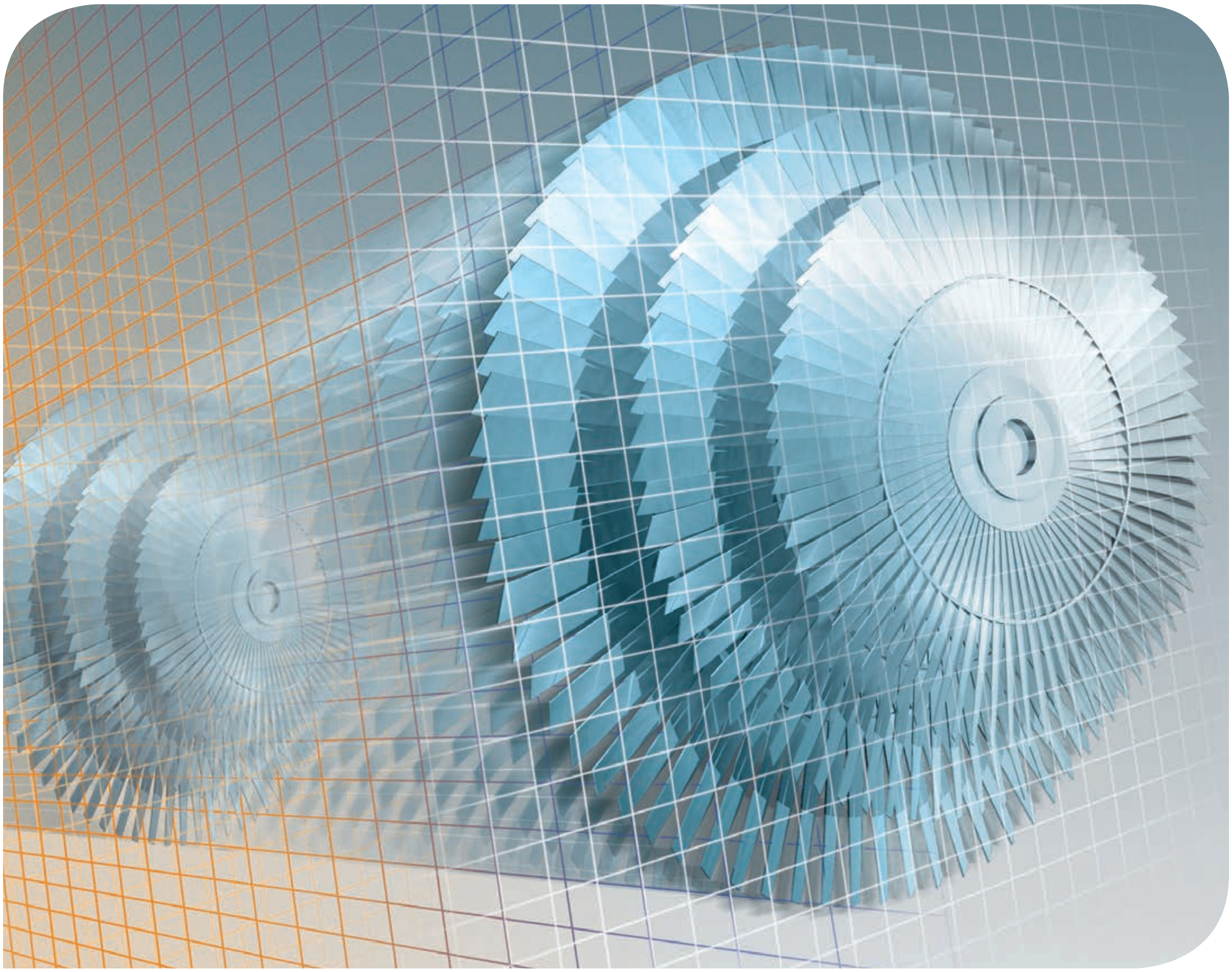
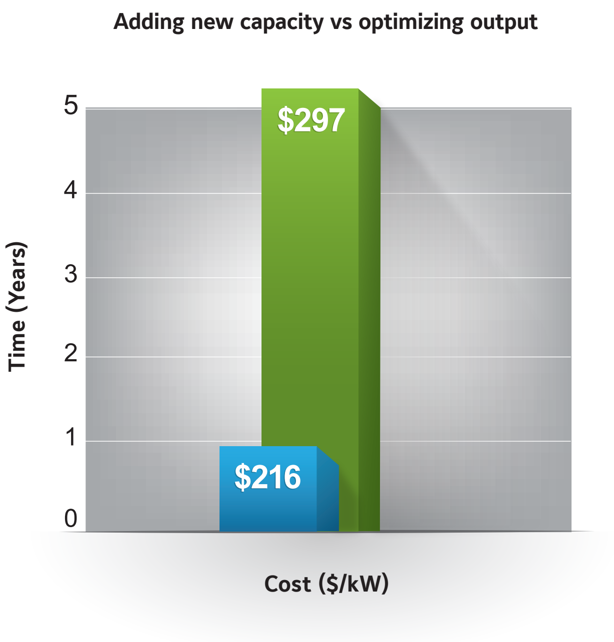
TURBINE INLET COOLING

Boost the output of gas-turbine generators



BY JOHNSON CONTROLS

The trend: increased power demand



Optimizing turbine output by adding inlet cooling can be achieved in less time and with 30% less capital outlay than adding new capacity. Independent analysis conducted for PJM Interconnection LLC (PJM2005) and Turbine Inlet Cooling Association (TICA).

The forecast

Energy consumption is increasing. According to the US Energy Information Administration's (EIA) July 2013 report, *International Energy Outlook*, world energy consumption will grow by 56% between 2010 and 2040. The report states that natural gas is the fastest growing fossil fuel, with global consumption increasing by 1.7% yearly. Higher demand will mean higher costs in the future.

The alternatives: add new capacity or optimize output

Gas-turbine generators are the most environmentally clean way to generate electricity using a fossil fuel. To meet the growing demand for power, adding additional gas-turbine generators seems like a logical option. However, siting new capacity is capital-intensive and can involve long permitting periods.

A better strategy is to enhance the output of existing generators by using Turbine Inlet Cooling (TIC) – a far less costly alternative. The cost of implementing TIC is $216/kW expended in one year, compared to $297/kW expended over five years to build a new plant.

The opportunity: optimize gas-turbine power output

The cost-effective optimized solution: inlet cooling

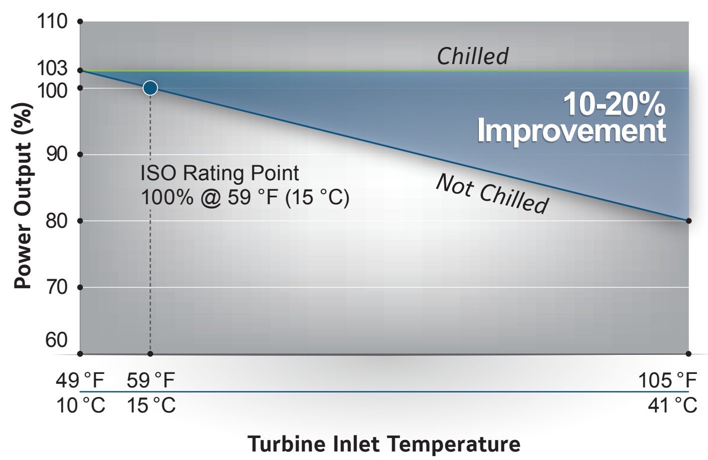
Today, there are various ways to enhance the power output of gas-turbines. The most cost-effective means is a process known as inlet cooling. This technology can expand a gas-turbine generator's capacity to produce 10 to 20% more electricity at 30% less cost than producing the same amount of power with a brand new generator.

With TIC, as the temperature of the air entering the turbine decreases, the density of the air increases, causing more air mass to flow through the turbine. Greater air mass causes greater power output from the turbine.

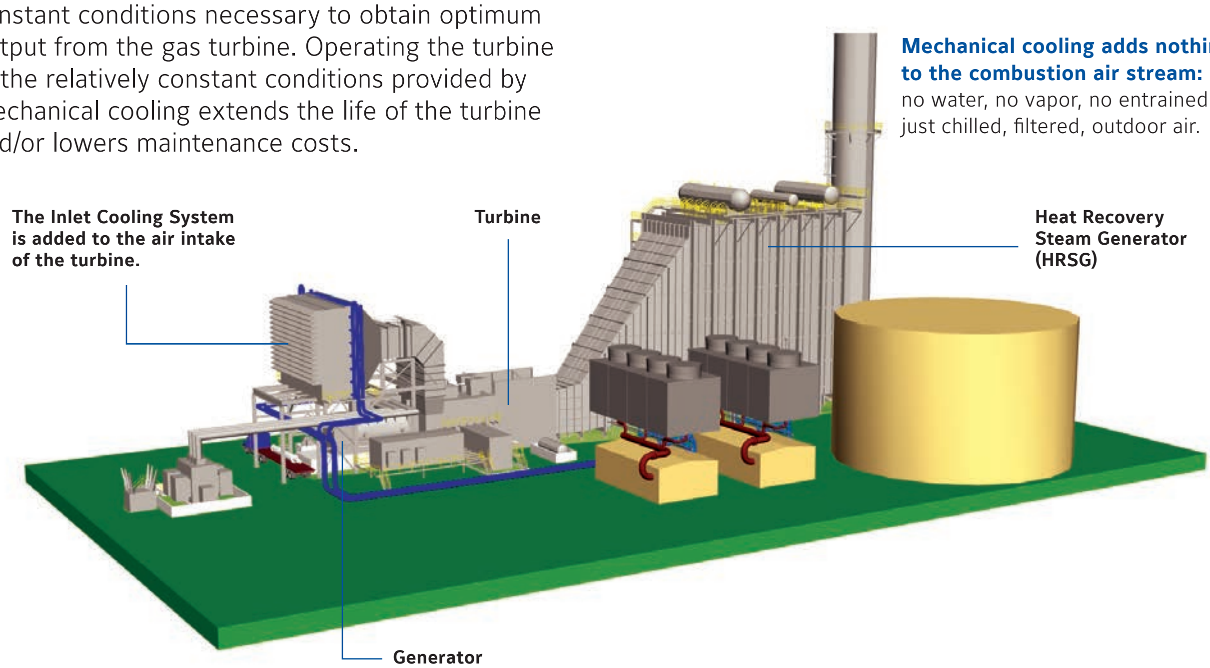
Mechanical cooling: the best inlet cooling method

The most consistently successful method of inlet cooling is mechanical cooling. Based on proven water-chiller and heat-exchanger technology, this method provides the cooling capacity, dependability, and constant conditions necessary to obtain optimum output from the gas turbine. Operating the turbine at the relatively constant conditions provided by mechanical cooling extends the life of the turbine and/or lowers maintenance costs.

Turbine inlet cooling power improvement example



Mechanical cooling adds nothing to the combustion air stream:
no water, no vapor, no entrained mineral; just chilled, filtered, outdoor air.



Inside an inlet cooling solution

System installation strategies

A TIC system requires careful coordination in engineering and design, equipment selection and procurement, field installation, commission, and start-up. A typical project can take one of two approaches:

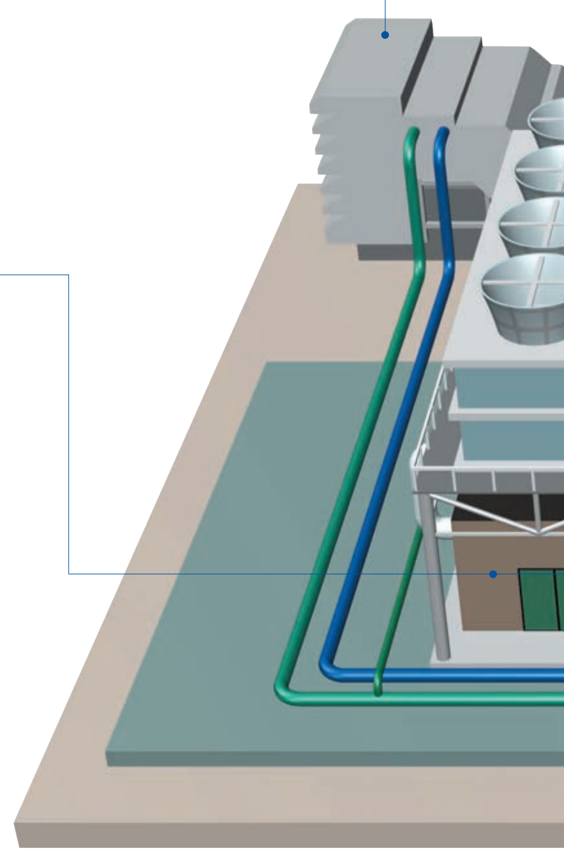
Field-erected approach: Major components are shipped to the job site, then assembled and piped on location. This is a complex approach involving construction managers, contractors, on-site labor and long lead times. Completion can take up to 18 months.

Packaged approach: Equipment is integrated into a complete system prior to shipment, then site installation is coordinated by in-house or outside project managers. This approach is quick and simple, taking advantage of the manufacturer's system and project-management expertise to provide a single-source solution. Installation is complete within six to eight months.

System configuration

A TIC system is comprised of a number of components, including chillers, piping, coils, controls and energy-storage tank units.

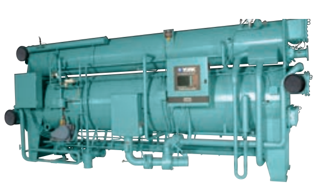
Filter housing with cooling-coil module	
Responsible for generating the cool air stream entering the turbine inlet	
Coil	Provides the heat-transfer between the chilled water and the incoming air, reducing the air-inlet temperature
Filter	Removes impurities from the air stream
Housing	Encloses the coil and provides the free area to accommodate air flow for the filter and coil



Modular water chiller plant	
Responsible for producing cooling	
Centrifugal Chillers	Centrifugal chillers use mechanical cooling technology to cool the water loop that has absorbed heat from the cooling-coil module. As the most efficient chiller equipment, the YORK model YK-EP chiller produces cooling at the lowest cost-per-ton of refrigeration and water cooled for thermal storage at off-peak hours. The YORK model CYK chiller provides the most efficient operation for producing cooling, ice for thermal storage at off-peak hours, as well as producing cooling for high-head applications with high ambient-air temperatures.
Absorption Chillers	Absorption chillers use a chemical process to produce chilled water. YORK model YIA and YPC absorption units use heat sources such as gas, steam or hot water, to drive the chemical reaction that produces economical cooling.

Model YK-EP
Centrifugal Chiller

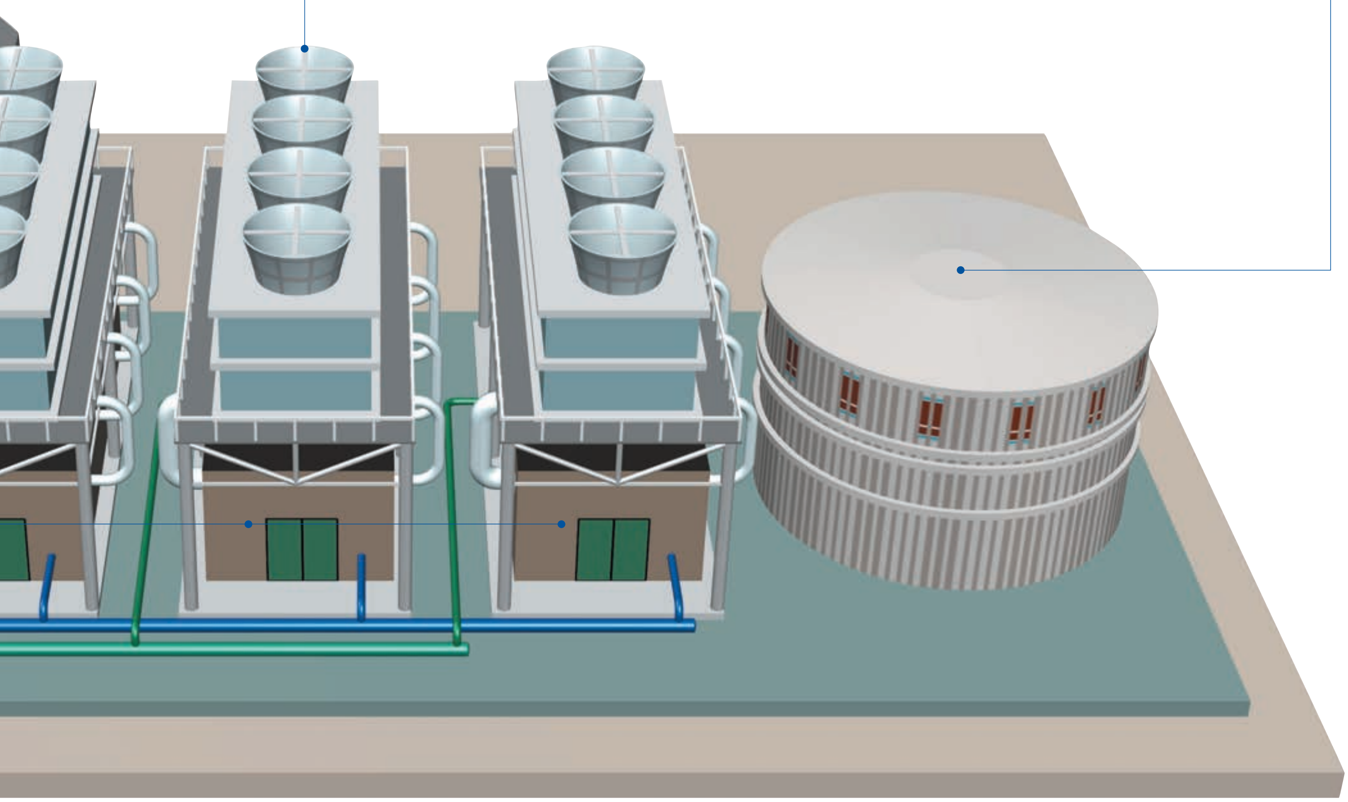
Model CYK
Centrifugal Chiller



Model YIA
Absorption Chiller

Thermal energy storage tank	
Technology used to create and store thermal energy at off-peak temperature hours. Thermal energy storage (TES) adds to the value proposition of chillers. Thermal energy storage tanks can be "charged" at night when electric demand is down, and "discharged" when the demand is highest. This maximizes power production and revenue, and reduces the amount of wasted energy.	
Ice Storage	Tank stores ice during low-load conditions, which can then serve as the cooling medium at peak conditions.
Cold Water Storage	Same as ice storage, but stores cold water instead of ice

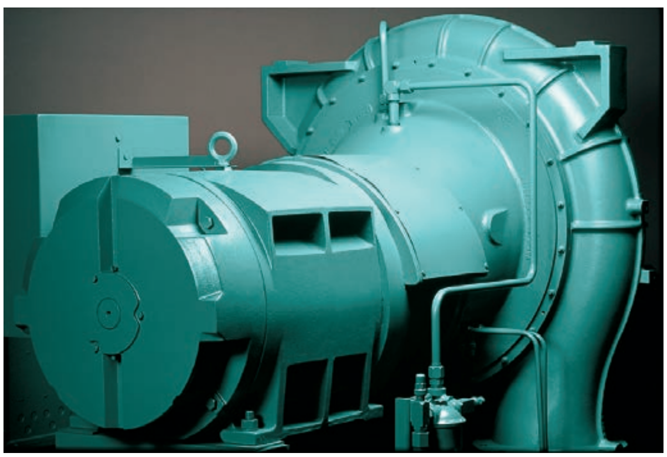
Heat-rejection equipment	
Equipment used to remove heat from the chillers	
Water-Cooled	Cooling towers use water to remove heat from the chiller(s)
Air-Cooled	Typically, radiators use fan-driven air to remove heat from the chiller(s)



Make YORK® chillers your choice for reliable inlet cooling

The industrial cooling experts

When you're selecting a chiller for a TIC system, consider YORK chillers manufactured by Johnson Controls, the industrial cooling experts. YORK chillers and compressors are used in some of the most demanding, 24/7 petrochemical and gas-compression applications on Earth. That same industrial-grade dependability is built into all YORK chillers that serve as the heart of a TIC system.



An example of a YORK open-drive compressor

The OptiView control center in-use

A TIC system can boost the turbine's output and reduce its capital cost, but only if the system operation is reliable. YORK chillers are renowned for their low incidence of repair and easy maintenance. Compressor and control-panel design are two examples of their industrial construction.

Open-drive compressors

Based on extensive industrial experience, YORK large-tonnage chillers use open-drive compressors, which provide two significant uptime advantages. In the event of an electric-motor burnout, the open motor can be simply swapped out for repair. But with burned-out hermetic inductor motors, the entire chiller is contaminated with combustion products and must be taken off-line for an extensive clean-up period. Open-drive compressors also provide improved access for routine maintenance tasks.

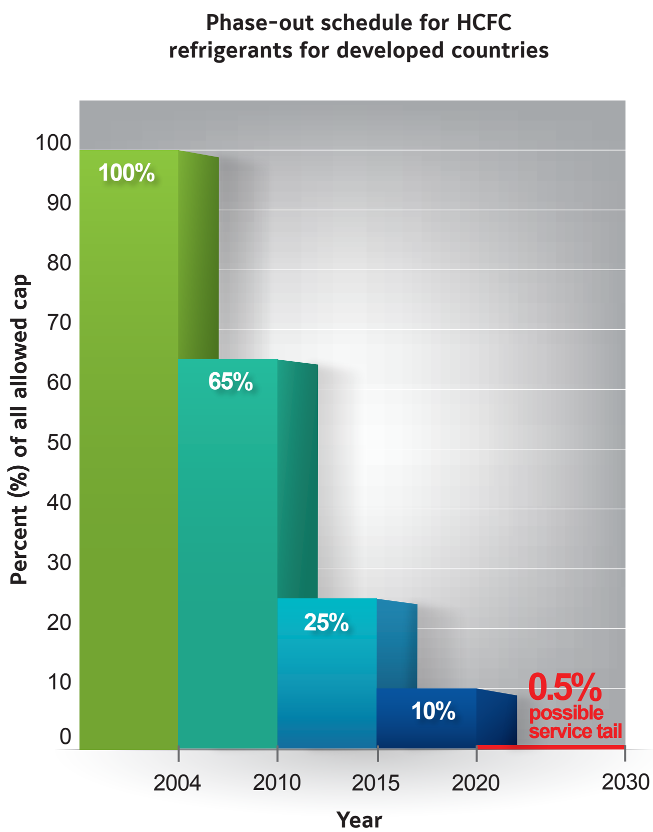
OptiView™ control center

For a clear, up-to-the-minute picture of chiller status, YORK chillers employ the intuitive and informative OptiView control center. The control center delivers real-time data on all key parameters in a graphical, easy-to understand format. Powerful logging and trending capabilities let you see how efficiently you are operating, and provide early warning of any developing problems.

World-wide service capability

To support daily operations, Johnson Controls offers the capabilities of the world's largest factory-owned HVAC&R service organization. Over 15,000 factory-trained technicians are located in over 150 strategic locations world-wide to handle start-up, maintenance, training, repair, emergency, and enhancement needs. Maintenance contracts are available to help owners quantify their maintenance cost as a budgeted annual expense.

Energy-efficient and environmentally responsible by design



Environmentally acceptable refrigerants

Power plants are under close public and governmental scrutiny for their environmental track record. By offering chillers that have zero ozone depletion and no phase-out date, Johnson Controls can aid in reducing your environmental footprint. Our absorption chillers use water as the refrigerant, while our centrifugal chillers use refrigerant HFC-134a.

Some manufacturers use refrigerant HCFC-123. This chemical has a phase-out schedule, meaning only a small quantity of refrigerant will be available in the future for servicing existing equipment; also known as a service tail. Businesses in countries that do not have domestic production of refrigerants will have to decide which HCFCs to import. Since the vast majority of installed equipment is based on HCFC-22, demand will likely dictate the entire service tail be allocated to it.

Low parasitic energy consumption

Turbine inlet cooling provides an energy-efficient and environmentally responsible way to enhance power generation capacity and efficiency. This formula for success begins with energy-efficient YORK chillers.

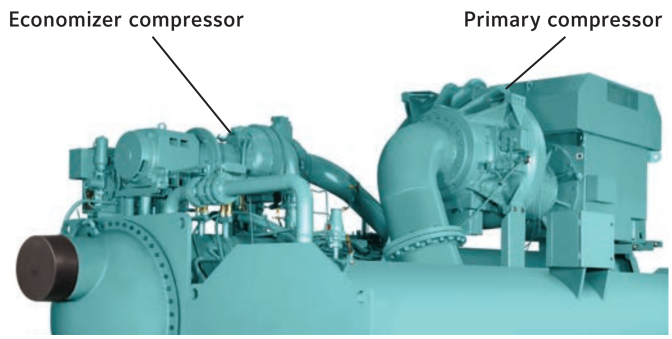
To minimize parasitic energy consumption, YORK chillers are designed for real-world energy performance – the combined performance at all operating conditions, not just at full-load design conditions. This is critical to maximizing energy efficiency for inlet cooling because in the case of thermal storage application, most of the hours are typically spent at off-design conditions. The end result is umatched energy efficiency that saves money and resources by returning more kW to the grid.

Model YK-EP chillers – unique compressor arrangement reduces energy costs in large TIC plants

If you are looking to reduce energy consumption in TIC systems, the YORK model YK-EP chiller can help. It has a capacity range of 2,500 to 3,200 TR (8,800 to 11,200 kW), and features a patent-pending, mechanical-compression economizer cycle. This economizer cycle delivers market-leading efficiency at design conditions, particularly at severe duty design.

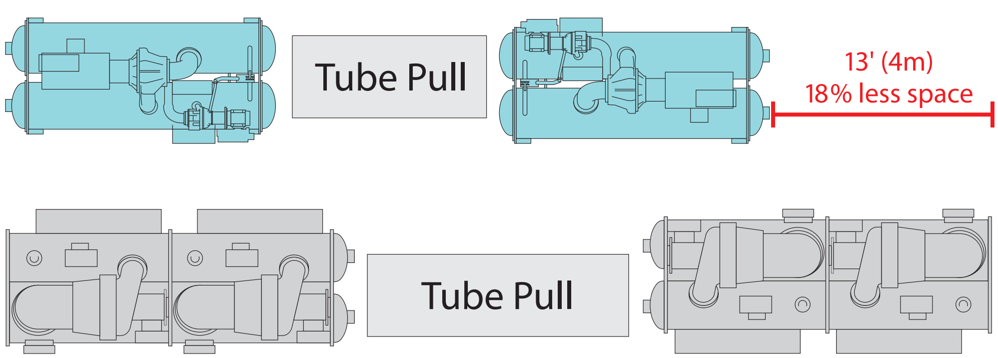
In addition, at off-design conditions (with lower loads and lower entering condenser water temperatures), the YK-EP chiller offers energy savings that really shine. That's critically important in water-thermal-storage applications, which spend the majority of their operating hours at off-design conditions.

The YK-EP chiller can utilize entering condenser water temperatures (ECWT) as low as 55 °F (13 °C) to reduce instantaneous energy consumption as much as 50% compared to chillers that can only use 75 °F (24 °C) ECWT minimum.



A unique configuration, coupling the primary compressor with an economizer compressor, makes the YK-EP chiller more efficient than other chillers.

You can save energy by piping them in a series-counterflow arrangement, reducing the compressor work needed on each chiller and cutting system energy use by as much as 8% at design conditions.



Two YK-EP chillers have an impressive 18% footprint advantage compared to the competition.

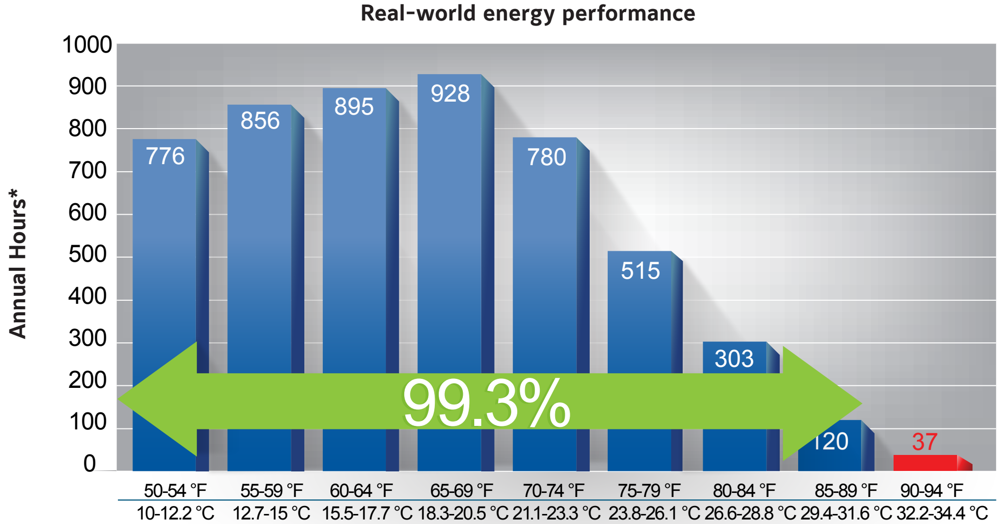
Model YK chillers – superior energy performance at off-design conditions

The capacity range of the YORK model YK chiller is 250 to 3,000 TR (880 to 10,540 kW). Both low-voltage (250 to 575 V) and medium-voltage (2,300 to 13,800 V) designs are available.

Hot or cold, humid or dry – your facility must handle the challenges of your particular climate. In fact, even within your specific climate zone, you see variations during days, nights, months, and seasons that create your facility's distinct, real-world operating conditions. These "off-design" temperatures allow YK chillers with OptiSpeed™ variable-speed drive (VSD) to slow down even at full loads and use 15% less electricity than conventional fixed-speed chillers. In TIC plants that require chillers of less than 3,000 TR (10,550 kW), the YORK model YK chiller has a capacity range of 250–3,000 TR (880–10,550 kW).

In the real-world, nearly 99% of a chiller's time is spent at off-design conditions. That's when colder weather conditions can reduce compressor workload by lowering the entering condenser water temperature (ECWT). The ability of YK chillers to take advantage of ECWT as low as 50 °F (10 °C) reduces compressor speed at off-design conditions. This helps deliver up to 30% more annual energy savings than fixed-speed chillers; regardless of how much time the chiller spends at full or part load.

Real-world energy performance



Dry-bulb Temperature Bins

**Chiller annual operating hours, US average weather*

Model CYK chillers – the high-head solution for Turbine Inlet Cooling

If a TIC application entails temperatures which are difficult for a standard centrifugal chiller to handle, the model CYK chiller is the best answer. The CYK centrifugal chiller incorporates a design using two centrifugal compressors arranged in series to handle air-cooled and brine-chilling applications at conditions outside the range of typical centrifugal chillers.

These units use the same technology employed in the renowned line of YORK YK single-stage centrifugal chillers. Using HFC-134a, CYK chillers are available in a wide range of capacities.

- For air-cooled applications (air-cooled radiators): 700 to 2,300 TR at 44 °F LWT (2,500 to 8,100 kWR at 7 °C LWT).
- For brine chilling: 700 to 1,600 TR at 20 °F LBT (2,500 to 5,600 kWR at -7 °C LBT)

The combination of standard components and unique performance characteristics make CYK chillers the technology of choice for jobs where standard chiller designs can't operate. Compound-system technology provides energy and performance advantages for TIC systems.

Understanding high-head applications

Certain job-site conditions require chillers to operate beyond the limits found in typical air-conditioning applications. These extreme conditions are characterized by leaving chilled fluid temperatures below 36 °F (2 °C), leaving condensing fluid temperatures above 105 °F (41 °C), or a combination of both.

When the leaving chilled fluid or leaving condenser fluid temperature exceeds standard limits, the lift on the compressor increases dramatically. The compressor must develop higher differential pressure on the refrigerant gas in the compression phase, which results in higher head pressure.

High-head conditions are found in two typical TIC systems cooling applications:

1. Air-cooled radiators for water chilling in locations that lack water for condensing.
2. Brine chilling for ice-thermal-storage applications.

YORK model CYK centrifugal chiller

Benefits of compressor compounding

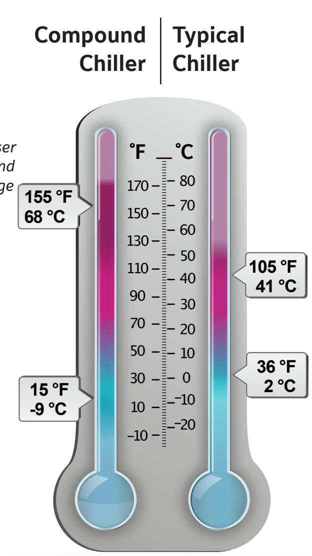
Standard components: Each CYK chiller employs common parts instead of a one-of-a-kind design. The compressors and heat exchangers use standard technology proven in the successful YORK YK packaged chiller line. Each compressor is driven by a standard, open-drive, electric motor.

Compact footprint: Compressors and motors are mounted above the shells to assure the smallest footprint for this type of chiller.

Greater adaptability: With the CYK chiller, the impeller diameter, width and speed can be optimized for each stage of compression based on operating conditions.

Operating Range

The leaving chilled and condenser water temperatures of compound chillers operate beyond the range of standard chillers.



Model YIA and YPC absorption chillers provide cooling with minimal electricity

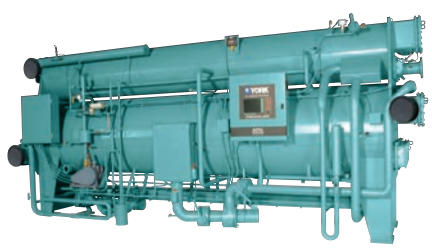
Absorption chillers are thermally driven: they can utililize either natural gas, steam or hot water. As a result they can provide TIC system cooling while consuming very little electricity, increasing the net electrical energy output from the power plant.

The model YPC absorption chiller represents the most efficient, commercially available absorption technology. Its two-stage design requires a remarkably low steam input rate of 9.8 lbs. per ton-hour (1.26 kg per kWh), which equates to a Coefficient of Performance (COP) of approximately 1.19. The higher the COP, the lower the operating costs; this means cost savings to your bottom line.

The model YIA absorption chiller can be powered by recovered waste heat in the form of hot water or low-pressure steam. The recovery process adds to the efficiency of the chiller by lowering the cost of fuel, reducing overall energy consumption, and drastically decreasing the amount of thermal and air pollution. The YIA single-stage design can also achieve a COP of approximately 0.70.

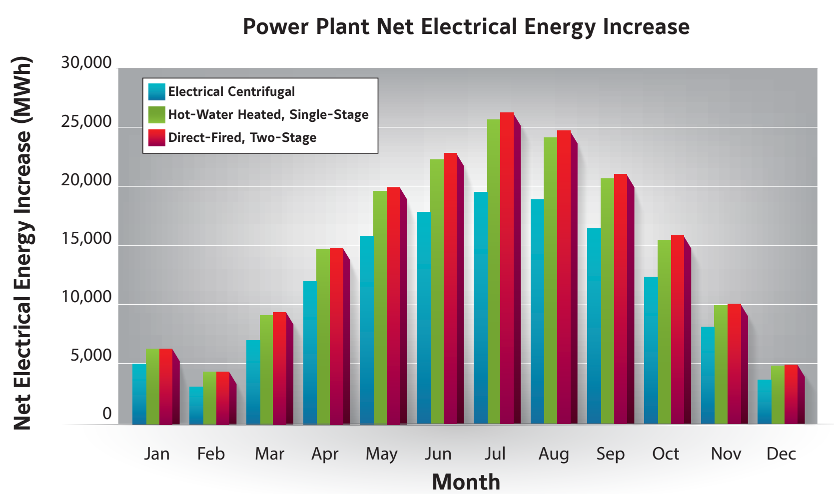
The YORK YIA chiller uses the best control panel in the industry, the OptiView™ control center. It features the revolutionary SmartPurge system, which maintains the proper vacuum in the chiller, thereby ensuring proper unit operation and longer life. Proper operation is also enhanced because the control center contains an auto-decrystallization circuit, controlled by crystallization-prevention logic. It is designed to keep the chiller running in even the most extreme circumstances. Past concerns about crystallization at low entering condensing temperatures have been eliminated with these new controls.

YORK absorption chillers have been providing reliable cooling for decades. The commitment Johnson Controls has to quality, reliability and service after the sale is evidenced by the number of YORK absorption chillers that have been in operation for over 40 years. Johnson Controls has a worldwide service network to provide the highest degree of technical support regardless of your location.



YORK model YIA absorption chiller

YORK model YPC absorption chiller



Net electrical energy increase resulting from addition of TIC using listed chiller types
(Source: Turbine Inlet Cooling Association.)

YORK chiller solutions meet your specific TIC system needs

YORK chillers, manufactured by Johnson Controls, are ideally suited for your TIC system. The broadest array of industrial-grade chillers offer capabilities designed to meet your exact requirements.

Energy flexibility and efficiency

YORK chillers can be driven by electricity, gas, steam, or hot water. They offer outstanding energy efficiency at both design and off-design conditions; for example, YORK chillers can take advantage of colder entering condenser water when it is available, allowing for continued operation in fluctuating weather conditions.

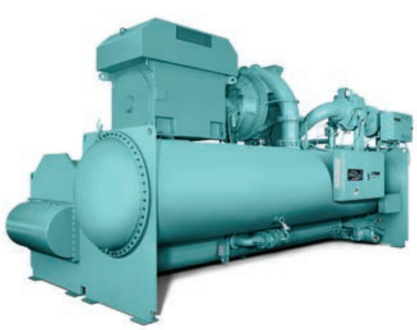
Ease of operation

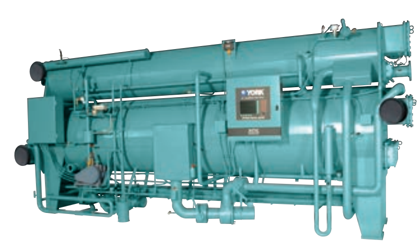
Microprocesser-based control centers deliver real-time data on all key parameters in a graphical, easy-to-understand format. This enables operators to run the chiller more efficiently and anticipate maintenance needs.

Customizable features

Let the industrial-cooling experience, capabilities, and technology of Johnson Controls help your team create the environment for success. Customize your chiller with the following features:

- Special dimensions for overseas container shipments or modular-package application
- Meduim-voltage motors (up to 13.8 kV)
- Special condenser waterside protection
- Special factory piping arrangement for series-counterflow installation
- Safety acccessories required for ice-duty operation
- Seamless integration with PLC-compatible controls
- NEMA 4X panels and wiring configuration
- Vibration monitoring
- RTD temperature sensors
- ASME documentation
- ISO quality control documentation
- AHRI factory performance testing





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