PFR

1974 - 1994

Operational Feedback

A M Judd

March 2021

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1974 - 1994

Operational Feedback

Why bother?

PFR Operational Feedback

Operational **data** from past reactors

are necessary to **validate**

the **safety** of future reactors.

Examples –

Power coefficient of reactivity

Natural convection cooling

The Prototype Fast Reactor

1961-1966 Design

- Preliminary Specification 1964
- Sanction to construct 1966
- Identification of NIV swelling 1966

1967-1974 Construction

- Reactor roof weld cracks 1969-1971

1974-1994 Operation

- Critical 1974
- Full Power 1977
- Evaporator leaks 1974-1981
- Primary oil leak 1992
- Closure 1994

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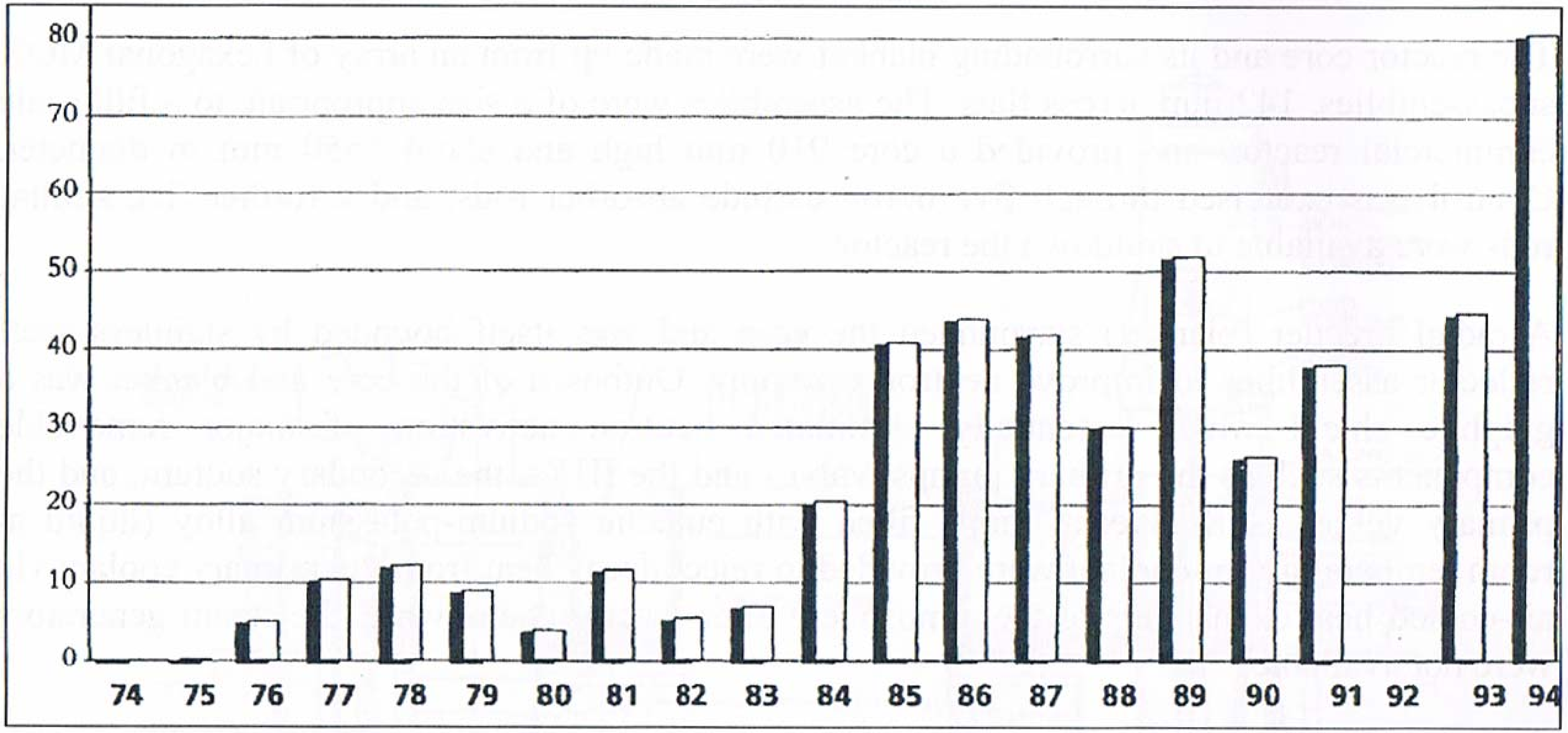
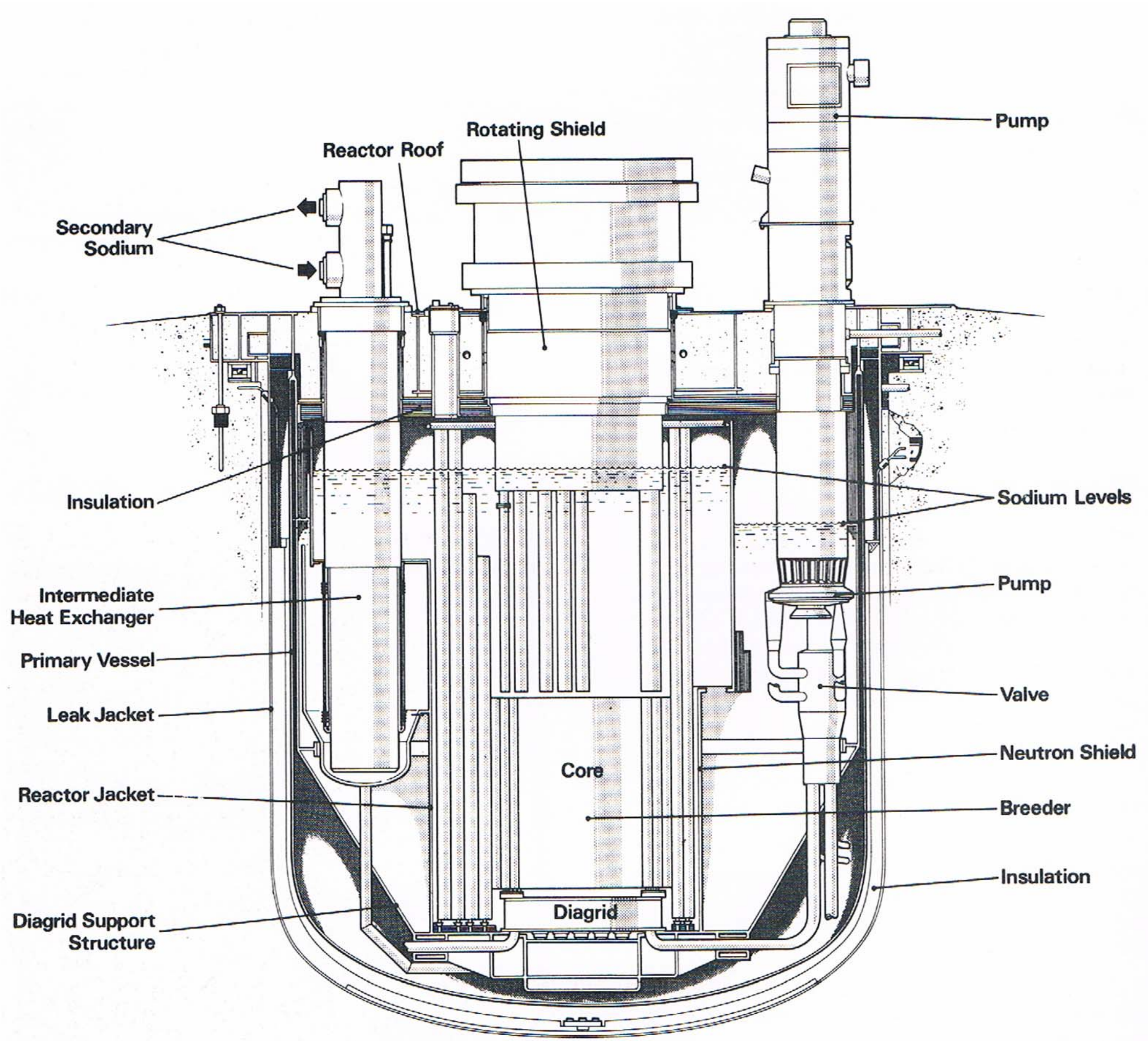


FIG. 2. PFR annual load factors 1974-1994
(1994 for three months' operation only-before decommissioning), %.



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250 MW(e)
600MW(th)

MOx fuel

PFR Operational Experiments

Coolant Inlet temperature coefficient of reactivity

Coolant Flow coefficient of reactivity

Power coefficient of reactivity

Natural convection cooling at low power

(Primary coolant pumps stopped)

Power Coefficient of Reactivity

Dependence of reactivity on power and coolant flow

$$\partial\rho/\partial P = a(P) + bP/F$$

a depends on temperature of fuel (Doppler and axial expansion)

b depends on expansion of core structure

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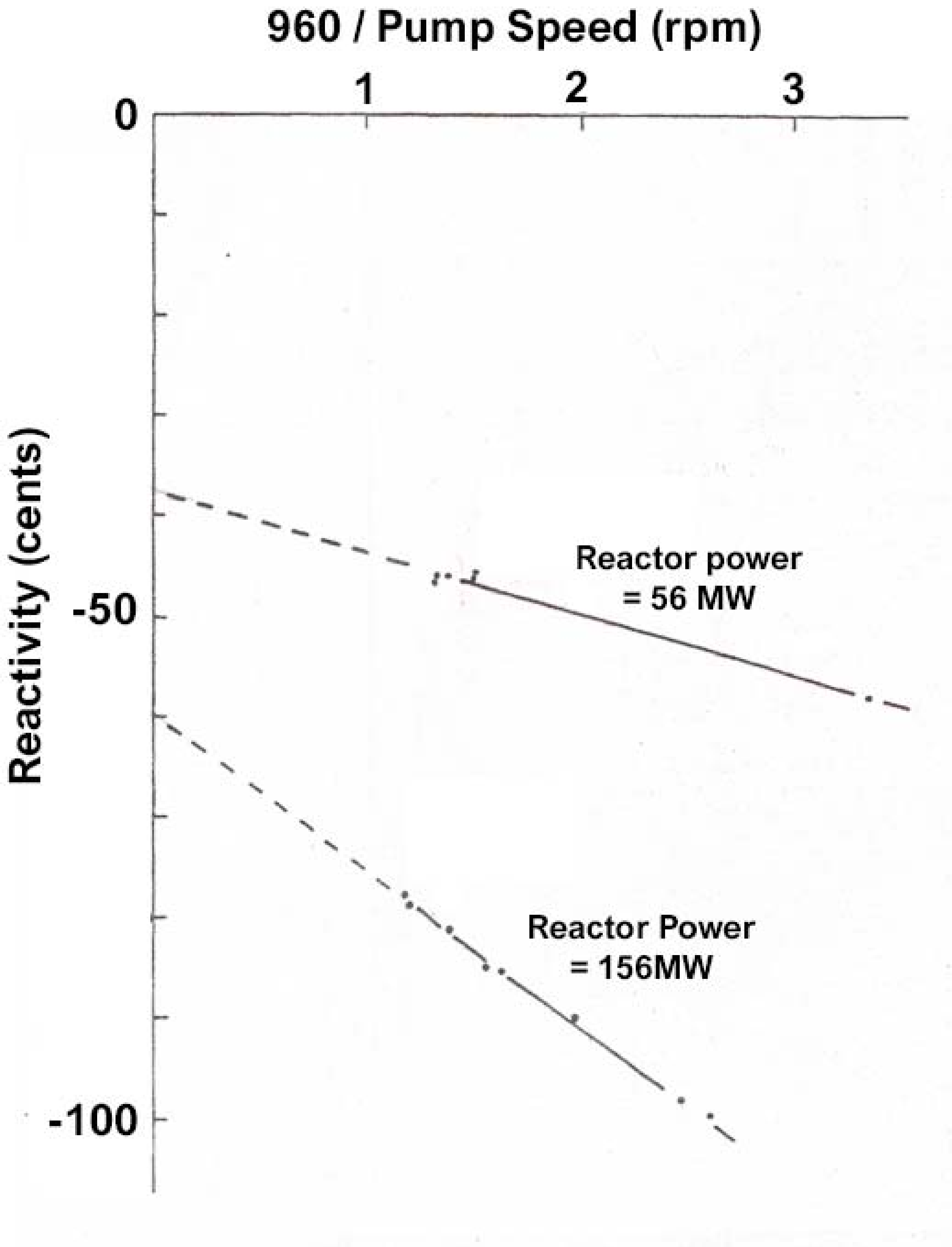
Power Coefficient
of Reactivity

Measurements of the flow-dependent term *bP/F*



Power Coefficient of Reactivity

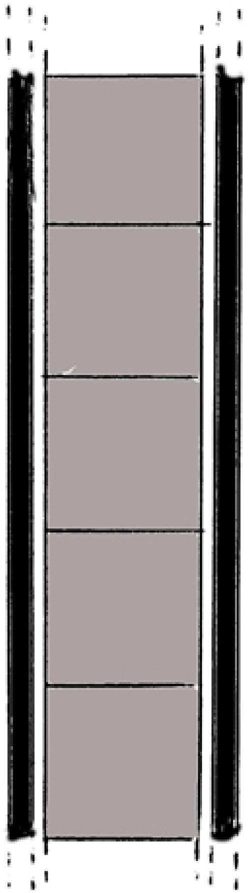
$$\rho_{Doppler} \approx - \ln(T_{abs})$$

The Doppler reactivity change varies roughly as

1/(absolute temperature)

Power Coefficient of Reactivity

Fuel axial expansion decreases with age

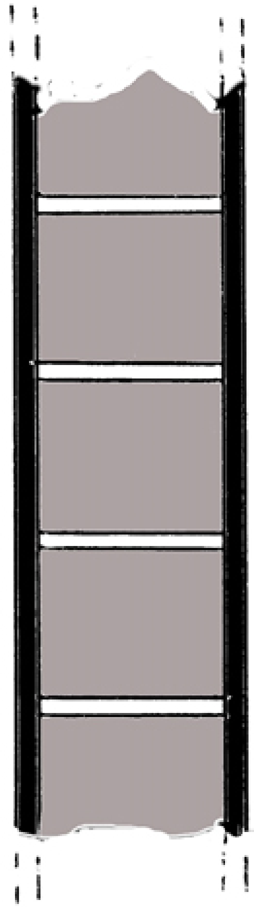


New fuel free from clad

Expands as fuel temp.

Old fuel adheres to clad

Expands as clad temp.



PFR Power Coefficient of Reactivity

Selected measurements of the flow-independent term *a(P)*

Date	**Power range** MW(th)	**Flow** %	**Power Coeff** cents/MW	**a(P)** cents/MW
Oct-75	16-50	30	-1.01 +/- 0.14	-0.48 +/- 0.14
	100-200	150	-0.76 +/- 0.04	-0.44 +/- 0.04
Aug-76	25-250	77	-0.58 +/- 0.02	-0.37+/- 0.02
	10-455	90	-0.51 +/- 0.02	-0.33 +/- 0.02
Dec-78	195-170	88	-0.47 +/- 0.02	-0.36+/- 0.02
	195-175	47	-0.54 +/- 0.02	-0.30 +/- 0.02
	240-280	90	-0.38 +/- 0.02	-0.26 +/- 0.02
	355-386	90	-0.44 +/- 0.02	-0.20 +/- 0.02
Mar-85	590-620	100	-0.20 +/- 0.05	-0.07 +/- 0.05
	470-620	100	-0.23 +/- 0.03	-0.10 +/- 0.03
	310-470	100	-0.24 +/- 0.03	-0.11 +/- 0.03

PFR Power Coefficient of Reactivity

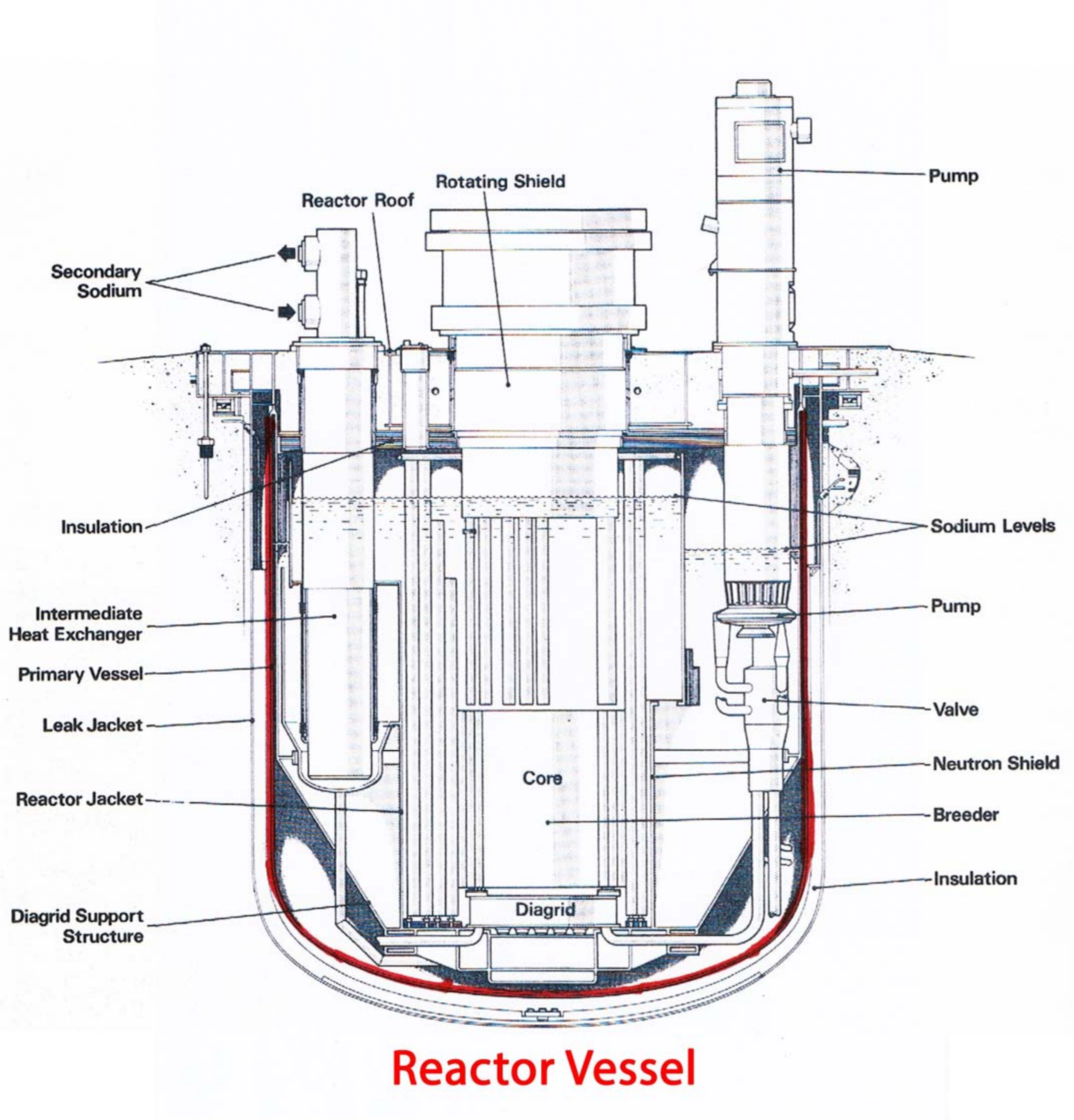
$$\partial\rho/\partial P = a(P) + b/F$$

Experimental data

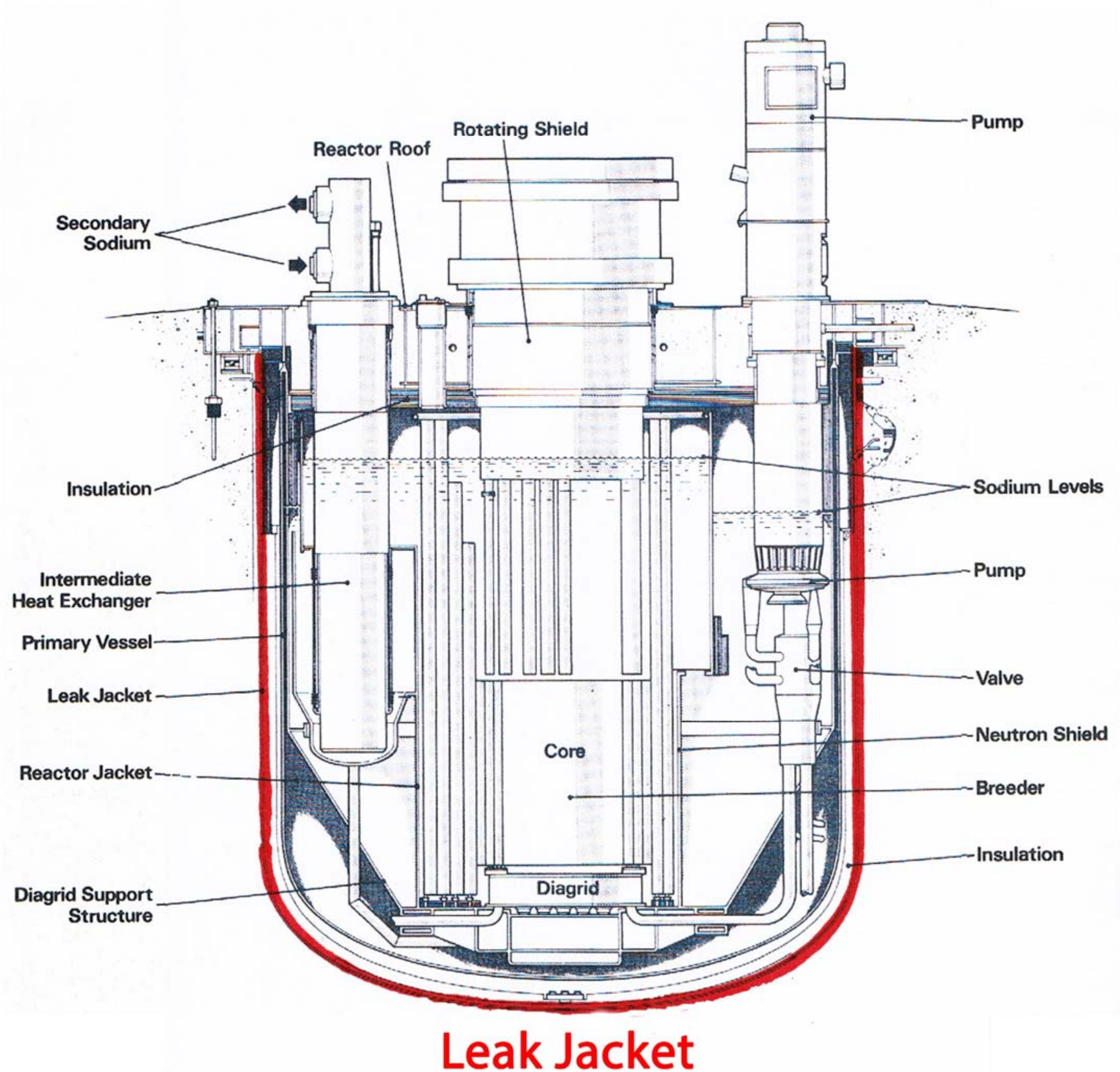
a decreases with increasing power
(due to Doppler)

a decreases with burnup of fuel
(due to adhesion of fuel to clad)

PFR Vessel


Rotating Shield
Reactor Roof
Pump
Secondary Sodium
Insulation
Sodium Levels
Pump
Intermediate Heat Exchanger
Primary Vessel
Valve
Leak Jacket
Neutron Shield
Core
Reactor Jacket
Breeder
Insulation
Diagrid
Diagrid Support Structure
Reactor Vessel

PFR Vessel



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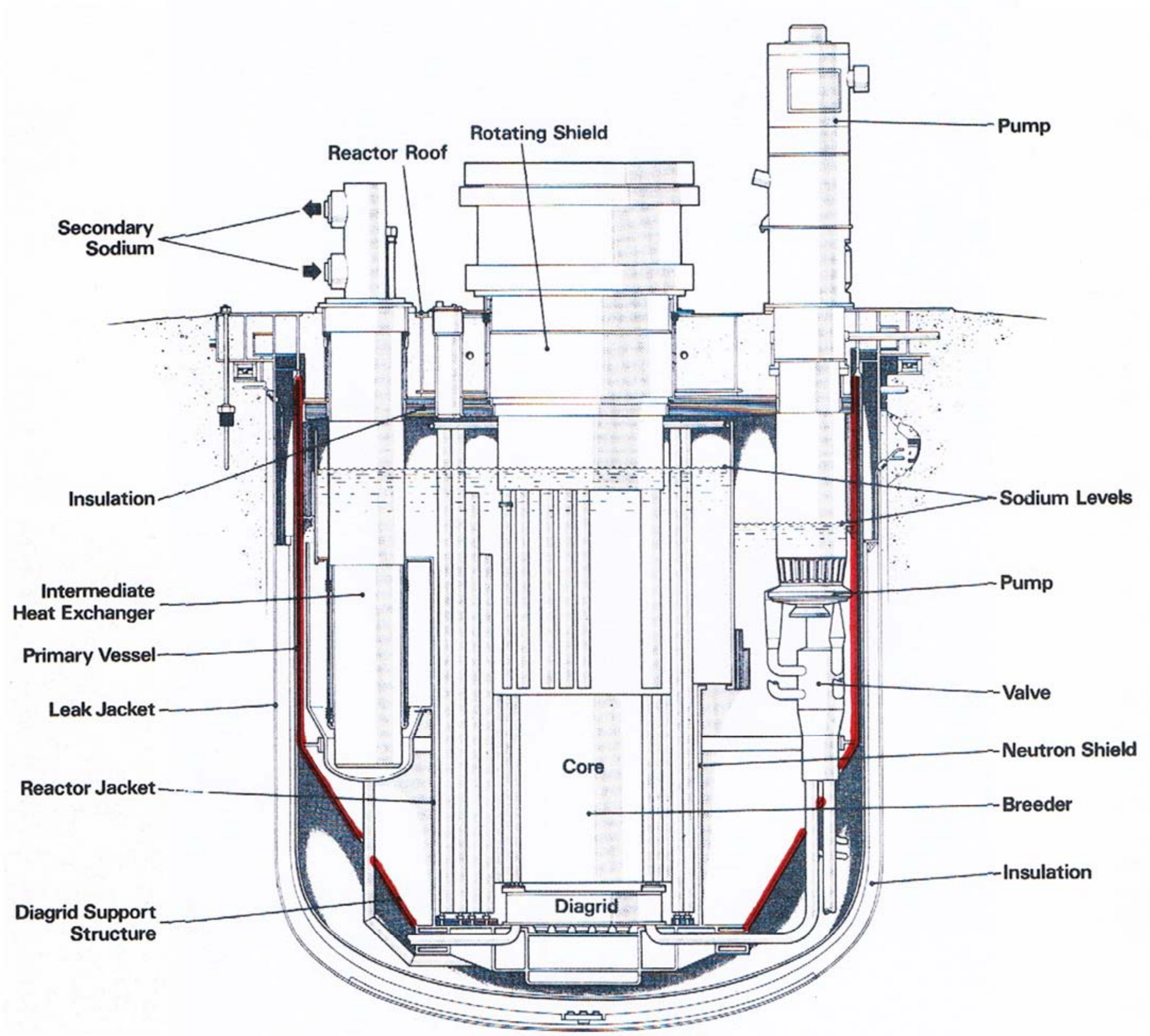
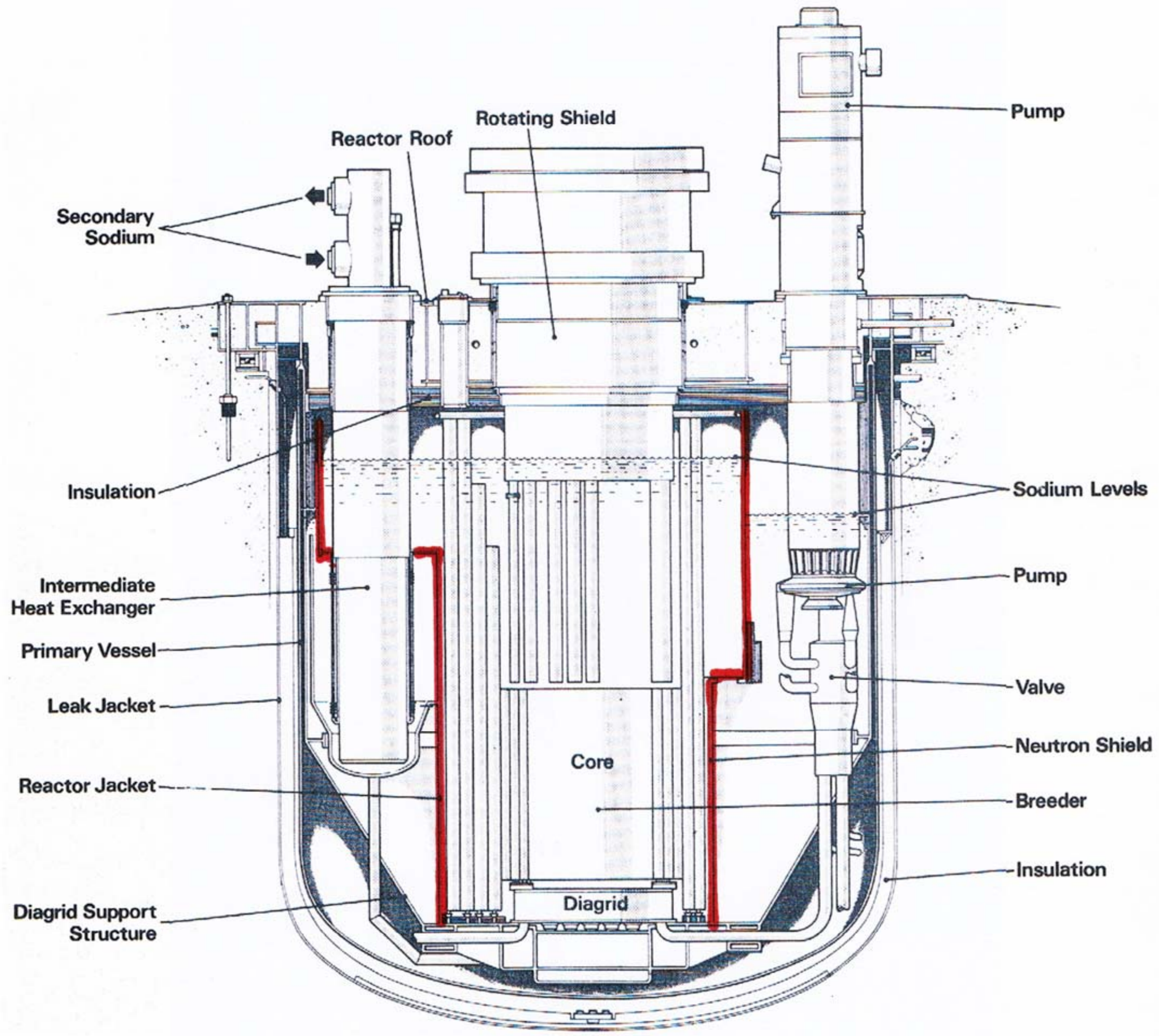
PFR Vessel



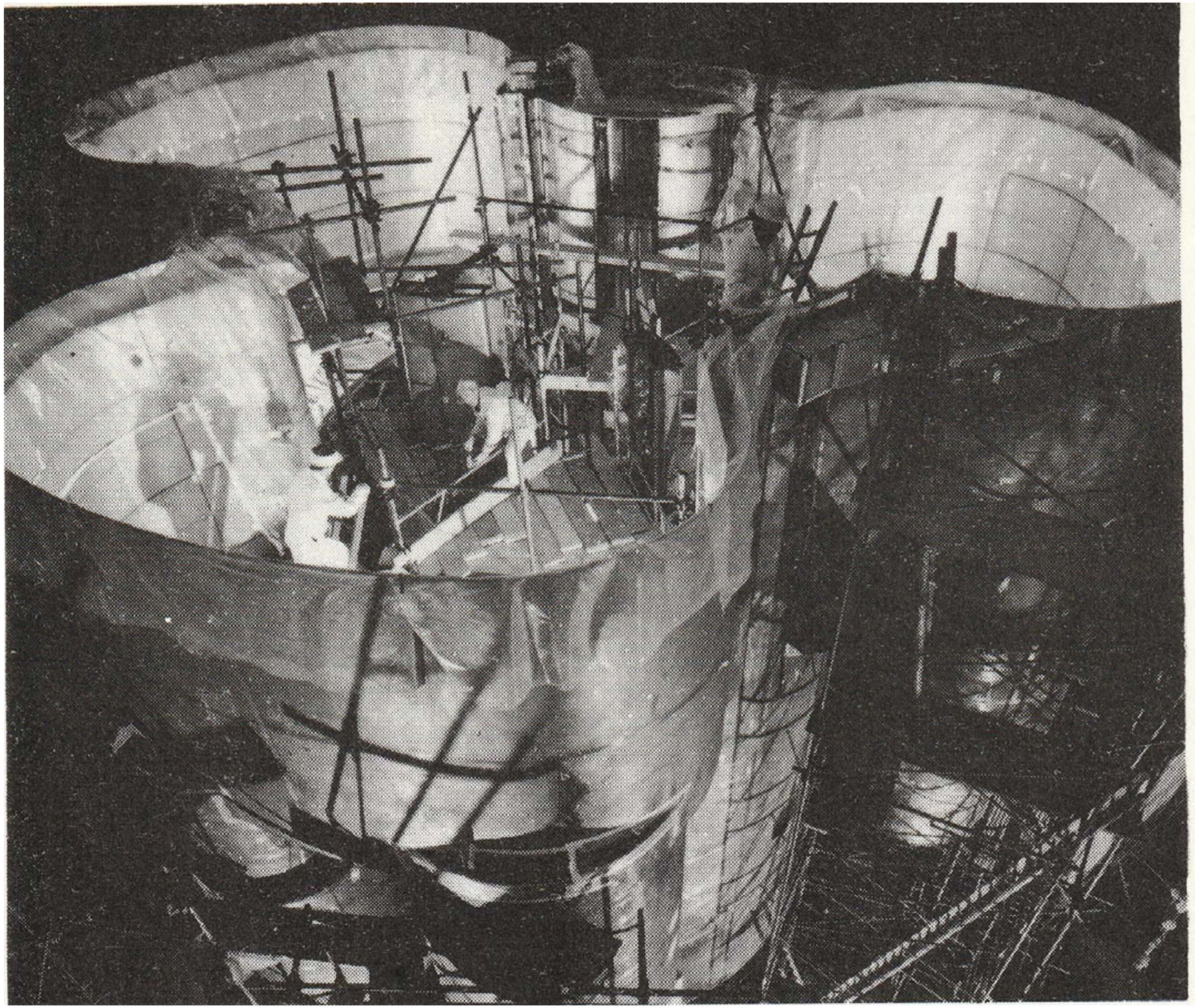
Diagrid Support

PFR Vessel



Reactor Jacket

PFR Reactor Jacket during construction



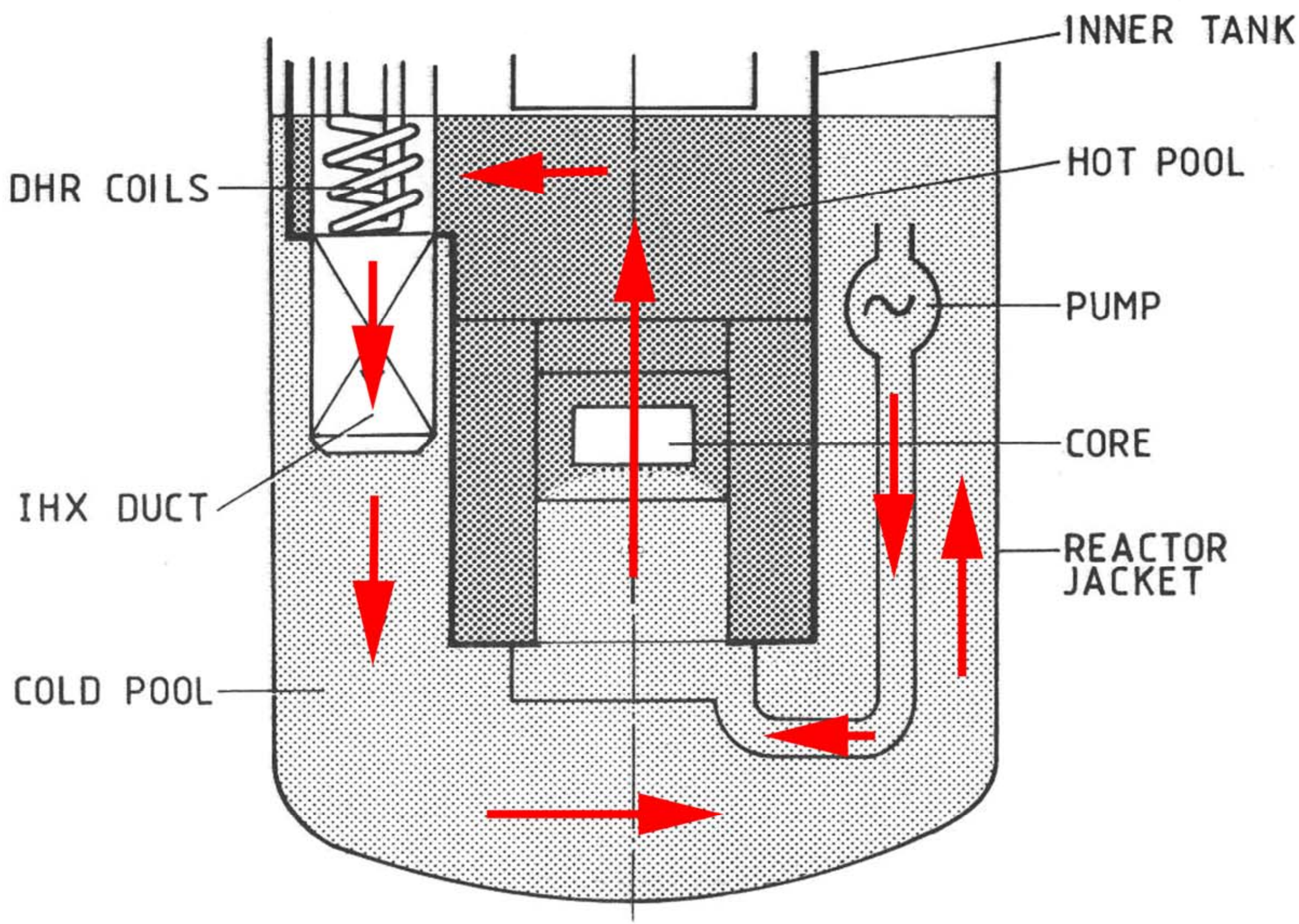
PFR Natural Convection Tests

Coolant pumps de-energised (free to rotate)

Reactor critical at low power (~ 10 MW)

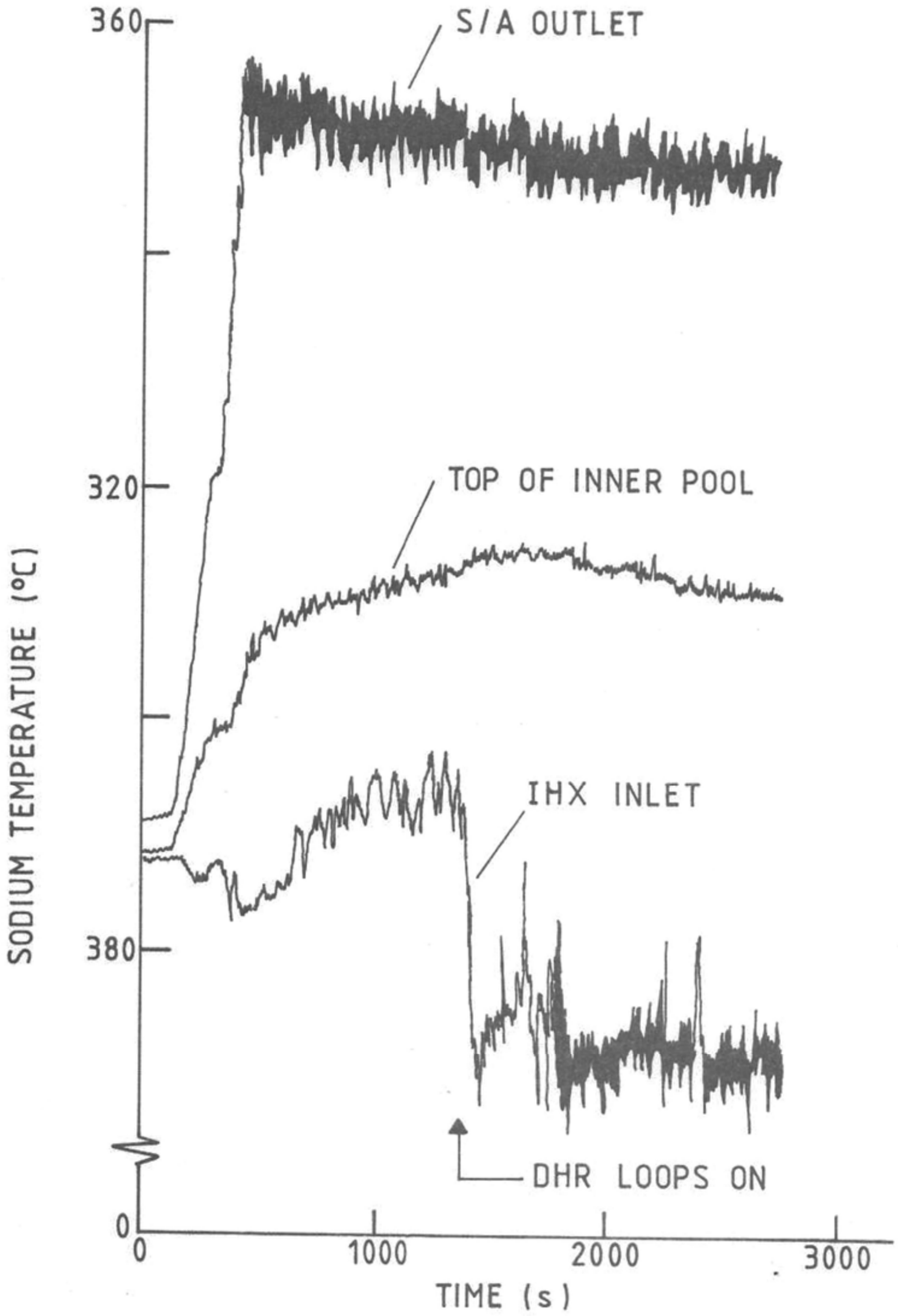
Decay Heat Rejection loops inactive, then active

PFR Natural Convection Tests
Expected Flow Pattern



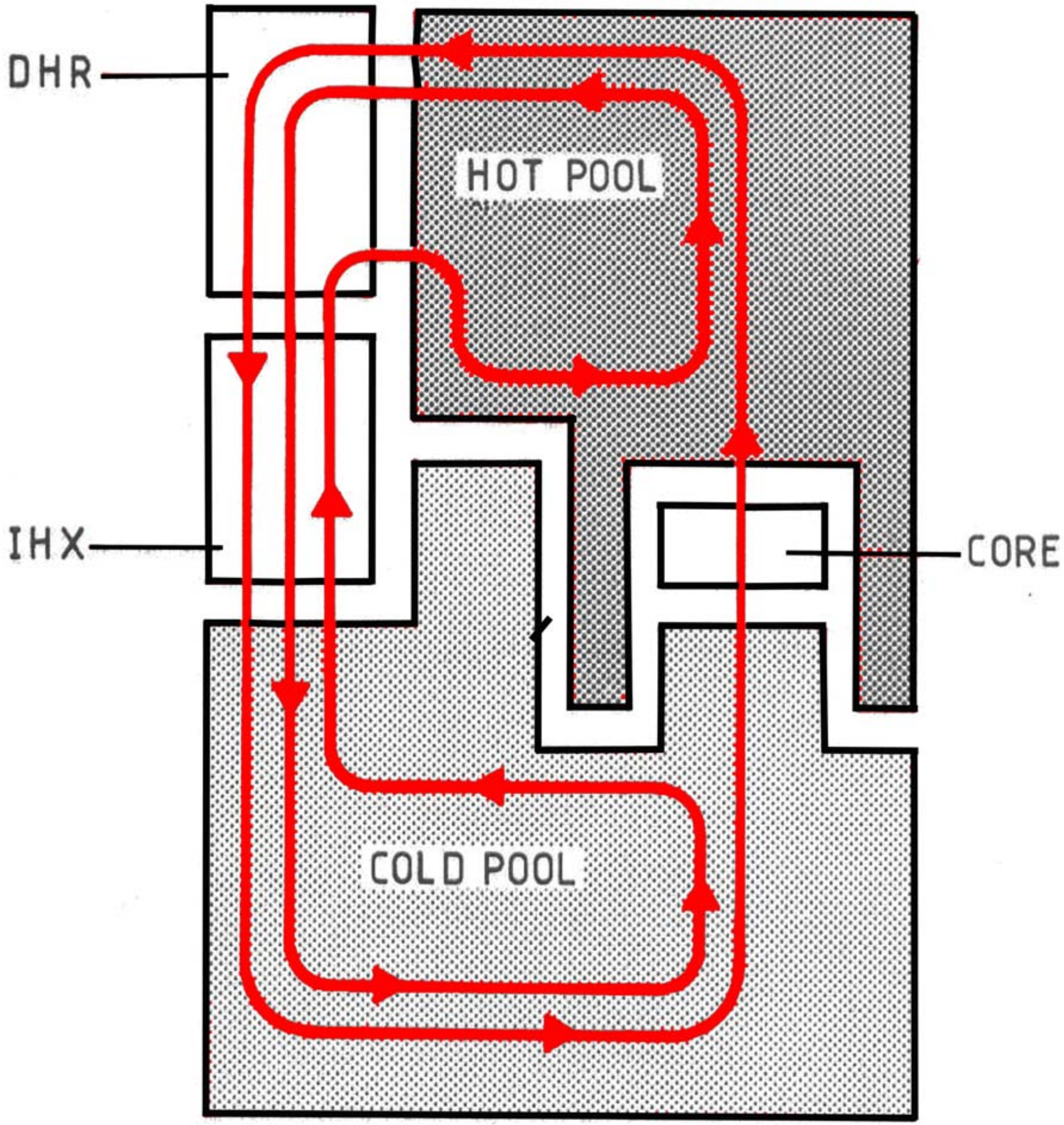
PFR Natural Convection Tests

Observed Temperatures



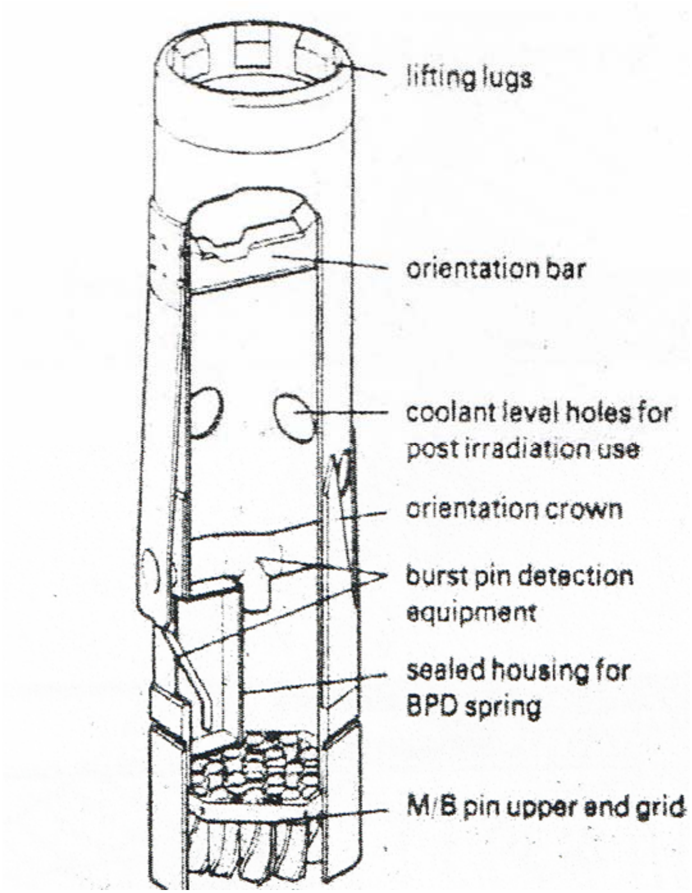
PFR Natural Convection Tests

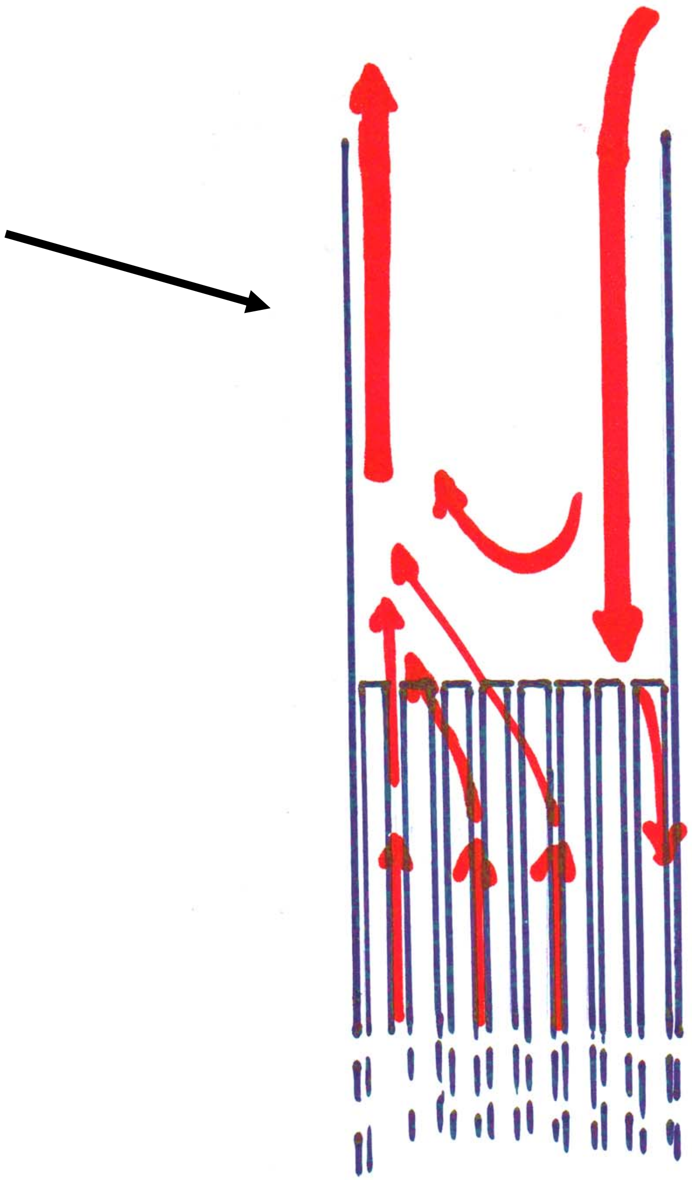
Deduced Main Flow Pattern



PFR Natural Convection Tests

Subassembly Outlet Conjectured Flow Pattern





Conclusion

Operational Feedback is valuable.

Safety parameters such as reactivity coefficients and natural convection flow patterns are affected by complex conditions in an operating reactor.

Therefore design predictions need validation by data from plant operation.