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ADJUSTING, BALANCING, AND TESTING OF BUILDING ENVIRONMENTAL SYSTEMS

Federal Contruction Council

Technical Report No. 59

Prepared by
THE STANDING COMMITTEE ON MECHANICAL ENGINEERING
of the
FEDERAL CONSTRUCTION COUNCIL
BUILDING RESEARCH ADVISORY BOARD
DIVISION OF ENGINEERING
NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES
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1971

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of the

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Note: Much of the investigative work required for the study was performed by a subcommittee comprising William A. Schmidt (Chairman) and William E. Utt with the assistance of four liaison representatives from federal agencies--George A. Brandstetter and Casto De Biasi of the Naval Facilities Engineering Command, W. R. Henry of the U.S. Postal Service, and John W. Markert of the Public Buildings Service.

FOREWORD

A large percentage of the occupants of a new building--whether government or privately owned--almost always are dissatisfied in some way with their building's environmental system. The dissatisfaction is reflected in a wide spectrum of complaints. One area is too hot and another is too cool; one area is too humid and another is too dry; in one area there is too little fresh air; and in another area the system is too noisy.

In some cases the cause of the dissatisfaction can be traced to the design of the system. For one reason or another--usually to save money--compromises were made in the design of the system which render it incapable of controlling temperature or humidity to the degree the occupants would like, or which adversely affect performance in some other way.

In too many cases, however, complaints are received about systems that were designed to provide much finer control and thus better performance than is actually realized. The fact that complaints are made about such systems in government buildings is of considerable concern to federal construction agencies--first, because it suggests that the government is not getting what is being specified (and presumably what is being paid for); second, because it reflects adversely on the reputation of the agencies; and third, because it results in many time-consuming and costly disputes between the designers, contractors, and agencies over what is wrong, who is at fault, and who is going to pay for making corrections. A principal reason for less-than-optimum performance of building environmental systems is that such systems are frequently not adjusted, balanced, and tested properly after installation. The logical question then is why this should be the case, inasmuch as the techniques for adjusting, balancing, and testing are well developed and widely known.

The Federal Construction Council requested its Standing Committee on Mechanical Engineering to undertake a study to answer this question and to recommend remedial action. This report of the Committee was prepared in response to that request.

On recommendation of the Federal Construction Council, the Building Research Advisory Board has approved the report for dissemination to employees and offices of the Federal Government.

The Board gratefully acknowledges the work of the Standing Committee on Mechanical Engineering and all others who gave assistance to the Committee in the preparation of this report.

JOHN P. GNAEDINGER, Chairman
Building Research Advisory Board

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I
INTRODUCTION

A. PURPOSES OF THE REPORT

The purposes of this report are to identify the principal reasons why building environmental systems are frequently not adjusted, balanced, and tested properly, and to recommend changes in the policies and practices of federal agencies that will help to ensure that these operations will be performed adequately in the future.

B. SCOPE AND LIMITATIONS OF THE REPORT

This report deals primarily with the policies and practices of agencies as they relate to specifications and contracts for adjusting, balancing, and testing building environmental systems. The report does not deal with the technology of or the procedures for performing these operations, per se. The recommendations presented in this report have been prepared in the context of the organizational arrangements relating to adjusting, balancing, and testing in existence in the building industry at the time of report preparation. Inasmuch as such organizational arrangements appear to be in a transitional phase, the Committee's recommendations should be considered as interim in nature.

C. DEFINITIONS

For the purposes of this report, the following definitions are used for terms relating to adjusting, balancing, and testing building environmental systems:

1. Building environmental system: The assemblage of components, devices, and equipment (both internal and external to a building) required for space heating, air conditioning, ventilating, humidity control, and air purity control.

2. Adjusting and balancing an environmental system: The procedure of setting the various control and regulatory devices in a system such that water and air distribution in the various parts of the system satisfy contract requirements.

3. Testing (an environmental system): The procedure of measuring water and air velocities, flow volumes, pressures, temperatures, and related sound levels in the various parts of a system, as required to properly adjust and balance the system, and in some

instances to establish compliance with contractual requirements (i.e., to assure quality).

D. DEVELOPMENT OF THE REPORT

This report presents the results of an investigation carried out by the Standing Committee on Mechanical Engineering. The study is based substantially on an examination of current agency policies and practices with regard to adjusting, balancing, and testing building environmental systems, and on a review of published reports and papers on the subject. The preliminary draft of this report was developed, and much of the related investigative work was performed by a special subcommittee who were assisted by liaison representatives from several of the agencies.

E. ORGANIZATION OF THE REPORT

The report includes two sections in addition to this Introduction: Conclusions and Recommendations, in which are presented, without elaboration, conclusions regarding the principal reasons for the poor performance of apparently well-designed environmental systems, plus recommendations for minimizing the problem in the future; and Discussion, in which the nature of the problem and the rationale underlying the conclusions and recommendations are presented.

II
CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The technology dealing with the adjusting, balancing, and testing of building environmental systems is well advanced. Nevertheless, such systems are not, in many cases, properly adjusted, balanced, and tested. The principal reason for this is that the contractual provisions under which such services are performed are frequently deficient in one or more of the following ways:

1. They do not indicate precisely what is required with respect to adjusting, balancing, and testing of the environmental system.

2. They do not require that such services be performed by knowledgeable individuals or organizations.

3. They do not require that such services be performed in accordance with established procedures.

B. RECOMMENDATIONS*

Agencies should review, and if necessary revise, their contractual provisions for adjusting, balancing, and testing building environmental systems in light of the following recommendations. Additionally, agencies should take appropriate action to ensure that contract documents for building environmental systems call for installation of the control devices and testing apparatus and connections required for proper adjusting, balancing, and testing of such systems. (For complex systems, contract documents should include separate single-line drawings relating to adjusting, balancing, and testing which indicate all testing locations and permanently installed testing devices and the flows to be achieved in various parts of the system.)

1. <u>Work to be Performed in Adjusting, Balancing, and Testing</u>

   Any government contract involving the installation or modification of a building environmental system should include specific

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*Inasmuch as organizational relationships with regard to adjusting, balancing, and testing appear to be in a transitional phase, the committee's recommendations should be considered interim in nature.

provisions for the adjusting, balancing, and testing of the system. The tasks in connection with such work should include:

a. Review of the plans and specifications prior to installation of the system, and submission of a report to the contracting officer indicating any deficiencies in the system which could preclude proper adjusting, balancing, and testing of the system.*

b. Inspection of the system prior to adjusting, balancing, and testing work to ensure that all specified components which will affect proper execution of such work are installed, and are operating properly; and submission of a report to the contracting officer indicating the results of the inspection.*

c. Measurement of water and air flows, and if appropriate, noise levels and room air motion throughout the system, and adjustment of such system control devices as valves, dampers, and drives, to ensure that air and water flows and noise levels in the various parts of the system are in accord with contract requirements. (If contract requirements cannot be met, the matter should be referred immediately to the contracting officer.)

d. Measurement of air and water temperatures as required to permit diagnosis of problems in the system and, if deemed desirable by the agency, to verify the performance of system components. (If performance verification is desired, temperature measurements should be made on a day when design conditions exist or with an imposed false load to simulate design conditions; otherwise, only those temperatures occurring as a result of conditions existing at the time of the test need be measured.)

e. Preparation of a report to the contracting officer indicating air and water flows and temperatures in the system, any difficulties in meeting contract specifications, and the reasons for such difficulties.*

f. Following acceptance of the report by the contracting officer, permanent marking of the settings on all control devices to permit restoration of original settings in the event that the control devides are tampered with in the future.

g. At the time of final acceptance, rechecking, in the presence of agency personnel, of randomly selected flows, temperatures, sound levels, and air motion.

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*The contracting officer should send copies of the reports to the organization responsible for design, for information or comment as appropriate.

2. Responsibility for and Execution of the Work

Although the prime contractor should be held basically responsible for ensuring that the building environmental system is properly adjusted, balanced, and tested in accordance with contract provisions, the agency should place certain restriction on who the contractor can hire to perform the work and how the work is to be performed--as follows:

a. Types of Organization Authorized to Provide Testing and Balancing Services-For uncomplicated jobs (e.g., involving 100 tons of refrigeration or less, with no unusual requirements) or for jobs at remote sites where an independent adjusting, balancing, and testing organization is not available or engaging such service is economically unfeasible, the contract should allow either the prime contractor or the installing mechanical subcontractor to perform the adjusting, balancing, and testing services--provided he uses personnel who meet the qualification requirements outlined in paragraph b. below. In all other cases, the contract should specify that the adjusting, balancing, and testing services must be performed by an independent organization which in no way is affiliated with either the prime contractor, the installing mechanical subcontractor, supplier, or manufacturer of equipment used in the environmental system, or the engineering firm responsible for the design of the system, and which meets the organizational qualification outlined in paragraph c. below and uses personnel who meet the qualification requirements outlined in paragraph b.*

b. Qualification of Personnel Doing Adjusting, Balancing, and Testing Work-Agency contracts should require that all personnel involved in adjusting, balancing, and testing work (except helpers working under the direct and close supervision of an engineer or technician) have a certificate or diploma showing that they have been thoroughly trained to do such work by either an educational institution or trade association having a well-structured and continuing program for training technicians in such work.**

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* A minority of Committee members believe that firms certified to perform adjusting, balancing, and testing under the standards and guidelines of the Associated Air Balance Council (AABC), the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA), and the Mechanical Contractors Association of America (MCAA) should be considered acceptable even if actually involved in the project for which the work is to be performed.

**e.g., the Associated Air Balance Council (AABC) or the Sheet Metal and Air Conditioning Contractors National Association, Inc. (SMACNA).

c. Qualifications of Independent Adjusting, Balancing, and Testing Organizations-Agency contracts should stipulate that in order for a firm to qualify as an independent testing and balancing organization, it must either be a member of the Associated Air Balance Council (AABC) or meet the criteria* for membership in the AABC, with the exception that organizations affiliated with manufacturers, contractors, or engineering firms (other than ones actually involved in the project for which the work is to be performed)** should be considered acceptable, so long as all other provisions of the criteria are satisfied.

d. Methods and Procedures to be Followed in Testing and Balancing Work-Agency contracts should require those performing testing and balancing services to follow such recognized guidelines for such work as those of the Associated Air Balance Council or the Sheet Metal and Air Conditioning Contractors National Association, Inc.

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* i.e., The Associated Air Balance Council general membership standards, as presented in AABC National Standards for Field Measurements and Instrumentation--Total System Balance, volume one, Associated Air Balance Council, 1967, Los Angeles, California.

**See first footnote on previous page.

III
DISCUSSION

A. GENERAL

Environmental systems in modern buildings--even those in relatively small buildings--are highly complex assemblages of refrigerating machines, boilers, ducts, pipes, fans, pumps, valves, dampers, control devices, and heat exchangers. In order to maintain the environment in each area of a building within acceptable limits, a system must be capable of supplying or removing precisely the right amount of heat from each area to compensate for the net heat loss or heat gain from that area. The system must do this under varying weather conditions and with various internal heat gains, and at the same time provide a certain minimum amount of fresh air--all automatically in most cases.

If a system is to satisfy these requirements, three things are essential. First, the system must be designed properly. This means that the engineer designing the system must select components of the proper type and capacity and that each is compatible, both functionally and dimensionally, with other elements of the system. Second, the system must be installed properly. This means that the mechanical contractor when assembling the system must use the type and capacity of components selected by the designer and must install each such component in the proper manner. Finally, and equally important, the system must be adjusted, balanced, and tested. This means that the various control devices in the system must be adjusted to ensure that the quantities of air and water flowing through the different parts of the system are in accordance with the designer's plan--as set forth in contract documents. Inasmuch as numerous flow and temperature measurements must be made in the course of balancing a system, the term "adjusting, balancing, and testing" is frequently used to describe this operation.

In the early days of air conditioning, when systems were simpler and less was expected in the way of performance, the adjusting, balancing, and testing of a system was a relatively straightforward task which could be, and usually was, performed by any reasonably well trained air conditioning mechanic. As systems became more complex, however, the job of adjusting, balancing, and testing also grew more complicated--so much so that in most cases it could no longer be performed properly by the average mechanic. It required instead the services of a technician with special knowledge of the proper procedures to be used.

For two reasons, however, the adjusting, balancing, and testing of systems continued for a number of years to be performed mainly by mechanics without the necessary training--with predictably poor results. First, most building owners and architect/engineer firms did not fully appreciate the need for having specially trained technicians perform the adjusting, balancing, and testing functions, and consequently, did not require use of such personnel in specifications; and for economic reasons, contractors did not provide them voluntarily. Second, there were relatively few highly qualified technicians available--the principal reasons being that for the most part the procedures had never been published and there were few if any formal training programs for such technicians.

The situation did not improve significantly until building owners, and architect/engineer firms recognized the problem and until companies specializing in adjusting, balancing, and testing work were formed. These companies, for the most part, provided adjusting, balancing, and testing services on a professional or semiprofessional basis, and a number of them eventually formed an association which, among other things, published technical manuals on testing and balancing. Subsequently, other organizations, notably associations of contractors in the mechanical field, and at least one government agency, instituted training programs and published manuals on adjusting, balancing, and testing for their own personnel.

A substantial number of organizations of various types can now adjust, balance, and test building environmental systems in a technically competent manner. Federal agencies have found, however, that there are also a number of organizations offering such services that do not have the necessary technical qualifications for such work--at least not for fairly complex systems.

The problem for the federal construction agencies, and the problem addressed in this report, is how to ensure that building environmental systems are properly adjusted, balanced, and tested, without unduly increasing the cost to the agencies of such work.

B. WORK TO BE PERFORMED IN ADJUSTING, BALANCING, AND TESTING

A number of years ago, when building environmental systems were comparatively uncomplicated and systems were not expected to maintain precise conditions, the main concern was that the flows in the various sections of the system were in the correct proportions, one to another. The process of adjusting flow control devices (e.g., dampers and valves) to proportion correctly the flows in the system was referred to only as balancing. It involved a minimum amount of testing, generally only some not-too-precise flow measurements. Design and installation problems were seldom serious enough to preclude balancing, and those that were serious were usually easy to correct.

As systems got more complex, however, and performance requirements increased, proper adjustment and balancing of a system required

considerably more testing and more testing precision. At the same time, the process of balancing and adjusting a system became increasingly sensitive to errors in the design and installation of the system. As a result of these developments, it became necessary for an organization providing adjusting, balancing, and testing services to review designs, check installation practices, and generally evaluate the performance of systems as part of its work.

Because adjusting, balancing, and testing organizations were, in essence, evaluating the performance of systems and the quality of installation work anyway, some building owners started assigning responsibility, either implicitly or explicitly, to the organization for such evaluation, along with their other duties. This practice has now become relatively widespread, and the committee believes it should be the practice of government agencies. However, the Committee also believes that, in the interest of avoiding misunderstandings as to exactly what is expected of the adjusting, balancing, and testing organization, the work to be performed needs to be stated in a precise manner.

Specifically, the Committee believes that contract documents covering adjusting, balancing, and testing work should require performance of the seven tasks listed under "Work to be Performed" in the recommendations.

C. RESPONSIBILITY FOR AND EXECUTION OF THE WORK

Traditionally, responsibility for adjusting, balancing, and testing building environmental systems has been delegated to the contractor on a project as part of his overall responsibility for installing a system which satisfies the contract plans and specifications, with few if any restrictions on how the work is to be done. For two reasons, the Committee agreed that some modification of this approach is in order. First, it was felt that adjusting, balancing, and testing work has become sufficiently complex that some special contractual requirements are needed to ensure that such work is performed properly. As indicated earlier, it is believed that a significant number of those attempting to do such work have not had the necessary qualifications. Second, it was felt that if quality assurance and system performance evaluation are to be part of the work performed in connection with adjusting, balancing, and testing of building environmental systems--as the Committee agreed they should be--consideration should be given to requiring that, in the interest of avoiding potential conflict of interest problems, the adjusting, balancing, and testing work be performed by an organization other than the system installer.

In the course of investigating the second matter, the Committee considered a number of alternatives, including:

1. Having the contracting agency directly hire an independent organization, without involving the contractor in any way.

2. Having the contracting agency develop its own adjusting, balancing, and testing force.

3. Requiring that the contractor employ an independent organization to perform adjusting, balancing, and testing services.

4. Not placing any limitations on the organizational relationship between the contractor and the adjusting, balancing, and testing organization (which, for example, would permit the installing subcontractor to perform the adjusting, balancing, and testing services).

On the basis of its investigation the Committee determined that the first alternative was unacceptable on the ground that it would increase the contract administration problems of agencies and could cause them to become entangled in disputes with the contractor over such matters as scheduling of work. The second alternative was equally unacceptable on the basis that the cost of establishing and operating an adjusting, balancing, and testing work force would be prohibitively high. The third alternative was judged to be the best for most situations, in that it provides for a degree of organizational separation--deemed desirable because of the quality-assurance as aspect of the work--without creating undue complications. The fourth alternative was deemed unacceptable for most situations because it would not ensure the desired degree of organizational separation. It was recognized, however, that many subcontractors have the technical competence to perform adjusting, balancing, and testing service, and that moreover it might be very difficult to obtain the services of an independent organization at a remote site, and finally that the cost associated with hiring such an organization might not be justified for small uncomplicated jobs. It was decided, therefore, that the fourth alternative should be permitted in such situations.

With regard to the problem of ensuring that the adjusting, balancing, and testing work is performed properly, the Committee determined that, as a minimum, three steps would be in order.

1. That personnel doing adjusting, balancing, and testing work be required to have some proof that they had received training in such work. The ideal solution, it was felt, would be to require some type of certification, similar to that required for welders. Investigation revealed, however, that although many organizations (e.g., trade associations, technical schools, and manufacturers) now provide training in adjusting, balancing, and testing, there is presently no universally accepted program for certifying the competence of graduates of training programs and there is little likelihood of development of a broadly applicable, completely fair certification program in the near future. Consequently, the Committee decided that as a practical matter the most that could be required would be a diploma or certificate from a trade association or educational institution indicating that an individual had satisfactorily completed a prescribed course of study.

2. That when an independent adjusting, balancing, and testing organization is used it should either be a member of the Associated Air Balance Council (AABC) or meet the criteria for membership in AABC. In effect this means that the Committee agrees with the criteria used by AABC for judging the qualifications of an adjusting, balancing, and testing organization, but that it does not feel that membership in AABC per se ought to be required. The Committee believes that there are a number of organizations--including professional engineering firms--that are fully qualified to carry out adjusting, balancing, and testing of environmental systems, but which for some reason are not members of AABC, and that such organizations should not be prohibited from working on government projects.

3. That recognized guidelines for adjusting, balancing, and testing work should be followed on federal government projects. The Committee feels that in the interest of ensuring against use of short-cut or untried procedures, agencies should require use of well established procedures on their jobs. Good guidelines on the subject have been prepared by the Associated Air Balance Council and by the Sheet Metal and Air Conditioning Contractors National Association.* The American Society of Heating, Refrigerating, and Air Conditioning Engineers is also believed to be considering the development of guidelines.

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*National Standards for Field Measurements & Instrumentation, Total System, Balance--Air Distribution-Hydronic Systems, Associated Air Balance Council, 1970, Los Angeles, California.

Manual for the Balancing and Adjustment of Air Distribution Systems, Sheet Metal and Air Conditioning Contractors National Association, Inc., 1967, Washington, D.C.