Chapter 1
Development of the Diesel Aircraft Engine

Most people in the United States who are interested in aviation associate the gasoline engine with the airplane as its power plant. True, the gasoline engine has made flight possible and it has been developed to a fine art. Progress does not stand still, however, and now the Diesel or compression ignition engine has become a challenger of the gasoline engine for aviation.

Today, the Diesel provides the motive power for fast streamlined trains and swift motorships as well as for powerful trucks, busses and tractors. Its use in warships and tanks is growing rapidly and it is being adopted for mechanized transport. Adoption of the Diesel for aviation has been relatively slow because of the difficulty in reducing its weight sufficiently for use in the air. Now this problem has been solved and we are on the threshold of a new era in aviation in which the Diesel will play an important part.

Dr. Rudolf Diesel

By common usage, the word Diesel has become synonymous for compression ignition engine and few people remember its inventor or the difficulties he encountered in its development. More than forty years have elapsed since the first industrial engine operating on this principle was built. It is nearly fifty years since the first patent was issued to Dr. Rudolf Diesel for his invention of an internal combustion engine with compression ignition.

Fig. 1.—Dr. Diesel, inventor of the compression ignition engine.

Dr. Diesel, like many inventors, had quite an adventurous career (Fig. 1). He was born in Paris of German parents on March 18, 1858, and when he was only twelve years old, his family had to flee from the city during the Franco-Prussian War. His parents settled in England and young Diesel was sent to relatives in Augsburg to receive a German education. There he completed his schooling and entered the Technical Institute at Munich to study engineering. His mechanical talents developed rapidly and he became particularly interested in thermodynamics, which study helped form the basis of his career.

While Diesel was studying at Munich, his teacher, Dr. Linde-the discoverer of liquid air-happened to mention one day that in a steam engine only 6 to 10 per cent of the heat produced was transformed into energy. This statement made in 1878 so impressed Diesel that from then on, the idea of a new power-saving engine remained uppermost in his mind. During the years which followed, Diesel was employed by Sulzer Brothers in Switzerland and later he became assistant professor at the Technical Institute at Munich. In 1889, he joined Dr, Linde in Paris as manager of his refrigeration plant and it was there that be began to make plans for the development of his engine.

Development of the Diesel Principle

Recalling his school days, Dr. Diesel remembered a "fire tube" with which he had experimented and in which combustible materials could be made to ignite by compressing air to a high temperature. This apparatus was like a bicycle pump but had a glass cylinder so that the effect of sharply pushing in the piston could be seen. This method of igniting fuel by compressing air to a high temperature was what Dr. Diesel wanted and he adopted the principle in his new engine. Virtually, the cylinder of his engine became a pneumatic fire tube with the piston compressing the air to ignite the fuel.

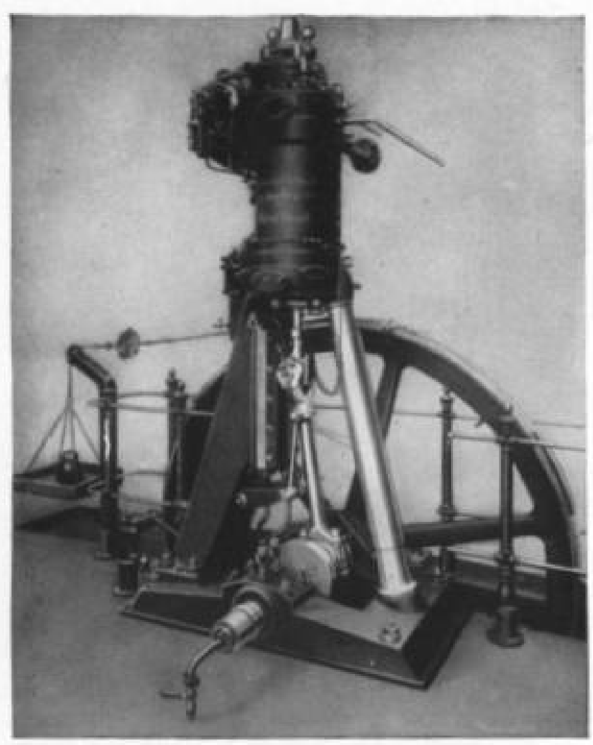

Fig. 2.—First commercially practical Diesel, 1897.

Abundance of coal in Germany and the idea of utilizing coal dust for fuel undoubtedly influenced Dr. Diesel when he applied for a patent. The first one issued to him, Patent No. 67,207 dated February 28, 1892, specified an engine with compression ignition using coal dust as fuel.

In 1893, at the age of 35, Dr. Diesel published a theoretical treatise entitled: "The Theory and Construction of a Practical Heat Engine." In the same year he began his experiments at Augsburg. Fortunately he was not handicapped by lack of funds and he obtained the assistance of two of the largest firms in Germany. These firms were Friedrich Krupp of Essen which backed him with the necessary capital, and Maschinenfabrik AugsburgNiirnberg (M.A.N.) which placed the necessary engineering facilities at his disposal.

The First Practical Heat Engines

After three years' work, in 1896 Dr. Diesel completed his first engine design to use coal dust for fuel and air compressed to high pressure and temperature to ignite it. This engine exploded and nearly killed him but he persevered and built another engine using petroleum for fuel. -His second engine built in 1897 was successful and justified his theories. It was of the slow-speed, type with a single vertical cylinder which developed 25 h.p. at 170 r.p.m. (Fig. 2). Subsequent tests showed that it had a thermal efficiency of 35 per cent compared with 12 per cent for the steam engine of that time 2

The First American Diesel

At the Machinery Exposition held in Munich in 1898, three engines built to Dr. Diesel's designs by Krupp, M.A.N. and Deutz constituted the biggest attraction. So much interest was aroused that by 1901 licenses had been granted in many countries and twenty-seven firms were building Diesel engines. Well-known firms such as Sulzer in Switzerland and Nobel in Russia began to build them on a large scale. In the United States, the first Diesel was built by the firm of Busch-Sulzer in St. Louis in 1898.

During the next fifteen years, Dr. Diesel received many invitations to visit other countries where he was honored and feted and addressed engineering conventions. In 1912, his visit to the United States was in the nature of a triumphal tour. At this time the marine Diesel. was fast being adopted for submarines and other naval vessels. After his return to Germany, Dr. Diesel was called to England to consult with the British Admiralty about the use of his engine in submarines. Traveling from Antwerp to Harwich on the night of September 29, 1913, he mysteriously disappeared from the ship, as did all of his important documents. Thus passed Dr. Diesel, the inventor of countless engines which bear his name.

Developments in Germany

Development of lightweight Diesels for aviation from heavy industrial and marine engines of this type was started in Germany in 1910. It was not until 1930, however, that the Diesel aircraft engine became really practical. Dr. Hugo Junkers initiated this development and before be died in 1935, be bad the satisfaction of seeing his Diesels successful in the air.

Dr. Hugo Junkers

Dr. Junkers' career is interesting in that like Dr. Diesel, be was deeply interested in thermodynamics which proved to be of great benefit to him in his work. He was born in 1859 and when he was twenty-nine years old, he began experimenting with gas engines at Dessau. There he began manufacturing heating devices and in 1897, he was appointed to the Chair of Thermal Studies at Achen Technical Academy.

At Dessau and Achen Dr. Junkers' thoughts began to turn to aviation and on February 1, 1910, be was granted Patent No. 253,788 for an "all wing" airplane, This invention consisted of a single hollow metal wing which housed within its framework not only the engines and their fuel tanks, but also the passengers and crew. The engines, even at that early date, were shown as being of the opposed-piston type. This thick section all-metal cantilever wing which at first was ridiculed and rejected as impractical has now, thirty years later, became the accepted pattern for high-speed airplanes and a successful all-wing" airplane has been built and flown.

Dr. Junkers' activities were not confined solely to his all-metal airplane. He was also interested in means of propulsion and subsequent to 1910, his time was divided between experiments with his airplane and work on a Diesel engine to propel it. He chose an opposed-piston engine design as he had achieved considerable success with this type of power plant in the industrial field. He also chose two-cycle operation for his engine with piston-controlled ports instead of valves and compressed air for scavenging the cylinders.

The First Junkers Diesels

The first two Junkers Diesels built for aviation were the four-cylinder MO-3 completed in 1913 and the six-cylinder MO-8 completed in 1914. The next experimental engine was the six-cylinder FO-2 built in 1916 which was rated at 500 h.p. at 2,400 r.p.m. A 1,000 h.p. Diesel was also designed at that time which showed the extraordinary progressiveness of Dr. Junkers.' All of these engines ran on fuel oil injected under pressure and were equipped with spark ignition.

Post World War I Development

Development after World War I was slow due to the restrictions imposed upon Germany by the Treaty of Versailles. When the FO-3 appeared the design had been changed to five vertical cylinders with compression ignition. This engine was exhibited at the International Aviation Exhibition in Berlin in 1926 and developed 830 h.p. at 1,200 r.p.m. (Fig. 3). A smaller size was considered more practical, however, so it was redesigned with six smaller cylinders and reappeared as the F04 in 1928. Then it was installed in a Junkers F-24 all-metal monoplane and in 1929, it made its first flight from Dessau to Cologne.

In 1931, after the F04 bad passed further type tests with a rating of 720 h.p. at 1,700 r.p.m., it was given the name of Jumo 4 and

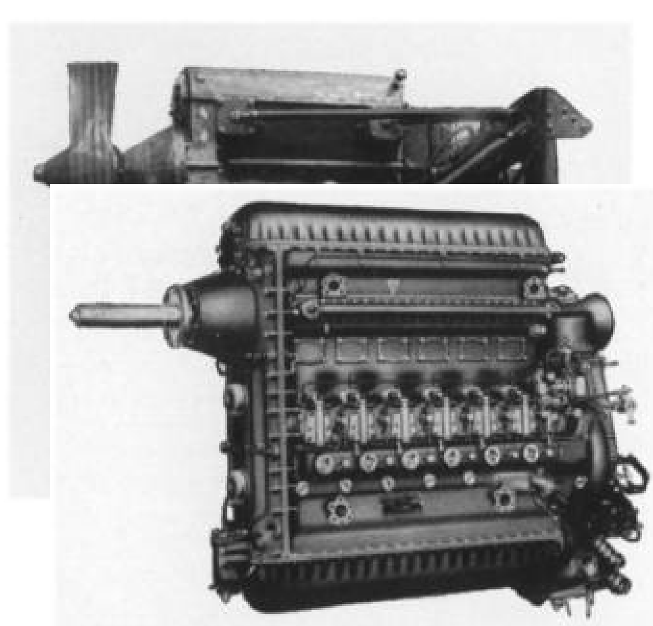

Fig. 4.—Junkers Jumo 205 Diesel aircraft engine, 1935-1939.

was placed in regular service on the airlines of Deutsche Lufthansa.4 Subsequently, the engine became known as the Jumo 204 and its output was increased to 770 h.p. at 1,800 r.p.m. In 1935, its manufacture was discontinued in favor of the Jumo 205 of similar construction but of considerably smaller size. Now the Jumo, 205 has been developed to the point where it has an output of 700 h.p. at 2,500 r.p.m. and 880 h.p. at 3,000 r.p.m. (Fig. 4). When equipped with an exhaust-driven super-charger it is known as the Jumo 207 and has a rating of 1,000 h.p. at 3,000 r.p.m. A slightly larger Diesel-the Jumo 206-has a rating of 1,200 h.p. and is now reportedly used in military planes. All of these engines have six vertical -water-cooled cylinders with two pistons in each cylinder and two crankshafts. Their specific weights range from 2.1 lb. per h.p. for the earlier models to 1.4 lb. per h.p. for the latest engines.

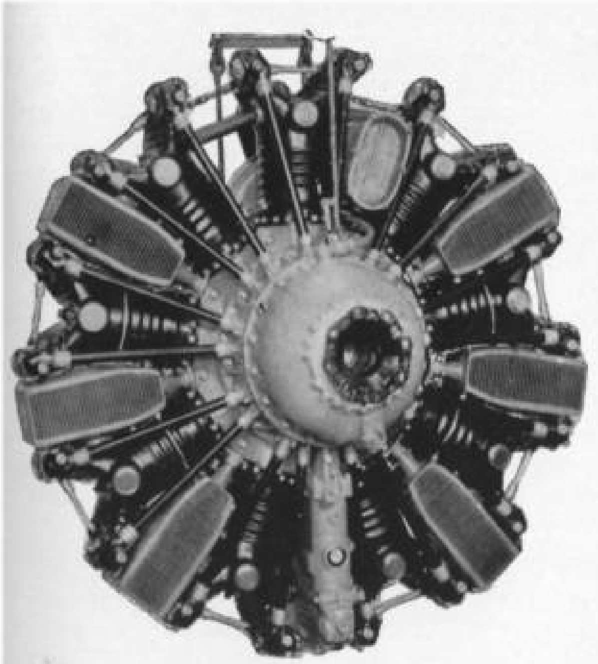
Fig. 5.—B.M.W.-Lanova 114 V-4 Diesel aircraft engine, 1938.

Another Diesel aircraft engine which has been developed in Germany is the B.M.W.-Lanova 114 V-4 Diesel built by B.M.W. Flugmotorenbau. G.m.b.H. (Fig. 5). Dr. Schwager has been responsible for much of the work on this nine-cylinder radial which is moderately supercharged and rated at 650 h.p. at 2,200 r.p.m. This engine, like the radial gasoline engines manufactured by the firm, functions on the four-cycle principle. It is unique in that although it is liquid-cooled, it is a self-contained unit with small radiators mounted between its cylinders where they do not increase the frontal area. This arrangement makes it interchangeable with air-cooled B.M.W. gasoline engines which are used for both civil and military purposes in Germany.

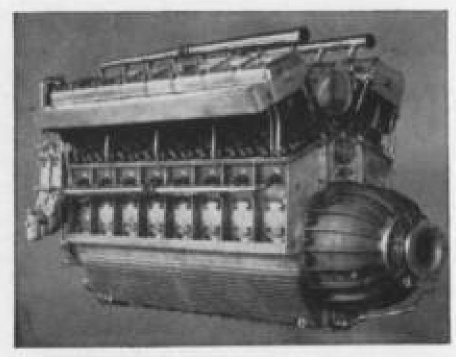
Fig. 6.—Mercedes-Benz DB 602 Diesel airship engine, 1936.

In addition to in-line Diesels for high-performance airplanes and radial Diesels for replacement units, there is still a third type which is manufactured in Germany. This is the Mercedes-Benz DB 602 Diesel built by Daimler-Benz A.G. for use in airships (Fig. 6). Sixteen individual water-cooled cylinders are used on this four-cycle engine which has a maximum power output of 1,320 h.p. at 1,650 r.p.m. and a specific weight of 3.3 lb. per h.p. Dr. Berger, chief engineer of the firm, designed this powerful Diesel which is unsupercharged. Four of them were used on the Zeppelin LZ-129, the *Hindenburg,* and four more of them were installed on the Zeppelin LZ-130, the *Graf Zeppelin.*

Developments in the United States

The first public showing of the Junkers FO-3 Diesel aircraft engine in Germany in 1926 created such world-wide interest that it was not long before experimental work of this nature was under way in the United States. Here most of our Diesel aircraft engine designers concentrated on four-cycle, air-cooled radials based upon gasoline aircraft engines with which they were familiar. This has worked out all right for low-powered and medium-powered engines, but for larger power plants two-cycle, liquid-cooled Diesels are needed. The Godfrey Manufacturing Corp. has done extensive single-cylinder experimental work with the last-mentioned type of engine and has prepared designs for a large Diesel aircraft engine embodying two-cycle operation.

The Packard Diesel

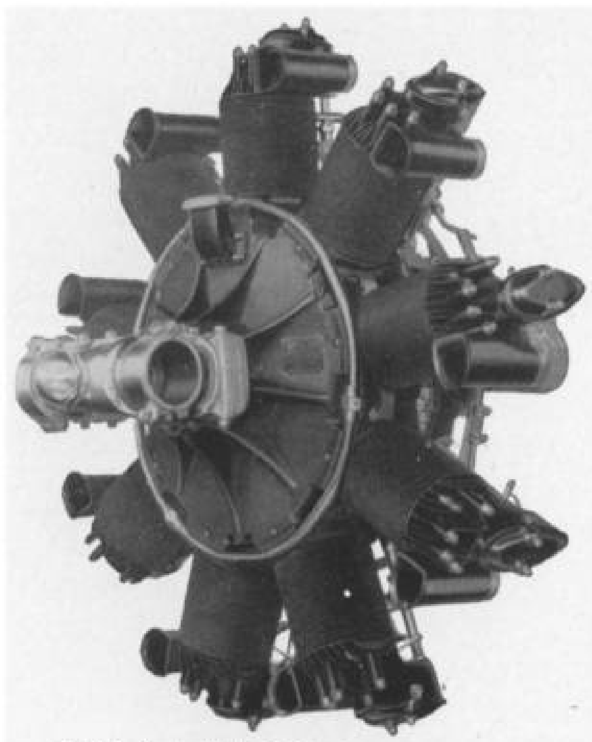
Fig. 7.—Packard DR-980 Diesel aircraft engine, 1929.

In the United States, the first Diesel aircraft engine to appear was the Packard. Work on this nine-cylinder, air-cooled radial was started in 1928 under the direction of Capt. Lionel Woolson, chief aeronautical engineer of the Packard Motor Car Co., and Professor Herman Dohner, a German engineer. Captain Woolson was considered one of the foremost engineers of his day and designed the 600 h.p. and 800 h.p. Packard water-cooled gasoline airplane engines for the United States Navy. He also designed the 400 h.p. Packard airship engines used on the *Shenandoah.* Behind him be bad the enthusiastic backing of one of the largest and best equipped engineering firms in the country whose experience with internal combustion engines dated back to 1900.

Development work on the Packard DR-980 Diesel was brought to a successful conclusion in 1929 when Capt. Woolson made the first crosscountry flight with a Diesel-engined airplane in the United States. He flew from Detroit to Langley Field covering the distance of 700 miles in 6 hours and 40 minutes. During a subsequent flight in a Stinson *Detroiter* from Detroit to Miami, the new Diesel showed remarkable economy and its cost for fuel oil was less than one cent a mile.

In 1930, the Packard DR-980 Diesel passed its 50-hour government test and was granted A.T.C. No. 43 with a continuous rating 225 h.p. at 1,950 r.p.m. (Fig. 7). At the National Aircraft Show held at Detroit that year the engine was a sensation with six airplanes in the show equipped with it as well as several others on the flying field. Among the latter was a tri-motored 11-passenger Ford 11-A airliner which was equipped with three Packard Diesels and could cruise at a fuel cost of three cents a mile.

Hardly had the Packard Diesel been launched on its career than tragedy overtook its forty-two year old inventor. On April 24, 1930, Captain Woolson and his two companions took off from Detroit for New York in a Verville *Air-Coach* equipped with one of the Diesels. Lost in a storm, they crashed near Attica, New York, and all were killed.

Following the death of Captain Woolson, the inventive genius and driving force behind aircraft engine production in the Packard factory came to a standstill. Production of the Diesels in their specially built and equipped factory was discontinued. Despite this change in policy, Packard Diesels continued to be used for a time and on May 28, 1931, Walter E. Lees and Frederick A. Bossy established the world's nonrefueling duration record with one of them in a Bellanca *Pacemaker* at Jacksonville, Florida. They took off with a load of 481 gallons of fuel oil and remained in the air for 84 hours and 32 minutes. This still constitutes the world's record for both Diesel-engined and gasoline-engined airplanes.

As an indication of the high esteem in which the Packard Diesel was held it should be mentioned that the Collier Trophy for the most important contribution to aviation during 1931 was awarded to the Packard Motor Car Company for its work with this type of engine.

The Guiberson Contributions

About the time that the Packard Diesel passed into oblivion, another Diesel aircraft engine of similar design appeared to take its place. This newcomer was a product of the Guiberson Diesel Engine Company of Dallas, Texas, a firm which had had considerable experience in the industrial Diesel field. Work on the first Guiberson Diesel aircraft engine was started in 1930 to the designs of F. A. Thaheld, a young Austrian engineer. Early in 1931, after more than 800 hours on the test stand, the nine-cylinder, air-cooled Guiberson A-980 Diesel was ready to take to the air. For the test flights, the services of Col. Arthur G. Goebel, famous for his transpacific flight between San Francisco and Honolulu, were secured. The Diesel was installed in his Waco biplane and on a test flight he covered the 960 miles from Dallas to Detroit on 96 gallons of furnace oil. The cost of this fuel, at seven cents a gallon, was only $6.72 or less than one cent a mile. Most of the return trip was made in a downpour of rain which did not affect the engine as it had no electrical ignition system.

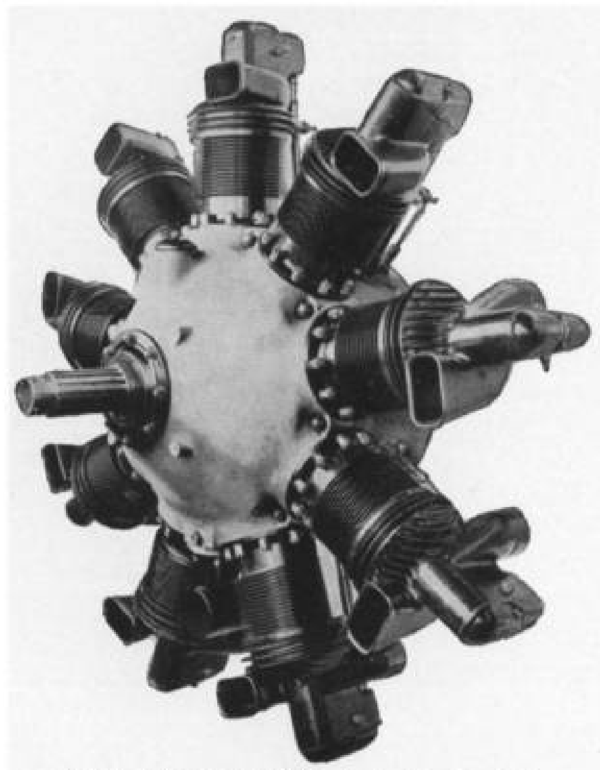

Fig. 8.—Guiberson A-980 Diesel aircraft engine, 1931.

Later in the same year Colonel Goebel reached an altitude of 21,686 ft. with this unsupercharged Diesel and flight tests proved that it bad a better performance than contemporary gasoline engines of the same power. In November, 1931, the Guiberson A-980 passed its government tests and was awarded A.T.C. No. 79 with a rated power output of 185 h.p. at 1,925 r.p.m. (The engine used is shown in Fig. 8.)

Despite the gloom which settled over the youthful Diesel aircraft engine industry after the Packard Diesel was abandoned, development of the Guiberson Diesel proceeded and was kept alive by the persevering efforts of S. A. Guiberson, Jr. Next, a slightly larger Diesel known as the Guiberson A-918 model was constructed under the supervision of C. C. Spangenberger, chief engineer of the firm. In 1934, the United States Navy showed considerable interest in the engine and two of the A-918 Diesels were delivered to the Bureau of Aeronautics for test These engines were rated at 253 h.p. at 2,100 r.p.m. and after improvements had been made, two more of them were ordered.

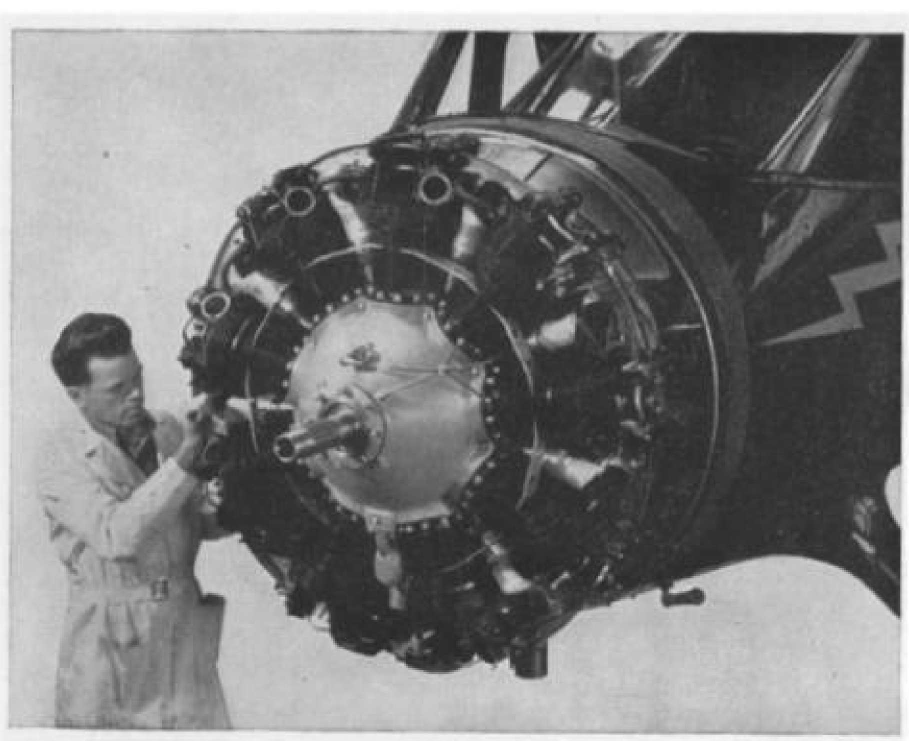

Fig. 9.—Guiberson A-1020 Diesel aircraft engine, 1940.

A later Guiberson. Diesel is the A-1020 model which is similar to its predecessors but has up-to-date valving (Fig. 9). This engine passed its civil government tests in 1940 and was awarded A.T.C. No. 220 with a rating of 310 h.p. at 2,150 r.p.m. It weighs 650 lb., or 2.1 lb. per h.p.

An identical Diesel is manufactured for use by the War Department in light tanks and this is known as the T-1020 model. Arrangements have been made for both of these engines to be manufactured by the Buda Company, well-known in the

Diesel field, in their factory located in Illinois. Still larger and more powerful Guiberson Diesels are projected for airplanes and tanks with power outputs up to 1,000 h.p. made possible by supercharging.

Other American Developments

Successful development of Diesel aircraft engines in the United States has been limited to Packard and Guiberson Diesels as these are the only engines which have been flown. Other Diesels have been built and bench-tested but for one reason and another, they have been abandoned. Mention should be made of the 75 h.p., two-cylinder, water-cooled Attendu airship engine built for a Navy airship in 1925 which weighed 6.5 lb. per h.p.; the 400 h.p., seven-cylinder aviation Diesel with radial, air-cooled cylinders which was completed in 1932 and weighed 3.5 lb. per h.p.; and the 1,200 h.p., twelve-cylinder Deschamps engine which was built in 1934 and weighed 2.0 lb. per h.p. The Deschamps V 3050 Diesel with its two banks of inverted liquid-cooled cylinders and low frontal area was a promising engine but financial diffficulties have prevented its further development and flight testing

DEVELOPMENTS IN GREAT BRITAIN

In 1927, a year after the first public showing of the Junkers FO-3 Diesel in Germany, the Bristol Aeroplane Co., Ltd., began work on a Diesel or compression-ignition (C.I.) engine as it is called in England. Financial aid was given by the British Air Ministry and the work was carried out under the direction of Dr. Roy Fedden, chief engineer of the engine division of the Bristol firm. Several years were devoted to research and after bench tests totaling more than 1,500 hours had been completed with single-cylinder Diesels it was decided that the results warranted the building of a fullsized engine.

The Bristol Diesels

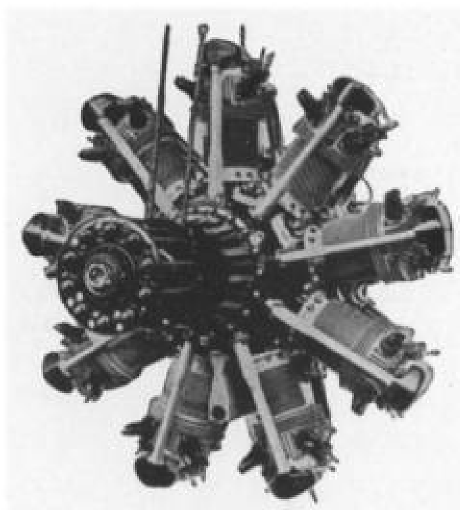
Fig. 10.—Bristol Phoenix Diesel aircraft engine, 1933.

The Bristol Phoenix, as this nine-cylinder, air-cooled Diesel was called, resembled the contemporary Bristol Jupiter VIII F gasoline engine to a great extent (Fig. 10). It was of the same size and displacement and with its rating of 430 h.p. at 2,000 r.p.m., it bad practically the same power output. Its first flights were made in 1933 when it was installed in a Westland Wapiti observation plane and took part in the annual Royal Air Force Display at Hendon. After a supercharger of moderate capacity had been added, the Phoenix was flown in the same airplane to an altitude of 27,453 ft. on May 11, 1934, by H. J. Penrose. This flight was made under the official observation of the Royal Aero Club and established the world's altitude record for Diesel-engined airplanes.

Subsequently, interesting comparisons were obtained by flying the Westland Wapiti with the Phoenix Diesel and the Jupiter VIII F gasoline engine. It was found that the Diesel-engined plane had the better performance as its rate of climb was increased by 15 per cent and its speed at altitude was increased by 4 per cent (Fig. 11). Its fuel consumption was also reduced by as much as 35 per cent. These improvements were due to the better power output characteristics of the Diesel at altitude (Fig. 12). Recently, further work has been done on the Bristol Phoenix and its crankshaft speed and supercharger impeller speed have been increased so that it is now rated at 635 h.p. at 2,100 r.p.m.

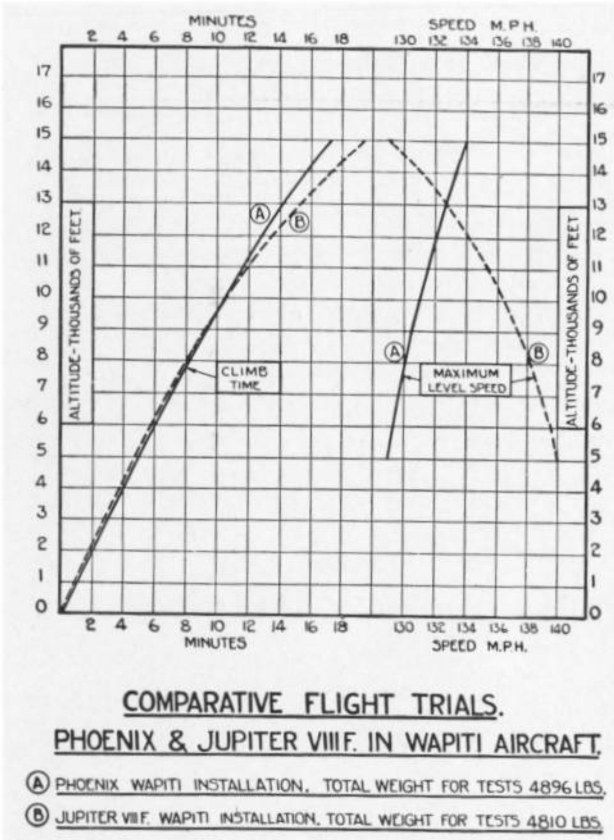

Fig. 11.—*Climb and altitude performance of Bristol Phoenix Diesel.*

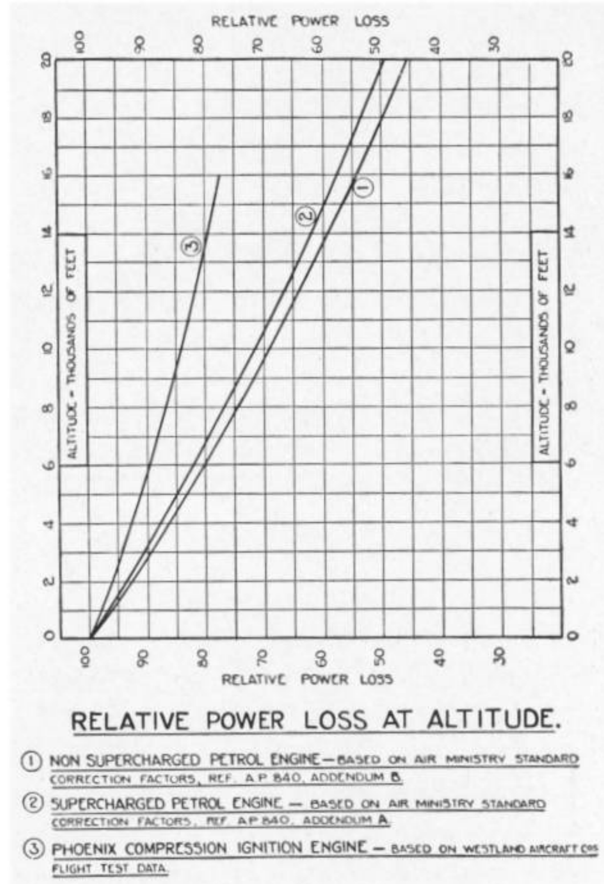

Fig. 12.—*Power loss at altitude of Bristol Phoenix Diesel.*

The Beardmore Diesels

Concurrent with the Bristol development, the firm of William Beardmore & Co., Ltd., designed an airship Diesel for the British Air Ministry which passed its tests in 1930. The Beardmore *Tornado,* as this engine was called, was of heavier construction than an airplane engine and with its eight-in-line, steam-cooled cylinders had a weight of 7.8 lb. per h.p. Five of these Diesels rated at 585 h.p. at 900 r.p.m. were installed on H. M. Airship R-101 which was destroyed in a storm while flying in India. Beardmore also designed an interesting airplane Diesel with horizontallyopposed cylinders for submerged installation inside the wing. This twelve-cylinder, watercooled engine was intended to develop 500 h.p. at 1,750 r.p.m. but it was never completed.

The Napier Experiments

Realizing the difficulties to be overcome in the development of a successful Diesel aircraft engine, the British Air Ministry then decided to investigate the Junkers Diesel which had established an excellent reputation for itself in Germany. In *1935,* after exhaustive tests of one of these engines by the air ministry, the -firm of D. Napier & Sons, Ltd., acquired a license to build the Junkers Jumo 4 and Jumo 5 in England. Several Napier *Culverins* with an output of *720* h.p. at 1,700 r.p.m. corresponding to the Jumo 4 were built and some of them were flight-tested in a Blackburn flying boat (Fig. 13). Nothing came of this project, however, and the Napier Cutlass of 535 h.p. corresponding to the Jumo 5 was never placed in production.

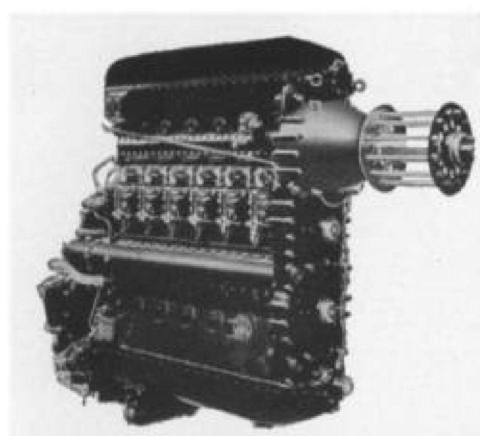

Fig. 13.—*Napier Culverin Diesel aircraft engine, 1935.*

Other British Developments

In addition to aiding in the development of these engines, the British Air Ministry also played a part in the conversion of two RollsRoyce *Condor* gasoline engines to Diesel operation. The Royal Aircraft Establishment and Ricardo also aided in this conversion but the best that they could obtain from -these twelve-cylinder, water-cooled engines was an output of 480 h.p. at 1,900 r.p.m. One of these converted engines weighing 2.9 lb. per h.p. was flown in a Hawker *Horsley* torpedo bomber in 1933.

The only other Diesel aircraft engine. built in England was the Sunbeam-Coatalen P-1 designed by Louis Coatalen, chief engineer of the Sunbeam Motor Car Co., Ltd. Coatalen was born in France but went-to England to obtain experience in the internal combustion engine held. In *1926,* he became interested in the possibilities of the Diesel and converted a small Benz engine to work on this principle. In 1929, he completed his first Diesel aircraft engine which was exhibibited at the Aero Show in London. This six-cylinder, water-cooled engine was rated at 104 h.p. at 1,500 r.p.m. but it was never flown.

Developments in France and Other Countries

In 1931 Coatalen left the Sunbeam firm and returned to his native country. There he continued his Diesel research on a six-cylinder Panhard while engaging in the manufacture of Lockheed hydraulic brakes. The Coatalen 12 Vrs 2 Diesel aircraft engine which he subsequently built was constructed in the remarkably short time of six months. It was exhibited in the Paris Aero Show in 1936. On the test bed, this twelve-cylinder water-cooled engine developed 600 h.p. at 2,200 r.p.m. and weighed 2.0 lb. per h.p. Coatalen later planned a two-cycle Diesel of approximately the same size as his four-cycle Diesel which he hoped would develop 1,000 h.p.

The Clerget Diesels

Pierre Clerget has built more four-cycle Diesel aircraft engines than anyone in France and a number of them have been test-flown. As long ago as 1930, he exhibited a nine-cylinder, air-cooled radial Diesel known as his 9-A model with a rating of 100 h.p. at 1,800 r.p.m. Since then, several models have been built and for a time the firm of Hispano-Suiza carried on this development work. Later, the French Air Ministry took over all Clerget developments and assisted him in building larger fourteen-cylinder Diesels. One of these engines,, known as the Clerget 14 F-01 and rated at 940 h.p. at 2,400 r.p.m. was test-flown to an altitude of 25,114 ft. in a Potez 25 observation plane in 1937 (Fig. 14). The pilot on this occasion was M. Detre and the Right was certified by the Aero Club of France.

Fig. 14.—Clerget 14 F-01 Diesel aircraft engine, 1937.

The latest Clerget development was a large sixteen-cylinder, watercooled Diesel known as the 16-H model which was bench-tested in 1939. This engine was designed to develop more than 2,000 h.p. and it weighed 1.9 lb. per h.p. Four exhaust-driven (turbo) superchargers were installed on it with the object of maintaining its rated power output to an altitude of approximately 20,000 ft. It was exhibited at the Paris Aero Show in 1938 with the designation "Type Transatlantique."

Another French Diesel, the Salmson SH 18 built under Szydlowski license, is interesting in that it is a water-cooled radial with its eighteen cylinders arranged in tandem pairs around the crankcase. Rated at 600 h.p. at 1,700 r.p.m. and designed to operate on the two-cycle principle, the SH 18 weighs 1.9 lb. per h.p. This engine was exhibited at the Paris Aero Show in 1934 but it has yet to prove itself in the air.

The C.L.M. Diesels

Not wanting to lag behind Great Britain in Diesel development, France also acquired a license to build the Junkers Jumo 5 Diesel in 1935. This license was taken out by the firm of Compagnie Lilloise de Moteurs S.A., more commonly known as C.L.M. Several engines known as the Lille 6 AS model were constructed with a rating of 600 h.p. at 2,200 r.p.m. Some flight testing was done with them in a Bernard 82 long-range monoplane with a view to attempting to establish a long distance record. At the present time the firm of C.L.M ' is showing little activity with Diesels of this type for aviation but is building them as railcar engines with power outputs of 150, 250 and 500 h.p.

The Jalbert-Loire Diesels

Jalbert-Loire Diesel aircraft engines built by Ateliers' et Chantiers de la Loire S.A., near Paris, have also received encouragement from the French Air Ministry and three different sizes of engines have been constructed. These comprise a fourcylinder 160 h.p. engine and a six-cylinder 235 h.p. engine with inverted in-line cylinders, and a sixteen-cylinder engine known as the 16-H model which has its cylinders in H-formation and develops 600 h.p. at 2,400 r.p.m. All of these engines are water-cooled and the largest one weighs 2.0 lb. per h.p.

Other French Developments

France certainly has not lacked for Diesel aircraft engine projects. Other engines worthy of mention are the nine-cylinder air-cooled Lorraine Diesel built in 1932 which was rated at 200 h.p. at 1,500 r.p.m. and weighed 3.5 lb. per h.p.; the eight-cylinder air-cooled Botali Diesel constructed in 1937 which developed 118 h.p. at 2,000 r.p.m. and weighed 2.2 lb. per h.p.; and the seven-cylinder air-cooled Delafontaine Diesel designed to have a power output of 400 h.p. None of these engines have been test flown.

Development in Other Countries

At the time that the Packard Diesel was active in the United States, a license to build this engine was acquired by the well known engine firm of Walter in Czechoslovakia. Although no Packard Diesels were built abroad, the future of this type of power plant appeared so promising that Ceskoslovenska Zbrojovka, part of the National Alms Factory, decided to design a Diesel of its own. Development work was started in 1930 and three years later the nine-cylinder, air-cooled ZOD 260-B Diesel passed its 50-hour test with a rating of 260 h.p. at 1,560 r.p.m. (Fig. 15). This two-cycle engine gave excellent results in small training planes with many hundreds of hours of flying to its credit. Dr. Ostroil and his follow engineers were responsible for the ZOD 260-B Diesel which weighed 2.3 lb. per h.p.


Fig. 15.—*Zbrojovka ZOD 260-B Ciesel aircraft engine, 1933.*

Italy is the only remaining country in which results of Diesel developments have been made public. This work is not of recent origin, however, as it was in 1930 that the Fiat ANA Diesel was built and flown. This engine had six in-line, water-cooled cylinders and was rated at 220 h.p. at 1,700 r.p.m. and weighed 4.0 lb. per h.p. A still earlier Diesel of Italian origin, the Garuff a, was exhibited at the Paris Aero Show in 1921. Considering the tremendous advantages to be derived from Diesel aircraft engines with their low fuel consumption, it is strange that more progress has -not been made with them in Italy where aircraft engine fuel is at a premium.

Japan has shown great interest in Diesel aircraft engines which is significant inasmuch as the firm of Mitsubishi has a license to build Junkers engines and airplanes. It is possible that arrangements have been made for the Junkers Jumo 205 Diesel to be manufactured in Japan as a number of -these engines have been used there for experimental purposes and have been reportedly installed in bombers used against the United States.

The U.S.S.R. is also alert to the possibilities of the Diesel for longrange flight operations and undoubtedly work on Diesels proceeded there, probably under the guidance of German engineers before Germany's attack on Russia in the second World War.