United States Patent

Lubanska

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[54] TREATMENT OF MOLTEN MATERIAL

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Nov. 27, 1968 Great Britain 56,250/68

[52] **U.S. Cl.** ....**75/60,** 75/0.5 BA, 75/0.5 C, 75/59, 264/12

[51] **Int. Cl.** **C21c 5/00,** C21c 7/00, B22d 23/08

[58] **Field of Search**......................75/0.5 BA, 51, 52, 59, 60; 264/12

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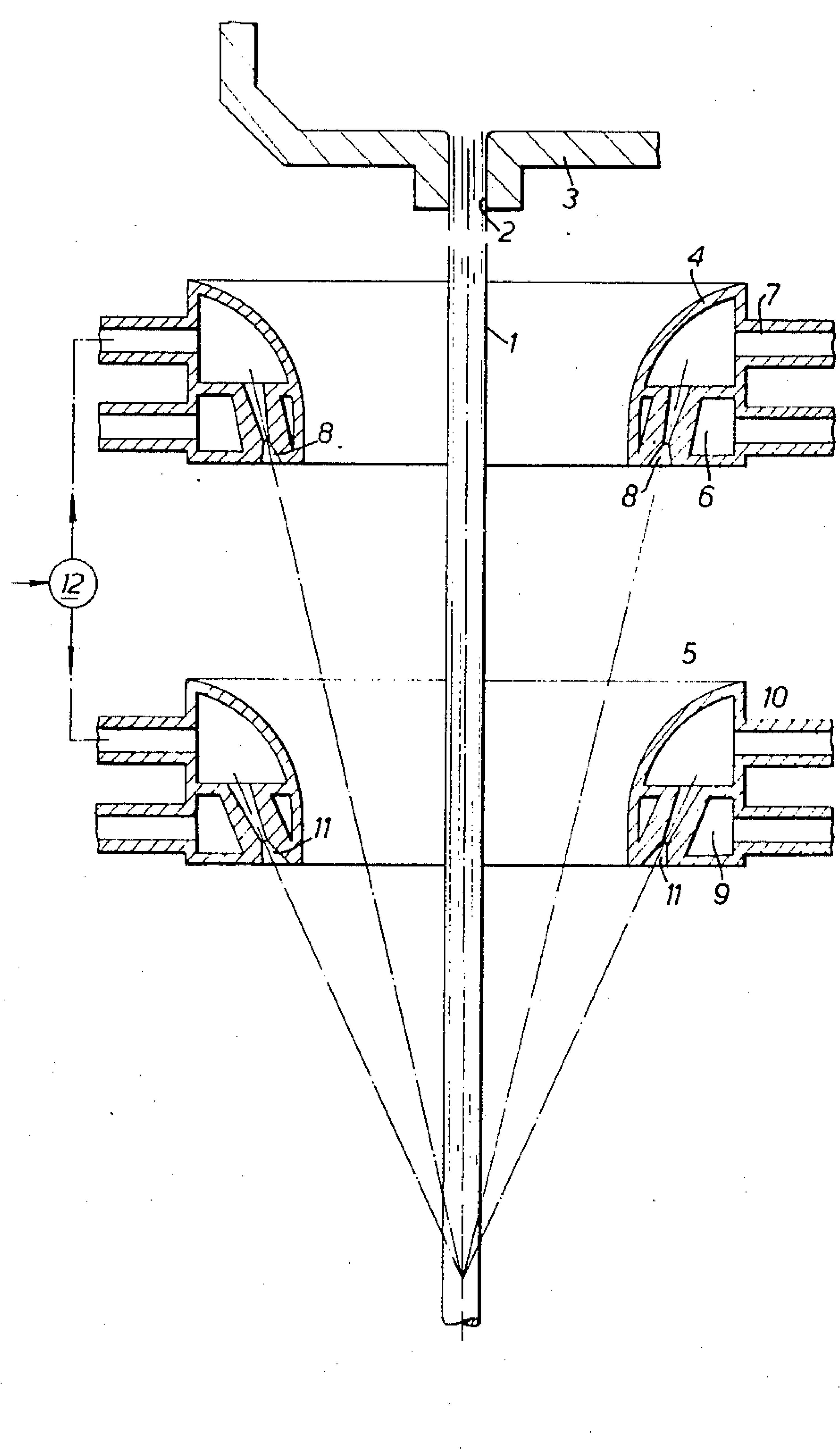
[57] **ABSTRACT**

A method of shattering a freely falling liquid stream by means of downwardly directed jets which strike the stream at a common impact zone. The jets issue from two or more nozzle systems, the flow from one system striking the stream at an angle different from that at which the flow from at least one other system strikes. Each nozzle system comprises one or more nozzles and the nozzle or nozzles of one system may be located at a level different from that at which the nozzle or nozzles or another system are located.

28 Claims, 6 Drawing Figures



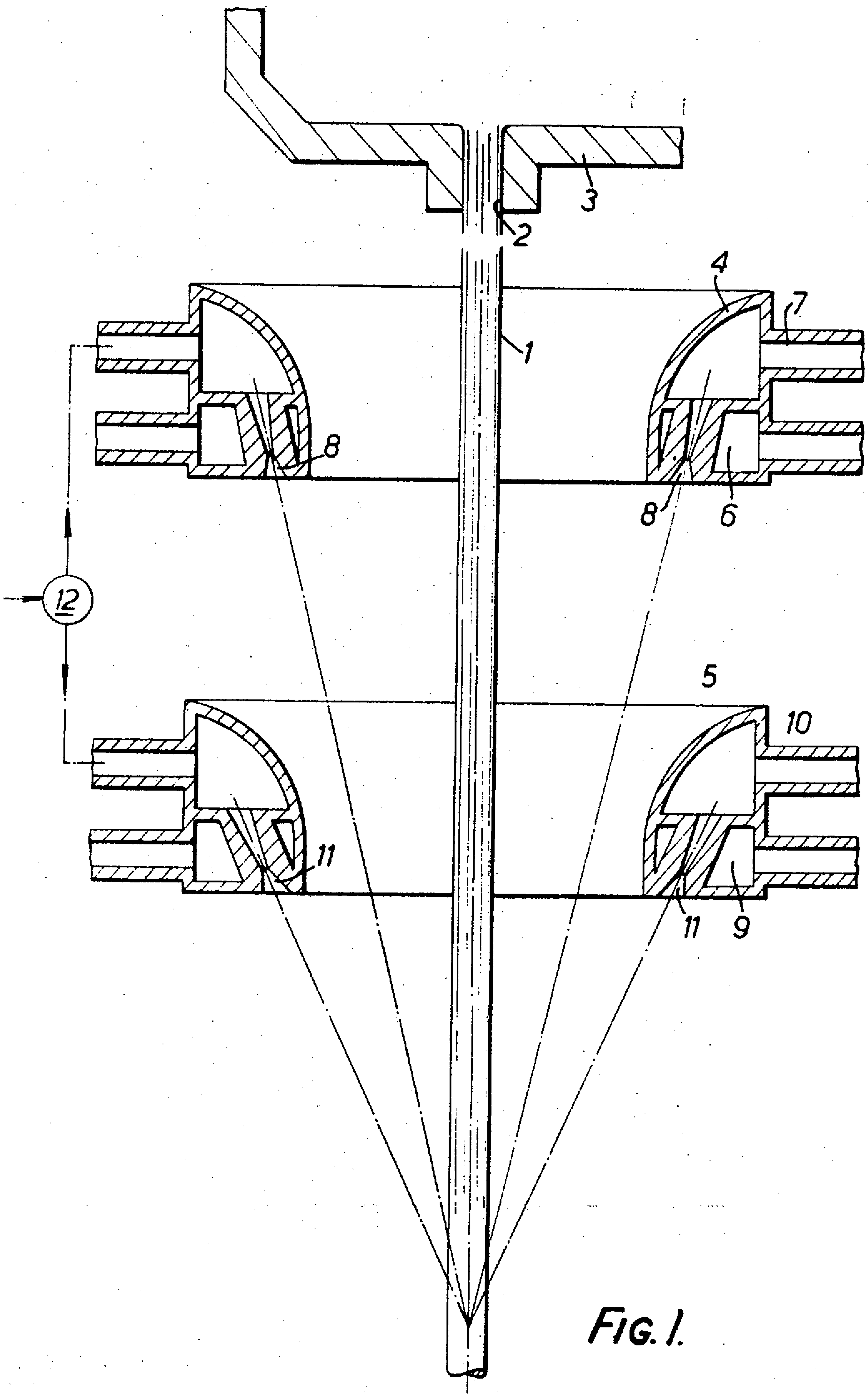


FIG. 1.

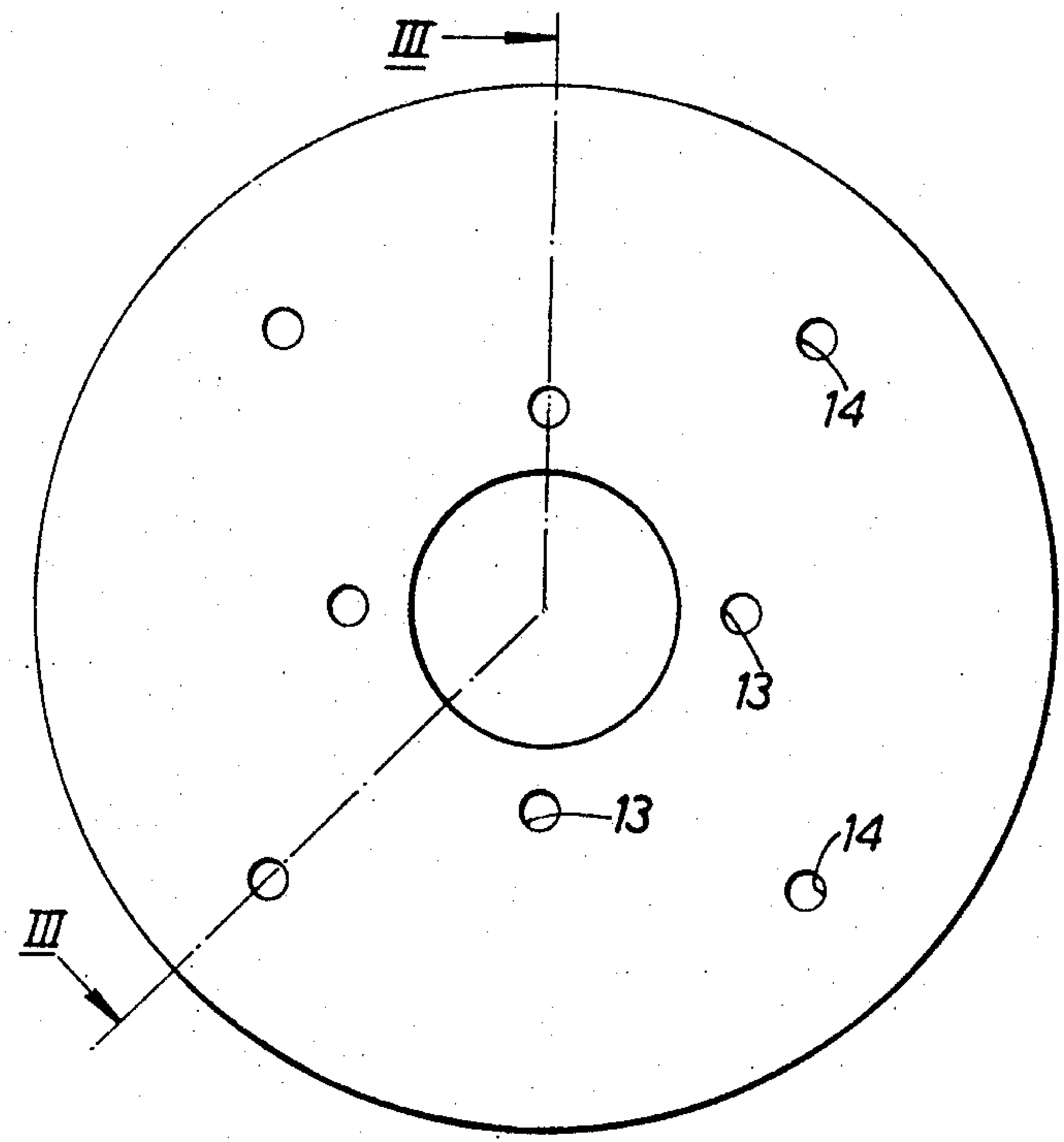


FIG. 2.

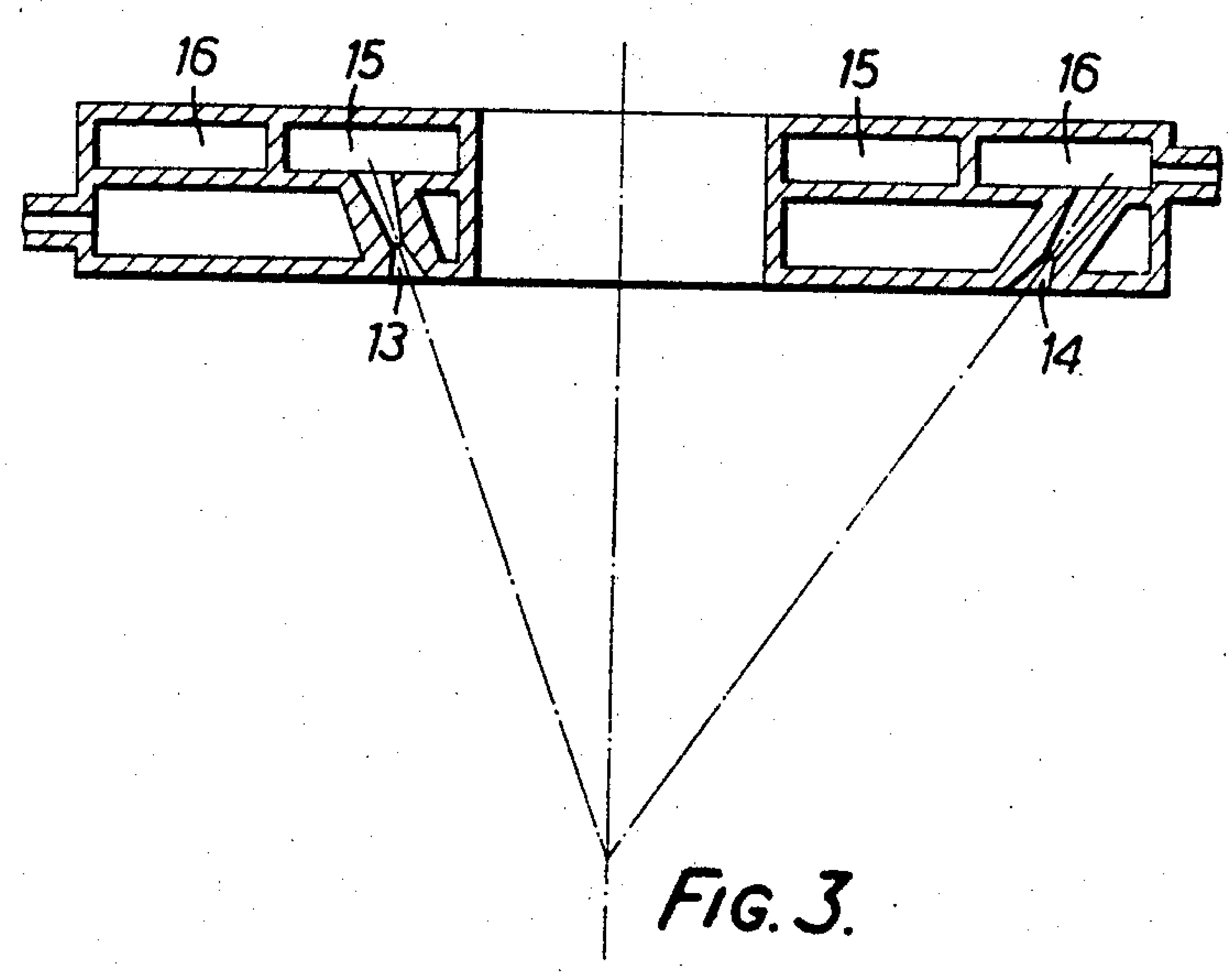


FIG. 3.

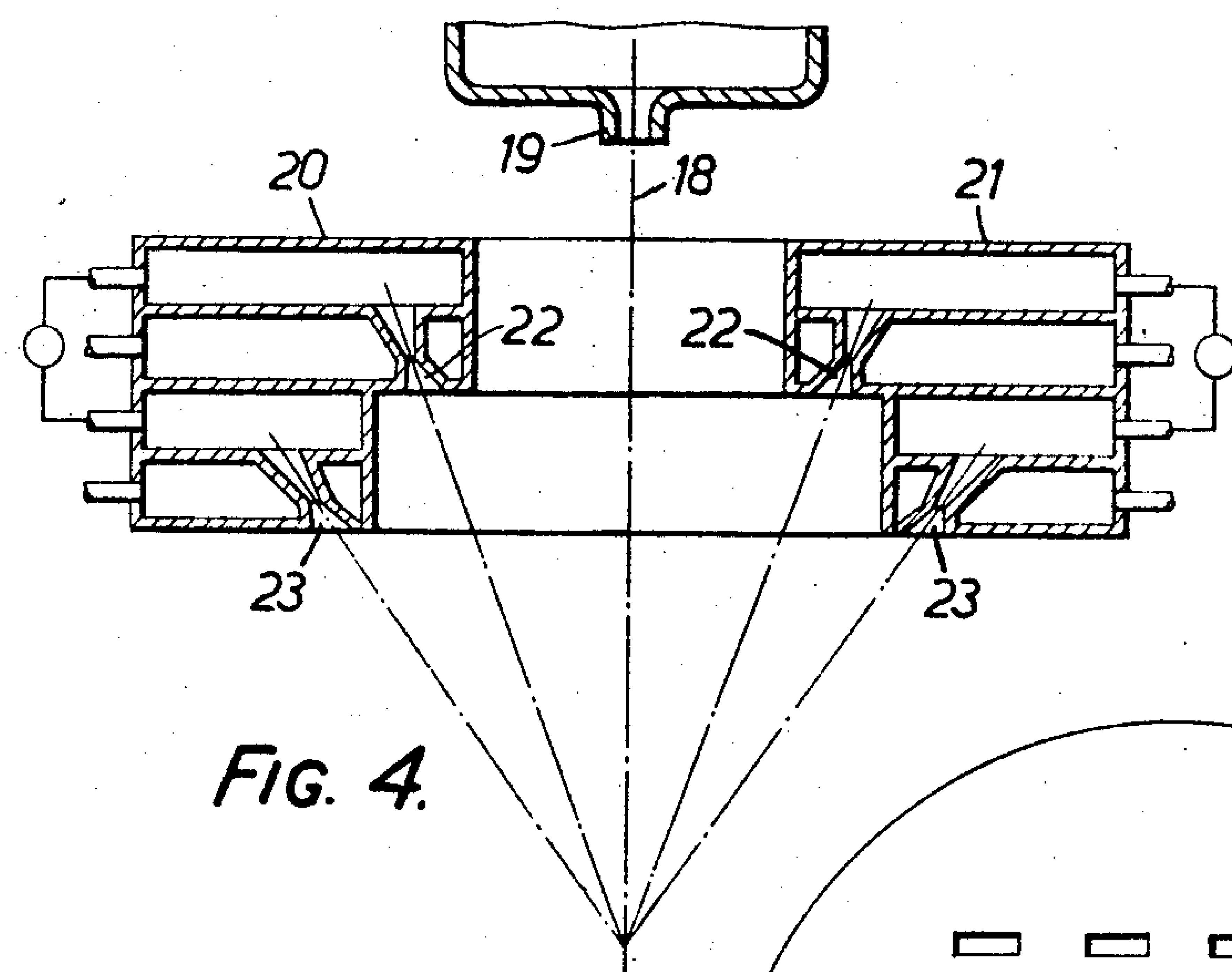


FIG. 4.

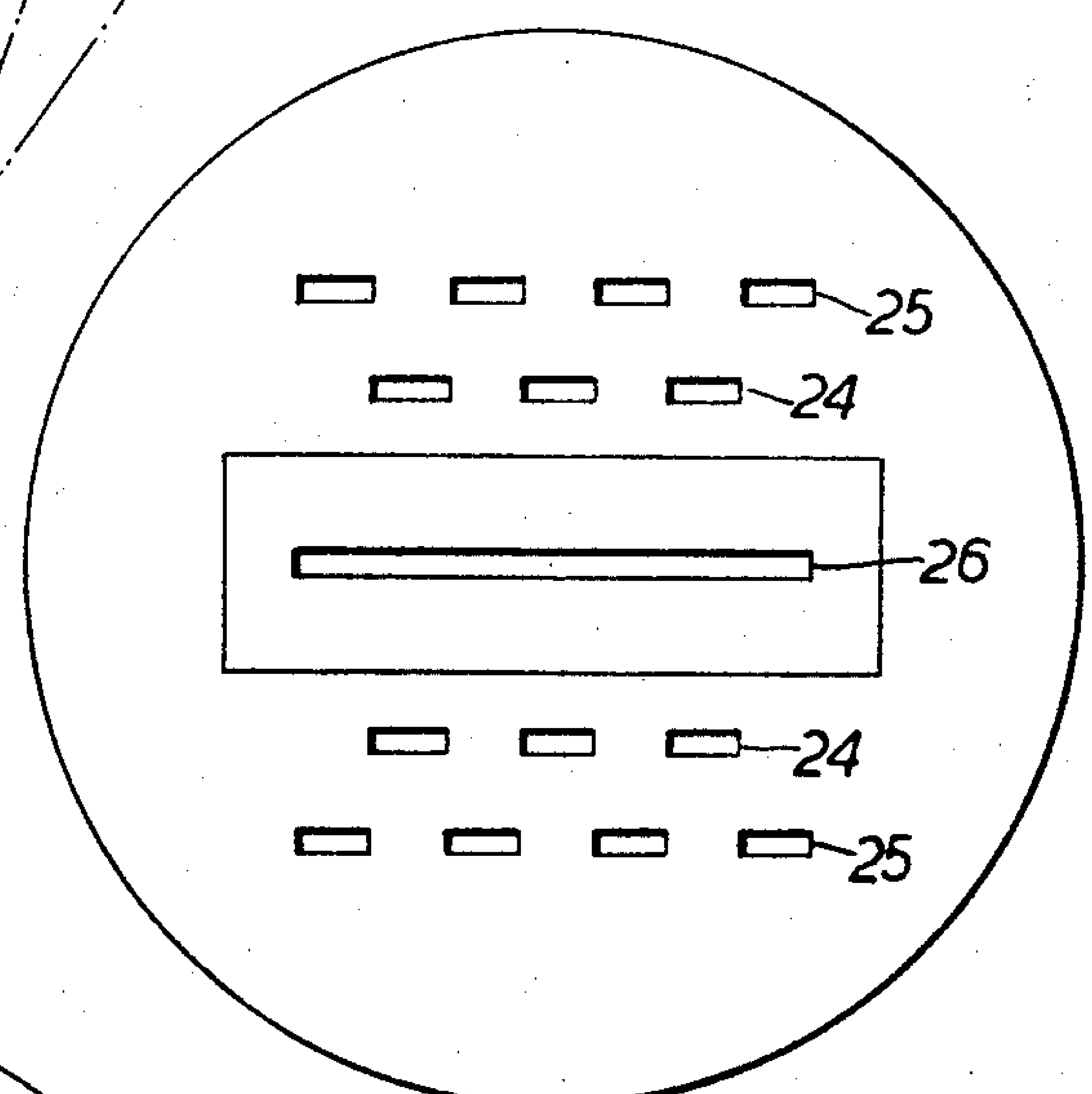


FIG. 5.

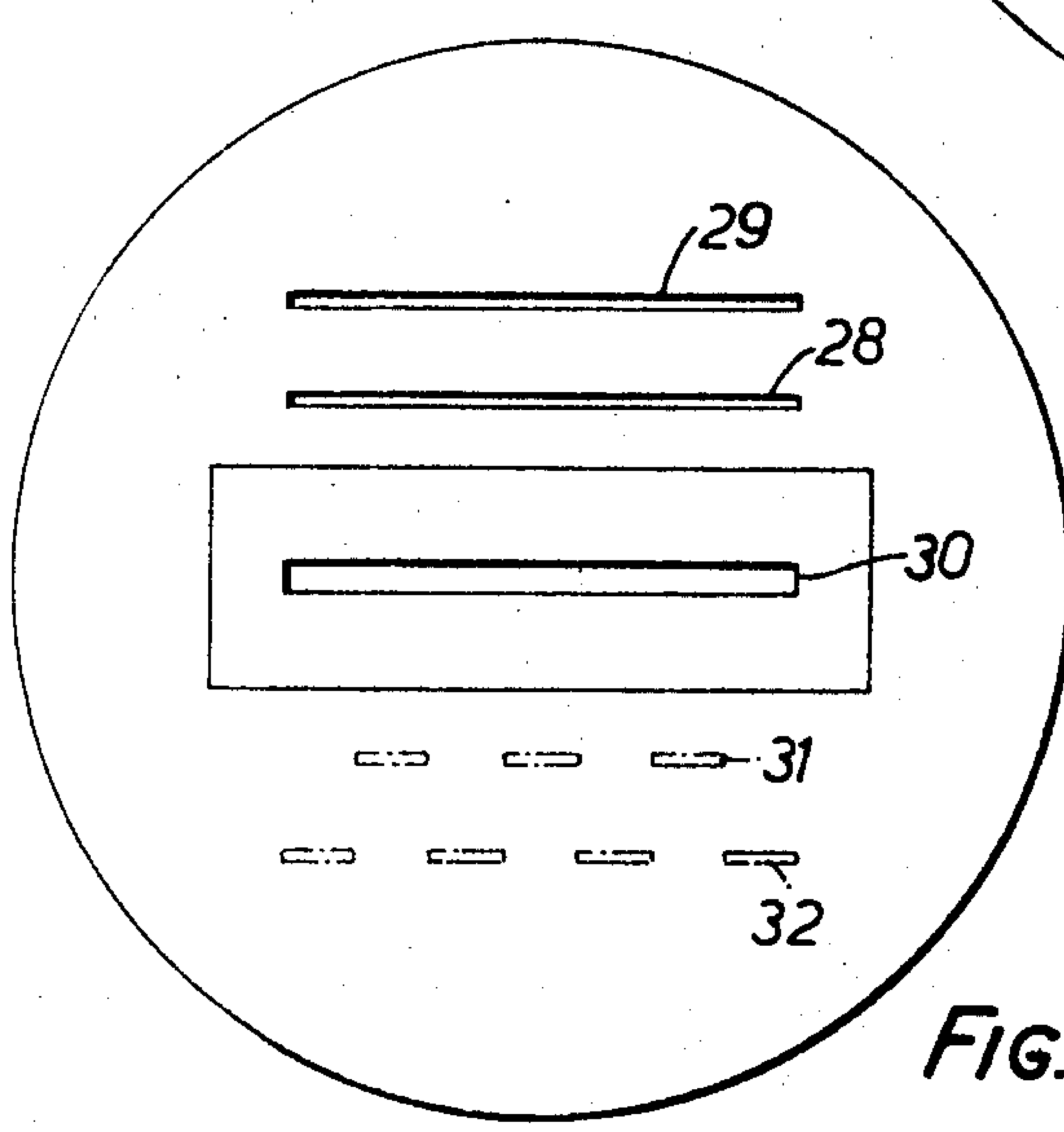


FIG. 6.

TREATMENT OF MOLTEN MATERIAL

This invention is concerned with improvements in and relating to the shattering of streams of liquid material by means of fluid jets. The invention is applicable to the treatment of molten metallic material with gases, for example, in the spray treatment of a freely falling stream of molten metallic material by the action of a reacting gas generally in the manner described in United Kingdom Pat. No. 949,610. The invention may also be applied to the formation of droplets in the production of powder.

Proceeding in accordance with the present invention in one aspect, there is provided a method of shattering a freely falling liquid stream which comprises causing downwardly directed jets of fluid from two nozzle systems to impact upon the liquid stream in a common impact zone, the arrangement being such that the angle to the vertical at which the flow from one nozzle system strikes the stream is different from that at which the flow from the other system strikes and that the vector sum, in a horizontal plane passing through the impact zone, of the forces applied to the stream by the flow from each system is substantially zero. It has been found that such procedure can be employed not only to achieve a desired degree of shattering of the liquid stream but also to impose a directional control upon the droplets produced.

According to the present invention in another aspect, there is provided a method of shattering a freely falling liquid stream which comprises causing downwardly directed jets of fluid from two nozzle systems situated at different levels to impact upon the stream in a common impact zone, the arrangement being such that the angle to the vertical at which the flow from one nozzle system strikes the stream is different from that at which the flow from the other system strikes.

The invention will now be described by way of example with reference to the accompanying diagrammatic drawings, in which:

FIG. 1 is a vertical cross-section taken through part of the nozzle configuration of apparatus for carrying out the invention;

FIG. 2 is a plan view illustrating a form of nozzle installation alternative to that shown in FIG. 1;

FIG. 3 is a sectional elevation taken on line III—III of FIG. 2;

FIG. 4 is a vertical cross-section taken through part of an alternative nozzle configuration; and

FIGS. 5 and 6 are plan views illustrating further forms of nozzle installation.

As shown in FIG. 1, a stream of molten material **1** (for example, molten metallic material) flowing from the outlet **2** of a tundish **3** falls through the central apertures of a pair of nozzle rings **4** and **5** of the same pitch circle diameter. The rings **4** and **5** are located on different levels; that is to say, the medians of the exit planes of the nozzles of the ring **4** lie on a horizontal plane spaced above the horizontal plane which contains the medians of the exit planes of the nozzles of the ring **5**. The upper ring **4** comprises a water-cooling passage **6**, a gas manifold **7** and a nozzle system comprising four equally spaced nozzles **8** (of which only two are shown), each communicating with the manifold; the lower ring **5** is similarly constructed, the cooling passage, gas manifold and nozzles being indicated by the reference numerals, **9**, **10** and **11** respectively.

The nozzles in both rings are of the convergent/divergent type and the throats are of similar cross-section. Although each nozzle **8** is shown disposed vertically above one of the nozzles **11**, the rings **4** and **5** may alternatively be so related in azimuth that each nozzle **8** is situated vertically above a portion of the ring **5** mid-way between a pair of the nozzles **11** in order to avoid interference between the boundaries of the jets of the two nozzle systems. The center lines of the nozzles **8** are each downwardly inclined at a common angle to the vertical and the center lines of the nozzles **11** are each inclined at a greater angle to the vertical such that the two sets of center lines are aimed at a common point on the vertical axis which passes through the center of the tundish outlet. The nozzles **8** and **11** are symmetrically disposed about the vertical axis which passes through the center of the tundish outlet in such a manner that if the velocities of the jets issuing from the nozzles of each nozzle system are equal, then the vector sums, in a horizontal plane passing through the impact zone, of the forces applied to the stream **1** by the four jets issuing from the nozzles **8** and by the four jets issuing from the nozzles **11** respectively are each substantially zero. With the arrangement illustrated, the four gas jets issuing from the nozzles **8** will impinge upon the surface of the molten material stream at a smaller mean angle to the vertical than will the four jets issuing from the nozzles **11**; furthermore, if all eight jets leave the respective nozzles with equal velocity, those issuing from the nozzles **8** will strike the stream with less force than do those issuing from the nozzles **11**, due to the greater slant distance travelled by the former jets. Movement of particles in a direction other than downwardly can lead to their undesired contact with parts of the apparatus situated at levels higher than the impact zone and may result in damage to, for example, the equipment for admission of the gas and molten metal; it has been found that, whilst providing satisfactory shattering of the stream, arrangements in accordance with the invention tend to prevent or minimize movement of particles in an upward direction away from the impact zone.

Factors other than difference in slant distance may be employed to achieve a desired relationship between the force with which the jets from the different nozzle systems strike the stream. For example, the jets may leave the respective nozzles with different momenta, the throat sizes of nozzles of each nozzle system being different and/or different pressures prevailing upstream of the nozzle exits; in the latter connection, there is shown in FIG. 1 valve means **12**, adjustment of which will result in differential control of the flows to the manifolds **7** and **10** respectively. It will be desirable, in general, to arrange that the pressures obtaining upstream of the nozzles are sufficient, at least in the case of the nozzles **11**, to ensure that the jets produced have supersonic cores which persist an appropriate distance toward the impact zone.

Whereas the arrangement illustrated in FIG. 1 comprises two rings each having four nozzles, it is to be appreciated that the arrangement may be so modified that either ring comprises some other number of nozzles; for example, the upper ring may comprise a single annular nozzle and the lower ring an array of three symmetrically arranged nozzles. The upper ring may be of smaller pitch circle diameter than the lower ring; also, the upper ring may be seated upon the lower ring in such a manner that no space exists between the two. Furthermore, more than two nozzle systems may be employed.

In the arrangement illustrated by FIGS. 2 and 3, a single nozzle ring is used and comprises two nozzle systems **13** and **14** in communication with gas manifolds **15** and **16** respectively, the medians of the exit planes of the nozzles of each system being located in the same horizontal plane. As will be seen from FIG. 2, the four nozzles of each system **13**, **14** are located symmetrically in a circular array about the vertical axis passing through the center of the tundish nozzle, the arrangement being such that if the velocities of the jets leaving each nozzle system are equal then the vector sum, in a horizontal plane passing through the impact zone, of the forces applied to the stream by the flow from each system is substantially zero. The eight nozzles are symmetrically arranged in a pattern such that the nozzles **13** are situated on a pitch circle diameter smaller than that on which the nozzles **14** are arranged. The eight nozzles are of equal throat diameter but, as will be seen from FIG. 3, the center lines of the nozzles **13** are inclined at a smaller angle to the vertical than are the center lines of the nozzles **14**, the angles being so chosen that the eight center lines meet at a common point on the vertical axis passing through the center of the ring. The pressures obtaining upstream of the nozzles **13**, **14** are so controlled that the force with which the jets issuing from nozzles **13** strike the molten stream is not greater than the force with which the jets issuing from nozzles **14** strike the stream.

It will be appreciated that in modifications of the embodiment illustrated by FIGS. 2 and 3, each system of nozzles may comprise any desired number of nozzles and that the number of nozzles in one system may differ from that of the other system; also, it will be desirable to provide that jet velocity at issuance from the nozzles **14** is such that supersonic conditions persist an appropriate distance toward the impact zone. Furthermore, more than two nozzle systems may be employed in modifications of any of the embodiments described.

Although the specific embodiments illustrated and described above all comprise circular arrays of nozzles discharging gas toward a cylindrical stream, the invention can also be applied (with appropriate disposition of the various nozzles) to arrangements in which the molten metal is poured in a stream having a dimension in one plane which is greater than that in a plane normal thereto.

In the embodiment illustrated in FIG. **4**, a sheet-like stream of molten material **18** flows from an outlet nozzle **19** of a tundish which, in a horizontal plane, has in a direction perpendicular to the plane of the paper a dimension several times larger than the dimension in a direction at right angles to the first-mentioned direction and to the vertical plane passing through the median line of the tundish nozzle. The stream **18** falls between two nozzle assemblies **20**, **21** each of which comprises a pair of cooled superposed, nozzles **22**, **23** which are arranged to discharge fluid jets which each extend across substantially the full width of the sheet-like material stream. The upper nozzles **22** are equi-spaced from the vertical plane passing through the median line of the tundish nozzle and the center line of each nozzle is downwardly inclined at the same angle to the vertical. The lower nozzles **23**, which are spaced further apart than the nozzles **22**, are similarly arranged, being equi-spaced from the previously mentioned vertical plane, but being downwardly inclined at a different common angle to the vertical.

The nozzles **22** constitute one nozzle system and the nozzles **23** constitute another nozzle system, the arrangement being such that if the velocities of the jets leaving each system are equal, then the vector sums, in a horizontal plane passing through the impact zone, of the forces applied to the stream by the two jets issuing from the nozzles **22** and by the two jets issuing from the nozzles **23** respectively, are each substantially zero. With the arrangement illustrated, the jets issuing from the nozzles **22** will impinge on the surface of the stream at a smaller mean angle to the vertical then will the jets issuing from the nozzles **23**; furthermore, if all four jets leave the respective nozzles with equal velocity, those issuing from the nozzles **22** will strike the stream with less force than do those issuing from the nozzles **23**, due to the greater slant distance travelled by the former jets.

Whereas the nozzles **22**, **23** have been described as being arranged to discharge fluid jets which extend across the full width of the liquid stream, each nozzle assembly **20**, **21** may comprise two rows of discrete equi-spaced nozzles, the median points at the exit planes of the nozzles of each row lying on a line extending parallel to the horizontal median line of the liquid stream. The nozzle rows of each nozzle assembly may be so related that each individual nozzle of the upper row is situated above a space intermediate adjacent nozzles of the lower row.

Referring now to FIG. **5**, the apparatus comprises a single nozzle assembly including four rows of discrete nozzles, the two inner rows **24** defining one nozzle system and the two outer rows **25** defining a second nozzle system. The exit planes of the nozzles of each system are located in the same horizontal plane and the medians of the exit planes lie on lines which extend parallel to the longitudinal extent of an elongate tundish nozzle **26**. The nozzles of each inner row **24** interdigitate the nozzles of the adjacent outer row **25**. The arrangement is such that each of the vector sums, in a horizontal plane passing through the impact zone, of the forces applied by the flow from a nozzle system to the sheet-like liquid stream falling from the tundish nozzle is substantially zero. In an alternative embodiment to that illustrated in FIG. **5**, the nozzle rows **24**, **25** are replaced by slot-shaped nozzles each extending substantially co-extensively with the longitudinal extent of the tundish nozzle.

In the embodiment illustrated in FIG. **6**, the apparatus comprises a nozzle assembly including only two elongate slot-shaped nozzles **28** and **29**, each nozzle constituting a nozzle system. The medians of the exit planes of the nozzles **28**, **29** are located in the same horizontal plane and the median line of each nozzle extends parallel to the longitudinal extent of an elongate tundish nozzle **30**. With the arrangement as illustrated, the jet issuing from the nozzle **28** will impinge on a surface of the liquid stream at a smaller mean angle to the vertical than will the jet issuing from the nozzle **29**. In an alternative embodiment, the nozzles **28**, **29** may be replaced by rows of mutually separated nozzles **31**, **32** respectively, as shown in broken line in FIG. **6**.

In a modification (not illustrated) of the embodiment illustrated in FIG. **6**, the nozzle **29** or the nozzles **32** may be located on a level different from that on which nozzle **28** or the nozzles **31** respectively is located; in such a modification, the assembly would be similar to either the nozzle assembly **20** or **21** illustrated in FIG. **4**.

Whereas the arrangements illustrated in FIGS. **4**, **5** and **6** comprise two nozzle systems, it is to be appreciated that either arrangement may be so modified that it comprises more than two nozzle systems.

When apparatus of the kind herein described is used in circumstances in which chemical reaction is desired between the gas and the molten stream, for instance in the refining of ferrous metal by reaction between oxygen or other oxidizing gas and metalloid impurities in the metal, it may be convenient to arrange that the gas striking the stream at a larger angle or angles to the vertical does so with sufficient force to achieve effective shattering of the stream, gas delivered by way of the other nozzle or nozzles being employed to give a total gas delivery suited to the requirements of the desired chemical reaction.

When apparatus of the kind illustrated in the drawings is used in the production of powder, the fluid for shattering the material stream may be a liquid. When liquid jets are used, the nozzles from which the jets issue would be of the convergent or parallel bore type as distinct from the convergent/divergent nozzles illustrated in the drawings.

I claim:

1. A method of minimizing the the upward movement of particles when shattering a freely falling liquid stream which method comprises the steps of causing downwardly directed jets of fluid from two nozzle systems to impact upon the liquid stream in a common impact zone, the arrangement being such that the angle to the vertical at which the flow from one nozzle system strikes the stream is less than that at which the flow from the other system strikes the stream, that the force with which the flow from the said one nozzle system strikes the stream is not greater than the force with which the flow from the said other nozzle system strikes the stream and that the vector sums, of the forces applied to the stream by the flows from each system in a horizontal plane passing through the impact zone are each substantially zero.

2. A method according to claim **1** wherein the arrangement is such that one nozzle system comprises a plurality of nozzles symmetrically arranged in a circular array about the vertical axis of the freely falling liquid stream.

3. A method according to claim **1** wherein the arrangement is such that each nozzle system comprises a plurality of nozzles symmetrically arranged in a circular array about the vertical axis of the freely falling liquid stream.

4. A method according to claim **1** wherein the arrangement is such that the two nozzle systems are situated at different levels.

5. A method according to claim **1** wherein the arrangement is such that the medians of the exit planes of the nozzles of the two nozzle systems lie in the same horizontal plane, each nozzle of one system lying at a different distance from the path of the liquid stream than each nozzle of the other nozzle system.

6. A method according to claim 1 wherein the liquid stream has in a first direction in a horizontal plane a dimension several times larger than the dimension in a second direction at right angles to the first direction and wherein the arrangement is such that each nozzle system produces a flow which extends across the two sides of major dimension of the liquid stream.

7. A method according to claim 6 wherein the arrangement is such that each system comprises two rows of mutually spaced nozzles, each row positioned opposite a side of major dimension of the path of the liquid stream, the medians of the exit planes of the nozzles of each row lying on lines extending parallel to the longitudinally extending horizontal median line of the liquid stream.

8. A method according to claim 7 wherein the jets from the nozzles of each row of one nozzle system interdigitate the jets from the nozzles of the adjacent rows of the other nozzle system.

9. A method according to claim 6 wherein the flow produced by each nozzle system comprises two coherent jets each extending across substantially the width of a side of major dimension of the liquid stream.

10. A method according to claim 1 wherein the fluid issuing from at least one nozzle system reacts chemically with the liquid stream or with impurities within the liquid stream.

11. A method according to claim 10 wherein the fluid is an oxidizing gas.

12. A method according to claim 11 wherein the fluid is oxygen.

13. A method according to claim 1 wherein the liquid stream is of a molten metallic material.

14. A method according to claim 13 wherein the liquid stream consists of molten ferrous metal.

15. A method according to claim 1 wherein the fluid issuing from at least one nozzle system comprises a liquid.

16. A method according to claim 15 wherein the bore or bores of the or each nozzle of at least one system is of convergent form.

17. A method according to claim 15 wherein the bore or bores of the or each nozzle of at least one system is parallel sided.

18. A method of shattering a freely falling liquid stream which comprises causing downwardly directed jets of fluid from two nozzle systems situated at different levels to impact upon the stream in a common impact zone, the arrangement being such that the angle to the vertical at which the flow from one nozzle system strikes the stream is less than that at which the flow from the other system strikes and that the force with which the flow from said one nozzle system strikes the stream is not greater than the force with which the flow from the said other nozzle system strikes the stream.

19. A method according to claim 18 wherein the arrangement is such that each nozzle system comprises a plurality of nozzles symmetrically arranged in a circular array about the vertical axis of the liquid stream, the diameter of the circle passing axis of the liquid stream, the diameter of the circle passing through the median of the exit plane of the or each nozzle of one system being equal to the diameter of the circle passing through the median of the exit plane of the or each nozzle of the other system.

20. A method according to claim 18 wherein the arrangement is such that each nozzle system comprises a plurality of nozzles symmetrically arranged in a circular array about the vertical axis of the liquid stream, the diameter of the circle passing through the median of the exit plane of the or each nozzle of one system being different from the diameter of the circle passing through the median of the exit plane of the or each nozzle of the other system.

21. A method according to claim 18 wherein the arrangement is such that the nozzles of each array of the two systems are so orientated that each nozzle of the upper array is situated vertically above a line passing between adjacent nozzles of the lower array.

22. A method according to claim 18 wherein the liquid stream has in a first direction in a horizontal plane, a dimension several times larger than the dimension in a second direction at right angles to the first direction.

23. A method according to claim 22 wherein the flow produced by each nozzle system comprises two coherent jets each extending across substantially the width of a side of major dimension of the liquid stream.

24. A method according to claim 22 wherein the arrangement is such that each system comprises two rows or mutually spaced nozzles, each row positioned opposite a side of major dimension of the path of the liquid stream, the medians of the exit planes of the nozzles of each row lying on lines extending parallel to the longitudinally extending horizontal median line of the liquid stream.

25. A method according to claim 24 wherein the jets from the nozzles of each row of one nozzle system interdigitate the jets from the nozzles of the adjacent row of the other nozzle system.

26. A method according to claim 18 wherein the bore or bores of the or each nozzle of at least one system is of convergent/divergent form.

27. A method according to claim 22 wherein the flow produced by each nozzle system comprises a coherent jet extending across substantially the width of a side of major dimension of the liquid stream, the flow from each system being caused to impact upon the same side of the liquid stream.

28. A method according to claim 22 wherein the arrangement is such that each system comprises a row of mutually spaced nozzles, the nozzles of each row lying opposite a common side of major dimension of the path of the liquid stream and extending parallel to the longitudinally extending horizontal median of the liquid stream.

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