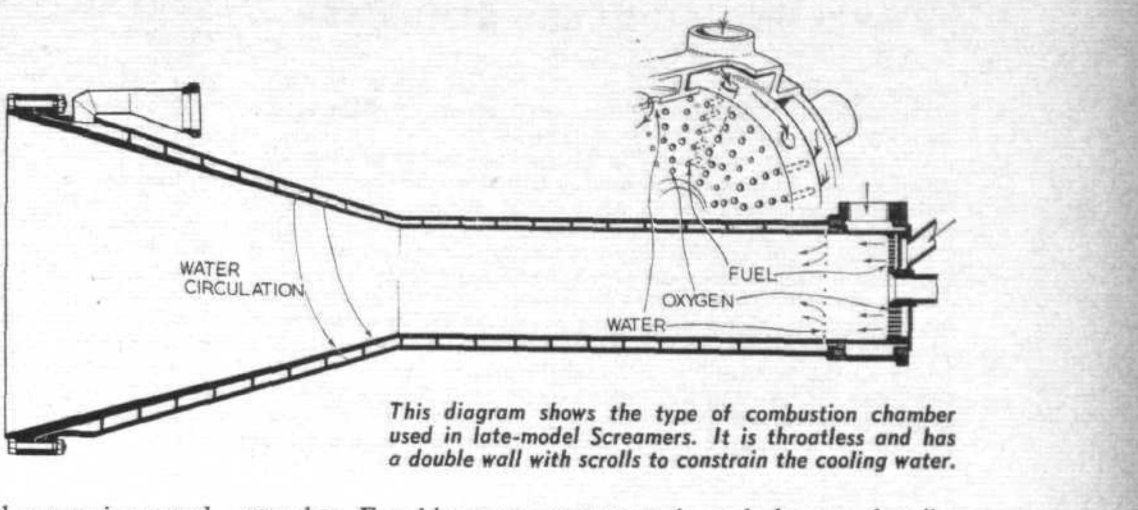
ARMSTRONG SIDDELEY SCREAMER...



This diagram shows the type of combustion chamber used in late-model Screamers. It is throatless and has a double wall with scrolls to constrain the cooling water.

Dowty Vardel hydraulic pumps. The oil circuit includes a heat exchanger cooled by the hydrocarbon fuel.

Gas to drive the turbine is supplied by a gas generator upon which many development man-hours were expended, largely in converting this unit from liquid-oxygen/methanol to liquid-oxygen/hydrocarbon fuel. In its essentials it resembles a miniature combustion chamber. At its head is an igniter body, forming a throatless chamber of 0.375in diameter. On either side of the igniter is mounted a high-frequency plug, the electrode of each being hollow and terminating at a 0.02in nozzle through which fuel is sprayed to form an impingement fan in the centre of the igniter. Liquid oxygen is sprayed from a 0.07in central hole in the head, so forming an oxygen-rich mixture capable of being easily ignited by the high-frequency discharge from the plug-body to the electrode.

The resultant jet of flame escapes through the water-cooled igniter body into a cup at the head of the gas generator proper. Here the flame meets liquid oxygen injected through two tangential swirl holes and fuel from three swirl injectors, forming a fairly oxygen-rich mixture which burns in the main body of the generator. An accompanying diagram shows the flow of water through the cooling scrolls in the chamber walls and also clarifies the method by which water is injected at the exit from the chamber. The resulting gas-flow has been found not to impair turbine life and to eliminate flame or smoke from the exhaust; furthermore, in spite of the quenching with water, no carbon is formed. Injection of water reduces the gas temperature to 625 deg C, the overall mass flow being about 2 lb/sec. The gas duct feeds three nozzles spaced around 120 deg of the turbine casing. From the turbine the gas is exhausted through twin ducts, *via* a snail-shell exhaust volute.

It is in the combustion chamber that the Screamer shows particularly marked departure from previous practice. Originally the work was centred upon orthodox throated chambers but it was soon found that good results could be obtained from a throatless chamber which, provided adequate performance can be obtained, is the optimum for low weight and good cooling. Theoretically the specific impulse is slightly reduced (compared with a throated chamber) owing to the fact that the heat is added to a rapidly moving gas stream. Various forms of chamber were run on liquid-oxygen and kerosine in 1951 and 1952 and the throatless chamber was the pattern which posed the fewest problems. The initial chambers were rated at 4,000 lb thrust and were fed from electrically driven pumps. Later, scaled-up chambers of 8,000 lb thrust were successfully tested, this thrust being first reached in September 1954.

Many variations were studied, with a view to determining the optimum method of injection of the water. One typical pattern of Screamer chamber, which is shown in the large drawing, accepts the water at the nozzle end; the water then passes round a cooling scroll in the divergent portion of chamber and back along the parallel section to a row of holes at the head of the chamber, through which it is injected to form a cooling film along the inner wall of the liner. In some designs of chamber axial coolant passages were formed using soft iron wire stretched along the divergent portion of nozzle.

Yet another type of chamber had five separate stages of water injection at various axial positions some 2-3in apart, fed with water from four external water pipes. Finally it was decided to inject all the water at the head of the chamber, with reverse flow through the double walls from an inlet at the nozzle end. Development was conducted with tubular slave chambers (without a divergent portion) machined from steel bar. To these were bolted flat back-plates drilled with radial or concentric rows of injection holes for the liquid-oxygen and hydrocarbon fuel. The final design of Screamer injector has like-on-like impingement jets in the centre and parallel (non-impingement) shower-head injectors around the outer portions.

At various stages in development the Screamer chamber was made in two portions bolted together at the junction of the parallel and divergent sections. In all designs the inner shell and outer case are made of S.21 mild steel, which is readily welded and has good thermal conductivity. The inner shell was hard-chrome-plated to resist erosion and other parts cadmium-plated to prevent rusting. Production chambers would have been tubular forgings but the development chambers were machined from solid. The back-plates in the Screamers so far built have also been machined from solid, the material being S.110 steel.

The starting and control system of the Screamer is relatively complex. For this reason no attempt is made here to describe the complete system in detail but the following is a full outline of the manner in which the motor is started and sustained.

Prior to firing, the three propellant feed valves are opened by energizing the suction-valve solenoid. This allows the propellants to flow from the main airframe tanks through filling valves to the starting tanks, and also to fill the main engine lines up to the stop and by-pass valves. One starting tank is provided for each of the three propellants, their purpose being to run the gas turbine up to speed during the starting cycle. The liquid-oxygen starting tank is a tubular steel cylinder containing a free-floating steel piston fitted with two Duaflex rings. Like the other starting tanks it is pressurized to 450 lb/sq in from a 3,000 lb/sq in nitrogen bottle, and it has an excess capacity in case the gas generator should be slow in starting. The tank automatically refills after each start, since it is connected to the pump suction and the head of liquid oxygen from the airframe tank is sufficient to refill the starting tank by pushing back the floating piston to its starting position. The fuel and water starting tanks are likewise machined from solid steel with an interior polished to a very high surface finish so that the synthetic rubber diaphragm within each tank shall not stick to the inner wall. At each end is a perforated plate, shown clearly in the large drawing, to prevent the diaphragm from being blown out of the tank.

Vapour formed by the liquid oxygen boiling in the warm pipes is released through priming valves on the starting tank and oxygen pump and also through by-passes from the valves associated with the gas generator and combustion chamber. Air trapped in the water and fuel lines can be bled off at suitable points. The Screamer starting-cycle is initiated by energizing the starting solenoid which allows nitrogen to open two paralleled valves which admit nitrogen pressure to the three starting tanks. At the same time nitrogen is used to purge various portions of the engine. From the starting tank the liquid oxygen is piped first to the stop and by-pass valve and igniter stop valve on the gas generator; fuel and water are each fed to the gas-generator and igniter valves and, *via* a pressure-balance valve, to the gas generator mixing section. The pressure of the water injected into the gas generator opens an air valve which allows nitrogen to open the main oxygen and fuel igniter stop valves; the combustible mixture then flows into the gas-generator igniter where it is immediately lit by the high-frequency plugs.

Should the igniter pressure not rise to its normal value within two seconds dangerous accumulations of propellants are prevented by a delay switch. Assuming normal ignition the rising igniter pressure opens a valve to admit the main gas-generator propellants, and also operates a switch which breaks the two-second delay circuit and at the same time makes the high-frequency circuit for the main combustion-chamber spark. A nitrogen-operated switch effects the change-over in ignition from the gas generator to the main combustion chamber.

Gas from the gas generator accelerates the turbine so that the three pumps feed propellants back to the main tanks *via* the by-pass lines from the three main stop and by-pass valves. In the same way as for the gas generator, the main flows of fuel and water are fed to the main combustion chamber through a pressure-balance valve (39-41 in the key). Water pressure immediately downstream of the pump energizes a switch and solenoid circuit, allowing nitrogen to admit igniter fuel and oxygen to the main chamber. Propellants fed to the main-chamber igniter are lit by sparks from the high frequency plugs and the resulting build-up of pressure opens another valve, allowing nitrogen to operate the main water stop and by-pass valve and also a pressure switch which breaks the delay circuit and switches off the plugs—just as in the circuits associated with the gas generator. Water pressure downstream of the main valve operates the main liquid-oxygen valves and the resulting oxygen pressure then operates the fuel valve, the propellants being fed in this sequence to the combustion chamber.