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(54) PROCESS FOR CONTROLLING THERMODYNAMIC PROCESSES IN A VORTEX TUBE, VORTEX TUBE FOR CARRYING OUT THE SAID PROCESS AND THE USE THEREOF.

(57) A process is proposed for controlling thermodynamic processes in a vortex tube by directing a stream of fluid under pressure into a nozzle inlet (4). In order to obtain the desired characteristics in the cold and hot streams without altering the construction of the tube, the fluid stream in the nozzle inlet (4) is controlled by altering the parameters of state of the thermodynamic processes taking place in the vortex tube. Control of the stream in the nozzle inlet (4) is effected by altering the path length of the stream, by splitting the stream into two rotating streams with their own respective path lengths, or by adjusting the speed, flow-rate and pressure of the stream at the entrance to the nozzle inlet. Controlling the stream in the vortex tube is effected by means of the helix (10) mounted in the cavity of the nozzle inlet (4) in such a way that its position in relation to the inlet stream can be altered, and a baffle (40) situated at the entrance to the inlet aperture (6). The invention can be used in industry, for example in the machining of components, the refrigeration industry and in medicine.

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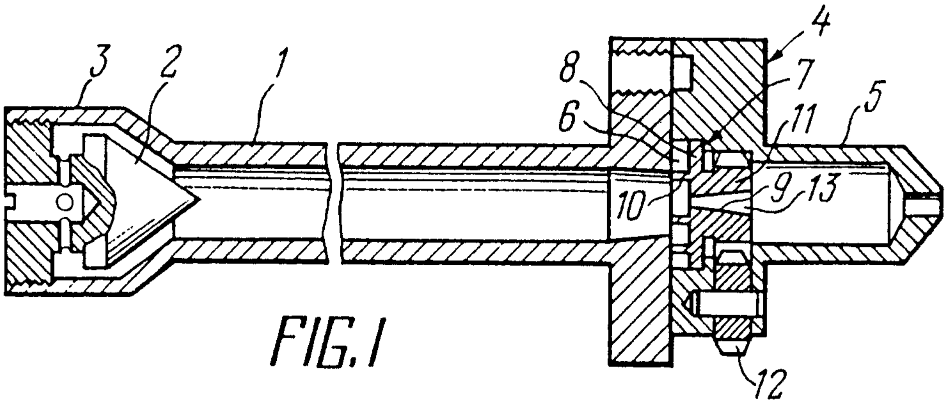

FIG.1

Field of the Invention

The present invention relates to the control and use of fluid media and, more specifically, to a method of controlling thermodynamic processes in a vortex tube, the vortex tube for effecting this method and its application.

State of the Art

The development of environment-friendly or environmentally benign production processes and technologies posese a key problem today. Therefore, it is of current interest to create mechods and devices for obtaining environment-friendly "working fluids" useful to man,which are used in undustry,agriculture and medicine.

For instance, water and oil-based fluids,called lubricant-coolants,are commonly used in the metal -working industry to cool metals being worked, and fluorine - and cholorine - bearing agents,called freons, are used in the refrigeration industry, to state and conserve products. Both agents are harmful by their impact on man and the enviroment.

One of possible solutions of this problem is to use environment-friendly fluids in industry, agriculture and medicine,which are obtained with the aid of vortex tubes using the Rank effect.

Known in the art is a method of controlling thermodynamic processes in a vortex tube using the Rank effect (A.V.Martynov and V.M. Brodyansri "What is a Vortex tube", Energia Publishers, 1976,pp.6 - 11), reseding in that a flow of pressurized fluid is fed to a nozzle inlet. In the nozzle inlet the fluid flow is expanded,twisted and delivired to a working tube, wherein the fluid flow is aplit into a cold and hot flows. The cold flow is with drawn via a cold flow branch, and the hot flow is conducted away via a valve from the opposite end of the working tube. Changing the position of the valve in the hot flow branch and the nozzle inlet pressure, the parameters of thermodynamic processes in the vortex tube are regulated, mostly these are the hot and cold flow temreraturs,flow rate and the flow efflux speed.

Known in the art is the design of a vortex tube having a working tube whose one end communicates via a valve with the hot flow discharge branch. The other end of the working tube communicates with a nozzle inlet arrenged coaxially to the working tube adjacent thereto and limited from the side opposite to the working tube by a diaphragm with an aperture though which the fluid is conducted away into the cold flow branch.

The fortex tube operates as follows.

A pressurized fluid flow is fed via an admission port into the nozzle inlet.The compressed fluid is expanded and split into cold and hot flows,first in the nozzle inlet and then in the working tube. The cold fluid flow is carried off through the diaphragm aperture in the cold flow branch.The hot fluid flow is carried off from the opposite end of the working tube via hte valve into the hot flow branch. Changing the position of the valve one can vary the rate and temperatures of the fluid cold and hot flows.In order to lower the temperature of the cold flow it is necessary to reduce the cold flow rate,using the valve so as to provide a larger flow section at the hot end of the working tube.Concersely,in order to increase the temperature of the hot flow the valve is used to close down the working tube sechion, there by reducing the flow section.

Cold and hot flows are formed only if the energy of an incoming flow in the vortex tube is distributed so that certain amount there of is carried off the cold flow and is imparted to the hot one. Energy redistribution is the result of complex thermodynamic processes occurring in the vortex tube.

Due to their unigue properties vortex tubes are extensively used in various industries,agriculture and medicine.

However,each design of the vortex tube provides for a limited possibility of alterring the parameters of cold and hot flows and in order to obtain diffirent parameters of the flows one has to change the design of the vortex tube which, in turn,restricts the fields of ots application.

Disclosure of the Invention

The invention is based on the problem of providing such a method of controlling thermodynamic processes in a vortex tube and the vortex tube effecting this mectod,in which the structural changes of the vortex tube make it possible to regulate, within a broad range,thermodynamic processes taking place in the vortex tube subject to a technical problem set forth,given constant geometric parameters of the vortex tube.

This problem is solved in the mechod of controlling thermodymamic processes in the vortex tube,consisting in the that the pressurized fluid flow is fed to the nozzel inlet,as the expanding fluid flow moves in the nozzele inlet it is twisted and enters the working tube,wherein the twisted fluid flow is split into cold and hot flows, and each of the flows is with drawn via the cold and hot flows branches, respectively. In so doing, one controls the parametrs of a thermodynamic process by regulating the fluid hot flow rate in the hot flow branch,charakterized in that subject to reguired characteristics of the fluid cold and hot flows, the fluid flow is controllied in the nozzle inlet by varying the parameters of thermodynamic processes occuring in the working tube.

It is expedient that the fluid flow be contrilled in the nozzele inlet by regulating the fluid flow path length in the nozzle inlet.

It is also expedient that the fluid flow be controlled in the nozzele inlet by splitting in into, as least,two rotating flows, each having a diffirent path length.

It is also expedient that the fluid flow be controlled by regulating the efflux speed, the flow rate and direction of the fluid flow at the entrance to the nozzel inlet.

The regulation of the fluid flow in the nozzel inlet enables one to obtain a broadrange of controlling the characteristics of the hot and cold flow at the outlet of the vortex tube without structural changes of its elements and control these characteristics,given the variation of the fluid flow rate or presure with the consumer.

In order to obtain a colder flow it is possible, in addition, to alter the speed of movement of the near-wall layers of a hot flow in the working tube.

In order to enhance the intensity of colling an entity, it is desirable that the cold flow efflux speed be regulated additionally at the cold flow branch outlet.

It is possible to additionally increase the convective heat transfer of the near-wall layers of fluid in the working tube to expand the limits of variation of the cold and hot flows.

In certain cases it is expedient that the fluid cold and/or hot flows be ionized additionally.

It is possible to alter the composition of cold and/or hot flows during the ionization of any fluid flows.

The ionization of cold and hot flows enhances the chemical impact of the fluid flow upon the entity,altering the conditions of contact between the surfaces or atabilizing the condition of the entity proper.

In order to change physico-chemical properties of the suter layer of the entity one should introduce addittionaly upon ionization a substance of a different state of aggregation.

It is possible to use gases andor liquids and mixtures there of as a fluid.

The problem of the invention is solved also by that in the vortex tube containing a working tube,one end of which communicates via a control valve with a hot flow dischange branch, and the other end with a nozzele inlet coaxially disposed there to,which is connected to the cold flow dischange branch, and via the admission port- to the source of fluid fed under pressure to the nozzle inlet,according to the invention, the nozzle inlet is provided with means controlling the fluid flow in the nozzele inlet subject to required characteristics of the cold and hot flows,varing the parametrs of thermodynamic processesoccurring in the vortex tube.

It is expedient that the nozzele inlet should be made in the form of a cylindrical sleeve with an admission port,one end of which should be connected to the working tube,and the other end should be covered by a diaphragm with a central aperture/opening,and a flat spiral, serving as means to control the fluid flow in the nozzle inlet,should be rigidly secured by one of its ease on the end surface of said diaphragm facing the working tube in the cylindrical sleeve,said diaphragm should be arranged with the possibility of turning around its axis.

It is possible to make the nozzele inlet in the form of a cylindrical sleeve with an admission port,one end of which should be connected to the working tube,andcylindrical sleeveswith a flanging,which serve to control the fluid flow,should bearranged in the cylindical sleeve coaxially and carableof turning with respect to each other and concentrically relative to thecylindrical sleeves,theone with a larges diameter should have a projection,and the cylindrical sleeve of a smaller diametre should have a groove at the ends facing the working tube,in so doing,the opening in the cylindrical sleeve with a smaller diameter serves as a duct to dischange the fluid cold flow to the cold flow branch.

It is possible that the cylindrical sleeves with flangings be arranged so as to be capable of telescopically moving with respect to each other.

It is necessary that the outside radius of the projection on the cylindrical sleeve with a langer diameter should be made smaller than the outside radius of the sleeve along the entire height of the projection.

In some cases itis possible to make the nozzle inlet operating in the form of an oblique Laval nozzle,in the short section of which a damper should be mounted at the entrance to the nozzele inlet,capable of rotating relative ti the fluid flow being fed.

This embodiment of the nozzle inlet makes the vortex tube an all-purpose one,independent of the user's conductions and allows for different combinations as to the rate,temperature and efflux speed of the fluid flow without changing geometric parametrs of the tube perse,given varing conductions of the user.

In order to increase the fluid efflux rate in the nozzle inlet, it is expedient that the internal surface of the cylindrical sleeveshould be made from material with a low friction coefficient.

It is possible that part of the outer surface of the working tube from the side of the hot flow branch be made developed, providing a convective exchange of the near-wall flow of fluid with the environment.

It is also possible that part of the working tube surface from the side of the hot flow branch be made corrugated,providing a change in the lenght of the path of the near-wall flow of fluid and its convective exchange.

In order to provide more possibilities for controllingthe spped and rate of the hot flow,the control valve of the hot flow dischange branch may made in the form of a coupling nut,screwed on the workung tube,and openings should be made at the end of sade tube at the level of the working tube near-wall level along the radius,and a confuser-diffuser nozzle with an adjustable annular gapshould be connected to the end of the coupling nut with the aid of a flange,in so doing,it is expendient that openings should be made in the flange,which correcpond to the radius of the coupling nut, and the nut and flange be mounted so as to ratate around the common central axis.

In order to control the speed,flow rate and the pitch of the tone of the fluid flow,it is desirable that the outlet part of the cold flow branch be made in the form of a twin Laval nozzle with a varing section of the second narrowing.

It is expendient that the fluid hot flow branch be made in the form of a set of cylindrical sleeves arrenged in a single cylindrical sleeve and each of the cylindrical sleeves be fitted with its own nozzle inlet,providing a required rate of the cold fluid flow and a smooth variation of temperature in the branches.

It is expedient that the vortex tube be additionally furnished with an ionizer to provide ionization of the cold and/or hot fluid flow.

It is possible that the ionizer be made as two electrodes connected to a power source,one electrode being the cylindrical part of the cold and/or hot flow branch with a ring electrode disposed at its end,and the other electrode being a corona dischange initiator,mounted inside the cold and/or hot flow branch,and it is expendient the initiator be connected either to the positive or negative pole of the power source.

It is possible the corona dischange initiator be made in the form of a needle stem on the external surface of which there should be arranged needle tags equal in height.

It is also possible to make the corona discharge initiator as a sinusoid.

It is possible to position the corona dischange initiator opposite or along the direction of the cold and/or hot fluid flow.

It is appropriate that a dielectric grid with an arbitrary size of cells should be installed upward of the corona dischange initiator.

It is also possible to apply an emission coating on the inner surface of the cylindrical part of the hot and/or cold flow branches in the zone of the arrangement of the corona dischange initiator.

It is expedient that a temperature sensitive element should be mounted t the ionizer output, and connected to a power source via a matching amplifier and a nolinear feedback.

The provision of the vortex tube with an ionizer and the shape of the initiators ensure a reguired degree of ionization of the flow subject to temperature,flow rate and pressure in the cold and/or hot flow branches.

In order to feed substances of a different state of aggregation to the cold and/or hot flows,it is appropriate that an ejector should be mounted at the cold and/or hot flow branch outlet.

It is possible to install the ejector at the ionizer outlet,which ensures the supply of the substances of a different state of aggregation to the cold and/or hot ionized flows.

It is possible to use the vortex tube as means to cool the outting zone in metal outting machines.

When using the vortex tube to cool the metal outting machine outting zone, a flexible hose with two exhaust ducts should be connected to the cold flow branch, a cold flow being fed in one duct to the outtting zone along the front surface of the otter,and also the cold flow being fed through the other exhaust duct to the gap between the article being machied and the rear surface of the outter, treatment being effected both by ionized and a simple cold flow.

It is possible to connect the ionized cold flow branch to a colling chamber,ensuring the storage of organic and inorganic agents and products.

It is also possible to connect the hot flow branch to the chamber, there by heating the chamber or heating the latter with its ionization.

Brief Description of Drawings

The invention will now be described by means of exemplary enbodiments there of,reference being made to the accompaning drawings, in which:

Fig.1 Shows a vortex tube with one of possible embouduments of the nozzle inlet, according to the invention;
Fig.2,3,4 are possible variants of the position of a spiral relative to the admission port in the nozzele inlet;
Fig.5 is a vaeiant of the diaphragm;
Fig.6 is a longitudinal section of the vortex tube with another variant of the nozzle inlet;
Fig 7,8 are possible variants of the position of cylindrical sleeves relative to the admission port in the nozzle inlet;
Fig 9,10,11 is the configuration of sleeves;
Fig 12 is the same as in Fig 5 with the arrangement of sleeve flangings on the outer surface of the vortex tube;
Fig 13 is a variant of the admission port in the form of a Laval nozzle;
Fig 14 is a variant of the duct to with draw the fluid hot flow;
Fig 15 is a variant of the duct to with draw the fluid cold flow;
Fig 16 is a variant of the hot flow branch;
Fig 17 is the vortex tube with ionizers installed in the cold and hot flow branches;
Fig 16 is a variant of the hot flow branch;
Fig 17 is the vortex tube with ionizers installed in the cold and hot flow branhes;
Fig 18,19 are variants of the initiator;
Fig 20,21,22 are variants of the ionizer;
Fig 23 is the vortex tube with an ejector;
Fig 24 is a variant of using the vortex to machine parts;
Fig 25 is a variant of using the vortex tube to cool the cooling chamber.

Detailed Description of the Invention

The method of controlling thermodynamic processes in a vortex tube based on the Rank effect,according to the invention,consists in that the flow of fluid is fed under pressure and tangentially via the admission port to the nozzle inlet. In the nozzle inlet an expanding flow of fluid is twisted and enters the working tube,where it is split into a cold and hot flows and each of them is dischanged via the cold and hot flow branches,respectively.

Subject to reguired characteristics of hot and cold flows thermodynamic processes in the vortex tube are normally controlled by regulating the hot flow rate.However,the method of the invention,given the same structure of the vortex tube,additionally controls the parameter s of a thermodynamic process in the working tube,regulating the fluid flow in the nozzle inlet per se,namely,changingthe lenght of the path of the fluid rotating flow in the nozzleinlet,splitting the fluid flow to, at least,two rotating flows,each having its own path/lenght,as well as regulating the efflux speed,the flow rate and direction of the fluid flow in the admission port of the nozzle inlet.

In addition,thermodynamic processes in the working tube are controlled by regulating the efflux speed of the cold and/or hot flows at the vortex tube outlet.

The efficiency of the vortex tube operation is enhanced by increasing the heat transfer from the near-wall layers of the fluidvortex flow in the working tube or by altering the speed of movement of the near-wall layrers of the hot flow.

In some cases,subject to the selection of an entity which is to be affected, hot and/or cold fluid flowsare ionized,varying the degree of ionization of the flow depending on its temperature.

Besides,prior to ionization or in the process of the latter,if necessary,the composition of the cold and/or hot flows is altered,and following the ionization an agent of a differentstate of aggregation is introduced in any of the fluid flows,changing the physico-chemical properties of the outer layer of an entity affected by the flow.

Subject to an objective set forth,hot and cold ionized flows of different composition are mixed in any ratio.

Used as a gaseuos mediom are air, argon, neon, krypton, hydrogen, carbon tetrachloride, carbon dioxide, nitrogen and other reguired fluids.

The method will beccome more apparent by describing the operation of devices accomplishing the given method.

The vortex tube effecting the method accorting to the invention,has a working tube 1 (Fig.1),one end of which is connected via a valve 2 to a hot fluid flow dischange branch 3, and the other end - to a vortex inlet 4,mounted coaxially to the working tube 1,and connected to the cold fluid flow dischange branch 5.

The pressurized fluid is fed to the vortex inlet 4 from a source through an admission port 6 (Fig.2,3,4) disposed tangentially to the nozzle inlet 4 (Fig.1). The nozzle oinlet 4 is fitted with means providing, subject to the reguired outlet characteristics of the cold and hot flows, the alteration of the nature of movement of the fluid flow directly in the nozzle inlet 4.

Prior to the description of possible structural embodiments of the nozzle inlet 4 let us consider thermodynamic processes taking place in the vortex tube.

The first condition,necessary for the vortex tube operation, is the presence of a flow rotating there in.In any rotating flow the speed of movement of an elementary fluid flow in each point may be represented as the sum of components, namely,tengential,axial and radial velocities. The tangential velocity characterizas the intensity of a rotating flow;axial - the axial motion of the flow along the working tube 1;and,lastly,radial vilocity characterizes the movement of the fluid flow along the radius of the tube 1.

The fluif flow in the working tube 1 of the vortex tube is rotated by feeding pressurized fluid flow to the nozzle inlet 4 via the admission port 6 positioned tangentially to its inner surface.Following the inside of the nozzle inlet 4 and the inside of the working tube 1, the fluid flow starts to ratate,characterized by tangiatial and axial velocities.The greatest tangential velocities will occur in the nozzle inlet 4,because it is precisely the place where the pressurized fluid flow is fed to from the admission port 6. Tangential velocities vary along the radius of the working tube 1, declining from the nozzle
inlet 4 towards the hot flow dischange branch 3. This is due to the slow-down of the flow because of the friction of the upper layers against the wall of the working tube 1.

The fore going thermodynamic processes,occurring in the vortex tube,bring abount different temreratures of the flow along the section of the working tube 1. In the peripheral layers it is higher,and in central layers it is lower.In order to plit the flow as to temperature the fluid hot flow is with drawn via the valve 2 to the hot flow branch 3, and the cold fluid flow is with drawn by a counter current to the cold flow branch 5.

Varing the position of the valve 2 relative to the working tube 1,one can alfer the flow rates and temperature of the cold and hot flows.To lower the cold flow temperature one should reduce the cold flow rate (valve 2 is opeed) and to raise the hot flow temperature,conversaly,valve 2 is closed.

Changing the flow section of the volve 2, one can obtaine a different distribution of the shares of gas escaping through the cold flow branch 3,respectively.The central flow directed towards the cold flow branch 5 can form only as a result of the passage of part of the fluid flow from the external to internal layers.This means that along side tangential and axial motions,there is also a radial motion in the flow,directed mostly from the periphery towards the center.thus in the working tube 1 the fluid flow has an opposite axial motion,namely,the external layers move from the nozzle inlet 4 towards the valve 2,and the internal ones move opposite the nozzle inlet 4 and the flow branch 5.

Thus, the vortex tube efficiency is contingent on two opposite factors:

- the fluid central (axial) layers are cooled by giving their energy to the peripheral layers,
- the fluid axial layers are preheated by feeding heat from the peripheral layers.

The combination of these factors provides the effect of colling the fluid at the outlet from the cold flow branch 5 and hot flow branch 3 of the vortex tube.

However,the range of adjusting the parameters of thermodynamic processes in the vortex tube is limited by geometric dimentions and the shape of the basic elements of the vortex tube and in order to obtain the required characteristics of hot and/or cold flows in solving a particular tecnical problemuse is made of vortex tubes of a different design with their geometric dimentions and shape of the basic elements,which fact hinders their broad utilization.

The structural improvements of the vortex tube elements that we have disclozed are aimed at enabling one to control thermodynamic processes in the working tube 1.

Figure 1 illustrates one of the possible variants of the nozzle inlet 4. The latter is shaped as a cylindrical sleeve 7 disposed coaxially/in line with the working tube 1 and mating there with.

At the other end the cylindrical sleeve 7 is limited by a diaphragm 8 with a central aperture 9. A flat spiral 10 (Fig.2,3,4) embracing the aperture9 is rigidly secured by one of its end edge at the end surface of the diaphragm 8 facing the nozzle inlet 4, and a gear wheel 11 (Fig.1) engaging another gear wheel 12 with marks and digits to rotate the diaphragm 8 around its own axis,is rigidly secured coaxially with the diaphragm 8 at the other end surface of the latter. In so doing 6the gear wheel 11 has a conic opening 13,which to geather with a central aperture 9 in the diaphragm 8 forms a duct to with draw
a colling flow to the cold flow branch 5.

As the diaphragm 8 rotates6 the spiral 10 (Fig.2,3,4) may occupydifferent positions relative to the admission port 6 of the nozzle inlet 4.

Given the spiral 10 is in a position shown in Fig.2,one vortex flow of the fluid is formed in the nozzle inlet 4.Rotating the diaphragm of the fluid is formed in the nozzle inlet 4.Rotating the diaphragm 8 along arrow A, one changes the lenght of the fluid flow path,i.e.,increases or reduces the rotary speed of the fluid flow and alters the parametrs of the fluid flow in the nozzle inlet 4, respectively.

Given the spiral 10 is in a position shown in Fig.3,the fluid flow is split to two flows as it leaves the opening 6,each of said flows having its own path lenght,rotaty speed,temperature and pressure as it leaves the nozzle inlet 4.

As the diaphragm 8 rotates along arrow B (Fig.3), the fluid flow, eaving the opening (Fig.4) to enter the nozzle inlet 4, is expanded and accelerates and then, is split to two flows,each having its own path lenght,rotaty speed,temperature and pressure upon leaving the nozzle inlet 4.

In order to regulate the rate of the cold flow dischanged into the branch 5, it is possible to make the diaphragm in the form of two disks 14 and 15 (Fig.5) with openings 16 and 17, arranged coaxially with the nozzle inlet 4 and capable of reciprocating relative to each other along the central axis,in so doing, a spiral 10 (Fig.5) being secured on the disk 14 as in the design in Fig.1 described above, and a gear wheel 11 (Fig.1) - on the disk 15. An elastic ring 18 is mounted in the openings 16 and 17(Fig.5),which alters the flow section of the central openings 16 and 17,as the disks 14 and 15 reciprocate,and as a result,reduces or increases the rate of the cold flow dischanged into the branch 5.

The availability of the spiral 10 in the nozzle inlet 4,possibility of changing its position relative to the admission port 6 with the aid of the diaphragm 8 (or disk 14) and possibility of regulating the dimentions of the dischange opening to with draw the cold flow into tye branch 5, are the means that help to control the parameters of the fluid flow in thenozzle inlet 4,causing the alteration of thermodynamic processes both in the nozzle inlet 4 and in the working tube 1 and ensuring the provision of reguired characteristics of cold and hot flows.

Also possible is another variant of the nozzle inlet in the vortex tube shown in Fig.6. A nozzle inlet 19 is made in the form of a cylindrical sleeve 20 installed line with the working tube 1 and mating there with, Mounted in the cylindrical sleeve 20,in line with the latter and concentrically capable of rotating with respect to each other and to the sleeve 20, are cylindrical sleeves 21,22,23,24,25,26 with flangings 27,28,29,30,31,32, arranged outside the nozzle inlet 19.The cylindrical sleeve 20 has an admission port 33 (Fig.7,8) through which the fluid flow tangentially enters the cylindrical sleeve 26, and through opening 34 (Fig.6) in the cylindrical sleeve 26 the cold flow is discharged to the cold flow branch 35.

The sleeves 22, 24 and 26 are fitted with grooves 36 (Fig.9.) and the sleeves 21, 23, 25 - with projections 37 (Fig.10,11). The projections 37 and grooves 36 face the working tube 1 (Fig.6).

The sleeves 21 through 26 are capable,if necessary,of telescopically moving relative to each other to provide a tangantial-spiral introduction of the vortex flow to the working tube 1.

Drawn on each of the flangings 27 through 32 and equally spaced from one another are lines 38(Fig.12) with digits allowing, given relative movement of the sleeves 21 through 26 (Fig.6) with respect to one another,for setting up various combinations of digits,regulating the lenghth of the fluid flow path in the nozzle inlet 19.

Besides,there may be a variant,where by the outside radius of the projection 39 on the sleeve 21 (Fig.11) with the largest diameter will be smaller than the outside radius of the sleeve 21 along the entire height of the projection 39. This structural embodiment of the nozzle inlet 19 provides the divisionof the fluid flow coming from the admission port 33 into tworotating flows,each) having its own path length.

As regards the rest,the desigh of the vortex tube is analogous to that of the vortex tube shown in Fig.1.

As in the design of the nozzle inlet 4 illustrated in Fig.1, in the nozzle inlet 19 (Fig.6) provision is made for the regulation of the length of the fluid flow coming from the admissionport 33 (Fig.7,8), by rotating the sleeves 21 through 26 with respect to one another and splitting the flow to two rotating flows (Fig.8) having different path length.

The result is the possibility of varying the parameters of thermodynamic processes in the working tube 1 subject to the required characteristics of cold and hot flows.

Another possible variant for altering the parameters of the state of thermodynamic processes in the nozzle inlet 4 (Fig.1) is the embodiment of the admission port 6 in the form of anobliqueLaval nozzle with a damper 40 being arrangedin the short section of this nozzle at the entrance to the nozzle inlet 4 (Fig.13,14) and capable of rotating relative to the fluid flow.

Changing the position of the damper 40 (position A and B in Fig.13),one can regulate the pressure at the entrance to the nozzle inlet, the fluid efflux speed,the fluidflow rate,as well as the orientation (entrance angle0 of the fluid flow to the nozzle inlet 4 subject to the possition of the spiral 10 relative to the admissionport 6. Varing the above parameters and the breadth-heightratio of the fluid flow,as it leaves the admission port 6,one can control the temperature characteristics of the hot and cold flows in the branches

5,3, of cold and hot flows,respectively.

For both designs of the nozzle 4 (Fig.1) and 19 (Fig.6) it is desirable that the inside of the spiral 10,the surfaces of the cylindrical sleeves 7 (Fig.1) and cylindrical sleeves 20,21 through 26(Fig.6) should be made from a material with a low friction coefficient, e.g., materials based on copper, nickel, cobalt, aluminium or the material of the type of metal Teflons,metal plastics,thus ensuring the provision of maximum possible speeds of movement of the vortex flow in the vortex inlet 4,19.

However,distribution of the portions of hot and cold fluid flows,escaping through the hot and cold flows,and the speed of their efflux through the branches appreciably affect the thermodynamic processes occurring in the vortex tube.

Let us consider one of the possible designs of the volve 2, installed at the end of the working tube 1 to dischange the hot fluid flow.

The valve (Fig.14) is made as a coupling nut 41,screwed on the working tube 1 in the end of which at the level of the near-wall layer of the working tube 1 along the radius there are made openings 42,and a confuser-diffuser nozzle 44 with an adjustable annular gap 45 connected by means of a flange 43 to the end of the coupling nut 41. In the flange 43 there are openings 46 positioned along the radius,corresponding to the radius of the openings 42 at the end of the coupling nut 41,both the nut 41 and the flange 43 are capable of rotating around their common central axis.

The valve 2 operates as follows.

A hot fluid flow is fed from the near-wall layers of the working tube 1 through the openings 42 and 46 to a diffuser 47,where upon reversing its direction,passes through the annular gap 45 in which its speed becomes cricical.Then,the flow is expanded in the confuser 48 of the nozzle 44 and enters the hot flow branch (hot shown in Fig.14).

This design of the valve provides intensive with drawal of the near-wall layers of fluid hot flow from the working tube 1 and in view of this the thermodynamic process parametrs in the working tube 1 change,namely,central cold fluid flows mix less intensively with the near-wall hot flows,hence,the effect of energy separation is enhanced and the vortex tube operates at lower temperatures.

The fluid cold flow efflux speed can be regulated by providing the fluid cold flow dischange duct in the form of a twin Laval nozzle (Fig.15),in so doing,the first narrow section 50 of the nozzle 49, arranged from the side of the entry of the fluid cold flow,has a constant area F1 of the section,and the second narrow section 51 of the nozzle 49 is made in the form of a rubber ring with a varving area F2 of the section.

This design of the cold flow dischange duct allows for controlling the cold flow efflux speed,providing different efflux conditions through changing the relation between the area F1 of thesection and the area F2 of the nozzle 49 section. If the area F2 is smaller than the area F1 of the section,as pressure Pa at the nozzle 49 outlet constantly drops from the value of pressure Po at the nozzle 49 inlet,the cold flow efflux speed reaches a critical value in the section 51.Given futher drop of pressure Pa,the subsonic ourrent in the expanding part 51 will hot change.If F1 is less than F2,then as the pressure Padrops,the critical speed of the cold flow efflux will be achieved in the section 50.Altering the F1-F2 ratio,one can attain the critical speed Fmax in the expanding part 52 of the nozzle 49.

The fluid cold flow efflux speed alters processes in the working tube 1 and affects the temperature of cold flow being with-drawn.

Besides, it should be also noted that the cold flow efflux speed also determines the pitch of tone,accompanying this efflux.

Hence,changing the area F1 of section 51,one can regulate the pitch of tone.

The flow rate and speed of the hot fluid efflux can be controlled by making the fluid hot flow branch as a set of cylindrical tubes 53 (Fig.16) arranged in a single cylindrical sleeve 54 mounted at the volve 2 outlet (Fig.1),each of the tubes 53 having its nozzle inlet 55.

An addition to the embodiment of different structural elements of the vortex tube, changing the parameters of thermodynamic processes in the working tube during operation subject to the required characteristics of hot and cold flows, we have provided structural improvements which make the vortex tube operation as a whole more effective.

Among such improvements is the intensification of heat transfer in the working tube 1 (Fig.1).

Heat transfer can be intensified by making part of the working tube 1 from the side of the hot flow branch as rough or corrugated, or making the outer surface of this part of the tube as developed.

In some cases there arises a need to use ionized cod and/or hot flows.

In this case the vortex tube isfurnished with an, ionizer ensurning the ionization of cold and/or hot flows.

Most often,the ionizer is mounted in the branch 5,3 of cold and/of hot flows.

Since the structural embodiment of the cold and hot flowionizers is the same, let us consider the making of the ionizer and its accommodation in the cold flow branch 5.

The ionizer is made in the form of two electrodes,one of which is a ring electrode 56 (Fig.17) installed at the end of the branch 5,and the other electrode is corona dischange initiator 57, positioned inside the cold flow branch 5 in line there with, and the ionizator 57 is connected to the negative terminal or the power source 58, and the ring electrode 56 - to the positive terminal.The initiator 57 can be made needle-shaped,the point being directed either along the movement of cold flow, or opposite the latter.

Arranging the initiatir 57 point opposite the cold flow appreciably reduces the structural dimentions (the length of the cold flow branch) of the vortex tube and increases the degree of ionization of the cold flow, because ionization begins right at the very entrance of the cold flow branch 5.

Besides, the initiator can be made in the form of a needle stem 59 (Fig.18) with needle tags 60 equal in height disposed on its outside.

Given such a design of the initiator,the local electric field strength is increased to reduce the dischange voltage.Breakdown may occur only upon futher rise of voltage.As a result,one can work with high voltages and great air pressure in the inter-electrode gap,given such design of the initiator.

It is possible to make the initiator in the form of a sinusoid 61. (Fig.19).

This design of the initiator also brings abount higher local electric field strength and a drop in dischange voltage,enabling the ionizer to operate with high voltages.

Selection on of a particular design of the initiator is stipulated by a required degree of ionization,the size of a branch,configuration of the passage channel of the ring electrode 56 which may be shaped as a truncated cone, or the latter turning into a cylinder (Fig.17).

A dielectric grid 62 (Fig.20) may be mounted between the initiator 57 and the ring electrode 56.

The presence of the dielectric grid 62 ensures the setting of charges on its surface whoch have the same sign as those on the initiator 57. As a result,the intensity drops between the initiator 57 and dielectric grid 62 to increase breakdown strength of this gap,but grows between the dielectric grid 62 and the ring electrode 56, which in turn,leads to a higher degree of ionization and a lower recombination coefficient.

Besides,an emission coating 63 (Fig.21) may be applied on the inside of the cold flow branch 5 in the zone of the location of the initiator 57.Films of titanium, zirconium, molybdenum and other chemically active agents, which easily evaporate and are mixed with an iionized flow,as the cold (or hot)flows are ionized,can be used as said emission coating.

Using an ionized cold flow of air with such additives,e.g., to cool tools when machininf parts,helps to form a chemically stable compound, protecting the tool against wear,one the tool frictional surfaces.

Let us consider the operation of the ionizer. From the nozzle inlet 4 (Fig.17) and the working tube 1 the fluid cold flow is fed to the cold flow branch 5.

In the branch 5 the cold flow gets into the zone of a corona dischange initiated by the initiator 57.The fluid cold flow ionized and goes out beyond the vortex tube through the opening in the ring electrode 56.

However,the degree of ionization of the fluid flow is suject to temperature and a temperature sensitive element 64 (Fig.22) is installed at the ionizer output. This element is connected to the power source 58 via a mathing amplifier 65 and a nonlinear feed-back 66.The nonlinear feed back 66 helps to assign a reguired functional relationship of the load current of the power source 58 and the fluid cold flow tenperature.The load current of the power source 58 repeats with a preset accuracy the shape of a signalfed to the input of a comparison circuit (connected in the power source 58,not shown in the drawing) from the output of the nonlinear feedback 66 circuit and subject to the cold flow temperature the load current changes and so does the corona dischange electric field strenght and,consequently, the degree of ionization of the fluid flow alters as well.

All that has been said above abount the ionizer relates both to the cold flow branch 5 and the hot flow branch 3.

In some cases,an ejector 68 (Fig.23),ensuring,if necessary,the suction of the agents of a different state of a different state of aggregation, is mounted at the outlet of the branch 5 (or branch 3) of cold (hot) flow.

In certain cases,if necessary,the branches 5 and 3 of cold and hot flows,respectively,are connected to a mixing chamber to maintain a desired temperature in the latter, adjusting the supply of cold and hot flows.

Let us consider a number of specific exemplary embodiments of the present invention.

One of the promising fields of the application of the disclosed designs of the vortex tube is its use for purposes of machining.

Using ionized cooled air for machining,as compared to the currently used technological means based on water and oil, drastically increases productivity, accuracy quality of machining throught cutting, expecially in machining high-alloy steels, corrosion-resistant and high-temperature alloys, as well as materials based on refractory agents. Besides, in this case,enviromentally benign or friendly production is provided and labour-conditions are improved.

To cool the cutting zoner there may be a variant,where by the cold or hot flow branch of the vortex tube is in the immediate proximity to the cutting zone.

Yet, there may be another variant of feeding cold or hot air flows to the cutting zone shown in Fig.24.

In order to cool the cutting zone by a cold air flow,a flexible hose 68 is connected to the cold flow branch 5.

The hose has two dischange ducts 69 and 70,in one of the ducts 69 the cold flow is fed to the cutting zone along the front surface of a cutting tool 71 and in the second duct 70 the cold flow is fed to the gap between an article 72 being machined and the rear surface of the cutting tool 71.

Most commonly used for cooling is an ionized cold air flow, yet, it is possible to use cooling modes where a cold flow is used with different additives introduced into the latter via the ejector 67 (Fig.23). The process of cutting with the use of an ionized cold flow has two basic features, the first is related to the use of air as a technological meduim,the second - to the activation of air with an electric dischange, i.e., the provition of an ionized air flow.One of its distitinctive features is a dramatic activation of oxidizing processes on the contact surfaces of an article 72 to be machined and the curring tool,an oxide film is formed on their surfaces, preventing the diffusion on the material of the tool 71, friction is reduced on the front surface of the tool and,as a result,the wear of the tool 71 is diminished during machining.

It is worthy of note that in order to decrease the wear of the tool,it is desirable that cooling be effected at a minus temperature (minus 1 ... minus 20 C), when in addition to embrittlement of the cutting zone,the gas-filled surface layer of an article 73 being machined is also embrittled.

It is clear that the machining of different materials calles for different temperature conditions and a particular degree od air flow ionization, and, some times, the introduction of the agents of a different state of aggregetion into the ionized air flow.All these operations can be parfomed by one and the same vortex tube of the disclosed design,which allows for adjusting the temperature of cold and hot flows within a broad range, as well as altering the degree of flow ionization subject to temperature and preset conditions.

Table 1 shows by way of example the results of machining 10Cr32Ni8stainless steel by mark P10 hard alloy tool using an all-purpose lathe.Variable parameters were:speed of cutting V,m/min,feed S,mm/round,depth of cutting t,min and various gaseous media.

Table 1

Description	Parameters of outting modes			Resistance T,min
	V, m/min	S,mm/round	t,min	
Machining in dry conditions	131 292,7	0,47 0.15	0,5 0,5	23 5,5
Machininf in cooled air medium	100,48 255.0	0,34 0,15	0,5 0,5	52 25
Machining in cooled ionized air medium	102 253	0,34 0,15	0,5 0,5	98 196

Drawing on the data obtained,one can make the following conclutions.

Using cooled ionized air as a lubricating-technological medium enhances 1 to 4 times the resistance of a cutting tool in the range of parameters of cutting under study as compared to dry machining.

The maximum effect (as to the tool resistance) from using ionized cooled air is observed at higher speeds of machining V being greater than 200 m/min.

Given a speedy heavy-duty machining,the given mode of cooling is actually the only one to ensure a marked increase in the toool resistance.

Besides, the rate of air efflux from the vortex tube and the air temperature appreciably affect the tool wear.Is has been found experimentally that the higher the rate of cooling air efflux from the vortex tube and the lower its temperature, the higher is the tool resistance.

For instance, as the air flow temperature changes from minus 5 to minus 40 C,the tool resistance grows 2.5 times,and as the speed of eir efflux from the branch increases from 160 m/s to 400 m/s,the tool resistance increases 4.3 times.

The above examples enable one to draw a conclusion about the possibility and necessity of using the cooled air flow in the form of high-speed jet to provide a convective heat transfer with the tool, because it is precisely these modes that most vividly show their advantage pover the tool resistance,when using a liquid cooling.

Still another possible field of application of the vortex tube is its use to creat cold in cooling chambers.

Let us consider one of possible designs of such unit.

The unit has a source 73 (Fig.25) of compressed air,connected to a vortex tube 74. The cold flow branch 75 of the vortex tube 74 is connected to a power source 76 and to a cooling chamber 77. Connected to the cooling chamber 77 is heat exchanger 78 which, in turn, is linked with a diffuser 79 to suck out the exhaust air.

The unit operates as follows.From the compressed air source 73 compressed air is fed to the fortex tube 74.From the vortex tube 74 via the branch 75 the ionized cold flow is fed to the cooling chamber 77 and from there the exhaust air is sucked out throughthe heat exchanger 78 and diffuser 79 and can be used again in the unit or for other purposes.

Using the ionized air flow in cooling chambers helps preserve food products at higher temperatures than in conventional cooling chambers.Thans to ionization the products can retaine their tasteness and nutritive properties without freezing.

A hot fluid flow in the vortex tube can be used to heat premises,and an ionized hot flow can be used for medical puposes, e.g.,to provide premises with ionized air,and in agriculture,by supplying ionized hot/air to greenhouses and nurseries.

Thus, due to a broad spectrum of the obtained parameters of hot and cold flows the disclosed designs of the vortex tube make it possible to use one and the same design of the vortex tube for various purposes and in different fields, there by facilitating the provision of environmentally benign of friendly production processes.

Industrial Applicability

The design of the vortex tube of the invention can be used in themanufacturing and freezing industries,as well as in medicine and agriculture.

Claims

1. A method of controlling thermodynamic processes in a vortex tube, consisting in that a pressurized fluid flow is fed to a nozzle inlet (4.9), as an expanding fluid flow moves in the nozzle inlet (4.9), it is twisted to enter a working tube (1), wherein the twisted fluid flow is divided into a cold and hot flows and each of the flows is discharged through branches (5.3) of cold and hot flows, respectively, in so doing, the thermodynamic processes parameters are controlled by adjusting the hot fluid flow rate in the hot flow branch (3), characterized in that subject to required characteristics of the cold and hot fluid flows, the fluid flow is controlled by adjusting the length of the fluid flow and/or the speed of efflux of the fluid flow in the nozzle inlet by altering the parameters of the conditions of thermodinamic processes in a working tube and diagragm of a nozzle inlet.

2. A method as defined in claim 1,characterized in that the field flow is controlled in the nozzle inlet (4.19) by adjusting the length of the fluid flow path in the nozzle inlet (4.19).

3. A method as defined in claim 1, characterized in that the fluid flow is controlled in the nozzle inlet by splitting it up into, at least, two rotating flows, each of which having a different path length.

4. A method as defined in claims 1,2, characterized in that the speed of the cold flow efflux is additionally adjusted at the outleet of the cold flow branch (5).

5. A method as defined in cleams 1,2, characterized in that a convective heat transfer of the near-wall layers of the fluid flows is additionally increased in a working tube (1).

6. A method as defined in cleam 1, characterized in that a cold and/or hot fluid flow is additionally ionized.

7. A method as defined in claim 6, characterized in that during the ionization of any fluid flows the composition of cold and/or hot flows is changed.

8. A method, as defined in claims 6, 7, characterized in that in addition following ionization a substance of a different aggregate state is introduced into any flow, effecting the alteration of physicochemical properties of the entity outer layer.

9. A method as defined in claim 1, characterized in that gases and/or liquids and mixtures thereof are used as a fluid.

10. A vortex tube, containing a working tube (1), one end of which vis a control valve (2) is connected to a hot fluid flow discharge branch (3) and other end - to a vortex inlet (4), mounted coaxially to a working tube (1), said vortex inlet being fitted with means affecting thermodinamic processes in the working tube and connected to the cold fluid flow discharge branch (5), and via an admisiion port (6) - to the sourse of fluid fed to the nozzle inlet (4) under pressure, characterized in that, the means is made so that it controls the movement of the fluid flow in the nozzle inlet and in the working tube, respectively, subject v t o the required characteristics of cold and hot flows, the geometric parameters of the vortez tube being unchanged.

11. A vortex tube, as defined in claim 10, characterizided in that the nozzle inlet (4) is made in the form of a cilindrical sleeve (7), with an admission port (6), one end of wich is connected to the working tube (1), and a diaphragm (8) with a central aperture (9) is adjacent to the other end, on one end surface of said diaphragm facing the working tube (1) there is rigidly secured by one of its edges at least one flat spiral (12), encompassing the aperture (9), serving as means to control the fluid flow in the nozzle inlet (4), the diaphragm (8) being arranged so as to rotate arround central axis.

12. A vortex tube, as defined in claim 10, characterized in that the nozzle inlet (19) is made in a form of cylindrical sleeve (20) with an admission port (33), one end of wich is connected to the working tube (1), and cylindrical sleeves (21, 22, 23, 24, 25, 26) with flangings (27, 29, 30, 31, 32) are concentrically disposed in the cylindrical sleeve coaxially and capable of rotating relative to one another and to the cylindrical sleeve (20), said cylindrical sleeves serving as means to control the fluid flow, in so doing, from each of the pair of the adjacent cylindrical sleeves (21, 22, 23, 24, 25, 26), the cylindrical sleeve (21, 23, 25) of a greater diameter has a projection (37), and the cylindrical sleeve (22, 24, 26) of a smaller diameter - groove (36), facing the working tube 1, the opening in the cylindrical sleeve (26) with the smaller diameter being the duct to withdraw the cold fluid flow to the cold flow brunch (5).

13. A vortex tube, as defined in claim 12, characterized in that the cylindrical sleeves (21, 22, 23, 24, 25, 26) with flanginngs (27, 28, 29, 30, 31, 32) are arranged relative to one another with the possibility of telescopic movement.

14. A vortex tube, as defined in claim 12, 13, characterized in that on the cylindrical sleeve (21) with the flanging (27), having the greatest diameter, the outside radius of the projection (39) is less than the outside radius of the sleeve (21) along the entire height of the projection (39).

15. A vortex tube,as defined in claims 10, 11, 12, characterized in that the admission port (6) of the nozzle inlet (4) is made in the form of an obligue Laval nozzle, and a damper (40) is disposed on the short section of said nozzle at the entrance to the nozzle inlet, capable of rotating relative to the fluid flow being fed.

16. A vortex tube, as defined in claims 11, 12, characterized in that the inside of the cylindrical sleeve (7,20) is made from a material with a low friction coefficient.

17. A vortex tube, as defined in claims 10, 11, 12, characterized in that part of the outside of the outside of th working tube (1) from the side of the hot flow branch (3) is made developed, ensuring a convective exchange of the near-wall fluid flow with the surrounding medium.

18. A vortex tube,as defined in claims 10, 11, 12, characterized in that part of the surface of the working tube (1) from the side of the hot flow branch (3) is made corrugated, ensuring the alteration of the near-wall fluid flow path lenght and the flow convective exchange.

19. A vortex tube, as defined in claims 10, 11, 12,characterized in that the control valve of the hot flow dischange branch is made in the form of a coupling nut (41), screwed on the working tube (1) at the level of the near-wall layer of the working tube (1), and a confuser-diffuser nozzle (44) with an adjustable annular gap (45) is connected to the end of the coupling nut (41) with the aid of a flange (43), in so doing, openings (46) are made in flangs (43), which correspond to the radius of the arrangement of the openings (42) at the end of the coupling nut (41) and the coupling nut (41) and flanges (43) are mounted so as to rotate around the common central axis.

20. A vortex tube,as defined in claims 10, 11, 12, characterized in that the outlet part of the cold flow branch (5) is made in the form of a twin Laval nozzle (49) with a varying section (51) of the second narrowing.

21. A vortex tube, as defined in claims 10, 11, 12, characterized in that the hot fluid flow branch is made as a set of cylindrical tubes (53) accomodated in the signle cylindrical sleeve (54) and each of cylindrical tubes (53) has its own nozzle inlet (55).

22. A vortex tube, as defined in claim 10, characterized in that it is additionally furnished with an ionizer, which ionizes the cold and/or hot fluid flows.

23. A vortex tube, as defined in claim 20, characterized in that the ionizer is made in the form of two electrodes, connected to a power source, one of which is a cylindrical part of the cold and/or hot flow branches with a ring electrode (56) installed at its end, and the other electrode is a corona dischange initiator (57), mounted inside the cold and/or hot flow branch (5,3), the initiator (57) being connected either to the positive or negative terminal of the power source (58).

24. A vortex tube, as defined in claim 23, characterized in that the corona dischange initiator is made in the form of a needle stem (55) with needle tags (60) equal in height and arranged on the outer surface of said stem.

25. A vortex tube, as defined in claim 23, characterized in that the corona dischange initiator is made in the form of a sinusoid (61).

26. A vortex tube, as defined in claims 23, 24, 25, characterized in that the corona dischange initiator (57) is installed opposite to, or along the movement of the cold and/or hot fluid flows.

27. A vortex tube, as defined in claim 23, characterized in that a dielectric grid (62) with an arbitrary size of cells is disposed upwards of the corona dischange initiator (57).

28. A vortex tube, as defined in claim 23, characterized in that an emission coating (63) is applied on the inside of the cylindrical part of the hot and/or cold flow branch (3,5) in the zone of the accommodation of the corona dischange initiator (57).

29. A vortex tube, as defined in claim 23, characterized in that a temperature sensitive element (64) is possitioned at the ionizer outlet and is connected to the power source (58) through a matching amplifier (65) and a nonlinear feedback (66).

30. A vortex tube, as defined in claim 23, characterized in that an ejector (67) is installed at the outlet of the cold and/or hot flow branch (5,3), which feeds the substances of a different aggregate state to the cold and/or hot flows.

31. A vortex tube, as defined in claim 23, characterized in that an ejector (67) is arranged at the ionizer outlet, which feeds the substances of a different aggregate state.

32. A vortex tube,as defined in claims 10, 11, 12, 22 characterized in that it is used as means of cooling the cutting zone in metal-cutting lathes.

33. A vortex tube,as defined in claim 32, characterized in that when using the vortex tube to cool the cutting zone in metal-cutting lathes,a flexible hose (68) is connected to a cold flow branch (75), said hose having two exhaust ducts (69,70), in one of which the cold flow is fed to the cutting zone along the front surface of the cutting tool (71), and through the other exhaust duct (70) - cold flow is fed to the gap between the article (72) to be worked and the rear surface of the cutting tool (71), working being effected both by an ionized and ordinary cold flow.

34. A vortex tube, as defined in claims 10, 11, 12, 22, characterized in that the branch (75) of the ionized cold flow is connected to the freezing chamber (77), ensuring the storage of organic and inorganic substances and products.

35. A vortex tube,as defined in claims 10, 11, 12, 22,characterized in that the hot flow branch is connected to the chamber, ensuring the heating of the chamber or heating with ionization.

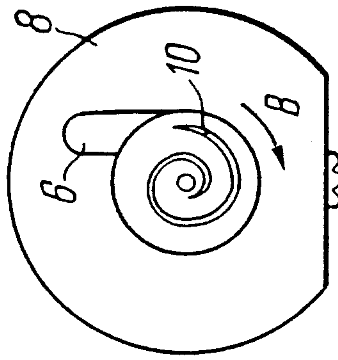

FIG.3

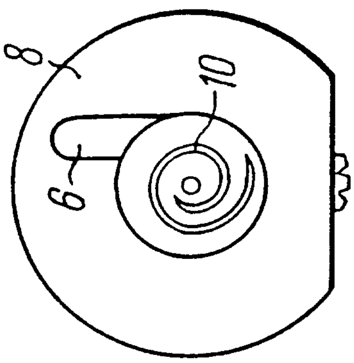

FIG.4

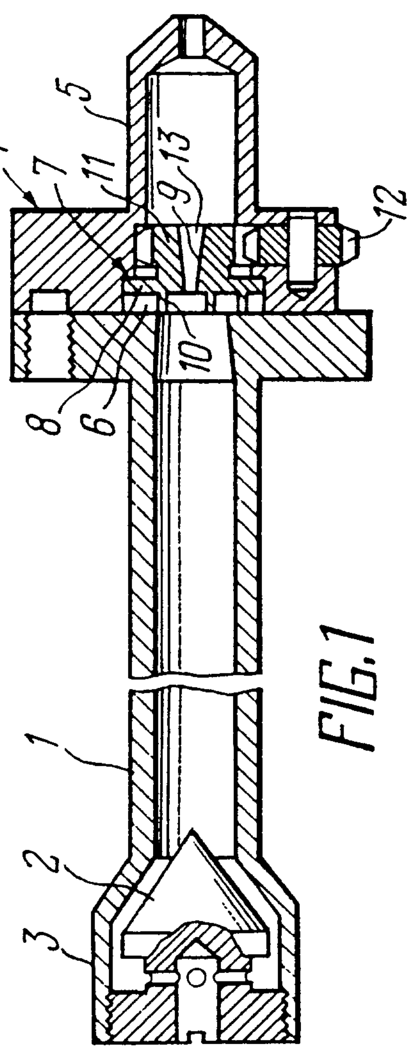

FIG.1

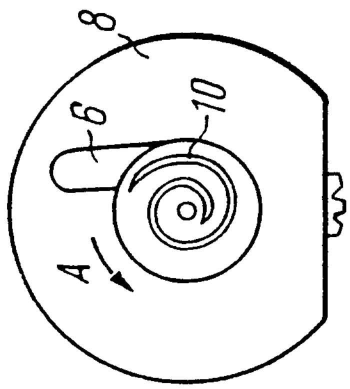

FIG.2

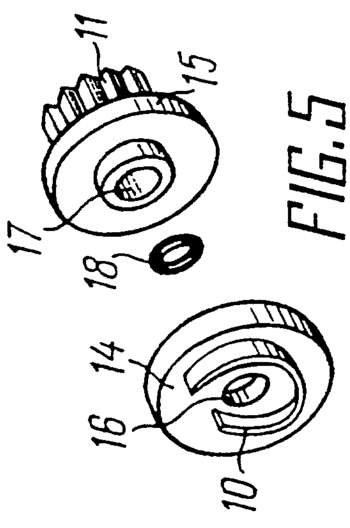

FIG.5

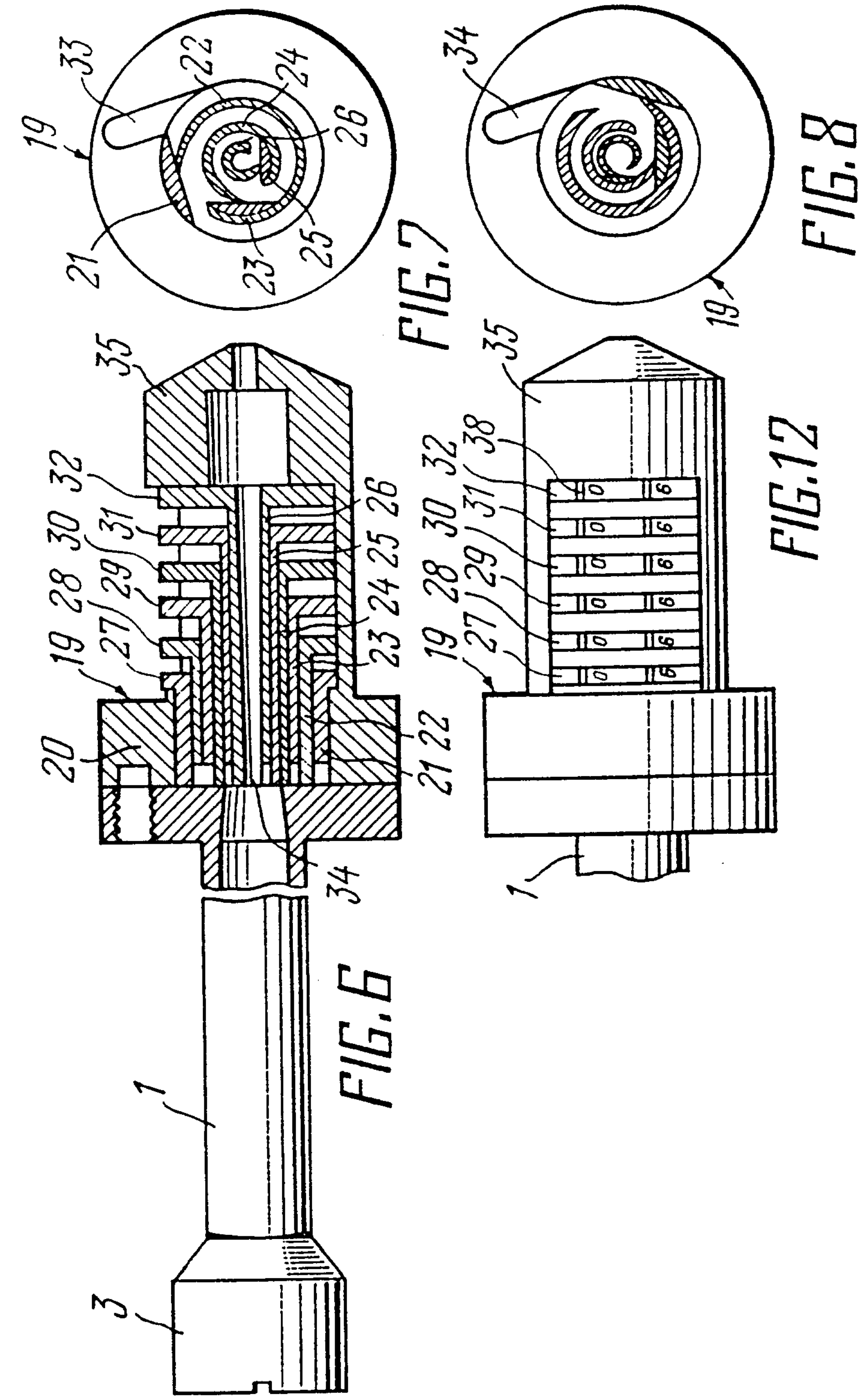

FIG.6

FIG.7

FIG.8

FIG.12

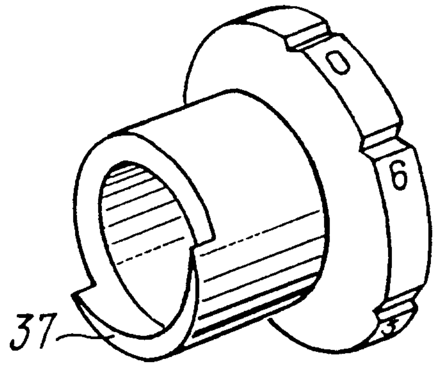

FIG.10

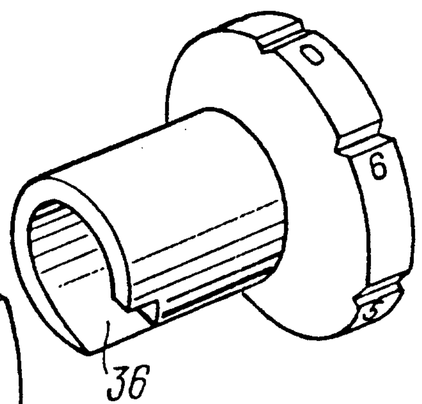

FIG.9

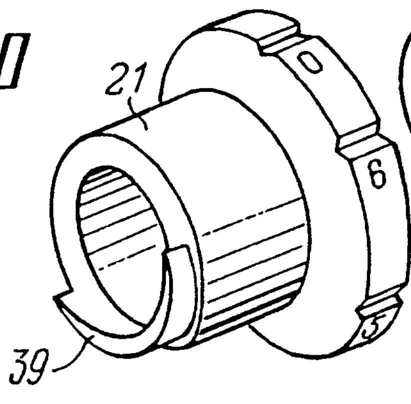

FIG.11

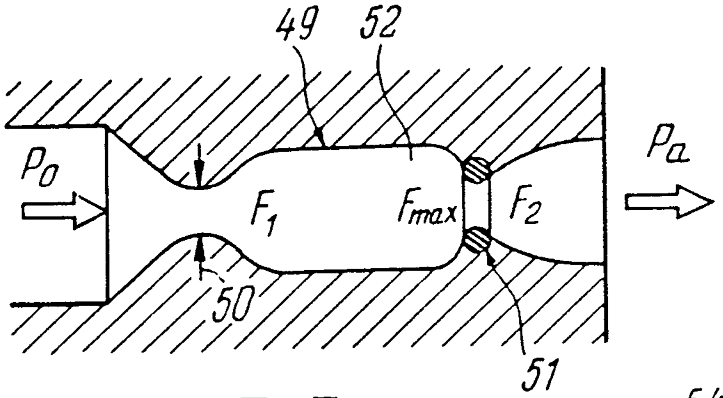

FIG.15

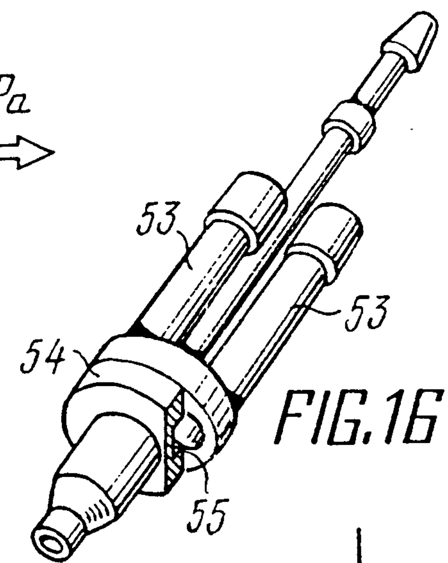

FIG.16

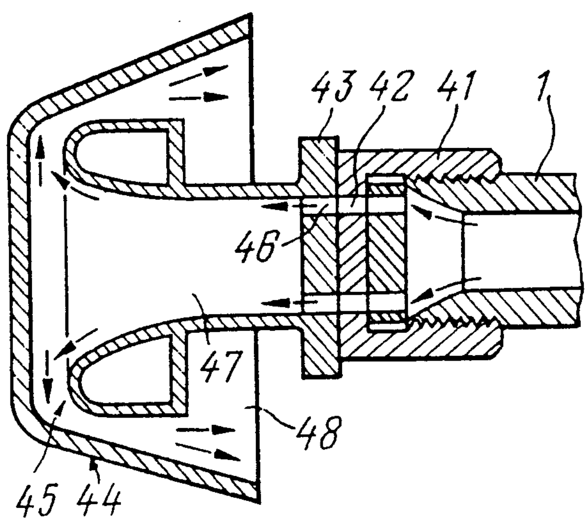

FIG.14

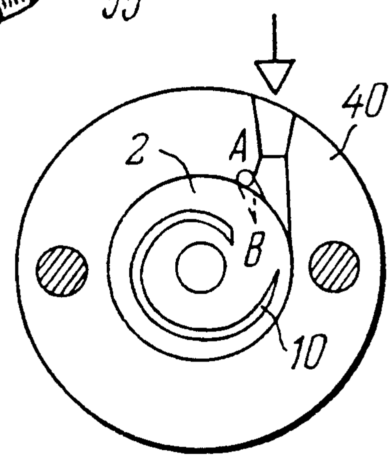

FIG.13

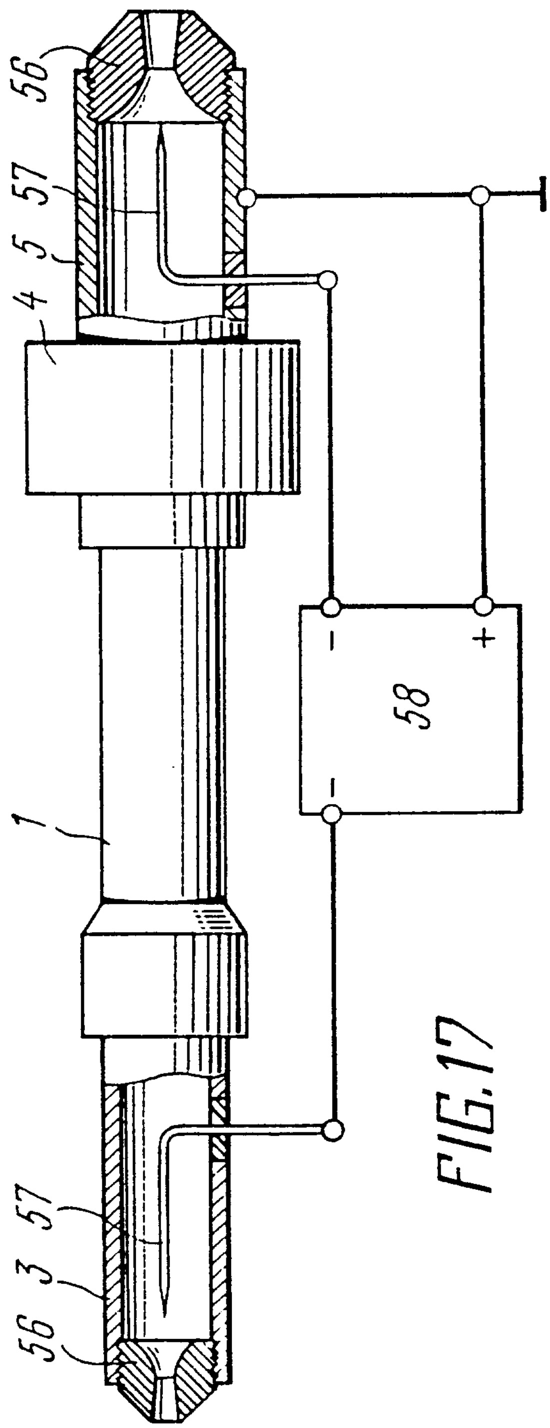

FIG.17

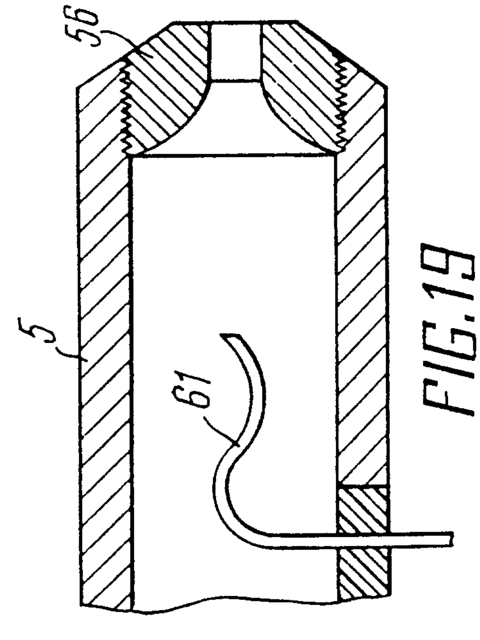

FIG.19

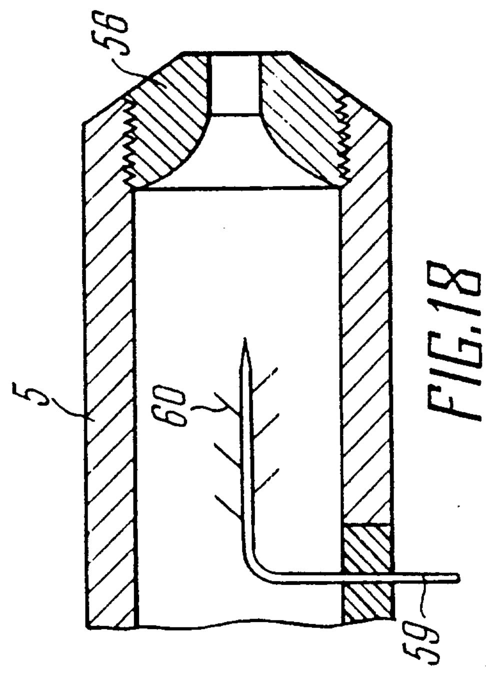

FIG.18

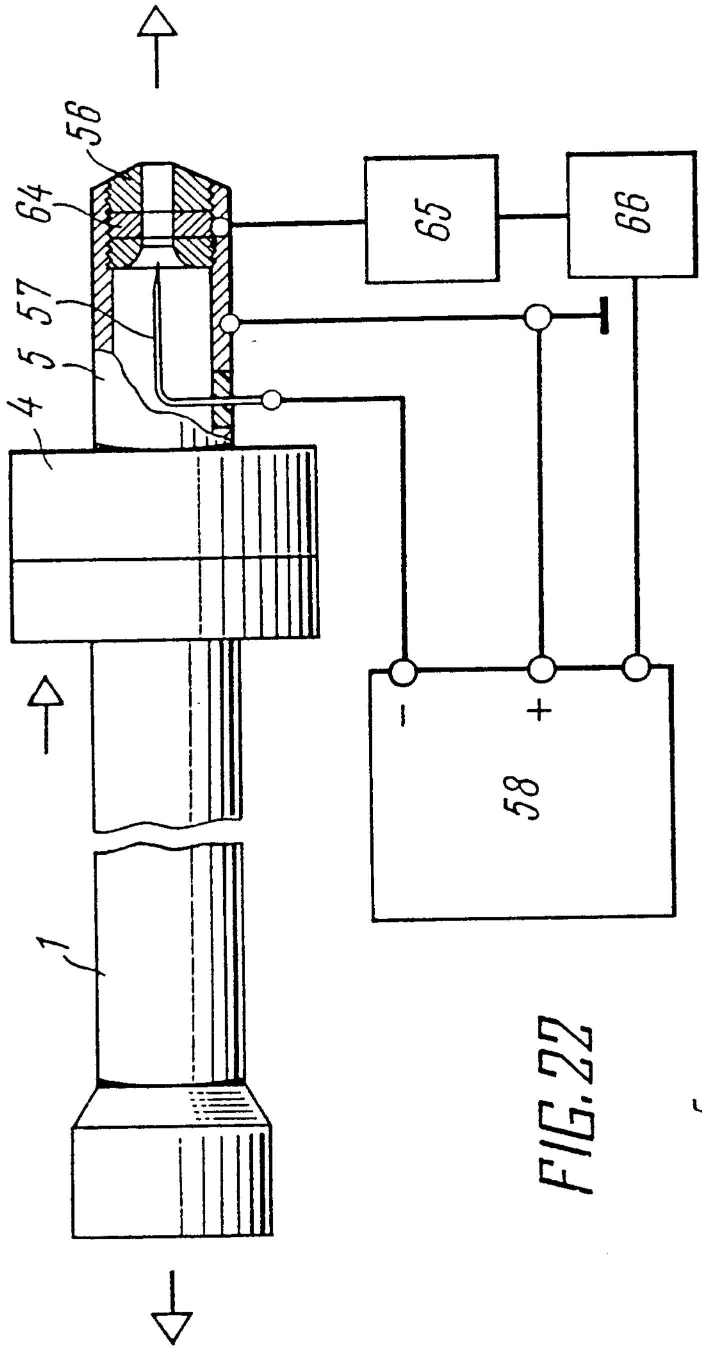

FIG. 22

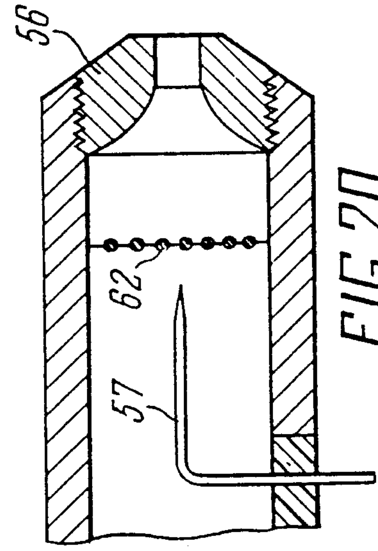

FIG. 20

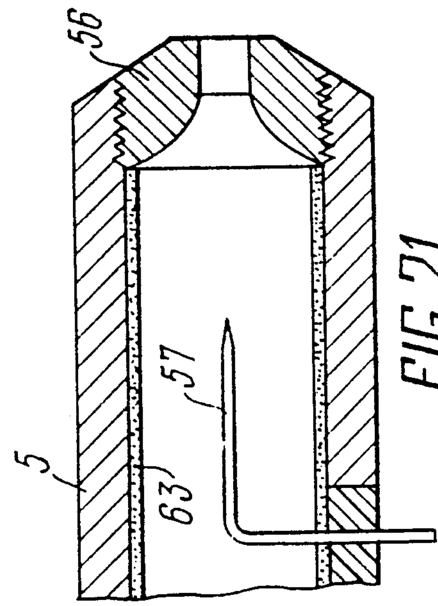

FIG. 21

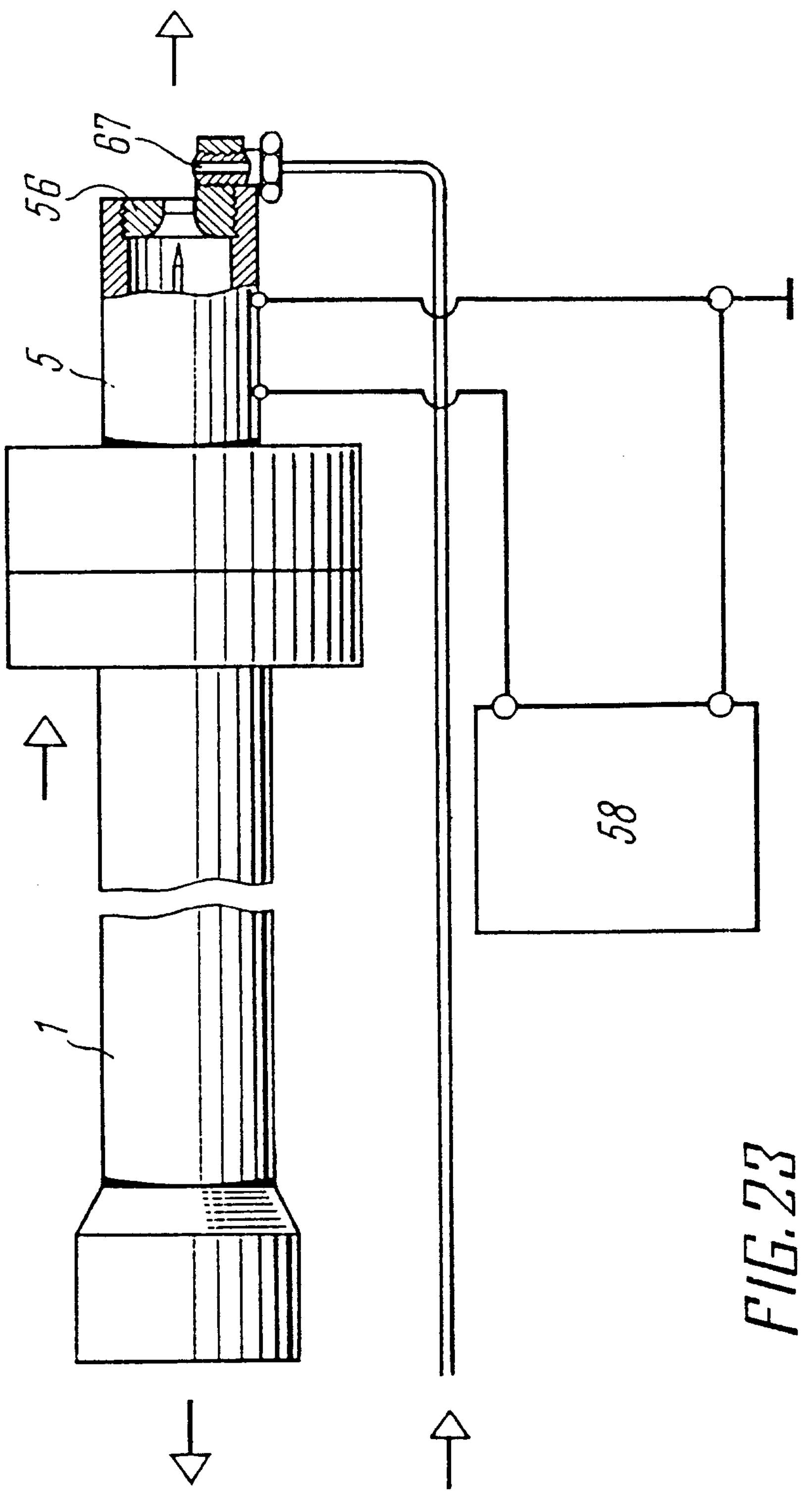

FIG. 23

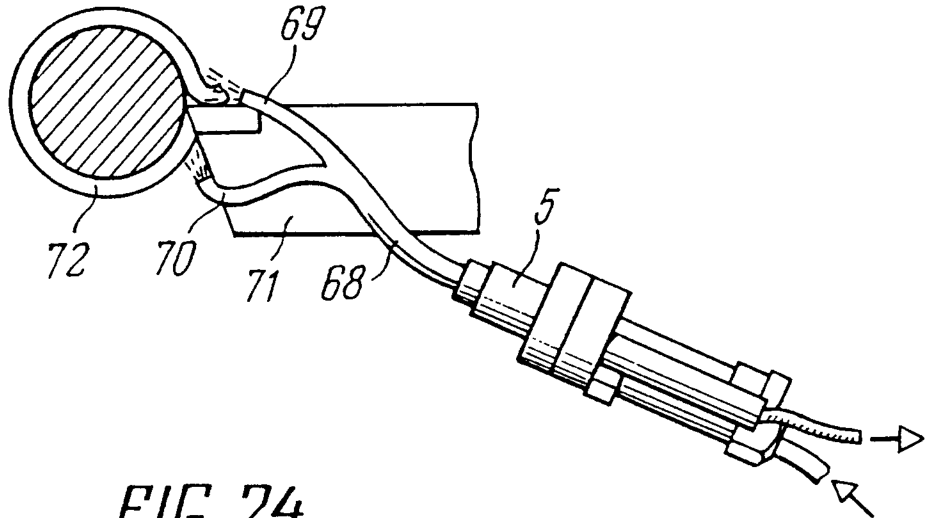

FIG. 24

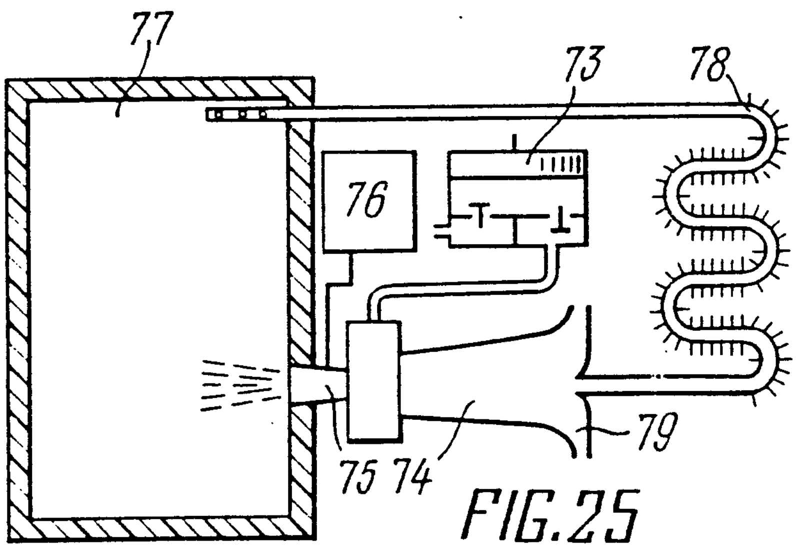

FIG. 25

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU93/00049

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 5: F25B 9/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl. 5: F25B 9/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SU, A, 1035356 (LYAMIN A.E. et al), 15 August 1983 (15.08.83)	1,7,12,19, 20
A	SU, A, 1138618 (KUIBYSHEVSKII AVIATSIONNYI INSTITUT IM.AKAD.S.P. KOROLEVA), 7 February 1985 (07.02.85)	1,2,4,12
A	SU, A, 682727 (VSESOJUZNYI NAUCHNO-ISSLEDOVATELSKII I PROEKTNYI INSTITUT PO PERERABOTKE GAZA), 30 August 1979 (30.08.79)	1,12
A	SU, A, 1044909 (KAZANSKII NAUCHNO-ISSLEDOVATELSKII TEKHNOLOGICHESKII I PROEKTNYI INSTITUT KHIMIKO-FOTOGRAFICHESKOI PROMYSHLENNOSTI), 30 September 1983 (30.09.83)	1,4,12,17
A	DE, A1, 3639893 (MARRESEARCH GESELLSCHAFT FÜR FORSCHUNG UND ENTWICKLUNG MBH), 1 June 1988 (01.06.88), abstract	1,12

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 October 1993 (12.10.93)	19 November 1993 (19.11.93)
Name and mailing address of the ISA/ RU	Authorized officer
Facsimile No.	Telephone No.