
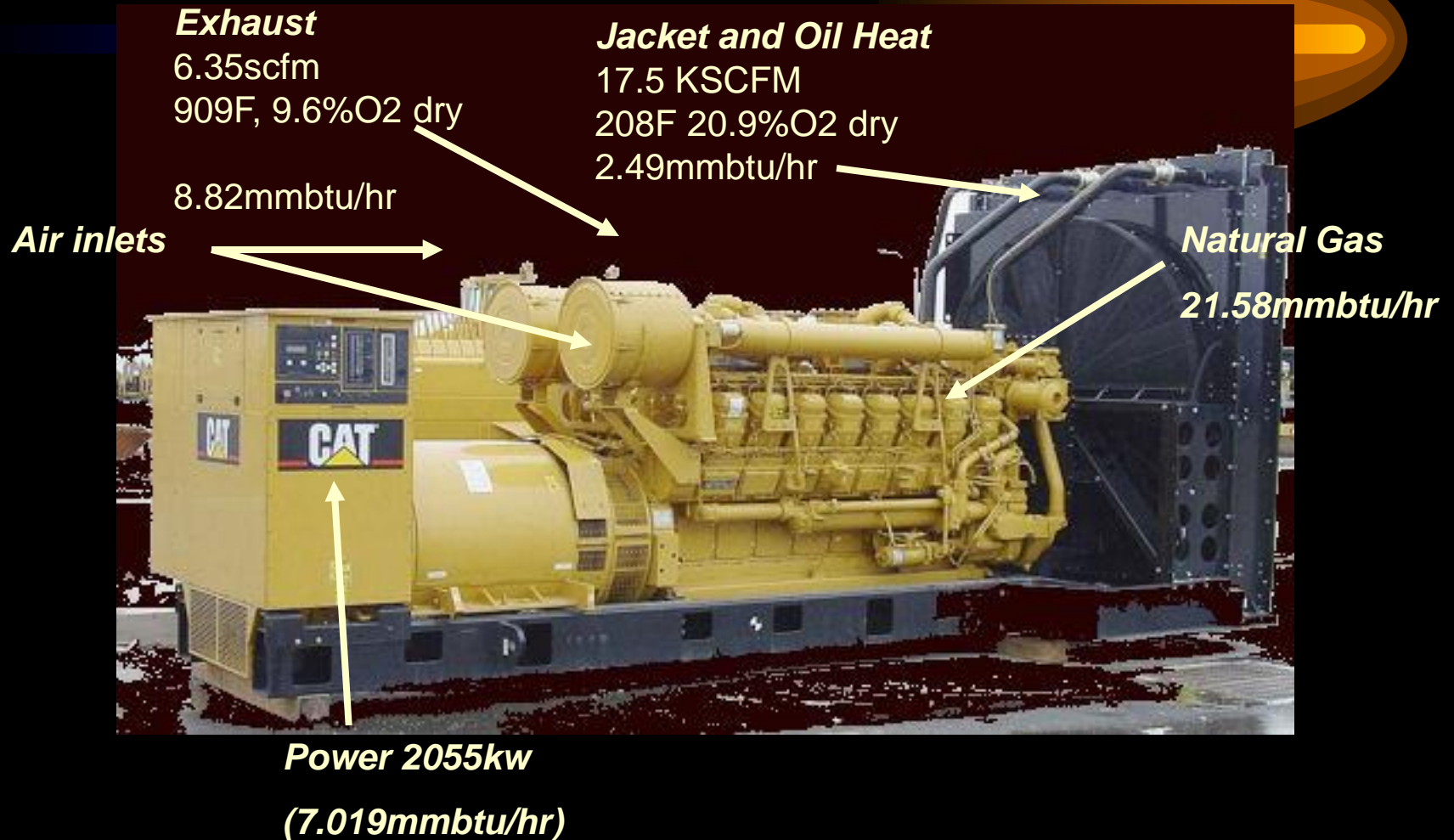


*Reciprocating Engine/Boiler
Co-Generation for
Power and Heat*



Uninterrupted Boiler Operation,
Fuel Savings, and NO_x Reduction by
Combining Reciprocating Engines with Boilers
Incremental HHV Heat Rate = 4042

Catapillar 3520 Natural Gas Engine



Cat 3520 Emissions

- NO_x = 70.6ppm @ 15% O₂ = 214ppm@3%O₂
- CO = 273.ppm@15%O₂ = 830ppm@3%O₂
- HC = 814ppm@15%O₂ = 2470ppm@3%O₂

Heat Rate without Heat Recovery

- 10,501 btu/kw-hr HHV
- Cost of Power = \$/mmbtu/ 95.2
 - For \$5/mmbtu gas power cost 5.25cents/kw-hr

Using Engine Exhaust & Excess Heat

270F Boiler Exchanger Exhaust
2% Oxygen

- **4021 btu/kw-hr HHV**
- **engine Exhaust is reburned**
 - **Emission Mitigation & Heat Recovery**
- **Jacket and Oil Energy Preheats Combustion Air.**
- **Cost of Power = \$/mmbtu / 248**



100klb/hour,
200psig steam,
230F feedwater,
107.7mmbtu/hr

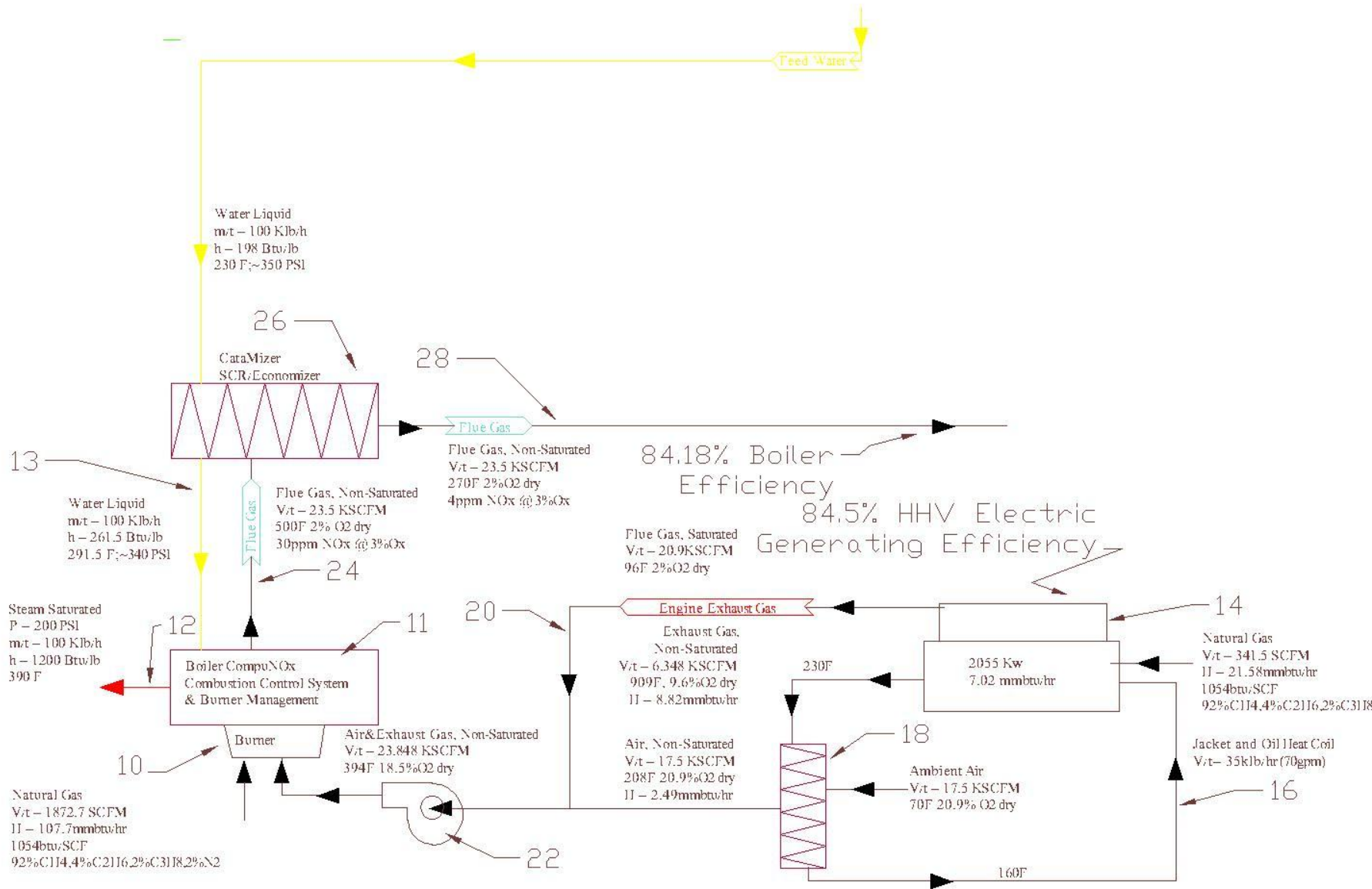
909F Engine Exhaust + 208F Air =
394F Combustion Air @ 18.5% Oxygen

Co-Generate with Boiler Heat Recovery

- Utilize Excess Generator Heat for Boiler
- Compu-NO_x is used to allow existing boiler to accommodate additional heat from engine exhaust
 - engine exhaust is fed into existing boiler burner for NO_x control and heat recovery
 - Flue gas recirculation is reduced to accommodate engine exhaust
 - Patent Pending

Compu-NO_x Modification of Boiler

- Use existing burner
- Combustion air fan control via variable speed drive
 - Low excess air operation for greater efficiency
 - Repeatable control of air fuel ratio
 - Flexibility for accommodating high excess air engine exhaust
 - **The Highest Efficiency Combustion Control Possible!**
- Engine exhaust used in place of flue gas recirculation for NO_x control
- Seamless control of boiler with or without engine exhaust



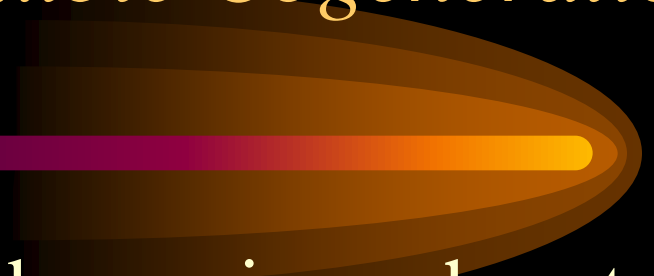
Backup Operation of Boiler & Ancillaries



- Boiler, feed pump, and DA is separated from grid and fed from engine power output
- Heat recovery of engine exhaust by boiler
- Two engines provide redundancy
- Loss of grid power has no effect on boiler

Economics

Most Efficient and Flexible Cogeneration



- Boiler operation is not affected by engine exhaust
 - Improves flexibility of operation
 - Generate exclusively for heat and power
 - Generate only during peak periods for load shedding and heat
 - Generate for independent power source for a boiler
- Engine waste heat supplements boiler input
- Generate power for 2 Cents per Kw-Hr 50 cents/therm

Independent Supply of Power to Boiler



- Loss of power costs \$100,000 per occurrence from loss of steam
- A boiler operating with an independent source of power is unaffected by loss of power

SAVE ON POWER

SAVE ON PRODUCTION