C&D TECHNOLOGIES, INC.
Power Solutions

Project Environmental, Health and Safety Aspects Guidance

Corporate Regulatory Compliance and Best Management Practices

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Index of Project Environmental, Health and Safety Guidance

In support of the C&D Technologies, Inc. corporate Environmental, Health and Safety Policy this document is provided to offer guidance to the organization on proper practice in the conduct of projects associated with the design and manufacturing of products.

1.0 Regulatory Compliance Guidance

C&D manufacturing facilities are subject to permitting requirements for process water treatment and discharge, stormwater discharge, non-contact cooling water discharge, hazardous, medical and special waste storage and disposal, fugitive and process stack air emissions, and tank /bulk storage. Failure to obtain the proper permits or approvals before commencing a project which could impact any of these aspects of our operations can subject C&D to regulatory penalties, fines and the potential for operational sanctions or criminal prosecution.

- When planning a new or modified process or operation, demolition or expansion, adequate time must be allowed for obtaining the necessary approvals or permits. Air and wastewater permit approvals can require 60 to 90 days. The E, H&S Administrator and Plant Manager of the affected facility should be involved as early as possible in the project planning so that appropriate action can be taken to avoid delay of the project.

- No new process or emission control equipment may be delivered or installed at a C&D facility without the approval of the facility or corporate E, H&S department.

- Changes in raw materials, processes, production rates, or emission rates may require modifications to an existing permit or registration, including the delisting of a permitted source if a piece of machinery or a production line is removed.

- Regulatory requirements vary considerably from location to location. The following is a partial list of equipment and activities that may require a permit or other form of regulatory approval. When in doubt, ask.

    - Process equipment (chemical and mechanical) that emits particulates, toxic substances like lead, or any kind of vapor or gas.

    - Increases in production levels or increases in hours of operation.

    - Storage tanks (above ground, on-ground, and underground) holding chemicals, water or waste.

1.0 Regulatory Compliance (Cont.)

- Air pollution control devices (baghouses, scrubbers).
- Fuel-burning equipment.
- Degreasing and other cleaning operations that employ solvents.
- Demolition or excavation that can cause airborne dust, stormwater run-off (even just of soil), disturbance of soil or materials that could contain contaminants, asbestos, etc.
- Process equipment that will create wastewater or non-contact cooling water.

2.0 Process Design and Controls

New manufacturing process design should take into consideration potential environmental, health and safety impacts. During design, the process should be broken down into its components and each examined for possible elimination of steps as well as the opportunity to increase yields and thereby reduce or eliminate wasteful by-products. New equipment and process design should seek to eliminate or reduce worker chemical and physical exposures (i.e., repetitive motion, noise, and lead).

Projected releases to the air, water and solid waste streams should be carefully analyzed during the design phase for opportunities for elimination or reduction using source reduction, recycle/reuse and as a final approach, "state-of-the-art" treatment technology. Only in the unusual event that no other options are available should toxic and hazardous materials be considered for incineration and landfill.

Superimposed on this analysis should be the search for alternative processes which are more "environmentally friendly" and which use less resources and energy. Key factors to consider are:

- **Elimination of Process Steps -** Assessment of manufacturing processes can reveal individual steps or groups of steps, which can be eliminated. This frequently can produce savings in materials, labor, energy, and equipment, as well as reduced environmental impact. Material substitution and introduction of new technologies often provide opportunities for elimination of process steps.
- **Waste Elimination/Reduction -** Opportunities for eliminating or reducing wastes are often revealed in assessments of processes.
- **Increase Yields -** Lower material, energy usage, and environmental impact per unit output can be demonstrated when process yields or efficiency are increased.

2.0 Process Controls (Cont.)

- **Emission Elimination/Reduction & Effluent Elimination/Reduction -** These types of projects are particularly desirable because of the impact emissions and effluents can have on the environment and public.

- **Detoxification of Discharges -** Minimizing the hazard presented by releases is an important consideration when eliminating/reducing the quantity is not possible.

- **Alternative Processes -** Seek to achieve neutral impact through alternative technologies and processes.

- **Energy Reduction** - These types of reductions can have significant decreased environmental impact not only at the site but also in the public arena of power generation. Energy efficiency should always be a goal in design.

- **Raw Materials -** In those cases where substitution for a hazardous material is not possible, these materials should be totally consumed or recycled within the process as much as feasible. In the design of a new process, consideration of the waste products that will be generated and their disposal requirements should be given. The process assessment should follow the track of waste elimination**,** substitution, reuse/recycle/incineration and landfill.

3.0 Employee Safety/Equipment Layout

Care must be taken not to create a new safety or chemical exposure problem for employees. Design of equipment layouts should include an assessment of safety aspects including the following:

- Properly guarded to prevent access to moving parts? NOTE: Equipment suppliers may not always offer equipment which meets OSHA guarding requirements. Do not assume equipment you are ordering will be fully compliant.

- Noise generation - Does the equipment create noise at 85 dB or higher? Will the noise of the new equipment contribute to the existing area noise level to create an exposure hazard?

- Is lighting in the area adequate for the operator(s) to clearly see what they are doing at the workstation(s)? Is light source behind the operator that creates shadows at the workstation?

- Does the new equipment design minimize the amount of worker movement and stress when doing the job functions?

3.0 Employee Safety/ Equipment Layout (Cont.)

- Is material handling equipment provided to minimize lifting handling exposures for the operator(s)? Is Best Available Technology being used?

- Does the new layout allow for clear and safe entry and exit from the area?

- Does the new layout allow adequate aisle space for industrial trucks and foot traffic? Is the operator placed in a traffic area?

- Are engineering controls adequate to control airborne contaminants below the Permissible Exposure Limit?

4.0 Air Emission Reduction and Control

When designing a new process or production installation, care should be taken to use the best available pollution control technologies to ensure air emissions are controlled adequately to meet regulatory standards. In the absence of regulatory standards, all C&D facilities shall manage their air emissions such that they:

- Do not endanger public health or the environment

- Do not create a public nuisance (e.g., noise, smog, odor, particulate deposition, opacity)

- Are routinely evaluated through testing or best-engineering estimates to assure proper function.

To the extent possible, new production processes, technologies, and raw materials shall be selected and designed so as to minimize the impact on air quality. Where necessary, emission control devices shall be incorporated into the original design.

If a new process uses a chemical not currently used at the affected facility, or extremely toxic or odorous chemicals, consideration should be given to first investigating alternatives to these chemicals and then to installing devices to provide appropriate and complete control.

Prior to the installation of control devices, the project team should first evaluate available options to minimize or eliminate air emissions at the source.

When designing a new process or operation, care should be taken to determine the proper access, maintenance and disposal means for the wastes, filters, sludges and residuals.

4.0 Air Emission Reduction and Control (Cont.)

Design should minimize the potential for release of contamination and employee harm during use, operation, maintenance and cleaning activities. Refer to section 14.0 of this document for the specific C&D ventilation design and fabrication specifications which are to be followed.

5.0 Product & Packaging Design

Responsible management of the environment requires a continuous process of improvement aimed at achieving neutral environmental impact from all operations, products and packaging within the constraints of existing technology and responsible business practice.

New product development should include an analysis of how the product will be used and how in the end it is disposed of. The ultimate fate of the product and any by-products from production need to be addressed relative to their possible reuse or recyclability.
The incorporation of recycled materials into any product, no matter what its ultimate fate, can represent an opportunity to reduce the overall environmental impact of that product.

The assessment of packaging should examine the primary container, any secondary or further overwrap and the total package. Opportunities to reduce the size, weight and volume of the total package should be assessed. Additionally, materials should be considered which would contribute to the reuse and/or recyclability of the total package and its components. Recycled materials should be used in all packaging components where feasible. The preference when assessing packaging in order of priority are:

- **No Packaging**
- **Minimal Packaging**
- **Returnable or Reusable Packaging** - A returnable package is returned to C&D or the industry for reuse and redistribution. A reusable package may be refilled by a customer or third party.
- **Recyclable / Recycled Material in Packaging -** A package designed to be both recyclable and composed of recycled materials is most preferable. Where this is not possible the package should be designed to be recyclable. The use of recycled content only is less preferred because although it offers a use for recycled materials, the package itself is at the end of its life cycle and will enter the solid waste stream for disposal.

Recyclability of a package is maximized when that packaging is made of a homogeneous material or of materials that do not need to be further separated prior to introduction into

5.0 Product & Packaging Design (Cont.)

the recycling process. Labels, closures and seals should be of a like or similar material to the primary package.

Recycled content should be composed as much as possible of postconsumer waste materials - a waste product or material generated by a business or consumer which has served its intended end use and which is discarded for disposal or recycling.

6.0 Water Conservation and Wastewater Management

New production processes, raw materials, equipment design and plant support operations shall be selected and designed to minimize the use of water and the unnecessary generation of wastewater volume and/or the introduction of pollutants to the existing wastewater effluent streams. Consideration should be given not only for the regulatory requirements, but also to potential water quality impacts resulting from the discharge. All designs shall ensure that the generation, collection and treatment of wastewater occurs in a manner that minimizes the potential for negative impact on the environment.

Care must be taken to ensure that the on-site potable water distribution system and the water supply systems (on-site or public) are protected from the possible contamination or pollution potentially caused by backflow or backsiphonage from a non-potable source by eliminating cross connections and installing backflow prevention devices (double check valves, vacuum breakers, air gaps, reduced pressure principle backflow preventers).

Wastewater from process operations, wash water, non-contact cooling water, cooling tower/boiler blowdown or any other water stream may not be discharged to the exterior of the building under any circumstances. Wastewater may not be discharged to any sanitary sewer system, stormwater sewer system, surface water body or ground water system without prior permit approval from the local environmental regulatory agency.

Siting of equipment and processes should take into account the potential contribution of contamination and solids to stormwater runoff. All designs should seek to minimize direct stormwater contact with processes, chemicals, or waste storage areas.

Water conservation and waste minimization options that should be considered during design include:

- Collection and reusing rinse water and cleaning wastes, for example, using the final rinse as a pre-rinse of the next cleaning cycle.
- Cleaning lines with the use of foam/plastic pigs or compressed air instead of, or prior to, flushing with water.
- Using self-draining piping designs.

6.0 Water Conservation and Wastewater Management (Cont.)

- Using low volume, high efficiency washing: 1) with the use of new nozzle heads/higher pump pressures on existing hoses; 2) installing high-pressure spray washers; or 3) using steam cleaners.

- Develop equipment cleaning procedures that prevent pollution, for example, maximizing production runs to reduce cleaning frequency.

- Using recycled water for the initial cleanup of equipment, floors and spills.

- Using mops and squeegees to reduce the water used for floor washing.

- Using high-pressure spray hoses to reduce the amount of water needed during cleaning.

For non-manufacturing areas, the following water conservation measures should be considered and implemented as appropriate:

- Install low-flush toilets, faucet aerators, and low-flow showerheads.

- Install recirculating cooling water systems.

- Use landscaping designs that require little or no irrigation.

- Employee education to changing water-use habits.

7.0 Piping Systems and Storage Tanks

All tank and piping systems shall conform to state-of-the-art design standards and meet all applicable governmental regulations. Particular emphasis shall be given to designing efficient and responsive leak detection installations that will provide early warning of any uncontrolled release.

Storage tank system components (such as secondary containment, liquid level sensors, alarms, switches, cathodic protection and coatings) shall be of a quality design and obtained from reliable manufacturers who will provide effective follow-up maintenance and servicing.

Tanks, connections and piping systems that are decommissioned or abandoned as the result of a project shall be removed, except where removal would undermine the foundations of existing structures.

7.0 Piping Systems and Storage Tanks (Cont.)

Tank and piping systems must be designed, located, operated, maintained and closed in a manner that will assure "No Leaks, No Spills" protection. All piping and tubing must be properly supported to avoid vibration, unnecessary stress and movement. PVC tubing may be used for pneumatic service to 125 psi. Recommended construction practice is as follows:

1. Above Ground Systems
   - Single wall tank construction of material compatible with the intended contents and the surrounding environment.
   - Impervious dike for collection and control of spills, leaks and rainwater.
   - Containment for 110% of volume of the largest tank within the containment dike.
   - Overfill protection and level controls.
   - Spill/leak prevention for liquid transfer points.
   - Fire protection per appropriate regulations.
   - Security/controlled access.
   - Cathodic protection for steel equipment.
   - Compliance with all regulatory requirements (i.e., SPCC, NPDES, RCRA, including local and state as applicable).

2. Underground Systems
   - Underground systems are to be avoided if possible.
   - Double barrier systems:
     - Double wall corrosion resistant construction, or
     - Single wall corrosion resistant construction with secondary impervious liner, or
     - Single wall corrosion resistant construction with secondary impervious vault.
   - Double leak detection systems:
     - Internal to detect breach of first barrier, or
     - External to detect breach of second barrier (i.e., vault or liner)
   - Cathodic protection for steel equipment.
   - Overfill protection and level controls.
   - Spill/leak protection for liquid transfer points.
   - Fire protection per appropriate regulations.
   - Security/controlled access.
   - Compliance with all regulatory requirements (i.e., SPCC, NPDES, RCRA, including local and state as applicable).

8.0 Hazardous Waste / Demolition / Chemical Usage

Care should be taken to minimize the introduction of processes that create new chemical wastes or increased volumes of waste to a facility. The location EHS administrator must receive the Material Safety Data Sheet for any chemical substances contemplated for use on-site prior to their delivery at the site. Project planning must include the identification of the waste disposal practices and any permits that will be required.

8.0 Hazardous Waste / Demolition / Chemical Usage (Cont.)

During projects that include demolition, care must be taken to work with the location environmental administration and the headquarters EHS staff to avoid regulatory problems. Prior to demolition of any building structure, an environmental assessment of the building materials and contents should be conducted. Special demolition and disposal practices may be required. Demolition materials contaminated with lead, asbestos or other toxic materials require special handling and these need to be identified prior to the start of the project.

Prior to any excavation, local utility providers shall be notified to identify the presence of any underground cable or piping systems. If, during excavation an unexpected tank or piping system is encountered, the excavation shall be halted immediately until the situation can be properly assessed. The corporate EHS department should be notified of the situation and included in the planning of corrective action. Petroleum or chemical smelling soil encountered shall be segregated from other excavation wastes on plastic sheeting for sampling and characterization by the facility EHS department.

*9.0 **Contractor Safety and Insurance Requirements***

Refer to 05-210, *Contractor Compliance: Safety & Loss Prevention* for detail.

Prior to the start of any work by a contractor at any C&D site, the purchasing department or the project manager or his/her designated representative shall provide the contractor(s) with a copy of the *General Rules and Regulations for Contractors of C&D Technologies and Its Divisions and Subsidiaries and Their Authorized Subcontractors.* Prior to the start of work, an executed copy of the Contractor Safety Certification shall be obtained along with a copy of the contractor's safety record and documentation of the contractor's insurance coverage.

Where contractor employees are exposed to lead materials during their work at C&D sites, protective coveralls or uniforms that are then left at the facility for disposal or laundering should be used to prevent the carrying of lead out of the facility. When working in lead contaminated areas, contractors should be instructed to use disposable shoe covers or wipe off their work shoes prior to leaving the C&D building.

10.0 Handling Contaminated Equipment

Guidance for recommended decontamination and handling methods may be requested from corporate EHS. Consult with the facility Environmental Administrator for site-specific guidance.

11.0 New Construction

All new construction and remodeling projects greater than 10,000 square feet shall be constructed and protected in accordance with Factory Mutual Global and Research Standards and any and all other applicable standards, codes, ordinances, regulations, and/or laws. It is the C&D project manager's responsibility to obtain Factory Mutual approval of building plans prior to the start of construction.

12.0 *New and* ***Custom Built Equipment***

All new equipment must meet OSHA and corporate requirements for safety prior to start-up on the production floor. All pinch points and moving components capable of causing injury must be guarded, and where applicable, equipment must be equipped with palm buttons with anti-repeat function. No foot pedals are to be used without the review and consent of the facility Health & Safety Administrator. Hand-loaded equipment will be equipped with sliding dies or equivalent safety tools. All equipment must be designed such that it can be easily locked out or disconnected for maintenance.

All equipment will conform to the National Electrical Code and any local electrical / building safety codes. Green push buttons will be used for "Start" buttons and red will only be used as "Stop" buttons. Rigid metal conduit or liquid-tight flexible conduit should be used wherever possible. The use of cords should be avoided.

When specifying new equipment the generation of excessive noise must be considered and designed out wherever possible. No single component or complete system should produce noise levels in excess of 85 dBA within 3 feet of the footprint. This performance specification should be required at the manufacturing facility and not necessarily in the C&D environment. However, consideration should be given to reducing the overall noise level to less than 85 dBA in the final manufacturing environment prior to full production startup.

13.0 Purchase or Divestiture of Real Estate

An environmental survey for all real estate property included in business acquisitions and divestitures must be conducted to identify environmental liabilities associated with the site prior to real estate transfer. All newly purchased or leased properties including businesses shall be brought into compliance with the C&D Technologies, Inc. policies and procedures as soon as feasible. The Vice President of EHS shall be promptly notified of all purchase or divestiture activities as soon as practicable.

Environmental surveys will be conducted by the Vice President of EHS, his/her designee(s) or a designated environmental consultant.

Sales / service offices are excluded from this policy unless there is reason to believe based on site history or known site practices that there may be environmental issues.

13.0 Purchase or Divestiture of Real Estate (Cont.)

An acceptable environmental survey will, at a minimum, include the following:

- A comprehensive site and facility tour.
- A review of site and facility processes, procedures and current and past equipment.
- An investigation of prior and past site usage.
- The identification of potential environmental concerns.
- The identification of surrounding land use (off-site).
- A comprehensive inquiry to all government agencies that have environmental jurisdiction at the site.
- An assessment of the geological, hydrogeological, topographical conditions as well as the historical meteorological trends.

14.0 Ventilation Design and Fabrication Specifications

EXHAUST SYSTEMS

A. Dust Collectors

1. Dust collectors shall be selected to control emissions to the applicable environmental agency standards with a safety margin of at least 100 percent. For example, if the discharge limitation is 0.5 pounds per hour, the collector shall achieve removal so that emissions will not exceed 0.25 pounds per hour.
2. Provisions shall be made for dust free removal of collected materials. This can be accomplished by employing the use of screw conveyors or rotary air locks that deliver material into a drum or other covered container.
3. If fabric collectors are selected for use on operations that could be reasonably expected to generate sparks or flames (e.g., casting, cast-on, grinding welding), provisions must be made for devices to prevent these sparks from igniting the fabric. The preferred collector for such applications is a low-pressure drop wet scrubber if it will meet the filtration efficiencies mandated by the controlling environmental agency.

B. Ducting

1. All ducting is to conform to attached abbreviated version of the Construction Specifications from Industrial Ventilation, The Conference of Governmental and Industrial Hygienists.
2. Transport velocities: 4,000 targeted nominal (3,800 to 4,500 acceptable) where lead oxide is present; 2,500 targeted nominal (2,000 to 2,500 acceptable) for casting and acid mist applications.
3. Ducting shall be galvanized steel; however, if intended operation is acid laden, then fiberglass or PVC ducting should be used.

4. Indoors, PVC or fiberglass ducting can be used. However, if the temperature can exceed 140º F, fiberglass ducting shall be used.
5. Outdoors, fiberglass ducting is used due to the high temperatures that can be reached on the roof.
6. Field dimensions shall be taken to assure proper fit and function.
7. Turning vanes are to be used at all square corners or where radii are less than two times the diameter.
8. Duct joints shall be sealed with caulk. Caulk is to withstand 16 inches of water negative pressure without rainwater infiltration. Flanged joints are to be sealed with a twenty-five year silicone caulk.
9. Methods for sealing duct penetrations through the roof or walls shall be approved by plant engineer. Penetrations through the roof shall go through a roof curb.
10. Pressure treated four by fours shall be used to support all duct located on the roof.
11. All welded joints shall be primed and finish coat painted (silver).
12. Duct cleanout access on all roof- mounted ducting shall be on 12-foot centers. The cleanouts are to extend out from round ducts so that a door can be opened without having any spillage into the environment.

C. Hood Design

1. Exhaust slot designed is the preferred method of construction.
2. Hood capture velocity shall exceed the velocity of dust release into the air.
3. Slot area shall not exceed ½ of the plenum area servicing the slot.
4. Size slots and system volume for a velocity of 2000 feet per minute (fpm).
5. No hood and/or slot are to exceed 5 feet in length unless it is serviced by two exhaust duct connections.
6. All slots to be covered with expanded grating to prevent gloves, rags and other materials from being sucked into the ventilation system.
7. Hoods shall taper into exhaust ducts at no more than a 90° angle.
8. Hoods shall be positioned so as to draw dust down or away from the operator's breathing zone. In no case is an exhaust hood to be positioned so that the operator can place themselves between the exhaust and the source of dust generation.
9. Hood settling chambers or plenums shall be supplied at all locations where heavy chunks of oxide are expected to accumulate. The purpose of the chambers is to prevent the heavier materials from transporting through the duct system and into the dust collectors.
10. In all cases where a settling chamber is installed and/or where collected materials are expected to accumulate, hinged, air tight access door shall be installed to permit removal of the accumulated dust.

D. Enclosure

1. All dust producing operations shall be enclosed as much as practical.
2. Enclosure design should begin by enclosing the entire operation and by supplying openings only where operator access is necessary.

E. Fans

1. Fan selection is to be made to best service the intended operation; e.g., fiberglass or PVC for acid laden exhaust, steel with high temperature bearings for high temperature applications, spark proof materials and motors where a potential for explosion exists.
2. All fans shall be belt driven and shall be guarded to prevent injury.
3. All fans shall be supplied with bolted access doors for access to wheels.
4. Under no circumstances are squirrel cage fan wheels to be used. Acceptable wheels include forward curved, backwardly inclined, paddle wheel (only where material transport is expected.
5. All non-floor mounted fans shall be supplied with vibration isolation bases and flexible inlet and outlet connections.
6. All fan motors shall be sized and selected to allow a 15 percent increase in the exhaust volume.
7. Fan inlet and outlet ducts shall be straight (no turns) for a minimum of four equivalent duct diameters unless specifically approved. In the event that the straight sections are not possible, a fan inlet box supplied by the fan manufacturer shall be installed and turning vanes are to be installed at the fan discharge.
8. Where possible, fans are to be located on the downstream side of the dust collection device to maintain a negative pressure on the collector. This ensures that any air leakage will result in discharges into the environment.
9. The fan outlet stack shall be independently supported so that the fan does not have to support the stack.
10. Test ports shall be provided in the stack to allow for stack testing. Plant engineer shall approve location of these test ports.
11. All non-galvanized steel located outdoors shall be primed and finish coat painted.

SUPPLY AIR SYSTEMS

A. Make-up Air Unit

1. Make-up air handling unit shall be a direct-fired air-handling unit manufactured by a manufacturer regularly engaged in the production of direct-fired air handlers.
2. Make-up air units shall be packaged air handlers which include casing, modulating burner, non-overloading fan, mixing chamber, modulating return air dampers and automated controls.
3. Make-up unit shall be constructed in accordance with ANSI Standards Z83.18 and Z83.4. Construction shall also conform to NFPA Standard 90A.
4. Unit shall be designed to provide slightly more make-up air than exhaust air.
5. Air handler shall, as specified in the specifications or on the plans, incorporate one of the following outdoor air control schemes:
    a. 100 % outdoor air (air make-up)
    b. 20 % outdoor air (air rotation)
    c. 20 - 100% variable air volume

d. 20 – 100%. Outdoor air (air Management)

6. Unit shall have both high-temperature and low-temperature shutdown.
7. Depending on facilities insurance carrier, gas manifold shall comply with required or specified insurance specifications (Factory Mutual (FM), Industrial Risk Insurance (IRI) etc.).

B. Ducting

1. All ducting is to conform to attached Construction Specifications from Industrial Ventilation, The Conference of Governmental and Industrial Hygienists.
2. Ducting in make-up air systems shall have a duct velocity between 1,800 to 2,500 fpm.
3. Duct with an aspect ratio of 1:1 (square) is preferred to reduce the space required for installation.
4. Round duct can be used if the project engineer approves costs and application.
5. For the majority of applications, the ducting shall be galvanized steel.
6. The use of fabric-perforated duct (blow-up) is permissible if large amounts of air have to be provided and the air cannot be provided through laminar flow diffusers. The velocity in the duct shall be 1,000 fpm and the velocity through the holes shall be 2,000 fpm.
7. All ducts supplying air to a diffuser shall have an opposed blade damper to vary and control the airflow to the diffuser.
8. Pressure treated four by fours shall be used to support all duct on the roofs.
9. Field dimensions shall be taken to assure proper fit and function.
10. Turning vanes are to be used at all square corners or where radii are less than two times the diameter.
11. Make-up air intakes shall be located so as to prevent the re-entrainment of contaminants exhausted from the plant.
12. Where necessary, make-up air delivery systems shall have the capability of raising the air temperature of the discharge air to 68° F. In all cases where heat is supplied, the systems supplying the heat are to conform to the US Factory Mutual Standards for the type of fuel being used.
13. All air supplied via an air make-up system shall be filtered by a nuisance type filter with a rated collection efficiency of 40 percent on dust-sized particles (> 10 microns)
14. Methods for sealing duct penetrations through the roof or walls shall be approved by plant engineer. Penetrations through the roof shall go through a roof curb.

C. Hood Design

1. The preferred design of a laminar flow diffuser is 2 foot by 4 foot; however, a 4-foot by 4-foot hood can be used if more than 1,600 cfm is required. If more than 1,600 cfm is to be delivered through diffuser, more than one duct shall be used.
2. Diffuser velocity shall be between 200 to 250 feet per minute (fpm) at the discharge face.
3. Diffusers shall deliver a uniform velocity across the face of the discharge.

4. The airflow is designed so that the velocity measured at the employees breathing zone is 100 – 150 feet per minute.
5. If supply hood is to be used in conjunction with exhaust enclosure or workbench, the supply air should be balanced so that the make-up air is provided equal to the amount of exhaust air.
6. Diffuser shall be constructed with several layers of perforated sheets that are removable for cleaning.
7. Lighting shall be installed with the diffuser as a means of task lighting.
8. Diffuser discharge face shall be located 7'-6" above the floor.

D. Fans

1. Fan selection is to be made to best service the intended operation; e.g., fiberglass or PVC for acid laden exhaust, steel with high temperature bearings for high temperature applications, spark proof materials and motors where a potential for explosion exists.
2. All fans shall be belt driven and shall be guarded to prevent injury.
3. All fans shall be supplied with bolted access doors for access to wheels.
4. All non-floor mounted fans shall be supplied with vibration isolation bases and flexible inlet and outlet connections.
5. All fan motors shall be sized and selected to allow a 15 percent increase in the exhaust volume.
6. Fan inlet and outlet ducts shall be straight (no turns) for a minimum of four equivalent duct diameters unless specifically approved. In the event that the straight sections are not possible, a fan inlet box supplied by the fan manufacturer shall be installed and turning vanes are to be installed at the fan discharge.
7. All non-galvanized steel located outdoors shall be primed and finish coat painted.

CONSTRUCTION SPECIFICATIONS FOR EXHAUST SYSTEMS

A. General

Interior of all ducts shall be smooth and free from obstructions with joints either welded or soldered airtight.

B. Materials

Ducts shall be constructed of black iron welded or of galvanized sheet steel riveted and soldered unless the presence of corrosive gases, vapors and mists, or other conditions makes such material impractical. Galvanized construction is not recommended for temperatures exceeding 400º F. Welding of black iron lighter than 18 gauge is not recommended.

C. Construction

1. For average exhaust systems on non-corrosive applications, the following metal thickness shall be supplied:

Diameter of Straight Ducts	MINIMUM U.S. Standard Gauge for Steel Duct		
	Class I	Class II	Class III
to 8”	24	22	20
Over 8” to 18”	22	20	18
Over 18” to 30”	20	18	16
Over 30”	18	16	14

   Additional metal thickness must be considered for Class II and Class III. The designed is urged to consult the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) standards for complete engineering design specifications.

   Class I. Light Duty: Includes non-abrasive applications such as paint spray, woodworking, pharmaceutical and food products; discharge ducts from dust collectors.

   Class II. Medium Duty: Includes non-abrasive material in high concentration (low pressure pneumatic conveying); moderate abrasive material; and highly abrasive materials in light concentrations. Typical examples are conveying of chemicals and wood dust; exhaust of grain dusts; buffing and polishing.

   Class III: Heavy Duty: Includes applications with high abrasive in low concentrations. Typical examples include abrasive cleaning operations; foundry shakeouts and sand handling systems; sand handling; and grinding.

2. For most conditions, round duct is recommended for industrial ventilation, air pollution control, and dust collecting systems. Compared to non-round duct, it provides for lower friction loss, and its higher structural integrity allows lighter gauge materials and fewer reinforcing members. Round duct should be constructed in accordance with Reference 5.11. Metal thickness required for round industrial duct varies with classification, static pressure, reinforcement, and span between supports. Metal thickness required for the different classes are based on design and use experience.

3. Rectangular ducts should only be used when space requirements preclude the use of round construction. Rectangular ducts should be as nearly square as possible to minimize resistance, and they should be constructed in accordance with Reference 5.12.

4. Spiral wound duct should only be used in interior spaces and not in any class above Class II. Unless flanges are used for joints, the duct should be supported close to each joint, usually within 2 inches. Joints should be sealed by methods shown to be adequate for the service.

5. Hoods should be a minimum of two gauges heavier than straight sections of connecting branches, free of sharp edges and burrs, and reinforced to provide necessary stiffness.

6. Longitudinal joints should conform to the standards established by the American welding Society (AWS) structural code. Double lock seams are limited to Class I applications only.

7. Girth joints of duct shall be made with inner lap in direction of air flow, with 1" lap on diameters to 19" and 1-1/4" laps for diameters over 19".

8. Elbows and bends should be a minimum of two gauges heavier than straight lengths of equal diameter and have a centerline radius of at least two and preferably two and one-half times the pipe diameter. Larger centerline radius elbows are recommended where highly abrasive dusts are being conveyed.

9. Elbows of 90º should be of a five-piece construction for round ducts up to 6 in. and of a seven-piece construction for larger diameters. Bends less than 90º should have a proportional number of pieces. Prefabricated elbows of smooth construction may be used.

10. Where the air contaminant includes particulate that may settle in the ducts, clean-out doors should be provided in horizontal runs, near elbows, junctions, and vertical runs. The spacing of clean-out doors should not exceed 12 feet for ducts of 12-inch diameter and less but may be greater for larger duct sizes. Removable caps should be installed at all terminal ends, and the last branch connection should not be more than 6 inches from the capped end.

11. Transitions in mains and sub-mains should be tapered. The taper should be at least five units long for each one-unit change in diameter or 30º included angle.

12. All branches should enter the main at the center of the transition at an angle not to exceed 45º with 30º preferred. To minimize turbulence and possible particulate fall out, connections should be to the top or side of the main with no two branches entering at opposite sides.

13. A straight duct section of at least six equivalent duct diameters should be used when connecting to a fan. Elbows or other fittings at the fan inlet will seriously reduce the volume discharge. The diameter of the duct should be approximately equal to the fan inlet diameter.

14. Discharge stacks should be vertical and terminate at a point where height or air velocity limit re-entry into supply air inlets or other plant openings.

D. System

1. Provide duct system supports of sufficient capacity to carry the weight of the system plus the weight of the duct half filled with material and with no load placed on connecting equipment.

2. Avoid using blast gates or other dampers. However, if blast gates are used for system adjustment, place each in a vertical section midway between the hood and the junction. To reduce tampering, provide a means of locking dampers in place after the adjustments have been made.

3. Allow for vibration and expansion. If no other considerations make it inadvisable, provide a flexible connection between the duct and the fan. The fan housing and drive motor should be mounted on a common base of sufficient weight to dampen vibration or on a properly designed vibration isolator.

4. Locate fans and filtration equipment such that maintenance access is easy. Provide adequate lighting in penthouses and mechanical rooms.

E. Codes

Where federal, state or local codes conflict with the preceding, the more stringent should be followed. Deviations from existing regulations may require approval.