ADVANCES IN ENERGY EFFICIENCY, CAPITAL COST, AND INSTALLATION SCHEDULES FOR LARGE CAPACITY COOLING APPLICATIONS USING A PACKAGED CHILLER PLANT APPROACH

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ABSTRACT

Cooling equipment, whether used to meet air-conditioning or process cooling loads, represents a large consumer of energy. Even more to the point, cooling loads and the associated cooling equipment energy consumption tend to be at maximum levels during periods of high ambient air temperatures. It is precisely at those times that the general demand for energy is at its peak and therefore the price or value of energy is also at its highest level. Cooling loads often drive the peak electric power demand of energy users and thus affect not only the level of consumption of high cost energy, but also affect the peak power demand. Together, the energy and demand costs equate to very high unit costs for operating cooling equipment. Accordingly, it is of interest to minimize cooling energy use and costs by maximizing the energy efficiency of cooling equipment installations.

A relatively new approach has been developed and is being increasingly used to maximize chiller plant efficiency. The approach involves the use of a standardized, pre-engineered, shop-fabricated approach to entire chiller plant installations. Compared to the traditional, piece-meal approach to chiller plants that utilize individual component specification, procurement and installation, the "packaged" or modular chiller plant approach often delivers substantially improved energy efficiencies. Also, the packaged plant approach achieves further benefits for large cooling system owners and operators. These additional benefits include: 1) dramatic reductions in unit capital costs of installed chiller plant capacity on a dollar per ton basis, 2) marked improvements in total procurement and installation schedules, 3) significantly smaller space requirements, and 4) enhanced control over total system quality and performance.

The capacities and performance characteristics of available chiller plant modules are described, including both electric and non-electric chiller technologies. Examples are presented to illustrate the typical sizes and locations of actual installations as well as the growth and extent of the use of this technology to-date. Case studies document the energy efficiency improvements, cost reductions in both operating and capital costs, and improvements in schedule and space utilization, of the packaged chiller plant approach relative to the traditional chiller plant approach.

PACKAGED CHILLER PLANT APPROACH

Table 1 provides a comparison of the typical attributes and performance of the packaged chiller plant approach relative to the conventional chiller plant approach.

Table 1
Benefits of Packaged vs. Conventional Approach

Benefit	Packaged	Convent'l
Energy Efficiency (kW/ton)	0.70-0.80	0.90-1.00
Eliminates Need for Building	Yes	No
Installed Capital Cost ($/ton)	800-1200	1500-2000
Deployment Schedule (mos.)	6-8	18-24
Compactness	Yes	No
Portability	Yes	No
Modular Concept	Yes	No
Constructability	Simple	Complex

The typical project capacities and the benefits of the packaged chiller plant approach are illustrated through a review of several case studies, two briefly summarized, and one presented in detail.

Case study - El Paso Corp., Macae, RJ, Brazil. A 37,500-ton chiller plant installation was satisfied through the use of fifteen (15) identical 2,500-ton packaged chiller plant modules. The system was brought on-line in phases during 2001 and 2002.

Case study - GE, Seropedica, RJ, Brazil. A 20,000-ton chiller plant installation was satisfied through the use of eight (8) identical 2,500-ton packaged chiller plant modules. The system was brought on-line in 2001.

CASE STUDY – NRG ENERGY BRAZOS VALLEY

1. Background

An owner (NRG Energy) contracted an EPC (Engineer, Procure, and Construct) Contractor (Black and Veatch - Zachary) to build a power plant involving two large 180 MW GE gas turbines near the suburbs of Houston, Texas. This power plant would also require an 11,000-ton central plant to provide chilled water for use in cooling the inlet air of the gas turbines to gain additional power during the summer. The owner was quite familiar with chilled water plants as they had a group that developed District Energy plants. They researched the various methods of providing chilled water with the lowest life-cycle costs when considering total installed costs and energy & maintenance costs. They had concluded that a Packaged Central Plant would give them the highest return on their plant. The owner recommended a company that had a lot of success with providing chilled water plants on other gas turbine applications and that this company had over 100 plants operating and successfully performing on inlet cooling applications.

Because the EPC Contractor had overall responsibility for bringing the project in on time and in budget, they were free to engineer their own best solution. After significant research the contractor also concluded that utilizing the Packaged Central Plant approach was the lowest cost method for achieving the design objectives and they selected TAS to provide and install this plant.

2. Pre-Construction

TAS, a founding pioneer and developer of Packaged Central Plants for turbine inlet cooling (TIC) applications owned pre-engineered designs and performance optimization programs that could project the generating impact of TIC on power output performance. TAS was able to show the advantages and costs for many system variables like the need for redundant, stand-by pumps; chiller, tower, and pump selections; design inlet air optimization; and series vs. parallel chiller piping. While TAS had standards, each was custom suited to a customer's unique needs. Fabrication drawings were tweaked to meet project specifications. TAS' engineering group had an electrical distribution skid that met the required need of the project. Requirements were established to optimize the systems.

TAS selected a package with optimal performance such that a guarantee of 0.72 KW/ton could not only be met, but also guaranteed. This power included chillers, chilled and condenser water pumps, cooling towers, and all ancillary loads like controls, lighting, etc.

With this input, TAS had immediately on hand a pre-engineered module selected with all required layout drawings, foundation plans, process flow diagrams, P & ID's, rigging and lifting plans, control systems drawings, electrical drawings, lighting layout, structural framing and piping details, cooling tower and pump details, and assembly drawings. Submittal and approval times were greatly reduced and price and performance were guaranteed.

Since the central plant was fully packaged, all architectural, civil, mechanical, and electrical coordination moved forward. Site construction did not wait on TAS; the packaged central plant was shop fabricated. Coordination had already occurred.

3. Shop Fabrication

Since all of these plants were conceptually pre-engineered, each piece could be fabricated with tight tolerances and factory quality control processes (i.e.

welding per ASME B31.1 standards). All long lead delivery items, chillers, towers, pumps, switchgear, and controls were released for production. Predetermined pipe spool pieces were cut. Shop construction began soon after. Frames were welded; platforms were assembled. Major components arrived and were set directly in place. Wiring was run and terminated. The central plant was completely assembled and tested to assure everything would fit and work when it was delivered to the site.

During the construction period, the Houston area experienced a tremendous amount of rain and flooding. Fortunately this did not delay the fabrication of the chiller plant in TAS' shop where work proceeded on schedule and where quality and workmanship met the specification.

4. Field Assembly and Commissioning

The effective footprint for the whole packaged central plant was a little under 6,000 square feet, or approximately 2 tons/sf. One engineer was amused with his observation that most field erected plants were a reciprocal of 3-4 sf/ton. All of the parties were relieved because of the minimal footprint required of these central plants.

The actual setting of the central plants occurred within five months of release. With the help of an 85-ton crane, the plant modules were set over a two-day period; final assembly was made within two weeks, well ahead of the construction schedule.

Commissioning was successful. Performance was met. The plants' fully integrated control and monitoring system interfaced well with the plants' digital control system.

After-market warranty and maintenance has been upheld with TAS' capable project and service group and also with the local Trane service office.

5. Broader Benefits

TAS has delivered their packaged central plants into the Commercial and Industrial markets through its **TAS –Packaged Solutions** Group. Besides all of the advantages outlined in the Brazos Valley case study – **guaranteed efficiency, compactness, pre-engineered quality, and lower price**, the packaged central plants bring additional advantages over conventional field erected central plants:

- **Flexible**
  1. Electric driven Centrifugal or screw or steam driven absorption chillers
  2. Water or air cooled condensers
  3. Broad size ranges (400 Tons to 8,000 Tons on a single plant)
  4. Manifolded multiple plants (TAS has done central plants up to 37,500 tons in one location)

- **Relatively Quiet**
  1. Low speed 3600 RPM direct-drive centrifugal chillers
  2. Standard insulated wall panels
  3. Optional cooling tower noise abatement

- **Adaptable**
  1. Available with low temperature chilling and thermal storage options
  2. Suited to heat recovery, BCHP, and cogeneration applications
  3. Readily accessible and easily maintained
  4. Ancillary skid for heating, electrical distribution, water treatment are also available
  5. Financing, leasing, or thermal outsourcing is available

- **Portable**

6. Conclusions and Recommendations

The packaged chiller plant modular approach provides dramatic improvements in several areas that are often critical to large users. These areas include:

- High Energy Efficiency
- Reduced Installed Capital Cost
- Shortened Construction Schedule
- Reduced Plant Footprint
- Enhanced Control of Quality & Performance
- Standard Parts, Operation & Maintenance
- Reduced Jobsite Problems and Risk
- Guaranteed Performance and Price

These benefits have been illustrated in actual installations.

The standardized packaged chiller plant design is available in modules ranging from 400 to 8,000 tons of capacity.

The relatively new approach of employing a packaged chilled plant represents a great opportunity for owners and operators of large cooling systems to

capture dramatic benefits, relative to the conventional, field-erected chiller plant approach.

AUTHORS' BIOGRAPHY

Tom L. Pierson is the Founder and CEO of Turbine Air Systems (TAS), a leading provider of Packaged Central Plants, with corporate offices located in Houston, Texas. Prior to founding TAS, Mr. Pierson was the General Manager of Houston Trane's Industrial Division where he specialized in Centrifugal and Absorption chillers for outdoor use in process applications and power plants. In 1987, Mr. Pierson and his team completed the world's first turbine inlet chilling project in California. During his 20-year tenure at Trane, Pierson sold and engineered industrial chilling systems composed of Centrifugal and Absorption chillers, pump skids, motor starters and controls systems for approximately 25 different Turbine Inlet Cooling (TIC) projects from 1987 through 1999.

In the late 1990's, Mr. Pierson realized that what the industry really needed was a completely packaged TIC solution similar to what had been done for the LM5000 and LM6000 gas turbines. The total chiller plant experience of Mr. Pierson includes over 338,000 tons of refrigeration. In the 3 years since its' founding in 1999, TAS has completed projects involving over 163,000 tons of Packaged Central Plants.

Mr. Pierson is a senior member of the Research Committee of ASHRAE and is a past Chairman of the Turbine Inlet Cooling Association (TICA). Mr. Pierson holds 2 U.S. Patents and has several additional patents pending.

Jerry Koch is the Sales Manager of TAS Packaged Central Plants. He is in charge of Industrial and Commercial Sales. Prior to his coming to TAS, Mr. Koch held key management positions with several large national mechanical contractors. He brings thirty years of practical application experience to TAS.

Jerry is a Member of ASHRAE and The American Institute of Constructors. He holds a Bachelor of Science in Civil Engineering from The University of Houston.

John Andrepont is the founder and president of The Cool Solutions Company, which is focused on the successful development, considering both technical and commercial aspects, of applications involving Thermal Energy Storage (TES), District Cooling, and Combustion Turbine Inlet Cooling (CTIC).

Mr. Andrepont has over a quarter century of experience, including involvement in nearly 100 TES projects representing over a million ton-hours of storage capacity and over 200 megawatts of peak load management. He has long been an active member of ASHRAE and the International District Energy Association (IDEA), and is a founding member and vice president of the Turbine Inlet Cooling Association (TICA). John is a graduate of Rensselaer Polytechnic Institute with Bachelor's and Master's degrees in Mechanical Engineering. He is an inventor of one dozen patented inventions.

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