Sept. 29, 1964 A. ZEITLIN ETAL 3,150,413

HIGH PRESSURE PRESSES AND COMPONENTS THEREOF

Filed Dec. 13, 1962 3 Sheets-Sheet 1

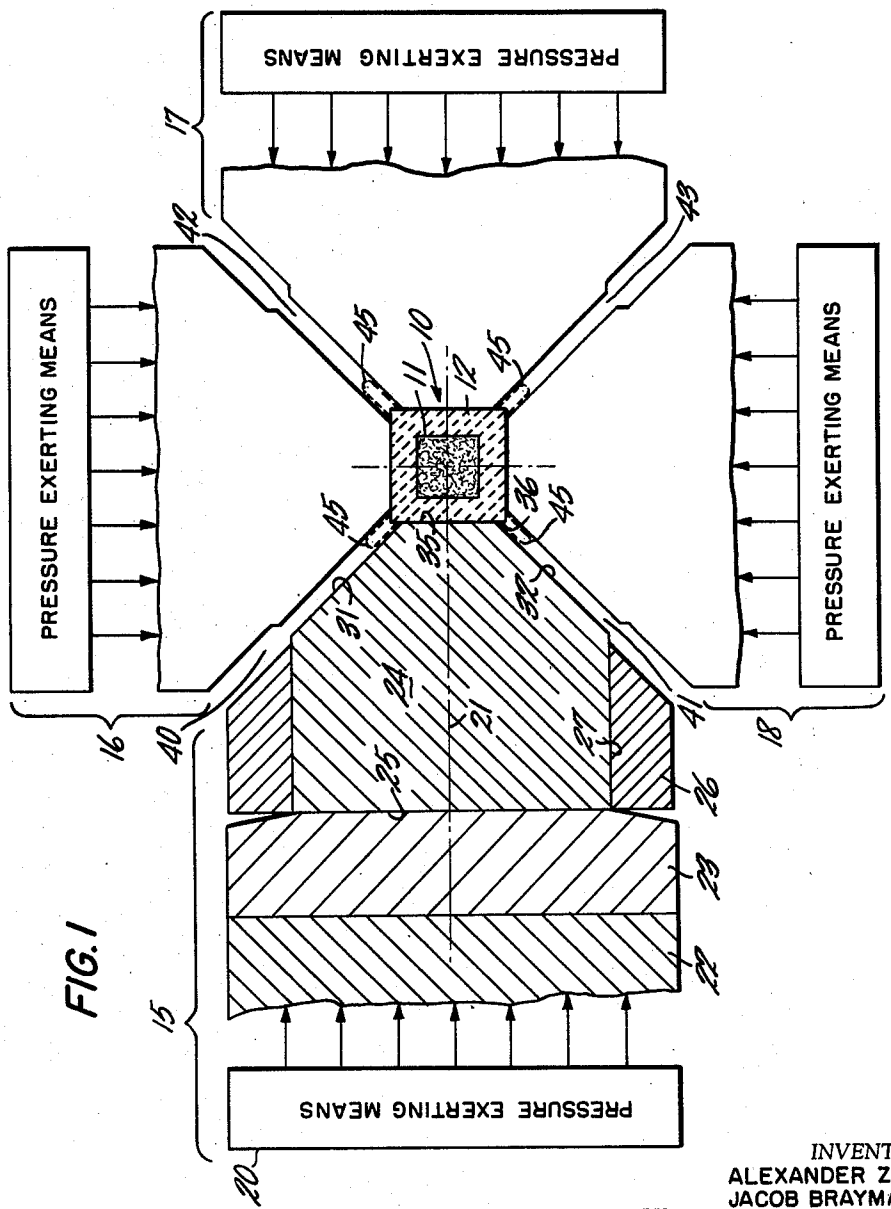


FIG. 1

INVENTORS
ALEXANDER ZEITLIN,
JACOB BRAYMAN &
GEORGE GERARD

BY Brumbaugh, Free, Graves & Donohue

their ATTORNEYS

Sept. 29, 1964 A. ZEITLIN ETAL 3,150,413

HIGH PRESSURE PRESSES AND COMPONENTS THEREOF

Filed Dec. 13, 1962 3 Sheets-Sheet 2

FIG. 2

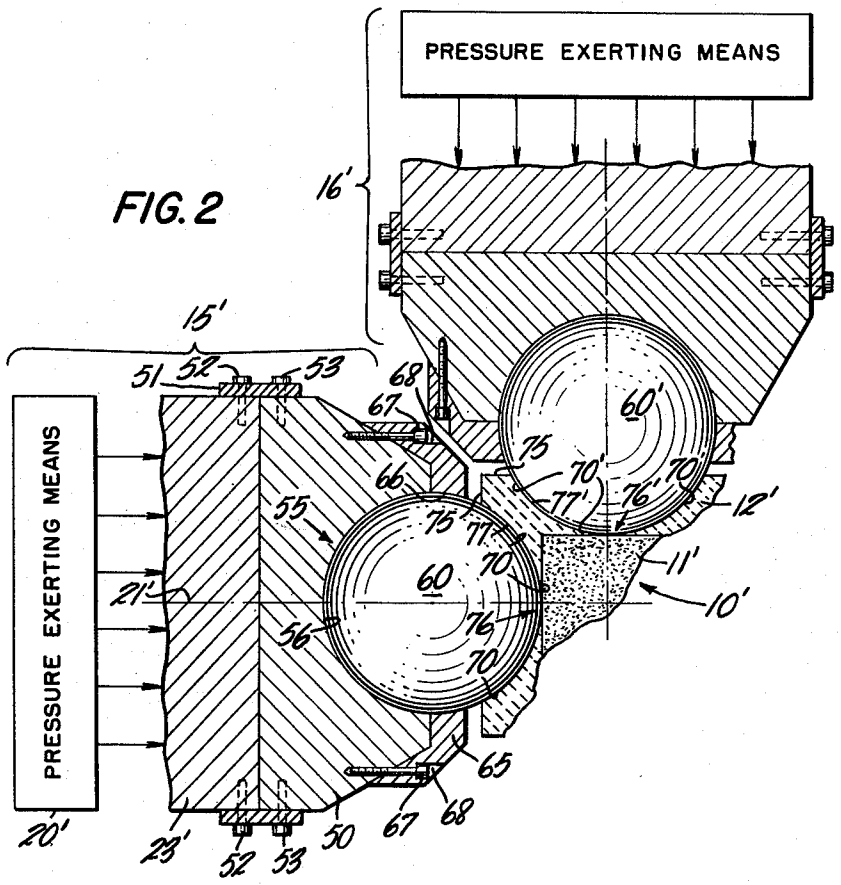
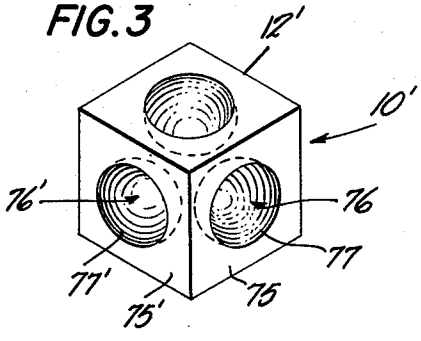


FIG. 3



INVENTORS
ALEXANDER ZEITLIN,
JACOB BRAYMAN &
GEORGE GERARD,

BY Brumbaugh, Free, Graves & Donohue

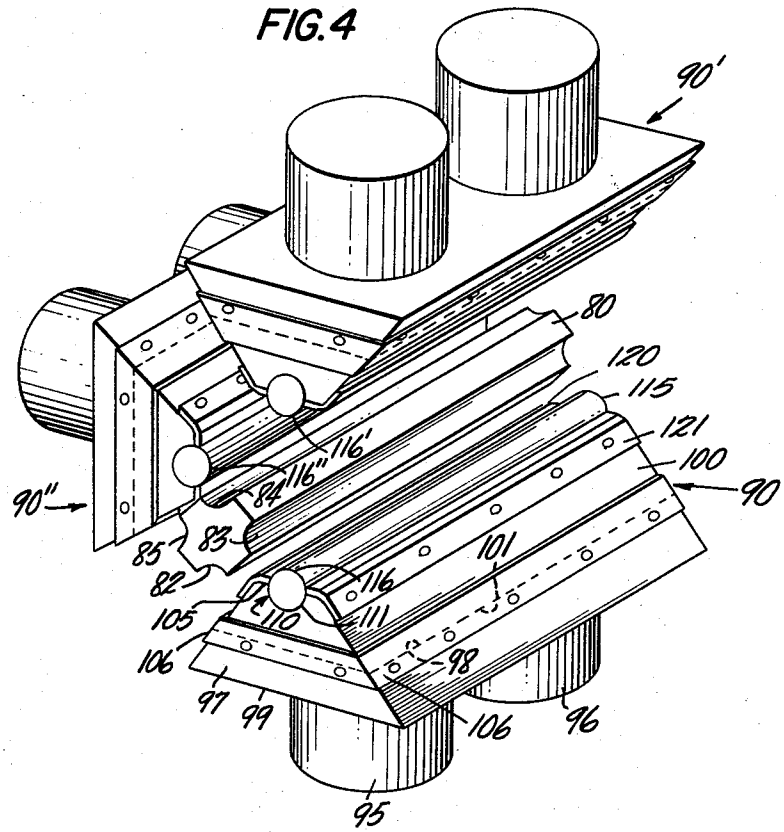
their ATTORNEYS

Sept. 29, 1964 A. ZEITLIN ETAL 3,150,413

HIGH PRESSURE PRESSES AND COMPONENTS THEREOF

Filed Dec. 13, 1962 3 Sheets-Sheet 3

FIG. 4



INVENTORS
ALEXANDER ZEITLIN,
JACOB BRAYMAN &
GEORGE GERARD,

BY Brumbaugh, Graves, Donohue & Raymond

their ATTORNEYS

United States Patent Office 3,150,413 Patented Sept. 29, 1964

3,150,413

HIGH PRESSURE PRESSES AND COMPONENTS THEREOF

Alexander Zeitlin, White Plains, and Jacob Brayman, Staten Island, N.Y., and George Gerard, Newton Center, Mass., assignors to Barogenics, Inc., New York, N.Y., a corporation of New York

Filed Dec. 13, 1962, Ser. No. 244,507
8 Claims. (Cl. 18—16.5)

This invention relates generally to presses for generating high pressure on an object. More particularly, this invention relates to stress-reducing improvements in such presses and in the components thereof.

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

FIGURE 1 is a schematic plan view (partly in cross section) of one type of prior art pressure-multiplying press;

FIGURE 2 is a schematic plan view in cross section of the FIGURE 1 press as modified to embody the present invention;

FIGURE 3 is an isometric view of the exterior of the pressure-receiving means shown in FIGURE 2; and

FIGURE 4 is an isometric view of another type of press embodying the invention.

In the description which follows, elements which are counterparts of each other will be designated by the same reference numbers but will be distinguished by the use of prime (') suffixes for the numbers. It is to be understood that, unless the context otherwise requires, a description herein of one element is to be taken as applicable also to all counterparts of the expressly described element.

Referring now to FIGURE 1, what is illustrated thereby is an apparatus for generating super high pressure by means of a cubic configuration of pressure-multiplying anvils as taught, for example, in U.S. Patent No. 2,968,837 issued to Zeitlin et al. on January 24, 1961. The pressure-receiving means 10 of the apparatus is comprised of a central body 11 of material to be compressed and of a cubic casing 12 around the body 11. The element 11 may be, for example, a mechanical part, a powdered chemical or a charge for making synthetic industrial diamonds, and the body 11 may be accompanied by additional elements (not shown) embedded in casing 12 as, say, a sample tube for containing the body 11 or electrothermal means for heating that body. The casing 12 is comprised of a pressure-transmissive material such as pyrophyllite, talc or brass.

The six faces of casing 12 are each contacted by the front end of one of a cubic array of six pressure-applying devices of which only four devices 15–18 are shown, and of which only the device 15 is partly shown in cross section. Each of the mentioned six pressure-applying devices is the same as or similar in most respects to the device 15.

The device 15 includes a pressure-exerting means 20 of which the specific character is of no particular importance, and which, accordingly, may be, say, a hydraulic cylinder and piston unit as taught in U.S. Patent No. 2,968,837, a pressure-transmitting medium as taught in U.S. Patent No. 3,044,113, issued to Gerard et al. on July 17, 1962 or a wedge surface as taught in U.S. Patent No. 3,049,756, issued to Gerard et al. on August 21, 1962. The means 20 and its counterparts may be mounted within a structure (not shown) which provides a pressure-absorbing backing therefor, and which is appropriate thereto as disclosed in the mentioned patents.

The pressure-exerting means 20 operates to drive along a centerline of action 21 toward casing 12 an assembly made up of: (*a*) a driving head 22 of cylindrical cross section normal to line 21, (*b*) a back-up plate 23 mounted (by means not shown) on the front of head 22, the back-up plate having a cylindrical cross section normal to line 21, (*c*) a tool head 24 having a rear face 25 abutting against the back-up plate 23, and (*d*) a binding ring 26 fitted on the cylindrical shank 27 of the tool head. The tool head may be made of materials conventional for this purpose such as cemented tungsten carbide, alloy steel or mild steel.

Forward of its shank 27, the tool head 24 has the two shown planar beveled faces 31, 32 and two further planar beveled faces (not shown). Those four beveled faces are disposed at 90° intervals around the head and are each inclined at 45° to the center line of action 21 of the head so as to render the front of the head in the shape of a truncated pyramid of square cross section normal to line 21.

The beveled faces of the tool head 24 converge towards and terminate at a square planar front face 35 which is the pressure-applying face of the tool head. Each beveled face intersects at an edge with the front face 35, each pair of adjacent beveled faces intersect at an edge which extends to a corner of the square front face 35, and various of the named edges intersect to form vertices at the corners of the front face 35. Moreover, the cylindrical surface of shank 27 intersects with rear face 25 to form a circular edge and intersects with the beveled faces of the tool head to form arcuate edges.

The face 35 of the tool head 24 contacts a casing face 36 which is one of the six exterior faces of the cubic casing 12. The tool head face 35 is somewhat smaller in size than the casing face 36 but is concentric with face 36 and has its edges parallel to those of face 36. This size and positioning relation of tool head face 35 to casing face 36 is duplicated in connection with each of the five other faces of cubic casing 12. That is, those five other casing faces are each contacted by a front face (identical with face 35) of a tool head carried by a respective one of the five pressure-applying devices which are in addition to device 15. Because each of the six tool head front faces is smaller in size than the casing face contacted thereby, all of the tool heads are separated from each other along their tapered sides by interspaces or gaps which radiate outwardly from the cubic central cavity defined by the front faces of the six tool heads. FIGURE 1 shows four of those gaps, namely, the gaps 40, 41, 42 and 43.

In operation, the pressure-receiving means or assembly 10 is placed in the central cavity between the front faces of the six tool heads. Thereafter, the apparatus is actuated to produce a driving by the six pressure-exerting means of the six tool heads along their center lines of action, the six heads thereby undergoing closing relative movements to compress the unit 10. Referring to pressure-applying device 15, because the front face 35 of tool head 24 is smaller in area than the rear face 25 of that head, the driving pressure transmitted from pressure-exerting means 20 through driving head 22 and back-up plate 23 to rear face 25 of tool head 24 is translated by the tool head 24 into a multiplied pressure exerted by the tool head front face 35 on the face 36 of the casing 12. A corresponding pressure multiplication is produced by each of the other five tool heads. Bursting of the shanks of the tool heads under the stresses developed therein by the pressure multiplication is prevented or at least reduced in occurrence by the binding rings which surround those shanks to give lateral support thereto.

As the tool heads press in on the pressure-receiving assembly 10, the pressure-transmissive material of which casing 12 is formed becomes increasingly plastic to produce a more or less hydrostatic pressure field in the casing and to communicate the pressure exerted by the tool heads to the body 11 of material to be compressed.

Simultaneously, some of the material of the casing extrudes into the gaps between the tool heads to there form gaskets represented in FIGURE 1 by the dotted lines 45. Those gaskets serve both to seal in the pressure being communicated through the main body of casing 12 to the object 11 and to provide some lateral support for the tapered sides of the tool heads.

By an operation of the sort described, extremely high pressures may be generated upon the pressure-receiving assembly 10 by each tool head or anvil which bears on that assembly. Because it is the front face of the anvil which experiences the high pressure, that face is, of course, the critical one. In prior experimental work, the anvil front face has been subjected to pressures of 100 kilobars and up. Although no presently known materials can directly withstand such pressure, limited useful life has been obtained from some materials by the use of appropriate tool structures.

The FIGURE 1 apparatus is characteristic of prior art super high pressure apparatus in that it employs tool heads with planar front and side faces which intersect to form edges and vertices of the exterior of the head. Tool heads of this sort have previously been used in tetrahedral and other polyhedral configurations as well as in the shown cubic configuration.

Examining now some of the disadvantages of those prior art polyhedral configurations.

(1) In any of such configurations, there are, as stated, edges on the tool head where the beveled sides of the tool head intersect. Also, the intersection of the beveled sides and the flat front face of the tool head results in further edges. Although these edges can be slightly rounded, they still remain as sharp stress raisers in the tool head.

(2) Another detrimental effect of those edges is that they make it extremely difficult for the gasket to completely form around the tool head. Moreover, as the gasket forms, the sharp edges of the tool head will intrude into it and tend to rupture it.

(3) Within the tool head or anvil, the stresses at the high pressure front face are diffused to lower levels as the cross sectional area of the anvil increases with distance away from that face. When, however, the stress passes from the tapered front portion of the anvil to the cylindrical shank portion thereof, a stress concentration occurs because the act of forcing the stress into another shape causes a "pinching" effect at the place where the cylindrical surface of the anvil shank joins the beveled planar faces on the forward part of the anvil.

(4) The bearing under pressure of the planar rear face of the tool head against its back-up plate produces a further stress concentration in the vicinity of the circular edge formed by the intersection of that planar rear face with the cylindrical peripheral surface of the shank of the tool head. In this connection, basic elasticity theory shows that when one cylindrical body is supported on a semi-infinite plate and loaded in direct compression, the stresses around the edge of the cylindrical load cylinder are extremely high and, in fact, approach infinity. These stresses result in edge brinelling and deformation.

(5) A "plate" effect in the tool head arises from the fact that the supported rear face of the head is larger in area than the front face at which the ultra high pressure is developed. In such circumstances, the tool head is analagous for stress analysis purposes to a plate subject to a load which is applied to only a small area of the front face of the plate, but which is resisted by the entire rear face of the plate. The resultant bending stresses induced in the tool head by this plate effect are additive with the stresses caused by the loading. Further stress components which are additive with the loading stress are the stress concentrations occurring at the edges formed by the intersection of all flat planes on the tool head. Moreover, the stresses arising from the plate effect are a maximum at the supported rear face of the tool head and at the high pressure front face thereof. The result is that surface imperfections may progress and eventually cause failure.

(6) Due to the method of supporting the anvil (by the flat surface of a back-up plate), any displacement of the center of gravity of the loading pattern from the geometric center of the anvil will cause an increase in the plate bending stress. Because of the high loading which the anvil, may, in practice, have to absorb, even a slight displacement may be very detrimental.

It is accordingly, an object of our invention to provide presses, pressure-multiplying devices, and tool assemblies wherein one, some or all of the above-noted stress concentrations will be reduced.

A further object of our invention is to provide a pressure-receiving assembly which is particularly suited for use with tool heads which are shaped to reduce stress concentrations therein.

Still a further object of our invention is to provide super high pressure apparatus comprised of the combination of tool heads shaped to reduce stress concentrations therein and of pressure-transmissive means particularly adapted to communicate pressure from those heads to the ultimate object to be compressed by the apparatus.

These and other objects are realized according to the invention by providing pressure-applying devices in which the forward part of the device is comprised of a support bolster and of a tool head which forwardly is rounded. The front end of the bolster has formed therein a socket in which the rear of the tool head is received in fitted relation. The front of the tool head projects forwardly from the front end of the bolster to provide for pressure applying purposes to tool head face which is salient from the bolster and is convexly arcuate from the bolster outwards. While the tool head may be in the shape of, say, a cylinder having a hemispherical front end of of an oblong block capped by half of a circular cylinder, preferably the rear as well as the front portion of the tool head is rounded. Examples of such preferred shapes for the tool head are a sphere or a circular cylinder or some other form which is of circular cross section in a plane through the center line of action of the tool head. Also, it is desirable in many instances for the tool head to be rotatable in the bolster socket in which the head is received.

While a shaped tool head of the sort described is useful in super high pressure apparatus of the type exemplified in FIGURE 1 wherein a plurality of such tool heads are arrayed in different planes around a pressure-receiving assembly, such a shaped tool head is also utility in other types of high pressure apparatus such as, for example, heavy duty forging presses (in which the pressure-receiving means is a billet) and super high pressure apparatus of the opposed piston variety.

According to another aspect of the invention, there is provided a pressure-receiving assembly in combination with or for use with a plurality of tool heads shaped as described. Such pressure-receiving assembly comprises a central object or body to be compressed and a casing around that body of pressure-transmissive material. An inventive feature of the assembly is that the exterior of the casing is characterized by hollows of which each is adapted to receive the salient, convexly arcuate face of a respective one of a plurality of shaped tool heads when the same are arrayed around that assembly.

One embodiment of the invention is shown by FIG. 2. Since the FIG. 2 structure is similar in a number of respects to that previously discussed in connection with FIG. 1, the FIG. 2 structure will be described primarily in terms of its differences from FIG. 1.

FIG. 2 shows only two of the six pressure-applying devices which are used in the super high pressure apparatus of cubic configuration to which that figure relates. In FIG. 2 the pressure-applying device 15' comprises as before a pressure-exerting means 20' which operably trans-

mits driving pressure to a driving head 23'. Disposed on the head 23' is a support bolster 50 of cylindrical cross section normal to the center line of action 21' of the head 23'. The bolster 50 is secured to head 23' by a ring 51 which encircles and overlaps with both elements, and which is bolted to the head 23' by radial bolts 52 and to the bolster 50 by radial bolts 53. As shown, the forward part of bolster 50 has a conical taper which renders the front end of the bolster smaller in cross section than the rear end thereof. The tapering of bolster 50 is not, however, primarily to provide a pressure-multiplying effect, but, instead, is primarily for the purpose of permitting bolster 50 to be positioned closer to the center of the FIG. 2 apparatus without coming into contact with adjacent support bolsters which are likewise tapered for the same purpose.

The front end of bolster 50 has formed therein a rounded socket 55 providing a hemispherical rearward seating surface 56. If desired or necessary, that seating surface may be hardened.

Received within socket 55 is the rear half of a tool head 60 in the form of a sphere and constiuted of a suitable tool material such as cemented tungsten carbide, alloy steel, mild steel, etc. As shown, the ball tool head 60 is seated in fitted relation in the socket 55 in the sense that the rear hemispherical face of the tool head is in intimate contact over its area with the hemispherical seating surface 56 of the socket.

The tool head 60 is retained in socket 55 by an annular clamp ring 65 of which the interior is shaped to provide outwardly of socket 55 and around the head 60 a groove 66 which is of spherical curvature in cross section, and which fits with and engages an inwardly curving band portion of the spherical surface of the tool head 60. The clamp ring 65 is secured at its outer periphery to the support bolster 50 by a plurality of angularly spaced axial bolts 67 which are received in countersunk holes 68 formed in the ring, and which extend rearwardly of those holes to be threadedly received in holes (not shown) formed in the tapered front end of the bolster. The seating of the ball tool head 60 in the bolster socket 55 and the retaining of the ball head by the clamp ring 60 are such that the ball tool head is free under pressure to rotate in the socket 55. If desired, the clamp ring can be dispensed with and the tool head retained in the bolster socket in some other suitable way as, say, by coating the rear face of the tool head with a viscid lubricant and relying on the viscidity of the lubricant film in the interface between the tool head and the socket seating surface 56 to retain the tool head in the socket.

Because of the spherical shape of the tool head 60, the front part of the head provides for pressure-applying purposes a hemispherical tool head face 70 which is salient from the bolster 50, and which is everywhere convexly arcuate from the bolster outwards. Evidently, the face 70 is edge free and likewise the rear hemispheric face of tool head 60 is edge free. The advantages of having tool head 60 so wholly edge free are numerous and are as follows.

(1) In contact with the support bolster is a rounded surface offering no discontinuities or sharp edges in contact with the bolster.

(2) In the anvil or tool itself, there are no sharp edges to induce stress concentrations under load.

(3) There are no sharp edges on the anvil to impede the formation of the gasket or to disrupt or break the forming gasket.

(4) In the described tool head wherein the head is of circular cross section in a plane through the center line of action of the head, the maximum stress occurs in the center of the circular cross section and therefore reduces drastically the effect on those stresses of surface imperfections due to manufacturing procedures. Propagation of the surface cracks can be greatly attenuated.

(5) The previously mentioned "plate" effect has been eliminated or minimized to such a great extent as to be completely negligible. This is so because the rounded tool head is loaded over a good portion of its front face and most of its rear face and therefore acts substantially as a straight compression member.

(6) Because the rounded tool head is free to rotate within the support bolster, the tool head cannot transmit any moment to the bolster. Therefore, the load applied from the bolster to the tool head and the load applied from the tool head to the pressure-receiving assembly must be co-linear, that is, in the same line. The result is that the described rounded tool head cannot be subjected to a bending moment such as can be developed in or on a conventional anvil or tool head of the type shown in FIG. 1. This elimination of bending moment and of the consequent bending deflection of the tool head or anvil results in a more uniform pressure distribution in the pressure-receiving assembly.

As illustrated by FIG. 2, the pressure-applying device 60' is a duplicate of the device 50' and, hence, will not be described in detail except to note that the tool head 60' of device 16' is spherical, has a hemispherical salient front face 70' and is in other respects identical with the tool head 60 of device 15'. Such identity with tool head 60 also characterizes the respective tool heads of the four other pressure-applying devices (not shown) which supplement the devices 15' and 16' to form an array of six such devices around the central cubic cavity.

While the described spherical tool heads and cylindrical, conically tapered support bolsters are shown in FIG. 2 as being used in a cubic array, the tools formed of such heads and bolsters have a configuration which is universal in the sense that the same tools may be as effectively used in a tetrahedral or other non-cubic array of pressure-applying devices.

Turning now to the pressure-receiving assembly 10' which is compressed by the pressure-applying devices of FIG. 2, that assembly is comprised as before of a body or object 11' of material to be compressed and of a pressure-transmissive casing 12' around the body 11'. The assembly 10' differs, however, from the assembly 10 of FIG. 1 in that in assembly 10' there is formed at the center of each of the square faces of casing 12 a hollow for receiving the salient tool head face of the pressure applying device opposite that casing face. Thus, as shown in FIG. 2, the square casing face 75 of casing 12' has formed therein a hollow 76 for receiving the front part of salient tool head face 70, the square casing face 75' of casing 12' has formed therein a hollow 76' for receiving the front part of the salient tool head face 70', and the other four faces of the cubic casing 12' have like hollows (not shown) formed therein. As exemplified by the interior wall surfaces 77 and 77' of, respectively, the hollows 76 and 76', each of the hollows in the exterior of casing 12 has an interior wall surface which is so shaped that the corresponding salient, tool head face fits snugly into the hollow. That is, the interior wall surface of each hollow is in the shape of a segment of a spherical surface having about the same radius as the salient hemispherical face of the corresponding tool head and having, moreover, the same center as that hemispherical face when the tool head associated with that hollow is properly seated in such hollow.

The hollows in the centers of the square exterior casing faces are well shown in FIG. 3 which is an isometric view of the cubic pressure-receiving assembly 10'. When the apparatus for which the assembly is designed employs arcuately faced tool heads in a tetrahedral or other non-cubic polyhedral array, the overall shape of the assembly 10' can, of course, be modified to be of a tetrahedral or other non-cubic polyhedral configuration which matches that of the array.

A pressure-receiving assembly having the described hollows therein is more useful with arcuately-faced tool

heads than an assembly which lacks such hollows, and of which an example is the assembly 10 of FIG. 1. This is so for the following reasons.

First, the presence of hollows in the exterior of the assembly permits the arcuately-faced tools to be statically positioned closer to the center of the tool-surrounded cavity than would be possible if the assembly had wholly flat exterior surfaces. This closer positioning of the tool in turn reduces the gaps between the tools to widths at which the pressure-transmissive material in the casing of the assembly can conveniently form gaskets in those gaps. To so be able to reduce the gap width is an important consideration in the use of arcuately-faced tools wherein the curving away of the working face of each such tool from those of the adjacent tools is a factor which tends to make the inter-tool gaps greater than if the tools were flat faced and edged as described in connection with FIG. 1.

Second, a pressure-receiving assembly having the described hollows is so shaped that the edge and corner portions of the casing extend further into the inter-anvil gaps than they would if the assembly were wholly flat faced as in FIG. 1. Thus, the presence of hollows in the assembly causes the gaskets dynamically created by the extrusion of casing material into the gaps to be partially preformed before the compressing operation even begins. Such partial preformation of the gaskets is particularly useful in implementing the dynamic formation of effective gaskets in the instance where arcuately-faced tools are employed, and where, therefore, the gaps between the tool head faces are wider and (consequently) gasket formation is more difficult than if the tools were flat faced and edged as in FIG. 1.

Third, it might be mentioned that the hollows in the pressure-receiving assembly permit the arcuate working faces of the cooperating tools to be positioned closer to the central body to be compressed (i.e., body 11' in FIG. 2) to thereby provide for a more efficient compression of that body by the tools when the latter are driven inwardly.

Excepting as noted, the operation of the FIG. 2 apparatus is substantially the same as the already described operation of the FIG. 1 apparatus, wherefore no further description of operation need be given herein in connection with FIG. 2.

FIGURE 4 illustrates an embodiment of the invention having a pressure-receiving means 80 which differs from those of FIGURES 1 and 2 in being elongated in the direction of its principal axis. The pressure-receiving means 80 may be either a homogeneous member (e.g., a billet as disclosed in co-pending application Serial No. 112,265, filed May 24, 1961 in the name of Gerard et al., now U.S. Patent 3,093,862, issued June 18, 1963, and owned by the assignee of this application) or, alternatively, the unit 80 may be an elongated composite assembly comprised of a central body of material to be compressed and a pressure-transmissive casing around that body. Composite pressure-receiving units of this sort are disclosed in co-pending applications owned by the assignee of this application, namely Serial No. 45,608, filed July 27, 1960 in the name of Gerard et al. (now U.S. Patent 3,080,609, issued March 12, 1963) and Serial No. 112,385, filed May 24, 1961 in the name of Gerard et al. (now U.S. Patent 3,091,804, issued June 6, 1963).

As shown, the pressure-receiving unit 80 is uniform in cross-section normal to its principal axis. Such cross-section would be square were it not for the fact that what would otherwise be the corners of the square are replaced by four axially running grooves 82–85 of which each has an interior wall surface conforming to an arc of a circular cylindrical surface.

The pressure-receiving unit 80 is surrounded by a square array of four axially elongated pressure-applying devices of which only three devices 90, 90' and 90'' are shown, and of which only the device 90 will be described in detail.

The pressure-applying device 90 has at its rear a pressure-exerting means in the form of a pair of hydraulic cylinder and piston actuating rams 95 and 96. Those rams operably produce forward movement of a driving head 97 shaped as an elongated rectangular block member having planar end faces and having a trapezoidal cross-section such that the forward face 98 of the block is smaller than the rear face 99 thereof.

Disposed on the forward planar face of head 97 is the matching rear planar face of a support bolster 100 also characterized by planar end faces and by a trapezoidal cross section such that the planar front face 105 of the bolster is smaller in area than the rear face 101 thereof. The bolster 100 is secured to head 97 by a plurality of clamp plates 106 which are bolted to an extend around the top of the head, and which have inwardly inclined, projecting portions overlapping and abutting with the bottom of bolster 100 to hold that bolster on the head by a wedging action.

The front face 105 of bolster 100 has formed therein an axially running groove-shaped socket 110 so shaped that the inner wall 111 of the socket conforms to the arc of a circular cylindrical surface matching that defined by the hollow 82 in pressure-receiving unit 80. As before, the surface 111 provides for socket 110 a rearward seating surface which, if desired, may be hardened.

Received within groove-shaped socket 110 is a circular cylindrical tool head 115 of which the rear half is in fitted relation with the seating surface 111 in the sense that the tool head rear surface is in intimate contact over its area with that seating surface. As before, tool head 115 is composed of a conventional material such as tungsten carbide, steel or the like.

The front half of tool head 115 provides outward of socket 110 a pressure-applying face 116 which is salient from bolster 100, and which is everywhere convexly arcuate from the bolster outwards in the plane through the centerline of action of device 90, and normal to the principal axis of the tool head. The radius of curvature in that plane of the pressure applying surface 116 is such that the front part of tool head 115 fits snugly into the groove-shaped hollow 82 of the central unit 80.

The tool head 115 is held in socket 110 by a pair of elongated bracket plates 120, 121 disposed on opposite sides of the bolster 100. Each of those plates is of an upside-down L shaped cross-section wherein the two legs of the L make an obtuse angle. The respective lower leg portions of the two bracket plates, 120, 121 are bolted on opposite sides of bolster 100 to the top side margins thereof. The upper leg portions of the two bracket plates extend over the bolster's front face 105 towards each other and towards tool head 115 to terminate in arcuate grooves which match the curvature of the tool head face 116, and which make contact outwards of socket 110 with axially running strip portions of that face.

As before, the tool head 115 need not be held in its socket by plates or the like, but, instead, some other suitable expedient may be employed to provide the holding action. The seating of the tool head in its socket, and the tool head's retention therein by the plates 120, 121 are such that the tool head 115 is rotatable under pressure within socket 110 in the mentioned plane normal to the principal axis of the tool head.

Because of their similarity to pressure-applying device 90, the other shown devices 90' and 90'' will not be described in detail except to note that they are characterized by respective arcuate salient tool head faces 116' and 116'' designed to fit snugly into, respectively, the groove shaped hollows 84 and 85 of the central pressure-receiving unit 80.

The FIG. 4 embodiment is completed by the elements (not shown) of (*a*) a fourth pressure-applying device similar to 90 and having at its front end an arcuate tool

head face designed to fit into hollow 83 of unit 80, (*b*) a frame which encloses all of the pressure-applying devices so as to provide a rearward backing and mounting therefore, (*c*) a pair of end members disposed at opposite ends of pressure-receiving unit 80 to prevent endwise extrusion during operation of material from that unit. The mentioned frame and the mentioned end members may be similar to those of the apparatus shown by FIGS. 6 and 7 of the aforementioned co-pending application Serial No. 45,608 filed July 21, 1960 in the name of Gerard et al.

Preliminary to a compressing operation, the tools of the four pressure-applying devices of the FIG. 4 press are advanced towards unit 80 to fit the salient face of the tool head of each device into the corresponding hollow formed in the central unit. Thereafter, the pressure-applying devices are actuated to cause the tools of all those devices to simultaneously apply high pressure through their salient faces on the unit 80. From the description previously given of the presses shown by FIGS. 1 and 2, the mode of operation of the FIG. 4 press should be evident, and, hence, need not be described herein in detail. The employment in the FIG. 4 press of tool heads with convexly arcuate faces and of a pressure-receiving assembly or means having hollows formed therein to receive those faces provides substantially the same advantages as those already described in connection with FIG. 2. While the tool heads of FIG. 4 have circular edges where the planar end faces of those heads intersect the cylindrical surfaces thereof, those edges do not create serious stress concentrations for the reason that in an axially elongated press the axial distribution of pressure in the elongated pressure-receiving means is non-uniform in a manner such that the pressure drops off to a low value at each of the opposite ends of that means.

The above described embodiments being exemplary only, it will be understood that additions thereto, omissions therefrom and modifications thereof can be made without departing from the spirit of the invention, and that the invention comprehends embodiments differing in form and/or detail from those which have been specifically described. Accordingly, the invention is not to be considered as limited save as is consonant with the recitals of the following claims.

We claim:

1. Pressure-multiplying apparatus comprising, a plurality of pressure-multiplying devices arrayed on separate sides of a central cavity with their front ends towards said cavity, said devices each comprising, a driving head, a support bolster disposed on said head and having a front end in which is formed a socket, and a tool head of which the rear is received in fitted relation in said socket, and of which the front projects forwardly of the front end of said bolster to provide for pressure-applying purposes a tool head face which is salient from said bolster and convexly arcuate from said bolster outwards, and said apparatus further comprising a casing for an object to be compressed, said casing being disposed in said cavity and having formed in exterior surfaces thereof a plurality of hollows of which each has fitted thereinto the said salient face of a respective one of said tool heads, and said casing being comprised of a pressure-transmissive material adapted under pressure applied from said tool heads to communicate said pressure to said body,

2. Apparatus as in claim 1 in which each of said tool heads has the form of a circular cylinder.

3. Apparatus as in claim 1 in which each of said tool heads has the form of a sphere.

4. A pressure-receiving assembly for a press wherein a plurality of pressure-multiplying devices are arrayed on separate sides of a central cavity for receiving said assembly with their front ends towards said cavity, and wherein the front ends of said devices are provided by tool heads having salient front faces, said assembly comprising, a central object to be compressed and a casing around said object, said casing having formed in exterior surfaces thereof a plurality of hollows of which each is adapted to have fitted thereinto the said salient face of a respective one of said tool heads, and said casing being comprised of pressure-transmissive material adapted under pressure from said tool heads to communicate said pressure to said object.

5. An assembly as in claim 4 in which said casing is in the form of a polyhedron and in which a one of said hollows is disposed at the center of each face of the polyhedron.

6. An assembly as in claim 5 in which the interior wall surface of each of said hollows is in the form of a segment of a spherical surface.

7. An assembly as in claim 4 in which said casing is of uniform cross section normal to a principal axis therefor, and in which said hollows are in the form of axially running grooves spaced from each other around said casing.

8. An assembly as in claim 7 in which the interior wall surface of each of said grooves is in the form of an arc of a circular cylindrical surface.

References Cited in the file of this patent

UNITED STATES PATENTS

1,802,197	Cooper	Apr. 21, 1931
2,563,690	Nalon	Aug. 7, 1951
3,107,395	Bundy	Oct. 22, 1963

FOREIGN PATENTS

849,727	Great Britain	Sept. 28, 1960

OTHER REFERENCES

German application D.A.S., 1,004,477, Mar. 24, 1957.