(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 November 2017 (16.11.2017)

WIPO | PCT

(10) International Publication Number
WO 2017/196240 A1

(51) International Patent Classification:
E03C 1/084 (2006.01) *E03C 1/04* (2006.01)
E03C 1/086 (2006.01) *G01K 13/02* (2006.01)

(21) International Application Number: PCT/SE2017/050466

(22) International Filing Date: 09 May 2017 (09.05.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/333,737 09 May 2016 (09.05.2016) US
62/407,387 12 October 2016 (12.10.2016) US

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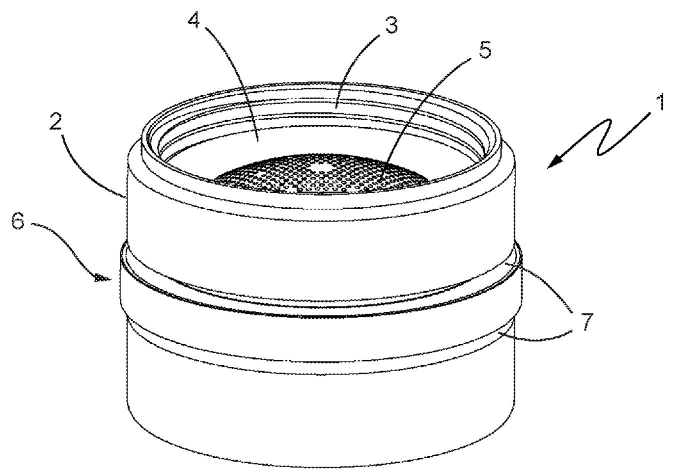
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

(54) Title: HOT WATER USE WARNING DEVICE FOR FAUCETS

FIG. 1



(57) Abstract: A low-cost hot water use warning device, having the shape of an aerator housing, including a metallic housing inner core (2) with threads configured for attachment to a faucet and a ridged indented channel for accommodating a thermochromic belt (6) or band that may constitute several layers including an outer thermochromic layer (10) capable of changing its color at a certain temperature, a second high thermal conductivity layer (11) made of copper for evening out temperature gradients and a third low heat conducting polymeric layer (12) for imposing a controlled delay. At each vertical side of the thermochromic belt are flanking wedge-shaped isolation grooves (7). The device operates as an awareness indicator for informing a faucet user of excessive temperature and duration of hot water use.

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Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

HOT WATER USE WARNING DEVICE FOR FAUCETS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims the priority from U.S. Provisional Application Ser. No. 62/333,737, filed May 9, 2016 and U.S. Provisional Application Ser. No. 62/407,387, filed October 12, 2016, both of which are incorporated by reference herein.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to water- and energy-efficiency solutions for faucets. More particularly, the invention relates to a low-cost visual metering device for informing a faucet user of excessive temperature and duration of hot water use, ultimately leading to a reduction of hot water use due to a change in user behavior.

[0003] A number of important technological solutions that saves water and hot water for faucets have become widely adopted by the market during the last decades. Perhaps the most revolutionary example is the mixing of air with the water flow through the use of aerators. Other examples include single-lever mixers, cold-start mixers, constant flow regulators, temperature limiters and thermostats. However, none of these technologies primarily targets bad user behavior leading to water waste, a reason to why many households report water and energy usage considerably higher than others of the same size, even when accounting for factors such as the number of faucets, showers and whether there is a dishwashing machine installed or not.

[0004] As building regulations continually impose rising demands on higher energy-efficiency and rational use of natural resources, the use of hot water has come to play an increasingly pivotal role in lowering the building total energy demand. In newly renovated or constructed multi-dwelling buildings for example, having already implemented solutions such as an energy-efficient building envelope and HVAC-system, hot water use alone can account for over 50% of the building total energy use. Hot water use further tends to be split evenly between faucets and showers. However, where for instance shower timers and flow-meters are offered and readily available on the market, few sensible solutions for raising user awareness are available for faucets. Most faucets cannot bear the same costs and apparatus size as the technology for a shower system is allowed to have. Therefore, there exists a need for a device such as the one disclosed by the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Exemplary embodiments of the present invention are illustrated in the accompanying drawings, in which:

FIG. 1 illustrates a hot water use warning device in perspective, according to an embodiment of the invention;

FIG. 2 is a vertical cross section of the hot water use warning device according to FIG. 1;

FIG. 3A shows an enlarged cross sectional view of a thermochromic belt portion as shown in FIG. 2;

FIG. 3B shows an enlarged cross sectional view of a thermochromic belt portion similarly as FIG. 3A but having a different configuration;

FIG. 4 illustrates a hot water use warning device in perspective featuring a wedge-shaped thermochromic belt, according to an embodiment of the invention;

FIG. 5 is a vertical cross section of the hot water use warning device according to FIG. 4;

FIG. 6 shows an enlarged cross sectional view of a wedge-shaped thermochromic belt portion as shown in FIG. 5;

FIGS. 7A and 7B diagrammatically illustrates the progression of a temperature gradient inside a thermochromic belt in an idealized case;

FIGS. 8A and 8B diagrammatically illustrates the progression of a temperature gradient inside a wedge-shaped thermochromic belt, in an idealized case;

FIG. 9 illustrates a hot water use warning device in perspective, according to another embodiment of the invention;

FIG. 10 is a vertical cross section of the hot water use warning device according to FIG. 9;

FIG. 11 shows an enlarged cross sectional view of a lower thermochromic belt portion as shown in FIG. 10;

FIGS. 12A and 12B are vertical cross sections of a hot water use warning device operating in a tilted condition, without and with an annular wetting cut-off groove;

FIG. 12C is a vertical cross section of a hot water use warning device operating with an aerating unit installed, showing the placement of an added inner isolation ring;

FIG. 13A shows an enlarged cross sectional view of a thermochromic belt portion according to FIG. 3B with an added outer isolation layer;

FIG. 13B shows an enlarged cross sectional view of a thermochromic belt portion according to FIG. 3B with an alternative configuration and comprising an outer isolation layer having bilaterally roughened surfaces;

FIGS. 14A and 14B are vertical cross sections of a modified hot water use warning device also capable of reacting to cold water use.

DETAILED DESCRIPTION

[0006] Hereinafter, embodiments of a hot water use warning device for faucets, according to the present invention, are described with reference to the accompanying drawings. One embodiment is shown in **FIGS. 1-3A**. According to **FIG. 1** the hot water use warning device **1** connects to a faucet orifice through the attachment of housing inner core **2** via its threads **3**. Housing inner core **2** is in this embodiment made of a high heat conductive metallic material that is manufactured in one piece so as to allow for an efficient transport of heat. Its circular shape is further designed to accommodate the placement of an aerating unit (not shown) attached to and directly beneath particle filter **5**. Washer **4** provides for a watertight seal against the faucet orifice. At the longitudinal approximate mid-center of housing inner core **2** runs an indented channel at right angle to the operational path of flow **9** (**FIG. 2**), affixing a thermochromic belt **6** having the shape of a ring and encircling the entire outer perimeter of housing inner core **2**. On each side of thermochromic belt **6** are flanking isolation grooves 7 which according to **FIG. 2**

are wedge-shaped marginal spaces in the indented channel that isolates the thermochromic belt **6** from lateral direct thermal contact with housing inner core **2**.

[0007] For all described embodiments, thermochromic belt **6** comprises a collection of reversible thermochromic pigments that changes color when a certain temperature, the activation temperature, is reached and returns to its original color when the temperature is decreased below the activation temperature. Thus, thermochromic belt **6** effectively operates as an energy consumption awareness indicator, or warning display, such that every time when water flow of a certain temperature and duration through the water carrying conduit **8** (**FIG. 2**) of hot water use warning device **1** occurs, heat is transported to and/or heat irradiation is successively absorbed by thermochromic belt **6**, thereby after some time giving rise to a visible color change on the outer perimeter of the thermochromic belt **6** and by this alerting the faucet user and the nearby environment of instances of excessive hot water use.

[0008] Now, as a principal illustration of heat transport through thermochromic belt **6** according to **FIGS. 1-3A**, reference is made to **FIGS.** 7**A** and **B**. At a certain timeframe *t*, heat with a temperature T1 has already diffused into the thermochromic belt according to the temperature gradient contour line 16. At a later time the heat has progressed as shown by **FIG. 7B**, the distance difference being dependent upon the thermal conductivity. Given then, temperature T2 lies below the activation temperature and T1 above, there will be a certain time delay before the display surface **17** and the thermochromic pigments residing here reach temperature T1 and consequently shift in color. The choice of material will be hugely decisive of the heat transfer rate, or in other words heat conductance or thermal diffusion rate.

[0009] In one embodiment, thermochromic belt **6** is a single piece of injection-molded thermoplastic having thermochromic pigments in the form of microencapsulated leuco dyes embedded into the polymer matrix. Suitable thermoplastics for this intermixing purpose and serving as polymer vehicles include, but are not limited to polyethylene (PE), polypropylene (PP) and acrylonitrile butadiene styrene (ABS). Masterbatches containing microencapsulated leuco dyes for blending with the aforementioned thermoplastics can be readily ordered from a number of manufacturers. Microencapsulated leuco dyes have been chosen because they are relatively cheap yet durable and being able to withstand a large number of activation cycles before degrading. Also, the embedding into a polymer matrix improves durability and decrease weathering effects. However, covering the outside of a molded thermoplastic with thermochromic pigments and thereafter optionally applying a light-filtering overcoat may also be an option. Further, if a higher degree of activation temperature accuracy is wished for, microencapsulated liquid crystals may be chosen as pigments instead. Some formulations of liquid crystals are able to provide of a spectrum of different colors within a given temperature interval.

[0010] In one embodiment, an activation temperature of 38°C is chosen and a red colored thermoplastic polymer is selected together with microencapsulated leuco dye pigments of the kind that is totally absorptive (substantially black) up to the activation temperature at which they become transparent, and thus reveals the red color in the blend. Therefore, in this embodiment, the visible color change will be that of going from black (or very dark red) in the “off-state” to red in the “on-state”. In another embodiment, blue (or cyan) colored leuco dye pigments that change into transparent when surpassing the activation temperature are chosen, as red would be the substantially opposite color according to the theory of the subtractive color mixing CMYK-model. It has further been found that utilizing blue pigments, in particular in combination with black pigments, is able to provide a more satisfying off-state appearance than what is possible by utilizing black pigments only.

[0011] In serving as the warning signal, an activation color of red would be a natural choice because it is both perceived by many as a “warning” color and is also perceived as indicative of high temperatures. In an alternative embodiment, the off-state would be represented by a green color reminiscent of environmental awareness, by the combination of dual green-to-clear and clear-to-red thermochromic pigments, sharing the same activation temperature (A-to-B representing a transition from a lower temperature to the activation temperature and where clear is implying a largely transparent shade).

[0012] By varying the thickness of thermochromic belt **6** and/or by expanding the vehicle polymer with air or blending it with materials of different heat conductance, it is possible to affect the time it takes for heat to transport from the inside perimeter to the outside perimeter of thermochromic belt **6**. As principally illustrated by **FIGS. 7A** and **B** and earlier discussed, this makes it possible to introduce a controlled delay of the color change. For example, a thermochromic belt could in this manner be constructed that turns red not until after 30 seconds of hot water use at a flow rate of 1 gpm. It is understood that the time it takes for heat to transport inside housing inner core **2** is also a delay factor. However, in embodiments where choosing a high heat conducting metallic material having a heat conductance or thermal conductivity of over 100 W/(m*K) for the housing inner core **2**, such as a brass-alloy, and one of the above mentioned low heat conducting thermoplastic polymers (all having thermal conductivities in the range 0.1 – 0.5 W/(m*K)) for the thermochromic belt **6**, the delay effect is very much a result of the dimensions and isolative properties of the thermochromic belt itself. Also, a quick heating of the housing inner core **2** would ensure that heat gradients start off at the inner perimeter of thermochromic belt **6** at approximately the same time, more closely resembling the ideal cases illustrated in **FIGS. 7A-8B**. For a significant evening-out effect of the heat gradients to occur at the transition between the housing inner core **2** and the low thermal conductivity layer **12**, the housing inner core **2** should be made from a material at least ten times as thermally conductive than the low thermal conductivity layer. However, for definition purposes a high thermal conductivity or high heat conductive material should in light of this specification be regarded as having at least twice the thermal conductivity as a low thermal conductivity material.

[0013] In another embodiment, a plurality of thermochromic rings are mounted in series in a stacked manner (preferably with some vertical space in between) along the outside of housing inner core **2**, being made from a thermally conductive polypropylene polymer, whereby the topmost ring will change color first, followed by the next, due to the diffusion of heat gradually spreading from the top of the structure and downwards. Further, the rings may be chosen to each have a different color change threshold, so as to allow an even greater time separation between the color changes. For example, the first may change color at 20 s of hot water use at 1 gpm, the second at 40 s of hot water use at 1 gpm and so on. The rings could in one sense also be fused together: several batches of thermochromic pigments of different characteristics, such as different activation temperatures and different colors, could be intermixed. For example, a black thermochromic pigment with activation temperature of 35°C could be mixed with a yellow thermochromic pigment with activation temperature of 43°C, along with a third non-thermochromic red color. Hence, this mixture would start off black, turn orange when the black clears, then finally red when the yellow clears.

[0014] Now referring to **FIG. 2**, having the thermochromic belt **6** positioned in a symmetrical manner with respect to the path of flow **9** (in the figure coinciding with the flow path axis L-L, running through the centroid of housing inner core **2**), and e.g. not tilted in a manner that one portion of the thermochromic belt **6** is closer to the faucet orifice than the other, will ensure that for most operational scenarios heat gradients originating from the faucet orifice reaches the thermochromic belt in approximately equal time (and thus the color change will appear more or less synchronously). A relatively narrow width of the thermochromic belt would further lessen the perceptibility of unwished demarcation lines manifesting on the thermochromic belt surface during the color change phase. Also, its inherent circumferential ring shape will ensure that the rotational alignment of housing inner core **2** when mounted does not have an influence on the visibility of the thermochromic belt.

[0015] In cases were an aerating unit is fitted inside the housing inner core **2**, most heat would generally originate from the upper portion of the housing inner core were the threads are, since the water carrying conduit **8** would then become largely isolated from direct contact with the housing inner core inside walls. Referring to **FIG. 3A**, as a means for further evening-out the heat gradients inside the thermochromic belt **6** and therefore also provide for a more uniform color change, a second high thermal conductivity layer **11** is in one embodiment introduced between a first thermochromic layer **10** and a third low thermal conductivity layer **12**. The thermochromic belt **6** would accordingly turn into a composite of three concentric rings. The high thermal conductivity layer **11** may advantageously be of a high heat conducting metallic material such as copper. Low thermal conductivity layer **12** and thermochromic layer **10** may both be thermochromic polymers of the earlier mentioned kinds, or for certain embodiments only the thermochromic layer **10** would have thermochromic properties and the low thermal conductivity layer **12** would instead be made from e.g. an expanded polypropylene polymer, for an even lower heat conductance. For many embodiments and operational conditions, the idealized heat transport illustrated by **FIGS. 7A-B** will be much more spatially uneven in practice. The temperature gradient contour line depicted here may in practice reach the uppermost portion of the thermochromic belt several seconds before reaching the lower portion. Also, for some operational conditions, heat may spread at different rates at different sections along the circumference of the belt. Apart from the evening-out effect that already occurs thanks to the interface between a high and low thermal conductivity layer, a high thermal conductivity layer **11** made from copper also effectively functions as an efficient heat sink that will buffer and even out the temperature gradients even further before ultimately reaching the thermochromic layer **10**. Additionally, in controlling the spread of heat, attachment isolation grooves **13** may be introduced to both lower the speed of heat transfer between the housing inner core **2** and the thermochromic belt and to, for example, increase the relative heat transfer to the lower portion of the thermochromic belt by narrowing the lower of the two attachment isolation grooves, as shown in **FIG. 3A**. The attachment isolation grooves **13** could contain a low heat conducing material, or simply be air gaps. It is understood that the attachment isolation grooves need not to be specifically annular grooves (they could e.g. be pits) and they could equally well be present in the low thermal conductivity layer **12** instead of the housing inner core.

[0016] Now referring to **FIG. 3B**, the flanking isolation grooves 7 are replaced (or perhaps more correctly implanted) with flanking isolation rinks **14**, in one embodiment made of a very low heat conducting material such as expanded polypropylene, which will lessen the effect of convective air heating of the sides of thermochromic belt **6** and also provide protection for dirt or debris to enter the flanking isolation grooves. However, an operational feature of the wedge-shaped flanking isolation grooves 7 that is hereby lost is the possibility of visual feedback to the user, both directly and through reflections if the housing inner core **2** is chrome plated. This feedback would essentially be that of visual representation of the heat transport on the sides of the thermochromic belt **6**, for those embodiments where the sides would have embedded thermochromic pigments. A temperature gradient line would then be physically manifested through a gradually progressing color demarcation line, which could be construed as a progressive or preemptive warning signal.

[0017] In more clearly utilizing the effect of a visible temperature gradient line, **FIGS. 4-6** (here the threads, washer and filter are not shown) illustrates an embodiment having a wedge-shaped thermochromic belt **15**, where its functionality is probably best understood by looking at **FIGS. 8A and B**. In a similar manner as in **FIGS. 7A** and **B** the temperature gradient contour line will move progressively to the left, however in doing so it will also visibly move vertically. Hence, given the temperature at the housing inner core **2** is above the thermochromic activation temperature, the operational effect will be that of a gradual vertical color progression until the entire wedge-shaped thermochromic belt **15** has changed its color.

[0018] In another embodiment, now referring to **FIGS. 9-11**, the hot water use warning device **1** comprises an upper thermochromic belt **18** for the purpose of also providing instant feedback to the user of the hot water temperature. This is essentially accomplished by letting a protruding member **20** of a high heat conducting housing inner core **2** protrude into close proximity with visible thermochromic pigments embedded along the outer perimeter of the upper thermochromic belt **18**, as shown in **FIG. 10**. In **FIGS. 9-11**, lower thermochromic belt **19** is a structurally modified kind of the thermochromic belt **6** as earlier described, but essentially having the same end-functionality. In one embodiment, a housing inner core **2** made of brass is over-molded with a thermoplastic thermochromic polymer (i.e. a polymer matrix with thermochromic pigments embedded, as earlier described), effectively forming a housing outer core **22**, as shown in **FIG. 10**. Aside from providing adaptable aesthetic possibilities and structural protection, housing outer core **22** is also performing the similar function as that of third low thermal conductivity layer **12** (**FIG. 3A**). In one embodiment and as shown in **FIG. 10**, stream contact flanges **21** are inwardly pointing protrusions of the housing inner core **2**, being able to make direct contact with the water stream, whereby a quicker and more responsive heating of the protruding member **20** is achieved. In another embodiment, now referring to **FIG. 11**, heat distributing member **23** serves a similar purpose as that of second high thermal conductivity layer **11** (**FIG. 3A**), that is to buffer and even out the temperature gradients before reaching the thermochromic layer **10**. Heat distributing member **23** may similarly be made out of copper or some other suitable high conductive material. Compared to the second high thermal conductivity layer **11** (**FIG. 3A**), heat distributing member **23** further comprises a heat pick-up arm **24**, which is a vertically extending structure emanating in an elbow shape from the back center region of a heat buffer platform **25**. In vertically extending beyond the uppermost portion of the heat buffer platform **25**, as shown, the heat pick-up arm **24** serves dual purposes. It “catches” temperature gradients originating from the vertical section of the housing center core **22** above the heat buffer platform **25** and “releases” them into the center region of the heat buffer platform, before they have time to reach the topmost region. It also catches temperature gradients originating from the housing inner core **2** wall in the horizontal direction and focuses them into the center region of the heat buffer platform. Thus, an even greater degree of controlled heating, and therefore a more even and a more defined color change, of the thermochromic layer **10** is possible. The disclosed structure would be especially useful when using over-molding techniques. In one embodiment, thermochromic layer **10** is of the same thermochromic polymer kind as the housing outer core **22** and an opaque paint, plating or overcoat is further applied to the areas according to **FIG. 9** that are outside of the illustrated thermochromic belt regions to prevent visible color changes occurring here.

[0019] In another embodiment and now again referring to **FIGS. 3A** and **B**, thermochromic belt **6** comprises flanking isolation rinks **14** in a single piece of molded or extruded thermoplastic vehicle polymer, having the areas where the flanking isolation rinks would be present painted, plated or coated to prevent or mask visible color changes from occurring in these areas. In such an embodiment, as a solution to avoid having to extend the width of these areas unduly it has been found particularly suitable to utilize a housing inner core made of an austenitic steel grade, such as EN 1.4305, instead of a brass alloy as austenitic steel has a much lower heat conductance than brass, typically around 15 W/(m*K), and would significantly add to the overall heat transport delay. In another embodiment and again referring to **FIG. 10**, the upper thermochromic belt **18**, protruding member **20** and stream contact flanges **21** are omitted, and in yet another embodiment the housing inner core **2** is further of the same material as, and integrated with the housing outer core **22**.

[0020] Now referring to **FIGS. 12A** and **B**, illustrating the hot water use warning device **1** operating in a tilted condition, with and without an annular wetting cut-off groove **27** present at its outlet. As can be seen in **FIG. 12A**, when there is no wetting cut-off groove present, part of the water stream **26** adheres to the surface of the housing inner core **2** and causes water to surround the edge of exit and even flow somewhat "upwards" as shown due to centripetal acceleration around the edge along with surface adherence forces of the water. The phenomenon causes an increase in heat transfer to the lower part of the housing inner core, which in turn results in an undesired accelerated directional (spot) heating of the thermochromic belt **6**. A solution for a more uniform heating of the thermochromic belt **6** under tilted operation is presented by the use of a wetting cut-off groove **27** that breaks the water adherence along the exit edge, as illustrated by **FIG. 12B**. Undue directional heat transfer is hereby lessened and the stream also becomes straighter at tilted operational conditions.

[0021] In another embodiment, and now referring to **FIG. 13A**, a fourth transparent outer isolation layer **28** placed over the thermochromic layer **10** will lessen the convective heat transfer between the thermochromic layer **10** and the outside environment, thereby retaining the color shift of the thermochromic layer **10** for longer durations. Depending on the material chosen, outer isolation layer **28** may also act as an efficient UV-filter for lowering the weathering effects of the thermochromic pigments.

[0022] In another embodiment, and now referring to **FIG. 13B**, outer isolation layer **28** further comprises a yellow to red colored visible light filter such as a red-shifted UV-absorber and/or a translucent red dye, for increased protection of the thermochromic pigments from long-term light damage but still being able to retain a good color shade and contrast between the off- and on-state if the underlying colors are purple to blue. In this embodiment, thermochromic layer **10** has been omitted and thermochromic pigments have been directly suspended into a low thermal conductivity layer **12**, adhering to a high thermal conductivity layer **11** made of copper, in turn adhering to a housing inner core **2** made of austenitic stainless steel. Such a configuration would effectively have the housing inner core **2** functioning as a second low thermal conductivity layer, adding significant time to the overall heat transport delay as earlier pointed out. For the purpose of further increasing perceived color intensity and uniformity, above the approximate positions of the flanking isolation rings **14** portions of the outer surface of the outer isolation layer **28** comprises a roughened surface **36** for collecting and dispersing outside light into the outer isolation layer **28**. To aid in distributing light rays entering through roughened surface **36**, glossy surface **37** is highly reflective for providing total internal reflection possibilities of the light rays. An example of a suitable material composition of outer isolation layer **28** would be a blend of polycarbonate and a thermoplastic elastomer such as TPU, for good environmental stress crack resistance yet still with a high absorption capability in the ultraviolet range. It is understood, that the outer isolation layer **28** could be omitted and have its light-filtering constituents intermixed with low thermal conductivity layer **12**.

[0023] Now turning to **FIG. 12C**, showing a vertical cross section of the hot water use warning device according to **FIG. 1**, with an added inner isolation ring **38** accommodated in a circular cut out groove on the interior of housing inner core **2**. The purpose of introducing inner isolation ring **38**, suitably made of a low heat conducting material such as expanded polypropylene or some other appropriate thermoplastic, would be to lessen the effect of convective cooling occurring due to the airflow in annular air gap **39**, which typically occurs when an aerating unit **40** is installed into the housing inner core **2** and operating at high flow rates. Reducing the effect of convective cooling at high flow rates would promote or amplify the consequence of a faster color shift of the thermochromic belt **6** when the flow rate is high, which is generally wished for.

Apart from this, such a circular cut out groove on the interior would be able to provide a higher thermal resistance for non-uniform heating of the lower part of the housing inner core **2**.

[0024] In another embodiment, and now referring to **FIGS. 14A** and **B**, the hot water use warning device **1** is modified to also provide the ability to react to and warn the user of too much cold water use. The drawings both show vertical cross sections of temporally separated operational states. An expandable pressure chamber **29** has an elastic annular wall that is connected to a rigid base plate containing aerator perforations **30** for providing means for individual water jets to exit the structure. Pressure chamber **29** is capable of expanding when water pressure builds up inside. **FIG. 14A** illustrates the onset of expansion when water flow has just been turned on and **FIG. 14B** illustrates the fully expanded state when water flow has been present for some given time period Δt. Attached to the pressure chamber base plate is a display actuator arm **31**, which in turn rests against or attaches to a viscoelastic delay segment **32**, for example a block of a memory foam material. In principle, the viscoelastic properties of the viscoelastic delay segment **32** would cause a mechanical deformation resistance that would prevent the display actuator arm **31** from promptly reaching the fully actuated state in **FIG. 14B**, but rather not until the viscoelastic delay segment **32** has been given enough time to reach its fully deformed state, as illustrated. The terminal end of display actuator arm **31** comprises a slanted impress surface **33** that, when the state in **FIG. 14B** has been reached, presses against pressure sensitive display **34**, also slanted as shown. Pressure sensitive display **34** has the ability to change its color appearance when subjected to a change in pressure, and is in one embodiment chosen to be a piezochromic polymer sheet being able to change color from black to red when slanted impress surface **33** presses against its surface. A transparent rigid cover glass **35** provides protection, structural integration with housing inner core **2** and a means for reaction forces to occur. In the figures, the pressure sensitive display only circumferentially stretches a portion of the cylindrically shaped housing inner core **2**. Faster response times when hot water is used compared to when cold water is used can be attained if choosing a viscoelastic material that deforms more easily when the surrounding temperature is higher (the temperature inside housing inner core **2** would inherently correlate with the water temperature).

[0025] Thermochromic pigments in the form of microencapsulated dyes and crystals have been first and foremost described herein. However, as understood by anyone skilled in the art that any thermochromic material or substance that changes spectral properties under influence of temperature may likewise be regarded as a collection of thermochromic pigments for the present invention to work as described.

[0026] It is understood that threads **3** may be non-existing in an embodiment and assembly were the housing inner core **2** is in fact an integral section of the faucet.

[0027] It is understood that the embodiments of the present invention which have been described herein are merely illustrative of the principles behind it. Numerous modifications may be made by those skilled in the art without departing from the true spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A hot water use warning device configured for attachment to a faucet, comprising:

a collection of reversible thermochromic pigments having substantially equal activation temperatures and annularly distributed in a ring shaped thermochromic belt along the outer circumference of a water carrying conduit;

wherein said thermochromic belt is substantially symmetrically placed with respect to the general flow path of water in said water carrying conduit, whereby heating of said reversible thermochromic pigments to a predetermined temperature occurs at approximately equal times and is regardless of the rotational alignment around the flow path axis of said thermochromic belt and,

wherein said thermochromic belt comprises a low heat conducting material circumferentially enclosing a housing inner core having a high heat conductance, whereby a delayed color change of said reversible thermochromic pigments is substantially controllable by varying the thickness of said thermochromic belt and an evening-out effect of heat gradients is introduced.

2. The hot water use warning device according to claim **1**, wherein said reversible thermochromic pigments are selected from the group consisting of microencapsulated leuco dyes and microencapsulated liquid crystals.

3. The hot water use warning device according to claim **1**, wherein said low heat conducting material is selected from the group consisting of polymers and elastomers, and said housing inner core having a high heat conductance is made from a metallic material.

4. The hot water use warning device according to claim **1**, wherein said housing inner core having a high heat conductance is made from stainless steel.

5. The hot water use warning device according to claim **1**, wherein said thermochromic belt has two flanking isolation grooves vertically positioned on either side, whereby said thermochromic belt is prevented from lateral direct thermal contact with said housing inner core and the color change is more uniform.

6. The hot water use warning device according to claim **5**, wherein said flanking isolation grooves are implanted with flanking isolation rinks.

7. The hot water use warning device according to claim **6**, wherein said flanking isolation rinks appear as masked areas on said thermochromic belt.

8. The hot water use warning device according to claim **1**, wherein said thermochromic belt comprises a high thermal conductivity layer adhering to said housing inner core and having a substantially higher thermal conductivity than said housing inner core.

9. The hot water use warning device according to claim **8**, wherein said high thermal conductivity layer is made from copper.

10. The hot water use warning device according to claim **5**, wherein said flanking isolation grooves have a wedge-shaped cross section profile and said housing inner core has a highly polished surface, whereby a visual representation of the heat transport on the sides of the thermochromic belt is possible.

11. The hot water use warning device according to claim **1**, wherein said housing inner core comprises attachment isolation grooves for further controlling the spread of heat and running along the bottom of the indented channel where the thermochromic belt attaches.

12. The hot water use warning device according to claim **1**, wherein said thermochromic belt comprises a wedge-shaped cross section, whereby a progressive or preemptive warning signal is visibly represented as a vertically moving temperature gradient line.

13. The hot water use warning device according to claim **1**, wherein said housing inner core comprises a wetting cut-off groove encircling the lower rim of exit, whereby a more uniform heating of the thermochromic belt under tilted operation is achieved.

14. The hot water use warning device according to claim **1**, wherein said thermochromic belt comprises a transparent outer isolation layer, whereby thermal isolation from convection cooling and increased protection against weathering is provided.

15. The hot water use warning device according to claim **14**, wherein said outer isolation layer comprises a red-shifted UV-absorber or a red-colored light filter.

16. The hot water use warning device according to claim **14**, wherein said outer isolation layer comprises a roughened surface laterally positioned as two horizontal bands having a glossy surface in-between, whereby outside light is allowed be collected and dispersed into said outer isolation layer for an increased illumination of the underlying structure.

17. The hot water use warning device according to claim **1**, wherein said housing inner core comprises a circular cut out groove on the interior of said housing inner core, whereby a higher thermal resistance for non-uniform heating of the lower part of the housing inner core is provided.

18. The hot water use warning device according to claim **17**, wherein said circular cut out groove accommodates an inner isolation ring, whereby the color change of said thermochromic belt occurs more quickly at high flow rates when an aerator unit is installed.

19. The hot water use warning device according to claim **1**, wherein said reversible thermochromic pigments includes blue-to-clear pigments intermixed with red pigments.

20. The hot water use warning device according to claim **1**, wherein said reversible thermochromic pigments are first selected from the group consisting of black-to-clear and blue-to-clear pigments and then intermixed with clear-to-red pigments, all pigments having substantially the same activation temperature.

21. The hot water use warning device according to claim **1**, wherein said reversible thermochromic pigments includes green-to-clear pigments intermixed with clear-to-red pigments, both having substantially the same activation temperature.

22. The hot water use warning device according to claim **2**, wherein the height of said thermochromic belt is less than 5 mm, whereby visibility of demarcation lines is reduced to a negligible perception level.

23. A hot water use warning device configured for attachment to a faucet, comprising:

a collection of reversible thermochromic pigments incorporated into a first thermochromic layer in thermal contact with a second high thermal conductivity layer in thermal contact with a third low thermal conductivity layer, having said low thermal conductivity layer being configured for attachment to and thermal contact with a faucet.

24. The hot water use warning device according to claim **23**, wherein said low thermal conductivity layer is in thermal contact with a housing inner core configured for attachment to a faucet.

25. The hot water use warning device according to claim **23**, wherein said high thermal conductivity layer comprises an elbow shaped heat pick-up arm embedded into said low thermal conductivity layer, whereby a more uniform and controlled color change of said thermochromic layer can be achieved.

26. The hot water use warning device according to claim **23**, further comprising an upper thermochromic belt being in substantially direct thermal contact with a protruding member radially reaching out from said water carrying conduit;

27. The hot water use warning device according to claim **26**, wherein said protruding member is connected to at least one high heat conducting stream contact flange reaching into said water carrying conduit, whereby a quicker and more responsive heating of said protruding member is achieved.

28. A hot water use warning device configured for attachment to a faucet, comprising:

a pressure chamber having a plurality of aerator perforations and capable of expanding when water pressure builds up inside;

a display actuator arm operationally attached to said pressure chamber and,

wherein said display actuator arm rests against a viscoelastic delay segment, whereby said viscoelastic delay segment gradually compresses when water flow is present and gradually returns to its original state when the water flow has been stopped.

FIG. 1

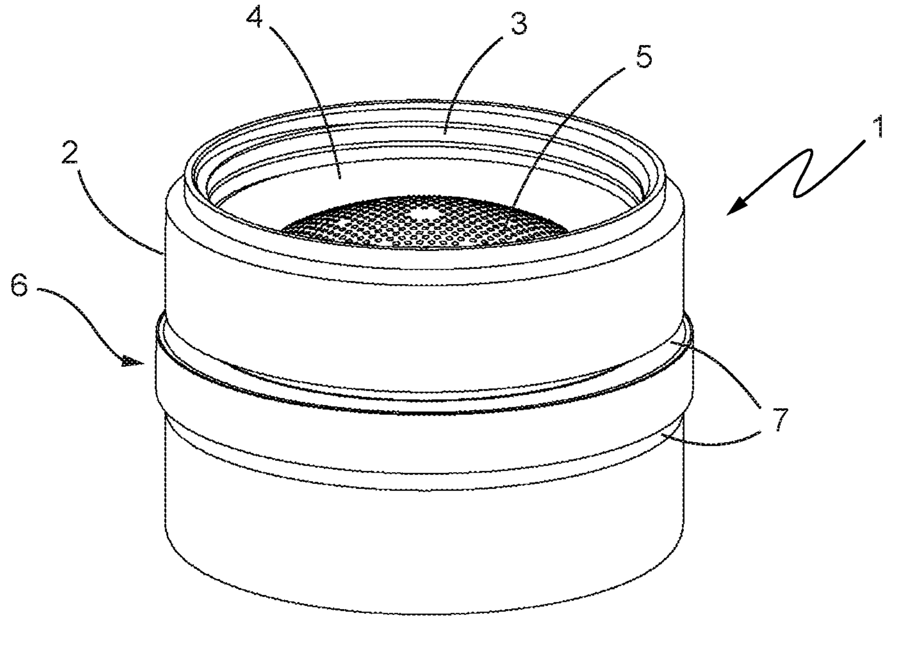


FIG. 2

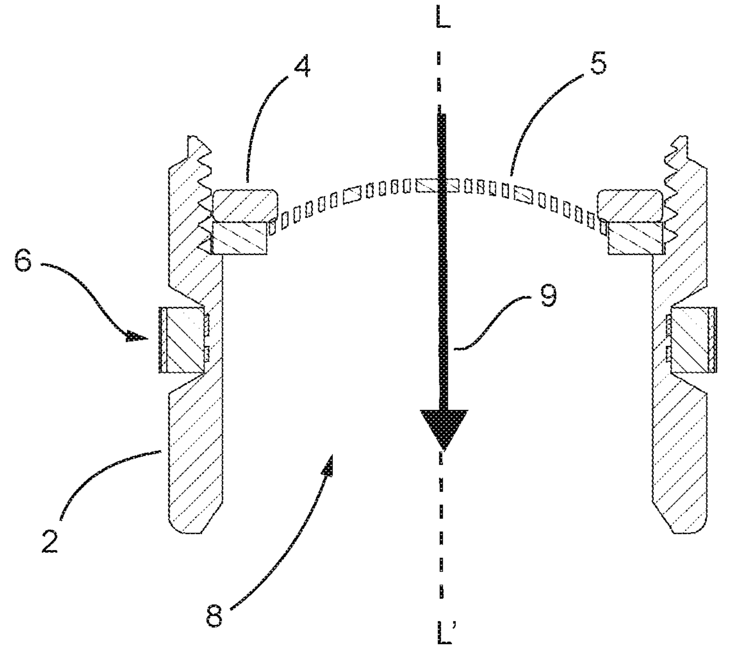


FIG. 3A

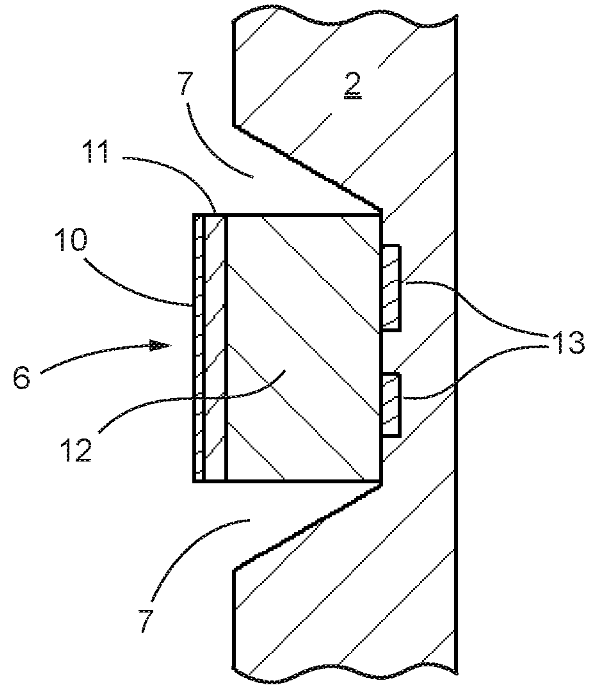


FIG. 3B

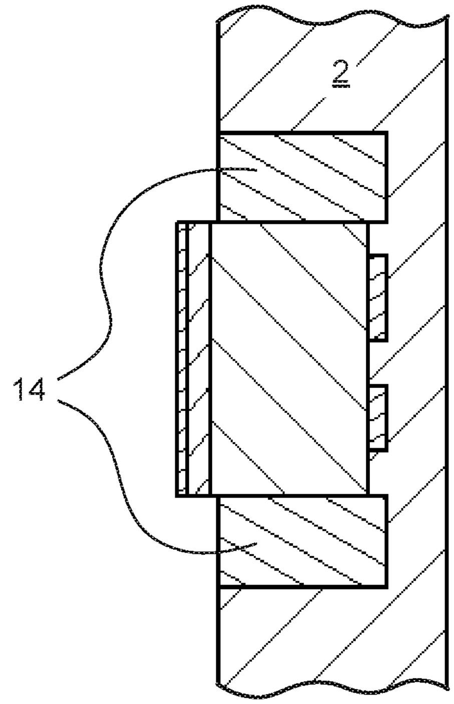


FIG. 4

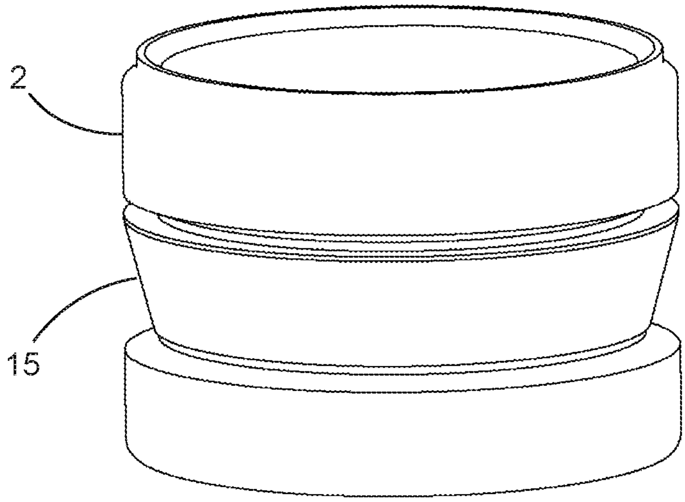


FIG. 5

FIG. 6

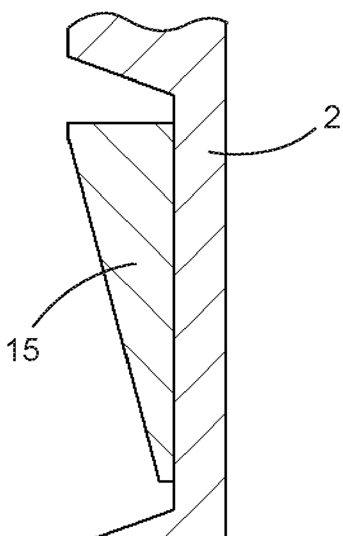


FIG. 7A

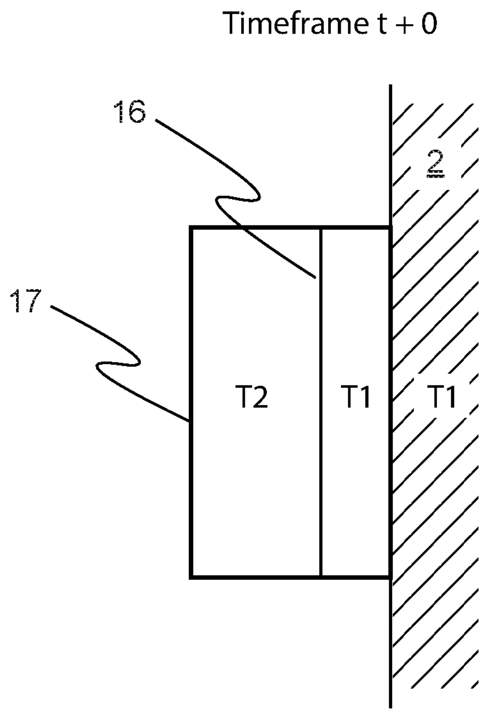


FIG. 7B

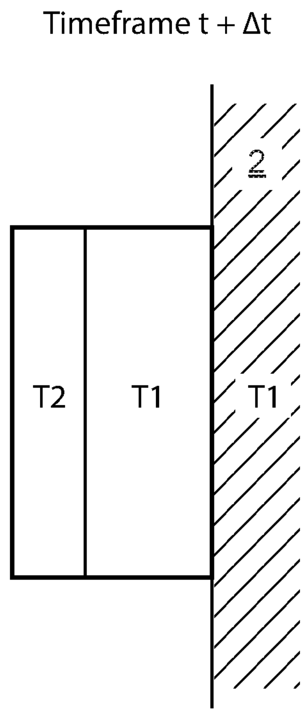


FIG. 8A

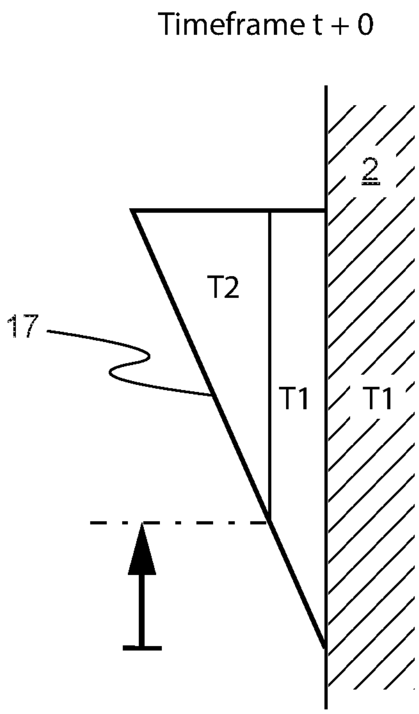


FIG. 8B

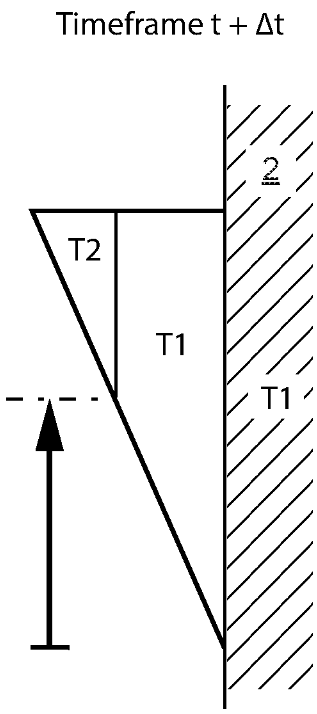


FIG. 9

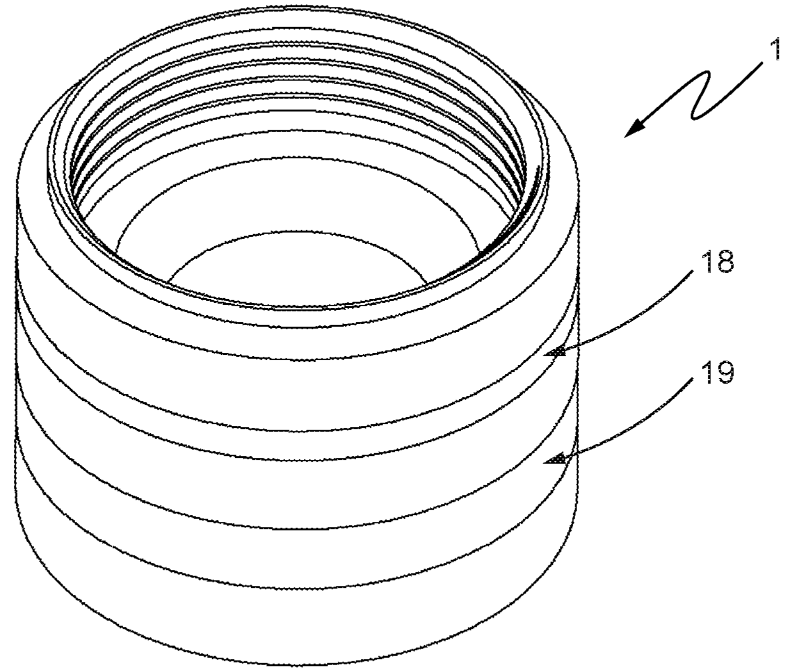


FIG. 10

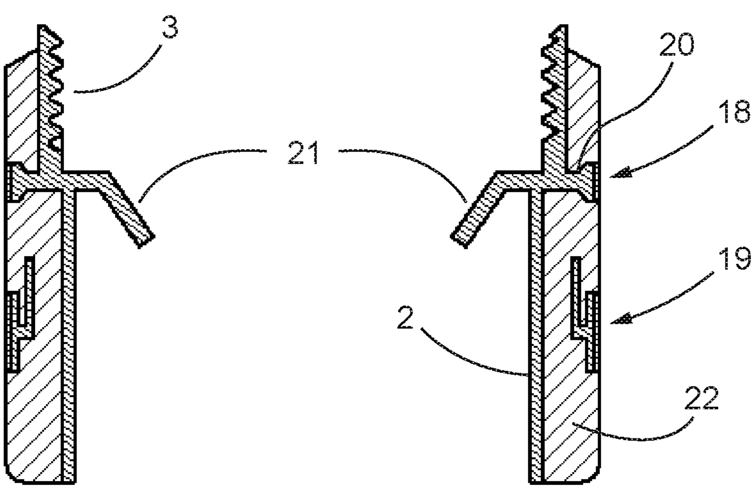


FIG. 11

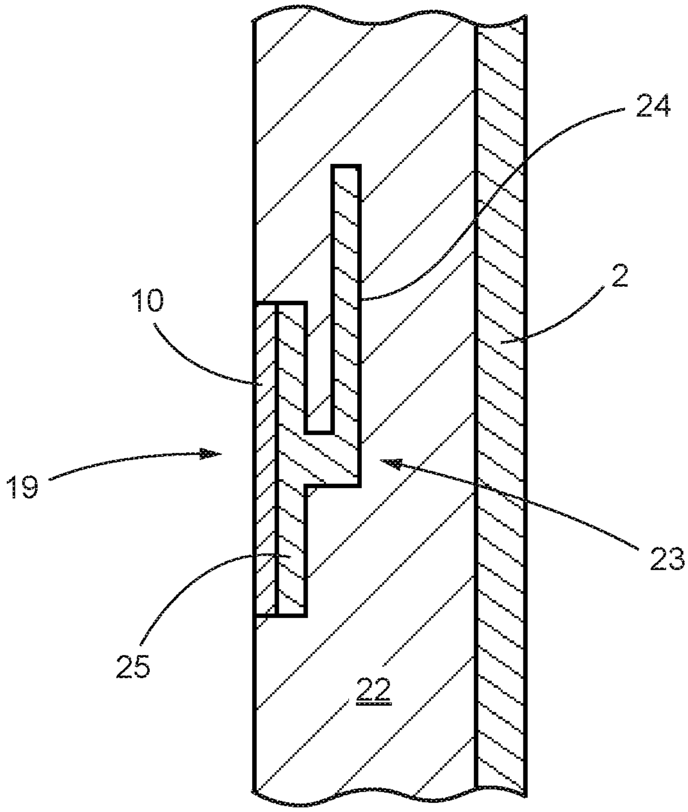


FIG. 12A

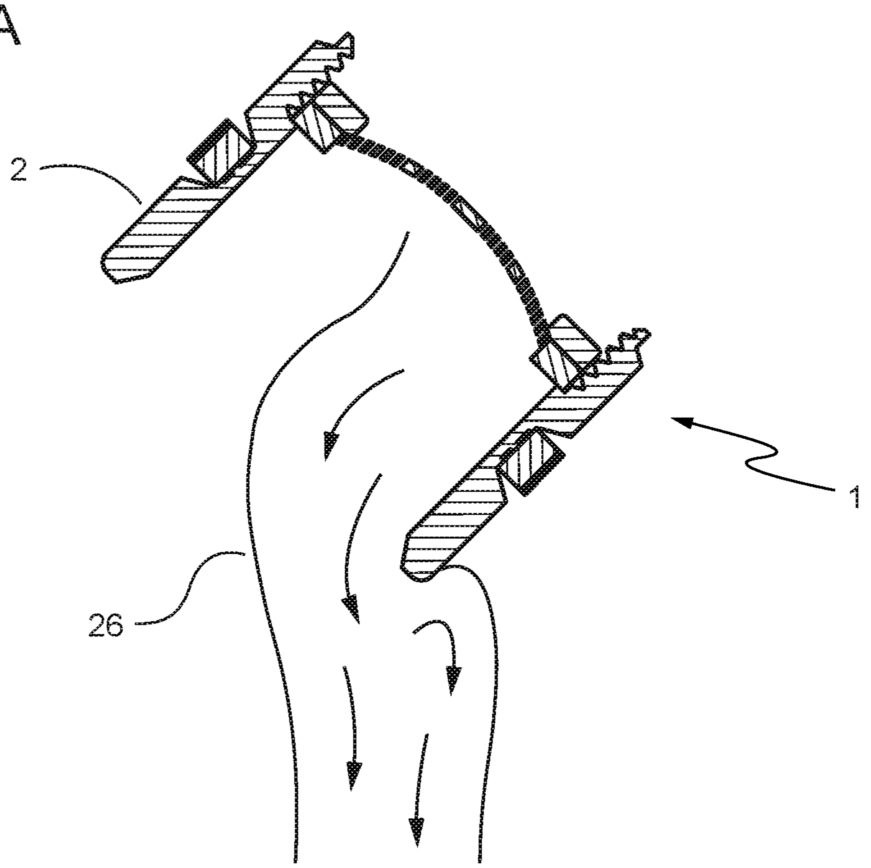


FIG. 12B

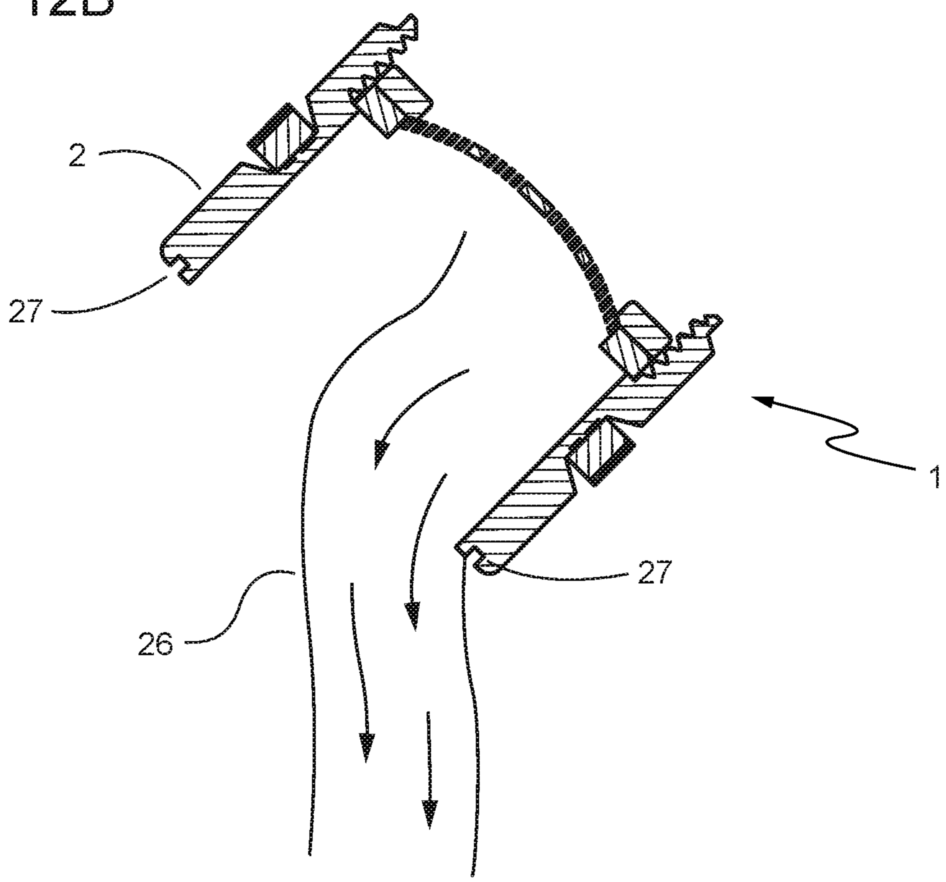


FIG. 12C

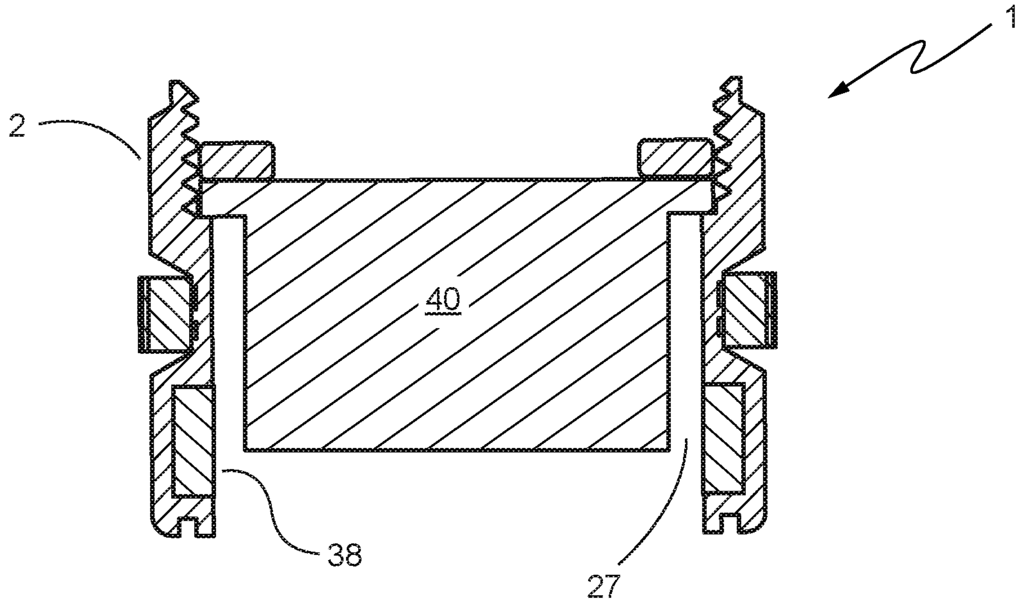


FIG. 13A

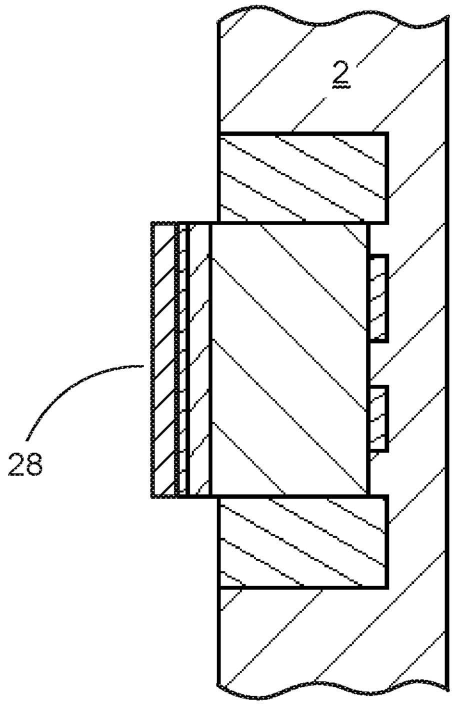


FIG. 13B

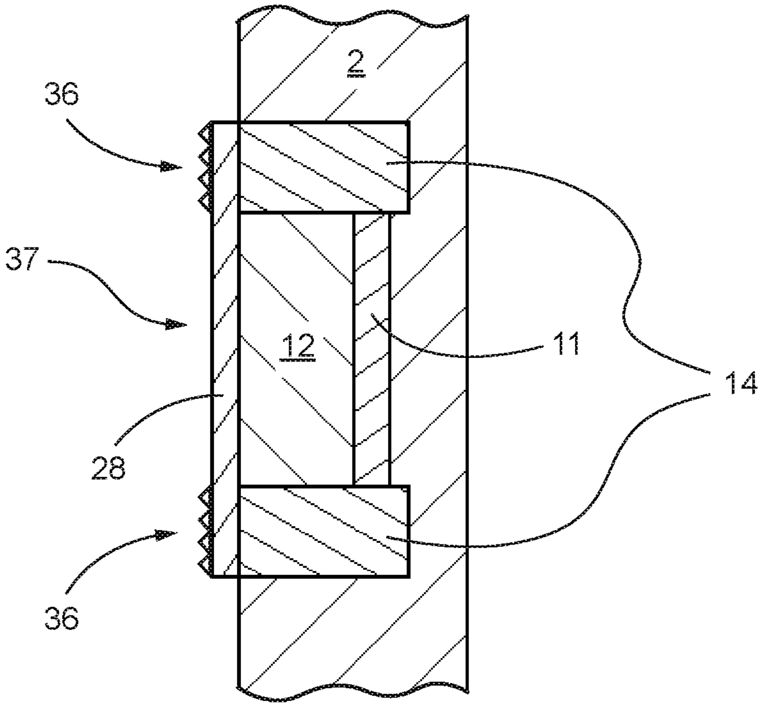


FIG. 14A

Timeframe t + 0

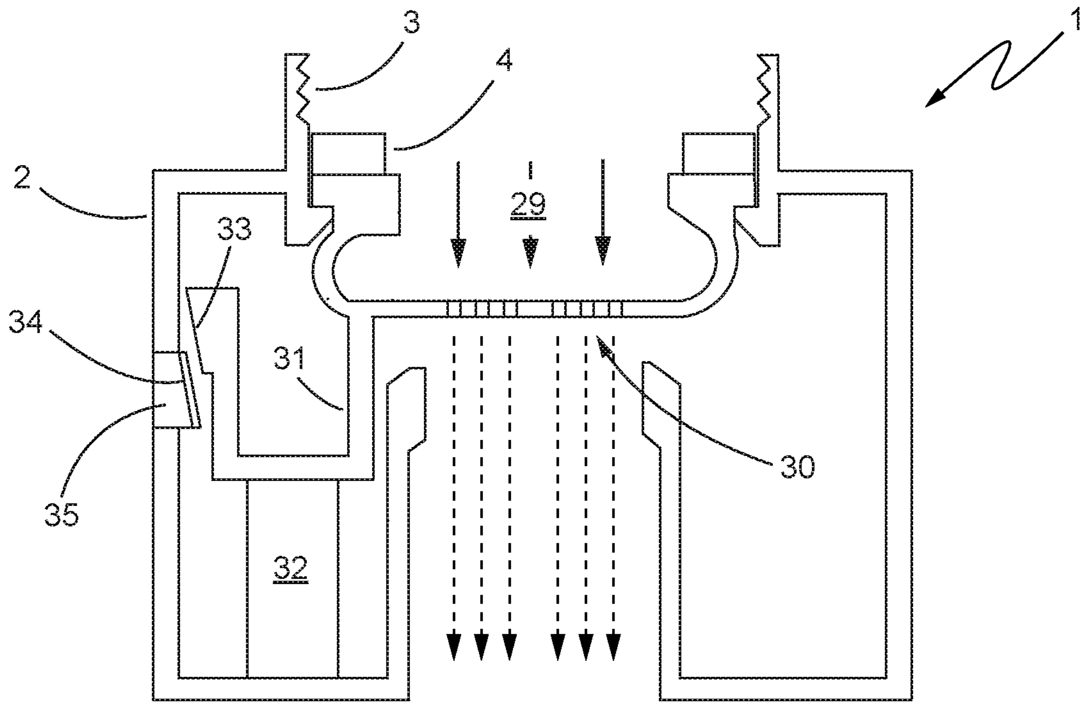
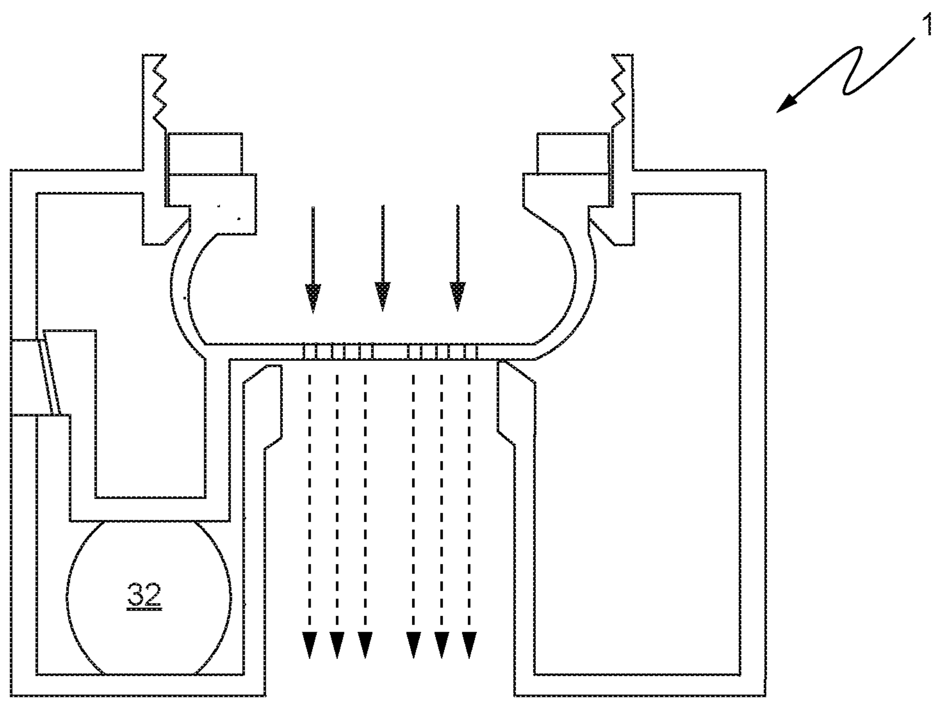


FIG. 14B

Timeframe t + Δt



INTERNATIONAL SEARCH REPORT

International application No
PCT/SE2017/050466

A. CLASSIFICATION OF SUBJECT MATTER
INV. E03C1/084 E03C1/086
ADD. E03C1/04 G01K13/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E03C G01K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 4 773 767 A (COLL ALAIN [FR]) 27 September 1988 (1988-09-27) column 2, lines 3-21; figures 1,2 column 2, line 39	1-5,14, 15,19-24 13
A	US 2013/269799 A1 (SWIST JASON [CA]) 17 October 2013 (2013-10-17) paragraph [0050]	8
Y	US 5 265 959 A (MELTZER JEFFREY N [US]) 30 November 1993 (1993-11-30) column 6, lines 30-56; figures 3,4,5,8	13

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 August 2017	16/10/2017

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Rosborough, John

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2017/050466

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-27

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/SE2017/050466

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 4773767	A	27-09-1988	CA	1306619	C	25-08-1992
			DE	3761703	D1	15-03-1990
			EP	0241369	A1	14-10-1987
			FR	2596842	A1	09-10-1987
			JP	S62294925	A	22-12-1987
			US	4773767	A	27-09-1988
US 2013269799	A1	17-10-2013	NONE			
US 5265959	A	30-11-1993	NONE			

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-27

   Hot water use warning device employing thermochromic material.

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2. claim: 28

   Hot water use warning device employing a pressure chamber.
