Steam Vacuum Refrigeration

old concept / modern application

The exact year in which the first steam vacuum refrigeration experiment was made is not known. But we do know that it was tried out some time before 1901 by Le Blanc of France and Parsons of England, who are generally credited with the development of the steam jet ejector.

Due to the inefficiency of early steam jet ejectors, the industrial applications of steam vacuum refrigeration were extremely limited. Also, auxiliary equipment such as pumps and controls suitable for the purpose had not yet been developed to a satisfactory performance level.

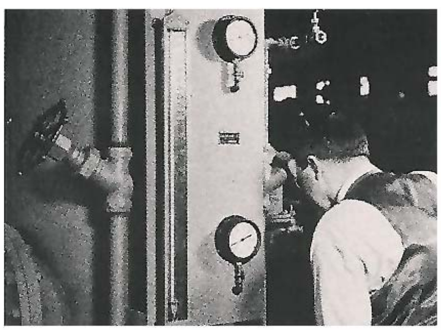
It can be stated, however, that improvements made in ejector design and other construction details by Graham Corporation over a period of years brought steam vacuum refrigeration to its present state - one of the most reliable and satisfactory methods of producing refrigeration.

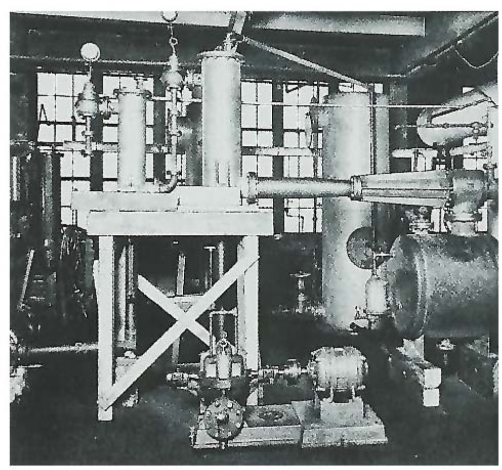
Graham r&d

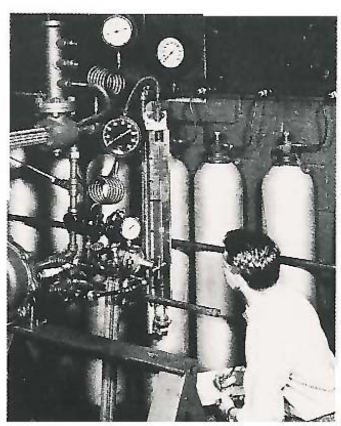
Out of ideas came experiments; and out of experiments came realities. Graham established a completely equipped laboratory in Batavia, New York, many years ago where the "facts of life" were determined about heat transfer and ejector equipment.

Testing still goes on, to up-date and improve the old; to experiment in the new. Although many ideas are discarded after exhaustive tests, practical advancement is the rule.

Testing of production equipment on order under actual operating conditions is carried on before final assembly and shipment. Only through such testing can the most accurate adjustments be determined on steam nozzles, controls, water distributors etc. Limitations as well as superiorities are thus established, assuring users of Graham equipment that it will perform efficiently and continuously from the start of operation.



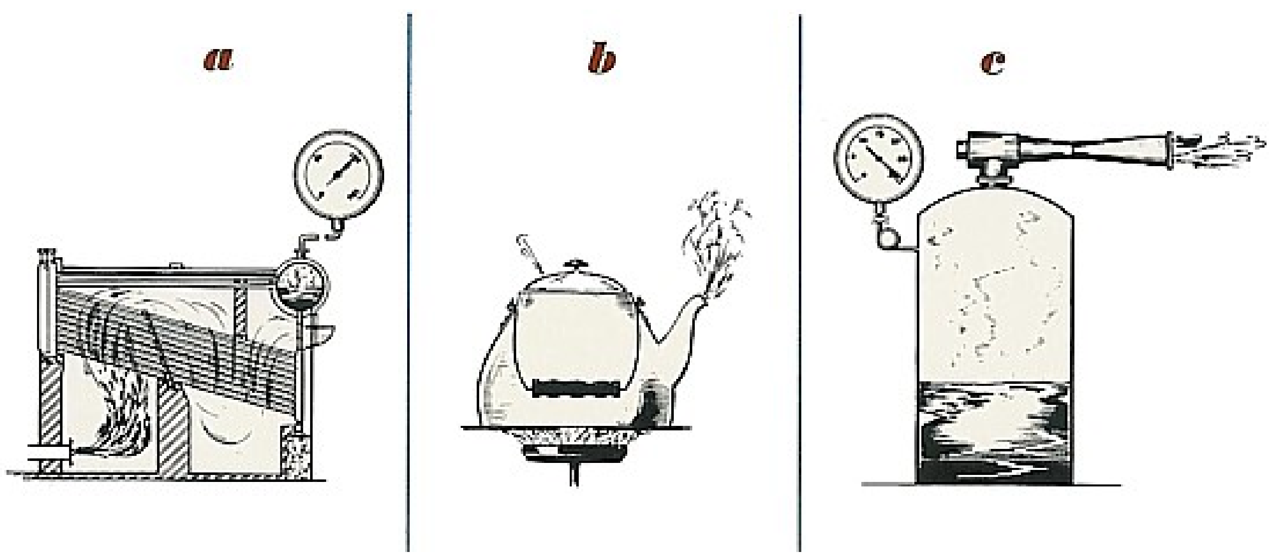




cooling with steam

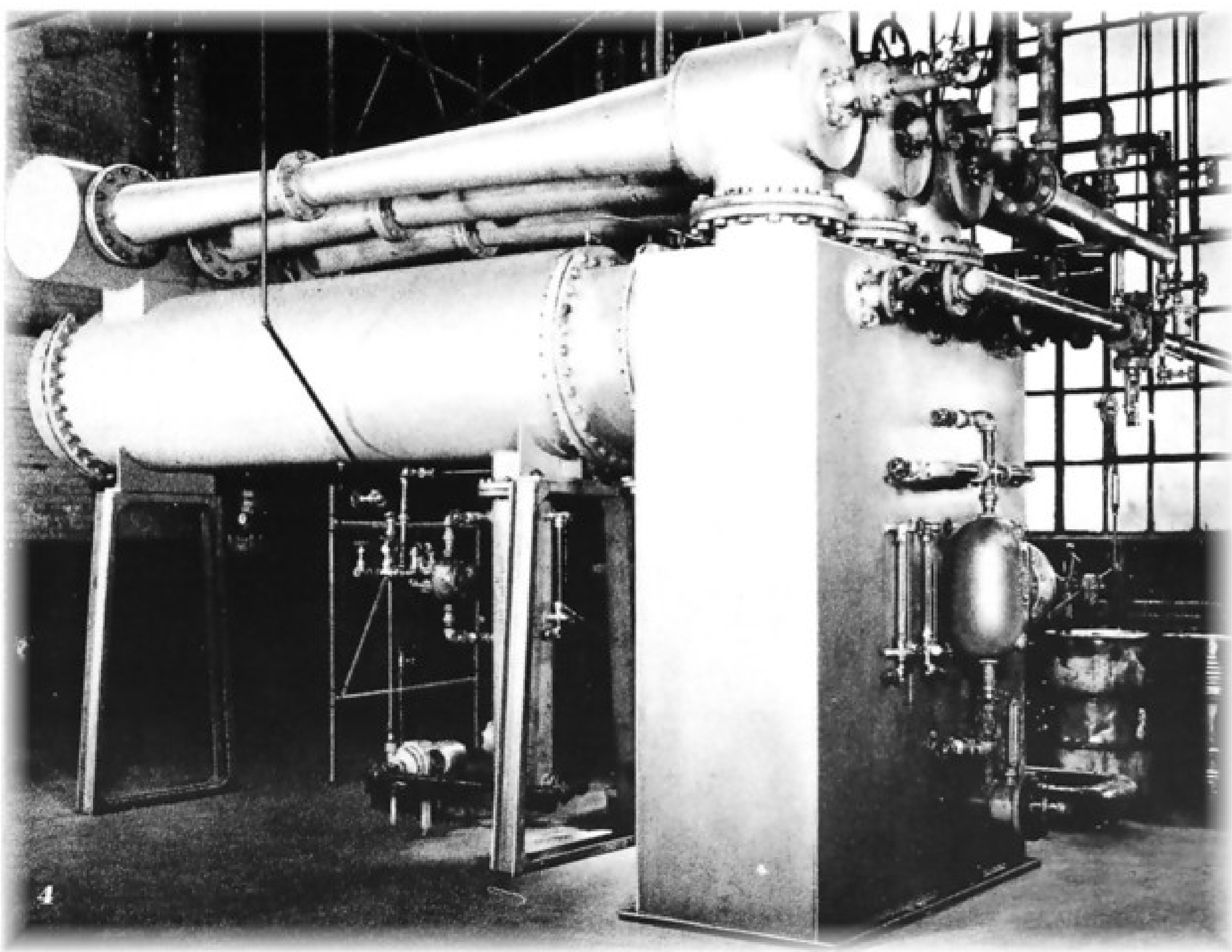
The principle of operation is simple. For each given pressure water has a corresponding boiling point or temperature of vaporization. For instance, at 114.7 psia, water will vaporize at 338 degrees F. (fig. a). At atmospheric pressure, 14.7 psia, the old fashioned tea kettle caused water to boil at 212 degrees F. (fig. b). When contained in a vessel and subjected to a vacuum of 0.1475 (7.6 mm hg abs) psia, water will boil or vaporize at 45 degrees F. (fig. c).

Hence, the steam vacuum refrigeration unit produces a pre-determined vacuum that corresponds to the chilled water temperature required, and thus flashes off water vapor until the balance of the water that does not flash is chilled to this required temperature. Each pound of water that changes its state and flashes into a vapor takes with it approximately 1068 btu's. Therefore, if we flash off 11.25 #/hr., we have extracted 12,000 btu/hr., or one ton of refrigeration.



selection factors

Large 3-booster machine in rubber manufacturing plant first cools rolls then uses chilled water for air conditioning.



Many considerations enter into the selection of a refrigeration system. If the user has an adequate supply of steam and water at reasonable cost, a steam vacuum system is recommended for chilling water to temperatures of 45 degrees F. or above.

absolute reliability

If the refrigeration requirement is for a process plant and must go on for 24 hours a day, every day, then Graham SVR would be the answer. The system does its job smoothly and freely without the constant attention of an operator or a multiplicity of controls.

minimum repair costs

Records from many installations show that the costs for repairs or replacement parts average less than $20.00 a year. Obviously, maintenance is not a factor here. Many of these machines have been in continuous service for 20 to 30 years.

water - the only medium

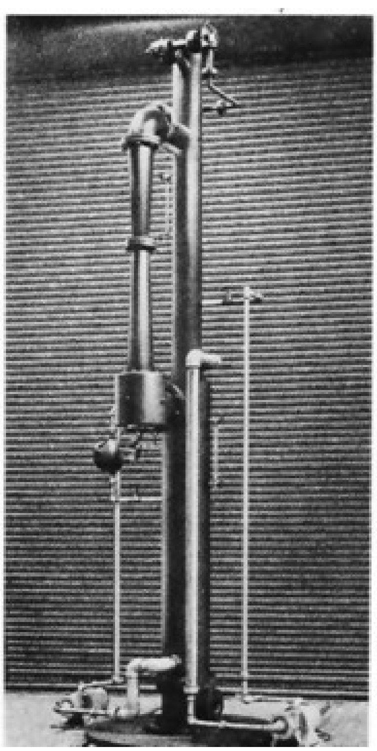
Operation is maintained through a continuous supply of water. No cut-offs due to lack of refrigerant; no costs for replacing expensive refrigerants through normal losses; and no toxic gases.

low pressure operation

Low pressure or exhaust steam may be used.

outdoor installation

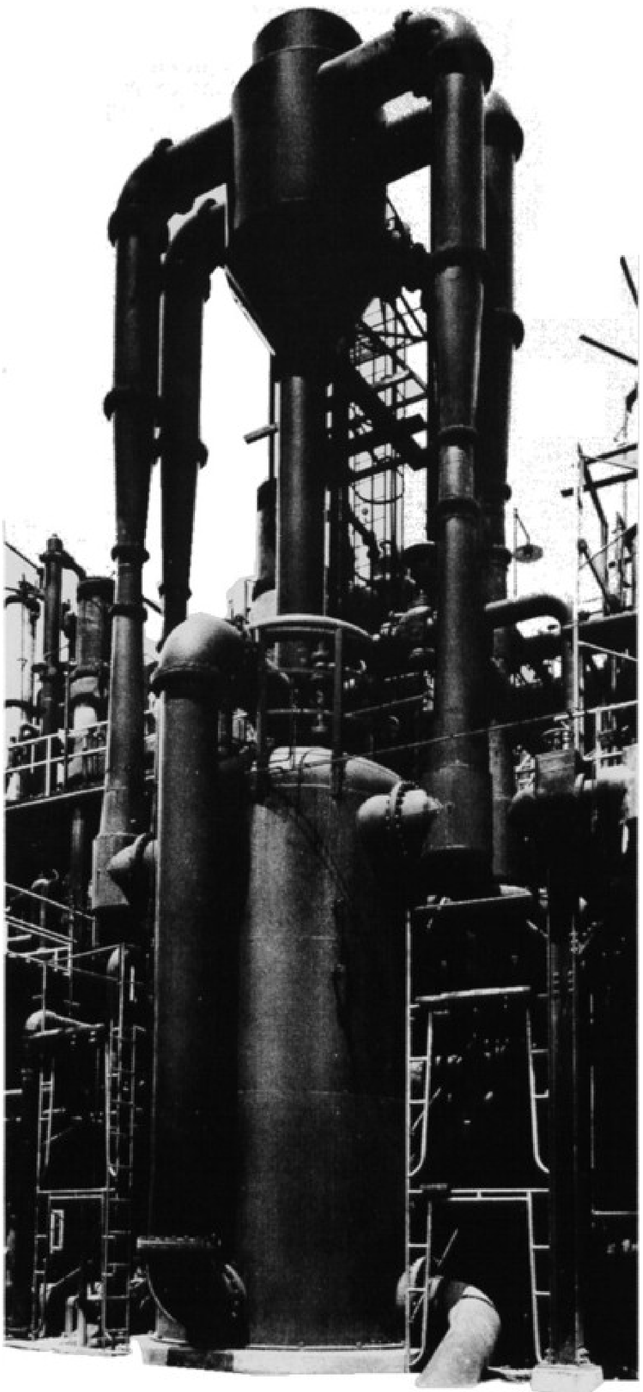
Graham SVR does not require a special building or inside space. The entire unit may be located outdoors. The roof of a building is often a convenient location - a saving in building costs which makes steam vacuum more desirable.



flexibility

Many combinations in arrangement are possible. The flash system and boosters may be situated some distance from the condensing unit, or all parts can be grouped together. The system may be designed vertically, horizontally or in a combination set-up.

*One of the smallest,
6.08 ton machine and air cooler
designed for chemical process plant.*

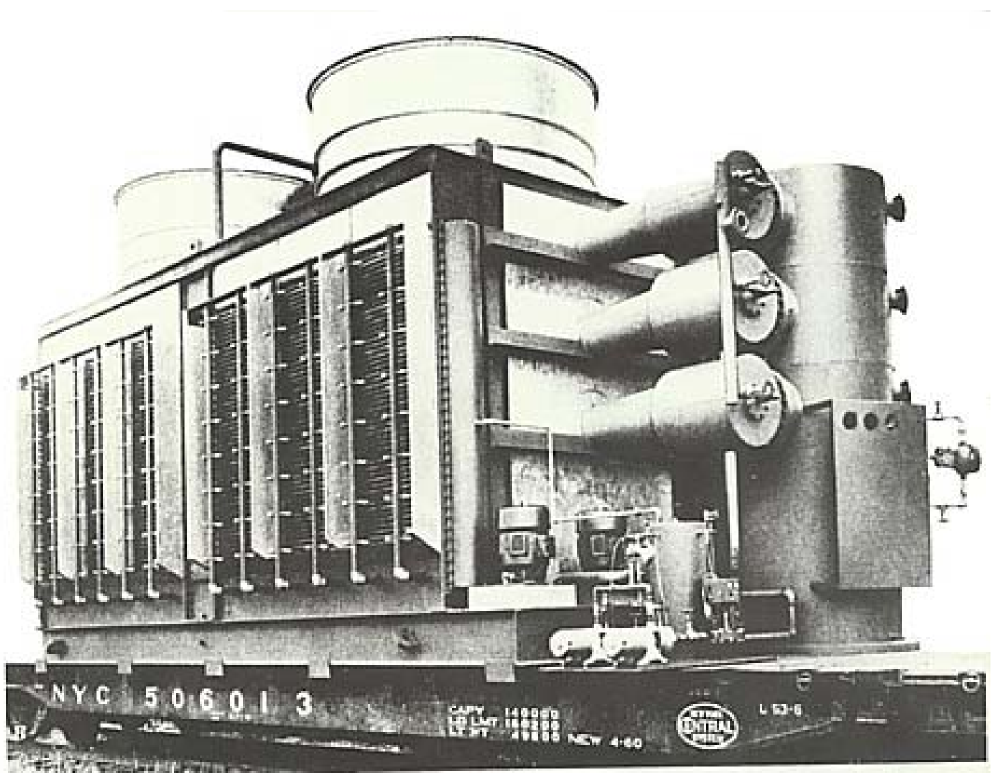


One of the largest.
Modern chilled water system
in large chemical plant.

design versatility

a guide to selection

On the way. 450 ton unit of the evaporative condenser type ready for shipment



The selection of any piece of equipment is usually determined by the end conditions it has to meet. But not always. Other considerations often influence selections, and it is in this area that Graham engineering offers the “extras”.

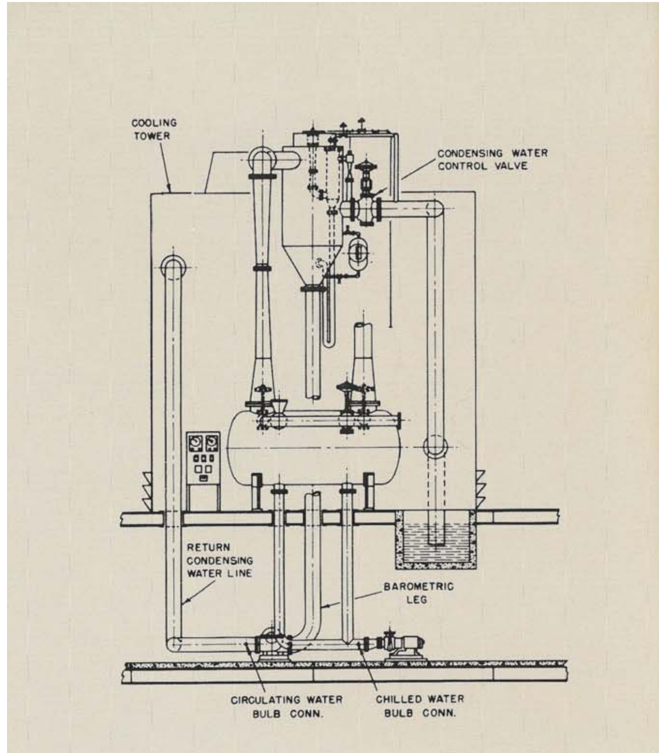
Graham has been solving heat transfer and vacuum problems in the process industries for more than 25 years, so our engineers are capable of coming up with the answers to your requirements.

It must be recognized that 35 degrees F. is just about the limit for chilled water, and, if possible, consideration should be given to producing the same tonnage of refrigeration at a higher temperature, say 45 degrees F. or 50 degrees F., since the higher the temperature of the chilled water the lower the first cost and operating cost.

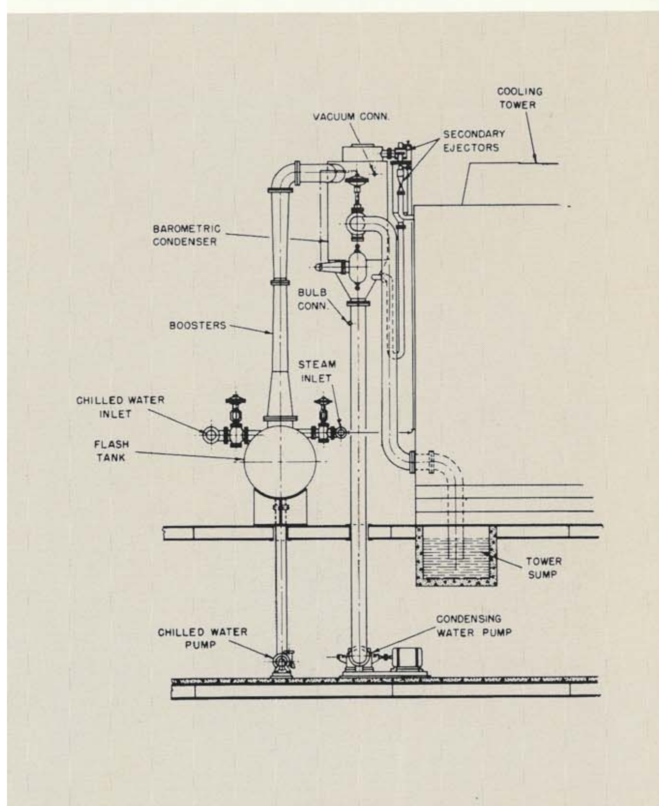
These machines can be designed to use less steam with added cooling water, or more steam with less cooling water. In setting up operating conditions information should be given as to which is more abundant, steam or water. The cost of these utilities should, of course, be considered since various combinations involving steam and water may be worked out to determine the minimum operating cost.

The booster stage may be operated on pressures down to 2 psig, whereas the secondary ejectors should not run on pressures below 25 psig. If pressures 25 psig or higher are not available, then other means of evacuating the main condenser may be supplied.

graham water cooling system



A compact and economical arrangement of a steam vacuum unit mounted alongside its cooling water. Permits condenser vacuum to draw cooling water directly into the jet condenser.



comparison of types

Graham machines are built in three types, the Surface Condenser, the Barometric Condenser and the Evaporative Condenser. The surface type and evaporative type afford a lower pumping cost for circulating water under some conditions but may be subject to cleaning at regular intervals.

The barometric is lower in first cost but does not accomplish the recovery of condensate. It also requires 34 feet for its barometric leg. But, as a “direct contact” type, it does not have the problem of regular cleaning cycles.

A choice can be made only after careful consideration of these conditions.

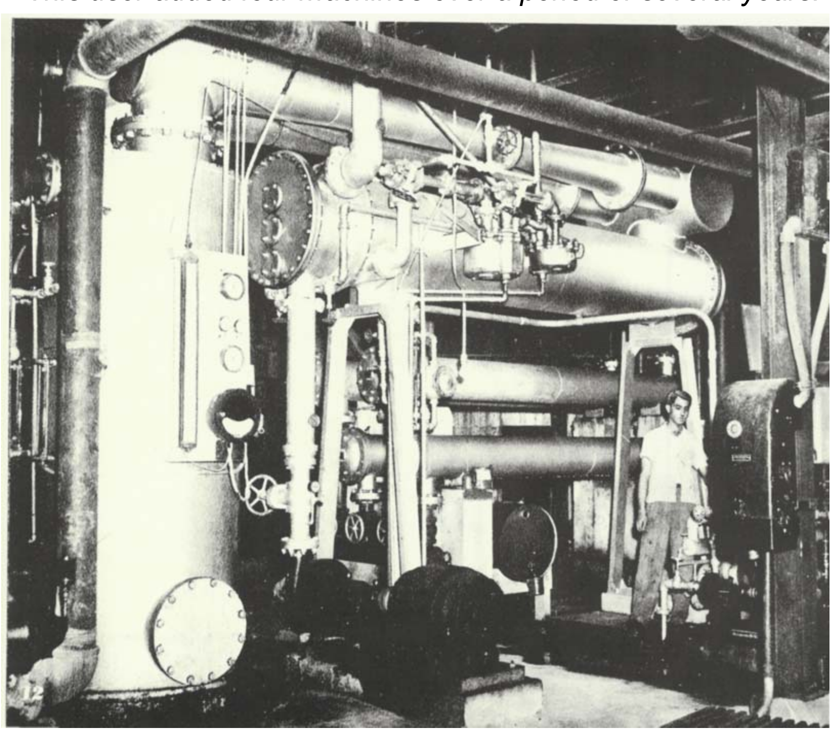
comparison of operations

A compact arrangement of the direct-contact type of condenser without the barometric leg is shown at left. This is typical of a roof installation mounted alongside a cooling tower. Note that the cooling water is drawn into the direct-contact condenser by the vacuum, and a single hotwell type pump returns the water to the cooling tower. This combination offers low first cost typical of the barometric type condenser. It has a relatively low pumping cost because the cooling water is drawn into the condenser by vacuum. A compact arrangement requiring no protecting structure.

Other factors which will govern the most economical operation are the sizes of boosters as applied to particular load patterns, as variations in loads require the use of multiple boosters and control devices which may vary from partial to full automatic. Controls may be installed to provide for conserving steam or water when these are affected by seasonal changes in cooled water temperatures.

general operation

Installation for dissipating heat of fermentation in modern alcohol plant. This user added four machines over a period of several years.



boosters – the steam compressors

When multiple boosters are used, the flash tank is divided into compartments, each operating in conjunction with its own booster. As the load increases or decreases, a booster will be turned on or off, and the water flow to that compartment will be on or off to synchronize with the corresponding steam valve. This may be done by automatic control or by hand.

With multiple flash units, it is possible to orient the assembly to fit any location. The boosters, flash tank and condenser can be designed so that the flash tank is vertical or horizontal (designed for series or parallel flow). There is no known situation where a steam vacuum refrigeration system cannot be designed to fit.

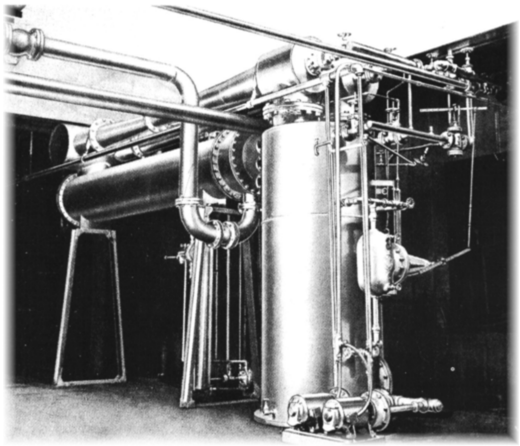
multi-stage flashing

When the cooling range is great – multi-stage flashing is employed.

In this system, chilled water is cooled in stages by flowing from one compartment to another, where successively higher vacuums are maintained. If cooling is in the 20°F. Δt range, stage cooling is usually recommended. The multi-stage unit is offered with manual or automatic control, and here again, the selection depends upon a study of load fluctuations or seasonal effects on cooling water temperatures. In many instances, this multi-stage unit can be supplied at no extra cost, with a saving in steam and water used.

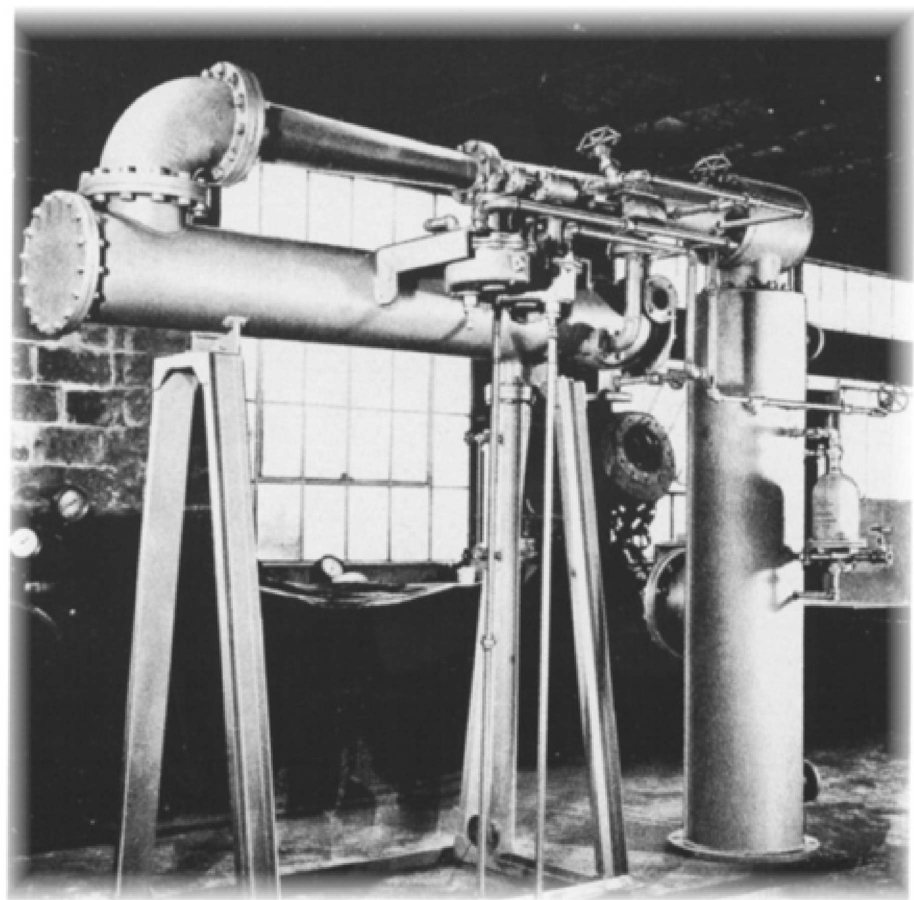
cooling tower operation

If the unit is designed to draw its condenser water from a cooling tower, it is preferable to operate the tower at the highest permissible temperature. This allows a smaller tower because of the great temperature difference between the ambient air and the water to be cooled. The added cost of the larger condenser required here usually does not amount to as much as the saving from the smaller cooling tower.



Dual duty: automatic unit in food processing plant supplies cooling water for air conditioning. The chilled water is then used to cool canned products after cooking.

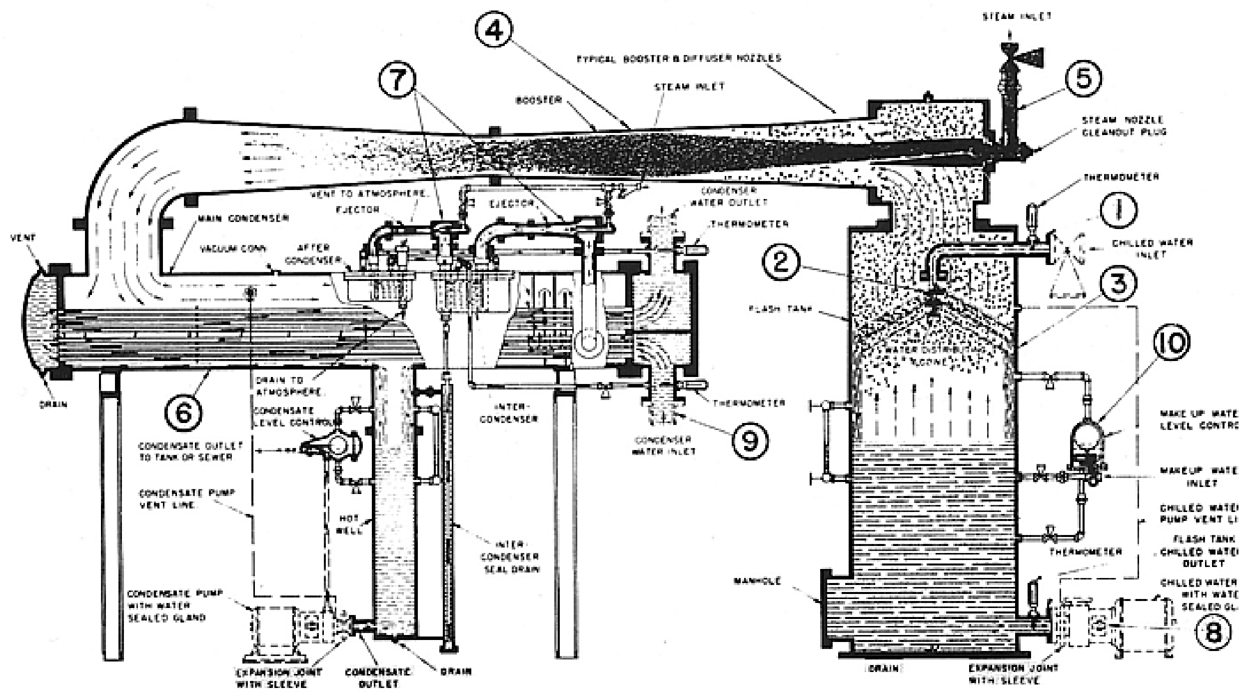
One of many smaller Graham units. Note simplicity of design and accessibility of controls.
As in larger units, design is concentrated on economy and reliability.

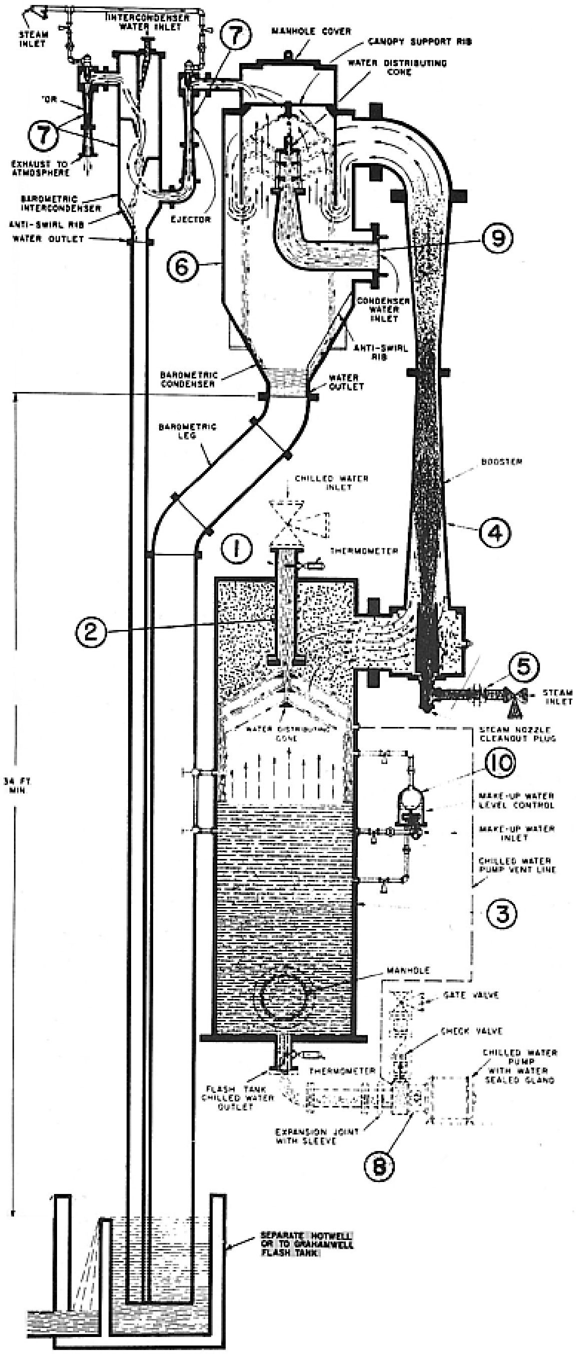


general operation

Sectional drawings of two systems show the surface condenser type below and the barometric condenser type at right.

The numbering is common to both drawings, since the key elements in operation are the same in each system.





1. Water Inlet: Water to be chilled flows to distributors in flash tank

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2. Distributors: Water flows over distributors, flashing off in the form of vapors

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3. Flash Tank: Holds supply of water under vacuum in process of being chilled

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4. Booster: Sets up vacuum in flash tank by action of propelling steam

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5. Steam Inlet: Propelling steam is admitted to booster which draws off flash vapors from flash tank and discharges into main condenser

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6. Main Condenser: Maintains vacuum at booster discharge by means of two stage ejector with inter-condenser

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7. Two Stage Ejector: May be operated at steam pressures of 25 psig or higher

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8. Centrifugal Pump: (Hotwell type) removes chilled water from bottom of flash tank

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9. Condenser Water Inlet: Circulating cooling water through main condenser

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10. Water Level Control: Maintains correct level in flash tank

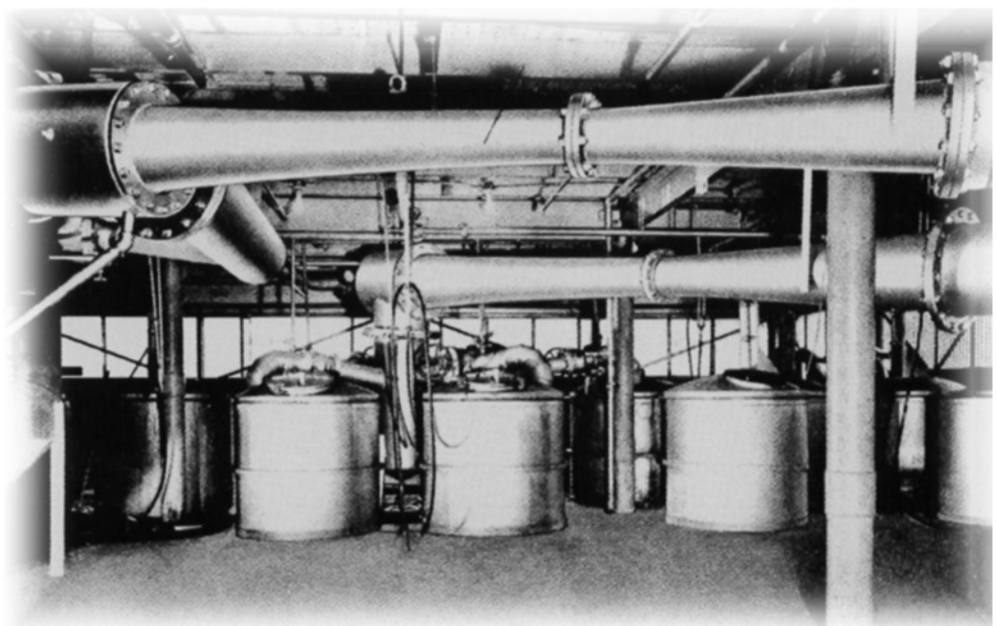
manufacturing & processing applications

Shop view of barometric type assembly scheduled for shipment to large chemical plant.

Many industries use SVR. Graham installations operate in chemical plants, oil refineries and food processing plants; and in the manufacture and/or processing of rubber, plastics, soap, textiles, beer and sugar syrups. The Graham system has been used by almost every industry that requires cold water.

A vacuum system for cooling and concentrating is shown below. A large amount of the water is removed through high vacuum, the addition of heat being provided by the ejector exhaust to produce the concentrated solution.

Many other applications of vacuum to cooling and concentrating situations are far too numerous to describe here. We have mentioned just a few to illustrate the advantages of processing at lower temperatures in this medium. Graham engineers are always available – not only for discussing vacuum problems, but when necessary, to investigate unusual conditions and issue diagnoses or to run tests in the Graham ejector test laboratory in Batavia, New York.



Graham vacuum at work in juice processing.
Most frozen juices processed in the U.S. are flash concentrated and cooled bv SVR.

special situations

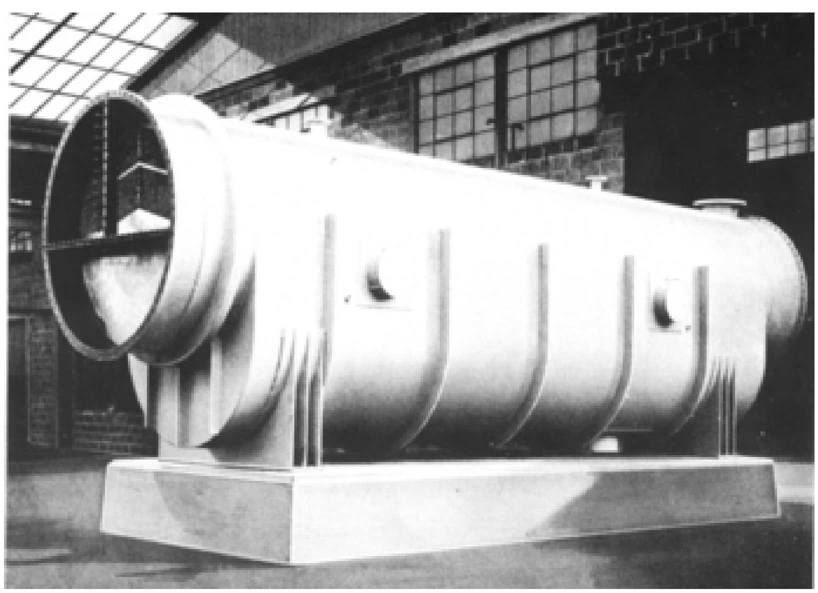
The Graham equipment shown below is installed in a lube oil refinery. The ejectors remove noncondensible gases and water vapor from the refined oil before it is packaged. Refinery installations involve problems not encountered in other services, and should be dealt with by a manufacturer experienced in designing systems especially for this industry. Graham has exactly this kind of experience – built up over the years into a vast accumulation of specialized know-how.

custom adaptations from standard parts

Excellently illustrated below is a Graham system in which the flash tank and condensers are built into one vessel. The lower section contains the flash chamber while the upper section contains spray nozzles or distributors which break up the water to be cooled into fine sheets, providing maximum flashing areas.

Above the spray nozzles, is the condensing zone in which the flashed vapors condense and give off latent heat of vaporization to the condenser circulating water for final heat rejection. This flash cooler is one of a three unit installation, each of which develops the equivalent of 3000 tons of refrigeration.

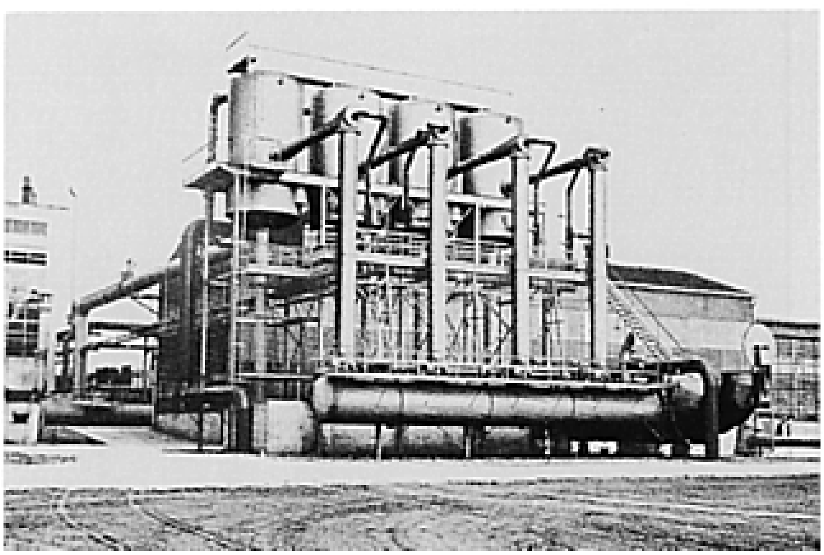
3000 ton flash cooler for nuclear service.



In other modifications of the standard unit, products are admitted directly into the flash chamber where they are cooled and concentrated. This is done, for instance, in concentrating and cooling liquid sugar. It is then processed in two stages. Likewise, concentrating is effected by submitting fruit juices and other food products to vacuum. Heat is frequently supplied through an external tubular heater.

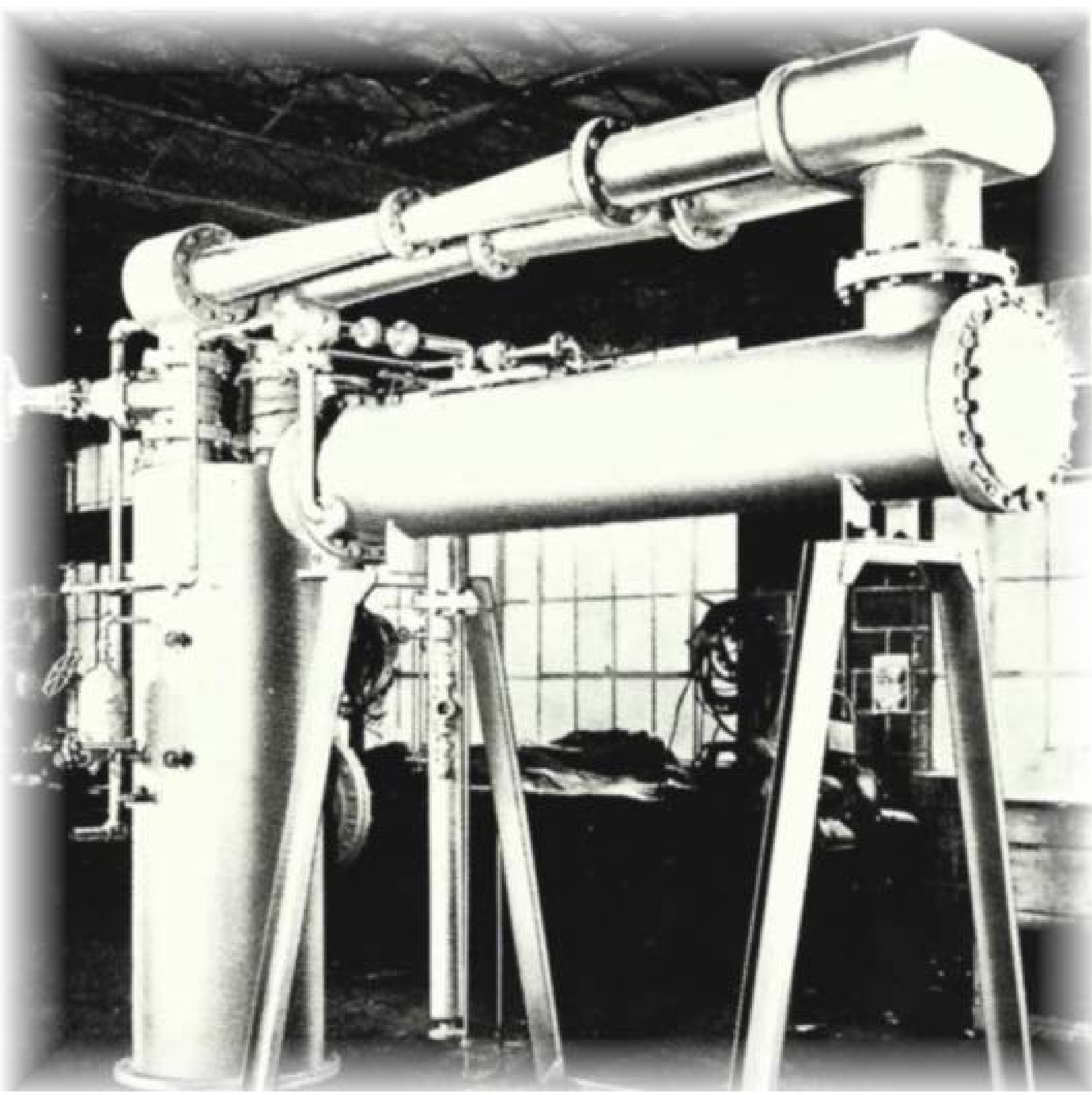
Another departure from the standard Graham application is shown below where some of the largest boosters ever made are evacuating a test cell of its engine gases and maintaining a series of vacuums and temperatures to simulate changes in altitudes. The boosters were taken from a standard system. The barometric condensers into which the boosters exhaust are unusual in that they are multi-stage and cool enormous quantities of fixed gases, as well as condense many thousands of pounds per hour of propelling steam.

Four of the largest steam jet ejectors ever made.
Each booster, compressing enough gas to supply a large community, discharges into a multi-stage barometric condenser/gas cooler.



mechanical features

Fully automatic Graham unit typical of many smaller machines installed inside existing building space.



standard components/special designs

The success of Graham SVR is due to the fact that all important components of all units are custom proportioned for this service, so coordinated that the overall effect is a smoothly functioning, balanced unit.

A steam jet ejector that might be perfect for maintaining a vacuum on a vessel probably would not perform satisfactorily in SVR assembly. A surface or barometric condenser that might maintain the vacuum necessary to operate a turbine or a general exhaust line from pumps might not be suitable as a condenser in a steam vacuum refrigeration unit.

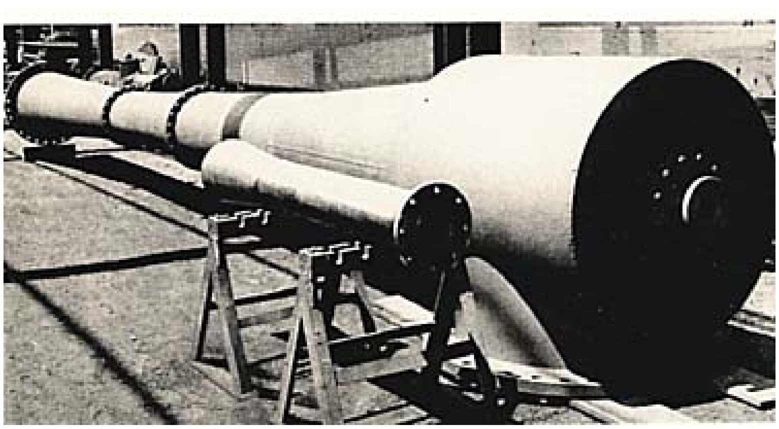
To illustrate: In SVR, ejectors must operate at many points on their characteristic curves, and when under automatic control, they must respond to load conditions immediately. The ordinary ejector, for other than SVR units, is designed about a single operating point and has a normal range of operation. Obviously, the use of such an ejector could have questionable results. The Graham ejector, therefore, is designed and fabricated to contain characteristics which are required for this particular application.

the ejector – heart of the unit

Most Graham ejectors and boosters for steam vacuum refrigeration service, regardless of size, are designed with a single steam nozzle. This means long, continuous service because the nozzle cannot clog easily, is not sensitive to wear, will not vibrate (loosening the nozzle plate) and is easier to work on or replace than, say, a cluster of smaller nozzles.

In effect, the ejector is the heart of the system. Trouble in the ejector means trouble in operating the machine, possibly a complete shutdown. So, the sturdy single steam nozzle is THE all-important feature here. Result: the Graham ejector is foolproof --- 100% reliable.

If multiple nozzles are required for some special design reason, they can be supplied.



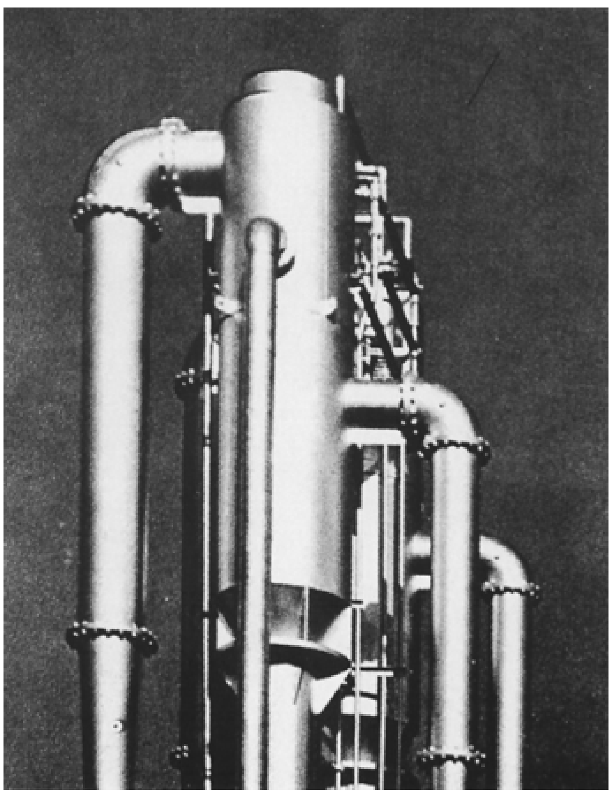
Large first stage booster for 500 ton machine.

Note single non-clogging steam nozzle.

condensers

Since a booster ejector is very sensitive to excessive back pressure, the condenser must be designed to respond to load changes instantly. Otherwise, there would be a lag in the continuous production of cold water. An ordinary surface or barometric condenser probably would not function efficiently in steam vacuum operation.

Graham experience, based on tests over many years, has established the exact proportions of the condenser to the type of operation required.



Graham refrigeration barometric condensers may be lined with rubber or glass; also may be fabricated from reinforced polyester or epoxy material when salt or brackish water is used.

flash tanks

The same holds true for flash tanks. Proportions, sizes and arrangements of water distribution equipment are of great importance, and only experience in designing, building, testing and installing can establish the correct designs for efficient, continuous operation.

Improper design of the flash tank will result in insufficient cooling of the chilled water and excessive carry-over to the customer. By correct proportioning of the flash tank and water distribution equipment, the necessary exposure of water to be flashed and the depth of submergence between compartments are provided – both essential.

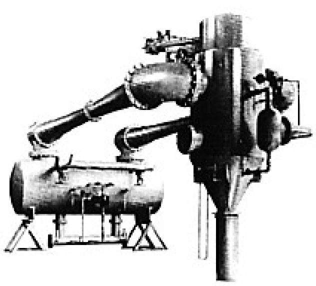
instruments and controls

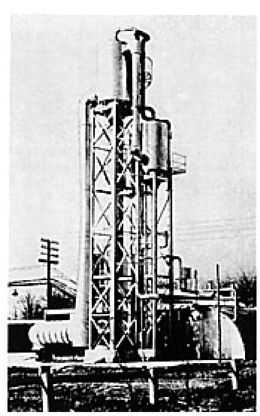
No SVR installation will operate efficiently with the best equipment without an accurate control system. The proper location of instruments, the settings and adjustments are all-important in automatic control, so widely used in these machines. Water levels, steam supply and chilled water temperatures involve the selection of the correct types of instruments. These must be considered in the overall plan of a well coordinated installation. It is in this area that Graham engineering counts heavily. It means that guesswork has been eliminated through long experience.

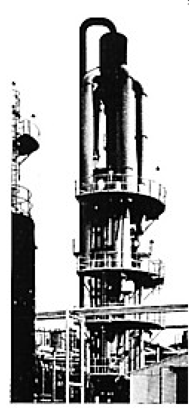
bouquets and buyers

Our best recommendations are those from satisfied users. Our users are not only satisfied; they are enthusiastic supporters. Any operator of this type of refrigeration will confirm that he has never experienced a forced shutdown; that his machine has never frozen; that it can start and stop automatically; that is will run day in and day out without attention and that it will produce useful refrigeration for 20, even 30 years with almost no maintenance.

If YOUR refrigeration requirement is for processing and if this must go on uninterrupted for 24 hours a day, then SVR is for you. Graham has gone all through the development and experimental stages. Every possible defect has been smoothed out or eliminated. On this proved formula, we offer to industry the safest, simplest, most trouble-free system that engineering skills have devised.







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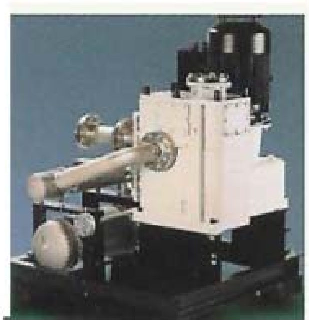

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