TAB journal

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MASTERING DDC TECHNOLOGY

AABC

Field Testing Digital Control Systems

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This article describes a case history in troubleshooting a clean-room DDC system. The manufacturer of new semiconductor "wafer fab stepper machines" was having difficulty calibrating air flow. The suspected cause of the problem was the plant exhaust system, which was designed to maintain stable air-flow rates of process exhaust.

An advanced energy-management system (EMS) was sensing extreme variances in the exhaust system's branch-duct flow rates. Attempts to compensate by allowing automated control of the branch-duct zone dampers, produced unmanageable system surges.

The control system's design was such that air-flow monitors in each main exhaust branch digitally converted the velocity pressure (VP) signal from the airfoil sensing grid to a 4-20ma percentage signal. The 4-20ma signal serves the energy management system for monitoring and control. The signal is periodically "checked" for required set point by the EMS, and damper position is corrected accordingly.

Since the EMS controls a large plant with thousands of inputs and control functions, there may be a lapse of thirty minutes before a specific monitoring location has its turn being sampled.

The exhaust system is extensive, with parallel fans and ten major branches serving 35,000 square feet of clean room, with a total exhaust flow of 70,000 CFM. There were no measurable indications of excessive surge when automatic control of the branch dampers was disabled. Results from repeated branch-duct velocity traversing were within 3% of the average.

Since the intent was to maintain constant exhaust pressure for the process machines, the immediate task was to verify conditions at the process. Fig. 1 and Table 1 indicate the configuration and test results of continuously monitoring the system static pressure. The listed values are representative of the entire monitored period. The values are an average of four test readings, with each reading at approximately a one-second interval.

As is evident, the exhaust system provides stable static pressure at the process connection, well within the process machine manufacturer's requirement. However, the automated

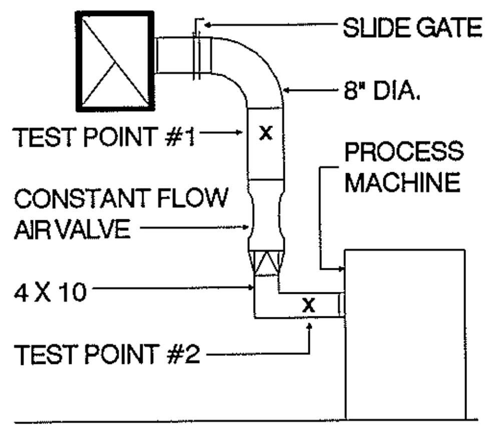

Fig. 1. Duct-pressure tests.

DUCT PRESSURE TESTS					
Above Air Valve at Test Point # 1			Below Air Valve at Test Point # 2		
-3.91"	-3.85"		-.0244"	-.0240"	
-3.88"	-3.88"		-.0246"	-.0251"	
-3.85"	-3.85"		-.0244"	-.0245"	
-3.89"	-3.90"		-.0245"	-.0243"	
-3.92"	-3.87"		-.0250"	-.0241"	
-3.86"	-3.86"		-.0243"	-.0235"	
-3.92"	-3.88"		-.0249"	-.0249"	
-3.92"	-3.84"		-.0252"	-.0241"	
-3.90"	-3.86"		-.0251"	-.0245"	
-3.87"	-3.85"		-.0253"	-.0252"	
-3.89"	-3.85"		-.0250"	-.0246"	
-3.89"	-3.87"		-.0253"	-.0247"	
-3.90"	-3.84"		-.0235"	-.0238"	
-3.90"	-3.87"		-.0252"	-.0245"	
-3.90"	-3.85"		-.0245"	-.0250"	
-3.89"	-3.85"		-.0244"	-.0233"	
-3.88"	-3.89"		-.0254"	-.0248"	
-3.84"	-3.91"		-.0240"	-.0243"	
-3.85"	-3.90"		-.0238"	-.0237"	
-3.86"	-3.87"	Average	-.0250"	-.0245"	Average

Table 1.

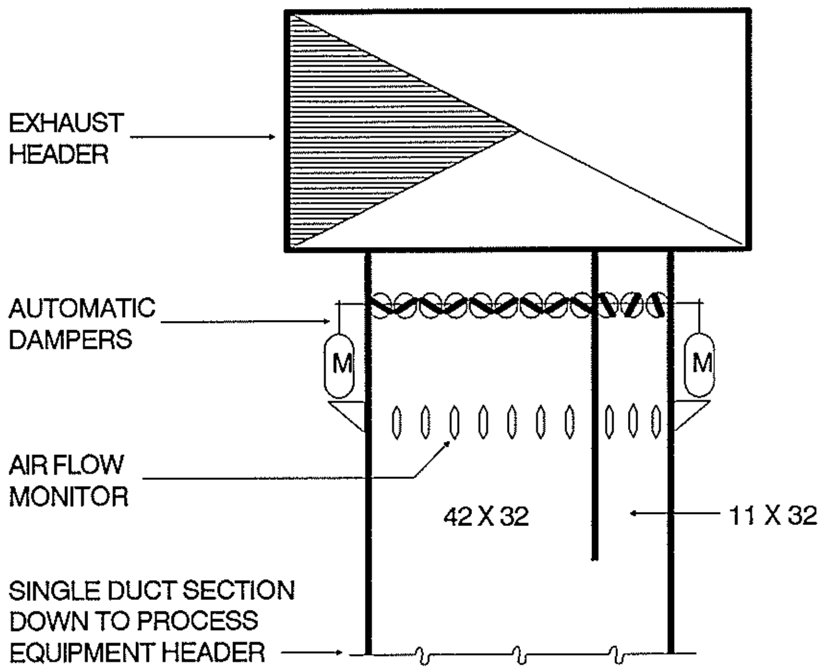

Fig. 2. Section view of zone damper and monitor.

zone-control system had to be defeated to obtain these results.

Attention then turned to the DDC system installed for zone flow control. Fig. 2 illustrates the design objective for each of ten zones. The parallel velocity sensors and automatic dampers in each zone serve two objectives. The smaller duct section is for controlling a decreased "low flow" set point (with the larger duct section closed) for emergency power operation. Also, either or both sections may be used for normal operation, as needed to match the calibrated range of the air-velocity sensors to the present flow requirements. (This was an involved control sequence for 1988.)

The velocity sensors have a 4-20ma output signal to the plant EMS control unit. The EMS periodically "looks" at the output signal and makes adjustment to the damper position to maintain the required flow rate. The monitoring system quickly became suspect.

Before digital technology, TAB technicians were not concerned with velocity pressure measurements at resolutions finer than 0.005" as this was the practical limit of typical manometers and gauges. The available digital technology of today has made it imperative that we concern ourselves with very fine measurements, bearing in mind that 0.005" variance in VP is 5 percent variance in velocity of 900 FPM, and that many HVAC applications are expected to control at better than 5% accuracy.

In the last issue of *TAB Journal* (Summer 1991), Sutton Page provided an excellent analysis of the resolution problem in his article "VAV Box Controllers Have Limitations." The concerns Mr. Page expressed are applicable to many flow-monitoring applications. We will leave the resolution problem as generally stated in the preceding paragraph and detailed in the recent *TAB Journal.*

Although in this application the design engineers made provisions to use the velocity sensors in their effective range, repeatability of readings remained a problem. An examination of the sampling method revealed a common experience with digital technology that was demonstrated and then evaluated throughout the plant system.

It is often said that one "cannot trust *a* digital reading." Use of the singular word "a" captures a characteristic of air flow that prohibits meaningful single digital readings. The flow of air down a duct line is percussive. Due to the compressibility of air, the effect of fittings, transitions, and even the individual fan blades, the flow of air is never stable. Also, the effect of ever-present eddy currents makes flow even more erratic, compounding the confusion for digital velocity-pressure sensors.

The digital indication isn't necessarily inaccurate, as the measured velocity pressure may actually be at a high or low condition at that instant.

With analog instrumentation, this effect is seemingly minimized with the inertia action of the mechanical movement of the indicator or the weight of oil/water in a tube manometer. With digital instrumentation, it is obvious that an averaging feature must be part of the program.

Fig. 3 illustrates velocity measured with a standard Pitot tube fastened at the duct center line. The measuring point is at a normally turbulent location, and the erratic nature of digital measurements is pronounced. (The center line readings were not expected to be as stable as the full cross-section grid should provide.) Values are at approximately 4.5-second intervals and vary ±15% from the average.

Fig. 4 shows measurements taken at the same location with a Shortridge "velprobe." The values are noticeably less erratic, since the velprobe is not as susceptible to turbulence and variations ±10% from the average.

The charts in Figs. 3A and 4A are moving averages of the same test data. Each point is an average of ten

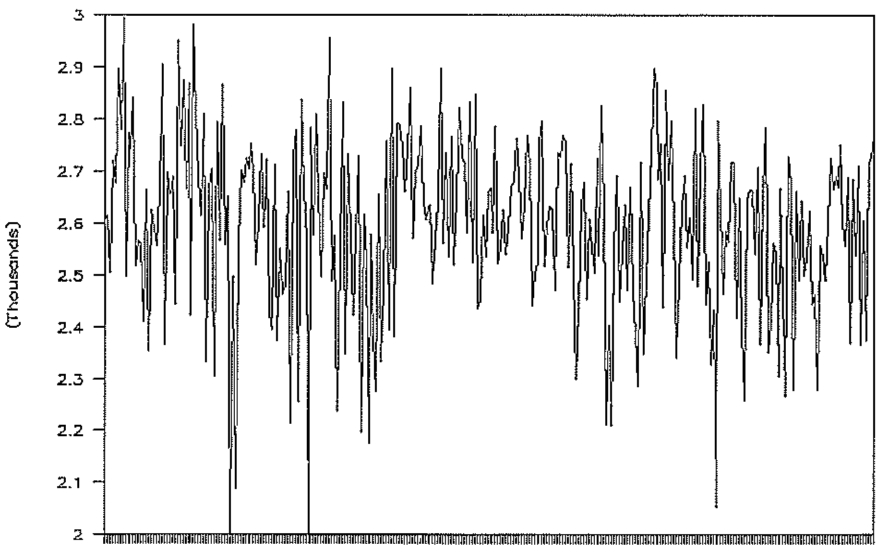

Fig. 3. Velocity measured with a standard Pitot tube.

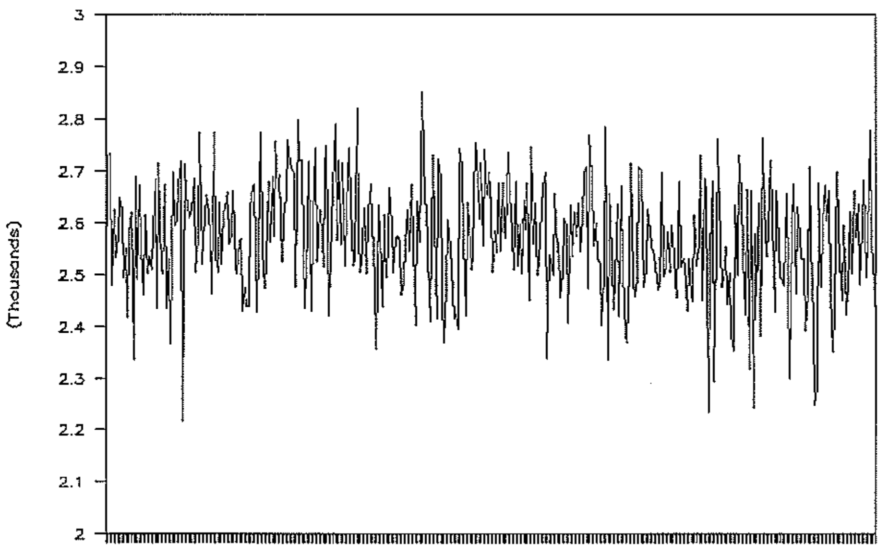

Fig. 4. Velocity measured with a "Velprobe."

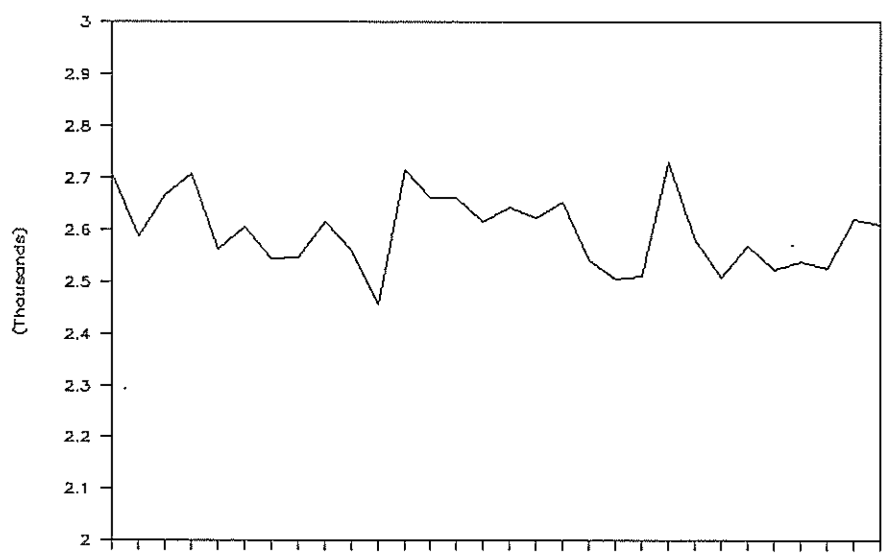

Fig. 3a. Moving average of Pitot-tube measurements in Fig. 3.

velocity readings taken during a 45-second period. The Pitot-tube sensor now has a ±5 percent variance (Fig. 3A), and the velprobe has a ±3 percent variance (Fig. 4A). Actual air flow was verified, by manually traversing, to vary no more than ±3 percent from the average.

Of course if all the sample values are averaged, we would have a straight-line, perfectly stable, air-flow condition! With critical ventilating systems, it is important to determine the extent of "averaging" appropriate to provide a true representation, without averaging away the normal system surging.

In this acid exhaust system application, the plant EMS central control unit was fully capable of conducting the same averaging exercise for the installed air-flow monitors. The programming was revised by the controls contractor, in coordination with the TAB agency, to provide a truly representative flow indication.

Concern for the necessity of appropriately averaging other monitored HVAC performance data extended into other areas of the plant. Area-pressurization hierarchy monitoring was an obvious function to evaluate.

With portable systems monitoring, it is of primary concern that the data loggers be capable of recording an averaged value. It is also important that the sampling time for the averaged value be selectable. This capability enables adjustments to the sampling time to allow for the percussive and turbulent characteristics of the media being measured and the digital sensitivity of the measuring device. In addition, normal system surging and the frequency of the control system response must remain evident with correct sampling periods.

SUMMARY

As digital control systems expand the capabilities and computer control of

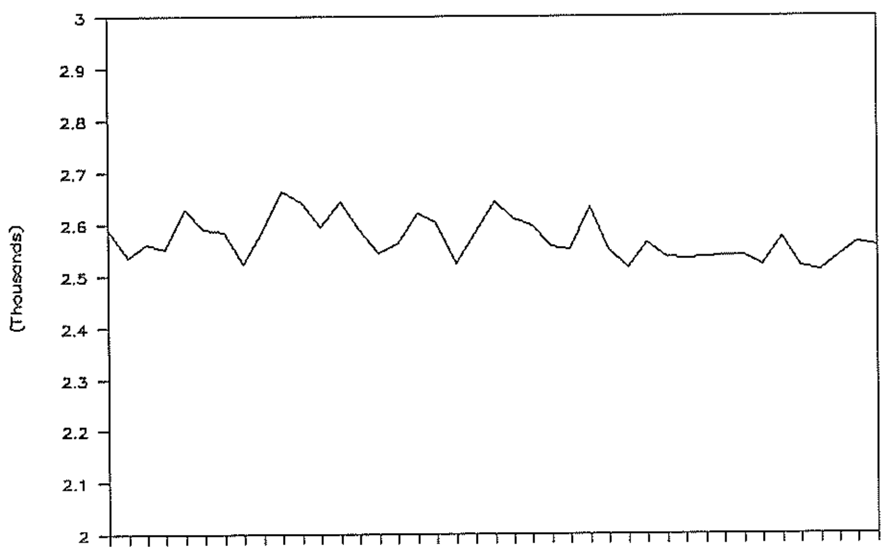

Fig. 4a. Moving average of "Velprobe" measurements in Fig. 4.

HVAC systems, test-and-balance agencies must adapt their testing services accordingly. As shown by the example in this article, one area where TAB agencies can lend assistance is in taking manual measurements with advanced instrumentation to solve problems of "field effect" in the application of seemingly correct control technology.

The increasing complexity of relationships between thermodynamics, control systems, digital instrumentation, and test procedures require a group effort to design, build, and bring a system on line. TAB experts with solid background in field testing and measurement are an essential part of this group effort.

Shop Talk with Bernie Moltz

When performing duct-leak testing, how certain are you that the test results reflect the entire duct section under test? If you aren't certain, you can hardly certify the test.

The duct-leak procedure described in the AABC *National Standards*, Chapter 23, is fine as far as it goes, but it does not provide a vehicle to assure the validity of the test. If blank-off plates are left in the duct, smoke and fire dampers are closed, or debris and foreign objects are present, the test would not be valid.

By the way, before you dismiss the possibility of there being "foreign objects" in a duct, consider this — a sheet-metal worker was once found sound asleep in a large high-pressure sound-lined duct.

Since access panels or doors are not usually provided in spiral high-pressure ducts for visual inspection of the interior, and with the ends of the ducts and takeoffs sealed for testing, the only pre-test inspections available are only visual and audible from the duct exterior.

There is a foolproof method for ensuring that the entire duct test section is in fact being tested. Fig. 1 is a typical duct-leak test setup. After it has been determined that the static pressure and leakage flow rates are within specified limits, while maintaining the pressures on the system, puncture or remove the blank off at Point A. If there is an appreciable change in the manometer indications (loss of static pressure and increase in orifice pressure drop) you can be reasonably sure that the entire duct section has been tested. If, on the other hand, there is only a slight, or none at all, in the manometer readings, you can be sure the duct is obstructed.

One should not certify a duct leak test until this or a similar check has been performed.

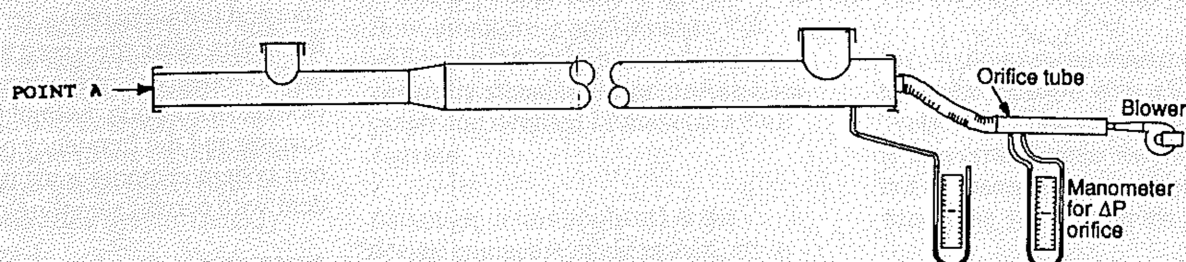

Fig. 1. A typical duct-leak test setup.