Safety, containment, filtration efficiency and energy conservation make the Paramount® Ductless Enclosure a viable alternative to a ducted fume hood

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Introduction

Safety is the primary purpose of any filtered enclosure or ventilated fume hood. In most situations, fume hoods remain the equipment of choice for ventilating hazardous airborne chemicals from the laboratory. However, there are applications where a ductless enclosure or ductless fume hood provides convenience and flexibility beyond what a traditional fume hood offers. For example:

- Ductless enclosures allow placement and flexibility in hard to duct areas such as the center or bottom level of a several story building.
- Ductless enclosures do not carry the initial expense and coordination of ductwork installation.
- Ductless enclosures are portable allowing them to be shared among several laboratories or stored when not in use.
- Ductless enclosures have no make up air requirements, and therefore may be used in air-starved laboratories.
- Ductless enclosures provide significant energy savings since costly tempered air is not exhausted from the laboratory.

The Paramount® Ductless Enclosure offers these "ductless" advantages while still addressing the safety concerns inherent to ductless technology. In addition, the Paramount conserves energy making it a green choice for laboratories needing protection from chemical fumes and vapors. This paper provides an in-depth discussion about the unique features of the Paramount and the rigorous testing performed that confirms its personnel protection effectiveness.

Protection from Fumes and Vapors

Chemicals used in laboratories can produce fumes and vapors that are hazardous to breathe. The Occupational Safety and Health Administration (OSHA) has set a legal limit in the United States, also known as the Permissible Exposure Limit (PEL) on every chemical. The PEL is generally expressed as a time-weighted average (TWA), which is the threshold limit value (TLV) or average exposure over an 8-hour workday or 40-hour work week, to which workers can be repeatedly exposed without adverse effect.

The National Institute for Occupational Safety and Health (NIOSH), which is part of the Centers for Disease Control and Prevention (CDC), was established to help ensure safe working conditions by providing research and making recommendations on exposure limits. Unlike OSHA, its safety and health standards are not enforceable under U.S. law. NIOSH sets its own TWA levels, which are submitted to OSHA for consideration in their formulation of legally-binding safety and health standards. This paper references NIOSH recommendations since they reflect the most current information available. By law, safety officers at all U.S. companies must follow OSHA health standards. Whether or not they adhere to NIOSH recommendations is the choice of the individual safety officer.

3' Paramount Ductless Enclosure, work surface and hydraulic lift base stand

Carbon Filters

Traditional fume hoods protect workers by capturing, containing and removing hazardous contaminants from the laboratory. Fume hoods function by drawing contaminants away from the operator so that inhalation is minimized. With a traditional fume hood, these contaminants are drawn through ductwork by means of a blower and exhausted to the outside where the fumes are diluted and dispersed at acceptably low concentrations.

The Paramount Ductless Enclosure uses carbon filters made of activated coconut shell carbon or carbon treated for specific applications to rid the work area of many hazardous fumes and vapors. Unlike traditional fume hoods, air passing through the enclosure's filters is returned to the laboratory. No ducting is required. Five carbon filter types are currently available:

- OV, for organic vapors
- AG, impregnated for the neutralization of acid and sulfur gases
- FORM, impregnated for the removal of formaldehyde
- AM, impregnated for the removal of ammonia and low molecular weight amines
- RAD, impregnated for the removal of iodine radiosotopes

In addition to these carbon filters, a sixth carbon filter is available that contains a mixed bed of activated and impregnated carbon media. This mixed bed filter, type MB, contains the following approximate percentages by weight:

- 43% OV, for organic vapors
- 19% AG, impregnated for the neutralization of acid and sulfur gases
- 19% FORM, impregnated for the removal of formaldehyde
- 19% AM, impregnated for the removal of ammonia and low molecular weight amines

Validated Filtration Efficiency

Filter capacity is defined as the percentage of the chemical mass adsorbed compared to the total carbon filter weight. The capacity is unique for each chemical and depends on the chemical's affinity for carbon. Carbon manufacturers publish theoretical filter capacities derived from a mathematical formula that considers adsorption potential, temperature, relative humidity, inlet concentration, vapor pressure and other factors. These theoretical values provide a relative measure of a filter's effectiveness with the understanding that exact values will vary with temperature, humidity, distribution across the media and chemical combinations. Chemical adsorption is a result of the chemical concentration in the airstream attempting to reach equilibrium with the carbon media. However, under actual operating conditions, "the capacity of an adsorption bed will seldom achieve equilibrium"[1] and "bed capacity is said to be 30 percent to 40 percent of equilibrium."[2]

As mentioned above, inlet concentration is one factor that affects filter capacity. A common misunderstanding regarding the capacity of activated carbon is that it adsorbs a predictable fixed weight of chemicals. In reality, the ultimate capacity of the activated carbon increases significantly as the concentration increases. See Table 1[3] for example.

Table 1: Percent-by-weight theoretical adsorption capacity for Chloroform ($CHCl_3$)

	@ 10 ppm	@ 100 ppm	@ 1000 ppm
Filter Capacity % adsorbed/weight of carbon	10.2%	20.1%	35.5%

The performance of any ductless enclosure is dependent on the ability of the filters to capture fumes and vapors. Since theoretical capacities offer a guideline but do not always translate into actual experience, the University of Kansas (Lawrence, Kansas) and an independent consultant tested the actual filter capacities in Paramount Ductless Enclosures. Actual capacities were compared to the carbon manufacturer's theoretical capacities to determine filtration efficiencies for various chemicals. Sampling probes monitored the exhaust directly above the Paramount. Exhaust concentrations were measured using analytical instrumentation. The analytical instrumentation allowed detection of minute quantities of the chemical, well below the inlet concentration. When the chemical under investigation was detected in the exhaust, filter saturation, also known as breakthrough, was noted.

The Paramount Ductless Enclosure equipped with OV filters was used to test filter efficiencies for acetone, ethanol, isopropyl alcohol and toluene (Figure 1). The Paramount Ductless Enclosure equipped with AG filters was used to test the filter efficiency for hydrochloric acid (Figure 2). Inlet concentrations, represented as evaporation rates in Table 2, varied from 14 ppm to 504 ppm. To speed the testing process, some of the chemicals were boiled to achieve higher evaporation rates (100 ppm and greater).

As suggested by the manufacturer, carbon filters usually have a 30 percent to 40 percent filtration efficiency when used with chemicals with high carbon affinity. The test results show a filtration efficiency of 33-43 percent for all the chemicals tested, with two exceptions. Since ethanol has a very low affinity for carbon, its filtration efficiency is predictably low at 17-19 percent. Ethanol's lower efficiency confirms the need to use it and any other chemical with low carbon affinity in very small quantities in a ductless enclosure. In contrast, the mineral acid filtration efficiency of hydrochloric acid approached 83 percent of the theoretical value and is attributed to the chemisorption process of the treated acid filters. To conclude, the filtration efficiency

Figure 1: 3' Paramount Ductless Enclosure Model 6963300 equipped with OV Carbon Filters - Toluene Test

This chart shows the capacity of OV carbon filters for toluene. The following parameters were present: Temperature 22° C, Humidity 40%, 175 CFM air volume, and 79 fpm face velocity. Evaporation was by heated container. Average evaporation rate was 3.32 ml/minute (155 ppm inlet concentration). Test time was 12.25 hours. The exhaust was monitored with a photoionization detector, gas chromatograph-mass spectrometer and Safety-First™ organic vapor sensor. Contact Labconco Corporation for charts showing test results on other organic solvents.

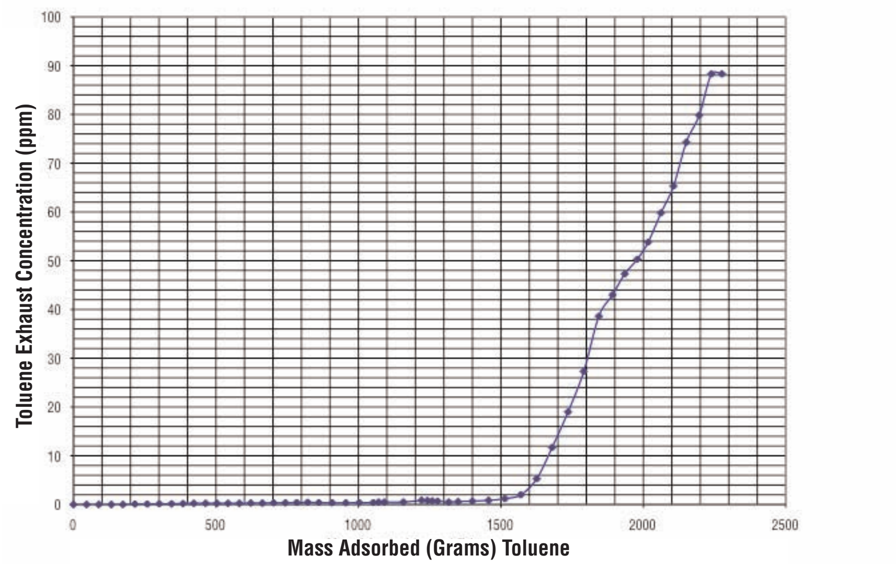

Figure 2: 3' Paramount Ductless Enclosure Model 6963300 equipped with AG Carbon Filters - Hydrochloric Acid Test

This chart shows the capacity of AG carbon filters for hydrochloric acid. The following parameters were present: Temperature 20° C, Humidity 41%, 175 CFM air volume, and 79 fpm face velocity. Evaporation was by heated container. Average evaporation rate was 1.72 ml/minute (100 ppm inlet concentration). Test time was 24.6 hours. The exhaust was continuously monitored at 1.5 ml/minute with acid gas colorimetric tubes until the beginning of a color change. Following the color change, the exhaust was tested every 15-30 minutes with HCl colorimetric tubes 1-10 ppm.

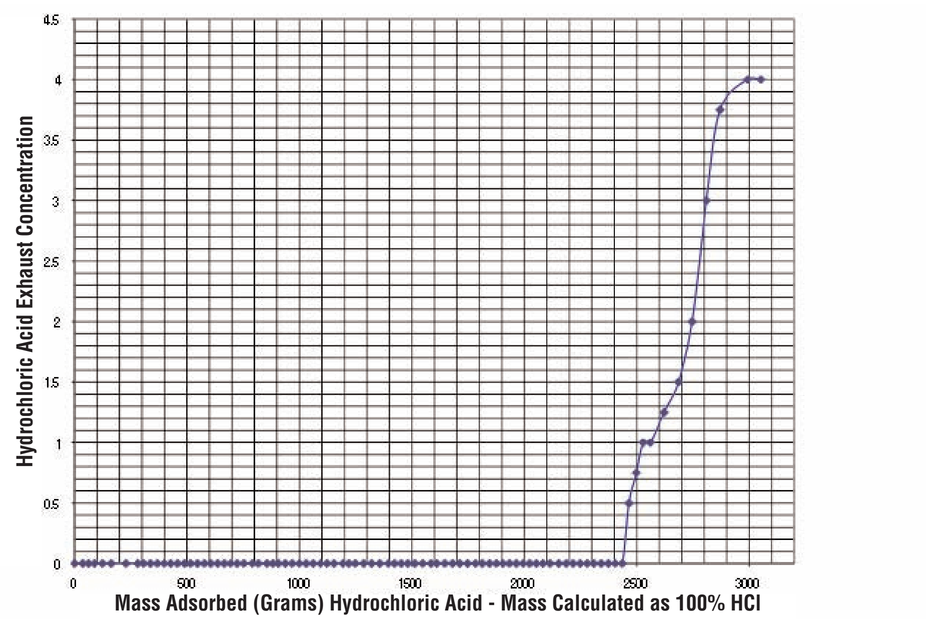

Table 2: Filtration Efficiency Test Results

Chemical	Exposure Limit	Evap. Rate	Paramount Width	No. of Filters	Carbon Filter Mass	Chemical Mass Adsorbed	Breakthrough Concentration	Filtration Capacity		Filtration Efficiency
								Tested	Theoretical	
Acetone	250 ppm	22 ppm	3'	4	13500 grams	153 grams	1-2 ppm	1.1%	2.8%	39%
Ethanol	1000 ppm	14 ppm	3'	4	13500 grams	32 grams	6-9 ppm	0.3%	1.6%	19%
Ethyl Alcohol	1000 ppm	206 ppm	3'	4	13500 grams	148 grams	6-9 ppm	1.1%	6.3%	17%
Isopropyl Alcohol	400 ppm	462 ppm	3'	4	13500 grams	824 grams	8-11 ppm	6.1%	17.7%	34%
Isopropyl Alcohol	400 ppm	504 ppm	2'	2	6750 grams	518 grams	5-13 ppm	7.7%	18.1%	43%
Toluene	100 ppm	155 ppm	3'	4	13500 grams	1317 grams	0.5-1 ppm	9.8%	29.7%	33%
Toluene	100 ppm	151 ppm	2'	2	6750 grams	725 grams	0.5-1 ppm	10.7%	29.7%	36%
37% Hydrochloric Acid	5 ppm	100 ppm	3'	4	18000 grams of treated carbon	2529 grams	0.5-1 ppm	14.1%	17.0%	83%

test results listed in Table 2 confirm that the filters installed in a Paramount Ductless Enclosure perform as suggested by the carbon filter manufacturer.

Determining When to Change the Carbon Filters

There are five means of determining when Paramount Carbon Filters should be changed.

1. **Safety-First™ Sensor.** The Paramount's Safety-First™ Organic Vapor Sensor detects contaminants in the exhaust indicating breakthrough. The sensor detects typical organic solvent vapors, smoke particulates, ammonia gases, formaldehyde gases, and hydrogen sulfide gases. The organic vapor sensor has a sensitivity range of 0.1-30 ppm. Table 3 provides Sensitivity Alert Concentrations for a variety of chemicals listed from low concentration to high.

2. **Time.** For applications that have very consistent inlet concentrations and operating times, "time" can be used to anticipate saturation or TWA levels based on prior experience. The Paramount Ductless Enclosure includes a built-in Filter Life Timer, programmable from the LCD control panel, to remind the user to check and/or replace the filters. When new filters are installed, it is recommended that the user program time intervals that alarm after specified operating hours have passed. At these intervals, the user should use chemical detection tubes or analytical instrumentation to check the exhaust contaminant concentration. The Filter Life Timer is particularly important for mineral acids such as hydrochloric acid, sulfuric acid, or nitric acid, which are undetected by the organic vapor sensor.

3. **Odor.** Odor is subjective. Sensitivity to odor, tolerance to odor and comfort level under odoriferous conditions vary from individual to individual. While odor is an indicator that chemicals are passing through the filter, several points need to be understood:
   a. Smell within the room is not necessarily an indication of saturation of the enclosure's filters or of hazardous exposure concentrations.
   b. Odor can be used as a prompt to do other checks of the chemical concentration.
   c. Organic chemicals recommended for use in the Paramount Ductless Enclosure have detectable odors before reaching the TWAs.
   d. Labconco advises users, or potential users, of how and when odor may play a part in limiting the life of the filter.

4. **Detector Tubes.** Color change indicators can be used to detect the presence of the chemical in the filtered exhaust. Tubes, such as those manufactured by Dräger*, Gastec* and Sensidyne*, monitor the presence of a specific chemical in the air. The vast majority of Detector Tubes available start measuring at or below the chemical's TWA. When a

Table 3: Chemical Sensitivity Alert Concentrations

Chemical Family	Chemical	Sensitivity Alert Concentration	Odor Threshold (ppm)	Exposure Limit TWA** (ppm)	Filter Capacity† (% W)	Filter Type
Aldehydes & Ketones	Cyclohexanone	0.2-0.5 ppm	0.068	50	22%	OV
Mixture of Aliphatic Hydrocarbons	Gasoline	0.3-1.0 ppm	0.3	300	11%	OV
Particulates	Cigarette smoke	0.4-1.0 ppm	N/A	N/A	N/A	OV & HEPA
Aldehydes & Ketones	Acetone	0.5-1.0 ppm	4.58	250	2%	OV
Aromatic Hydrocarbons	Toluene	0.5-1.0 ppm	0.16	100	20%	OV
Ethers	Methyl Tert-Butyl Ether	0.5-1.0 ppm	0.053	50	9%	OV
Sulfur Compounds	Hydrogen Sulfide	0.5-2.0 ppm	0.0005	10	10%	AG
Nitrogen Compounds	Diethylamine	1.5-2.0 ppm	0.186	10	7%	OV
Esters	Ethyl Acetate	1.5-4 ppm	0.61	400	9%	OV
Ethers	Diethyl Ether	2-4 ppm	2.29	400	4%	OV
Aldehydes	Formaldehyde	2-4 ppm, best to use other detector methods	0.87	0.1 ceiling, 0.016	10%	FORM
Nitrogen Compounds	Ammonia Solution (Ammonium Hydroxide)	2-5 ppm	5.75	25	10%	AM
Alcohols	Ethyl Alcohol***	2.5-6 ppm	0.136	1000	1.3%	OV
Acids	Acetic Acid	5-6 ppm	0.016	10	4%	OV
Halogens	Chlorobenzene	5-8 ppm	0.741	10	20%	OV
Alcohols	Isopropyl Alcohol	8-11 ppm	22	200	7%	OV
Aliphatic Hydrocarbons	Hexane	9-15 ppm	21.9	50	11%	OV
Alcohols	Methanol***	15-25 ppm	141	200	0.1%, very low	not recommended
Mineral Acids	Hydrochloric Acid	Not detected.†† Use other means.	0.77	5	17%	AG

* *Dräger is a trademark of Draeger Safety, Inc. Luebeck, Germany; Gastec is a trademark of Gastec Corporation, Kanagawa, Japan; and Sensidyne® is a registered trademark of Sensidyne, LP, Florida, U.S.A.*

** *Time-weighted average recommended by NIOSH*

† *Based on 10 ppm inlet concentration*

*** *Important Note: Clean up procedures using alcohols or volatile chemicals with low filter capacity could saturate the filters quickly.*

†† *Important Note: The vapor sensor does not detect mineral acid gases such as hydrochloric acid, nitric acid, or sulfuric acid. Other detector means such as a mineral acid sensor or interval timed sampling with sampling tubes must be used.*

The chart is only a guideline. Frequent chemical testing or filter monitoring is recommended. If chemical suitability is ever in question, always work below the acceptable exposure limit/TWA to maximize both safety and filter performance.

OV=*Organic Vapors,* AG=*Acid-Sulfur,* FORM=*Formaldehyde,* AM=*Ammonia-Amine* user observes a color change in the tube, the filter should be replaced immediately.

5. **Analytical Instrumentation.** This method is the most accurate means of measuring concentrations of any chemical. Analytical instrumentation is required when no Detector Tubes are available or when the Safety-First Sensor does not apply to the chemical in question. It is also required when saturation concentration is below the measurement range detectable by Detector Tubes or the Safety-First Sensor. Due to the broad range of chemicals and instrumentation available, Labconco cannot make specific recommendations on the analytical equipment or procedure.

HEPA Filters

Besides carbon filters, Paramount Ductless Enclosures may also be equipped with high efficient particulate air (HEPA) filters, which retain airborne particles such as those released by some chemical powders and solids. Paramount HEPA Filters are 99.99% efficient.

A HEPA filter is a disposable dry-type filter, constructed of boron silicate microfibers cast into a thin sheet, much like a piece of paper. Although the media is a flat sheet, the glass microfibers form a complex three dimensional matrix that traps particulate matter but allows gases to pass through. The filter media is folded to increase its surface area.

HEPA filters are rated on their ability to retain particles 0.3 micron (μm) in diameter. The filters are tested by injecting an aerosol of Dioctyl Phthalate (DOP), poly-alpha-olefin (PAO) or mineral oil, which has a large number of 0.3 μm droplets, into the upstream side of the filter during operation. Readings are taken on the opposite side of the filter to quantify the number of droplets that penetrate. Thus, if a filter allows one droplet or fewer to penetrate the filter with an initial concentration of 10,000, the filter is rated at 99.99% efficient.

Determining When to Change the HEPA Filters

Methods to determine when a HEPA filter should be changed are very different from carbon filters. Unlike carbon filters, HEPA filter efficiencies are not specific to the chemical particulate being trapped; any airborne particle in its path is trapped including dust. Since cleanliness of the room can affect filter life, time is not a reliable indicator. Detector tubes are designed for gaseous contaminants, not particulate contaminants.

Upon installation and at least annually, the HEPA filters should be checked for leaks. In addition, safety officers may routinely conduct surrogate monitoring of the enclosure. After introducing a potent, non-toxic powder to the enclosure and having operators simulate typical handling methods, air in the laboratory is sampled and tested for the surrogate. Surrogate testing provides a safe means to check the enclosure's ability to contain particulates without the potential of operator exposure to toxic powders.

Stackable Filters

A total of seven different Paramount Filters are available, six carbon and one HEPA. Paramount Ductless Enclosures require that two filters be stacked. For single chemical applications, the two filters may be the same. For mixed chemical applications, two different filters may be used. In other cases, when the chemical emits both gaseous and particulate contaminants, a carbon and HEPA filter would be recommended. The mixed bed filter provides greater flexibility for multiple low volume gaseous chemicals.

High Performance Containment

The Paramount Ductless Enclosure uses the same patented technologies used in many Labconco ducted fume hoods (U.S. Patent 6,461,233). Air is directed into and through the air chamber to maximize containment of contaminants as shown in Figure 4. The containment-enhancing and aerodynamic designs of the lower air foil, upper sash foil, side air foils, upper dilution air supply, and zoned rear perforated baffle work in concert to produce horizontal airflow patterns that significantly reduce chemical concentrations through the work area as illustrated in Figure 3.

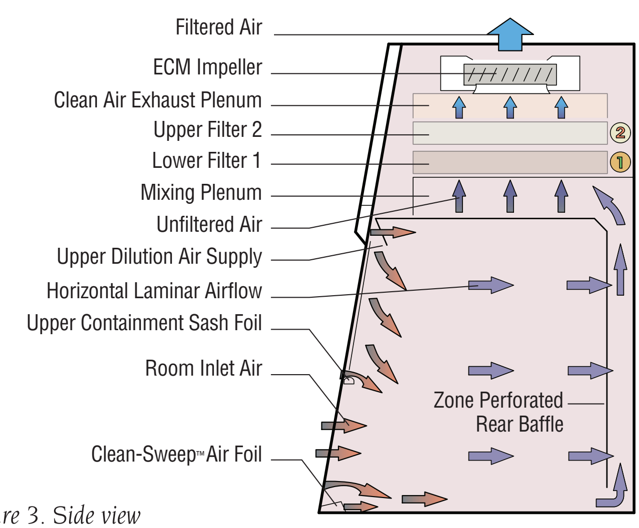

Figure 3. Side view illustrating air flow.

The unique lower air foil shape and Clean-Sweep™ openings direct air to sweep the work surface and create a constant protective barrier from contaminants. The radiused upper sash foil includes an open air passage directly atop the sash foil into the enclosure chamber and directs chemical concentrations away from the sash opening. The side entry air foils allow turbulence-free air to enter the enclosure from the sides and allow clean air to sweep the interior walls (Figure 4). The upper dilution air supply provides by-pass air from above the work surface to constantly bathe the inside of the sash and upper chamber with clean air to reduce chemical concentrations. The zoned rear perforated baffle directs horizontal laminar air streams to the three zones to minimize the potential for air to roll forward, preventing contaminants from moving toward the sash opening and user's breathing zone.

Figure 4

ASHRAE 110-1995 Validated Performance Containment

Results of testing performed on Paramount Ductless Enclosures confirm their ability to contain gases and airborne particulates. ASHRAE 110-1995 testing concluded that Paramount Ductless Enclosures maintain containment of gases at face velocities of 60 fpm and greater (Table 4). Average concentrations during tracer gas tests were less than 0.05 ppm and no escape was observed during the smoke tests. *Industrial Ventilation*: A *Manual of Recommended Practice* recommends fume hood face velocities between 60-100 fpm. Paramount Ductless Enclosures are factory set to be operated at 80 fpm but may be decreased on site to 60 fpm or increased to 100 fpm and still remain within *Industrial Ventilation's* guidelines.

Table 4: ASHRAE 110-1995 Test Results

Paramount Width	Airflow (CFM)	Avg. Face Velocity (fpm)	Mannequin Position	ASHRAE 110-95 Tracer Gas Test Results (ppm)		
				Avg.	Min.	Max.
2'	85	60	Center Standing	0.01	0.00	0.03
			Perimeter Scan	0.01	0.00	0.03
	115	80	Center Standing	0.01	0.00	0.04
			Perimeter Scan	0.01	0.00	0.04
	145	100	Center Standing	0.01	0.00	0.03
			Perimeter Scan	0.01	0.00	0.06
3'	130	60	Center Seated	0.01	0.00	0.15
			Center Standing	0.01	0.00	0.05
			Perimeter Scan	0.01	0.00	0.04
	175	80	Center Seated	0.01	0.00	0.04
			Center Standing	0.01	0.00	0.02
			Perimeter Scan	0.01	0.00	0.05
	220	100	Center Seated	0.01	0.00	0.04
			Center Standing	0.01	0.00	0.04
			Perimeter Scan	0.01	0.00	0.04
4'	175	60	Center Standing	0.01	0.00	0.04
			Perimeter Scan	0.01	0.00	0.06
			Left Standing	0.01	0.00	0.03
	235	80	Center Standing	0.01	0.00	0.05
			Right Standing	0.01	0.00	0.03
			Perimeter Scan	0.01	0.00	0.04
	295	100	Left Standing	0.01	0.00	0.04
			Center Standing	0.01	0.00	0.03
			Right Standing	0.01	0.00	0.03
			Perimeter Scan	0.01	0.00	0.05
5'	220	60	Left Standing	0.01	0.00	0.02
			Center Standing	0.01	0.00	0.02
			Right Standing	0.01	0.00	0.06
			Perimeter Scan	0.01	0.00	0.02
	295	80	Left Standing	0.01	0.00	0.03
			Center Standing	0.01	0.00	0.02
			Right Standing	0.01	0.00	0.02
			Perimeter Scan	0.01	0.00	0.03
6'	350	60	Left Standing	0.01	0.00	0.02
			Center Standing	0.01	0.00	0.02
			Right Standing	0.01	0.00	0.02
			Perimeter Scan	0.01	0.00	0.02
	465	80	Left Standing	0.01	0.00	0.04
			Center Standing	0.01	0.00	0.02
			Right Standing	0.01	0.00	0.02
			Perimeter Scan	0.01	0.00	0.02
	580	100	Left Standing	0.01	0.00	0.02
			Center Standing	0.00	0.00	0.02
			Right Standing	0.01	0.00	0.02
			Perimeter Scan	0.01	0.00	0.02

Particulate Test Data

To validate the design and performance of the Paramount Ductless Enclosure, Labconco conducted particulate testing to confirm its ability to provide excellent containment. SafeBridge Consultants, Incorporated (Mountain View, California) then analyzed the samples. Naproxen sodium, a non-potent active pharmaceutical ingredient, was selected as the surrogate for the study because it is safe to handle, readily detectable in air at low concentrations, has a high dustiness quotient and challenging electrostatic properties. The study was designed to assess potential exposure to airborne concentration of naproxen sodium for three operators of varying skill levels and physical statures. More importantly, it assessed the containment performance of the ductless enclosure relative to the likely concentrations of the surrogate generated by weighing and dispensing tasks at the access opening.

Test results showed a personal exposure below 25 ng/m^3 with the enclosure operating at 80 fpm face velocity. The Paramount Ductless Enclosure demonstrated superb containment when used by an operator using excellent technique and good containment when used by an operator using marginal technique. While no enclosure can compensate for improper technique, these tests confirm that the ductless enclosure provides a safe work environment.

Airflow Monitor

Federal Register 29 CFR Part 1910 and ANSI Z9.5-2003 Standard-Laboratory Ventilation recommend that fume hoods have a monitoring device to ensure that safe operating speeds are maintained. The Paramount Ductless Enclosure includes a Smart-Flow™ Airflow Monitor, which continuously monitors airflow and displays face velocity on the LCD. The monitor enables the Paramount's ECM motor to automatically adjust for conditions such as temperature, barometric pressure and filter loading. Safe airflow is always maintained.

Energy Conservation

The Paramount Ductless Enclosure uses less energy than a traditional ducted hood since heated or cooled air is not exhausted from the laboratory. Unlike other ductless fume hoods, the Paramount uses an electronically commutated motor (ECM) that is quieter and more energy efficient than conventional motors. Table 5 illustrates the potential energy savings achieved by the 95% efficient ECM motor. For example, a 3' ductless enclosure uses only 65-93 watts of energy and costs only $11-16 per year to operate. Furthermore, ductless hoods incur no installation costs and have potential operating costs well below that of traditional fume hoods.

Conclusion

Significant engineering developments have resulted in a ductless enclosure that offers the advantages of utmost safety, superior airflow containment, validated filtration efficiency and improved energy conservation. Depending on the end user's specific chemical application and suitability, the Paramount Ductless Enclosure can provide effective containment of airborne chemicals and particulates and provide superior energy and cost savings when compared to traditional ducted fume hoods.

Table 5: Paramount Ductless Enclosure: Typical Energy Use and Operating Costs

Paramount Width	2'	3'	4'	5'	6'
Total Power with blower/lights on (watts)*	66	65-93	99-150	153	241
Electric Energy Cost ($) (based on 2000 hours per year at $0.078/kwh[4])	$11	$11-16	$16-25	$26	$40
Installation Cost	$0	$0	$0	$0	$0
Operating Filter Cost ($) (based on one annual organic filter change)	$400	$800	$1200	$1200	$1600
Total Annual Operating Cost	$411	$816	$1225	$1226	$1640
Traditional Fume Hood Comparison (based on $7 per CFM at 100 fpm)**	$1015	$1540-1995	$2065-2660	$2590	$4060

** Power usage is based on operating the blower to achieve 80 fpm airflow volume. Since Paramount Enclosures in 3' and 4' widths are available with two sash heights, their airflow volumes and, therefore their energy costs, vary.*
*** To determine the energy costs of using a traditional fume hood in selected locations, visit http://fumehoodcalculator.lbl.gov.*

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[2] Ibid., p. 37.
[3] Ibid., p. 35.
[4] E. Mills and D. Sartor, "Energy Use and Savings Potential for Laboratory Fume Hoods," *Energy* 30 (2005): 1862.

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