
On-site waste gasification may well be an attractive method for industrial waste disposal. This would most likely hold true in large industrial plants where additional steam generating capacity is not required, but where existing steam generators can readily be adapted for combustion of low heating value gas produced in a fixed bed gasifier.

The data presented in this paper is somewhat difficult to evaluate because the prime reference Ref. [3] has not been published. The authors kindly made selected tables available; but a comprehensive review was not possible.

It would seem that the economic evaluation for a system producing clean, cool gas is optimistic for the following reasons:

1. We are told that the gasifier efficiency of 75 percent was reduced, because of higher sensible heat loss, from a study efficiency of 78.14 percent taken from Ref. [3]. However, the study efficiency was based on lower heating value. Higher heating value efficiency for the study would be at least 10 percentage points lower. Efficiency calculations on a higher heating value basis are inherently less than efficiency calculations on a lower heating value basis provided moisture or hydrogen is present in the fuel. Since fuel savings calculations in the evaluation were based on higher heating value of the waste, an efficiency of less than 75 percent probably should have been used. In any event, the change from lower heating value to higher heating value should not have been made without explanation. Note in Table 8 that a ten percent reduction in Fuel Savings would result in a 22 percent increase in Minimum Disposal Charge.

2. The capital and operating cost figures do not seem to include the cost of scrubber water and water cleanup. To cool the fuel gas, at least 25 kilograms (pounds) of water must be circulated for each kilogram (pound) of waste. Considerable makeup water and water cleanup will be required.

3. Unless one assumes that it is customary for plant personnel to haul compacted waste to a central point for pickup by an outside hauler, there would not seem to be provision for intraplant hauling in the evaluation.

For those contemplating an industrial waste gasification system, several cautions are offered:

1. The suggested system for direct feeding from closed containers should be carefully considered for any given situation because:
   a. In many industrial plants, the waste produced in one area will differ radically from that produced in other areas;
   b. The gasifier operator has no visual control over the feed, and consequently cannot remove the occasional oversized or otherwise unsuitable objects that turn up in any waste stream.

2. Having personally grappled with a compacted or fed incinerator, I shudder at the problems associated with the suggested system which involves hoisting containers of compacted waste, attaching the containers to the gasifier, attaching a hydraulic mechanism to the containers, and feeding with further compaction, sight unseen, into the gasifier.

3. Although not mentioned in this paper, Ref. [2] and [3] indicate that gasifying air must be
heated to 650 C – 800 C (1200 F – 1500 F). This is accomplished in an airheater using 1350 C (2500 F) gas produced by combusting a portion (roughly 15 percent) of the fuel gas. Thus, metal temperatures in the airheater would be in the neighborhood of 950 C (1800 F) during normal operation. Airheater design will be critical.

When the waste produced in large industrial plants (20,000 or more employees) is to be considered, it would be reasonable to consider a close-coupled gasifier/steam generator. In my opinion, an evaluation on this basis would be more likely to be viable than the suggested system.

DISCUSSION by S. LaMont Matthews, CH2M HILL, Consulting Engineers, Corvallis, Oregon.

The authors are to be commended for providing their readers with a detailed description of a generalized procedure for estimating costs for industrial, on-site, waste gasification processes. However, generalizing a specific case raises some questions. The concepts and costs presented could be more useful if background had been given about the type of industry used as the prototype and the characteristics of the waste material.

The authors' statement that compaction of the waste prior to transport is inevitable because of the waste quantities, is not necessarily true. Quantity is only one of several factors to be considered when deciding to transport waste, whether it be compacted or loose. The distance to the disposal site and the type of waste also are major factors. On receiving and feeding the gasifier, the authors make no mention of the possibility that some front-end processing may be required before feeding the gasifier system. Again, a definition of the type of waste assumed for this system would be helpful.

When presenting cost data of this type, we have found that a time base is essential to any cost estimate. Rapidly changing costs for materials and labor make evaluation and future use of cost estimates very difficult, unless a reference year or ENR index is used.

In obtaining costs for the gasifier and fuel-gas processing system, the authors indicate that these costs were scaled from a 1974 estimate. Do these estimates allow for the 15 to 20 percent increase in construction costs that have occurred since mid-1974 to the present time? Also, a significant increase in capital, operation and maintenance costs will occur if shredding is required for some types of plant waste.

Finally, I would like to question the operating cost summary for this system. Is the operating cost for the gasification plant only, or are the maintenance and operation of the solid waste collection system also considered?

AUTHOR'S REPLY

REPLY to Roger S. Hecklinger

1. A gasifier conversion efficiency of 75% based on higher heating value (in combination with a utilization efficiency of 95% of the efficiency of the fuel being replaced) represents our estimate of the performance that might be expected from a well designed air blown waste gasifier in a typical industrial situation. It was based on an assortment of information, not the least of which was historical experience with coal fired gas producers. The data of Ref. [3] cannot be applied directly since the feedstock was very wet refuse, just the opposite of the present case. However, we believe that it is consistent with the value used.

We do not agree with the discussor’s argument that efficiency based on a higher heating value necessarily is lower than efficiency based on lower heating value. The relative values depend both on how much energy and how much hydrogen is lost between waste and fuel gas, and this will depend on the waste and the gasification system. For a dry, industrial waste the difference between lower and higher heating value could be expected to be less than 10% and the difference between efficiencies would be considerably less than this no matter what the system.

To illustrate consider a typical industrial refuse with the following characteristics:

ash = 10%
moisture = 10%
HHV = 7100 Btu/lb

The composition of the combustible fraction, per mole carbon might be described as follows:

1.58 mol H
0.63 mol O
0.017 mol N
0.0015 mol S
0.0027 mol C1

A simplified flow diagram is sketched below. At any point the difference between higher and lower
heating value can be expressed in terms of the mass of hydrogen at that point, $X_H$, as follows:

\[
\Delta \text{HV} = 9472 \times X_H
\]

The hydrogen content of the waste can be calculated as follows:

\[
X_H = 0.10 \times 2.016/18.016 + 0.8 \times 1.58 \times 1.008/24.06 = 0.0641
\]

Some water formation can be expected during pyrolysis. Typically half of the oxygen in the waste would go to forming water. As a result the mass of hydrogen in the form of water at the scrubber becomes

\[
X_{H/W} = 0.10 \times 2.016/18.016 + 0.8 \times 0.5 \times 0.63 \times 2.016/24.06 = 0.0323
\]

Ignoring tars and oils, which also may be involved in the removal of hydrogen, the net hydrogen remaining in the fuel gas after scrubbing is

\[
X_H = 0.0641 - 0.0323R
\]

where $R$ is the fraction of the water at that point that is condensed and removed at the scrubber. The difference between higher and lower heating value can then be calculated, and works out to 608 Btu/lb for the waste and between 302 Btu/lb ($R = 1$) and 608 Btu/lb ($R = 0$) for the fuel gas leaving the scrubber. Note that all values are for 1 lb of waste.

The lower heating value of the fuel gas is unaffected by the removal of water since water in the vapor state has a lower heating value of 0. Conversely the removal of water vapor will reduce the higher heating value of fuel gas by 1060 Btu/lb water vapor removed. If we assume that 10% of the fuel gas is consumed in the air heater, and that the overall efficiency based on lower heating value is 78%, the simplified energy balance can be drawn as follows:

Efficiencies then become

\[
\begin{align*}
5064/6492 &= 78\% \text{ based on LHV} \\
5611/7100 &= 79\% \text{ based on HHV, } R = 0 \\
5336/7100 &= 75\% \text{ based on HHV, } R = 1
\end{align*}
\]

Thus it can be seen that under some circumstances the efficiency based on higher heating value actually can be greater than efficiency based on lower heating value. If a fairly high fraction of the water is removed — which would be typical of scrubbing situations — a reduction in efficiency could be expected but of a much lower magnitude than suggested by the discussor.

In practice many system variations are possible. For example recycling of water and/or scrubbed tars and oils to various points in the gasifier, as well as direct combustion heating of gasification air, are possible. The details of the system chosen can have a definite effect on the relationship between efficiencies. Based on some computer modeling (done after the paper was written) it appears that the efficiency difference for many cases of interest actually is less than 1% for relatively dry wastes. The efficiency still may be lower than 75% but that is more likely to be the result of system and feedstock characteristics and not the difference between higher and lower heating value based efficiencies.

In some cases the efficiency may be considerably greater than 75%. For example close coupled systems can give efficiencies in the magnitude of
90%. These systems tend to be most applicable to fairly simple, large, single point applications such as the steam generator application suggested by the discussor.

It also should be noted that if a high fraction of hydrogen is removed at the scrubber the gasifier efficiency based on HHV is lowered, but the utilization efficiency will be increased. If the flue gas temperature leaving the boiler, furnace or whatever is using the fuel gas is reasonably low, the loss in performance due to dilution is quite small and can be more than compensated for by the reduction in latent heat loss caused by the removal of hydrogen. As a result the utilization efficiency, compared to natural gas, can go over 100%.

2. The capital costs were based on closed loop cooling systems which reject heat to cooling water via a heat exchanger. Sufficient cooling water was assumed to be available. The cost of cooling water and waste water treatment was assumed to be negligible in comparison with the other operating costs associated with the gasification system.

3. Conversion to gasification was assumed to have no influence on waste materials handling up to the compactor. Hauling of containers to the gasifier was assumed to be a function of the gasifier operating personnel. Relatively little time would be involved. The assumptions made are as discussed under “Transition From Haul-Away to On-Site.”