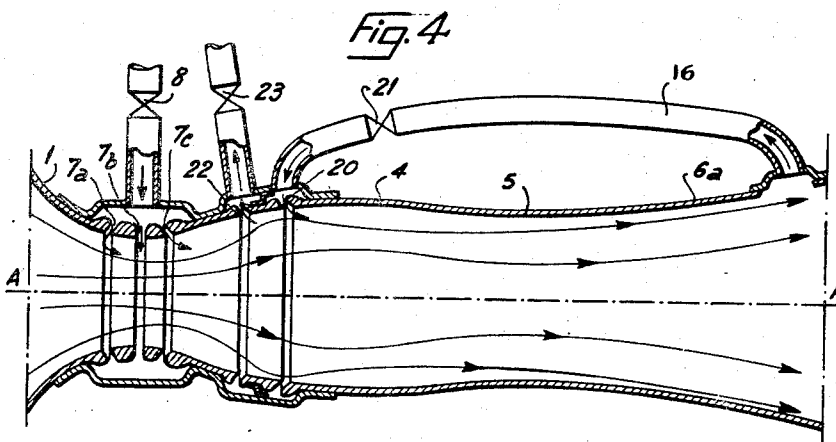
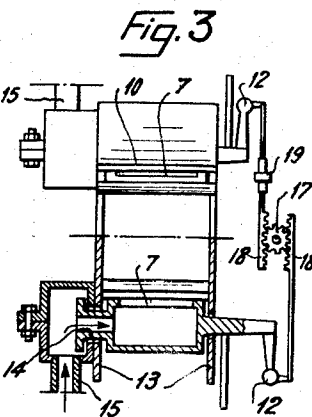
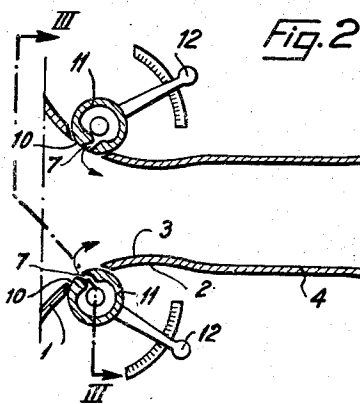
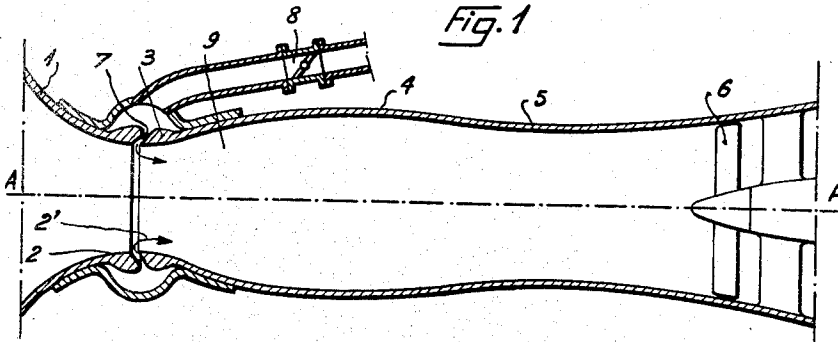


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SUPERSONIC WIND-TUNNEL FOR A VARIABLE MACH NUMBER

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SUPERSONIC WIND-TUNNEL FOR A VARIABLE MACH NUMBER

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It is known that in a supersonic wind-tunnel, the Mach number in the testing chamber is a function of the ratio between the surface area of the rectangular cross-section of this chamber and that of the sonic neck arranged on the upstream side of this chamber.

In practice, the dimensions of the testing chamber are laid down before the wind-tunnel is constructed; in order to obtain different Mach numbers in this chamber, this implies the necessity of varying the section of the sonic neck situated on the upstream side of the chamber.

In order to make it possible to carry out tests with several Mach numbers, wind-tunnels have been built in which the part which includes the sonic neck could be removed and replaced by another neck of different dimensions. This costly and lengthy process does not enable a progressive variation of the surface of the neck, and thus of the speed in the testing chamber, to be obtained.

Various mechanical methods of varying this surface in a progressive manner have been proposed, amongst which the following may be cited:

(1) The arrangement of a neck with a deformable wall; amongst other drawbacks, this method involves great difficulty in manufacture and its cost is high.

(2) Arrangement of a shutter unit. In this case the major disadvantage is that of introducing a wake zone with attached shock-waves in the very centre of the jet and which thus interfere with the model.

(3) The arrangement of a neck with asymmetric and displaceable wall. One of the drawbacks is the asymmetry of the limit layers.

Asymmetric walls make it necessary in practice to pass the flow between two flat walls and prevent any tests being made in a circular jet. Deformable walls for a jet of circular cross-section are very difficult to construct.

The present invention enables this problem of the construction of a supersonic wind-tunnel for a progressive variable and controllable Mach number to be solved in a simple and effective manner. In accordance with the invention, the cross-section of the sonic neck on the upstream side of the testing chamber is regulated by aerodynamic striction by means of one or a number of auxiliary gaseous jets which can be regulated, and which are formed by nozzles in the proximity of the material sonic neck of the wind-tunnel, and in particular in the zone which extends from the upstream side of the said neck to the neck itself.

The auxiliary jet or jets may be arranged in a symmetrical manner. For example, a single jet may be provided discharged from a nozzle in the form of a slot which occupies the whole section of the discharge nozzle which forms the conduit including the sonic neck, and this section may be, in particular, a rectangular section.

The jet or jets which restrict the cross-section of passage available to the main jet and their effect, may be

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regulated progressively by acting either on their intensity, or on their direction, or on both these characteristics conjointly.

There is an advantage in sustaining the striction jet or jets by providing means adapted to bring a fluid to fill the wake-zones produced on the downstream side of the jet or jets. There is also an advantage in providing means to ensure the reattachment of the auxiliary jets to the physical walls on the downstream side of the sonic neck and on the upstream side of the testing chamber. These means may comprise suction openings or slots.

The nozzles for the auxiliary jets are supplied with fluid from a source which has a total pressure greater than the static pressure of the main jet at the zone in which these nozzle discharge, for example, from the compressor which supplies the wind-tunnel in the case in which this latter is of the compression type, or from an auxiliary compressor, or again from the external atmosphere, especially in the case in which the wind-tunnel is of the suction type. The level of static pressure in the sonic neck is in this case very much lower than the level of atmospheric pressure.

The supply of the wake-zones of the jets may be effected in the same way, or by tapping-off from any point whatever of the wind-tunnel at which the pressure level is suitable.

The description which follows below with regard to the attached drawings (which are given by way of example only and not in any sense by way of limitation) will make it quite clear how the invention may be carried into effect, the special features which are brought out, either in the drawings or in the text, being understood to form a part of the said invention.

Fig. 1 is a view in axial cross-section of one form of embodiment of a discharge nozzle for an improved supersonic wind-tunnel in accordance with the invention.

Figs. 2 and 4 are axial half cross-sections of alternative forms of embodiment.

Fig. 3 is partly an end view and partly a view in cross-section following the line III—III of the embodiment in accordance with Fig. 2.

In the form of embodiment shown in Fig. 1, the discharge-nozzle of the wind-tunnel is coupled at 1 to the intake of the gas which supplies this wind-tunnel, this gas being of any particular nature (for example, air) and may be displaced through the discharge-nozzle by any particular means (compressor, ejector, etc.). The gas which has passed through the discharge-nozzle may also be re-cycled wholly or in part towards the discharge-nozzle in accordance with a known method. The discharge-nozzle may be a body of revolution about the axis A—A. It forms a narrowed portion or neck 2, and then widens out progressively into a divergent portion 3 up to the testing chamber 4 which has a substantially constant cross-section. The chamber 4 is coupled on the downstream side to an air-evacuation device which may be of any type and may comprise for example a convergent portion 5 followed by an extractor fan shown diagrammatically by its moving wheel 6. The walls of the discharge-nozzle are constructed in accordance with the known technique for supersonic discharge-nozzles, in such manner that the flow in the chamber 14 is in conformity with fixed conditions, and in particular has a speed greater than that of sound, which is the lowest speed which it is proposed to obtain in the chamber 4.

In accordance with the invention, the discharge-nozzle comprises in the vicinity of its neck 2, an annular slot 7 forming a nozzle directed towards the interior, through which there can be introduced a gas at a total pressure greater than the static pressure of the main jet of the wind-tunnel in the vicinity of the neck 2. When the

valve 8 is opened, thus enabling the flow of auxiliary gas admitted to be progressively regulated, this auxiliary gas forms inside the discharge-nozzle a kind of fluid wall which modifies the cross-section of passage available for the main flow arriving at 1. There is thus formed a new neck 2' which is variable and which is substantially smaller than the physical neck 2.

For given conditions of the rate of flow of auxiliary gas (mass of flow and speed which produces it), the cross-section of passage available for the main flow depends on the angle of injection of the auxiliary gas with respect to the axis of the discharge-nozzle. If the auxiliary gas is injected parallel to the walls in the direction of the main flow, it occupies inside the discharge-nozzle a cross-section which is proportional to its rate of flow. If the injection slot is inclined towards the interior of the discharge-nozzle, the auxiliary gas soon becomes detached from the walls of the nozzle, leaving between itself and these walls a zone of depression 9 of dead gases which play the part of a physical obstacle which would have the same profile as that of the detached auxiliary jet, so that the restricted neck 2' is smaller than in the case of an injection made parallel to the walls.

For a given rate of flow and pressure of the auxiliary gas, there exists a value of the angle of injection with the axis of the discharge-nozzle such that the neck 2' is a minimum: this value corresponds to an injection directed towards the upstream side of the discharge-nozzle and depends on the conditions of construction of the discharge-nozzle. On the other hand, for a given angle of injection, the section of the neck 2' becomes smaller as the momentum of the auxiliary jet becomes greater.

Fig. 1 shows a nozzle 7 inclined at about 45° towards the upstream side of the main flow. The progressive passage from the physical neck 2 of the discharge-nozzle to a fluid neck 2' having the minimum cross-section, that is to say the variation of the Mach number of the flow from a minimum value corresponding to the physical shape of the discharge-nozzle up to a maximum value corresponding to the power available from the source of auxiliary gas, is obtained by varying the opening of the valve 8 from zero to its maximum.

The variation in cross-section of the neck may also be controlled by varying the angle of injection for the same rate of flow of auxiliary gas, or by varying the angle of injection and the rate of flow simultaneously. Figs. 2 and 3 show an embodiment of this kind applied to a discharge-nozzle having a rectangular section. A little on the upstream side of the neck 2, and on two opposite sides, the wall of the discharge-nozzle is provided with slots 10 which are closed by cylinders 11, the external wall of which is tangential to the internal wall of the discharge-nozzle. These cylinders are hollow and are arranged to rotate about their respective axes, this rotation being controlled by levers 12, one for each cylinder. As can be seen from Fig. 3, the cylinders are pivotally mounted in fixed walls 13, one of the pivot spindles carrying the lever 12, the other pivot 14 being drilled axially and placing the corresponding cylinder in communication with a source 15 of fluid under pressure. Along a generatrix of each cylinder is provided a slot 7, through which the fluid under pressure is injected into the discharge-nozzle. It will be seen that, by causing each cylinder to rotate by means of its lever 12, the angle under which the fluid is injected into the discharge-nozzle can be modified and, in consequence, the cross-section at the neck of the nozzle, available for the main flow, is also varied. In general, the levers 12 will be coupled to each other in such manner that a single controlling action will produce equal but opposite rotations of the cylinders and thus the jets discharged through the slots 7 will be symmetrically disposed and equally throttling, although an individual adjustment of one cylinder with respect to the other will be preferably provided in order to obtain this symmetry by experiment. There

has been shown diagrammatically in Fig. 3 a pinion 17 actuating two toothed racks 18 which are respectively pivoted to the levers 12. The coupling between one of these toothed racks and the corresponding lever 12 comprises a screw 19 having two oppositely-cut threads of the kind employed in tensioning devices and this enables the relative positions of the cylinders 11 to be regulated.

In order that the jet of auxiliary gas may be sufficiently maintained so as to form a continuous wall capable of being finally coupled with the fixed wall of the divergent portion on the downstream side of the neck and on the upstream side of the chamber, it is useful to fill the space between the physical wall of the discharge-nozzle and the fluid wall formed by the auxiliary jet.

A supply of this kind can be effected either by the intermediary of one or a number of jets of auxiliary gas injected on the downstream side of the constrictive jet, and which may have a lower pressure, since in a supersonic discharge-nozzle, the level of static pressure continues to decrease on the downstream side of the neck, or alternatively the supply may be taken from the atmosphere or from a zone in the circuit having a suitable pressure.

In the form of embodiment which is shown in Fig. 4, the nozzle 7 of Fig. 1 is sub-divided into three successive nozzles 7a, 7b, 7c, which have different inclinations. The first, which is inclined towards the upstream side of the main flow, has the greatest effect on the reduction of the cross-section available to the main flow. The second, which is at right angles to the axis, and the third which is inclined towards the downstream side, supply the depression zone and assist in the maintenance of the continuity of the fluid wall and in giving this fluid wall the correct shape of neck. The nozzles 7b and 7c may be narrower than the nozzles 7a, so as to supply a smaller flow of auxiliary fluid.

These nozzles, supplied by the valve 8, are supplemented by an annular nozzle 20 located on the downstream side of the neck and the output of which may be regulated by a valve 21. This nozzle 20 is inclined towards the downstream side of the main flow, in such manner that the auxiliary jet which is discharged from it, is almost parallel to the wall of the discharge-nozzle, this injection acting as an injection of a limit layer facilitating the coupling of the fluid wall to the physical wall of the discharge-nozzle. Between the neck and the nozzle 20 is provided a slot 22, coupled through a valve 23 to a source of sub-pressure. The suction effected by this nozzle 20 enables the point of coupling of the fluid wall to the fixed wall to be determined in an exact manner.

It will be understood that a suitable adjustment of the valves 8, 21 and 23 enables the form and the progression of the fluid wall which surrounds the main flow to be regulated.

In all the forms of embodiment described above, the source of auxiliary gas may be of any particular kind. It is only necessary that it should give, at the outlet of the blowing nozzles inside the discharge-nozzle, a total pressure which is greater than the static pressure of the main flow at that point. This source may be a special compressor, a steam boiler, etc.

The blowing nozzles may also be supplied from the delivery side of the compressor of the wind-tunnel, if the latter is of the compressor type, since the expansion effected inside the discharge-nozzle introduces a substantial drop in the static pressure in the main flow. Adjustable pressure-reducing devices may furthermore be placed on the supply lines of the various nozzles in order to regulate exactly the supply pressures.

On the other hand, it is to be observed that in many cases, the neck of the discharge-nozzle and the divergent portion which follows it are under a very low vacuum with respect to the atmosphere. The injection may in these cases be carried out by atmospheric air. An arrangement of this kind has been shown in Fig. 4 for the

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supply of the slot 20, which is coupled by a conduit 16 to a point situated on the downstream side of the measuring chamber, close to the outlet of the divergent portion 6a which follows this chamber, and at which the main flow is re-compressed.

It will, of course, be understood that modifications may be made to the forms of embodiment which have just been described above, in particular by the substitution of equivalent technical means, without thereby departing from the spirit or from the scope of the present invention.

What we claim is:

1. A supersonic wind-tunnel comprising a test chamber, a duct communicating with said chamber and having a convergent-divergent wall, means for circulating air through said duct and chamber, means providing a nozzle opening through said duct and chamber, means providing a nozzle in the form of a slot-like passage opening through said wall at the throat thereof and facing in an upstream direction, and controllable means for supplying pressure fluid to said nozzle, thereby forming in

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said throat a jet separating from said wall as it issues from said nozzle.

2. Wind-tunnel as claimed in claim 1 wherein the means providing a nozzle comprise successive adjacent slot-like passages facing in diverging directions.

3. Wind-tunnel as claimed in claim 2 wherein the slot-like passage farthest downstream faces in a downstream direction.

4. Wind-tunnel as claimed in claim 2 wherein the slot-like passages are supplied with pressure fluid from a common controllable supply means.

5. Wind-tunnel as claimed in claim 1 wherein the means providing a nozzle is orientable.

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