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(54) THERMAL ACTUATOR

(71) We, CARRIER CORPORATION, a corporation duly organized under the laws of the State of Delaware, United States of America, having its principal place of business at Syracuse, New York, United States of America,

do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

The present invention relates to thermal actuators of the type having a pressure chamber and a piston extending from the chamber and adapted to be driven therefrom on the exertion of pressure from within the chamber.

Thermal actuators or thermal hydraulic actuators of the type aforesaid employ an expansible and contractable material enclosed in the high pressure chamber and a heating element for expanding said material to drive the piston from the chamber. One such thermal actuator is described in U.S. Patent No. 3,029,595 issued to John F. Sherwood. A thermal actuator of this type which is now commercially available is a model TH750 thermal linear actuator marketed by the Thermal Hydraulics Corporation of Glendora, California. Thermal actuators of the foregoing type are characterized by their compact construction and by the great force exerted by the piston when the material in the pressure chamber is heated and expanded.

Thermal actuators of the type aforesaid are used, for example, in air conditioning apparatus for actuating a damper mechanism for a fan-coil unit, the mechanism having a lever arm mounted for engagement by the piston of the thermal actuator to rotate the damper for the purpose of controlling the flow of air through the fan-coil unit.

Means are provided in the preceding apparatus to de-energize the thermal actuator after the piston has been driven from the pressure chamber by an amount determined by the desired working stroke of the piston. However, prior thermal actuators as described above suffer the potentially dangerous shortcoming of lacking means for controlling the movement of the piston from the pressure chamber, when for some reason the thermal actuator is not de-energized when the piston has moved through its working stroke. For example, the means for de-energizing the thermal actuator could be a limit switch in the circuit of the heating element of the actuator, positioned to be opened by the piston when the latter has moved through the working stroke. If the switch were not opened as intended, the piston could be propelled from the pressure chamber with dangerous force.

The present invention provides a thermal actuator comprising: a housing having interior surfaces defining a chamber for holding a thermally expansible material; electrically energizable heating means disposed within the chamber for heating the thermally expansible material; an opening in said housing in communication with said chamber; a piston mounted for reciprocating movement in said opening and having a working stroke; said piston being driveable from said housing as a result of the energization of said heating means and the expansion of the thermally expansible material against the piston if said working stroke is exceeded; sealing means in said opening in fluid sealing engagement with said piston for preventing the thermally expansible material from leaving said chamber; said piston having a first portion provided with an outside dimension smaller in diameter than the diameter of the opening in the housing so that a clearance space is present between the piston first portion and the housing on the opposite side of said sealing means to said chamber, said first portion extending through said sealing means into said chamber into engagement with the expansible material, said piston having a second portion extending outside said housing for engaging a workpiece, the piston being structured so that pressure sufficient to impart movement thereto in excess of the distance represented by the working stroke will render the sealing means inoperative by communicating the clearance space between the piston first portion and the surface of the housing through which the piston reciprocates with the expansible material such that the expansible material may flow out of the chamber into the clearance space to relieve the pressure on the piston.

The invention will be more particularly, described with reference to the accompanying drawings, in which:-

Figure 1 is a detailed, cutaway view of a thermal actuator constructed according to the present invention, as incorporated in a fan-coil unit having a moveable damper assembly.

Figure 2 shows a thermal actuator as known in the prior art, also incorporated in a fan-coil unit.

Figures 3 and *4* show additional embodiments of a thermal actuator, according to the invention, each figure consisting of detailed, cutaway views of the thermal actuator as incorporated in a fan-coil unit.

Thermal actuators of the type to which the present invention pertains include a pressure chamber having a thermally expansible material, such as wax, encased therein and a moveable piston which extends from the pressure chamber. Means such as an electrically energizable heating element are provided in the pressure chamber for heating the material to expand it, to in turn apply hydraulic pressure to the piston to drive it from the chamber. The piston is normally used to move some mechanical member a predetermined distance which defines the working stroke of the piston. It is known to de-energize the heating element after the piston has moved through its working stroke to avoid unnecessary wear on the thermal actuator, to control the usage of energy in the actuator, and to avoid the application of deleterious force on other mechanical members by the piston. Such arrangements are highly effective, but because of the great pressure which is applied to the piston of the thermal actuator, there is a danger of substantial damage and injury should the heating element fail to be de-energized at the proper time. The continued application of pressure to the piston could damage the mechanical members being moved or the thermal actuator itself. Furthermore, if the movement of the piston were blocked after moving through its working stroke and suddenly released from the blocked position, it would be propelled from the pressure chamber with tremendous force and could seriously injure persons or damage property in its path.

Referring now to the drawings, there is illustrated in Figure 1 a thermal actuator 1 mounted in a fan-coil unit 3 of the type having a moveable damper assembly 5 which is shown in partial detail for the sake of clarity. The damper assembly includes a damper 7 which is moveable between alternate positions to control the flow of air across a refrigerant coil. Damper 7 is fixed on a rotatable shaft 9. Shaft 9 is rotated by a lever arm 11 which is clamped on shaft 9 by means of a nut and bolt assembly 13. Lever arm 11 is biased in the counterclockwise direction by a coil spring 15 hooked at one end to lever arm 11, and at the other end to a nut and bolt assembly 17.

Thermal actuator 1 is provided for rotating the damper 7 in the clockwise direction against the bias of spring 15. Thermal actuator 1 includes a piston 19 which is driven upwardly as viewed in the drawings when the actuator is activated. A pushrod 21 is disposed in the path of piston 19, and adapted to engage and rotate lever arm 11 when moved upwardly by piston 19. The actuator is bolted to a support yoke 23 which is in turn attached to a support bracket 25. Bracket 25 is bolted to a wall (not shown) of the fan-coil unit.

A bearing mounting bracket 27 is riveted or otherwise attached to support bracket 25 between thermal actuator 1 and lever arm 11. Bracket 27 includes a pair of parallel, horizontal legs 29 and 31 which extend into the plane of the drawing. Legs 29 and 31 are provided with aligned circular holes through which co-axial, cylindrical plastics bearings 33 and 35 extend. The bearings are dimensioned to receive in sliding engagement cylindrical pushrod 21. Pushrod 21 is co-axial with piston 19 and moveable therewith. A circular spring support plate 37 is attached to pushrod 21, and the face of support plate 37 nearest piston 19 is a flat surface, perpendicular to the axis of pushrod 21. The opposite end 39 of pushrod 21 is domed and is in sliding engagement with a surface 41 of lever arm 11. The configuration of end 39 effects a point contact with lever arm 11, and the point of contact is at or very close to the axis of pushrod 21.

A helical compression spring 43 is confined between leg 31 of bearing mounting bracket 27 and spring support plate 37. Spring 43 is retained and positioned by pushrod 21 which extends along the axis of the spring and within the confines of the spring coils. The characteristics of thermal actuator 1 and spring 43 are such that when piston 19 moves upwardly in response to the engergization of the thermal actuator as described below, the force is sufficient to compress spring 43. However, when the thermal actuator is de-energized, spring 43 has sufficient force to force piston 19 downwardly into the body of the thermal actuator.

Spring 15, which biases arm 11 in the counterclockwise direction, is of sufficient strength to rotate arm 11 counterclockwise when thermal actuator 1 is de-energized. However, spring 15 is of insufficient strength to stop the clockwise rotation of arm 11 when piston 19 is being driven upwardly in response to the activation of thermal actuator 1.

Thermal actuator 1 comprises a high pressure housing 45, preferably cylindrical in cross-section, closed at one end by a shaft-bearing block 47 provided with external threads 49 for engaging internally threaded sleeve portion 51 of housing 45. The opposite end of housing 45 is closed by an integrally formed wall 53 in which are mounted electrodes 55. Electrical leads 57 pass through openings in an end sleeve molded in housing 45.

Piston 19 is mounted in a bearing 61 in bearing block 47, with the piston end extending into a high pressure chamber 63 in high pressure housing 45. Chamber 63 contains an electrical heating element 65 and is completely filled with material such as paraffin or other suitable expansible and contractable material capable of actuating piston 19 by thermal expansion of the compound. It has been found advantageous to fabricate high pressure housing 45 and shaft bearing block 47 of thermal actuator 1 from brass, and to also use a bearing 61 of brass construction.

Piston 19 comprises a shaft having a small diameter portion 67 integral with or rigidly connected to a large diameter portion 69.

Shaft bearing block 47 has a cylindrical bore 73 along whose axis piston 19 moves. The diameters of large diameter portion 69 and bore 73 are such that large diameter portion 69 of piston 19 is in sliding engagement with the walls defining bore 73, so that the path of movement of piston 19 is linear along the axis of the bore.

A seal 75 is confined across the open end of high pressure chamber 63 between the abutting surfaces of high pressure housing 45 and shaft bearing block 47. Seal 75 has a bore 77 for receiving in close sliding engagement the cylindrical surface of narrow portion 67 of piston 19, and cooperates with the foregoing portions to retain the paraffin in high pressure chamber 63.

The operation of damper 7 is preferably controlled by a thermostat (not shown) which is electrically connected to thermal actuator 1 for regulating the energization of heating element 65. Damper 7 is arranged relative to the refrigerant coil and the source of air being directed thereacross, so that the damper blocks the flow of air across the coil when the room temperature is below the set value of the thermostat, and admits the flow of air across the coil when the room temperature is above the set value. When the thermostat detects a temperature below its set value, an appropriate switch is closed to energize heating element 65. The material in high pressure chamber 63 expands when heated and exerts great pressure against and around that part of the portion 67 of piston 19 disposed in high pressure chamber 63 (see Figure 2). The pressure exerted on piston 19 drives the piston upwardly as viewed in the drawings, to in turn drive pushrod 21 against lever arm 11. The force exerted by piston 19 is sufficient to overcome the resisting forces exerted by springs 15 and 43, and pushrod 21 rotates lever arm 11 and damper 7 in the clockwise direction.

In order to limit the travel of piston 19, a limit switch 79 is mounted on support bracket 25. Limit switch 79 has a trip lever 81 located in the path of movement of lever arm 11. Limit switch 79 is included in the electrical circuit of heating element 65 such that the latter is de-energized when trip level 81 is tripped. When heating element 65 is de-engerized, spring 43 forces piston 19 downwardly so that portion 67 of piston 19 is driven back into high pressure chamber 63. At the same time, spring 15 rotates lever arm 11 counterclockwise until either large diameter portion 69 engages an internal collar 83 in shaft bearing block 47 or until heating element 65 is re-energized in response to a signal from the thermostat.

In the event that the room temperature remains below the set point of the thermostat, heating element 65 is repeatedly energized to effect the clockwise rotation of lever arm 11 against trip lever 81. Since limit switch 79 has the effect of de-energizing heating element 65, the heating element is repeatedly energized and de-energized as lever arm 11 trips trip lever 81, and the lever arm is rotated counterclockwise by spring 15 until trip lever 81 is released. Therefore, as long as the room temperature remains below the set point of the thermostat, lever arm 11 oscillates slightly by an amount equal to the distance between the on and off positions of trip lever 81. This oscillating action is neither noticeable nor objectionable.

The foregoing arrangement has been found to be highly effective in use. However, prior thermal actuator such as the one shown in Figure 2, are subject to a potentially hazardous occurrence. (With the exception of the piston of the device shown in Figure 2, all components of the latter device are identical to those shown in :Figure 1, and corresponding parts have been designated with corresponding numbers. The piston and components thereof of the device shown in Figure 2 are indicative of the prior art and are designated by the numbers of corresponding parts in Figure 1 with prime suffixes. The piston 19′ of the device shown in Figure 2 comprises a small diameter portion 67′, a large diameter portion 69′ and, between the portions 67′ and 69′ a still larger diameter piston portion 69′ which is a close sliding fit in bore 73.) When heating element 65 is energized such as in response to an activation signal from a thermostat, the material in chamber 63 melts and expands, exerting great pressure within the chamber and forcing piston 19′ upwardly. As piston 19′ moves upwardly, it urges pushrod 21 upwardly to rotate lever arm 11 in the clockwise direction. If the system were functioning properly, lever arm 11 would contact trip lever 81 (see Figure 1) to break the circuit through heating element 65 to de-energize the heating element. however, if switch 79 should malfunction and heating element 65 were not de-energized after trip 81 was tripped, pushrod 21 would continue to be forced upwardly, possibly being temporarily held in position by lever arm 11 should the latter cease to rotate. The pressure within chamber 63 would nevertheless continue to build up, and if pushrod 21 were suddenly disengaged from lever arm 11 or if piston 19′ and pushrod 21 should become disengaged, piston 19′ would be propelled with great speed and force from thermal actuator 1′. Piston 19′ would become a dangerous projectile and could cause serious bodily injury or property damage.

The inventors of the present invention, having recognized the preceding problem, have provided a structure for preventing such an occurence. Specifically, the present invention contemplates relieving the pressure in pressure chamber 63 after the piston has moved beyond a predetermined distance such as its working stroke, which would indicated that the de-activation switch for the thermal actuator had not served its function. Such pressure relief is provided according to the following embodiments of the invention, by modifying the piston of the prior art to enable the pressurized expansible material from pressure chamber 63 to flow out of the chamber after the piston has moved through the critical predetermined distance to thereby obviate the dangerous buildup of pressure and prevent the piston from being projected from the thermal actuator.

Piston 19′ in Figure 2 is shown at the top of its working stroke, which, in the arrangement of Figure 1, would occur when lever arm 11 has engaged and tripped trip lever 81 of switch 79. The cylindrical portion67′ can be seen to extend into pressure chamber 63. Referring back to Figure 1, the working stroke of piston 19 is indicated by the distance L. This distance is determined by establishing the position of the piston, the pushrod or the lever arm when springs 43 and 15 have moved piston 19 and lever arm 11, respectively, to their lowermost positions as viewed in the drawings. Such condition occurs when heating element 65 is de-energized and the spring force exceeds the pressure force from within high pressure chamber 63. The top of the working stroke (which is the condition shown in the drawings) is established by determining the position of the foregoing element when trip lever 81 has been tripped. The lowermost position of portion 67 of piston 19 is illustrated in phantom in Figure 1.

In the course of the normal operation of thermal actuator 1, the surface defining bore 77 of seal 75 is in fluid sealing engagenet with the cylindrical surface of portion 67 of piston 19. In order to prevent the dangerous buildup of fluid pressure in high pressure chamber 63 in the event that piston 19 moves beyond its working stroke, means are provided for breaking the fluid seal between seal 75 and piston portion 67 when the piston moves to such extent.

According to the embodiment of the invention illustrated in Figure 1, the length of portion 67 of piston 19 is such that, after piston 19 has moved through its working stroke L, portion 67 passes through an out of bore 77 of seal 75. While portion 67 is in bore 77, the outer surfce of portion 67 forms a fluid seal with the surface defining bore 77 to prevent molten material in chamber 63 from leaving the chamber. However, once portion 67 is disengaged from the surface of bore 77, the molten expansible material flows from chamber 63 into the bore 73. Such flow relieves the pressure within the chamber because of the increased volume thereof.

In the embodiment shown in Figure 1, the end 85 of piston 9 is the seal breaking means. The length of the part of piston portion 67 extendable into chamber 63 (when piston portion 69 is in engagement with collar 83) is generally equal to the length L of the working stroke of piston 19. In the normal operation of the apparatus shown in Figure 1, seal 75 remains engaged with piston 19 and the high pressure which occurs in chamber 63 is maintained while heating element 65 is energized. However, if piston 19 moves beyond its intended working stroke, end 85 of piston 19 which normally is disposed in chamber 63 moves out of seal 75 terminating the engagement of the seal with piston 19 (See Figure 1) and allowin the expansible material to flow out of the chamber into the bore 73. The dangerous buildup of pressure behind piston 19 is thereby prevented and the piston cannot be projected from the thermal actuator.

Another embodiment of the invention is illustrated in Figure 3, wherein a groove 87 is provided in piston portion 67″ at a position commencing generally at the position at portion 67″ of piston 19″ which is disposed inbore 77 of seal 75 when the piston has moved through its working stroke. (Like parts in Figures 3 and 4 have been given like numerical designations to corresponding parts in Figure 1 and the pistons and piston components of Figures 2 and 3 have been given double prime and triple prime suffixes respectively.) Thus, when piston 19″ moves beyond its working stroke, groove 87 breaks the fluid seal between piston 19″ and seal 75, relieving the pressure in high pressure chamber 63.

The embodiment illustrated in Figure 4 is similar to that shown in Figure 3, but the grooves in the preceding Figure have been replaced with a flattened area 89 which performs the foregoing fluid seal function as described above.

The invention of which several embodiments have been described fulfills the intended objects. Apparatus has been provided which controls the movememt of the piston of a thermal actuator of the type having a thermally expansible material contained in a chamber for driving the piston therefrom. Such control effects the relief of pressure in the chamber in the event the piston moves beyond its working stroke. The foregoing apparatus is particularly useful for moving the damper of a fan-coil unit in a safe and effective manner.

WHAT WE CLAIM IS:-

1. A thermal actuator comprising: a housing having interior surfaces defining a chamber for holding a thermally expansible material; electrically energizable heating means disposed within the chamber for heating the thermally expansible material; an opening in said housing in communication with said chamber; a piston mounted for reciprocating movement in said opening and having a working stroke; said piston being driveable from said housing as a result of the energization of said heating means and the expansion of the thermally expansible material against the piston if said working stroke is exceeded; sealing means in said opening in fluid sealing engagement with said piston for preventing the thermally expansible material from leaving said chamber; said piston having a first portion provided with an outside dimension smaller in diameter than the diameter of the opening in the housing so that a clearance space is present between the piston first portion and the housing on the opposite side of said sealing means to said chamber, said first portion extending through said sealing means into said chamber into engagement with the expansible material, said piston having a second portion extending outside said housing for engaging a workpiece, the piston being structured so that pressure sufficient to impart movement thereto in excess of the distance represented by the working stroke will render the sealing means inoperative by communicating the clearance space between the piston first portion reciprocates with the expansible material such that the expansible material may flow out of the chamber into the clearance space relieve the pressure on the piston.

2. A thermal actuator according to claim 1, wherein the first portion of the piston is of a length such that when the piston is moved over a distance greater than the working stroke the first portion of the piston will clear the sealing means to communicate the chamber with said clearance space.

3. A thermal actuator according to claim 1, wherein the first portion of the piston has its periphery relieved over a part of the length thereof to provide a by-pass through the sealing means when the working stroke is exceeded.

4. A thermal actuator substantially as herein described with reference to and as shown in Figues 1, 3 or 4 of the accompanying drawings.

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1564126 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

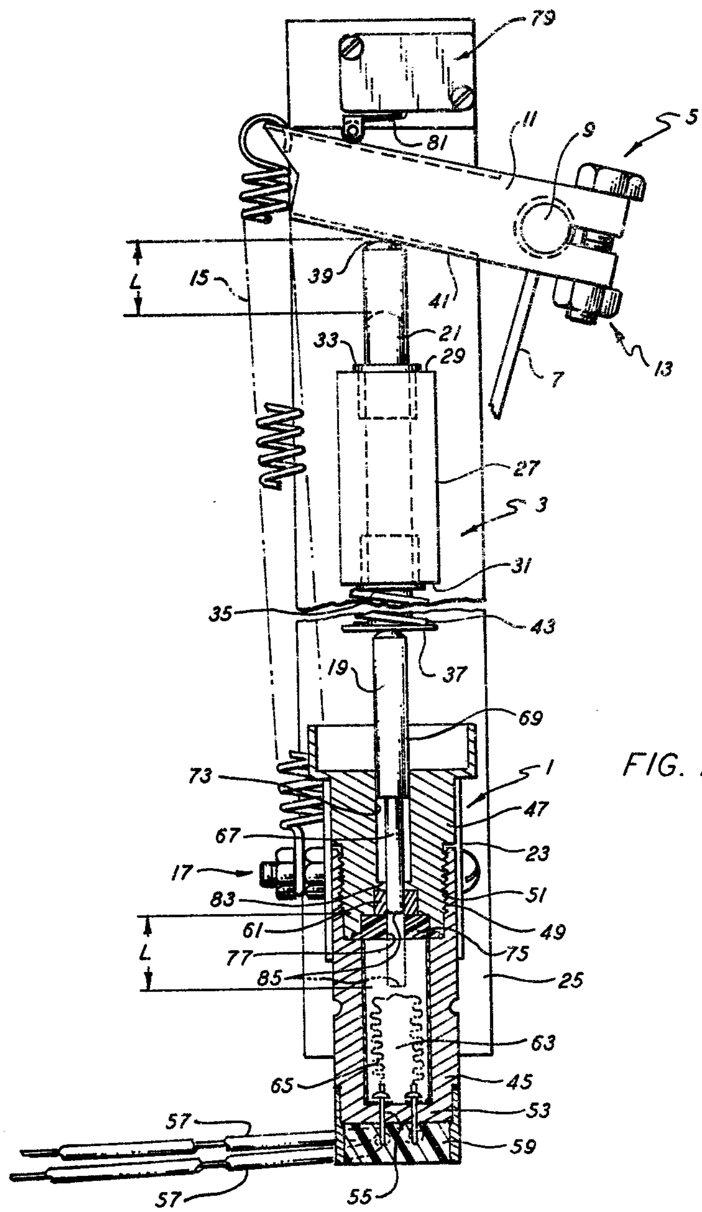

FIG. 1

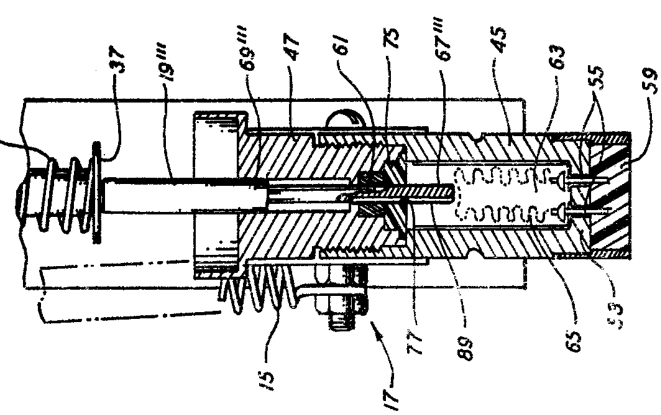

FIG. 4

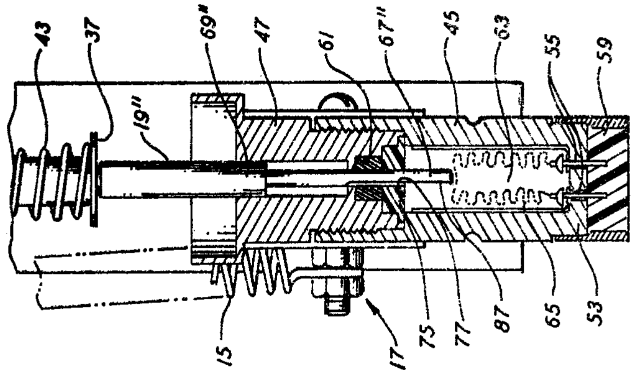

FIG. 3

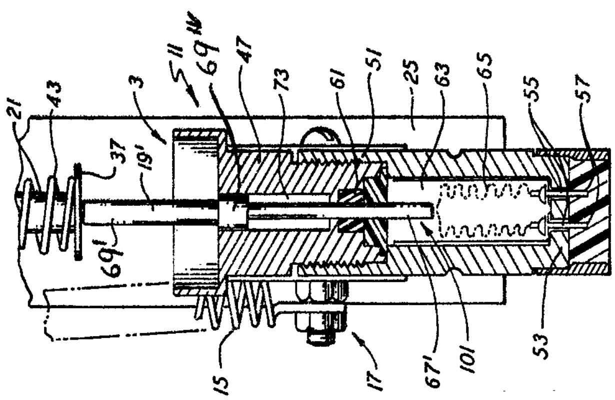

FIG. 2
Prior Art