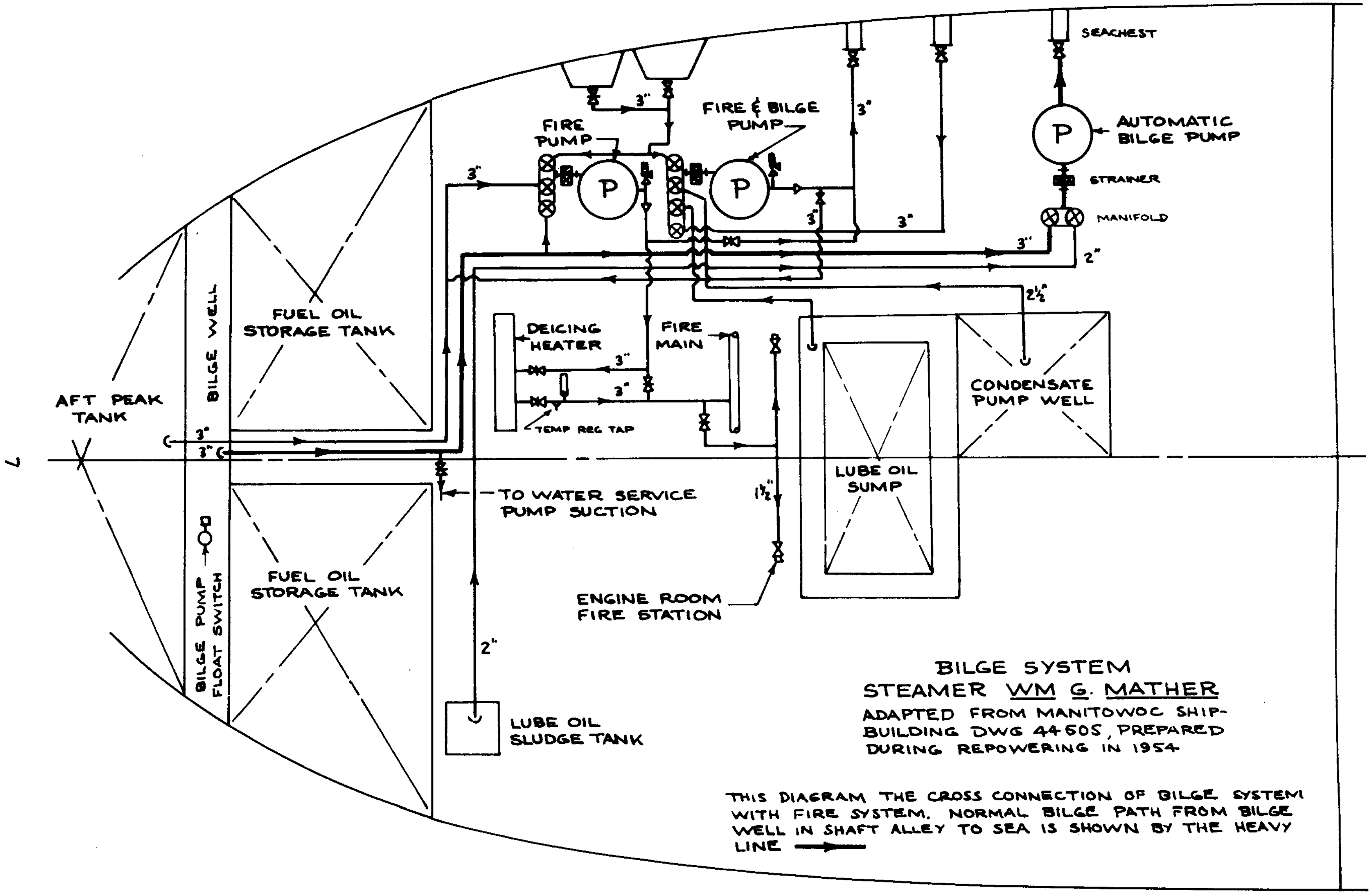

Figure 2. Bilge Piping Schematic for Steamer WILLIAM G MATHER.

The investigation was carried out by on-board examination of five Cleveland Cliffs ships in their normal operation during the 1973 shipping season. The investigator, who is an engineer having experience with theory, design, and operation of marine machinery, inspected the bilges and piping thereto, measured or estimated flows where possible, observed operating practices, questioned the operating engineers, collected water samples, and examined piping drawings. The investigation concentrated on the propulsion machinery spaces, but also covered compartments housing steering engines and bow thrusters, and the areas in vicinity of deck machinery.

Details of ship-place-date are these:

PONTIAC	Cuyahoga River; Cleveland to Detroit	5/1/73, 5/2/73
CADILLAC	Cuyahoga River	5/8/73
WM P SNYDER	Cuyahoga River	5/9/73
RAYMOND H REISS	Detroit to Cleveland	5/11/73
WM G MATHER	Detroit to Cleveland	5/21/73

These ships were chosen to give a variety of power plants; PONTIAC and MATHER are steam turbine vessels, REISS is diesel, CADILLAC is conventional steam reciprocating, and SNYDER is uniflow steam reciprocating.

DIFFERENCES BETWEEN GREAT LAKES AND SEA PRACTICE

Diesel

There is no essential difference among Great Lakes inland, and sea practice with respect to diesel machinery, especially if discussion is limited to U.S. vessels. For example, the popular General Motors (Electromotive Division) locomotive engine is being applied to new vessels building in all three areas with no differences in engines or their auxiliary systems.

Many foreign ocean-going vessels, however, are powered by low-speed diesel engines capable of burning "heavy" fuels, usually mixtures of residual oil and a lighter distillate. Because residual oil contains most of the impurities present in the original crude oil, these ships are usually provided with fuel washing systems in which the oil is mixed with fresh water (dissolves water soluble impurities), then passed through a centrifuge to remove the water. The removed water is oily and thereby constitutes a source of oily bilge water. This water is added at a maximum of about 10 percent of the oil flow. Fuel for a 10,000 hp engine will therefore produce an oily water flow of roughly one gallon per minute. Although no ships of the U.S. Great Lakes fleet are so equipped, many of the foreign vessels entering the Lakes are powered by low-speed diesel engines, and it seems likely that many are therefore washing fuel in the manner described.

Steam turbine practice on the Great Lakes is almost identical to ocean practice. Differences that are apparent are largely of historical nature: no steamers have been built on the Lakes in almost 20 years, while they continue to be built for ocean service. A development in this interval significant to the bilge question is the widespread adoption of the oil-lubricated stern bearing, which obviates the need for a lubricating water flow through the bearing and into the bilges. A randomly-chosen ocean ship is likely to be newer than any steam laker, and therefore less likely to have the stern tube bilge source. Note, though, that the oil-lubricated stern tube is not exclusive to steam vessels, but is used as well on diesel ships.

The greatest difference between ocean and Great Lakes practice occurs in the case of reciprocating steam ships. The biggest factor is the almost total absence of these vessels in modern ocean service. In effect, there is nothing to compare the Great Lakes vessels to. Looking back, though, a major difference can be seen in the condensate systems. Typical Great Lakes engines exhaust into a jet condenser, wherein the steam mixes with lake water, and is discharged directly overboard. Cylinder oil is thus discharged overboard. Sea practice used a surface condenser; condensate did not contact sea water, and was continuously recycled. Cylinder oil was removed by filter sponges that were periodically washed to renew them. Wash water containing the removed oil was doubtless dumped into the bilges, whence it found its way overboard. The end result was therefore much the same.

SECTION IV

SOURCES OF WATER IN MACHINERY SPACE BILGES

STEAM TURBINE SHIPS

This discussion is based on inspection of the PONTIAC and WILLIAM G MATHER. It begins with a simple list of bilge water sources, followed by comments on each. No significance is implied by the order in which the sources are listed. Numbers in parentheses are the approximate numbers of such sources.

- Shell condensation (1)
- Stern gland leakage (1)
- Pump and turbine gland leakage (20)
- Gage glass blowdown (4)
- Deck drains from auxiliary spaces (2)
- Condenser vents (3)
- Lube oil purifier (1)
- Tank overflows (4)
- Tank drains (4)
- Pump casing drains and vents (20)
- Sea chest drains (6)
- Safety valve drains (4)
- Relief valves (8)
- Contaminated drains (1)
- Moisture separators (2)
- Deck wash connections (2)
- Sample sink (1)
- Valve glands (50)
- Piping system drains (10)
- Engineers' lavatory and washing machine (2)

(In the following discussion, features of the non-turbine ships are mentioned if they are not unique to the type of power plant.)

Shell Condensation

Although some condensation is usually visible on the inner hull surfaces in the machinery spaces, this is a trivial source.

Stern Gland Leakage

This water leaks along the propeller shaft from the sea, or is injected into the stern tube bearing area--and subsequently leaks inward--by the fresh water cooling system (for cooling and lubrication). In either case, the leakage is sea water, except that it may be contaminated if grease lubricant is used in the gland (as is done on the MATHER). The rate is highly variable, depending on the amount of wear that has accumulated, and on the individual chief engineer's favored practice. An estimated 1 gal/min was observed on the PONTIAC, about 5 gal/min on the MATHER.

Pump and Turbine Glands

Some leakage through the glands of centrifugal pumps is required for cooling and lubrication, though the rate is highly variable, depending upon the condition of the gland packing. Rates on operating pumps were observed from near zero to an estimated 1 gal/min .

Flow through centrifugal feed pumps is essential at all times to keep them from overheating during periods when demand by the boiler may fall to zero, and this flow is often obtained by large gland leakage. This practice was observed on both the PONTIAC and MATHER, with the flows estimated to be in the neighborhood of 1 gal/min .

The connecting rods of reciprocating pumps generally show a slight leakage also. At the steam end, the leakage may be partially in the form of vapor.

Propulsion turbine glands are typically fitted with a leakage collection system that should prevent leakage to the exterior under ordinary circumstances. However, drain pockets are also provided, with a pipe leading to the bilge to direct any leakage that may occur, showing that some leakage is anticipated. Auxiliary turbines are typically fitted with carbon packing that reduces leakage to a trifling amount, and that largely steam.

Gage Glass Blowdown

Boiler gage glasses occasionally need flushing to remove solids that might interfere with visibility. Amount of water released to bilges varies according to need and engineers' practice. It is probably less than 10 gal/day .

Deck Drains from Auxiliary Spaces

This is principally drainage from the steering engine space, which is typically adjacent to the main machinery space on a somewhat higher level than the main operating platform. A noticeable flow from this source is likely only in the case of a steam steering engine (used on all ships observed except the diesel-propelled REISS), which may have some leakage around connecting rods and valve stems. A flow on the order of 0.1 gal/min was observed on the PONTIAC; essentially zero on the other vessels.

Condenser Vents

Circulation of water through condensers may be impeded by air trapped at high points in the circulating system, these usually being in the condenser heads. Vents from the heads are therefore provided, with pipe leading directly to bilge. The vent may or may not be used, depending on draft of the ship (i.e., air binding should be worse at light draft, since this puts the condenser higher with respect to the waterline), and on the chief engineer's judgement as to need. It was observed in use only on the PONTIAC; and there only for the main condenser; flow was an estimated 2 to 3 gal/min .

Lube Oil Purifier

Heavy contaminants, mostly water, are centrifuged from the main lube oil system (serves propulsion turbines, reduction gears, and propulsion shaft bearings). Rate of water extraction may run from near zero to about 1 gal/day . Although the quantity is small, this is a significant source because the imperfection of the separation process leaves some oil in the water. This, then , is one of the identifiable sources of oily bilge water. The practice observed on the MATHER is to hold the water in a slop tank, then reprocess it through the purifier to remove as much remaining oil as possible, before discharge to bilge.

Tank Overflows

Water tanks operating under atmospheric pressure are provided with overflows (if above atmospheric, then relief valves) piped to bilge. Typical are potable water tank, fresh water drain collecting tank, contaminated drain tank. Nominally, flow issues only during an abnormal operating condition, such as overfill of the potable water tank. Oil tanks, such as fuel and lube oil tanks, must be provided with vents or overflows, but these are not led to the bilge. No overflows were observed.

Tank Drains

Tank drains are necessary to permit draining for repair work and winter layup. No flow during operation.

Heat Exchanger Drains

Same discussion as *tank drains*.

Pump Casing Drains and Vents

Same discussion as *tank drains*. Also, vents opened to bleed air during initial startups, and to flush casing of pumps taking suction from the sea after encounters with mud. The latter action was observed on the

PONTIAC fire and general service pump in the Cuyahoga River, discharging about 10 gal/min to the bilges.

Sea Chest Drains

Same discussion as *tank drains*. Also, mud flushing may be necessary as discussed just above.

Safety Valve Drains

Condensation is likely on the downstream side of safety valves following operation, hence a drain line open to bilge is provided for each valve. Flow to be expected only following an operational aberration (should never happen) that causes safety valves to lift.

Relief Valves

Relief valves on piping systems, heat exchangers, turbine casings, etc, generally discharge to the bilge. There should be no flow in normal operation. Relief valves on fuel oil and lube oil piping systems discharge to the low pressure parts of these systems.

Contaminated Drains

Contaminated drains are the condensed returns from steam heating coils in fuel tanks. Although the water is normally clean, there is the possibility of leakage of oil into the coils, hence the name "contaminated." The drains are collected in a tank where they can be inspected through a sight glass for contamination. If oil appears, the incoming drains can be diverted into the bilges. Although this diversion is normally zero, it might be on the order of 10 gal/min in the event of contamination.

This is another identifiable source of oily bilge water, although a zero-flow source in normal circumstances.

Moisture Separators

These remove moisture from the compressed air used for pneumatic controls, and to operate portable tools. This water drains to the bilge in trivial amounts.

Priming Pump Discharge

The priming pump is used to draw air from the suction side of ballast pumps to establish flow when these are started. Some water must appear toward the end of the priming cycle, and this is discharged to the bilge. Quantity should be on the order of 10 gallons per voyage.

Deck Wash Connections

Some sea water piping system, such as the firemain, will have one or more hose connections for use in washing floor plates or equipment in the machinery spaces. Use depends on the need for such practices.

Sample Sink

Water samples are periodically drawn from the boiler for chemical analysis, with excess going to bilges via sink drain. The samples must be cooled by flowing through a small heat exchanger as they are drawn, and the cooling water also goes into the bilges, either directly or via the sample sink drain. Flow from this cooler was observed on the SNYDER at about 10 gal/min . Flow should be intermittent, only for 30 seconds, say, once per watch while a sample is being drawn.

Valve Glands

Leakage around stems of valves is possible, depending on the condition of the packing. A large sea valve on the REISS was observed to be leaking at an estimated 1 gal/min .

Piping System Drains

Generally the same discussion as *tank drains*. However, one case of operational use was observed; on the MATHER the firemain drain was open continuously, discharging about 5 gal/min to the bilge. This was said to be a common practice, intended to keep circulation through the piping to avoid freezing during early season operation. Drains from steam piping to remove condensation usually are piped to a drain collecting tank, but some such drains may instead go to the bilge, with brief slight flow during warmup.

Engineers' Lavatory and Washing Machine

Engineers' lavatory drains to the bilge if it is below the waterline. A washing machine in the engine room is likely to be found only on reciprocating engine ships, there for washing filter sponges used to filter oil from the main condensate.

DIESEL SHIP

This discussion is based on inspection of the RAYMOND J REISS, the only diesel ship in the Cleveland Cliffs fleet, and one of the few diesel ships in the established (i.e., built before 1970) U.S. Great Lakes fleets.

This ship is a converted steamer, and retains many steam auxiliary systems, fed by a pair of auxiliary boilers. The list of sources discussed for the steam turbine ships is generally applicable, with only the items directly associated with the main engines being different. The main condenser vent, the turbine gland leakage, and the lube oil purifier from the preceding list are absent. On the other hand, the propulsion diesel engine provides no additional source of either bilge water or bilge oil in its normal operation.

Feed water for the REISS auxiliary boilers is treated by an ion-exchange softener (comparable treatment for the MATHER and PONTIAC main boilers is provided by distillation). This unit requires occasional regeneration (not observed, however) which entails a discharge of back-flush water to the bilge.

My visit to the REISS occurred shortly after a casualty to the engine lube oil system, an event that dumped a large quantity of oil into the bilge. The bilges were very oily at the time, as is reflected in the bilge water samples described in Section VI.

Diesel vessels in general may differ in significant respects from the REISS. The STEWARD J CORT (Bethlehem Steel), first of the recent new-buildings in the U.S. Lakes fleet following a moratorium of about 15 years, has no auxiliary steam system, hence reduced piping and no oil-dripping reciprocating steam pumps. Centrifugal purifiers for fuel oil and lube oil may or may not be used; neither, for example, is aboard the CORT. That vessel burns a low-viscosity fuel, which requires only minimal treatment before use, and the same is true of the REISS.

RECIPROCATING STEAM

With the exception of the main propulsion engine, the situation here is much the same as aboard the steam turbine ships. That is an important exception, however, when the engine is the traditional open design (CADILLAC). Some condensation of steam occurs within the engine cylinders. At least some of the condensation leaks around piston rods, and some steam leakage condenses immediately outside the engine. The resulting water drips to the engine room tanktop, whence it flows toward the bilge sump. Although the flow is not large (difficult to estimate, but perhaps on the order of 1 gal/min), it is highly significant in that it flushes oil leakage from the engine toward the bilge sump. Part of this flow may be cooling water applied externally to bearings.

The uniflow steam engine (SNYDER) does not produce bilgewater, except perhaps for some condensation during warmup. There is no condensation in normal operation; indeed, the prevention of this condensation is the major motivation behind the uniflow design. The engine is also provided with a crankcase oil sump, much in the manner of the diesel engine, so that there is no oil drainage onto the tanktop requiring flushing water.

Both types of reciprocating engines contribute water to the bilges indirectly, by way of the treatments required of their boiler feed water. Exhaust from these engines is condensed in a jet condenser, a device that mixes its cooling water with the exhaust steam. The resulting mixture is discharged overboard, but a minor part of it (on the order of 10%) is returned to the boilers. This feed water, being mostly lake water, must be treated to remove natural impurities. The processing equipment used (zeolite process) requires periodic regeneration, including a backflush which goes into the bilges.

The exhaust steam is oily, since lubricating oil is injected directly into the engine cylinders. The water taken from the condenser for boiler feed is therefore oily, and the oil must be removed by filtration. The filter elements are sponges which are washed periodically in a conventional household washing machine. If this machine is located low in the ship, its drain goes to the bilges.

The zeolite backflushing and the sponge washing should together contribute a quantity on the order of 100 gal/day to the bilges.

SECTION V

SOURCES OF OIL IN MACHINERY SPACE BILGES

INTRODUCTION

Since all moving machinery must be lubricated, and since leakage or careless handling of lubricants and fuel seemingly must occur occasionally, it is impossible to pinpoint all sources. Some definite sources were identified, however, and these are discussed in this section. These sources are:

- stern tube lubricant
- lube oil and fuel oil purifiers
- contaminated drains
- drippage from steering gear and reciprocating pumps
- drippage from oil burners
- reciprocating propulsion engines

DISCUSSION

Stern Tube Lubricant

The sterntube of the MATHER is lubricated by a grease (Mobilgrease L-3) injected by a hand pump at a rate of about 0.5 gal/day. Most of the grease is swept out into the machinery space bilges by the flow of cooling water inward along the propeller shaft. The other four vessels observed do not use this method of lubrication.

Lube Oil and Fuel Oil Purifiers

Lube oil purification by centrifuge is used on steam turbine ships, may be used on diesel ships, and similar fuel oil purification may be used on diesel ships (only the steam turbine case actually observed here). The water removed from the oil carries some oil with it as a consequence of the incompleteness of the process. This water, discharged normally to the bilge, is therefore a source of oil.

Contaminated Drains

Steam heating coils are commonly used in fuel tanks as a means of reducing the viscosity of the oil. Since oil leakage into the piping (at a defective joint, say) is possible, and since oil must be kept out of the boilers, returning condensate is inspected for oil contamination. This is accomplished by holding the condensate briefly in a tank arranged for easy visual detection of an oil film on the water surface. If such a film appears, the return flow of water is manually diverted to the bilges until the defect is corrected or isolated. If the defect recurs, this process then becomes a source of oil in the bilges.

Drippage From Steering Gear and Reciprocating Pumps

Steam steering engines (observed on all ships except the REISS, which has electrohydraulic gear) and reciprocating pumps require lubrication of exposed parts (e.g., piston rods), and thus experience some drippage of oil to the deck,and then ultimately to the bilges. This is a typical source on all the ships observed, but because of careful housekeeping was contributing nothing to bilge contamination. For example, all obvious drips were seen to be served by ex-coffee cans that were presumably emptied (into a slop oil container, into the cargo, etc, but hopefully not into the bilge sump) periodically by the crew. But there is obviously the possibility of neglect and of spillage from the many open containers of oil.

Drippage From Oil Burners

Burners being removed from the furnace and serviced may drip fuel oil along the firing aisle. However, there was no evidence of bilge contamination from this source on the ships examined, apparently due to careful housekeeping practices by the crew.

Reciprocating Propulsion Engines

The conventional (i.e., non-uniflow) steam engine, as found aboard the CADILLAC in the present study, is lubricated by once-through supply of oil to its many sliding and rotating bearings. The oil is allowed to drain to the tanktop, whence it flows to the bilge sump, aided by water leakage from the engine. The quantity involved can be estimated from lube oil consumption rates, as is noted below.

Both the CADILLAC engine and the uniflow SNYDER engine discharge cylinder lubricant via the exhaust steam. This oil does not appear in the bilges, but goes directly overboard via the condenser discharge.

An estimate of the oil entering the Lakes from the two reciprocating engines can be made from consumption figures supplied by the respective chief engineers, checked against annual purchase by Cleveland Cliffs. The following rates of consumption were supplied by the chief engineers of the CADILLAC and SNYDER: CADILLAC, 5 quarts per day cylinder oil, 10 gallons per day bearing oil; SNYDER, 9 gallons per trip cylinder oil. If it be assumed that the operating season is 270 days per year, and that the SNYDER's 9 gallons per trip is approximately 1½ gallons per day, the annual contributions are easily computed. There is a third ship powered by reciprocating engine, the CHAMPLAIN, in the Cleveland Cliffs fleet. Since its engine is four-cylinder, its consumption may be estimated at 4/3 that of the CADILLAC (3 cylinders). The calculation can then be completed to give the following results:

	Cylinder Oil (via condenser)	Bearing Oil (via bilges)
CADILLAC	340	2700
SNYDER	405	--
CHAMPLAIN	450	3600
	1195 gal/year	6300 gal/year
Purchased, 1972	1105	5500

The last line is abstracted from the Cleveland Cliffs purchase summary for 1972, and shows fair confirmation of the estimate. (It also suggests that I have overestimated the influence of the additional cylinder on the CHAMPLAIN.)

A more tenuous estimate can be made of the oil discharged by the total of reciprocating ships on the Great Lakes. As of 1970 there were reported (A. T. Kearney Co. report to U.S. Maritime Administration, *Research Prospectus for Marine Pollution Control on the Great Lakes*, 1972) to be 190 ships of the U.S. and Canadian Lakes fleets with reciprocating engines. If it can be assumed that the ships named above are a representative sample, then the estimates are

Cylinder oil	1105 × 190/3 =	69,700 gallons/year
Bearing oil	5500 × 190/3 =	348,000 gallons/year

Because of the large uncertainties in these estimates, they should be regarded as very rough indeed.

SECTION VI

BILGE WATER SAMPLES

INTRODUCTION

As an adjunct to the work discussed in preceding sections, samples of bilge water, and of water contributing to the total bilgewater problem, were collected. Since it was possible to extract only a few samples from each ship, the samples are intended to be representative of what may be found, and no statistical implications are intended (e.g., samples from bilge pump discharge do not necessarily represent average conditions.

Several of the samples represent condenser overboard discharge from reciprocating-engined ships (CADILLAC and SNYDER). Although this is not truly bilgewater, it is known to contain oil originating from engine cylinder lubrication. The samples are therefore included.

SAMPLE IDENTIFICATION

Turbine Steamer PONTIAC

1. Engine room bilges just forward of reduction gear. Water in this area was originating principally from the main condenser vent. Vessel in Cuyahoga River.
2. Shaft alley bilges just forward of bilge sump. Representative of water as it enters sump. Vessel in Cuyahoga River.
3. Cuyahoga River water. Taken for comparison with other samples, particularly 1. and 4., and for other vessels sampled in the river.
4. From tank top at near main condensate pumps. Principal source of water appeared to be vent from nearby cooling water pump. Source of oil in this water not definitely identified. Vessel in Cuyahoga River.

Reciprocating Steamer CADILLAC

1. Condenser overboard discharge (should contain engine cylinder oil). Vessel in Cuyahoga River.
2. Bilge pump discharge. Principal source of bilge water at the time of sampling was propulsion engine drainage. Surface of bilge sump visually much oilier than this sample. Vessel in Cuyahoga River.
3. Surface of bilge sump. This sample lost.
4. Boiler room tank top. Source of water unknown.

Reciprocating Steamer WILLIAM P SNYDER

1. Condenser overboard discharge (should contain cylinder oil). Vessel in Cuyahoga River.
2. Bilge pump discharge. This sample should be relatively clean, since operators periodically skim oil from the bilge sump before the gross film reaches pump suction level. Vessel in Cuyahoga River.
3. Boiler room bilge sump. Vessel in Cuyahoga River.

Diesel Ship RAYMOND J REISS

1. Detroit River water. For comparison with bilge samples. Vessel off Monroe.
2. Engine room bilge. Taken outboard of aft end of propulsion engine. Bilges throughout flooded and very oily. Vessel in western end of Lake Erie.
3. Bilge pump discharge. This sample and 2. also may be contaminated with detergents because of recent attempts of crew to clean up spilled oil. Vessel in western end of Lake Erie.

Turbine Steamer WILLIAM MATHER

1. Bilge pump discharge. Vessel in lower Detroit River, off Grosse Isle.
2. Detroit River, taken from a sea chest drain. Sample may be contaminated by sea chest filler remaining from winter layup. Vessel in

lower Detroit River, off Grosse Isle.

3. Bilge sump. This sample skimmed from tops of the sump, and so should be oilier than sample 1. Major contaminent appeared to be stern tube lubricant. Vessel in western end of Lake Erie.
4. Stern tube leakage. This is lake water, but may be contaminated with stern tube lubricant. Vessel in western end of Lake Erie.
5. Engine room bilge. Taken near main condensate pump, and principal water source appeared to be this pump. Vessel in western end of Lake Erie.
6. Drip from contaminated drain tank drain. Vessel in western end of Lake Erie.

SAMPLE COLLECTION AND ANALYSIS

All samples were collected in new 32-oz polyethylene laboratory bottles. Bilge pump discharge samples (Cadillac 2, Snyder 2, Reiss 3, Mather 1) were drained from bilge sump casing vents. Condenser overboard discharge samples (Cadillac 1, Snyder 1) samples were drained from condensate pump vents. River and lake water samples (Pontiac 3, Reiss 1, Mather 2) were drained from cooling water piping within the engine room. Mather 4 and 6 samples taken by holding bottle into continuously running streams of the water. All other samples taken by dipping bottle into puddle; in the case of sump samples (Cadillac 3, Snyder 3, Mather 3), they were skimmed from the surfaces.

Analyses were performed according to the methods in "Standard Methods for the Examination of Water and Wastewater," 13th Edition, 1971, A.P.H.A., save for the TOC determinations which were done using the sealed ampule oxidation technique using an Oceanography International Corp. system. TOC numbers obtained in this way should be as good, if not better than those obtained by the injection method.

Analytical procedures in "Standard Methods" are quite comparable to, although not in all cases exactly the same as, those in the EPA manual.

Results of anlayses are summarized in Table 1.

Table 1. SAMPLE SUMMARY

Sample	Volume, ml.		Description	Remarks
	Initial	Water		
Mather #1	700	700	Bilge Pump Discharge	no apparent oil phase; some large filamentous (rope-like) particulate matter
Mather #2	700	650	Detroit River and Seachest Filler	no apparent oil phase; low conc. sett. sol; mod. turbidity; susp. sol.
Mather #3	800	800	Bilge Pump	no apparent oil phase; very high conc. sett. sol; partic. matter sim. Mather #1
Mather #4	700	600	Stern Tube (Lake Erie)	no apparent oil phase; low conc. susp. & sett. sol; some partic. sim. Mather #1
Mather #5	700	650	Eng. Rm. Bilge Near Condensate Pumps Cond. Sump	no apparent oil; poss. emulsion; mod. susp. sol; high turbidity
Mather #6	200	200	Drip from contam. drain tank	no apparent oil; mod. sett. sol; low susp. sol.
Snyder #1	1000	950	Condenser Overboard, Cuyahoga River	no apparent oil; mod. sett. & susp. sol; water colored
Snyder #2	900	800	Bilge Pump Discharge	no apparent oil; low-mod. sett/susp sol; some partic. matter sim. Mather #1
Snyder #3	700	650	Boiler Room Sump	no apparent oil; suspect presence of oil; water colored; low sett. sol; mod. susp. sol.
Pontiac #1	600	600	Fwd of Reduction Gear	no apparent oil; high sett. sol; mod susp sol; water colored

Table 1 (continued). SAMPLE SUMMARY

Sample	Volume, ml.		Description	Remarks
	Initial	Water		
Pontiac #2	600	575	Shaft Alley	oil phase present; mod. susp. sol; low sett. sol.
Pontiac #3	800	800	Cuyahoga River	no apparent oil phase; partic. sim. Mather #1; mod. sett. sol; high susp. sol.
Pontiac #4	700	700	Under Mn Condenser	oil present; turbid & highly colored; mainly w/oil; high susp. & sett. sol.
Reiss #1	800	800	Lake Erie near Mouth Detroit River (cool sys.)	no apparent oil; high susp. sol; mod. sett. sol.
Reiss #2	900	900	Engine Room Bilge	oil phase apparent; extremely turbid; oil/water emulsion/dispersion
Reiss #3	800	800	Bilge Pump Discharge	oil phase apparent; extremely turbid; oil/water emulsion/dispersion
Cadillac #1	800	800	Condenser Discharge	ext. high sett. & susp. sol; highly colored & turbid; black material present in sample.
Cadillac #2	800	800	Bilge Pump Discharge	no apparent oil; mod. sett. & susp. sol; some partic. sim. Mather #1
Cadillac #4	800	800	Boiler Room Tank Top	ext. high sett. & susp. sol; highly colored and turbid; no apparent oil

**NOTE: there was no "Cadillac #3" sample.

Table 2. TOTAL, FIXED, AND VOLATILE NON-FILTRABLE RESIDUE

Sample	Total (mg/ltr)	Fixed (mg/ltr)	Volatile (mg/ltr)
Mather #1	1.0	ND	1.0
Mather #2	5.5	4.5	1.0
Mather #3	97.3	12.0	85.3
Mather #4	7.0	4.0	3.0
Mather #5	86.0	ND	86.0
Mather #6	NR	NR	NR
Snyder #1	99.0	84.0	15.0
Snyder #2	15.0	10.0	5.0
Snyder #3	13.0	7.0	6.0
Pontiac #1	172.5	137.5	35.0
Pontiac #2	14.5	1.0	13.5
Pontiac #3	6.0	ND	86.0
Pontiac #4	427.5	277.5	150.0
Reiss #1	12.0	8.5	3.5
Reiss #2	200.0	ND	200.0
Reiss #3	900.0	ND	900.0
Cadillac #1	127.0	97.0	30.0
Cadillac #2	6.8	2.0	4.8
Cadillac #4	146.5	28.5	118.0

ND : not detected
NR : not run; insufficient sample
Method: APHA, 1971

Table 3. pH, COLOR AND TURBIDITY

Sample	pH	Color	Turbidity, FU	Remarks
Mather #1	6.9	5	4	---
Mather #2	7.0	5	5	---
Mather #3	6.6	10	10	---
Mather #4	7.1	10	4.8	---
Mather #5	6.4	25[a]	40	color due to oil
Mather #6	3.9	5	6	---
Snyder #1	6.4	20	23	---
Snyder #2	6.2	10	6	---
Snyder #3	6.0	5	8	---
Pontiac #1	6.7	20	22	---
Pontiac #2	7.2	20	8	---
Pontiac #3	6.4	25	9	---
Pontiac #4	10.0	150[b]	83	---
Reiss #1	6.5	5	10	---
Reiss #2	5.7	125[a]	48	color due to oil
Reiss #3	NR	125[a]	50	color due to oil
Cadillac #1	6.9	10	32	---
Cadillac #2	6.6	5	8	---
Cadillac #4	5.5	5	4.5	---

NR : not run

[a] color by 1:5 dilution
[b] color by 1:10 dilution

Table 4. TOTAL ORGANIC CARBON

Sample	(mg/ltr)
Mather #1	3.1
Mather #2	2.2
Mather #3	10.3
Mather #4	2.4
Mather #5	46.7
Mather #6	0.8
Snyder #1	7.0
Snyder #2	2.9
Snyder #3	4.1
Pontiac #1	10.6
Pontiac #2	16.0
Pontiac #3	5.7
Pontiac #4	77.5
Reiss #1	1.6
Reiss #2	2.33×10^3
Reiss #3	625.0
Cadillac #1	11.3
Cadillac #2	4.1
Cadillac #4	6.3

Table 5. OIL AND GREASE

Sample	Oil (mg/ltr) × 10
Mather #5	4
Mather #3	3
Pontiac #1	7
Pontiac #2	0.8
Pontiac #4	5
Reiss #2	131.2
Reiss #3	39.2
Cadillac #1	not detected

SECTION VII

APPENDIX

CLEVELAND CLIFFS FLEET 1973

	TONNAGE gross/net	YEAR BUILT	YEAR ENGINE	POWER	ENGINE TYPE
CADILLAC	9053/6364	1943	1943	2500	stm recip(3X)
Champlain	8757/5569	1943	1943	2500	stm recip(4CC)
Charles M White*	9115/5719	1951	1946	9900	stm turbine
Cliffs Victory*	11151/7309	1951	1945	9350	stm turbine
Edward B Greene	11726/8730	1952	1952	7700	stm turbine
Frontenac	7898/5980	1923	1954	5500	stm turbine
PONTIAC	7918/5903	1917	1955	5500	stm turbine
RAYMOND H REISS	8220/6496	1916	1966	4320	diesel
Thomas F Patton*	9115/5719	1951	1946	9900	stm turbine
Thomas M Girdler*	9115/5719	1951	1946	9900	stm turbine
Walter A Sterling*	13122/9879	1961	1942	7700	stm turbine
WILLIAM G MATHER	8653/6772	1925	1954	5500	stm turbine
WILLIAM P SNYDER JR	8603/6650	1912	1950	5000	stm recip(U)
Willis B Boyer	8603/6650	1911	1952	4950	stm turbine

Notes:

1. Ships with * by name were converted from ocean service. Year given in third column is date of conversion.
2. Power is shaft horsepower for turbine ships, indicated horsepower for reciprocating engine ships, and brake horsepower for the diesel ship.
3. U = uniflow, 4CC = four-cylinder compound, 3X = triple expansion.
4. Data on tonnages and powers is taken from the *Record*, American Bureau of Shipping, 1972.

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16. ABSTRACT

Sources of bilge water and of oil in bilge water were surveyed aboard five ships of the Cleveland Cliffs Iron Company. The ships included two powered by steam turbines, one by a uniflow steam engine, one by a conventional reciprocating steam engine, and one by a diesel engine. It is found that many sources of bilge water are clean sources. Although no accurate estimate of the water thus contributed to the bilges can be offered, it is concluded that diverting these sources from the bilges could ease the task of separating, storing, and disposing of oil wastes. Several samples of water were taken from each ship, and analyzed for total, fixed and volatile non-filterable residue, color, pH, turbidity, total organic carbon, and oil and grease concentration.

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