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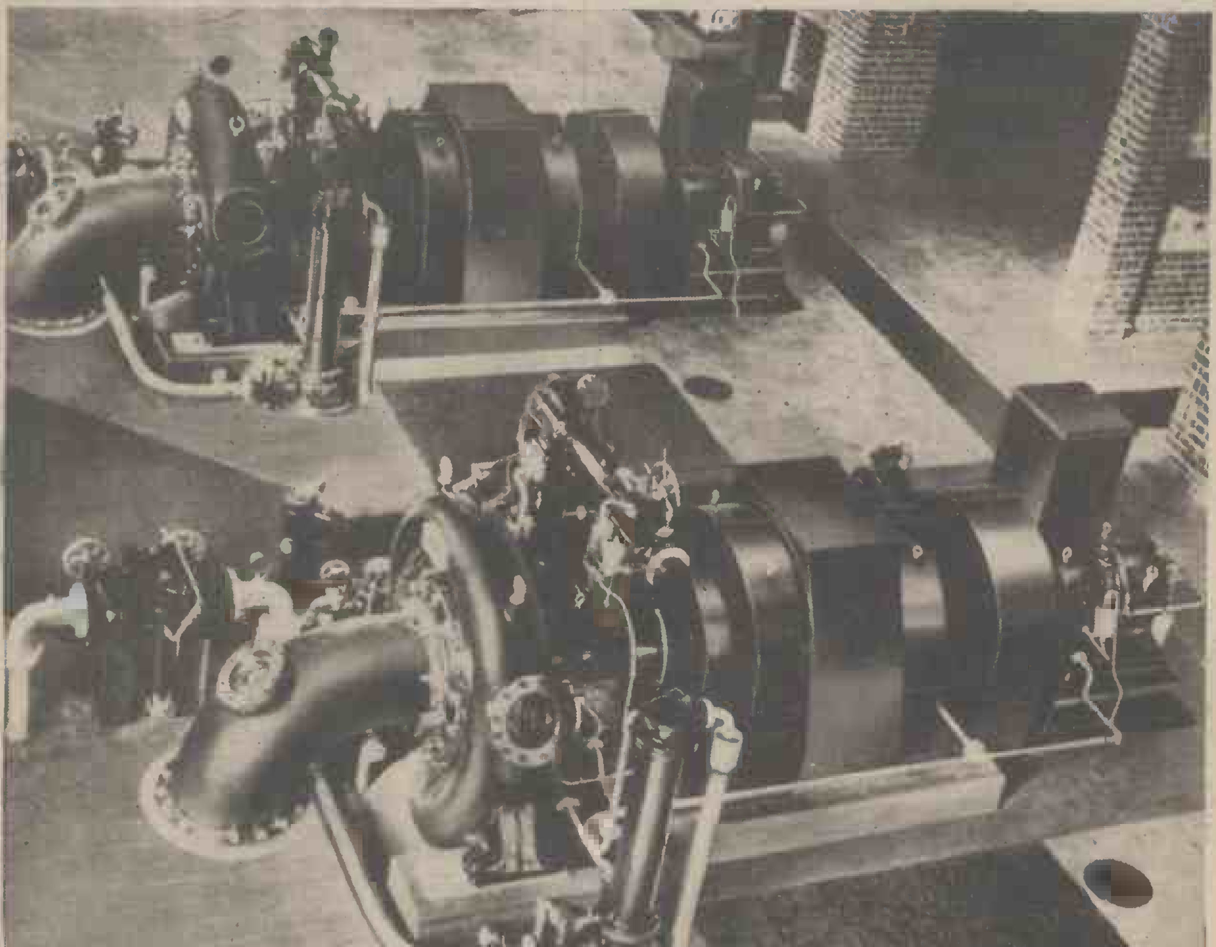


TURBINE-DRIVEN GENERATORS IN THE VICTORIA FALLS POWER STATION *(See page 417)*

Rocket Propulsion

The HWK 109-509 Walter Engines

By K. W. GATLAND

(Continued from page 388, August issue)

The only rocket powered interceptor to see service during the war, the Messerschmitt 163BO was fitted with an HWK 109-509A1 Walter engine. This photograph shows the landing skid and tail-wheel fully extended. The main wheels, attached to the skid, were jettisoned once the machine was airborne.

THE design of the Walter aircraft engines was *regenerative*; that is to say, the fuel component of the liquid propellant was circulated prior to its injection for burning through a cooling jacket encompassing the combustion chamber and nozzle. In this arrangement the fuel acts to cool the motor, and, conversely, to vaporise the fuel by pre-heating, with the result that there is a marked gain in the thermal efficiency.

Another important factor of regenerative design is that the inner wall of the combustion chamber can be quite thin and yet withstand full combustion stresses.

One of the first experimenters to employ this system was the German, Dr. Eugen Sänger, who first demonstrated his fuel-cooled rocket motor in 1931. This unit has been fully described in an earlier article (PRACTICAL MECHANICS, March, 1945, p. 200), and it will be recalled that the one essential requirement was a high pressure fuel-feed system, and that Sänger achieved his very successful results in the use of a Bosch diesel pump which permitted pressures within the jacket of 450 to 2,200 lb./sq. in. As the fuel-feed pressure must necessarily be greater than that resulting from combustion, the stress directed on the firing wall of the chamber acted toward the axis of the motor. Thus, the inner wall was of a much thinner section than could otherwise be employed, and of an appreciably higher order of conductivity. All outward directed pressure was absorbed by the outer shell, which could be of heavier construction as it was not subject to extremes of temperature. This explains the reason why no particularly high-grade steels were used in many of Germany's most efficient rocket motors, including the V-2, when motors employing highly durable materials in their construction but not regenerative operating, were disrupted after merely a few seconds' firing.

Since the time of Sänger's early experiments, a number of other motors employing the same principle had been developed, many of which were featured in tests carried out by the American Rocket Society.

It was, in fact, Nathan Carver, a member of this group, who provided a further important contribution toward solving the problem of motor burn-out, which when combined with Sänger's scheme made the possibility of efficient liquid rocket engines a certainty.

This was, of course, the " concentric-feed " principle which Carver first demonstrated

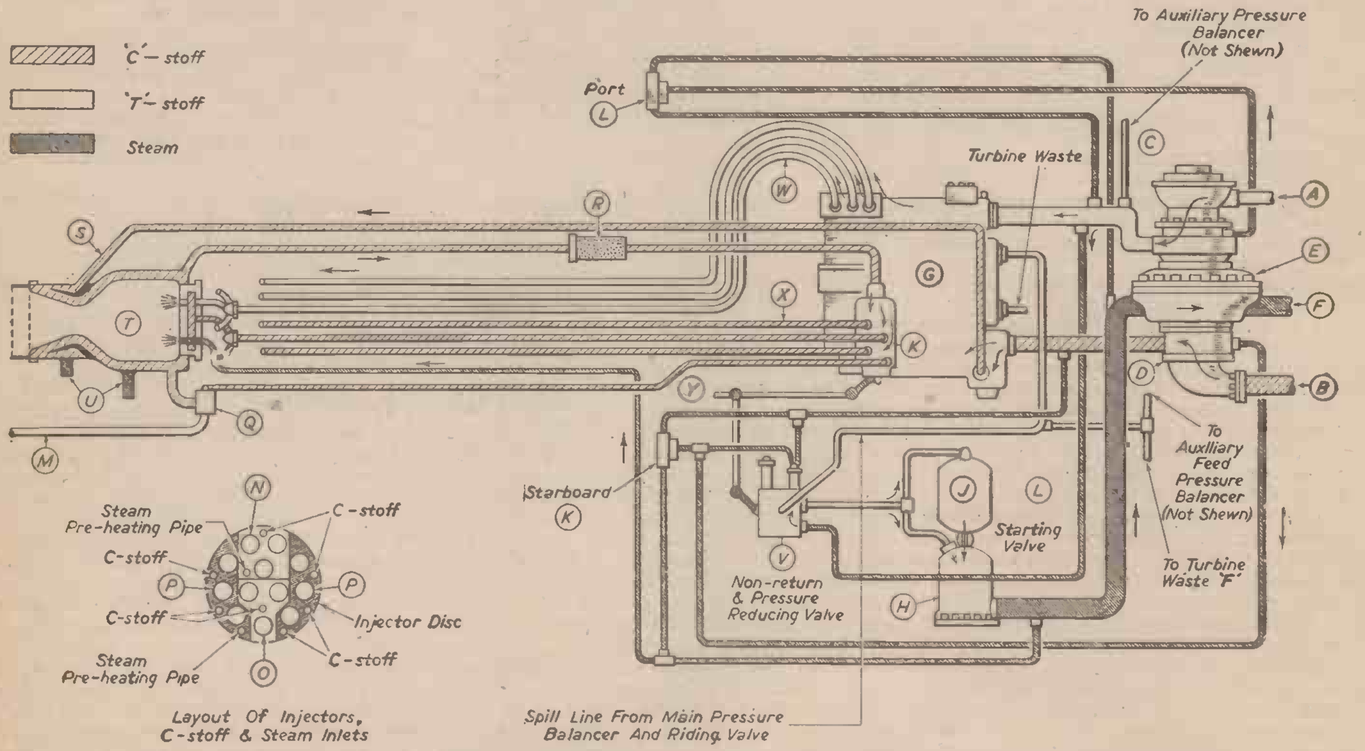


Fig. 76.—Diagrammatic layout of the HWK 109-509C—main system. The cruising motor has been omitted for clarity.

A. T-stoff inlet from tanks.
B. C-stoff inlet from tanks.
C. T-stoff pump.
D. C-stoff pump.
E. Turbine.
F. Steam exhaust from turbine.
G. Distributor. (Main pressure balancer.)
H. Steam producer.
J. Starting reservoir.
K. Control valve.
L. T-stoff to turbine.
M. Scavenge pipe.
N. Stage one.
O. Stage two.
P. Stage three.
Q. Scavenge valve.
R. Filter.
S. C-stoff inlet to jacket.
T. Combustion chamber.
U. Supports for auxiliary motor.
V. Turbine control valve.
W. T-stoff feed lines.
X. C-stoff feed lines.
Y. Pilot's control lever.

NOTE: All notation in the text refer to this figure.

during the small-scale rocket aeroplane trials at Greenwood Lake, N.Y. in 1936 (PRACTICAL MECHANICS, February, 1945, p. 158) and which was later taken up with even greater success by other technicians of his Society, principally, R. C. Truax and J. H. Wyld. His associates, in fact, produced several concentric-feed regenerative types which in conception were essentially nothing less than small-scale versions of the power unit of the V-2.

As the result of similar and more intensified research which was proceeding under military supervision in Germany, the prototype engine of the A4 long-range rocket appeared, and with it the motors of the Messerschmitt 163 series.

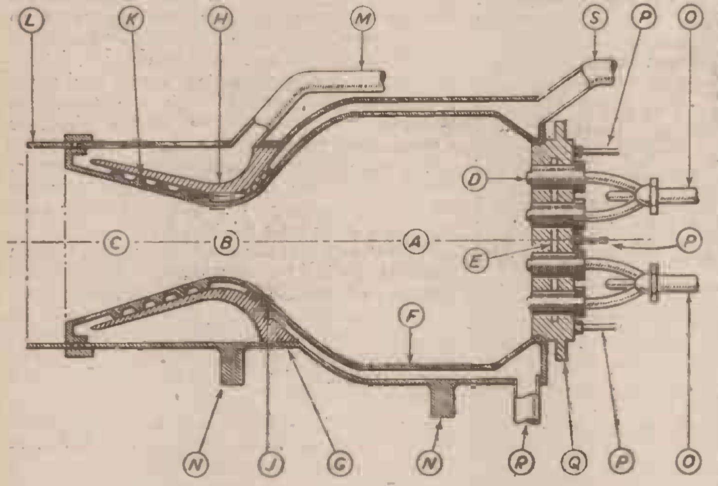


Fig. 77.—Sectional diagram of the HWK 109-509C combustion chamber.

A. Combustion chamber.
B. Nozzle throat.
C. Nozzle mouth.
D. Injector.
E. Orifice for C-stoff entry into injectors.
F. Inner shell of combustion chamber.
G. Outer shell of combustion chamber.
H. Concentric-flow section.
J. Helical vanes on concentric-flow section.
K. Helical vanes on inner shell.
L. Outer shell over nozzle.
M. Coolant inlet.
N. Supports for auxiliary motor.
O. T-stoff inlets.
P. C-stoff inlets.
Q. Injector disc.
R. Drain pipe.
S. Coolant outlet.

The HWK 109-509 Walter Units

The HWK 109-509 engines (the HWK 109-509C main system is shown in Fig. 76) comprised two main sub-assemblies: (a) the rocket motor, and (b) its turbine-driven pumps, accessories and controls, separated by approximately 4ft. of feed lines, these being completely encased by a metal conduit which transmitted the thrust. In the case of the 109-509A1 unit, the total weight (less propellant) was only 814lb., while the amount of T-stoff and C-stoff necessary to operate the Messerschmitt 163BO during its four minutes period of powered flight was 3,418lb. and 1,031lb. respectively.

The combustion chamber (Fig. 77) was constructed of rough forged carbon steel, being of cylindrical section rounded at the head and flowing into a convergent-divergent expansion nozzle. Its length was approximately 11in., the internal diameter 9.50in., the volume 825 cu. in., and the throat area of the nozzle 5.15 sq. in.

The inner walls were only ⅛in. in thickness, yet able to withstand temperatures of nearly 2,000 deg. C. and pressures approaching 24 atmospheres. An ⅛in. average gap separated the inner and outer walls of the motor through which the C-stoff coolant flowed.

Of rolled carbon steel construction, the outer shell of the motor was seam-welded, the nozzle being joined to the chamber portion at the mouth. A 6.50in. diameter disc, on which were mounted the injector valves for the propellant, was also welded—at the head of the chamber.

Situated in the space between the inner and outer shells of the nozzle was a concentric flow section, ensuring a rapid and even flow of coolant around that most vulnerable portion of the motor. This was an aluminium alloy casting and embodied three helical vanes situated to coincide with the convergent section of the nozzle, intended to swirl the C-stoff evenly around the liner in its path to the fuel injectors. A further set of five vanes was attached to the outer surface of the liner at the divergent section.

The propellant entered for combustion at the chamber head, passing through twelve pressure actuated valves mounted on the disc plate. The latter was machined from carbon steel bar, while the separate injectors, which screwed into the plate, were of stainless steel.

Operation of the Motor

The oxydiser passed down the centre of each valve, but upon entering the chamber, was deflected outwards from the axis by means of a cone.

This cone was obviously the crucial part of the injector, and being spring loaded, not only prevented blow-backs but also acted as a regulator.

It will be seen from the figure that the supply of fuel to the motor was through a main distributor (G), and that a pipe first brought the C-stoff to the coolant jacket. The fuel solution, having circulated around the motor, was then filtered and delivered back to the distributor, passing through a control valve where its pressure was regulated prior to being fed for combustion. All of the pipes, to and from the motor, passed inside the metal thrust conduit, the fuel pipes branching out into subsidiary feeds just before reaching the head of the combustion chamber. These, of course, fed into the twelve injectors.

Apart from flowing through a filter and control valve in the distributor, the T-stoff fed directly from the pump into the chamber. There were seven inlets and these led into a cavity inside the injector plate, the fuel passing again through filters and then into the injectors via an annular orifice surrounding the deflector cone, finally entering the chamber and mixing with the oxydiser. Combustion took place spontaneously at the deflector cones, each injector providing its own "concentric-feed."

The T-stoff underwent vigorous decomposition, liberating nascent oxygen, which was burnt with the alcohol as the main source of heat. Actually, the violent reduction of the peroxide, under heat and catalytic action, also released mass in the form of superheated steam, adding materially to the weight of the exhaust.

In order to overcome the possibility of explosions when the motor was expended of propellant, it was necessary to drain any C-stoff that remained from the coolant jacket. This was catered for by a pipe which passed from the jacket at a point beneath the chamber to a valve (Q). All the while the turbine-drive of the pumps operated, this valve was closed, but when the pumps ceased to function and pressure fell off, the valve was allowed to open and the remaining fluid in the jacket passed out through the scavenge pipe (M)

Starting

The starting procedure consisted first in working the pumps, but this did not entail releasing propellant to the combustion chamber with its voracious consumption of approximately 1,000lb. per minute. The pilot initiated the turbine drive by moving the lever of his control quadrant to "Idling," energising the starter motor and opening the tank flow-cocks. This electric starter, which was geared direct to the turbine shaft, drove the pumps at low power, causing the feed-lines to fill with propellant. The pressure, however, was not sufficient to overcome the valve setting in the main T-stoff line to the steam producer, which activated the turbine.

In units which were not fitted with electric starters, there was an auxiliary starting reservoir which contained sufficient T-stoff to operate the turbine for six seconds, thereby allowing time for peroxide from the main supply to reach the steam generator. A by-pass line fed back a small quantity of peroxide into the steam generator (H), and the turbine quickly developed sufficient power in the pumps to operate the normal feed to the steam producer. The bypass then automatically cut out.

This procedure was necessary each time the motor was re-started after the aircraft has been gliding with power off.

The Steam Generator

The steam generator comprised a porcelain-lined pressure vessel with a wire cage fitted inside in which were distributed a number of porous pellets impregnated with calcium permanganate and potassium chromate. From the reservoir, the T-stoff fed by gravity into the generator, where, upon meeting the catalyst, there resulted a violent decomposition into super-heated steam and gaseous oxygen. Actually, the peroxide was sprayed on the catalyst from the top of the generator, and the cage itself rested on a perforated sheet of metal near the floor of the container. A large pipe conveyed the steam from the base to the nozzles of the turbine, and after operating the rotor, the waste gases were vented to atmosphere.

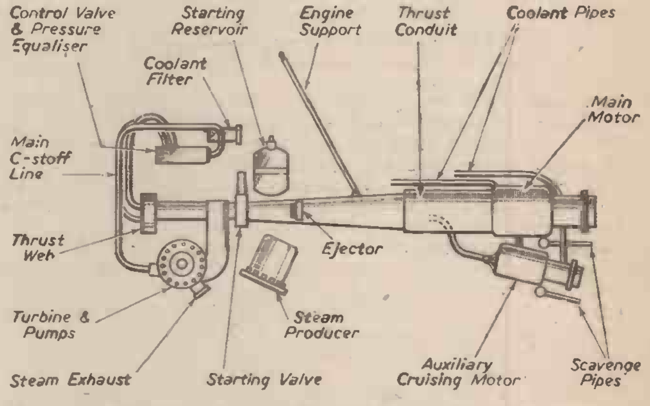


Fig. 78.—Diagram showing the layout of the main components in the HWK 109-509C Walter bi-fuel rocket engine.

In the developed engine HWK 109-509C, two small pressure lines ran from the main steam pipe to convey pressure to the ejector valves (K and L), which were provided for the purpose of extracting air from the pumps when the power has been cut for any reason. This was, of course, a safety measure to prevent airlocks and to afford protection from explosions which might otherwise have occurred. The steam used here was eventually exhausted into the combustion chamber, being also used to pre-heat the fuel during starting operations.

The Turbine-pump

In order to maintain pressures of the order of 350-360lb./sq. in. in the feed lines and motor jacket, it was obvious that the solution did not lie in the use of gas-operated pressure chargers. The difficulties confronting the designer of a mechanical driven pump were enormous, and had it not been found possible to use concentrated hydrogen peroxide as the steam producer, it is doubtful whether either the rocket fighters or the V-2 would have performed anything like as well as they did, for reciprocating engines and the extra fuel entailed meant so much more unwanted weight.

The pumps of the HWK 109-509 were called upon to supply over 20 lb. of propellant for every second the motor was operating under conditions of maximum thrust and at a pressure sufficient to maintain a combustion chamber pressure of over 350lb./sq. in.

The turbine group comprised a single-stage turbine with two centrifugal impellers mounted on a common shaft at either side. Machined from chrome steel, the 10in. diameter turbine rotor was housed within an aluminium alloy casting. The T-stoff impeller was manufactured from 13 per cent. chrome steel, while the materials of the fuel impeller were not so critical so long as copper was avoided in the alloy. It was, however, usual to employ aluminium or aluminium alloy, although chrome steels with an optimum percentage of 18 to 21 chromium was a possible alternative. Their housings were also of chrome steel.

For the remainder of the feed system, the hydrogen peroxide lines were of aluminium alloy, though, of course, not containing copper, while the fuel solution was carried by pipes of mild steel.

From "Idling" to "Power"

Immediately sufficient pressure was registered on an indicator in the cockpit, the pilot moved his throttle lever into the first gate. This caused the propellant to feed through three of the injectors (N). The second power phase brought into operation three additional injectors, while the third and final setting functioned the remaining six.

In the case of the improved HWK 109-509 motors, there was in addition to the main rocket motor a cruising chamber, the complete layout of which is shown in Fig. 78. The auxiliary chamber, which was supported beneath, was also regenerative, but had only three injectors. It operated at a fixed power, the 109-509C version developing fully 880lb. thrust.

For climb, both chambers were operated to obtain maximum power, but for cruising, the main motor could be cut out, the use of the auxiliary chamber providing a better solution than simply throttling back on the main system. This enabled a given thrust in the lower power setting to be taken over by the smaller chamber, with the result that efficiency was much improved and a lower propellant consumption obtained.

Performance Data

In the combustion chamber, the chemical energy of the propellant was converted to heat energy, 1,430 C.H.U. being theoretically available for each pound consumed. The maximum thrust resulting from the main chamber was 4,400lb. with a combustion pressure of 353lb./sq. in. and a chamber temperature of 1,950 deg. C.

With the thrust averaging 3,700lb., however, the temperature was reduced to between 1,750 and 1,900 deg. C. The propellant ratio was then between 3.7 and 3.3 to one.

The thermal efficiency was found to be in the region of 28 per cent. at maximum thrust, falling to something less than 10 per cent. at the maximum setting. This poor value of efficiency was, of course, favourably offset by the inclusion of the cruising chamber in newer designs. The reason for this is obvious in that the smaller throat area and chamber volume permitted higher pressures than would have been possible in the larger motor with the same number of injectors in use.

(To be continued.)

Items of Interest

Exhibition of Non-utility Furniture

EXPERTS met in London on April 25th to look at some 1,000 designs for non-utility furniture submitted for inclusion in the Government-sponsored "Britain Can Make It" Exhibition, which opens this month at the Victoria and Albert Museum.

Permits will be issued for the timber required for constructing the selected designs, and from this range of furniture the final selection for the exhibition will be made.

New furniture will be an important feature of the exhibition—displayed in furnished rooms and in nurseries, gardens, offices, and restaurants.

Since there will be complete freedom in the choice of materials for the furniture exhibits, British manufacturers will have the opportunity of showing that the restrictions of the war years have not affected their leadership in design and craftsmanship. It is anticipated that some of the furniture selected will be based on the wartime advances in new techniques and new materials.

The large number of entries for this section is evidence of the keen interest displayed by British manufacturers in the "Britain Can Make It" Exhibition. It is also a remarkable tribute to the resiliency with which British furniture manufacturers are facing problems of reconstruction.

Non-utility post-war developments in all kinds of consumer goods will be shown at the exhibition, which is being organised by the Council of Industrial Design and financed by the Government. No space is being sold, for all exhibits are to be carefully selected to illustrate the best in British industrial design. Selections for other sections of the exhibition will be made later in the summer.

The exhibits are to be chosen by experts drawn from a panel of selectors under the chairmanship of Lord Woolton.

The Audiometer

THE audiometer was first used to record sound in 1910. Since then it has recorded traffic, Dame Nellie Melba, H.M. the King, Chamberlain, Churchill, gunfire, Hitler's voice and most imaginable sounds. It operates by direct recording, unlike the "talkie." Used in study of Underground Railway noises and for the silencing tests on Imperial Airways. This instrument made the first known records of London's traffic long before era of talking pictures. (See illustration below.)

Comfort for Air Transport

TO add to the comfort of passengers travelling in an aircraft means have been devised to minimise transmission of sound and other vibrations to the interior of the cabin and other compartments of an aeroplane.

A further object is an improved method of regulating the temperature of the cabin.

The invention comprises an aircraft compartment in which an inner cell or chamber is suspended through the medium of resilient vibration—damping members attached to members of the outer frame. The arrangement is such that except at the points of its suspension, the inner cell compartment is entirely surrounded by an airspace sealed from the outer atmosphere.

The transmission of sound and other vibrations depends to a large extent upon the existence of rigid physical connections. And, in order to prevent or at least minimise such transmission, it is important that the smallest practical number of suspension mountings be employed. Then the conducting efficiency of such physical connections as are essential can be reduced by incorporating resilient damping means at the minimum cost of added weight.

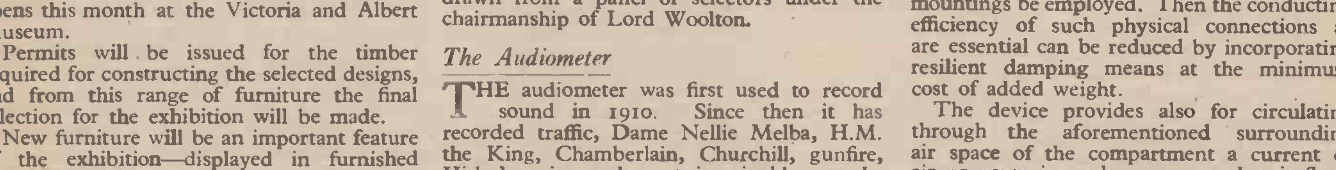
The device provides also for circulating through the aforementioned surrounding air space of the compartment a current of air or gases in such a manner that it flows over the outer surfaces of the inner cabin. The temperature is regulated above or below the atmospheric temperature which it is desired to maintain in the cabin.

Portable Fire Alarm

WHEN people retire to bed at night the remains of fuel in the grate are sometimes left burning. In these circumstances sparks from the grate are a not uncommon cause of a fire.

To guard against such a contingency, there has been devised a portable fire alarm which can be placed on the hearthrug. In case of fire, this automatically sounds an alarm of sufficient duration to awaken the occupants of the house.

As no electrical connections have to be made, the device is readily portable, and can be carried from one room to another and used where it is most required.



Sound wave photograph of an atomic bomb explosion. Taken on the audiometer by Prof. A. M. Low. This is a visual record of the greatest underwater explosion ever known.