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Serving the HVAC Test and Balance and Engineering Industries

Testing and Balancing for Indoor Air Quality

Measurements with Tracer Gas

Stringent IAQ Bills Introduced in Congress

Performance Monitoring of HVAC Systems

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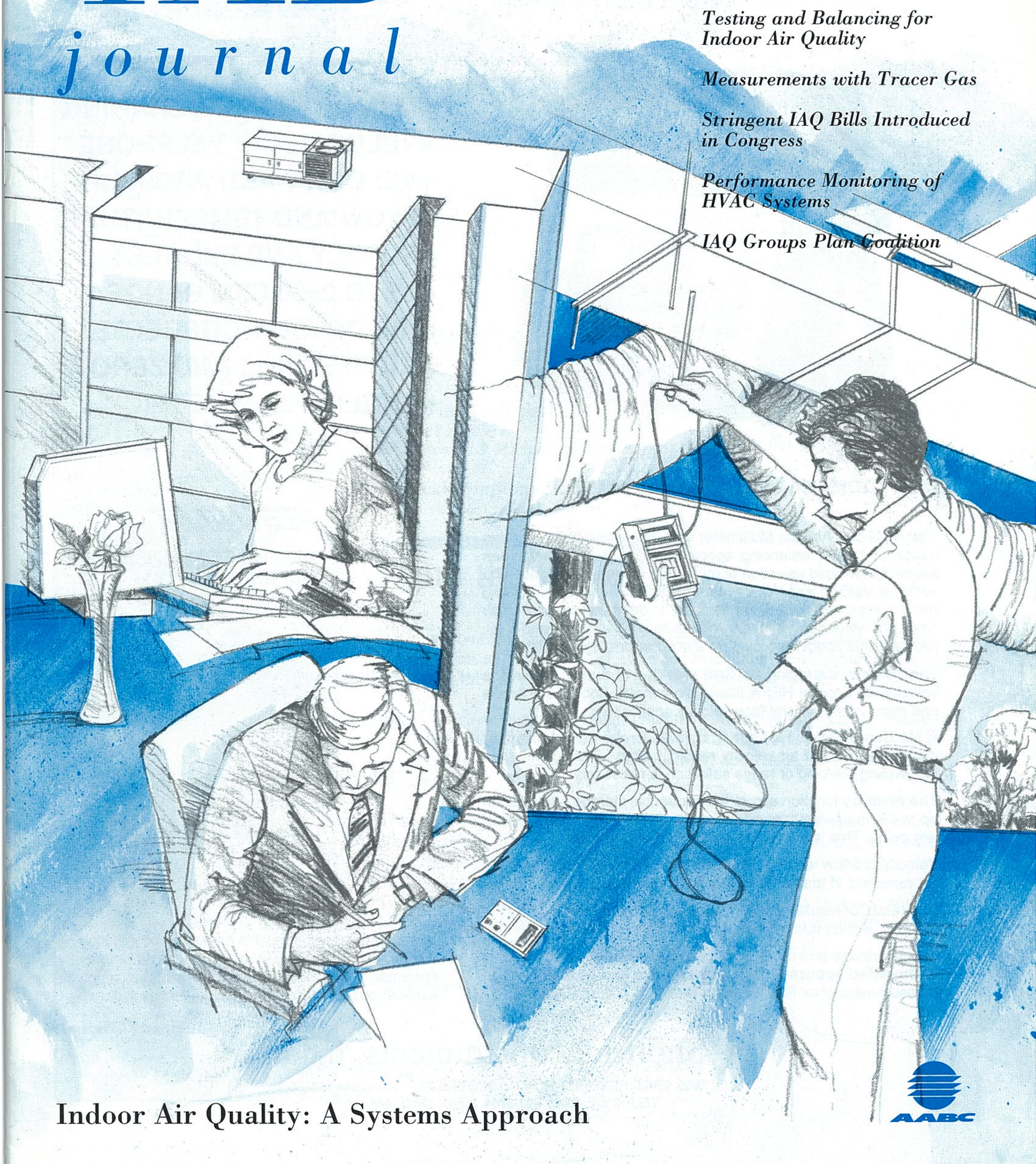

Indoor Air Quality: A Systems Approach

AABC

Performance Monitoring of HVAC Systems

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How well is the HVAC system *really* performing? Complete answers have eluded building owners and consulting engineers. The reasons have been diverse, but may all be attributable to one difficulty — the problem in getting HVAC system to "hold still" long enough for field technicians to gather actual operating data.

The continuous changes in load and control system response always introduce errors in test data if all components are not measured simultaneously. And the labor cost of taking simultaneous measurements on all components of an HVAC system is prohibitive. This difficulty, however, is quickly becoming a thing of the past. Recent advances in field instrumentation, data-logging technology, and methodology have made it unnecessary to make the system "hold still." Any HVAC system may now be performance-tested in all its dynamics.

Typically, field-test data is gathered on existing HVAC systems to: 1) determine ways to reduce operating costs; 2) help plan remodelling and building load additions; and 3) monitor indoor air quality. These general categories are interconnected, and it becomes difficult to address one issue without considering the other two.

Routine TAB procedures have become somewhat basic in evaluating and resolving problems associated with existing HVAC systems. It is difficult to provide a one-time-through routine test of major HVAC systems and hope to address all issues with the narrow range of test data provided. This is especially true with VAV systems that are very dynamic, especially in industry (where there may be major load variances between the day and night shifts), or in glass buildings (where the change in sun angles can have a major effect on system performance). The danger is that relying on this partial data may lead to mistaken engineering conclusions that do not allow for all variances from the HVAC test conditions.

Exciting advances in test instrumentation and data logging systems have greatly extended the capability of HVAC system surveys. The accuracy, resolution, and repeatability of instrumentation greatly exceed capabilities of just a few years ago. Many instruments produce an output signal to interface with data-logging units. There is also an ever-increasing array of sensing devices for direct application with data loggers. Data loggers themselves are also becoming more versatile and simpler to apply. This newly available technol-

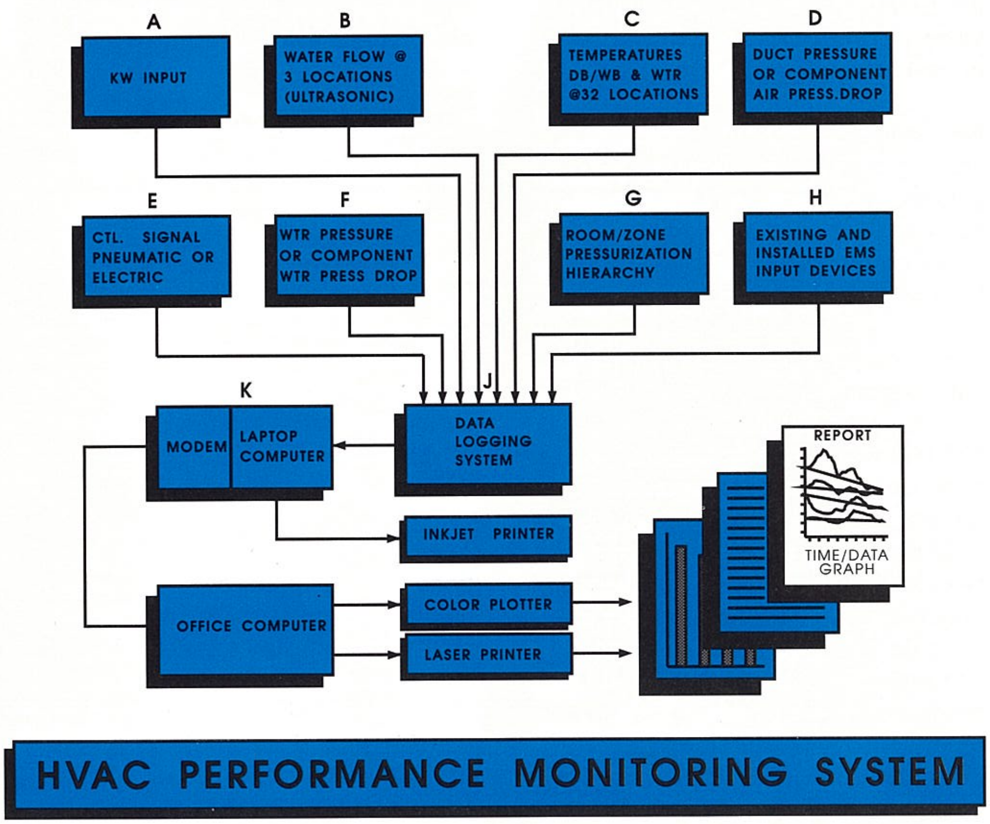


Fig. 1. The performance monitoring system is portable and and may be installed in less than one day. Readings approximately every second may be averaged and recorded at intervals of seconds to hours, for any period of time. Recorded data may be windowed.

ogy allows for continuous monitoring of all components of any system. The rewards are immediately apparent when reviewing a survey report where all test data is simultaneous, and the cause-and-effect relationship of components is graphed on minute-by-minute time/data charts. Today, the actual building-load shifts and system capacities may be accurately demonstrated instead of assumed.

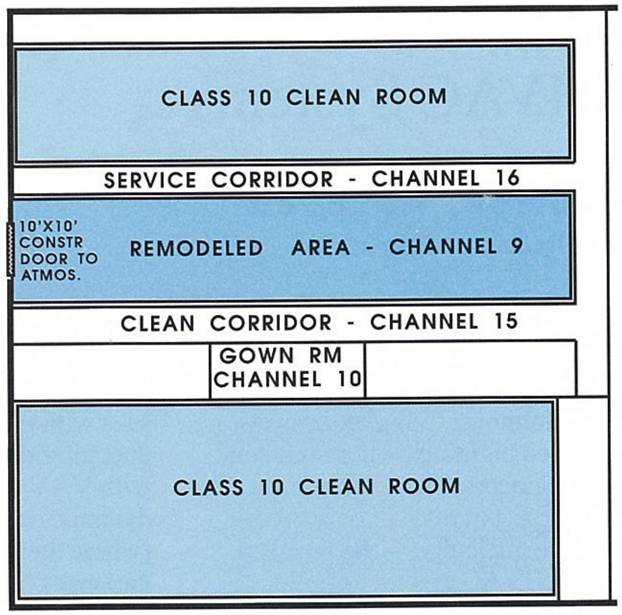
A complete array of instrumentation may be installed on a typical air-handling unit in about six man hours and removed in about two man hours. (Of course the required time increases if access to the air-handling unit is difficult.) Once installed, the system may record for any period. A span of 24 hours is most common, but some systems are monitored for a full week.

Of course, data loggers do not eliminate the need for manual testing. Manual testing of air-flow rates, pressure drops, and some temperatures is necessary to provide a reference value and verify accurate functioning of the data-logging system.

Nevertheless, field-labor expenses are very reasonable when data loggers are used, especially when compared to the cost of employing experienced field technicians for continuous data-gathering.

There can be disadvantages in using data loggers, however. Security and cost can be a problem, as up to $35,000 worth of instrumentation may need to be left sitting on the project. Also, the time saved in the field is partially offset by the greater workload back at the office, where it may take five or ten times longer to compile the vast amount data into a comprehensible report than would be necessary for the standard TAB report. Also, evaluations and recommendations by either the resident PE or consulting PE may be included in the survey scope. So the cost of a survey can vary greatly depending on the extent of services.

Facility layout and scope of work. Scope: balance existing fans in remodeled area to maintain lower pressure than surrounding clean areas; monitor area pressures during remodeling to ensure pressurization hierarchy is maintained, even when large construction door is open.



Most applications are more limited in scope. For example, monitoring just the flow and temperature of chilled and hot water may be sufficient for evaluating the load of each air-handling unit. In some cases, only total flow and temperature data on central-plant chilled water is required.

Other more basic applications include monitoring duct static pressure to verify EMS controls, and monitoring total water inflow and pressure from the municipality. (This last example is very important for industrial plants that may have expansion plans or expenses based on municipal water usage and metering.) There is no limit to applications. Between the customers' needs and the ingenuity of skilled technicians, the possibilities are endless.

There are a few monitoring applications directly applicable to indoor-air-quality surveys assessing outside-air intake, total air flows, and building pressures. Intake of outside air varies as a VAV air handler responds to building load. This problem has confronted design and TAB engineers from the beginning. It becomes a little more complex if return-air fans are involved, or if loads vary to a large extent.

In colder climates, the OSA heating coil is a logical place for monitoring air flow. The volume is established by coil or duct velocity traverse, and related to the measured coil air pressure drop. A pressure transducer of suitable range is then connected for monitoring coil pressure drop, and its accuracy is compared with the standard test instrument. A routine application of the flow vs. pressure drop formula is then used to generate computer printouts and charts of varying flow rates.

In warmer climates, there is seldom a heating coil on the OSA intake. It is then necessary to monitor dry bulb temperatures of the return air, OSA, and mixed air. Standard calculations for mixed-air streams are applied to chart percentage of OSA. The total air flow is manually measured and related to a component pressure drop such as the filter bank, and the pressure drop is monitored. Variances in total air flow are then available for charting purposes. Experience dictates the importance of obtaining an accurate mixed-air temperature for this application. Ideally, the air handler will be a blow-through unit, allowing temperature to be measured near the fan intake.

For a draw-through unit, it may be necessary to measure "mixed air" temperature at many locations across the entering side of the main coils, and verify that face velocity is fairly uniform. Fortunately, it is not difficult to monitor many temperature locations with today's data loggers.

Building pressure is also monitored with pressure transducers. A unit with the range of -0.5"- 0.5" serves well for building and room pressure applications. Care should be exercised that wind loads will not affect the atmosphere reference. It is also best to keep the pressure-sensing tubes within a reasonable length, and span the long distances within the building with the signal wire, if necessary, to reach atmosphere.

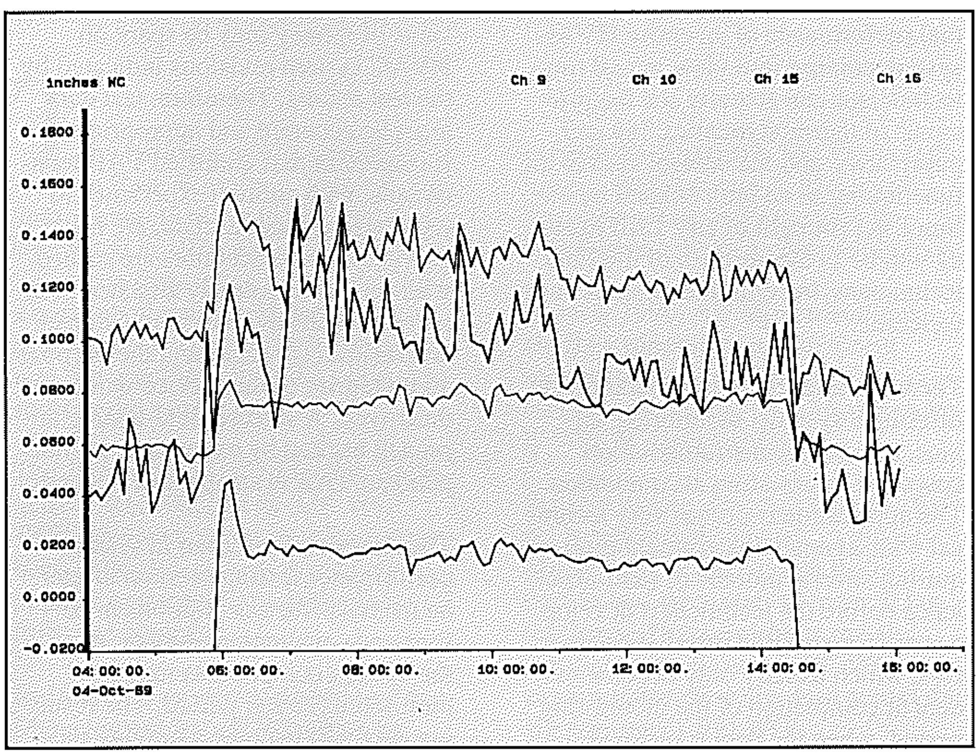
When setting up a data logger to measure an air handler, it is easy monitor a large number of performance characteristics. Supply-duct pressure and temperature, fan motor kw input, control air pressure for the fan pitch or vortex damper, and control-valve signal can all be readily recorded. This additional data will permit more detailed analysis of total system performance. It also will enable an independent (to the system) comparison of the accuracy and response of the installed energy management system, if one exists.

All AHU system components are now accessible to monitoring instrumentation. The widespread use of building energy management systems has created a large array of sensing devices, which are easily connected to data loggers and, with some ingenuity, adaptable to a fully portable system. The most common sensor output signal is 4-20 ma, representing 0-100% of selected range. Most data loggers will accept the same as an input signal, and the better loggers have selectability for other ma ranges and VDC ranges. The advantage of monitoring the ma signal is that the signal is not greatly affected by signal wire length, and therefore allows easier connections between sensors and loggers. Also, sensors already installed as part of the EMS may be connected to the logger for survey purposes.

Sensors may be grouped into portable packages to suit the needs of TAB services. We have found custom plexiglass boxes to be convenient for housing appropriate arrays. One box has a group of five pressure transducers, range of -0.5" to 0.5", and a 24 VDC transformer, for use in room pressurization hierarchy monitoring. Another unit has a series of transducers ranging from 0 - 1" to 0 - 5" for AHU plenum/duct pressure and component pressure drop monitoring. A third box has a VDC transformer and connections for 0-100 lb. pressure transducers for monitoring control signals and water pressures, including coil inlet/outlet water pressures and pumping heads.

Many TAB instruments are available with ma outputs. A watt meter is a necessity. Since many surveys involve older buildings without installed water flow metering devices, an ultrasonic water flow test meter is also necessary. Even with newer buildings, there generally will be no metering devices where you want to measure the flow. The newer ultrasonic instruments are also capable of measuring DI water flows, which has proven to be very important in semiconductor factories. In fact, the watt meters and ultrasonic test instruments become so useful that the need for two of each becomes apparent for simultaneous flow comparisons.

Temperature testing is often carelessly done. Yet temperatures are so important to HVAC testing that they should never be taken lightly. Careful monitoring at different locations within a plenum can easily identify temperature stratification. Also, systems monitoring reveals the whole performance picture through simultaneous data logging for all components, presented on a time/data chart.



Pressurization hierarchy for the four areas pictured above, during a period when a construction door was left open. Atmosphere reference is aero.

Thermistors are the logical choice for temperature sensing. Theoretically, thermocouples are the more accurate, but thermistors are durable, and most importantly, test values communicated to the data logger are not appreciably affected by wire length. This advantage is apparent when connecting 32 test locations throughout an air-handling system, with many lead extensions of varying lengths.

We have found surface probes for water temperatures to be very accurate, with quick response time, but only if a temperature-conducting putty is used. Another possible option is to screw a 1/4" MPT Pete's Plug into an installed gauge tap, open the cock, and slip in a long probe to reach the fluid flow.

The data loggers are, of course, central to all systems monitoring. A collection of four loggers with 16 inputs each is more convenient then one unit with 64 inputs. This allows the units to be separated for a few different project locations, or brought together for an all-encompassing survey project. Another advantage is that one logger may be in the mixed-air plenum, one at the coil header, one at the MCC, etc. Having several loggers also means that the TAB agency need not go out of business while loggers are being repaired or calibrated.

If all the data loggers are from the same manufacturer, it is simple to relate all units together for the large projects, and easier for the technicians and office staff to become accustomed to the technical procedures. Another consideration is that by staying with one brand, one will only have a single computer program involved, so the reported data will be consistent throughout the reports and subsequent follow-up surveys.

An important feature to be included with each data logger unit is a metering capability. That is, after all inputs are connected, the technicians should be able to step through each channel and see the test value present at the data logger. This will allow for verification of accuracy, and assurance that each channel is correctly connected. The metering ability should be accessible at any time, without interrupting the data-logging period.

Another convenient feature is the ability to download the data into a laptop computer at the project site. This allows immediate analysis of the data before disconnecting the sensors. The laptop computer and a small inkjet printer will provide a hard copy of the data and charts for immediate evaluation with the building engineers. This permits adjusting HVAC system operation, if necessary, and beginning a new monitoring run, before everything is disconnected. In a world where "fast" is becoming more important everyday, these conveniences are expected.

The systems monitoring application is a natural extension of the abilities of proficient TAB agencies. One pleasant surprise is that with the actual performance of an entire HVAC system coming into view in real time, technicians can actually *see* the principals of thermodynamics, fan and pump laws, and the control system all functioning as an inter-related whole. Since the strength of any TAB agency will be in the abilities of the field technicians, the enlightenment is very welcome.

There are important considerations in offering a systems monitoring service, beyond the instrumentation costs and information accumulation. The application becomes very technical with advanced instrumentation, requiring several months of field experience before the technicians develop a sense for possible installation errors, which usually only become evident at completion of the monitoring period, when the data is recalled.

Interestingly, if enough system characteristics are monitored, an error may become evident due to the contrast with the vast amount of data that does match correctly. Depending on the frequency of projects, and the number of technicians involved, it may be six months to a year before the TAB agency is fully comfortable and confident with the service. Naturally, technical difficulties are always a possibility, and should be accepted as such when a 24-hour run has to be repeated.

Once the approach becomes established, time-lapse surveys become appropriate for various routine TAB services. It may become general procedure for chiller and cooling tower testing. Sometimes a continuous record of hydronic system total flow is of use during terminal test and balance. Verification of consistent flows in house support systems for manufacturing processes may be desirable for extended TAB services.

All personnel must recognize that they are supplying an HVAC testing service that may have major consequences to the building owner. Large sums of money may be spent on HVAC system revisions indicated by the test results. Therefore, test data must be accurate and appropriate. It is important that qualified TAB technicians, with enough experience to recognize erroneous data, are involved. If the procedures are rushed, with sensors carelessly attached at incorrect locations, and output signals not verified for accuracy, the purpose and integrity of the service will be destroyed. A sincere field-testing approach backed by experience in independent TAB is an absolute necessity.

The snapshot limitation in system performance testing need no longer be the basis for assumptions in performance evaluation. Any or all of the system components may be monitored for any period. The resulting data will become a moving picture capturing all the dynamics inherent in any HVAC operation.