Technologies For Biomass Utilization

PART 3

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PART 3

- Classification of gasifiers
  - Updraft, Closed top downdraft, Open top downdraft, Open top downdraft re-burn system
  - ***We exclude fluid bed class of systems here as they are not appropriate at lower power levels***
- Stratification or flame propagation upstream
- Gasification efficiency and gas cal value vs. moisture dependence, why so and need for drying
- Other classification of gasifiers – closely coupled systems, decoupled systems, cold gas systems

How are gasifiers classified ?

These are classified into three types depending on the gas and feed stock flow path.

Down Draft

Up Draft

* High tar
* For thermal use
* Better gas quality
* For better thermal use

Cross Draft

* High moisture wood
* High tar
* For thermal use

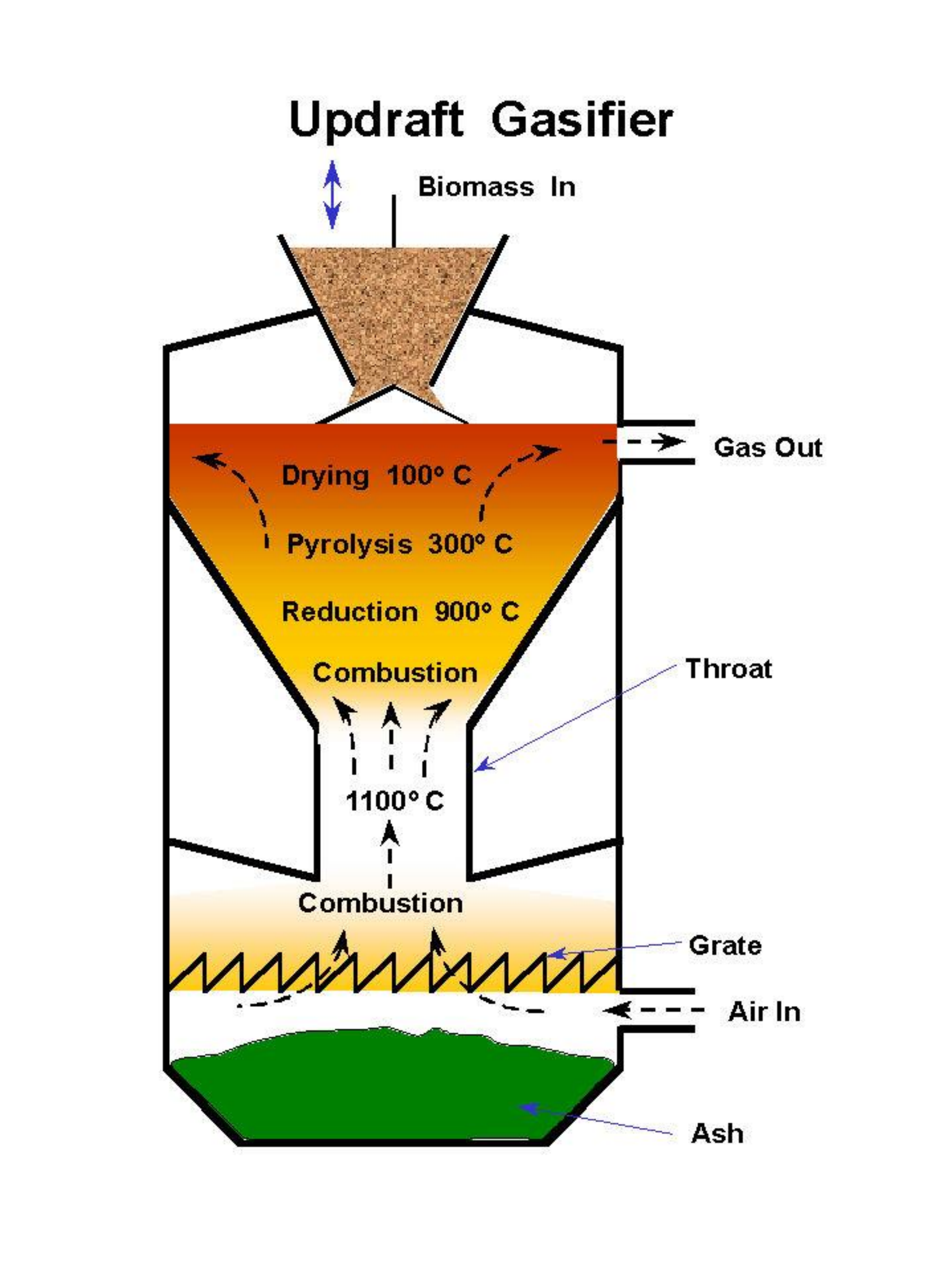
Closed Top

* World War II design
* Reasonably dry wood
* Better gas quality
* For engine and thermal use

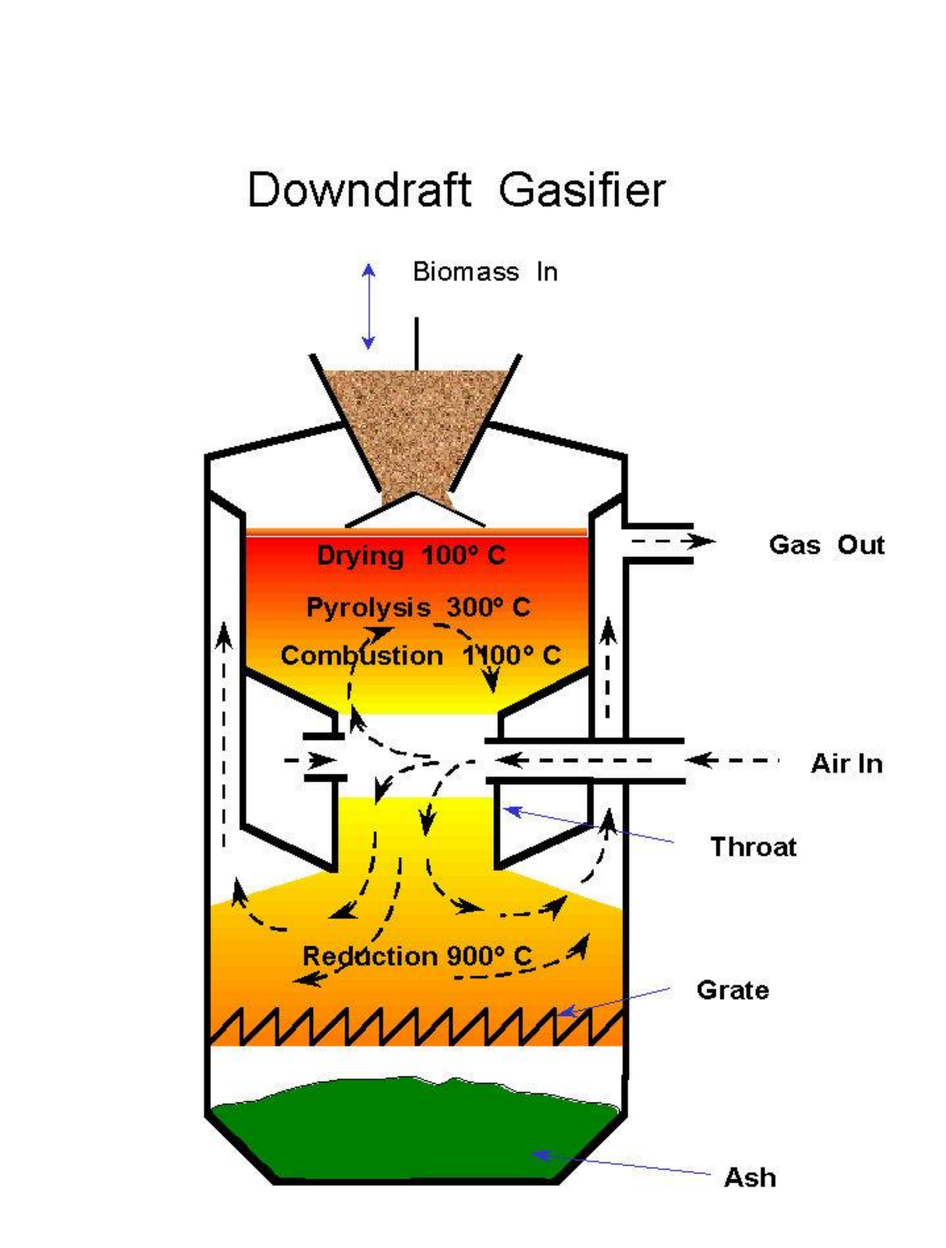
Open Top

* Recent development
* Reasonably moist wood
* Much better gas quality
* For engine and thermal use

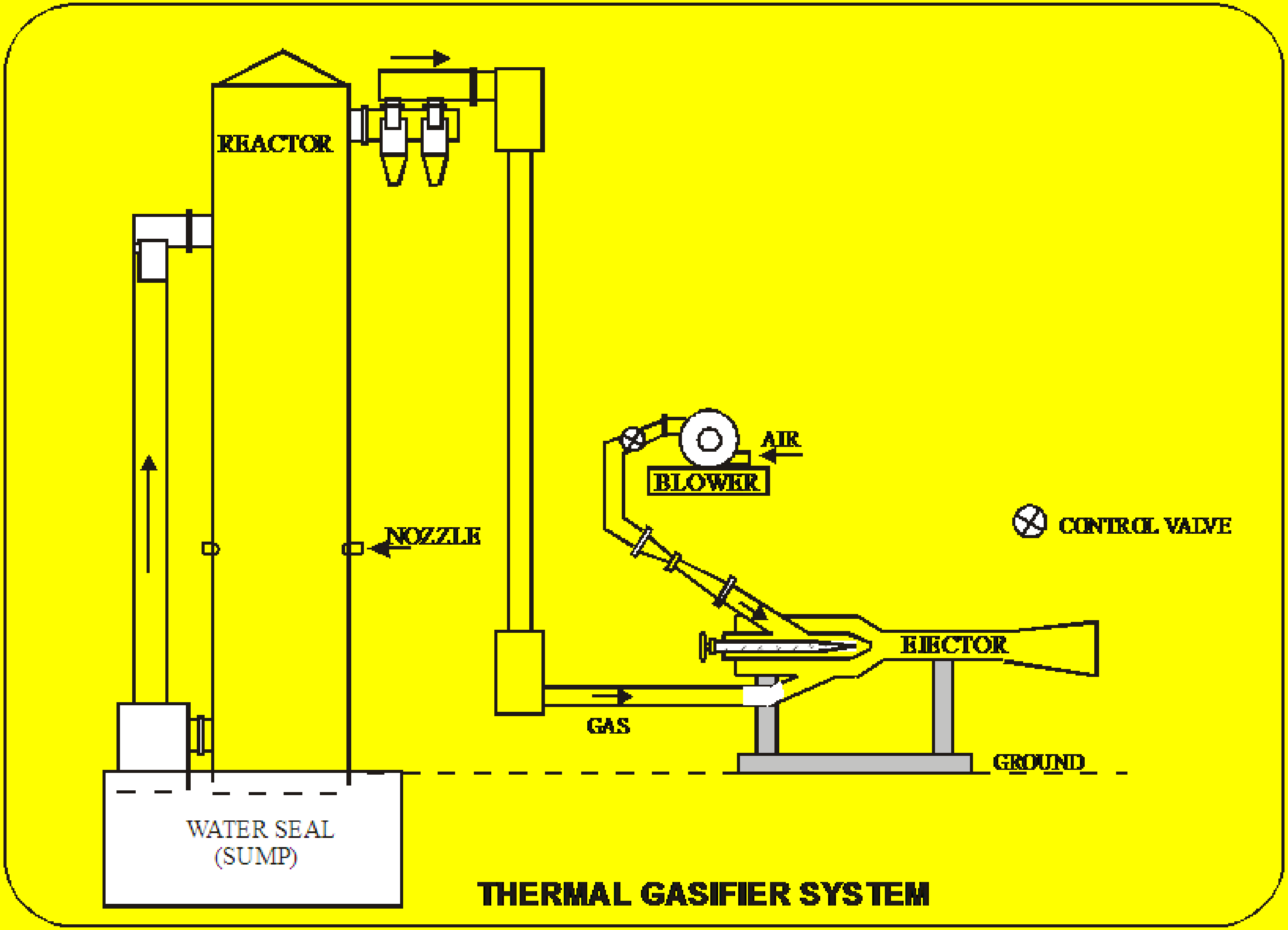
A classical Updraft gasifier



A Closed top WW II class gasifier

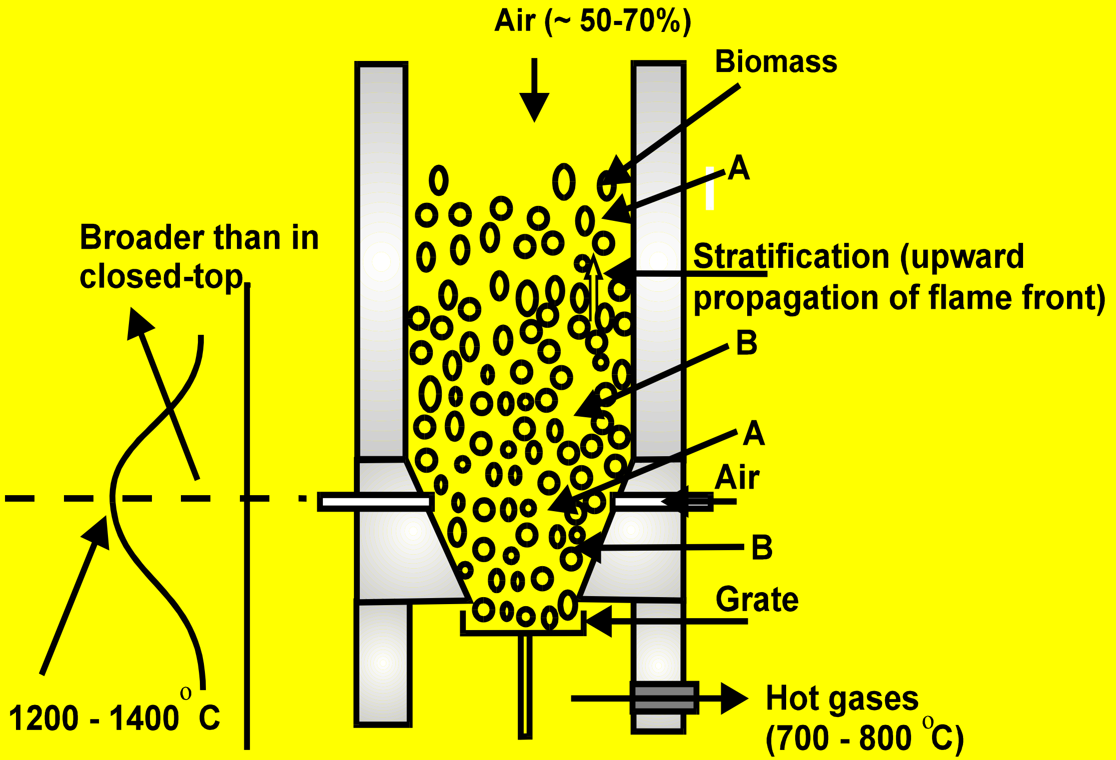


An open top re-burn IISc gasifier



What happens inside the downdraft open top reactor?

When side air nozzles are closed, the combustion front inside a working reactor will propagate at 0.6 to 1.0 m/hr



When side air nozzles are open, the flame front moves up, remains stationary or moves down depending on the relative flow rates from the top and the side.

A flame tube apparatus

A tube filled with gaseous fuel-air mixture and ignited at the top. A flame propagates downwards. Similarly, if the fuel gas is replaced by a solid fuel bed with spaces for air, a flame will propagate downwards as well. This is called stratification.

The producer gas –air flame propagates at 0.55 m/s

On stratification rates

The stratification rate refers to the movement of the solid fuel front. This can also be called regression rate. If we recognize that the solid density times the solid regression rate must roughly equal the gas density times gas propagation rate, we get

600 x 1.0 / 3600 = 0.16 m/s

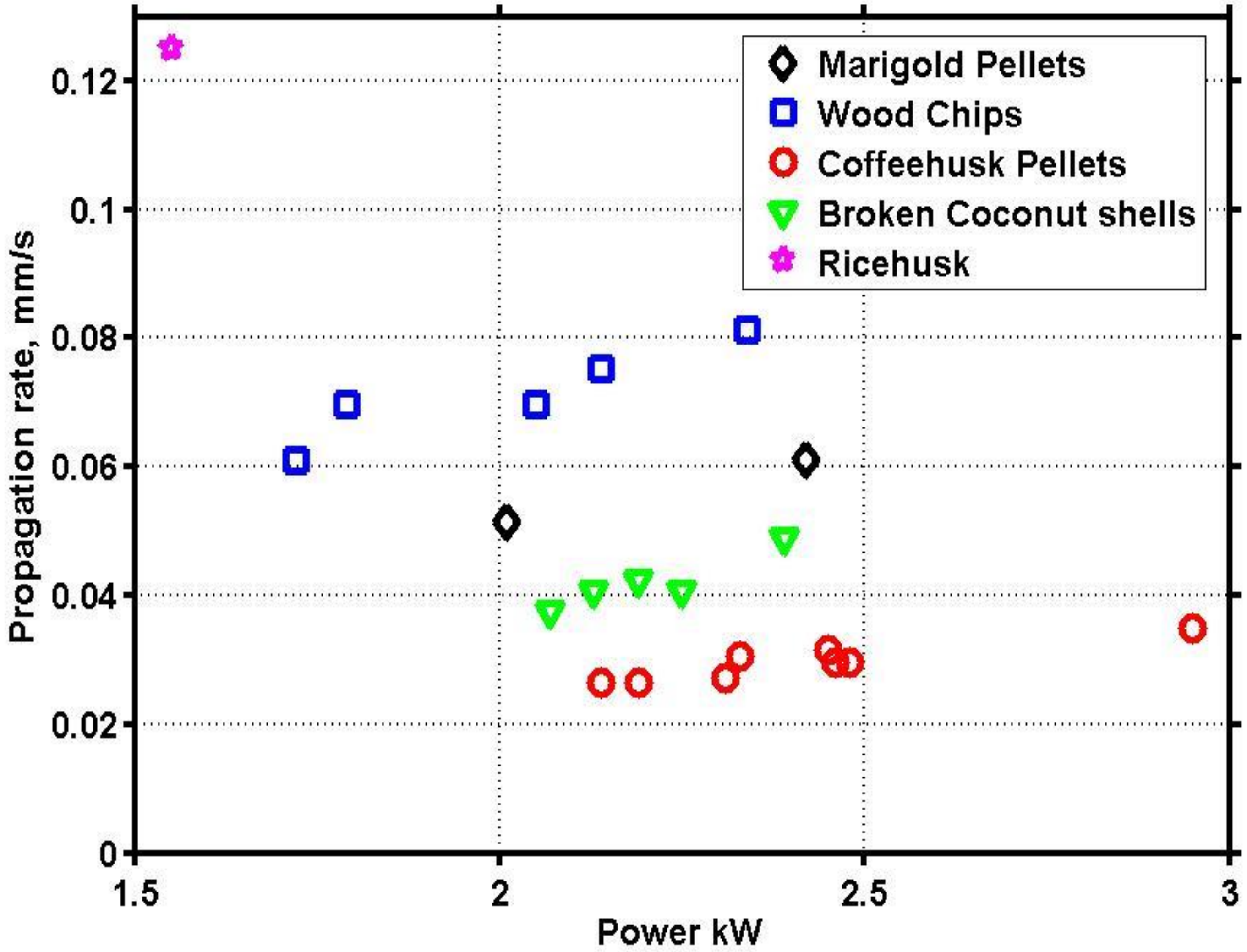
The fact that this is lower, but comparable with gaseous propagation speeds (0.55 m/s) is consistent (there are other limiting features, like gas to solid heat transfer here).

Stratification rates, contd

- The stratification rates depend on the density of the fuel and the flow rate of air through the system – called superficial velocity, the speed of the air stream in empty container.
- Let us look at the results…

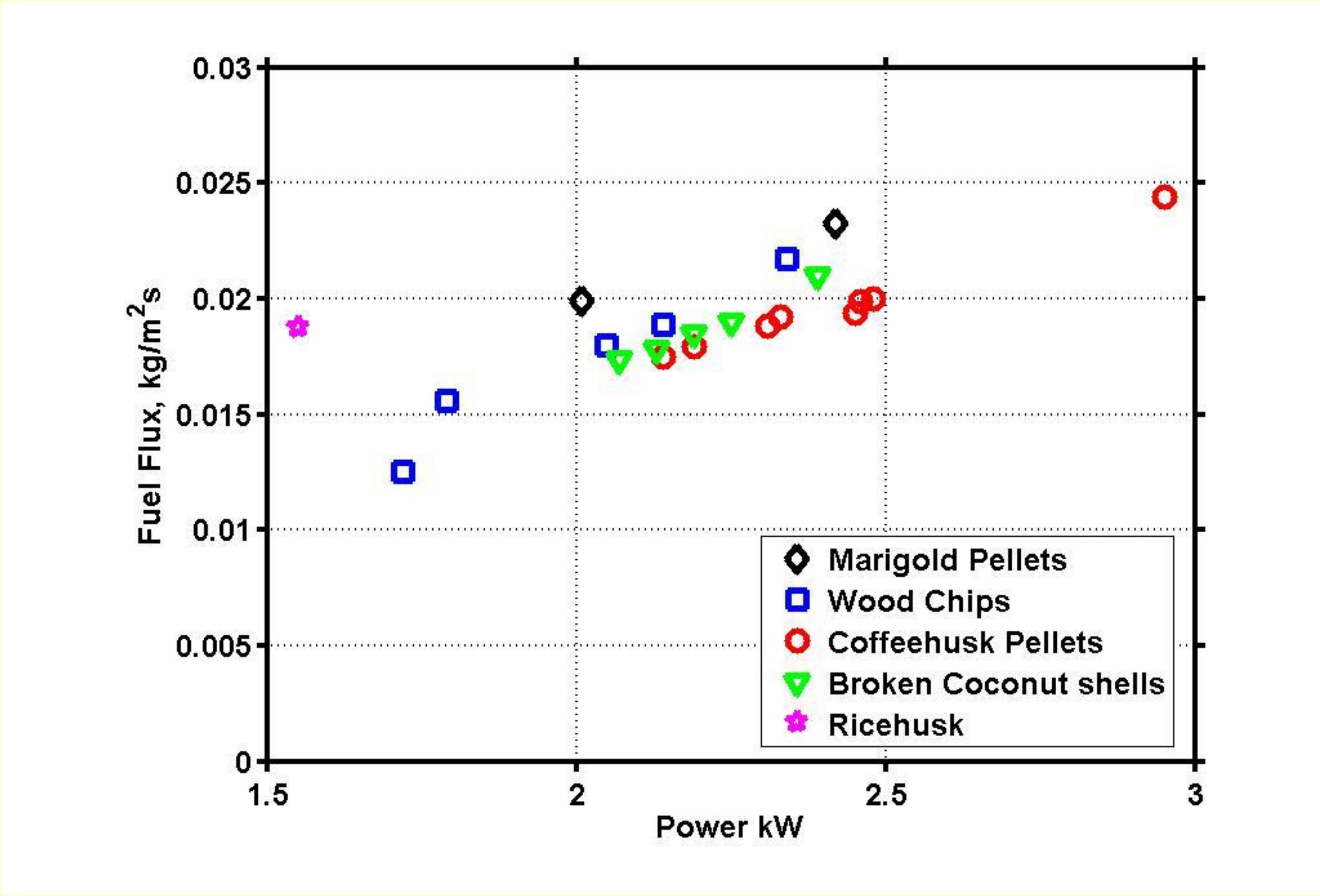
Stratification rates, contd

Power shown below is related to air flow, typically, 1 kg/h biomass + 1.7 kg/h air = 4.5 kW.



Stratification rates, contd

Notice that use of the product of density and linear propagation rate has produced an order in the behavior. All the results collapse on a single curve with a linear variation of the rate with air flow rate or power



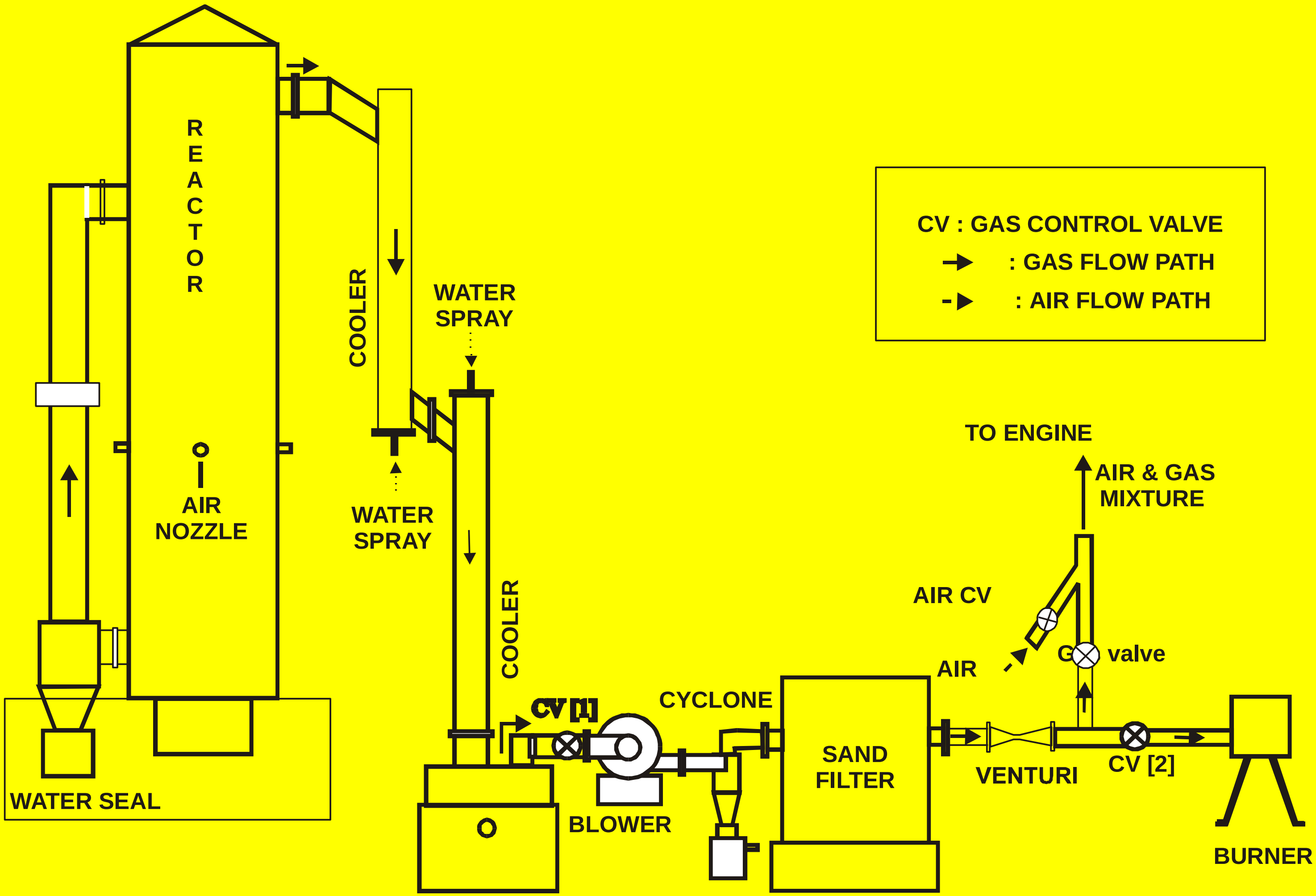
Gasification efficiency

How much of the calorific value of the biomass is extracted into the gas?

efficiency = Cold (or Hot) gas flow rate x Calorific value of the gas / Mass consumption rate of the solid fuel x Calorific value of the solid biomass

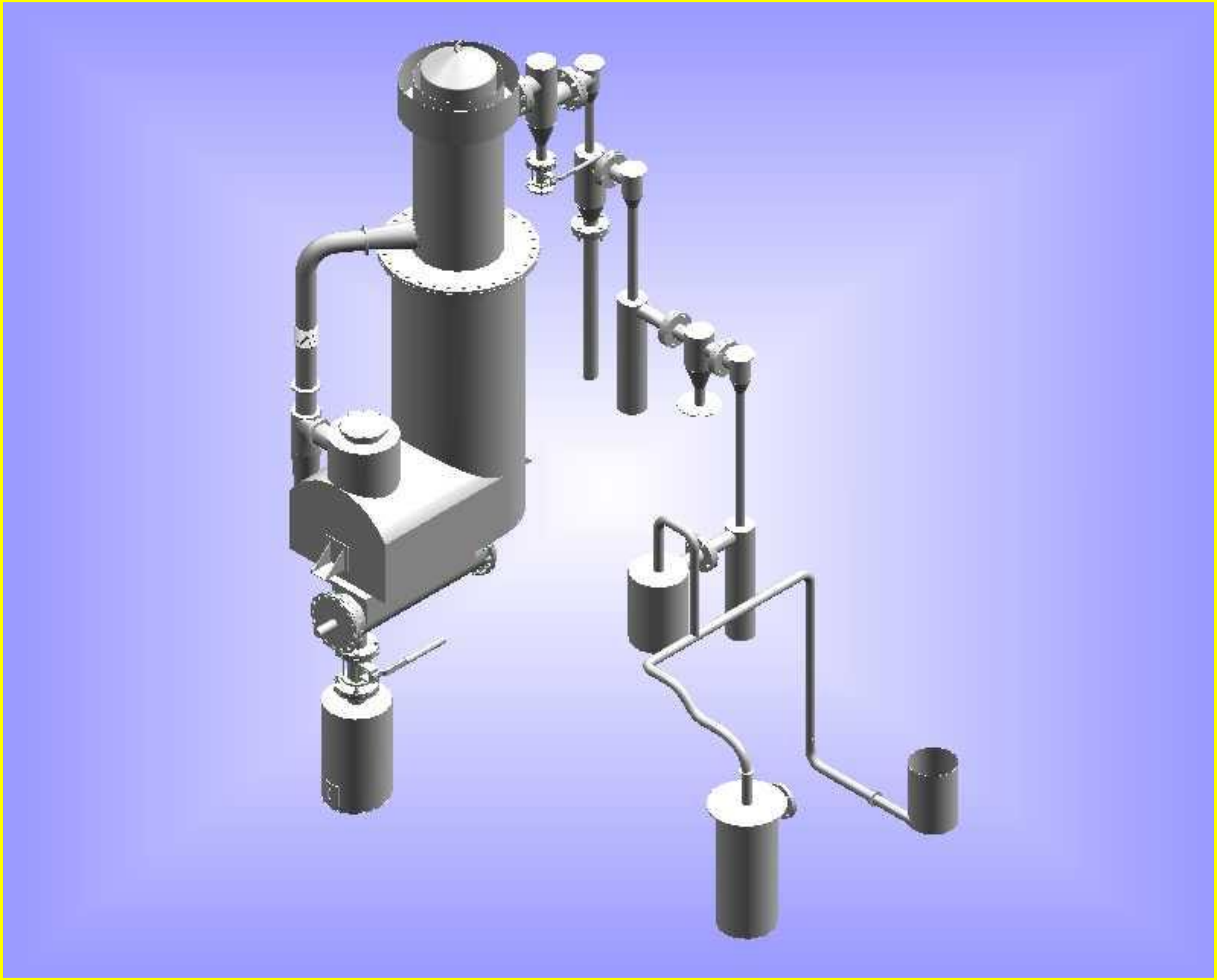
Cold (hot) gas flow rate/ solid fuel consumption rate ~ 2.5 to 2.7 (2.7 to 2.9) . The difference is due to water vapor. This is about 8 to 10 % of the hot gas flow rate.

A cold clean gas thermal gasifier

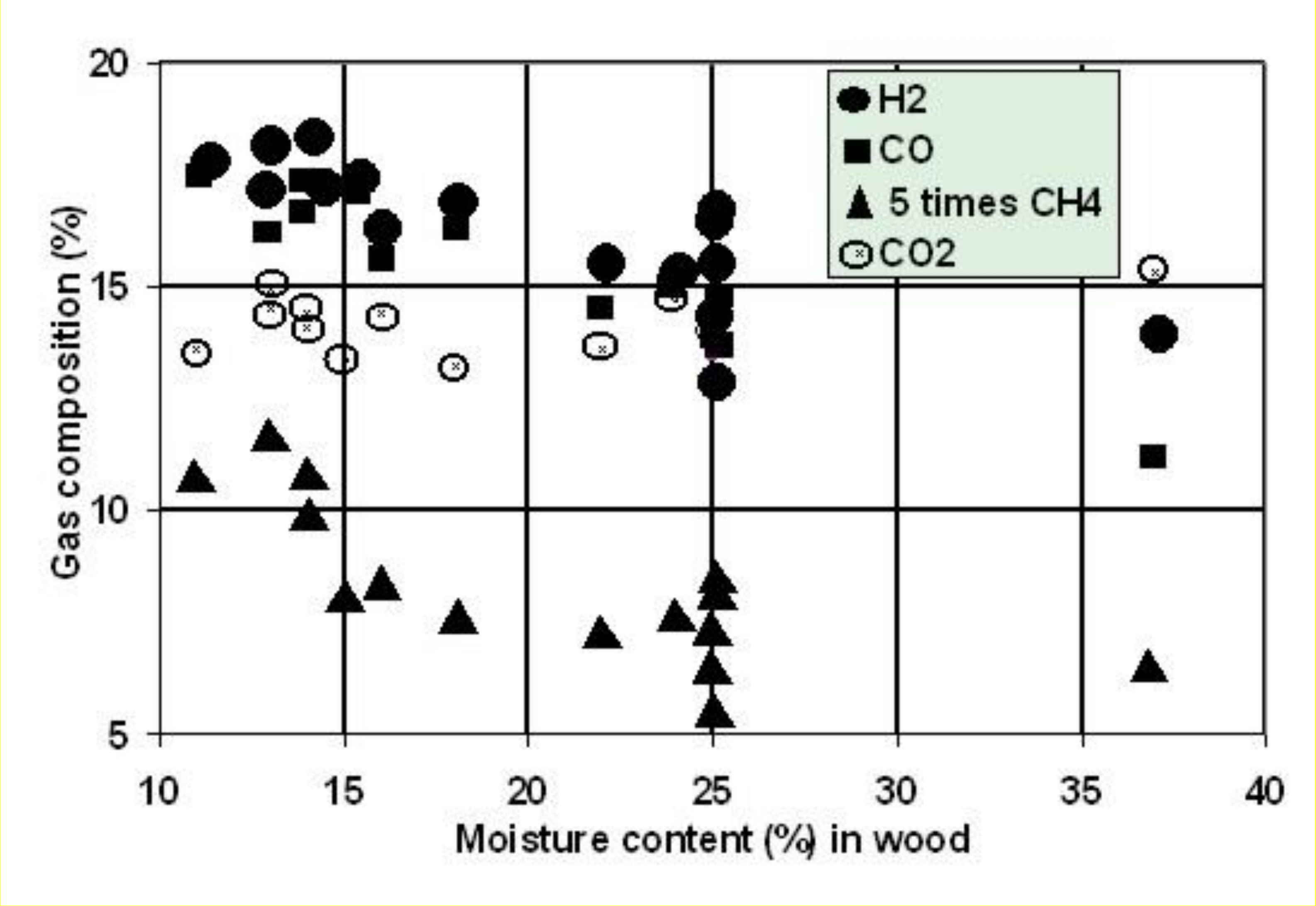


SCHEMATIC OF WOOD GASIFIER FOR POWER GENERATION

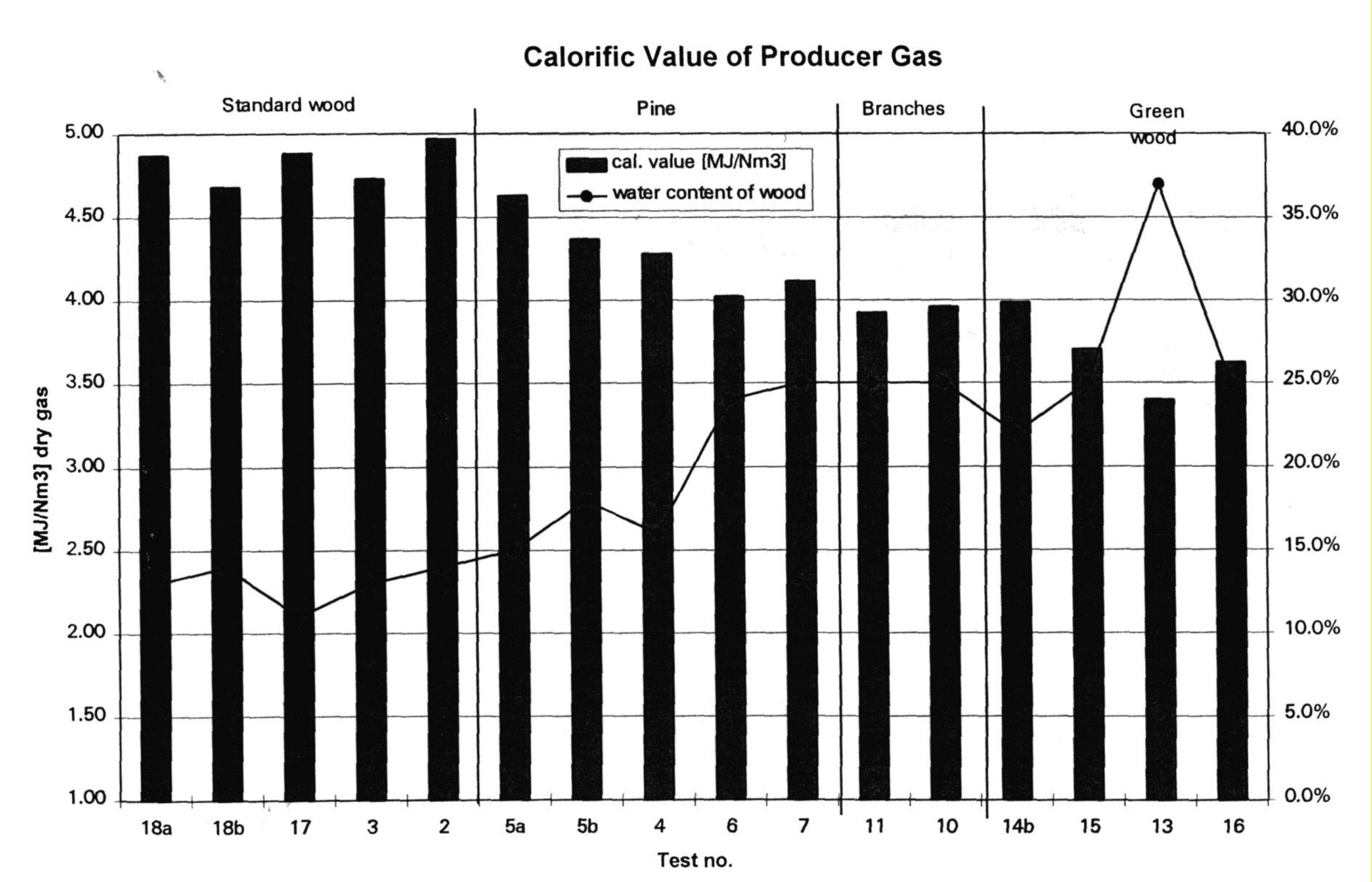
A gasifier in 3D



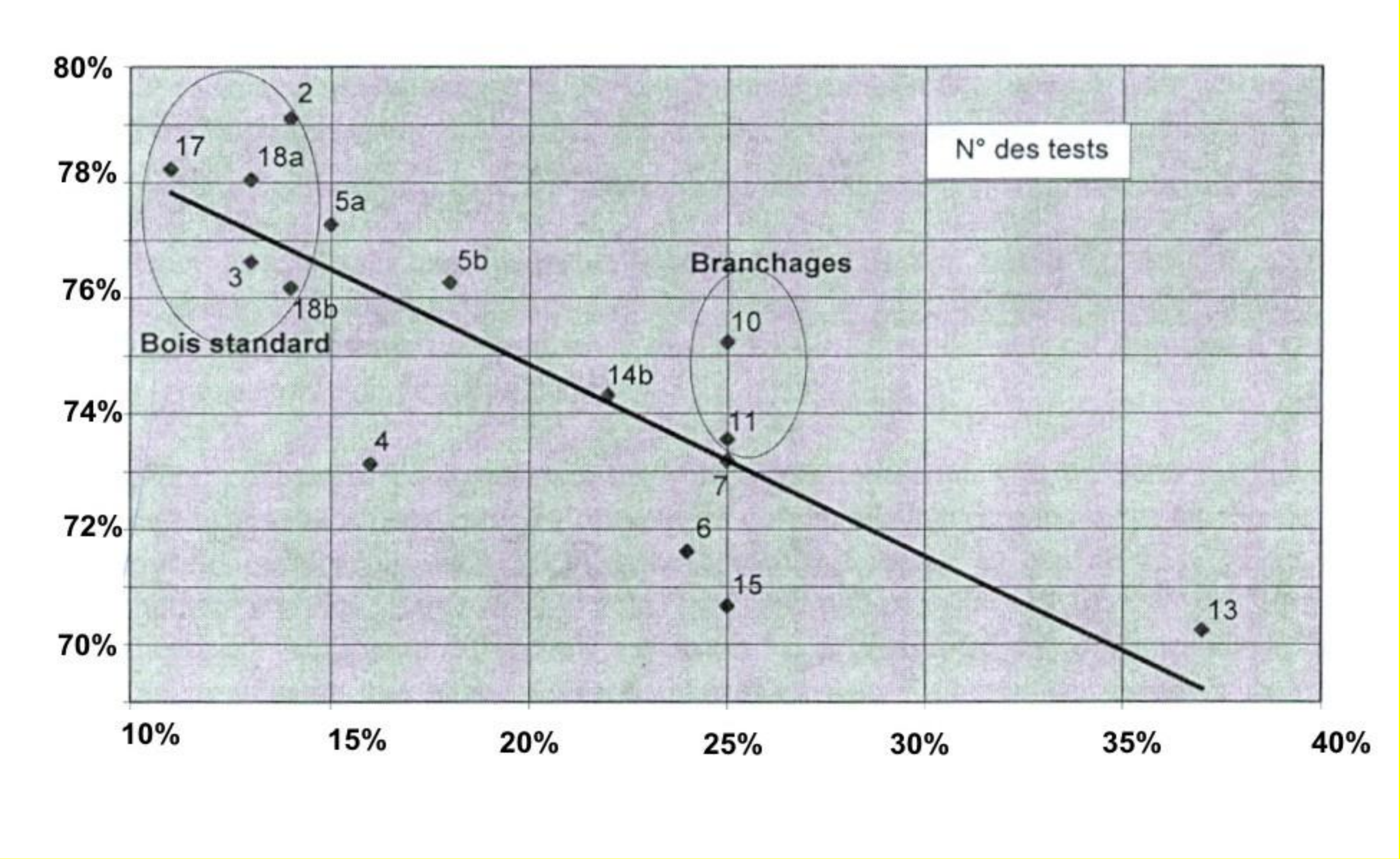
Cold gas composition vs. Moisture fraction in biomass



Calorific value vs. Moisture content



Gasification efficiency vs. moisture fraction



Implications of Gasification Efficiency vs. moisture fraction

- Drying the biomass helps recovering the heat in the biomass through gasification process better.
- Use of more dry biomass implies energy put in is higher.
- Hence drying the biomass helps deliver better energy in the gas
- Drying process requires low grade heat (heat at temperatures of 100 C) and can be helped using the exhaust of the systems.

Importance of drying

- Many designers of biomass based combustion / gasification systems claim greatness of their designs as they can use as-received biomass (particularly from Europe).
- They have bypassed understanding the “double trouble!” aspects of moisture.
- Really, do we understand why it is so?…

Why is the effect of moisture so?

1. One needs to add heat to vaporize the water in the biomass and if there is more moisture, more heat is drawn.
2. Peak temperatures attained are lower.
3. This reduces the conversion of gaseous products (CO_2, H_2O and some higher hydrocarbons to CO and H_2)
4. Hence the gas quality becomes poorer.

What about combustion systems – like closely coupled systems?

1. The heat released by combustion goes to heating the moisture as well.
2. This reduces the peak temperatures attained in the system.
3. This effectively reduces the efficiency of heat utilization (water boiling efficiencies will be lower)
4. Reducing moisture is double benefit because, peak temperatures are higher for lower flow rates of active fluid (and hence biomass)

Effects of biomass size

- Common expectations are that whatever size that is available must function. If it does not, dismiss the combustion device as not useful.
- The ides of using an appropriate size is to provide a sufficient surface area for volatiles to get generated and provide enough power.
- Too large a size cannot give enough volatiles
- Too fine a size generates so much volatiles that it cannot find enough air for clean combustion and so, one will create a sooty flame.
- One must stay in the middle range and perhaps use a mix of sizes.

Effects of biomass size

- Take the example of a stove of 2 to 3 kW capacity. The chamber carrying the fuel is typically 60 x 100 mm.
- One can use biomass sticks that are 10 to 20 mm cross section (say, diameter of the uneven stick). One can load about 5 to 6 sticks in three to four layers. This is reasonable.
- If one were to use a stick of 30 mm dia, one can only lay a total of 6 to 7 sticks.
- These larger size sticks will take time to ignite and it would be difficult to generate volatiles to sustain the power demanded.

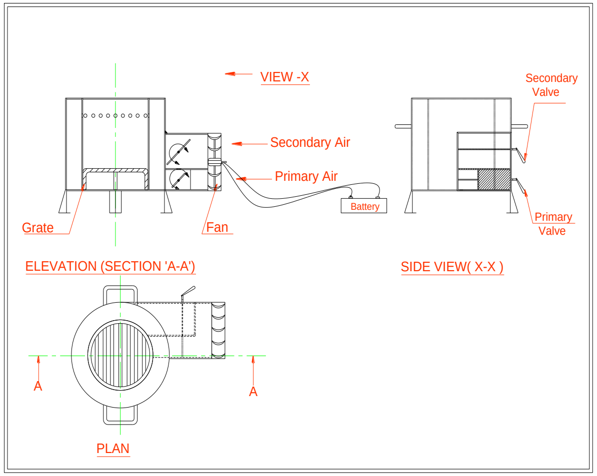
Effects of Biomass size

- The golden rule is to use a mix of biomass sizes about 1/6th to 1/8th of the diameter of the vessel interior.
- A 400 mm dia reactor for a 275 kW_{th} gasifier uses biomass about 40 to 60 mm size. 10 % 100 mm or 20 mm pieces is OK.
- A 200 mm reactor for a 80 kW_{th} gasifier uses 25 to 35 mm size biomass.
- Departures on the larger side will lead to lower quality gas (cal value) and on the smaller side will generate a gas with more tar in a gasifier (or soot in a combustion system).

Other classifications of Thermal Gasifiers

- Combustion coupled gasifiers
  - Gasifier Stoves
    - For woody fuel
      1. Fire and forget (or fixed mass combustion)
      2. Continuous operational systems
    - For pulverized fuel
- Combustion decoupled gasifiers
  - Hot “non-clean” gas combustion
  - Cold clean gas combustion

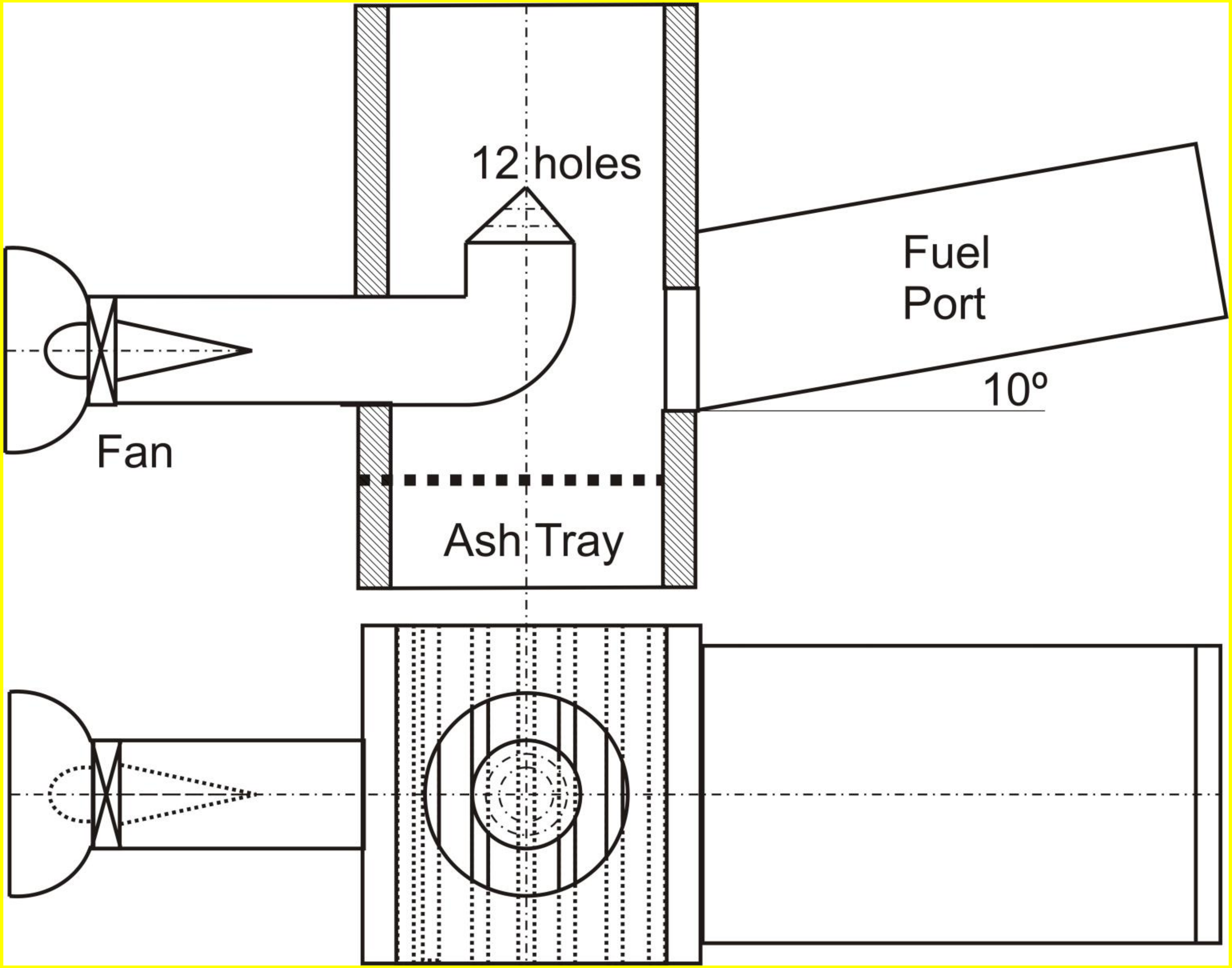
Solid Biomass Stove



- Forced Draft Gasification Stove
- Good for solid bio-residues
- Power level ~ 2 – 4 kWth

Air is provided by a small fan, distributed below grate and at the top. The bottom air is primary air for gasification and the top air is secondary air is for the combustion of gaseous fuel. The ***power of the stove*** is directly proportional to the ***air flow rate*** through the bed since the gasification process maintains the air-to-fuel ratio appropriately. This is valid over a range termed “turn down ratio, typically about 3.

Inclined continuous feed gasifier stove



Inclined continuous feed stove

- It works *significantly by gasification*.
- The energy delivery zone is not far from the heat release zone.
- The design is extremely compact.
- It uses a 12 V battery to generate an air jet at 2.5 to 3 m/s velocity to help ejector action.
- The flow is aided by free convection.
- One can use sticks, pellets and even fine biomass. Higher the density of the biomass, lesser is the attention demanded.