

THERMOCOMPRESSORS

MULTI-STAGE EJECTOR SYSTEMS
SYSTEMS □ THERMOCOMPRESSORS □
WATER CHILLERS — CHILL-VACTORTM □
BAROMETRIC CONDENSERS □ LIQUI
MS — SCRUB-VACTORTM □ MULTI-STAGE
LIQUID RING VACUUM PUMPS □ JET B
□ EDUCTORS □ **CROLL-REYNOLDS** □
□ COMBINATION EJECTOR/LIQUID
SYSTEMS □ DISTILLATE RECOVERY
AND BAROMETRIC CONDENSE
POWERED VACUUM SYSTEMS □ CO
RING VACUUM PUMP SYSTEMS □

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THERMO-COMPRESSOR



FIG. 1

INTRODUCTION

Continuing increases in the cost of energy, and projected shortages of fuel oil feed stocks, have re-emphasized the need for the development of alternate fuels and conservation of our present resources. Reclamation and reuse of valuable heat energy from processing operations represents one of the best opportunities for fuel conservation.

Croll-Reynolds has been involved with heat recovery since the early 1940's when thermocompressors were first used by the U.S. food and dairy industries to recapture and recompress spent steam from multi-effect evaporators. Since then, applications for Croll-Reynolds Thermocompressors have continued to increase as process engineers in the petrochemical, chemical, power, food and paper industries find new areas of plant operations where energy from steam can be recovered and reused.

Since thermocompressors operate on a wide variety of motive gases and pressures they offer an unusual degree of flexibility to answer the varied needs of today's process requirements.

The design and construction of a thermocompressor is similar to that of a steam ejector commonly used for producing a vacuum. As an ejector, the thermocompressor consists of four basic parts: nozzle, mixing chamber, steam chest and diffuser, shown in Figure 1.

In basic theory, a thermocompressor and an ejector are identical. The basic difference lies only in the application.

In some cases, an ejector is referred to as a "booster." This term generally applies to a steam ejector that is used to compress or to boost steam or gas to a given pressure and temperature at which it can be condensed.

A thermocompressor, on the other hand, is used to entrain and compress a low pressure fluid to an intermediate, reusable pressure/temperature. The resultant recompressed fluid can then be used for another process and its heat value, which might otherwise have been wasted, reclaimed.

Some applications refer to suction and discharge conditions in terms of "saturation temperatures." A low temperature suction fluid is entrained and mixed with a higher temperature fluid, then discharged at some predetermined intermediate temperature, hence the term "Thermocompressor."

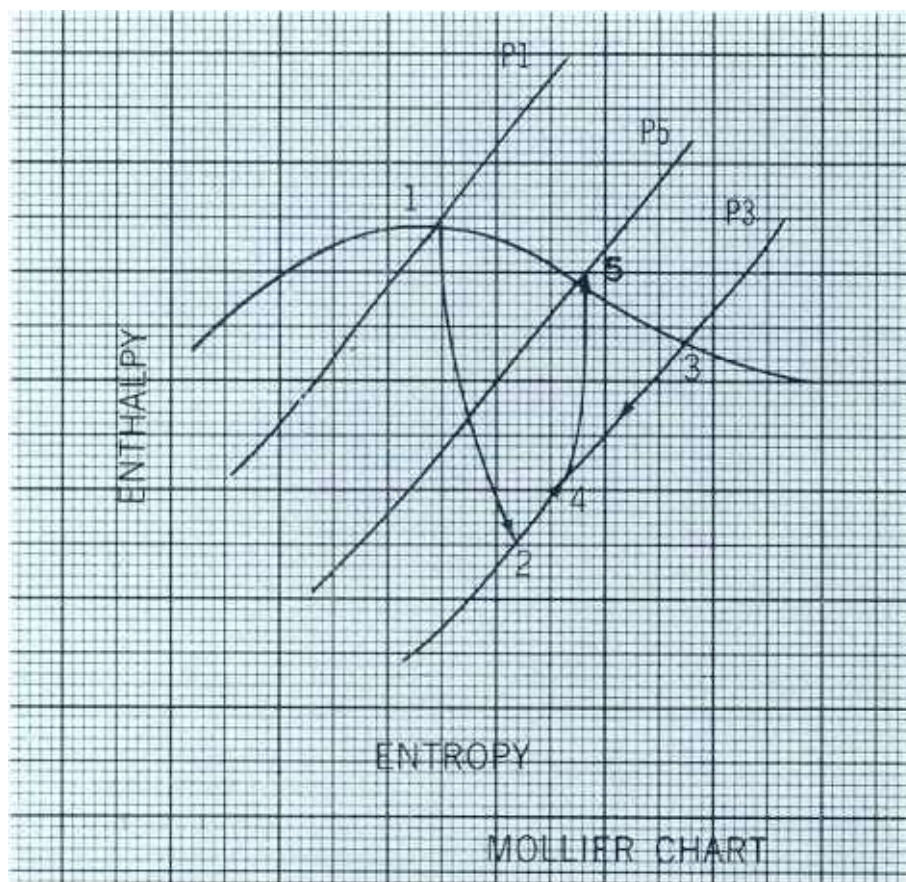


FIG. 2

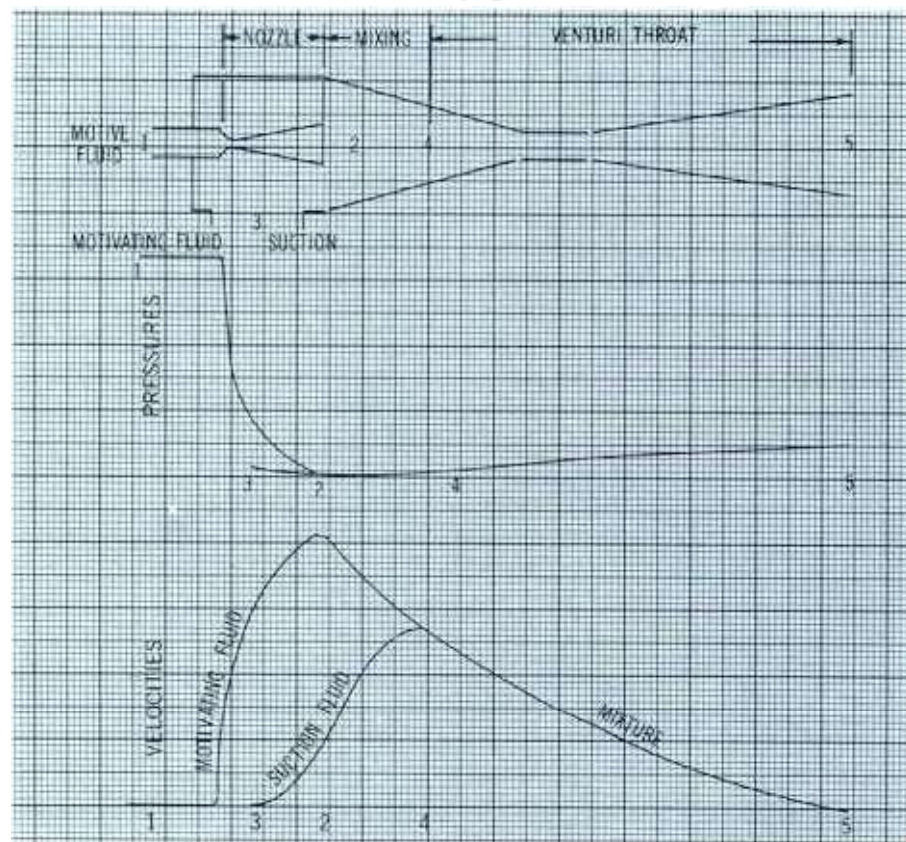


FIG. 3

THERMOCOMPRESSOR OPERATION

A thermocompressor uses high pressure steam or gas as a motive fluid. The motive enters the steam chest and expands through the converging-diverging nozzle.

This high velocity fluid then entrains the suction fluid entering at the suction inlet, forcing both into the mixing chamber where the two fluids are combined.

The mixed fluids are then recompressed to an intermediate pressure through the diffuser, which functions as a nozzle in reverse, reconvert velocity energy to pressure energy.

This three step process can be followed graphically on the Mollier diagram shown in Figure 2. Illustrated is a typical thermocompressor using high pressure steam as the motive fluid and saturated water vapor as the suction fluid. A typical pressure/velocity relationship for a thermocompressor is shown in Figure 3.

THERMOCOMPRESSOR EFFICIENCY

Since the steam thermocompressor principle approaches a theoretically isentropic process, its overall efficiency can be expressed as a function of the entrainment efficiency. Because of impact and turbulence, the entrainment of the low velocity suction fluid by the high velocity motive fluid results in an unavoidable loss of kinetic energy. The kinetic energy of the mixture that remains is only a fraction of that originally possessed by the motive fluid.

The fraction that is successfully transferred to the mixture through the exchange of momentum is referred to as "entrainment efficiency." The portion of the motive energy which is lost is transferred into heat that is absorbed by the mixture, producing an increase in enthalpy.

A thermocompressor has its optimal efficiency at a single set of suction, discharge and motive pressure conditions. At this point, it also has its maximum capacity. Different capacities can be obtained by altering the suction and/or discharge pressures.

Each thermocompressor has a characteristic performance curve as illustrated on Curve CRT #129 (see page 21). Note that the capacity at the given suction and discharge conditions is directly related to the steam pressure. By throttling the steam input to the thermocompressor the steam consumption is reduced, but the compression range is reduced as well. This is not, however, a straight-line relationship. At low pressures, the capacity is reduced more significantly as a function of absolute pressure than at higher pressures.

The steam nozzle is a fixed orifice metering device. Any change in the motive pressure causes a proportionate change in the quantity of motive fluid. This relationship is a function of the ratio of the absolute pressures—for example: a thermocompressor designed to use motive steam at 100 psig will use 43.5% more steam at 150 psig. In the opposite direction, it will use 21.7% less steam at 75 psig. As this relationship indicates, operating at design discharge pressure, while using higher than design steam pressure, will result in wasted steam and higher energy costs.

CRITICAL VS. NON-CRITICAL DESIGN

Thermocompressor designs are defined as either critical or non-critical, depending on the required compression ratio.

When fluid velocity in the diffuser throat is sonic, the design is defined as being critical. For a steam motivated unit, handling steam, sonic velocity exists when the compression ratio (discharge pressure/suction pressure) is equal to or greater than 1.8 to 1.

The value of this ratio changes as a function of the ratio of the specific heat of the motive and suction fluids.

The motive steam pressure used to operate critical design units cannot be decreased without a resulting change in the suction pressure unless the discharge pressure is decreased proportionately. If the discharge pressure is not decreased, a sudden increase in suction pressure will result. This is illustrated by the dotted line on Curve CRT #129. The relationship between motive pressure and discharge pressure depends on the specific characteristics of the individual unit design.

For operating conditions where the fluid velocity is subsonic, (i.e., where the compression ratio, discharge/suction pressure is less than 1.8 to 1), it is known as a "non-critical design" unit. Here, changes in the motivating pressure and discharge pressure will cause gradual changes in both the suction pressure and capacity. While it is possible, in some cases, to increase capacity by increasing the motive pressures, the increase is not proportional.

Lower capacities can be obtained by throttling the motive steam pressure.

THERMOCOMPRESSOR TYPES

Croll-Reynolds fixed-orifice Thermocompressors are available in either single nozzle or multiple nozzle designs. Each has its own distinctive advantages, as outlined below.

Single nozzle units can be equipped with an automatically controlled spindle. This regulates motive steam flow through the nozzle to compensate for varying suction/discharge conditions. The spindle actually adjusts the cross-sectional area of the orifice, thereby changing the motive flow while still maintaining the upstream pressure.

SINGLE NOZZLE

The design and construction of a Croll-Reynolds single nozzle fixed orifice Thermocompressor is similar to that of a standard steam ejector illustrated in Figure 4.

Single nozzle units are used for either critical or non-critical flow, but usually for one set of design conditions only. While a modest degree of variation can be achieved by throttling the motive steam valve upstream of the unit, this reduces the energy available to the thermocompressor, thereby decreasing its efficiency.

The prime advantage of a single nozzle Croll-Reynolds Thermocompressor is its compact size. Single nozzle units are offered in sizes ranging from 2" to 6" suction and discharge, although, larger units can be made available. Where first cost is the prime consideration, single nozzle units are considered. Single nozzle units are the preferred approach where very large compression ratios are involved.

SINGLE NOZZLE SPINDLE OPERATED

The diffuser configuration of a Croll-Reynolds single nozzle Thermocompressor, equipped for spindle operation, is similar to that of a standard fixed orifice unit. The nozzle itself, however, is quite different.

The nozzle and spindle assembly combines a rounded entrance orifice with a straight section into which a tapered spindle is guided (Figure 5). Its operation is very much like that of a needle valve. The length of the spindle travel is based upon actual design specifications.

Spindle operated units are used where suction and discharge pressure vary greatly, requiring large compensating changes in motive fluid flow. Higher efficiencies are obtained by maintaining high motive pressures rather than by throttling.

The pneumatic actuator is an air-to-open device that operates on an air pressure range of 3 to 15 psi. The user's sensing device employed for triggering the actuator may be activated by temperature, pressure, flow or pressure ratio. Typical performance of a spindle operated unit is shown on CRT #148 (see page 21).

MULTIPLE NOZZLE

Croll-Reynolds multiple nozzle Thermocompressors are unique in both design and performance. In most cases, they can offer steam savings of 10% to 15% when compared with single-nozzle units designed for the same conditions. In many specialized installations even greater savings result.

The construction of the multiple nozzle fixed orifice thermocompressor is the same as the single nozzle unit, except that it employs several steam nozzles. The usual configuration has one nozzle on center with remainder of the nozzles equally spaced peripherally around it (Figure 6). This type of unit may be used for applications requiring critical or non-critical flow design. Its characteristic curve is similar to that of the single nozzle unit.

The advantage of the multiple nozzle design is its substantially higher efficiency versus the single nozzle thermocompressor. It is also considerably shorter in length than an equally rated single nozzle unit. Multiple nozzle units are made 8" diameter and larger.

Although multiple nozzle units are significantly more efficient at a given set of conditions than the standard single nozzle design, they have less flexibility than a spindle operated unit, since they cannot automatically compensate for variations in conditions. Since they are designed to operate the same as single nozzle units, throttling the motive pressure reduces the energy available to each nozzle in a multiple nozzle thermocompressor, decreasing its efficiency.

MATERIALS OF CONSTRUCTION

The no-moving parts simplicity of the Croll-Reynolds thermocompressor minimizes costly maintenance and down-time problems. Another outstanding advantage is that it can be fabricated from any workable or weldable material that the user's special needs may demand.

The standard materials of construction for the small, single nozzle units, (sizes #1 through #6) are cast iron body and stainless steel steam nozzle.

Both the spindle operated and multiple nozzle thermocompressors have carbon steel bodies and stainless steel nozzles as standard materials of construction. In spindle operated units, spindle and spindle guide are also stainless steel.

For most conventional applications, these materials will withstand abrasion and corrosion resulting from the passage of steam at supersonic speeds through the basic body and the stainless steel nozzle. However, where highly corrosive conditions exist, or where special industry requirements demand (as in the food industry), units can be fabricated entirely of stainless steel or from Hastelloy, Titanium, and other exotic alloys.

Since the user is best qualified to determine the corrosive properties of the process gas in his application, materials of construction are normally specified by the customer. Croll-Reynolds Company will, of course, offer its technical input based upon our over half century of experience in the design and manufacture of steam jet ejectors and similar equipment for the processing industries.

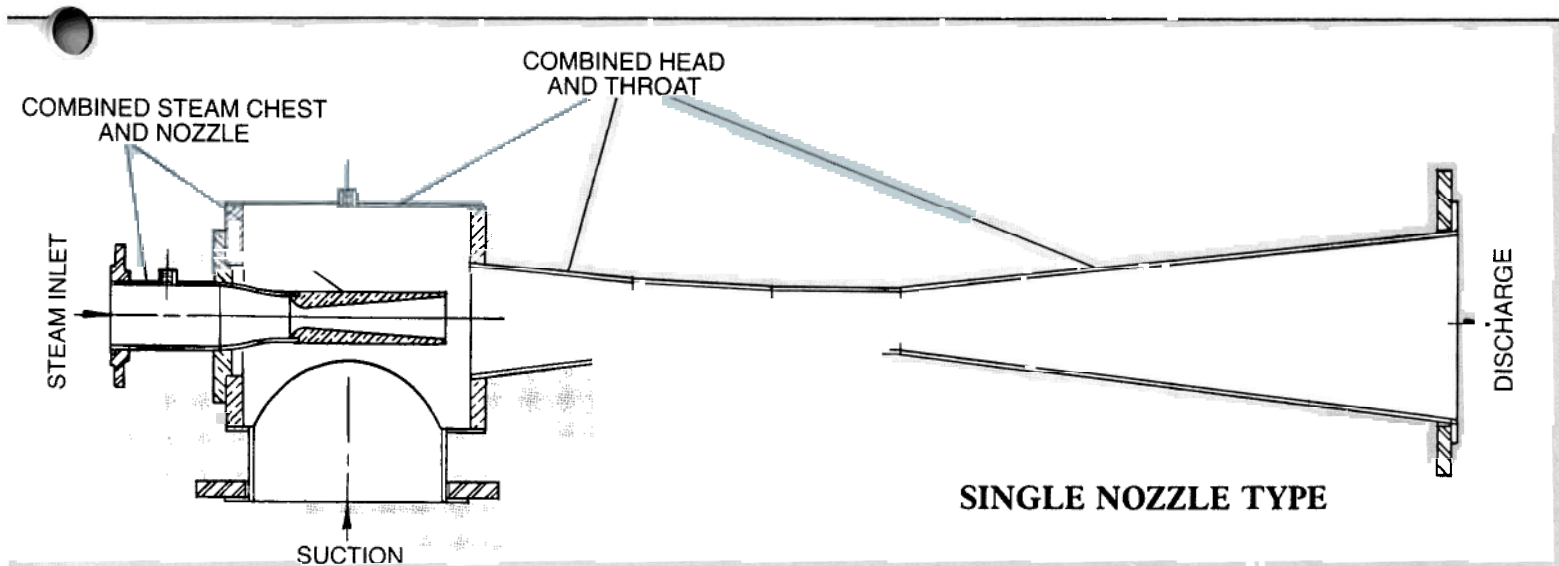


FIG. 4

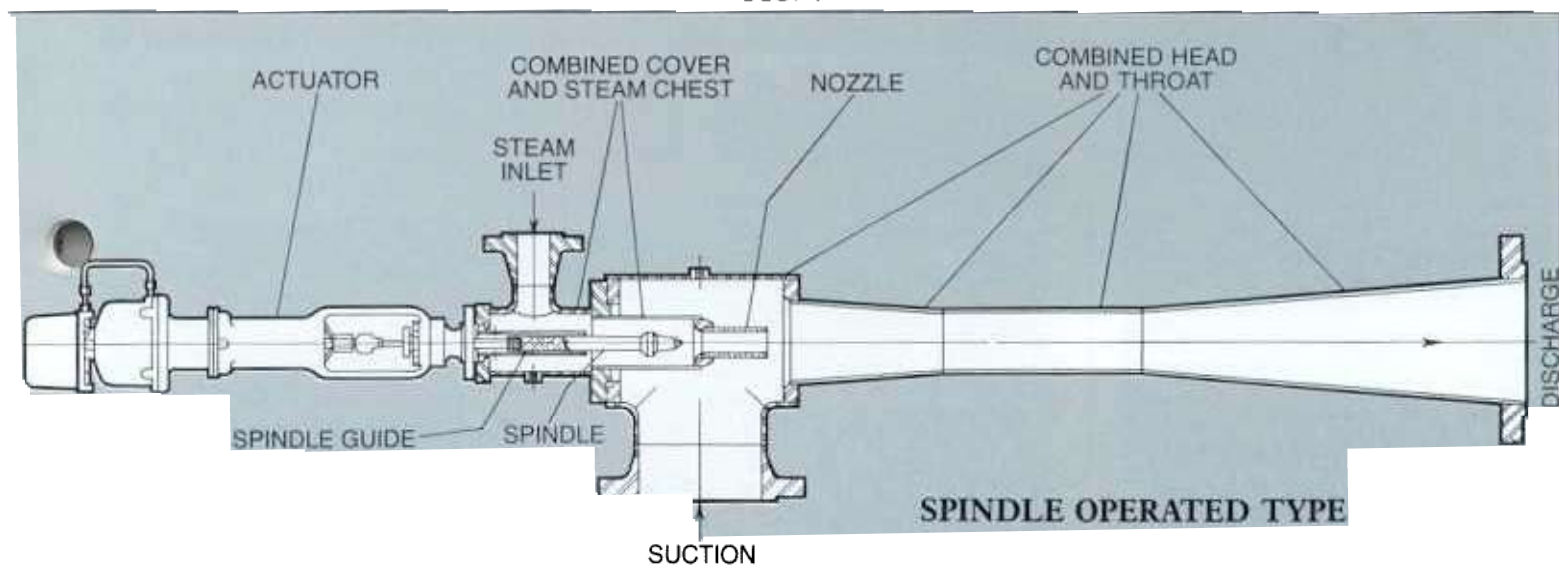


FIG. 5

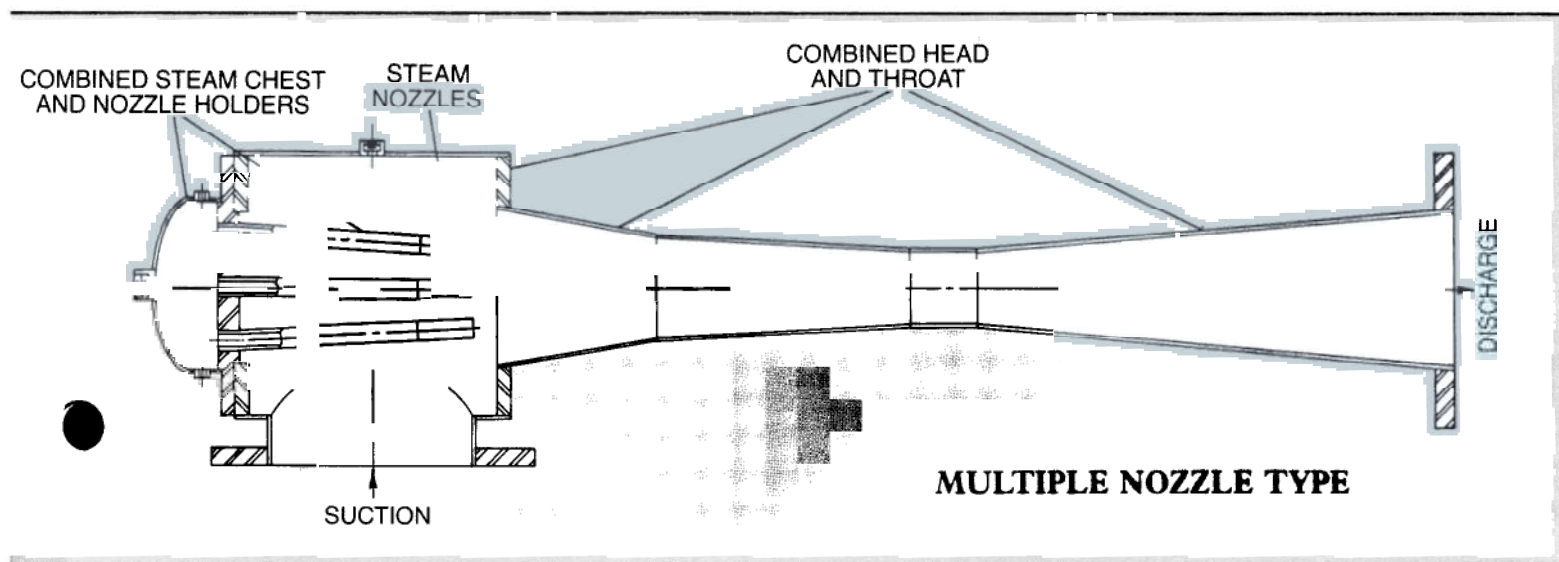


FIG. 6

THERMOCOMPRESSOR APPLICATION

Croll-Reynolds, the leading manufacturer of thermocompressors, has supplied units for a broad spectrum of applications. The following are some examples of the major areas where thermocompressors are effecting significant cost savings.

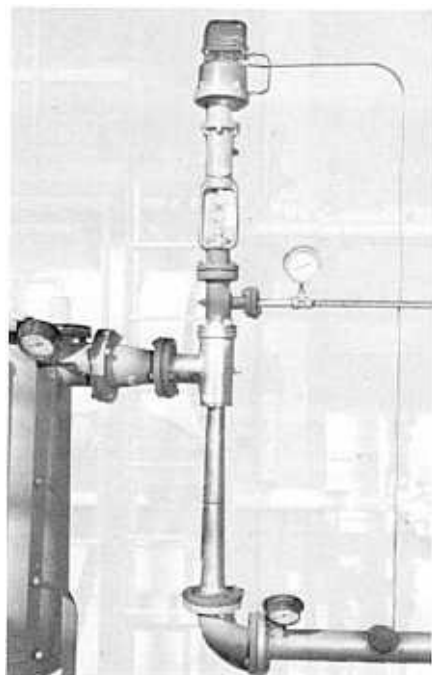


FIG. 7

INDUSTRIES

PAPER PRODUCTION (FIGURE 7) requires tremendous amounts of steam to dry wet films of wood fiber slurry. Spindle operated units provide important energy conservation because of their ability to compensate for variations in the temperature of the dryer and changes in discharge pressure.

PETRO-CHEMICAL PROCESSING EQUIPMENT (FIGURE 8) such as dryers, stills, strippers, and deodorizers usually discharge water vapor at relatively low pressures. A thermocompressor compresses this vapor to a reusable higher pressure.

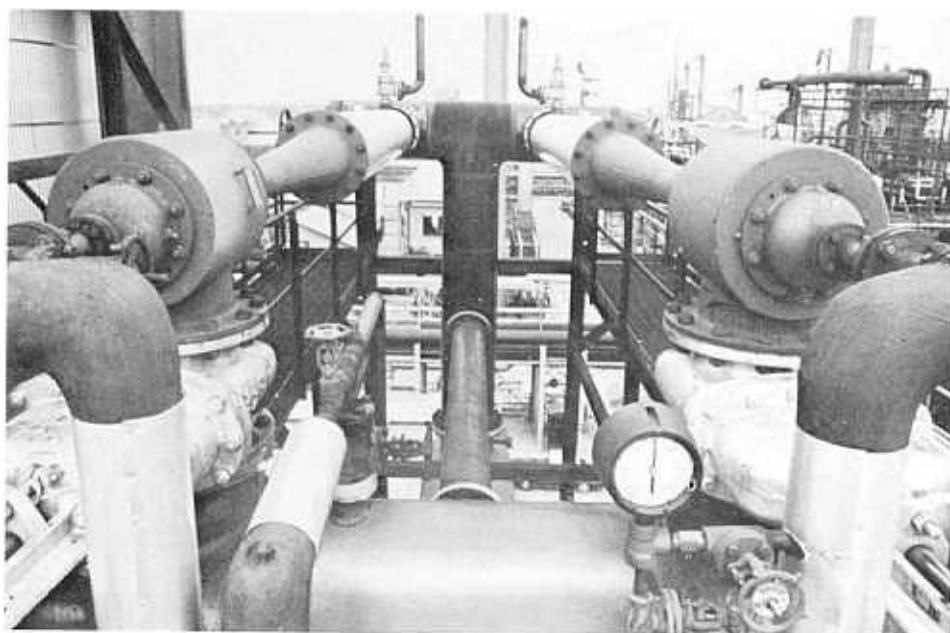


FIG. 8

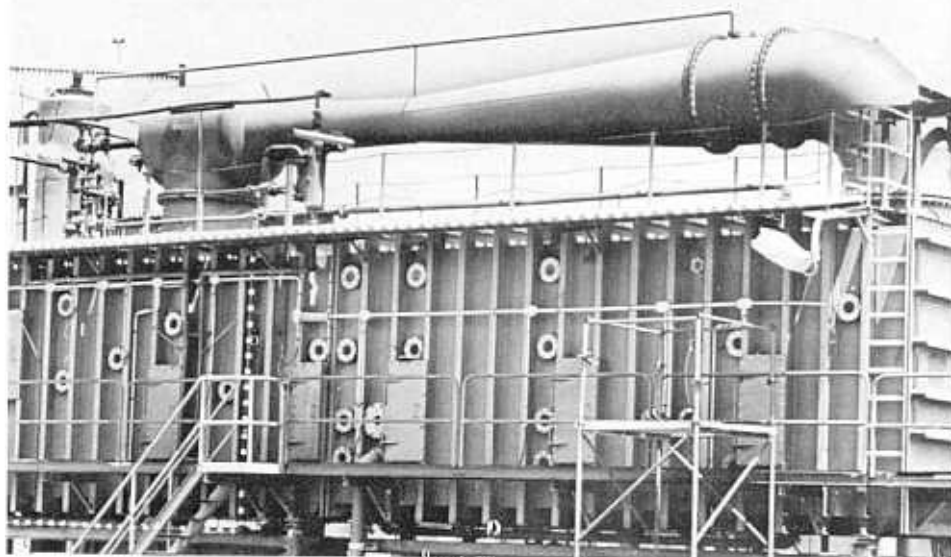


FIG. 9

DESALINATION (FIGURE 9): Multi-effect evaporators used in sea water desalination employ Croll-Reynolds Thermocompressors after the final effect to capture and recycle energy which might otherwise be wasted.

FOOD CONCENTRATES (FIGURE 10) such as fruit and vegetable juices, tomato paste, etc., are processed in evaporators and dryers. Significant savings can result from recompressing the vapors removed from the food products and then returning them to the process at a higher temperature.

PHARMACEUTICAL PRODUCTS (FIGURE 11) are frequently heat sensitive, requiring evaporation or drying at relatively low temperatures. Thermocompressors can yield maximum efficiency when operated at the low temperature ranges required for such applications.

DAIRY AND SIMILAR EVAPORATORS (FIGURE 12) normally operate under a partial vacuum to minimize potential heat damage to the food flavor. Thermocompressors cut costs here.

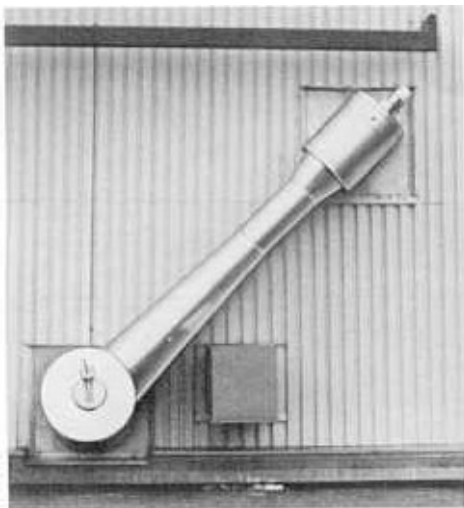


FIG. 10

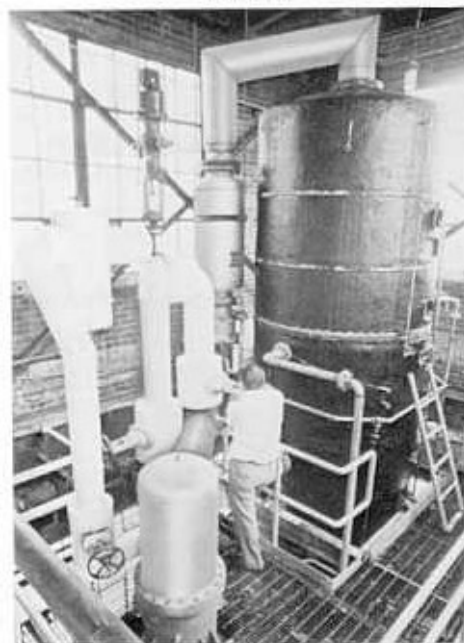


FIG. 11

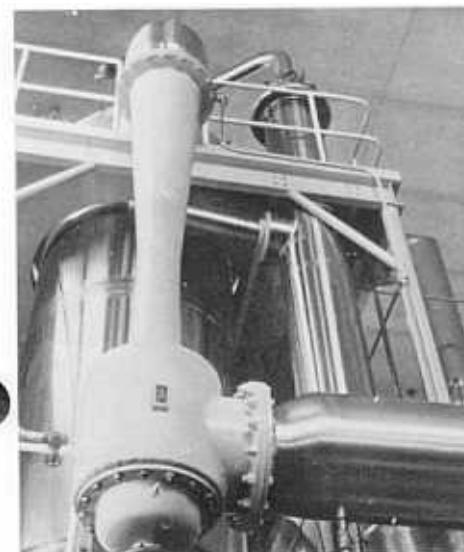


FIG. 12

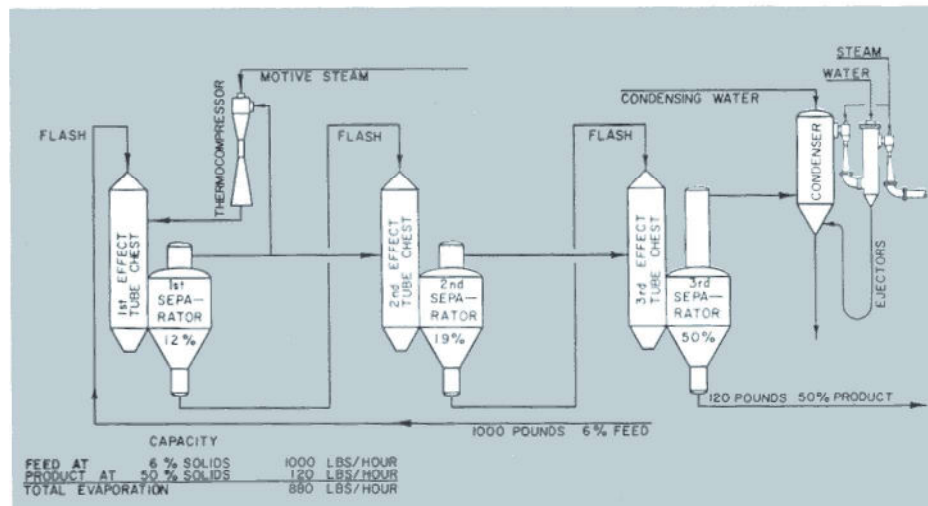


FIGURE 13: Simplified flow chart for a steam thermocompression, triple effect, falling film evaporator. The system processes 1000 pounds per hour of whey from 6 per cent to 50 per cent solids.

APPLICATIONS

EVAPORATORS

Evaporators in general, lend themselves to the use of thermal recompression as an effective method of achieving significant reduction in live steam consumption. A portion of the overhead vapors, which contain significant heating value known as "latent heat of vaporization," can be recycled to the steam chest. The thermocompressor essentially replaces the pressure regulator or the reducing valve that controls the steam pressure and temperature for evaporation. Under most conditions it can easily be applied to single and multiple-effect units.

The thermal recompression evaporator can operate over a much wider range of pressures than a typical mechanical recompression unit. More importantly, a Croll-Reynolds Thermocompressor requires a relatively low capital investment to achieve meaningful energy savings in the overall operation. Properly applied, a Thermocompressor offers energy savings equivalent to the addition of another effect at substantially lower equipment and installation cost.

For these reasons, users are specifying thermal recompression in the initial design of their units. In existing installations, evaporators are being retrofitted to increase their overall thermal efficiency and, in some cases, increase the quality of the end product. Figure 13 illustrates this type of installation.

MIXERS

Croll-Reynolds Thermocompressors can also be used for mixing gases (steam, air, natural gas, etc.) at different temperatures or different pressures to achieve an intermediate condition. The proportion of the two gases can be accurately and consistently controlled. The proportions of the mixture are limited only by the motive-to-load ratio.

PAPER DRYERS

The regulation of steam temperature on the rolls of Yankee Dryers, used in the Paper Industry, is an ideal application for a Spindle Operated Thermocompressor. The pneumatically controlled unit maintains the pressure drop across the dryer to allow for the Delta P through the rolls, flash tank and piping. Equally efficient temperature control is achieved in several other industries with thermocompressors.

WASTE HEAT RECOVERY SYSTEMS

It is the important area of energy conservation that the Thermocompressor exhibits its most cost-effective advantage. In this type of application, "waste" high temperature condensate is collected in a centralized flash chamber then flashed at atmospheric temperature and re-circulated. Condensate from heating jackets or kettles can be flashed, recompressed by the Thermocompressor, and then recirculated back into the jacket, with significant savings in energy costs. The percentage of recovery achieved by this technique is shown in Curve CRT #147 (see page 20).