BIOMASS GASIFICATION: What is it? Can it be used now?

By

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January 21, 2006

Overview

- Historical review
  - Where did it come from?
  - Why did they develop it?
- What exactly is it?
  - Fundamental Chemical Analysis
  - Process Analysis
- Was it worth it?
  - Where did it go & why?

Overview – Cont'd

- What has happened since?
- Where is it now?
  - Modern techniques
  - Current technical challenges
  - Future developments
- More Information
  - References used for today's presentation
  - Gasification Unit Construction References
  - Additional resources

Historical review

- Where did it come from?
  - Germans discovered combustible gas in the steel making processes of early 1800s
  - Europeans developed gas generators during 1840s to use coal, peat, wood and coke making heating gas

Historical review – cont'd

- Why did they develop it?
  - Coal was plentiful
  - This process could use waste materials such as plant fiber, cotton bolls, rice & wheat chaff
  - In 1890s, "suction gas" engines were gaining in popularity for stationary power plants NOTE: liquid fuels were gaining in usage
  - After WWI, liquid fuels remained popular. France, England & Italy only used BMG in their colonial possessions

Historical review – cont'd

- Why did they develop it? – Cont'd
  - As the Germans prepared for WWII, their scientists and engineers were given the fuel shortage crisis that existed during WWI. They developed a system to use local resources found within their area: wood, peat and coal

What exactly is Biomass Gasification (BMG)?

- Fundamental Chemical Analysis
  - Hydrocarbon fuel combustion
    1) Complete combustion (ideal)

       Hydrocarbon + Oxygen = Carbon Dioxide + Water

       Methane (Natural gas)

       $$CH_4 + O_2 = CO_2 + H_2O$$

       Propane (LP)

       $$C_3H_4 + 4O_2 = 3CO_2 + 2H_2O$$

What exactly is Biomass Gasification (BMG)?

- Fundamental Chemical Analysis
  - Hydrocarbon fuel combustion
    2) Incomplete combustion

       Ex. Wood + O_2 = $\alpha(C_NH_x)$ + H_2 + CO + CO_2 + H_2O
       Cellulose, Semi-Cellulose, Lignin

    Notice the $\alpha(C_NH_x)$ term. This represents multiple reactions:

    ➢ The heavier hydrocarbon being reduced or "broken" to form a lighter hydrocarbon such as methane & propane AND

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       Ex. $C_3H_8 + O_2 = \alpha(C_NH_x) + H_2 + CO + CO_2 + H_2O$

       - There is not conversion of the heaviest hydrocarbons called tar in wood fuels. These compounds can contain up to $C_{24}H_{12}$ or $C_8H_8O_3$ depending on the fuel and gasifier type. There is an inverse relationship between the yield of "tars" and the reaction temperature of the gasifiers; that is, the higher the reaction temperature the lower the amount of tar
       - CO carbon monoxide has roughly the same heat content as H_2 & both are ~1/3 CH4 (methane – natural gas).

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- Fundamental Chemical Analysis
  - Hydrocarbon fuel combustion
    2) Incomplete combustion

       Ex. Typical produced gas composition from an earlier Updraft gasifier using charcoal:

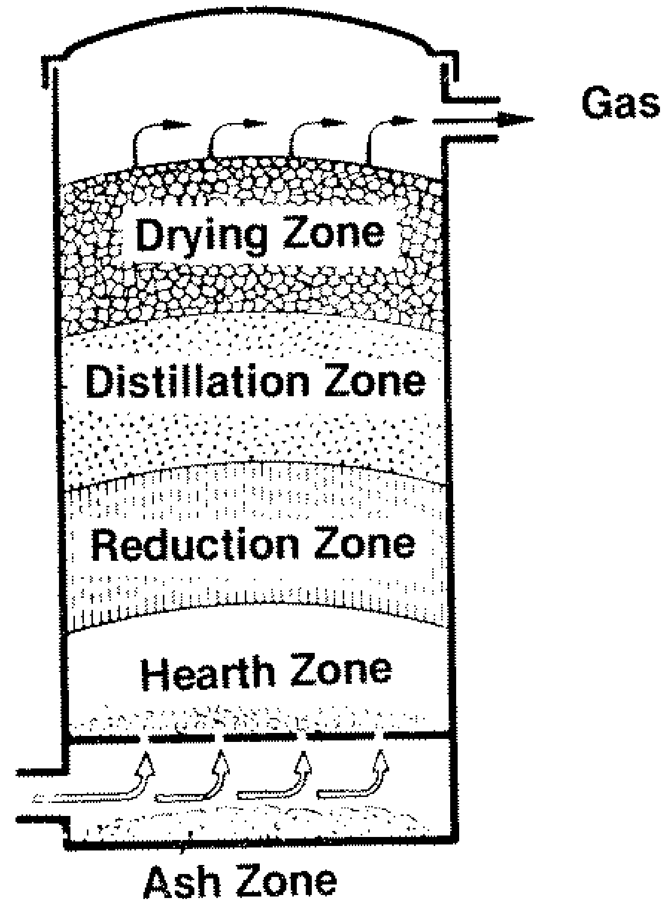
➢ CO_2	Carbon dioxide	.5%
➢ CO	Carbon monoxide	33.8%
➢ H_2	Hydrogen	2.8%
➢ CH_4	Methane	0.0%
➢ N_2	Nitrogen	63.4%

What exactly is Biomass Gasification (BMG)? Cont'd

- Process Analysis
  - Typical Gasification Process
  - Gasifier Designs
    1) Updraft gasification Design Analysis
    2) Downdraft gasification Design Analysis
    3) Cross draft gasification Design Analysis

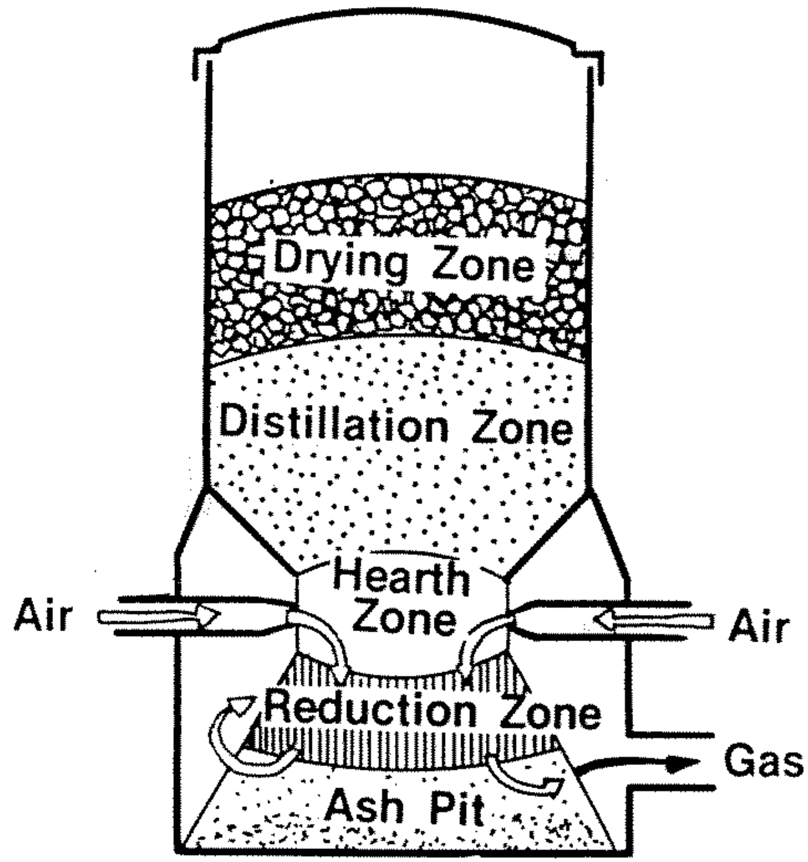
What exactly is Biomass Gasification (BMG)? Cont’d

- Updraft Gasification Design Analysis
- Simple design
- Not sensitive to fuel selection if it is a no-low tar fuel
- Has a long start time
- Delay in response
- Best used for large, long use applications
- Pegasus pg 79 figure 9



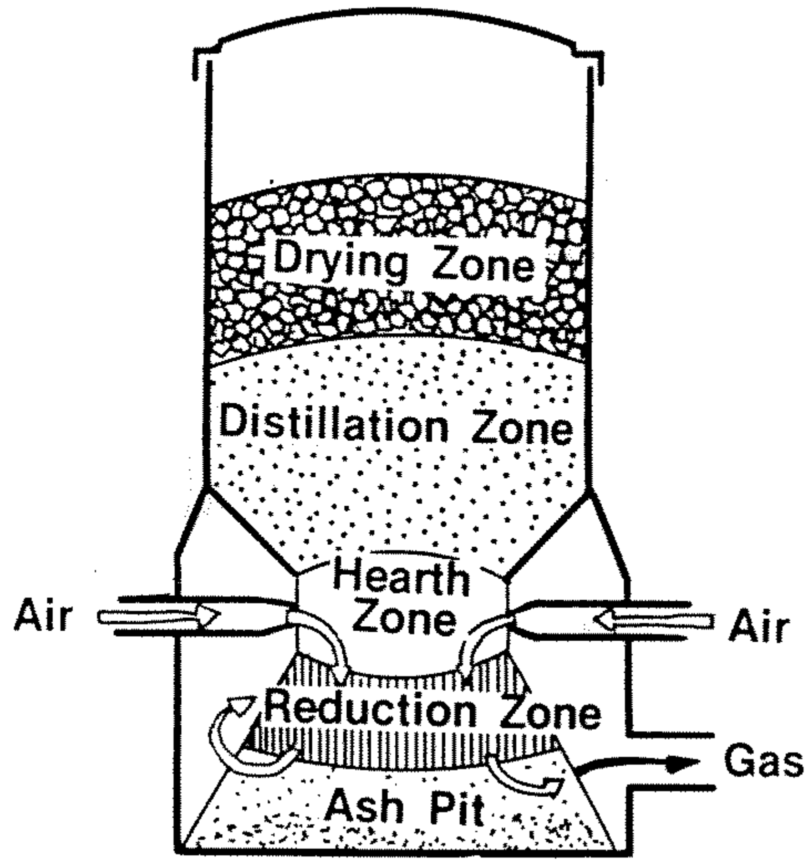
What exactly is Biomass Gasification (BMG)? Cont'd

- Downdraft gasification
- Figure from Pegasus pg 82 fig 14
- The general idea behind this design is that the tarry oils and vapors given off in the distillation zone are highly unstable at high temperatures. In order to reach the gas outlet they must pass through the partial combustion zone where a high amount will be cracked and reduced non-condensable gaseous products before leaving the gasifier. Although the general principle behind this seems convincingly easy, in practice it requires some testing and **high skill** to come up with a downdraft gas producer capable of generating a tar free gas under **equilibrium conditions**.



What exactly is Biomass Gasification (BMG)? Cont'd

- Downdraft gasification
- Can use high tar fuels (wood, peat)
- Quicker in response
- Has shorter start time
- Complex design
- Can't use high ash content fuels
- Fuel pellet size must be uniform – may bridge



What exactly is Biomass Gasification (BMG)? Cont'd

- Downdraft gasification system

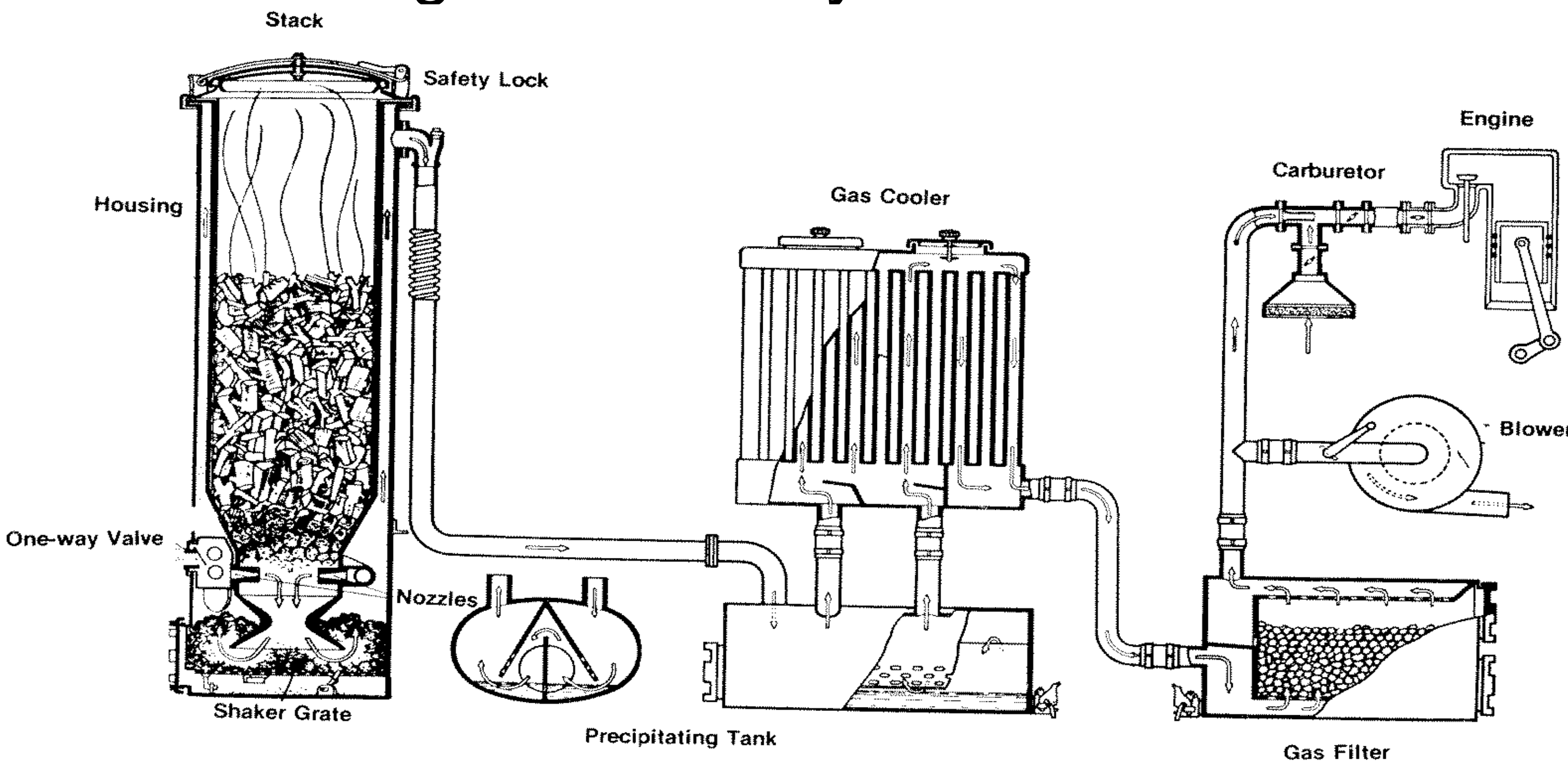
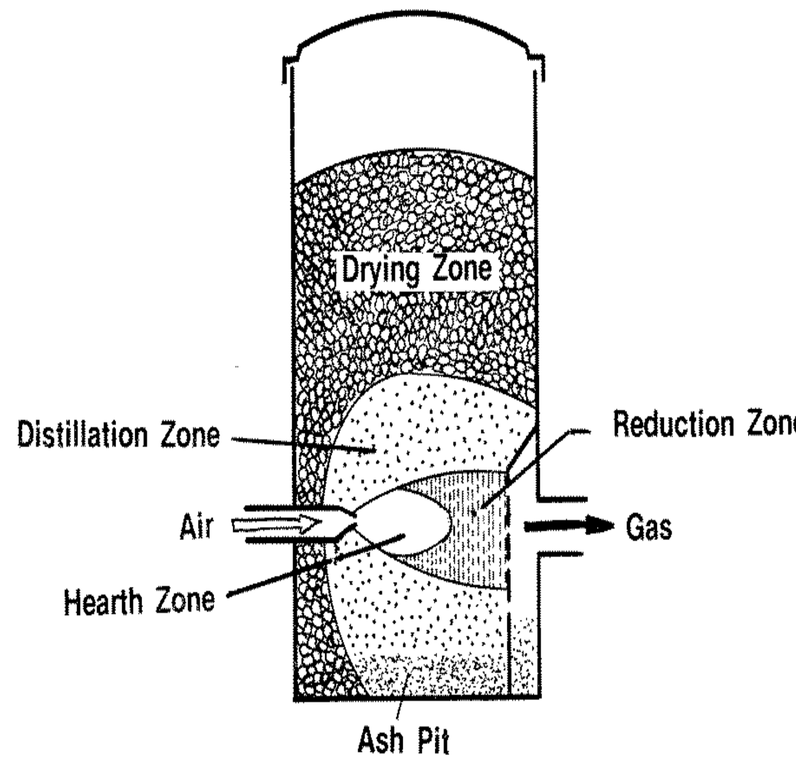


FIG. 6: SCHEMATIC VIEW OF DOWNDRAFT PEGASUS

What exactly is Biomass Gasification (BMG)? Cont’d

- Cross draft gasification
- Can’t use high tar fuels
- Quicker in response
- Has shorter start time
- Complex design
- Can’t use high ash content fuels
- Fuel pellet size must be uniform – may bridge
- Pegasus pg 85



What exactly is Biomass Gasification (BMG)? Cont'd

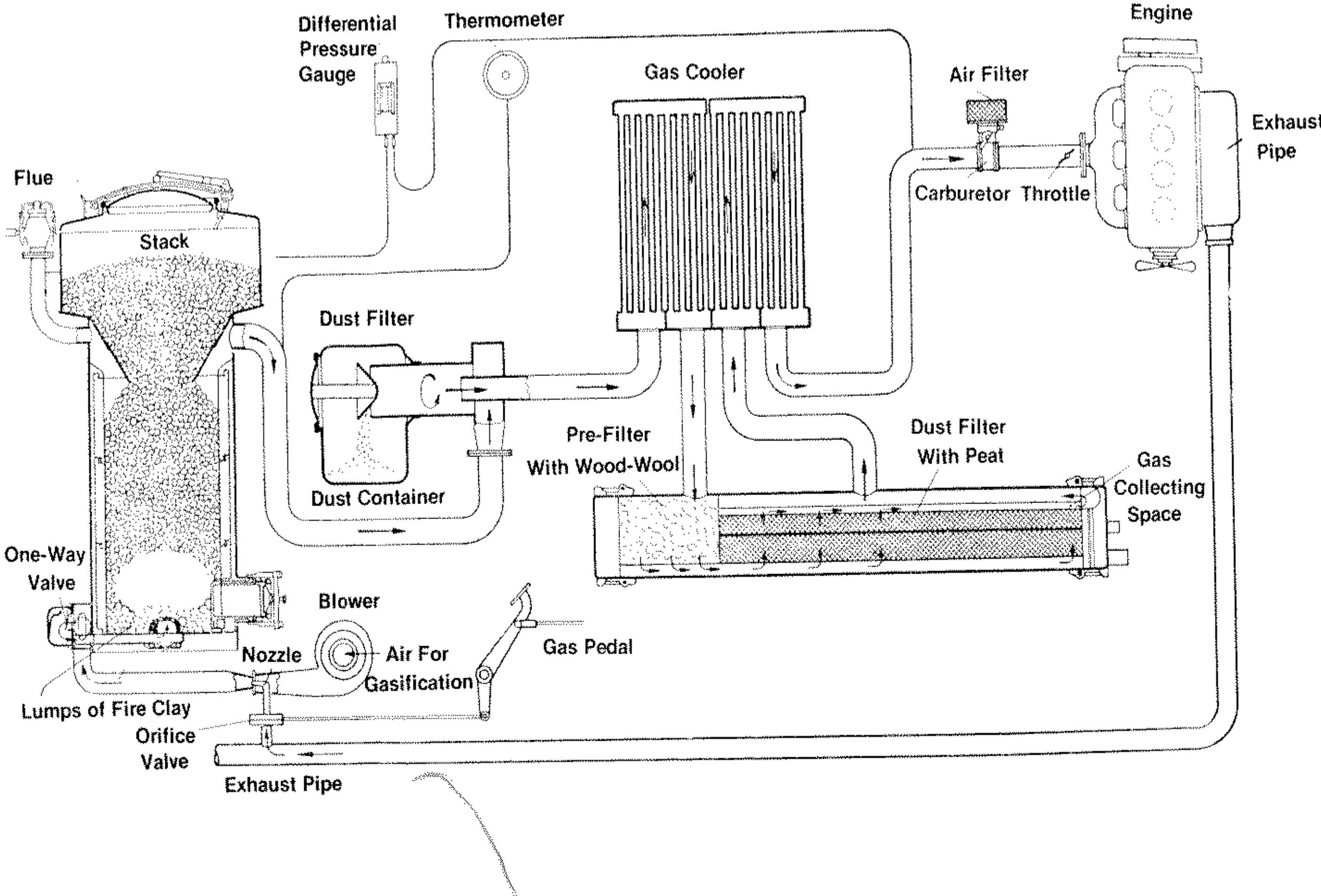


FIG. 42 PEGASUS OF DEUTZ DESIGN, DRY GASIFICATION

What exactly is Biomass Gasification (BMG)? Cont'd

ORNL Photo 5321-86

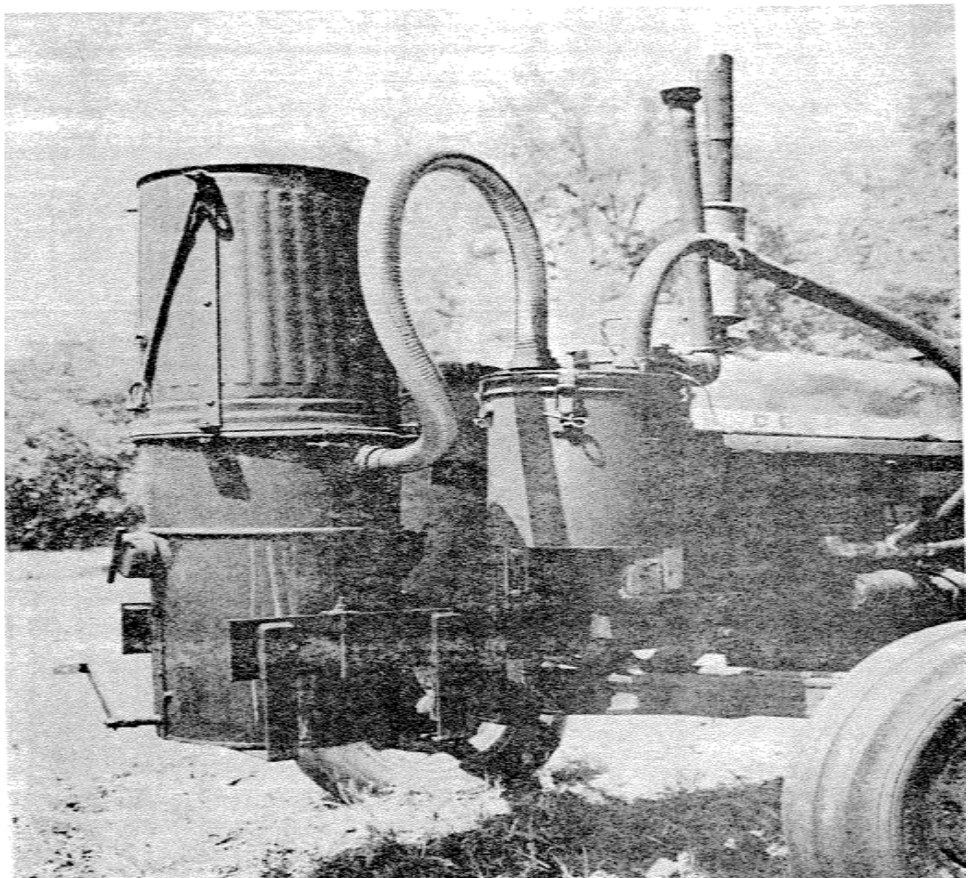


Fig. S-2. The prototype wood gas generator unit mounted onto a tractor.

What exactly is Biomass Gasification (BMG)? Cont'd

ORNL-Photo 5325-86

Fig. S-3. Wood gas generator unit in operation during field testing.

What exactly is Biomass Gasification (BMG)? Cont'd

- Process Analysis
  - Fuel Selection: a gasifier can be designed to gasify virtually any <u>solid</u> fuel
  - Fuel Quality:
    - A function of carbon content
    - Fuel Grain or Pellet Size (& uniformity)
    - Bulk Weight (calorie value per volume)
    - Tar Content
    - Moisture Content
    - Dust Tendency
    - Ash and Slag Tendency
    - Reaction Response

What exactly is Biomass Gasification (BMG)? Cont'd

- Process Analysis
  - Fuels Analysis:
    - Wood

Advantages	Disadvantages
– Plentiful	- Bulkiness
– Easy to ignite	- Varied Moisture Content
– Moderate Calorie Content	- Limited "Preferred" Species
– Mod - Low ash content	- Varied Tar & Ash Content
– Sulphur free	- Moderate Stability of Combustion

What exactly is Biomass Gasification (BMG)? Cont'd

- Process Analysis
  - Fuels Analysis:
    - Coal

Advantages	Disadvantages
– Easy to ignite	- Bulkiness
– High heat content	- High Calorie Content
– Low ash content	- Limited Access
– Low ash content	- Sulphur Content
– High Stability of Combustion	

Was it worth it?

- Where did it go & why?

  Practical Performance

  – Engine have ~2/3 OEM HP w/liquid fuel
  – Constant monitoring & adjustment of the gasifier to obtain reasonable performance because an optimum design for all fuel conditions wasn't achieved AND they were still complex!
  – Work to prepare and grade fuel
  – After WWI and WWII, liquid fuel shortages subsided.

What has happened since?

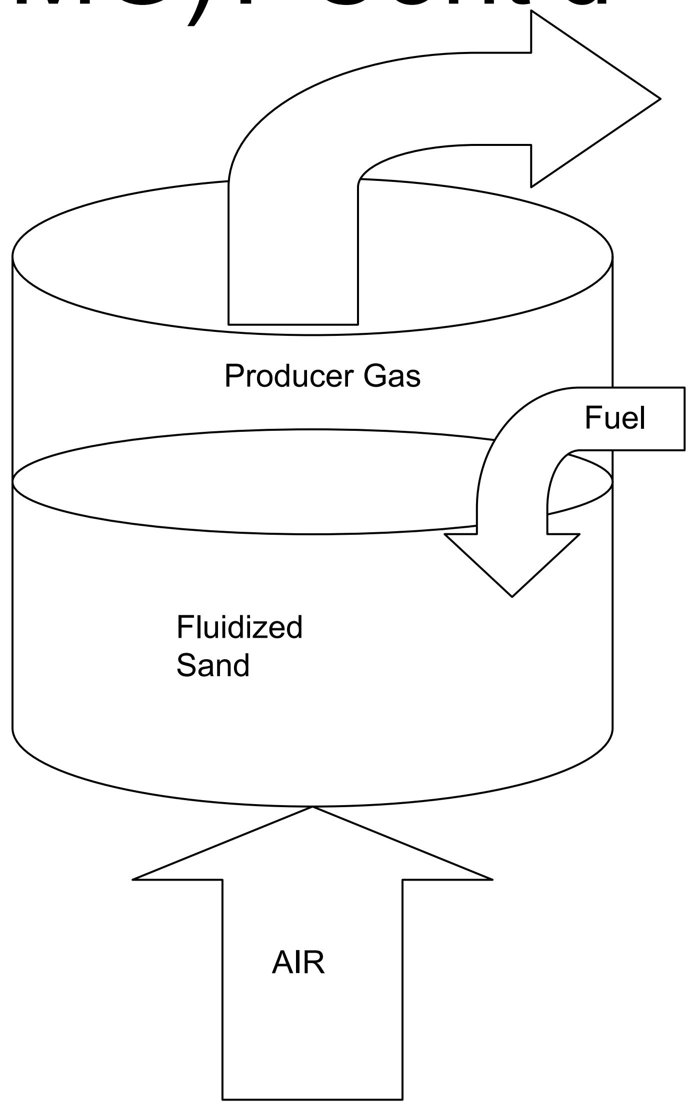
- Discovery of steam injection
  - Useful only for dry fuels such as coal or seasoned woods
  - Adds H_2 and O_2 from H_2O by disassociation to produced gas which increases its heat content and usability
  - Helps keep ashes from forming clinkers
  - Can help control overheating
  - Harmful for wet fuels such as green wood
  - Takes heat away from combustion
- See Pegasus unit pg 53.

Where is it now?

- Modern techniques
  - Discovery of fluidization beds
  - Definition: a fluidization bed is a chamber with a perforated floor having pressurized air flowing vertically where a particle medium, usually sand, is contained. The pressurized and flowing air levitates the medium allowing it to act as a fluid.

What exactly is Biomass Gasification (BMG)? Cont'd

- Fluidization gasification
- Can use most fuels (wood, peat and coal) including agriculture "waste" such as straw, corn stover and manure. Has potential to use municipal waste such as garbage.
- Quicker in response
- Has shorter start time
- Complex design
- **Lends itself to complete combustion applications which would allow it to use liquid wastes such as used engine oil, non-recyclable plastics, junk mail & old shoes, garbage for generation of heat.**



Where is it now?

Where is it now?

- Most research efforts are being spent on fluidization bed technology
- Current technical challenges
  - Better initial combustion of tars
    - US, Germany, Scandinavian countries & Japan are leading, but many other countries are pursuing this technology.
  - Conversion of produced tars into usable fuel

Where is it now?

- Future developments
  - Multiple fuel capabilities in a continuous process
  - Smaller units – most research and patentable ideas are for larger commercial and industrial applications
- Complementary &/or competing technologies
  - Landfill gas

For more information

- References:
  - The Pegasus Unit by Skov & Papworth
  - Small Scale Gas Produder-Engine Systems by Ali Kaupp
  - Biomass Gasifier “Tars” by Milne, Abatzoglou & Evans

For more information

- Gasification Unit Construction References:
  - Construction of a Simplified Wood Gas Generator for Fueling Internal Combustion Engines in a Petroleum Emergency by Harry LaFontaine via FEMA
  - Small Scale Gas Produder-Engine Systems by Ali Kaupp
  - The Pegasus Unit by Skov & Papworth

For more information

- Resources
  - The Biomass Energy Foundation Press
    1810 Smith Rd. Golden, CO 80401
  - Biomass Technology Group
    www.btgworld.com
  - Gasifiers
    www.gasifiers.org