Jan. 19, 1954 J. A. CHALOM 2,666,279

NOZZLE FOR EXPANSION AND COMPRESSION OF GASES

Original Filed Jan. 17, 1949

Fig. 1

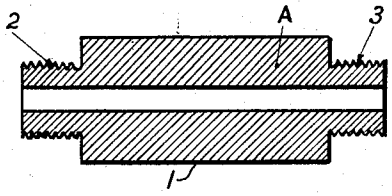


Fig. 2

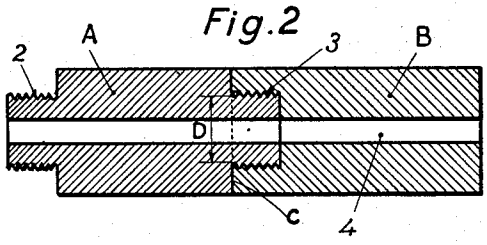


Fig. 4

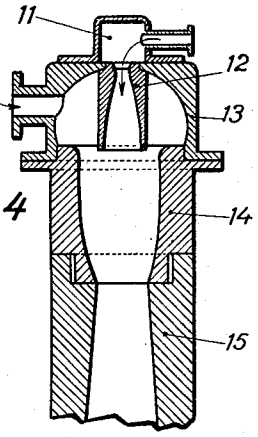


Fig. 5

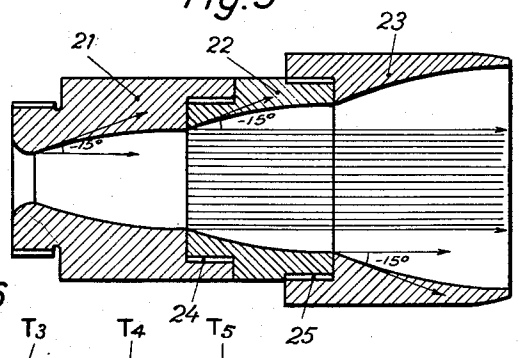


Fig. 3

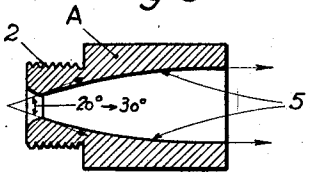


Fig. 6

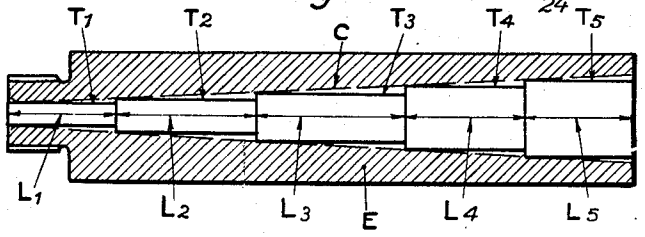
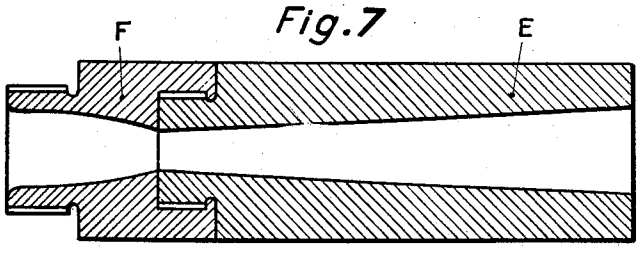


Fig. 7



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NOZZLE FOR EXPANSION AND COMPRESSION OF GASES

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Original application January 17, 1949, Serial No. 71,339, now Patent No. 2,583,726, dated January 29, 1952. Divided and this application March 3, 1950, Serial No. 147,461

Claims priority, application France January 26, 1948

1 Claim. (Cl. 51—11)

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This application is a division of application Serial No. 71,339, filed January 17, 1949, now Patent No. 2,583,726, granted January 29, 1952.

This invention relates to nozzles for the expansion and compression of gases and vapors, such as for instance the nozzles of supersonic ejectors.

It is an object of this invention to provide nozzles of the kind indicated above, in which the losses of energy are reduced to a minimum.

The invention is based on the following findings:

If a gas jet carrying sharp and abrasive particles such as sand grains is injected into a cylindrical bore, for instance by replacing the nozzle of a sand blast apparatus by a metal piece formed with a cylindrical bore, it will be found that there is quickly formed a hollow revolution surface with a concave profile facing the axis and which at a certain distance from the entrance of the bore attains a maximum diameter which merges into contracted and expanded sections. The length of the bore and its diameter determine, all other factors remaining constant, the diameter at each point and the distance from the entrance at which the largest diameter hollow is situated.

If the hollowed-out piece is cut through at the largest diameter, there is obtained a nozzle, the profile of which is concave toward the axis and is joined by means of an angular profile in its narrowest section with a rounded part of a minimum diameter only a little greater than that of the initial bore. A concave profile of this kind enables the streams of fluid expanded at maximum speed at the maximum section to travel in parallel and thus to reduce the shocks to a minimum.

At the neck of the nozzle where the cross-section is the lowest, while the speed of the fluid comes closest to the velocity of sound, the profiles are joined along an angular profile with a tangent angle at the maximum of more than 10 and up to 15 degrees. This type of profile, obtained by the automatic hollowing of the piece by a sand blast or the like differs definitely from the customary profiles in which as a rule opening cones of only about 7 degrees are used.

The new profile of far more rapid evolution leads to shorter nozzles, which is advantageous. By making use of these facts, and by systematic experimenting it becomes possible to calculate the elements of diameter and length of the bore to be obtained in predetermined cases.

The production of such a profile and its applications are illustrated diagrammatically by

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way of example in the drawings affixed to this specification and forming part thereof.

In the drawings

Fig. 1 is an axial section of a nozzle blank designed to be subjected to the hollowing-out treatment according to the invention.

Fig. 2 is a similar view of a blank fitted with an auxiliary piece before being treated.

Fig. 3 is the finished nozzle.

Fig. 4 is an axial section of an ejector fitted with an expansion and a super-sonic compression nozzle.

Fig. 5 illustrates the adaptation of the concave profile according to the invention to a multistage nozzle.

Fig. 6 shows a blank for the production of subsonic nozzles according to the invention by means of a modified treatment according to the invention, and

Fig. 7 shows a compression nozzle in which a super-sonic element of concave profile is combined with a sub-sonic expansion nozzle produced in accordance with the invention.

Referring to the drawings and first to Figs. 1 and 2, Fig. 1 shows a blank A of dimensions approximately calculated for the nozzle to be produced, being a cylinder 1 with threaded endpieces 2 and 3 of smaller diameter which serve for the provisional and the permanent mounting in place of the blank and the finished nozzle, respectively. The two threaded endpieces might of course be replaced by some other fixation means. The thread 3 is so chosen that the diameter at the bottom of the thread is equal to the diameter of the exhaust end of the nozzle to be produced. An auxiliary cylinder B of about equal length is screwed down on the endpiece 3 and the two united cylinders are now bored axially, the diameter of the bore being slightly smaller than the neck of the nozzle. The united pieces are then mounted by the threaded endpiece in the exhaust of a sand blower which is now started running. The said blast passing through the bore 4 hollows out the bore until the inner diameter of the bore in the end plane C of the body A becomes equal to the diameter of the endpiece 3. When this point is reached, the auxiliary cylinder drops and the blower is shut off. The body A is now hollowed out according to the profile 5, which is the one desired, being concave towards the nozzle axis in its super-sonic section and having, in the sections corresponding to the highest velocities, tangents substantially parallel to the axis, while for velocities near sound velocity, near the neck of the nozzle, the tangents

on the connecting section are inclined at angles, of more than 10 and up to 15 degrees, to the axis.

This sandblasting method thus allows of machining within very short periods of time and without any cautious handling very hard metals the use of which is necessitated by the very high temperature of the gases flowing through the nozzles.

The end of each operation is indicated automatically by the dropping off of the auxiliary cylinder B. The nozzle A can then be finished by filing the outer edge of the exhaust end and bringing the diameter of the neck to the exact measure required.

The ejector shown in Fig. 4 is formed with nozzles of concave profile serving for ejecting air or steam from condensers or other apparatus. It comprises a steam intake compartment 11, a super-sonic expansion nozzle 12 with concave profile, a suction box 13, a super-sonic compression nozzle 14 with concave profile and a subsonic diffuser 15. The end of the nozzle 12 is beveled and placed somewhat to the inner side of the intake end of the nozzle 14.

Owing to their concavities facing the axis of the nozzles, the profiles according to the invention offer a great variety of inclinations towards the axis, starting from a maximum at the neck to their disappearance at the widest opening, and allowing to obtain, by an association of such different profiles, a general profile which presents angle points with an angle of more than 10 and up to 15 degrees between the tangents on these points, common to two profiles. This is in direct contrast to the conventional profiles hitherto used which allowed only minute changes of inclination between two profiles which were themselves little inclined and lacked any valuable inclinations. Obviously this is an important result of the use of concave profiles according to the invention.

If a nozzle is for instance used for an expansion of steam to a predetermined lower pressure, it is known that, if this pressure rises, while all other conditions remain unchanged, the adhesion of the steam jet to the wall will cause the expansion to be lowered to a value which may be very much lower than the pressure which then obtains effectively, and that this expansion will be followed by a sudden recompression by shock wave, all this resulting in considerable losses of kinetic energy.

Since industrial apparatuses fitted with expansion nozzles must be able to function under more or less considerable changes of working conditions, such nozzles are as a rule made shorter than the length theoretically corresponding to mean conditions. However, if the loss of output suffered by a rising of the expansion pressure above these conditions is avoided, there exists another cause for losses by the undulatory flow at the exhaust when the expansion pressure is lower than the mean conditions of operation. These losses can also attain an important value.

In order to avoid these inconveniences, the combination of super-sonic concave profiles according to this invention allows me to give to the general profile of the nozzle a discontinuous curvature by abruptly varying the value of the angle of the tangent at the profile relative to the nozzle axis from its minimum value to its maximum value. One thus obtains a discontinuous profile composed of two or more curves opening towards the axis, the points where the different curves meet, being characterized by a double

value of the angle of the tangent on that point, one being substantially zero, the other one for instance 15 degrees. The angle points which are thus obtained between a certain number of sections of a nozzle corresponding to a certain number of exhaust conditions, by favoring the separation of the gas currents from certain values of exhaust conditions on, allow me to obtain, from the best adapted section on, parallel exhaust. This parallel exhaust flow then passes without any inconvenience through sections of larger diameter which have not much to do with the functioning of the nozzle. The figure shows schematically such an operation under conditions arising between the maximum pressure drop corresponding to the first element alone and the minimum pressure drop corresponding to the entire nozzle. This solution was not possible with the conical profiles of low angle apex in which one would have been limited to an insignificant change of angles. The solution thus results directly from the type of profile obtained by the method of fabrication according to this invention.

Fig. 5 illustrates diagrammatically the expansion nozzle of a steam ejector, according to the invention, in which the parts of which it is composed, are assembled by means of screw threaded sections machined as perfectly as possible so that the adjoining profiles merge into one another as perfectly as possible. The number of parts is a function of the range of aspiration pressures to be obtained, but it may also be dictated by the machining facilities available. Experience has shown that if the maximum section exceeds four times the minimum section, the period of time required for machining the profile of the nozzles by way of sandblasting as indicated above begins to become prohibitive. It is therefore advisable to compose the nozzle of the number of pieces which is closest to the quotient by 4 relative to the maximum and minimum sections of the entire nozzle.

Obviously, since the method according to the invention produces a concave profile of a novel type, it might be possible to produce by less economical machining methods of the classical kind nozzles which might come near to the profiles according to the invention, no matter whether the profile is simple or, as explained above, composed of a series of concave elements succeeding each other by definite angle points, corresponding at the parallel exhaust to the axis of a profile extended by the adjoining part, open at 20–30 degrees, of the next following profile.

Without departing from the invention, it is also possible to utilize modified forms of proceeding for the production of rather short concave profiles, for which the method according to the invention furnishes automatically the profiles with continuously varying curvature as explained above, which are useful for super-sonic expansion nozzles.

It is for instance possible, by laying down all the elements of importance in machining, such as the properties of the metal, the kind and size of the abrasive matter, the air pressure, the diameter and length of the section to be reamed, to synchronize the period of time required for obtaining a nozzle of the desired profile. Once this period has been established by tests, it will be sufficient to stop the sand blast at the end of this period. The concave profile with parallel gas exhaust is then obtained again and again without the necessity of a drop of material as in the modification first described.

On the other hand the method according to

this invention, by facilitating the hollowing out of the blanks, enables long profiles corresponding to sub-sonic velocities to be fabricated automatically. To this end a blank of the desired length may be pierced, not by a cylindrical bore, but by a hollow constituted by a plurality of coaxial cylindrical bores T_1, T_2, T_3 . . . (Fig. 6) of increasing diameters which succeed one another within the central section of the blank. The length L_1, L_2, L_3 . . . and the diameters of these cylindrical borings will be determined by tests or empirically.

Under these conditions there is obtained with the aid of the grinding blast a continuous oblong profile which closely follows the desired profile, and by synchronisation or by any other means announcing the end of the fabricating period, oblong sub-sonic profiles can be produced.

By combining, as shown in Fig. 7, a super-sonic diffuser F of concave profile with a sub-sonic diffuser E of oblong profile, a diffuser is obtained which will be capable of compressing a flowing gas from super-sonic velocities down to a velocity approaching zero.

The new method can be carried through with the aid of any suitable fluid, besides compressed air, for instance steam, and with any other suitable abrasive matter, besides sand. The form of the jet may be changed during operation, for instance near the end.

Various changes may be made in the performance of this invention and in the means employed for this purpose without departing from the invention or sacrificing the advantages thereof.

I claim:

A tubular multistage nozzle comprising as part of its boring a plurality of supersonic exhaust portions of concave profile in relation to the nozzle axis, arranged in series, said inlet portion having a substantially conically converging axial section ending in a throat having the smallest cross-section of the nozzle, the first exhaust portion which extends from said throat in the direction towards the exhaust end of the nozzle, having a profile concave in relation to the nozzle axis and being so formed near said throat that the tangent to it, starting from said throat, encloses with the nozzle axis an angle ranging between about ten and fifteen degrees, the second exhaust portion arranged in series with said first one having a profile concave in relation to the nozzle axis and starting with a cross-sectional area of passage about equal to the cross-sectional area of the end of said first exhaust portion, the tangent of the first part of said second exhaust portion enclosing with the nozzle axis an angle ranging between about ten and fifteen degrees and the tangents to the successive sections of said second exhaust portion enclosing with said axis successively smaller angles.

JOSEPH ARON CHALOM.

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