one of the factors in definition, and should be so considered when planning a technique. A slow film speed, and generally a high contrast, are associated with fine grain. If the exposure time were of no consequence, such a film would almost completely displace all others. A contrasty, fine-grain film may be used with a higher kilovoltage than films of lesser contrast, to secure the same resultant contrast in the radiograph, and with the improved definition provided by such a film, an even lower radiographic contrast, produced by a further increase in kilovoltage, is permissible. The greater X-ray output arising from the higher kilovoltage helps to offset the slower speed of the film.

A given film shows increasing graininess with increasing hardness of radiation. This effect is not noticeable for small changes in kilovoltage, such as minor adjustments to change the penetration where the approximately correct kilovoltage is established. A similar effect is found with tungstate intensifying screens, but in this case the film is simply recording the characteristics of the screen, whose light is almost exclusively responsible for the exposure. Screen graininess is usually coarser and more diffuse in appearance than film graininess. In general, a fine-grain, high-contrast film (direct exposure type) is to be preferred for exacting work, and the coarse-grain film, or one for use with intensifying screens, left for the cases where thick materials are to be examined, requiring the fastest radiographic recording medium.

By way of illustration, consider the choice of materials for the radiography of 2in. steel plate. If the maximum kilovoltage available is 220, screen-type film will be used with tungstate screens. The actual kilovoltage used, however, will be adjusted to the lowest value consistent with a reasonable time of exposure. A direct-exposure type film with lead screens would be used at 300 kV. The slower, fine-grain type is preferable from the standpoint of quality, and continues to be all the way up through the 1000-kV region to gamma-rays. This type is recommended for gamma-ray work when overnight exposures can be made, but if only two or three hours can be spared, the faster type must be used.

The great bulk of magnesium and aluminium work is done at such low kilovoltages that the limit of the machine is seldom reached, even if a slightly higher kilovoltage is used to offset the slow speed of a fine-grain film. Screen-type film, when exposed to direct X-rays (with or without lead screens), usually has a low contrast and intermediate graininess and speed. Its application in this manner is quite limited, and it is supplanted by the higher contrast films.

The simultaneous exposure of two films, superimposed in the cassette, permits a shortening of exposure time and has the additional advantage of increasing contrast when the two radiographs are viewed superposed. If lead screens are used, a third sheet of lead unmounted would be sandwiched between the two films. This procedure is equivalent to increasing the latitude of the film, since high densities corresponding to thinner metal may be viewed in the single films and low densities representing thick sections may be viewed with the films superposed.

MICRORADIOGRAPHY

Microradiography differs from ordinary radiography primarily in the fact that it is customary to enlarge the radiographs in order to study the fine structure of the specimen. For enlargements of 50 or 100 diameters, special fine-grain emulsions are essential. These have a much lower X-ray speed than the emulsions commonly used in the radiography of materials. Successful commercial applications of the microradiographic procedure have been in such unrelated fields as studying the cemented joint in corrugated cardboard and distinguishing between natural and cultured pearls. Of particular interest to the metallurgist is the fact that enlargements of low-voltage radiographs of thin specimens of an alloy are capable of disclosing the difference in absorption of segregated constituents.

The general procedure is to prepare a specimen of the metal by grinding it down to a few thousandths of an inch in thickness. It is then mounted close to or in contact with a special fine-grain photographic plate and radiographed. The X-ray tube voltage chosen is likely to be in the range from 5000 to 20,000 volts. Trials will be necessary to find out just what radiation quality is best suited to a given kind of material. It may be desirable to select a particular target material for the X-ray tube in order to match the radiation with the absorption characteristics of the alloy to best advantage. Whether the continuous spectrum from one target at a certain voltage is better than the line emission spectrum from another is a point on which complete agreement is lacking. Certain it is, however, that attention must be paid to the choice of radiation quality for best results to be obtained. After processing, the radiograph is enlarged by ordinary optical projection or viewed through a low-power microscope.

The Rolls-Royce "Merlin 61" Supercharged Fighter Engine

LAST week we accepted the invitation of Rolls-Royce, Ltd., to inspect an example of the firm's new "Merlin 61" supercharged aero-engine, which is being fitted by the Royal Air Force to the improved "Spitfire" now operating with Fighter Command. By using a double-stage supercharger, with a water-cooled passage between the first and second stages of the supercharger and a cooler between the supercharger outlet and the induction pipe to the rear cylinder, it is found possible with the new engine to develop double the power output, as compared with that of the "Merlin III," the first engine to be fitted to the "Spitfire" fighters. When operating at a height of 40,000ft., the charge of air and fuel is now raised by the supercharger to six times the pressure of the surrounding atmosphere. Accompanying this article we reproduce engravings showing the end and side views of the new engine, along with a diagrammatic drawing giving a section through the supercharger and illustrating the arrangement of the cooling system.

Engine Particulars

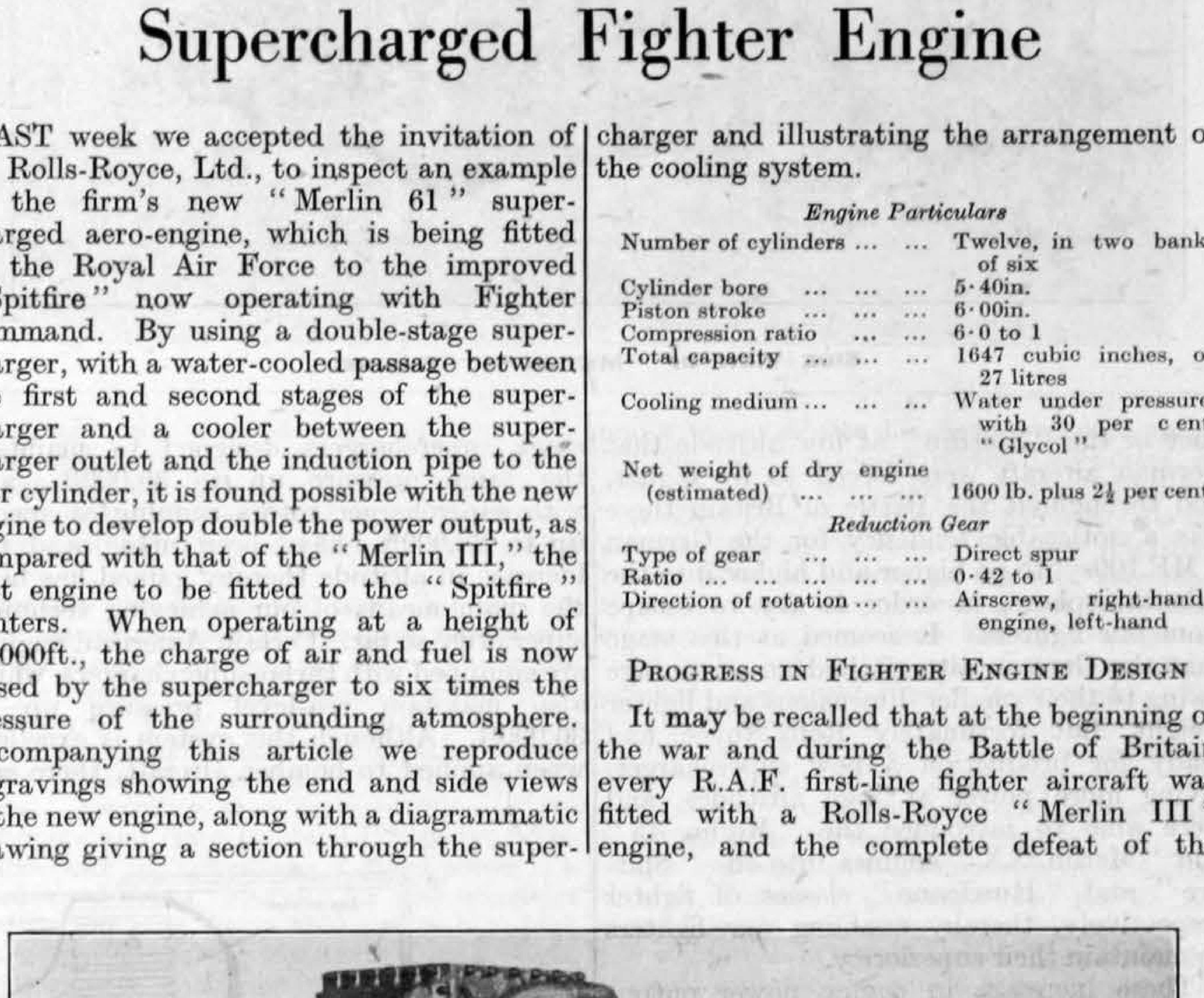
Number of cylinders	Twelve, in two banks of six
Cylinder bore	5·40in.
Piston stroke	6·00in.
Compression ratio	6·0 to 1
Total capacity	1647 cubic inches, or 27 litres
Cooling medium	Water under pressure, with 30 per cent. "Glycol"
Net weight of dry engine (estimated)	1600 lb. plus 2½ per cent.

Reduction Gear

Type of gear	Direct spur
Ratio	0·42 to 1
Direction of rotation	Airscrew, right-hand; engine, left-hand

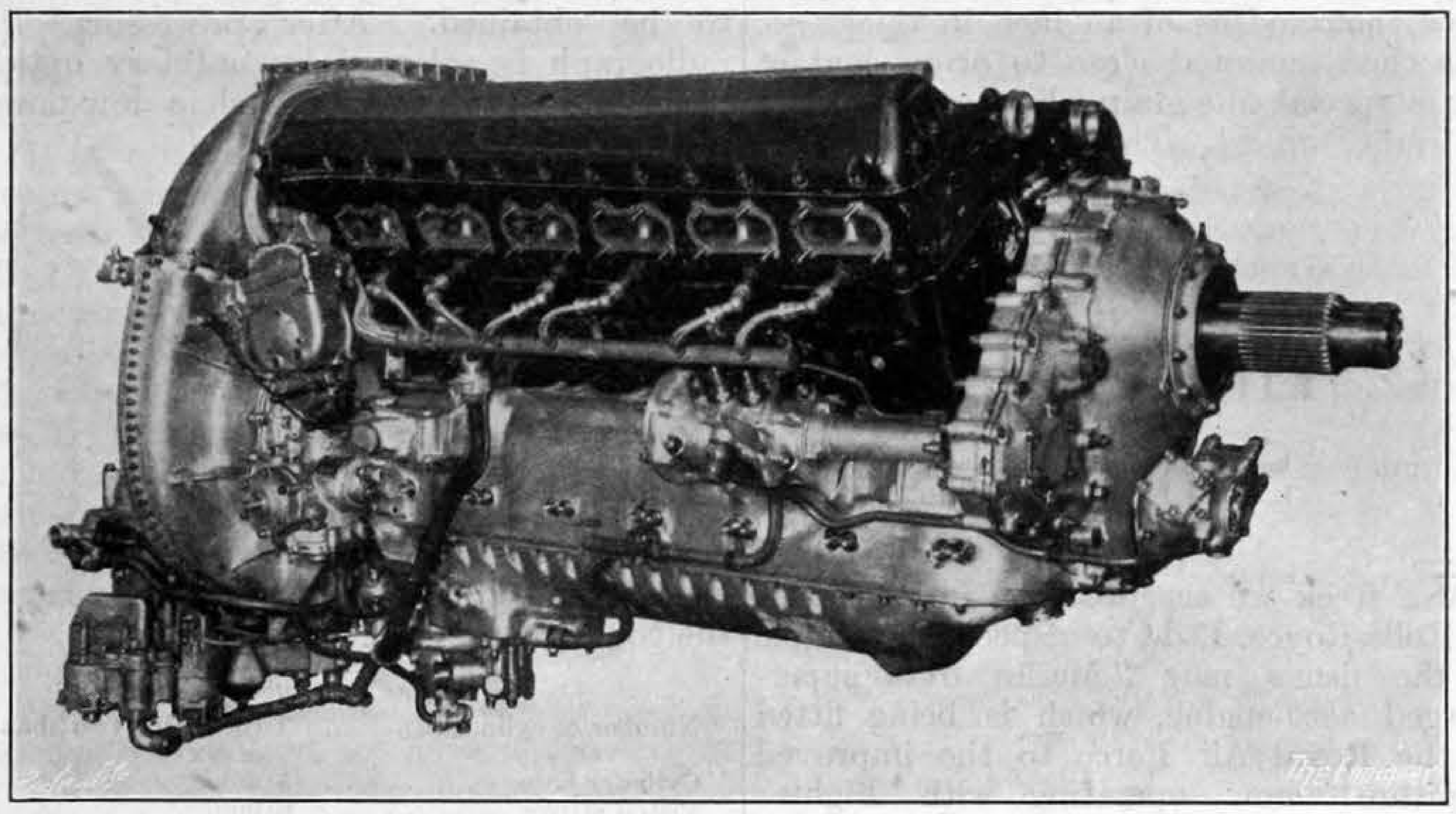
PROGRESS IN FIGHTER ENGINE DESIGN

It may be recalled that at the beginning of the war and during the Battle of Britain every R.A.F. first-line fighter aircraft was fitted with a Rolls-Royce "Merlin III" engine, and the complete defeat of the



ARRANGEMENT OF SUPERCHARGER OF "MERLIN 61" ENGINE

Luftwaffe in August and September, 1940, definitely established the technical superiority of British machines. The superiority was not obtained by chance, but every move of the enemy had been anticipated and a definite counter-move worked out. Early in the war, German aircraft resorted to low-flying tactics, and in order to counter this, Rolls-Royce immediately increased the sea-level power of the "Merlin" engine by 40 per cent. by raising the supercharger pressure. This move so improved the perform-



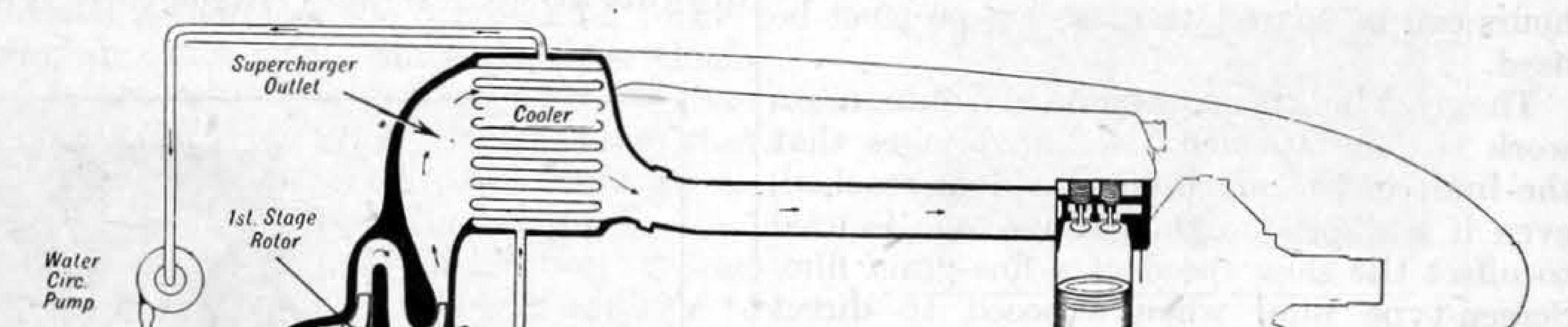
SIDE VIEW OF "MERLIN 61" ENGINE

ance of the "Spitfire" at low altitude that German aircraft were forced to fly higher, and throughout the Battle of Britain there was a noticeable tendency for the German "ME.109s" to go higher and higher into the substratosphere, in order to try to escape from our fighters. It seemed at this stage that the German aircraft had an advantage owing to their smaller dimensions and lighter weight, but fortunately Rolls-Royce had ready for production a new supercharger, giving more power at high altitudes, and were able to introduce the "Merlin 45" and "Merlin XX" engines into the "Spitfire" and "Hurricane" classes of fighter respectively, thereby enabling our fighters to maintain their superiority.

These increases in engine power output were achieved without any radical change to the aircraft, and the flow of fighters from our factories was not affected in the slightest by the modifications made. A continuous supply of improved fighters to the R.A.F. was maintained, as the basic engine remained unaltered, excepting that a new supercharger had to be manufactured in large quantities. The war demands that the performance of all types of military aircraft, and particularly that of fighter aircraft, shall continually improve. Ranking above the need for more and more aircraft of all types is the overriding necessity that our aircraft shall have technical superiority over those of the enemy. It soon became apparent that in the "Spitfire" we had a supreme aircraft from the aerodynamic and military points of view, and all that was required to keep this machine on the top of the list was a steady improvement in the performance of the "Merlin" engine with which it was fitted. An advantage to the R.A.F. was that any improvement thus obtained could be immediately applied to existing aircraft and could be put into service with the minimum of time. With these facts in mind, Rolls-Royce, Ltd., has continually striven to increase the power output of the "Merlin" engine by improvement to the supercharger and carburetter, a logical development being the "Merlin 61," with two-stage supercharger and cooler.

The advantages of the system may be effectively reviewed by comparing the aero-engines which power the various first-line aircraft to the nations engaged in the war. German engines, without exception, are fitted with a single-stage supercharger, designed to maintain ground level pressure in the engine induction system up to a height of 20,000ft.

Rolls-Royce engines, equipped with single-stage superchargers designed to maintain the same pressure up to 30,000ft., and with supercharger rotors running at speeds up to 28,000ft., have been made, and the increase in altitude thereby gained has been the main means of our achieving technical superiority so far. Certain American engines are equipped with turbo-superchargers, which also maintain sea-level pressure up to 30,000ft. Although this system is excellent when applied to bomber aircraft, there are,



DIAGRAMMATIC ARRANGEMENT OF SUPERCHARGER

however, technical reasons which make it less suitable for fighter aircraft. Finally, the two-stage supercharger maintains the desired pressure up to 40,000ft., and stands out above all others as the most successful means of obtaining high power and high altitudes. At 40,000ft. the charge is compressed to a pressure of six times the surrounding atmospheric pressure, the power of the original "Merlin III" engine being doubled, while at a height of 20,000ft. the output of the new engine is 50 per cent. larger than that of the original "Merlin III."

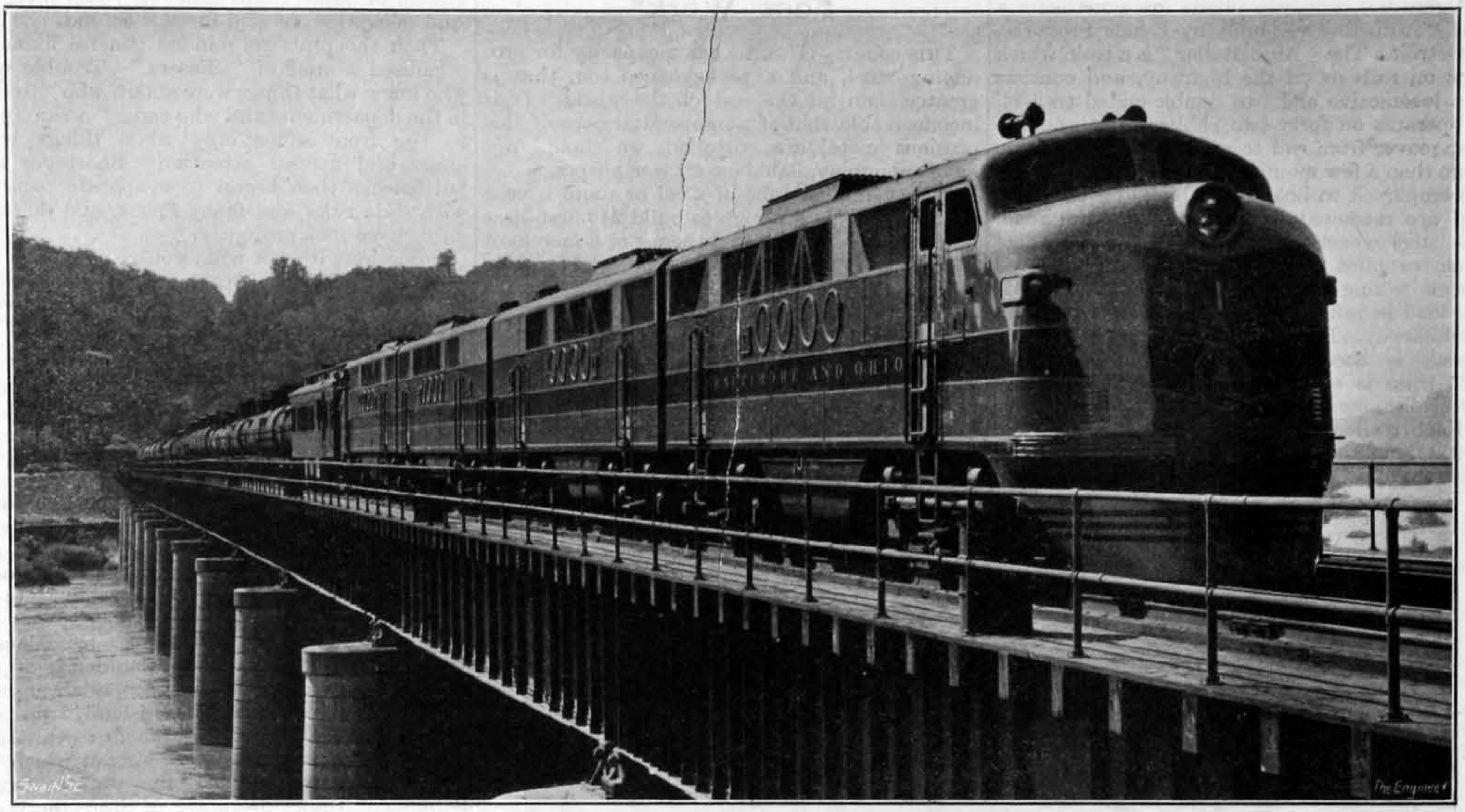
SUPERCHARGER DESIGN AND ARRANGEMENT

It will be seen from the accompanying drawing that the two-speed, two-stage supercharger has two rotors mounted on a common shaft, the arrangement being two superchargers in series. The mixture of air and petrol drawn through the carburetter is compressed by the first-stage supercharger, and it then passes through a cooled passage to the inlet of the second-stage supercharger, in which its pressure is again raised. After passing through a cooler, which is supplied from an air-cooled radiator, the mixture is delivered to the main induction pipe, which feeds the twelve cylinders, grouped in vee formation in two banks of six. The cooling of the mixture as it is delivered from the outlet of the second stage is effected in the square box-like structure containing the cooler elements, which is mounted between the rear of the cylinder blocks and the supercharger casing. As previously mentioned, in addition to the main cooler there is a water-jacketed passage between the two supercharger stages, which contributes to the cooling of the charge. The supercharger cooling system is entirely separate from that of the engine, and the radiator for cooling the circulating fluid and dissipating the heat abstracted from the compressed charge can be placed in any convenient position in the aircraft.

In the "Spitfire" it is mounted under the wing of the machine in a duct which also contains one of the main engine cooling radiators. The other engine cooling radiator is placed in a similar position on the opposite wing, and alongside it is arranged the engine oil cooler. An advantage of the liquid cooling system is that it can be made considerably smaller than if the heat exchange was made direct with the atmosphere. By this means a short induction system is retained, the space taken up being small, while the view of the pilot is unimpaired.

The results obtained from the improved "Spitfire" powered with the new engine we have described have, we learn, more than fulfilled the hopes and expectations of all who have helped in the work. Every aspect of this wonderful fighter aircraft has been tremendously improved by the introduction of the "Merlin 61." This outstanding development of an already fine engine should do much to counteract the tendency there sometimes is in this country to belittle the qualities of our military equipment and to

BALTIMORE AND OHIO RAILROAD OIL ELECTRIC FREIGHT LOCOMOTIVE



exaggerate the good points of our adversaries' equipment. The completion and entry into service of the "Merlin 61" is a proof, if such were needed, that we are in no way lagging behind, either in the matter of technical development or in the speed with which new ideas are put into service. The advent of the new German "Focke-Wulf 190" on the battle front, with its 1600 H.P. air-cooled supercharged engine (see THE ENGINEER for August 14th), caused some uninformed persons to believe that the Germans had stolen a march on us in the high-performance fighter class of aircraft, but, as enemy fighter losses continually show, the improved "Spitfire" with its new "Merlin 61" engine was there to surpass it.

B. and O. Railroad Oil Freight Locomotive

THE Baltimore and Ohio Railroad Company's main line oil freight locomotive "No. 1" made its initial run from Chicago to the eastern seaboard of the United States by pulling one of the heaviest through rail shipments of petroleum on record. The solid train of tank wagons left Chicago on the morning of August 1st bound for a distribution depôt at Twin Oakes, near Philadelphia, Pa.

The train had a deadweight of 5300 gross tons, and the locomotive pulling it was built by the Electro-Motive Corporation. This freight locomotive of 5400 H.P. provides the first instance of such a unit being operated in regular freight service on any railway in America. The train was scheduled to make the run from Chicago to its destination without change of locomotives or the dropping of any of the loaded wagons. The run of 911 miles called for five stops at stated points for the customary crew changes and for inspection, and it was necessary only at two of the stopping points to refuel the locomotive on that epoch-making trip.

Previous test runs of the locomotive, when drawing heavy-tonnage trains, indicated that on this especially long run the locomotive would be able to haul about 175 times the volume of oil consumed by its engines. As the 911-mile run was, in effect, also a test run, Baltimore and Ohio engineers were desirous of obtaining accurate data regarding the unit's performance on this unusual operation, and to that end a dynamometer car was attached just behind the locomotive to furnish a check on the functioning of "No. 1."

Because the engine was new, and also for other reasons, no attempt was made to establish a speed record. Instead, the aim was to maintain an average speed for the entire run of about 20 miles an hour. In fact, the train made 23·4 miles an hour, and it stopped at certain of the terminals or stations for as long as two hours. According to a representative of the Baltimore and Ohio Railroad Company, "The run showed the advantage of diesel power in a number of ways, overall, for the excellent hauling job of a heavy-tonnage train; high availability in making the entire run on which, had steam engines been used, it would have been necessary to change engines five times; and despite long terminal delays, good average speed was achieved because of quick acceleration."

The locomotive illustrated herewith is one of a group built for the Baltimore and Ohio Railroad and, like the main line oil passenger locomotives on certain crack B. and O. trains, is a product of the Electro-Motive Division of General Motors, at the La Grange, Ill., plant. It measures 193ft. from its streamlined head to its rear coupler, and is composed of four short power wagons, each containing a sixteen-cylinder General Motors, two-cycle C.I. engine, conservatively rated at 1350 H.P. The crankshafts of each of these four engines, with a total horsepower of 5400, are connected directly to four electric generators, which feed power into traction motors mounted on the trucks. There are sixteen traction motors, each of which is geared to two wheels, making every one of the thirty-two wheels of the locomotive a "power wheel."

The locomotive can pull a freight train at 70 miles an hour, as compared with a maximum speed of 120 miles an hour for its sister main line passenger locomotive, but in actual freight train operation a speed of 70 miles an hour is not required nor attained. Water is used only in the radiators. The fuel oil tank capacity is 4800 gallons.

We are informed that it is possible for the locomotive to start a long heavy train—either on the level or on an upgradient—and to get the train up to a balanced speed in less time and within a shorter distance than are required by the most powerful steam locomotive in doing the same job under identical conditions.

A novel feature of the new locomotive is its electric braking system. Electric retarding brakes have been used on some of the older types of electric locomotives, which draw their current from power lines through trollies or third rails, but it is a new feature on independent oil-engined freight locomotives. By simply reversing the fields of the locomotive's sixteen traction motors they become generators. The electric current, so generated, is fed into grids on the roof of the locomotive power units and is dissipated in the form of heat.

The operating crew's compartment is similar to that of the oil passenger locomotive. All control levers are easily accessible and, with the exception of one lever that controls the traction motor connections, they are identical to the controls of a steam locomotive, namely, throttle, reverse bar, train and locomotive air brakes, sander, bell valve, and whistle cords. Therefore it is simple for an engineer to switch over from steam to oil after only a few hours' of instruction.

An instrument board, similar to an automobile dashboard, has indicators which show track speed, air brake pressures, wheel slip, and train control indications. Back in the engine-rooms are indicators that signal engine trouble and hot journal bearings. Automatic windshield wipers and defroster slot are provided. Adequate ventilation in the cab is assured by roll-down side windows, and the cab can be heated in cold weather merely by throwing a switch. The rear wall and roof of the cab are soundproof against train and engine noises, thus enabling the crew to carry on conversation without raising their voices.

The power wagon framing is on the trussed bridge principle. The streamlined front end is especially braced and has a battering ram conformation to protect the crew in case of a collision. The crew's safety is further provided for by placing the cab high in the nose and above and behind any normal point of impact.

RAILWAY CHANGES IN INDIA.—The Bengal and North-Western Railway and the Rohilkund and Kumaon Railway are to be taken over by the Government of India, and will be amalgamated as from January 1st, 1943, after which they will be known as the Oudh and Tirhut Railway.