Consulting-Specifying Engineer

Testing and Balancing Specifications: A New Paradigm

Making the controls contractor responsible for testing, adjusting and balancing would improve the process and reduce finger pointing

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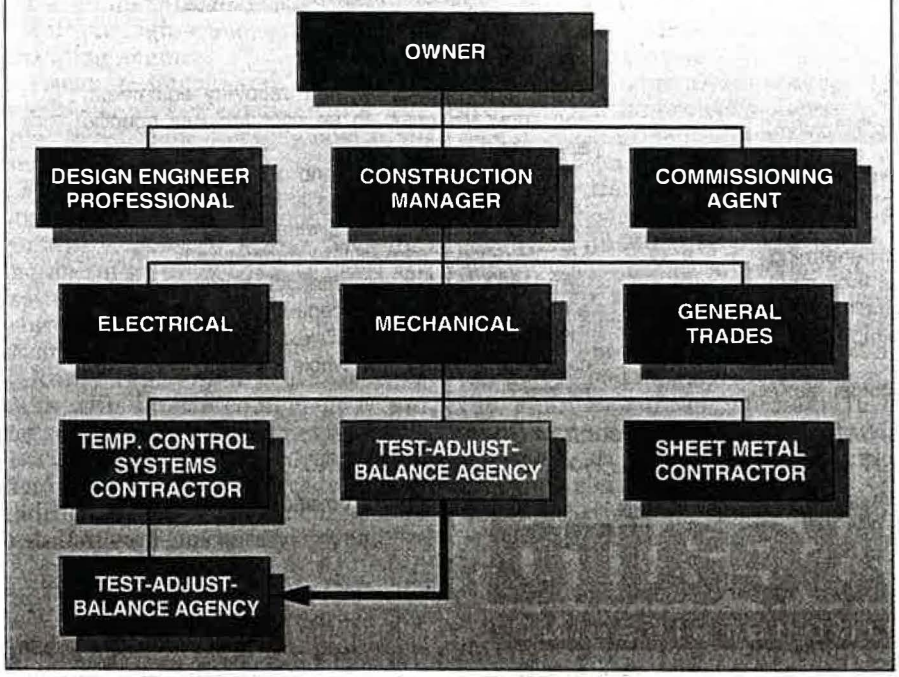
For many years, the heating, ventilating, and air conditioning (HVAC) industry has recognized the need to verify systems performance, an exercise known as testing and balancing. Recently, building commissioning—an expanded, more formalized verification process—has gained prominence, in large part due to the increasing sophistication of microprocessor-based controls.

A critical part of the commissioning process is testing, adjusting and balancing (TAB). Most TAB problems are rooted in areas affected by temperature controls. Thus, projects can best be served when specifications put TAB work in the controls contractor's hands. This reduces confusion and potential finger pointing.

FIGURE 1 – **PROPOSED ORGANIZATIONAL STRUCTURE**



An organization structure that puts testing, adjusting and balancing work under the controls-system contract reduces confusion and the potential for finger pointing.

Conventional approaches

Problems with the conventional TAB process include minimal accountability due to shared responsibilities among contractors, insufficient contractual provisions for the TAB contractor's contribution to problem solution and potential conflict of interest by having TAB work subcontracted by the mechanical contractor. In addition there is a systemic problem associated with the specialization necessary to understand and manipulate temperature-control system components.

Whether or not commissioning is adopted, bringing systems on-line involves numerous parties (see Figure 1). Most often, specifications call for an independent certified TAB firm to bid as a subcontractor to the mechanical contractor. Another approach has the TAB firm contracted directly by either the owner, construction manager or general contractor. Alternately, the work can be included in a contract to a third-party commissioning agent. These approaches result in many responsibilities shared among several entities.

Using a variable-air-volume terminal unit with a reheat coil that has tested low on air as an example, consider some of the issues that can surface and the likely responsible parties (shown in parentheses):

- Controls problems, e.g., terminal-unit flow control or duct static-pressure control (controls contractor).

• Insufficient inlet static pressure due to improperly installed, fabricated or designed ductwork (sheet metal subcontractor or design engineer).
• Air-handling unit not performing as specified or equipment pressure drops too great (manufacturer).
• Improper system set-up for test procedure to simulate design intent (TAB contractor).

Within each of these is the potential for subissues and other responsible parties. Roles become fuzzy when problems surface. All parties, including the design engineer, are forced to balance a desire to get things working with a need to limit costs. While the owner's main concern is for the results only a total system can provide, the usual method of subcontracting frequently leaves only the design engineer with an understanding of and interest in the integrated design concept. However, the design engineer usually has no contractual authority to perform work necessary to fix HVAC problems.

Generally, when a performance problem surfaces, the burden of proof correctly lies with the TAB contractor. Unfortunately, after identifying the problem, he also has to retest, sometimes several times. These iterations normally constitute extra work, but he usually does not get paid for this without a struggle. His contract almost never gives him authority for coordinating solutions, yet there are great expectations put upon him for these responsibilities.

Further, more often than not, the TAB contractor is a subcontractor to the mechanical contractor, who, it can be argued, is like the fox guarding the hen house. Conflicts of interest can surface no matter how roles and responsibilities are assigned.

Controls procurement

Over the last several years, design and installation of temperature control systems has become more problematic. Microprocessor-based control systems are more complex than their pneumatic predecessors.

The engineer of record cannot design the software control system. Instead, he or she typically establishes a program description or functional intent and leaves software design to a control contractor. The engineer establishes criteria in a performance specification, and this work is bid with the overall project.

This frequently results in a low-bid control contractor who does not understand the mechanical design concept. The engineer, on the other hand, may not understand the software well enough to review the contractor's interpretation and implementation of the design at submittal. This results in a less-than-optimal controls system, which should be the heart of a good HVAC system.

Although some might dispute the extent of the problems, few would say there are no problems. An approach is needed in which a contractual interest in the HVAC system's complete operation is created for the contractor best suited to understand the work. We suggest that specified TAB work is put into the hands of the controls contractor and controls contracts are established by means of a procurement process separate from the bidding of other work.

To implement such a process, it is critical that consensus over the following items be reached between the owner and design professional in the project's formative stages:
• The roles of the design engineer, owner, commissioning agent, construction manager, general contractor, mechanical subcontractor, controls contractor and TAB contractor.
• The method of procuring the temperature-control system.
• The control-system submittal review process.

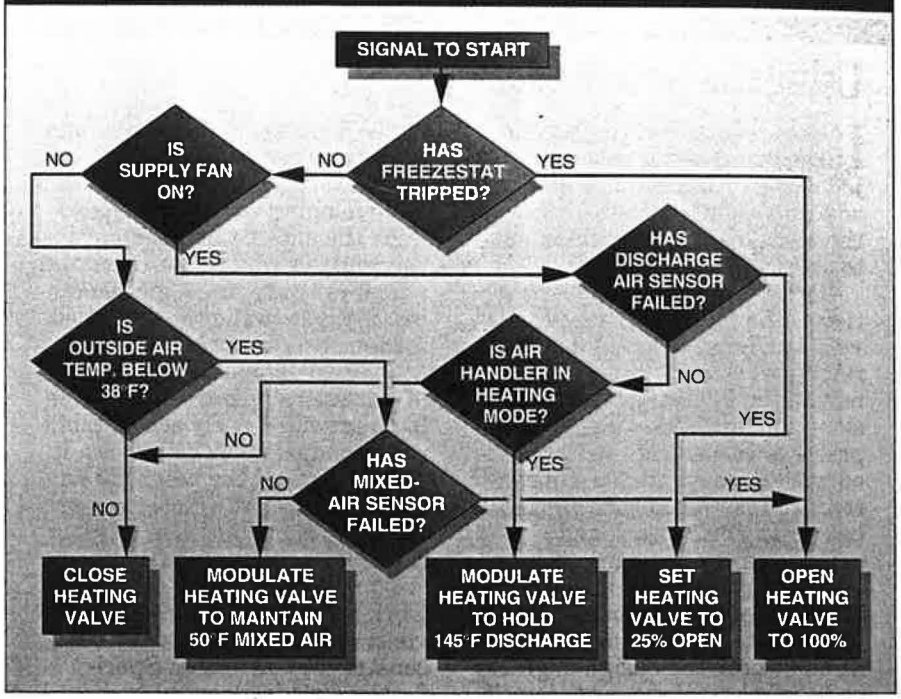
The design phase

As the project's design phase proceeds, it is important to identify control-system needs and owner expectations for: functional intent, system access, expansion capabilities, existing system compatibility and cost.

Within constraints of owner desires, the need for competitive pricing and supplier capabilities, a list of acceptable controls contractors should be reduced to the most desirable. One or more of these contractors should be brought in to review proposed system requirements to aid in the development of design specifications that will result in the most efficient and cost-effective solution to system needs.

Contract documents should group together HVAC control and setup portions of the work into the control

FIGURE 2 – CONTROL-LOGIC FLOW DIAGRAM



Requiring typical logic-flow diagrams in the controls contractor's bid allows the engineer to evaluate the contractor's ability to understand and perform the work.

A controls-contractor list should be reduced to the most desirable

Using the New Model

Ideas presented in this article have been used in several projects. Never did we attempt to adhere absolutely to the letter of the ideas, but we did remain true to their spirit.

A good example is the renovation of the Michigan State University Chemistry Building. This retrofit of a 1962-vintage building, now in the final stages of commissioning, illustrates some of the practical considerations associated with this new way to subcontract the testing, adjusting and balancing (TAB) work and procure control systems.

The project incorporated a construction manager. Fishbeck, Thompson, Carr & Huber was hired as both the design engineer and commissioning agent. Specifications made the controls contractor responsible for performance of the TAB work.

A list of two acceptable controls contractors was based on the need to interface with an existing campuswide control network and the selected contractors' demonstrated ability to achieve performance levels required by MSU. This included the ability to provide effective fume-hood face-velocity control on more than 200 1960s-vintage fume hoods.

Halfway through the design phase, the two controls companies were asked to prepare price proposals based on schematic designs, equipment lists and preliminary control requirements. Along with their itemized costs, they were required to provide information sufficient to show complete understanding of the design intent and their approach to it. In addition to standard control-system contract items, their bids included TAB work and supply of variable-air-volume terminal units, reheat coils and fume-hood exhaust dampers.

Based on submitted information a quality-based selection was made. The selected controls company then became a part of the design team, providing assistance in developing control schemes.

At the end of the design phase the controls contractor submitted a final contract price, incorporating changes to the controls work made subsequent to the preliminary price proposal. Having the itemized preliminary proposal in hand provided early accountability for budget responsibilities. It also minimized the potential for the contractor to inflate numbers for final pricing and possible subsequent change orders.

The contract for the general work was then bid in a conventional fashion through the construction manager. Specifications made clear the required division of work. For example, terminal units, even though purchased by the controls contractor, were installed by the sheet-metal subcontractor.

In a slight deviation from the listed recommendations, the commissioning agent generated the HVAC system functional performance tests. While this worked fine in this instance, there are several advantages to having the controls contractor develop these steps. First, doing so provides an opportunity to revisit control coding and potentially catch flaws in the logic. Also, the controls contractor is most familiar with hardware limitations. But whoever writes the initial steps, careful review for completeness is essential. After review, the modified test steps were adopted.

Performance of all HVAC systems was verified in all modes of operation under different conditions with the commissioning agent directing the testing steps and recording results, the controls contractor executing test steps and MSU personnel present to witness the testing and increase system familiarity. □

contractor's work scope. The intent is to maximize single-source control and responsibility for control, setup and performance. Division of Work paragraphs define intended contract divisions and contractor responsibility to coordinate with the engineer.

Separate documents for temperature-control systems, systems verification/TAB contract and specialized systems and components must be provided in each control-system bid set. To clearly indicate areas of responsibility for coordination purposes, the mechanical subcontractor's bid set will require unique but coordinated versions of these specification sections, including the Division of Work paragraph.

Depending on project requirements, specialized systems may include variable-speed drives, pure-water systems, medical-gas systems, pressure-regulating stations, boiler controls, chemical-treatment systems, heat-pump systems, package-rooftop units, computer-room air-conditioning units, humidifiers, dehumidifiers and variable-air-volume terminal units.

Bid phase

Controls work ideally is obtained through a procurement contract prior to bidding of the general contract. However, the timing of the design process usually makes it more practical to bid controls at the same time, but independently, of the general contract and assign it to the general contractor through an allowance. Where a construction manager is involved, control work can be handled as a separate contract.

The controls contractor's bid should include samples of typical logic-flow diagrams (see Figure 2), allowing the design engineer to evaluate the contractor's ability to understand and perform the work. The engineer should lead in the evaluation and interview process to identify system differences and their implications. Automatic acceptance of the low bidder among suppliers—which are rarely equal—is removed.

Construction phase

Controls submittals should include logic-flow diagrams in addition to

Controls work should be procured before general contract bidding

normal hardware, software and written sequence-of-operation submittals. The engineer can review these documents in detail to verify understanding, intent and ability to provide the control methods intended.

The controls contractor must provide system verification/testing, adjusting and balancing services for all HVAC systems. A certified AABC or NEBB subcontractor is not required, but specifications should detail the method and reporting procedures and requirements. If the controls contractor cannot address this scope of work, it should subcontract the services of a qualified TAB contractor. The commissioning agent will spot check system balancing after submission of the balance report as part of the review process.

The controls contractor will be required to demonstrate all control systems in all modes of operation to the commissioning agent as a review for final compliance with operational intent (see Figure 3). Functional performance test descriptions, developed by the controls contractor, must be approved by the design and commissioning agent prior to field testing.

Any faulty or incomplete control system installation found during testing and the resultant rebalancing will fall within the control contractor's scope of work. An agreed upon construction-coordination process will dictate responsibilities for additional test and verification exercises when issues arise relating to faulty or incomplete work by other parties.

The following procedures serve as a guideline:

- Trouble-shooting of problems during the start-up or warranty period will first be addressed by the controls contractor.
- If components are operating as intended and the problem's root cause still is not apparent, the commissioning agent will then become involved in the analysis of the problem.
- If further investigation becomes necessary and the design engineer is required to become involved, the project contractor will be responsible for any costs related to the failure of the installation work to comply with the contract documents.

Each project will differ in terms of the players involved (e.g., whether there is a commissioning agent or a construction manager), scale and complexity, and owner needs and expectations. Time constraints also can play a role. For each project, these factors establish boundaries inside which the ideas presented here must be adapted to fit.

FIGURE 3 – **SAMPLE REPORT**

AIR-HANDING EQUIPMENT DATA SHEET

JOB NAME	MSU CHEMISTRY		JOB NUMBER	92023V	PAGE	1		
SYSTEM	EAST EXHAUST		TEST ENGINEER	DVD/PEK	DATE	5-11-94		
UNIT NUMBER			EF-4			EF-5		
LOCATION			EAST PENTHOUSE			EAST PENTHOUSE		
AREA SERVED			LAB WING EAST			LAB WING EAST		
MANUFACTURER			ABC FAN			ABC FAN		
MODEL NUMBER			XXX SIZE 600 CLASS II			XXX SIZE 600 CLASS II		
			DESIGN RATED	INITIAL TEST	FINAL TEST	DESIGN RATED	INITIAL TEST	FINAL TEST
FAN	TOTAL CFM		65,000	59,900	74,150*	65,000	64,350	73,500*
	R.A. CFM							
	O.A. CFM							
	TOTAL S.P."		5.0	≈5.0	≈4.7	5.0	≈4.5	≈4.2
	SUCTION S.P."			-5.0	-4.70		4.5	-4.20
	DISCHARGE S.P."							
	FILTER P.D."							
	FAN RPM		742	696	750	742	695	750
MOTOR	BHP		70.9	53.2	73.7	70.9	49.2	73.1
	(1) VOLTAGE		460	480	465	460	478	460
	(2) VOLTAGE			482	468		478	458
	(3) VOLTAGE			482	470		478	460
	(1) AMPERE		85	65	83	85	62.5	84.4
	(2) AMPERE			66	84		63.1	84.0
	(3) AMPERE			65	83		63.1	84.0
	MFG.	FRAME	QRS MOTOR		444 U	QRS MOTOR		444 U
	HP	SF	75		1.15	75		1.15
	RPM	PH	1770		3	1770		3
HEATER/ STARTER	MFG.	MODEL NO.	XYZ		XXX-2	XYZ		XXX-2
	AMP RATING		88			88		
	NO OF HEATER		3			3		
	TYPE/CLASS	SIZE	W76		2	W76		2
SHEAVE MOTOR FAN	TYPE	KEY	LUB.	FIXED	3/4 X 5/8	ZERK	FIXED	3/4 X 5/8	ZERK
	O.D."	P.D."	SHAFT"	23	22 5/8	3 7/16	23	22 5/8	3 7/16
	TYPE	KEY	LUB.	FIXED	3/4 X 1	YES	FIXED	3/4 X 1	YES
	O.D."	P.D."	SHAFT"	9 3/4	9 3/8	2 7/8	9 3/8	9 3/8	2 7/8
	NO. OF BELTS	SPAN"		(4) 5V X 1320		39 3/4	(4) 5V X 1320		39 3/4

*BASED ON 24-POINT TRAVERSE AT STACK DISCHARGE

Summary

Because of the substantial dependence of testing, adjusting and balancing work on temperature controls, giving the controls contractor responsibility to perform TAB work has always made sense. Today, with the increasing complexity of the control equipment and programs, it is important to also make certain the controls contractor has adequate understanding and resources available to install a high-quality system consistent with the engineer's design intent.

Guidelines and examples presented in this article offer ideas that are intended to stimulate further discussion about how to best achieve these ends. □