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AN EVALUATION OF ACCIDENTAL WATER-REACTIONS WITH LITHIUM COMPOUNDS IN FUSION REACTOR BLANKETS

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AN EVALUATION OF ACCIDENTAL WATER-REACTIONS WITH LITHIUM COMPOUNDS IN FUSION REACTOR BLANKETS

ABSTRACT

Efforts to mitigate potential problems of lithium-based blankets for fusion reactors include the use of lithium compounds for breeding purposes. This report investigates the safety aspects of these alloys relative to the use of pure lithium in a water-cooled blanket. Included in the study is a modification of the LITFIRE computer code to predict the thermal response of an internal blanket breeder-water interaction.

For the problem analyzed, results indicate that some of the lithium-lead alloys may pose safety problems approximate to those associated with the use of liquid lithium. Li_2O is shown to be significantly safer than liquid lithium, while results using LiAl are similar to those of the lithium-lead alloys.

In addition, the study provides an overview of this safety question, signaling areas that require further development.

ACKNOWLEDGEMENTS

Many people helped bring this effort to conclusion. In particular, Mark Tillack and Steve Piet, and Rachel Morton provided the needed hints to run LITFIRE and locate material properties.

Gail Jacobson transformed the written notes into a typed manuscript.

This report is based on a thesis submitted by the first author as part of the requirements for the degree of M.S. in Nuclear Engineering.

TABLE OF CONTENTS

Table of Contents (continued)

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. INTRODUCTION

Advancements in plasma physics research, together with a growing concern for the risks of energy production in the public sector, has led to an increasing number of detailed fusion safety studies. Topics, including routine and accidental releases of tritium, activation of structural material by neutron bombardment, and the consequences of lithium fires, are currently under various degrees of investigation. The findings of these studies are incorporated in subsequent fusion reactor designs, answering some questions and creating still more.

This work is the product of a research program whose objective is to minimize the potential problems of a lithium-based blanket for fusion reactors. Such a blanket is practically forced upon us by the choice of a D-T fuel mixture for first generation fusion power plants [1]. The needed tritium is bred via the reactions:

$$^{6}\text{Li (n,T) } ^{4}\text{He} + 4.8 \text{ MeV}$$

$$^{7}\text{Li (n,n'T) } ^{4}\text{He} - 2.5 \text{ MeV.}$$

Initially, natural lithium (92.58% ^{7}Li, the rest ^{6}Li), a liquid at operating blanket temperatures, was the primary candidate for blanket breeder and/or coolant materials, due to its excellent breeding and heat transfer qualities, effectiveness in neutron moderation and relatively low pumping power need as compared to other liquid metals [2]. However, with time and study, serious disadvantages in the use of liquid lithium emerged.

Pure lithium is highly reactive with air, water and concrete; all materials that will be in abundant supply in the reactor environment. Experimentation at the Hanford Engineering Development Laboratory (HEDL) and computer modelling studies at MIT using the computer code LITFIRE (to be discussed in more detail later in this report) indicate that temperatures and pressures in the reactor containment area, in the event of a sizable lithium spill, can attain critically high values [3]. Figure 1.1 shows such a possibility. Such an event could provide a pathway for release of tritium or structural activation products, providing a hazard to plant personnel or the outside world.

This problem and others, including corrosion, difficulties in tritium recovery, and magnetohydrodynamic instabilities [4], have led designers to consider alternative materials for fusion blankets. Among such considerations are lithium-lead alloys.

This report will provide a preliminary analysis of lithium-lead alloys for use as breeding materials from the safety point of view. While it is thought that these materials provide less of a hazard than the use of liquid lithium, little has been demonstrated. Thus, there is the need to formulate some framework for a comparison.

Before actual calculations can be made, a basis must be established. The NUWMAK reactor design by the University of Wisconsin (1978) was chosen for this purpose, due to its use of $Li_{62}Pb_{38}$ eutectic as the tritium breeder. The primary hazard here involves interaction between the lithium-lead alloy breeder and the boiling water coolant, inside the blanket. Specifics of this design are further discussed in Chapter 2.

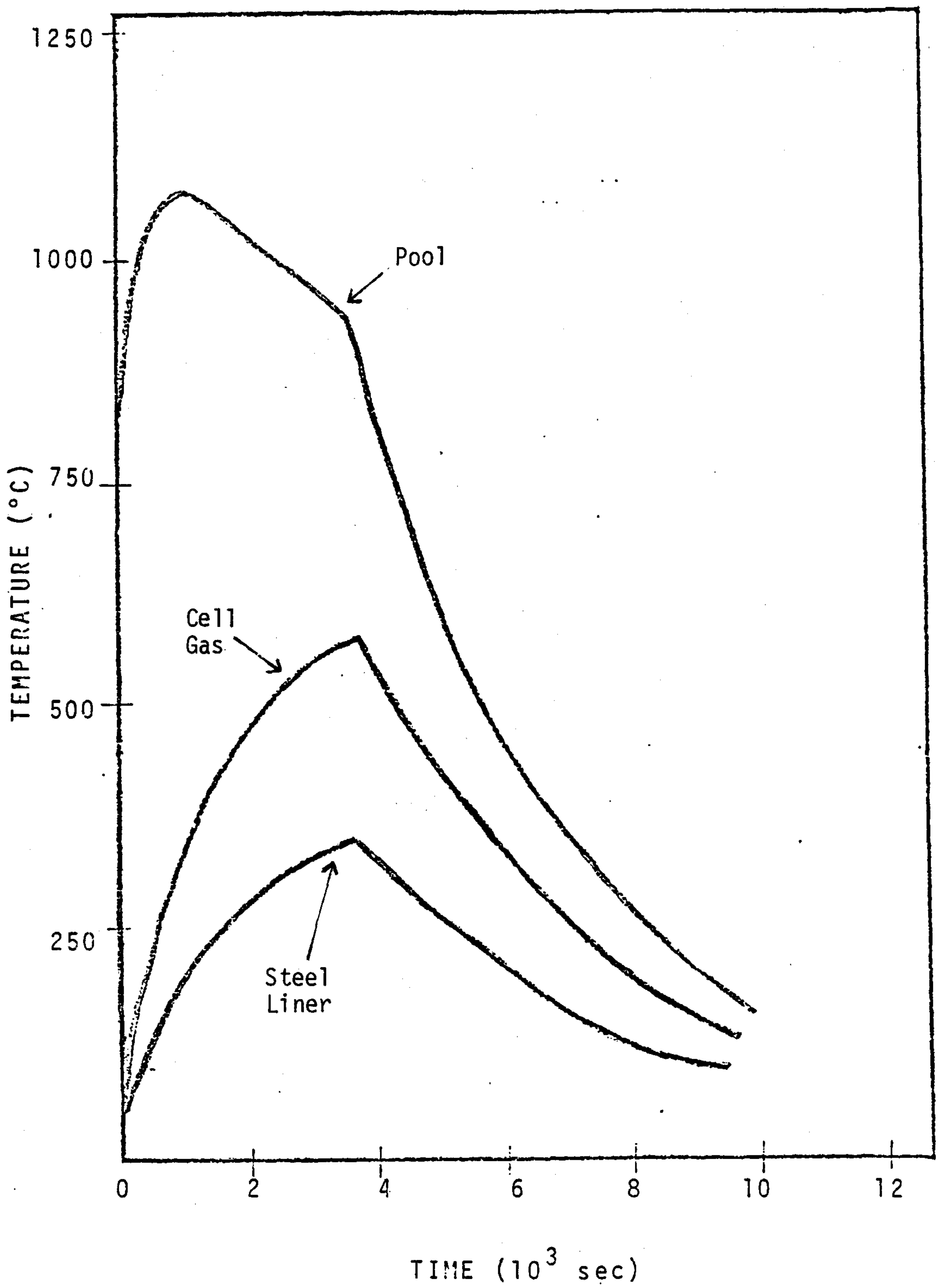


Figure 1.1 LITFIRE predictions for consequences of lithium spill in UWMAK III containment (Reference 3).

Using this basis, two separate studies are performed. The first is a static calculation: the breeder and coolant are allowed to interact immediately and the subsequent equilibrium final temperature of the blanket materials is determined. This is presented in Chapter 3. The second study is a dynamic calculation, using LITFIRE, of the temperature histories at various points in the blanket, if some accident allows breeder and coolant to come into contact. This is presented in Chapter 4. It should be stressed that in both studies, the values obtained are not sufficient evidence in themselves. Rather, these values must be compared with similar calculations employing the use of pure lithium. In this way, a measure of the relative hazards of the alternate breeders can be assessed.

CHAPTER 2. BLANKET DESIGN BASIS DESCRIPTION

2.1 Introduction

NUWMAK, a conceptual thermonuclear reactor designed by the Fusion Engineering Program of the University of Wisconsin in March 1979, is one of a number of second generation studies aimed at maximizing the strengths of fusion while minimizing the weaknesses. This work builds upon the findings of a number of first generation designs aimed at identifying the important problems of fusion power.

The design philosophy of this study was to search for an "end product that has the potential to be reliable, maintainable, environmentally acceptable, and reasonably economic [4]." To do this, a number of changes were made to the preceeding reactor concept, UWMAK III, including: an increase in the magnetic field to increase power density, a simplification of design to facilitate maintainence (as well as eliminate large cost items), the selection of structural materials to minimize resource requirements and costs, and a change in blanket breeder and coolant materials to reduce thermal fatigue and thereby increase reliability. The resulting structure is shown in Figures 2.1 and 2.2

The new elements in blanket breeder and coolant materials are of particular interest to those concerned with fusion safety studies. Utilized in NUWMAK are: (a) $Li_{62}Pb_{38}$ eutectic for the breeding material, used because its melting point is very near the blanket operational temperature and thus, the latent heat of melting can provide energy storage, and (b) boiling water for the coolant, the "perfect choice," discarded previously with the presence of pure lithium as the breeder.

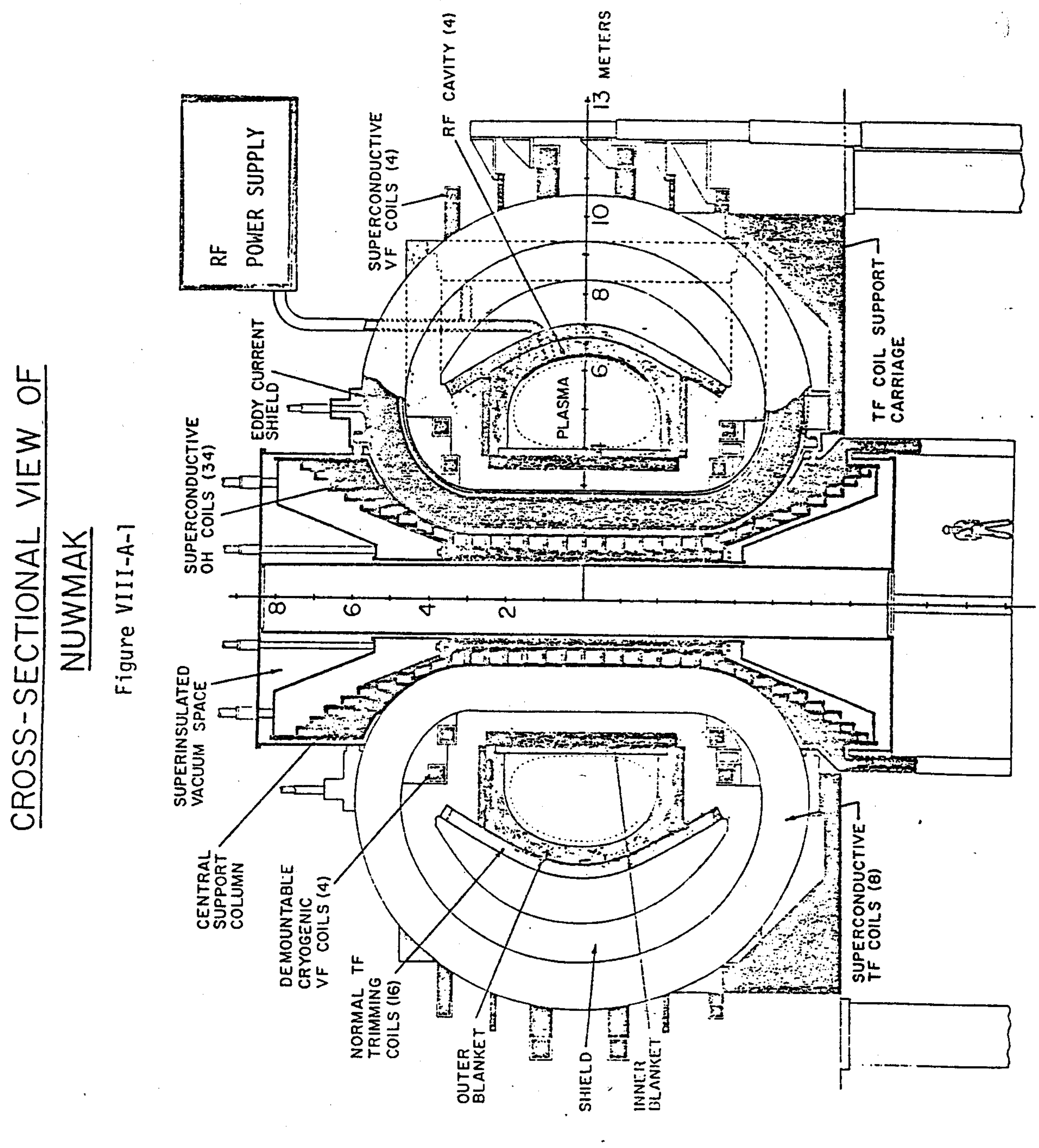


Figure 2.1 Cross-sectional View of NUWMAK (Reference 4).

TOP VIEW OF NUWMAK

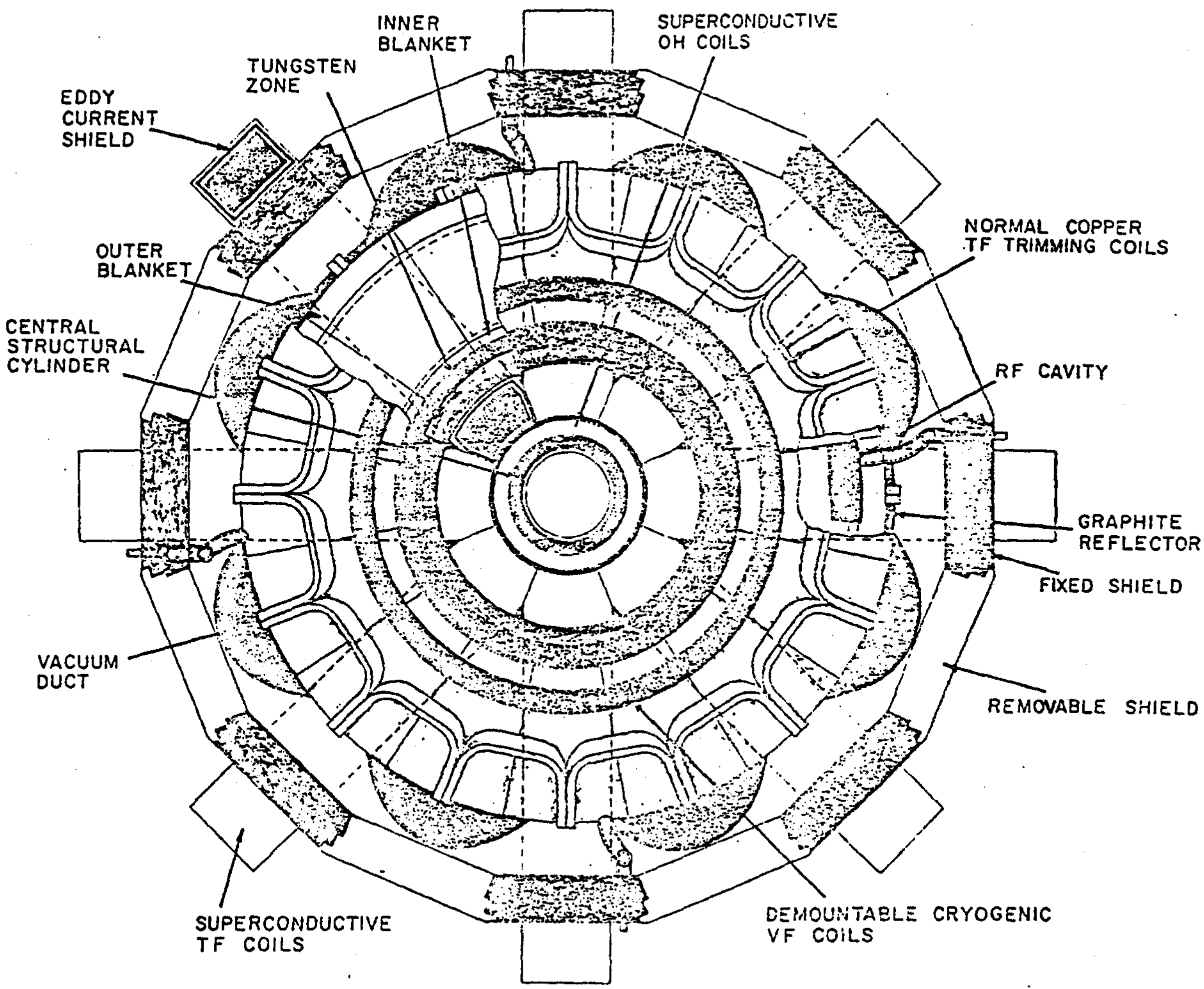


Figure 2.?
(Reference 4)

A preliminary survey of the hazards of lithium-lead alloys indicates that interaction with water is by far the more severe problem, as these materials are relatively inert in air. NUWMAK, in addition to its use of $Li_{62}Pb_{38}$, provides an opportunity for the breeder and coolant to come into contact, specifically a breach in the cooling system inside the blanket. Thus, NUWMAK is the logical first choice for a basis for an investigation of the relative safety of the lithium-lead alloys.

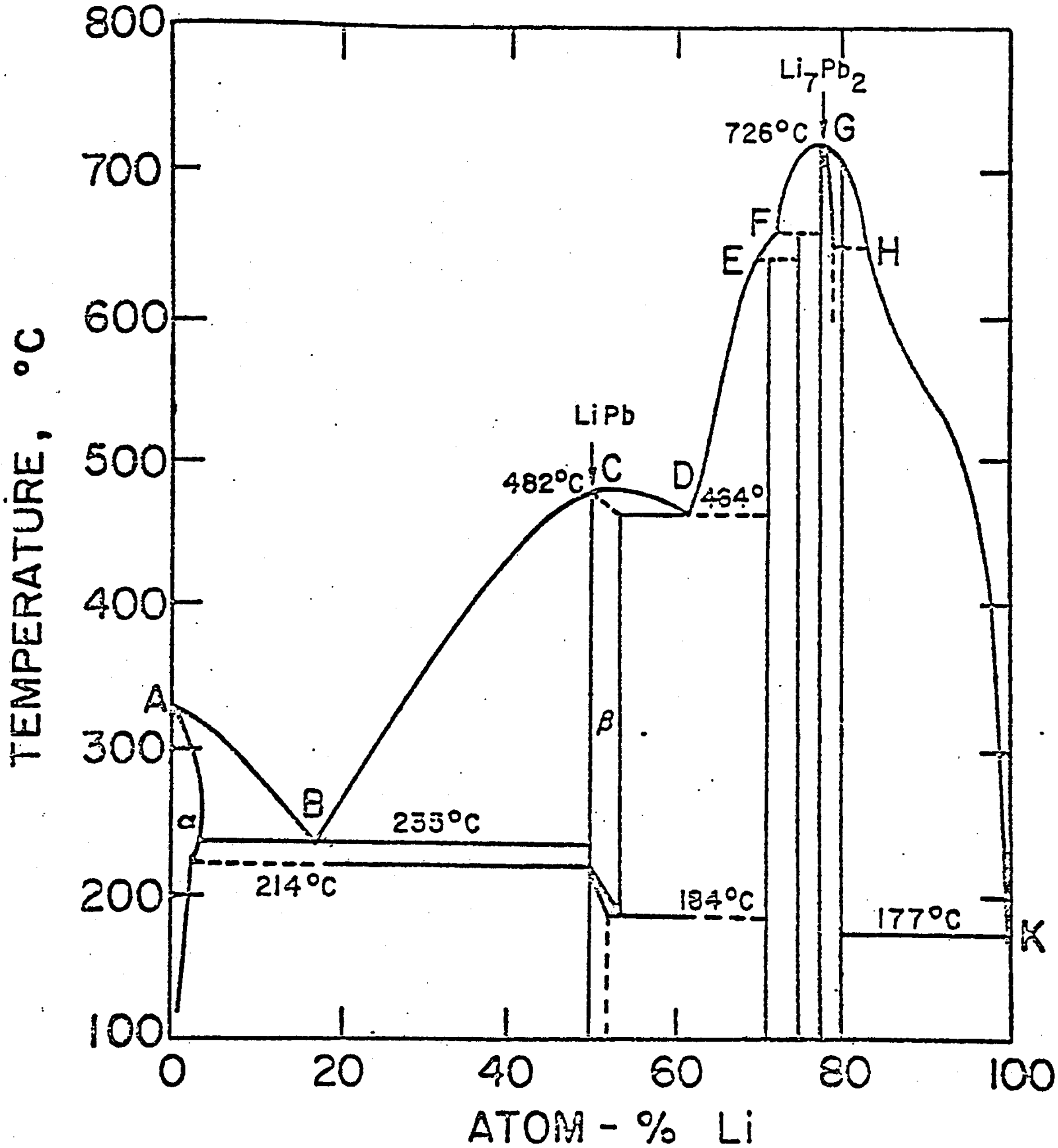
2.2 Breeding Materials

2.2.1 Lithium-lead alloys

The lithium compound selected as the tritium breeding material must satisfy many requirements. It must have desirable neutronic and irradiation characteristics, chemical stability at blanket operating temperatures, and be compatible with other blanket materials. More importantly, the compound must breed and release tritium at sufficient rates to fuel the reactor, yet limit the tritium inventory in the blanket to reasonable levels.

Lithium-lead compounds are interesting materials. Figure 2.3 shows the phase diagram of a Li-Pb two component mixture. However, beyond Li_7Pb_2, considered the most attractive lithium-lead alloy for breeding purposes, little else on the subject of Li-Pb physical properties is certain. An accumulation of data relevant to this study through a literature search and "data synthesis" is presented in Appendix A.

Two neutronic characteristics of the lithium-leads, breeding cabability and long-lived activation products, have been studied. In the latter only ^{205}Pb presents any problem in the long term unless significant amounts of impurities exist. This is not expected to be serious [4]. Breeding



Pb-Li PHASE DIAGRAM

Figure 2.3
(Reference 4)

capability depends on the amount of lead present.

Li_7Pb_2 has been examined in detail and exhibits an excellent breeding property. This is due to the presence of lead, which acts as a neutron multiplier. Figure 2.4 shows the effect of lithium concentration in the lithium-lead breeder on the total breeding ratio. The total bulk shield thickness required to protect toroidal field coils is shown for reference. It is evident that a reduction of the lithium concentration will cause a substantial loss of fuel multiplication. However, the reduction of lithium also tends to enhance magnet protection by virtue of more effective nuclear radiation shielding by the added lead [5].

A diffusion study by Wiswall [6] shows that the soluability of tritium in Li-Pb is much lower than that in pure lithium, as the activity of lithium is very low due to the presence of lead. Thus, the tritium inventories can be much smaller, tritium diffusivities relatively higher, and tritium recovery much easier. Specifically, Fig. 2.5 shows that Li_7Pb_2 has the lowest inventory of any of a number of proposed breeders. A problem here could be the fact that Li_7Pb_2 becomes a "chunk" at high temperature. This would increase the diffusion path of tritium and make recovery difficult [4].

A more serious problem of the lithium-leads involves their compatibility with the blanket environment. All react to some extent with water. Table 2.1 shows the results of experimentation to investigate this at Argonne National Laboratory. It can be seen that Li-Pb alloys can react vigorously with water, more so at elevated temperatures. However, a significant result is that $Li_{17}Pb_{83}$ exhibited only moderate reaction with water. Also, insufficient hydrogen was evolved by the alloy reactions to attain ignition conditions, unlike the case with liquid lithium.

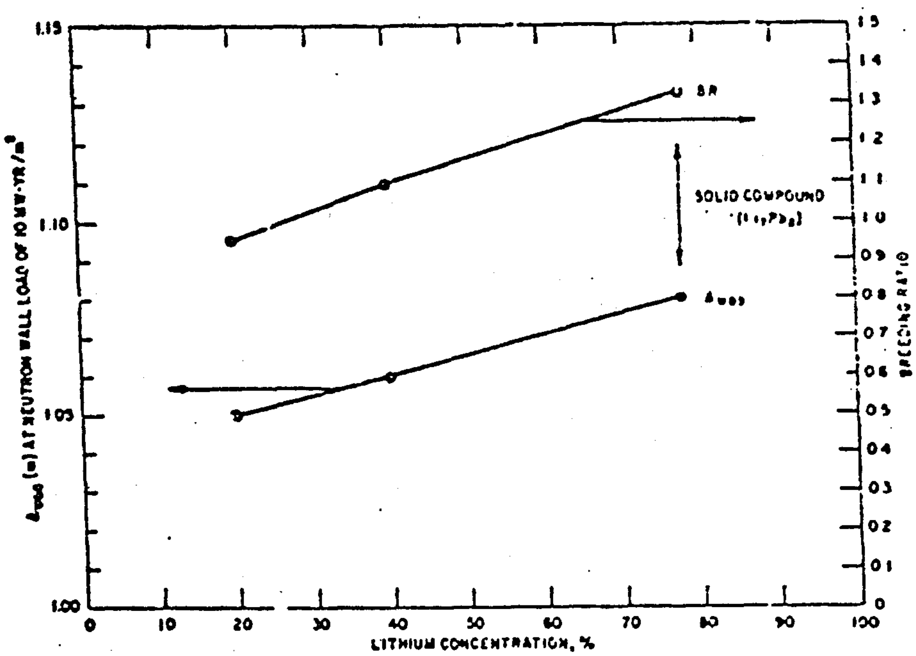


Figure 2.4 Effects of lithium concentration in a lithium-lead breeder on shielding requirement and tritium breeding (Reference 5).

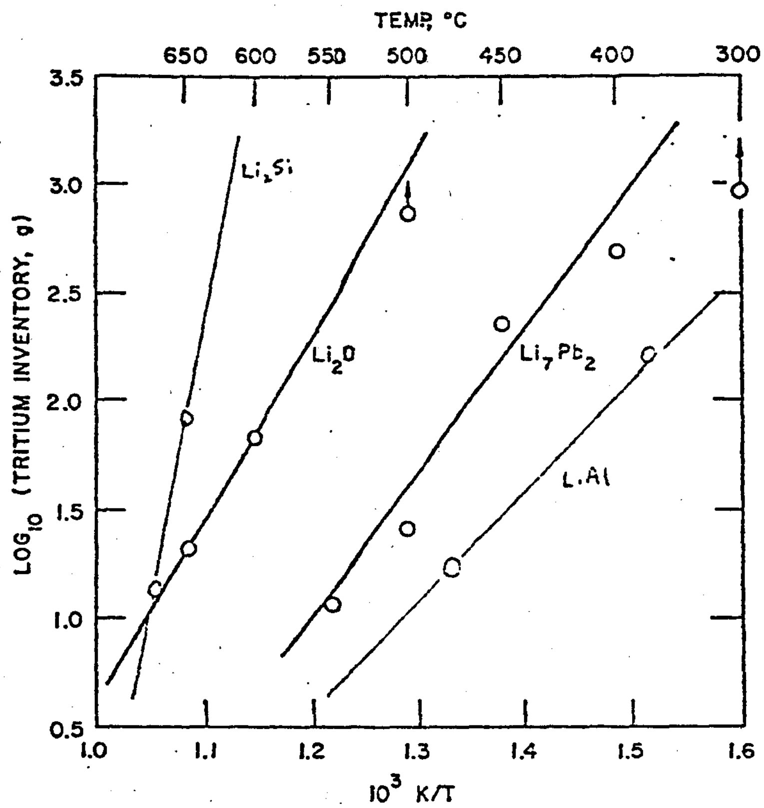


Figure 2.5 Estimated tritium inventory in alternative breeder blankets for a 3000 MW_{th} reactor (Reference 9).

TABLE 2.1

Reactions of Li-Pb Alloys and Lithium with Water

Case	Sample			Water Temp/°K	Reaction
	Composition	State	Temp/°K		
1	Li_7Pb_2	s	773	298	Modest
2	Li_7Pb_2	s	773	369	Vigorous
3	Li_7Pb_2	s	873	368	Vigorous
4	Li_7Pb_2	ℓ	1103	368	Very Vigorous
5	$Li_{0.62}Pb_{0.38}$	ℓ	773	368	Vigorous
6	$Li_{0.17}Pb_{0.83}$	ℓ	773	368	Very modest
7	Li	ℓ	773	368	H_2 Detonation
8	Li[a]	ℓ	773	368	Detonation

(Reference 7)

[a] Injected under water

In all reactions, LiOH (melting point at 470 °C) is formed. Liquid LiOH is an extremely corrosive substance and would degrade the integrity of the activated structural materials [7]. Fortunately, Li-Pb is relatively inert in air. It was reported [8] that "LiPb (50-50 mixture) resembles Pb in every respect except density. LiPb would not ignite, even when exposed to the flame of a gas-air torch." Therefore, though a Li-Pb - H_2O reaction could be very serious, it is not expected to be as severe as an accident involving pure lithium. Table 2.2 provides a summary of the advantages and disadvantages of the lithium-lead alloys.

2.2.2 Alternative Breeders

For completeness, LiAl and Li_2O, also candidates for the tritium breeding material, will be analyzed with regard to safety in this study. Other strong candidates, specifically Li_2SiO_3 and $LiAlO_2$, have been ignored in this study since they have no appreciable reaction with water.

LiAl is in many ways akin to Li_7Pb_2, such as a similarity in reactivity with water. However, the latter material is preferred by designers due to a superior tritium breeding capability. This is because there is a lower lithium-atom density in LiAl and no neutron multiplier, with the absence of Pb. Tritium extraction characteristics are also poorer than that of Li_7Pb_2 [9]. The primary activation product is ^{26}Al, more of a problem than ^{205}Pb. Physical properties of this breeder are also unexplored and are discussed in Appendix A. The phase diagram is shown in Fig. 2.6.

Li_2O has a marked advantage over the lithium-lead alloys in the matter of reaction with water. Because it is in oxide form, this compound does not evolve hydrogen upon reaction and produces less heat [9]. It is

TABLE 2.2

Summary of Favorable and Unfavorable Features of Lithium-Lead Breeders

Lithium-Lead Alloys

Advantages	Disadvantages
1. High breeding ratio attainable	1. Poor technology base: high degree of uncertainty in properties
2. Probably less reactive with water than liquid Li	2. Reactive with water coolant
3. Tritium recovery appears feasible with low-pressure helium	3. High blanket weight
4. Lead helps shield magnets	4. Uncertain radiation damage effects
	5. Uncertain tritium release mechanism
	6. Requires blanket changeout during reactor life
	7. Activation product: ^{205}Pb

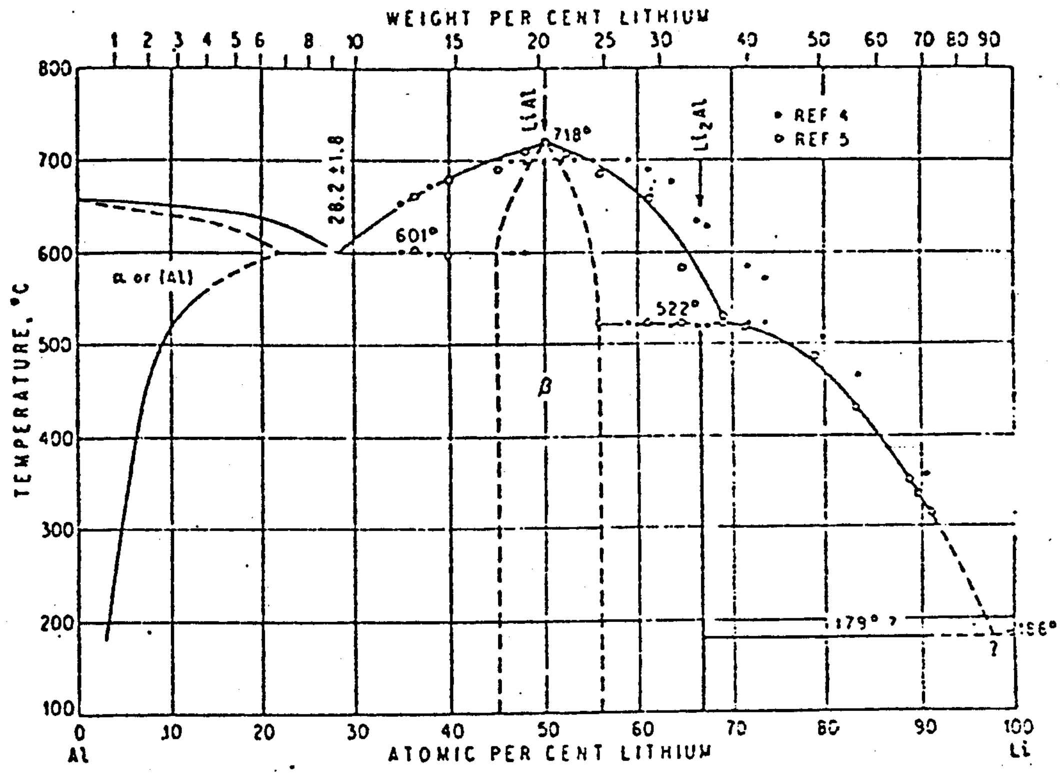


Figure 2.6 Phase Diagram for LiAl System.
(Reference 9)

therefore expected that the use of this breeder will not pose a major safety problem. However, Li_2O has fallen into disfavor because it has a high lithium-atom density. This, combined with a poor diffusion rate, leads to excessive tritium inventories. Physical properties of this breeder are also discussed in Appendix A.

2.3 Coolant

Many factors affect the choice of coolant. Unique in power production to fusion is the interrupted burn cycle of the plasma. This produces the problem of thermal fatigue in the first wall and blanket, caused by the fluctuating temperature of these structures with the plasma burn cycle. The temperature change is a combination of three effects:

1. Coolant temperatures rise, $T_{c,out}-T_{c,in}$
2. Film temperature drop, $T_{wall} - T_c$ $(=Q/h)$
3. Temperature difference across the first wall, $\Delta T = Q\,\chi/k$ [4].

While the third effect depends on structural materials, the first two can be greatly reduced by choice of the proper coolant, one which has a small coolant temperature rise that simultaneously provides a large heat transfer coefficient. This describes a boiling liquid and the first logical choice is boiling water.

A considerable technology has been developed through the years for the use of water as a coolant in energy production. There exist many advantages. Water is an excellent heat-transfer fluid, costs little and is readily available. It is easy to pump and is non-corrosive with conventional structural materials.

It is interesting to note, however, that up to this point, few designers have considered water for the primary coolant. There exist a number of concerns and questions including neutronics, tritium, and safety considerations. In addition, the use of a boiling water or steam coolant will require high pressure containment. The NUWMAK design calls for cooling water at 300 °C and 8.6 MPa (1250 psi). This poses additional design and safety problems.

The safety concerns of a water-cooled blanket have been discussed. It should be noted that this problem effectively prohibited the use of water as a coolant until alternative breeders to lithium were suggested. Even so, current designs using water stress the use of strong cladding materials for coolant channels.

High-integrity cladding is also the prescription to minimize tritium diffusion into the cooling water. Tritiated water is a safety hazard and recovery of the tritium is difficult and expensive. However, recent studies using permeation rates for stainless steel cooling tubes show tritium losses could be less and 1 Ci/day, assuming the formation of oxide films inside the tubes [9]. Irregardless, it is obvious that the coolant loop cannot be used for tritium recovery, necessitating some recirculation of the breeder.

The necessity of avoiding contact between breeding materials and coolant tends inherently, to increase structural material content in the blanket. From a neutronics point of view, this increase tends to degrade the tritium breeding ability, due to increased parasitic neutron absorption. However, the strong neutron slowing-down power of water improves breeding performance by increasing the ^{6}Li (n,T) ^{4}He reaction rate for low energy neutrons. This decreases parasitic absorption by the structural materials [5]. Therefore, proper design and choice of materials can leave the tritium breeding capability of a water-cooled blanket virtually unchanged.

Figure 2.7 shows this phenomenon for various breeders, with 316 stainless steel used as structural material. It is important to note that the addition of water significantly improves the breeding ratio in the Li_7Pb_2, more so than the other breeders. This is due to reduced parasitic absorption in lead as well as the stainless steel.

Table 2.3 summarizes the advantages and disadvantages of the water-cooled blanket concept. Chief among the assets is the use of available technology in its construction. The major liabilities appear to be the safety problem and limited choices in compatible breeding and structural materials. Further study in both areas is necessary before a final decision can be made.

2.4 NUWMAK Blanket Design

2.4.1 Structural Materials

Many structural materials have been considered for a water-cooled blanket design, including: austenitic stainless steel, high nickel alloys and selected titanium, vanadium and niobium alloys [9]. Table 2.4 summarizes an assessment of these candidates with regard to properties associated with the blanket environment.

One of the liabilities of the water-cooled design is apparent. The vanadium and niobium materials, which respond well to neutron bombardment, are eliminated due to water corrosion problems. Also noted is a general lack of data regarding the compatibility of these structural materials with the lithium-lead alloys. Since decomposition of these alloys is not

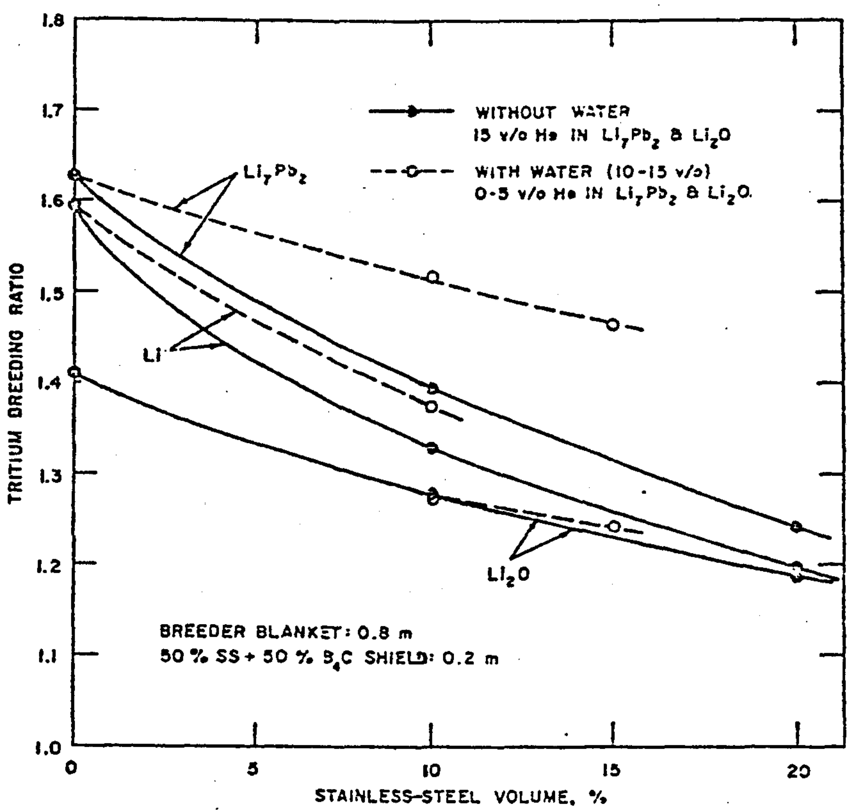


Figure 2.7 Impact of Structural Material Content (316 SS) on Tritium Breeding (Reference 6).

TABLE 2.3

Summary of Favorable and Unfavorable Features of
the Water-Cooled Blanket Concept

Water Coolant

Advantages	Disadvantages
1. Excellent heat-transfer fluid	1. Highly reactive with candidate breeding materials
2. Well-developed technology base	2. Reaction product (LiOH) is very corrosive
3. Low cost and readily available	3. Requires high-pressure containment
4. Relatively low temperature ($\sim$ 320 °C) operation	4. Cannot be used for tritium recovery
5. Compatible with conventional structural materials	5. Expensive to remove tritium from H_2O (safety)
6. Low pumping power need	6. Water tends to be a sink for tritium
7. Enhances tritium production	7. Nb and V, candidate structure materials are incompatable
8. Liquid at room temperature	

TABLE 2.4

Summary of Structural Material Assessment for the Water-Cooled Blanket Concept

Property Requirement	Rating*				
	Fe	Ni	Ti	V	Nb
Bulk Radiation Effects	2	2	?	1	1
Compatibility with H_2O	1	1	1	4	4
Compatibility with Liquid Li	3	5	3	1	1
Compatibility with Solid Li_2O and Li_7Pb_2	3	3	3	3	3
Compatibility with H(DT) Environment	1	1	3	1	1

* Rating numbers defined as follows:

1. Compares favorably with other candidate structural materials.
2. Limits operating life but probably acceptable under certain conditions.
3. Little data available but may be a limiting factor.
4. Probably not viable for conditions of interest.

desirable, this question should be studied.

The NUWMAK design utilizes Ti-6Al-4V alloy for the first wall and coolant tube material due to its high strength-to-weight-ratio, good fatigue resistance, fabricaility, low long term residual activity and well established industry [4]. Physical properties of this alloy are shown in Table 2.5. The NUWMAK shield is more conventional, primarily B_4C.

2.4.2 Mechanical Design

The blanket of NUWMAK is shown in Fig. 2.8. The blanket structure is Ti-4Al-4V which operates at a temperature of approximately 350 °C. The coolant is boiling water at 300 °C and 1250 psi. The breeder is $Li_{62}Pb_{38}$ eutectic, operating at approximately 400 °C. The design life for each blanket module is two years.

The blanket is divided into eight modules in the reactor. Each module is fed and discharged coolant and breeding materials separately. There are two blanket units in each module; the inner blanket near the machine axis and the outer blanket, as seen in Fig. 2.8. These two units are completely separate from each other.

The first wall consists of a continuous bank of tubes running in the vertical direction. Beyond this, the blanket is cooled with rows of vertical tubes on a triangular pitch. The spacing between rows of tubes is progressively increased towards the back of the blanket to account for the radially decreasing nuclear heating [4]. Radial struts are spaced at 20 cm intervals, reinforcing the first wall against the hydrostatic pressure of the breeding material, which fills the space between the coolant tubes.

TABLE 2.5

Physical Properties of Ti-6-4

Atomic Weight	45.9
Melting Point	1668 °C
Mass Density	4.4 g/cm^3
Yield Strength	530 MPa
Modulus of Elasticity	85 GPa
Yield-to Weight Ratio	120 N-m/g
Thermal Condcutivity	.12 W/cm-K
Coefficient of Thermal Expansion	10×10^{-6}/°C
Heat Capacity	668.8 J/kg-K

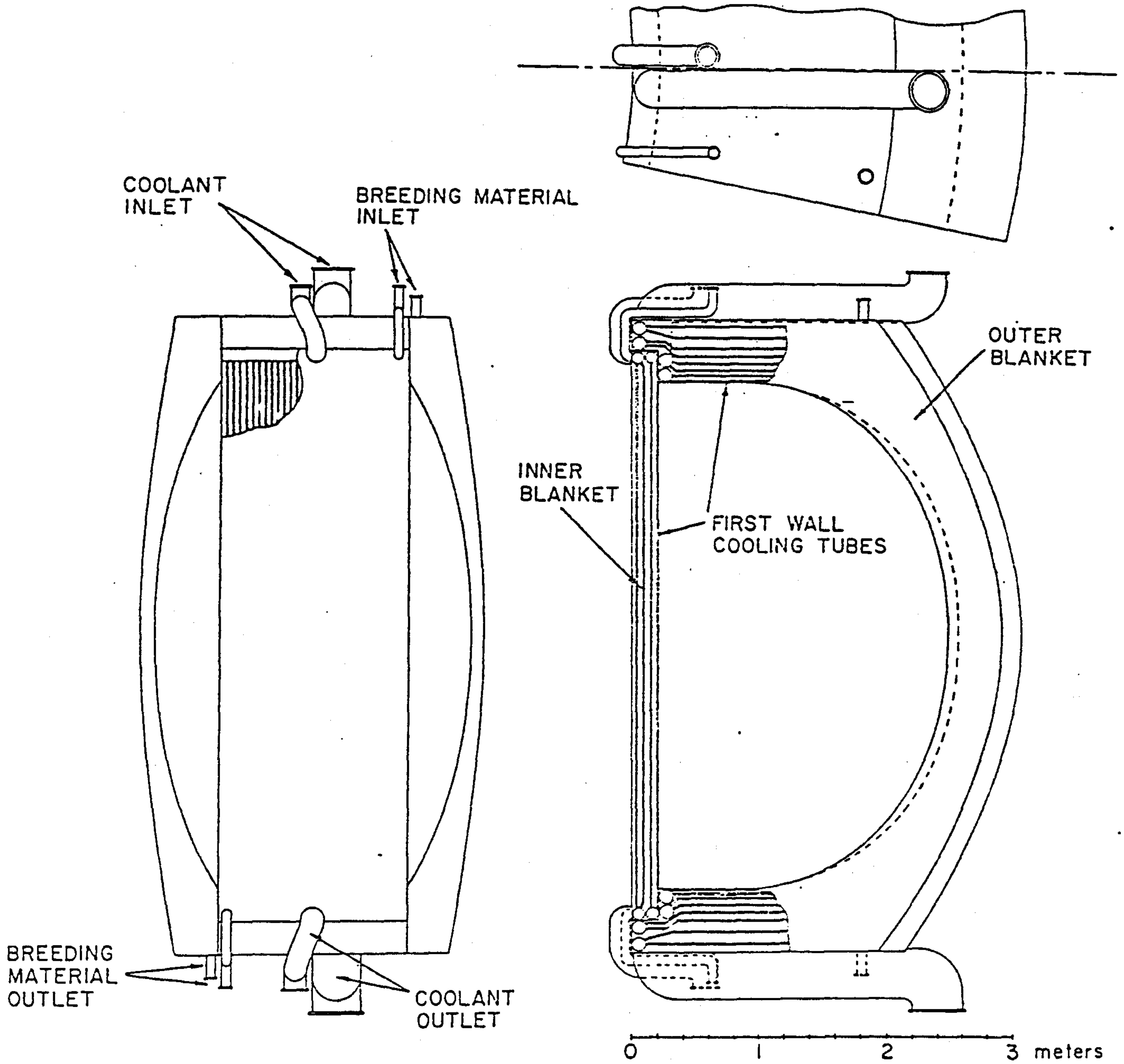


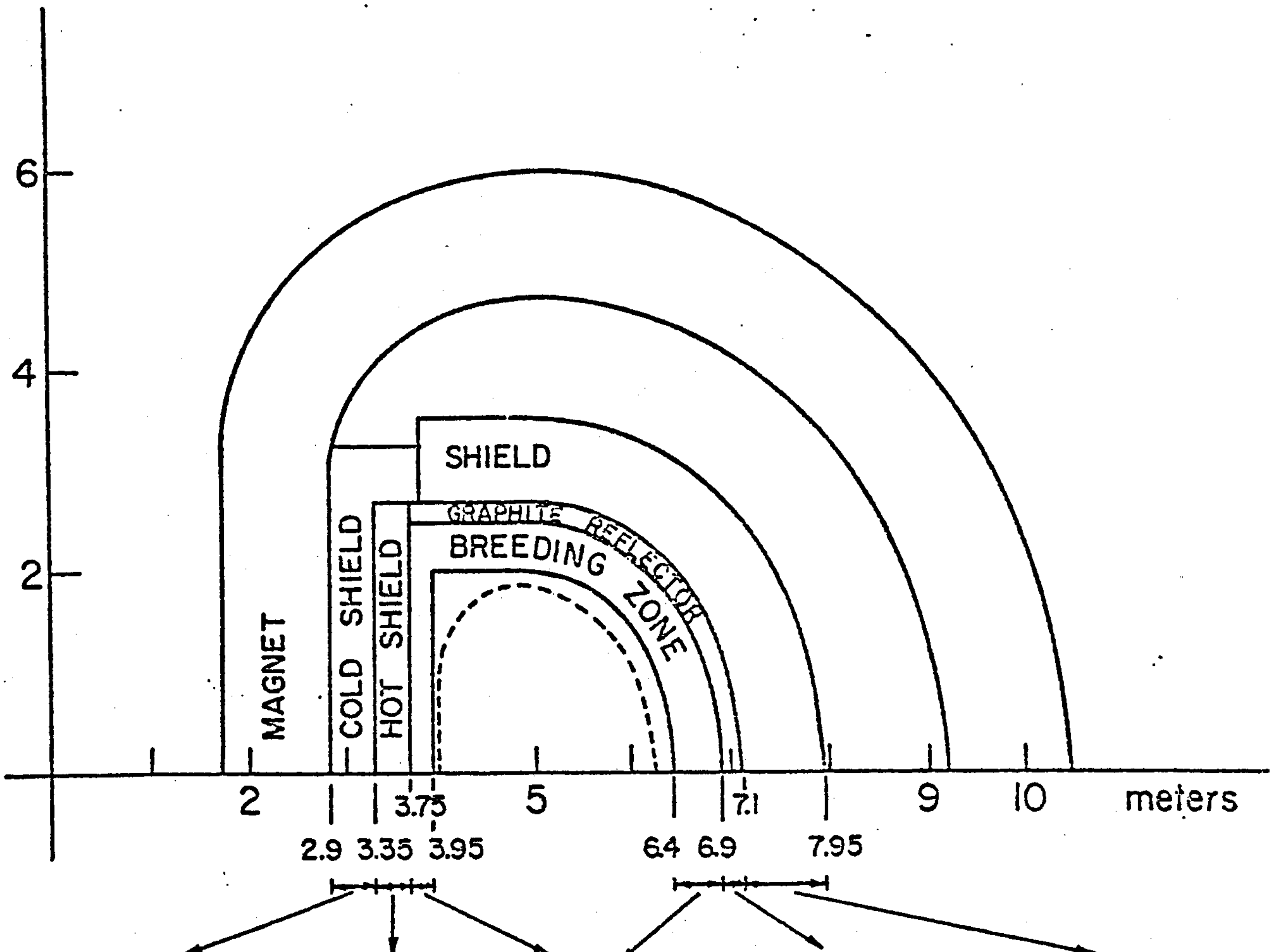
Figure 2.8 Cross-Sectional View of Blanket (Reference 4).

At the blanket's edge is a thin graphite reflector. Beyond this is a shield to protect the cryogenic magnet coils. The shield is primarily B_4C, operating at approximately 150 °C. Figure 2.9 shows a schematic diagram of this system.

2.4.3 Summary of Important Parameters

The major features of the NUWMAK design are given in Table 2.6. In addition, important blanket parameters pertinent to this study are given in Table 2.7. These values are used where appropriate in subsequent calculations.

SCHEMATIC OF THE BLANKET AND SHIELD FOR NUWMAK



COLD SHIELD	HOT SHIELD	BREEDING ZONE	GRAPHITE REFLECTOR	SHIELD
3.5% Ti alloy	4% Ti alloy	5.7% Ti alloy	3.5% Ti. alloy	3.5% Ti alloy
95.25% B_4C	93% W	89.4% Pb Li	95.25% C	95.25% B_4C
1% H_2O	2% H_2O	3.7% H_2O	1% H_2O	1% H_2O
0.25% Pb	1% Pb	1.2% Pb	0.25% Pb	0.25% Pb

Figure 2.9
(Reference 4)

TABLE 2.6

Major Features of NUWMAK Design

Power	
Total Thermal Power	2283 MW_{th}
Net Electric Power	660 MW_e
Plasma	
Major Radius	5.13 m
Minor Radius	1.13 m
Plasma Height to Width Ratio (b/a)	1.64
Plasma Current	7.2 MA
Toroidal Beta	6%
$n_e \tau_E$	2×10^{14} cm^{-3}-sec
q(a)	2.64
Magnet	
On-Axis Toroidal Field	6.05 Tesla
Toroidal Field at NbTi Conductor	11.5 Tesla
Stabilizer	Aluminum
Number of Toroidal Field Coils	8
Number of Cu Trim Coils	16
Blanket	
Structural Material	Titanium Alloy
Coolant	Boiling Water
Breeding Material	$Li_{62}Pb_{38}$
Average Neutron Wall Loading	4.34 MW/m^2

TABLE 2.7

Summary of Important Blanket Parameters

Plasma Burn Time	225 sec
Plasma Down Time	20 sec
Coolant Temperature	300 °C
Coolant Pressure	8.6 MPa
Total Coolant Flow Rate	1500 kg/sec
Total Coolant Tube Surface Area	4350 m^2
Heat Transfer Coefficient of Boiling Water	20000 Btu/hr-ft^2- °F
Coolant Tube OD	1.3 cm
Coolant Tube ID	1.0 cm
N. Tubes in Outer Blanket Module	475
Pitch Length	12 cm
Space for Breeder in Outside Blanket Module	17.72 m^3
Breeder Temperature	400 °C
Shield Temperature	150 °C

CHAPTER 3. EQUILIBRIUM T_f CALCULATION

3.1 Introduction

Lithium-lead alloys are considered less of a safety hazard due to the presence of lead, which is thought to slow down the water reaction, decrease the heat of reaction and help absorb what heat is released. However, a number of physical properties are altered with the addition of lead. Since most of these properties have direct bearing on an interaction with water, the consequences of such an interaction are not directly predictable.

For this reason, a preliminary analysis of the Li-Pb - H_2O reaction is performed using a static calculation. In this case, the breeder inside one blanket module is allowed to interact completely with varying amounts of the water available to that module. Assuming the heat of reaction is contained within the blanket, the equilibrium temperature of the reaction products, unreacted breeder and blanket structural materials is then determined.

Such a scenario is unrealistic, but this calculation is important for two reasons. First, it serves as a reference for further study. Second, with its assumptions, such a calculation may indicate the maximum attainable blanket temperature in a particular module in the case of an internal blanket water interaction.

3.2 Assumptions and Methodology

The outer blanket section of an individual module is chosen for consideration. The inner blanket section contains only a nominal amount of breeder and the consequences of an accident in that section do not appear as severe. Data from the NUWMAK design (Table 7.H.2) indicates that an outer blanket module contains 38.4 tonnes of titanium structural material, 106.0 tonnes of graphite and 17.7 m^3 of space to contain the breeder. Therefore, the amount of breeder present can be determined with knowledge of the density.

The initial temperature of breeder and graphite is 400 °C. The structural materials are at a temperature of 350 °C and the coolant is at 300 °C and 1250 psi. The reaction between breeder and coolant is assumed to be immediate and complete at 400 °C, the heat of reaction helping to raise the water temperature to that point. The heat of reaction can be determined using:

$$\Delta H_r = \Delta H^\circ_{25} + \Sigma\Delta H_{prod} - \Sigma\Delta H_{react}, \quad \text{cal/g breeder} \qquad (3.1)$$

where ΔH°_{25} is the standard heat of hydrolysis at 25 °C and ΔH_{prod} and ΔH_{react} are the enthalpy changes of reaction products and reactants, respectively, as they are heated from 25 °C to 400 °C.

The amount of coolant water available to the outer blanket module can be determined by analysis of NUWMAK's steam generating unit. In this respect, NUWMAK is very much like a fission boiling water reactor [4]. Examination of the Dresden BWR reveals that the total coolant volume in the 3411 MW_{th} plant's cooling system is 11,695 ft^3 [10]. Scaling this down to NUWMAK's 2283 MW_{th} output and assuming the average density of water in the coolant loop to be 62.37 lb/ft^3 (an overestimate), it can be shown that approximately 15,260 pounds of water are available to interact with the breeder in one module.

It is assumed that a fixed percentage of this cooling water interacts with the breeder. Thereafter, no loss of heat is allowed from the blanket. The resulting final equilibrium temperature can be calculated using the expression

$$T_f = T_o + \frac{Q_R}{(M_s\overline{C}_s + M_b\overline{C}_b + \Sigma M_{Ri}\ \overline{C}_{Ri})} \quad , \tag{3.2}$$

where
T_f = final equilibrium blanket temperature
T_o = initial blanket temperature
Q_R = reduced heat of reaction
M_s = structural mass
M_b = remaining breeder mass after reaction
M_R = reaction product mass after reaction
$\overline{C}_i$ = mean specific heat for each component

Reaction products include hydrogen gas, LiOH and the alloy element.

A proper evaluation of the $M_i\overline{C}_i$ terms in the above equation varies with each component. For example, LiOH is evaluated above its melting point as

$$M_{LiOH}\ \overline{C}_{LiOH} = \frac{M_{LiOH}\left[\overline{C}_s(T_{melt} - T_o) + \Delta H_{melt} + \overline{C}_L(T_f - T_{melt})\right]}{T_f - T_o} \tag{3.3}$$

where
$\overline{C}_s$ = mean solid specific heat of LiOH
$\overline{C}_L$ = mean liquid specific heat of LiOH at 470 °C
ΔH_{melt} = heat of melting for LiOH at 470 °C
T_{melt} = melting point of LiOH (470 °C)

Similar expressions can be written for the other components.

The reduced heat of reaction can be written as

$$Q_R = xM_c \left[a_o \Delta H_R - \overline{C}_c (T_o - T_c)\right] - M_{Ti} \overline{C}_{Ti} (T_o - T_{Ti}), \qquad (3.4)$$

where M_c = mass of total available coolant

M_{Ti} = mass of titanium structural material

$\overline{C}_c$ = mean specific heat of coolant

$\overline{C}_{Ti}$ = mean specific heat of titanium structural material

T_c = coolant temperature

T_{Ti} = titanium structural material temperature

x = fraction of available coolant reacting

a_o = reaction stoichiometric combination constant

This is done to raise the coolant and titanium alloy structure to the initial blanket temperature of 400 °C.

3.3 Results and Discussion

Figure 3.1 shows the resulting equilibrium blanket temperatures for the various breeders under consideration, plotted against the reacting percentage of available water. A number of interesting results are noted.

First, as expected, the pure lithium breeding blanket reached the highest temperature upon reaction with water. The dotted line signifies that with a high percentage of available water reacting, some of the unreacted lithium will begin to vaporize at a temperature also close to the melting point of steel. This indicates a potential for further problems if a steel blanket liner is used.

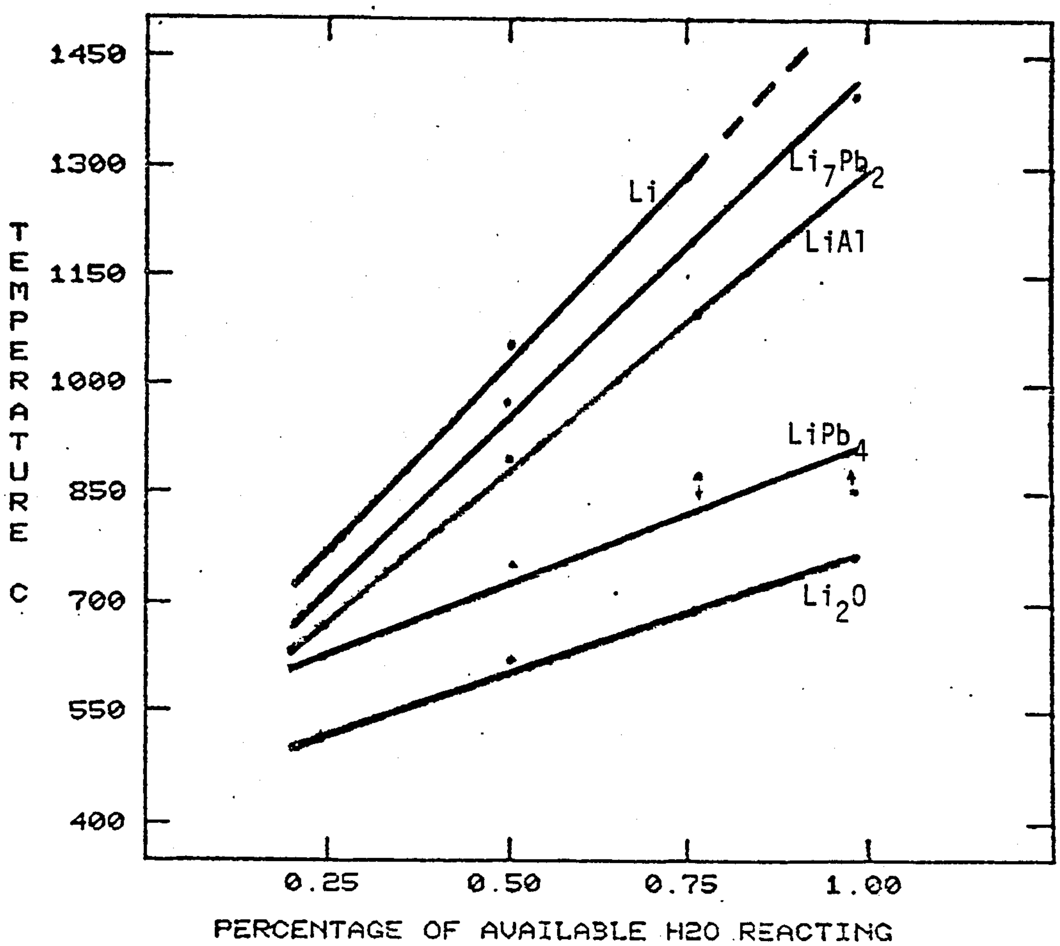


Figure 3.1 Equilibrium Final Temperature Profiles for Various Breeders in the Static Calculation.

Li_7Pb_2 and LiAl are very much alike. Though lower equilibrium temperatures are exhibited than those of the pure lithium breeder, the difference is not very large to be significant. At low percentages of reacting available water, there is no difference.

Li_2O and $LiPb_4$, on the other hand, appear to be significantly "cooler" than the pure lithium case. In the case of Li_2O, the key difference is a very low heat of reaction with water. $LiPb_4$, with a relatively high density, is the only case in which there exists more available water than breeder. Thus, a limited heat of reaction and large residue of lead leads to reduced equilibrium temperatures.

CHAPTER 4. DYNAMIC CALCULATION USING LITFIRE

4.1 Introduction

Though valuable as a reference, the calculations of Chapter 3 have little to do with a plausible internal blanket breeder-coolant interaction. It is incorrect to assume that these materials will react instantly at a constant temperature; it is imprudent to declare that the flow of cooling water will cease and that all heat will be retained within the blanket perimeter. Clearly, a dynamic formulation is needed.

To this end, the LITFIRE computer code is modified to estimate the thermal response of the NUWMAK blanket to possible accidents. In this modification, called the internal blanket accident option, the breeder and water react in a zone located in the middle of the breeder mass. The leakage of water into this "reaction zone" is determined by the number of broken coolant tubes, set small enough to justify the assumption that this is the limiting effect on the reaction rate. The heat of reaction is transferred to the breeder mass by conduction and free convection, to the blanket liner and shield by further conduction, and out of the blanket via forced convective cooling by unbroken coolant tubes. Figure 4.1 shows the heat flow diagram for this system.

It is hoped this model presents a truer picture of what will happen within the blanket in the event of a cooling system leak. Again, due to uncertainties concerning data and some assumptions, this study can only provide a measure of relative safety, compared with the trials utilizing liquid lithium.

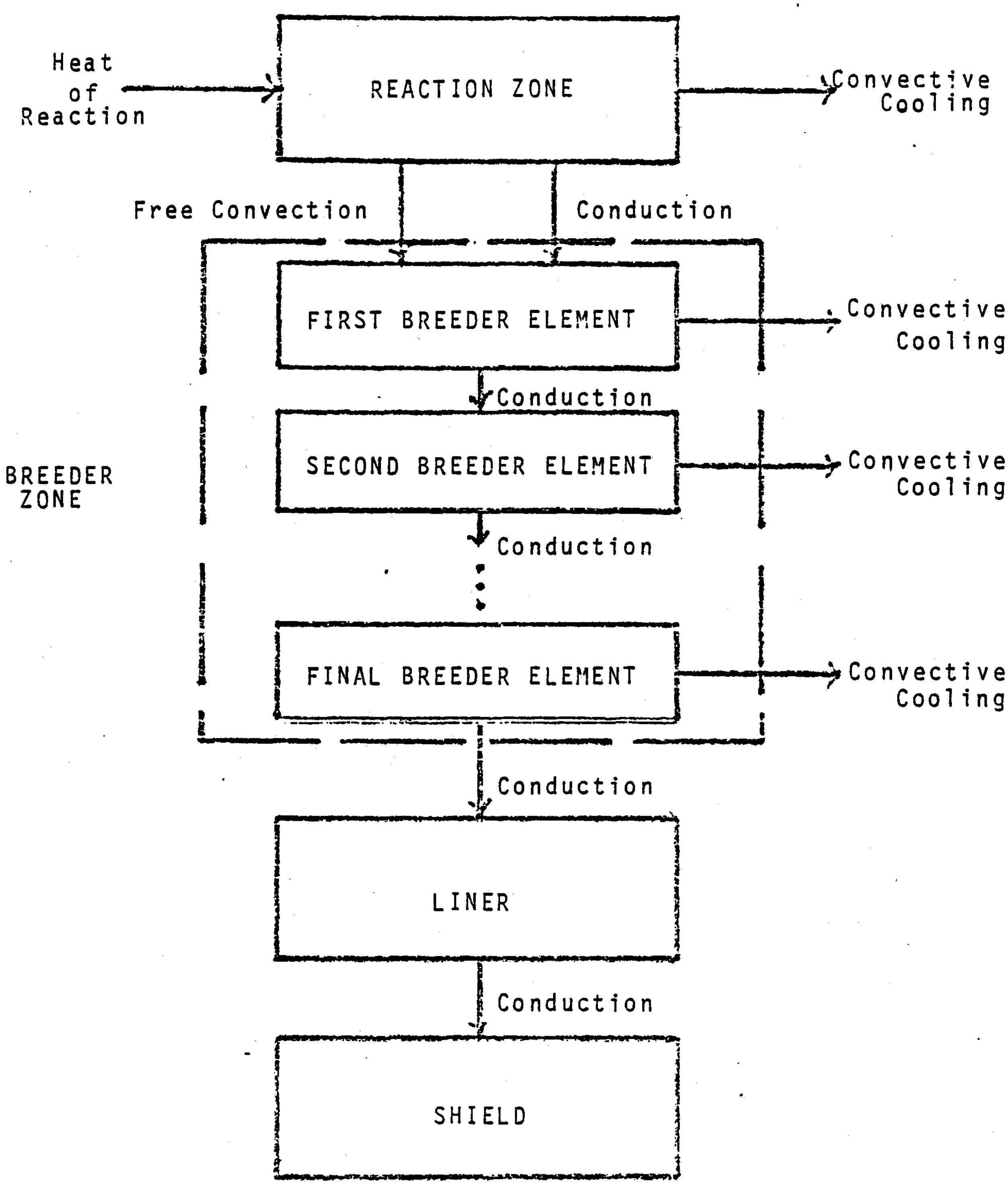


Figure 4.1 Internal Blanket Accident Option Heat Flow Diagram.

4.2 LITFIRE Description

LITFIRE is a computer code developed at MIT [11] to predict the consequences of a hypothetical lithium spill in a fusion reactor containment. It was first written in 1977 as a mofidication of the Argonne National Laboratory code SPOOLFIRE, used to model the consequences of sodium fires. LITFIRE was later modified and improved in 1980 [3], utilizing the experimental results of small-scale lithium spill tests performed at the Hanford Engineering Development Laboratory.

In this code, the flow of heat is traced from the lithium reaction zone source to reactor containment components, and eventually out to the ambient. This system is simulated by a nodal network in which each node has a heat capacity and temperature equal to that of its physical counterpart. Heat flows between nodes are calculated using standard heat transfer correlations.

To provide the reactor containment thermal and pressure response, LITFIRE solves a set of coupled heat and mass transfer equations. This is done by using the method of finite differences for the spacial dimensions, and either Simpson's rule or a Runge-Kutta method in the time domain [3]. Properties are computed at each time step from the integral equation

$$Y(t) = Y(t_o) + \int_{t_o}^{t} dt' \, dY/dt',$$

where the rates of change dY/dt are given for each node by finite difference solution of the heat transfer relations.

4.3 Internal Blanket Accident Option

4.3.1 Assumptions and Structural Model

The internal blanket accident option models an accidental interaction of coolant water and lithium-based breeder in the center of an outside blanket module. This interaction is caused by a breach of several neighboring coolant tubes, while the reactor as a whole undergoes normal operation.

It is assumed that this event is undetected, thus assuring continuance of the plasma burn and coolant recirculation. It is felt that the three monitored parameters relevant to an accident of this type, namely bulk breeding material temperature, coolant temperature, and coolant flow rate, will not change appreciably until later stages of the accident.

The reaction rate is immediate and limited by the leakage of water into the breeding material. The leakage rate, dictated by the number of broken coolant tubes, is set very low, 0.6 kg/sec (three broken tubes), to make this assumption reasonable. Although there is a suspicion that the water reaction rate of the lithium-lead alloys is slow at low temperatures, no data exists. It is also assumed that the reaction zone pressure at high temperatures does not significantly retard the leakage rate of water into the zone.

The reaction zone is very difficult to characterize. However, certain assumptions can be made. First, the zone can be considered spherical, as boiling water at 8.6 MPa will disperse equally in all directions upon tube rupture. The reaction zone must be large enough to accomodate the influx of breeder and coolant, thus the zone radius should be large compared to the coolant tube pitch length. However, to accomodate the assumption that the water reaction is instantaneous, the reaction zone volume should be small, compared to that of the blanket module.

The initial radius of the reaction zone for three ruptured coolant tubes is set at one foot. This is over six times the characteristic distance separating the three coolant tubes in question. The volume of this zone is less than 2% of the total blanket volume. This seems reasonable for the small leakage rate. Further research in this area would aid the accuracy of the model.

The reaction products (LiOH and alloy element, if any) remain in the reaction zone, thus increasing the radius of this zone with time. The heat capacity of this expanded zone is calculated summing the products of the individual heat capacity of each component multiplied by the weight percent.

The nodal structure of this system is shown in Figure 4.2. It can be seen that the reaction zone and breeder mass are broken into a number of sections. This is to more accurately account for heat transfer by conduction. The number of sections in each zone is selected so as to keep the element widths to approximately 6 inches. These elements increase and decrease in width with time in the reaction zone and breeder zone, respectively, as the reaction zone expands.

The blanket elements are spherical, like the reaction zone, to facilitate computation. The outer element is therefore irregularly shaped to account for the NUWMAK geometry. This is not expected to create any difficulty, as it is doubtful that much heat will be

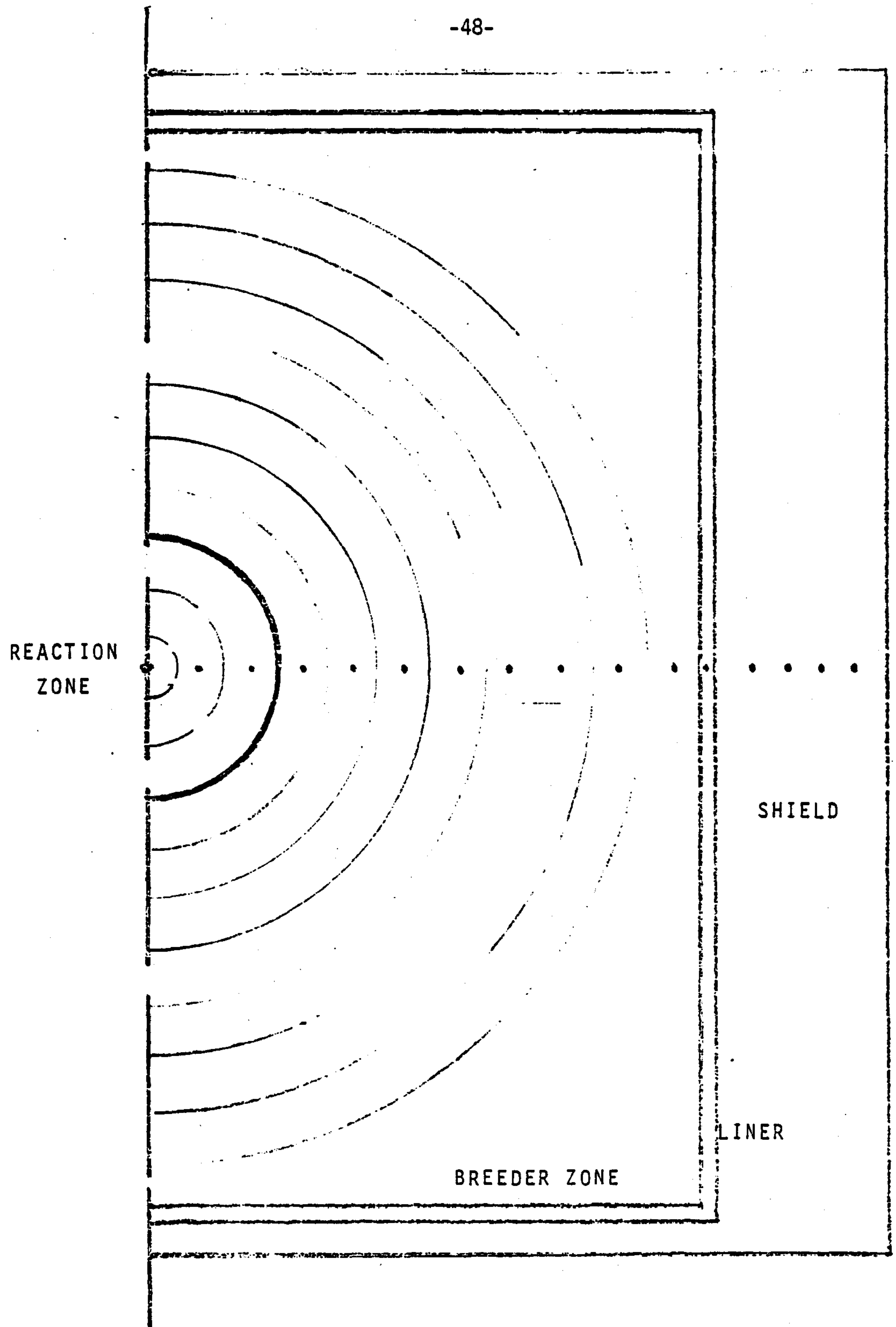


Figure 4.2 Internal Blanket Accident Option
Node Structure.

transferred to this region. For completeness, the steel liner and B_4C shield are also monitored in the code. The conduction of heat is assumed to stop at the far edge of the shield.

The heat of reaction is distributed evenly throughout the reaction zone, heating the reactants and reaction products. Heat is removed by conduction and free convection to the breeder zone, and via forced convection by unbroken coolant tubes as shown in Fig. 4.1. The surface area of cooling tubes in each element is calculated as a volume percentage of the total.

Finally, it should be noted that the densities and thermal conductivities of the lithium-lead alloys and other alternate breeders are held constant with temperature in this analysis. As discussed in the appendix, this data has only been determined at one temperature. Rather than increase uncertainties with various correlations, the values are unaltered.

4.3.2 Heat Transfer Mechanisms

A. Heat of Reaction

All of the alternate breeders considered in this study react to some extent with water. Table 4.1 shows the reactions of interest. Other reactions also take place, such as the production of Li_2O_2, but are discarded as they play a very minor role. For example, the peroxide is unstable above 250 °C [11] and is not produced above that temperature.

Reaction occurs at the reaction zone temperature T_{cz}. The heat of reaction can be calculated using

$$\Delta H_R = H^\circ_{25} + \Sigma\Delta H_{prod} - \Sigma\Delta H_{react} \, , \quad \text{Btu/lb breeder} \qquad (4.1)$$

TABLE 4.1

Breeder-Coolant Reactions of Interest

	ΔH_{hyd} (kJ/g-atom of Li)
$Li + H_2O \rightarrow LiOH + 1/2\ H_2$	205
$1/7\ Li_7Pb_2 + H_2O \rightarrow LiOH + 1/2\ H_2 + 2/7\ Pb$	200
$LiPb_4 + H_2O \rightarrow LiOH + 1/2\ H_2 + 4Pb$	170
$LiAl + H_2O \rightarrow LiOH + 1/2\ H_2 + Al$	200
$Li_2O + H_2O \rightarrow 2LiOH$	64

where H°_{25} is the standard heat of hydrolysis at 25 °C and ΔH_{prod} and ΔH_{react} are the enthalpy changes of the reaction products and reactants, respectively, as they are heated from 25 °C to T_{cz}.

Since the reaction is immediate, limited by the leakage of water into the reaction zone, the reaction rate is the leakage rate. This can be written as

$$R_w = \dot{m}\, N_T \qquad \text{lb } H_2O/\text{sec} \tag{4.2}$$

where $\dot{m}$ is the mass flow rate of water through one tube and N_T is the number of ruptured tubes. Thus, the total heat generation rate inside the reaction zone can be given by

$$Q = a_o\, \Delta H_R\, \dot{m}\, N_T \qquad \text{BTU/sec} \tag{4.3}$$

where a_o is the stoichiometric combination constant for the breeder and water in the given reaction.

B. Sensible Heat Addition to Reactants in the Reaction Zone

A portion of the heat of reaction is used to heat the inflowing coolant water and breeder to the reaction zone temperature. This can be written as

$$Q_s = N_T\, \dot{m}_w\, c_w\, (T_{cz} - T_c) + \dot{m}_b\, c_b\, (T_{cz} - T_L) \qquad \text{BTU/sec} \tag{4.4}$$

where $\dot{m}_w$ is the mass flow rate of water in a coolant tube

c_w is the mean specific heat of the coolant

$\dot{m}_b$ is the mass influx of breeder to the reaction zone

c_b is the mean specific heat of the breeder

T_c is the coolant temperature

T_L is the bulk breeder temperature.

In this case, the influx of breeder into the reaction zone is considered equal to the leakage rate of the coolant into the zone, as reaction is immediate . This mass transfer is further discussed in the free convection section.

C. Forced Convective Cooling

Forced convection, due to the continued coolant recirculation through undamaged tubes, is an important heat transfer mechanism. Because only a small number of the 475 coolant tubes in an outside blanket module are damaged, cooling will take place in both the breeding and reaction zones. The cooling tube surface area in each element can be determined as a volume percentage of the blanket as a whole. For example, the initial reaction zone, approximately 2% of the blanket by volume, comes into contact with roughly 2% of the total cooling tube surface area. This total area can be determined using the information in Table 2.7.

This total heat flow can be computed for each element using

$$Q_c = \left[\frac{\delta}{k_{Ti}A_{so}} + \frac{1}{hA_{sI}}\right]^{-1} (T_i - T_c) \qquad \text{BTU/sec} \qquad (4.5)$$

where δ is the coolant tube thickness

k_{Ti} is the thermal conductivity of the titanium alloy

A_{so} is the outer coolant tube surface area

A_{sI} is the inner coolant tube surface area

h is the boiling water heat transfer coefficient

T_i is the bulk temperature of the element in question.

D. Conduction

Conduction plays a major role in the transfer of heat from the reaction zone to the breeder mass. The heat conduction term between two elements can be expressed as

$$Q_{cond_{ij}} = A_i \left[\frac{k_i k_j}{k_i + k_j}\right] (T_i - T_j)/d_{ij} \qquad \text{BTU/sec} \qquad (4.6)$$

where A_i is the inner element surface area

k_i is the inner element thermal conductivity

k_j is the outer element thermal conductivity

T_i is the inner element bulk temperature

T_j is the outer element bulk temperature

d_{ij} is the separation distance between the elements.

The surface area assigned to each element is at its outer perimeter. In the above expression, it is assumed that the inner element is at a higher temperature, as is the case at all times in the LITFIRE option.

E. Free Convection

A preliminary order of magnitude analysis indicates that the free convective enhancement to conduction is Pr $Gr^{1/2}$, where Pr and Gr are the Prandl and Grashof numbers. For a 400 °C temperature difference between the reaction and breeder zones in the lithium case, this enhancement is better than a factor of ten. Thus, free convection is an important mode of heat transfer in the model.

As mentioned before, there will be mass transfer in the breeding zone due to the influx of this material into the reaction zone. It is this movement that allows convective cooling of the reaction zone by the first breeder zone element.

Given the spherical shape of the reaction zone, the semi-empiracle relation

$$\overline{Nu} = 2.0 + 0.60\ Gr^{1/4}\ Pr^{1/3} \tag{4.7}$$

is useful to find the average heat transfer coefficient for $Gr^{1/2} \cdot Pr^{1/3} < 200$. $\overline{Nu}$ is the average Nusselt number and is related to the average heat transfer coefficient $\overline{h}_m$ by

$$\overline{Nu} = \overline{h}_m\ L/k \tag{4.8}$$

where L, the characteristic distance, is in this case the reaction zone diameter.

Thus, the heat flow due to free convection can be described by

$$Q'_c = \frac{A_{cz}\ k_b}{D}\ (2.0 + 0.60\ Gr^{1/4}\ Pr^{1/3})(T_{cz} - T_L)\ \frac{BTU}{sec} \tag{4.9}$$

where A_{cz} is the reaction zone surface area and k_b is the bulk breeder thermal conductivity. $Gr = \frac{D^3\rho^2 g\beta\Delta T}{\mu^2}$ and $Pr = \frac{c_p\mu}{k}$ are applicable to the fluid breeders.

F. Radiation

Using an order of magnitude analysis, the radiative heat flow is related to the conductive heat flow by

$$Q_{rad} = \frac{\sigma T^3 L}{k} \; Q_{cond} \tag{4.10}$$

where σ is the Stefan-Boltzmann constant. At 1500 °F, this radiative heat flow is a factor of ten less than that of conduction in a lithium breeder. Therefore, radiation is neglected in the model.

4.3.3 The Numerical Scheme

The temperature of a thermal element may be found from the solution to

$$mc \, \frac{dT}{dt} = q_1 + q_2 + q_3 + \ldots, \quad T = T_o \text{ at } t = t_o, \tag{4.11}$$

where mc is the element's heat capacity and q_1, q_2, q_3 ... are heat flows into the element, shown in Fig. 4.1. This may also be expressed as

$$T = \int_{t_o}^{t} \frac{1}{mc} \left(q_1 + q_2 + q_3 + \ldots\right) dt + T_o. \tag{4.12}$$

In LITFIRE, this is expressed as

$$T = \text{INTGRL } (T_o, \text{ dt/dt}). \tag{4.13}$$

A set of sub-routines is used to perform the integrations using either Simpson's Rule or a Runge-Kutta method.

For example, heat flows into the reaction zone are the heat of reaction, sensible heat addition to the reactants, conduction, free convection and forced convective cooling. Therefore, the temperature of the reaction zone at time t can be determined in LITFIRE by using Eq. (4.13) and

$$\frac{dT}{dt} = \frac{1}{mc} [Q - Q_s - Q_{cR} - Q_{cond_{RL1}} - Q_c'] \tag{4.14}$$

where the subscript R denotes the reaction zone and L1 denotes the first breeder element. Q, Q_s, Q_{cR}, $Q_{cond_{RL1}}$, and Q_c' can be determined using Equations (4.3), (4.4), (4.5), (4.6), and (4.9), respectively. Similar equations can be written for each thermal element in the model.

4.4 Results and Discussion

Figure 4.3 shows the thermal response of the reaction zone (TCZ), first breeder element (TLI1) and middle breeder element (TLI4) over the first 1000 seconds for a lithium breeder accident, as described earlier in this chapter. Similar graphs are plotted in Figures 4.4 through 4.7 for Li_7Pb_2, $LiPb_4$, LiAl and Li_2O breeders, respectively. A number of interesting points are noted.

First, the general shapes of the curves in each case are similar, although different maximum temperatures are attained. A change of time step shows no appreciable difference. The reaction zone rises rapidly, reaching a maximum value within the first two minutes of the coolant tube breaks. Thereafter, the temperature decreases monotonically,

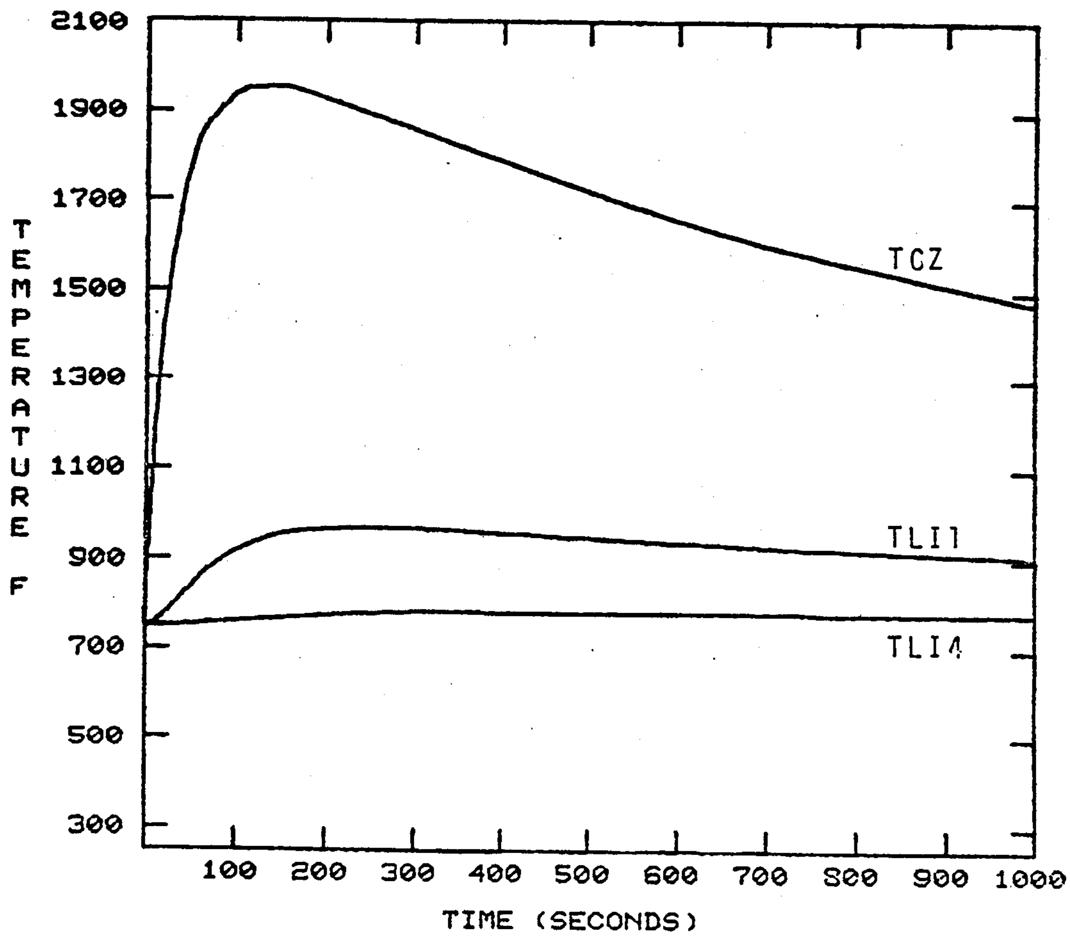


Figure 4.3 Lithium Breeder Thermal Response to Water Interaction.

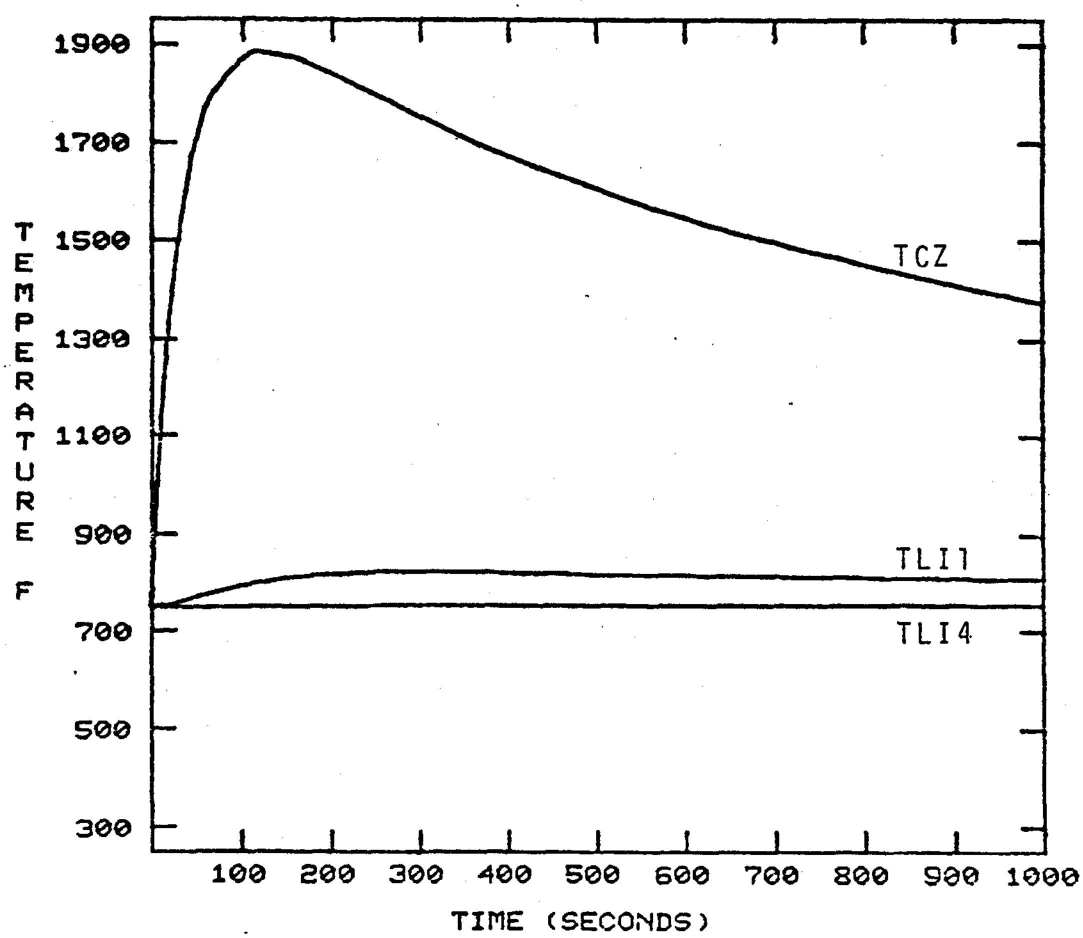


Figure 4.4 Li_7Pb_2 Breeder Thermal Response to Water Interaction.

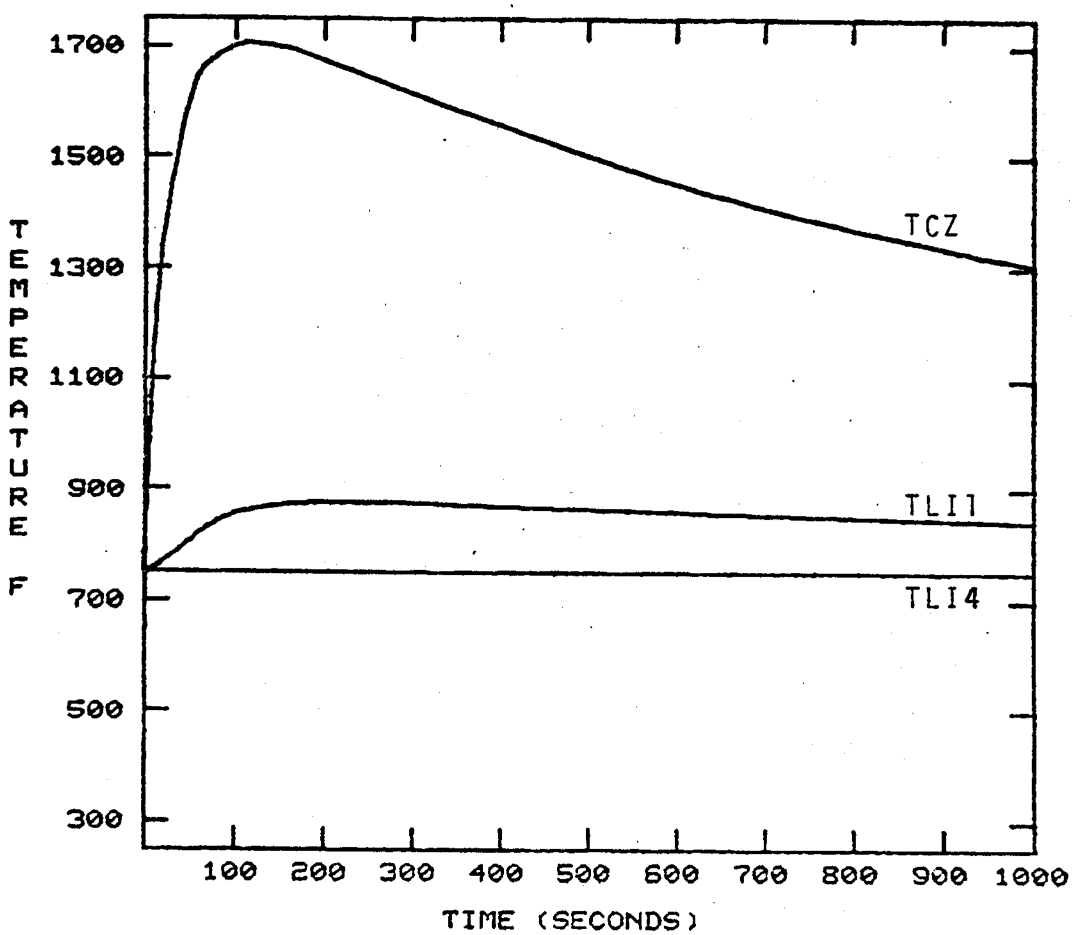


Figure 4.5 $LiPb_4$ Breeder Thermal Response to Water Interaction.

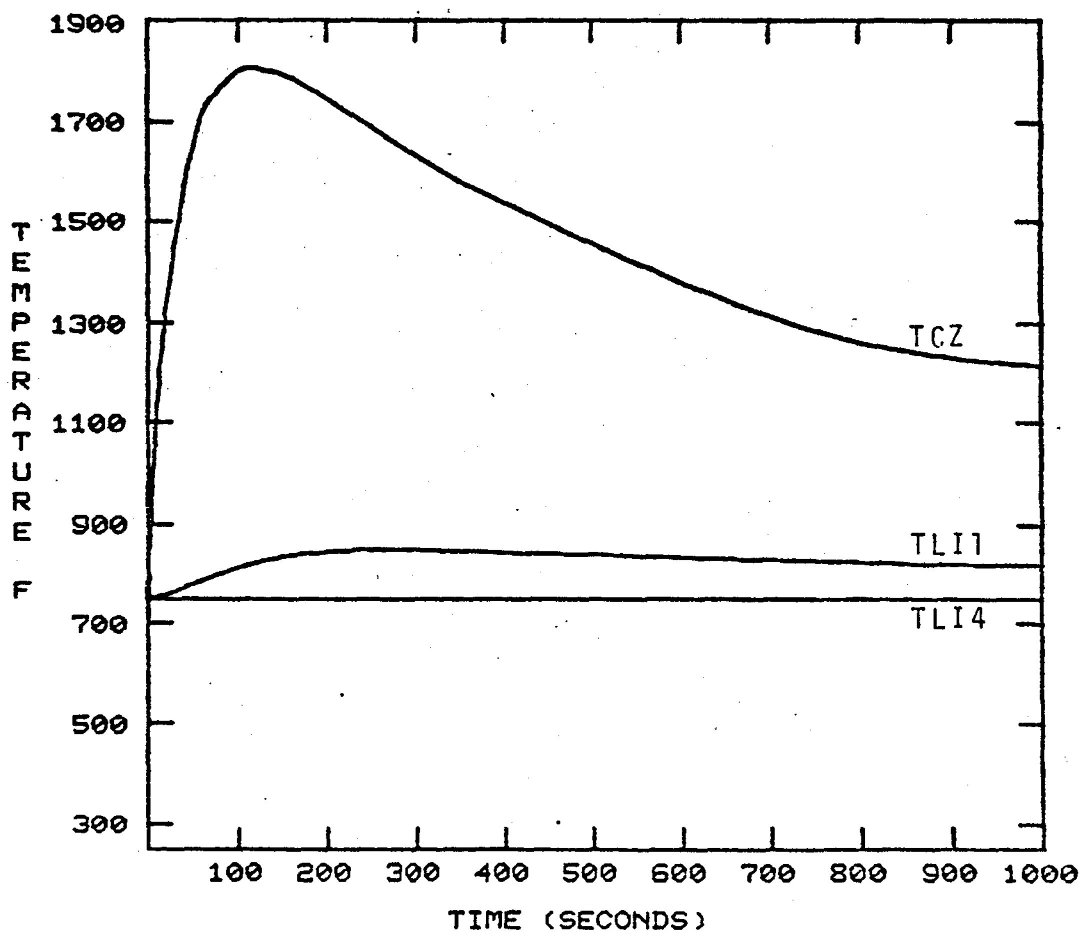


Figure 4.6 LiAl Breeder Thermal Response to Water Interaction.

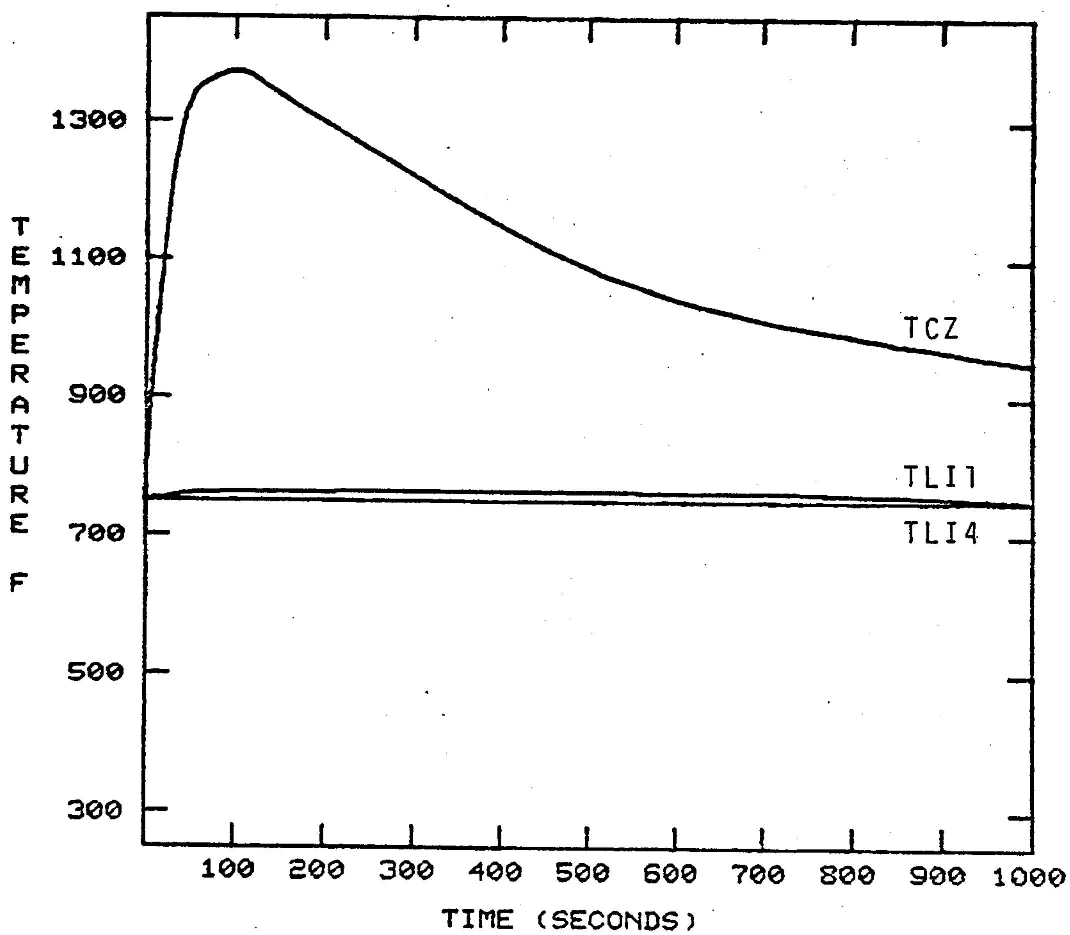


Figure 4.7 Li_2O Breeder Thermal Response to Water Interaction.

more gradually as time progresses. The first blanket element exhibits similar behavior, but at lower temperatures and lagging over a minute behind. The middle blanket element is relatively unchanged, slowly increasing 50 °F in the lithium case and nearly constant in the alternate breeders.

This behavior may be due to different characteristic times for the various heat transfer processes. The heat of reaction in the reaction zone is instantaneous and relatively large compared to the conductive and convective flows, thus a rapid initial rise. Eventually, as the temperature difference between the reaction zone and first breeder element increases, so do the conductive and convective flows and the temperature profile flattens and decreases. Thereafter, as this temperature difference decreases, the reaction zone temperature decreases more gradually. This continues until the breeder (or water, in the $LiPb_4$ case) is depleted, eliminating the heat of reaction. Thereafter, all zones are eventually recooled to 752 °F. The first 1000 seconds are shown as the entire process takes upwards to 11 hours (4×10^4 seconds).

The relatively small volume of the reaction zone (less than 2% of the blanket module volume) may account for both the high temperatures attained in the reaction zone and the large temperature difference between this zone and the first breeder element (approximately 1000 °F in the lithium run). A small volume implies a small mass and surface area. The small mass is very sensitive to the heat of reaction and the small surface area impedes conductive and convective flows out. As the reaction zone expands, this effect is diminished.

The blanket liner, shield and other breeder elements were also monitored. All zones outside of the fourth breeder element showed no significant change. Thus, the accident appears to be effectively localized. The second and third breeder elements showed similar behavior as the first, with progressively shorter time lags.

Figure 4.8 presents a comparison of the reaction zone temperature profiles for the various breeders. As expected, the liquid lithium breeder produces the highest temperatures. Also expected, using the results of Chapter 3 as reference, is that the Li_2O breeder temperatures are significantly less. This breeder has a definite safety advantage compared to pure lithium.

The same can not be said, however, of the lithium-lead breeders and LiAl. Though less, the resulting temperatures are well within the range of the lithium case, as close as 70 °F (Li_7Pb_2) and not further apart than 250 °F ($LiPb_4$). These differences are insignificant at a base temperature of 1950 °F.

This result was surprising in the case of $LiPb_4$. Equation (4.14) indicates that the temperature rate of change in the reaction zone is inversely proportional to the reaction zone mass. Since the reaction zone volume is initially fixed and there is a factor of 20 increase in the density of $LiPb_4$ over that of Li (at 400 °C, the density of Li is 0.51 g/cm^3; the density of $LiPb_4$ is 9.9 g/cm^3), it was felt that the temperature rise would be proportionally decreased.

However, a closer look at Eq. (4.14) indicates that the temperature rate of change is also inversely proportional to the reaction zone specific heat. In this case, the specific heat of $LiPb_4$, approximately

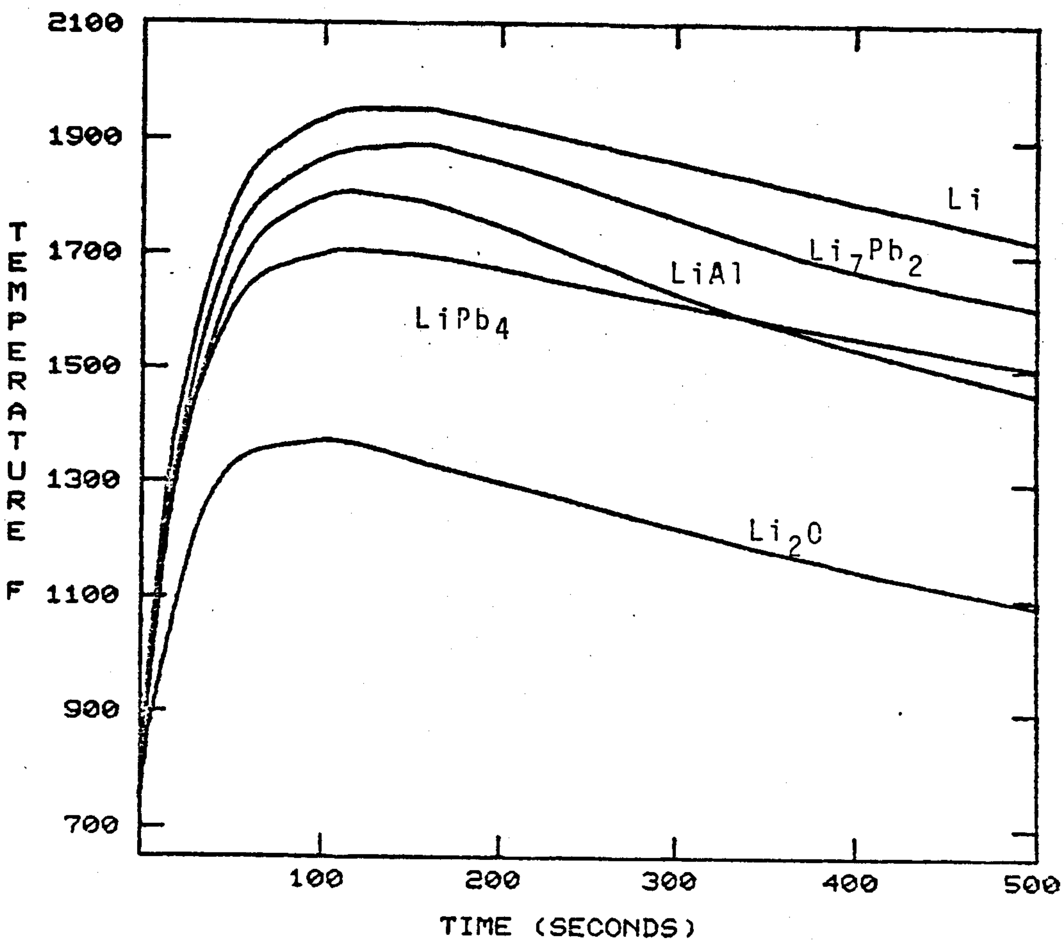


Figure 4.8 Comparison of Reactor Zone Temperature Profiles of the Various Breeders

that of Pb, is nearly a factor of 20 less than that of pure lithium (at 400 °C, the specific heat of lithium is 1.01 cal/g - °F; that of $LiPb_4$ is 0.041 cal/g - °F). Thus, the terms in the denominator of Eq. (4.14) effectively cancel each other out and the slightly different reaction zone temperature profiles of Li and $LiPb_4$ are simply a reflection of the slightly different heats of reaction of the two breeders with water.

A comparison of the thermal responses of the first breeder elements for the various breeders, shown in Fig. 4.9, is also interesting. Again, the lithium case produces the highest temperatures and the Li_2O case produces the lowest. The lithium-lead alloy and LiAl results are again similar. Here the Li_7Pb_2 element is cooler overall due to a very low thermal conductivity, experienced in the lithium-lead system at a 20% lithium atom percentage [13]. However, in this comparison, the differences between these alloys and the lithium case are more pronounced. This indicates that the use of liquid lithium will produce more widespread accidental consequences.

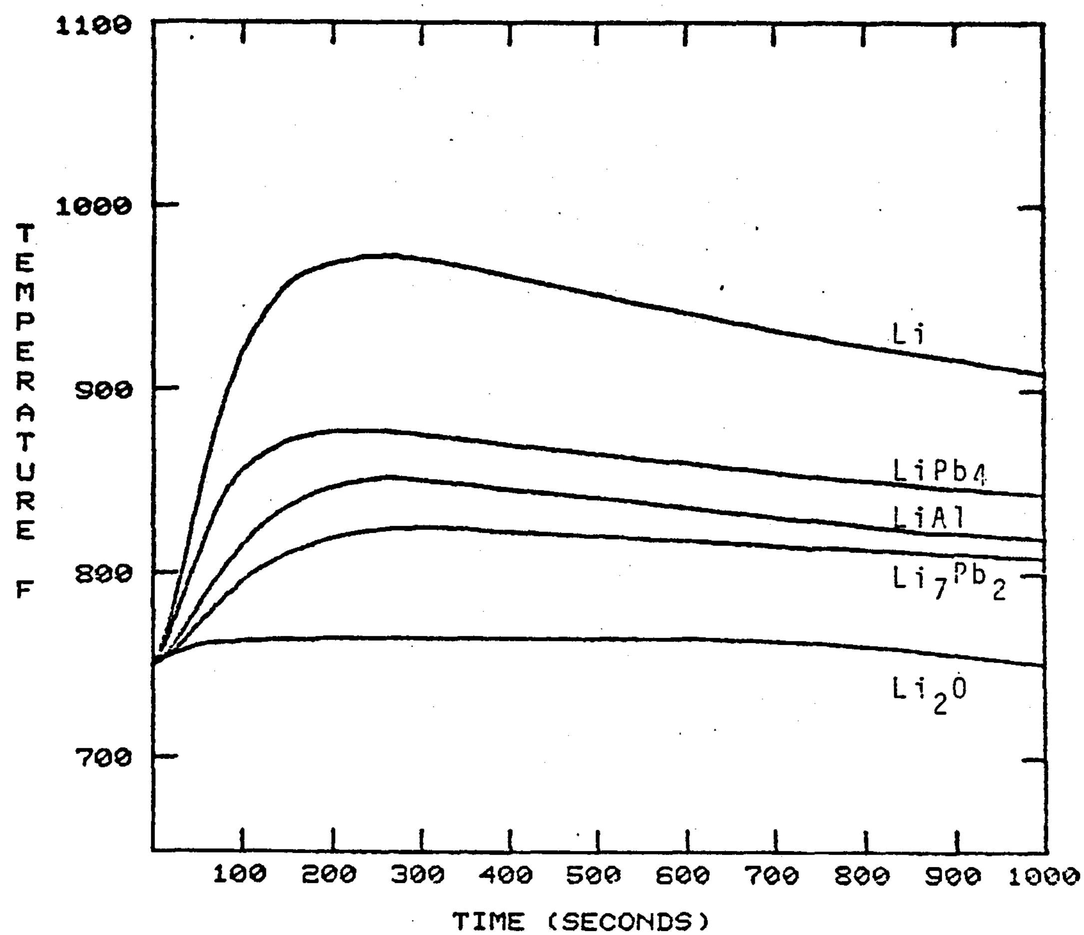


Figure 4.9 Comparison of First Breeder Element Temperature Profiles of the Various Breeders.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

Results indicate that the lithium-lead alloys may not be significantly safer than pure lithium as a fusion reactor breeding material, utilizing the NUWMAK geometry. In both calculations, short term temperatures resulting from interaction of Li_7Pb_2 and $LiPb_4$ with water, though lower, are within a few hundred degrees of those associated with the use of liquid lithium.

However, a proper conclusion to this study is that a conclusion cannot yet be made. The calculations of Chapters 3 and 4 provide an overview of the safety question, raising some interesting observations and determining areas that need to be explored in more detail.

First, the lithium-lead alloys and LiAl can pose safety problems approximate to those of liquid lithium, as noted above. This can be quite serious, as shown in Chapter 3, with temperatures reaching to the melting point of steel in a water-cooled blanket. For this reason alone, further study of these alternate breeders is required.

Results of Chapter 4 indicate that such an interaction could go undetected, as a continuance in coolant recirculation may keep the consequences localized. Measurable quantities, like bulk breeder temperature and coolant temperature and flow rate are practically unperturbed. Thus, further design work might include features to mitigate this problem.

Uncertainties in characterizing the reaction zone in the dynamic model render the resulting temperature profiles less meaningful. Further work in this area, perhaps experimental, would make the model more accurate.

Finally, better physical properties data on the alternate breeders is required. In particular, an understanding of the water reaction rates is central to the study of these materials. If it can be proved, as surmized, that these rates are significantly lower than those of liquid lithium, a significant reduction in safety hazards may be assured.

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APPENDIX A

Physical Property Data

Table A.1 summarizes the important physical property data of the various alternate breeders analyzed in this report. Except as indicated, all of these values are gathered from the previously identified references. It is important to realize that, aside from the lithium and melting point data, all numbers are estimates at best.

For reasons detailed earlier, only the physical properties of the lithium breeder are allowed to vary with temperature in calculations of Chapters 3 and 4. The correlations used are:

$$\rho = 0.5368 - 1.0208 \times 10^{-4} T \ (\text{g/cm}^3)$$

$$k = 10.48 + 4.98 \times 10^{-3}(T - 180.6) - 0.58 \times 10^{-6}(T - 180.6)^2 \ (\text{cal/sec-m-°C})$$

$$c_p = 1.0037 - 0.01063x + 0.00564x^2 - 0.001279x^3 \ (\text{cal/g °C})$$

where $x = .004938T - 6.20741$

Here, ρ = density of lithium

k = thermal conductivity of lithium

c_p = specific heat of lithium

T = lithium temperature in °C

The latent heats of melting for the alloy breeders are determined using the correlation

$$H_{melt}/T_{melt} \sim 2.2$$

This is an average value for metallic alloys [14].

The thermal conductivity of $LiPb_4$ is estimated with the correlation

$$k_m = k_1 w_1 + k_2 w_2 - 0.72(k_2 - k_1)(w_1 w_2)$$

This is appropriate for a binary liquid mixture. Here, the weight fraction w_2 refers to the component having the larger value of k [14].

The specific heat data of the alloy breeders is determined using the relation

$$c_{p_{alloy}} = X_{Li}\, c_{p_{Li}} + X_A\, c_{pA}$$

where X_{Li} = weight fraction of lithium

X_A = weight fraction of the alloy element

c_{pA} = specific heat of the alloy element

$c_{p_{Li}}$ = specific heat of lithium

The specific heat values for the alloy elements, lead and aluminum, can be found in the literature.

TABLE A.1

Summary of Physical Properties of Candidate Breeding Materials at Standard Conditions

Properties	Lithium	Li_7Pb_2	$LiPb_4$	LiAl	Li_2O
Melting Point, °K	453	999	508	973	1970
ΔH_{melt}, cal/g mole	722.4	2200[a]	1120[a]	2140[a]	—
Density, g/cm^3	0.51	4.59	9.9	1.76	2.01
Li atom density, g/cm^3	0.51	0.49	0.08	0.37	0.93
Thermal conductivity w/m-k	50	∿20	∿35[a]	30	1.73
Specific Heat cal/g °K	1.01	0.14[b]	0.041[b]	0.44[b]	0.35
Heat of Reaction with Water $\frac{kJ}{g\text{-atom Li}}$	245	200	170[c]	200	64
Atomic weight	7	463	835	34	30

a. correlation

b. interpolated value

c. estimated

APPENDIX B

Complete Listing of LITFIRE

```
C      LITFIRE COMPUTER CODE IS A MODIFICATION OF THE CODE SPOOL-FIRE DELIT00010
C      AT ARGONNE NATIONAL LABORATORY.  LITFIRE DESCRIBES THE TEMPERATURLIT00020
C      PRESSURE HISTORY OF A FUSION REACTOR CONTAINMENT TO LITHIUM FIRE LIT00030
C      AND WAS DEVELOPED IN THE NUCLEAR ENGINEERING DEPARTMENT AT MIT INLIT00040
C                                                                       LIT00050
C        THIS VERSION OF LITFIRE HAS A MANDATORY ONE NODE IN THE LITHIUMLIT00060
C     POOL, WITH A SUSPENDED (INSULATED) PAN OPTION                     LIT00070
C      THE CONTAINMENT IS SINGLE CELL                                   LIT00080
C     DEFINITION OF VARIABLES AND UNITS                                 LIT00090
C                                                                       LIT00100
C      THIS IS A RELATIVELY COMPLETE LISTING OF THE VARIABLES,CONSTANTS,LIT00110
C      PARAMETERS USED IN THE COMPUTER CODE LITFIRE II , ACCURATE AS OF LIT00120
C      SEPTEMBER 30, 1980.    FURTHER DOCUMENTATION ABD SOME DERIVATIONSLIT00130
C      MAY BE FOUND IN THE LITFIRE PROGRAMMER'S MANUAL                  LIT00140
C                                                                       LIT00150
C      AINS     OUTSIDE EXPOSED AREA OF INSULATING LAYER ON PAN  (FT2)  LIT00160
C      AKLI    THERMAL CONDUCTIVITY OF LITHIUM   BTU/FT.-SEC. DEG. F    LIT00170
C              INPUT AS BTU/FT. HR. DEG. F                              LIT00180
C      AK1,AK2   PROD. OF THERMAL COND. AND PRANDTL NO.  BTU/SEC-FT-DEG.LIT00190
C     AMLI       ATOMIC MASS OF BREEDER                                 LIT00200
C      AMPB      ATOMIC MASS OF ALLOY METAL                             LIT00210
C      APAN    PAN EXTERNAL AREA FOR HEAT TRANSFER                      LIT00220
C        ARE         SURFACE AREA OF BREEDER ELEMENT                    LIT00230
C      ASLI SURFACE AREA OF LITHIUM        FT2                          LIT00240
C     ATI      INNER SURFACE AREA OD COOLANT TUBES IN ELEMENT           LIT00250
C      ATO     OUTER SURFACE AREA OF COOLANT TUBES IN ELEMENT           LIT00260
C      AW     EXPOSED WALL AREA    FT2                                  LIT00270
C      AWB        AREA OF THE STEEL CONTAINMENT BELOW THE SPILL PAN    FTLIT00280
C      B   USED IN CALC. THERMAL RESIST. OF LINER-GAP-CONC.   FT.       LIT00290
C      BB           ANALOGOUS TO B , ONLY FOR FLOOR CONCRETE            LIT00300
C      B1 & B2   COEFFICIENT OF GAS EXPANSION  ,   1/DEG. F             LIT00310
C      BLIN   TIME AFTER SPILL AT WHICH INERT GAS FLOODING AND          LIT00320
C             EXHAUST BEGINS   SEC                                      LIT00330
C      BLOUT   TIME AFTER SPILL AT WHICH FLOODING AND EXHAUST STOPS  SECLIT00340
C      BLOWR  INERT GAS INPUT RATE  LB/SEC                              LIT00350
C      BLOWV   INERT GAS INPUR RA.E    FT3/MIN                          LIT00360
C      BREDTH     LENGTH AROUND THE SIDE OF THE SPILL PAN   IN FEET     LIT00370
C  *** "C" IS THE INITIAL USED FOR INDICATIONG A THERMAL DIFFUSIVITY.  ILIT00380
C      CONDUCTIVITY BETWEEN TWO NODES DIVIDED BY THE HEAT CAPACITY OF ONLIT00390
C      THOSE NODES                                                      LIT00400
C      C1     CONTAINMENT GAS TO WALL STEEL       IN GAS                LIT00410
C      C2     PAN TO CONT GAS            IN GAS                         LIT00420
C      C3     STEEL LINER TO CONCRETE WALL        IN WALL               LIT00430
C      C4(I)  CONCRETE NODE I TO NODE I+1         IN WALL CONCRETE      LIT00440
C      C5     CONCRETE WALL TO AMBIENT            IN CONCRETE           LIT00450
C      C6     CONTAINMENT GAS TO WALL STEEL       IN STEEL              LIT00460
C      C7     STEEL LINER TO CONCRETE WALL        IN STEEL              LIT00470
C      C8     STEEL LINER TO CONCRETE FLOOR       IN STEEL              LIT00480
C      C9     STEEL LINER TO CONCRETE FLOOR       IN CONCRETE           LIT00490
C      C10(I) CONCRETE FLOOR NODE I TO NODE I+1  IN FLOOR CONCRETE      LIT00500
C      C11    STEEL TO AMBIENT (NO CONCRETE OPTION)  IN STEEL           LIT00510
C      C13    PAN TO GAS           IN PAN                               LIT00520
C      CCZG   COMBUSTION ZONE TO CONTAINMENT GAS IN GAS                 LIT00530
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C      CCZP   POOL TO COMBUSTION ZONE            IN POOL                 LIT00540
C      CGCZ   COMBUSTION ZONE TO CONTAINMENT GAS IN COMBUSTION ZONE      LIT00550
C      CGLI   POOL TO CONTAINMENT GAS (NO COMBUSTION)  IN POOL           LIT00560
C      CH   CONTAINMENT HEIGHT      FT                                   LIT00570
C      CIN12      INNER TO OUTER INSULATION         IN INNER INSULATION LIT00580
C      CIN21      INNER TO OUTER INSULATION         IN OUTER INSULATION LIT00590
C      CIN1PN      STEEL PAN TO INNER INSULATION          IN INSULATION  LIT00600
C      CLIG   POOL TO CONTAINMENT GAS (NO COMBUSTION)  IN GAS            LIT00610
C      CLIPAN      POOL TO SPILL PAN   IN POOL     (SUSP PAN OPTION)     LIT00620
C      CLIST  LITHIUM POOL TO FLOOR STEEL        IN LITHIUM              LIT00630
C      CPANLI     POOL TO PAN            IN PAN                          LIT00640
C      CPCZ   LITHIUM POOL TO COMBUSTION ZONE    IN COMBUSTION ZONE      LIT00650
C      CPNIN1      STEEL PAN TO INNER INSULATION          IN PAN         LIT00660
C      CSBLI  LITHIUM POOL TO FLOOR STEEL        IN STEEL                LIT00670
C      CCZ         AMOUNT OF HEAT BEING DEVELOPED IN THE COMB. ZONE  (BTLIT00680
C      CMBR     TOTAL COMBUSTION RATE      LB. LI/SEC.-FT2               LIT00690
C      CMBRH    TOTAL COMBUSTION RATE      LB. LI/HR.-FT2                LIT00700
C      CMBRHI   INITIAL COMBUSTION RATE   LB. LI/HR-FT2                  LIT00710
C      CMBRN  COMB. RATE FOR NITROGEN REACTION  LB. LI/SEC.-FT2          LIT00720
C      CMBRO  COMB. RATE FOR OXYGEN REACTION   LB. LI/SEC.-FT2           LIT00730
C      CMBRW  COMB. RATE FOR WATER VAPOR REACTION   LB. LI/SEC.-FT2      LIT00740
C      CPA  INERT GAS SPECIFIC HEAT  BTU/LB.-DEG. F                      LIT00750
C      CPAB   SPEC. HEAT OF FLOODING GAS  BTU/LB-DEG.F                   LIT00760
C      CPCON       HEAT CAPACITY OF FLOOR AND WALL CONCRETE              LIT00770
C      CPH2        HEAT CAPACITY OF HYDROGEN GAS                         LIT00780
C      CPINS     SPECIFIC HEAT OF INSULATION   BTU/LB DEG F              LIT00790
C      CPLI SPECIFIC HEAT OF LI        BTU/LB. -DEG. F                   LIT00800
C       CPLI1       MEAN HEAT CAPACITY OF BREEDER AS SOLID    BTU/LB MOLLIT00810
C      CPLIN  SPEC. HEAT OF LITHIUM NITRIDE          BTU/LB.-DEG. F      LIT00820
C      CPLIO      SPECIFIC HEAT OF LITHIUM OXIDE   BTU/LB.-DEG. F        LIT00830
C      CPLIOH     SPECIFIC HEAT OF LIOH           BTU/LB-MOLE F          LIT00840
C      CPMCZ     EFFECTIVE HEAT CAPACITY OF COMB. ZONE   BTU/DEG F       LIT00850
C      CPMH2    HEAT CAPACITY OF HYDROGEN IN CONTAINMENT   BTU/DEG. F    LIT00860
C      CPMLIH   HEAT CAP. OF LITH. HYDROXIDE IN CONT.      BTU/DEG. F    LIT00870
C      CPMLIN   HEAT CAP. OF LITH. NITRIDE IN CONT.      BTU/DEG. F      LIT00880
C      CPMLIO   HEAT CAP. OF LITHIUM OXIDE IN CONTAINMENT   BTU/DEG. F   LIT00890
C      CPMNI   HEAT CAPACITY OF NITROGEN IN CONTAINMENT   BTU/DEG. F     LIT00900
C      CPMOX   HEAT CAPACITY OF OXYGEN IN CONTAINMENT   BTU/DEG. F       LIT00910
C      CPMWA    HEAT CAP. OF WATER VAP. IN CONTAINMENT    BTU/DEG. F     LIT00920
C      CPN2        HEAT CAPACITY OF NITROGEN GAS                         LIT00930
C      CPPAN     SPECIFIC HEAT OF SPILL PAN     BTU/LB-DEG F             LIT00940
C       CPPB    HEAT CAPACITY OF ALLOY METAL IN BREEDER ZONE   BTU/LB-F LIT00950
C      CPPB1      MEAN HEAT CAPACITY OF ALLOY METAL SOLID    BTU/LB MOLELIT00960
C      CPPL    LIQUID HEAT CAPACITY OF ALLOY METAL        BTU/LB R       LIT00970
C     CPPZ    HEAT CAPACITY OF ALLOY METAL IN REACTION ZONE   BTU/LM F  LIT00980
C      CP1     USED TO CALCULATE CP CHANGE OF ALLOY METAL   BTU/LB R    LIT00990
C      CP2         USED TO CALCULATE CP CHANGE OF ALLOY METAL   BTU/LB RLIT01000
C      CPSTL       HEAT CAPACITY OF STEEL LINER    (BTU/LB-DEG F)        LIT01010
C      CPWA     SPEC. HEAT OF WATER VAPOR     BTU/LB.-DEG. F             LIT01020
C      CF       THERMAL IMPEDANCE BETWEEN BREEDER ELEMENTS   IN INNER ELLIT01030
C     CT     THERMAL IMPEDANCE BETWEEN BREEDER ELEMENTS   IN OUTER ELEMELIT01040
C      DELH    STANDARD HEAT OF HYDROLSIS OF BREEDER      BTU/LB MOLE   LIT01050
C      DELOUT   OUT TIME STEP    SEC.                                    LIT01060
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C      DELT      INTEGRATION TIME STEP    SEC.                         LIT01070
C      DFILM        LITHIUM VAPOR FILM THICKNESS      FT    (OUTPUT IN INLIT01080
C      DIFF       DIFFUSION  OEFF. TO COMB. ZONE    FT2/SEC.            LIT01090
C      DIFFLI       LITHIUM VAPOR DIFFUSION COEFFICIENT    FT2/SEC      LIT01100
C     DPROD    'ENTHALPY CHANGE OF REACTION PRODUCTS IN REACTION ZONE    LIT01110
C      DP1,DP2,DP3      PSIA INCREASE IN CONTAINMENT PRESSURE DUE TO EACLIT01120
C      DREAC     ENTHALPY CHANGE OF REACTANTS IN REACTION ZONE          LIT01130
C      DT1          POOL TIME STEP     (TEMP./RATE OF CHANGE OF TEMP.)  LIT01140
C      DT2          CONT. GAS TIME STEP                                 LIT01150
C      DT3          STEEL WALL TIME STEP                                LIT01160
C      DT4          COMBUSTION RATE TIME STEP                           LIT01170
C      DT5          COMBUSTION ZONE TEMP. TIME STEP                     LIT01180
C      DTBDT(I)   CONC. FLOOR TEMP. RATE OF CHANGE, NODE I   DEG. F/SEC.LIT01190
C      DTCDT(I)   CONC. WALL TEMP. RATE OF CHANGE, NODE I   DEG. F/SEC. LIT01200
C      DTMIN   MINIMUM TIME STEP TO BE USED   SEC.                      LIT01210
C      DT1,...DT4   USED IN CALCULATING TIME STEP   SEC.                LIT01220
C      DYNAMI   SUBROUTINE USED IN CONTROLLING INTEGRATION LOOPS        LIT01230
C      D1,D2   KINEMATIC VISCOSITY OF CELL GAS (SQUARED)   FT4/SEC2     LIT01240
C      EFILM        FILM DEPTH OF DEPLETED ZONE ABOVE COMB. ZONE (IN INCHLIT01250
C      EMCONC     THERMAL EMISSIVITY OF CONCRETE                        LIT01260
C      EMCZ     THERMAL EMISSIVITY OF COMBUSTION ZONE                   LIT01270
C      EMG   THERMAL EMISSIVITY OF CELL GAS                             LIT01280
C      EMINS      THERMAL EMISSIVITY OF INSULATION AROUND PAN           LIT01290
C      EMLI    THERMAL EMISSIVITY OF LITHIUM POOL                       LIT01300
C      EMSTL      THERMAL EMISSIVITY OF STEEL LINER                     LIT01310
C      ESCR   HEAT REMOVAL RATE BY EMERGENCY SPACE COOLING   BTU/SEC    LIT01320
C      ESCTIN   TIME AFTER SPILL WHEN ESCR BEGINS   SEC                 LIT01330
C      EXHSTR  RATE OF CONTAINMENT GAS EXHAUST  LB/SEC                  LIT01340
C      EXHSTV   RATE OF CONTAINMENT GAS EXHAUST   FT3/SEC               LIT01350
C      EXX   USED IN CALC. MASS & HEAT TRANSF. COEFF.    1/FT3          LIT01360
C      EX1,EX2   USED IN CALCULATING MASS & HEAT TRANSF. COEFF.  1/FT   LIT01370
C      FCT1,FCT2,FCT3      FRACTION OF NITROGEN PRESENT IN EACH INJECTIONLIT01380
C      FF1,FF2   USED IN HEAT BALANCE EQS. FOR SPRAY FIRE   BTU         LIT01390
C      FMLEAK   FRACT. OF MASS LEAKED OUT OF CONTAINMENT                LIT01400
C      FMLEFT       FRACTION OF MASS STILL WITHIN CONTAINMENT           LIT01410
C      FNI   WT. FRACTION OF NITROGEN IN CELL GAS                       LIT01420
C      FOUT         LOSS RATE OF CONT. GAS WHICH EITHER LEAKS OR IS EXHAULIT01430
C      FOX   WT. FRACTION OF OXYGEN IN CELL GAS                         LIT01440
C      FRA    FRACTION OF COMBUSTION PRODUCTS EVOLVED INTO CELL GAS     LIT01450
C      FWA    WT. FRACTION OF WATER VAPOR IN CELL GAS                   LIT01460
C      G   AIR GAP BETWEEN STEEL LINER AND CONCRETE FLOOR   FT.         LIT01470
C             (INPUT AS INCHES)                                         LIT01480
C      GIN   GRAVITATIONAL CONSTANT      32.2 FT/SEC2                   LIT01490
C      H   INTERIOR FILM COEF.   BTU/SEC-FT**2-DEG. F                   LIT01500
C      HA       EXTERIOR FILM COEF.   BTU/SEC. FT**2 DEG. F             LIT01510
C             (INPUT AS BTU/HR FT**2 DEG F                              LIT01520
C      HB     HEAT TRANSFER COEFFICIENT TO POOL   BTU/SEC-FT2-DEG F     LIT01530
C      HBINF        EQUILIBRIUM VALUE OF HB                             LIT01540
C      HCO      HEAT TRANSFER COEFICIENT OF BOILING WATER   BTU/SEC-FT2 LIT01550
C      HF   GAS TRANSPORT COEFF. TO POOL     FT/SEC.                    LIT01560
C      HFINF        EQUILIBRIUM VALUE OF HF                             LIT01570
C      HIN COEFFICIENT FOR HEAT TRANSFER CORRELATIONS (H, HB, HF)       LIT01580
C      HTCAPG  HEAT CAPACITY OF CONTAINMENT ATMOSPHERE  BTU/DEG.F       LIT01590
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C       I            GENERAL PURPOSE DO LOOP INDEX                         LIT01600
C       IB           DO LOOP INDEX USED FOR FLOOR CONCRETE ITERATIONS      LIT01610
C       INIT    INITIALIZING SUBROUTINE FOR INTEGRATION CALCULATIONS       LIT01620
C       INJEC1,INJEC2,INJEC3      FLAGS FOR GAS INJECTION ... INJEC=1 INDILIT01630
C                                 THAT THE PARTICULAR INJECTION HAS OCCURRLIT01640
C       INTGRL   ARITHMETIC STATEMENT FUNCTION FOR FINDING INTEGRALS       LIT01650
C      J1=1     IF LITHIUM IS BREEDER                                      LIT01660
C       J2=1     IF HYDROGEN IS EVOLVED                                    LIT01670
C       K     LEAK RATE CONSTANT FROM CONTAINMENT    2.588E-09             LIT01680
C       KCON         THERMAL CONDUCTIVITY OF THE FLOOR AND WALL CONCRETE   LIT01690
C       KGAP         THERMAL COND. OF THE AIR GAP BETWEEN THE LINER AND COLIT01700
C       KFILM    THERM. COND. OF LI POOL/COMB. ZONE FILM  BTU/SEC-FT-F     LIT01710
C       KIN1     THERMAL CONDUCTIVITY OF INNER INSULATION - CALC. IN PROGLIT01720
C       KIN2     THERMAL CONDUCTIVITY OF OUTER INSULATION - CALC. IN PROGLIT01730
C       KPAN      THERMAL CONDUCTIVITY OF LI PAN      BBTU/HR-FT-DEG F     LIT01740
C       KSTL         THERMAL CONDUCTIVITY OF THE STEEL LINER (BTU/HR-FT-DELIT01750
C       L    CONCRETE WALL ELEMENT THICKNESS    FT.                        LIT01760
C       LBN        DISTANCE BETWEEN TWO BREEDER ELEMENTS                   LIT01770
C       LEAK    CELL GAS LEAKAGE RATE FROM CONTAINMENT    1/SEC.           LIT01780
C       LEAKO    INITIAL CELL GAS LEAKAGE RATE FROM CONTAINMENT  1/SEC.    LIT01790
C       LIBP     LITHIUM BURNED IN POOL FIRE         LB.                   LIT01800
C       LIC         MASS OF LITHIUM IN CONTAINMENT         LB.             LIT01810
C       LIL          AMOUNT OF LI LEFT IN POOL , BUT NOT ALLOWED TO BE LESLIT01820
C                    THAN LIT/10 FOR NUMERICAL STABILITY IN HEAT TRANSFER LIT01830
C       LILP         TRUE AMOUNT OF LITHIUM IN POOL  (LB)                  LIT01840
C       LIS      LITHIUM USED IN SPRAY FIRE          LB.                   LIT01850
C       LIT        MASS OF LITHIUM IN POOL INITIALLY       LB.             LIT01860
C       L1    CONCRETE FLOOR ELEMENT THICKNESS    FT.                      LIT01870
C       MA    WT. OF INERT GAS IN CELL      LB.                            LIT01880
C       MAI          INITIAL MASS OF INERT GAS IN CONTAINMENT  (LB)        LIT01890
C       MAIR    WT. OF CELL GAS    LB.                                     LIT01900
C       MB       MASS OF BREEDER ELEMENT           LB MOLE                 LIT01910
C        MCZ          REACTION ZONE MASS             LB MOLES              LIT01920
C       MCZ1        INITIAL REACTION ZONE MASS          LB MOLE            LIT01930
C       MH2     WT. OF HYDROGEN IN CONT. CELL GAS     LB.                  LIT01940
C       MLIH      WT. OF LITHIUM HRYDROXIDE IN CONT. CELL GAS    LB.       LIT01950
C       MLIN      WT. OF LITHIUM NITRIDE IN CONT. GAS CELL       LB.       LIT01960
C       MLINI    MASS OF LITHIUM NITRIDE IN CONT. INITIALLY    LB          LIT01970
C       MLIO    WEIGHT OF LITHIUM OXIDE IN CELL GAS. PRESENTLY ALL OT THE LIT01980
C               SPRAY FIRE PRODUCT REMAINS IN THE CELL GAS.  A FRACTION    LIT01990
C               OF THE PRODUCTS FROM THE POOL FIRE IS ADDED      LB.       LIT02000
C       MLIOI    MASS OF LITHIUM OXIDE IN CONT. INITIALLY    LB            LIT02010
C       MLIOH  ` MASS OF LIOH PRODUCT IN LB MOLES                          LIT02020
C       MNI      WEIGHT OF NITROGEN IN CONTAINMENT CELL GAS      LB.       LIT02030
C       MNII    INITIAL WEIGHT OF NITROGEN IN CONTAINMENT   LB             LIT02040
C       MNIINJ         RATE OF INJECTION OF NITROGEN DURING A 60 SEC INTERVALLIT02050
C                      USED TO MODEL HEDL PROCEDURE    (LB/SEC)            LIT02060
C       MNINJ1,MNINJ2,MNINJ3       MASS OF NITROGEN INJECTED  (LBS)        LIT02070
C       MOX     WEIGHT OF OXYGEN IN CELL GAS     LB.                       LIT02080
C       MOXI    INITIAL WEIGHT OF OXYGEN IN CONTAINMENT    LB.             LIT02090
C       MOXINJ        RATE OF INJECTION OF OXYGEN USED TO MODEL HEDL EXPERILIT02100
C                     PROCEDURE.   OCCURS DURING A 60 SEC. INTERVAL(LB./SECLIT02110
C       MOINJ1,MOINJ2,MOINJ3       MASS OF OXYGEN INJECTED (LBS.)          LIT02120
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C       MPB         MASS OF ALLOY METAL PRODUCT IN LB MOLES             LIT02130
C      MWA    WEIGHT OF WAT. VAP. IN CONTAINMENT CELL GAS    LB.        LIT02140
C      MWAI    MASS OF WATER VAPOR IN CONT. CELL GAS INITIALLY   LB     LIT02150
C       NA        NUMBER OF ELEMENTS IN BREEDER ZONE                    LIT02160
C      NAME(I)   INPUT CONTAINING PROGRAM TITLE AND HEADING             LIT02170
C      NL = NUMBER OF CONCRETE WALL NODES                               LIT02180
C      NL1 = NUMBER OF CONCRETE FLOOR NODES                             LIT02190
C      NLM1,NL1M1      WALL AND FLOOR CONCRETE NUMBER OF NODES MINUS ONE LIT02200
C      NT     NUMBER OF COOLANT TUBES DAMAGED                           LIT02210
C      OUTINT       LEAK FRACTION                                       LIT02220
C      OVERP   CONTAINMENT OVER PRESSURE   PSIG                         LIT02230
C      OXLB OXYGEN BURNED   LB.                                         LIT02240
C      OXLBI   OXYGEN BURNED INITIALLY   LB.                            LIT02250
C      OXLFS   OXYGEN LEFT AFTER SPRAY FIRE   LB.                       LIT02260
C      PA.  GAS PRESSURE IN CELL    PSIA                                LIT02270
C      PAZERO   INITIAL CELL PRESSURE    PSIA                           LIT02280
C      PBMELT     MELTING POINT OF ALLOY METAL        R                 LIT02290
C      PERCEN     'PERCENTAGE BY NUMBER OF PEROXIDE (VS. MONOXIDE) FORMEDLIT02300
C                 COMBUSTION                                            LIT02310
C      PLIV     PARTIAL PRESSURE OF LITHIUM VAPOR      PSIA             LIT02320
C      PZERO       CONTAINMENT PRESSURE AFTER SPRAY FIRE                LIT02330
C      'QC   FORCED CONVECTIVE COOLING HEAT FLOW                        LIT02340
C      QCN  HEAT OF COMB. FOR NITROGEN REACTION   BTU/LB. LI            LIT02350
C      QCO     HEAT OF COMBUSTION FOR OXYGEN REACTION    BTU/LB. LI     LIT02360
C      QCO1 HEAT OF COMBUSTION FOR MONOXIDE REACTION    BTU/LB. LI      LIT02370
C      QCO2 HEAT OF COMBUSTION FOR PEROXIDE REACTION    BTU/LB. LI      LIT02380
C      QCW    HEAT OF COMB. FOR REACTION WITH WATER VAPOR   BTU/LB. LI  LIT02390
C      QIN   HEAT ADDITION TO CELL GAS FROM SPRAY FIRE   BTU            LIT02400
C      QLIOH      LATENT HEAT OF MELTING FOR LIOH        BTU/LB-MOLE    LIT02410
C.     QMELT    HEAT OF FUSION OF BREEDER          BTU/LB MOLE          LIT02420
C      QMELTP      HEAT OF FUSION OF ALLOY METAL        BYU/LB MOLE     LIT02430
C      QOUT1,2,3,4    USED IN HEAT BALANCE EQS. FOR SPRAY FIRE    BTU   LIT02440
C  QRAD    INDICATES A RADIATIVE HEAT FLOW      BTU/SEC                 LIT02450
C      QRADB      FROM STEEL FLOOR (PAN) TO FLOOR CONC. OR TO AMBIENT   LIT02460
C      QRADC      FROM STEEL WALL TO WALL CONCRETE OR TO AMBIENT        LIT02470
C      QRADCG     FROM SPILL PAN TO CELL GAS                            LIT02480
C      QRADG      FROM LI POOL TO GAS (NO COMB.) OR FROM COMB ZONE TO CELLLIT02490
C      QRADP      FROM COMB. ZONE TO LITHIUM POOL (COMB. ZONE MODEL ONLY)LIT02500
C    QRADS        FROM SPILL PAN TO STEEL FLOOR                         LIT02510
C      QRADW      FROM COMB ZONE TO WALL STEEL OR FROM LI POOL TO WALL STLIT02520
C      QVAP    HEAT OF VAPORIZATION OF LITHIUM      BTU/LB              LIT02530
C     QWA     HEAT OF REACTION OF BREEDER WITH WATER                    LIT02540
C     RAREA       SURFACE AREA OF REACTION ZONE                         LIT02550
C   THE SYMBOL "R" DESIGNATES A TEMPERATURE RATE OF CHANGE IN SOME NODE LIT02560
C      TO RADIATION HEAT TRANSFER BETWEEN THAT NODE AND SOME OTHER NODE LIT02570
C      RADB      IN FLOOR STEEL DUE TO RAD. TO FLOOR CONC. OR TO AMBIENT LIT02580
C      RADC      IN WALL STEEL DUE TO RAD. TO CONCRETE OR TO AMBIENT    LIT02590
C      RADCB     IN FLOOR CONCRETE    FROM STEEL FLOOR (PAN)            LIT02600
C      RADCC     IN WALL CONCRETE    FROM STEEL WALL                    LIT02610
C      RCZG      IN GAS     FROM COMBUSTION ZONE                        LIT02620
C      RCZP      IN LITHIUM POOL  FROM COMBUSTION ZONE                  LIT02630
C      RCZW      IN WALL STEEL   FROM COMBUSTION ZONE                   LIT02640
C      RGASPA     IN PAN DUE TO RAD. TO CONTAINMENT GAS                 LIT02650
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C       RGLI     IN POOL DUE TO RAD. TO GAS  (NO COMB)                      LIT02660
C       RLIG     IN GAS DUE TO RAD. FROM POOL  (NO COMBUSTION)              LIT02670
C       RLIW     IN WALL STEEL   FROM LITHIUM POOL  (NO COMB)               LIT02680
C       RPAGAS    IN CELL GAS DUE TO RAD. FROM LI PAN                       LIT02690
C       RPANST    IN WALL STEEL DUE TO RAD. FROM LITHIUM PAN                LIT02700
C       RSTPAN    IN PAN DUE TO RAD. TO FLOOR STEEL                         LIT02710
C       RWLI     IN LITHIUM POOL   FROM RAD. TO WALL STEEL  (NO COMB)       LIT02720
C       RA        MEAN RADIUS OF COMBUSTION PRODUCT PARTICLES    MICRONS LIT02730
C       RCMBH2   STOICH. COMB. RATIO FOR H2O VAPOR REACT.   LB. LI/LB. H2LIT02740
C       RCMBN   STOICH. COMB. RATIO OF NITROGEN REACT.   LB. LI / LB. N  LIT02750
C       RCMBO   STOICH. COMB. RATIO FOR OXYGEN REACTION  LB. LI/LB. O    LIT02760
C       RCMBO1 STOICH. COMB. RATIO FOR MONOXIDE REACTION     LB. LI/LB. OLIT02770
C       RCMBO2-STOICH. COMB. RATIO FOR PEROXIDE REACTION     LB. LI/LB. OLIT02780
C       RCMBW   STOICH. COMB. RATIO FOR WAT. VAP. REACT.  LB. LI/LB. H2O LIT02790
C       RELERR   MAXIMUM ALLOWABLE FRACTIONAL TEMP. CHANGE ACROSS A SINGLLIT02800
C                 INTEGRATION STEP.  USED TO VARY TIME STEP.               LIT02810
C       RHCON       DENSITY OF FLOOR AND WALL CONCRETE                      LIT02820
C       RHLI    DENSITY OF LITHIUM   LB. / FT3                              LIT02830
C       RHOA   DENSITY CELL GAS LB/FT3                                      LIT02840
C       RHOAI   INITIAL DENSITY OF CELL GAS   LB/FT3                        LIT02850
C       RHOLIH    DENSITY OF LITHIUM HYDROXIDE   LB/FT3                     LIT02860
C       RHOLIN    DENSITY OF LITHIUM NITRIDE    LB/FT3                      LIT02870
C       RHOLIO     DENSITY OF LITHIUM OXIDE   LB/FT3                        LIT02880
C       RHOLIV    LITHIUM VAPOR DENSITY ABOVE POOL        LB/FT3            LIT02890
C       RHPAN     DENSITY OF LI SPILL PAN          LBS/FT**3                LIT02900
C       RHPB     DENSITY OF ALLOY METAL      LB-MOLE/FT3                    LIT02910
C       RHSTL       DENSITY OF STEEL LINER  (LB/FT3)                        LIT02920
C       RIFCZG   RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND THE LIT02930
C              CELL GAS                                                     LIT02940
C       RIFCZP   RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND        LIT02950
C                THE POOL SURFACE                                           LIT02960
C       RIFCZW   RADIATIVE INTERCHANGE FACTOR BETWEEN COMB. ZONE AND        LIT02970
C              CONTAINMENT WALLS                                            LIT02980
C       RIFPAG    RADIATIVE INTERCHANGE FACTOR - PAN TO GAS                 LIT02990
C       RIFPAS    RADIATIVE INTERCHANGE FACTOR - PAN TO STEEL FLOOR         LIT03000
C       RIFPG   RAD. INT. FAC. BETWEEN POOL AND CELL GAS                    LIT03010
C       RIFPW   RAD. INT. FACT. BETWEEN POOL AND WALL                       LIT03020
C       RIFSLC   RADIATIVE INTERCHANGE FACTOR BETWEEN STEEL LINER           LIT03030
C                AND CONCRETE SURFACE                                       LIT03040
C       RIN UNIVERSAL GAS CONSTANT   1545 FT. LBF./LB.MOLE-DEG. F           LIT03050
C       RNILB  RATE OF NITROGEN CONSUMPTION       LB./ SEC                  LIT03060
C       RN2   DEGREE TO WHICH NITROGEN-LI REACTION OCCURS.  VALUE IS        LIT03070
C               BETWEEN ZERO AND ONE (=0 FOR NO REACTION, =1 FOR COMPLETELIT03080
C       ROXLB   RATE OF OXYGEN CONSUMPTION BY POOL FIRE   LB./SEC.          LIT03090
C       RRAD     INITIAL RADIUS OF REACTION ZONE          FT                LIT03100
C       RTLI,RTG,RADB,RADW,RADCB,RADCW          VARIOUS RATES OF TEMP.      LIT03110
C              CHANGE OF NODES   DEG. F/SEC.                                LIT03120
C       RVOL   INITIAL REACTION ZONE VOLUME     FT3                         LIT03130
C       RVOL1       REACTION ZONE VOLUME            FT3                     LIT03140
C       RWALB   RATE OF WATER VAPOR CONSUMPTION      LB./SEC                LIT03150
C       RWCZ,RCZW,RCZG,RADB,RADW,RADCB,RADCW,RLIW,RWLI,RGLI,RLIG ----      LIT03160
C           VARIOUS RATES OF TEMP. CHANGE OF NODES   DEG. F/SEC             LIT03170
C        R1         COEFFICIENT OF BREEDER IN WATER REACTION EQUATION       LIT03180
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C     R2    COEFFICIENT OF ALLOY METAL IN WATER REACTION EQUATION         LIT03190
C      SFLCR   HEAT REMOVAL RATE BY EMERGENCY COOLING OF STEEL             LIT03200
C              FLOOR LINER    BTU/SEC                                      LIT03210
C      SFLTIN   TIME AFTER SPILL WHEN SFLCR BEGINS   SEC                   LIT03220
C      SIGMA  STEPHAN-BOLTZMAN CONSTANT  ...   .1713E-8 BTU/FT**2/HR/R**LIT03230
C      SPILL    TOTAL WEIGHT OF LITHIUM SPILLED   LB.                      LIT03240
C      SPRAY     WEIGHT FRACTION OF LITHIUM CONSUMED IN THE SPRAY FIRE   LIT03250
C      TA    AMBIENT TEMPERATURE   DEG. F                                  LIT03260
C      TAU     TIME CONSTANT FOR TRANSIENT NATURAL CONVECTION              LIT03270
C      TONE,TTWO,TTHREE     TIME IN SECONDS AT WHICH EACH INJECTION OCCULIT03280
C      TB(I)   TEMP. OF ITH NODE OF CONCRETE FLOOR   DEG. R               LIT03290
C      TBIC(I)   INITIAL TEMP. OF ITH NODE OF CONCRETE FLOOR   DEG. R     LIT03300
C      TBF, TCF,TGF, ETC.   CORRESPONDING TEMP. IN DEGREES FAHRENHEIT     LIT03310
C      TBLOW  INERT GAS INLET TEMP.   DEG. R                               LIT03320
C      TC(I)   TEMP. OF ITH NODE OF CONCRETE WALL   DEG. R                LIT03330
C      TCIC(I)   INITIAL TEMP. OF ITH NODE OF CONCRETE WALL   DEG. R      LIT03340
C      TCZ          COMBUSTION ZONE TEMPERATURE     DEG R                  LIT03350
C      TCZF       ' COMBUSTION ZONE TEMP. IN FARENHEIT                     LIT03360
C      TCZI         INITIAL VALUE OF COMB. ZONE TEMP.     DEG R            LIT03370
C      TE    EQUILIBRIUM TEMP. RESULTING FROM SPRAY FIRE   DEG. R          LIT03380
C      TFEFF  NORMALIZED TEMP. OF LI POOL/COMB. ZONE FILM                  LIT03390
C      TG    GAS TEMP. AFTER SPRAY FIRE     DEG. R                         LIT03400
C      TGF          CONTAINMENT GAS TEMP.  IN FARENHEIT                    LIT03410
C      TGZERO      INITIAL CELL GAS TEMP.      DEG. R                      LIT03420
C      THF,THW CONCRETE FLOOR AND WALL THICKNESSES                         LIT03430
C              INPUT AS INCHES, USED IN FT. FOR PROGRAM)                   LIT03440
C      THKIN1      INNER INSULATION THICKNESS INPUT AS INCHES              LIT03450
C      THKIN2      OUTER INSULATION THICKNESS INPUT AS INCHES              LIT03460
C      THKPAN     SPILL PAN THICKNESS IN FEET   (INPUT AS INCHES)          LIT03470
C      TIME    TIME AFTER SPILL HAS OCCURRED   SEC.                        LIT03480
C      TIMEF   STOP INTEGRATION TIME    SEC.                               LIT03490
C      TIMEO      OUTPUT TIME INDICATOR      SEC.                          LIT03500
C      TINS1      TEMP. OF INNER NODE OF INSULATION    DEG R               LIT03510
C      TINS2      TEMP. OF OUTER NODE OF INSULATION    DEG R               LIT03520
C      TLI      LITHIUM TEMP. IN POOL      DEG. R                          LIT03530
C      TLIF         LITHIUM POOL TEMP. IN FARENHEIT                        LIT03540
C      TLII         INITIAL LITHIUM POOL TEMP.  (DEG R)                    LIT03550
C      TLIO   INITIAL LITHIUM POOL TEMP.      DEG. R                       LIT03560
C      TMELT    MELTING TEMP. OF LITHIUM    DEG. R                         LIT03570
C      TN           TEMPERATURE OF BREEDER ZONE ELEMENT       R            LIT03580
C      TO    TEMP. OF CELL GAS AFTER SPRAY FIRE   DEG. R                   LIT03590
C      TPAN   LITHIUM PAN TEMP  (DEG R)     SUSP PAN OPTION                LIT03600
C      TPANF  LITHIUM PAN TEMP  (DEG F)                                    LIT03610
C      TPANZO    INITIAL PAN TEMPERATURE IN DEGREES R                      LIT03620
C      TS    STEEL WALL LINER TEMP.   DEG. R                               LIT03630
C      TSB    STEEL FLOOR LINER TEMP.   DEG. R                             LIT03640
C      TSBF        FLOOR STEEL LINER TEMPERATURE IN DEGREES FARENHEIT     LIT03650
C      TSBI   INITIAL STEEL FLOOR LINER TEMP.    DEG.R                     LIT03660
C      TSF          WALL STEEL LINER TEMPERATURE IN FARENHEIT              LIT03670
C      TSZERO    INITIAL STEEL WALL LINER TEMP.   DEG. R                   LIT03680
C      TVAP    BOILING POINT OF LITHIUM     DEG. R                         LIT03690
C      T1    FILM TEMP. BETWEEN CELL GAS AND POOL    DEG. R                LIT03700
C      T2    FILM TEMP. BETWEEN CELL GAS AND STEEL WALL LINER   DEG. R    LIT03710
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C      USUBA   HEAT TRANSF. COEFF., CONTAINMENT-AMBIENT  BTU/SEC-FT2-DEGLIT03720
C      V    CELL FREE VOLUME      FT3                                 LIT03730
C       VOL       VOLUME OF BREEDER ELEMENT                           LIT03740
C      W     THICKNESS OF STEEL POOL LINER      FT.                   LIT03750
C              (INPUT AS INCHES)                                      LIT03760
C      WA    WT. FRACTION OF INERT GAS IN ATMOSPHERE                  LIT03770
C      WAB          'WEIGHT FRACTION OF INERT GAS IN FLOODING GAS     LIT03780
C      WN2  WEIGHT FRACTION OF NITROGEN IN ATMOSPHERE                 LIT03790
C      WN2B    WEIGHT FRACTION OF NITROGEN IN FLOODING GAS            LIT03800
C      WO2   WEIGHT FRACTION OF OXYGEN IN ATMOSPHERE                  LIT03810
C      WO2B  WEIGHT FRCTION OF OXYGEN IN FLOODING GAS                 LIT03820
C      WWA          WEIGHT FRACTION OF WATER VAPOR IN CONTAINMENT ATMOSPHLIT03830
C      WWAB   WT. FRACTION OF WATER VAPOR IN FLOODING GAS             LIT03840
C      XBLOW    USED IN CONJUNCTION WITH IBLOW,                       LIT03850
C      XESC   USED IN CONJUNCTION WITH IESC                           LIT03860
C      XMAIR   AMOUNT OF GAS IN CONTAIMENT AFTER SPRAY   LB.-MOLES    LIT03870
C      XLI      WEIGHT FRACTION OF LITHIUM IN LIPB ALLOY              LIT03880
C      XPB    WEIGHT FRACTION OF ALLOY METAL    .                     LIT03890
C      XMOL   MOL. WEIGHT OF CONTAINMENT GAS   LB./LB.-MOLE           LIT03900
C      XMOLA     MOLECULAR WT. OF INERT GAS   LB./LB.-MOLE            LIT03910
C      XMOLAB  MOL. WT. OF INERT FLOODING GAS,                        LIT03920
C      XSFL          INDICATES EMERGENCY COOLING OF FLOOR STEEL       LIT03930
C                         XSFL=0. FOR NO COOLING , XSFL=1. FOR COOLING    LIT03940
C                 (1/SEC.)                                            LIT03950
C      XSFLC  USED IN CONJUNCTION WITH ISFLC                          LIT03960
C      YALICZ   EFFECTIVE THERMAL ADMITTANCE,  FILM-COMB. ZONE BTU/SEC-DLIT03970
C      YALIG      EFFECTIVE THERMAL ADMITTANCE, POOL-CELL GAS BTU/SEC-DEGLIT03980
C      YAPCZ      EFFECTIVE THERMAL ADMITTANCE POOL-COMB. ZONE  BTU/SEC-DLIT03990
C      ZLI    THICKNESS OF LITHIUM NODE       FT.                     LIT04000
C      ZZ     TEMPERATURE RATE OF CHANGE  IN BREEDER ELEMENT          LIT04010
C      ZZ1   POOL TEMP. RATE OF CHANGE   DEG. F/SEC.                  LIT04020
C      ZZ2    LI SPILL PAN TEMP. RATE OF CHANGE  (DEG R/SEC)          LIT04030
C      ZZ4   CELL GAS TEMP. RATE OF CHANGE   DEG. F/SEC.      |       LIT04040
C      ZZ5   STEEL WALL LINER TEMP. RATE OF CHANGE   DEG. F/SEC.      LIT04050
C      ZZ6    COMB. ZONE TEMP. RATE OF CHANGE    DEG. F/SEC           LIT04060
C      ZZ7   FLOOR STRUCTURE TEMP. RATE OF CHANGE   DEG. F/SEC.       LIT04070
C      ZZ8    INNER INSULATION TEMP. RATE OF CHANGE  (SUSP. PAN OPTION) LIT04080
C      ZZ9    OUTER INSULATION TEMP. RATE OF CHANGE  (SUSP. PAN OPTION) LIT04090
C      ZZ99   USED TO ENSURE POSITIVE COMBUSTION RATE                 LIT04100
C                                                                     LIT04110
C    PROGRAM DECISION FLAGS                                           LIT04120
C                                                                     LIT04130
C      IBLOW = 1  FLOOD CONTAINMENT WITH INERT GAS.                   LIT04140
C            = 0  NO CONTAINMENT FLOODING.                            LIT04150
C      ICMB = 0  NO OXYGEN LEFT AFTER SPRAY FIRE.                     LIT04160
C           = 1  THERE IS STILL OXYGEN LEFT AFTER SPRAY FIRE.         LIT04170
C                SET INITIALLY TO 1 AND THEN RESET TO 0 WHEN THE      LIT04180
C                PROGRAM CALCULATES THAT THE OXYGEN HAS RUN OUT.      LIT04190
C      ICNI = 1  NITROGEN REACTIONS POSSIBLE.                         LIT04200
C           = 0  NITROGEN REACTIONS NOT POSSIBLE.                     LIT04210
C      ICZ = 1  COMBUSTION ZONE MODEL USED     ,                      LIT04220
C          = 0  COMBUSTION ZONE MODEL NOT USED                        LIT04230
C      IESC = 1  EMERGENCY SPACE COOLING OPTION                       LIT04240
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               C          = 0  NO EMERGENCY SPACE COOLING                          LIT04250
               C      ILIT = 0  NO LITHIUM LEFT TO BURN.                           LIT04260
               C           = 1   LITHIUM LEFT TO BURN (INITIAL CONDITION).         LIT04270
               C      IMETH = 1  RUNGE-KUTTA METHOD OF INTEGRATION USED.           LIT04280
               C            = 3   SIMPSON'S RULE METHOD OF INTEGRATION USED.       LIT04290
               C      IPAGE   NO. OUTPUT LINES PER PAGE                            LIT04300
               C      ISFLC = 1  EMERGENCY COOLING OF STEEL FLOOR LINER OPTION     LIT04310
               C            = 0  NO EMERGENCY COOLING OF STEEL FLOOR LINER         LIT04320
               C      FLAG = .TRUE.    NO WALL CONCRETE                            LIT04330
               C      FLAG1 = .TRUE.   NO FLOOR CONCRETE                           LIT04340
               C      FLAGJ = .TRUE.   INJECTIONS OF DRY GAS DURING RUN            LIT04350
               C      FLAGL = .TRUE.       LILP IS FIXED AT A MINIMUM              LIT04360
               C      FLAGS = .TRUE.         YES ON SUSPENDED PAN GEOMETRY         LIT04370
               C      FLAGSI = .TRUE.  IF USER WISHES INPUT/OUTPUT IN SI UNITS     LIT04380
               C      IOPTB=1      IF INTERNAL BLANKET ACCIDENT OPTION IS TO BE USED  LIT04390
               C                                                                   LIT04400
0001                 IMPLICIT REAL (K,L,M)                                         LIT04410
0002                 DIMENSION TCF(20),TBF(20),TB(20),TC(20),DTCDT(20),DTBDT(20),  LIT04420
                    .        TCIC(20),TBIC(20),NAME(100),L(20),L1(20),C4(20),C10(20), LIT04430
                    .         TN(20),RAD(20),ARE(20),VOL(20),CF(20),CT(20),ZZ(20), LIT04440
                    .          TNF(20) ,QC(20),ATO(20),ATI(20)                     LIT04450
0003                 LOGICAL FLAG,FLAG1,FLAGL,FLAGS,FLAGJ,FLAGSI,FLAGIO            LIT04460
0004                 REAL INTGRL                                                   LIT04470
0005                 REAL NT,MLI,MCZ,MLIOH,MLIO,MLIT,MLIY                          LIT04480
0006                 REAL NA,LBN,LBR,LB2,MB(20)                                    LIT04490
0007                 REAL J1,J2                                                    LIT04500
0008                 COMMON IMETH,ICOUNT,ISTORE,INOIN,IPASS,DELT,XIC(101),ZZZ(501)  LIT04510
0009                 COMMON /UNITS/ AW,V,CH,G,KGAP,W,K,HA,HIN,THW,THF,TMELT,TVAP,TCZI, LIT04520
                    .   KPAN,RHPAN,CPPAN,TPANZO,APAN,AWB,THKPAN,BREDTH,ASLI,SPILL,QCO1,LIT04530
                    .   QCO2,QCN,QCW,QVAP,FLAGJ,FLAGS,FLAGIO,IBLOW,IESC,ISFLC,RHOLIN,  LIT04540
                    .   RHOLIO,RHOLIH,CPA,CPLI,RHLI,AKLI,CPSTL,RHSTL,KSTL,CPCON,RHCON,  LIT04550
                    .   KCON,PAZERO,TGZERO,TSZERO,TSBI,TA,TLII,DP1,DP2,DP3,ESCR,SFLCR,  LIT04560
                    .   CPAB,TBLOW,EXHSTV,BLOWV,TBF,TCF,THKIN2,THKIN1,AINS,CPINS,RHINS,LIT04570
                    .   IOPTB,NT,RRAD,AMLI,HCO,QLIOH,CPLIOH,PBMELT,CP1,CP2,RHPB,       LIT04580
                    .AMPB,XLI,CPPL,CPLI1,CPPB1,R1,R2,J1,J2,QMELT,QMELTP,DELH           LIT04590
0010                 COMMON /EXTRA/ TINS1F,TINS2F,TB,TC,TG,TGF,TSB,TSBF,TS,TSF,TCZ,  LIT04600
                    .   TCZF,TLI,TLIF,TPAN,TPANF,OVERP,MOX,MNI,LILP,HF,HB,EFILM,DFILM,  LIT04610
                    .   TINS1,TINS2                                                LIT04620
               C*******************************************************************LIT04630
               C    INPUT SECTION           ***********                            LIT04640
               C*******************************************************************LIT04650
               C                                                                   LIT04660
               C**********      READ IN TITLE AND HEADINGS      **********         LIT04670
0011             998 CONTINUE                                                      LIT04680
0012                 READ(5,707,END=999)  (NAME(I),I=1,100)                        LIT04690
0013             707 FORMAT(20A4)                                                  LIT04700
               C                                                                   LIT04710
               C   *****      READ IN FLAGS AND OPTIONS       *****                LIT04720
0014                 READ (5,705) FLAG,FLAG1,FLAGS,FLAGJ,FLAGSI.IBLOW,IESC,ISFLC,IOPTB LIT04730
0015           705   FORMAT (5(L1,1X),4(I1,1X))                                    LIT04740
               C                                                                   LIT04750
               C**********      READ IN CONTAINMENT SPECIFICATIONS      **********  LIT04760
0016                 READ(5,702) AW,V,CH,WO2,WWA,WA                                LIT04770
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0017          READ(5,702) G,KGAP,W,K,EMGF,BETA                                  LIT04780
0018          READ (5,702) THW,THF,AWB                                          LIT04790
0019          READ (5,709) NL,(L(I),I=1,NL)                                     LIT04800
0020          READ (5,709) NL1,(L1(I),I=1,NL1)                                  LIT04810
0021     709  FORMAT (I2,15F5.3)                                                LIT04820
0022          IF (FLAGS) READ (5,702) TPANZO,APAN,    AINS,BREDTH               LIT04830
0023          IF (FLAGS) READ (5,702) THKPAN,THKIN1,THKIN2                      LIT04840
0024          IF (FLAGS) READ (5,702) KPAN,RHPAN,CPPAN,RHINS,CPINS,EMINS        LIT04850
0025          READ(5,702)TEHCZO,XMEHC,AEHC,CPEHC                                LIT04860
         C                                                                      LIT04870
         C********    READ IN HEAT TRANSFER CORRELATION COEFFICIENTS       *****LIT04880
0026          READ(5,702) HIN,HINEHC,HINGS,HINSAM,TAUCZ                         LIT04890
         C                                                                      LIT04900
         C**********      READ IN SPILL PARAMETERS      **********              LIT04910
0027          READ(5,702) ASLI,SPILL,SPRAY,FRA,RA,XMOLA                         LIT04920
0028      702 FORMAT(6F12.4)                                                    LIT04930
         C                                                                      LIT04940
         C**********      READ IN REACTION CONSTANTS      **********            LIT04950
0029          READ(5,702) QCO1,QCO2,QCN,QCW                                     LIT04960
0030          READ(5,702) RCMBO1,RCMBO2,RCMBN,RCMBW,RCMBH2                      LIT04970
0031          READ(5,702) TMELT,TVAP,QVAP,EMCZ,TCZI,PERCEN                      LIT04980
         C                                                                      LIT04990
         C**********      READ IN PHYSICAL CONSTANTS      **********            LIT05000
0032          READ(5,702) RHOLIO,RHOLIN,RHOLIH,CPA                              LIT05010
0033          READ(5,702) CPLI,RHLI,AKLI,EMSTL,EMLI,EMCONC                      LIT05020
0034          READ(5,702) CPSTL,RHSTL,KSTL,CPCON,RHCON,KCON                     LIT05030
         C         RHSTL IS CORRECTED FOR EXTRANEOUS FLANGES, ETC.              LIT05040
         C                                                                      LIT05050
         C**********      READ IN INITIAL CONDITIONS      **********            LIT05060
0035          READ(5,702) PAZERO,TGZERO,TSZERO,TSBI,TA,TLII                     LIT05070
         C                                                                      LIT05080
         C**********      READ IN INTEGRATION CONTROL PARAMETERS      ********** LIT05090
0036          READ(5,706) IMETH, DTMIN, TIMEF, RELERR, DELOUT                   LIT05100
0037      706 FORMAT(I4,5F12.4)                                                 LIT05110
         C                                                                      LIT05120
         C**********      READ IN INJECTION PARAMETERS      **********          LIT05130
0038          IF (FLAGJ) READ(5,1030)TONE,DP1,FCT1,TTWO,DP2,FCT2,TTHREE,DP3,FCT3LIT05140
0039     1030 FORMAT(9F8.4)                                                     LIT05150
         C                                                                      LIT05160
         C**********      CONTAINMENT FLOODING WITH INERT GAS OPTION    *********LIT05170
0040      708 FORMAT(I4)                                                        LIT05180
0041          IF(IBLOW.EQ.1) READ(5,702) WO2B,WWAB,WN2B,XMOLAB,CPAB,TBLOW,BLOWV,LIT05190
                                         EXHSTV,BLIN,BLOUT                      LIT05200
0042          XBLOW=0.                                                          LIT05210
0043          IF(IBLOW.EQ.1) GO TO 437                                          LIT05220
0044          BLIN=0.                                                           LIT05230
0045          BLOUT=0.                                                          LIT05240
0046          WO2B=0.                                                           LIT05250
0047          WAB=0.                                                            LIT05260
0048          WN2B=0.                                                           LIT05270
0049          WWAB=0.                                                           LIT05280
0050          XMOLAB=1.                                                         LIT05290
0051          CPAB=1.                                                           LIT05300
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0052          TBLOW=1.                                                         LIT05310
0053          BLOWV=0.                                                         LIT05320
0054          EXHSTV=0.                                                        LIT05330
0055      437 CONTINUE                                                         LIT05340
0056          WAB=1.-WO2B-WN2B-WWAB                                            LIT05350
0057          BLOWR = 1.35E-03 * BLOWV                                         LIT05360
0058          EXHSTR = 1.35E-03 * EXHSTV                                       LIT05370
        C                                                                      LIT05380
        C**********     EMERGENCY SPACE COOLING OF CONTAINMENT OPTION    ******LIT05390
0059          XESC=0.                                                          LIT05400
0060          IF(IESC.EQ.1) READ(5,702) ESCR,ESCTIN                            LIT05410
0061          IF(IESC.EQ.1) GO TO 439                                          LIT05420
0062          IF(ISFLC.EQ.1) READ(5,702) SFLCR,SFLTIN                          LIT05430
0063          XSFL=0.                                                          LIT05440
0064          SFLCR=0.                                                         LIT05450
0065          ESCR= 0.                                                         LIT05460
0066          ESCTIN=0.                                                        LIT05470
        C                                                                      LIT05480
0067      439 CONTINUE                                                         LIT05490
0068          IF(ISFLC.EQ.1) GO TO 440                                         LIT05500
        C**********     EMERGENCY STEEL FLOOR LINER COOLING OPTION    *********LIT05510
0069          SFLTIN=0.                                                        LIT05520
0070      440 CONTINUE                                                         LIT05530
        C                                                                      LIT05540
        C***********     INTERNAL BLANKET ACCIDENT OPTION      ***********     LIT05550
0071          IF (IOPTB .EQ. 1) READ (5,702) NT,RRAD,AMLI,HCO,QLIOH,CPLIOH     LIT05560
0072          IF (IOPTB .EQ. 1) READ (5,702) PBMELT,CP1,CP2,RHPB,AMPB,XLI      LIT05570
0073          IF (IOPTB .EQ. 1) READ (5,702) CPPL,CPLI1,CPPB1,R1,R2            LIT05580
0074          IF (IOPTB .EQ. 1) READ (5,702) J1,J2,QMELT,QMELTP,DELH           LIT05590
0075          IF (IOPTB .EQ. 1) GO TO 441                                      LIT05600
0076          NT=0.                                                            LIT05610
0077          RRAD=0.                                                          LIT05620
0078          AMLI=7.0                                                         LIT05630
0079          HCO=1.                                                           LIT05640
0080          QLIOH=0.                                                         LIT05650
0081          CPLIOH=1.                                                        LIT05660
0082    441   CONTINUE                                                         LIT05670
        C**********************************************************************LIT05680
        C    PRINT OUT THE INPUT          ***********                          LIT05690
        C**********************************************************************LIT05700
        C                                                                      LIT05710
0083          RCMBO=((100.-PERCEN)*RCMBO1+PERCEN*RCMBO2)/100.                  LIT05720
0084          QCO=((100.-PERCEN)*RCMBO1*QCO1+PERCEN*RCMBO2*QCO2)/(RCMBO*100.)  LIT05730
0085          ZLI=SPILL/RHLI/ASLI                                              LIT05740
0086          WRITE(6,802) (NAME(I),I=1,60)                                    LIT05750
0087    802   FORMAT ('1',3(20X,20A4,/),/)                                     LIT05760
0088          WRITE(6,142) CPLI,RHLI,RHOLIO,AKLI,EMLI,CPSTL,RHSTL,RHOLIN,KSTL, LIT05770
             .   EMSTL,CPCON,RHCON,RHOLIH,KCON,EMCONC,        KGAP,EMCZ        LIT05780
0089          WRITE(6,143) AW,V,THW,K,CH,W,THF,G                               LIT05790
0090          WRITE(6,144) ASLI,SPILL,SPRAY,WO2,ZLI                            LIT05800
0091          WRITE (6,153)             FLAGS,FLAGJ,FLAGSI                     LIT05810
0092          WRITE(6,155) HIN,HINEHC,HINGS,HINSAM                             LIT05820
0093          WRITE(6,145) QCO,RCMBO,TVAP,RCMBH2,PERCEN,QCN,RCMBN,TMELT,FRA,   LIT05830
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                  .   QCW,RCMBW,QVAP,RA                                           LIT05840
0094                 WRITE(6,146) TGZERO,TLII,TSBI,WA,PAZERO,TSZERO,TCZI,TA,WWA   LIT05850
0095                 WRITE(6,147) IMETH,DTMIN,TIMEF,RELERR,DELOUT                 LIT05860
0096                 WRITE (6,148) IBLOW,IESC,ISFLC,FLAG,FLAG1,IOPTB              LIT05870
0097                 WRITE(6,149) WO2B,BLOWV,ESCR,SFLCR,CPA,WWAB,BLOUT,ESCTIN,SFLTIN, LIT05880
                  .   CPAB,WN2B,BLIN,EXHSTV,TBLOW,XMOLA,XMOLAB                    LIT05890
0098                 IF(FLAGS) WRITE(6,151) TPANZO,APAN,AWB,THKPAN,BREDTH,KPAN,RHPAN, LIT05900
                  .   CPPAN,EMINS                                                 LIT05910
0099                 IF(FLAGS) WRITE(6,152) THKIN1,THKIN2,AINS,RHINS,CPINS        LIT05920
0100                 WRITE(6,154)TEHCZO,XMEHC,AEHC,CPEHC                          LIT05930
0101                 IF (IOPTB .EQ. 1)  WRITE(6 1101)  NT,RRAD,AMLI,HCO,QLIOH,CPLIOH, LIT05940
                  .       PBMELT,CP1,CP2,RHPB,AMPB,XLI,CPPL,CPLI1,CPPB1,R1,R2,    LIT05950
                  .        J1,J2,QMELT,QMELTP,DELH                                LIT05960
0102          142    FORMAT(' PHYSICAL PROPERTIES'/1X,19(1H-)//T10,'CPLI = ',F12.4, LIT05970
                  .T35,'RHLI = ',F12.4,T60,'RHOLIO = ',F12.4,T85,'AKLI = ',F12.4, LIT05980
                  .T110,'EMLI = ',F12.4//T10,'CPSTL = ',F12.4,T35,'RHSTL = ',F12.4, LIT05990
                  .T60,'RHOLIN = ',F12.4,T85,'KSTL = ',F12.4,T110,'EMSTL = ',F12.4// LIT06000
                  .T10,'CPCON = ',F12.4,T35,'RHCON = ',F12.4,T60,'RHOLIH = ',F12.4, LIT06010
                  .T85,'KCON = ',F12.4,T110,'EMCON = ',F12.4//                   LIT06020
                  .                   T60,'KGAP = ',F12.4,T85,'EMCZ = ',F12.4,//)  LIT06030
0103          143    FORMAT(' INNER CONTAINMENT DIMENSIONS'/1X,28(1H-)//T10,'AW = ', LIT06040
                  .F12.4,T35,'V = ',F12.4,T60,'THW = ',F12.4,T85,'K = ',F12.4//T10, LIT06050
                  .'CH = ',F12.4,T35,'W = ',F12.4,T60,'THF = ',F12.4,T85,'G = ', LIT06060
                  .F12.4,//)                                                      LIT06070
0104          144    FORMAT(' SPILL PARAMETERS'/1X,16(1H-)//T10,'ASLI = ',F12.4,T35, LIT06080
                  .'SPILL = ',F12.4,T60,'SPRAY = ',F12.4,T85,'WO2 = ',F12.4,T110, LIT06090
                  .'ZLI = ',F12.4//)                                              LIT06100
0105          155    FORMAT(' HEAT TRANSFER CORRELATION COEFFICIENTS'/1X,38(1H-)//T10, LIT06110
                  .   'HIN = ',F12.4,T35,'HINEHC = ',F12.4,T60,'HINGS = ',F12.4,  LIT06120
                  .   T85,'HINSAM = ',F12.4//)                                    LIT06130
0106          145    FORMAT(' COMBUSTION PARAMETERS'/1X,21(1H-)//T10,'QCO = ',F12.4, LIT06140
                  .T35,'RCMBO = ',F12.4,T60,'TVAP = ',F12.4,T85,'RCMBH2 = ',F12.4, LIT06150
                  .T110,'PERCEN = ',F12.4,//T10,'QCN = ',F12.4,T35,'RCMBN = ',F12.4, LIT06160
                  .T60,'TMELT = ',F12.4,T85,'FRA = ',F12.4//T10,'QCW = ',F12.4,T35, LIT06170
                  .'RCMBW = ',F12.4,T60,'QVAP = ',F12.4,T85,'RA = ',F12.4//)      LIT06180
0107          146    FORMAT(' INITIAL CONDITIONS'/1X,18(1H-)//T10,'TGZERO = ',F12.4, LIT06190
                  .T35,'TLII = ',F12.4,T60,'TSBI = ',F12.4,T85,'WA = ',F12.4,T110, LIT06200
                  .'PAZERO = ',F12.4//T10,'TSZERO = ',F12.4,T35,'TCZI = ',F12.4,T60, LIT06210
                  .'TA = ',F12.4,T85,'WWA = ',F12.4//)                            LIT06220
0108          147    FORMAT(' INTEGRATION CONTROL PARAMETERS'/1X,30(1H-)//T10,    LIT06230
                  .'IMETH = ',I4,T35,'DTMIN = ',F12.4,T60,'TIMEF = ',F12.4,T85,   LIT06240
                  .'RELERR = ',F12.4,T110,'DELOUT = ',F12.4//)                    LIT06250
0109          148    FORMAT(' OPTIONS IN EFFECT'/1X,17(1H-)//T10,'IBLOW = ',I4,T35, LIT06260
                  .'IESC = ',I4,T60,'ISFLC = ',I4,T85,'FLAG = ' ,L4,T110,'FLAG1 = ', LIT06270
                  .L4//T10,'IOPTB = ',I4//)                                       LIT06280
0110          149    FORMAT(' MISCELLANEOUS INPUT'/1X,19(1H-)//T10,'WO2B = ',F12.4,T35,LIT06290
                  .'BLOWV = ',F12.4,T60,'ESCR = ',F12.4,T85,'SFLCR = ',F12.4,T110, LIT06300
                  .'CPA = ',F12.4//T10,'WWAB = ',F12.4,T35,'BLOUT = ',F12.4,T60,  LIT06310
                  .'ESCTIN = ',F12.4,T85,'SFLTIN = ',F12.4,T110,'CPAB = ',F12.4//T10,LIT06320
                  .'WN2B = ',F10.4,T30,'BLIN = ',F10.4,T50,'EXHSTV = ',F10.4,T70, LIT06330
                  .'TBLOW = ',F10.4,T90, 'XMOLA = ',F10.4,T110,'XMOLAB = ',F10.4) LIT06340
0111          151    FORMAT(///,' DATA FOR SUSPENDED PAN OPTIONAL GEOMETRY:',/,1X, LIT06350
                  .   41(1H-),//T10,'TPANZO = ',F12.4,T35,'APAN = ',F12.4,T60,'AWB = LIT06360
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                .',F12.4,T85,'THKPAN = ',F12.4,T110,'BREDTH = ',F12.4//T10,        LIT06370
                .  'KPAN = ',F12.4,T35,'RHPAN = ',F12.4,T60,'CPPAN = ',F12.4,T85,  LIT06380
                .  'EMINS = ',F12.4)                                               LIT06390
0112       152   FORMAT(//T10,'THKIN1 = ',F12.4,T35,'THKIN2 = ',F12.4,T60,'AINS = 'LIT06400
                .,  F12.4,T85,'RHINS = ',F12.4,T110,'CPINS = ',F12.4)              LIT06410
0113       153   FORMAT (T60,'FLAGS = ',                                           LIT06420
                .  L1,T85,'FLAGJ = ',L1,T110,'FLAGSI = ',L1//)                     LIT06430
0114       154   FORMAT(//' EXTANEOUS HEAT CAPACITY NODE DATA'/1X,33(1H-)//T10,    LIT06440
                1  'TEHCZO = ',F12.4,T35,'XMEHC = ',F12.4,T60,'AEHC = ',F12.4,     LIT06450
                2  T85,'CPEHC = ',F12.4)                                           LIT06460
0115      1101   FORMAT(' INTERNAL BLANKET OPTION INPUT'/1X,29(1H-)//T10,          LIT06470
                .'NT = ',F10.1,T35,'RRAD = ',F10.2,T60,'AMLI = ',F10.2,            LIT06480
                .T85,'HCO = ',F10.2,T110,'QLIOH = ',F10.2//T10,'CPLIOH = ',F10.2,  LIT06490
                .T35,'PBMELT = ',F10.2,T60,'CP1 = ',F10.3,T85,'CP2 = ',F10.5,      LIT06500
                .T110,'RHPB = ',F10.2//T10,'AMPB = ',F10.2,T35,'XLI = ',F10.3,     LIT06510
                .T60,'CPPL = ',F10.3,T85,'CPLI1 = ',F10.2,T110,'CPPB1 = ',F10.2//  LIT06520
                .T10,'R1 = ',F10.3,T35,'R2 = ',F10.3,T60,'J1 = ',F10.1,            LIT06530
                .T85,'J2 = ',F10.1,T110,'QMELT = ',F10.2//T10,'QMELTP = ',F10.2,   LIT06540
                .T110,'DELH = ',F10.1)                                             LIT06550
           C                                                                       LIT06560
           C*******************************************************************LIT06570
           C    INITIALIZE PROGRAM VARIABLES             ***********               LIT06580
           C*******************************************************************LIT06590
           C                                                                       LIT06600
0116             EMF=0.9                                                           LIT06610
0117             GAMMA=1.4                                                         LIT06620
0118             FPG=1.                                                            LIT06630
0119             FPW=1.                                                            LIT06640
0120             IF(FLAGS)FPG=0.23                                                 LIT06650
0121             IF(FLAGS)FPW=0.384                                                LIT06660
0122             C3=0.                                                             LIT06670
0123             C5=0.                                                             LIT06680
0124             C7=0.                                                             LIT06690
0125             C8=0.                                                             LIT06700
0126             C9=0.                                                             LIT06710
0127             CMBRHI=0.                                                         LIT06720
0128             LIBP=0.                                                           LIT06730
0129             LILOX=0.                                                          LIT06740
0130             LILNI=0.                                                          LIT06750
0131             LEAKO=0.                                                          LIT06760
0132             MLIN=0.                                                           LIT06770
0133             MLINI=0.                                                          LIT06780
0134             MLIH=0.                                                           LIT06790
0135             MH2=0.                                                            LIT06800
0136             OXLB=0.                                                           LIT06810
0137             OXLBI=0.                                                          LIT06820
0138             HTCAPG=1.                                                         LIT06830
0139             OUTINT=0.                                                         LIT06840
0140             TIME=0.                                                           LIT06850
0141             RADCC=0.                                                          LIT06860
0142             RADCB=0.                                                          LIT06870
0143             RADB=0.                                                           LIT06880
0144             ZZ2=0.                                                            LIT06890
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      ZZ8=0.                                                            LIT06900
      ZZ9=0.                                                            LIT06910
      ZZ6=0.                                                            LIT06920
      CMBRO=0.                                                          LIT06930
      CMBRN=0.                                                          LIT06940
      CMBRW=0.                                                          LIT06950
      RNILB=0.                                                          LIT06960
      ROXLB=0.                                                          LIT06970
      RWALB=0.                                                          LIT06980
      IG=0                                                              LIT06990
      J=IOPTB                                                           LIT07000
      XPB=1.-XLI                                                        LIT07010
      CGZ=0.                                                            LIT07020
      MLIY=0.                                                           LIT07030
      MLIOH=0.                                                          LIT07040
      RVOL=4.189*RRAD**3                                                LIT07050
      MCZ1=RVOL/(AMLI/RHLI)                                             LIT07060
      MLI1=625.87*RHLI/AMLI-MCZ1                                        LIT07070
      MLIT=0.                                                           LIT07080
      HA=1.                                                             LIT07090
      H=1.                                                              LIT07100
      NN=8                                                              LIT07110
      NA=8.                                                             LIT07120
      ND=NN-1                                                           LIT07130
      DO 31 J=1,NN                                                      LIT07140
      TN(J)=TLII                                                        LIT07150
   31 ZZ(J)=0.                                                          LIT07160
      ZZ(1)=1.                                                          LIT07170
      ZZ1=1.                                                            LIT07180
      CPLI=CPLI*AMLI                                                    LIT07190
      CPMLI=CPLI                                                        LIT07200
      CPPZ=1.                                                           LIT07210
      DO 185 IAM=1,20                                                   LIT07220
      C4(IAM)=0.                                                        LIT07230
      C10(IAM)=0.                                                       LIT07240
      DTCDT(IAM)=0.                                                     LIT07250
  185 DTBDT(IAM)=0.                                                     LIT07260
      IF(FLAGSI) CALL SI                                                LIT07270
      DELT=DTMIN                                                        LIT07280
      HF=0.                                                             LIT07290
      HB=0.                                                             LIT07300
      RCMBO=((100.-PERCEN)*RCMBO1+PERCEN*RCMBO2)/100.                   LIT07310
      QCO=((100.-PERCEN)*RCMBO1*QCO1+PERCEN*RCMBO2*QCO2)/(RCMBO*100.)   LIT07320
      FLAGIO=.FALSE.                                                    LIT07330
      IF (.NOT. FLAGS) TPANZO=0.                                        LIT07340
      TPAN=TPANZO                                                       LIT07350
      TINS1I=0.5*(TPANZO+TGZERO)                                        LIT07360
      TINS2I=TGZERO                                                     LIT07370
      TINS1=TINS1I                                                      LIT07380
      TINS2=TINS2I                                                      LIT07390
      TEHC=TEHCZO                                                       LIT07400
      DFILM=0.                                                          LIT07410
      INJEC1=0                                                          LIT07420
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            INJEC2=0                                              LIT07430
            INJEC3=0                                              LIT07440
            TAU=120.                                              LIT07450
            SIGMA=4.7611E-13                                      LIT07460
            IF (IOPTB .EQ.1) SIGMA=0.                             LIT07470
            NLM1=NL-1                                             LIT07480
            NL1M1=NL1-1                                           LIT07490
            FLAG1=.FALSE.                                         LIT07500
            FLAGL=.FALSE.                                         LIT07510
            IF (IOPTB .EQ. 1) GO TO 25                            LIT07520
            FLAG=.FALSE.                                          LIT07530
            IF(THW .LT. 0.01) FLAG=.TRUE.                         LIT07540
            IF(THF .LT. 0.01) FLAG1=.TRUE.                        LIT07550
   25       LIS=SPILL*SPRAY                                       LIT07560
            LIT=SPILL-LIS                                         LIT07570
            WN2=1.-WO2-WWA-WA                                     LIT07580
            XMOL=1./(WO2/32.+WN2/28.+WWA/18.+WA/XMOLA)            LIT07590
            RIN=1545./XMOL                                        LIT07600
            TIMEO=-.001                                           LIT07610
            TLI=TLII                                              LIT07620
            LILP=LIT                                              LIT07630
            LIL=LILP                                              LIT07640
            ZLI=LILP/RHLI/ASLI                                    LIT07650
            TCZ=TCZI                                              LIT07660
            FMLEFT=1.0                                            LIT07670
            GIN=32.2                                              LIT07680
            TS=TSZERO                                             LIT07690
            TSB=TSBI                                              LIT07700
            DO 1001 I=1,NL                                        LIT07710
            TCIC(I)=TSZERO                                        LIT07720
            TC(I)=TSZERO                                          LIT07730
 1001       L(I)=THW*L(I)/12.                                     LIT07740
            DO 1002 I=1,NL1                                       LIT07750
            TBIC(I)=TSBI                                          LIT07760
            TB(I)=TSBI                                            LIT07770
 1002       L1(I)=THF*L1(I)/12.                                   LIT07780
            ICZ=1                                                 LIT07790
            ICMB=1                                                LIT07800
            ILIT=1                                                LIT07810
            ICNI=1                                                LIT07820
            RHOA=PAZERO*144./RIN/TGZERO                           LIT07830
            RHOAI=RHOA                                            LIT07840
            IPAGE=50                                              LIT07850
            MNII=WN2*RHOAI*V                                      LIT07860
            MNI=MNII                                              LIT07870
            MOXI=WO2*RHOAI*V                                      LIT07880
            MLIOI= LIS*(1.+RCMBO)/RCMBO                           LIT07890
            MWAI=WWA*RHOAI*V                                      LIT07900
            MWA=MWAI                                              LIT07910
            MAI=WA*RHOAI*V                                        LIT07920
            MA=MAI                                                LIT07930
            LIC=LIS                                               LIT07940
    C                                                             LIT07950
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              C**********      CONVERSION TO FT. - LB. - SEC.      **********
              C
0250                W=W/12.
0251                G=G/12.
0252                THW=THW/12.
0253                THF=THF/12.
0254                IF(FLAGS)THKPAN=THKPAN/12.
0255                IF (FLAGS) THKIN1=THKIN1/12.
0256                IF (FLAGS) THKIN2=THKIN2/12.
0257                IF(FLAGS) KPAN=KPAN/3600.
0258                AKLI=AKLI/3600.
0259                KSTL=KSTL/3600.
0260                KCON=KCON/3600.
0261                KGAP=KGAP/3600.
0262                IF(.NOT. FLAGS) THKPAN=W
0263                IF(.NOT. FLAGS) KPAN=KSTL
0264                IF (IOPTB .EQ.1)  GO TO 850
              C
              C                     *********************
              C**********      CHECH THAT ENOUGH OXYGEN IS LEFT FOR POOL FIRE AFTER SPR
              C
0265                OXLFS=WO2*RHOA*V- LIS/RCMBO
0266                IF(OXLFS.LT.0.0)  LIS=RCMBO*WO2*RHOAI*V
0267                IF(OXLFS.LT.0.0) OXLFS=0.0
              C
              C***************************************
              C*   SPRAY FIRE COMPUTATION STARTED    *
              C***************************************
              C
0268                IF(LIS.LE.0.0) GO TO 627
0269                TO=TGZERO
0270                QIN= LIS*(QCO+CPLI*(TLI-TO))
0271                FF2=QIN
0272                TE=TGZERO+1.
0273            140 CONTINUE
              C**********      SPECIFIC HEAT FOR DILITHIUM OXIDE      **********
              C     CP = .0602*T**.326  T = DEG. R
              C     IF A DIFFERENT REACTION PRODUCT IS DESIRED, THE INTEGRAL OF THE
              C     DESIRED PRODUCT MUST BE SUBSTITUTED IN QOUT1.
              C***********
0274                QOUT1=(1.+RCMBO)/RCMBO*LIS*(0.0602/1.326)*(TE**1.326-TO**1.326)
0275                QOUT2=WN2*RHOA*V*(.172*(TE-TO)+8.57E-6/2.*(TE**2.-TO**2.)+1.02E-9
                   .      /3.*(TE**3.-TO**3.))
0276                QOUT3=OXLFS*(.184*(TE-TO)+3.2E-6/2.*(TE**2.-TO**2.)+1.36E04*
                   .             (1./TE-1./TO))
0277                QOUT4=WWA*RHOA*V*(0.44*(TE-TO))+WA*RHOA*V*CPA*(TE-TO)
0278                FF1=QIN-QOUT1-QOUT2-QOUT3-QOUT4
0279                IF(FF1*FF2.LT.0.) GO TO 150
0280                TE=TE+1.
0281                IF(TE.GT.1.0E06) GO TO 910
0282                FF2=FF1
0283                GO TO 140
              C      PORTION OF PROGRAM FOR GETTING INITIAL GAS TEMP. AND PRESS.   ***
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0284            627 CONTINUE                                                      LIT08490
0285                TE=TGZERO                                                     LIT08500
0286            150 CONTINUE                                                      LIT08510
0287                TG=TE                                                         LIT08520
0288                MOX=MOXI-LIS/RCMBO                                            LIT08530
0289                MOXI=MOX                                                      LIT08540
0290                MLIO=MLIOI                                                    LIT08550
0291                XMAIR=MNI/28.+MOX/32.+MA/XMOLA+MWA/18.                        LIT08560
0292                PZERO=1545.*XMAIR*TG/144./V                                   LIT08570
0293                PA=PZERO                                                      LIT08580
0294                TGZERO=TG                                                     LIT08590
0295                WRITE(6,726) TG,PZERO                                         LIT08600
0296           726  FORMAT (//' SPRAY FIRE RESULTS'/1X,18(1H-)//5X,'TGZERO = ',F6.1,  LIT08610
               .'    PZERO = ',F6.3///)                                           LIT08620
0297                IF (FLAGJ)WRITE(6,1090)TONE,DP1,FCT1,TTWO,DP2,FCT2,TTHREE,DP3,FCT3LIT08630
0298           1090  FORMAT(//,' GAS INJECTION DATA',/,1X,18(1H-)//3(5X,'AT TIME = ',  LIT08640
               .F8.0,5X,'DELTA P = ',F8.4,5X,'FCT N2 = ',F8.4,//)///)             LIT08650
               C**********     SPRAY FIRE COMUTATION CONCLUDED     **********     LIT08660
               C                                                                  LIT08670
0299           850  CALL INIT                                                     LIT08680
               C                                                                  LIT08690
               C************************************                              LIT08700
               C*   START OF DYNAMIC CYCLE           *                            LIT08710
               C*   ---------------------            *                            LIT08720
               C*   START OF INTEGRATION CYCLE       *                            LIT08730
               C************************************                              LIT08740
               C                                                                  LIT08750
0300            200 CONTINUE                                                      LIT08760
               C        ARTIFICIAL INJECTION OF OXYGEN AND NITROGEN               LIT08770
               C                  TO MODEL HEDL EXPERIMENTAL PROCEDURE            LIT08780
0301                MOXINJ=0.                                                     LIT08790
0302                MNIINJ=0.                                                     LIT08800
0303                IF (.NOT. FLAGJ) GO TO 1060                                   LIT08810
0304                IF (TIME .LT. TONE .OR. TIME .GT. TONE+60.) GO TO 1040        LIT08820
0305                IF(INJEC1 .EQ. 0 .AND. DP1 .GT. 0.0) WRITE(6,1080) TONE,DP1   LIT08830
0306           1080  FORMAT(/,' INJECTION OF GAS AT TIME = ',F8.0,' TO RAISE PRESSURE BLIT08840
               .Y ',F8.4,' PSI')                                                  LIT08850
0307                INJEC1=1                                                      LIT08860
0308                MOINJ1= 2.9822*V/TG*DP1*(1.-FCT1)                             LIT08870
0309                MNINJ1= 2.6094*V/TG*DP1*FCT1                                  LIT08880
0310                MOXINJ=MOINJ1/60.                                             LIT08890
0311                MNIINJ=MNINJ1/60.                                             LIT08900
0312           1040  IF(TIME .LT. TTWO .OR. TIME .GT. TTWO+60.) GO TO 1050        LIT08910
0313                IF(INJEC2 .EQ. 0 .AND. DP2 .GT. 0.0) WRITE(6,1080) TTWO,DP2   LIT08920
0314                INJEC2=1                                                      LIT08930
0315                MOINJ2= 2.9822*V/TG*DP2*(1.-FCT2)                             LIT08940
0316                MNINJ2= 2.6094*V/TG*DP2*FCT2                                  LIT08950
0317                MOXINJ=MOINJ2/60.                                             LIT08960
0318                MNIINJ=MNINJ2/60.                                             LIT08970
0319           1050  IF(TIME .LT. TTHREE .OR. TIME .GT. TTHREE+60.) GO TO 1060    LIT08980
0320                IF(INJEC3 .EQ. 0 .AND. DP3 .GT. 0.0) WRITE(6,1080) TTHREE,DP3 LIT08990
0321                INJEC3=1                                                      LIT09000
0322                MOINJ3= 2.9822*V/TG*DP3*(1.-FCT3)                             LIT09010
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0323             MNINJ3= 2.6094*V/TG*DP3*FCT3                                      LIT09020
0324             MOXINJ=MOINJ3/60.                                                 LIT09030
0325             MNIINJ=MNINJ3/60.                                                 LIT09040
0326       1060  CONTINUE                                                          LIT09050
0327             IF (IOPTB .EQ. 1) GO TO 21                                        LIT09060
           C                                                                       LIT09070
           C        COMPUTE PHYSICAL PROPERTIES DEPENDENT ON TEMPERATURE           LIT09080
           C     CALCULATE AIR COMPOSITION AND SPECIFIC HEAT AT CONST. VOLUME   ***LIT09090
           C                                                                       LIT09100
0328             MAIR=MOX+MNI+MWA+MH2+MA                                           LIT09110
0329             RHOA=MAIR/V                                                       LIT09120
0330             FOX=MOX/MAIR                                                      LIT09130
0331             FWA=MWA/MAIR                                                      LIT09140
0332             FNI=MNI/MAIR                                                      LIT09150
0333             CPMOX= (0.184 + 3.2E-06*TG - 1.36E04 /(TG**2))*MOX                LIT09160
0334             CPMNI = (0.172 + 8.57E-06*TG + 1.02E-09*TG**2)*MNI                LIT09170
0335             CPWA=0.44                                                         LIT09180
0336             CPH2=3.76                                                         LIT09190
0337             CPLIH=0.67                                                        LIT09200
0338             CPN2=(0.172+8.57E-06*TG+1.02E-09*TG**2)                           LIT09210
0339             CPLIO=.0602*TG**.326                                              LIT09220
0340             CPLIN=.3368+3.67E-4*TG                                            LIT09230
0341             CPMLIO=CPLIO*MLIO                                                 LIT09240
0342       21    CPLZ=CPLI                                                         LIT09250
0343             AKLZ=AKLI                                                         LIT09260
0344             TLI=1216.                                                         LIT09270
0345             IF (J2 .EQ. 0.) GO TO 851                                         LIT09280
0346             TLIK=(TLI-462.)/1.8+273.                                          LIT09290
0347             TCZK=(TCZ-462.)/1.8+273.                                          LIT09300
0348             CPPB=CP1+CP2*TLIK                                                 LIT09310
0349             CPPZ=CP1+CP2*TCZK                                                 LIT09320
0350             IF (TLI .GT. PBMELT) CPPB=CPPL                                    LIT09330
0351             IF (TCZ .GT. PBMELT) CPPZ=CPPL                                    LIT09340
0352             CPFAC=0.004938*TLI -6.20741                                       LIT09350
0353             CPFAZ=0.004938*TCZ -6.20741                                       LIT09360
0354             CPLI=1.0037-.01063*CPFAC+.00564*CPFAC**2-.001279*CPFAC**3         LIT09370
0355             IF (TCZ .GE. 1302.) CPLZ=0.995                                    LIT09380
0356             IF (TCZ .GE. 1302.) GO TO 1255                                    LIT09390
0357             CPLZ=1.0037-.01063*CPFAZ+.00564*CPFAZ**2-.001279*CPFAZ**3         LIT09400
0358       1255  CPLI=XLI*CPLI+XPB*CPPB                                            LIT09410
0359             CPLZ=XLI*CPLZ+XPB*CPPZ                                            LIT09420
0360             CPLI=CPLI*AMLI                                                    LIT09430
0361             CPLZ=CPLZ*AMLI                                                    LIT09440
0362             IF (J1 .NE. 1.) GO TO 851                                         LIT09450
0363             RHLI=33.49-.0035*(TLI -460.)                                      LIT09460
0364             AKLI=(10.48+2.767E-03*(TLI -817.)-0.322E-06*(TLI -817.)**2)/1488. LIT09470
0365             AKLZ=(10.48+2.767E-03*(TCZ -817.)-0.322E-06*(TCZ -817.)**2)/1488. LIT09480
0366             IF (IOPTB .EQ. 1) GO TO 851                                       LIT09490
0367             CPLI=((LIT-LIBP)*CPLI+LILOX*CPLIO+LILNI*CPLIN)/LILP               LIT09500
0368       851   IF (TCZ .LT. TMELT) DREAC=19500.+8.2*(TCZ-672.)+CPLZ*(TCZ-537.)   LIT09510
                .*R1                                                              LIT09520
0369             IF (TCZ .GE. TMELT) DREAC=19500.+8.2*(TCZ-672.)+R1*CPLI1*         LIT09530
                .(TMELT-537.)+R1*QMELT+R1*CPLZ*(TCZ-TMELT)                        LIT09540
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0370          HYD=J2*3.5*(TCZ-537.)                                           LIT09550
0371          LIOHL=(2.-J2)*12.5*(TCZ-537.)                                   LIT09560
0372          LIOHG=19070.+20.74*(TCZ-1338.)*(2.-J2)                          LIT09570
0373          OML=CPPZ*(TCZ-537.)*R2                                          LIT09580
0374          OMG=R2*(CPPB1*(PBMELT-537.)+QMELTP+CPPZ*(TCZ-PBMELT))           LIT09590
0375          TEM1=AMIN1(PBMELT,1338.)                                        LIT09600
0376          TEM2=AMAX1(PBMELT,1338.)                                        LIT09610
0377          IF (TCZ .LT. TEM1) DPROD=HYD+LIOHL+OML                          LIT09620
0378          IF (TCZ .LT. TEM1) GO TO 1601                                   LIT09630
0379          IF (TCZ .GE. TEM2) DPROD=HYD+LIOHG+OMG                          LIT09640
0380          IF (TCZ .GE. TEM2) GO TO 1601                                   LIT09650
0381          IF (PBMELT .GT. 1338.) DPROD=HYD+LIOHG+OML                      LIT09660
0382          IF (PBMELT .LT. 1338.) DPROD=HYD+LIOHL+OMG                      LIT09670
0383    1601   QWA=DELH+DPROD-DREAC                                           LIT09680
0384          IF (IOPTB .EQ. 1) GO TO 22                                      LIT09690
0385          HTCAPG=CPMOX+CPMNI+CPMLIO+CPA*MA+CPLIN*MLIN+CPLIH*MLIH+CPH2*MH2 LIT09700
             .     +CPWA*MWA                                                  LIT09710
0386          HTCAPG=HTCAPG/GAMMA                                             LIT09720
         C    *****      THIS HEAT CAPACITY (CPA) IS GOOD FOR CARBON DIOXIDE ONLYLIT09730
0387          CPA=0.175+6.69E-05*TG-1.05E-08*TG**2.                           LIT09740
         C                                                                    LIT09750
         C         TWO MILLIMETERS ARE ASSUMED TO COVER THE POOL OPTICALLY    LIT09760
0388          ZP=(LILOX/RHOLIO+LILNI/RHOLIN)/ASLI                             LIT09770
0389          IF(EMLI.LT.EMF)EMLI=0.2+(EMF-0.2)*ZP/0.00656                    LIT09780
         C                                                                    LIT09790
0390          EMG=1.-EXP(-(MLIO/RHOLIO+MLIN/RHOLIN+MLIH/RHOLIH)*2.27E05*CH/V/RA)LIT09800
0391          EMG=EMG*EMGF                                                    LIT09810
0392          IF (EMG.LT.0.005) EMG=0.005                                     LIT09820
         C         THE RIF'S FOR RADIATION FROM THE POOL USE TAUCZ INSTEAD OF (1LIT09830
         C         THE ALLOWS US TO MODEL POOL TO COMBUSTION ZONE COUPLING WITH LIT09840
         C         FLEXIBILITY                                                LIT09850
0393          RIFPW=1./((1.-EMLI)/EMLI+(1.-EMSTL)*ASLI/EMSTL/AW+1./((1.-EMG)  LIT09860
             . *(ICZ*(TAUCZ-1.)+1.)*FPW+EMG/(ASLI/AW+1./FPG/(ICZ*(TAUCZ-1.)+1.)LIT09870
             . )))                                                            LIT09880
0394          RIFCZW=1./((1.-EMCZ)/EMCZ+(1.-EMSTL)*ASLI/EMSTL/AW+1./((1.-EMG) LIT09890
             .      +EMG/(1.+ASLI/AW)))                                       LIT09900
0395          RIFPG=EMLI*EMG/(EMG-EMG*EMLI+EMLI/FPG/(ICZ*(TAUCZ-1.)+1.))      LIT09910
0396          RIFCZG=(EMCZ*EMG)/((1.-EMCZ)*EMG+EMCZ)                          LIT09920
0397          IF(FLAGS)RIFPAS=1./((1.-EMINS)/EMINS+(1.-EMSTL)/EMSTL*AINS/AW+  LIT09930
             .         (AINS/AW+1.)/(1.+AINS/AW*(1.-EMG)))                    LIT09940
0398          IF(FLAGS)RIFPAG=EMINS*EMG/(EMINS+EMG-EMINS*EMG)                 LIT09950
0399          RIFSLC=(EMSTL*EMCONC)/(EMSTL+EMCONC-EMSTL*EMCONC)               LIT09960
0400          RIFCZP=(EMLI*EMCZ)/(EMCZ+EMLI-EMCZ*EMLI)                        LIT09970
         C                                                                    LIT09980
         C**********     CALCULATING GAS HEAT TRANSFER COEFFICIENTS   **********LIT09990
0401          IF(ICZ.EQ.1) T1=0.5*(TG+TCZ)                                    LIT10000
0402          IF(ICZ.EQ.0) T1=0.5*(TG+TLI)                                    LIT10010
0403          T2 = 0.5*(TG +TS )                                              LIT10020
0404          T3E=0.5*(TG+TEHC)                                               LIT10030
0405          IF(FLAG) T4H=(TS+TA)/2.                                         LIT10040
0406          IF(.NOT. FLAG) T4H=(TC(NL)+TA)/2.                               LIT10050
0407          B1 = 1.0/T1                                                     LIT10060
0408          B2 = 1.0/T2                                                     LIT10070
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FORTRAN IV G1  RELEASE 2.0           MAIN              DATE = 80270        18/07/48              PAGE 0020

0409              B3E=1.0/T3E                                                              LIT10080
0410              B4H=1.0/T4H                                                              LIT10090
0411              D1 = ((4.94E-05*T1 +0.0188)/(RHOA*3600.0))**2                            LIT10100
0412              D2 = ((4.94E-05*T2 +0.0188)/(RHOA*3600.0))**2                            LIT10110
0413              D3E=((4.94E-05*T3E+0.0188)/(RHOA*3600.))**2                              LIT10120
0414              D4H=((4.94E-05*T4H+0.0188)/(.074*3600.))**2                              LIT10130
0415              AK1=(0.014+1.92E-05*(T1-460.))/3600.                                     LIT10140
0416              AK2=(0.014+1.92E-05*(T2-460.))/3600.                                     LIT10150
0417              AK3E=(0.014+1.92E-05*(T3E-460.))/3600.                                   LIT10160
0418              AK4H=(0.014+1.92E-05*(T4H-460.))/3600.                                   LIT10170
0419              EX2 = (GIN*B2*ABS(TG -TS)/D2)**0.3333                                    LIT10180
0420              EX3E=(GIN*B3E*ABS(TG-TEHC)/D3E)**0.3333                                  LIT10190
0421              IF(FLAG)EX4H=(GIN*B4H*ABS(TA-TS)/D4H)**0.3333                            LIT10200
0422              IF(.NOT.FLAG)EX4H=(GIN*B4H*ABS(TA-TC(NL))/D4H)**0.3333                   LIT10210
0423              H=HINGS*AK2*EX2                                                          LIT10220
0424              HEHC=HINEHC*AK3E*EX3E                                                    LIT10230
0425              HA=HINSAM*AK4H*EX4H                                                      LIT10240
            C**********      CALCULATING SOME PRELIMINARY THERMAL DIFFUSIVITIES            LIT10250
            C                          BETWEEN NODES   (MORE TO COME)                      LIT10260
0426        22    B=L(1)/(KCON*2.)+G/KGAP+W/(KSTL*2.)                                      LIT10270
0427              BB=L1(1)/(KCON*2.)+G/KGAP+W/(KSTL*2.)                                    LIT10280
0428              USUBA=KCON*HA/(KCON+HA*L(NL)/2.)                                         LIT10290
0429              C1=KSTL*H*AW/HTCAPG/(W*H/2.+KSTL)*(-1)                                   LIT10300
0430              C11=KSTL*HA/(RHSTL*CPSTL*W*(KSTL+W*HA/2.))                               LIT10310
0431              IF(FLAG) GO TO 779                                                       LIT10320
0432              C3=1./(B*L(1)*RHCON*CPCON)                                               LIT10330
0433              DO 1010 I=1,NLM1                                                         LIT10340
0434        1010  C4(I)=2.*KCON/(RHCON*CPCON*L(I)*(L(I)+L(I+1)))                           LIT10350
0435              C5=USUBA/(RHCON*CPCON*L(NL))                                             LIT10360
0436              C7=1./(B*W*RHSTL*CPSTL)                                                  LIT10370
0437        779   C6=KSTL*H/(RHSTL*CPSTL*W*(W*H/2.+KSTL))                                  LIT10380
0438              IF  (IOPTB .NE. 1) GO TO 878                                             LIT10390
0439              C1=0.                                                                    LIT10400
0440              C6=0.                                                                    LIT10410
0441              C8=1./(0.5*W/KSTL/ASLI+0.43/KCON/ASLI)/                                  LIT10420
                 .(CPSTL*RHSTL*ASLI*W)                                                     LIT10430
0442              C9=1./(0.5*W/KSTL/ASLI+0.43/KCON/ASLI)/                                  LIT10440
                 .(CPCON*RHCON*ASLI*0.86)                                                  LIT10450
0443        878   DO 1020 I=1,NL1M1                                                        LIT10460
0444        1020  C10(I)=2.*KCON/(RHCON*CPCON*L1(I)*(L1(I)+L1(I+1)))                       LIT10470
0445              IF (IOPTB .EQ. 1)  GO TO  524                                            LIT10480
0446              IF(FLAG1) GO TO 780                                                      LIT10490
0447              C8=1./(BB*W*RHSTL*CPSTL)                                                 LIT10500
0448              C9=1./(BB*L1(1)*RHCON*CPCON)                                             LIT10510
0449        780   IF(ICZ.EQ.1) EXX=(GIN*B1*ABS(TCZ-TG)/D1)                                 LIT10520
0450              IF(ICZ.EQ.0) EXX=(GIN*B1*ABS(TLI-TG)/D1)                                 LIT10530
0451              IF   (EXX .LE. 0.0) GO TO 300                                            LIT10540
0452              EX1 = (EXX)**0.3333                                                      LIT10550
0453              CEHCGS=HEHC*AEHC/HTCAPG                                                  LIT10560
0454              CGSEHC=HEHC*AEHC/XMEHC/CPEHC                                             LIT10570
            C                                                                              LIT10580
            C**********     CALCULATING GAS CONVECTION COEFFICIENT     **********          LIT10590
0455              DIFF=241.57/(132.0+T1/1.8)*(T1/493.2)**2.5/3600.                         LIT10600
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FORTRAN IV G1  RELEASE 2.0           MAIN             DATE = 80270          18/07/48              PAGE 0021

0456              HFINF=HIN*DIFF*EX1                                                    LIT10610
0457              HBINF=HIN*AK1*EX1                                                     LIT10620
0458              IF (TAU .LT. DELT) TAU=DELT                                           LIT10630
0459              HF=HF+(HFINF-HF)*DELT/TAU                                             LIT10640
0460              HB=HB+(HBINF-HB)*DELT/TAU                                             LIT10650
0461              IF(TIME.GT.ESCTIN) XESC=1.                                            LIT10660
0462              IF(TIME.GT.SFLTIN) XSFL=1.                                            LIT10670
            C                                                                           LIT10680
            C**********     TESTING FOR COMBUSTION       **********                     LIT10690
0463              ICNI=0                                                                LIT10700
0464              TEZ=(TCZ+TLI)/2.                                                      LIT10710
0465        585   IF (TEZ.LE.2340. .AND. FOX.LE.0.28 .AND. MNI.GT.0.0) ICNI=1           LIT10720
0466              IF(.NOT.(ILIT.EQ.0 .OR.(ICMB.EQ.0 .AND. ICNI.EQ.0) .OR. TLI.LT.       LIT10730
                 .     TMELT)) GO TO 525                                                LIT10740
0467              IF(ICZ.EQ.1)WRITE(6,529)ICZ,ICNI,ILIT,ICMB,TCZ,FOX,TLI                LIT10750
0468        529   FORMAT(' COMBUSTION HAS JUST STOPPED.  PARAMETERS ARE: ICZ=',I1,      LIT10760
                 .'  ICNI=',I1/' ILIT=',I1,'  ICMB=',I1,'  TCZ= ',F8.2,'  FOX= ',       LIT10770
                 .F7.3,'  TLI= ',F8.2)                                                  LIT10780
0469              IF(ICZ.EQ.1) IPAGE=IPAGE+2                                            LIT10790
0470              GO TO 522                                                             LIT10800
0471        524   CONTINUE                                                              LIT10810
0472              IF (IOPTB .EQ. 1) GO TO 23                                            LIT10820
            C                                                                           LIT10830
            C                                                                           LIT10840
            C*******************************************************************************LIT10850
            C      COMPUTATIONS USING COMBUSTION ZONE MODEL          ***********        LIT10860
            C*******************************************************************************LIT10870
            C                                                                           LIT10880
            C**********     COMPUTING RATE OF LITHIUM COMBUSTION      **********        LIT10890
0473        525   RN2=0.                                                                LIT10900
0474              ICZ=1                                                                 LIT10910
0475              IF(TEZ.LT.1900. .AND. FOX.LE.0.28)   RN2=                             LIT10920
                 .     (1.0-FOX/0.28)/EXP(((1900.-TEZ)/665.)**2.75)                     LIT10930
0476              IF(TEZ.GE.1900. .AND. TEZ.LE.2340. .AND. FOX.LE.0.28)   RN2=          LIT10940
                 .     (1.0-FOX/0.28)*(1.-((TEZ-1900.)/440.)**2)                        LIT10950
0477              CMBRO=HF*FOX*RHOA*RCMBO                                               LIT10960
0478              CMBRN=HF*FNI*RHOA*RCMBN*RN2                                           LIT10970
0479              CMBRW=HF*FWA*RHOA*RCMBW                                               LIT10980
0480              CMBR = CMBRO + CMBRN + CMBRW                                          LIT10990
0481              RNILB=CMBRN*ASLI/RCMBN                                                LIT11000
0482              ROXLB=CMBRO*ASLI/RCMBO                                                LIT11010
0483              RWALB=CMBRW*ASLI/RCMBW                                                LIT11020
            C                                                                           LIT11030
            C**********     COMPUTATION OF LITHIUM VAPOR DIFFUSION      **********      LIT11040
0484              PLIV=(10.**(4.8831-14180.2/TLI))*14.7                                 LIT11050
0485              RHOLIV=PLIV*144./RIN/TLI                                              LIT11060
0486              DIFFLI=3.56E-03*((TLI/460.)**1.81)/PA                                 LIT11070
0487              DFILM=DIFFLI*RHOLIV/CMBR                                              LIT11080
0488              EFILM=DFILM*12.                                                       LIT11090
            C          THE FILM THERMAL CONDUCTIVITY IS A WEIGHTED AVERAGE OF NITROGLIT11100
            C          LITHIUM VAPOR , WITH PLIV AS THE WEIGHTING FACTOR                LIT11110
0489              TFEFF=(TCZ+TLI)/2.+459.67                                             LIT11120
0490              KNIT=.0432+TFEFF*(.0078-TFEFF*(8.2E-04+TFEFF*2.08E-04))               LIT11130
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0491           KLIT=0.55+TFEFF*(-4.99E-04+TFEFF*1.206E-07)                  LIT11140
0492           KFILM=(PLIV*(KLIT-KNIT)+PA*KNIT)/14.7/3600.                  LIT11150
         C                                                                  LIT11160
         C**********     COMPUTATION OF HEAT TRANSFER COEFFICIENTS     **********LIT11170
0493           YAPCZ=KFILM*AKLI*ASLI/(DFILM*AKLI+KFILM*ZLI/2.)              LIT11180
         C THIS HEAT CAPACITY IS SHEER GUESSWORK     THE 0.1 IS FOR VERY LOW COMBLIT11190
0494           CPMCZ=ASLI*((1.+RCMBO)/RCMBO*CMBRO*CPLIO+(1.+RCMBN)/RCMBN*CMBRN*  LIT11200
              .   CPLIN+((1.+RCMBW)/RCMBW-(1./RCMBH2))*CMBRW*CPWA+(1.+RCMBH2)/   LIT11210
              .   RCMBH2*CMBRW*CPH2+RN2*HF*FNI*RHOA*CPN2)*300.+1.0          LIT11220
0495           IF (CPMCZ/ASLI .LE. 0.001) CPMCZ=0.001*ASLI                 LIT11230
0496           CGCZ=HB*ASLI/CPMCZ                                           LIT11240
0497           CCZG=HB*ASLI/HTCAPG                                          LIT11250
0498           CPCZ=YAPCZ/CPMCZ                                             LIT11260
0499           CCZP=YAPCZ/(CPLI*LIL)                                        LIT11270
0500           CCZ=(CMBRO*QCO+CMBRN*QCN+CMBRW*QCW)*ASLI                     LIT11280
0501           CLIST=2.*ASLI*AKLI*KSTL/(LIL *CPLI*(ZLI *KSTL+W*AKLI))       LIT11290
0502           CSBLI=2.*AKLI*KSTL/(RHSTL*W*CPSTL*(ZLI *KSTL+W*AKLI))        LIT11300
0503     23    IF (IOPTB .EQ. 0) GO TO  852                                 LIT11310
0504           CMBR=1.                                                      LIT11320
0505           YAPCZ=1.                                                     LIT11330
0506           TG=TLI                                                       LIT11340
0507           RVOL1=RVOL+MLIOH*0.15*(2.-J2)+MPB/RHPB                       LIT11350
0508           RRAD=(3.*RVOL1/4./3.14)**(1./3.)                             LIT11360
0509           RAREA=12.57*RRAD**2                                          LIT11370
0510           LBR=(5.3-RRAD)/2.                                            LIT11380
0511           LBN=LBR/NA                                                   LIT11390
0512           LB2=LBN/2.                                                   LIT11400
0513           DO 32 J=1,NN                                                 LIT11410
0514           RAD(J)=RRAD+J*LBN                                            LIT11420
0515           ARE(J)=12.57*RAD(J)**2                                       LIT11430
0516     32    VOL(J)=4.19*RAD(J)**3                                        LIT11440
0517           ATOCZ=RVOL1*2.34                                             LIT11450
0518           ATICZ=ATOCZ/1.3                                              LIT11460
0519           QCCZ=1./(5.33/ATOCZ+1./(HCO*ATICZ))                          LIT11470
0520           ATO(1)=(VOL(1)-RVOL1)*2.34                                   LIT11480
0521           MB(1)=(VOL(1)-RVOL1)*RHLI/AMLI                               LIT11490
0522           DO 37 J=2,NN                                                 LIT11500
0523           ATO(J)=(VOL(J)-VOL(J-1))*2.34                                LIT11510
0524     37    MB(J)=(VOL(J)-VOL(J-1))*RHLI/AMLI                            LIT11520
0525           DO 24 J=1,NN                                                 LIT11530
0526           ATI(J)=ATO(J)/1.3                                            LIT11540
0527     24    QC(J)=1./(5.33/ATO(J)+1./(HCO*ATI(J)))                       LIT11550
0528           A=R1/(2.-J2)                                                 LIT11560
0529           MLI=MLI1-A*MLIOH                                             LIT11570
0530           MCZ=MCZ1+A*MLIOH+MPB                                         LIT11580
0531           IF (IG .EQ. 1) CPLIOH=20.74                                  LIT11590
0532           CPMCZ=MCZ1*CPLZ/MCZ+MPB*CPPZ/MCZ+A*MLIOH*CPLIOH/MCZ          LIT11600
0533           CCZ=(NT*0.025)*((-1.)*QWA-18.*(TCZ-612.)-CPLI*(TCZ-TLI)*R1)/MCZ  LIT11610
0534           IF(ICZ .EQ. 0)  CCZ=0.                                       LIT11620
0535           CF(1)=1./((LB2/(AKLZ*RAREA)+LB2/(AKLI*RAREA))*MCZ*CPMCZ)     LIT11630
0536           CT(1)=1./((LB2/(AKLZ*RAREA)+LB2/(AKLI*RAREA))*MB(1)*CPLI)    LIT11640
0537           DO 33 J=2,NN                                                 LIT11650
0538           CF(J)=(AKLI*ARE(J-1))/LBN/(CPLI*MB(J-1))                     LIT11660
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0539      33    CT(J)=(AKLI*ARE(J-1))/LBN/(CPLI*MB(J))                           LIT11670
0540            CLIST=1./((LB2/(AKLI*ARE(NN))+0.5*W/(KSTL*ARE(NN)))*CPLI*MB(NN))  LIT11680
0541            CSBLI =1./((LB2/(AKLI*ARE(NN))+0.5*W/(KSTL*ARE(NN)))             LIT11690
               .*CPSTL*RHSTL*W*ARE(NN))                                          LIT11700
0542            TDIF=TCZ-TN(1)                                                   LIT11710
0543            CGCZ=0.                                                          LIT11720
0544            CCZG=0.                                                          LIT11730
0545            IF (TDIF .LT. 50.) GO TO 26                                      LIT11740
0546            IF (TLI .LT. TMELT) GO TO 26                                     LIT11750
0547            CGCZ=RAREA*AKLI/(RRAD*2.)*(2.0+0.001*((2.65E-04*(TCZ-TLI)        LIT11760
               .*RRAD**3)**0.25))/(CPMCZ*MCZ)                                    LIT11770
0548            CCZG=(RAREA*AKLZ/(RRAD*2.))*(2.0+0.001*((2.65E-04*(TCZ-TLI)      LIT11780
               .*RRAD**3)**0.25))/(CPLI*MB(1))                                   LIT11790
0549      26    IF (TCZ .GE. 1325.)  GO TO 860                                   LIT11800
0550            GO TO 861                                                        LIT11810
0551      860   IF (IG .NE. 0) GO TO 862                                         LIT11820
0552            IG =1                                                            LIT11830
0553            Q=CPMCZ*MCZ*ZZ6                                                  LIT11840
0554            MLIO=MLIOH                                                       LIT11850
0555            TIM=MLIOH*QLIOH/Q                                                LIT11860
0556            MLIT=TIM*NT*0.025                                                LIT11870
0557            MLIY=MLIT+MLIO                                                   LIT11880
0558      862   IF (MLIOH .LE. MLIY)  GO TO 863                                  LIT11890
0559      861   CGZ=0.                                                           LIT11900
0560            GO TO 852                                                        LIT11910
0561      863   CGZ=1.                                                           LIT11920
0562      852   IF (IOPTB .EQ. 1) GO TO 2452                                     LIT11930
0563            QRADP=SIGMA*ASLI*(TCZ**4-TLI**4)*RIFCZP                          LIT11940
0564            QRADW=SIGMA*ASLI*(TCZ**4-TS**4)*RIFCZW                           LIT11950
0565            QRADG=SIGMA*ASLI*(TCZ**4-TG**4)*RIFCZG                           LIT11960
0566            RCZW=QRADW/(W*AW*RHSTL*CPSTL)                                    LIT11970
0567            RCZP=QRADP/(LIL*CPLI)                                            LIT11980
0568            RCZG=QRADG/HTCAPG                                                LIT11990
0569            IF(.NOT. FLAG1) QRADB=SIGMA*ASLI*(TSB**4-TB(1)**4)*RIFSLC        LIT12000
0570            IF(FLAG1)QRADB=SIGMA*ASLI*(TSB**4-TA**4)*EMSTL                   LIT12010
0571            IF(.NOT. FLAG) QRADC=SIGMA*AW*(TS**4-TC(1)**4)*RIFSLC            LIT12020
0572            IF(FLAG)QRADC=SIGMA*AW*(TS**4-TA**4)*EMSTL                       LIT12030
0573            RADB=QRADB/(W*ASLI*RHSTL*CPSTL)                                  LIT12040
0574            RADC=QRADC/(W*AW*RHSTL*CPSTL)                                    LIT12050
0575            IF(.NOT. FLAG1) RADCB=QRADB/(L1(1)*ASLI*RHCON*CPCON)             LIT12060
0576            IF(.NOT. FLAG) RADCC=QRADC/(L(1)*AW*RHCON*CPCON)                 LIT12070
0577            QRADY=SIGMA*ASLI*(TLI**4-TS**4)*RIFPW                            LIT12080
0578            QRADZ=SIGMA*ASLI*(TLI**4-TG**4)*RIFPG                            LIT12090
0579            RLIW=QRADY/(W*AW*RHSTL*CPSTL)                                    LIT12100
0580            RWLI=QRADY/CPLI/LIL                                              LIT12110
0581            RGLI=QRADZ/CPLI/LIL                                              LIT12120
0582            RLIG=QRADZ/HTCAPG                                                LIT12130
          C                                                                      LIT12140
          C**********************************************                        LIT12150
          C*   CALCULATING TEMPERATURE RATES OF CHANGE   *                       LIT12160
          C*       (WITH COMBUSTION)                      *                      LIT12170
          C**********************************************                        LIT12180
0583            IF(IOPTB .EQ. 0) GO TO 1100                                      LIT12190
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FORTRAN IV G1  RELEASE 2.0            MAIN            DATE = 80270        18/07/48              PAGE 0024

0584          2452  CONTINUE                                                              LIT12200
0585                ZZ6=CCZ/CPMCZ-CF(1)*(TCZ-TN(1))-CGCZ*(TCZ-TN(1))                      LIT12210
                   .-(QCCZ*(TCZ-1032.)-QCCZ*180.)/(CPMCZ*MCZ)                             LIT12220
0586                ZZ(1)=CT(1)*(TCZ-TN(1))+CCZG*(TCZ-TN(1))-CF(2)*(TN(1)-TN(2))          LIT12230
                   .-(QC(1)*(TN(1)-1032.)-QC(1)*180.)/(CPLI*MB(1))                        LIT12240
0587                DO 34 J=2,ND                                                          LIT12250
0588          34    ZZ(J)=CT(J)*(TN(J-1)-TN(J))-CF(J+1)*(TN(J)-TN(J+1))                   LIT12260
                   .-(QC(J)*(TN(J)-1032.)-QC(J)*180.)/(CPLI*MB(J))                        LIT12270
0589                ZZ(NN)=CT(NN)*(TN(NN-1)-TN(NN))-CLIST*(TN(NN)-TSB)                    LIT12280
                   .+CLIST*450.-(QC(NN)*(TN(NN)-1032.)-QC(NN)*180.)/(CPLI*MB(NN))         LIT12290
0590                IF (IOPTB .EQ. 1)  GO TO  523                                         LIT12300
              C                                                                           LIT12310
              CALCULATE COMBUSTION ZONE TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)        LIT12320
0591          1100  ZZ6=(CCZ-(QRADP+QRADW+QRADG))/CPMCZ-(J-1)*QVAP*CMBR*ASLI/CPMCZ        LIT12330
                   .-CPCZ*(TCZ-TLI)-CGCZ*(TCZ-TG)                                         LIT12340
0592                IF(TCZ .LT. TLI) ZZ6=(TLI-TCZ)/DELT                                   LIT12350
              C                                                                           LIT12360
              CALCULATE LITHIUM TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)                LIT12370
0593                ZZ1=CCZP*(TCZ-TLI)+RCZP-CLIST*(TLI-TSB)+(J-1)*QVAP*CMBR*ASLI*CCZP/LIT12380
                   .YAPCZ-RWLI-RGLI+J*CCZG*(TCZ-TLI)                                      LIT12390
                   .+47800./(CPMLI*MLI)*J                                                 LIT12400
              C                                                                           LIT12410
              CALCULATE CELL GAS TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)               LIT12420
0594                ZZ4=C1*(TG-TS)+CCZG*(TCZ-TG)+RCZG+XBLOW*BLOWR*CPAB*(TBLOW-TG)         LIT12430
                   .   /HTCAPG-ESCR*XESC/HTCAPG+CEHCGS*(TEHC-TG)+RLIG                     LIT12440
              C                                                                           LIT12450
              CALCULATE WALL STEEL TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)             LIT12460
0595                IF(.NOT. FLAG) ZZ5=C6*(TG-TS)-C7*(TS-TC(1))+RCZW-RADC+RLIW            LIT12470
0596                IF(FLAG)ZZ5=C6*(TG-TS)-C11*(TS-TA)+RCZW-RADC+RLIW                     LIT12480
0597                GO TO 523                                                             LIT12490
              C                                                                           LIT12500
              C                                                                           LIT12510
              C*************************************************                          LIT12520
              C*   COMPUTATIONS WITHOUT COMBUSTION ZONE MODEL     *                       LIT12530
              C*************************************************                          LIT12540
              C                                                                           LIT12550
0598            522 CONTINUE                                                              LIT12560
0599                ICZ=0                                                                 LIT12570
0600                CMBR=0.0                                                              LIT12580
0601                RN2=0.0                                                               LIT12590
0602                YALIG=AKLI*HB*ASLI/(AKLI+HB*ZLI/2.)                                   LIT12600
0603                CLIG=YALIG/HTCAPG                                                     LIT12610
0604                QRADW=SIGMA*ASLI*(TLI**4-TS**4)*RIFPW                                 LIT12620
0605                QRADG=SIGMA*ASLI*(TLI**4-TG**4)*RIFPG                                 LIT12630
0606                RLIW=QRADW/(W*AW*RHSTL*CPSTL)                                         LIT12640
0607                RWLI=QRADW/CPLI/LIL                                                   LIT12650
0608                RGLI=QRADG/CPLI/LIL                                                   LIT12660
0609                RLIG=QRADG/HTCAPG                                                     LIT12670
0610                IF(.NOT. FLAG1) QRADB=SIGMA*ASLI*(TSB**4-TB(1)**4)*RIFSLC             LIT12680
0611                IF(FLAG1)QRADB=SIGMA*ASLI*(TSB**4-TA**4)*EMSTL                        LIT12690
0612                IF(.NOT. FLAG) QRADC=SIGMA*AW*(TS**4-TC(1)**4)*RIFSLC                 LIT12700
0613                IF(FLAG)QRADC=SIGMA*AW*(TS**4-TA**4)*EMSTL                            LIT12710
0614                RADB=QRADB/(W*ASLI*RHSTL*CPSTL)                                       LIT12720
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0615           RADC=QRADC/(W*AW*RHSTL*CPSTL)                                  LIT12730
0616           IF(.NOT. FLAG1) RADCB=QRADB/(L1(1)*ASLI*RHCON*CPCON)           LIT12740
0617           IF(.NOT. FLAG) RADCC=QRADC/(L(1)*AW*RHCON*CPCON)               LIT12750
0618           CGLI=YALIG/(LIL*CPLI)                                          LIT12760
0619           CLIST=2.*ASLI*AKLI*KSTL/(LIL *CPLI*(ZLI *KSTL+W*AKLI))         LIT12770
0620           CSBLI=2.*AKLI*KSTL/(RHSTL*W*CPSTL*(ZLI *KSTL+W*AKLI))          LIT12780
         C                                                                    LIT12790
         C*********************************************                      LIT12800
         C*   CALCULATING TEMPERATURE RATES OF CHANGE    *                    LIT12810
         C*        (WITHOUT COMBUSTION)                  *                    LIT12820
         C*********************************************                      LIT12830
         C                                                                    LIT12840
         CALCULATE LITHIUM TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)         LIT12850
0621     864   ZZ1=CGLI*(TG-TLI)-CLIST*(TLI-TSB)-RWLI-RGLI                    LIT12860
         C LET COMBUSTION ZONE FOLLOW POOL TEMPERATURE FOR POSSIBLE REIGNITION LIT12870
0622           ZZ6=(TLI-TCZ)/DELT                                             LIT12880
         C                                                                    LIT12890
         CALCULATE CELL GAS TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)        LIT12900
0623           ZZ4=C1*(TG-TS)+CLIG*(TLI-TG)+RLIG+XBLOW*BLOWR*CPAB*(TBLOW-TG)  LIT12910
              .   /HTCAPG-ESCR*XESC/HTCAPG+CEHCGS*(TEHC-TG)                   LIT12920
         C                                                                    LIT12930
         CALCULATE WALL STEEL TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)      LIT12940
0624           IF(.NOT. FLAG) ZZ5=C6*(TG-TS)-C7*(TS-TC(1))+RLIW-RADC          LIT12950
0625           IF(FLAG)ZZ5=C6*(TG-TS)-C11*(TS-TA)+RLIW-RADC                   LIT12960
0626       523 CONTINUE                                                       LIT12970
         C                                                                    LIT12980
         C*********************************************                      LIT12990
         C*   COMPUTATIONS VALID WITH EITHER MODEL       *                    LIT13000
         C*********************************************                      LIT13010
         C                                                                    LIT13020
0627           ZZE=CGSEHC*(TG-TEHC)                                           LIT13030
         CALCULATE FLOOR STEEL TEMPERATURE RATE OF CHANGE (DEG. R / SEC.)     LIT13040
0628           IF(.NOT.FLAG1)ZZ7=CSBLI*(TLI -TSB)-C8*(TSB-TB(1))-RADB-        LIT13050
              .   XSFL*SFLCR*12./(W*ASLI*RHSTL*CPSTL)                         LIT13060
0629           IF(FLAG1)ZZ7=CSBLI*(TLI -TSB)-C11*(TSB-TA)-RADB-XSFL*SFLCR*12./ LIT13070
              .   (W*ASLI*RHSTL*CPSTL)                                        LIT13080
0630           IF(FLAG) GO TO 777                                             LIT13090
         C                                                                    LIT13100
         CALCULATE WALL CONCRETE TEMPERATURE CHANGE                           LIT13110
0631           DTCDT(1)=C3*(TS-TC(1))+C4(1)*(TC(2)-TC(1))+RADCC               LIT13120
0632           DTCDT(NL)=C4(NLM1)*(TC(NLM1)-TC(NL))-C5*(TC(NL)-TA)            LIT13130
0633           DO 5 I=2,NLM1                                                  LIT13140
0634     5     DTCDT(I)=C4(I)*(TC(I+1)-TC(I))+C4(I-1)*(TC(I-1)-TC(I))         LIT13150
0635     777   CONTINUE                                                       LIT13160
         C                                                                    LIT13170
0636           IF(FLAG1) GO TO 778                                            LIT13180
         C                                                                    LIT13190
         CALCULATE FLOOR CONCRETE TEMPERATURE CHANGE                          LIT13200
0637           DTBDT(1)=C9*(TSB-TB(1))+C10(1)*(TB(2)-TB(1))+RADCB             LIT13210
0638           DTBDT(NL1)=C10(NL1M1)*(TB(NL1M1)-TB(NL1))                      LIT13220
0639           DO 50 IB=2,NL1M1                                               LIT13230
0640     50    DTBDT(IB)=C10(IB)*(TB(IB+1)-TB(IB))+C10(IB-1)*(TB(IB-1)-TB(IB)) LIT13240
0641     778   CONTINUE                                                       LIT13250
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0642          IF (IOPTB .EQ. 1) GO TO 854
0643          IF (.NOT. FLAGS) GO TO 527
        C
        CALCULATIONS WITH SUSPENDED LITHIUM SPILL PAN
        C
0644          HPAN=0.714*HB
0645          AHT=ASLI+ZLI*BREDTH
0646          TET1=0.0025*(TINS1-460.)-2.5
0647          KIN1=(.70892+.36584*TET1+.04565*TET1**2-.00791*TET1**3)/43200.
0648          TET2=0.0025*(TINS2-460.)-2.5
0649          KIN2=(.70892+.36584*TET2+.04565*TET2**2-.00791*TET2**3)/43200.
0650          YPAGAS=AINS/(THKIN2/2./KIN2+1./HPAN)
0651          C2=YPAGAS/HTCAPG
0652          C13=YPAGAS/(RHINS*AINS*THKIN2*CPINS)
0653          QRADS=SIGMA*AINS*(TINS2**4-TSB**4)*RIFPAS
0654          QRADCG=SIGMA*AINS*(TINS2**4-TG**4)*RIFPAG
0655          RPANST=QRADS/(RHSTL*AWB*W*CPSTL)
0656          RSTPAN=QRADS/(RHINS*AINS*THKIN2*CPINS)
0657          RGASPA=QRADCG/(RHINS*AINS*THKIN2*CPINS)
0658          RPAGAS=QRADCG/HTCAPG
0659          CLIPAN=2.*AHT/(LIL *CPLI)/(ZLI /AKLI+THKPAN/KPAN)
0660          CPANLI=2.*AHT/(RHPAN*APAN*THKPAN*CPPAN)/(ZLI /AKLI+THKPAN/KPAN)
0661          CPNIN1=2./(RHPAN*APAN*THKPAN*CPPAN)/(THKPAN/KPAN/APAN+THKIN1/
             .   KIN1/AINS)
0662          CIN1PN=2./(RHINS*AINS*THKIN1*CPINS)/(THKPAN/KPAN/APAN+THKIN1/
             .   KIN1/AINS)
0663          CIN12=2./(RHINS*CPINS*THKIN1)/(THKIN1/KIN1+THKIN2/KIN2)
0664          CIN21=CIN12*THKIN1/THKIN2
        C
        C        MODIFYING LITHIUM TEMR. RATE OF CHANGE
0665          ZZ1 =ZZ1 +CLIST*(TLI -TSB)-CLIPAN*(TLI -TPAN)
        C
        C        MODIFYING CELL GAS TEMP. RATE OF CHANGE
0666          ZZ4=ZZ4+C2*(TINS2-TG)+RPAGAS
        C
        C        MODIFYING FLOOR STEEL TEMP. RATE OF CHANGE
0667          ZZ7=ZZ7-CSBLI*(TLI -TSB)+C6*(TG-TSB)+RPANST
        C
        CALCULATE LITHIUM SPILL PAN TEMP. RATE OF CHANGE (DEG R/SEC)
0668          ZZ2=CPANLI*(TLI -TPAN)+CPNIN1*(TINS1-TPAN)
        C
        C        CALCULATE INSULATION TEMPERATURE RATE OF CHANGE
0669          ZZ8=CIN1PN*(TPAN-TINS1)+CIN12*(TINS2-TINS1)
0670          ZZ9=CIN21*(TINS1-TINS2)+C13*(TG-TINS2)-RSTPAN-RGASPA
        C
0671    527   CONTINUE
        C
        C***********************************
        C**    CALCULATING OVERPRESSURE    **
        C***********************************
0672          XMAIR=MOX/32.+MNI/28.+MA/XMOLA+MWA/18.
0673          PA=1545.*XMAIR*TG/144./V
0674          OVERP=PA-PAZERO
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0675              IF (TIME.GT.BLIN) XBLOW=1.                                     LIT13790
0676              IF (TIME.GT.BLOUT) XBLOW=0.                                    LIT13800
            C                                                                    LIT13810
            C***********************************                                 LIT13820
            C**    CALCU. TOTAL LEAKAGE       **                                 LIT13830
            C***********************************                                 LIT13840
            C           AEROSOL REMOVAL COMPUTATION FOR EMG ....                 LIT13850
            C     BETA IS THE INVERSE STICKING COEFFICIENT (IN SECONDS) FOR AEROSOLSLIT13860
            C     IMPACTING THE WALL     -     STICK GIVES THE RATE AT WHICH AEROSOLLIT13870
            C     REMOVED THROUGH STICKING TO THE WALL                           LIT13880
0677              STICK=AW/(V*BETA*12.)                                          LIT13890
            C                                                                    LIT13900
0678              IF (OVERP)10,10,11                                             LIT13910
0679           10 LEAK=0.                                                        LIT13920
0680              GO TO 12                                                       LIT13930
0681           11 LEAK = K*OVERP**0.5                                            LIT13940
0682           12 CONTINUE                                                       LIT13950
0683              FOUT=EXHSTR/MAIR*XBLOW+LEAK                                    LIT13960
0684              FMLEFT= EXP(-OUTINT)                                           LIT13970
0685              FMLEAK = 1. -FMLEFT                                            LIT13980
            C                                                                    LIT13990
            C*************************                                           LIT14000
            C*   DO INTEGRATIUNS     *                                           LIT14010
            C*************************                                           LIT14020
            C                                                                    LIT14030
0686              LIBP=INTGRL(0.,CMBR*ASLI)                                      LIT14040
0687              LILOX=INTGRL(0.,(1.+RCMBO)/RCMBO*CMBRO*ASLI*(1.-FRA))          LIT14050
0688              LILNI=INTGRL(0.,(1.+RCMBN)/RCMBN*CMBRN*ASLI*(1.-FRA))          LIT14060
0689              OXLB=INTGRL(OXLBI,ROXLB)                                       LIT14070
0690              MOX=INTGRL(MOXI,WO2B*BLOWR*XBLOW-MOX*FOUT-ROXLB+MOXINJ)        LIT14080
0691              MNI=INTGRL(MNII,WN2B*BLOWR*XBLOW-MNI*FOUT-RNILB+MNIINJ)        LIT14090
0692              MA=INTGRL(MAI,WAB*BLOWR*XBLOW-MA*FOUT)                         LIT14100
0693              MWA=INTGRL(MWAI,WWAB*BLOWR*XBLOW-MWA*FOUT-RWALB)               LIT14110
0694              MLIO=INTGRL(MLIOI,-MLIO*FOUT+(1.+RCMBO)/RCMBO*CMBRO*ASLI*FRA-  LIT14120
                .    MLIO*STICK)                                                 LIT14130
0695              MLIN=INTGRL(MLINI,-MLIN*FOUT+(1.+RCMBN)/RCMBN*CMBRN*ASLI*FRA-  LIT14140
                .    MLIN*STICK)                                                 LIT14150
0696              MLIH=INTGRL(0.,-MLIH*FOUT+((1.+RCMBW)/RCMBW-1./RCMBH2)*CMBRW   LIT14160
                .       *ASLI*FRA-MLIH*STICK)                                    LIT14170
0697              MH2=INTGRL(0.,-MH2*FOUT+(1.+RCMBH2)/RCMBH2*CMBRW*ASLI)         LIT14180
0698        854   IF (CGZ .EQ. 1.) GO TO 8541                                    LIT14190
0699              TCZ=INTGRL(TCZI,ZZ6)                                           LIT14200
0700              GO TO 8542                                                     LIT14210
0701        8541  TCZ=1338.                                                      LIT14220
0702              IOPTB =1                                                       LIT14230
0703        8542  IF (IOPTB .EQ. 0) GO TO  855                                   LIT14240
0704              DO 35 J=1,NN                                                   LIT14250
0705        35    TN(J)=INTGRL(TLII,ZZ(J))                                       LIT14260
0706              TLI=TN(4)                                                      LIT14270
0707              TSB=INTGRL(TSZERO,ZZ7)                                         LIT14280
0708              GO TO 856                                                      LIT14290
0709        855   TG=INTGRL(TGZERO,ZZ4)                                          LIT14300
0710              TLI=INTGRL(TLII,ZZ1)                                           LIT14310
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0711              IF(TLI.GE.TVAP) GO TO 820
0712              TS=INTGRL(TSZERO,ZZ5)
0713              TPAN=INTGRL(TPANZO,ZZ2)
0714              TINS1=INTGRL(TINS1I,ZZ8)
0715              TINS2=INTGRL(TINS2I,ZZ9)
0716              TEHC=INTGRL(TEHCZO,ZZE)
0717              DO 750 I=1,NL
0718              TC(I)=INTGRL(TCIC(I),DTCDT(I))
0719          750 CONTINUE
0720              OUTINT=INTGRL(LEAKO,LEAK)
0721               TSB=INTGRL(TSBI,ZZ7)
0722        856   DO 751 I=1,NL1
0723              TB(I)=INTGRL(TBIC(I),DTBDT(I))
0724        751   CONTINUE
            C
0725              CALL DYNAMI(TIME,&200)
            C
            C*********************************************************
            C*   POST INTEGRATION SECTION                            *
            C*   CHECK OVERP AND TLI FOR STOP CONDITION              *
            C*   CHECK AND CORRECT FOR LITHIUM AND OXYGEN SUPPLY     *
            C*********************************************************
            C
0726              IF (IOPTB .EQ. 0) GO TO  180
0727              MPB=R2*NT*0.025*TIME
0728              MLIOH=(2.-J2)*NT*0.025*TIME
0729              IF (MLIOH/(2.-J2) .GE. 847.8)  ICZ=0
0730              IF(MLIOH/(2.-J2) .GE. 847.8)  WRITE(6,879)  TIME,MLIOH
0731        879   FORMAT(1X,'WATER DEPLETED',1X,F6.2,1X,F6.2)
0732              IF (ICZ .EQ. 0 .AND. TCZ .LE. 1340.) GO TO 858
0733              GO TO 503
0734          180 CONTINUE
0735              LILP=LIT-LIBP+LILOX+LILNI
0736              IF(LILP.LE.0.) LILP=0.0
0737              ZLI=LILP/RHLI/ASLI
0738              ALPHA=AKLI/(RHLI*CPLI)
0739              IF((LILP .LT. 0.1*LIT) .AND. (ALPHA*DELT .GT. ZLI*ZLI .OR. LILP
                 . .LT. 1.0)) FLAGL=.TRUE.
0740              IF (.NOT. FLAGL) LIL=LILP
0741              IF(TG.LT.500. .AND. OVERP.LT.1.) GO TO 745
0742              IF (TLI .LT. TMELT) GO TO 743
0743              IF(ICMB.EQ.0 .OR. MOX.GE.0.0) GO TO 201
0744              OXLB=OXLFS
0745              ICMB=0
0746              CMBRO=0.0
0747              ROXLB=0.0
0748          201 CONTINUE
0749              IF(ILIT.EQ.0 .OR. (LIT-LIBP).GE.0.01) GO TO 500
0750              OXLB=LIT/RCMBO
0751              ILIT=0
0752              LIT=LIBP
0753              CMBR=0.0
0754              CMBRO=0.0
```

```
            CMBRN=0.0
            CMBRW=0.0
            ROXLB=0.0
            RNILB=0.0
            RWALB=0.0
        500 CONTINUE
            IF(MNI.GE.0.0) GO TO 202
            MNI=0.0
            ICNI=0
            CMBRN=0.
            RNILB=0.0
        202 CONTINUE
            IF(MWA.GE.0.0) GO TO 502
            MWA=0.0
            CMBRW=0.0
            RWALB=0.0
        502 CONTINUE
            CMBRH=3600.*(CMBRO+CMBRN+CMBRW)
            IF (CMBRH .GE.0.01 .OR. TIME .LE. 10.) GO TO 503
            CMBRO=0.0
            CMBRN=0.0
            CMBRW=0.0
            CMBRH=0.0
            ROXLB=0.0
            RNILB=0.0
            RWALB=0.0
        503 CONTINUE
      C
      C**********************************
      C*   CONVERT TEMP. TO DEG. F       *
      C**********************************
      C
            IF (FLAGSI) CALL SI
            IF(FLAGSI) GO TO 8
            DO 6  I=1,20
            TBF(I) =TB(I)-460.
          6 TCF(I)=TC(I)-460.
            TGF=TG-460.
            DO 36 I=1,NN
      36    TNF(I)=TN(I)-460.
            TSBF=TSB -460.
            TSF=TS-460.
            TCZF=TCZ-460.
            TLIF=TLI-460.
            TPANF=TPAN-460.
            TEHCF=TEHC-460.
            TINS1F=TINS1-460.
            TINS2F=TINS2-460.
      8     CONTINUE
      C
      C***************************
      C*   TIME STEP CONTROL      *
      C***************************
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0798              IF (IOPTB .EQ. 0) GO TO  865                              LIT15380
0799              DT1=ABS(RELERR*TN(1)/ZZ(1))                               LIT15390
0800              DT3=ABS(RELERR*TN(4)/ZZ(4))                               LIT15400
0801              DT5=1.0E06                                                LIT15410
0802              IF (ICZ .EQ. 0) GO TO 915                                 LIT15420
0803              DT5=ABS(RELERR*TCZ/ZZ6)                                   LIT15430
0804        915   BILGE=AMIN1(DT1,DT3,DT5)                                  LIT15440
0805              BIL=(BILGE-DELT)/DELT                                     LIT15450
0806              IF (ABS(BIL) .GT. 0.1) DELT=BILGE                         LIT15460
0807              IF(TIME .LT. 8000.) DELOUT=50.                            LIT15470
0808              IF(TIME .LT. 20.) DELOUT=1.                               LIT15480
0809              IF (TIME .LE. 1.0) DELOUT=0.1                             LIT15490
0810              IF(TIME .GE. 8000.) DELOUT=600.                           LIT15500
0811              ALPHA1=RHLI*CPMLI/AKLI                                    LIT15510
0812              ALPHA2=RHSTL*CPSTL/KSTL                                   LIT15520
0813              ALPHA3=RHCON*CPCON/KCON                                   LIT15530
0814              T1=0.3*LBN**2/ALPHA1                                      LIT15540
0815              T2=100.                                                   LIT15550
0816              T3=0.075*W**2/ALPHA2                                      LIT15560
0817              T4=0.3*0.43**2/ALPHA3                                     LIT15570
0818              BIT= AMIN1(T1,T2,T3,T4)                                   LIT15580
0819              IF (DELT .GT. BIT) DELT=BIT                               LIT15590
0820              IF(DELT.LT.DTMIN) DELT=DTMIN                              LIT15600
0821              IF(DELT.GT.DELOUT) DELT=DELOUT                            LIT15610
0822              GO TO 866                                                 LIT15620
0823        865   DT1=ABS(RELERR*TLI/ZZ1)                                   LIT15630
0824              DT2=ABS(RELERR*TG/ZZ4)                                    LIT15640
0825              DT3=ABS(RELERR*TS/ZZ5)                                    LIT15650
0826              IF(ILIT.EQ.0 .OR. ICZ.EQ.0) GO TO 735                     LIT15660
0827              DT5=ABS(RELERR*TCZ/ZZ6)                                   LIT15670
0828              ZZ99=(CMBRH-CMBRHI)/DELT                                  LIT15680
0829              IF(ZZ99.EQ.0.) GO TO 735                                  LIT15690
0830              DT4=ABS(RELERR*CMBRH/(CMBRH-CMBRHI)*DELT)                 LIT15700
0831              CMBRHI=CMBRH                                              LIT15710
0832              IF(IPASS.EQ.1) DT4=1.E06                                  LIT15720
0833              GO TO 736                                                 LIT15730
0834          735 CONTINUE                                                  LIT15740
0835              DT4=1.0E06                                                LIT15750
0836              DT5=1.0E06                                                LIT15760
0837          736 CONTINUE                                                  LIT15770
0838              BILGE=AMIN1(DT1,DT2,DT3,DT4,DT5)                          LIT15780
0839              BIL=(BILGE-DELT)/DELT                                     LIT15790
            C THIS CONDITION IS TO REMOVE INSTABILITY DUE TO STEEP NITROGEN REACTIONLIT15800
0840              IF(TCZ.GT.1900..AND.ABS(BIL).GT.0.1)DELT=DELT+(BILGE-DELT)/10.    LIT15810
0841              IF(.NOT.(TCZ.GT.1900..AND.ABS(BIL).GT.0.1))DELT=BILGE     LIT15820
0842              IF(TIME .LT. 8000.) DELOUT=50.                            LIT15830
0843              IF(TIME .LT. 20.) DELOUT=1.                               LIT15840
0844              IF (TIME .LE. 1.0) DELOUT=0.1                             LIT15850
0845              IF(TIME .GE. 8000.) DELOUT=600.                           LIT15860
            C***   TESTING CONDUCTION LIMIT ON TIME STEP   ***              LIT15870
0846              ALPHA2=((THKPAN+ZLI)/(ZLI/AKLI+THKPAN/KPAN))/             LIT15880
                 .  ((RHLI*CPLI*ZLI+RHPAN*CPPAN*THKPAN)/(THKPAN+ZLI))       LIT15890
0847              PYU=0.075*(THKPAN+ZLI)**2/ALPHA2                          LIT15900
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0848              PYU=0.075*(THKPAN+ZLI)**2/ALPHA2                                  LIT15910
0849              IF(DELT.GT.PYU)DELT=PYU                                           LIT15920
0850              IF(DELT.LT.DTMIN) DELT=DTMIN                                      LIT15930
0851              IF(DELT.GT.DELOUT) DELT=DELOUT                                    LIT15940
0852              IF(TIME.LT.1.0) DELT=.10                                          LIT15950
0853              IF(TCZ.GT.1900. .AND. DELT.GT.20.) DELT=20.                       LIT15960
            C                                                                       LIT15970
            C**********************                                                 LIT15980
            C*   OUTPUT SECTION    *                                                LIT15990
            C**********************                                                 LIT16000
            C                                                                       LIT16010
0854        866   IF (TIME .LT. TIMEO) GO TO 810                                    LIT16020
0855              TIMEO=TIMEO+DELOUT                                                LIT16030
0856              IF(IPAGE.GE.50) WRITE(6,803) (NAME(I),I=1,92)                     LIT16040
0857          803 FORMAT('1',3(20X,20A4,/),//,32A4)                                 LIT16050
0858              IF(IPAGE.GE.50) IPAGE=0                                           LIT16060
0859              IPAGE=IPAGE+1                                                     LIT16070
0860              IF (IOPTB .EQ. 0) GO TO  857                                      LIT16080
0861              WRITE (6,882) TIME,TCZF,TNF(1),TNF(2),TNF(4),TSBF,TBF(1),MLIOH    LIT16090
0862        882   FORMAT (7(F9.2,1X),F9.4)                                          LIT16100
0863              GO TO 810                                                         LIT16110
0864        857   RCCZP=CCZP*(TCZ-TLI)                                              LIT16120
0865              WRITE(6,804) TIME,DELT,CMBRH,LILP  ,OVERP,EMG,EMLI,LIBP,TSF,TGF,  LIT16130
             .         RN2,TCZF,TLIF,TPANF,MOX,MNI                                  LIT16140
0866        804   FORMAT(2X,F7.1,1X,4(F6.2,1X),2(F7.2,1X),F8.2,1X,2(F7.2,1X),F6.2,  LIT16150
             .         3(1X,F8.2),2(1X,F9.2))                                       LIT16160
0867          810 CONTINUE                                                          LIT16170
0868              IF(TIME.GT.TIMEF) GO TO 900                                       LIT16180
            C     RETURN TO TOP OF DYNAMIC CYCLE                                    LIT16190
0869              GO TO 200                                                         LIT16200
            C                                                                       LIT16210
            C************************                                               LIT16220
            C*     ERROR POINTERS    *                                              LIT16230
            C************************                                               LIT16240
            C                                                                       LIT16250
0870          743 CONTINUE                                                          LIT16260
0871              WRITE(6,744)                                                      LIT16270
0872          744 FORMAT(' POOL TEMP. HAS DROPPED TO LITHIUMS MELTING TEMP.')       LIT16280
0873              GO TO 900                                                         LIT16290
0874          745 CONTINUE                                                          LIT16300
0875              WRITE(6,746)                                                      LIT16310
0876          746 FORMAT(' CELL GAS TEMP. AND PRESS. HAVE RETURNED TO NORMAL')      LIT16320
0877              GO TO 900                                                         LIT16330
0878          820 CONTINUE                                                          LIT16340
0879              WRITE(6,821)                                                      LIT16350
0880          821 FORMAT(' LITHIUM TEMP. ABOVE BOILING POINT')                      LIT16360
0881              GO TO 900                                                         LIT16370
0882          910 CONTINUE                                                          LIT16380
0883              WRITE(6,725)                                                      LIT16390
0884          725 FORMAT(1X,'NO ROOT FOUND FOR SPRAY FIRE FOR TEMP.S LESS THAN ',   LIT16400
             .          '1 MILLION DEG. R')                                         LIT16410
0885              GO TO 900                                                         LIT16420
0886        858   WRITE (6,859) TIME                                                LIT16430
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 859  FORMAT ('BREEDER IS COOLING,  TIME IS  ',F7.1)
      GO TO 900
  300 CONTINUE
      WRITE(6,710)
  710 FORMAT(' EXX IS NEGATIVE--CANNOT TAKE ROOT')
      WRITE(6,711) TCZ,CMBRH,ZZ6,ZZ5,RN2
  711 FORMAT(' MESSED UP VARIABLES',5E10.3)
  900 CONTINUE
      WRITE(6,713)
  713 FORMAT(' PROGRAM EXECUTION STOPPED BY PROGRAM')
      WRITE(6,101) DT1,DT2,DT3,DT4,DT5
  101 FORMAT(' VALUES', 5E10.3)
C    RETURN TO BEGINNING OF PROGRAM AND READ IN NEW DATA.  IF NO NEW DAT
C    AVAILABLE, PROGRAM EXECUTION WILL AUTOMATICALLY BE STOPPED BY END
C    PARAMETER IN THE FIRST STATEMENT.
      GO TO 998
  999 CONTINUE
      CALL EXIT
      END
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C     THESE 3 SUBROUTINES ARE DESIGNED TO BE USED IN A MAIN PROGRAM WHICHLIT16630
C     SIMULATES A DYNAMIC SYSTEM EXPRESSED AS A SET OF ODE'S. THESE ODE'SLIT16640
C     MAY BE REEXPRESSED AS A SET OF INTEGRALS WHICH MUST BE INTEGRATED  LIT16650
C     SIMULTANEOUSLY THROUGH THE DOMAIN OF INTEREST STARTING WITH THE APPLIT16660
C     INITIAL CONDITIONS.  FOR EXAMPLE, THE FUNCTION Y MAY BE FOUND FROM LIT16670
C     SOLUTION OF  DY/DT = RATE = F(Y,T) AND Y=YO AT T=TO. THIS MAY BE   LIT16680
C     REWRITTEN Y = INTGRL(YO, RATE), THE OPEN INTEGRAL OF RATE OVER T STLIT16690
C     AT YO. A SET OF ODE'S MAY BE TREATED IN A SIMILIAR MANNER.         LIT16700
C         THE MAIN PROGRAM SHOULD CONSIST OF TWO MAIN PARTS, THE INITIALILIT16710
C     SECTION AND THE DYNAMIC SECTION.  THE DYNAMIC SECTION IS FURTHER DILIT16720
C     INTO INTEGRATION AND POST-INTEGRATION SECTIONS.                    LIT16730
C         THE INITIAL SECTION SHOULD BE USED FOR INPUT, CALCULATION OF NELIT16740
C     CONSTANTS, AND FOR CALCULATING AND SETTING OF INITIAL CONDITIONS. ILIT16750
C     SHOULD CONTAIN THE REAL INTGRL, COMMON, AND CALL INIT STATEMENTS.  LIT16760
C         THE INTEGRATION SECTION SHOULD START WITH A NUMBERED CONTINUE  LIT16770
C     STATEMENT AND END WITH THE CALL DYNAMI  STATEMENT.  IT SHOULD CONTALIT16780
C     ALL CALCULATIONS OF PROGRAM VARIABLES AND NON-CONSTANT RATES. ALL ILIT16790
C     FUNCTION STATEMENTS SHOULD APPEAR IN A GROUP IMMEDIATELY PRECEDING LIT16800
C     CALL DYNAMI STATEMENT.                                             LIT16810
C         THE INTEGRATION SECTION WILL BE LOOPED SEVERAL TIMES DURING EACLIT16820
C     INTEGRATION STEP (SIMPSON'S RULE USES 4 LOOPS PER STEP, RUNGE-KUTTALIT16830
C     5 LOOPS PER STEP).  DYNAMI CONTROLS THE INTEGRATION BY TELLING THE LIT16840
C     INTGRL FUNCTION WHAT STEP IT SHOULD PERFORM NEXT. THE INTEGRATION  LIT16850
C     VARIABLE TIME IS ALSO CONTROLED BY DYNAMI.  IT MAY OR MAY NOT BE INLIT16860
C     ED DURING EACH LOOP. TIME SHOULD BE INITIALIZED IN THE INTIAL SECTILIT16870
C     DYNAMI UTILIZES MULTIPLE RETURNS TO CONTROL PROGRAM FLOW.  THE STATLIT16880
C     NUMBER PASSED TO DYNAMI SHOULD BE THAT OF THE FIRST STATEMENT IN THLIT16890
C     INTEGRATION SECTION. THIS CAUSES THE PROPER INTEGRATION LOOPING. ATLIT16900
C     END OF EACH INTEGRATION STEP A NORMAL RETURN IS EXECUTED AND CONTROLIT16910
C     RETURNS TO THE FIRST STATEMENT FOLLOWING CALL DYNAMI. THIS SHOULD BLIT16920
C     THE FIRST STATEMENT OF THE POST-INTEGRATION SECTION.               LIT16930
C         BECAUSE VARIABLE VALUES MAY DIFFER FROM THEIR TRUE VALUE DURINGLIT16940
C     INTEGRATION LOOPING, ALL PROGRAM LOGIC AND VARIABLE TIME STEP CALCULIT16950
C     EXECUTED ONCE AT THE END OF EACH INTEGRATION STEP. TIME AND ALL VARLIT16960
C     CONTAINED WITHIN THE INTEGRATION SECTION WILL BE UPDATED TO THEIR 'LIT16970
C     VALUES BEFORE CONTROL IS TRANSFERED TO THE POST-INTEGRATION SECTIONLIT16980
C     THIS SECTION SHOULD CONTAIN AT LEAST ONE IF STATEMENT WHICH STOPS PLIT16990
C     EXECUTION. AND THE LAST STATEMENT SHOULD BE A GO TO ST.NO. WHERE STLIT17000
C     IS THE STATEMENT NUMBER OF THE FIRST STATEMENT IN THE INTEGRATION SLIT17010
C         APPROXIMATELY 100 INTEGRATIONS MAY BE PERFORMED SIMULTANEOUSLY.LIT17020
C                                                                        LIT17030
C     VARIABLE LIST                                                      LIT17040
C                                                                        LIT17050
C       A   MATRIX WHICH STORES THE INTERMIATE VALUES CALCULATED DURING ELIT17060
C       DELT   INTEGRATION TIME STEP                                     LIT17070
C       DXDT   RATE BEING INTEGRATED. CALCULATED USING  INTEGRAL VALUE ASLIT17080
C              RETURNED BY INTGRL DURING THE PREVIOUS LOOP AND TIME SET BLIT17090
C              DYNAMI.  USED BY INTGRL AS CALLED FOR BY ICOUNT.          LIT17100
C       ICOUNT   TELLS INTGRL WHICH INTEGRATION LOOP IS PRESENTLY BEING DLIT17110
C       IMETH = 1 USE RUNGE-KUTTA METHOD                                 LIT17120
C             = 3 USE SIMPSON'S RULE                                     LIT17130
C       INOIN   TELL DYNAMI HOW MANY INTGRL STATEMENTS THERE ARE IN THE MLIT17140
C               PROGRAM.                                                 LIT17150
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FORTRAN IV G1  RELEASE 2.0              MAIN                DATE = 80270          18/07/48                PAGE 0002
              C      IPASS   TELLS INTGRL TO DO TWO SPECIAL FUNCTIONS DURING THE FIRSTLIT17160
              C              EXECUTIONS OF THE INTEGRATION SECTION.                   LIT17170
              C      ISTORE   TELLS INTGRL WHERE TO STORE THE RESULT OF ITS INTERMEDIALIT17180
              C              CALCULATION IN MATRIX A.                                 LIT17190
              C      XIC   MATRIX WHICH STORE  INTIAL CONDITIONS AND THEN IS UPDATED TLIT17200
              C            PRESENT INTEGRAL VALUE AT THE END OF EACH INTEGRATION STEP.LIT17210
              C      XXIC   INITIAL CONDITION                                         LIT17220
              C                                                                       LIT17230
 0001                SUBROUTINE DYNAMI(TIME,*)                                        LIT17240
 0002                COMMON IMETH,ICOUNT,ISTORE,INOIN,IPASS,DELT,XIC(101),A(501)      LIT17250
 0003                IF(IPASS.EQ.0) GO TO 40                                          LIT17260
 0004                IF(IMETH.EQ.1) GO TO 10                                          LIT17270
              C                                                                       LIT17280
              C     SIMPSON'S RULE (DEFAULT) IMETH>2                                  LIT17290
              C                                                                       LIT17300
 0005                IF(ICOUNT.EQ.4) GO TO 4                                          LIT17310
 0006                IF(ICOUNT.EQ.3) GO TO 3                                          LIT17320
 0007                TIME=TIME+DELT/2.                                                LIT17330
 0008                ICOUNT=ICOUNT+1                                                  LIT17340
 0009                RETURN 1                                                         LIT17350
 0010              4 CONTINUE                                                         LIT17360
 0011                ISTORE=0                                                         LIT17370
 0012                ICOUNT=1                                                         LIT17380
 0013                IPASS=IPASS+1                                                    LIT17390
 0014                INOIN=0                                                          LIT17400
 0015                RETURN                                                           LIT17410
 0016              3 CONTINUE                                                         LIT17420
 0017                ICOUNT =4                                                        LIT17430
 0018                RETURN 1                                                         LIT17440
              C                                                                       LIT17450
              C     RUNGE-KUTTA METHOD -FIXED STEP-  IMETH=1                          LIT17460
              C                                                                       LIT17470
 0019             10 CONTINUE                                                         LIT17480
 0020                IF(ICOUNT.EQ.5) GO TO 4                                          LIT17490
 0021                IF(ICOUNT.EQ.4) GO TO 14                                         LIT17500
 0022                IF(ICOUNT.EQ.2) GO TO 12                                         LIT17510
 0023                TIME=TIME+DELT/2.                                                LIT17520
 0024                ICOUNT=ICOUNT+1                                                  LIT17530
 0025                RETURN 1                                                         LIT17540
 0026             12 CONTINUE                                                         LIT17550
 0027                ICOUNT=3                                                         LIT17560
 0028                RETURN 1                                                         LIT17570
 0029             14 CONTINUE                                                         LIT17580
 0030                ICOUNT= 5                                                        LIT17590
 0031                RETURN 1                                                         LIT17600
 0032             40 CONTINUE                                                         LIT17610
 0033                IPASS=1                                                          LIT17620
 0034                RETURN                                                           LIT17630
 0035                END                                                              LIT17640
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              C    THIS SUBROUTINE INITIALIZES VARIABLES USED BY THE INTEGRATION ROUTILIT17650
              C    IT SHOULD BE PLACED IN THE INITIALIZATION SECTION OF THE MAIN PROGRLIT17660
              C    BEFORE THE FIRST STATEMENT OF THE DYNAMIC SECTION.  SEE DYNAMI FOR LIT17670
              C    LIST AND INTEGRATION DESCRIPTION.                                  LIT17680
              C                                                                       LIT17690
0001                SUBROUTINE INIT                                                   LIT17700
0002                COMMON IMETH,ICOUNT,ISTORE,INOIN,IPASS,DELT,XIC(101),A(501)       LIT17710
0003                IPASS=0                                                           LIT17720
0004                ISTORE=0                                                          LIT17730
0005                ICOUNT=1                                                          LIT17740
0006                INOIN=0                                                           LIT17750
0007                RETURN                                                            LIT17760
0008                END                                                               LIT17770
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                C     FUNCTION INTGRL PERFORMS THE ACTUAL INTEGRATIONS. IN THE MAIN     LIT17780
                C    PROGRAM, ALL INTGRL STATEMENTS SHOULD BE PLACED IN A GROUP AT THE ELIT17790
                C    OF THE INTEGRATION SECTION.  ALL RATE CALCULATIONS SHOULD PRECEDE TLIT17800
                C    GROUP AND IT SHOULD BE IMMEDIATELY FOLLOWED BY THE CALL DYNAMI STATLIT17810
                C    FOR VARIABLE LIST AND DESCRIPTIONS SEE DYNAMI.                     LIT17820
0001                  REAL FUNCTION INTGRL(XXIC,DXDT)                                   LIT17830
0002                  COMMON IMETH,ICOUNT,ISTORE,INOIN,IPASS,DELT,XIC(101),A(501)       LIT17840
0003                  IF(IPASS.EQ.0) GO TO 40                                           LIT17850
0004                  ISTORE=ISTORE+1                                                   LIT17860
0005                  IF(IMETH.EQ.1) GO TO 10                                           LIT17870
                C                                                                       LIT17880
                C    SIMPSON'S RULE (DEFAULT) IMETH GREATER THAN 2                      LIT17890
                C                                                                       LIT17900
0006                  IF(ICOUNT.EQ.4) GO TO 4                                           LIT17910
0007                  IF(ICOUNT.EQ.3) GO TO 3                                           LIT17920
0008                  IF(ICOUNT.EQ.2) GO TO 2                                           LIT17930
0009                1 CONTINUE                                                          LIT17940
0010                  INOIN=INOIN+1                                                     LIT17950
0011                  IF(IPASS.EQ.1) XIC(INOIN)=XXIC                                    LIT17960
0012                  A(ISTORE)=DXDT                                                    LIT17970
0013                  INTGRL=XIC(INOIN)+DELT*DXDT/2.                                    LIT17980
0014                  A(500-ISTORE)=INTGRL                                              LIT17990
0015                  RETURN                                                            LIT18000
0016                2 CONTINUE                                                          LIT18010
0017                  A(ISTORE)=DXDT                                                    LIT18020
0018                  INTGRL=A(500+INOIN-ISTORE)+DELT*DXDT/2.                           LIT18030
0019                  RETURN                                                            LIT18040
0020                3 CONTINUE                                                          LIT18050
0021                  INTGRL=XIC(ISTORE-2*INOIN)+DELT/6.*(A(ISTORE-2*INOIN)+4.*         LIT18060
                     .             A(ISTORE-INOIN)+DXDT)                                LIT18070
0022                  XIC(ISTORE-2*INOIN)=INTGRL                                        LIT18080
0023                  RETURN                                                            LIT18090
0024                4 CONTINUE                                                          LIT18100
0025                  INTGRL=XIC(ISTORE-3*INOIN)                                        LIT18110
0026                  RETURN                                                            LIT18120
                C                                                                       LIT18130
                C    RUNGE-KUTTA METHOD -FIXED STEP-  IMETH=1                           LIT18140
                C                                                                       LIT18150
0027               10 CONTINUE                                                          LIT18160
0028                  IF(ICOUNT.EQ.5) GO TO 15                                          LIT18170
0029                  IF(ICOUNT.EQ.4) GO TO 14                                          LIT18180
0030                  IF(ICOUNT.EQ.3) GO TO 13                                          LIT18190
0031                  IF(ICOUNT.EQ.2) GO TO 12                                          LIT18200
0032               11 CONTINUE                                                          LIT18210
0033                  INOIN=INOIN+1                                                     LIT18220
0034                  IF(IPASS.EQ.1) XIC(INOIN)=XXIC                                    LIT18230
0035                  A(ISTORE)=DELT*DXDT                                               LIT18240
0036                  INTGRL=XIC(INOIN)+.5*A(ISTORE)                                    LIT18250
0037                  RETURN                                                            LIT18260
0038               12 CONTINUE                                                          LIT18270
0039                  A(ISTORE)=DELT*DXDT                                               LIT18280
0040                  INTGRL=XIC(ISTORE-INOIN)+.5*A(ISTORE)                             LIT18290
0041                  RETURN                                                            LIT18300
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FORTRAN IV G1  RELEASE 2.0            INTGRL            DATE = 80270          18/07/48                PAGE 0002

 0042              13 CONTINUE                                                        LIT18310
 0043                 A(ISTORE)=DELT*DXDT                                             LIT18320
 0044                 INTGRL=XIC(ISTORE-2*INOIN)+A(ISTORE)                            LIT18330
 0045                 RETURN                                                          LIT18340
 0046              14 CONTINUE                                                        LIT18350
 0047                 AA=DELT*DXDT                                                    LIT18360
 0048                 INTGRL=XIC(ISTORE-3*INOIN)+1./6.*(A(ISTORE-3*INOIN)+2.*         LIT18370
                 .  A(ISTORE-2*INOIN)+2.*A(ISTORE-INOIN)+AA)                          LIT18380
 0049                 XIC(ISTORE-3*INOIN)=INTGRL                                      LIT18390
 0050                 RETURN                                                          LIT18400
 0051              15 CONTINUE                                                        LIT18410
 0052                 INTGRL=XIC(ISTORE-4*INOIN)                                      LIT18420
 0053                 RETURN                                                          LIT18430
 0054              40 CONTINUE                                                        LIT18440
 0055                 INTGRL=XXIC                                                     LIT18450
 0056                 RETURN                                                          LIT18460
 0057                 END                                                             LIT18470
```

```
               C        SI IS USED AT THE OPTION OF THE USER TO CONVERT  LITFIRE SO THA
               C        IT ACCEPTS INPUT AND DELIVERS OUTPUT IN SI UNITS
               C        USE JOULES / METERS / SEC / PASCALS
               C        SPECIAL CARE SHOULD BE TAKEN THAT ALL OUTPUT VARIABLES WHICH
               C        MUST BE CONVERTED APPEAR IN THIS SUBROUTINE
               C
 0001                 SUBROUTINE SI
 0002                 IMPLICIT REAL (K,L,M)
 0003                 DIMENSION TBF(20),TCF(20),TB(20),TC(20)
 0004                 LOGICAL FLAGJ,FLAGS,FLAGIO
 0005                 COMMON /UNITS/ AW,V,CH,G,KGAP,W,K,HA,HIN,THW,THF,TMELT,TVAP,TCZI,
                     .   KPAN,RHPAN,CPPAN,TPANZO,APAN,AWB,THKPAN,BREDTH,ASLI,SPILL,QCO1,
                     .   QCO2,QCN,QCW,QVAP,FLAGJ,FLAGS,FLAGIO,IBLOW,IESC,ISFLC,RHOLIN,
                     .   RHOLIO,RHOLIH,CPA,CPLI,RHLI,AKLI,CPSTL,RHSTL,KSTL,CPCON,RHCON,
                     .   KCON,PAZERO,TGZERO,TSZERO,TSBI,TA,TLII,DP1,DP2,DP3,ESCR,SFLCR,
                     .   CPAB,TBLOW,EXHSTV,BLOWV,TBF,TCF,THKIN2,THKIN1,AINS,CPINS,RHINS
 0006                 COMMON /EXTRA/ TINS1F,TINS2F,TB,TC,TG,TGF,TSB,TSBF,TS,TSF,TCZ,
                     .   TCZF,TLI',TLIF,TPAN,TPANF,OVERP,MOX,MNI,LILP,HF,HB,EFILM,DFILM,
                     .   TINS1,TINS2
 0007                 IF(FLAGIO) GO TO 1
               C
               C                   INPUT VARIABLES - CHANGE TO ENGLISH
 0008                 RHOLIO=RHOLIO*0.06243
 0009                 RHOLIN=RHOLIN*0.06243
 0010                 RHOLIH=RHOLIH*0.06243
 0011                 CPA=CPA*0.000239
 0012                 CPLI=CPLI*0.000239
 0013                 RHLI=RHLI*0.06243
 0014                 AKLI=AKLI*0.5778
 0015                 CPSTL=CPSTL*0.000239
 0016                 RHSTL=RHSTL*0.05243
 0017                 KSTL=KSTL*0.5778
 0018                 CPCON=CPCON*0.000239
 0019                 RHCON=RHCON*0.06243
 0020                 KCON=KCON*0.5778
 0021                 PAZERO=PAZERO*101325.
 0022                 TGZERO=TGZERO*1.8
 0023                 TSZERO=TSZERO*1.8
 0024                 TSBI=TSBI*1.8
 0025                 TA=TA*1.8
 0026                 TLII=TLII*1.8
 0027                 HA=HA*0.176
 0028                 IF(.NOT. FLAGJ) GO TO 2
 0029                 DP1=DP1*101325.
 0030                 DP2=DP2*101325.
 0031                 DP3=DP3*101325.
 0032          2      IF(IESC .EQ. 1) ESCR=ESCR*9.478E-04
 0033                 IF(ISFLC .EQ. 1) SFLCR=SFLCR*9.478E-04
 0034                 IF(IBLOW .EQ. 0) GO TO 3
 0035                 CPAB=CPAB*0.000239
 0036                 TBLOW=TBLOW*1.8
 0037                 EXHSTV=EXHSTV*35.315
 0038                 BLOWV=BLOWV*2119.
```

```
3     AW=AW*10.764                                          LIT19010
      V=V*35.315                                            LIT19020
      CH=CH*3.281                                           LIT19030
      G=G*39.37                                             LIT19040
      KGAP=KGAP*0.5778                                      LIT19050
      W=W*39.37                                             LIT19060
      THW=THW*39.37                                         LIT19070
      THF=THF*39.37                                         LIT19080
      TMELT=TMELT*1.8                                       LIT19090
      TVAP=TVAP*1.8                                         LIT19100
      TCZI=TCZI*1.8                                         LIT19110
      ASLI=ASLI*10.764                                      LIT19120
      SPILL=SPILL*2.205                                     LIT19130
      QCO1=QCO1*0.00043                                     LIT19140
      QCO2=QCO2*0.00043                                     LIT19150
      QCN=QCN*0.00043                                       LIT19160
      QCW=QCW*0.00043                                       LIT19170
      QVAP=QVAP*0.00043                                     LIT19180
      IF(.NOT. FLAGS) GO TO 4                               LIT19190
      KPAN=KPAN*0.5778                                      LIT19200
      RHPAN=RHPAN*0.06243                                   LIT19210
      CPPAN=CPPAN*0.000239                                  LIT19220
      TPANZO=TPANZO*1.8                                     LIT19230
      APAN=APAN*10.764                                      LIT19240
      AWB=AWB*10.764                                        LIT19250
      THKPAN=THKPAN*39.37                                   LIT19260
      BREDTH=BREDTH*3.281                                   LIT19270
      THKIN1=THKIN1*39.37                                   LIT19280
      THKIN2=THKIN2*39.37                                   LIT19290
      AINS=AINS*10.764                                      LIT19300
      RHINS=RHINS*0.06243                                   LIT19310
      CPINS=CPINS*0.000239                                  LIT19320
4     CONTINUE                                              LIT19330
      RETURN                                                LIT19340
1     CONTINUE                                              LIT19350
C                                                           LIT19360
C                 OUTPUT VARIABLES - CHANGE TO SI           LIT19370
      FLAGIO=.TRUE.                                         LIT19380
      DO 7 I=1,20                                           LIT19390
      TBF(I)=TB(I)*0.5556-273.                              LIT19400
7     TCF(I)=TC(I)*0.5556-273.                              LIT19410
      TGF=TG*0.5556-273.                                    LIT19420
      TSBF=TSB*0.5556-273.                                  LIT19430
      TSF=TS*0.5556-273.                                    LIT19440
      TCZF=TCZ*0.5556-273.                                  LIT19450
      TLIF=TLI*0.5556-273.                                  LIT19460
      IF(FLAGS) TPANF=TPAN*0.5556-273.                      LIT19470
      TINS1F=TINS1*0.5556-273.                              LIT19480
      TINS2F=TINS2*0.5556-273.                              LIT19490
      OVERP=OVERP*6893.                                     LIT19500
      MOX=MOX*0.454                                         LIT19510
      MNI=MNI*0.454                                         LIT19520
      LILP=LILP*0.454                                       LIT19530
```

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FORTRAN IV G1  RELEASE 2.0          SI              DATE = 80270        18/07/48            PAGE 0003

               HF=HF*0.3048                                                         LIT19540
               HB=HB*5.68                                                           LIT19550
               EFILM=DFILM*0.3048                                                   LIT19560
               RETURN                                                               LIT19570
               END                                                                  LIT19580
```

APPENDIX C

Sample Input to LITFIRE

LI PB4

PHYSICAL PROPERTIES

CPLI = 0.0340 RHLI = 617.7000 RHOLIO = 1.0000 AKLI = 20.0200 EMLI = 1.0000

CPSTL = 0.1350 RHSTL = 487.0000 RHOLIN = 1.0000 KSTL = 25.0000 EMSTL = 1.0000

CPCON = 0.2300 RHCON = 156.0000 RHOLIH = 1.0000 KCON = 15.0000 EMCON = 1.0000

KGAP = 1.0000 EMCZ = 1.0000

INNER CONTAINMENT DIMENSIONS

AW = 1.0000 V = 1.0000 THW = 0.0 K = 1.0000

CH = 1.0000 W = 0.1260 THF = 41.3000 G = 0.0

SPILL PARAMETERS

ASLI = 354.0000 SPILL = 19700.0000 SPRAY = 0.0 WO2 = 0.0 ZLI = 0.0901

FLAGS = F FLAGJ = F FLAGSI = F

HEAT TRANSFER CORRELATION COEFFICIENTS

HIN = 1.0000 HINEHC = 0.0 HINGS = 0.0 HINSAM = 0.0

COMBUSTION PARAMETERS

QCO = 0.0 RCMBO = 1.0000 TVAP = 4000.0000 RCMBH2 = 1.0000 PERCEN = 0.0

QCN = 0.0 RCMBN = 1.0000 TMELT = 915.0000 FRA = 0.0

QCW = 6960.0000 RCMBW = 0.3900 QVAP = 1718.0000 RA = 0.0

INITIAL CONDITIONS

TGZERO = 1032.0000 TLII = 1212.0000 TSBI = 762.0000 WA = 1.0000 PAZERO = 1250.0000

TSZERO = 762.0000 TCZI = 1212.0000 TA = 700.0000 WWA = 1.0000

INTEGRATION CONTROL PARAMETERS

IMETH = 3 DTMIN = 0.2000 TIMEF = 8000.0000 RELERR = 0.0060 DELOUT = 2000.0000

```
OPTIONS IN EFFECT
-----------------

      IBLOW =    0           IESC =    0           ISFLC =    0           FLAG =    T           FLAG1 =    F
      IOPTB =    1

MISCELLANEOUS INPUT
-------------------

      WO2B =       0.0       BLOWV =      0.0      ESCR =       0.0       SFLCR =       0.0      CPA =        1.0000
      WWAB =       0.0       BLOUT =      0.0      ESCTIN =       0.0     SFLTIN =       0.0     CPAB =        1.0000
      WN2B =     0.0     BLIN =     0.0     EXHSTV =     0.0   TBLOW =     1.0000  XMOLA =     1.0000  XMOLAB =     1.0000

EXTANEOUS HEAT CAPACITY NODE DATA
---------------------------------

      TEHCZO =    1300.0000  XMEHC =      0.0      AEHC =       0.0       CPEHC =      1.0000
INTERNAL BLANKET OPTION INPUT
-----------------------------

      NT =        3.0        RRAD =      1.00      AMLI =     835.00      HCO =       5.56      QLIOH =    5029.00
      CPLIOH =      12.50    PBMELT =   1081.50    CP1 =      0.028       CP2 =    0.00001      RHPB =     710.00
      AMPB =     207.00      XLI =      0.008      CPPL =      0.033      CPLI1 =     34.35     CPPB1 =        6.93
      R1 =      1.000        R2 =      4.000       J1 =       0.0         J2 =        1.0       QMELT =    2011.70
      QMELTP =    2203.00                                                                     DELH =   -71560.0
```

APPENDIX D

Sample Output of LITFIRE

Li Pb4

TIME	TCZ	TLI1	TLI2	TLI4	TSB	TB	MLIQH
0.0	752.00	752.00	752.00	752.00	302.00	302.00	0.0
0.10	757.33	752.00	752.00	752.00	304.63	302.00	0.0075
0.20	762.65	752.00	752.00	752.00	307.24	302.00	0.0150
0.30	767.93	752.01	752.00	752.00	309.83	302.00	0.0225
0.40	773.19	752.01	752.00	752.00	312.41	302.00	0.0300
0.50	778.43	752.01	752.00	752.00	314.96	302.00	0.0375
0.60	783.65	752.02	752.00	752.00	317.50	302.00	0.0450
0.70	786.83	752.03	752.00	752.00	320.02	302.00	0.0525
0.80	794.00	752.04	752.00	752.00	322.52	302.00	0.0600
0.90	799.14	752.05	752.00	752.00	325.00	302.00	0.0675
1.00	804.26	752.06	752.00	752.00	327.47	302.00	0.0750
1.10	809.35	752.08	752.00	752.00	329.91	302.00	0.0825
2.10	859.03	752.32	752.00	752.00	353.44	302.02	0.1575
3.10	900.54	753.62	751.82	752.00	373.95	302.03	0.2325
4.10	938.93	754.08	751.83	752.00	394.43	302.06	0.3075
5.10	975.22	754.64	751.84	752.00	413.48	302.09	0.3825
6.10	1009.55	755.29	751.85	752.00	431.22	302.12	0.4575
7.10	1042.04	756.03	751.86	752.00	447.72	302.17	0.5325
8.10	1072.82	756.84	751.87	752.00	463.08	302.21	0.6075
9.10	1102.00	757.73	751.89	752.00	477.38	302.26	0.6825
10.10	1129.66	758.68	751.91	752.00	490.68	302.32	0.7575
11.10	1155.91	759.68	751.92	752.00	503.06	302.38	0.8325
12.10	1180.84	760.75	751.95	752.00	514.58	302.44	0.9075
13.10	1204.51	761.85	751.97	752.00	525.30	302.51	0.9825
14.10	1227.02	763.01	752.00	752.00	535.28	302.58	1.0575
15.10	1248.41	764.20	752.02	752.00	544.57	302.66	1.1325
16.10	1268.77	765.43	752.05	752.00	553.21	302.73	1.2075
17.10	1288.15	766.69	752.09	752.00	561.26	302.81	1.2825
18.10	1306.60	767.98	752.12	752.00	568.74	302.89	1.3575
19.10	1324.18	769.29	752.16	752.00	575.71	302.97	1.4325
20.10	1340.93	770.62	752.20	752.00	582.20	303.06	1.5075
70.29	1672.56	833.53	756.51	752.00	667.63	308.32	5.2721
120.29	1708.40	864.77	761.45	752.03	671.56	313.80	9.0218
170.29	1693.60	876.10	764.68	752.09	673.23	319.20	12.7714
220.28	1666.21	878.83	766.37	752.15	674.79	324.48	16.5211
270.26	1635.69	878.09	767.14	752.21	676.28	329.67	20.2693
320.18	1605.05	876.00	767.43	752.25	677.71	334.76	24.0138
370.11	1575.35	873.41	767.48	752.27	679.09	339.74	27.7583
420.24	1546.87	870.66	767.42	752.28	680.43	344.65	31.5178
470.16	1519.94	867.91	767.30	752.29	681.72	349.45	35.2623
520.29	1494.34	865.21	767.16	752.30	682.97	354.17	39.0218
570.22	1470.23	862.60	767.00	752.30	684.18	358.78	42.7663
620.14	1447.43	860.09	766.83	752.31	685.35	363.31	46.5108
670.27	1425.78	857.66	766.67	752.32	686.49	367.76	50.2702
720.20	1405.36	855.35	766.51	752.33	687.59	372.11	54.0148
770.12	1386.02	853.13	766.35	752.33	688.66	376.38	57.7593
820.25	1367.61	850.99	766.19	752.34	689.71	380.58	61.5188
870.18	1350.22	848.95	766.04	752.35	690.72	384.69	65.2633
920.10	1333.69	847.00	765.89	752.35	691.70	388.73	69.0078
970.23	1317.92	845.12	765.75	752.36	692.67	392.69	72.7672

Li Pb4

TIME	TC2	TLI1	TLI2	TLI4	TSB	Q	MLOH
1020.16	1302.98	843.32	765.61	752.37	693.60	396.57	76.5117
1070.28	1288.69	841.59	765.47	752.37	694.52	400.39	80.2712
1120.21	1275.12	839.93	765.34	752.38	695.41	404.13	84.0157
1170.14	1262.18	838.34	765.21	752.39	696.27	407.80	87.7603
1220.26	1249.78	836.81	765.09	752.39	697.13	411.41	91.5197
1270.19	1237.97	835.34	764.97	752.40	697.95	414.94	95.2642
1320.12	1226.68	833.93	764.84	752.41	698.75	418.41	99.0087
1370.24	1215.83	832.57	764.72	752.41	699.54	421.82	102.7682
1420.17	1205.48	831.26	764.60	752.42	700.31	425.16	106.5127
1470.30	1195.52	829.99	764.48	752.43	701.05	428.46	110.2722
1520.22	1186.00	828.77	764.37	752.44	701.79	431.68	114.0167
1570.15	1176.87	827.61	764.27	752.44	702.51	434.84	117.7612
1620.28	1168.06	826.47	764.18	752.45	703.21	437.96	121.5207
1670.20	1159.63	825.37	764.08	752.46	703.89	441.01	125.2652
1720.13	1151.51	824.33	763.99	752.46	704.56	444.01	129.0097
1770.26	1143.67	823.30	763.90	752.47	705.22	446.96	132.7692
1820.18	1136.16	822.33	763.82	752.48	705.86	449.85	136.5137
1870.11	1128.91	821.37	763.73	752.49	706.48	452.69	140.2582
1920.24	1121.90	820.45	763.65	752.49	707.09	455.50	144.0177
1970.16	1115.16	819.55	763.58	752.50	707.70	458.24	147.7622
2020.29	1108.63	818.69	763.50	752.51	708.29	460.94	151.5217
2070.22	1102.34	817.84	763.42	752.51	708.86	463.59	155.2662
2120.14	1096.27	817.05	763.36	752.52	709.43	466.20	159.0107
2170.27	1090.38	816.25	763.28	752.53	709.98	468.77	162.7702
2220.20	1084.70	815.49	763.22	752.54	710.53	471.28	166.5147
2270.12	1079.20	814.76	763.15	752.55	711.06	473.76	170.2592
2320.25	1073.96	814.02	763.09	752.55	711.58	476.21	174.0187
2370.18	1068.71	813.33	763.02	752.56	712.09	478.60	177.7632
2420.10	1063.71	812.66	762.96	752.57	712.58	480.95	181.5077
2470.23	1058.85	811.98	762.90	752.58	713.07	483.28	185.2672
2520.16	1054.15	811.34	762.84	752.58	713.56	485.55	189.0117
2570.28	1049.57	810.72	762.78	752.59	714.04	487.81	192.7712
2620.21	1045.15	810.11	762.72	752.60	714.50	490.01	196.5157
2670.14	1040.85	809.50	762.66	752.61	714.95	492.18	200.2602
2720.26	1036.65	808.93	762.60	752.62	715.40	494.33	204.0197
2770.19	1032.59	808.38	762.54	752.62	715.83	496.43	207.7642
2820.12	1028.65	807.83	762.49	752.63	716.26	498.50	211.5087
2870.24	1024.80	807.28	762.44	752.64	716.69	500.54	215.2682
2920.17	1021.06	806.76	762.39	752.65	717.11	502.56	219.0127
2970.30	1017.41	806.26	762.35	752.66	717.52	504.53	222.7722
3020.22	1013.87	805.77	762.31	752.67	717.92	506.48	226.5167
3070.15	1010.42	805.28	762.26	752.68	718.31	508.39	230.2612
3120.28	1007.05	804.79	762.22	752.68	718.69	510.29	234.0207
3170.20	1003.78	804.34	762.18	752.69	719.07	512.14	237.7652
3220.13	1000.58	803.90	762.14	752.70	719.44	513.97	241.5097
3270.26	997.46	803.46	762.10	752.71	719.81	515.79	245.2692
3320.18	994.42	803.04	762.07	752.72	720.18	517.56	249.0137
3370.11	991.46	802.61	762.03	752.73	720.54	519.33	252.7582
3420.24	988.56	802.18	761.99	752.74	720.88	521.05	256.5176
3470.16	985.73	801.78	761.96	752.75	721.23	522.76	260.2620

LI PB4

TIME	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3520.29	982.96	801.40	761.93	752.76	721.56	524.44	264.0215
3570.22	980.27	801.02	761.90	752.77	721.89	526.09	267.7661
3620.14	977.63	800.65	761.86	752.78	722.22	527.74	271.5105
3670.27	975.05	800.28	761.83	752.79	722.54	529.34	275.2700
3720.20	972.54	799.91	761.80	752.80	722.86	530.93	279.0146
3770.12	970.08	799.55	761.77	752.81	723.17	532.51	282.7590
3820.25	967.66	799.19	761.74	752.82	723.48	534.04	286.5186
3870.18	965.31	798.86	761.71	752.83	723.78	535.57	290.2629
3920.10	963.00	798.53	761.69	752.84	724.09	537.08	294.0076
3970.23	960.73	798.21	761.66	752.86	724.38	538.55	297.7671
4020.16	958.53	797.89	761.64	752.87	724.67	540.02	301.5115
4070.28	956.37	797.58	761.61	752.88	724.95	541.49	305.2710
4120.26	954.22	797.27	761.59	752.89	725.23	542.91	309.0195
4170.26	952.10	796.96	761.56	752.90	725.51	544.35	312.7695
4220.26	950.04	796.65	761.53	752.91	725.79	545.79	316.5195
4270.26	948.03	796.34	761.50	752.92	726.06	547.18	320.2695
4320.26	946.05	796.05	761.48	752.94	726.33	548.55	324.0195
4370.26	944.12	795.77	761.46	752.95	726.59	549.93	327.7695
4420.26	942.24	795.50	761.44	752.96	726.85	551.29	331.5195
4470.26	940.38	795.23	761.42	752.97	727.11	552.61	335.2695
4520.26	938.57	794.96	761.40	752.98	727.36	553.92	339.0195
4570.26	936.79	794.70	761.38	753.00	727.61	555.23	342.7695
4620.26	935.04	794.45	761.36	753.01	727.86	556.52	346.5195
4670.26	933.34	794.20	761.34	753.02	728.11	557.77	350.2695
4720.26	931.65	793.95	761.32	753.03	728.34	559.02	354.0195
4770.26	930.02	793.70	761.30	753.05	728.58	560.27	357.7695
4820.26	928.39	793.45	761.28	753.06	728.82	561.51	361.5195
4870.26	926.81	793.21	761.26	753.07	729.04	562.70	365.2695
4920.26	925.25	792.98	761.24	753.08	729.27	563.88	369.0195
4970.26	923.72	792.75	761.23	753.10	729.49	565.07	372.7695
5020.26	922.22	792.53	761.21	753.11	729.72	566.26	376.5195
5070.26	920.73	792.31	761.20	753.12	729.93	567.41	380.2695
5120.26	919.30	792.10	761.18	753.14	730.14	568.53	384.0195
5170.26	917.86	791.89	761.17	753.15	730.36	569.66	387.7695
5220.26	916.46	791.69	761.16	753.17	730.57	570.78	391.5195
5270.26	915.09	791.48	761.14	753.18	730.78	571.91	395.2695
5320.26	913.71	791.28	761.13	753.19	730.98	573.00	399.0195
5370.26	912.40	791.08	761.12	753.21	731.18	574.06	402.7695
5420.26	911.08	790.89	761.10	753.22	731.38	575.12	406.5195
5470.26	909.77	790.69	761.09	753.24	731.57	576.18	410.2695
5520.26	908.52	790.51	761.08	753.25	731.77	577.25	414.0195
5570.26	907.27	790.32	761.07	753.27	731.96	578.31	417.7695
5620.26	906.02	790.13	761.05	753.28	732.15	579.32	421.5195
5670.26	904.83	789.94	761.04	753.30	732.34	580.32	425.2695
5720.26	903.64	789.76	761.03	753.31	732.53	581.32	429.0195
5770.26	902.46	789.57	761.02	753.33	732.72	582.32	432.7695
5820.26	901.30	789.39	761.00	753.34	732.90	583.32	436.5195
5870.26	900.18	789.23	761.00	753.36	733.08	584.32	440.2695
5920.26	899.05	789.06	760.99	753.37	733.26	585.28	444.0195
5970.26	897.93	788.89	760.98	753.39	733.43	586.22	447.7695

LI PB4

TIME	TC2	TLT1	TLT2	TM	TSB	TB	MLIOH
6020.26	896.86	788.73	760.97	753.40	733.60	587.16	451.5195
6070.26	895.79	788.57	760.96	753.42	733.77	588.09	455.2695
6120.26	894.73	788.41	760.95	753.44	733.94	589.03	459.0195
6170.26	893.67	788.25	760.94	753.45	734.11	589.97	462.7695
6220.26	892.66	788.10	760.93	753.47	734.28	590.91	466.5195
6270.26	891.66	787.95	760.93	753.49	734.44	591.81	470.2695
6320.26	890.66	787.80	760.92	753.50	734.60	592.69	474.0195
6370.26	889.66	787.65	760.91	753.52	734.76	593.56	477.7695
6420.26	888.69	787.50	760.90	753.54	734.92	594.44	481.5195
6470.26	887.76	787.36	760.90	753.55	735.08	595.31	485.2695
6520.26	886.82	787.22	760.89	753.57	735.23	596.19	489.0195
6570.26	885.88	787.08	760.89	753.59	735.39	597.06	492.7695
6620.26	884.94	786.93	760.88	753.61	735.54	597.94	496.5195
6670.26	884.05	786.80	760.87	753.62	735.70	598.79	500.2695
6720.26	883.18	786.67	760.87	753.64	735.84	599.61	504.0195
6770.26	882.30	786.53	760.86	753.66	735.99	600.42	507.7695
6820.26	881.43	786.40	760.86	753.68	736.13	601.23	511.5195
6870.26	880.55	786.27	760.85	753.70	736.28	602.04	515.2695
6920.26	879.70	786.13	760.85	753.71	736.42	602.86	519.0195
6970.26	878.89	786.01	760.84	753.73	736.56	603.67	522.7695
7020.26	878.07	785.88	760.84	753.75	736.70	604.48	526.5195
7070.26	878.00	785.84	760.84	753.77	736.85	605.29	530.2695
7120.26	878.00	785.91	760.86	753.79	736.99	606.11	534.0195
7170.26	878.00	785.99	760.91	753.82	737.12	606.86	537.7695
7220.26	878.00	786.08	760.96	753.84	737.25	607.61	541.5195
7270.26	878.00	786.18	761.01	753.86	737.38	608.36	545.2695
7320.26	878.00	786.27	761.07	753.89	737.51	609.11	549.0195
7370.26	878.00	786.37	761.12	753.91	737.64	609.86	552.7695
7420.26	878.00	786.46	761.17	753.93	737.77	610.61	556.5195
7470.26	878.00	786.56	761.23	753.96	737.90	611.36	560.2695
7520.26	878.00	786.65	761.28	753.98	738.03	612.11	564.0195
7570.26	878.00	786.74	761.33	754.01	738.16	612.86	567.7695
7620.26	878.00	786.84	761.39	754.03	738.29	613.61	571.5195
7670.26	877.99	786.93	761.44	754.06	738.42	614.35	575.2695
7720.26	878.00	787.03	761.50	754.08	738.54	615.04	579.0195
7770.26	878.00	787.12	761.55	754.11	738.67	615.73	582.7695
7820.26	877.97	787.21	761.60	754.13	738.78	616.42	586.5195
7870.26	877.83	787.27	761.65	754.16	738.90	617.10	590.2695
7920.26	877.60	787.32	761.69	754.19	739.02	617.79	594.0195
7970.26	877.27	787.33	761.72	754.21	739.14	618.48	597.7695

PROGRAM EXECUTION STOPPED BY PROGRAM

VALUES 0.845E+04 0.0 0.100E+03 0.0 0.114E+04