Scoping Calculations of Power Sources for NEP*

Felix C. Difilippo
Oak Ridge National Laboratory
Engineering Physics and Mathematics Division
P.O. Box 2008, Bldg. 6025, MS-6363
Oak Ridge, Tennessee 37831-6363 USA

Viewgraphs to be presented at the *Nuclear Propulsion Technical Interchange Meeting*, October 20-23, 1992, NASA Lewis Research Center.

* Managed by Martin Marietta Energy Systems, Inc., under contract DE-AC05-84OR21400, U.S. Department of Energy.

Definition of the Problem (From NASA-LERC)

Power Levels (P): 10-50 Mw
Core Life (D): 2-10y

Which Implies:

Energy Released: 7305-182,625 Mwd; or
the burnup of ~: 9.1-228 Kg of ^{235}U

Types of Reactors to be Analyzed:

1. **High Temperature Gas-Cooled Reactors of the NERVA derivative type.**

2. **Lithium-Cooled Advanced Fuel Pin. One-phase flow.**

3. **Lithium-Cooled Cermet. One-phase flow.**

For an input *P* and *D*, it is required to calculate:

(a) Composition and Masses of the core.

(b) Mass of the Reflector.

(c) Mass of the Shielding.

(d) Temperature and Pressure Distributions.

Elements to Build the Reactors

1. Gas Cooled, NERVA Type

<u>Core</u>

(a) Fuel Element, hexagonal 1.913 cm flat to flat, dispersion of UC-ZrC in a graphite matrix, 19 coolant holes (d = 2.8mm), ZrC clad.

(b) Support Element: ZrH_2 on inconel tube, central and lateral coolant around the ZrH_2, pyrolitic graphite and graphite as thermal shield.

<u>Coolant</u>: He (for direct Brayton cycle)

<u>Reflector</u>: Be, radial

<u>Control</u>: B_4C sheet on drums that rotate in reflector

Safety Rods in Core

Pressure Vessel: Outside the reflector

Elements to Build the Reactors (continued)

2. Advanced Fuel Pin

Core: Rods, 6.35mm diameter (may vary); UN pellets; clad, tantalum alloy (Astar-811C or T-111) 0.635mm thick; tungsten liner 0.122mm thick; He gas gap 0.025mm thick.

Coolant: Liquid Lithium

Reflector: OBe

Control: B_4C sheets on drums in reflector.

Pressure Vessel: Between Core and Reflector

Elements to Build the Reactors (continued)

3. Cermet (ceramic-metal)

Core: Hexagonal Fuel Element; UO_2 (or UN) in a matrix of W (with some Re); clad, W-Re-Mo alloy.

Coolant: Liquid Lithium

Reflector: Be

Control: B_4C sheets on drums in Reflector.

Pressure Vessel: Between Core and Reflector.

Shielding

(Common to the three designs)

LiH or B_4C for neutrons, W-Mo alloy for gammas.

Geometry: shadow shield.

Estimation based on

(a) source term,

(b) first collision shielding,

(c) removal cross section, and

(d) buildup factors.

Results for the Gas-Cooled Reactor

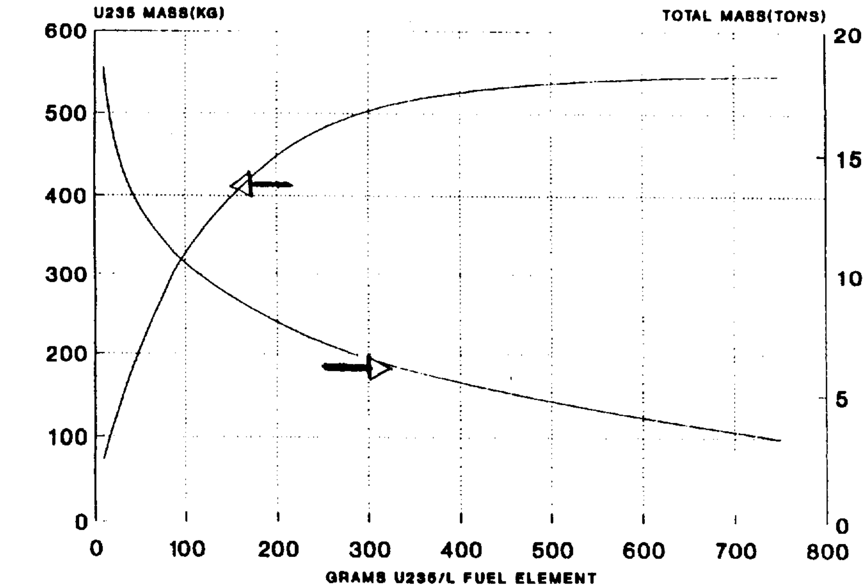
Variables to choose in order to meet demand:

(1) ^{235}U density in fuel element

(2) Ratio S/F of the number of support over fuel elements

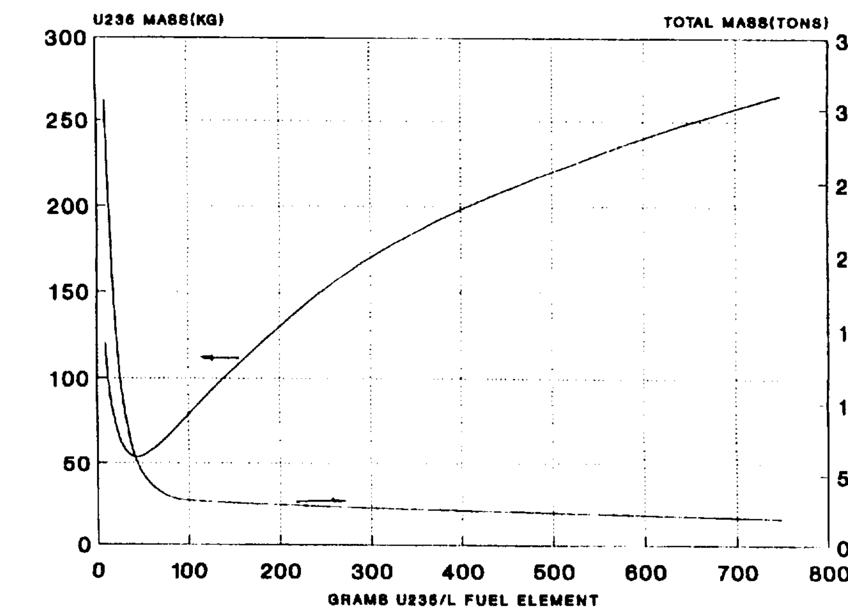
Given conditions at channel inlet (flow, p and T) compute pressure, temperatures and velocities considering single phase 1D steady flow. Use usual correlations from ANS handbook about gas-cooled reactors.

U235 CRITICAL MASS AND TOTAL MASS
NO SUPPORT ELEMENTS

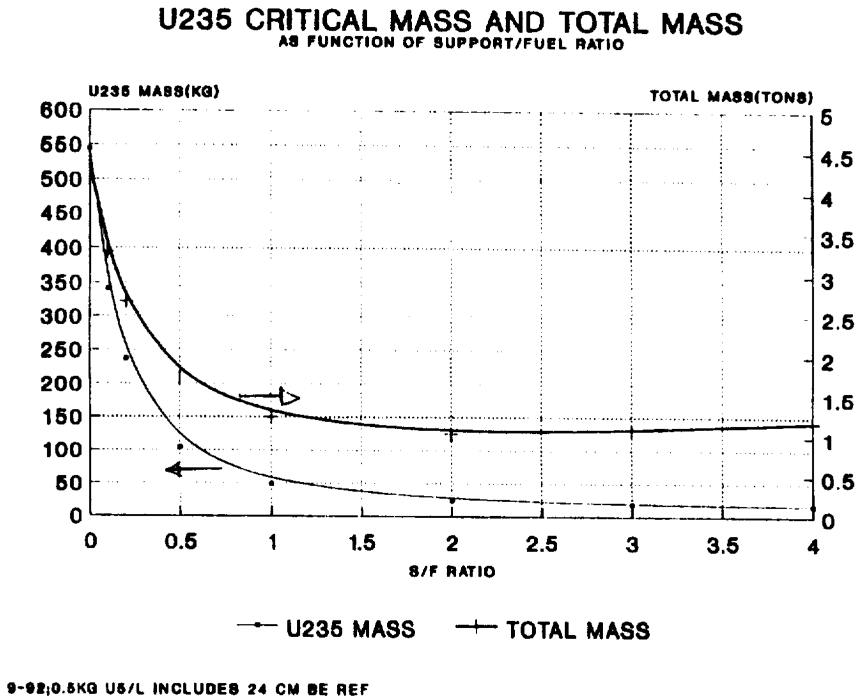


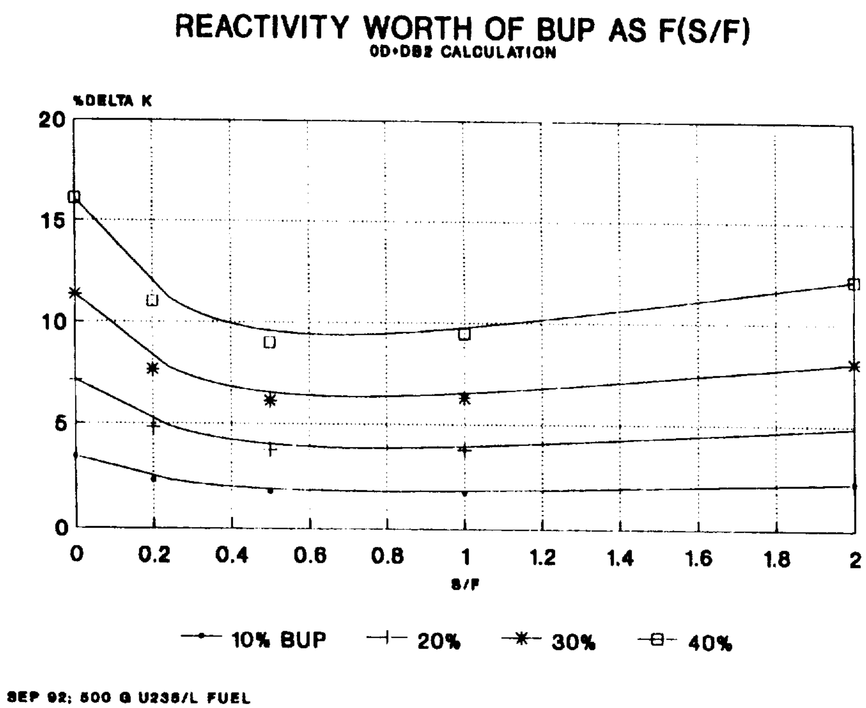
SEP 92; TOTAL MASS INCLUDES 24 CM BE REF

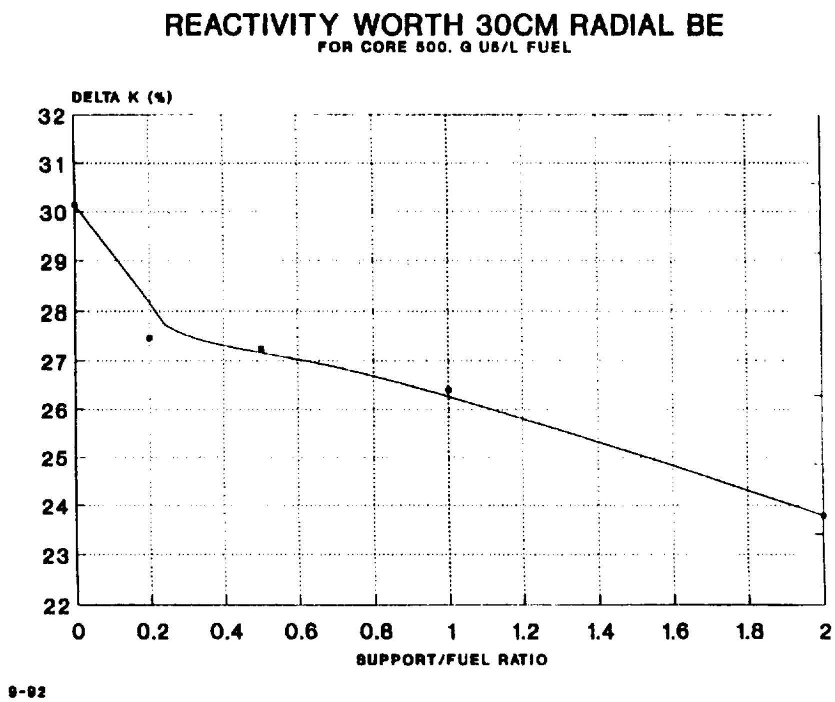
U235 CRITICAL MASS AND TOTAL MASS



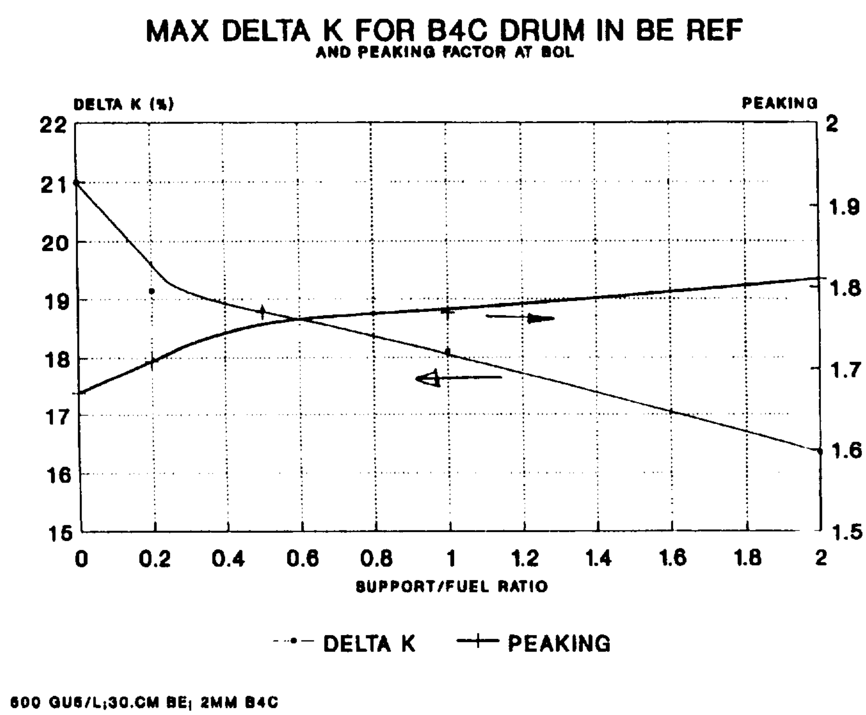
SEP 92; TOTAL MASS INCLUDES 24 CM BE REF S/F = 0.145


U235 CRITICAL MASS AND TOTAL MASS
AS FUNCTION OF SUPPORT/FUEL RATIO
U235 MASS(KG)
TOTAL MASS(TONS)
S/F RATIO
U235 MASS
TOTAL MASS
9-92;0.5KG U5/L INCLUDES 24 CM BE REF


REACTIVITY WORTH OF BUP AS F(S/F)
0D+DB2 CALCULATION
%DELTA K
S/F
10% BUP
20%
30%
40%
SEP 92; 500 G U235/L FUEL

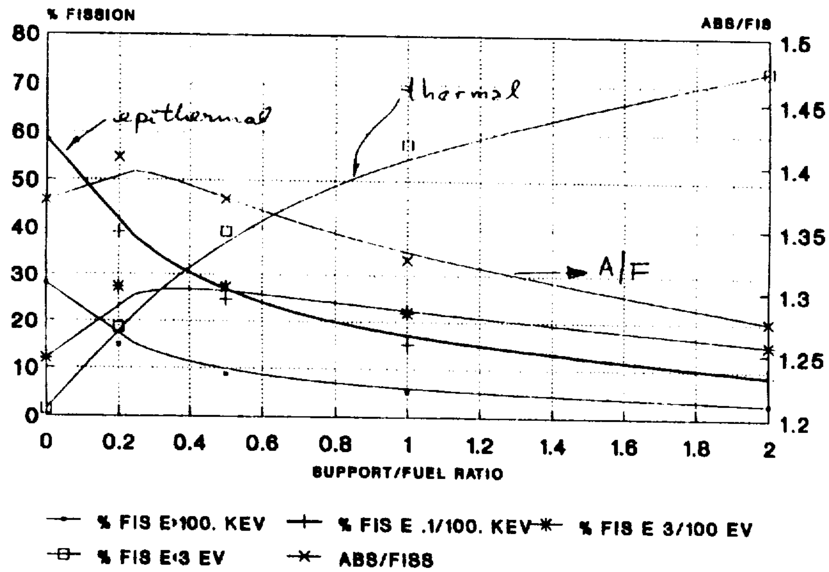


REACTIVITY WORTH 30CM RADIAL BE
FOR CORE 500. G U5/L FUEL
DELTA K (%)
32
31
30
29
28
27
26
25
24
23
22
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
SUPPORT/FUEL RATIO
9-92



MAX DELTA K FOR B4C DRUM IN BE REF
AND PEAKING FACTOR AT BOL
DELTA K (%)
PEAKING
22
21
20
19
18
17
16
15
2
1.9
1.8
1.7
1.6
1.5
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
SUPPORT/FUEL RATIO
DELTA K
PEAKING
500 GU5/L;30.CM BE; 2MM B4C

SPECTRAL INDICES AND ABS/FIS IN U235



500 GU5/L;30.CM BE; 2MM B4C

Initial Approach for Use of this Model

Fuel density of 500g ^{235}U/L fuel is a reasonable compromise between good heat transfer and low total mass for the reactor.

Then, the parameter S/F is chosen to meet the demand:
P (Power), D (core Life), BU (% at burnup)

(1) With P, D, and BU estimate ^{235}U mass at BOL for slightly subcritical bare reactor. This then define S/F.

(2) With S/F and BU define $\Delta k)_{BU}$ due to burnup.

(3) Add (a) estimated Δk due to steady Xe and Sm (~3% max), (b) Δk Xe for buildup after trip, (c) 2% Δk for EOL operation and (d) 2% (estimated) due to structural material.

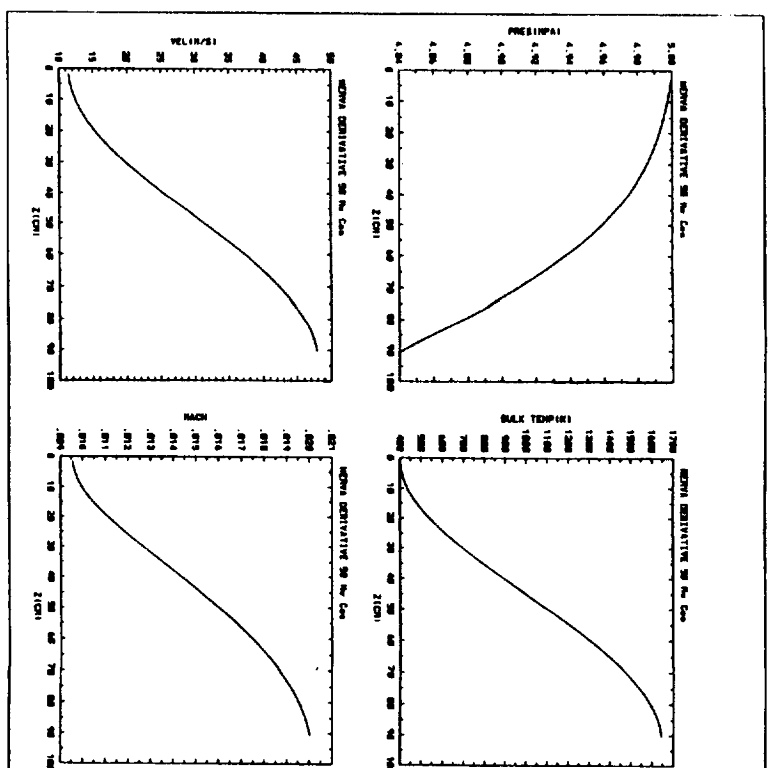
Initial Approach for Use of this Model (continued)

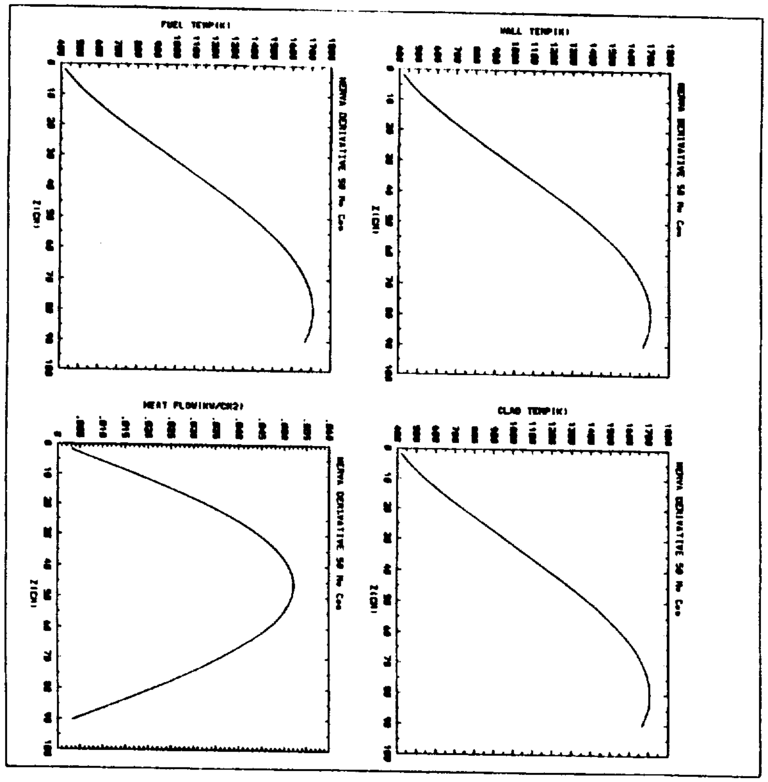
(4) With S/F find Δk of 30cm Be reflector.

(5) If 30cm of Be does not match the required Δk go to (1) change the ^{235}U mass.

(6) Check if control rods in reflector are sufficient to control the reactor.

(7) Check consistency of the A/F assumed.





Results for Initial Use of the Model

- A model has been generated to allow initial scoping calculations of gas-cooled reactor power sources for NEP.

- High power, long mission would require control mechanism in the core or burnable poison.

- The algorithm to use the model is going to be attached to the thermalhydraulic and shielding calculations in order to have a PC program useful for mission analysis. Work in progress.

- The previous criteria is going to be applied to the other two designs.