

A Study of the Effects Caused by Freezing

Automatic Sprinkler Heads.

Introduction.

The writer was prompted to investigate the various Automatic Sprinkler Heads made by American Companies, as a result of the heavy losses by water damage after the heads had frozen and thawed. Therefore these tests would only be applicable to the wet system. The heads either discharged their full flow, or are weakened to such an extent, that they leak profusely under the pressure to which they are subjected. It is, in many cases, considered more serious to have a weak leaky head than a head which allows full flow, for the following reasons: if the heads leak slowly, the water will pass the alarm valve, (if one is installed in the system) and the leak will not be detected for some time, especially if they are located in deserted parts of the factory or in store rooms. They will therefore do much more damage than a head allowing full flow, as this flow will be detected almost immediately by the alarm valve located on the outside of the building.

These losses due to water damage are settled by the Insurance Companies which hold the fire risks, and they always agree to such terms in cases of sprinklered risks, as they are called.

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Object of Tests.

The purpose of testing these heads was to detect the weaknesses in the heads themselves, whether by shearing or crushing of parts, or by strains in the arms of the head.

The writer wishes to state that he is very grateful to Mr. Gorham Dana, Head of the Underwriters Inspection Bureau of New England, for his interest and suggestions in the matter.

The Different Systems as Installed.

There are at present three sprinkler systems which are installed; viz: the wet system, the dry system, and the wet sprinkler-heating combination system.

In the wet system all pipes are filled with water and in case of fire the head opens and water is immediately thrown over the surrounding region.

With the dry system a dry pipe valve is furnished. This is a differential valve with air pressure on one side and water pressure on the other side. The pipes in the building are pumped full of air to a low pressure, filling the pipe between the heads and the dry pipe valve. When a head opens in this system, the air pressure is lowered; the dry pipe valve is opened by the drop in pressure on the air side of the valve, and water is admitted to the pipes leading to the sprinkler heads, reaching the fire a few seconds after the head opens. This system is used where the heads are subjected to very low temperature; such as cold storage plants, exposed rooms, etc.

The third system spoken of is the sprinkler-heating combination. This is a wet system filled with hot water. The water is circulated through the buildings, the temperature of the water being anywhere from 60° Fahrenheit to 212° Fahrenheit. The temperature required to open the head is generally between 155° Fahrenheit and 165° Fahrenheit. To prevent the heads from opening, a short pipe

leads from the main pipe to the head, allowing a large air pocket between the water and the seat of the sprinkler head. As air is a poor conductor of heat, the high temperature of the water does not effect the solder of the head. This system has only recently been patented, and is meeting with marked success; being much more economical to install than two separate systems, viz: one for heating and one for sprinkler service.

Practical Arrangement of Heads.

It is the custom in practice to locate Sprinkler Heads about six feet apart. These heads are generally located on reducing tees or reducing couplings; the last head of the branch pipe being connected to the end of the pipe by a $\frac{3}{4}$ -inch -- $\frac{1}{2}$ -inch reducing elbow. All heads are upright; that is, with the deflector towards the ceiling, with the exception of a few cases where the head is inverted. The heads are inverted to allow a neater appearance in halls or panelled ceilings, or in cases where head room does not allow ample room over the head. In the exceptional cases the pipes leading to the head are generally concealed in the ceiling for architectural beauty. The heads are installed upright so as to allow the deflector to throw the water over the proper floor area, viz: 10 ft. sq.

Size of Orifice in Head.

The $\frac{1}{8}$ -inch diaphragm of ring-nozzle outlet has been taken for the standard and practically all sprinklers as made today comply with this standard. A few heads with 1-inch outlets, called jumbo heads, have been made for use at the top of elevators and similar places, but these heads are much less sensitive and it is considered better practice today to install several smaller ones in place of one large head. There is a slight difference in the discharge from the different makes of heads ranging from 15 gallons to 30 gallons per minute, according to the water pressure.

Previous Tests.

In many cases there is an air pocket between the water and the seat of the sprinkler head. This air accumulates from the water, rising to the higher points in the pipe line. However, this is not true in all cases, and in this work it is assumed that there is no air in the pipe in the practical installation. Therefore, means were used in the installation of the apparatus to force all air out of the pipes, before subjecting the head to freezing temperature, as this gives the worst possible condition.

Some years ago, tests for freezing were made by one of the large fire insurance companies of Providence. The different heads were filled with water and subjected to low temperature, no consideration being paid to any air pockets which might have been present under the seat of the heads. The results of the tests showed that occasionally a head would open or leak by freezing. The matter was reported and dismissed. However, the troubles increased as the systems were installed, and nothing more in this line has been done to determine just how the heads failed when frozen.

Tests on Heads and Requirements for Construction.

The following are certain tests and requirements for construction made on all sprinkler heads, by the Underwriter's Bureau of New England, before they are approved to be used in this district.

1. Discharge Capacity:

As a basis for these rules, it is required that each automatic sprinkler have an unobstructed outlet of such size and form that with 5 pounds pressure maintained at the sprinkler, it will discharge approximately 12 gallons per minute.

2. Pressure Test.

An automatic sprinkler upon original test must not leak at or under a pressure of 300 pounds hydrostatic pressure.

3. Water Hammer Test.

Sprinklers upon original test must not burst or leak by suddenly increasing the pressure from 0 to 300 pounds, repeated 500 or more times.

4. Fusing Point.

An automatic sprinkler when intended for ordinary use must, when immersed in hot fluid, fuse at not less than 155^o Fahrenheit, nor more than 165^o Fahrenheit. Head not to be under pressure in this test. "Hard heads", in like manner, must fuse at not less than 275^o Fahrenheit, or more than 300^o Fahrenheit. The fusing point of solder should not change with age.

5. Action in Opening.

On original test an automatic sprinkler on fusing must open without perceptible halt or hesitation at any point of the opening action. All freed parts must be thrown clear. This test to be made without subjecting the sprinkler to pressure, or depending upon the action of a coiled spring.

6. Position.

An automatic sprinkler must be designed to open and spray satisfactorily in an upright or pendant position.

7. Distribution of Water from Sprinklers.

Sprinkler upright or pendant with deflector 4 to 6 inches below smooth ceiling and 10 feet above smooth floor.

(a) Shall, under 5-pound nozzle pressure, wet ceiling over an area of not less than 3 to 4 feet in diameter.

(b) Shall, when under 5-pound nozzle pressure, throw approximately 90 per cent of water inside an area 10 feet square on floor.

(c) Shall, when under 50-pound pressure, throw not less than 75 per cent of water inside the 10 feet square area.

(d) Distribution in both above tests to be approximately uniform over the 10 feet square area.

(e) Water should not be cut up into fine spray.

(f) Rotary deflectors are allowable, but the distribution must be satisfactory with deflector fixed.

(g) The distribution in any direction shall not be obstructed by yoke, levers, or other parts of sprinkler..

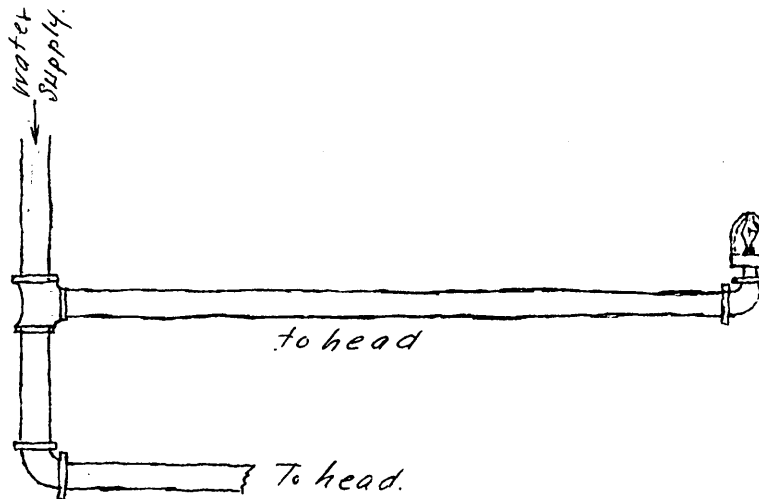
8. Materials.

Automatic sprinklers must contain no iron, steel, or fibrous material subject to the effect of corrosion.

Method of Testing.

The piping in these tests was arranged as regards size, length between heads, etc. as is the case in actual installation. The following diagram and sprinkler rules will give some idea as to the required size of pipe and arrangement of same.

To allow as much expansion of the ice as possible, 6-ft. lengths of $\frac{3}{4}$ -inch pipes were used, connected to a common header. This header was made up of $\frac{3}{4}$ -inch tees and short nipples between the tees as in following sketch.



This arrangement would allow for more expansion of ice than in the regular sprinkler system, and therefore results would be on the safe side, and would apply to the regular installation with worse effects than these tests show. The header was used to keep the ice formed, from backing out of the pipe during the thawing period. The ice could not back out in the practical installation, due to bends and longer pipes to cause greater friction.

All pipes used were $\frac{3}{4}$ -inch, as required by insurance bureaus, between the last two heads of any branch pipe.

The heads were screwed into the $\frac{3}{4}$ -inch -- $\frac{1}{2}$ -inch reducing elbows at the end of the 6-ft. pipes, and then the system was filled with water, care being taken to invert the heads in order to drive out any air which might be pocketed in the heads themselves. The pipes were then connected to the city main, where a static pressure of 85 lbs. was obtained. As regards pressure, it seems to make little difference whether there is pressure or not on the freezing apparatus.

During the winter months all tests were run over night, the pipes extending from a window in the laboratory. The temperature during the night was obtained from the local weather bureau. This was done to make sure that the heads did not freeze twice during the night; as the case happened in once instance, where the temperature rose during the night to considerable above freezing and then dropped again during the early morning before heads were observed.

When the outside temperature could not be used owing to warmer weather, the apparatus was set up in the insulated room in the basement of the Walker Building. The room was piped with an ammonia refrigeration system, and temperature as low as zero Fahrenheit was reached, and this temperature was maintained during the day. The refrigeration machine was shut down at night, and the temperature in the room gradually rose during the night, but still remained below freezing. (32° Fahrenheit) until morning.

After each freezing period, the heads were removed from the apparatus, examined closely, and tested for pressure

by means of a high pressure hydraulic pump. Heads which had opened during the test, were examined with their parts, to note the effects caused by the freezing.

Each head tested was placed in an envelope with its parts and the following data noted on the envelope, viz: the type of head by whom made, temperature range during freezing, pressure for leakage, and any peculiarities observed.

List of Heads Tested.

<u>Heads.</u>	<u>Manufacturers.</u>
Grinnell, Improved, 1903.	General Fire Extinguisher Co., Providence, R.I.
Garrett, Issue A.	Globe Automatic Sprinkler Co., Cincinnati, Ohio.
Manufacturers, Issue C.	Automatic Sprinkler Co. of America, New York, New York.
International, Issue B.	International Sprinkler Co., New York, New York.
Rockwood, Issue D.	Rockwood Sprinkler Co., Worcester, Mass.
Walworth.	Walworth Manufacturing Co., Boston, Mass.
Neracher, Improved, 1902.	General Fire Extinguisher Co., Providence, R.I.
Niagara, Issue B.	Automatic Sprinkler Co. of America, New York, New York.
Rundle Spence, Type A.	Rundle Spence Co., Milwaukee, Wis.
Associated, Type A.	Associated Automatic Sprinkler Co., Philadelphia, Pa.
+Rundle Spence, Type B.	Rundle Spence Co., Milwaukee, Wis.

+ This type of head has not been tested the Inspection Bureau and no name has been applied to it.

Observation of Results of Tests
on the Respective Heads.



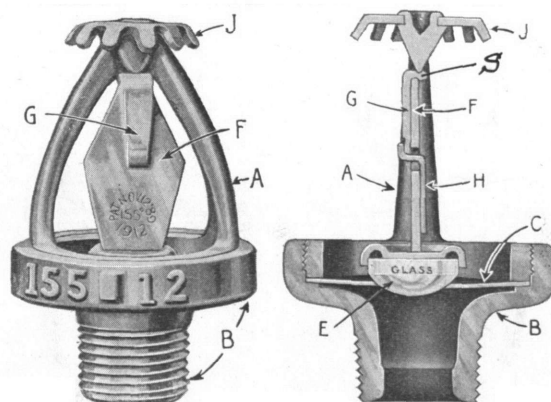
Grinnell, Improved, 1903.

Grinnell, Improved, 1903.

Diaphragm C was thrust out by the ice, and lever G was sheared off at point S. The glass valve E was not broken in any of the tests.

All other five heads failed in a similar manner, viz: by shearing at point S.

When tested for pressure, the lever sheared at a pressure of 400 lbs. per sq. in. These heads failed at a low pressure owing to the large area exposed to the water under the diaphragm.





Garrett, Issue A.

Garrett, Issue A.

Three tests on this type of head resulted in each case in distorting lever S, directly under its supporting seat. This sheared in such a manner that the valve of the head was loose, and could be turned around with the fingers.

In this case the head leaked at a pressure of 2 lbs. per sq. in., and would therefore have to be replaced by a new head.

Two other tests showed no effects in the head, the leakage pressure being as high as 1400 lbs. per sq. in.

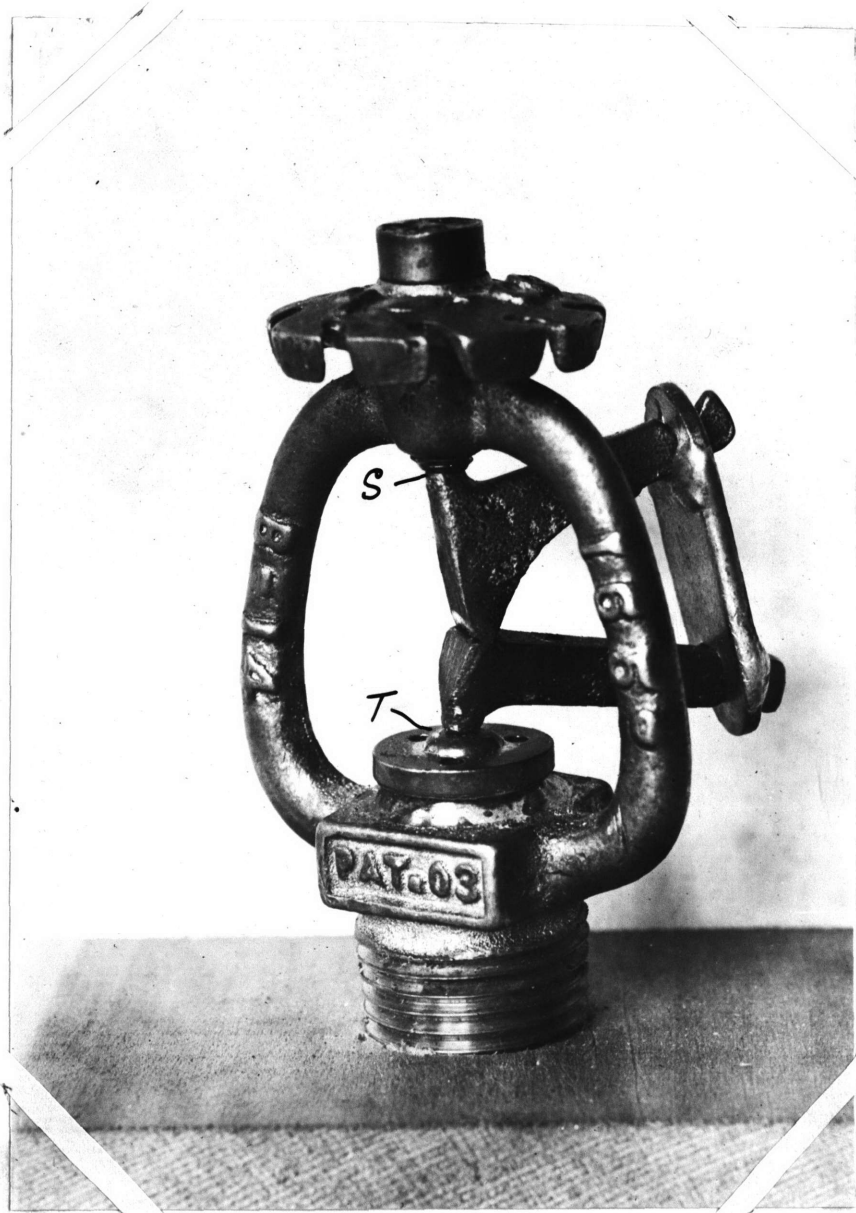


Manufacturers, Issue C.

Manufacturers, Issue C.

In four tests made, the thrusts of the ice caused the point of arm C to crush into cap E. This cap is a hollow button which bears on a porcelain valve F. By crushing cap E, the ice thrust the valve off its seat entirely, and allowed full flow.

One other test showed a weakened head, resulting in a leakage pressure of 50 lbs. per sq. in.



International, Issue B.

International, Issue B.

As a result of freezing two heads of this type, the thrust was taken on points S and T. The levers at these points were compressed enough to allow the force of the ice to thrust the valve from its seat; thus allowing full flow of water when thawed.

One test showed no effect on the head, and the leakage pressure was 1200 lbs. per sq. in.

Two tests bruised the levers sufficiently to loosen the valve, and leakage pressure, in both cases, was 10 lbs. per sq. in.



Rockwood, Issue D.

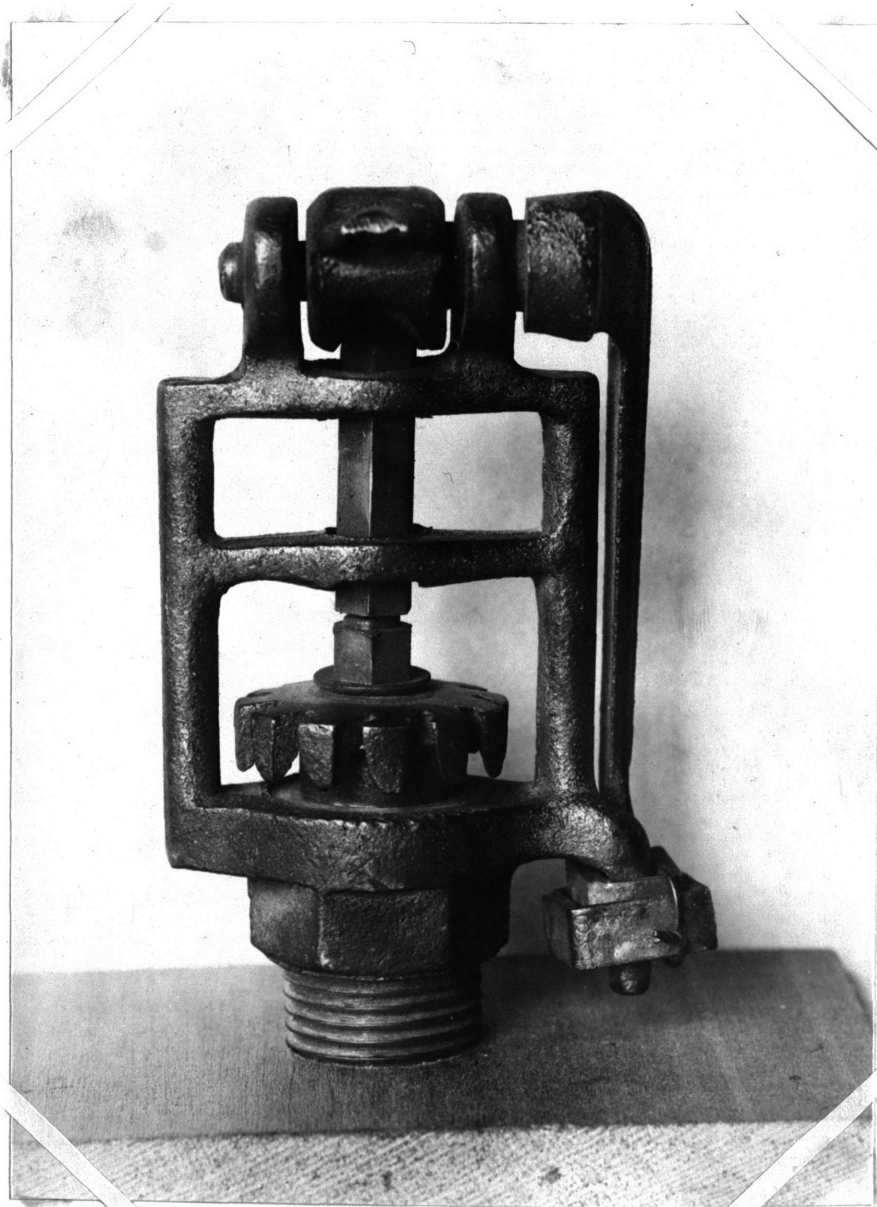
Rockwood, Issue D.

The result of freezing this sprinkler head expands the German Silver diaphragm, placed between the valve and seat, and, as a rule, ruptures this diaphragm.

It is claimed by the Rockwood Company that this diaphragm takes care of any expansion due to freezing. The results of tests show that this was true in two tests out of five.

In the other two tests the parts were picked up, and no marked defects were found on the valves or links. In this case the arms, L and M, must have been elongated enough to allow the valve to fly off its seat. In one case the tee, six feet from the head, was burst; thus relieving the valve of the high ice thrust.

The leakage pressure in the two previous cases was as low as 15 lbs. per sq. in.



Walworth.

Walworth.

Two heads were all that could be obtained of this type. The freezing seemed to have no marked effects on the head.

This type of head is one of the first manufactured in this country, and at present is not approved by the Underwriter's Inspection Bureau of New England.



Neracher, Improved, 1902.

Neracher, Improved, 1902.

Four tests on this head opened the valve completely. The pressure of the ice compressed the struts S and T. One other test resulted in the valve reseating, offset on its seat; thus allowing water to pass freely between the valve and the seat.

When tested for pressure, a perfect head leaked at 750 lbs. per sq. in.



Niagara, Issue B.

Niagara, Issue B.

The valve of this type of head was completely opened in four tests out of five. The thrust of the ice was taken up by the disk M crushing into the valve P. This valve is a hollow ^{German Silver}~~pressed steel~~ button.

The fifth test weakened the head resulting in a loose valve, with leakage of 5 lbs. per sq. in.



Rundle Spence, Type A.

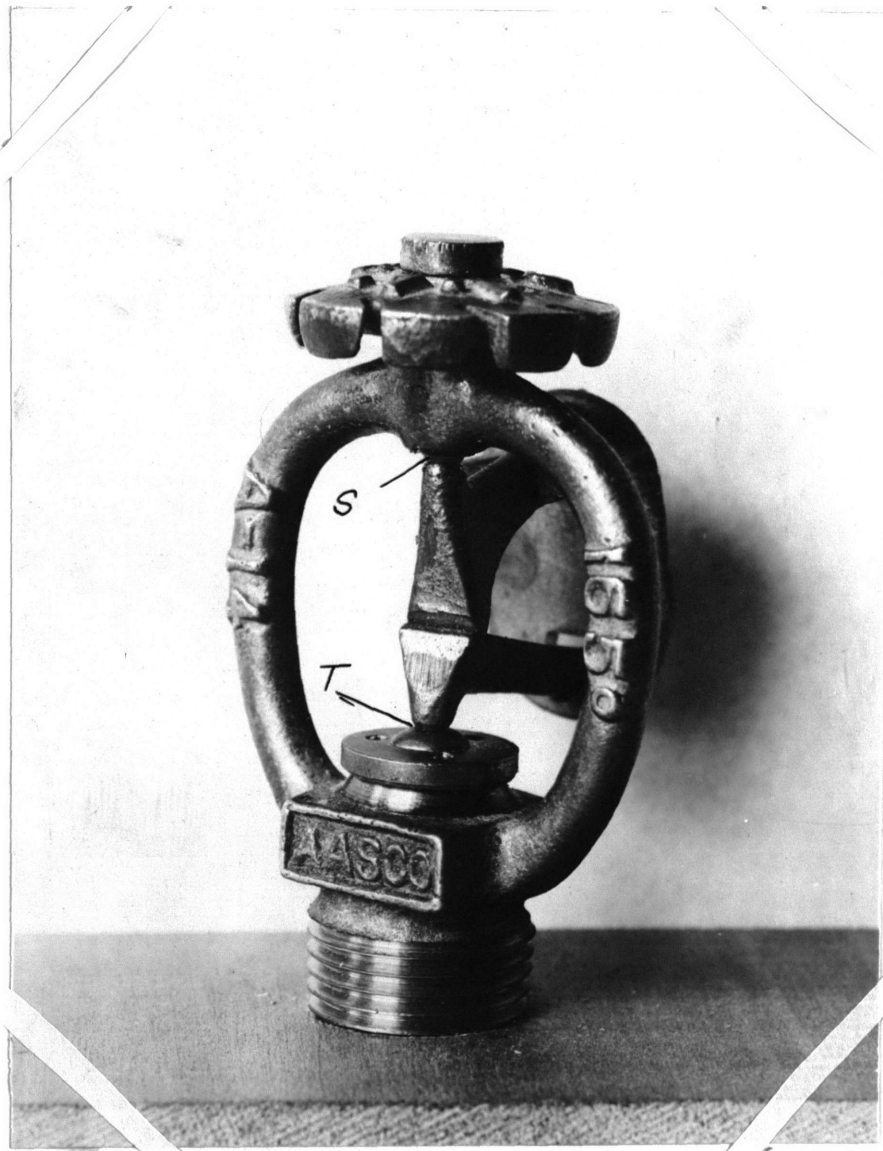
Rundle Spence, Type A.

This head is a copy of the Neracher, and therefore the results of tests made are very similar.

Three tests on this head resulted in the valve opening completely. Struts E and F being compressed into their seats, allowed the valve to shear by its seat.

Two other tests resulted in the valve reseating offset on its seat; and, although this would not be noticed until the ice thawed, it allowed water to pass freely between the valve and the seat.

Leakage pressure of this head was at 700 lbs. per sq. in.

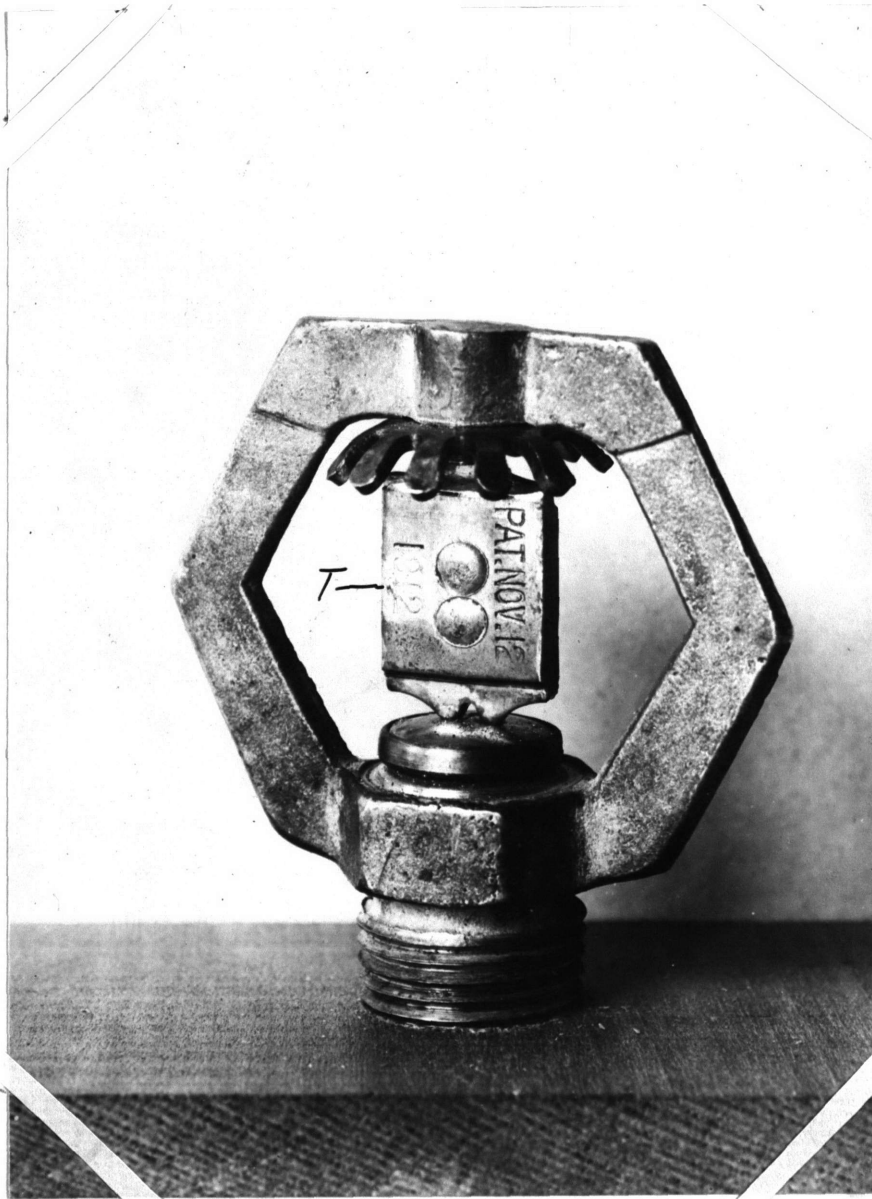


Associated, Type A.

Associated, Type A.

The result of freezing these heads caused defects very similar to those observed in the freezing of the International Sprinkler Heads.

The thrust of the ice was taken on points S and T, in three tests out of five. The arms at these points were crushed sufficiently to allow the force of the ice to shear the valve from its seat, giving full flow. The other two tests showed no effects on the head, although the valve was loose on its seat, allowing a leakage pressure in these cases of 5 lbs. per sq. in.



Rundle Spence, Type B.

Rundle Spence, Type B.

This appeared to be one of the strongest heads tested. Two cases of freezing resulted in the strut T crushing at the top and bottom, and caused the valve to be loose on its seat. The leakage pressure after freezing was as high as 50 lbs. per sq. in.

Three other freezing tests showed no marked effects, and the water pressure rose to 1200 lbs. per sq. in. before leakage occurred.

Conclusion.

As a summary of the defects in automatic sprinkler heads caused by freezing, the writer concludes that in the majority of tests made, the heads failed or were weakened to such an extent that, in practice, they would have to be replaced by new heads.

All failures were caused either by elongation of arms, crushing of struts, or crushing of caps over the valves. In many cases the pipes leading to the sprinkler heads were burst; but this, as a rule, did not seem to reduce the bursting pressure on the heads.

It appears to be quite an uncertainty as to the pressure exerted by ice when in the thawing stage. No figures could be found on this subject.