## ARMSTRONG SIDDELEY SAPPHIRE . . .

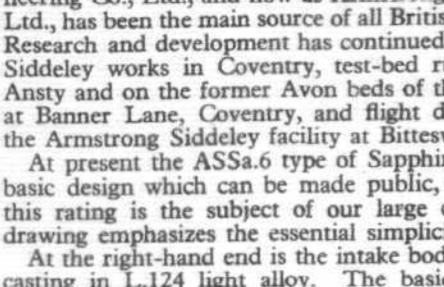
to specify Sa.6-type Sapphires, with no change in delivery date. Large numbers of engines were involved, and the former Hawksley factory at Brockworth, Glos, adjacent to one of the Gloster Aircraft plants, was re-opened specifically for the manufacture of the Sapphire. Tooling continued during 1952 and the first engines were delivered in the summer of 1953.

Since that date the Brockworth factory, operated by a Hawker Siddeley Group company known originally as Brockworth Engineering Co., Ltd., and now as Armstrong Siddeley (Brockworth), Ltd., has been the main source of all British production Sapphires. Research and development has continued at the main Armstrong Siddeley works in Coventry, test-bed running is conducted at Ansty and on the former Avon beds of the Standard Motor Co., at Banner Lane, Coventry, and flight development is based at the Armstrong Siddeley facility at Bitteswell.

At present the ASSa.6 type of Sapphire is the most advanced basic design which can be made public, and a typical engine of this rating is the subject of our large cutaway drawing. This drawing emphasizes the essential simplicity of the engine.

At the right-hand end is the intake body, which is a large sand casting in L.124 light alloy. The basic casting includes four radial struts, the leading edges of which are made separately and bolted on, as is a forwards extension to the central hub portion. Accessory and oil-pump drives can be led down any pair of struts, those chosen depending on the installation. The starter, described later, is attached to the front of the intake hub and a steel housing is bolted on at the rear to carry the Ransome and Marles ball thrust bearing for the front end of the main rotor assembly. The front mounting of the engine (non thrust-carrying) is attached to an integrally cast lug at the top of the intake.

An additional bolted-on extension at the rear of the hub serves to locate the inner ends of the fixed inlet guide vanes, which are cast in S.80 steel. The outer ends of these vanes are located in diagonal slots in carrier half-rings which slide into a recessed groove around the front periphery of the compressor casing. The latter has a constant diameter and is cast in top and bottom halves in L.51 aluminium alloy. The complete casing is held together



*A detail of the compressor construction employed in the original form of the engine, showing the location of rotor blades in discs welded together.*

by bolts through the integrally cast flanges. External stiffening ribs are incorporated, these being more closely spaced transversely than longitudinally.

After machining to the internal diameter the casing is provided with carrier slots for the 13 stages of stator blading, the eighth to the last stages being similar. The first seven rows of stator blades are close-formed stampings in stainless steel and the high-pressure stages are machined from rough steel stampings. Each half-stage (180 deg) of blades is carried in dove-tail slots in half carrier rings, the first seven stages being cemented in with Marco cold-setting resin. This resin retains the blades rigidly, but from 0.002 to 0.010in of tip-rock is allowed to remain on the h-p stages. The first seven stages are shrouded. Each shroud ring is made in four quadrants from rolled brass strip, holes in the shrouds accommodating small "pips" on the stator blades which are finally induction-brazed with silver solder. The complete half units of stator blades are then slid into grooves in the casing, a locating button on each ring butting against the joint face in each half casing.

The compressor rotor drum is forged in MAT.101 (Armstrong Siddeley specification) aluminium alloy, and is then copy-turned to seven stepped diameters, retaining a constant wall thickness. The large drawing shows the form of the longitudinal dogs which are milled into the outer circumference at each step in order to provide a positive drive to the rotor discs. It can be seen that the first three stages (1-p) comprise relatively thick discs forged in Cr-Mo steel. These are a clearance fit on the drum and their drive is transmitted by Hirth couplings on each stage engaging with coupling rings dogged to the drum, the first stage also being driven by the Hirthed rear face of the front main shaft. The latter is a steel extension from the front of the drum, attached to it by fitted D-head bolts and carried by the front bearing.

All the remaining rotor stages (4th to 13th) employ two discs of S.96 steel for each stage. Each disc is turned, on both sides simultaneously, until the finished diameter on the outer part of the radius is no more than 0.062in.

Blading in the first three rows is close-forged in S.62 stainless steel. The finished blades are slid into fir-tree slots broached in the discs and are then locked by "dumb-bell" clips punched from steel strip. From the fourth to the seventh stage the blades are close-forged in aluminium alloy, machined only at the root and tip, the remaining six stages of blades (8th to 13th) being of stainless steel. Each stage of high-pressure (4th to 13th) blades is carried between the two discs of that stage, to which they are through-riveted with two steel, pan-head rivets to each blade.

Each completed stage, comprising a pair of discs and sandwiched blading, is then induction heated to about 200 deg C, fitted on to the rotor drum and pushed hard up against the appropriate drive dogs. When cold the discs have an interference fit of approximately 0.008in, this being sufficient to keep the assembly rigid even in the face of centrifugal growth or gyroscopic loads. By packing the drum with dry ice the rotor can be dismantled, should this be necessary.

In the assembly of the rotor, rotating shrouds (or spacer rings), are fitted between each adjacent pair of blade stages. Rolled rings of E.N.24V h-t steel are each cut to form two or three final shrouds which are machined to engage with the edges of the blade platforms. When running these shrouds are in very close proximity to the brass stator shroud lips.

At the rear end of the rotor drum is attached the steel rear main drive shaft, secured by fitted D-head bolts, and to this is dogged a steel thrust-equalizing disc carrying stainless-steel labyrinth strips held in place by caulking wire. When the rear end of the rotor is tightened up the six rear rows of blading are pinched by some 0.005in against the rear of a row of flange projections at the seventh stage on the drum. The front of the same flange reacts an axial load imparted by the final assembly of the front shaft, the latter creating an axial "nip" of about 0.020in in the cold, static condition. Thus the entire rotor is maintained in proper axial engagement at all times. Final balancing is achieved with the aid of mild-steel plates bolted to the front main shaft flange and steel blocks located by grub screws in dovetail slots in the rear main shaft.

At the outlet from the compressor is placed a row of stainless-steel straightener vanes. Originally there were two rows, but a single row of wide-chord vanes has proved preferable, and these are retained in helical dovetail slots in a carrier ring bolted to the front face of the engine centre section. These vanes ensure that the air delivery to the combustion chamber is as truly axial as possible.

The centre section itself virtually forms the backbone to the whole engine. To it is attached the compressor casing at the front and the combustion chamber at the rear, and all thrust loads and most of the weight of the engine are borne by the main mounting trunnions, one on each side of this unit. Consisting of inner and outer walls (forming a diffusing passage) joined by 10 radial struts, the original form of centre section was completely profiled from a one-piece forging in MAT.102 aluminium alloy, with a forged diameter of 38in and thickness of 11in. Originally in America (as discussed later) but now also in Britain, this design has given way to a fabricated assembly, although many Sa.6s were turned out with the former pattern.

As now employed in production engines the centre section is formed from simple sections of mild-steel sheet, precision welded together in a jig. The finished weight of the fabricated centre-section differs little from that of the "hogged" light-alloy unit.

At the front end of the centre section is bolted a strong diaphragm carrying the centre bearing; this diaphragm is either an aluminium-alloy forging or a steel fabrication according to the pattern of centre section concerned. The front face of the diaphragm also carries the labyrinth sleeve mating with the labyrinth on the thrust-equalizing disc. At the hub of the diaphragm is shrunk in the ferritic-steel centre-bearing housing.

The rear main shaft is machined from S.96 steel, driving *via* a coupling incorporating fitting bolts, the nut lengths being precisely cut to balance out the front unbalanced couple of the turbine unit. Involute gear teeth on the driven coupling take the drive to splines on the compressor rear main shaft, the rear end of the latter having a moly-lubricated, HTS-steel spherical bearing (51) seating the front end of the main shaft and transmitting the pull of the turbine while permitting slight axial misalignment. The driven coupling also supports the sleeve containing air passages carrying the inner track of the centre bearing.

In a similar manner the rear extension to the turbine main shaft carries the sleeve for the turbine bearing, but this assembly also contains the turbine-locking mechanism. Mounted in the extension is a split cone (55) and locking nut with a spring-loaded plunger (58) which locks against internal teeth in the turbine shaft. When tightened up the whole turbine assembly is locked rigidly against the front (split) and rear cones, dismantling requiring removal of the metering plug (64) and the use of a long-handled spanner pushed hard against the sprung plunger.

Support for the rear roller bearing is provided by a formed,