March 24, 1931. D. N. CROSTHWAIT, JR., ET AL 1,797,258

STEAM TRAP

Original Filed Dec. 30, 1927

Fig. 1.

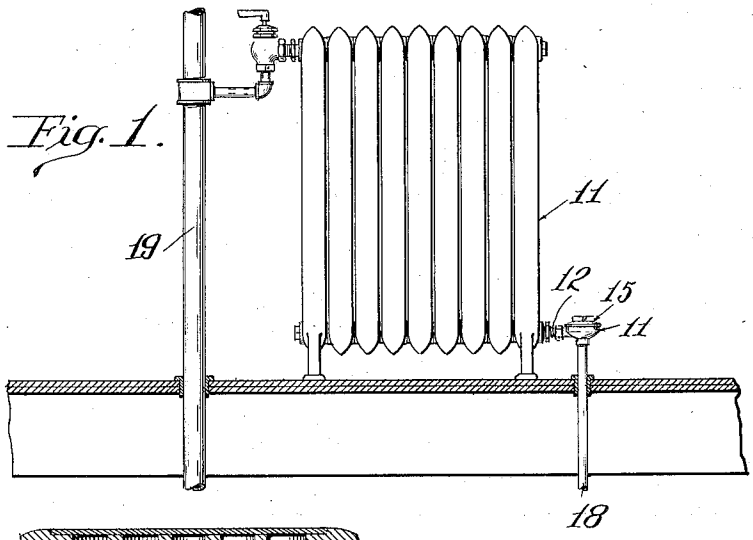


Fig. 2.

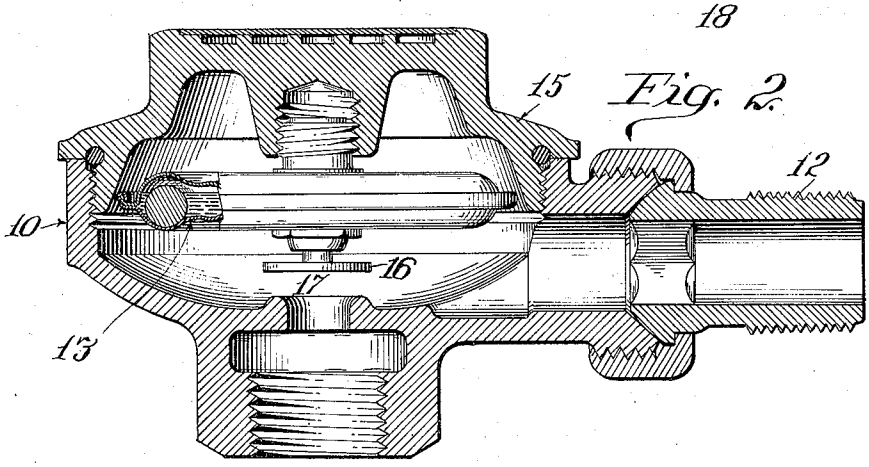
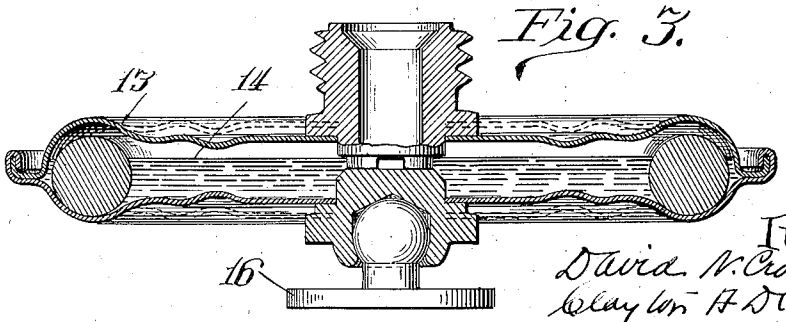


Fig. 3.



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UNITED STATES PATENT OFFICE

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STEAM TRAP

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This invention relates to steam traps, more particularly to the type involving the use of a hermetically sealed expansible and contractible vessel or capsule containing a vaporizable fluid, and to the utilization of such traps for effecting the retention of steam in and the evacuation of condensate and non-condensible gases from steam spaces, for example the radiators of a steam heating system.

A steam trap in order to be efficient must retain all of the steam in the radiator, or other steam space which it controls, without allowing any substantial portion of it to escape, and, on the other hand, must allow water of condensation and non-condensible gases to drain out by gravity, to be forced out by the incoming steam, or be drawn out by a vacuum in the outlet pipe, depending upon the type of heating system with which the trap is used and upon the particular phase of its operation. For instance, in a vacuum steam heating system the condensate and air will ordinarily have to pass through the trap from a zone of higher pressure, the radiator, to a zone of lower pressure, the return pipe, when the system is under steam; but when the system is cold, the trap, in order to operate effectively, must permit outflow by gravity of condensate from and to spaces which may be at substantially the same pressure. The altitude of the apparatus through variation in barometric pressure is also a variable factor.

The primary object of the present invention has been to provide a steam trap which will meet these requirements more effectively than traps heretofore known, that is to provide, a trap which, without readjustments, will retain the steam against leakage and also allow substantially complete evacuation of condensate and non-condensible gases when subjected to external pressures varying over a very wide range extending below, as well as above atmospheric pressure.

The application of the invention to practice is illustrated in the accompanying drawing, wherein—

Fig. 1 is a view in side elevation of the radiator of a steam heating system provided with a steam trap conforming to the principles of this invention;

Fig. 2 is a vertical section of the trap; and

Fig. 3 is a similar sectional view, the full lines showing the contour of the capsule after it has been exhausted, and as it is at ordinary temperature, 70 degrees F., for example, the dotted lines illustrating the contour of the capsule, as manufactured, that is before being exhausted.

The mechanical features of the trap and its capsule are known, the invention dealing exclusively with the nature of the volatile liquid used and with certain other features incidental thereto. The invention is not, therefore, limited to any particular construction of trap or any particular form of capsule.

The trap, as shown in the drawings, comprises a casing 10 connected to the radiator 11 by a nipple 12, and a corrugated flexible metal capsule 13 containing a volatile liquid 14, the capsule being adjustably secured to the cover plate 15 of the casing and provided on its under side with a valve 16 adapted to engage a valve seat 17 having a port communicating with the return pipe 18. Steam is supplied to radiator 11 through a supply pipe 19.

The capsule 13 is hermetically sealed and contains a liquid which vaporizes at a temperature below the minimum steam temperatures to which the trap is exposed. The expansible and contractible capsule is subject on the inside to the vapor pressure developed, on rising temperatures, by the vaporization of the liquid 14. On the outside it is subject to steam pressures in the radiator. The internal vapor pressures must exceed the external steam pressures by an amount sufficient to expand the metal capsule and move the valve. But the fulfillment of this condition alone is not enough for efficient operation. In order that the trap may operate without either leaking steam or retaining condensate the excess of internal pressure over external pressure must be substantially constant for each temperature throughout the operative temperature range of the heating system. The ratio of steam pressure to temperature is not constant. As temperatures increase, pressures increase disproportionately, as will

be seen from the following table taken from "Marks & Davis Tables and Diagrams of the Thermal Properties of Saturated and Superheated Steam", 1909, showing the comparative temperatures and pressures of saturated steam, the water phase employed in steam heating, the column at the left side of page giving first sub-atmospheric pressures measured by a mercury manometer and then superatmospheric pressures in pounds per square inch, the figures in the column of absolute pressures at the right of the page being those nearest to one decimal point the correct pressures for the corresponding temperatures:

Steam pressures	Steam temperatures	Absolute steam pressures lbs. per square inch
	°F.	
26 inches of mercury	125	1.9
24 inches of mercury	140	2.9
20 inches of mercury	161	4.8
16 inches of mercury	176	6.8
12 inches of mercury	187	8.8
8 inches of mercury	196	10.7
4 inches of mercury	205	12.7
0 lbs. per square in	212	14.7
2 lbs. per square in	218	16.7
4 lbs. per square in	224	18.7
6 lbs. per square in	230	20.7
8 lbs. per square in	235	22.7
10 lbs. per square in	239	24.7
12 lbs. per square in	243	26.7
14 lbs. per square in	248	28.7
16 lbs. per square in	252	30.7
18 lbs. per square in	255	32.7
20 lbs. per square in	259	34.7
22 lbs. per square in	262	36.7
24 lbs. per square in	265	38.7

The above figures are based on a standard barometer of 29.921 inches of mercury or approximately 14.7 lbs. per square inch atmospheric pressure.

Inasmuch as there is no single known substance which volatilizes at a point sufficiently below the boiling point of water to give an excess of internal pressure that will effectively expand the capsule of a trap and move the valve to its seat, and which has vapor pressures paralleling the vapor pressures of water over the range of temperatures such as given above, and which will in other respects fulfil the requirements of a volatilizable fluid for the capsule, it has been necessary to find a mixture, solution or compound which will serve the purpose. But before approaching this primary requirement the several variable conditions which have to be considered in the making of the trap will be summarized. These conditions are:

(1) The components of the liquid mixture must be such that they will not change or react, chemically, with each other at any temperature to which the instrument may be subjected in use.

(2) The liquid must not react, chemically or electrolytically, with the metal of the capsule so as to corrode it or impair its elasticity, or injure the seal between its metal parts.

(3) The liquid itself must not be impaired through chemical reactions set up between it and the metal of the capsule or the solder or fluxes used in manufacturing and sealing the capsule.

(4) The vapor should be a saturated vapor for all working temperatures. That is, at all temperatures to which the instrument is subjected there must remain some unvolatilized liquid in the capsule. If, as in some types of thermostatic traps, the amount of liquid is so small that all of it is volatilized at the higher temperatures of the working range, the vapor will be unsaturated at such higher temperatures so that its pressures will depend not only upon temperatures, but also on volumes which latter increase, necessarily, as the capsule expands. The vapor pressure of a saturated vapor is independent of changes in volume. Hence by using a vapor which is saturated for all working temperatures this variable factor may be eliminated.

(5) The liquid must have, as stated above, a boiling point sufficiently below that of water to develop at all working temperatures a vapor pressure sufficient to expand the capsule and set the valve firmly upon its seat. In practice, for a capsule of the type shown in the drawings this excess of internal pressure over external pressure, for each temperature of the range of working temperatures, should be about 11 lbs. per square inch; although it will be understood that the required internal pressure may be more or less in accordance with the mechanical structure of the instrument and the service which it is called upon to perform.

(6) The liquid must have a low specific heat (coefficient of thermal capacity) in order that it may respond sensitively to temperature changes.

(7) The liquid must have a low latent heat of vaporization for the same reason.

(8) The liquid must have a high coefficient of conductivity also for the same reason.

(9) In the manufacture of the traps the capsules must be adjusted to compensate for variations in elasticity of the metal so that this factor will be uniform for all instruments. The adjustment of the capsules may be accomplished in accordance with the method described in the copending applications filed September 30, 1925, Serial No. 59,706; filed September 10, 1927, Serial No. 218,845; and filed September 10, 1927, Serial No. 218,846.

(10) The capsule should be exhausted of its air before being sealed and while it is at ordinary room temperature, by which is intended approximately 70 degrees F. Preferably the capsule is exhausted to a vacuum as high as feasible and at least above any vacuum to which it may be subjected from the outside, so that when used in low pressures the capsule will not be caused to ex-

pand by internal air pressure; and also so that under all pressure conditions the expansion will be due substantially entirely to the internal vapor pressure developed and not to any considerable extent to pressure of air. In practice a vacuum within two inches of the barometric vacuum is obtained. In any case, the presence of the residual air in the capsule, even though the quantity is small, must be taken into account in the selection of the liquid mixture, since this residual air will expand less on rising temperatures than will the vapors developed from the liquid. A higher vacuum than that above mentioned might be obtained, except for the cost, and in such case the liquid mixture will necessarily be altered slightly to compensate for the diminished quantity of air.

(11) Finally, the component liquids must be selected so that for every temperature within the working range the excess of internal pressure over external steam pressure will be approximately constant and this can be most effectively accomplished by using components which are miscible or soluble with each other in the proportions used at all operating temperatures rather than by using liquids which are not mutually soluble at all or some temperatures within the operating range. However, the excess of internal pressure need not be absolutely constant. In fact it is preferable that the internal vapor pressure curve should not exactly parallel the external steam pressure curve. The internal pressures may desirably increase slightly over the external pressures and so provide the additional force necessary to compensate for the velocities of the outgoing fluids which increase disproportionately, that is as the squares of the pressures, in relation to the increase of radiator pressures, the pressure in the return or outlet pipe remaining ordinarily substantially constant. By describing the excess of internal pressure over external pressure as approximately or substantially constant for all temperatures of the working range, we do not intend to exclude the slight and desirable increase of internal over external pressures above referred to.

The selection of components for the liquid for the capsule is made in accordance with the following principles: (*a*) when liquids are mixed which dissolve one in the other, partly or wholly, the vapor pressure of the mixture is less than the sum of the vapor pressures of the constituents and may even be less than the vapor pressure of either constituent alone; (*b*) the greater the degree of mutual solubility, the less is the vapor pressure of the mixture in comparison with the sum of the vapor pressures of the constituents; (*c*) as temperatures change the solubilities of the components one with respect to the other change.

Any of the liquids suitable for use in thermostatic traps, if taken singly, will, within the range of the desirable working temperatures, increase as temperature rises disproportionately to the increase of vapor pressure of water over the same range, so that if a single liquid is used the excess of its vapor pressure over the vapor pressure of saturated steam, if correct for a low temperature will be too great for a high temperature, and if correct for a high temperature, will be too small for a low temperature; with the result that the valve of the trap will not open or close properly and at the right time except at temperatures within a relatively narrow compass. In accordance with the invention one otherwise suitable liquid for the trap is mixed with another, or with more than one other, in such proportions that, considering one liquid as a base liquid, the tendency of its vapor pressures to increase with rising temperatures is partially offset by its solution with the other liquid or liquids to an extent sufficient to give resulting vapor pressures for the mixture in excess of the vapor pressures of saturated steam by a constant amount, or approximately so, for all temperatures within the desired range. The approximation of the vapor pressure curve of the liquid mixture to parallelism with the vapor pressure curve of saturated water vapor is obtained by adjusting the proportions of the constituent liquids in accordance with known or readily obtainable data as to the solubilities and vapor pressures of the liquids concerned, and in accordance with the well known laws governing the vapor pressures of liquid mixtures, to give a liquid mixture having the desired vapor pressures for each temperature within the range of the trap.

For example, for steam pressures from a vacuum of 25 inches of mercury to 25 lbs. per square inch above atmosphere excellent results have been obtained by a mixture consisting of chemically pure benzene (C_6H_6) 99.5% by volume and denatured alcohol, United States Treasury Department Formula No. 30, 0.5%; the denatured alcohol consisting of ten parts by volume of ethyl alcohol (C_2H_5OH), and one part of methyl alcohol (CH_3OH), the total amount of alcohol being 95% by volume and the balance water.

The presence of the small quantity of water in the alcohol should be taken into account. It tends to increase the vapor pressure of the mixture at the lower temperatures of the range where the vapor pressures of the benzene are too small. Benzene and alcohol are mutually soluble, substantially at all working temperatures of the instrument. Water is only slightly soluble in benzene at the low temperatures, but becomes more soluble as temperatures rise so that its effect is practically nil at the higher temperatures, at which the vapor pressure curve for ben-

zene is too far from the vapor pressure curve of saturated steam, the water vapors at these high temperatures being absorbed in the base liquid or solvent. The effect of the alcohols, in the proportion stated, is to modify the vapor pressure of the benzene at both ends of the range of temperatures to make the vapor pressure curve more nearly parallel with the curve representing steam pressures.

The effect of the residual air in the capsule is to increase the pressure within the capsule at the lower temperatures without proportionate increase at the higher temperatures, since the rate of increase of the pressure of air, with rising temperatures, is very much less than the rate of increase of the vapors of the contained liquids.

Analogous results can be obtained by the use of different constituent liquids in different proportions, the same principle of compensation however being utilized. For example, one can employ distilled water 71.5% by volume, denatured alcohol (Formula No. 30) 28%, and benzene 0.5%.

It will be observed that this formula water and alcohol are used in large amounts and benzene in a relatively minute quantity. The principle involved in making this and other possible compounds of these or different constituent liquids is the same as that which dictated the proportions of the first specified formula. Guided by this principle the selection of particular constituents and the determination of their proportions will be a mere matter of routine chemical laboratory work. Where different constituents are to be employed care should be taken to select liquids that will comply with requirements stated under captions (1) to (3) and (5) to (8) above. Enough liquid mixture should be used so that some will remain unvolatilized at all working temperatures. The air should be exhausted from the capsule before it is sealed preferably to produce as high a vacuum as possible. The amount of residual air should be determined, and the effect of its presence on vapor pressures compensated for all temperatures of the working range.

Claims:

1. A steam trap comprising a valve and an expansible and contractible capsule to operate the valve containing a mixture of, by volume, approximately 99.5% benzene and 0.5% of denatured alcohol of United States Treasury Department Formula No. 30.

2. A steam trap comprising a valve and a sealed expansible and contractible capsule for operating the valve which is substantially evacuated of air and containing such quantity of a mixture of approximately 99.5% by volume of benzene and 0.5% of denatured alcohol of United States Treasury Department Formula No. 30, that the vapor developed by application of heat to the capsule will be a saturated vapor for all temperatures within the working range of the instrument.

3. A steam trap comprising a valve and a sealed expansible and contractible capsule to operate the valve containing, in quantity sufficient to give a saturated vapor for all operative temperatures of the instrument, a mixture of benzene and alcohol in such proportions that the internal vapor pressures will be in excess of the vapor pressures of saturated steam by an amount constant for all temperatures corresponding to steam pressures from a vacuum of approximately 25 inches of mercury to a pressure above atmosphere of approximately 25 pounds per square inch.

4. A steam trap comprising a valve and a sealed expansible and contractible vessel to operate the valve, substantially evacuated of air and containing, in an amount to give a saturated vapor for all operative temperatures of the instrument, approximately 99.5% by volume of benzene, approximately 0.05% of methyl alcohol, minute quantities of air and water, and ethyl alcohol to make up 100%.

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