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(54) **A method of cleaning industrial components and a jet assembly for use therein.**

(57) An industrial component fluid jet (10) has a nozzle (12) comprising two coaxial tubes. The outer tube has a stepped bore. An annular swirl plate (15) is spigotted into an intermediate diameter bore portion (16) and has an end of the inner tube (22) spigotted into it. Cleaning fluid passed through the swirl plate (15) emerges into a chamber (21) with an axial directional component and a spinning action to form a hollow cone spray. Fluid emerging from the inner tube (22) only forms a pinpoint jet but cooperates with spinning fluid emerging simultaneously from the swirl plate (15) to form a solid cone jet. The jet (10) may be operated and orientated by a robot.

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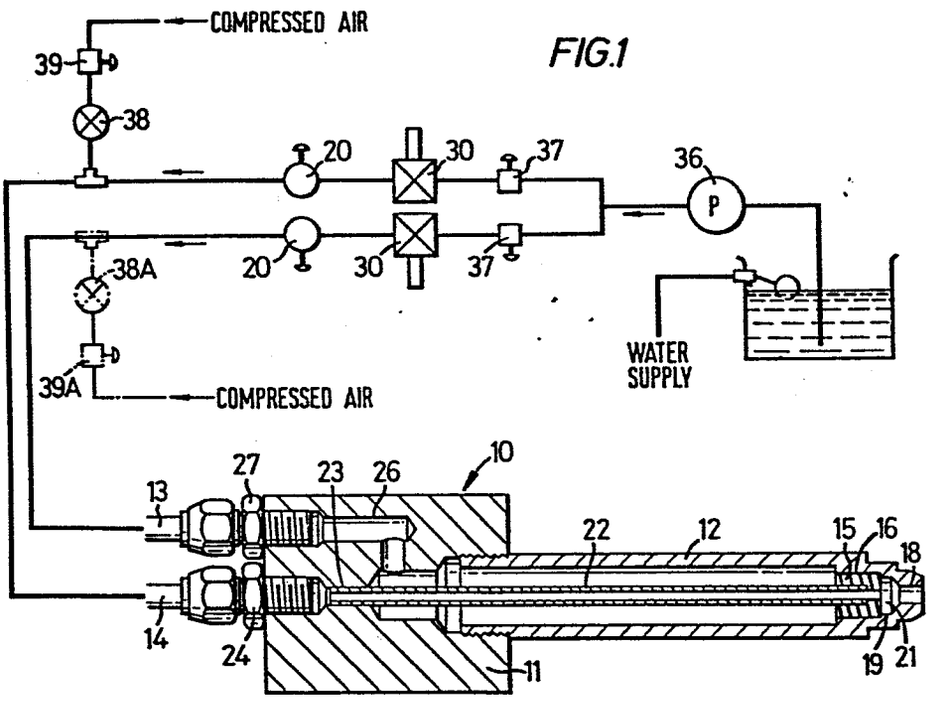
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FIG.1

# "A METHOD OF CLEANING INDUSTRIAL COMPONENTS AND A JET ASSEMBLY FOR USE THEREIN"

## DESCRIPTION

This invention relates to cleaning industrial components.

UK-A-1573424 and UK-A-2006913 disclose industrial component washing machines in which high kinetic energy jets of cleaning fluid having a selected pattern and orientation are each directed at a corresponding selected portion of a component to be cleaned by a respective jet which is located with precision.

The use of robots to support and locate jets used in washing of industrial components has been proposed. In accordance with such proposals, jet assemblies selected from a series of different gripper-held jet assemblies would be used. Each assembly would contain a dedicated jet designed for a specific type of washing. For example there would be a jet designed to form the so-called pinpoint jet of washing fluid, that is to say a jet of fluid which has a substantially uniform cross-section throughout its length, for washing blind tapped holes and small oil

galleries in engine blocks. Also there would be jets which form a hollow cone of washing fluid and jets which form a solid cone of washing fluid for general surface cleaning. Other jets which form jets of compressed air for drying would also be provided. The robot would be programmed to select the jet assembly to be used, to transport the selected jet assembly to the washing location, to control it for the washing step, and then to return it to the storage location prior to selecting another jet for another washing or drying step. A considerable amount of the wash cycle time was lost in the changeover operations. A proposal to minimise this loss of time by arranging a number of jet assemblies as a group or cluster carried by a single robot was found to be less satisfactory than expected because of the complex form of the group or cluster and the danger of impact of parts of it with the engine block or other component being washed.

JA-A-58-98154 discloses alternation of the width of a paint spray pattern automatically in correspondence with the shape of an object to be painted by a spray gun carried by a robot, but paint spray apparatus is designed to form a mist of atomised paint which has low kinetic energy and is not suitable for forming a high energy jet of fluid such as is

needed for cleaning. GB-A-2001262 discloses a jet which may be used to form such a low kinetic energy mist of atomised fluid. Although the pattern of the jet can be altered, it cannot be used to form a high energy hollow cone of fluid because the fluid enters the nozzle chamber in a circumferential direction to form the vortex and without an axial directional component. Also the fluid expands as it enters the chamber so that its speed falls.

According to one aspect of this invention there is provided a method of cleaning industrial components as defined by Claims 1 to 10.

According to another aspect of this invention there is provided a jet assembly which is suitable for use in the foregoing method and which is defined by Claims 10 to 15.

According to a further aspect of this invention there is provided a jet assembly as defined by Claims 16 and 17.

Examples of apparatus in which the present invention is embodied will now be described with reference to the accompanying drawings, of which:-

Figure 1 is a schematic diagram of apparatus for controlling operation of a jet assembly in which this invention is embodied, the jet assembly being

shown in cross-section;

Figure 2 is a fragment of the nozzle of the jet assembly shown in Figure 1 illustrating its operation to form a hollow cone;

Figure 3 is a view similar to Figure 2 illustrating operation of the jet assembly to form a pinpoint jet of fluid;

Figure 4 is a view similar to Figures 2 and 3 illustrating operation of the jet assembly to form a full cone of washing fluid;

Figure 5 is a view in perspective of an industrial parts washing machine in which the present invention is embodied;

Figure 6 is a perspective view of robot apparatus incorporated in the machine shown in Figure 5;

Figure 7 is a view in perspective illustrating operation of the robot supported jet assembly shown in Figure 6 to form a pinpoint jet of washing liquid and direct that pinpoint jet at a preselected portion of an industrial component to be cleaned;

Figure 8 is a view similar to Figure 7 but illustrates operation of the jet to form and direct a cone of washing fluid at a respective portion of the

component;

Figure 9 is an elevation of another form of jet assembly including a pair of jet nozzles similar to that shown in Figures 2 to 8; and

Figure 10 is a view in perspective of an industrial parts processing installation in which this invention is embodied.

Figure 1 shows a jet assembly 10 comprising a manifold block 11 from which a nozzle 12 projects and to which two hoses 13 and 14 are connected. The nozzle 12 comprises a tubular body having a bore which reduces in diameter in three steps adjacent its end remote from the manifold 11. An annular swirl plate 15 is spigotted into the larger intermediate diameter bore portion 16. The central aperture 17 of the annular swirl plate 15 has a diameter which is smaller than the diameter of the smallest diameter bore portion 18 which forms an opening at the outer end of the nozzle 12. The smaller intermediate diameter bore portion 19 forms a chamber 21 between the swirl plate 15 and the opening 18, the annular end wall of the chamber 21 adjacent the opening 18 tapering towards the opening 18. One end of a tube 22 is spigotted into the central aperture 17 of the annular swirl plate 15. The tube 22 extends through the tubular

body of the nozzle 12 and its other end is spigotted into a bore 23 in the manifold block 11. The bore 23 leads to a union 24 to which the hose 14 is connected.

The tube 22 comprises an inner conduit which communicates with the chamber 21. The major part of the tubular body of the nozzle 12, which forms the largest diameter bore portion 25, comprises an outer conduit which surrounds the tube 22 and cooperates therewith to form an annular passage leading around the tube 22 from a passage 26 in the manifold block 11 to the chamber 21, communication between the annular passage and the chamber 21 passed the swirl plate 15 being via spiral passages formed by four helical grooves in the outer cylindrical surface of the swirl plate 15 and the adjacent portions of the bore portion 16. The passage 26 is connected to the hose 13 via a union 27.

Each hose 13, 14 is provided with a flow control valve 20 and with a solenoid shut-off valve 30. The hoses 13 and 14 are connected in parallel to an output of a pump 36 which is a source of washing fluid under pressure. A pressure regulator 37 in each hose 13, 14 between the pump 36 and the respective shut-off valve 30 regulates the pressure upstream of that shut-off valve 30 such that the

pressure upstream of the valve 30 in the hose 14 is higher than that upstream of the valve 30 in the hose 13. A supply of compressed air having its own shut-off valve 38 and pressure regulating valve 39 is connected to the hose 14 between the shut-off valve 30 in the hose 14 and the union 24.

Figure 2 shows that the nozzle 12 forms a hollow cone spray when washing fluid is supplied through the annular passage and the spiral passages formed by the swirl plate 15 to the chamber 21, the shut-off valve in the hose 14 being closed so that no fluid is supplied via the tube 22. Flow through the spiral passages imparts a spinning action to the fluid so that it enters the chamber 21 with such a spinning action and with an axial directional component and forms a vortex in the chamber 21 which causes formation of the hollow cone.

Figure 3 shows that a pinpoint jet of washing fluid is formed when washing fluid is supplied to the opening via the tube 22 only, the shut-off valve in the hose 13 being closed so that no washing fluid is supplied by the annular passage and the spiral passages to the chamber 21.

Figure 4 shows that a full cone is formed when washing fluid is supplied by both the tube 22

and the annular passage and the spiral passages to the chamber 21, the two supplies of washing fluid interacting in the chamber 21 to form the full cone. As can be seen from the drawing, the spinning flow that emerges from the spiral passages into the chamber 21 with an axial directional component, spins around the substantially uniform cross-section stream that emerges from the tube 22 in an area of the chamber 21 which has substantially the same cross-sectional area of the four spiral passages. Hence the flow emerges from the spiral passages into the chamber 21 without significant loss in kinetic energy (this is the case also when a hollow cone spray pattern is formed as illustrated in Figure 2). It is necessary to regulate the flows through the two paths by adjustment of the respective flow control valves in order to obtain the optimum spread of the full cone.

A compressed air jet is formed when the shut-off valves 30 in the two hoses 13 and 14 are closed to shut off the supply of washing fluid and the compressed air supply is opened by opening its respective solenoid shut-off valve 38 so that compressed air is supplied through the tube 22 to the opening 18.

When the jet assembly 10 is used to wash an

industrial component, such as an engine block, by a method in which this invention is embodied, it may be mounted on an arm of a robot which is programmed to effect a sequence of movements of the arm automatically whereby the jet assembly 10 is located and oriented automatically at each of a programmed sequence of locations and orientations in space, the program being appropriate for the components to be washed and the robot being located adjacent a washing station at which each of a series of the components to be washed is located in turn for washing. In addition to locating and orientating the jet assembly 10, the robot controls operation of the solenoid-operable shut-off valves 30 to effect the required supply of washing fluid to the chamber 21 via the annular passage and the spiral passages, or the tube 22 or both, dependent upon the form of washing fluid jet required for the particular washing operation to be performed in accordance with the program, or to effect closure of the two washing fluid shut-off valves 30 in the hoses 13 and 14 and to open the compressed air supply shut-off valve 38 for the drying steps of the washing cycle.

Although the compressed air supply as described would function to displace washing fluid

that had accumulated in the nozzle 12, it may be desirable to provide a form of venting to clear washing fluid from the nozzle 12 for the drying step.

The robot may be adapted to control operation of the nozzle 12 to effect pulsing of the washing fluid jet supply during a washing step if desired.

A supply of compressed air having its own shut-off 38A valve and pressure regulating valve 39A may be connected to the hose 13 between the shut-off valve 30 in the hose 13 and the union 27 instead of or in addition to the supply of compressed air connected to the hose 14. In the latter arrangement, the pattern of the jet of compressed air may be varied automatically if desired by controlled operation of the respective shut-off valves 38 and 38A in much the same way as has been described above with reference to Figures 2, 3 and 4 when the shut-off valves 30 in the hoses 13 and 14 are closed to shut-off the supply of washing fluid.

Automatic operation of the shut-off valves 30, 38 and 38A to effect the required supply of washing fluid or compressed air to the chamber 21 via the annular passage and the spiral passages, or the

tube 22 or both, dependent upon the form of fluid jet required for the particular washing or drying operation to be performed in accordance with the program could be under the control of separate control means functionally interlinked with the robot so that the jets are formed in synchronism with the programmed movements effected by the robot, rather than being controlled by the robot itself as described above.

Figure 5 shows an industrial parts washing machine comprising a housing 40 with a loading hatch 41 through which a component to be washed is passed into and withdrawn from a work station within the housing 40. There is a turntable 42 at the work station. A number of fixed jet assemblies 43 are located and orientated with precision around the work station. A robot 44 is provided within the housing 40.

Figure 6 shows the robot 44 in more detail. It carries a jet assembly 45 at the end of its arm. The configuration and construction of each jet assembly 43, 45 is as has been described above as the jet assembly 10 with reference to Figures 1 to 4.

The machine includes a control panel 46 which is interlinked with the robot 44 and which incorporates programmed control means for controlling

operation of the fixed jets 43 as well. Conveniently the programmed control means are microprocessors and such microprocessors may be incorporated in the robot 44 as well.

In operation of the machine, a component to be cleaned is conveyed to the loading hatch 41. An automatic door of the hatch 41 is opened to allow the component to be introduced into the interior of the housing 40 and be loaded on the turntable 42. The automatic door of the hatch 41 closes automatically once the component is positioned and locked on the turntable 42. The programmed control means incorporated in the control panel 46 and in the robot 44 select the appropriate robot control program signal and instruct the robot control system to commence the wash cycle.

The robot 44 washes one face and 25% of the top of the work envelope of the component and returns to a safe location within the enclosure 40. The pattern of the jet of fluid directed at the component by the jet assembly 45 and the wash action are controlled directly from the robot microprocessor and are therefore totally integrated into the robot program. Figure 7 shows operation of the jet assembly 45 to direct a pinpoint jet of washing fluid at a

selected part of the component. Figure 8 shows the jet assembly 45 directing a cone spray of washing fluid at the component.

The turntable 42 is now indexed through 90° and through this operation the static jet assemblies 43 are operated in accordance with the program of the programmed microprocessors in the control panel 46 to remove gross swarf content from the component.

After indexing through 90°, the robot 44 is instructed to continue the cleaning cycle on the next face and part of the top of the component. This cycle is continued until each side has received a robot wash and the overall component has received four flushes.

A drying cycle then commences, including direction of compressed air by the jets 43 and 45 onto the component. The robot 44 operates to effect drying of the nearest face of the component in a similar manner to the washing operation. General drying is effected by operation of blower fans incorporated in the housing 40 whilst the turntable 42 is indexed. After drying is complete, the blow-off fans are stopped, the supply of compressed air to the jet assemblies 43 and the robot jet assembly 45 is stopped by appropriate operation of the compressed air

shut-off valves 38. The automatic door of the loading hatch 41 opens and the component is removed.

Figure 9 shows an alternative arrangement in which the present invention is embodied. A manifold 28 carries two nozzles 29 and 31. The construction of each nozzle 29, 31 is substantially similar to the construction of the nozzle 12 described above with reference to Figure 1 and the connections through the manifold 28 of each nozzle 29, 31 to the respective pair of hoses 32 and 33, 34 and 35, are substantially similar to the equivalent connection of the nozzle 12 to the respective pair of hoses 13 and 14 as described above with reference to Figure 1. The axis of the nozzle 31 is oblique to the axis of the nozzle 29 so that jets emitted from the two nozzles 29 and 31 converge. The outer end of the nozzle 29 is further from the manifold 28 than is the outer end of the nozzle 31.

In use of the apparatus shown in Figure 9, the manifold 28 is mounted on the arm of a robot. The washing operation is substantially as described above with reference to operation of the nozzle 12. The arrangement of the two nozzles 29 and 31 increases the scope of the washing operations that can be performed. For example the space between two portions of a

surface that can be washed by the jet assembly shown in Figure 9 can be increased by moving the two nozzles 29 and 31 closer to that surface, or can be reduced by moving the nozzles 29 and 31 further away. This is because the jets converge. The nozzle 29 can be effectively shut off so that washing is effected only by the nozzle 31 by bringing the nozzles so close to the surface being washed that the surface abuts the outer end of the nozzle 29.

The jet assemblies described above with reference to Figures 1 to 4 or 9 may be designed so as to be physically and functionally compatible with a machine installation as illustrated in Figure 10 which includes a robot 50 which is arranged to select and locate automatically at a work station 51-54 one of a group of different tools, whereby the jet assembly is one of the group 55 of tools available for automatic selection. For this purpose the jet assembly may be formed with a shank or other suitable connecting and locating means adapted to locate the jet assembly at the work station 51-54 and to connect the jet assembly to a source of fluid pressure of the machine, the jet assembly being usable for various cleaning purposes, e.g. removal of debris or contaminants, such as swarf and oils. The normal

coolant/fluid available for use during the operating cycle of the machine could be directed through the jet for such purposes.

CLAIMS

1. A method of cleaning industrial components in which a high kinetic energy jet of cleaning fluid having a selected pattern and orientation and being formed by flow of fluid through a jet (10, 43, 45) is directed at a corresponding selected portion of a component being cleaned, characterised in that high kinetic energy fluid flow to and through the jet (10, 43, 45) is controlled automatically in accordance with a programme whereby the pattern of the resultant high energy jet of fluid is predetermined and selected automatically from a range of such patterns.

2. A method according to Claim 1 in which such automatic control is achieved by one or more of the steps of varying the pressure of fluid flow fed to the jet (10, 43, 45), of selecting one or more of a plurality of different paths for flow of fluid through the jet (10, 43, 45), and of varying the nature of the fluid medium fed to and through the jet (10, 43, 45).

3. A method according to Claim 1 or Claim 2, wherein operation of the jet (10, 43, 45) is controlled automatically in accordance with the

programme to effect pulsing of the resultant jet of fluid.

4. A method according to any one of Claims 1 to 3, wherein the jet is designed so as to be physically and functionally compatible with a machine which is arranged to select and locate automatically at a work station (51-54) one of a group (55) of different tools, whereby the jet is one of the group of tools available for automatic selection.

5. A method according to Claim 4, wherein the normal coolant/fluid available for use during the operating cycle of the machine is directed through the jet for cleaning purposes, e.g. removal of debris or contaminants, such as swarf and oil, from a work piece.

6. A method according to Claim 1 in which a programmed robot (44) locates and orientates the jet (10, 43, 45) at each of a programmed sequence of locations and orientations relative to the component and flow of fluid under pressure to and through the jet (10, 43, 45) is controlled automatically so that a jet of fluid is directed at a selected portion of the

component by the jet (10, 43, 45) in synchronism with said programmed sequence.

7. A method according to Claim 6, wherein the range of patterns of jet of washing fluid comprises a hollow cone, a solid cone and a so-called "pinpoint" pattern which is a stream of fluid which maintains a substantially uniform cross-section for a significant travel from the jet by which it is directed.

8. A method according to Claim 7, wherein a solid cone pattern of jet of washing fluid is formed by combining a hollow cone pattern of jet of washing fluid with a "pinpoint" pattern of jet of washing fluid.

9. A method according to any one of Claims 6 to 8, wherein the automatic control of fluid flow to and through the jet (10, 43, 45) is effected by the robot (44) in accordance with the programme.

10. A method according to any one of Claims 6 to 9, wherein a supply (36) of washing fluid to and through the jet (10, 43, 45) is shut off automatically after a washing phase and a source of compressed air

is connected to the jet (10, 43, 45) so that a jet of compressed air is directed at the component by the jet (10, 43, 45) for a drying phase.

11. A jet assembly (10, 43, 45) suitable for use in performing a method according to any one of Claims 1 to 10, the jet assembly (10, 43, 45) comprising a nozzle (12) with an opening (18) at one end and forming a chamber (21) which communicates with the opening (18) and which has a cross-section which is larger than the cross-section of the opening (18); an inner conduit (22) having a cross-section smaller than the cross-section of the opening (18), communicating with the chamber (21) opposite the opening (18) and being arranged so as to form a jet of cleaning fluid under pressure which has a substantially uniform cross-section and to direct that jet substantially coaxially through the opening (18); an outer conduit surrounding the inner conduit (22) and cooperating therewith to form an annular passage leading around the inner conduit (22) to the chamber (21), and swirl means (15) in the annular passage operable to coact with a flow of fluid under pressure to the chamber (21) through the annular passage whereby such fluid enters the chamber (21) with a spinning action and a

significant axial directional component and high kinetic energy, forms a vortex in the chamber (21) and, in the absence of fluid emerging from the inner conduit (22), emerges from the opening to form a high kinetic energy hollow cone jet of cleaning fluid.

12. A jet assembly according to Claim 11, wherein the annular passage is connected to one source of fluid under pressure via one shut off valve (38) and the inner conduit (22) is connected to another source of fluid under pressure via another shut off valve (38).

13. A jet assembly according to Claim 12, wherein the pressure of fluid in the other source is higher than that of fluid in said one source.

14. A jet assembly according to Claim 12 or Claim 13, wherein the inner conduit (22) is also connected to a source of compressed air via a further shut off valve (38).

15. A jet assembly according to any one of Claims 12 to 14 when appended to Claim 6, wherein operation of the shut off valves (38) is controlled

automatically in accordance with the programmed sequence by operation of the programmed robot (44) which carries the jet assembly (43, 44).

16. A jet assembly characterised in that it comprises two nozzles (29 and 31) mounted on a manifold (28) which is adapted to be carried by a robot, each nozzle (29, 31) being adapted to emit a jet of fluid through an opening (18) at its end remote from the manifold (28), the opening (18) of one of the nozzles (29, 31) being spaced further from the manifold (28) than the opening (18) of the other and the axis of the opening (18) of one of the nozzles (29, 31) being oblique to the axis of opening (18) of the other nozzle (29, 31).

17. A jet assembly according to Claim 16, wherein each nozzle (29, 31) forms a chamber (21) which communicates with the respective opening (18) and which has a cross-section which is larger than the cross-section of the respective opening (18); an inner conduit (22) having a cross-section smaller than the cross-section of the respective opening (18), communicating with the chamber (21) opposite the opening (18) and being arranged so as to form a jet of

fluid under pressure which has a substantially uniform cross-section and to direct a jet substantially coaxially through the opening (18); an outer conduit surrounding the inner conduit (22) and cooperating therewith to form an annular passage leading around the inner conduit (22) to the chamber (21), and means (15) operable to coact with a flow of fluid under pressure to the chamber (21) through the annular passage whereby such fluid forms a vortex in the chamber (21) and, in the absence of fluid emerging from the inner conduit (22), emerges from the opening (18) to form a hollow cone.

FIG.1

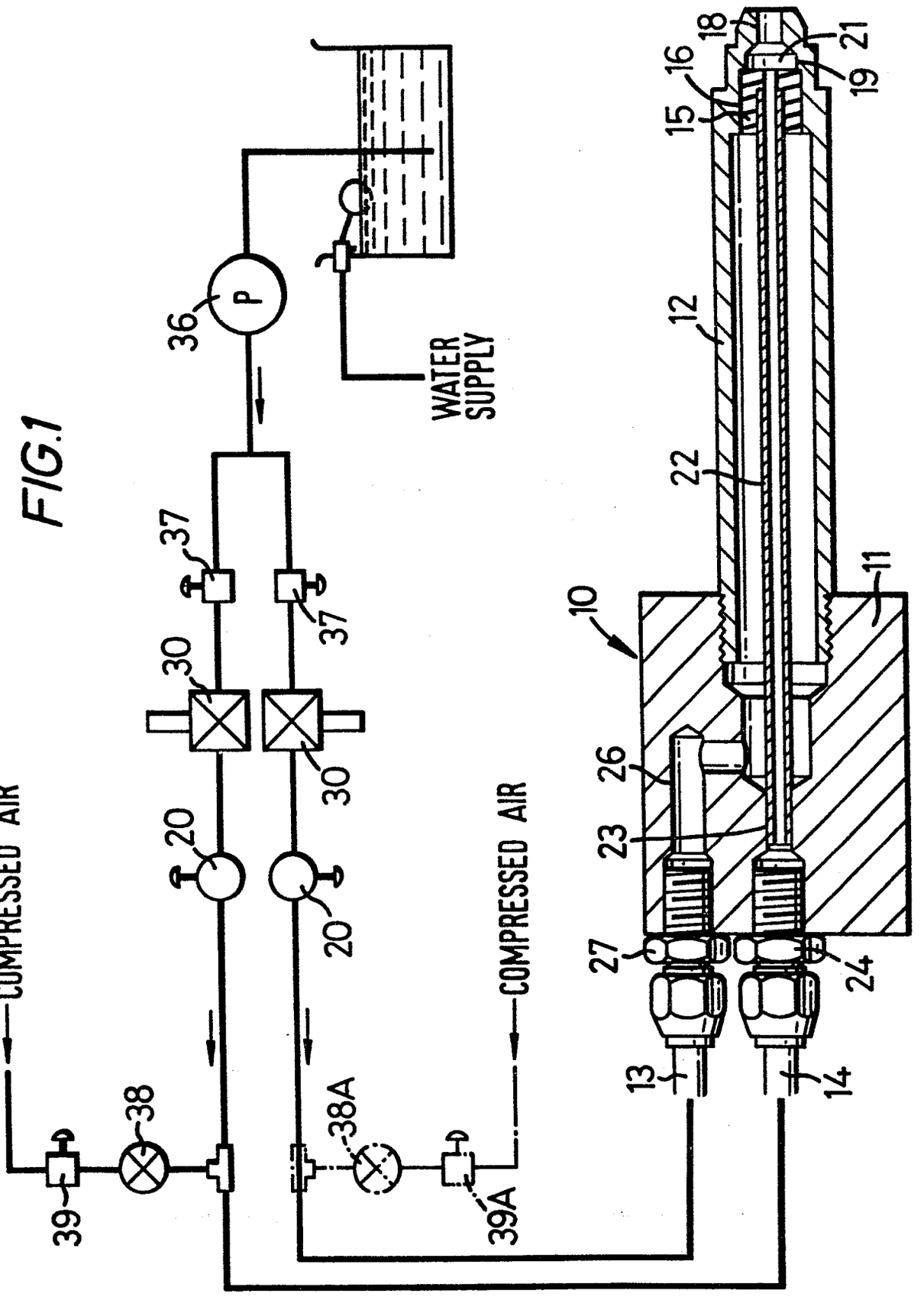
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FIG.2

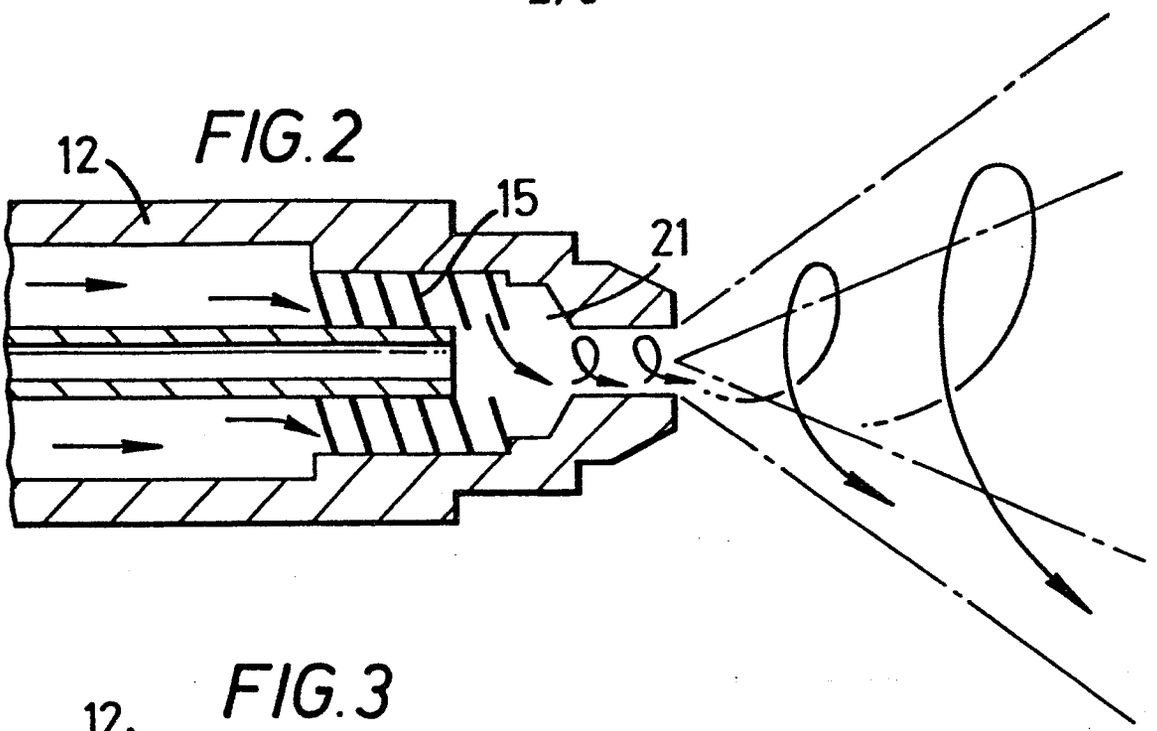



FIG.3

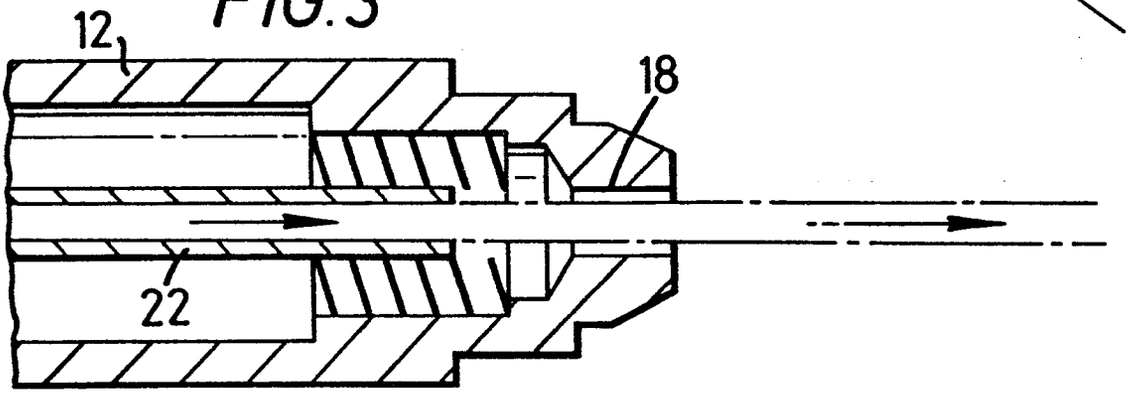
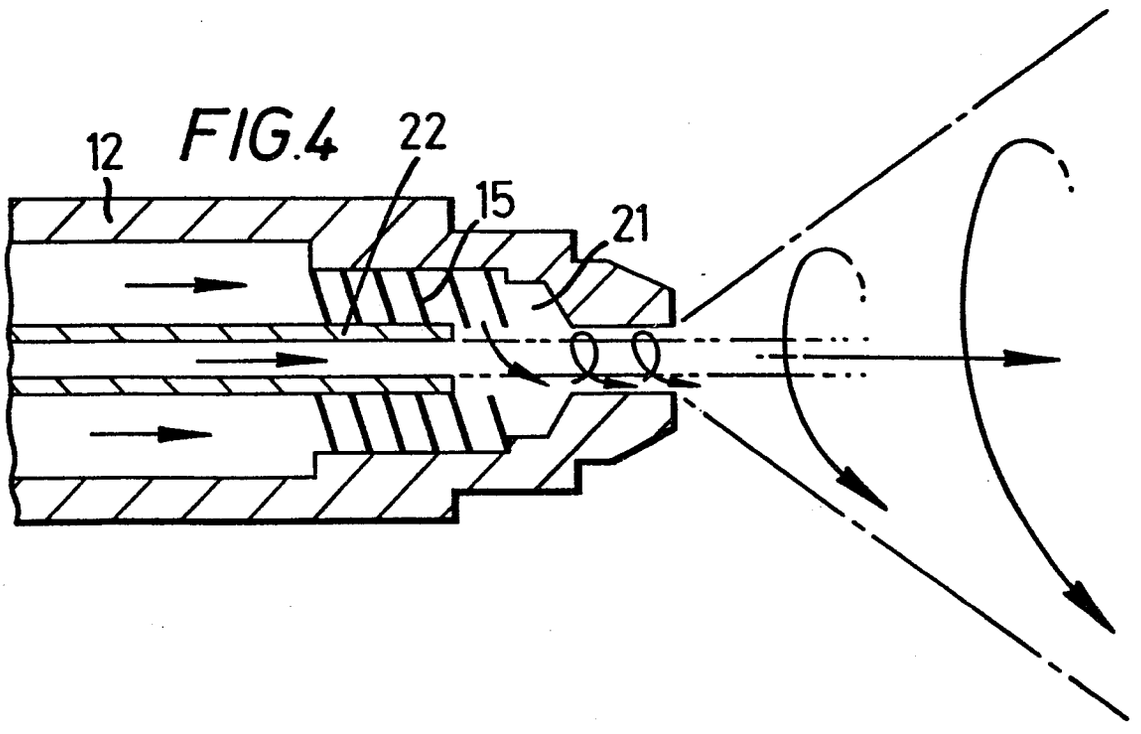



FIG.4



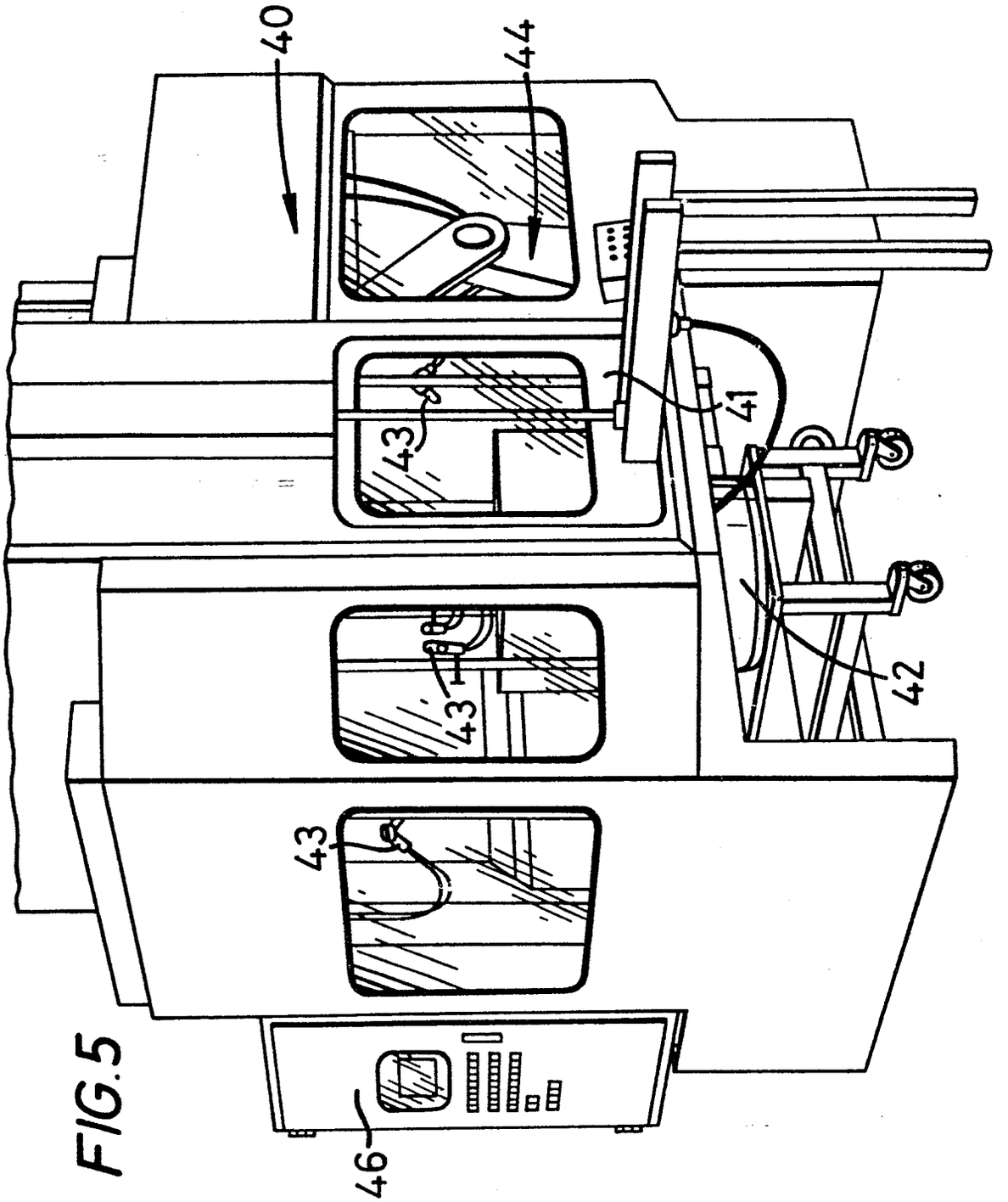



FIG.5

FIG.6

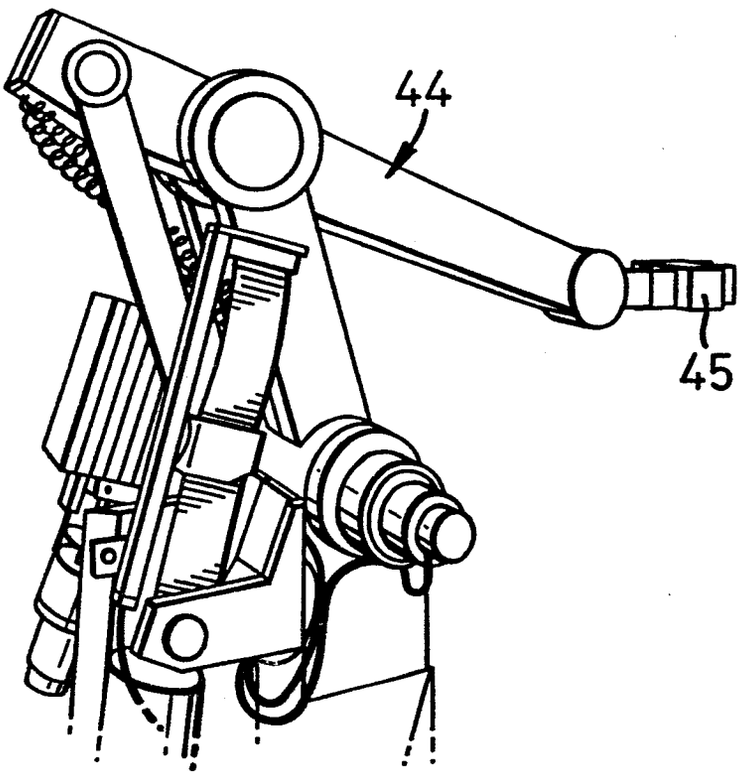


FIG.7

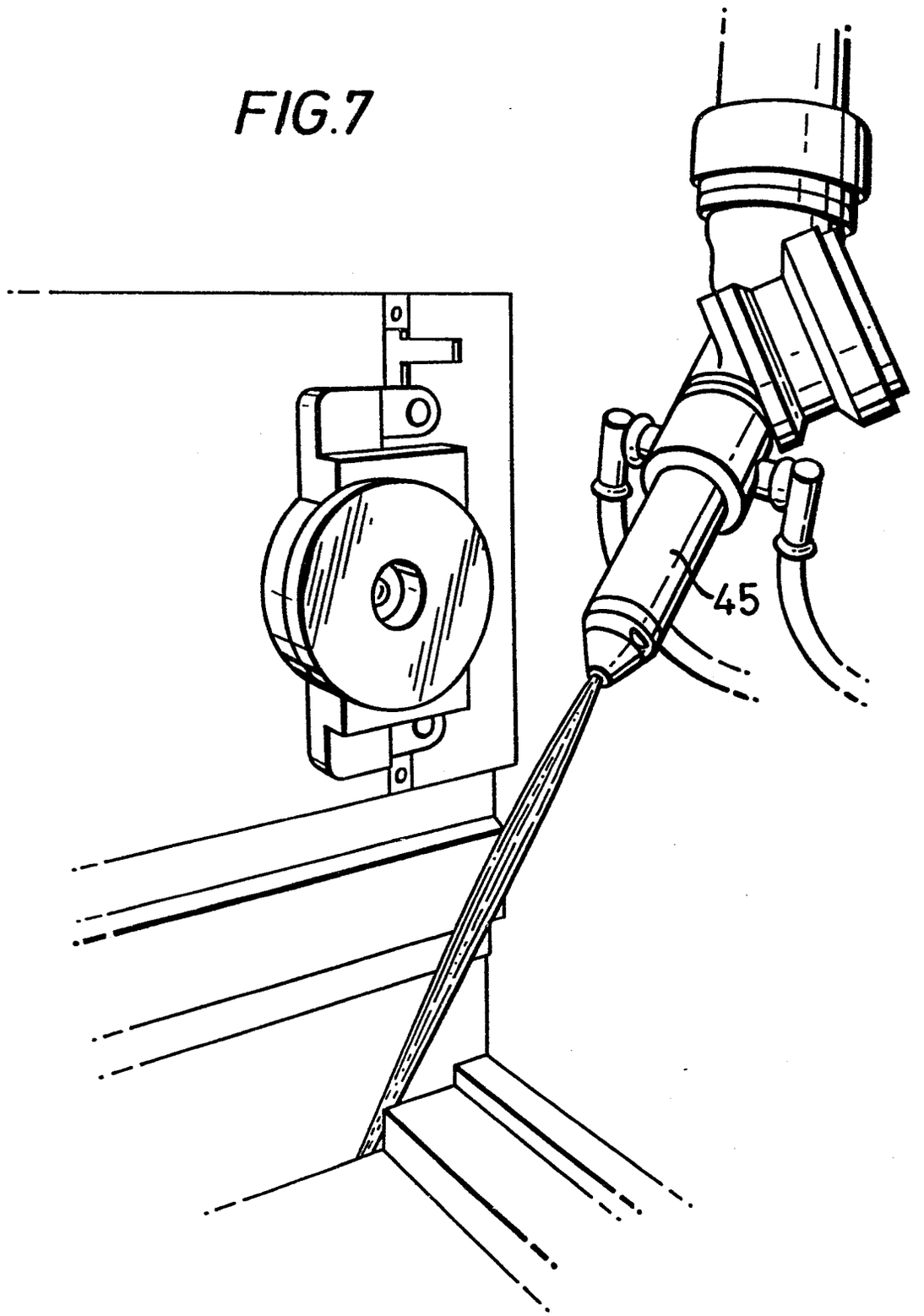
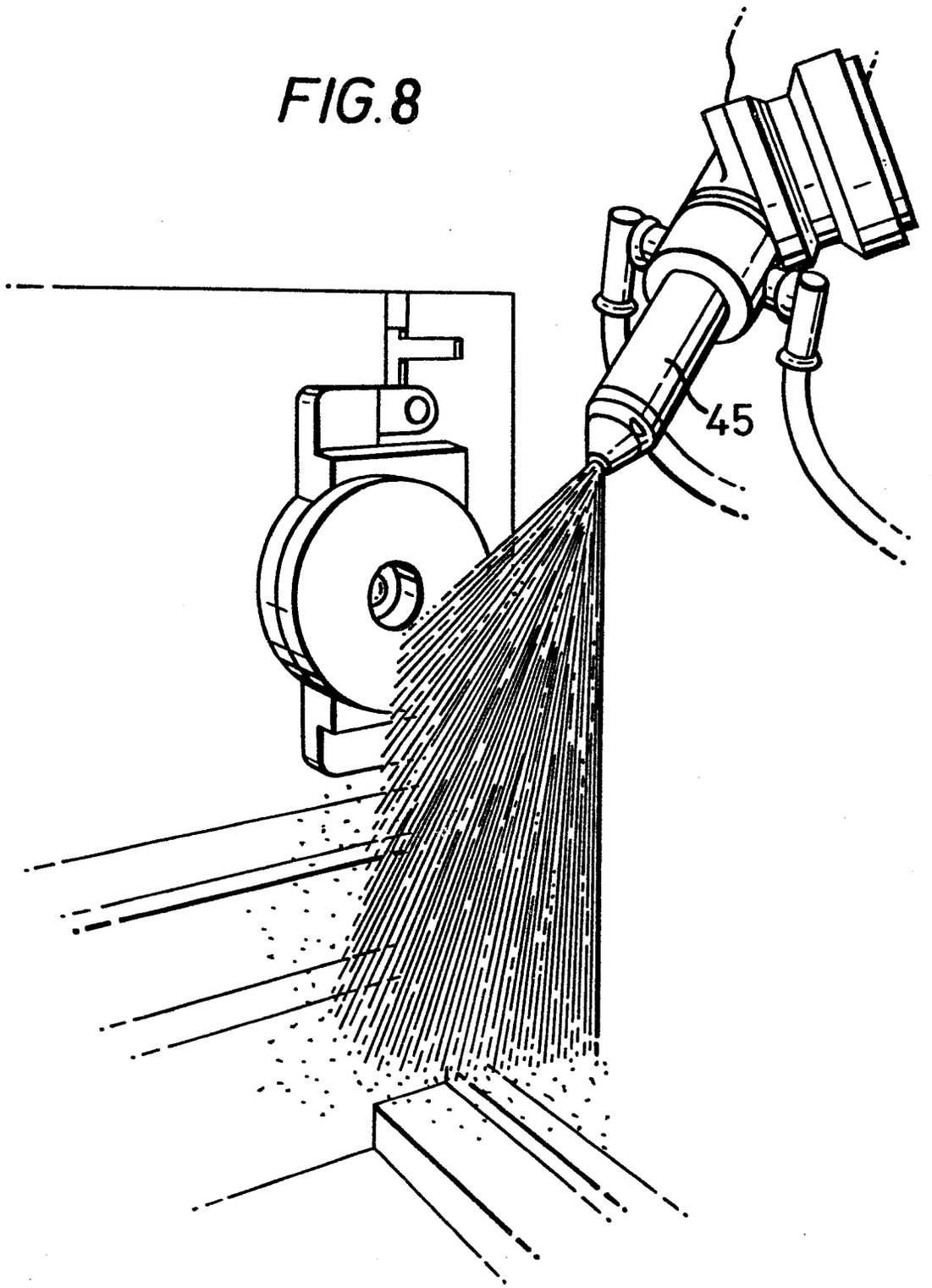


FIG.8



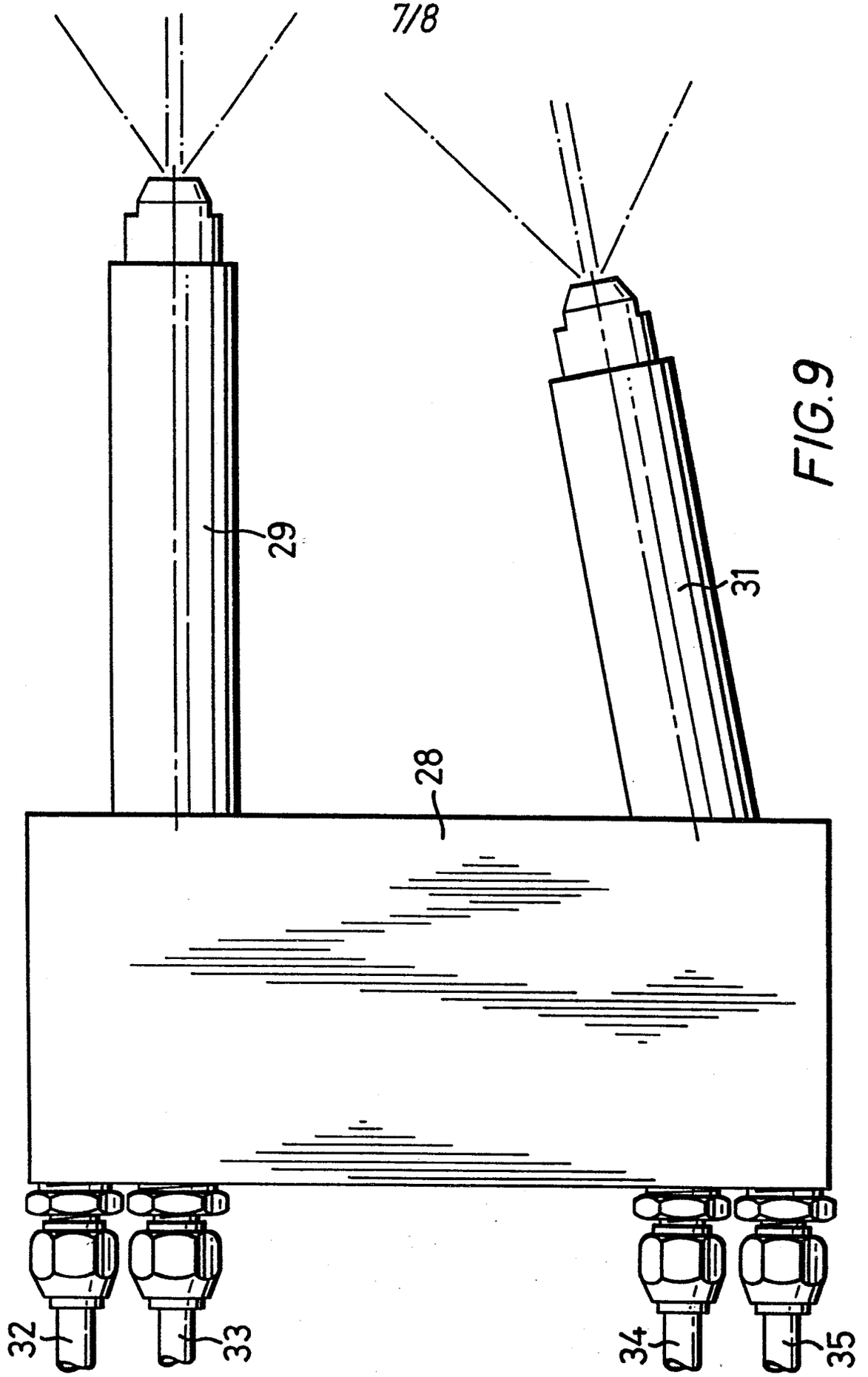



FIG.9

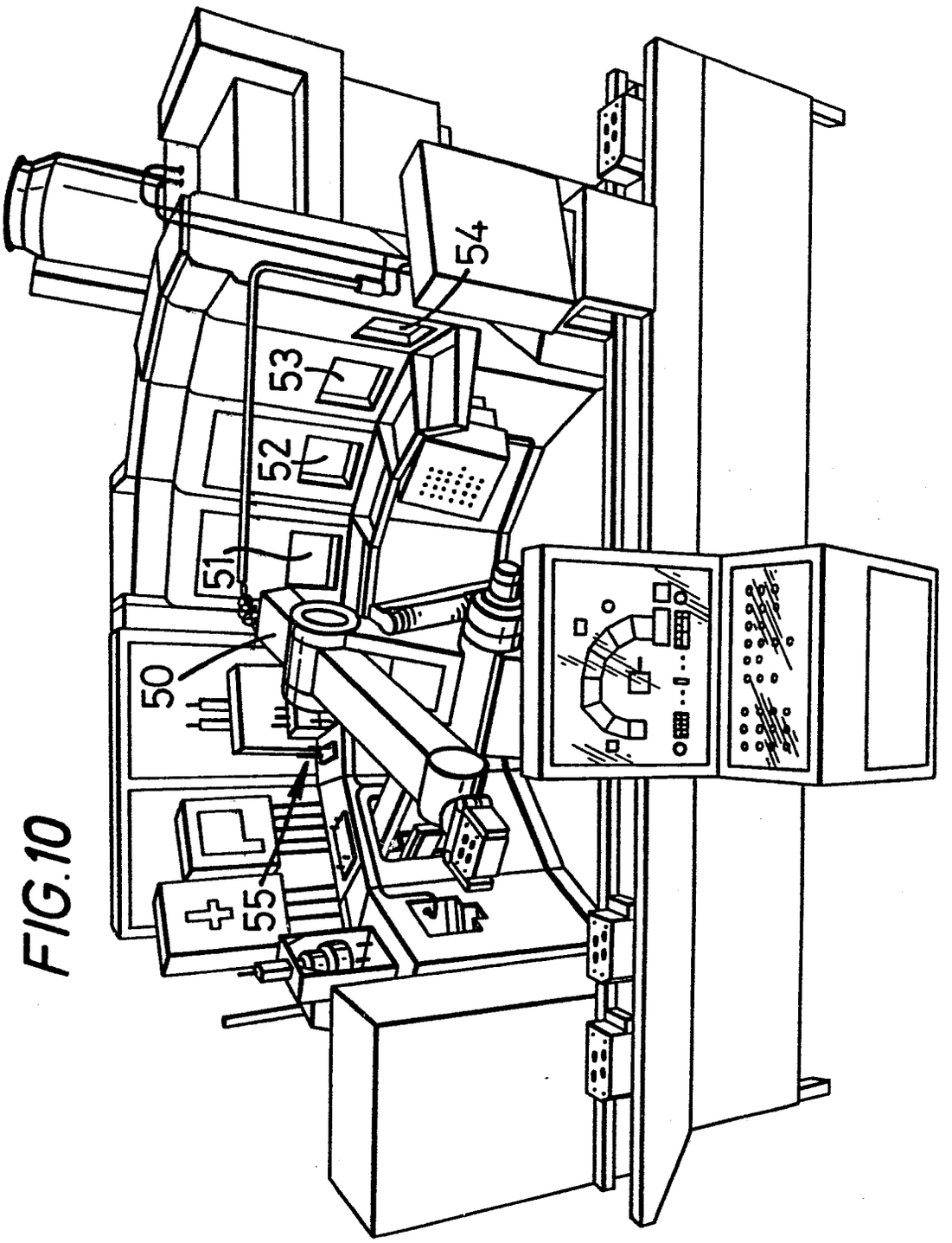



FIG.10

European Patent Office

0140505

Application number

EP 84 30 5549

# EUROPEAN SEARCH REPORT

## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl 4) |
|---|---|---|---|
| D,Y | JP-A-58 098 154 (MOTOHISA TANAKA)<br>* Abstract * | 1,2,8 | B 05 B 1/12<br>B 05 B 12/00<br>B 05 B 13/04<br>B 08 B 3/02 |
| D,Y | GB-A-1 573 424 (CERA INT. LTD.)<br>* Page 1, lines 55-81 * | 1,2,8 | |
| D,A | GB-A-2 001 262 (BAYER A.G.)<br>* Whole document * | 1,2,8, 11,13, 17 | |
| A | US-A-4 228 958 (PERRY)<br>* Column 1, line 67 - column 2, line 2; column 5, lines 2-8; figures 1,2 * | 1,2,4-6,9,10,16 | TECHNICAL FIELDS SEARCHED (Int. Cl.4) |
| A | US-A-3 674 207 (CARBONETTI et al.)<br>* Abstract, line 3; column 3, line 45 * | 1,15 | B 05 B<br>B 08 B |
| A | EP-A-0 034 687 (DE VILBISS)<br>* Page 3, lines 11-12; page 4, line 13 * | 2,4,5 | |

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 20-11-1984 | JUGUET J.M. |

CATEGORY OF CITED DOCUMENTS

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Y : particularly relevant if combined with another document of the same category
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P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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EP 84 30 5549



## DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (Int. Cl.4) |
|---|---|---|---|
| A | US-A-3 888 420 (BOELKINS)<br><br>* Column 3, line 46; column 4, lines 16-33; figure 6 *<br><br>----- | 3,11, 17 | |

TECHNICAL FIELDS SEARCHED (Int. Cl.4)

The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
|---|---|---|
| THE HAGUE | 20-11-1984 | JUGUET J.M. |

CATEGORY OF CITED DOCUMENTS

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