EXPERIENCES WITH TURBINE AND COMPRESSOR CASCADES IN AN ANNULAR TEST FACILITY [*]

by

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The non-rotating annular test facility at "Laboratoire Thermique Appliquée" (LTA) has been taken into operation and experiments have been performed in turbine and compressor cascades in the transonic flow regime. This annular wind tunnel is an enlarged version of the small nozzle described at the 1976 Symposium /1/. The outer diameter of the test section is 400 mm with a channel height of 40 mm (Fig.1).

The non-rotating facility permits a continuous variation of the Machnumber and flow angle upstream of the test cascade in the regions of $0, \lesssim M_1 \lesssim 1,4$ and $16^\circ \lesssim \beta_1 \lesssim 50^\circ$ respectively. The change in the flow quantaties is regulated with the two guide vanes in the radial part of the nozzle, as well as with the total pressure in the two inlet settling chambers.

Due to this regulation possibility of two different inlet flow quantaties it is possible to vary the radial flow angle - and velocity - distributions upstream of the test cascade. For further influence of these distributions a boundary suction is used in three different positions.

Preliminary tests have shown that the flow in the test section is identic over the circumferential direction. Furthermore, the blade pressure distribution shows the same behaviour.

The largest advantage of an annular cascade over a linear one is the self regulation of flow periodicity in circumferential direction. This implies also a very easy and continuous variation of upstream and downstream flow quantities.

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[*] This contribution was presented as flow visualization in a movie film at the Symposium.

Experiments with an annular turbine cascade

Experiments have been performed in a typical low pressure steam turbine stage. The upstream flow velocity was increased continuously with constant, and also with variable, flow angle until choking. Downstream flow conditions were varied, with continuous change in the backpressure, from limit loading to sonic outlet condition.

A few Schlieren pictures at different outlet Mach numbers, taken in the annular facility, are shown in fig. 2. In fig. 2a, a local supersonic zone has arisen on the suction side of the profil. This domain is terminated with a normal shock. The cascade is in this case not yet choked, the outlet Mach number is less than unity.

In such a flow condition, the normal shock on the profil was highly unstable. Oscillations of up to 10 - 15% of the chordlength could be noted, although the free stream turbulence was less than about 2%.

The reason for the large shock oscillations lies therefore probably in the shock-boundary layer interaction. Furthermore, unsteady experiments in an identical cascade showed that this shock oscillation could lead to selfexcited blade vibrations.

The base pressure was measured on two profiles at midspan. Contrary to results published in the open literature, the experiments in the annular turbine cascade indicates that the back pressure (p_2) is less than the base pressure (p_B) (Fig.3).

At constant downstream Mach number, M_2, the pressure ratio p_B/p_2 changes with a variation in incidence. However, all the measurements indicate a value greater than unity. The reason for the different results in annular and linear cascades are probably due to differences in backpressure between the different channel types. The base pressure, p_B, is governed by the profile, and is probably identic in linear and annular cascades.

Experiments with an annular compressor cascade

A compressor cascade (Fig.4) was also investigated in the annular test facility.

The upstream Mach number, M_1, can be varied continuously from subsonic, over the transonic, to supersonic flow regions. No special phenomena was noticed as the upstream flow went through the sonic velocity.

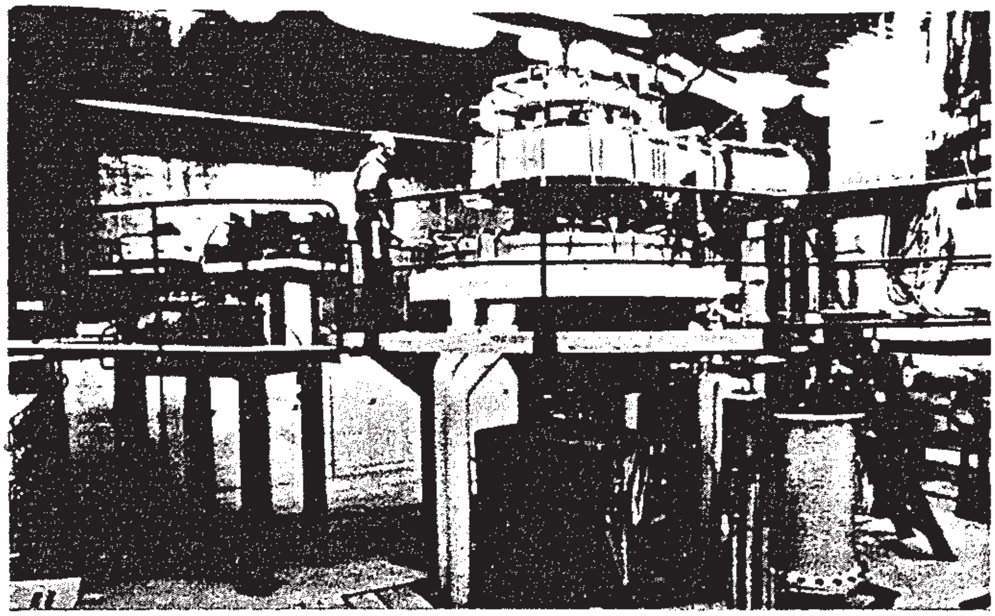
The normal shocks could be seen to be highly unstable as a stroboscopic light source was used (Fig.4). The shockmovement was in some cases over 20% of the chordlength. This very unstable shockdisplacement could not be noted with a continuous light source. The shock appeared in this case only as a wide zone (see Fig.4). The turbulence were also in these tests below 2%. With increasing backpressure, the shock in the cascade was moved continuously towards the leading edge. During this period, the unique incidence of the cascade was not influenced. A further increase in back pressure showed that the bow shock however also can be detached from the profile in this Mach region, if the pressure is high enough.

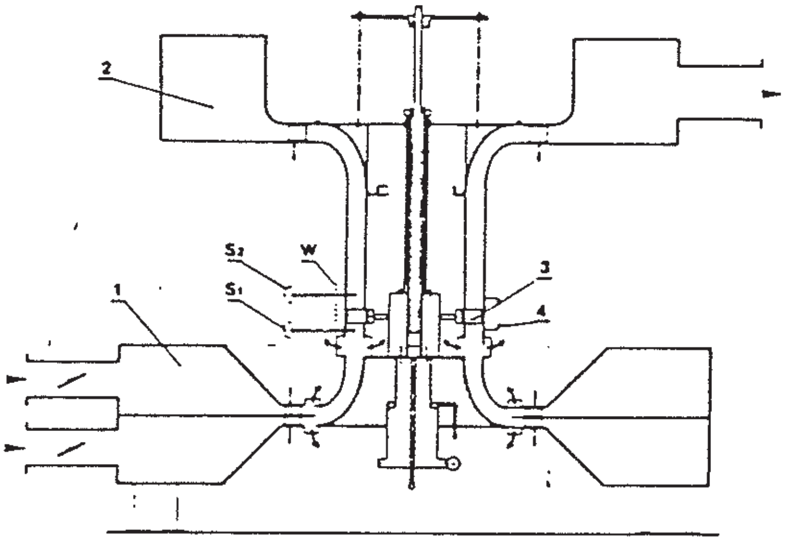
In this case, both the Mach number and the flow angle decreased continuously.

Detailed experiments on both cascades are performed, and will be published, together with a description of this non-rotating annular test facility, at a later time.

References:

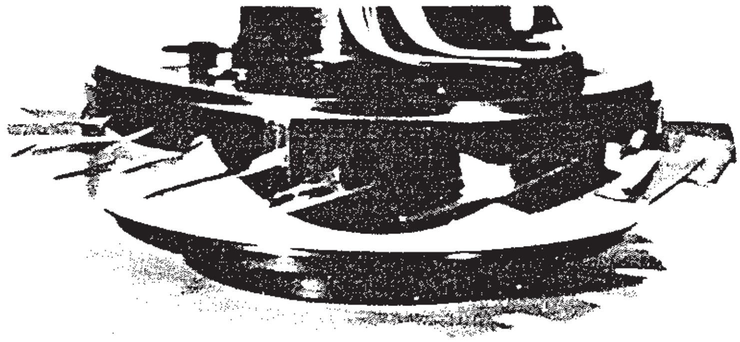
/1/ A.Bölcs T.Fransson "A New Configuration of Wind Tunnel and Some Experience With an Annular Cascade for Transonic Flow Conditions"
Proceedings of the Symposium on "Measuring Techniques in Transonic and Supersonic Cascades and Turbomachines", Lausanne, Switzerland, 1976





1	inlet chamber	S	probes
2	outlet chamber	W	pressure tappings
3	test cascade	↗	boundary layer suction
4	window for optical visualization	⊡	guide vanes

Fig. 1 Annular test facility at LTA



Annular turbine model cascade

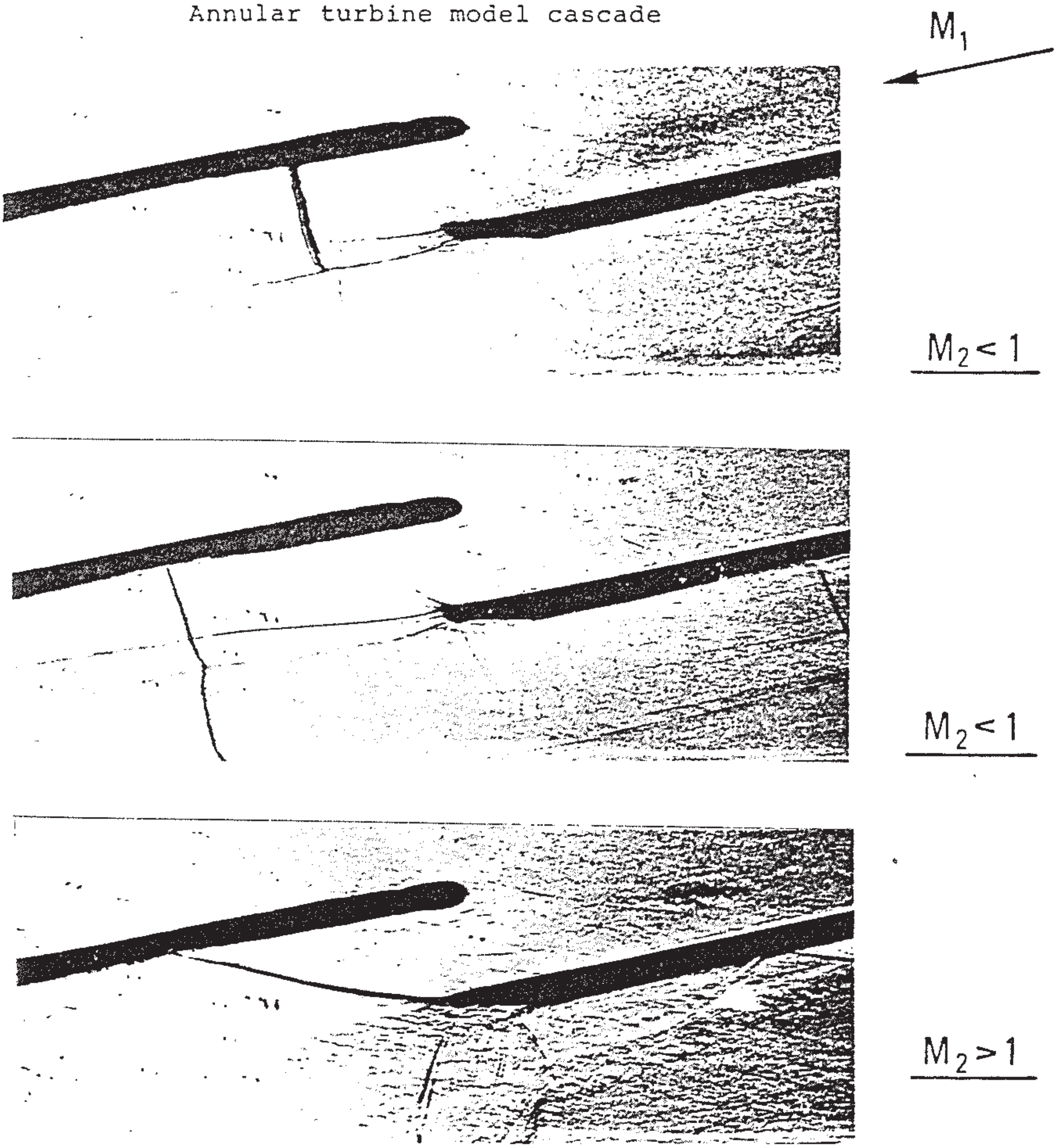


Fig. 2 Schlieren pictures in the annular test facility at different outlet Mach numbers

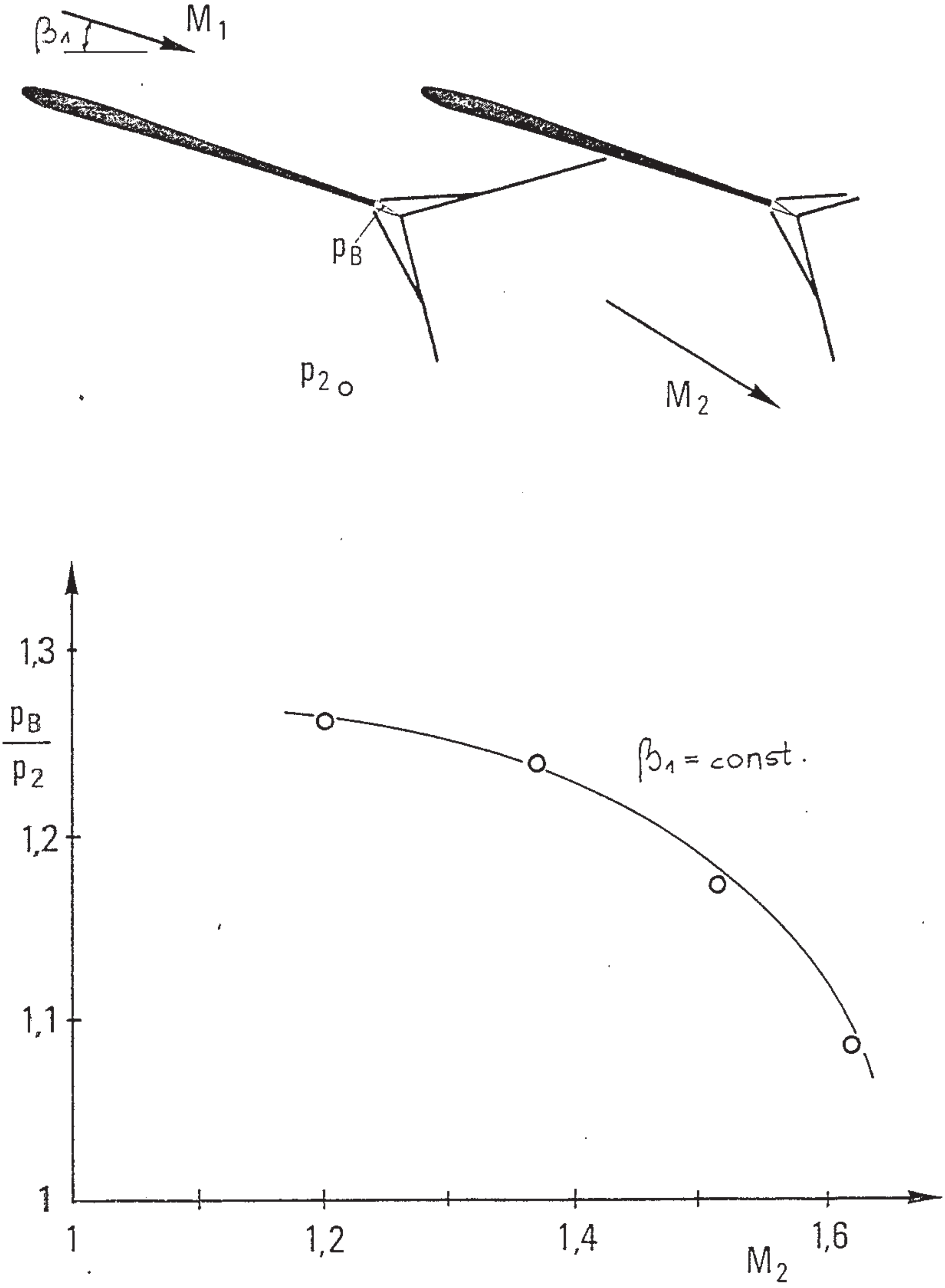
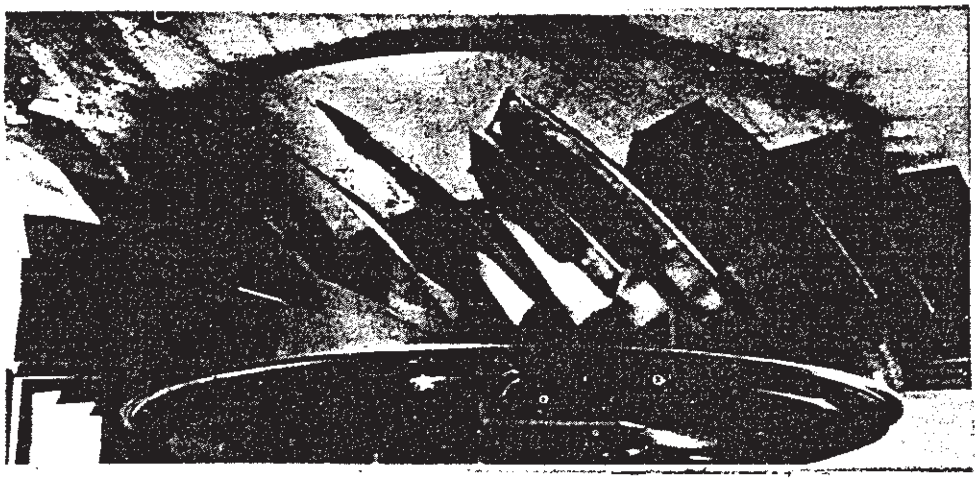
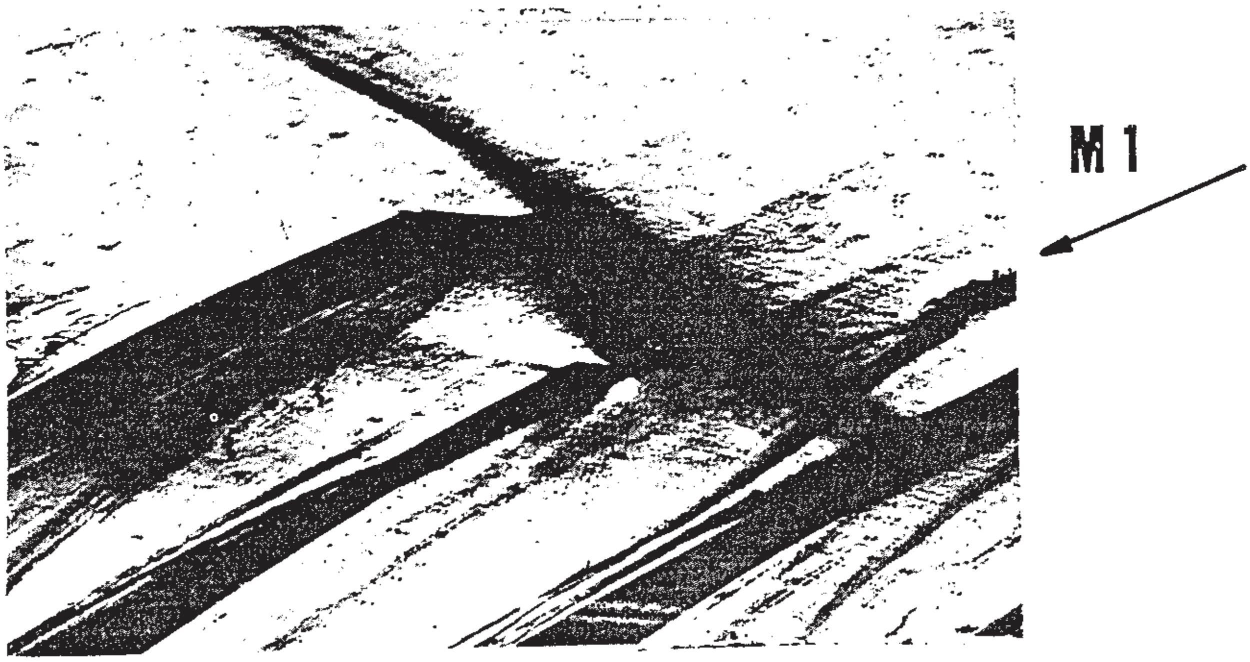


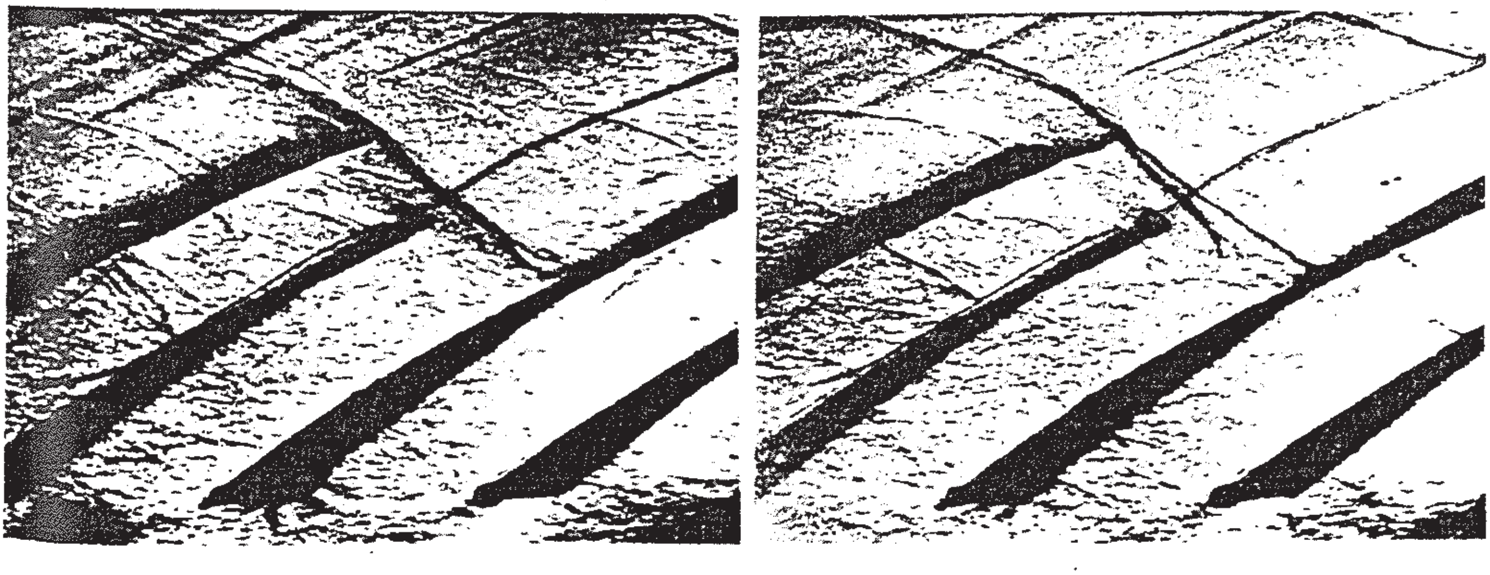
Fig. 3 Ratio base pressure to back pressure as a function of downstream Mach number.



Annular compressor cascade



Schlieren picture at $M_1 \sim 1,15$ with continuous light source



Schlieren pictures at $M \sim 1,15$ with stoboscopic light source
(Flash duration ∿50 nsec)

<u>Fig. 4</u> Annular compressor cascade