April 19, 1960 J. B. OTTESTAD ET AL 2,932,951

FORMING APPARATUS

Filed March 8, 1957

4 Sheets-Sheet 1

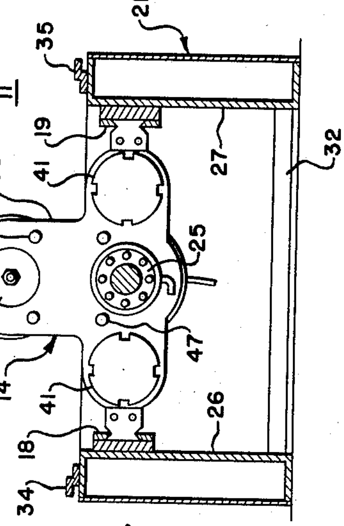

FIG. 4

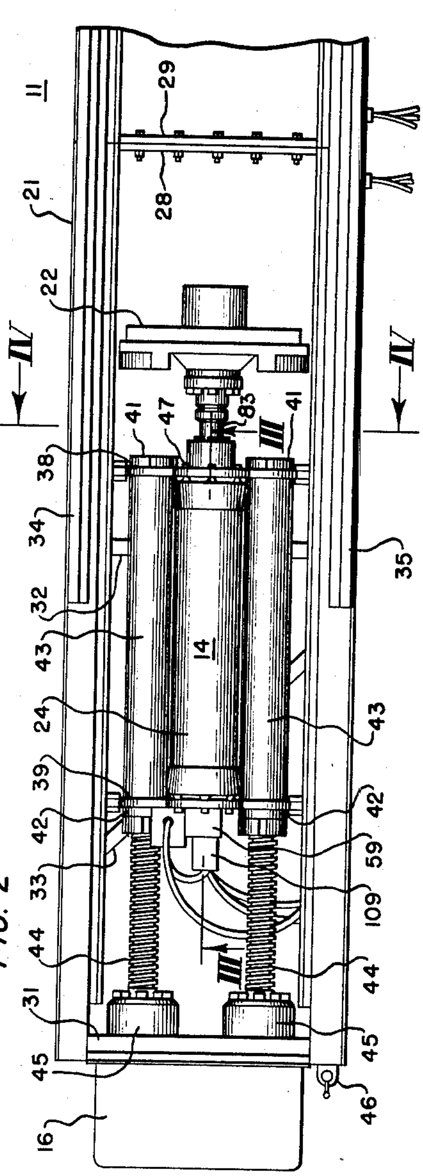

FIG. 2

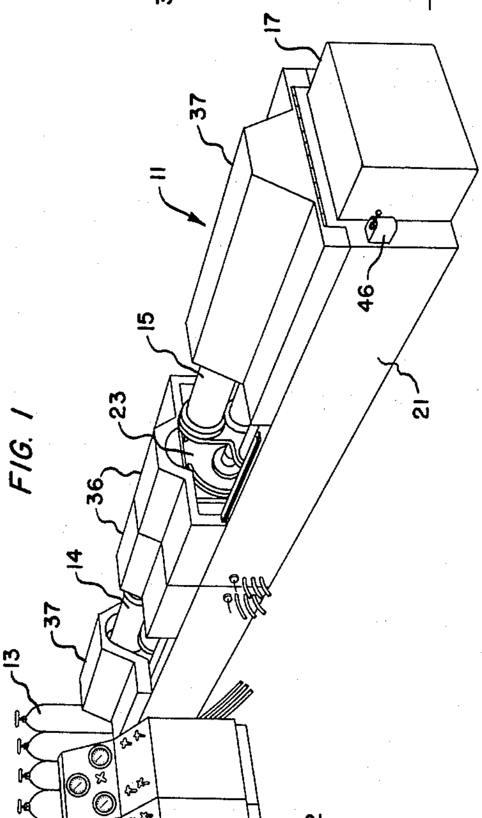

FIG. 1

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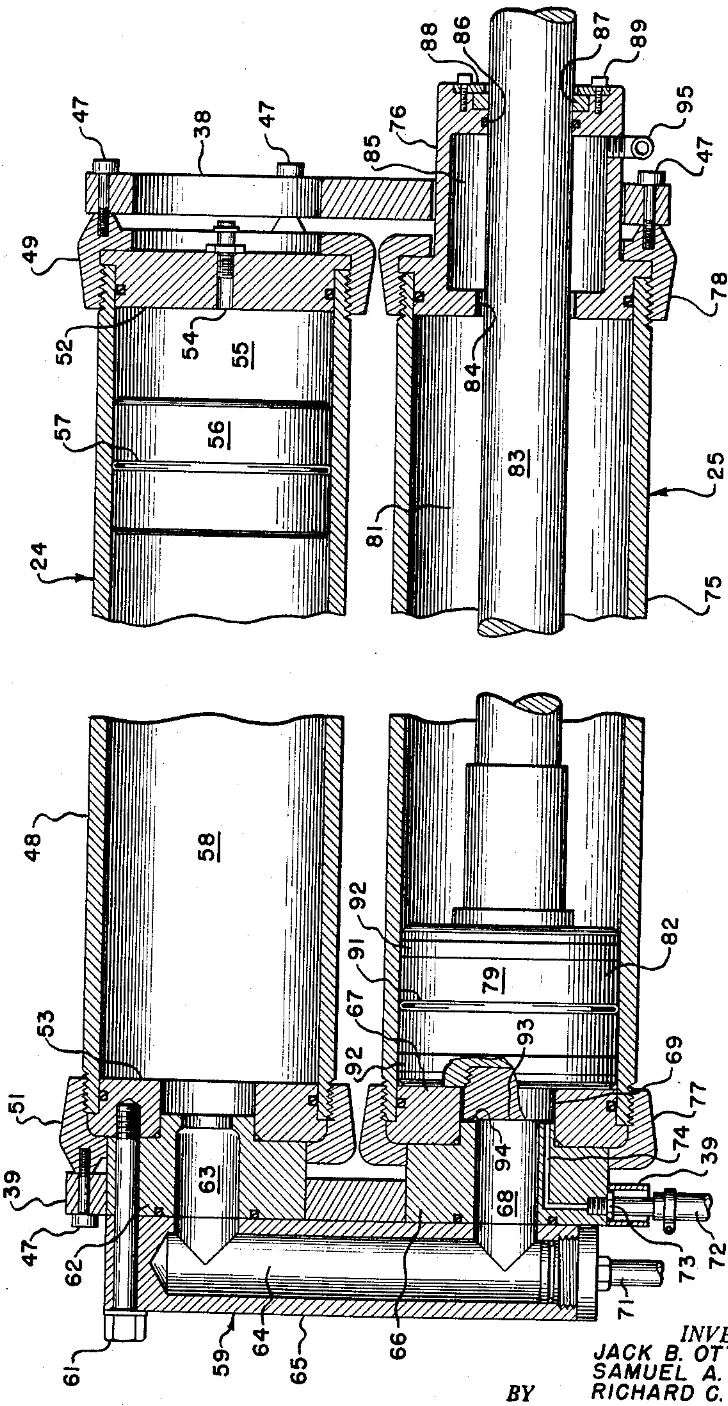
4 Sheets-Sheet 2

FIG. 3



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4 Sheets-Sheet 3

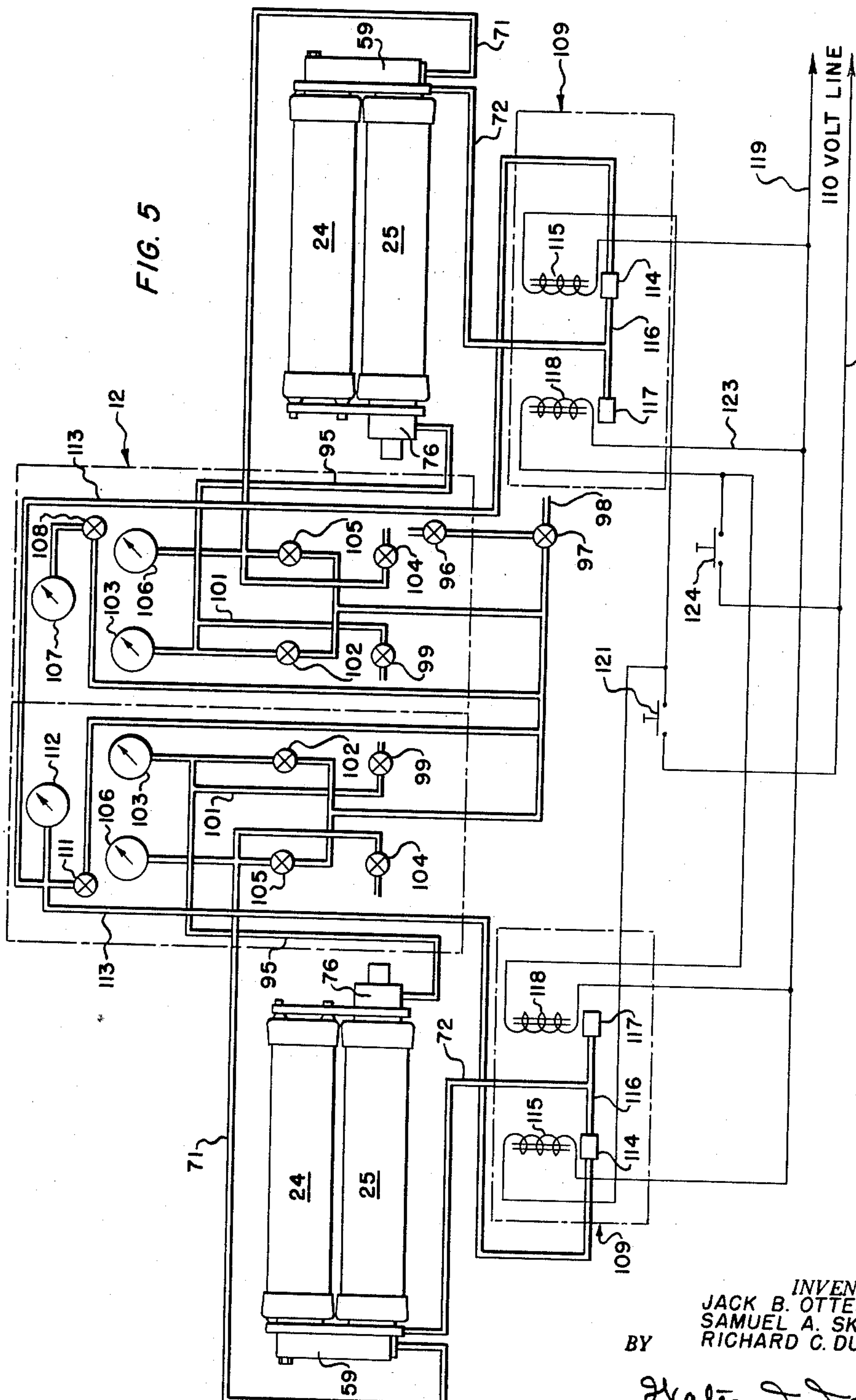

FIG. 5

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Filed March 8, 1957 4 Sheets-Sheet 4

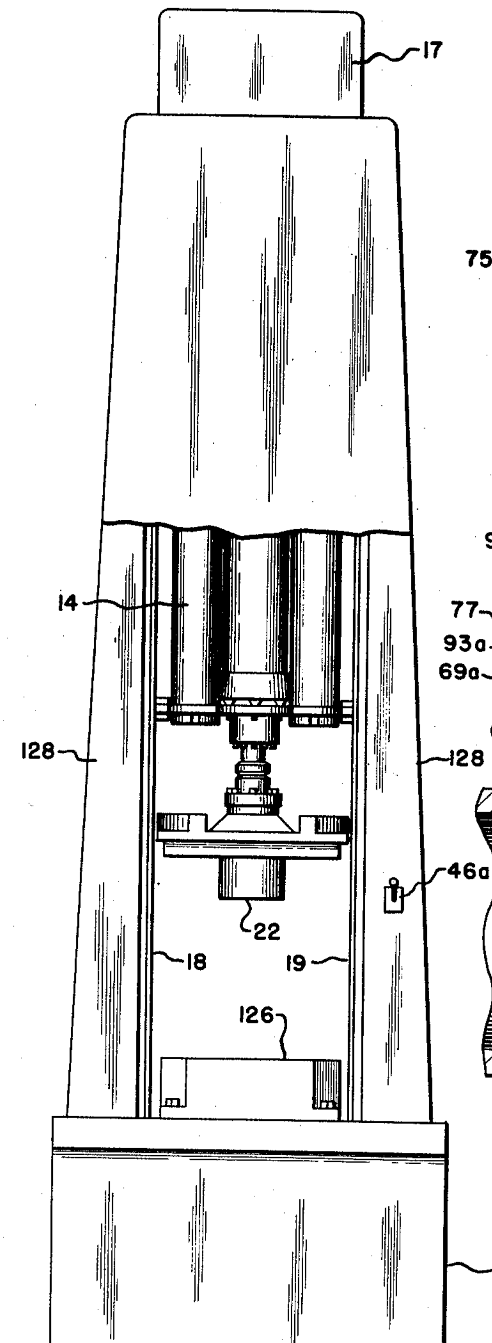

FIG. 7

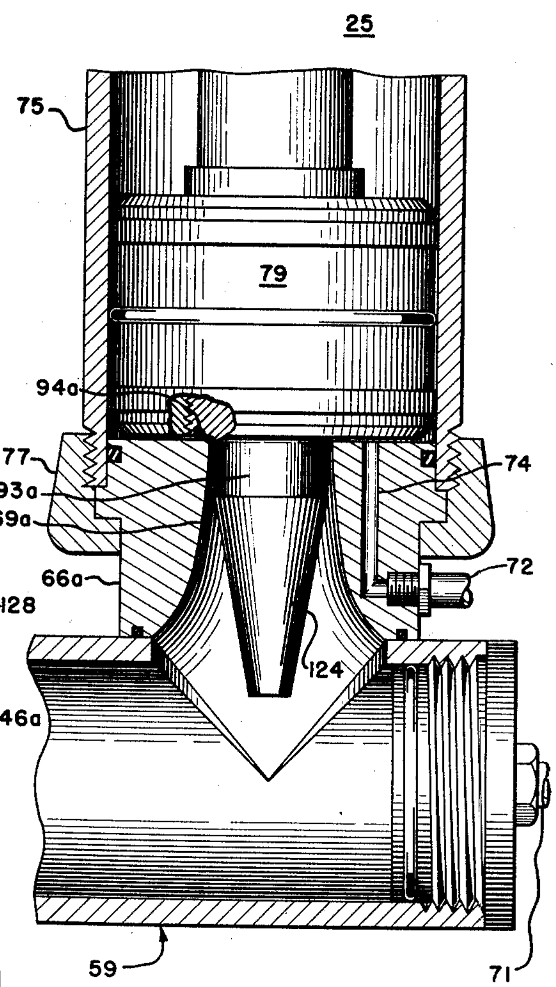

FIG. 6

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FORMING APPARATUS

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Application March 8, 1957, Serial No. 644,903

6 Claims. (Cl. 60—97)

The present invention relates to an apparatus utilizing pressurized fluid for generating impact forces, and more particularly to such an apparatus which utilizes pressurized fluid to generate high velocity impact forces for the forming of materials.

An application for which the apparatus of the present invention is particularly well suited is the forging of material by a material holding member or members which, through the agency of fluid under pressure, are forcibly driven into engagement with a stationary element, or with each other, as the case may be. Various machines are presently used for forming or forging materials in this general manner. Some machines are of the "single-ended" type, and are characterized by a single thrust column or ram member which is adapted to be driven through a work stroke and against a workpiece supported upon a stationary platform or the like. Other machines are of the "double-ended" type and employ a pair of opposed ram members adapted to be driven toward each other to forge or form a workpiece interposed therebetween. A particular example of a machine of the latter, double-ended type comprises a pair of opposed pistons which are slidable within pressure cylinders so that their piston rods may be brought into forcible engagement at the end of a work stroke. Work movement of the pistons is effected through the application of fluid pressure to the pressure cylinders whereby the piston rods or impactors are caused to move toward each other to forge the workpiece interposed therebetween. A particular example of a single-ended machine of the prior art is one in which the single thrust column is constructed and driven in a manner substantially identical to that of the double-ended type except, of course, for the fact that the single thrust column is directed against a stationary platform rather than against an opposed piston, as in the case of the double-ended or double impact type of forming machine. However, in each of these examples, and for that matter in other machines of the prior art, there does not exist any wholly satisfactory mechanism for generating and utilizing a substantially instantaneous force for effecting a high velocity movement of the piston or pistons, as the case may be, and still provide an easily adjustable and predictable thrust level and time-thrust pattern. In addition, previous machines have not been characterized by being able to generate a sustained force irrespective of the velocity and displacement of the impactor or impactors. Insofar as is known, existing impact machines depend, not upon a rapid release of stored energy, but rather depend upon a comparatively gradual build-up of fluid pressure within the pressure cylinder or cylinders to effect the desired work movement of the pistons. Thus the time and force of impact can be controlled only by externally controlling the build-up of pressure. The flow of pressure fluid required to trigger the pistons is considerable and has to be closely correlated with the movement of the pistons throughout their entire stroke. In the double-ended machines, the various environmental factors which affect their operation may even spoil the desired coordination of the rates of movement of the opposed pistons. Thus, because of the dynamic nature of the pressure build-up, the necessary controls must be precise and highly responsive, and are rather complex, expensive, and difficult to install and maintain.

In contrast, the present invention comprises an arrangement of one or more thrust columns or ram elements which are each driven by an actuator means which depends upon a preliminary accumulation or storage of pressure energy, followed by a sudden release or triggering of that pressure energy. This pressure accumulation or storage prior to triggering is had without preliminary actuation or movement of the ram elements, and hence the rate of flow of the pressure fluid during the energy accumulation period is not a dynamic variable as it was in the case of the pressure build-up in machines of the prior art. Instead, the present apparatus or machine stores the necessary pressure energy, and in the double-ended embodiment additionally provides a means for coordinating the triggering or sudden release of the ram elements so that a rapidly applied thrust load occurs at the time and energy level desired. Further, the force generated by this release of energy may be precisely calculated so that the velocities and forces which will be encountered at the moment of impact may be easily predicted. As will be more completely described hereinafter, the triggering of the ram elements is effected through the use of a relatively small volume of pressure fluid, and this small volume of fluid permits economical, simple, and effective synchronization of the movement of the ram elements. Further, metering means may be provided whereby the form and character of the thrust-time pattern may be dictated. For details of an actuator mechanism particularly fitted for use in the present invention for driving each of the ram elements, reference may be made to my co-pending application, Serial No. 617,014, filed October 19, 1956.

It will be seen that with the present machine all of the advantages of high velocity impact forming may be obtained without the present difficulty of complex controls or the use of explosives. Materials which ordinarily prematurely work harden and crack when formed by other devices, such as drop hammers and the like, now may be successfully formed with the present machine. In addition, one embodiment of the present invention utilizes opposed ram elements whereby complete dissipation of energy is had without shock to the foundation of the apparatus, and thus resulting in a lightweight machine which may easily be repositioned in other factory areas, as desired. An additional feature of this embodiment is its dual construction, which permits separation of the opposed ram units whereby each may be used independently as a single-ended unit, somewhat in the manner of a special drop hammer or press wherein an adjustment may be made in the thrust-time pattern, in contrast with the usual drop hammers and presses and their lack of flexibility of thrust-time pattern adjustment. Another embodiment of the present invention is specifically designed as a single-ended machine for impact forming.

It is therefore an object of the present invention to provide an improved apparatus for generating impact forces against a workpiece and which is characterized by an initial accumulation of pressure energy followed by a sudden, controlled release of that energy.

Another object of the invention is the provision of a unique apparatus for forming materials which is adapted to effect the storage of fluid under pressure, and which is further adapted to be subsequently actuated to rapidly and controllably release such stored energy.

An additional object of the invention resides in the provision of an improved apparatus for generating high impact forces and which may be adjusted to alter the time of occurrence and energy of such impact forces.

Another object of the invention is to provide an improved apparatus for generating high impact forces and which is characterized by a work stroke having a controlled thrust-time pattern.

A further object of the invention is to provide a unique apparatus embodying ram means for rapidly imparting energy to a workpiece for forming it into a predetermined condition.

It is another object of the present invention to provide an improved apparatus which includes pressure cylinders whose piston or ram elements are each individually triggered for movement toward each other, the triggering mechanism being adapted to substantially simultaneously actuate the triggering mechanisms of the pressure cylinders whereby the time and location of impact may be predetermined.

Another object of the invention is to provide an improved apparatus for forming materials which comprises a pair of opposed fluid pressure actuated ram elements adapted to be driven against each other, the apparatus being lightweight and comparatively simple to manufacture and transport.

An additional object of the invention resides in the provision of a novel apparatus which includes a pair of opposed pressure cylinders having piston elements therein which are adapted to be driven toward each other under the influence of pressurized fluid, said apparatus including means for triggering the pressure cylinders independently or simultaneously, and the apparatus being adapted to be split apart whereby a pair of machines are formed, each of which are independently actuable to drive a piston rod or ram element outwardly of a pressure cylinder to perform a work operation.

Other objects and features of the present invention will be readily apparent to those skilled in the art from the following specification and appended drawings wherein is illustrated a preferred form of the invention, and in which:

Figure 1 is a perspective view of one embodiment of the impact apparatus of the present invention, together with the control means therefor and a source of pressure fluid;

Figure 2 is a plan view of approximately half the impact apparatus, the covers having been removed for clarity;

Figure 3 is a sectional view taken along line III—III of Figure 2;

Figure 4 is a sectional view taken along line IV—IV of Figure 2;

Figure 5 is a schematic or diagrammatic illustration of the fluid and electrical circuits for the impact apparatus;

Figure 6 is an enlarged cross-sectional view of the actuator assembly portion of a third embodiment of the present invention, rotated 90 degrees counterclockwise from the view of Figure 3, and particularly illustrating a metering means; and

Figure 7 is an elevational view of a second embodiment of the present invention.

Referring to the drawings and more particularly to Figures 1, 2 and 4, there is illustrated an embodiment of the impact apparatus of the present invention which is generally designated **11**, and which is particularly adapted for the high velocity impact forming of sheet materials such as metallic workpieces. A control means **12** is provided to enable an operator to adjust and establish the pressure conditions under which initial triggering of apparatus **11** takes place, as will hereinafter be more particularly described, and a pressure source **13** provides the necessary pressure fluid for operation of the impact apparatus **11**. Pressure source **13** may be any fluid under pressure, the term "fluid" being used in its broad sense to

include various mediums such as air, nitrogen, or liquids, but in the present embodiment source **13** is illustrated in the form of four pressure bottles containing nitrogen under pressure. However, it should be understood that a high pressure compressed air plant could be used just as effectively, if desired. As shown, pressure source **13** is suitably connected by pressure lines to control means **12**, as will be described.

Impact apparatus **11** comprises, generally, a pair of carriage, or impact, assemblies **14** and **15** whose position with respect to each other may be adjusted, respectively, by a pair of drive means **16** and **17**. As will be seen, actuation of drive means **16** and **17** serves to move carriage assemblies **14** and **15** along a pair of guideways **18** and **19** of a frame **21** to establish the length of the work stroke of apparatus **11**. More particularly, after adjustment of carriage assemblies **14** and **15** in the positions desired, assemblies **14** and **15** serve as a fixed support for a pair of platen elements **22** and **23** which, when driven toward each other at high velocity, serve to transmit high velocity forces to a workpiece (not shown). The described movement of the platen assemblies of each of the impactors **22** and **23** is accomplished by mechanism or apparatus which is internally carried within the corresponding assembly **14** or **15**. As will be seen, each of assemblies **14** and **15** mounts an accumulator assembly **24** within which is accumulated or stored pressure energy for subsequent release to an actuator assembly **25**. Inasmuch as assemblies **14** and **15** in this embodiment are identical, only the means or mechanism of assembly **14** will be described. It is understood, of course, that the mechanism of assembly **15** is identical and that the description thereof is omitted for purpose of brevity. In addition, the present invention is not limited to a pair of impactor assemblies as will be apparent from the other embodiments hereinafter described.

In impact apparatus **11**, wherein impact assemblies are opposed, the collision or impact of impactors **22** and **23** takes place with a substantially complete absorption of energy, and very little energy is transferred to frame **21** of the apparatus **11** whereby frame **21** may be made of comparatively light-weight construction. Since no heavy structure or foundation is necessary to support apparatus **11**, apparatus **11** is easily transportable to different locations, and may be fabricated of comparatively inexpensive materials. Thus, frame **21** comprises a pair of upstanding channels **26** and **27** which form the sides of frame **21**, and which are divided at the middle of apparatus **11** into two sections. The inner ends of one section of channels **26** and **27** are welded to a middle plate **28**, and the inner ends of the other section of channels **26** and **27** are welded to a plate **29** which is identical to plate **28** and is arranged in abutment therewith. Both plates **28** and **29** extend across the bottom of apparatus **11** and up both sides thereof in U shape, and are bolted together along their periphery. With this construction, it will be apparent that apparatus **11** may be split into two halves, and the capability of each of these halves or sections to function as a high velocity impact forming machine will subsequently be described. However, this embodiment of the present invention contemplates use of both halves in a composite or double impact machine wherein the forces of impact are substantially completely absorbed rather than the less efficient forming attendant upon the use of a single impact machine.

The outer ends of channels **26** and **27** are welded to end plates **31** for structural rigidity, and further strengthening is provided by a lateral member **32**, which is transversely disposed between and welded to channels **26** and **27**, and by a diagonally disposed lateral member **33** similarly secured to channels **26** and **27**.

A pair of tracks **34** and **35** are bolted or screwed to the upper surfaces of channels **26** and **27**, and serve to slidably accommodate a pair of covers **36** which are movable inwardly over the impact area to protect operators from debris or metal particles which may be thrown off during the forming operation. A pair of end covers 37 similar to covers 36 are hinged at their outer ends to swing upwardly and outwardly to permit access to the mechanism of apparatus 11, although in their normal position covers 37 are disposed as illustrated in Figure 1.

The pair of guide ways 18 and 19 are rigidly secured to the sides 26 and 27 of apparatus 11 and each embodies a longitudinally extending groove or track which is adapted to slidably accept and support a pair of end support plates 38 and 39 forming a part of carriage assembly 14. More particularly, at their sides, each of plates 38 and 39 integrally carries elements which are formed to slidably cooperate with ways 18 and 19 of frame 21. As illustrated, support plates 38 and 39 are each shaped somewhat in the form of an inverted T whose lateral legs extend outwardly into cooperation with ways 18 and 19.

The lateral legs of plates 38 and 39 are each apertured to receive, respectively, a pair of end caps 41 and a pair of end caps 42. Between these caps 41 and 42 are arranged a pair of comparatively thick-walled pipes or cylinders 43 which are internally threaded at their ends to receive the externally threaded ends of caps 41 and 42. With this construction the cylinders 43 serve to space apart plates 38 and 39 and impart structural rigidity to carriage assembly 14.

Impact assembly 14 is advanced and retracted along ways 18 and 19 by a pair of drive screws 44 which are coupled to assembly 14 by threaded connection to end caps 42. The left or driven end of drive screws 44 is carried within a pair of housing members 45, and are driven in usual manner by drive means 16 under the control of a switch member 46. The details of drive means 16 are not important to the present invention, since drive means 16 is utilized merely to position carriage or impact assembly 14 along the ways 18 and 19, and accordingly drive means 16 will not be discussed in further detail.

Accumulator and actuator assemblies 24 and 25 of assembly 14 are secured, one above the other, between support plates 38 and 39, and are maintained in position by any suitable means, such as by machine screws 47 threadably disposed through plates 38 and 39 and into suitable end bosses of accumulator and actuator assemblies 24 and 25. Thus, assemblies 24 and 25 are movable with assembly 14.

Accumulator assembly 24 serves to store or accumulate pressure energy for later transfer to actuator assembly 25, and comprises an elongated cylinder 48 which is threaded at its ends to carry end caps 49 and 51 which receive the machine screws 47 for securement of assembly 14 to plates 38 and 39. Carried in fluid tight relationship within the ends of cylinder 48 are an adapter 52 and an adapter 53, Figure 3, adapter 52 being provided with a fitting 54 for charging with hydraulic fluid or the like a chamber 55 formed between the inner wall of adapter 52 and one wall of a free floating piston 56 which is slidably disposed within cylinder 48. An O-ring 57 is provided to insure fluid tight mating between piston 56 and the inner wall of cylinder 48.

It will be apparent that the amount of pressure energy which may be stored in the chamber 58 formed between adapter 53 and piston 56 may be adjusted by filling or draining chamber 55. However, if this adjustment of pressure level is not desired, piston 56 may be eliminated, and the chamber 55 completely charged with pressure fluid from source 13.

A fluid passage from accumulator assembly 24 to actuator assembly 25 is provided by a manifold assembly 59 which is secured in position at the left end of assemblies 24 and 25 by a plurality of bolts 61, one of which is shown in Figure 3. Assembly 59 includes an adapter plate 62 which has a central port 63 therethrough, and which is disposed in fluid tight relationship with a suitable opening provided in adapter 53 of accumulator assembly 24. Port 63 communicates with a port 64 provided in an end plate 65, which is also rigidly secured in position by bolts 61, as illustrated. At its lower end the end plate 65 is arranged in fluid tight relationship with an adapter 66 which is similarly arranged in fluid tight relationship with an end wall 67 of actuator assembly 25. Adapter 66 has a central bore 68 which communicates with bore 64 of end plate 65 and which is in alignment with an opening or orifice 69 centrally located in end wall 67.

Fluid under pressure is carried from pressure source 13 to end plate 65 by a conduit 71 suitably threaded or fitted at the lower end of plate 65 and communicating with bore 64 whereby pressure fluid may be conveyed through bore 64 and bore 63 to chamber 58 of assembly 24. As will be seen, prior to triggering of apparatus 11, this fluid under pressure acts upon a first or smaller effective pressure area of assembly 25, and, after triggering, acts over a second or larger effective area to cause the work stroke of impactor 22. Such triggering is effected by channeling triggering fluid pressure from pressure source 13, through a conduit 72, and thence through a fitting 73 which is carried within a suitable opening provided in the lower portion of support plate 39. Fitting 73 is threadably fitted within a tapped hole provided therefor in adapter 66, and opens into a fluid passageway 74 provided in adapter 66. This passageway 74 in turn opens to the inner face of plate 66 in the peripheral area bounded by orifice 69 and bore 68.

Actuator assembly 25, which receives the stored energy of accumulator assembly 24, comprises a casing or cylinder 75 which accommodates at its ends, in fluid tight relationship, adapter plate or end wall 67 and a deceleration member 76, respectively. Wall 67 and member 76 are held in position by a pair of end caps 77 and 78, respectively, which are threaded into the ends of cylinder 75, and which embody bosses, one of which is shown for cap 78 in Figure 3, which serve to threadably accept a plurality of machine screws 47 for the support of actuator assembly 25.

A piston 79 is reciprocably movable within a chamber 81 formed by the inner walls of cylinder 75, and comprises a piston head 82 integrally connected to a piston rod 83 which is slidable through an orifice 84 centrally located in the left end wall of deceleration member 76, and slidable through a chamber 85 formed by the hollow interior of member 76. Fluid tight relationship between rod 83 and the right end wall of member 76 is maintained by employment of an O-ring 86 in member 76. Bearing and support for rod 83 is provided by a bearing 87 which is held in position by a cover 88 secured to member 76 by bolts 89. The piston head 82 is similarly provided with an O-ring 91 for fluid tight cooperation with cylinder 75, and a pair of annular wearing elements 92, made of a suitable wear-resistant material such as Micarta or the like, are disposed within mating grooves in piston head 82 to promote a freely slidable relationship between piston 79 and cylinder 75 without danger of scoring of either. Thus it will be seen that piston 79 is freely slidable reciprocably within assembly 25, and in its travel to the left abuts or substantially abuts against the inner face of end wall 67.

In a suitable threaded central opening provided in piston head 82 there is disposed a seal holder 93, which embodies a seal ring 94 bonded in a central annular groove in the left-most or outer face of head 82. In this regard, it is important to note that the disposition of seal holder 93 is such that, with piston 79 at its farthest point of travel to the left, holder 93 will substantially completely fill the space bounded by the circumference of orifice 69 and the right end face of adapter 66. Further, seal ring 94 abuts against and is adapted to effect a sealing relationship with the right end face of adapter 66 at a point radially inwardly of passageway 74. With this arrangement it will be apparent that with piston **79** in its left-most position the pressurized fluid of assembly **24** will act against the inner area defined by seal **94**, this area hereinafter being conveniently referred to as the seal, first, or initial effective pressure area. In the quiescent or static position of piston **79** prior to triggering, the force of the pressurized fluid acting against the inner area defined by seal **94** is opposed by the force of fluid pressure acting against the other or rod face of piston **79**. This latter pressure is admitted within chamber **81** through a conduit **95** provided at the right end of assembly **25**. By reason of the differential pressure area between the seal or first pressure area (A_1) and the area of the rod face of piston **79** (A_2), it will be seen that much higher unit pressures must be developed against the first area before a particular or "set" unit pressure acting against the rod face of piston **79** may be overcome to move piston **79** to the right. Thus, a certain pressure of P_2 (pounds per square inch) is established within chamber **81**, forcing piston **79** to the left and bringing seal **94** into sealing relationship with adapter **66**. Next, a pressure P_1 (pounds per square inch) is developed against the seal area A_1 bounded by seal **94**, and allowed to build up to a level just below the level where piston **79** is in equilibrium. That is P_1 times A_1 is slightly less than P_2A_2. At this point piston **79** remains urged against adapter **66** by the slight unbalance in pressure, and seal **94** remains in seated relationship. Then, upon an increase in pressure P_1, or upon the admission of triggering fluid into passageway **74** in the present embodiment of the invention, seal **94** is unseated and the resulting unbalanced pressure forces cause an unbalanced thrust to be developed against the left face of piston **79** which will cause the piston to move to the right. There is, in effect, an internal amplification of pressure forces by reason of the sudden exposure of the larger or second effective pressure area of the left face of piston **79** caused by the unseating of seal **94** and the exposure of this second face to the pressure P_1. It will be remembered that pressure P_1 is considerably in excess of pressure P_2 and the travel to the right of piston **79** will consequently be at a high rate of acceleration, producing high velocities at the end of the work stroke.

During the travel of piston **79** to the right the fluid within chamber **81** will be compressed, thereby serving as an effective cushion between piston **79** and the right end of assembly **25**. However, a further decelerative effect is provided by the comparatively slow or metered passage of this compress fluid from chamber **81** to chamber **85** of deceleration member **76**. However, it has been found in practice that the decelerative action provided by the compression of fluid in chamber **81** is ordinarily ample of itself to slow piston **79** at the end of its stroke, and accordingly, the effect of the pressure drop across orifice **84** may be eliminated if desired.

As shown in Figure 2, the inner end of piston rod **83** is rigidly affixed to platen assembly **22**, and it will be evident that as platen **22** is driven through a work stroke it can form or shape a workpiece interposed between it and another element opposing the force of platen **22**. In the present embodiment this other element is of course the platen assembly **23**, but, as previously described, the other element may well be a stationary foundation or platform supporting a die or the like. In any event, the high velocity work strokes of platens **22** and **23** will form workpieces with such rapidity that the work hardening ordinarily attendant upon such a forming operation is substantially eliminated. Further, through utilization of both platen assemblies **22** and **23** in the composite machine or impact apparatus **11**, very efficient high velocity forming will be afforded by reason of the double impact or combined velocity of impactors **22** and **23**, and a great reduction in energy transfer to frame **21** will be afforded by reason of the almost complete absorption of energy which is characteristic of double impact forming.

After a work stroke, piston **79** may be repositioned to the left for cycle of operation by admitting fluid under pressure to chamber **85** through conduit **95**.

Referring now to Figure 5, the fluid and electrical circuits for initiating operation of apparatus **11** will next be described. A schematic representation of accumulator and actuator assemblies **24** and **25** is included in Figure 5 for clarity of illustration, and the area enclosed by dash-dot outlines is representative of the control means **12** of Figure 1. For clarity of description the components of control means **12** will be described in connection with the cycle of operation of apparatus **11**. Thus, a bleed valve **96**, which is left open when apparatus **11** is not in operation, is closed and a supply valve **97** is opened to admit fluid pressure from a conduit **98** connected to pressure source **13**. With the opening of supply valve **97** there is pressure to control means **12**, but as yet no pressure to the accumulator and actuator assemblies **24** and **25**.

A pair of bleed valves **99**, which are open at this time to vent to the atmosphere, through a conduit **101** and conduit **95**, any pressure which may exist within chambers **81** and **85** of actuator assembly **25**, are next closed. Then a pair of pressure regulator or throttle valves **102** are opened to admit pressure from supply conduit **98**, through various connecting conduits, through conduit **95**, and thence into chambers **81** and **85**. This pressure is known as the "set" pressure, as hereinabove mentioned, and is permitted to build up to some predetermined value, as read at a pair of indicators **103**. After the predetermined set pressure has been reached, throttle valves **102** are closed.

The desired pressure energy to be stored within accumulator assembly **24** is next established in similar fashion. Thus, a pair of bleed valves **104**, which ordinarily vent to atmosphere any pressure which may exist within accumulator assembly **24** and manifold assembly **59**, are closed and a pair of regulator or throttle valves **105** are opened to admit fluid pressure from supply conduit **98**, through interconnecting conduits, to conduit **71**, and thence to accumulator assembly **24** and manifold **59**. This pressure is permitted to build up in chamber **58** of accumulator assembly **24** to a value, which when acting over the effective pressure area bounded by seal **94**, will be somewhat less than the force resulting from the pressure within chamber **81** acting against the rod face of piston **79**. The pressure necessary to accomplish this balance is indicated at a pair of indicators **106**, and throttle valves **105** are then closed.

Piston **79** is now in a state of equilibrium, and the effectuation of the triggering operation will next be described.

The full source pressure, which is read at an indicator **107**, put into operation by a valve **108**, is admitted to a pair of solenoid mechanisms **109**, one for each of the impact assemblies **14** and **15**. This pressure is admitted to mechanisms **109** by opening a valve **111**, and the level of pressure to which solenoid mechanisms **109** are subjected is indicated by an indicator **112**. A pair of conduits **113** carry the fluid pressure from control means **12** to the pair of solenoid mechanisms **109**. Since solenoid mechanisms **109** are identical, for convenience only one of mechanisms **109** will be described in detail.

Each conduit **113** is connected to a usual and conventional solenoid actuated valve **114** which is normally closed, but which is opened upon energization of a solenoid **115**. A conduit **116** provides a fluid couple between solenoid actuated valve **114** and a similar usual and conventional solenoid actuated valve **117** which is normally open, but which is closed upon energization of a solenoid **118**. Conduit **116** in turn is connected by conduit **72** to the triggering fluid passageway **74** in adapter **66**.

With this arrangement, simultaneous energization of the pair of solenoids **115** effects actuation of the pair of valves **114** which, as will be seen, causes a simultaneous triggering of actuator assemblies **25** by the admission of fluid pressure to passages **74** of adapters **66**.

Valves **117** are provided in the system to bleed to atmosphere any pressure fluid which may leak past valves **114**. It will be apparent that if valves **117** were not provided any leakage of fluid past valves **114** might build up to a level which would undesirably cause a misfire by prematurely actuating assemblies **25**. These normally open valves **117** are closed by energization of solenoids **118** just prior to energization of the solenoids **115** which open valves **114**.

The electrical circuit which enables simultaneous actuation of the pair of solenoid mechanisms **109** includes an electrical lead **119**, which connects one side of a power source to solenoid **115**. In turn, solenoid **115** is connected through a switch **121** to the other side of the power source by an electrical lead **122**. Similarly, one side of solenoid **118** is connected to one side of the power source by leads **119** and **123**, and the other side of solenoid **118** is connected through a normally open switch **124** to conduit **122**.

Actuator assemblies **25** are triggered by closing or depressing switch **124**, which simultaneously closes the pair of normally open valves **117**, and next closing switch **121**, which simultaneously opens the pair of normally closed valves **114**. Fluid under pressure is immediately admitted through conduits **72** to triggering passageways **74** of adapters **66**, breaking the seal of seal rings **94**, and the above-described firing or actuation of assemblies **25** follows. It will be apparent that this method of firing makes it possible to control the time of firing of the actuators within a fraction of a second, and facilitates the taking of records by photographic means or the like timed to operate upon the firing of the actuators. In addition, the volume of the triggering lines **72**, which are preferably kept as short as possible by mounting solenoid mechanisms **19** upon manifolds **59** as illustrated in Figure 2, is so small in comparison to that of the orifice or opening **69** that it has little or no effect upon the dynamic operation of the machine or apparatus **11**.

To prepare for another cycle of operation pistons **79** are returned to their initial position by opening bleed valves **104**. Next, valves **102** are opened to admit fluid pressure to the rod side of pistons **79**, thereby urging pistons **79** to the left until seal rings **94** again come into seating relationship over orifice **69**. The cycle of operation is then repeated as desired.

Figure 6 illustrates an embodiment of the present invention having means for controlling the output acceleration or thrust of apparatus **11** so that acceleration or thrust-time patterns of a predetermined character may be produced on the workpiece. The embodiment of Figure 6 is substantially identical to the embodiment illustrated, for example, in Figure 3, and for this reason there is illustrated only a detail of that portion of the embodiment which differs over the embodiment of Figure 3. The common features of the embodiments of Figure 3 and Figure 6 include a similar piston **79** reciprocably mounted within a cylinder **75**, an adapter member **66*a*** closing the manifold side of cylinder **75**, and an end cap **77** threadably secured to the end of cylinder **75** and maintaining adapter **66*a*** in sealed relationship with cylinder **75**. Manifold **59** is associated in sealed relationship with the end of adapter member **66*a*** and is held in position by means identical to that hereinabove described in connection with the embodiment illustrated in Figure 3.

In substitution for the seal holder **93** of the embodiment of Figure 3, a seal holder **93*a*** is threadably secured to piston **79**, and carries a seal ring **94*a*** in a position so that seal ring **94*a*** is placed in sealed or seated relationship with adapter **66*a*** when piston **79** is in its downward position, as viewed in Figure 6, or in its position to the left, as viewed in Figure 3.

Seal holder **93*a*** also functions as a metering pin, and for this purpose embodies a portion **124** which protrudes into an orifice **69*a*** and serves to selectively vary its area. In addition, adapter **66*a***, which in this embodiment serves as a combination end wall and adapter plate for cylinder **75**, includes the orifice **69*a*** which varies in cross section as it proceeds inwardly from manifold **59** to cylinder **75**. As is well known to those skilled in the art, the configuration of orifice **69*a*** and metering pin or seal holder **93*a*** serves to alter the character of the thrust-time pattern produced by piston **79*a*** during its work stroke. For example, instead of the total available force being applied to the piston instantaneously and during the entire actuation period, the pressure and consequently the force applied against the piston may be selectively controlled through the action of the metering pin and orifice. In forming certain materials it has been found that the optimum high velocity force applied to the material is one which increases at a rather low rate followed by a rapidly applied high level force of short duration. Through the utilization of a regulating element, such as metering pin **124**, in combination with orifice **69*a***, a desired force, which can be controlled as a function of time, can be produced on the material to be formed. This result is produced by the regulation of the rate of transfer of fluid from manifold **59** to the interior of cylinder **75**. Control and adjustment of thrust-time pattern is desirable in forming a variety of materials and in a variety of situations. Where different thrust-time patterns are desired, different metering pins such as **93*a*** may be attached to the piston as described hereinbefore.

In Figure 7 there is illustrated a further embodiment of the present invention which is particularly useful as a single-ended impact machine. It is in effect a half of the apparatus **11** previously described, although, as will be seen, certain modifications have been made to better suit it for its single-ended operation. Thus, a vertically disposed carriage or impactor assembly **14** is provided which is substantially identical to the assembly **14** hereinabove described. This assembly **14**, which, of course could be disposed just as well in a horizontal position, is slidable on ways **18** and **19**, and is adjustable in its vertical position along ways **18** and **19** by operation of guide means **17** in the same manner described in connection with the first embodiment of the present invention.

A die or work holder **126** is rigidly supported by a comparatively heavy foundation or platform **127** which serves to absorb or receive the heavy impact shock of impactor **22** striking work holder **126**. In addition, ways **18** and **19** are rigidly secured to foundation **127** by tapered and comparatively heavy side structures **128**. A switch member **46*a*** is provided to assist in positioning impactor assembly **14** along ways **18** and **19**, switch **46*a*** acting to control drive means **17** in a manner identical to the first embodiment. It will be apparent from this embodiment how easily the general arrangement of the present invention is adaptable to single or double-ended operation. The primary modification necessary to effect the necessary change is in mounting structure. Of course, it will be apparent that the mounting structure or frame of the embodiment of Figure 7 may be changed for different applications. The frame structure does not form a part of the present invention, other than to support the other components, and it is contemplated, for example, that a lighter structure for foundation **127** and sides **128** could be employed, for example, in the forming of plastic materials by extruding or the like.

It should also be noted that the embodiment of Figure 7, by reason of its similarity to the embodiment of Figure 2, is controlled and operated, and functions in a maner substantially identical to that described in connection with the first embodiment.

Thus, in the description hereinabove made, an apparatus has been described which utilizes pressurized fluid for generating impact forces, and which is particularly suited to the high velocity impact forming of materials. The apparatus stores or accumulates pressure energy, and triggers the release of that energy, suddenly, but at a predetermined time and in a predetermined manner. In this connection, the apparatus is adapted to provide a variety of thrust-time patterns by simple modifications and adjustments. An apparatus has been described which embodies a pair of opposed ram elements which are substantially simultaneously actuable for imparting energy to a workpiece for forming it into a predetermined condition. This latter double-ended machine may also be split, as described, to provide a pair of single-ended machines, if desired. In addition, a single-ended embodiment has also been described to show how this could be done, and in each embodiment the desirable amplification of pressure areas inherent in the actuation of the embodiments has also been shown.

While certain preferred embodiments of the invention have been specifically disclosed, it is understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

What we claim is:

1. A high velocity impact apparatus comprising a cylinder embodying a first orifice member and a second orifice member, a piston movable within said cylinder, force transmitting means connected to said piston and slidably positioned in the orifice of said second orifice member, said piston being movable in a first direction to cover the orifice of said orifice member and movable in a second direction to urge fluid through the orifice of said second orifice member and apply force through said force transmitting means, means for admitting fluid under pressure through the orifice of said second orifice member into said cylinder to force said piston in said first direction, means defining between said first orifice member and said piston a lesser effective pressure area than the total effective pressure area of said piston, and means for applying force to said piston to overbalance the fluid pressure forcing said piston in said first direction and allow greater fluid pressure than the fluid pressure forcing said piston in said first direction to pass through the orifice of said first orifice member over the total effective pressure area of said piston to effect movement of said piston in said second direction, said piston movement being increasingly slowed by the flow of fluid through the orifice of said second orifice member.

2. A high velocity impact apparatus comprising a cylinder embodying a first orifice member and a second orifice member, a piston movable within said cylinder, force transmitting means connected to said piston and slidably positioned in the orifice of said second orifice member, said piston being movable in a first direction to cover the orifice of said first orifice member and movable in a second direction to urge fluid through the orifice of said second orifice member and impart movement to said force transmitting means, means for admitting a first fluid pressure through the orifice of said second orifice member into said cylinder to force said piston in said first direction, means defining between said first orifice member and said piston a lesser effective pressure area than the total effective pressure area of said piston, means for admitting a second fluid pressure into said cylinder against said lesser effective pressure area of said piston, said second fluid pressure being greater than said first fluid pressure but less than an amount necessary to overbalance said first fluid pressure, and means for applying force to said piston to overbalance said first fluid pressure forcing said piston in said first direction, whereby said second fluid pressure is exerted over the total effective pressure area of said piston and said piston moves in said second direction to impart high velocity travel to said force transmitting means, said force transmitting means travel being increasingly slowed by the flow of fluid through the orifice of said second orifice member.

3. A high velocity impact apparatus comprising an actuator cylinder embodying a first orifice member and a second orifice member, a piston movable within said actuator cylinder, force transmitting means connected to said piston and slidably positioned in the orifice of said second orifice member, said piston being movable in a first direction to cover the orifice of said first orifice member in sealed relationship and movable in a second direction to urge fluid through the orifice of said second orifice member and transmit force through said force transmitting means, means for admitting fluid under pressure through the orifice of said second orifice member into said cylinder to urge said piston in said first direction, means defining between said first orifice member and said piston a lesser effective pressure area than the total effective pressure area of said piston, means for admitting fluid pressure through said first orifice member and against said piston in an amount just below that necessary to balance the force of the fluid under pressure urging said piston in the first direction, and triggering means for admitting additional fluid under pressure against said piston to overbalance the force of the fluid under pressure urging said piston in the first direction, whereby the fluid pressure through the orifice of said first orifice member is exerted over the total effective pressure area of said piston imparting high velocity travel to said piston and said force transmitting means, said piston travel being increasingly slowed by the flow of fluid through the orifice of said second orifice member.

4. A high velocity impact apparatus comprising an actuator cylinder embodying a first orifice member and a second orifice member, a piston movable within said actuator cylinder, force transmitting means connected to said piston and slidably positioned in the orifice of said second orifice member, a seal member carried by said piston and defining a lesser effective pressure area than the total effective pressure area of said piston, said piston being movable in a first direction to move said seal member into sealed relationship about the orifice of said first orifice member and movable in a second direction to urge fluid through the orifice of said second orifice member and impart force to said force transmitting means, means for admitting fluid under pressure through the orifice of said second orifice member into said cylinder to urge said piston in said first direction to maintain said seal member in said sealed relationship, means for admitting fluid pressure through the orifice of said first orifice member and against said piston in an amount just below that necessary to balance the force of the fluid under pressure urging said piston in the first direction, and triggering means for admitting additional fluid under pressure against said piston to overbalance the force of the fluid under pressure urging said piston in the first direction, break the sealed relationship of said seal member, and expose the total effective pressure area of said piston to the fluid pressure admitted through the orifice of said first orifice member, whereby said piston moves in the second direction to impart high velocity travel to said force transmitting means, said force transmitting means travel being increasingly slowed by the flow of fluid through the orifice of said second orifice member.

5. A high velocity impact apparatus comprising an actuator cylinder embodying a first orifice member and a second orifice member, a piston movable within said actuator cylinder, force transmitting means connected to said piston and slidably positioned in the orifice of said second orifice member, said piston being movable in a first direction to cover the orifice of said first orifice member and movable in a second direction to urge fluid

through the orifice of said second orifice member and apply force through said force transmitting means, means for admitting fluid under pressure through the orifice of said second orifice member into said cylinder to force said piston in said first direction, means defining between said first orifice member and said piston a lesser effective pressure area than the total effective pressure area of said piston, and valve means actuable for admitting additional fluid under pressure into said cylinder against said piston and outside said lesser effective pressure area to overbalance the fluid pressure forcing said piston in said first direction and allow greater fluid pressure than the fluid pressure forcing said piston in said first direction to pass through the orifice of said first orifice member over the total effective pressure area of said piston to effect movement of said piston in said second direction, said piston movement being increasingly slowed by the flow of fluid through the orifice of said second orifice member.

6. An apparatus comprising a cylinder having a first integral wall and a second integral wall transversely mounted therewithin, said integral walls each having an orifice therethrough, a piston carried within said cylinder, said piston having an integral piston rod slidably positioned in the orifice of said second wall, a metering member carried by said piston and movable into and out of the orifice of said first wall, said piston being slidable in a first direction to cover the orifice of said first wall, and slidable in a second direction to urge fluid through the orifice of said second wall and move said piston rod, means for admitting fluid under pressure through the orifice of said second wall into said cylinder to force

said piston in said first direction, means defining between said first wall and said piston a lesser effective pressure area than the total effective pressure area of said piston, and means for applying force to said piston to overbalance the fluid pressure forcing said piston in said first direction and allow greater fluid pressure than the fluid pressure forcing said piston in said first direction to pass through the orifice of said first wall over the total effective pressure area of said piston to effect movement of said piston in said second direction, said piston movement being increasingly slowed by the flow of fluid through the orifice of said second wall, and said metering member acting to regulate the flow of said greater fluid pressure through the orifice of said first wall to thereby effect a piston stroke of predetermined thrust-time pattern.

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