or views of the Attorney General. Such is not the case. The Supreme Judicial Court did not examine the merits of the question of whether or not the Harvard Corporation was engaged in a breach of trust and did not sustain the Attorney General in his statement that there was no breach of trust. The Court stated that the action of the Attorney General in not lending his name to a suit was a purely executive decision and not subject to review by the Court.

On 15 Apr., the Association for the Arnold Arboretum, Inc., an independent organization of more than 1000 members from all parts of the United States and Canada, having no connection with Harvard and being opposed to Harvard's present plan for the Arnold Arboretum, issued a 12-page pamphlet entitled *A Review of the Arnold Arboretum Controversy*. Readers who wish to understand the persistent issues of this controversy may receive a copy by writing to our office, 50 State Street, Boston 9, Mass.

THOMAS V. RANKIN, *Executive Secretary*
Association for the Arnold Arboretum, Inc.

29 April 1955.

Role of Nitrogen Oxides in Formation of Engine Deposits

Although the presence of oxides of nitrogen in exhaust gases from automotive engines has long been recognized (*1*), the importance of nitrogen fixation with respect to engine deposits seems to have been overlooked. We have studied kinetically the extent to which the reaction

$$N_2 + O_2 \rightleftarrows 2NO$$

can take place during the operation of a gasoline engine; from the study it has been calculated that, under normal engine conditions, the temperature is sufficiently high and sufficient time is available for the formation of an appreciable amount of nitric oxide. Furthermore, we have shown by engine tests that the quantity formed is dependent upon the operating variables that affect time, temperature, and concentration of gases within the flame. Oxides of nitrogen are found in increasing amounts in exhaust gases as leaner air-fuel mixtures, higher loads, and increased spark advance (up to the point of maximum power) are employed; nitrogen oxide (measured as nitrogen dioxide) up to 0.8 percent by volume of the exhaust gas has been encountered (*2*).

We have observed also that oxides of nitrogen are reactants in the formation of low-temperature engine varnish. Their importance in varnish-forming reactions was strongly indicated in advance by the fact that analyses showed nitrogen to be present in appreciable amounts in hundreds of deposit samples taken from engine locations exposed to combustion gases. More nitrogen was present than could be accounted for by the natural nitrogen content of the fuel and lubricant or by that contained in the additives that might have been used. Chemical and spectral tests indicate that the bulk of the nitrogen in these engine deposits is in the form of aliphatic nitro groups.

A striking demonstration of the part played by oxides of nitrogen in varnish-forming reactions was effected by operating a test engine under low-temperature varnish-forming conditions with an artificial atmosphere composed of oxygen and carbon dioxide; varnish deposits were not formed. When, however, sufficient nitrogen dioxide was added to the artificial atmosphere to give a concentration approximating that usually found in exhaust gas, heavy varnish deposition took place. Variations on this experiment have confirmed these results.

Although varnish formed under low-temperature conditions appears to result from primary reactions involving either raw or partially oxidized fuel components and oxides of nitrogen contained in blow-by gases, further work indicates that at high operating temperatures varnish formation can, when certain oils are used, proceed in absence of nitrogen dioxide. Tests have been made with a stable nonvarnish-forming fuel and the oxygen-carbon dioxide atmosphere under engine conditions that caused severe oil deterioration. When a relatively unstable lubricating oil was employed with this combination, piston varnish was deposited. This suggests that engine varnishing may be attributed to at least two possible causes. (i) reactions between fuel materials and nitrogen dioxide when the engine is operating at a low coolant and oil temperature; (ii) oxidation reactions of unstable lubricating oil when the engine is operating under high-temperature conditions. Combinations of these mechanisms is obviously possible.

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References and Notes

1. A. C. Egerton and T. K. Hanson, *Proc. Roy Soc. London* **A163**, 90 (1937).
2. Details of the analytic method employed will be submitted elsewhere for publication.

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