TOTAL QUALITY COMMISSIONING FOR HVAC SYSTEMS TO ASSURE HIGH PERFORMANCE THROUGHOUT THE WHOLE LIFE CYCLE

By: Grahame E. Maisey, P.E., and Beverly Milestone, LEED AP
Building Services Consultants

INTRODUCTION

Current HVAC systems are not coming close to approaching life cycle performance expectations for energy, operation and maintenance, occupant comfort and productivity and longevity. HVAC systems in buildings claiming to be sustainable, with integrated, energy conscious design and extensive commissioning are not realizing predicted energy efficiency and suffer deteriorating energy and maintenance performance over a short period. Additional and fundamental commissioning are start-up quality assurance programs only that do not provide a life cycle, high performance assurance program. Continuous commissioning is being used to continually adjust the HVAC systems to regain good performance from the original systems, but again, is not a life cycle, high performance assurance program.

Total Quality Commissioning (TQC) is a practical, Total Quality Assurance program that assures whole life cycle results. TQC provides an integrated, expert, knowledge-based, life cycle performance assessment. Through clarification and edification of detailed life cycle system goals and objectives, TQC makes certain the optimum HVAC systems are chosen and sized correctly, thus allowing the systems to maintain life cycle high performance.

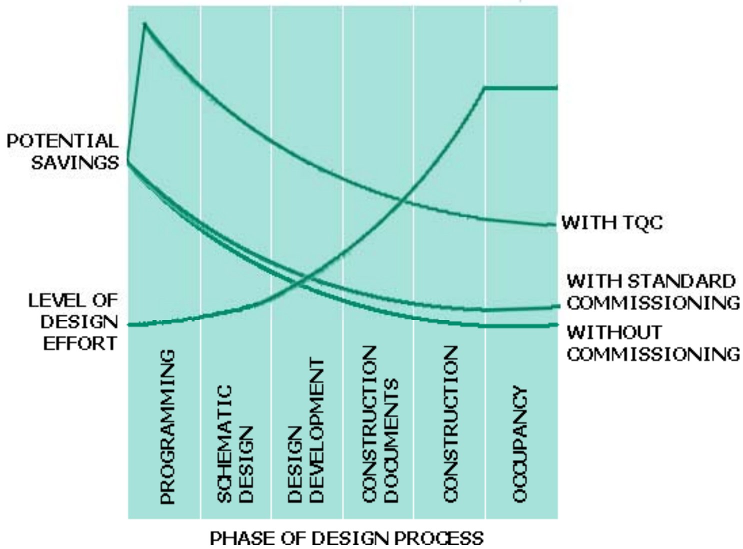

FIGURE 1. – POTENTIAL SAVINGS THROUGH TQC

UNDERSTANDING WHERE AND HOW MAJOR SAVINGS CAN BE MADE

As the graph above demonstrates, the biggest decisions and the decisions that have the most impact on the system success or otherwise are made in the programming and the early schematic design phases. These major decisions are the HVAC system selection and sizing. These decisions are usually made with very little input or exchange of information and ideas within the whole building design team, including the owners' representatives and the architect. With a detailed interrogation of the owners and their representatives, and the architect, a highly detailed outline of the HVAC system life cycle performance requirements can be formed such that a highly detailed response can be developed. This process is the most important but also the most overlooked process in the HVAC system design. As an analogy, it can be likened to a bride walking into a bridal shop and asking for a $100,000 wedding gown directly off the nearest hanger and walking out the shop instead of the dress being carefully hand crafted and measured and fitted on several occasions. In other words, this is a very expensive item that should not be either briefly nor arbitrarily selected and sized.

THE FIRST STEP - GOALS AND OBJECTIVES

The first step in TQC is to help the Client define their goals and objectives. This is done through asking a series of questions and then using the answers to define the detailed characteristics required. Life cycle goals and objectives must be detailed from the Client and fully documented so that any system selection and sizing action can be examined against the documented criteria. The overall goals and objectives can often be reduced to a long-life, loose-fit, high performance system; the devil is in the details!

HOW TQC ACHIEVES THIS:

1. DETAILED CLIENT REQUIREMENTS

One of the basic problems with current designs is the lack of communication between the Client and the design team. The Client should not be expected to produce detailed requirements if the design team does not explain in detail how the building will need to work through the various changes and modifications over the whole period of its life cycle. The design team must explain in detail how operations and maintenance are practiced and how they can be minimized. They must also explain in detail how the energy flows in buildings and how to minimize energy use. Most importantly, the design team must explain in detail how comfort affects productivity and how it can be manipulated and improved.

Thus can detailed Client requirements for the HVAC system can be solicited from informed Clients. To help inform the Client, we use three questions to solicit detailed requirements:

> How long do you want the system to work for and at what level of efficiency and effectiveness? This question is usually never asked or documented, but we can

examine how a system is selected and sized against severe requirements, for example - a very efficient and effective life cycle of 50 years, if this is what the Client requires.

What level of maintenance do you have and expect to have for the life cycle of this system? This question is never asked but is absolutely essential in system selection. Most current system selections will be changed by the Client responses to this question.

Do you have an Energy Master Plan or any longer term goals for energy systems? This question examines the broader implications of future energy sources and security of energy sources, etc.

These questions will reveal a series of characteristics that need to be detailed, FLAME^3 can be used as an acronym: Flexibility, Longevity, Adaptability, Maintainability, Expandability, Efficiency and Effectiveness. These characteristics, when detailed, can describe quite accurately the Clients' detailed requirements and then the response of the selection and sizing procedure from the design team.

2. DETAILED DESIGN INTENT

After collecting the answers to the three questions above, we can begin to define the Client requirements for system characteristics. For example – from these answers we can now tell how efficient the systems need to be, how flexible and adaptable, how long lived, etc. The next step is to begin the most important document that is never written - the Detailed Design Intent. This document combines the Design Intent, the Basis Of Design and the Clients Brief into one document and adds significant details. The document is written in non-technical language so that all parties can understand every aspect of the design, construction and operation of the systems commissioned. It explains in detail how and why all the selection and sizing decisions were made and how the system was designed and constructed and should be operated and maintained and modified as necessary in the future. The Detailed Design Intent provides clarity to the entire design process and helps eliminate gray areas. It is a living document that should be constantly updated as the project proceeds.

TQC RESULTS:

1. OCCUPANT COMFORT AND PRODUCTIVITY

Productivity is the reason comfort conditioning systems, or HVAC systems, are installed into most buildings. The comfort of the occupants is one of the determining factors on how productive they will be. Improving occupant productivity by 4% is a larger monetary gain than saving all the energy and maintenance costs in most office buildings. Hospitals, schools and industrial facilities should be considered similarly so we can assess the relative importance of the various factors. It should be stated here that the best solution to any problem will always maximize productivity while minimizing energy and maintenance costs.

The largest cost of a HVAC system comes from providing excellent comfort conditions throughout the life cycle, providing flexibility, expandability and maintainability.

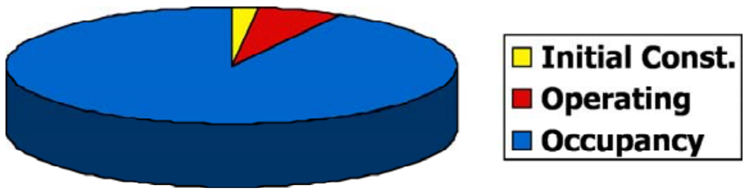

FIGURE 2 – TYPICAL 30 YEAR COSTS OF AND OFFICE

Usual comfort conditions are stated as compliant with ASHRAE for comfort, ventilation, etc. However these conditions are based on 20% of the occupants dissatisfied and other rather low aspirations for the systems. We need to raise the bar significantly to provide good comfort conditions.

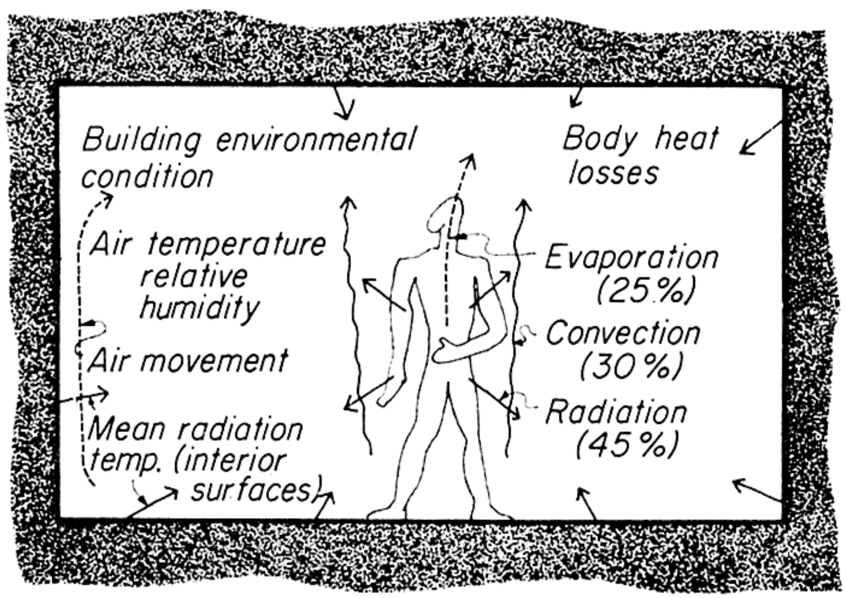

FIGURE 3 – BODY HEAT LOSSES - Control not only the ambient temperature but also the radiant temperature, a more significant comfort condition for humans. Also control the humidity year round for both comfort and health.

The following figures provide good explanations and examples of high comfort systems.

Proceedings of the Fifth International Conference for Enhanced Building Operations, Pittsburgh, Pennsylvania, October 11-13, 2005

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 4 – RADIANT COOLING + HEATING PANELS - Control the air flows in the building, do not facilitate the potential spread of disease and indoor pollution. This will usually entail supplying 100% outside air to a building. Energy recovery and minimizing air volumes are essential. Displacement ventilation systems and mixed mode systems will become more popular.

Building owners and operators are becoming increasingly aware of the problems being caused by the ventilation system. Starting with sick building syndrome, ventilation systems are causing more and more problems. The transfer of air from room to room or the transfer through the recirculation of the air is one of the chief causes of the spread of health problems in schools and hospitals.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 5 – DEDICATED OUTSIDE AIR SYSTEMS WITH RADIANT COOLING + HEATING

FIGURE 6 – DISPLACEMENT VENTILATION SYSTEM (Air Volume Limited to 0.35cfm/ft2) --

2. OPERATING AND MAINTENANCE EFFICIENCY

Most designs do not take adequate account of maintenance requirements of the systems, particularly long-term requirements. A detailed, expert knowledge of how HVAC systems work throughout their life cycle is imperative if we are to correctly weigh the operating and maintenance requirements.

FIGURE 7 – SHEARING LAYERS OF HVAC SYSTEMS

3. ENERGY EFFICIENCY

Life cycle efficiency of a HVAC system is more important than the initial efficiency. Although most designs assume it will cost more to install a more efficient system, this is usually not so. Most current HVAC system designs are oversized by 35%, and the boiler and chillers are 100% oversized, so correctly sizing the system will save 15% to 20% of the installation cost. A more efficient system will be a smaller system, so money can be saved.

Energy use of a HVAC system must be analyzed so we can examine how to reduce it.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 8 – OFFICE BUILDING ENERGY USE, NE USA

The above pie chart demonstrates that the HVAC system uses 40% of the total energy in an office building.

Distribution systems can consume 50% of the total HVAC energy use and it almost always electrical energy. We must reduce the distribution energy use by 50% to 80%. This can be done readily by examining, in detail, where the energy is used. Reducing air handling unit pressure drop and pumping energy use will save over 50% in most systems. Sizing the system to the minimum size will save 25% of the standard energy use.

OTHER BENEFITS OF TQC:

WHOLE SYSTEM INTEGRATION

Most designs put pieces of equipment together and assume they will work together harmoniously. Yet this is not necessarily so. A system needs to be analyzed from a whole system perspective to examine how the pieces of equipment will both work together and with the building to control the environment. Heating and cooling control requires close examination, how to transition from heating to none to cooling. Humidity control needs examination and ventilation flows require close scrutiny. TQC looks at how systems work together to find the most efficient and effective system for the individual project or facility.

INTEGRATING WHOLE SYSTEM WITH WHOLE BUILDING

Computer simulations of whole building energy flows are very useful, but the simulation of the HVAC systems is not accurate and can be very misleading. Computer calculations are only as good as the questions asked and the data inputted. The answer is to use the computer to simulate whole building energy flows and use them for the building fabric and lighting optimization. Energy 10 and EnergyPlus are two good simulation programs.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 9 – ENVIRONMENTAL EFFECTS

Expert knowledge of HVAC systems is required to check that they will integrate into the building energy flows. Examining and analyzing how the HVAC system will operate under varying conditions is the best simulation that is currently possible.

CURRENT POPULAR HVAC SYSTEMS

The following systems, although popular today, would undoubtedly not meet the system characteristics of any Client as they are all fundamentally flawed in one area or another – be it unmaintainable, inflexible, inefficient, not long lived, etc.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 10 – FAN ASSISTED VAV SYSTEM - Fan assisted VAV systems are popular however, they have many drawbacks and are not recommended for long-term performance. They are a huge first cost, are expensive to operate and nearly impossible to maintain even with the most advanced digital controls. They are also not expandable.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 11 – UNDER FLOOR AIR DISTRIBUTION SYSTEM - Under Floor Air Distribution Systems are becoming popular. They have certain advantages in providing comfort and productivity initially, but have the problem of being inflexible. They may cost more money to operate than other systems over the long-term.

ENVIRONMENTAL HVAC SYSTEMS

Environmental HVAC systems are definitely more sustainable than the above mentioned popular systems. Although first costs can sometimes be greater, they can be designed to be highly flexible and adaptable, not to mention efficient and long lived. Systems employing earth or geothermal conditions can provide increased efficiency. Providing year round humidity control is essential, especially east of the Mississippi with this region's highly humid summers and dry winters. Providing optimum humidity control adds to the comfort conditions and allows for moderating temperatures.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 12 – GEOTHERMAL SYSTEM WITH ROTARY WHEEL – Although the geothermal portion of this system is highly advisable, the rotary wheel is not. The rotary wheel does not perform well for very long and has an average useful life cycle of six years.

FIGURE 13 – LIQUID DESICCANT SYSTEM - A liquid desiccant system can provide excellent indoor environmental conditions. The system can provide humidity and ventilation control and can combine with geothermal and solar heating to provide radiant cooling and heating. This system is particularly suitable for humid climates and cooler climates that require humidity in the winter.

CONCLUSIONS

Total Quality Commissioning is a comprehensive method for attaining sustainable, high performance for the life cycle of a HVAC system. It begins early in a project and asks questions that lead to answers that define the characteristics required of the HVAC system by the Client. It thereby allows for proper system selection and sizing of the HVAC systems and removes gray areas and questions regarding how and why the systems were selected. It is imperative that careful consideration be given to the selection and sizing of a HVAC system as it represents a long term investment, hopefully for 50 to 60 years, and affects the productivity of the building which is worth more than all the costs and savings put together. However, it is very possible, using TQC, to select and size HVAC systems to cost less and perform better for an extended life cycle.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 14 – 50 YEAR COSTS OF OPERATING BUILDINGS - Originally from Stuart Brand's Book How Buildings Learn, with our sustainable addition. We analyzed several systems in our three papers on the Whole Building Design Guide (www.wbdg.org)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

FIGURE 15 – KEN YEANG'S ANALYSIS OF HVAC SYSTEMS - Ken Yeang's analysis of HVAC systems is a useful matrix, but has several flaws in systems evaluation. We analyzed several systems in our three papers on the Whole Building Design Guide (www.wbdg.org)