

## CARBON MONOXIDE EXHAUST SYSTEM DESIGN CRITERIA FOR VEHICLE MAINTENANCE FACILITIES

It is important to understand that this contaminant is a known and lethal health hazard. Before attempting to design a system, it is imperative that sufficient information about the application is gathered so that the designed system will provide the end user with a safe work environment. A sample "System Design Worksheet"(form 1) is attached. *Make sure that the largest engine to be tested is identified.* It is essential that the end user provide this information at the start of the design process. For the installed system to function correctly, the sizing of the connecting hose, ducting and fan must be determined based on the *type of vehicle, type of engine, cubic inch displacement, and testing requirements.*

Vehicle Exhaust Systems differ from other types of air handling applications in several ways. First, the air being conveyed contains a high concentration of health related hazardous materials including carcinogenic contaminants. It frequently enters the system in a super heated state, under pressure and at high velocity, creating a rapidly expanding gaseous compound. The exhaust system to be designed must have sufficient air flow capability to overcome the flow rate as well as the expansion rate of the exhaust gasses with a negative pressure system. In addition, it must not have an affect on the performance of the engine being tested by creating either a backpressure or vacuum condition, which can alter the readings on the testing instruments. For this reason selection of the connecting components to the exhaust pipe, hose size, and air flow rate are critical considerations.

Discussion with the end user regarding the type and location of the exhaust pipes, along with engine information and testing requirements is essential when reviewing prospective manufacturers of the exhaust systems to be used as the basis of specification. Design professionals in the vehicle exhaust industry are available and typically willing to provide assistance. They should be consulted regarding application requirements and current product information.

### APPLICATION: AUTO/LIGHT TRUCK

Most of the vehicles in this category have gas engines up to 400 cu/in, and small diesel engines up to 300 cu/in. Current building codes dictate 300 CFM per bay as an exhaust air requirement through a source capture system. This is adequate in most cases; however, many auto manufactures offer diesel trucks with 6+ liter diesel engines. These require 450 CFM to handle the required high idle run tests. In facilities that maintain these vehicles, several bays need to be dedicated for this use and have an exhaust pick up, ducting and fan sized accordingly.

## SYSTEM DESIGN: AUTO/LIGHT TRUCK

Underfloor duct systems with floor receptacles offer convenient location of exhaust ports close to auto tailpipes and require a minimum of hose; overhead ducted systems, however may be preferred. With either design, a single exhaust pickup should be located between each car bay so that whichever side the exhaust pipe is located on, there will be an exhaust hose within easy reach. In the case of dual exhaust vehicles, a hose from each side can be used and on the rare occasion where two adjacent vehicles, one or both having a dual exhaust, are to be run simultaneously, “Y” assemblies can be provided to accommodate venting each of the vehicles at the same time. *Two vehicles should never be required to be vented through the same exhaust pickup.*

Vehicle exhaust is an expanding contaminant that needs to be conveyed at higher velocity than typical air moving systems to minimize the expansion effect. For this reason *duct sizing should be based on 2500 fpm*. In underfloor systems, the minimum pipe diameter is based on the size requirements for the floor receptacle. As a result, velocities in ducting farthest away from the fan may appear low, however, where hose assemblies are stored in the under floor duct, much of the cross sectional area is obstructed, allowing the flow rate to be adequate for a functional system. Schedule 40 PVC pipe is an acceptable ducting medium for conventional underfloor systems\*, galvanized spiral pipe for minimum 5” static pressure is acceptable for overhead systems. Since EPA regulations do not allow direct drainage of these systems to ground water, additional considerations for underfloor systems need to include provisions for removal of water that may inadvertently collect in the system and the collection of debris that may be swept and/or sucked into the system. An illustration of a trunk and riser duct arrangement is included (illustration 1) that incorporates a dry sump for collection and evaporation of condensation along with a screened refuse cleanout plenum for preventing debris from being drawn into the fan.

*\*Stainless steel spiral should be used in underfloor dyno applications in place of PVC.*

*Velocity in the connecting hose needs to be at least 3400 fpm* for effective capture and conveyance of the exhaust at the tail pipe. For this reason 4” diameter hose is used in providing the 300 CFM per bay requirement for gas cars/light trucks and 5” diameter for diesel pickup trucks removing 450 CFM. The configuration of the adapter that actually connects to the exhaust pipe and the manner in which it attaches is a matter of choice. The end user should participate in this selection. Taking the time to review product literature and requesting samples for evaluation is extremely helpful.

For auto and light truck no-load testing, the exhaust hose should be rated for a minimum of 375F continuous exposure. The approach to hose storage relates to both system configuration and cost. For the *underfloor receptacle* (illustration 2), hose storage is accomplished by sliding the flexible hose assembly into the floor receptacle; for overhead systems two basic types are available, hanging hoses affixed directly to the ducting and storage reels to which the hose is attached and wound up. The *hanging hose* (illustration 3) can be pulled up to store above head height by hand with either a *rope and pulley, cable and winch, or spring balancer*. In addition there is a telescoping hose assembly available. If using *storage reels* (illustration 4), retraction can be accomplished with a *hand winch, spring retractor, or power operator*. Total system costs will vary considerably based on both equipment selection and installation considerations. It is important to understand the needs and budget of the end user at the beginning of the design process.

## APPLICATION: DIESEL ENGINE VEHICLES

The use of diesel engines is extremely diverse, utilizing a wide range of engine size and power requirements. It is important to note that not all diesel engines power vehicles, many power equipment such as pumps, generators, and compressors. While most diesel engines are 4 cycle, there is a sizable number of 2 cycle engines in use, most are turbo charged and all 2 cycle engines produce twice as much exhaust as the same cubic inch displacement 4 cycle engine. Where automobile maintenance facilities have less diversity in engine size, diesel shops can be exposed to a much wider range of sizes and types of engines. It is therefore, imperative that accurate information about the application be obtained at the beginning of the design process.

There are four ranges of operating performance to deal with in designing a system for exhausting the output from turbo diesel engines: *idle running only, no-load testing through maximum RPM, partial load for hydraulic testing, and full load dynamometer testing.*

The following chart provides an *approximate* exhaust CFM requirement per cu/in for 4 cycle\* turbo diesel engines:

IDLE RUNNING ONLY	CU/IN X .6
NO-LOAD TESTING TO 2100RPM	CU/IN X 1.5
PARTIALLOAD/HYDRAULIC TESTING	CU/IN X 2.05
FULL LOAD DYNAMOMETER TESTING**	CU/IN X 4.15

\*To determine CFM requirements for 2cycle engines, multiply the 4 cycle total by 2.

\*\*Testing requirements for dyno's vary considerably; get complete information on the specific application and consult industry professionals for air volume and design criteria.

## SYSTEM DESIGN: DIESEL ENGINE VEHICLES

Diesel exhaust is a highly compressed gaseous contaminant that expands very rapidly once outside the exhaust pipe. At high RPM, even at no-load, it can emit from the exhaust pipe at flow rates exceeding 7,000 fpm. To entrain the exhaust and not effect the engine performance, additional ambient air is needed to bleed into the system at the adapter connection. This does not create a direct suction or backpressure on the engine and provides a cooling effect that retards the expansion rate and constrains the exhaust stream injected into the pickup assembly, preventing the hazardous fumes from backing out of the system. For design purposes, the CFM values that are derived from the table above have the required additional air built in to the equation.

*Duct velocities in these systems need to be kept at a minimum of 2500 fpm.* When designing around standard duct diameters, velocities will vary, but they should be kept within a 300 fpm range to maintain a consistent flow that will keep the expanding contaminants moving safely through the ducting and out of the facility. Higher velocity systems for engines over 1000 cu/in and/or dynamometer applications are appropriate, but need not exceed 3500 fpm as a design velocity. It is important that discharge ducting not be reduced in size, requiring an increase in velocity on the discharge side of the fan.

*Velocity in the connecting hose needs to be at least 3400 fpm* but should not exceed 4500 fpm. The hose diameter is determined by these flow rates the CFM required for the cu/in displacement of the largest engines to be tested in conjunction with type of testing to be performed. If the exhaust gases are attempted to be conveyed at lower fpm and/or less than the required CFM, it is likely that the expansion rate of the contaminant will overcome the flow rate in the hose causing hazardous fumes to back out of the system at the intake connection. If velocities greater than 4500 fpm are used, the hydrocarbons and other solid particulate in the air stream will “sand blast” the interior of the exhaust hose, especially at bend points, abrading the thermal containment compounds that coat the fabric from which the hose is made. This will cause premature hose failure.

Temperature is always a potential problem, especially if the actual performance requirements exceed the system design. Diesel exhaust temperatures can range from 450F at extended idle to over 1000F during load testing. For this reason, the exhaust hose should be rated for a minimum of 700F continuous exposure. For applications that involve consistent partial load testing and/or dynamometer testing, hose having an 1100 continuous exposure rating should be used.

Once the exhaust requirements have been determined based on the cu/in displacement and testing parameters for the vehicles to be maintained, exhaust pickup locations need to be identified. The primary connecting hoses or “drops” need to be placed in close proximity to the exhaust pipes. For ease of use, lateral reach should be kept to a minimum. To do this it is important to know if the majority of the vehicles have high or low exhaust and if there are dual exhaust vehicles and/or vehicles with unusual exhaust pipe configurations. The type of hose storage equipment to be used depends a great deal on application and also on cost. If the opportunity exists to place the drops between bays and be able to conveniently serve both bays alternately with the same hose, a significant cost savings is accomplished. If, however, the distance between bays is too great, attempting to use one drop will result in longer hose and be more cumbersome to handle.

If all or most of the exhaust pipes are high, a *hanging hoses* (illustration 3) approach, utilizing shorter primary hoses can be used that are permanently connected to the duct system. This simplifies storage requirements and extension hoses can be provided that easily couple to the primary hoses to reach the occasional low exhaust pipe. Where a wider range of exhaust pipe locations occurs in the same bay, the use of storage reels (illustration 4) may be useful. If obstructions exist, such as overhead cranes, the use of *extension arms* (illustration 5) with lateral reach and positioning capability need to be evaluated. In addition, high exhaust pipes should be able to be connected from the ground with the use of *positioning poles* or “*diesel cane*” type adapter (illustration 6). Review manufacturers' product information on extension arms, connection adapters, couplings, safety brake-away connectors, and positioning hardware for specific equipment selection. Total system costs will vary considerably based on both equipment selection and installation considerations. It is most important to understand the needs and budget of the end user up front. Having good information at the start of the design process is critical.

# Vehicle Exhaust System Design Worksheet

For system evaluation, complete both sides and return to Car-Mon representative

Submitted by \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

Phone \_\_\_\_\_ Fax \_\_\_\_\_ E-Mail \_\_\_\_\_

Facility worksheet applies to: \_\_\_\_\_

Contact \_\_\_\_\_ Phone \_\_\_\_\_

# A

## Private Passenger Vehicles

Type of vehicle:  Cars  Vans  Pick-up Trucks  High Performance  Other

Make and Model of Vehicles \_\_\_\_\_

\_\_\_\_\_

Is dynamometer testing performed?  Yes  No If yes, is it:  Engine dyno  Chassis dyno  
 Single exhaust  Dual exhaust  Special exhaust configurations (include illustration in Section D on back)

## Commercial and Industrial Vehicles

Truck  Construction equipment  Bus  Military vehicle  Other \_\_\_\_\_

Make and Model of Vehicles \_\_\_\_\_

\_\_\_\_\_

Is dynamometer testing performed?  Yes  No If yes, is it:  Engine dyno  Chassis dyno

Are there natural gas vehicles?  Yes  No

Type of exhaust pipe (check all that apply):  Single exhaust  Dual exhaust  Horizontal  Raincap  
 Curved stack  Straight stack  Special exhaust configurations (include illustration in Section D on back)

## Engine Data

Diesel  Gas  2-cycle  4-cycle

Engine manufacturer \_\_\_\_\_ Model No. \_\_\_\_\_ C.I.D. or liters \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

Are engines turbocharged?  Yes  No If yes, what is maximum boost pressure? \_\_\_\_\_ p.s.i.

Maximum rated RPM of engine: \_\_\_\_\_ Maximum operating RPM of engine: \_\_\_\_\_

## Building Data

Existing  New Type: \_\_\_\_\_

Number of bays: \_\_\_\_\_ Overhead crane?  Yes  No Electrical requirements \_\_\_\_\_ / \_\_\_\_\_ / \_\_\_\_\_

Potential obstructions (include illustration in Section D on back):

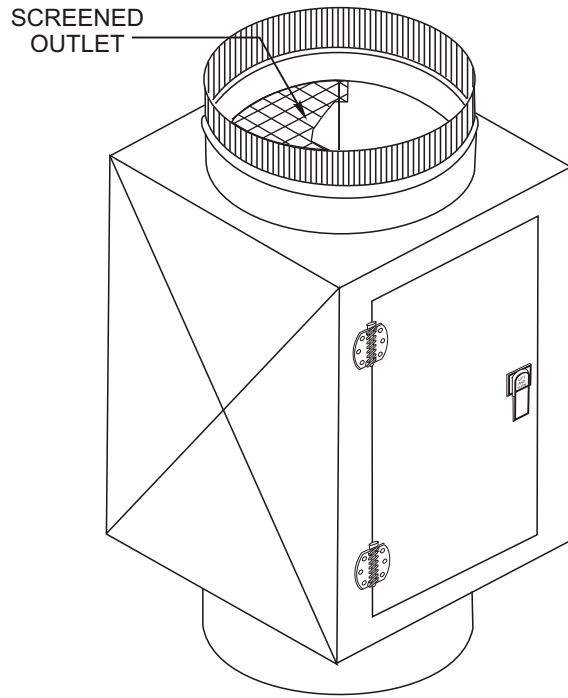
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# B

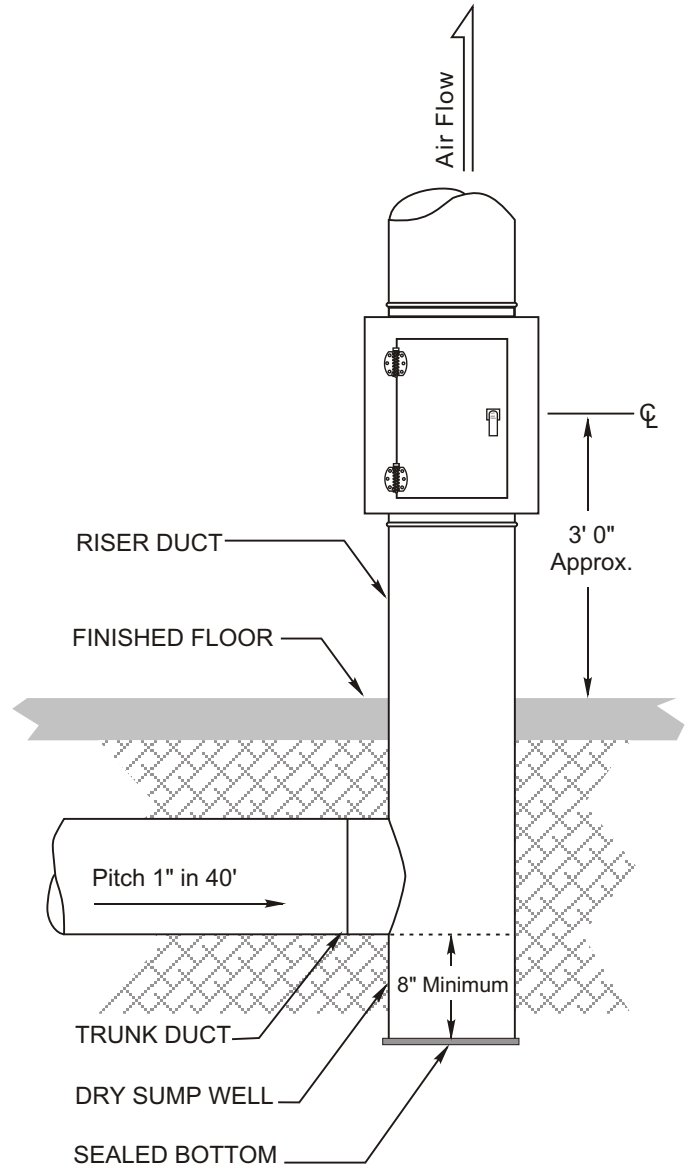
# C

# ILLUSTRATION #1 REFUSE CLEAN-OUT PLENUM

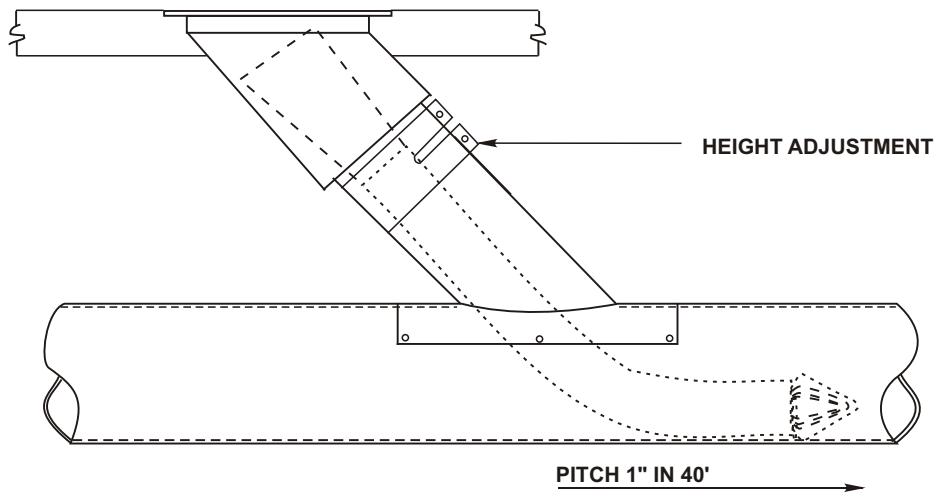
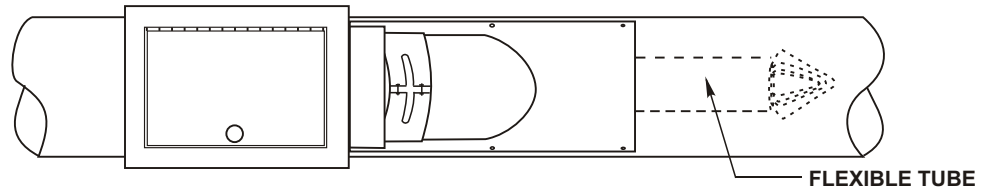


Air Flow

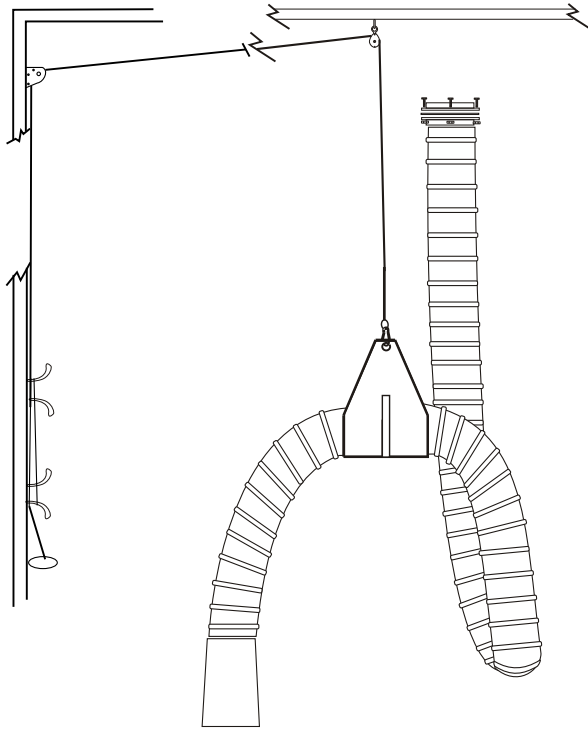
An upward-pointing arrow with the text "Air Flow" written vertically next to it, indicating the direction of air circulation.



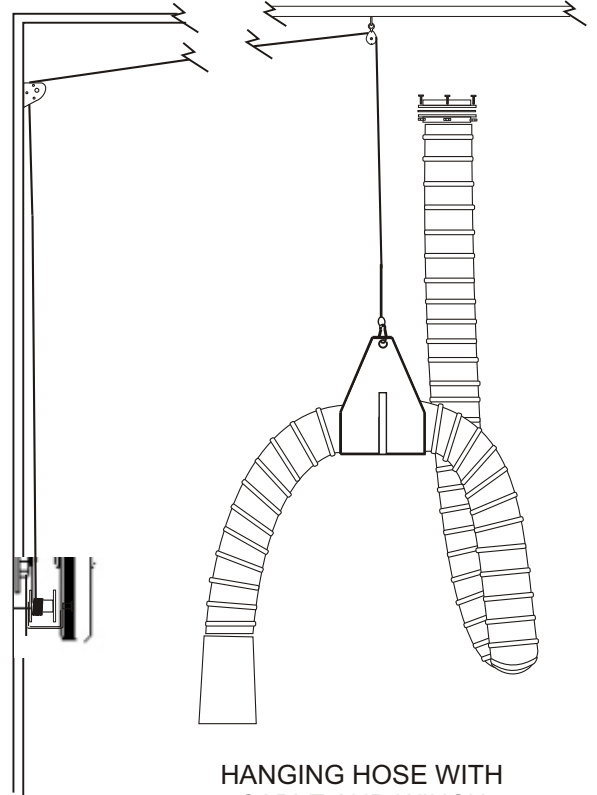
## ILLUSTRATION #2 UNDERFLOOR RECEIPTACLE



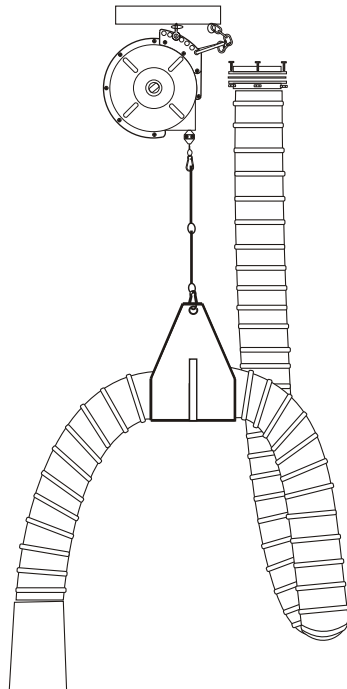
### ILLUSTRATION #3 HANGING HOSE



HANGING HOSE WITH  
ROPE & PULLEY

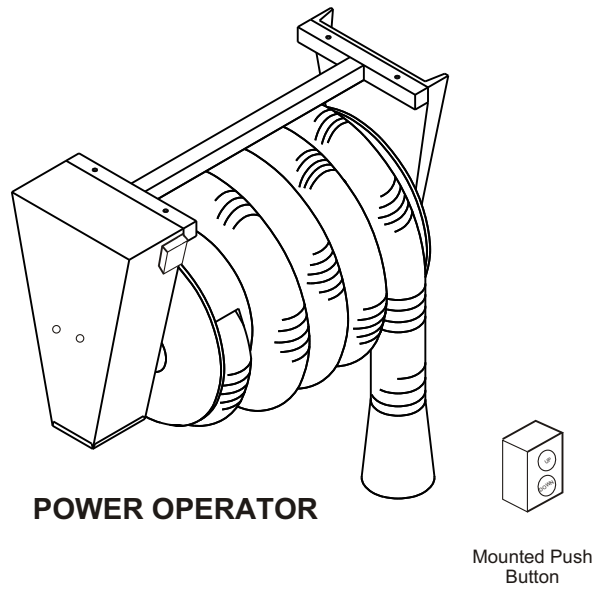
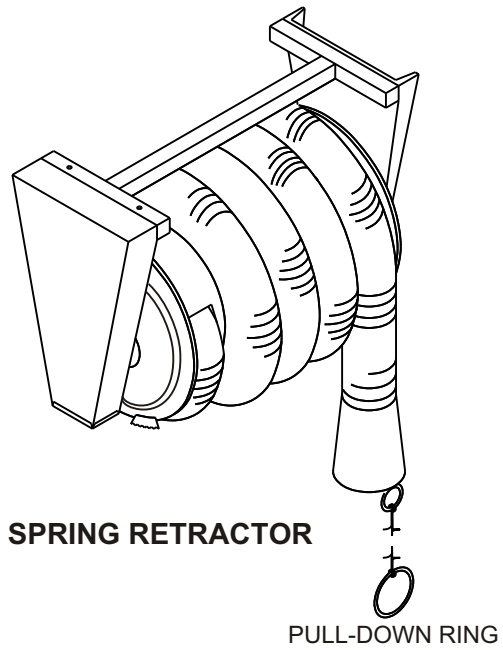
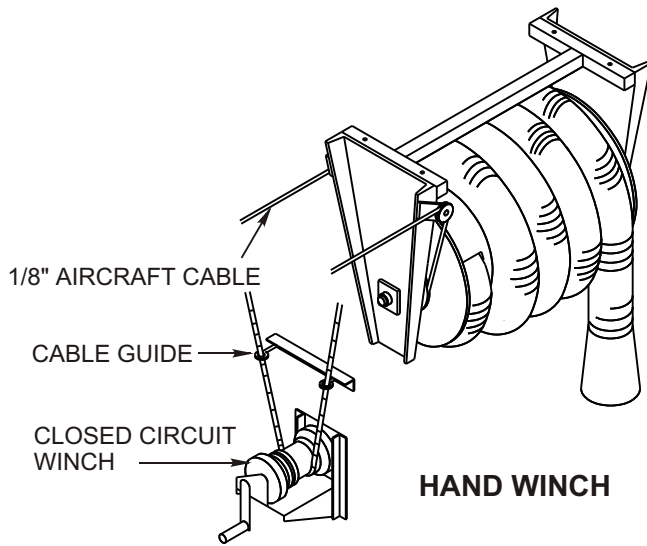


HANGING HOSE WITH  
CABLE AND WINCH

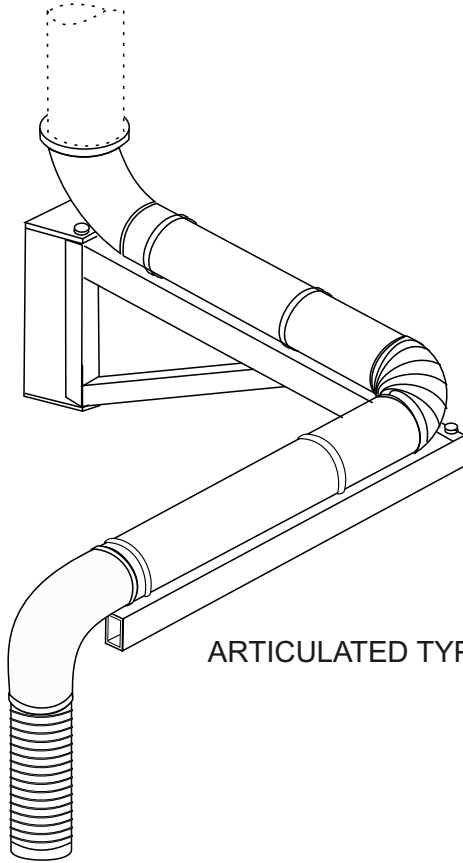


HANGING HOSE WITH  
SPRING BALANCER

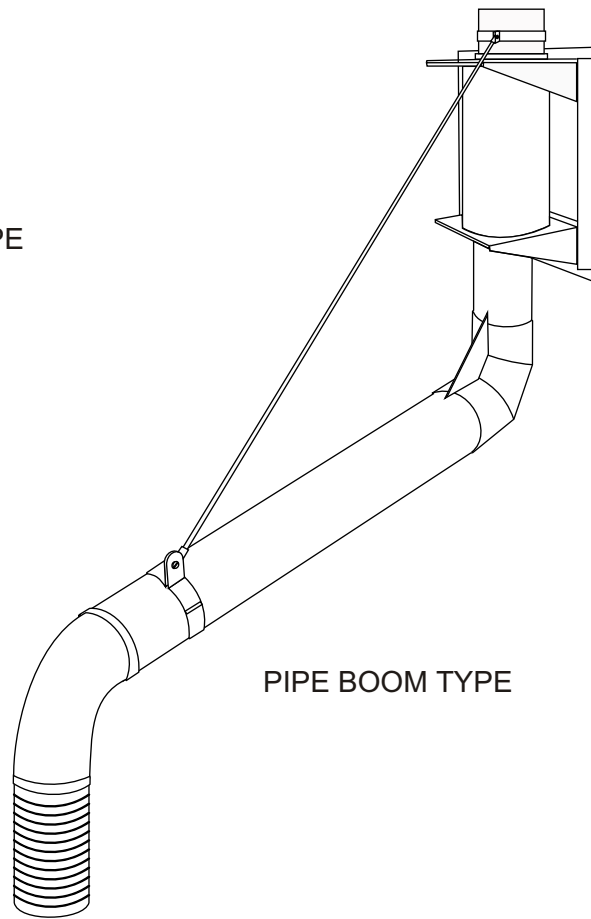
# ILLUSTRATION #4 STORAGE REELS



**ILLUSTRATION #5  
EXTENSION ARMS**

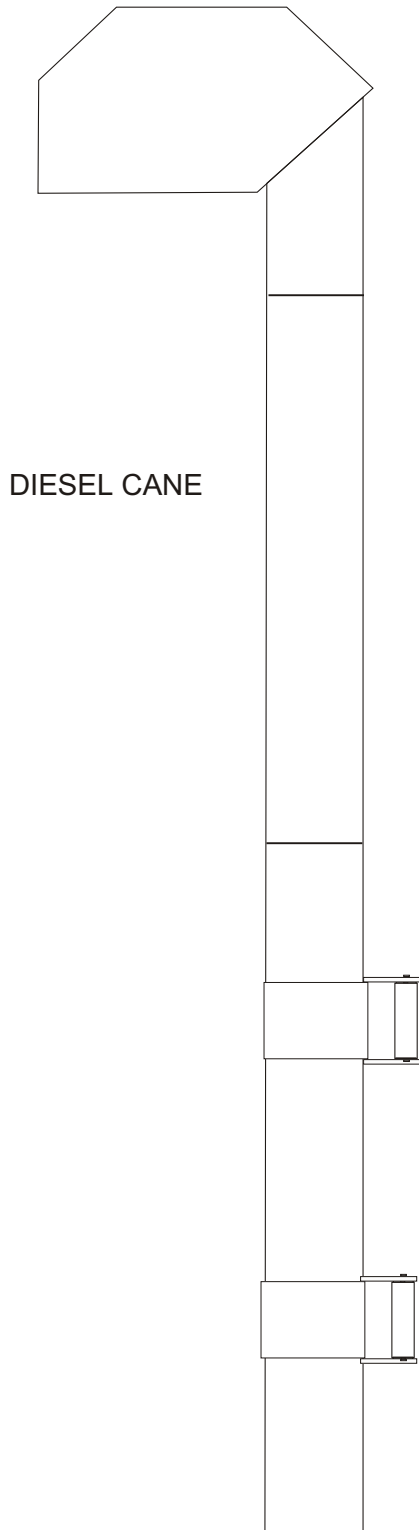


ARTICULATED TYPE

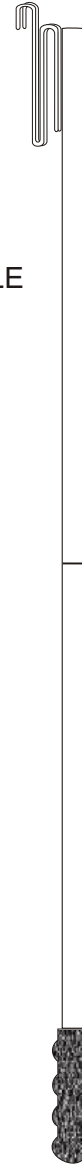


PIPE BOOM TYPE

**ILLUSTRATION #6  
POSITIONING ACCESSORIES**



DIESEL CANE



POSITIONING POLE