

May 26, 1970

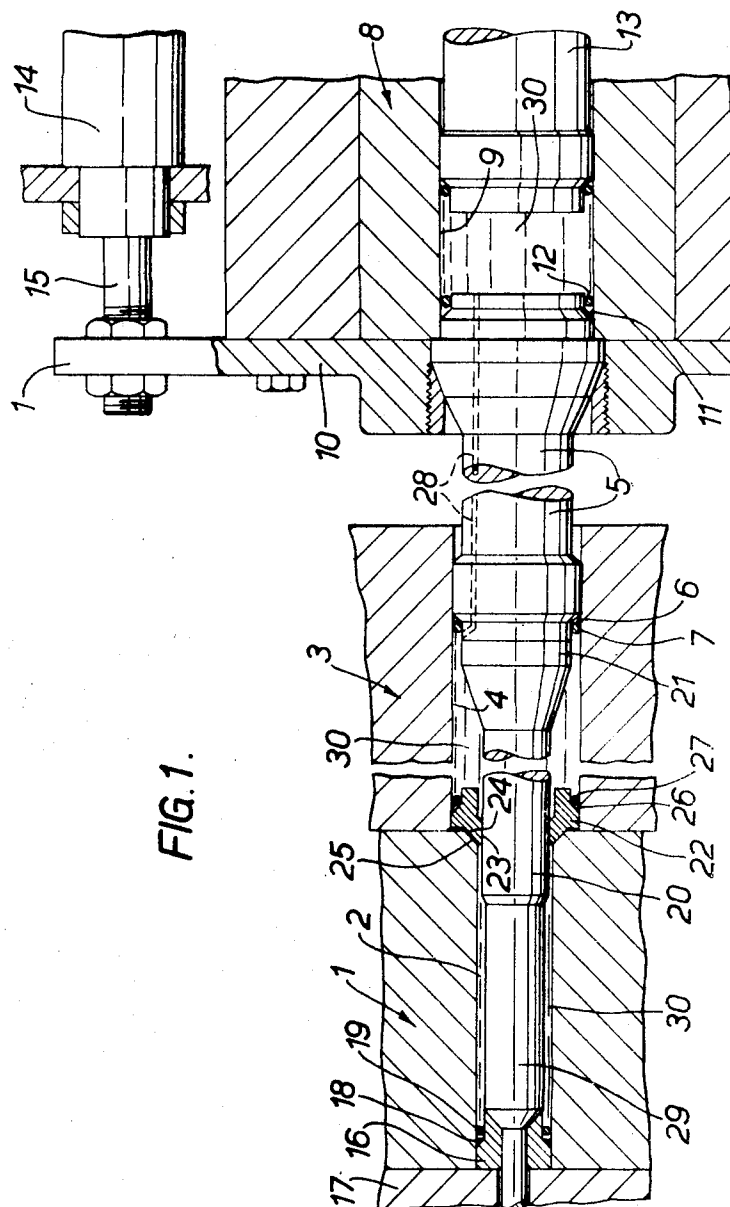
D. GREEN

3,513,676

HYDROSTATIC EXTRUSION APPARATUS

Filed Jan. 24, 1968

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FIG. 2.

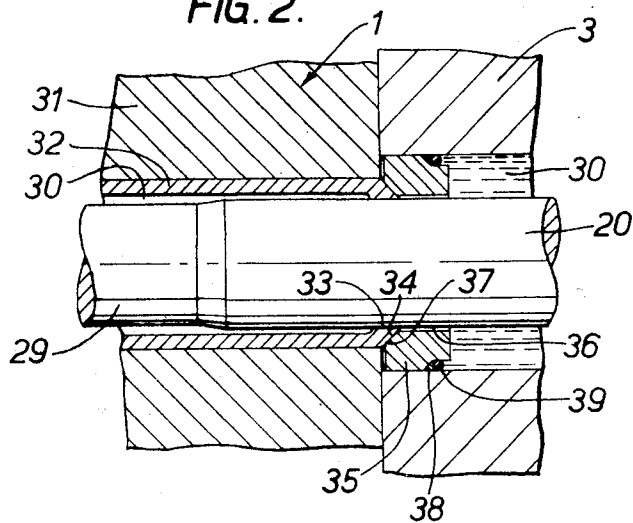
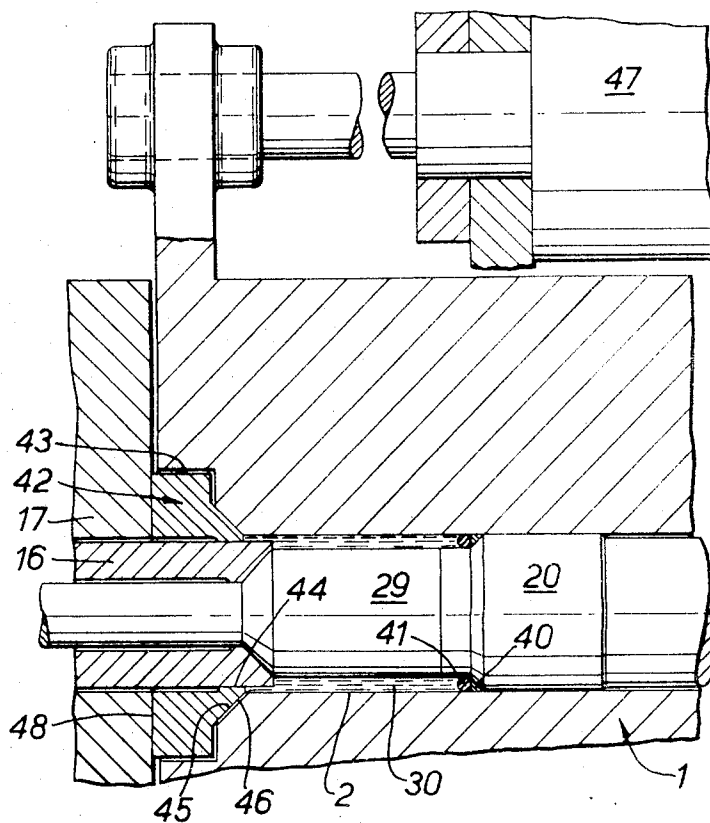


FIG. 3.



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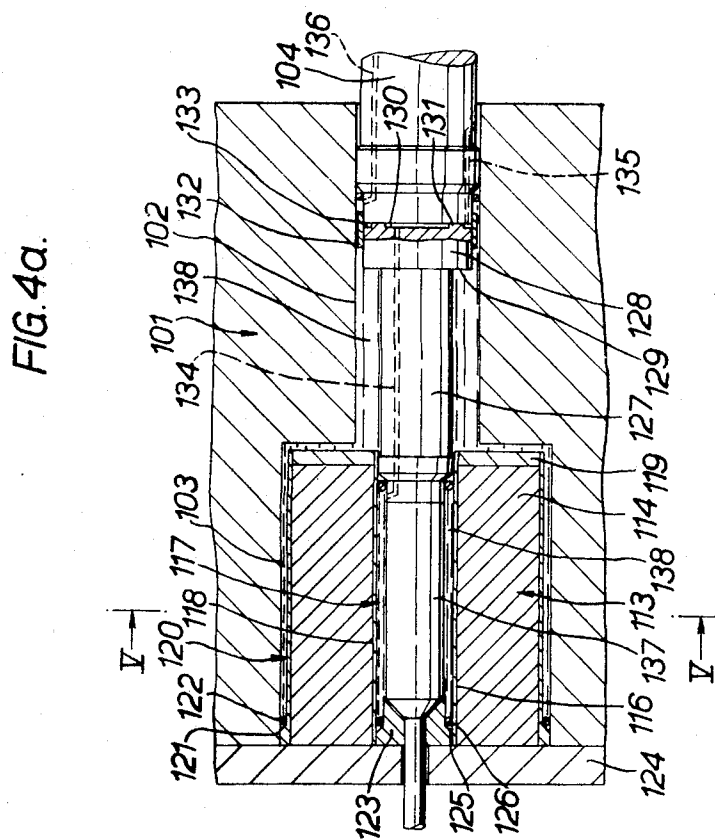
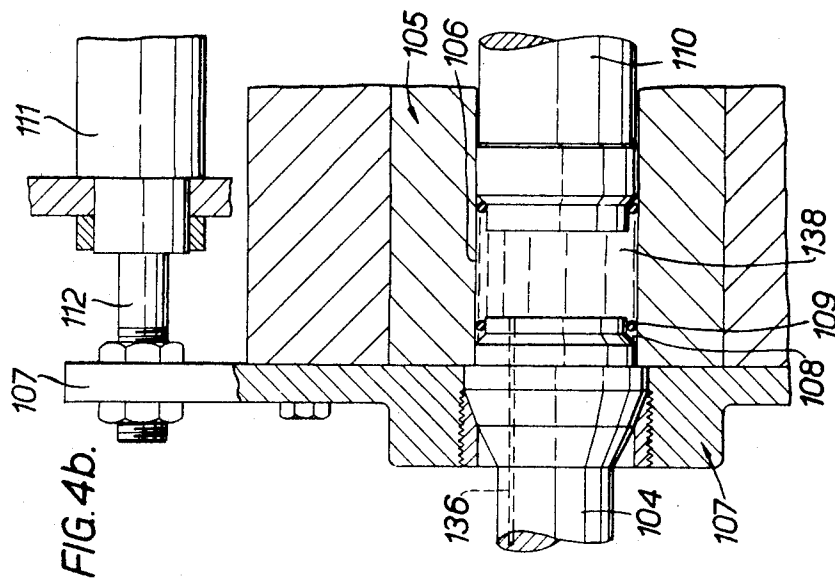
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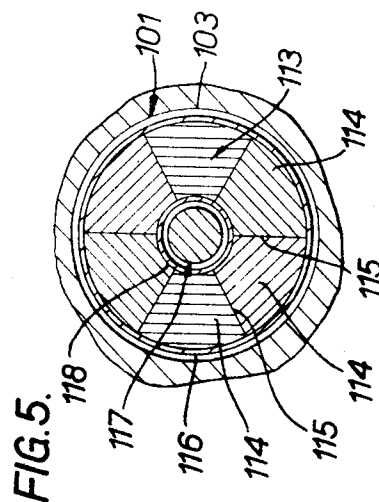
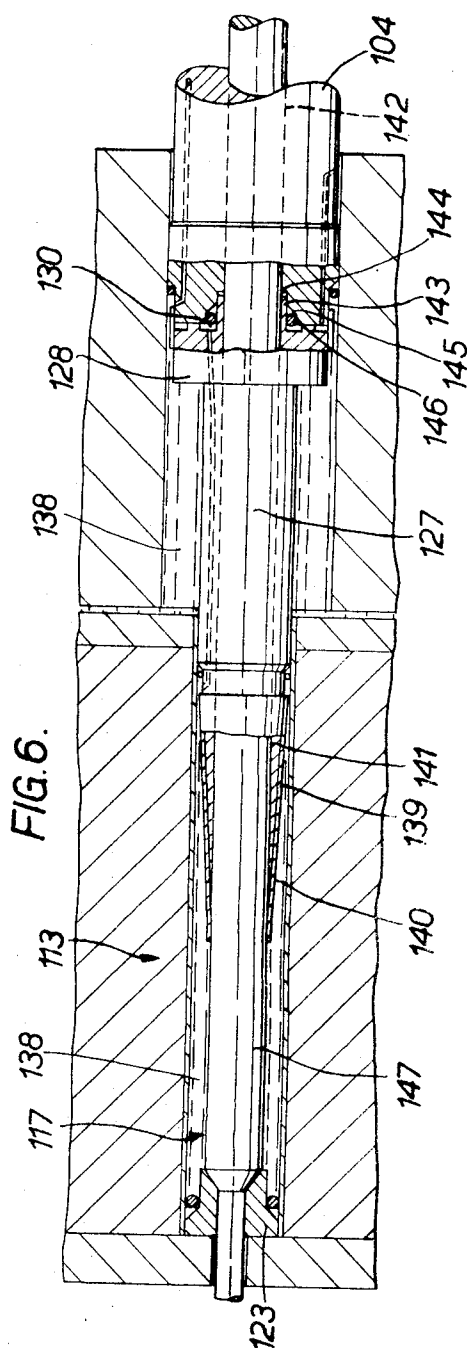
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HYDROSTATIC EXTRUSION APPARATUS
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5,149/67

Int. Cl. B21c 23/08

U.S. Cl. 72—60

8 Claims

ABSTRACT OF THE DISCLOSURE

Means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber comprising a two members having contracting sealing faces, a leak path for liquid from the bore of the extrusion chamber being between the contacting faces of the two members and means being provided for loading one of the members against the other so as to establish a controllable pressure between the contacting faces of the two members.

BACKGROUND OF THE INVENTION

This invention relates to extrusion apparatus and in particular to apparatus for carrying out a hydrostatic extrusion process. In a conventional extrusion process a billet held within a chamber is subjected to a direct mechanical loading to extrude the billet from the chamber through a die. The billet is a close fit in the chamber and extrusion pressure is applied on the end face of the billet by a ram operating in the bore of the chamber. Hydrostatic extrusion has several advantages over conventional extrusion and differs from conventional extrusion in that a liquid is used to apply extrusion pressure on the billet. The liquid envelops the billet in the chamber and is pressurised to act directly on the billet. Because the liquid envelops the billet there is no frictional contact between the chamber and the billet. Die friction is also reduced because the pressurised liquid adjacent the throat of the die provides hydrodynamic lubrication between the extruding material and the die.

The invention is particularly concerned with apparatus for carrying out an extrusion process wherein a billet as well as being subjected to the pressure of liquid in an extrusion chamber is also subjected to a direct axial loading in a direction toward the die the billet being extruded through the die under the combined stresses arising from the liquid pressure and the direct axial loading applied on the billet. A direct axial loading may be applied on the billet by a ram entered into the rear end of the extrusion chamber and bearing on the rear end face of the billet. As the billet is extruded the ram maintains contact with the rear end face of the billet and sweeps the volume of the extrusion chamber so that as extrusion of the billet proceeds liquid must be removed from the bore of the extrusion chamber whilst being held at the pressure required to maintain extrusion of the billet. It is also desirable to remove excess liquid from the bore of the extrusion chamber as extrusion of the billet proceeds so that little liquid remains in the extrusion chamber at the termination of billet extrusion thus avoiding the release of a blast of high pressure liquid which would otherwise occur on completion of extrusion of the billet.

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SUMMARY OF THE INVENTION

It is an object of the present invention to provide means for controlled bleeding of liquid from the bore of an extrusion chamber whilst a billet is being hydrostatically extruded from the extrusion chamber.

According to the invention means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber comprises two members having contacting sealing faces, a leak path for liquid from the bore of the extrusion chamber being between the contacting faces of the two members and means being provided for loading one of the members against the other so as to establish a controllable pressure between the contacting faces of the members.

In one form the invention provides bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber having an extrusion die fitted at one end of the bore and a plunger entered into the other rear end of the bore for pressurisation of liquid surrounding a billet in the bore of the extrusion chamber and for applying a direct axial loading on the billet said bleed means comprising an annular bleed ring fitted around the plunger at the rear end of the bore of the extrusion chamber, said bleed ring having an internal cylindrical surface embracing the plunger and an external circumferential frusto conical surface engaging with a complementary internal frusto conical surface around the end of the bore of the extrusion container, means being provided for applying a loading on the end face of the bleed ring external to the bore of the extrusion chamber to load the external frusto conical surface of the bleed ring against the complementary internal frusto conical surface in the end of the bore of the extrusion chamber and by reaction between these surfaces thereby loading the internal cylindrical surface of the bleed ring radially inwards into contact with the surface of the plunger, liquid bleeding from the bore of the extrusion chamber during extrusion of the billet passing between the surface of the plunger and the internal cylindrical surface of the bleed ring.

In another form the invention provides bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion container having a tubular liner in its bore, an extrusion die being fitted in one end of the liner and a plunger being entered into the other rear end of the liner for pressurisation of liquid surrounding a billet in the liner of the extrusion chamber bore and for applying a direct axial loading on the billet, said bleed means comprising an annular bleed ring fitted around the plunger at the rear end of the bore of the extrusion chamber, said liner having an internal cylindrical rim embracing the plunger at the rear end of the bore of the extrusion chamber and the end surface of the liner adjacent the bleed ring being of external frusto conical form, the bore of the bleed ring extending into an end surface of internal frusto conical form complementary to and engaging with the frusto conical end surface of the liner, means being provided for applying a loading on the end face of the bleed ring external to the bore of the extrusion chamber to load the internal frusto conical end surface of the bleed ring against the external frusto conical end surface of the liner and by reaction between these surfaces thereby loading the internal cylindrical rim of the liner radially inwards into contact with the surface of the plunger, liquid bleeding from the bore of the extrusion chamber during extrusion of the billet passing between the surface

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of the plunger and the internal cylindrical rim of the liner.

In both the latter forms of the invention the required loading on the end face of the bleed ring external to the bore of the extrusion chamber may be provided by pressurisation of liquid in a secondary container coextensive with the extrusion chamber and from which the plunger enters the rear end off the bore of the extrusion chamber, the bleed ring being sealed around its external circumferential surface in the bore of the secondary container.

In a further form the invention provides bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber fitted at one end of the bore with an extrusion die and having a plunger entered into the other rear end of the bore for pressurisation of liquid surrounding a billet in the bore of the extrusion chamber and for applying a direct axial loading on the billet, said bleed means comprising a bleed ring fitted around the die, the bleed ring having an internal cylindrical rim contacting the external surface of the die and an external frustoconical end surface engaging with and complementary to an internal frustoconical surface around the end of the bore of the extrusion chamber, means being provided for applying a loading on the end face of the bleed ring external to the bore of the extrusion chamber to load the external frustoconical surface of the bleed ring against the internal frustoconical surface around the end of the bore of the extrusion chamber and by reaction between these surfaces thereby loading the internal cylindrical rim of the bleed ring radially inwards in contact with the external surface of the die, liquid bleeding from the bore of the extrusion chamber during extrusion of a billet passing between the external surface of the die and the internal cylindrical rim of the liner.

In the latter form of the invention the extrusion die may be mounted on an end plate separate from the extrusion chamber and means are provided for loading of the extrusion chamber towards the end plate so that the end face of the bleed ring external to the bore of the extrusion chamber is loaded against the end plate to provide the loading of the bleed ring necessary for controlled bleeding of liquid from the bore of the extrusion chamber.

Another form of apparatus employing bleed means in accordance with the invention comprises an extrusion chamber having a bore fitted at one end with an extrusion die, a secondary liquid container having a bore coextensive with the bore of the extrusion chamber, a plunger entered into the rear end of the bore of the extrusion chamber from the secondary liquid container, a main ram of larger diameter than the diameter of the plunger entered into the rear end of the secondary liquid container, the plunger having a cylindrical head of the same diameter as the main ram, the end face of the head of the plunger having a raised annular rim thereby defining a recess in the end face of the plunger head, the leading end face of the main ram bearing against the annular rim on the plunger head, the annular rim on the end face of the plunger head being radially spaced from the edge of said end face, means being provided slidably sealing between the main ram and the head of the plunger thereby defining a closed annular space between the opposing end faces of the main ram and the head of the plunger, said closed annular space surrounding the annular rim on the end face of the plunger head, a passageway leading through the plunger from the bore of the extrusion container to the recess in the end face of the plunger head, means for pressurisation of liquid in the bore of the secondary container, means for applying an adjustable loading on the main ram and thereby loading the plunger to pressurise liquid surrounding a billet in the bore of the extrusion chamber and to apply a direct axial loading on the billet in the extrusion chamber and means for exhaustion of liquid from the closed annular space which is defined between the opposing end faces of the main ram and the head of the plunger, the cross sectional area of the extrusion chamber, the area of the annular rim, on the end face of the plunger head, the area

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of the recess in the end face of the plunger head, and the cross sectional area of the main ram being determined in accordance with the pressure to be applied in liquid in the secondary container such that on application of a restricted degree of loading to the main ram to cause build up of pressure in liquid in the extrusion chamber the interfacial pressure produced between the annular rim on the end face of the plunger and the end face of the main ram is always higher than the pressure generated in liquid in the extrusion chamber and such that when full loading is applied on the main ram to cause extrusion of the billet under pressure of liquid in the bore of the extrusion chamber and the direct axial loading applied on the billet by the plunger the interfacial pressure resulting between the annular rim on the end face of the plunger and the end face of the main ram is less than the pressure in the liquid in the extrusion container, whereby as the billet extrudes liquid bleeds from the bore of the extrusion container, through the passageway in the plunger into the recess in the end face of the plunger head, the liquid then passing out between the annular rim on the end face of the plunger head and the opposing end face of the main ram, the liquid then being exhausted from the closed annular space which is defined between the opposing end faces of the main ram and the head of the plunger.

DESCRIPTION OF THE DRAWINGS

Hydrostatic extrusion apparatus in accordance with the invention will now be described by way of example with reference to the accompanying drawings in which:

FIG. 1 is a longitudinal sectional elevation of one form of apparatus in accordance with the invention

FIG. 2 is a longitudinal sectional elevation showing a modification of FIG. 1

FIG. 3 is a longitudinal elevation showing a second modification of FIG. 1

FIGS. 4a and 4b are longitudinal sectional elevations of related parts of a second form of apparatus in accordance with the invention

FIG. 5 is a cross section along the line V—V in FIG. 4

FIG. 6 is a modification of the apparatus shown in FIGS. 4a and 4b.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In FIG. 1 of the drawings there is shown an extrusion chamber 1 having a longitudinal bore 2. A secondary cylinder 3 is mounted with its bore 4 coextensive with the bore 2 of the chamber 1. A main ram 5 is entered into and slidably sealed in the bore 4 of the cylinder 3 by a copper mitre ring 6 and rubber O-ring seal 7. The main ram 5 is fitted in sealed engagement with a cylinder 8 which has a bore 9. The cylinder 8 is mounted on a cross head 10 which also carries the main ram 5. The assembly of the ram 5, the cylinder 8 and the cross head 10 is movable axially relative to the fixed extrusion chamber 1 and the secondary cylinder 3. The ram 5 is sealed in engagement with the cylinder 8 by a copper mitre ring 11 and a rubber O-ring 12. A hydraulic ram 13 operates in the cylinder 8. An auxiliary hold back cylinder 14 is connected with the cross head 10 by a shaft 15.

An extrusion die 16 is fitted in the outer end of the bore 2 in extrusion chamber 1. The die 16 is mounted on a back plate 17 and is sealed in the bore 2 of the chamber 1 by a copper mitre ring 18 and a rubber O-ring 19.

A plunger 20 is entered into the bore 2 of the chamber 1. The main ram 5 bears on a head 21 on the plunger 20.

A bleed ring 22 embraces the plunger 20 in the cylinder 3. The bleed ring has an internal cylindrical surface 23 contacting the surface of the plunger 20 and an external frustoconical surface 24 engaging with a complementary frustoconical surface 25 in the end of the bore 2 in the extrusion chamber 1. The bleed ring 22 is sealed in the bore 4 of the cylinder 3 by a copper mitre ring 26 and a rubber O-ring 27.

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A longitudinal passageway 28 in the main ram 5 connects the bore 4 of the cylinder 3 with the bore 9 of the cylinder 8.

In operation of this form of apparatus a billet 29 is held within the bore 2 of extrusion chamber 1 in position to be extruded through the die 16.

Initially the front end of the plunger 20 is spaced from the rear end of the billet 29. Hydraulic liquid 30 surrounds the billet 29 in the bore 2 of extrusion chamber 1. Hydraulic liquid 30 also fills the bore 4 of cylinder 3 and the bore 9 of the cylinder 8.

The ram 13 is operated to raise the hydraulic liquid 30 in the bore 9 of the cylinder 8 to a constant pressure (e.g. 80 tons per square inch). The assembly of the cylinder 8 and the main ram 5 is mounted to be movable with the cross head 10 towards the fixed cylinder 3 and extrusion chamber 1. Therefore the main ram 5 loads the plunger 20 into the bore 2 of extrusion chamber 1 to pressurise the hydraulic liquid 30 surrounding the billet 29 in the bore 2 of the extrusion container 1. A pressure of, for example, 200 tons per square inch is generated in the hydraulic liquid 30 surrounding the billet 29. The pressure generated in the hydraulic liquid 30 in the bore 9 of the cylinder 8 is transmitted to the liquid 30 in the bore 4 of cylinder 3 through the longitudinal passageway 28 in the main ram 5. The pressure of the liquid 30 in the bore 4 of cylinder 3 acts on the end face of the bleed ring 22 to force the frustoconical face 24 of the ring 22 against the frustoconical face 25 in the end of the bore 2 of the extrusion chamber 1, thereby producing a contact pressure between the internal cylindrical surface 23 of the bleed ring 22 and the surface of the plunger 20. The bleed ring 22 is dimensioned so that on application of the full loading of the main ram 5 the contact pressure generated between the internal cylindrical surface 23 of the bleed ring 22 and the surface of the plunger 20 is slightly less than the pressure generated in the hydraulic liquid 30 surrounding the billet 29 in the extrusion container 1. For example if application of full loading of the ram 5 generates a pressure of 200 tons per square inch in the liquid 30 contained by the extrusion chamber 1 the bleed ring 22 is dimensioned so that a contact pressure of 195 tons per square inch is established between the internal cylindrical surface 23 of the bleed ring 22 and the surface of the plunger 20. Under these conditions liquid can bleed from the bore 2 of extrusion chamber 1 into the bore 4 of cylinder 3 between the internal cylindrical surface 23 of the bleed ring 22 and the surface of the plunger 20.

In operation of the apparatus a proportion of the loading of the rams is held off by the hold back cylinder 14 whilst the pressure is rising in the liquid 30 surrounding the billet 29 in the extrusion chamber 1.

The amount of the loading of the main ram 5 which is held off is adjusted so that the final pressure achieved in the liquid 30 within the extrusion chamber 1 is slightly less than the contact pressure of the bleed ring 22 with the plunger 20. In the example given above wherein the contact pressure generated between the bleed ring 22 and the plunger 20 is 195 tons per square inch, hold off of the loading of the ram 5 is adjusted so that a final pressure of 190 tons per square inch is generated in the liquid 30 in the extrusion chamber 1. Under these conditions bleed off of liquid from the extrusion chamber 1 is prevented. The hold off of the loading of the ram 5 is now released and the pressure of the liquid 30 in the extrusion chamber 1 rises to the operating pressure (e.g. 200 tons per square inch) which is higher than the pressure between the contacting surfaces of the bleed ring 22 and the plunger 20 (e.g. 195 tons per square inch). Hence bleed off of liquid occurs from the extrusion chamber 1 into the cylinder 3 between the contacting surfaces of the bleed ring 22 and the plunger 20. With bleed off of liquid in this manner from the extrusion chamber 1 the plunger 20 moves into the bore 2 of the extrusion chamber 1 and comes into contact with the end face of the billet 29.

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On contact of the plunger 20 with the end face of the billet 29 a proportion of the loading of the plunger 20 is applied directly on the billet 29 and the pressure in the liquid 30 surrounding the billet 29 drops by a small amount. However the pressure in the liquid 30 surrounding the billet 29 remains sufficiently high for bleed off of liquid from the extrusion chamber 1 to continue so that the billet 29 is extruded through the die 16 by the action of pressure in the liquid 30 surrounding the billet 29 and the direct axial loading applied on the billet 29 by the plunger 20. As extrusion of the billet 29 proceeds the plunger 20 moves into the bore 2 of the extrusion chamber 1 maintaining contact with the rear end face of the billet 29. Also during extrusion the main ram 5 moves into the bore 4 of the cylinder 3 and maintains the required loading on the plunger 20. As the main ram 5 moves into the bore 4 of the cylinder 3, liquid 30 is transferred from the bore 4 of the cylinder 3 into the bore 9 of the cylinder 8 through the longitudinal passageway 28 in the main ram 5.

The apparatus described above has several advantages particularly when employed for hydrostatic extrusion at high pressures in the extrusion chamber. Firstly as extrusion of the billet 29 proceeds high pressure liquid is removed from the extrusion chamber 1 and when extrusion of the billet 29 is almost complete little high pressure liquid will remain in the extrusion chamber 1 so that the dangers of release of a blast of high pressure liquid during the final stages of extrusion of the billet are avoided.

Secondly only the extrusion chamber 1 has to be resistant to the very high extrusion pressure. The cylinders 3 and 8 are subjected to pressures considerably lower than the extrusion pressure and thus the need for a number of high pressure vessels is avoided.

Thirdly the plunger 20 is subjected to an axial loading equal to the extrusion pressure and therefore is liable to fail by crushing. However as the plunger 20 is surrounded by liquid under pressure in the cylinder 3 the pressure of this liquid provides a lateral supporting force for the plunger 20 making it more resistant to crushing under the high axial loading.

FIG. 2 of the drawings shows a modification of the apparatus shown in FIG. 1. In FIG. 2 the extrusion chamber 1 is of segmented construction comprising for example six segments 31 having contacting radial faces the segments 31 being a shrink or force fit in a massive outer containment (not shown). The chamber 1 has a tubular liner 32 having an internal cylindrical rim 33 embracing the plunger 20. The end face 34 of the liner 32 is of frustoconical form. A bleed ring 35 surrounds the plunger 20 in the secondary cylinder 3. The bleed ring 35 has a bore 36 extending into an internal frustoconical face 37 complementary to and engaging with the frustoconical end face 34 of the liner 32. The bleed ring 35 is sealed in the bore 4 of the cylinder 3 by a copper mitre ring 38 and a rubber O-ring 39. Operation of the apparatus is the same as described above in relation to FIG. 1 but in the case of the modification of FIG. 2 pressure of hydraulic liquid 30 in the bore 4 of cylinder 3 acts on the end face of the bleed ring 35 to force the internal frustoconical face 37 of the bleed ring 35 against the frustoconical end face 34 of the liner 32, thereby producing a contact pressure between the internal cylindrical rim 33 of the liner 32 and the surface of the plunger 20. The bleed ring 35 is again dimensioned so that a contact pressure slightly less than the pressure generated in the liquid 30 surrounding the billet 29 in the chamber 1 is established between the internal rim 33 of the liner 32 and the surface of the plunger 20. Therefore during extrusion of the billet 29 liquid can bleed from the chamber 1 into the cylinder 3 between the rim 33 of the liner 32 and the surface of the plunger 20. The liner 32 is also compressed axially in the bore of the chamber 1 by the bleed ring 35 so that outwards extrusion of the liner 32 from the bore of the chamber 1 is prevented.

FIG. 3 of the drawings shows a second modification of the apparatus shown in FIG. 1. In FIG. 2 the plunger 20 is sealed in the bore 2 of the extrusion chamber 1 by a copper mitre ring 40 and a rubber O-ring 41. A bleed ring 42 is fitted in a counter bore 43 in the end of the bore 2 of the chamber 1. The bleed ring 42 has an internal cylindrical rim 44 which contacts the external surface of the die 16, the die 16 being independently mounted on the back plate 17. The bleed ring 42 also has an external frustoconical end face 45 which contacts a complementary frustoconical end face 46 at the base of the counter bore 43 in the bore 2 of the extrusion chamber 1. The chamber 1 is fitted with auxiliary shift cylinders 47.

Operation of the apparatus is again basically similar to the operation of the apparatus of FIG. 1 as described above. However in the case of apparatus modified as shown in FIG. 3 the extrusion chamber 1 is loaded by the auxiliary shift cylinders 47 so as to load the external end face 48 of the bleed ring 42 against the die back plate 17. Thus the bleed ring 42 is loaded so that its external frustoconical end face 45 is forced against the complementary frustoconical end face 46 in the end of the bore 2 of the container 1. Thus a contact pressure is produced between the internal cylindrical rim 44 of the bleed ring 42 and the external surface of the die 16. Depending on the dimensions of the bleed ring 42, a loading is applied by the auxiliary shift cylinders 47 so as to produce a contact pressure between the internal rim 44 of the bleed ring 42 and the external surface of the die 16 slightly less than the pressure generated in the liquid 30 surrounding the billet 29 in the chamber 1. Thus during extrusion of the billet 29 liquid bleeds from the chamber 1 between the internal rim 44 of the bleed ring 42 and the external surface of the die 16.

Although the modification of FIG. 3 is described in relation to the apparatus of FIG. 1 the arrangement of FIG. 3 may be employed for extrusion at lower liquid pressures in the chamber 1 by direct loading of the plunger 20. In this case the loading applied to the plunger must again be sufficient to attain the required pressure in liquid in the chamber 1 and also to apply a direct axial loading on the billet.

In FIGS. 4a and 4b of the drawings there is shown a fixed cylinder 100 having a longitudinal bore 102 opening out at one end into a larger diameter cylindrical housing 103. A main plunger 104 is entered into and slidably sealed in the bore 102 of the cylinder 101.

As shown in FIG. 4b the main plunger 104 is fitted in sealed engagement with a cylinder 105 which has a longitudinal bore 106. The cylinder 105 is mounted on a crosshead 107 which also carries the main plunger 104. The assembly of the plunger 104, the cylinder 105 and the crosshead 107 is movable axially relative to the fixed cylinder 101. The plunger 104 is sealed in engagement with the bore 106 of the cylinder 105 by a copper mitre ring 108 and by a rubber O-ring 109. A main hydraulic ram 110 operates in the bore 106 of the cylinder 105. An auxiliary 111 is connected with the crosshead 107 by a shaft 112.

As shown in FIGS. 4a and 5 an extrusion container 113 is fitted in the cylinder 101 within the housing 103. The extrusion container 113 is of segmented construction comprising six segments 114 having contacting radial faces 115. The segments 114 are contained within an outer sleeve 116 and define a bore 117 fitted with an internal liner sleeve 118. An annular plate 119 seals the internal end faces of the segments 114. The outer sleeve 116 of the container 113 is of smaller diameter than the internal diameter of the housing 103 so that an annular space 120 is defined between the sleeve 116 and the internal bore surface of the housing 103. A copper mitre ring 102 and a rubber O-ring 122 seal between the sleeve 116 and the internal bore surface of the housing 103 at the outer end of the annular space 120. An extrusion die 123 is fitted in the outer end of the bore 117 in the container

113. The die 123 is mounted on a back plate 124 and is sealed in the bore 117 of the container 113 by a copper mitre ring 125 and a rubber O-ring 126.

A secondary plunger 127 is entered into and slidably sealed in the bore 117 of the container 101. The plunger 127 has a head 128 of larger diameter than the diameter of the plunger 127, the head 128 of the plunger 127 having an annular face 129 which is exposed to the pressure of hydraulic liquid in the bore 102 of the cylinder 101. The end face of the head 128 of plunger 127 has a shallow recess 130 surrounded by an annular rim 131. A copper sleeve 132 seals between the head 128 of the plunger 127 and the end of the main plunger 104. The sleeve 132 encloses an annular bleed space 133 defined between the head 128 of plunger 127 and the end face of the main plunger 104.

A longitudinally passageway 134 in the secondary plunger 127 connects the recess in the head 128 of the secondary plunger 127 with the bore 117 of the container 113. A bleed passageway 135 in the main plunger 104 leads from the bleed space 133 which is defined between the head 128 of plunger 127 and the end face of the main plunger 104. A longitudinally passageway 136 in the main plunger 104 connects the bore 102 of the cylinder 101 with the bore 106 of the cylinder 105.

In operation of the apparatus described above a billet 137 is held within the bore 117 of the container 113 in position to be extruded through the die 123. Hydraulic liquid 138 in the bore 117 of the container 113 surrounds the billet 137. Hydraulic liquid 138 also fills the bore 106 of the cylinder 105, the bore 102 of the cylinder 101 and the annular space 120 surrounding the container 113 in the housing 103 of the cylinder 101.

The main ram 110 is operated to raise the hydraulic liquid 138 in the bore 106 of the cylinder 105 to a constant pressure. The pressure of the hydraulic liquid 138 in the bore 106 of the cylinder 105 is transmitted to the hydraulic liquid 138 in the bore 102 of the cylinder 101 through the longitudinal passageway 136 in the main plunger 104. As the annular space 120 surrounding the 113 in the cylinder 101 is interconnected with the bore 102 of the cylinder 101 the hydraulic liquid 138 in the annular space 120 is raised to the same pressure as the liquid 138 in the bore 102. The pressure of the hydraulic liquid 138 in the space 120 acts on the outer sleeve 116 of the container 113 to apply a radially inwards supporting force on the segments 114 of the container 113.

The assembly of the cylinder 105 and the main plunger 104 is mounted to be movable with the crosshead 107 towards the fixed cylinder 101. Therefore the main plunger 104 loads the secondary plunger 127 into the bore 117 of the container 113 to pressurise the hydraulic liquid 138 surrounding the billet 137 in the bore 117 of the container 113. Initially a proportion of the loading applied by the main plunger 104 on the secondary plunger 127 is held back by the auxiliary cylinder 111. A degree of hold back is applied on the main plunger 104 such that the pressure generated in the liquid 138 in the bore 117 of the container is slightly less than the pressure required to cause simple hydrostatic extrusion of the billet 137 through the die 123. The pressure of the liquid 138 in the bore 117 of container 113 is transmitted through the longitudinal passageway 134 in the plunger 127 to hydraulic liquid in the recess 130 which is defined in the head 128 of the plunger 127. The apparatus is constructed such that under these conditions of operation the interfacial pressure existing between the annular rim 131 on the plunger head 128 and the end face of plunger 104 is higher than the pressure of the liquid 138 in the bore 117 of container 122. Hence the interfacial pressure between the rim 131 and the end face of the plunger 104 is higher than the pressure of the hydraulic liquid in the recess 130 and liquid cannot bleed past the rim 131 from the recess 130. Hence at this point of operation the system

is in stable equilibrium and the billet 137 does not extrude.

The hold back of the auxiliary cylinder 111 on the main plunger 104 is now released so that the main plunger 104 applies an increased loading on the secondary plunger 127. Therefore the pressure of the hydraulic liquid 138 in the bore 117 of the container 113 rises and it follows that the pressure of the hydraulic liquid in the recess 130 in the plunger head 128 also rises by the same amount. The apparatus is arranged such that under these conditions of operation, with the full loading of the main plunger 104 applied on the secondary plunger 127, the interfacial pressure existing between the annular rim 131 on the head 128 of the secondary plunger 127 and the end face of the main plunger 104 is lower than the pressure of hydraulic liquid in the recess 130. Hence hydraulic liquid bleeds from the recess 130 past the rim 131 into the bleed space 133 and vents to atmosphere through the passageway 135 in the main plunger 104. Hence hydraulic liquid 138 is bled from the bore 117 of the container 113 through the passageway 134 in the secondary plunger 127. The secondary plunger 127 moves into the bore 117 of the container 113 until it contacts the end face of the billet 137 when a proportion of the loading of the plunger 127 is applied directly on the billet 137. At this point the pressure in the hydraulic liquid 138 surrounding the billet 137 in the container 113 drops slightly but remains sufficiently high to ensure continuance of bleeding of liquid past the rim 131 on the head 127 of the plunger 128. The billet 137 is subjected to a stress system arising from the pressure of the hydraulic liquid 138 in the container 113 and the direct mechanical loading applied on the billet 137 by the plunger 127. The stress system produced in the billet 137 is sufficient to cause extrusion of the billet 137 through the die 123. As extrusion of the billet proceeds hydraulic liquid 138 continues to bleed out of the bore 117 of the container 113 through the passageway 134 in the secondary plunger 127. Thus the secondary plunger 127 moves into the bore 117 of the container 113 and maintains continuous contact with the end face of the billet 137 as the billet 137 extrudes. The main plunger 104 follows the movement of the secondary plunger 127, hydraulic liquid 138 being transferred from the bore 102 of the cylinder 101 into the bore 106 of the cylinder 105 through the longitudinal passageway 136 in the main plunger 104.

For operation of the apparatus as described above it is a requirement that whilst hold back is applied on the main plunger 104 by the auxiliary ram 111 the interfacial pressure at the rim 131 on the head 128 of the plunger 127 must be greater than the pressure of the hydraulic liquid 138 in the bore 117 of the container 122. Conversely when hold back of the main plunger 104 is released the interfacial pressure at the rim 131 must be less than the pressure of the liquid 138 in the bore 117 of the container 113. This requirement is achieved by suitable dimensioning of the parts of the apparatus.

One form of apparatus meeting the requirements for operation in the manner described has the following dimensions:

Diameter of bore 117 of container 113 . . . 3"
Area of annular end face 129 of head 128 of plunger 127 . . . 5.58 sq. in.
Area of recess 130 in head 128 of plunger 127 . . . 6.49 sq. in.
Area of annular rim 131 on head 128 of plunger 127 . . . 2.87 sq. in.
Diameter of bore 106 of cylinder 105 . . . 6.75"

If the main ram 110 is loaded to produce a pressure of 80 tons per square inch in the liquid 138 in the bore 106 of cylinder 105 the loading of 1,860 tons will be applied on the main plunger 104. If initially 73 tons of the loading of the main plunger 104 is held off by the auxiliary

cylinder 111 the liquid in the bore 117 of the container 113 will be raised to a pressure of 190 tons per square inch and the interfacial pressure at the rim 131 on the head 128 of plunger 127 will be 193 tons per square inch. On release of hold back of the main plunger 104 the pressure in the liquid 138 in bore 117 of container 113 will rise to 200 tons per square inch but the interfacial pressure will only rise to 196 tons per square inch thus allowing bleed off of the liquid 138 from the bore of the container 113. The form of apparatus shown in FIGS. 4a, 4b and 5 of the drawings is applicable to the extrusion of individual billets only. FIG. 6 of the drawings shows an adaptation of the apparatus enabling semi-continuous extrusion. The apparatus is adapted in the manner disclosed in copending cognate British applications Nos. 1,982/66, 21,389/66, 21,390/66, 25,488/66 and 25,489/66.

In FIG. 6 parts corresponding to parts in FIGS. 4a, 4b and 5 are given the same reference numbers.

In the arrangement of FIG. 6 the secondary plunger 127 has a conically tapered nosepiece 139 which is divided into segments by being slotted longitudinally. The nosepiece 139 is fitted with a rubber sealing sleeve 140. A longitudinal passageway 141 in the plunger 127 is continuous with a longitudinal passageway 142 in the main plunger 104. The head 128 of the plunger 127 has a boss 143 engaging in a recess 144 in the face of the main plunger 104. The boss 143 is slidably sealed in the recess 144 by a copper mitre ring 145 and a rubber O-ring 46.

In use of this form of apparatus a long billet 147 has its leading end entered into the bore 117 of the extrusion container 101 through the passageways 142 and 141 in the plungers 104 and 127. The apparatus is operated to extrude the leading end of the billet 147 through the die 123. The pressure of the hydraulic liquid in the bore 117 of the container 113 acts on the outside of the rubber sealing sleeve 140 which encloses the nosepiece 139 of the plunger 127. The sleeve 140 is pressed into sealing engagement with the nosepiece 139 and the billet 147. Also the segments of the nosepiece 139 are pressed into clamping engagement with the billet 147. When the leading end of the billet 147 has been extruded pressure in the system is release so that the nose piece 139 of the plunger 127 is released from clamping engagement with the billet 147 and the plunger 127 can be drawn back to expose a new length of the billet 147 in the bore of the extrusion container 113.

I claim:

1. Means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber comprising a member fitted concentrically in one end of the bore of the extrusion chamber, a bleed ring fitted around said member and having an internal circumferential surface engaging with the external surface of the member, a leak path for liquid from the bore of the extrusion chamber being between the internal surface of the bleed ring and the external surface of the member, means for sealing against leakage of liquid from the bore of the extrusion chamber past the periphery of the bleed ring and means for loading of the bleed ring so as to establish a controllable pressure between the internal surface of the bleed ring and the external surface of the member.

2. Bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber the extrusion chamber having an extrusion die fitted at one end of the bore and a plunger entered into the rear end of the bore for pressurisation of liquid surrounding a billet in the bore of the extrusion container and for applying a direct axial loading on the billet, said bleed means comprising, an annular bleed ring fitted around the plunger at the rear end of the bore of the extrusion chamber, said bleed ring having an internal cylindrical surface embracing the plunger and an external circumferential frustoconical sur-

face engaging with a complementary internal frustoconical surface around the end of the bore of the extrusion container, means being provided for applying a loading on the end face of the bleed ring external to the bore of the extrusion chamber to load the external frustoconical surface of the bleed ring against the complementary internal frustoconical surface in the end of the bore of the extrusion chamber and by reaction between these surfaces thereby loading the internal cylindrical surface of the bleed ring radially inwards into contact with the surface of the plunger, liquid bleeding from the bore of the extrusion chamber during extrusion of the billet passing between the surface of the plunger and the internal cylindrical surface of the bleed ring.

3. Bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion chamber having a tubular liner in its bore, an extrusion die being fitted in one end of the liner and a plunger being entered into the other rear end of the liner for pressurisation of liquid surrounding a billet in the liner of the extrusion chamber bore and for applying a direct axial loading on the billet said bleed means comprising an annular bleed ring fitted around the plunger at the rear end of the bore of the extrusion chamber, the liner having an internal cylindrical rim embracing the plunger at the rear end of the bore of the extrusion chamber and the end surface of the liner adjacent the bleed ring being of external frustoconical form, the bore of the bleed ring extending into an end surface of internal frustoconical form complementary to and engaging with the frustoconical end surface of the liner, means being provided for applying a loading on the end face of the bleed ring external to the bore of the extrusion chamber to load the internal frustoconical end surface of the bleed ring against the external frustoconical end surface of the liner and by reaction between these surfaces thereby loading the internal cylindrical rim of the liner radially inwards into contact with the surface of the plunger, liquid bleeding from the bore of the extrusion chamber during extrusion of the billet passing between the surface of the plunger and the internal cylindrical rim of the liner.

4. Bleed means as claimed in claim 2 wherein the means for applying the required loading on the end face of the bleed ring external to the bore of the extrusion chamber comprises a secondary container coextensive with the extrusion chamber and from which the plunger enters the rear end of the bore of the extrusion chamber and means for pressurising liquid in the bore of the secondary container, the bleed ring being sealed around its external circumferential surface in the bore of the secondary container.

5. Bleed means as claimed in claim 3 wherein the means for applying the required loading on the end face of the bleed ring external to the bore of the extrusion chamber comprises a secondary container coextensive with the extrusion chamber and from which the plunger enters the rear end of the bore of the extrusion chamber and means for pressurising the liquid in the bore of the secondary container, the bleed ring being sealed around its external circumferential surface in the bore of the secondary container.

6. Bleed means for controlled bleeding of high pressure liquid from the bore of an extrusion container fitted at one end of the bore with an extrusion die and having a plunger entered into the other rear end of the bore for pressurisation of liquid surrounding a billet in the bore of the extrusion chamber and for applying a direct axial loading on the billet, said bleed means comprising an annular bleed ring fitted around the die the bleed ring having an internal cylindrical rim contacting the external surface of the die, and an external frustoconical end surface engaging with and complementary to, an internal frustoconical surface around the end of the bore of the extrusion container, means being provided for applying a loading on the end face of the bleed ring external to the

bore of the extrusion chamber to load the external frustoconical end surface of the bleed ring against the internal frustoconical surface around the end of the bore of the extrusion chamber and by reaction between these surfaces thereby loading the internal cylindrical rim of the bleed ring radially inwards in contact with the external surface of the die, liquid bleeding from the bore of the extrusion chamber during extrusion of the billet passing between the external surface of the die and the internal cylindrical rim of the liner.

7. Means as claimed in claim 6 wherein the extrusion die is mounted independently on an end plate separate from the extrusion chamber and means are provided for loading of the extrusion chamber towards the end plate so that the end face of the bleed ring external to the bore of the extrusion chamber is loaded against the end plate to provide the loading of the bleed ring necessary for controlled bleeding of liquid from the bore of the extrusion chamber.

8. Apparatus for hydrostatic extrusion of a billet from an extrusion chamber through a die fitted at one end of the bore of the extrusion chamber a secondary liquid container being arranged with its bore co-extensive with the bore of the extrusion chamber a plunger being entered into the rear end of the bore of the extrusion chamber from the secondary liquid container, a main ram of larger diameter than the diameter of the plunger being entered into the rear end of the secondary liquid container, the plunger having a cylindrical head of the same diameter as the main ram, the end face of the head of the plunger having a raised annular rim thereby defining a recess in the end face of the plunger head, the leading end face of the main ram bearing against the annular rim on the plunger head, the annular rim on the end face of the plunger head being radially spaced from the edge of said end face, means being provided slidably sealing between the main ram and the head of the plunger, thereby defining a closed annular space between the opposing end faces of the main ram and the head of the plunger, said closed annular space surrounding the annular rim on the end face of the plunger head, the plunger containing a passageway therethrough leading from the bore of the extrusion chamber to the recess in the end face of the plunger head, means being provided for pressurisation of liquid in the bore of the secondary container, means being provided for applying an adjustable loading on the main ram, thereby loading the plunger to pressurise liquid surrounding a billet in the bore of the extrusion container and to apply a direct axial loading on the billet in the extrusion chamber and means being provided for exhaustion of liquid from the closed annular space which is defined between the opposing end faces of the main ram and the head of the plunger, the cross sectional area of the extrusion chamber, the area of the annular rim, on the end face of the plunger head, the area of the recess in the end face of the plunger head, and the cross sectional area of the main ram being determined in accordance with the pressure to be applied in liquid in the secondary container such that on application of a restricted degree of loading to the main ram to cause build up of pressure in liquid in the extrusion chamber the interfacial pressure produced between the annular rim on the end face of the plunger and the end face of the main ram is always higher than the pressure generated in liquid in the extrusion chamber and such that when full loading is applied on the main ram to cause extrusion of the billet under pressure of liquid in the bore of the extrusion chamber and the direct axial loading applied on the billet by the plunger the interfacial pressure resulting between the annular rim on the end face of the plunger and the end face of the main ram is less than the pressure in the liquid in the extrusion container, whereby as the billet extrudes liquid bleeds from the bore of the extrusion container, through the passageway in the plunger into the recess in the end face of the plunger head, the liquid then passing out between the annular rim on the end face of the plunger head and

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the opposing end face of the main ram, the liquid then being exhausted from the closed annular space which is defined between the opposing end faces of the main ram and the head of the plunger.

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