US 20080138167A1

(19) **United States**

(12) **Patent Application Publication**

(10) **Pub. No.: US 2008/0138167 A1**

(43) **Pub. Date: Jun. 12, 2008**

Wallace

(54) **DIRECT TENSION INDICATING WASHERS**

(76) Inventor: **Ivan Wayne Wallace**, Walpole, NH (US)

Correspondence Address:
CANTOR COLBURN, LLP
20 Church Street, 22nd Floor
Hartford, CT 06103

(21) Appl. No.: **11/875,224**

(22) Filed: **Oct. 19, 2007**

Related U.S. Application Data

(60) Provisional application No. 60/874,457, filed on Dec. 12, 2006.

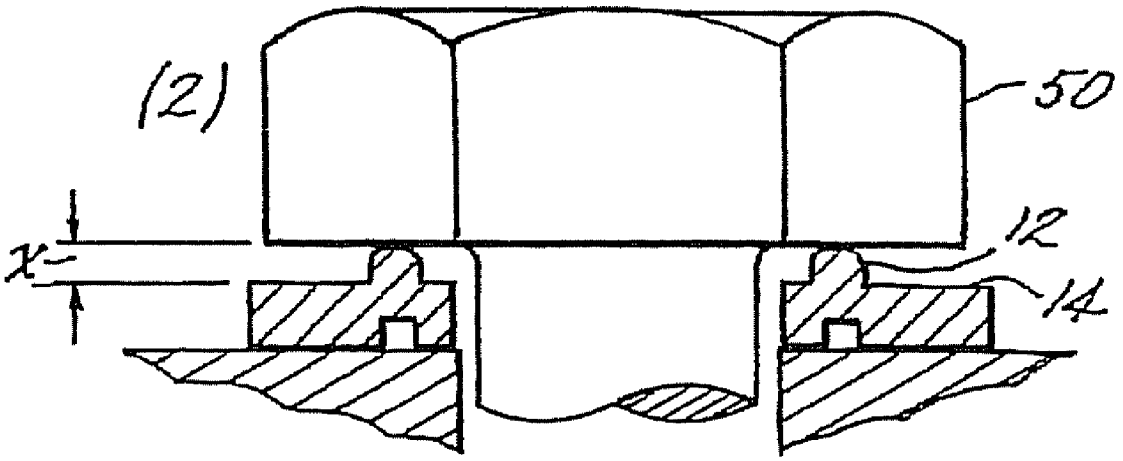
Publication Classification

(51) **Int. Cl.**
F16B 31/02 (2006.01)

(52) **U.S. Cl.** **411/14**

(57) **ABSTRACT**

A direct tension indicating washer including: a first surface having a discrete protuberance formed thereon; a second surface having a discrete indentation formed opposite the protuberances; and an indicating material positioned in the indentation, wherein the indicating material has a cured skin on an outside of the indicating material and a compressible, liquid core in an interior of the indicating material. When the bolt tension reaches a predetermined level, the liquid cores erupts through the cured skin causing a climactic and dramatic appearance of the indicating material about an edge of the washer.



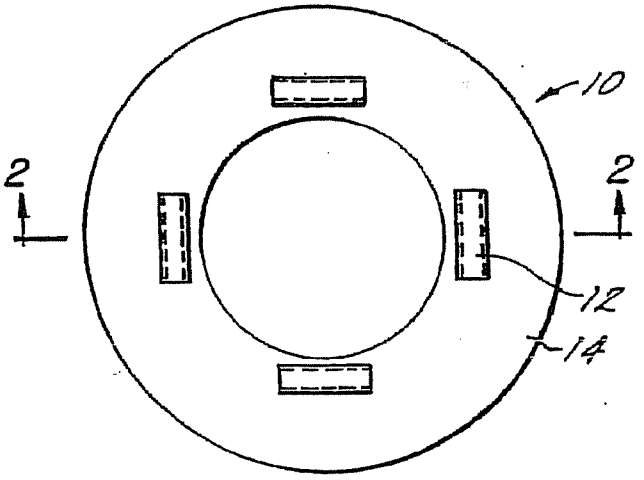


FIG. 1
(PRIOR ART)

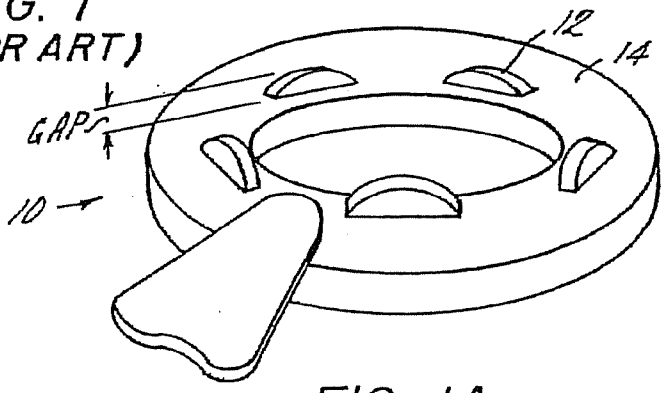


FIG. 1A
(PRIOR ART)

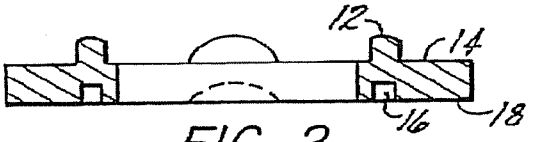


FIG. 2
(PRIOR ART)

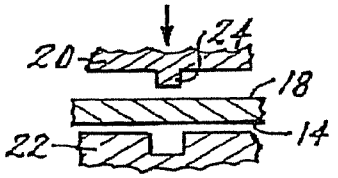


FIG. 3
(PRIOR ART)

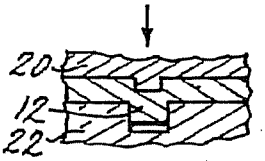


FIG. 4
(PRIOR ART)

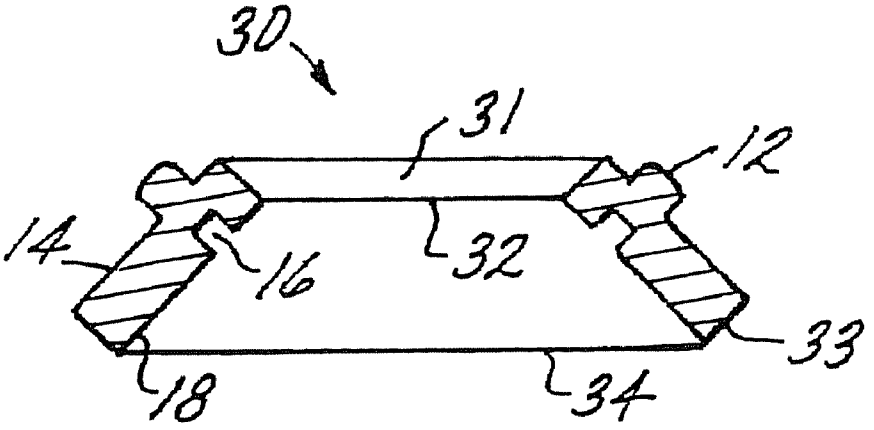


FIG. 5

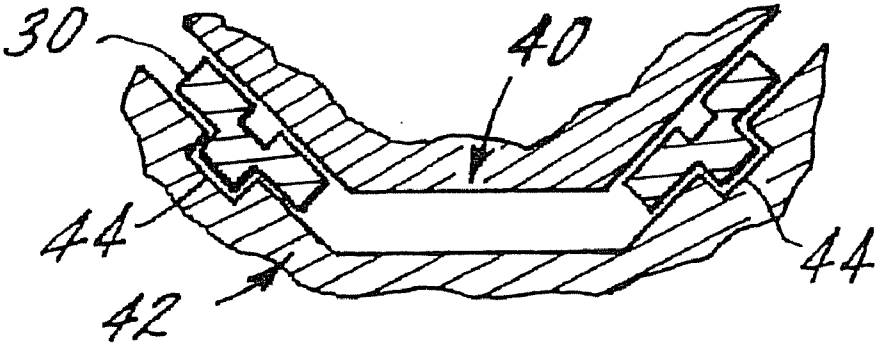


FIG. 6

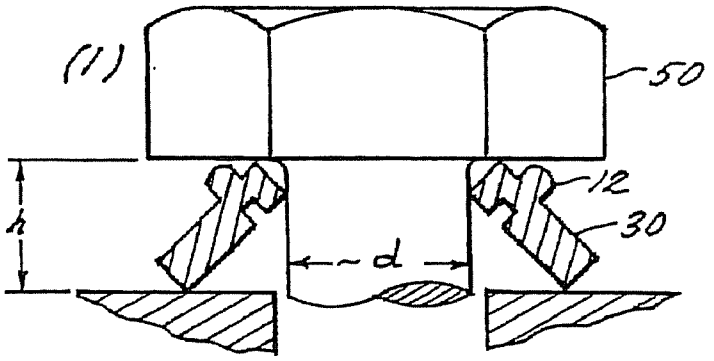


FIG. 7

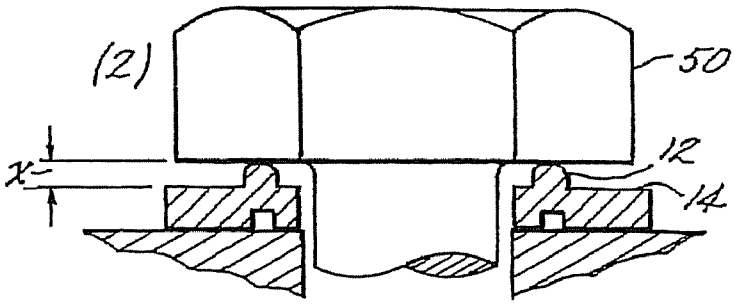


FIG. 8

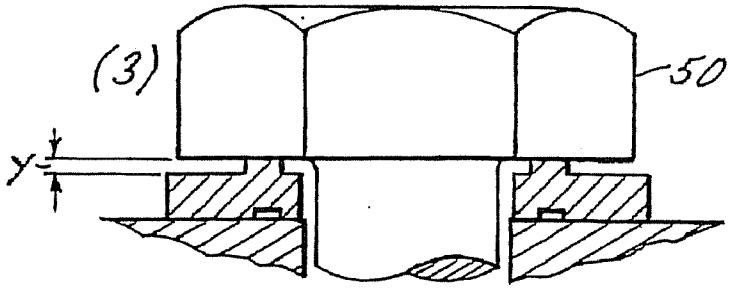


FIG. 9

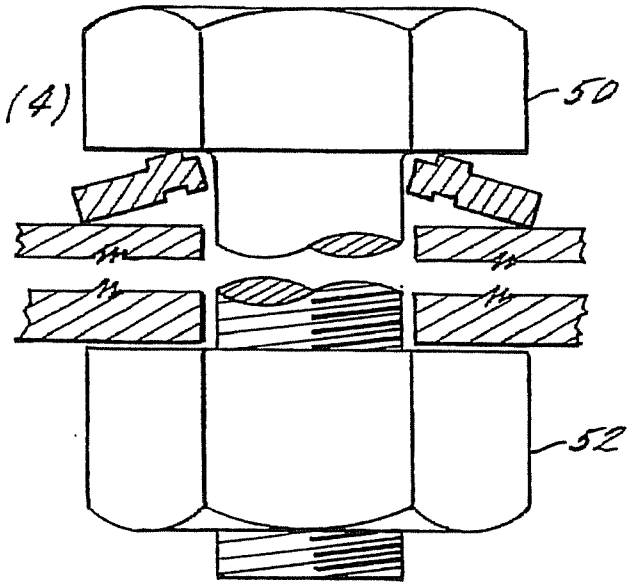


FIG. 10

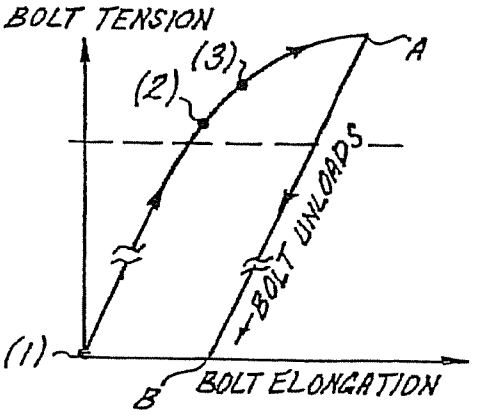


FIG. 11
(PRIOR ART)

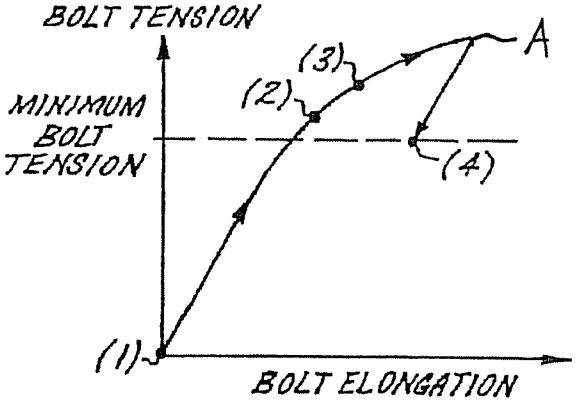


FIG. 12

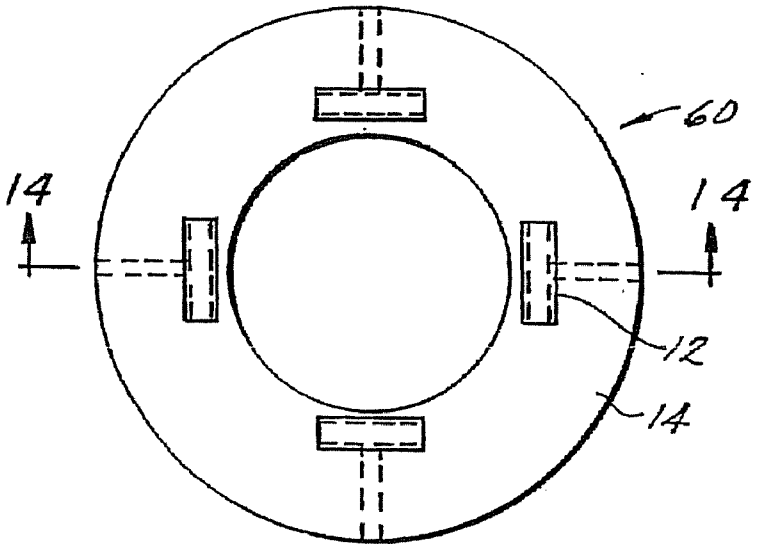


FIG. 13

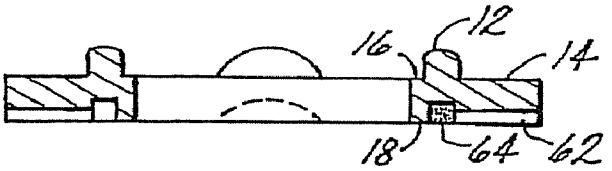


FIG. 14

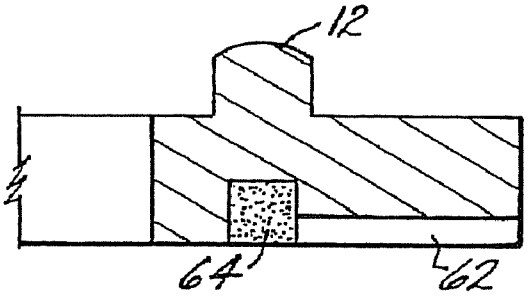


FIG. 15

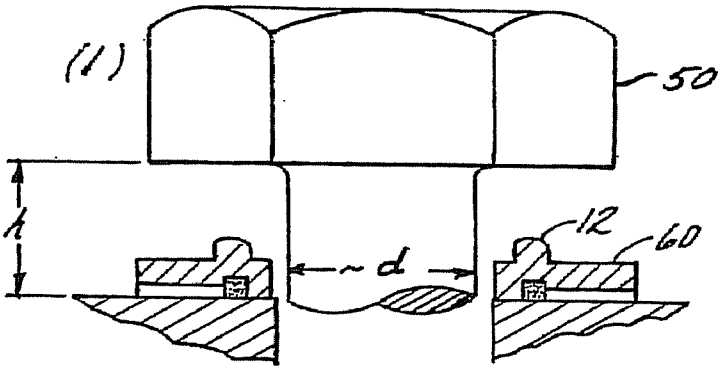


FIG. 16

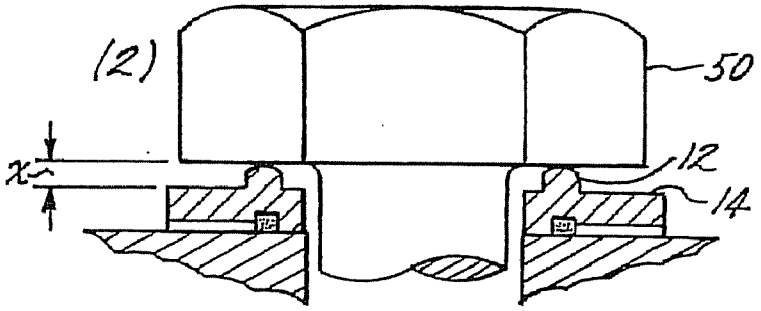


FIG. 17

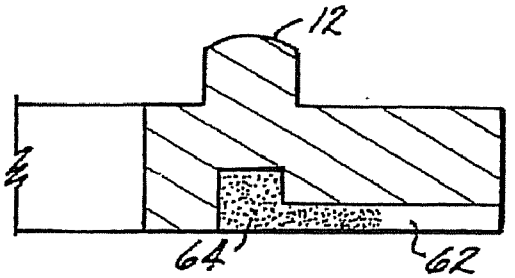


FIG. 18

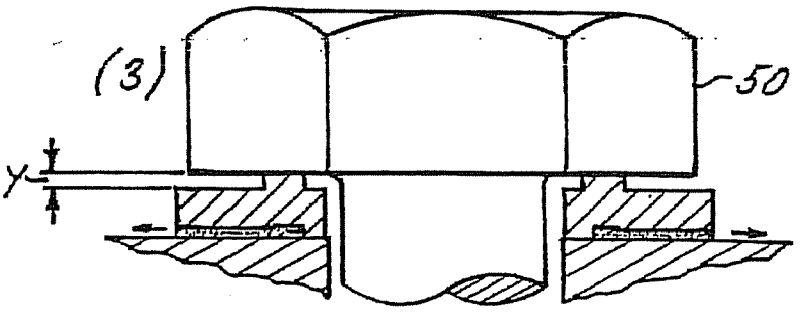


FIG. 19

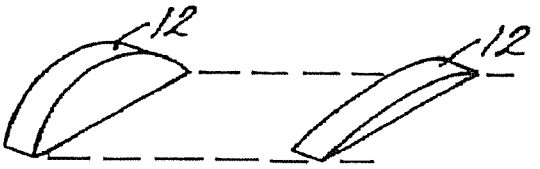


FIG. 20

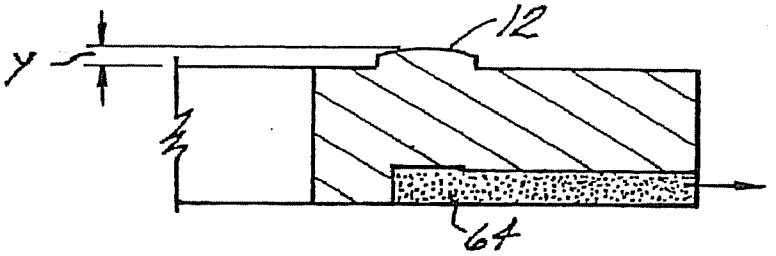


FIG. 21

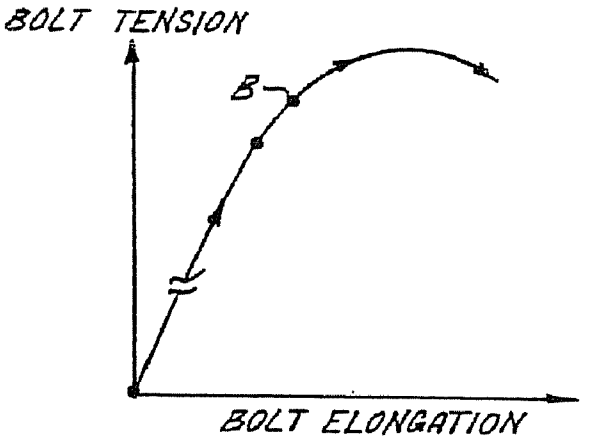


FIG. 22

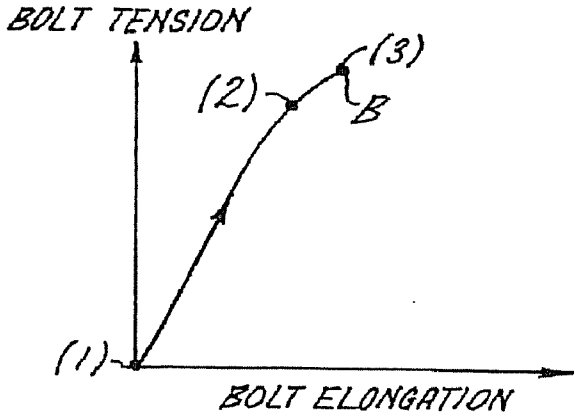


FIG. 23

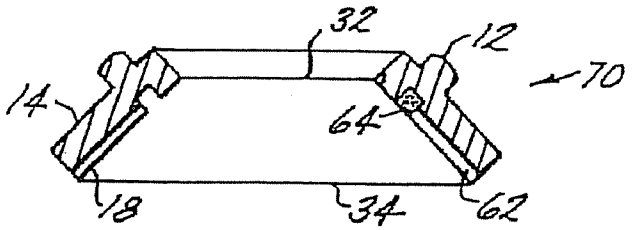


FIG. 24

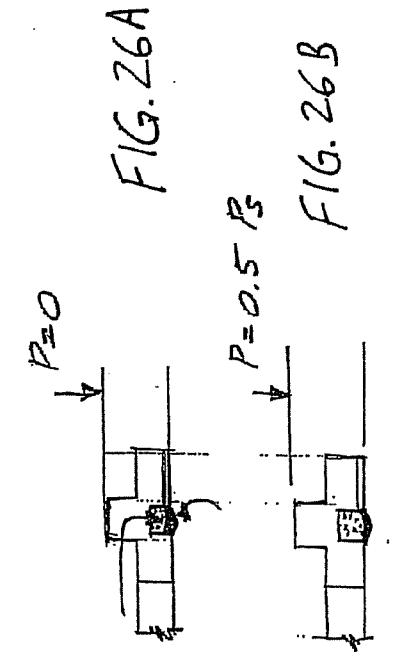


FIG. 26A

FIG. 26B



FIG. 26C

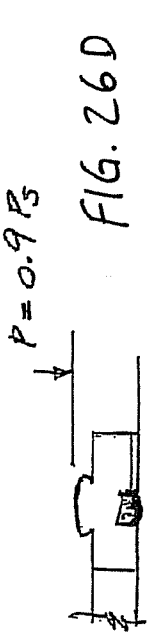


FIG. 26D

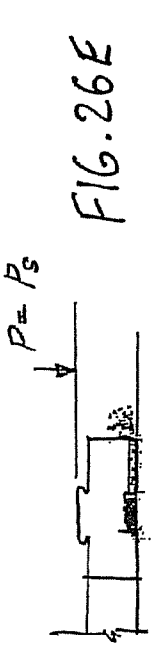


FIG. 26E

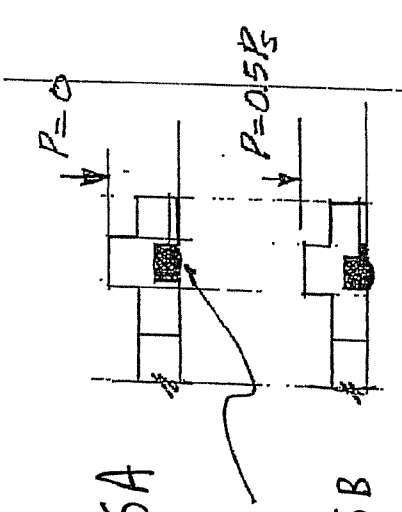


FIG. 25A

FIG. 25B

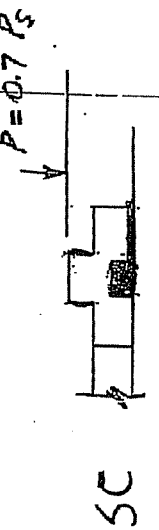


FIG. 25C

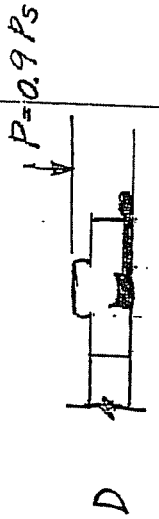


FIG. 25D

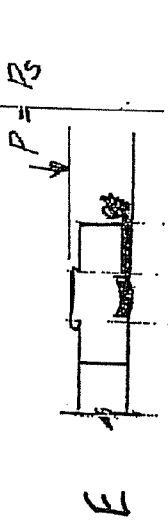


FIG. 25E

DIRECT TENSION INDICATING WASHERS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. provisional patent application Ser. No. 60/874,457 filed Dec. 12, 2006, the entire contents of which are incorporated herein by reference.

BACKGROUND

[0002] The invention relates in general to direct tension indicating and maintaining washers and in particular to direct tension indicating and maintaining washers that maintain bolt tension and/or indicate when the proper bolt tension has been achieved.

[0003] High strength metal bolts, along with their corresponding nuts, when used in metal connections, are almost always intended to be installed so that they are tensioned. The tensioning is usually accomplished by turning the nut relative to the bolt a specified amount of rotation or until a certain torque resistance has been reached. The tension in the bolt stretches the bolt and compresses the connection plates between the bolt head and nut so the connection plates do not slip relative to each other. It is this slip resistance which holds structures such as bridges and buildings together.

[0004] FIG. **1** is a top view of a conventional direct tension indicating washer **10**, commonly referred to as a DTI. The direct tension indicating washer **10** includes a series of protuberances **12** formed on a first surface **14**. As shown in FIG. **2**, corresponding indentations **16** are formed in a second surface **18** of the direct tension indicating washer **10**. As shown in FIGS. **3** and **4**, the direct tension indicating washer **10** is manufactured through a stamping operation in which the blank metal washer **10** is placed between a tool **20** and a die **22**. Pressure is applied to the tool **20** (e.g. by a press) and a protrusion **24** on the tool **20** creates the protuberance **12**, and the corresponding indentation **16**, in the direct tension indicating washer **10** as shown hi FIG. **4**.

[0005] The DTI is manufactured so that when the tightening of the bolt forces the protrusions **12** to compress, or reduce height, sufficiently, the bolt is said to have sufficient tension to meet code requirements. Determination of sufficient protrusion compression is accomplished in the field by the attempt to insert a feeler gage of specified thickness (e.g. 0.015") into the residual gap between the underside of the bolt head and the first surface **14** of the DTI. FIG. **1**A shows a feeler gage being placed on a first surface of a direct tension indicating to test bolt tension (the bolt is not shown for clarity). If the attempt to insert the feeler gage is unsuccessful, that is, the inspector cannot insert the feeler gage into the gap half way radially around the DTI circumference between the DTI protuberances, the residual DTI gap (the space between the first surface of the direct tension indicating washer and the bottom of the bolt head) is said to be, on average, of dimension less than the thickness of the feeler gage, and is therefore judged acceptable. Conventional direct tension indicating washers are manufactured so that surfaces **14** and **18** are parallel and perpendicular to the longitudinal axis of the bolt which they are made to fit on, that is when the bolt is inserted through the inner diameter.

[0006] Conventional direct tension indicating washers, though well suited for their intended purposes, have several drawbacks. First, the process of attempting to insert the feeler gage into the DTI gap is time consuming and must be done after the bolt installer has stopped the tightening process. Second, over time, bolt tension declines as the bolt/nut threads seat into the mating steel surfaces and as external loads shake the connections and try to pry the bolt/nut apart. This problem is especially prominent in connections that are subject to vibration such as bridges, structures subject to earthquakes, connections supporting moving cranes and other equipment, etc. As the bolt tension declines, so does the clamping force and the capacity to carry external loads by resistance to slip. The conventional direct tension indicating washer **10** is flat and has the disadvantage that, after bolt installation, the protrusions **12** are essentially flattened inelastically and will not spring back to their original positions if the bolt begins to loose tension.

SUMMARY

[0007] Embodiments of the invention include a direct tension indicating washer including: a first surface having a discrete protuberance formed thereon; a second surface having a discrete indentation formed opposite the protuberances; and an indicating material positioned in the indentation, wherein the indicating material has a cured skin on an outside of the indicating material and a liquid core in an interior of the indicating material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Referring now to the drawings wherein like elements are numbered alike in the several Figures:

[0009] FIG. **1** is a top view of a conventional direct tension indicating and maintaining washer;

[0010] FIG. **1**A is a perspective view of the use of a feeler gage to test bolt tension;

[0011] FIG. **2** is a cross-sectional view of the direct tension indicating and maintaining washer shown in FIG. **1** taken along line **2-2**;

[0012] FIGS. **3** and **4** illustrate a process for creating the protuberances/indentations in the conventional direct tension indicating and maintaining washer;

[0013] FIG. **5** is a cross-sectional view of a direct tension indicating and maintaining washer in accordance with a first embodiment of the invention;

[0014] FIG. **6** illustrates a process for forming the direct tension indicating and maintaining washer shown in FIG. **5**;

[0015] FIGS. **7-9** illustrate the state of the direct tension indicating and maintaining washer during the installation process;

[0016] FIG. **10** illustrates the state of the direct tension indicating and maintaining washer after a decrease in bolt elongation;

[0017] FIG. **11** is a graph of bolt tension versus bolt elongation when using the conventional direct tension indicating and maintaining washer shown in FIGS. **1-2**;

[0018] FIG. **12** is a graph of bolt tension versus bolt elongation when using the direct tension indicating and maintaining washer shown in FIG. **5**;

[0019] FIG. **13** is a top view of direct tension indicating washer in an alternative embodiment of the invention;

[0020] FIG. **14** is a cross-sectional view taken along line **14-14** of FIG. **13**;

[0021] FIG. **15** is an enlarged view of a portion of the direct tension indicating washer of FIG. **14**;

[0022] FIGS. **16-21** illustrate the state of the direct tension indicating washer of FIG. **13** during the installation process;

[0023] FIG. **22** is a graph of bolt tension versus bolt elongation when using the conventional direct tension indicating washer shown in FIGS. **1-2**;

[0024] FIG. **23** is a graph bolt tension versus bolt elongation when using the direct tension indicating washer shown in FIG. **13**;

[0025] FIG. **24** is a cross-sectional view of a direct tension indicating and maintaining washer in yet another embodiment of the invention;

[0026] FIGS. **25**A-**25**E illustrate emission of indicating material with increased bolt tension; and

[0027] FIGS. **26**A-**26**E illustrate emission of indicating material with increased bolt tension in an alternate embodiment.

DETAILED DESCRIPTION

[0028] FIG. **5** is a cross-sectional view of the direct tension indicating and maintaining washer of the present invention shown generally at **30**. The direct tension indicating and maintaining washer is similar to the conventional washer shown in FIG. **1** in that a first surface **14** includes protuberances **12** and the second surface **18** includes indentations **16**. The direct tension indicating and maintaining washer **30** has an opening formed therein having an inner diameter wall **31**. The inner diameter wall **31** meets the second surface **18** at an inner diameter edge **32**. The direct tension indicating and maintaining washer **30** has an outer diameter having an outer diameter wall **33**. The outer diameter wall **33** meets the second surface **18** at outer diameter edge **34**. The inner diameter edge **32** lies in a plane different from the plane of the outer diameter edge **34**. In the exemplary embodiment shown in FIG. **5**, the direct tension indicating and maintaining washer **30** has a conical cross section. It is understood that other geometries may be used.

[0029] FIG. **6** illustrates a step in the process of making the direct tension indicating and maintaining washer **30**. First, the protuberances **12** and indentations **16** are formed as described above with respect to FIGS. **3** and **4**. Second, the direct tension indicating and maintaining washer **30** is placed between a second tool **40** and a second die **42**. The second die includes recess **44** for receiving the protuberances **12** formed on the first surface of the direct tension indicating and maintaining washer **30**. Pressure is applied to the tool **40** and the direct tension indicating and maintaining washer is formed into the conical shape shown in FIG. **5**.

[0030] Although FIG. **6** illustrates a metal stamping manufacturing process, there are other processes, such as metal machining or metal casting, may be used to form the direct tension indicating and maintaining washer **30**. In some cases, the metal product will be heat treated by quenching and tempering after forming to produce the required spring-like load/deformation properties. In an exemplary embodiment, the direct tension indicating and maintaining washer **30** is made from carbon steel, but stainless steel and other alloy products and non ferrous metals may also be used.

[0031] FIGS. **7-9** illustrate the state of the direct tension indicating and maintaining washer **30** during the installation process. FIG. **7** illustrates the placement of the direct tension indicating and maintaining washer **30** adjacent to a bolt head **50** which is threaded to a nut **52** (shown in FIG. **10**). The conditions shown in FIG. **7** are identified as stage **1** where the bolt is at rest. As the bolt **50** is tightened by turning its nut **52**, the direct tension indicating and maintaining washer **30** is flattened as shown in FIG. **8**. At this state, identified as stage **2**, the protuberances **12** on the first surface **14** of the direct tension indicating and maintaining washer **30** have not been fully compressed. The DTI gap, the distance between the first surface **14** and the bottom of the bolt head, is designated as x. Although the direct tension indicating and maintaining washer **30** has been flattened so that the inner diameter edge and the outer diameter edge lie in the same plane, the direct tension indicating and maintaining washer **30** maintains its resiliency and will tend to return to its original conical shape when the bolt tension is released. As the bolt **50** is further tightened, the protuberances **12** are compressed and tightening is discontinued when the DTI gap is at or below a predetermined distance y. At this point, the bolt installer knows that the bolt tension is equal to or greater than the required minimum. This state is identified as stage **3** and is shown in FIG. **9**. The tension may now be tested with a feeler gage as shown in FIG. **1**A.

[0032] FIG. **10** illustrates the state of the direct tension indicating and maintaining washer **30** as external loads, metal to metal deformation, or seating in of the bolt, vibration, temperature and other influences cause the bolt to tend to lose elongation. As shown in FIG. **10**, the direct tension indicating and maintaining washer **30**, due to its resilient nature, pushes against the bottom of the bolt **50** and maintains tension on the bolt. Accordingly, the direct tension indicating and maintaining washer **30** not only indicates when a predetermined bolt tension has been achieved upon bolt installation but maintains bolt tension even as the bolt tension would tend to decline during the life of the bolt/nut assembly.

[0033] FIG. **11** is a graph of bolt tension versus bolt elongation for a bolt/nut assembly using the conventional direct tension indicating washer **10** shown in FIG. **1**. As the bolt is tightened, the bolt tension and the bolt elongation increase as shown in FIG. **11** until the bolt installer is satisfied that the proper tension is achieved at point A. Bolt elongation refers to the increase in bolt length due to tension on the bolt. As shown in FIG. **11**, any reduction in the bolt elongation (due to vibration, temperature, etc.) will cause the bolt tension to tend to decline until ultimately, the bolt tension is zero or close to zero (point B).

[0034] FIG. **12** is a graph of bolt tension versus bolt elongation for a bolt/nut assembly using the direct tension indicating washer **30** shown in FIG. **5**. As the bolt is tightened, the bolt tension and the bolt elongation increase as shown in FIG. **12** until the bolt installer is satisfied that the proper tension is achieved at point A. The numerals **1-4** in FIG. **12** correspond to states **1-4** illustrated in FIGS. **7-10**. Subsequently, any decrease in bolt elongation will cause a reduction in bolt tension (from A to a minimum level). However, the bolt tension will be maintained at a minimum level **4** by the force applied by virtue of the resilient nature of the direct tension indicating washer **30**.

[0035] FIG. **13** is a top view of a direct tension indicating washer **60** in an alternative embodiment of the invention. The direct tension indicating washer **60** is similar to the direct tension indicating washer **10** shown in FIG. **1** in that protuberances **12** are formed on a first surface **14** and corresponding indentations **16** are formed on a second surface **18**. The direct tension indicating washer **60** also includes channels **62** that lead from each indentation **16** to the outer diameter of the direct tension indicating washer **60**. The indentation **16** is filled with an indicating material **64** as shown in detail in FIG.

15. The direct tension indicating washer **60** is manufactured in a process similar to the direct tension indicating washer **30**. A tool and die are used to stamp the protuberances **12**, indentations **16** and channels **62** into a blank washer. Other processes, such as metal machining or metal casting may be used to form the direct tension indicating washer **60**. In some cases, the metal product will be heat treated by quenching and tempering after forming to produce the required spring-like load/deformation properties. In an exemplary embodiment, the direct tension indicating washer **60** is made from carbon steel, but stainless steel, nonferrous metals, and other alloy products may also be used. The indicating material **64** is an extrudable, elastomeric solid material such as colored silicone or other materials such a butadiene urethane.

[0036] FIGS. **16-21** illustrate the state of the direct tension indicating washer **60** as a bolt **50** is tightened on the direct tension indicating washer **60**. As shown in FIG. **16**, the bolt is placed through an opening in the center of the direct tension indicating washer **60**. This state is identified as stage **1** in FIG. **16**. As the bolt **50** is tightened, the bottom of the bolt head contacts the protuberances **12** and begins to compress the protuberances towards the first surface **14** as shown in FIG. **17**. FIG. **18** is an enlarged view of one of the indentations **16** illustrating that the force exerted by the protuberance **12** on the indicating material **64** forces the indicating material into channel **62**. This state is identified in FIG. **17** as stage **2**.

[0037] FIG. **19** illustrates the state of the direct tension indicating washer **60** when the bolt **50** has been tightened to a predetermined tension. When the desired bolt tension is achieved, the protuberances **12** have been compressed into the indentations **16** by a distance sufficient to force the indicating material **64** completely through the channel **62** so that the indicating material **64** appears at the outer diameter of the direct tension indicating washer **60**. FIG. **20** shows the change in volume of the protuberances **12** from stage **1** to stage **3**. The change in volume of the indentations **16** is calibrated to the volume of channel **62**. FIG. **21** is an enlarged view of one of the protuberances **12** and the channel **62** when the predetermined bolt tension has been achieved. As shown in FIG. **21**, the indicating material **64** has been forced through the channel **62** and exits the channel at the outer diameter of the direct tension indicating washer **60**.

[0038] FIG. **22** is a graph of bolt tension versus bolt elongation when using a convention direct tension indicating washer such as that shown in FIG. **1**. The desired bolt tension is shown at point B. The bolt installer, however, has no indication that the desired bolt tension has been reached and continues to tighten the bolt past the desired bolt tension B. FIG. **23** is a graph of bolt tension versus bolt elongation when using the direct tension indicating washer **60** shown in FIGS. **13-14**. The numerals **1-3** on the graph of FIG. **23** correspond to stages **1-3** shown in FIGS. **16-21**. When the desired bolt tension is achieved at point B, the indicating material **64** will appear at the outer diameter of the direct tension indicating washer **60** and the bolt installer knows to discontinue tightening of the bolt. If the extruded indicating material has worn away over time, and confirmation of bolt tension is needed, a feeler gage may be used to confirm adequate bolt tension as shown in FIG. **1**A.

[0039] FIG. **24** is a cross sectional view of another embodiment of the invention. The direct tension indicating washer **70** in FIG. **24** combines the features of direct tension indicating washer **30** and direct tension indicating washer **60** described above. Accordingly, the direct tension indicating washer **70** both maintains tension by using a conical washer body but also includes the channel **62** and indicating material **64** for immediate detection of the proper bolt tension. The inner diameter edge **32** lies in a plane different than the plane of the outer diameter edge **34**.

[0040] FIGS. **25**A-**25**E illustrates emission of the indicating material with increased bolt tension. As shown in FIG. **25**, as bolt tension, P, increases from zero to Ps, the intended calibration tension, the indicating material exits the channel. In FIG. **25**A, the indicating material is silicone, which typically cures in the indentation prior to use. When cured, although flexible, the silicone is not compressible. Consequently, as the volume of the indentations becomes smaller as the protuberance is compressed, the silicone begins appearing on the outside at around 70% of the intended bolt pretension, shown as P=0.7 Ps in FIG. **25**C. This sometimes confuses bolt installers, and they stop tightening at that point. To simply fill the depression with less silicone, does result in a later (higher bolt preload) appearance of silicone, however this practice is risky because of inherent variables in the metal strength the bolt pretension sometimes climbs too high before the silicone is clearly visible. Additional silicone exits the channel as the bolt tension reaches the desired level as shown in FIGS. **25**D and **25**E.

[0041] Accordingly, in alternate embodiments of the invention, a different indicating material is used in the indentations. FIGS. **26**A-**26**E illustrate emission of indicating material with increased bolt tension in an alternate embodiment. In the embodiment of FIG. **26**, the indicating material has compressibility and modified polymerization to control the release of indicating material through the channel.

[0042] The indicating material in FIGS. **26**A-**26**E is made more compressible than typical silicone. The compressibility is achieved by formulating and then energetically mixing the silicone under an inert blanket of nitrogen in such a way as to deposit micro bubbles of nitrogen into the silicone. In lieu of nitrogen, ultra-dry air may be used. These micro-bubbles have the property of being compressible within the liquid silicone, while not affecting the curing properties of the silicone.

[0043] Modified polymerization generates a cured skin over the compressible silicone in the indentation. Most moisture/heat cured silicones have the property of curing from the outside surface inward without stopping, thereby resulting, after a complete cure, in uniform properties all the way through the cured and solid elastomeric silicone. Embodiments of the invention use silicone with an additive material mixed into the liquid silicone which has, when triggered by heat or infrared radiation, the effect of terminating the polymerization process. This process results in the polymerization of about 1 millimeter of thickness, leaving the remaining silicone core encapsulated in liquid form, ready to compress and then explode out in liquid form.

[0044] In one embodiment, the silicone is cured by the addition of a platinum based catalyst containing an amine or sulphur based molecular sieve which has the capability of poisoning the curing reaction when activated by heat. After the liquid silicone is deposited into the metal DTI, a short interval of time will allow the surface curing to begin, and then an application of heat will terminate the curing process, leaving the liquid compressible core.

[0045] In an alternate embodiment, the compressible silicone is deposited in the indentation. The compressible silicone is then capped right away with a second fast curing skin

which can be any of a large number of materials, sprayed of otherwise deposited on top of the compressible silicone underneath. The indentation is then flash cured by heat or Ultraviolet Light (UV) so that the compressible silicone underneath stops curing.

[0046] When this combination of skinned over and liquid core of compressible silicone is used, the onset of silicone appearance at the periphery of the DTI is delayed as shown in FIGS. **26**A-**26**E. As shown in FIGS. **26**A-**26**D, as the bolt tension increases from 0 to 0.9 Ps, the silicone indicating material is not emitted through the channel right to the end. This is due to the compressibility of the silicone and the cured skin on the outside of the indicating material. At a particular bolt pretension about 90-95% of the intended bolt calibration load, the silicone appearance on the outside is climactic and dramatic as shown in FIG. **26**E, effectively alerting the installer that the correct bolt pretension has been achieved.

[0047] While preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to be understood that the present invention has been described by way of illustration and not limitation.

What is claimed is:

1. A direct tension indicating washer comprising:

a first surface having a discrete protuberance formed thereon;

a second surface having a discrete indentation formed opposite the protuberance; and

an indicating material positioned in the indentation, wherein the indicating material has a cured skin on an outside of the indicating material and a liquid core in an interior of the indicating material.

2. The direct tension indicating washer of claim **1** wherein the indicating material is mixed under nitrogen prior to being polymerized.

3. The direct tension indicating washer of claim **1** wherein the indicating material is mixed under ultra-dry air prior to being polymerized.

4. The direct tension indicating washer of claim **1** wherein the cured skin is formed by initiating polymerization of the indicating material and terminating the polymerization upon formation of the cured skin.

5. The direct tension indicating washer of claim **4** wherein polymerization is terminated by applying energy to the indicating material.

6. The direct tension indicating washer of claim **5** wherein the indicating material includes a platinum based catalyst.

7. The direct tension indicating washer of claim **1** wherein cured skin is a fast curing skin deposited on top of the liquid core indicating material.

8. The direct tension indicating washer of claim **1** further comprising a channel leading from the indentation to an outer diameter of the direct tension indicating washer.

9. The direct tension indicating washer of claim **1** wherein:

the first surface has a plurality of discrete protuberances formed thereon;

the second surface has a plurality of discrete indentations, each indentation formed opposite one of the protuberances; and

a plurality of channels formed in the second surface, each channel leading from one of the indentations to an outer diameter of the direct tension indicating washer

* * * * *