Some Prime Mover Problems

By C. A. Norman
Professor of Machine Design, The Ohio State University

The gasoline engine has helped us to the automobile and has helped us to fly, and the glory of these achievements has shed over it a nimbus which it, as an engine, hardly deserves. In the first place, it is an extremely "un-mechanical" construction. An engine which cannot reverse; which is dependent for its operation on pinhole passages kept open by suction pressure merely, on permanent magnets and intricate electrical connections, on electrical insulations against high tension in the very working cylinder, exposed to temperatures of several thousand degrees F., on spark-gaps subject to every conceivable manner of fouling to which a spark-gap should not be subject, and that in a place where it cannot be seen; an engine so gotten up is certainly the very opposite of what an engine ought to be which is to be entrusted to amateurs for operation under the most trying and variable conditions, to say nothing of what an engine ought to be to which we have to entrust our lives up in the air. It is certainly a tribute to the ingenuity and detail skill of the mechanical—and electrical—engineering profession that such an engine has been made workable at all. But with full acknowledgment hereof, let us not forget that as long as we rely on such an engine in our automobiles and our aeroplanes, stoppages and break-downs with many an involuntary landing "behind the enemy's lines," will be unavoidable.

The "un-mechanical" construction is, however, only one weakness of the gasoline engine. There is another, in a way more serious. The engineering profession may pride itself on the way in which it has made many of the "un-mechanical" features workable. Its utter inability to do anything to improve the thermal efficiency of the gasoline engine, and the whole type of engines to which it belongs, is, however, humiliating. Of every pound of fuel supplied an explosion motor, it turns not over one-fourth into power and wastes three-fourths, mainly in jacket water and exhaust. Do not think that this is a weakness of merely theoretical interest! The United States Geological Survey estimates that at the present rate of increase of consumption the whole available crude oil supply of the country will be exhausted by 1935. There is no reason to suppose, either, that this is too pessimistic an estimate, or that the rate of increase will be reduced automatically without anyone's knowing just how. As a matter of fact, the climbing price of gasoline, in spite of desperate efforts to add to the supply, clearly indicates what is taking place. Every young engineer, then, who today goes into oil engine manufacture must realize that before he is forty he must either have found another liquid fuel for his engine, he must have very materially improved the efficiency of his engine, or he must go out of business.

Regarding the possibilities of finding another fuel, we shall here be short. Mr. Ford is reported to be actively interested in the development of alcohol as a motor car fuel. The wartime fuel of the German automobiles was reported to be 80% alcohol, 20% benzol, and 200 grains (per gallon?) naphthalene. Any one of these substances could be used alone; naphthalene, however, only with special arrangements for initial liquefaction. As for alcohol, it can under ordinary conditions, barring legislative interference, be produced at a very low cost from by-products of sugar and pulp manufacture. In case of its use on a large scale, the supply of such by-products would, however, be insufficient and the price would be artificially skyrocketed by the law of supply and demand. The main source of industrial alcohol in Germany is the potato. It is, however, not probable that potato alcohol could in the United States, for some time to come, be put on the market in competition with gasoline. Later on, the situation may change. It is up to the industrial chemist and the scientific farmer, however, to discover a plant product capable of enormous yield per acre and rich in starch or sugar convertible into alcohol. These efforts the mechanical engineer can only watch as a spectator. A little more directly interested he may be in benzol manufacture on a large scale. A ton of gas coal yields less than two gallons of benzol. Yet, if we coked all our coal before use, the amount of benzol obtainable would relieve the liquid fuel situation for a good many years to come. Naphthalene similarly is a product of dry-distillation of coal. Heavy coal tars suitable for Diesel and semi-Diesel engines come from the same source. So that the motor engineer, for his own salvation, should be keenly interested in the universal introduction of by-product coking ovens, to begin with, wherever coke is produced anyway; later, perhaps, where any cokeable coal at all is put on the market.

There are other methods of producing liquid fuel from coal. Many of these, though not commercially possible under ordinary conditions, may have been put into operation in Central Europe under war conditions. It will be highly interesting at the end of the war to see just what has been done in this direction.

There then are forces at work trying to help the mechanical engineer out of his critical situation. It is up to the mechanical engineer, however, to see that he does not remain idle. Just at the present time there is on the whole among so-called "practical" engineers an astounding indifference to the requirements of the situation, a humiliating disposition to drown themselves in details and mechanical "stunts" to the total neglect of greater engineering issues. Not that "efficiency" is so perfectly disregarded and scorned as it was among "practical" men a few years ago. Quite the contrary. In certain lines of steam engineering, the cry for efficiency has even led to ridiculous extremes in constructions and guarantee stipulations. An engineer who writes "efficiency" on his shield today need not fear that openings will be lacking for his services. In the oil engine line this instinct is, however, largely kept dormant. True, it must be admitted that increasing the efficiency of a present day internal-combustion engine is a very difficult problem. Say that we use in our cylinders an expansion ratio as high as ten to one. Even so, we extract theoretically during the expansion stroke only fifty per cent of the heat energy present in the gas, leaving fifty per cent in the exhaust. Cooling diverts to jacket water some fifteen to twenty per cent during the expansion and fifteen to twenty per cent during the discharge, so that only twenty-five to thirty-five per cent is turned into power, and only twenty-five to thirty-five per cent remains in the exhaust. The heat in the jacket water is usually lost entirely for power purposes. In some chemical factories in Europe, the jacket water has been used as hot water, large quantities of such being required. In this way, an over-all heat utilization of over seventy per cent has been attained. Where this is done, there is no longer need for shamefacedness. The difficulty in using jacket water for power purposes is that there is too much of it. It has often been proposed to take the jacket water and turn it into steam with the aid of the exhaust. A high-grade steam plant would turn twenty per cent of the steam energy into power. With Diesel engines as main motors, we could in this way attain a plant thermal efficiency of perhaps forty-five per cent. In order to do this we would, however, have to boil the water partly in the jacket. Ordinarily, we use so much water that the exhaust could turn only a small fraction thereof into steam. The complication of this arrangement, besides, makes it possible only in large stationary plants, or eventually on board ships. For automobiles and aeroplanes it cannot be thought of.

There is another way of utilizing exhaust heat, but this presupposes a type of combustion engine radically different from the one at present in use and will not be dealt with here.

In this article it might, however, be stated that one or two engineers of the very highest reputation have actually proposed to coat the working cylinder on the inside with an insulating lining,—for instance, of fused quartz. It is perfectly possible to construct, let us say, a Diesel type engine with an arrangement like this, at least for experimental purposes. The heat losses during expansion, and consequently the amount of jacket water, would then be very much reduced. With a similar insulation of the discharge passages, practically all of the waste heat would be left in the exhaust and would be ample to turn the jacket water into steam. Of course, the "practical engineer" will scoff at the idea of having refractory material in his working cylinder. Similarly, the practical steam engineer of forty years ago scoffed at the idea of having a burning flame there. If the "practical" engineer always had his way, many great improvements would never come about.

All the methods of increasing combustion engine efficiency referred to above are nevertheless not of a very encouraging nature, and are makeshifts at best. Where applicable, they should not be neglected, however.

There is another thing the thinking mechanical engineer should bear in mind. That is the necessity of learning to use heavier fuel oils in our portable engines. No matter what the "public" thinks, the man who uses a steam automobile today and gets ten miles out of a gallon of kerosene is a better engineer than the one who uses an explosion engine and gets twenty miles out of a gallon of gasoline. Gasoline is a very small fraction of the natural oil at best, and at the present time the demand for gasoline is entirely out of proportion to the demand for heavier oil. In consequence, the temptation is ever present for the oil companies to try to work kerosene into new and unnecessary uses, while from the point of view of the imperative necessity of husbanding our resources, we should rather try to reduce the consumption of oil in every manner possible. In this connection, a word should be said in favor of the Diesel, or semi-Diesel, type of engine. The writer is not convinced that all has been done that could be done to introduce this type of engine into automobile work. Thirty-five per cent efficiency instead of twenty-five percent is well worth striving for. It would add almost fifty per cent to the life of our fuel resources. Even for gasoline as a fuel, this fact would give the Diesel type the preference. The excessively small injection valve necessary with high-speed engines and the incomplete combustion which spray injection would give are difficulties that must be overcome. There are, however, ways in which they can be overcome.

The writer will not lengthen this article unnecessarily by going very much into the subject of coal. Be it said, however, that even our coal supply is by no means inexhaustible. The best estimate the Geological Survey can make is that it will be exhausted in one hundred and thirty years. This means that long before that time the price of coal will have risen to many times its present level, making people look for a substitute. An added stimulus in this direction is the circumstance that coal is a grimy servant, and its production a kind of work that Americans already hate to undertake. Perhaps in a not too far distant future, men will only at tremendous wages agree to bury themselves underground among poisonous and inflammable gases. All points to the necessity for the greatest economy and efficiency in the use of coal. By high superheat and high pressure the average steam-plant efficiency in the United States can be doubled and should be doubled. New types of boilers should be introduced, and new power machinery designed.

And after all this is done, we should not tarry in looking about for another, more subtle, more inexhaustible, more pleasant utilized source of power. Water power will do its share. There is considered to be a minimum of about 27 million horsepower of this kind available in the United States. This, however, is less than the 30 and some million horsepower we already use in our industries and will therefore not give a permanent relief. Besides, while we can rearrange our population and build all our great industrial cities within a few hundred miles of water falls, we cannot supply all our cities, nor all our railroads with water power, and we can hardly hope to transmit it efficiently to our ships and aeroplanes. A portable source of power is a necessity. An electric storage battery is a clumsy one. A very high efficiency has been obtained from primary batteries oxidizing carbon, but only for short periods. All considered, we need some way of fixing power in a portable form, yielding power again in great quantities either electrically or thermodynamically.

If such a "power compound" sufficiently light and sufficiently cheap is found, we can then proceed to the great problem of "fixing" solar energy. The sun radiates down one horsepower per square yard, 5000 horsepower per acre of every surface the radiation hits perpendicularly. In Meadi, Egypt, a solar plant develops 22 horsepower per acre. This seems like a small amount, but there are millions of acres in the Sahara and millions more in our arid west. Contemplative Orientals grinding out power compounds for the more energetic west would be an arrangement that the writer would very thoroughly enjoy.