June 14, 1960 A. M. CADDELL 2,940,660

COMPRESSOR WITH AIR COOLER BETWEEN STAGES

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FIG. 1

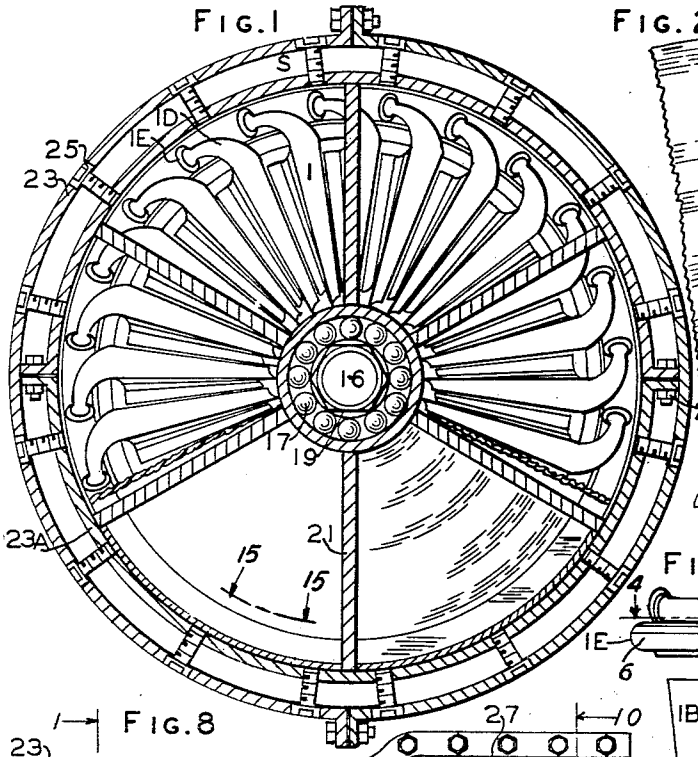


FIG. 2

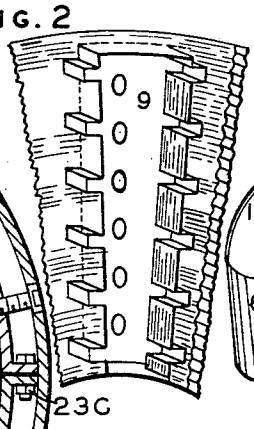


FIG. 3

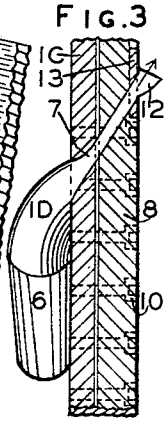


FIG. 4

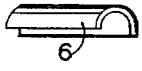


FIG. 5

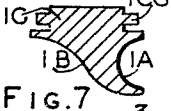


FIG. 6

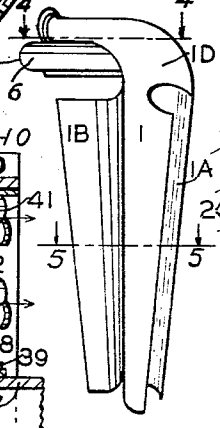


FIG. 7

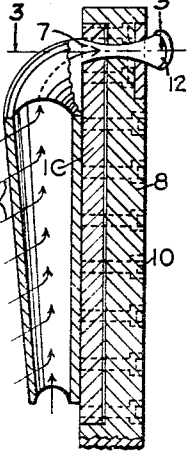


FIG. 8

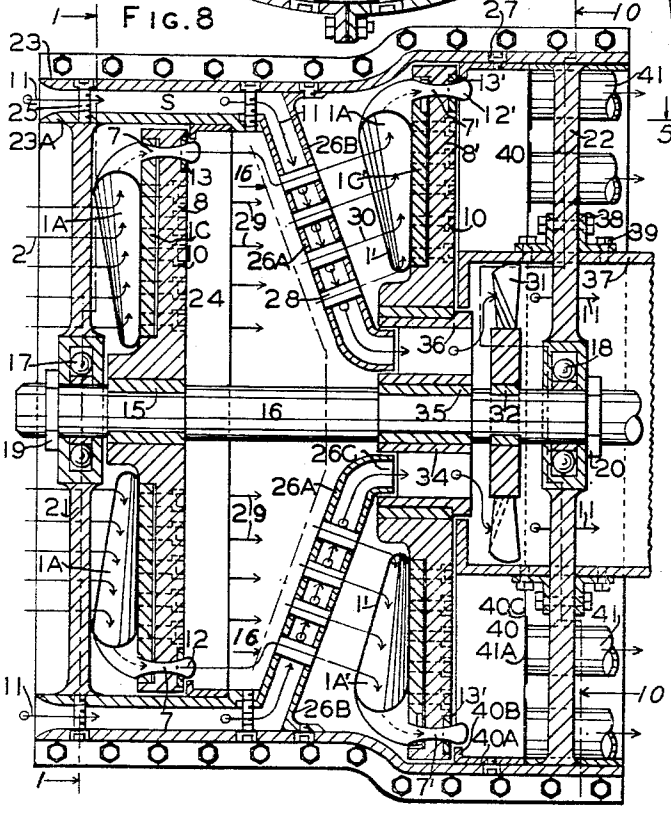
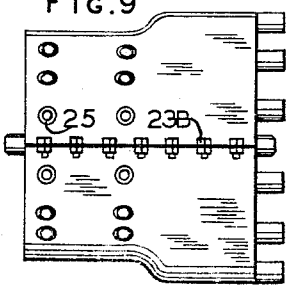


FIG. 9



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FIG. 10

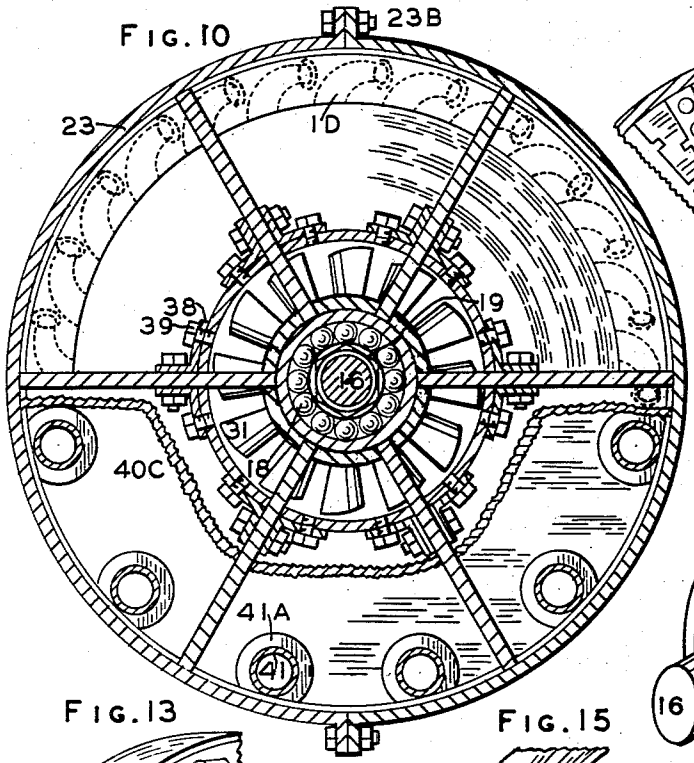


FIG. 11

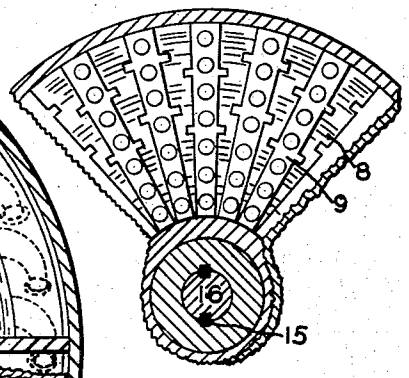


FIG. 12

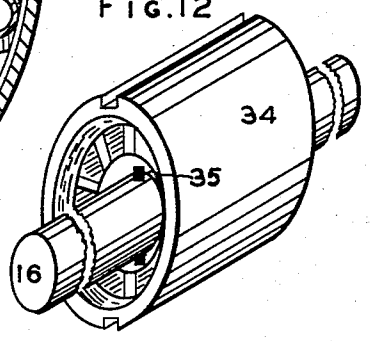


FIG. 13

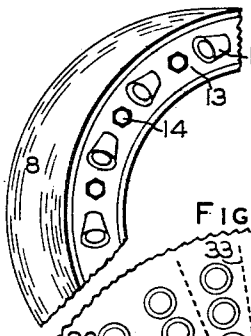


FIG. 14

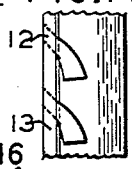


FIG. 15

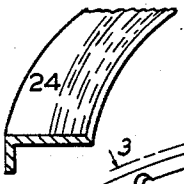


FIG. 16

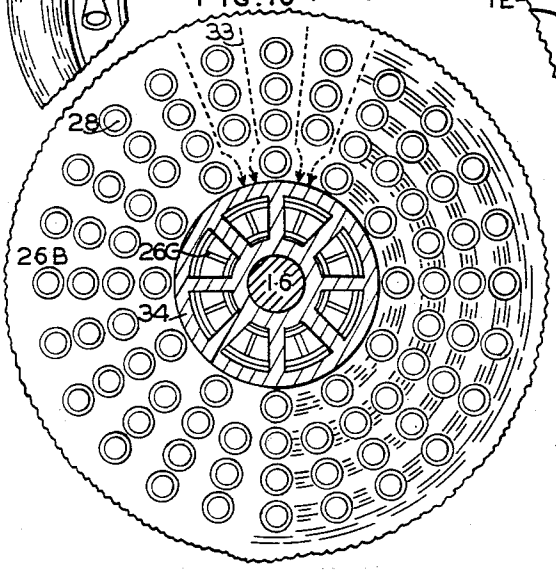
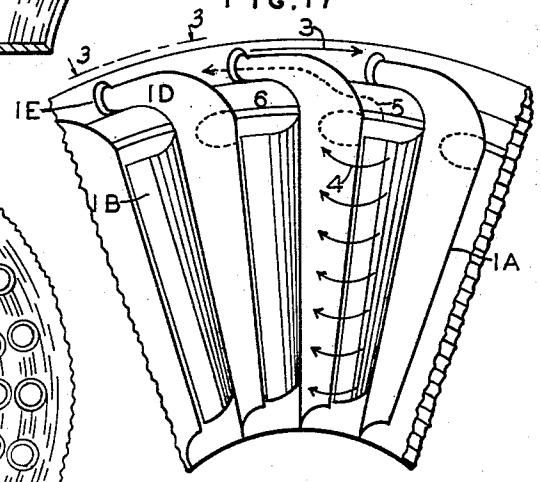


FIG. 17



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United States Patent Office 2,940,660 Patented June 14, 1960

2,940,660

COMPRESSOR WITH AIR COOLER BETWEEN STAGES

Alfred M. Caddell, 1318 W. Hunting Park Ave., Philadelphia, Pa.

Original application Apr. 11, 1956, Ser. No. 577,567. Divided and this application June 5, 1957, Ser. No. 663,688

7 Claims. (Cl. 230—130)

This application is taken as a division from pending application entitled Centrifugal Fluid Compressor With Axial Delivery, filed April 11, 1956, Serial No. 577,567.

In accordance with Boyle's law of gases, if air is compressed into one-half its original volume without change in temperature, its pressure will amout to twice what it was before compression. But it is not possible to compress air without increasing its temperature unless it is done very slowly to allow heat to escape. Therefore, if, for example, 60 degrees F. air is compressed at high speed into half its original volume, its temperature will rise to at least 120 degrees F., not taking into account the heat induced by friction; if compressed to one-quarter of its original volume (4 to 1 compression ratio) its temperature will rise to 240 degrees F., and so on.

However, if air of too high a temperature is made available to an engine's combustors, such high temperature will seriously affect the output efficiency of the engine. For too high temperature means too highly expanded air with consequent deficiency in oxygen which, in turn, means insufficiency of flame temperature and a drop in expansion pressure against a turbine. Therefore, to maintain high oxygen content and high compression ratio in combustion air, interstage cooling of the initially compressed air becomes a must.

Fig. 1 is a frontal, composite view of the compressor taken on the lines 1—1, Fig. 8.

Fig. 2 is an enlarged view of a single recess, together with side indentations, formed in the forward wall of the rotor's disc for the housing of the base and lugs of a single vane structure, shown in Figs. 1, 6, 8 and 17.

Fig. 3 is a top view of a section of the disc showing in part the base of a structure and, the hooded part of said structure, taken on the lines 3—3, Fig. 17.

Fig. 4 is a three-quarter view of a U-channel member identified by 6, taken on the lines 4—4, Fig. 6.

Fig. 5 is a sectional view showing the construction of a concavo-concave vane structure and its lugs, taken on the lines 5—5, Fig. 6.

Fig. 6 is a three-quarter view of a single vane structure showing the pumping side thereof, the deflecting side, the hood formation and the U-channel member.

Fig. 7 is an enlarged side view of a single concavo-concave vane structure, showing its base mounted in position within its recess in the forward face of the disc.

Fig. 8 is a cross-sectional side view of the complete compressor, showing the components thereof in position and the flow of air therethrough, including interstage cooling by ambient temperature air.

Fig. 9 is a half-size, external side view of the compressor.

Fig. 10 is a composite view of the compressor, looking from the rear, taken on the lines 10—10, Fig. 8.

Fig. 11 is a partial view of a disc showing frontally a number of recesses in the forward face thereof.

Fig. 12 is a three-quarter view of the spider formation identified as 34 in this view and in Fig. 8 in functioning position.

Fig. 13 is a partial three-quarter view showing plate 13, which carries a plurality of nozzles 12, Figs. 3, 7, 8, 13 and 14.

Fig. 14 is a partial view, looking downward on the inner surface of rim, of flange 24 mounted in a recess in disc 8 and shown in Fig. 8.

Fig. 15 is a partial view of flanged rim 24 shown in position in Fig. 8.

Fig. 16 is a partial view of the interstage cooling means, taken on the lines 16—16, Fig. 8.

Fig. 17 is an enlarged view of a group of concavo-concave vane structures shown in Fig. 1. Arrows show their construction and functioning.

As shown in Figs. 1 and 8, outer casing 23 is of double-walled construction at its forward end, wall 23A encompassing rotor disc 8 and flanged rim 24, Figs. 8 and 15, which comprises the first stage of compression. As shown also in Figs. 1, 8 and 9, walls 23 and 23A are spatially joined to each other by a plurality of bolts 25.

By means of the thus created space, identified as S, between said casing walls, cooling air is channeled into the interior of the compressor, as per arrows 11, which have small circles on their trailing ends to distinguish them from the arrows indicating the flow of compressed air through the compressor. Whereas space S comprises the intake of the interstage cooling means, double-wall, funnel-like structure, the forward wall of which is identified as 26A and the rear wall as 26B, comprises the means whereby heat built up in the air compressed by the first rotor is transferred to cooling air flowing between these walls. An almost complete view of this funnel-like structure is shown in Fig. 16, the small diameter termini of said walls being visible within the confines of spider formation 34 shown centrally in this figure and, later described.

As shown in Fig. 8, the foremost wall of this funnel structure, 26A, is secured to inner casing wall 23A by means of spacing screwbolts 25, whereas wall 26B, the extreme radial end of which deflects air downwardly between the funnel walls, is secured to outer casing wall 23 by a plurality of bolts 27. The inner terminals of these walls are secured to each other by spoke formation 26C, shown in Figs. 8 and 16, the spoke members thereof integrally spacing and securing each wall to the other.

To permit passage of the compressed air from the first stage of compression to the second stage, a plurality of tubes 28, positioned in ring-like formation, traverse and are made secure to funnel-like walls 26A and 26B, shown in Figs. 8 and 16.

As indicated by directional arrows 29, the air compressed by the first rotor strikes the forward side of wall 26A, then flows through tubes 28 and, as per arrows 30, enters pumping vane 1A' of the structures mounted in recesses in the forward wall of disc 8' of the second rotor assembly.

During the passage of the compressed air along wall 26A and through tubes 28, cooling air is entering through space S and flowing inwardly between the funnel-like walls. As will be apparent, tubes 28 are exposed to this cooling air stream, and the compressed air being conveyed by these tubes surrenders its heat to the cooling air flowing between and around the tubes before entry to the vane structures of the second-stage rotor. To make available a sufficient flow of cooling air in case of stationary gas turbine operation, fan 31, shown in Figs. 8 and 10, is keyed as at 32 to shaft 16. As will be obvious, should the compressor be employed in connection with a turbine for turboprop or jet operation, ram pressure would deliver a constant and sufficient supply of cooling air for heat transfer purposes. The flow of cooling air around and between tubes 28 is indicated by arrows 33, shown in dotted outline, Fig. 16.

Spider construction **34**, an enlarged three-quarter view of which is shown in Fig. 12, is keyed to shaft **16** as at **35**, Figs. 8 and 12, and disc **8'**, in turn, encompasses and is keyed to this spider construction, as at **36**. As will be apparent in Figs. 8 and 12, air passageways are formed through spider **34** to permit the flow of cooling air therethrough simultaneously with the passage of compressed air through tubes **28**.

As previously mentioned, Figs. 8 and 16 show the terminals of walls **26A** and **26B** extending into the confines of spider **34**, a close operating tolerance prevailing between the revolving spider and the stationary funnel-like structure. This close tolerance is for the purpose of maintaining separation of the cooling and the compressed air. Upon receiving momentum via fan **31**, the cooling air is directed rearwardly through duct **37** to any desired destination. This duct is secured to open framework construction **22** by means of brackets **38** which are secured to the construction by screw-bolts **39**.

As will be seen in Fig. 8, disc **8'** extends radially a greater distance than that of disc **8** and, therefore, vane structures **1'**, which are identical in construction to those of vanes **1**, provide a very strong centrifugal, or suction, pull upon the compressed air passing through tubes **28**, thus relieving the pressure of air from within annular member **24**. Channels **7'** are formed through base **1C'** of vane structures **1'** and communicate with nozzles **12'** mounted in ring-like flange **13'** which is positioned near the periphery of disc **8'** similarly to the construction as described in connection with the first-mentioned rotor.

Chamber **40** is mounted around the inner wall of casing **23**. This chamber consists of annular member **40A** and a flange **40B**, which extends inwardly to within close proximity of nozzles **12'**, and a wall **40C**. The compressed air from nozzles **12'**, mounted in plate **13'**, is discharged within the area defined by said annular member, flange and rear wall in a direction opposite to that of rotation, thus providing additional reactive drive to the compressor assembly.

Obviously, as many stages of compression as may be desired can be added in this type of compressor. Annular ducts **41**, shown in Figs. 8 and 10, are provided to convey the air compressed by the last stage of compression to any desired destination, such as the combustors of a gas turbine engine. These ducts are secured to rear wall **40C** by flange means, such as at **41A**, Figs. 8 and 10.

Having described my invention, I claim:

1. In a centrifugal fluid compressor having stages for increasing the compression ratio of air, an annular casing open to atmosphere across its frontal area said casing being comprised of a construction having two spaced walls, a first stage of compression having a rotor mounted for rotation therein, said rotor being comprised of a shaft, a disc having a forward and a rear wall and being mounted thereupon, a plurality of two-sided structures having bases removably fixed in said forward wall, said structures extending outwardly into free air and having on one side concave vanes having inner and outer ends for pumping air upstream and on their other side a surface for deflecting air into the pumping vane following next in rotation, horn-like hoods formed at the peripheries of said pumping vanes and continuing angularly thereto in a direction opposite to that of rotation, said hoods converging to form an orifice at the small end of said horn-like construction for the compression of said air, channels formed diagonally through said bases and through said disc, an annular plate mounted in the rear wall of said disc adjacent its periphery, a plurality of open-end nozzles extending through said plate for discharging said air in an opposite-to-rotation direction, a ring-like open-end member secured to the inner wall of said casing for receiving against the inner surface thereof the air discharged from said nozzles, said inner wall encompassing the first stage of compression, the outer wall continuing rearwardly with respect to said first stage and at an increased radius relative thereto to form a housing, a second stage of compression mounted in said housing and having fluid connection with said first stage of compression, an interstage cooling system positioned between said stages for absorbing heat from the air compressed in the first stage prior to its entry into said second stage, said system being comprised of said spaced double walls and walls merging therewith and extending inwardly to form a double-walled funnel-like construction, a spider construction mounted concentrically around said shaft, a second rotor fixedly mounted around said spider construction to comprise said second stage of compression, said latter rotor being identical in construction to and having a radius greater than that of the first-mentioned rotor for the further compression of said air therein, a chamber defined by walls mounted on the inner wall of said housing rearwardly of said second rotor for receiving said further compressed air and a plurality of conduits extending through the rear wall of said chamber for conveying said compressed air axially from the compressor.

2. In a compressor as described in claim 1, an annular member secured to the inner wall of the casing surrounding the first stage of compression, said member having a flange extending inwardly adjacent the rear wall of the disc of said first stage, a plurality of nozzles in said disc protruding diagonally rearward therefrom said flange having a close tolerance relation with said disc and closely encircling said nozzles, said member being open on the end opposite said flange for the axial passage of air discharged from said nozzles in said opposite-to-rotation direction.

3. In a compressor as described in claim 1, an annular chamber comprised of walls abutting the inner wall of the housing surrounding the second stage of compression, a flange extending inwardly on the end of said chamber adjacent the disc of said second stage, a plurality of nozzles in said disc protruding diagonally rearward therefrom, said flange having a close tolerance relation with said disc and closely encircling said nozzles, the wall of said chamber opposite said flange having a plurality of conduits extending therethrough for the axial conveyance of air discharged by said nozzles in said opposite-to-rotation direction.

4. An interstage cooling system in a compressor having stages for increasing the compression of air, said system being comprised of a construction having two annular walls spaced from each other and open to atmosphere, said walls forming a casing for said compressor, a forward and a rear wall spaced from each other to form a double-walled funnel-like structure, the wide end thereof merging with said two annular walls and the narrow end terminating in flanges, a plurality of spokes joining said narrow end to form air passageways therebetween, a first stage of compression having a rotor mounted on a shaft for rotation in said casing, said rotor having vane structures for pumping air upstream and compressing it prior to its discharge in a direction opposite to that of rotation toward the forward wall of said funnel-like construction, a spider construction fixedly and concentrically mounted on said shaft rearwardly of said funnel-like construction, a second stage of compression comprised of a rotor fixedly mounted on said spider construction and having fluid connection with said first stage of compression, said latter rotor having a formation identical with that of the first stage but having a greater radius relative thereto for exerting a suction pull on the fluid discharged from said first-stage rotor, a recess in said spider construction for close tolerance reception of said flanges therein, said spider construction having passageways extending throughout its length, suction means mounted on said shaft for drawing cooling air from atmosphere between said annular casing walls, between said funnel-like walls, between said spider construction and expelling it rearwardly from said compressor.

5. In a compressor having an interstage cooling sys-

tem as described in claim 4, a plurality of holes extending transversely through said funnel-like structure a like number of open-end tubes inserted in said holes and made flush with the outer surfaces of said forward and rear walls for the conveyance of air discharged from the rotor of the first stage of compression into the area occupied by the rotor of the second stage of compression, said open-end tubes being spaced between said funnel-like walls to permit said cooling air to flow therearound.

6. In a centrifugal compressor as described in claim 1, said spider construction being comprised of an inner and an outer wall spaced by elongated spoke-like members formed integrally therewith and being positioned therebetween throughout substantially the full length of said construction, said members being equi-spaced to provide air-flow channels therebetween, a recess formed in one end of said outer wall for freely receiving said double-walled funnel-like construction, said construction being open to atmosphere at its forward end and terminating in spaced, concentric flanges that extend into said recess and have close tolerance relation therewith, a keyway formed in said shaft and in the outer surface of said inner wall for the insertion of a key therein, a keyway formed on the outer surface of the outer wall and in the base of said second stage disc for the insertion of a key therein, said keys and keyways comprising a means for transmitting power from said shaft to said disc for the rotation of said second rotor.

7. In a centrifugal air compressor as described in claim 1 said interstage cooling system comprising, an airflow passageway formed between the walls comprising said casing and continuing between the walls comprising said funnel-like construction, said latter walls extending rearwardly inward from their larger diametered ends toward their smaller diametered ends and terminating in concentrically spaced flanges, a plurality of interconnecting spokes connecting said flanges to each other, a plurality of tubes positioned in ring-like formation and extending transversely through the forward wall of said funnel-like construction, through the space between said walls and through the rear wall thereof for conveying compressed air discharged from the first rotor to the area swept by the pumping vanes of the second rotor, a fan mounted on said shaft aft of said spider construction for speeding the flow of atmospheric air between said casing walls, between said funnel walls and between the spoke-like formations of said spider construction simultaneously with the flow of compressed air across the forward wall of said funnel-like construction and through the transversely positioned tubes exposed in said channel to the flow of said atmospheric air therearound.

No references cited.