Kalina Cycle® Basics

- Marriage between –
  
  Rankine (power) Cycle & Ammonia Absorption Refrigeration

- 30 to 50 % more efficient

- Ammonia-water mixture working fluid

- Many inherent advantages

- System designs exploit virtues of fluid
Kalina Cycle® Systems for Low Temperature Heat Sources

KCS 11

- Geothermal Brine in
- HE-6 Evaporator
- HE-4 Evaporator
- HE-3 HT Recuperator
- HE-2 LT Recuperator
- HE-1 Condenser
- Feed Pump
- Cooling water / air in

KCS 34

- Geothermal Brine in
- HE-4 Evaporator
- HE-3 HT Recuperator
- HE-2 LT Recuperator
- HE-1 Condenser
- Feed Pump
- Cooling water / air in

KCS 34g

- Geothermal Brine in
- HE-3 Evaporator
- HE-2 LT Recuperator
- HE-1 Condenser
- Feed Pump
- Cooling water / air in

2012
Ammonia-Water Phase Diagram

Ammonia-Water Solution, % Ammonia by Weight

°F °C

P = 300 psia (20.7 bar-a)

Saturated Vapor
Saturated Liquid

1 2 3 4 5 6 7 8 9

0 10 20 30 40 50 60 70 80 90 100

2012
Heat Acquisition Temperature Profile

Boiling 84% Am-Wtr at 300 psia (20.7 bar-a)
Boiling Isopentane at 100 psia (6.9 bar-a)

unused heat source by isopentane

17% preheat

5 exchanger pinch

8 boiling

2012
Heat Rejection Phase Diagram

P = 128 psia (8.8 bar-a)

Ammonia-Water Solution, % Ammonia by Weight

Turbine Exhaust
Recuperator
Condenser
Condenser Outlet
Heat Rejection Temperature Profile
Ammonia-Water

Condensing 84% Am-Wtr at 128 psia (8.8 bar-a)
Preheat & partial vaporizing
84% Am-Wtr at 300 psia (20.7 bar-a)

Turbine Exhaust
Recup. Inlet
Recup. Outlet
Condenser Inlet
Condenser Outlet
Feedpump Inlet (Sat. Liq.)
Feedpump Outlet (Sat. Liq.)
Recup. Outlet
Recup. Inlet

Cooling Water

Condenser
Recuperator
Progression of Work

- Ideal Absolute Work
- Absolute Work Forfeited to Heat Sink
- Potential Work (Infinite)
- Actual Work of ORC
- Actual Work of Kalina Cycle

2^nd law limit

\[
\frac{(760 - 530)}{760} = \frac{685 - 540}{685} = 30.26\% \quad 21.17\%
\]
Benefits of Ammonia-Water Fluid Properties

- Variable boiling & condensing temperatures
- Excellent thermodynamic properties
- Excellent heat transfer coefficients
- Ammonia-Water fluid will not freeze
- Pressure stays above atmospheric
Materials and Equipment Design

- Carbon steel acceptable (no copper)
- Neoprene, Buna-N acceptable (no Viton)
- Standard steam turbine design
- Standard centrifugal pumps
- Shell & tube, or plate type exchangers
Environmental Aspects of Ammonia & Kalina Cycle®

- **Ammonia:**
  - Bio-degradable
  - Used extensively as a fertilizer

- **Does not contribute to:**
  - global warming (near zero GWP)
  - smog
  - depletion of ozone layer (zero ODP)

- **Higher efficiency conserves:**
  - fossil fuels
  - water (for condenser)
Flexibility of Kalina Cycle®

- Ammonia-water concentration can be readily changed to give optimum efficiency if:
  - heat source changes
  - cooling temperature changes
Conclusions

- Host of new ideas
- Merger of power & refrigeration technologies
- Uses standard materials & equipment
- Easy to operate
- Safer alternative to hydrocarbons
- Environmentally benign
- Readily adjusted for changing conditions
- Most efficient cycle available