

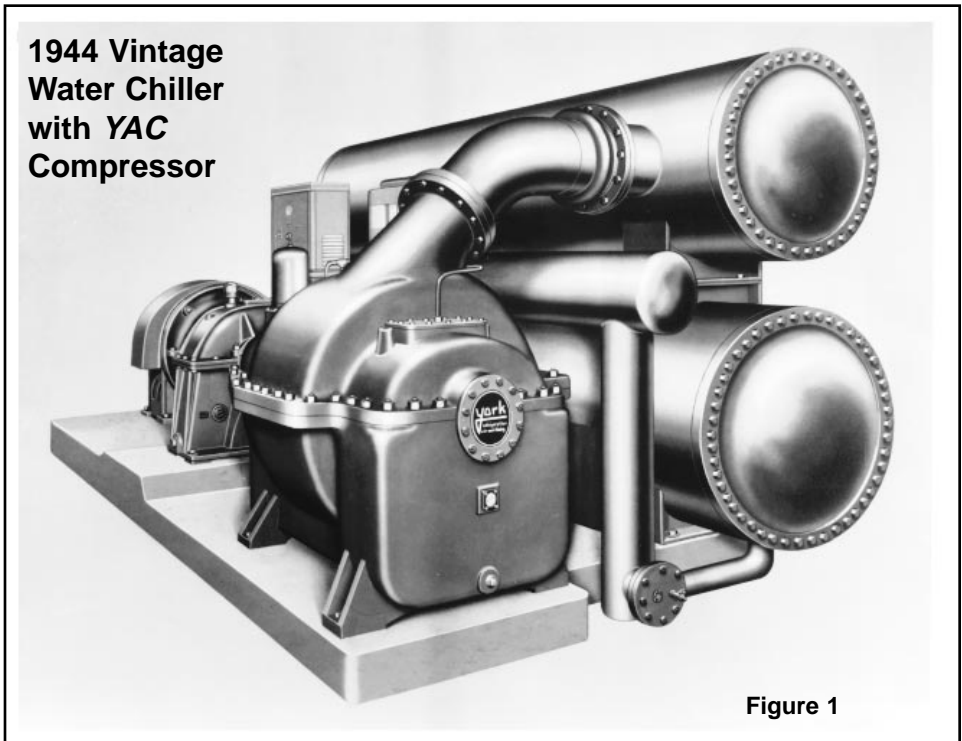
# YORK<sup>®</sup> Centrifugal Compressors

## A BRIEF HISTORY...

### YAC COMPRESSORS

Originally, YORK's centrifugal compressors (for many years called "turbo" compressors) were two and three-stage air-conditioning machines manufactured for YORK by the Allis-Chalmers Manufacturing Company in West Allis, Wisconsin under a licensing agreement entered into by the York Corporation and Allis-Chalmers in 1938. Allis-Chalmers was itself licensed to manufacture centrifugal compressors by the Brown Boveri Corporation in Baden, Switzerland. Because Brown Boveri was a prestigious manufacturer of turbomachinery that had been manufacturing centrifugal air-conditioning and refrigeration compressors since 1925, YORK's early sales literature cited the Brown Boveri connection with Allis-Chalmers as evidence of the high quality of the YORK Allis-Chalmers (YAC) design.

The first of the "YAC" compressors, as they came to be called, was a test compressor built in West Allis in 1939. The first production unit was shipped from West Allis in 1940. The heat exchangers and



1944 Vintage  
Water Chiller  
with YAC  
Compressor

Figure 1

accessories needed to make a complete water-cooling (air-conditioning) system were manufactured in York, Pennsylvania. Manufacture of the compressor was shifted to York in 1942.

A unique feature of the YAC compressors, beginning in 1941, was their use of "pre-rotation vanes" (PRV) to adjust compressor performance for part-load operating conditions. The "PRV", as they were named, were adjustable guide vanes located at the inlet of a compressor's first centrifugal impeller.

The vanes could swirl (rotate) the refrigerant flow as it entered the impeller and thereby reduce the volume of flow through the impeller when the cooling load was reduced. Other manufacturers used bypass valves and throttle valves to reduce load. YORK's inlet guide vanes produced more efficient part-load flow reduction than did the control valves used by others. Today (1996) every centrifugal compressor manufacturer in the air-conditioning industry uses inlet pre-rotation vanes for part-load capacity control.

## YAC Chiller Cut-Away

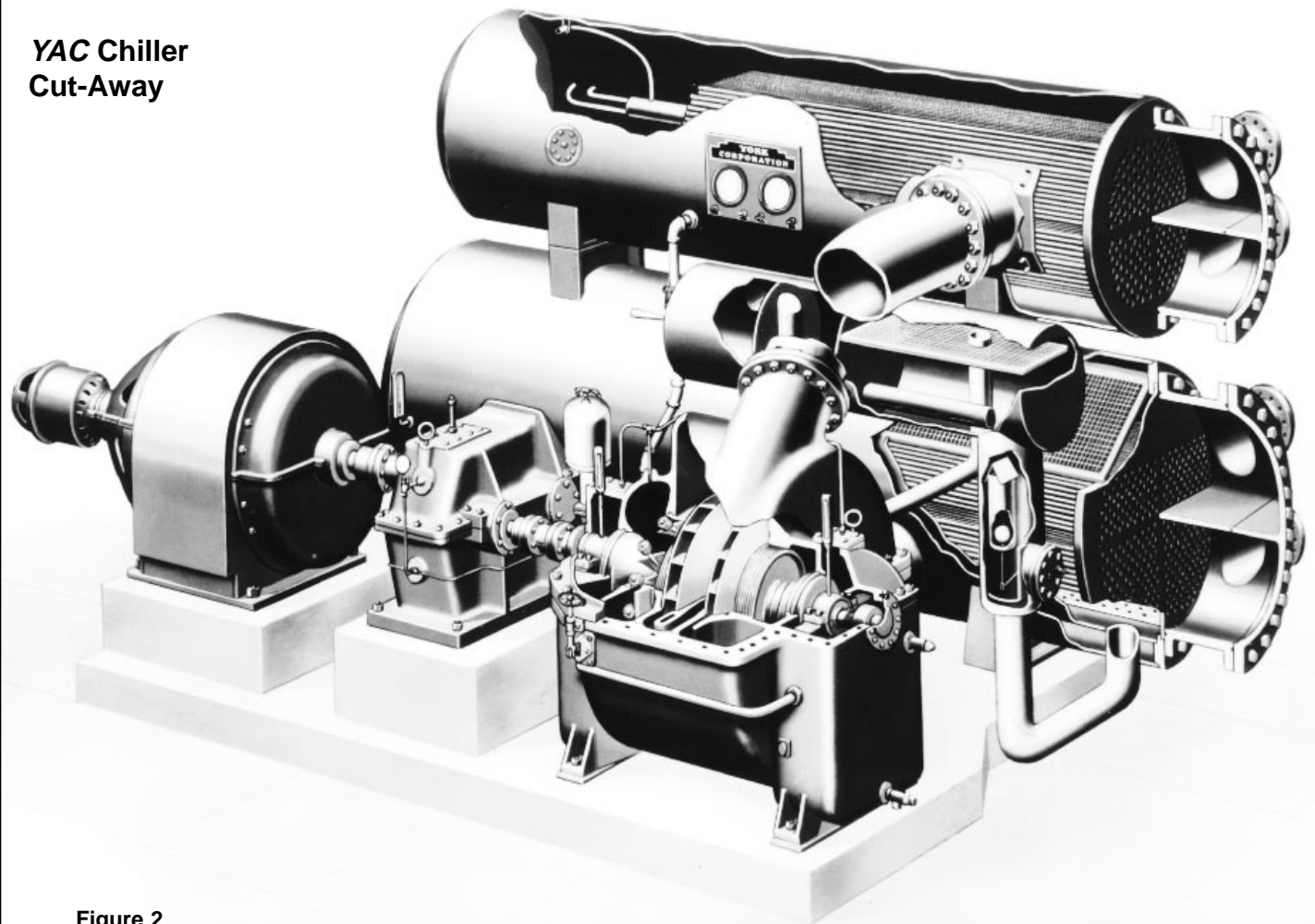


Figure 2

Some four-stage YAC refrigeration compressors were manufactured in York, beginning in 1945. YORK terminated its licensing agreement with Allis-Chalmers in 1954, but continued to produce two, three, and four-stage compressors of the YAC design until 1960. There were 943 YAC compressors manufactured in four frame sizes between 1939 and 1960. These compressors used refrigerants 11, 12, 13, and 114. Their largest horsepower was 2500. Their air-conditioning capacities ranged from 200 to 2200 tons. Their low-

est refrigeration temperature was -130 deg F. Figures 1 and 2 show YAC compressors in water-cooling systems. These figures were first published in a YORK advertisement that appeared in *Refrigerating Engineering* in 1944. *Refrigerating Engineering* was a monthly magazine published by the American Society of Refrigerating Engineers (ASRE), one of the two societies that merged in 1959 to become the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

One of the YORK exhibits at the Industrial Museum of York County, on West Princess Street in York, is a two-stage YAC compressor that was manufactured in 1951. This compressor used refrigerant 11 to produce 206 tons of air conditioning for a hosiery mill in North Carolina.

The YAC compressors were replaced by two new YORK designs, the Series L compressor in 1954, and the Series M compressor in 1956.

## L COMPRESSORS

The first of the new compressors, known as “L” compressors, used refrigerants 11 and 114 in two frame sizes for air-conditioning capacities between 90 and 600 tons. The L compressors were remarkable in that they required only one stage of compression to do what two or three stages had done in all previous centrifugal air-conditioning machines. This made L compressors much smaller and simpler than other designs.

YORK’s single-stage centrifugal air-conditioning compressor was an industry “first” that was copied, in

one form or another, by almost every other centrifugal air-conditioning manufacturer in the world. Even the Trane Company, which makes a point of only using multi-

stage centrifugal compressors in North America, uses a single stage compressor for the 50 Hz market in Europe.

1954 “L” Compressor Used in the New Bldg. 19

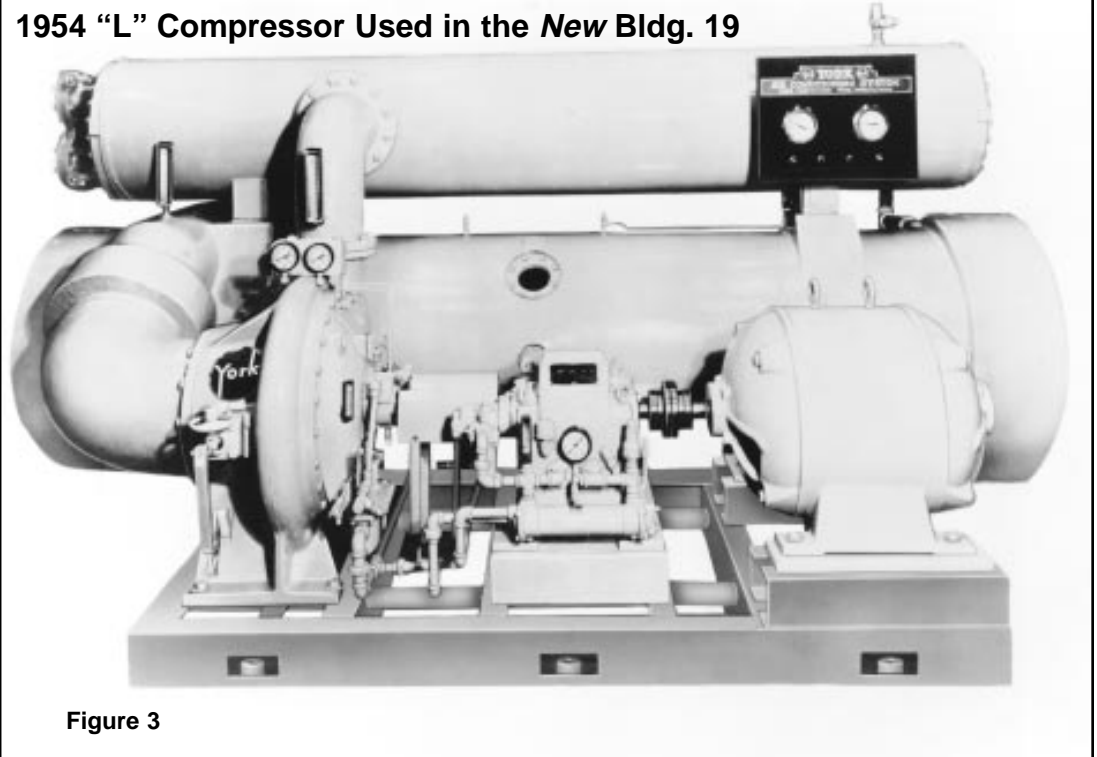


Figure 3

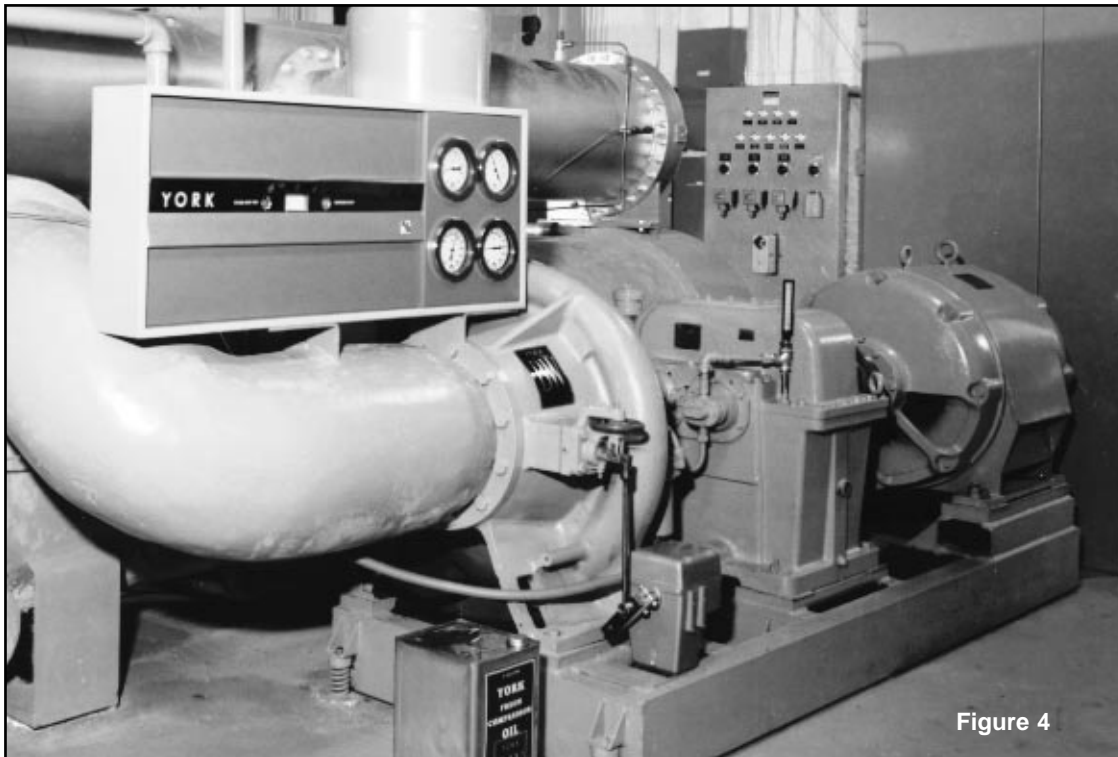


Figure 4

The first production L compressor, and a new water-cooling system to go with it, was built in 1954 and used to air condition YORK’s then-new Engineering Laboratory on Richland Avenue, Building 19. This unit provided 150 tons of cooling with refrigerant 11. Figure 3 is a 1954 photograph of the historic Building 19 unit, which was removed from service in early 1996, after 41 years of operation, and is slated to become another YORK exhibit

## An Industry First!

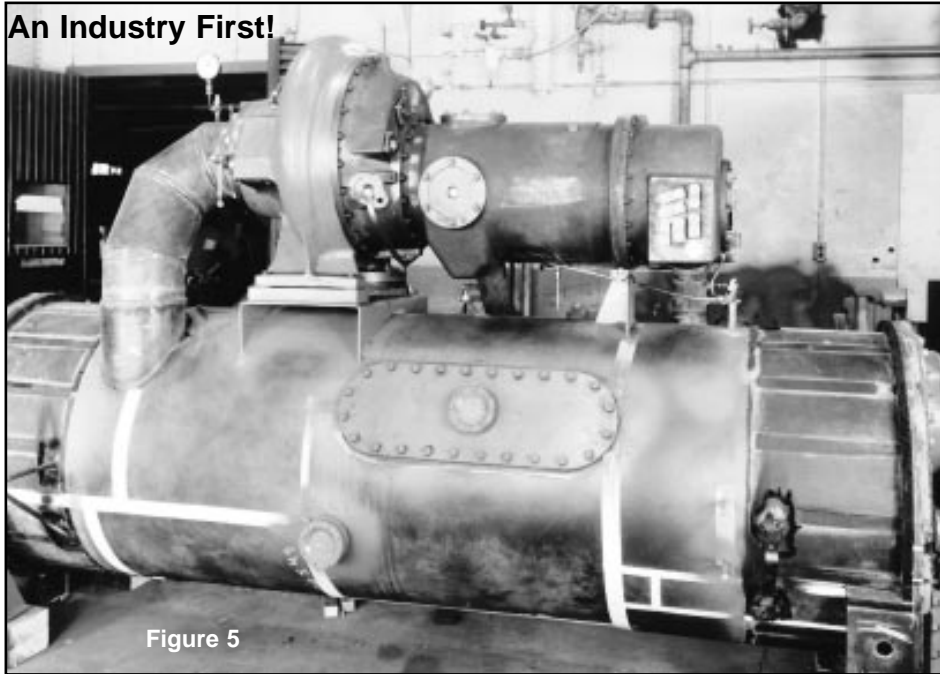


Figure 5

at the Industrial Museum of York County.

The L compressors were called “Turbomatic” compressors, and the water-cooling systems in which they were used were called “Turbomatic” systems. Figure 4 is another photograph of a Turbomatic compressor and system.

There were 485 L compressors built between 1954 and 1959, after which time another “industry-first” compressor superseded the L design. This was the Series T or “T” compressor which YORK still manufactures today.

## T COMPRESSORS

Most centrifugal compressors are driven by electric motors whose rotational speeds are less than the speeds required by the compressors. Gears are used to change the motor speed

to the compressor speed. Before the advent of YORK’s T compressor, separate gear box assemblies were installed between the motor and the compressor, as can be seen in the pictures of the YAC and Turbomatic water-cooling systems previously

mentioned. The T compressor did not need a separate gear box because it had internal gears.

Making the speed-increasing gears an integral part of the compressor reduced the size, complexity, and cost of the total motor-gear-compressor drive train. Most of the world’s air-conditioning centrifugal compressors today are single-stage compressors with built-in (internal) gears. The industry’s first such compressor, the YORK T compressor, was made in York, Pennsylvania in 1958.

To go with the industry’s most compact centrifugal compressor drive train, YORK developed the industry’s most compact water-cooling system. This was accomplished by combining the evaporator, condenser, and refrigerant flow control into one “tri-duty” shell (later called

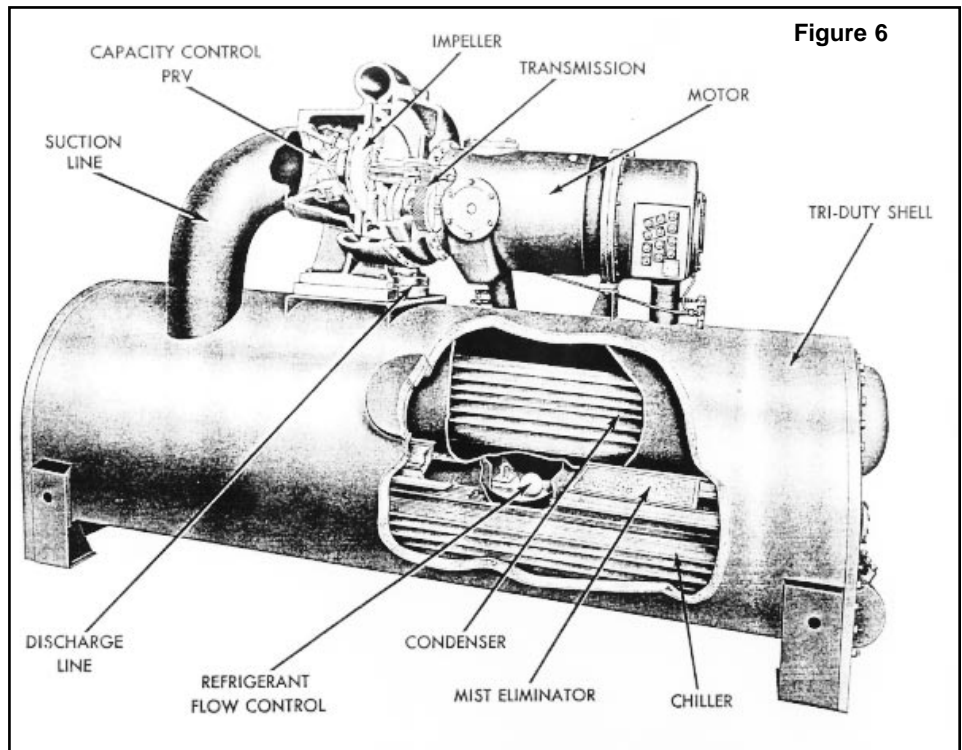


Figure 6

a “monoshell”) and then mounting the motor-compressor assembly on top of the shell.

The result was the industry’s first completely factory-packaged centrifugal water-cooling unit, introduced by YORK in 1958. These packaged centrifugal chillers were named “Turbopaks”. Refrigerants 11, 113, and 114 were originally

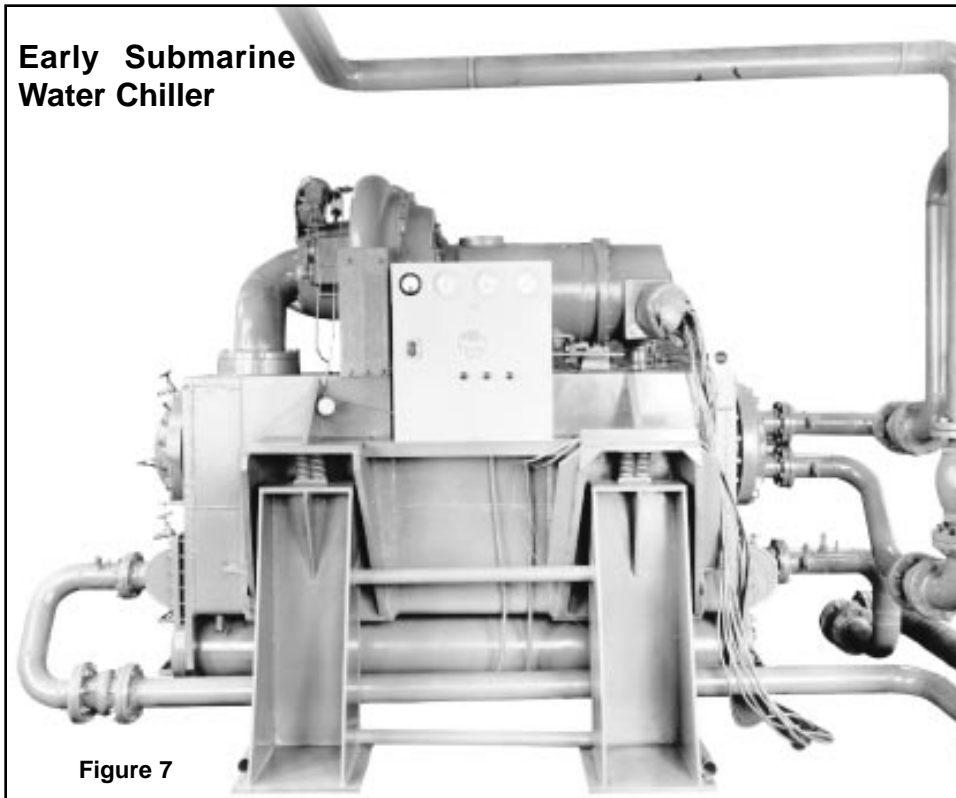
used in two compressor frame sizes to cover the range from 65 to 600 air-conditioning tons.

The number of frame sizes eventually became four, using only refrigerant 11, with a maximum capacity of 1000 tons. The monoshell eventually became two separate shells. The name of the systems became “CodePaks”.

The compact T compressor and Turbopak system was very attractive to the U.S. Navy, especially for submarine service. In the early 1960s, York began manufacturing special T compressors and systems that could meet the very stringent noise, vibration, and shock-load requirements

of nuclear submarines. Since that time, YORK has supplied virtually

(1996) one YORK submarine unit produces 225 air-conditioning tons using refrigerant 114.



Today’s commercial T compressors use refrigerant 123 in four frame sizes to provide 150 to 850 air-conditioning tons. Every other manufacturer of centrifugal chillers has copied the YORK concept of providing “packaged” centrifugal units in place of the former “field-erected” designs.

Figure 5 is a 1959 shop photograph of the industry’s first centrifugal water-cooling package.

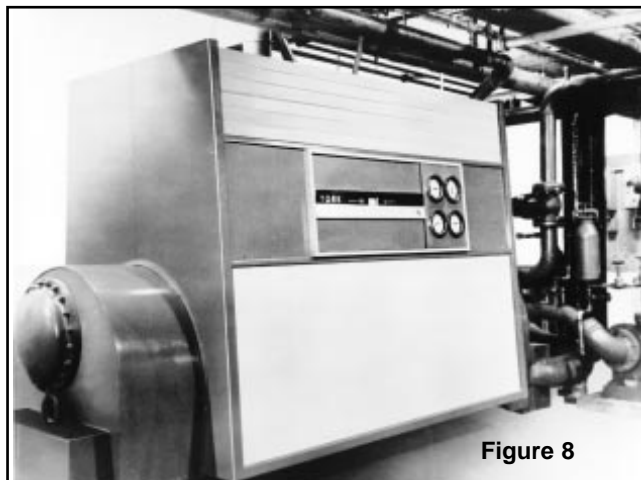
all of the centrifugal air-conditioning units used in all of the Navy’s submarines.

YORK’s first nuclear submarine units used refrigerant 11 and produced 110 tons of cooling. Now

Figure 6 is a “cutaway” version of Figure 5. Figure 7 is a photograph of one of the first submarine units. The motors in these figures were called “hermetic” motors because they were built into the compressors and operated in a refrigerant atmosphere.

The compressors were called “hermetic compressors” because their motors were hermetic.

Before the mid 1950s, no manufacturer but the Trane Company used hermetic motors for their centrifugal compressors. By the end of the 1950s, all of



Early Design "K"

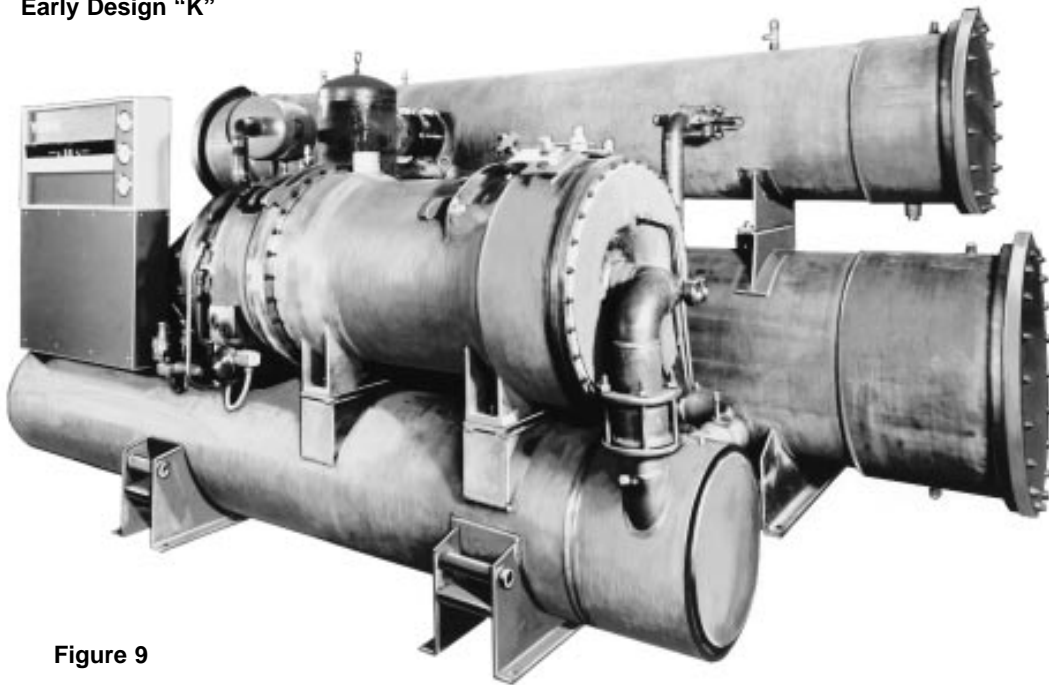


Figure 9

1983, the demand for YORK's open motors had become so great that the use of hermetic motors was discontinued in all T compressors except those that were used in nuclear submarines. Today, YORK is the industry's only manufacturer of centrifugal chillers that uses open motors in standard factory packages.

### K COMPRESSORS

**Y**ORK produced yet another single-stage compressor, the Series K or "K" compressor, in 1962. This design used refrigerant 12 in two frame sizes to cover the air-conditioning range between 400 and 1000 tons. The systems in which these compressors

the centrifugal chiller manufacturers used hermetic motors. YORK's first hermetic centrifugal compressor was produced in 1958.

YORK's early Turbopaks could be furnished with an acoustic enclosure if a customer wanted an enclosure. Figure 8 is a 1959 photograph of a hermetic Turbopak in an acoustic enclosure (called a "doghouse" by many YORK employees). The enclosures were discontinued after only a few years because most customers did not want to pay the additional cost of an enclosure.

YORK T compressors were unusual in that they could be driven either by hermetic motors or by conventional "open" (open to the atmosphere) motors, whichever a customer might prefer. The open motors were air-cooled instead of refrigerant-cooled, and thus could not be enclosed in a "doghouse".

During the 1960s, most customers preferred hermetic motors, but a shift in favor of open motors, which YORK strongly encouraged, began in the 1970s. Open motors were more efficient than hermetic motors, and easier to service. By

Later "K" Version  
Used for Years



Figure 10

were used consisted of separate heat-exchanger and motor-compressor assemblies that were joined together at the jobsite.

Figure 9 shows an early hermetic K compressor and its water-cooling system. Only 26 of these compressors and systems were built because the design was complex and costly to manufacture.

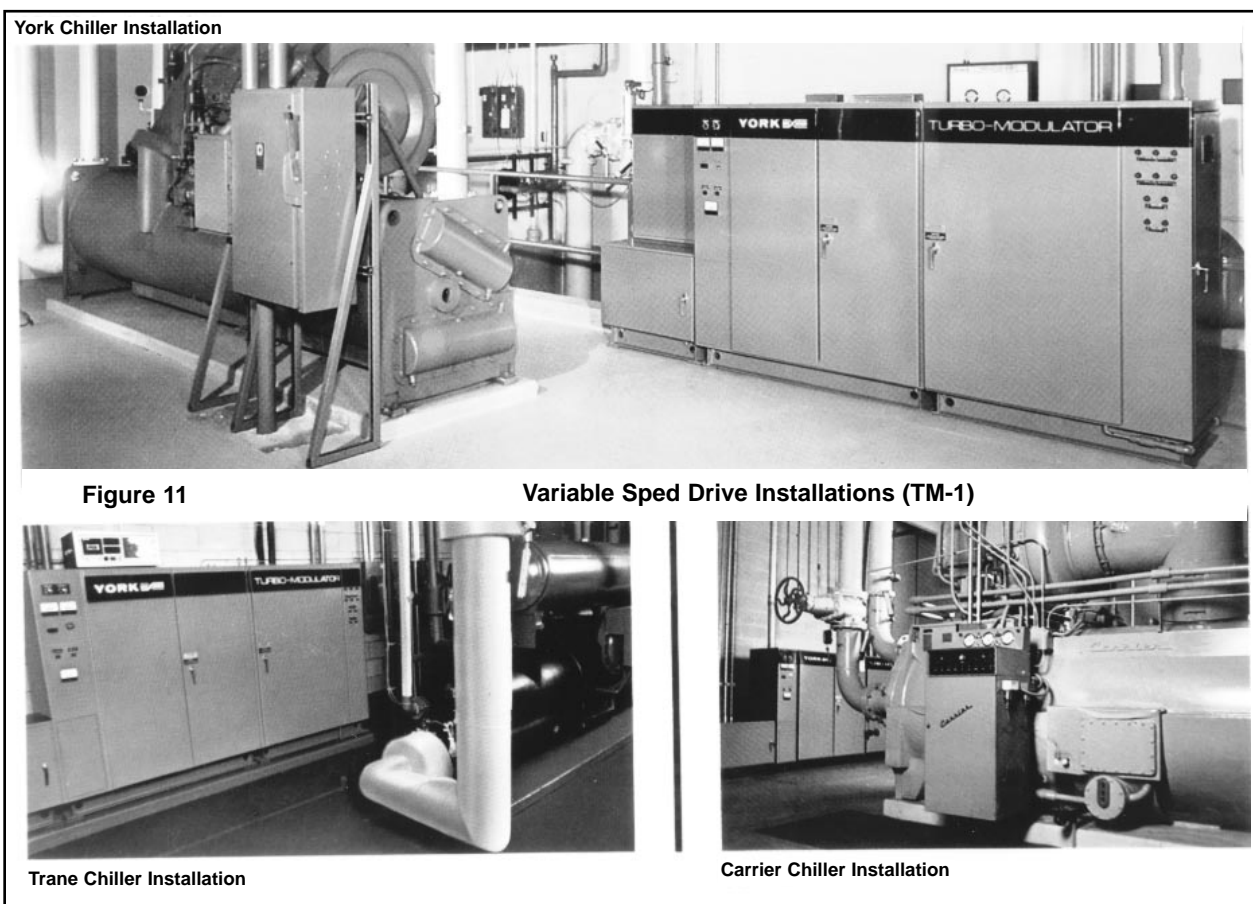
In 1968, a completely redesigned K compressor was introduced, along with a new Turbopak system that provided the industry's then-largest water-cooling factory package. The compressor used refrigerant 12 in one frame size to provide 650 to 1030 tons. Beginning in 1972, refrigerant 500 was also used to increase the capacity to 1335 tons.

Figure 10 shows the redesigned K compressor and its new Turbopak system. The motor in this figure is an open motor. YORK initially provided both hermetic and open

motors for the redesigned units, but the hermetic motors were discontinued in 1986.

The K compressor is still manufactured by YORK today, in three frame sizes that use refrigerants 22 and 134a in factory-packaged systems with capacities between 350 and 2100 tons.

installations. The first such retrofit was in the Sydney Opera House in Sydney, Australia. There, in 1975, three 550-ton Worthington motor-compressor assemblies were replaced by three hermetic T compressors. What was unheard-of before 1975 has become commonplace today. YORK's centrifugal driveline retrofit assemblies, using both T compressors and K compressors, were called "Codekits".



### COMPRESSOR RETROFITS

**A** noteworthy aspect of YORK's centrifugal compressors was their ability to replace competitors' compressors in field "retrofits" of competitors'

### INVERTER DRIVES

**A**nother industry-first for YORK was the use of a solid-state electronic inverter to vary the speed of centrifugal compressor drive motors. The

inverter, named a “Turbo-Modulator”, changed the motor’s speed by changing the electrical frequency of the motor’s power supply. Reducing the motor-compressor speed during part-load operation reduced the compressor’s flow capacity even more efficiently than did PRV control. This lowered the part-load power consumption (and power cost) to previously-unachievable levels.

The first Turbo-Modulators were added to existing centrifugal chillers, beginning in 1977 with the retrofit of the Turbopak chiller that was cooling YORK’s Administration Building, Building 36. In 1978, YORK began retrofitting Carrier and Trane units with YORK Turbo-Modulators. Shipment of Turbo-Modulators with new YORK Turbopaks began in 1979.

Figure 11 contains photographs of three 1978 retrofits of existing chiller installations.

The Carrier Corporation began supplying inverters for their centrifugal chillers in the late 1980s. The Trane Company followed suit in the early 1990s. Because of that, YORK no longer retrofits Carrier and Trane units with YORK inverters.

The original Turbo-Modulator was a large free-standing box that was used for air-conditioning capacities of 150 to 550 tons. Today’s Turbo-Modulators are so compact that they can be included in YORK’s centrifugal water-cooling packages for capacities up to 650 tons.

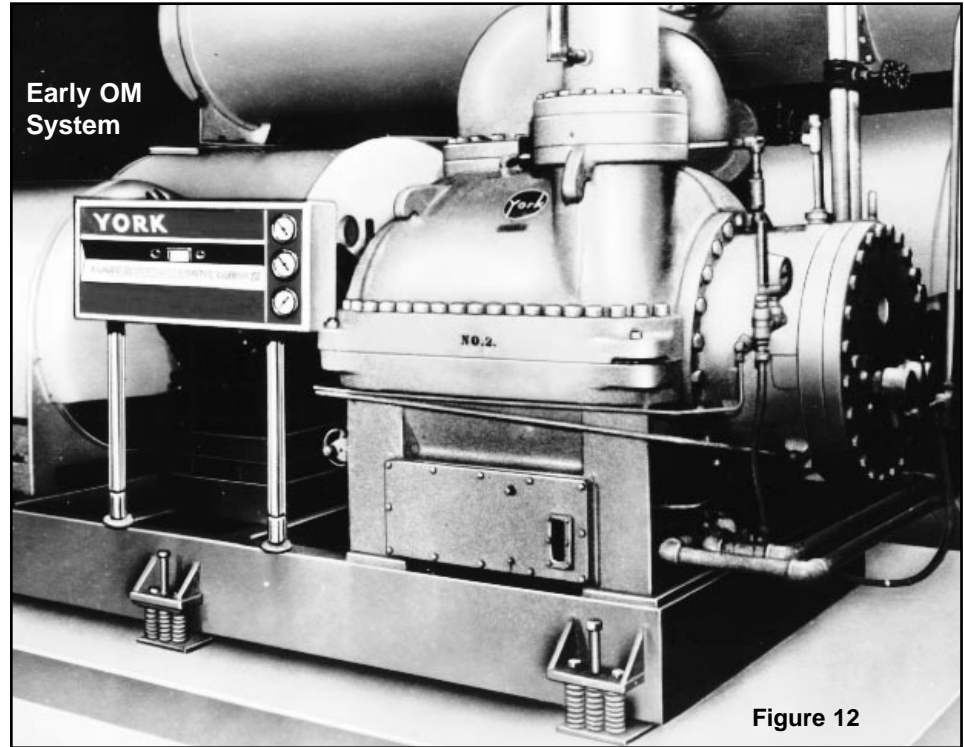


Figure 12

## M COMPRESSOR

Single-stage compressors played only a part in the gradual replacement of YORK’s YAC design that occurred between 1954 and 1960. A new multi-stage centrifugal compressor, the Series M or “M” compressor, began replacing large YAC compressors in 1956.

Like the YAC compressors, the M compressors (also called “Turbomaster” compressors) were used for air-conditioning and refrigeration applications. But unlike the YACs, the M compressors were also used for process gas compression. Refrigerants 11, 12, 13, 13b1, 22, 114, 134a, 500, 502, 503 and ammonia, plus air, butadiene, butane, carbon dioxide, ethane, ethylene, iso-butane, propane, propylene, methane, natural gas, and

other hydrocarbon mixtures were all compressed by M compressors. Many of the hydrocarbons on the list were compressed as refrigerants for process cooling in chemical plants and refineries.

Two to eight stages were employed in three frame sizes. The highest horsepower was 10,000. The highest pressure was 600 psig. The lowest temperature was -182 deg F.

Two stages were used in water-cooling systems. The largest air-conditioning load was 8500 tons. Figure 12 is a picture of an early M compressor in a large water-cooling system that was called an “OM Turbomaster” system.

Two M compressors were sometimes connected in series and driven by a single driver. The two combined compressors were called one “tan-



## One of the Rare York "M" Compressor Tandem Drivelines...

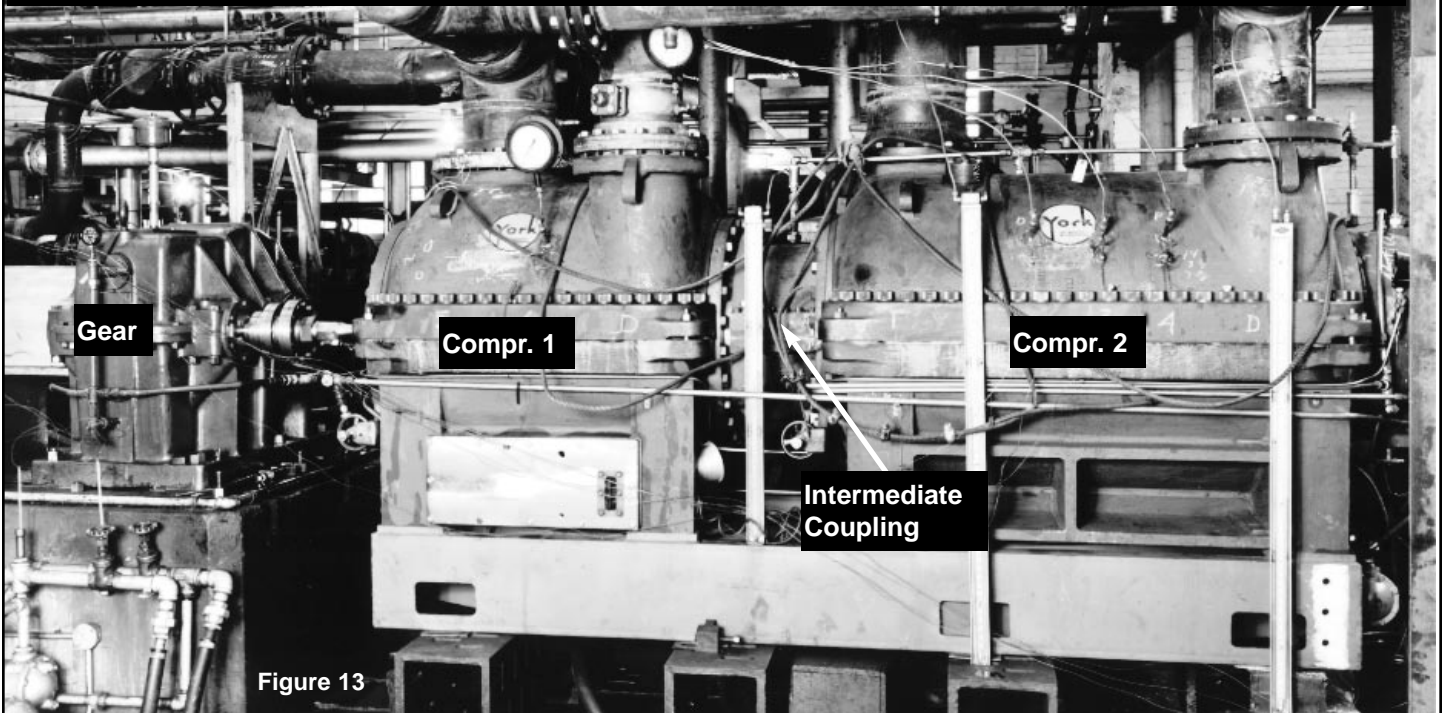


Figure 13

dem compressor". Figure 13 is a photograph of an early tandem compressor on a compressor test block. There were 12 tandem compressors manufactured between 1957 and 1989. One of the tandem compressors was actually run backwards, as an expansion turbine, to drive an electrical generator. The turbine working fluid was iso-butane. The power output was 12,600 hp.

YORK still manufactures M compressors today, in three frame sizes with one to eight stages, for process-gas compression, refrigeration, and air-conditioning applications. Air-conditioning loads of 2100 to 8500 tons are handled by two-stage compressors, in two frame sizes, using refrigerants 22 and 134a.

### MB COMPRESSORS

A special high-pressure version of the M compressor, called a "barrel" compressor, and

designated the Series MB compressor, was used to compress natural gas up to 1500 psig. There were 22 barrel compressors manufactured in one frame size between 1974 and 1985. The highest horsepower was

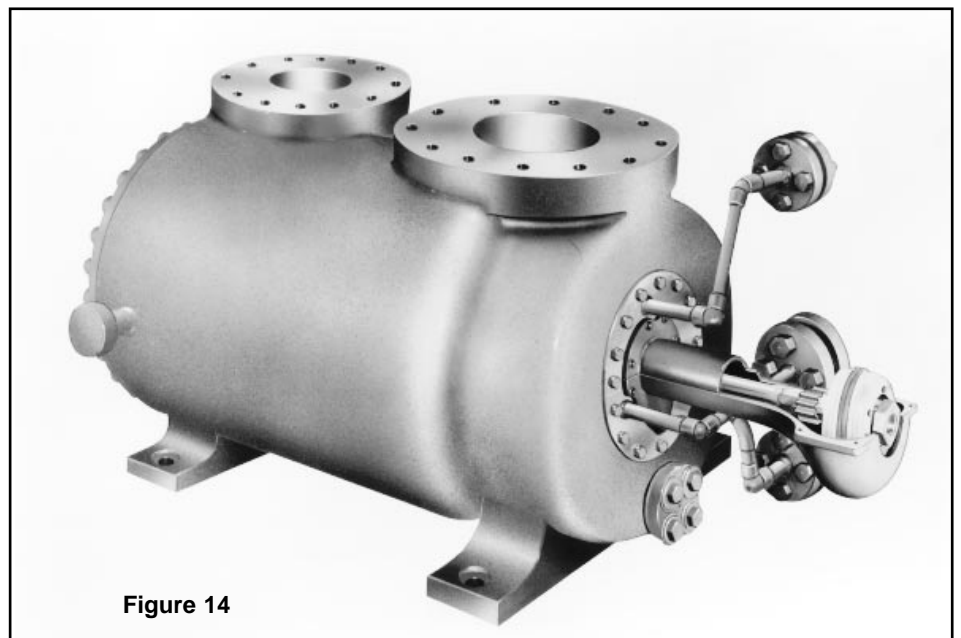
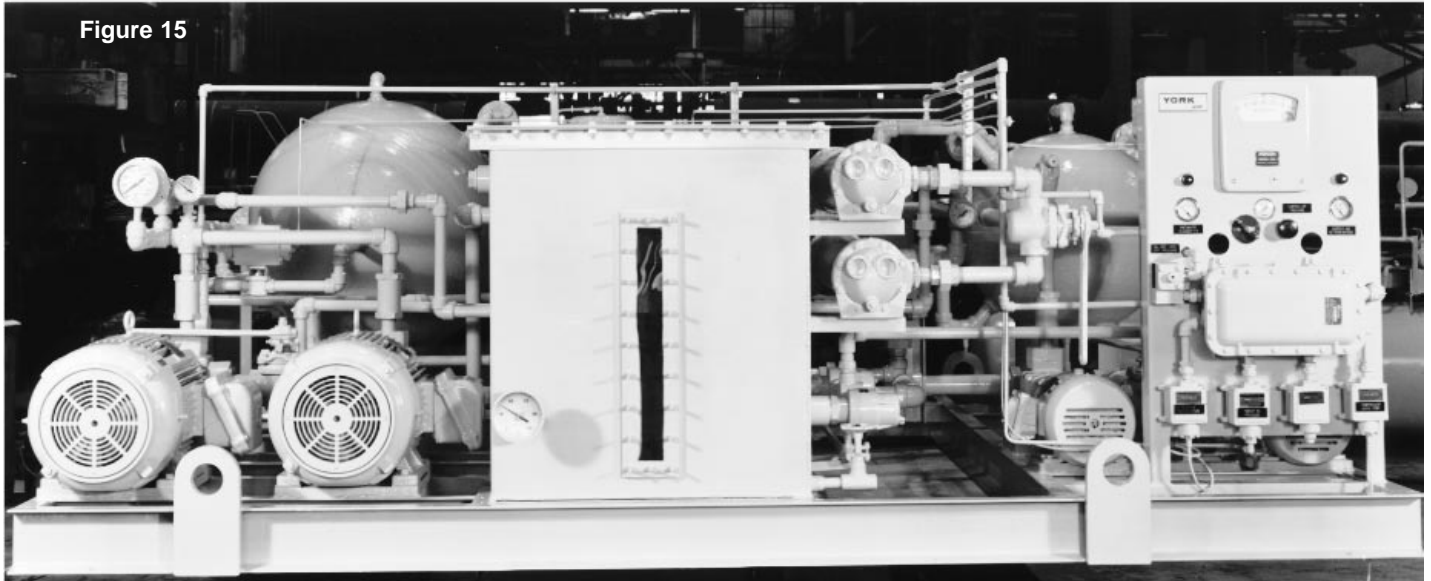


Figure 14

Figure 15



4377. Figure 14 is a picture of a barrel compressor that was made from a 1973 photograph of the first (test) compressor.

Figure 15 is a 1973 photograph of the special "external" oil lubricating and sealing system that was used by barrel compressors. All previous YORK compressors had "internal" lube and seal systems which operated in an atmosphere of the gas that was being compressed. The very high pressures at which barrel compressors operated made an internal lube system impractical. A more-complicated, external oil system was required in which the lubricating and seal oil operated under the pressure of atmospheric air.

## OVERSEAS MANUFACTURE

**Y**ORK, which entered the centrifugal compressor industry in 1939 as a licensee of the Allis-Chalmers Manufacturing Company, itself became a licensor of centrifugal

compressor technology in 1964 when Mitsubishi Heavy Industries, Ltd. was licensed by the York Division of the Borg-Warner Corporation to manufacture centrifugal compressors and systems of YORK design in Takasago, Japan. Both T compressors and M compressors were manufactured in Takasago. The licensing agreement ended in 1990, but Mitsubishi still produces T compressors and M compressors in Takasago.

In 1984, the York Division of the Borg-Warner Corporation licensed Blue Star, Ltd. to manufacture T compressors in Thane, India. In 1985, York Division licensed the Mando Machinery Company to manufacture T compressors in Anyang, South Korea. Both of these licensing agreements are still in effect.

T compressors were also manufactured in Basildon, England by York Shipley, Ltd., a wholly-owned subsidiary of YORK. Basildon manu-

facture began in 1962 and ended in 1986.

## TODAY

**I**n 1996, YORK is the world's leading manufacturer of centrifugal air-conditioning and refrigeration compressors. These compressors, and the systems in which they are used, are among YORK's most successful and most important products.

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J.M.Schultz  
15 November 1996



## About the Author...

John M. (Jack) Schultz was YORK's Chief Engineer for Turbocompressors (Centrifugal Compressors) from 1963 until 1979.

In 1953, Jack came to the York Corporation from the Ingersoll-Rand Company to become a member of YORK's Turbocompressor Engineering Department. The Manager of the "Turbo" Department then was J. Hilbert (Andy) Anderson. Jack had worked for Andy at the Ingersoll-Rand Company from 1947 until 1951, when Andy left Ingersoll-Rand to join the York Corporation.

When Jack Schultz joined YORK in 1953, the YAC compressors were in production, and development of the single-stage L compressor was underway. The design and development of new centrifugal compressors continued under Andy Anderson's leadership until Andy left YORK in 1963, at which time Jack was named to head the Turbocompressor Department.

Jack retired from YORK as Chief Engineer for Centrifugal Systems in 1985. Since his retirement, Jack has continued to serve YORK as a centrifugal compressor and centrifugal systems consultant.

15 November 1996

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