# APPLICATION NOTES

No. WED10/90

**Information from the Application Engineers at Waukesha Engine/Waukesha Power Systems**

## LANDFILL GAS FUEL TREATMENT SYSTEMS

Within the last decade, the utilization of landfill gas has gained both economical and environmental acceptance. The extraction of landfill gas provides a valuable source of energy (in the form of methane), while simultaneously reducing the hazards created by the emissions of the raw gas into the local surroundings. The utilization of landfill gas is not without potential drawbacks, however. Due to the nature of landfill gas production, this fuel commonly contains a variety of liquids, solids, and halogenated hydrocarbons (acidifiers),which, if allowed to remain in the fuel, can quickly lead to corrosive or abrasive engine damage. The selection of proper gas processing equipment is therefore of critical concern for landfill applications.

A survey of existing landfill sites shows that a wide variety of equipment exists for the removal of liquids, solids, and halogenated hydrocarbons. This article will discuss the various fuel treatment components available for removal of these contaminants, followed by recommendations as to the selection and arrangement of this equipment.

***NOTE:** The recommendations regarding the removal of solids and liquids can also be applied to field gas and digester gas applications.*

### LIQUID REMOVAL

Landfill gas is saturated with moisture as it emerges from the landfill wells. If allowed to condense, this moisture can lead to corrosion and liquid-loading problems within the fuel train. There are four basic methods for removing this moisture from the gas: droplet interception, cooling/condensing, absorption, and adsorption.

### DROPLET INTERCEPTION

To remove liquid droplets (also referred to as "aerosols"), often both a scrubber vessel and coalescing filter are used. A scrubber generally consists of a large cylindrical vessel containing numerous serpentine baffles. As the gas stream enters this vessel, the gas velocity is reduced, causing the heavy water droplets to fall to the vessel bottom due to gravity. The gas stream then enters the baffled section, where gas velocity increases. Here, inertia will cause the remaining droplets to be thrown against the baffle walls with vigorous force, thus "scrubbing" the droplets from the gas stream. These droplets eventually trickle down the baffle wall and drop to the vessel bottom. A drain is then used to remove the collected liquids.

A coalescing filter consists of a tube-shaped cartridge of randomly oriented glass fibers. As the gas stream flows through this media, the liquid droplets will impinge and adhere to these fibers. These droplets then travel along the fibers to a point where several fibers intersect. Here, the droplets unite or "coalesce" to form larger droplets, as shown in Figure 1. This process continues until the droplets have enough mass to trickle down the length of the cartridge. At this point, the droplets fall into a low turbulence area at the bottom of the coalescer housing, where a drain is used to remove the collected liquid.

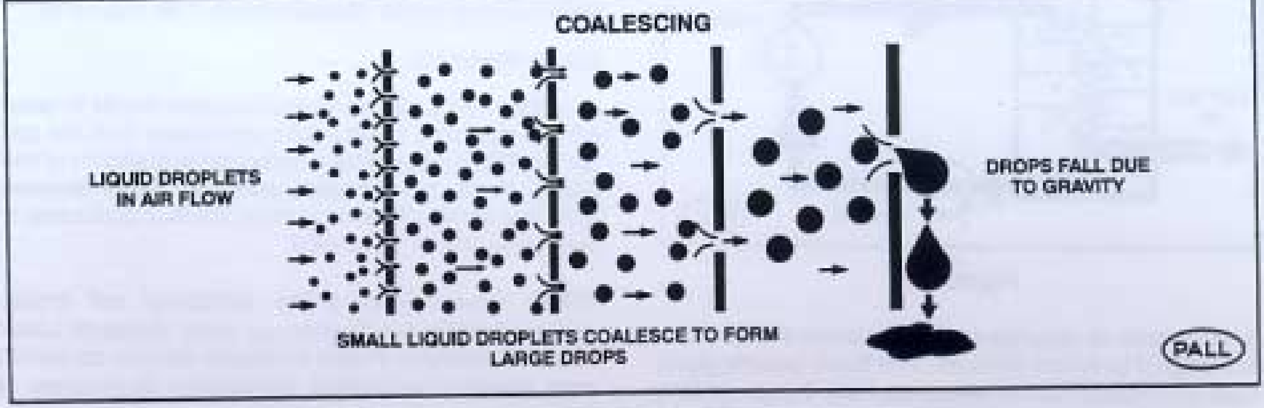



Figure 1.

A coalescing filter has, in effect, an infinite capacity for liquid droplets, since these droplets can be coalesced and drained from the filter housing as quickly as they enter. Due to its construction, however, a coalescing filter will also trap solid particles in its media, which will eventually create a large enough pressure drop to necessitate change-out of the cartridge.

## COOLING/CONDENSING

Another method of drying the gas stream involves the use of a heat exchanger. Various devices and thermodynamic processes can be used for this purpose, with gas-to-air and gas-to-refrigerant being the most common. The function of this device is simply to reduce the temperature of the landfill gas. As the gas temperature is reduced, the gas loses its capacity to hold moisture. This moisture then condenses out, and is separated from the gas stream through the use of a droplet interception device (i.e. dropout tank, scrubber, coalescer, etc.).

## ABSORPTION

The absorption (or "deliquescent") type of dryer utilizes a vessel containing salt beads (or "desiccants") which have a high affinity for moisture. As water vapor comes in contact with this desiccant, a reaction takes place, causing the water vapor to turn liquid, and the desiccant to dissolve. The resulting liquid solution then flows to the bottom of the vessel, where it is drained away. Because they are consumed as they absorb moisture, the desiccant beads must be replenished on a regular basis.

For this type of device, the gas stream must be filtered prior to reaching the desiccant, so as to prevent compressor oil carry-over from fouling the desiccant. Post-filtration is also required, so as to prevent any desiccant dust from traveling downstream, where it could cause abrasive damage to internal engine parts.

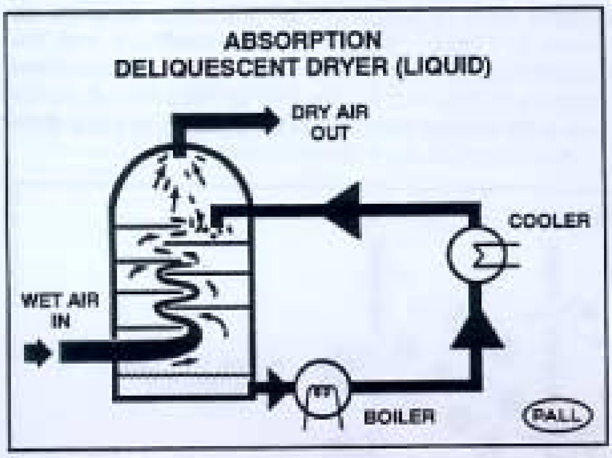



Figure 2.

Another form of absorbent drying involves the use of a liquid agent to attract moisture. This liquid (usually glycol based) is brought into intimate contact with the gas stream, where the water vapor is drawn out of the gas stream due to its attraction to the glycol. This glycol/water solution is then separated from the now dehydrated gas stream, and is fed to a regeneration system where the water and other contaminants are removed (see Figure 2). The regenerated glycol is then used again for further absorption.

## ADSORPTION

Unlike deliquescent desiccants (which dissolve when moisture is absorbed), an adsorbent desiccant remains solid. With this type of desiccant, the water vapor is molecularly attracted to the surface layer of the beads; there are no chemical interactions (see Figure 3). Activated alumina and molecular sieve catalysts are commonly used as adsorbing desiccant materials.

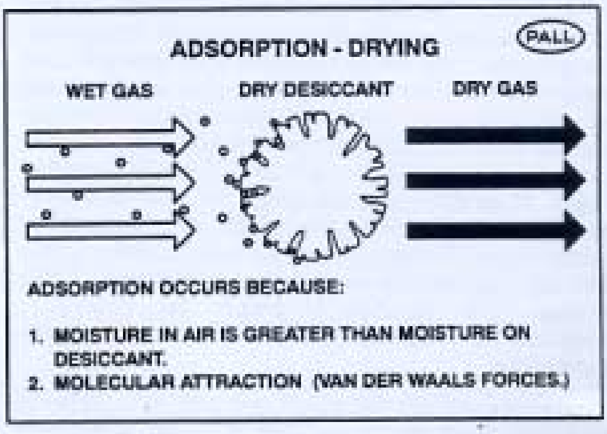



Figure 3.

Once these desiccant beads are fully saturated, they are then dried or "regenerated" so that they may be used again. The method of regeneration is usually of the heated "thermal-swing" variety. Simply stated, thermal-swing dryers pass dry, heated gas through the desiccant bed to evaporate and remove water from the desiccant beads. Once dry, the beads are then able to be reused for further water adsorption.

To provide uninterrupted dehydration capabilities, an adsorbing dryer must therefore utilize two desiccant vessels: one vessel dehydrates the saturated gas stream while the other vessel is regenerating, then vice-versa.

## SOLID REMOVAL

In addition to liquids, a properly designed landfill filtration system must also remove solid particulates from the gas stream. These particulates usually consist of silicons or iron oxides of sub-micronic size, which are highly abrasive within the engine. To remove these solids, a particulate or coalescing filter is relied upon.

***NOTE:*** *Dryers which utilize desiccants will require additional particulate filtration, as these desiccant beads can shed fine dusts. Proper particulate filtration equipment must therefore be located immediately downstream of these dryers to prevent this dust from entering the engine.*

## HALOGENATED HYDROCARBON REMOVAL

Presently, there are two processes being used to remove halogenated hydrocarbons from landfill gas. Both methods are based on processes previously described in the LIQUID REMOVAL section.

The first method utilizes the adsorption process: desiccant beads of activated carbon are used to molecularly attract and adsorb halogenated hydrocarbons from the gas stream. Thermal-swing regeneration is then used to strip the halogens from the desiccant. The halogen-laden purge gas is then sent downstream to a cold-water heat exchanger/condenser, where the halogens are removed in liquid form.

The second method of halogen removal utilizes the glycol absorption technique: A glycol solvent is brought into contact with the landfill gas stream, where both the water and halogenated hydrocarbons are absorbed into the glycol solvent. The contaminated glycol is then sent to a regeneration vessel, where the solution is flashed to a low pressure and high temperature. This boils off the water and halogens, which are then sent to an incinerator for destruction.

Further information regarding halogenated hydrocarbons can be found in the Waukesha Engine Tech Data Book (reference S-7884), and also in SDBC 1100.

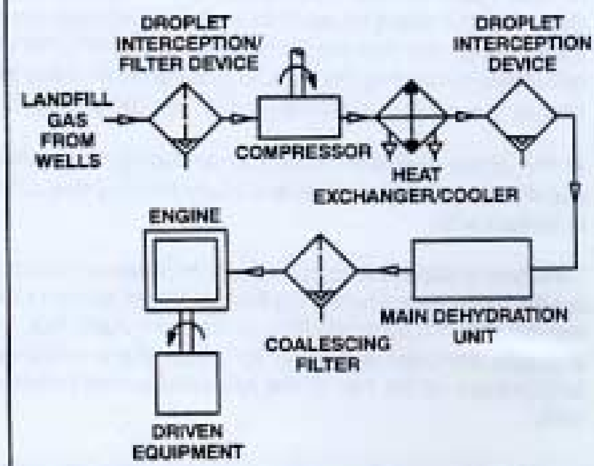
## FILTRATION SYSTEM RECOMMENDATIONS

As a minimum, the fuel treatment system should be similar to that of Figure 4. This type of system addresses the removal of liquids and solids, not halogenated hydrocarbons (for systems with halogenated hydrocarbon removal equipment, contact the equipment manufacturer for specific fuel system recommendations).

The system inlet should utilize a droplet interception device, i.e., a scrubber or coalescer. A scrubber is the most commonly used device, as it is simple and virtually maintenance free. A coalescer, on the other hand, is more effective than a scrubber, but will require periodic filter change-outs.

Immediately downstream of the compressor, a heat exchanger/cooler (gas-to-air) is recommended so as to remove the heat absorbed by the landfill gas during the compression process. This reduction in temperature will also cause liquids to condense out of the gas, which can then be removed from the gas stream through the use of a droplet interception device.

At this point, a dehydration unit is placed in the system to further remove water vapor from the gas stream. A recommendation as to the selection of the dehydration unit is difficult, due to the vast differences in operation, maintenance, and expense. Table 1 offers some guidelines to the advantages and disadvantages of each type.




**Typical Landfill Gas Fuel Treatment System***

* ACTUAL FUEL COMPOSITION MAY DICTATE MORE, FEWER, OR DIFFERENT COMPONENTS THAN ILLUSTRATED ABOVE.

**Figure 4.**

**Table 1.**

| UNIT | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| **Absorbent: Deliquescent Desiccant** | Low Initial Cost. Simplicity- no moving parts. No energy input required. | Offers limited moisture removal (20° F reduction of inlet dewpoint). Requires pre-and post-filtration. Recurring cost of desiccant replacement. |
| **Absorbent: Glycol** | Removes water and some halogenated hydrocarbons (40° F reduction of inlet dewpoint). | Requires regeneration process to restore glycol quality. |
| **Adsorbent Desiccant** | Offers greatest moisture removal ability (–40° F absolute pressure dewpoint). No water to drain. | High initial cost. Requires pre- and post-filtration. Requires periodic changeout of the desiccant. Requires regeneration process to restore desiccant quality. |
| **Cooling/ Condensing (Gas to Refrigerant)** | Offers consistent absolute pressure dewpoint of 35° F. No post-filtering required. | Requires energy input for refrigeration circuit. |

A quality coalescing filter is highly recommended as the final piece of equipment in the fuel treatment system. The coalescer should be placed upstream of the engine-mounted regulator (as close as practical) so as to eliminate any liquids which have condensed out of the gas stream. The following guidelines are recommended for the selection of the coalescing filter:

1) the coalescer must be specifically designed to remove liquids and solids from a gaseous stream.

2) it must utilize an inside-to-outside flow path through the coalescing media.

3) it must have a 1 micron absolute particulate rating, or a 1 micron Beta ratio of no less than 10,000.
(Beta ratio is determined by a test, whereby a known number of particles of a given size are placed upstream of a filter, and the resulting number of these particles which pass through the filter are then counted. The Beta ratio is calculated by dividing the number of particles sent into the filter by the number of particles which passed through it.)

4) the entire coalescer assembly (including the housing and drain) must be compatible with any liquids it may come in contact with.

To further ensure that no liquid water condenses out within the fuel train components, the fuel treatment system must reduce the moisture content of the fuel such that the pressure dewpoint is at least 20° F below the measured temperature of the fuel at the engine-mounted regulator inlet.

***NOTE:*** *Pressure dewpoint is defined as the temperature at which water vapor will begin to condense out of a gas at its given pressure; i.e., a low pressure dewpoint value indicates a relatively dry gas.*

For solid particulate filtration of the landfill gas, Waukesha Engine recommends a 1 micron absolute rated fuel filtration system. As previously stated, a quality coalescing filter will meet this requirement.

In addition to fuel filtration, a Waukesha 1 micron bypass lube oil filter is mandatory for landfill applications, so as to remove any solid particles which have entered the crankcase via blow-by gases.

In conclusion, the fuel treatment system plays a major role towards assuring engine performance and durability. By addressing each of the fuel contaminants (liquids, solids, and halogenated hydrocarbons), the dangers associated with landfill gas can be greatly reduced. As of yet, no single device alone will adequately process landfill gas. Rather, several devices must be wisely selected, each placed in a strategic location, performing a specific task.

Contact Waukesha Engine Division Application Engineering for further information regarding the fuel treatment of landfill gas.

"FUEL FILTRATION:
NOMINAL VS ABSOLUTE RATINGS"

Most filter manufacturers rely on a Nominal Filter Rating, which has been defined thusly by the National Fluid Power Association: "An arbitrary micron value assigned by the filter manufacturer, based upon removal of some percentage of all particles of a given size or larger. It is rarely well defined and not reproducible". It is therefore incorrect to assume that a fuel filter with a nominal rating of 1 micron will retain all particles 1 micron or larger.

Absolute rating is defined as follows: "The diameter of the largest hard spherical particle that will pass through a filter under specified test conditions. It is an indication of the largest opening in the filter element." Absolute ratings are therefore a much better indication of a fuel filter's ability to remove contaminants of a given size.

For further information regarding the operation of Waukesha Engines on landfill gas, see the following literature:

SDBC 1100: Guidelines For Landfill Gas Use in Waukesha Gas Engines.

Gaseous Fuel Specification, Waukesha Engine Division Technical Data Book, S-7884-C.

Engine Lubricating Oil Recommendations, Waukesha Engine Division Technical Data Book, S-1015-X.

Running Right on Alternative Fuels, Waukesha Maintainer, Volume 9 Issue 2, 1987.

Landfill Energy Applications, EGSA paper 89-S-300, John Peffer, Application Engineer - Waukesha Power Systems.

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