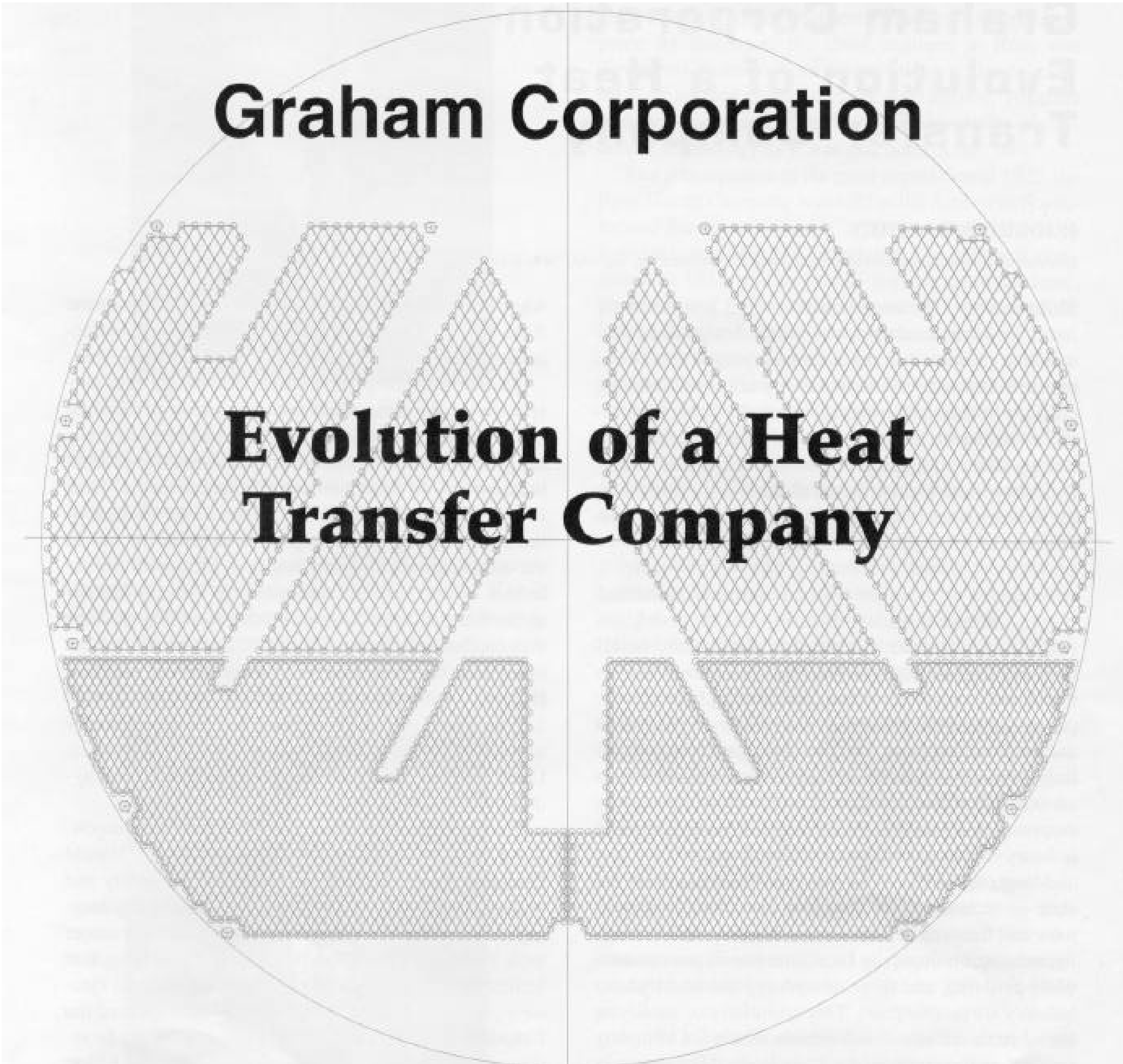
- Heat In History -



Graham - Building tomorrow's solutions through today's vision and leadership in engineering, quality and performance.

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GRAHAM CORPORATION - EVOLUTION OF A HEAT TRANSFER COMPANY

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Today the Graham Corporation designs and builds both heat transfer and vacuum equipment for the chemical, petrochemical, petroleum refining and electric power generating industries, including cogeneration and geothermal plants. The rise of Graham from a fledgling company to a leader in the heat transfer industry is an example of the evolution of a typical manufacturing company, and parallels the advance of the heat transfer industry in the 20th century.

Many engineers have a predisposition to accept the state of technology as they first encounter it in their jobs as "*the way it has always been done*." In reality, most technologically based companies are continuously evolving, and those comprising the heat transfer industry are no exception. This evolution can usually be traced to the efforts of individuals within the company rather than the company as a whole. In this case, as in many others, the growth of Graham as a company can be associated primarily with the founders.

Graham Manufacturing was first incorporated in New York State in 1936 by Harold Graham. The company as it exists today was founded by Harold Graham and Frederick Berkeley in 1941. The association of these two men, however, dates back to the mid-1920's, when they were both employees and stockholders in the Ross Heater & Manufacturing Company, a manufacturer of heat transfer equipment in Buffalo, New York.

To put the state of condenser technology into perspective at the time when the association of Graham and Berkeley began, only 20 years had elapsed since the great battles over condenser technology had erupted in Brooklyn. As described in a 1980 article in the "*Heat In History*" section by Joseph Sebald, the demise of the reciprocating steam engine as a prime mover in the electric power industry began in 1905 with the selection of two surface condensers by Thomas Murray at the Kent Avenue Station. It was becoming obvious that condensers serving engines did not need to meet the more exacting requirements of those serving turbines. Because of the desired low turbine back pressure of 1-2 inches HgA, two-stage vacuum pumps were initially utilized in conjunction with these surface condensers. Later, multi-staged steam jet ejectors replaced the hydraulic pumps.

Harold Graham was born in 1889 in New Glasgow, Nova Scotia. (see Figure 1 for a portrait of Harold Graham). At age 16 he went to McGill University and graduated in 1909 with a degree in Mechanical Engineering. After graduation, he started his engineering career with Westinghouse in Pittsburgh, and it was there that he first became involved in the design of steam jet ejector equipment. During World War I, Harold joined the Canadian Engineers and served in France. When he returned from the war, he was employed by the Elliott Company in Pittsburgh and continued to develop his reputation in the field of steam jet ejectors and vacuum condensers.

Frederick Berkeley was born in Brooklyn, New York in 1901 (see Figure 2 for a portrait of Frederick Berkeley). He graduated from Cornell University in 1923 as a Mechanical Engineer and went to work for the Ross Heater & Manufacturing Company in Buffalo, New York. He had become interested in the design

of heat exchangers while working on laboratory experiments in heat transfer at Cornell.

Not long after Berkeley joined Ross, he was given the task of locating an engineer for the company. Harold Graham was recommended as being a very able engineer in the field of steam jet ejectors and surface condensers. Graham came to work for the Ross Heater Company in the mid-1920's. It was while he was at Ross that he conceived the idea of building surface condensers with welded steel shells rather than cast iron sections. It is believed that the Ross Heater Company built the first fabricated steel surface condensers.

Figure 2 Frederick D. Berkeley (1901 - 1962)

During this period Berkeley and Graham became close friends and stockholders in the Ross Heater Company. At that time, the chief engineer at Ross was Townsend Tinker, whose contributions to the development of surface condensers are well known. Together these men combined to increase the knowledge of condenser technology as it was practiced at that time.

As a consequence of the great depression of 1929, the Ross Heater Company was sold to the American Radiator and Standard Sanitary Corporation (later American Standard, and now ITT Standard). The sale was completed in 1935, and as part of the sale contract, Ross, Berkeley and Graham were required to stay out of the heat exchanger field for a period of one year.

After a year's absence from the vacuum and heat transfer field, Harold Graham incorporated his own company in 1936 as the Graham Manufacturing Company. His reputation as an engineer allowed him to obtain contracts for steam ejector equipment and surface condensers, which he designed and contracted to a fabricating shop in Buffalo to build. He continued this type of operation for approximately two years.

Meanwhile, Frederick Berkeley went to work for the Lummus Company as a sales engineer for heat transfer equipment. In 1938, Harold Graham joined Berkeley at Lummus. In 1941, Berkeley and Graham decided they should form a new company of their own. Scott Ross was brought in as a third partner in the company.

Figure 3 Tank suction heater built for U.S. Navy (1942).

The first contract sold was an order for tank suction heaters for the Navy. (see Figure 3.)

Production of these heaters started in a leased plant in Oswego, New York. It was not long afterwards that the Batavia, New York, plant which Graham now occupies was purchased. Surface condenser units continued to be fabricated in Oswego, while steam ejectors and auxiliary condensers were built in Batavia. Very little commercial work was done during the war years because government restrictions on material made it practically impossible to deliver equipment for non-military purposes.

In 1943 Scott Ross retired and sold his share of the company to Berkeley and Graham. During the war years their effort was almost entirely in the field of surface condensers and heat exchangers for shipboard applications. Graham earned the *Maritime M* and *Victory Fleet* awards from the U.S. Maritime Commission for outstanding production achievement in the design and manufacture of heat transfer and vacuum equipment for World War II. Several hundred surface condensers were supplied for use in T2 tankers, (see Figure 4) and the Graham design was adapted throughout the maritime for shipboard

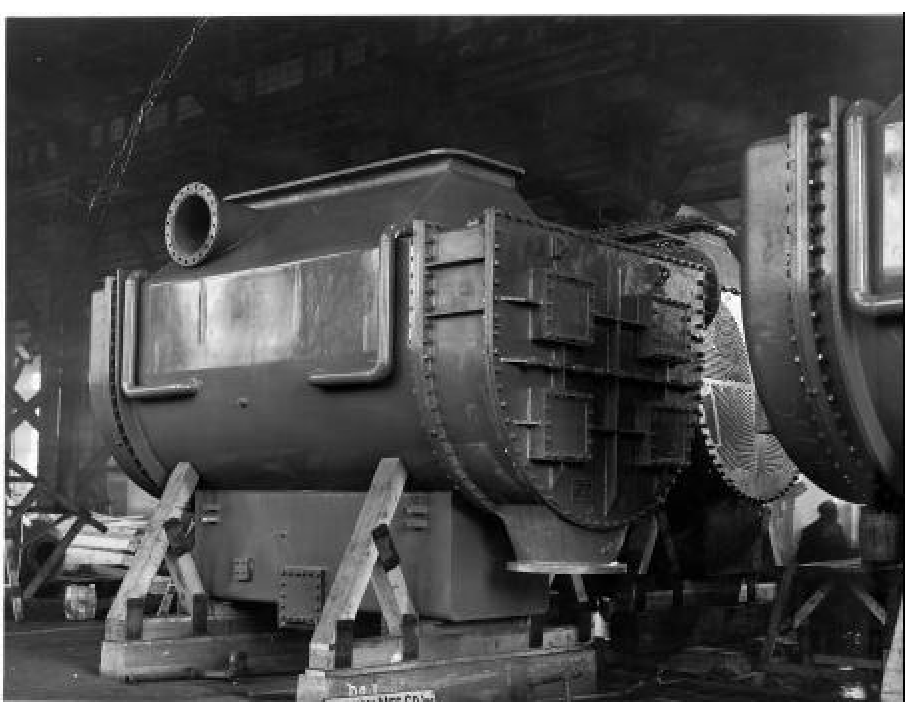

Figure 4 Main surface condenser for T2 tanker ships (1942).

Figure 5. Steam Vacuum Refrigeration Unit

applications.

At the end of World War II many government contracts were canceled and production was cut back. It took tremendous effort and determination on the part of the Graham organization to convert the operation to commercial applications. Graham Manufacturing became well known in the fields of shell and tube heat

Figure 6. Frederick D. Berkeley III

exchangers, evaporators for power plant use, deaerating feedwater heaters, steam vacuum refrigeration systems, steam jet ejectors, vertical marine evaporators, surface condensers, barometric condensers, and a new design, the Heliflow heat exchanger. The Heliflow design was an invention of Harold Graham, built during the 1940's for boiler sample cooling. It proved to be such a successful design that it was patented and later adapted to commercial applications.

Following World War II, Graham became involved in the development of steam vacuum refrigeration units, (see Figure 5) which were primarily utilized by the pulp and paper industry. The continuous demand for large amounts of cold water for these processing plants could be satisfied through the utilization of booster ejectors. Low pressure waste steam from the plant heating boilers was used with booster ejectors to lower the makeup water temperature to below 40^{o}F through evaporative cooling under vacuum conditions.

The leadership of the company changed hands following the death of Harold Graham in 1956.

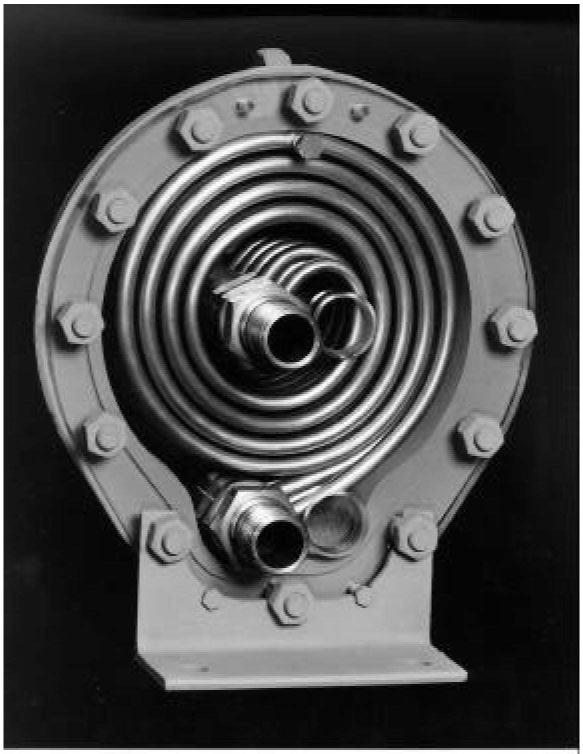

Figure 7. Heliflow Heat Exchanger

Frederick Berkeley succeeded him as president. In 1962, Frederick Berkeley III became president of the Graham Manufacturing Company. (see Figure 6 for portrait of Frederick Berkeley III).

In many ways the story of the growth and change of Graham illustrates the evolution of the heat transfer industry during this century. Unique opportunities to apply the heat transfer expertise of a company become available through exposure to diverse industries. As with other companies in this field, the future of Graham lies in new applications of heat transfer and vacuum equipment for the growing needs of industry. As an illustration of this, three unique opportunities to apply the heat transfer expertise gained through experience are described in the following examples. In each case, knowledge from various disciplines is required to meet the requirements of a specific application.

EXTREME OPERATING APPLICATIONS

Essentially, the Heliflow is an embodiment of the familiar shell and tube heat exchanger, with the tubes coiled in a spiral configuration and enclosed in a casing (see Figure 7). The primary advantage of the Heliflow is in its compact arrangement of coiled tubes. Because of the unique design, a Heliflow can support processes that operate under extreme conditions of temperature and pressure. As an example of operating under extreme temperatures, the capture and reclamation of volatile organic compounds from process streams often occurs below -100^{o}F. Information from several disciplines was necessary to establish design techniques to model performance in an application involving both the freezing of hydrocarbon fluids and the assessment of reclamation efficiency as a function of time. Furthermore, it is essential to understand heat transfer characteristics for the vaporization of LN_2, as liquid nitrogen is often the cryogenic fluid of choice.

Heliflow heat exchangers can also be used where the operating pressure is extremely high. Examples of this type of application would be: (1) supercritical water oxidation, where water is pressurized to 3300 PSIG at temperatures above 720° F; (2) supercritical fluid extraction, with N-pentane above its critical point; and (3) for enhanced oil and gas recovery, where nitrogen is pressurized to 10,000 PSIG for injection into a well to displace oil and gas.

DO_2 SYSTEM

Also in the 1980's, the demand for cogeneration and combined cycle power plants increased due to favorable legislation and financial considerations. It has long been recognized that the performance of a surface condenser is dependent on numerous factors. The amount of noncondensible gases in the condenser tube bundle space is certainly one of

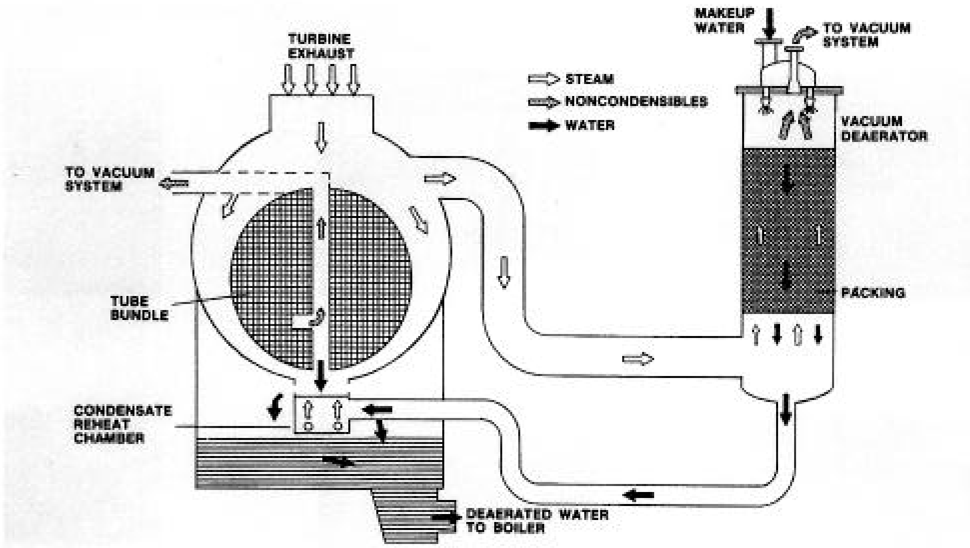

Figure 8 Condenser/vacuum deaerator flow schematic.

the most important variables, since the amount of dissolved oxygen in the outlet condensate is related to the concentration in the vapor phase. In order to enhance condensation, it is necessary to control both the noncondensible gas concentration and its distribution inside the unit.

In a cogeneration system (and similarly in a combined cycle system) a significant portion of the boiler steam is consumed as part of the normal operation. Under these circumstances the addition of makeup water containing large amounts of oxygen into the condenser would result in an unacceptable concentration in the condensate leaving the hotwell. It became apparent that supplementary treatment was required.

Again, the solution to this problem requires a combination of knowledge from several sources: heat transfer, deaeration, power plant operation. In the system that was developed to treat the continuously varying influx of makeup water, the main condenser is connected to a vacuum deaerator where water is introduced into the boiler feedwater system. Water to be deaerated enters the vacuum deaerator, where it comes into contact with exhaust steam from the main condenser. The primary removal of the noncondensible gas occurs in the packed section of the vacuum deaerator where both contact area and residence time are optimized (see Figure 8). Noncondensible gas and water vapor are vented from the system through a small booster ejector to a hybrid vacuum system connected to the main condenser. A number of these units are currently operating successfully in both cogeneration and combined cycle power plants.

VACUUM CONDENSER TECHNOLOGY

Another example of utilizing knowledge from various disciplines to meet the requirements of a specific application was the result of combining vacuum engineering technology with heat transfer to support the expansion in refining and petrochemical markets that took place in 1970-1990. The applications are very demanding, and commercial software does not reliably predict vacuum condenser performance.

One instance of this occurs in urea fertilizer plants, where process loads from vacuum concentrators contain air, water vapor, ammonia and carbon dioxide. It this case it is essential to be able to predict condenser performance where the application is under a vacuum (70-225 mm HgA), but also involves both phase and chemical equilibrium calculations, plus the build-up of reaction products. Water, ammonia and carbon dioxide systems undergo several electrolytic chemical reactions that are exothermic in nature. Developing a design methodology for this service is extremely difficult

A second application for vacuum condensers is in the oleochemical market (glycerin, fatty acids and fatty alcohol's), where the use of vacuum precondensers ahead of a vacuum system is common. These vacuum condensers operate at very low pressure (less than 10 mm HgA), and the prediction of thermal and hydraulic performance under such conditions is complex. Condensers must be designed that provide a low pressure drop (a must at such low operating pressures) and adequate condensation, along with noncondensible gas cooling.

Industry continues its pursuit of improvements in process efficiency, pollution reduction and less costly routes to manufacture their products. The challenges of industry in this regard fall on the doorstep of the heat transfer community because heat exchange is vital to most unit operations.

The story of Graham is illustrative of how heat transfer companies have a positive influence on processes and unit operations within the expansive chemicals, petrochemicals and refining market sectors.

Roderick E. Athey is Director of Research and Developr for Graham Corporation in Batavia, New York. His rese projects at Graham encompass investigations in the fi of heat transfer (condensers, deaerators, coiled-tube exchangers etc.), and vacuum technology (ejec vacuum pumps, and noncondensible gas removal condensers). He has been active in the developmen products for the power, chemical process, and industries.
Before joining Graham, Dr. Athey was Technical Director for Chicago Heater Company and for the Marley Heat Transfer Company, major suppliers of both deaerators and condensers. He received a Ph.D degree from the University of Kansas in Chemical Engineering, where his research was in the areas of boiling heat transfer. He has published articles on noncondensible gas removal in condensers and has a number of patents in this field. Dr. Athey is a licensed Professional Engineer in New York, Colorado, and Kansas.