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AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,
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DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT,
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UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ,
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(54) Title: IMPROVED BULLET SEAL

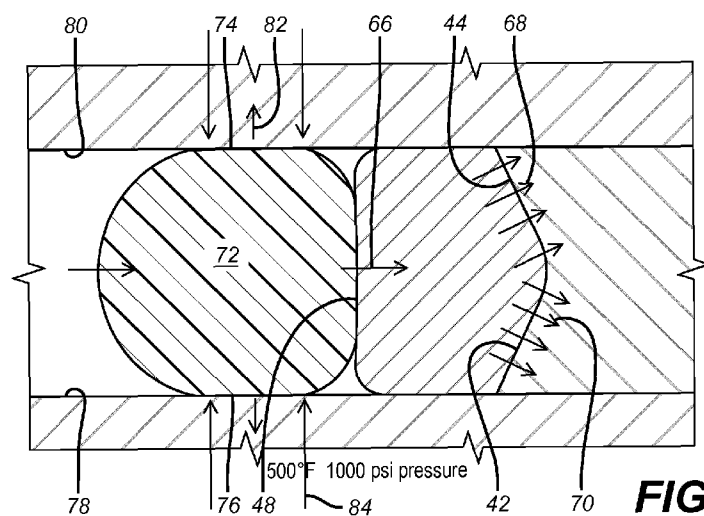


FIG. 19

(57) Abstract: A bullet seal tail section is reconfigured from a groove flanked by tapered surfaces that engage an o-ring seal to an end design on the bullet seal that has tapered surfaces that meet at a first angle and a pin with an end taper that has counterpart surfaces that slope more with respect to an axis of the seal. The o-ring is on an opposite side of the pin from the tail of the bullet seal. Large differentials evenly push out the bullet seal tail and uniformly compress the o-ring for a larger contact area at greater contact force than previously known. The o-ring is reformed into a generally quadrilateral shape from round due to the applied loading.

IMPROVED BULLET SEAL

Inventors: Siby Varghese and Goang-Ding Shyu

FIELD OF THE INVENTION

[0001] The field of the invention is bullet seals and more particularly mirror image assemblies separated by an o-ring that abuts a tail of the bullet seal.

BACKGROUND OF THE INVENTION

[0002] FIGS. 1-8 depict the prior art design starting with the no differential pressure condition and concluding with loading to 20,000 PSI in FIG. 7. Opposed bullet seal segments **10** and **12** are shown with their respective tail ends **14** and **16** separated by o-ring **18**. In the traditional manner each of the tail ends **14** and **16** define a groove **20** and **22** respectively. Tapered surfaces **24** and **26** extend on opposed sides of groove **22**. Since the designs are mirror image only one will be described. At a loading of 250 PSI in FIG. 2 the gaps have closed and the groove **22** is still intact. However, at 1250 PSI as shown in FIG. 3 the groove **22** has collapsed. Thereafter, as shown in FIG. 4 the o-ring **18** begins to more noticeably distort when the loading is increased to 4,000 PSI. The engagement surface **28** of the o-ring **18** starts to decrease as the loading increases in FIGS. 5-7 from 10,000 PSI to 15,000 PSI in FIG. 6 to the level of 20,000 PSI in FIG. 8. The o-ring **18** more visibly distorts out of round as seen in this progression of greater loading. As a result, there is an uneven length of engagement of the sealing surface **30**. FIG. 8 illustrates why this happens. Arrow **32** is a horizontal force component acting at a distance **34** from axis **36**. This moment causes the groove such as **22** to collapse as shown in the other FIGS. The fact that bullet seals typically operate at elevated temperatures such as about 500 degrees F. only accentuates this effect. What results is a narrow band of peak sealing force at the contact location shown in the circle in FIG. 9. FIG. 10 is a mathematical model illustrating the same contact location and pressure differential and temperature as FIG. 9 but showing computed stress values. These FIGS. Will later be compared against the present invention to illustrate the point that at comparable pressure and temperature loading conditions a larger contact area occurs with the present invention and a higher contact force is attained to enhance sealing integrity.

[0003] Those skilled in the art will realize that the prior bullet seal design has been used for decades under the assumption that the interaction of the o-ring seal **18** with the tapered surfaces **24** and **26** will splay the end positions apart into the surrounding sealing surfaces on the inside diameter and the outside diameter. In fact, the groove was made wider to try to get this desired motion in the prior design. Studies have shown that rather than getting the desired effect of the groove, its presence hastened collapse of the sides that define the groove into the groove, which also drew the end on the exterior surface of the bullet seal away from the outer sealing surface or at least reduced the contact stress rather than enhancing it as shown in the present invention.

[0004] Those skilled in the art will appreciate that the present invention attains greater contact loading by in essence getting rid of the groove between sloping surfaces and inserting a pin that has sloping surfaces that are at slightly greater angles than the end of the bullet seal. The back of the pin that faces the o-ring is preferably a radial surface. On high loading the o-ring deforms symmetrically with a longer length of engagement of the sealing surface with a higher contact force than the prior design of FIGS 1-10. The loading at the tail end of the bullet seal is more uniformly distributed which contributes to minimizing or preventing separation of the contact surface from the opposing sealing surface. The offset of the angles on the pin from the opposing tapers at the end of the bullet contribute to the reduction or prevention of separation of the tail end of the bullet seal from the adjacent sealing surface. The offset angles in the range of 1-10 degrees with about 5 degrees preferred results in uniformly pushing the tail end of the bullet seal resulting in doubling the length of the contact area from the prior design. These and other features of the present invention will be more readily apparent to those skilled in the art from a review of the detailed description of the preferred embodiment and the associated drawings while recognizing that the full scope of the invention is to be determined by the appended claims.

SUMMARY OF THE INVENTION

[0005] A bullet seal tail section is reconfigured from a groove flanked by tapered surfaces that engage an o-ring seal to an end design on the bullet seal that has tapered surfaces that meet at a first angle and a pin with an end taper

that has counterpart surfaces that slope more with respect to an axis of the seal. The o-ring is on an opposite side of the pin from the tail of the bullet seal. Large differentials evenly push out the bullet seal tail and uniformly compress the o-ring for a larger contact area at greater contact force than previously known. The o-ring is reformed into a generally quadrilateral shape from round due to the applied loading.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0006]** FIG. 1 is a section view of a prior art design in the run in condition;
- [0007]** FIG. 2 is the view of FIG. 1 subjected to 250 PSI differential pressure;
- [0008]** FIG. 3 is the view of FIG. 2 subjected to 1250 PSI differential pressure;
- [0009]** FIG. 4 is the view of FIG. 3 subjected to 4,000 PSI differential pressure;
- [0010]** FIG. 5 is the view of FIG. 4 subjected to 10,000 PSI differential pressure;
- [0011]** FIG. 6 is the view of FIG. 5 subjected to 15,000 PSI differential pressure;
- [0012]** FIG. 7 is the view of FIG. 6 subjected to 20,000 PSI differential pressure;
- [0013]** FIG. 8 is the view of FIG. 1 subjected to 100 PSI differential pressure and showing force distribution;
- [0014]** FIG. 9 is the view of FIG. 1 subjected to 20,000 PSI differential pressure and showing the reduced engagement length for sealing;
- [0015]** FIG. 10 is the view of FIG. 9 subjected to 20,000 PSI differential pressure showing the decreased zone of maximum contact stress;
- [0016]** FIG. 11 is the design of the present invention subjected to 0 PSI pressure differential;
- [0017]** FIG. 12 is the design of FIG. 11 subjected to 250 PSI differential pressure;
- [0018]** FIG. 13 is the design of FIG. 12 subjected to 1250 PSI differential pressure;
- [0019]** FIG. 14 is the design of FIG. 13 subjected to 4,000 PSI differential pressure;

[0020] FIG. 15 is the design of FIG. 14 subjected to 10,000 PSI differential pressure;

[0021] FIG. 16 is the design of FIG. 15 subjected to 15,000 PSI differential pressure;

[0022] FIG. 17 is the design of FIG. 16 subjected to 20,000 PSI differential pressure;

[0023] FIG. 18 is a close up view of the seal of the present invention showing the angular difference between the pin and the tail of the adjacent seal at 100 PSI loading;

[0024] FIG. 19 is the view of FIG. 18 at 1000 PSI loading and showing the even force distribution on the tail of the seal;

[0025] FIG. 20 shows o-ring deformation at 15,000 PSI loading developing length of sealing engagement;

[0026] FIG. 21 is the view of FIG. 20 under 20,000 PSI loading;

[0027] FIG. 22 shows contact stresses and length of engagement at 20,000 PSI for the view of FIG. 21.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0028] Referring to FIGS. 11-17 it can be seen that the bullet seal **40** has been redesigned to eliminate the deep groove with parallel walls in favor of a more open chevron shape which is defined by end walls **42** and **44**. An adjacent pin **46** has a flat back **48** that faces the o-ring **50** and is preferably perpendicular to the axis **52** as better seen in FIG. 18. Surface **48** may have a slight slope or can be formed of multiple surfaces or an arcuate shape without departing from the scope of the invention. Included angle **54** is smaller than included angle **56** formed by surfaces **58** and **60** on the pentagonal shaped pin **62** leaving a gap **64** between the pin **62** and the bullet seal **40** at axis **52** under low load conditions such as 100 PSI that is illustrated in FIG. 18. This angular difference in opposing surfaces that is preferably in the order of about 5 degrees but can vary between 1 and 10 degrees ultimately accounts for even loading on surfaces **42** and **44** in response to a radial force represented by arrow **66** branches into components represented by arrow groups **68** and **70** to result in closing the gap **64** and uniform outward loading to enhance contact stress and contact area. At the same time with the differential at only 1000 PSI note how the o-ring **72** has taken the shape of surface **48** of the pin **62**. The o-

ring **72** has also started to form an enlarging contact surface **74** and **76** on opposed sealing surfaces **78** and **80**. Arrows **82** and **84** respectively represent the loading force from the o-ring **72** and the reaction force from the opposing sealing surfaces. FIGS. 20-22 show what happens at higher pressure loading. The contact stress in FIG. 22 is somewhat higher than the known design shown in FIG. 10 and the contact area is dramatically larger in the order of twice as large. What this means is the present invention results in more reliable sealing as the contact area has doubled for identical loading conditions of 500 degrees F and 20,000 PSI.

[0029] The performance improvement comes from one or more new features not found in the old design. The deep groove with parallel walls such as **20** or **22** has been eliminated in favor of a more broadly open chevron shape using surfaces **40** and **42**. There is now a pin with leading surfaces **58** and **60** preferably at a slightly greater angle from the axis **52** than opposing surfaces **42** and **44** on the bullet seal **40**. This provides uniform outward loading as shown in FIG. 19 and prevents or minimizes the collapsing of the bullet seal which would otherwise reduce contact sealing area.

[0030] FIGS. 11-17 illustrate the mirror image layout with an o-ring **90** straddled by mirror image pins **92** and **94** and further out the opposed bullet seals **40** and **96**. As the loading at 500 degrees F increases the o-ring **90** is reformed into more of a quadrilateral or square shape confined as it is on radially opposite sides by sealing surfaces **98** and **100**. In the axial direction the confining surfaces are **102** and **104** of pins **92** and **94** respectively. Here the symmetrical o-ring deformation contributes to a greater sealing contact area when the differential pressures get to the level of 20,000 PSI as illustrated in FIG. 17.

[0031] Those skilled in the art will also appreciate that the pins **92** and **94** are annular ring shapes as are the bullet seals such as **40** and of course the o-rings **72** or **90**. All fit in an annular gap defined by opposed circular surfaces such as **98** and **100**. An assembly can be a mirror image as in FIGS. 11-17 or it can be one directional such as FIGS. 18-21.

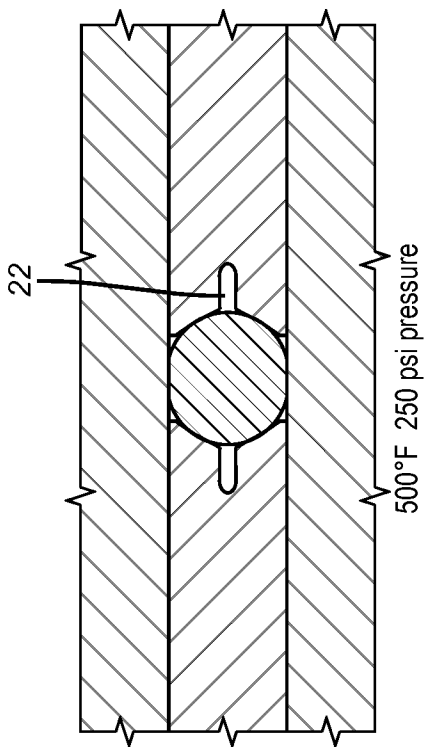
[0032] The above description is illustrative of the preferred embodiment and many modifications may be made by those skilled in the art without

departing from the invention whose scope is to be determined from the literal and equivalent scope of the claims below:

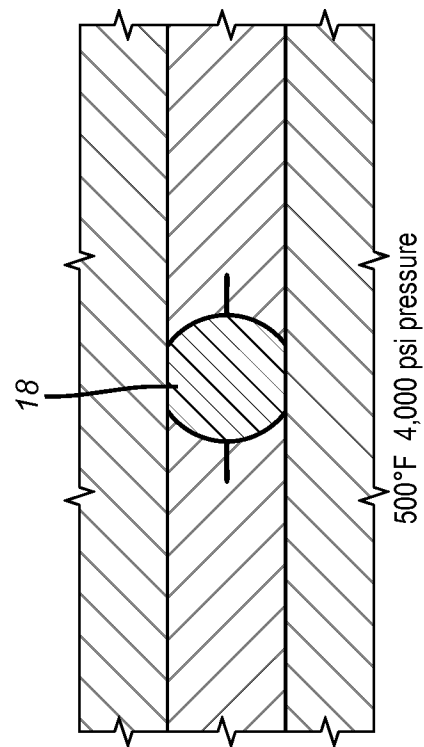
We claim:

1. A bullet seal assembly for an annular space between opposed sealing surfaces, comprising:
 - at least one bullet seal member having a tail end comprising adjacent bullet seal surfaces;
 - an o-ring;
 - at least one pin disposed between said o-ring and said tail end to transmit differential pressure loading on said o-ring to said bullet seal adjacent surfaces in a manner to move said bullet seal adjacent surfaces to the opposed sealing surfaces.
2. The assembly of claim 1, wherein:
 - said pin comprises adjacent pin surfaces opposed to said adjacent bullet seal surfaces and sloping at a different angle with respect to an axis of said bullet seal than said adjacent bullet seal surfaces.
3. The assembly of claim 2, wherein:
 - said slope of said adjacent pin surfaces is greater than said slope of said adjacent bullet seal surfaces.
4. The assembly of claim 3, wherein:
 - the slope difference between said pin adjacent surfaces and said bullet seal adjacent surfaces is in the range of 1-10 degrees.
5. The assembly of claim 4, wherein:
 - the slope difference between said pin adjacent surfaces and said bullet seal adjacent surfaces is about 5 degrees.
6. The assembly of claim 1, wherein:
 - said pin comprises a radial surface that abuts said o-ring.
7. The assembly of claim 6, wherein:
 - said radial surface is oriented substantially perpendicularly to the axis of said bullet seal.
8. The assembly of claim 1, wherein:
 - said o-ring conforms to the shape of said pin at a contact location therebetween as differential pressure on the assembly is increased.
9. The assembly of claim 1, wherein:
 - said o-ring transforms from a circular shape in section to a quadrilateral shape on increased differential pressure loading.

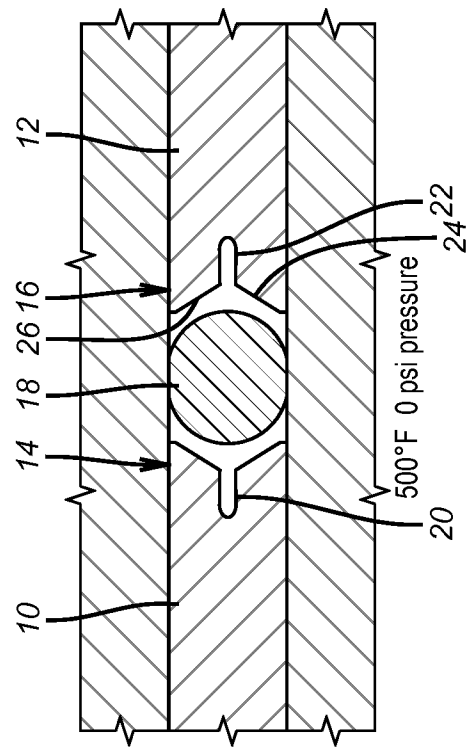
10. The assembly of claim 1, wherein:
said pin has a pentagon shape.
11. The assembly of claim 7, wherein:
said pin comprises adjacent pin surfaces opposed to said adjacent bullet seal surfaces and sloping at a different angle with respect to an axis of said bullet seal than said adjacent bullet seal surfaces.
12. The assembly of claim 1, wherein:
said at least one bullet seal comprises a plurality of bullet seals with said tail ends facing each other;
said at least one pin comprises a plurality of pins oriented in mirror image orientation to each other;
said o-ring is disposed between said pins.
13. The assembly of claim 12, wherein:
said pins present radial surfaces to abut said o-ring.
14. The assembly of claim 13, wherein:
said o-ring deforms on increasing pressure differential acting on the assembly by reconfiguring from a round shape in section toward a quadrilateral shape against said radial surfaces and the opposed sealing surfaces.
15. The assembly of claim 1, wherein:
said bullet seal tail end is formed without an axial groove defined by parallel walls.
16. The assembly of claim 1, wherein:
said pin uniformly distributes load to said adjacent bullet seal surfaces toward said opposed sealing surfaces.
17. The assembly of claim 1, wherein:
said o-ring increases contact with said opposed sealing surfaces as pressure differential on the assembly increases.
18. The assembly of claim 1, wherein:
said o-ring has a larger contact area with the opposed sealing surfaces under equivalent differential pressure loading as a bullet seal with an axial groove formed by parallel walls disposed between tapered peripheral surfaces and an adjacent o-ring.



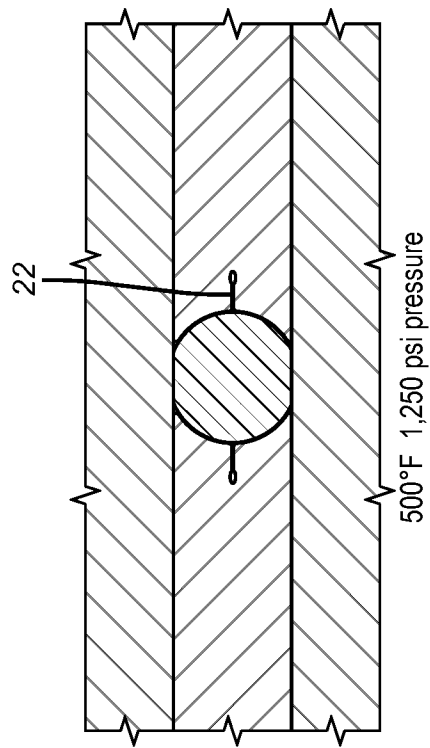
(PRIOR ART)
FIG. 2



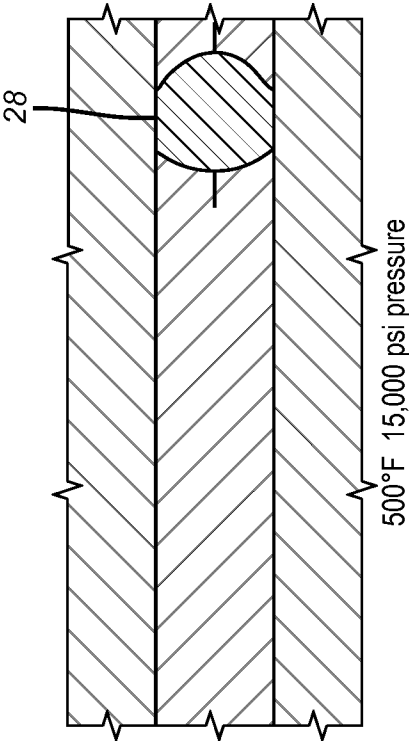
(PRIOR ART)
FIG. 4



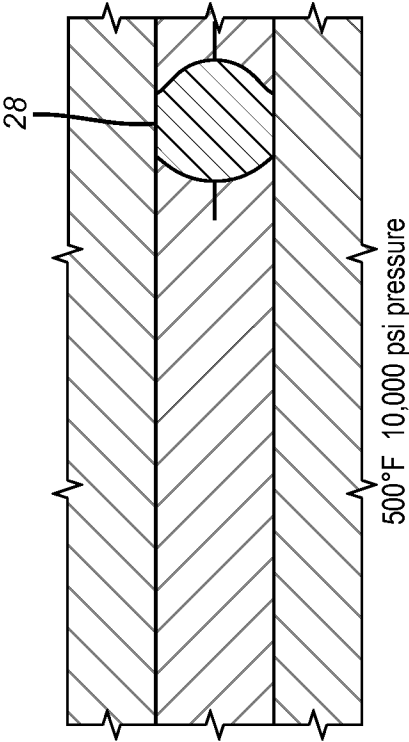
(PRIOR ART)
FIG. 1



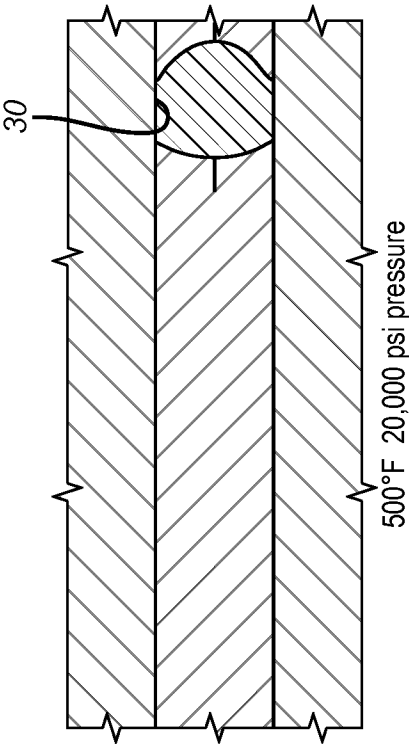
(PRIOR ART)
FIG. 3



(PRIOR ART)
FIG. 6

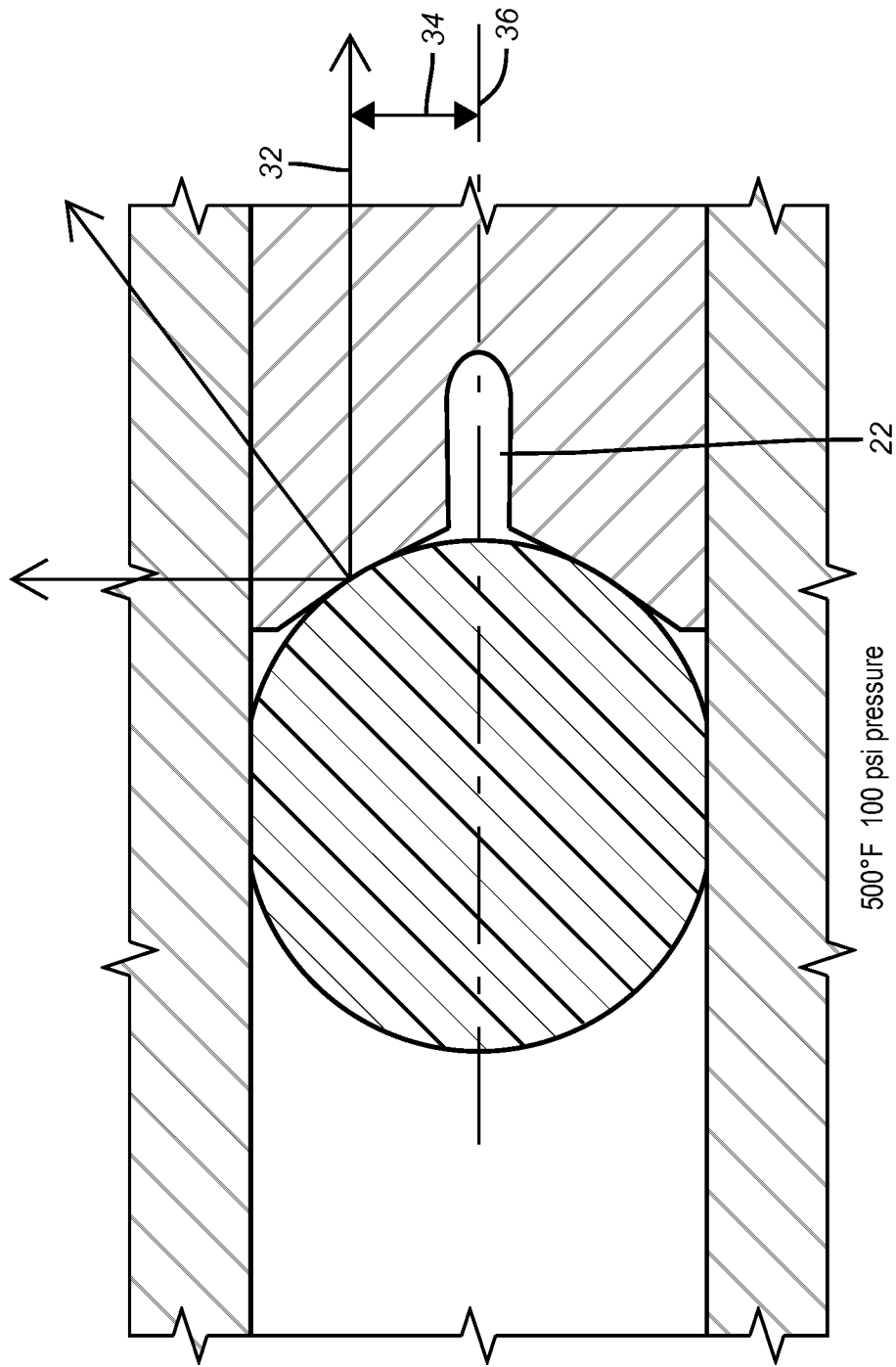


(PRIOR ART)
FIG. 5

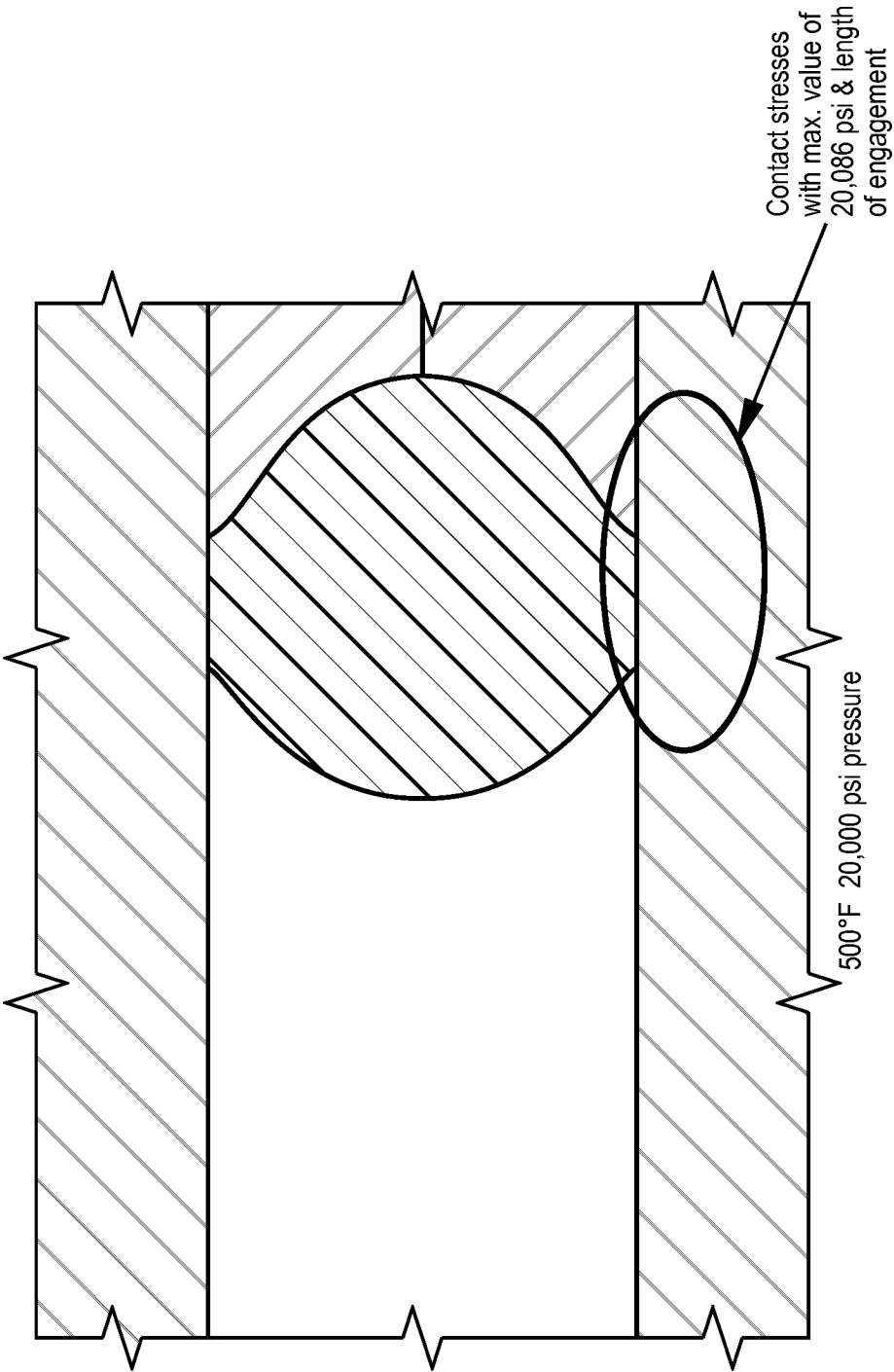


(PRIOR ART)
FIG. 7

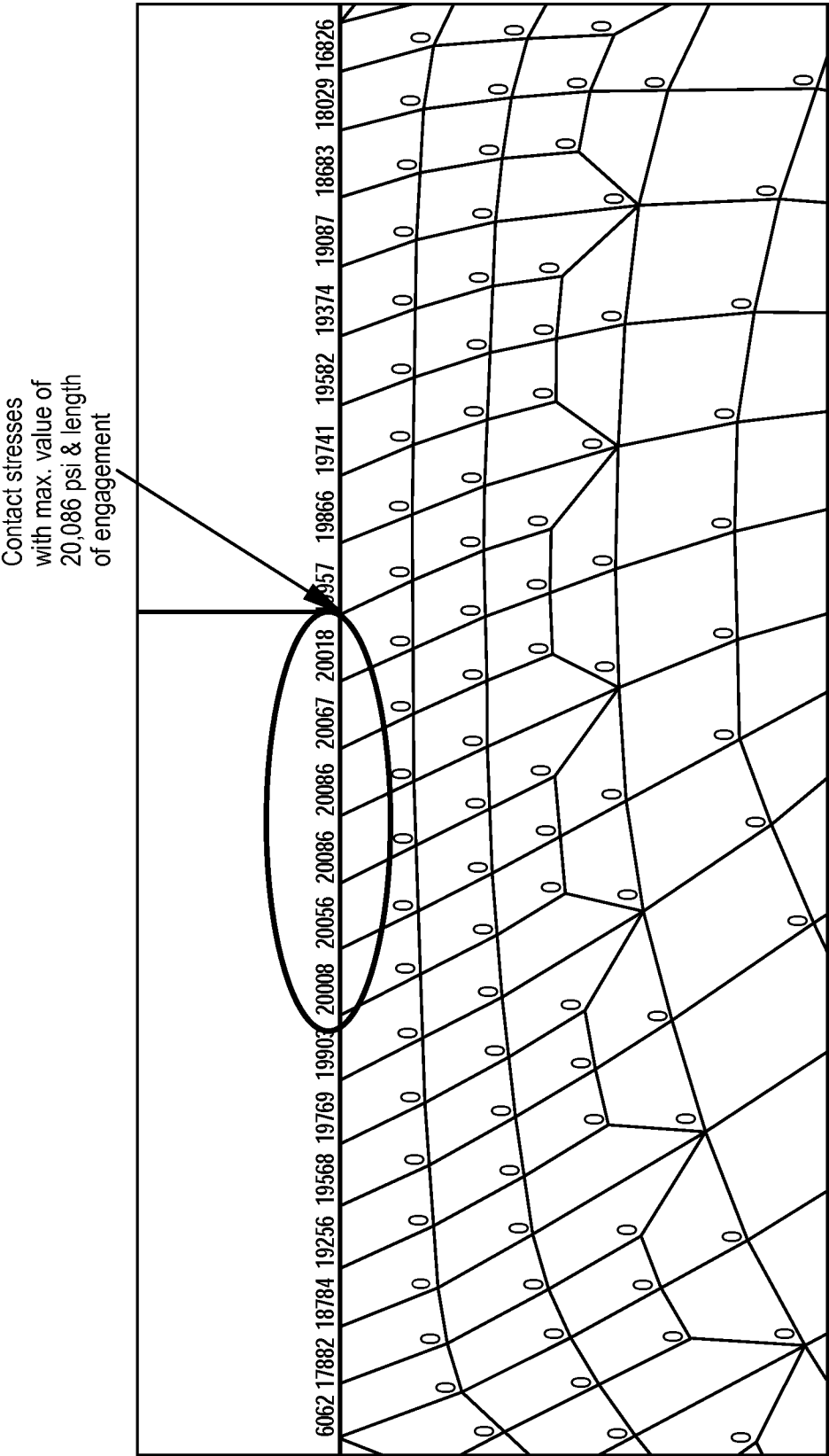
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4/10



(PRIOR ART)
FIG. 9



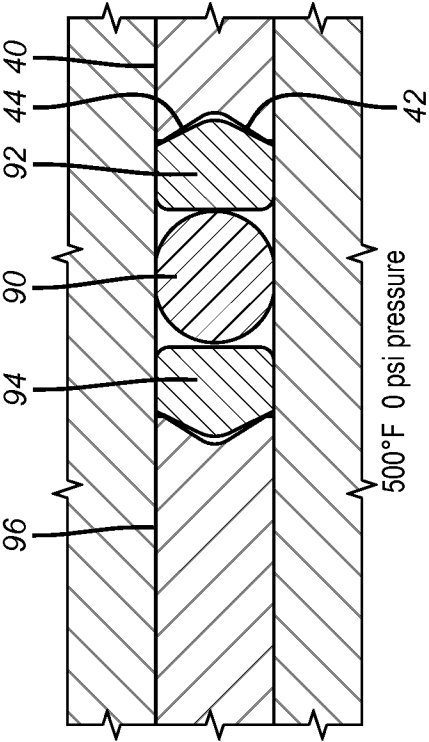


FIG. 11

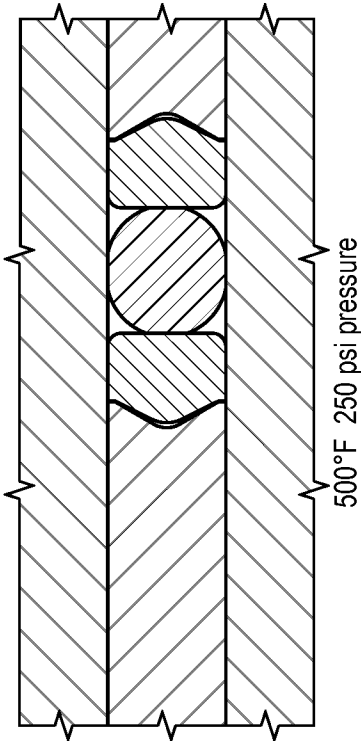


FIG. 12

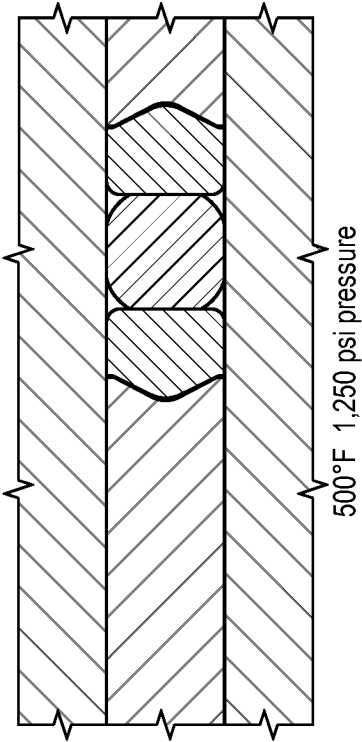


FIG. 13

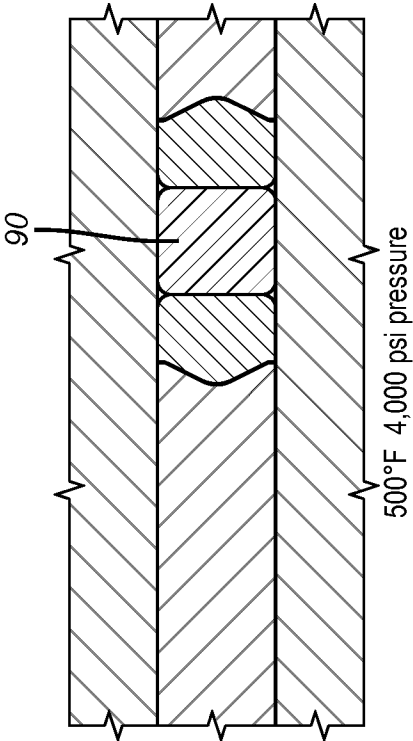


FIG. 14

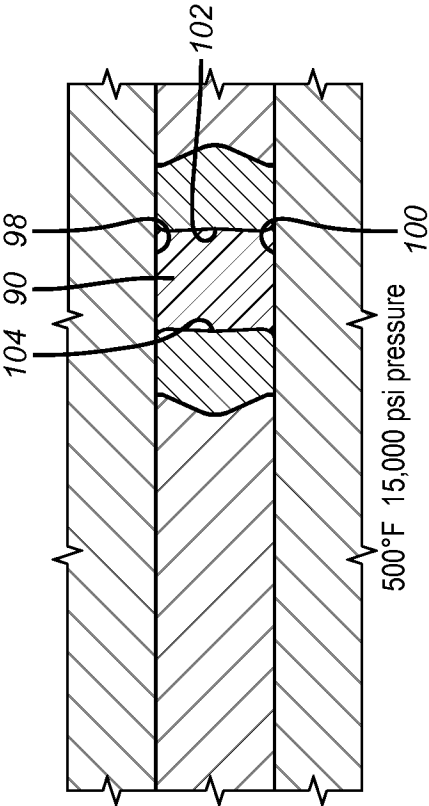


FIG. 16

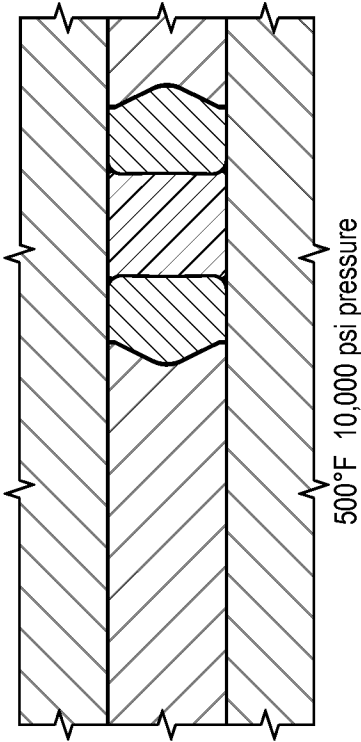


FIG. 15

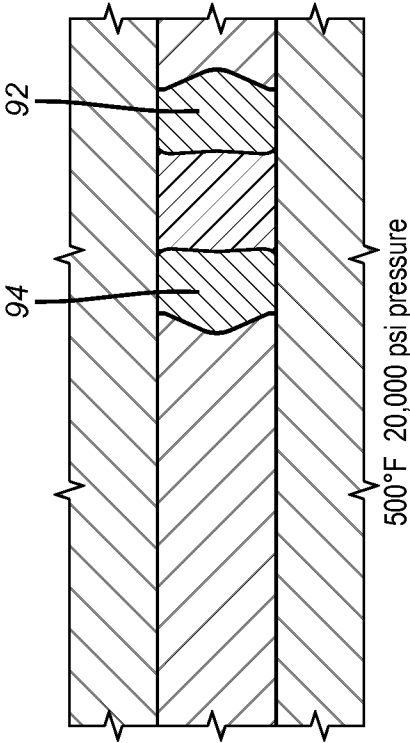


FIG. 17

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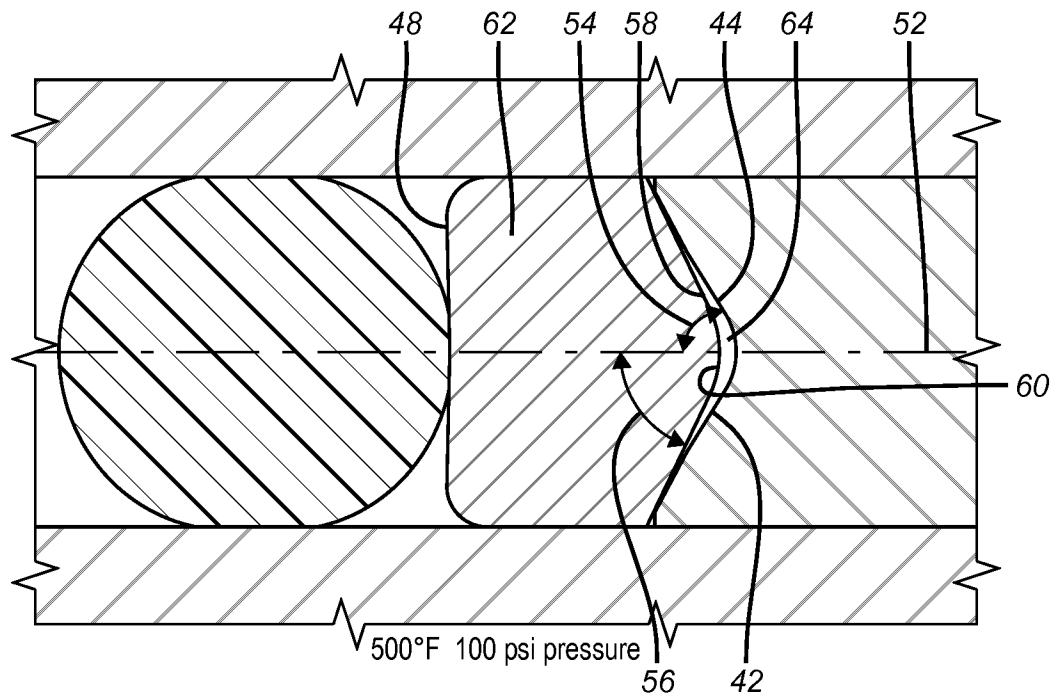


FIG. 18

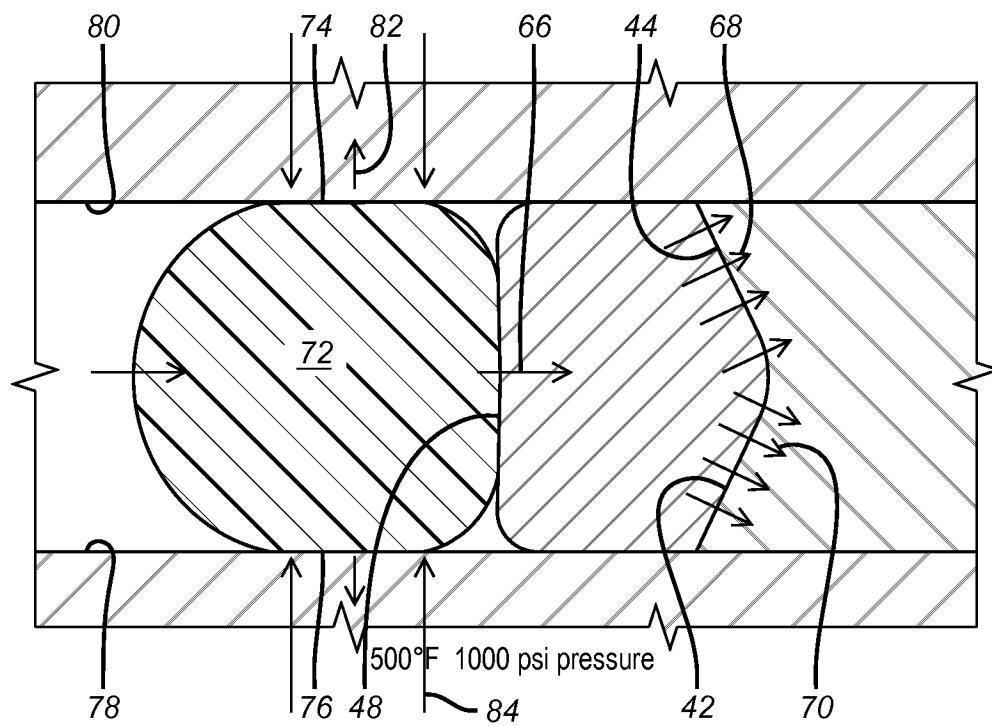


FIG. 19

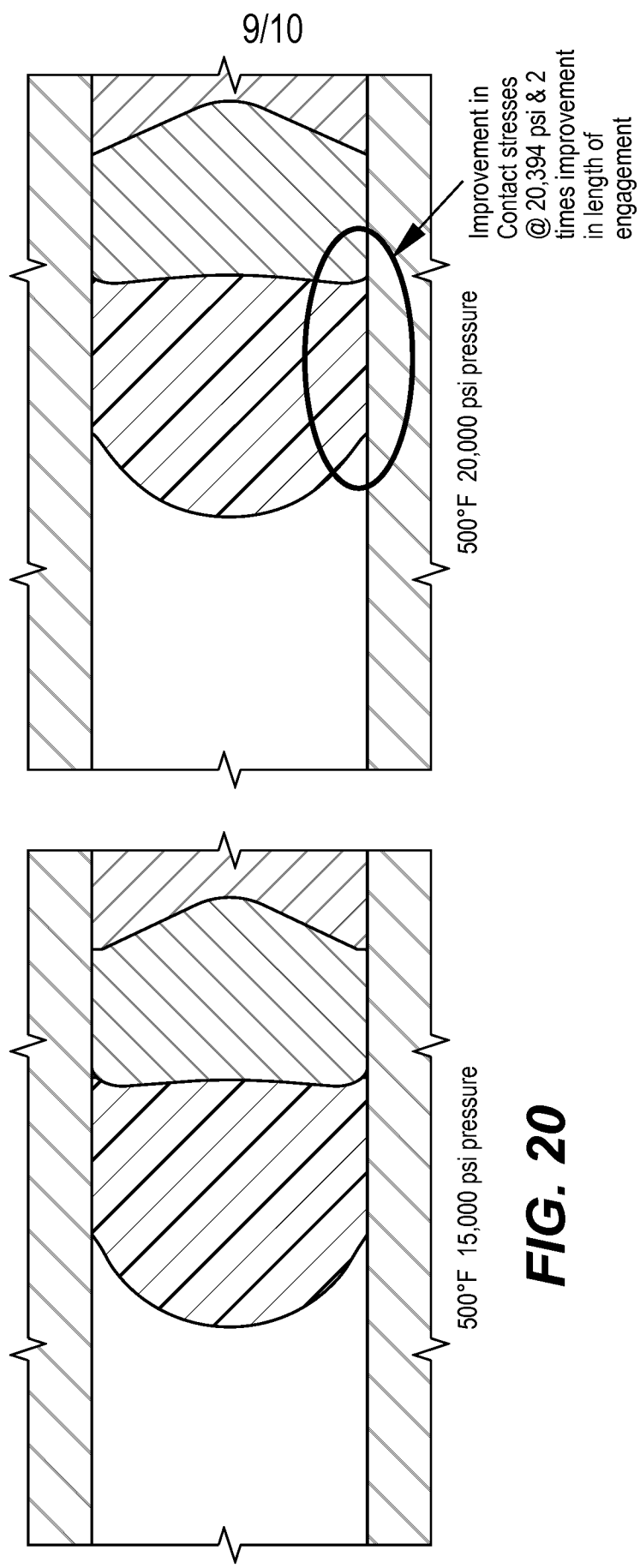


FIG. 20

FIG. 21

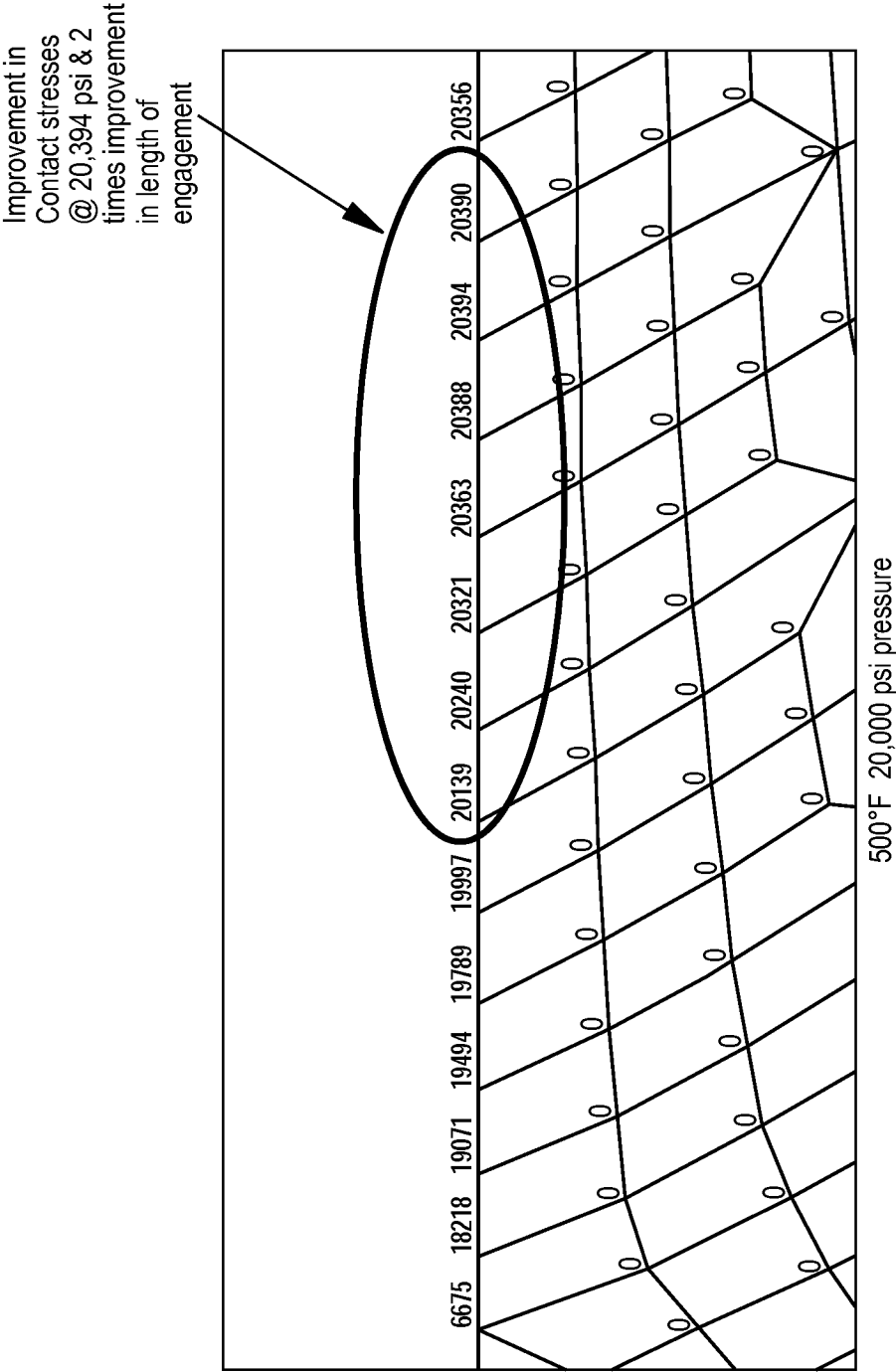


FIG. 22

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/035340

A. CLASSIFICATION OF SUBJECT MATTER F42B 5/067(2006.01)i, F42B 30/00(2006.01)i				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED				
Minimum documentation searched (classification system followed by classification symbols) F42B 5/067; E21B 33/128; F16J 15/28; E21B 33/12; F16J 15/16; F42B 30/00				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Korean utility models and applications for utility models Japanese utility models and applications for utility models				
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) eKOMPASS(KIPO internal) & keywords: bullet seal, pin, o-ring, mirror image, differential pressure, sloping				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
A	US 7779925 B2 (JACOB, JEAN-LUC) 24 August 2010 See column 6, line 36 - column 7, line 52 and figures 1-5.	1-18		
A	US 2006-0066058 A1 (HOLT et al.) 30 March 2006 See paragraphs [0020]-[0021],[0030] and figures 1-4.	1-18		
A	US 5611547 A (BAUGH et al.) 18 March 1997 See column 4, line 35 - column 6, line 2 and figures 1-3.	1-18		
A	WO 2012-121745 A2 (PARKER-HANNIFIN CORPORATION) 13 September 2012 See paragraph [0032] and figures 1-4	1-18		
A	US 7401788 B2 (WILLIAMS et al.) 22 July 2008 See column 2, lines 12-37 and figures 2-3.	1-18		
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; border: none;"> * Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family </td> </tr> </table>			* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family
* Special categories of cited documents: "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family			
Date of the actual completion of the international search 19 August 2014 (19.08.2014)		Date of mailing of the international search report 19 August 2014 (19.08.2014)		
Name and mailing address of the ISA/KR  International Application Division Korean Intellectual Property Office 189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140		Authorized officer CHOI, Hyun Goo Telephone No. +82-42-481-8288 		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/035340

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