Optimizing Separation and Power Production

for

Two- and Three-Phase Well Flows

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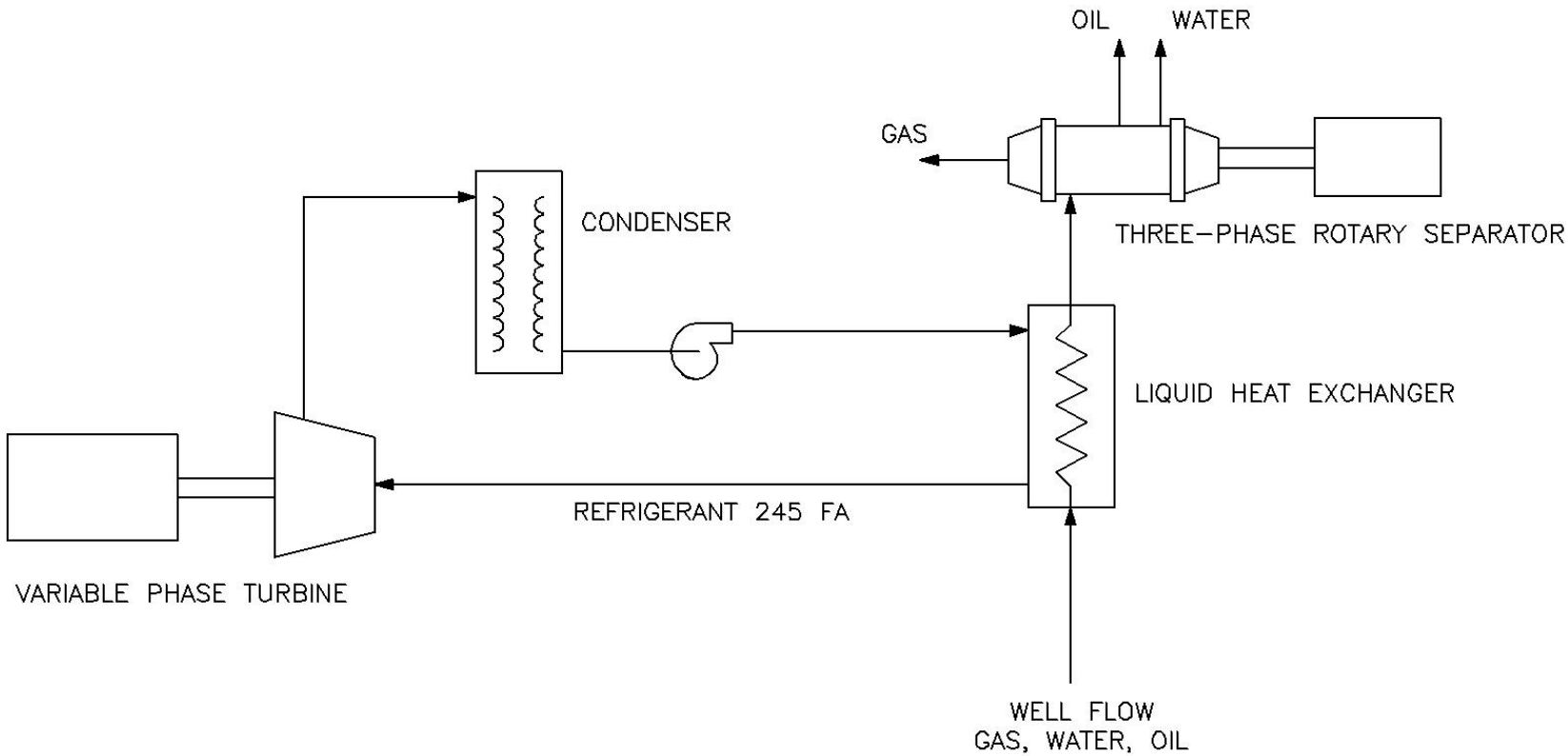
Outline

- System Requirements
- System Description
- Component Experience
    - Axial Two-Phase Turbines
    - Two- and Three-Phase Separating Turbines
- Performance for Three-Phase Well Flow

Requirements for Viable Geothermal Energy Production In an Oil and Gas Setting

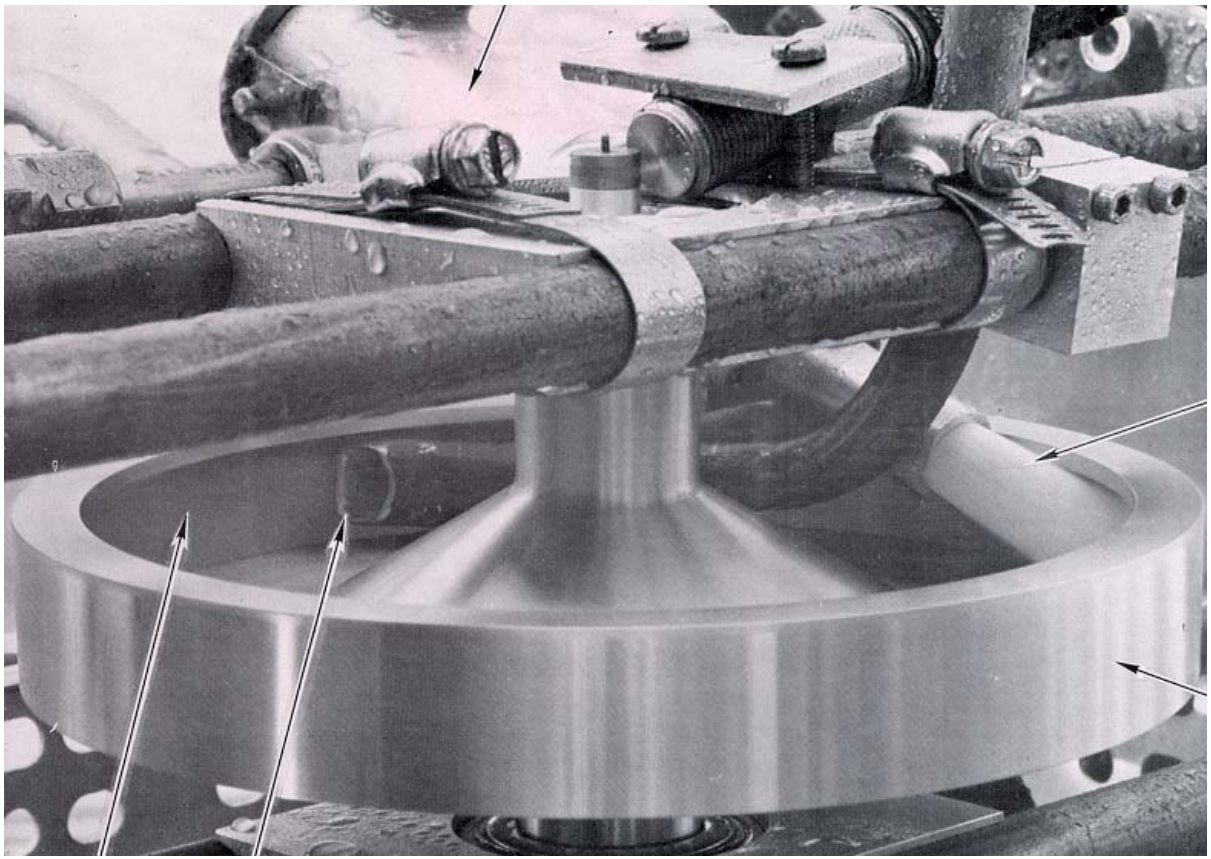
- Meet Oil & Gas Industry Standards – API Specifications
- Minimize Cost per Kilowatt Hour
    - Maximize Power Production for Produced Fluids
    - Minimize Equipment Cost
    - Minimize Installation Cost
    - Minimize O & M Cost
- Produce Dry Gas
- Produce Clean Water
- Produce Water Free Oil
- Portable Equipment
- Environmentally Benign

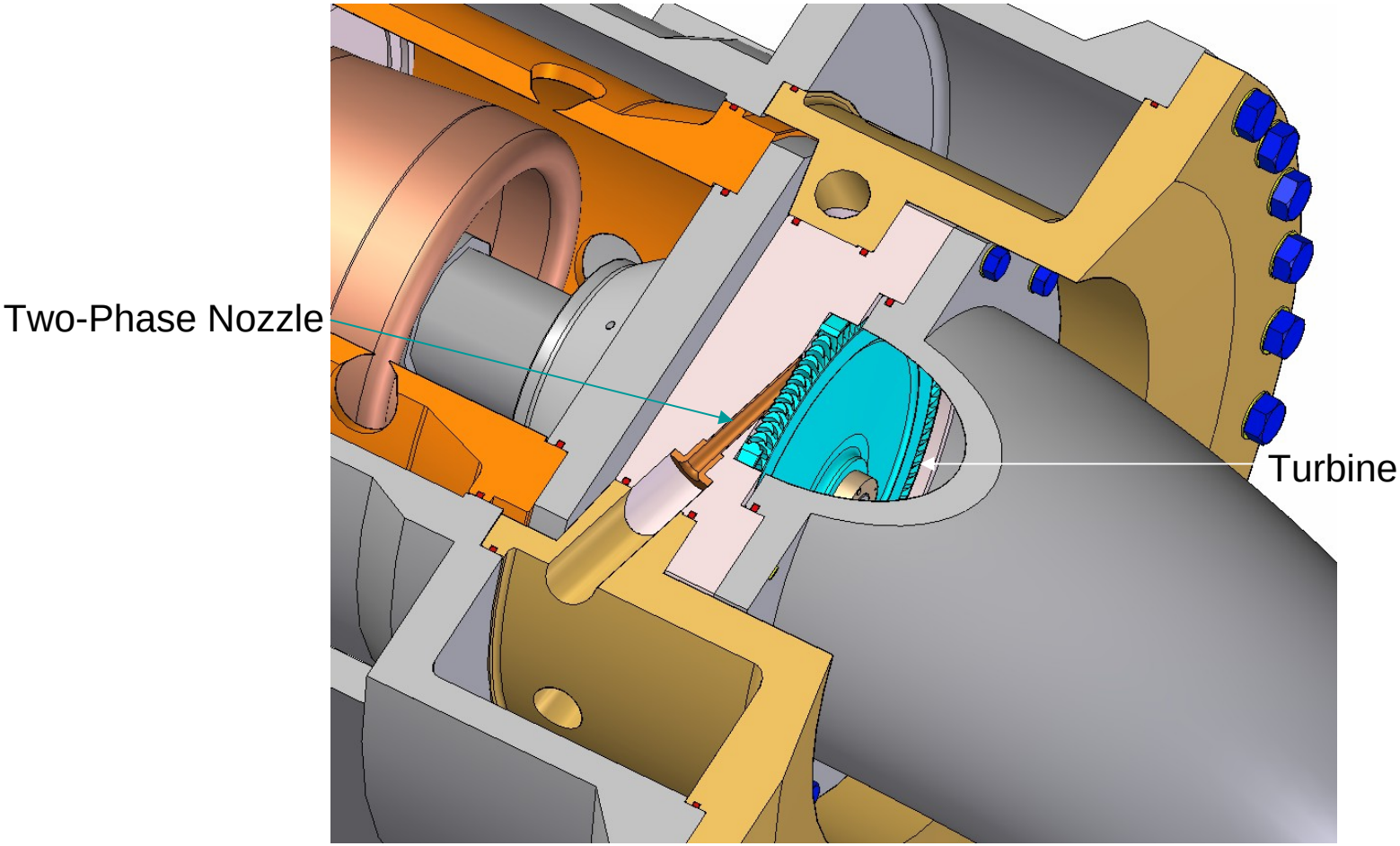
System Description



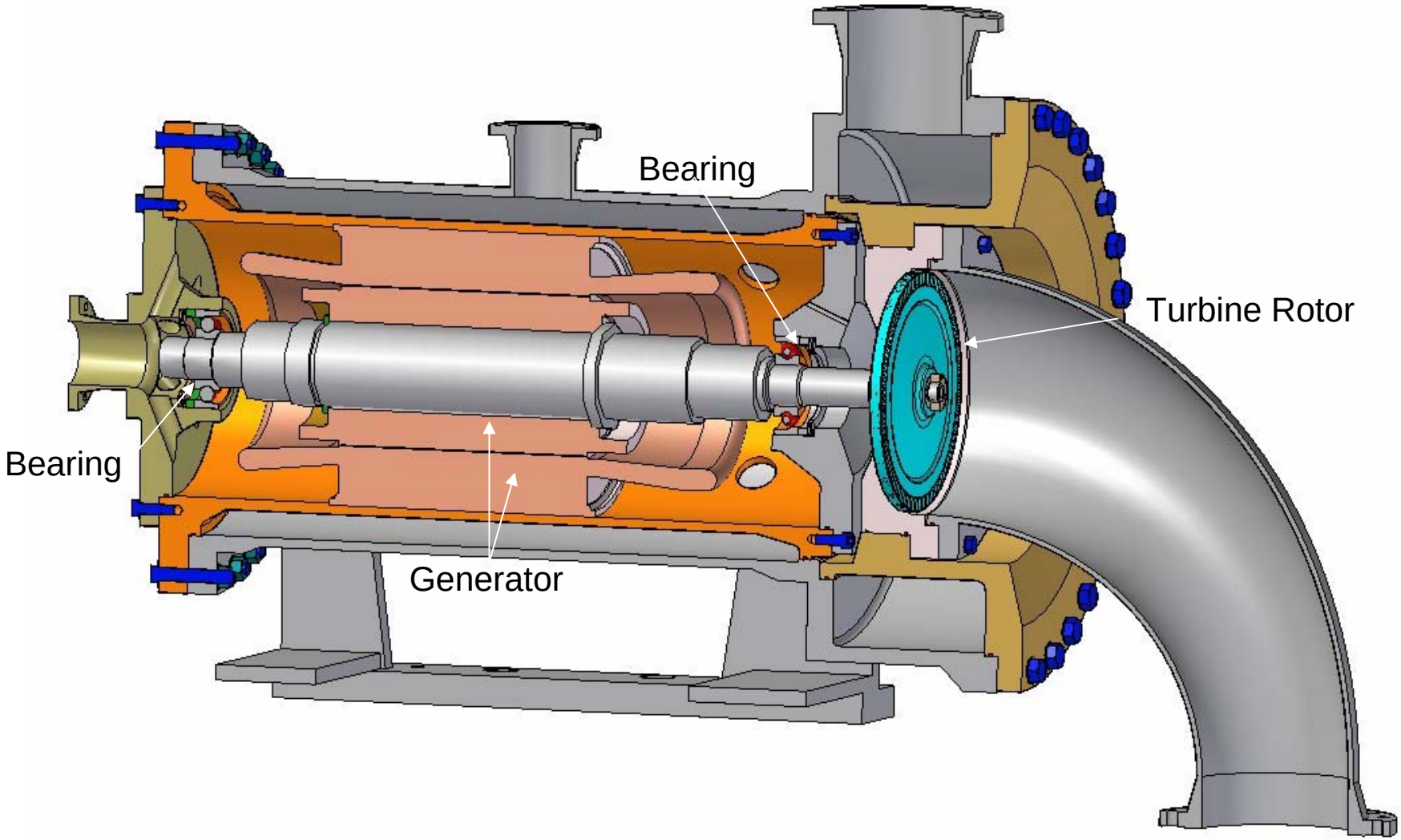
Schematic of Separating Power System for Three-Phase Well Flow

Two-phase Nozzle With Rotary Separator

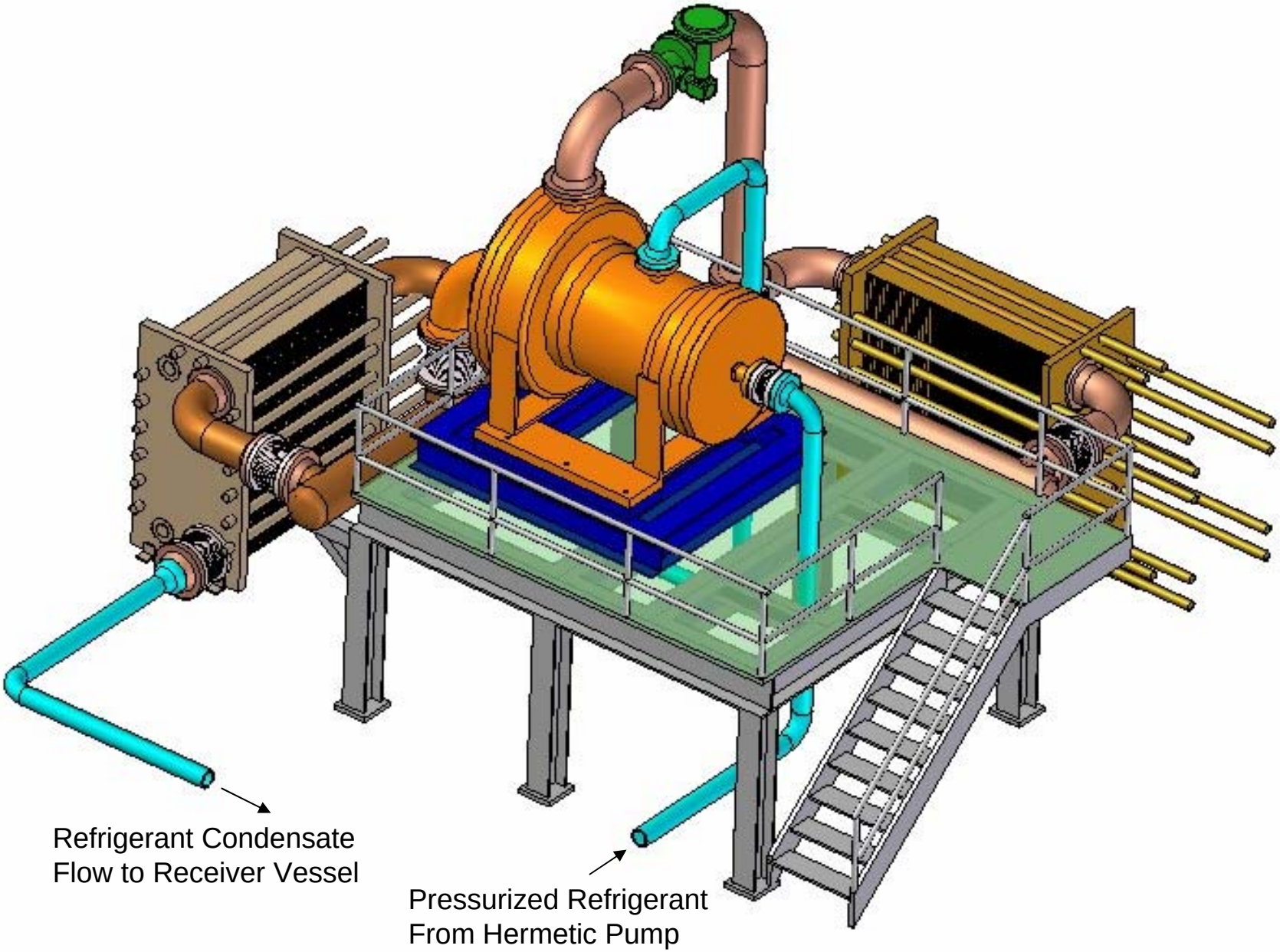




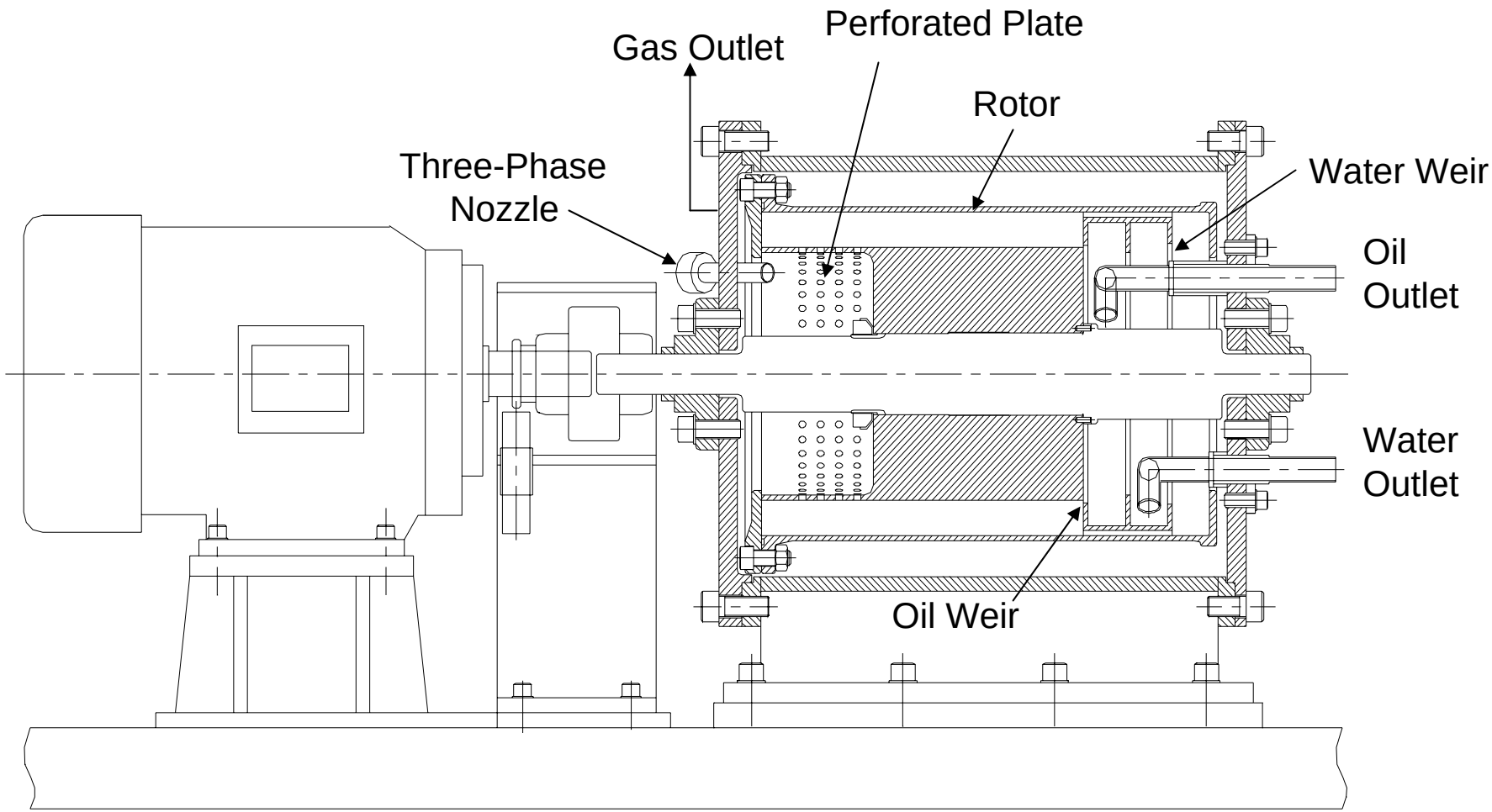
Variable Phase Turbine
Nozzle and Rotor Arrangement



Hermetic Variable Phase Turbine-Generator



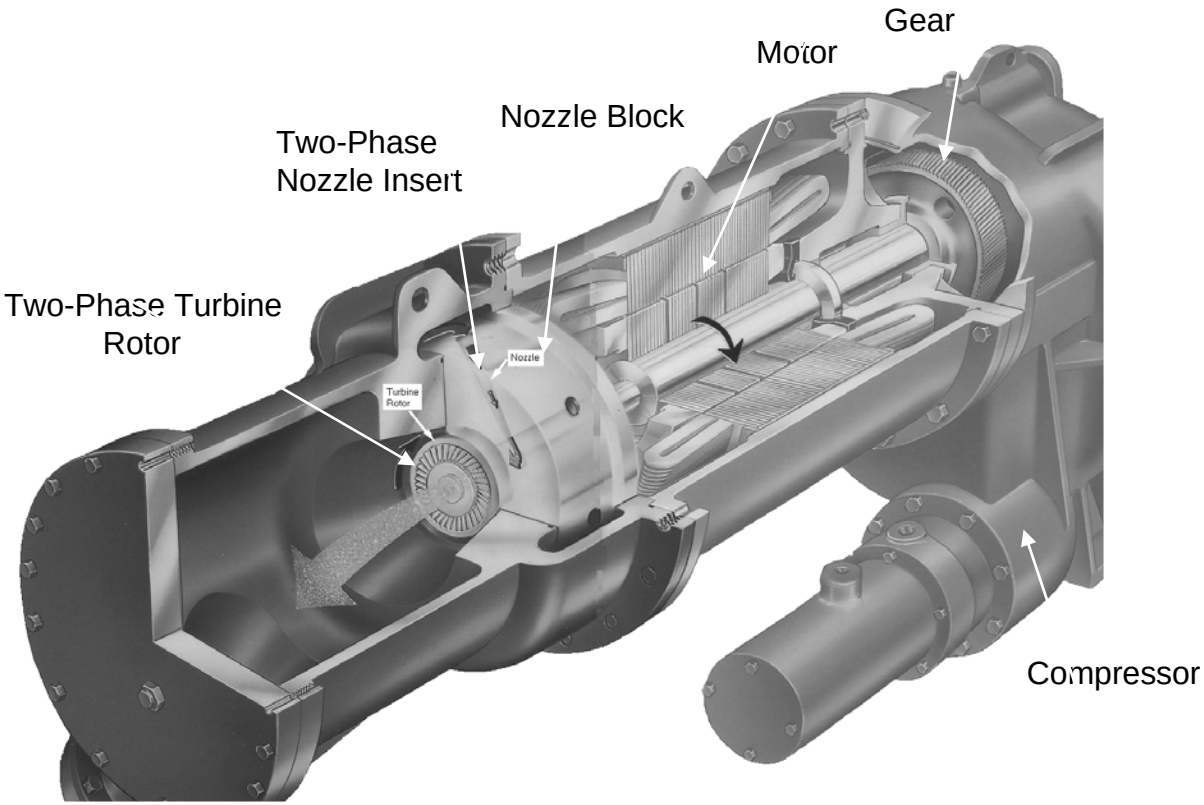
Arrangement of 1 Megawatt Variable Phase Power System



Three-Phase Separator

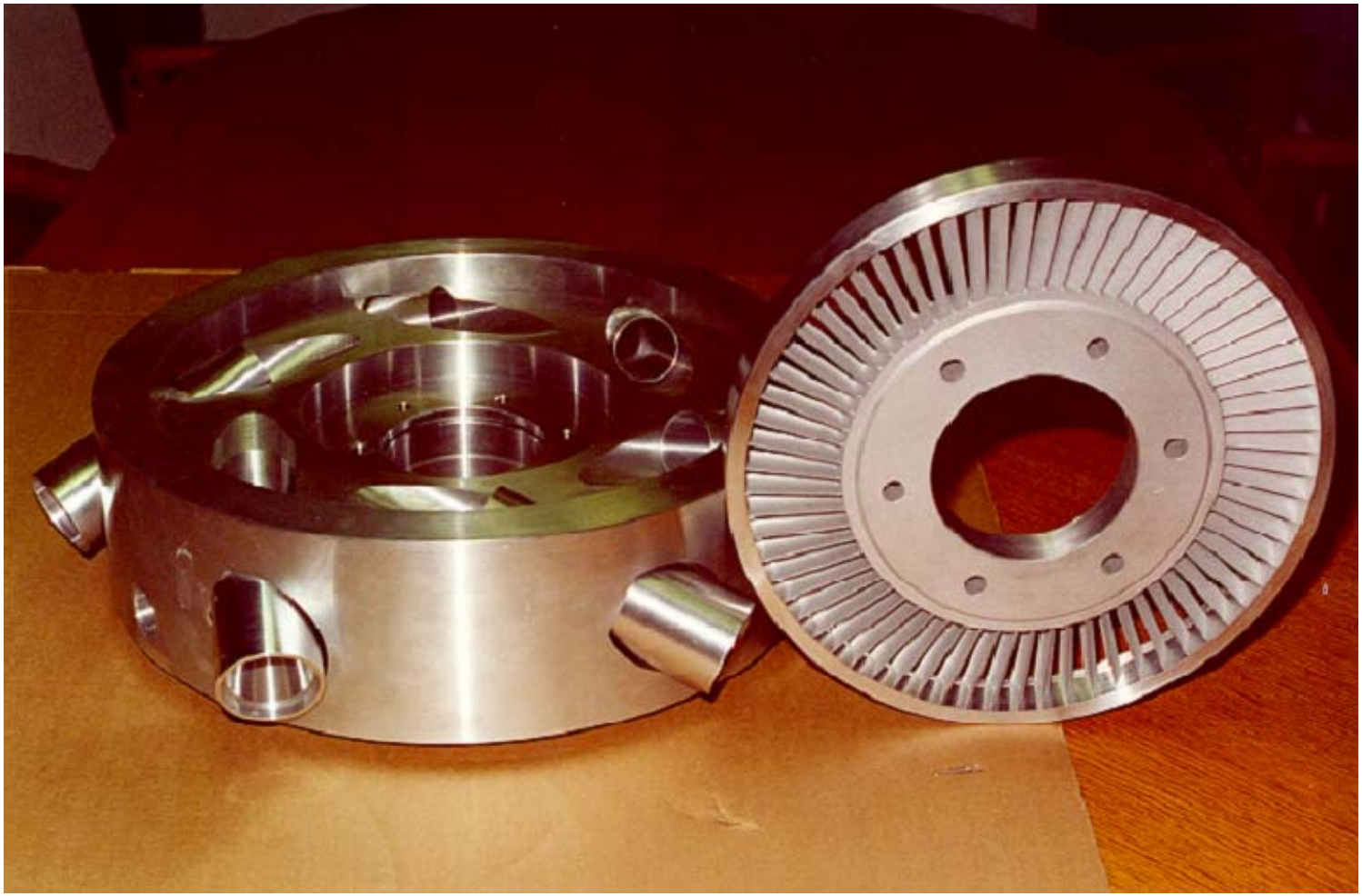
Component Experience

Commercial Two-Phase Refrigerant Rotor

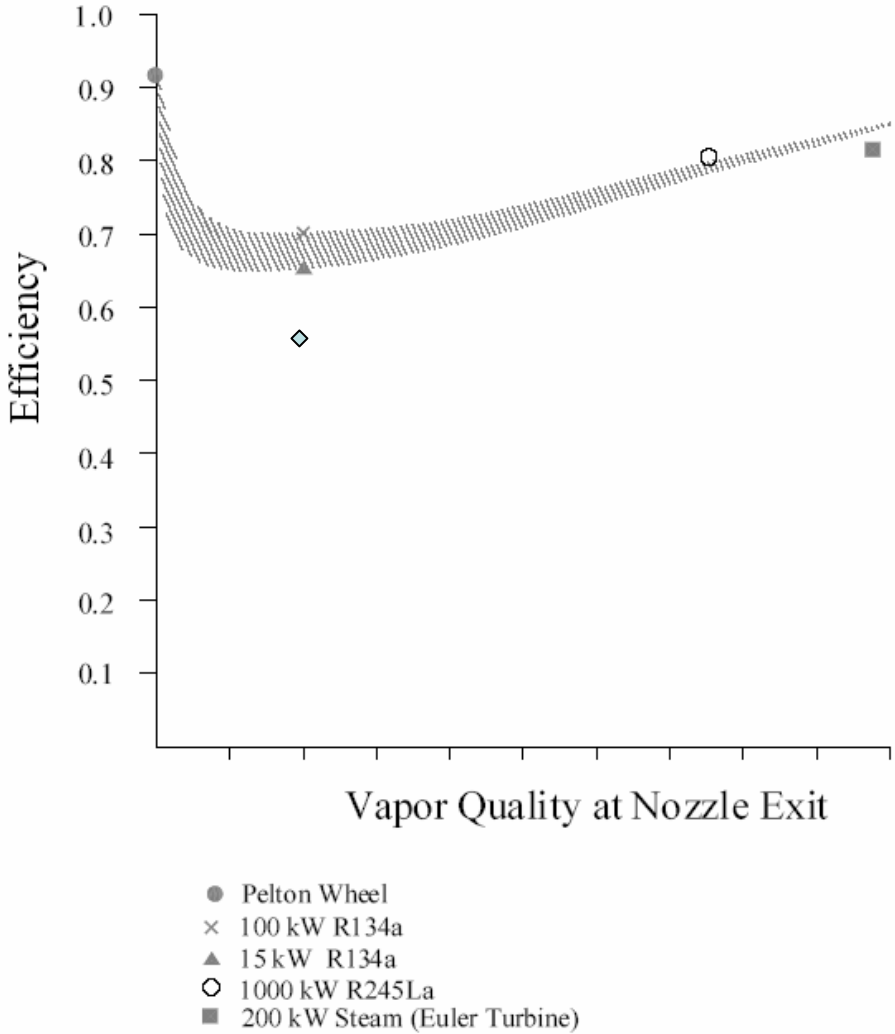


Cutaway of Chiller with Two-Phase Turbine, after Carrier

500 Ton Chiller with Two-Phase Turbine, after Carrier

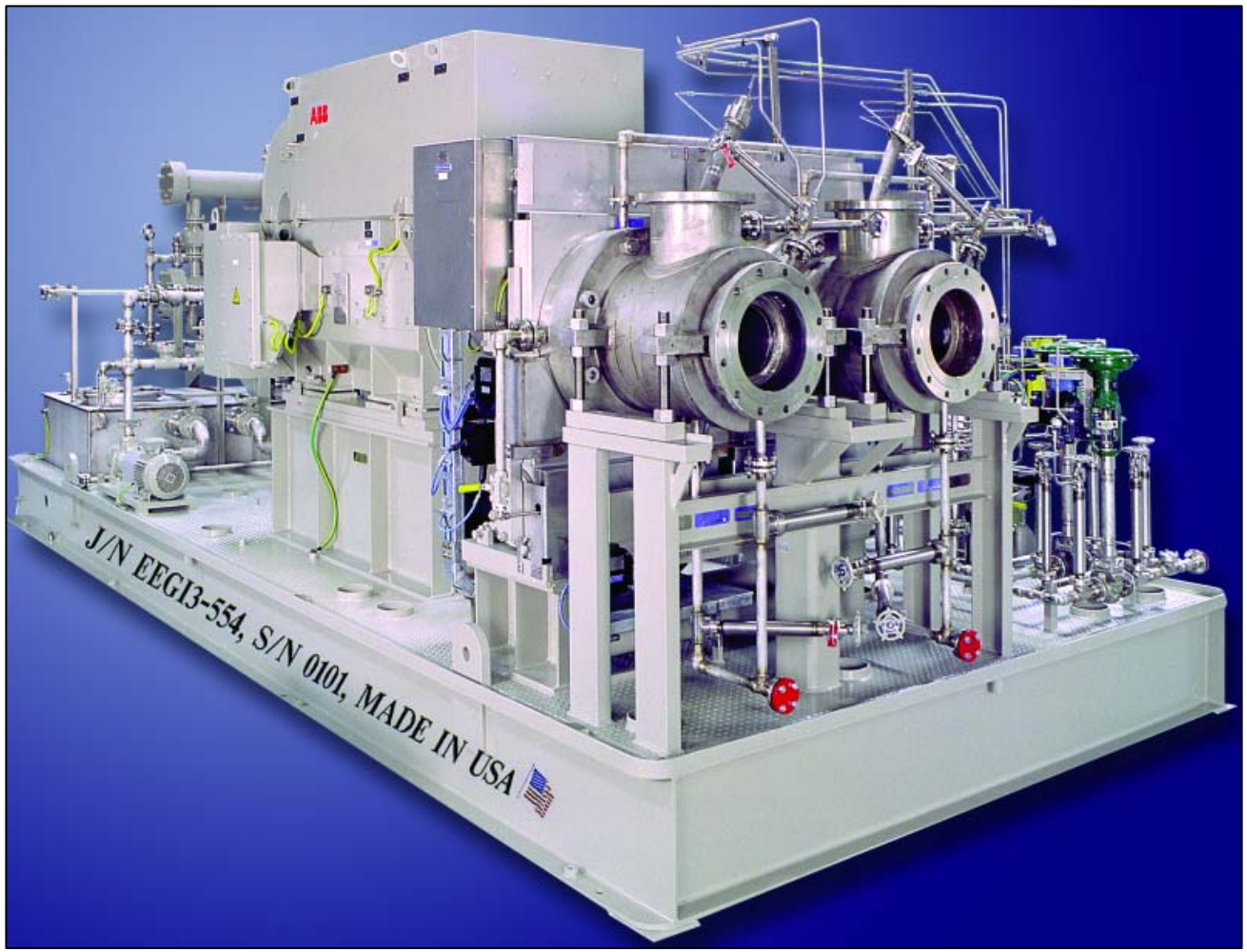


100 kW Two-Phase Axial Turbine Components for Refrigerant Power Generation

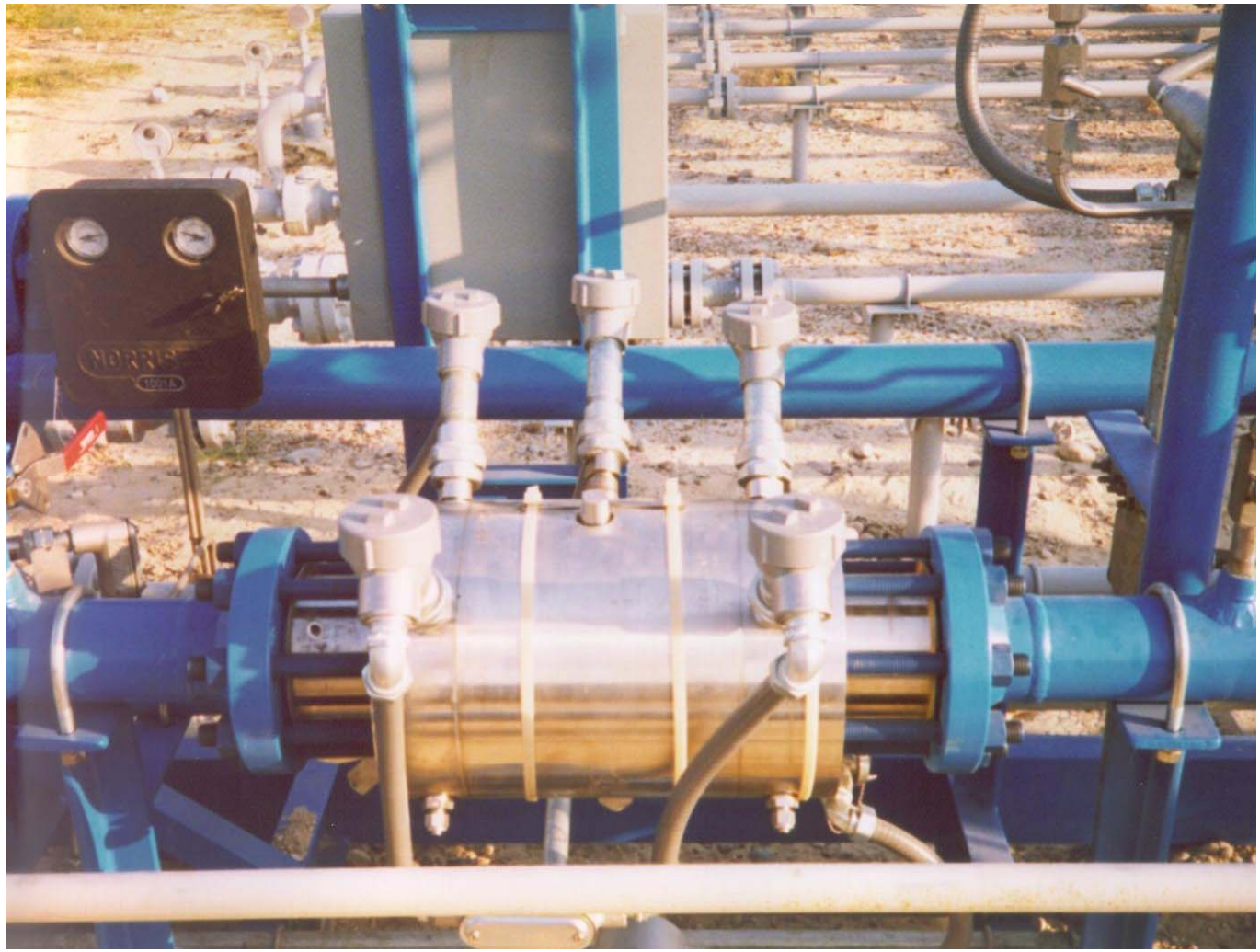


Efficiency of Axial Impulse Turbines

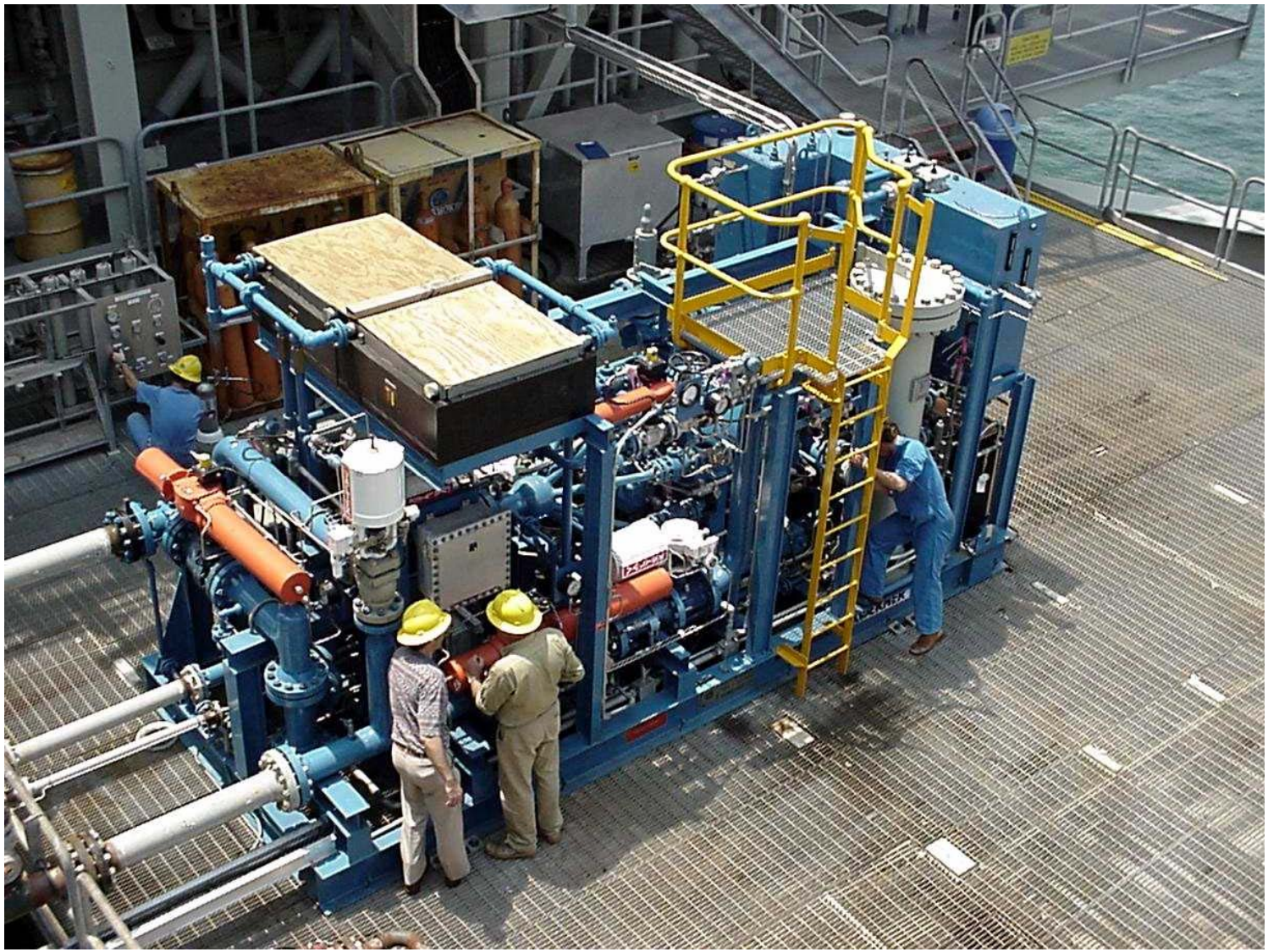
Hermetic LNG Pump, After ACD, Inc.



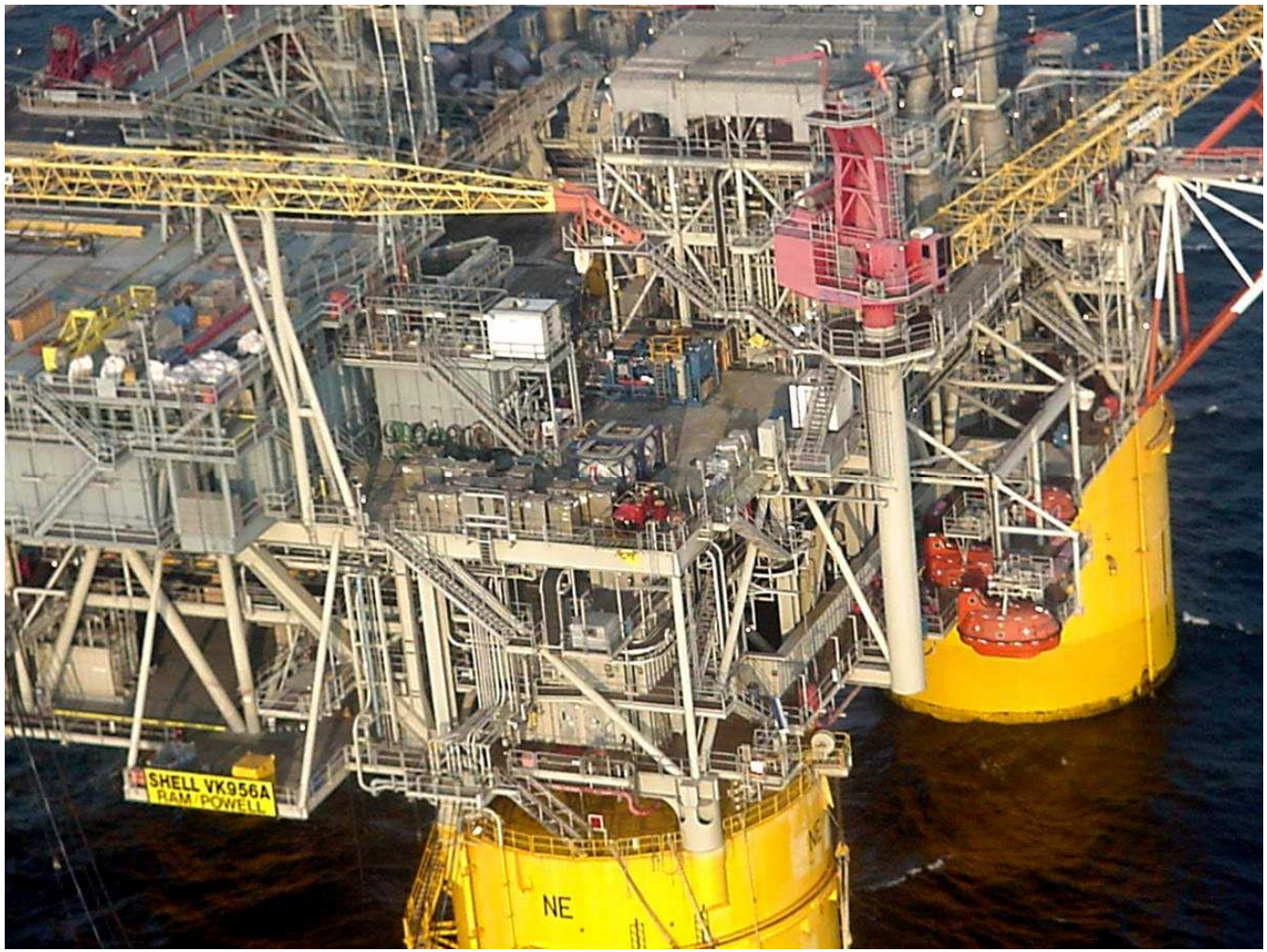
Hydrocarbon Turbine Generator, After Mafi-Trench



Inline Two-Phase Rotary Separator Operating at Laredo Gas Field
After Chevron



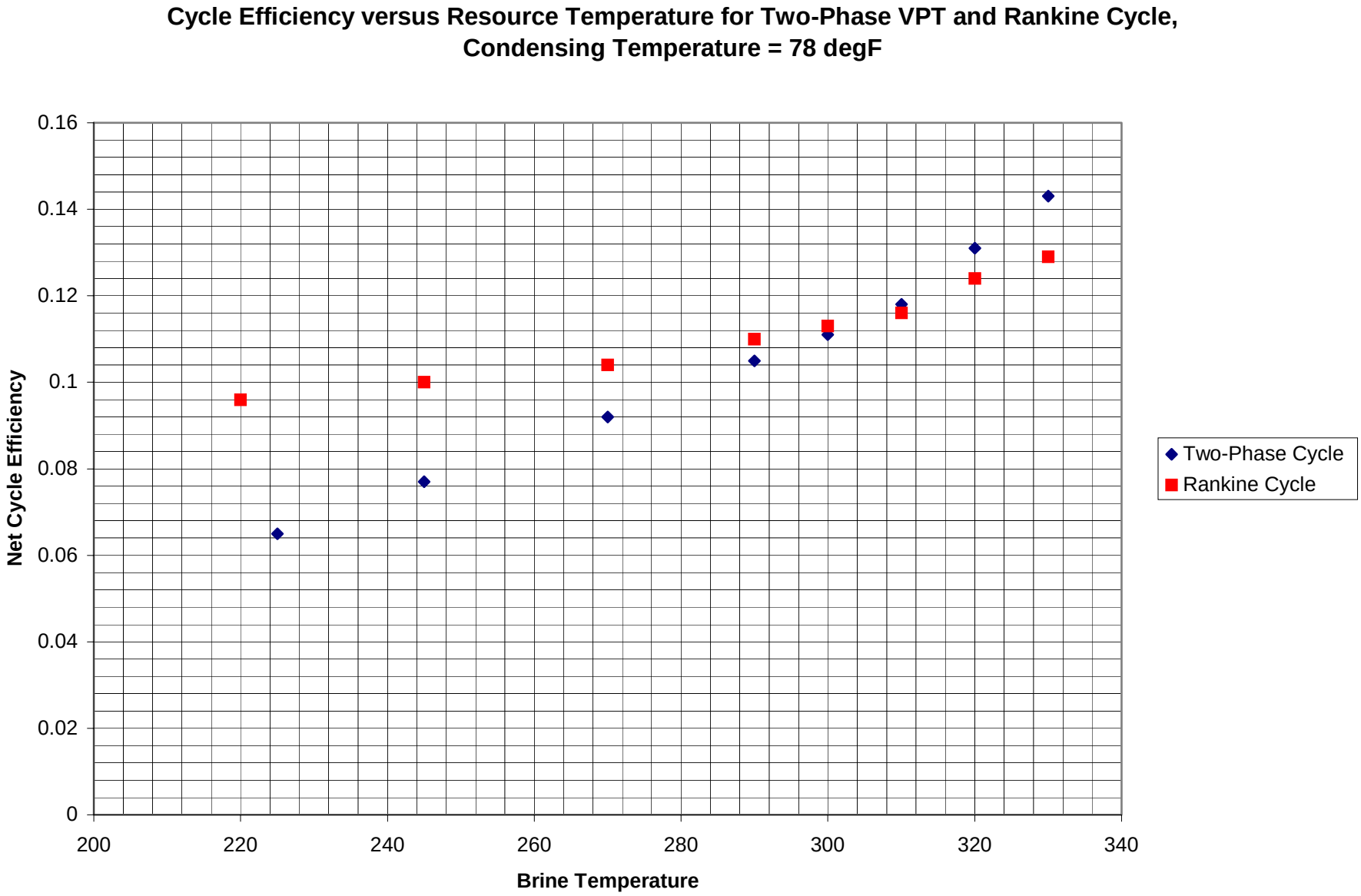
Two-Phase Separating Turbine on Ram-Powell Platform, after Dresser-Rand



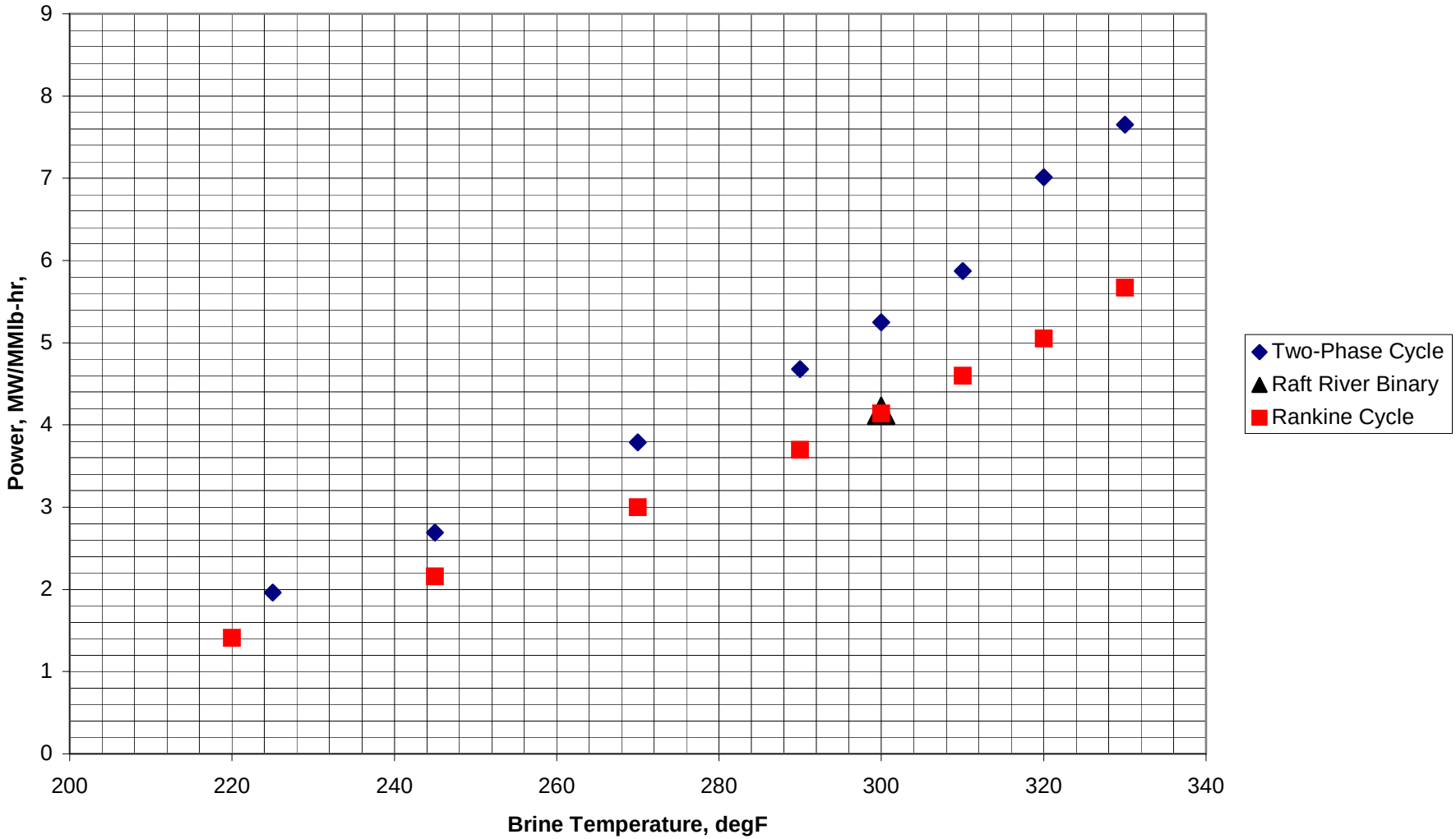
Ram-Powell Platform with Separating Turbine Installed, after Shell Deepwater

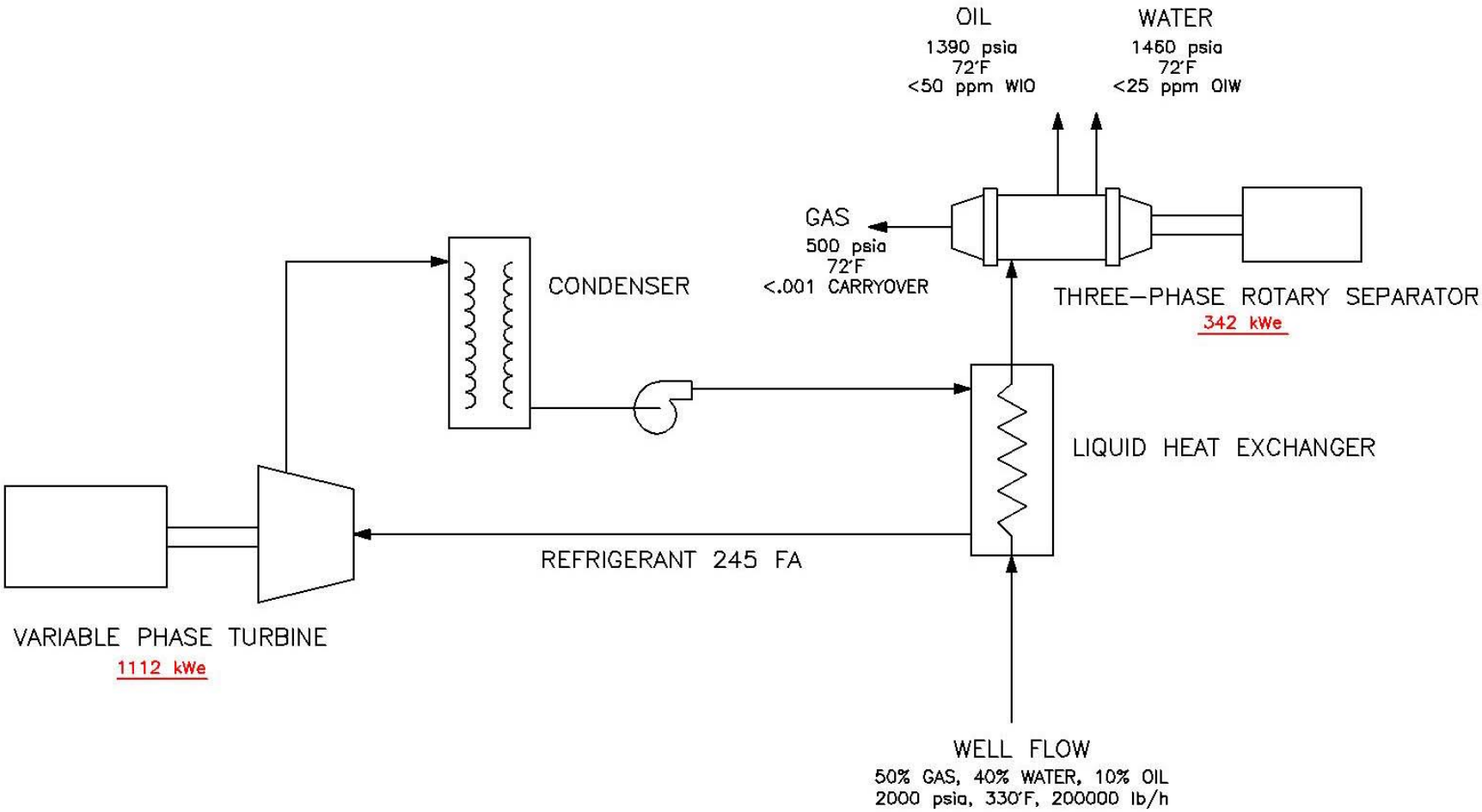
Three-Phase Separating Turbine on Ewing Banks Platform. After Dresser-Rand

System Performance


Cycle Efficiency versus Resource Temperature for Two-Phase VPT and Rankine Cycle, Condensing Temperature = 78 degF
Net Cycle Efficiency
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
200
220
240
260
280
300
320
340
Brine Temperature
Two-Phase Cycle
Rankine Cycle

Power Produced per Million Pounds per Hourof Brine for Two-Phase VPT Cycle Compared to Rankine Cycle and Raft River Binary





Performance of Separating Power System for Three-Phase Well Flow

1454 kWe vs **830** kWe for Rankine Cycle

Conclusions

- Application of Proven Two-Phase Refrigeration Technology and Proven Oil and Gas Two-Phase and Three-Phase Technology can Maximize Power Production and Separation for Two-Phase and Three-Phase Moderate Temperature Well Flows

- Production Advantages as Well as Power Production will Promote Early Acceptance by Oil & Gas Industry

- Experience by Technology Stakeholders in the Oil & Gas Industry Will Produce Systems Acceptable to that Industry