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Jan. 24, 1961 A. ZEITLIN ET AL **2,968,837**

SUPER-HIGH PRESSURE APPARATUS

Filed April 6, 1959 3 Sheets-Sheet 1

FIG.1.

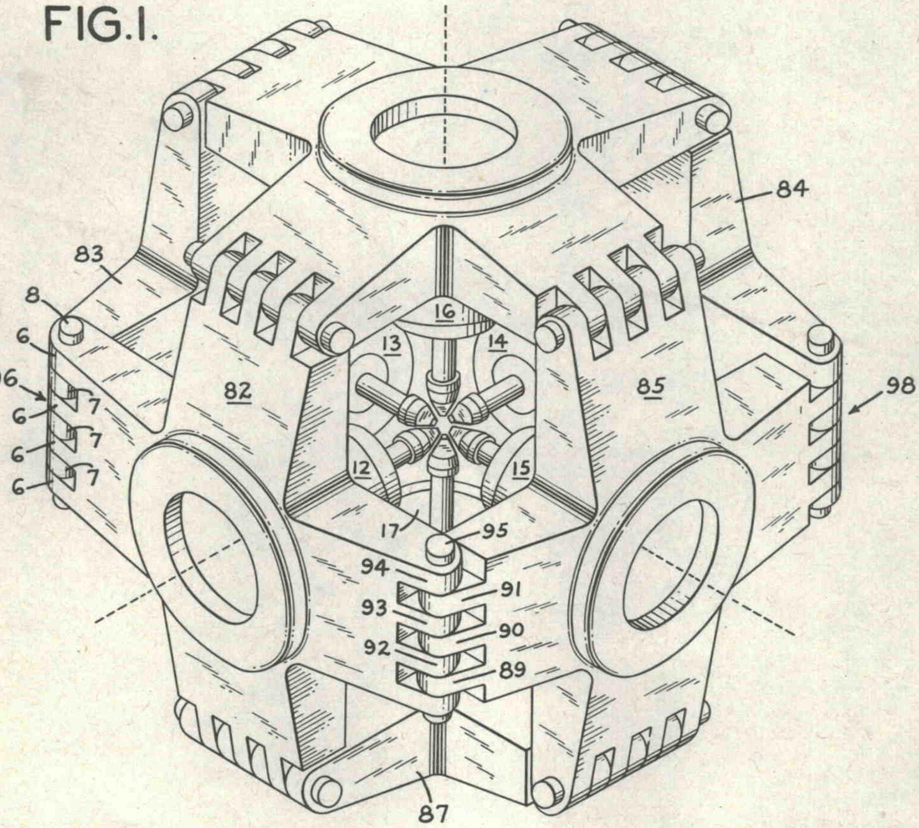

FIG.3.

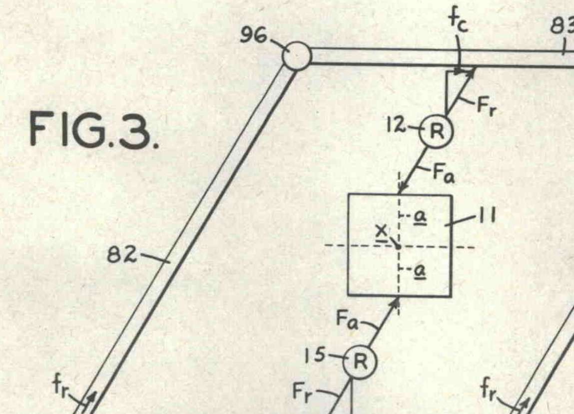

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FIG. 2.

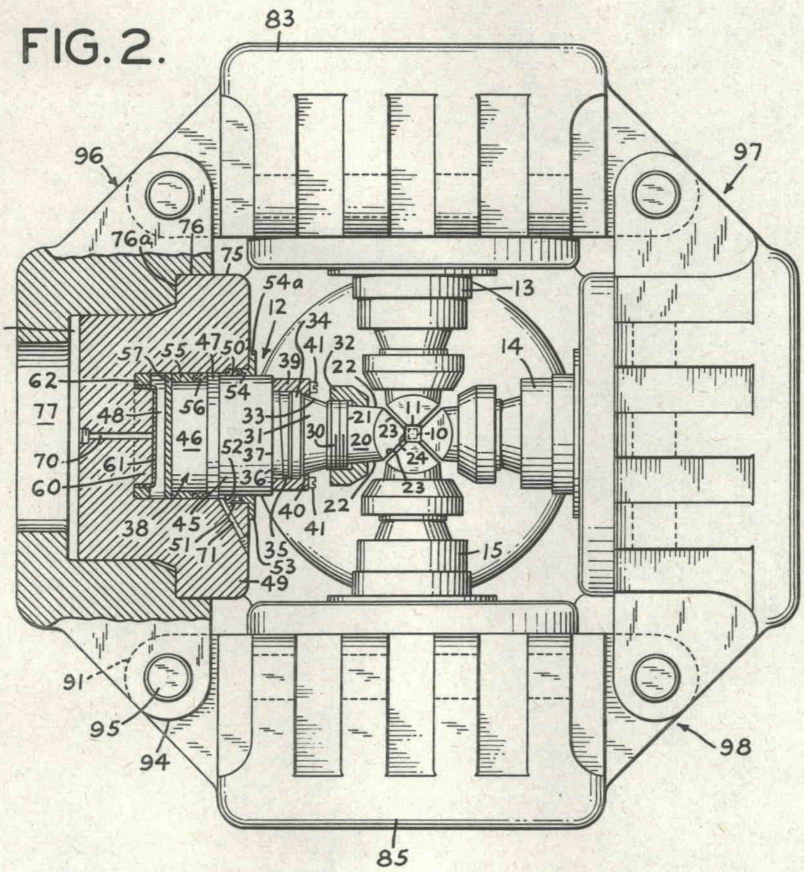
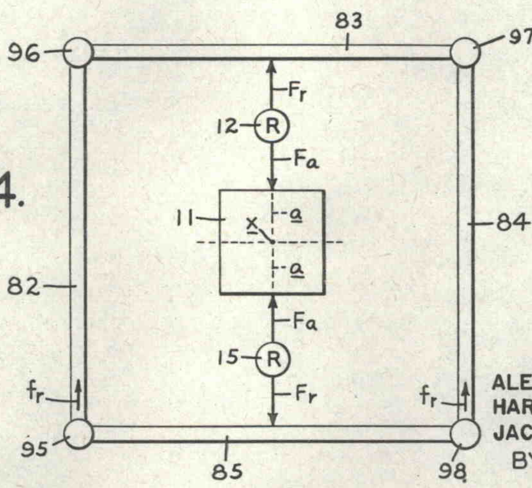


FIG. 4.



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SUPER-HIGH PRESSURE APPARATUS

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FIG. 5.

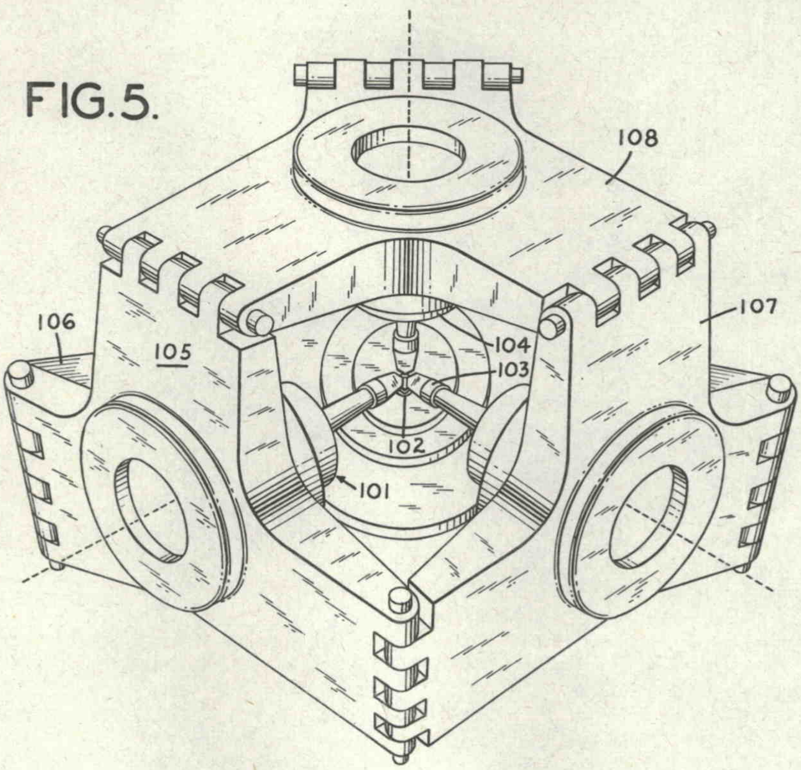
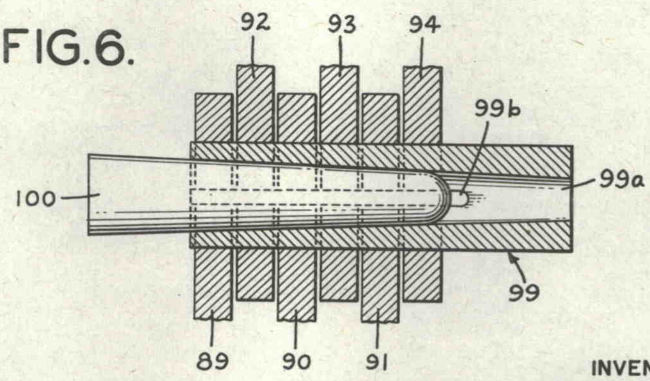


FIG. 6.



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SUPER-HIGH PRESSURE APPARATUS

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13 Claims. (Cl. 18—16)

This invention relates to apparatus for producing super-high pressures, including pressures as great as 100,000 atmospheres or more. More particularly, this invention relates to mounting means for the pressure generating units in such apparatus and to improved pressure generating units.

In the operation of such apparatus, very large reactive forces are produced by the pressure generating units, and, heretofore, such reactive forces have tended to deform the apparatus, resulting in breakdown or misalignment of the pressure generating units and deterioration in overall performance. Eccentric loads have often been present, and it has been a common occurrence for the pressure generating units to buckle or break.

It is an object of the invention disclosed herein to provide apparatus for producing super-high pressure wherein the reactive forces exerted by the ram units on the mounting frame will not set up stresses and moments to deform the frame and misalign the ram units.

Another object of the invention is to provide super-high pressure apparatus wherein undesired moments of force will not be communicated from one part to another of the mounting frame for the ram units.

Another object of the invention is to provide super-high pressure apparatus wherein reactive forces operably exerted by ram units on a mounting frame will tend to bring into better alignment the center lines of action of the ram units.

Another object of the invention is to provide improved pressure generating units for super-high pressure apparatus.

A further object of the invention is to provide super-high pressure apparatus having a mounting frame which permits convenient access to the interior of the apparatus, and which is characterized by ease of disassembly, transportation in disassembled state, and reassembly.

The invention may be embodied in apparatus having a plurality of pressure generating units disposed at various angles about a central position and adapted to exert on an object at such position a plurality of pressure producing forces. The pressure generating units may operate by hydraulic, pneumatic, mechanical or other action, and may be cylinder and piston ram units or of other form. As hereinafter disclosed, the pressure generating units may be provided with means for adjusting the angular alignment between the front ends and rear ends thereof, and, in the event that such units are fluid operated, they may embody certain features of construction which will minimize leakage.

The invention may be applied in instances where the center lines of action of all pressure generating units lie in a common plane. More frequently, however, in super-high pressure work, the center lines of action of the pressure generating units will be disposed in three dimensions about the object. In that case, the center lines of action may be considered as approximating or corresponding to perpendiculars from the centers of the faces of a polyhedron which encloses the ram units and the object to

be compressed, such perpendiculars ideally intersecting at a common central point. This polyhedron may be a regular polyhedron as say, a tetrahedron, cube or octahedron (all of which have faces which, on each polyhedron, are regular polygons all of the same size and shape), or the polyhedron may be of an irregular configuration in one or more dimensions. If the polyhedron is irregular, the forces exerted by the pressure generating units on the object to be compressed are usually not all equal, but are adjusted relative to each other to satisfy the equations of static equilibrium that the net sum of all forces on the object be zero in all three dimensions and that the net sum of all moments of force on the object be zero in all three dimensions.

In accordance with the invention, there is provided a plurality of crossheads which mount the pressure generating units to project inwardly from such crossheads toward the central object to be compressed. Each crosshead is disposed in relation to the associated ram unit to have the major extent of the crosshead transverse to the center line of action of such unit and to have such line of action intersect the crosshead at a central point in the major extent thereof. The crossheads are each marginally connected to abutting crossheads to form a frame which encloses and supports the pressure generating units. By mounting each pressure generating unit on a crosshead having the described disposition in relation to the center line of action of the unit, and, further, by connecting the so disposed crossheads together to form a frame, as hereinafter described, the stresses developed by the reactive forces of the pressure generating units may be controlled and their tendency to deform the frame and misalign the pressure units may be substantially reduced.

The crossheads may, preferably, be connected with each other by hinges, such hinges comprising a hinge pin which connects adjacent crossheads by passing through a series of interspersed clevises projecting from the crossheads. Assembly and disassembly of the frame is thereby greatly facilitated, and there are operational advantages which are hereinafter explained.

We have discovered that a cubic configuration for super-high pressure apparatus provides advantages not provided by the tetrahedral configuration. Accordingly, the invention will hereinafter be described primarily in terms of apparatus having such cubic configuration.

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

Fig. 1 is an isometric view of an embodiment of the invention wherein the configuration of the embodiment corresponds to a regular six-sided polyhedron, i.e., a cube;

Fig. 2 is a plan view of the embodiment of Fig. 1 taken partly in cross section in a horizontal plane passing through the vertical center of the Fig. 1 embodiment;

Figs. 3 and 4 are schematic explanatory diagrams of forces and moments which are operative in the Fig. 1 embodiment;

Fig. 5 is an isometric view of an embodiment according to the present invention wherein the embodiment corresponds in configuration to a regular tetrahedron, and;

Fig. 6 is a view in cross section of a preferred form of hinge pin.

Referring now to Figs. 1 and 2, the reference numeral **10** designates (Fig. 2) a sample of material, workpiece or other object which is to be subjected to superhigh pressure. The object **10** is encased in a solid block **11** of pyrophillite in the shape of a cube. For convenience, the elements **10** and **11** are not shown in Fig. 1. Corresponding to the six faces of the pyrophillite cube **11** are six pressure generating units **12–17** (Fig. 1) which, in the present instance, take the form of hydraulically actuated, cylinder and piston "ram" units. All of the ram units 12–17 are comprised of substantially identical parts. Therefore, only the ram unit 12 will be described in detail.

As shown in Fig. 2, the front end of ram unit 12 comprises a cylindrical anvil 20 which has a rear face 21, and which is characterized by a slight inward conical taper 22 for a distance forward of the rear face. This slight conical taper gives way at the front end of the anvil to a sharp inward taper 23 which is produced by chamfering the front end of the anvil at 90° intervals around its circumference in such manner that, in the chamfered region, the anvil will have a square cross section of diminishing size as the front face 24 of the anvil is approached. This front face 24 is of square configuration and of slightly smaller size than the registering square face of the pyrophillite cube 11. When anvil 20 is in proper alignment, the sides of its front face 24 will be parallel to the sides of the corresponding square of the pyrophillite cube 11, the center of the front face 24 of the anvil will coincide with the center of the corresponding face of cube 11 when the anvil and the cube are in contact, and the center line of action of the pressure exerted by the anvil on the cube will pass through those coincident centers perpendicularly to the plane of contact between anvil and cube.

The rear face 21 of the anvil 20 is seated against the forwardly disposed, circular face of a radially projecting, forward flange portion 30 of a stand 31 having a conically tapered center portion 33 and a radially projecting, rear flange portion 34. The anvil 20 is locked to the stand 31 by a collar 32 which, at its front end, grips the conical taper 22 of the anvil 20, and which, at its rear end, threadedly engages the periphery of the flange portion 30 of the stand. By rotating collar 32 in the appropriate direction, the anvil 20 may be uncoupled from the stand 31 or may be brought into tight fitting relation therewith.

The circular rear face of the rear flange portion 34 of stand 31 is seated against the forwardmost of two axially aligned cylindrical shoes 35 and 36. The rearmost shoe 36 is seated in turn against the cylindrical end face 37 of a hydraulic piston 38. Each of the shoes 35 and 36 has a slight diametral taper. Therefore, by relatively rotating the shoes 35 and 36, it is possible to make slight angular adjustment between the central axis of the piston 38 and the center line of action of the assembly comprised of stand 31 and anvil 20.

When suitable angular adjustment has so been obtained, the stand 31, shoes 35, 36 and piston 38 are clamped together by a sleeve 39 having an inwardly projecting annular lip 40 which fits over and engages the rear flange 34 of the stand 31. When flange 34 has been so engaged by lip 40, the sleeve 39 is secured to the front end of the piston 38 by screws 41 which are distributed at angular intervals around the sleeve, and which axially extend through apertures (not shown) in the sleeve to be received in threaded holes (not shown) in the piston. By rotating these screws 41 in the direction appropriate to draw sleeve 39 towards piston 38, a tight fitting assembly may be obtained of stand 31, shoes 35, 36 and the piston.

The hydraulic piston 38 comprises a larger diameter forward portion 45, a smaller diameter rearward portion 46, and a bearing ring 47 which is an integral part of the piston, and which is of greater diameter than either the forward portion 45, or the rearward portion 46. The piston 38 is received within a cylinder 48 formed in a cylinder block 49 of circular cross section. The forward portion 45 of the piston is encircled by an annular packing ring 50 disposed in an annular recess 51 which radially enlarges the forward end of the cylinder, and which provides an annular shoulder 52 at right angles to the cylinder axis. The packing ring 50 is forced against the shoulder 52 by a gland 53 having a sleeve portion 54 which is inserted into recess 51 to bear against the packing ring. The gland 53 also has a radially projecting, annular flange 54*a* seated against the forward surface of cylinder block 49. The gland is secured to the cylinder block 44 by screws (not shown) passing through flange 54*a* to be received in threaded holes in the cylinder block.

The rearward portion 46 of the piston 38 is encircled by a bushing 55 and by an annular packing ring 56 which is interposed between the bushing and the bearing ring 47. A circular plate 57 is disposed to the rear of piston portion 46, and is secured thereto by axially extending screws (not shown). The periphery of plate 57 axially registers with the bushing 55. Accordingly, when the screws which attach plate 57 to piston portion 46 are turned to draw the plate towards the piston portion, the plate 57 will press against the bushing 55 to thereby squeeze the packing ring 56 between the bushing and the bearing ring 47. As will be evident, the plate 57, bushing 55 and packing ring 56 will travel with the piston 38.

The rear end of the cylinder 48 is characterized by a circular hub 60 which extends axially into the cylinder, and which is of smaller radius than the cylinder. An expandible diaphragm 61 of Buna rubber or the like is stretched over the front of the hub with the margins of the diaphragm being folded back over the axially extending, peripheral surface of the hub to lie flat against such peripheral surface. The diaphragm 61 is clamped in place by an annular ring 62 which is inserted into the annular space between the hub and the cylinder wall, and which is thereafter drawn towards the rear end of the cylinder by the turning of screws (not shown) which pass axially through the ring 62 to be received in threaded apertures (not shown) in the cylinder block 49. The drawing of the ring, as described, towards the rear end of the cylinder will cause the periphery of the diaphragm 61 to be tightly clamped between the hub 60 and the ring 62 to thereby form a fluid tight space between the diaphragm and the hub.

For the purpose of inducing forward travel of the piston 38, hydraulic fluid under pressure is introduced into the space between the front end surface of the hub 60 and the expandible diaphragm 61 by a conduit 70 passing through the cylinder block 49 and hub 60. The presence of the diaphragm precludes the leakage of hydraulic fluid which would otherwise occur if the high pressure fluid were permitted to flow freely into contact with the rear end of piston and thereby be subject to extrusion out of the ram unit through the clearance space between the piston and the cylinder.

Under the pressure of the fluid, the diaphragm 61 expands to displace forwardly the piston 38, and to thereby cause the piston to exert pressure through the anvil 20 on the pyrophillite block 11 and on the object 10 encased thereby. After the object 10 has been compressed in this manner for a desired time interval, the piston 38 is returned to its normal rearward position by injecting air into the space between bearing ring 47 and stationary packing ring 50 by way of a conduit 71 which runs diagonally from the front surface of cylinder block 49 to the said space.

As shown in Fig. 2, the entire ram unit 12 is supported in place by having the cylinder block 49 received within a cylindrical well 74 formed in the reinforced central portion of a crosshead 82. The cylinder block 49 has at its forward end a radially projecting flange portion 75 which is received within an annular recess 76*a* radially enlarging the front end of well 74 and providing an annular shoulder 76 against which the flange 75 bears. The cylinder block 49 is secured to crosshead 82 by screws (not shown) which pass through apertures (not shown) in flange 74 to be received in threaded holes in the cylinder block. If desired, the cylinder block 49 and the crosshead 82 may be formed from one unitary piece, in which case the well 74, flange 75, recess 76a and shoulder 76 are eliminated.

For the purpose of permitting hydraulic connections to be made to the ram unit 12 and of otherwise permitting convenient access to the rear end of the ram unit, the central reinforced portion of the crosshead 82 has formed therein a cylindrical bore 77 which is concentric with but of smaller radial size than the cylindrical well 74.

As shown in Fig. 1, the ram units 13–17 are each mounted in the same way as ram unit 12. In the embodiment shown in Fig. 1, each crosshead is disposed to have its major extent lie transverse to the center line of action of the associated ram unit, and to have such line of action pass approximately or, preferably, exactly through the geometric center of the major extent of the crosshead. Moreover, each crosshead has margins which are each parallel to and adjacent to a margin of an adjacent crosshead, and the crossheads are each marginally connected to adjacent crossheads to form a polyhedral frame enclosing the ram units and supporting the ram units in substantially predetermined spaced position relative to each other.

We have found that this arrangement of the frame and pressure generating units has distinct advantages. The frame is completely self-supporting and high pressures are not exerted against any bed or other foundation support. The frame may also be constructed with a minimum number of major or heavy components. Furthermore, when the frame is cubical in form, the ram units are balanced in pairs and directly oppose each other. Such arrangement facilitates an optimum alignment and balance of forces on the central object and reduces the angular moments which during operation tend to deform the frame and cause misalignment of the pressure generating units.

In some applications of the invention, it might be desired that all acting ram units lie in a common plane as do the shown units 12–15. In that case, there would be no ram units and crossheads corresponding to the units 16, 17 and the crossheads 86, 87. The frame formed of the marginally connected crossheads would then be closed in the two dimensions in which the acting ram units lie and would be open in the third dimension.

In the polyhedral frame shown in Fig. 1, the six crossheads 82–87 lie in the surfaces of a cube and each of the crossheads might, if desired, be of square configuration, in which case the frame would be cubical in form. In practice, however, it is preferable to cut away the corners of each crosshead to shape each such crosshead in the form of a cross and produce a frame with a configuration substantially like that shown in Fig. 1. The cruciform configuration of the crossheads 82–87 provides openings for convenient access to the interior of the apparatus and also reduces the overall weight of the frame, while retaining the required mechanical strength.

We have discovered that important advantages in operation are secured by employing an articulated frame. Such a frame is produced by having the crossheads connected through joints which offer relatively low resistance to angular movement between adjacent crossheads and permit self-alignment of the frame under the stresses developed in operation. For example, hinges may be employed to connect each crosshead to its contiguous crossheads. As shown in Fig. 1, the hinges may be comprised of a set of clevises 89, 90, 91 projecting from the left-hand margin of crosshead 85 and interleaved with a second set of clevises 92, 93, 94 projecting from the right-hand margin of crosshead 82 to provide a continuous central bore through both sets of clevises and a hinge pin 95 which passes through such central bore, to join the crossheads 82 and 85. Similar hinges may be employed, as shown in Fig. 1, to connect each crosshead with each of the four other crossheads which are adjacent thereto. The frame formed of the crossheads may be easily disassembled and reassembled by the simple procedure of driving the hinge pins out of and back into the bores provided by the interleaved sets of clevises. No turning or other manipulation of connecting elements is required.

If desired, the hinge pin 95 may be constructed to be expandible by using as a pin the combination (Fig. 6) of an outer cylindrical collet 99 having a conically tapered bore 99a and an inner mandrel 100 fitted into bore 99a at one end of the collet, and having a conical taper matching that of the bore. The collet is split at one end by one or more axially running slots 99b extending from one end of the collet. The collet may be substantially uniformly expanded in diameter by driving the mandrel into the bore of the collet, and play between the hinge pin and the clevises may thereby be eliminated.

In the described hinge pin and clevis swingable connection, a tension or compression force acting thereon from one of the connected crossheads will be distributed among the clevises on that crosshead, to be divided into separate smaller stresses which are aliquot fractions of the tension or compression force, and which act in shear against a corresponding number of cross sections of the hinge pin. The total holding strength of the hinge is thus equal to the sum of the holding strengths of the individual cross sections thereof which are subjected to shearing stress. A total holding strength is thereby provided which is several times greater than the holding strength which would be provided if an equal cross sectional area of the pin or other connector were subjected to a stress acting in tension. The hinge pin and clevis arrangement thereby provides the required holding strength with the minimum of bulk and weight. Also, disassembly and reassembly of the frame is facilitated.

Figs. 3 and 4 illustrate some of the forces and moments acting in the Fig. 1 embodiment and show schematically some principal elements involved in the production of such moments and forces, namely crossheads 82–85, connectors 95–98 for joining the crossheads together into a frame, ram units 12 and 15, and the central cubic block 11 of pyrophillite. In both figures the point x marks the center of cubic block 11, the rams 12 and 15 act upon the block 11 with forces represented by the arrows F_a, and the same ram units 12 and 15 simultaneously react upon their respective crossheads 83 and 85 with forces represented by the arrows F_r. In both figures, the dotted line a—a through the center point x is the line with which the center lines of action of the rams 12 and 15 will coincide when such ram units are aligned to act with maximum efficiency upon the block 11.

Fig. 3 represents (with much exaggeration) a situation in which the frame is not quite true so that the crossheads 82, 84 are not, as desired, exactly at right angles to the crossheads 83, 85, but, instead, are inclined at an angle to the last named crossheads. In this situation, if it be assumed that the center line of action of each of ram units 12 and 15 is a line which forwardly passes through the center of the square face of block 11 which is presented thereto, and which rearwardly passes through the center point of the associated crosshead, it will be seen from Fig. 3 that the rams 12 and 15 will act upon the block 11 with respective forces F_a which do not pass through the center point x, and are not in alignment with each other. Because of this misalignment of the forces F_a, there will be a substantial loss in the amount of super-high pressure which the apparatus can effectively exert upon the pyrophillite block 11. If the connector elements 95–98 are such as to provide rigid connections between the crossheads 82–85, there is no convenient way by which this misalignment of the forces F_a can be overcome.

Furthermore, in the situation shown in Fig. 3, the rams 12 and 15 will exert on crossheads 83, 85 reactive forces F_r which are not at right angles to the crossheads. Because of this lack of right angle relation, the force

F_r on the crosshead **83** will have a component f_c in line with the lie of crosshead **83** and directed away from the crosshead **82**. Also, the force F_r on crosshead **85** will have a component f_c in line with the crosshead **85** and directed towards crosshead **82**. These two components f_c will act as a moment of force. If the connector elements **95–98** are of such character as to rigidly connect together the crossheads **82–85**, the mentioned moment of force will be communicated to both of crossheads **82** and **84**, and will set up substantial stresses thereon. Such stresses might be so great as to cause intolerable deformation or mechanical failure of the frame.

Such obstacles to satisfactory operation are substantially eliminated when the connector elements **95**, **98** are such as to connect together in swingable relation the crossheads **82–85**. The problem of stresses set up by the aforementioned moments of force is eliminated because the moments of force cannot be communicated to the crossheads **82**, **84** through the hinges. Also, the misalignment of the forces F_a on cube **11** will be eliminated or substantially reduced because the articulated frame formed by crossheads **82–85** and the hinges **95–98** will respond automatically to the forces exerted on the frame to bring the forces F_a into better alignment. This is so for the following reasons.

When the ram units **12** and **15** exert the shown reactive forces F_r outwardly upon, respectively, the crossheads **83** and **85**, the component of each force F_r which is at right angles to the lie of the crosshead subjected thereto is a component which will always be many times greater than the component which is in line with the lie of the crosshead. Consequently, the reactive forces F_r will tend to spread apart the crossheads **83**, **85** by the maximum possible amount. Because the elements **95–98** are hinge connectors rather than rigid connectors, the reactive forces F_r will actually be effective to cause an increase in the spacing of crossheads **83**, **85**, in the situation represented by Fig. 3. However, by so increasing the spacing between the last named crossheads, the mentioned reactive forces will cause the entire frame formed of all the crossheads and all the hinge connectors to change in configuration from the parallelogram shown in Fig. 3 to the perfect square which is shown in Fig. 4. Since the center line of action of each of the rams **12** and **15** passes through the center of the face presented thereto by cube **11** and through the center of the associated crosshead, as shown in Fig. 4, the effect of the described realignment of the frame will be to bring the center lines of action of both of ram units **12** and **15** approximately or exactly to that ideal alignment condition where such center lines of action are both in coincidence with the line *a—a* through the center point *x* of the cube **11**.

Such realignment of the articulated frame of hinge connectors and crossheads into a square can be stated in terms of a general principle which we have discovered. That principle is that an articulated polyhedral frame will respond to forces originating from within, and directed outwardly against the face members of the frame along center lines of action approximately at right angles to the face members and through the centers thereof, to adjust itself in configuration to conform as closely as possible to an ideal geometric polyhedron after which the frame is modeled. The greater the forces exerted outwardly upon the face members of the articulated polyhedral frame, the truer will be the actual configuration of the frame to the theoretical configuration of the ideal polyhedron. It is thereby practical to obtain with such an articulated frame a more accurate and reliable alignment in operation of the pressure generating units of super-high pressure apparatus than if a rigid frame were employed to mount such pressure generating units.

Returning to a consideration of Fig. 4, it will be seen that the crosshead **85** is urged outwardly by a reactive force F_r from the ram unit **15**. This outward

urging of the mentioned reactive force F_r is counteracted by restraining forces f_r exerted by the crossheads **82** and **84** (among others) through the connector elements **95** and **98** on the crosshead **85**. Since in Fig. 4 the crossheads **82** and **84** are at right angles to the crosshead **85**, the restraining forces f_r will also act at right angles to the crosshead **85** and, hence, will have no component which is in line with the lie of crosshead **85**. The situation where the restraining crossheads are at right angles to the restrained crosshead, and where, accordingly, the restraining forces f_r act at right angles to the restrained crosshead is particularly advantageous because the restraining crossheads need provide less strength in tension than if the restraining forces acted at other than right angles to the restrained crosshead. However, even where the frame is, for example, tetrahedral so that the restraining forces act at other than right angles to a given crosshead to be restrained, the connection in hinged relation of the crossheads provides a substantial advantage. The fact that the frame is self truing as described and tends to conform to the configuration of the ideal polyhedron after which the frame is modeled, serves to produce a close to perfect balance of the components of the restraining forces which act in the plane of each crosshead. If it happens, as a transient matter, that the balance is not quite perfect, the frame will automatically realign itself to produce a perfect balance, and the restraining forces cannot set up any moments of force which will produce cumulative stresses on the frame.

In Fig. 5 there is shown another embodiment in which the frame is in the form of a tetrahedron. In this embodiment, the pyrophillite block (not shown) is in the form of a tetrahedron, and the four triangular faces of the tetrahedral block are acted upon by four ram units **101–104** whose center lines of action pass through the said four faces at right angles thereto and through the centers thereof to intersect at a common point marking the center of the pyrophillite block. The front faces of the anvils of the ram units are in the shape of equilateral triangles of smaller size than the registering equilateral triangular faces of the tetrahedral pyrophillite block. The mountings for the four ram units **101–104** are provided by four crosshead plates **105–108**. Each crosshead plate is disposed to have the plane of its major extent perpendicular to the center line of action of the associated ram unit, and to have such line of action pass through the center of the crosshead. Moreover, each crosshead is connected to every other crosshead by a plurality of hinge means disposed at the margins of the crossheads. The crossheads **105–108** are thus joined in swingable relation to form an articulated tetrahedral frame.

As will be noted, the crossheads **105–108** are not of the triangular configuration which would conform to the corresponding triangular faces of a perfect geometric tetrahedron. The configuration of the crossheads is that of the triangular faces of a geometric tetrahedron when such triangular faces have been modified by having the vertex portions thereof cut away. Such crossheads permit convenient access through the frame to the interior of the apparatus, and permit a reduction in weight while maintaining the required mechanical strength. With respect to the details of the ram units and of the hinges, the Fig. 5 embodiment is similar to the embodiment shown in Figs. 1 and 2.

The frame may also be in the form of an octahedron. For example, eight of the quasi-triangular crossheads shown in Fig. 5 may be joined into an octahedral frame in which each crosshead centrally supports one of eight ram units. With the ram units in octahedral disposition, the front faces of the anvils would be in the shape of equilateral triangles and would press on a central pyrophillite block formed in the shape of a regular octahedron. Such octahedral disposition of the ram units would be similar to the cubic disposition shown in Fig. 1 in that the ram units would be balanced in pairs. Moreover, for a given total pressure area provided by the anvils, the octahedral disposition, like the cubic disposition, permits a greater volume of material in the pyrophillite block than could be provided in the tetrahedral arrangement shown in Fig. 5.

It will be understood that the above-described embodiments are exemplary only and that the invention set forth herein comprehends embodiments differing in form and/or detail from the above-described embodiments. Hence, the invention is not to be considered as limited save as is consonant with the scope of the following claims.

We claim:

1. In apparatus having a plurality of pressure generating units adapted to exert pressures on a centrally located object, a polyhedral arrangement of crossheads, each crosshead supporting one of said pressure generating units, said crossheads forming an articulated selfaligning polyhedral frame supporting said pressure generating units in mutually spaced relation.

2. Apparatus as in claim 1 with the pressure generating units so arranged that the direction of all generated pressures pass through the geometric center of the apparatus.

3. Apparatus as in claim 1 with the pressure generating units so arranged that all generated pressures remain in static equilibrium.

4. Apparatus as in claim 1 wherein the polyhedral frame has the configuration of a regular polyhedron.

5. Apparatus as in claim 1 wherein the articulation and selfaligning of the frame is obtained by means of hinged connections between the crossheads.

6. Apparatus for applying high pressure to an object comprising a plurality of pressure generating units and crossheads, each pressure generating unit being centrally mounted on one of said crossheads to project inwardly toward said object and each crosshead being connected through movable joints with adjacent crossheads to form an articulated frame enclosing and supporting said pressure generating units.

7. In apparatus having a plurality of pressure generating units disposed about a central object and adapted to exert pressure on said object, the combination therewith comprising, a plurality of crossheads each mounting one of said units to project inwardly towards said object, each crosshead being disposed in relation to its associated pressure generating unit to have the major extent of the crosshead lie transverse to the center line of action of the unit and to have such line of action intersect the crosshead at a central location in the major extent thereof, and each crosshead having margins which are each contiguous to a margin of an adjacent crosshead, the said crosshead being each connected with adjacent crossheads at such contiguous margins to form a frame enclosing said pressure generating units and supporting said units in mutually spaced relation.

8. In apparatus having a plurality of pressure generating units disposed about a centrally located object and adapted to exert on said object a plurality of pressure producing forces, the combination therewith comprising, a plurality of crossheads each mounting one of said units to project inwardly from such crosshead towards said object, each crosshead being disposed in relation to its associated pressure generating unit to have the major extent of the crosshead lie transverse to the center line of action of the unit and to have such line of action intersect the crosshead at a central location in the major extent thereof, the said crossheads being each yieldably connected through joints with adjacent crossheads to form an articulated frame supporting said pressure generating units in mutually spaced relation.

9. Apparatus as in claim 8 wherein said crossheads are connected by hinges.

10. Apparatus as in claim 8 wherein said crossheads are connected by hinges each comprised of a set of clevises extending outward from one of two adjacent crossheads interleaved with a set of clevises extending outward from the other of said two crossheads to form a central bore through both sets of clevises, and a hinge pin traversing said central bore and connecting in swingable relation said two sets of clevises.

11. Apparatus as in claim 10 wherein said hinge pin is a combination comprising, an outer cylindrical member which is split at one end and which has a conically tapered bore extending axially into said pin from said one end and diminishing in diameter with progress away from said end, and an inner cylindrical member having a conically tapered portion which matches the taper of said bore and which is received therein, the said inner member being adapted to selectively adjust the effective diameter of said outer member by adjustment in axial position of said inner member relative to said outer member.

12. Apparatus for applying high pressure at a central region thereof to a test body comprised of an object to be compressed and a casing therefor of pressure-transmitting material, said apparatus comprising, a plurality of at least three units of which each is operative to generate pressure on said object, and of which each is comprised at least of an anvil having a smaller front face than rear face, the anvils of said units being disposed with their front faces towards and rear faces away from said region and being distributed about said region to enclose it in at least two dimensions excepting for gaps left between each anvil and the ones adjacent thereto to permit movement of said anvils relative to and towards the center of said region, and a plurality of crossheads of which each has a central portion backing a respective one of said units, and of which each crosshead is connected with adjacent crossheads to form a frame enclosing and supporting said pressure generating units.

13. Apparatus for applying high pressure at a central region thereof to a test body comprised of an object to be compressed and a casing therefor of pressure-transmitting material, said apparatus comprising, a plurality of at least three units of which each is operative to generate pressure on said object, and of which each is comprised at least of an anvil having a smaller front face than rear face, the anvils of said units being disposed with their front faces towards and rear faces away from said region and being distributed about said region to enclose it in at least two dimensions excepting for gaps left between each anvil and the ones adjacent thereto to permit movement of said anvils relative to and towards the center of said region, and a plurality of crossheads of which each has a central portion backing a respective one of said units, and of which each crosshead is connected through movable joints with adjacent crossheads to form an articulated frame enclosing and supporting said pressure generating units.

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