C.P. No. 336
(18,730)
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Brief Description of the R.A.E. Intermittent Supersonic Wind Tunnel Plant

By

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LONDON: HER MAJESTY'S STATIONERY OFFICE

1957

PRICE 2s 6d NET

C.P. No. 336

U.D.C. No. 533.6.071.1/.2: 533.6.011.5

Technical Note No. Aero 2459

June, 1956

ROYAL AIRCRAFT ESTABLISHMENT

Brief description of the Royal Aircraft Establishment Intermittent Supersonic Wind Tunnel Plant

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K. G. Winter

SUMMARY

The plant is vacuum-operated on a closed circuit with storage of the air in a flexible container. The useful Mach number range is up to about 4.5. For the largest of the tunnels (15 in. × 16 in.) the maximum running time is of the order of 20 seconds over the whole Mach number range. Runs of 10 to 15 seconds duration can be made every five minutes.

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1 Introduction

The R.A.E. intermittent Supersonic Wind Tunnel Plant was designed in conjunction with the 7000 H.P. continuous tunnel described by Knowler[1]. The plant is vacuum-operated ('suckdown') on a closed circuit with storage of the air in a flexible container. The pressure ratio available is sufficient for running up to Mach numbers where heating of the air is necessary (say M = 5). An external view of the complete plant is shown in Fig 1 and a perspective cut-away drawing in Fig 2.

The plant was arranged to have four tunnel lines. Two lines are occupied by small pilot tunnels of 4 in. × 4 in. and 7 in. × 4 in. working sections intended primarily for tunnel development work. Of the other two lines, one is occupied by a 9 in. × 9 in. tunnel and one was arranged to accommodate either of the working sections (18 in. × 18 in. and 28 in. × 16 in.) of the continuous tunnel. The 15 in. × 16 in. tunnel is now fitted in this last line. The resources of the plant are currently being increased by the addition of a 7 in. × 7 in. Hypersonic tunnel. A description of this facility is beyond the scope of this note. In addition to the tunnel lines there is a further pipe from the flexible container to the vacuum vessels used for returning air when the plant is closed down. The plant came into operation during 1950.

2 Vacuum system

The vacuum storage is provided by two welded steel vessels of total capacity 35,000 cu.ft (Fig 3). Three of the tunnels run into one vessel and the fourth into the other; by manipulation of valves and blanking plates it is possible to utilise either tank independently.

The tanks are evacuated by reciprocating double-acting twin-cylinder Pearn pumps (Fig 4). The two cylinders can be used in stage or in parallel, the latter alternative being adopted. There are twenty one pumps each driven by an electric motor of nominally 15 H.P.* In practice twenty pumps only are used, maintenance always being carried out on one. By doing this the pumps are always kept in good condition. The performance of the pumps is shown in Fig 5.

From the pumps the air is fed through an oil separator either directly, or through a small 'charging' drier, to the balloon. The oil separator is necessary to avoid contamination of the silica gel in the drying plant. It is simply a partitioned box, in which trays of 'activated charcoal' are inserted with a final stage of felt filters.

3 Dry air container ('Balloon')

The dry air container can be likened to a pie-dish with a crust on top. The pie dish is formed by a brick wall some seven feet high with two straight parallel sides joined by semi-circular ends and resting on a concrete base. The interior of the wall is cement-faced and covered with a bitumastic coating (Fig 6). The crust is the upper half of the balloon fabric container (Fig 7) which forms a complete envelope lining the pie dish. It is attached to the top of the wall by clamps and adhesive. The total capacity is about 40,000 cu.ft.

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* Use of these particular pumps in this quantity was dictated solely by their availability. If pump room size were of fundamental importance, a fewer number of pumps of greater capacity could clearly have been used.

The shape of the balloon was chosen to fit inside a 'Romney' prefabricated steel building which is supported at the level of the top of the brick wall on two rows of 'flying buttresses'. Louvres in the roof of the building permit egress and ingress of air as the balloon is inflated and deflated.*

The pipe line from the pumps comes in at one end of the container and the connections to the four tunnels are made in one of the straight walls. Along this wall (see Fig 6) a wooden framework is fitted to avoid the possibility of the fabric being sucked over the entrance to a tunnel. The height of the balloon is indicated in the tunnel room by a weight suspended from a wire passing over pulleys to a bridle attached to the fabric.

Two pairs of relief valves form a further safety precaution for the fabric. These consist of square flanged plates standing in troughs of mercury round the perimeter of square apertures. The pressure relief valves blow at $\frac{1}{4}$ in. of water excess pressure and the suction valves at $\frac{1}{2}$ in. of water depression.

4 Drying Plant (Fig 8)

There are two silica gel beds. A small bed containing $\frac{1}{4}$ ton of gel is used to dry the initial charge from the vacuum vessels to the balloon. Thereafter air from the balloon is circulated at a rate of 2500 c.f.m. through a large bed containing 3 tons of gel. This bed removes any water vapour which permeates through the balloon fabric. The original specification was that the air should be maintained at a absolute humidity of 0.0005 with an allowable permeation of moisture through the fabric of 0.08 lb/min. Rough experiments have shown the latter figure to be excessive. Humidities of about 0.0002 are in fact maintained.

The plant was designed to operate on a 24 hour cycle of 8 hours running and 16 hours activating and cooling of the silica beds. In fact several days running can be tolerated before re-activation is necessary.

5 Arrangement of Tunnels

5.1 Valves

Each of the four tunnel lines is fitted with a flap valve upstream of the working section, to retain the air in the balloon when the working section is open, and a quick-acting valve downstream of the working section. The opening time of the quick-acting valves is 1 to 2 seconds. Two types of valves are used, both of which have proved satisfactory. One type is operated hydraulically, a jack replacing the screw of a screw-down circular gate valve. Two of these valves of 12 in. and 20 in. diameter are used.

The other type of which again there are two, 18 in. circular and 27 in. square, is of more elaborate design. A sketch of the 27 in. valve used in the 15 in. × 16 in. tunnel is shown in Fig 9. A rectangular steel plate with a brass seat provides the seal. The plate is operated by pneumatic jacks. In the edges of the plate are fitted rollers which run on tracks. In the closed position the rollers are clear of the tracks. When the valve is operated, airbags, located behind the tracks, are inflated, lifting the valve plate off its seat, so that during its movement it runs on the rollers and avoids scuffing the seat.

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* No particular virtues are claimed for this balloon arrangement compared to gasometer-like arrangements. When the building work housing the balloon is taken into account, the costs are probably about the same.

5.2 15 in. x 16 in. working section

Of the working sections the 15 in. × 16 in. (Fig 10) is the only one warranting description. It is of extremely simple construction, consisting of top and bottom channels to which glass sides are clamped. The height of 15 in. was chosen as giving adequate safety factor on the $1\frac{1}{2}$ in. glass immediately available, and the width 16 in. to enable use to be made of the existing contraction and diffuser of the 28 in. × 16 in. tunnel, by lining only two sides.

The nozzle blocks in the working section are of the fixed interchangeable type. Existing blocks for Mach numbers up to 2.5 are of teak, but subsequent pairs up to M = 4.5 are being manufactured as iron castings coated with araldite.

The model is supported on a quadrant* with an incidence range of $\pm 22\frac{1}{2}^{\circ}$, carried in a section separate from the working section. The quadrant is moved by a hydraulic jack, the travel of which is controlled by adjustable stops. The tunnel is not at present fitted with a variable supersonic diffuser. One is being designed together with a new model-support section.

6 Running times

The running time of a vacuum operated intermittent tunnel is given by (see for example Lucasiewicz^2)

$$t = \frac{V}{\mu v} \frac{\Delta p}{p_a}$$

where V is the volume of the tanks

v the tunnel volume flow at atmospheric density

μ an empirical factor which is equal to the adiabatic index in the absence of heat transfer.

p_a atmospheric pressure

Δp pressure rise in tanks during run.

Values of μ have been measured for the 15 in. × 16 in. tunnel at Mach numbers of 2.0, 2.25 and 2.5. The values depend upon running time and are given for maximum runs with pumps running in Fig 11 together with an assumed variation over the whole Mach number range. Using these values of μ and the values of breakdown pressure ratio of Fig 12, again measured up to M = 2.5, calculated values of maximum running time for various initial pressures are given in Fig 13. The running times at the higher Mach numbers would of course be increased appreciably by the use of a variable diffuser.

In Fig 14 the time required for pumping for runs down to breakdown at M = 2.5 is plotted against running time. The curves show that it is not economonical to use runs of more than 20 seconds duration (vacuum vessel pressure at start of run 3 in Hg) and in fact runs of about 15 seconds are usual.

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* The quadrant shown in Fig 10 is in fact the 'half quadrant' and has an incidence range of only ±12°.

REFERENCES

No.	Author	Title, Etc.
1	A. E. Knowler	The No.19 Wind Tunnel at Farnborough Aircraft Engineering. June 1955.
2	J. Lucasiewicz	Development of Large Intermittent Wind Tunnels Journal of the Royal Aeronautical Society April 1955.

W.T.2078.CP.336.K3 - Printed in Great Britain.

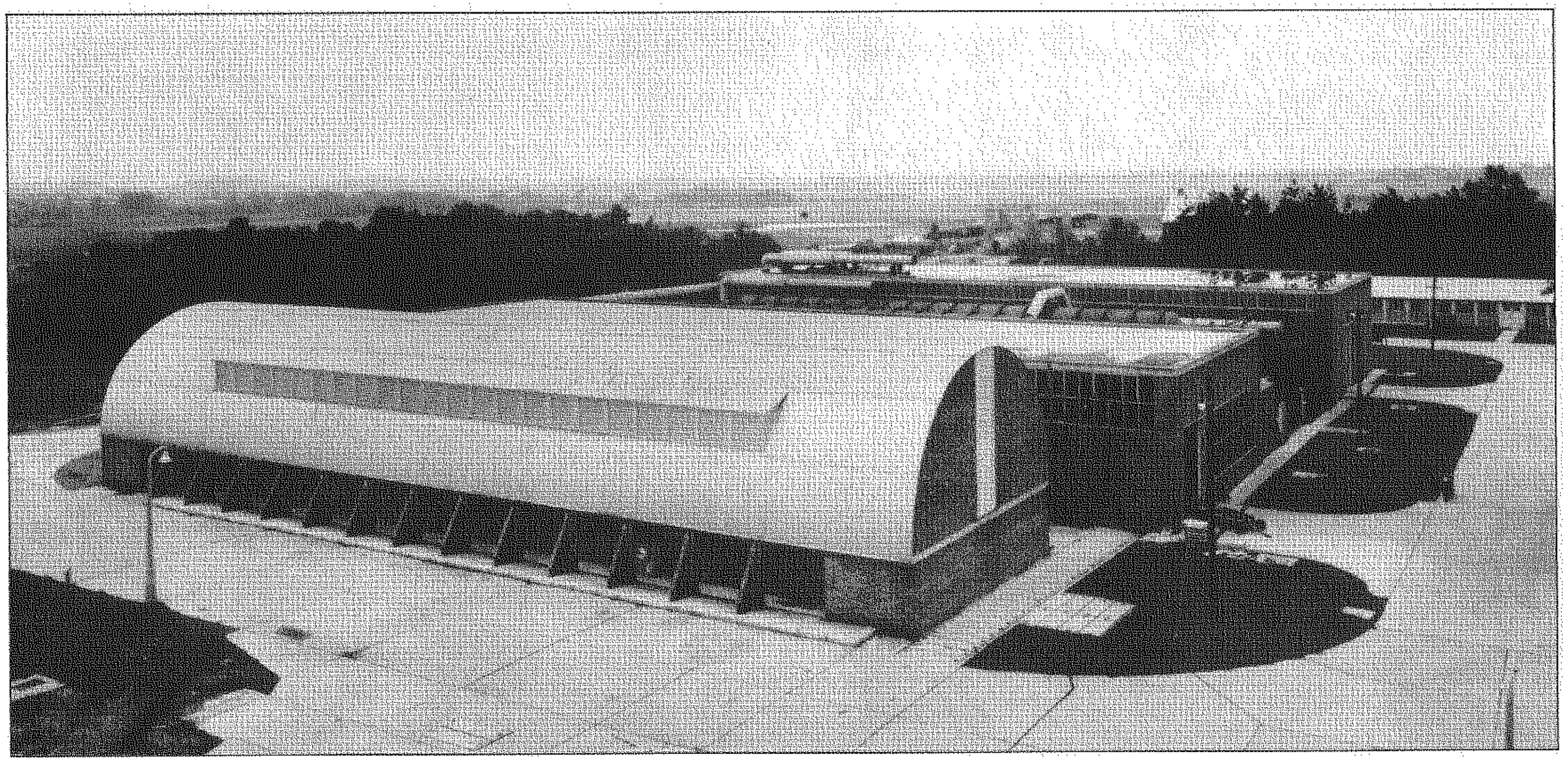
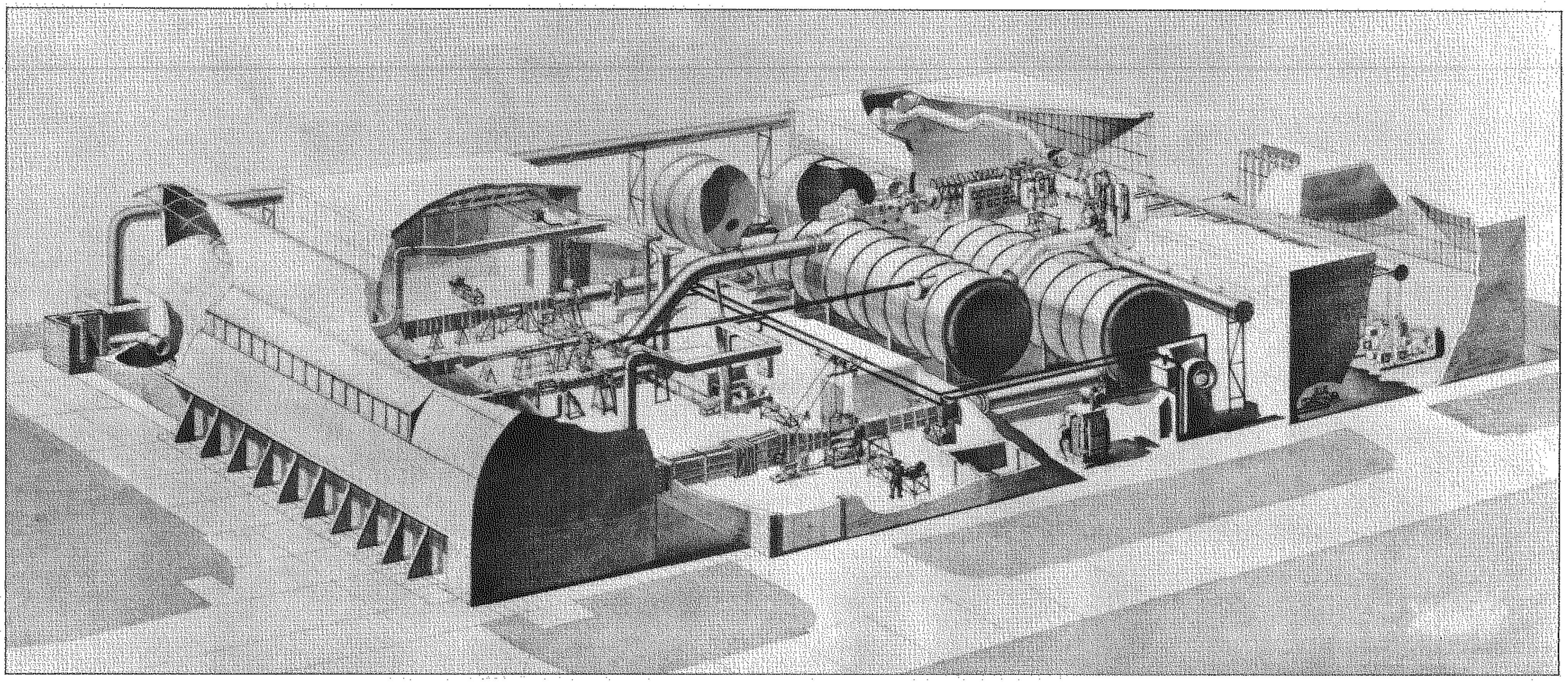


FIG.1. EXTERNAL VIEW OF PLANT

THE R·A·E INTERMITTENT SUPERSONIC AND HYPERSONIC TUNNEL PLANT



SUPERSONIC TUNNELS MACH NUMBER RANGE UP TO 4·5

WORKING SECTION SIZES
9 INS X 9 INS
4 INS X 4 INS
7 INS X 4 INS
15 INS X 16 INS

HYPERSONIC TUNNEL MACH NUMBER RANGE 5·0-9·0

STORAGE CAPACITY 270 CU: FT AT 200 ATM
STAGNATION PRESSURE — 50 ATM
MAXIMUM STAGNATION TEMPERATURE — 680°C
WORKING SECTION – SIZE — 7 INS X 7 INS
TWO COMPRESSORS EACH 100 H.P.

VACUUM VESSEL CAPACITY — 30,000 CU: FT
VACUUM PUMPS — 21 EACH 15 H.P.

FIG.2.

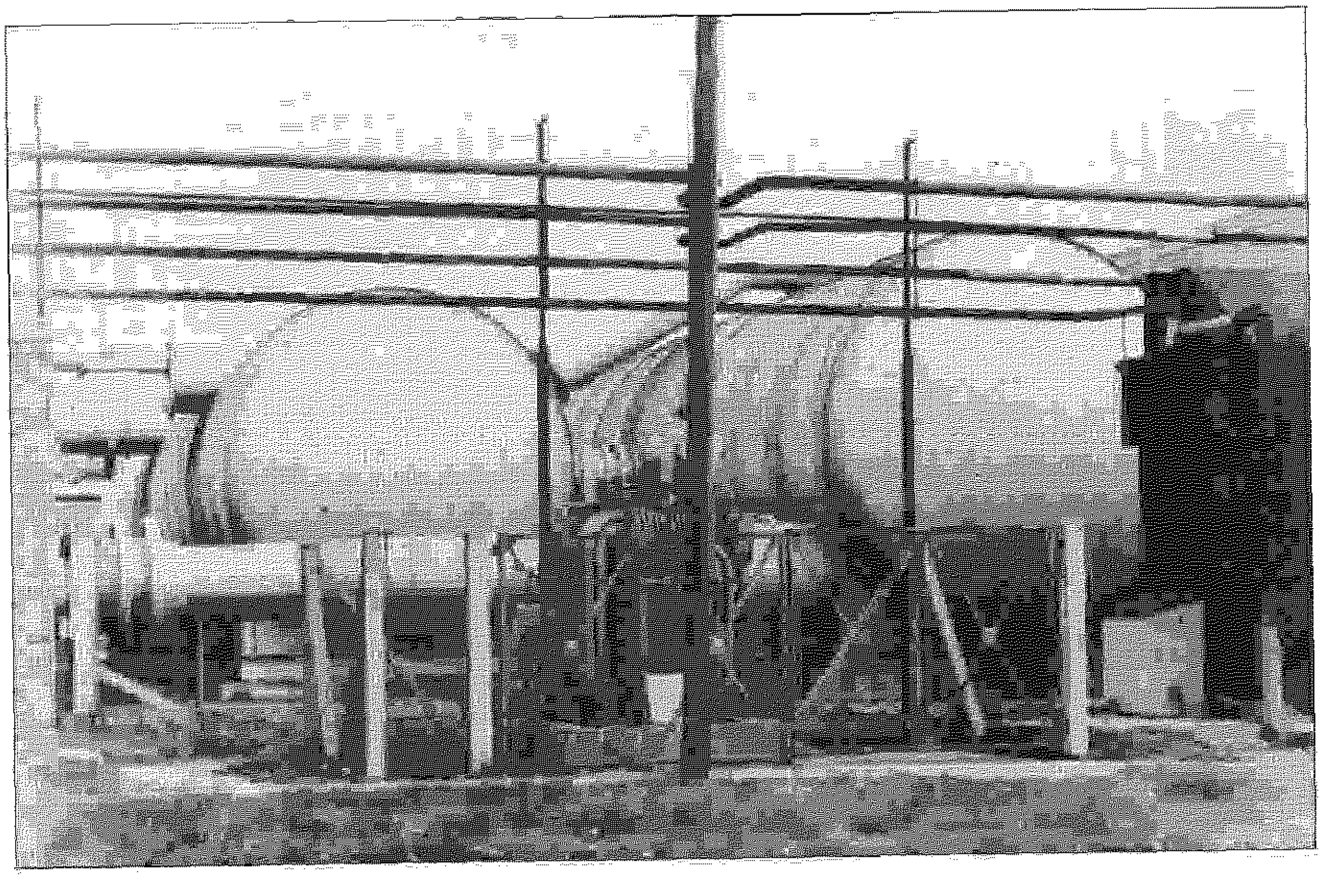


FIG.3. VACUUM VESSELS

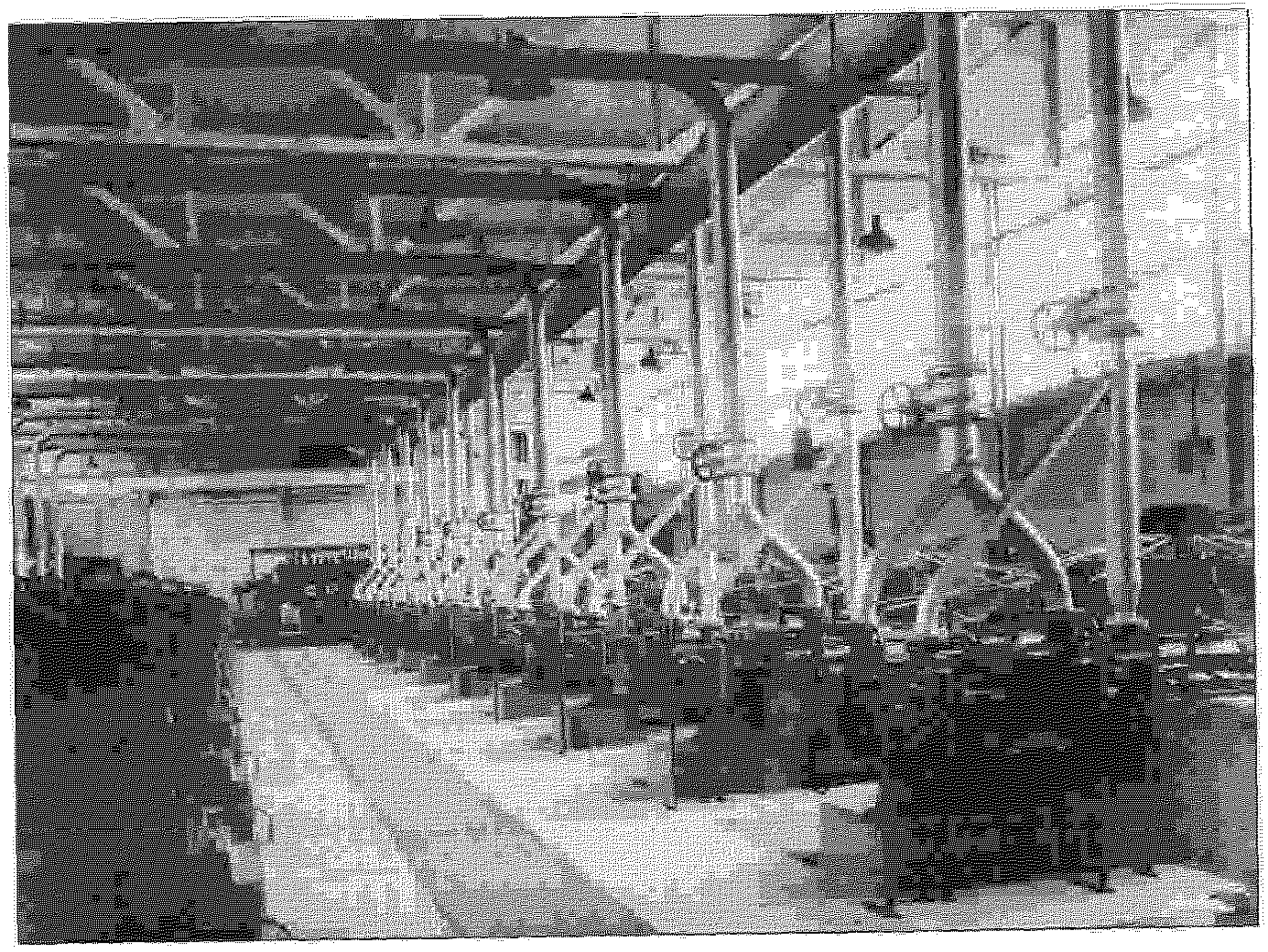


FIG.4. VACUUM PUMPS

FIG.3 & 4

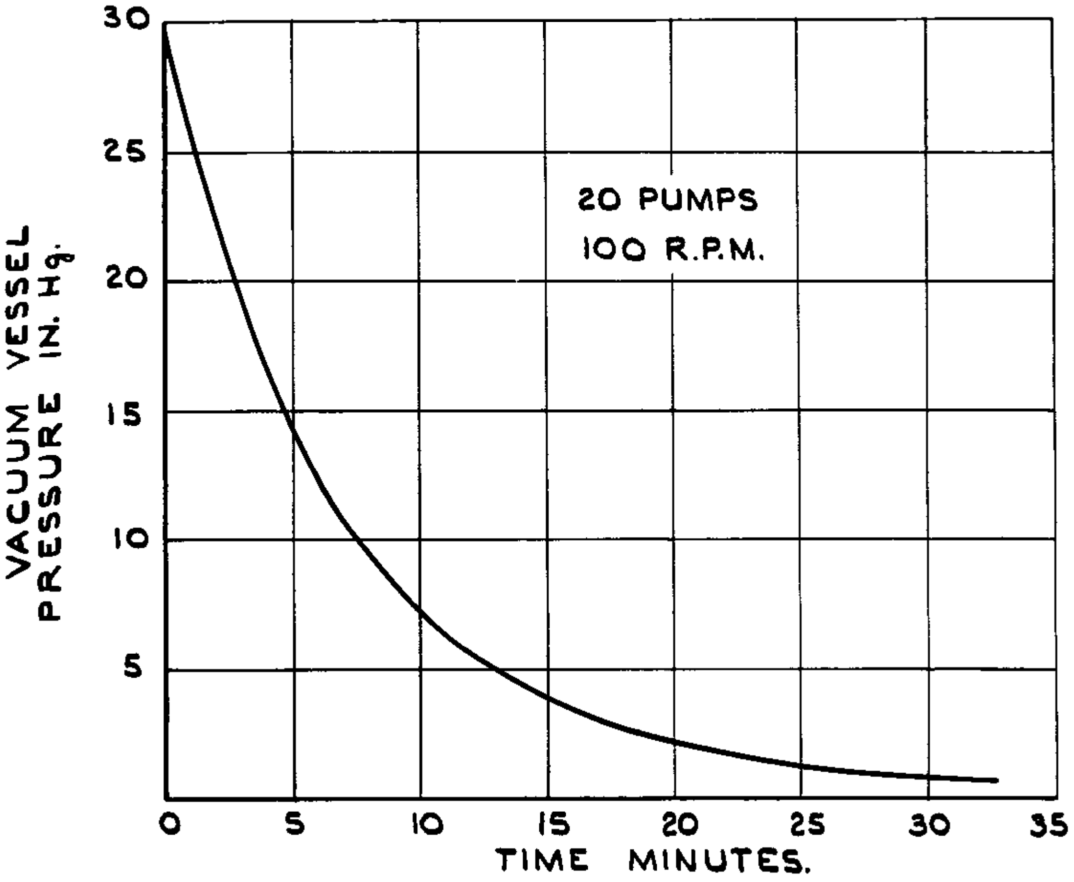


FIG. 5. PUMP PERFORMANCE.

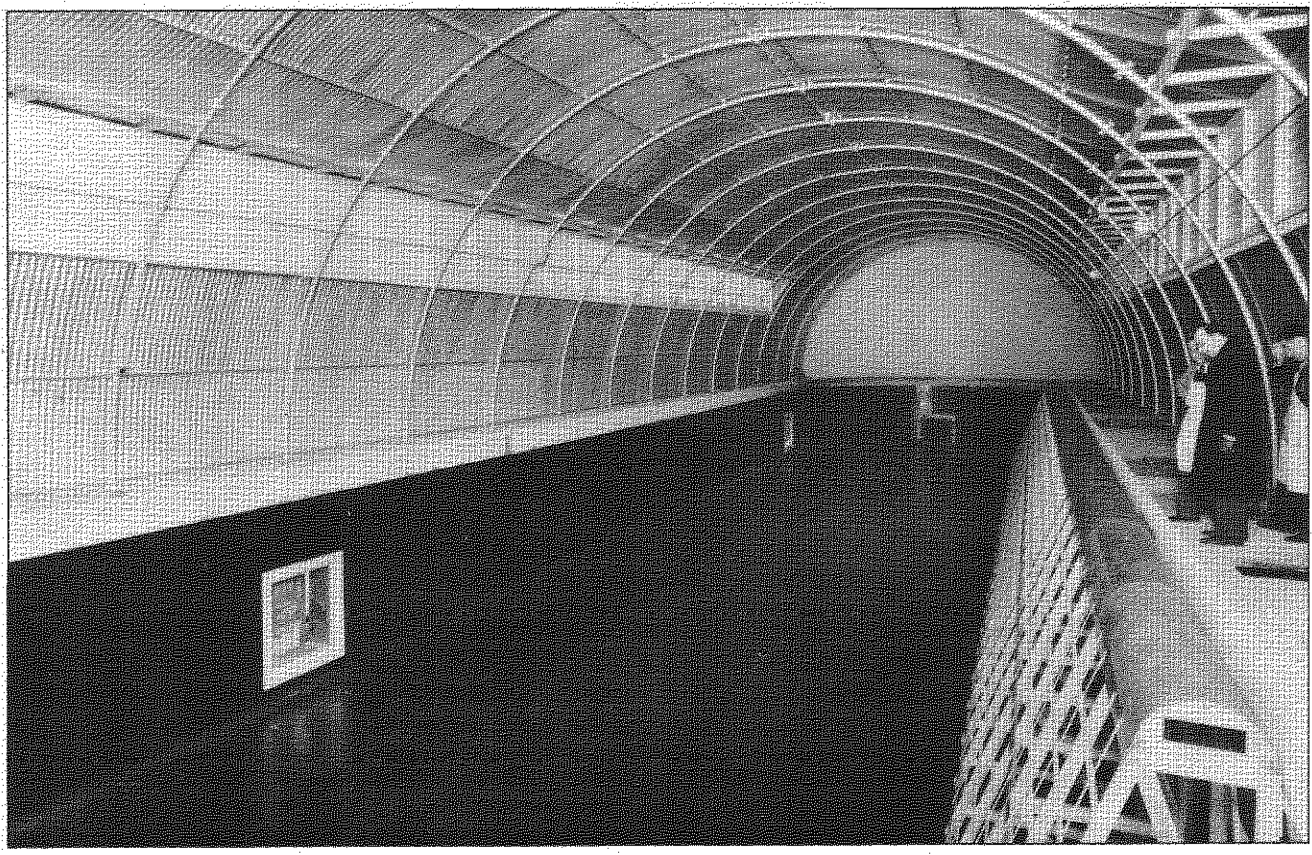


FIG.6. INTERIOR OF BALLOON HOUSING BEFORE FITTING OF FABRIC

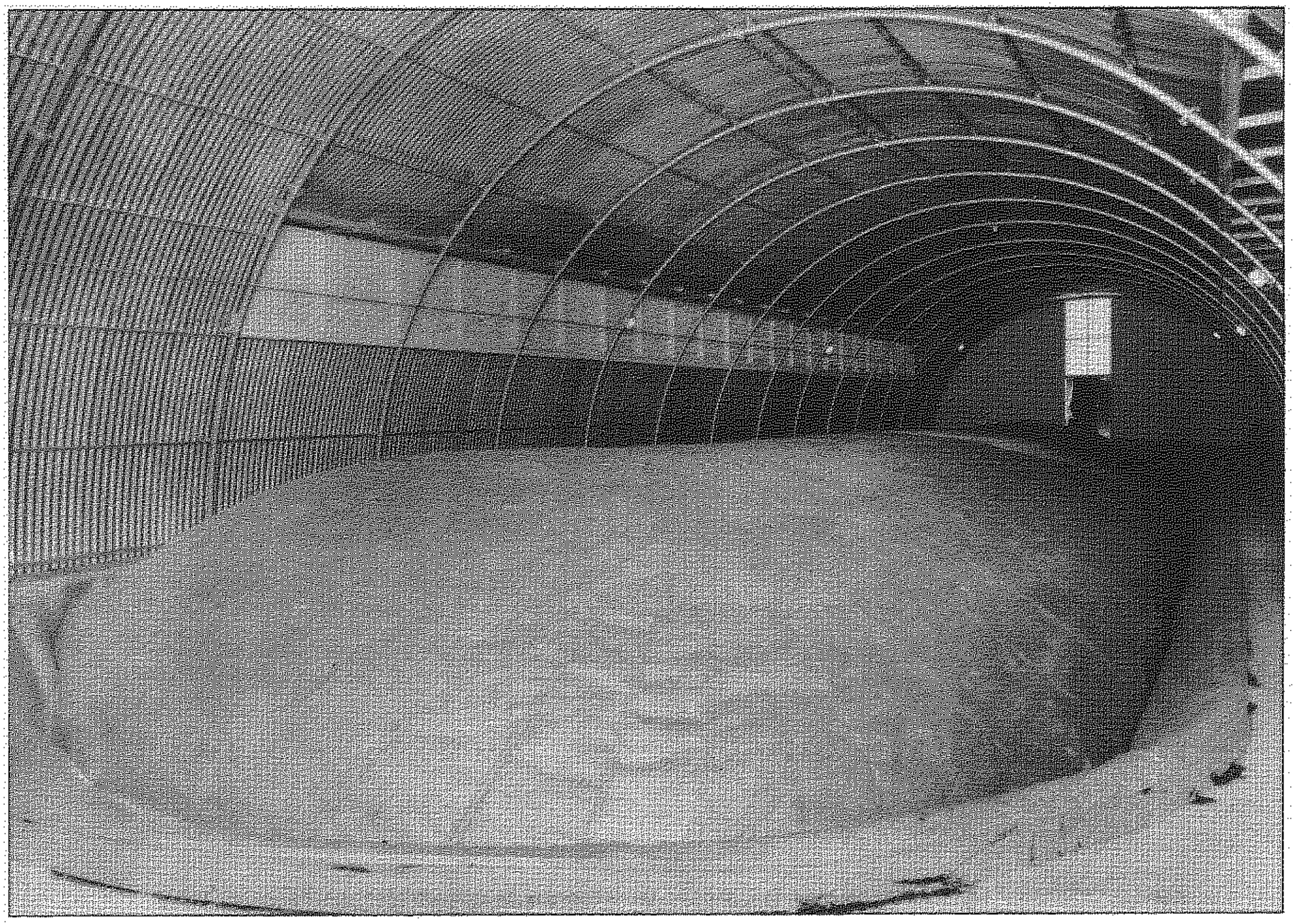


FIG.7. INTERIOR OF HOUSING SHOWING BALLOON

FIG.6 & 7

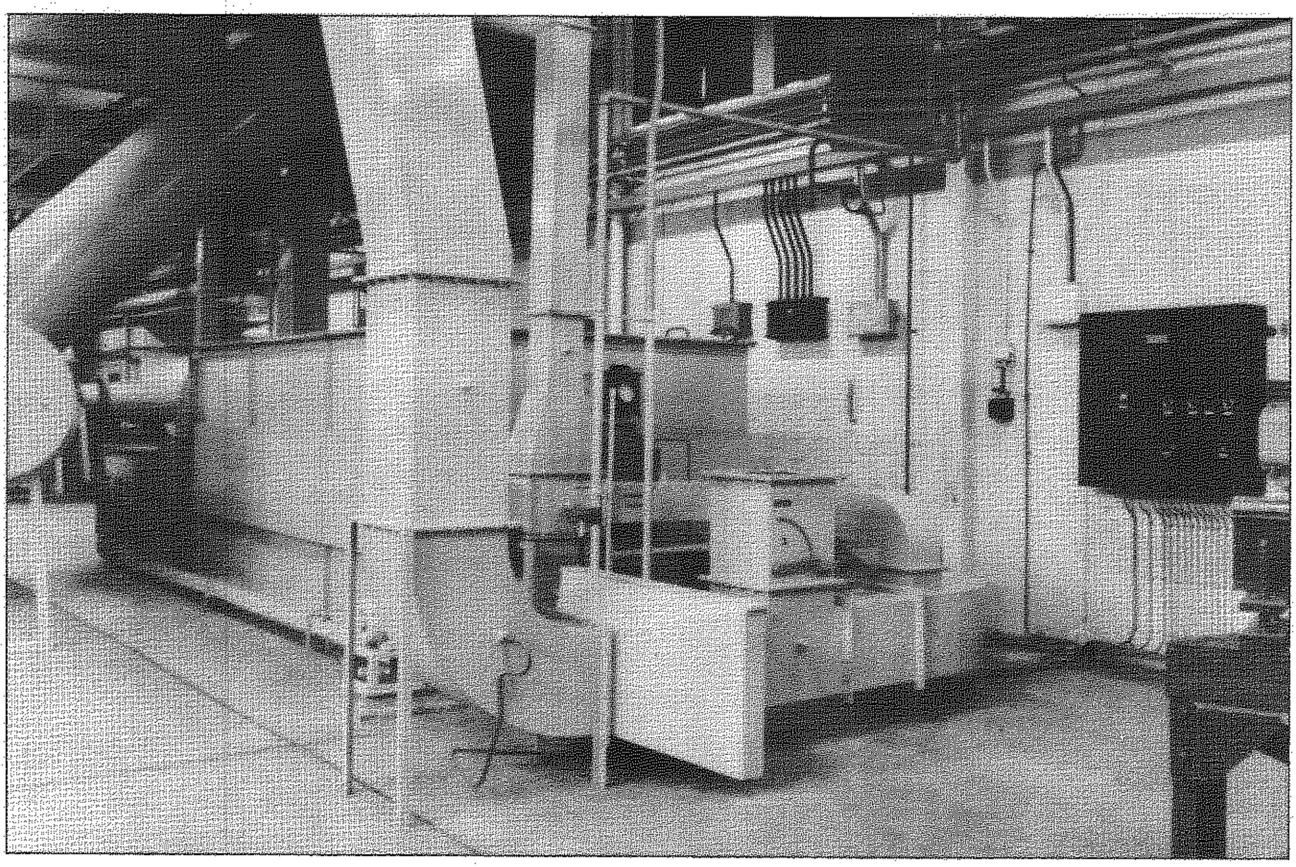


FIG.8. DRYING PLANT

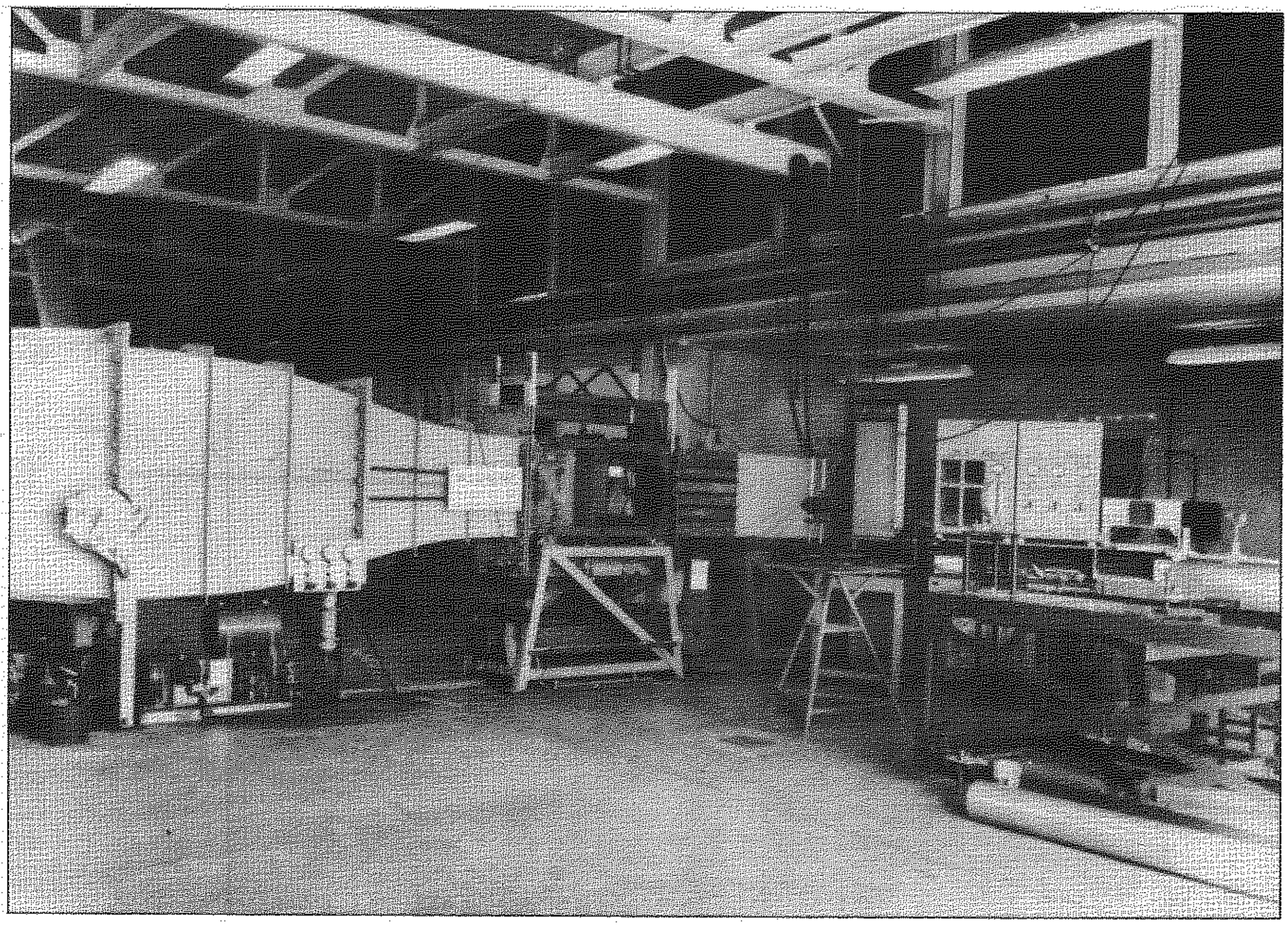


FIG.10. 15 inch x 16 inch WIND TUNNEL

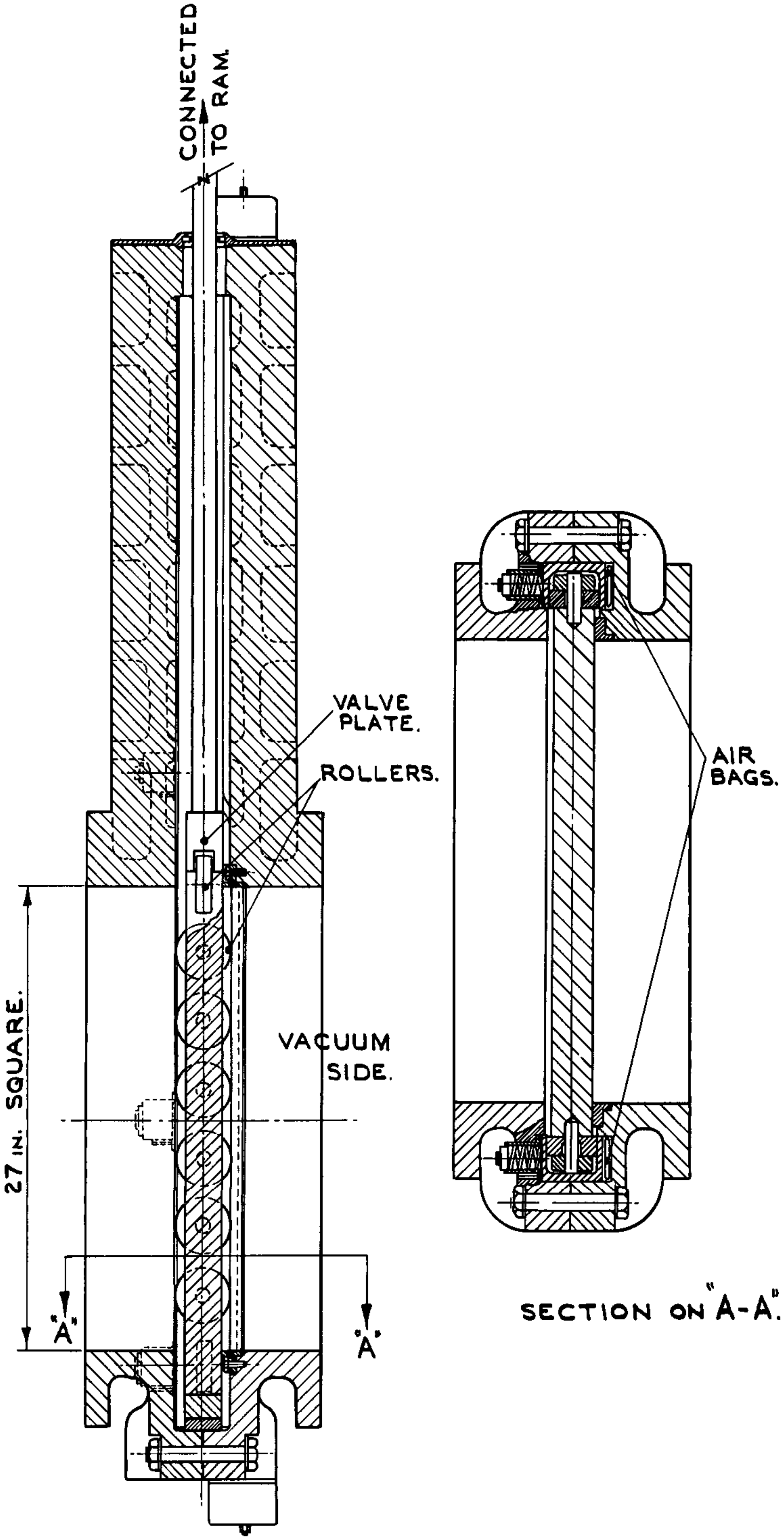


FIG. 9. 27 IN. QUICK ACTING VALVE 15 IN. × 16 IN. TUNNEL.

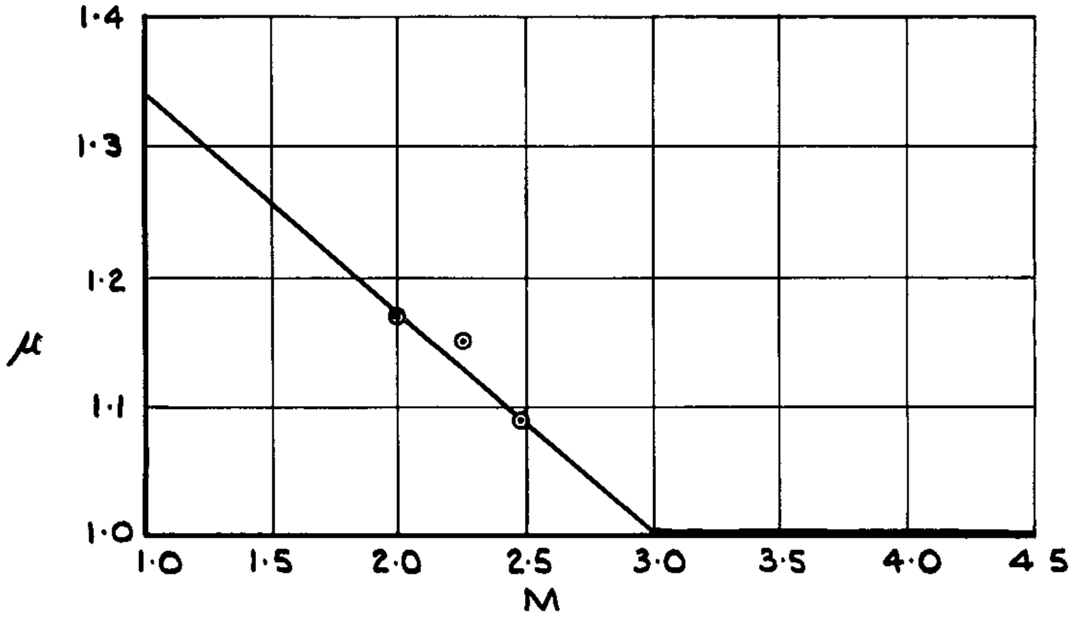


FIG. 11. VALUES OF 'μ' ASSUMED IN EXPRESSION FOR RUNNING TIME.

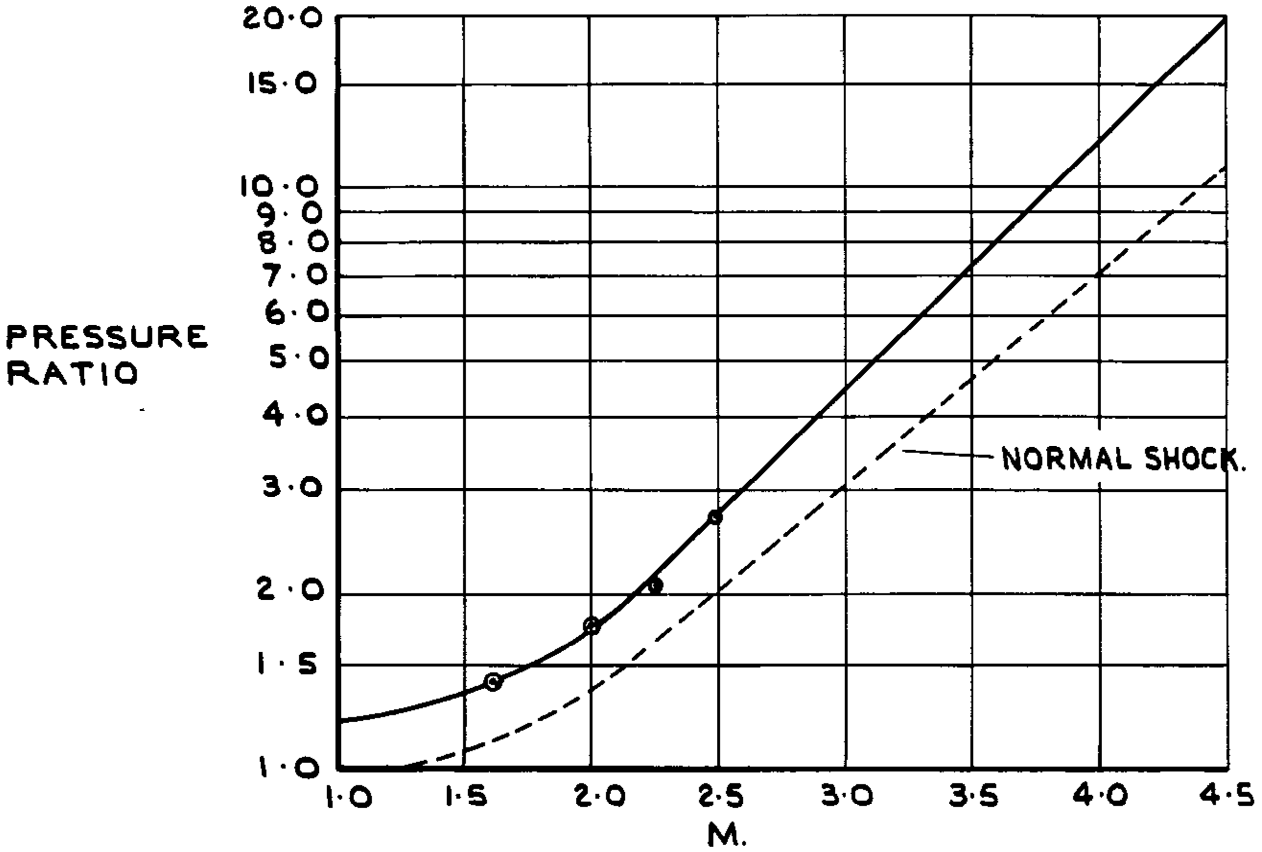


FIG. 12. ASSUMED VALUES OF BREAKDOWN PRESSURE RATIO.

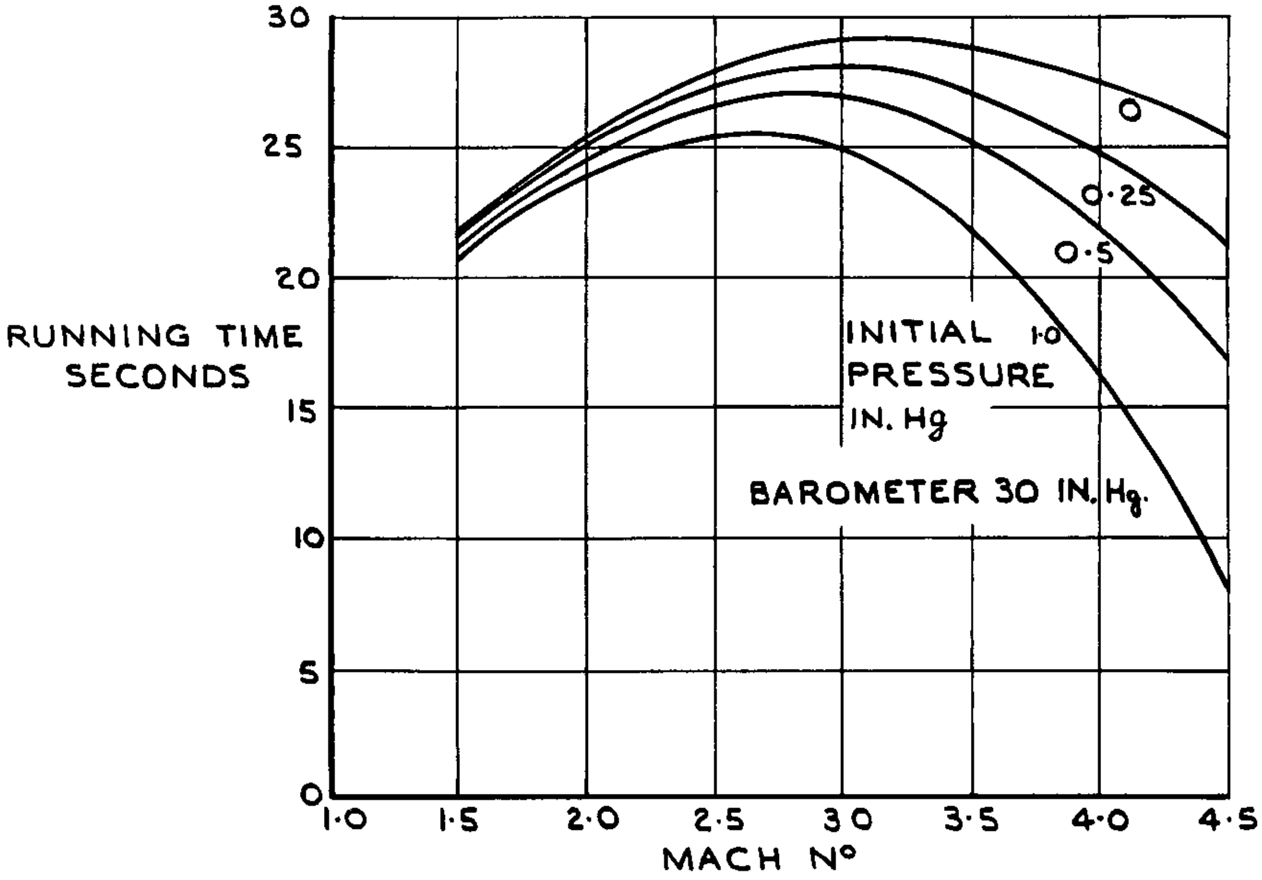


FIG. 13. RUNNING TIME FOR 15IN. × 16IN. TUNNEL.

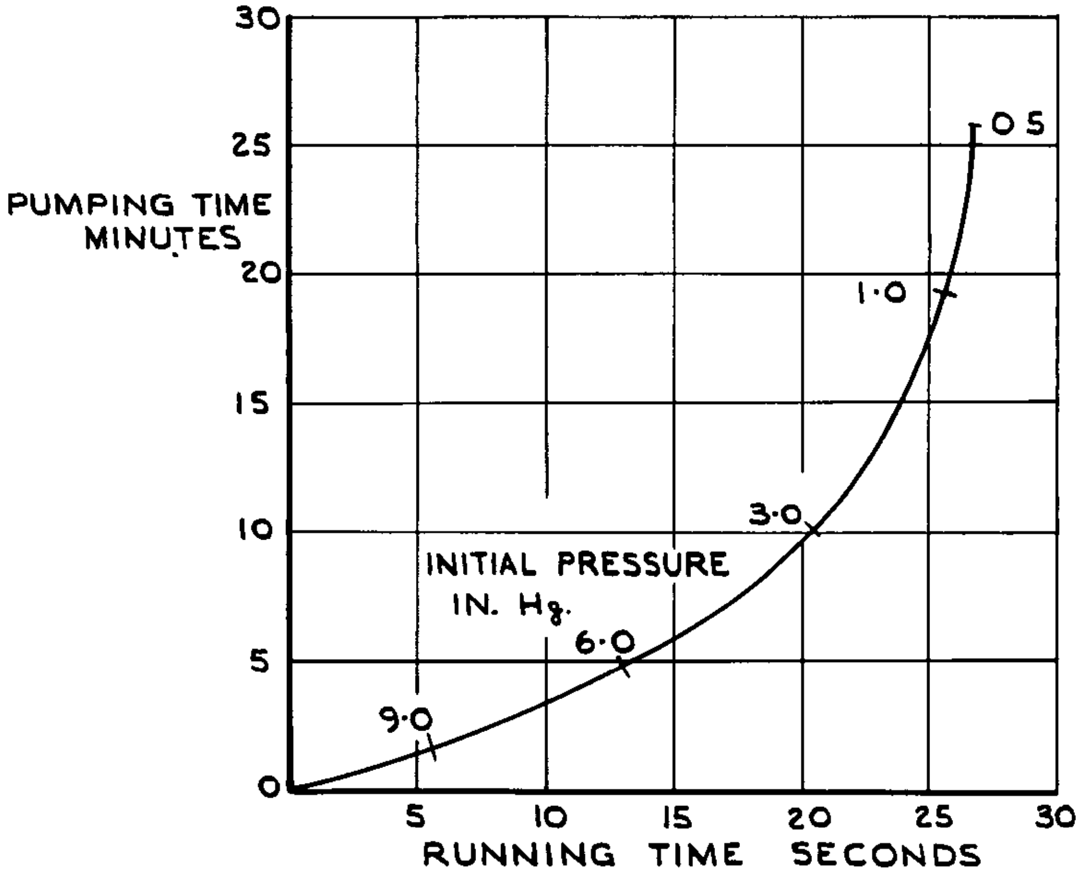


FIG. 14. EFFECT OF DURATION OF RUN ON TIME BETWEEN RUNS - 15IN × 16IN TUNNEL M = 2·5

C.P. No. 336

(18,730)

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PRINTED IN GREAT BRITAIN

S.O. Code No. 23-9010-36

C.P. No. 336