TASK SHEET 1B

COMBINED GENERAL AND FUME HOOD EXHAUST

and

DUCT VELOCITIES

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Introduction

Historically, the City of Seattle has not allowed combining general exhausts and fume hood exhaust systems, but the City rule (DPD/SFD, 2005) changed in November, 2005, to allow combined systems. While disallowed in Seattle until recently, most other jurisdictions have always allowed combined systems, and there is a good track record on systems installed and in service for more than 20 years.

Combining the general (local) with the fume hood exhaust represents a prudent approach to laboratory facility design if supported by the local, state and federal codes, established design practice, and user preferences. Such an approach yields the possibility of simplifying the level of required maintenance due to lesser number of duct runs and accessories, an ease of future system modifications due to the usage of a main common plenum, and reduction in overall capital and operational costs.

This Task Sheet discusses the advantages and limitations of combining fume hood and general exhaust from a laboratory. If properly specified, designed, and constructed with adherence to good laboratory work practices, the major concerns surrounding combined exhausts systems can be eliminated. In addition, duct velocities down to 500 fpm, utilization of common materials of construction, and cost efficient operation can be achieved.

Requirements for Separate Exhausts

For any exhaust system, three types of exhausts should be kept separate from the general exhausts: 1) perchloric acid hoods, 2) radioisotope hoods, and 3) Class 2, Type B biological systems. These exhausts present problems due to contamination issues or large pressure drops from HEPA filters. It is normal practice to have separate hoods and ductwork for the perchloric acid and radioisotope hoods. Biological exhausts normally have a separate system due to HEPA filter requirements.

Flammability Requirements

Under all circumstances, the contaminated air stream shall be diluted sufficiently to prevent concentrations that exceed 25% of a lower explosion limit of the contaminant. Combining fume hood exhaust and local exhaust will provide enhanced dilution of lower volume contaminated air streams over much of the exhaust system. However, the exhaust flow rate in the duct immediately downstream from the fume hood emitting flammable materials will have the highest contaminant concentrations and will be the limiting case.

Specifying Duct Velocities

Specification for minimum duct velocities is dependent on satisfaction of multiple natural system constraints. This Task Sheet proposes allowing minimum duct velocities as low as 500 fpm if the natural system constraints are satisfied. An upper limit of duct velocities is typically 2500 to 3000 fpm based on noise considerations and static pressure limitations. A range of 500 fpm to 2500 fpm would allow a turndown ratio of up to 5:1.

The constraints on lower duct velocities are discussed below:

Transport Velocity - Ranges of exhaust duct velocities (fpm) depend on the nature of the contaminant and potential for contaminant deposition. Duct velocities should be sufficient to prevent the settling and accumulation of dry aerosols or particulates. Further discussion on this topic can be found in **Appendix A**. The appendix presents information that supports the minimum duct velocity of 500 fpm for exhausts with fumes and other sub-micron size particulates. Also presented are recommended duct velocities for other types of particulate materials to be transported.

Ductwork Layout and Design – The physical configuration and design of the ductwork layout should consider minimization of horizontal duct runs, abrupt directional changes, and provide smooth interior transitions. The system designer should consider the use of round ductwork versus rectangular. Selection of round ductwork offers the following advantages:

- Resists settling of dry particles
- Lower first cost, fabrication and installation
- Resistance to collapse under higher negative pressures
- Minimizes internal spaces that promote contaminant deposition

System Volume Control – Exhaust system can be characterized as either Constant Air Volume (CAV) or Variable Air Volume (VAV). The selection of the volume control system is dependent on the application.

CAV exhaust systems are generally dedicated to a single process or exposure control device. The volume requirement is constant and ductwork velocities and sizing can be quickly determined based on the contaminant or air volume to be transported. Ductwork should be sized to minimize velocities, improving operational cost and lowering system noise generation.

VAV exhaust systems, by nature, are more dynamic. These systems serve multiple processes or exposure control devices. System volumes vary based on the diversity of occupancy, equipment use, or process operations. As the diversity increases duct velocities increase proportionally to system volume. Duct velocity will typically range from 500-2500 fpm, for normal laboratory operations, and the ductwork system should be designed and sized accordingly.

Volume Verification – System volumes can be measured and verified, within acceptable accuracy, on systems operating with velocities as low as 500 fpm, for example with a pitot tube traverse.

Corrosion Considerations for Combined Exhausts

In the experience of ECT and others, corrosion within existing ductwork is relatively uncommon. The most common situation causing corrosion is the use of acid baths that emit large quantities of acidic vapors. It is recommended that exhausts from acid baths be either scrubbed or vented into separate exhaust systems. Another possible source of corrosion is galvanic corrosion. Galvanic corrosion control is discussed in **Appendix B.**

When selecting materials and designing ducts, the designer should take into consideration potential effluents that are known or predicted to be generated in the laboratories and subsequently be transported by the exhaust system.

- Ambient temperature of the space where the ducts and fans operate may affect the vapor condensation in the exhaust system and thus exacerbate metal corrosion with or without the presence of chemical agents or HM (Hazardous Material) gases. A ductwork system operating in low ambient temperatures is subject to a lesser attack when the lengths of duct runs are minimized and the air velocities are maximized, therefore; the designer should minimize exposure of the ductwork system to low ambient temperature conditions. The designer should also consider issues of engineering economics such as the impact of cross sectional duct areas and duct pressures on first cost and subsequent operating costs.

- Horizontal runs of duct, more so than vertical ducts create surfaces for contaminant accumulation and moisture deposition and should be avoided. Where the potential for condensation exists, the ducts should be sloped and condensate drains should be utilized (the recommended slope of the horizontal runs is 1 inch per 10 feet of duct length). It should also be realized that the duct condensate may contain hazardous materials and acids in solutions. As such, the design and construction of the duct manifold should prevent air and liquid leaks.

- The basic requirement appearing in many codes and good practice recommendations calls for the exhaust ducts to be made of solid, non-porous and non-flammable material. The most common exhaust duct materials used in today's design practice are coated carbon steel, galvanized steel (*See scope for ASTM Standard,* **Appendix C, Table 3** *for specifications for Galvanized Steel*), and stainless steel. Stainless steel (S.S.) is one of the most commonly used materials for laboratory exhaust ductwork systems due to its corrosion resistance.

- Other types of laboratory exhaust duct materials are non-flammable polyvinyl chloride (PVC) pipe, fiberglass reinforced plastic (FRP) and a variety of other materials. Some duct materials, their applications, advantages, limitations, and compatibility are shown in **Appendix C, Table 4**.

Summary

It is recommended that fume hood exhausts and general exhausts be combined for most laboratory situations. Exhausts from perchloric acid hoods, radioisotope hoods, and HEPA-filtered biological exhausts are normally excluded from combined exhausts. Acid baths should be excluded due to high corrosion potential. Duct minimum velocities down to 500 fpm can be used for ordinary laboratory emissions of gases, smoke, and fumes with mostly submicron sized particles. Sticky particles, large amounts of condensable vapors, dusts, and lints should have duct cleanouts or emission controls at the fume hood source. Galvanized steel can be used for most fume hood exhausts and all general exhausts, except where condensation of acidic (or base) vapors is possible. Guidelines are given on choosing duct materials and avoiding corrosion.

References

Seattle Department of Planning and Development/Seattle Fire Department. Joint Ruling DPD Director's Rule 30-2005/SFD Administrative Rule 27.03.05

Heinsohn, R.J. Industrial Ventilation: Engineering Principles. Wiley-Interscience, 1991.

EPA, *AP-42. Emission Factors*. Section 12.19, January 1995

Sippola, M.R., and W.W. Nazaroff, "Modeling of Particle Deposition in Ventilation Ducts". Proceedings: Indoor Air 2002.

ASTM A653 / A653M - 08 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.

Appendix A - Transport Velocities

Contaminant types include gases, very fine particulates in the form of smoke, fumes that could condense to very fine solid particulate form, vapors that could condense to liquid form, and dusts and powders with relatively large particle sizes.

Duct velocities should be sufficient to prevent the settling and accumulation of dry aerosols or particulates. Particulates larger than a few microns in size will have significant settling velocities. For submicron particulates such as that found in smoke and fumes, settling velocities are negligible. A 1 micron particle will have a settling velocity of approximately 0.013 fpm for round particles with density 2.5 times that of water, which is 4 orders of magnitude less than the minimum duct velocity of 500 fpm recommended in this Task Sheet.

Particles from condensation of fumes are generally submicron in size (EPA). Deposition of fumes in ductwork will be primarily due to diffusion to the duct surface rather than gravitational settling. An experimental program by Sippola and Nazaroff (*Proceedings Indoor Air Conference*, 2002) determined that at 500 fpm, that there are almost no losses due to deposition in ductwork for submicron particles. Calculating laboratory scale emissions can vary significantly with the procedures. An upper limit on fume emission rates can be estimated by comparison to welding, which has known emission factors (EPA). Based on 8 hours of operation, a typical welding operation will generate a few grams per day of particulate fume material. For this emission rate, the deposition of fumes in ductwork will be on the order of a few grams per year or less. For operations, which may produce emissions larger than a few grams per day, emission controls including filtration is recommended to be installed at the source in the fume hood.

For ductwork systems that transport mists, sticky particles or condensing materials, provisions for duct cleaning or emission controls at the source should be provided. Duct cleaning provisions usually include; drains, ductwork sloped to drains, cleanout openings, water spray cleaning systems, and so forth. When condensable vapors are to be exhausted, the designer should consider the effects of cold temperatures on the exhaust duct and make provision to prevent unwanted or uncontrolled condensation. If condensation nuclei are also present in the exhausted air/vapor mixture, this consideration is even more important.

Air containing dry particles should be moved at a velocity sufficient to "scour" or transport particles through the ductwork due to the turbulence of the transporter air. Velocities of 2000-5000 ft/min are common for dust and lint applications. Non-condensable vapors, submicron size particulates, and gases mix intimately with the air and may be moved at any convenient velocity, determined by the economy of duct sizes and power consumption.

Table 1 below provides the industry accepted duct velocities for various contaminants, as adapted from the *Industrial Ventilation, Engineering Principles* (R. J. Heinsohn, 1991). The recommended ranges are higher than would be calculated from theory for minimum transport velocities to compensate for complications due to aging equipment and/or damaged duct work.

Table 1. Industry Accepted Duct Velocities

	NATURE OF CONTAMINANTS	EXAMPLES	VELOCITY RANGE fpm
1	Non-condensable vapors, gases	All forms	500[1] – 2,000
2	Fumes/Smoke and sub-micron particles[2]	Zinc and aluminum Oxide fumes	500[1] – 2,000
3	Condensable vapors and sticky particles[3]	All forms	1000 – 2,000
4	Very fine light dust[3][4]	Cotton lint, wood flour Litho-powder	2,000 – 2,500
5	Dry dust and powders [3][4]	Cotton dust	2,500 – 3,000
6	Average industrial dust[3][4]	Shavings Sawdust, grinding dust	3,500 – 4,000
7	Heavy dusts[3][4]	Metal turnings, lead	4,000 – 4,500
8	Heavy moist dust[3][4]	Buffing lint (sticky) Lead dust w/ small chips	4,500 and more

Notes:

(1) A lower limit of 500 fpm provides the ability to accurately measure flow in the duct using commonly applied techniques including Pitot tube traverse. Lower duct velocities are routinely observed in VAV exhaust system branch ducts serving VAV Fume Hoods and do not affect the containment ability of the hood.

(2) Fumes (generated from heated solids) and smoke are typically composed of submicron sized particles. Deposition rates of submicron particles in ductwork are typically low as discussed in the text.

(3) Provisions for drains, cleanout and/or wash down must be provided if significant quantities can condense or deposit in the duct system.

(4) Contaminants of this nature are not usually experienced in a laboratory and should be controlled prior to entering the ductwork system. Particles larger than several microns should be controlled at point of emission.

Appendix B - Galvanic Corrosion

All metals have a property called nobility. It is a measure of a metal's resistance to corrosion when in contact with another metal. A greater relative difference in nobility between the two metals in contact indicates a greater corrosion potential. **Table 2** ranks the most common metals used in construction in increasing nobility, called the galvanic number.

Table 2. The Relative Nobility of Common Metals

Galvanic Number	Nobility	Construction Material
1	Least Noble	Aluminum
2	↓	Zinc
3		Steel
4		Iron
5		Stainless Steel - Active
6		Tin
7		Lead
8		Copper
9	Most Noble	Stainless Steel - Passivated (after fabrication or machining)

When two metals are submerged in an electrolyte, while electrically connected, the less noble metal will experience galvanic corrosion. The rate of corrosion is determined by the electrolyte and the difference in nobility.

Ductwork systems rarely experience any significant Galvanic Corrosion because the construction materials have similar nobilities and system components are not submerged in or are not in the presence of an electrolyte. Special joinery methods can be implemented in the event dissimilar metals must be joined and there is a concern about Galvanic Corrosion, *See **Appendix C, Figure 1*** for example of the joinery method.

Appendix C – Reference Tables and Figures

Table 3. ASTM A653 / A653M - 08 Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process

This specification covers steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process in coils and cut lengths. The material is available in several designations as follows: commercial steel, forming steel, deep drawing steel, extra deep drawing steel, structural steel, high strength low alloy steel, high strength low alloy steel with improved formability, solution hardened steel, and bake hardenable steel. Structural steel, high strength low alloy steel, solution hardened steel, and bake hardenable steel are available in several grades based on mechanical properties. Yield strength, elongation, and bending properties of the steel shall be determined. A bend test shall be done to the coated sheets.	
1.1	This specification covers steel sheet, zinc-coated (galvanized) or zinc-iron alloy-coated (galvannealed) by the hot-dip process in coils and cut lengths.
1.2	The product is produced in various zinc or zinc-iron alloy-coating weights [masses] or coating designations.
1.3	Product furnished under this specification shall conform to the applicable requirements of the latest issue of Specification A 924/A 924M, unless otherwise provided herein.
1.4	The product is available in a number of designations, grades and classes in four general categories that are designed to be compatible with different application requirements.
1.4.1	Steels with mandatory chemical requirements and typical mechanical properties.
1.4.2	Steels with mandatory chemical requirements and mandatory mechanical properties.
1.4.3	Steels with mandatory chemical requirements and mandatory mechanical properties that are achieved through solid-solution or bake hardening.
1.5	This specification is applicable to orders in either inch-pound units (as A 653) or SI units (as A 653M). Values in inch-pound and SI units are not necessarily equivalent. Within the text, SI units are shown in brackets. Each system shall be used independently of the other.
1.6	Unless the order specifies the "M" designation (SI units), the product shall be furnished to inch-pound units.

Table 4. Duct Materials and Compatibility

Materials	Applications	Advantages	Limitations
Galvanized Steel	Widely used for most air handling systems. Not recommended for corrosive product handling, or temperatures above 400º F (200º C)	High strength, rigidity, durability, rust resistance in ordinary conditions, availability, non-porous, workability.	Weldability, paintability, weight, corrosion resistance.
Stainless Steel	Duct systems for kitchen exhaust, moisture-laden air, fume exhaust.	High resistance to many common forms of corrosion (but care is definitely required in alloy selection).	Material cost, workability, availability.
Fiberglass Reinforced Plastic (FRP)	Chemical exhaust, scrubbers, underground duct systems.	Corrosion resistant, ease of modification.	Cost, weight, range of chemical and physical properties, brittleness, fabrication, code acceptance.
Polyvinyl Chloride (PVC)	Exhaust systems for chemical fumes and hospitals, underground duct systems.	Corrosion resistance, weight, weldability, ease of modification.	Cost, fabrication, code acceptance, thermal shock, weight.
Carbon Steel (Black Iron)	Breechings, Flues, stacks, hoods, other high temperature duct systems, kitchen exhaust systems, ducts requiring paint or special coating.	High strength, rigidity, durability, availability, paintability, weldability, non-porous.	Corrosion resistance, weight.
Aluminum	Duct systems for moisture-laden air, louvers, special exhaust systems, ornamental duct systems. Often substituted for galvanized steel in HVAC duct systems.	Weight, resistance to some forms of corrosion, availability.	Low strength, material cost, weldability, thermal expansion.
Copper	Duct systems for exposure to outside elements and moisture-laden air.	Accepts solder readily, durable, resists corrosion, non-magnetic.	Cost, electrolytic action of in contact with galvanized steel, thermal expansion, stains.
Polyvinyl Steel (PVS)	Underground duct systems, moisture-laden air and corrosive air systems.	Corrosion resistance, weight, workability, fabrication, rigidity.	Susceptible to coating damage, temperature limitations (250º F or 120º C Max.), weldability, code acceptance.
Concrete	Underground ducts, air shafts.	Compressive strength, corrosion resistance (although steel reinforcement in concrete must be properly treated).	Cost, weight, porous, fabrication (requires forming processes).
Rigid Fibrous Glass	Interior HVAC low-pressure duct systems.	Weight, thermal insulation and vapor barrier, acoustical qualities, ease of modification, inexpensive tooling for fabrication.	Cost, susceptible to damage, system pressure, code acceptance, questionable cleanability.
Gypsum Board	Ceiling plenums, corridor ducts, airshafts.	Cost, availability.	Weight, code acceptance, leakage, deterioration when damp.

Figure 1. Ductwork connection for dissimilar metals using flanged connections. Fasteners for the flanges are to be made from the noblest material.
(Stainless Steel Bolts in this example)