April 27, 1965 F. P. BUNDY ETAL 3,179,979

HIGH PRESSURE DIE

Filed Sept. 25, 1962

Fig. 1.

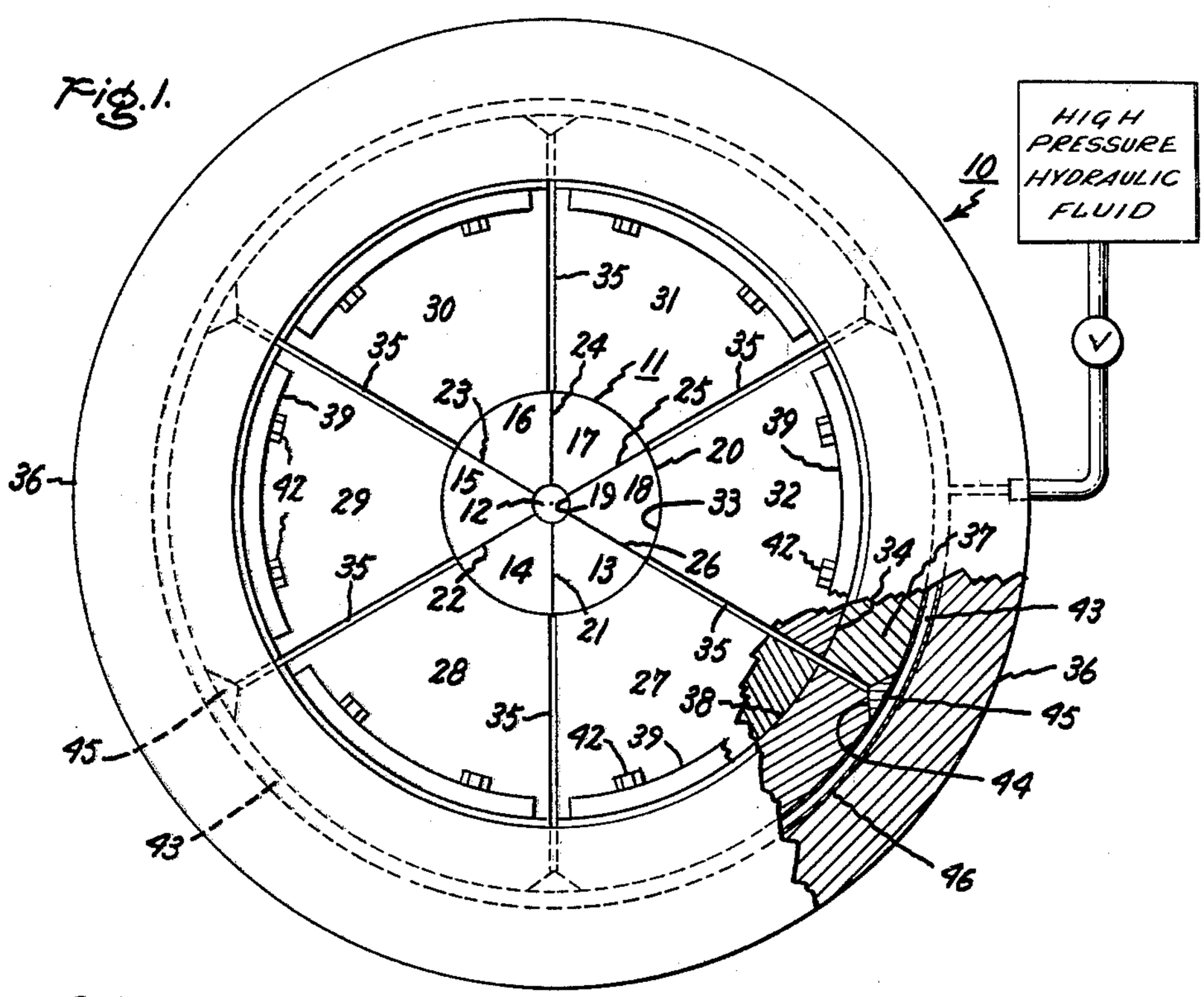
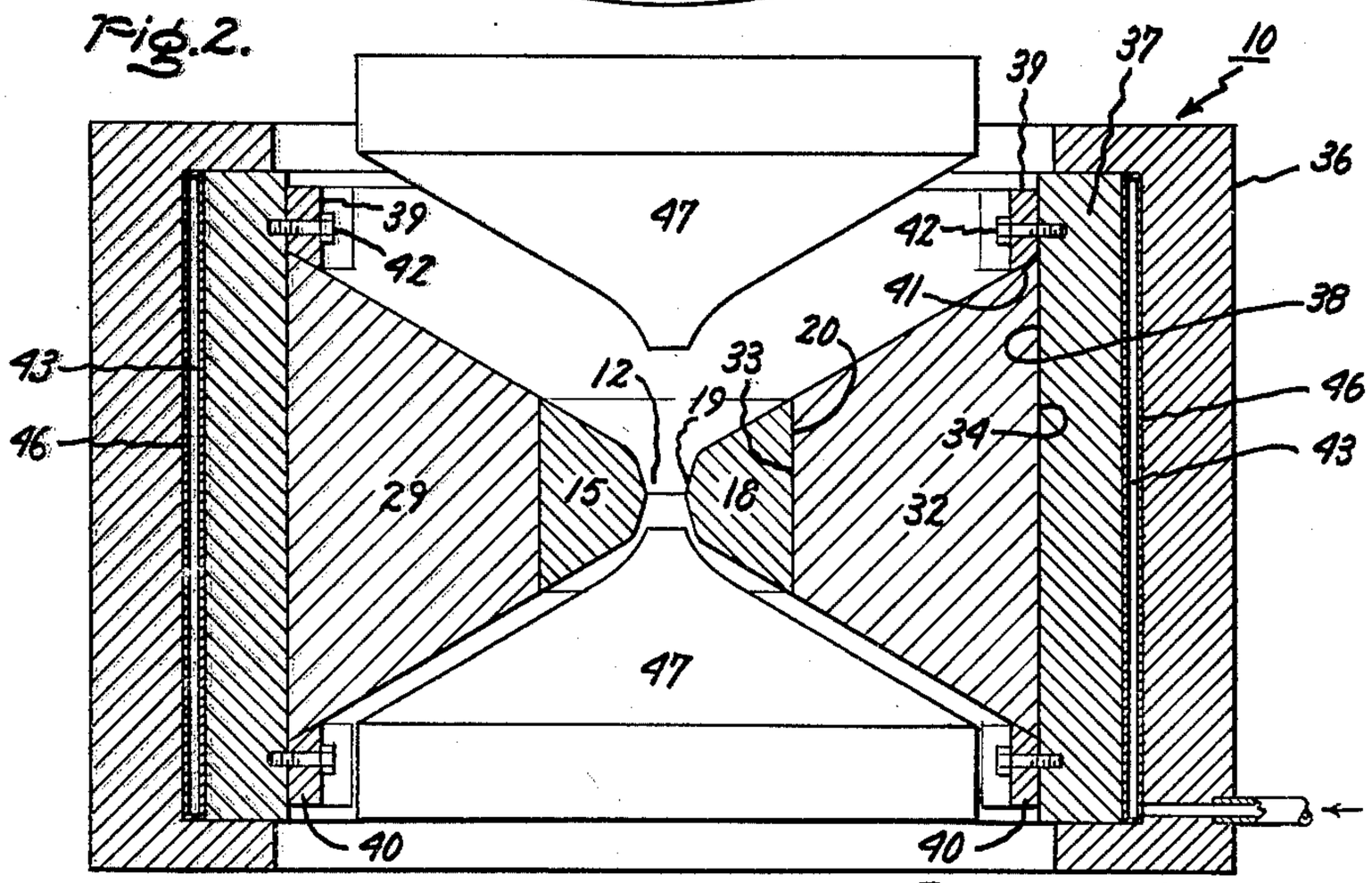


Fig. 2.



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HIGH PRESSURE DIE

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This invention relates to a high pressure die assembly and more particularly to an annular belt or die assembly utilized in high pressure apparatus where the die member of the assembly comprises a plurality of segments.

A high pressure high temperature apparatus utilizing a die member is disclosed in U.S. Patent 2,941,248—Hall. Briefly described, the Hall disclosure relates to a high pressure apparatus which includes a pair of tapered punches mounted in opposite, opposed, and spaced apart relationship, and an annular die member, having a tapered opening therethrough, positioned concentrically therebetween. Relative motion between the opposed punches permits the tapered punches to move into the tapered opening of the annular die member to compress a specimen material therein to high pressures. A gasket member is employed between the punches and the die member. There is also disclosed in the aforementioned patent the methods of assembly of the die member, the materials of construction, and the preferred use thereof. More particularly, the die assembly comprises an annular die member of a very hard material, such as cemented carbide, having a convergent divergent coaxial opening therethrough. This die member is in turn surrounded by a plurality of press fitted hard steel binding rings for increased strength purposes. The combination of the flared or converging diverging opening, the materials utilized, and the binding rings, aids in preventing failure from circumferential hoop stresses or stress in the lateral direction in the die. With the use of such a high pressure, high temperature apparatus for ever increasing higher pressures and higher temperatures, it has been found that certain problems are encountered. In one instance, as to be expected, over-pressures result in failure of either the die assembly, the punches, or both. Repetitive operation near the limits of design stress effects deformation in the die in the form of stretching of the opening leading to failure. In another instance, for larger dies a particular problem relates to the difficulty of manufacturing large pieces of high strength materials, such as the cemented carbides.

It is thus an object of this invention to provide an improved die assembly for a high pressure, high temperature apparatus.

It is another object of this invention to provide radial constricting means for a die member in a high pressure, high temperature apparatus.

It is yet another object of this invention to provide a segmental die in a die assembly for high pressure high temperature apparatus.

It is another object of this invention to provide a segmental die member with additional segmental constricting means applied thereto to strengthen the die member for high pressure, high temperature apparatus.

Briefly described, a preferred form of this invention includes an annular die member having a convergent divergent aperture therethrough which comprises a plurality of circumferentially positioned equal segments in contiguous lateral relationship to each other. Additionally, this die member is surrounded by a series of outer circumferentially spaced additional segments which bear radially inward upon the inner segments. Surrounding the entire assembly thus defined, is constricting means which provide radially inwardly directed forces to maintain all the segmented portions in adjacent contiguous relationship.

This invention will be better understood when taken in connection with the following description and the drawing in which:

FIG. 1 is a top sectional view of one preferred form of the belt apparatus of this invention; and

FIG. 2 is a cross sectional elevational view of the invention as described in FIG. 1.

Referring now to FIG. 1, there is illustrated a belt or die assembly **10** in accordance with a preferred form of this invention. Assembly **10** includes a central die member **11** comprising a plurality of circumferentially spaced equal segments which interfit to define a convergent divergent opening **12** therethrough. In one form of this invention, die member **11** is divided into six equal wedge shaped segments **13**, **14**, **15**, **16**, **17** and **18** with each segment subtending an angle of 60°. Cemented carbides and very hard tool steels are preferred materials for the mentioned segments. Each segment, taking for example segment **18**, includes a smaller frontal or inner surface **19** defining a portion of the opening **12** and a larger or outer rear surface **20**. The assembly of segments also defines adjacent contiguous surfaces **21**, **22**, **23**, **24**, **25** and **26** which are smoothly fitted. The arrangement defines an annular die member having a convergent divergent opening therethrough. The die member is positioned between opposed punches of a high pressure apparatus as described so that the punches may move into the opening **12** to compress a specimen therein. The shape of the opening **12** determines generally the shape of the punches to be employed. Thus, the opening may be varied in shape to accommodate different shaped punches such as a pyramid, trapezoid, etc. However, a preferred punch configuration is that of a frustoconical configuration as described in the aforementioned Hall patent.

Die member **11** is laterally surrounded by a plurality of additional circumferentially spaced ram segments which define an opening in which die member **11** is positioned. In one form of this invention six ram segments **27**, **28**, **29**, **30**, **31**, and **32** are employed. Each ram segment, taking for example ram segment **32**, includes an inner smaller surface **33** and an outer larger surface **34**. In positioning the ram segments in their operative relationship as illustrated, the frontal surfaces of the rams for example surface **33** of ram segment **32** engages the rear surface for example **20** of die segment **18**. One preferred arrangement is, as illustrated in FIG. 1, where the die segments and the ram segments are in concentric relationship to each other. However, one inner surface of a ram segment may engage a pair of outer surfaces of a die segment. The engaging surfaces are illustrated as arcuate but may have various configurations suitable for aligning or pressure transmitting purposes.

Since the ram segments are adapted to have some radially inward movement if necessary, or some movement for alignment, their subtended angle is also 60° however on a shorter radius. In this manner a gap or slot **35** is defined between each ram member and the ram members become movable radially. The slot also minimizes the necessity for close tolerance machining of the ram segments. In the assembly as illustrated, a radial inward pressure applied to the rear surfaces **34** of the ram segments **27**, **28**, **29**, **30**, **31**, and **32** is multiplied to a greater pressure at the surfaces between the die segments and the ram segments and also at the frontal surfaces **19** of the die segments defining the aperture **12**. Various means may be utilized in order to provide this pressure. One preferred arrangement is that as illustrated in FIG. 2.

Referring now to FIG. 2, the illustrated belt assembly

10 includes an annular abutment member 36 having a channel cross section and which is utilized as a cylinder for a piston cylinder arrangement. The pistons for this piston cylinder arrangement are arcuate sections 37, one for each of the ram segments 27, 28, 29, 30, 31, and 32. These arcuate sections 37 have inner surfaces 38 which mate with outer surfaces 34 of the rams segments 27, 28, 29, 30, 31, and 32. Their substended angle is the same as the subtended angle of the ram segments, i.e., 60°. Each ram segment is attached to its piston segment by suitable means such as for example by means of a pair of clamping arcs 39 and 40. Since the ram segments taper or slope inwardly towards the opening 12 the clamping arcs also have tapered engaging surfaces 41. Thus, the provision of screws 42 passing through arcs 39 and into piston sections 37 support the ram segments and pistons as a unitary assembly. The ram and piston segments are then positioned in cylinder member 36 as illustrated in FIGS. 1 and 2 and define an annular hydraulic pressure zone 43 between the pistons 37 and cylinder member 36.

One method of assembly includes placing for example five ram piston units in cylinder member 36 and then to place the remaining piston in cylinder 36. The remaining piston may be in two sections to facilitate insertion. Next, the ram segments are attached to the pistons. A suitable slight double taper on the inner surfaces 33 of the ram segments and a complemental taper on the outer surfaces 20 of the die segments maintain the die assembly 11 in position.

To provide sealing of slots 35, each of the pistons 37 is chamfered at their opposed surfaces to define wedge openings 44 (FIG. 1) therebetween. Each wedge opening is fitted with a wedge shaped filler member 45 for sealing purposes. Sealing rings or members may be employed between wedge members 45 and the surfaces of the wedge openings 44, and between pistons 37 and cylinder 36, if desirable. Alternately, the volume 43 is fitted with an annular flexible tube member 46 wherein a suitable high pressure fluid is introduced.

In the operation of this invetnion the required ram motion is very small, little more than required to compensate for the elastic deformation of the apparatus. It has been observed that the inside diameter of the die increases during use and that when this increase amounts to about 0.030 inch for any size die so far use, the die fails, usually by severe radial cracking and spalling. The interior portions of the die which are usually of cemented carbide materials indicate repetitive plastic deformation beyond the usual 0.1 percent strain normally tolerated by the kinds of cemented carbides employed. This deformation sets a limit upon the useful lifetime of the die and the pressure which it can contain without immediate failure. In the practice of this invention the die assembly is positioned between a pair of oppositely spaced apart tapered or frustoconical punch members 47 as in the apparatus of the aforementioned Hall patent. The assembly is then positioned for example, between the platens of a hydraulics press for relative movement between the punch members to cause progression of the punch members 47 into the convergent divergent opening 12 to compress a material therein to high pressures. During this operation the die assembly is plastically deformed and attempts to increase in its circumferential and radial dimensions. Also, during operation, high pressure hydraulic fluid is introduced into the cylinder assembly into volume 43 which forces ram segments 27, 28, 29, 30, 31, and 32 radially inwardly, or prevents radially outward movement of the die. Therefore, the deformation of the belt or die assembly is controlled within prescribed limits. Furthermore, the slight movement of the assembled parts permitted by the segmental relationship favors better pressure distribution. A preferred practice in the use of the die assembly of this invention is to correlate the force applied to the punches to the force applied to the ram segments. Thus, for example, an increase in punch force from zero to maximum is paralleled by an increase in hydraulic pressure in cylinder 36 from slightly more than zero to a prescribed maximum. This latter prescribed maximum may be that predetermined maximum which will provide a predetermined radial expansion of the die assembly. The operation is further described as including the feature that the die 11 is initially placed under compressive hoop stress and during operation this stress is maintained. Furthermore, the stress between the die segments 13, 14, 15, 16, 17 and 18, at the surfaces 21, 22, 23, 24 and 25, is maintained greater than the pressure being generated in reaction volume 12.

The practice of this invention may include the use of various lubricant or gasket materials. For example, the die segments may be coated with jewelers rouge at surfaces 21, 22, 23, 24, 25 and 26 for high friction or may have a thin sheet gasket therebetween of for example pyrophyllite, talc, etc. The gaps 35 may also be filled with a suitable gasket material.

While a specific method and apparatus in accordance with this invention is described and shown, it is not intended that the invention be limited to the particular description nor to the particular method or apparatus indicated, and it is intended by the appended claims to cover all modifications within the spirit and scope of this invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die assembly having an opening therein into which at least one of said punch members progresses to compress a material, said die assembly comprising in combination:

(*a*) an annular die member,

(*b*) a plurality of ram segments equally circumferentially positioned about and contiguous with the outer perimeter of said annular die member,

(*c*) abutment means extending in a closed curve around the outer perimeter of said ram segments and,

(*d*) means disposed between said abutment means and said ram segments to controllably apply selectively variable force thereto independently of the force effecting relative movement of said opposed punch members and directed radially inwardly of and substantially girding said die member to prevent excessive radial expansion thereof under the radially outwardly directed force generated with said opposed punch members.

2. A high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die assembly having an opening therein into which at least one of said punch members progresses to compress a material, said die assembly comprising in combination:

(*a*) a plurality of die segments interfitting to define a die member having an aperture therein,

(*b*) a plurality of ram segments equally circumferentially positional about and contiguous to the outer perimeter of said annular die member,

(*c*) abutment means extending in a closed curve around the outer perimeter of said ram segments, and

(*d*) means disposed between said abutment means and said ram segments to controllably apply selectively variable force thereto independently of the force effecting relative movement of said opposed punch members and directed radially inwardly of and substantially girding said die member to prevent radial expansion thereof under the radially outwardly directed force generated with said opposed punch members.

3. A high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die assembly having an opening therein into which at least one of said punch members progresses

to compress a specimen material, said die assembly comprising in combination:

(*a*) a plurality of wedge shaped die segments each having an inner smaller surface and an outer larger surface, said segments being positioned with the outer surfaces thereof in the aggregate defining a generally cylindrical face and the inner surfaces thereof defining a centrally-disposed die aperture,

(*b*) a plurality of wedge shaped ram segments equally circumferentially positioned about the assembled die segments, said ram segments having smaller arcuate inner surfaces and larger outer surfaces with the smaller inner surfaces thereof engaging the larger outer surfaces of said wedge shaped die segments,

(*c*) abutment means extending in a closed curve around the outer perimeter of said ram segments, and

(*d*) means disposed between said abutment means and said ram segments to controllably apply selectively variable force thereto independently of the force effecting relative movement of said opposed punch members and directed radially inwardly of and substantially girding said die member segments to prevent excessive radial expansion thereof under the radially outwardly directed force generated with said opposed punch members.

4. The invention as recited in claim 3 wherein at least three die segments and at least three ram segments are employed.

5. A high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die assembly having an opening therein into which at least one of said punch members progresses to compress a specimen material to high pressures, said die assembly comprising in combination:

(*a*) a plurality of wedge die segments interfitting to define an annular die member having an aperture therein,

(*b*) said wedge shaped die segments having smaller inner surfaces and larger outer surfaces and interfitting so that the smaller inner surfaces in the aggregate define the said aperture,

(*c*) a plurality of wedge shaped ram segments equal in number to said die segments and circumferentially positioned about said annular die member,

(*d*) said wedge shaped ram segments having smaller inner surfaces and larger outer surfaces with the smaller inner surfaces bearing against the larger outer surfaces of said wedge shaped die segments,

(*e*) the subtended angle of each of said wedge shaped ram segments being similar to the subtended angle of said wedge shaped die segments with the projected apex of each ram segment being offset radially from the projected apex of a companion die segment as center so that a gap is defined between adjacent wedge shaped ram segments,

(*f*) each of said ram segments being positioned relative to its companion die segment with the plane bisecting the subtended angle of the ram segment lying in a common plane with the plane bisecting the subtended angle of the companion die segment,

(*g*) abutment means extending in a closed curve around the outer perimeter of said ram segments, and

(*h*) means disposed between said abutment means and said ram segments to controllably apply selectively variable force thereto independently of the force effecting relative movement of said opposed punch members and directed radially inwardly of and substantially girding said die segments to prevent excessive radial expansion thereof under the radially outwardly directed force generated by said opposed punch members.

6. The invention as recited in claim 5 wherein said force applying means comprises a hydraulic piston cylinder assembly operatively connected to said ram segments.

7. The invention as recited in claim 5 wherein said force applying means include piston means on the larger outer surfaces of said ram segments and means to selectively introduce high pressure hydraulic fluid between said piston means and the abutment means to controllably provide the radially constricting force to said die assembly.

8. A high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die assembly having an opening therein into which at least one of said punch members progresses to compress a material to high pressures, said die assembly comprising in combination:

(*a*) a plurality of wedge shaped die segments positioned in interfitting relationship to define an annular die member having a convergent divergent opening therethrough,

(*b*) said die segments having smaller inner arcuate surfaces and larger outer arcuate surfaces with said inner surfaces in the aggregate defining said convergent divergent aperture,

(*c*) a plurality of wedge shaped ram segments equal in number to said die segments and circumferentially positioned around said die member,

(*d*) each of said ram segments having an inner arcuate smaller surface and an outer larger surface,

(*e*) each of said ram segments being positioned relative to a companion die segment with the plane bisecting the subtended angle of the ram segment lying in a common plane with the plane bisecting the subtended angle of the companion die segment with the smaller inner arcuate surface of said ram members engaging the larger outer surface of said die segment,

(*f*) the subtended angle of each of said ram segments being the same as the subtended angle of each of said die segments with the projected apex of each ram segment being offset radially from the projected apex of its companion die segment as center so that a gap is defined between adjacent individual ram segments,

(*g*) a portion of the larger outer surface of each of said ram segments defining an arcuate piston,

(*h*) an annular cylindrical ring of channel cross-section surrounding said ram segments to receive said piston portions in a piston-cylinder arrangement,

(*i*) a flexible tube member disposed between said ring and the arcuate pistons, and

(*j*) means connected to said tube member to selectively admit high pressure hydraulic fluid therein whereby a variable radially constricting hydraulic force may be controllably applied to said die assembly independently of the force for effecting relative movement of said opposed punch members to cause said ram segments to bear against said die segments to restrict radial expansion thereof under the radially outwardly directed force generated by said opposed punch members.

9. In a high pressure apparatus having a pair of opposed punch members relatively movable for coaction together with a die apparatus having a convergent divergent aperture therethrough into which at least one of said punch members progresses to generate high pressures in a specimen material disposed therein, said die apparatus having means disposed about the perimeter thereof for controllably applying selectively variable force thereto directed radially inward to minimize radial expansion of said die apparatus during operation, the method comprising, applying less than maximum inwardly-directed force to said die apparatus, independently of the force for effecting relative movement of said opposed punch members, compressing the specimen material in said die apparatus, and independently increasing the in-

wardly directed force to the degree required to limit expansion of said aperture at high pressures.

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