Knibb

THE HELICOPTER

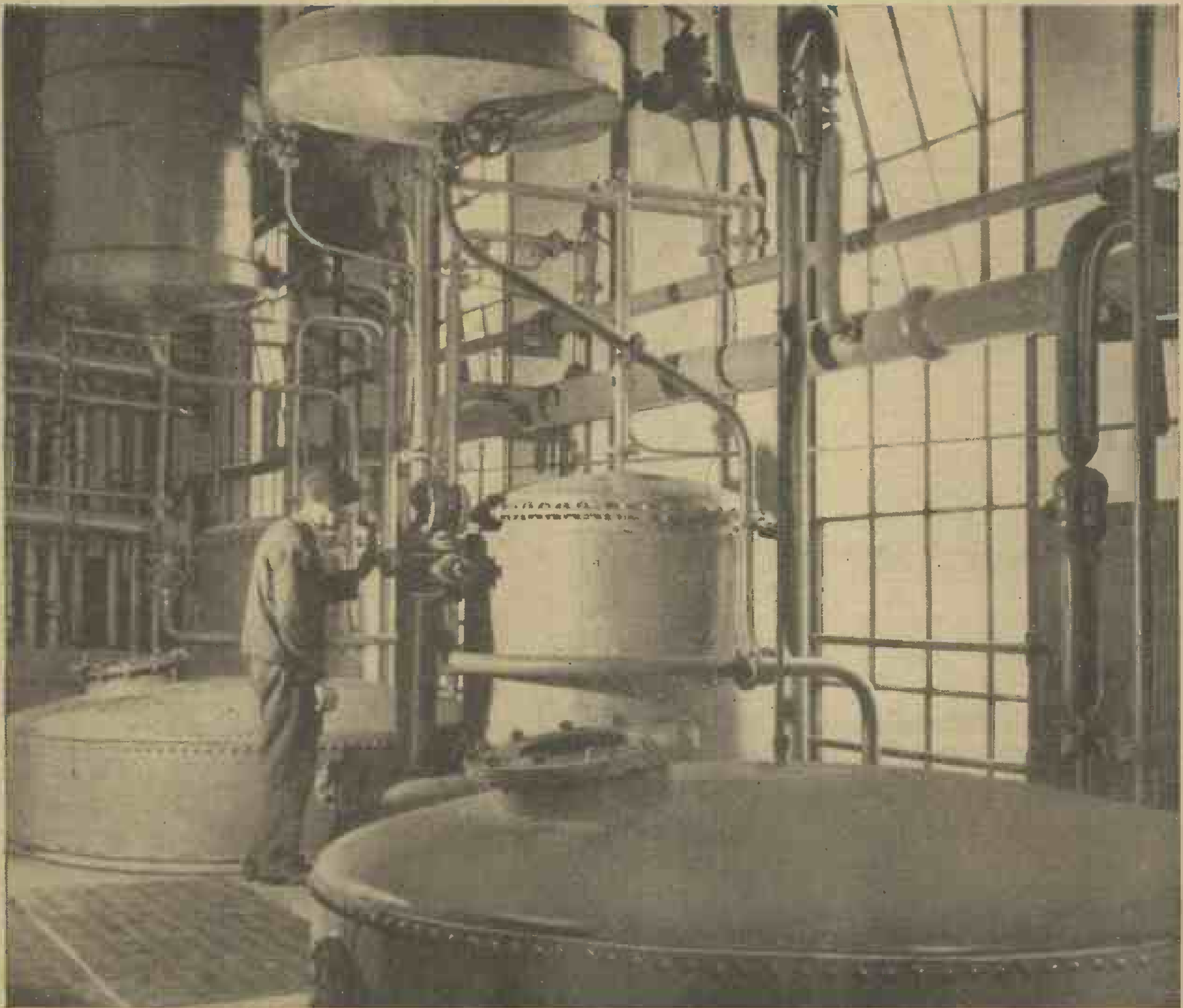
NEWNES

PRACTICAL MECHANICS

9d.

EDITOR: F. J. CAMM

JUNE 1946



A TAR DISTILLATION PLANT (*See page 331*)

Rocket Propulsion

Ground-to-air Rockets : American Guided Missiles

By K. W. GATLAND

(*Continued from page 278, May issue*)

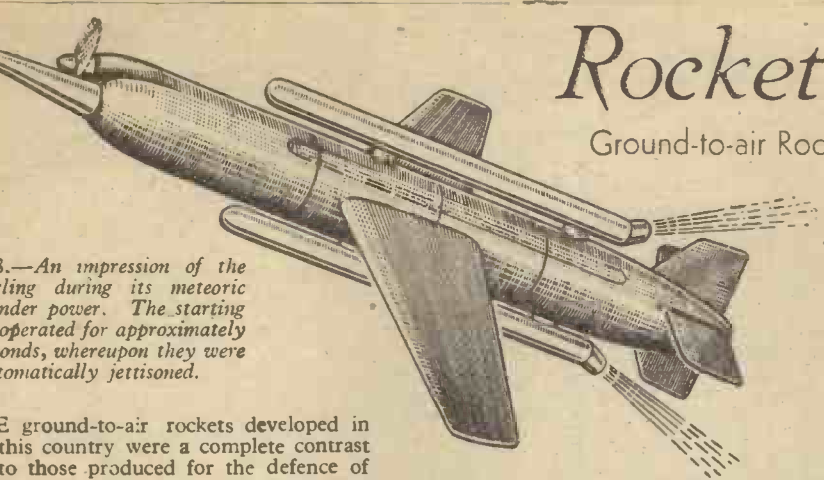


Fig. 68.—An impression of the Smetterling during its meteoric climb under power. The starting rockets operated for approximately four seconds, whereupon they were automatically jettisoned.

THE ground-to-air rockets developed in this country were a complete contrast to those produced for the defence of the Reich.

The British Z-batteries, which had their first large-scale demonstration in 1943 and were key weapons in the defence system evolved to combat the "flying-bomb," were the essence of simplicity. They comprised simply a rotational base platform on which were supported two adjustable launching rails, and each projector was operated by a crew of two, loader and firer.

The Z-rockets, which were approximately 6ft. long and 4in. in diameter, burned stick-formed cordite, and were fired electrically. A 20lb. warhead comprised the nose section, and four small guide fins were fitted at the tail (Fig. 67).

Operation

The projectiles having been loaded, the crew took up their positions, one on each side of the platform. The direction and elevation set, the firer then depressed the firing lever, and the missiles would streak away, perhaps climbing as high as 20,000ft. to reach their objective. The operators were protected against flame and blast by steel side screens, which were adequate cover from the rockets as they sped away from the rails above their heads. Reloading was generally a matter of a minute, or slightly less.

Although intended primarily as a barrage weapon, the Z-projector had provision for direct sighting against ground-straffing aircraft.

The Home Guard was largely responsible for manning the Z-batteries of the London area during the flying-bomb attacks, when numbers of V1s were either directly exploded in flight or sufficiently deflected by blast to crash harmlessly in open ground. In a multiple arrangement, with 48 projectors to a site, they encompassed the target with a veritable "minefield" of blast and shrapnel, from which few aircraft, piloted or otherwise, emerged unscathed.

The Germans, however, found no such simple solution. Actually, theirs was a more difficult problem owing to the high-flying "Fortress," among other high performance bombers, which were pressed into service at an early stage of the Allied bombing plan. Germany's defence clearly demanded something more than cordite rockets.

It was obvious that explosive missiles able to range to 40,000ft., perhaps more, would be needed, and needed quickly, if the devastating assaults on the crucial Rhineland areas were to be checked before German industry became an irreparable ruin.

To this end the production of three distinct classes of defensive weapons was set in hand, as follows: (a) high performance jet and rocket-propelled fighters, (b) air-to-air rocket firing aircraft, and (c) ground-to-air rocket missiles. All had an important place in an elaborate defence system to protect the Rhineland, and there appears little doubt that had it been possible for the Germans to bring this plan to early fruition the pages of history would have told a very different story. As it was, the scheme was still very incomplete at the time of the collapse.

The threat to industry and transport had become so acute as the result of the first few months' air battering that even aircraft firms and their design staffs were brought into the scheme to provide explosive missiles; not only this, but factories that for years had been producing equipment for the army were switched to the manufacture of component parts.

Examples of the weapons produced by aircraft builders were the air-to-air missile Henschel 298 (described in the previous article), the Messerschmitt designed Eizian (Gentian), and the Schmetterling, which was made the responsibility of Junkers. All three embodied wings, and the Eizian, of which little information is available, appeared as a small version of the Me.163, with four motor units.

The three other principal ground-to-air weapons, however, would be more correctly termed "projectiles." The Rheintochter R1 (and later the R3, an improved version) was a massive rocket shell designed on the "step" principle, and the Wasserfall resembled a scaled-down version of the A4 long-range projectile. Finally, there was the manned projectile Bachem BP-20 Natter (Viper), which, like most of the other projects, was still undergoing experiment at the war's ending.

The Schmetterling

Designed by Professor Wagner, of Junkers, the Schmetterling (Fig. 68) was to have been homed to its target by radio. The Germans considered the accuracy of the missile to be such that one Allied bomber would have been destroyed by every one they released. It was obviously the key weapon of the scheme, and, as such, bore the ominous designation "V3." Its development was A1 priority, and at the time of the defeat the weapon was ready for quantitive production.

The Schmetterling appeared as a small mid-wing aeroplane. It embodied a long cylindrical fuselage and a short-span wing attached approximately half-way along its length. A cruciform stabiliser unit was fitted at the tail-end.

The fuselage was assembled in sections, each section housing one of the main components, and, with a 55lb. warhead, which extended from the port side of the nosing, its overall length was 13ft. 1¼in. A small air-stream propeller was fitted at starboard as power for the electrical services.

In the section directly behind the warhead were a compressed air tank and radio. The second and third compartments contained propellant tanks, and the after-most section housed the control gear and main rocket motors. The latter could be either two 109-558 or two 109-729 bi-fuel units, employing 98 per cent. nitric acid with 57 per cent. m-xylidine plus 43 per cent. triethylamine, which gave a duration at full thrust of 33 seconds. This, incidentally, was

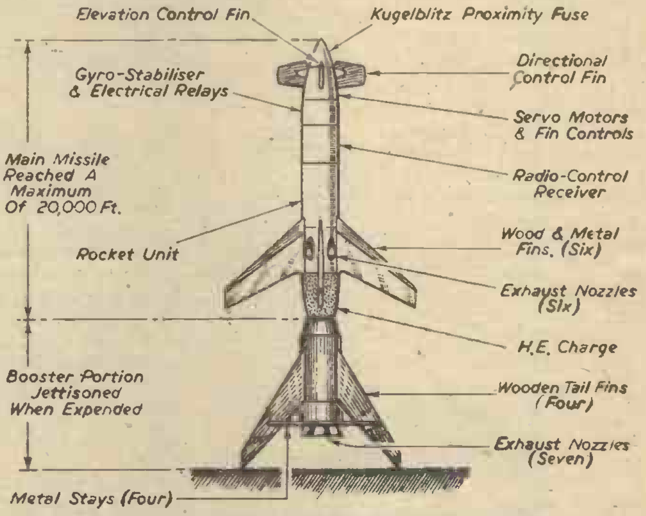
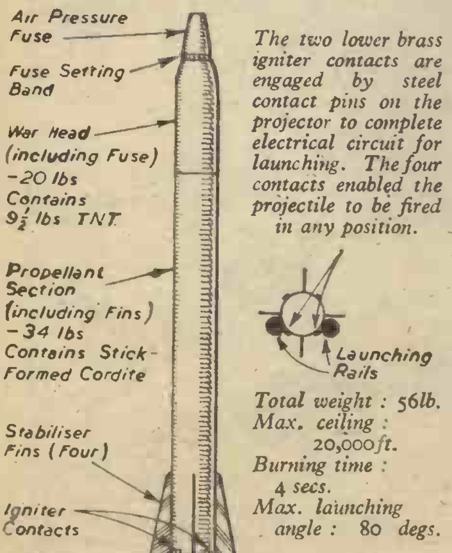


Fig. 69.—Part-sectional diagram showing the internal layout of the Rheintochter R.I.



The two lower brass igniter contacts are engaged by steel contact pins on the projector to complete electrical circuit for launching. The four contacts enabled the projectile to be fired in any position.

Total weight : 56lb.
Max. ceiling : 20,000ft.
Burning time : 4 secs.
Max. launching angle : 80 degs.

Fig. 67.—The "Z-battery" rocket. Produced by the Projectile Development Department of the Ministry of Supply.

also the propellant of the X-4 described in the previous article.

The method of wing construction was unique in that the structure was *cast* as a complete unit, including the main spar, trailing edge and six main ribs. There were also diagonal webs interlacing the ribs and a tubular member extended from the fuselage through the two innermost ribs as the main wing fixing. The structure was covered with a thin light-alloy skin, and spoilers were attached at the trailing edge near the tips for lateral control.

The tail unit was also cast and covered in the same manner as the wing.

The missile was launched by two dry-fuel rocket units, one attached above the fuselage and the other below. These rendered a high initial acceleration, and when their propellants became exhausted, within about four seconds, they automatically disengaged and dropped away.

The production model had a wing span of 6ft. 2in. and a tail span of 3ft. 3in. The all-up weight was 970lb., which was reduced to 55lb. after the A.T.O. rocket had been jettisoned.

The performance figures speak for themselves: ceiling, 50,000ft.; range, 20 miles with a maximum speed of 620 miles per hour.

The Rheintochter R1

Another interesting ground-to-air development was the Rheintochter R1 (Fig. 69), designed by Rheinmetall Borsig. A massive two-step rocket, weighing almost 1½ tons, it was intended to be directed to its target by two radar plots, one on the target bomber and the other on the projectile, correlated by a ground operator.

The R1 had a total length of 18ft. 10½in., of which approximately one-third comprised the second stage "booster" portion. The main missile measured 11ft. 10½in. and was 1ft. 8in. in diameter. It embodied six large fins having a total span of 8ft. 8in., which swept back 40in. from the leading edge. They had a root chord of 2ft. 8½in. and a tip chord of 10in. Four controlling fins, linked to operate in opposed pairs, were fitted at the nosing, the top and bottom fins for directional flight and the lateral fins for elevation.

From nose to tail, the first stage comprised the following main components: proximity fuse, control fin motors, gyroscopes, radio directive gear, rocket unit (with six outward inclined exhaust venturis), and, finally, aft of the tail fins, a 50lb. charge of high explosive.

The "booster" unit was 4ft. 10½in. long and 22in. in diameter. Inside was a powerful dry-fuel rocket unit which exhausted from the rear through seven nozzles. Four fins were also fitted, having a total span of 7ft. 3in., a 2ft. 8½in. root chord and a tip chord of 12in.

The control fins and fixed stabilisers were of thin section and constructed largely of wood. A heavy gauge metal covering was embodied in the after surfaces of the six fins on the main missile.

It is of interest to note that the trailing edges of the two sets of stabilisers were not finished off sharply as is the case in normal aerofoil practice and on other missiles, but were cut square to thicknesses narrowing from 1½in. at the root to ⅜in at the tip. The controlling fins were similarly tapered from a root thickness of ½in. to ¼in. at the tip. This construction follows closely the theory of the Sänger super-sonic aerofoil (PRACTICAL MECHANICS, January, 1946, p. 134), in which, it will be recalled, the section is thin with a knife-like leading edge and the maximum thickness well aft. It is this type of section that has the greatest penetration at speeds in the region of sound, the reason being that the compressibility flow will always break away from the surface shortly behind the mid-section of the aerofoil, involving the trailing edge in pronounced rarefaction.

The Rheintochter R1 was launched from an inclined ramp, the second stage "booster" being used for initial propulsion. This became expended of fuel at an approximate height of two kilometres, whereupon it was automatically jettisoned. At this juncture, the main portion of the missile would further accelerate under its independent power to reach a maximum speed of approximately 1,000 miles per hour.

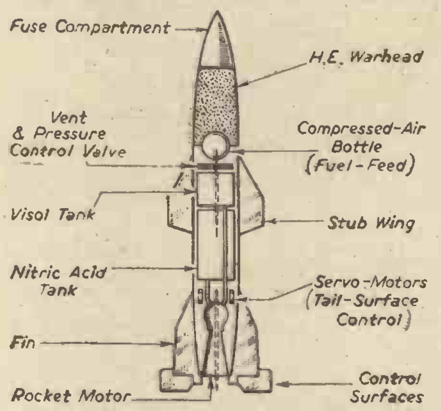


Fig. 70.—The Wasserfall. This part-sectional diagram gives some idea of the layout of the main components.

Despite its majestic appearance, the projectile had an effective ceiling of only 20,000ft. It employed dry-fuel in both stages—diglycoldinitrate—but in an effort to improve the range the R3 version had a liquid bi-fuel unit in the main missile.

The Wasserfall

An offshoot of the A-1/A-10 projectile development programme at Peenemunde, the Wasserfall (Fig. 70) clearly resembled the V2. It was, of course, smaller, having a length of 24ft. and a maximum diameter of 3ft., but nevertheless appeared enormous as an A.A. rocket. Its fully loaded weight was in the region of 3½ tons. There were also four short-span wings attached about halfway between the nose and tail, and, as with the V-rocket, four air-stream fins with controllable tail surfaces were fitted at the rear as well as movable graphite vanes in the jet. In first experimental models, these control aerofoils were operated by a Siemens K.12 automatic gyro-pilot.

Propulsion of the Wasserfall was by the reaction of visol and nitric acid, which fed into a single combustion chamber mounted in the tail.

Less than 50 of these missiles were fired in free-flight, and of these only 12 were successful. Needless to say, they were not used in action.

A scale model of the missile was on view at the British Museum, South Kensington, during the "Exhibition of German Aeronautical Developments" held there earlier this year.

The model in question, which was stated to be a quarter the size of the actual weapon, had apparently been hurriedly disposed of in the local pond at Nordhausen at the time of the surrender. It was found when the area was later investigated by the Allies, and still bore traces of dried mud on its green painted surface.

U.S. Guided Missiles

It is perhaps not widely known in this country that several types of guided missiles were produced in America. The majority of these were to original designs, and at least one was proved to be superior in general performance to its best German counterpart.

The design of these ground-to-air, air-to-air, air-to-ship weapons was put into the hands of a Government establishment known as the Naval Aircraft Modification Unit's Pilotless a/c Division.

The entire development was carried out by this Division, including the research and testing of rocket propulsors, intermittent and turbo-jet power plants, radio-control, target-seeking and telemetering devices. A number of the missiles incorporated television "eyes" which enabled the controller on the ground or in the parent aircraft to view the progress of his charge on a television screen and to guide it into the target by radio-control. The Germans were definitely far behind the Americans in matters of radio-control and target-seeking, though they were obviously more advanced in rocket technique.

A particularly interesting rocket missile was "Little Joe" (Fig. 71), a radio-guided anti-aircraft weapon which could be launched

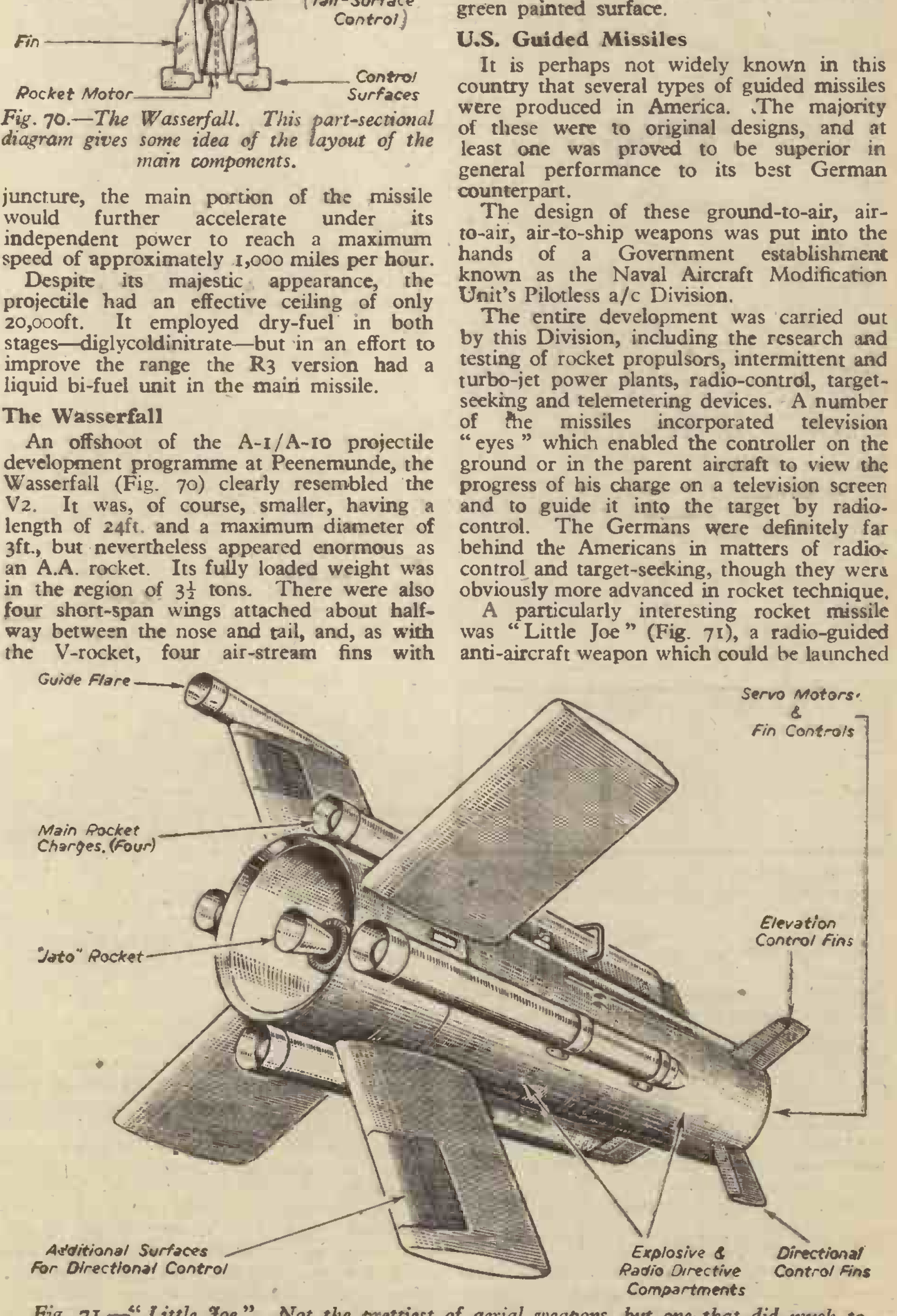


Fig. 71.—"Little Joe." Not the prettiest of aerial weapons, but one that did much to counter the Japanese "Baka" suicide 'plane.

either from the surface or the air. It was originally designed to combat the Japanese "Baka" suicide 'plane, and was powered by four main rocket charges and one 1,000lb. thrust Jato starting unit.

"Little Joe" was an ungainly weapon, and one of the first guided missiles that America produced. Four square-cut stabilisers were attached at the rear, two of which had controllable aerofoils, and four smaller fins were fitted around the nosing in a similar fashion to the arrangement on the Rheintochter R1. The main rocket units were equally spaced around the tail-fins, and the one Jato rocket was housed within the after section of the projectile body, the nozzle emerging from the rear.

The missile incorporated a 100lb. warhead, which was detonated by a proximity fuse.

Radio-guided Winged Missiles

Equipped with television and radio-controlled, the rocket powered "Gorgon" KAZN-1 (Fig. 72) was fired from the surface against flying targets, from the air to surface targets, and from air-to-air.

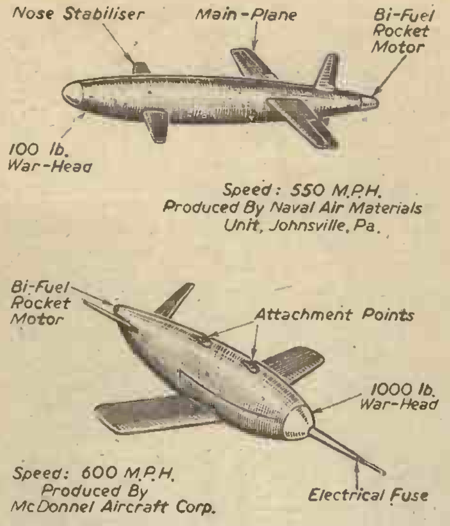


Fig. 72.—The Gorgon (above) and the Gargoyle below) ; two examples of American winged missile development.

In terms of aeronautical practice, its design was unorthodox in that the horizontal stabiliser was situated at the nose, the main plane at the rear. The vertical stabiliser extended equally above and below the rear fuselage.

The fuselage was 16ft. in length and nicely streamlined, the wings tapered and 11ft. in span. Wood was used throughout in its construction, including the laminar flow wings, which were to standard design and interchangeable with other missiles.

The power unit was patterned on the German bi-fuel acid-aniline rocket engines, which propelled the "Gorgon" at a maximum speed approaching 700 miles per hour.

Another missile in this class was the "Gargoyle" (Fig. 72), a miniature low-wing monoplane with a heavily dihedraled tail plane which served the dual purpose of vertical and horizontal stabilisers. It sped towards its target at approximately 650 miles per hour under power from a single bi-fuel rocket unit, a flare in the tail assisting in its sighting. Like the majority of other missiles, it was guided remotely by a radio control unit, either from the ground or from the air. *(To be continued)*

The Design of Induction Motors

Brief Notes Forming a Useful Guide

By H. SPARKE

WHEN designing an induction motor to satisfy the requirements of any given set of conditions, it is generally very useful to obtain an approximate idea of its probable principal dimensions.

Particulars of the supply, such as voltage, frequency and number of phases must be known, and also the B.H.P. and speed of the motor, to suit the individual case.

Number of Poles

The relationship between the number of poles, synchronous speed and the frequency is given by the formula :

$$p = \frac{120\sim}{n}$$

where

$\sim$ is the frequency.
n is the r.p.m.
p is the number of poles.

No. of Poles	Synchr. Speed	Actual Speed
2	3,000	2,900
4	1,500	1,440
6	1,000	970
8	750	725
10	600	580

The actual speed is always slightly less than synchronous speed, between 2 and 5 per cent.

Size of Rotor

Assuming that 2 per cent. of the gross power will be wasted in heat in the rotor, for every kilowatt of power there will be 20 watts wasted in the rotor, so that there will have to be 20 sq. in. of rotor surface per kilowatt of power, or 15 sq. in. per horse-power. This condition is slightly better in large motors, and slightly worse in smaller machines.

The working surface of the rotor is π DL, where D is the diameter and L is the gross length of the core.

Therefore, $\frac{\pi DL}{H.P.} = 15$ and $DL = 4.77$ H.P., or, in other words, the product of length and diameter of core must be approximately five times the horse-power.

The relative values of L and D are determined after next considering the speed. Where the r.p.m. required from the motor is not known the following formula may be used :

$$D = 220\sqrt{\frac{H.P.}{V}}$$

This gives a good value for D in inches where V is the permissible peripheral velocity in ft./min. In deciding the value of V, 4,000 ft./min. is a safe value for motors up to 50 h.p. and as the diameter increases the peripheral speed can be increased to double this value for large diameter rotors.

If, however, the r.p.m. is known, by virtue of the number of poles and frequency of supply, the diameter is therefore dependent upon the surface speed. Dividing this surface speed by the r.p.m., we arrive at the length round the periphery, after which dividing by π the resulting diameter is arrived at in inches.

When arriving at the bore of the stator core it is vital to keep the air gap as small as possible, .04in. is sufficient and 1/16in. in a machine of 50 h.p.

Windings

Before an appropriate winding is finally arrived at, the voltage must be considered. The simplest method is to apply dynamo principles, and to fix the number of conductors in series in terms of their lengths and speed and strength of the field they cut.

When a three-phase winding is connected in delta, the voltage across the windings of one phase will be line voltage, but if star connected will be .58 of the line voltage. There is a positive advantage in star connection, as in the case of the stator, by so doing it is possible to use a thicker wire with fewer turns than would be possible with delta connection.

Consequently, not only is the room taken up by insulation less, but the winding labour is reduced.

Current

The voltage of supply being fixed, the method of grouping fixes the voltage on each of the phases separately. Knowing this and also the total watts supplied, and assuming a probable power factor cos ϕ, a value for c, the current in each branch can be approximated

$$w = \sqrt{3}\, v\, c \cos\phi$$

$$c = \frac{w}{\sqrt{3}\, v \cos\phi}$$

Efficiency

For a 5 h.p. machine w will be equal to $5 \times 746 = 3{,}730$, but assuming a full load efficiency of 88 per cent. the watts to be supplied will have to be 4,238 in order to yield 5 h.p. The duties of the stator are to carry the current to provide in each of the three phases a B.E.M.F. equal to the supply voltage.

Stator Conductors

The calculation of stator conductors is carried out by use of the formula ;

$$(V_1 - V_2) \times 10^8 = q\, B\, \lambda v_1$$

where

V_1 = voltage across each phase.
V_2 = volts lost in resistance of stator conductors.
q = breadth coefficient.
B = flux density.
λ = total length of conductor in cms.
v_1 = linear periphery speed (synchronous) in cms./sec.

Lost volts may be taken as 5 per cent. for small machines.

Rotor Conductors

Considering the ironwork of the rotor, the total length of laminated iron parallel to the shaft is the same as the stator, and the clearance between the two having been settled as small as possible, where the number of poles are numerous the centre portion of the laminated discs are inoperative. This allows for the laminated portion of the rotor to be constructed as a ring mounted upon a spider. The number of rotor conductors should be different to the number of slots on the stator, so that there is no tendency at starting or at any speed below synchronous for the motor to cog magnetically.

The greater the cross section of the rotor conductors the greater will be the efficiency of the rotor, provided sufficient iron space is also allowed. There is nothing to be gained by making the total cross section greater than the total cross section of the stator, and in practice is a little less.

These conductors are of solid copper, and only lightly insulated, and can be put into much less space than the stator conductors, and for this reason the rotor slots are generally smaller than one half of those in the stator