Electricity Production in SP -100

- **Concentrate on two areas;**
  A.) Heat Transport System
  B.) Thermoelectric Conversion

Heat Transport System

Objective: Transfer the thermal energy from the reactor to the thermoelectric conversion modules with;

A.) Minimum energy loss (use multi-foil insulation around the pipes)

B.) High reliability (redundant, high efficiency thermoelectric pumps which have no moving parts)

C.) Minimum mass

====================

One unique requirement is the need to thaw the reactor once in orbit.

Use heat pipes (from the reactor core) which trace the coolant pipes

----

Overall Requirements

1.) Deliver 2,000 kW_t to the T/E elements

2.) **Must meet all requirements on reliability and safety for 10 calendar years, which includes 7 full power operating years.**

3.) **Heat transport system must be capable of thaw and start up in space**

4.) **Heat transport system must be capable of extrapolation to higher power levels**

Figure (System layout)

Note; reactor has 12 cooling circuits

Note; two major assemblies welded together well away from the neutron source.

Note; the 12 redundant 2-pass T/E pumps feed 12 separate heat exchangers through headers. The pressure drop is so low that the loss of a single T/E pump results in only a small reduction in the loop flow.

Figure

Note; The loop is thawed out by trace heat pipes as shown in the figure.

old

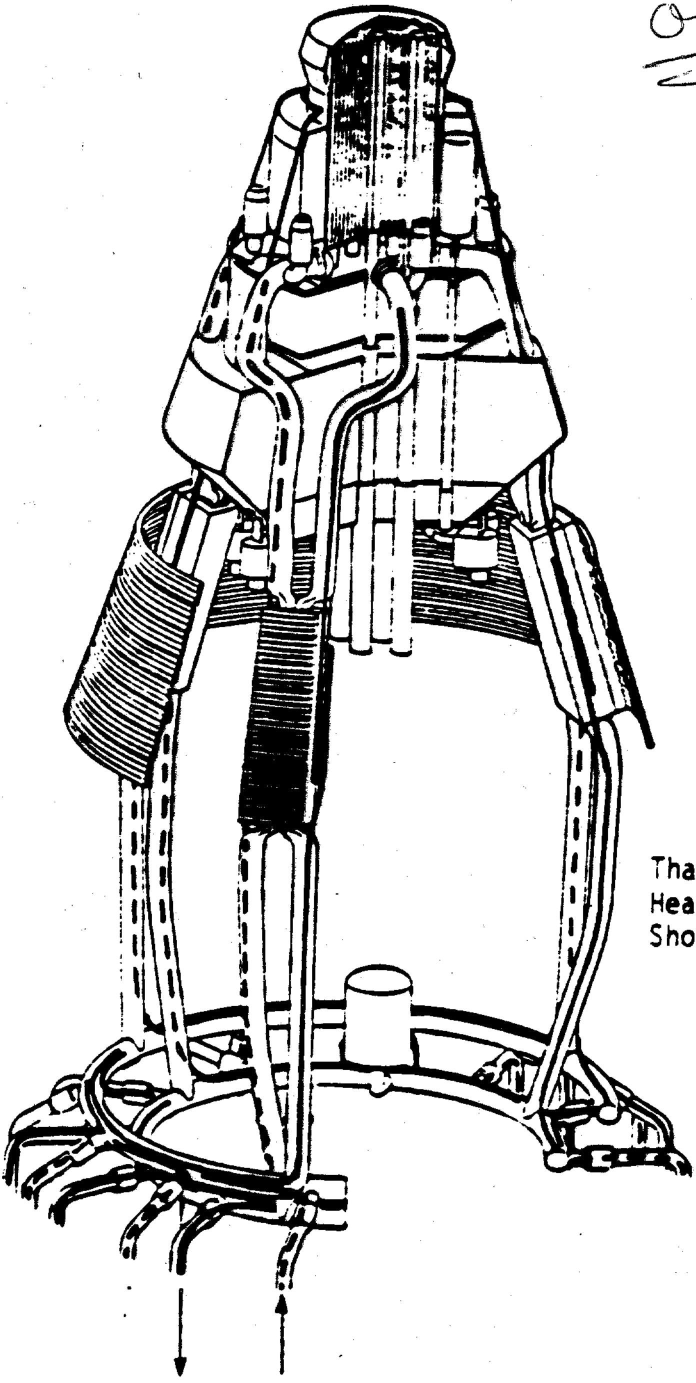
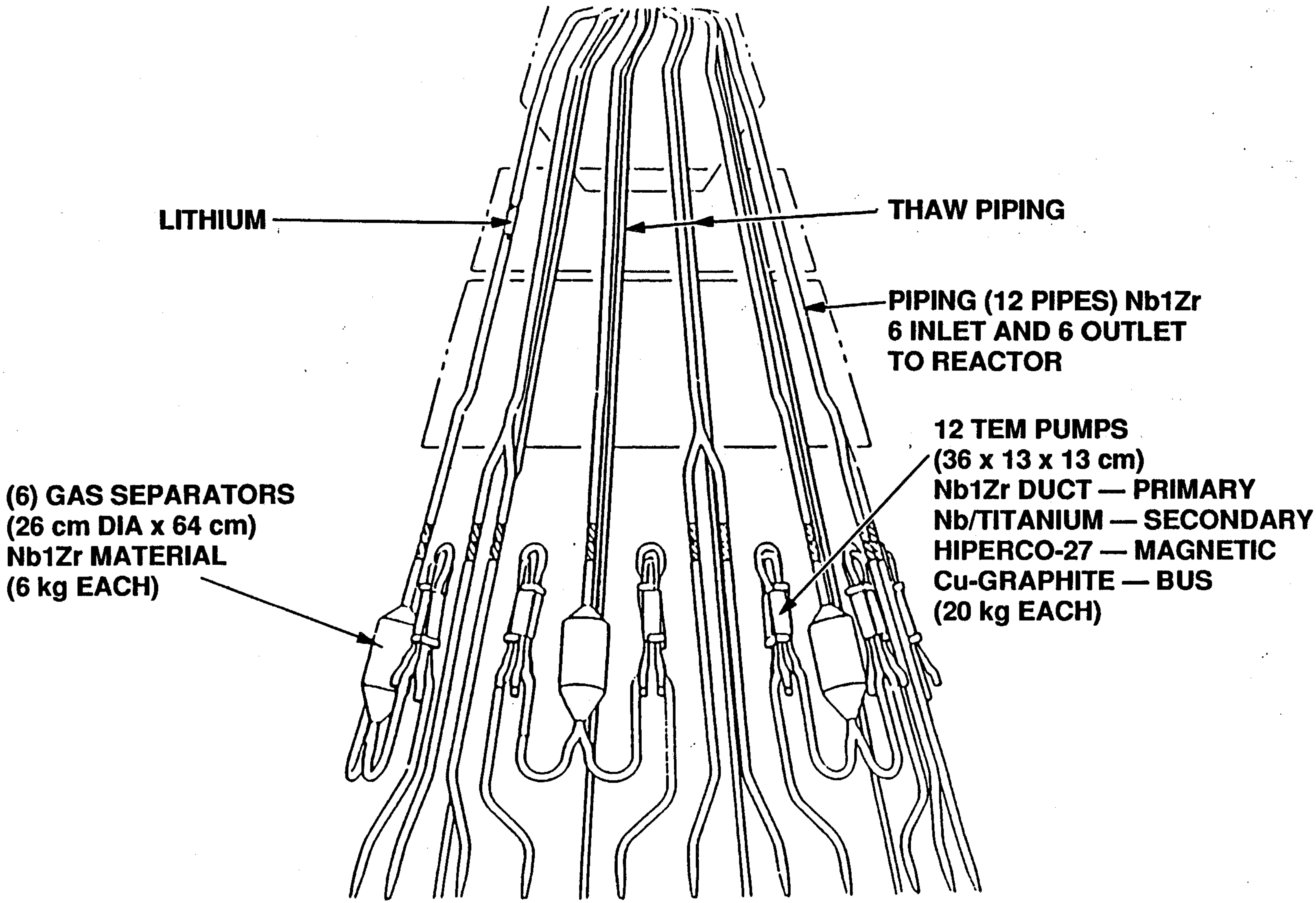


Figure 5-3 SP-100 Loop Thaw Assist Heat Pipes

Heat Transport Subsystem



Total Mass of the System

158 kg including Lithium (up to welded joints)

Piping and accumulators

TEM pumps

Multi-foil insulation covering reactor assembly and piping

Thaw heat pipes

==============================

TEM Pump

Figure

(note pump is DC and generates its own electricity internally from T/E between the hot coolant and the colder radiator)

Piping Considerations

Material = PWC -11

- **Reactor inlet and outlet, as well as the hot and cold manifold are 6 cm in diameter but only 0.1 cm thick.**

- **the 24 (12 sets) of PWC -11 pipes running from the manifolds to the heat exchangers are 4 cm in diameter and 0.1 cm in thickness**

Accumulators

Needed to perform 2 functions;

- **Accommodate volume expansion during thaw process**

- **Control pressure in the loop (using gas spring)**

==========================

Thermopile Heat Exchangers

Figure of single pass, multi-channel unit

- **PWC -11 material is only 0.075 cm thick**

- **T_{in}=1350°K, T_{out}=1310°K**

- **Flow in turbulent regime, N_{Re}=40,000 and heat transfer coefficient ≈ 25,000 watts/m^2-°K**

Insulation

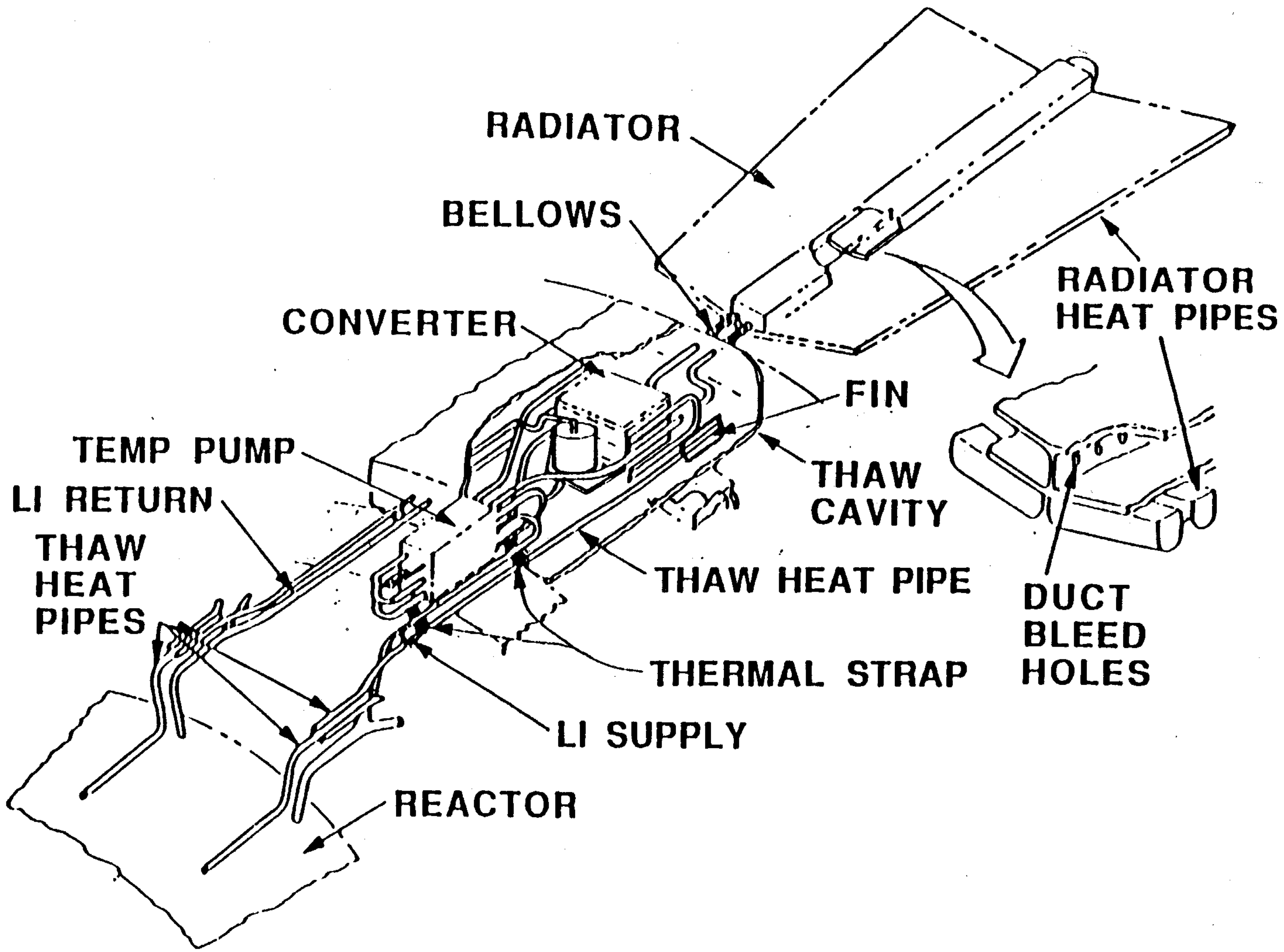
- ***Lightweight design consists of 40 layers of 0.0005-cm thick Ti foil with ZrO_2 cloth separators.***

- ***Coated with Mo to resist Lasers***

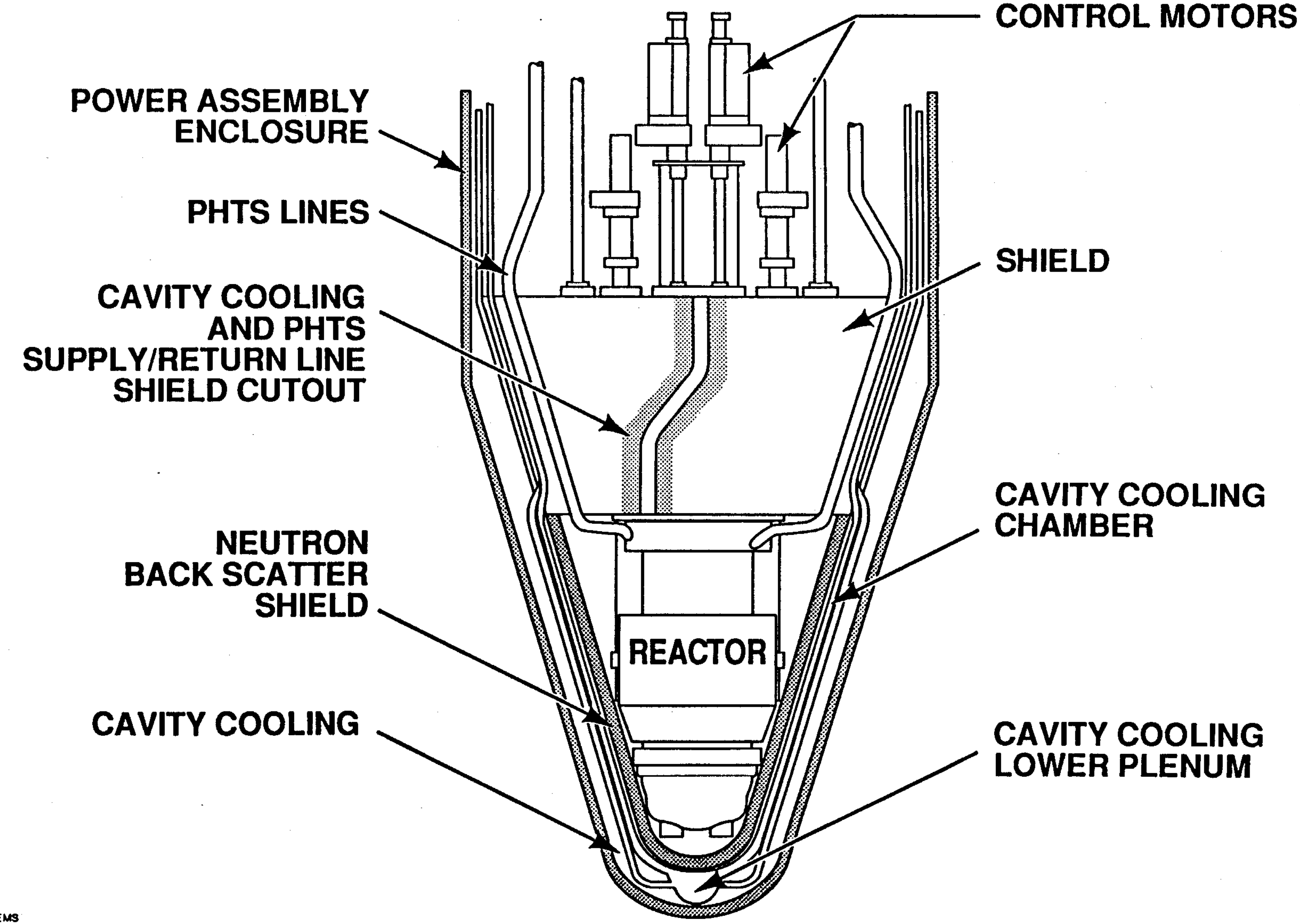
- ***Effective emissivity = 0.03***

JPL/Los Alamos

SYSTEM THAW



Cavity Cooling System



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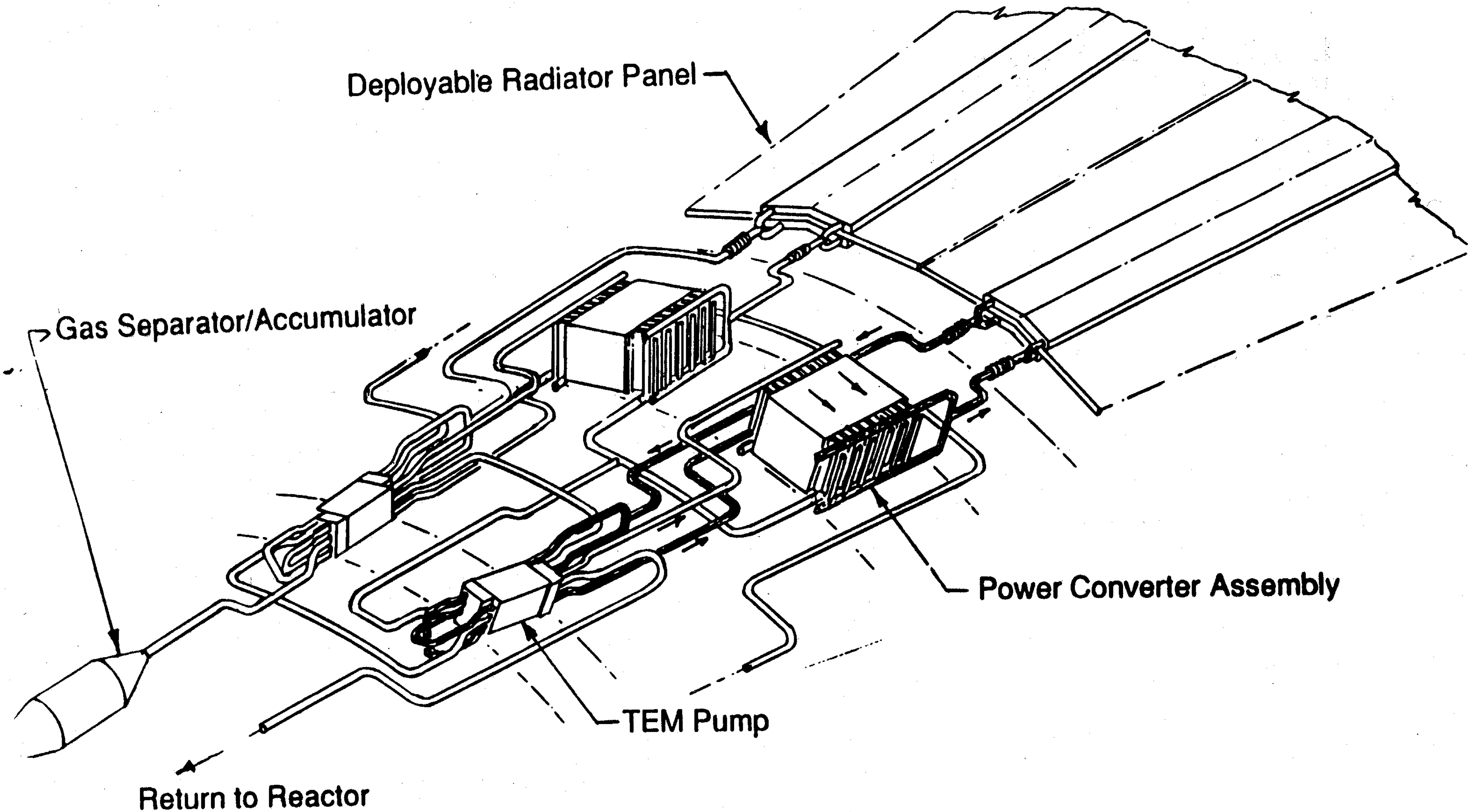
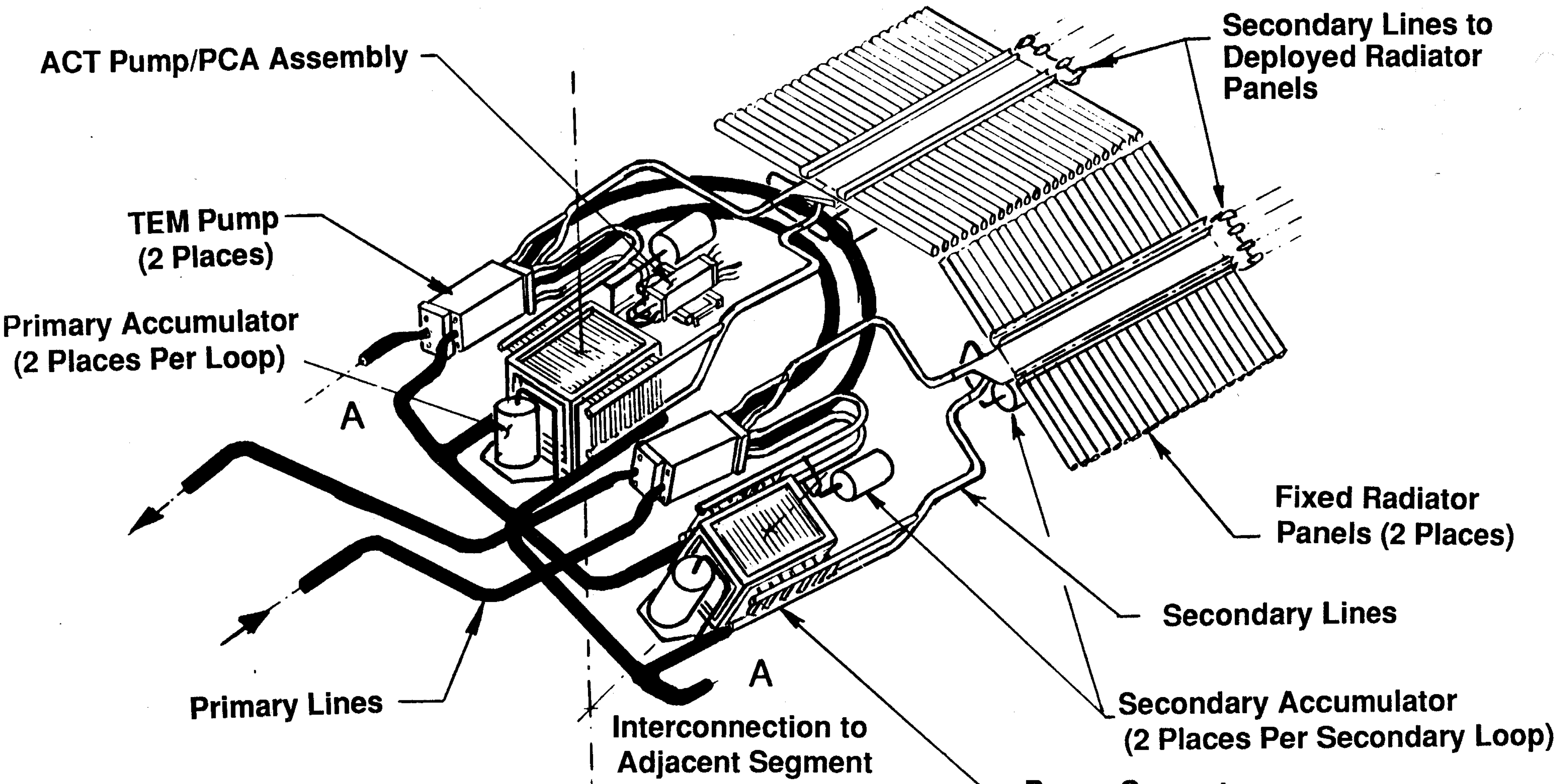


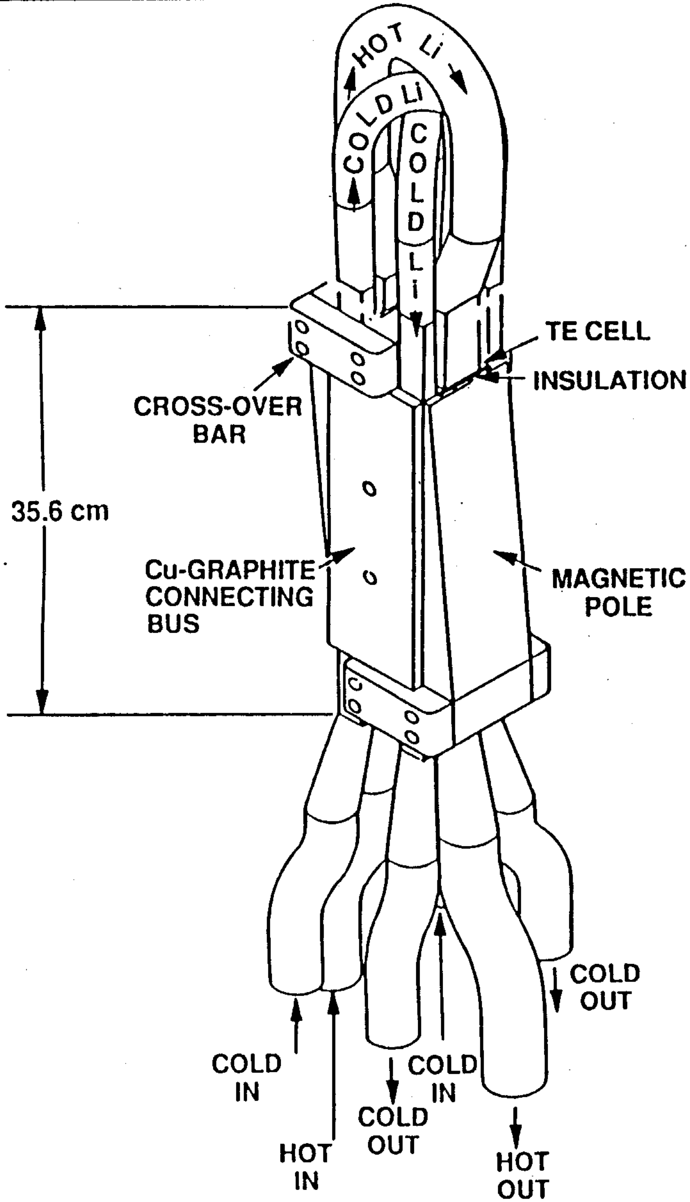
Figure 18. Heat Transport with Linked/Integrated Pumps

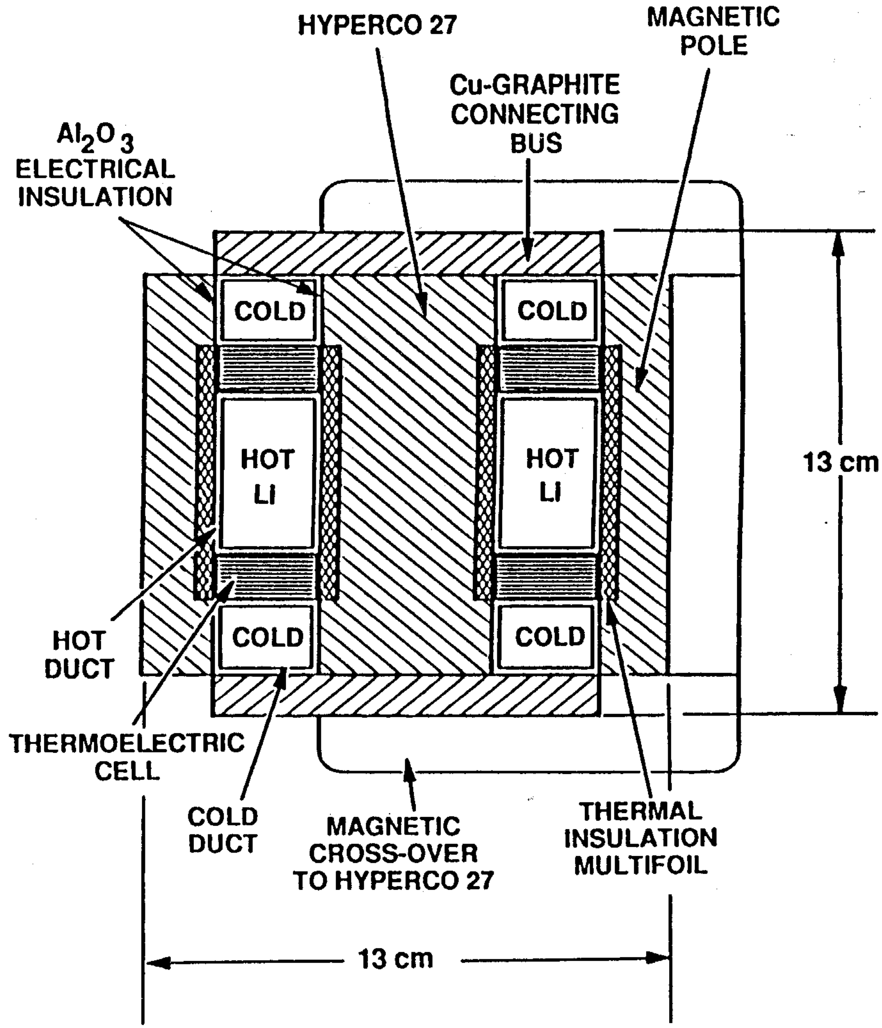
1. of these
Power lines - Hot Side
Open Lines - cold Side

Pump/PCA Segment

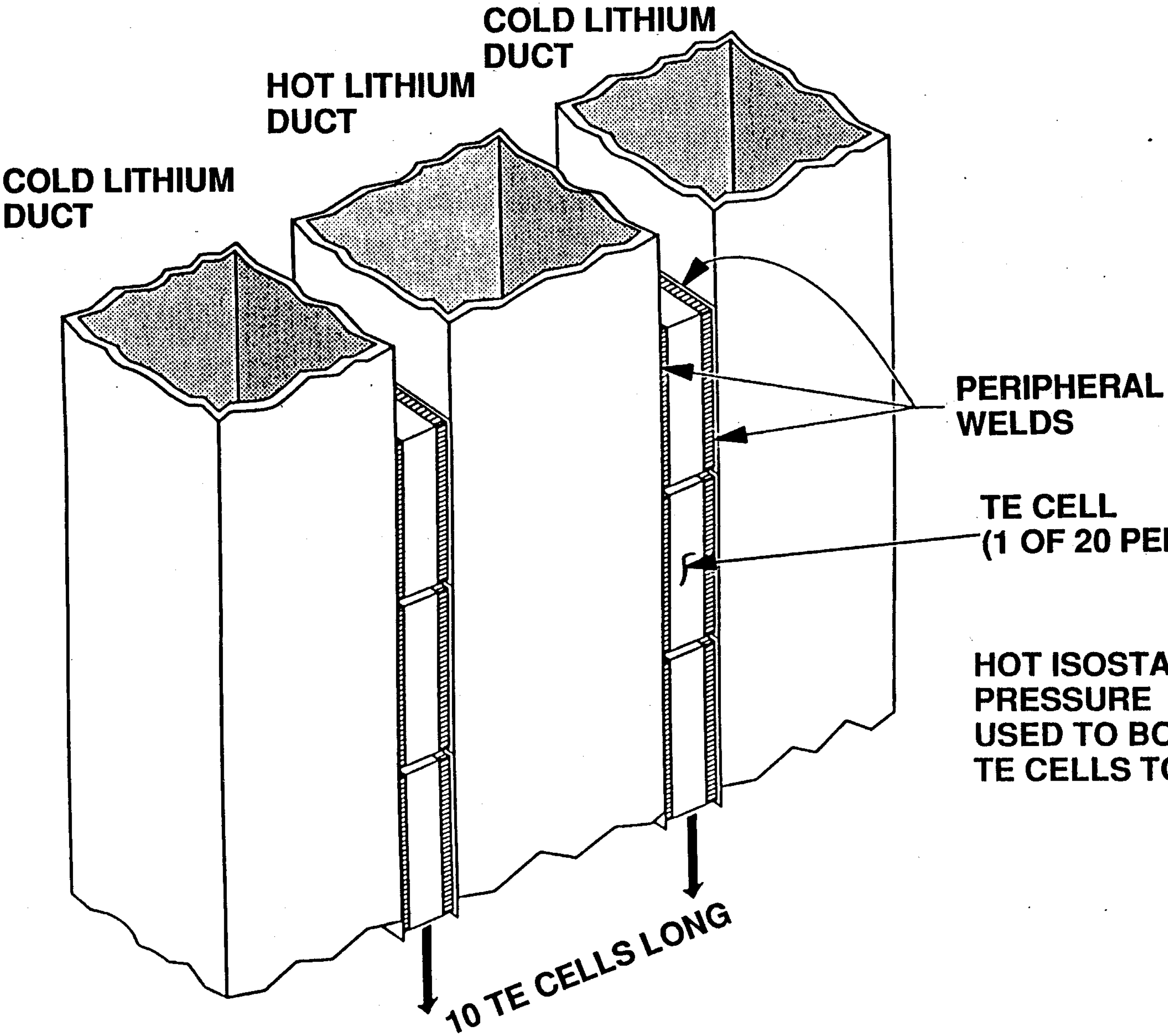


(ACT Tracelines Not Shown)


HOT Li
COLD Li
COLD Li
TE CELL
INSULATION
CROSS-OVER BAR
35.6 cm
Cu-GRAPHITE CONNECTING BUS
MAGNETIC POLE
COLD IN
HOT IN
COLD OUT
COLD IN
HOT OUT
COLD OUT


HYPERCO 27
MAGNETIC POLE
Cu-GRAPHITE CONNECTING BUS
Al_2O_3 ELECTRICAL INSULATION
COLD
COLD
HOT LI
HOT LI
COLD
COLD
13 cm
HOT DUCT
THERMOELECTRIC CELL
COLD DUCT
MAGNETIC CROSS-OVER TO HYPERCO 27
THERMAL INSULATION MULTIFOIL
13 cm

Bonding TE Cells to Pump Ducts



HOT ISOSTATIC PRESSURE USED TO BOND TE CELLS TO DUCTS

Overall Performance

- **Total system design pressure=157 kPa**

- **All system velocities <10 m/s**

- **Heat losses =158 kW_t Approximately 40 % comes from the cold side of the T/E pumps**

- **Mechanical property safety factors**
    - **Creep strength exceeds load by 3X**
    - **Yield strength exceeds load by 20X**
    - **Ultimate strength exceeds load by 30X**
    - **Fatigue strength exceeds thermal loading (0.01 cm/cm) by 5X on strain and more than 50X on the number of cycles**

Properties of Lithium

See Table

Key features;

- **Low density**
- **High boiling point**
- **Low vapor pressure**
- **High thermal conductivity**
- **High specific heat**
- **Relatively low pumping power**

Time to complete thaw

- **Measure first temperature increase--0.9 hr**
- **Melt Li in reactor----------------------0.6 hr**
- **Heat Li from 454°K to 1350 °K--------1.2 hr**
- **Melt Li in heat transport system-----2.65 hr**
- **Complete circulation and thermal equilibrated---------------------------0.2 hr**
- **Fixed and deployed radiator thaw----2.0 hr**

7.55 hr

TABLE 5-2

Physical Properties of

Potential Coolants for SP-100

	Li	Na	NaK	K
DENSITY, G/CM^3	0.53	0.97	0.89	0.86
MELTING POINT, °K	454	371	260	337
BOILING POINT, °K	1606	1155	1058	1033
VAPOR PRESSURE, PSI				
1220K	0.3	25	40	70
1350K	1.2	62	112	135
ELECTRICAL RESISTIVITY, MICRO-OHM (1350K)	49	53	140	125
THERMAL CONDUCTIVITY. W/CM-°K (1350K)	0.61	0.42	0.22	0.23
VISCOSITY. CENTIPOISE	0.161	0.13	0.11	0.084
SPECIFIC HEAT, J/KG °K	4170	1290	1060	833
RELATIVE CONVECTIVE FILM COEFFICIENT*	1.0	0.85	0.60	0.65
RELATIVE PUMPING POWER*	1.0	8.5	17	42

* NORMALIZED TO LITHIUM