METHOD OF MANUFACTURING A CURVED FLAPPER

A method of making a curved flapper for use in a subsurface safety valve from flat plate material is provided. In one embodiment of the method of the invention, the flat plate material may be rolled into a curved section of material, whether it be a partial or complete cylinder, from which the curved flapper may be machined. In another embodiment of the method of the invention, the flat plate material may be a block of material of sufficient width such that the curved flapper may be machined therefrom. In another embodiment of the method of the invention, the flat plate material may be stamped into a partial cylinder, from which the curved flapper may be machined.
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METHOD OF MANUFACTURING A CURVED FLAPPER

RELATED APPLICATIONS

This application claims the benefit of U. S. Provisional Application No. 60/050,585, filed June 24, 1997.

BACKGROUND OF THE INVENTION

1. Field Of The Invention

The present invention relates to a subsurface safety valve used for controlling fluid flow in a well conduit and, more particularly, to a method for manufacturing a curved flapper for use in a subsurface safety valve.

2. Description Of The Related Art

Subsurface safety valves are commonly used in wells to prevent uncontrolled fluid flow through the well in the event of an emergency, such as to prevent a well blowout. Conventional safety valves use a flapper which is biased by a spring to a normally closed position, but is retained in an open position by the application of hydraulic fluid from the earth’s surface. A typical subsurface safety valve employing a “flat” flapper is shown and described in U.S. Pat. No. 4,161,219, which is commonly assigned hereto. A subsurface valve employing a “curved” flapper is shown and described in U.S. Pat. No. 4,926,945, which is commonly assigned hereto and incorporated herein by reference. Curved flappers are used in a subsurface safety valve to provide a larger bore in the safety valve, as compared to the safety valve bore when using a flat flapper. As such, by increasing the size of the bore through the safety valve, curved flappers allow for increased well production through the safety valve.

As shown and described in U.S. Pat. No. 4,983,803, which is commonly assigned hereto and incorporated herein by reference, it is known to manufacture curved flappers from a metal
tubular member. It is also known to manufacture curved flappers from solid metal rods. It is preferred that curved flappers be manufactured from material that complies with National Association of Corrosion Engineers (NACE) Standard MR0175. At the present time, the metal tubular members and rods from which curved flappers may be manufactured that meet NACE Standard MR0175 are available with maximum yield strengths of approximately 130,000 p.s.i. While curved flappers manufactured from metal tubes and rods having yield strengths up to approximately 130,000 p.s.i. have achieved, and still do achieve, satisfactory performance for given pressure ratings, there has developed a need in the oil and gas industry for subsurface safety valves having curved flappers with pressure ratings greater than the pressure ratings heretofore attainable with presently available metal tubes and rods. To achieve greater pressure ratings, the curved flappers should be manufactured from materials that have yield strengths above approximately 130,000 p.s.i. and comply with NACE Standard MR0175. It is not economically feasible at the present time for tube and rod fabricators to provide metal tubes or bars with yield strengths above approximately 130,000 p.s.i. and still be in compliance with NACE Standard MR0175. However, yield strengths greater than approximately 130,000 p.s.i. are available in metal flat plate material that meets NACE Standard MR0175. Currently, metal flat plate material is available with yield strengths of up to approximately 180,000 p.s.i., while still complying with NACE Standard MR0175. Accordingly, the primary objective of the present invention is to provide a cost-efficient method of manufacturing curved flappers from metal flat plate material that has yield strengths above approximately 130,000 p.s.i. and complies with NACE Standard MR0175 in order to achieve pressure ratings greater than the pressure ratings presently attainable when curved flappers are made from metal tubes or bars. It should be emphasized that the above-discussed yield strengths are approximate and not intended to be specific. As such, yield
strengths slightly greater or less than those noted are still intended to be within the spirit and scope of the present invention.

**SUMMARY OF THE INVENTION**

The present invention is directed generally to a method for manufacturing a curved flapper for use in a subsurface safety valve. In one aspect, the method of the present invention includes the steps of: providing a flat plate of material; rolling the flat plate of material into a curved section of material having a desired radius; and machining the curved section of material to form the curved flapper. Another feature of this aspect of the invention is that the flat plate of material has a yield strength greater than approximately 130,000 p.s.i. Another feature of this aspect of the invention is that the flat plate of material is of the type commonly known as MP35N. Another feature of this aspect of the invention is that the flat plate of material complies with NACE Standard MR0175. Another feature of this aspect of the invention is that the flat plate of material has a predetermined thickness based upon the design of the subsurface safety valve. Another feature of this aspect of the invention is that the curved section of material is a partial cylinder. Another feature of this aspect of the invention is that the curved section of material is a complete cylinder. Another feature of this aspect of the invention is that the radius of the curved section of material conforms to the desired radius of the curved flapper. Another feature of this aspect of the invention is that the machining step further comprises the steps of: honing an interior surface of the curved section of material for providing a finished concave sealing surface; and cutting a circular section with a hinge out of the curved section of material. Another feature of this aspect of the invention is that the curved section of material is a complete cylinder. Another feature of this aspect of the invention is that the method further includes cutting a second circular section with a hinge out of the cylinder wherein the second section is diametrically opposite to the first section. Another feature of this aspect of the invention is that
the first and second sections and hinges are simultaneously cut out of the cylinder. Another feature of this aspect of the invention is that the curved section of material is a partial cylinder. Another feature of this aspect of the invention is that the cutting is performed by an electric discharge machine. Another feature of this aspect of the invention is that the cutting is performed by a milling machine. Another feature of this aspect of the invention is that holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper. Another feature of this aspect of the invention is that the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material. Another feature of this aspect of the invention is that the method further includes the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step. Another feature of this aspect of the invention is that the hard surface coating is created by physical vapor deposition. Another feature of this aspect of the invention is that the hard surface coating is a titanium nitride coating. Another feature of this aspect of the invention is that the hard surface coating is created by a ceramic spray. Another feature of this aspect of the invention is that the ceramic spray is zirconia. Another feature of this aspect of the invention is that the ceramic spray is silicon nitrate. Another feature of this aspect of the invention is that the machining step further comprises the steps of: honing an interior surface of the cylinder for providing a finished concave sealing surface; simultaneously cutting first and second circular sections, each of which includes a hinge, out of the cylinder wherein the second section is diametrically opposite to the first section; and prior to cutting out the sections, drilling a hole through the cylinder in a plane transverse to the longitudinal axis of the cylinder for forming hinge holes in the cut out curved flappers formed from the first and second circular sections. Another feature of this aspect of the
invention is that the cutting is performed by an electric discharge machine. Another feature of this aspect of the invention is that the cutting is performed by a milling machine. Another feature of this aspect of the invention is that the hinge includes a longitudinal axis and each curved flapper is cut out of the cylinder such that the longitudinal axis of each hinge is parallel to a longitudinal axis of the cylinder. Another feature of this aspect of the invention is that the method further includes the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step. Another feature of this aspect of the invention is that the hard surface coating is created by physical vapor deposition. Another feature of this aspect of the invention is that the hard surface coating is a titanium nitride coating. Another feature of this aspect of the invention is that the hard surface coating is created by a ceramic spray. Another feature of this aspect of the invention is that the ceramic spray is zirconia. Another feature of this aspect of the invention is that the ceramic spray is silicon nitrate.

In another aspect, the method the present invention includes the steps of: providing a block of material; cutting a curved section of material of desired radius from the block of material; and machining the curved section of material to form the curved flapper. Another feature of this aspect of the invention is that the block of material has a yield strength greater than approximately 130,000 p.s.i. Another feature of this aspect of the invention is that the block of material is of the type commonly known as MP35N. Another feature of this aspect of the invention is that the block of material complies with NACE Standard MR0175. Another feature of this aspect of the invention is that the block of material has a predetermined thickness, based upon the design of the curved flapper to be manufactured, sufficient to completely cut the curved flapper out of the block of material. Another feature of this aspect of the invention is that the cutting step is performed by an electric discharge machine. Another feature of this aspect of the invention is
invention is that the cutting step is performed by a milling machine. Another feature of this aspect of the invention is that the machining step further comprises the steps of: honing an interior surface of the curved section of material for providing a finished concave sealing surface; and cutting a circular section with a hinge out of the curved section of material. Another feature of this aspect of the invention is that the curved section of material is a partial cylinder. Another feature of this aspect of the invention is that the cutting is performed by an electric discharge machine. Another feature of this aspect of the invention is that holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper. Another feature of this aspect of the invention is that the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material. Another feature of this aspect of the invention is that the method further includes the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step. Another feature of this aspect of the invention is that the hard surface coating is created by physical vapor deposition. Another feature of this aspect of the invention is that the hard surface coating is a titanium nitride coating. Another feature of this aspect of the invention is that the hard surface coating is created by a ceramic spray. Another feature of this aspect of the invention is that the ceramic spray is zirconia. Another feature of this aspect of the invention is that the ceramic spray is silicon nitrate.

In another aspect, the method of the present invention includes the steps of: providing a flat plate of material; stamping the flat plate of material into a curved section of material of desired radius; and machining the curved section of material into the curved flapper. Another
feature of this aspect of the invention is that the flat plate of material has a yield strength greater than approximately 130,000 p.s.i. Another feature of this aspect of the invention is that the flat plate of material is of the type commonly known as MP35N. Another feature of this aspect of the invention is that the flat plate of material complies with NACE Standard MR0175. Another feature of this aspect of the invention is that the flat plate of material comprises a predetermined thickness based upon the design of the curved flapper to be manufactured. Another feature of this aspect of the invention is that the stamping step further comprises the step of using a punch and die to form the flat plate of material into a curved section of material. Another feature of this aspect of the invention is that the punch comprises a convex surface, and the die comprises a concave surface, the concave and convex surfaces each having a radius of curvature corresponding to the desired radius of the curved flapper. Another feature of this aspect of the invention is that the curved section of material is a partial cylinder. Another feature of this aspect of the invention is that the radius of the curved section of material conforms to the desired radius of the curved flapper. Another feature of this aspect of the invention is that the machining step further comprises the steps of: honing an interior surface of the curved section of material for providing a finished concave sealing surface; and cutting a circular section with a hinge out of the curved section of material. Another feature of this aspect of the invention is that the curved section of material is a partial cylinder. Another feature of this aspect of the invention is that the cutting is performed by an electric discharge machine. Another feature of this aspect of the invention is that the cutting is performed by a milling machine. Another feature of this aspect of the invention is that holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper. Another feature of this aspect of the invention is that the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of
the hinge is parallel to a longitudinal axis of the curved section of material. Another feature of this aspect of the invention is that the method further includes the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step. Another feature of this aspect of the invention is that the hard surface coating is created by physical vapor deposition. Another feature of this aspect of the invention is that the hard surface coating is a titanium nitride coating. Another feature of this aspect of the invention is that the hard surface coating is created by a ceramic spray. Another feature of this aspect of the invention is that the ceramic spray is zirconia. Another feature of this aspect of the invention is that the ceramic spray is silicon nitrate.

In another aspect, the method of the present invention includes the steps of: providing a piece of material; forming the piece of material into a curved section of material of desired radius; and machining the curved section of material to form the curved flapper. Another feature of this aspect of the invention is that the piece of material is a flat plate of material having a yield strength greater than approximately 130,000 p.s.i. and complying with NACE Standard MR0175. Another feature of this aspect of the invention is that the forming step further comprises the step of rolling the flat plate of material into a curved section of material having a radius of curvature conforming to the desired radius of the curved flapper. Another feature of this aspect of the invention is that the forming step further comprises the step of stamping the flat plate of material by use of a punch and die into a curved section of material having a radius of curvature conforming to the desired radius of the curved flapper. Another feature of this aspect of the invention is that the piece of material is a block of material having a yield strength greater than approximately 130,000 p.s.i., complying with NACE Standard MR0175, and having a predetermined thickness, based upon the design of the curved flapper to be manufactured, sufficient to completely cut the curved flapper out of the block of material. Another feature of
this aspect of the invention is that the machining step further comprises the steps of: honing an interior surface of the curved section of material for providing a finished concave sealing surface; and cutting a circular section with a hinge out of the curved section of material. Another feature of this aspect of the invention is that holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper. Another feature of this aspect of the invention is that the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material. Another feature of this aspect of the invention is that the method further includes the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.

**BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1 is a perspective view of a flat plate of material which may be rolled into a curved section of material from which a curved flapper may be manufactured in accordance with the method of the present invention.

Figure 2 is a perspective view of a curved section of material, which was rolled from the flat plate material shown in Figure 1.

Figure 3 is a perspective view of a curved flapper manufactured in accordance with the method of the present invention from the curved section of material shown in Figure 2. Figure 4 is an elevational view illustrating the method of manufacturing a curved flapper from a cylinder in accordance with the present invention.

Figure 5 is a cross-sectional view taken along line 5-5 of Figure 4.

Figure 6 is an elevational perspective view of the cylinder as shown in Figure 5.
Figure 7 is a perspective view of a block of material from which a curved flapper may be manufactured in accordance with the method of the present invention.

Figure 8 is a perspective view of a punch and die illustrating how a flat plate of material is stamped into a curved section of material, similar to the curved section of material shown in Figure 2, from which a curved flapper may be manufactured in accordance with the method of the present invention.

While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to those embodiments. On the contrary, it is intended to cover all alternatives, modifications, and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

As explained above, the primary objective of the present invention is to provide a cost-efficient method of manufacturing curved flappers from metal flat plate material having yield strengths above approximately 130,000 p.s.i. in order to achieve pressure ratings greater than the pressure ratings presently attainable when curved flappers are made from metal tubes or bars. Referring to the drawings in detail, wherein like numerals denote identical elements throughout the several views, it can be seen, with reference to Figures 1-3, that in a specific embodiment of the method of the present invention, a curved flapper 18 is manufactured from a flat plate material 10 (Figure 1) of a predetermined thickness T having a yield strength above approximately 130,000 p.s.i. In a specific embodiment, the flat plate material 10 may be of the type commonly known as MP35N (UNS R30035). The flat plate material 10 is mechanically rolled into a curved section of material 12 (Figure 2) having a radius of curvature R equal to the desired radius of curvature of the curved flapper 18. In a specific embodiment, the curved section of material 12 may be a partial cylinder 14, as shown in Figure 2, or a complete cylinder
16, as shown in Figures 4-6. The predetermined thickness \( T \) of the flat plate material 10 shown in Figure 1 is selected based upon the dimensions of the curved flapper 18 desired to be manufactured.

After the rolling step of this embodiment of the method of the present invention, the curved flapper 18, as shown in Figure 3, is machined from the curved section of material 12 to provide a finished sealing surface 20, a hinge 22, and an aperture 24 through the hinge 22, as described in U.S. Pat. No. 4,983,803, discussed above. For completeness, the method described in U.S. Patent No. 4,983,803 of manufacturing a curved flapper from a cylinder, such as the cylinder 16 shown in Figures 4-6 that was rolled from the flat plate material 10 shown in Figure 1, will now be described. While the method will described below in relation to the complete cylinder 16, the method is equally applicable to manufacturing the curved flapper 18 from the partial cylinder 14, as shown in Figure 2, whether that partial cylinder 14 be manufactured: (1) by rolling, as described above; (2) from a block of material, as described below in connection with Figure 7; or (3) by a stamping process, as described below in connection with Figure 8.

Referring now to Figures 4-6, there is shown a length of the complete cylinder 16, which has been rolled from the flat plate material 10 (Figure 1), from which the curved flappers 18 are to be machined. The interior surface 26 of the cylinder 16 is honed whereby the internal diameter of the cylinder 16 provides the finished sealing surface 20 for the curved flappers 18. The length of the cylinder 16 is selected depending upon the number of curved flappers 18 it is desired to manufacture at one time. In the example given in Figures 4-6, a sufficient length of the cylinder 16 is shown to manufacture four curved flappers 18 for purposes of illustration only. If desired, the interior surface 26 may be provided with a hard surface. In a preferred embodiment, the hard surface may be a titanium nitride (TIN) coating that is applied by physical vapor deposition.
(PVD), a well known process. Alternatively, the hard surface may be provided by a ceramic spray such as zirconia or silicon nitride. This provides a low cost hard sealing. Of course, with a coating, the interior surface 26 would then be honed or lapped, such as to a 0.020 micron finish. In any event, it is preferable to hone or lap the interior surface 26 of the cylinder 16 to provide all of the sealing surfaces for a multiplicity of the curved flappers 18 which are to be manufactured out of the cylinder 16. Alternatively, the hardening step may be carried out after the curved flappers 18 have been cut out from the cylinder 16.

After the honing and/or hardening steps, the next step is to drill holes 28 in the cylinder 16 before machining the curved flappers 18. The drilled holes 28 form the hinge apertures 24 in the hinges 22 of the curved flappers 18, as shown in Figure 3. The holes 28 are preferably drilled through the cylinder 16 in a plane that is transverse to the longitudinal axis 17 of the cylinder 16. After the curved flappers 18, along with their hinges 22, have been cut out of the cylinder 16, in the manner explained below, the hinge apertures 24 are all prepared to receive pivot pins (not shown) for connecting the curved flappers 18 to a subsurface safety valve of the type disclosed in U.S. Pat. No. 4,926,945.

The final step is to use a cutting tool 30 to cut the curved flappers 18 out of the cylinder 16. Preferably, the cutting tool 30 is an electronic discharge machine (EDM) wire, although a regular milling machine may be utilized. In any event, the cutting tool 30 cuts a circular section and hinge out of the cylinder 16. Preferably, a second circular section and hinge is also cut out of the cylinder 16 wherein the second section is diametrically opposed to the first section. Thus, as best seen in Figure 4, first and second curved flappers 18a and 18b are cut out of the cylinder 16 and the curved flappers 18a and 18b are diametrically opposite to each other in the cylinder 16. Preferably, the cutting tool 30 simultaneously cuts out both curved flappers 18a and 18b at
the same time. The cutting tool 30 is then used in the same manner to cut out curved flappers 18e and 18d. Each curved flapper 18 is preferably cut out of the cylinder 16 such that a longitudinal axis 23 (see Figure 3) of each hinge 22 is parallel to the longitudinal axis 17 of the cylinder 16.

As explained above, while the method has been described in relation to the complete cylinder 16, the method is equally applicable to manufacturing the curved flapper 18 from the partial cylinder 14, as shown in Figure 2, whether that partial cylinder 14 be manufactured: (1) by rolling, as described above; (2) from a block of material, described in the next paragraph in connection with Figure 7; or (3) by a stamping process, as described below in connection with Figure 8.

With reference to Figure 7, in another specific embodiment of the method of the present invention, the curved flapper 18 may be manufactured from a block of material 32 having a thickness T' sufficient to machine the curved flapper 18 therefrom without rolling the block of material 32. Instead of rolling the block of material 32, the block 32 is first machined into a curved section of material 12 as shown in Figure 2, and as indicated by the dashed lines in Figure 7. A cutting tool (not shown) is used to cut the curved section of material 12 from the block of material 32. Preferably, the cutting tool is an electronic discharge machine, although a regular milling machine may be utilized. Alternatively, the block 32 may be placed into a fixture for mounting onto a lathe so that an offset interrupted cutting method, known to those skilled in the art, may be used to cut the curved section of material 12 from the block 32. The curved flapper 18 is then machined from the curved section of material 12 in the manner described above.

In yet another specific embodiment of the method of the present invention, the curved flapper 18 may be manufactured from the flat plate material 10, as shown in Figure 1, which is
formed into a partial cylinder 14', as shown in Figure 8, not by rolling, but, instead, by a
stamping or punch and die process. Referring now to Figure 8, a punch 34 having a convex
surface 36 and a die 38 having a concave surface 40 is used to stamp the flat plat material 10
(Figure 1) into a partial cylinder 14', similar to the partial cylinder 14 shown in Figure 2. The
curved flapper 18 may then be machined from the partial cylinder 14' in the manner described
above. The concave and convex surfaces 36 and 40, of the punch 34 and die 38, respectively,
are each provided with a radius of curvature corresponding to the desired radius of curvature of
the curved flapper 18.

It is to be understood that the invention is not limited to the exact details of construction,
operation, exact materials or embodiments shown and described, as obvious modifications and
equivalents will be apparent to one skilled in the art. For example, it should be emphasized that
the above-discussed yield strengths are approximate and not intended to be specific. As such,
yield strengths slightly greater or less than those noted are still intended to be within the spirit
and scope of the present invention. Accordingly, the invention is therefore to be limited only by
the scope of the appended claims.
CLAIMS

1. A method of manufacturing a curved flapper for use in a subsurface safety valve comprising the steps of:

   providing a flat plate of material;

   rolling the flat plate of material into a curved section of material having a desired radius;

   and

   machining the curved section of material to form the curved flapper.

2. The method of claim 1, wherein the flat plate of material has a yield strength greater than approximately 130,000 p.s.i.

3. The method of claim 2, wherein the flat plate of material is of the type commonly known as MP35N.

4. The method of claim 2, wherein the flat plate of material complies with NACE Standard MR0175.

5. The method of claim 1, wherein the flat plate of material has a predetermined thickness based upon the design of the subsurface safety valve.

6. The method of claim 1, wherein the curved section of material is a partial cylinder.

7. The method of claim 1, wherein the curved section of material is a complete cylinder.
8. The method of claim 1, wherein the radius of the curved section of material conforms to the desired radius of the curved flapper.

9. The method of claim 1, wherein the machining step further comprises the steps of:
   honing an interior surface of the curved section of material for providing a finished concave sealing surface; and cutting a circular section with a hinge out of the curved section of material.

10. The method of claim 9, wherein the curved section of material is a complete cylinder.

11. The method of claim 10, further including cutting a second circular section with a hinge out of the cylinder wherein the second section is diametrically opposite to the first section.

12. The method of claim 11, wherein the first and second sections and hinges are simultaneously cut out of the cylinder.

13. The method of claim 9, wherein the curved section of material is a partial cylinder.

14. The method of claim 9, wherein the cutting is performed by an electric discharge machine.
15. The method of claim 9, wherein the cutting is performed by a milling machine.

16. The method of claim 9, wherein holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper.

17. The method of claim 10, wherein the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material.

18. The method of claim 9, further including the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.

19. The method of claim 18, wherein the hard surface coating is created by physical vapor deposition.

20. The method of claim 19, wherein the hard surface coating is a titanium nitride coating.

21. The method of claim 18, wherein the hard surface coating is created by a ceramic spray.

22. The method of claim 21, wherein the ceramic spray is zirconia.
23. The method of claim 21, wherein the ceramic spray is silicon nitrate.

24. The method of claim 7, wherein the machining step further comprises the steps of:

- honing an interior surface of the cylinder for providing a finished concave sealing surface;
- simultaneously cutting first and second circular sections, each of which includes a hinge, out of the cylinder wherein the second section is diametrically opposite to the first section; and
- prior to cutting out the sections, drilling a hole through the cylinder in a plane transverse to the longitudinal axis of the cylinder for forming hinge holes in the cut out curved flappers formed from the first and second circular sections.

25. The method of claim 24, wherein the cutting is performed by an electric discharge machine.

26. The method of claim 24, wherein the cutting is performed by a milling machine.

27. The method of claim 24, wherein the hinge includes a longitudinal axis and each curved flapper is cut out of the cylinder such that the longitudinal axis of each hinge is parallel to a longitudinal axis of the cylinder.
28. The method of claim 24, further including the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.

29. The method of claim 28, wherein the hard surface coating is created by physical vapor deposition.

30. The method of claim 29, wherein the hard surface coating is a titanium nitride coating.

31. The method of claim 28, wherein the hard surface coating is created by a ceramic spray.

32. The method of claim 31, wherein the ceramic spray is zirconia.

33. The method of claim 31, wherein the ceramic spray is silicon nitrate.

34. A method of manufacturing a curved flapper for use in a subsurface safety valve comprising the steps of:

   providing a block of material;

   cutting a curved section of material of desired radius from the block of material; and

   machining the curved section of material to form the curved flapper.

35. The method of claim 34, wherein the block of material has a yield strength greater than approximately 130,000 p.s.i.
36. The method of claim 35, wherein the block of material is of the type commonly known as MP35N.

37. The method of claim 35, wherein the block of material complies with NACE Standard MR0175.

38. The method of claim 34, wherein the block of material has a predetermined thickness, based upon the design of the curved flapper to be manufactured, sufficient to completely cut the curved flapper out of the block of material.

39. The method of claim 34, wherein the cutting step is performed by an electric discharge machine.

40. The method of claim 34, wherein the cutting step is performed by a milling machine.

41. The method of claim 34, wherein the machining step further comprises the steps of:

honing an interior surface of the curved section of material for providing a finished concave sealing surface; and

cutting a circular section with a hinge out of the curved section of material.
42. The method of claim 41, wherein the curved section of material is a partial cylinder.

43. The method of claim 41, wherein the cutting is performed by an electric discharge machine.

44. The method of claim 41, wherein the cutting is performed by a milling machine.

45. The method of claim 41, wherein holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper.

46. The method of claim 41, wherein the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material.

47. The method of claim 41, further including the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.

48. The method of claim 47, wherein the hard surface coating is created by physical vapor deposition.

49. The method of claim 48, wherein the hard surface coating is a titanium nitride coating.
50. The method of claim 47, wherein the hard surface coating is created by a ceramic spray.

51. The method of claim 50, wherein the ceramic spray is zirconia.

52. The method of claim 50, wherein the ceramic spray is silicon nitrate.

53. A method of manufacturing a curved flapper for use in a subsurface safety valve comprising the steps of:
   providing a flat plate of material;
   stamping the flat plate of material into a curved section of material of desired radius; and
   machining the curved section of material into the curved flapper.

54. The method of claim 53, wherein the flat plate of material has a yield strength greater than approximately 130,000 p.s.i.

55. The method of claim 54, wherein the flat plate of material is of the type commonly known as MP35N.

56. The method of claim 54, wherein the flat plate of material complies with NACE Standard MR0175.
57. The method of claim 53, wherein the flat plate of material comprises a predetermined thickness based upon the design of the curved flapper to be manufactured.

58. The method of claim 53, wherein the stamping step further comprises the step of using a punch and die to form the flat plate of material into a curved section of material.

59. The method of claim 58, wherein the punch comprises a convex surface, and the die comprises a concave surface, the concave and convex surfaces each having a radius of curvature corresponding to the desired radius of the curved flapper.

60. The method of claim 53, wherein the curved section of material is a partial cylinder.

61. The method of claim 53, wherein the radius of the curved section of material conforms to the desired radius of the curved flapper.

62. The method of claim 53, wherein the machining step further comprises the steps of:

honing an interior surface of the curved section of material for providing a finished concave sealing surface; and

cutting a circular section with a hinge out of the curved section of material.

63. The method of claim 62, wherein the curved section of material is a partial cylinder.
64. The method of claim 62, wherein the cutting is performed by an electric discharge machine.

65. The method of claim 62, wherein the cutting is performed by a milling machine.

66. The method of claim 62, wherein holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper.

67. The method of claim 62, wherein the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material.

68. The method of claim 62, further including the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.

69. The method of claim 68, wherein the hard surface coating is created by physical vapor deposition.

70. The method of claim 69, wherein the hard surface coating is a titanium nitride coating.

71. The method of claim 68, wherein the hard surface coating is created by a ceramic spray.
72. The method of claim 71, wherein the ceramic spray is zirconia.

73. The method of claim 71, wherein the ceramic spray is silicon nitrate.

74. A method of manufacturing a curved flapper for use in a subsurface safety valve comprising the steps of:

   providing a piece of material;

   forming the piece of material into a curved section of material of desired radius; and

   machining the curved section of material to form the curved flapper.

75. The method of claim 74, wherein the piece of material is a flat plate of material having a yield strength greater than approximately 130,000 p.s.i. and complying with NACE Standard MR0175.

76. The method of claim 75, wherein the forming step further comprises the step of rolling the flat plate of material into a curved section of material having a radius of curvature conforming to the desired radius of the curved flapper.

77. The method of claim 75, wherein the forming step further comprises the step of stamping the flat plate of material by use of a punch and die into a curved section of material having a radius of curvature conforming to the desired radius of the curved flapper.
78. The method of claim 74, wherein the piece of material is a block of material having a yield strength greater than approximately 130,000 p.s.i., complying with NACE Standard MR0175, and having a predetermined thickness, based upon the design of the curved flapper to be manufactured, sufficient to completely cut the curved flapper out of the block of material.

79. The method of claim 74, wherein the machining step further comprises the steps of:

honing an interior surface of the curved section of material for providing a finished concave sealing surface; and

cutting a circular section with a hinge out of the curved section of material.

80. The method of claim 79, wherein holes are drilled into the curved section of material before cutting out the circular section and hinge, for forming a hinge hole in the hinge of the cut out curved flapper.

81. The method of claim 79, wherein the hinge includes a longitudinal axis and the curved flapper is cut out of the curved section of material such that the longitudinal axis of the hinge is parallel to a longitudinal axis of the curved section of material.

82. The method of claim 79, further including the step of applying a hard surface coating to the interior surface of the curved section of material prior to the honing step.