June 17, 1969 J. D. McALLAN 3,449,935

APPARATUS AND METHOD OF METAL EXTRUSION

Filed Sept. 16, 1966 Sheet 1 of 4

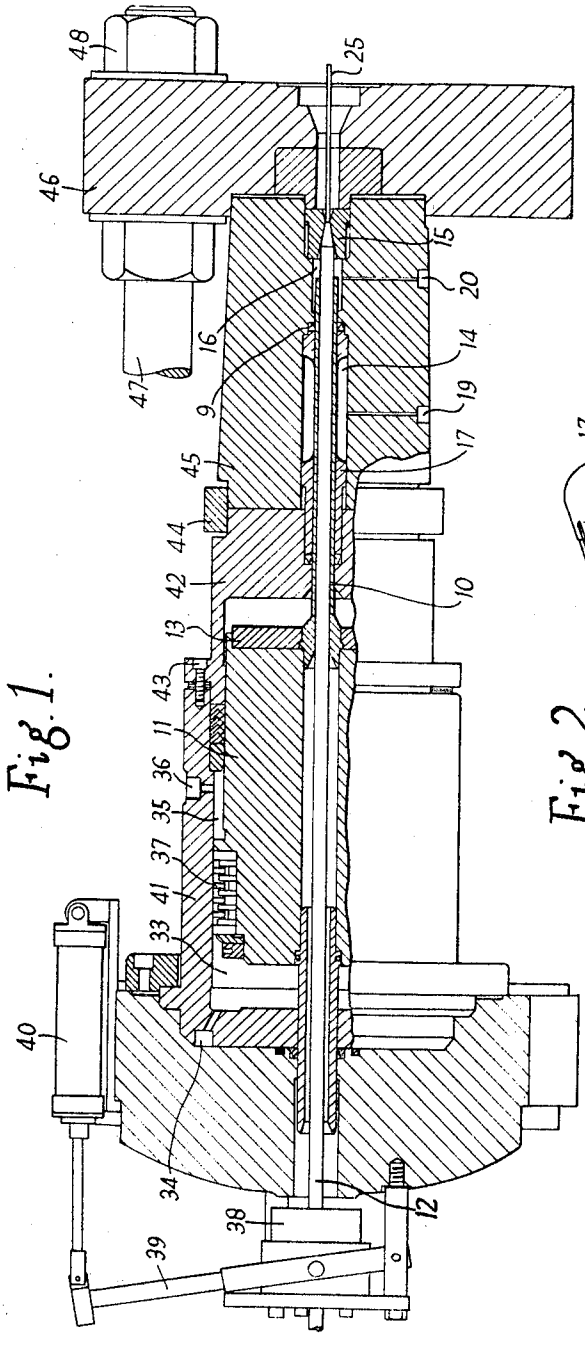

Fig. 1.

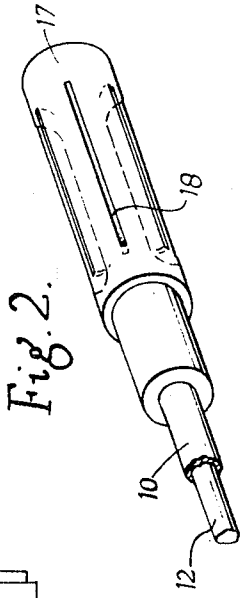

Fig. 2.

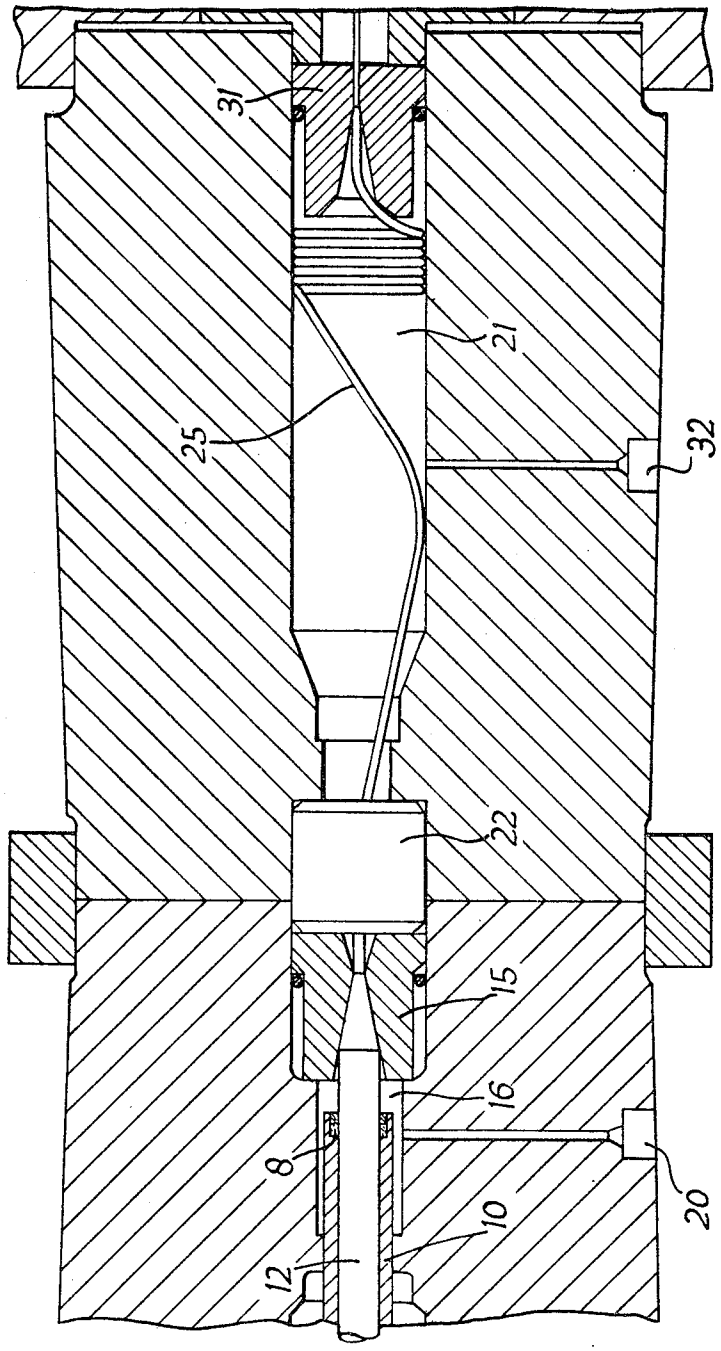

Fig. 3.

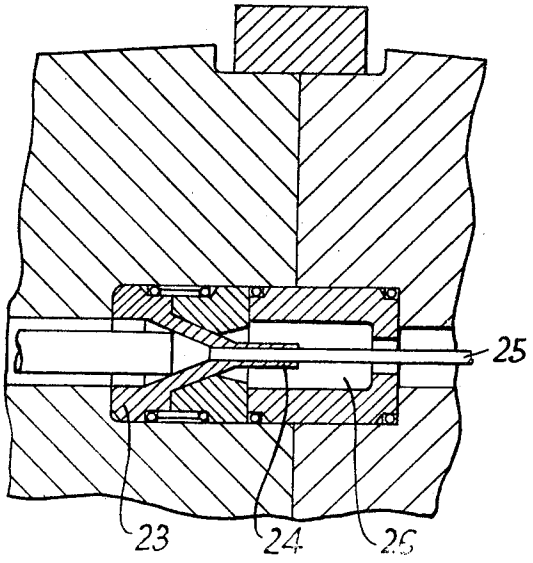

Fig. 4.

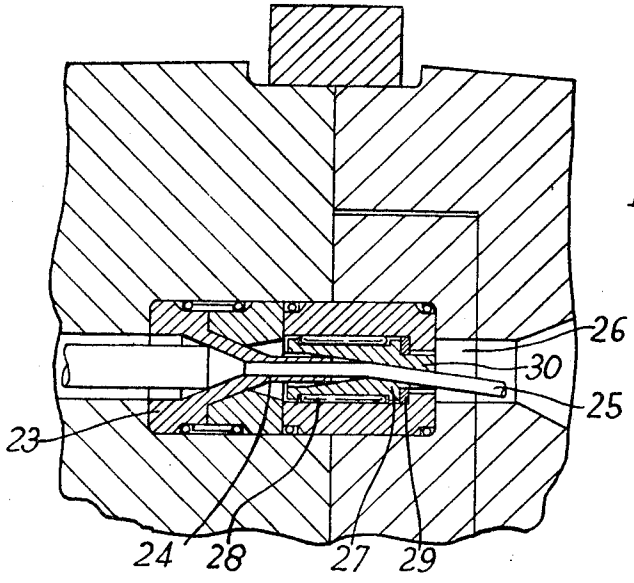

Fig. 5.

June 17, 1969 J. D. McALLAN 3,449,935

APPARATUS AND METHOD OF METAL EXTRUSION

Filed Sept. 16, 1966 Sheet 4 of 4

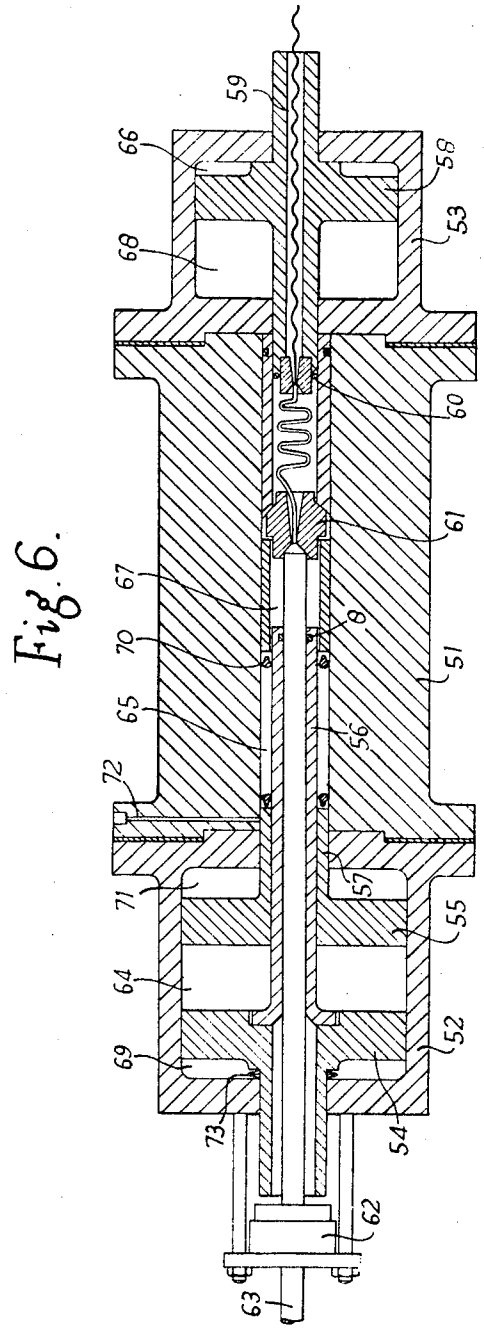

Fig. 6.

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APPARATUS AND METHOD OF METAL EXTRUSION

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U.S. Cl. 72—60 18 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus and method for extruding a metal billet of unrestricted length wherein the apparatus includes a tubular ram arranged to receive the billet with a small clearance, a die disposed in an extrusion chamber, means for applying radial pressure to the ram to cause it to grip the billet, a jack operatively connected to the ram, means for applying axial pressure to the jack to cause it to advance the ram and billet to promote extrusion of the billets through the die, means for applying fluid pressure to the extrusion chamber of a value sufficient at least to prevent outward plastic flow of the billet between the ram and the entrance to the die under the axial stress produced by the ram, means for applying axial pressure to the jack in the reverse direction at a time when radial pressure is no longer applied to the ram whereby the ram moves backwards over the billet and means for holding the billet stationary during the backward movement of the ram. A storage chamber may also be provided into which the extruded metal issues, and a die may be located at the opposite end of the storage chamber and means may be provided for applying fluid pressure to the storage chamber whereby a second stage of extrusion takes place therefrom which may be intermittent or continuous.

The present invention relates to the extrusion of metals and more particularly to apparatus and a method by means of which a metal billet of unrestricted length can be extruded either intermittently or continuously.

In the known arrangements by which extrusion is carried out by hydraulic means, the billet is surrounded by a high pressure liquid so that it extrudes through a die due to hydrostatic pressure. Each operation necessitates preparing the billet by cutting it to an appropriate length, chamfering one end in readiness for the inlet of the die and sealing the billet into a container, all of which, even with a breech mechanism in the latter instance, is time-consuming, and precludes a product of unrestricted length.

The chief object of the invention is to avoid these repeated setting-up steps, also to achieve higher net extrusion ratios than are presently possible hydrostatically and to produce a continuous product such as wire.

According to the invention, apparatus for extruding a metal billet of unrestricted length comprises a tubular ram arranged to receive the billet with a small clearance, a die disposed in an extrusion chamber, means for applying radial pressure to the ram to cause it to grip the billet, a jack operatively connected to the ram, means for applying axial pressure to the jack to cause it to advance the ram and billet to promote extrusion of the billet through the die, means for applying fluid pressure to the extrusion chamber of a value sufficient at least to prevent outward plastic flow of the billet between the ram and the entrance to the die under the axial stress produced by the ram, means for applying axial pressure to the jack in the reverse direction at a time when radial pressure is no longer applied to the ram whereby the ram moves backwards over the billet and means for holding the billet stationary during the backward movement of the ram.

There may be provided in addition to the above apparatus a storage chamber into which the extruded metal issue, a die at the opposite end of the storage chamber and means for applying fluid pressure to the storage chamber whereby a second stage of extrusion takes place therefrom, which may be intermittent or continuous.

The exit from the die at the entrance to the storage chamber is preferably provided with a tubular projection of substantially the same internal diameter as the extruded product, this projection contracting on the product and clamping it firmly if the pressure in the storage chamber exceeds that on the other side of the said die, thus isolating the storage chamber so that, for example, the second stage of extrusion may take place whilst the first stage ram is being retracted.

The invention also relates to a method of extruding a metal billet of unrestricted length comprising the steps of feeding the billet into a tubular ram of slightly greater diameter than the diameter of the billet, applying radial fluid pressure to the tubular ram to cause it to contract to grip the billet, advancing the ram and hence the billet to produce extrusion through a die, removing the radial pressure to disengage the billet from the ram and retracting the ram while holding the billet stationary. Preferably the billet between the tubular ram and the die is subjected to a fluid pressure of a value at least sufficient to prevent outward plastic flow of the billet under the axial stress produced by the ram. Before this pressure can be applied the nose of the billet must be pressed into the entry orifice of the die so as to prevent the escape of the pressurised fluid through the die.

Various embodiments of the invention will now be described in detail, by way of example only, with reference to the accompanying drawings comprising FIGURES 1–6.

FIGURE 1 is a side elevation, partly in section, of metal extruding apparatus according to the invention;

FIGURE 2 is a perspective view of a core bar with part of a tubular ram and the billet extending therethrough;

FIGURE 3 illustrates diagrammatically the addition of a second stage of extrusion;

FIGURE 4 is an enlarged view of a die assembly having a tubular projection assumed to extend into a storage chamber as shown in FIGURE 3;

FIGURE 5 is a view similar to that of FIGURE 4 illustrating a coiler mechanism applied to the die assembly of FIGURE 4;

FIGURE 6 is a modified arrangement on the lines of FIGURE 1 but with a movable second die whereby the necessary high pressures are generated within the equip-

ment and only a low pressure external source is required.

Referring to FIGURE 1, a tubular ram **10** is fixedly attached through a flange **13** to a jack **11**. A circular section billet **12** of unrestricted length is fed into the tubular part of the ram. Billets measuring 5/8" in diameter and 12' in length have been used successfully during experiments. Lengths may generally be attached to one another successively if any given length is not sufficiently long for the job in hand, or the extrusion machine may be fed from a plant continuously producing billet material. Surrounding a portion of the tubular ram is a gripper chamber **14** adapted to receive fluid under pressure to provide the required grip by the ram on the billet by contracting the tubular part thereof on the billet prior to the extrusion of the foremost part thereof through die **15**.

Disposed within the gripper chamber is a supporting member **17**, referred to as a core bar, and shown in greater detail in FIGURE 2. This member, which is fixed in the assembly, serves to guide and support the ram against any tendency to buckle when driven forward to extrue the billet. The core bar extends over a substantial part of the length of the ram and, because of longitudinal slots **18** disposed therein and extending formost of the length of the bar, a small quantity of pressurised fluid, conveniently oil, reaches the surface of the ram to cause it to contract and also facilitates its movement through the core bar. The core bar is in equilibrium, being surrounded by the high pressure fluid and thus has no tendency to contract thereon when pressure is applied in the gripper chamber. The core bar is slightly relieved in the region of the slots so that fluid in the gripper chamber can flow around it and thus enter the slots and proceed to the surface of the ram. The disposition of the core bar in this chamber reduces the volume to a few cubic inches, which when occupied by high pressure fluid, is sufficient to maintain the ram in gripping contact with the billet in spite of the axial force required to promote extrusion through the die **15**. The shrink fit then occurring between the ram and the billet, possibly assisted by a seal (such as seal **8** in the embodiment illustrated in FIGURE 3 which is to be later described), prevents fluid from escaping from a chamber **16** which is described below.

A pressure chamber **33** defined by the outer casing **41** of the apparatus and the end of the jack **11** has a duct **34** leading thereto through which fluid under pressure from a fluid pressure supply reservoir (not shown) provides the force required to advance the jack and attached ram axially towards the die. Fluid seals **37** are provided to prevent leakage between the jack and the outer casing **41**. This outer casing also defines with the jack a fluid pressure chamber **35** on the opposite side of the jack head through which pressure fluid is applied by way of a duct **36** to withdraw the ram during the retracting phase of each cycle of operation. A head **42** is attached to the casing **41** by screws one of which is shown at **43**. The head **42** is assumed to be secured by the ring **44** to the container **45** embodying both the gripping chamber **14** and the extrusion chamber **16** which is immediately in front of the die **15**. Fluid under pressure is introduced into this chamber through a duct **20** which is preferably connected to a pressure intensifier (not shown) adapted to deliver a constant high pressure during the forward stroke of the ram.

Owing to the small clearance between the ram and the billet, when the pressure on the ram is released and the ram is drawn back to repeat the forward stroke, it tends to drag the billet back with it. To ensure that this movement shall not take place, a back stop **38** is provided. This stop conveniently consists of a collet chuck with gripping jaws of the type usually used as a lathe attachment and is operated through a lever **39** from cylinder **40** controlled by fluid pressure.

The assembly is held together by two end plates, that

at the rear being shown at **46**. These plates are connected by four parallel bolts such as **47** extending between corresponding corners, the bolts being provided with nuts such as **48**. The plates are bored centrally, the front one to admit the billet to be extruded and the back one to permit the product of the extrusion to issue forth from the apparatus.

The detailed operation of the apparatus is as follows:

A billet **12** is inserted into the apparatus from left to right and passes through the back stop **38**, the jack **11** and the tubular ram **10**, coming to rest against die **15**. Fluid under pressure is introduced through duct **19** to the gripper chamber **14** causing the ram to contact on the billet. Fluid pressure is applied to the chamber **33** to advance the jack **11** and move the ram and hence the billet tightly against the die **15** to seal the extrusion chamber **16**. High pressure fluid is now introduced into the extrusion chamber **16** through the duct **20**, the jack **11** is advanced and extrusion takes place.

The hydrostatic pressure in the extrusion chamber must be at least sufficient to prevent outward plastic flow of the billet between the end of ram **10** and the entrance to die **15** but is preferably sufficient to promote hydrostatic extrusion. As shown in FIGURE 1, the extruded metal emerges from the die at **25**.

In order that the ram may make a return stroke after a working stroke, the pressure in the extrusion chamber **16** must be released, this being followed by the release of the pressure in gripper chamber **14** to relax the grip of the ram on the billet. To prevent any tendency for the billet to move backwards, the back stop is now operated to grip the billet and maintain it steady during the back stroke of the ram. The ram is then caused to slide back over the billet by the application of fluid pressure through duct **36** to act on the jack **11**. It will be noted that the area on which this pressure operates is very much smaller than for the forward stroke since a much smaller force is needed.

For true hydrostatic extrusion, the high pressure fluid in the extrusion chamber **16** must subject the billet to inward stresses exceeding the yield stress of the billet material and the axial stress on the billet should at least equal the radial stress produced by the high pressure fluid. Nevertheless if a greater extrusion ratio is desired, satisfactory extrusion of the billet through the die can take place with the axial stress greater than the radial stress so long as the difference does not exceed the yield stress of the material.

The gripping pressure should not exceed the elastic limit of the material so that the surface of the portion of the billet not extruded remains unmarked. Holding the material without spoiling its surface is considered desirable by many manufacturers. This effect is obtained by using gripping pressures such as to not permit the gripping force to exceed the elastic limit of the billet material.

Referring now to FIGURE 3 of the drawings, when it is desirable to employ a second stage of extrusion to provide further reduction in the cross-sectional area of the product, there is provided, subsequent to the die **15**, additional apparatus for this purpose. This apparatus comprises a generally cylindrical storage chamber **21** in which the product **25** is collected and a projection member **22** for directing the product into the chamber. This member, shown in detail in FIGURE 4, comprises a die **23** having a tubular projection **24** extending into an ante-chamber **26**. This tubular projection may be integral with the die or attached thereto. The storage chamber **21** may be at atmospheric pressure or at some back pressure during extrusion through the die **15**. On raising the pressure in storage chamber **21** the tubular projection **24** will grip the product **25** from the die **23** thus avoiding any tendency for backward movement and extrusion will take place through die **31**.

If back pressure in storage chamber **21** is sufficient to cause hydrostatic extrusion through die **31** and if the pres-

sure in chamber **16** exceeds the pressure in storage chamber **21** by the extent necessary to extrude material through die **15**, the first product from die **31** may be caused to emerge continuously notwithstanding the fact that extrusion through die **15** is intermittent.

When the product **25** issues into the chamber **21**, it tends to form a coil therein as shown in somewhat idealised form in FIGURE 3, so that an appreciable amount of the first extrusion product may be stored. To promote this operation in an orderly manner, the arrangement of FIGURE 5 may be employed. This incorporates in the ante-chamber **26** a coiler mechanism comprising a reel member **27** rotatable on needle roller bearings **28** and co-operating with an anti-friction thrust ring **29**. The member **27** has an extension **30** provided with a bore extending from the centre of the member **29** of the same diameter as the tubular projection **24** and disposed at a slight angle to the axis of the chamber **21**. This arrangement provides that the product **25**, on leaving the tubular projection **24**, is directed by the reel **27** into the chamber **21** at an angle to the axis of the chamber and additionally with a component of direction tangential to chamber **21** and will therefore coil therein more readily. As the product coils in the chamber **21**, it rotates the reel **27**.

A second die **31** positioned at the exit of the chamber **21**, FIGURE 3, co-operates in the further and continued extrusion of the metal coiled within the chamber. When fluid pressure is applied in the chamber by way of the duct **32**, the coiled metal extrudes through this die. Being usually much reduced in gauge at this stage, the second extrusion product may be wound on to a spool, or if a finer gauge product is required, the wire is directed through a further storage chamber and die or series of chambers and dies.

When a plurality of storage chambers are employed, the pressures in the chambers may be adjusted in such a manner that simultaneous extrusion can be obtained from alternate chambers, all the chambers being provided with tubular projection members and preferably also with coiler-mechanism. Difficulty will arise if conditions are such as to result in under- or over-filling of a cylindrical chamber. In the first instance the product will become straight within the chamber so that necking occurs and probably resultant breakage. This can be avoided by suitably limiting the pressure in that chamber. Over-filling is less likely to occur since when the receiving cylindrical chamber approaches the full condition, the hydrostatic pressure attains such a value in relation to that in the previous extrusion chamber that extrusion ceases. It is desirable, however, to time the application of pressure to the extrusion chambers to avoid billet breakage or overfilling of the chamber into which extrusion is taking place.

The arrangement described in FIGURE 1 depends for its operation on the supply of high pressure fluid from an external source, and this is fed into a central bore at different places, particularly to the extrusion chamber and the gripping chamber. The ducts whereby this is done constitute a source of weakness in the main frame and it is therefore preferable for this to be eliminated and for the whole device to be operated from a comparatively low external pressure, the required high pressure being generated therefrom in the device itself.

A modified construction which enables this to be done is shown in FIGURE 6 which indicates in line diagram form the relationship of the various parts.

As before, the main body **51** within which extrusion takes place is very heavily constructed to resist the high pressures concerned and it is provided at one end with a cylinder **52** of much lighter construction and a similar cylinder **53** at the other end. Working within the cylinder **52** are two pistons **54** and **55**, **54** carrying the tubular ram **56**, while **55** has an extension **57** closely fitting the bore in the main body. The cylinder **55** is provided with the piston **58** mounted on a hollow rod **59** carrying a die **60** at its left-hand end. The space between this die and the main die **61** forms a storage chamber in which the first extrusion product through the main die tends to coil. The die **61** is arranged to act as a valve in that it is movable on its seat to permit fluid flow past it when the pressure on the right-hand side exceeds that on the left-hand side. As in the previous arrangement, a backstop **62** is provided, the function of which is to hold the billet **63** during the return stroke of the ram.

The interaction of the various parts will be followed from the description of a typical cycle. At this point in the cycle the backstop **62** is disengaged by control arrangements not shown to enable the billet to pass freely therethrough. This piston **55** is now moved to the right by pressure applied to the space **64**. In view of the comparatively large diameter of the piston **55**, this pressure can be comparatively low but will serve to produce in due course the necessary high pressure in the gripping chamber **65**. The movement of the piston **55** will cease when this pressure has been attained and as a result the ram **56** is caused to contract so as to grip the billet **63**. The pressure in space **64** is preferably maintained automatically at a predetermined maximum value by the provision of a suitable relief valve, not shown. This is desirable in view of subsequent movements of the pistons **54** and **55**. Piston **58** at the other end of the main block is now moved to the left by the application of low pressure to space **66** and this causes corresponding movement of the die **60** and hence extrusion therethrough of the product remaining in the storage chamber from earlier extrusion cycles through the die **61**.

The increase in pressure in the storage chamber causes the die **61** to shift slightly off it seating and as a result pressure rises in the space **67** forming the first stage extrusion chamber. Piston **58** is now retracted by applying low pressure to space **68** and exhausting space **66**, and as this movement takes place, the pressure in the storage chamber falls off and the die **61** re-seats to maintain the high pressure in the space **67**. The pressure in the storage chamber may be allowed to drop to atmospheric pressure on a suitable value of back pressure.

Piston **54** is now moved to the right by applying pressure to space **69** and as a result the ram **56** and the billet **63** are moved forward and extrusion takes place through die **61**. The magnitude of the pressure applied to the space **69** determines the axial stress in the billet. For extrusion under hydrostatic conditions this should at least equal the radial stresses due to the pressure in space **67**, but if a higher extrusion ratio is desired, the axial stress may be arranged to exceed the radial stress so long as it does not do so by more than an amount equal to the flow stress of the billet material. As a result of the forward movement of the ram **56**, the pressure in space **67** tends to rise but any increase is prevented by the valving action of the seal **70** at the die end of the chamber **65**. This has the effect of increasing the pressure in the space **65** which causes the piston **55** to move to the left to maintain the gripping pressure at the predetermined level dependent on the constant pressure in the space **64**.

At the end of the extrusion stroke, the backstop **62** is engaged to hold the billet and prevent it backward movement. Piston **55** is now moved backwards, i.e. to the left in FIGURE 6, by applying pressure to the space **71** and exhausting space **64**. Consequently pressure falls off in space **65** and also in space **67** so that the gripping pressure is released and the pressure in space **64** permits the piston **54** to move to the left and thus retract the ram to the starting position.

During the course of the cycle, there is a progressive transfer of fluid from right to left by way of die **61** and seal **70** which would produce a progressive movement of piston **55** to the left and interfere with proper operation. This is taken care of, however, by the leak provided by the channel **72** which is uncovered if the piston **55** is moved sufficiently far to the left and then permits a momentary escape of fluid.

It is important that the piston **54** shall be capable of slight movement to the left from its normal fully-retracted position during the pressure build-up at the beginning of the cycle, so that the movement of die **61** from its seating is not prevented by the billet acting as a strut between die **61** and ram **56**, and to ensure this a pair of Belleville spring washers **73** is provided to prevent the shoulder of piston **54** engaging with the end of the cylinder **52** at the end of the retracting movement.

The arrangement just described for pressurising the extrusion chamber depends on the movement of the piston **58** generating pressure in the storage chamber and this cannot take place unless the hole in the die **60** is sealed. This will not be the case when a new billet is inserted into the machine and a special starting operation is therefore necessary. This may consist in the removal of the cylinder **53** together with the die **60** to permit the insertion of a plug in the die. The cylinder is then replaced and several normal cycles are performed which will produce sufficient extrusion product in the storage chamber. Thereupon the cylinder **53** is again detached and the plug removed from the die **60** and replaced by the end of the extrusion product. The cylinder **53** is then replaced and thereafter normal operation is possible.

As an alternative to detaching the cylinder **53**, a sealing cap may be placed over the end of the rod **59** which will enable sufficient pressurisation to result for extrusion to take place through the die **61** and the end of the extrusion product will eventually find its way into the die **60**, possibly with the assistance of a guide associated therewith in the storage chamber.

The present invention may be combined with a continuous casting plant from which stock is fed direct. This presents the advantage that the stock can enter the exrustion plant while still hot, so that with many substances extrusion is much facilitated and higher extrusion ratios are possible with a consequent reduced number of extrusion stages.

The sequence of operation in each cycle may be automatically controlled preferably by a suitable timer which energises electrically operated valves to control the working fluid. After a few trials to determine the optimum periods, this will enable the process to be automatic, particularly if the billet material is being continuously produced.

I claim:

1. Apparatus for extruding a metal billet of unrestricted length comprising a tubular ram arranged to receive the billet with a small clearance, a die disposed in an extrusion chamber, means for applying radial pressure to the ram to cause it to grip the billet, a jack operatively connected to the ram, means for applying axial pressure to the jack to cause it to advance the ram and billet to promote extrusion of the billet through the die, means for applying fluid pressure to the extrusion chamber of a value sufficient at least to prevent outward plastic flow of the billet between the ram and the entrance to the die under the axial stress produced by the ram means for applying axial pressure to the jack in the reverse direction at a time when radial pressure is no longer applied to the ram whereby the ram moves backwards over the billet and means for holding the billet stationary during the backward movement of the ram.

2. Apparatus as claimed in claim **1** in which the means for applying radial pressure to the ram comprises a fluid pressure chamber disposed around at least part of the ram.

3. Apparatus as claimed in claim **2** in which the means for applying radial pressure to the ram comprises an annular piston surrounding the tubular ram and movable axially of the ram within the pressure chamber, means for advancing the piston in the direction of the die to pressurise the pressure chamber, unidirectional sealing means preventing flow of fluid from the pressure chamber to the extrusion chamber but enabling fluid to flow in the opposite direction past the sealing means to relieve any excess pressure in the extrusion chamber arising from the advance of the tubular ram into the extrusion chamber in the course of extrusion, and means for limiting the force applied to the piston to advance it as aforesaid, whereby it is enabled to retreat when fluid flows from the extrusion chamber past the sealing means into the pressure chamber to relieve excess pressure in the extrusion chamber.

4. Apparatus as claimed in claim **2** in which the pressure chamber includes a fixed tubular supporting member disposed around the ram with a small clearance therefrom and provided with radial slots to permit fluid in the pressure chamber to contact the surface of the ram.

5. Apparatus as claimed in claim **2** in which the necessary fluid pressures are applied to the different chambers from an external source.

6. Apparatus as claimed in claim **2** in which the necessary fluid pressures in the different chambers are produced as a result of the application of low pressure to produce movement of a jack of considerably greater diameter than the diameter of the chambers.

7. Apparatus as claimed in claim **1** including a storage chamber into which the extruded metal issues, a die at the opposite end of the storage chamber and means for applying fluid pressure to the storage chamber whereby continuous extrusion takes place therefrom.

8. Apparatus as claimed in claim **7** in which the fluid pressure in the storage chamber for producing extrusion is less than the pressure in the extrusion chamber during the extrusion operation therefrom.

9. Apparatus as claimed in claim **8** in which valve means are provided between the storage chamber and extrusion chamber operable to permit the flow of fluid from the former to the latter when the pressure in the former exceeds the pressure in the latter but to impede the flow of fluid from the latter to the former.

10. Apparatus as claimed in claim **9** in which the die at the entrance to the storage chamber rests in a seating from which it is movable, whereby it functions as the said valve means and whereby the extrusion chamber is pressurised when the storage chamber is pressurised.

11. Apparatus as claimed in claim **7** in which the die at the opposite end of the storage chamber is movable axially to raise the pressure in that chamber to a value sufficient to produce hydrostatic extrusion.

12. Apparatus as claimed in claim **7** in which a tubular projection attached to the die at the entrance to the storage chamber and of the same diameter as the neck of the die extends a short distance into the storage chamber and is arranged to contract under pressure in the chamber on to the extrusion product thus preventing backward movement of the extrusion product when pressure is reduced in the extrusion chamber to a level below that of the pressure in the storage chamber.

13. Apparatus as claimed in claim **12** in which a rotatable coiler member is disposed adjacent the tubular projection, said member having an obliquely disposed bore of a diameter similar to that of the tubular projection and arranged to receive the product issuing therefrom and assist it in coiling in the storage chamber.

14. A method of extruding a metal billet of unrestricted length comprising the steps of feeding the billet into a tubular ram of slightly greater diameter than the diameter of the billet, applying radial fluid pressure to the ram to cause it to contract to grip the billet, advancing the ram and hence the billet to produce extrusion through a die, removing the radial pressure to disengage the billet from the ram and retracting the ram while holding the billet stationary.

15. A method as claimed in claim **14** including applying to the billet between the ram and the entrance to the die, a surrounding hydrostatic pressure sufficient at least to prevent outward plastic flow of the billet under the axial stress applied to it by the ram.

16. A method of extruding a metal as claimed in claim **14** including directing the extruded metal to a storage

chamber where it is collected, and applying fluid pressure to the chamber to cause continuous extrusion of the metal through a die at the opposite end of the storage chamber.

17. A method as claimed in claim **16** including gripping the extruded metal issuing from the die at the entrance to the storage chamber when the pressure in the storage chamber exceeds the pressure on the other side of the said die.

18. A method as claimed in claim **16** in which the extruded metal is directed through a series of storage chambers in which the cross sectional area of the billet is reduced successively.

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U.S. Cl. X.R.

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