Commissioning Turbine Inlet Air Chilling Systems

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1. Importance of Successful Commissioning
   In the Power Industry the performance of a Turbine Inlet Air Cooling (TIAC) system is linked to the performance of the Power Plant itself by the Power Plant's rated output that is contractually guaranteed by the Power Plant designer and/or contractor. This makes the successful commissioning of TIAC systems more mission critical than the "normal" cooling system project. A properly defined and executed commissioning plan is essential to this success.

2. Commissioning Starts During the Project Proposal Phase
   Properly selecting and rating the system equipment is essential to meeting performance guarantees. Accurate equipment ratings which address manufactures tolerances and system losses must be taken more seriously as compared to "normal" HVAC or refrigeration proposals because typical load diversity cannot be considered as a safety factor in equipment sizing calculations for TIAC systems. The equipment must be sized for the plants design cooling load which many instances exceeds ASHRAE 0.4% ambient design conditions. This is particularly true due to the presence of performance penalties or liquidated damages on inlet air temperature, chilled water temperature and parasitic KW (system KW consumption). Performance penalties can be substantial, sometimes as high as $250,000 per °F, and must be incorporated early in the design philosophy to avoid them.

3. Commissioning Continues Through The Execution Of The Entire Project.
   The Commissioning process continues through project engineering, equipment purchasing and manufacturing, factory testing, system fabrication and site installation. Maintaining comprehensive quality control processes and procedures during all project phases is extremely important to a successful system startup and commissioning. Examples of commissioning throughout the entire project include:

   A. Engineering – properly designing the inlet cooling coil delta-T (supply vs. return temperatures) is an inherent part of the system design that affects all other equipment ratings and the eventual success of system start-up. A proper understanding of this includes:

      1) System delta-T and capacity must include system losses such as thermal heat gain and pump heat gain.

      2) At startup the delta-T is impacted by no fouling in clean heat transfer surfaces that have been designed to include Fouling Factors. This may cause low flow or laminar conditions at low loads in the very large inlet cooling coils.

      3) Typically startup and testing occur at part loads where delta-T's become lower but must be maintained to keep equipment running efficiently.

      4) Controls become a central component of delta-T and flow maintenance and must be properly programmed prior to start-up.

B. Equipment Purchasing and Factory Testing

1) All manufacturers base their ratings on industry-approved tolerances. Typically all ratings are +/- 5% whether it is TR's, KW, GPM or heat of rejection. These tolerances become greater when the equipment is running at part load or off design conditions.

2) Examples of tolerances are:
   a) Chillers and Refrigeration compressor ratings must adhere to American Refrigeration Institute (ARI) defined tolerances.
      (1) Chillers must adhere to ARI-550, compressors to ARI-520.
      (2) +/- 5% @ full load (also depends on delta-T)
      (3) +/- 18% @ 25% full load (also depends on delta-T)
   b) Cooling Towers ratings must adhere to Cooling Tower Institute (CTI) defined tolerances.
   c) Pumps must adhere to Hydraulic Institute (HI) defined tolerances.

3) When system performance guarantees are tied to liquidated damages it is incumbent on the supplier to remove these tolerances or run the risk of capacity shortfall or higher parasitic KW.

4) Guaranteed equipment ratings and performance can be tested and verified by factory testing. The results of factory testing can then become part of a total system site performance test.

C. Fabrication

Making sure that the hydronic piping systems are routed and installed per the system drawings is important so system pressure drops do not exceed pump design conditions. For example, higher than design pump heads on cooling tower piping will limit heat of rejection capacity and may limit chiller capacity and inlet air temperature on a design day (i.e. failed performance test).

4. Start-Up and Commissioning Protocol

A. The Performance Test procedures and protocol for a combustion turbine and the Power Plant itself are very detailed and comprehensive. Power Plant commissioning personnel manage and execute the total plant commissioning effort and will inherently involve, manage, and supervise the TIAC contractor during the process.

B. TIAC systems also require Performance Test procedures and protocol with performance curves and correction factors. These procedures and the expected part load performance data need to be submitted and approved early in the project. It is not uncommon that part load performance data be requested during the proposal phase.

C. Commission Procedures should follow ASHRAE guidelines such as: 1-1996,111-1988, 41.3-1989, and 41.6-1994.
   - 1-1996 / *The HVAC Commissioning Process*
   - 111-1988 / *Practices for Measurement, Testing, Adjusting, and Balancing of Building Heating, Ventilation, Air-Conditioning, and Refrigeration Systems*.
   - 41.3 – 1989 / *Standard Method for Pressure Measurement*
   - 41.6 – 1994 / *Method for Measurement of Moist air Properties*

D. Coordination with power plant owner/operator is critical as mentioned later.

5. Milestone Events During Start-Up and Commissioning. The milestone steps associated with startup and commissioning of a TIAC system are:

A. A complete and thorough documentation package must be maintained documenting the commissioning milestones and supporting activities. Owner/Customer approvals and sign-off will be required at most milestones.

B. System Hydrostatic Pressure Test – Medium and large systems can have an internal volume of 50,000 to 100,000 gallons of water. Coordinating, providing and installing this large amount of water requires careful planning. The contractor must execute the proper system fill of the test water and removal of trapped air. Must have defined procedure to take the system to the required system test pressure.

C. Controls loop checks – Must verify all control wiring continuity and functional verification that equipment and valves are performing as intended.

D. Electrical testing and checkout: of all electrical gear and wiring must be completed. This includes relay settings, high pot testing; megger testing, life safety equipment, etc.

E. System Flush – This is the first time the pumping and hydronic system is operated. The piping system must have sufficient startup strainers/filters to remove dirt, slag, scale, etc. Flushing may take several days for larger systems.

F. Drain system of flush water – Proper disposal of dirty flush water (possibly in large quantities) also requires careful planning. The draining must be done from all low points to make sure all dirty water is removed. Proper air venting and/or vacuum breaks are necessary to attain complete draining (and protect automatic air vents). Environmental testing of drain water may also be required for some sites.

G. Loading or charging of the system chilled water or glycol charge should occur immediately following the draining of the flush water. Allowing the system to sit empty after draining the flush water will allow oxidation and surface rust to develop on wet surfaces exposed to air.

H. On glycol systems the proper volume of glycol charge and method of installation must be determined several weeks in advance so the correct quantity can be calculated, ordered, delivered, and properly mixed to the correct solution concentration.

I. Mixing the glycol to the correct concentration can occur during the charging process or before.

   1) Mixing during the charging process uses a predetermined quantity of 100% concentration glycol pumped from barrels or a tanker truck into the piping system. Deionized water is then added to the system in a predetermined quantity to completely fill the system. Mixing the 100% glycol and the water occurs by running the system pumps. Using non-deionized water will prematurely break down the inhibitors in the glycol.

   2) Alternatively a premixed solution of glycol and water can be ordered prior to loading it into the system. The predetermined volume and concentration level of glycol/deionized water solution is purchased and delivered in barrels or tanker truck(s) for easier filling into the system. This is particularly easier on large systems. Deionized water must also be used in the premixed solution.

J. After charging the glycol concentration must be verified to make sure it is the correct percentage.

   1) % by weight or % by volume? Miscommunication on this solution unit of measurement can lead to incorrect glycol concentration levels.

   2) A refractometer must be used for accurately measuring the concentration levels of ethylene glycol.

   3) All glycol must in “Inhibited” (contain corrosion inhibitors).

K. For water only systems potable water is required to assure cleanliness and proper PH of the water. Shortly after charging the water into the system, corrosion inhibitors need to be added to adequately protect the system.

L. Regardless of whether the system operates on a glycol solution or water, the filling process can be time consuming just as it was during hydro testing. The proper venting of air is critical to completely fill the entire system. Filling from multiple points will speed up the process. Typically filling and flooding of the pump piping will allow you to intermittently turn on the pumps to push the charge into the system.

M. Loading of glycol or water is the beginning of "system operation". Prior to this event, all equipment is setup, aligned, rotations checked and prestart-up check lists have been completed but, once glycol or water is in the system everything is ready to run as one (or should be).

N. Of course one major item is also needed to run and that is an actual cooling load. If the turbine(s) are not operational the chillers will only be able to cool or "pull down" the glycol or water loop itself. This will only allow the system to run fully unloaded for about an hour before the chillers are satisfied and cycle off. An inlet air cooling load is necessary to commission the system. One new Power Plants this is not always easy to accomplish. Often the plant is involved in complex commissioning efforts and coordination can be difficult. From turbine shutdowns to the grid not being ready to receive the 15 to 20% boost in output are examples of interruptions to TIAC commissioning.

O. Typically 48 to 72 hours of continuous loaded operation, while the turbine(s) are running at base load, is needed to "shake out", balance and debug the chilling system. Of course, additional commissioning activities are required after this point such as
   - Cleaning strainers and filters
   - Formal test and balance of the hydronic system to accurately set flows and pressures.
   - Hot alignment of open drivelines
   - Check for leaks
   - Check full load amps on equipment motors
   - Verify all system set points
   - Verify all system functionality and modes of operation.
   - Complete all startup reports, documentation and turnover packages to owner.

P. Operator training is very important to a successful commissioning. Operators should be trained prior to startup; they should also participate in startup activities to attain hands-on experience. Power plant operators are typically not familiar with large chilled water systems and an extensive training program is sometimes necessary.

Q. The final step in the commissioning process is the TIAC system performance test. It must follow the protocol as defined in the submitted and approved test procedures which include definition of:
1) Data to be measured
2) Measuring devices and associated tolerances
3) Data logging methods and duration of test
4) Personnel involved in testing
5) Method of interpreting and calculating test results.
6) Statement of Performance criteria to be met.
7) Pass/Fail results.