Marginal Heat Rate

- Basic Concepts
  - Industrial plants need steam for process purposes.
  - The generation of steam is a “First Law” problem.
  - The generation of electricity is a “Second Law” problem.
    - Heat must be converted into work.
    - There must be heat rejection to a low temperature sink.
    - The maximum theoretical efficiency is (Thot – Tcold)/Thot

Marginal Heat Rate

- Basic Concepts
  - An incremental, or marginal, amount of additional fuel can produce steam at a temperature and pressure higher than that needed by the process.
  - In doing so, the high temperature steam can generate some electricity and “reject” heat to the process

Marginal Heat Rate

- An example problem
  - Steam for a chemical plant is needed at 250 psig, saturated.
  - The total steam flow is 500,000 lb/hr
  - The enthalpy of this steam is 1202.2 BTU/lb.
  - All of the steam that is used is condensed and returned to the boiler at 15 psig as saturated liquid.
  - The enthalpy of the liquid is 218.3 BTU/lb.
  - For a boiler with 86% boiler efficiency, the required heat input from fuel is (1202.2 – 218.3)/.86, or 1144 BTU/lb of steam generated.

Marginal Heat Rate

- An example problem
  - Steam for cogeneration can be generated at 1200 psig and 750 F (superheated steam).
  - The enthalpy of the steam is 1345 BTU/lb.
  - This steam would operate a steam turbine that would exhaust the steam at the conditions required by the process, ie 250 psig. A little superheat would be left in the steam to protect the turbine from condensation. The steam would be used for process and the condensate would be returned to the boiler as in the prior example.
  - The heat input from the fuel is (1345 – 218.3)/.86, or 1310 BTU/lb of steam generated.

Marginal Heat Rate

- An example problem
  - The steam turbine isentropic efficiency is 90% and the generator efficiency is 97% (conservative).
  - The steam turbine output can be calculated by the enthalpy difference corrected for these efficiencies, ie, (3413/(1345 – 1202.2))/0.9/0.97 = 27.4 lb steam/kwhr.
  - With 500,000 lb/hr steam flow, the output is 18.3 Mw.
  - The incremental fuel flow is (1310 – 1144) * 500,000 or, 83 MMBTU/hr.
  - The marginal heat rate is 83MMBTU/hr/18,300 Kw or, 4521 BTU/Kwhr.