Energy-Crop Gasification

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Biomass may be obtained from many sources. Already mentioned at this conference are switchgrass, corn stover, sawdust, willow, biodegradable waste, *etc*. However, its availability in a variety of forms is problematic. Chemical engineers, of which I am one, like homogeneity; heterogeneity means feeding problems and handling problems; as feed source varies, moisture and chemical content vary. Gasification and combustion are the most readily applicable technologies for processing biomass of various kinds for production of biofuels and other chemicals and materials.

Gasification, which has been around for a long time, is a thermochemical process that converts carbohydrates into hydrogen and carbon monoxide under oxygen-starved conditions.Its use was accelerated during WWII when wood was gasified and converted into liquid fuel for internal combustion engines including electrical generators. In post-war years, some farmers had gasification systems attached to tractors and other equipment, which worked fairly well.

The Process

In a gasifier, the fuel undergoes three main processes:

- Pyrolysis without O_2
  - also known as devolatization
  - volatile components of the fuel are released
  - some fuel is converted into char,
- Combustion in excess O_2
  - the volatile products and some char react with oxygen and steam to form carbon dioxide and carbon monoxide, which provides heat,
- Gasification in O_2-starved conditions
  - the char then reacts with the carbon dioxide and steam to produce carbon monoxide and hydrogen, commonly known as syngas.

As a separate process, pyrolysis is used to produce bio-oil; the same equipment can be used for gasification by operating it differently.

Gasifiers

Several types of gasifiers are available; attendant advantages and disadvantages are shown in Table 1. In the updraft gasifier (Fig. 1), air is blown upward and the biomass is fed downward. The down-draft gasifier is similar, but drawing air from the top and producing cleaner products with less tar (creosote); however, there are problems with the way the material is fed and how it can be handled and moisture tolerance is limited. With both methods the products are carbon monoxide (CO) and hydrogen (H_2)—syngas—which can be converted to a number of products.

The fluidized bed gasifier is the most popular type (Fig. 2). It can use a variety of feeds, usually ground to a powder. However, more tar is formed and particulates are produced due to the turbulence in the bed.

With the circulating fluidized bed (Fig. 3), we basically blow the bed out, separate it in a cyclone and recycle it back around. It is similar to the fluidized bed system, but with even more tars and particulates.

In the entrained-flow gasifier (Fig. 4), the material is entrained in a pipe in the reactor, not in a bed. It works differently and causes different problems.

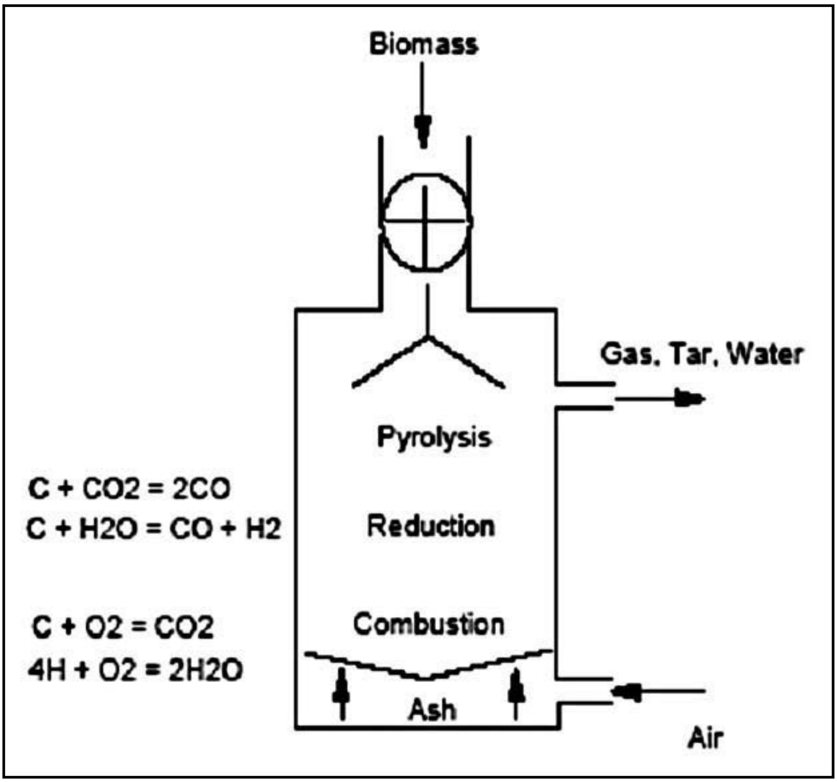

Figure 1. Updraft gasifier.

TABLE 1. GASIFIER TYPES AND THEIR ADVANTAGES AND DISADVANTAGES.

Gasifier type	Advantages	Disadvantages
Updraft	Low carbon in ash Can handle feeds with high moisture content Good for small-scale application	Feed-size limitations High tar yields Scaling limitation
Downdraft	Low particulates in syngas Low-tar content in syngas	Feed-size limitations Sensitive to moisture in feed Scaling limitations
Fluidized bed	Can handle large-scale applications Can handle multiple feed characteristics	Medium tar yield Higher particulate loading
Circ. fluidized bed	Best for large-scale applications Can handle multiple feed characteristics Very versatile	Medium tar yield High particulate loading
Entrained flow	Low tar yield	Particle size limits High particle loading Needs large volumes of carrier gas

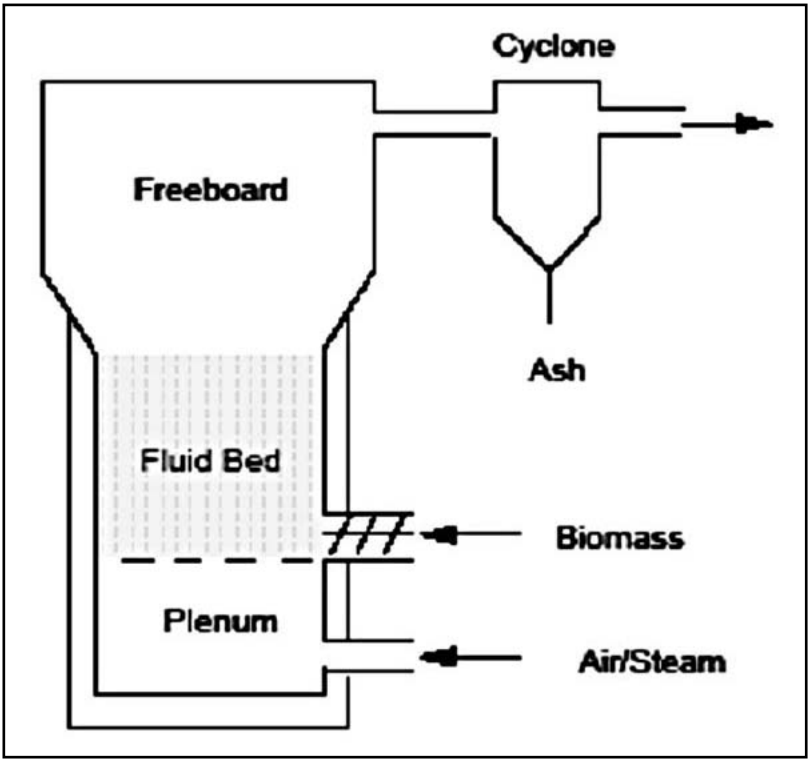

Figure. 2. Fluidized-bed gasifier.

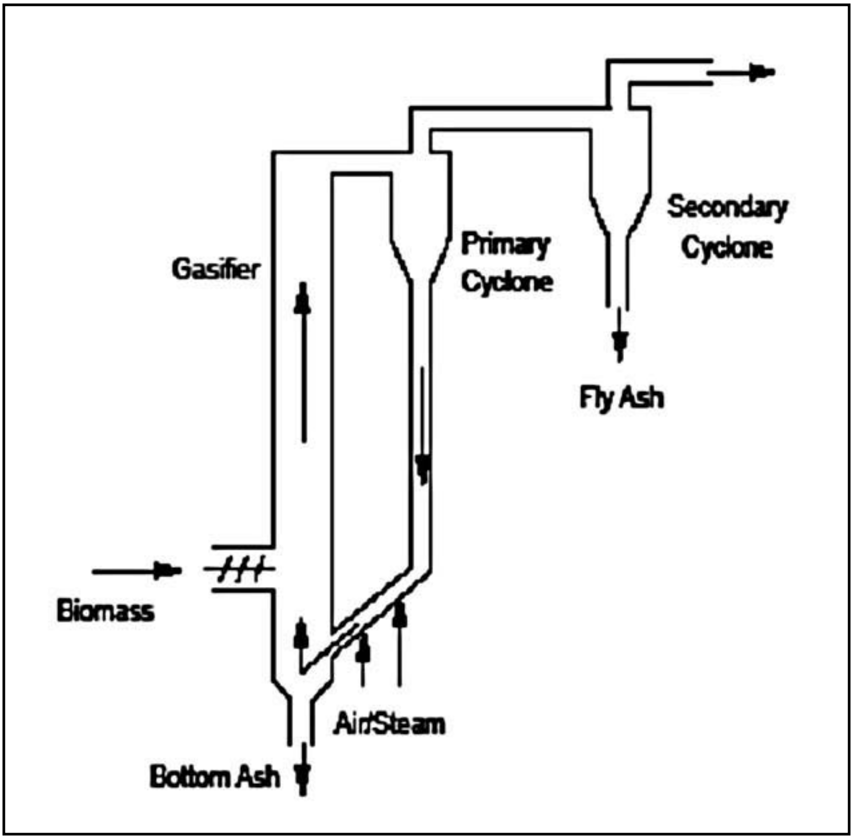

Figure 3. Circulating fluidized-bed gasifier.

Syngas

Syngas is used mainly for production of electricity. The heat produced generates steam, which generates electricity. It can also be used to produce chemicals, involving fairly easy catalytic conversions from CO and H_2, *e.g.* via the Fischer-Tropsch reaction. A biofuel product on the horizon is dimethyl ether (DME). Ethanol can also be produced, as can true gasoline and true diesel, from syngas.

Resolving Problems

Figure 5 illustrates one of the processes that we've been working on at Mississippi State University (MSU): biological conversion of syngas to ethanol and refining the ethanol using standard processes. The yield is relatively low and our microbiologists are working on new microorganisms for increased rapidity of production and higher yields.

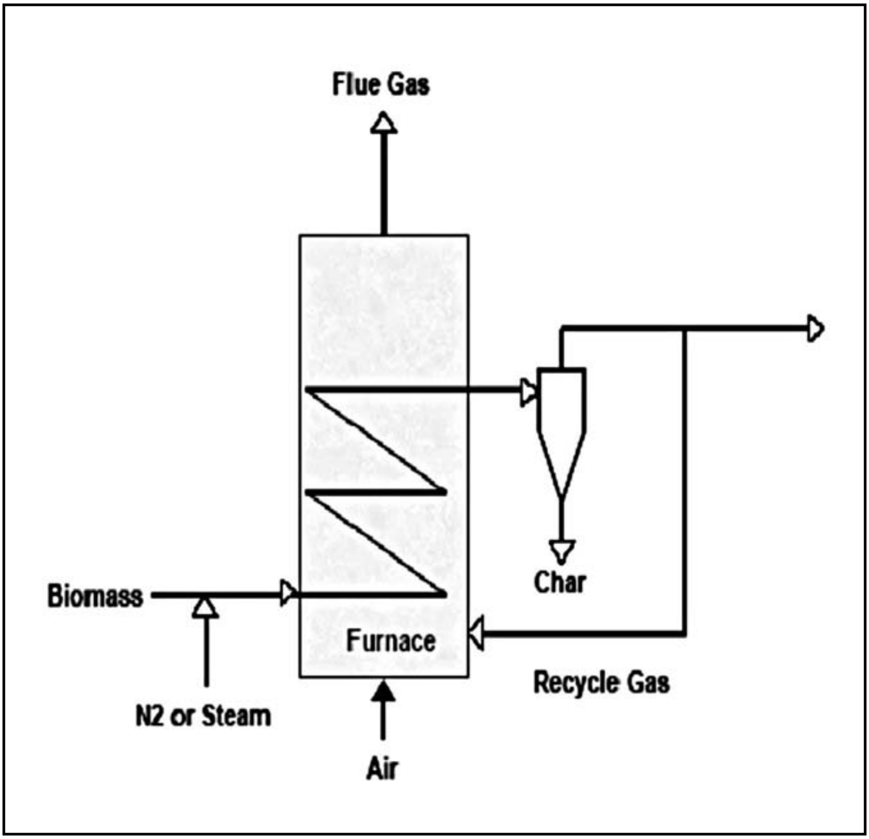

Figure 4. Entrained-flow gasifier.

A major problem is biomass feeding, particularly in terms of low density. Transportation of crop residues, for example, more than about 100 miles would cost more than energy reclaimed from it. Particulate formation is another difficulty, particularly with downstream equipment. Tar is another issue—unwanted hydrocarbons in the gas that decrease its quality. The tars can interfere with downstream biological systems.

Figure 6 shows a power plant at which switchgrass bales are burned to generate electricity. Moisture content is critical, affecting operation of the gas fire and amount of tar produced. A large amount of bulky material is stored outside the facility because covered storage is expensive. In theory it's attractive, but in practice just handling this amount of material is an issue.

On the technical side, there is no standard for particulate level or tar. In other words, we don't know how much tar or how much particulate we can run in certain pieces of

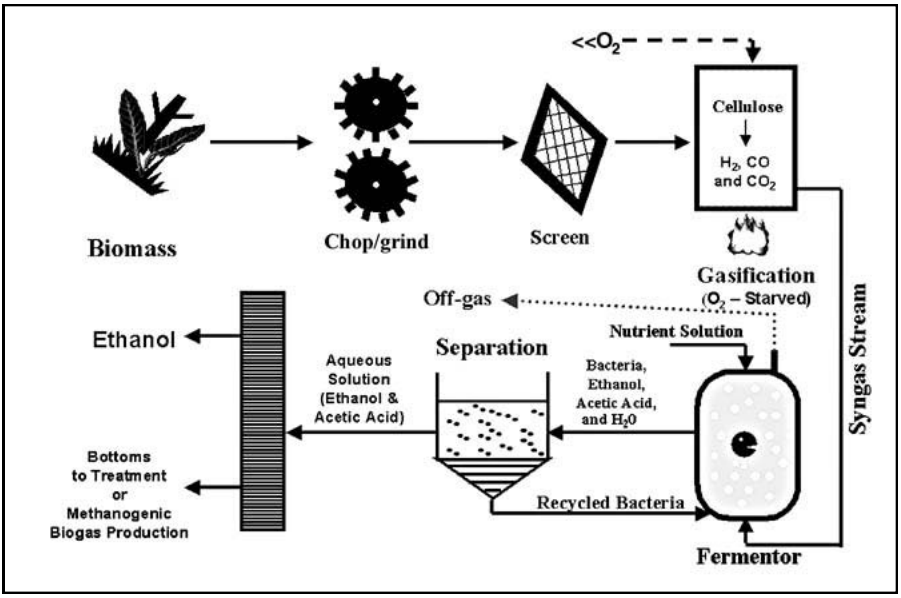

Figure 5. Gasification conversion for ethanol production (biorefinery).

Figure 6. Feedstock storage and handling.

equipment. Furthermore, there's no definition for tar. We know what it is when we see it, but it has not been chemically defined. And there are no standard protocols for sampling. Numerous studies have been done, but, with different protocols used, they cannot be precisely compared. Therefore, when we talk about gasification (and tar, *etc.*) and what we are going to use it for, many issues require resolution.

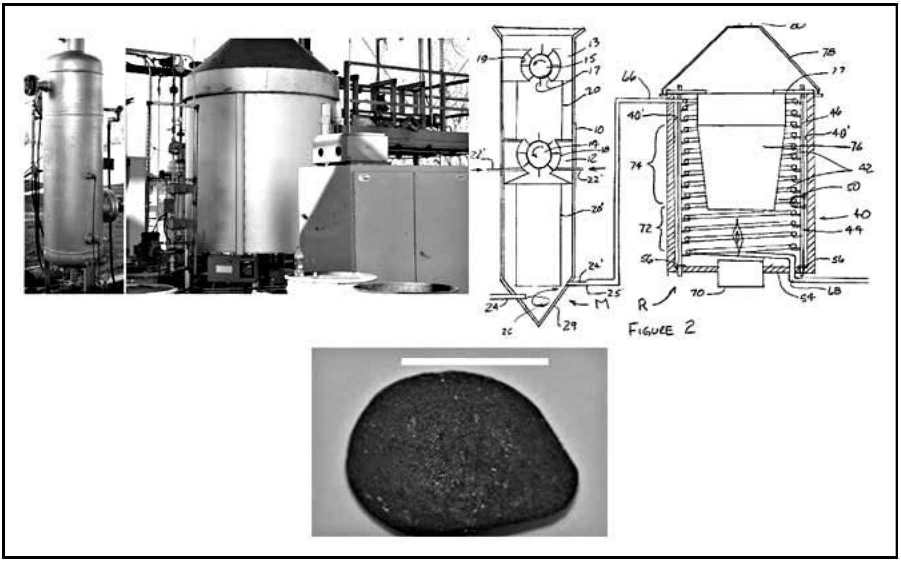

Figure 7. Entrained-flow gasifier with syngas-cleanup module, showing a tar ball (bar=0.5 inch).

As far as end-use is concerned, combustion requires some kind of nozzle for introduction, but if tar is present the injection system will become gummed up as will pistons. Gas turbines are even less tolerant. If the syngas is to be compressed for downstream use, there is even less tolerance. If hydrogen from syngas is eventually used with fuel cells it will have to be extremely clean or the whole process will be contaminated.

Figure 7 shows an entrained-flow gasifier at MSU's Institute for Clean Energy Technology, designed and manufactured by Mississippi Ethanol LLC. A proprietary sprayed-water process is employed in a scrubber with baffles to collect tars and ash that had been gumming up the downstream system,producing tar balls as shown (Fig. 7). Scrubbing cleans up the syngas but produces the environmental problem of disposal of contaminated water and tar balls.

Figure 8 shows a down-draft unit at MSU, manufactured at the Community Power Corporation, in Denver. With input from the National Renewable Energy Laboratory (NREL) we purchased this unit to test. It is intended as a system for purchase by farmers and villages. It was designed originally to accept aspen as the feedstock, and redesigned at MSU to handle pine. The catalytic bed, designed to convert the tar, became plugged when pine was used. Despite this and other operational problems, it now works well enough to produce a number of materials that are under examination in the laboratory.

Figure 9 represents a system that we have designed for on-going study of tars, and effectiveness of various catalysts for their destruction. And Fig. 10 shows a circulating, fluidized bed currently under construction in the laboratory.

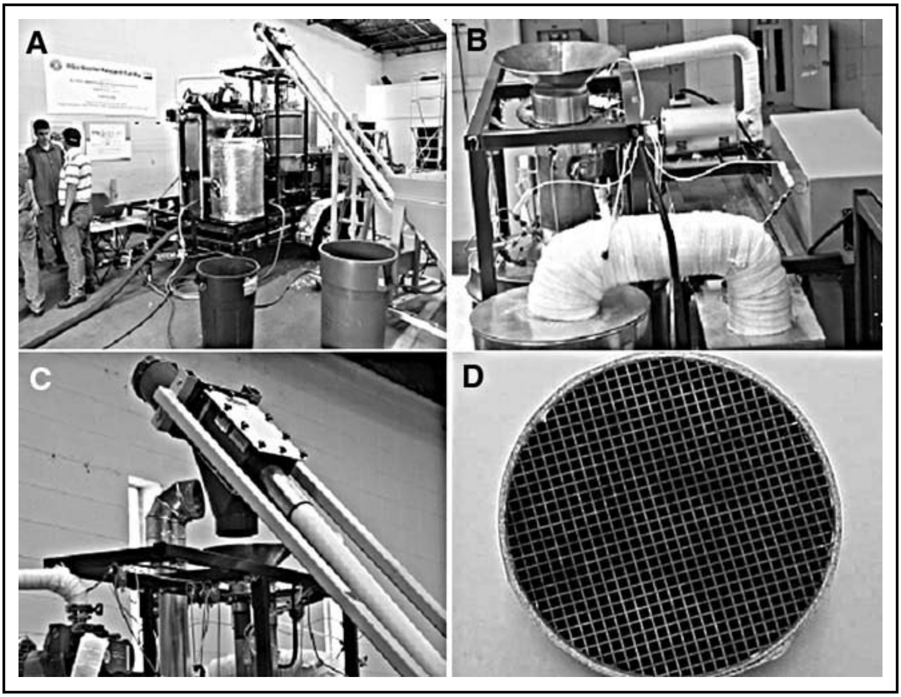

Figure 8. Down-draft gasification unit at MSU;
A–overall, B–top, C–feed system, D–Pt/Rh catalyst block.

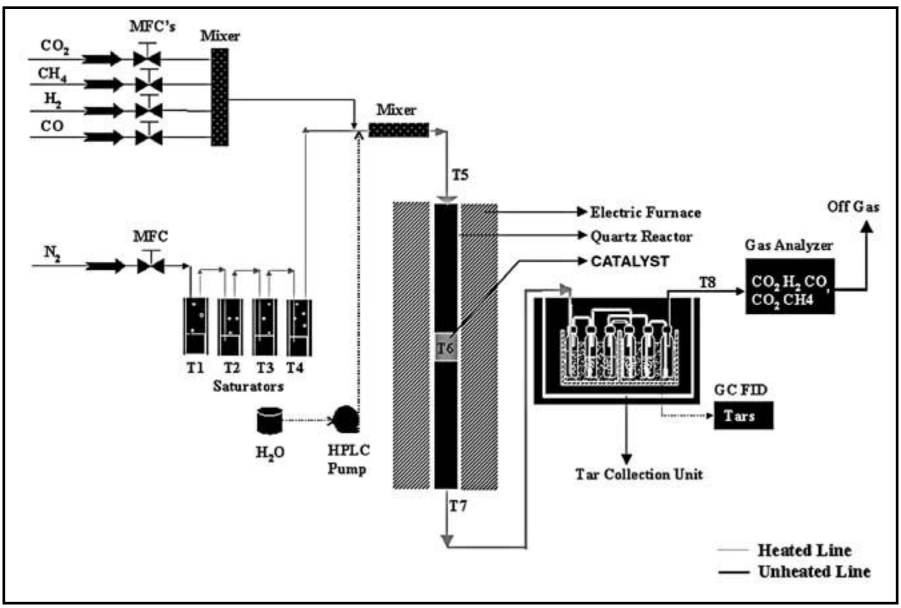

Figure 9. Schematic of a laboratory-scale catalytic reactor tar-treatment study

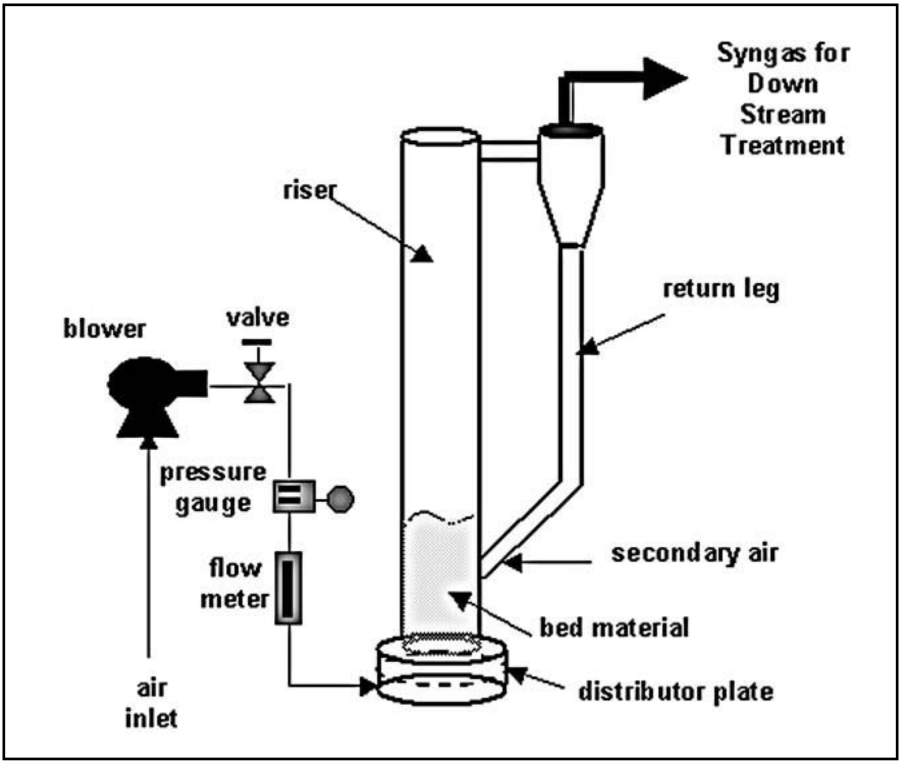

Figure 10. MSU circulating fluid-bed design.

Sledgehammer Adjustment

Although gasification is a well developed “sledgehammer” adaptable to many types of feedstock, problems remain to be solved. One of our particular interests is in how best to utilize the product, syngas.

MARK BRICKA is an associate professor in the Dave C. Swalm School of Chemical Engineering at Mississippi State University (MSU) and director of the Environmental Technology Research and Applications Laboratory. Previously he served for 20 years as a research environmental engineer with the US Army Corps of Engineers and was employed as a process engineer at PPG Industries where he applied chemical engineering principals to solve environmental problems. He received his BS in chemical engineering from the University of Alabama in 1982, his MS in chemical engineering from Mississippi State University in 1988 and his PhD in environmental engineering from Purdue University in 1989.

His research interests include alternative energy and environmentally related aspects, including syngas production, cleanup, distributed power generation as well as pyrolysis oil production, stabilization and utilization. He has authored numerous technical papers in the environmental and alternative-energy areas.

Dr. Bricka received numerous army citations for outstanding research and recently was awarded the Sigma Xi Ralph Powel Award for Outstanding Research at MSU. He is director of the Mississippi Chapter of the Air and Waste Management Association and a member of the Mississippi Biomass Council and of the American Institute of Chemical Engineers.