Session 9 - Wet Steam

COMPARISON BETWEEN TRANSONIC VELOCITY MEASUREMENT AND CALCULATION IN A LOW PRESSURE STEAM TURBINE

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Abstract :
Velocity measurements are performed in a 600 MW fossil fired low pressure steam turbine with a transonic probe. The results are compared to those obtained with a through-flow code based on streamline curvature method.
A new convergent - divergent nozzle will be constructed for calibration of the probe for higher mach numbers up to 1.5.

1 - INTRODUCTION

In order to validate the steam turbine calculation softwares and to improve knowledge of steam flow in different components of nuclear power plants, a transonic probe was designed for EDF's applications.
A steam tunnel has also been constructed for the probe calibration.
The study of the turbine's last stage steam fow in a 600 MW fossil-fired plant oriented the choice of Mach numbers (up to M = 1.3) for the first calibration of this probe (Réf [1]).

The comparaison between the through-flow calculation results and the experiments will also be performed for the turbine of the new EDF's 1400 MW nuclear plants. In this case the probe has to he calibrated up to Mach number 1.5.
The steam tunnel test chamber has to be modified for this new application.

2 - BRIEF DESCRIPTION OF THE PROBE

The steam velocity probe is described in detail in reference [1]. The figure 1 shows the probe and the detail of the probe head.
In order to minimise the transonic domain for which the measurements are not very reliable, the thickness of the probe is reduced as much as possible (3 mm).

The theoretical Mach number range for which the sonic blockage can modify the measurement results is from 0.85 to 1.15.

3 - CALIBRATION STEAM TUNNEL

The first calibration of the probe up to Mach number 1.3 was performed with a convergent nozzle.

A new supersonic convergent-divergent nozzle is designed in order to calibrate the probe for Mach number 1.4.

Figures 2 and 3 show the steam tunnel and the test chamber.

The new convergent- divergent nozzle is reproduced in figure 4.

The perforated grids and the flaps used for increasing the Mach number with the convergent nozzle will be maintained in the test chamber for the convergent divergent nozzle.

It may enable us to increase the Mach number up to 1.5.

The experiments are necessary to confirm the possibility of reaching higter Mach numbers in this configuration.

4 - MEASUREMENT IN 600 MW TURBINE

A thrangh-flow computer programme is used to analyse the performance of the steam turbines at design point and under off-design conditions (Réf [2]).

It is based on streamline curvaturemethod and allows the treatment of subsonic and transonic turbines for convergent and convergent-divergent blades, typical of the last stages of low pressure turbines.

This code has to be validated by the measurements in test and actual turbines.

One of the test case chosen to validate the code is a 600 MW fossil-fired turbine.

The measurements and calculations are performed for 72 % and 88 % part loads regimes.

Pressure and velocity are measured in 3 different sections : upstream of the last fixed blades, downstream of the last moving blades and two different positions between the two blade rows (figure 5).

5 - *CALCULATION–MEASUREMENT COMPARAISON*

Figure 6 shows the results of comparaison between the measured and calculated pressure distribution.
Near the hub the difference is about 12 % and there is quite negligible difference near the casing.
The measured Mach numbers downstream of the last moving blades (figure.7) are well predicted by the calculations excepting the two last points near the casing.
Usually there is a good agreement between the measured and calculated fluid angles (example figure 8).
Two examples of the measurements in transonic zones are shown in figure 9 and 10.
The angular position of the probe changes also in two figures.
The large difference between the two measured profiles requires further investigation.

The following phenomena could explain the difference between the measurement and calculation :

. Local transonic blocage and shock wave interaction.
. Presence of connection devices not calculated by the through-flow programme.
. Measurement points situated in the wakes.
. Other 3D effects.
. Accuracy of total flow rate calculated by through flow programme and the extraction flow rates needed to run the code.
. Unsteady flow effects.

6 - *CONCLUSION*

The overall agreement between calculations and measurements with the transonic probe is satisfactory in a 600 MW fossil-fired turbine.
Some of the discrepancies are not due to the axisymetrical hypothesis of the calculation and require further analysis.
A new steam tunnel has been designed and is now under construction for further calibration of the probe up to Mach 1.5 in order to investigate the flow in the new 1400 MW nuclear turbine.

REFERENCES :

[1] M. BRUNOT
A new transonic probe; 9th Symposium on measuring techniques for transonic and supersonic Flow in Cascades and turbomachinery" Oxford March 1988.

[2] C. BIRR-MEZA , P. GRISON
Through-flow analysis in large low pressure turbine at off design condition. Insitution of Mechanical Engineers, September 1987.

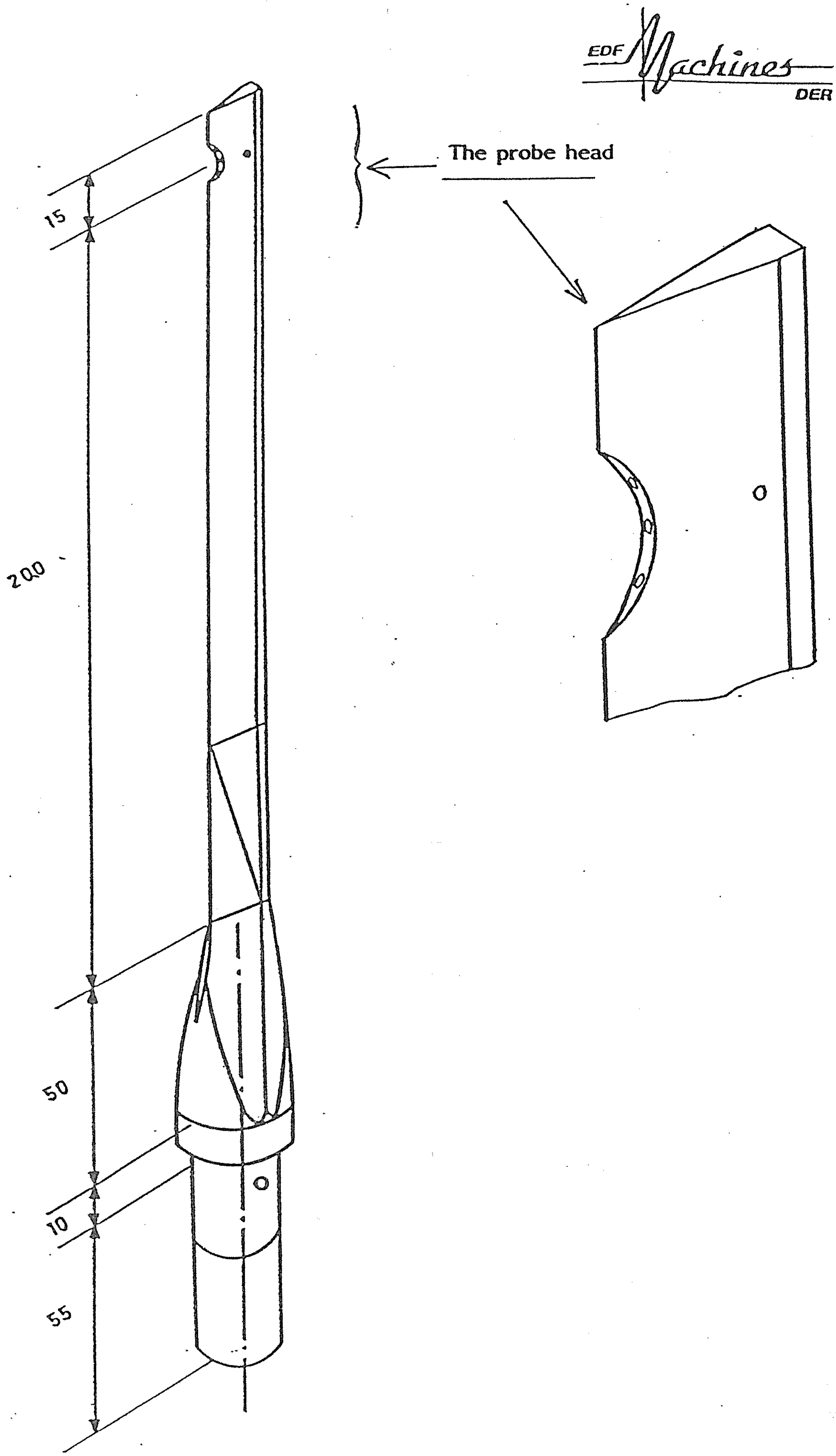


Fig.1 : The probe

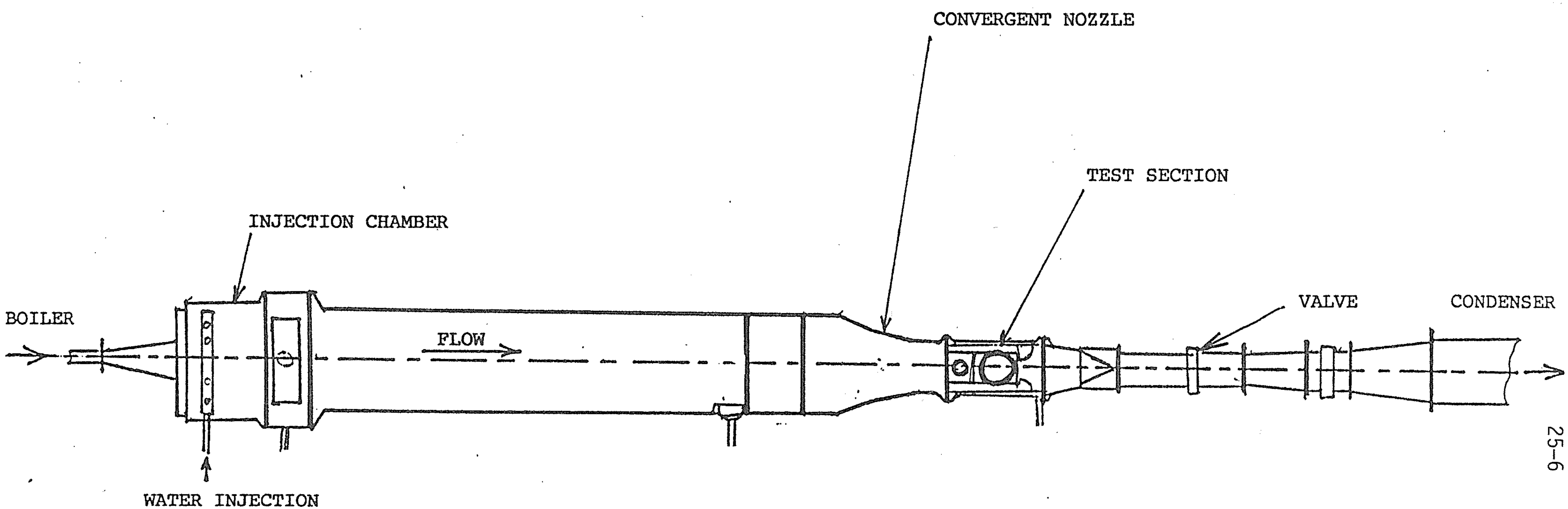


Fig.2 TRANSONIC WET STEAM TUNNEL (V S D)

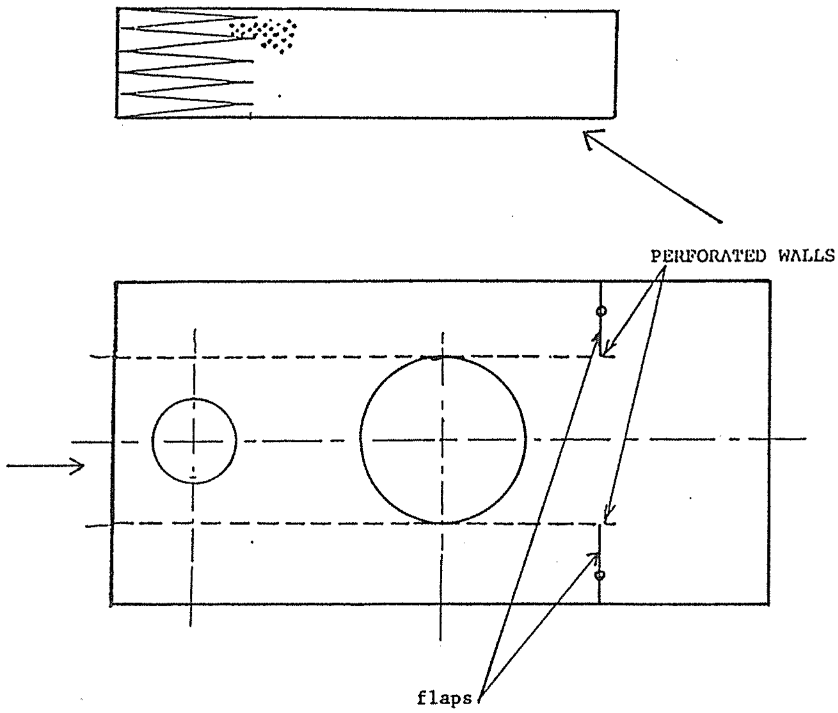


Fig.3 TEST CHAMBER

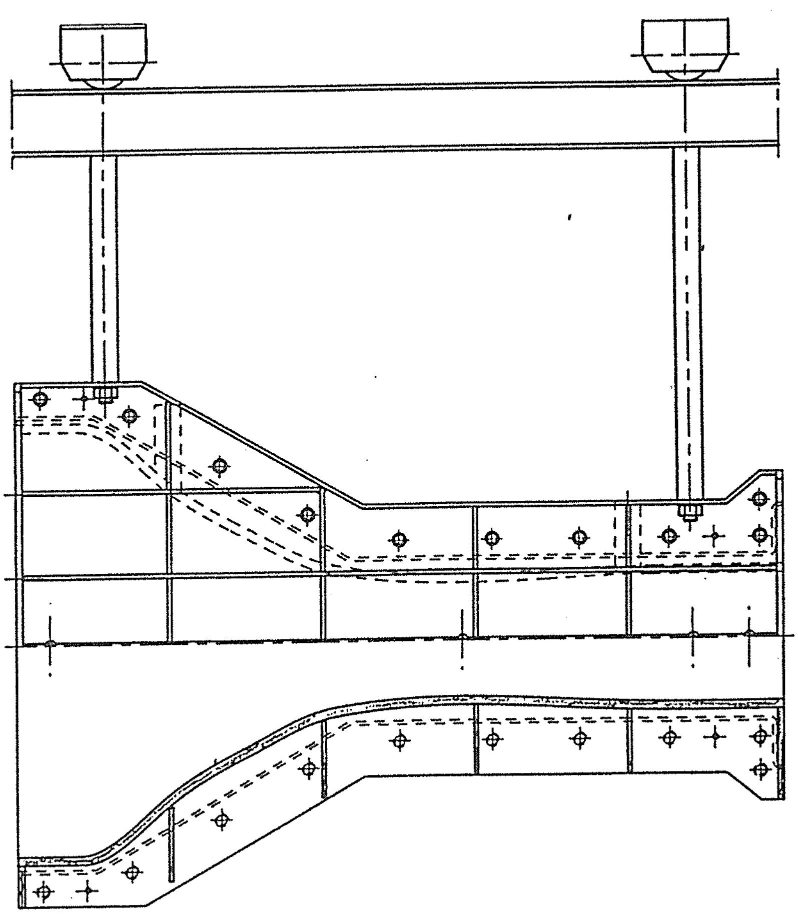
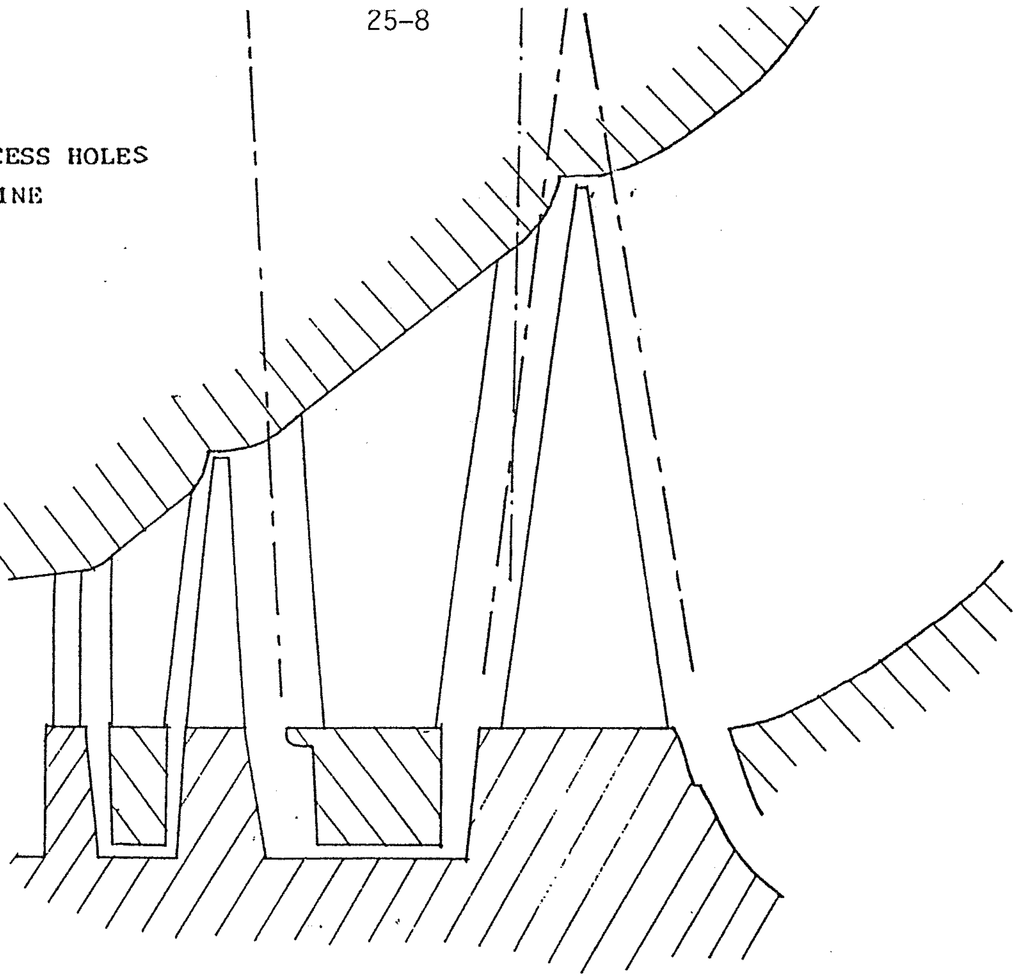


Fig. 4 : New Convergent-divergent nozzle

Fig.5 - POSITION of ACCESS HOLES IN 600 MW TURBINE



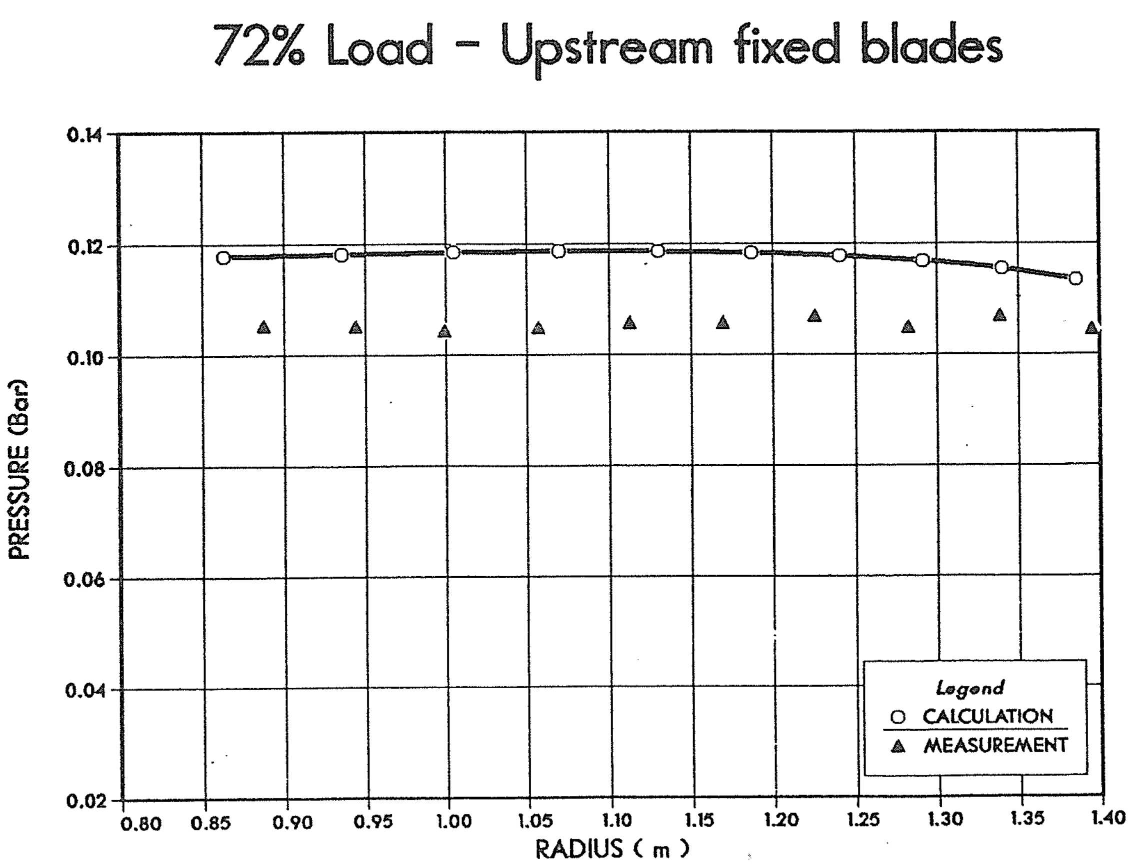


Fig. 6

EDF Machines

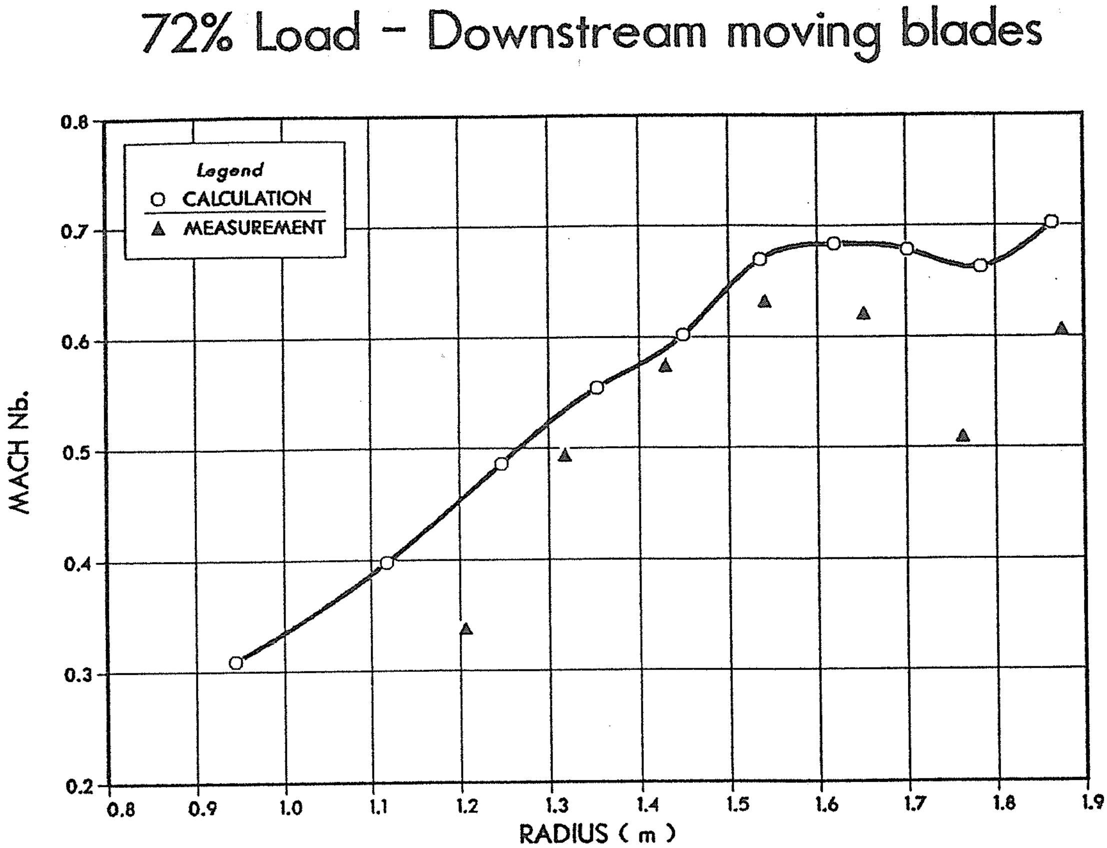

72% Load - Downstream moving blades
Legend
CALCULATION
MEASUREMENT
MACH Nb.
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
RADIUS (m)

Fig. 7

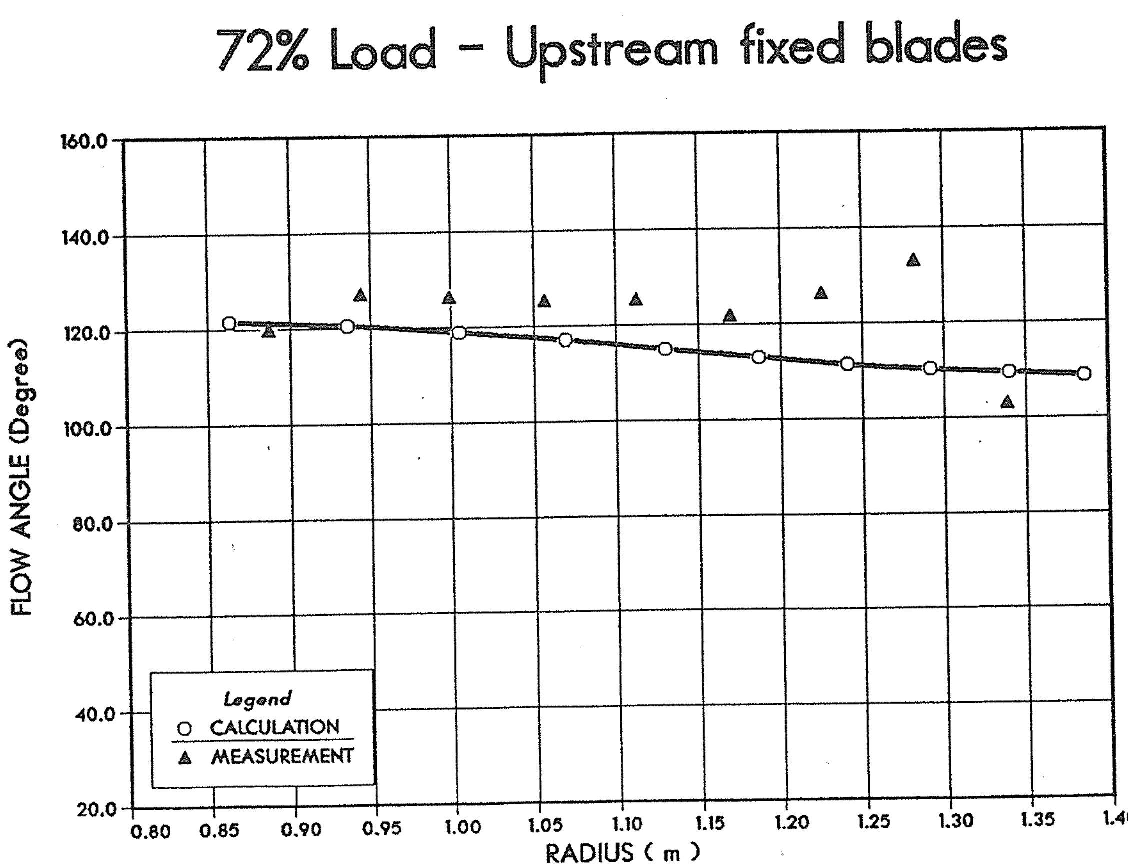

72% Load - Upstream fixed blades
Legend
CALCULATION
MEASUREMENT
FLOW ANGLE (Degree)
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.80
0.85
0.90
0.95
1.00
1.05
1.10
1.15
1.20
1.25
1.30
1.35
1.40
RADIUS (m)

Fig. 8

72% Load - Between two blade rows

1 st. POSITION

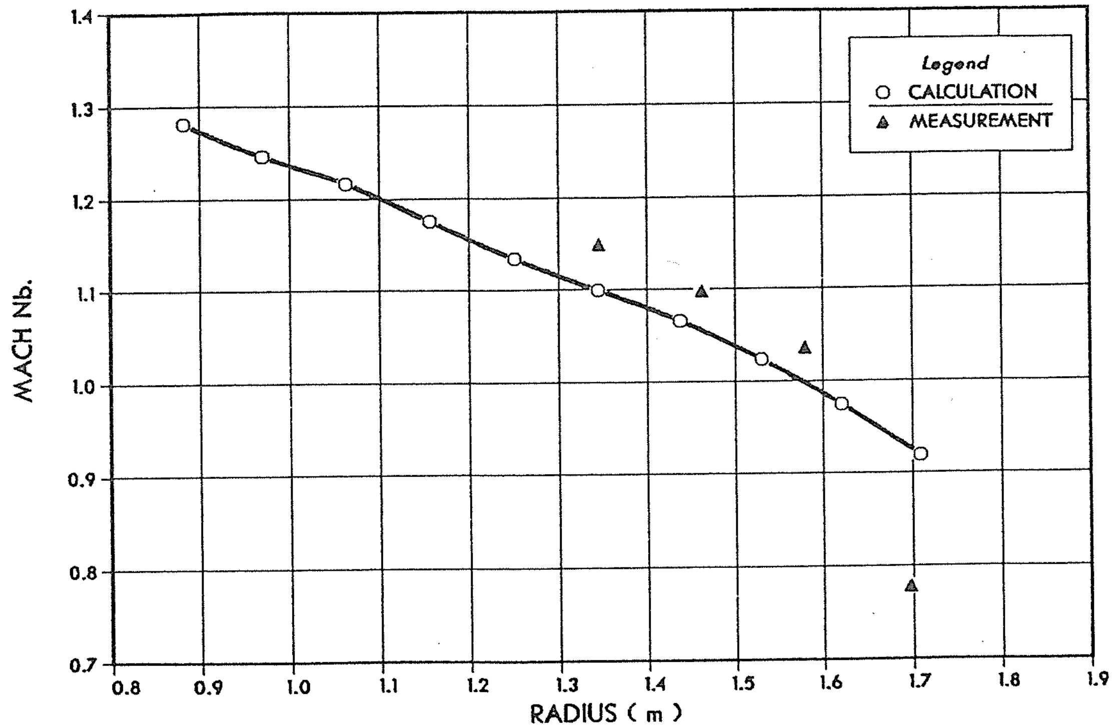


Fig. 9

72% Load - Between two blade rows

2 nd. POSITION

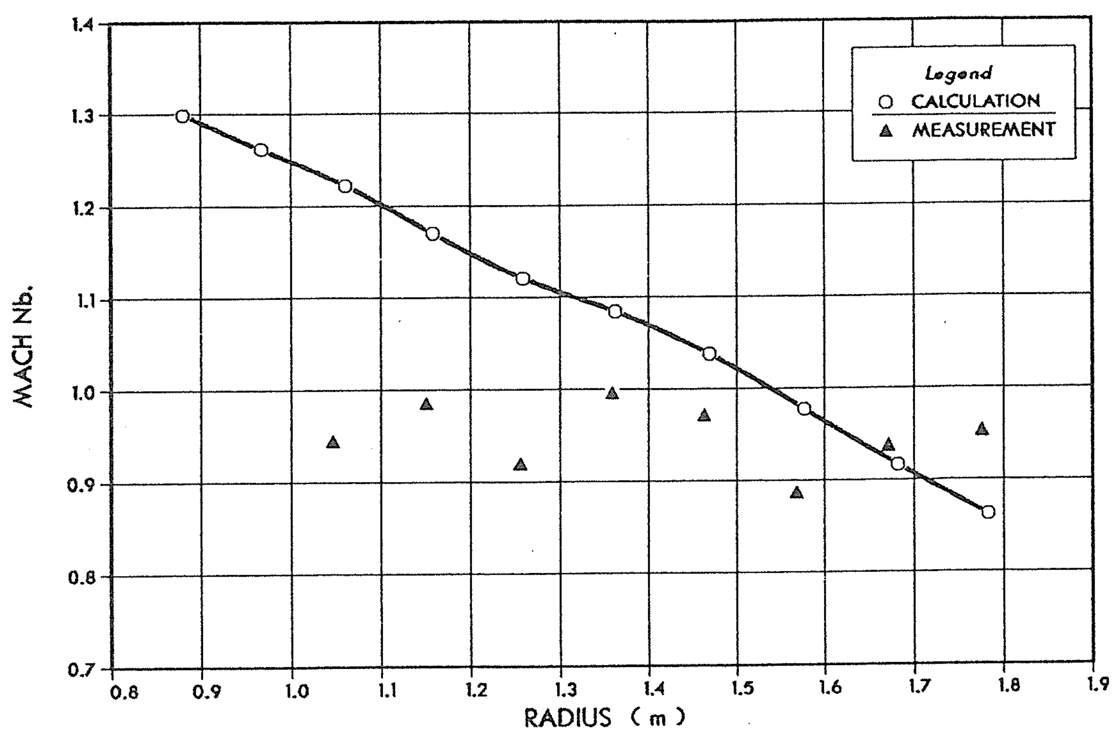


Fig. 10