Final Report No. 66.
ITEM No. 25

DORNIER STRUCTURAL STRENGTH TEST EQUIPMENT AND METHODS.

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BRITISH INTELLIGENCE OBJECTIVES
SUB-COMMITTEE

LONDON - H.M. STATIONERY OFFICE

DORNIER Structural Strength Test

Equipment and Methods

Reported by

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SUMMARY

This report describes the methods and equipment used at the Dornier structural laboratory for testing the strength of the D.O.335 complete airframe. The writer visited the Dornier laboratory on the 26th July, 1945, when the test specimen and test gear were being made ready for a test to be witnessed by French technicians, The test gear was completely mechanised and centrally controlled and had many interesting features which were discussed and photographed.

1.0. Introduction

The writer was sent from the Royal Aircraft Establishment as a member of C.I.O.S. Party No. 641 which visited the Dornier Works. Friedrichshafen, during the period 21st - 27th July, 1945. Since the main purpose of the visit was to investigate the production methods and capacity of Dorniers, these notes, which describe the airframe strength test equipment and test methods used at Dorniers, were not included in the team's production report.

The test laboratory was located at WASSERBURG, near FRIEDRICHSHAFEN, in a building which had previously been used as a riding school. Dorniers had finished their strength tests on a complete D.O.335 airframe just before the ending of hostilities. The specimen had been tested under seven different loading conditions, four related to the fuselage and three to the wings. The fuselage tests were done first, the fuselage being repaired before the wing was tested.

The French authorities, on arrival after the tests, arranged for the Dornier staff to repair the broken wing and re-assemble the test rig (which had been partly dismantled) so that the test could be repeated before French technical witnesses. The target date for this test was 1st August, 1945.

The laboratory was visited by the R.A.E. representative on the 26th July, 1945, and the test equipment, which was fully mechanised and centrally controlled, was demonstrated by the French officers in charge. A moderate load (about 30% of ultimate) was applied to the specimen, the mechanical and electrical features of the rig were observed and a number of photographs taken.

2.0. Test Conditions.

The test conditions represented low incidence, a speed of 900 Km. per hour, and an ultimate factor of 1.8 x 5 = 9.0.

The Dornier staff explained that destruction tests are normally preceded by a proof test to factor 1.35 x 5 = 6.75 (i.e. 75% of ultimate). Deflections of the specimen are measured throughout the tests and the permanent set remaining after the proof test should not exceed 5% of the deflection at ultimate load. After failure of the specimen, material control tests are made and a correction applied to the initial test result.

3.0 Test Specimen and Loading Attachments.

The specimen consisted of a complete airframe less tail surfaces and wing tips. Steel dummy wing tips each fitted with a single loading lug were used in place of the normal tips. The engines at the front and rear of the fuselage were represented by dummy steelwork which included lugs for the application of inertia loads. The fuselage shell was loaded through external straps passing over the frames, and the wing spar was loaded vertically by means of attachments of the type shown in Fig.1. Drag loads were applied to the wing at four points on each side, through straps attached to the top and bottom skin of the box spar. Two, and in some cases three, pick-up points ('A') were provided on the top beam of the spar loading attachments. These could be used as alternative C.P. positions or could be used for counterpoise attachments.

Fig.2 is a photograph showing the port wing and the port side of the fuselage looking forward.

Fig.3 shows the starboard side of the rear fuselage with external loading straps passing over the two frames immediately aft of the long opening in the side of the fuselage shell in way of the rear engine.

Fig.4 shows the port wing viewed from behind the dummy wing tip. The loading attachments on the spar can be seen, also the straps for applying the drag load.

4.0. Test Frame.

The test frame consisted of a permanent structure of rolled steel sections, cruciform in plan, with one bay for the wing and one for the fuselage and front engine mounting. The structure rested on the floor but was not attached to the floor. Diagonal bracing was provided in the vertical and horizontal panels so that the frame was suitable for a variety of types of loading.

The vertical loads on the specimen were reacted on the test frame through loose steel beams clamped across the top or bottom booms of the frame. The fore and aft loads were reacted in a similar manner through vertical beams clamped to the side of the test frame. Temporary walkways, level with the wing, were provided around the inside of the test frame.

The construction of the frame may be seen in Figs. 2, 3, 5 and 6.

5.0. Counterpoising of Specimen.

The weight of the specimen, including airframe, dummy engines, dummy wing tips, spar loading attachments etc., was completely counterpoised by means of cables, pulleys and cast iron weights. Counterpoise cables were attached to a number of points on the wing, fuselage and steel dummies. On the inner part of the wing a special system of counterpoise links and levers was connected to the spar loading attachments at points behind the main linkage used for loading the wing. The counterpoise rig can be seen in Figs. 2, 3, 4, 5, 6 and 7.

6.0. Load Distribution Rig.

The loading attachments on the wing were connected together into groups by means of systems of links and levers. Fig. 4 shows these systems, the levers of which consisted of pairs of rolled steel channels back to back.

Similar link and lever systems were used to distribute the fuselage loading. These may be seen in Fig.3 suspended from the loading straps passing over the fuselage.

Each group of levers was connected to the test frame structure by means of a dynamometer in series with a motor driven straining unit. This assembly can best be seen in Fig.4, which shows (top, centre) the dynamometer suspended below the straining unit and connected to the middle group of levers on the port wing. From Figs. 2 and 4 it will be seen that each half wing was loaded vertical by four dynamometer-straining units the outer of which was connected directly to the dummy wing tip.

7.0. Method of applying strain and measuring load.

The straining units were essentially power driven turnbuckles. They each consisted of a square threaded screw with a pin joint at one end and a cross-head at the other end. The crosshead could slide axially, but not rotate, in a guide tube on which was mounted an electric motor driving through enclosed gearing, a nut which rotated on the straining screw. A pin-joint attachment was provided on the end of the guide tube remote from the nut and gearing. The units were used for tension loading through the pin-jointed ends.

Fig.4 top, centre, shows the straining unit above the dynamometer. The exposed thread of the screw is at the top. The motor is to be seen on the right-hand side of the guide tube, the upper end of which carries the casing for the nut and the geared drive.

The dynamometers were of the type shown in Figs. 8 - 10. The load indicating needle was operated through a pinion and quadrant actuated by deflection of the double U-shaped plate spring at the back of the dial (Fig.9). The distance between the tips of the 'U' increased when the instrument was loaded in tension. A safety bolt is shown passing through the tips of the 'U' and providing a means of protecting the instrument from excessive loading.

The dynamometers were also fitted with load selecting needles, geared desyns, and electric wiring and contacts for connecting the dynamometer to the motor of the straining unit and to the central control station. The latter, and the functions of the straining and measuring gear as a whole, are described in the next paragraph.

The straining units and dynamometer units were available in three sizes:- 5, 10 and 20 metric tons, and were capable of straining at a rate of 18 m.m. per minute.

8. 0. Control of loading gear.

In designing the loading gear Dorniers had aimed to provide for remote control, by a single operator, of up to 24 dynamometer-straining units of different sizes. These units were not all equally loaded although there was duplication of the port loading on the starboard side. The control unit, after its initial adjustment for any particular test, should synchronise the various straining units so that each portion of the specimen received its correct proportion of load in step with all other parts of the specimen. This aim is made difficult by the differences between the deflection of the outer wings and the deflection of the inner wings and fuselage, which requires varied rates of strain between the various straining units.

The control scheme was complicated but was very largely successful. It was noted that some of the straining units reached the desired increment of loading more quickly than others and that as each unit reached its target load it commenced to 'hunt' and continued to do so until the remaining units were balanced.

The control unit is shown in Figs. 11 and 12.

The upper half of the front face of this unit consisted of 24 arc-shaped load scales, each of which could be connected to a straining-dynamometer unit. Immediately below these arcs is a series of small red and green electric bulbs which flashed to indicate whether the actual load at any dynamometer was above or below the desired load. The horizontal panel in the lower front face of the controller contained a scale which indicated the load on the specimen as a whole.

Fig.13 is a photograph of the arrangement drawing showing the control unit, straining unit and dynamometer with diagrammatic connections.

The left-hand half of Fig.13 is a sectional diagram of the control unit. The right-hand half shows a cantilever test specimen (top), from which a dynamometer (shown in front and side view) is suspended. Below the dynamometer the motor driven straining unit is shown anchored to a fixed base. The bottom right corner shows an autographic load deflection recorder which was not, however, in use on the test, deflections being measured by the scale and telescope method described in para.9.0.

Returning to the control unit, the base of the instrument contained a vertically moving carriage, supported at its corners on screw jacks geared together and to a small electric motor. The position of the carriage, indicated on the scale in the bottom of the front face of the unit, was used as a measure of the load on the specimen as a whole.

Along the top of the carriage there were 24 inclined slide bars, one for each dynamometer. Each slide bar carried a strut in contact with a lever pivoted at a fixed point on the back of the cabinet so that movement of the strut along the inclined bar changed the lever ratio and rotated the lever about its pivot. The struts could be locked in any desired positions on their slide bars. Movement of the levers operated vertically guided racks engaging with quadrants which carried load selection needles over the 24 loading scales on the front face of the cabinet. The quadrants also engaged with desynns connected to the dynamometers.

Each of the 24 scales was served by two needles, the load selecting needle already mentioned, and a load indicating needle, which by means of desynns repeated in the control unit the load indicated on the dynamometer.

Each dynamometer had two needles, an indicator needle giving the actual load carried by the dynamometer, and a load selecting needle coupled by desynns to the load selector needle in the control unit.

The method of operation was as follows:- the slide bar carriage in the control unit would be raised to indicate a convenient small load - say 10% of ultimate load, on the specimen as a whole. The strut on each slide bar would next be adjusted and locked so that the lever, rack and quadrant moved the load selection needle of the control unit to the 10% load appropriate to its dynamometer-straining unit. By means of the desynn coupling between the control unit and the dynamometers, the above setting of the control selector needles would produce automatically a similar setting of the selector needles in the various dynamometers. The latter were so designed that any difference between the position of the load selector and load indicator needles caused the straining unit motor to function in the direction tending to reduce such a difference. A green light glowed in the control unit when the motor was running in the loading direction, a light changing to red if the selected load was exceeded and the motor switched to the unloading direction.

As previously mentioned, the actual load on each dynamometer was repeated by desynns to the control unit so that the operator could observe the complete set of indicator needles rising towards the positions of the selector needles. It was noted that as the overall indicated load approached the selected load, there was a good deal of alternate flashing of the green and red lights. The method of control and the interaction of the dynamometer-straining units through the specimen, and test frame was evidently causing 'hunting'.

Above the 10% selected load, successive increments could be applied merely by raising the carriage in the control unit on its motor driven jacks. No further adjustment of the slide bar struts was necessary.

9.0. Measurement of Deflection.

The deflection instruments for the wing test were not completely assembled at the time of the visit but the scheme was explained. Deflections were to be measured at four or five sections along each half span by means of scales suspended below the front and rear webs of the box spar. The scales were to be observed by means of a single telescope mounted on a special steel outrigger platform below the centre line of the airframe. This outrigger was attached to the fuselage frames below the wing. One observer was required for the telescope with an assistant who directed the beam of an adjacent flood lamp on to the scale under observation.

This method gives direct readings of the wing deflection relative to the airframe centre line, since the telescope rises, rolls and pitches with the specimen as a whole. Great care must be taken, however, in the attachment of the telescope platform to the specimen to avoid shift of the datum during test due to local distortions of the airframe structure. The telescope and flood-light operators risk injury if the specimen breaks while they are at their station below the centre section.

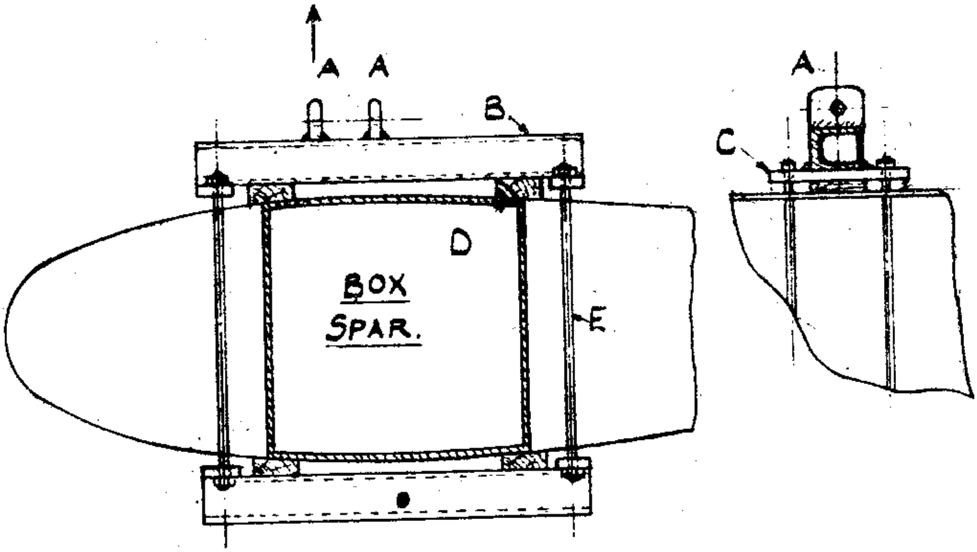
An autographic load-deflection recorder is shown in the diagram Fig.13 (bottom right). In this instrument the drum is evidently rotated by deflection of the specimen while the stylus is moved axially along the drum by a desynn coupling to the load indicating carriage in the control unit. The autographic measurement of deflections seems to have been still in the scheme stage since it was not in use on the test. No further information was obtained on this point.

10.0. Measurement of Strains.

No strain gauges of any sort had been fitted to the test specimen at the time of the visit. From conversations with the French officers in charge and with the Dornier staff it seems that Dorniers relied on mechanical gauges of the Huggenburger type and that they had no electrical strain gauges.

11. 0. Conclusions.

Since the M.A.P. party was due to leave the Friedrichshafen area before the date of the airframe test, the French authorities were requested to send a copy of the test report, when available, to the Royal Aircraft Establishment, Farnborough.



SPAR LOADING ATTACHMENTS.

D.O. 335.

A: STEEL LUGS WELDED TO MAIN ATTACHMENT.
B. STEEL BOX BEAM MADE FROM CHANNEL & PLATE.
C. STEEL CLAMP PLATE WELDED TO MAIN ATTACHMENT.
D. WOOD PACKING STRIP (THICKER THAN C).
E. CLAMPING BOLTS.

FIG. 1.

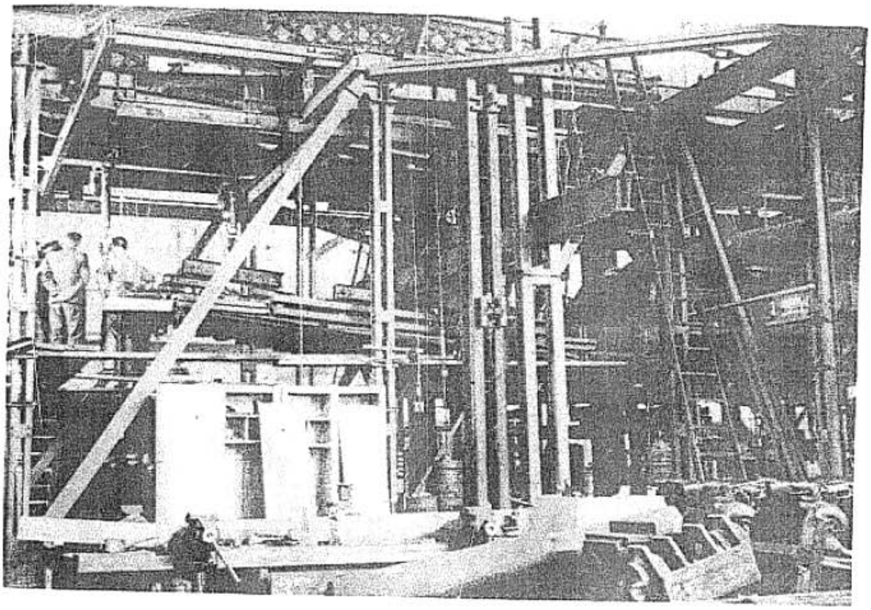


FIG 2.

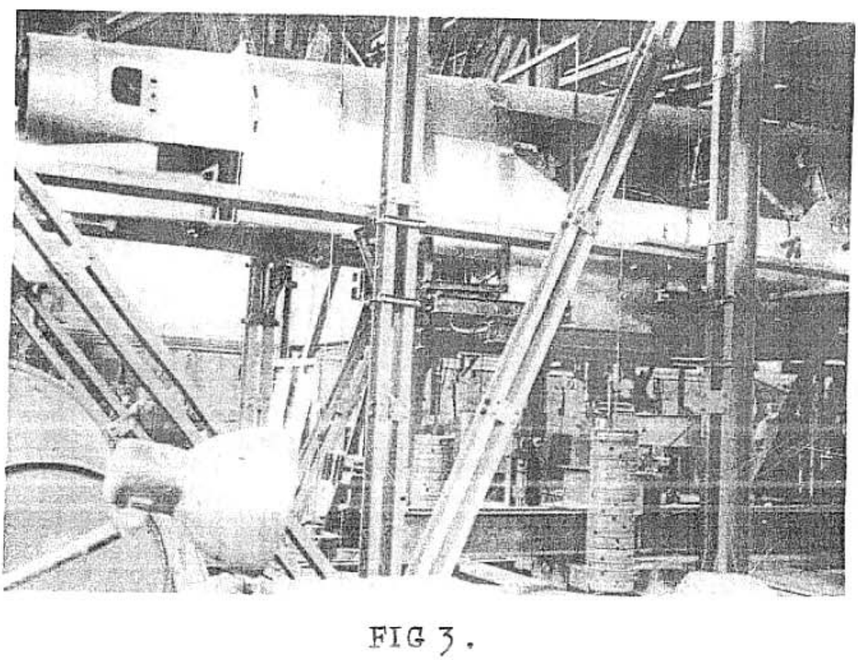


FIG 3.

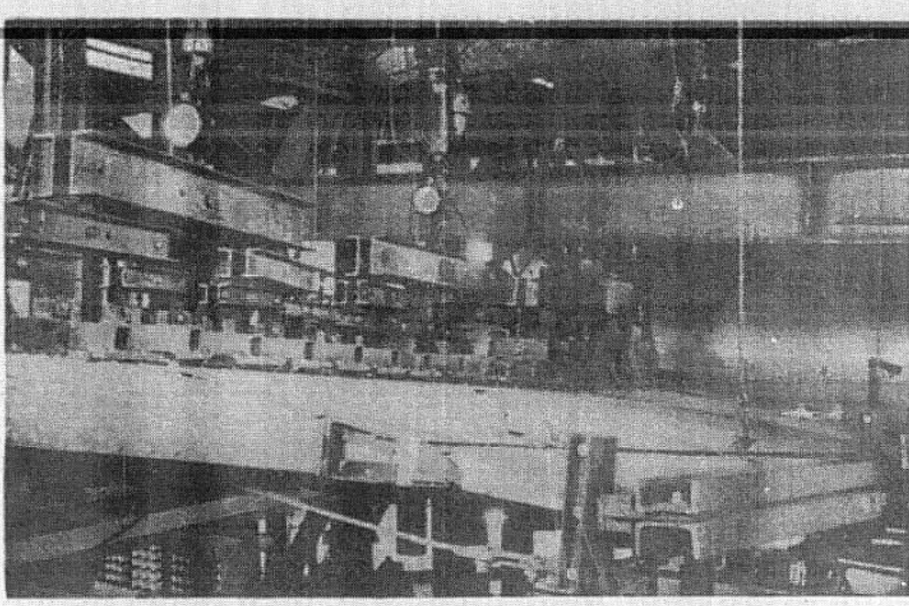


FIG 4.

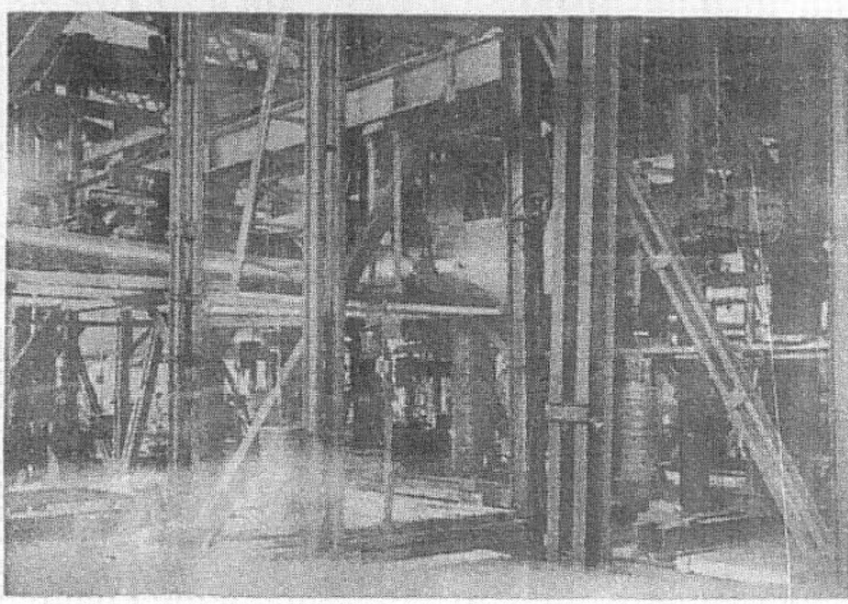


FIG 5.

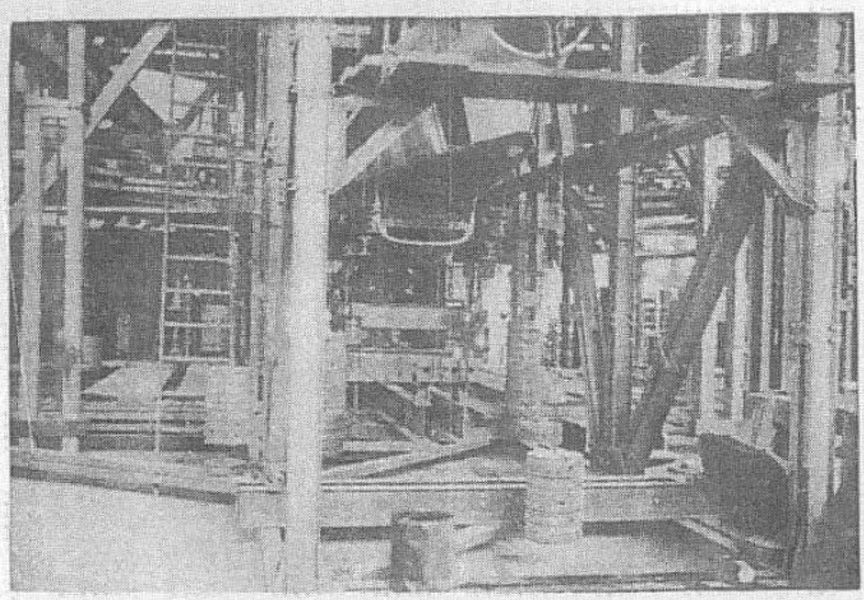


FIG 6.

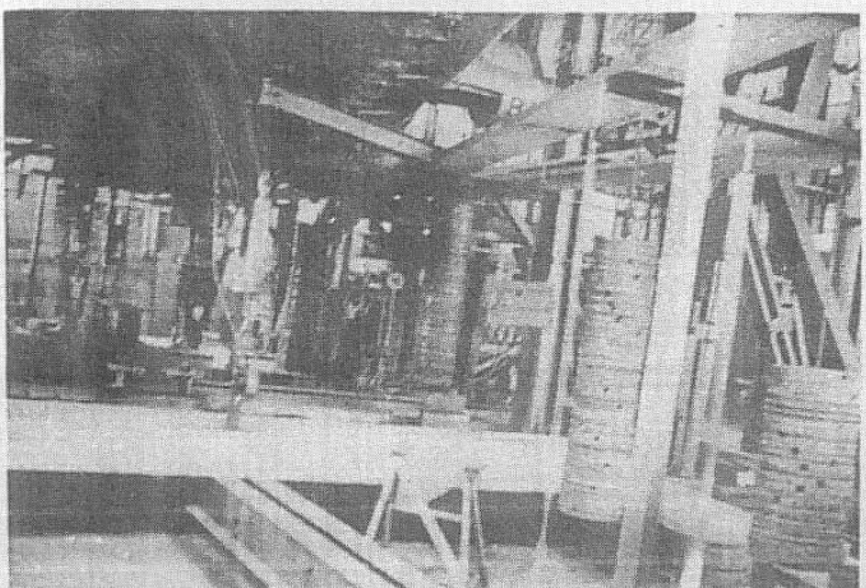


FIG 7.

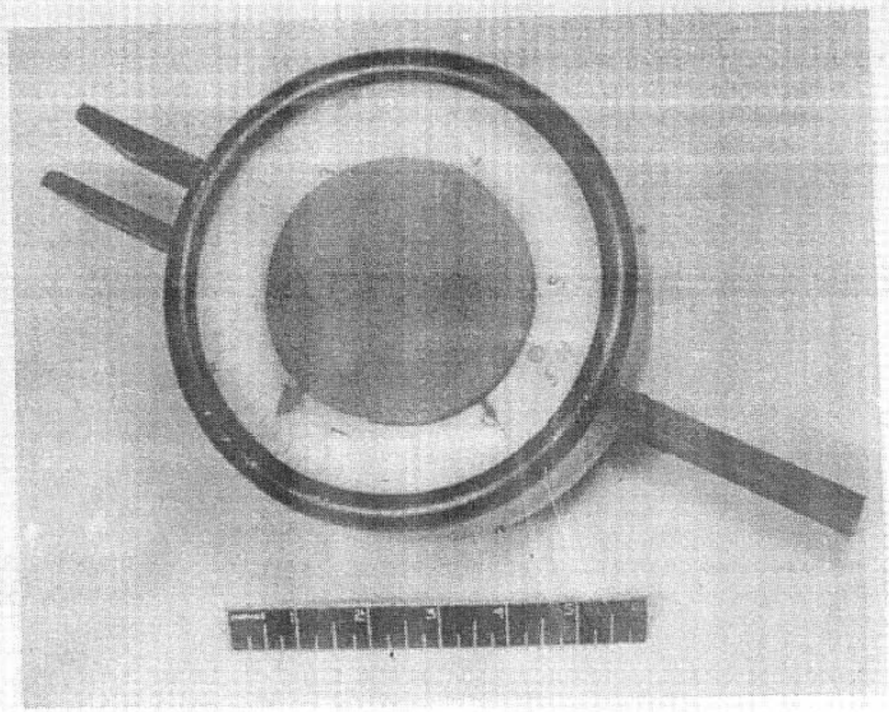


FIG 8.

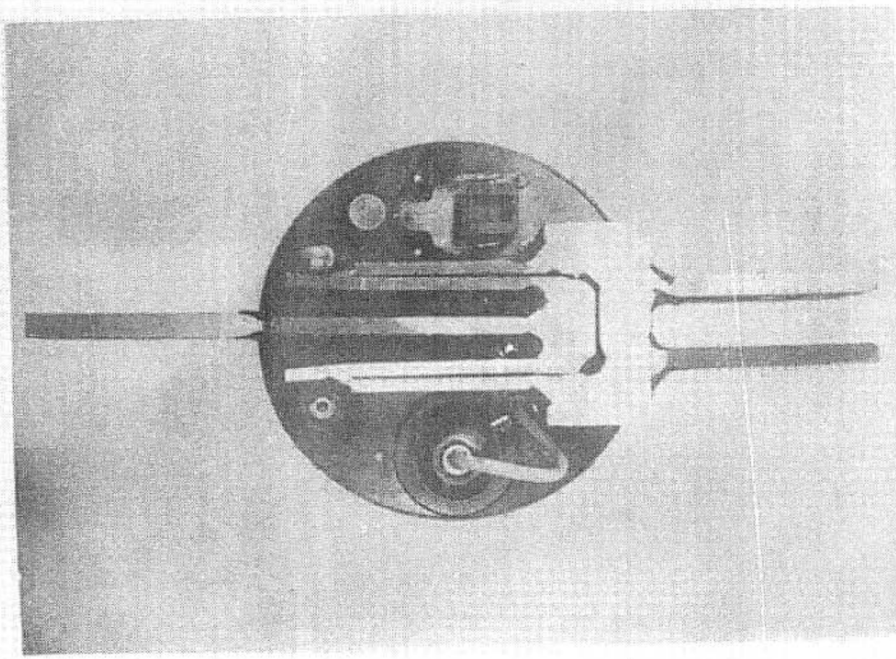


FIG 9.

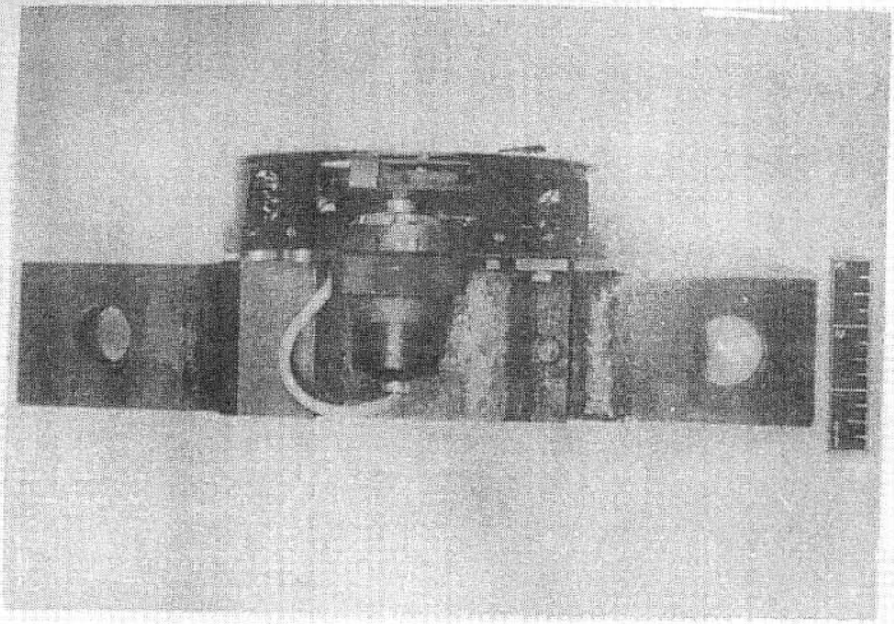


FIG 10.

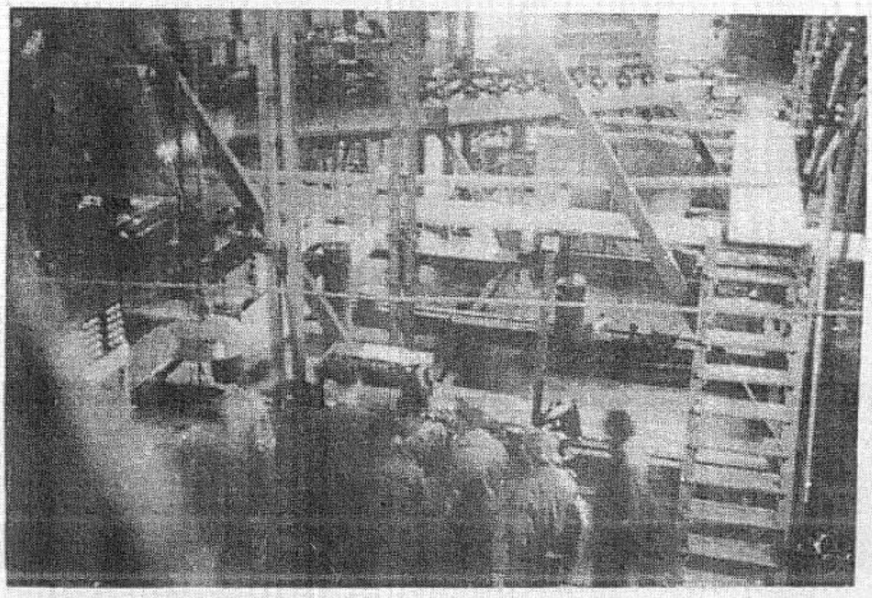


FIG 11.

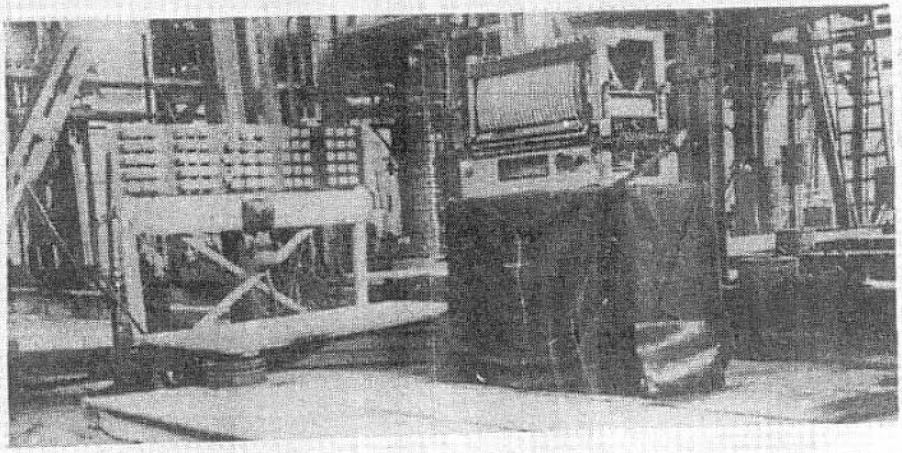


FIG 12.

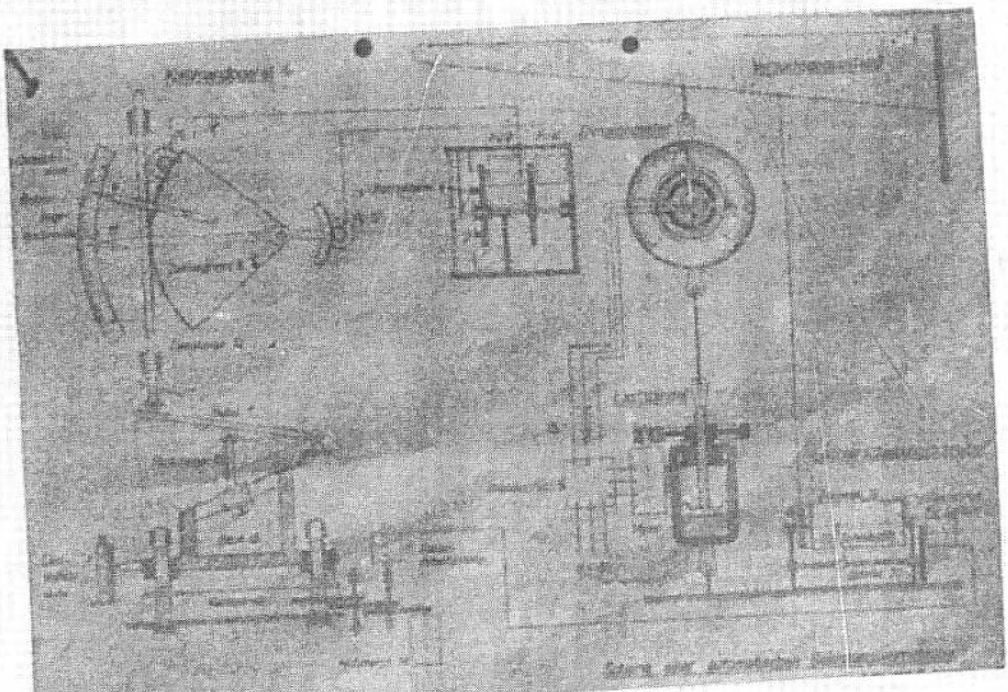


FIG 13.