23526/88

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952

APPLICATION ACCEPTED AND AMENDMENTS

ALLOWED 16-2-90

506325

APPLICATION FOR A PATENT

We, MB GROUP PLC. (formerly Metal Box Public Limited Company), a British company of Caversham Bridge House, Waterman Place, Reading, Berkshire, RG1 8DN, United Kingdom, hereby apply for the grant of a Patent for an invention entitled "CONTINUOUS EXTRUSION OF METALS", which is described in the accompanying Complete specification.

This application is a further application made by virtue of sub-section (1) of Section 51 of the Patents Act 1952 in respect of an invention disclosed in the Complete specification lodged in respect of Application No. 23863/84.

Our address for service is Care of: COWIE, CARTER & HENDY, Patent Attorneys, of 71 Queens Road, Melbourne 3004, Victoria, Australia.

DATED this 6th day of October, 1988.

COWIE, CARTER & HENDY

By: [signature]

Patent Attorneys for
MB GROUP PLC.

To: The Commissioner of Patents,
COMMONWEALTH OF AUSTRALIA.

OWIE, CARTER & HENDY
Patent Attorneys
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COMMONWEALTH OF AUSTRALIA

Patents Act 1952-1962

Forms 7 and 8
(Combined Form)

Declaration in Support of an Application for a Patent

In support of the application made by MB GROUP PLC

for a patent for an invention entitled: CONTINUOUS EXTRUSION OF METALS

I, ROBERT ANTHONY OWEN, Authorised Signatory
(INSERT FULL NAME) (CAPACITY)

of and care of the applicant company do solemnly and sincerely declare as follows:

1. ~~I am / We are~~ ~~the applicant(s) for the patent.~~

or

I am authorised by the applicant for the patent to make this declaration on its behalf.

Strike out Para 2. for non-convention

2. The basic application(s) as defined by section 141 of the Act was/were made

in ....

on the ....day of ....19 ...., No. ....,

by ...., and

in ....

on the ....day of ....19 ...., No. ....,

by ...., and

in ....

on the ....day of ....19 ...., No. ....,

by ....

The basic application(s) referred to was/were the first application(s) made in a Convention country in respect of the invention the subject of the application.

3. ~~I am / We are~~ ~~the actual inventor(s) of the invention.~~

or John East and Ian Maxwell

of 138 Windrush, Highworth, Wiltshire, England and 1 St. Anne's Road, Caversham, Reading, Berkshire, England, respectively

MELBOURNE 8704

20 DEC 88 10 57

~~is~~ are the actual inventor(s) of the invention and the facts upon which the applicant is entitled to make the application are as follows:- At the time of making of the invention each of the said inventors was an employee of the applicant and the invention was made under circumstances such that it belongs to the applicant under Section 34(1)(fa) of the Patents Act 1952.

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(56) Prior Art Documents
AU 539859 77098/81 B21C 23/08
US 4419324
US 4283931

(57) Claim

1. Apparatus for effecting continuous extrusion of metal from a feedstock in particulate or comminuted form, which apparatus includes:-

(a) a rotatable wheel member arranged for rotation when in operation by a driving means, said wheel member having formed peripherally thereon a continuous circumferential groove;

(b) a cooperating shoe member which extends circumferentially around a substantial part of the periphery of said wheel member and which has a portion which projects in a radial direction partly into said groove with small working clearance from the side walls of said groove, said shoe member portion defining with the walls of said groove an enclosed passageway extending circumferentially of said wheel member;

(c) feedstock inlet means disposed at an inlet end of said passageway for enabling feedstock in loose particulate or comminuted form to enter said passageway at said inlet end whereby to be engaged and carried frictionally by said wheel member, when rotating, towards the opposite, outlet end of said passageway;

(d) an abutment member carried on said shoe member and projecting radially into said passageway at said outlet end thereof so as to substantially close said passageway at that end and thereby impede the passage of feedstock frictionally carried in said groove by said wheel member, thus creating an extrusion pressure in said passageway at said outlet end thereof; and

(e) a die member carried on said shoe member and having a die orifice opening from said passageway at said outlet end thereof,
through which orifice feedstock carried in said groove and frictionally compressed by rotation of said wheel member, when driven, is compressed and extruded in continuous form, to exit from said shoe member via an outlet aperture; and which apparatus is characterised in that said passageway comprises a primary zone extending downstream from said inlet end of said passageway, in which primary zone said particulate or comminuted feedstock is compacted, by rotation of said wheel member, to progressively eliminate voids in the advancing feedstock and so form an agglomerated mass of feedstock metal, and an adjoining, substantially shorter, secondary zone disposed downstream of said primary zone and extending to said die orifice, in which secondary zone said mass of metal is progressively compressed, by rotation of said wheel member, to a desired extrusion pressure sufficient to extrude said mass of

metal through said die orifice, the radial depth of said passageway being substantially unchanging in said primary zone, and decreasing gradually in said secondary zone in the direction of rotation of said wheel member at a relatively high rate and in such a manner as to produce in that zone adjacent said die orifice a metal flow pattern more closely resembling that which is achievable with feedstock in solid form.

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We hereby certify that the attached specification in duplicate is a true copy of the original specification lodged on October 7, 1988. Pages 23 to 25 are in triplicate.

COWIE, CARTER & HENDY

By:

Patent Attorneys for
MB GROUP PLC.

M005484 10/01/89

CONTINUOUS EXTRUSION OF METALS

TECHNICAL FIELD

This invention relates to an apparatus for effecting continuous extrusion of metal from a feedstock in particulate or comminuted form, which apparatus includes:-

(a) a rotatable wheel member arranged for rotation when in operation by a driving means, said wheel member having formed peripherally thereon a continuous circumferential groove;

(b) a cooperating shoe member which extends circumferentially around a substantial part of the periphery of said wheel member and which has a portion which projects in a radial direction partly into said groove with small working clearance from the side walls of said groove, said shoe member portion defining with the walls of said groove an enclosed passageway extending circumferentially of said wheel member;

(c) feedstock inlet means disposed at an inlet end of said passageway for enabling feedstock to enter said passageway at said inlet end whereby to be engaged and carried frictionally by said wheel member, when rotating, towards the opposite, outlet end of said passageway;

(d) an abutment member carried on said shoe member and projecting radially into said passageway at said outlet end thereof so as to substantially close said passageway at that end and thereby impede the passage of feedstock frictionally carried in said groove by said wheel member, thus creating an extrusion pressure in said passageway at said outlet end thereof; and

(e) a die member carried on said shoe member and having a die orifice opening from said passageway at said outlet end thereof, through which orifice feedstock carried in said groove and frictionally compressed by rotation of said wheel member, when driven, is compressed and extruded in continuous form, to exit from said shoe member via an outlet aperture.

BACKGROUND ART

European patent publication EP 0 052 506 A1 discloses a continuous extrusion apparatus having the features (a) to (e) set out above.

In the course of operating an apparatus having that group of features, a large amount of heat is generated within the apparatus. This heat, if not satisfactorily dissipated, will cause the various parts of the apparatus to operate at relatively high temperatures.

Unduly high operating temperatures result in rapid wear and plastic deformation, and sometimes early failure, of the most highly loaded parts (e.g. the die and abutment members) of the apparatus, so that such parts have to be replaced at relatively short time intervals. Replacements are expensive, and require considerable periods during which the apparatus is non-productive. Moreover, replacement of a damaged part results in an undesirable discontinuity in the output extrusion product being produced at the time of the replacement, since a join has then to be made (as for example, by welding) between the end of the product that issued before the replacement and the end of the later product that issues after the replacement. Thus, such apparatus can achieve only a relatively low overall economic performance.

To avoid the need for frequent replacement of worn, deformed or failed parts, it is necessary to reduce the temperatures at which the most highly stressed parts of the apparatus operate. To that end, more effective heat extraction means have been devised, are disclosed herein, and have been disclosed and claimed in the copending Australian patent 23,863/84.

The present invention is concerned with one further way of preventing the said operating temperatures from reaching undesirably high values. Thus, the present invention provides in an apparatus having the above-recited features (a) to (e), firstly a means for localising the generation of heat and confining it to a region from which it can be rapidly conveyed to an adjacent cooling zone, from where it can be readily extracted by the cooling means claimed in the aforesaid copending Australian application; and secondly a means for reducing the amount of input energy that is expended and lost in prior art apparatus in simply shearing the compressed feedstock metal carried with the wheel member relative to the stationary feedstock metal that is adherent to the stationary shoe member.

DISCLOSURE OF INVENTION

According to the present invention, an apparatus having the above-recited features (a) to (e) is characterised in that said passageway comprises a primary zone extending downstream from said inlet end of said passageway, in which primary zone said particulate or comminuted feedstock is compacted, by rotation of said wheel member, to progressively eliminate voids in the advancing feedstock and so form an agglomerated mass of feedstock metal, and an adjoining secondary zone disposed downstream of said primary zone and extending to said die orifice, in which secondary zone said mass of metal is progressively compressed, by rotation of said wheel member, to a desired extrusion pressure sufficient to extrude said mass of metal through said die orifice, the radial depth of said passageway being substantially unchanging in said primary zone, and decreasing gradually in said secondary zone in the direction of rotation of said wheel member at a relatively high rate and in such a manner as to produce in that zone adjacent said die orifice a metal flow pattern more closely resembling that which is achievable with feedstock in solid form.

Such an improved apparatus has been found to obviate the above-mentioned disadvantages of the prior art apparatus. Thus, lower operating temperatures are now achieved; wear and deformation of the most highly stressed parts are reduced; less energy is lost in shearing the compressed feedstock metal at the interface between the moving and stationary metal; non-productive down-time is substantially reduced; and the overall econonic performance is improved.

Preferably, said shoe member portion is constituted in said secondary zone by an insert which is removably secured in said shoe member; which extends circumferentially upstream from said abutment member; which incorporates said die member; and which has a surface facing towards the bottom of said groove, which surface is shaped to provide the desired gradual decrease in radial depth of said passageway in said secondary zone.

Advantageously, said surface of said insert comprises a plane surface inclined at a small angle to a tangent to the bottom of said groove.

Preferably, said plane surface is inclined at a said angle such that the ratio of the area of said abutment member exposed to metal under said extrusion pressure to the radial cross-sectional area of said passageway at the upstream, entry end of said secondary zone is substantially equal to the ratio of the apparent density of the feedstock entering said secondary zone at said entry end thereof to the density of the compressed, fully compacted feedstock lying adjacent said abutment member.

In one preferred arrangement, said plane surface is inclined at a said angle such that the said area of said abutment member exposed to said compressed metal is approximately half the said radial cross-sectional area of said passageway at said entry end of said secondary zone.

The aforesaid shaping of the said surface of the said shoe member portion assists in reducing (compared to other arrangements not having the present inventive features) (a) the redundant work done on the feedstock, (b) the amount of flash produced, and (c) the bending moment imposed on the abutment member by the metal under pressure lying adjacent its upstream face.

Furthermore, the choice of a said planar working surface for the said insert results in a reduction (compared to such inserts not having such a planar working surface) in the cost of making that insert.

Other features and advantages of the present invention will appear from a reading of the description that follows hereafter, and from the claims appended at the end of that description.

BRIEF DESCRIPTION OF DRAWINGS

One continuous extrusion apparatus embodying the present invention will now be described by way of example and with reference to the accompanying diagrammatic drawings in which:

Figure 1 shows a medial, vertical cross-section taken through the essential working parts of the apparatus, the plane of that section being indicated in Figure 2 at I-I:

Figure 2 shows a transverse sectional view taken on the section indicated in Figure 1 at II-II;

Figures 3 and 4 show in sectional views similar to that of Figure 2 two arrangements which are alternatives to that of Figure 2;

Figure 5 shows a schematic block diagram of a system embodying the apparatus of the Figures 1 and 2;

Figure 6 shows a graph depicting the variation of a heat extraction rate with variation of a cooling water flow rate, as obtained from tests on one apparatus according to the present invention;

Figures 7 to 9 show, in views similar to that of Figure 2, various modified forms of a wheel member incorporated in said apparatus: and

Figure 10 shows, in a view similar to that of Figure 1, a modified form of the apparatus shown in the Figures 1 and 2.

MODES OF CARRYING OUT THE INVENTION

Referring now to Figures 1 and 2, the apparatus there shown includes a rotatable wheel member 10 which is carried in bearings (not shown) and coupled through gearing (not shown) to an electric driving motor (not shown) so as to be driven when in operation at a selected speed within the range 0 to 20 RPM (though greater speeds are possible).

The wheel member has formed around its periphery a groove 12 whose radial cross-section is depicted in Figure 2. The deeper part of the groove has parallel annular sides 14 which merge with a radiused bottom surface 16 of the groove. A convergent mouth part 18 of said groove is defined by oppositely-directed frusto-conical surfaces 20, 22.

A stationary shoe member 24 carried on a lower pivot pin 26 extends around and cooperates closely with approximately one quarter of the periphery of the wheel member 10. The shoe member is retained in its operating position as shown in Figure 1 by a withdrawable stop member 28.

The shoe member includes centrally (in an axial direction) a circumferentially-extending projecting portion 30 which projects partly into the groove 12 in the wheel member 10 with small axial or transverse clearance gaps 32, 34 on either side. That projecting portion 30 is constituted in part by a series of replaceable inserts, and comprises a radially-directed abutment member 36, an abutment support 38 downstream of the abutment member, a die block 40 (incorporating an extrusion die 42) upstream of the abutment member, and an arcuate wear-resisting member 44 upstream of said die block. Upstream of the member 44 an integral entry part 46 of the shoe member completes an arcuate passageway 48 which extends around the wheel member from a vertically-oriented feedstock inlet passage 50 disposed below a feedstock hopper 52, downstream as far as the front face of the abutment member 36. That passageway has a radial cross-section which in the Figure 2 is defined by the annular side walls 14 and bottom surface 16 of the groove 12, and the inner surface 56 of the said central portion 30 of the shoe member 24.

The said abutment member 36, die block 40, die 42 and arcuate member 44 are all made of suitably hard, wear-resistant metals, e.g. high-speed tool steels.

The shoe member is provided with an outlet aperture 58 which is aligned with a corresponding aperture 60 formed in the die block 40 and through which the extruded output metal product 61 (e.g. a round wire) from the orifice of the die 42 emerges.

On rotation of the wheel member 10, comminuted feedstock admitted to the inlet end of the said arcuate passageway 48 from the hopper 52 via the inlet passage 50 is carried by the moving groove surfaces of the wheel member in an anti-clockwise direction as seen in Figure 1 along the length of said arcuate passageway 48, and is agglomerated and compacted to form a solid slug of metal devoid of interstices in the lower section of the passageway adjacent said die block 40. That slug of metal is continuously urged under great pressure against the abutment member by the frictional drag of the moving groove surfaces. That pressure is sufficient to extrude the metal of said slug through the orifice of the extrusion die and thereby provide an extruded output product which issues through the apertures 58 and 60 in the shoe member and die block. In the particular case, the output product comprises a bright copper wire produced from small chopped pieces of wire which constitute the said feedstock.

A water pipe 62 secured around the lower end of the shoe member 24 has an exit nozzle 64 positioned and secured on the side of the shoe member that lies adjacent the wheel member 10. The nozzle is aligned so as, when the pipe is supplied with cooling water, to direct a jet of water directly at the downstream parts of the abutment member where it lies in and abuts the groove 12 in the wheel member 10. Thus, the tip of the free end of the abutment member (where in operation most of the heat is generated) and the adjoining surfaces of the wheel member and groove are directly cooled by the flow thereover of water from the jet directed towards them.

The die block 40 is provided with internal water passages (not shown) and a supply of cooling water for enveloping the output product leaving the die and extracting some of the heat being carried away in that product. But no such internal passages are formed in the abutment member. Thus, the strength of that member is not reduced in the interests of providing internal water cooling for cooling that member.

If desired, the cooling of the apparatus may be enhanced by providing cooling water sprinklers 65 over the hopper 52 so as to feed some cooling water into the said arcuate passageway 48 with the comminuted feedstock.

In the Figure 2, the slug of compacted metal in the extrusion zone adjacent the die block 40 is indicated at 66. From that metal slug, the output product is extruded through the extrusion die 42 by the pressure in that zone. That pressure also acts to extrude some of the metal through the said axial clearance gaps 32 and 34 between the side walls of the groove and the respective opposing surfaces of the die block and abutment member. That extruded metal gradually builds up in a radial direction to form strips 68 of waste metal or "flash". In order to prevent those waste strips growing too large to handle and control, a plurality of transversely-directed teeth 70 are secured on the divergent walls 20, 22 which constitute the said mouth 18 of the groove 12. Those teeth are uniformly spaced around the wheel member, the teeth on one of the walls being disposed opposite the corresponding teeth on the opposite wall. If desired, the teeth on one wall may alternatively be staggered relative to corresponding teeth on the other wall.

In operation, the inclined surfaces 72 of the die block 40 deflect the extruded waste strips 68 obliquely into the paths of the respective sets of moving teeth 70. Interception of such a waste strip 68 by a moving tooth causes a piece of that strip to be cut or otherwise torn away from the extruded metal in the clearance gap. Thus, such waste extruded strips are removed as soon as they extend radially far enough to be intercepted by a moving tooth. In this way the "flash" is prevented from reaching unmanageable proportions.

The said teeth do not need to be sharp, and can be secured in any satisfactory manner on the wheel member 10, e.g. by welding.

In the Figures 3 and 4 are shown other teeth fitted in analogous manners to appropriate surfaces of other forms of said wheel member 10.

In those alternative arrangements, the external surfaces of the wheel member 10 cooperate with correspondingly shaped surfaces of the cooperating shoe member 24 whereby to effect control of the flash in a particular desired way. In Figure 3, the flash is caused to grow in a purely tranverse or axial direction, until it is intercepted by a radially projecting tooth, whereupon that piece of flash is torn away from the extruded metal in the associated clearance gap.

In Figure 4, the flash is caused to grow in an oblique direction (as in the case of Figure 2), but is intercepted by teeth which project radially from the surface of the wheel member 10.

For various reasons that will appear later, it may be desirable, or even necessary, to treat the extrusion product (wire 61) issuing from the continuous extrusion apparatus described above in an extrusion product treatment apparatus before passing it to a product collection and storage means. Moreover, it may be desirable or advantageous to treat the extrusion product whilst it still remains hot from the continuous extrusion process in which it was produced.

Such a treatment apparatus may, for example, be arranged to provide the extrusion product with a better or different surface finish (for example, a drawn finish), and/or a more uniform external diameter or gauge. Such a treatment apparatus may also be used to provide, at different times, from the same continuous extrusion product, finished products of various different gauges and/or tolerances. For such purposes, the said treatment apparatus may comprise a simple drawing die through which said extrusion product is first threaded and then drawn under tension, to provide a said finished product of desired size, tolerance, and/or quality. The use of such a treatment apparatus to treat the extrusion product would enable the continuous extrusion die 42 of the continuous extrusion apparatus to be retained in service for a longer period before having to be——————————

discarded because of the excessive enlargement of its die aperture caused by wear in service. Moreover, such a treatment apparatus may have its die readily and speedily interchanged, whereby to enable an output product of a different gauge, tolerance and/or quality to be produced instead.

One example of a continuous extrusion system incorporating a continuous extrusion apparatus and an extrusion product treatment apparatus will now be described with reference to the Figure 5.

Referring now to the Figure 5, the system there shown includes at reference 100 a continuous extrusion apparatus as just described above and, if desired, modified as described below, the output copper wire produced by that apparatus being indicated at 102, and being drawn through a sizing die 104 (for reducing its gauge to a desired lower value) by a tensioning pulley device 106 around which the wire passes a plurality of times before passing via an accummulator 108 to a coiler 110.

The pulley device 106 is coupled to the output shaft of an electrical torque motor 112 whose energisation is provided and controlled by a control apparatus 114. The latter is responsive to (a) a first electrical signal 116 derived from a wire tension sensor 118 which engages the wire 102 at a position between the extrusion apparatus 100 and the sizing die 104, and which provides as said first signal an electrical signal dependent on the tension in the wire 102 at the output of the extrusion apparatus 100; and to (b) a second electrical signal 120 derived from a temperature sensor 122 which measures the temperature of the wire 102 as it leaves the extrusion apparatus 100.

The control apparatus 114 incorporates a function generator 124 which is responsive to said second (temperature) signal 120 and provides at its output circuit a third electrical signal representative of the yield stress tension for the particular wire 102 when at the particular temperature represented by the said second (temperature) signal. That third electrical signal 126 is supplied as a reference signal to a comparator 128 (also part of said control apparatus) in which the said first (tension) signal 116 is compared with said third signal (yield stress tension). The output signal of the comparator constitutes the signal for controlling the energisation of the torque motor.

In operation, the torque motor is energised to an extent sufficient to maintain the tension in the wire leaving the extrusion apparatus 100 at a value which lies a predetermined amount below the yield stress tension for the particular wire at the particular temperature at which it leaves the extrusion apparatus.

Whereas in the description above reference has been made to the use of a water jet for cooling the abutment member tip, jets of other cooling liquids (or even cooling gases) could be used instead. Even jets of appropriate liquified gases may be used.

Regarding the flash-removing teeth 70 referred to in the above description, it should be noted that:-

(a) the shaping of the leading edge (i.e. the cutting or tearing edge) of each tooth is not critical, as long as the desired flash removal function is fulfilled;

(b) the working clearance between the tip of each tooth 70 and the adjacent opposing surface of the stationary shoe member 24 is not critical, and is typically not greater than 1 to 2 mm, according to the specific design of the apparatus;

(c) the greater the number of teeth spaced around each side of the wheel member 10, the smaller will be the lengths of "flash" removed by each tooth;

(d) the teeth may be made of any suitable material, such as for example, tool steel; and

(e) any convenient method of securing the teeth on the wheel member may be used.

The ability of the apparatus to deliver an acceptable output extrusion product from feedstock in loose particulate or communited form is considerably enhanced by causing the radial depth (or height) of the arcuate passageway 48, in a pressure-building zone which lies immediately ahead (i.e. upstream) of the front face 54 of the abutment member 36, to diminish relatively rapidly in a preferred manner in the direction of rotation of the wheel member 10, for example in the manner illustrated in the drawings.

The removable die block 40 is arranged to be circumferentially co-extensive with that zone, and the said progressive reduction of the radial depth of the arcuate passageway is achieved by appropriately shaping the surface 40A of the die block that faces the bottom of the groove 12 in the wheel member 10.

That surface 40A of the die block is preferably shaped in a manner such as to achieve in the said zone, when the apparatus is operating, a feedstock metal flow pattern that closely resembles that which is achieved when using instead feedstock in solid form. In the preferred embodiment illustrated in the drawings, that surface 40A comprises a plane surface which is inclined at a suitable small angle to a tangent to the bottom of the groove 12 at its point of contact with the abutment member 36 at its front face 54.

That angle is ideally set at a value such that the ratio of (a) the area of the abutment member 36 that is exposed to feedstock metal at the extrusion pressure, to (b) the radial cross-sectional area of the passageway 48 at the entry end of said zone (i.e. at the radial cross-section adjacent the upstream end of the die block 40) is equal to the ratio of (i) the apparent density of the feedstock entering that zone at said entry end thereof, to (ii) the density of the fully-compacted feedstock lying adjacent the front face 54 of the abutment member 36.

In one satisfactory arrangement, the said plane surface 40A of the die block was inclined at an angle such that the said area of the abutment member that is exposed to feedstock metal at the extrusion pressure is equal to one half of the said radial cross-sectional area of the passageway 48 at the entry end of said zone (i.e. at the upstream end of the die block).

If desired, in an alternative embodiment the surface of the die block facing the bottom of the groove 12 may be inclined in the manner referred to above over only a greater part of its circumferential length which extends from the said upstream end of the die block, the part of the die block lying immediately adjacent the front face 54 of the abutment member being provided with a surface that lies parallel (or substantially parallel) with the bottom of the groove 12.

The greater penetration of the die block 40 into the groove 12, which results from the said shaping of the surface 40A referred to above, serves also to offer increased physical resistance to the unwanted extrusion of flash-forming metal through the clearance gaps 32 and 34, so that the amount of feedstock metal going to the formation of such flash is greatly reduced. Moreover, that penetration of the die block into the groove 12 results in reductions in (a) the redundant work done on the feedstock, (b) in the amount of flash produced, and (c) the bending moment imposed on the abutment member by the metal under pressure. Furthermore, the choice of a plane working surface 40A for the die block reduces the cost of producing that die block.

Whereas in the above description, the wheel member 10 is driven by an electric driving motor, at speeds within the stated range, other like-operating continuous extrusion machines may utilise hydraulic driving means and operate at appropriate running speeds.

As an alternative to introducing additional cooling water into the passageway 48 via the sprinklers 65, hopper 52 and passage 50, such additional cooling water may be introduced into that passageway (for example, via a passage 67 formed in the shoe member 24) at a position at which said passageway is filled with particulate feedstock, but at which said particulate feedstock therein is not yet fully compacted.

It is believed that the highly beneficial cooling effects provided by the present invention arise very largely from the fact that the heat absorbed by a part of the wheel member lying temporarily adjacent the hot metal in the confined extrusion zone upstream of the abutment member is conveyed (both by thermal conduction and rotation of the wheel member) from that hot zone to a cooling zone situated downstream of the abutment member, in which cooling zone a copious supply of cooling fluid is caused to flow over relatively large areas of the wheel member passing through that cooling zone so as to extract therefrom a high proportion of the heat absorbed by the wheel member in the hot extrusion zone.

In this cooling zone access to the wheel member is less restricted, and relatively large surfaces of that member are freely available for cooling purposes. This is in direct contrast to the extremely small and confined cooling surfaces that can be provided directly adjacent the extrusion zone in the parts of the said shoe member (i.e. the die block and abutment member) that bound that extrusion zone. As has been mentioned above, the cooling surfaces that can be provided in those parts are severely limited in size by the need to conserve the mechanical strengths of those parts and so enable them to safely withstand the extrusion pressure exerted on them.

The conveying of heat absorbed by the wheel member to the said cooling zone can be greatly enhanced by the incorporation in said wheel member of metals having good thermal conductivities and good specific heats (per unit volume). However, since the said wheel member, for reasons of providing adequate mechanical strength, is made of physically strong metals, (e.g. tool steels), it has relatively poor heat transmission properties. Thus, the ability of the wheel member to convey heat to said cooling zone can be greatly enhanced by incorporating intimately in said wheel member an annular band of a metal having good thermal absorption and transmission properties, for example, a band of copper.

Such a thermally conductive band may conveniently be constituted by an annular band secured in the periphery of the said wheel member and preferably constituting, at least in part, the part of said wheel member in which the said circumferential groove is formed to provide (with the shoe member) the said passageway (48).

In cases where the extrusion product of the machine is of a metal having suitably good thermal properties, the said thermally conductive band may be composed of the same metal as the extrusion product (e.g. copper).

In other cases, said thermally-conductive band may be embedded in, or be overlaid by, a second annular band, which second band is of the same metal as the extrusion product of the machine and is in contact with the tip portion of the said abutment member, the two bands being of different metals.

Metals which may be used for the said thermally-conductive band are selected to have a higher product of thermal conductivity and specific heat per unit volume than tool steel, and include the following (in decreasing order of said higher product):-

Copper, silver, beryllium, gold, aluminium, tungsten, rhodium, iridium, molybdenum, ruthenium, zinc and iron.

The rate at which heat can be conveyed by such a thermally-conductive band from the extrusion zone to the cooling zone is dependent on the radial cross-sectional area of the band, and is increased by increasing that cross-sectional area. Thus, for a given cross-sectional dimension measured transversely of the circumference of the wheel member, the greater the radial depth of a said band, the greater the rate at which heat will be conveyed to the cooling zone by the wheel member.

Calculations have shown that for a said wheel member having an effective diameter of 233 mm, and a speed of rotation of 10 RPM, and a said thermally-conductive band of copper having a radial cross-section of U-shape, the rate "R" of conveying heat from the extrusion zone to the said cooling zone by the wheel member, by virtue of its rotation alone, varies in the manner shown below with variation of the radial depth or extent to which a said abutment (36) cooperating with the wheel member penetrates into that copper band, that is to say, with variation of the radial thickness "T" of the copper band that remains at the bottom of the said circumferential groove (12). These calculations were based on a said copper band having with the adjacent parts (tool steel) of the wheel member an interface of generally circular configuration as seen in a radial cross section. Hence, the radial cross-sectional area "A" of the copper band varies in a non-linear manner with the said radial thickness "T" of copper at the bottom of said groove (12).

T (mm)	A (sq. mm)	R (kW)
1.0	18.0	5.1
1.5	22.7	6.4
2.0	27.4	7.7
2.5	32.1	9.1
3.0	36.8	10.4

In one practical arrangement having such a wheel member and a 2 mm radial thickness T of said copper band at the bottom of said groove (12), when operating at said wheel member speed and extruding copper wire of 1.4 mm diameter at a speed of 150 metres per minute, heat was extracted from the wheel member and abutment member in said cooling zone at a rate of 10 kW by cooling water flowing at as low a rate of 4 litres per minute and providing at the surfaces to be cooled in said cooling zone a jet velocity of approximately 800 metres per minute.

This heat extraction rate indicates that heat was reaching the cooling zone at a rate of some 2.3 kW as a result of the conduction of heat through the said conductive band, the adjacent wheel member parts, and the abutment member, induced by the temperature gradient existing between the extrusion zone and the cooling zone.

This measured rate of extracting heat by the cooling water flowing in the cooling zone compares very favourably with a maximum rate of heat extraction of some 1.9 kW that has been found to be achievable by flowing cooling water in the prior art manner through internal cooling passages formed in the abutment member.

Figure 6 shows the way in which the rate of extracting heat from the wheel member and abutment member in said cooling zone was found to vary with variation of the rate of flow of the cooling water supplied to that zone.

The extrusion machine described above with reference to the drawings was equipped for the practical tests with a said thermally-conductive band of copper, which band is shown at reference 74 in Figure 10, and indicated, for convenience only, in dotted-line form in Figure 2. (It should be noted that Figure 2 also depicts, when the copper band 74 is represented in full-line form, the transverse sectional view taken on the section indicated in Figure 10 at II-II.) As will be understood from reference 74 in Figure 2, the said copper band had a radial cross section of U-shape, which band lined the rounded bottom 16 of the circumferential groove 12 and extended part-way up the parallel side walls of that groove.

Figure 7 shows in a view similar to that of Figure 2 a modification of the wheel member 10. In that modification, a solid annular band 76 of copper having a substantially rectangular radial cross-section is mounted in and clamped securely between cooperating steel cheek members 78 of said wheel member, so as to be driven by said cheek members when a driving shaft on which said cheek members are carried is driven by said driving motor. The band 76 has, at least intially, a small internal groove 76A spanning the tight joint 78A between the two cheek members 78. That groove prevents the entry between those cheek members of any of the metal of said band 76 during assembly of the wheel member 10. Complementary frusto-conical surfaces 76B and 78B on said band and cheek members respectively permit easier assembly and disassembly of those parts of the wheel member 10.

The circumferential groove 12, is formed in the copper band by pivotally advancing the shoe member 24 about its pivot pin 26 towards the periphery of the rotating wheel member 10, so as to bring the tip of the abutment member 36 into contact with the copper band, and thereby cause it to machine the copper band progressively deeper to form said groove 12 therein.

Figure 8 shows an alternative form of said modification of Figure 7, in which alternative the thermally-conductive band comprises instead a composite annular band 80 in which an inner core 82 of a metal (such as copper) having good thermal properties is encased in and in good thermal relationship with a sheath 84 of a metal (for example, zinc) which is the same as that to be extruded by the machine.

Figure 9 shows a further alternative form of said modification of Figure 7, in which alternative the thermally-conductive band comprises instead a composite band 86 in which a radially-inner annular part 88 thereof is made of a metal (such as copper) having good thermal properties and is encircled, in good termal relationship, by a radially-outer annular part 90 of a metal which is the same as that to be extruded by the machine. Said circumferential groove is machined by said abutment member wholly within said radially-outer part 90 of said band.

Metals which can be extruded by extrusion machines as described above include:-

Copper and its alloys, alumirium and its alloys, zinc, silver and gold.

It should be noted that various aspects of the present disclosure which are not referred to in the claims below have been made the subjects of the respective sets of claims of other concurrently filed Australian patent applications, namely numbers:

23,863/84 (our reference 2020AU)
23,525/88 (our reference 2020AUDIV1)
23,527/88 (our reference 2020AUDIV3)

~~CLAIMS~~ The claims defining the invention are as follows:-

1. Apparatus for effecting continuous extrusion of metal from a feedstock in particulate or comminuted form, which apparatus includes:-

(a) a rotatable wheel member arranged for rotation when in operation by a driving means, said wheel member having formed peripherally thereon a continuous circumferential groove;

(b) a cooperating shoe member which extends circumferentially around a substantial part of the periphery of said wheel member and which has a portion which projects in a radial direction partly into said groove with small working clearance from the side walls of said groove, said shoe member portion defining with the walls of said groove an enclosed passageway extending circumferentially of said wheel member;

(c) feedstock inlet means disposed at an inlet end of said passageway for enabling feedstock in loose particulate or comminuted form to enter said passageway at said inlet end whereby to be engaged and carried frictionally by said wheel member, when rotating, towards the opposite, outlet end of said passageway;

(d) an abutment member carried on said shoe member and projecting radially into said passageway at said outlet end thereof so as to substantially close said passageway at that end and thereby impede the passage of feedstock frictionally carried in said groove by said wheel member, thus creating an extrusion pressure in said passageway at said outlet end thereof; and

(e) a die member carried on said shoe member and having a die orifice opening from said passageway at said outlet end thereof, through which orifice feedstock carried in said groove and frictionally compressed by rotation of said wheel member, when driven, is compressed and extruded in continuous form, to exit from said shoe member via an outlet aperture; and which apparatus is characterised in that said passageway comprises a primary zone extending downstream from said inlet end of said passageway, in which primary zone said particulate or comminuted feedstock is compacted, by rotation of said wheel member, to progressively eliminate voids in the advancing feedstock and so form an agglomerated mass of feedstock metal, and an adjoining, substantially shorter, secondary zone disposed downstream of said primary zone and extending to said die orifice, in which secondary zone said mass of metal is progressively compressed, by rotation of said wheel member, to a desired extrusion pressure sufficient to extrude said mass of metal through said die orifice, the radial depth of said passageway being substantially unchanging in said primary zone, and decreasing gradually in said secondary zone in the direction of rotation of said wheel member at a relatively high rate and in such a manner as to produce in that zone adjacent said die orifice a metal flow pattern more closely resembling that which is achievable with feedstock in solid form.

2. Apparatus according to Claim 1, wherein said shoe member portion is constituted in said secondary zone by an insert removably secured in said shoe member and extending circumferentially upstream from said abutment member, which insert incorporates said die member, and which insert has a surface facing towards the bottom of said groove, which surface is shaped to provide said gradual decrease in

radial depth of said passageway in said secondary zone.

3. Apparatus according to Claim 2, wherein said surface of said insert comprises a plane surface inclined at a small angle to a tangent to the bottom of said groove.

4. Apparatus according to Claim 3, wherein said plane surface is inclined at a said angle such that the ratio of the area of said abutment member exposed to metal under said extrusion pressure to the radial cross-sectional area of said passageway at the upstream, entry end of said secondary zone is substantially equal to the ratio of the apparent density of the feedstock entering said secondary zone at said entry end thereof to the density of the compressed, fully compacted feedstock lying adjacent said abutment member.

5. Apparatus according to Claim 4, wherein said plane surface is inclined at a said angle such that the said area of said abutment member exposed to said compressed metal is approximately half the said radial cross-sectional area of said passageway at said entry end of said secondary zone.

6. Apparatus according to any one of the Claims 1 to 5, substantially as hereinbefore described with reference to and as illustrated by any relevant single figure or group of associated figures in the accompanying diagrammatic drawings.

DATED this 9th day of January, 1989

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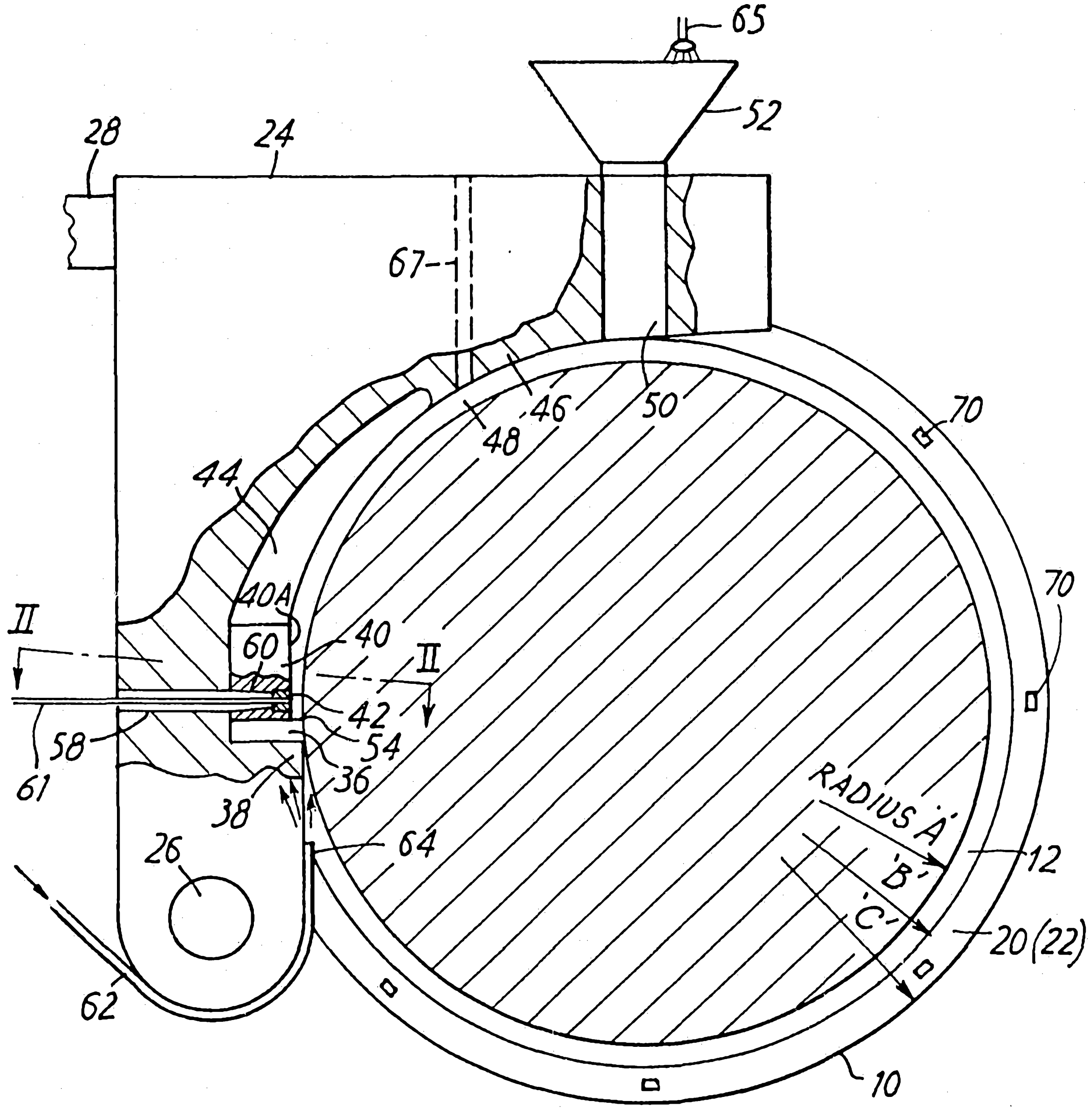

FIG.1

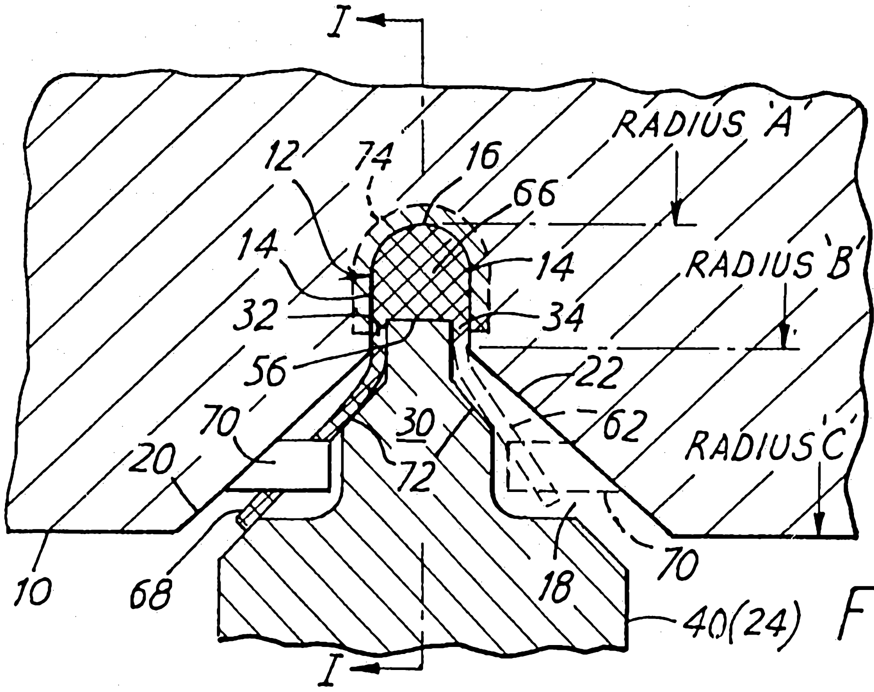

FIG. 2

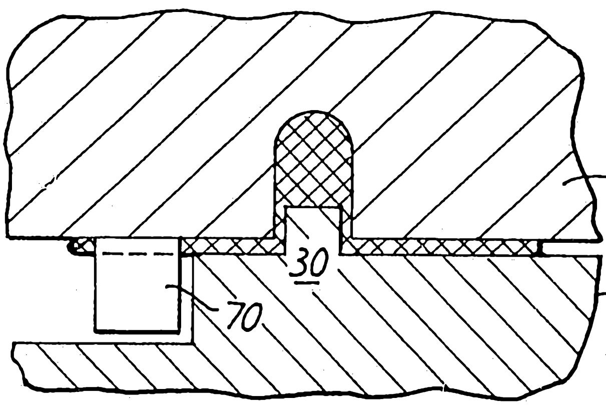

FIG. 3

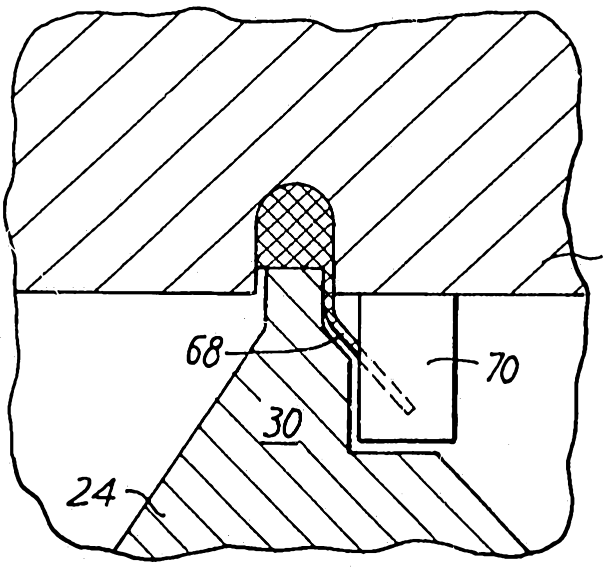

FIG. 4

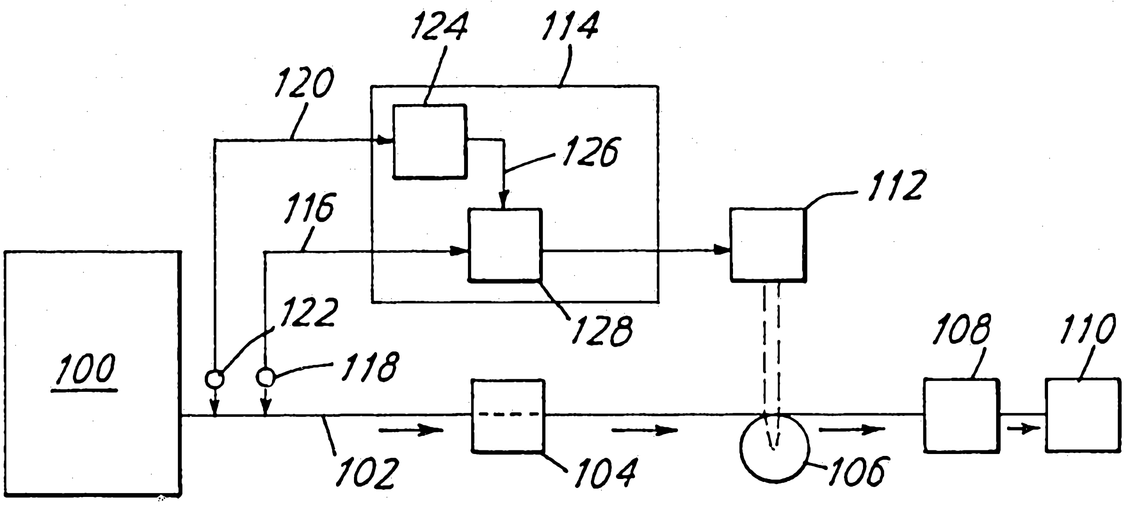
124
114
120
126
112
116
122
128
108
110
100
118
102
104
106

FIG.5

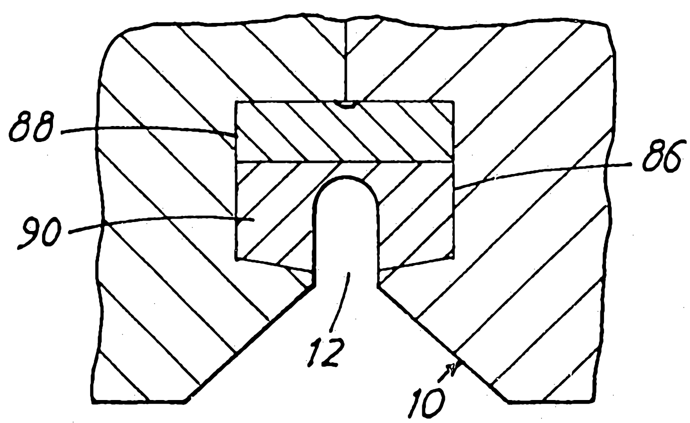
88
86
90
12
10

FIG.9

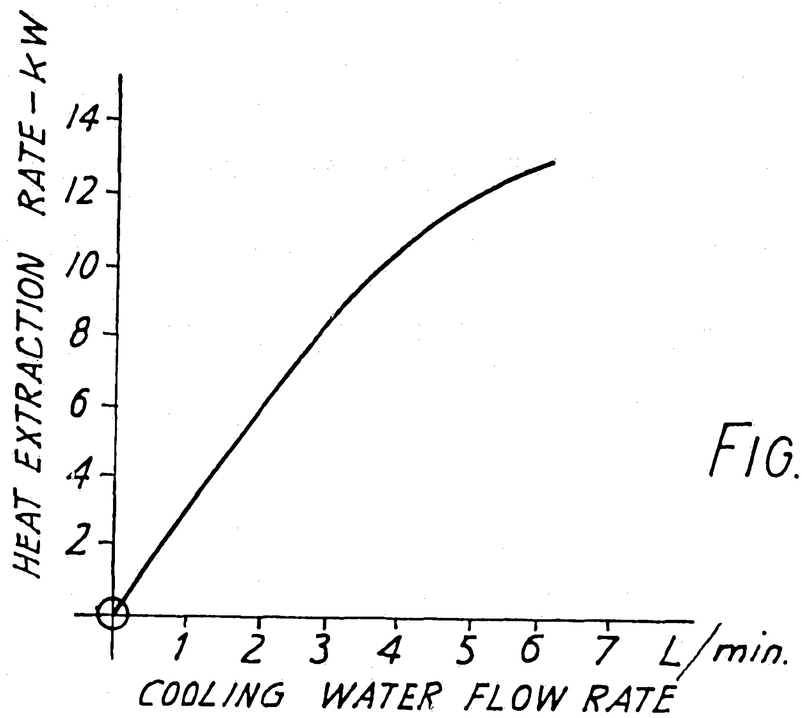

FIG.6

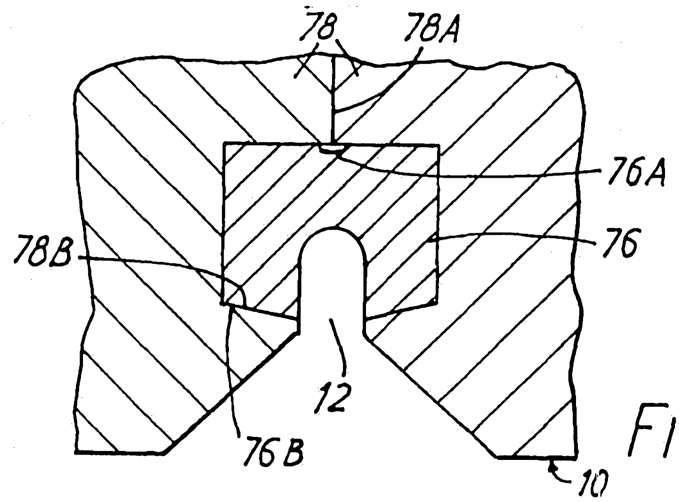

FIG.7

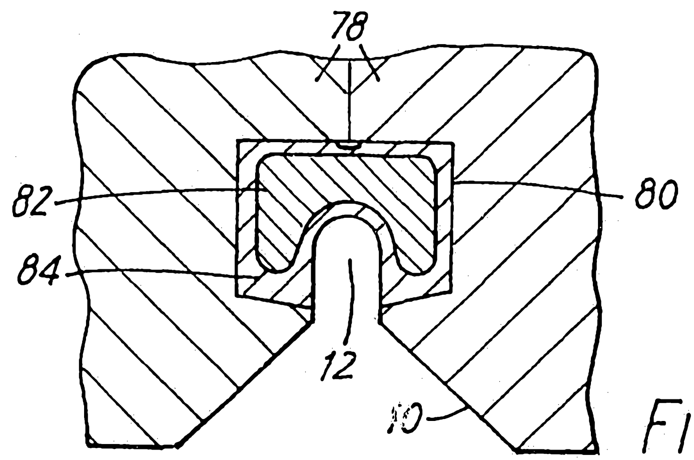

FIG.8

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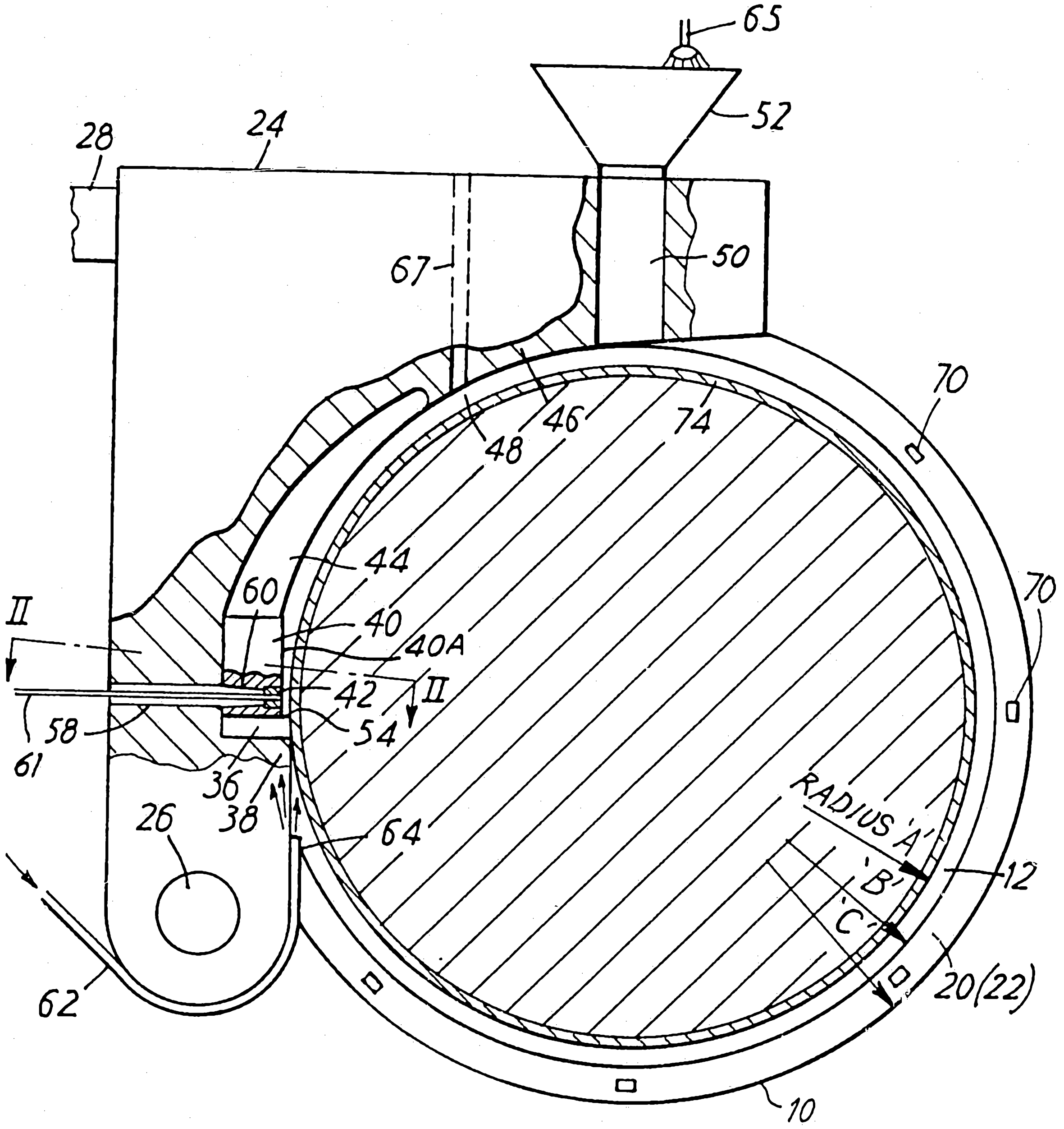

FIG.10