PROCESS FOR CONFIRMING & ENSURING EFFECTIVE SYSTEM OPERATION:

ASHRAE 62.1-2013 COMPLIANCE: ADDENDUM K

FläktGroup SEMCO has developed comprehensive Laboratory Risk Assessment software which has been proven effective in analyzing laboratory exhaust airstreams to assist the EH&S professionals in completing their analyses to ensure a safe and effective installation of total energy wheels.

This software can been used to document compliance with ASHRAE Standard 62.1 as well as the IMC Hazardous Exhaust exemption. More importantly, the analysis utilizes project specific design data such as exhaust air quantities, chemical inventory lists and independent total energy recovery wheel carry-over data to assess any potential health risk or nuisance odor associated with the air supplied from the energy recovery system to the occupied space.

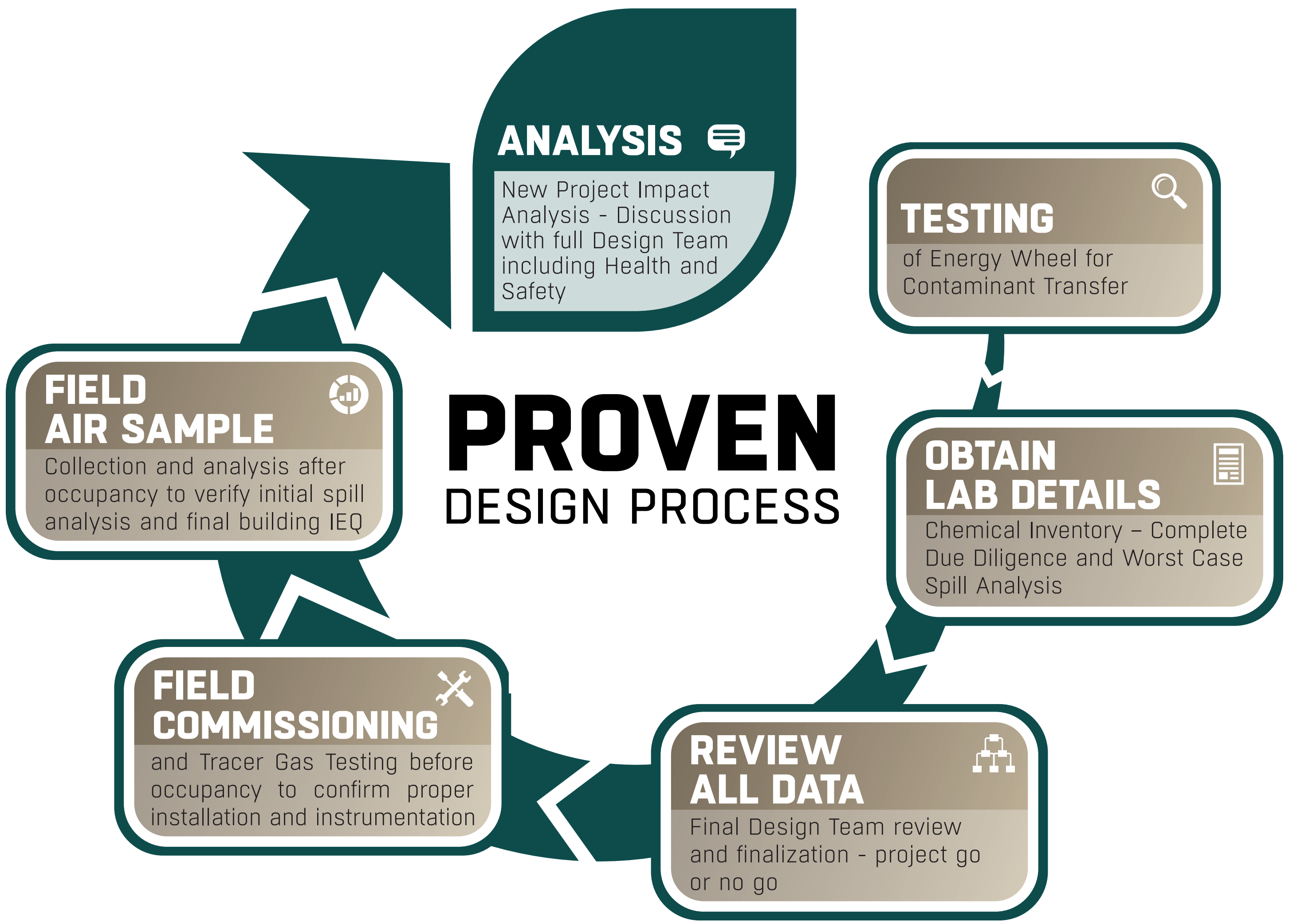


FIGURE 1. Key Steps to Ensure a Successful Project.

A proven "due-diligence through commissioning process" built around the FläktGroup SEMCO Risk Analysis software has been used for hundreds of successful FläktGroup SEMCO True 3Å total energy wheel installations in laboratories globally.

A review of the proven design process summarized as **FIGURE 1** shows that there are three essential technical evaluations that must be completed to ensure code compliance and document effective operation with regard to laboratory health and safety:

- Laboratory Risk Analysis modeling and evaluation
- Independent total energy wheel contaminant carry-over data documentation
- Field commissioning of recovery system with tracer gas and TVOCs

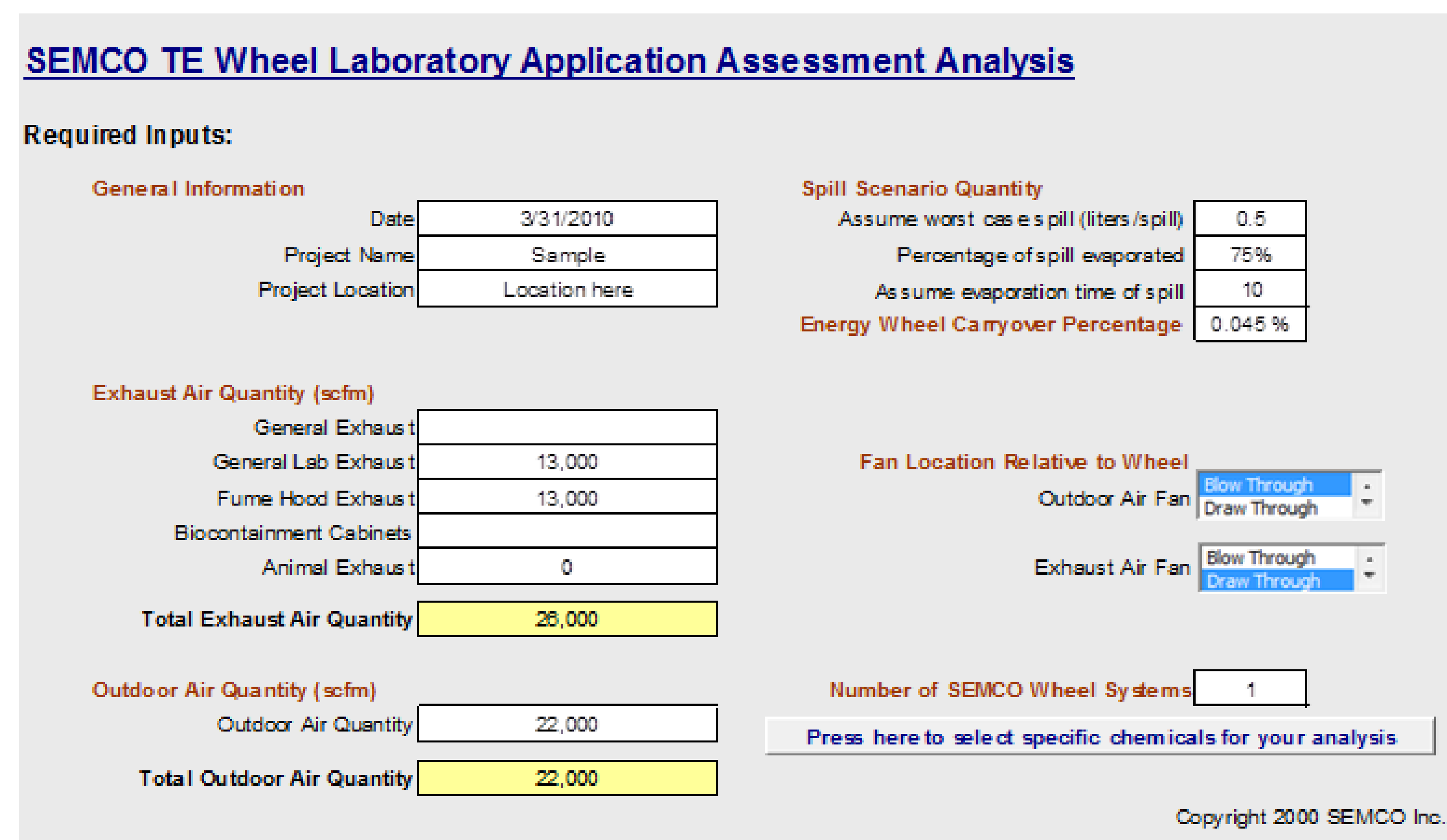
FläktGroup SEMCO Lab Assessment Risk Analysis

The FläktGroup SEMCO Laboratory Risk Analysis relies on the CDC/NIOSH database of chemicals to provide threshold limit values for the individual exhaust air contaminants. The analysis is designed to be conservative in that it provides a flag if under a "worst case" spill scenario the projected supply air stream contaminant concentration delivered to the laboratory space exceeds the threshold limit value (TLV) for the individual chemical. The threshold limit value is the concentration at which workers can be exposed for 8 hours per day and 5 days per week without any anticipated health risk.

Likewise, the American Industrial Hygiene Association's database of odor thresholds for chemicals, where available, is used to compare the supply air chemical concentration under the "worst case" spill scenario against 50% of the established odor detection limit. If 50% of the odor detection level is reached, a flag is shown to indicate a possible nuisance odor situation. Although there may be no health risk, certain chemicals that have very low odor detection levels are checked to see if a spill might result in odors being temporarily detected throughout the building during a "worst case" spill situation or at times of heavy use.

In this analysis, the design exhaust and outdoor airflows are used along with a specified contaminant spill quantity and the associated chemical properties to approximate the resultant exhaust air challenge concentration to the recovery wheel system. Both laboratory and field data are used to determine the FläktGroup SEMCO True 3Å product's ability to limit contaminant carryover, and this limit is used within the analysis to determine the supply air contaminant concentration of each chemical used based on the "worst case" spill quantity.

FIGURE 2: Sample of input sheet for FläktGroup SEMCO Laboratory Risk Analysis



Assumptions and Inputs:

The first page of the analysis (**FIGURE 2**) is the input summary sheet, showing the exhaust and outdoor airflows involved. It breaks down the combined exhaust airstream to reflect whether it is general exhaust, general lab exhaust or fume hood exhaust. This sheet specifies the spill quantity used, evaporation time along with other important parameters needed to complete the analysis. The most important being the total energy recovery wheel carry-over data.

The output pages (**FIGURE 3**) include a summary listing of all assumptions made followed by listing of all chemicals selected for analysis (reflecting the chemical inventory sheet provided). For each chemical listed there is a corresponding threshold limit value (TLV) reported, an estimated supply air concentration delivered to the space along with a calculation of the percentage of allowable TLV limit reached. If the estimated supply air concentration reaches the allowable threshold limit value, even under this "worse case spill scenario" a flag is reported.

The output sheet also shows the odor threshold value for the chemicals selected where available. A comparison is made between the estimated supply air contaminant concentration under the "worse case spill scenario" and the odor threshold data. If the supply air concentration reaches 50% of the odor threshold value a flag is reported. In this way, chemicals that may have essentially no health risk yet might cause and nuisance odor due to purge inefficiency during a spill can be evaluated for isolation off the system if appropriate.

The "worst case spill scenario" generally assumes a spill of the largest possible quantity used by a researcher (generally in the range of 500 ml) that is not contained and fully evaporates within 5 minutes into the combined exhaust system.

FIGURE 3. Sample of output sheet for FläktGroup SEMCO Laboratory Risk Analysis

SEMCO Recovery Wheel Carry-over Analysis: "Spill Scenario" **Project: Sample**

General Exhaust	0 CFM	Assume worst case spill amount	0.5 liters
General Lab Exhaust	13,000 CFM	Assume evaporation time of spill	10 minutes
Fume Hood Exhaust	13,000 CFM	Molecular weight (average)	92 based on toluene
Biocontainment Cabinets	0 CFM	Calculated Exhaust Spill Concentration	18.9 PPM
Animal Exhaust	0 CFM		
Total exhaust airflow	26,000 CFM	Wheel maximum carry-over %	0.045 %
Total supply airflow	22,000 CFM	Calculated "worse case" supply PPM	0.0085 PPM

* denotes inputs that can be changed by the user within recommended range

Project Assessment Tool for SEMCO Total Energy Wheel Systems: TLV Values from CDC/NIOSH Database

Chemical Compound	TLV NIOSH[1] (PPM)	"Worst Case" Spill Scenario[3]		Odor Threshold[4] (PPM) (if available)	Flag
		Supply Air Concentration[2] (PPM)	% of TLV		
ACETALDEHYDE	100	0.017748	0.02%	0.067000	
ACETIC ACID	10	0.013023	0.13%	0.074000	
ACETONE	750	0.013495	0.00%	0.400000	
BENZYL ALCOHOL	NA	0.007247			
CYCLOHEXANE	300	0.009318	0.00%	0.520000	
ETHYL ACETATE	400	0.008894	0.00%	0.170000	
ETHYLENE GLYCOL	NA	0.012624			
n - HEXANE	50	0.009101	0.02%	65.000000	
2 - HEXANOL	NA	0.007673			
1 - PROPANOL	200	0.013045	0.01%		

Confirming Addendum K Compliance using the FläktGroup SEMCO Laboratory Risk Analysis Software

The FläktGroup SEMCO Laboratory Risk Analysis software provides a comprehensive way to confirm compliance with ASHRAE 62 Addendum K. By comparing the exhaust air contaminant concentrations entering the energy recovery system during normal use against the appropriate "hazardous determination" metric chosen by the EH&S team; it can be determined if the exhausted air contamination concentrations are high enough to be considered harmful. If not, the exhausted airstream entering the total energy recovery device can be correctly classified as ASHRAE 62 Class 3 air and a suitable total energy recovery device can be used with laboratory exhaust in compliance with ASHRAE 62.

For this "compliance analysis", only chemicals having a NFPA 704 rated class of 3 or 4 would have to be evaluated since these chemicals would reach a "harmful or hazardous" level at much lower concentrations then other chemicals used within the facility. Most university laboratories, for example, will have very few if any NFPA 704 class 4 chemicals on hand. If so, these chemicals would be used in very low quantities and would be analyzed based on the quantities allocated from the storage room at any one time.

Using the conservative definition of hazardous exhaust employed by the IMC, the analysis would look to confirm that the exhaust air concentration for each chemical, during normal use, is below 1 percent of the median lethal concentration established. For NFPA Class 3 chemicals, the median lethal concentration range is between 1,000 to 3,000 parts per million. The FläktGroup SEMCO Laboratory Risk Analysis Software would therefore be used to show that the exhaust air concentration to the recovery system under normal use conditions would be less than between 10 and 30 parts per million for any class 3 chemicals used.

Alternate Approach: Developed in Conjunction with Health and Safety Professionals

An alternate approach to reach Addendum K compliance is to utilize the FläktGroup SEMCO Lab Assessment Risk Analysis software to evaluate all chemicals of concern that will be used within a laboratory facility, simulating a worst case spill scenario as previously described (see pages 3 and 4). This analysis confirms whether the air quality delivered from the energy recovery system to the laboratory space is maintained well below the threshold limit values established for the exhausted chemicals, even during this worst case spill condition.

The majority of Health and Safety professionals view this alternate approach to be more relevant to their concerns and consider a system delivering laboratory supply air that is maintained well below the threshold limit value of all exhausted contaminants to be a safe and acceptable design. In fact, the methodology used for this "worse case spill analysis" was developed in conjunction with leading Health and Safety professionals and employed with success over the past 20 years.

Comprehensive Desiccant Contaminant Carry-over Testing of the Total Energy Wheel is Essential for AHSRAE 62 Compliance and Any Safety Analysis

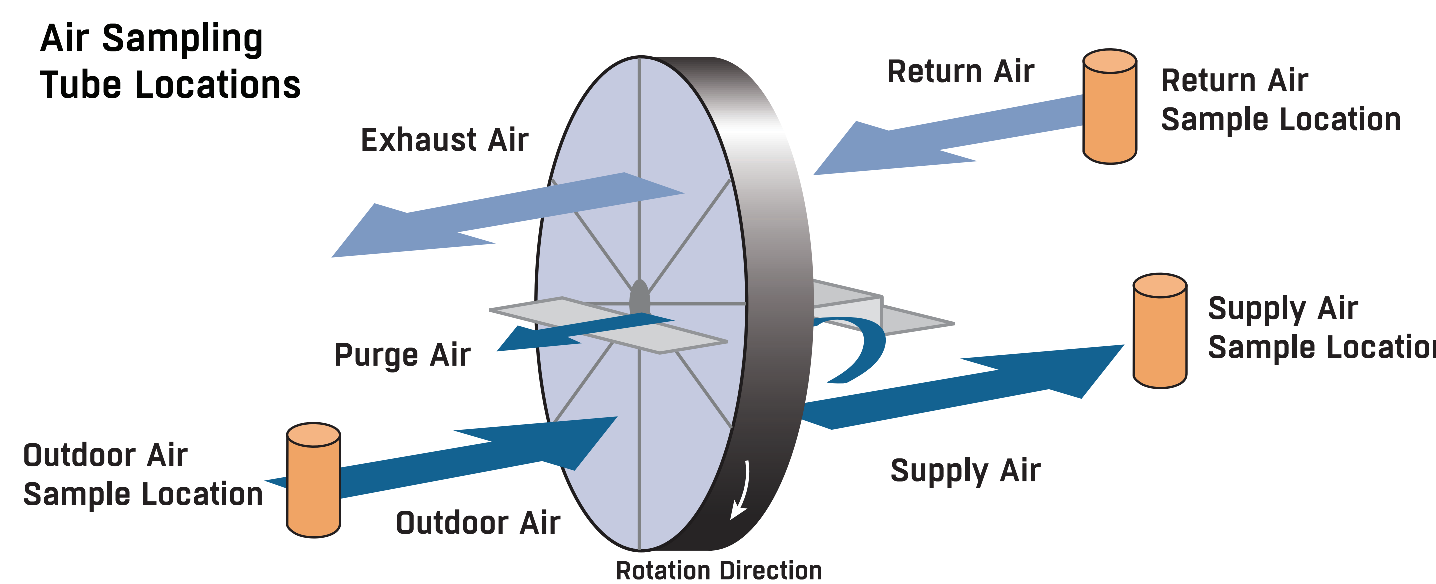
Both the analysis required to confirm ASHRAE 62 Addendum K and IMC Hazardous Exhaust compliance directly rely on independent testing of the total energy wheel confirming the ability to limit the carry-over of contaminants of concern. Without comprehensive, independent contaminant testing the risk assessment required to satisfy Health and Safety professionals is impossible to perform. Research has shown that the difference in contaminant transfer between commercially available total energy devices ranges from non-detectable to over 30%. (Please see FläktGroup SEMCO white paper entitled "Not All 3A Recovery Wheels Limit Contaminant Transfer").

ASHRAE Standard 84 – Method of Testing Air to Air Heat Exchangers

The ASHRAE Standard 84 test procedure for air to air energy recovery devices provides the methodology for this testing. Is states that "where specific contaminants are of concern for cross contamination, the methodology presented in Equation 6 may be used to assess the transfer of the specific contaminant." Equation 6 defines how the percentage of contaminant transfer is defined based on sulfur hexafluoride (SF6) tracer gas testing. SF6 is used to quantify seal leakage and purge inefficiency specifically because it will not be transferred by any desiccant coating due to its unique chemical properties.

The standard allows for any chemical contaminant of concern to be used to challenge the total energy recovery device and provides the methodology for measuring and defining the amount of transfer or "carryover" that exists. Samples are collected within the different chambers of the heat exchanger, as shown below, to quantify what percentage of the return air challenge concentration is transferred over to the supply airstream.

FIGURE 4. Sampling Location for ASHRAE 84 Contaminant Carry-over Testing



Defining Contaminant of Concern for Testing

To allow for the analyses required to complete a credible laboratory spill analysis, multiple families of strategic chemicals must be used to challenge the total energy devices to properly represent the 5000 plus chemicals that might be encountered. In addition, precision instrumentation capable of detecting these challenge chemicals at very low concentrations must be employed. Finally, qualified independent research professionals must evaluate the data and confirm the carry-over potential for any given technology.

Representative chemicals were strategically selected by the Georgia Tech Research Institute to represent the groups of contaminants typically encountered within indoor air including laboratory applications. This list has proven highly effective for analyses completed for laboratory projects constructed over the past 20 years.

- Acetaldehyde – small aldehyde, water soluble and polar
- Acetic acid – small acid, water soluble and polar
- Methanol – smallest alcohol, water soluble very polar
- Isopropyl alcohol – small alcohol, water soluble and polar
- Methyl isobutyl ketone – small ketone, somewhat water soluble and polar
- Xylene – Aromatic hydrocarbon, non-polar and water immiscible
- Carbon dioxide – Small oxide, non-polar and water soluble
- Propane – Alkane (straight chain hydrocarbon), non-polar, water immiscible
- Sulfur Hexafloride – Inert tracer gas, very large, non-polar and not water soluble

Recommended Project Field Commissioning:

As shown within **FIGURE 1**, proper field commissioning before and after building occupancy to verify the output provided by the initial spill analysis is recommended. This commissioning should be completed in two distinct phases; SF6 testing before occupancy and TVOC testing following occupancy and during normal laboratory activity.

Once all construction and final air balancing is completed, but before occupancy, commissioning with SF6 tracer gas as per the ASHRAE Standard 84 should be completed for each recovery system. This testing is easily done. Due to the unique properties of the tracer gas, very accurate documentation of any air leakage within the air handling system, the energy recovery device seals and any purge inefficiency can be made. Any leakage of air associated with all of these factors can be limited to below .045% of the exhaust air challenge concentration for a well-designed system.

As importantly, this test also provides an accurate quantification of any re-entrainment that exists between the outlet of the exhaust air fan/stack and the fresh air inlet louver. Commissioning has shown that this re-entrainment is typically one order of magnitude greater than that associated with a properly designed total energy recovery wheel system.

TVOC Sampling and Commissioning

Once the laboratory is occupied and in full use, total volatile organic compound (TVOC) commissioning can be completed to accurately quantify the quality of air delivered to the laboratory space and to identify the specific contaminants that are in the highest concentration within the air exhausted from the laboratory facility. This testing provides the following important information:

- Identification of specific exhaust air chemicals and concentrations (top ten)
- Validation of initial "spill analysis" risk assessment
- Quantifies overall supply air quality (TVOC)
- Documents any contaminant transfer by the total energy recovery device
- Allows indoor air quality comparisons with other building types

Air samples are collected over an extended period from the laboratory exhaust airstream, outdoor airstream and supply airstream after the total energy wheel, then analyzed using a high precision Mass Spectrometer/Gas Chromatograph.

Air samples are collected onto Radiello TVOC sampling tubes. These tubes have a porous mesh outer casing containing a mix of adsorbent materials which effectively capture and hold airborne chemical contaminants. An effective access to the adsorbent tube's inner core results from the long, narrow tube geometry. Photo to the right shows the sample tube without the protective sampling enclosure.

Figure 5 shows a photo of a precision thermal desorption gas chromatograph and mass spectrometer (TD/GC/MS), such as that used by the Georgia Tech Research Institute, suitable for measurement of the low contaminant concentrations associated with indoor air quality research. The sampling tubes are first desorbed into this instrument then analysis of the results needs to be manually completed to identify individual chemicals and their concentrations.

FIGURE 5. Gas chromatograph/mass spectrometer used to analyze TVOC samples

Evaluating the TVOC Data and Comparisons with Other Building Types:

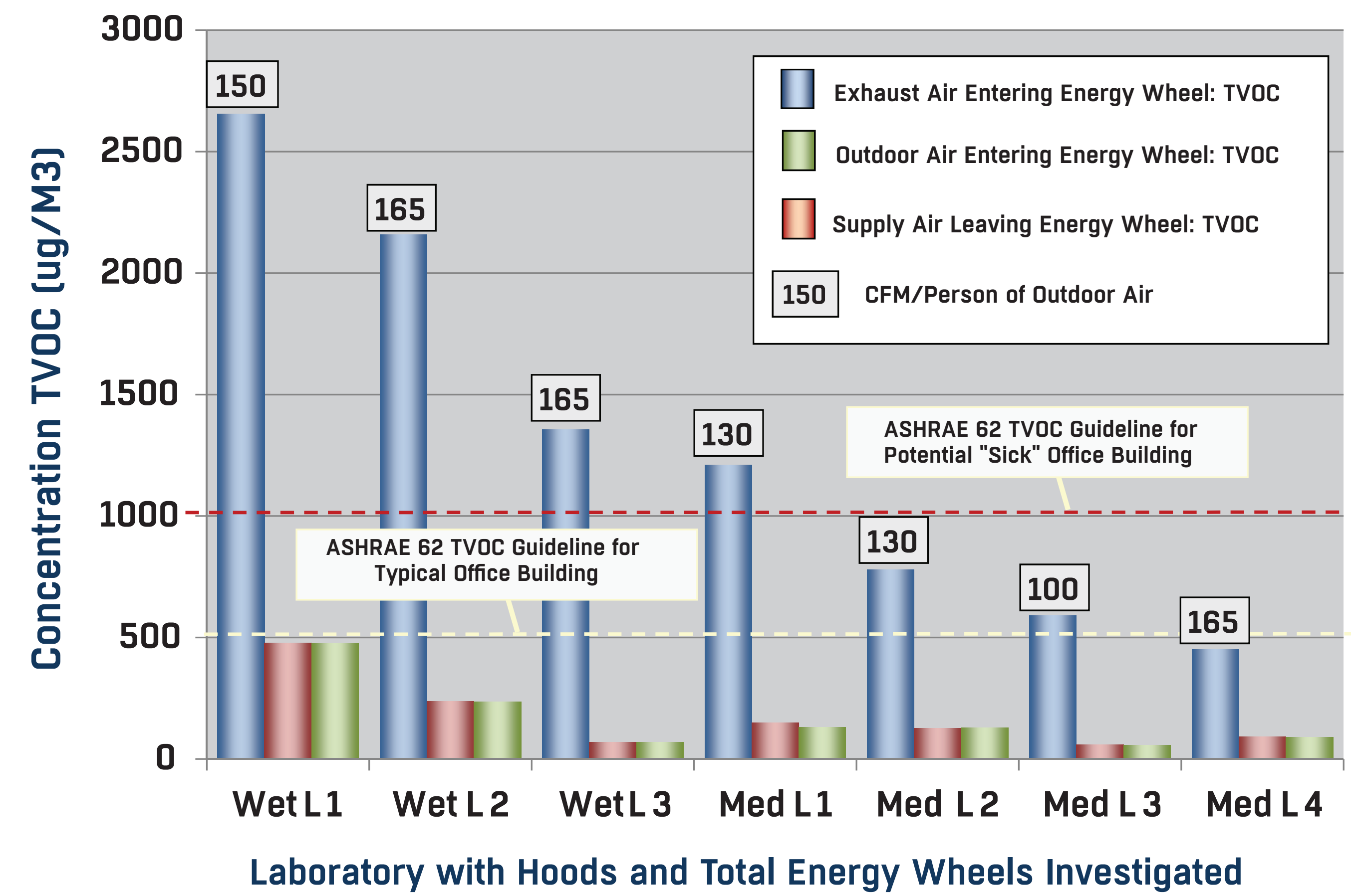
A properly functioning total energy recovery laboratory installation is confirmed when TVOC data confirms no detectible transfer of contaminants between the exhaust air stream leaving the hoods/space and the supply air stream leaving the recovery system, once corrected for any re-entrainment between the exhaust air fan outlet and indoor air intake.

More importantly, Health and Safety is confirmed when the laboratory space is shown to have contaminant concentrations well below their threshold limit values (TLV). Due to the very high air exchange rates required, experience has shown that the air quality within most laboratory spaces equals that of the air supplied from the energy recovery system. It is counter-intuitive, but research has confirmed that the air quality within properly designed and commissioned laboratory buildings is typically cleaner than the air in more conventional commercial buildings.

FläktGroup SEMCO was asked to present at the 2015 ASHRAE Summer Conference Seminar entitled "Apply ANSI/ASHRAE Addendum K for Laboratory Hoods". In this presentation, air quality data collected from seven laboratory facilities served by the FläktGroup SEMCO TE True 3Å technology. The resultant air quality data is summarized by Figure 6.

As shown, the supply/laboratory air quality is exceptional when contaminant carry-over is eliminated within the energy wheel. In every case, the supply air quality exceeded that recommended by ASHRAE for typical office buildings. In five out of seven cases, the quality of the exhaust air from the laboratory hoods was similar to that found in poorly ventilated office buildings. In all cases, the exhaust air contaminant concentrations we well below "harmful" levels, can would clearly be classified as ASHRAE Class 3 air.

FIGURE 6. TVOC Data from Seven Laboratories with Hood Exhaust and FläktGroup SEMCO True 3Å Technology



FläktGroup SEMCO

SPECIALIZED HEALTHY AIR SOLUTIONS

Addendum K White Paper, Part 2 - FläktGroup Semco 2022-03

EXCELLENCE IN SOLUTIONS

FläktGroup SEMCO delivers smart and energy efficient Indoor Air and Critical Air solutions to support every application area. We offer our customers innovative technologies, high quality and outstanding performance supported by more than fifty years of accumulated industry experience. The widest product range in the market, and strong market presence in 65 countries worldwide, guarantee that we are always by your side, ready to deliver Excellence in Solutions.

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