Laboratories for the 21st Century

Technical Bulletin

System Static Pressure Optimization

Standard design and operating practice for laboratory ventilation systems usually results in system static pressure setpoints that are higher than actually required. Dynamically optimizing system static pressure can reduce energy use and improve airflow control in laboratories. Recent results at EPA's Research Triangle Park Facility in Durham, North Carolina show a 15% reduction in annual energy costs with a simple payback of about 2 years.

1 Introduction

Laboratory ventilation systems usually run at a high static pressure relative to most commercial buildings due to high air change requirements, exhaust and control devices, special filtration needs, etc. There are several ways to design for lower pressure-drop, as described in the Labs21 Best Practice Guide on Low Pressure-Drop Design (http://www.labs21century.gov/toolkit/bp_guide.htm). This bulletin focuses on dynamically optimizing static pressure during normal operation, in order to optimize airflows while minimizing energy use. This strategy will be described using an example of its implementation in the EPA Research Triangle Park (RTP) facility.

This bulletin first describes the technical approach to this strategy. Next, it describes the resources and project implementation resources and approach. Finally, it presents a cost-benefit analysis of the implementation at RTP.

2 Technical Approach

2.1 Summary

The technical approach for dynamic static pressure optimization can be generalized as a five-step process:

- Step 1: Review current static pressure set points and assess overall potential for optimization.
- Step 2: Measure current static pressure and airflows. Conduct tests to empirically determine current static pressure set points for the supply and exhaust systems to meet flow requirements during occupied and unoccupied modes.
- Step 3: Determine optimum static pressure by incrementally reducing static pressure set points while simultaneously collecting building automation system (BAS) trends of fan variable frequency drives (VFD), system static pressures, variable volume exhaust (VVE) box damper positions, VVE flow sensor volumes, variable air volume (VAV) box damper positions and VAV box flows. Each series of data should be collected while modulating the systems from fully unoccupied operation to full occupied operation at each static set point.
- Step 4: Consider options to reduce system static pressure requirements. For example, it might be possible to satisfy the exhaust flow requirements for biological safety cabinets (BSCs) at a lower system static pressure, or to put them on a separate fan and not penalize the general exhaust static pressure requirement.
- Step 5: Prepare operating guidelines for facilities personnel to maintain optimized static pressure control.

2.2 Implementation at EPA RTP

EPA's RTP facility consists of several laboratory modules, each with its own set of air handling units. Static pressure optimization was done on each module sequentially. As an illustrative example, the technical process and results from laboratory module 'D' are described below. This module has 137,025 sq.ft. of laboratory space, an atrium of about 30,000 sq.ft., and a 27,405 sq.ft. penthouse. It has 6 air handling units with a total capacity of 228,000 cfm.

Static Pressure Tests

A series of System Operating Mode Tests (SOMTs) were conducted with all labs in occupied and unoccupied modes, over a range of system static pressure set-points. The BAS was used to collect data from six air handling units, five exhaust fans, two static pressure sensors in the exhaust plenum, two static pressure sensors in the supply ducts and all of the individual supply VAV boxes and exhaust VVE boxes. Air supply volumes were measured at unoccupied operation and occupied operation for comparison to the aggregate sum of flow reported by the BAS. Flow measured at individual VAV and VVE control boxes along with position of the flow control dampers were recorded over the range of operating modes and system static pressures. Table 1 summarizes the static pressure set-points for each SOMT.

Table 1. Summary of set-points for static pressure tests in laboratory module 'D'.

Test Condition	**Existing**	**Existing**	**Test 1**	**Test 2**	**Test 3**	**Test 4**	**Test 5**
Operating Mode	Unocc.	Occ.	Occ.	Occ.	Occ.	Occ.	Occ.
Exhaust Static Pressure Setpoint (in. w.g.)	3.1	3.1	2.6	2.3	2.0	1.8	1.5
Supply Static Pressure Setpoint (in. w.g.)	3.1	3.1	2.6	2.3	2.0	1.8	1.5

Measurements of supply flow during the SOMTs indicated that the total supply volume was approximately 77,800 cfm with all labs unoccupied and 100,500 cfm with all labs occupied. The difference between occupied and unoccupied flow is approximately 22,700 cfm. The aggregate sum of flows reported by the BAS for individual supply terminal boxes was in close agreement with measured values. The BAS reported the unoccupied flow as approximately 81,100 cfm during unoccupied operation and 104,200 cfm during occupied operation. Thus, the error between measured flows and those reported by the BAS was less than 5%.

Determination of Optimum Static Pressure Set-Points

As noted above, the BAS captured damper positions and flow for each of the VAV and VVE terminal boxes. The data was compiled, sorted and analyzed to determine the range of damper positions and percent difference between measured flows and flow set-points for each box at each of the system static pressure set-points. Figure 1 shows the number of supply boxes in various damper "% open" ranges for selected static pressure setpoints. Figure 2 shows the similar plot for the exhaust boxes. As expected, the figures show that as the static pressure is reduced, the number of boxes in the higher "% open" ranges increases. The key to optimizing system static pressure is to ensure that this distribution is not skewed heavily to the left or the right.

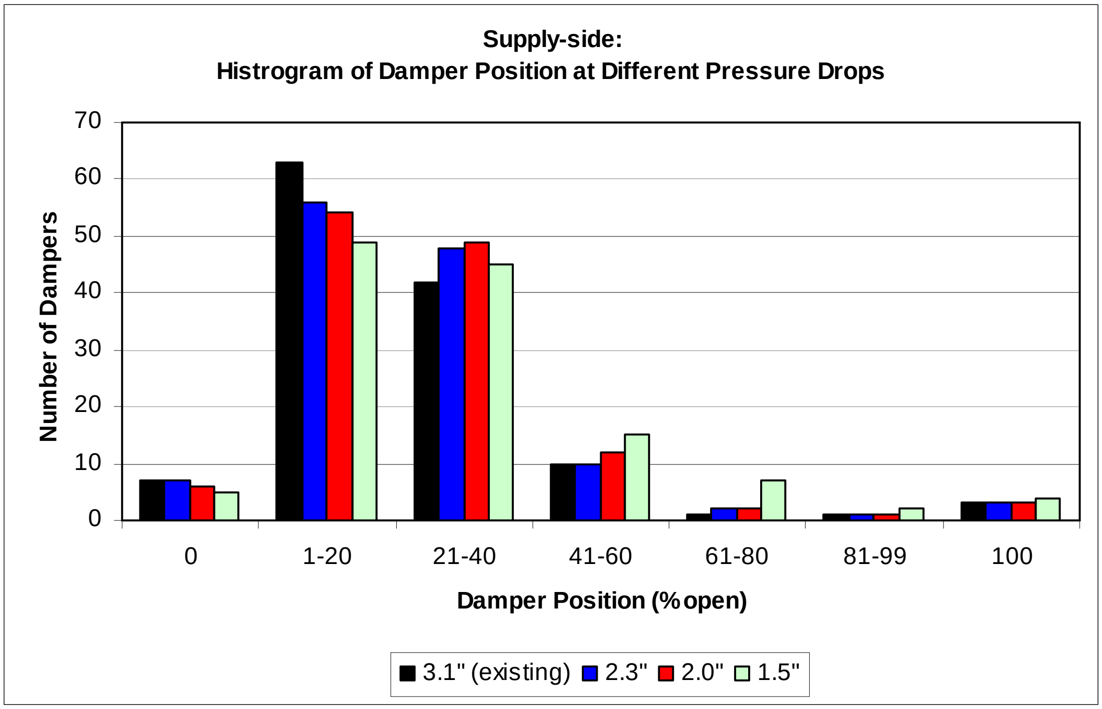

Figure 1. Frequency distribution of damper positions for supply-side boxes at various setpoints

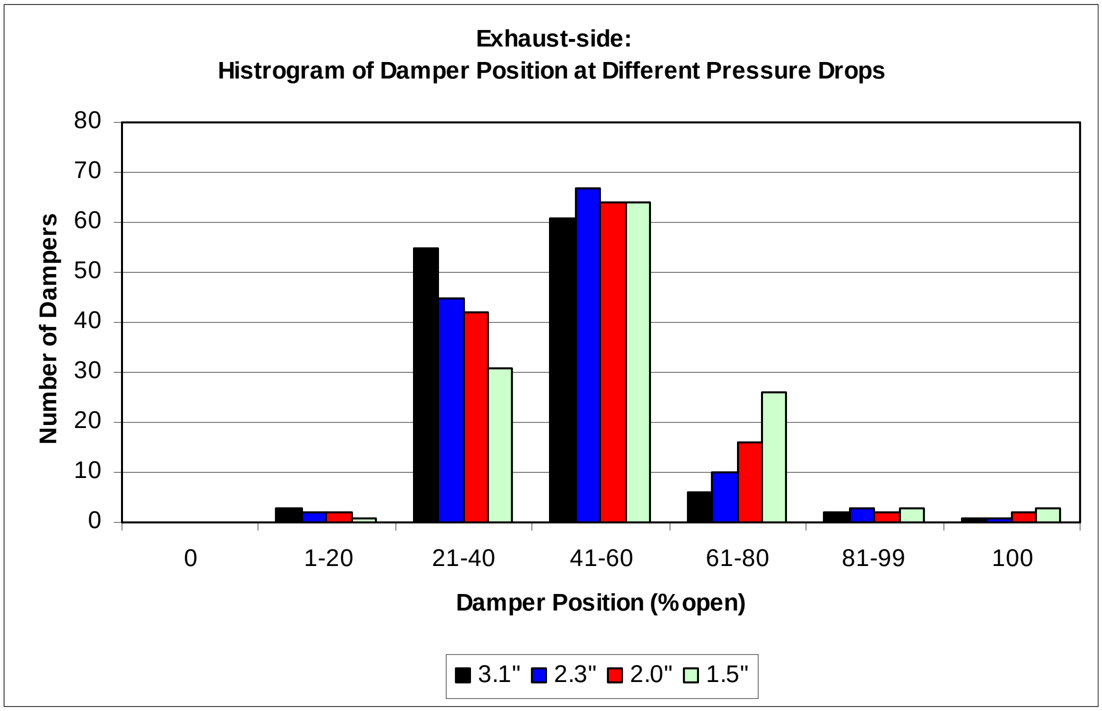

Figure 2. Frequency distribution of damper positions for exhaust-side boxes at various setpoints

Analysis of the data identified the boxes that determine the minimum allowable system static pressures, and indicated that the static pressure set-points for both supply and exhaust systems are at least 25% higher than required to provide satisfactory flow. The optimum static pressure set-points and their impact on VFD operation and fan power are provided in Table 2.

Table 2. Fan operating parameters under existing and optimized static pressure set points for laboratory module D.

	Static pressure (in. w.g.)	**Aggregate Fan VFD %**	**Sum Fan kW**	**Sum Fan Amps**
Supply–Existing	3.1	98.3	123	203
Supply–Optimal	2.0	90.6	91	176
Difference	*1.1 (35%)*	*8%*	*32 (26%)*	*27 (13%)*
Exhaust–Existing	3.1	92.0	107	167
Exhaust–Optimal	2.3	86.3	93	156
Difference	*0.8 (26%)*	*6%*	*14 (13%)*	*11 (7%)*

Note: The fan data is the summation of data from 3 fans serving this building.

The tests and data analysis also yielded the following findings and recommendations:

- A number of VAV and VVE boxes require additional maintenance and/or verification of proper box operation.
- In one of the labs, a BSC is currently driving the minimum static pressure requirement. If this continues to be the case after it has been re-certified, EPA will consider providing a dedicated exhaust for this BSC, so that the static pressure for the general air handling unit can be reduced.
- The BAS should be programmed to automatically produce trend reports on VVE and VAV damper positions and flows.
- Standard operating procedures should be developed for diagnostic performance tests that challenge system operation similar to the SOMT procedures. The standard operating procedures can be used to enhance the preventative maintenance program and ensure proper system operation in the future.

Next Step: Fan Sequence Optimization

As a follow up to this project, EPA will begin an effort to further reduce fan energy use by optimizing fan operation sequence - a series of tests will be conducted to determine the optimum sequence of exhaust fan and air handler operation. Currently at RTP a number of exhaust fans and air handlers run at 100% output with one unit on each system operating with variable output to meet the static pressure set point. Recommended alternative control strategies utilizing a different sequence of fan operation that could meet system static pressure requirements but operate with lower energy use will be implemented. The tests will be conducted under different operating scenarios or fan sequences while modulating the systems from fully unoccupied operation to fully occupied operation. The optimum fan sequence will be determined by evaluating the ability to maintain the new system static pressure and the resulting summary of overall energy use. A future technical bulletin will summarize the results of this effort.

3 Implementation Approach and Resources

Personnel resources

This project was a team effort involving the following:

- The technical service provider (Exposure Control Technologies) had primary technical responsibility for the development and execution of the testing protocol.
- The in-house operations and maintenance contractors (CHI) operated the building automation system and aided with the tests.
- The on-site facilities staff provided oversight of site activities.
- The on-site energy management staff coordinated between CHI and facilities.
- The environmental health and safety officer (EHS) reviewed all the test data.
- The EPA energy manager served as project manager.

Project scheduling

Overall project timeline was six weeks. The actual on-site testing and optimization for each module was done over a weekend, starting on Friday evening and extending through Sunday. Users were notified in advance about these tests, but continued to work during the tests since the test protocol accounted for any user activity during the course of testing. This minimized disruption to research and other user activities.

4 Cost and Benefits

The project scope included static pressure optimization for several laboratory modules. Table 1 summarizes the project costs and savings for a typical module. Based on energy savings alone, the data shows this to be a very cost effective project. In addition to the energy savings, static pressure optimization also improves airflow and temperature control. The EHS officer strongly advocated for this project because it provides him with continuous verification of airflows – akin to a continuous certification process.

Table 1. Features, costs and benefits for laboratory module 'D' at the EPA RTP facility

Gross area (labs, penthouse, atrium)	194,430 sf
Number of VAV boxes	255
Number of fumehoods	61
Project cost (including in-house personnel time)	$30,000
Total kW before project (supply and exhaust fans)	230 kW
Total kW after project (supply and exhaust fans)	184 kW
Estimated annual energy cost savings	$20,000
Project simple payback	1.5 years

The above results are specifically for module 'D'. Aggregate results from several modules show a 15% reduction in annual energy costs with a simple payback of about 2 years.

5 References

Low-pressure drop HVAC design for laboratories, Labs21 Best Practice Guide. Available on the web: http://www.labs21century.gov/toolkit/bp_guide.htm

6 Acknowledgements

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