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REPORT ON

Potential Health Hazard from the Use of Leaded Fuel in a Coleman Model Army Field Range Fire Unit

I. Purpose

(a) To determine the magnitude of the health hazard arising from the use of leaded gasoline for fuel in the fire unit; and secondarily,

(b) To determine the effective length of life of the filter discs used to remove the lead.

II. Conclusions

1. No health hazard exists from the breathing of lead in air when the stove is operated in rooms or enclosures under normal conditions of ventilation. Small amounts of lead escape through the burner. A small portion of this lead will be deposited on the surface of cool cooking receptacles while the remainder will escape into the air.

2. There is no danger that food prepared in receptacles will be contaminated, but the unit should not be used to prepare food which comes into direct contact with the flame (broiling or grilling).

3. With a rated fuel of 1.77 cc. of tetraethyl lead per gallon, satisfactory operation with a minimum of cleansing was obtained for 114.76 hours with a single filter unit.

III. Procedure and Discussion

In order to ascertain the fate of all the lead and thereby to establish the magnitude of the health hazard, the amount of lead present in the quantity of gasoline consumed in the stove was determined by analysis and balanced against the amount found in the flue gases plus that retained in the burner itself. The unit was placed in the cabinet designed to enclose the burner, and a suitable hood and stack were provided in order to measure the quantity of flue gas produced and to determine its lead content. The equipment employed for this purpose was similar to that described in a report dated June 1, 1941, except that a larger exhaust fan was installed, the use of which effectively prevented back drafts on windy days. An orifice disc for measuring flue volumes was also installed in the flue pipe. The volumes of flue gas as measured by this means were employed to check the values obtained indirectly by analysis of the carbon dioxide content of the flue gas. (Findings based on the latter values have been included in this report as in previous reports.) That this method was satisfactory is demonstrated in Table 4, in which, among other data, the total lead content of the flue gas has been calculated from the volumes arrived at by the two methods of measurement.

In Table 1 are listed the results on the five series of tests, D, E, F, G, ~~H~~, made with the present Coleman model. Series G was the one employed for the balance study reported in Table 4. The other data listed in Tables 2 and 3 were also obtained from this series.

All runs except those of series G were made with fuel containing 2.82 cc. of tetraethyl lead per gallon. This type of fuel was no longer available, however, and since it was convenient to use a type which was on the market, all runs in series G were made

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with gasoline containing 1.77 cc. of tetraethyl lead per gallon.

Series D

This series was originally planned to serve as the balance test. Because of operational difficulties, however, very high values were obtained for the effluent lead and it became evident that the lead removal was inadequate. This inefficiency was attributed to lack of sufficient heat at the generator to cause pyrolysis of the tetraethyl lead. Operation of the burner was continued, however, until a 50-pound pressure failed to give satisfactory performance at the end of 22 hours. During this run the burner slots became clogged with a yellowish deposit and had to be cleaned several times. When the run was finished, the vapor tube was almost completely filled with a grayish deposit, which had practically closed its two screens.

Series E

E-1 of this series was carried out to determine whether the high results obtained in series D were due to variability in the porosity of the individual filters. In this run the burner was not cleaned, but a clean vapor tube and a flame valve were employed. The result was in agreement with that reported for series D. E-2 was made with the same disc that had been employed in E-1, but more heat was applied to the generator heaters by removing all but the inner circle of closures in the heater outlets of the generator, thereby increasing the number of openings from 22 to 37. In this test the burner slots were cleaned before the unit was lighted. As may be seen from Table 1 there was a slight improvement in performance.

Series F

The two tests in this series were made for the purpose of comparing the variability of filters made of Johns-Mansville asbestos and another merely designated as "Lorico." The results are in agreement with those obtained in series E, indicating that the variations in filter material are not significant.

High findings were obtained in E-2, F-1, and F-2 in spite of the increased heat of the generator. Most likely they were due to gradual volatilization of lead deposited in the burner following the tests in series D. Except for occasionally scraping the burner slots, no attempt had been made to clean the burner itself since the start of series D.

<u>Series G</u>

Before series G tests were started, the burner, vapor tube, and flame valve were cleaned as thoroughly as possible by scraping away all deposited scale, following this by treatment of the contaminated surfaces with hot dilute nitric acid and a hot 20% solution of ammonium acetate. The cabinet, hood, and piping equipment were also dismantled and the surfaces were thoroughly cleaned first by scraping with a wire brush and then by wiping down the surfaces with clean rags. For this test, as we have stated above, the only fuel available was that containing 1.77 cc. of tetraethyl lead per gallon. As in the previous tests, each period of operation extended over 3.5 hours, the unit being allowed to cool to room temperature before the next test was started. In order to operate the unit as consistently as possible, the flue gas temperature was observed by means of a pyrometer and the temperature was kept practically constant by manipulating the air pressure and flame valve. The temperature control was chosen so as to give a constant consumption of 0.40 gallon of fuel per hour. The unit operated satisfactorily for a period of 114.76 hours at air pressure at or below 50 pounds.

It was intended to terminate the test at the end of 80.66 hours and therefore the cabinet and hood were dismantled and cleaned (the collected deposit was removed by wiping the surfaces with filter paper). The flame valve and vapor tube were also cleaned and all deposits and scrapings were reserved for analysis. Meanwhile a request was received that the test be continued until a pressure of 50 pounds was required for operation. (The unit had still been operating at pressures below 50 pounds.) The cabinet and hood were therefore reassembled and the period of the test was extended to 114.76 hours. This was done with the uncleaned burner and disc, the only clean parts installed being a vapor tube and flame valve. At the end of this period, the stove and hood equipment were again dismantled and thoroughly cleaned. The burner, vapor tube, and flame valve were cleaned as before at the start of the test, while the hood, cabinet, and piping were wiped down with strips of filter paper. All deposits and solutions were reserved for lead analyses, the results of which are recorded in Table 4. Two sets of values are given to enable comparison of the adequacy of the methods employed in determining the volume of flue gases. In this table correction is made for the lead present in the small quantity of fuel drained at the start of each run after the generator had attained proper operating temperature. Correction of the amount of lead in the flue gas had also been made for the amount deposited on the walls of the cabinet, hood, and piping up to the locus of the precipitator tube.

In Table 2 are listed the values for lead found in the flue gas for the individual periods of operation. These values have not been corrected for the amount of lead lost as deposit on the walls of hood, cabinet, or piping, or for the small amount of lead present in the average amount (10 grams) of fuel drained from the burner at the start of each run. As can be seen from the data, the performance of the filter gradually improved until it had been operated for 63 hours, probably because of the filling-up of the pores of the filter by the lead salts. Longer operation caused a slight increase in the lead passed by the burner. This slight decrease in efficiency may be due to a number of causes:

1. The gradual filling-up of the lower portion of the generator, plus the heat, may cause the filter case gradually to expand, until it practically seats itself over the generator heater outlets. This causes a drop in the heat output at the heater outlets, and impairs the pyrolytic efficiency of the generator. This condition can be remedied by installing a pin over each heater outlet to keep the generator from seating itself over the heater outlets.
2. The lead deposited on the lower surface of the generator acts as a heat insulator and thus prevents the attainment of the necessary pyrolytic temperature. This might be remedied by increasing the size of the generator unit or by providing the generator with a baffle plate which would keep the deposit off the lower wall. The use of the latter would also tend to prevent wetting of the filter disc by the boiling gasoline. It may very well be that the latter condition causes the passage of a small amount of liquid fuel through the filter, thus tending to increase slightly the quantity of lead passed into the air.

In Table 3 are recorded the average figures for the passage of lead into the flue gas during successive periods of a 3.5 hour run. The averages for comparable periods in 32 completed 3.5 hour runs were employed in compiling these data. The table also records the hourly lead output and it shows that the largest amount of lead is passed during the first hour of operation, while almost half of this amount is passed during the first 15 minutes of operation. The quantities of lead found during the various intervals of time have also been calculated on the basis of the content of 10 cubic meters of flue gas and the dilution required to reduce these quantities to the accepted maximum safe limit of 1.5 mg. per 10 cubic meters is also indicated. Thus it may be seen that whenever ventilation is necessary (when the unit is operated in enclosed spaces) considerably more ventilation will be required during the first hour than during any subsequent period.

In interpreting the dilution data, it should be borne in mind that a forced draft was employed in these tests and that under normal operating conditions there will be a smaller volume of flue gas with a consequently higher lead concentration. Ventilation under these conditions must be several times that indicated in the table.

Run J

Following the test in series G, a 3.5 hour test was made with the thoroughly cleaned unit and a new Johns-Manville filter. In this case fuel containing 2.82 cc. of tetraethyl lead per gallon was used and the conditions of operation were the same as in the G series. These data offer additional proof that the poor performance in the case of series D, E, and F was due to insufficient heat at the generator heaters and to volatilization of lead which had deposited in the burner during tests in series D. On the basis of the results of series G (Table 2) and test J, it may be predicted that performance would improve with length of operation of the same disc and that the burner would be as effective with fuel of higher lead content as with the lower.

Operational Difficulties

In all these tests very few mechanical difficulties were encountered, and the unit operated with a minimum of attention except that required to maintain comparable conditions in the successive runs.

In series D, it was necessary to clean the burner slots at least after every 7 hours of operation. After a test of 21 hours duration, it was necessary to insert a clean vapor tube and flame valve.

In series E and F, no cleanings were required and operations were satisfactory.

In series G, operation was very satisfactory. Burner slots did not clog. The vapor tube and flame valve were changed after 40.55 hours, but inspection showed that the vapor tube was still open as were the filter screens. At this time, for reasons described above, the filter disc was removed from the unit. When the request was received to continue the test, the disc was replaced but could not be tightened in place because of galling of the bolt provided for this purpose. On this account, a new bolt had to be made.

In series J, no operational difficulties were encountered except at the start when the new disc was inserted. This did not fit properly into its copper seat and a small leak developed. On inspection, it was seen that the seating had occurred at an angle which gouged out sufficient material to cause the leak. A new copper seat was inserted and the test was satisfactorily concluded. In order to avoid this difficulty in the field, it might be advisable to incorporate into the burner casting a series of pins so placed that the filter disc would just fit inside them. This would prevent the positioning of the disc at an angle.

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Table 1

Resume of Results on All Tests

Test	Duration of Test Hours	Gallons Fuel Used	Gallons per Hour	Lead in Fuel Used Grams	Lead in Flue Gas Grams	% of Total Pb in Flue Gas	Remarks
D-Series	22	10.45	0.475	31.5	7.54	23.8	Only outer circle of heater outlets of generator used
E-1	3.64	1.73	0.49	5.3	1.02	19.2	New filter, cleaned vapor tube and flame valve but burner not cleaned. Heater outlets same as above.
E-2	3.5	1.59	0.455	4.73	0.67	14.2	Same filter as E-1, burner slots cleaned, and all but inner circle of heater outlets of generator opened. Openings increased from 22 to 37.
F-1	3.5	1.73	0.495	5.16	0.742	14.35	Same as E-2 except new filter disc containing new Johns-Mansville filter.
F-2	3.5	1.64	0.47	4.88	0.629	12.85	Same as above but Lorico filter used.
G-Series*	114.75	47.9	0.417	89.57(a)	4.55(a)	5.07(a)	Burner, vapor tube, and flame valve cleaned as well as hood, piping, and cabinet. Fresh filter. Balance study.
[illegible]	3.5	1.44	0.412	4.29	0.287	6.69	Equipment cleaned following balance study, new filter disc.

*This series of tests with 1.77 cc. $Pb(Et)_4$/gallon fuel. All other runs with 2.82 cc. $Pb(Et)_4$/gallon fuel.

(a) These values are not corrected for lead in fuel drained from lighting valve at start of each 3.5 hour run or for lead recovered in hood, cabinet, and piping. Only total lead recovered in flue gas as calculated from electrolytic precipitator tube analyses has been used.

Table 2

Lead Recovery (as per cent) from Flue Gas in Individual
3.5 Hour Tests of Series G

Test	Hours of Test	Cumulative Hours	% of Total Pb in Flue Gas	Operating Pressure
G-A	3.5	3.5	5.43	20-21 lb.
G-B	3.5	7.0	5.90	20-22 lb.
G-C	3.5	10.5	7.05	20-24 lb.
G-D	3.5	14.0	5.83	20-24 lb.
G-E	3.5	17.5	4.70	23-30 lb.
G-F	3.4	20.9	4.65	25-28 lb.
G-G	3.6	24.5	5.33	25-35 lb.
G-H	3.5	28.0	5.36	26-33 lb.
G-J	3.5	31.5	4.83	30-35 lb.
G-K	3.5	35.0	4.43	30-36 lb.
G-L	3.57	38.57	4.50	28-35 lb.
G-M	3.5	42.07	4.84	28-34 lb.
G-N	3.5	45.57	3.87	26-34 lb.
G-O	3.59	49.16	4.17	28-36 lb.
G-P	3.5	52.66	4.20	28-38 lb.
G-R	3.5	56.16	4.22	26-35 lb.
G-S	3.5	59.66	3.68	26-38 lb.
G-T	3.5	63.16	3.36	26-37 lb.
G-U	3.5	66.66	3.59	29-40 lb.
G-V	3.5	70.16	4.93	30-41 lb.
G-W	3.5	73.66	4.14	30-42 lb.
G-X	3.5	77.16	4.58	35-43 lb.
G-Y*	3.5	80.66	5.05	35-43 lb.
G-Z	3.5	84.16	6.05	30-39 lb.
G-AA	3.5	87.66	5.85	30-41 lb.
G-BB	3.5	91.16	5.47	33-44 lb.
G-CC	3.5	94.66	5.27	35-44 lb.
G-DD	3.5	98.16	6.38	35-44 lb.
G-EE	3.5	101.66	6.48	36-45 lb.
G-FF	3.5	105.16	7.10	36-47 lb.
G-GG	3.5	108.66	4.80	35-50 lb.
G-HH	3.6	112.26	7.08	38-50 lb.
G-JJ	2.5	114.76	4.60	40-50 lb.
		Avg.	5.07	

*At this point it was originally decided to end test. Hood and piping were cleaned, but test was continued to 50 lb. pressure on request of the Office of the Quartermaster General.

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Table 3

Data for Lead Distribution in Flue Gas for a 3.5 Hour Test of Series G
(Values based on Averages for 32 Complete 3.5 Hour Runs)

Time Interval Minutes	Mg. Pb in Flue Gas	% of Total Pb in Flue Gas	Mg. Pb in Flue Gas per Hour	Mg. Pb/10 Cu. M. Flue Gas		Dilution of Flue Gas Required to Reduce Pb Concentration to 1.5 mg. Pb/10 Cu. M	
15	45.73	32.95		17.4		11.6	
15	12.62	9.09		4.8		3.2	
30	17.13	12.34	75.48	3.26	9.95	2.17	6.6
60	27.42	19.76	27.42		3.62		2.42
60	24.18	17.42	24.18		3.18		2.12
30	11.67	8.44	23.34		3.08		2.06
210	138.75 (0.1388 gram)	100.00					

Average amount of lead in fuel consumed per 3.5 hour test = 2.735 grams

Average per cent of total lead in flue gas = 5.07

Average amount of flue gas per hour = 2680 cu. ft. = 75.8 cubic meters

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Table 4

Balance Study of Series 3

			A		B	
Gallons of fuel used	47.9					
Lead in fuel used	89.57 g.					
Lead in fuel drained from starting valve and not used	0.42 g.					
Corrected lead in fuel used		89.15 g.				
Lead found in flue gas (precipitator samples)		4.55 g.				
Lead found in cabinet, hood, and flue piping		0.56 g.				
Total Lead in Flue Gas			5.11 g.	5.73%	5.45 g.	6.11%
Lead in vapor tube and flame valve			8.41 g.	9.43%	8.41 g.	9.43%
Lead in burner parts			1.77 g.	1.98%	1.77 g.	1.98%
Lead in filter disc and housing			72.10 g.	80.90%	72.10 g.	80.90%
Lead unaccounted for			1.76 g.	1.96%	1.42 g.	1.58%
			89.15 g.	100.00%	89.15 g.	100.00%
Total lead recovered			87.39 g.	98.04%	87.73 g.	98.42%

A -- based on amount of flue gas as calculated from CO_2 analysis

B -- based on amount of flue gas as calculated from orifice readings