American Chemical Society
147th National Meeting
Philadelphia, Pa.,
April 5-10, 1964

FUEL CONTAMINATION IN A MARINE DIESEL ENGINE

A Radiotracer Study

by

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ABSTRACT

A radiotracer method was applied to the problem of elucidating the mechanism of contamination of crankcase oil by fuel combustion products in a marine diesel engine. The method consisted of adding an oil soluble radioisotope to the fuel and tracing its route to the various lubricants used in the engine. It was found that of the total amount of combustion products and by-products which enter the crankcase oil, 65% enters by simple contamination via reintroduction of used cylinder lubricant and 35% by a condensation mechanism.

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One of the more common designs for large diesel engines is the crosshead-type single-acting two-cycle engine in which the pistons are cooled by pumping non-additive crankcase oil through a special annular path within the piston. Lubrication of this engine takes place by: a) continuously injecting fresh cylinder oil directly onto the cylinder wall, and b) by proper distribution of a separate crankcase oil stream to other parts of the engine. That is, two nominally independent lubrication systems are employed, one using alkaline oil on a once-through basis to lubricate the cylinders and to combat acid corrosion by combustion gases and the other using a high grade non-additive oil to lubricate the bearings and cool the piston (see Figure 1). A serious problem frequently faced in such operation arises from the buildup of acidity and deposits in the non-additive crankcase oil which threaten to foul the piston cooling ports. The question generally asked is: Has the crankcase oil deteriorated due to its own instability or has it somehow become

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contaminated with fuel combustion products which are difficult to distinguish from crankcase oil decomposition products?

Experimental

To answer this question, a tracer experiment was run aboard a diesel-powered ship during a 24-hours trip between San Francisco and San Pedro, California. Radioactive cobalt-60, as the oil soluble naphthenate, was introduced into the fuel tank and thoroughly mixed with the fuel. Continuous samples of crankcase oil, gland oil (see Figures 1 and 2), and spent cylinder oil (sludge oil) were taken during the entire trip in order to have representative samples. The various oils were then analyzed for %w calcium, vanadium, and sulfur. Also determined were the cobalt-60 content and total acid number. The cobalt-60 content was measured by dip counting one-kg samples with a two-inch NaI(Tl) crystal coupled to a conventional scaler. The data appear in Table 1.

TABLE 1. ANALYSIS OF VARIOUS OILS

Sample	Acid No.[a]	Ca,[d] ppm	V, ppm	S, %w	Co^{60} (cpm/gram)	% of Total Co^{60} Added[b]
New Crankcase Lubricant	Nil	Nil	Nil	0.21	Nil	-
Gland Oil Drain (Used Crankcase Lubricant)	0.3	17	8	0.24	1.61	0.0124
Crankcase Oil (Used Lubricant Taken from crankcase)	0.3	3	2	0.21	.006[c]	0.003
Used Cylinder Oil (Sludge Oil)	>20	1,500	570	2.0	103.3	0.063

a) Total acid No., electrometric-mg KOH/g sample.
b) Percent of Co^{60} added to system, found in the total quantity of the oil.
c) Result from ashing 9 kilograms of oil and counting the ash.
d) Calcium analysis by flame photometry - precision <±5%.
Vanadium analysis by colorimetry - " <±5%.
Sulfur analysis by quartz tube - " <±3%.

Calculations

Several useful calculations may be made from the data in Table 1. First, one compares the difference in the calcium and vanadium contents of the gland oil and the used cylinder oil. From Figure 1, it is clear that if used cylinder oil finds its way through the air box, into the gland oil stream, the latter will become contaminated by the burden in the used cylinder oil. That this may occur is borne out by the analysis of the gland oil in which gross calcium is 17 ppm, vanadium is 8 ppm, and the net calcium is 14 (17 less 3 already in the crankcase oil), and net vanadium is 6 ppm. Assuming that this increase in calcium comes only from the used cylinder oil, one finds that $100 \times \frac{14}{1500} = 0.93\%$ of the gland oil is cylinder oil. Further, using the vanadium as the tie element, the value is: $\frac{6}{570} \times 100 = 1.05\%$, a value very close to that for calcium. Thus, it appears that the gland oil is contaminated with 1%w of used cylinder oil. Next, comparing the relative amounts of Co^{60} activity in the gland oil and used cylinder oil, one finds $\frac{1.61}{103.3} \times 100 = 1.56\%$ of the activity in the used cylinder oil is in the gland oil. This value is higher by 0.56% than the 1% found from the calcium and vanadium ratios. Thus, this surplus amount of activity (~35% of the total activity in the gland oil) must have entered the gland oil by a mechanism other than direct contamination with used cylinder oil. This mechanism is, most reasonably, a condensation of combustion product blow-by onto the piston rod which is wet with gland oil.

In normal practice the great bulk of the gland oil is returned to the crankcase proper. In the experiment described, about 100 liters of gland oil per day was being returned to the crankcase. A simple calculation based on the properties of the used cylinder oil showed that, if one liter of the cylinder oil entered the crankcase per day (1% of 100 liters), it was contributing

0.6 g/day of vanadium and 100 grams/day of iron, both excellent oxidation catalysts. To this one must add the additional quantity of acidic sulfur, soot, etc., in the combustion by-products which condense onto the piston rod and are also carried into the crankcase by the gland oil. Thus, the rate of contamination of the crankcase oil by used cylinder oil is high enough to markedly affect the properties of the crankcase oil over several months' operation.

Conclusion

Considerable fuel contamination of the crankcase oil is possible in a large marine diesel of the type described above. This contamination occurs via the gland oil which is returned to the crankcase and which may be oil originating either from the crankcase by working its way up the piston rod to lubricate the gland or cylinder oil not scavenged as sludge oil. Two modes of contamination may then occur. The first is simple solution of a small amount of the highly contaminated used cylinder oil by the gland oil; the second is by condensation of some of the combustion blow-by products onto the oil-wet piston rod. The former mechanism accounts for about 65% of the contamination in the gland oil; the latter about 35%.

A simple remedy to this problem lies in diverting the gland oil before it can return to the crankcase (~30 gal/day). Additionally, the use of a much more basic cylinder lubricant would reduce the potency of used cylinder oil as a serious contaminant by combating metal corrosion by the acidic combustion blow-by.

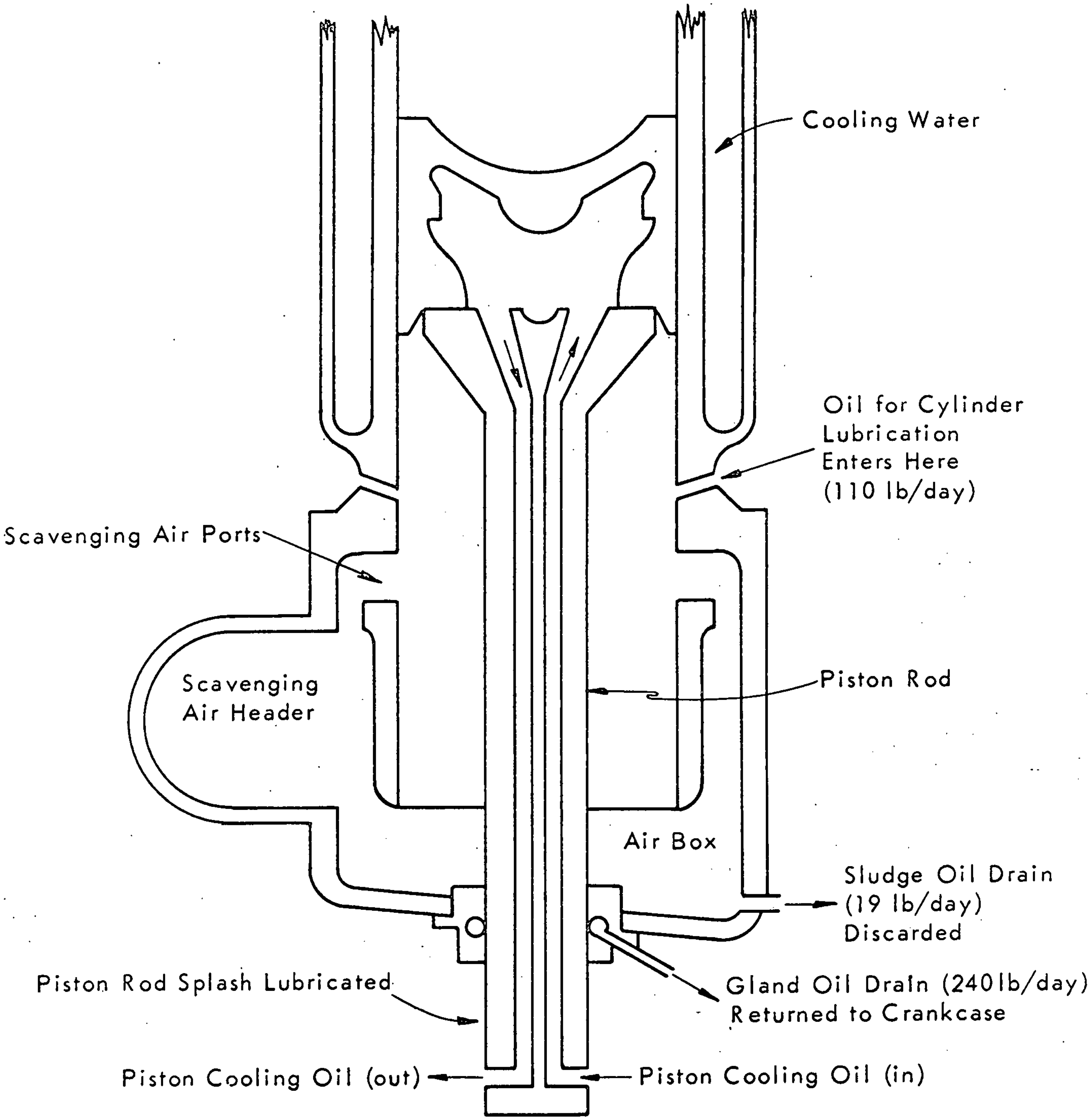

Figure 1. PISTON COOLING AND LUBRICATION CROSSHEAD TYPE SINGLE ACTING 2 CYCLE DIESEL ENGINE

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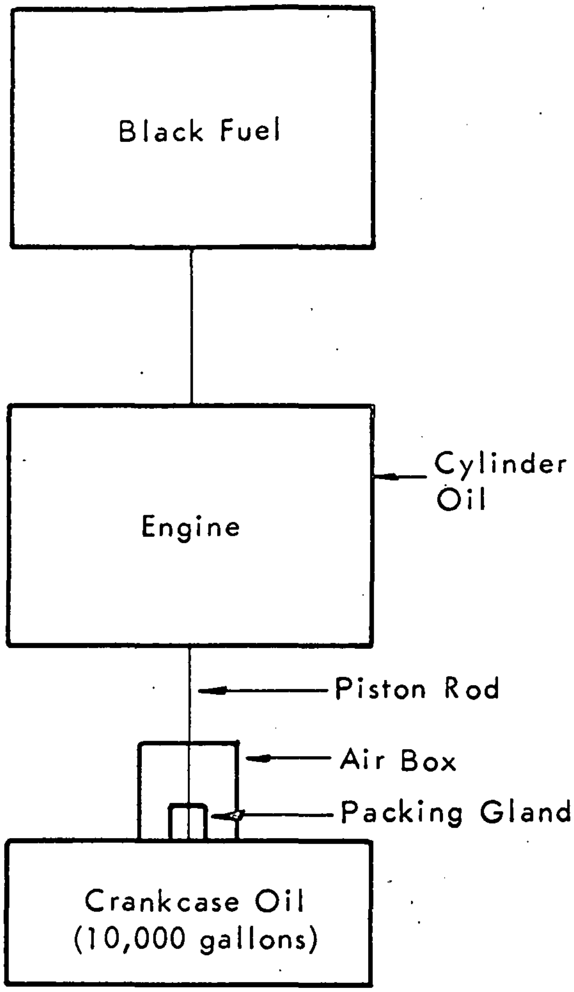

Figure 2. BLOCK DIAGRAM OF FUEL/LUBRICANT SYSTEM

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