Sept. 17, 1963 G. GERARD ETAL 3,103,699

SUPER-HIGH PRESSURE APPARATUS

Original Filed Jan. 8, 1959 2 Sheets-Sheet 1

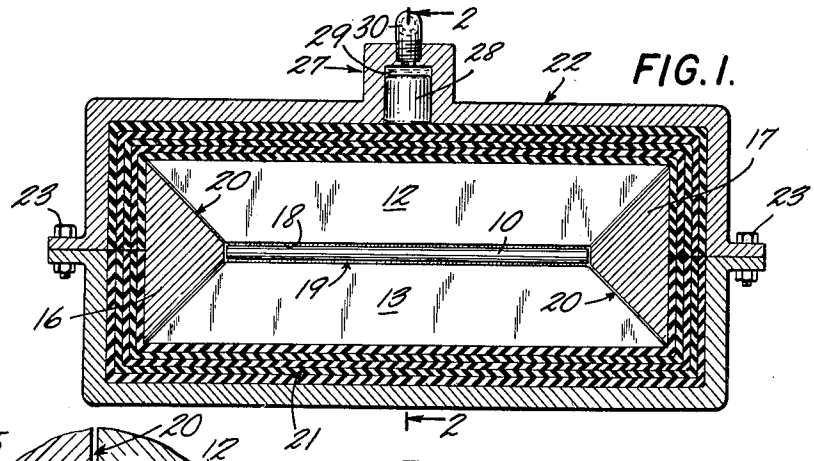


FIG. 1.

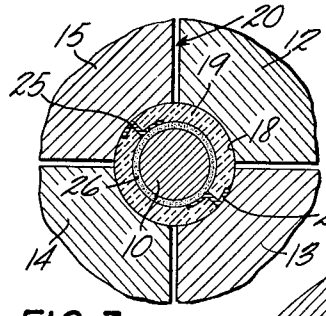
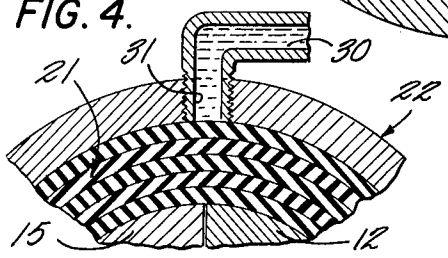


FIG. 3.

FIG. 2.

FIG. 4.



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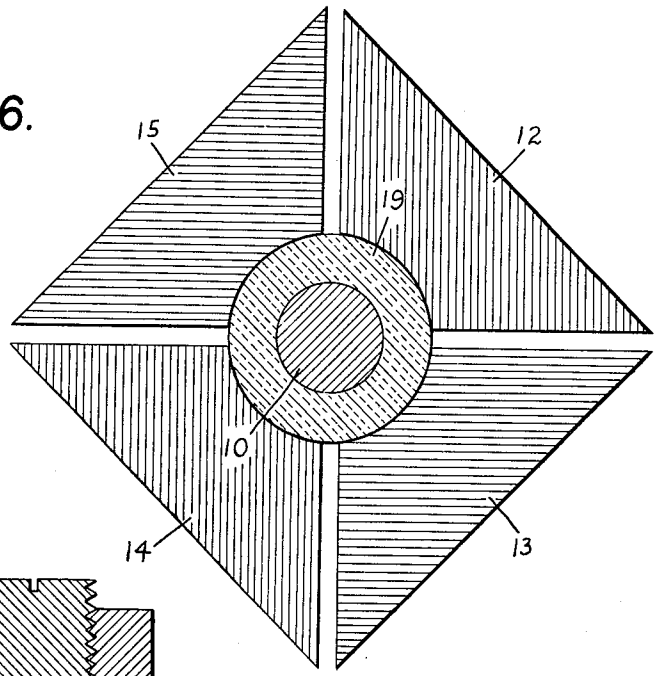
their ATTORNEYS.

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FIG. 6.



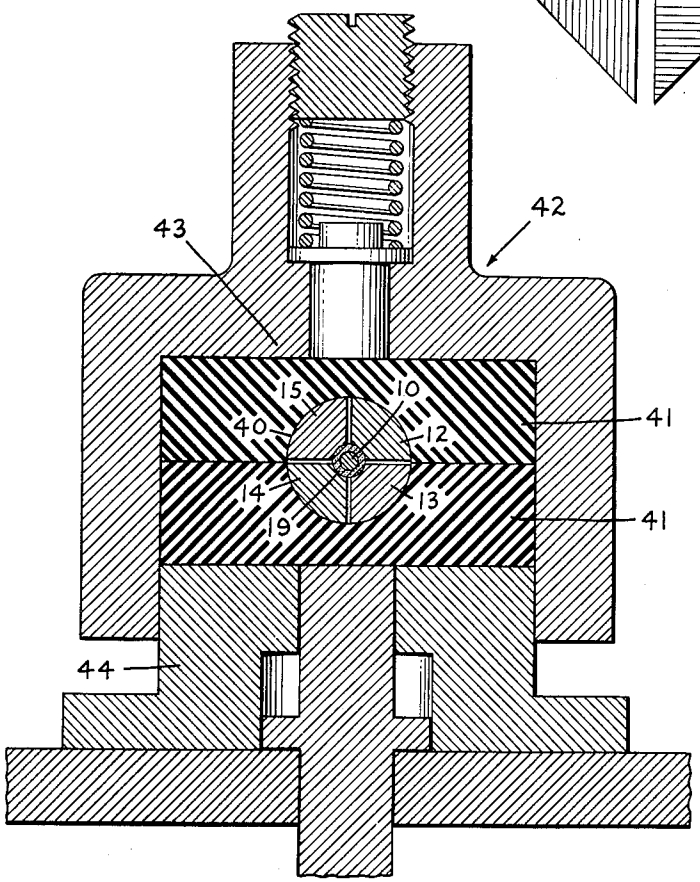


FIG. 5

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SUPER-HIGH PRESSURE APPARATUS

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Original application Jan. 8, 1959, Ser. No. 785,690, now Patent No. 3,044,113, dated July 17, 1962. Divided and this application Feb. 5, 1962, Ser. No. 171,239

5 Claims. (Cl. 18—5)

This invention relates to super-high pressure apparatus and more particularly, to a new and improved apparatus for applying higher pressures than have heretofore been attainable to objects of any size or shape.

This application is a division of our co-pending application Serial Number 785,690, filed January 8, 1959, for "Super-High Pressure Apparatus," and now Patent 3,044,113, granted July 17, 1962.

Generally, the structural requirements of many newly developed forms of apparatus, such as jet and rocket engine systems, often exceed the physical characteristics such as fatigue life, yield strength, and modulus of rigidity of the materials now available. Little improvement of these characteristics is to be expected by further refinements in the materials or in heat treating procedures. On the other hand, the application of extreme pressures to such materials now appears to be an effective way of improving their physical characteristics as by inducing phase changes and promoting the alloying of materials that cannot be alloyed at normal pressures.

Heretofore, however, apparatus for subjecting objects to extremely high pressures has been limited as to the size and shape of the objects and has required massive support structures. Also, the presently available apparatus is subject to hydraulic cylinder leakages, cylinder expansion and similar well known problems of high pressure apparatus.

Accordingly, it is an object of this invention to provide new and improved high pressure apparatus capable of applying pressures in the range of 20,000 to 200,000 atmospheres and in excess of 200,000 atmospheres.

Another object of the invention is to provide apparatus of the above character capable of applying extreme pressures to objects of any size or shape.

A further object of the invention is to provide apparatus of the above character having relatively simple and inexpensive structures.

These and other objects of the invention are attained by encasing an object to be subjected to extreme pressure in a viscous pressure-transmitting medium and enclosing it in a pressure-multiplying device comprising a plurality of wedge-shaped segments converging toward the object. The pressure-multiplying device is surrounded by a resilient pressure-transmitting medium in contact with the larger ends of all the segments, while a housing capable of withstanding conventional high pressures encloses the resilient medium and includes a device for applying high pressure to the resilient medium.

Further objects and advantages of the invention will be apparent from a reading of the following description in conjunction with the accompanying drawings in which:

FIG. 1 is a view in longitudinal section through a representative form of super-high pressure apparatus arranged according to the invention;

FIG. 2 is a cross-sectional view of the apparatus of FIG. 1 taken on the lines 2—2 and looking in the direction of the arrows;

FIG. 3 is a magnified sectional fragmentary view showing the central portion of the apparatus of FIG. 2;

FIG. 4 is a fragmentary view showing a modified form of the apparatus of FIG. 1;

FIG. 5 is a view in front elevation and cross-section of another modified form of the invention; and

FIG. 6 is a view in cross-section of the member 11 shown in FIG. 2 when modified to be of exterior cubic shape.

In the typical embodiment of the invention shown by way of example in the drawings and described hereinafter, the high pressure apparatus is arranged to subject a longitudinal work piece, such as a shaft 10, to pressures up to 200,000 atmospheres or more. It will be understood, however, that the object to which extreme pressures are applied may be of any desired shape and that there is no limitation on the size of the object since the apparatus may be arranged with any appropriate configuration and capacity.

In order to exert super-high pressures, the apparatus of FIGS. 1 and 2 includes a cylindrical pressure-multiplying member 11 comprising six wedge-shaped segments 12–17 having inner surfaces forming a cavity 18 conforming generally to the outer shape of the shaft 10, the end segments 16 and 17 being conical in form. These segments are made of any suitable material such as tungsten carbide, for example, which is capable of withstanding the extreme pressures under consideration without substantial deformation or disintegration. It will be understood that any number of pressure-multiplying segments can be used in apparatus according to the invention and their shape may vary according to the configuration of the work piece 10 and the member 11. For example, if the work piece is of compact shape, the member 11 may be a sphere, cube or tetrahedron and may be divided into four, six or eight identical wedge-shaped segments, FIG. 6 showing the member 11 when comprised, as described, of six identical anvils assembled together to render member 11 of cubic exterior shape. Furthermore, the shape of the cavity 18 need not conform to the contour of the work piece 10, since the cavity is filled with a pressure-transmitting medium, as described below. Thus, for objects of complex shape, such as turbine blades, for example, the cavity may have the nearest simple geometrical shape capable of enclosing the object.

Within the cavity 18, the shaft 10 is encased in a pressure-transmitting shell 19 composed of any material which is semi-plastic or highly viscous but substantially maintains its shape at the extreme pressures to be generated. Preferably, because of its ease of machining and its electrical and heat insulation properties, the material utilized in the invention is a pyrophyllite, such as Tennessee grade A lava. Each of the segments 12–17 has its inner face in contact with the shell 19 and the dimensions of all the segments are chosen so that, with their inner faces in contact with the shell, there is a narrow gap 20 between each adjacent pair of segments.

Inasmuch as the degree of pressure-multiplication achieved by the wedge-shaped segments 12–17 is dependent on the relative areas of their outer and inner surfaces, the outer diameter and length of the member 11 are selected relative to the diameter and length of the cavity 18 in accordance with the desired super-high pressure to be obtained in the cavity and the pressure to be applied

to the apparatus at the outside of the member **11**. Thus, for example, if a pressure-multiplication of 100 is desired and the cavity is approximately 1 inch in diameter, the member **11** need only be approximately 10 inches in diameter. This relation holds for cavities of uniform cross-section regardless of the length of the cavity. For irregularly shaped cavities, however, the relative areas of each segment must be selected so that all the segments have the same pressure-multiplication factor. Again in this case, a narrow gap **20** must be included between the adjacent faces of the segments.

Surrounding the pressure-multiplying member **11** is a layer **21** of pressure-transmitting material, the entire assembly being enclosed in a close fitting metal housing **22** of high strength. If desired, the layer **21** and the housing **22** may each be made in two parts which are separably joined as by bolts **23** or other suitable means to provide easy access to the member **11**. In order to heat the work piece **10** while applying pressure, two electrical conductors **24** are carried in through the housing **22** and the layer **21** and are joined to opposite segments **13** and **15** of the member **11**. Also, as shown in FIG. 3, two conductive electrodes **25** are mounted in the shell **19** to carry current to the interior of the shell and are oriented to contact the segments **13** and **15**, respectively. A resistive graphite layer **26** surrounds the shaft **10** within the shell and has its outer surface in contact with the two electrodes **25** at diametrically opposite positions to generate heat when power is applied to the conductors **24**. When the work piece is to be heated in this manner, the viscous pressure-transmitting material should provide good electrical and heat insulation and the lava referred to above serves this purpose well. In addition, thermocouple leads (not shown) may also be connected through the shell **19** and through two other segments **12** and **14** in a similar manner to measure the temperature of the work piece.

In order to apply pressure to the layer **21**, the housing **22** includes a cylinder **27** communicating with the interior of the housing and a piston **28** is slidably mounted therein. At its outer end, the cylinder **27** has a cavity **29** to receive hydraulic fluid which is joined to a conventional hydraulic system (not shown) providing pressures of 2,000 atmospheres and up, for example, in any well-known manner through a conduit **30**. The pressure-transmitting medium **21**, which is preferably formed of successive layers of rubber as in conventional rubber pad presses, should be firm enough to prevent extrusion into the gap **20** under pressure, but also sufficiently resilient to provide equal pressure over the entire outer surface of the member **11** in response to operation of the piston **28**. For this purpose, the inner layers of rubber adjacent the member **11** may be substantially firm and the outer layers more flexible.

In operation, conventional high pressure is applied to this embodiment of the invention through the conduit **30** and the piston **28**. This pressure should be a fraction of the desired super-high pressure commensurate with the multiplying factor of the member **11**. Thus, to apply pressures in the range of 300,000 atmospheres to the shaft **10** with a pressure multiplication of 100 as described above, the pressure applied to the piston **28** should be about 3,000 atmospheres. As the piston **28** is driven into the rubber layer **21**, the pressure of the fluid in the cavity **29** is applied to the entire outer surface of the member **11** because of the pressure equalization throughout the pressure-transmitting medium **21**. The resulting force on the outer surface of the member is transmitted through the segments **12–17** to the much smaller inner surface at the cavity **18**, generating the desired super-high pressure at the outer surface of the shell **19**.

Inasmuch as the pyrophyllite material of the shell **19** becomes semi-plastic or highly viscous at pressures above about 50,000 atmospheres, the material constitutes a pressure-transmitting medium at these pressures and applies

the extreme pressure from the inner surfaces of the segments to the entire outer surface of the work piece **10**. Also, the semi-plastic material acts as a seal by filling in the gaps **20** between the segments in the vicinity of the shell **19**. If the work piece is to be heated during compression, electrical current is passed through the conductors **24**, the segments **13** and **15**, and the electrodes **25** to heat the graphite layer **19**.

In the embodiment of the invention shown in FIG. 3, the pressure of the hydraulic system is applied through the conduit **30** and an aperture **31** into the housing **22** directly to the outside of the pressure-transmitting layer **21**. In this instance, the pressure-transmitting medium should provide a fluid-tight enclosure about the member **11** to prevent any hydraulic fluid from passing into the gaps **20**. Inasmuch as this embodiment has no piston stroke limitation and any necessary quantity of fluid may be forced into the housing, it is not necessary to provide a close fit between the rubber layer **21** and the housing **22**.

Although the invention has been described herein with reference to specific embodiments, many modifications and variations therein will readily occur to those skilled in the art. For example, any suitable means may be utilized for applying pressure uniformly to the outside surface of the member **11**. Thus, the member may be inserted in an appropriately formed cavity **40** in the rubber pad **41** of a conventional rubber pad press **42** of the type, for example, which is shown in FIG. 5 of U.S. Patent No. 2,375,599, issued May 8, 1945 to Lewis E. Walton. Thereafter, pressure is exerted by driving the platens **43**, **44** of the press together. Accordingly, all such variations and modifications are included within the intended scope of the invention as defined by the following claims.

We claim:

1. Apparatus for applying extreme pressure to an object comprising an enclosure, pressure-multiplying means within the enclosure comprising a plurality of wedge-shaped segments converging toward the object, viscous pressure-transmitting means surrounding the object and substantially enclosed by the segments, resilient pressure-transmitting means surrounding the pressure-multiplying means, and piston means for displacing the resilient pressure-transmitting means within the enclosure.

2. Apparatus according to claim 1 wherein the resilient pressure-transmitting means comprises a layer of rubber.

3. Apparatus according to claim 1 wherein the viscous pressure-transmitting means comprises a layer of pyrophyllite enclosing the object.

4. Apparatus according to claim 1 including means for heating the object comprising a shell of electrically resistive material surrounding the object and conductive means for carrying current to the resistive shell including two of the segments.

5. Super high pressure apparatus for compressing an object encased by pressure transmitting material comprising, an array of pressure multiplying units each having a rear end, a smaller front end and a front face at the smaller end thereof, and a taper converging towards and terminating at the front face thereof, said units being disposed in three dimensions to define by such faces of all said units a central cavity adapted to contain said encased object, and said units being each rendered inwardly movable relative to the others by gaps of which one is between the tapered portion of each one unit and the tapered portions of each of other units by which the tapered portion of said one unit is enveloped except at the gaps between said other units, unit-containing means having the form of a sleeve which is of annular cross section and is interiorly and exteriorly circular in the plane of said cross section, said unit containing means having interiorly thereof a unit-receiving space circumferentially bordered by interior wall surface portions of such means, said unit array being centrally disposed in

relation to said space to have the rear ends of at least some of the units thereof respectively abut against said wall surface portions, means with a support surface in abutting contact with said unit-containing means to provide an external support for said last named means when pressure is exerted thereon, and a single pressing member movable relative to said support means into contact with a portion of the combination of said unit-containing means and said unit array to exert on said combination a pressure urging said unit containing means against said support means and driving all said units inwardly relative to and towards each other while remaining separated by said gaps so as to create a pressure engagement between the front face of each such unit and an opposite area of the pressure transmitting material encasing an object in said cavity.

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3,044,113 Gerard et al. ---------- July 17, 1962