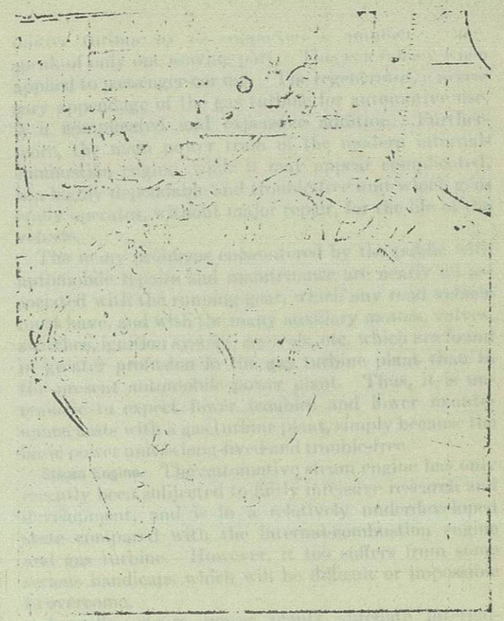
engine and the environment



Ten years from now, at least 100 million more I-C engines will have been built. Pending the development of a substitute, a radical change in engine design is imperative if atmospheric pollution is ever to be cleared up. This should be one of the goals of future versions of the Clean Air Act.

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THE IMAGE of the internal-combustion engine has changed in recent years from that of a benefactor of mankind to a major villain in the ecological wars. But since this engine powers most of the movement of goods as well as people—railroads, trucking, inland marine, much ocean shipping, and the movement of fluids through pipelines—eliminating or even seriously curtailing its use cannot even be contemplated until adequate substitutes have been provided.

Possible Substitutes

The set of possible substitutes for the conventional automobile engine is relatively large, and all of its members have been looked at with varying degrees of effort and intensity. The set includes, among others, continuous-combustion engines following the Rankine (steam engine), Brayton (gas turbine), or Stirling cycles; electric drives powered by batteries, fuel cells, or more exotic thermoelectric, photovoltaic, or thermionic devices; and various hybrids involving combinations of two or more individual systems.

The Department of Health, Education and Welfare, through the National Air Pollution Control Administration, has funded several studies to examine comprehensively and evaluate possible alternative power systems, to identify those that hold the most promise, and to make recommendations concerning additional needed research and development. Kirk and Dawson[2] summarized these studies as well as those of other government agencies and industrial laboratories in a paper presented at the 1969 Winter Annual Meeting of ASME. They identified the most promising possibilities for various classes of vehicles, but indicated that for passenger-car use only the steam engine, gas turbine, and high-temperature alkali-metal batteries hold any real promise. Stirling-cycle engines were added as another possibility for bus or truck applications.

Some other potential contenders often discussed in the popular press were ruled out on the basis of cost, weight, life, or availability of critical materials. Among these were the silver-zinc battery, which suffers from high cost, limited cycle life, and the fact that the

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Based on a paper contributed by the ASME Diesel and Gas Engine Power Division.

[2] Kirk, R., and Dawson, D., "Low Pollution Engines: Government Perspectives on Unconventional Engines for Vehicles," ASME Paper No. 69-WA/APC-5.

entire annual production of silver would provide batteries for only a small portion of the annual automobile production, and the fuel cell in its various forms, all of which are heavy, expensive, and cannot yet utilize easily available fuels.

Among the alkali-metal batteries listed as favorable, the lithium–chlorine and sodium–sulfur pairs have received the most attention. These must operate at high temperatures (1100 and 500 F respectively), and present serious difficulties with respect to safety and start-up. The authors list these as possibilities for long-term application which they define as 10 or more years from the inauguration of a serious research and development effort. Thus, only the steam engine and gas turbine are serious contenders over the next several years.

It hardly needs to be said that the use of battery-powered automobiles would not eliminate pollution due to combustion, but would rather shift it from the engine to the central power plant. The result would be a shift in the nature of the pollutants, from unburned hydrocarbons to sulfur dioxide for example, but might not effect a substantial overall improvement. If nuclear power plants are considered, then thermal and radioactive pollution are produced, with thermal pollution probably the most difficult to control. While the central station can operate at a higher efficiency than the automobile engine, the product of the long line of efficiencies from central power station through transmission lines, transformers, battery chargers, battery discharge, and motor and controls would probably be less, or at least no greater, than that of the individual engine.

Serious Contenders

Of the two serious contenders over a reasonably short time span, the steam engine and the gas turbine, the turbine has received by far the most attention.

Gas Turbine. This device, in large-power-output units, has taken over the airways, and has made inroads into the marine and stationary power plant fields. In spite of intensive work by the major automobile companies and by several other engine builders, it has not been successful in the automobile field and is just beginning to appear in heavy truck and bus applications. There appear to be several reasons why this is so:

The gas turbine, like most prime movers other than the combustion engine, is inherently a high-power-output device, while the passenger automobile requires only a modest power source—and, hopefully, its average horsepower will decrease in the future. The high output of the turbine results from its necessarily high rotative speed. An attempt to build small gas turbine plants results in small flow passages which are difficult to manufacture with the necessary precision, and which suffer from boundary-layer effects. Turbines are also inherently constant-load, constant-speed engines and do not operate well or efficiently over the extreme range of loads and speeds demanded by the automobile. Furthermore, both materials costs and manufacturing costs are substantially higher for the turbine than for the engine, and few of the people involved in these problems predict a major change in this situation.

One of the major advantages attributed to the automotive turbine by its supporters is simplicity. They speak of only one moving part. This is a fallacy when applied to passenger-car use. The regenerator, a necessary appendage of the gas turbine for automotive use, is a complicated and expensive addition. Furthermore, the main power train of the modern internal-combustion engine, while it may appear complicated, is a highly dependable and trouble-free unit which generally operates, without major repair, for the life of the vehicle.

The many problems encountered by the public with automobile repairs and maintenance are nearly all associated with the running gear, which any road vehicle must have, and with the many auxiliary motors, valves, switches, ignition system, controls, etc. which are found in greater profusion in the gas turbine plant than in the present automobile power plant. Thus, it is unrealistic to expect fewer troubles and lower maintenance costs with a gas turbine plant, simply because the basic power unit is long-lived and trouble-free.

Steam Engine. The automotive steam engine has only recently been subjected to fairly intensive research and development, and is in a relatively underdeveloped state compared with the internal-combustion engine and gas turbine. However, it too suffers from some serious handicaps which will be difficult or impossible to overcome.

Actually, steam power plants antedate internal-combustion engines, and their theory and practice are well developed and well understood. It has long been known, for example, that the efficiency of a small simple steam plant is exceedingly poor. Large modern steam power plants have efficiencies which equal or are slightly better than those of good modern diesel engines, but these good efficiencies are achieved by the use of extreme temperatures and pressures, and by the addition to the plant of auxiliary equipment and cycle complications which are only possible in very large plants. In an automotive steam engine, these complications are impossible, and high temperatures and pressures create lubrication and other problems.

It seems unlikely then that these plants could approach the modern combustion engine in economy. Supporters of steam cars have made claims of good efficiencies, but there is a dearth of test data supporting these claims, and it is difficult to see how they could be achieved.

Both the cost and weight of the steam plant are also unfavorable compared with the current engine. General Motors' experimental steam engine, for example, was 450 lb heavier and delivered one-half the horsepower of the conventional engine which it replaced.

Other problems with Rankine-cycle plants are freezing if water is used as the working substance, and temperature limitations which will result in poorer economy if other fluids now in sight are employed.

Internal-Combustion Engine. It seems clear, then, that the internal-combustion engine is superior, and is likely to remain superior, to any potential competitor in nearly every respect except exhaust pollution. Furthermore, even though the gas turbine, the steam engine, or a battery-powered system may some day be suitable for at least some classes of automotive vehicles, there is, at the present time, no replacement sufficiently well