CATERPILLAR®

Electric Power Application and Installation Guide

Crankcase Ventilation

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Crankcase Ventilation

Crankcase Emissions

Crankcase emissions or "Fugitive Emissions" result from piston ring blow-by. The volume of blow-by varies due to cylinder pressure, piston ring pressure and component wear. Crankcase emissions contain essentially exhaust gases, wear particles and oil/air/gas/fuel emissions. The proportions of these elements vary due to fuel type, engine type, engine speed, load and maintenance history. Blow-by is made up of Hydrocarbons (HC), Carbon Monoxide (CO), Carbon Dioxide (CO_2), Nitrogen Oxides (NO_x) and traces of sulfates and aldehydes. Crankcase, Hydrocarbon emissions are normally 3% of the total exhaust emissions tested at the mid-life of the engines. However, due to piston ring tolerances, the crankcase Hydrocarbon emissions can become as much as 20% of the total Hydrocarbon emissions. The amount of NO_x present in the blow-by decreases depending on the air/fuel ratio of the engine. The more lean the intake, the less NO_x that should be present. The sulfates and aldehydes will change depending on the fuel. An engine running on diesel fuel, landfill gas or digester gas will have more sulfides present in the blow-by than an engine running on natural gas.

As blow-by forms it builds pressure inside the crankcase; hence, it is important that the pressure is relieved. To prevent pressure buildup within the crankcase, vent tubes are provided to allow gas to escape (see Figure 1). Removing the blow-by from the crankcase is not very difficult, but the

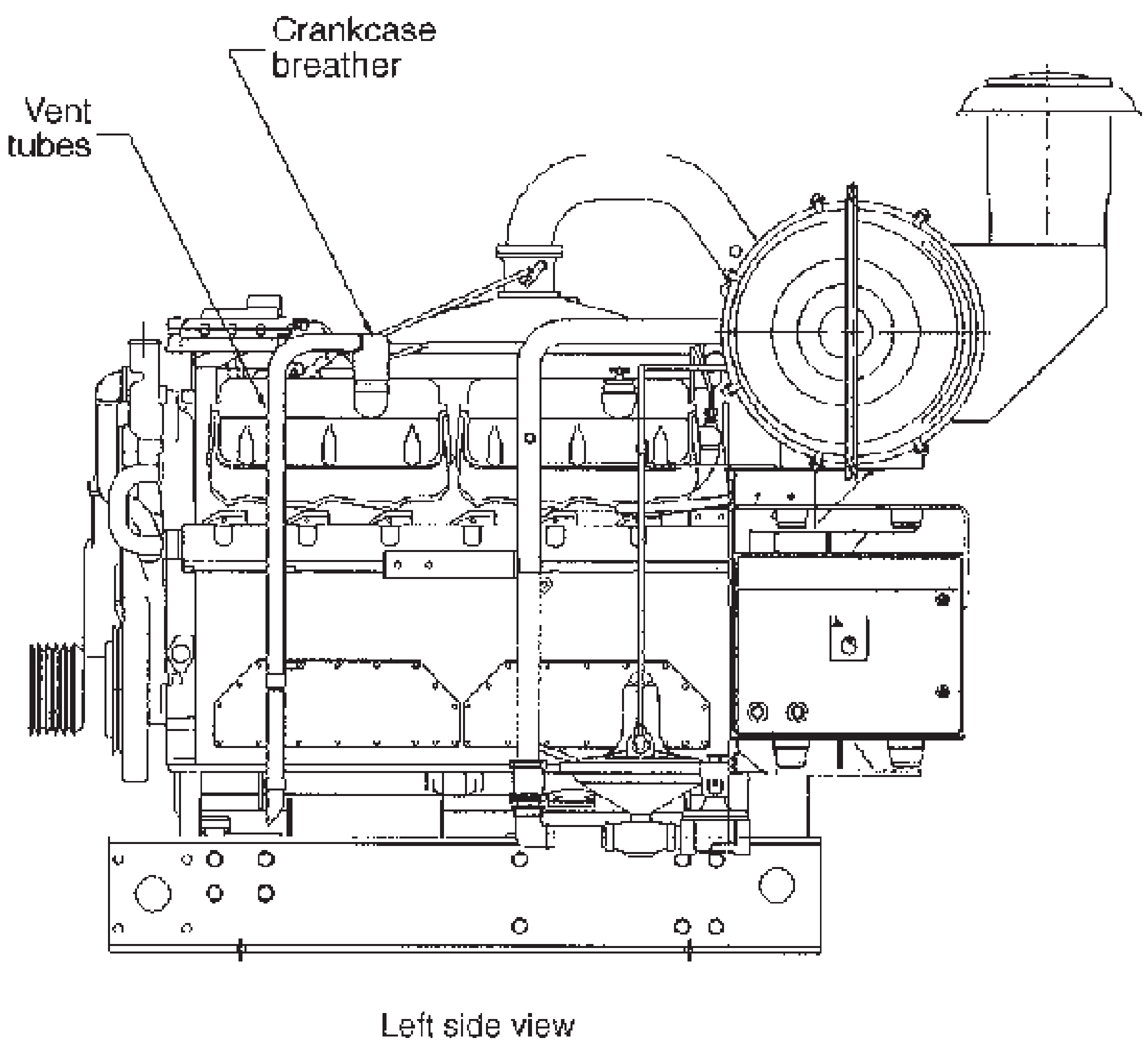

Figure 1.

question of what to do with the blow-by once it leaves the crankcase is challenging. Basically, there are two techniques used in dealing with blow-by: "Ingestive" and "Non-Ingestive." "Ingestive" involves placing the blow-by back into the combustion process and "Non-Ingestive" is using some method of venting the blow-by to the atmosphere.

The following paragraphs outline the benefits and drawbacks of each type of system.

Crankcase Ventilation ("Ingestive")

As emission laws become more stringent, it is inevitable that crankcase emissions (or blow-by) will be included in total system emission values. Certain parts of Europe and California are already counting blow-by in the emission numbers. In the future, ventilating crankcase emissions to the atmosphere will be discouraged or prohibited.

To eliminate the worry of crankcase emissions, the blow-by can be returned to the combustion process. This method is commonly known as Positive Crankcase Ventilation (PCV) in the automobile industry. On naturally aspirated engines, like most cars, the blow-by can easily be returned to the combustion process without much added cost or engine component concern. The addition of a turbo-charger makes PCV a much more challenging task.

There are two ways of re-introducing the blow-by fumes back into the combustion process on a turbo charged engine. The blow-by can be put in the system at low pressure (before the turbocharger) or at high pressure (after the turbo charger).

Low Pressure Ingestive System

A low pressure, ingestive system involves piping the crankcase emissions into the low pressure side of the turbo charger (see Figure 2). The blow-by is drawn from the crankcase through the vent tubes, into the oil condensing device (or blow-by filter) and "sucked" back through the air cleaner by the turbo charger.

There are a number of hazards that can occur when applying an "ingestive" PCV system to a turbocharged engine, including:

- Reduced spark plug life
- Fouled or damaged turbocharger or aftercooler
- Reduced detonation margin, engine detonation, damaged pistons
- Reduced load capability and operation
- Reduced efficiency
- Reduced component life

Additionally, most tests have shown that no matter how effective the blow-by filter, over time, enough oil will be adsorbed to coat the aftercooler. This oil will act as an insulator, reducing the cooling capabilities of the aftercooler.

The G3516B packages offer an optional low-pressure ingestive PCV system in the price list. This system is specially designed for use with Caterpillar Gas Engines. Caterpillar highly recommends that this system be used if a PCV is going to be applied on this engine. This system complies with the design recommendations listed below (including a standard cleanable aftercooler.)

If a non-Caterpillar supplied system is going to be applied, extreme care should be observed to make sure the system design complies with the following list of recommendations for designing a low pressure, ingestive, PCV system:

- A cleanable aftercooler should be used and cleaned regularly.
- The blow-by MUST be sent through a filtering system prior to entering the turbocharger.
- The system must ensure the draw on the crankcase does not exceed 26 mm H_2O (1.0 in. H_2O). (i.e. A pressure relief valve should be placed between the turbocharger and the filtering system)
- Blow-by filters should be replaced or cleaned every oil change.
- System must be designed to handle two times the engine blow-by measurements to account for normal engine wear.

- A minimum oil removal rate of 99.97% is required. Oil removal rate can be calculated as follows:

$$\% \text{ Removal} = \frac{\text{Blow-by concentration (before PCV – after PCV)}}{\text{Blow-by concentration before PCV}}$$

- Caterpillar's recommendation is that the oil should NOT be returned to the crankcase for a non-approved system. If oil is planned to be returned to the crankcase, trend S•O•S samples of recovered oil every 100 hours of engine operation up to 800 hours to certify that the recovered oil does not reach condemning limits. If oil exceeds condemning limits, DO NOT return oil to the crankcase.

- System must have a bypass to eliminate the possibility of crankcase over pressurization if the filter element clogs.

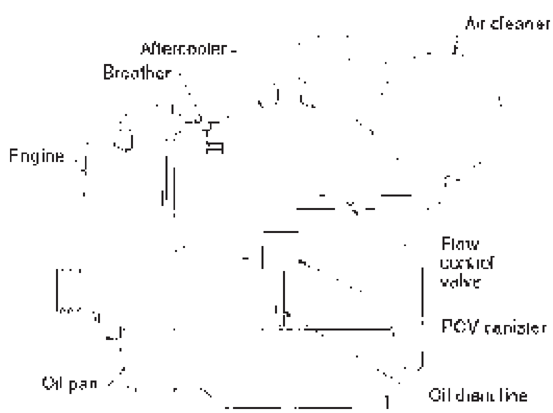

Figure 2. Ingestive, low pressure system.

High Pressure Ingestive System

A high pressure PCV system involves removing the blow-by from the crankcase and pumping it directly into the intake plenum (see Figure 3). This type of system removes the risk of coating the aftercooler and turbo, but the crankcase fumes should still be filtered to reduce the amount of oil going into the intake stream.

The limiting factor of this type of system is cost. An extra pump would be expensive and difficult to mount. Therefore, this type of system has been bypassed for the less effective, but more economical low pressure system.

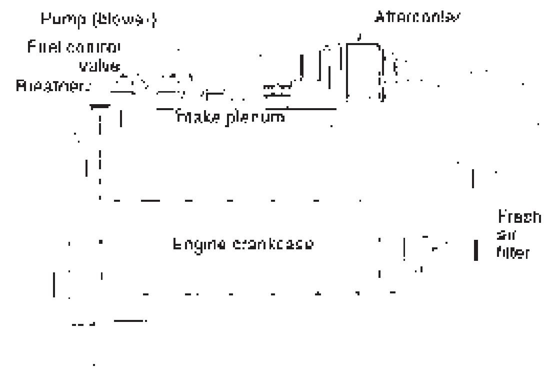

Figure 3. Ingestive, high pressure system.

Water in Engine Oil

Crankcase emissions are essentially concentrated exhaust fumes; therefore, they contain a considerable amount of water vapor. When oil is separated from the blow-by and filtered back into the oil sump, there is the risk of water condensing. Engines have a considerable amount of water in their exhaust, which has resulted in many PCV suppliers recommending that the excess oil be drained into a separate container.

When water is introduced to the engine oil, it forms an emulsion that clogs oil filters. As the amount of water increases, the ability for the additives to disperse the water in the oil decreases. The heat of the oil usually burns off water particles, but condensed blow-by contains so much water that the water can actually cool the oil and form sludge. Cooler oil temperatures may cause water and oil to combine to form dangerous acids that can corrode metals, thus reducing the lubricating qualities of the oil.

Introducing Fresh Air into Crankcase

Removing blow-by out of the crankcase may not be enough to ensure an emission free crankcase environment. It may be necessary to add fresh air directly into the crankcase in order to distill the air inside the crankcase. The quantity of this air should be about two times the volumetric flow rate of the blow-by.

One risk of adding fresh air might be the cold ambient air cooling off the crankcase, resulting in water condensing from the existing crankcase fumes. Therefore, it may be necessary to heat the air before introducing it to the crankcase.

Crankcase Pressure

The conventional wisdom of internal combustion engines is that the engine should operate at a slight positive pressure in order to keep any "engine surrounding" contaminants out of the engine. The effect of a PCV system tends to create a slight vacuum on the crankcase [0.25 kPa (1 in. H_2O) MAXIMUM]. The negative crankcase pressure is accepted in order to have fugitive emissions removed from the crankcase.

Under no circumstances should crankcase pressures vary more than 25.4 mm (1.0 in.) H_2O from ambient barometric pressure for 3300, 3400, and 3500 diesel and gas engines as well as 3600 diesel engines. The shutdown or maximum value for G3600 engines is 102 mm H_2O (4.0 in. H_2O). Restrictions higher than the limit on passive systems will worsen any oil leaks. A powered system should draw no more than a 25.4 mm (1.0 in.) H_2O vacuum, or dirt and dust could be drawn into the engine past the main seals. Measurement should be made at the engine dipstick location with the engine at operating temperature, speed and load.

Crankcase Ventilation ("Non-Ingestive")

Most areas do not include crankcase emissions as part of the total emissions for an engine. In order to save cost and potential engine hazards, it may benefit the customer to vent the blow-by to the atmosphere. The following discussion explains how venting an engine's blow-by should be performed.

When ventilating the crankcase, it is important not to vent crankcase fumes directly into the engine room without filtration. Fumes may clog air filters and increase air inlet temperature, possibly causing engine damage. Problems in electrical equipment can be caused by exposure to the fumes. The fumes can also be a health hazard if discharged in a poorly ventilated room. Therefore, crankcase emission should be ventilated to the atmosphere, by means of a venting system.

When there are multiple engines at a site, a separate vent line is required for each engine to prevent fumes and moisture produced by a running engine from entering an idle engine. The addition of moisture into an engine can cause corrosion and buildup of harmful deposits.

Crankcase vent pipes must be large enough to minimize back pressure. Normal blow-by on a new engine will be approximately 0.02 m^3/hr bkW (0.5 ft^3/hr bhp). Adequately size the pipes to accommodate a worn engine, with a blow-by rate of 0.04 m^3/hr bkW (1 ft^3/hr bhp). Size the vent pipe with a maximum of 13 mm H_2O (0.5 in. H_2O)pressure drop at full load.

These formulas allow the crankcase ventilation designer to calculate a pipe diameter which will give a back pressure less than 13 mm H_2O (0.5 in. H_2O).

Calculate back pressure by:

$$P\ (\text{kPa}) = \frac{L \times S \times Q^2 \times 3.6 \times 10^6}{D^5}$$

$$P\ (\text{in. } H_2O) = \frac{L \times S \times Q^2}{187 \times D^5}$$

P = Back pressure (kPa), (in. H_2O)
psi = 0.0361 × in. water column
kPa = 6.3246 × mm water column
L = Total Equivalent Length of pipe (m) (ft)
Q = Exhaust gas flow (m^3/min), (cfm)
D = Inside diameter of pipe (mm), (in.)
S = Density of gas (kg/m^3), (lb/ft^3)
S (kg/m^3) = 1.08
S (lb/ft^3) = 0.067

To obtain equivalent length of straight pipe for various elbows:

$L = \frac{33D}{X}$ Standard Elbow (Radius of elbow = pipe diameter)

$L = \frac{20D}{X}$ Long Elbow (Radius > 1.5 diameter)

$L = \frac{15D}{X}$ 45° Elbow

$L = \frac{66D}{X}$ Square Elbow

Where X = 1000 mm or 12 in.

Calculate the pipe diameter according to the formula, then choose the next larger commercially available pipe size.

As can be seen, if 90° bends are required, a radius of two times the pipe diameter helps lower resistance.

Loops or low spots in a crankcase vent pipe must be avoided to prevent condensation from building up in the pipe and restricting the normal fumes discharge. Where horizontal runs are required, install the pipe with a gradual, 41.7 mm/m (1/2 in/ft), slope from the engine (see Figure 4). The weight of the vent pipes will require separate off-engine supports as part of the installation design. Any horizontal or vertical run of pipe that cannot be disassembled for cleaning should have clean-out ports installed.

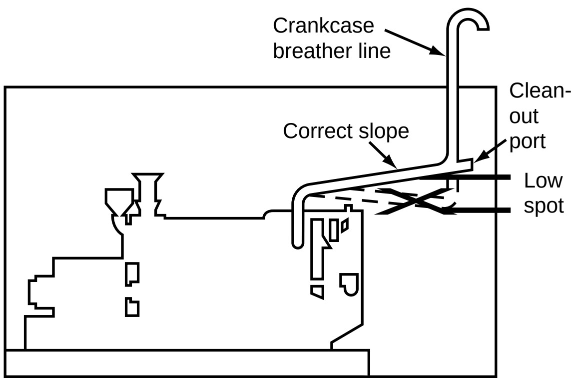

Figure 4. Pipe installation.

Crankcase fumes must not discharge into the air ventilation ducts or exhaust pipes. They will become coated with oily deposits creating a fire hazard.

Vent the crankcase pipe directly into the atmosphere and direct it to keep rain or spray from entering the engine. Give consideration to equipment located near the discharge area as well as to the building itself. If not handled properly, very small amount of oil carry-over can accumulate and become unsightly and even harmful to auxiliary equipment.

A drip collector installed near the engine will minimize the amount of oil discharge through the vent pipe. It is necessary to provide some type of trap that will prevent crankcase gases from venting into the engine room, (see Figure 5). If a trap as in Figure 5B is used, the designer must be sure the drip collector can be removed or drained for disposal. Another alternative is to install a valve on the end of the drip pipe and periodically drain it.

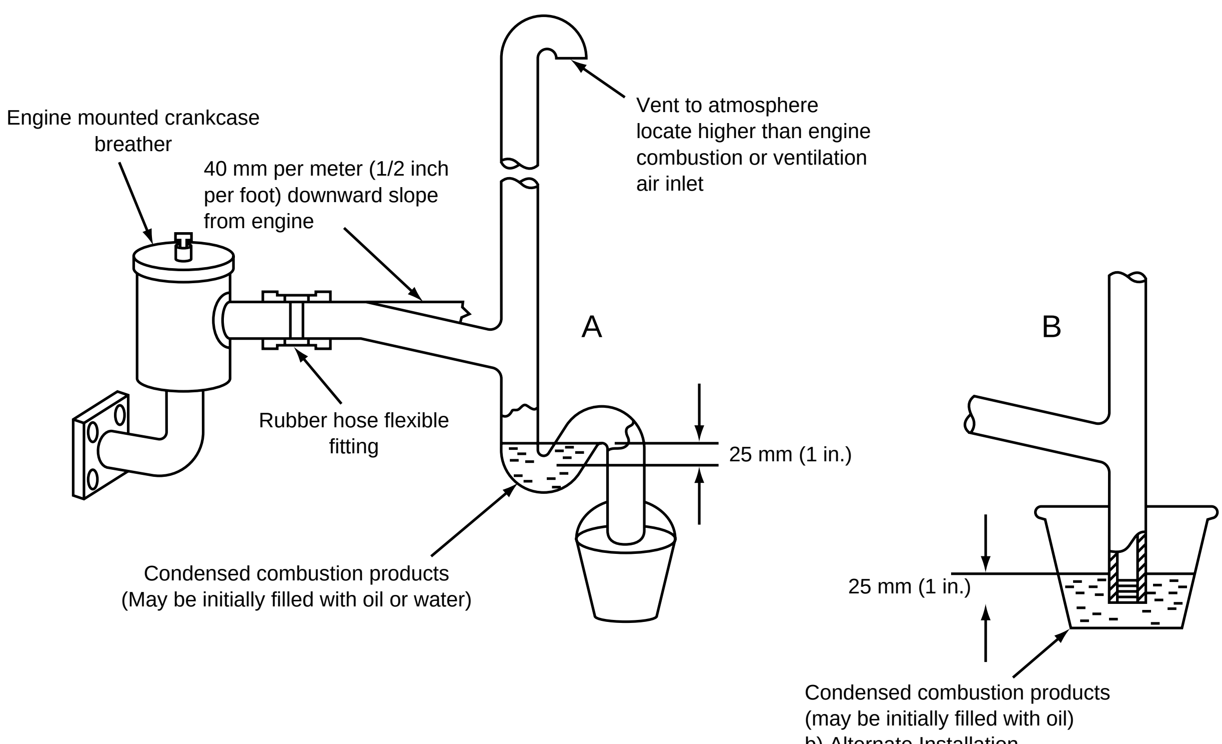

Figure 5. Illustrations of traps.

Figure 6 illustrates a powered fumes disposal system for a multiple engine installation. There are two main advantages to a powered system: the fumes will become diluted with air for better dispersal into the atmosphere, and it can improve oil life by removing the nitric oxides from the crankcase before they can cause nitration of the oil.

Since a vacuum will be drawn with a powered system, the addition of a small air filter somewhere on the engine crankcase is required. This will filter the air entering the crankcase and prevent dirt from being introduced into the oil. A valve connected in the line to each engine controls the flow of crankcase fumes out of the engine.

Crankcase Emission's Affect on Oil Life

One of the goals of a PCV system is to increase the oil life of the engine. The removal of crankcase fumes can reduce the amount of oil degradation. It has been shown that a non-ingestive PCV system can double the oil life of an engine. However, the affects of PCV on oil life will vary with engine size, load, engine hours and ambient conditions.

Crankcase Emission Amount

Normal blow-by on a new engine will be approximately 0.02 m^3/hr bkW (0.5 ft^3/hr bhp). Adequately size the pipes to accommodate a worn engine, 0.04 m^3/hr bkW (1 ft^3/hr bhp). Size the vent pipe with a maximum of 13 mm H_2O (0.5 in. H_2O) pressure drop at full load.

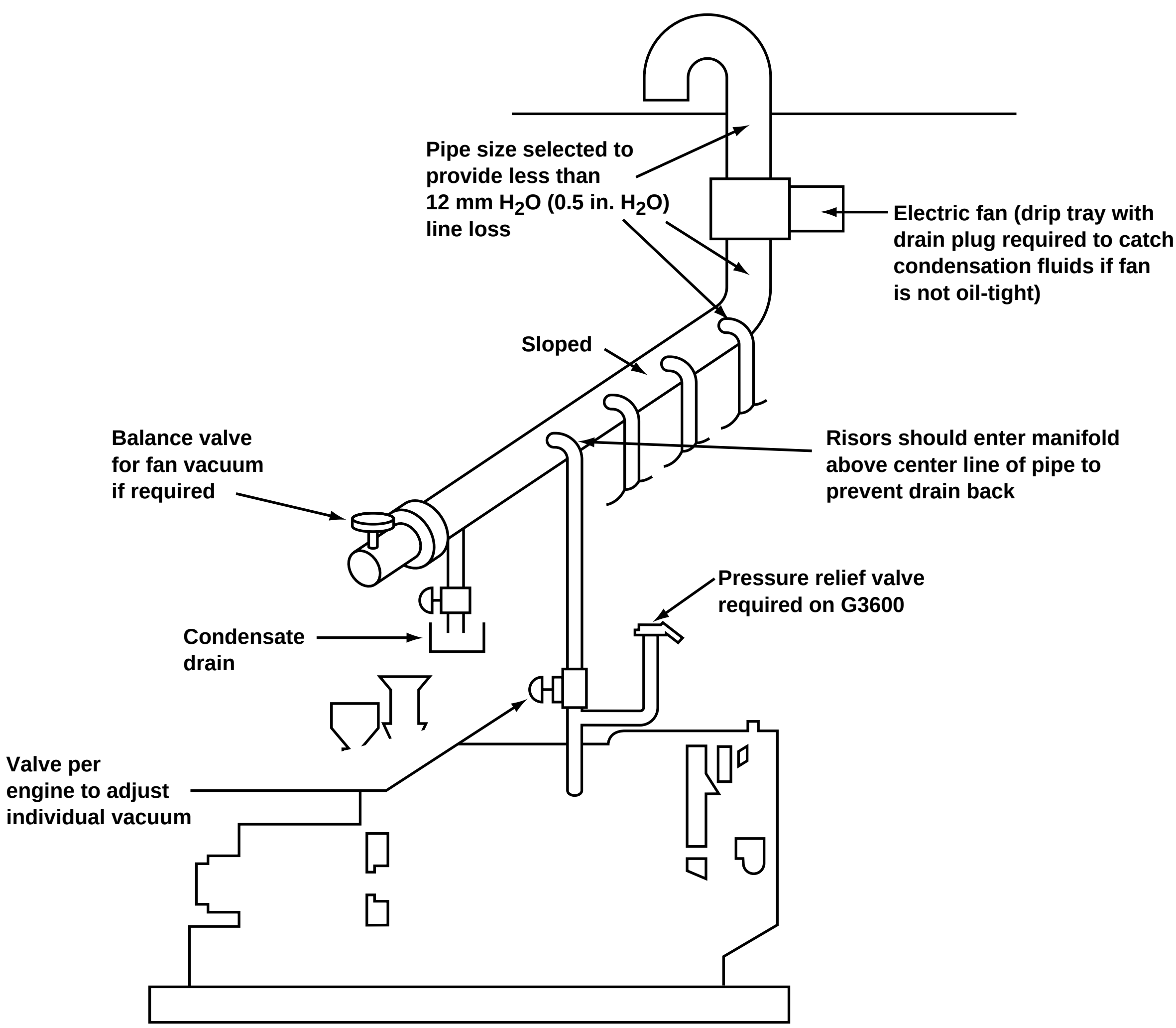

Figure 6. Powered fumes disposal system.

Measuring Engine Blow-by and Diluting Crankcase Emissions

The following is a step-by step procedure on how to dilute the crankcase with fresh air. This will measure the blow-by of an engine. This information is needed when designing a crankcase ventilation system.

To set up the system, a Blow-by/Air Flow Indicator (part number 8T2700) is required.

1. Measure the amount of combustion blow-by for a given engine. This is done by closing the crankcase ventilation valve, blocking the crankcase air filter, and attaching the Blow-by Indicator to the oil fill spout. The reading on the indicator is the engine's blow-by. All measurements are to be taken with the engine running at rated speed, load, and temperature.

2. Unplug the crankcase air filter and connect the Blow-by Indicator to it. Slowly open the crankcase ventilation valve until the indicator reads the same as in step 1.

This procedure will allow an equal amount of air to be drawn into the crankcase as is being blown past the piston rings. This will sufficiently dilute the fumes and increase oil life.

This procedure should be done for each engine. Make a final check of the crankcase pressure to insure the vacuum on the engine is less than 25.4 mm H_2O (1 in. H_2O).

Sometimes it is difficult to precisely size the blower for a powered system. If the only blower available is too large, it may draw too much vacuum on the crankcase ventilation valves and make adjustments difficult.
To overcome this problem, a balance valve can be connected on the vacuum side of the blower to allow air to be drawn in the system and reduce the vacuum pressure on the adjusting valves.

An optional relief valve may be used to limit crankcase pressure to 0.14 kPa (0.5 in. H_2O). This is used to avoid problems if the crankcase ventilation fan is not engaged.

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