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The purpose of the present presentation is to provide a brief reflection on our current understanding of the unprotected transient overpower accident, and try to place it into perspective with regard to the overall question of the FFTF core energetics.

As you know, a very pessimistic view of the TOP accident was taken at the time of the PSAR in that the basic assumptions included

- 1) axial centerline failure of fuel pins,
- 2) a rapid coolant ejection mechanism, and
- 3) neglect of fuel motion prior to the core disassembly phase.

Subsequent early tests in the TREAT reactor revealed that substantial fuel motion occurs upon pin failure, and the essence of these observations was incorporated in our analysis at the time the Design Safety Assessment document was written. Most of our work over the last year or so has been to refine these analyses, and to more directly compare our models to experimental results from the TREAT reactor. This work has continued to give us confidence that the unprotected transient overpower accident in the FFTF is a fairly benign event.

Rather than go into detail with regard to specific baseline calculations, however, I felt it might be more beneficial--for the purpose of this meeting--to step back a moment and try to take an overview of the entire envelope of potential TOP concerns. The first VU-GRAPH is included to summarize the topics which are believed to be relevant to this end.

First, I would like to provide a quick review of our Base TOP Analysis and, within this context, highlight the key assumptions we are making in our analysis, outline the potential accident paths involved in the TOP, and use this framework for discussing the key questions existing at this time. The emphasis will be on what we know, what we don't know, and how to make suitable allowances for our areas of uncertainty.

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Next, I plan to address the experimental data base, with particular emphasis on the E and H-series data, and its relevance to the questions of axial failure location and hydraulic fuel sweepout.

As a result of some of the ambiguities yet remaining from the experimental data, I will then focus attention on some preliminary calculations performed wherein total blockage of localized pin regions is assumed--both for irradiated and for fresh core conditions.

Finally, I would like to draw some conclusions from this combined analytical/experimental base to place into better perspective the role of the unprotected TOP accident for FFTF HCDA considerations. Here, the focus will be on the case which can be made for early accident termination and in-place cooling. Based upon this assessment, I then plan to point out that even under conditions of extreme improbability, the TOP accident is bounded by the energy release numbers already calculated for the Loss of Flow Accident.

BASE TOP ANALYSIS

The next VU-GRAPH summarizes the expected behavior for the unprotected TOP.

- 1) First, having postulated an external reactivity input source and assumed that the protective system fails, the ultimate mode of shutdown must be via the avenue of fuel failure and eventual fuel removal. In this regard, there exists substantial evidence--both analytically and experimentally, that failure of the pins will occur well above the core centerline--particularly for those pins containing a significant amount of molten fuel at the time of failure.
- 2) The subsequent fuel/coolant dynamics process then ensuing is expected to lead to a rapid neutronics shutdown, and
- 3) a non-energetic fuel dispersal.

Hence,

- 4) overall accident termination occurs with an essentially intact core.

Now, what are the key assumptions imbedded in this scenario? The following VU-GRAPH is included to address that question.

- 1) First, the assumption is made that, indeed, axial failure locations will be well above the axial core midplane.
- 2) Secondly, on the question of failure incoherency, there are two major areas, i.e., failure incoherency between subassemblies (which are included, at least to a limited degree), and failure incoherency within subassemblies (which we have previously ignored). This latter factor is, in fact, potentially very important as I hope to make clear later in the discussion.
- 3) Third, based on early TREAT results, all nominal calculations are based on the assumption that a considerable amount of fuel is hydraulically swept out of the active core region by the coolant. In recognition of the ambiguity of some of the more recent TREAT results, however, we do not assume all mobile fuel reaching the coolant channel is cleanly swept out--in fact, of the order of 50% is normally assumed to remain behind.
- 4) Finally, we have to make some assumptions with regard to the magnitude of the reactivity insertion mechanism which initiates the accident. It might be worth reminding you that in the case of the FFTF, the peak reactivity insertion rate achievable by withdrawing the most reactive rod at the maximum rate of withdrawal is only about 3¢/sec. In the PSAR, the base case was constructed around a 50¢/sec insertion accident, i.e., a ramp rate over an order of magnitude larger than that deemed possible from any physical movement of a given subassembly, and even larger rates were investigated. The range of interest is then certainly limited by a few ¢/sec to a few &/sec, as shown on this VU-GRAPH, for a total insertion of approximately 4 to 5 dollars.

The next VU-GRAPH is included to help place the overall TOP potential accident sequence into perspective. Hopefully, this VU-GRAPH will help to focus the importance of the key assumptions outlined on the previous VU-GRAPH.

You will note several possible accident paths, but they are not all considered to have the same probability. Although probability numbers are not available, we have used a procedure of

Dr. Fauske of ANL to include all general paths leading to the ultimate question of post-accident heat removal (PAHR), but have highlighted the expected--or most probable path--by the heavy arrows, i.e., the path around the left side of the figure. In fact, the path to the right is predicated on axial centerline failure and, as you will note, this hypothesis leads quite directly to a classical case of mechanical core disassembly--particularly if plugging in the coolant channel is also assumed. It is possible that even with such a postulated failure location that fuel sweepout would slow down the accident sequence sufficiently to allow early termination without hydrodynamic disassembly. However, any sequence down the right-hand side is regarded as highly improbable because of the very substantial analytical and experimental evidence supporting a high axial failure location.

You will note that the path around the left describes the expected behavior in accordance with my earlier remarks. The probability of substantial fuel sweepout appears quite high for failed fuel which has been pre-irradiated, since the cladding will fail prior to the time of massive melt fractions in the pins. The case for sweepout upon failure of fresh pins is not so strong, due to the combined situation of a high melt fraction at failure and the possibility of a locally voided coolant channel (resulting from boiling) acting as a receptacle for expelled fuel. It is possible that a considerable amount of localized plugging near or slightly above the rupture site would occur for fresh fuel. As will be noted from a later VU-GRAPH, however, any plugging would be expected to be confined to the central 50-70% of the pins within the failed subassembly; hence, substantial by pass flow around the outer 2 or 3 rows of pins would provide peripheral cooling and allow an early accident termination--even without any hydraulic sweepout at all! This is most important point; one to which I will return in later discussions.

To summarize, the only path we can envision in which the TOP accident could lead to a sizeable energy release is if either

- 1) Total plugging takes place, or
- 2) A plug at the radial center of the subassemblies propagates to the hex can walls prior to neutronics shutdown.

In either case it is possible to envision a sequence leading to a gradual meltdown of the core, i.e., entering the transition phase, in a manner similar to that of the LOF. Even in this case, however, it should be noted that plugging patterns should be localized--due to the marked difference in failure conditions for differing fuel types. Remember that the pumps are still on in this case, and a reduction in power will allow unfailed regions of the core to be cooled far more effectively than in the LOF situation.

This brings us then to our key questions, as shown in the next VU-GRAPH:

- 1) The case which can be made for axial failure locations well above the core midplane,
- 2) The extent of fuel plateout or plugging in the coolant channel, and
- 3) The fresh core. Here as was pointed out earlier, the major concern is that of plugging since--as will be noted later in the discussion--this core configuration has the highest propensity of discharging large amounts of molten fuel into a largely dry coolant channel.

EXPERIMENTAL DATA

In an attempt to address these major questions, I would like to turn to the experimental data base which we now have in hand. The following VU-GRAPH summarizes results from the tests most relevant to the TOP accident sequence. The H-series tests were conducted to simulate a 50¢/sec ramp insertion and the E-series tests were driven somewhat harder to simulate a 3\$/sec ramp insertion. H2 and E4 were fresh pins whereas the remaining tests all contained at least one irradiated pin. H5, H4, and E6 had a central irradiated pin surrounded by six peripheral fresh pins, whereas E7 and E8 had a full complement of seven irradiated pins.

The first major question in the analysis, as you recall, was that of axial failure location. Although it is difficult in some of these tests to designate the precise axial failure location, certainly in all cases, failure occurred well above the axial midplane. This is a very significant result, and is in keeping with our understanding of fuel failure mechanisms.

The second major question, i.e., the propensity for hydraulic fuel sweepout, doesn't have such positive results. You will note that all of the E-series

tests for which we have data (namely E4, E6, and E7) plugged quite solidly. It is interesting to note that considerable flow could be reestablished in all of the lower ramp H-series tests--a trend which is intuitively reasonable since more time is available for dispersing the fuel in the lower ramp rate cases. But even for these 50¢/sec simulations, it must be acknowledged that considerable plugging did take place.

It should be pointed out, however, that the MARK-IIA test vehicle was designed primarily for obtaining fuel failure-type data in a flowing system and we are simply trying to extract as much meaningful data beyond failure as we possibly can. Unfortunately, there are at least two aspects of the tests which tend to reduce the applicability of the data to this question of sweepout, as shown in the next VU-GRAPH.

First, the system hydraulics of the MARK-IIA loop are significantly different from that of the real reactor. The coolant velocity is only about half that of full flow FFTF conditions and the system pressure and inertial parameters are such that a given pin failure would allow a much greater perturbation to coolant flow conditions in the test vehicle than under actual reactor accident conditions--thus leading to a considerably greater propensity for plugging in the test environment.

Secondly, any fuel movement which occurred in the tests had essentially no reactivity influence on the TREAT reactor, i.e., on the power burst, whereas such motion is the controlling factor on terminating the power burst in an actual reactor. Hence, in many of the test cases, considerable overdriving took place, i.e., a large amount of molten fuel was generated after pin failure.

I should point out, however, that despite the fact that a considerable amount of eventual pluggingg did occur in several of the tests, in all cases the fuel was configured in a less reactive arrangement after the tests than existed prior to failure. Hence, even under full plugging conditions, such motion from several pins in a reactor would lead to a reduction in the power level.

We can then summarize the applicability of the test results in the following VU-GRAPH. First, the axial failure location appears to be well above the axial midplane. Here I should point out a potential difference between fresh and irradiated pins which may not be apparent from simply observing the tests to date. Since the TREAT test pins were EBR-II irradiated, they were only 13 inches in length and had a relatively uniform microstructure throughout their length. For full length pins in FFTF, the changing microstructure toward the axial pin extremities means that the cladding may be more rapidly pressurized in these gas-bearing regions of the pins which approach or reach the melting point. This is an additional factor which, for irradiated pins, tends to solidify the case of an axial failure location well above the core midplane.

For fresh pins, so much molten fuel can be retained prior to pin failure that it is quite likely that coolant boiling will precede cladding failure. Since boiling will occur first at the top of the active core region, cladding dryout conditions will first occur in this region and this factor further supports the conclusion of failure near the top for fresh core conditions.

As I said earlier, the overall fuel movement in all of the tests was toward a less reactive configuration. However, plugging did occur and we are still studying means of how to interpret this data as it may relate to accident situations in a real reactor.

ANALYSIS INCLUDING PLUGGING

Having now looked at our base calculations, key assumptions, and supporting experimental data, we ask the question, "What can we really defend--at this time--as a realistic, yet conservative, accident bound for the unprotected TOP situation?"

The following VU-GRAPH sets the stage for the models used in recent calculations in an attempt to answer this question. You may recall from an earlier VU-GRAPH that I noted our current inclusion of failure incoherency between subassemblies. However, up until now we have not explicitly allowed for an incoherence within subassemblies. Yet, if one looks at the coolant temperature distribution across a typical subassembly in FFTF, we note, as shown on the figure, a sizeable drop near the outer 2 or 3 rows of pins. This difference between the coolant temperature of the inner

50 to 70 per cent of the pins and the outer rows is of the order of 100°F at steady state and could rise to around 300°F at the inception of boiling. Hence, since cladding properties are very important to failure for both fresh and irradiated pins, the central cluster of pins would be expected to fail well before the outer rows. This, of course, means less reactivity feedback due to fuel motion--since fewer pins are initially involved--but it also means a clear flow path even if fuel leaving the failed inner pins should form a total blockage at the rupture point. This is an extremely important point! As we see from the sketch at the right, because of the unresolved question of fuel plugging, we have conducted a preliminary set of calculations wherein we assume no hydraulic fuel sweepout at all, i.e., the fuel freezes in the channel at the axial position of cladding rupture. However, you will note that a considerable bypass flow is possible--at least early in the expulsion process before the outer pins fail.

What we are really attempting to determine is whether sufficient reactivity loss due to fuel motion, flowing from high worth regions of the core inside the fuel pin to a low worth rupture location--even without moving once it moves into the coolant channel--provides sufficient reactivity shutdown to arrest the power burst and prevent failure in the outer row of pins.

Perhaps the following VU-GRAPH will help to visualize the difference between this plugging model and the base TOP model. On the left is a sketch of the fuel disposition in the channel for the Base Model approximately 80 msec after pin failure. You will note that about 50% of the fuel has been arbitrarily assumed to plate out over the region once occupied by the FCI zone but the other half has been hydraulically swept out of the active core region.

In the current plugged case model, all of the ejected fuel is assumed to pile up at the rupture location, i.e., no fuel sweepout is allowed to occur. This blockage is forced to be highly localized. Almost full blockage, for this case, occurs in approximately 40 msec with only a small buildup of fuel plating 2 inches systematically above and below the axial rupture site.

The following VU-GRAPH contains the reactivity balance for a BOC-4 case with and without plugging. You will note that even for total blockage of half as many pins as involved in the base case, neutronics shutdown is

expected in about 0.3 sec. It should be pointed out that, for these preliminary calculations, the sodium void model was not altered, i.e., ejection of the fuel into the coolant stream was assumed to drive the lower sodium slug down well past the core midplane before reversing. In actuality, in order to be consistent with the model of plugging only in the central region of the subassembly, it is doubtful that any sodium void region would extend downward much below the plug. Taking such an effect into account would mitigate the positive sodium void contribution and drive the net reactivity downward much faster.

A comparison of the power trace for this plugged case vs. the base case is shown in the following VU-GRAPH, where it is noted that even though the power reduction is slightly delayed, it nevertheless occurs rapidly.

The following VU-GRAPH shows similar results for a range of BOC-4 parametric cases in which the prime parameter was axial failure location. As would be intuitively obvious, as the axial failure location is moved down toward the core midplane, the shutdown is delayed. In fact, if it is moved low enough, the reactivity connotations of fuel motion can be positive. However, here I should re-emphasize that strong evidence suggests a high axial location for failure. Hence, the results from the lower failure location is really only of academic interest.

Next I would like to turn to the fresh core. As noted earlier, this has always been a case for concern since, as denoted on the following VU-GRAPH,

- 1) coolant boiling will probably precede pin failure, thereby
- 2) allowing a substantial amount of molten fuel to squirt into a largely voided region--thus leading to a relatively high propensity for plugging.

Since earlier analysis has demonstrated the sensitivity of such an accident sequence to axial failure location, it is important to note from the following VU-GRAPH that the failure is expected to occur near or at the top of the pin. Our confidence here is bolstered primarily from the fact that

- 1) Boiling is initiated at the Top,
- 2) Downward voiding is slow relative to the rate of increase in heat flux, and
- 3) The available data (specifically from H2 and E4) is in support of this contention.

Actually, as we now try to apply these results to the FFTF, a high failure location seems more certain. Since the coolant velocity in FFTF is double that of the MARK-IIA loop and the primary loop has considerably more inertia, the rate of boiling propagation down into the core should be considered.

We have performed some preliminary calculations for the fresh core in which we have assumed total regional plugging as in the BOC-4 case, and the message is essentially the same. Namely, it does appear that neutronic shutdown can be obtained very rapidly--even with no hydraulic sweepout--and in fact, rapidly enough to drop the power before failure of pins in the outer rows of the subassembly will fail.

The following VU-GRAPH summarizes the conclusions for the prospects of supplying in-place cooling for the fresh core. Based on preliminary calculations our current best judgment is that the power burst can be terminated prior to voiding the outer subchannels within the affected subassemblies. Because of the full flow conditions, we should be able to demonstrate cooling fairly large planar blockages in-place even though these are heated plugs--and if cooling cannot be maintained, the bottom and sides will certainly be cooled such that the path of least resistance is upward-- into a less reactive configuration.

It should be also noted that, in contrast to LOF conditions, a potential exists to reestablish flow in the outer subchannels even if boiling cannot be prevented during the accident. Finally, even for fully plugged conditions, a pressure of approximately 1-- psi will drop across this heated plug and provide a mechanism for dislodging portions to permit some upward flow.

CONCLUSIONS

In trying to sum up this discussion, I'm sure the importance of the axial failure location must be obvious. It is for this reason that a considerable amount of effort has been expended to determine where fuel pins of different microstructure and irradiation history would fail under unprotected TOP conditions. Perhaps it would be helpful, therefore, to show you some of the calculational results of our new Damage Parameter correlation technique

The first VU-GRAPH represents predicted results for a moderately high power pin (≈ 10 kw/ft peak power) in which the central restructuring region comprises about the middle half of the pin. Failure is predicted to occur near the top of the central void region, with a shaded error band extending approximately ± 3 inches from that point. The second VU-GRAPH represents a high power (12.5 kw/ft peak power) pin in which the central void region extends nearly the full length of the pin. Here the failure is predicted to occur at the top of the pin--again with an error band of approximately 6 inches. The damage parameter for the lower half of the pin continually drops off and is not plotted.

The essential message is clear: Pin failures are expected to occur well above the axial midplane and may--for the hottest pins--occur very near or at the top of the active core region. If we now return to the earlier VU-GRAPH which contained the general accident path tree, we can hopefully view the overall situation from a better perspective.

Both analytical and experimental evidence strongly supports the position that we do not expect central axial failure locations. Hence, we would expect an accident path down the right side of this VU-GRAPH to be extremely improbable. It might be helpful to point out, however, that even if one did hypothesize massive failures near the midplane, the reactivity insertion due to fuel rapidly moving toward the core centerline would be limited to the neighborhood of a hundred dollars/sec. Such conditions, although arising from a different mechanism, were considered in the PSAR and the eventual energy yield was fairly modest--even though it employed a very pessimistic conversion of thermal energy to work energy--mainly because a β -In equation of state is controlling for such situations.

Turning our attention to the left side of the VU-GRAPH, therefore, I hope it is apparent that there exists a much stronger possibility for terminating the unprotected TOP accident in "Phase I" than in the case of the LOF. There is a strong indication that enough reactivity loss can be obtained due to fuel motion from high worth to low worth regions to terminate the power burst--even if hydraulic sweepout does not occur! This observation, combined with the failure incoherency within subassemblies, implies a strong

case for demonstrating in-place cooling following the excursion. It should be clearly emphasized that much larger blockages can be cooled under full flow conditions than is the case for LOF conditions.

Even though we expect substantial hydraulic sweepout of fuel, we have shown that a considerable amount of localized plugging can be tolerated. Even if total plugs were to form in individual subassemblies, however, the whole core would not necessarily get into the boiling pool resulting from the "Transition Phase". And even under these conditions, whatever recriticality conditions might be postulated to occur due to those subassemblies which do lose their geometry, the relatively higher net reactivity at such a time would tend to reduce the recriticality ramp rate, on a per subassembly basis, below that of the LOF.

Before concluding, it is perhaps worth noting, as shown in the following VU-GRAPH, that very little fuel is expected to be removed from the core, under TOP conditions, to burden post-accident heat removal requirements outside the core. For base case calculations, in which substantial hydraulic fuel sweepout is expected, only about 3% of the original fuel inventory is computed to leave the active core prior to permanent neutronic shutdown. If we postulate the type of plugging discussed today, i.e., solid plugging at the rupture location for the hot central pins within the failed subassemblies, the total fuel reaching the coolant channel may be as high as 10%. However, since it has been postulated to plug, very little of this would eventually be carried throughout the vessel. In the extreme case of solid plugging throughout the subassemblies, a transition phase similar to the LOF would be entered and the demand upon the PAHR system would be comparable to that case.

The final VU-GRAPH summarizes our conclusions on the TOP accident sequence.

First early termination appears to be by far the most likely sequence. Substantial shutdown is expected from fuel sweepout--especially for irradiated cores--but such sweepout is not essential to the conclusions.

Secondly, failure incoherency within the subassemblies--combined with early shutdown--provides a strong case for in-place cooling. It should be

noted that a substantially larger blockage is allowable with the pumps on than is the case for LOF conditions.

Finally, the above arguments are believed to greatly mitigate the concern for core recompaction leading to a potential recriticality. Even under such a hypothesis, however, the only mechanistic path envisioned possible for such an event is via a massive plugging process which would lead to a transition phase.

It should be remembered that very large insertion rates were considered in the calculations which led to the 150 MW-sec work energy design basis, and it is very difficult to envision any mechanistic path which would lead to ramp rates larger than those already considered. In fact, the only mechanistic path envisioned to lead to a potential gradual core meltdown is via a massive plugging process. As unlikely as this is, as noted from today's discussion, such an event would lead to a transition-type phase in a manner not dissimilar to the conditions already considered within the context of the LOF accident sequence.

I hope that this discussion helps to place into better perspective the role of the unprotected TOP accident in the overall question of FFTF core energetics.

BASE TOP ANALYSIS

- OVERVIEW
- KEY ASSUMPTIONS
- POTENTIAL ACCIDENT PATHS
- KEY QUESTIONS

EXPERIMENTAL DATA

- SUMMARY OF E&H --SERIES
- RELEVANCY TO AXIAL FAILURE LOCATION
- RELEVANCY TO SWEEPOUT

ANALYSIS INVOLVING PLUGGING

- BASE MODEL
- BOC-4
- BOL

CONCLUSIONS

- EARLY TERMINATION
- IN-PLACE COOLING
- REACTIVITY INSERTION BOUND

EXPECTED UNPROTECTED TOP BEHAVIOR

1. FAILURE NEAR TOP OF PINS
(FOR PINS CONTAINING SIGNIFICANT AMOUNTS OF
MOLTEN FUEL)
2. RAPID NEUTRONICS SHUTDOWN
3. NON-ENERGETIC FUEL DISPERSAL
4. TERMINATION WITH ESSENTIALLY INTACT CORE

KEY ASSUMPTIONS: BASE TOP ANALYSIS

AXIAL FAILURE LOCATION WELL ABOVE AXIAL MIDPLANE

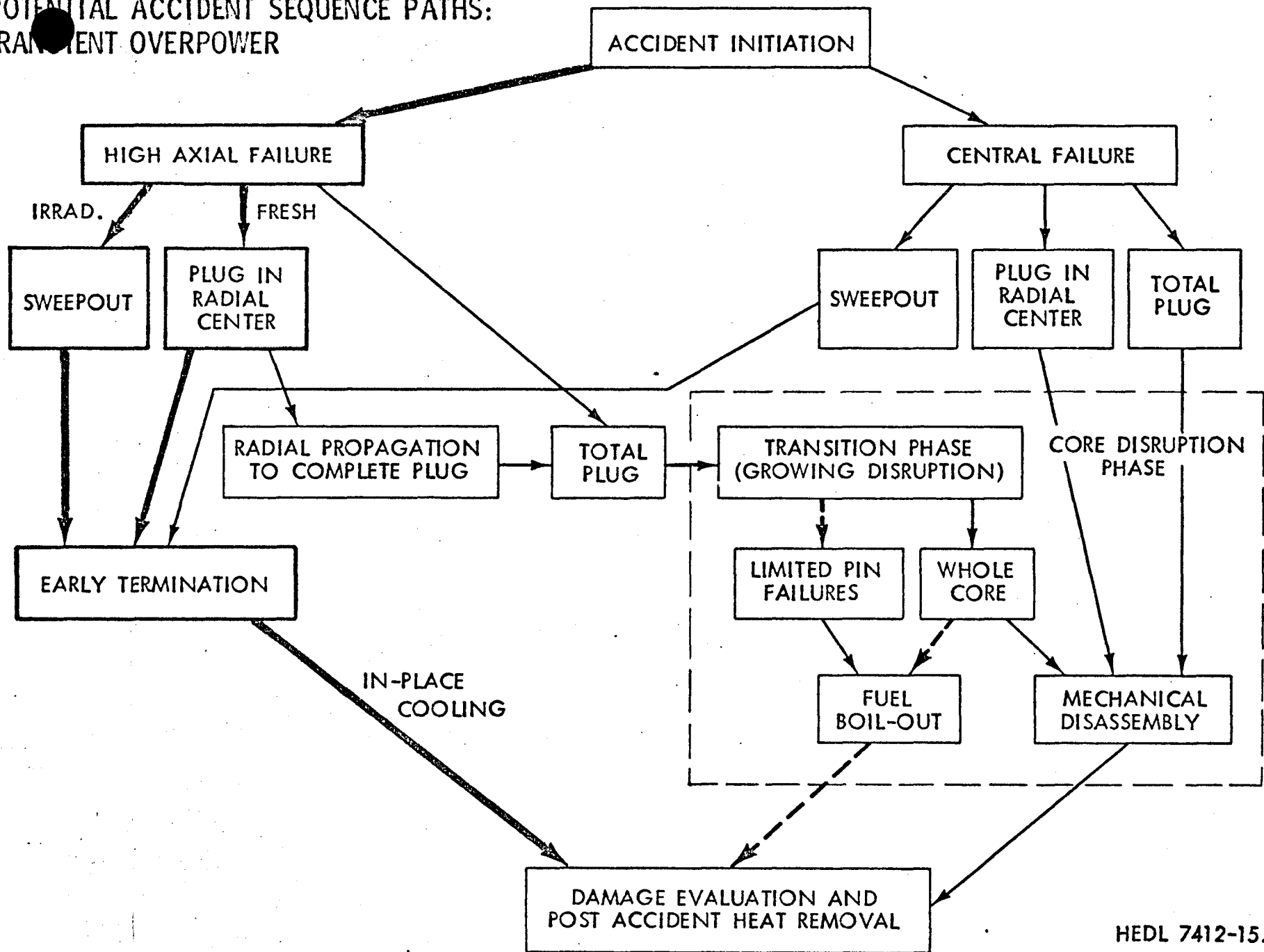
INCOHERENCY

1. BETWEEN SUBASSEMBLIES (INCLUDED)
2. WITHIN SUBASSEMBLIES (NOT INCLUDED)

HYDRAULIC SWEEPOUT

RAMP RATE \leq FEW $\$/\text{SEC}$; \approx \$4 MAXIMUM INSERTION

POTENTIAL ACCIDENT SEQUENCE PATHS:
TRANSIENT OVERPOWER



KEY QUESTIONS: BASE TOP ANALYSIS

- AXIAL FAILURE LOCATION (THE CASE FOR OFF-CENTER FAILURE)
- FUEL PLATEOUT (EXTENT OF PLUGGING)
- FRESH CORE (HIGHEST PROPENSITY FOR PLUGGING)

EXPERIMENTAL DATA
 VEHICLE: MARK-IIA LOOP

<u>TEST</u>	<u>RAMP</u>	<u>FUEL TYPE</u>	<u>FRESH/ IRRAD</u>	<u># PINS</u>	<u>AXIAL FAILURE LOCATION</u>	<u>% FLOW AFTER TEST</u>	<u>COOLANT EJECTION MECHANISM</u>
H2	50¢/SEC*	UNRES.	F	1	TOP	>0	BOILING
H5	50¢/SEC	EQUIAXED	I	1+6	3/4 UP	45	MILD FCI
H4	50¢/SEC	COLUMNAR	I	1+6	2/3 UP	10	F.G. RELEASE
E4	3\$/SEC*	UNRES.	F	1	TOP	0	BOILING
E8	3\$/SEC	EQUIAXED	I	7	---	---	----
E6	3\$/SEC	COLUMNAR	I	1+6	3/4 UP	0	F.G. RELEASE
E7	3\$/SEC	COLUMNAR	I	7	>3/4 UP	0	F.G. RELEASE

*NO PRE-HEAT

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MAJOR NONPROTOTYPIC ASPECTS OF MARK-IIA LOOP RESULTS

1. SYSTEM HYDRAULICS

- COOLANT VELOCITY \approx 1/2 THAT OF FFTF
- PRESSURE AND INERTIAL PARAMETERS ALLOW MUCH GREATER FLOW PERTURBATION THAN IN FFTF

2. TEST OVERDRIVING

- NO REACTIVITY INFLUENCE ON TREAT
- LARGE AMOUNT OF MOLTEN FUEL GENERATED AFTER PIN FAILURE

TEST RESULTS TO DATE

I. AXIAL FAILURE LOCATION

A. WELL ABOVE AXIAL MIDPLANE

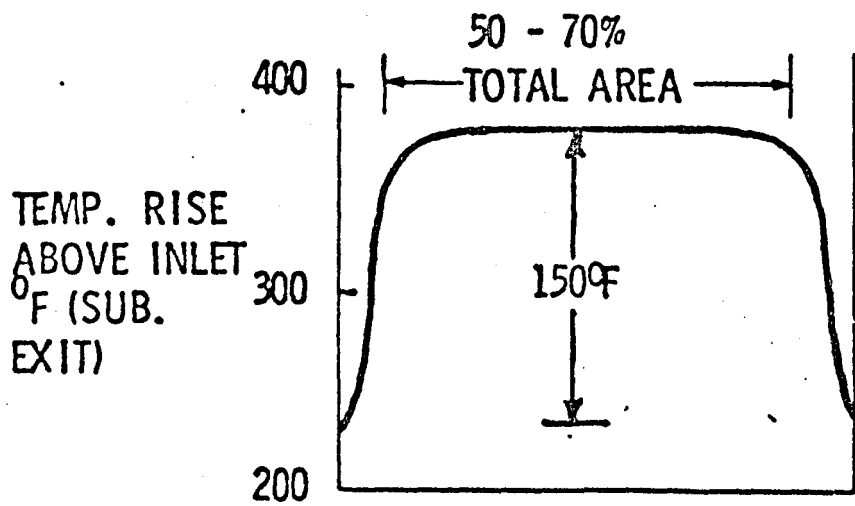
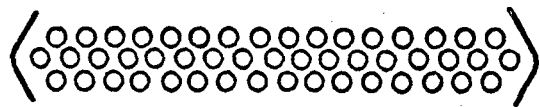
- IRRADIATED PINS: DIFFERING MICROSTRUCTURE TOWARD TOP
- FRESH PINS: BOILING INITIATED AT TOP

II. FUEL SWEEPOUT

- #### A. OVERALL FUEL MOTION TOWARD LESS REACTIVE CONFIGURATION
- #### B. PLUGGING POTENTIAL STILL UNDER STUDY*

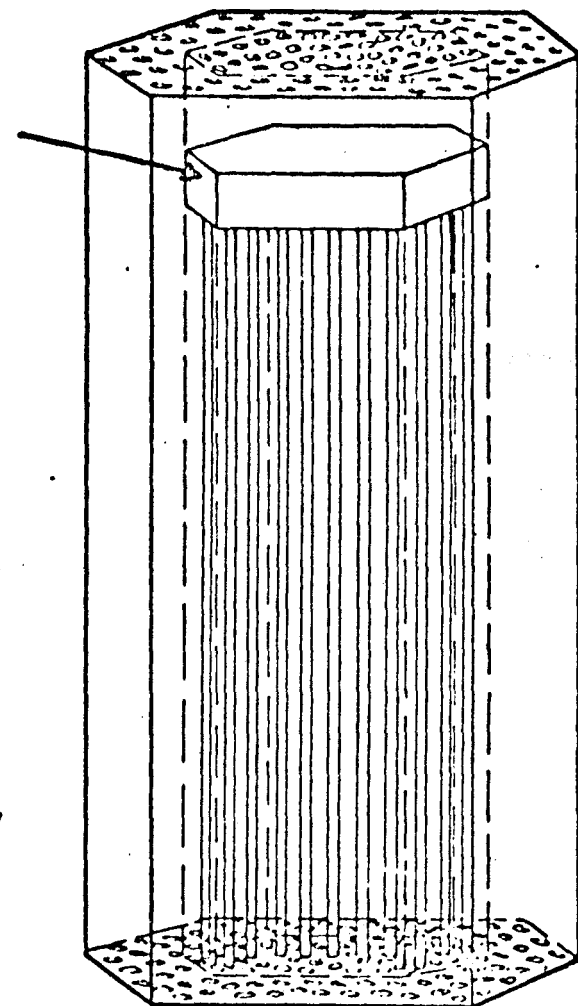
*QUESTION OF NONPROTOTYPIC EFFECTS OF HYDRAULIC AND OVERDRIVING

INCOHERENCY AND PLUGGING MODEL

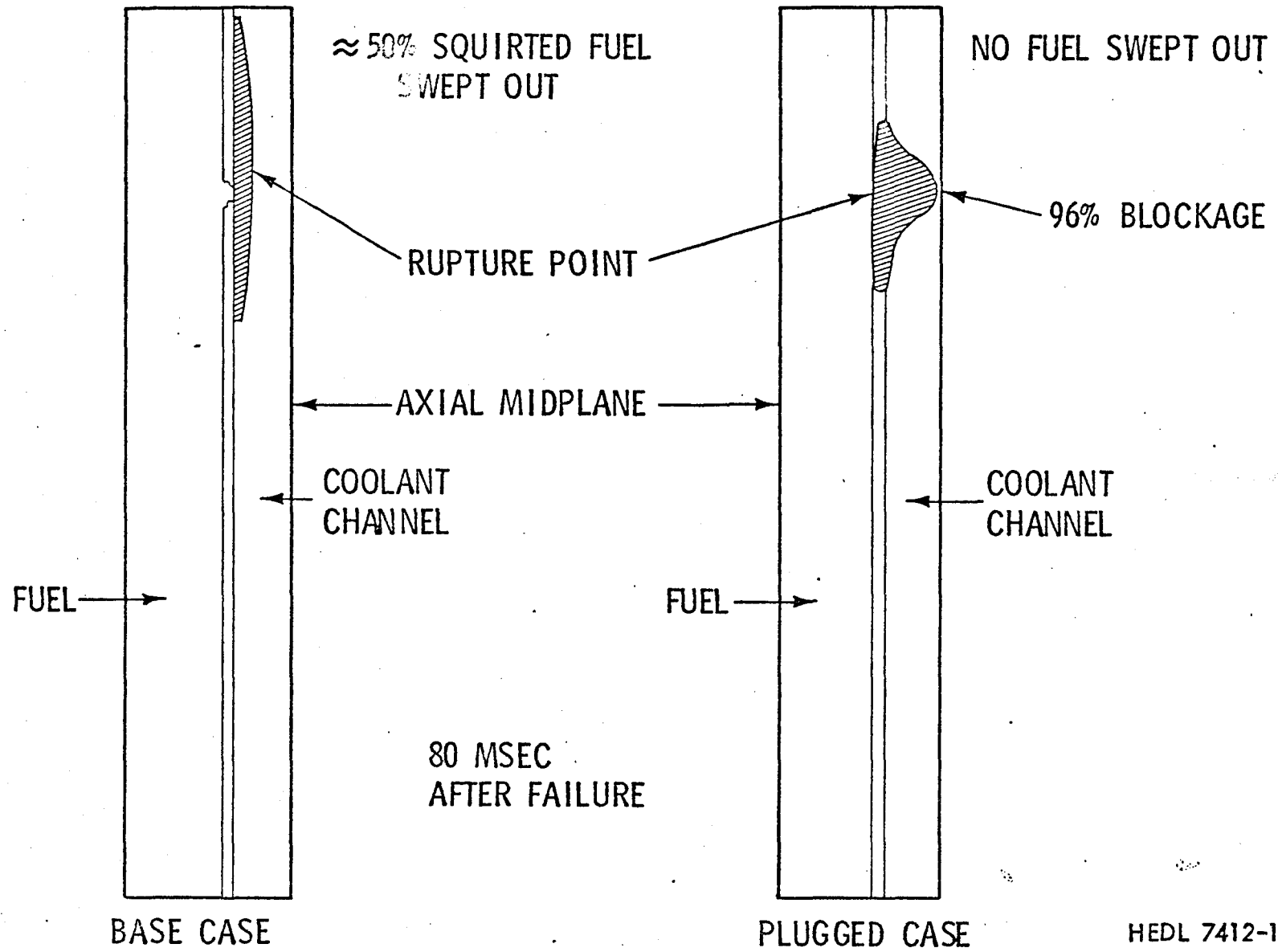


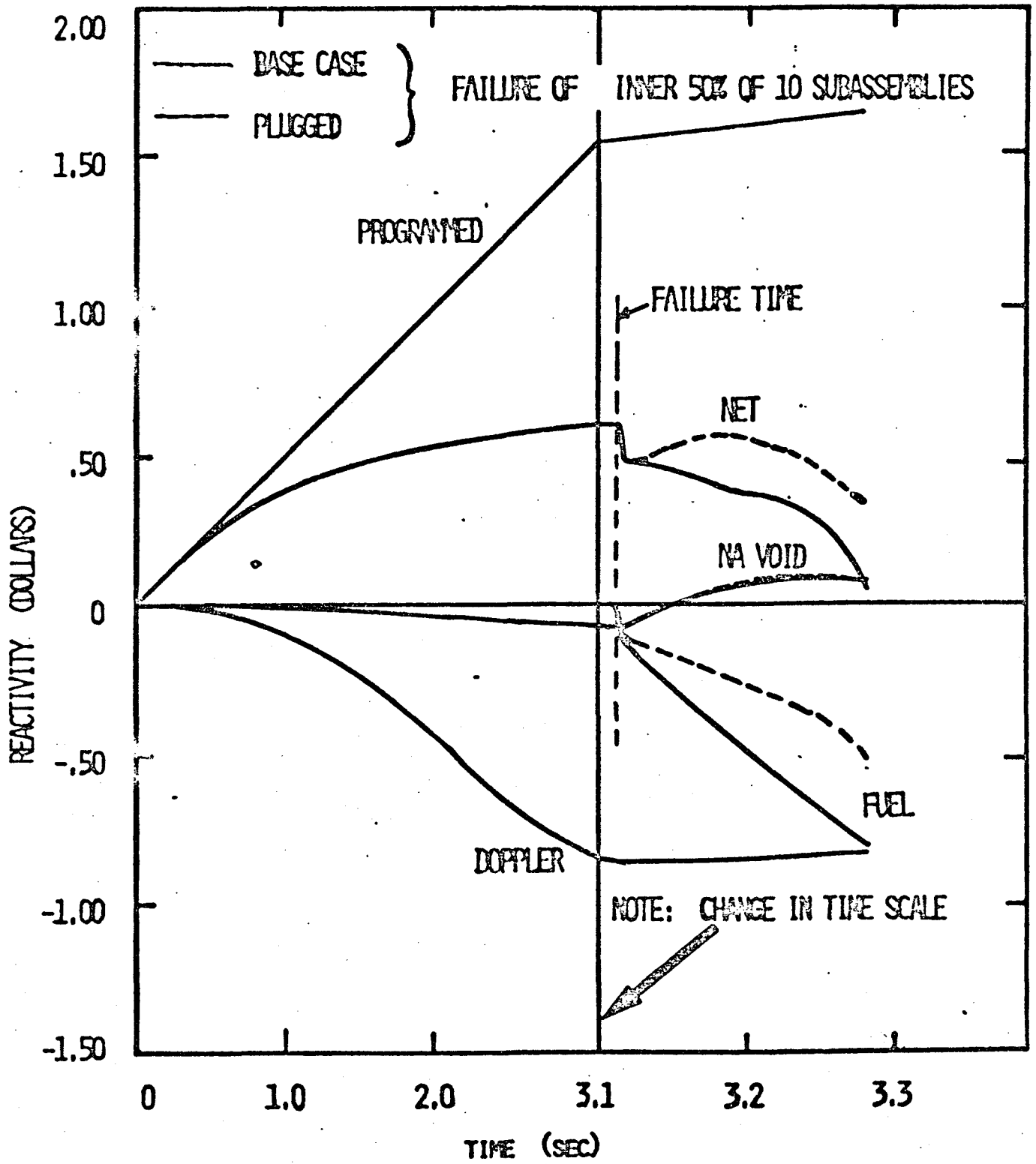
SUBASSEMBLY

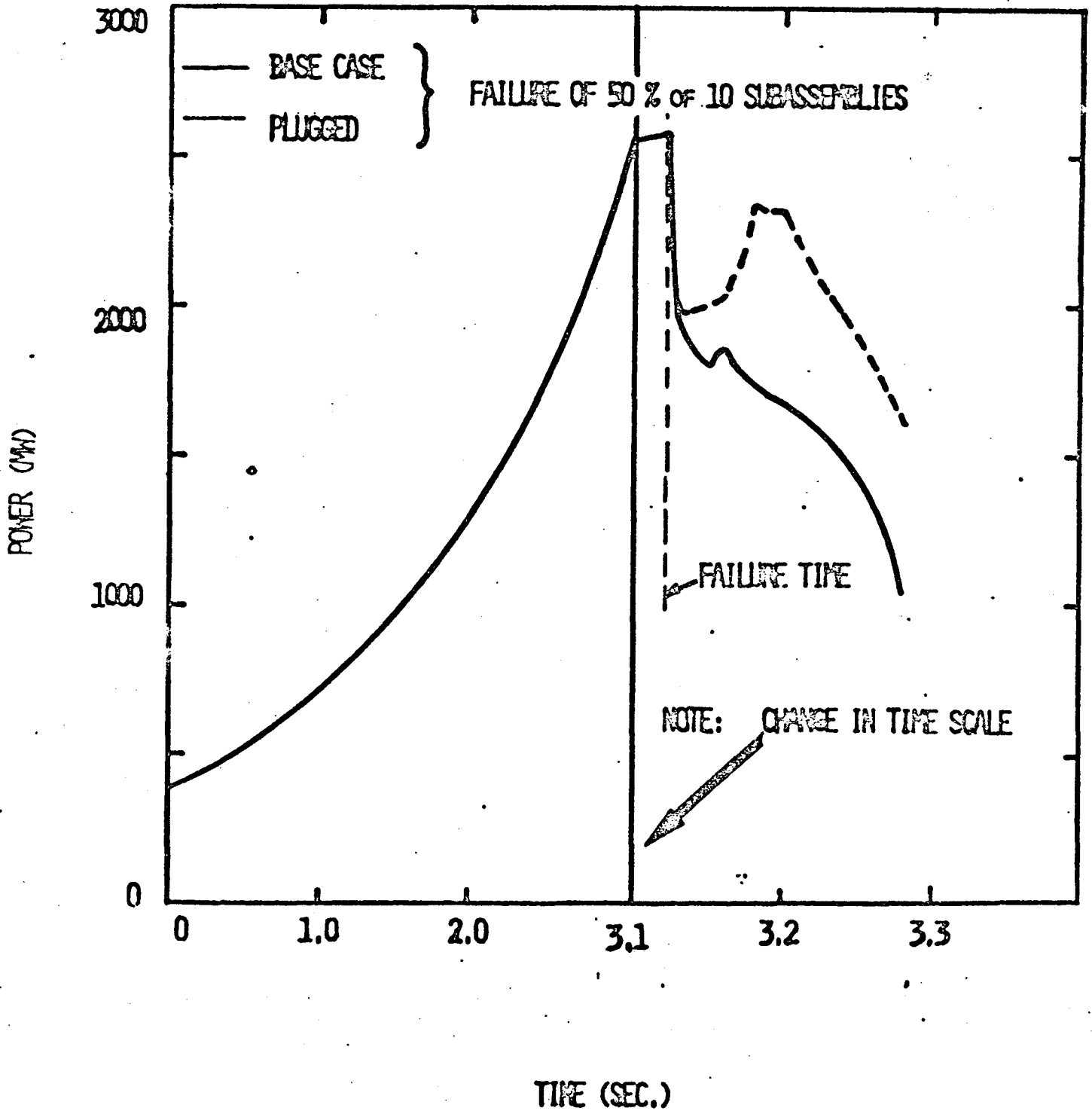
PLUGGED REGION



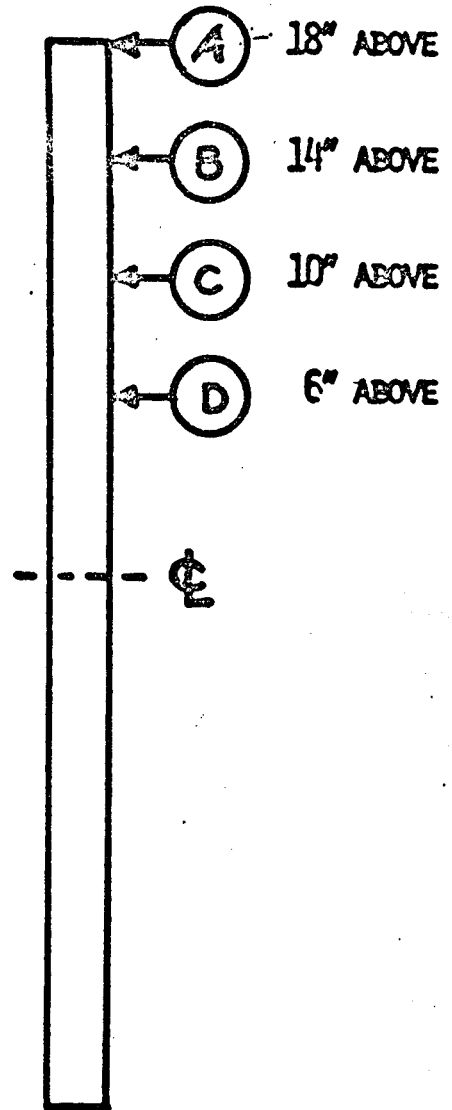
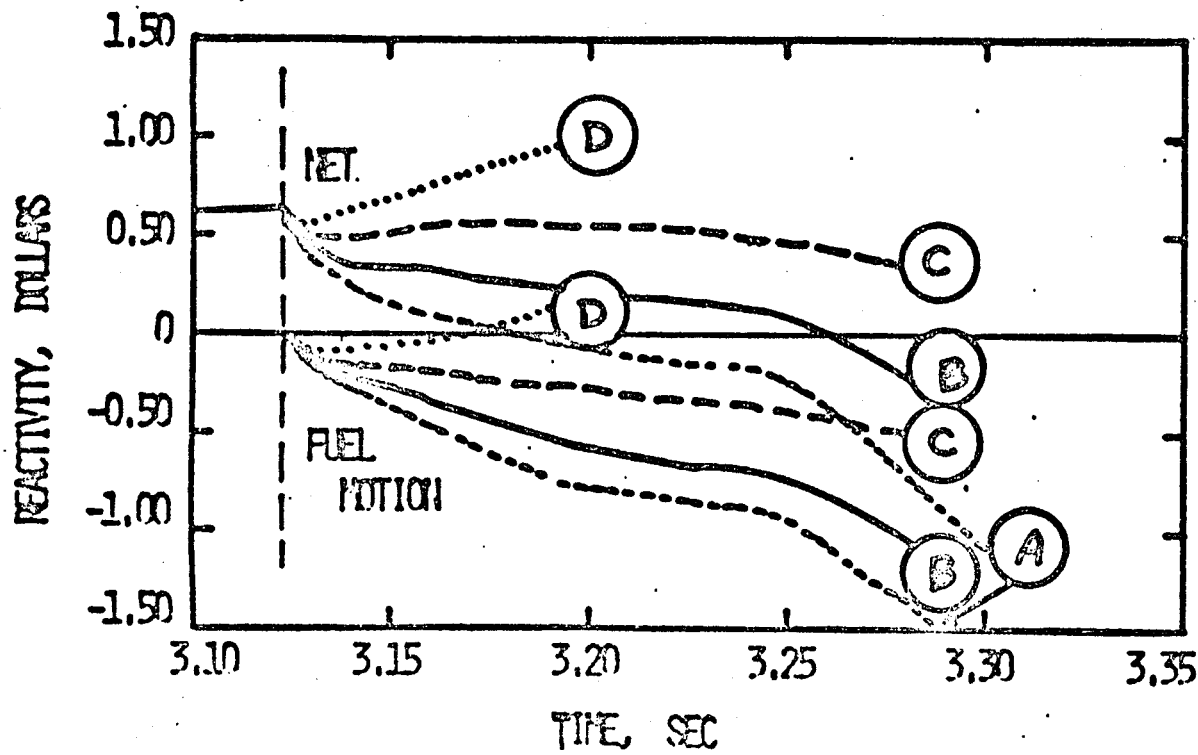
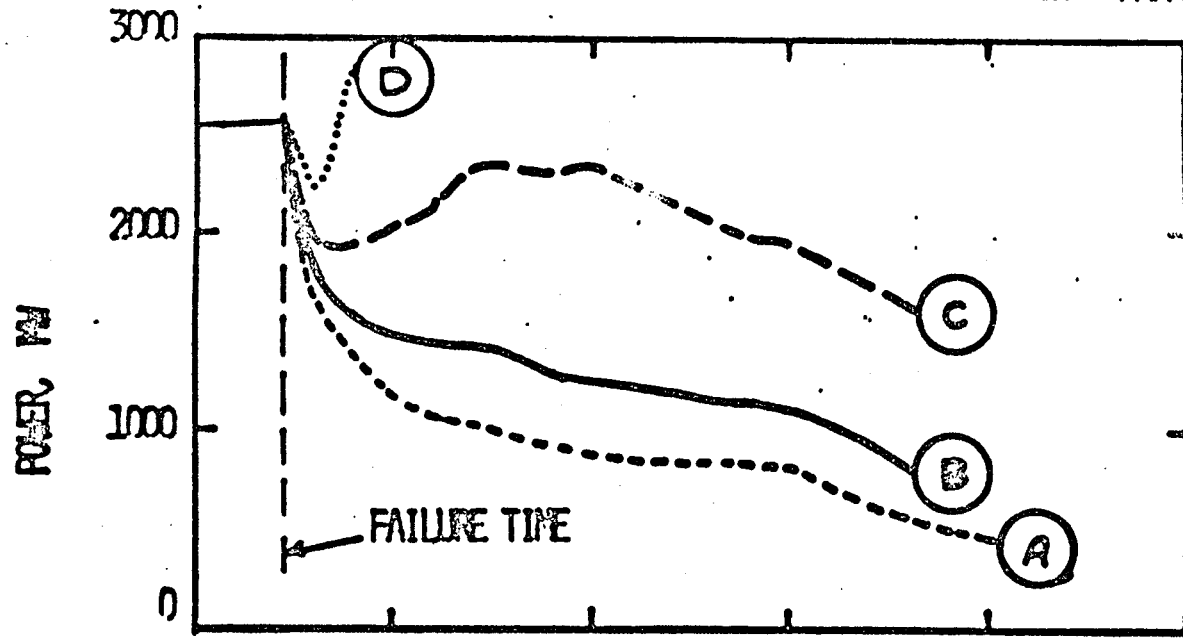
BOC-4 TWO CHANNEL CORE







PRELIMINARY EOC-4 PLUGGING PARAMETRICS



FRESH CORE

WORST CASE SINCE

1. BOILING MAY OCCUR PRIOR TO FAILURE
2. SUBSTANTIAL MOLTEN FUEL EXPELLED AT TIME OF FAILURE
HIGHEST PROPENSITY FOR PLUGGING

FRESH CORE: FAILURE LOCATION

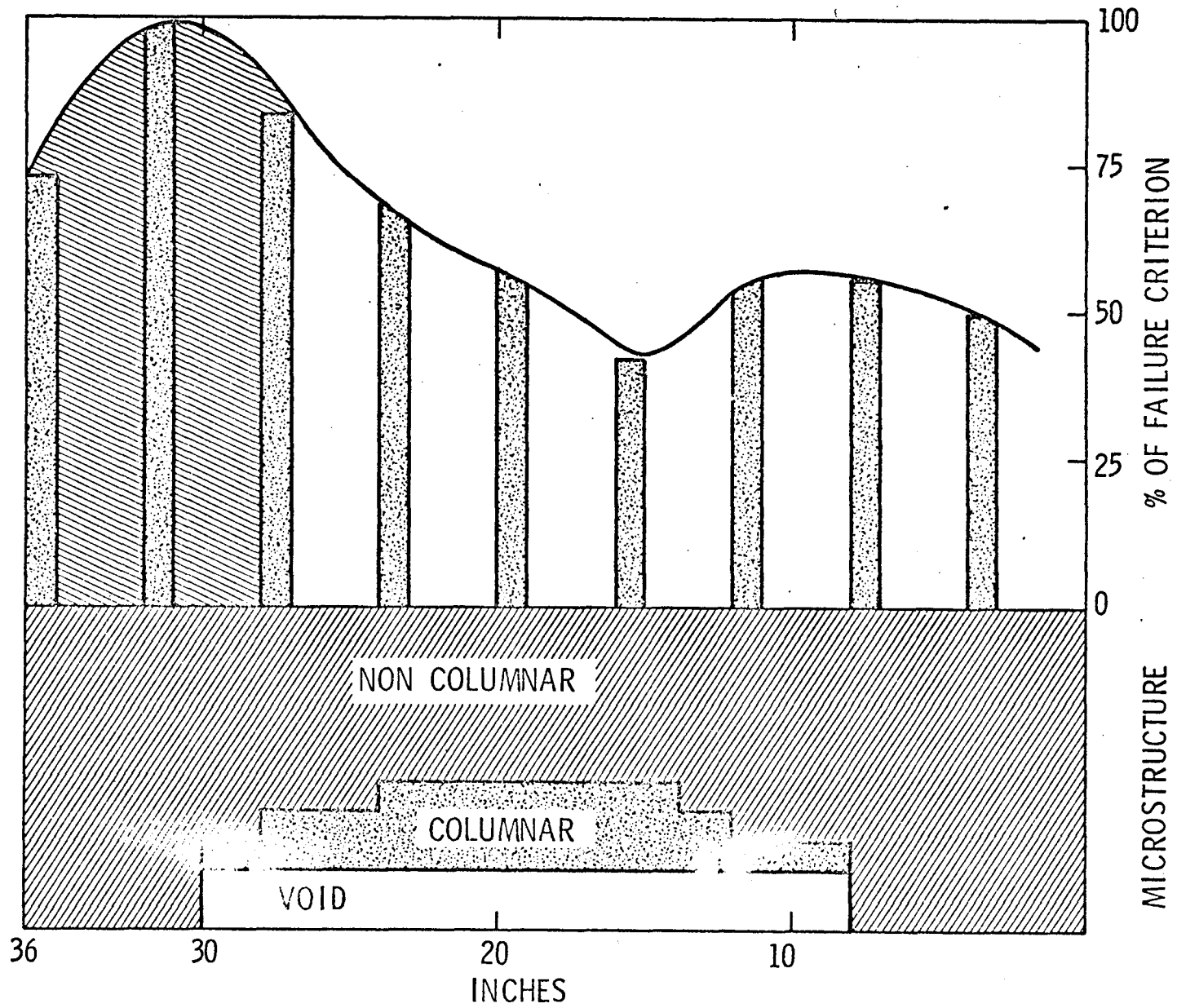
NEAR OR AT TOP OF FUEL COLUMN

- BOILING INITIATES AT TOP
- DOWNWARD VOIDING SLOW RELATIVE TO INCREASE IN HEAT FLUX
- SUPPORTING EXPERIMENTAL DATA

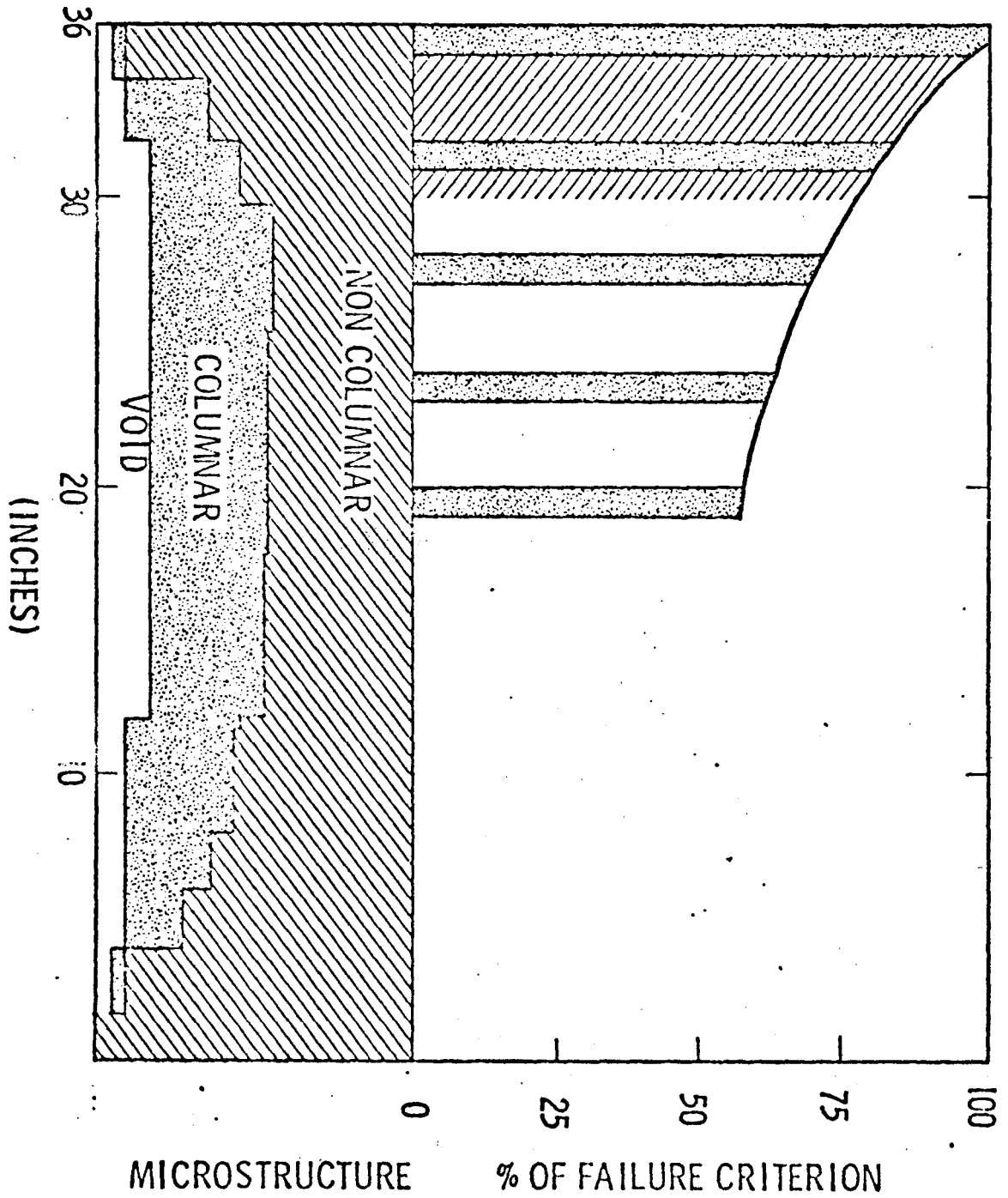
FRESH CORE: IN-PLACE COOLING

- I. CURRENT JUDGMENT SUGGESTS POWER BURST TERMINATION PRIOR TO VOIDING IN OUTER SUBCHANNELS
 - A. CAN COOL SMALL BLOCKAGES IN PLACE
 - B. IF BLOCKAGE LARGE ENOUGH TO PREVENT COOLING, PATH OF LEAST RESISTANCE IS UPWARD
- II. POTENTIAL EXISTS TO RE-ESTABLISH FLOW IN OUTER SUBCHANNELS EVEN IF PRIOR VOIDING OCCURS
- III. EVEN FOR TOTAL PLUGGING CONDITIONS, ≈ 100 PSI PRESSURE DROP ACROSS HEATED PLUG WOULD TEND TO DISLODGE PORTIONS TO PERMIT UPWARD FLOW

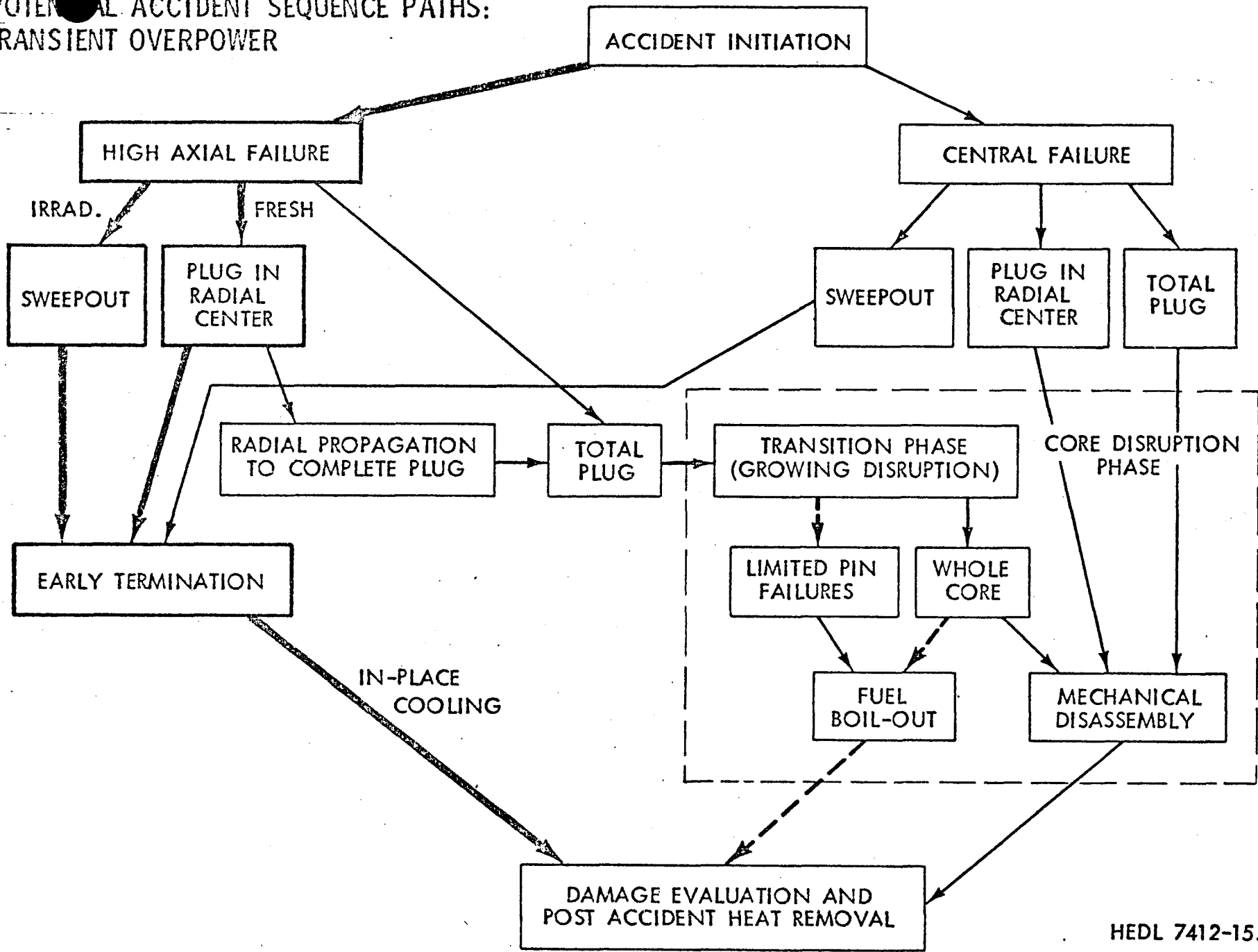
AXIAL REACTOR POWER: 10 KW/FT



11.5 - 12.5 KW/FT PIN 50 #/SEC TRANSIENT



POTENTIAL ACCIDENT SEQUENCE PATHS:
TRANSIENT OVERPOWER



TOP INPUT TO PAHR REQUIPEMENTS

EXPECTED CASE: SUBSTANTIAL HYDRAULIC SWEEPOUT

◇ - 3% OF FUEL REMOVED FROM CORE

PLUGGED CASE: CENTRAL SUBCHANNELS SOLIDLY PLUGGED AND
NO HYDRAULIC SWEEPOUT

◇ - 10% OF FUEL IN COOLANT CHANNEL (SMALL % OF
THIS EVENTUALLY REMOVED).

CONCLUSIONS

A. EARLY TERMINATION

- SHUTDOWN REACTIVITY FROM FUEL MOTION
- HYDRAULIC SWEEPOUT NOT ESSENTIAL

B. IN-PLACE COOLING

- FAILURE INCOHERENCY WITHIN SUBASSEMBLIES
- SUBSTANTIALLY LARGER BLOCKAGE ALLOWABLE THAN UNDER LOF CONDITIONS

C. REACTIVITY INSERTION BOUND

- STRONG ARGUMENTS TO PREVENT RECRITICALITY CONCERNS
- EVEN UNDER EXTREME CONDITIONS, NO INSERTION MECHANISM IDENTIFIED WHICH EXCEEDS RATE CONSIDERED IN

I. PSAR

II. CURRENT LOF ANALYSIS