CHAPTER 3

The Guiberson Diesel

The Guiberson A-1020 Diesel aircraft engine represents the most advanced type of four-cycle Diesel which has been produced in the United States. It is a nine-cylinder air-cooled radial which can hardly be distinguished from an up-to-date gasoline aircraft engine. Ten years research work and many hundreds of thousands of dollars have been spent in the development of Guiberson Diesel aircraft engines. The A-1020 model is not supercharged but it performs well at high altitudes (Fig. 26).

Fig. 26.—Guiberson A-1020 Diesel aircraft engine rated at 310 h.p.

The Crankcase

The crankcase of the engine is made of aluminum alloy and consists of a front section and a rear section held together with nine through bolts. The nose section is integral with the front section as the propeller drive is direct and there is no necessity for a gear housing. The rear section contains the valve tappet guides and the mountings for the nine individual fuel injection pumps. An accessory section made of aluminum alloy is attached to the crankcase by the nine through bolts and nine additional studs and nuts (Fig. 27). Provision is made for attaching the various accessories by means of studs screwed into the accessory section. Drives are contained in this section to operate them.

The Cylinders

The cylinder barrels are machined from steel forgings and are provided with shallow cooling fins. The cylinder heads are made of aluminum alloy with deep cooling fins around the combustion chambers and the exhaust valve rocker arm boxes and exhaust outlets. The heads are screwed and shrunk onto the barrels and each cylinder is attached to the power section of the crankcase by means of a flange and twelve studs and nuts.

The Crankshaft

The crankshaft is of the single-throw type, made in two pieces and machined from solid steel forgings. It is supported in roller bearings of large diameter in the front and rear sections of the crankcase and in a ball thrust bearing in the nose which absorbs the propeller thrust and axial loads. The crankshaft is bored for lightness and drilled for forced-feed lubrication. A vibration damper in the form of a spring-loaded counter-balance weight is attached to the rear cheek of the crankshaft.

The Connecting Rods

The master connecting rod is machined from an I-section steel forging and has a steel-backed lead-bronze bushing in its big-end. The eight articulated or link rods are of the same construction and are fitted with bronze bushings in their big-ends. The link rods are machined all over and have bronze bushings in their small-ends. This construction is shown in the longitudinal section view of the engine.

The Pistons

The pistons are machined from heat-treated aluminum alloy castings. The top surface of the piston is concave so that it forms a semispherical combustion chamber in conjunction with the concave interior of the cylinder head. Each piston is fitted with three compression rings and one oil ring above the piston pin and one oil scraper ring below it. The piston pin is of the floating type with aluminum alloy plugs at each end to prevent it from scoring the cylinder wall.

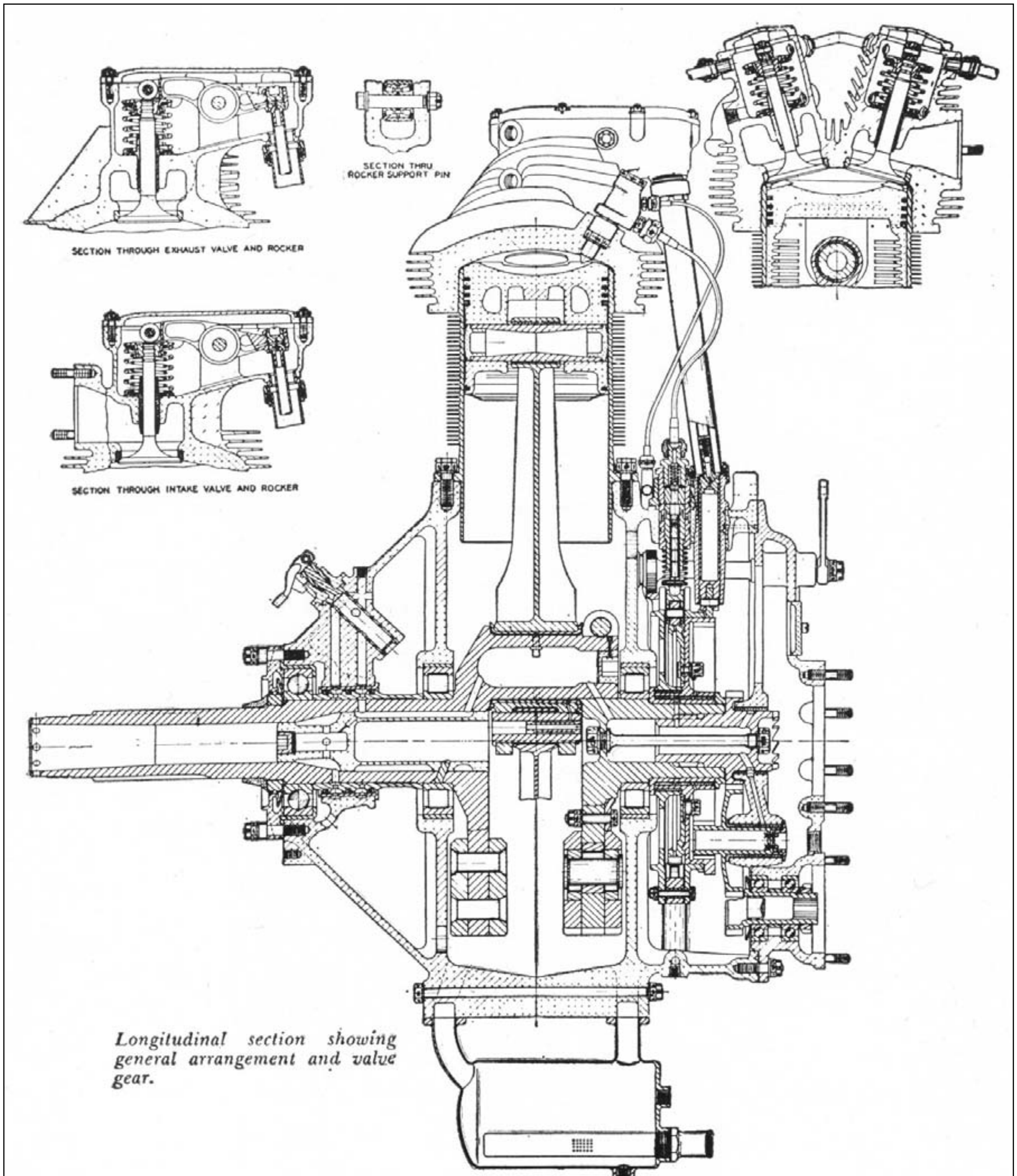

Fig. 27.—*Sectional views of Guiberson A-1020.*

The Valves

The valving consists of an inlet valve and an exhaust valve of the poppet type operating in valve seats of aluminum bronze and Silcrome steel respectively shrunk in the cylinder head. The valves are actuated by means of rocker arms enclosed in oil-tight boxes and enclosed push rods and roller tappets. The push rods are made of steel tubing and are fitted with hardened and ground ball ends. The rocker arms are mounted on ball bearings and have adjustable sockets for the push rod ends.

Fig. 28.—Machining master rods in the Buda Company factory.

The Cams

The cam ring which actuates the valve tappets is machined from a steel forging and has four lobes. It is supported on a duro bronze bushing on the rear end of the crankshaft and is driven by means of an intermediate gear wheel which rotates it in the opposite direction to the crankshaft at one-eighth engine speed. A four-lobed cam ring for actuating the injection pumps is attached to the valve cam ring by bolts and nuts with slots for adjustment.

The Fuel Pumps

The nine individual Guiberson fuel injection pumps used on the engine are flange-mounted around the rear section of the crankcase where they connect with fuel supply passages drilled in the castings. Tapered roller actuating arms are provided between the stems of the plungers of the injection pumps and their cam ring. The actuating arms are mounted eccentrically on a control plate which can be rotated slightly so as to vary the amount of plunger lift and the commencement of injection (Fig. 29). The injection pumps are connected with the injectors in the cylinder heads by equal lengths of high-pressure seamless steel tubing. The injectors are mounted so that their axes are at an angle of 30 degrees from the vertical axes of the cylinders.

The Lubrication System

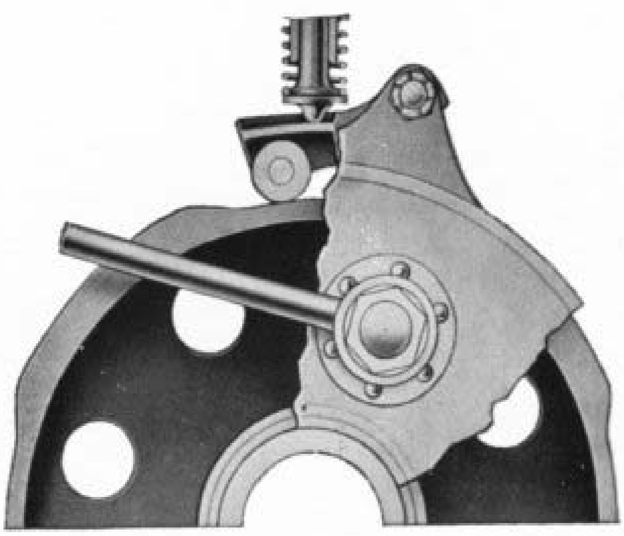

Fig. 29.—Control plate for fuel injection pumps.

The lubrication system functions on the dry sump principle as in a gasoline aircraft engine. Lubricating oil is delivered under pressure through the hollow crankshaft to the main bearings and the cam rings. The cylinder walls, the crankshaft thrust bearings, the piston pins and the injection pump tappets are lubricated by splash. The oil sump is in the form of a separate unit located between the two bottom cylinders of the engine.

The Accessories

The accessory section which is attached to the rear section of the crankcase contains drives and mountings for the various accessories. These accessories comprise one pressure-feed and two scavenge pumps of the rotary-gear type, a pressure relief valve and a Cuno metal-disc filter for the lubrication system; a Pesco rotary-vane transfer pump and a Purolator metal-disc filter for the fuel system; a cartridge starter contacting the end of the crankshaft for starting the engine; and an Eclipse electric generator for charging the batteries in the airplane.

FUEL INJECTION SYSTEM

The fuel injection system used on the Guiberson A-1020 Diesel aircraft engine differs considerably from the Bosch injection system described in a previous section. Although the Guiberson injection pump is also of the plunger type, the length of the stroke of its plunger is variable and not constant as in the Bosch. Control of the output of the pump is obtained by varying the quantity of fuel admitted into the pressure chamber. The design of the pump is such that constant output at any particular throttle setting is maintained without recourse to a governor or other mechanism.

The plunger of the Guiberson injection pump has a groove cut around its stem and a hole drilled in its center connecting its top surface with the groove. When the plunger approaches the end of its downward or inactive stroke, fuel flows through small inlet ports into the barrel as soon as the top of the plunger sinks below the inlet port openings. The quantity of fuel which enters the pressure chamber in the barrel above the plunger depends upon the length of plunger stroke which in turn governs the amount of uncovering of the inlet ports. The flow of fuel into the barrel is accelerated considerably by the partial vacuum created by the downward movement of the plunger (Fig. 30).

When the plunger rises on its active stroke and it reaches its cut-off position it covers the inlet ports completely. The fuel in the pressure chamber then is compressed to a pressure of approximately 2,500 lb. per sq. in. and the necessary fuel charge is forced out through a spring loaded non-return valve into the discharge tubing leading to the injector. The fuel remaining in the pressure chamber is released as soon as the plunger reaches its release position with the top surface of the plunger communicating with the inlet ports by way of the central hole and the groove. The remainder of the fuel in the pressure chamber then by-passes into the inlet ports and the intake side of the pump.

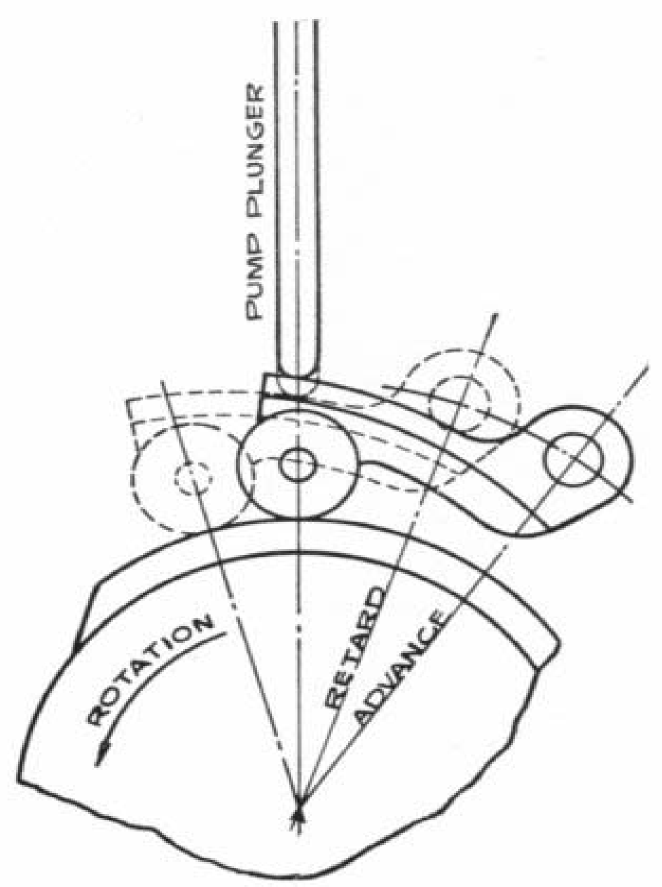

Fig. 31.—Variable timing is obtained by rotating the cam ring.

Fuel Injection Control and Operation

Control of the amount of plunger lift is obtained by the well-known mechanical principle of the sliding wedge. In this case the wedge takes the form of a roller actuating arm located between the pump plunger and the cam ring. The actuating arm is mounted eccentrically on a rotatable control plate which can be moved so as to have the effect of increasing or decreasing the height of the wedge. Timing of commencement of fuel injection corresponding to advance and retard of firing in a gasoline aircraft engine results automatically when the cam ring is rotated (Fig. 31).

For full throttle, the control plate is moved until the amount of plunger lift is reduced to the point where the plunger uncovers all of the inlet port at the end of its down stroke and a maximum fuel charge is admitted. Intermediate throttle positions are obtained when the inlet port is uncovered Partially and a reduced quantity of fuel enters the pressure chamber. Closed throttle position results when the amount of plunger lift is increased to the point where the plunger does not uncover the inlet port at all during its down stroke and no fuel is admitted.

The output of the injection pump at any particular throttle setting is maintained constant by the compensating action of the plunger. If the engine speed decreases, the pump plunger uncovers the inlet port or portion thereof longer and a larger quantity of fuel is admitted increasing the engine speed to normal. If the engine speed increases unduly above normal, this compensating action is reversed.

The injectors used on the engine are operated hydraulically by the pressure of the fuel and are of the closed type. The spring loaded nozzle valve in the injector is opened by the differential action of the fuel against its tapered end. The fuel is sprayed through a multi-hole nozzle having three small holes direct into the combustion chamber in the engine cylinder. The fan-shaped spray of finely atomized fuel created mixes quite well with the air charge.

The use of individual fuel injection pumps on the Guiberson A-1020 Diesel aircraft engine is in line with similar installations of fuel injection equipment on radial Diesels such as the Clerget 14 F-01, the Salmson SH 18 and the ZOD 260-B. It is advantageous on a radial engine because the high-pressure lines connecting the pumps and the injectors can be relatively short, thereby eliminating any possibility of fuel surge between the injection periods. The additional drive required for individual injection pumps consists of another cam ring which can be attached to the cam ring actuating the valve tappets. The injection pumps can be mounted with their bodies extending into the cam ring housing so that they are lubricated automatically by the oil spray from the crankcase.

BENCH AND FLIGHT TESTS

After the first Guiberson A-1020 Diesel aircraft engine bad been completed it was submitted to numerous bench tests at the factory before it was installed in an airplane. The manufacturer ,s tests consisted of 50 hours at full throttle in runs of 5 hours' duration, and 50 hours at 75 per cent throttle also in 5-hour periods. The Government tests to which it was submitted consisted of 50 hours at full throttle in periods of 5 hours each conducted under the strict supervision of the Civil Aeronautics Authority (Fig. 32).

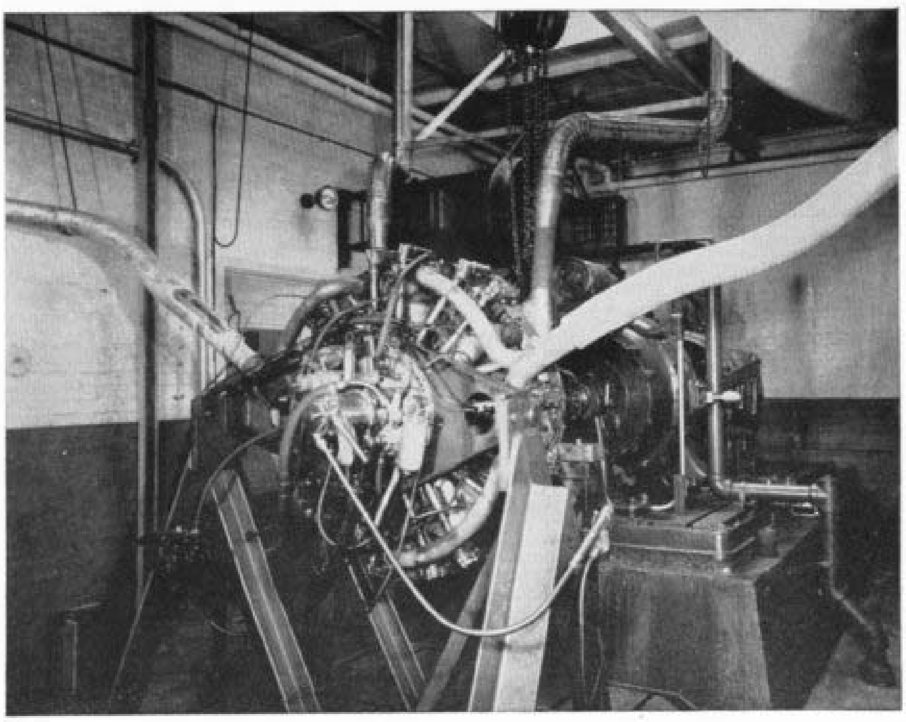

Fig. 32.—*Guiberson A-1020 Diesel on the test bed.*

The C.A.A. bench tests were completed satisfactorily in January, 1940. The maximum power output of the engine was held to 310 h.p. which it developed at a crankshaft speed of 2,150 r.p.m. The maximum power output curve was practically a straight line peaking at 325 h.p. at 2,275 r.p.m. after which it fell off rapidly. The fuel consumption at full load at 2,150 r.p.m. was found to be 0.42 lb. per h.p. per hour and at cruising speed the consumption was 0.37 lb. per h.p. per hour. The lubricating oil consumption at full load was 0.008 lb. per h.p. per hour, equivalent to 2.47 lb. or 0.33 gallons per hour (Fig. 33).

The Actual Flight Test

For the 10 hours' flight tests which are also a prerequisite for government approval the engine was installed in a 4-place Stinson *Reliant* monoplane which previously had been powered with a supercharged Wright *Whirlwind* R 760 E2 gasoline aircraft engine rated at 320 h.p. at 2,200 r.p.m. As the two engines were of approximately the same diameter the same cowling was used for the Diesel installation. With out propeller and fuel it was found that the Diesel installation was only 6 lb. heavier than that of the gasoline engine installation. The engine itself weighed 650 lb., or 2.1 lb. per h.p. No difficulty was encountered in mounting the engine and it was found that the Diesel started readily or.) ordinary furnace oil at the first impulse of the starter.

The official flight tests for the C.A.A. were completed satisfactorily and on one of the flights an altitude of 18,300 ft. was attained with the airplane still climbing at the rate of 500 ft. per min. This altitude compares very favorably with the ceiling of 14,500 ft. guaranteed for the gasoline-engined Stinson and indicates that a ceiling of at least 20,000 ft. could be attained by the Diesel-engined Stinson without supercharging. A.T.C. No. 220 was issued for the Guiberson A-1020 Diesel aircraft engine in April, 1940, giving it a continuous rating of 310 h.p. at 2,150 r.p.m. at sea-level.

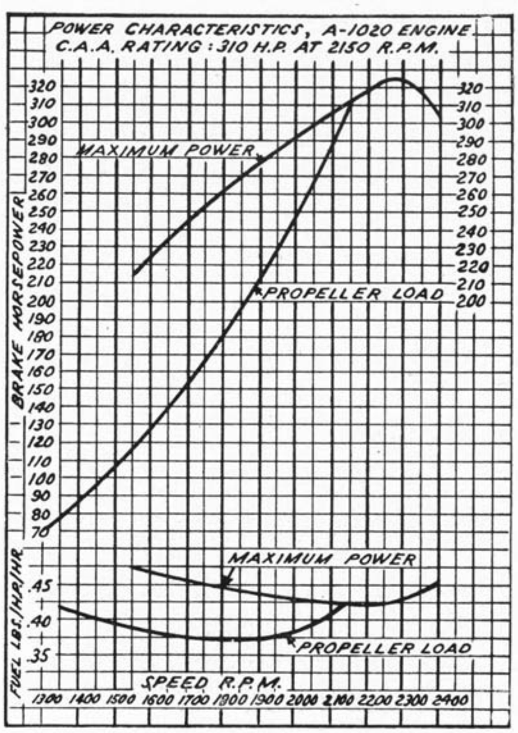

Fig. 33.—Power and fuel consumption curves.

With regard to the excellent performance of an unsupercharged Diesel at high altitudes, it should be mentioned that this type of engine can run with excess air at sea-level and low altitudes as it is not fuel sensitive and its air-to-fuel ratio is comparatively flexible. The Guiberson A-1020 Diesel runs with 18 per cent excess air at sea-level without supercharging, with its valve timing arranged so that the volume of air compressed in each cylinder is equivalent to 118 per cent of the cylinder's displacement. At high altitudes it does not experience the same air shortage and lack of oxygen for combustion as does a gasoline engine.

The results obtained with the Guiberson A-1020 Diesel aircraft engine at relatively high altitudes without the use of a supercharger compare very favorably with those obtained with a gasoline aircraft engine equipped with a supercharger of medium output. It is also found that when a gear-driven supercharger is fitted to a Diesel the latter has a performance superior to that of a gasoline engine equipped with the same type of supercharger.

The superior performance of a supercharged Diesel aircraft engine was demonstrated by M. Clerget a short time ago. He conducted a series of comparative flight tests with his Clerget 14 F-01 Diesel equipped with a gear-driven Gnome-Rhone 1-speed supercharger and then substituted a gasoline aircraft engine of approximately the same power output and equipped with a similar supercharger in the airplane. He used the same propeller on the two engines so as to ensure accurate results.

It was found that while the two engines ran at the same crankshaft speed and developed the same power output at sea-level and up to their rated altitude of 7,800 ft., above this altitude there was a marked difference in their crankshaft speeds and corresponding power outputs. In the case of the Diesel its crankshaft speed increased from 1,745 r.p.m. at an altitude of 7,800 ft. to as much as 1,880 r.p.m. at an altitude of 25,000 ft. without changing the throttle setting. In the case of the gasoline aircraft engine its crankshaft speed decreased from 1,745 r.p.m. at 7,800 ft. to 1,650 r.p.m. at 25,000 ft. accompanied by a considerable loss in power output.

FLIGHTS WITH THE ENGINE

After the Guiberson A-1020 Diesel had received its A.T.C., the Diesel-engined Stinson was flown from the factory to Washington, D. C., to demonstrate it before high-ranking Army, Navy, and civil aviation officials. The flight of 1,500 miles from Dallas, via Birmingham and Charleston, was completed in 10 hours and 35 minutes flying time at an average speed of 142 m.p.h. An altitude of approximately 3,000 ft. was maintained with the engine cruising at 220 h.p. at 1,800 r.p.m. Regular Texaco Diesel Chief fuel oil costing 6 cents a gallon such as is used in Caterpillar tractors was consumed at the rate of 11 1/2 gallons an hour or 0.37 lb. per h.p. per hour and its total cost was only $6.90. Lubricating oil to the extent of 3 gallons at $1.40 a gallon added $4.20 to the expenditure, making a total cost of $11.10 for fuel and oil for the entire journey. The fuel cost of less than 12 cent a mile is an unheard-of figure for flight operations in this country.

After creating a very favorable impression at Washington the Stinson was flown to New York where the public had an opportunity of seeing it at Roosevelt Field (Fig. 34). The engine installation was found ' to be perfectly normal and one could not tell that a Diesel was hidden underneath the regular cowling on the airplane. Demonstrations showed that the engine started quickly with a cartridge starter and that it idled quietly and evenly without vibration. When the throttle was pushed open the engine accelerated just like a gasoline engine and at cruising speed there was no evidence of smoky exhaust.

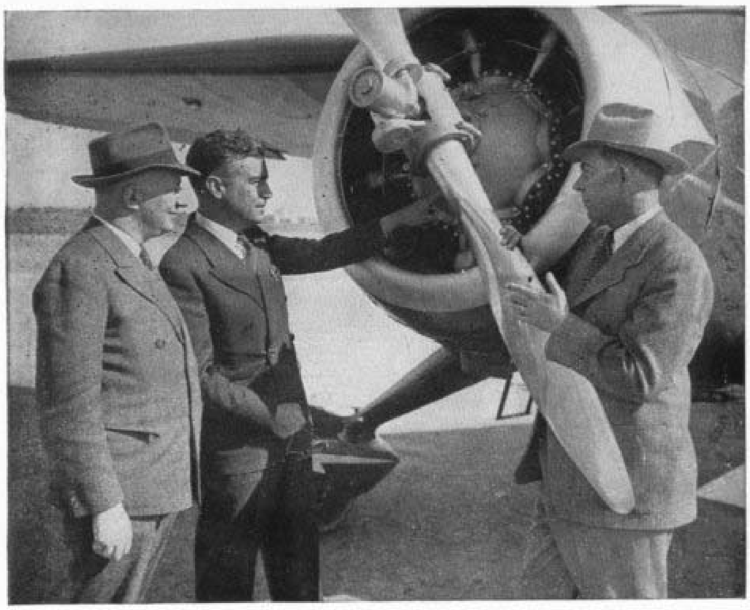

Fig. 34.—Paul H. Wilkinson; E. L. Taylor, Pilot; and Allen Guiberson viewing the engine at Roosevelt Field, New York.

The return flight to the Guiberson factory at Dallas was made by way of Chicago and at the latter city the Diesel-engined Stinson also received much favorable comment. It was obvious to those who saw the airplane and its engine that flying would be appreciably safer when Diesels and their non-explosive fuel were available for private airplanes as well as for commercial and military aircraft. Among those who welcomed the Stinson at Chicago were officials of the Buda Company, an outstanding firm in the Diesel industry which has arranged to manufacture Guiberson Diesels in its extensive factory at Harvey, near Chicago, anticipating a considerable demand for these engines and possibly other models for the United States government.

FUTURE POSSIBILITIES

The arrangements which have been made between the Guiberson Diesel Engine Company and the Buda Company are that the-latter will manufacture Guiberson air-cooled radial Diesels for use in both airplanes and tanks. The tank engine is known as the T-1020 model and is identical in size and design with the A-1020 aircraft engine. For cooling purposes the T-1020 engine is equipped with a large fan in front of its cylinders which is gear-driven from an extension of its crankshaft. .So great has been the demand for these tank engines for the United States Army that special air-conditioned buildings have been built at the Buda factory in which the engines are manufactured by the latest flowline production methods. These buildings are unique and anticipate air-raid "blackouts" in that they are constructed without windows and are equipped with fluorescent lighting.

As most of the parts of the A-1020 and T-1020 Diesels are identical the production of the engines is of a very flexible nature. If there is an urgent demand for aircraft engines few changes are required in the machine shop or the production line to divert tank engine parts for this purpose. Not only does this arrangement facilitate production but it also helps to reduce production costs. Present-day low production cost of gasoline engines was not obtained until the engines could be produced in considerable quantities. The same thing applies to the Diesel aircraft engine-its production costs can only be reduced to those of the gasoline engine by increasing its production volume, and selling considerable quantities of engines.

As for the future of the Guiberson A-1020 Diesel, it should find a ready market for small airplanes such as the popular Stinson *Reliant.* Other models also are contemplated for future development. For instance, by reducing the number of cylinders from nine to seven an engine with a power output of approximately 240 h.p. could be obtained. Further reduction in the number of cylinders to five would give an engine of approximately 170 h.p. It is also possible to increase the power output of the A-1020 without adding to the number of its cylinders by equipping it with a gear-driven supercharger. In this way its power could be boosted to approximately 400 h.p.