Gasification of Solids and Liquids

- Commercial Applications and Potential Uses for Plastic Waste

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What is Gasification?

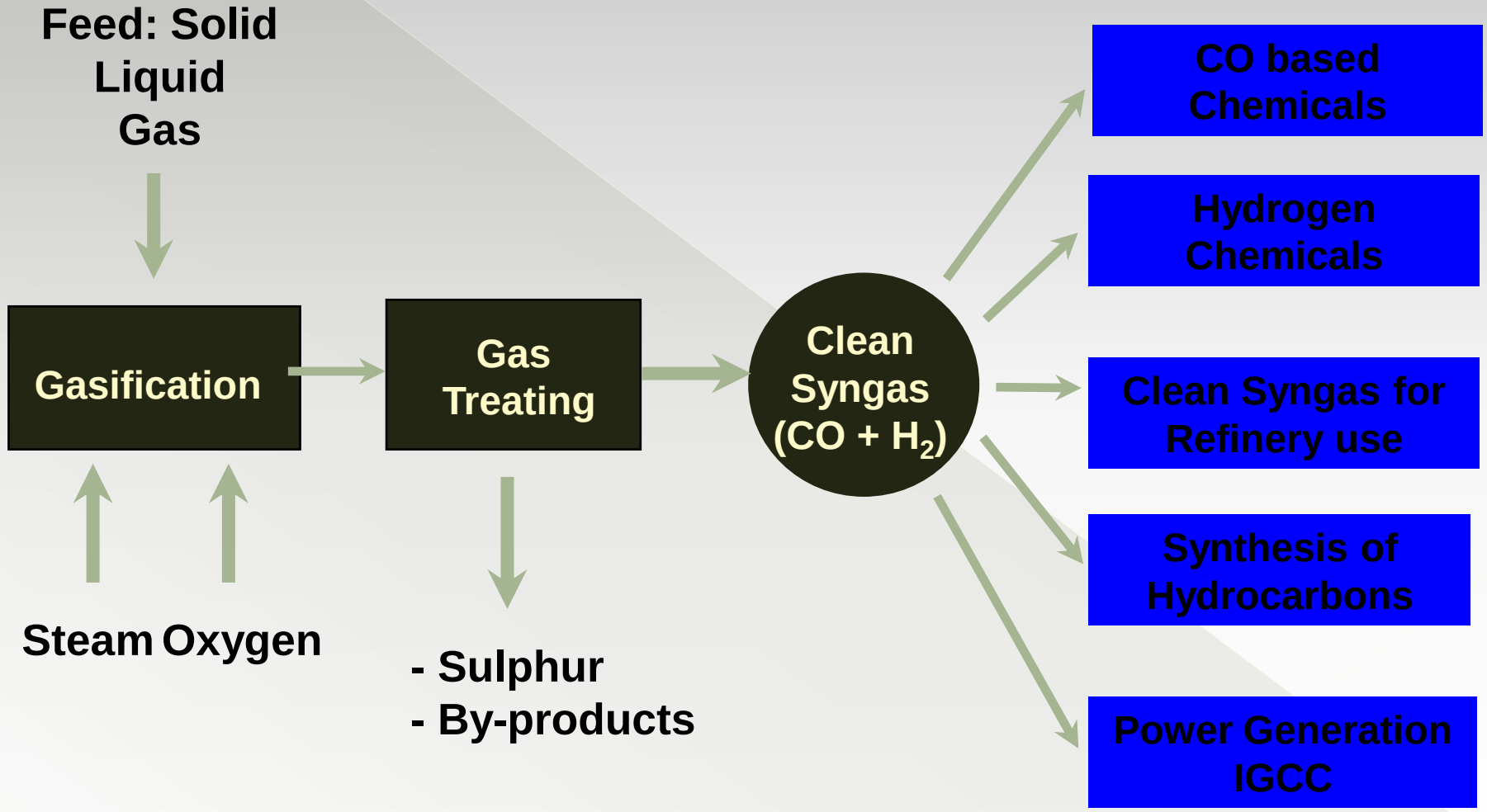
- Complete combustion

$$2\,(CH_2) + 3\,O_2 \longrightarrow 2\,CO_2 + 2\,H_2O$$

- Gasification is partial combustion

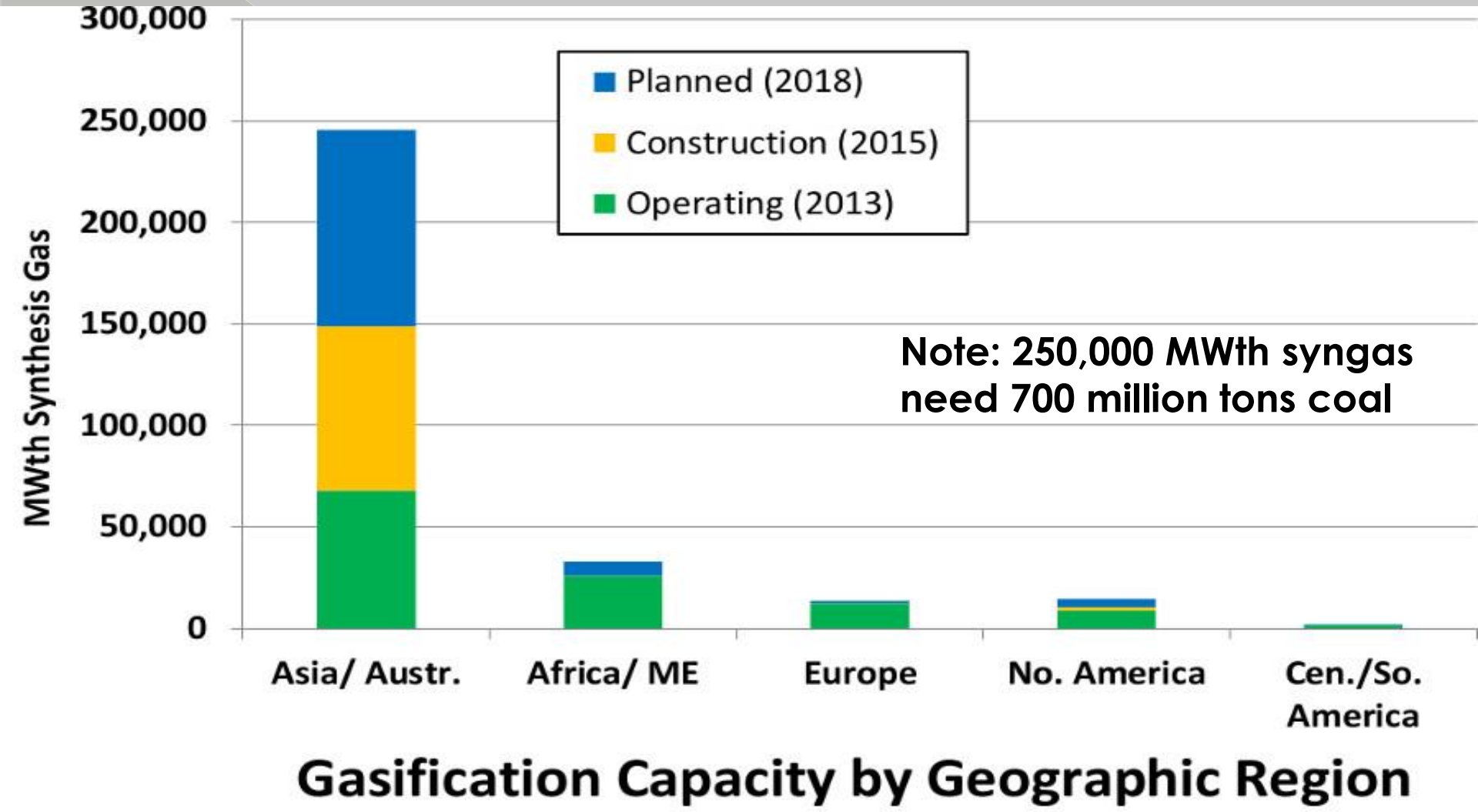
$$2\,(CH_2) + O_2 \longrightarrow 2\,CO + 2\,H_2$$

Why Gasification
Enabler of Utilization of All Feedstocks



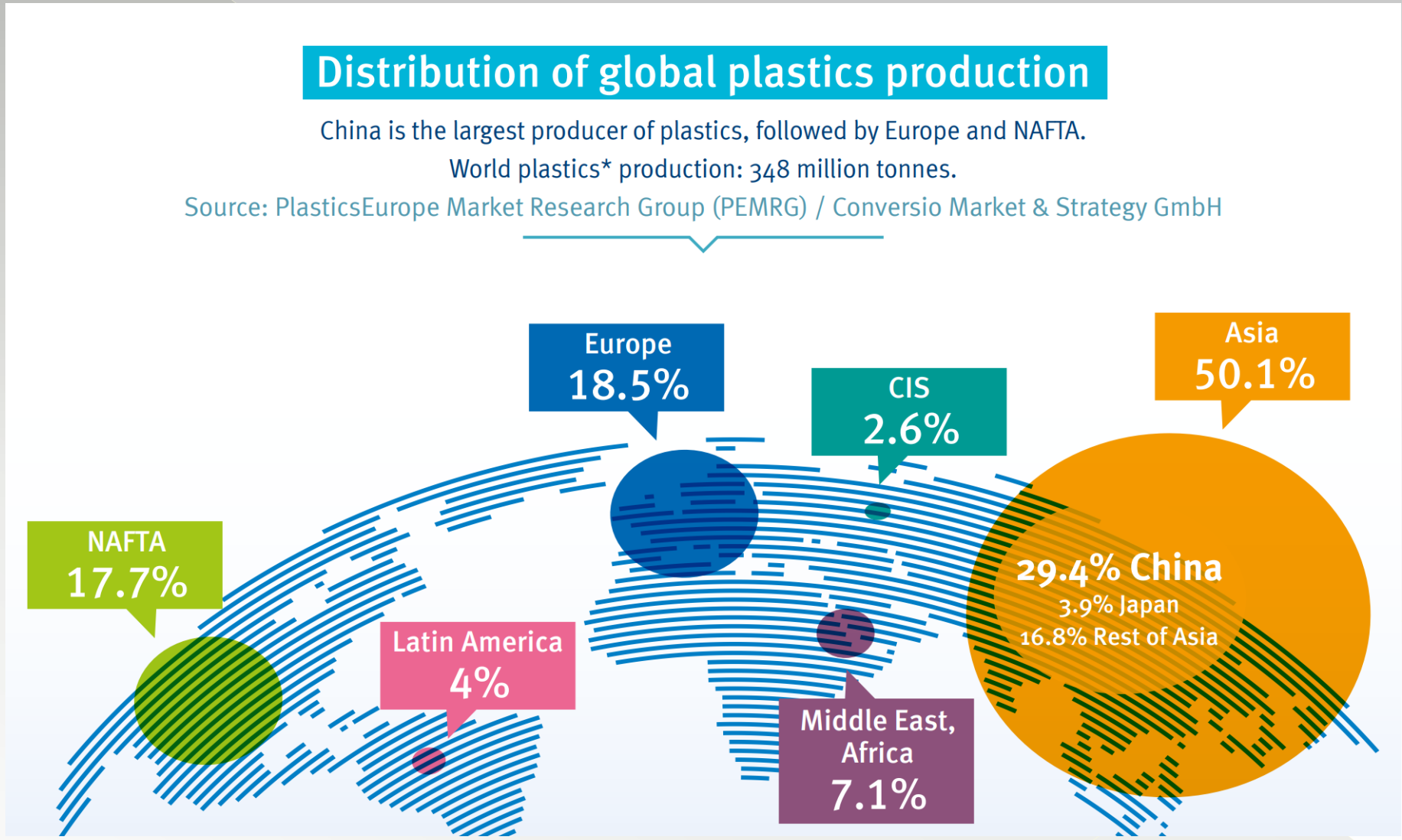
Courtesy: Shell

Where Are Gasification Plants



Courtesy: Gasification Council

Global Plastics Production



Courtesy: Plasticseurope.org

Commercial Gasification Processes

- Non-Catalytic Reactors
- Oxygen blown, entrained flow
- High Temperature and elevated pressure
- Feeding systems: dry solid or liquid pumping
- Selection of reactors
- Steam generation in waste heat exchanger

Gasification Processes Operations

- **Liquid Feed**
- Vacuum residue @ ~1300 ^{o}C, 35-65 bar
  Vacuum cracked residue
  Asphalts/Tar

- **Slurry Feed**
- Coal/Anthracite/Coke @ ~1350 ^{o}C, 20-80 bar

- **Solid Feed**
- Coal/Anthracite/Coke @ ~1550 ^{o}C, 25-45 bar

Gasification Process for Liquid Feed

- Oxygen blown, at pressures up to 65 bar
- Direct pumping applied to diverse liquid feedstocks: vacuum-flashed cracked residue, asphalt, Orimulsion, liquid coke
- Slurry pumping applied to diverse solid feedstocks: Coal, Anthracite, Petroleum coke
- Refractory-lined reactor
- Top fired
- High-pressure steam generation in waste heat exchanger

Shell Gasifier for Liquid Feed. Refractory Lined Reactor

Courtesy: Internet

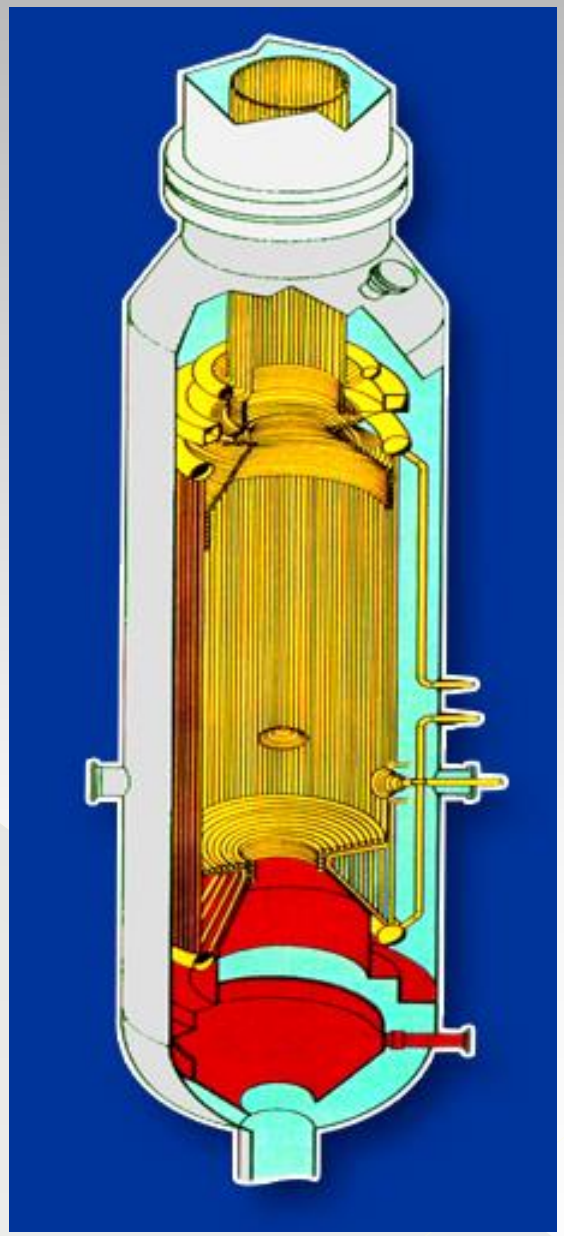
Commercial Shell Gasification Plants

Courtesy: Internet

Gasification Process Dry Feed

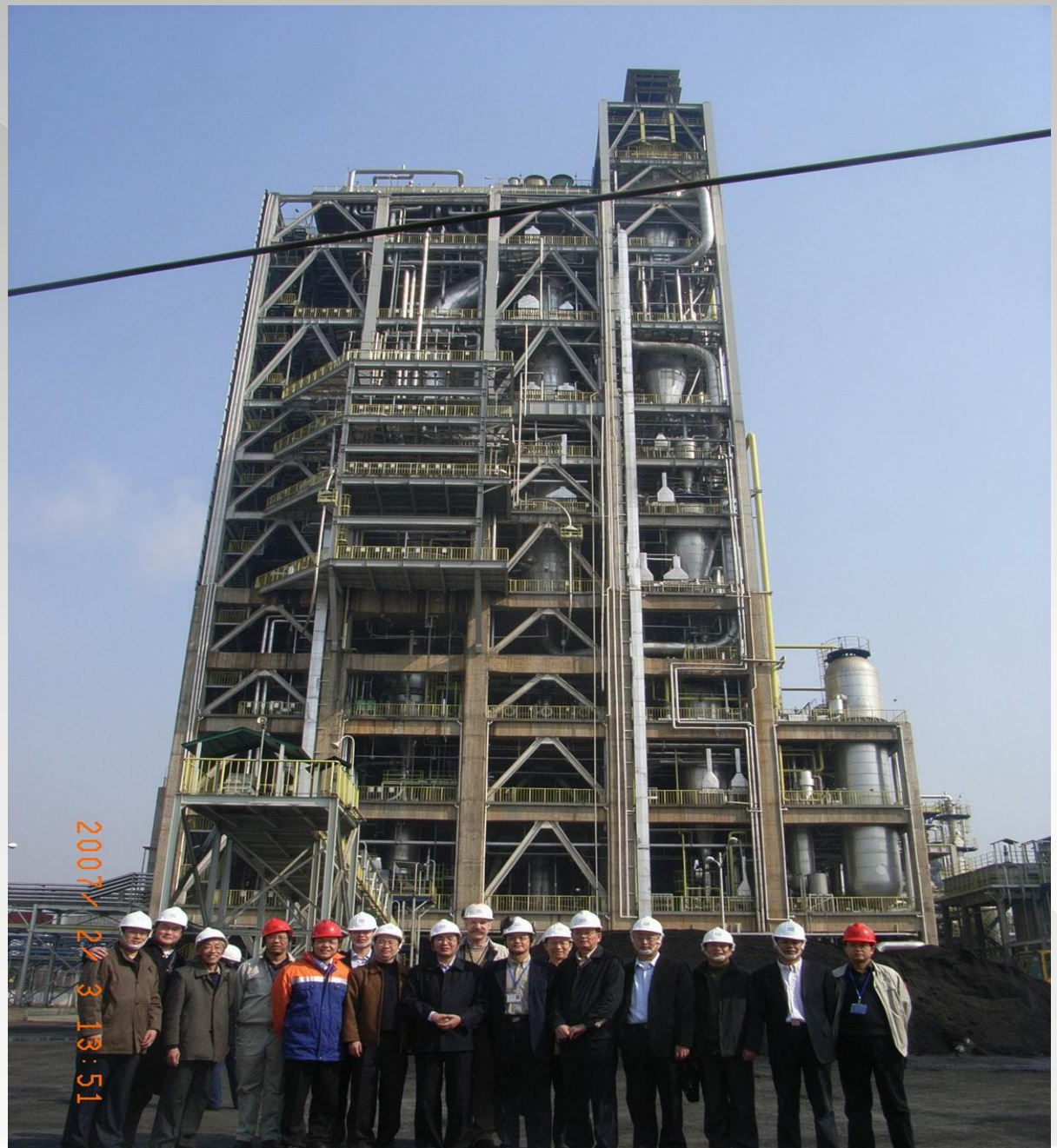
- Dry solid powwer feed, assisted by inert gases
- Oxygen blown, entrained flow gasifier, at pressures up to 45 bar
- Applicable to diverse feeds: bituminous coals, lignite, anthracite, petroleum coke
- Slagging membrane wall reactor
- Side fired or top fired
- High-pressure steam generation in waste heat exchanger

Shell Gasifier for Solid Feed. Membrane Wall Reactor



Courtesy: Internet

China Coal Gasification Plant



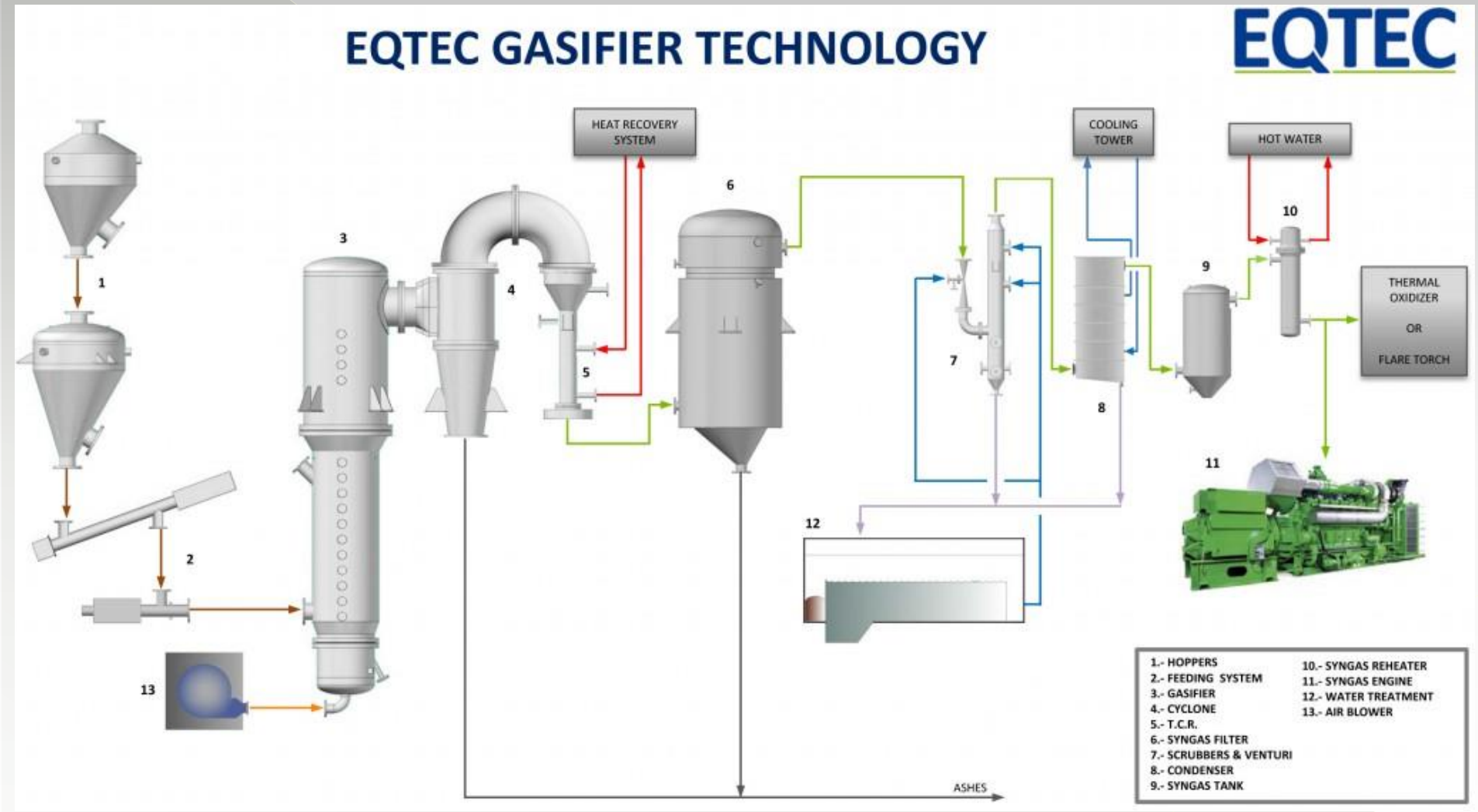
Application to Plastics Recycling

- Continuous (entrained flow) vs batch operation
- Fixed bed? Fluidized bed?
- Oxygen vs air as oxidation agent
- Atmospheric vs elevated pressures
- Dry feed vs Liquid feed
- Selection of reactors: membrane wall, refractory, top fired vs side fired
- Steam generation and waste heat recovery

Gasification Process Concepts

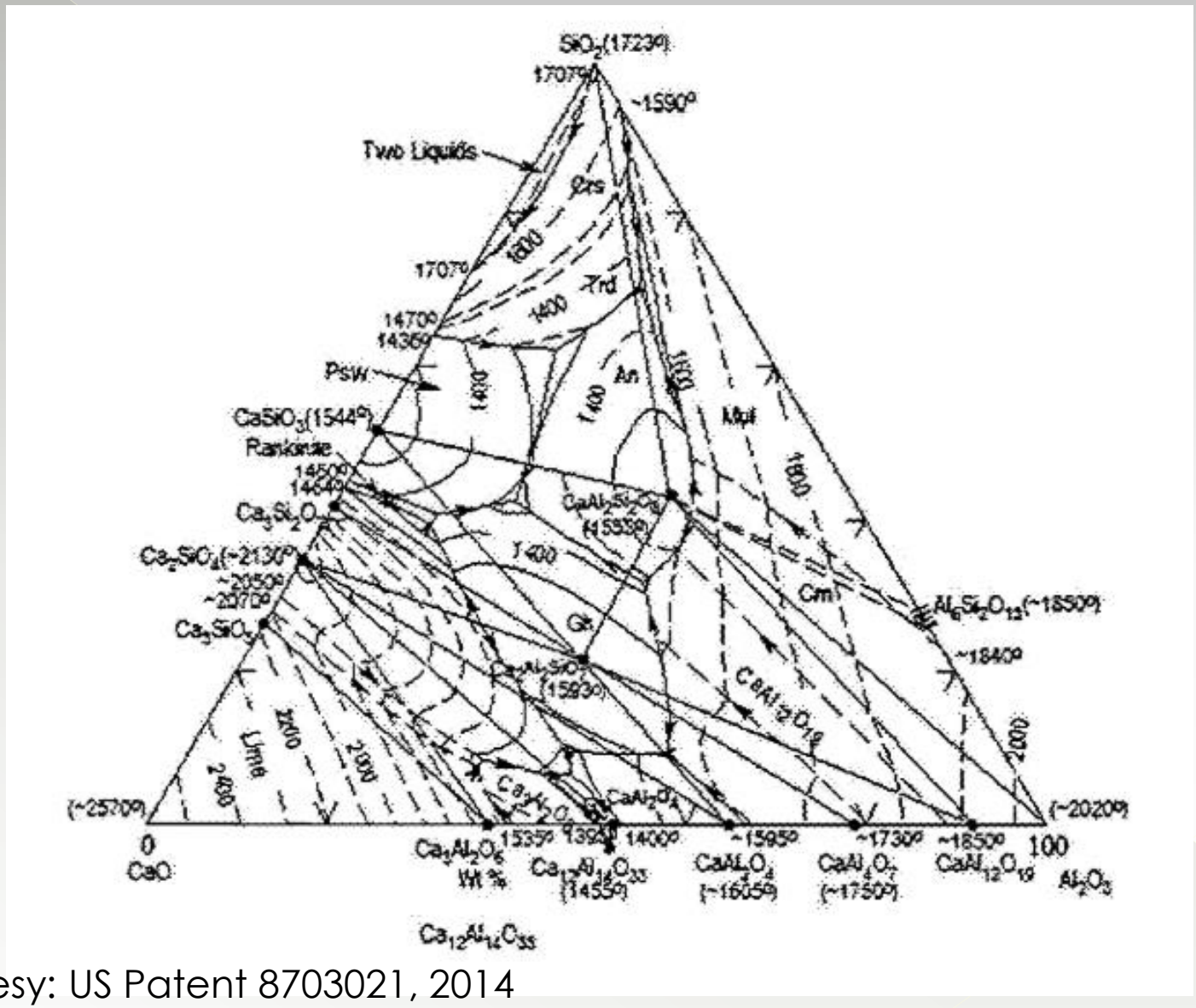
	Liquid Feed	Solid Feed
Feeding system	Liquid pumping	Dense phase dry feed
Gasification Region	Non-slagging	Slagging
Reactor Internals	Refractory lining	Membrane wall

Dry Feed System with Hoppers



Courtesy: EQTEC

Phase Diagram for Slagging Gasifiers

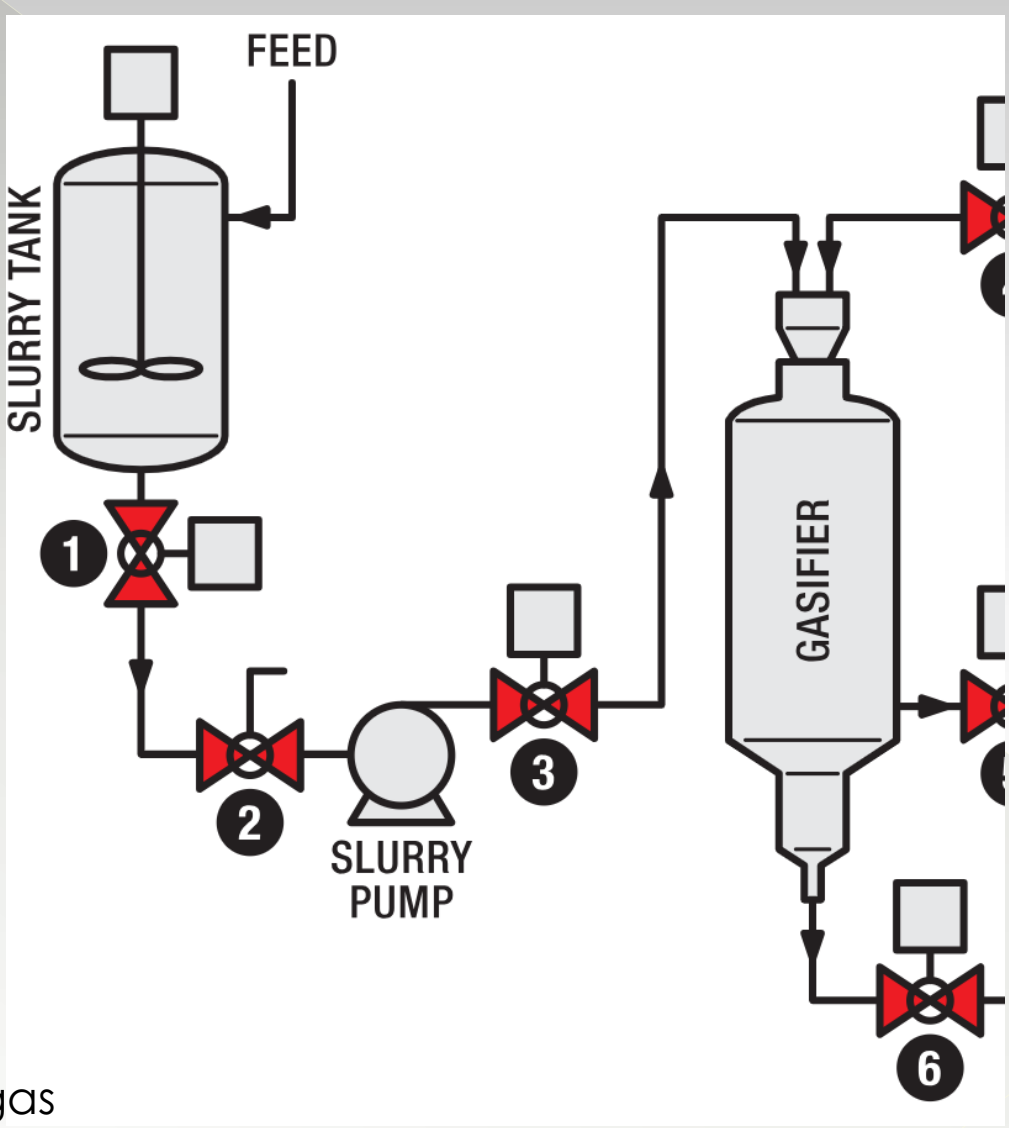


Courtesy: US Patent 8703021, 2014

Questions of Dry Feeding

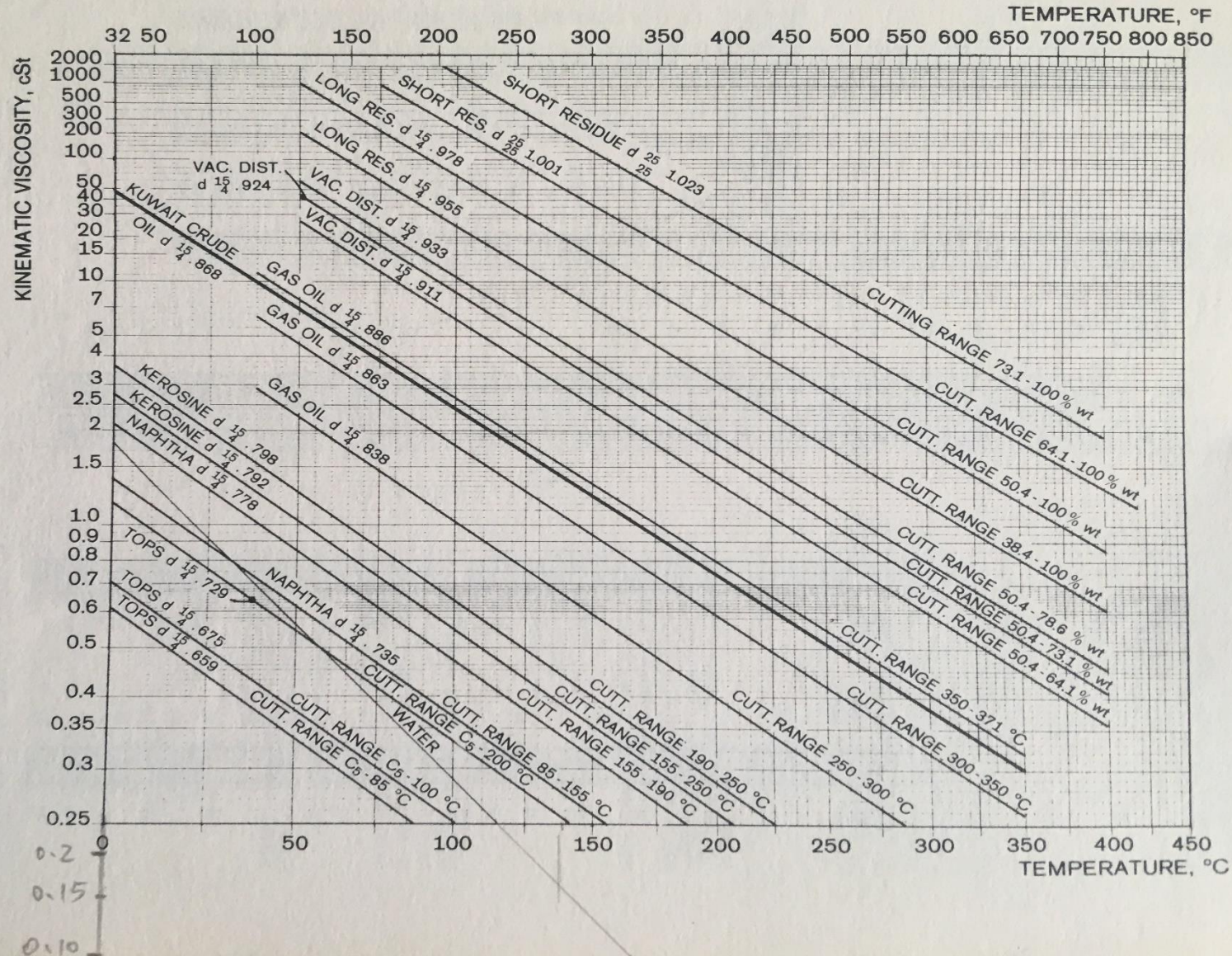
- Can the plastic waste be ground into fine powders?
- What are the engineering innovations to make this feasible?
- What are the characteristics of fine plastic powder?
- What are the flowing characteristics of fine plastic powder?
- What are the reactivity of the fine plastic powder in the presence of (pure) oxygen?

Liquid Feed System with Pump



Courtesy: Mogas

Viscosity of Oil Fractions



Questions of Liquid Feeding

- Will the plastics become liquid at elevated temperatures to be pumped around?
- What are the engineering measures to make this feasible?
- What are the flowing characteristics of the "plastics liquid"?
- Is this a sensible option?
- Is slurry feed a better option?
- Slurrying need the plastics to be ground to powder
- What are the slurrying characteristics of plastics solid powder?

Summary

- Gasification of solid and liquid feedstock technologies well established
- Large-scale commercial applications proven
- Technically challenging when applying established gasification technologies to plastic wastes
- Fundamental process concepts to be selected
  - Continuous (entrained flow) vs batch operation
  - Oxygen vs air as oxidation agent
  - Atmospheric vs elevated pressures
  - Dry feed vs Liquid feed
  - Steam generation and waste heat recovery
- Feeding system crucial in gasification of plastics wastes
- Do we need a fundamentally different process concept for the gasification of plastics wastes

"QUESTIONS YOU CANNOT ANSWER ARE USUALLY FAR BETTER FOR YOU THAN ANSWERS YOU CANNOT QUESTION."

Yuval Noah Harari
(21 Lessons for the 21st Century)

THANK YOU!

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