Power Cycles for Low Temperature Geothermal Heat

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CONTEXT
Converting 150°F - 300°F geothermal heat to power

- "Binary" cycle
  - re-inject geothermal brine
  - closed cycle power plant

Limitations of Steam Power Plants with Low Temperature Glide Heat

- Deep vacuum - large and costly components
- Boiling temperature selection - Hobson’s choice
- Condensing temperature - similar tradeoff

STEAM ENGINE

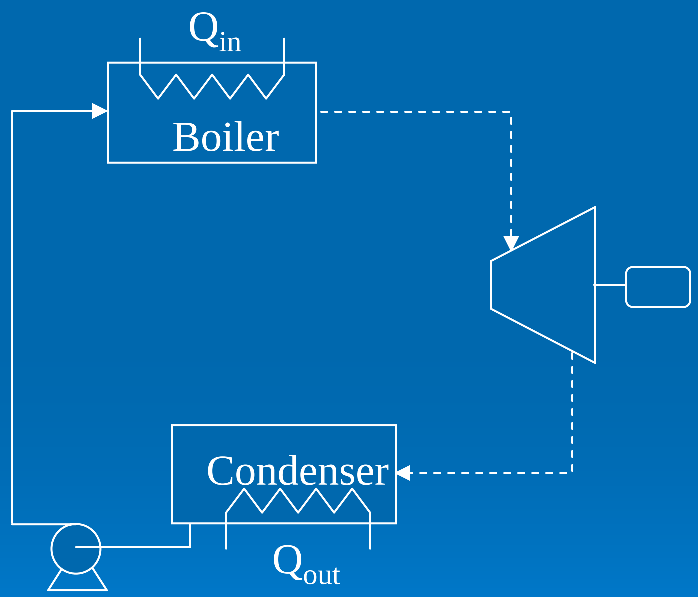
- Water pump for coal mine
- Cumberland, 1878
- 300 ft plunger pump
- 32 ft beam
- 6x improvement over Watt, Newcomen
- 200 hp

POWER PLANT SELECTION

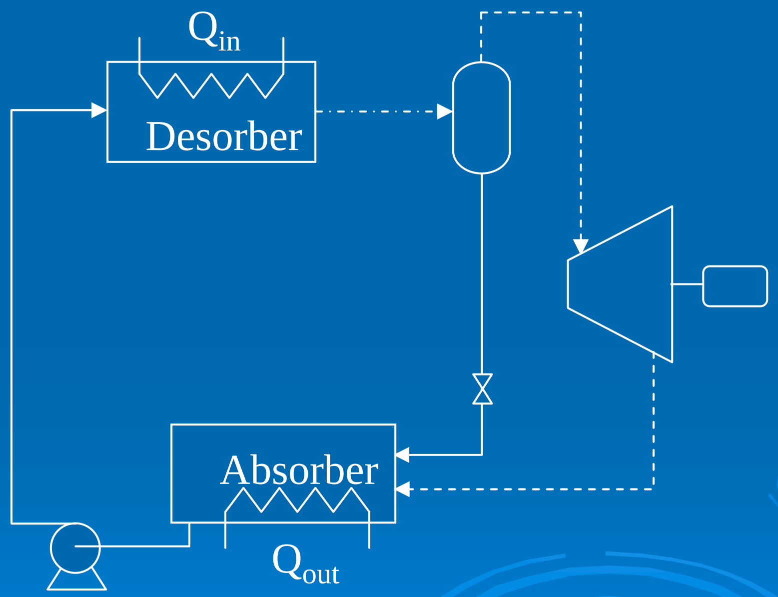
- Cycle selection
  - Rankine Power Cycle
  - Absorption Power Cycle
- Working fluid selection
  - H_2O
  - NH_3
  - Organic (flammable)
  - Organic (non-flammable)

Power Cycle Comparison

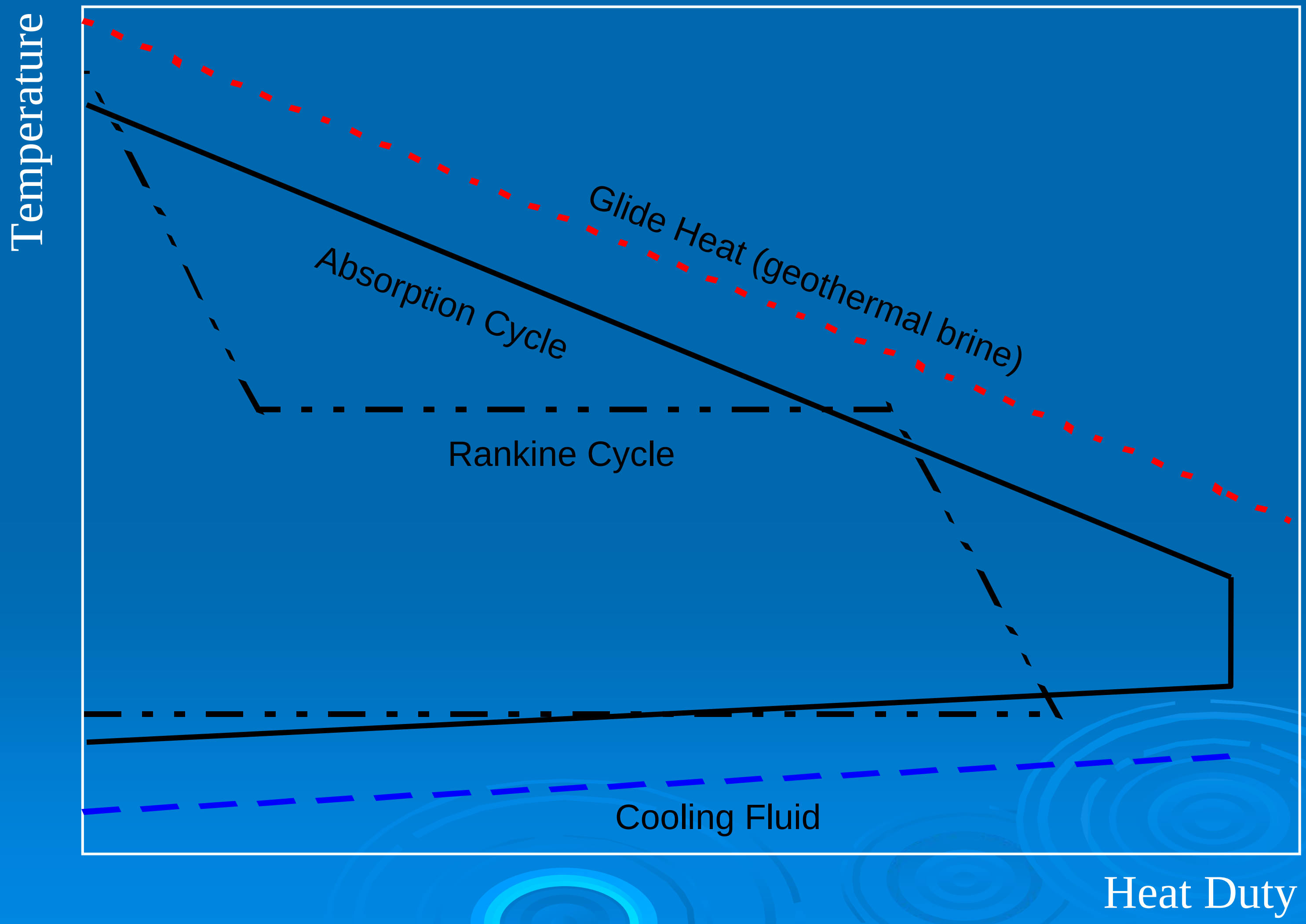
Rankine



Absorption



Qualitative Power Cycle Comparison



WORKING FLUID

- Four generic choices
- Rankine cycle usually single component
- Absorption cycle always binary fluid
  - volatile or non-volatile absorbent
- Key comparison: properties at 95°F

Working Fluid Properties
Condensing at 35°C (95°F)

		H_2O	NH_3	Propylene	R134a
Pressure [bar/psia]		0.056 / 0.816	13.51 / 195.9	14.72 / 213.5	8.88 / 128.7
Latent Heat [kJ/kg, Btu/lb]		2417.8 / 1039.5	1122.4 / 482.5	314.3 / 135.1	168.2 / 72.3
Density $[kg/m^3]$	Liquid	994.0	587.5	486.3	1167.6
	Vapor	0.04	10.46	31.51	43.41
Lqiuid Thermal Conductivity [W/m-K]		0.61	0.46	0.11	0.08
Liquid Heat Capacity [kJ/kg-K]		4.18	4.87	2.78	1.47
Liquid Viscosity [$\times10^6$, kg/m-s]		719.6	119.6	83.3	171.7
Condensation coefficient [W/m^2-K]		3589	2865	693	610

Absorption Power Cycle

- Optimal pressures - compact, economical equipment
- Glide-matching heat input
- Glide-matching heat rejection - more efficient, and conserves water
- Uses more of the glide heat

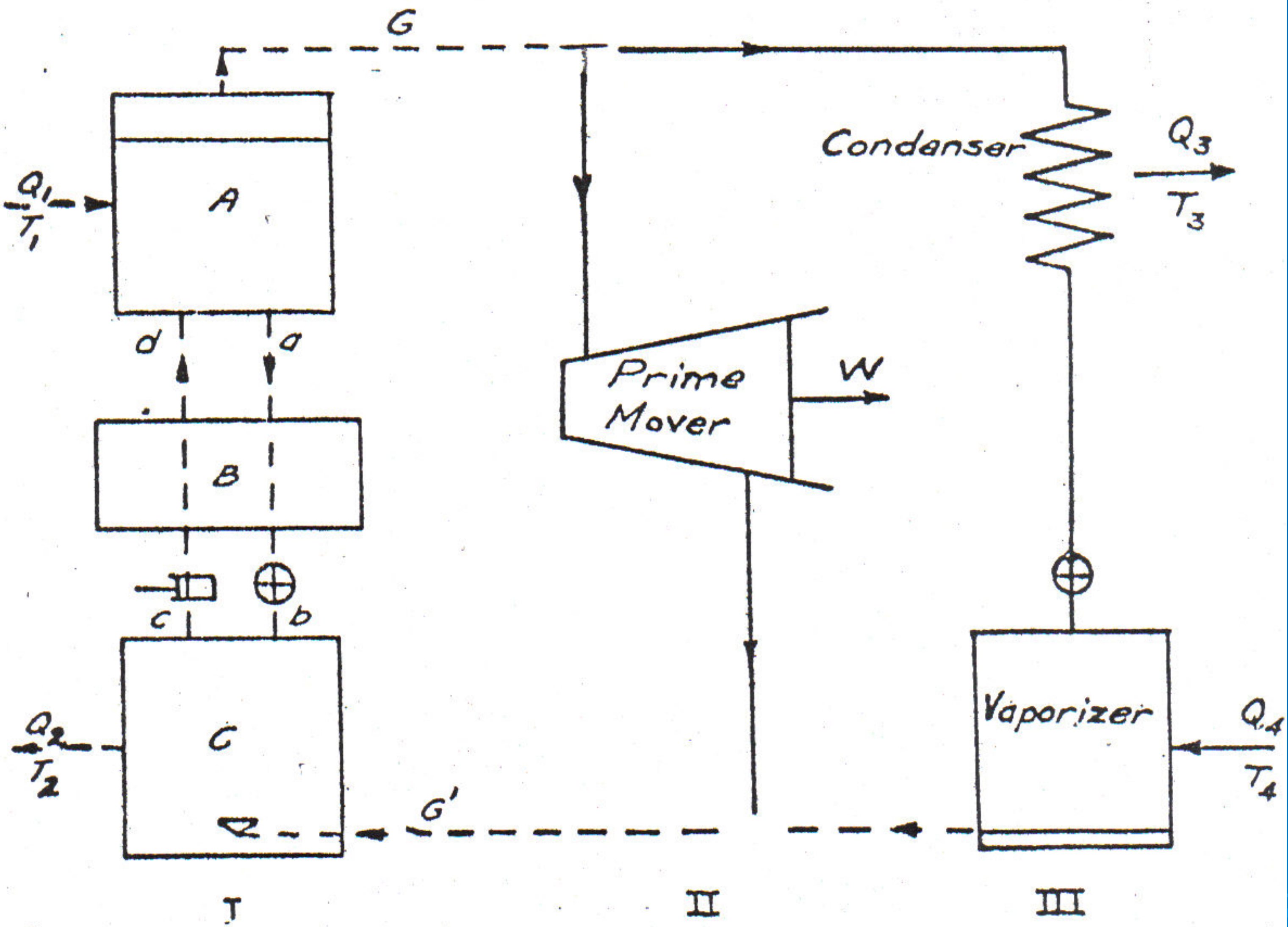


FIG. 2. Elementary Solution Cycle.
I.—Basic Solution Thermo-Compression Process; II.—Power Process; III.—Refrigeration Process.

Improvement in Chloride of Calcium Engines.

No. 124,594. Patented March 12, 1872.

Fig. 3.

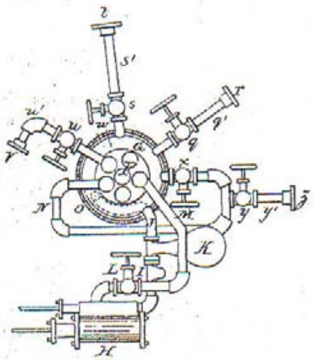


Fig. 2.

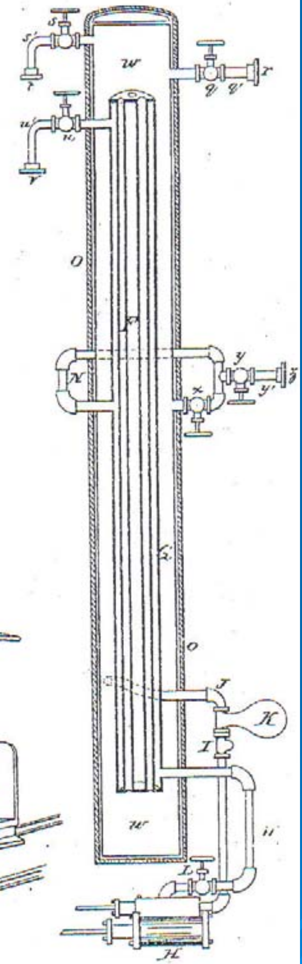
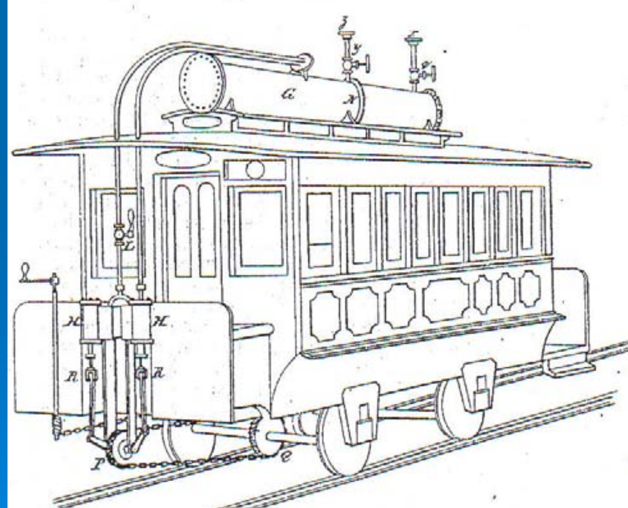


Fig. 4.



Witnesses:

Inventor:

Emile Lamm

THE HONIGMANN FIRELESS LOCOMOTIVE ENGINE.

see V 340

Fig.6.

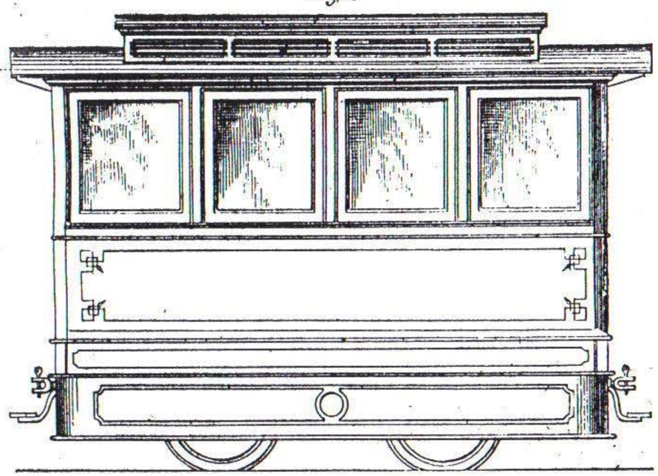


Fig.5.

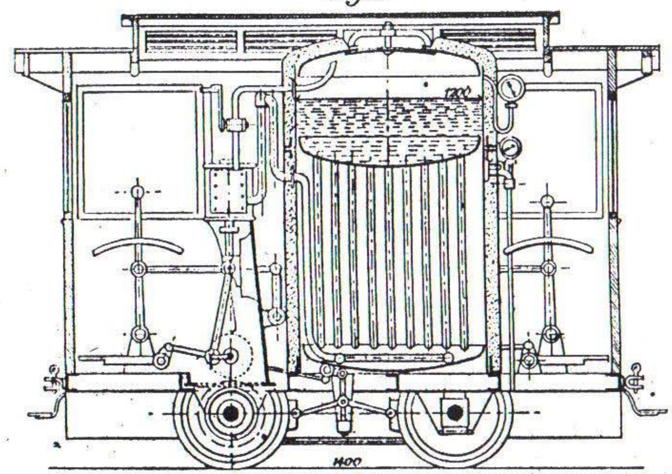


Fig . 1

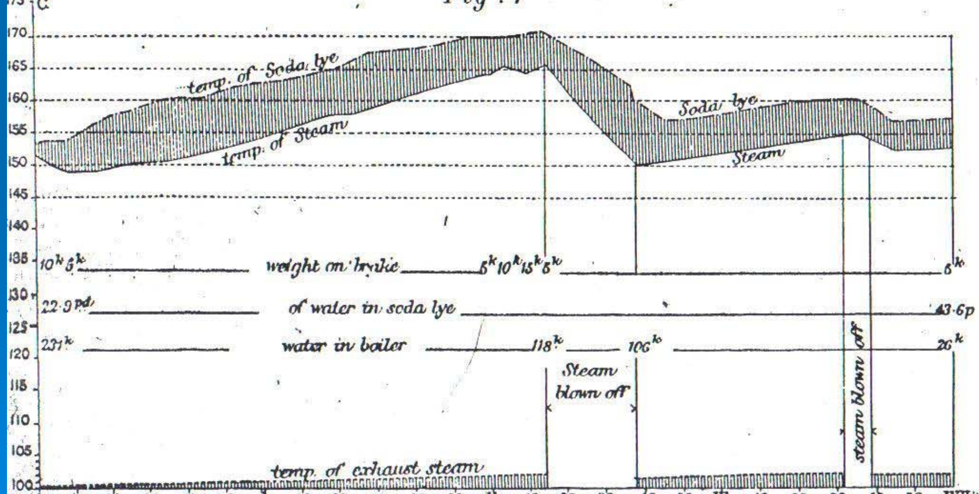
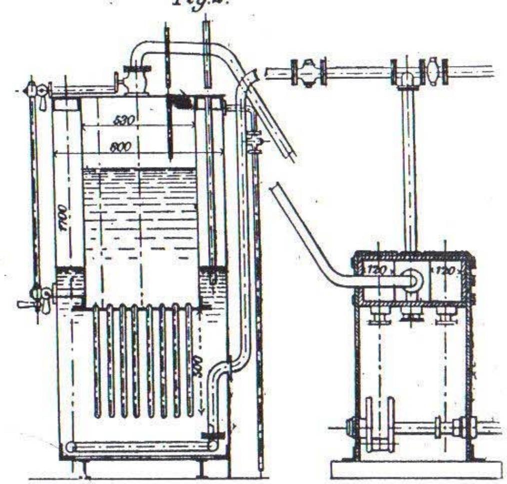
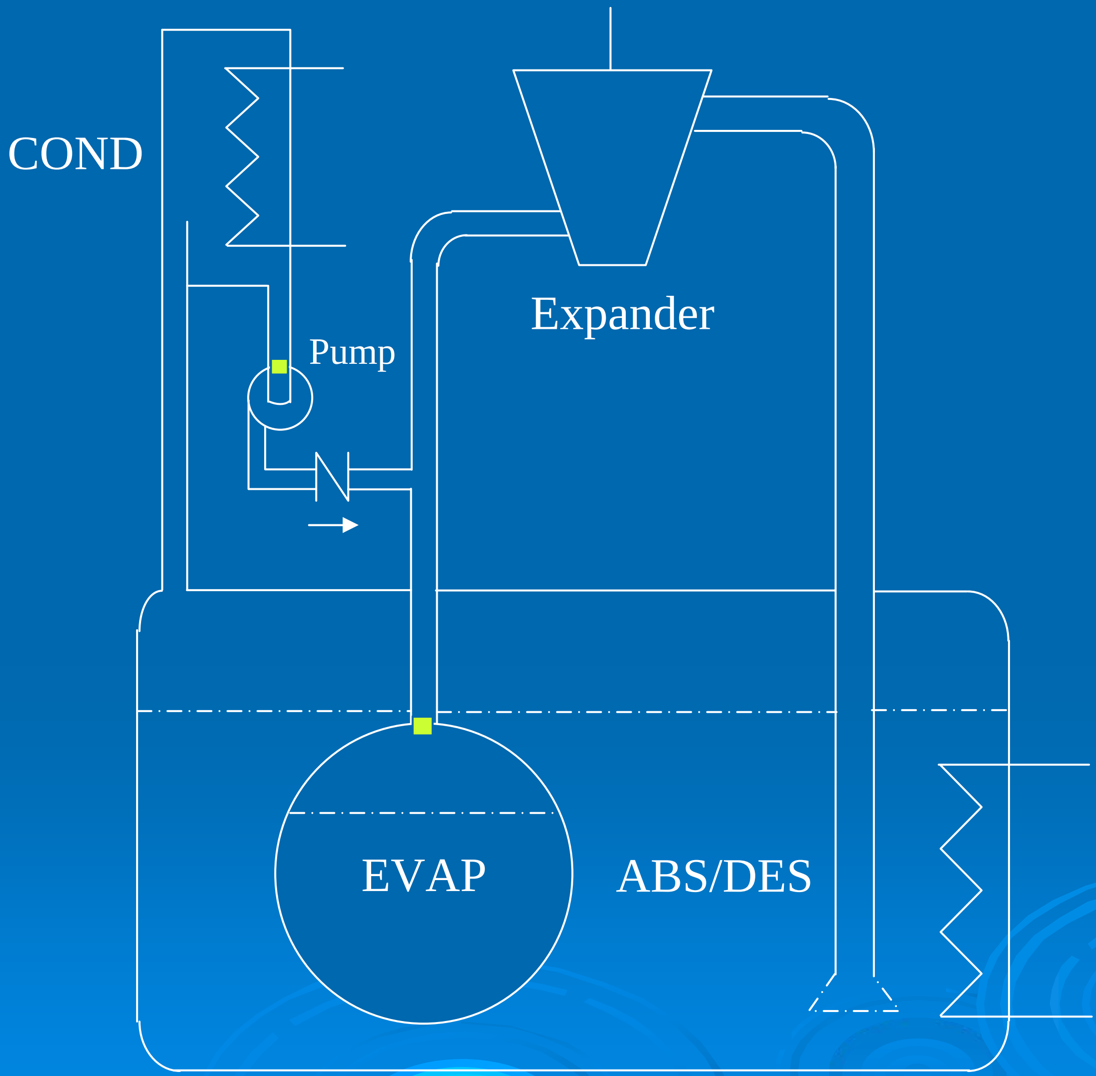


Fig.2.



Intermittent Absorption Power Cycle



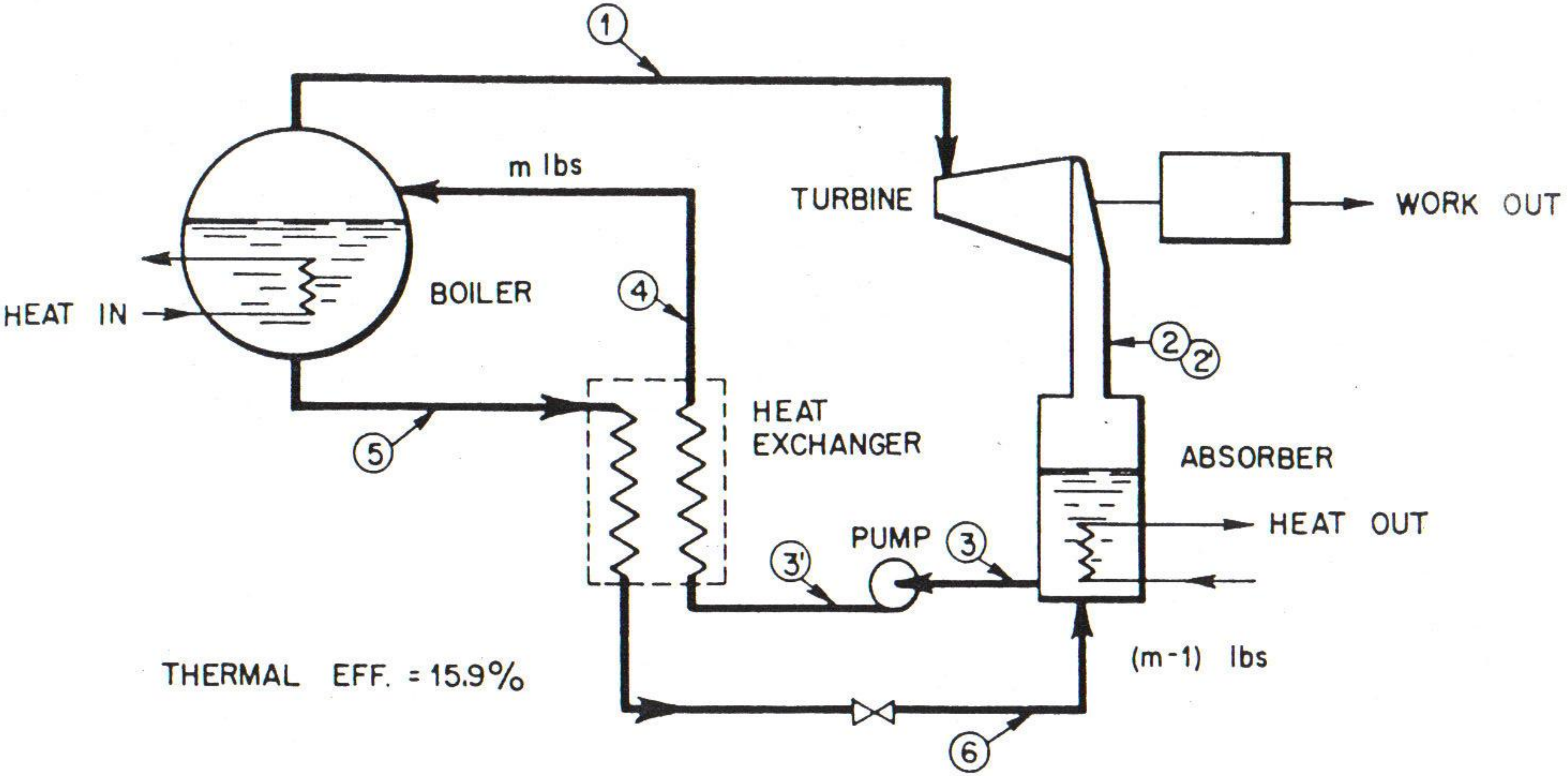
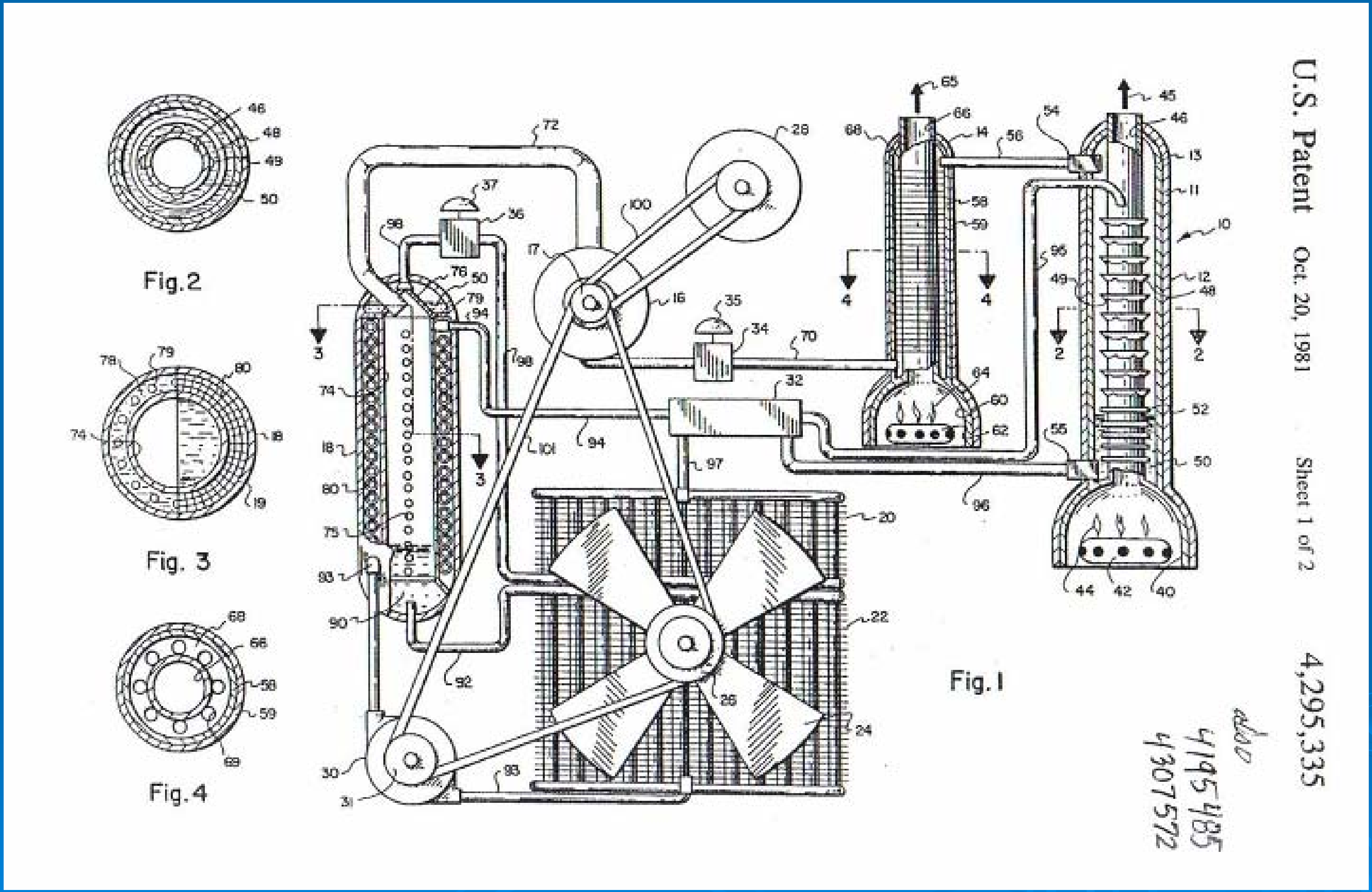
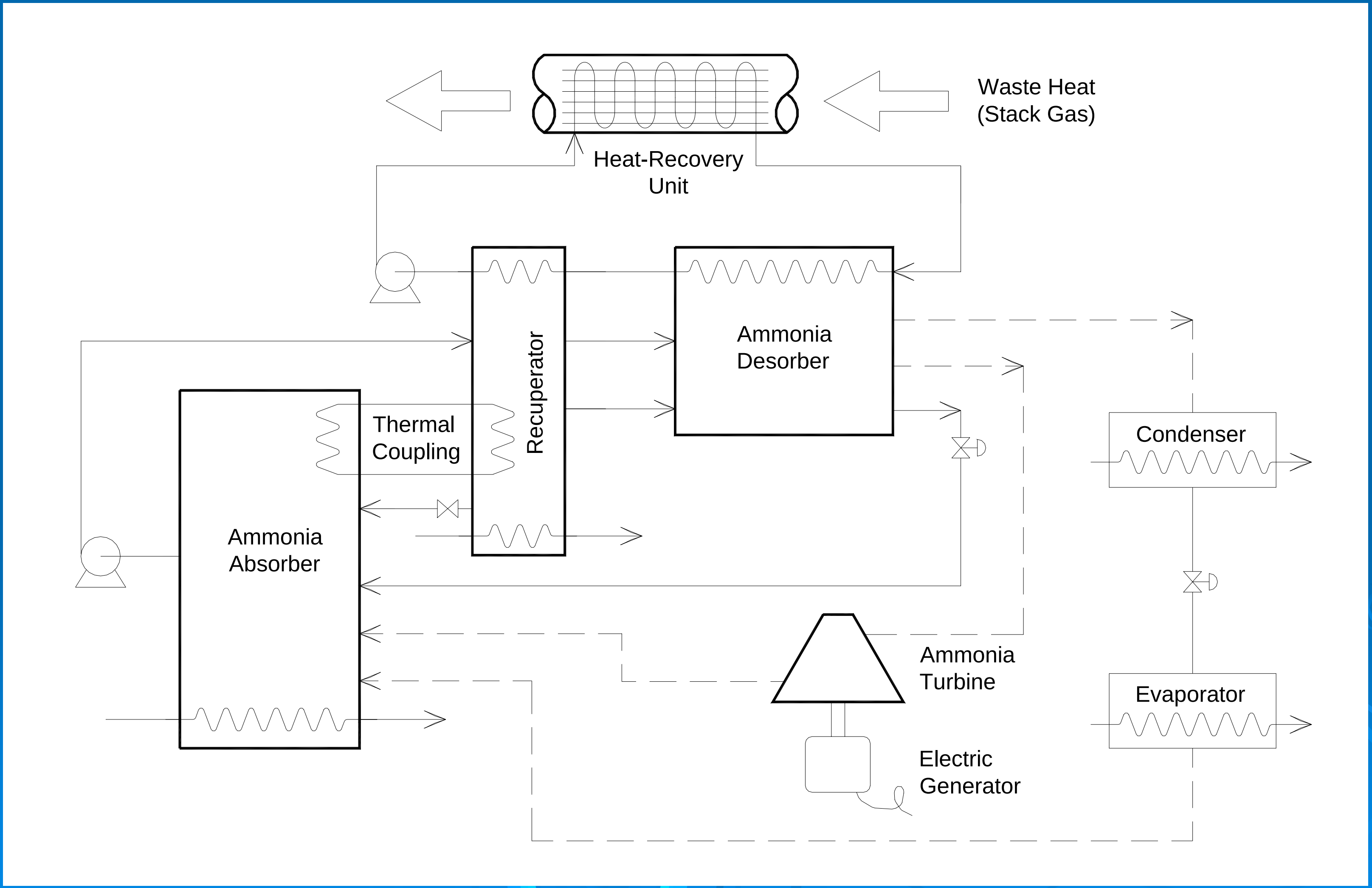


Figure 9. Ammonia-Water Power Cycle (Without Analyzer, Case IV)


U.S. Patent Oct. 20, 1981 Sheet 1 of 2 4,295,335
Fig.1
Fig.2
Fig. 3
Fig.4
also
4195485
4307572

Flow Schematic of Dual Function Absorption Power Cycle



SUMMARY
For low temperature geothermal power:

- Absorption power cycles are more efficient, due to glide matching
- System parasitics magnify the importance of cycle efficiency
- Ammonia working fluid provides:
  - favorable cycle pressures
  - best transport properties (low cost HX)
  - lowest parasitics (low pumping power)
  - smallest turbine
  - no fire suppression requirement

Economics

- Our planet needs as much energy conservation (and CO_2 reduction) as $ can buy
- All power sources (renewable, geothermal, efficiency) should compete on level playing field
- Even-handed subsidies are justified
- Targeted subsidies should be suspect

CONCLUSIONS

- More efficient cycles and working fluids are available for converting low temperature heat to power
- They are also more economic at similar production levels
- The underlying technology has been around for over a century
- It is important to pursue this higher efficiency and improved economics

Dual Function Absorption Cycle