Design and Analysis of Thermal Shut-Off Valve Used in SWAS Panel and Its Performance Characteristics For Flow of Water in A Boiler

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Abstract - Steam and Water Analysis System panel is used in power plant industry to check the purity of water so that there should not be any loss occur due to water. Every year 50% of the turbine failure is only due to the water we use. So it's necessary to check water every moment, but it is not possible every time to take the sample and use it in laboratory testing hence in power plant industry we use Steam and Water Analysis System panel to monitor automatically water every moment. Steam and Water Analysis System panel contained with so many sophisticated devices hence it is necessary to maintain the temperature of water entering the panel to a specified temperature. For this company uses pressure reducer, heat exchanger to reduce pressure and temperature respectively. The Thermal Shut off Valve relates generally to the valve art and is more particularly directed to a shut-down valve which assures immediate and irrevocable shut-down of lines carrying flammable or toxic materials in the event a predetermined ambient temperature level is reached, such as by the presence of a fire in the vicinity of the tank. Mainly what we have done is the reverse engineering of an already existing product as per the company specifications with some changes in the design part. We have also scaled down the operating temperature of the thermal shut off valve, which was done as per the company specifications. Drawings, a major part of the project was undertaken on Solid Works. Thermal analysis was done on Ansys 15.0. Primary objective of reducing the cost of manufacturing and bringing down of the entire unit cost was kept in mind and was the primary driving notion.

I. INTRODUCTION

Thermal shut off valve:

It is being used in SWAS panel for high temperature protection before high temperature samples can reach instrumentation. A thermal shut- off valve comprising a valve housing, means within said housing movable between a first position wherein said valve is open so as to permit flow there through and a second position wherein said valve is closed so as to block flow there through, means within said housing normally urging said movable means towards said second position, and thermally actuated means mounted outside of said housing normally maintaining said movable means in said first position, said thermally actuated means comprising a fusible link, first means holding one end of said link, and second means holding the other end of said link, said first and second means cooperating so as to hold said link under tension, said second means comprising a rigid lever arm having a fulcrum position, one end of said arm engaging said other end of said link and means adjustably and releasably holding the other end of said arm in spaced relation to said housing with said fulcrum portion in blocking engagement with said movable means to prevent movement thereof to said second position, whereby when said link fuses due to the presence of the predetermined degree of heat the tension exerted on said link by said lever arm causes said link to separate, thus releasing said lever arm thereby said fulcrum portion automatically moves away from said blocking engagement, thus permitting said movable means to move second position pursuant to the impetus of said urging means.

CONSTRUCTION OF TSV:

The TSV includes an elongate, tube like housing which has an inlet port and an outlet port. An insert is threaded in to a stepped bore and such insert has a central passage that extends along the valve long axis. There is a cross-hole intersecting the passage and a valve seat is held in its fixed position by the insert.

A stem extends through the central passage and has respective ends attached to the reset button and to the valving member of the valve body. A sealing ring prevents liquid leakage from the valve interior region as the stem moves with respect to the insert. The valve is configured to permit mounting through an instrument panel and is retained there by a lock nut which engages the thread.

The valving member, part of a cap like device threaded to the body piece, has an annular valving surface which is angled with respect to the axis. When the device and its valving member are in the floe blocking second position, the surface is against the seat and floe through the opening in the seat is prevented. In a specific embodiment, the device has two opposed wrench flats, which are used during assembly to tighten the device with respect to the body piece.

The body piece also includes an elongate bore, an enlarged chamber at one end of the bore and an enlarged cavity at the other end of such bore. The sensing portion of a temperature sensing device is in the chamber and axial length of the body piece and the location of the shoulder are cooperatively selected so that when the temperature sensing device is mounted as shown, such device is clamped and restrained between the cap-like device and the shoulder, thereby fixing the position of the temperature sensing device in the body.

An end plug is threaded to the body piece and secures one end of a spring, the other end of which is in a pocket in a latching cam. The cam has an annular protruding shoulder and a relieved annulus, the diameter of which is smaller than the diameter of the shoulder. The body piece has a plurality of openings through it, each for receiving a separate steel sphere with slight clearance.

When the cam, the cam shoulder and the spheres are in their respective positions, the spheres extends radially outwards beyond the outer surface of the body piece and engage an annular latching face formed in the housing at an angle to the long axis. The coaction of the cam shoulder, spheres and latching face hold the body in the position in the housing.

The device actuator is coupled to the latching mechanism by bearing against the adjustment stem threaded in to the latching cam. When the temperature of the sensing portion is at or above the set point of the sensing device e.g. 1400F, the device actuator moves to the right and urges the cam and its cam shoulder right wardly with respect to the body piece and against the urging of the spring. Such movements permit the spheres to be "cammed" (by the cooperative action of the compression-type body biasing spring and the latching face) in to their respective openings and in to the clearance annulus between the latching cam and body piece. When the spheres are thus withdrawn in to the body, they no longer restrain the body at the position in the housing and such body and its valving member are moved in a first direction by the spring until the valving surface is against the seat.

The unique portion and flow path arrangement of the new valve has inlet and outlet ports are spaced axially from one another. When considered along the long axis of the valve, both the valve seat and the valving member are between the ports.

The body has two apertures formed in it and such apertures constitute a chamber inlet aperture and a chamber outlet aperture, respectively. When the valve body and its valving member are in the first position with the valving member away from the valve seat, the two apertures and the chamber are in fluid flow path through the chamber and a process liquid flowing along the path is in intimate, heat transfer relationship to the sensing portion. Liquid flowing along the path contacts the sensing portion for rapid valve response.

The body includes a protruding rib-like land extending away from the axis. Where the valve body and the interior of the housing have generally cylindrical cross-section (the usual case), the land is an annular land and is in sliding engagement with the valve of the housing. Considered axially, one of the apertures is on either side of the land which functions to direct flow through the two apertures. Liquid is preventing from migrating to the cylindrical spring pocket by a U-cup seal and back up ring. (It is to be appreciated that while the valve has a high pressure rating, the liquid flowing through it is or should be at relatively low pressure).

The valve also has a spring bearing disc and a cylindrical guide in overlapping relationship with the nose of the plug. When the valve is open, the edge of the guide is against the gland and serves as a positive stop limiting rightward travel of the valve body in the housing.

Specific embodiments of the new valve have convenience features, as well. There is a reset button attached to the stem and recessed in a shroud when the valving member is away from the seat. When the latch mechanism is released and the valve "trips" so that the valving member closes against the seat, the stem and button moves leftwardly and the button protrudes from the shroud. The button thereby provides a visual indication that the valve is closed. And when the device cools to a temperature below the set point, depressing the button re-latches the mechanism.

Another convenience feature is a position indicating switch having a sliding plunger spring-biased leftwardly and abutting the nose of the plug threaded in to the body piece. The switch has an electrical contact which changes state (i.e. from open to close or close to open) when the valving member moves from the first position to the second position. In a specific embodiment, the contact is open (as shown in the dashed line) when the valve is in the open position and closes when the plunger moves leftwardly as the valve closes. The contact wires are brought out through a wiring nut and permit one or a group of valves to be connected to an annunciator, a control system or a computer.

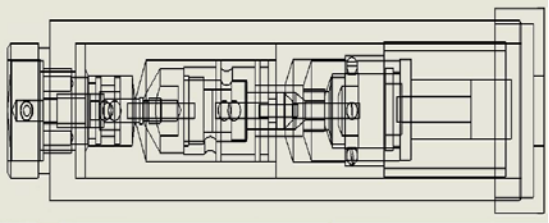
WORKING OF TSV:

The new temperature sensitive valve is particularly useful in industrial processes, e.g. power generation, crude oil cracking and refinement, which involves liquids at sometimes at elevated temperature and where the liquids must occasionally be "tapped" from the process for

analysis. The valve includes an elongate housing extending along a long axis and having a stationary valve seat in such housing. A valving member, a part of the valve body, is also in the housing and is mounted for movement in a first direction (i.e. toward the seat) from a flow permitting first position spaced from the seat to a flow blocking second position against the seat.

A latching mechanism is coupled to the valving member and retains such member in the first position when the temperature of the liquid flowing through the valve is below a shutoff temperature. An actuator is coupled to the latching mechanism and moves in the second direction (i.e. away from the seat) when the temperature of the fluid is above the shutoff temperature. At such elevated temperature, the actuator releases the latching mechanism, permitting the spring-urged valving member to close against the seat.

The new valve includes an inlet port and an outlet port formed in housing and such ports are spaced from one another. In a particular embodiment of the valve (and when considering along the long axis of the valve), both the valve seat and the valving members are between the ports.



In another aspect of the invention, a portion of the valve body is "hollowed out" to form a chamber. The actuator is in (and part of) a wax filled temperature sensitive device (which is known as per se) which has a head or sensing portion the chamber. There is a fluid flow path through the chamber and fluid flowing along the path is in intimate, heat transfer relationship to the sensing portion and, most preferably, contacts the sensing portion for rapid valve response in the presence of a fluid at elevated temperature. (It is understood that the temperature sensitive device is filled with wax which expands at a rather sharply-defined elevated temperature and urges the device actuator away from the sensing portion.)

In yet another aspect of the invention, the body includes a protruding rib-like land extending away from the axis. Where the valve body and housing interior have generally cylindrical cross-section (the usual case), the land is an annular land. There are two flow apertures, both in fluid communication with the chamber. One aperture is on either side of the land functions as a structure to direct flow through the apertures.

When the valve body and its valving member are in the first position with the valving member away from the valve seat, there is a liquid flow path through the body and the chamber. Such flow path is in flow communication with the inlet port, the opening through the valve seat the two flow apertures, the chamber in the body and the outlet port.

Specific embodiments of the new valve have convenience features, as well. There is a reset button which is recessed in the housing when the valving member is away from the seat. When the latch mechanism is released and the valve “trips” so that valving member closes against the seat, the button protrudes from the housing. Another convenience feature is a position indicating switch having an electrical contact which changes state (i.e. from open to closed or from closed to open) when the valving member moves from the first position to the second position.

The new valve is configured to permit panel mounting and is for use on process systems operating at pressure up to about 5000 p.s.i. When the liquid flowing through the valve reaches set point temperature, e.g. 1200F, 1400F or 1600F, the time required in releasing the latch mechanism and close the valve is of the order of 5 seconds or less. Other details of the new valve are set forth in the following detailed description and in the drawings.

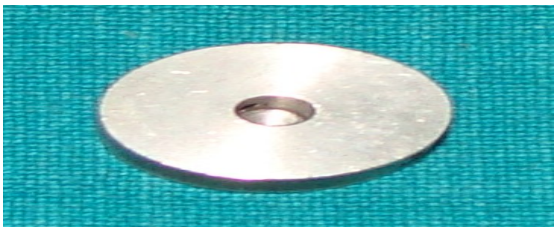
TSV AND ITS DETAILS:

1. Elongated tube like casing:

Name of the component: Elongated tube like housing with inlet and outlet port.

Material: SS316
Function: It is being used as an outer covering for valve body and has provision for connection to position indicating switch and boiler. The inlet and outlet ports welded on it are used for entering and leaving of boiler water.
Manufacturing process used: Threading operation, surface turning, honing, welding operations, facing operation, drilling, boring operation.

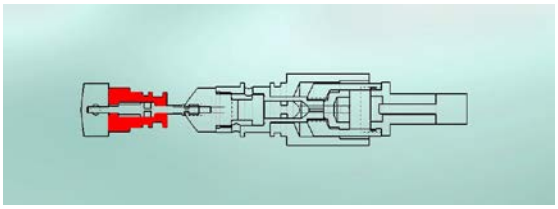
2. Reset button:

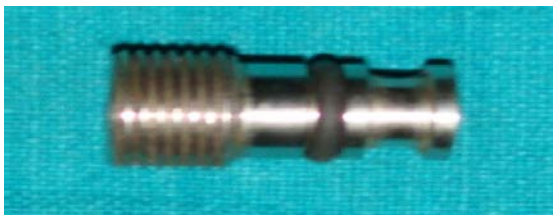


Name of the component: Reset button

Material: SS316
Function: It provides a visual indication that the valve is closed and when the temperature sensing device cools to a temperature below the set point, depressing the button re-latches the mechanism.
Manufacturing process used: surface finishing, drilling, taper turning, surface turning, facing.

3. Insert with central passage:





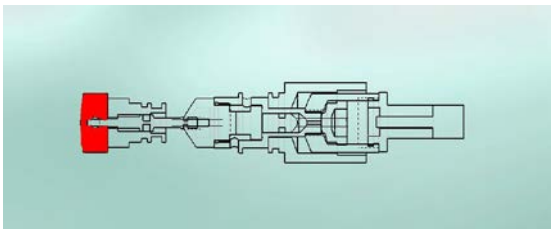
Name of the component: Insert with central passage.

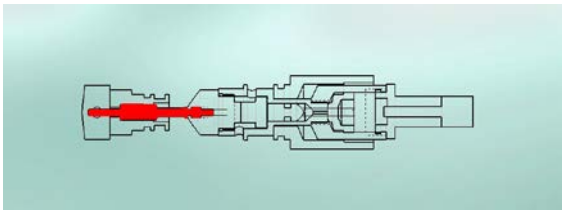
Material: SS316

Function: Cross hole intersecting the central passage and the valve seat are held in position by the insert.

Manufacturing process used: Threading operation, surface turning, boring, grooving, facing, honing.

4. Stem:

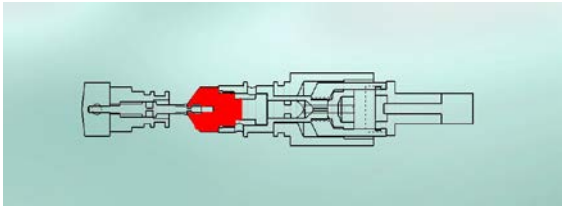


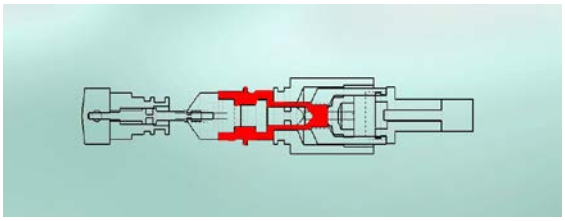


Name of the component: Stem

Material: SS316
Function: Stem extends through the central passage of insert and has respective ends attached to a reset button and to the valving member of the valve body.
Manufacturing process used: Threading operation, surface turning, grooving, facing.

5. Cap like device:

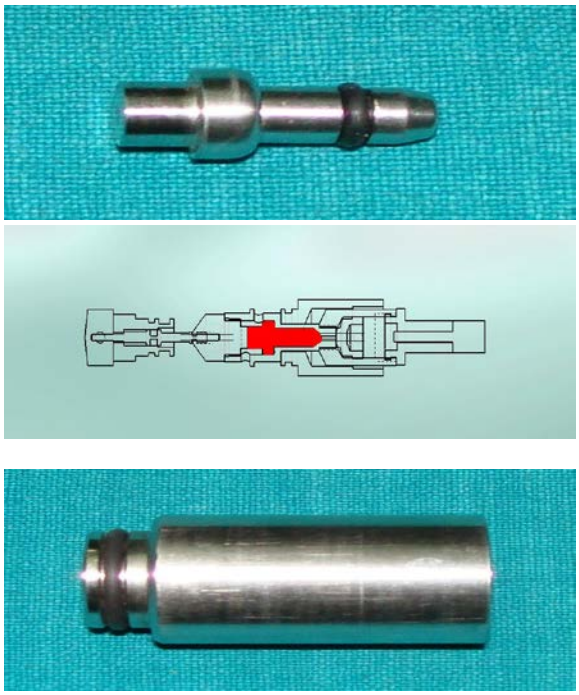




Name of the component: Cap like device Material: SS316

Function: A valving member part of a cap like device threaded to the body piece, has an annular valving surface which is angled with respect to the axis. When the cap like device and its valving member are in flow blocking position the front surface of device is against the seat and flow through the opening is prevented.
Manufacturing process used: Threading operation, surface turning, facing operation, taper turning, drilling, honing and internal threading.

6. Temperature sensing chamber:



Name of the component: Temperature sensing chamber.

Material: SS316

Function: It is containing first a wax material and then temperature sensing device inside a groove drilled in it. As the temperature reaches predefined temperature limit wax get expanded due to thermal expansion and push the temperature sensing device in forward direction. It is clamped and restrained between the cap like device and the shoulder, thereby fixing the position of the temperature-sensing device in the body.
Manufacturing process used: Surface turning, facing operation, taper turning, grooving, honing, chamfering and drilling operation.

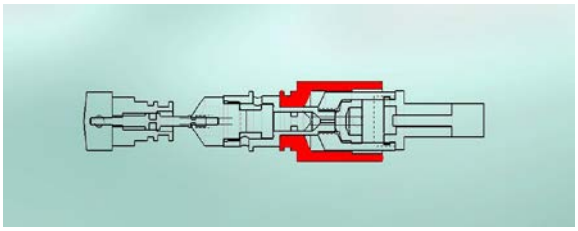
7. Holding device:

Name of the component: Holding device Material: SS316

Function: It is being used to hold the cap like device and temperature sensing device.

Manufacturing process used: Threading operation, surface turning, honing, facing operation, boring, drilling.

8. Annular latching face:

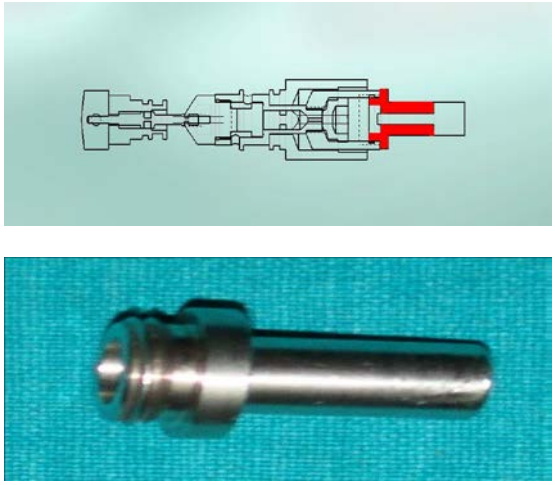


Name of the component: Annular latching face.

Material: SS316

Function: It is along with cam shoulder and spheres used to hold the body in the position in the housing.
Manufacturing process used: Surface turning, facing operation, grooving, boring, honing.

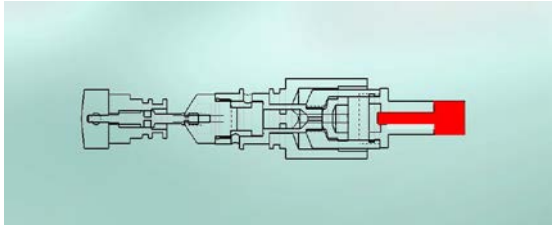
9. End plug:



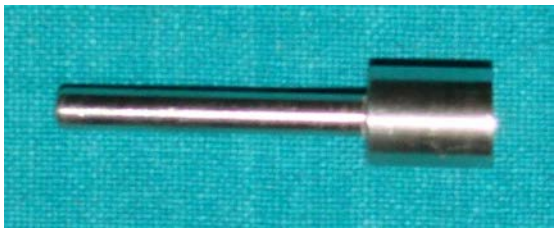
Name of the component: End plug

Material: SS316

Function: An end plug is threaded to the body piece and secures one end of the small spring.
Manufacturing process used: Threading operation, surface turning, facing operation, boring, honing.



10. Sliding plunger:

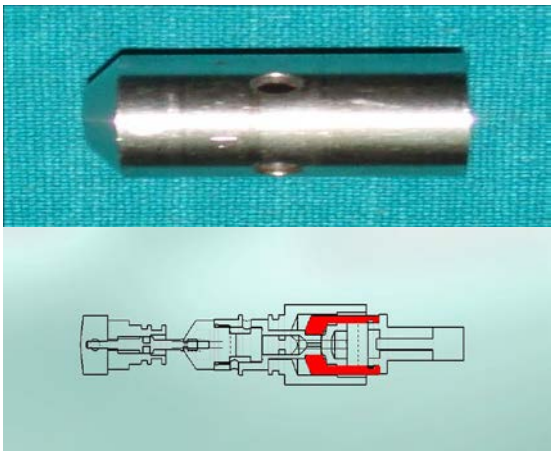


Name of the component: Sliding plunger

Material: SS316

Function: It is being used to actuate the position indicating switch which has electrical contact.
Manufacturing process used: Surface turning, facing operation.

11. Body piece:

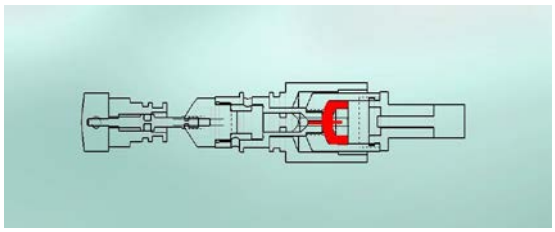


Name of the component: Body piece

Material: SS316

Function: The body piece has a plurality of openings through it, each for receiving a separate steel sphere with slight clearance.
Manufacturing process used: Surface finish, facing operation, drilling, taper turning, boring, honing.

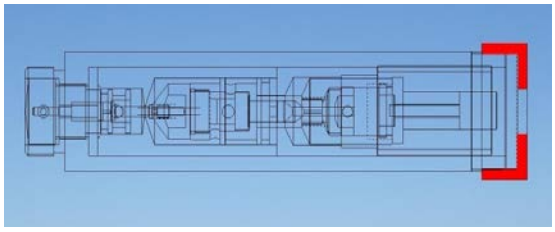
12. Latching cam:



Name of the component: Latching cam

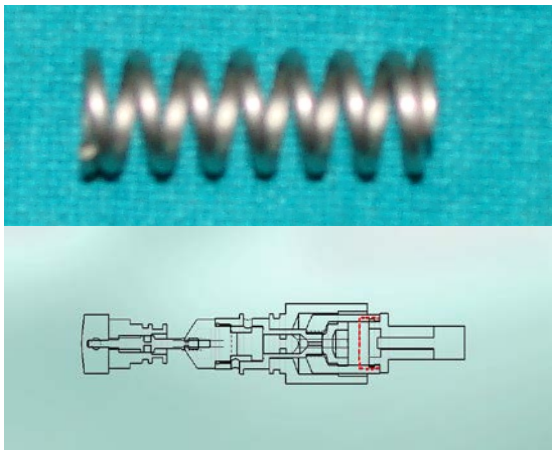
Material: SS316

Function: The latching cam has an annular protruding shoulder and a relieved annulus, the diameter of which is smaller than the diameter of shoulder. It is being used to hold the body in the position in the housing.



Manufacturing process used: Surface turning, facing operation.

13. Small spring:

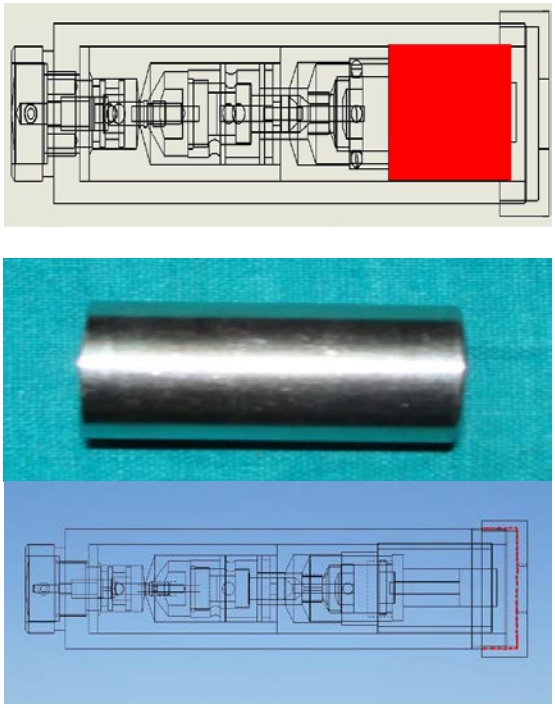


Name of the component: Small spring

Material: SS316

Function: It is being pressed between the latching cam and end plug.
Manufacturing process used: NA (Standard)

14. Large spring:



Name of the component: Large spring

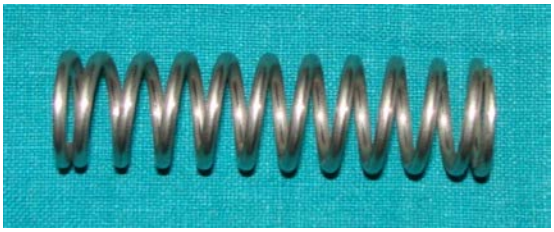
Material: SS316

Function: It is being pressed between the end cap and end plug.
Manufacturing process used: NA (Standard)

15. End cap:

Name of the component: End cap
Material: SS316
Function: It is being used to keep the larger spring in compression and provide the provision for connection of electrical transducer.
Manufacturing process used: Surface turning, facing operation, drilling, internal threading, boring.

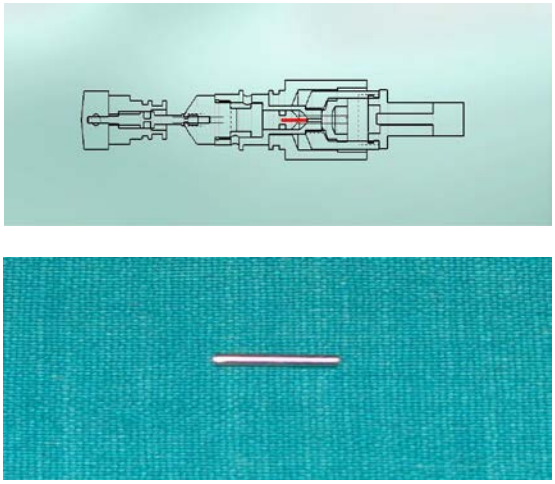
16. Cylindrical spring pocket:



Name of the component: Cylindrical spring pocket.

Material: SS316
Function: It is used as outer covering for larger spring.
Manufacturing process used: Threading operation, surface turning, honing, welding operations facing operation.

17. Temperature sensing device:



Name of the component: Temperature sensing device
Material: SS316
Function: It is being used to sense the expansion of wax material and providing the actuation force to the sliding plunger.
Manufacturing process used: surface turning, facing, polishing to a mirror finish.

II. TEMPERATURE SENSING PORTION OF THE TSV

The sensing portion of a temperature-sensing device is in the chamber and axial length of the body piece and the location of the shoulder are cooperatively selected so that when the temperature sensing device is mounted as shown, such device is clamped and restrained between the cap-like device and the shoulder, thereby fixing the position of the temperature-sensing device in the body. The material used in sensing portion should have large volume expansion with increase in temperature up to 250C.

Sensing material used in sensing portion (Paraffin Wax):

One of the reasons for using paraffin wax as actuator material is its huge volume expansion when melted, 10-20%. Paraffin wax can also be loaded with hundreds of MPa and still shows a useful expansion. Scaling of a thermal actuator is also favourable looking at activation time and power consumption making it interesting for a microactuator. By combining the paraffin with simple materials and processes, such as printed circuit boards and UV-curable adhesives (Epoxy), prototypes can be realized quickly.

In this laboratory experiment a thermal paraffin membrane actuator is fabricated using UV-curable epoxy on a PCB with copper heaters. The actuator is characterized and tested with the aid of a contact probe.

III. SELECTION OF WAX MATERIAL

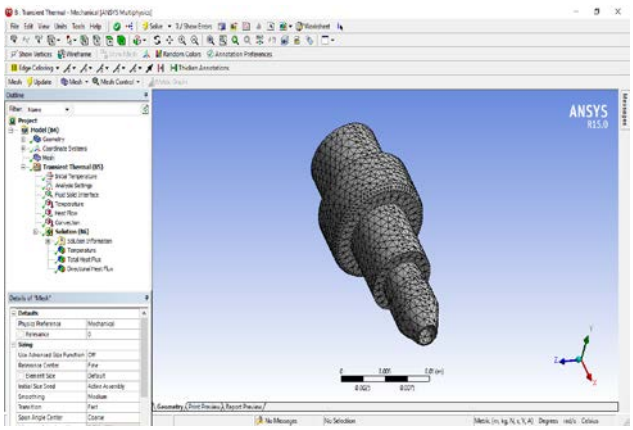
As per the requirement we have selected Astorstat HA18 paraffin wax from the Astorstat® - Product Selection Guide which has following properties:

a. Congealing Point (ASTM D938): 27.2 - 28.3°C or 81 - 83°F.
b. Start to Open Point (Astor® DST-007): 27.2 - 28.3°C or 81 - 83°F.
c. Terminal Point (Astor DST-007): 32.8 - 33.9°C or 91 - 93°F.
d. Volume of Expansion (Astor DST-007): 14-18%.
e. Travel (Astor DST-007): 5.88 - 6.89 mm or 0.23 - 0.27 in.

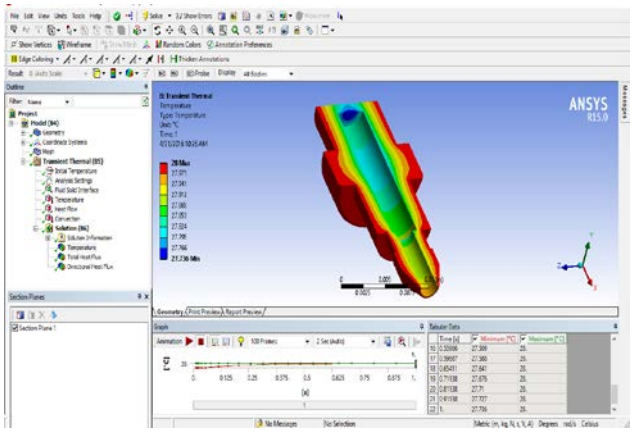
IV. TRANSIENT THERMAL ANALYSIS OF WAX CONTAINER

Transient thermal analysis of wax container was done on ANSYS R15.0 workbench software. Geometric modelling was done in Solid works, and then the file is exported in iges format. This iges file is imported in ANSYS R15.0 and then the analysis was done with given boundary conditions. Following results were obtained as follows:

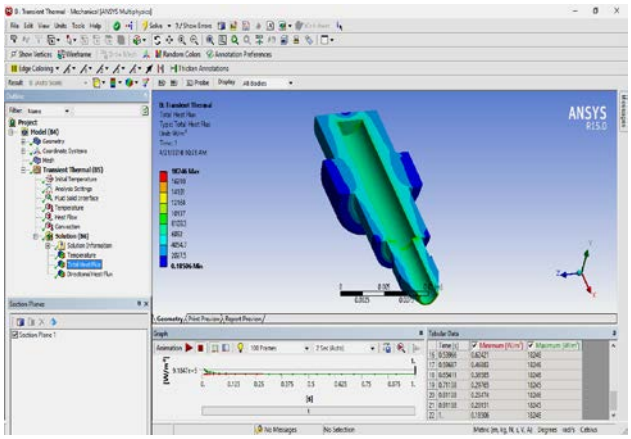
(a.) Meshing



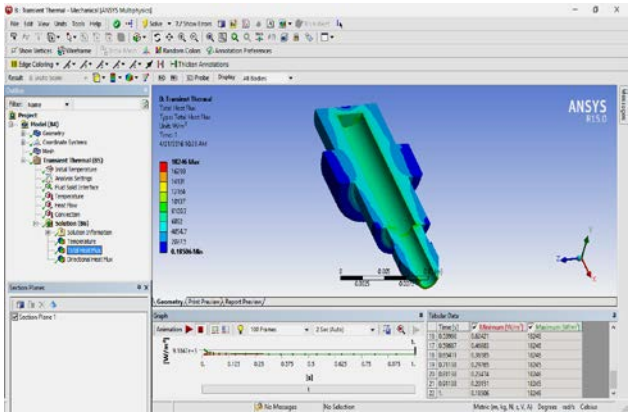
(b.) Temperature distribution



(c.) Heat Flux Distribution

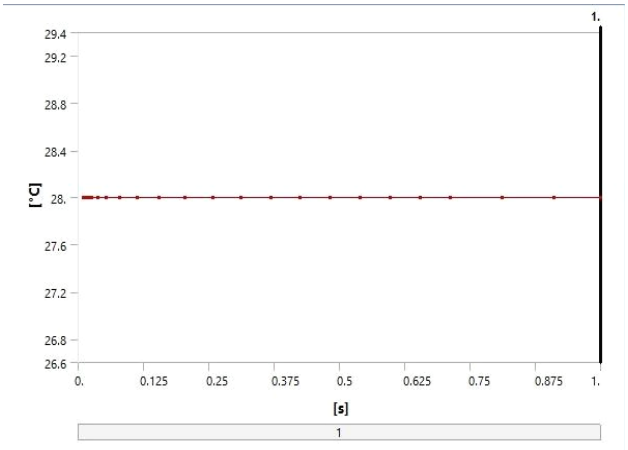


(d.) Directional heat flux distribution

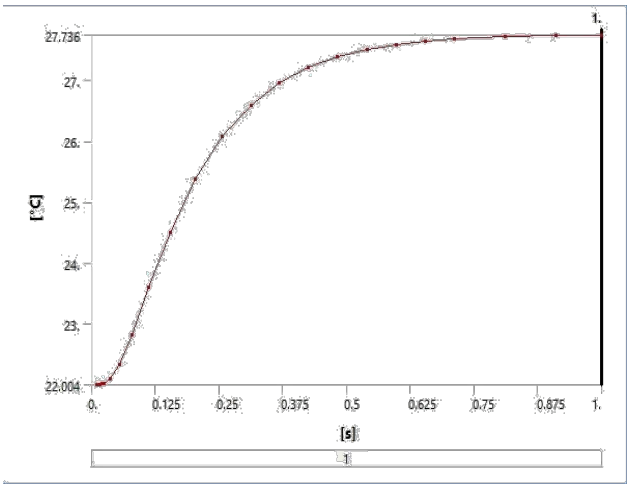


V. RESULTS

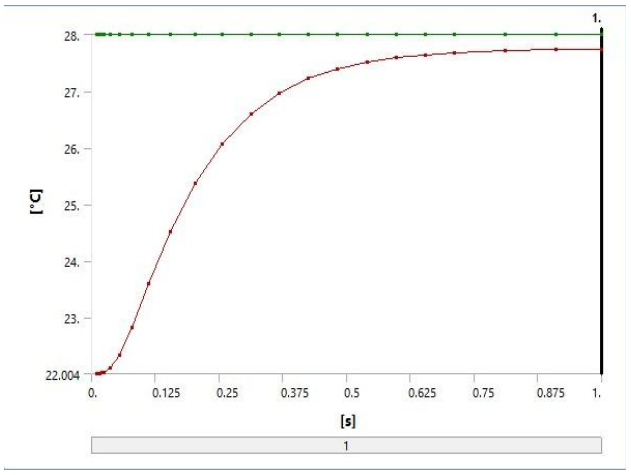
Model (B4) > Transient Thermal (B5) > Solution (B6) > Solution Information > Temperature – Global Maximum



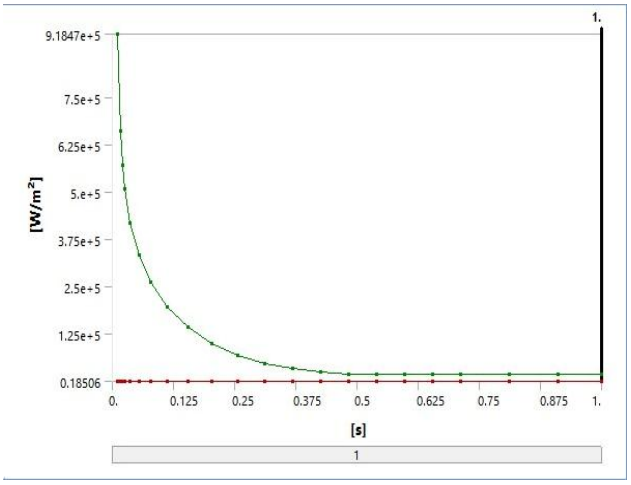
Model (B4) > Transient Thermal (B5) > Solution (B6) > Solution Information > Temperature – Global Minimum



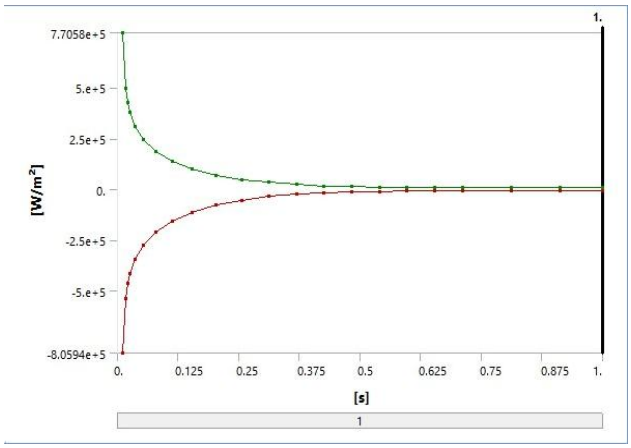
Model (B4) > Transient Thermal (B5) > Solution (B6) > Temperature



Model (B4) > Transient Thermal (B5) > Solution (B6) > Total Heat Flux



Model (B4) > Transient Thermal (B5) > Solution (B6) > Directional Heat Flux



VI. CONCLUSION

- Thermal analysis (FEA) of temperature sensing chamber is done on ANSYS R15.0 software with the given boundary conditions.
- Drawings of all components were made on Solid Works in both 2D and 3D.
- Assembly was done on Solid Works.
- Operating temperature of the thermal shut off valve was reduced to 280C by careful selection of wax.
- Market price of the imported product is about Rs.65000/- (INR). It is brought down to Rs.10000/- (INR) approximately.
- Mass production can further reduce this cost.
- Forbes Marshall Pvt. Ltd. has been provided with all the detailed drawings of all the parts of Thermal shut-off valve.
- Hydrostatic testing has been already done, results were satisfactory.

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