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MULTI-ANVIL FORCE COMPENSATING PRESSURE APPARATUS

Filed June 14, 1960

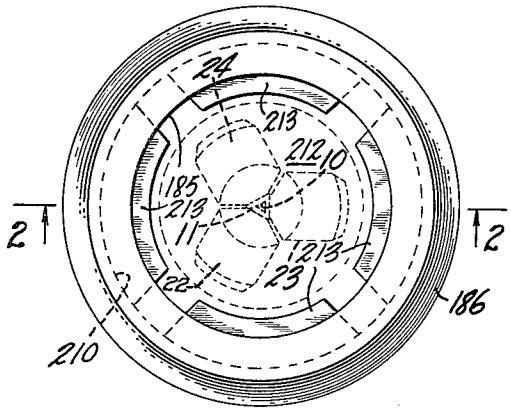


FIG. 1

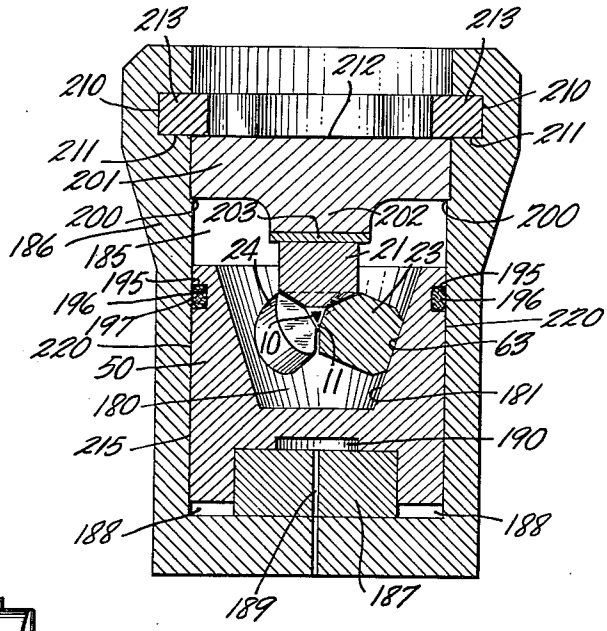


FIG. 2

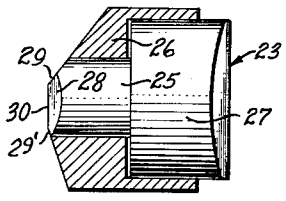


FIG. 3

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MULTI-ANVIL FORCE COMPENSATING PRESSURE APPARATUS

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6 Claims. (Cl. 18—16)

This invention relates to apparatus for producing high pressure on an object, and, more particularly, to apparatus of this sort wherein such high pressure is produced by a plurality of anvils acting on the object. The present application is a continuation-in-part of our copending application Serial No. 833,809 filed August 13, 1959 and entitled, "Pressure Apparatus." The apparatus disclosed in the present application is similar to that shown in FIG. 1 in our U.S. Patent 3,044,113 issued July 17, 1962 in that a single pressing member is adapted by movement relative to a reference datum to actuate all of a plurality of pressure-multiplying anvils disposed in three dimensions around a central cavity to compress an object in that cavity.

For a better understanding of the invention, reference is made to the following description and to the accompanying drawings wherein:

FIG. 1 is a plan view of an embodiment of the invention in which the anvils slide in relation to a means which backs those anvils;

FIG. 2 is a front elevation, taken partly in cross-section, of the FIG. 1 embodiment;

FIG. 3 is a view of a cross section in the vertical plane of one of the anvils of the FIG. 1 embodiment;

Referring now to FIG. 1, the numerals **10** and **11** designate, respectively, a sample to be compressed and a body of pyrophyllite which encloses that sample, and which is in the form of a regular tetrahedron. The sample **10** may be inserted in the pyrophyllite body **11** in the manner described by H. T. Hall in this article published at pages 267–275, volume 29 of The Review of Scientific Instruments (1958). Thus, the sample may be inserted alone or may be contained within a metal cylinder (not shown) which in turn is inserted within the pyrophyllite body **11**. If desired, electrical connections may be made to the cylinder by silver foil strips (not shown) which extend from the cylinder to the surface of the pyrophyllite body **11** to provide respective electrical terminals in the form of metal tabs lying flat on the separate faces of such body.

The top of tetrahedral body **11** is contacted by an anvil **21** (FIG. 2). A plurality of anvils **22**, **23** and **24** are shown in FIG. 1 as contacting the three downward facing sides of body **11**.. The axes of the four anvils coincide with the four axes of the tetrahedral body **11** which pass at right angles to the faces of such body and through the centers of such faces. The anvils **22** and **24** have substantially the same structure as the anvil **23** whose construction appears in detail in FIG. 3 to which reference is now made.

The anvil **23** includes a hard end piece **25** which is made, say, of cemented tungsten carbide, and which has a truncated front end providing the anvil tip. The anvil also includes a bearing ring **26** and a pressure disk **27**, both made of steel. The end piece **25** is received with a hard press fit within a forward bore of the bearing ring **26** which provides lateral support for the end piece. The pressure disk **27** is received with a close fit within a larger rearward bore of the bearing ring **26** to make contact with the rear end of the hard end piece **25**.

The hard end piece **25** of anvil **23** is chamfered at its front at 120° intervals around its periphery to produce a diminishing taper formed by three chamfer faces of which the faces **28**, **29** and **29'** are shown in FIG. 3, the latter two faces being seen edgewise. This taper shapes the front contact face **30** of the end piece **25** to be in the form of an equilateral triangle. The edges of this triangle are somewhat less in length than the edges of the equilateral triangle formed by the face of the pyrophyllite body **11** with which the face **30** of end piece **25** is brought into contact. For example, the face **30** of the end piece may measure ½" on an edge, whereas the corresponding face of body **11** may measure 9/16" on an edge. The slanting chamfer planes formed in the front end of end piece **25** are continued out to the cylindrical surface of the bearing ring **26** by chamfering the front end of the bearing ring at 120° intervals and with the same inclination as the chamfers of the end piece.

The vertical anvil **21** is generally similar in construction to the predominantly horizontal anvils **22**—**24**. The upper or rear face of the vertical anvil is flat.

As shown by FIG. 2, the anvils **22**—**24** are fitted within the interior of a sleeve **50** so as to slide over such interior to be wedged inwardly by such sleeve when the entire anvil array is subjected to a compressive load.

The wedging action of the sleeve is produced by having the sleeve interior in the form of a conically tapered bore **180** (whose wall is inclined 71.5° to the horizontal) and by having the rearward face of each of anvils **22**—**24** shaped to match (i.e. be concentric with) the area of the conically tapered wall **181** of the bore which is opposite such rearward face at, say, the time when the anvils of the array have been driven inwardly towards object **11** by the full amount for which the array is designed.

Small plastic (e.g., nylon) spacers in the form of buttons may be inserted in the gaps existing between the chamfered faces of the four anvils which are employed. As so inserted, the spacers serve to hold the anvils in tetrahedral disposition prior to a pressing operation. The spacers are of low compressive strength and, hence, are easily flattened during such operation.

The sleeve **50** is in the nature of a piston received with a tight sliding fit in the bottom of a cylindrical bore **185** formed in a housing **186**. Such bore **185** contains therewithin a smaller diameter, concentric hub **187** which projects upwardly from the bottom of the bore to be received with a tight sliding fit in a cylindrical recess formed in the bottom of the cylindrical sleeve **50**. As shown, the hub **187** provides a seat for sleeve **50** such that an annular clearance space **188** is produced between the bottom of the bore and the bottom of the sleeve when the sleeve is at rest. To the end of moving the sleeve **50** within bore **185**, the hub **187** has formed therein a fluid conduit **189** which is coaxial with the housing and hub, and which extends through the bottom of the housing and then through the hub to permit injection of hydraulic fluid behind the sleeve. This hydraulic fluid is initially received in an axially shallow, cylindrical recess **190** of smaller diameter than hub **187** and formed in sleeve **50** to be directly above the outlet (at the top of the hub) of the hydraulic fluid conduit **189**.

At its upper end, the sleeve **50** has formed therein a circumferential annular recess **195** into which is received an annular sealing "ring" **196** which may be, say, either of the O-ring or of the chevron packing type, and which is squeezed between sleeve **50** and the interior wall **197** of bore **185** to provide a tight fluid seal. As will be noted, the sealing ring **196** is disposed above the region at which the predominantly horizontal anvils **22**—**24** bear against the interior of sleeve **50**. The reason for this location of the ring **196** will be later explained.

The bore **185** of housing **186** has a slight radial en-

largement over the vertical interval thereof which extends from the top of the housing to a point somewhat above the sleeve **50**. The lower end of this radially enlarged section of bore **185** provides within the bore a shallow, circumferential annular seat **200** for the upper part of a reaction head **201** for the vertical anvil **21**. The lower part of such head is in the form of a downwardly projecting boss **202** of which the undersurafce is a horizontal, planar bearing surface **203** against which the upper face of vertical anvil **21** is adapted to abut with a flat contact. If desired, the anvil **21** may be made integral with the reaction head **201**.

Between operations, the head **201** is removable from the bore **185** to permit insertion or manipulation therein of the anvil array. As a preliminary, however, to a pressing operation, the head **201** is locked in place in the bore **185**. To this end, the upper part of the mentioned bore has formed therein an annular, circumferential channel **210** having a rectangular cross section and having, also, a bottom wall **211** which is vertically flush with the top surface **212** of reaction head **201** when that head is resting on its annular seat **200**. Into this recess **210** there are inserted a plurality of sector-shaped lugs **213** which are short enough in arc length to permit them to be turned to horizontal position within the upper part of bore **185**. At the same time, the lugs **213** are large enough in radial dimension to overlap the top **212** of head **201** even though the lugs have been fully inserted into the annular channel **210** so as to abut against the radially outward wall thereof. By virtue of so overlapping with the head **201**, the lugs **213** preclude upward movement thereof within the bore **185**.

Assuming that the reaction head **201** has so been locked in place, the apparatus is operated by injecting hydraulic fluid under pressure through conduit **189** into the bore or cylinder **185** and behind the sleeve **50** to drive such sleeve towards the reaction head. When the sleeve **50** is so driven, it tends to carry with it the anvils **22—24** and the central object **11**. Such object cannot, however, displace vertical anvil **21** upwardly inasmuch as the vertical anvil is backed by the reaction head **201**. Hence, instead of the central object **11** moving upward, the head **201** exerts through anvil **21** on that object a progressively increasing, downwardly directed force. The effect of this downward force is to produce a downward sliding of the rear faces of anvils **22—24** over respective portions of the conically tapered interior wall **181** of sleeve **50** such as to cause those anvils to be wedged by such wall towards object **11** to render it simultaneously compressed by all four anvils.

To the end of permitting free sliding of the butt faces of anvils **22—24** over the slide surfaces respectively provided therefor by the conically tapered inner wall **180** of sleeve **50**, a bearing sheet (not shown) of polytetrafluoroethylene (for which the trademark is Teflon) may be inserted between each such butt end the slide surface by which the butt face is backed. A similar sheet of polytetrafluoroethylene may be inserted between the vertical anvil **21** and the bearing surface **203** by which the reaction head **201** drives that anvil. The mentioned plastic sheets have a twofold purpose. First, in the case of the sheets inserted between the anvils **22—24** and their corresponding slide surfaces, such sheets serve as an excellent lubricant between the rear faces of the anvils and the slide surfaces when those sheets are subjected to the high pressure which are produced in the described apparatus. Second, when all four anvils are backed by plastic sheets, the sheets serve to insulate the four anvils from the other metallic parts of the apparatus. Therefore, the anvils may be used as lead-in or lead-out elements for current or voltage passing through the described terminals on the faces of the body **11**.

As an alternative to the attainment of lubrication by plastic sheets, liquid or solid film lubricants may be inserted between the rear faces of the anvils **22—24** and the slide surfaces in order to render those anvils free sliding over those surfaces.

By continuing the advancement under pressure of sleeve **50** toward head **201**, the pressure on the tetrahedral pyrophyllite body **11** is intensified until the body **11** and encased sample, have been compressed to the desired degree, or until the capacity of the apparatus has been reached. During the compression, some of the pyrophyllite in the body **11** extrudes into the interstices between the front faces of the four anvils to form a gasket. The remaining pyrophyllite becomes plastic or semi-plastic to act as an excellent transmitter throughout its mass of the pressure exerted thereon. Hence, the pyrophyllite transmits the pressure from the anvils to the encased sample at a very high pressure value, as say, pressure on the order of 125,000 atm. The anvils **22—24** each exert on the interior of sleeve **50** an outwardly directed force which progressively increases in magnitude as the compressive loading of the anvil array increases. Those outwardly directed forces produce in the sleeve the following two effects. First, the restraint offered by the sleeve to the movement under those forces of anvils **22—24** is a factor which results in the development in the sleeve of internal stresses. Evidently, the concentration of such stresses must be maintained sufficiently low at all points in the sleeve body to avoid rupturing of the sleeve by the loading impressed thereon from the anvil array.

Second, assuming that undue stress concentrations in the sleeve have been successfully avoided, nonetheless the loading of the sleeve produces therein a deformation in the nature of an elastic expansion. Such expansion is undesirable since, in proportion to its amount, it diminishes the wedging displacements of anvils **22—24** towards the object **11** to be compressed, whereby those displacements become less than the displacement towards that object of the vertical anvil **21**. Because of this inequality of displacement, in the course of a compressing operation the gaps between adjacent lower anvils are rendered larger than the gaps between such lower anvil and the vertical anvil **21**. It follows that more pyrophyllite will be extruded from the object **11** into the larger lower gaps than into the small upper gaps, and, accordingly, the central object will be subjected to an asymmetrical compression which seriously reduces the efficiency of the pressing operation.

One way of dealing with the stressing and expansion of the sleeve is, of course, to make the sleeve of sufficient thickness to reduce to acceptable levels both the stress concentrations therein and the elastic deformation thereof. At large tonnages, however, a sleeve of the necessary thickness becomes cumbersome, expensive and largely ineffectual. Further, even at moderate loading tonnages a thick sleeve has a limit to its effectiveness in that the loading force on the sleeve is opposed only in a passive manner.

In the described embodiment, on the other hand, the loading on the sleeve is actively opposed by means as follows. When hydraulic fluid is injected through conduit **89** into cylinder **185**, some of this fluid migrates from the shown recess **190** into the interspace **220** which is bounded at its upper end by the sealing ring **196** and, below this ring, by the interior and exterior walls of, respectively, the cylinder **185** and the sleeve **50**. Because the interspace **220** is fluid sealed at its upper end by the ring **196**, during the compressing operation the hydraulic fluid in such interspace is maintained at approximately the same pressure as that which urges the sleeve **50** upwardly in the hydraulic cylinder **185**.

Now, in order to produce a progressive upward driving of the sleeve **50**, over the duration of a compressing operation the pressure on the hydraulic fluid is progressively increased to thereby produce the heretofore described progressive increase in the outwardly directed forces exerted on the interior of the sleeve by the anvils **22—24**. In the instance, however, of the FIGURE 12,

13 modification, because the sealing ring **196** is disposed above the region where those anvils act on the interior of the sleeve, the pressurized fluid in the interspace **220** vertically extends above and surrounds such region. Hence, as the hydraulic fluid pressure builds up to produce the described progressive increase in the outwardly directed forces acting on the interior of the sleeve, the same increasing hydraulic pressure acts in the interspace **220** at the level of those forces and against the exterior perimeter of the sleeve to exert thereon an inwardly directed force which is in line with those outwardly directed forces and which actively opposes them. It follows that the mentioned outwardly directed forces are at all times dynamically compensated for by the pressure of the hydraulic fluid.

The described compensating effect eliminates to a large degree the radial expansion of the retaining sleeve due to anvil loading. Such reduction in the radial expansion of the sleeve produces, in turn, a more equal compression by all four anvils of the sample **10** to be compressed and of its pyrophyllite jacket. Evidently, the counterbalancing of the forces exerted outwardly on the sleeve by the pressure exerted inwardly thereon permits the use of a sleeve which, for a given loading tonnage, may be considerably thinner, lighter, and less expensive than the sleeve which would be required if no such counterbalancing were present. Further, such counterbalancing of the outwardly directed forces on the sleeve results in a substantial reduction in the stresses therein, particularly discontinuity stresses occurring at the junction of the vertical cylindrical wall of the sleeves and the bottom thereof. Still further, it is to be noted that the described compensation of the sleeve for anvil loading may be obtained as an advantage which costs nothing in terms of extra structure necessary to yield such advantage. This is so inasmuch as the sealing ring **196** and interspace **220** which provide the compensation are conventional features of a hydraulic drive system, and inasmuch as a hydraulic drive system would commonly be used to actuate an anvil press of the sort described.

The above described modification being exemplary only, it will be understood that the invention herein comprehends apparatus differing in form and/or detail from that modification. For example, evidently, the sleeve need not have a conically tapered interior surface to the end of wedging ones of the anvils towards the central object. Instead, such anvils may be wedged by planar slide surfaces.

As another example, while the compensation of the anvil retaining sleeve for anvil loading has been specifically described herein in connection with the embodiment shown herein, each of the embodiments shown in our application Serial No. 833,809 by FIGURES 1 to 3, by FIGURES 4 and 5, by FIGURES 6 and 7, by FIGURES 8 and 9, and by FIGURES 10 and 11 is an embodiment which can likewise be modified to provide for similar compensation of the sleeve thereof. Further, while in the embodiment shown herein the same hydraulic piston and cylinder combination provides the means by which the anvil array is actuated and the means by which the sleeve is compensated for the loading exerted thereon by the anvil array, the invention is also of application in instances where the pressurized hydraulic fluid which compensates the sleeve for anvil loading is separate from the means which actuate the anvils. Thus, for example, the invention is of application in the instance where the anvil array is actuated by the movement of a head, pressure plate or the like towards a stationary sleeve surrounding ones of the anvils of the array, but where, as described herein, the stationary sleeve is surrounded by hydraulic fluid manifesting a pressure which increases in correspondence with the increasing loading of the sleeve by the actuated anvil array.

Accordingly, the invention is not to be considered as limited save as is constant with the scope of the following claims.

We claim:

1. Apparatus comprising, an array of anvils disposed to converge from various sides on an object, a sleeve surrounding ones of said anvils and adapted at a region of contact with them to restrain them from outward movement, means adapted by loading said anvil array with a progressively increasing force acting through said sleeve-surrounded anvils against the restraint provided by said sleeve to render said object simultaneously compressed by all the anvils in said array, a fluid-containing housing surrounding the outer circumference of said sleeve and mechanically separated from such circumference opposite said region of contact by a fluid-accommodating annular interspace, and means to increasingly pressurize with hydraulic fluid said interspace between said sleeve and housing to thereby exert on the outside of said sleeve an inward pressure which increases in correspondence with said force to reduce deformation thereby of said sleeve.

2. Apparatus comprising, an array of anvils disposed to converge from various sides on an object, a sleeve surrounding ones of said anvils and adapted to restrain them from outward movement, a hydraulic cylinder in which said sleeve is received as a piston, means to permit injection of hydraulic fluid into said cylinder so as to produce movement therein of said sleeve, means responsive to said movement to load said anvil array with a progressively increasing force acting through said sleeve-surrounding anvils against the restraint provided by said sleeve so as to render said object simultaneously compressed by all the anvils in said array, and fluid sealing means surrounding said sleeve forward of where said force acts thereon and adapted to retain pressurized hydraulic fluid injected into said cylinder in the interspace bounded by said cylinder, sleeve and sealing means.

3. Apparatus comprising, an array of anvils disposed to converge from various sides on an object, a sleeve surrounding ones of said anvils and adapted to restrain them from outward movement, a housing having formed therein a hydraulic cylinder in which said sleeve is received as a piston, means to permit injection of hydraulic fluid into said cylinder so as to produce therein a movement of said sleeve which urges said array towards an end of said housing disposed forwardly of said array, a stationary reaction head disposed within said housing at said end thereof to bear against said array when so urged, means adapted when said array bears against said head to load said anvil array with a progressively increasing force acting through said sleeve surrounded anvils against the restraint of said sleeve, and fluid sealing means surrounding said sleeve forward of where said force acts thereon and adapted to retain pressurized hydraulic fluid injected into said cylinder in the interspace bounded by said cylinder, sleeve and sealing means.

4. Apparatus as in claim 3 in which said reaction head is removable from said housing, said apparatus further comprising head securing means to lock said head in place in said housing during said sleeve movement.

5. Apparatus comprising, an array of anvils disposed to converge from various sides on an object, a sleeve surrounding ones of said anvils and adapted to restrain them from outward movement, a housing having formed therein a hydraulic cylinder in which said sleeve is received as a piston to have the back end thereof mechanically separated by an interspace from the part of said housing forming the rear wall of said cylinder, means to increasingly pressurize with hydraulic fluid said interspace between said sleeve and housing so as to produce in said cylinder a movement of said sleeve which urges said array towards an end of said housing disposed forwardly of said array, and a stationary reaction head disposed within said housing at said forward end thereof to bear against said array when so urged so as to load

said anvil array with a progressively increasing force acting through said sleeve surrounded anvils against the restraint of said sleeve.

6. Apparatus comprising, a housing having formed therein a hydraulic cylinder open at one end and closed at the other, a piston received in said cylinder to be separated from the circumferential wall thereof by an annular interspace surrounding said piston and adapted to be filled with hydraulic fluid, said piston having formed therein a cavity open only at the end of said piston towards the open end of said cylinder and adapted to contain an object to be compressed, means inserted in the open end of said cavity and adapted by relative motion with said cavity to develop therein pressure on said object and also pressure directed radially outwards on the circumferential bounding surface of said cavity, and means to render the fluid in said interspace pressurized to exert on the circumference of said piston a pressure directed radially inwards to oppose said pressure on said cavity bounding surface.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,049,756 August 21, 1962

George Gerard et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 5, line 31, for "sleeves" read -- sleeve --; column 6, line 31, for "surrounding" read -- surrounded --.

Signed and sealed this 11th day of December 1962.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents