TRUCK POWER

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INTRODUCTION

This report will discuss the relative merits of different methods of powering heavy trucks. No attempt is made to limit the heavy truck term to logging trucks, because for the most part, if these engines will be suitable for the average heavy truck, they will also be suitable for logging trucks.

In comparing the advantages and disadvantages of these different methods of truck propulsion, allowances must be made when applying them to off-highway logging trucks, as these units are not bothered as much by weight restrictions which will nullify some of the advantages and disadvantages relating to weight.

TRUCK POWER

GASOLINE ENGINES

Gasoline engines, which for many years were the mainstay for small and medium-heavy trucks, are now losing ground.

Karl Otto made the first practical application of the four cycle gas engine in 1876. The basic principles have remained the same but it has taken many millions of dollars and thousands of man-hours to bring the Otto cycle engine to its present level of efficiency.

At the present time these engines have only one advantage over their principle competitor: the diesel engine. This advantage is a lower initial cost. This lower cost is the product of two things: 1. The difference in price between fuel ignition system used in the Otto cycle engine and the fuel injection system as used in the diesel engine. This fuel injection system has to be able to measure fuel in quantities as small as one thousandths of a pound and to be able to withstand pressures up to 40,000 lb/in^2 which have been measured in some unit injector systems. Thus the reason for its higher cost compared to the simple ignition system. 2. Since the gas engine is used exclusively in passenger cars many parts can be mass produced in larger quantities and therefore cheaper than parts of the diesel engine. This lower cost is largely overcome by decreased maintenance cost of larger diesel engines and lower fuel costs.

Liquified Petroleum

The use of liquified petroleum "LP" gas, may help the gas engine regain some of its lost markets. Engines using this fuel can use a higher compression ratio and it is a cleaner burning fuel. Pope and Talbot used the "LP" conversion unit but found it did not perform to their expectations and they therefore dropped it. Engines which have been designed especially for this type fuel will probably prove to be much more efficient.

A disadvantage of this type engine is the high cost of fuel unless a great many users can be found in one locality. Because it is piped long distances, a large amount has to be used to realize lower fuel cost.

DIESEL ENGINES

The diesel engine was first operated sucessfully by Rudolph Diesel in 1897. It differs principally from the Otto cycle engine in that only air is admitted during the intake stroke. The fuel is injected under great pressure when the piston nears headcenter. The fuel is ignited by the high temperature of the compressed air in the cylinder. This differs from the Otto cycle where air and fuel are admitted to the cylinder at the same time and ignition is achieved by a spark. The Diesel engine burns a heavier fuel and usually operates at a lower piston speed than the Otto cycle engine.

The emphasis on Diesel engines has increased a great deal in recent years. Some European companies are using Diesel engines in automative and other small installations. With the development of the Diesel engines with lower lb/hp ratios the objections which people have raised because of their extra weight will be nullified. This will make possible the use of Diesel engines in places where weight is a critical factor.

Some companies have been experimenting with high-speed Diesel engines. Examples of this are the Cummins Diesel Co. and the Caterpillar Tractor Company. The Caterpillar people have demonstrated that a small bore, air-cooled Diesel engine can run to speeds of 6,000 rpm without undue sacrifice of economy. At the present time the high price of the materials used on this engine would make it impractical for commercial production.

Cummins Diesel Co. has showed the versatility of the

Diesel when they entered a race car in the 500 mile Indianapolis race equipped with a Diesel engine. This engine performed quite well and set a new qualifying record in 1952. The weight/hp ratio of this engine was 2.47 and it delivered 350 bhp at 4000rpm. This racer had to retire after 72 laps in the main event because of accumulated dirt in the supercharger.

The advent of low weight, high speed Diesel engines will afford the gas engines much more serious competition in light weight engine fields. As the Diesel engine is used for more and more jobs its prime cost will probably be lowered to where it can more adequately compete with gas engines on the basis of initial cash outlay.

TURBINES

The new arrival in the field of truck transportation is the gas turbine. Turbines using steam for power have been used for many years. Since it is very impractical to use steam in small units, turbines using steam have been restricted to large installations. Because of the large amount of auxiliary equipment and the high temperature and speeds reached in turbines many people did not think it would be practical to produce a small gas turbine which would have reasonable efficiency. With the high state of development of modern metals this low weight gas turbine is now within reach.

VIEWS ON TURBINES

There are two widely divergent schools of thought concerning the possibilties of turbines in the truck field. It is hard to find unbiased information about the possibilities of the turbine unit. Engineers working for companies engaged in turbine research are very optomistic about the turbines and those engineers designing diesel engines see no hope at all for gas turbine units.

The latter group believes that with the modern diesel engine becoming so efficient and since we have such a wealth of information on this type of engine it would be foolish to change horses in the middle of the stream. At the present time the diesel engine is much more efficient than the turbine and operating information is practically non-existant about the turbine.

This group believes that the teriffic cost of retooling factories for turbine production, the lack of repair facilities, and the close tolerances turbines operate under ~~which~~ would necessitate very expensive repair equipment which will stop the turbine from taking over for many years.

I believe these people have a very good argument in many respects but the gas turbine is too young to start comparing it with the piston engine with all its' years of operation. If the turbine were to be compared with the diesel engine of 20 years ago I believe it would equal or be superior to it. The horse was more efficient and reliable than the gas or the diesel engine when they first came out.

The former group believes the turbine will take over the field of truck power in the not too distant future. The advances in design and fuel consumption have been quite rapid for the amount of time and money which have been spent on gas turbines. A prediction of the director of the Ford Motor Company Scientific Labratory is that the turbine units will in time be lighter, and cheaper than conventional power plants for both commercial power plants and motor cars.

<u>RESEARCH TRENDS</u>

At the present time there are quite a few companies experimenting with gas turbines for automotive and truck uses. In England the main emphasis is on bus propulsion. These English companies have been very optomistic about the test results from their experimental vehicles. One company stated it had achieved a mileage per gallon in their turbine unit comparable to that obtained in their piston powered units.

In the United States much of the research has been directed toward truck propulsion. Some of the automotive companies have been examining the possibilities of using the gas turbine in automobiles, but articles from these companies are very scarce.

SIMPLICITY OF OPERATION

A piston engine consists of a reciprocating engine in which the energy from fuel is converted to mechanical energy through the effort of pistons, valves, crankshafts, flywheels, and other necessary engine parts. From here the power goes to an automatic mechanical transmission or a fluid generator and finally a speed reducer at the end of the system. In addition to the many parts you have an intricate system of lubrication and cooling. Since the motions of the pistons is constantly reversing, the engine has to be correctly designed and installed to cut down on the vibration which the piston motion causes.

In comparison the gas turbine offers a simple device consisting of a prime mover and a torque converter in a single unit, only two rotational elements and a speed reducer are required. The turbine has about a tenth of the number of moving parts as the piston engine. In a piston engine the designer has a big problem in matching the horsepower and torque curves of a engine. He cannot sacrifice high horsepower for low torque or vice-versa. A turbine engine, on the other hand delivers its' maximum torque at zero speed of the output shaft. This occurs when you need it most, that is, when you are trying to get a load started moving. As soon as the load begins to move the torque drops off and the horsepower picks up.

BOEING GAS TURBINE

To give the reader an idea of some of the problems facing a producer of turbine engines and the qualities and capabilities of present turbine engines I have chosen the

Boeing gas turbine as an example.

Boeing has been experimenting with turbines for some time and at the present time they have quite a few in different test jobs and vehicles. Boeing is probably the leading experimenter in turbines for heavy vehicles in this country.

Boeing has delivered about 250 Model 502-2 to the U.S. Navy. The model 502-2 is their second model, the 502-1 being their first. The unit is a 230 lb engine delivering 175 hp. These units have been exceeding their scheduled 350 hour overhaul time. Boeing's next model is the 520-10, which is a further development of the 502-2. In this engine the pressure ratio was increases from 3.5 to 4.5, and the continuous hp was raised to 240 while the weight only rose to 280 lb. This gives the engine a hp increase of 65 and a weight of only 50 lb. compared to the 502-2. The fuel consumption of the 502-10 is about 20% greater than that of the 502-2.

These turbines units have been installed in Navy personal boats, Navy Kaman helicopters, Cessna L19, an Army engineers pipe line set, a sixty KVA 400 cycle generator set, a portable air compressor unit, an Army ordinance 6x6, and a Kenworth truck and trailer. Most of the present users of the turbine are the military. Since the military is limited more by the weight than by the economy in regard to fuel consumption the turbine will probably be used more extensively by the military than by industry until it becomes more efficient.

ADVANTAGES OF THIS UNIT

The advantages of this turbine unit are: less noise, smoothness of running, ideal torque characteristics, almost complete elimination of cooling requirements, good flexibility, ability to operate on a much more lenient fuel and lubricant specifactations, small size, and light weight. The turbine will take up about 1/7 of the space of a diesel engine of comparable output. The starting of a turbine is quick and dependable, and it operates well at any altitude.

<u>WHY LACK OF DEMAND?</u>

The principal reasons for the present lack of commercial demand are the uncertainty of reliability and life expectancy, the high manufacturing cost, and the high fuel consumption.

<u>THE UNCERTAINTY OF RELIABILITY AND LIFE EXPECTANCY</u>. Boeing claims that satisfactory life of turbine wheels can be provided with complete operating dependability. In their efforts to lengthen blade life they have developed a safety factor against wheel burst, eliminated wheel rubs from blade stretch, eliminated blade base and blade airfoil failures from vibration fatigue, controlled starting and acclerating overheating, controlled unequal distribution of temperature in the hot gas stream, prevented the likelyhood of blade damage because of foreign objects in the gas stream, and developed inspection techniques.

The development of efficient and accurate inspection techniques is very important in the manufacturing of turbines because of the high rate of rotation of the turbine wheel. A defect, which in a piston engine would be considered very minor, may become very important in a turbine wheel rotating at 10,000 rpms. This places a grave responsibility on the manufacturer to develop accurate inspection methods.

With the military using many of these engines much data can be obtained regarding the reliability and life expectancy of these engines. Information of this type will have to be quite definite before many orders from commercial firms can be expected, as they will use the diesel with its' known capabilities and limitations before they will expend their capitol on an unknown item.

<u>HIGH MANUFACTURING COSTS</u>. The high cost of manufacturing

a turbine at the present time will stop the entree of the turbine into commercial field until the price is reduced. All the development to achieve a turbine having dependability consistent with piston engines has prevented the reducing of the cost. It is not only a matter of mass producing the turbine, but you first have to produce a limited number at a profit before you can begin to mass produce them unless you have a great amount of backing capitol.

In order to reduce the price of a turbine you have to reduce the price of the turbine wheel, which is the most expensive part of a turbine. To reduce the cost of producing a turbine wheel you have to reduce the excess handling time, cut down the number of operations, and reduce the chance of rejection. With hand welding the percentage of rejection has been quite high. Automatic welding techniques will help reduce this chance of rejection.

Starting with the cast blade and ending with the balanced rotor assembly requires a total of 144 steps and 84 seperate operations. Handling time was 84% of flow time, actual making time was only 3.5%. Automatic welding can reduce the total welding time for the turbine wheel from 5.7 hours to 48 minutes with better consistency and with no sacrifice in the quality of the weld.

The high cost of special alloys is not a barrier to low cost turbines as is often thought. The material cost of the alloys in the present turbine wheel is about 40$, while the total cost is about 1000$.

Boeing believes that without using any special purpose tools they can reduce the turbine wheel cost to about 250$/wheel. This would be accomplished by reducing the number of operations by better production techniques.

<u>FUEL CONSUMPTION</u>. Fuel consumption is the third drawback of present turbines. At the present rate of development Boeing should be able to bring the fuel consumption down

to that of competing engines as far as cost of the fuel used in a equal period of time is concerned.

The first run of the first model 502-1 used fuel at the rate of 1.81b/bhp/hr. This run took place in 1947. In 1949 the first run of their second model, 502-2, used 1.41 lb/bhp/hr. the fuel consumption of their present production is 1.11 lb/bhp/hr. At the present rate of improvement Boeing believes it can reduce fuel consumption to o.7 lb/bhp/hr. by 1957. This would more nearly compare with modern diesel engines whose consumption is approximately 0.4 lb/bhp/hr..

A turbine fuel consumption of 0.7 lb/bhp/hr. would probably compare very favorably with that of present diesel engine when you consider the cost of the fuel. A turbine can burn very low quality fuel in comparison with diesel engines.

SUMMARY

I believe the future use of gas turbines in the automotive field will have to be viewed with considerable optpmism. Gas turbines have many advantages over conventional automotive power plants such as a very high hp/lb ratio, good torque characteristics, small in size, simplicity of operation , ability to operate on very lenient fuel specifications, ability to operate without a cooling system, and less noisy. To offset these advantages at the present time are high initial cost, high fuel consumption, and uncertainty of operating life and dependability.

The diesel engine will probably remain as the chief source of power for trucks for many years to come. If the turbine performs to all expectations it would still require a great deal of time for retooling, setting up of repair facilities, and other necessaries.

The gas engine is on the way out unless the use of "LP" gas in large amounts can result in an increase of this type of engine.

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