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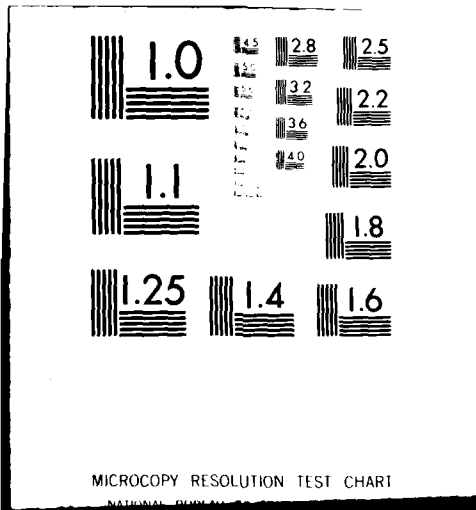
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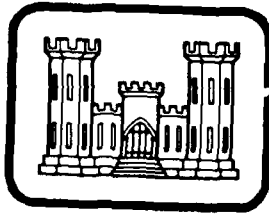
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FACILITIES ENGINEERING SUPPORT AGENCY

REPORT FESA-TS-2085

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PERFORMANCE EVALUATION OF STEAM TRAPS AND ORIFICE PLATES

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U. S. ARMY FACILITIES ENGINEERING SUPPORT AGENCY
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Steam traps and orifice plates have been examined to assess their utility as condensate control devices in typical Army steam systems. Specific types of devices have been recommended for the various major user in Army facilities. Selection of the size of each device should be made in accordance with manufacturers recommendations. Inspection and maintenance of steam devices is critical to their proper operation and to energy conservation. → cont. (over)			

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cont

20. Industrial maintenance firms may perform this function in cases where there are insufficient Facilities Engineering personnel to provide periodic inspections.

SUMMARY

A steam trap is somewhat like an automatic valve which is designed to bar the passage of steam while permitting the passage of water and air. Steam traps in most applications are located in condensate return lines from process or heating equipment and are often referred to as drips or drains. Thus, the traps are intended to keep steam in the steam pipes or a steam heated device. In so doing, a trap will pass the steam which has condensed to water, air, CO₂, and non-condensibles out of the steam distribution system. This permits condensate to flow back to the steam generating point where it is once more heated to make steam, unless impurities which might harm the boiler are present.

A steam trap is but one small part of a large system. There are really only three fundamentals to consider when attempting to view a trap independent of the system.

- . Properly sized traps of the correct type and working properly will provide the best energy economy.
- . Traps which are failed closed will back up condensed water into the nearest heat exchange device and cause it to cool down.
- . Traps which have failed open will pass steam and waste significant amounts of energy.

It is apparent from the above that the following steps will insure the best economy and reliability in steam trap operation:

- . Select the proper type of trap for the operating conditions existing now.
- . Inspect each trap on a regular basis to insure that it is operating properly.

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Immediately repair or replace any trap suspected of malfunction.

Steam traps should almost always be protected from dirt and scale by the installation of in-line strainers or use traps with integral strainers. Dirt pockets should be considered when especially dirty conditions exist. Strainers and dirt pockets require regular inspection and cleaning.

One key to energy efficient operation of steam systems is the regular inspection and timely maintenance of steam trap stations. Such regular inspection has become an impossibility because of reduced manpower head-count in all Facilities Engineers' staffs. The result, while not audited, is that there must be a large loss of steam energy. This conclusion was based on analogous studies in the chemical process industry. It could be postulated that some relief might be achieved by a wider use of low-maintenance disc traps or very low maintenance orifice plates. However, both of these low maintenance devices should be protected from dirt and scale by in-line strainers. And, the strainers must be inspected and cleaned at least as often as a trap should be inspected. Thus, traps having low maintenance requirements should have little impact on the man-hour requirements of an effective steam trap inspection program. The applicability of this circumstance might be measured by the installation of a few orifice plates in selected services where historical records would permit judging the utility of these simple devices.

It is recommended that the Facilities Engineer at each Army post secure the services of a local or national industrial maintenance firm to carry out a regular inspection program of all steam trap stations. This recommendation appears to offer a significant potential for reducing energy use. This potential might not otherwise be realized because of insufficient manpower on current Facilities Engineers' staffs.

PREFACE

Mr. T. G. Gressett, Senior Staff Engineer on the Corporate Engineering staff of Johns-Manville Corporation provided valuable inputs and guidance based on his 30 years experience with high and low pressure steam systems.

Mr. T. H. Sadler, a Senior Research Engineer on the Pipe Technology staff of the Johns-Manville Research and Development Center provided valuable assistance in the review of the technical literature and steam trap manufacturers' catalogs.

The following Facilities Engineering personnel were interviewed to obtain an overview of some steam systems employed by the Army.

J. Hayes - Fort Rucker
D. Edmonds - Fort Carson
L. May - Fort Campbell
M. Todd - Fort Bragg
W. Kaiser - Fort Sill

A special acknowledgement is given to the Yarway Corporation for granting permission to reproduce illustrations and text from its very informative publication, "Industrial Steam Trapping Course". Material from this publication has been used extensively in the section of this report describing the various types of steam traps.

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INTRODUCTION

Steam traps are necessary and yet much maligned for their reported undependable performance. Energy conservation programs at any facility where steam is used will eventually focus on the steam traps as a suspected source of both problems and opportunities. The suspicions are well founded because a trap with a leak as small as 1/32-inch can be wasting 50 million Btu per year. A one-half inch trap failed in the open position can be wasting over 3 million Btu per day, and a trap failed in the closed position is denying needed energy to a building, autoclave, washer or other equipment.

The function or purpose of a steam trap is to separate usable steam from water condensed out of the steam, air and any other non-condensable gases. The usable steam is then most frequently piped on to subsequent heat exchangers while the condensed water may be returned via pipes to the steam boiler. This is a rather simple process and the design and function of many types of steam traps is also quite simple.

The purpose of this report was to conduct both literature and market surveys to determine current state-of-the-art devices for use in steam systems to retain steam while releasing non-condensibles and condensate. An analysis and evaluation of the information was to be made of the various types of devices to include the following information.

- Identify the types of devices.
- Evaluate available data and test reports for overall performance, efficiency, costs, operating characteristics, steam loss, required maintenance, safety and code compliance.
- Include potential energy savings and cost effectiveness of the devices as well as a life-cycle cost comparison.

Generalized references in some of the literature suggest the first device used to separate condensate from steam may have been a "do-it-yourself" groove filed in the seat of a globe valve. This may then have been the predecessor of the drain orifice which appears to be the first manufactured device designed to pass condensate while holding back most of the steam. The deficiencies of this device have been reported to include an inability to handle large fluctuations in load and an inherent operating characteristic of always passing some steam. Undoubtedly design sophistication was lacking in the early days which meant that the aperture in drain orifices may not have been properly sized thus adding to the operating woes alluded to on occasion. The inability to handle large load fluctuations made the drain orifice rather useless during system start-ups as the small opening was unable to accommodate the large volumes of condensed water in a reasonable length of time. It was also reported that drain orifices frequently plugged with scale or other foreign particles. This fact may have accelerated the development of a device called a strainer. This is a filter device placed in the drain line, upstream of an orifice, or trap, designed to remove solid particles from the condensed water.

The first mechanically functioning steam trap was called a bucket trap and it was followed by a succession of steam trapping devices referred to by a myriad of names but all operating on one or a combination of three basic principles.

- Devices which are operated by the changing level of water within the device.
- Devices which are operated by the differences in temperature between steam and water condensed from the steam.
- Devices which are operated by the differences in thermodynamic properties of water and steam.

The principles of operation of the various types of traps are discussed in the section titled, Types of Steam Traps.

The technical literature and discussions with steam specialists indicate that there have been no new developments in steam trapping hardware or technology in over twenty-five years. Steam trap manufacturers may disagree with this conclusion. However, a review of technical sales literature tends to confirm the conclusion. New developments in steam trap hardware appear to be improvements and refinements aimed at:

- improving reliability
- increasing maintenance interval
- reducing maintenance cost

This report has been limited to a study of steam traps in accordance with the task order. It is critical to be aware that a steam trap is but a very small part of the steam system. Engineering and energy analyses must view the entire system. Even consideration of the operation of one individual trap should take into account its interface with appurtenant devices such as essential dirt pockets, strainers and blow down valves.

Much of the technical literature and sales brochures contained words and expressions which might be termed as "jargon" of the steam business. Also, different types of engineering disciplines seemed to have a tendency to talk about steam systems in somewhat different terms ranging from the thermodynamic outlook of chemical engineers to the nuts and bolts approach of stationary engineers. An effort has been made to minimize the use of special words and phrases in this report. A glossary of terms has been included in the Appendix in the hopes that it may be of some assistance to those who wish to pursue additional reading on this topic.

This report also contains the Market Survey, Literature Survey, Functions of Steam Traps, Types of Steam Traps, Selection of Steam Traps, Maintenance of Steam Traps, Energy Analysis, Economic Analysis, Conclusions, and Recommendations.

MARKET SURVEY

Method

The market survey was intended to identify manufacturers of appropriate steam/condensate separation devices; seek out the operating characteristics and benefits of each device; secure comparative testing results of various devices; and identify maintenance procedures and potential energy savings. The following actions were taken to achieve the objectives of the survey:

- letter to manufacturers
- interviews with engineers who specialize in steam system design for the Johns-Manville Corporation
- interviews with manufacturers' representatives
- telephone interviews with Facilities Engineering, Chiefs of Utilities
- review of National Building and Mechanical Codes, National Fire Code, ASHRAE Standards and ASME Code

Survey of Manufacturers

The letter sent to steam trap manufacturers is reproduced on the following page:



**Johns-Manville
Sales Corporation**

Research & Development Center

Ken-Caryl Ranch
Denver, Colorado 80217
(303) 979-1000

October 26, 1979

Dear Sir:

Johns-Manville Research and Development Center has been contracted to provide basic information on steam traps and orifice plates. Would you please send me your catalogs, sales and technical literature relating to proper selection, installation and maintenance of steam traps. Price lists would also be helpful as would illustrations of the various types of traps which would be suitable for inclusion in our final report.

Thank you for your help.

Yours truly,

P. B. Shepherd

The source of manufacturers solicited was the Thomas Register⁽¹⁾ and all firms listed under the following categories were solicited:

- steam traps
- radiator traps
- steam return traps
- thermodynamic traps
- thermostatic traps

Approximately 100 inquiries were mailed and 27 responses were received. This was an excellent response to a survey of this nature. The quality of information supplied by many manufacturers was also excellent. No testing data were provided by any manufacturer. The firms which responded to the letter are listed on pages 10 through 15.

American Air Filter Company, Inc.
215 Central Avenue
Louisville, Kentucky 40277

- thermostatic traps
- float and thermostatic traps
- inverted bucket traps

Armstrong Machine Works
816 Maple Street
Three Rivers, Michigan 49093

- inverted bucket traps
- float and thermostatic traps
- thermodynamic traps
- thermostatic traps

Barnes and Jones, Inc..
34 Crafts Street
Newtonville, Massachusetts 02160

- thermostatic traps
- float and thermostatic traps

(1) Thomas Register of American Manufacturers; Thomas Publishing Company; N.Y. (1979).

Clark Reliance
15901 Industrial Parkway
Cleveland, Ohio 44135

thermodynamic traps
float traps
inverted bucket traps
thermostatic traps
float and thermostatic traps

Dunham-Bush, Inc.
175 South Street
West Hartford, Connecticut

inverted bucket traps
thermostatic traps
float and thermostatic traps
float traps

Erwel, Inc.
412 Main St.
Ridgefield, Connecticut 06877

thermostatic traps
inverted bucket traps
thermodynamic traps
float and thermostatic traps
float traps

Flexitallic Gasket Company, Inc.
P. O. Box 680
Camden, New Jersey 08101

orifice

Gestra, Inc.
215 Union Street
Hackensack, New Jersey 07601

float traps
thermodynamic traps
thermostatic traps

float and thermostatic traps

Hoffman Specialty
1700 West Tenth Street
Indianapolis, Indiana 46222

thermostatic traps
float and thermostatic traps
inverted bucket traps
thermodynamic traps

Hubbell Corp.
Mundelein, Illinois

no traps

The Johnson Corp.
Three Rivers, Michigan

no traps

Kaye and MacDonald, Inc.
11-15 Central Avenue
West Orange, New Jersey 07052

float traps
inverted bucket traps

Lawler ITT
Indianapolis, Indiana

no traps

- Marpac
1900 Dempster St.
Evanston, Illinois 60204

orifice unions

New Jersey Meter Co.
89 Terminal Ave.
Clark, New Jersey 07066

thermodynamic traps

Nicholson
12 Oregon St.
Wilkes-Barre, Pennsylvania 18702

thermostatic traps
float traps
float and thermostatic traps
thermodynamic traps

Richmond Foundry and Manufacturing Co.
P. O. Box 5247
Richmond, Virginia 23220

NOT steam traps - plumbing traps only

RP&C Valve
8150 West Ridge Road
Fairview, Pennsylvania 16415

float and thermostatic traps
thermodynamic traps
inverted bucket traps
float traps

Sarco
1951 26th St.
Allentown, Pennsylvania 18105

thermostatic traps
float and thermostatic traps
inverted bucket traps
thermodynamic traps
float traps

Selic and Bird, Inc.
P. O. Box 108
Sea Girt, N. J. 08750

thermostatic traps

Southern Fluid Control Corp.
4491 North East 6th Terrace
Fort Lauderdale, Florida 33334

thermodynamic traps
inverted bucket traps

Star Steam Specialties
1 Yale Avenue
P. O. Box 151
Clayton, Delaware 19703

inverted and open bucket traps
thermodynamic traps
float traps
float and thermostatic traps

Trerice Co.
12950 W. Eight Mile Rd.
Detroit, Mich. 48237

bucket traps

Velan Engineering & Valve
Beekmantown Road
Plattsburgh, N. Y. 12901

thermostatic traps
float traps
bucket traps
thermodynamic traps
inverted bucket traps

Watson-McDaniel

thermodynamic traps

Wright-Austin Company
3245 Wright St.
Detroit, Michigan 48207

float traps
float and thermostatic traps

Yarway Corporation
Blue Bell, Pennsylvania 19422

thermostatic traps
thermodynamic traps
bucket traps
inverted bucket traps
float traps
float and thermostatic traps
orifice traps

Several respondents followed up their mail reply with calls and visits from local and factory representatives. A few provided excellent text-book-style literature on steam traps. One, Yarway Corporation, graciously granted permission to reproduce text and illustrations in this report. These excerpts are properly noted where they appear.

There was general agreement among manufacturers concerning the following subjects:

- steam system principles and operation
- selection of trap types and sizes for specified service conditions
- maintenance and inspection procedures.

Many manufacturers offer several types of traps and thus appeared to offer objective and sound engineering bases for selecting the best type and size trap for various service conditions. The exception to this

observation was with regard to orifices for condensate removal from drain lines. Only four manufacturers offered this device and two of those offered only this device.

Manufacturers' Guarantees

Five manufacturers of steam traps referenced guarantees in their literature. It is possible that others may also offer guarantees and it might be wise to request a copy of such a guarantee when a trap is purchased. Following is a brief condensation of the guarantees found in this study. Note that there is a rather wide disparity of terms.

Armstrong -

One year guarantee limited to repair or replacement of parts with no allowance for labor or refund of purchase price.

Erwel -

Two year guarantee requires that the purchaser return the trap to the factory for repair or replacement.

Nicholson -

One year guarantee requires that the purchaser return the trap to the factory for repair or replacement.

Velan -

Guaranteed for three years to function properly and give satisfaction. (No terms disclosed)

Yarway -

Warranted for three years for performance and service.

Interviews With Army Facilities Engineers

Telephone surveys of several facilities were made. The purpose of these surveys was to identify the nature of various steam systems, experience factors, and inspection and maintenance procedures in use. The excellent cooperation of the Chiefs of Utilities at the following facilities is greatly appreciated:

Fort Carson
Fort Campbell
Fort Rucker
Fort Bragg
Fort Sill

Many similarities were found among the steam services at the various facilities:

1. There is usually at least one large and several major, central steam plants operating "around-the-clock." These generate so-called high pressure steam ranging from about 100 psig up to 170-180 psig.
2. There may be many other, smaller central plants operating around 30-50 psig.
3. There are very many dozens of small, low pressure boilers producing low pressure, 5-30 psig, steam.
4. The principle use for steam is for heating and/or absorption cooling.
5. Separate boilers serve laundries and hospitals.

6. Bucket type steam traps service the bulk of facilities' steam services.
7. Float and thermostatic traps service almost all of the remaining facilities' steam services.
8. Steam trap type and size is set by Corps of Engineers initial design and installation. Trap replacement is invariably of like type and size. This is apparently, but not confirmed, true even in cases where the steam service load may have changed sufficiently over the years to suggest consideration of a different size and/or type of trap.

Another similarity among the facilities is that they do not have sufficient, trained personnel to carry out a planned and systematic program of steam trap inspection and maintenance. Trap inspection frequencies were reported to vary between "once-a-year" and "whenever someone complains about the heat." This situation is understandable based on the reported present actual levels of staffing. However, it is indicative of a major opportunity for cost saving and energy use reduction. About the most "sophisticated" trap inspection schedule found was a monitoring of changes in condensate return temperature and makeup water requirements as symptoms of malfunctioning traps.

Code and Standards Compliance

The major mechanical codes do not have any requirements relating specifically to steam traps. The ASME code applies to high pressure (over 15 psig) steam systems. It also has no requirements referencing steam traps. Underwriters' Laboratories do not have a label nor a listing service for steam traps.

There are apparently no public standards, codes nor accrediting laboratories to govern the selection and installation of steam traps. It might also be said that there exists nothing in these areas to guide a purchaser

in the wise selection and installation of traps. Only ANSI/FCI Standard 69-1-1977 contains a Pressure Rating Standard for Steam Traps. NBS Standard R244-51 relates to low pressure radiator traps and float and thermostatic traps.

LITERATURE SURVEY

The literature survey was conducted by Ms. Suzanne D. A. Graham of the Corporate Information Center staff at the Johns-Manville Research and Development Center. Two computer-based searches of engineering sources were employed:

Compendex, Engineering Index, Inc.

ISMEC Mech. Engr., Data Courier, Inc.

Only 42 references were disclosed whose abstracts suggested that they might be pertinent to the goals of this assignment. Many of these 42 articles, it developed, were written by representatives of steam trap manufacturers. Thus, we were faced with a minimal technical literature reservoir which could objectively be classified as broad based and unbiased. All references together with others disclosed during this study are listed in the BIBLIOGRAPHY.

Engineering handbooks did not provide useful information relating to the selection of steam traps which were not even indexed in the standard handbooks for Chemical, Civil and Mechanical Engineering. The ASHRAE Handbook⁽¹⁾ described many of the devices commonly used and offered some generalized guidelines for trap selection.

FUNCTIONS OF STEAM TRAPS

Steam traps, including fixed and adjustable orifices, are designed with the goal of providing the following functions:

1. The device should hold or retain steam in a

(1) The ASHRAE Handbook; 1976 Systems; 13.18-23.

heat exchanger so that the steam may give up that tremendous amount of heat (latent) available when it changes phase from vapor to liquid. A heat exchanger in this case may be any device relying on heat from condensing steam to fulfill its function. Examples of "heat exchanger" may include such things as:

- . hospital autoclave
- . laundry steam press
- . residential radiator
- . chemical reactor

2. The device should be capable of discharging water condensed from the steam through the device to a pipe which (in most Army facility applications) returns the water to the steam boiler to be reheated into steam. In many applications the device should also be capable of separating air, carbon dioxide, and other non-condensable gases from the steam and discharging these unwanted, even harmful, gases to the atmosphere. Most steam traps are designed to achieve energy conservation by not permitting usable steam to enter the drain line with the water nor be vented to the atmosphere with the air.

A steam trap is, obviously, an integral part of a total steam system. One should not consider the operation of steam traps without relating this operation to the function of the total system. A detailed discussion of steam systems was not one of the facets of this assignment. Therefore, the total steam system will be considered only as its operating characteristics relate to selecting a suitable type and size of steam trap.

The description of the proper function of a steam trap makes it clear that this is an energy conservation device. A steam trap which is operating according to the described functions will help to ensure that the steam system may operate at its maximum efficiency. A steam trap which is not operating properly will

guarantee that energy and money are being wasted. Traps of improper type and/or size also are energy wasters. Fortunately, there are many reputable manufacturers whose catalogs and field representatives provide suitable guidance for selecting traps for any type of steam system.

TYPES OF STEAM TRAPS

There are only three types of steam traps. Or, there are over thirty types of steam traps. It appears that manufacturers' proprietary terminology has created a myriad of different traps when, in fact, all traps operate according to one or a combination of three fundamental principles which are:

- . mechanical
- . thermostatic
- . thermodynamic.

There exist within each type three or four basic variations which are fairly widely used and have a broadly accepted, descriptive name. These are:

- . mechanical
 - bucket trap
 - inverted bucket trap
 - float trap
- . thermostatic
 - bellows
 - bimetallic
 - float and thermostatic (Note - this is the only combination function trap which appears to have universal recognition as a "type" of trap.)
- . thermodynamic
 - disc
 - rod or piston

-orifice plate (Note - The orifice plate may be regarded by some as not a true thermodynamic trap.)

Some firms may describe conventional traps in terms which might lead the reader to believe that the trap could be a new development differing in function from conventional traps. Some firms offer specialty traps of combined functions such as thermostatic and thermodynamic. These may have value in limited applications, but they will not be described here because of their potential limited application. Some manufacturers offer traps which combine traps with built-in strainers or strainers and blow-down valves.

The illustrations of the basic types of steam traps and much of the descriptive material referencing those illustrations have been taken from the "Industrial Steam Trapping Course" provided by the Yarway Corporation. All traps are first and fundamentally a properly sized orifice which is designed to pass condensed water while not passing steam. An orifice plate is an "always open" device which passes the condensate and some steam. All other conventional traps have some means for closing and opening the orifice. Thus, when they are operating according to their design, the orifice will be opened on demand to permit flow of condensate then close to prohibit the loss of steam.

Mechanical Traps

The first category of steam traps is referred to as mechanical traps. These are traps which open or close according to the level of liquid in the body of the trap and, therefore, have also been referenced as liquid - level sensitive.⁽¹⁾

Open Bucket Trap

This trap might also be called the upright bucket trap and is illustrated in Figures 1 & 2. This was a very early type of trap and consists essentially of a bucket or float (A), open at the top, operating within a housing (B). The bucket pivots around a fulcrum (C).

(1) Monroe, E. S. Jr.; Select the Right Steam Trap; Chemical Engineering; 129-134; January 3, 1976.

Attached to the bucket is a valve rod (D) extending upward through a discharge tube (E). At the top of the valve rod is a discharge valve (F) which seats in the orifice (G). In some designs the bucket surrounds the discharge tube and slides up and down along the tube rather than being hinged to a pivot as just described, but the operation is essentially the same.

When condensate comes to this trap, it gradually fills up the body and floats the bucket, causing the latter to rise and close the valve. Finally condensate spills over the top of the bucket and the bucket sinks. This opens the valve and the pressure inside the trap body forces the water up through the discharge tube and out of the orifice.

As soon as the bucket is emptied sufficiently it floats again, closing the valve and the cycle is repeated.

In the earlier models of the open bucket traps, the accumulation of air in the body of the trap often became a problem.

The first method of overcoming this difficulty was the insertion of a hand operated pet cock or valve in the top of the trap body. This had its disadvantages, for it required an operator to go around and bleed the air out of the traps.

Later models were equipped with a thermostatic element, usually of the bellows type, which automatically vents the air from the trap body. As air is cooler than the steam, the element opens to let out the air, but closes on steam.

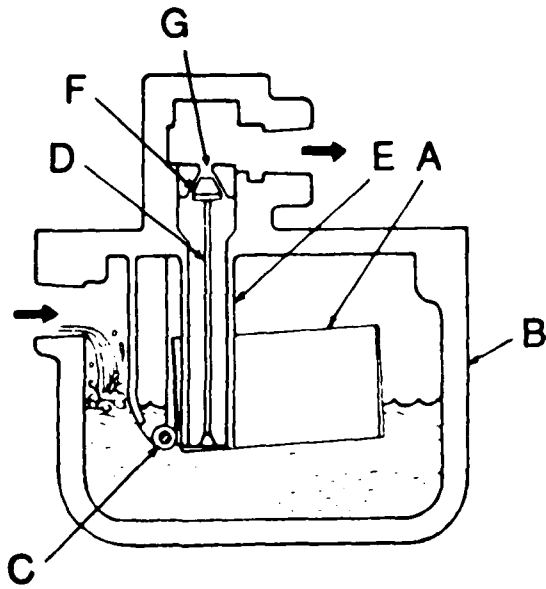


Figure 1. Open bucket trap.

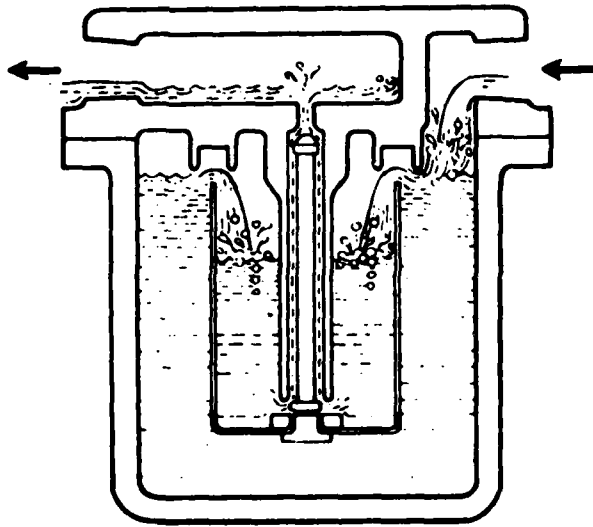


Figure 2. Open bucket trap.

Inverted Bucket Trap

A more recent and more commonly used type of bucket trap is the inverted bucket trap shown in Figures 3 & 4. It is somewhat similar to the open bucket trap, but in this case the bucket (A) is inverted and is open at the bottom.

To the top of the bucket is attached a valve linkage mechanism (B) which permits the discharge valve (C) to open and close as the bucket falls and rises.

When the bucket is at rest, it hangs downward with the valve open.

Condensate enters the trap either from the side as shown in Figure 3 flowing down the passage (D) on the side of the trap and then upward under the open end of the bucket, or if the trap has a bottom inlet, the condensate will enter directly under the bottom of the bucket as shown in Figure 4.

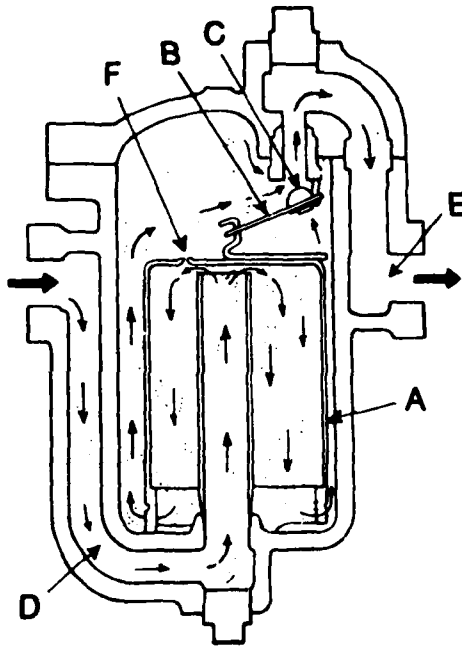


Figure 3. Inverted bucket trap.

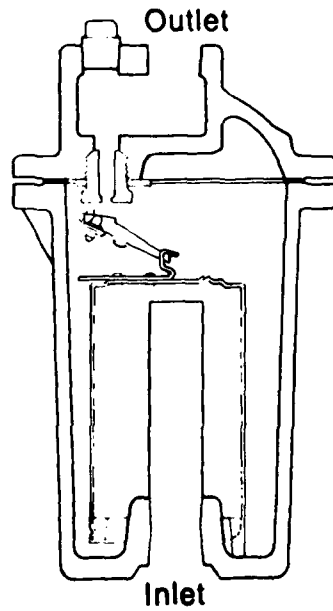


Figure 4. Inverted bucket trap.

In operation, as long as condensate is flowing to the trap, the bucket stays down and flow continues out the orifice and discharge passage (E). Now when steam reaches the trap it fills the bucket which floats and rises to close the valve.

The steam in the bucket slowly condenses and also bleeds off through the small vent (F) in the top of the bucket. Thus, the bucket loses its buoyancy and finally sinks, opening the valve again to discharge more condensate.

While the vent (F) (about 1/16 inch in diameter in a 1/2 inch trap) allows some of the steam in the bucket to bubble up into the body of the trap and condense, another important purpose of the vent is to permit passage of the air and non-condensable gases. If it were not for this vent, the bucket would soon be filled with air which forces the valve to close, and makes the trap inoperative.

Because there is frequently a considerable amount of air to be eliminated from the lines on start-up, it is necessary to get rid of this air promptly in order to obtain quick heat-up of the apparatus.

Flow of air through the vent is limited as it is due only to the buoyancy of the air in the water. Therefore, if large amounts of air must be eliminated, some means must be found to increase the venting capacity.

It is not possible merely to make the vent larger for then so much steam would bleed through that there would be a serious steam loss every time the valve opened.

If enlarged beyond a certain point, the vent would then allow steam to bleed through so rapidly the bucket would never rise to close the valve, and this would cause an even greater steam loss.

Some manufacturers of these traps therefore provide, as a substitute for the regular type, a bucket with a second or auxiliary air vent (G in Figure 5) for handling large volumes of air and gas. This auxiliary

vent is much larger than the regular vent and is provided with a disc valve controlled by a thermostatic bimetallic strip (H).

When the trap is cold, the bimetallic strip bends downward opening the auxiliary vent valve wide. This provides quicker air elimination during the start-up period.

As warmer condensate and air enter the bucket, the bimetallic strip gradually bends toward the closed position. This, of course, reduces the capacity of the auxiliary air vent. However, the air is always cooler than the steam, so as long as any air is present the auxiliary vent will be at least partly open. When all air is eliminated and steam fills the bucket the auxiliary vent closes completely leaving only the fixed vent open.

Where this auxiliary vent valve is needed, it is, of course, most important that it be kept in good working order, for if it is not, the trap will either be very sluggish or else it will waste steam.

Inasmuch as the mechanical traps as a class have cast iron bodies (except for the higher ranges of steam pressures where steel is used) that are always at least partially full of water, care must be taken to prevent freezing in outdoor installations in cold weather areas. Should the trap freeze up, not only would there be danger from backing up condensate in the line ahead of the trap, but the trap could be damaged.

When a mechanical trap is properly sized, there usually is not much danger from freezing, but if the trap is oversized it may not discharge frequently enough to prevent the water in the trap body or reservoir from freezing.

Therefore, if the trap is either lightly loaded or subject to severe freezing conditions, it should be well insulated.

Suppose, for example, the trap is draining an outdoor overhead steam line and discharging to an overhead return line and also that the trap is located

near ground level for ease in servicing. In such a case both the incoming condensate line and the discharge line should be insulated together to prevent the latter from freezing. The trap should also be well insulated and provision should be made for draining the trap body on shutdown.

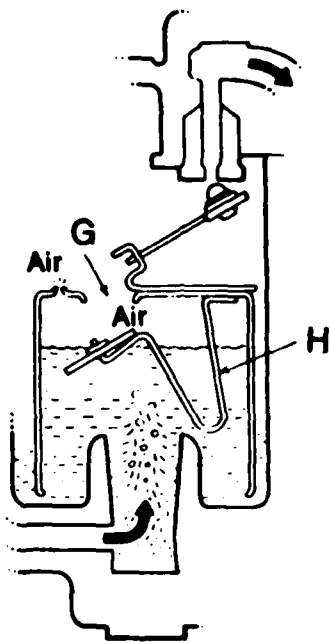


Figure 5. Inverted bucket trap.

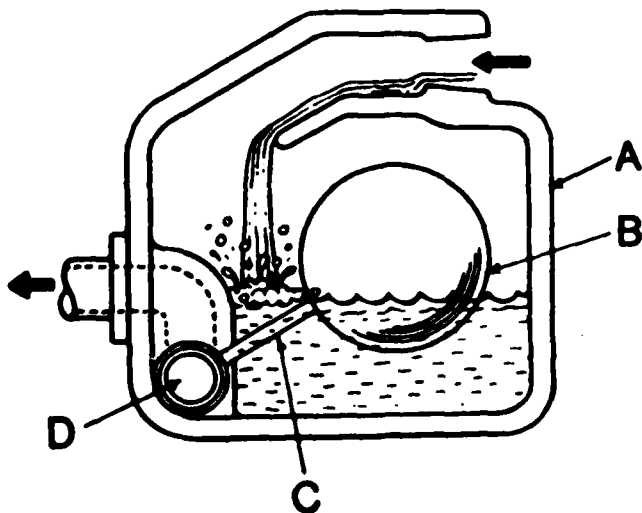


Figure 6. Float trap.

Float Trap

This is one of the earliest types of steam traps. It consists essentially of a closed housing (A), usually cast iron, within which is a ball float as shown in Figure 6.

In the simplest form of this trap, the float (B) is attached to the end of a rod or lever (C). The opposite end of the lever is attached to a discharge valve (D).

When condensate fills the body or housing of the trap, the float rises, gradually opening the discharge valve. Increasing condensate flow raises the float and opens the valve wider, adjusting it to suit the condensate load and maintaining the proper condensate level within the trap body.

The float trap is a good reliable type of trap but, for a given condensate capacity, is considerably larger and heavier than some of the later types of traps.

In recent years the use of this type of trap has been largely confined to relatively light condensate loads on low pressure heating units.

Thermostatic Traps

There are several types of thermostatic traps but all work on the same basic principle -- they respond to temperature changes in the line -- opening to cool condensate -- closing on steam.

Bellows Trap

A commonly used type of thermostatic trap is the heavy duty bellows type in Figure 7. The operating element consists of a corrugated bellows (A) mounted within a housing, usually of cast iron. At the bottom of the bellows is mounted a valve (B) which closes the orifice (C) when the bellows expands.

The bellows may be a simple metal assembly, or it may be filled with a liquid, such as alcohol or water, which has a boiling point below that of water.

The liquid-filled bellows traps are sometimes called balanced thermostatic traps. When condensate approaching steam temperature comes to the trap, the liquid inside the bellows vaporizes building up a pressure inside, which causes the bellows to expand and close the outlet valve.

The valve remains closed until radiation of heat from the body of the trap, and cooling of the condensate within the trap and in the line ahead of the trap, allows the vapor within the bellows to slowly condense. The bellows then contracts opening the valve wide again.

Time required to condense the vapor within the bellows depends on a number of factors, such as the size and material of trap body, length of pipe between trap and the apparatus it is draining, and temperature of the air surrounding the trap. Obviously the cooler the locations, the faster the trap will be able to cycle or respond to temperature changes in the line ahead of it.

As the valve is wide-open when the trap is cool, this type of trap provides quick start-up of equipment and excellent air handling ability.

To obtain the best performance from this type of trap, the bellows is usually designed so that it will close as near steam temperature as possible.

This type of trap is freeze-proof if mounted to drain properly when the system is shut down.

The bellows trap does have some limitations in application, however. As the bellows is fairly sensitive to water hammer, care should be taken to avoid any dips in the line ahead of the trap, or sudden pressure changes which might permit slugs of water to strike and damage the bellows.

Some designs are provided with a baffle surrounding the bellows to cushion the blow from water hammer and minimize the possibility of damage to the bellows element.

In most designs the upper pressure limit for which this type of trap is recommended is 300 psig. Best performance is usually obtained when the trap body is uninsulated and a cooling leg of several feet of uninsulated pipe is provided ahead of the trap.

Recently developed bellows type thermostatic trap designs include modifications intended to make the bellows more resistant to water hammer and overexpansion, as well as to make the trap more responsive to changing load and pressure conditions. These traps are also equipped with a ductile iron body and cover for use at operating pressures up to 600 psig.

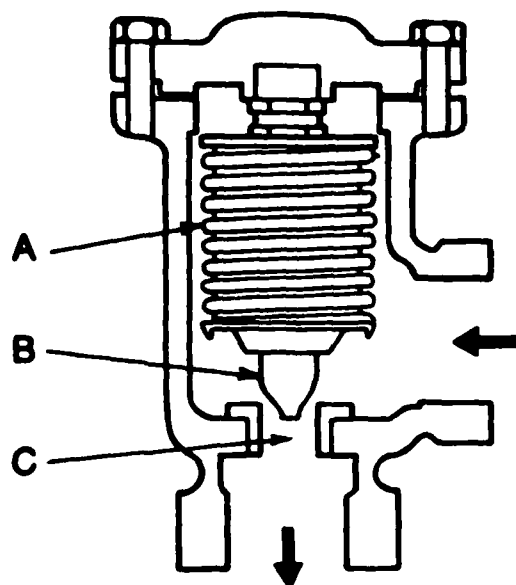


Figure 7. Bellows trap.

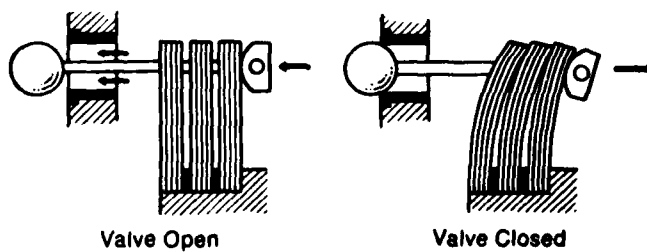


Figure 8. Valve of bimetallic trap.

Bimetallic Traps

Some types of thermostatic traps are operated by the bending of a bimetallic strip as shown in Figure 8. This bimetal element bends back and forth as condensate or steam comes to the trap.

As condensate and air, cooler than the steam, come to the trap, the element bends one way opening the valve. When hot steam arrives, the element bends the opposite way, closing the valve.

The bimetallic element is similar to the element that operates the ordinary household room thermostat except that it is of a heavier construction.

In one form of trap the bimetallic element is made up of a number of laminations in order to increase the force available to open and close the valve.

As the valve in this trap is wide-open when the trap is cold, it provides quick start-up of equipment by eliminating all air and cold condensate. When up to operating temperature range, however, response is more sluggish as time is required for the dissipation and absorption of heat to open and close the trap valve.

Another type of thermostatic trap is operated by the expansion of a liquid in a long enclosed tube which causes the tube to expand and close a valve in the end of the trap housing. A similar type employs the expansion and contraction of a metal rod to open and close the valve.

Float and Thermostatic Traps

This type of trap combines the float mechanism and principle with a thermostatic element. The latter is usually of the bellows-type although bimetallic elements are also used in some makes. See Figure 9.

The addition of the thermostatic element provides much greater air handling ability, particularly at start-up, than possible with the float mechanism alone and the float trap portion provides variable flow according to the condensate load.

The higher the float rises, the wider it opens the discharge valve, so that the trap actually becomes a level controlling device to drain the condensate as fast as it arrives at the trap. Discharge continues right up to steam temperature.

This type of trap is particularly adaptable to the lower range of steam pressures and will continue to operate even at very low pressure differentials. In many designs it is limited to a maximum operating pressure of 125 psig.

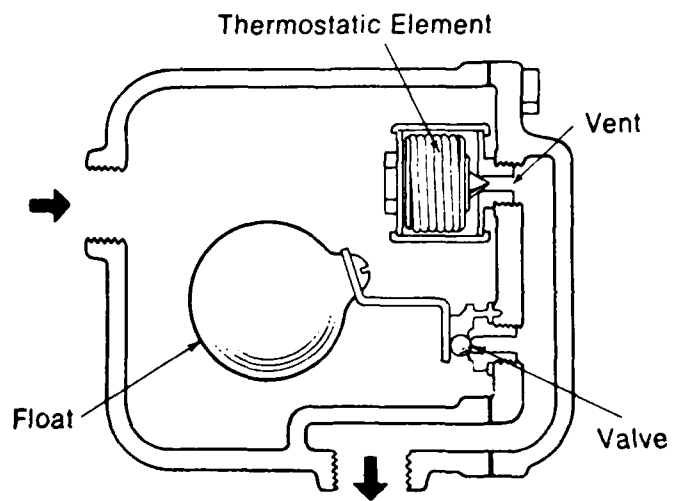


Figure 9. Float and thermostatic trap.

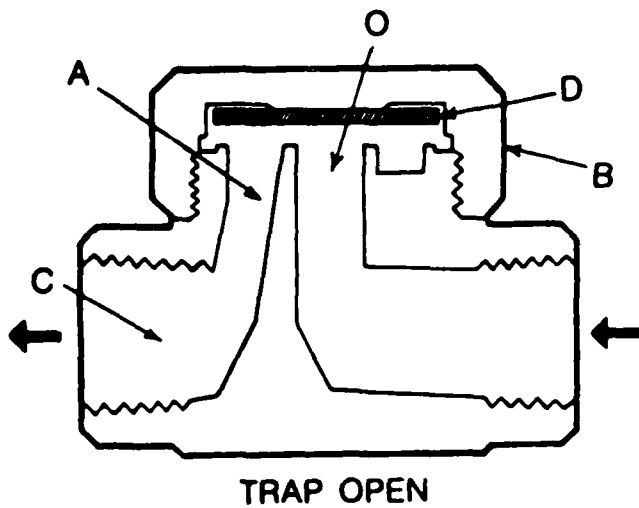


Figure 10. Disc trap.

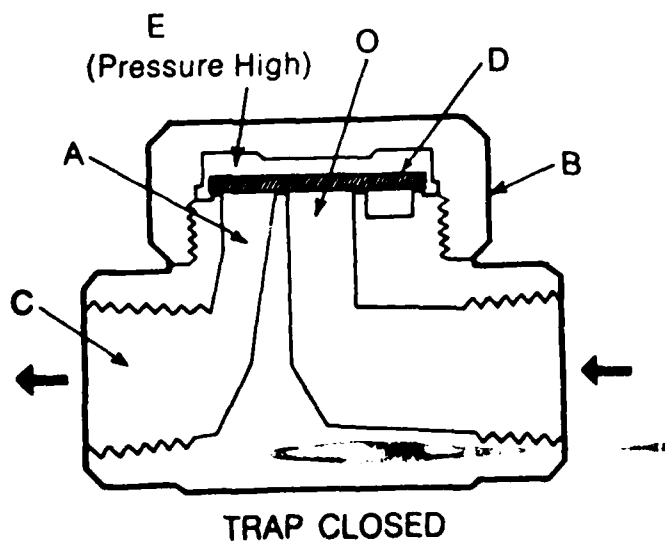


Figure 11. Disc trap.

Thermodynamic Traps

This third class of steam traps utilizes the heat energy in hot condensate and steam to control the opening and closing of the trap.

Disc Trap

One of the most recently developed types of thermodynamic traps is known as the disc-type shown in Figures 10 and 11.

It consists of a round flat disc (D) positioned over a center inlet orifice (O) and an annular discharge (A) leading off through a discharge port (C). All are enclosed within a bonnet (B) mounted on the body of the trap.

When operation starts, pressure in the inlet orifice (O) pushes the disc (D) up vertically off the two concentric seating surfaces surrounding the inlet and outlet ports. This allows discharge to flow out through the discharge port (C).

Now when very hot condensate and steam come to the trap, the high velocity of flow outward past the rim of the disc (D) up into the chamber (E) tends to reduce the pressure on the under-side of the disc, causing some of the condensate to turn to flash steam. At the same time the flashing condensate flowing outward at high velocity strikes the side wall of the chamber (E) causing a build-up of pressure in the chamber snapping the disc shut.

The disc remains in the closed position until the pressure in the bonnet falls due to the condensing of the steam in the bonnet. When pressure in the bonnet falls sufficiently, the disc rises, condensate flows out and the cycle is repeated.

This type of trap is essentially a time-cycle-device. In other words, under normal operating conditions, each time the disc closes on steam at a given pressure and temperature, it will stay closed for approximately the same length of time. This means that if condensate comes to the trap in the middle of a cycle, it will have to wait until pressure in the bonnet falls sufficiently to permit the disc to open.

A variation described as a tilting disc trap, operates in somewhat the same manner as the disc trap described above, except that the valve disc is arranged so that it opens and closes the valve with a tilting action rather than moving straight up and down as in the preceding type.

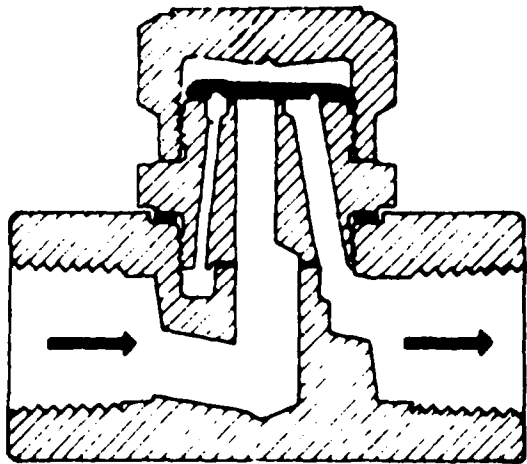
The tilting disc impulse trap is designed primarily for light to medium condensate loads and is illustrated in Figures 12 and 13.

When condensate enters this trap it pushes the disc upward with a tilting action because the inlet orifice (O) is off center. (To the left of center in the illustration.) Discharge then goes out through the discharge ports (D) in the seat plate. When the steam and steam temperature condensate come to the trap, the bonnet fills with steam and the increased pressure closes the disc in a somewhat similar manner to that described for the disc trap above.

The tilting or lever action of the valve in the tilting disc trap is claimed to minimize wear on the parts and also aid in reducing the noise from the trap discharge.

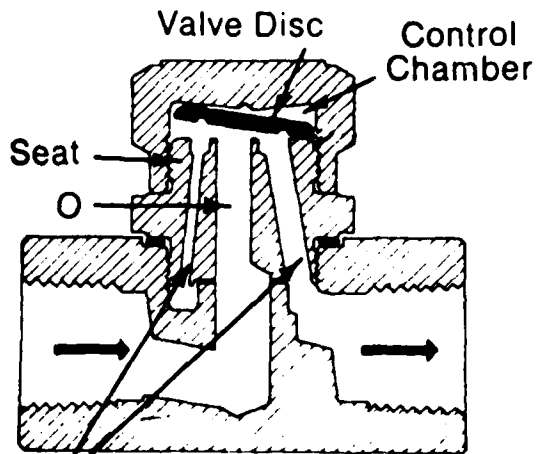
As in the case of the disc-type trap, this trap also operates on a time cycle. In other words, the time between opening and closing will be relatively constant for a given set of load and pressure conditions.

When the tilting disc trap is closed by the steam and flash steam entering the bonnet, it stays closed until the steam in the bonnet condenses and also bleeds off slowly between the ground surfaces of the seat and the disc.



CLOSED POSITION

Figure 12. Tilting disc trap.



D OPEN POSITION

Figure 13. Tilting disc trap.

This "bleeding off" actually comprises a very slight control flow but is so small it is barely perceptible at the trap discharge. This slight control flow also permits bleeding off of air and non-condensable gases and aids in prevention of air binding.

Both the disc and tilting disc-types of traps just described are effective from the upper limits of their recommended capacity ratings down to the lightest condensate loads.

Several other varieties of disc-type traps have recently been made available, but all operate on the same general principles just described for the disc and tilting disc-types of traps.

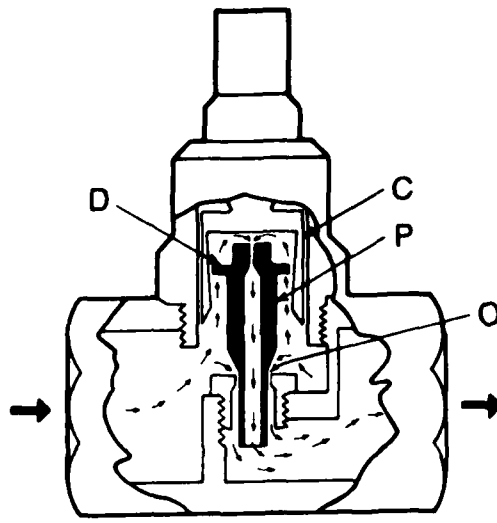
Piston Valve Trap

A more recent thermodynamic trap is the piston trap in Figures 14 & 15.

Without going into the technical details of the engineering theory involved, the operation of this trap is described very simply in the following paragraphs.

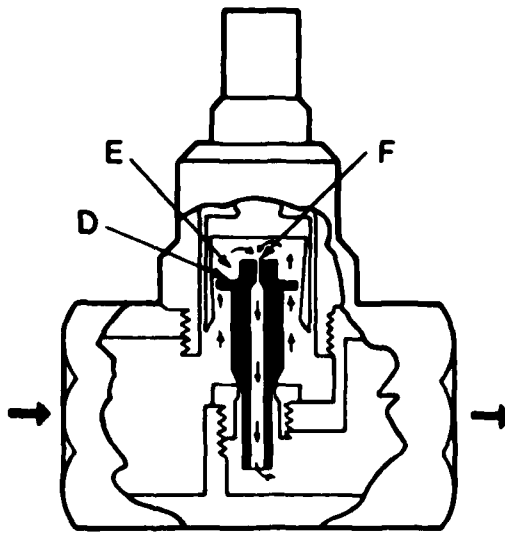
This trap may consist essentially of a piston type valve (P) operating within a control cylinder (C).

The lower end of the valve has a tapered seating surface which opens and closes orifice (O).



VALVE OPEN

Figure 14. Piston trap.



VALVE CLOSED

Figure 15. Piston trap.

When steam is turned on in the system ahead of the trap, pressure is exerted on the under-side of the piston disc (D), on the valve (P), pushing it upward to open the orifice (O), so the condensate and air can flow out at full capacity.

The valve opens wide on start-up for full discharge of condensate and to quickly get rid of any air that may have accumulated in the system.

The valve stays wide open until condensate nears steam temperature.

Opening and closing of this trap is regulated by the slight condensate flow which goes up past the piston disc (D) to the intermediate pressure area in the control chamber (E). It then flows out the control orifice (F) in the hollow stem of the valve to the lower pressure in the discharge port of the trap.

When condensate nears steam temperature, these pressure drops cause it to flash in the control chamber (E) and in the control orifice (F). This chokes the flow through the control orifice which increases the pressure in the control chamber (E), snapping the valve shut to prevent the loss of live steam.

As long as the condensate remains hot enough to continue the flashing, the valve remains closed. When it cools slightly, the flashing decreases. This reduces pressure in the control chamber allowing the valve to reopen and the cycle is repeated.

The control flow continuously samples the condensate flow coming to the trap and causes the valve to open or close quickly at the proper time - to open wide on condensate, but close when steam reaches the trap.

Therefore, the quick response provided by the control flow in this trap aids in bringing steam equipment up to temperature quickly and in maintaining high, even temperatures of the apparatus. This promotes high efficiency of the overall operation.

The control flow consists of only a slight percentage of the full flow through the main orifice. This means that only an amount of condensate equal to this small percentage is required to completely fill the control orifice at all times. When the main valve is closed and as long as this slight amount of condensate flow is maintained, there can be no measurable flow of steam through the control orifice.

Orifice Traps and Plates

These devices have been listed under thermodynamic traps because double plate and labyrinth orifices provide some semblance of flow control based on thermodynamic principles.

Orifice plates depicted in Figure 16, were an early method of controlling the flow of condensate. This is simply a plate or disc inserted in the discharge line or drain line from the apparatus. In the center of the disc is a hole or orifice.

In order to pick the right size orifice it is necessary to calculate the amount of condensate flow, based on the condensing rate of the equipment or apparatus, and also to know the pressure and temperature at the orifice. When these three figures are known, the proper size of orifice can be picked from an orifice table.

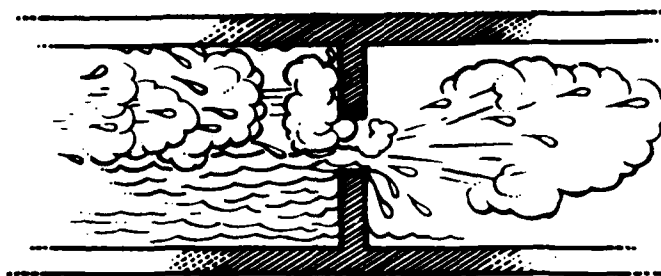


Figure 16. Orifice plate.

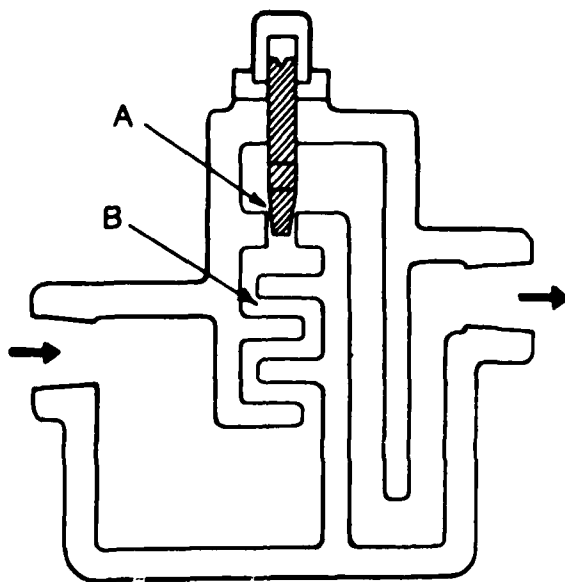


Figure 17. Labyrinth orifice trap.

When the size of the orifice has been calculated correctly and conditions in the condensate line remain approximately constant, the orifice plate is a very efficient device. However, constant conditions such as this are encountered rather infrequently in the usual industrial application.

Single orifice plates are frequently sold in combination with a strainer because these devices are especially sensitive to dirt clogging. Claims for extremely low maintenance are likely true only under clean operation conditions.

Frequent inspection and cleaning of the strainer is likely to be a necessity to maintain the operation of the orifice plate itself. These devices are most likely to find application in condensate drains from very high pressure steam mains (+600 psig) under circumstances where load does not vary more than 25 percent from design load. One manufacturer recommends parallel trapping with a conventional trap to handle start-up condensate loads. Single orifice plates nearly always leak some steam.

Double orifice plates were probably the first improvement on the single orifice plate. Hot condensate flashing to steam between orifices may serve to choke the flow of the second orifice thereby providing a limited amount of self-regulation.

The labyrinth type orifice is more like a trap and was one of the earliest thermodynamic traps. In one form shown in figure 17 it combines an adjustable orifice (A) with labyrinth passages (B) to control the flow of condensate. Due to pressure drop through the labyrinth passages and the adjustable orifice, some condensate turns to flash steam as condensate approaches steam temperature. This provides a measure of automatic flow control, for the nearer the condensate approaches steam temperature, the greater will be the flashing and therefore the greater the choking effect of the flash steam.

As with the orifice plate, if the condensate load does not fluctuate to any great degree this trap is quite satisfactory, but if load, pressure, or temperature vary considerably it is likely to either back-up condensate or blow live steam.

SELECTION OF STEAM TRAPS

The purpose of this topic is to provide guidance for the reader in selecting the types of steam traps to use in the various applications found within Army facilities. There is, of course, an additional step to take in selecting the size of a particular type of trap. Selecting trap size is a topic well covered in nearly all manufacturers' literature and will not be covered in detail here. It is very important to select the proper trap size as both undersizing and oversizing produce penalties in operating costs. Use manufacturers' literature and the guidance of manufacturers' representatives to select the proper size of trap. Also, use the information in this report to select the proper type of trap.

Table 1 summarizes information obtained in the market and literature surveys concerning the performance of the various types of steam traps. Curiously, there was direct contradiction among several of the sources. The appearance of ?'s in the Table indicate that there was not a good consensus judgement revealed by this study or that no information was obtained.

The greatest extent of steam use in Army facilities involves steam distribution systems, heating units and absorption units. Three types of traps are best suited for use on steam distribution drains.

- Thermodynamic disc traps are the first choice and especially where freezing conditions may occur.

- Insulated, inverted bucket traps are the alternate choice where freezing conditions may occur.
- Float and thermostatic traps are an alternate choice up to 150 psig. These traps should not be used where there is a danger of freezing. These traps are especially indicated where heavy condensate loads are encountered during frequent system start-ups.
- Non-insulated, inverted bucket traps are an alternate choice where there is no danger of freezing.

The choice of traps for heating units (both air and water heat exchangers) and absorption units is as follows:

- Use float and thermostatic traps properly protected from freezing.
- If a freezing danger exists, consult manufacturers' representatives to select the proper insulated, inverted bucket traps.

Specialty equipment such as hospital sterilizers and jacketed cookers should be analyzed according to the operating conditions of each unit. Manufacturers' representatives should be consulted as all types of traps have potential applications and no generalized guidelines may be offered.

TABLE 1

PERFORMANCE OF VARIOUS STEAM TRAPS

Description	Mechanical Traps			Thermostatic Traps				Thermodynamic Traps		
	Bucket Bucket	Inverted Bucket	Float	Metal Bellows	Liquid Bellows	Bimetallic	Float & Thermo- static	Disc	Piston	Orifice
General Pressure Range	to 250	to 150	to 150	to 150	to 150	to 170	to 150	to 600	?	Very High
Capacity	Good	Fair	Excellent	Fair	Fair	Fair	Excellent			
Starts Up Lead	Fair	Excellent	Excellent	Excellent	Excellent	?	?	Poor		?
Resists Surges	Excellent	Excellent	Excellent	Poor	Poor	Poor	Excellent	Varies		No
Resists Back Pressure	Yes	Varies	Varies	Yes	Yes	Varies	Varies	Yes		No
Resists Freezing	Most	No	Yes	Yes	Yes	Yes	No	Yes		Yes
Resists Hammer	Insufficient	Excellent	Poor	Poor	Poor	Poor	Poor	Excellent		Yes
Resists Capacity	Moderate	Very High	Low	Low	Low	Low	Very High	Moderate		Excellent
Resists Back Pressure	Excellent	Excellent	Fair	Fair	Fair	?	Good	Poor		?
Resists Performance	Excellent	Excellent	Excellent	Excellent	Excellent	?	Excellent	Poor		Poor
Resists Freezing	Excellent	Excellent	Fair	Fair	Fair	?	Excellent	Poor		Poor
Resists Hammer	Varies	?	Varies	Varies	Varies	?	Poor	Poor		Acceptable
Resists Capacity	Usually	Usually	Usually	Usually	Usually	?	Closed	Varies		?
Resists Back Pressure	Closed	Closed	Closed	Closed	Closed		Usually	Usually		Always
Resists Performance	Yes	Yes	No	No	No	No	No	Closed		Open
Resists Freezing	Excellent	Excellent	No	No	No	No	Excellent	Excellent		No
Resists Hammer	Varies	No	No	No	No	No	Excellent	Excellent		?
Resists Capacity	Varies	No	No	No	No	No	Excellent	Varies		?
Resists Back Pressure	Good	Good	Good	Good	Good	Good	Good to	Varies		?
Resists Performance	Small	Small	Small	Small	Small	Small	Excellent	Poor		No Intc
Resists Freezing	Yes	Yes	Yes	Yes	Yes	Yes	Excellent	No		?
Resists Hammer	Low	Low	Low	Low	Low	Low	Low	High and		General
Resists Capacity	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure,	Low		Purpose
Resists Back Pressure	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Pressure		Heavy
Resists Performance	High	High	High	Moderate	Moderate	Low	High	Drains		Drains
Resists Freezing	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Hammer	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Capacity	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Back Pressure	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Performance	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Freezing	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Hammer	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Capacity	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Back Pressure	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Performance	High	High	High	Moderate	Moderate	Low	High	Very Low		Low
Resists Freezing	High	High	High	Moderate	Moderate	Low	High	Very Low		Low

INSPECTION AND MAINTENANCE OF STEAM TRAPS

Maintenance of steam traps and regular inspection routines to detect traps requiring maintenance are a challenging and vexing problem for utilities personnel at Army facilities. It was shown in the Market Survey that Army facilities have insufficient personnel to carry on an adequate inspection and maintenance program. It follows logically from this that there must be many failed and malfunctioning traps at every Army facility. This conclusion is based upon the results of surveys of manufacturing and chemical process industries. (1) (2)

The energy savings which can be achieved through a timely and thorough maintenance program are likely to be very large. It is not possible to quantify such savings. However, some general guidelines are offered in the section of this report titled, Energy Analysis.

Failures of steam traps can usually be attributed to one of three causes. (3)

1. Misapplication. Selecting the wrong type of trap will not only result in inefficient operation but may also reduce the operating life of the trap.
2. Incorrect size. An oversized trap will cycle rapidly and wear out prematurely. An undersized trap will not completely drain condensate and the heater will not operate properly.
3. Neglect. Failure to detect signs of early wear and dirt build-up will lead to premature failure of the trap. Intelligent system design with proper use of strainers and dirt pockets is strongly indicated.

(1) Factory, 67, March 1975.

(2) Laidley, C. W.; Steam Trap Maintenance, Energy Conservation Seminar of Chemical Industry Task Force On Conservation.

(3) Ibid.

Inspection routines and criteria for disclosing faulty traps are presented in detail for those facilities which might, at some time, find the information useful. It is recognized that there are not enough people available to follow these procedures at the present time. Therefore, it is recommended that Army facilities implement steam trap maintenance and inspection programs through outside service contracts.

Several firms which might be able to provide this service are listed below.

Honeywell Inc.
Minneapolis, Minnesota
612-870-5200
Mr. Don Tadvick
National Operation's Manager

Honeywell Inc.
5555 DTC Parkway
Englewood, Colorado 80111
303-779-6200
Mr. James F. Cumiskey

Steam Team
P.O. Box 61167
Houston, Texas 77028
713-523-6400
Mr. Burns Clelland

Team Inc.
P.O. Box 123
Alvin, Texas 77511
713-331-6154
Mr. William Bramblett

Steam System Management
Basin Road Industrial Center
New Castle, Delaware 19720
302-322-5411
Mr. Dick Kerr

Regular inspection and timely maintenance of steam traps have been shown to be good ways to reduce energy use and save money. The hiring of skilled service companys to provide at the very least, inspection can be one effective way to

address the problem of insufficient staff people to perform the necessary inspection and maintenance services.

Inspection of a Steam Trap

The technical and manufacturers' literature contain much information on steam trap inspection. One factor that is repeatedly stressed is that the symptoms of a failed or malfunctioning steam trap are likely to be an indication of a problem in the steam system although the suspected trap may be capable of functioning properly. Several different methods for inspecting or checking of trap operation are discussed in the following sections.

Visual Test

A test which allows visual inspection of a steam trap's operation is considered to be the best approach. The method must be used with the knowledge that it is not infallible and its reliability varies among the various types of traps. This procedure requires that a test valve be installed in the condensate return line just beyond the trap. A typical set-up has been sketched in Figure 18. The inspection of trap operation requires that the valve in the condensate return line be closed and the test valve then be opened. Observation of what comes out of the test valve offers excellent insight into the operation of the trap. The possibilities are discussed below:

1. Nothing comes out of the test valve may mean that the trap may have failed in the closed position. However, this condition may also be indicative of such system or other problems as:
 - There may be a vacuum in the system heat exchange unit preventing drainage of the unit.
 - There may be a leaky by-pass valve behind the trap.
 - A dirty trap, or dirty line and only cleaning of the strainer and trap may be needed.
 - The pressure may be too high for the trap due to incorrect sizing, worn trap, malfunctioning reducing valve or vacuum in return line.

- Air vent may not be working properly.
 - The trap may be installed backwards if it is a thermodynamic disc trap.
2. Continuous discharge from the trap is not necessarily an indication of a problem. For example, float and thermostatic traps and orifice plates may continuously discharge condensate which can flash into steam when released to the atmosphere. It is very important to have a trained and skilled observer who can distinguish between superheated steam leaking through a failed trap and flash steam that is saturated steam which is formed when hot condensate is released to the atmosphere.

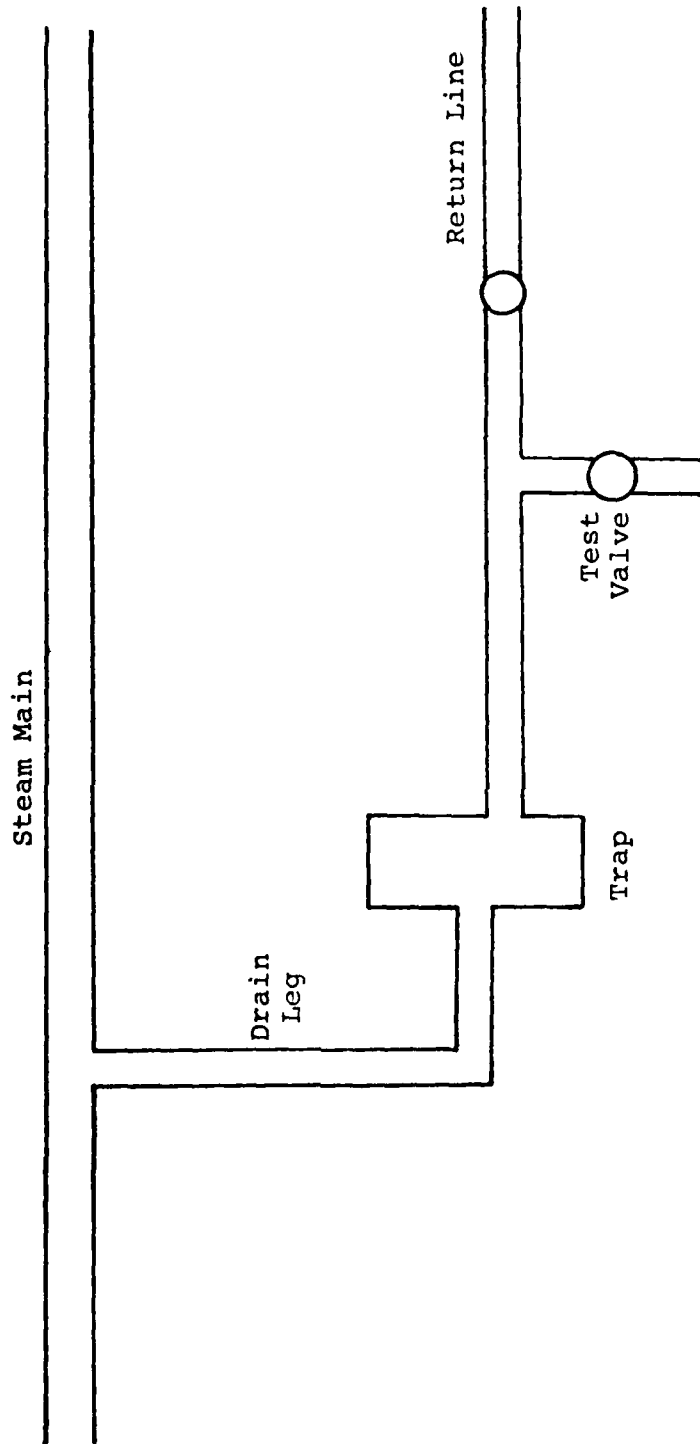


Figure 18 - Steam Trap Test Valve Hookup

Continuous discharge from other types of traps is usually indicative of a problem which might be a trap failed open. However, other possible problems include:

- The trap is too small.
 - There may be excessive water in the steam lines.
3. The trap is functioning properly if discharge from the trap is intermittent with no appreciable water or steam visible between discharges. This is not true of orifice plates which usually discharge continuously. It may not be true of float and thermostatic traps.

You may have indications of trap problems even after observing a good test on a trap. Remember, no single in-service test is foolproof. Additional tests may be needed. But, before making more tests consider the following:

- The trap may be a little undersized for the application.
- Other failed traps may be passing steam creating back pressure or overloading the condensate return line.
- The condensate return line may be too small.
- The vent in the condensate tank may not be working.

Audible Test

All tests which have been referenced for trap inspection have their detractors as well as their proponents. A test which permits one to "hear" the trap operating seemed to be the second most popular. An audible test may involve simply a listening stick placed on the trap. Other variations range from stethoscopes up through ultrasonic equipment.

The principle of audible inspection is based upon the observation that each type of trap has a characteristic sound and sequence when operating properly. Conversely, there is a different sound or no sound when the trap has failed. It should be stressed again that the sound of a malfunctioning trap is only a symptom of a problem in the steam system. The

trap may be capable of functioning properly and the real problem may be elsewhere or may be an improper type or poorly sized trap.

It is difficult to describe sound beyond the usual, "it sounds like a ----", approach. Descriptions of trap sounds are taken directly from the literature and manufacturers' brochures. These descriptions are applicable when the inspector is listening to a trap with a stethoscope or a rod held firmly against the trap.

Bucket traps - A properly operating bucket trap will make a cycling sound as it opens and closes. The frequency or repetitiveness of the sound was not described. A failed bucket trap (they seem to always fail open) has been described as making a whistling sound or a "whooshing" sound. Note that we have elected not to footnote references to the adjectives describing the sounds.

Thermostatic Traps - References to the sound of thermostatic traps proved to contain direct contradictions. The descriptions are repeated below, again without references, because of the contradictions.

A properly operating thermostatic trap may make no sound; or the sound of periodic discharge may be heard; or continuous but fluctuating velocity sounds may be heard. A thermostatic trap failed closed will make no sound. A thermostatic trap failed open will make a whistling sound.

Thermodynamic Traps (Disc and Piston) - A properly operating trap will make a clicking sound or snapping sound as it opens and closes several times per minute. A failed trap (they fail open) will make a rapid chattering sound.

Orifice Plate - No reference was found for the audible inspection of orifice plates.

Perhaps the major drawback to audible tests is that sound may be transmitted for great distances along the piping of steam lines. Thus, the sound one hears emanating from a trap may be coming from a nearby trap while the trap being inspected has failed closed and is making no sound of its own. Another example of false interpretation could be a chattering sound indicating failure of a thermodynamic disc

trap when one is really hearing the superimposed clicking of several properly operating disc traps.

Audible testing as described here seems to be poorly regarded by many. The benefits of audible testing are speed and low cost. However, this sort of testing may have reliability only when performed by a skilled and experienced technician who has had a lengthy association with a specific steam system.

A more modern approach to audible testing of steam traps is the application of ultrasonics. The advantage claimed here is that frequencies greater than 35,000 Hz are quickly attenuated so that extraneous sounds do not travel far.⁽¹⁾ Thus, the discharge from only one trap may be heard by an inspector equipped with earphones or by properly affixing a loudspeaker. Experience in using ultrasonic testers is required because each type of trap has a different response.

Only one source describing ultrasonic trap sounds was found and this source is quoted directly.⁽²⁾ "Thermostatic traps, when properly sized for the load, will discharge intermittently. Therefore, if the trap is operating properly, a loud hissing sound will be heard during discharge; no sound will be heard when the trap is closed. If hissing continues after closing, the trap is leaking. Hissing does not necessarily mean that the trap is losing steam. If the condensate load is greater than the amount of leakage, steam will not be lost. However, if the condensate load is less than the leakage, the hissing will continue for a prolonged period and the trap will cycle only when the condensate load exceeds the leakage, allowing subcooling of the condensate. If the trap continues to cycle regularly, it is probably functioning properly."

(1) Hilmer, M.; Techniques for Testing Steam Trap Operation; Plant Engineering, 147-150; March 17, 1977.

(2) Ibid.

"Some thermostatic traps tend to throttle under certain load conditions. When these conditions exist, the test instrument will emit a continuous hissing. When this occurs, the trap can be tested only by reducing the load. Under light-load conditions, even these traps cycle rhythmically."

"Bucket traps operate intermittently. The tester will easily learn to distinguish between normal and malfunctioning operation. When the trap is working properly, a hissing noise will be heard during discharge, and, when the trap closes, the sound stops. Continuous hissing indicates that the trap is blowing, which may result from a loss of prime under light loads, or a malfunction of the trap mechanism."

"Thermo-dynamic trap opening and closing frequently depends on the trap load and the mechanical condition of the trap. If the trap cycles fewer than 10 times per minute, it is operating normally. But, if the trap is worn, its cycling rate will increase significantly; the trap will sound somewhat like a machine gun. If the thermo-dynamic trap discharges continuously, the loading may exceed capacity, or return line pressure may be too high. The return line pressure and the pressure upstream of the trap should be checked."

"Impulse traps have a piston in a conical cylinder and are intermittent in operation. A bleed hole is drilled through the piston, allowing flow from inlet to outlet even when the trap is closed. Therefore, with the trap closed, a hissing sound will be heard. But the trap is not necessarily wasting steam. If it is properly sized, it will still operate intermittently. A loud roar when the trap is in the full discharge position will be followed by a much lower noise level. If a loud noise is heard continuously, the trap is either overloaded or is stuck in the open position and should be repaired."

"Float-thermostatic traps have a tendency to discharge continuously, particularly at low or moderate pressures, and modulate according to the load ahead of the trap. Under these conditions, ultrasonic testers are of no value. However, when float-thermostatic traps are used at high pressures, they tend to discharge intermittently, and, if the tester indicates a rhythmic intermittent discharge, the trap is working properly."

Temperature Test

Measuring the temperature of the condensate return pipe beyond the trap was once touted as a reliable means for checking steam trap operation. Another temperature check regimen was to measure the temperature difference between the pipe entering and the pipe leaving the steam control device. Today, condensate pipe temperature is deemed as a reliable indicator of trap operation ONLY if the trap has failed closed. In this case, the trap and adjacent downstream pipe will be very close to ambient temperature.

The reader is cautioned to make temperature measurements with a surface pyrometer. Sensing pipe temperature by grasping it with a bare hand will cause more serious burns than it will disclose malfunctioning traps.

There remain some sources who recommend using temperature tests as a method for judging the conditions of a steam trap. The following comments on the use of downstream pipe temperature as an indicator of steam trap condtemperatureion illustrate why it was judged to be the least suitable test.

- If the line is at ambient temperature, the trap has failed closed. (Note also that if a trap makes no sound it has failed closed.)
- If the line is warm or hot you have no idea of the condition of the trap because the temperature may have been influenced by other traps discharging into the same condensate return line.
- If the line is warm or hot, it could also be due to the trap failing open or merely passing a lot of condensate at steam temperature.

It was claimed that measurement of surface temperature and steam pressure at the trap will give good information on trap operation.⁽¹⁾ Readers who are equipped to make both measurements are referred to the footnote for further information.

The use of infra-red thermography has recently been suggested as offering potential for judging the condition of steam traps.

(1) Webb, T.; Steam Trapping; Energy Research, I; 179-185; (1977).

Several manufacturers have published good guides on trap inspection procedures and the interpretation of symptoms detected during inspection. The reader is referred to the following documents which should be available from trap manufacturers' representatives. The information provided in these will be a useful supplement to and expansion of the condensed presentation in this report.

H.O. Trerice Company; Trerice Sales Manual, Sales Letter J-18; pp. 1 and 2.

Armstrong Machine Works; Steam Conservation Guidelines for Condensate Drainage; pp. 39, 40.

Yarway Industrial Steam Trapping Course.

Inspection Frequency

Suggestions for inspection frequency vary widely depending on line pressure, condensate load, type of trap and source of the suggestion. It is recommended that each trap be inspected by a contracted maintenance firm once each four months. Circumstances and experience will guide each Facilities Engineer to modifications of this interval. One year should be the absolute maximum interval between inspection and a six month interval may prove to be right for many typical Army steam trap applications.

Maintenance

The follow-up to inspection of steam traps is maintenance of suspected faulty traps. Remember that the symptoms of a failed trap may only indicate that you have the wrong trap for the job or that something else is wrong within the steam system. When you are certain that the trap requires attention, you have no choice but to replace the trap. Some types of modern traps are designed to permit in-service replacement of working parts. These types of traps should reduce downtime and cost. The suspect trap or trap assembly may be bench-tested for a certain assessment of its operation. Good traps mistakenly removed and reconditioned traps may then be placed in supply inventory for future use as needed.

Bench testing of traps and trap components is beyond the scope of this report. Steam trap manufacturers should be

able to supply information for building a line for the shop testing of traps. One manufacturer sponsored a technical article depicting the detailed design of an inexpensive test stand.(1)

Forced trap replacement offers an opportunity to review the two critical questions, "Is this the right type of trap?" and "Is this the proper size of trap?" Conditions within the steam system may have changed thereby influencing the condensate load on this trap. Frequent failures at one trap station could be a sign that one should change the trap type and/or size. Trap selection is discussed on pages 50 and 51.

ENERGY ANALYSIS

Selecting the proper type of trap following the recommendations given on pages 48 to 50 is the first step in energy conservation related to steam trap operation. The next step is to select the proper size of trap relying on manufacturers' literature and the assistance of manufacturers' representatives. All traps of proper size and type should not pass live steam when they are operating properly. Orifice plates, on the other hand, will pass a little live steam continuously.

An energy analysis is limited to assessing the energy lost when a steam trap fails open or develops a leak. The steam trap literature has approached this by assessing the energy lost as function of the size of leak or trap orifice and steam pressure. Table 2 shows the type of data usually displayed in articles and manufacturers' literature.

(1) Hilmer, M.; Techniques for Testing Steam Trap Operation; Plant Engineering, 147-150; March 17, 1977.

TABLE 2
STEAM LOSSES AT VARIOUS OPENINGS (1) (2)

Size of Orifice Opening or Effective Leak Diameter, In.	Steam Pressure, psig				
	5	25	50	100	150
	Steam Lost, Pounds Per Hour				
0.03	<1	1	2	3	5
0.06	2	5	7	16	19
0.12	8	18	30	53	76
0.25	32	73	119	211	303
0.50	126	292	476	844	1212

(1) Sisson, W.; Power Engineering; p. 55, September 1975.

(2) Yates, W.; Hydrocarbon Processing; 267, March 1975.

One thousand pounds of steam is very nearly equal to one million BTU. Assume an oil fired boiler efficiency of 75 percent and Table 2 may be reconstructed to reflect the annual energy loss as shown in Table 3.

TABLE 3
APPROXIMATE ANNUAL ENERGY LOSSES DUE TO
STEAM LEAKS AT VARIOUS PRESSURES

Size of Orifice or Effective Leak Diameter, In.	----- Steam Pressure, psig -----				
	5	25	50	100	150
	----- Energy Lost, MMBTU Per Year -----				
0.03	3	15	25	345	60
0.06	25	60	80	185	225
0.12	95	210	345	620	885
0.25	375	850	1390	2465	3540
0.50	1470	3410	5560	9560	14160

ECONOMIC ANALYSIS

Selection and analysis of steam trap operation does not lend itself to life-cycle cost analysis for the following reasons:

- . A steam trap is but a small part of a large steam system.
- . Maintenance costs for any given type of trap have not been published and would be quite variable depending on the type of service.
- . The service lives of the various traps will be highly variable according to the type of service. A qualitative estimate of the relative service life of the various types of traps has been given in Table 1.

The economic considerations affecting trap inspection and repair or replacement are, however, quite simple and compelling. Traps which fail "closed" will quickly influence one or more upstream heat exchangers: i.e., heaters do not heat; sterilizers do not sterilize; cookers do not cook; etc. Such malfunctions will likely be quickly noted and trap replacement becomes a necessity to restore proper operation of needed facilities. The only economic consideration here is to select the cheapest trap of the type recommended on page 50-51 and the size calculated according to the trap manufacturers' recommendations.

Traps which leak or fail "open" will pass live steam to the condensate return line. This live steam is expensive. Table 4 displays the annual cost of "lost steam" for oil fired boilers, 75 percent efficient, based on a cost of \$4.17 per MMBTU for No. 2 heating oil in DoE Region 1.

TABLE 4

APPROXIMATE ANNUAL COST OF STEAM LEAKS

Size of Orifice or Effective Leak Diameter, In.	----- Steam Pressure, psig -----				
	5	25	50	100	150
	----- Annual Cost of Lost Steam, \$ -----				
0.03	13	63	104	146	250
0.06	104	250	334	771	938
0.12	396	876	1439	2585	3690
0.25	1564	3544	5796	10279	14762
0.50	6130	14220	23185	39865	59047

Trap prices are low compared to the annual cost of lost steam. For example, an inverted bucket with a 1/2 inch orifice for 100 psig service might cost as little as \$35 or up to \$300 depending to a large extent on the construction materials. A 1/2 inch disc trap sells for \$50 to \$75. Replacement assemblies for these traps might cost from \$10 to \$20. Cost analysis seems to be quite insignificant when one considers that a failed open, 1/2 inch orifice on 100 psig service can cost just over \$50,000 annually. Another example might be a 1/2 inch heater trap on 5 psig service. A small leak of equivalent 1/16 inch diameter could waste about \$100 per year yet the cost of a new trap would be less than \$25.

The economics of steam trap inspection and maintenance are compelling. The discounted payback periods for prompt attention to failed traps would be measured in weeks rather than years. It is for this reason that it is recommended that all Army facilities engage the services of a local industrial maintenance service for regular inspection of steam traps.

CONCLUSIONS

Condensate control devices (steam traps) are essential to the efficient and economical operation of steam distribution systems.

Regularly scheduled inspection programs are essential to survey steam trap operation and appurtenant devices such as in-line strainers and dirt pockets.

Steam traps which leak or fail open can annually waste steam whose value is many times that of a new trap or trap repair kit.

Army Facilities Engineers do not have sufficient manpower to conduct an effective steam trap inspection program.

Selection of the proper type and correct size of trap for each different application will produce the most energy efficient operation of steam distribution systems.

Orifice plates appear to offer little potential for effective application in low and moderate pressure steam systems whose load may fluctuate more than 25 percent from design conditions.

Strainers which are installed to protect orifice plates from plugging must be inspected and cleaned or replaced according to a regular schedule.

RECOMMENDATIONS

It is recommended that Army Facilities Engineers engage the services of commercial or industrial maintenance companies to conduct a regular inspection of all steam trap stations. The inspection reports should identify all steam trap stations which may require maintenance.

It is recommended that the size and type of each trap be reviewed whenever a trap requires replacement.

Select steam trap size according to manufacturers recommendations.

Select steam trap type from the following list.

<u>Type of Service</u>	<u>Freezing Conditions</u>	<u>Type of Steam Trap</u>	
		<u>1st choice</u>	<u>Alt. Choice</u>
Steam distribution drains, normal condensate load	yes .	thermodynamic disc	insulated inverted bucket
	No	thermodynamic disc	float and thermostatic inverted bucket
Steam distribution drains, heavy condensate load or frequent start up	yes	thermodynamic disc	--
	no	float and thermostatic	thermodynamic disc
Heating and absorption units	yes	insulated inverted bucket	consult manufacturers reps as no clear-cut choices of general types exist
	no	float and thermostatic	

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APPENDIX

Glossary

Adiabatic Expansion

See Throttling.

Blow Down

Discharge a portion of boiler water to reduce solids content or remove sludge.

Drip

See DRAIN.

Drain

A smaller pipe leading from a larger steam pipe positioned so that condensed water in the steam line will flow through the drain pipe usually to a steam trap or orifice. The "DRAIN" may also contain steam and air.

Entropy

This often maligned term is seldom referenced in low (± 250 lb) pressure steam systems, so we will ignore it.

Enthalpy

The heat that was put into something to raise its temperature from 32°F to where it is now. Conventional unit is BTU/lb. Note that if something changed from liquid to vapor in getting from 32°F to where it is now you add the heat required to convert it to vapor.

Latent Heat

Heat applied to a substance to change its state from solid to liquid or liquid to vapor.

Live Steam

Steam which has not done the work for which it had been produced.

Saturated Steam

Steam at the temperature at which it was formed (at the same pressure).

Sensible Heat

Heat that changes the temperature of a substance without affecting its gaseous, liquid or solid state.

Super Heated Steam

Steam whose temperature is higher than that at which it was formed (at the same pressure).

Throttling

Expansion of steam without any change in heat content of the steam.

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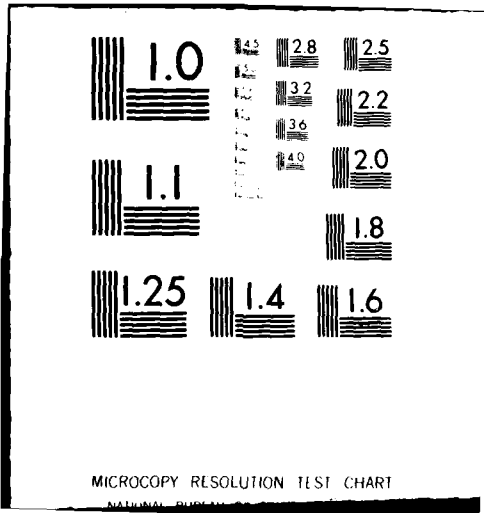
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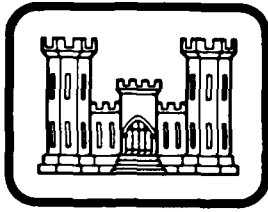
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PERFORMANCE EVALUATION OF STEAM TRAPS AND ORIFICE PLATES

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Steam traps and orifice plates have been examined to assess their utility as condensate control devices in typical Army steam systems. Specific types of devices have been recommended for the various major user in Army facilities. Selection of the size of each device should be made in accordance with manufacturers recommendations. Inspection and maintenance of steam devices is critical to their proper operation and to energy conservation. → cont. (over)			

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20. Industrial maintenance firms may perform this function in cases where there are insufficient Facilities Engineering personnel to provide periodic inspections.

SUMMARY

A steam trap is somewhat like an automatic valve which is designed to bar the passage of steam while permitting the passage of water and air. Steam traps in most applications are located in condensate return lines from process or heating equipment and are often referred to as drips or drains. Thus, the traps are intended to keep steam in the steam pipes or a steam heated device. In so doing, a trap will pass the steam which has condensed to water, air, CO₂, and non-condensibles out of the steam distribution system. This permits condensate to flow back to the steam generating point where it is once more heated to make steam, unless impurities which might harm the boiler are present.

A steam trap is but one small part of a large system. There are really only three fundamentals to consider when attempting to view a trap independent of the system.

- . Properly sized traps of the correct type and working properly will provide the best energy economy.
- . Traps which are failed closed will back up condensed water into the nearest heat exchange device and cause it to cool down.
- . Traps which have failed open will pass steam and waste significant amounts of energy.

It is apparent from the above that the following steps will insure the best economy and reliability in steam trap operation:

- . Select the proper type of trap for the operating conditions existing now.
- . Inspect each trap on a regular basis to insure that it is operating properly.

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Immediately repair or replace any trap suspected of malfunction.

Steam traps should almost always be protected from dirt and scale by the installation of in-line strainers or use traps with integral strainers. Dirt pockets should be considered when especially dirty conditions exist. Strainers and dirt pockets require regular inspection and cleaning.

One key to energy efficient operation of steam systems is the regular inspection and timely maintenance of steam trap stations. Such regular inspection has become an impossibility because of reduced manpower head-count in all Facilities Engineers' staffs. The result, while not audited, is that there must be a large loss of steam energy. This conclusion was based on analagous studies in the chemical process industry. It could be postulated that some relief might be achieved by a wider use of low-maintenance disc traps or very low maintenance orifice plates. However, both of these low maintenance devices should be protected from dirt and scale by in-line strainers. And, the strainers must be inspected and cleaned at least as often as a trap should be inspected. Thus, traps having low maintenance requirements should have little impact on the man-hour requirements of an effective steam trap inspection program. The applicability of this circumstance might be measured by the installation of a few orifice plates in selected services where historical records would permit judging the utility of these simple devices.

It is recommended that the Facilities Engineer at each Army post secure the services of a local or national industrial maintenance firm to carry out a regular inspection program of all steam trap stations. This recommendation appears to offer a significant potential for reducing energy use. This potential might not otherwise be realized because of insufficient manpower on current Facilities Engineers' staffs.

PREFACE

Mr. T. G. Gressett, Senior Staff Engineer on the Corporate Engineering staff of Johns-Manville Corporation provided valuable inputs and guidance based on his 30 years experience with high and low pressure steam systems.

Mr. T. H. Sadler, a Senior Research Engineer on the Pipe Technology staff of the Johns-Manville Research and Development Center provided valuable assistance in the review of the technical literature and steam trap manufacturers' catalogs.

The following Facilities Engineering personnel were interviewed to obtain an overview of some steam systems employed by the Army.

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L. May - Fort Campbell
M. Todd - Fort Bragg
W. Kaiser - Fort Sill

A special acknowledgement is given to the Yarway Corporation for granting permission to reproduce illustrations and text from its very informative publication, "Industrial Steam Trapping Course". Material from this publication has been used extensively in the section of this report describing the various types of steam traps.

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INTRODUCTION

Steam traps are necessary and yet much maligned for their reported undependable performance. Energy conservation programs at any facility where steam is used will eventually focus on the steam traps as a suspected source of both problems and opportunities. The suspicions are well founded because a trap with a leak as small as 1/32-inch can be wasting 50 million Btu per year. A one-half inch trap failed in the open position can be wasting over 3 million Btu per day, and a trap failed in the closed position is denying needed energy to a building, autoclave, washer or other equipment.

The function or purpose of a steam trap is to separate usable steam from water condensed out of the steam, air and any other non-condensable gases. The usable steam is then most frequently piped on to subsequent heat exchangers while the condensed water may be returned via pipes to the steam boiler. This is a rather simple process and the design and function of many types of steam traps is also quite simple.

The purpose of this report was to conduct both literature and market surveys to determine current state-of-the-art devices for use in steam systems to retain steam while releasing non-condensibles and condensate. An analysis and evaluation of the information was to be made of the various types of devices to include the following information.

- Identify the types of devices.
- Evaluate available data and test reports for overall performance, efficiency, costs, operating characteristics, steam loss, required maintenance, safety and code compliance.
- Include potential energy savings and cost effectiveness of the devices as well as a life-cycle cost comparison.

Generalized references in some of the literature suggest the first device used to separate condensate from steam may have been a "do-it-yourself" groove filed in the seat of a globe valve. This may then have been the predecessor of the drain orifice which appears to be the first manufactured device designed to pass condensate while holding back most of the steam. The deficiencies of this device have been reported to include an inability to handle large fluctuations in load and an inherent operating characteristic of always passing some steam. Undoubtedly design sophistication was lacking in the early days which meant that the aperture in drain orifices may not have been properly sized thus adding to the operating woes alluded to on occasion. The inability to handle large load fluctuations made the drain orifice rather useless during system start-ups as the small opening was unable to accommodate the large volumes of condensed water in a reasonable length of time. It was also reported that drain orifices frequently plugged with scale or other foreign particles. This fact may have accelerated the development of a device called a strainer. This is a filter device placed in the drain line, upstream of an orifice, or trap, designed to remove solid particles from the condensed water.

The first mechanically functioning steam trap was called a bucket trap and it was followed by a succession of steam trapping devices referred to by a myriad of names but all operating on one or a combination of three basic principles.

- Devices which are operated by the changing level of water within the device.
- Devices which are operated by the differences in temperature between steam and water condensed from the steam.
- Devices which are operated by the differences in thermodynamic properties of water and steam.

The principles of operation of the various types of traps are discussed in the section titled, Types of Steam Traps.

The technical literature and discussions with steam specialists indicate that there have been no new developments in steam trapping hardware or technology in over twenty-five years. Steam trap manufacturers may disagree with this conclusion. However, a review of technical sales literature tends to confirm the conclusion. New developments in steam trap hardware appear to be improvements and refinements aimed at:

- improving reliability
- increasing maintenance interval
- reducing maintenance cost

This report has been limited to a study of steam traps in accordance with the task order. It is critical to be aware that a steam trap is but a very small part of the steam system. Engineering and energy analyses must view the entire system. Even consideration of the operation of one individual trap should take into account its interface with appurtenant devices such as essential dirt pockets, strainers and blow down valves.

Much of the technical literature and sales brochures contained words and expressions which might be termed as "jargon" of the steam business. Also, different types of engineering disciplines seemed to have a tendency to talk about steam systems in somewhat different terms ranging from the thermodynamic outlook of chemical engineers to the nuts and bolts approach of stationary engineers. An effort has been made to minimize the use of special words and phrases in this report. A glossary of terms has been included in the Appendix in the hopes that it may be of some assistance to those who wish to pursue additional reading on this topic.

This report also contains the Market Survey, Literature Survey, Functions of Steam Traps, Types of Steam Traps, Selection of Steam Traps, Maintenance of Steam Traps, Energy Analysis, Economic Analysis, Conclusions, and Recommendations.

MARKET SURVEY

Method

The market survey was intended to identify manufacturers of appropriate steam/condensate separation devices; seek out the operating characteristics and benefits of each device; secure comparative testing results of various devices; and identify maintenance procedures and potential energy savings. The following actions were taken to achieve the objectives of the survey:

- letter to manufacturers
- interviews with engineers who specialize in steam system design for the Johns-Manville Corporation
- interviews with manufacturers' representatives
- telephone interviews with Facilities Engineering, Chiefs of Utilities
- review of National Building and Mechanical Codes, National Fire Code, ASHRAE Standards and ASME Code

Survey of Manufacturers

The letter sent to steam trap manufacturers is reproduced on the following page:



**Johns-Manville
Sales Corporation**

Research & Development Center

Ken-Caryl Ranch
Denver, Colorado 80217
(303) 979-1000

October 26, 1979

Dear Sir:

Johns-Manville Research and Development Center has been contracted to provide basic information on steam traps and orifice plates. Would you please send me your catalogs, sales and technical literature relating to proper selection, installation and maintenance of steam traps. Price lists would also be helpful as would illustrations of the various types of traps which would be suitable for inclusion in our final report.

Thank you for your help.

Yours truly,

P. B. Shepherd

The source of manufacturers solicited was the Thomas Register⁽¹⁾ and all firms listed under the following categories were solicited:

- steam traps
- radiator traps
- steam return traps
- thermodynamic traps
- thermostatic traps

Approximately 100 inquiries were mailed and 27 responses were received. This was an excellent response to a survey of this nature. The quality of information supplied by many manufacturers was also excellent. No testing data were provided by any manufacturer. The firms which responded to the letter are listed on pages 10 through 15.

American Air Filter Company, Inc.
215 Central Avenue
Louisville, Kentucky 40277

- thermostatic traps
- float and thermostatic traps
- inverted bucket traps

Armstrong Machine Works
816 Maple Street
Three Rivers, Michigan 49093

- inverted bucket traps
- float and thermostatic traps
- thermodynamic traps
- thermostatic traps

Barnes and Jones, Inc..
34 Crafts Street
Newtonville, Massachusetts 02160

- thermostatic traps
- float and thermostatic traps

(1) Thomas Register of American Manufacturers; Thomas Publishing Company; N.Y. (1979).

Clark Reliance
15901 Industrial Parkway
Cleveland, Ohio 44135

thermodynamic traps
float traps
inverted bucket traps
thermostatic traps
float and thermostatic traps

Dunham-Bush, Inc.
175 South Street
West Hartford, Connecticut

inverted bucket traps
thermostatic traps
float and thermostatic traps
float traps

Erwel, Inc.
412 Main St.
Ridgefield, Connecticut 06877

thermostatic traps
inverted bucket traps
thermodynamic traps
float and thermostatic traps
float traps

Flexitallic Gasket Company, Inc.
P. O. Box 680
Camden, New Jersey 08101

orifice

Gestra, Inc.
215 Union Street
Hackensack, New Jersey 07601

float traps
thermodynamic traps
thermostatic traps

float and thermostatic traps

Hoffman Specialty
1700 West Tenth Street
Indianapolis, Indiana 46222

thermostatic traps
float and thermostatic traps
inverted bucket traps
thermodynamic traps

Hubbell Corp.
Mundelein, Illinois

no traps

The Johnson Corp.
Three Rivers, Michigan

no traps

Kaye and MacDonald, Inc.
11-15 Central Avenue
West Orange, New Jersey 07052

float traps
inverted bucket traps

Lawler ITT
Indianapolis, Indiana

no traps

- Marpac
1900 Dempster St.
Evanston, Illinois 60204

orifice unions

New Jersey Meter Co.
89 Terminal Ave.
Clark, New Jersey 07066

thermodynamic traps

Nicholson
12 Oregon St.
Wilkes-Barre, Pennsylvania 18702

thermostatic traps
float traps
float and thermostatic traps
thermodynamic traps

Richmond Foundry and Manufacturing Co.
P. O. Box 5247
Richmond, Virginia 23220

NOT steam traps - plumbing traps only

RP&C Valve
8150 West Ridge Road
Fairview, Pennsylvania 16415

float and thermostatic traps
thermodynamic traps
inverted bucket traps
float traps

Sarco
1951 26th St.
Allentown, Pennsylvania 18105

thermostatic traps
float and thermostatic traps
inverted bucket traps
thermodynamic traps
float traps

Selic and Bird, Inc.
P. O. Box 108
Sea Girt, N. J. 08750

thermostatic traps

Southern Fluid Control Corp.
4491 North East 6th Terrace
Fort Lauderdale, Florida 33334

thermodynamic traps
inverted bucket traps

Star Steam Specialties
1 Yale Avenue
P. O. Box 151
Clayton, Delaware 19703

inverted and open bucket traps
thermodynamic traps
float traps
float and thermostatic traps

Trerice Co.
12950 W. Eight Mile Rd.
Detroit, Mich. 48237

bucket traps

Velan Engineering & Valve
Beekmantown Road
Plattsburgh, N. Y. 12901

thermostatic traps
float traps
bucket traps
thermodynamic traps
inverted bucket traps

Watson-McDaniel

thermodynamic traps

Wright-Austin Company
3245 Wright St.
Detroit, Michigan 48207

float traps
float and thermostatic traps

Yarway Corporation
Blue Bell, Pennsylvania 19422

thermostatic traps
thermodynamic traps
bucket traps
inverted bucket traps
float traps
float and thermostatic traps
orifice traps

Several respondents followed up their mail reply with calls and visits from local and factory representatives. A few provided excellent text-book-style literature on steam traps. One, Yarway Corporation, graciously granted permission to reproduce text and illustrations in this report. These excerpts are properly noted where they appear.

There was general agreement among manufacturers concerning the following subjects:

- steam system principles and operation
- selection of trap types and sizes for specified service conditions
- maintenance and inspection procedures.

Many manufacturers offer several types of traps and thus appeared to offer objective and sound engineering bases for selecting the best type and size trap for various service conditions. The exception to this

observation was with regard to orifices for condensate removal from drain lines. Only four manufacturers offered this device and two of those offered only this device.

Manufacturers' Guarantees

Five manufacturers of steam traps referenced guarantees in their literature. It is possible that others may also offer guarantees and it might be wise to request a copy of such a guarantee when a trap is purchased. Following is a brief condensation of the guarantees found in this study. Note that there is a rather wide disparity of terms.

Armstrong -

One year guarantee limited to repair or replacement of parts with no allowance for labor or refund of purchase price.

Erwel -

Two year guarantee requires that the purchaser return the trap to the factory for repair or replacement.

Nicholson -

One year guarantee requires that the purchaser return the trap to the factory for repair or replacement.

Velan -

Guaranteed for three years to function properly and give satisfaction. (No terms disclosed)

Yarway -

Warranted for three years for performance and service.

Interviews With Army Facilities Engineers

Telephone surveys of several facilities were made. The purpose of these surveys was to identify the nature of various steam systems, experience factors, and inspection and maintenance procedures in use. The excellent cooperation of the Chiefs of Utilities at the following facilities is greatly appreciated:

Fort Carson
Fort Campbell
Fort Rucker
Fort Bragg
Fort Sill

Many similarities were found among the steam services at the various facilities:

1. There is usually at least one large and several major, central steam plants operating "around-the-clock." These generate so-called high pressure steam ranging from about 100 psig up to 170-180 psig.
2. There may be many other, smaller central plants operating around 30-50 psig.
3. There are very many dozens of small, low pressure boilers producing low pressure, 5-30 psig, steam.
4. The principle use for steam is for heating and/or absorption cooling.
5. Separate boilers serve laundries and hospitals.

6. Bucket type steam traps service the bulk of facilities' steam services.
7. Float and thermostatic traps service almost all of the remaining facilities' steam services.
8. Steam trap type and size is set by Corps of Engineers initial design and installation. Trap replacement is invariably of like type and size. This is apparently, but not confirmed, true even in cases where the steam service load may have changed sufficiently over the years to suggest consideration of a different size and/or type of trap.

Another similarity among the facilities is that they do not have sufficient, trained personnel to carry out a planned and systematic program of steam trap inspection and maintenance. Trap inspection frequencies were reported to vary between "once-a-year" and "whenever someone complains about the heat." This situation is understandable based on the reported present actual levels of staffing. However, it is indicative of a major opportunity for cost saving and energy use reduction. About the most "sophisticated" trap inspection schedule found was a monitoring of changes in condensate return temperature and makeup water requirements as symptoms of malfunctioning traps.

Code and Standards Compliance

The major mechanical codes do not have any requirements relating specifically to steam traps. The ASME code applies to high pressure (over 15 psig) steam systems. It also has no requirements referencing steam traps. Underwriters' Laboratories do not have a label nor a listing service for steam traps.

There are apparently no public standards, codes nor accrediting laboratories to govern the selection and installation of steam traps. It might also be said that there exists nothing in these areas to guide a purchaser

in the wise selection and installation of traps. Only ANSI/FCI Standard 69-1-1977 contains a Pressure Rating Standard for Steam Traps. NBS Standard R244-51 relates to low pressure radiator traps and float and thermostatic traps.

LITERATURE SURVEY

The literature survey was conducted by Ms. Suzanne D. A. Graham of the Corporate Information Center staff at the Johns-Manville Research and Development Center. Two computer-based searches of engineering sources were employed:

Compendex, Engineering Index, Inc.

ISMEC Mech. Engr., Data Courier, Inc.

Only 42 references were disclosed whose abstracts suggested that they might be pertinent to the goals of this assignment. Many of these 42 articles, it developed, were written by representatives of steam trap manufacturers. Thus, we were faced with a minimal technical literature reservoir which could objectively be classified as broad based and unbiased. All references together with others disclosed during this study are listed in the BIBLIOGRAPHY.

Engineering handbooks did not provide useful information relating to the selection of steam traps which were not even indexed in the standard handbooks for Chemical, Civil and Mechanical Engineering. The ASHRAE Handbook⁽¹⁾ described many of the devices commonly used and offered some generalized guidelines for trap selection.

FUNCTIONS OF STEAM TRAPS

Steam traps, including fixed and adjustable orifices, are designed with the goal of providing the following functions:

1. The device should hold or retain steam in a

(1) The ASHRAE Handbook; 1976 Systems; 13.18-23.

heat exchanger so that the steam may give up that tremendous amount of heat (latent) available when it changes phase from vapor to liquid. A heat exchanger in this case may be any device relying on heat from condensing steam to fulfill its function. Examples of "heat exchanger" may include such things as:

- . hospital autoclave
- . laundry steam press
- . residential radiator
- . chemical reactor

2. The device should be capable of discharging water condensed from the steam through the device to a pipe which (in most Army facility applications) returns the water to the steam boiler to be reheated into steam. In many applications the device should also be capable of separating air, carbon dioxide, and other non-condensable gases from the steam and discharging these unwanted, even harmful, gases to the atmosphere. Most steam traps are designed to achieve energy conservation by not permitting usable steam to enter the drain line with the water nor be vented to the atmosphere with the air.

A steam trap is, obviously, an integral part of a total steam system. One should not consider the operation of steam traps without relating this operation to the function of the total system. A detailed discussion of steam systems was not one of the facets of this assignment. Therefore, the total steam system will be considered only as its operating characteristics relate to selecting a suitable type and size of steam trap.

The description of the proper function of a steam trap makes it clear that this is an energy conservation device. A steam trap which is operating according to the described functions will help to ensure that the steam system may operate at its maximum efficiency. A steam trap which is not operating properly will

guarantee that energy and money are being wasted. Traps of improper type and/or size also are energy wasters. Fortunately, there are many reputable manufacturers whose catalogs and field representatives provide suitable guidance for selecting traps for any type of steam system.

TYPES OF STEAM TRAPS

There are only three types of steam traps. Or, there are over thirty types of steam traps. It appears that manufacturers' proprietary terminology has created a myriad of different traps when, in fact, all traps operate according to one or a combination of three fundamental principles which are:

- . mechanical
- . thermostatic
- . thermodynamic.

There exist within each type three or four basic variations which are fairly widely used and have a broadly accepted, descriptive name. These are:

- . mechanical
 - bucket trap
 - inverted bucket trap
 - float trap
- . thermostatic
 - bellows
 - bimetallic
 - float and thermostatic (Note - this is the only combination function trap which appears to have universal recognition as a "type" of trap.)
- . thermodynamic
 - disc
 - rod or piston

-orifice plate (Note - The orifice plate may be regarded by some as not a true thermodynamic trap.)

Some firms may describe conventional traps in terms which might lead the reader to believe that the trap could be a new development differing in function from conventional traps. Some firms offer specialty traps of combined functions such as thermostatic and thermodynamic. These may have value in limited applications, but they will not be described here because of their potential limited application. Some manufacturers offer traps which combine traps with built-in strainers or strainers and blow-down valves.

The illustrations of the basic types of steam traps and much of the descriptive material referencing those illustrations have been taken from the "Industrial Steam Trapping Course" provided by the Yarway Corporation. All traps are first and fundamentally a properly sized orifice which is designed to pass condensed water while not passing steam. An orifice plate is an "always open" device which passes the condensate and some steam. All other conventional traps have some means for closing and opening the orifice. Thus, when they are operating according to their design, the orifice will be opened on demand to permit flow of condensate then close to prohibit the loss of steam.

Mechanical Traps

The first category of steam traps is referred to as mechanical traps. These are traps which open or close according to the level of liquid in the body of the trap and, therefore, have also been referenced as liquid - level sensitive.⁽¹⁾

Open Bucket Trap

This trap might also be called the upright bucket trap and is illustrated in Figures 1 & 2. This was a very early type of trap and consists essentially of a bucket or float (A), open at the top, operating within a housing (B). The bucket pivots around a fulcrum (C).

(1) Monroe, E. S. Jr.; Select the Right Steam Trap; Chemical Engineering; 129-134; January 3, 1976.

Attached to the bucket is a valve rod (D) extending upward through a discharge tube (E). At the top of the valve rod is a discharge valve (F) which seats in the orifice (G). In some designs the bucket surrounds the discharge tube and slides up and down along the tube rather than being hinged to a pivot as just described, but the operation is essentially the same.

When condensate comes to this trap, it gradually fills up the body and floats the bucket, causing the latter to rise and close the valve. Finally condensate spills over the top of the bucket and the bucket sinks. This opens the valve and the pressure inside the trap body forces the water up through the discharge tube and out of the orifice.

As soon as the bucket is emptied sufficiently it floats again, closing the valve and the cycle is repeated.

In the earlier models of the open bucket traps, the accumulation of air in the body of the trap often became a problem.

The first method of overcoming this difficulty was the insertion of a hand operated pet cock or valve in the top of the trap body. This had its disadvantages, for it required an operator to go around and bleed the air out of the traps.

Later models were equipped with a thermostatic element, usually of the bellows type, which automatically vents the air from the trap body. As air is cooler than the steam, the element opens to let out the air, but closes on steam.

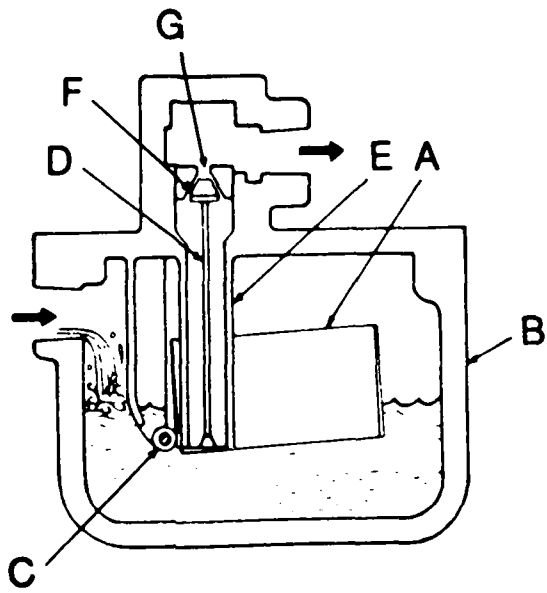


Figure 1. Open bucket trap.

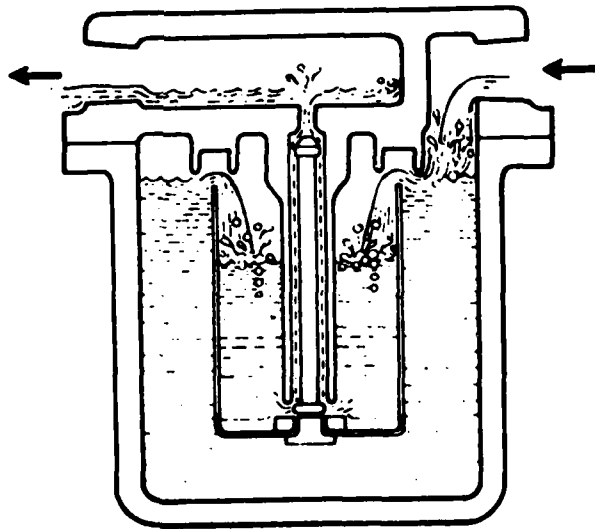


Figure 2. Open bucket trap.

Inverted Bucket Trap

A more recent and more commonly used type of bucket trap is the inverted bucket trap shown in Figures 3 & 4. It is somewhat similar to the open bucket trap, but in this case the bucket (A) is inverted and is open at the bottom.

To the top of the bucket is attached a valve linkage mechanism (B) which permits the discharge valve (C) to open and close as the bucket falls and rises.

When the bucket is at rest, it hangs downward with the valve open.

Condensate enters the trap either from the side as shown in Figure 3 flowing down the passage (D) on the side of the trap and then upward under the open end of the bucket, or if the trap has a bottom inlet, the condensate will enter directly under the bottom of the bucket as shown in Figure 4.

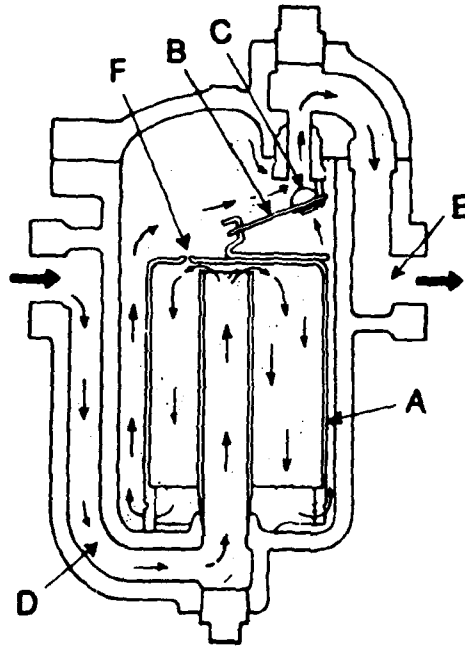


Figure 3. Inverted bucket trap.

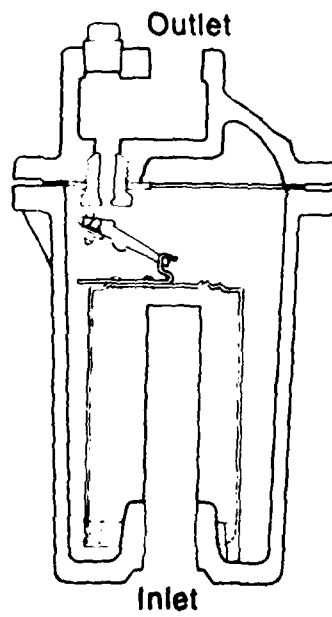


Figure 4. Inverted bucket trap.

In operation, as long as condensate is flowing to the trap, the bucket stays down and flow continues out the orifice and discharge passage (E). Now when steam reaches the trap it fills the bucket which floats and rises to close the valve.

The steam in the bucket slowly condenses and also bleeds off through the small vent (F) in the top of the bucket. Thus, the bucket loses its buoyancy and finally sinks, opening the valve again to discharge more condensate.

While the vent (F) (about 1/16 inch in diameter in a 1/2 inch trap) allows some of the steam in the bucket to bubble up into the body of the trap and condense, another important purpose of the vent is to permit passage of the air and non-condensable gases. If it were not for this vent, the bucket would soon be filled with air which forces the valve to close, and makes the trap inoperative.

Because there is frequently a considerable amount of air to be eliminated from the lines on start-up, it is necessary to get rid of this air promptly in order to obtain quick heat-up of the apparatus.

Flow of air through the vent is limited as it is due only to the buoyancy of the air in the water. Therefore, if large amounts of air must be eliminated, some means must be found to increase the venting capacity.

It is not possible merely to make the vent larger for then so much steam would bleed through that there would be a serious steam loss every time the valve opened.

If enlarged beyond a certain point, the vent would then allow steam to bleed through so rapidly the bucket would never rise to close the valve, and this would cause an even greater steam loss.

Some manufacturers of these traps therefore provide, as a substitute for the regular type, a bucket with a second or auxiliary air vent (G in Figure 5) for handling large volumes of air and gas. This auxiliary

vent is much larger than the regular vent and is provided with a disc valve controlled by a thermostatic bimetallic strip (H).

When the trap is cold, the bimetallic strip bends downward opening the auxiliary vent valve wide. This provides quicker air elimination during the start-up period.

As warmer condensate and air enter the bucket, the bimetallic strip gradually bends toward the closed position. This, of course, reduces the capacity of the auxiliary air vent. However, the air is always cooler than the steam, so as long as any air is present the auxiliary vent will be at least partly open. When all air is eliminated and steam fills the bucket the auxiliary vent closes completely leaving only the fixed vent open.

Where this auxiliary vent valve is needed, it is, of course, most important that it be kept in good working order, for if it is not, the trap will either be very sluggish or else it will waste steam.

Inasmuch as the mechanical traps as a class have cast iron bodies (except for the higher ranges of steam pressures where steel is used) that are always at least partially full of water, care must be taken to prevent freezing in outdoor installations in cold weather areas. Should the trap freeze up, not only would there be danger from backing up condensate in the line ahead of the trap, but the trap could be damaged.

When a mechanical trap is properly sized, there usually is not much danger from freezing, but if the trap is oversized it may not discharge frequently enough to prevent the water in the trap body or reservoir from freezing.

Therefore, if the trap is either lightly loaded or subject to severe freezing conditions, it should be well insulated.

Suppose, for example, the trap is draining an outdoor overhead steam line and discharging to an overhead return line and also that the trap is located

near ground level for ease in servicing. In such a case both the incoming condensate line and the discharge line should be insulated together to prevent the latter from freezing. The trap should also be well insulated and provision should be made for draining the trap body on shutdown.

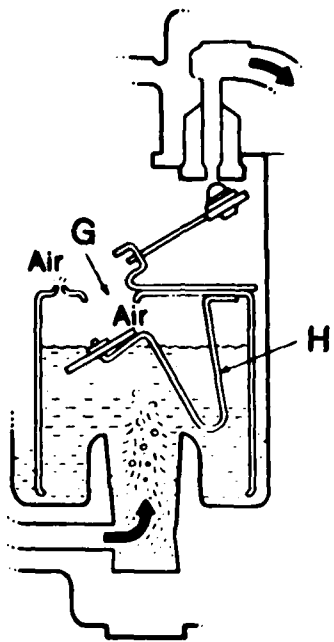


Figure 5. Inverted bucket trap.

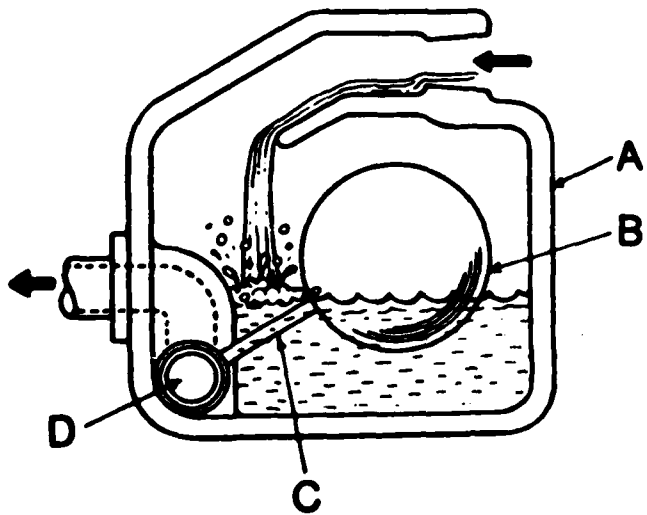


Figure 6. Float trap.

Float Trap

This is one of the earliest types of steam traps. It consists essentially of a closed housing (A), usually cast iron, within which is a ball float as shown in Figure 6.

In the simplest form of this trap, the float (B) is attached to the end of a rod or lever (C). The opposite end of the lever is attached to a discharge valve (D).

When condensate fills the body or housing of the trap, the float rises, gradually opening the discharge valve. Increasing condensate flow raises the float and opens the valve wider, adjusting it to suit the condensate load and maintaining the proper condensate level within the trap body.

The float trap is a good reliable type of trap but, for a given condensate capacity, is considerably larger and heavier than some of the later types of traps.

In recent years the use of this type of trap has been largely confined to relatively light condensate loads on low pressure heating units.

Thermostatic Traps

There are several types of thermostatic traps but all work on the same basic principle -- they respond to temperature changes in the line -- opening to cool condensate -- closing on steam.

Bellows Trap

A commonly used type of thermostatic trap is the heavy duty bellows type in Figure 7. The operating element consists of a corrugated bellows (A) mounted within a housing, usually of cast iron. At the bottom of the bellows is mounted a valve (B) which closes the orifice (C) when the bellows expands.

The bellows may be a simple metal assembly, or it may be filled with a liquid, such as alcohol or water, which has a boiling point below that of water.

The liquid-filled bellows traps are sometimes called balanced thermostatic traps. When condensate approaching steam temperature comes to the trap, the liquid inside the bellows vaporizes building up a pressure inside, which causes the bellows to expand and close the outlet valve.

The valve remains closed until radiation of heat from the body of the trap, and cooling of the condensate within the trap and in the line ahead of the trap, allows the vapor within the bellows to slowly condense. The bellows then contracts opening the valve wide again.

Time required to condense the vapor within the bellows depends on a number of factors, such as the size and material of trap body, length of pipe between trap and the apparatus it is draining, and temperature of the air surrounding the trap. Obviously the cooler the locations, the faster the trap will be able to cycle or respond to temperature changes in the line ahead of it.

As the valve is wide-open when the trap is cool, this type of trap provides quick start-up of equipment and excellent air handling ability.

To obtain the best performance from this type of trap, the bellows is usually designed so that it will close as near steam temperature as possible.

This type of trap is freeze-proof if mounted to drain properly when the system is shut down.

The bellows trap does have some limitations in application, however. As the bellows is fairly sensitive to water hammer, care should be taken to avoid any dips in the line ahead of the trap, or sudden pressure changes which might permit slugs of water to strike and damage the bellows.

Some designs are provided with a baffle surrounding the bellows to cushion the blow from water hammer and minimize the possibility of damage to the bellows element.

In most designs the upper pressure limit for which this type of trap is recommended is 300 psig. Best performance is usually obtained when the trap body is uninsulated and a cooling leg of several feet of uninsulated pipe is provided ahead of the trap.

Recently developed bellows type thermostatic trap designs include modifications intended to make the bellows more resistant to water hammer and overexpansion, as well as to make the trap more responsive to changing load and pressure conditions. These traps are also equipped with a ductile iron body and cover for use at operating pressures up to 600 psig.

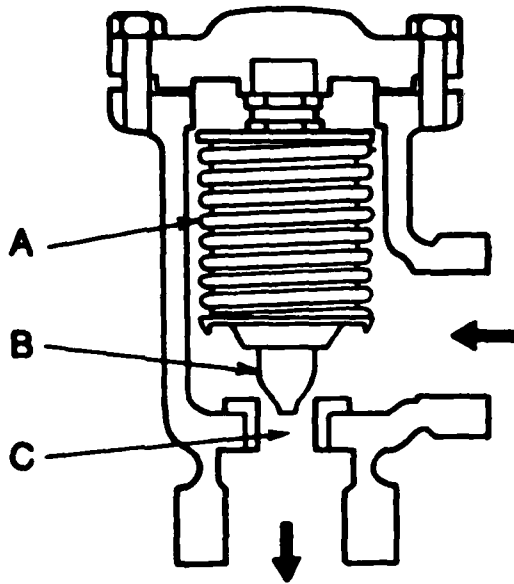


Figure 7. Bellows trap.

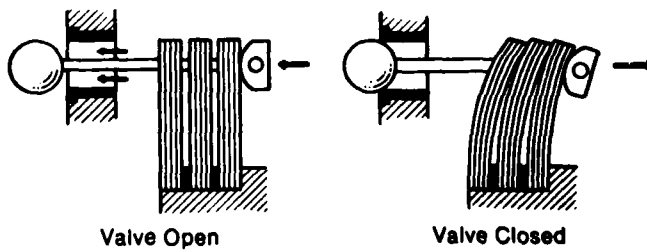


Figure 8. Valve of bimetallic trap.

Bimetallic Traps

Some types of thermostatic traps are operated by the bending of a bimetallic strip as shown in Figure 8. This bimetal element bends back and forth as condensate or steam comes to the trap.

As condensate and air, cooler than the steam, come to the trap, the element bends one way opening the valve. When hot steam arrives, the element bends the opposite way, closing the valve.

The bimetallic element is similar to the element that operates the ordinary household room thermostat except that it is of a heavier construction.

In one form of trap the bimetallic element is made up of a number of laminations in order to increase the force available to open and close the valve.

As the valve in this trap is wide-open when the trap is cold, it provides quick start-up of equipment by eliminating all air and cold condensate. When up to operating temperature range, however, response is more sluggish as time is required for the dissipation and absorption of heat to open and close the trap valve.

Another type of thermostatic trap is operated by the expansion of a liquid in a long enclosed tube which causes the tube to expand and close a valve in the end of the trap housing. A similar type employs the expansion and contraction of a metal rod to open and close the valve.

Float and Thermostatic Traps

This type of trap combines the float mechanism and principle with a thermostatic element. The latter is usually of the bellows-type although bimetallic elements are also used in some makes. See Figure 9.

The addition of the thermostatic element provides much greater air handling ability, particularly at start-up, than possible with the float mechanism alone and the float trap portion provides variable flow according to the condensate load.

The higher the float rises, the wider it opens the discharge valve, so that the trap actually becomes a level controlling device to drain the condensate as fast as it arrives at the trap. Discharge continues right up to steam temperature.

This type of trap is particularly adaptable to the lower range of steam pressures and will continue to operate even at very low pressure differentials. In many designs it is limited to a maximum operating pressure of 125 psig.

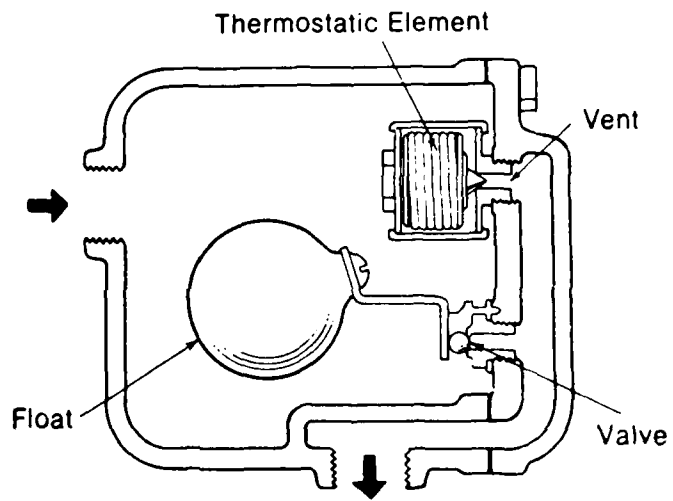


Figure 9. Float and thermostatic trap.

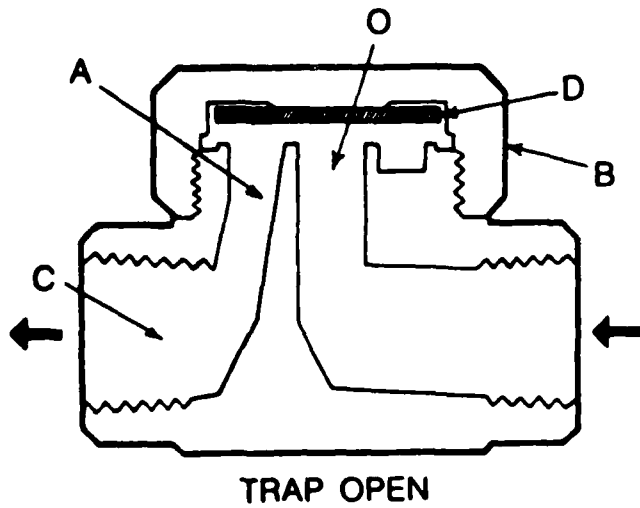


Figure 10. Disc trap.

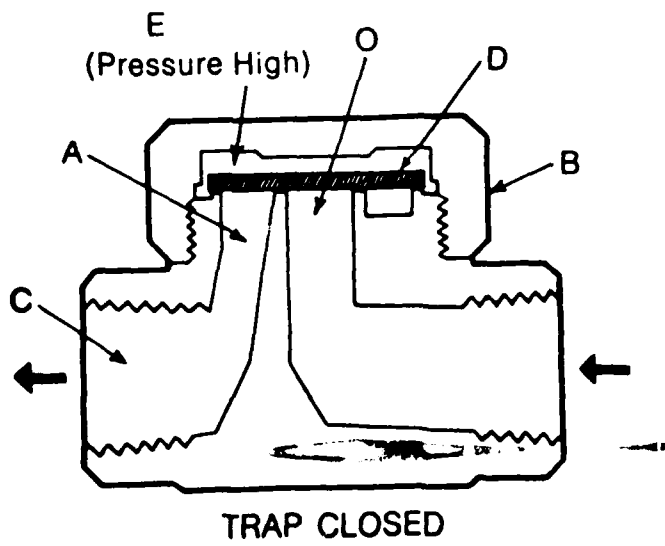


Figure 11. Disc trap.

Thermodynamic Traps

This third class of steam traps utilizes the heat energy in hot condensate and steam to control the opening and closing of the trap.

Disc Trap

One of the most recently developed types of thermodynamic traps is known as the disc-type shown in Figures 10 and 11.

It consists of a round flat disc (D) positioned over a center inlet orifice (O) and an annular discharge (A) leading off through a discharge port (C). All are enclosed within a bonnet (B) mounted on the body of the trap.

When operation starts, pressure in the inlet orifice (O) pushes the disc (D) up vertically off the two concentric seating surfaces surrounding the inlet and outlet ports. This allows discharge to flow out through the discharge port (C).

Now when very hot condensate and steam come to the trap, the high velocity of flow outward past the rim of the disc (D) up into the chamber (E) tends to reduce the pressure on the under-side of the disc, causing some of the condensate to turn to flash steam. At the same time the flashing condensate flowing outward at high velocity strikes the side wall of the chamber (E) causing a build-up of pressure in the chamber snapping the disc shut.

The disc remains in the closed position until the pressure in the bonnet falls due to the condensing of the steam in the bonnet. When pressure in the bonnet falls sufficiently, the disc rises, condensate flows out and the cycle is repeated.

This type of trap is essentially a time-cycle-device. In other words, under normal operating conditions, each time the disc closes on steam at a given pressure and temperature, it will stay closed for approximately the same length of time. This means that if condensate comes to the trap in the middle of a cycle, it will have to wait until pressure in the bonnet falls sufficiently to permit the disc to open.

A variation described as a tilting disc trap, operates in somewhat the same manner as the disc trap described above, except that the valve disc is arranged so that it opens and closes the valve with a tilting action rather than moving straight up and down as in the preceding type.

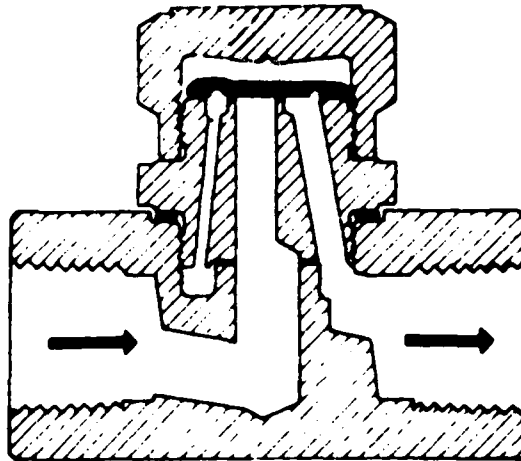
The tilting disc impulse trap is designed primarily for light to medium condensate loads and is illustrated in Figures 12 and 13.

When condensate enters this trap it pushes the disc upward with a tilting action because the inlet orifice (O) is off center. (To the left of center in the illustration.) Discharge then goes out through the discharge ports (D) in the seat plate. When the steam and steam temperature condensate come to the trap, the bonnet fills with steam and the increased pressure closes the disc in a somewhat similar manner to that described for the disc trap above.

The tilting or lever action of the valve in the tilting disc trap is claimed to minimize wear on the parts and also aid in reducing the noise from the trap discharge.

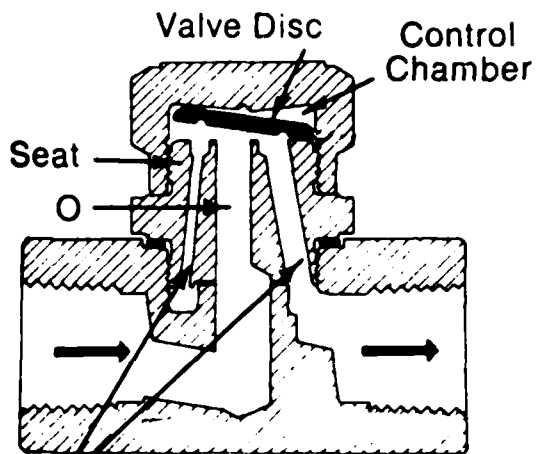
As in the case of the disc-type trap, this trap also operates on a time cycle. In other words, the time between opening and closing will be relatively constant for a given set of load and pressure conditions.

When the tilting disc trap is closed by the steam and flash steam entering the bonnet, it stays closed until the steam in the bonnet condenses and also bleeds off slowly between the ground surfaces of the seat and the disc.



CLOSED POSITION

Figure 12. Tilting disc trap.



D OPEN POSITION

Figure 13. Tilting disc trap.

This "bleeding off" actually comprises a very slight control flow but is so small it is barely perceptible at the trap discharge. This slight control flow also permits bleeding off of air and non-condensable gases and aids in prevention of air binding.

Both the disc and tilting disc-types of traps just described are effective from the upper limits of their recommended capacity ratings down to the lightest condensate loads.

Several other varieties of disc-type traps have recently been made available, but all operate on the same general principles just described for the disc and tilting disc-types of traps.

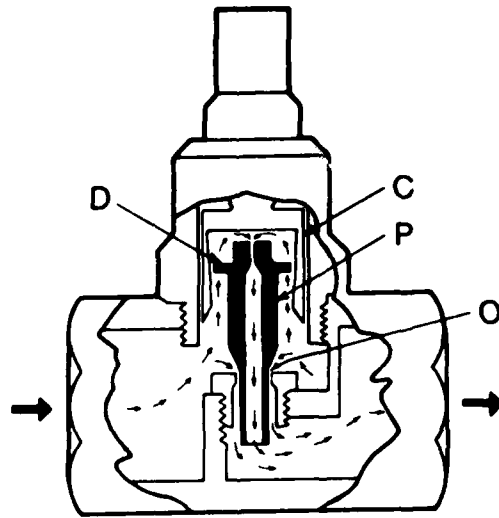
Piston Valve Trap

A more recent thermodynamic trap is the piston trap in Figures 14 & 15.

Without going into the technical details of the engineering theory involved, the operation of this trap is described very simply in the following paragraphs.

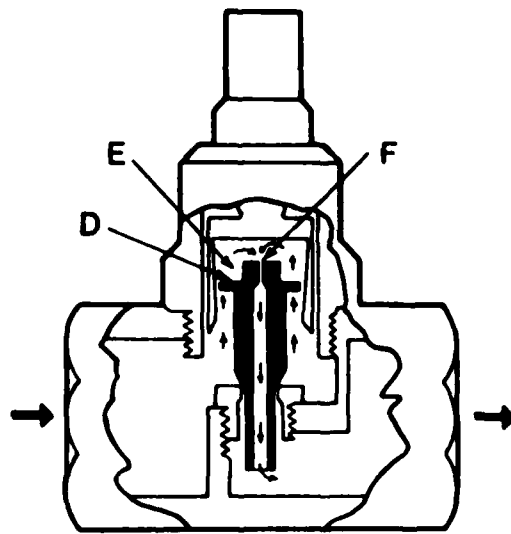
This trap may consist essentially of a piston type valve (P) operating within a control cylinder (C).

The lower end of the valve has a tapered seating surface which opens and closes orifice (O).



VALVE OPEN

Figure 14. Piston trap.



VALVE CLOSED

Figure 15. Piston trap.

When steam is turned on in the system ahead of the trap, pressure is exerted on the under-side of the piston disc (D), on the valve (P), pushing it upward to open the orifice (O), so the condensate and air can flow out at full capacity.

The valve opens wide on start-up for full discharge of condensate and to quickly get rid of any air that may have accumulated in the system.

The valve stays wide open until condensate nears steam temperature.

Opening and closing of this trap is regulated by the slight condensate flow which goes up past the piston disc (D) to the intermediate pressure area in the control chamber (E). It then flows out the control orifice (F) in the hollow stem of the valve to the lower pressure in the discharge port of the trap.

When condensate nears steam temperature, these pressure drops cause it to flash in the control chamber (E) and in the control orifice (F). This chokes the flow through the control orifice which increases the pressure in the control chamber (E), snapping the valve shut to prevent the loss of live steam.

As long as the condensate remains hot enough to continue the flashing, the valve remains closed. When it cools slightly, the flashing decreases. This reduces pressure in the control chamber allowing the valve to reopen and the cycle is repeated.

The control flow continuously samples the condensate flow coming to the trap and causes the valve to open or close quickly at the proper time - to open wide on condensate, but close when steam reaches the trap.

Therefore, the quick response provided by the control flow in this trap aids in bringing steam equipment up to temperature quickly and in maintaining high, even temperatures of the apparatus. This promotes high efficiency of the overall operation.

The control flow consists of only a slight percentage of the full flow through the main orifice. This means that only an amount of condensate equal to this small percentage is required to completely fill the control orifice at all times. When the main valve is closed and as long as this slight amount of condensate flow is maintained, there can be no measurable flow of steam through the control orifice.

Orifice Traps and Plates

These devices have been listed under thermodynamic traps because double plate and labyrinth orifices provide some semblance of flow control based on thermodynamic principles.

Orifice plates depicted in Figure 16, were an early method of controlling the flow of condensate. This is simply a plate or disc inserted in the discharge line or drain line from the apparatus. In the center of the disc is a hole or orifice.

In order to pick the right size orifice it is necessary to calculate the amount of condensate flow, based on the condensing rate of the equipment or apparatus, and also to know the pressure and temperature at the orifice. When these three figures are known, the proper size of orifice can be picked from an orifice table.

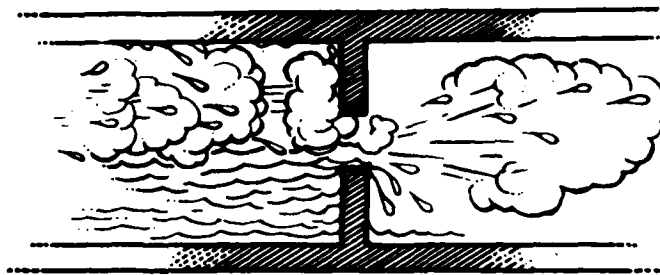


Figure 16. Orifice plate.

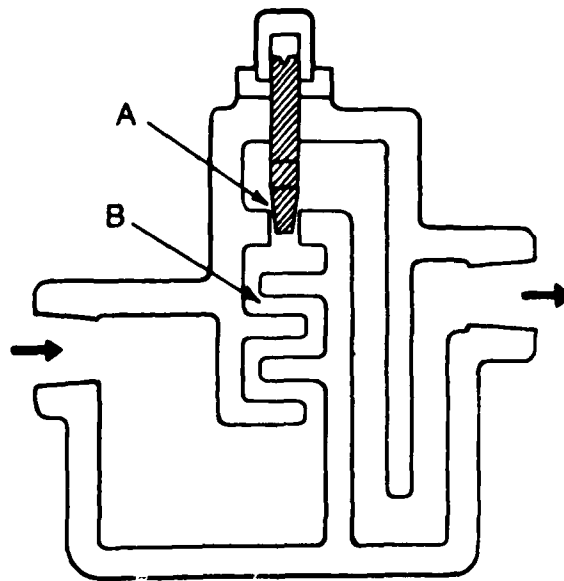


Figure 17. Labyrinth orifice trap.

When the size of the orifice has been calculated correctly and conditions in the condensate line remain approximately constant, the orifice plate is a very efficient device. However, constant conditions such as this are encountered rather infrequently in the usual industrial application.

Single orifice plates are frequently sold in combination with a strainer because these devices are especially sensitive to dirt clogging. Claims for extremely low maintenance are likely true only under clean operation conditions.

Frequent inspection and cleaning of the strainer is likely to be a necessity to maintain the operation of the orifice plate itself. These devices are most likely to find application in condensate drains from very high pressure steam mains (+600 psig) under circumstances where load does not vary more than 25 percent from design load. One manufacturer recommends parallel trapping with a conventional trap to handle start-up condensate loads. Single orifice plates nearly always leak some steam.

Double orifice plates were probably the first improvement on the single orifice plate. Hot condensate flashing to steam between orifices may serve to choke the flow of the second orifice thereby providing a limited amount of self-regulation.

The labyrinth type orifice is more like a trap and was one of the earliest thermodynamic traps. In one form shown in figure 17 it combines an adjustable orifice (A) with labyrinth passages (B) to control the flow of condensate. Due to pressure drop through the labyrinth passages and the adjustable orifice, some condensate turns to flash steam as condensate approaches steam temperature. This provides a measure of automatic flow control, for the nearer the condensate approaches steam temperature, the greater will be the flashing and therefore the greater the choking effect of the flash steam.

As with the orifice plate, if the condensate load does not fluctuate to any great degree this trap is quite satisfactory, but if load, pressure, or temperature vary considerably it is likely to either back-up condensate or blow live steam.

SELECTION OF STEAM TRAPS

The purpose of this topic is to provide guidance for the reader in selecting the types of steam traps to use in the various applications found within Army facilities. There is, of course, an additional step to take in selecting the size of a particular type of trap. Selecting trap size is a topic well covered in nearly all manufacturers' literature and will not be covered in detail here. It is very important to select the proper trap size as both undersizing and oversizing produce penalties in operating costs. Use manufacturers' literature and the guidance of manufacturers' representatives to select the proper size of trap. Also, use the information in this report to select the proper type of trap.

Table 1 summarizes information obtained in the market and literature surveys concerning the performance of the various types of steam traps. Curiously, there was direct contradiction among several of the sources. The appearance of ?'s in the Table indicate that there was not a good consensus judgement revealed by this study or that no information was obtained.

The greatest extent of steam use in Army facilities involves steam distribution systems, heating units and absorption units. Three types of traps are best suited for use on steam distribution drains.

- Thermodynamic disc traps are the first choice and especially where freezing conditions may occur.

- Insulated, inverted bucket traps are the alternate choice where freezing conditions may occur.
- Float and thermostatic traps are an alternate choice up to 150 psig. These traps should not be used where there is a danger of freezing. These traps are especially indicated where heavy condensate loads are encountered during frequent system start-ups.
- Non-insulated, inverted bucket traps are an alternate choice where there is no danger of freezing.

The choice of traps for heating units (both air and water heat exchangers) and absorption units is as follows:

- Use float and thermostatic traps properly protected from freezing.
- If a freezing danger exists, consult manufacturers' representatives to select the proper insulated, inverted bucket traps.

Specialty equipment such as hospital sterilizers and jacketed cookers should be analyzed according to the operating conditions of each unit. Manufacturers' representatives should be consulted as all types of traps have potential applications and no generalized guidelines may be offered.

TABLE 1
PERFORMANCE OF VARIOUS STEAM TRAPS

Function	Mechanical Traps			Thermostatic Traps			Thermodynamic Traps			
	Bucket	Inverted Bucket	Float	Metal Bellows	Liquid Bellows	Bimetallic	Float & Thermo-Static	Disc	Piston	Orifice
Unlimited Pressure Range	to 250	to 150	to 150	to 150	to 150	to 150	to 150	to 600	?	Very High
Unlimited Capacity	Good	Good	One	Fair	Fair	Fair	Excellent	to 600	?	Very High
Prevents Start Up Surges	Excellent	Excellent	Excellent	Excellent	Excellent	?	Excellent	Fair	?	?
Prevents Start Up Surges	Yes	Excellent	Excellent	Poor	Poor	?	Excellent	Varies	?	?
Prevents Start Up Surges	Yes	Varies	Varies	Varies	Varies	Varies	Varies	Yes	Yes	Yes
Prevents Freezing	Best	No	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Prevents Hammer	Insulate	Excellent	Poor	Poor	Poor	?	Poor	Excellent	Excellent	Excellent
Prevents Hammer	Moderate	Moderate	Very High	Low	Low	?	Very High	Moderate	?	?
Prevents Hammer	Excellent	Excellent	?	Fair	Fair	?	Good	Fair	?	?
Prevents Hammer	Excellent	Excellent	?	Excellent	Excellent	?	Excellent	Poor	?	Poor
Prevents Hammer	Excellent	Excellent	?	Excellent	Excellent	?	Excellent	Poor	?	Poor
Prevents Hammer	Excellent	Excellent	?	Fair	Fair	?	Poor	Poor	?	Questionable
Prevents Hammer	Best	?	?	Varies	Varies	?	Closed	Varies	?	?
Prevents Hammer	Usually	Usually	Usually	Usually	Usually	?	Closed	Usually	?	Always
Prevents Hammer	Closed	Closed	Closed	Closed	Closed	?	Closed	Usually	?	Open
Prevents Hammer	No	No	No	No	No	No	No	No	No	No
Prevents Hammer	Excellent	?	?	No	No	No	Excellent	Excellent	?	?
Prevents Hammer	Varies	?	?	No	No	No	Excellent	Varies	?	?
Prevents Hammer	Varies	?	?	Good	Good	Good	Good to	Poor	?	No Inlet
Prevents Hammer	Varies	?	?	Small	Small	Small	Excellent	?	?	No Inlet
Prevents Hammer	?	?	?	?	?	?	?	?	?	?
Prevents Hammer	Low	Low	Low	Low	Low	Low	Low	High and	?	High
Prevents Hammer	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure	Pressure,	Low	?	Pressure
Prevents Hammer	Best	Continuous	Continuous	Best	Best	Water	Continuous	Drains	?	Heavy
Prevents Hammer	High	High	High	Moderate	Moderate	Coils	High	Drains	?	Traps
Prevents Hammer	High	High	High	Moderate	Moderate	Low	High	Drains	?	Traps
Prevents Hammer	High	High	High	Moderate	Moderate	Low	High	Drains	?	Traps
Prevents Hammer	High	High	High	Moderate	Moderate	Low	High	Drains	?	Traps
Prevents Hammer	High	High	High	Moderate	Moderate	Low	High	Drains	?	Traps

INSPECTION AND MAINTENANCE OF STEAM TRAPS

Maintenance of steam traps and regular inspection routines to detect traps requiring maintenance are a challenging and vexing problem for utilities personnel at Army facilities. It was shown in the Market Survey that Army facilities have insufficient personnel to carry on an adequate inspection and maintenance program. It follows logically from this that there must be many failed and malfunctioning traps at every Army facility. This conclusion is based upon the results of surveys of manufacturing and chemical process industries.(1)(2)

The energy savings which can be achieved through a timely and thorough maintenance program are likely to be very large. It is not possible to quantify such savings. However, some general guidelines are offered in the section of this report titled, Energy Analysis.

Failures of steam traps can usually be attributed to one of three causes.(3)

1. Misapplication. Selecting the wrong type of trap will not only result in inefficient operation but may also reduce the operating life of the trap.
2. Incorrect size. An oversized trap will cycle rapidly and wear out prematurely. An undersized trap will not completely drain condensate and the heater will not operate properly.
3. Neglect. Failure to detect signs of early wear and dirt build-up will lead to premature failure of the trap. Intelligent system design with proper use of strainers and dirt pockets is strongly indicated.

(1) Factory, 67, March 1975.

(2) Laidley, C. W.; Steam Trap Maintenance, Energy Conservation Seminar of Chemical Industry Task Force On Conservation.

(3) Ibid.

Inspection routines and criteria for disclosing faulty traps are presented in detail for those facilities which might, at some time, find the information useful. It is recognized that there are not enough people available to follow these procedures at the present time. Therefore, it is recommended that Army facilities implement steam trap maintenance and inspection programs through outside service contracts.

Several firms which might be able to provide this service are listed below.

Honeywell Inc.
Minneapolis, Minnesota
612-870-5200
Mr. Don Tadvick
National Operation's Manager

Honeywell Inc.
5555 DTC Parkway
Englewood, Colorado 80111
303-779-6200
Mr. James F. Cumiskey

Steam Team
P.O. Box 61167
Houston, Texas 77028
713-523-6400
Mr. Burns Cielland

Team Inc.
P.O. Box 123
Alvin, Texas 77511
713-331-6154
Mr. William Bramblett

Steam System Management
Basin Road Industrial Center
New Castle, Delaware 19720
302-322-5411
Mr. Dick Kerr

Regular inspection and timely maintenance of steam traps have been shown to be good ways to reduce energy use and save money. The hiring of skilled service companys to provide at the very least, inspection can be one effective way to

address the problem of insufficient staff people to perform the necessary inspection and maintenance services.

Inspection of a Steam Trap

The technical and manufacturers' literature contain much information on steam trap inspection. One factor that is repeatedly stressed is that the symptoms of a failed or malfunctioning steam trap are likely to be an indication of a problem in the steam system although the suspected trap may be capable of functioning properly. Several different methods for inspecting or checking of trap operation are discussed in the following sections.

Visual Test

A test which allows visual inspection of a steam trap's operation is considered to be the best approach. The method must be used with the knowledge that it is not infallible and its reliability varies among the various types of traps. This procedure requires that a test valve be installed in the condensate return line just beyond the trap. A typical set-up has been sketched in Figure 18. The inspection of trap operation requires that the valve in the condensate return line be closed and the test valve then be opened. Observation of what comes out of the test valve offers excellent insight into the operation of the trap. The possibilities are discussed below:

1. Nothing comes out of the test valve may mean that the trap may have failed in the closed position. However, this condition may also be indicative of such system or other problems as:
 - There may be a vacuum in the system heat exchange unit preventing drainage of the unit.
 - There may be a leaky by-pass valve behind the trap.
 - A dirty trap, or dirty line and only cleaning of the strainer and trap may be needed.
 - The pressure may be too high for the trap due to incorrect sizing, worn trap, malfunctioning reducing valve or vacuum in return line.

- Air vent may not be working properly.
- The trap may be installed backwards if it is a thermodynamic disc trap.

2. Continuous discharge from the trap is not necessarily an indication of a problem. For example, float and thermostatic traps and orifice plates may continuously discharge condensate which can flash into steam when released to the atmosphere. It is very important to have a trained and skilled observer who can distinguish between superheated steam leaking through a failed trap and flash steam that is saturated steam which is formed when hot condensate is released to the atmosphere.

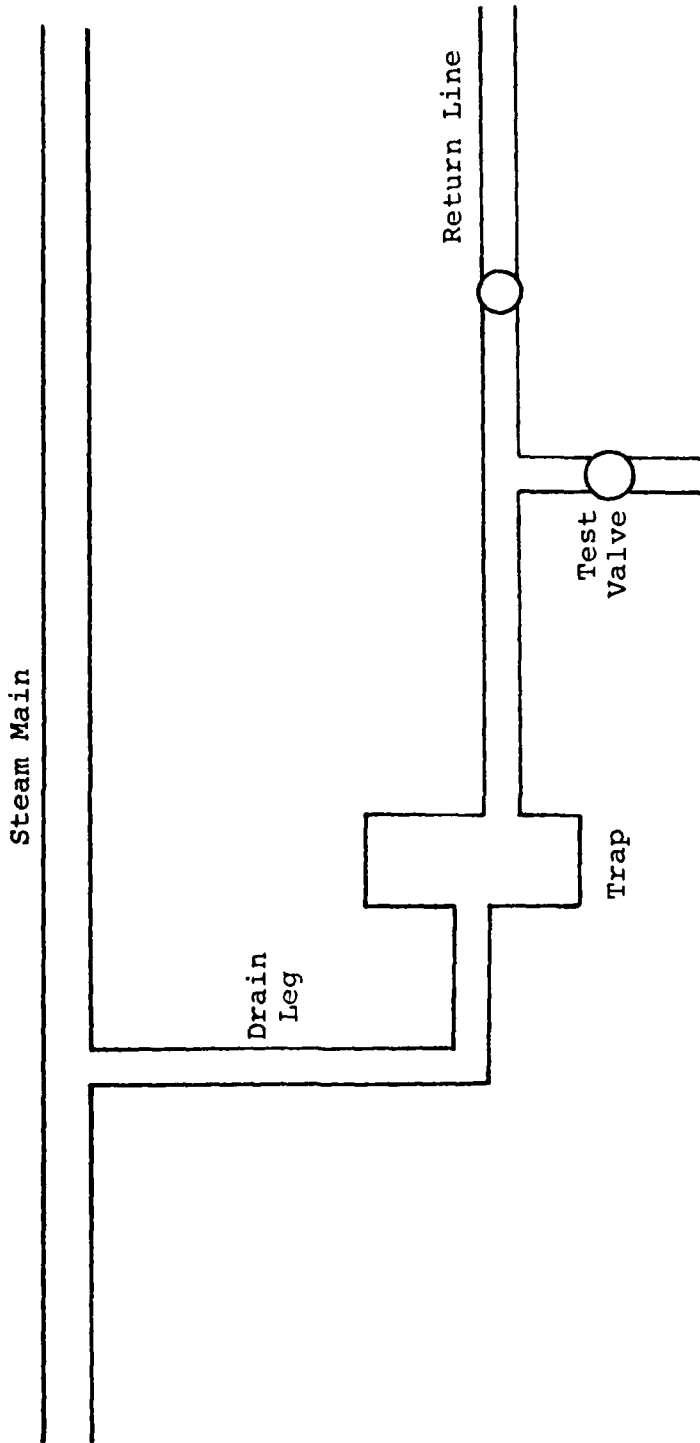


Figure 18 - Steam Trap Test Valve Hookup

Continuous discharge from other types of traps is usually indicative of a problem which might be a trap failed open. However, other possible problems include:

- The trap is too small.
 - There may be excessive water in the steam lines.
3. The trap is functioning properly if discharge from the trap is intermittent with no appreciable water or steam visible between discharges. This is not true of orifice plates which usually discharge continuously. It may not be true of float and thermostatic traps.

You may have indications of trap problems even after observing a good test on a trap. Remember, no single in-service test is foolproof. Additional tests may be needed. But, before making more tests consider the following:

- The trap may be a little undersized for the application.
- Other failed traps may be passing steam creating back pressure or overloading the condensate return line.
- The condensate return line may be too small.
- The vent in the condensate tank may not be working.

Audible Test

All tests which have been referenced for trap inspection have their detractors as well as their proponents. A test which permits one to "hear" the trap operating seemed to be the second most popular. An audible test may involve simply a listening stick placed on the trap. Other variations range from stethoscopes up through ultrasonic equipment.

The principle of audible inspection is based upon the observation that each type of trap has a characteristic sound and sequence when operating properly. Conversely, there is a different sound or no sound when the trap has failed. It should be stressed again that the sound of a malfunctioning trap is only a symptom of a problem in the steam system. The

trap may be capable of functioning properly and the real problem may be elsewhere or may be an improper type or poorly sized trap.

It is difficult to describe sound beyond the usual, "it sounds like a ----", approach. Descriptions of trap sounds are taken directly from the literature and manufacturers' brochures. These descriptions are applicable when the inspector is listening to a trap with a stethoscope or a rod held firmly against the trap.

Bucket traps - A properly operating bucket trap will make a cycling sound as it opens and closes. The frequency or repetitiveness of the sound was not described. A failed bucket trap (they seem to always fail open) has been described as making a whistling sound or a "whooshing" sound. Note that we have elected not to footnote references to the adjectives describing the sounds.

Thermostatic Traps - References to the sound of thermostatic traps proved to contain direct contradictions. The descriptions are repeated below, again without references, because of the contradictions.

A properly operating thermostatic trap may make no sound; or the sound of periodic discharge may be heard; or continuous but fluctuating velocity sounds may be heard. A thermostatic trap failed closed will make no sound. A thermostatic trap failed open will make a whistling sound.

Thermodynamic Traps (Disc and Piston) - A properly operating trap will make a clicking sound or snapping sound as it opens and closes several times per minute. A failed trap (they fail open) will make a rapid chattering sound.

Orifice Plate - No reference was found for the audible inspection of orifice plates.

Perhaps the major drawback to audible tests is that sound may be transmitted for great distances along the piping of steam lines. Thus, the sound one hears emanating from a trap may be coming from a nearby trap while the trap being inspected has failed closed and is making no sound of its own. Another example of false interpretation could be a chattering sound indicating failure of a thermodynamic disc

trap when one is really hearing the superimposed clicking of several properly operating disc traps.

Audible testing as described here seems to be poorly regarded by many. The benefits of audible testing are speed and low cost. However, this sort of testing may have reliability only when performed by a skilled and experienced technician who has had a lengthy association with a specific steam system.

A more modern approach to audible testing of steam traps is the application of ultrasonics. The advantage claimed here is that frequencies greater than 35,000 Hz are quickly attenuated so that extraneous sounds do not travel far.⁽¹⁾ Thus, the discharge from only one trap may be heard by an inspector equipped with earphones or by properly affixing a loudspeaker. Experience in using ultrasonic testers is required because each type of trap has a different response.

Only one source describing ultrasonic trap sounds was found and this source is quoted directly.⁽²⁾ "Thermostatic traps, when properly sized for the load, will discharge intermittently. Therefore, if the trap is operating properly, a loud hissing sound will be heard during discharge; no sound will be heard when the trap is closed. If hissing continues after closing, the trap is leaking. Hissing does not necessarily mean that the trap is losing steam. If the condensate load is greater than the amount of leakage, steam will not be lost. However, if the condensate load is less than the leakage, the hissing will continue for a prolonged period and the trap will cycle only when the condensate load exceeds the leakage, allowing subcooling of the condensate. If the trap continues to cycle regularly, it is probably functioning properly."

(1) Hilmer, M.; Techniques for Testing Steam Trap Operation; Plant Engineering, 147-150; March 17, 1977.

(2) Ibid.

"Some thermostatic traps tend to throttle under certain load conditions. When these conditions exist, the test instrument will emit a continuous hissing. When this occurs, the trap can be tested only by reducing the load. Under light-load conditions, even these traps cycle rhythmically."

"Bucket traps operate intermittently. The tester will easily learn to distinguish between normal and malfunctioning operation. When the trap is working properly, a hissing noise will be heard during discharge, and, when the trap closes, the sound stops. Continuous hissing indicates that the trap is blowing, which may result from a loss of prime under light loads, or a malfunction of the trap mechanism."

"Thermo-dynamic trap opening and closing frequently depends on the trap load and the mechanical condition of the trap. If the trap cycles fewer than 10 times per minute, it is operating normally. But, if the trap is worn, its cycling rate will increase significantly; the trap will sound somewhat like a machine gun. If the thermo-dynamic trap discharges continuously, the loading may exceed capacity, or return line pressure may be too high. The return line pressure and the pressure upstream of the trap should be checked."

"Impulse traps have a piston in a conical cylinder and are intermittent in operation. A bleed hole is drilled through the piston, allowing flow from inlet to outlet even when the trap is closed. Therefore, with the trap closed, a hissing sound will be heard. But the trap is not necessarily wasting steam. If it is properly sized, it will still operate intermittently. A loud roar when the trap is in the full discharge position will be followed by a much lower noise level. If a loud noise is heard continuously, the trap is either overloaded or is stuck in the open position and should be repaired."

"Float-thermostatic traps have a tendency to discharge continuously, particularly at low or moderate pressures, and modulate according to the load ahead of the trap. Under these conditions, ultrasonic testers are of no value. However, when float-thermostatic traps are used at high pressures, they tend to discharge intermittently, and, if the tester indicates a rhythmic intermittent discharge, the trap is working properly."

Temperature Test

Measuring the temperature of the condensate return pipe beyond the trap was once touted as a reliable means for checking steam trap operation. Another temperature check regimen was to measure the temperature difference between the pipe entering and the pipe leaving the steam control device. Today, condensate pipe temperature is deemed as a reliable indicator of trap operation ONLY if the trap has failed closed. In this case, the trap and adjacent downstream pipe will be very close to ambient temperature.

The reader is cautioned to make temperature measurements with a surface pyrometer. Sensing pipe temperature by grasping it with a bare hand will cause more serious burns than it will disclose malfunctioning traps.

There remain some sources who recommend using temperature tests as a method for judging the conditions of a steam trap. The following comments on the use of downstream pipe temperature as an indicator of steam trap condtemperatureion illustrate why it was judged to be the least suitable test.

- If the line is at ambient temperature, the trap has failed closed. (Note also that if a trap makes no sound it has failed closed.)
- If the line is warm or hot you have no idea of the condition of the trap because the temperature may have been influenced by other traps discharging into the same condensate return line.
- If the line is warm or hot, it could also be due to the trap failing open or merely passing a lot of condensate at steam temperature.

It was claimed that measurement of surface temperature and steam pressure at the trap will give good information on trap operation.⁽¹⁾ Readers who are equipped to make both measurements are referred to the footnote for further information.

The use of infra-red thermography has recently been suggested as offering potential for judging the condition of steam traps.

(1) Webb, T.; Steam Trapping; Energy Research, I; 179-185; (1977).

Several manufacturers have published good guides on trap inspection procedures and the interpretation of symptoms detected during inspection. The reader is referred to the following documents which should be available from trap manufacturers' representatives. The information provided in these will be a useful supplement to and expansion of the condensed presentation in this report.

H.O. Trerice Company; Trerice Sales Manual, Sales Letter J-18; pp. 1 and 2.

Armstrong Machine Works; Steam Conservation Guidelines for Condensate Drainage; pp. 39, 40.

Yarway Industrial Steam Trapping Course.

Inspection Frequency

Suggestions for inspection frequency vary widely depending on line pressure, condensate load, type of trap and source of the suggestion. It is recommended that each trap be inspected by a contracted maintenance firm once each four months. Circumstances and experience will guide each Facilities Engineer to modifications of this interval. One year should be the absolute maximum interval between inspection and a six month interval may prove to be right for many typical Army steam trap applications.

Maintenance

The follow-up to inspection of steam traps is maintenance of suspected faulty traps. Remember that the symptoms of a failed trap may only indicate that you have the wrong trap for the job or that something else is wrong within the steam system. When you are certain that the trap requires attention, you have no choice but to replace the trap. Some types of modern traps are designed to permit in-service replacement of working parts. These types of traps should reduce downtime and cost. The suspect trap or trap assembly may be bench-tested for a certain assessment of its operation. Good traps mistakenly removed and reconditioned traps may then be placed in supply inventory for future use as needed.

Bench testing of traps and trap components is beyond the scope of this report. Steam trap manufacturers should be

able to supply information for building a line for the shop testing of traps. One manufacturer sponsored a technical article depicting the detailed design of an inexpensive test stand.(1)

Forced trap replacement offers an opportunity to review the two critical questions, "Is this the right type of trap?" and "Is this the proper size of trap?" Conditions within the steam system may have changed thereby influencing the condensate load on this trap. Frequent failures at one trap station could be a sign that one should change the trap type and/or size. Trap selection is discussed on pages 50 and 51.

ENERGY ANALYSIS

Selecting the proper type of trap following the recommendations given on pages 48 to 50 is the first step in energy conservation related to steam trap operation. The next step is to select the proper size of trap relying on manufacturers' literature and the assistance of manufacturers' representatives. All traps of proper size and type should not pass live steam when they are operating properly. Orifice plates, on the other hand, will pass a little live steam continuously.

An energy analysis is limited to assessing the energy lost when a steam trap fails open or develops a leak. The steam trap literature has approached this by assessing the energy lost as function of the size of leak or trap orifice and steam pressure. Table 2 shows the type of data usually displayed in articles and manufacturers' literature.

(1) Hilmer, M.; Techniques for Testing Steam Trap Operation; Plant Engineering, 147-150; March 17, 1977.

TABLE 2
STEAM LOSSES AT VARIOUS OPENINGS (1) (2)

Size of Orifice Opening or Effective Leak Diameter, In.	Steam Pressure, psig				
	5	25	50	100	150
	Steam Lost, Pounds Per Hour				
0.03	<1	1	2	3	5
0.06	2	5	7	16	19
0.12	8	18	30	53	76
0.25	32	73	119	211	303
0.50	126	292	476	844	1212

(1) Sisson, W.; Power Engineering; p. 55, September 1975.

(2) Yates, W.; Hydrocarbon Processing; 267, March 1975.

One thousand pounds of steam is very nearly equal to one million BTU. Assume an oil fired boiler efficiency of 75 percent and Table 2 may be reconstructed to reflect the annual energy loss as shown in Table 3.

TABLE 3
APPROXIMATE ANNUAL ENERGY LOSSES DUE TO
STEAM LEAKS AT VARIOUS PRESSURES

Size of Orifice or Effective Leak Diameter, In.	----- Steam Pressure, psig -----				
	5	25	50	100	150
	----- Energy Lost, MMBTU Per Year -----				
0.03	3	15	25	345	60
0.06	25	60	80	185	225
0.12	95	210	345	620	885
0.25	375	850	1390	2465	3540
0.50	1470	3410	5560	9560	14160

ECONOMIC ANALYSIS

Selection and analysis of steam trap operation does not lend itself to life-cycle cost analysis for the following reasons:

- . A steam trap is but a small part of a large steam system.
- . Maintenance costs for any given type of trap have not been published and would be quite variable depending on the type of service.
- . The service lives of the various traps will be highly variable according to the type of service. A qualitative estimate of the relative service life of the various types of traps has been given in Table 1.

The economic considerations affecting trap inspection and repair or replacement are, however, quite simple and compelling. Traps which fail "closed" will quickly influence one or more upstream heat exchangers: i.e., heaters do not heat; sterilizers do not sterilize; cookers do not cook; etc. Such malfunctions will likely be quickly noted and trap replacement becomes a necessity to restore proper operation of needed facilities. The only economic consideration here is to select the cheapest trap of the type recommended on page 50-51 and the size calculated according to the trap manufacturers' recommendations.

Traps which leak or fail "open" will pass live steam to the condensate return line. This live steam is expensive. Table 4 displays the annual cost of "lost steam" for oil fired boilers, 75 percent efficient, based on a cost of \$4.17 per MMBTU for No. 2 heating oil in DoE Region 1.

TABLE 4

APPROXIMATE ANNUAL COST OF STEAM LEAKS

Size of Orifice or Effective Leak Diameter, In.	----- Steam Pressure, psig -----				
	5	25	50	100	150
	----- Annual Cost of Lost Steam, \$ -----				
0.03	13	63	104	146	250
0.06	104	250	334	771	938
0.12	396	876	1439	2585	3690
0.25	1564	3544	5796	10279	14762
0.50	6130	14220	23185	39865	59047

Trap prices are low compared to the annual cost of lost steam. For example, an inverted bucket with a 1/2 inch orifice for 100 psig service might cost as little as \$35 or up to \$300 depending to a large extent on the construction materials. A 1/2 inch disc trap sells for \$50 to \$75. Replacement assemblies for these traps might cost from \$10 to \$20. Cost analysis seems to be quite insignificant when one considers that a failed open, 1/2 inch orifice on 100 psig service can cost just over \$50,000 annually. Another example might be a 1/2 inch heater trap on 5 psig service. A small leak of equivalent 1/16 inch diameter could waste about \$100 per year yet the cost of a new trap would be less than \$25.

The economics of steam trap inspection and maintenance are compelling. The discounted payback periods for prompt attention to failed traps would be measured in weeks rather than years. It is for this reason that it is recommended that all Army facilities engage the services of a local industrial maintenance service for regular inspection of steam traps.

CONCLUSIONS

Condensate control devices (steam traps) are essential to the efficient and economical operation of steam distribution systems.

Regularly scheduled inspection programs are essential to survey steam trap operation and appurtenant devices such as in-line strainers and dirt pockets.

Steam traps which leak or fail open can annually waste steam whose value is many times that of a new trap or trap repair kit.

Army Facilities Engineers do not have sufficient manpower to conduct an effective steam trap inspection program.

Selection of the proper type and correct size of trap for each different application will produce the most energy efficient operation of steam distribution systems.

Orifice plates appear to offer little potential for effective application in low and moderate pressure steam systems whose load may fluctuate more than 25 percent from design conditions.

Strainers which are installed to protect orifice plates from plugging must be inspected and cleaned or replaced according to a regular schedule.

RECOMMENDATIONS

It is recommended that Army Facilities Engineers engage the services of commercial or industrial maintenance companies to conduct a regular inspection of all steam trap stations. The inspection reports should identify all steam trap stations which may require maintenance.

It is recommended that the size and type of each trap be reviewed whenever a trap requires replacement.

Select steam trap size according to manufacturers recommendations.

Select steam trap type from the following list.

<u>Type of Service</u>	<u>Freezing Conditions</u>	<u>Type of Steam Trap</u>	
		<u>1st choice</u>	<u>Alt. Choice</u>
Steam distribution drains, normal condensate load	yes .	thermodynamic disc	insulated inverted bucket
	No	thermodynamic disc	float and thermostatic inverted bucket
Steam distribution drains, heavy condensate load or frequent start up	yes	thermodynamic disc	--
	no	float and thermostatic	thermodynamic disc
Heating and absorption units	yes	insulated inverted bucket	consult manufacturers reps as no clear-cut choices of general types exist
	no	float and thermostatic	

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APPENDIX

Glossary

Adiabatic Expansion

See Throttling.

Blow Down

Discharge a portion of boiler water to reduce solids content or remove sludge.

Drip

See DRAIN.

Drain

A smaller pipe leading from a larger steam pipe positioned so that condensed water in the steam line will flow through the drain pipe usually to a steam trap or orifice. The "DRAIN" may also contain steam and air.

Entropy

This often maligned term is seldom referenced in low (± 250 lb) pressure steam systems, so we will ignore it.

Enthalpy

The heat that was put into something to raise its temperature from 32°F to where it is now. Conventional unit is BTU/lb. Note that if something changed from liquid to vapor in getting from 32°F to where it is now you add the heat required to convert it to vapor.

Latent Heat

Heat applied to a substance to change its state from solid to liquid or liquid to vapor.

Live Steam

Steam which has not done the work for which it had been produced.

Saturated Steam

Steam at the temperature at which it was formed (at the same pressure).

Sensible Heat

Heat that changes the temperature of a substance without affecting its gaseous, liquid or solid state.

Super Heated Steam

Steam whose temperature is higher than that at which it was formed (at the same pressure).

Throttling

Expansion of steam without any change in heat content of the steam.

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