Heat Recovery at Alaska Center for Energy and Power

ACEP
Alaska Center for Energy and Power

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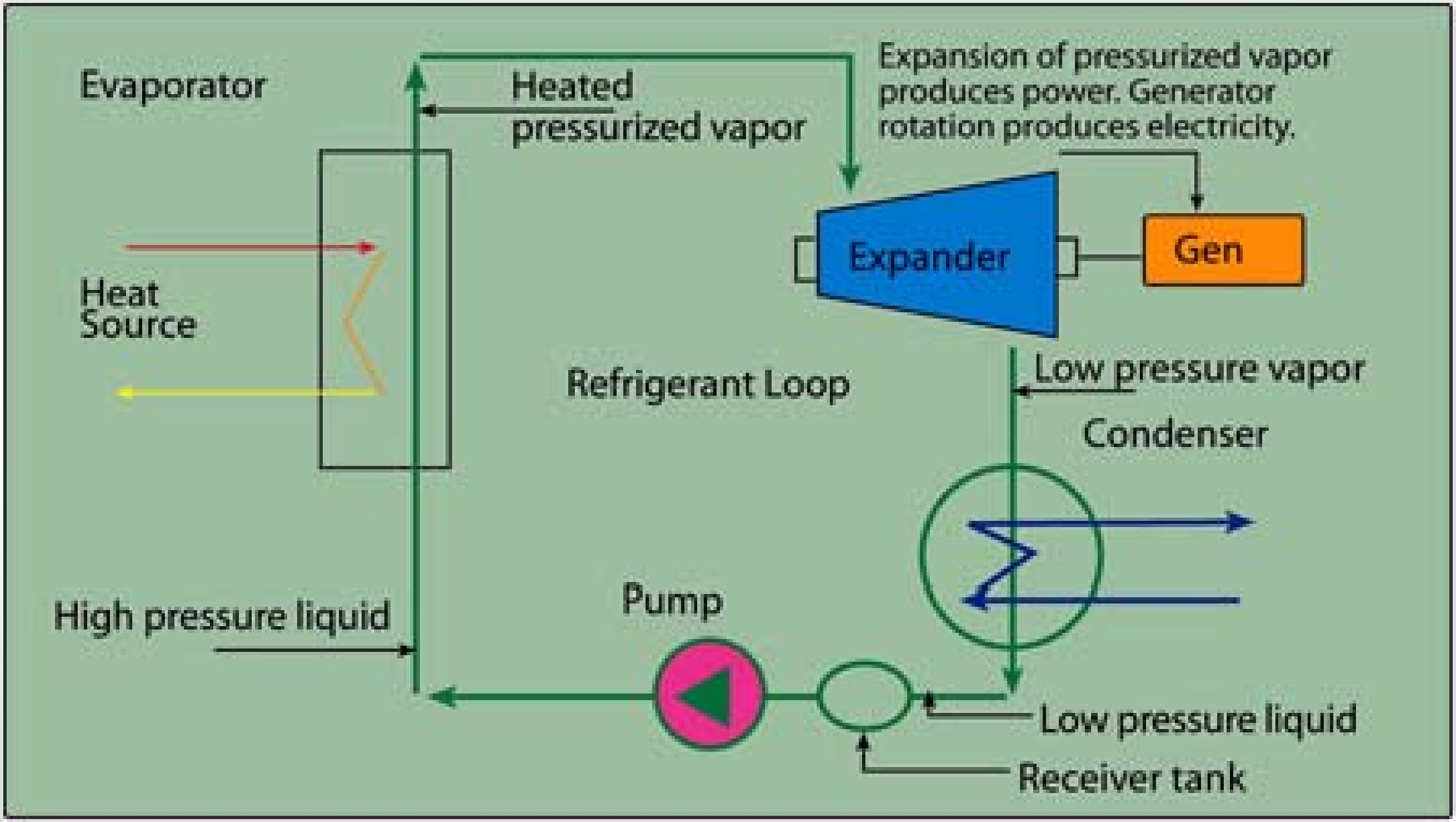
Organic Rankine Cycle

- Power generation through use of an Organic Rankine Cycle (ORC) unit with heat recovery from diesel generator.
- Laboratory and field tests.
- Funded by Denali Commission and Alaska Energy Authority.

ORC Technology



Project objectives:

- To achieve ORC efficiency of 10% and corresponding fuel efficiency by ~3%.
  - Reduced fuel consumption
  - Lower costs
  - Reduced greenhouse gas emissions

- To evaluate feasibility, operation / maintenance requirements, and economic impact.

- To develop guidelines for ORC application, particularly in rural Alaska.

Effect of ORC on overall efficiency

Starting engine fuel efficiency (kw-hr/gal)	14.5	14.5	14.5
Gal fuel per 1000 kW-hr	68.9655	68.9655	68.9655
Cost per 1000 kW-hr (at $6.50/gal)	$448.28	$448.28	$448.28

ORC efficiency improvement (%)	10	9	5
ORC fuel efficiency improvement (kW-hr/gal)	1.6675	1.50075	0.83375
Net fuel efficiency (kW-hr/gal)	16.1675	16.00075	15.33375
Gal fuel per 1000 kW-hr	61.8525	62.4971	65.2156
Cost per 1000 kW-hr (at $6.50/gal)	$402.04	$406.23	$423.90

Cost savings	$46.24	$42.05	$24.38

Potential cost savings

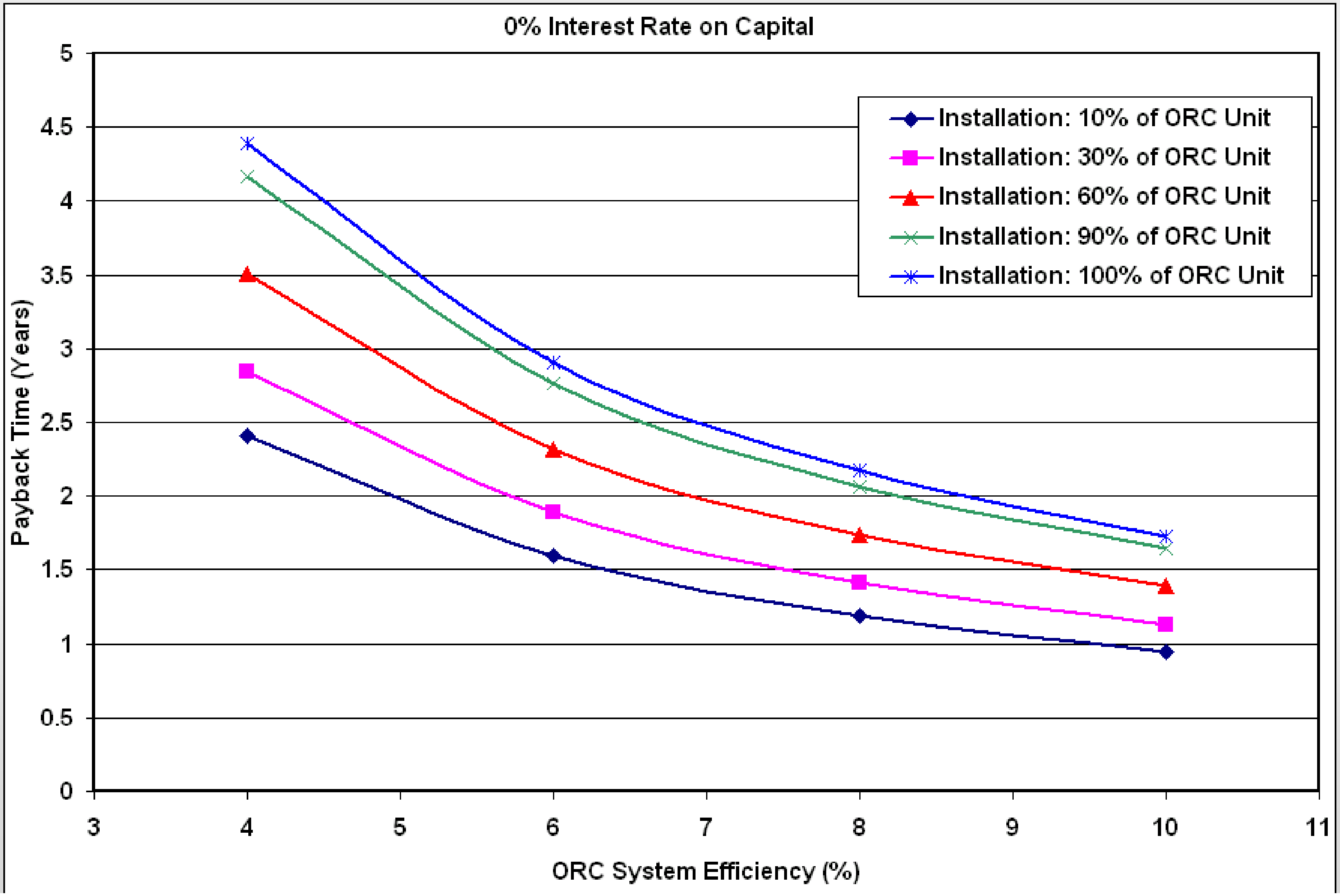
ORC efficiency improvement (%)	**10**	**9**	**5**
Cost savings per 1000 kW-hr/gal	$46.24	$42.05	$24.38

Hypothetical community with power generation = 4 million kW-hr

Potential annual savings with ORC	**$184,960**	**$168,200**	**$97,520**

Economic Analysis (payback time)

ORC unit cost = $128,000 / Fuel efficiency = 14 kw-hr/gal



ORC qualifies as “emerging technology”…

- ORC technology currently used in large-scale and industrial applications around the world.

- Few data exist on small-scale applications.

- NO data in Alaska.

- Alaska has unique environmental and climatic conditions. Rural villages have unique operating conditions.

- There is a need for laboratory / field performance data for optimal application and design improvement.

Heat Recovery Study

Heat Recovery from Diesel Exhaust for Heating

1. **Experimental study of feasibility, performance, and economic analysis.**
2. **Development of a design and economic analysis computer program for rural power plant engineers to conduct preliminary design and determine whether applying exhaust heat for heating to any of the village power plants is beneficial.**
   (Complete)

Heat Recovery for Power

1. **Experimental study of feasibility, performance, and economic analysis.**
2. **Development of a tool to make comments on design, to help laying out test plan.**
3. **Development of system maps for selecting appropriate diesel generator and optimizing the system performance (for different engine operating and environmental conditions).**

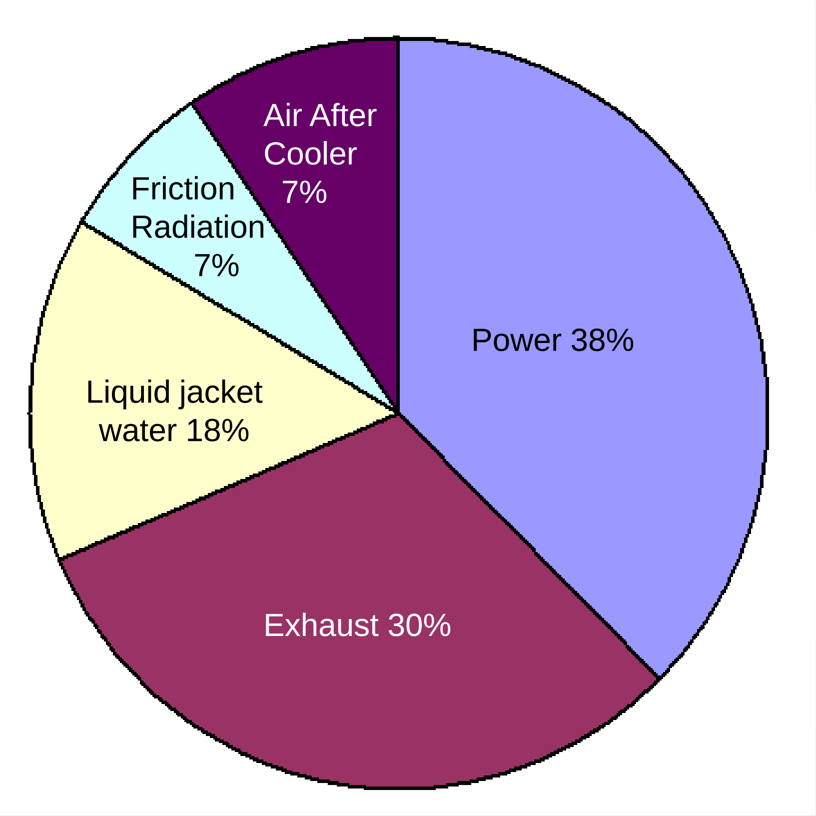
Potential

Exhaust Heat energy recovery for heating:

- Heat recovery: 15% fuel energy
- Fuel savings: 15% fuel used by engine
- Winter season only
- Restricted application (Only for heating)

Heat energy recovery for power (for generator set average load less than about 1 MW):

- Engine efficiency improvement: About 4%
- Fuel savings: About10% (14.5kW-hr/gallon)
- May be for the whole year
- Flexibility in application

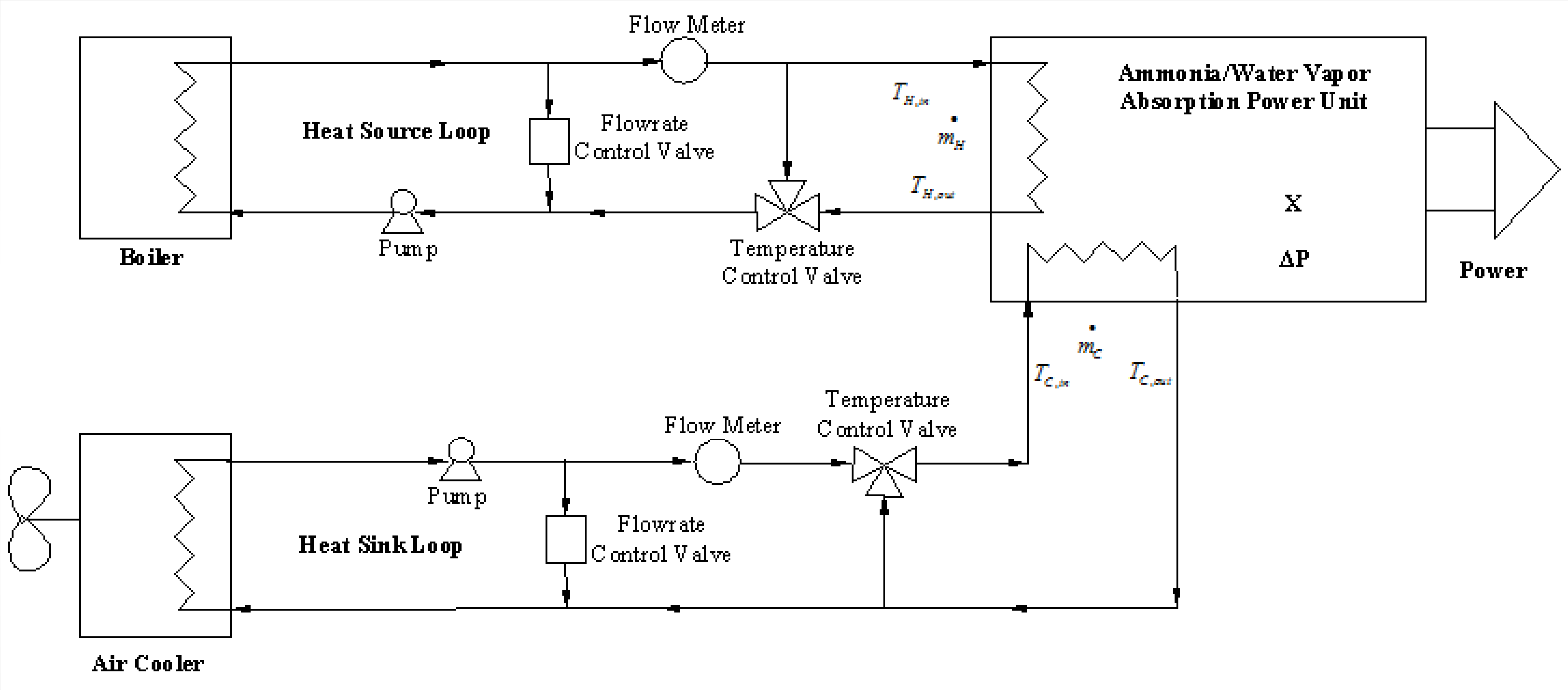


Other Considerations

- Infrastructure in existing power and heating systems.
- Load patterns in power and heating usages.
- Environmental and surrounding conditions (i.e. temperatures, stream, etc.).
- Operation loss.
- Performance characteristics of individual technologies (e.g. working fluid, positive pressure cooling).

Research is needed for the development of appropriate methods and tools to assist the selection of best fit technology to optimize the benefit to individual villages.

Heat Recovery Unit for Power:
General Components in Application



Heat Recovery for Power

Ammonia –water system (VS ORC):

Theoretically it is more efficient (Need real life data to approve it).

It can use positive pressure for cooling side.

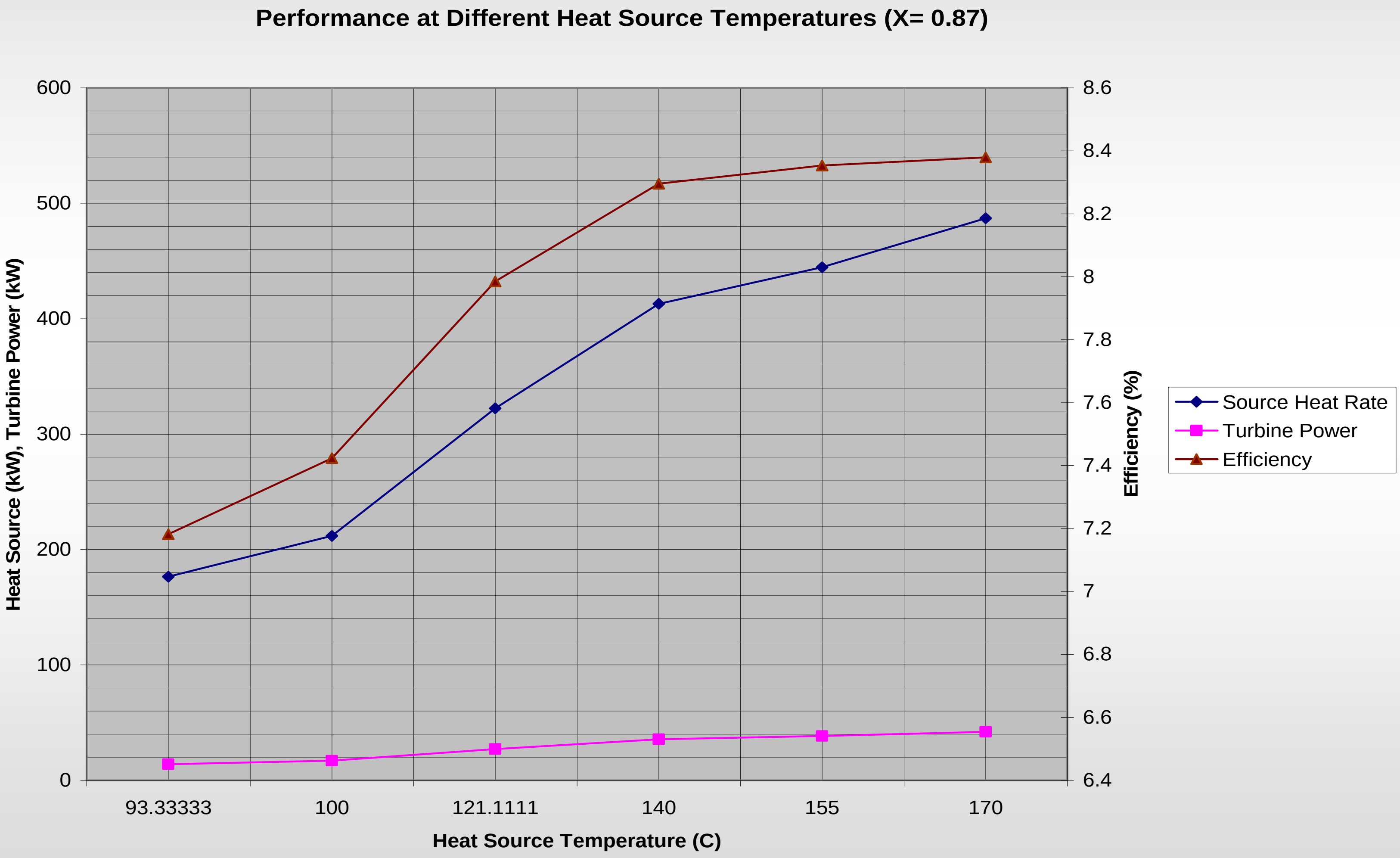
It needs a separator and an absorber.

Other factors needs to be considered include:

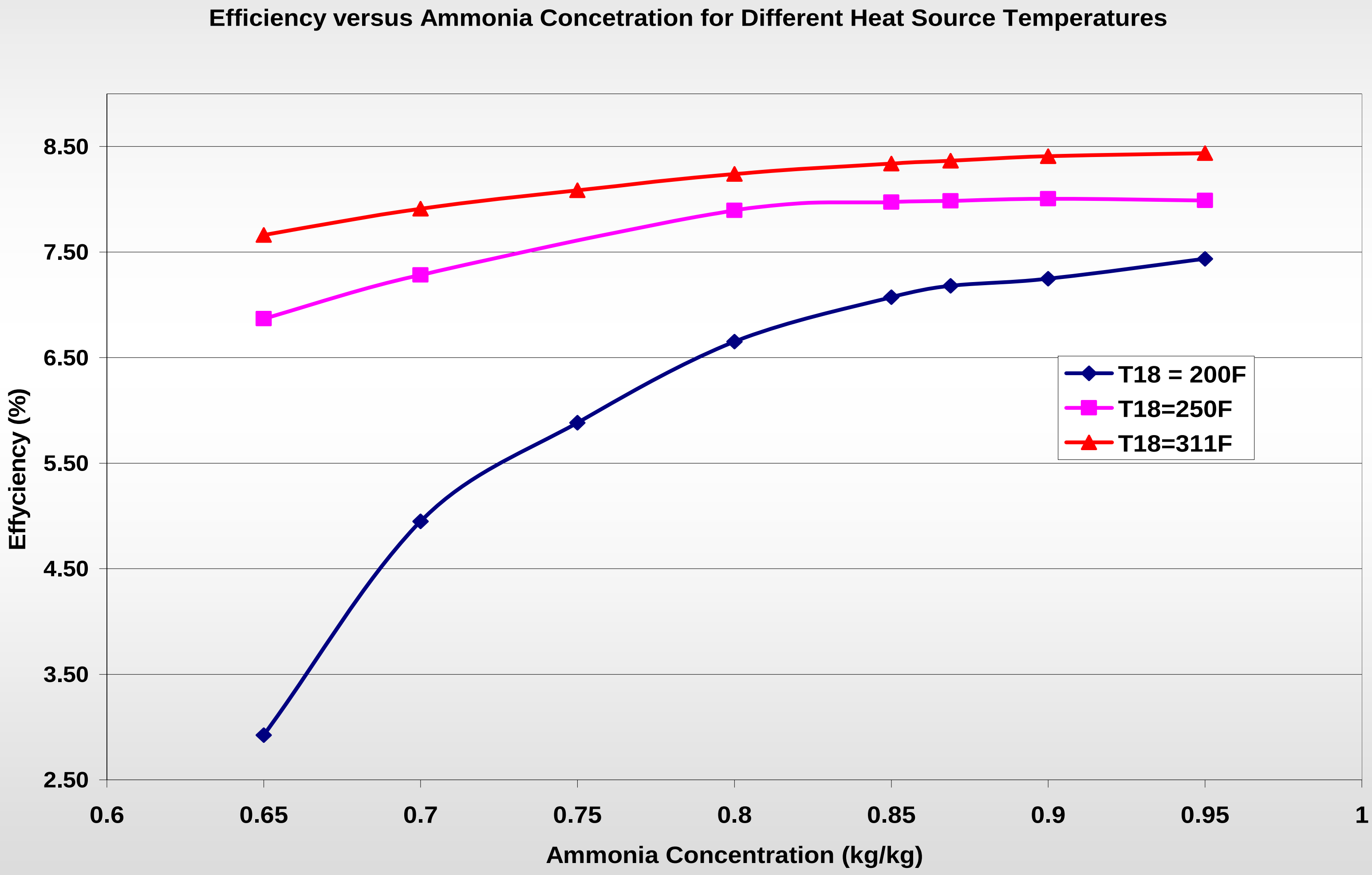
- Heat exchanger design.
- Ammonia concentration limit (at high ambient temperature).
- Etc.

Current Projects: Ammonia-Water Cycle

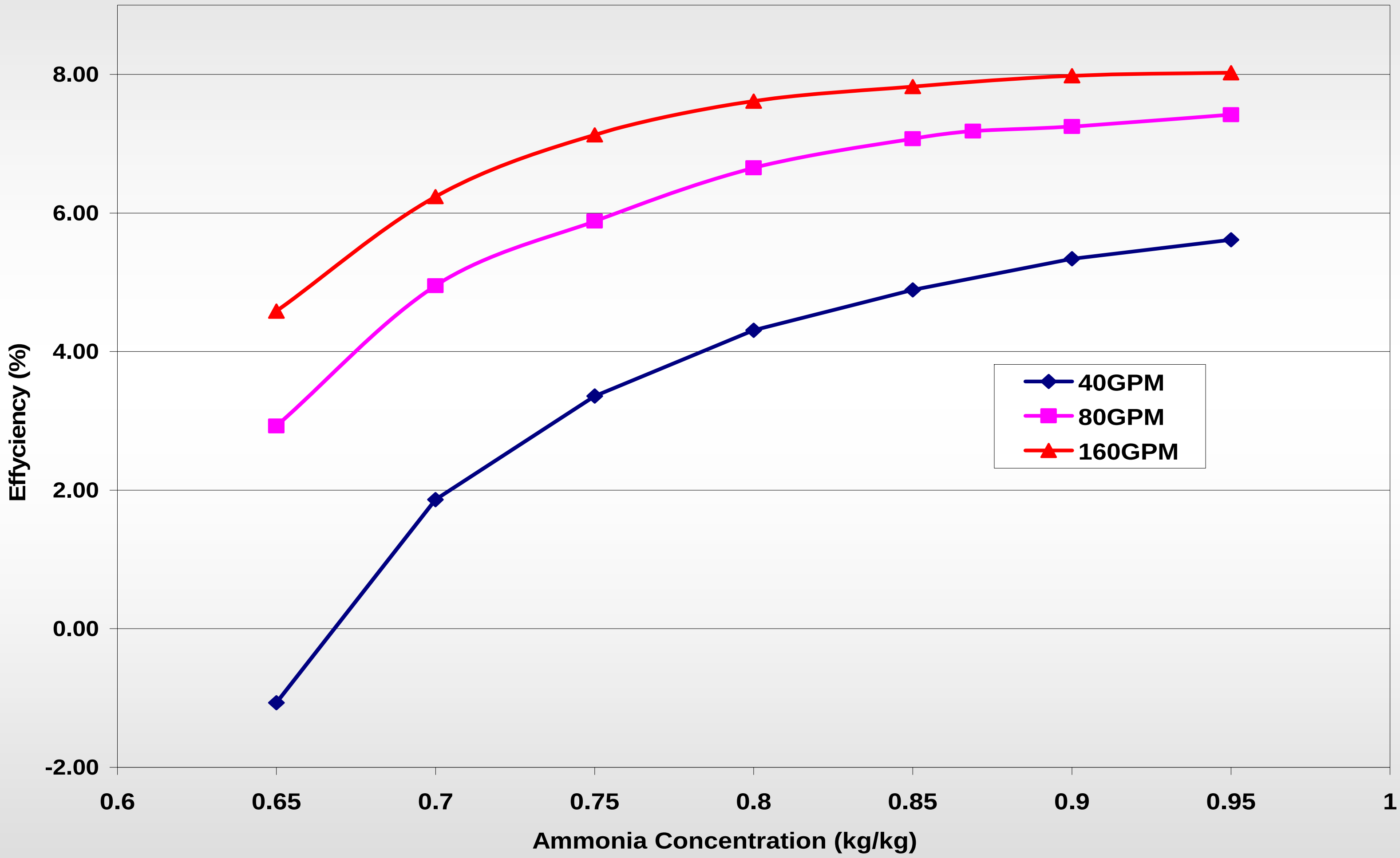
Heat Source: System Performance VS Heat Source Temperatures with Ammonia Concentration X= 0.87



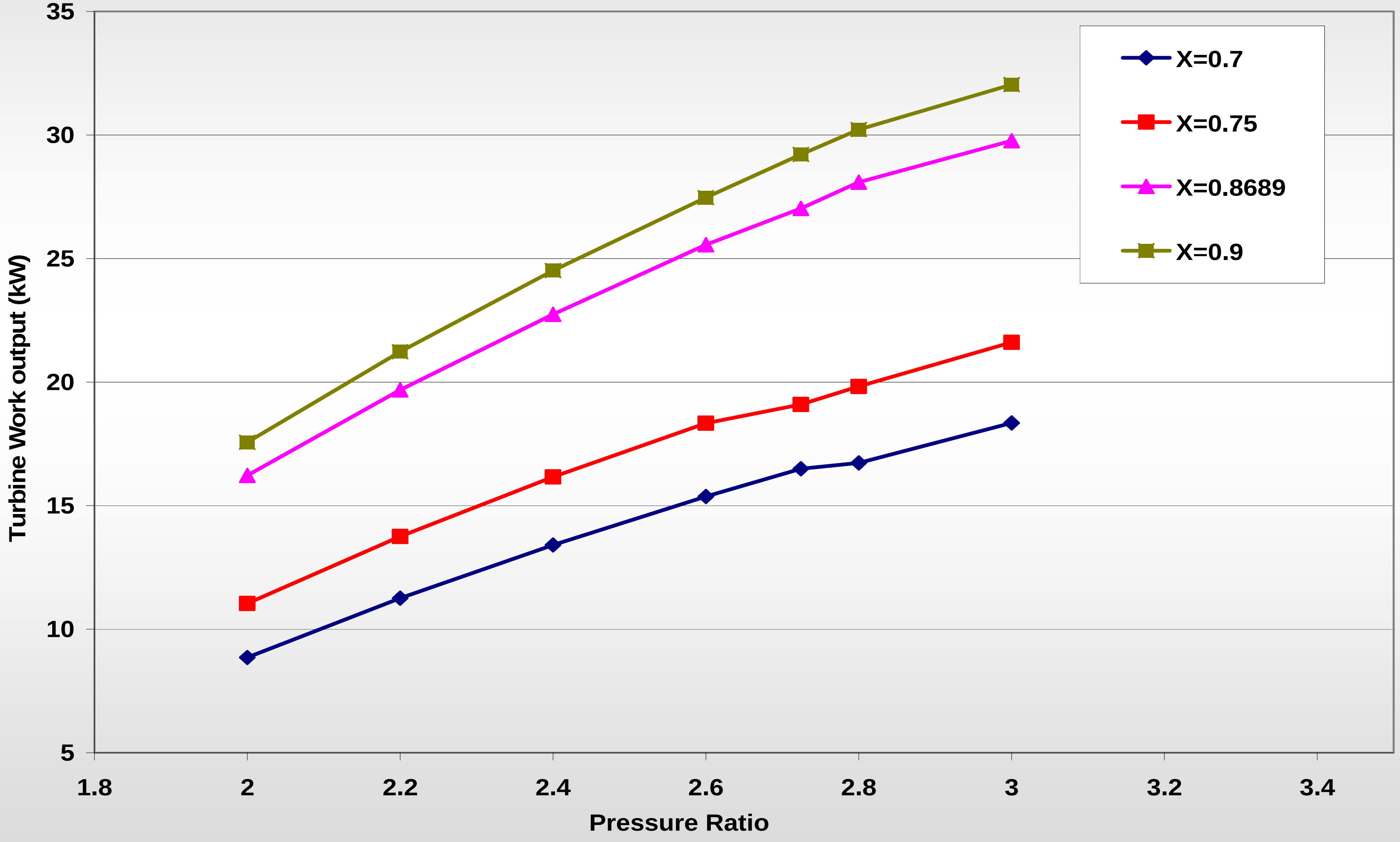
Heat Source: Efficiency versus Ammonia Concentration and Source Temperatures



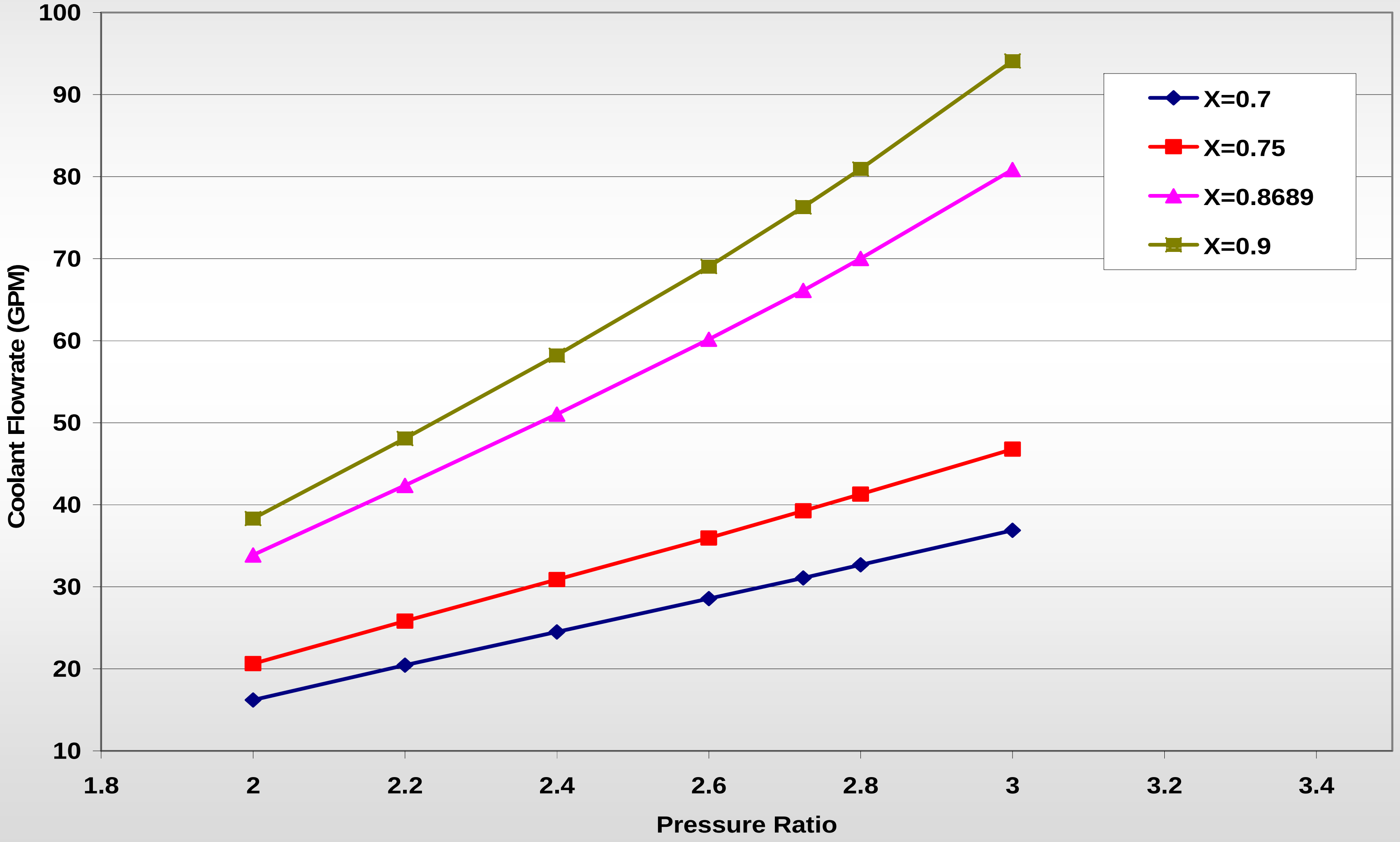
Heat Source: Efficiency versus Source Flow Rate and Ammonia Concentration



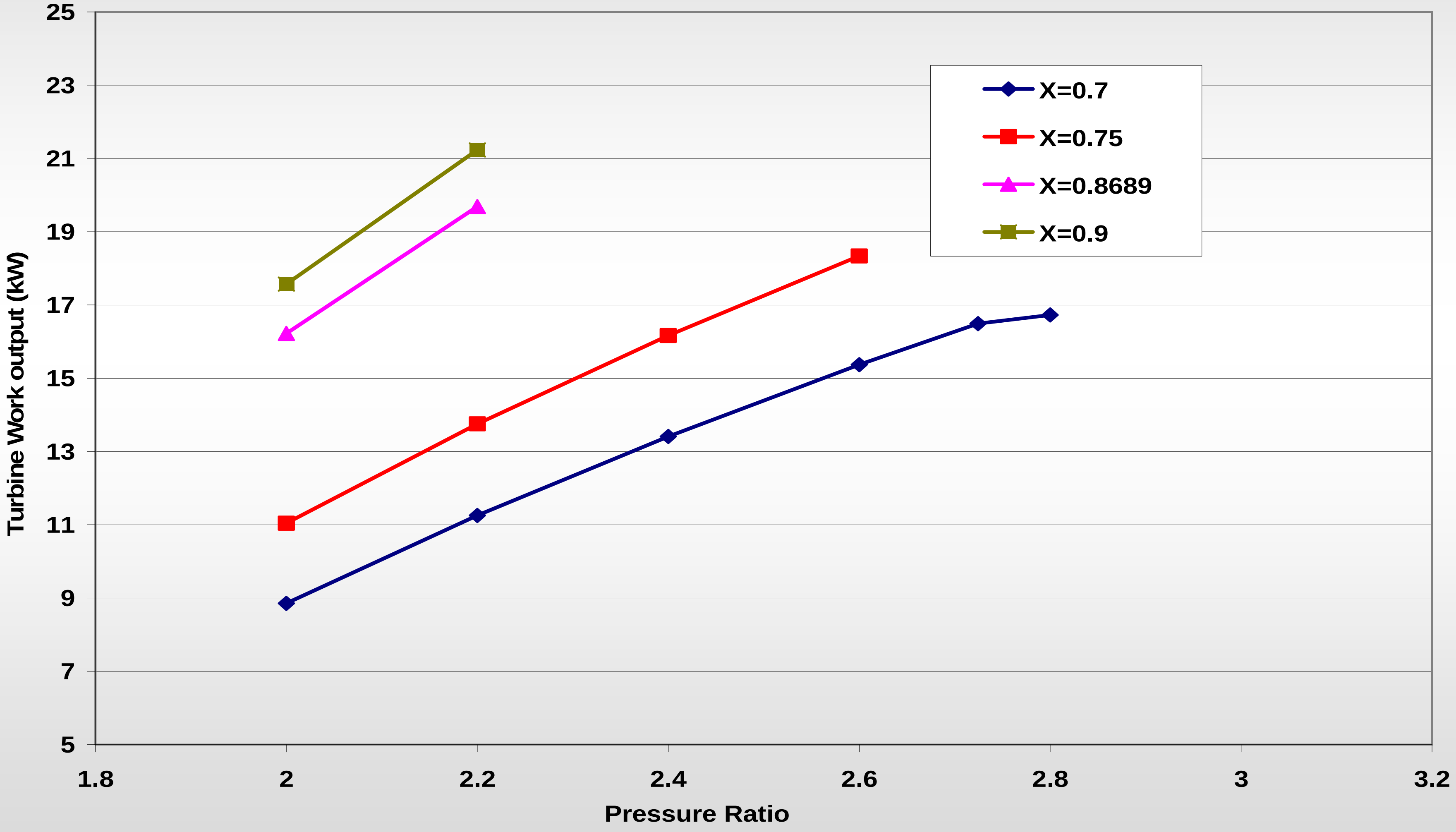
Heat Sink: Turbine work vs. Pressure ratio for and Ammonia Concentration for cooling temperature of 40°F



Heat Sink: Coolant flow rate vs. Pressure ratio and Ammonia Concentration for Cooling temperature of 40^{o}F



Heat Sink: Turbine work vs. Pressure ratio and Ammonia Concentration for cooling temperature of 100ºF



System Map

Major Components:

Heat source, heat sink, power system.

Assumptions and calibration.

Selected Independent Parameters for Maps:

Heating fluid temperature and flow rate

Cooling fluid temperature

System ammonia concentration and turbine pressure drop.

Dependent Parameters:

System net efficiency, turbine work, input heat rate, cooling flow rate, cooling rate.

(More if needed)

Design Consideration and Testing (Operation) Components Selection

- Heat exchanger size
- Ammonia concentration
- Fluid flow controls
- Pumps
- Cooling device for heat sink
  - (e.g. dry cooler, cooling tower, river, ground water)
- Heat source temperature
- Screw expander characteristics

ORC System - Soon

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