

S P E C I F I C A T I O N

Docket No. 174-93030

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TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN that I, Peter Michael Kent, have invented new and useful improvements in a

DYNAMIC METAL-TO-METAL SEAL

of which the following is a specification:

BACKGROUND OF THE INVENTION

1. Field of the Invention:

This invention relates in general to gate valves, and in particular to an improved metal-to-metal seal for sealing between a movable stem and a stem opening in a valve body.

2. Description of the Prior Art:

A typical gate valve has a body with a flow passage extending through it. The flow passage intersects a central cavity wherein is located a gate that is perpendicular to the flow passage. In communication with the central cavity is a stem opening. A stem extends through the stem opening and into the central passage where the stem is connected to the gate. Selective movement of the stem causes the gate to move between closed and open positions that obstruct flow or allow flow, respectively, through the flow passage.

There are generally two types of gate valves: the rising-stem type, and the non-rising-stem type. In the rising-stem type, the stem moves only axially, without rotation, to move the gate between closed and open positions. In the non-rising-stem type, the stem only rotates, without moving axially, and the rotation of the stem, in conjunction with a gear connection between the stem and the gate, causes the gate to move between open and closed position.

Since the central cavity of the gate valve and the stem opening are in communication, the space between the stem and the stem opening must be sealed to avoid leakage. At first, elastomeric seals were used. However, since elastomeric seals do not have the necessary longevity, especially in corrosive environments, metal seals have become popular for several applications.

Several metal-to-metal seals have been developed for sealing between a movable stem and a stem opening in a valve body. However, generally such seals made prior to this invention have



- 1 disadvantages such as premature wear, damage to the sealing
- 2 surface, insufficient sealing capacity under certain conditions,
- 3 and excessively short service life.

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SUMMARY OF THE INVENTION

It is the general object of the invention to provide an improved metal-to-metal seal for sealing between a movable stem and a stem opening in a valve body. The improved metal seal has an annular seal body through which the stem extends. The seal has a flexible annular seal leg depending from the seal body for sealing against the stem. The inner surface of the seal leg has at least one groove defining a plurality of sealing lands, including at least a lower sealing land and upper sealing land. The undeflected inner diameter of the lower sealing land is selected so that upon insertion of the stem through the seal, the seal leg deflects outward. The undeflected diameter of the upper sealing land is selected so that it is larger than the undeflected inner diameter of the lower sealing land. The undeflected diameters of additional sealing lands are selected so that they are successively larger than the undeflected inner diameters of the sealing lands below them.

Increased fluid pressure in the stem opening causes the seal leg to flex inward, causing additional sealing lands to contact the stem, thus increasing the effective sealing surface while maintaining the contact forces between the stem and seal at beneficial levels. The above improvements result in a metal-to-metal seal with improved sealing capabilities and longer service life.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a vertical sectional view illustrating a portion of a typical gate valve, including the improved metal seal of the present invention.

Figure 2 is a view, partly in section, of the improved metal seal of the present invention shown in FIG. 1.

Figure 3 is an enlarged sectional view of the seal leg of the metal seal of FIG. 2 shown in its undeflected position.

Figure 4 is a sectional view of the seal leg of FIG. 3 being deflected outward by the stem of the valve.

Figure 5 is a sectional view of the seal leg of FIG. 4 being deflected inward by pressure in the stem opening.

Figure 6 is a table of the normal forces at various contact points between the seal leg and the stem at various pressure differentials.

Figure 7 is a graph of the information of FIG. 6, with the normal forces on the vertical axis, the nodes on the horizontal axis, and with each line representing a different pressure differential.

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1 DETAILED DESCRIPTION OF THE INVENTION

2
3 FIG. 1, shows a portion of a gate valve 10 of the rising-
4 stem type. Gate valve 10 has a valve body 12 having a stem
5 opening 14. The stem opening 14 has a stepped inner diameter 16
6 defining an upwardly facing shoulder 18. A stem 20, having an
7 outer diameter 22, is located through stem opening 14. Stem 20
8 is connected to a gate (not shown). Stem 20 moves axially within
9 stem opening 14 and moves the gate between open and closed
10 positions. Stem 20 does not rotate.

11 A metal seal 30 is located inside stem opening 14. Metal
12 seal 30 has an annular seal body 32, a flexible annular seal leg
13 34, and an annular support leg 36 that is concentric with and
14 surrounds seal leg 34. Seal body 32 has a stepped outer diameter
15 38 that mates with stepped inner diameter 16 of stem opening 14.
16 Stepped outer diameter 38 of seal body 32 has a circumferential
17 outer recess 40 for housing an elastomeric seal 42 in sealing
18 engagement with stem opening 14. Support leg 36 depends from
19 lower portion 44 of seal body 32. Support leg 36 has a lower end
20 46 that abuts upwardly facing shoulder 18 in stem opening 14.

21 Referring now mainly to FIGS. 2 and 3, seal body 32 has a
22 generally cylindrical inner diameter 48 which is slightly larger
23 than outer diameter 22 of stem 20. Inner diameter 48 of seal
24 body 32 has a plurality of circumferential lubricating grooves
25 50 that are axially spaced apart one from the other. Seal body
26 32 also has a circumferential inner recess 52 at upper portion
27 54 of seal body 32 for housing a chevron seal 56. Chevron seal
28 56 acts as a back-up seal between seal body 32 and stem 20.

29 Seal body 32 has a flexible annular seal leg 34 depending
30 from lower portion 44 of seal body 32 for sealing against stem
31 20. A flex recess 58 is located at the lower end of inner
32 diameter 48 of seal body 32, at the junction between lower
33 portion 44 of seal body 32 and seal leg 34. Flex recess 58
34 facilitates the flexing of seal leg 34.

35 Seal leg 34 has an upper section 60, a middle section 62,
36 and a lower section 64. Upper section 60 extends downwardly and
37 inwardly from seal body 32. Middle section 62 extends downwardly



1 and inwardly from the lower end of upper section 60, but in a
2 more downward direction than upper section 60. Upper section 60
3 and middle section 62 both have generally uniform cross sections.
4 Lower section 64 extends in the same direction as middle section
5 62, but has a tapered cross-section. Outer surface 66 of lower
6 section 64 tapers towards inner surface 68 of middle and lower
7 sections 62 and 64 as it approaches tip 70 of seal leg 34.

8 Inner surface 68 of middle and lower sections 62 and 64 has
9 a plurality of axially spaced apart grooves 72a-d. Grooves 72
10 result in a plurality of axially spaced apart sealing lands 74a-
11 e. Sealing lands 74 include lower sealing land 74a, intermediate
12 sealing land 74b, upper sealing land 74c, and additional sealing
13 lands 74d-e. Lower sealing land 74a is located at tip 70 of seal
14 leg 34, intermediate sealing land 74b is located above lower
15 sealing land 74a, upper sealing land 74c is located above
16 intermediate sealing land 74b, and additional sealing lands 74d-e
17 are located above upper sealing land 74c.

18 Each sealing land 74a-e has a corresponding sealing land
19 surface 76a-e. Since angle 78 of inner surface 68 of middle and
20 lower sections 62 and 64 is very small, sealing land surfaces
21 76a-e are very close to being cylindrical surfaces. As will be
22 discussed later, during operation, seal leg 34 flexes inward, and
23 sealing land surfaces 76a-e come into contact with stem 20, at
24 which point sealing land surfaces 76a-e are cylindrical surfaces.

25 Since seal leg 34 is angled downwardly and inwardly, sealing
26 lands 74e-a have successively smaller undeflected diameters.
27 Therefore, sealing land 74e has an undeflected diameter that is
28 larger than the undeflected diameter of sealing land 74d, which
29 is in turn larger than the undeflected diameter of sealing land
30 74c, which is in turn larger than the undeflected diameter of
31 sealing land 74b, which is in turn larger than the undeflected
32 diameter of sealing land 74a.

33 The undeflected diameters of sealing lands 74a-b are
34 selected so that they are slightly smaller than outer diameter
35 22 of stem 20. On the other hand, the undeflected diameters of
36 sealing lands 74c-e are selected so that they are slightly larger
37 than outer diameter 22 of stem 20. Selecting such sealing land



1 diameters results in seal leg 34 being deflected outwardly upon
2 insertion of stem 20 through seal 30. More specifically, upon
3 insertion of stem 20 through seal 30, sealing land surfaces 76a-b
4 will be in contact with stem 20, while sealing land surface 76c-e
5 will not be in contact with stem 20.

6 Referring now mainly to FIG. 1, seal 30 is located inside
7 stem opening 14, and lower end 46 of support leg 36 abuts
8 upwardly facing shoulder 18 in the stem opening 14. Above seal
9 30 is located retaining ring 90. A downwardly facing surface of
10 retaining ring 90 abuts upper portion 54 of seal body 32.
11 Retaining ring 90 has a recess in its outer diameter that houses
12 elastomeric seal 92, and a recess in its inner diameter that
13 houses elastomeric seal 94. Elastomeric seal 92 is in sealing
14 engagement with stem opening 14, and elastomeric seal 94 is in
15 sealing engagement with stem 20. Lower retaining nut 96 is
16 located above retaining ring 90. Lower retaining nut 96 is
17 threadedly attached to stem opening 14 so that a lower surface
18 of lower retaining nut 96 abuts an upper surface of retaining
19 ring 90. Intermediate retaining nut 98 is located above lower
20 retaining nut 96 and is threadedly attached to stem opening 14
21 so that a lower surface of intermediate retaining nut 98 abuts
22 an upper surface of lower retaining nut 96. Finally, upper
23 retaining nut 100 is located above intermediate retaining nut 98
24 and is threadedly attached to stem opening 14 so that a lower
25 surface of upper retaining nut 100 abuts an upper surface of
26 intermediate retaining nut 98. The retaining ring 90 and lower,
27 intermediate, and upper retaining nuts 96, 98, and 100 function
28 as a retaining means to maintain seal 30 in abutment with
29 upwardly facing shoulder 18 of stem opening 14.

30 In operation, the above described structure functions as
31 follows. Stem 20, located within stem opening 14 of valve 10,
32 moves axially and in turn moves a gate (not shown) between closed
33 and open positions to selectively control flow through valve 10.
34 During operation, the region of stem opening 14 below seal 30 is
35 at elevated pressures, this region is referred to as high
36 pressure region 102 in the figures. The pressures in high
37 pressure region 102 can vary from very low pressures to very high



1 pressures in excess of 10,000 psi. Low pressure region 104, on
2 the other hand, is at a lower pressure than high pressure region
3 102. Fluids therefore have a tendency to escape from high
4 pressure region 102 to low pressure region 104.

5 As described above, metal seal 30 is located inside stem
6 opening 14 and is kept in abutment with upwardly facing shoulder
7 18 by a retaining means comprising retaining ring 90, lower
8 retaining nut 96, intermediate retaining nut 98, and upper
9 retaining nut 100. Also, stem 20 is located through stem opening
10 14 and through seal 30. Since stem 20 is located through seal
11 30, seal leg 34 is deflected outwardly.

12 Referring now to FIG. 4, when the pressure differential
13 between high pressure region 102 and low pressure region 104 is
14 zero, lower sealing land 74a and intermediate sealing land 74b
15 are in contact with stem 20, and sealing lands 74c-e are not in
16 contact with stem 20. Since lower and intermediate sealing lands
17 74a and 74b are being maintained in a deflected position by
18 contact with stem 20, there exist normal forces at the points of
19 contact.

20 FIG. 6 shows a table of the normal forces at various contact
21 points, or nodes 106a₁-e₁, for various pressure differentials.
22 The table of FIG. 6 was developed by finite element analysis.
23 For each of eleven representative pressures, FIG. 6 gives the
24 normal forces, in pounds/radian, for each node 106a₁-e₁. Although
25 the units for the normal forces given in FIG. 6 are pounds-
26 force/radian, since they were derived by analyzing points rather
27 than areas, the values given are not representative of the actual
28 forces but are only indicative of the relative size of the
29 forces.

30 Referring now to both FIGS. 4 and 6, one can see that nodes
31 106a₁ and 106a₂ on lower sealing land 74a, and nodes 106b₁ and
32 106b₂ on intermediate sealing land 74b, are in contact with stem
33 20 since positive values for the normal forces at those nodes are
34 shown in FIG. 6 for a zero psi pressure differential. On the
35 other hand nodes 106c₁-e₁ on sealing lands 74c-e are not in
36 contact with stem 20 since normal forces of zero appear in FIG.
37 6 for nodes 106c₁-e₁ for a zero psi pressure differential.

1 As the pressure differential between high pressure region
2 102 and low pressure region 104 increases, seal leg 34 deflects
3 inward, thus flexing inner surface 68 of middle and lower
4 sections 62 and 64 of seal leg 34 towards stem 20. As the
5 pressure differential increases, seal leg 34 continues to flex
6 inward, and, eventually, additional sealing lands 74 come into
7 contact with stem 20. For example, looking at upper sealing land
8 74c, when the pressure differential is about 1000 psi, node
9 106c₁, on the lower portion of upper sealing land 74c, comes into
10 contact with stem 20, while node 106c₂, which is on the upper
11 portion of upper sealing land 74c is not yet in contact with stem
12 20. As the pressure differential increases towards 3000 psi,
13 more of upper sealing land 74c contacts stem 20 until the entire
14 upper sealing land 74c is in contact with stem 20, as is the case
15 when the pressure differential reaches 3000 psi. As the pressure
16 differential continues to increase, additional sealing lands
17 gradually come into contact with stem 20. The values in FIG. 6
18 show that once the pressure differential reaches 9000 psi, all
19 of sealing lands 74a-d are in contact with stem 20, and only
20 sealing land 74e is not in contact with stem 20. FIG. 5 shows
21 seal leg 34 and stem 20 with sealing lands 74a-d in contact with
22 stem 20.

23 The increase in the number of sealing lands 74 contacting
24 stem 20 with increasing pressure differential results in a
25 corresponding increase in sealing surface. The increased sealing
26 surface that results with increasing pressure helps to maintain
27 a positive seal as the pressure differential increases.

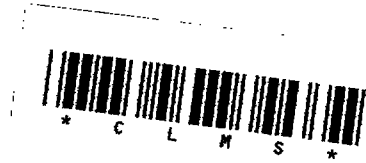
28 The present invention also results in more beneficial normal
29 force levels between the seal leg 34 and stem 20. To obtain a
30 positive seal, relatively high normal forces are required along
31 the sealing surfaces. On the other hand, excessive normal forces
32 at the contact points are undesirable because they result in
33 damage to the sealing surfaces and eventual deterioration of seal
34 integrity. The design of the present invention results in
35 sufficiently large normal forces to provide a positive seal,
36 while at the same time maintaining the forces at a low enough
37 level to prevent damages to the sealing surfaces. Since seal leg



1 34 is flexible, the sealing surface increases with increasing
2 pressure. The gradual increase in sealing surface prevents the
3 normal forces at any one location along seal leg 34 to become
4 excessively large. Furthermore, the shape of seal leg 34 ensures
5 that each sealing land 74 maintains a sufficiently high normal
6 force against stem 20 at any of the various pressure
7 differentials that might be encountered during operation of valve
8 10. Referring again to FIG. 6, and looking generally at the
9 normal force values for each node as the pressure differential
10 increases, FIG. 6 shows that the normal forces at each node
11 generally increase, or at least do not decrease drastically, as
12 the pressure differential increases. FIG. 7 shows the
13 information of FIG. 6 in graphical form, with the normal forces
14 on the vertical axis, the nodes on the horizontal axis, and with
15 each line representing a different pressure differential.

16 While the invention has been particularly shown and
17 described with reference to a preferred embodiment, it will be
18 understood by those skilled in the art that various changes in
19 form and detail may be made therein without departing from the
20 spirit and scope of the invention.





What is claimed is:

1. In a gate valve having a valve body, an axially
movable stem extending through a stem opening in the valve
5 body for moving a gate between open and closed positions,
the improvement comprising:

a metal seal having an annular seal body through
which the stem extends;

10 the metal seal having a flexible annular seal leg
depending from the seal body for sealing against the stem,
the seal leg having a tip at its lower end;

an inner surface of the seal leg having at least one
groove axially spaced from the tip, defining a lower
sealing land at the tip and at least one upper sealing
15 land spaced above the groove;

the lower sealing land having an undeflected inner
diameter that is slightly less than the outer diameter of
the stem so that the seal leg will flex outward as the
stem inserts through the seal; and

20 the upper sealing land having an undeflected inner
diameter that is greater than the undeflected inner
diameter of the lower sealing land and selected such that
the upper sealing land contacts the stem as the stem
inserts through the seal and such that increased fluid
25 pressure in the stem opening causes the upper sealing land
to apply greater contact force against the stem and causes
the seal leg to flex inwardly so that the effective
sealing surface between the metal seal and the stem is
increased with increasing pressure.

30

2. The valve according to claim 1 wherein the seal body
has an inner diameter slightly greater than the diameter
of the stem and wherein the seal body has a plurality of
axially spaced apart lubricating grooves located on the
35 inner diameter of the seal body.





3. The valve according to claim 1 wherein the stem opening has an upwardly facing shoulder, and wherein the seal further comprises:

the support leg depending from the seal body
5 concentric with and surrounding the seal leg;

a support leg having a lower end which abuts the upwardly facing shoulder; and

wherein the valve further comprises retaining means for retaining the seal with the support leg in abutment
10 with the upwardly facing shoulder.

4. The valve according to claim 1 wherein the upper and lower sealing lands are substantially cylindrical surfaces.

15

5. The valve according to claim 1 further comprising an elastomeric seal on an exterior diameter of the seal body in sealing engagement with the stem opening.

20 6. The valve according to claim 1 wherein the seal body has a generally cylindrical inner diameter having a flex recess located at a junction of the seal body and seal leg at the lower end of the inner diameter of the seal body, to facilitate flexing of the seal leg.

25

7. A metal seal for a gate valve having a valve body, an axially movable stem extending through a stem opening in the valve body for moving a gate between open and closed positions, the metal seal comprising:

30 an annular seal body through which the stem extends;
a flexible annular seal leg depending from the seal body for sealing against the stem, the seal leg having a tip at its lower end;

an inner surface of the seal leg having a plurality
35 of axially spaced apart grooves defining a lower sealing

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land at the tip, and at least one intermediate sealing land and an upper sealing land spaced above the lower sealing land;

5 the lower sealing land having an undeflected inner diameter that is slightly less than the outer diameter of the stem so that the seal leg will flex outward as the stem inserts through the seal;

10 the intermediate sealing land having an undeflected inner diameter that is greater than the undeflected inner diameter of the lower sealing land;

the upper sealing land having an undeflected inner diameter that is greater than the undeflected inner diameter of the intermediate sealing land; and

15 the undeflected inner diameters of the sealing lands selected such that increased fluid pressure in the stem opening causes the seal leg to flex inwardly so that the effective sealing surface between the metal seal and the stem is increased with increasing pressure due to the intermediate sealing land and upper sealing land coming
20 into contact with the stem.

8. The metal seal according to claim 7 wherein the seal body has an inner diameter slightly greater than the diameter of the stem and wherein the seal body has a
25 plurality of axially spaced apart lubricating grooves located on the inner diameter of the seal body.

9. The metal seal according to claim 7 wherein the stem opening has an upwardly facing shoulder, and wherein the
30 seal further comprises:

a support leg depending from the seal body concentric with and surrounding the seal leg;

the support leg having a lower end which abuts the upwardly facing shoulder; and

35 wherein the valve further comprises retaining means

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for retaining the seal with the support leg in abutment with the upwardly facing shoulder.

10. The metal seal according to claim 7 wherein the upper
5 sealing land, intermediate sealing land, and lower sealing land are substantially cylindrical surfaces.

11. The metal seal according to claim 7 further
10 comprising an elastomeric seal on an exterior diameter of the seal body in sealing engagement with the stem opening.

12. The metal seal according to claim 7 wherein the seal
body has a generally cylindrical inner diameter having a
flex recess located at a junction of the seal body and
15 seal leg at the lower end of the inner diameter of the seal body to facilitate flexing of the seal leg.

13. A gate valve comprising in combination:

a valve body;

20 an axially moveable stem extending through a stem opening in the valve body for moving a gate between the open and closed positions;

a metal seal located in the stem opening and having an annular seal body through which the stem extends;

25 a flexible annular seal leg depending from the seal body for sealing against the stem, the seal leg having a tip at its lower end;

an inner surface of the seal leg having a plurality of axially spaced apart grooves defining a lower sealing
30 land at the tip, and at least one intermediate sealing land and an upper sealing land spaced above the lower sealing land;

the lower sealing land having an undeflected inner diameter that is slightly less than the outer diameter of
35 the stem so that the seal leg will flex outward as the





stem inserts through the seal;

the intermediate sealing land having an undeflected inner diameter that is greater than the undeflected inner diameter of the lower sealing land;

5 the upper sealing land having an undeflected inner diameter that is greater than the undeflected inner diameter of the intermediate sealing land;

the undeflected inner diameters of the sealing lands selected such that increased fluid pressure in the stem opening causes the seal leg to flex inwardly so that the effective sealing surface between the metal seal and the stem is increased with increasing pressure due to the intermediate and upper sealing lands subsequently and sequentially coming into contact with the stem;

15 the seal body having an inner diameter slightly greater than the diameter of the stem and having a plurality of axially spaced apart lubricating grooves located on the inner diameter of the seal body;

the stem opening having an upwardly facing shoulder;

20 and

the seal body having a support leg depending from the seal body concentric with and surrounding the seal leg, the support leg having a lower end which abuts the upwardly facing shoulder.

25 14. The gate valve according to claim 13 further comprising a retaining means for retaining the support leg in abutment with the upwardly facing shoulder.

30 15. The gate valve according to claim 13 wherein the upper sealing land, intermediate sealing land, and lower sealing land are substantially cylindrical surfaces.

16. The gate valve according to claim 13 further comprising an elastomeric seal on an exterior diameter of

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the seal body in sealing engagement with the stem opening.

17. The gate valve according to claim 13 wherein the seal
body has a generally cylindrical inner diameter having a
5 flex recess located at a junction of the seal body and
seal leg at the lower end of the inner diameter of the
seal body to facilitate flexing of the seal leg.

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