LABORATORY EVALUATIONS OF THE 4th ML OF TEL

I. Reports Related to Engine Durability and Deposit Effects

1. Report No. PR-24, "The 4th Ml of TEL"

This report summarizes a large number of data accumulated since 1954. It covers the antiknock effectiveness and economics, as well as the durability and deposit effects, of high TEL concentrations. For convenience it is divided into three sections: Antiknock Effectiveness, Engine Durability, and Deposit Effects.

The results reported in the Engine Durability and Deposit Effects sections are based on over 4,000,000 miles of vehicle testing in light and medium passenger car service and in heavy duty truck service. In addition to this, 12,000 hours of testing was done in two farm tractor fleets plus several thousand hours of dynamometer testing. In all cases, the comparison was made between engines operated on 3.17 gms Pb per gallon and 4.23 gms Pb per gallon.

The results of many tests, in various types of engines and service conditions, indicate that higher TEL concentrations can be used without deleterious effects on valve life and engine wear. There may be a slight increase in wear of some engine components when 4.23 gms Pb is used. However, this increase is not critical, since the wear rates are well within acceptable limits. Also, data indicate that engine cleanliness may be improved by higher TEL concentrations.

Dynamometer and road tests have shown that the 4th ml of TEL decreased the miles to spark-plug fouling in some engines, but the decrease was small compared to the variations in plug life among engines of different makes. These tests also showed that the 4th ml of TEL does not significantly affect stabilized knock or surface-ignition requirements.

2. Report No. IR 61-4, "Deposit Effects with Lead Antiknocks"

The type of combustion chamber deposits that are formed in light-duty passenger car service, such as prolonged driving in city and suburban areas, may cause surface ignition if the vehicle is suddenly accelerated to relatively high speeds. In high compression engines, surface ignition is often accompanied by objectionable noise, generally termed rumble.

Such deposit effects are influenced by fuel and lubricant composition as well as by engine design. TEL and TML were

compared at each of two lead concentrations and with each of two scavenger formulations. The lead concentrations were 3.17 and 4.23 gms per gallon. The scavengers were those used in Motor Mix and Aviation Mix.

Differences were observed between TEL and TML and between Motor Mix and Aviation Mix; but no significant differences were found between the two lead concentrations.

3. Report No. TS-177, "Field Service Experience of Vehicles Operating on High Lead Content Fuels"

A survey was conducted on 34 fleets representing 555 commercial vehicles, with gross weights (GVW) ranging between 4000 and 78,500 pounds, which have operated for the past two years on fuels containing on the average 3.38 gm to 4.23 gm Pb per gallon. During the two or three years prior to this the average yearly level of the fuels on which these fleets operated was 2.55 to 3.17 gm per gallon. The records of maintenance practices by these fleets indicate valve life, piston ring life, cylinder bore wear, bearing life and spark plug life have not materially changed during the past four or five years. The discussions with the Maintenance Superintendents of these fleets also have confirmed this.

During the past year periodic contacts have been made with the Service Departments of the various automobile companies, the Engineering and Service Departments of the commercial vehicle manufacturers, and with the Engineering and Service Departments of the tractor companies for discussions concerning engine durability problems. We have not found any evidence that field problems which might be related to fuel utilization are greater in any specific geographic areas than in others. This suggests field service problems in all areas, whether the vehicles are operating on high or low lead content gasolines, are being handled satisfactorily by the dealers.

4. Report No. ER-436, "Effect of 4th Ml TEL on Engine Performance and Durability--Continental MS-330 Engineer Corps Engines"

The test program was conducted using two Continental MS-330 Engineer Corps engines operated under a modification of Military Specification MIL-E-11278B. The specification was modified to indicate the possible difference in spark plug performance of this model engine on fuel containing 3 ml (3.17 grams Pb) TEL and 4 ml (4.23 grams Pb) TEL per gallon of gasoline.

The results of these 1000-hour tests showed that increasing TEL from 3 to 4 ml per gallon produced:

1. No change in valve life.
2. No change in power loss due to deposits.
3. No change in spark plug life if the plugs had been serviced according to the MIL-E-11278B Military Specification. This is further explained in the discussion of test results.
4. An 18% increase in combustion chamber deposit weight.
5. A 14% decrease in piston-top deposit weight.

5. Report No. ER-437, "Effect of 4th Ml TEL on Engine Performance and Durability--Military Standard Engines Model 2A016-2"

The test program was conducted using four Model 2A016-2, Military Standard engines. These engines were operated under a modification of the Military Specification MIL-E-11278B. The specification was modified to indicate the possible difference in spark plug performance of this model engine on fuel containing 3 ml (3.17 grams Pb) TEL and 4 ml (4.23 grams Pb) TEL per gallon of gasoline. Two engines were operated 1000 hours on each lead concentration.

The results of these 1000-hour tests showed that:

1. No valve failures occurred in any engine.
2. Exhaust valve lash loss was not affected by increasing lead concentration from 3.17 gm to 4.23 gm per gallon.
3. Power loss due to deposits was negligible at both lead concentrations.
4. Total combustion chamber deposits were 15% less in engines operated on 4.23 gm Pb than in engines operated on 3.17 gm Pb.
5. No differences in spark plug performance would have been noted if the plugs had been serviced in accordance with MIL-E-11278B. However, no plug servicing was done, and the plugs were left in the engines until failure occurred. Under this procedure, spark plug life was 29% less at the higher lead concentration.
6. The difference in performance and durability are greater between engines operated on the same TEL concentration than between engines using different TEL concentrations.

II. Reports Related to Miscellaneous Aspects of Higher Lead Concentrations

1. Paper No. 57-10, "Particulate Lead Compounds in Automobile Exhaust Gas" by D.A. Hirschler, L.F. Gilbert, F.W. Lamb, and L.M. Niebylski

This paper presents the results of a comprehensive study of the amount, composition, and particle size distribution of

the lead compounds present in the exhaust gases of automobile engines operated on fuels containing tetraethyllead. It was found that city-type driving tends to exhaust considerably less lead than is burned by the car and that the excess lead which deposits on exhaust system surfaces tend to be exhausted under higher speed or higher load conditions. The data also show the amount of lead exhausted, expressed as a percent of lead burned, is the same for both the 3.0 and 4.0 ml TEL/gallon concentrations.

2. Report PR-24A, "The Effect of 4th Ml TEL on Lubricating Oil Performance in 'MS' Tests"

There was no significant difference between the "MS" test results obtained with 3.17 gm and 4.23 gm Pb. This is in spite of the fact that the tests were run with a commercial 10W-30 motor oil which had a MIL-L-2104A additive treatment instead of the usual Supplement 1 level of additive treatment. Thus, the 4th ml of TEL does not contribute to varnish or sludge deposits, rusting, wear, oil ring clogging, or oil screen clogging in the "MS" Sequences I, II, III, and V.

The foregoing results of the "no effect" of 4th ml of TEL on engine deposits are in agreement with those previously observed in FL-2, EX-3, and L-4 tests (Reported in PR-24). It is concluded that increasing fuel lead content from 3.17 gm to 4.23 gm per gallon will have an insignificant effect on the performance of lubricating oils.

III. Reports Related to Antiknock Effectiveness and Economics

1. Report No. PR-24, "The 4th Ml of TEL"

This report summarizes a large number of data accumulated since 1954. It covers the antiknock effectiveness and economics, as well as the durability and deposit effects of high TEL concentrations. For convenience it is divided into three sections: Antiknock Effectiveness, Engine Durability, and Deposit Effects.

A comparison of tetraethyllead with refinery processing as a means of producing gasoline octane number indicates several possible advantages for TEL. For example, it has been observed that the resulting increase in Research Octane number alone does not adequately reflect the practical benefits stemming from higher TEL content. Motor octane number, usually a better criterion of the high-speed high power output and part-throttle road antiknock performance of a fuel, often is increased more than the Research octane number when TEL is used. Thus, with TEL, antiknock quality can be raised without increasing fuel sensitivity.

TEL also gives gasoline better road performance than would be anticipated from laboratory engine ratings. The trend toward more aromatics and fewer olefins will increase this "road bonus" in the future. As compared with processing, additional TEL shows an advantage at full-throttle at the average speed for maximum knock, and this superiority tends to increase at higher speeds. Additional TEL is particularly effective under part-throttle knock conditions.

The inherent flexibility that TEL provides in refining operations is another distinct advantage. By using TEL to produce competitive octane numbers, refiners can better schedule refinery operations and capital investment for processing equipment. Since each refiner's operation is unique in itself, no attempt has been made to show the effects of increased lead in all types of fuels.

2. Report No. RT-97, "Road Octane Correlations for Premium Gasolines - 1960"

3. Report No. RT-98, "Road Octane Correlations for Regular Gasolines - 1960"

4. Report No. RT-99, "Part-Throttle Road Octane Correlations for Premium Gasolines - 1960"

5. Report No. RT-111, "Road Rating Fuels in the General Motors ES-59 Test Engine"

6. Report No. RT-113, "TEL Road Bonus"

7. Report No. RT-130, "Prediction Systems for Road Antiknock Quality of Premium Gasolines - 1961"

The above reports present the results of programs conducted to develop correlation equations for predicting road antiknock performance of commercial gasolines from laboratory inspection data. Previous studies, conducted at a constant tetraethyllead (TEL) level, have shown that laboratory Research and Motor octane numbers and hydrocarbon-type content are satisfactory variables for predicting the road behavior of fuels.

Continuing investigations have indicated that the inclusion of tetraethyllead content (TEL) significantly increases the accuracy of such equations when TEL is a variable. Equations of the following general form were selected:

$$\text{Road O.N.} = a + b\,(R) + c\,(M) + d\,(O) + e\,(\text{TEL}) + f\,(A)$$

where R = Research octane number
M = Motor octane number
O = Olefins, Vol.%
A = Aromatics, Vol.%
TEL = Tetraethyllead, ml/gal

The coefficients for TEL in standard production automobiles have shown average values as high as 0.488 (Report No. RT-113) at some speeds and throttle settings. This means that under these conditions, when two gasolines have the same Research and Motor octane numbers and the same general hydrocarbon-type concentrations, the one with the higher TEL content will on the average, rate 0.488 octane numbers better on the road for each ml TEL (1.057 gm Pb) difference. The coefficients for TEL in the experimental General Motors EB-59 Test Engine at 12.1 to 1 compression ratio (Report No. RT-111) was as high as 1.155 under one set of operating conditions.

8. Report No. RT-112, "Road and Laboratory Antiknock Data on Lead Alkyls"

9. Report No. RT-132, "Road and Laboratory Antiknock Data on Lead Alkyls in the General Motors EB-59 Test Engine"

The results included in these reports are from programs designed to evaluate the performance of the various lead alkyl antiknock compounds in a variety of fuels (representive of 57% of U.S. production) run in both regular and premium requirement cars. Lead content ranged between 1.58 gm Pb and 3.70 gm Pb/gallon and the reports deal primarily with data presentation. The data indicate the lead level significantly contributes to road octane quality when rated by the Modified Uniontown method; i.e., the average lead coefficient was as high as 0.384.

10. Paper No. 61-10, "Economics of Antiknock Selection" by W.W. Sabin and C.J. Wolf. Western Petroleum Refiners Association (now NPRA) San Antonio, Texas, April 10, 1961.

Material in this paper serves to demonstrate that changes in refinery gasoline composition can often result in significant savings to the refiner when full advantage can be taken of the flexibility permitted by the various lead antiknocks available. The advantages to the refiner of the flexibility of operation permitted by higher lead contents (3.7 gm Pb/gallon) are shown also.