FUME HOOD
PERFORMANCE TEST AND
LIFE CYCLE COST ANALYSIS

FOR

UNIVERSITY OF WISCONSIN MILWAUKEE

UWM

CHEMISTRY BUILDING FUME HOOD REPLACEMENT PROJECT
PHASE 2

PREPARED BY

STATE OF WISCONSIN

DEPARTMENT OF ADMINISTRATION
DIVISION OF FACILITIES DEVELOPMENT

February 21, 2000

EXECUTIVE SUMMARY

The purpose of this report is to present the results of an engineering and economic evaluation between chemical fume hoods from two manufacturers who submitted bids for the University of Wisconsin Milwaukee Chemistry Fume Hood Replacement Project (DFD #98303). The project scope called for furnishing and installing 94 new fume hoods.

Bids were received on January 11, 2000 by Lab Crafters, Inc. of Ronkonkoma, New York and by Fisher Hamilton, Inc. of Two Rivers, Wisconsin. There was a large disparity between the bid prices of the two companies. Lab Crafters, Inc. submitted a bid of $873,012.00 and Fisher Hamilton submitted a bid of $406,580.17.

The bid specifications for this project were written for a single source bid from Lab Crafters, Inc.. Engineering staff from the Division of Facilities Development has performed extensive research into the Lab Crafters fume hood and found it was clearly in the best interest of the State to pursue a sole source bid from them on this project. Independent performance testing of this fume hood shows it provides much safer containment than conventional fume hoods while dramatically reducing energy costs. This technology is designed to use up to 50% less exhaust and makeup ventilation air than conventional fume hoods. The Division was aware of the premium cost for the Lab Crafters fume hood so a detailed life cycle cost analysis was performed during the design phase of this project. Even though the Lab Crafters fume hood had higher first costs, the life cycle cost analysis strongly favored this product over other conventional fume hoods.

The Fisher Hamilton bid included a statement that their product met containment requirements. Because of this and the large disparity in bid prices, the Division of Facilities Development arranged extensive on-site performance testing of each fume hood in order to reach our own conclusion. The testing was carefully arranged to give Fisher Hamilton, Inc. every opportunity to prove their product met the specified performance requirements of the Lab Crafters fume hood. The fume hood Fisher Hamilton provided for the on-site testing was not the model the Division was expecting. The fume hood furnished had several modified features that differed from the catalog model Fisher Hamilton listed on their bid form. The Division pursued testing of this fume hood anyway to allow Fisher Hamilton the opportunity to provide the State with an equal product. The Fisher Hamilton fume hood sash opening height was not in conformance with the specification. Lab Crafters formally objected to this. Instead of making Fisher Hamilton adjust their sash height, they were allowed to have their fume hood tested as furnished. In turn Lab Crafters was allowed to adjust their fume hood to match the non-conforming Fisher Hamilton sash height conditions. The test equipment and setup used for the on-site testing was also carefully arranged to offer both manufacturers virtually identical conditions.

On-site performance testing at UW Milwaukee reaffirmed that the Lab Crafters fume hood operates safer and uses much less building ventilation air than the fume hood Fisher Hamilton proposes to use. Although Fisher Hamilton's bid indicated their product could meet specified containment requirements at low air volumes, the UW Milwaukee test results in this report show otherwise.

Using the on-site performance test results, the Division of Facilities Development performed energy calculations and another life cycle cost analysis to verify whether the initial design phase economic analysis was still valid. The subsequent life cycle cost analysis uses actual project costs from bids received for the entire project, not estimated costs which were used in the previous design phase calculations. The final economic outcome favored the Lab Crafters fume hood alternative primarily due to its significantly lower annual energy costs.

In addition to the energy savings, the Lab Crafters life cycle cost alternative was positively influenced by reduced ventilation equipment first costs. By using the Lab Crafters fume hoods at lower air volumes, the project can eliminate one of two large air handling systems. Both systems would be required with conventional fume hoods in order to meet makeup air ventilation needs. The reduction in ventilation system equipment costs along with the yearly energy savings results in a total life cycle cost savings of over $428,000 if the Lab Crafters fume hood is selected in lieu of the Fisher Hamilton fume hood.

In addition to this life cycle cost savings, a significant cost that was not factored into the economics was the real future costs of increasing campus heating and cooling plant capacities. Using lower flow fume hoods will reduce overall campus heating and cooling requirements. As new buildings and additions are constructed every year, the heating and cooling resources of campus plants must be conserved. Any opportunity to defer the expensive capital costs required to increase plant capacities will surely benefit the State of Wisconsin.

It should be noted that the results of the life cycle cost analysis in this report are unique to this project. Energy costs can vary by facility. Also, the opportunity to eliminate a large air handling system and offset some of the low flow fume hood premium costs may not be available in all project situations.

While life cycle cost comparisons of systems are an important decision making tool, safety of laboratory fume hood systems can not be undersold by economics. People who attend our state universities and use these facilities must be protected from the many hazards in the laboratory; the inability of a fume hood to prevent breakdowns in containment against toxic or potentially fatal compounds is unacceptable.

The efforts expended for this report have proven that low-flow fume hood technology by Lab Crafters is not only economically viable but can also offer a higher degree of safety and containment than today's conventional fume hoods.

In conclusion, the Division of Facilities Development recommends awarding the fume hood contract for the UW Milwaukee Chemistry Fume Hood Replacement project to Lab Crafters, Inc. The safety and energy saving capabilities the product provides makes this decision the proper one that serves the best interests of the State of Wisconsin.

TABLE OF CONTENTS

BACKGROUND INFORMATION

The University of Wisconsin – Milwaukee Chemistry building, constructed in the early 1970's, is a two wing building that includes a four story South educational wing and an eight story North research wing. On August 18, 1999, the State of Wisconsin Building Commission authorized bidding and construction for the North Wing Fume Hood Replacement Project (DFD #98303). The main objectives of this project are to improve laboratory safety conditions by replacing non-code complying fume hoods with new fume hoods and insure a safe operating ventilation system for the research laboratories. The scope of this project includes replacement of 114 existing chemical fume hoods with 92 new chemical fume hoods.

Several alternatives were evaluated during design to determine the most economic solution while maintaining safety as the utmost priority.

Concurrent with the preliminary design phase of this project, engineering staff in the Division of Facilities Development was actively researching the Lab Crafters Air Sentry™ fume hood which claimed to offer exceptional levels of safety for the user while at the same time reducing ventilation requirements by half of conventional systems. During this research process, University of Wisconsin – Madison Environmental Health and Safety staff conducted an independent test of a Lab Crafters Air Sentry fume hood installed at the University of Illinois - Chicago[1]. Their results confirmed safe operation and containment by this fume hood at an open sash face velocity of approximately 50 feet per minute under challenging air current conditions that simulated a less than ideal laboratory setting.

The low-flow fume hood concept proposed for this project does not violate any current safety standards. Safe containment is the performance goal of every fume hood. Standards and rules such as OSHA 29 CFR Part 1910 Occupational Exposures to Hazardous Chemicals in Laboratories and ANSI Z9.5-1992 American National Standard for Laboratory Ventilation clearly indicate that they do not specify minimum face velocities for fume hoods. Face velocities established in the past by the fume hood industry may not necessarily be a direct indication of good containment. Tracer gas tests have proven this. As the OSHA rule states, "OSHA recognized that there was considerable debate over what optimum velocities should be in light of differences in hood design and methods of operation. Moreover, it was felt that requiring specific face velocities was not consistent with the performance orientation of the standard."[2] Likewise, the ANSI Z9.5 Standard says, "The standard does not establish a standard for face velocity because of the importance of other parameters and the existence of an applicable performance test (ANSI/ASHRAE 110)"[3].

While several conventional alternatives were evaluated and initially considered, the final design concept for the UW Milwaukee Chemistry project proceeded with the Lab Crafters low-flow fume hood option. This decision was made after confirmation of its containment abilities and a life cycle cost analysis that showed low-flow fume hoods were the preferred economic choice for this project[4].

At the time, the Division of Facilities Development was aware of a significant first cost premium for the Lab Crafters fume hood. These figures were used along with historical costs from conventional fume hood projects to perform the initial economic comparison. The low-flow fume hood option allowed designers to completely eliminate the need for a second major air handling system that would have been necessary with the conventional fume hood option. This not only offset some of the first cost premiums for the low-flow fume hoods, but also appealed to the Division for several reasons. Energy costs required to heat and cool the ventilation air of a second air handling unit could be dramatically reduced, maintenance costs of the second major air handling system could be eliminated, and future increases in campus heating and cooling plant capacity could be deferred.

Over the past several years, the Division of Facilities Development has built many major laboratory and research building projects using conventional fume hoods. To the Division's knowledge, no manufacturer other than Lab Crafters, Inc. has advertised the ability to meet stringent containment requirements while operating at low-flow conditions. Of the competing manufacturers that the Division is aware of, none catalog such a product. The Division of Facilities Development had concerns about unqualified bidders not being able to meet a performance specification written around the low-flow fume hood for the UW Milwaukee Chemistry project. As a result, the Division believed it was in the best interests of the State to contract the fume hoods from only one source in accordance with Wisconsin Statutes Section 16.855(10). The fume hood specification was issued using a class 1 advertisement for a single source bid from Lab Crafters, Inc.

On January 11, 2000, the Division of Facilities Development received bids from Lab Crafters, Inc. for $873,012.00 and from Fisher Hamilton, Inc. for $406,580.17. The Lab Crafters bid was consistent with cost figures they previously had given the Division for life cycle costing. The Fisher Hamilton bid was much lower than the historical fume hood costs the Division used. The Fisher Hamilton bid form also listed the model number of the product they proposed to use for this project, a statement to the effect that they met containment requirements with this product, and also a disclaimer statement regarding operation of fume hoods at 40 feet per minute. Because Fisher Hamilton, Inc. qualified their bid with unsolicited material, it was rejected in accordance with Wisconsin Administration Code Adm 21.08(e).

Regardless of the rejected bid, the Division of Facilities Development felt it was necessary to carefully review both products due to the wide disparity between bid prices. This was necessary to determine whether the Fisher Hamilton product did in fact meet the performance of the specified Lab Crafter's product and to verify whether or not the initial life cycle cost analysis was still valid. This report presents the details of this investigation.

REQUEST FOR PERFORMANCE TESTING

Before the life cycle cost analysis could be verified, it was absolutely necessary to determine that both hoods could perform safely for this project.

The Division of Facilities Development requested Fisher Hamilton, Inc. and Lab Crafters, Inc. to each ship a five-foot fume hood to the University of Wisconsin - Milwaukee Chemistry building for on-site testing. Each manufacturer was to retain ownership of their fume hood. When testing was complete, the Division of Facilities Development returned the fume hoods to the manufacturer's facilities.

Laboratories 214 and 238 were selected in the North wing Chemistry building to accommodate installation of the test hoods. Both rooms were identical in size and floor plan layout. They were each vacated and carefully arranged to provide identical conditions for both manufacturers. Photographs in Figures 1 and 2 show the installed test hoods in these labs.

Figure 1
Laboratory Room 214
Fisher Hamilton Test Hood

Figure 2
Laboratory Room 238
Lab Crafters Test Hood

An independent fume hood installer was contracted by the Division to accept delivery of the two fume hoods, set the fume hoods in place and to remove the fume hoods upon completion of testing. Both manufacturers were allowed to witness and inspect the third party installation.

The mechanical ventilation systems were installed identically for both laboratories. Supply air was introduced through a round perforated supply duct at the laboratory wall opposite the fume hood to limit uncontrollable room air currents. The fume hood exhaust ductwork was installed identically for both fume hoods up to the balance damper furnished by the fume hood manufacturers.

An AABC (Associated Air Balance Council) certified testing and balancing firm was contracted by the Division to set and verify supply and exhaust air flows in each laboratory. A copy of the certified balance report is included in appendix C of this report.

Initial performance testing for both fume hoods was conducted on February 3rd and 4th, 2000 by two independent sources. Tom Smith of Exposure Control Technologies, Inc. and Jack Wunder of the University of Wisconsin – Madison Environmental Health and Safety Department conducted the performance testing together. Both parties have extensive experience with ANSI/ASHRAE 110 fume hood testing procedures. Neither manufacturer objected to the arrangement of Tom Smith and Jack Wunder performing the tests together. Both manufacturers were allowed to witness the initial testing procedures and review the results as they became available.

After initial evaluation of the February 3rd and 4th test results by the Division of Facilities Development, it was determined that follow-up testing was required to obtain further performance information on each fume hood for purposes of conducting the economic analysis. Due to scheduling demands with removal of both hoods, this testing was performed on February 11, 2000 by Jack Wunder of UW Madison and Dan Motl of the Division of Facilities Development. Arrangements were not made to invite the manufacturers to witness the follow-up testing because of the short notice scheduling. If the follow-up testing results are in dispute, the Division is prepared to perform the tests again publicly to show repeatability of the results.

PERFORMANCE CRITERIA

The fume hood bid documents for the UW Milwaukee Chemistry building contain a specification for factory performance testing to insure the fume hoods furnished would meet stringent safety requirements[5]. This performance criteria was the basis for comparing the capabilities of the two fume hoods.

The performance test in the specification is based on the ANSI/ASHRAE 110-1995 Standard – Method of Testing Performance of Laboratory Fume Hoods[6]. This test method is a nationally recognized standard and, in the opinion of the Division of Facilities Development, is the best available means for determining performance for a fume hood. A thorough description of the test protocol is described in the standard listed in the reference section of this report. The standard basically consists of three tests: face velocity measurements, flow visualization by smoke testing and tracer gas testing to determine the containment capabilities of the fume hood. Photographs in Figures 3 through 5 show the standard's velocity measurement and smoke tests being conducted at UW Milwaukee.

Figure 3
Face Velocity Measurement

Figure 4
Low Volume Smoke Test

Figure 5
High Volume Smoke Test

The tracer gas test is the portion of the standard that identifies quantitative containment levels for a fume hood. Figure 6 shows a schematic of a typical tracer gas containment test setup. Sulfur Hexaflouride (SF6) gas is released from a cylinder through an ejector located inside the fume hood at a known rate. A sample probe mounted at a mannequin's breathing zone pulls a sample of air from this location which is then run through a leak detector or gas analyzer. The detector or analyzer is calibrated for the SF6 gas and gives an output in parts per million of the SF6 gas that is detected in the mannequin's breathing zone.

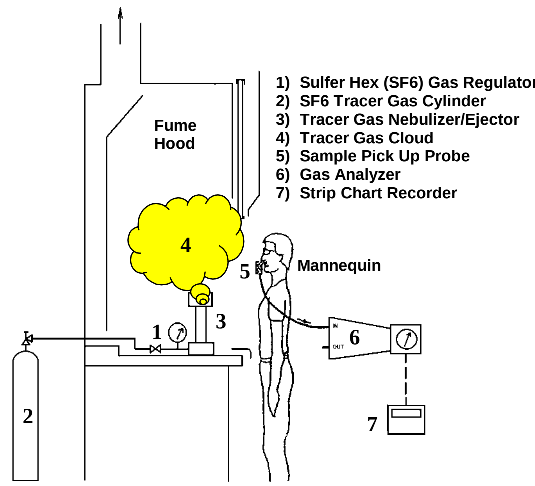

Figure 6
Tracer Gas Containment Test

The ANSI/ASHRAE 110 standard is a test method and does not specify a pass/fail threshold for the parts per million of SF6 gas. The ANSI Z9.5 1992 Laboratory Ventilation Standard does define a class A fume hood as one that performs at or under a threshold of 0.05 ppm concentration of tracer gas released at a rate of 4.0 liters per minute inside the fume hood for an "as manufactured" condition[7]. The abbreviated nomenclature used is 4.0AM0.05 where "AM" references an "as-manufactured" condition.

Factory fume hood performance testing is one indicator that allows owners to evaluate fume hood operation. However, conditions for factory performance testing can easily be idealized in the test cell at a manufacturer's facility. It is safe to say that it is easier to pass an "as manufactured" factory performance test than it is to pass an on-site "as-used" performance test. Room conditions and environmental factors in an as-used installation are much less predictable than the controlled environment inside a factory test cell.

The specification for this project established a threshold of 0.05 ppm at a tracer gas release of 8.0 liters/minute. This criteria was also specified as a not-to-exceed threshold. Although the ANSI/ASHRAE 110 standard allows averaging of measured concentrations for the timed duration of a tracer gas test, the Division of Facilities Development and many safety personnel believe that maximum or peak values can not be ignored. Peak values above the threshold concentration represent "spillage" or break down of a fume hood's containment and when these occur on a repeatable and continual basis, the fume hood user's health may be compromised. Using averages will tend to hide the peak values from test performance ratings. The Division believes it is in the best interest of the user's safety to establish specifications that require performance based on maximum concentrations.

The test specification for the UW Milwaukee project called for tracer gas testing to be performed with the mannequin's sample probe located at two different elevations. This is an extremely important criteria since it provides containment results representing people of different heights. As the February 3rd and 4th performance testing results in this report show, the test fume hoods had much more difficulty containing in the lower mannequin position than in the higher mannequin position. This makes sense since the breathing zone of shorter people is closer to the work surface of the fume hood where chemical reactions and releases typically occur.

Another criteria that the project specification included was the mandate to test the fume hoods with a cross draft in front of the hood. This requirement was important to simulate room air distribution effects or effects from people walking behind the fume hood operator. These are real conditions that can occur in even the most well designed laboratories.

To further simulate an "as-used" condition, the project specification called for the fume hoods to be tested under a loaded condition. This was accomplished by stacking cardboard boxes inside the fume hood in a configuration that intentionally challenged the containment of the hood. Fume hoods are rarely used in actual situations without some degree of loading by containers, apparatus, or equipment. This criteria, although not a perfect representation of real conditions, does represent a degree of challenge that an empty hood does not see.

The photograph in Figure 7 shows the tracer gas test arrangement with the cross draft fan unit and the fume hood loaded with boxes. Note the cross draft velocity was set using a variac on the fan motor and was measured with an articulated hot wire anemometer probe.

Figure 7
Tracer Gas Arrangement with Cross Draft and Hood Loading

PERFORMANCE TEST EQUIPMENT

Tom Smith uses an ITI leak meter for the ANSI/ASHRAE 110 tracer gas testing. His equipment was set up with a data collection system and notepad PC with software that allowed real-time output of the testing results.

Jack Wunder uses a Foxboro Miran 1A gas analyzer for the ANSI/ASHRAE 110 tracer gas testing. He has data logging and strip chart capabilities that also offer real-time output of the testing results.

Both sets of equipment were on-site and available for use during the February 3rd and 4th testing dates. It was mutually agreed that Tom Smith's ITI leak meter would be used for conducting the tests on both fume hoods during these two days.

The follow-up testing on February 11, 2000 by Jack Wunder and Dan Motl was performed using the Foxboro Miran 1A equipment.

It should be noted that Fisher Hamilton uses the ITI leak meter at its Two Rivers, Wisconsin testing facility. Their factory test was conducted using the ITI equipment. Lab Crafters uses the Foxboro Miran gas analyzer in its Ronkonkoma, New York testing facility. Their factory test was conducted using the Foxboro Miran equipment.

PERFORMANCE TEST RESULTS

Factory Performance Test Results:

Both manufacturer's were requested to furnish factory test reports for the fume hoods they were sending to UW Milwaukee. The purpose of this request was to allow the Division of Facilities Development to evaluate "as manufactured" test results in accordance with the specification.

Lab Crafters furnished a complete factory performance test report that is included in appendix B of this report. According to their results, the Air Sentry fume hood they provided passed the not-to-exceed 8.0AM0.05 at an average face velocity of 42 feet per minute under all conditions specified.

Fisher Hamilton furnished a factory performance test report that was stamped confidential and as a result, the contents of their report are not included as part of this report. The report submitted by Fisher Hamilton did not include all specified test conditions. The factory test results did not pass the not-to-exceed 8.0AM0.05 for all conditions.

On-Site Performance Test Results:

The on-site performance testing results for the February 3rd and 4th, 2000 testing is contained in appendix A of this report.

The Division of Facilities Development has evaluated these results and has the following observations:

a) Neither fume hood passed a not-to-exceed 8.0AU0.05 threshold for all specified conditions. This was not unexpected since, as mentioned above, as-used test results can rarely duplicate as-manufactured test results due to less than ideal environmental factors in an as-used laboratory setting. The appendix A report results do however depict a significant difference in magnitude of failure between the two fume hoods.

b) It is clear that the most challenging test condition was the lower mannequin position where the breathing zone was set at 18 inches above the work surface. The Fisher Hamilton fume hood had serious containment problems in the static condition. Major spilling occurred in the initial test at this position. The test was re-run to verify repeatability of the results. As the appendix A report indicates, the Fisher Hamilton fume hood did not achieve specified containment at this position under any of the static tests. The Lab Crafters fume hood did not meet specified not-to-exceed containment at this condition either. Again, the appendix A report results depict the difference in magnitude of failure between the two fume hoods for this condition.

c) The cross draft and box loading tests were intended to increase the challenge for each fume hood. It is suspected that the selected arrangement of the boxes and/or the position of the cross draft fan did little to challenge the fume hoods and may have even enhanced performance to a certain degree.

The February 3rd and 4th test results for both fume hoods leads the Division of Facilities Development to believe that the not-to-exceed 8.0AU0.05 criteria with a 40 FPM average face velocity test condition may not be achievable in an “as-used” condition.

Based on this conclusion, the Division of Facilities Development determined that further testing was necessary to identify the average face velocity where each hood would pass the specified not-to-exceed 8.0AU0.05 performance rating. With the results of this further testing, it was then possible to perform energy calculations based on the respective airflow that each fume hood needed for meeting the specified performance rating. Using the energy calculations in conjunction with first costs, maintenance costs and replacement costs, the life cycle cost analysis could then be verified.

The February 11, 2000, Jack Wunder and Dan Motl performed additional testing to obtain this information. It was decided that all testing would be conducted with the mannequin located in the center position of the fume hood and lowered so its breathing zone was 18 inches above the work surface. Since this proved to be the critical location from the previous testing, successful containment at this condition would likely mean successful containment at all other locations and conditions.

The fume hoods were tested in both a static condition with no cross drafts or box loading and also with a cross draft and box loading. The cross draft was set to 50 FPM behind the mannequin. The position of the fan unit was arranged to intentionally challenge the containment of both fume hoods.

Testing was conducted with both fume hoods operating at an average face velocity of 40 FPM. The Miran gas analyzer produced results that could be correlated with previous testing done on February 3rd and 4th using Tom Smith's ITI leak meter. For both hoods it appeared that the magnitude of failure was larger with the Miran instrument than it was using the ITI leak meter. It is suspected this could be attributed to the Miran instrument using a higher sampling rate than the ITI leak meter. Regardless, it was reaffirmed that both fume hoods could not meet the not-to-exceed containment threshold at this face velocity.

Air flows for each fume hood were increased by approximately 10 FPM increments until each respective hood would pass the not-to-exceed 8.0AU0.05 specification. After each air flow adjustment, a tracer gas test was run for both static and cross draft with hood loading conditions. Face velocity measurements for each increment were recorded and are included in appendix D of this report.

The graphs on the following pages depict the tracer gas results for each fume hood in both the static (non-challenged) condition and the cross draft and hood loading condition. The tabular data recorded by a Metrosonics dl-3200F data logger is given in appendix E of this report.

The blue data line represents the not-to-exceed threshold concentration of 0.05 ppm SF6 gas. The red data line represents the maximum concentrations of the Fisher Hamilton fume hood. The green data line represents the maximum concentrations of the Lab Crafters fume hood.

Note the first static test for the Fisher Hamilton fume hood was re-run after the initial test produced spikes above the 0.05 ppm threshold. The sensitivity on the Miran gas analyzer was checked to insure there was no appreciable instrument error contributing to the test results. The test results shown on page 8 are those of the retest after the sensitivity check was performed.

The tracer gas test results show that the Lab Crafters fume hood is capable of safely meeting the specified containment threshold under all conditions at a 51 FPM average face velocity. The corresponding exhaust air flow for the Lab Crafters fume hood is 470 CFM based on the 51 FPM average face velocity and a measured face area of 9.21 square feet. This exhaust CFM was used to calculate the total required make up air volume for the system. The total building fume hood exhaust plus general room exhaust requires 60,000 CFM of conditioned makeup air for the North wing. This value is used for the Lab Crafters energy calculation shown on page 13.

The tracer gas test results show that the Fisher Hamilton fume hood is capable of safely meeting the specified containment threshold at some average face velocity between 60 and 77 FPM for static conditions only. The cross draft and fume hood loading tests show that the Fisher Hamilton fume hood failed the not-to-exceed specified containment threshold at its highest average face velocity of 87 FPM. The magnitude of failure for several of these tests resulted in not only the peak maximum concentration exceeding the threshold, but also the average concentration exceeding the 0.05 ppm threshold value. These values are shown on the graphs as a red dashed line. The testing results for the Fisher Hamilton fume hood were limited to the 87 FPM average face velocity because the balance damper could not be opened any further to increase the exhaust. The corresponding exhaust air flow for the Fisher Hamilton fume hood is 864 CFM based on a 90 FPM average face velocity and a measured face area of 9.60 square feet. For purposes of establishing a required air flow, it is assumed that containment could be achieved just beyond the last failure point The total building fume hood exhaust plus general room exhaust requires 96,300 CFM of conditioned makeup air for the North wing. This value is used for the Fisher Hamilton energy calculation shown on page 14.

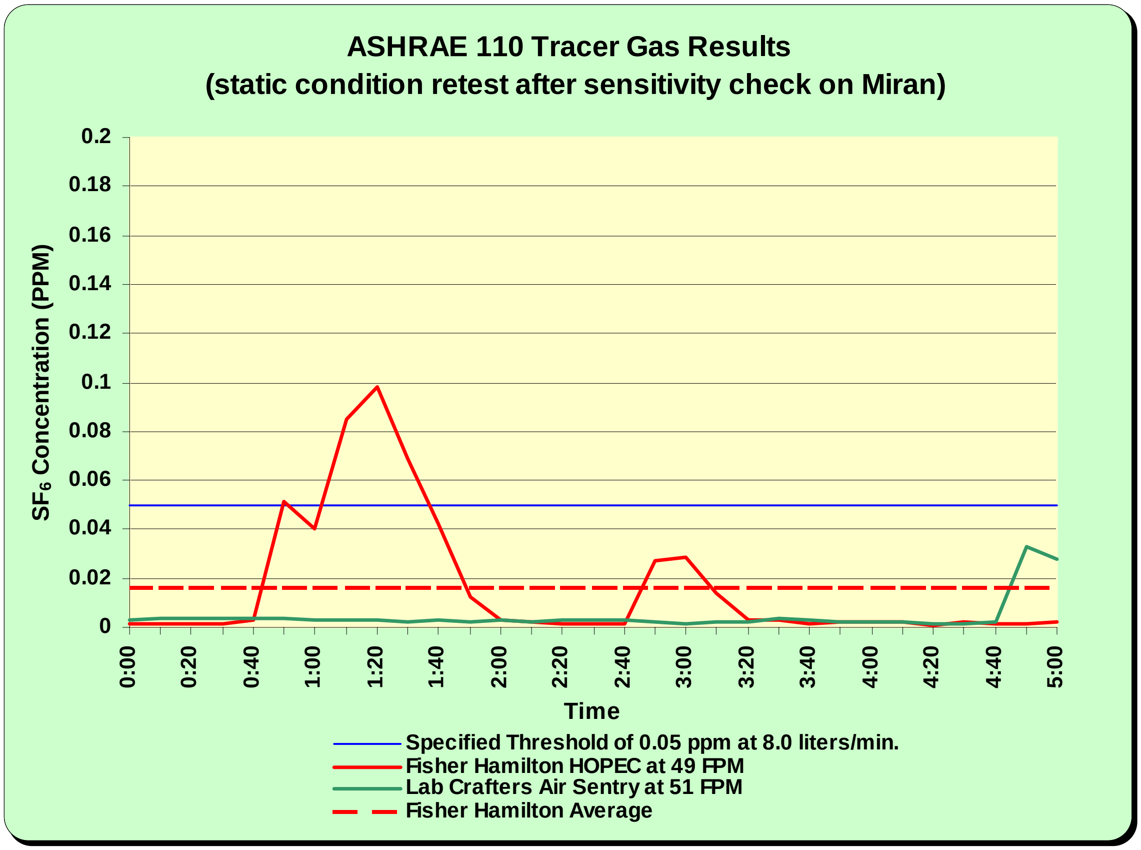

Figure 8

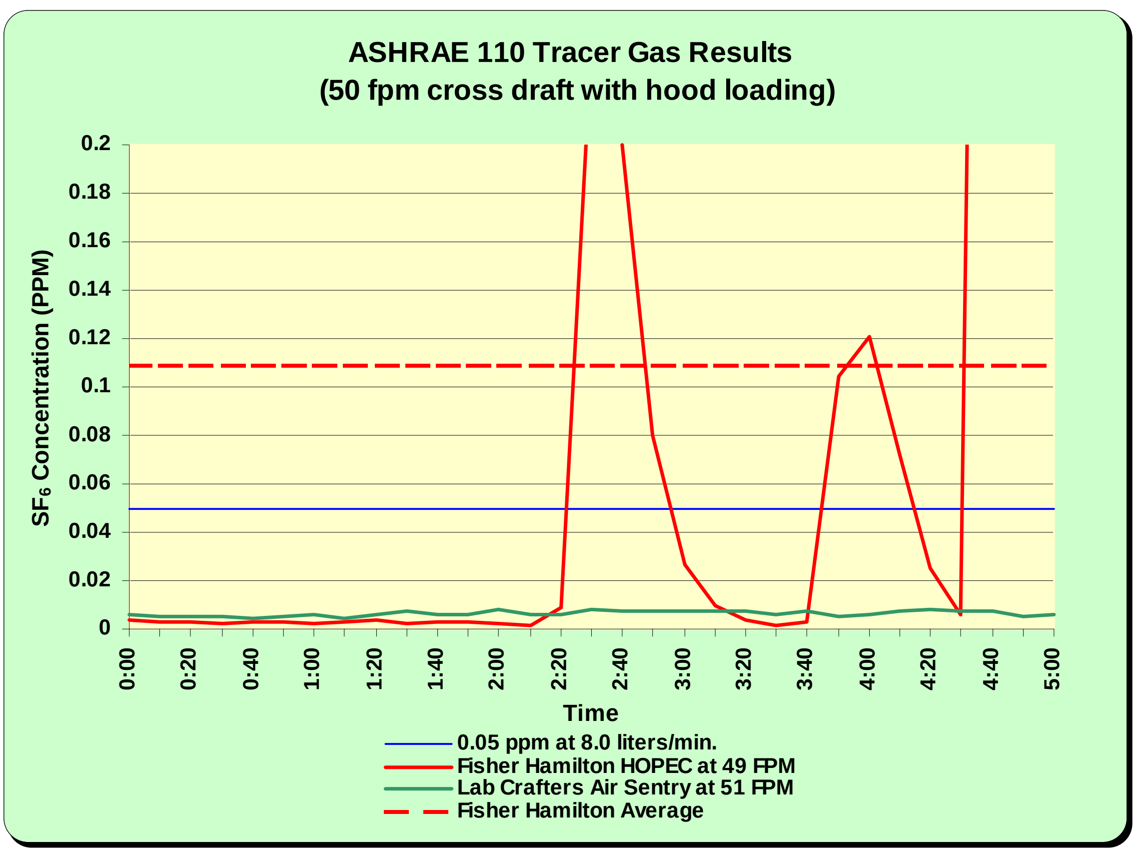

Figure 9

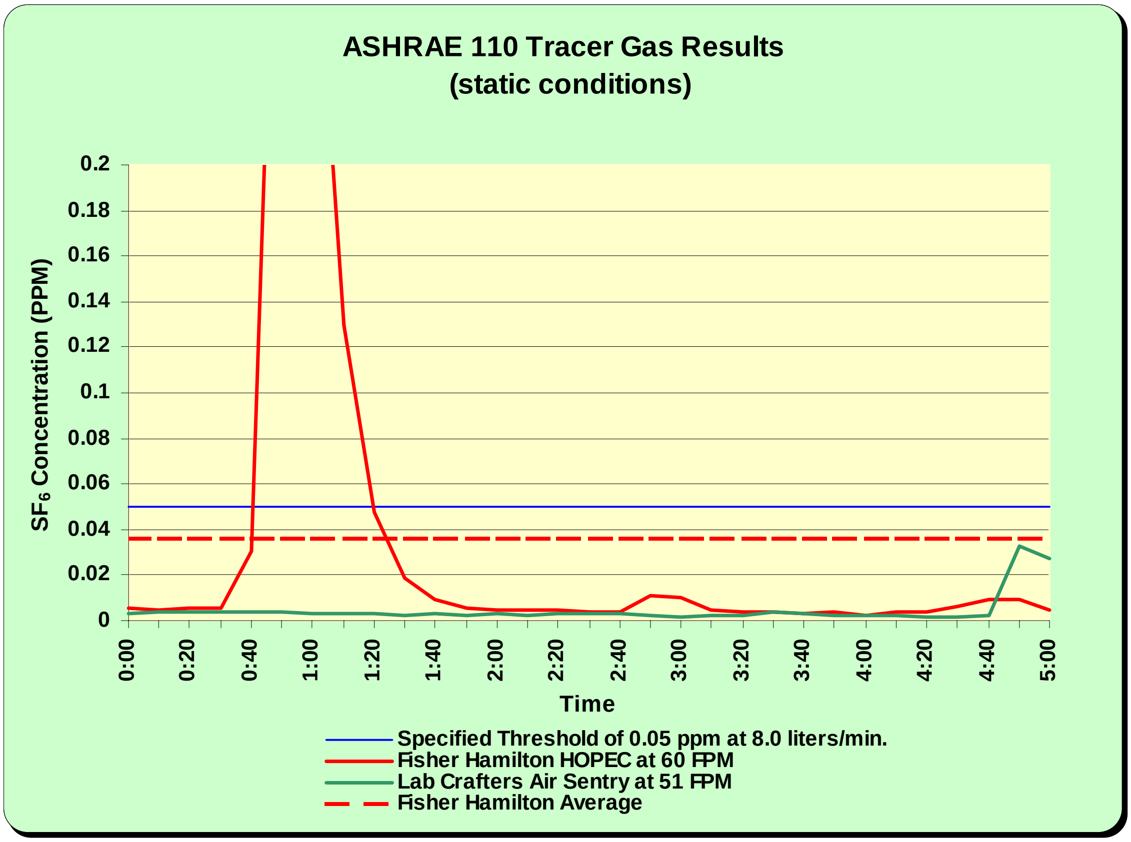

Figure 10

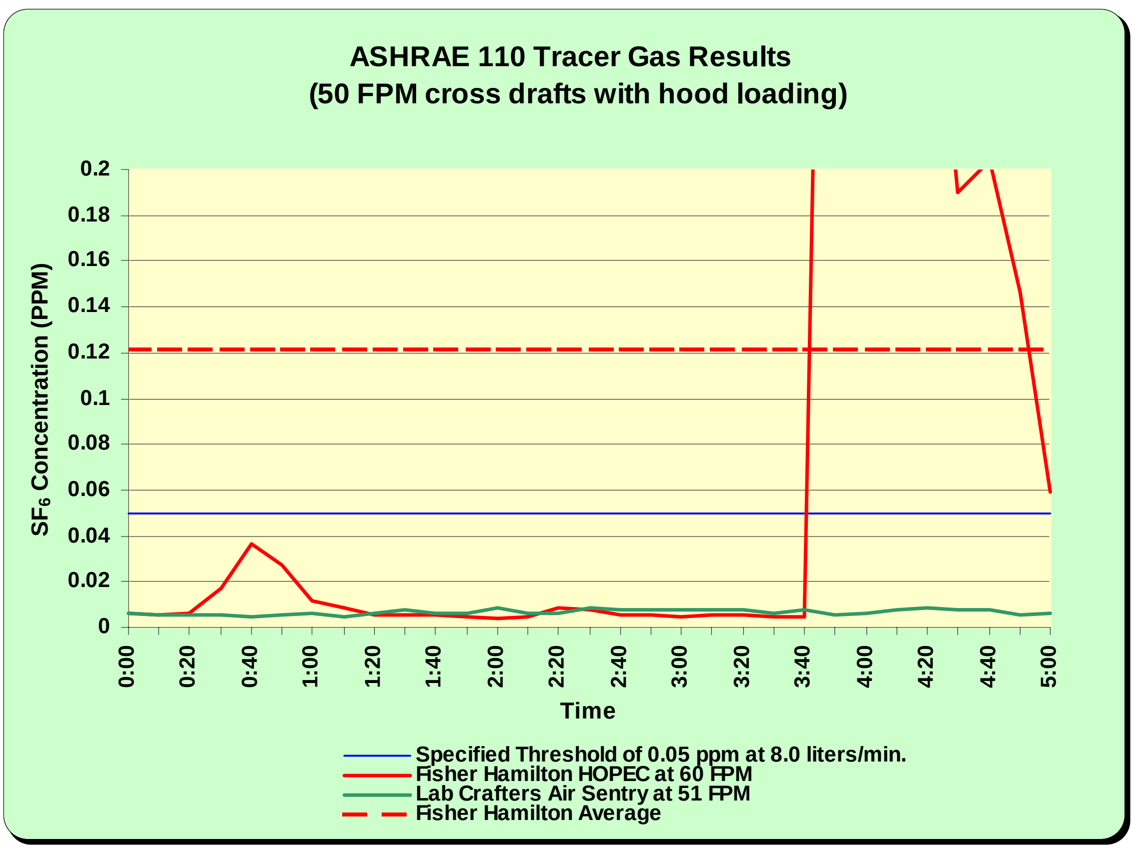

Figure 11

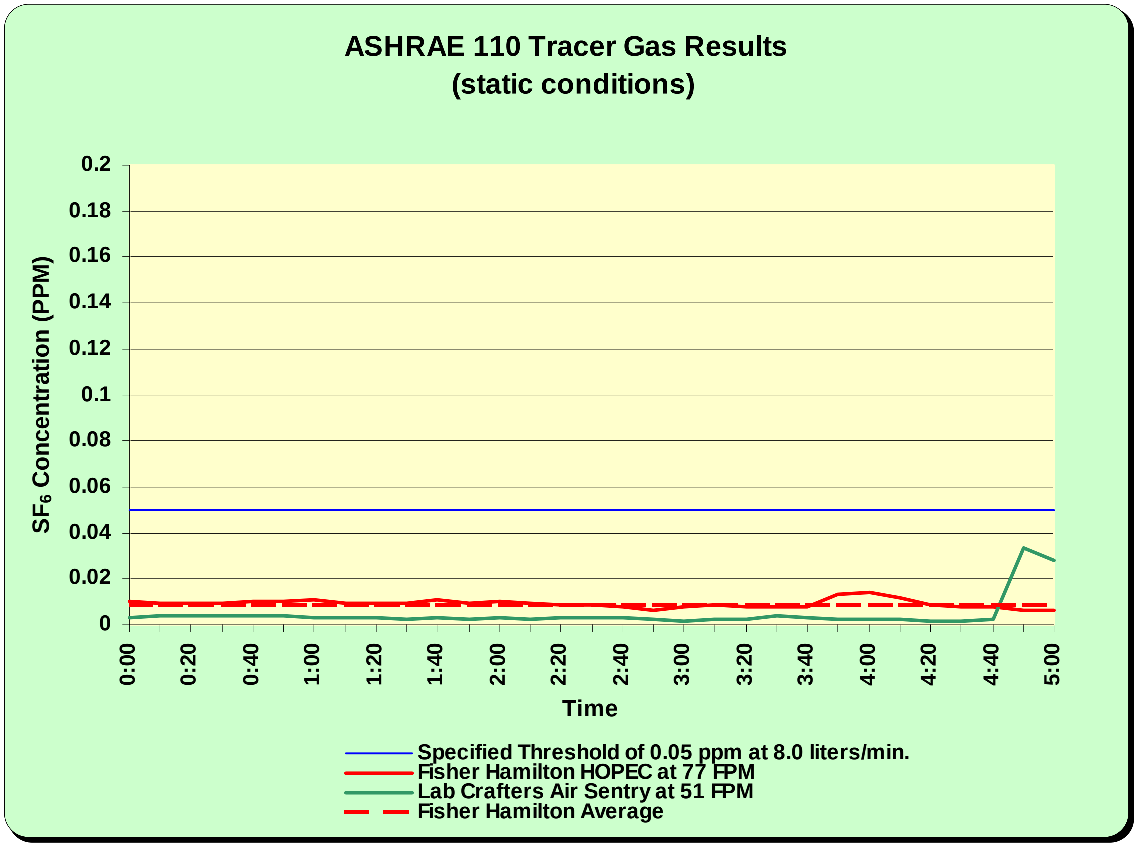

Figure 12

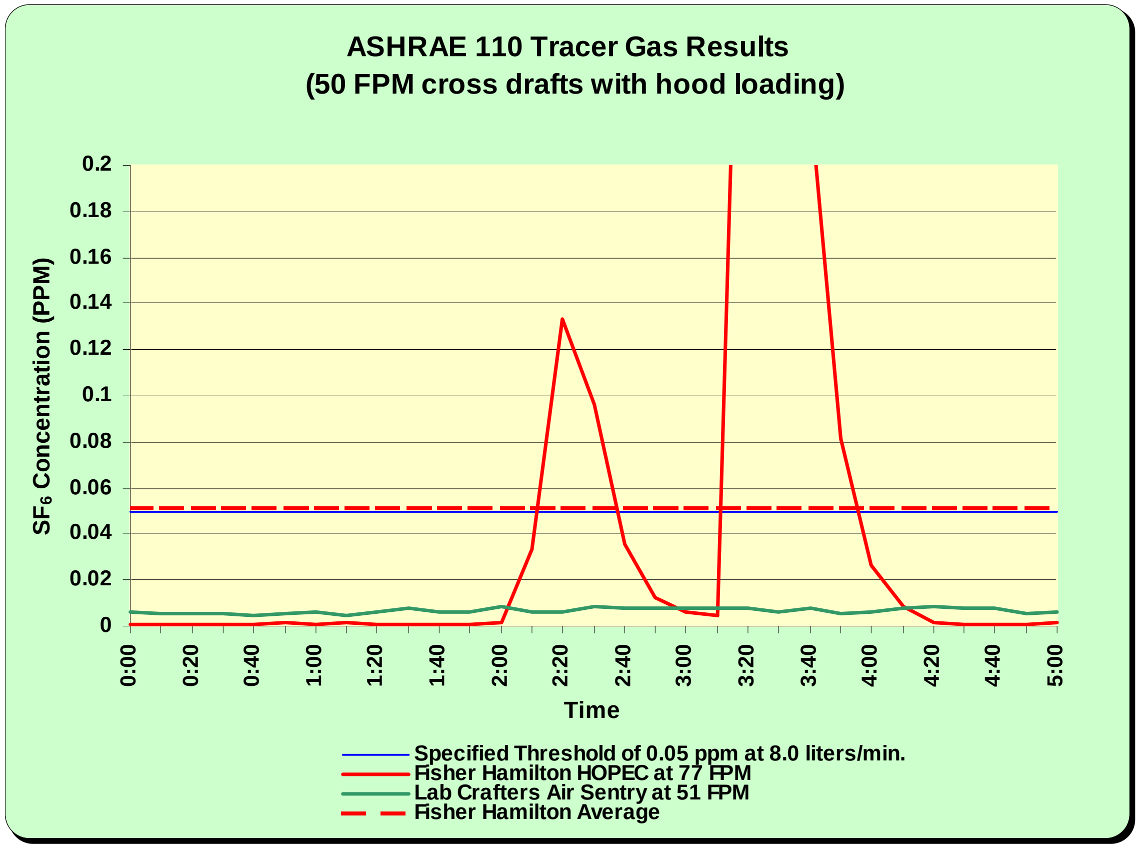

Figure 13

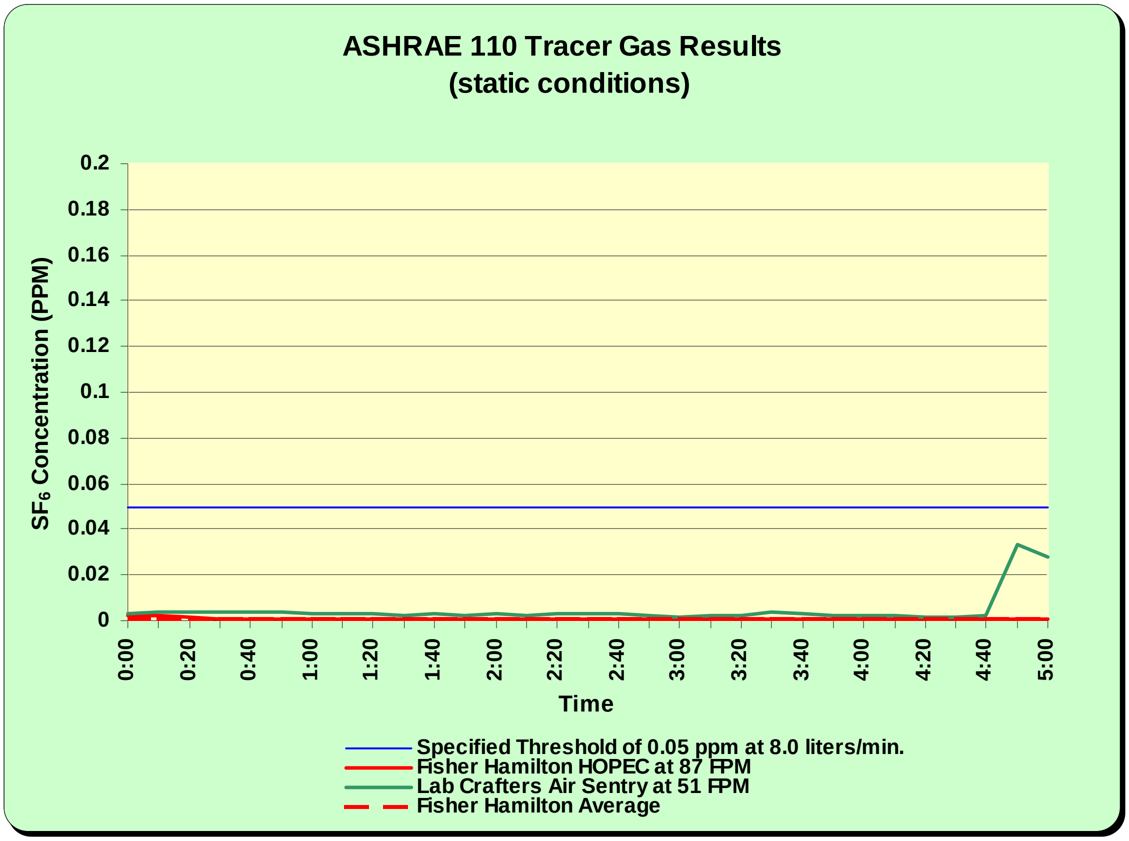

Figure 14

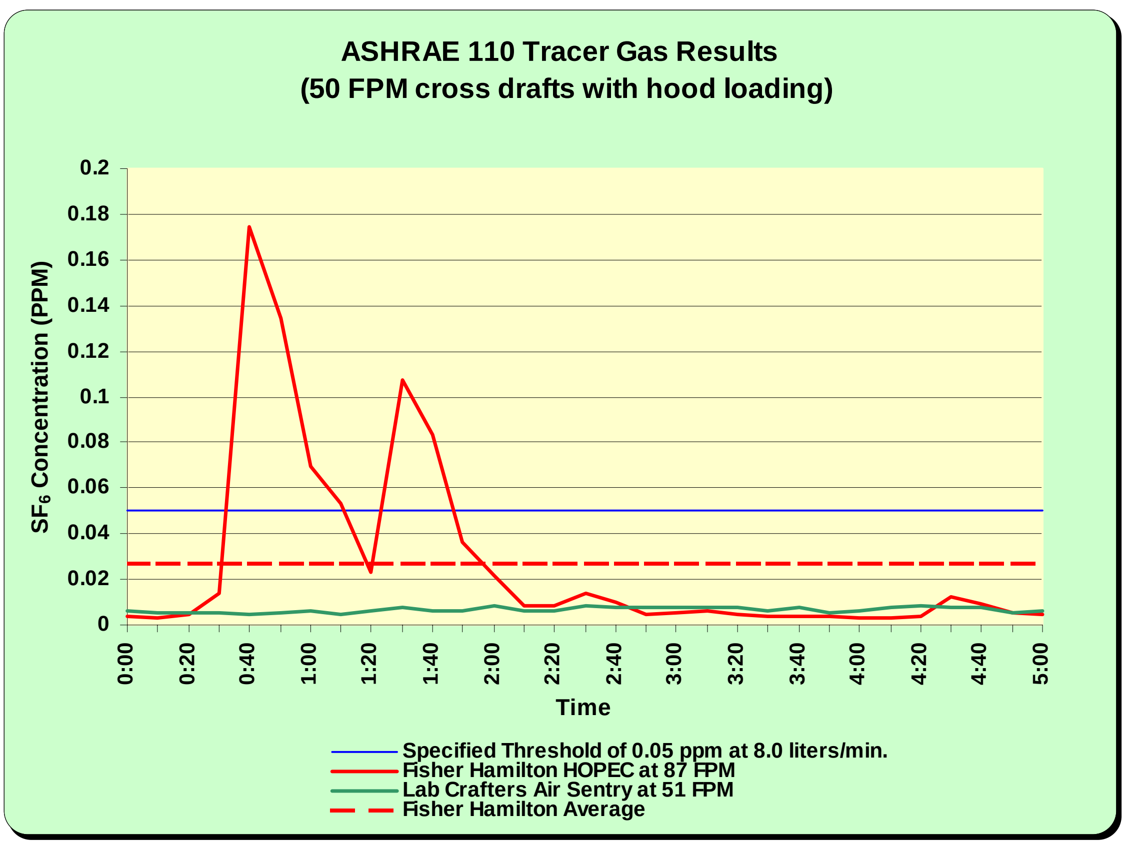

Figure 15

ENERGY CALCULATIONS

The energy calculations on pages 13 and 14 account for the ventilation energy and the fan motor energy for the supply and exhaust systems serving the North wing research laboratories.

The ventilation energy was calculated using the bin method. Bin temperature data and operating hours were obtained from Carrier E20-II engineering software. A copy of the printout data is included in appendix F.

The existing makeup air handling systems serving the North wing research labs have a run-around glycol heat recovery system that will continue to be used with the fume hood replacement and ventilation modifications regardless of which fume hood alternative is selected. For the energy calculations, an overall thermal efficiency of 45% was assumed for this heat recovery system. This includes an estimated energy efficiency loss for the pumping energy used by the run-around loop.

The supply air system serving the North wing research laboratories uses hot water reheat coils to control space temperatures in each individual room. To simplify the energy calculations and avoid the need for an hourly reheat load analysis, the energy for reheat was applied to makeup air supplied over 60,000 CFM. Because reheat loads vary with space cooling load conditions and are independent of fume hood exhaust, it can be assumed the reheat load will be identical for both fume hood alternatives up to the 60,000 CFM used by the Lab Crafters alternative. Therefore, the energy calculations for both alternatives are missing this unknown reheat load component. Knowing this component would simply add equal values of used energy to both alternatives. As a result, the total energy costs are relative and not total actual costs.

The energy rates used in the calculations are historical averages from UW Milwaukee's past records. This information is recorded by the university and is kept on file at the Division of Facilities Development. The ventilation heating and cooling rates are actual production costs for steam and chilled water furnished by the campus heating plant. Electrical rates for motor energy is based on historical records for this campus.

Fan motor energy calculations were based on the air volumes determined above and design system pressures for each fan system. Each alternative assumed 70% fan efficiencies and 90% motor efficiencies in determining brake horsepower.

The results of the energy calculations are broken down for steam, chilled water and electrical costs. These annual costs are used in the life cycle cost analysis spreadsheets on pages 16 and 17.

UW Milwaukee Chemistry Phase 2 Fume Hood Replacement
ENERGY CALCULATIONS

ALTERNATIVE 1 - Lab Crafters Fume Hoods Operating at 50 FPM

Outside Air Dry Bulb	Outside Air Wet Bulb	Outside Air Enthalpy	Heat Recovery Discharge Dry Bulb	Heat Recovery Discharge Wet Bulb	Cooling and Heating Coil Entering Air Enthalpy	AHU Discharge Air Dry Bulb	AHU Discharge Air Wet Bulb	AHU Discharge Air Enthalpy	AHU Coil Enthalpy Difference	AHU Coil Dry Bulb Temperature Difference	HV-9 Discharge Air Reheat Dry Bulb	Reheat Load for HV-9	Total Cooling Load (Btuh) (4.5xcfmxenthalpy diff.)	Total Heating Load (Btuh) (1.08xcfmxtemp diff.) + Reheat Load for HV-9	Bin Hours/Year	Cooling BTUs	Heating BTUs
90.0	71.6	35.7	81.9	69.3	33.7	52.0	51.0	21.0	12.7	-	70.0	0.0	3431700	0	27.1	92999070	0
85.0	68.9	33.4	79.2	67.0	31.9	52.0	51.0	21.0	10.8	-	70.0	0.0	2921400	0	67.1	196025940	0
80.0	66.2	31.2	76.4	65.0	30.3	52.0	51.0	21.0	9.3	-	70.0	0.0	2497500	0	182.7	456293250	0
75.0	63.5	29.1	73.7	62.9	28.7	52.0	51.0	21.0	7.7	-	70.0	0.0	2070900	0	374.5	775552050	0
70.0	60.8	27.2	~~70.9~~	-	-	52.0	51.0	21.0	6.2	-	70.0	0.0	1668600	0	563.7	940589820	0
65.0	58.1	25.4	~~68.2~~	-	-	52.0	51.0	21.0	4.4	-	70.0	0.0	1174500	0	690.0	810405000	0
60.0	55.4	23.7	~~65.4~~	-	-	52.0	51.0	21.0	2.6	-	70.0	0.0	707400	0	748.6	529559640	0
55.0	52.7	22.0	~~62.7~~	-	-	52.0	51.0	21.0	1.0	-	70.0	0.0	267300	0	746.4	199512720	0
50.0	-	`	~~59.9~~	-	-	52.0	-	-	-	2.0	70.0	0.0	-	129600	706.0	-	91497600
45.0	-	-	~~57.2~~	-	-	52.0	-	-	-	7.0	70.0	0.0	-	453600	669.6	-	303730560
40.0	-	-	~~54.4~~	-	-	52.0	-	-	-	12.0	70.0	0.0	-	777600	660.0	-	513216000
35.0	-	-	51.7	-	-	52.0	-	-	-	0.3	70.0	0.0	-	22680	662.0	-	15014160
30.0	-	-	48.9	-	-	52.0	-	-	-	3.1	70.0	0.0	-	200880	647.8	-	130130064
25.0	-	-	46.2	-	-	52.0	-	-	-	5.8	70.0	0.0	-	379080	593.1	-	224832348
20.0	-	-	43.4	-	-	52.0	-	-	-	8.6	70.0	0.0	-	557280	494.3	-	275463504
15.0	-	-	40.7	-	-	52.0	-	-	-	11.4	70.0	0.0	-	735480	370.7	-	272642436
10.0	-	-	37.9	-	-	52.0	-	-	-	14.1	70.0	0.0	-	913680	249.0	-	227506320
5.0	-	-	35.2	-	-	52.0	-	-	-	16.9	70.0	0.0	-	1091880	149.3	-	163017684
0.0	-	-	32.4	-	-	52.0	-	-	-	19.6	70.0	0.0	-	1270080	81.3	-	103257504
-5.0	-	-	29.7	-	-	52.0	-	-	-	22.4	70.0	0.0	-	1448280	41.2	-	59669136
-8.0	-	-	28.0	-	-	52.0	-	-	-	24.0	70.0	0.0	-	1555200	35.6	-	55365120

		Cooling	Heating
TOTAL BTUs/YR.		4000937490	2435342436
Ton-Hours/Yr.		333411	-
Lbs. Steam/Yr.		-	2442670
Average Chilled Water Production Cost ($/Ton-Hr)	$	0.023	-
Average Steam Production Cost ($/1000 lbs)		-	$ 3.85
Total Relative Chilled Water Production Cost/Yr.	**$**	**7,668**	**-**
Total Relative Steam Production Cost/Yr.		**-**	**$ 9,404**
Supply Fan Energy Cost/Yr.	$	16,421	
Exhaust Fan Energy Cost/Yr.	$	5,474	
Total Fan Electrical Energy Cost/Yr.	**$**	**21,895**	

Fan Energy Calculations
Based on 60,000 cfm Supply and Exhaust

	Supply	Exhaust
Total System Static Press.	6.0	2.0
Combined Fan/Motor Effic.	63%	63%
BHP	90	30
KW	67	22
Hours of Operation/Yr	8760	8760
KWH	6E+05	2E+05
Electric Rate ($/KWH)	0.028	0.028

UW Milwaukee Chemistry Phase 2 Fume Hood Replacement
ENERGY CALCULATIONS
ALTERNATIVE 2 - Fisher Hamilton Fume Hoods Operating at 90 FPM

Outside Air Dry Bulb	Outside Air Wet Bulb	Outside Air Enthalpy	Heat Recovery Discharge Dry Bulb	Heat Recovery Discharge Wet Bulb	Cooling and Heating Coil Entering Air Enthalpy	AHU Discharge Air Dry Bulb	AHU Discharge Air Wet Bulb	AHU Discharge Air Enthalpy	AHU Coil Enthalpy Difference	AHU Coil Dry Bulb Temperature Difference	HV-9 Discharge Air Reheat Dry Bulb	Reheat Load for HV-9	Total Cooling Load (Btuh) (4.5xcfmxenthalpy diff.)	Total Heating Load (Btuh) (1.08xcfmxtemp diff.) + Reheat Load for HV-9	Bin Hours/Year	Cooling BTUs	Heating BTUs
90.0	71.6	35.7	81.9	69.3	33.7	52.0	51.0	21.0	12.7	-	70.0	705672.0	5507879	705672	27.1	149263507	19123711
85.0	68.9	33.4	79.2	67.0	31.9	52.0	51.0	21.0	10.8	-	70.0	705672.0	4688847	705672	67.1	314621634	47350591
80.0	66.2	31.2	76.4	65.0	30.3	52.0	51.0	21.0	9.3	-	70.0	705672.0	4008488	705672	182.7	732350666	128926274
75.0	63.5	29.1	73.7	62.9	28.7	52.0	51.0	21.0	7.7	-	70.0	705672.0	3323795	705672	374.5	1244761040	264274164
70.0	60.8	27.2	~~70.9~~	-	-	52.0	51.0	21.0	6.2	-	70.0	705672.0	2678103	705672	563.7	1509646661	397787306
65.0	58.1	25.4	~~68.2~~	-	-	52.0	51.0	21.0	4.4	-	70.0	705672.0	1885073	705672	690.0	1300700025	486913680
60.0	55.4	23.7	~~65.4~~	-	-	52.0	51.0	21.0	2.6	-	70.0	705672.0	1135377	705672	748.6	849943222	528266059
55.0	52.7	22.0	~~62.7~~	-	-	52.0	51.0	21.0	1.0	-	70.0	705672.0	429016.5	705672	746.4	320217916	526713581
50.0	-	`	~~59.9~~	-	-	52.0	-	-	-	2.0	70.0	705672.0	-	913680	706.0	-	645058080
45.0	-	-	~~57.2~~	-	-	52.0	-	-	-	7.0	70.0	705672.0	-	1433700	669.6	-	960005520
40.0	-	-	~~54.4~~	-	-	52.0	-	-	-	12.0	70.0	705672.0	-	1953720	660.0	-	1289455200
35.0	-	-	51.7	-	-	52.0	-	-	-	0.3	70.0	705672.0	-	742073	662.0	-	491252591
30.0	-	-	48.9	-	-	52.0	-	-	-	3.1	70.0	705672.0	-	1028084	647.8	-	665993074
25.0	-	-	46.2	-	-	52.0	-	-	-	5.8	70.0	705672.0	-	1314095	593.1	-	779389982
20.0	-	-	43.4	-	-	52.0	-	-	-	8.6	70.0	705672.0	-	1600106	494.3	-	790932594
15.0	-	-	40.7	-	-	52.0	-	-	-	11.4	70.0	705672.0	-	1886117	370.7	-	699183720
10.0	-	-	37.9	-	-	52.0	-	-	-	14.1	70.0	705672.0	-	2172128	249.0	-	540859972
5.0	-	-	35.2	-	-	52.0	-	-	-	16.9	70.0	705672.0	-	2458139	149.3	-	367000212
0.0	-	-	32.4	-	-	52.0	-	-	-	19.6	70.0	705672.0	-	2744150	81.3	-	223099428
-5.0	-	-	29.7	-	-	52.0	-	-	-	22.4	70.0	705672.0	-	3030161	41.2	-	124842650
-8.0	-	-	28.0	-	-	52.0	-	-	-	24.0	70.0	705672.0	-	3201768	35.6	-	113982941

	Cooling	Heating
TOTAL BTUs/YR.	6421504671	10090411330
Ton-Hours/Yr.	535125	-
Lbs. Steam/Yr.	-	10120774
Average Chilled Water Production Cost ($/Ton-Hr)	$ 0.023	-
Average Steam Production Cost ($/1000 lbs)	-	$ 3.85
Total Relative Chilled Water Production Cost/Yr.	**$ 12,308**	**-**
Total Relative Steam Production Cost/Yr.	**-**	**$ 38,965**

Fan Energy Calculations
Based on 96,300 cfm Supply and Exhaust

	Supply	Exhaust
Total System Static Press.	6.0	5.0
Combined Fan/Motor Effic.	63%	63%
BHP	144	48
KW	107	36
Hours of Operation/Yr	8760	8760
KWH	9E+05	3E+05
Electric Rate ($/KWH)	0.028	0.028

Supply Fan Energy Cost/Yr.	$ 26,355
Exhaust Fan Energy Cost/Yr.	$ 8,785
Total Fan Electrical Energy Cost/Yr.	**$35,140**

PROJECT COSTS

The first costs used in the life cycle cost analysis are total project costs for each alternative, not just fume hood first costs. Total project costs were used to account for the affect each fume hood alternative has on the building ventilation systems.

The bid documents based on the Lab Crafters fume hood design eliminates a large heating and ventilating unit (HV-9) which is one of the two existing air handling systems in the eighth floor serving the North wing research labs. The second air handling unit is an air conditioning unit that will be used to heat and cool the North wing as well as meet the low-flow fume hood makeup air requirements.

The Fisher Hamilton fume hood option requires that both air handling systems remain to meet the make up air requirements for their hoods. The heating and ventilating air handling unit (HV-9) in the eighth floor mechanical room must be provided with chilled water utilities fed from the basement and must also have chilled water coils, reheat coils and controls installed in it. Each lab space served by the HV-9 supply system must have additional duct and diffuser work done in them for the proper distribution of room air. These additional HVAC and control costs are a part of this alternative's total project cost.

It should be noted that future costs for additional campus heating and cooling plant capacity could have been factored into the more energy consuming Fisher Hamilton fume hood alternative, but were not. Although these costs are real, it would be very difficult to place a value and time line on plant expansion needs as the result of this project alone.

On February 8, 2000, bids were received for bid package 2 of the North wing fume hood replacement project. This included separate and combined bids for general construction work, HVAC work, plumbing work, electrical work and asbestos abatement work. Since the bids were based on the design for low-flow fume hoods, these actual bid numbers are used for the first cost of the Lab Crafters alternative.

The Fisher Hamilton life cycle cost alternative uses the same actual bid numbers with adjustments for the additional HVAC and control costs that are required to make this option work. The adjustments made for the additional air handling system work were reviewed with the low bid HVAC contractor to insure that these estimates were reasonable.

LIFE CYCLE COST ANALYSIS

The total life cycle cost, calculated in the spreadsheets on pages 17 and 18, represent the present value investment the State of Wisconsin would make for each alternative. This investment includes project first cost, maintenance costs, replacement costs and yearly energy costs. This analysis accounts for inflation and the time value of money.

As mentioned previously, this analysis does not include future additional costs the State would incur as the result of campus heating and cooling plant expansion requirements imposed by the alternative with the higher heating and cooling loads.

Breakdowns for first costs of each life cycle cost alternative are given on page 16.

A replacement cost in year 20 was figured into the Lab Crafters alternative life cycle cost analysis. This represents replacement of the electric Belimo motor actuator on the VFV™ control system. Failure studies by Belimo are documented and for this application a 20 year life expectancy is realistic for the motors.

Maintenance costs were estimated for both alternatives. Fume hood maintenance was calculated for both alternatives as $50/year/hood. Air handling and fan system maintenance was estimated as $5,000 per year for the Lab Crafters fume hood alternative with one air handling system. The maintenance cost for the Fisher Hamilton fume hood alternative was estimated as $8,000 per year. The $3,000 increase was to account for the second air handling system required for this alternative. A sensitivity analysis was performed on the maintenance cost estimates to determine their impact on the total cycle cost. Results are noted in the conclusion of the report.

The life cycle energy costs are explained above and are shown in detail on pages 13 and 14.

UW MILWAUKEE CHEMISTRY PHASE 2 COST BREAKDOWN - ALTERNATIVE 1
LAB CRAFTERS FUME HOODS

Lab Crafters Fume Hoods	$	873,012.00		
General Construction	$	383,000.00		
Plumbing	$	78,990.00		
HVAC	$	228,400.00		
Electrical	$	182,500.00		
Asbestos Abatement	$	49,680.00		
DDC Control Work	$	65,000.00		
Testing and Balancing	$	32,200.00		
ASHRAE 110 Fume Hood Testing	$	27,600.00		
Construction Cost Subtotal			**$**	**1,920,382.00**
Construction Contingency			**$**	**57,611.46**
DFD Supervision	$	79,119.74		
A/E Fees	$	155,000.00		
Code Plan Review	$	5,000.00		
Fume Hood Performance Testing	$	15,000.00		
Design and Supervision Subtotal			**$**	**254,119.74**
TOTAL PROJECT COST			**$**	**2,232,113.20**

UW MILWAUKEE CHEMISTRY PHASE 2 COST BREAKDOWN - ALTERNATIVE 2
FISHER HAMILTON FUME HOODS

Fisher Hamilton Fume Hoods	$	406,580.17		
General Construction	$	383,000.00		
Plumbing	$	78,990.00		
HVAC	$	228,400.00		
* Additional HVAC Costs HV-9	$	96,500.00		
Electrical	$	182,500.00		
Asbestos Abatement	$	49,680.00		
DDC Control Work	$	65,000.00		
Additional DDC Costs for HV-9	$	25,000.00		
Testing and Balancing	$	32,200.00		
ASHRAE 110 Fume Hood Testing	$	27,600.00		
Construction Cost Subtotal			**$**	**1,575,450.17**
Construction Contingency			**$**	**47,263.51**
DFD Supervision	$	64,908.55		
A/E Fees	$	155,000.00		
Code Plan Review	$	5,000.00		
Fume Hood Performance Testing	$	15,000.00		
Design and Supervision Subtotal			**$**	**239,908.55**
TOTAL PROJECT COST			**$**	**1,862,622.22**

* Additional HVAC Costs to convert HV-9 to Air Conditioning System		
Extension of chilled water piping to penthouse for HV-9	$	29,000.00
Cooling coil and reheat in HV-9	$	64,000.00
HV-9 filtration system upgrade	$	10,000.00
HV-9 supply air distribution in labs	$	58,500.00
Credit for not doing work on AC-6	$	(65,000.00)
Total	$	96,500.00

T L C C WORKSHEET (revised 12/97) **State of Wisconsin, Division of Facilities Development**

PROJECT:	UW MILWAUKEE CHEMISTRY PHASE 2	BY:	**d. motl**
	FUME HOOD REPLACEMENT	DATE:	Feb-00

ECON FAC (%)		TIME FAC(YRs)		ALT NO:	1
GEN INFLA:	3	BASE PT:	0	SCOPE:	
DISC RATE:	4	STUDY PD:	25	Fume Hood Replacement	
BOND RATE:	5	BOND PD:	20	Air Sentry at 50 fpm	

INITIAL COSTS:		YEAR(n)	BPV FAC	PV FAC	COST	PV
1	Project Construction Cost	0	0.8422	1.0000	2,232,113	1,879,930
2		0	0.8422	1.0000	0	0
3		0	0.8422	1.0000	0	0
4		0	0.8422	1.0000	0	0
5		0	0.8422	1.0000	0	0
6		0	0.8422	1.0000	0	0
	TOTAL PV OF INITIAL COST (+) =				2,232,113	1,879,930
REPLACEMENTS COSTS:		YEAR(n)	BPV FAC	PV FAC	COST	PV
1	VFV Belimo Motor Replacement	20	0.8422	0.4564	25,300	9,725
2		0	0.8422	1.0000	0	0
3		0	0.8422	1.0000	0	0
	TOTAL PV OF REPLACEMENT COST (+) =				25,300	9,725
ANNUAL COSTS:		ESCAL(%)	SPV FAC	PV FAC	COST/YR1	PV
1	Fume Hood Maintenance	5	18.5523	1.0000	4,600	85,340
2.	Air Handling Unit Maintenance	5	18.5523	1.0000	5,000	92,761
3.		0	11.5287	1.0000	0	0
	TOTAL PV OF ANNUAL RECURRING COSTS (+/-) =				9,600	178,102
NON-ANNUAL COSTS:			YEAR(n)	PV FAC	COST	PV
1			10	0.6756	0	0
2			15	0.5553	0	0
3			20	0.4564	0	0
4			0	1.0000	0	0
	TOTAL PV OF NON-ANNUAL COSTS (+/-) =				0	0
ANNUAL ENERGY COSTS:		ESCAL(%)	SPV FAC	PV FAC	COST/YR1	PV
1	NATURAL GAS	2.8	14.8767	1.0000	0	0
2	LIGHT OIL	3.2	15.4654	1.0000	0	0
3	COAL	1.9	13.6627	1.0000	0	0
4	ELECTRICITY	2.3	14.1842	1.0000	21,895	310,564
5	STEAM	2.8	14.8767	1.0000	9,404	139,901
6	CHILLED WATER	2.3	14.1842	1.0000	7,668	108,765
7	OTHER	0	11.5287	1.0000	0	0
	TOTAL PV OF ENERGY COSTS (+/-) =				38,967	559,229

RESIDUAL VALUE:	YEAR INSTALLED	USEFUL LIFE	RPV FAC	PV FAC	COST	PV
1.	0	40	0.2107	1.0000	0	0
2.	25	25	1.0000	0.3751	0	0
3.	15	15	0.2705	0.5553	0	0
TOTAL PV OF RESIDUAL VALUE (-) =					0	0

TOTAL LIFE CYCLE COST = SUM OF PV'S = 2,626,986

TOTAL ANNUAL WORTH = T.L.C.C. X (A/P i, n) = 168,159

NOTES:
1. Initial Costs are based on actual bid prices for project.
2. Replacement cost of VFV motor are based on Belimio life cycle testing and calculations. See appendix
3. Mainenance costs are based on $50/yr/fume hood plus $5000/year/single hvac system serving the fume hoods.
4. Energy costs are based on ventilation load and fan motor energy. Reference energy calculations in this report.

T L C C WORKSHEET (revised 12/97) **State of Wisconsin, Division of Facilities Development**

PROJECT:	UW MILWAUKEE CHEMISTRY PHASE 2	BY:	**d. motl**
	FUME HOOD REPLACEMENT	DATE:	Feb-00

ECON FAC (%)		TIME FAC(YRs)		ALT NO:	2
GEN INFLA:	3	BASE PT:	0	SCOPE:	
DISC RATE:	4	STUDY PD:	25	Fume Hood Replacement	
BOND RATE:	5	BOND PD:	20	HOPEC Hood at 90 FPM	

INITIAL COSTS:		YEAR(n)	BPV FAC	PV FAC	COST	PV
1	Project Construction Cost	0	0.8422	1.0000	1,862,622	1,568,737
2		0	0.8422	1.0000	0	0
3		0	0.8422	1.0000	0	0
4		0	0.8422	1.0000	0	0
5		0	0.8422	1.0000	0	0
6		0	0.8422	1.0000	0	0
	TOTAL PV OF INITIAL COST (+) =				1,862,622	1,568,737

REPLACEMENTS COSTS:		YEAR(n)	BPV FAC	PV FAC	COST	PV
1		15	0.8422	0.5553	0	0
2		0	0.8422	1.0000	0	0
3		0	0.8422	1.0000	0	0
	TOTAL PV OF REPLACEMENT COST (+) =				0	0

ANNUAL COSTS:		ESCAL(%)	SPV FAC	PV FAC	COST/YR1	PV
1	Fume Hood Maintenance	5	18.5523	1.0000	4,600	85,340
2.	Air Handling Unit Maintenance	5	18.5523	1.0000	8,000	148,418
3.		0	11.5287	1.0000	0	0
	TOTAL PV OF ANNUAL RECURRING COSTS (+/-) =				12,600	233,758

NON-ANNUAL COSTS:		YEAR(n)	PV FAC	COST	PV
1		10	0.6756	0	0
2		15	0.5553	0	0
3		20	0.4564	0	0
4		0	1.0000	0	0
	TOTAL PV OF NON-ANNUAL COSTS (+/-) =			0	0

ANNUAL ENERGY COSTS:		ESCAL(%)	SPV FAC	PV FAC	COST/YR1	PV
1	NATURAL GAS	2.8	14.8767	1.0000	0	0
2	LIGHT OIL	3.2	15.4654	1.0000	0	0
3	COAL	1.9	13.6627	1.0000	0	0
4	ELECTRICITY	2.3	14.1842	1.0000	35,140	498,434
5	STEAM	2.8	14.8767	1.0000	38,965	579,672
6	CHILLED WATER	2.3	14.1842	1.0000	12,308	174,580
7	OTHER	0	11.5287	1.0000	0	0
	TOTAL PV OF ENERGY COSTS (+/-) =				86,413	1,252,685

RESIDUAL VALUE:	YEAR INSTALLED	USEFUL LIFE	RPV FAC	PV FAC	COST	PV
1.	0	40	0.2107	1.0000	0	0
2.	25	25	1.0000	0.3751	0	0
3.	15	15	0.2705	0.5553	0	0
TOTAL PV OF RESIDUAL VALUE (-) =					0	0

TOTAL LIFE CYCLE COST = SUM OF PV'S = 3,055,181

TOTAL ANNUAL WORTH = T.L.C.C. X (A/P i, n) = 195,568

NOTES:

1. Initial Costs are based on actual bid prices for project.
2. This alternative assumes no replacement costs for fume hood components.
3. Mainenance costs are based on $50/yr/fume hood plus $8000/year/two hvac system serving the fume hoods.
4. Energy costs are based on ventilation load and fan motor energy. Reference energy calculations in this report.

CONCLUSION

The wide disparity between the bid prices of Fisher Hamilton and Lab Crafters warranted the in depth analysis that this report presents.

After extensive on-site performance tests were conducted for both fume hoods, their point of safe operation was determined as defined by this project's threshold for containment, not-to-exceed 8.0AU0.05.

Every effort was made to offer each manufacturer the identical conditions for on-site testing. By the same token, each manufacturer's fume hood was placed under the same exact challenges based on the specifications of this project.

It must be understood that the design of this project never intended to allow as-used operation of the fume hoods with a full open sash at the 40 FPM face velocity test condition. This criteria was established for testing purposes only and its function was to push the limits of the hood. The results of the on-site testing accomplished this.

The most prudent and safe operating mode for the fume hoods on this project is with the combination sash fully lowered and the user working through or preferably around the horizontal sashes. This will result in higher face velocities and a higher degree of personal protection. However, it has been the Division's experience that fume hoods are rarely operated this way and sash closure is rarely enforced in laboratories. Because of this, it was necessary to test the fume hoods with a full open sash under stringent specification requirements to insure safe containment when users intentionally or unintentionally do not lower the fume hood sash.

The low-flow fume hood concept proposed for this project does not violate any current safety standards. Safe containment is the performance goal of every fume hood. Standards and rules such as OSHA 29 CFR Part 1910 and ANSI Z9.5 clearly indicate that they do not specify minimum face velocities for fume hoods. Face velocities established in the past by the fume hood industry may not necessarily be a direct indication of good containment. Tracer gas tests have proved this. As the OSHA rule states, "OSHA recognized that there was considerable debate over what optimum velocities should be in light of differences in hood design and methods of operation. Moreover, it was felt that requiring specific face velocities was not consistent with the performance orientation of the standard"[2]. Likewise, the ANSI Z9.5 Standard says, "The standard does not establish a standard for face velocity because of the importance of other parameters and the existence of an applicable performance test (ANSI/ASHRAE 110)"[3].

With the extremely stringent performance test conditions this project required for the low-flow fume hoods that were specified for this project, it will be difficult for anyone to argue that the design concept is contrary to prudent safety standards.

The Lab Crafters Air Sentry fume hood design met the specified containment criteria at 51 FPM and the resulting life cycle cost for this alternative is $2,626,986.

The Fisher Hamilton HOPEC fume hood design did not meet the specified containment criteria for all conditions. Based on assumptions that it has the capability to meet the containment criteria at 90 FPM for all conditions, the resulting life cycle cost for this alternative is $3,055,181.

The difference between the life cycle cost alternatives is $428,195, favoring the Lab Crafters Air Sentry fume hood design. This represents a present value savings to the State of $428,195 for selecting alternative 1 over alternative 2.

Because the maintenance costs were estimated, a sensitivity analysis was performed to determine the affect these had on the life cycle costs for the two alternatives. The analysis showed that by eliminating the added maintenance cost for the second air handling system in the Fisher Hamilton alternative and doubling the fume hood maintenance cost in the Lab Crafters alternative the difference between the life cycle costs was still significant at $287,198.

RECOMMENDATION

Recommendation of the preferred option for fume hood design must be done objectively according to the results of available testing data and economic analysis. The results of the testing and economic analysis between the Fisher Hamilton fume hood and the Lab Crafters fume hood led to a firm conclusion at the end of this report. Based on this conclusion, the Bureau of Engineering in the Division of Facilities Development recommends using the Lab Crafters Air Sentry fume hood for this project with a minimum design criteria of 51 FPM average full open sash face velocity.

REFERENCES

1. **University of Wisconsin Madison – Facilities Planning and Management. Video Tape of Testing Results for the Air Sentry Fume Hood at University of Illinois – Chicago. February 10, 1999. 15 Minutes.**

2. **Federal Register Vol. 55 No. 21, Department of Labor, Occupational Safety and Health Administration. 29 CFR Part 1910 Occupational Exposures to Hazardous Chemicals in Laboratories; Final Rule. January 1990. Page 3318.**

3. **American Industrial Hygiene Association. ANSI/AIHA Z9.5-1992 American National Standard for Laboratory Ventilation. 1993. Page 13.**

4. **State of Wisconsin, Division of Facilities Development. Design Phase Life Cycle Cost Analysis of Fume Hood Alternatives for Chemistry Building Fume Hood Replacement Project at UW Milwaukee Phase 2, DFD Project No. 98303. 45 pages.**

5. **State of Wisconsin, Division of Facilities Development. Project Specification Manual, Chemistry Building Fume Hood Replacement Phase 2 Bid Package 1 University of Wisconsin Milwaukee, DFD Project No. 98303. p. 11610-8.**

6. **American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. ANSI/ASHRAE 110 –1995 Method of Testing Performance of Laboratory Fume Hoods. 1995. 16 pages.**

7. **American Industrial Hygiene Association. ANSI/AIHA Z9.5-1992 American National Standard for Laboratory Ventilation. 1993. Page 3.**