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A NEW STEAM CHANNEL FOR CALIBRATING TRANSONIC PROBES

Résumé

The new large steam tunnel is presented with its performances.

Emphasis is given to the special probe support as it avoids perturbation of the flow in the vicinity of the wall.

1 - INTRODUCTION

This article covers the use of transonic probes for measuring the velocity of wet steam in operational stage steam turbines.

In these stages Mach number of 1.6 may be attained.

ELECTRICITE DE FRANCE has already developed five-hole probes which permit the measurement of Mach numbers up to 0.8. This is enough to measure the flow behind the last moving blades, but for measurement behind the last fixed blades, problems of sonic blockage occur with the introduction of a probe : it was therefore necessary to develop a special transonic probe.

So E.D.F decided few years ago to build a special transonic wet steam channel to design and calibrate the necessary new transonic probes. This transonic wet steam channel (In french : Veine Supersonique Diphasique - V S D) is at GENNEVILLIERS and the first trial is due to begin in one or two weeks.

2 - THE TRANSONIC WET STEAM TURBINE (fig. 1)

The tunnel works in wet steam. Steam is provided by an existing boiler. The steam flows through the injection chamber in which it is cooled by water injection; this also enables the wetness of steam to be varied. There follows a chamber 6 m long to establish thermodynamic equilibrium between the droplets and the the steam, an then a convergent nozzle 1.8 m long followed by the test section. Finally the steam is condensed in an existing condenser. Two valves at the inlet and outlet are used to adjust the pressure and the velocity in the test section. Both the convergent nozzle and the test chamber can easily be changed according to test requirements.

3 - PERFORMANCES (fig.2)

Fluid	: Steam or wet steam
Flow rate	: 1.4 10 4.0 kg/s
Pressure	: 0.2 to 0.4 bar
Temperature	: Saturation to superheated
Wetness	: 10 % to superheated
Mach Range	: - now 1,25 to subsonic Mach numbers - we can theoretically reach 1.6 Mach by replacing the convergent nozzle by convergent-divergent nozzles.

The V S D is operated from a control room and the thermodynamical conditions are obtained by special data acquisition and prediction programs.

4 - THE TEST CHAMBER (fig. 3)

This is 1.2 m long with an operating section 0.2 m wide abd 0.3 m high, which has two horizontal perforated walls. This ventilated nozzle enables a continuously variable Mach number to be obtained. In particular many supersonic Mach numbers are possible. This ventilated nozzle also limits the blockage effect caused by introducing a probe.

The permeable walls are 0.91 m long, and each is inclined with divergence of 30'. The porosity is about 14,1 % (fig. 4). A section of 0.2 x 0.3 has been chosen to limit the sonic blockage when we introduce a 3 mm probe into it. These sizes are representative of the sizes encountered in full-scale turbine in respect of blockage effects.

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The V S D can operate in ventilated configuration, as well as in free-jet configuration (fig.5).

The test chamber is fitted on both sides with metallic windows Ø 130 for free-jet tests and with pyrex windows Ø 300 for visualisations at the 2/3 of the test chamber, in ventilated configuration.

Some holes have been provided for static pressure measurements along the test chamber, as well as some Prandtl tubes on some windows.

The test chamber is designed for visualisation of the bow shock wave in front of transonic probes in order to select the best shape of them, and to calibrate the resultant transonic probes. The transonic probe will be a pressure probe with four or five holes, and to calibrate it a motorized probe support has already been built.

5 - THE PROBE SUPPORT (fig. 6)

The probe support can be mounted in place of a window in free-jet configuration as well as in ventilated configuration. It enables the probe to be rotated in two axes : α and β (pitch and yaw angle). The motorized probe support can be operated from the control room with a remote-control system designed for this purpose.

The way the probe is introduced in the test section with the probe support has been planned to solve problems of transonic perturbation in front of the probe in the vicinity of the wall (fig. 7).

The probe support has in fact been designed so that the two probe rotation axes are situated at its leading edge. As illustration 8 shows, the special shape of the hole prevents perturbation upsteam.

6 - FULL-SCALE TURBINE TESTS

The purpose is measure of velocity, wetness and pressure, in the low-pressure stages of a 600 MW turbine, especially behind the three last rotors as we see in illustration 9.

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7 - CONCLUSION

The first trials with this wet-steam tunnel will begin in a few weeks. We have first to familiarize ourselves with this new large tunnel : then we shall be able to manufacture new transonic probes and calibrate them. Initially, calibration will be done for Mach numbers up to 1.25, in accordance with the current limits of our tunnel.

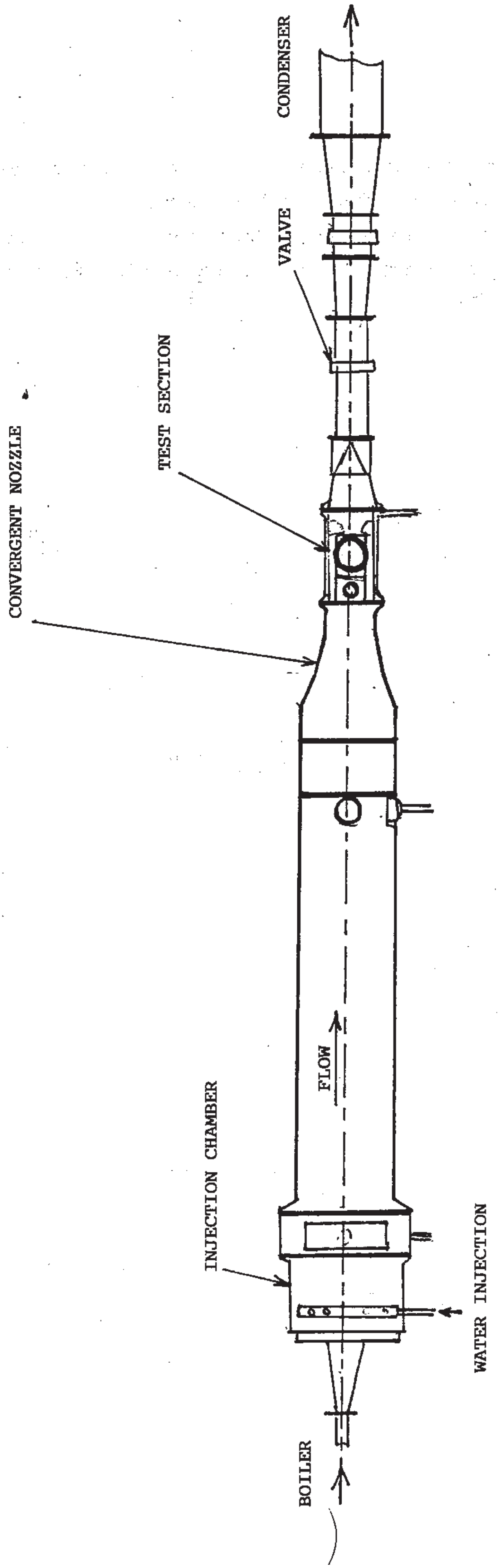

Fig. 1 - THE TRANSONIC WET STEAM TUNNEL (V S D)

FIGURE 2 - PERFORMANCES

FLOW RATE : 1.4 to 4.0 kg/s (5 to 14.5 t/h)

PRESSURE : 0.2 to 0.4 bar

TEMPERATURE: Saturation to superheated

WETNESS : 10 % to superheated

MACH RANGE : Subsonic to 1.25
to 1.6

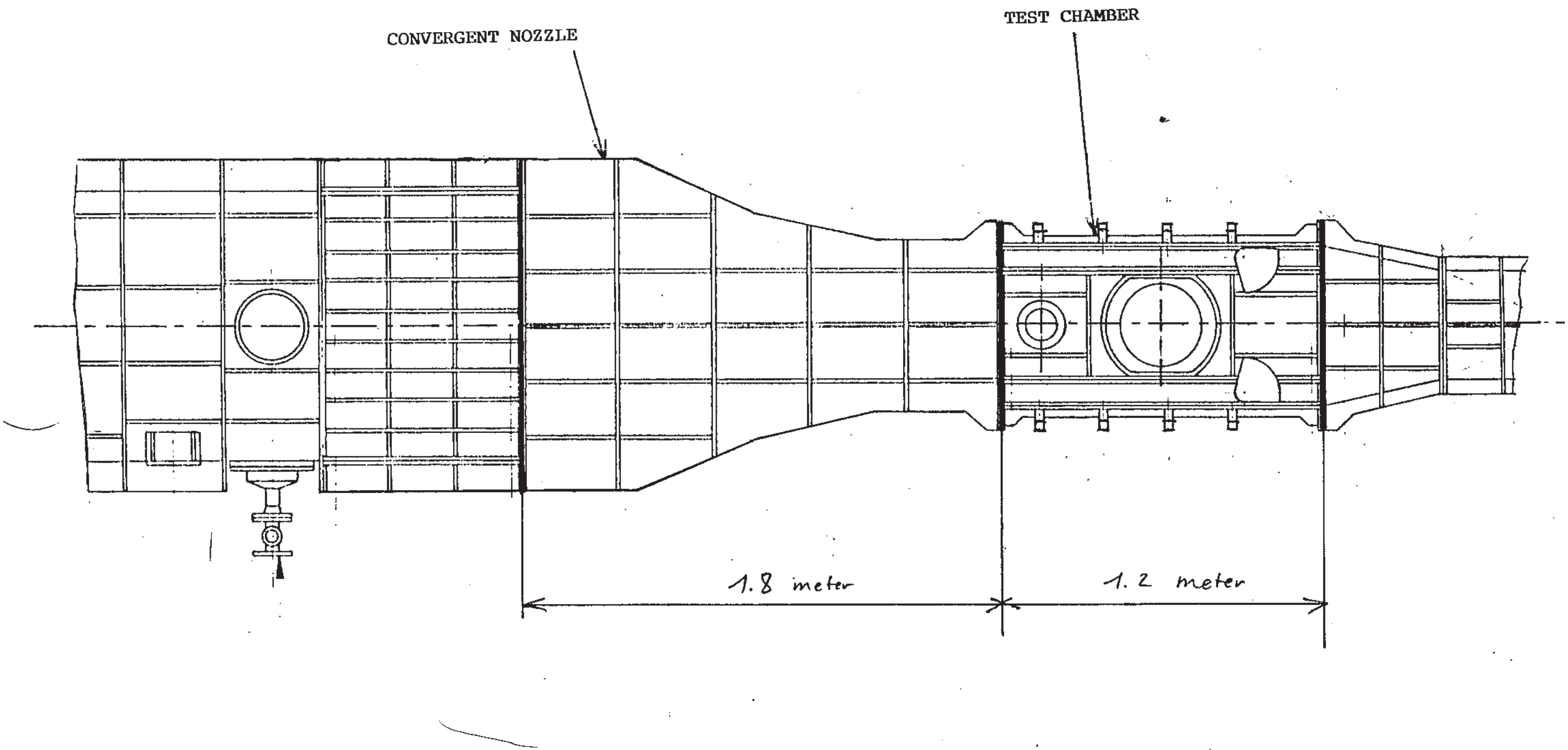

Fig.3 - THE TEST CHAMBER

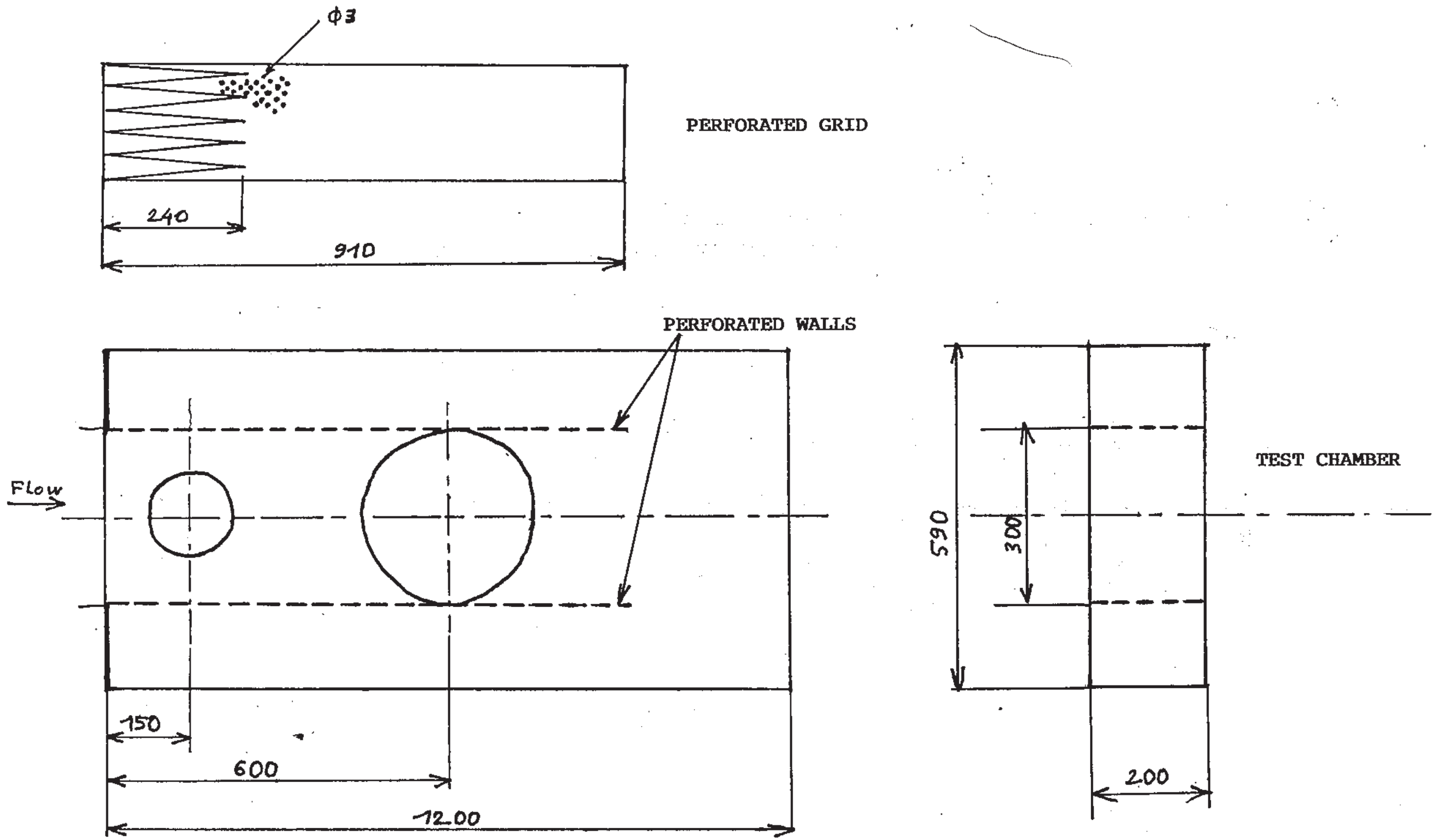

Fig. 4 - PERFORATED NOZZLE

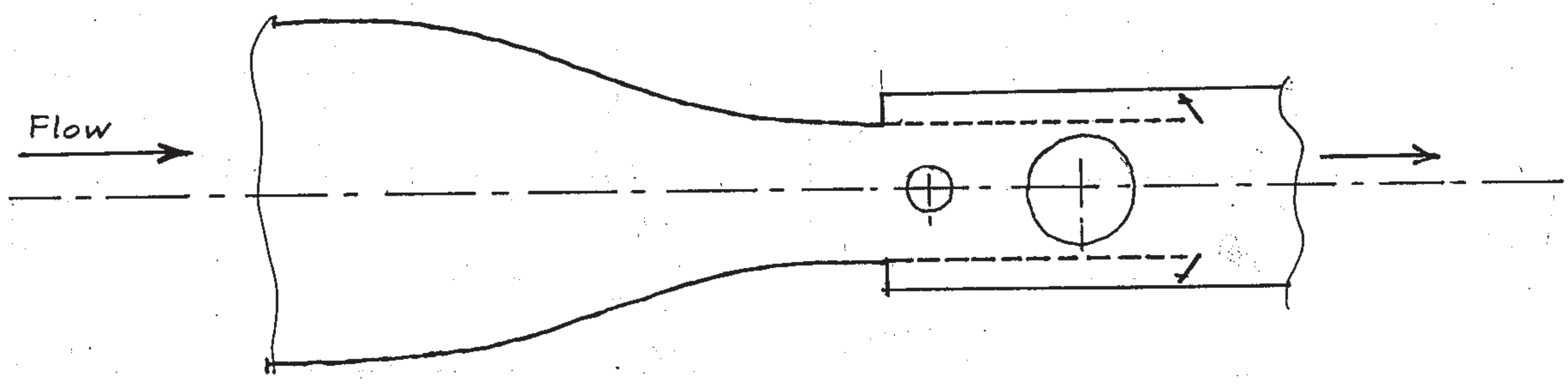

Fig. 5 - V S D VENTILATED CONFIGURATION
FREE JET CONFIGURATION : Without the perforated walls

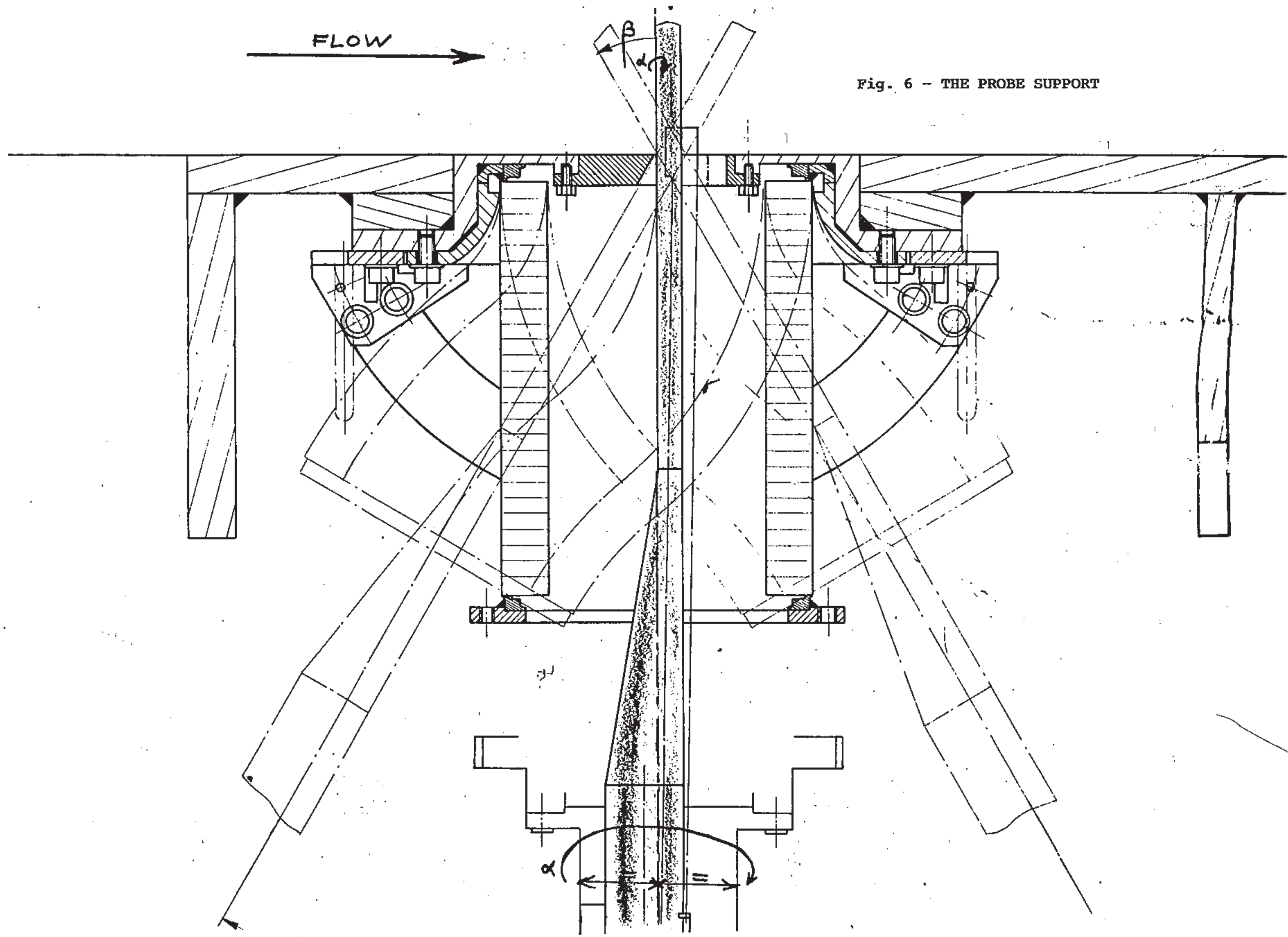

Fig. 6 - THE PROBE SUPPORT

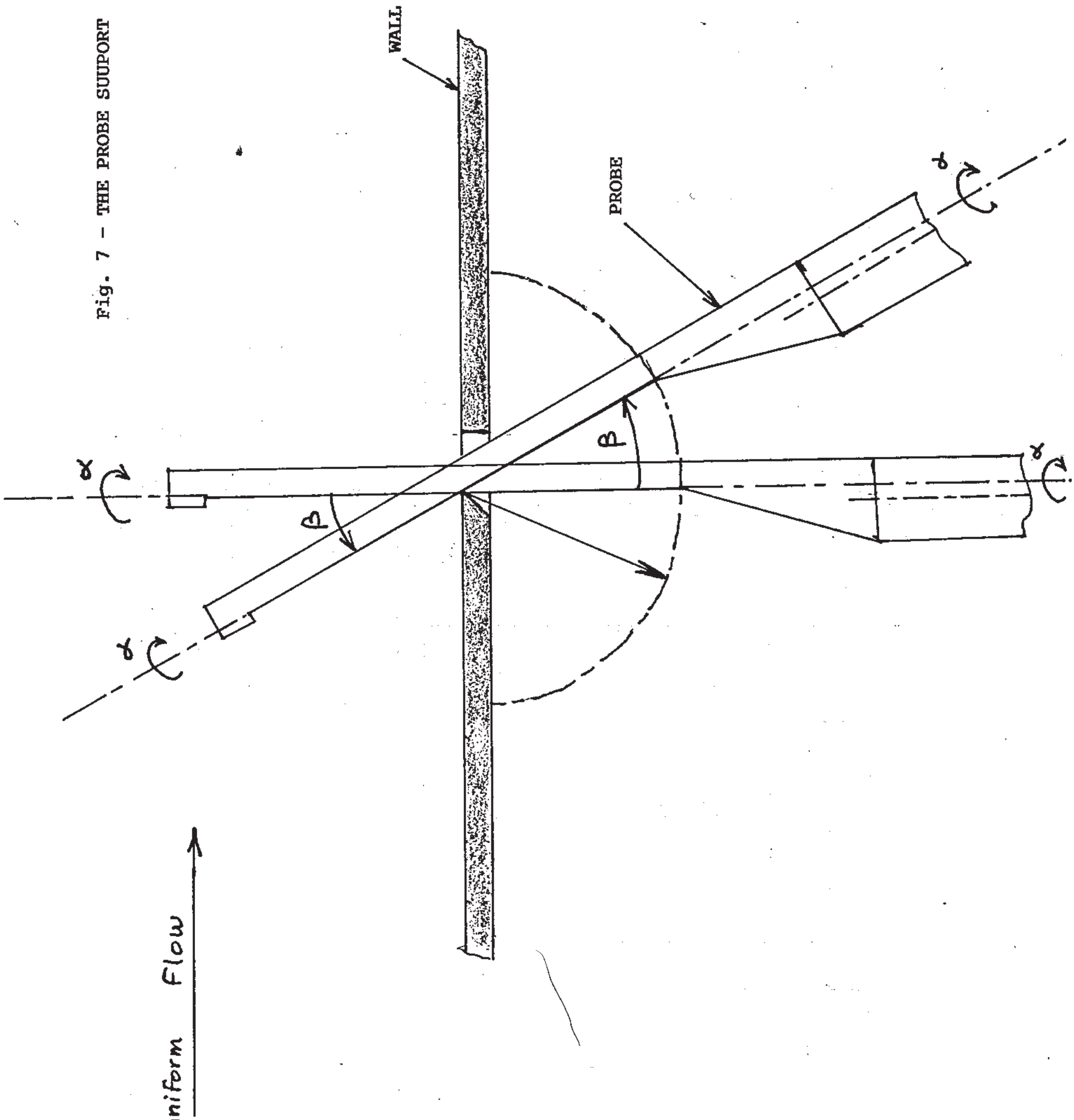

Fig. 7 - THE PROBE SUUPORT

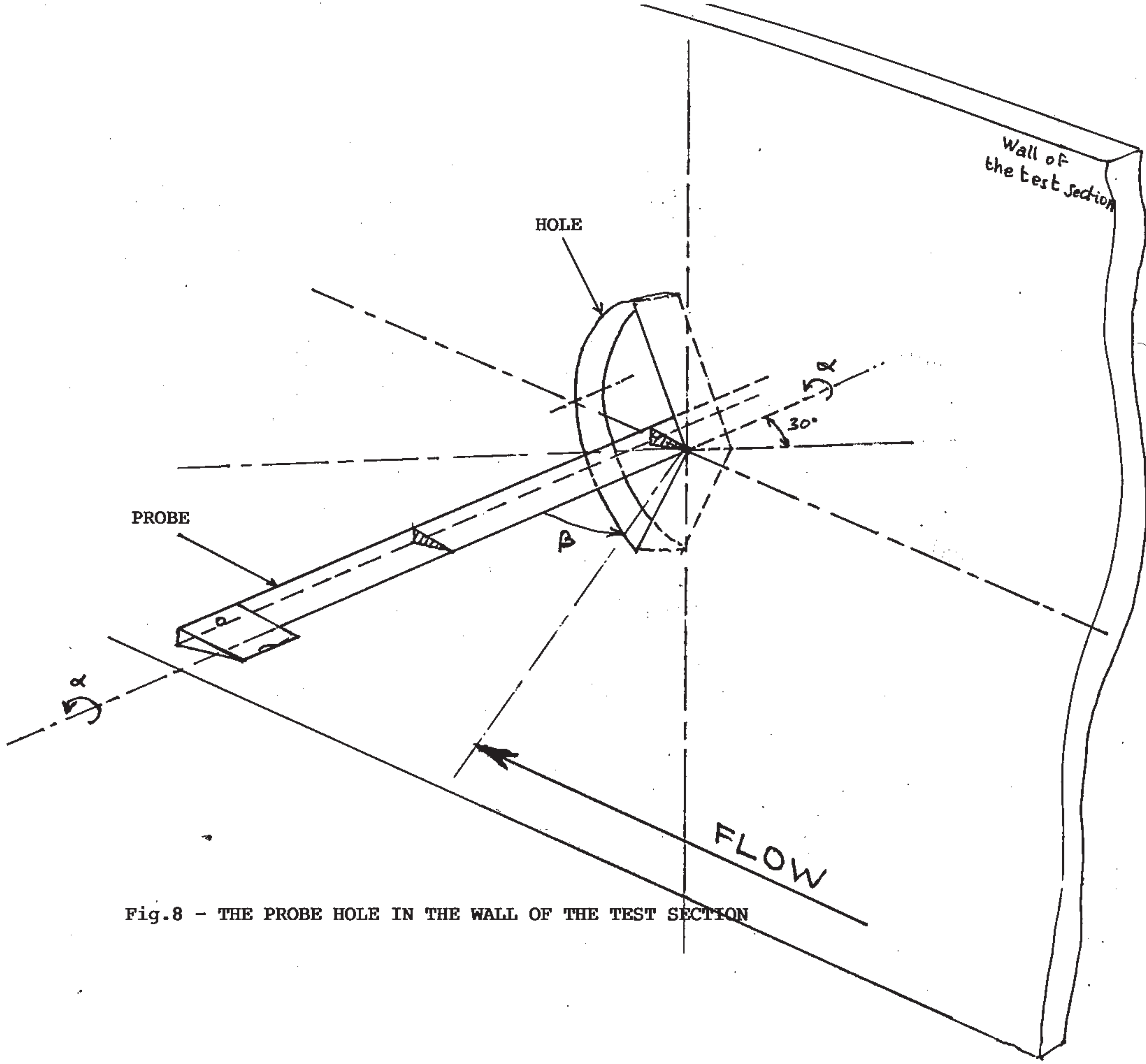

Fig.8 - THE PROBE HOLE IN THE WALL OF THE TEST SECTION

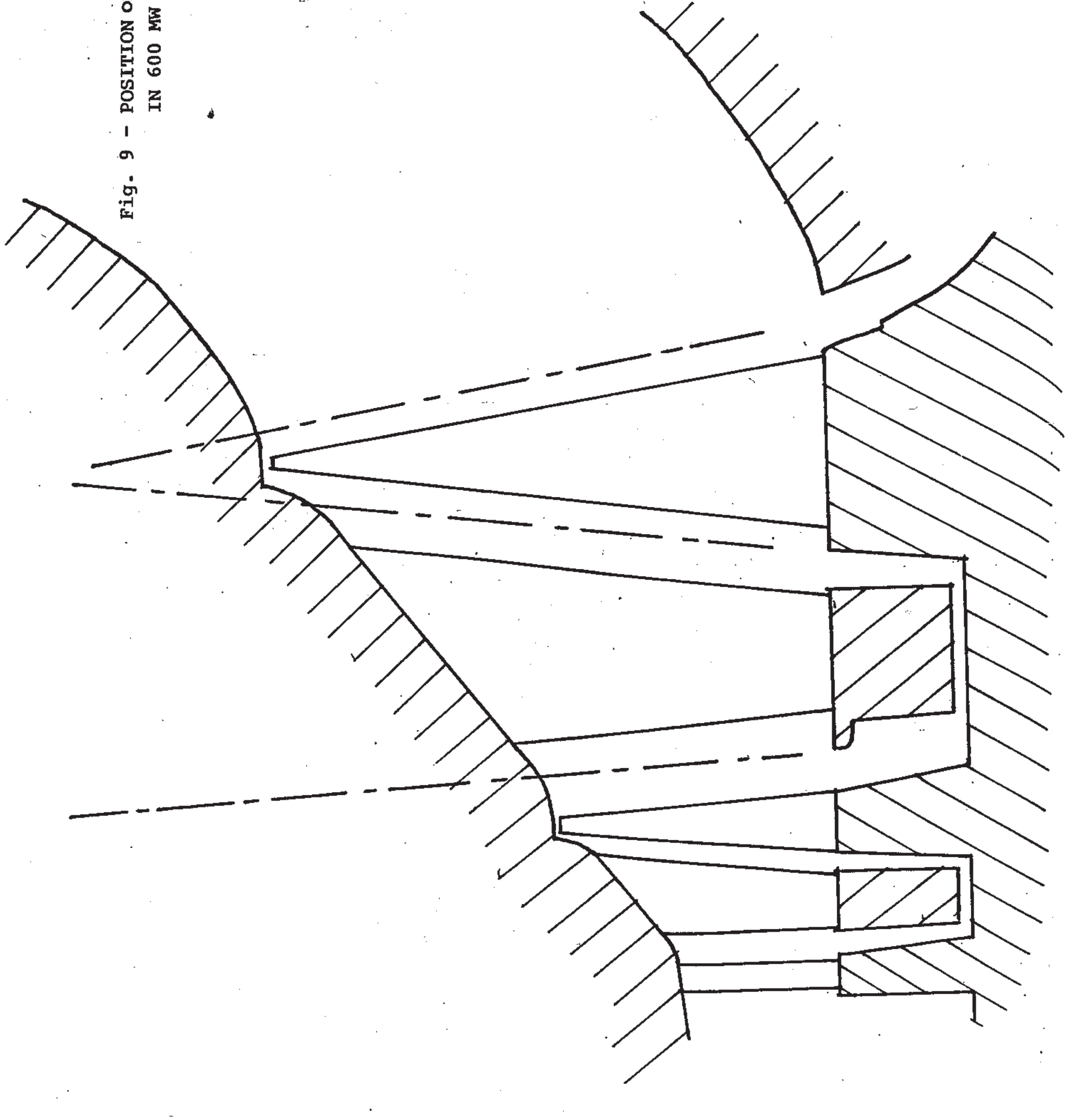

Fig. 9 - POSITION of ACCESS HOLE
IN 600 MW TURBINE