NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
1003-20-4838

July 1 to Sept. 30, 1954

NBS REPORT
3685

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PROGRESS REPORT ON ENGINE AIR CLEANING

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to

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NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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A visit was made to the Cadillac Motor Car Division, GMC at Detroit, Michigan, to discuss and abstract the report on their investigation of engine wear using two dusts of 0 to 2-1/2 micron and 0 to 40 micron size respectively. This report had not been published and no copies were available but the company consented to having it examined and abstracted.

The tests were conducted on an 8-cylinder tank engine with a standard M-5 oil-bath air cleaner, with and without using a precleaner. It was found that only dust particles of less than 2-1/2 micron size would pass the oil-bath air cleaner. It was found that the efficiency of the standard oil-bath air cleaner alone averaged 99.5% but with the addition of a 67% efficient precleaner the overall efficiency dropped to 98.8% while lengthening the service period of the oil-bath cleaner about three times. The theory was advanced that the precleaner breaks up the larger dust particles giving the oil-bath cleaner more fine dust to handle. It is the fine dust particles that pass the oil-bath cleaner, thus decreasing the overall efficiency.

In order to obtain a supply of dust similar to that found in the absolute filter cloth used during the air cleaner tests a 0 to 2-1/2 micron dust from the Phoenix, Arizona area was specially prepared by the A. C. Spark Plug Division,

OMC. For equal masses and concentrations of dust in the inlet air this very fine dust was found to cause 92% less top cylinder wear and 63% less top piston ring wear than 0 to 40 micron dust of the same origin.

It was also found that dust entering the crankcase affected the bearings, piston skirts and oil rings more than the dust entering the induction system. The latter is responsible for more wear at the top of the cylinders and pistons above the compression rings.

A chrome-plated compression ring in the upper groove decreased the wear at the top of the cylinder sufficiently to eliminate the taper ordinarily encountered in the top inch of piston travel. The wear with the chromeplated compression ring ranged from 10 to 22 percent of that observed with conventional rings. The wear of the second compression ring and the oil ring was not affected by chrome-plating the top ring. A chrome-plated oil ring resulted in increased wear by this ring. Manufacturing difficulties make it too difficult to control the accuracy of the chrome-plated oil ring, resulting in high oil consumption. The higher oil consumption results in a heavier oil film on the cylinder walls which carries more abrasive and results in greater wear.

When dust was fed directly into the crankcase the cylinder wear was much more uniform from top to bottom; there was

less wear at the top of the ring travel and more at the bottom. The piston wear was much greater, particularly at the bottom of the skirt and, while the piston ring wear was better, the oil ring had worn much more than the top compression ring. The bearing wear was extremely high. Whereas the blow-by was excessive when the dust was fed into the induction system because of the top ring and cylinder wear, it remained reasonable when the dust was fed into the crankcase. The oil consumption was higher in latter case, probably because of the piston and bearing clearances. The difference in wearing characteristics resulting from dust entering the crankcase and the intake manifold should provide a very useful basis for analyzing the causes of wear in a badly worn engine.

While in Detroit, it was considered advantageous to visit the A. C. Spark Plug Division, GMC in Flint, Michigan, since this Division builds and tests all air cleaners for the General Motors Corporation. The Division has recently concluded a contract with the Continental Motor Corporation to develop an air cleaner for helicopters. They were, therefore, reluctant to discuss this problem.

However, they showed the National Bureau of Standards representatives an air filter presently used for helicopters consisting of a wire mesh panel one inch thick which they had received from Continental Motor Corporation. They considered it in-

filter inadequate in efficiency as well as dust holding capacity.

Tests of the standard automotive oil-bath air cleaners at the A. C. Spark Plug Division, GMC were said to show 100% efficiency on dust particles greater than 100 microns in diameter. However, they were trying to improve the filtering efficiency for very small particles.

The air cleaner test apparatus used by this Division generally conformed to that described in Army Specification 90-21. Inquiries regarding the effectiveness of a flannel cloth as an absolute filter for air cleaner tests were answered with the information that this cloth did retain about [illegible] of all dust that passed through the test filter and that they did not know of any better material for the purpose. The engineer who operated this test apparatus recommended that at least three tests under each condition should be made to obtain a good average value. The Division was setting up a test to determine the features of a Farr-Rotomatic cyclonic type filter as a precleaner with a flannel cloth after filter.

Findings of Other Investigations on Engine Wear

The test results of the only two other investigations made on the subject of engine wear are summarized in the following pages.

Mr. C. T. O'Harrow of the Allis-Chalmers Mfg. Co. investigated the wear of an engine with wet cylinder sleeves due to dusts of three size classifications and from three different sources. Although the chemical analysis of the dusts collected from the Allis-Chalmers' Test Field, from Phoenix, Arizona, and from St. Anthony, Idaho, varied widely as to their content of silica, alumina and ferric oxide and also in loss on ignition, Mr. O'Harrow was unable to detect any correlation between the chemical composition of the dusts and the rate at which they caused wear to the engine.

There was some difference in wear produced by dusts of the same size classification, but of different origins. The dust collected at West Allis and at St. Anthony, Idaho, produced generally higher rates of wear than dust originating in the Phoenix, Arizona area, in spite of the fact that higher rates of engine wear are often encountered in the Phoenix area during actual use of engines. These tests indicated that this is not because the Phoenix dust is more abrasive, but apparently because the air around Phoenix contains more of the fine dust particles that are not effectively caught by the air cleaners.

Mr. E. A. Davis of the Australian Aeronautical Research Laboratories drew the following conclusions from his tests;

a. When dust is fed to an engine constantly at a moderate rate the wear at the top of the cylinder and the average cylinder wear are proportional to the amount of dust fed. The wear of the top compression rings is also proportional to the dust fed, but with alloy pistons, a preliminary growth takes place so that the final change in dimensions is not indicative of the wear. The total weight of metal worn from the cylinder walls, piston and rings is proportional to the weight of dust fed for a wide range of wear.

b. The higher the dust feed rate the less wear is produced per unit weight of dust. Under the conditions of the tests the ratio of the total metal wear to the amount of dust fed decreased from 1.6 to 1.0 when the dust concentration was increased from 1 mg per cu.ft. to 6 mg per cu.ft.

c. Other factors being equal, the wear produced by a given weight of dust depends on the size of the dust. The maximum wear occurs with a dust size of about 15 microns, the wear with 100 micron dust being about half that of 15 micron dust.

Coarse dust particles larger than 100 microns are easily removed aerodynamically. The less easily retained fine particles, down to less than one micron size, should be prevented from entering the engine if wear is to be kept to a minimum.

Conclusions

The three investigations on engine wear, due to dust, which have been summarized above and which are the only ones known to have been made on this subject, to date, cover only a few of the possible variables. Therefore, the total knowledge of the effect of dust particle sizes and concentration on the engine wear is rather limited. It might seem obvious that the larger the particles and the greater the concentration the heavier the wear. On the other hand, it is quite likely that large particles in excess of 100 micron size will not force their way into the interstices between piston and cylinder and are ejected through the exhaust without causing much wear; and particles below 1 micron size, or so, do not bridge the oil film and thus produce a lapping effect rather than an abrasive one, but even so it has been shown that the presence of small particles weakens the oil film.

The removal of the large dust particles from the induction air can be accomplished with practically 100% efficiency with moderate difficulty whereas the fine particles which still cause considerable wear are hard to collect in a simple filter.

State of Laboratory Work

The assembly of the test apparatus was completed about Sept. 1st. Tests are now being conducted to determine the

operational characteristics of a standard 300 cfm squirrel cage blower that has been modified to work as a rotating filter or precleaner in accordance with the experience obtained with a small pilot model. Besides the possible desirability for some additional structural changes, the present tests will furnish information as to the efficiency of the filter at different rotor speeds, blow-down ratios, air flow rates, dust concentrations and the effect of dusts of different fineness. The observations made to date are incomplete, but the efficiency of the rotating filter appears to be somewhat better than that reported in the literature for other precleaners and the pressure drop is considerably less than for the cyclonic type filter. The results will be presented in the next progress report.

After the tests with the rotating filter are completed the helicopter engine, which just arrived here from Ft. Sill, Oklahoma, will be analysed for causes of excess wear.

The procurement of a good commercial air cleaner applicable to helicopter use has been postponed until information is obtained regarding the specifications contemplated for such equipment. It is considered desirable that a commercial air cleaner be tested here to compare its performance with the present concepts of the duty expected of helicopter air cleaners.