ELEMENTS OF REFRIGERATION

NEWNES

PRACTICAL MECHANICS

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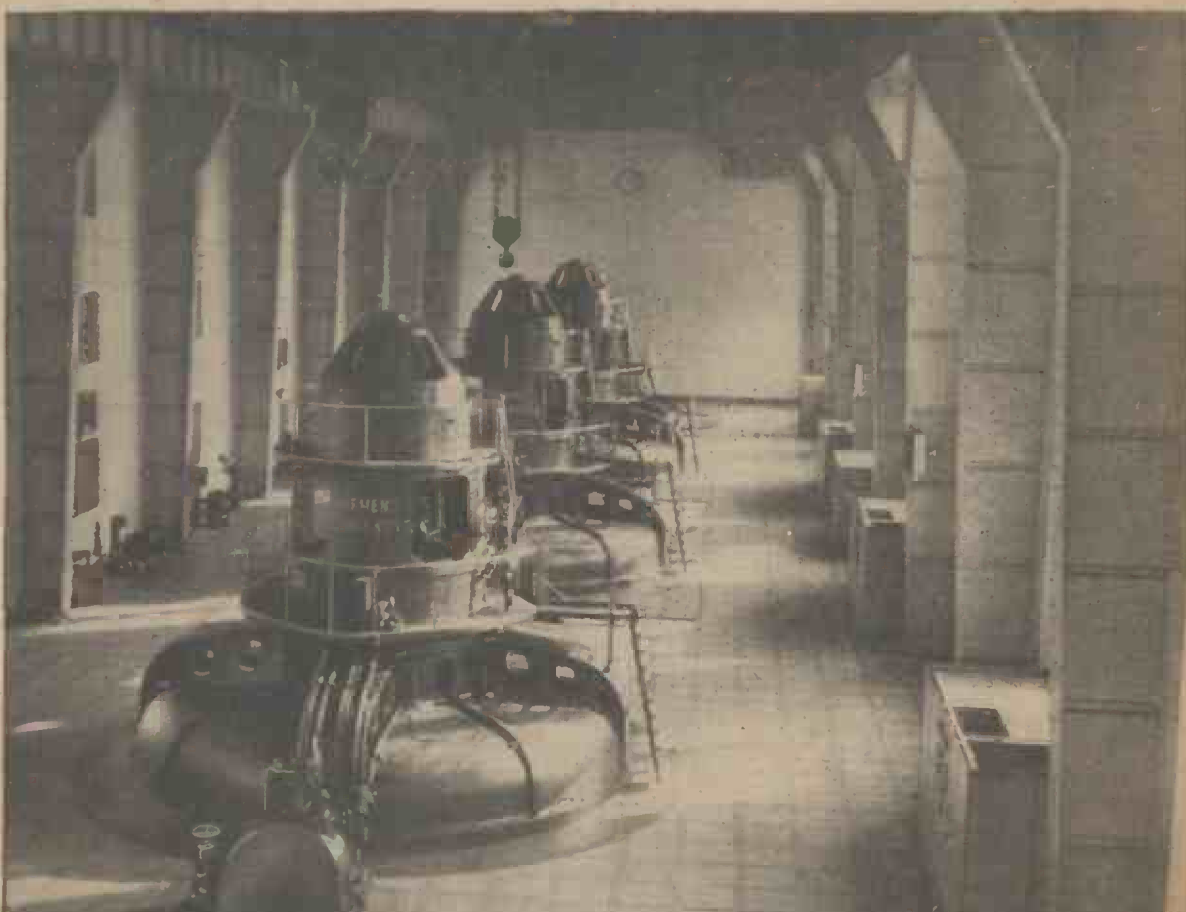
EDITOR: F. J. CAMM

APRIL 1946



THE SHANNON ELECTRICITY SCHEME (See page 245)

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PRACTICAL MECHANICS

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Editor : F. J. CAMM

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FAIR COMMENT—BY THE EDITOR

The British Interplanetary Society

IT is not so many years ago that the Interplanetary Society was regarded with scorn by so-called scientific people. The V-1 and the V-2 and the atomic bomb have, however, placed the society in the forefront of scientific institutions. It has a most important duty to perform in disseminating knowledge on this modern scientific subject.

The Interplanetary movement commenced in this country in October, 1933, when P. E. Cleator founded the British Interplanetary Society with headquarters in Liverpool. E. Burgess in June, 1936, formed the Manchester Interplanetary Society, and a journal, *The Astronaut*, appeared in April, 1937. Thereafter followed the Paisley Rocketeer Society in Scotland, the Leeds Rocket Society and the Hastings Interplanetary Society. Then occurred an internecine conflict resulting in the formation of the Manchester Astronautical Association in December, 1937, followed by the disbanding of the Hastings and the Leeds groups.

The outcome was the production of a common bulletin which also contained news of a Midlands group of B.I.S. members.

A few months before the war the M.I.S. voluntarily disbanded and the P.R.S. followed suit. The B.I.S. continued and convened an emergency meeting at the commencement of hostilities at which it was decided that the society should cease to function for the duration of the war. The M.A.A. thus became the only functioning body by holding its meetings and issuing periodically a journal under the title of *Spacewards*.

Astronautical Development Society

THERE was another group of interplanetary enthusiasts operating at Surbiton, Surrey, known as the Astronautical Development Society, and our contributor, K. W. Gatland, was responsible for its organisation. Contact between these two societies was made in 1941 and in early 1942 a joint monthly bulletin was issued followed in October, 1942, by the joint journal *Spacewards*.

There resulted an affiliation of the two organisations resulting in the Combined British Astronautical Societies in 1944. Regular meetings of this body were started in September, 1944, and a few months later the possible amalgamation of the B.I.S. and the C.B.A.S. was discussed. Many other meetings followed, and on June 13th an informal but important meeting of the B.I.S. took place in London at which it was decided to reform the society and apply for incorporation. In the following June the prospects of forming a national society were discussed. At a later meeting this was unanimously decided upon and L. J. Carter was authorised to prepare a Memorandum and Articles of Association and to make the required application for the incorporation of the British Interplanetary Society. The certificate of incorporation was obtained on December 31st, 1945, from which date the B.I.S. commenced its activities.

We set these facts on record because, living as we are in the midst of history, it is proper that future generations should know how the interplanetary movement started. The early days of the Royal Society of Arts, the Institution of Mechanical Engineers and many other learned societies, are punctuated by the same difficulties as have beset this new movement. We have no doubt that in one hundred years' time the B.I.S. will be regarded with the same scientific reverence as the other learned societies. Certainly it has justified the vision, the energy and the enterprise of those who have sponsored the movement, and the wisdom of those who saw that there was strength in unity and none in division and separate rivalries.

The personnel of the B.I.S. is composed of scientific people, not cranks, and it has a most important task to perform in educating the public to the possibilities of the atomic era and the rocket era as well as the jet-propulsion era in which we all now live.

No doubt as time goes on the terms of membership will be made more difficult, and it behoves all those who have a genuine scientific interest in the subject to get into touch with the British Interplanetary Society whose registered offices are at Albemarle House, Piccadilly, London, W.1.

Radio Noises

IT has long been accepted that, since the sun emits electromagnetic waves in the form of light and heat, it must also emit radio waves of extremely weak intensity. Normally, this intensity is so feeble as to be quite undetectable on radio receivers in the 1 to 10 metre band.

But it has been recently found by British radio workers that, when there is a big and active sunspot group on the sun the solar radio emission can be increased up to 100,000 times in the 1 to 10 metre band; and this radio emission can then be detected on sensitive receivers on the earth's surface. It is natural to assume that these abnormal bursts come, not from the sun's disc as a whole, but from the localised active sunspot area. Many present-day Army receivers, particularly those used in radar, are now so sensitive that they can detect this abnormal solar emission, when it occurs, if their receiving aerials are pointed in the direction of the sun. The effect produced on listening in headphones or loudspeakers is that of a hissing noise, hence the term "radio noise."

At present there is a large and important group of sunspots on the sun's disc which can easily be seen by the naked eye, looking through smoked glass. This group, according to the Astronomer Royal (Sir Harold Spencer Jones) is the largest observed since 1926. Since the sun itself is rotating (it makes a complete rotation in 27 days) it was expected that the sunspot group would cross the central meridian on February 5th last, Solar noise from it was detected by Mr. J. S. Hey and his colleagues, Maj. S. J. Parsons, Maj. J. W. Phillips and Mr. G. S. Stewart, of the Operational Research Group, Ministry of Supply, on January 30th, on their equipment in Richmond Park. Through the kind co-operation of Lt.-Col. H. A. Sargeaunt (Superintendent, Operational Research Group, Ministry of Supply) a continuous watch has been maintained. Valuable assistance has been given by Army operators, mainly from A.A. Command. It is believed that this is the first time that the noise phenomenon has been continuously studied in this way.

The Demonstration of Solar Noise

THE demonstration of solar noise had been arranged by Sir Edward Appleton, G.B.E., K.C.B., F.R.S., and the Operational Research Group, Ministry of Supply. The solar "noise" was demonstrated as a disturbance on a cathode-ray screen such as is used for the delineation of radar echoes. It was also demonstrated as an audible hissing noise on a loudspeaker and on a measuring instrument which indicated the strength of the radiation. The wavelength of the receiver used was about 5 metres. Proof that the radio noise comes from the sun was demonstrated using a directional aerial.

It has long been known that sunspots affect short-wave radio transmission because they cause abnormalities in the ionised reflecting layers in the upper atmosphere. We now know that when sunspots become active the sequence of events is somewhat as follows:

(a) First, the enhanced radio noise is heard. The radiation causing this noise travels with the speed of light, and travels from sun to earth in about eight minutes.

(b) The radio noise is usually followed by and associated with short-wave "fade-outs." These are due to the formation of an absorbing "blanket" underneath the Heaviside layer so that radio waves are strongly absorbed there. This "blanket" is due to a burst of ultra-violet light and causes a fade-out of from half to one hour's duration.

Rocket Propulsion

War Developments—the Field Rocket Projectile

By K. W. GATLAND

HAVING related the achievements of private individuals and research organisations unconnected with governments, let us now investigate the innumerable military rockets which saw service during World War 2.

Mention has already been made of the fact that in the years leading to the outbreak of hostilities the Allied Governments—and the British Government in particular—remained apathetic of the research that was then undergoing open and rapid development at the hands of the amateur rocket societies.

We have seen, too, how the newly formed National Socialist Government, in 1934, instituted a purge on Germany's privately established rocket groups, confiscating their records and throwing into concentration camps all those technicians who refused to co-operate in formulating the rocket to the Nazi plan.

In the closely-guarded rocket laboratories, workshops, and testing grounds that resulted from the ascension of the National Socialists, the fruits of years of painstaking research by honest and well-meaning technicians—whose aims were none more sinister than the outcome of the meteorological sounding rocket and the rocket mail carrier—were minutely investigated. Upon their work, in fact, was largely built the military research programme, which many years later had its result in Peenemunde—the Baltic research station. There, as is now well known, originated the V-2; power units for innumerable rocket interceptors, remotely controlled air to air, ground to air, air to ship, winged "flak" rockets and projectiles; and many others to come, had the war not ended when it did.

When war came to Britain the followers of "Blimp" were eventually swept aside, and pursuing the path of the pre-war amateurs the Government war rockets slowly but surely evolved, as also did similar rockets in Russia and the U.S.A.

Classification of Types

The developments of the war have been so numerous and varied that, to avoid confusion, it will be necessary to abandon the accustomed sequence and to detail each type of rocket device separately from first to the most recent.

There are nine main types of rocket weapons and devices, and it will be most convenient to deal with them in the following order: (a) field projectiles; (b) aircraft firing projectiles (R.P.); (c) ground to air "flak" projectiles; (d) air to ship "flak" projectiles; (e) ground to air "flak" projectiles (manned); (f) long-range projectiles; (g) assisted take-off accelerators (A.T.O.), and (h) rocket propelled aircraft.

The Field Rocket Projectile

Undoubtedly, the points of greatest significance about the field rocket projectile are its light weight, its portability, and the ease with which it is constructed with a minimum of skilled labour. A similar calibre gun, on the other hand, would be appreciably weighty, difficult to manœuvre, and require for its building special materials, a large variety of complex shaping machines, and highly skilled forgers and machinists.

The rocket has one disadvantage: it can only be considered accurate at close range. With present methods of stability and control—in cases where the latter exists—the rocket projectile is hopelessly inferior to the orthodox

(*Continued from page 211, March issue.*)

shell over distances of more than half a mile. This must not be taken to infer that it will always be so. Much hope is held in the development of radio-acoustic "self-directing" devices for use against vehicles, ships, and aircraft. The "Schmetterling"—Germany's V-3—was to have been acoustically homed into bombers. The designer of this unique air weapon, Professor Wagner of Junkers, in fact, considered the weapon to be so effective that he predicted the destruction of one Allied bomber for every missile that the Germans launched.

The small close-range rocket, however, lacks nothing. It is sufficiently accurate for anti-tank use, and is easily transported and operated in difficult country, in many cases single-handed, requiring little more than a simple tube for its launching. One of the German rocket projectors, in fact, was named the "stove-pipe," so great was the resemblance to common stove-piping. Again, compare the gun with its complex rifling, breech and firing mechanism, its great weight and relative immobility.

In a multiple launching arrangement the rocket has, too, become a valuable barrage weapon. Who will forget the sight of fiery trailed "flak" rockets arcing up into the night sky at the first approach of Nazi bombers or V-1s? The British Z-batteries went into full-scale action in 1943; but had *serious* work started on their production—really, a simple matter for the right people—even at as late a time as 1939, who knows how much damage, death and suffering might have been averted from our cities and towns, so poorly defended at the time of the "blitz"? The rocket-projectors, so simple and effective an answer, arrived too late to stem the main attacks of the Luftwaffe—*yet almost identical projectors had been in use for firing amateur research rockets years before the war, both in Britain and America.*

It has been openly admitted that the development of the Z-battery involved seven years of research. A useful comparison is the Russian launcher and projectile with which "Stormovik" IL-2 aircraft so successfully turned the Nazi "spearheads" at Stalingrad. This projector, which was among the first rocket weapons to be used in the war, was officially reported to have been developed and produced *within twelve weeks*. It is well known, also, that the Soviet forces used multiple land projectors at Stalingrad.

The least that can be said of the British development is that it gives added emphasis to the need for a central pool of rocket data and literature, from which Government technicians and amateurs alike could draw information. As we have had cause to mention earlier, much original work has been done with rockets, but much more has been duplication.

The "Katusha"

The "Katusha" was actually the first rocket weapon of the war, being itself a development of a multiple rocket device which had been employed by the Russians against the Turks as long past as 1830.

It was used with disastrous effect on the Nazi forces at Stalingrad, where it was considered to have been a key weapon in the city's defence. The projectiles, which were fired in quick succession from batteries of launching ramps, burned "solid" propellant, had an overall length of between 5 or 6ft. and a weight (including explosive head) of about 50lb. Their burning time was less than two seconds.

Another Russian weapon in use at about the same time was a small-calibre anti-tank projector which fired 30 armour-piercing rocket shells simultaneously. The launching tubes were mounted in five rows of six on a light carriage and set to discharge the rockets over a fairly wide area. It was, of course, ideal against massed tank formations.

First German Field Rocket

The Germans first employed rockets in the field on the Russian Front.

They were initially used as smoke curtain projectiles, although it was not long after that explosive and incendiary rocket carriers made their appearance.

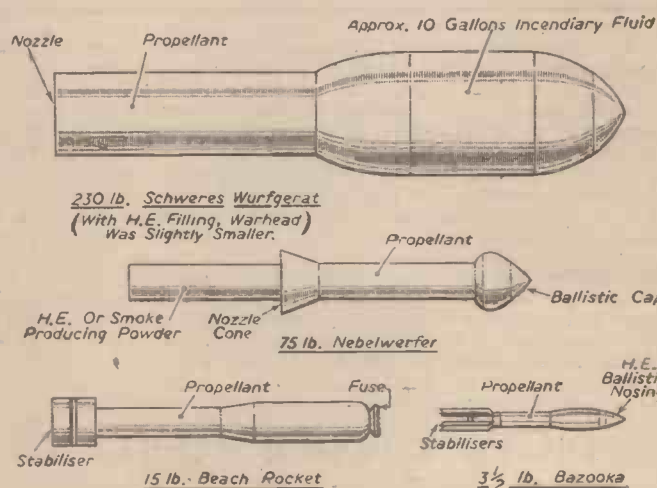

Fig. 61.—Four of the most prominent field rockets used during the war. (Scale .05in. = 1.0in. approx.)

Later it was announced that Rommel was employing anti-tank rockets in Libya, and this type was also used by the retreating German armies in Tunisia and Italy.

The Schweres Wurfgerat

The chemical and incendiary rockets developed by the Germans were of two main types. First the large rockets of 12½in. and 10in. calibre, which were employed in the Schweres Wurfgerat (heavy throwing engine). The former was an incendiary carrier, while the latter contained high explosive, and both types had an effective range of 2,000 yards.

A unique feature of this projector was that the transit case was also the launching rack, from which the rockets were fired at any desired elevation.

At first, however, they were launched singly, but eventually cases were assembled together in two layers of three to form a six-ramp projector, and the complete set-up mounted on a gun-carriage. Ignition was achieved electrically by successively firing squibs.

The projectiles used in this launcher, as we have already observed, were of two classes. Both, however, were to the same basic design, although the head of the explosive rocket was slightly smaller than the one having an incendiary filling. The warhead of the 12½in. calibre type contained a little more than 10 gallons of incendiary fluid.

Attached behind the warhead was a propellant tube of smaller calibre which housed a double-base powder, somewhat similar to cordite. Stability was achieved by axial rotation caused by offset exhaust apertures in the base-plate.

The total weights were 180lb. and 230lb. respectively.

The Schweres Wurfgerat was largely used in Italy, and, mounted on motor-trucks, it was employed to quell risings of Polish patriots in Warsaw. Towards the close of the European war, however, several of these projectors were captured by the Czechs and used effectively against Nazi forces surrounded in some Channel ports.

Nebelwerfer 41

The second main rocket type was smaller, being of 6in. and 8in. calibre, and used in the Nebelwerfer 41 (Smoke-thrower Model, 1941). In this device the projectiles were launched from steel tubes, which were mounted in groups of six on small gun-carriages. Firing was accomplished electrically, with a delay of one second between each round.

Unlike the projectiles of the Schweres Wurfgerat, the propellant in the 6in. calibre type was housed in the rocket head, exhaust being made through 24 tangential nozzles in a conical centre-section. The explosive, or smoke-producing powder, was contained within a tubular tail-section.

Stability was, of course, effected by axial rotation, but was in part due to the placing of the centre of reaction forward of the centre of gravity.

The nozzle cone had a diameter of 6in.; the propellant and rear tubes slightly less. The rocket's overall length was 3ft. 6in.

A sheet steel ballistic nosing was also fitted, and it is of interest to note that its maximum cross-sectional diameter was greater than that of the propellant tube. This, presumably, was chiefly intended to stabilise the rocket while in the launching tube, the nozzle cone having about the same dimension.

It has already been mentioned that the nose form is the essential feature for consideration at near-sonic and super-sonic velocities. This is because of the compressibility region that is built up at the front of the body, which takes the form of hyperbolic sound waves and constitutes the main drag. Because of this and other practical considerations, such as explosive capacity, balance, etc., little account has been given to maintaining a smooth body line aft of the nosing in the majority of war projectiles. For a more detailed account of compressibility phenomena, the reader is referred to an earlier article in this series, PRACTICAL MECHANICS, January, 1946, pp. 133-135.

The smoke-curtain projectile was the first of the type to be used in action, and weighed slightly less than 75 lbs. The Germans later employed the rocket fitted with a modified aft container of explosive in place of the smoke-producing powder. The latter were used at Stalingrad and Veliki to supplement field howitzers, and had a range of about 7,000 yards and an average velocity of 1,000 feet per second. They weighed approximately the same as the smoke-producing rockets.

The 8in. calibre model had a more orthodox appearance. The explosive was contained in the nose, and the propellant at the rear. Stability was again obtained by body rotation, exhaust being made through off-set holes in the base-plate of the propellant tube.

It weighed 200 pounds, and was credited with a range of approximately 9,000 yards.

British and U.S. Developments

A development of the Z-battery projector (which will be detailed in a later article) was employed during the decisive El Alamein battle in order to concentrate a great fire power against the German Army, which was then going all out for a break-through into Egypt.

It is significant to note that while the Germans apparently favoured rockets stabilised by axial rotation, the British and

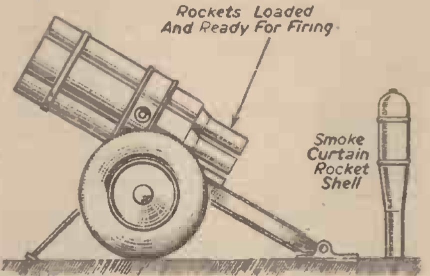

Fig. 62.—The Nebelwerfer: a six-barrelled rocket projector mounted on a wheeled chassis.

American rockets were un-rotating and stabilised by fins. There is no doubt that both systems have disadvantages, and one that is most noticeable is a pronounced tendency for finned projectiles to turn into the wind. Conversely, there is a small loss of propulsive efficiency in causing body rotation.

The principal single-unit anti-tank projectors were, of course, the American "Bazooka" and the German "Panzer Fist." These were the lightest projectors used during the war, and both could be fired single-handed, although they were generally operated by a team of two.

First, because it was by far the most significant, the "Bazooka"—officially known as "Rocket Launcher, A.T.M. 1." Apart from the Russian "Katusha," it was undoubtedly the most important field rocket of the war and saw large-scale service in Europe as well as in the Far East.

The "Bazooka" was essentially a close-hand weapon—300 yards was its limiting range. It was developed to the specification for a light, easily transported rocket projector having the fire power of a large calibre gun and capable of being operated by, at most, two men. How the requirement was met is now past history, but it is as well to recall that this and similar rocket weapons were decisive instruments in the final overthrow of the Axis.

As previously mentioned, the projector was operated by a two-man team—the launcher, who carried the 12 lb. firing tube, and the loader, who had care of the projectiles, which he carried in a special compartmented canvas bag.

The launching tube, open at both ends, was about 4ft. 2in. long and less than 3in. in diameter. A shoulder stock was fitted to the tube, and this contained two ordinary dry-cell flashlight batteries used in the ignition of the projectile. Launching was initiated by a normal type trigger placed forward of the stock. A hand grip was also attached close to the mouth.

Preparatory to loading, the launcher assumed a "one knee down position," having the projector over his right shoulder, into which the stock fitted snugly. The projectile was then inserted into the aft end of the open tube by the loader, who catched it with a wire retaining device to prevent it from slipping out backwards. He would then step to the side of the projector and move a small contact switch from "Safe" to "Fire," finally tapping the launcher on the shoulder to signal readiness for firing.

The loader would, of course, take due care that he was well to the side and clear of the rearward blast effect of the projectile when it was eventually fired.

The launcher, having sighted his target, depressed the firing trigger, and with a blast of flame rearward from the tube, the projectile sped rapidly towards its objective. The projectile was so designed that it ceased firing before emerging from the tube, and thus the launching crew were not affected in the slightest by flame or blast. There was little or no recoil.

Although the missile's striking velocity was quite low, it had great penetrative ability. This was because the explosive was detonated on impact, with the result that a hole was blown through the armour plate and the interior of the tank filled with blast, which was generally fatal to all within.

The projectile of the "Bazooka" was about 20in. long, had a maximum diameter of 2½in., and an approximate weight of 3½lb. It was stabilised in flight by six fixed sheet-metal fins.

The explosive was contained within a ballistic nosing, and around this was fitted a thin band of copper, necessary for the ignition circuit. A wire connected the battery, trigger switch and contact box, and through the moveable contact arm the current was transmitted to the copper band on the projectile. A further connection was made from the band to an electrical ignition squib, fixed within the nozzle of the propellant chamber. The other end of the wire attached to the squib was grounded to the projector.

German Anti-tank Weapons

The German counterpart of the "Bazooka" was the "Panzerfaust" ("Panzer Fist").

It was hardly comparable, however, for its effective range was little more than 50 yards. Although not the main German rocket weapon for the purpose, it was, nevertheless, supplied in quantity to the Volksturm for delaying tanks.

The principal anti-tank projector was much larger, having a tube of about 6ft. in length and 6in. diameter. Unlike the "Bazooka," a heavy metal shield was fitted to the launching tube in order to guard the crew from blast and flame. A hole in the shield, in which was mounted a frame sight, enabled the launcher to direct his fire in conjunction with a second sight on the muzzle of the tube.

Although the weapon was rather heavy and had to be supported during firing, it was claimed that it could be carried by one man. In principle, both these German weapons were similar to the "Bazooka."

Rocket Projector Boats

The next important development was the rocket-firing boat. These craft were used to support troops in landing operations and, as such, no apology is offered for including them under the head of "Field Projectile."

The rocket-boats first went into action during the British invasion of Sicily, much to the consternation of the defending troops. Their value once proved, they were later adopted by the U.S. Navy, and figured prominently on D-Day during the assault upon the European continent. Similar boats were used in the landings on Walcheren, and also in the Pacific, where they materially assisted in the invasion of the Philippines, Iwojima and Okinawa.

The vessels originally employed for projecting rockets were ordinary tank-landing craft.

The projectors were mounted in the fore of the vessel and, prior to firing, all but one of the crew had to retreat below decks in order to evade the terrific blast. The operator was specially clad.

These steel rocket-boats carried hundreds of explosive rockets, which were fired in overlapping salvos from the fixed projectors in which they were stowed. They were launched at about 50 to 60 degrees, about a dozen or more at a time.

Other launching systems were later developed in which the rockets were able to be fired individually or in rapid succession. Each projector consisted of a double pile of six rockets so placed that the bottom one of each pile was in the firing position on the launching rails. The rockets were fired successively by electrical impulse and, as the first shot away, the whole pile dropped down so that the next rocket entered the firing position and was launched, whereupon a further rocket entered for firing, and so on, until all were expended. These projectors were mounted in groups of four along the sides of the ship. In certain instances, two sets of launchers were mounted on lorries for use on land.

The projectiles used in these launching systems weighed 15lb. The explosive head had a diameter of 4½in. to which was attached a cordite-filled propellant tube of 3in. diameter. A 4½in. diameter circular stabiliser was fitted at the extreme rear.

A 5in. projectile was later developed, as well as one of even larger calibre, but details of these are, unfortunately, lacking.

The value of the rocket-firing ship was, of course, in that it enabled a weight of fire to be directed comparable with that of a modern battleship. It was not a weapon of great accuracy, however, but was, nevertheless, ideal from the point of view of laying concentrated fire on relatively large areas.

(To be continued)

The Gloster Meteor IV

Constructional Details of this Record-breaking Aircraft

THE Meteor IV—a twin-engined, jet-propelled, single-seater fighter—is a low wing monoplane of all-metal construction, with tricycle alighting gear and two Rolls-Royce Derwent Series V engines.

The whole aircraft is built on a "unit" system, thus:

- Fuselage nose.
- Front fuselage (with nose wheel, pilot's cabin and magazine bay).
- Centre section (with the centre plane aerofoils, the two undercarriage units, the two nacelles and fuel tank bay).
- Outer planes (each with ailerons and detachable tip).
- Rear fuselage (complete with tail portion, which includes the lower fin).
- Tail unit (consisting of upper fin, upper and lower rudders, tail plane, and two "half-elevators").

Front view of the Gloster Meteor jet-propelled aircraft.

The fuselage nose houses the gun camera and nose-wheel mounting structure, and is otherwise a fairing which has special side panels to resist the gun blast.

Solid Bulkheads

The basis of the front fuselage structure is two fore-and-aft vertical diaphragms and three solid bulkheads. The nose-wheel mounting structure is on the first or nose-wheel bulkhead. The internal structure is sealed between the nose-wheel bulkhead and the seat bulkhead to form a pressure cabin on later aircraft. The third or front spar bulkhead is used to bolt to a similar bulkhead in the centre section. The centre section and the rear fuselage are of semi-monocoque construction; and two rearmost frames of the rear fuselage are extended upwards to form posts for the lower fin and to give attachment points for the tail plane and upper fin.

The main plane is a two-spar, stressed-skin structure. The centre section spars are spaced by six major ribs, interspaced with lighter skin ribs. Each engine nacelle is built of two main frames attached towards the outer ends of the spars. The two undercarriage bays, the upper and lower air brakes and the flaps are all between the nacelles and the "centre fuselage." The outer planes, which are joined to the centre section at both spars, have plate and lattice type ribs. The internally mass-balanced ailerons are all-metal structures with automatic balance tabs. The outer plane tip is detachable for production and replacement reasons.

The components of the tail unit are of stressed-skin construction. The high tail plane, necessitated by the jet from the propelling nozzles, splits the rudder into two parts. Trimming tabs are fitted to each "half-elevator" and to the lower portion of the rudder.

Hydraulic Undercarriage

The hydraulically operated, levered-suspension tricycle alighting gear consists of two independent undercarriage units which retract inboard and a nose-wheel unit which retracts rearwards, the wheel itself being housed between the rudder pedals in the front fuselage. In addition to the normal electrical indicators, there is a mechanical downlock indicator for the nose-wheel unit, showing just forward of the windscreen.

The stick-type control column has a hinged spade grip, and the rudder pedals have parallel action. Trimming tabs are operated by normal-type hand wheels.

Power Units

While the earlier Marks of Gloster Meteor aircraft were fitted with Rolls-Royce Welland jet-propulsion engines, the later Marks are fitted with Rolls-Royce Derwent engines. This engine was a record breaker from the outset, in that it was designed and the first engine was on test within a period of three and a half months, developing no less than 2,000 lb. thrust at 16,500 r.p.m.

Each engine is mounted between two centre section ribs using trunnion-type side mountings, one of which is free to float sideways to allow for expansion.

The engine is steadied at the rear by a "diamond" bracing, which again will allow for expansions. The generator (port nacelle), the hydraulic pump (starboard nacelle) and the vacuum pumps (both nacelles) are driven by auxiliaries—drive gearboxes, each mounted on the front spar in front of its respective engine, and from which it is driven by an extension shaft. The self-sealing fuel tank is divided by a transverse diaphragm; each compartment normally feeds one engine, but there is an interconnecting balance cock which is normally closed. The feed to the burners is maintained by external electric (tank mounted) and engine-driven pumps.

A central drop fuel tank is carried beneath the centre section as required. The oil system for each engine is self-contained, there being no airframe oil tank. The engine-driven hydraulic pump operates the alighting gear, flaps and air brakes. An emergency hand pump will operate all services.

The pneumatic system operates the gun cocking gear and the undercarriage brakes; there is no nose-wheel braking. There are two air containers in the rear fuselage; no compressor is fitted.

Power for the electrical system is supplied by a 24-volt, 1,500-watt, engine-driven generator on the port engine, charging two 12-volt accumulators. An electrical remote control two-way radio is mounted in the rear fuselage. Beam approach and I.F.F. installations are also fitted.

Armament

The armament consists of four 20 mm. belt-fed Hispano guns mounted in the outer structure of the front fuselage and fired electrically by a selective "wobble" button on the spade grip. The four ammunition tanks (one for each gun) are in a magazine bay, immediately behind the pilot, with ready access for re-arming. A gun camera is mounted in the fuselage nose fairing, and the control for this camera is incorporated in the gun button and may be used without the guns if required.

Other equipment includes a combined cabin pressurising and heating system, a gun heating system, windscreen de-icing and de-misting and an oxygen system.

Meteors are now being fitted with full photographic equipment and are being tropicalised.