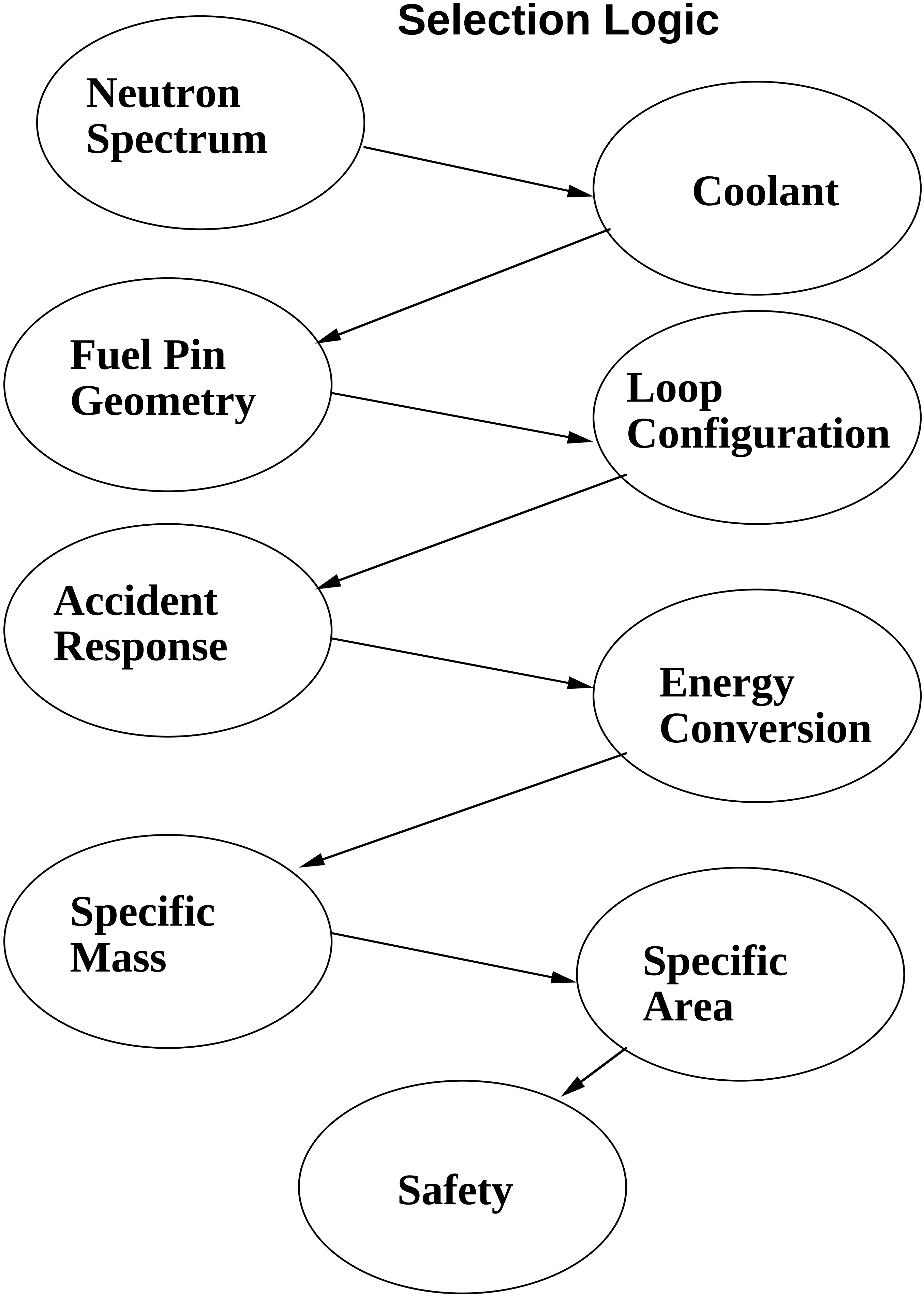
Selection Logic



Nuclear Core Issues

Reactor Type	Mean Neutron Energy	Examples
Fast	0.30 MeV	SP-100, Cosmos-1900
Epithermal	1-10 eV	Rover (NERVA)
Thermal	0.05-0.1 eV	SNAP-10A, TOPAZ

Key Differences-Thermal vs Fast Reactors

- **Low ^{235}U Critical Mass for Thermal Reactor**

  - Advantage where unit cost is paramount or many units are required

  - Unsuitable for long life time, very high power reactors
    - **Overly large burn-up fraction**
    - **Loss of control capability**
    - **Fuel degradation**

- **Hydrogen Moderated Reactors Temperature Limited (900 to 950 °K unless moderator is separately cooled)**

• Beryllium Moderated reactors Similarly Limited in Temperature (Helium Formation)

• Graphite (Carbon) Moderated Reactors large and Relatively Heavy

• Fast Reactor Restart Not Limited by Fission Product Poisoning

• Compactness Favors High Fuel Density Fast Reactor Designs

Fissile Fuel Depletion

• 1 MWd (thermal) ≈ 1 g ^{235}U burned

• 7 years at 2.0 MW_t ≈ 5 kg ^{235}U burned

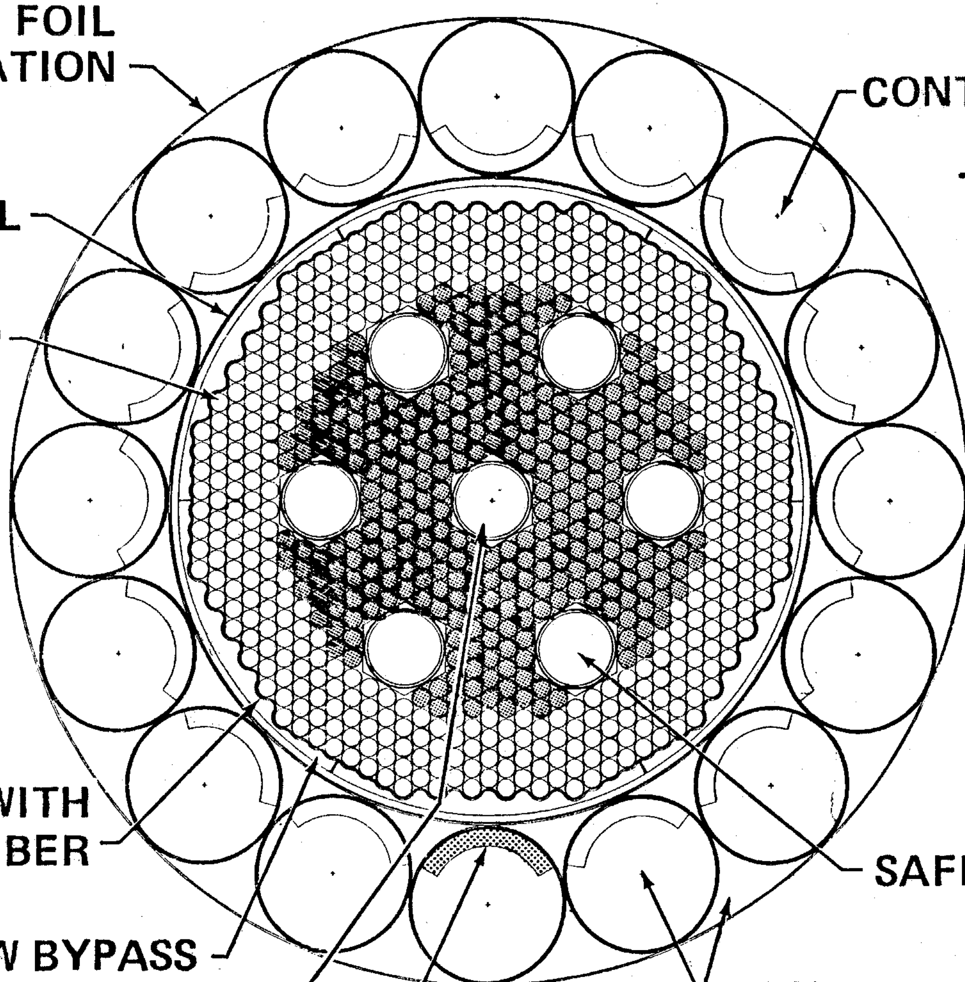
This is:

50% of ^{235}U loading of 2.0 MW_t Thermal Reactor

3% of ^{235}U loading of 2.0 MW_t Fast Reactor

BASELINE REACTOR CROSS SECTION

EARLY Design 1986



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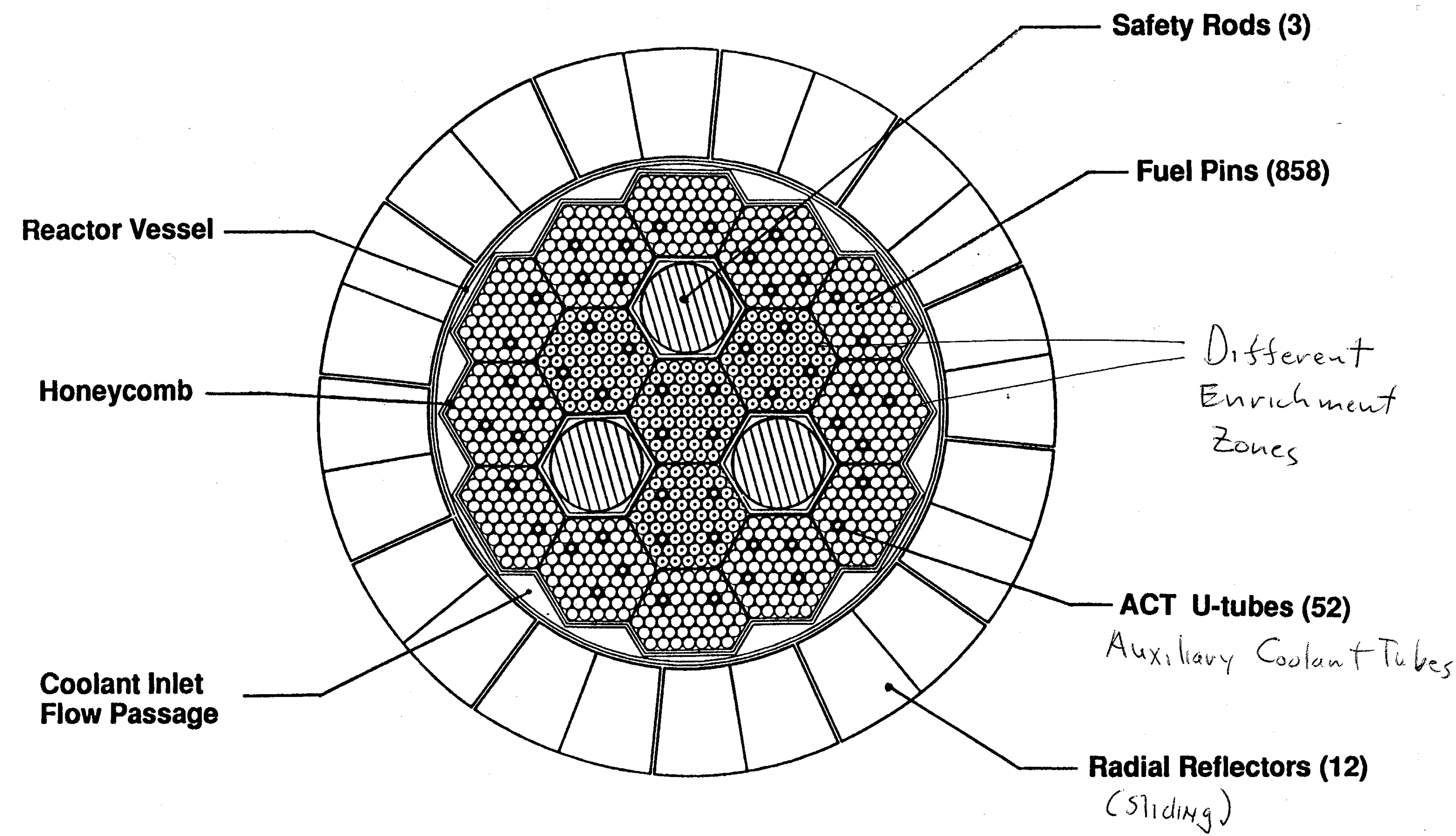
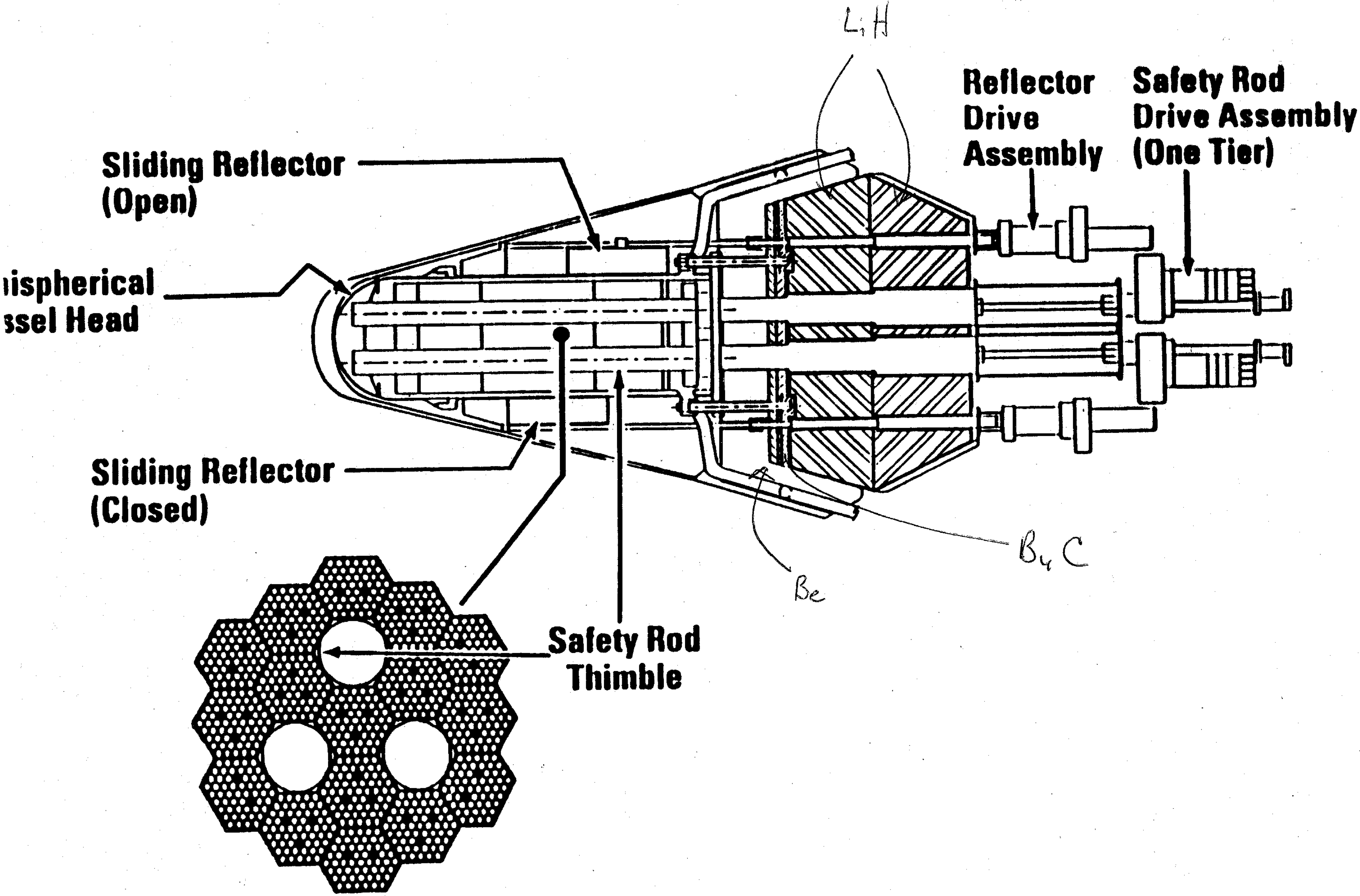
Reactor Core Design





3 Safety Rod Core

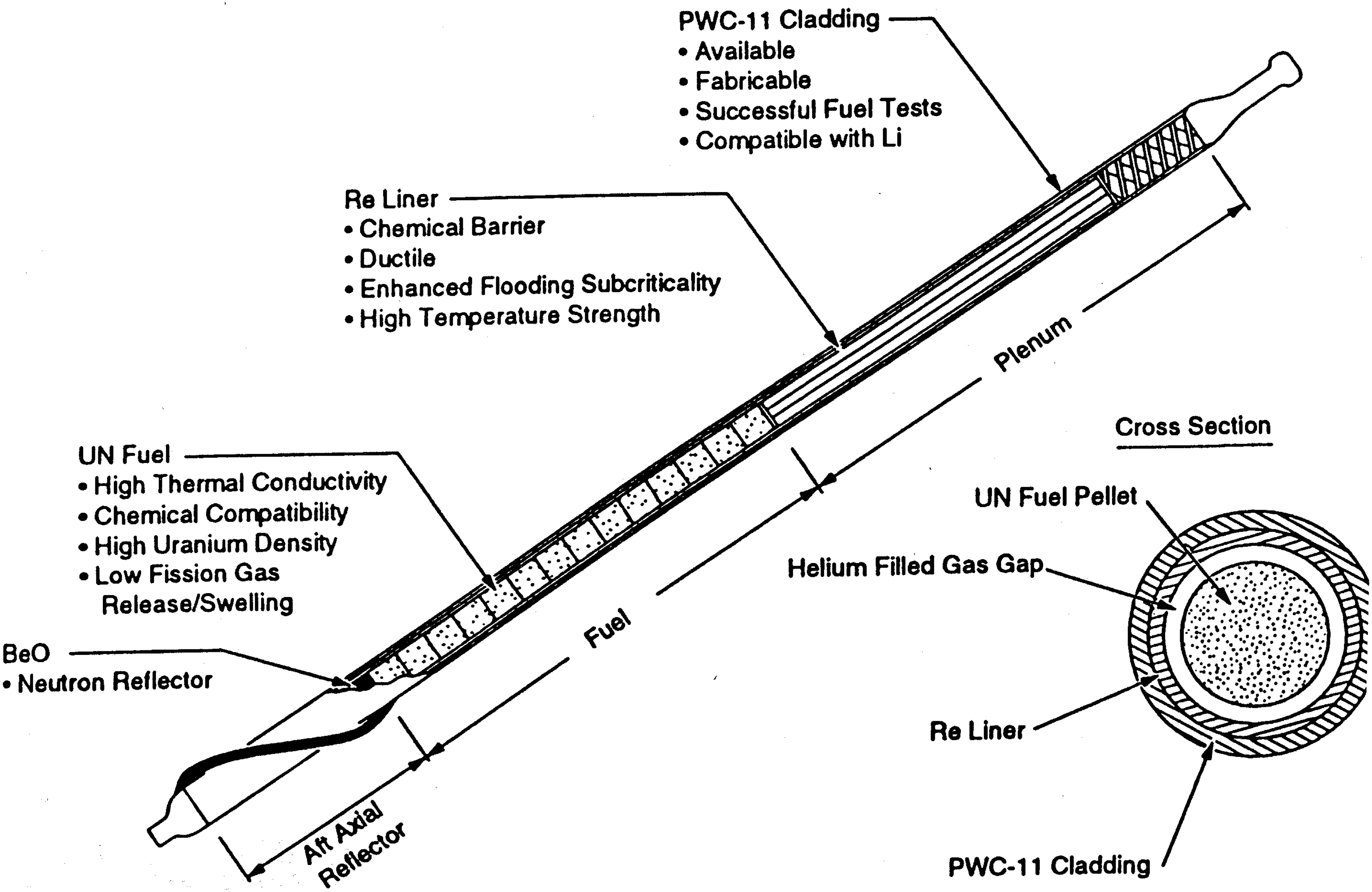


FIGURE 3. SP-100 Fuel Pin (Truscello and Rutger 1992).

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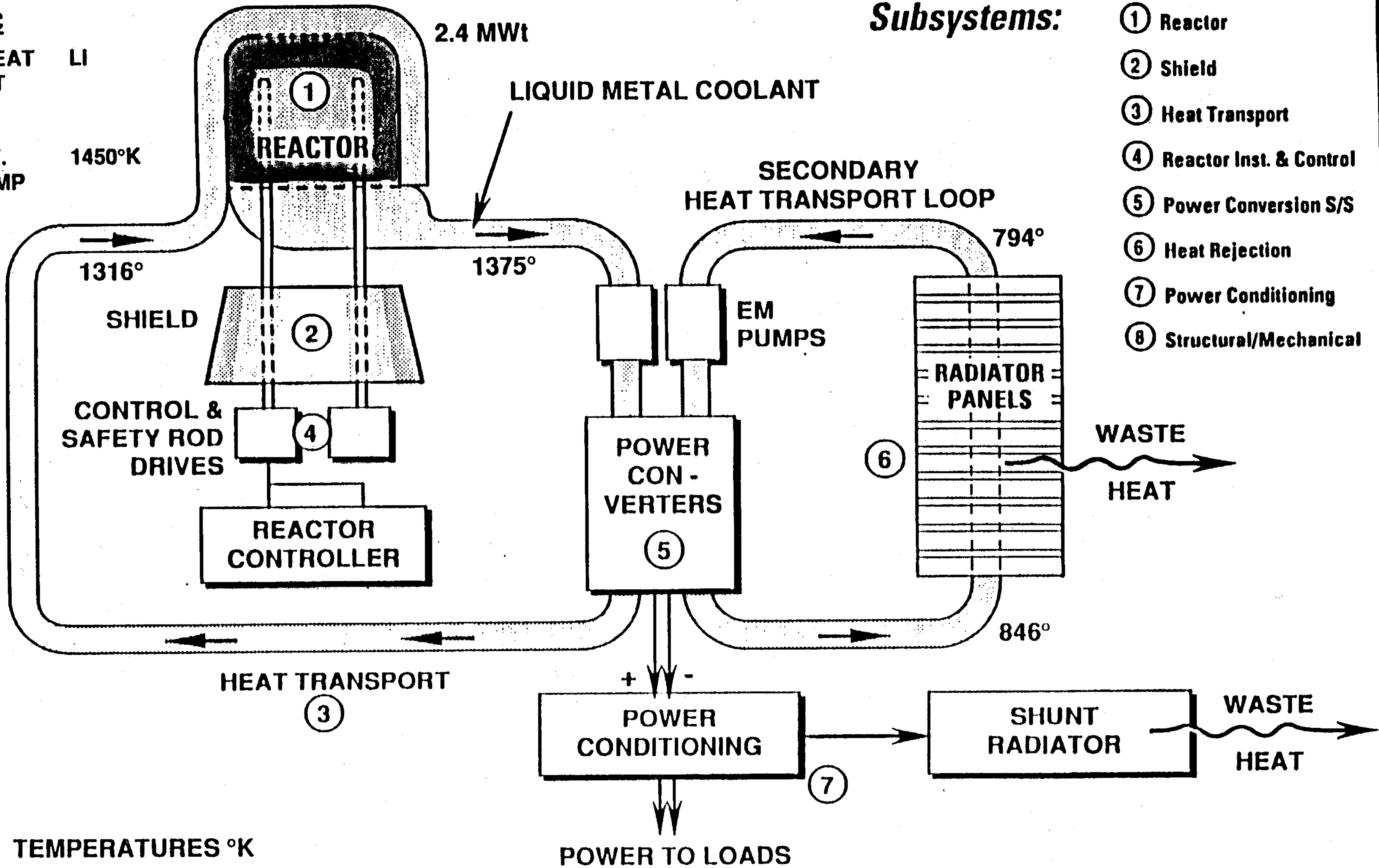
SIMPLIFIED SYSTEM DIAGRAM

TECH SPEC

- PRIMARY HEAT TRANSPORT FLUID — LI
- MAX REACT. OUTLET TEMP — 1450°K



Subsystems:

1. Reactor
2. Shield
3. Heat Transport
4. Reactor Inst. & Control
5. Power Conversion S/S
6. Heat Rejection
7. Power Conditioning
8. Structural/Mechanical

TEMPERATURES °K

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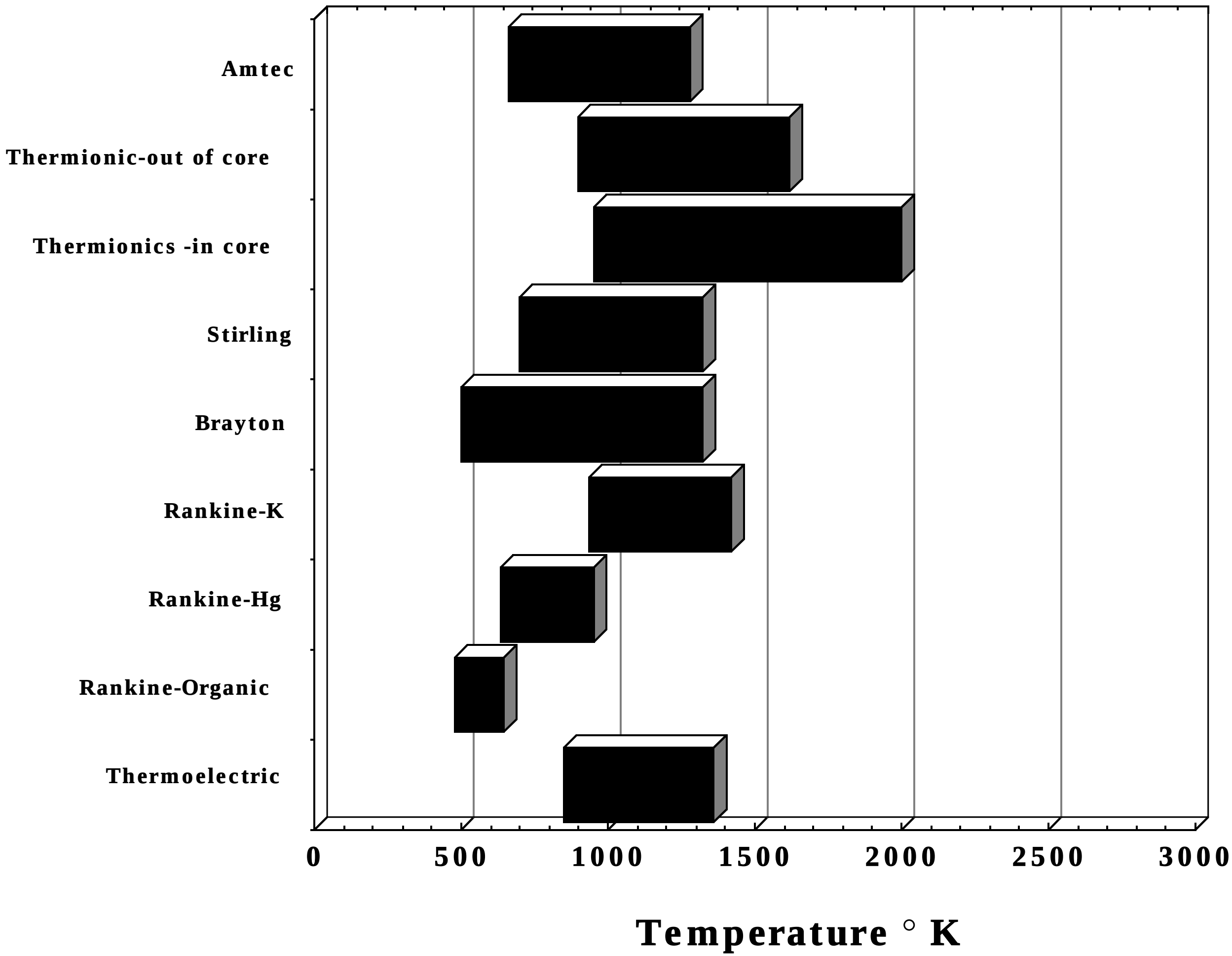
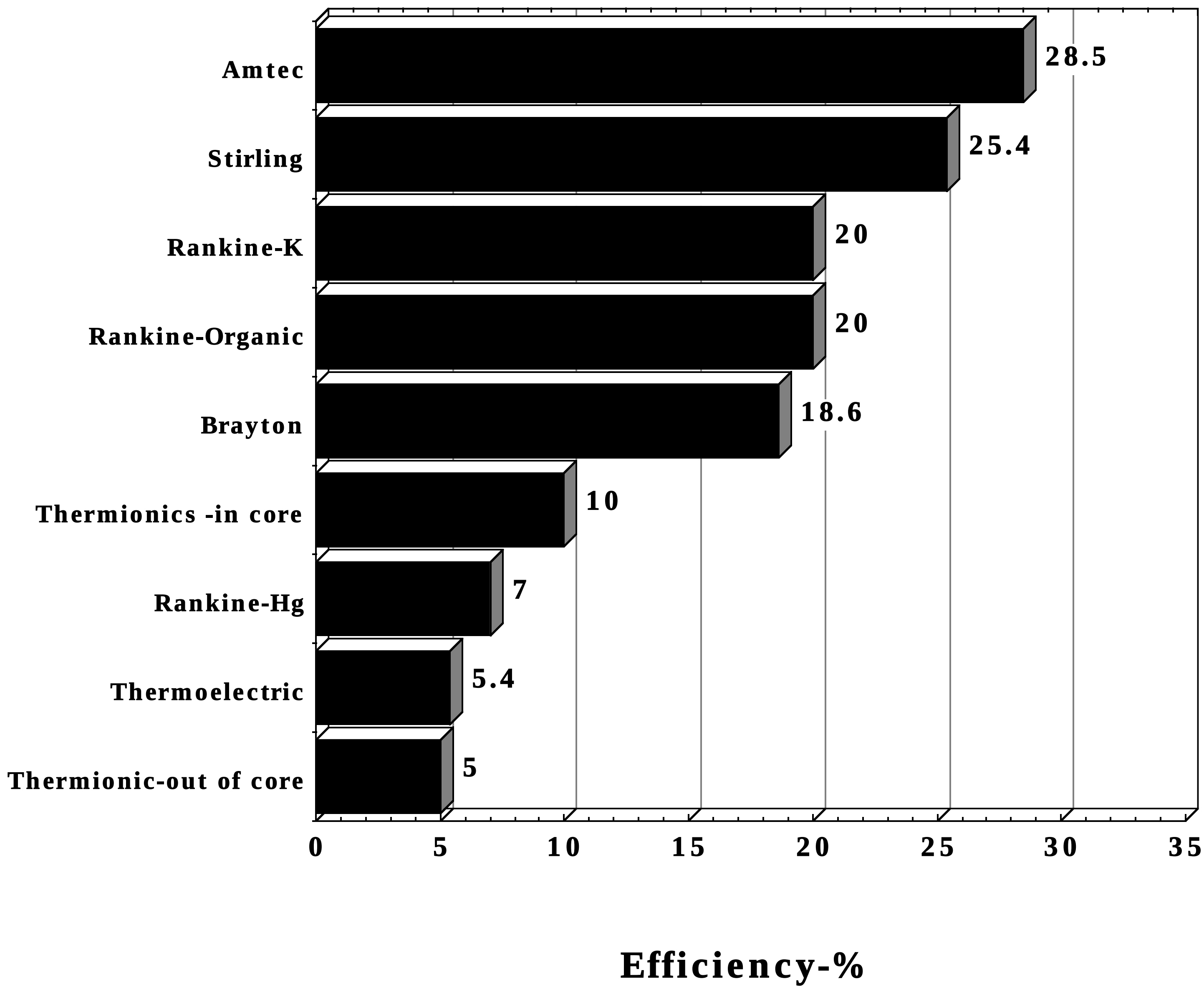
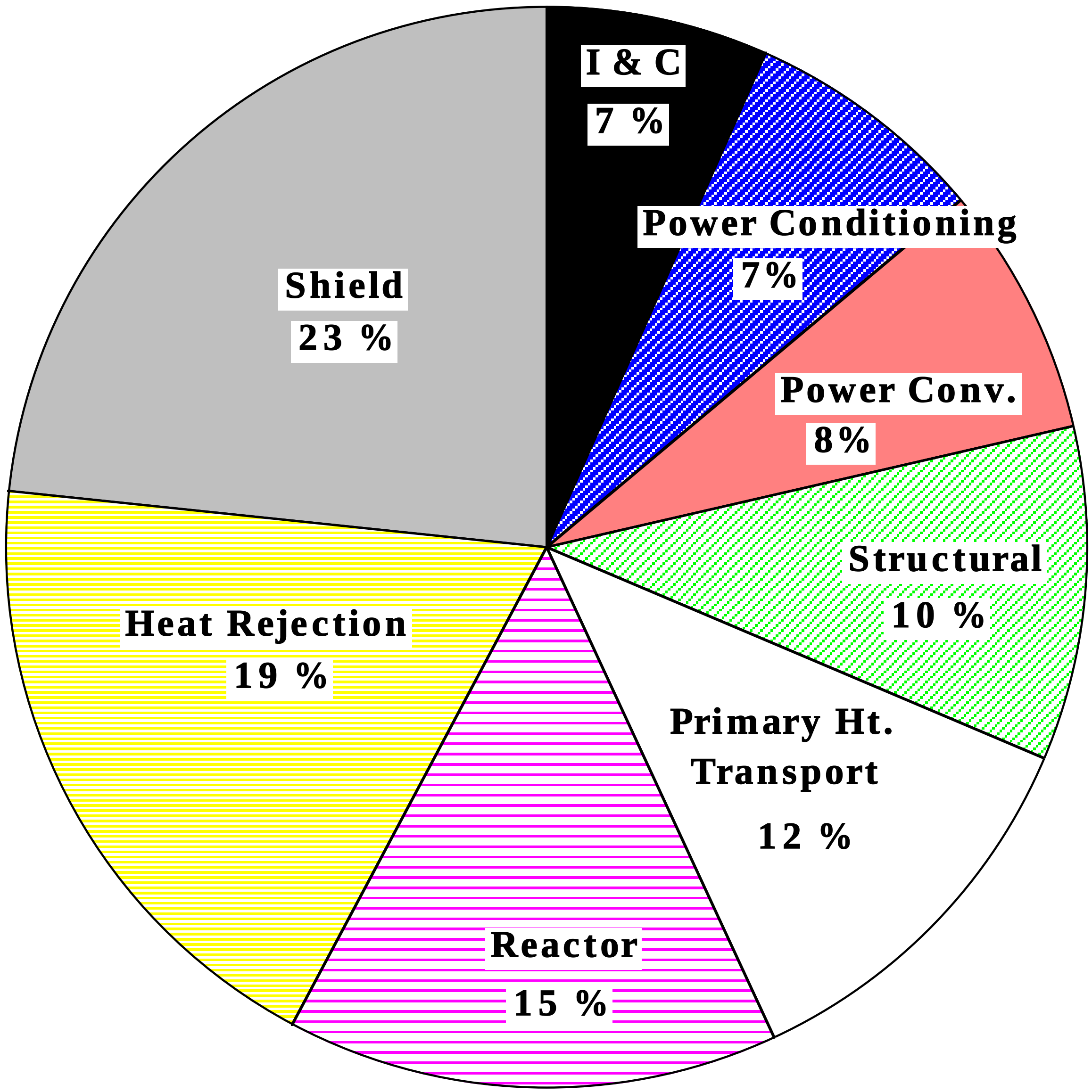
Operating Temperature Range for SP-100 Power Conversion Schemes



Conversion Efficiencies for SP-100 Systems



Mass Distribution of SP-100 Power Source (1988)



Total Mass = 5422 kg

Mass Summary/History

Subsystem	Mass by Subsystem (kg)			
	SDR Baseline May 1988	Design Update Sept. 1990	Current Status June 1992	1994
Reactor	803.	703.	647.	650
Shield	1255.	975.	892.	890
Primary Heat Transport	632.	480.	543.	540
Reactor I&C	359.	310.	377.	x380
Power Conversion	409.	449.	543.	x530
Heat Rejection	1149.	1106.	933.	960
Power Conditioning, Control & Distribution	417.	393.	402.	400
Mechanical/Structural	425.	221.	238	250
Total	5449.	4637.	4575.	4600

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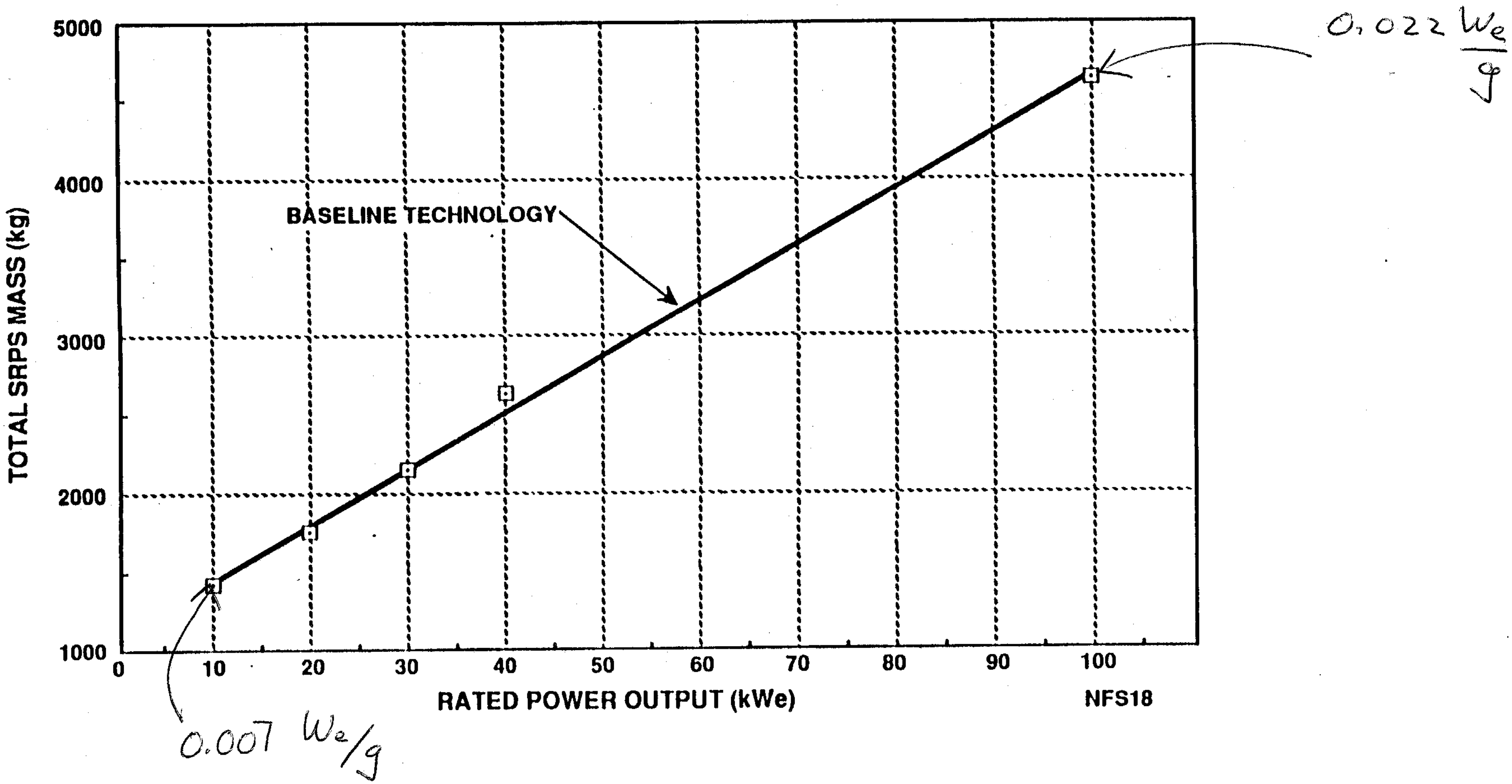
SP-100 FLIGHT SYSTEM MASS – 10 TO 100 kWe



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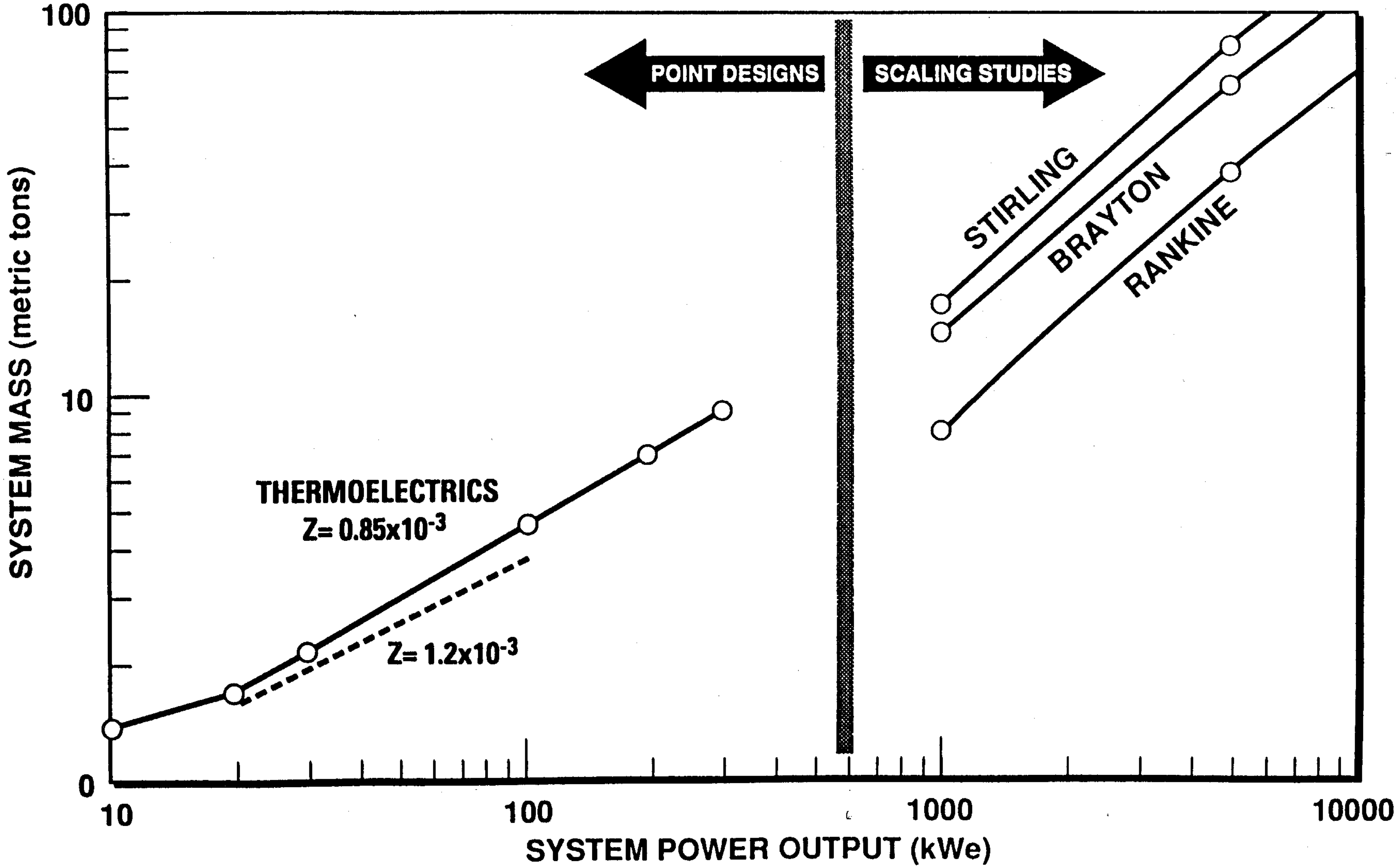
SP-100 Scalability / Flexibility

~0.1 We/g



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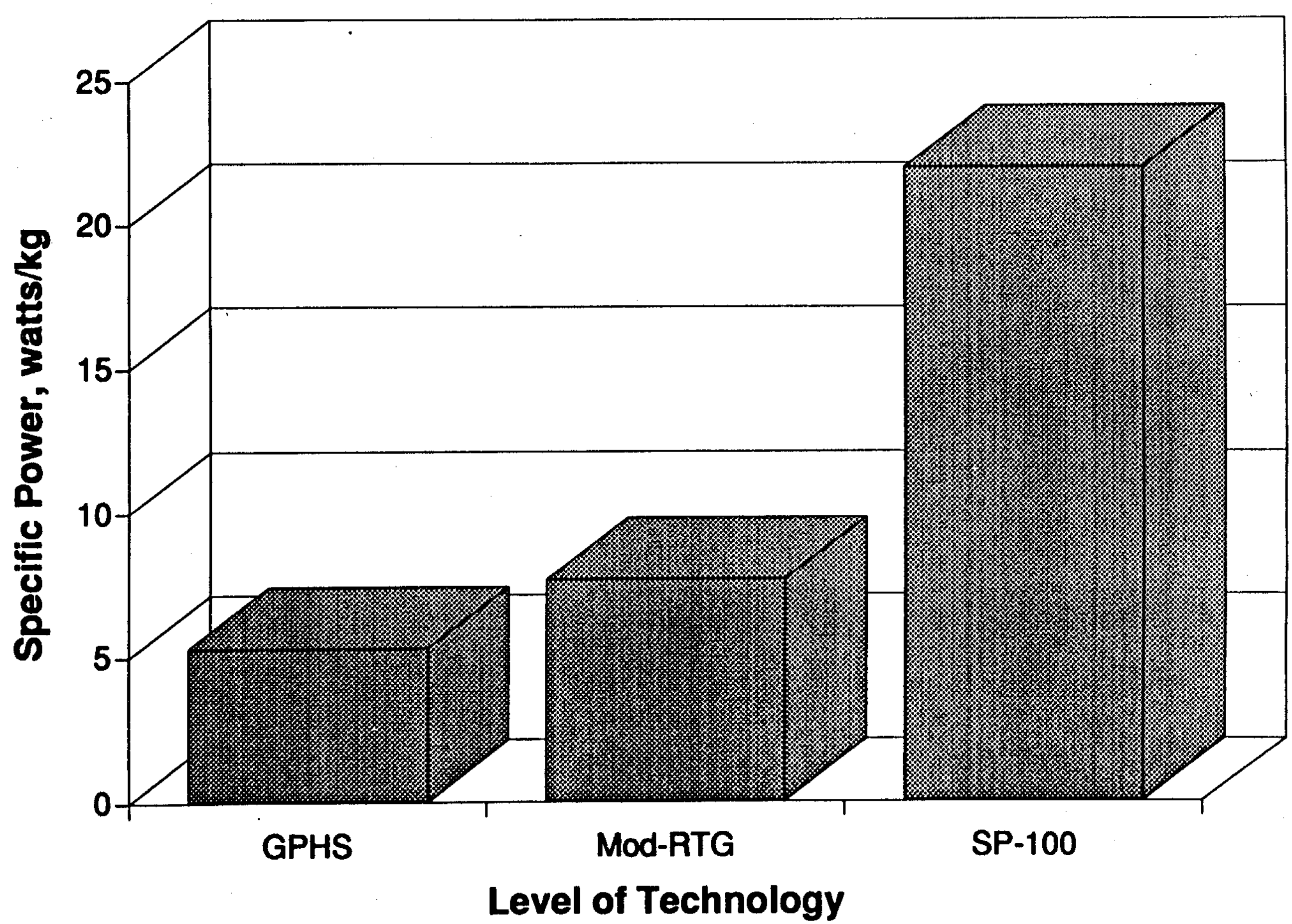
Comparison Of Specific Power In Space Nuclear Technologies



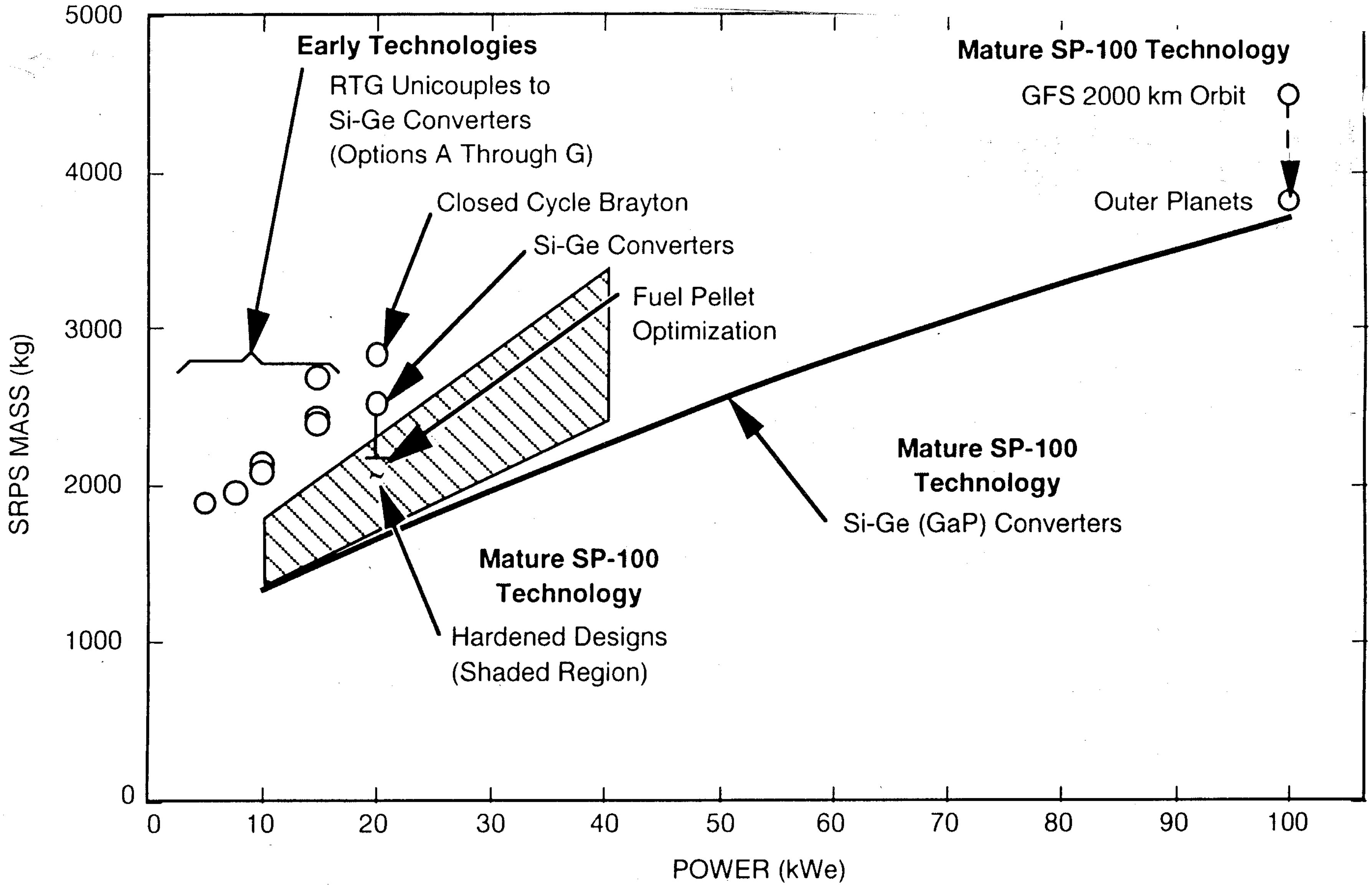


FIGURE 3. Effect of Technology Development on Mass Versus Power Relationship.

SP-100 TECHNOLOGY RAPID DEVELOPMENT APPROACH

1994 – NEAR-TERM TECHNOLOGY
10-40 kWe
5 YEAR LIFE/3 YEAR FULL POWER
200-80 Kg/kWe

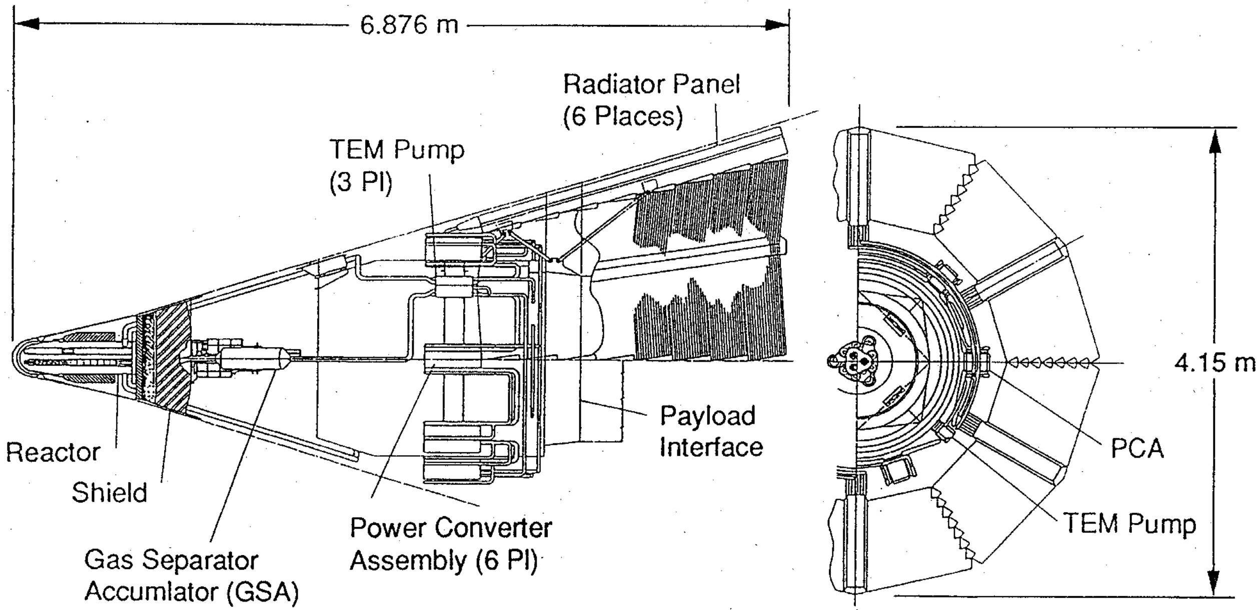
1996 – INTERMEDIATE TECHNOLOGY
10-60 kWe
7 YEAR LIFE/5 YEAR FULL POWER
180-55 Kg/kWe

1998 – MATURE TECHNOLOGY
10-300 kWe
10 YEAR LIFE/7 YEAR FULL POWER
160-30 Kg/kWe

SP-100 REACTOR THERMOELECTRIC TECHNOLOGY

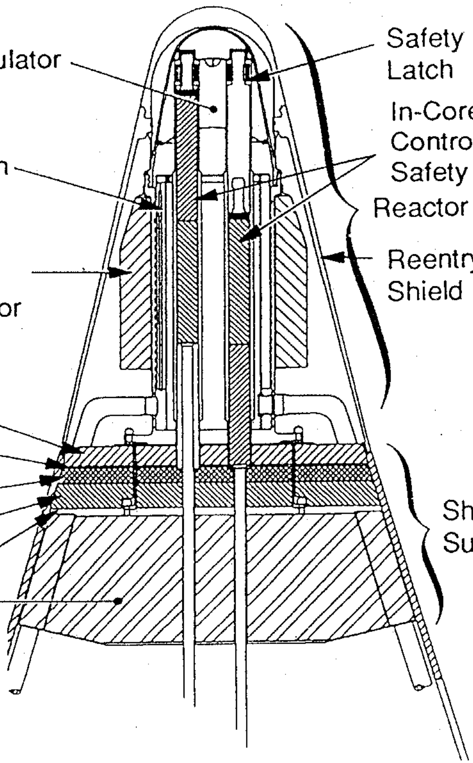
	NEAR-TERM	INTERMEDIATE	MATURE
SYSTEM			
Power	10-40 KWe	10-60 KWe	10-300 KWe
Lifetime	3/5 Years	5/7 Years	7/10Years
REACTOR			
Fuel	UN	UN	UN
Coolant	Lithium	Lithium	Lithium
Clad	Nb1Zr/Re	PWC-11/Re	PWC-11/Re
Structure	Nb1Zr	Nb1Zr	PWC-11
Outlet Temperature	1350 K	1375 K	1400 K
REACTOR I&C			
Mode	Dual	Dual	Seperate
Safety	In-Core	In-Reflector	In-Core
Control	In-Core	In-Reflector	Reflector
HEAT TRANSPORT			
Pump	TEM	TEM	TEM
Material	Nb1Zr/PWC-11	Nb1Zr/PWC-11	PWC-11
TE Material	SiGe-0.67X10-3/K	SiGe(GaP)-0.72X10-3/K	SiGe(GaP)-0.85X10-3/K
CONVERTER			
Type	Multicell	Multicell	Multicell
Power	8.8We/Cell	10.8We/Cell	12.8We/Cell
TE Material	SiGe-0.67X10-3/K	SiGe(GaP)-0.72X10-3/K	SiGe(GaP)-0.85X10-3/K
RADIATOR			
Heatpipe	K-Ti\2.5cm Dia.	K-Nb1Zr\2.5cm Dia.	K-Ti\1.3cm Dia.
Fins	Ti	C-C	C-C
Armor	Ti	C-C	C-C
Duct	Ti	Nb1Zr	Ti

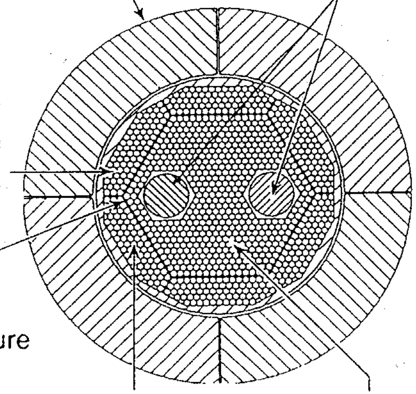
20-kWe SPACE REACTOR THERMOELECTRIC SYSTEM



Key System Parameters	
Net Power EOM 5 yr	20.6 kWe
System Mass	2350 kg
Reactor Outlet Temp.	1375 K
Total Radiator Area	30.8 m^2

20-kWe REACTOR AND SHIELD SUBSYSTEMS





Parameter	Value
Thermal power (kW)	596
Reactor mass, kg	420
Fuel column height (cm)	30.7
Reactor vessel O.D. (cm)	30.8
Radial reflector thickness (cm)	8.1
Reactor vessel length (cm)	108
Shield mass, kg	660

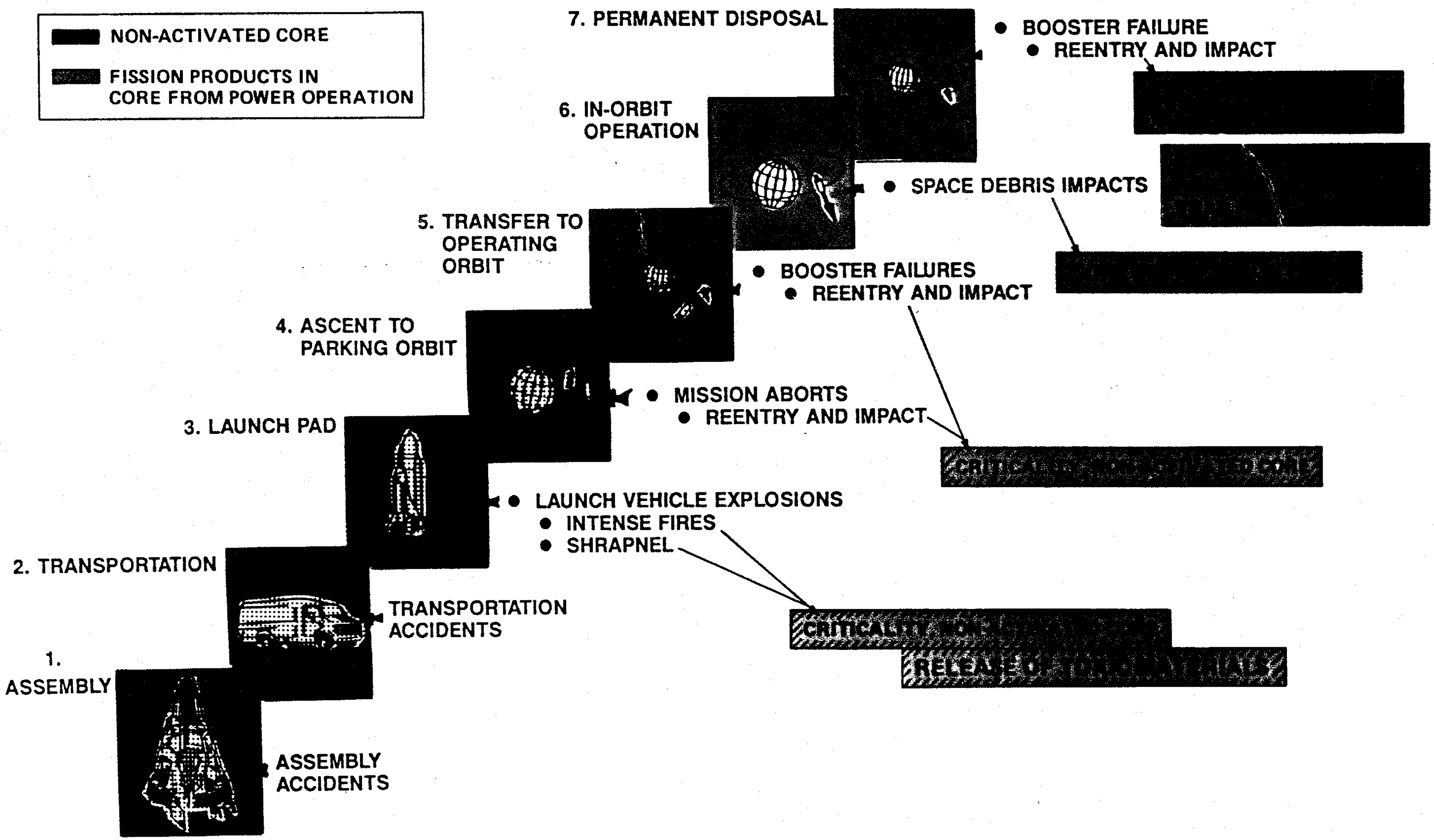
Basic SP-100 Safety Strategy

- Keep The Reactor Free Of Radioactive Fission Products Until A Safe Operating Orbit Is Achieved.
  - Launch With A Non-Activated Core
  - Design To Prevent Criticality Under Launch and Ascent Accidents Conditions
  - Provide Secure Command and Control Communications To Prevent Unauthorized Startup And Operation
  - Start Operation Only After Successful Attainment Of Orbit

- Select Operating Orbits So That Radioactive Can Decay To Negligible Levels Before Reentry Or Provide Highly Reliable Boost Capability.

- Design To Assure Intact Reentry and Burial, Even Though This Is An Unplanned Event

POTENTIAL MISSION ACCIDENTS AND HAZARDS



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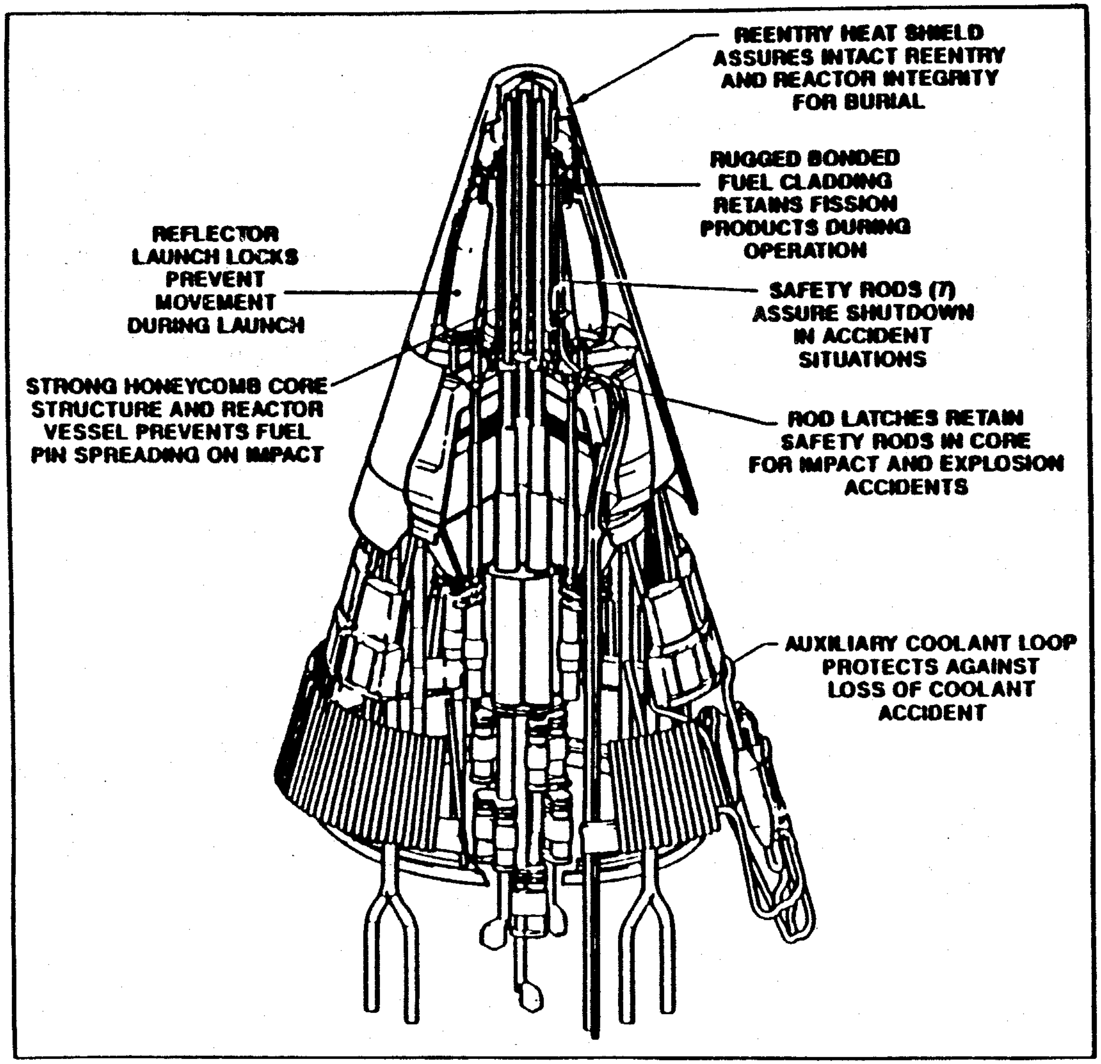
KEY SAFETY FEATURES



- CONTROL ELEMENTS AUTOMATICALLY SHUT REACTOR DOWN UPON LOSS OF POWER
- TWO INDEPENDENT SHUTDOWN SYSTEMS
- PROMPT NEGATIVE REACTIVITY COEFFICIENT ASSURES STABLE REACTOR CONTROL
- ONLY 4 OUT OF 12 REFLECTORS REQUIRED FOR SHUTDOWN
- NON-ACTIVATED CORE AT LAUNCH
- LARGE NEGATIVE VOID COEFFICIENT ENHANCES SHUTDOWN UPON LOSS OF COOLANT
- CONTROL ELEMENTS MOVED INDIVIDUALLY AND IN INCREMENTAL AMOUNTS TO PREVENT RAPID REACTIVITY ADDITION
- RHENIUM POISON PROVIDES THERMAL NEUTRON ABSORPTION FOR WATER FLOODING

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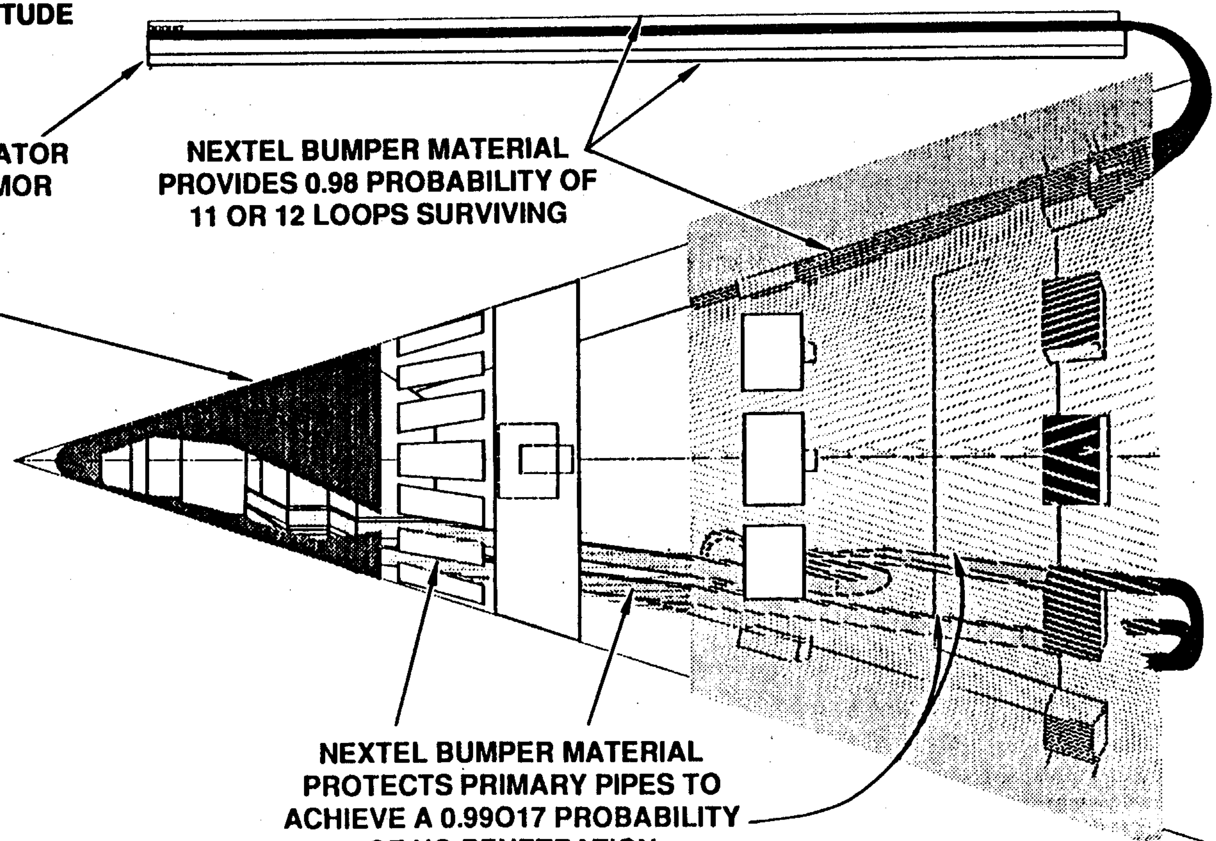
SPACE ENVIRONMENT REQUIREMENTS AND ALLOCATIONS

NASA DOE DOD SP 100

TECHNICAL SPECIFICATION

• ASSUMED DEBRIS	SPHERICAL Al IMPACTS AT 10 km/sec
• ASSUMED METEOROIDS	0.5 gm/cm^3 IMPACTS AT 20 km/sec
• MASS FLUENCE DEBRIS AND METEOROIDS	1100 km
• PROBABILITY OF ZERO PENETRATIONS OF CRITICAL COMPONENTS BASED ON NASA-SP-8042	0.99 FOR 10 years
• ATOMIC OXYGEN AND EARTH ORBIT PLASMA	500 km ALTITUDE 28° INCL



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