FEATURE

Specifying Commissioning for HVAC Systems

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The objective of HVACR systems commissioning is to bring a building's HVACR systems from a state of static completion into dynamic operation.

The commissioning process requires many specialised operations by separate persons or organisations. When those operations are not made a part of the construction contract requirements by adequate specifications, the contractor has no basis for pricing the work; consequently, the work is not done under the contract.

This paper provides guidance for planning and specifying HVAC systems commissioning work including the cleaning and identification of equipment and piping, cleaning and degreasing piping systems, chemical treatment program, lubrication, graphic operating instructions, operating and maintenance manuals, control system checkout, preparation for testing and balancing, and instruction of operating and maintenance personnel.

Introduction

When ASHRAE established a Task Group on Testing and Balancing in 1968, the early organisational meetings included much discussion on the desirability of including systems commissioning under the overall subject of testing and balancing. The consensus was that the two subjects, though closely related, are diverse enough to justify separate treatment in the ASHRAE technical committee structure. Testing and balancing had received the most publicity and ASHRAE member support and was the logical subject for a new task group which developed into TC 9.7, Testing and Balancing, in 1972. At about that time, a new task group was established to study the maintainability, reliability, and durability of ASHRAE-related systems. That TG became the TC on Maintenance, Maintainability and Reliability, which has been recently retitled TC 1.7 Operation and Maintenance.

In studying the scope of interests assigned to TC 1.7, the need for systems commissioning became evident. TC 1.7 has coordinated with TC 9.1, Large Building Air Conditioning Applications, to sponsor a series of papers to define

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systems commissioning and to provide material for the recently formed ASHRAE Guideline Project Committee GPC-1 on Systems Commissioning. The symposium papers presented during the 1986 Annual meeting in Portland, Oregon and the videotaped presentations of several of those papers by the individual authors has shown the overall interest in this subject.

This paper is a development of a paper by the same title which was presented at the ASHRAE Annual Meeting at Portland, Oregon in 1986.

Organisation of the project manual

Most construction projects are built under the drawings and specifications system, with the size, number, and location of work shown on the drawings and with the quality, type, and features of work covered in the technical specifications. The specifications are usually bound with the contractual-legal sections of the contract documents into a volume called the "Project Manual". The technical specifications are frequently organised in a Division-Section format in accordance with The Construction Specifications Institute's Masterformat. The "Masterformat", familiarly known as the CSI Format, provides a uniform approach for the organisation of the specification material in Divisions 1 through 16. The Divisions of most interest to those in the HVACR field include Division 1, covering "General Requirements", Division 15, covering "Mechanical", and Division 16 covering "Electrical". Sitework, structural work, and architectural type work are all covered in the sections in between.

The authors of the CSI Format have tried several approaches to finding the appropriate place for the intangible type work specified under sections such as testing and balancing, warranty maintenance, and systems commissioning. The location of testing and balancing specifications has been shifted in revisions of the CSI Format between Divisions 1 and 15. The location of systems commissioning, when it is recognised by the Masterformat, may be subjected to similar juggling. Many engineers prefer to keep the specifications for both testing and balancing work and systems commissioning work in Division 15, "Mechanical", for the greatest ease of administration. Some architects prefer to have the work specified in Division 1, "General Requirements", in order that their field personnel may include the mechanical work in their project closeout. In those cases where the engineer's fee is determined as a percentage of construction cost, any work designed by the engineer must be specified under Division 15 so that the cost of that work will be included in the "Mechanical" cost so that the fee determination will be on an accurate basis.

This writer was a member of the original task group on testing and balancing. His interest in the completion phase of projects designed in his office was put to good use in preparing a CSI guide specification on testing and balancing in 1968 followed by CSI monographs on systems commissioning and warranty maintenance. The testing and balancing guide specification has been widely used but the monographs have not been widely distributed.

"Warranty maintenance" is another name for "first year's maintenance in the contract" and is used by some multi-building owners in the Southeast. "Systems commissioning" is another name for "system setup, start-up, and checkout". These three subjects are closely related and — when taken together in their logical sequence of systems commissioning; testing, balancing, and adjusting; and warranty maintenance — can provide those operations that are vital to a smooth-running, efficient, and effective set of building systems.

Another related subject is "fine tuning automatic control system", which outlines procedures for setting up automatic temperature control systems for the optimum operation of occupied buildings, using feedback comments from the building occupants.

Systems commissioning — What it is and how to specify it

What is systems commissioning? Is it start-up and checkout? Is it preparation for testing and system balancing? Or is systems commissioning just the cleanup of all the little details left undone from the construction phase, which must be done before the request for final inspection?

The answer to these questions is "YES." Systems commissioning is all of these things and more besides.

Systems commissioning is the work done after the pipefitters, plumbers, sheet metal workers, insulators, and control systems installers have completed their work and left the site. It includes all those varied and all-important tasks required to change a static complex of ductwork, piping, and equipment into a dynamic, operating environmental control system, ready to serve the building with a reasonable expectation of delivering performance within the design intent.

Because of the multiple trades involved in the work, and the detailed nature of the work of systems commissioning, it is desirable to use a checklist approach to ensure that all the work is done in a timely and proper manner. It is also necessary to completely specify the work. The requirements for preparation for testing and balancing, as evolved for the CSI monograph on testing and balancing, serve as a useful checklist for discussing systems commissioning and for writing the specifications to cover the work of systems commissioning.

The "state of static completion" requires the performance of some "dynamic" operations in order to safeguard the equipment from damage during the period of completion.

A typical checklist might include these items:

1. Verify that air distribution products have been installed and given a preliminary adjustment.
2. Verify that filter installation is complete.
3. Verify that lubrication of equipment is complete.
4. Verify that instrumentation installation is complete.
5. Verify that hydronics systems have been cleaned, degreased, and filled with heat transfer fluid.
6. Verify that refrigerating systems have been leak tested, evacuated, and charged with refrigerant and fresh oil.
7. Verify that the equipment start-up is complete.
8. Verify that stuffing boxes and packing glands on pumps and valves have been adjusted.
9. Verify that equipment and connections required for chemical treatment program have been installed.
10. Verify that rotation of electric motors and ratings of overload heaters has been checked.
11. Verify that rotating equipment has been aligned and that belt drive tension has been adjusted.
12. Verify that control diagrams and sequences have been corrected to "as-built."
13. Verify that safety and operating control setpoints are as designed and that automatic control sequences have been checked for proper operation as specified under the automatic control system section.
14. Verify that equipment and installations have been cleaned, that temporary coverings, stickers, and tags have been removed, and that operating instructions shipped with equipment have been turned over for use in the operating and maintenance manuals.
15. Verify that painted finishes have been repaired where damaged.
16. Verify that equipment and piping identification work has been completed, with valve tags installed, valve tag diagrams and schedules and a piping identification system posted.
17. Verify that damaged fins on extended surface heat transfer coils have been combed out or replaced.
18. Verify that one set of operating and maintenance manuals has been prepared for use by testing and balancing technicians during their work.

Additional items that should be included when specifying system commissioning work are:

19. Conduct training sessions for

building operating and maintenance personnel to provide instructions in all aspects of the system for operations and maintenance.

20. Complete installation of graphic operational data such as start/stop instructions, valve tag schedule, and piping identification schedule.

21. Plan and implement a water treatment program, with initial qualitative testing of samples taken of fluids in the hydronic systems and of the domestic water supply, and give instructions to the supplier of the treatment chemicals as to the results desired.

A review of the systems commissioning checklist will reveal that there is a thread of continuity through the operations, with each one serving as a prerequisite to the next operation and each being dependent upon performance of preceding operations. It is recommended that the specifications arising from the checklist be structured to maintain the same continuity as the checklist.

Now let's get down to the specifics of specifying. The CSI three-part section format, with work organised under categories of General, Products, and Execution, serves as useful means for organising the specifications. Under that format, the parts would contain these elements:

Part 1 — General

1.1 General Requirements. Relate the system commissioning work to the overall project.

1.2 Description of Work. Give a thumbnail description of the work to be done with some mention of the philosophy of results intended.

1.3 Report Submittals: List the reports that are required to be prepared under systems commissioning.

Part 2 — Products

2.1 Identification Materials. Describe the stencils, tapes, tags, engraved nameplates, and pipe legend markers.

2.2 Graphics for Operational Data. Describe the reproduction process desired to give long lived, nonfading prints of control diagrams, equipment and valve schedules, and sequences of operation. Describe the frame and glazing desired, such as "3 mm thick polycarbonate sheet in extruded aluminum frame". The mounting method should allow the operator to remove the framed material for close examination.

2.3 Organisations Approved for Cleaning and Degreasing. If the supervision of cleaning and degreasing operations and furnishing chemicals is to be done by an outside organisation, list those organisations along with chemical suppliers when the organisation is not primarily a chemical vendor.

2.4 Chemicals for Water Treatment. List the acceptable manufacturers, and describe the packaging desired. Normally, the specific chemicals to be fed in the system are not known at the time of specifying.

2.5 Equipment for Water Treatment. Describe the equipment to be installed under the system commissioning section. An educated guess must be made as to the specific form in which the chemicals will be furnished, such as briquette, liquid, or powder, in order that an equipment type may be specified. Because each chemical treatment manufacturer has specific formulations for control of algae, corrosion, and scale, it is wise to coordinate the feeding equipment with the chemicals to be fed by specifying both chemicals and equipment under systems commissioning. It is necessary in this case to provide for connecting points into the piping system and equipment as plugged or valved outlets specified and detailed under the piping and equipment installation work.

Part 3 — Execution

3.1 Air distribution Checkout. Provide for a visual check that air distribution products are installed and adjusted for "best guess" performance.

3.2 Filter Checkouts. Provide for a visual check of filter installation. For panel filters, provide for adjustment of latching devices, installation of end spacers in filter boxes, and for proper latching and sealing of access doors. For roll filters, check for installation of media in curtain guides and over tensioning devices for interlocking of controls with fan operation and for setting of pressure and time controls.

3.3 Lubrication. Provide for preparation of a lubrication schedule listing for each piece of equipment requiring lubrication, the points to be lubricated, the product and the application device to be used, and the frequency of lubrication required. Next, provide for the initial lubrication of the equipment, along with flushing of anti-rust compounds that may have been furnished by the manufacturer.

3.4 Instrumentation. Provide for a verification of proper installation of the instrumentation items specified in other sections, such as air filter gauges, pressure gauges, pump manifolds, thermometers, thermometer wells, pitot-tube traverse stations, and flow-measuring devices. That check should include verification of (1) location of point for reading, to be certain that the device is measuring what it is intended to measure; (2) proper style or type of device, such as thermometer well for bi-metal stem versus test well for a glass stem thermometer; (3) scale range, such as a compound gauge installed at condenser water pump suction or in other locations to place the normal reading at near midrange of the scale; (4) proper installed position of instruments as required to allow reading from a convenient location, for reading pairs of instruments from one location, and for access to install and remove instruments, such as to locate thermometer test wells to allow space where 533 mm long glass stem thermometers are used; and (5) calibration of instruments, such as air filter gauges and pressure gauges.

3.5 Hydronics System Heat Transfer Fluids. Specify the work of cleaning and degreasing piping systems, pre-treatment of. fluid in closed circulation systems, and charging of antifreeze solutions or other heat transfer fluids. The procedures for cleaning may be simple, such as a simple flushing at city water pressure, a more thorough pressure flushing using temporary booster water pumps, or a chemical treatment followed by pressure water flushings. After initial cleaning, the piping systems are ready for pump start-up. Specify fine mesh temporary start-up strainers inside the normal strainer baskets to remove the remaining particulates above the strainer mesh size. During start-up straining operations, the pressure drop across the strainer must be monitored and the strainer medium must be changed when the pressure drop becomes excessive. Each change of media should go to a finer mesh until the desired level of particulate size and concentration is achieved. On systems having a continuing inflow of particulate contaminants, such as from cooling towers set in basins at grade level or from underground piping systems, it is desirable to provide a centrifugal-type separator in the circulating lines, either as a bypass strainer to flush the pump seals or as a full line separator. The overall subject of cleaning, with the many methods of cleaning and pretreatment, is a very complex subject which could take hours to discuss in detail.

The procedures for degreasing present a similar situation. I will only say that degreasing needs to be coordinated with cleaning and pretreatment by a person familiar with chemical reactions to avoid injury to personnel performing the degreasing and damage to the piping system through reaction between chemical compounds used for cleaning, degreasing, and pretreatment. Pretreatment must be carried out carefully since it is usually done by feeding fairly high concentrations of chemicals into the system with system pumps running. Damage to pump shaft seals often results when cleaning, degreasing, and pretreatment operations are improperly performed. The water used in filling the system must be clean and pure, generally domestic potable water. Do not cross connect condenser water systems serving wood-filled cooling towers or you will have splinters in the chilled water system. Care must be exercised in filling hydronic piping systems to avoid cross-connections and backflow to the potable water systems.

Charging brine or glycol systems require careful coordination in the system design phase to provide the specialty products needed for filling and pressurising the system. The charging process is simplified by application of diaphragm-type compression tanks in these systems and using air venting procedures which include venting air from system through piping immersed in containers of the circulated fluid.

Initial charging and pressurisation of medium temperature water (MTW) and high temperature water (HTW) systems must be specified in detail to assure proper system operation and to protect piping and equipment from pressure surges and destructive water hammer. Careful coordination in the system design phase is required to provide the specialty items required for system pressure control by inert gas, generally nitrogen. System operating pressures in the 1.1 MPa to 1.4 MPa (gauge) range require careful selection of piping system components and careful leak testing of the completed piping system.

3.6 Refrigerating System Charging. Provide for verification that all operations specified under the system installation section have been completed, including evacuation, charging refrigerant, dehydration, and providing fresh oil. Often, factory-charged systems will be found to have improper refrigerant charge and must be adjusted to the proper operating charge for the temperature and load conditions of the installation. When systems with winter charge receivers for condenser capacity control are started during summer conditions, they must be rechecked during outside conditions approaching minimum to assure that an adequate charge is present to provide control of head pressure. The charge must be adjusted to the level necessary to control head pressure at the winter design temperature.

As a follow-up on this part of systems commissioning, specify the monitoring of moisture in the refrigerant circuits and the changing of dehydrator cores when their moisture-holding capacity is reached.

3.7 Equipment Start-up. Adequate start-up procedures can be the most effective insurance of all to protect against premature failure of the building systems. Ideally, start-up procedures would be performed by factory-trained service technicians, but realistically, start-up procedures are performed by either the contractor's start-up crew or by the manufacturer's agent's sales personnel. In each case it is desirable to work from a checklist.

Such checklists should be divided into three time frames: (1) pre-start-up, (2) first run observation, and (3) equipment checkout.

Typical operation performed in each part are:

1. Pre-start-up Inspection:

A. Verify proper equipment mounting and setting.

B. Verify that wiring is complete for control, interlock and power.

C. Verify alignment of motors and drives.

D. Verify proper connections of piping and accessories.

E. Verify that lubrication has been done.

2. First Run Observation:

A. Verify direction of rotation

B. Verify setting of safety controls.

C. Monitor heat build-up in bearings.

D. Check motor loads against nameplate ratings.

3. Equipment Checkout:

A. Verify the proper overload heater sizes.

B. Verify function of safety and operating controls.

C. Verify proper operation of equipment.

D. Report on inspection, observation and checkout procedures.

Some owners, particularly governmental agencies, may require certification by affidavit that start-up procedures have been performed and that equipment installation is in accordance with the manufacturer's written installation recommendations. Under such requirements, the start-up procedures take on additional contractual importance because of their effect of extending the warranty terms beyond the normal scope.

3.8 Stuffing Boxes and Packing Glands. Provide for adjustment of stuffing boxes on pump shafts and for packing glands on valve stems. Stuffing boxes on pumps are packing glands using packing material to suit the pump duty, with graphite and lubricant impregnated asbestos being an old standby for condenser water service. Valve packing may be TFE impregnated asbestos, solid TFE, or O-rings. In all packing materials there is a lubricant to ease the friction in rotation. In pumps, the frictional heat generated is cooled by a liquid, either the pumped liquid or an external liquid supplied to lantern rings in the packing gland. Therefore, adjustment of pump stuffing boxes requires that some liquid leakage be present during operation. To stop liquid leaks on stuffing boxes is to cause damage by overheating of packing and shaft. Mechanical shaft seals do not leak when in good condition so that a leaking seal may be a sign of incipient failure. Valve packing, on the other hand, can be adjusted just tight enough to stop leaks but not tight enough to bind the stem.

3.9 Motor Rotation and Overload Heaters. Provide for a visual inspection and verification of motor rotations. It is possible for motor rotations to have been checked by the electrician when power connections were made on temporary electric power. Then, when final connections were made to the permanent transformer bank, crossed phasing reversed the rotation of all three-phase motors on the system. This is an important check, which causes some unusual operating conditions when overlooked, and is difficult to explain to the layman.

Provide for checking and recording overload heater data and operating conditions. The first step is to abstract the motor nameplate amperage for the voltage applied, then read the motor's full-load current and the voltage at the terminal box. If the applied voltage is different from the motor nameplate, determine whether the applied voltage is within the range allowed under the motor guarantee. If not, take the necessary action to change the motor or the applied voltage.

When the voltage is off the nameplate value, but within the allowable range, compute the equivalent amperage at nameplate voltage and compare to the overload heater amperage rating range. At this time, consider whether the ambient temperature of the starter is above, below, or the same as the ambient temperature of the motor. If the two ambient temperatures are not the same, use overload heaters of higher range for "hot area" starters or ones of lower range for "cold area" starters to compensate the heater trip point for heat gains or losses with the environment.

3.10 Alignment of Drives. Provide for procedures to align drives, belt and direct coupled, and to adjusting belt tension. When checking axial alignment of shaft couplings, it is also necessary to check the end clearance between shafts as a final step in this procedure. Improper clearance in the coupling will cause noise and premature failure of the power transmitting elements of the coupling.

When aligning sheaves in V-belt drives, several points bear discussion. With single groove fixed- and variable-pitch sheaves, the drive is aligned with the faces of both sheaves parallel and on the same centre-line. With multiple-groove variable sheaves driving fixed-pitched sheaves, a problem arises in that the groove spacing on the variable-pitch sheaves varies with adjustments in pitch diameter and the spacing is never the same as on the fixed-pitch sheave. In this case, the best approach is to align drives with sheave faces parallel and with centre-lines of the grooved widths of sheaves in line. Belt tension can cause problems. If belts are too loose, slipping results, which glazes belt edges and groove faces thus causing more slipping and more glazing, with declining performance and noise on the driven machine. On the other hand, if the belts are too tight, excessive loads are imposed on the belts. When motors with belt drives are to be cycled from electric load management automation systems, the conventional belt drive is likely to be the source of trouble when multi-groove variable pitch sheaves are used. It is best to use fixed-pitch sheaves with composite belts having multiple deep vee sections laminated to a flat belt backing. That combination avoids stretching individual belts on start-up from unequal friction in the grooves due to glazing. In the composite belt, gripping is done by the vee sections and the stretch producing power transmission is done by flat belt backing.

3.11 Control Diagrams and Sequences. Provide for co-ordination with work under the automatic control system to have the control diagrams and sequences of operation corrected to "as installed", reflecting changes brought about in response to contract modifications and to the more pragmatic changes in diagrams and sequences to make the installed system control the building systems as intended by the designer. These latter changes are often evolved when performing a final control system checkout, where each sequence is checked throughout its full range and setpoints are verified. In multiunit systems, it is desirable to have one system diagram and its sequence per drawing for the outlying mechanical rooms with the central plant diagrams on several drawings. Labelling control instruments with functional designations on the drawings and in the sequences, as well as installing corresponding nameplates on each instrument, is a great help in checkout and in maintenance. These latter points should be specified under the automatic control systems section.

3.12 Safety and Operating Control Setpoints. Provide for systematic checkout of safety and operating controls of equipment, along with operational check of associated control sequences, such as condenser water bypass valves, cooling tower fan cycling, and pump pressure bypass. Because most of the safety controls, and some of the operating controls are furnished factory mounted with the equipment, there will be no checkout of their operation under the automatic control system unless that checkout is specified in enough detail to be priced by the automatic controls system contractor. The checkout of safety and operating controls system checkout of associated control sequences can be combined with the work mentioned under 3.11 above.

3.13 Clean-up of Installation. Provide for a thorough cleaning of the installation either in preparation for finish painting or for final acceptance. Many different types of operations are required in this work, including removal of temporary coverings installed for protection of the work; removal of adhesive-applied stickers, except those giving specific maintenance instruction, which were intended to remain for use; removal of cord and wire affixed tags, except equipment identification stencils; washing down surfaces that are to receive finish painting, using cleaning compounds intended for that use; cleaning other surfaces, either those with factory finish or those that are not to receive any additional finish painting; cleaning coating spatters and overruns from insulation installation and finishing; and cleaning inside control cabinets, to remove dirt and scrap material from connections to the panel, by blowing out with compressed air or by vacuum cleaning with brush tipped and pointed wands. Cleaning of internal portions of the system is covered under other headings.

3.14 Painting. Provide for touch-up of factory finishes that have been marred. This touch-up is intended to cover the scratches and abrasions that can be prepared by light sanding or by derusting with chemical compounds such as naval jelly, then coated with a compatible primer followed by a matching top coat. Where major damage has occurred on a finished surface, the entire piece should be refinished, and specific instructions given for the work. Provide for field painting of black steel and iron which is exposed to view, using a rust-inhibiting primer and top-coat system, following the manufacturer's recommendation for surface preparation and application of the products.

3.15 Identification of Equipment, Piping and Valves. Provide for identification of equipment with nameplates and stencilled legends giving information such as, on air-handling units, air volume and static pressure, what is accessible through access door, and caution legends such as "Do Not Open with Fan Running". Provide for identification of piping using either colour-coded tape band markers or with legend stencilled on painted backgrounds. In either system, apply directional markers adjacent to equipment and valves. For systems in buildings with full-time operating personnel, the colour-coded tape banding system is very effective. For systems operated by nontechnical personnel types, the abbreviated legends are best, and a minimum of abbreviation is desirable.

Provide for identification of valves using systematically numbered valve tags on the valves, keyed into small-scale diagrams locating the valves, and with a valve schedule that lists for each tag number the valve size, service, and function, such as "101.3 Cold Water, Building Service Cutoff". Specify the attachment method, considering frequency of usage, whether handwheel or lever operated, extent of insulation, and visibility of valve location.

3.16 Fin Straightening. Provide for inspection of finned surface heat transfer coils for damaged fins. Where plate type fins are bent, comb out the fins using combs available for each fin spacing, such as 8 fins per inch or 14 fins per inch.

Where helical wound fins are bent, straighten the fins with a blunt blade, like a putty knife, and inspect for separation of the fin from the tube. Heavy fin damage may be reason for rejection of the coil. It is alarming to see the equipment shipped from factories with heavy fin damage. Some manufacturers have failed to instill in their workers an understanding of the necessity for protecting the delicate finning on close pitched finned surface coils.

3.17 Maintenance Manuals. Provide for the preparation of manuals containing operational and maintenance data for the systems. This work is properly the subject of a separate specification section, but it is often covered by a two-sentence paragraph in another mechanical work section. The manuals are often specified to be furnished in duplicate, sometimes in triplicate. Because of the work involved in assembling a proper manual, the number of manuals to be furnished must be determined by the actual need. For that reason, it is not customary for either the architect or the engineer to hold a file copy, although there are times during the first year that one wishes he had kept a copy. One copy of the manual should be prepared, on a preliminary basis if necessary, for use in test and balance work, to be returned for reissue when the work is completed.

Manuals should be organised in three parts as follows:

Part 1 — General. Provide data on the installing contractor, with principal subcontractors and equipment vendors, including home address, telephone number, and special telephone number for service departments on normal and emergency call basis. Include copies of inspection certificates issued for building systems. Include copies of the start-up certificates and reports.

Part 2 — Operating Instructions. Provide narrative description of system start-stop procedures, seasonal change-over procedures, and routine maintenance intervals keyed into Part 3. Include valve tag schedule and diagrams and piping identification legend, as colour code or abbreviations.

Part 3 — Maintenance Instructions. Provide copies of manufacturer's maintenance instructions along with shop drawings of the specific equipment and parts list, when a parts list has been prepared. On shop assembled equipment, such as rooftop equipment penthouses, it is desirable to have a bill of material with purchase order numbers for the vendor's identification of equipment orders. Include contractor's shop and setting drawings, lubrication charts and schedules, water treatment program data and test and balance reports.

The maintenance instructions for a simple project may be contained in a single loose-leaf notebook, but more complex projects will require multiple volumes with pockets and fold-out drawings. An excellent reference source for maintenance manual format and contents in the ASHRAE 1984 SYSTEMS HANDBOOK, Chapter 39.

3.18 Instructions to Owner's Operating and Maintenance Personnel. Provide for formal instructions to the building's operating and maintenance personnel. These sessions need to be organised in a classroom setting to review the operating and maintenance manual, followed by a walking tour of the building reviewing and identifying elements of each system. On a simple project, the walking tour may be adequate, but it is desirable to review the instructions at least once in the peace and quiet of a classroom. In either event, obtain a receipt from the owner's representative for the completed sessions.

The astute design professional will use this part of the system commissioning work as the principal training ground for building system operating and maintenance personnel and for facilities management personnel who will be responsible for the building operation and maintenance at the completion of the project. In order to achieve maximum results, the training operations desired must be defined and thoroughly described in the specification for systems commissioning.

The items which must be specified include:

1. Curriculum — a listing of the systems and equipment that are to be covered in the training operations and the operating and maintenance manuals to be used.

2. Instructor qualifications — a listing of the experience and training required for the instructors in the training sessions, including factory training courses.

3. Contact hours — the number of hours required in the classroom and in the field for each item of equipment and system for which training is specified.

4. Classroom — the requirements for the classroom as to seating capacity, provisions for audio-visual presentations, and chalkboards.

5. Training aids — special requirements for cutaway models, training panels, and demonstration models of installed equipment.

3.19 Graphic Operational Data. Provide copies of data prepared under other paragraphs arranged and displayed to become graphic operational data. Most of the data will be in a form to be framed, with frame and glazing to be as specified under 2.2 above. In some cases, it is desirable to set up operating instructions on a step-by-step basis with a framed set of instructions in large print co-ordinated with large numbers at each switch or other device to be operated.

For example, the motor starter panelboard serving air conditioning equipment would have a large "1" on the front, the starter serving the air handling unit would have a large "2" displayed by the pushbutton station, the starter serving the chilled water pump would have a large "3" displayed by the pushbutton station, and the starter for the hot water pump would have a large "4" displayed by the hand-off-automatic switch. The narrative operating instructions for daily start-stop would include under heading:

"TO START SYSTEM"

STEP 1. GO TO STARTER PANELBOARD MARKED "1".

STEP 2. AT STARTER PUSHBUTTON STATION MARKED "2" PRESS "START" BUTTON UNTIL GREEN LIGHT SHOWS.

STEP 3. AT STARTER PUSHBUTTON STATION MARKED "3" PRESS "START" BUTTON UNTIL GREEN LIGHT SHOWS.

STEP 4. AT STARTER SELECTOR SWITCH MARKED "4" TURN POINTER KNOB TO "AUTO" POSITION. GREEN LIGHT WILL SHOW IF OUTSIDE TEMPERATURE IS BELOW 65 °F.

A similar sequence is necessary under the heading "TO STOP SYSTEMS". Such instructional sequences can be invaluable where non-technical personnel will be in charge of the daily start-stop of building environmental control systems.

The usual graphic operational data will include simple daily start-stop instructions, seasonal changeover instruction, piping identification legend, valve identification schedule and diagrams, lubrication schedule, and control diagrams with operating sequences.

A useful addition to the graphic operating data on projects of medium size is a set of drawings and specifications left in metal containers mounted on the wall of the mechanical equipment room with the other graphic operational data. The drawings will be in a round tube and the specification and submittal data will be in a rectangular box with hinged top and each appropriately labelled.

3.20 Water Treatment Program. Provide for a complete chemical water treatment program with preliminary water testing, recommendations for chemical treatment dosage and feeding method for each system, monthly testing of systems under treatment, services of a consulting chemist, and supply of chemicals for one year's operation.

The work of this program must be co-ordinated with the work of cleaning, degreasing, and pretreatment under 3.5 above.

As mentioned under 2.5 above, some of the water treatment equipment may be provided under systems commissioning. Specify how the equipment is to be mounted, connected, and controlled. This requires co-ordination with the other specification sections for piping connection points, materials for connecting water treatment equipment, and for electrical connections to provide power and control.

Specify testing to include (1) initial qualitative testing of domestic water supply and of the heat exchange fluids in the systems to establish the program as to chemicals to be fed, the form in which the chemicals are to be supplied, equipment to be used to feed the chemicals, the feeding rate, and the concentrations to be maintained; (2) testing of the chemical concentration shortly after treatment is started to verify the dosage and to establish a continuing feed rate; and (3) 12 monthly tests with reports to complete a year of chemical treatment. The monthly tests will be used to adjust the feed rates to accomplish specific goals for chemical treatment. Where active corrosion is anticipated due to changing water conditions, such as use of well water or cooling tower water in chilled water systems during winter operation, it is desirable to provide a corrosion control coupon loop and a monitoring program. This pipe loop contains a series of threaded tees, each tee having a plug in one end and a coupon with an identifying number of its original weight in milligrams. After exposure to circulating water for varying periods of time, the coupons will be withdrawn, cleaned, and weighed. From a comparison of the final weight to the original weight, the per cent loss in weight, and corrosion rates can be determined, and the water conditions can be modified before serious damage is done to the system.

With all this specified, the work of systems commissioning can be priced by the contractor, can be checked by the engineer, and can serve to get the system off to a good start.

Conclusions

You may look back at these recommendations and think, "That is ridiculous! Any good contractor knows why and how to do all that, and more besides". But stop and think about it. In a competitive marketplace, the "good" contractor who knows how to do all this without your specifying it will never get an opportunity to do it. He will be underbid by the "fair" contractors who don't know how and why these systems commissioning operations need to be done. When you carefully write the systems commissioning specifications from a guide like this, you will provide a degree of quality control on your projects. This will justify the "good" contractor in doing a thorough job and may give the "fair" contractor that added measure of expertise needed to be a "good" contractor. ■