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NUCLEAR REGULATORY COMMISSION

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

EMERGENCY CORE COOLING SYSTEMS

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Holiday Inn
Park Center Plaza
Center Room
282 Almaden Boulevard
San Jose, California

Friday,
December 3, 1982

The subcommittee meeting on Emergency Core Cooling Systems for the Advisory Committee on Reactor Safeguards was convened at 8:30 a.m.

PRESENT FOR THE ACRS:

M. PLESSET, Chairman
Z. ZUDANS
T. THEOFANOUS
V. SCHROCK
D. WARD
I. CATTON
J. EBERSOLE
C. TIEN

DESIGNATED FEDERAL EMPLOYEE:

P. BOEHNERT

ALSO PRESENT:

MR. ALAMGIR
MR. SHIRALKAR
MR. COLLINS
MR. SHERWOOD
MR. QUIRK
MR. WOOD
MR. SOZZI
MR. ANDERSEN
MR. DENNISON
MR. SUTHERLAND

P R O C E E D I N G S

DR. PLESSET: Good morning.

We will continue with further discussion that we had begun yesterday with GE, and Mr. Quirk will introduce the presenters.

MR. QUIRK: Good morning.

I'd like to introduce our first speaker who will talk on TRAC qualification. Mohammed Alamgir.

MR. ALAMGIR: Good morning. My name is Mohammed Alamgir. I work in the Core Qualification area, the name of my unit is Local System Technology.

Today I'll be sharing with you some of my experiences with TRAC that I have been engaged with in the last few months in trying to qualify the GE version of TRAC-BWR. So, what you'll see today are snapshots of that effort.

(Slide.)

The code that we'll be discussion is TRACBC02, which is a version created at Idaho and then improved upon by adding on GE models. We have selected a spectrum of experimental facilities which will address some of the analytical models in the code, as well as try to address its aplicability towards a reactor or a reactor simulator.

So, what we have here are five experimental facilities, starting with a simple vessel blowdown case which addresses void distrubution and level swell. Then a simple single bundle film boiling test run at Oakridge. Then a complete system blowdown case of a BWR simulator, TLTA, or the Two-Loop Test Apparatus, which is more or less one deep in the core region. And, then a three-dimensional facility, of which you have already heard yesterday from Gary Dix, the Steam Sector Test Facility comprising of fifty-eight bundles, and it's idiomatic, meaning that core steam injection was utilized.

We also have in our list the only available reactor data, the Peach Bottom Turbine Trip Test. And, we'll be trying to assess the hydraulics of the code. We will not address the neutronics in these tests, we'll input the power and try to assess thermohydraulics.

(Slide.)

The status of the qualification is that it's nearly complete, although my slides are not complete. So, you will be seeing what I have done, let's say, two weeks ago.

(Slide.)

And, before I go onto the comparisons I'd like to take a few minutes and talk about qualification itself. As I see it, the purpose of qualification is to ascertain whether a code is, first of all, valid analytically; second, whether it meets application criteria; and, some other people put in also strict, stringent measures, or limitations let's say, that demand that the code perform within certain error bounds that the results be accurate within such and such, and so forth.

DR. CATTON: Do you participate in the standard problem program, the International Standard Problems Program with TRAC?

MR. ALAMGIR: No.

I have not been involved in that.

DR. CATTON: They have some interesting problems that might fit under your qualification data base.

DR. SCHROCK: Excuse me, could I pursue a question that I asked yesterday about the relationship between BO2 and BD2?

Dr. Zudans asked if BO2 is going to be released, and I think the answer we got is that, no, it's a developmental code which is aimed at providing improved models for BD2. If I understood this correctly, BD2 will be the released version.

Now, if that's not the correct impression could you tell me what the relationship is? What we're hearing now is that you're qualifying BO2. Qualifying it in what sense? For use in calculations that will be presented in licensing arguments, or where does it fit into the whole picture?

MR. ALAMGIR: This is a stepping stone towards a future TRACBD1 MarkI Code, which will have in addition to what we have in TRACBO2 some more models. And, there are people from Model Development who will be better able to answer that question.

But, this is an intermediate code going towards TRACBD2 Mark II. As to BD1, Bharat Shiralkar is probably in a better position to answer that.

MR. SHIRALKAR: This is Bharat Shiralkar.

I think Jens Andersen mentioned yesterday that we are cooperating with Idaho in developing these models. These models will eventually be given to Idaho and some of them already have. But, they have the eventual responsibility to decide which models will eventually get into the code.

The assessment is tied together. We regard this as a preliminary assessment for the BD2 version. The BD2 version will have some more features than what we have, primarily in the valence sub-plate(ph) and the neutronics areas.

DR. SCHROCK: So, the impression I had yesterday is the correct one that --

MR. SHIRALKAR: Yes.

DR. SCHROCK: -- what you're talking about here is preliminary assessment, it's not aimed at qualifying this code for use in any sense in this particular form in the licensing arguments?

MR. SHIRALKAR: That is, I believe, another function, yes.

DR. SCHROCK: For BO2?

MR. SHIRALKAR: For BO2.

For BO2 as it stands today, we would like to use it to demonstrate the performance --

DR. SCHROCK: But then, Bharat, the question about its release becomes a fairly important one because people are going to need to examine it closely if that's the way it's going to be used.

MR. SHIRALKAR: I think that we would be prepared to discuss with the NRC, for example, in detailed models and the performance of the code for that purpose, yes.

DR. SCHROCK: So, what you're saying now, then, is that BO2 will be a proprietary code that is labeled TRAC and will be used in that way?

MR. SHIRALKAR: Let me just say that we have no plans to release it at this time. It's not proprietary in the sense that there are no proprietary models in it, all the models that we feel we will add to it.

DR. SCHROCK: Yes.

MR. SHIRALKAR: Just particular configuration of the code, we don't plan to release, for example, the code setter.

DR. ZUDANS: You said there are no proprietary models. Returning back to yesterday's presentation it was stated that the CCFL at the bottom end of the rod bundle wasn't based on proprietary data.

How would that fit into your statement?

MR. SHIRALKAR: The CCFL model is not proprietary. The CCFL model basically asmyptotes to a pre-guidelines form of the CCFL correlation. The coefficient that you use to fit it may be a function of the particular experiment.

DR. PLESSET: Well, I think we better go on.

DR. CATTON: Will ROSA III data be used?

MR. ALAMGIR: No, not in this set.

(Slide.)

Next we'll take a look at the results. In the comparisons that will follow, if you do not see any uncertainty band on the figure it means that undertainty is less than the width of the line.

In most cases special and differential pressure uncertainties are very small, so we have not included those.

(Slide.)

These are the particular tests and the facilities that we have talked about. They are not in the order that I showed you in the first slide. We have four tests in the TLTA, two separate Effects Tests, the last two, 6441 and 5424. And, the first two are System Blowdown-type Tests, one with ECC and one without ECC.

The SSTF, we have chosen four tests from there. Two Separate Effects Tests, one addresses the upper plenum mixing in TRAC, the other addressing upper plenum nodalization of a multi-dimensional case like a BWR. This addresses how we can optimally nodalize a system. This one addresses mixing of ECC in the lower plenum in a BWR-4 type configuration, and also addresses the condensation of steam in the lower plenum.

(Slide.)

And, finally SRT-3 is a system response test in SSTF. We'll be showing you results of these two cases. In fact, anything with asterisks will be presented today.

We already talked about BWR transients, the Peach Bottom Tests, the three tests with three different initial powers and inlet subcooling.

(Slide.)

Then we have talked about the vessel blowdown, which is a simple vessel with disc rupture and subsequent flashing and level swell. We have two tests in that and we'll be showing you this one today. And, the Oakridge Film Boiling Test.

DR. CATTON: How extensive is your sutdy of nodalization?

MR. ALAMGIR: Why don't we move on and then maybe you'll find a better point.

DR. CATTON: Fine.

(Slide.)

MR. ALAMGIR: Not very.

DR. CATTON: "Not very" is risky business.

MR. ALAMGIR: Pardon?

DR. CATTON: "Not very" is risky business.

MR. ALAMGIR: Yes.

We will answer that specifically when we come to when we come to it.

(Slide.)

These are some of the things I've already talked about. Vesel blowdown addresses flashing level swell in a free pool and also void distribution. Oakridge addresses film boiling. The measured temperatures are like 1500. This is perhaps -- yes, this is the highest temperature experiment that we have in our list.

TLTA DBA cases, we'll be looking at performance of TRAC as far as predicting the key phenomena and also the sequence of events. We'll also be looking at its performance as to prediction of critical flow, countercurrent flow limiting, as well as breakdown of CCFL, hydraulics in the lower plenum, performance of the jet pumps, and the bundle response.

(Slide.)

In the SSTF we will be primarily looking at -- for the ECC mixing case, we'll be looking at the subcooling distribution in the upper plenum, performance of spray and the submerged jet.

(Slide.)

In the multiple bundle CCFL case we'll be looking at parallel channel hydraulics and see how TRAC can handle that.

(Slide.)

Vessel Blowdown. Let's take a look at the facility. It's a fourteen foot vessel, initial water level is about 5.5 feet, eventually here for limiting the flow. And, the fluid is saturated initially at about 1000 psia, reactor conditions.

There are DP strings here which measured differential pressures, from which we can also obtain void fraction. And, since there is no breakflow measurement in this directly we will use these to obtain mass in the system at any given time and from there we derive the breakflow for this case.

(Slide.)

Incidentally, these tests were conducted by Gary Sozzi, who is in the audience.

Let's look at some of the system responses. First, we'll look at that system pressure. The preduction is the solid line and we see that initially there is agreement, but then a slight divergence in the calculations.

DR. CATTON: How many nodes?

MR. ALAMGIR: Fourteen axial nodes in the vessel.

DR. CATTON: Why not twenty-eight?

MR. ALAMGIR: We have tried thirty-four and that's -- we have reached a limit, it's asymptotic.

DR. SCHROCK: Excuse me.

Why doesn't your track preduct the undershoot? You have your correlation in that, don't you?

MR. ALAMGIR: BO2 doesn't have --

DR. SCHROCK: Does not.

MR. ALAMGIR: -- the non-equilibrium, pressure undershoot.

DR. SCHROCK: Okay, I thought it had.

MR. ALAMGIR: RELAP has.

DR. SCHROCK: Okay.

DR. TIEN: You say you have fourteen axial nodes?

MR. ALAMGIR: Yes.

DR. TIEN: Then you actually tried thirty-eight?

MR. ALAMGIR: Thirty-four.

DR. TIEN: Thirty-four. In between?

MR. ALAMGIR: No, not --

MR. TIEN: No, just the two of them?

MR. ALAMGIR: Yes.

DR. TIEN: You find the fourteen and thirty-four, they are --

MR. ALAMGIR: Thirty-four, yes.

DR. TIEN: -- axial nodes.

MR. ALAMGIR: Thirty-four axial nodes.

The results are quite close.

DR. TIEN: Yes.

MR. ALAMGIR: Breakflow follows the pattern of the pressure in the center of that one, we have good agreement in that it was liquid flow mainly.

DR. CATTON: Could I pursue that just a little more?

MR. ALAMGIR: Yes.

DR. CATTON: What happens if you use seven nodes?

MR. ALAMGIR: We'll address that in the TLTA. We have used a lesser number of nodes than this in the Two-Loop Test Apparatus.

DR. CATTON: Okay, well this is a clean test apparatus.

MR. ALAMGIR: Yes.

DR. CATTON: Probably you get cleaner information than you do on the TLTA.

MR. ALAMGIR: Perhaps, it's --

DR. CATTON: What was the height of this, again?

MR. ALAMGIR: Fourteen.

DR. CATTON: It's about the same length as the core, isn't it?

MR. ALAMGIR: Yes.

DR. CATTON: Do you think you can carry-over some of the thinking about nodalization from here, and maybe you ought to have more than five nodes in the core?

(Pause.)

Go ahead.

MR. ALAMGIR: There are many other things we have to consider --

DR. CATTON: Oh, like money, I'm sure.

MR. ALAMGIR: No, I mean while we model the core, it's not only -- this is one-dimensional.

DR. CATTON: But, so is your fuel bundle.

MR. ALAMGIR: But, the bypass is three-dimensional. if we are talking about multi-dimensional facilities.

(Slide.)

This is the prediction of the two-phase level and that's the data. You see from the breakflow calculation the prediction that when the pressure diverges the breakflow is underpredicted. We will see this happening again in the TLTA and we have found what appears to be a plausible explanation for this. So, why not we wait until we see the TLTA results for this explanation of the pressure difference.

(Slide.)

But, the main interest was to see if it predicts void distribution and here we have plotted the void distribution for three regions in the vessel. This one is near the break plane, and these two are in the lower part of the bundle. It appears to be quite acceptable, I believe.

(Slide.)

This previous case was run where pressure was calculated by the code. This is a calculation where pressure was imposed. And, we see that the two-phase level preduction is slightly better during this part where we don't have the pressure difference and the density difference or the specific volume difference doesn't show up.

DR. TIEN: Again, I'm not quite clear. Could I come back?

A general question in your computation: Suppose you have seven or fourteen axial nodes and then you have -- in the blowdown test you have eleven variations with respect to time -- what kind of resolution you can get in terms of two-phase level? Do you check about the limit, whether that is consistent with the nodalization?

MR. ALAMGIR: There is an explicit two-phase level tracking model in the code. So that obviates the necessity of very small nodes.

DR. TIEN: I see.

DR. SCHROCK: If you go back to the first data slide on that and look at the breakflow --

(Slide.)

-- the middle picture with void fractions predicted by TRAC, it looks as though your course nodalization is producing a sudden increase in the stagnation density feeding the critical flow in the calculation which doesn't occur in an experiment.

And so, the nodalization would seem to be the problem, wouldn't it?

MR. ALAMGIR: What we are seeing in the calculation is swelling up of the mixture into the break plane.

DR. SCHROCK: Yes, but the data don't show that.

MR. ALAMGIR: We have data only plotted every five seconds, we haven't tried to go into detail and see if -- the data was obtained, the data for breakflow was obtained by looking at the inventory in the vessel, plotting that as a function of time, taking slope.

It does not -- those are not as fine intervals as the TRAC calculation. I'm not sure whether it exists in the data or not.

DR. SCHROCK: Well, okay.

There is no data point for the pure steam flow in the early phase of it.

(Pause.)

Yes. Then maybe my conclusion was wrong. Okay, excuse me. It's hard to tell.

(Slide.)

MR. ALAMGIR: So, we feel that for this simple blowdown case the interfacial shear models in TRAC appears to do a quite acceptable job.

(Slide.)

Let's now move on to another separate effects test, the Oakridge Film Boiling Test. This is a high temperature, high pressure experiment, very well controlled, experimentally well-instrumented.

(Slide.)

This is the Oakridge THTF Loop and here is the test section. The experiment was run with a small break here while the pump was running. So, what happened was that the pressure showed initially, like, 1800 psia and it dropped a little, stayed nearly constant. Whereas, in the bundle the power was raised from 2 megawatts to 8 megawatts in a matter of three seconds to initiate film boiling.

The flow was maintained constant until about twenty seconds and the bundle went into film boiling.

(Slide.)

Here we show the calculated density at exit of the bundle compared with the TRAC calculations. And, in the lower picture the bundle exit mass flow rate.

(Slide.)

This is a prediction of the fuel rod temperature, or heater rod temperature, near the upper part of the bundle. And, you have perhaps seen this yesterday. It's worth noting that the prediction is quite good and we should also note that this is a relatively flow mass flux case, with mass flux less than about 300 kg/m sec.

Our case, the qualification case is the more challenging one where the power stays high for a much longer time and the mass flux is four times as high.

(Slide.)

And, this is what we got with TRAC for this case. So, there was a difference of 200°K between TRAC and data. We looked at the reas[illegible] why. The first difference was that it's this. Then we looked at what TRAC does in calculating film boiling temperatures in this first flow. We found that it calculates droplet heat transfer, and in order to do that it needs a droplet diameter.

Currently in TRAC what is specified is a Weber(ph) number, which is like mass flux-squared; v-squared, which is mass flux-squared. And, it also has a density term along with that mass flux squared. And, Weber(ph) number is said to be a constant value.

So, in fact there -- I meant droplet diameter, not density.

Let me put this slide on, perhaps that will --

(Slide.)

DR. TIEN: You say what Weber(ph) number you used?

MR. ALAMGIR: 6.5.

DR. TIEN: 6.5.

MR. ALAMGIR: This is what I meant.

The droplet diameter is calculated and it's inversely proportional to mass flux-squared. So, for high mass flux case we'll have a smaller calculated diameter, but there is a cut-off value in TRAC which is 10^{-3}.

So, for this case actually the calculated diameter goes below that, but it's set at that value in the calculation.

DR. TIEN: 6.5 appears to be lower than the critical Weber number, right? For the break-up.

(Pause.)

Maybe Jens Andersen could comment. What's the rationale of using 6.5?

DR. ANDERSEN: My name is Jens Andersen.

The rationale was that the critical value is about 13, but you have a spectrum of different droplet sizes and we chose 6.5 to be the most representative of the mean droplet size, with 13 being an upper limit.

DR. TIEN: So, that's just an estimate, but you find it agrees with your experimental data?

DR. ANDERSEN: Yes.

DR. SCHROCK: I think that's an improvement over this idea of just arguing that the size of the drops in entrainment will be determined by the Weber criterion on break-up of the drops that have been formed, because the process of formation of the drops is quite distinct from the break-up of the drops that are subsequently formed.

So, I think that's a good improvment, I think that's a good idea.

(Pause.)

MR. ALAMGIR: That was the reason why the interfacial area was underestimated leading to an overprediction of the vapor superheat and ultimately overprediction of rod temperature.

So, it's not in the Heat Transfer Model for film boiling, but in the cut-off value that the problem lies.

(Slide.)

And, I'll show you the difference in vapor superheat quickly. This is the TRAC calculation and that's data. It's overpredicted for this range.

(Slide.)

Based on that we can conclude that --

DR. CATTON: Could you put that data back on again?

(Previous slide.)

That looks pretty -- the data looks pretty close to saturation except for that little bump. It's almost as if you --

MR. ALAMGIR: Almost.

DR. CATTON: It's almost as if you'd be better off using an equilibrium calculation than the non-equilibrium that's in TRAC.

MR. ALAMGIR: Except here, though.

DR. CATTON: Except there.

But, that looks small relative to all the other noise. I said it looks like you might be better off using equilibrium than non-equilibrium.

MR. ALAMGIR: TRAC basically is a code which can handle non-equilibrium by its very virtue. It doesn't distinguish from the outset, it will calculate for what the situation is.

DR. CATTON: I understand.

But, maybe it's not -- it looks like it's not as non-equilibrium as TRAC thinks it is.

MR. ALAMGIR: As I mentioned, the difficulty -- or, the difference lies in this cut-off droplet diameter.

DR. CATTON: I understand.

(Pause.)

I just want to make the point that sometimes people look too hard for complexities and they build in all sorts of things into the codes that are not needed.

(Pause.)

MR. ALAMGIR: Well, of course the ideal thing to have would be a droplet field which would conserve the droplets, which would allow alteration of droplet size along the path.

(Slide.)

Now, I jumped onto the second conclusion before I finished that.

We saw that it predicts film boiling temperatures for low mass flux case; it overpredicts for a high mass flux case. And, that is the reason.

DR. TIEN: Is it possible you can say a few words about how you calculated the droplet field model, heat transfer?

MR. ALAMGIR: Jens Andersen.

DR. ANDERSEN: Excuse me?

DR. TIEN: Just briefly about the dispersed flow droplet --

DR. ANDERSEN: Excuse me, can you repeat the question, please?

DR. TIEN: I wonder if you can say a few words about the model you used to calculate the dispersed flow droplet field, you know, heat transfer.

DR. ANDERSEN: Okay, there are two models in the code. There's one model for the interfacial heat transfer between the droplets and the steam, and there's another model for the wall heat transfer.

And, the two models are tied very closely together in calculating the overall wall heat transfer. If I start with the interfacial heat transfer, that's a fairly standard correlation for the interfacial heat transfer between the superheated steam and the interface.

I do not remember the name of the correlation but it's the standard one where you have .75 times the square root of the Reynaud's(ph) number. The limiting value for very low

Reynaud's number is 2, which is the theoretically limit for lamina flow.

For the wall heat transfer between the wall and the superheated steam we're using a Dittus-Boelter type correlation where we use the wall temperature and the actual superheated steam temperature. But, the correlation is modified for the effect of the presence of the droplets and that's actually the model you participated in developing we are using.

I can make one comment because there was a comment yesterday during the discussion of how we calculate heat transfer during boiling, and there was a reference to some of the earlier Oakridge results.

When we apply correlation, either a Dittus-Boelter type correlation or a Groeneveld-type correlation, we use the actual superheated vapor temperature and the correlation. And, that tends to give good agreement with the data. The conclusion which at some time came out of Oakridge that the Groeneveld correlation overpredicted the heat transfer by a factor of 2 -- no, I'm sorry not Groeneveld, but Dugelosonof (ph) -- comes when you use the saturation temperature on the correlation.

If you use the superheated vapor temperature you get quite good agreement with the data.

DR. SCHROCK: But, the data are not really very detailed with regard to a mixed mean temperature determination.

DR. ANDERSEN: No, I agree --

DR. SCHROCK: The probe is place in one location and that's taken to be the mixed mean temperature --

DR. ANDERSEN: Yes.

DR. SCHROCK: -- without any real proof.

DR. ANDERSEN: And, in many cases you have radiation heat transfer and you don't really know how representative the temperature is. I agree it's a very difficult problem.

The problem we saw in the Oakridge test, in one of the tests, we apparently overpredicted the interfacial -- no, underpredicted the interfacial heat transfer significantly leading to too high a superheat.

DR. SCHROCK: Thank you.

(Slide.)

MR. ALAMGIR: We'll move on to look at the results of the TLTA TRAC calculations.

The first case is where we have ECC. Let me go through this experiment very briefly by looking at the sketch. This is a schematic of TLTA with the loops removed.

(Slide.)

These are some of the controlled parameters in the experiment: power; intact loop pump which goes down and is isolated at twenty seconds; steam line flow, the valve is closed at about ten seconds; the ECC systems, the first one to come on is HPCS at twenty-seven seconds, LPCS at sixty-three, and LPCI at seventy-one seconds.

(Slide.)

Let me back off a little bit and say that system pressure initially is, like, 1000 psia, saturation temperature. And, the two loops are pumping and core inlet flow upward into the bundle with an average void fraction around .6.

As soon as the break valves are opened the downcomer water starts discharging through the resuck suction break and ultimately it comes to the point where it doubles, the jet pump is uncovered. So, there is a loss of suction.

But, before that the broken loop pump is isolated and this broken loop jet pump goes into reverse flow. This happens at about -- in about one second, or so, after initiation of the blowdown.

Then this water level starts dropping and loss of suction off occurs for the jet pump. And, when the mixture level in the downcomer reaches the reserve suction line lower plenum flashing occurs, which sends a surge of flow into the core.

And, following that the flashing continues. What happens is that this mixture level in the lower plenum starts coming down from where it was at the top until it reaches the exit plane of the jet pumps.

At that point the vapor generated in the lower plenum has an added path for venting, so it can vent through the broken loop jet pump out through the drive line break. And, since there is reduced vapor inflow at that point into the bundle,the bundle mass starts reducing. That initiates bulk dryout in the most part of the bundle.

With HPCS coming on slightly ahead of this the dryout -- or the heatup rate is slowed down. But, it's not until about fifty or sixty seconds that the midplane shows some indication of rewet.

When the LPCI, which comes into the bypass, comes on at about seventy-one seconds it condenses the steam in the bypass and that condensation draws in water from the upper plenum and it comes into, that water comes into the bypass and leaks into the bundle.

As it leaks into the bundle it slowly gets sucked in by that vapor going in through the side entry orifice. And, also there is liquid drainage from the top. The combination is that the bundle shows subsequent rewet. But, the final rewet comes when the two-phase level starts rising, not as a result of lower plenum rising but as a result of liquid holdup due to the side entry orifice CCFL.

So, we'll try to follow those in our TRAC comparisons.

(Slide.)

First, we'll look at the system pressure response in the TLTA. This pressure increase is due to closure of that steamline valve. Following that the pressure starts dropping and at this point the lower plenum flashing occurs, a lot of steam is generated, and it slows down the depressurization rate.

And, at about thirty-five seconds or so the jet pump exit plane is uncovered. And, from there on we see divergence of the calculation from the data. However, the early pressure is quite well predicted.

(Slide.)

We'll next look into the important flows in the system. First, the broken loop jet pump, which I said would reverse in one second or so. The normal flow direction is downward, so initially it's about 10 kg/sec pumping into the lower plenum.

But, after a second the loop is isolated and it reverses. And, the jet pump model in TRAC, the jet pump component modeled in TRAC, follows that pretty well. It goes through a normal flow mode into a reverse flow mode with mixing occuring at the throat of that jet pump nozzle.

So, there is quite a combination of flow going on there, but TRAC seems to handle that pretty well for the first part --

DR. SCHROCK: Do you understand why the longer term pressure prediction is so poor when the mass flow prediction that's -- oh, the time scale is different.

MR. ALAMGIR: Yes, this is early time, twenty seconds.

DR. SCHROCK: What's happening at fifty seconds, and so forth?

MR. ALAMGIR: This jet pump flow data for that is not credible after this because we base it on delta-P measurements and there is flashing going on in the lower plenum. It's not valid.

DR. SCHROCK: Is there a break flow used to --

MR. ALAMGIR: Yes, we are coming to the break flow.

DR. SCHROCK: Okay.

(Slide.)

MR. ALAMGIR: This is the intact loop jet pump, and that is isolated at twenty seconds so it shows zero flow. But, prior to that there is a coastdown as the pump speed is reduced and the DOCA(ph) data, TRAC appears to follow the trend of the data and shows the uncovering of the jet pump suction at about almost the same time. A loss of suction would mean loss of pumping of liquid into the lower plenum.

So, the flow rate decreases and from there on there is this gradual coastdown.

(Slide.)

The result of these two comparisons, the combined effect is that we have a prediction of core inlet flow which looks like this, which is quite acceptable.

We see the lower plenum flashing occuring at almost the same time, and that since a surge of lower plenum fluid through the side entry orifice into the bundle. And, here's the data for that; that's TRAC.

(Slide.)

Let's look at the suction line break flow.

(Slide.)

Here is the two-phase level in the downcomer, and the TRAC prediction of the two-phase level using the Level Tracking Model. These are three-level probe meter data points. There are three positions where we can track whether it's liquid or vapor co. ductivity elements, in a sense.

So, it looks like the level transient is agreeing quite well. And, here we show the break plane, or recirc. suction pipe plane, and the level seems to reside there right at the center line of the break.

And, my sketch for this is poor. It should be residing at the bottom face of that pipe.

(Slide.)

Following that level transient in the downcomer we see that the suction line break flow is agreeing quite well for the single face portion, which is this part. And, then when the recirc. suction is uncovered -- it's two-phase -- the flow drops dramatically closely

DR. SCHROCK: I guess I would come back to my question, then, on the pressure. I have a hard time understanding why the pressure is predicted with an error or more than a hundred percent when the break flow seems to be pretty close, even out to a hundred seconds.

MR. ALAMGIR: The break flow is underpredicted in the later transient. When it's predominantly steam flow -- let me take that back.

In the later transient TRAC calculates predominantly steam flow, whereas there is evidence from the experimental data that there is some entrainment in the break flow, some entrainment of the liquid.

DR. SCHROCK: Let me put the question another way.

At a hundred seconds the error in system pressure exceeds a hundred percent.

MR. ALAMGIR: Yes.

DR. SCHROCK: Do you think it's not important to understand why the code makes such a prediction?

MR. ALAMGIR: It is important, and we have looked into that. And, I'll have some analysis on that very shortly.

(Slide.)

But, the indication of that is right here in this sketch, which is the break flow rate in the drive line nozzle. And, you can see that in the experiment we measured a higher break flow rate, meaning that there was smaller volumetric flow or more liquid compared to the TRAC calculation.

The reason lies in the hydraulics at the jet pump exit plane.

Why don't I show you that before we move on.

(Slide.)

DR. CATTON: Have you done things like take that mass flux rate and derive the code with that?

MR. ALAMGIR: No, not with TLTA.

DR. CATTON: It'd be interesting to do that because then you could sort of sort out where the problems might lie.

MR. ALAMGIR: When we look at the level transient in the lower plenum we find that, as we mentioned, the level will come down up to the jet pump exit plane. And, it does start about thirty seconds.

Here we have two plots. This one is for the inner TRAC ring. There are two rings in the TRAC model: the inner rings comprises the region inside, or let's say not covering the jet pumps; the outer ring covers the jet pumps.

So, when the level comes down in the lower plenum it stays at the jet pump exit plane for the inner ring. But, for the outer ring it slowly goes down, the level slowly drops.

(Pause.)

Now, there is potential for entrainment from here onto that little pipe there.

DR. CATTON: Once it's below that skirt shouldn't they be the same?

MR. ALAMGIR: Pardon?

DR. CATTON: Once it's below the skirt shouldn't it be the same?

MR. ALAMGIR: Should not what --

DR. CATTON: Shouldn't the level be the same, don't those regions --

MR. ALAMGIR: No, the vapor is venting through this jet pump here.

(Slide.)

The vapor is venting through this jet pump. So, the level below, the level here would be affected. It's not the same as in the unaffected region.

(Slide.)

The reason is this: We have what we call a Bernoulli effect for liquid withdrawal when there is steam flow near a small pipe or an orifice. And, there are correlations available in the literature for the onset of this entrainment, but there is no correlation for the amount of entrainment. And, this is a direct quote from Zuber.

(Slide.)

We have looked at the value of this parameter, which I call entrainment factor, which is the ratio of this Froude number over the length over diameter ratio. And, we have looked at that ratio from the TRAC calculation.

Let me show you what it looks like for the TLTA lower plenum.

(Slide.)

This is what it looks like. The ratio, which if it is 1 -- or if it is greater than 1 -- it would mean that there is tendency for entrainment of this kind. We find that it exceeds 1 at the period when the level is dropping below the jet pump exit plane.

This is lacking in any code that I know. So, it's my feeling that the difference in pressure calculated and the experimental pressure is mostly due to liquid entrainment of this kind.

DR. CATTON: That's going to be a tough problem, isn't it? Because below that arrow where you have two-phase flow you have bubbles in the water. That's going to change the characteristics, too.

Don't you define two-phase level as being where it changes from continuous liquids to continuous steam?

MR. ALAMGIR: Continuous two-phase misture into predominantly steam.

DR. CATTON: So, below that line that says "two-phase level" you have a bubbly misture.

MR. ALAMGIR: True.

DR. CATTON: And, I'm not sure that the criterion has even been worked out for circumstances where it's a bubbly misture. I think it's only been done for situations where it's a nice, clean, quiescent system and you gradually change your delta-P's until you can entrain.

MR. ALAMGIR: That's correct.

It is a possibility.

DR. CATTON: Do you know of any separate effects kinds of studies of that phenomena that are going on?

MR. ALAMGIR: No.

DR. CATTON: Then it looks to me --

DR. SCHROCK: There is some -- Rieman is doing some in Germany, and I'm starting to do some for Novak-Zuber now. But, it's only in the planning stages on our end. But, there has been some work done in Germany. I can send you a copy of that.

DR. CATTON: With the bubbly mixtures?

DR. SCHROCK: No, it's not with bubbly mixtures, that is correct.

DR. CATTON: So, again that's going to be quite different than what he needs to look at.

DR. SCHROCK: Yes.

Also, I think that these correlations in ZUber's report are all taken from literature in which the pressure differences were quite modest, so there are no compressibility effects involved in those correlations.

And, that's another area where I think the correlations will be influenced in our applications, where we're really talking about entrainment into critical flow sections and the compressibility of the vapor phase will clearly be important.

MR. ALAMGIR: Okay.

(Slide.)

Let's look at some regional pressure drops which, in the regions of small wall friction, can be translated into mass inventories. We'll look at the core pressure drop first for that transient.

(Slide.)

Lower plenum flashing. At thirty-five seconds or so there is venting of steam through the jet pump orifices, relatively more rapid drainage from the bundle. With onset of the ECC systems the bundle inventory increases as aided by side entry orifice CCFL.

Here's the performance in the bypass. There is continuing CCFL at the top of the bypass and as soon as LPCI comes in it condenses the steam and breaks that CCFL, so the upper plenum fluid can then partly drain into the bypass and fill it up.

But, the bypass has another part which is this lower part called the guide tube, and there is also CCFL at this interface between the guide tube and the bypass. This drop in delta-P indicates that the guide tube CCFL also breaks down at that time and fills up the guide tube after it first fills the bypass.

(Slide.)

Here's the delta-P in the guide tube showing that CCFL breakdown.

(Slide.)

If we look at the peak clad temperature in the TLTA we'll see there are typically there at least two peaks of temperature -- or a third.

In looking at the temperatures we'll be looking at this peak and see how TRAC handles that. This peak, by the way, happens to be in the film boiling region where had seen some difficulty with one of the high mass flux cases.

Let's see how this TLTA case falls in that comparison.

(Slide.)

What we have plotted here is the temperature at 120 inch elevation in the bundle and the solid line is TRAC. We see that it is slightly overpredicting, but not to the degree or the extent that we have seen in the film boiling, in the Oakridge test.

We also see that the void fraction calculated in TRAC indicates that it appears to be in dispersed droplet form. The power level is quite high at the time that it goes into film boiling and it rewets as soon as there is decay of the power.

We also notice that the mass flux is roughly the same as in the Oakridge Film Boiling Test at the time the DNB occurs.

(Slide.)

Now we'll look at temperatures in the bundle. There are many dotted lines in each figure and each of those represent one thermocouple at a given axial elevation. I have marked the locations for those rods for which these plots are made.

There are four measurement thermocouples at that elevation, which is 71 inches. And, we see the comparison, the first fall agreeing quite well as far as the initial dryout -- or dryout initiation -- is concerned. Then we have relatively similar heat-up and turnaround. And, TRAC is kind of averaging the data as we would expect it to do. because it is one-dimensional it does not consider differences across the plane in the bundle.

(Slide.)

Here we have a temperature comparison at the middle of the bundle and the lower part of the bundle. All seem to agree pretty well. What comes out is that the dryout initiation and rewet appears to be handled well.

DR. TIEN: Could you say on that graph what rewet criteria you used?

MR. ALAMGIR: Yes.

The two criteria for rewet, one is -- if we have cocurrent upflow and the temperature is greater than T-minimum then we have one criteria, that the temperature should be less than T-minimum; and, the critical quality must not be exceeded.

That's the criteria that was satisfied in the first peak. Here there is really no definition of rewet for transition boiling, it's slow decrease in mass flux -- that's increase in heat flux.

DR. TIEN: That's in the TRAC code?

MR. ALAMGIR: I believe so.

DR. ANDERSEN: Okay, there are several ways you can rewet in TRAC. If we look at -- just going back to the boiling code, we require that the temperature is less than the minimum temperature at the boiling curve plus an additional criterion that there is sufficient liquid present in the bundle.

And, the correlation that we use to describe that is similar to the Boiling Links correlation we use to describe the initial boiling transition, saying that the quality should be less than a critical quality as obtained from the Boiling Links correlation.

So, essentially what we say is that the quality should be such that if it rewets it would stay in a nucleid boiling situation and not exceed the critical quality.

DR. TIEN: Could I ask then, what correlation do you use to determine your T-min?

DR. ANDERSEN: The T-min. is the Iluegi(ph) correlation.

DR. TIEN: So, it's a function of flow and --

DR. ANDERSEN: Yes, the flow impressions.

(Slide.)

MR. ALAMGIR: Looking at the performance of TRAC for this, I would say, complex system blowdown case I think it did a reasonably good job for predicting the events and the phenomena.

Of course, that fundamental phenomena was missing so we didn't predict it. Missing in the code.

(Slide.)

We have also seen a favorable performance as far as prediction of flows and regional pressure drops, as well as dryout and rewet initiation.

(Slide.)

We've seen that the critical flow model calculates the subpool -- let me take it back -- the single phase and the two-phase critical flow quite well, as you can see from the short-term critical flow comparison in TLTA.

(Slide.)

The jet pump performance for normal and reverse flow is quite good.

(Slide.)

There is a specific jet pump component in TRAC and it is doing quite a good job.

(Slide.)

The CCFL correlation is, as Jens mentioned, of the Cutat-Glacia(ph) form, and we use different constants for the side entry orifice and upper tie plate. And, with those it seems to predict the drainage and the accumulation of inventory in the bundle quite well, as we see from the pressure drop comparison.

(Slide.)

The heat transfer models for transition boiling and nucleid boiling appears to be acceptable. There is no glaring sample or any non-conformity there.

(Slide.)

Rewet criteria in film boiling is also satisfied, as we saw in the first peak when we compared the temperatures at early time.

(Slide.)

We found that the system pressure is underpredicted.

DR. CATTON: Excuse me.

MR. ALAMGIR: Yes?

DR. CATTON: Are you referring to the previous slide when you make that statement?

MR. ALAMGIR: In reference to the temperature --

DR. CATTON: To the temperature traces you showed on the previous slide?

MR. ALAMGIR: No, the one before that.

(Second previous slide.)

The temperature at four seconds, this one.

DR. CATTON: Yes.

(Pause.)

Okay, your middle level didn't rewet at all on that second slide.

(Previous slide.)

MR. ALAMGIR: There is a reason for that. This is the lower part of the bundle. This will rewet, and I've looked at the conditions in the bundle at that location at the last time step. It will rewet when the fluid level rises as fluid leaks into the bundle from the bypass.

DR. CATTON: But, the data shows a very distinct rewet.

MR. ALAMGIR: The data is R4.

DR. CATTON: For all three thermocouples it shows distinct rewet and TRAC does not.

MR. ALAMGIR: There is a variation in rewet timing.

DR. CATTON: I understand.

But, if the solid line is TRAC it shows no rewet. And, also in the one above -- if you could pull that down --

(Adjusts slide.)

DR. CATTON: -- all I see on the top one is an indication of the heat transfer coefficient getting larger, I don't see any rewet process going on there either.

MR. ALAMGIR: When I said rewet, the rewet is meant to be in film boiling. There is hardly any definition of the rewet in transition boiling, or no specific --

DR. CATTON: Well, it certainly is.

DR. TIEN: I'd like to pursue this further. It's related to the question I tried to draw out.

It looks like from the data, it seems more like falling film, or type film rewet, instead of -- you keep saying the transition boiling, film boiling, and so on. It's a very sharp distinct temperature drop.

Apparently this is not being taken care of in the TRAC code. Is that correct, my interpretation?

MR. ALAMGIR: Let me preface the answer by saying that in the experiment --

DR. CATTON: But, it's happening in the next level down at the same time, so I wouldn't think it's falling film.

DR. TIEN: Yes.

DR. CATTON: I think they're getting water around it and you're quenching the thermocouples, that's all.

MR. ALAMGIR: In the experiment it's two-dimensional phenomena where you have preferential liquid drainage from one side, and maybe the other side is dry. And, TRAC is averaging the conditions at the inner plane.

DR. CATTON: But, all your thermocouples quenched.

MR. ALAMGIR: All of the measured --

DR. CATTON: If they're where the black dots they're pretty well distributed. And, I think that would be kind of a unique occurence that you've located your thermocouples where the water happened to be.

MR. ALAMGIR: They quench and --

DR. CATTON: Look down at the middle one so we can get away from Dr. Tien's falling film.

MR. ALAMGIR: This is the peak power plot and this is at the very low power level in the bundle.

DR. CATTON: But, isn't that about the middle of the bundle?

MR. ALAMGIR: No.

DR. CATTON: Oh, that has nothing --

MR. ALAMGIR: This is the middle of the bundle.

DR. CATTON: I thought the arrows pointed to where the --

MR. ALAMGIR: No, this is the top of the bundle here.

DR. CATTON: Yes?

MR. ALAMGIR: That's the middle of the bundles, which is this.

DR. CATTON: And, the next one down is the bottom?

MR. ALAMGIR: Next one is bottom.

DR. CATTON: Well, what's the one down below?

MR. ALAMGIR: 10 inch elevation. Very low.

DR. CATTON: Okay, well let's look at the one that's the low power. You show distinct quench from your data, and means it's a lot of water, or at least the heat transfer coefficient is very high. Yet TRAC doesn't pick that up at all.

So, I don't call that a good -- I mean, I don't know how you can make the conclusion about rewet in TRAC from that data.

MR. ALAMGIR: The rewet was that this conclusion pertains to the first rewet that we saw, film boiling-type rewet.

MR. TIEN: Yes, film boiling.

But, still in this second or third peak the TRAC cannot predict. Your explanation is that TRAC only gives you an average.

MR. ALAMGIR: Yes.

DR. TIEN: But, it's just like a top curve for all fuel rods, it shows a very distinct quench, right? So, if you say even an average it should be still a very distinct quenching.

(Pause.)

Am I correct in saying that? I'm confused a little bit.

DR. ANDERSEN: What you're saying, it is right that in the midplane you get liquid coming down from the top. I don't think it's a progressing falling film from the top because the rewet happens much faster than you would expect if you had a progressing falling film from the top. You would expect a much later rewet time.

I think what you see is that you see multi-dimensional effect. In certain areas of the bundle you have a lot of liquid and certainly a thermocouple rewets and later on that liquid sloshes around and appears at some otherplace in the same axial elevation, and that thermocouple dries out.

And, TRAC obviously cannot, being a one-dimensional code, do that.

DR. SCHROCK: But, Jens, when similar are done with the PWR TRAC they do a better job of predicting multiple rewets, and they look more like the experimental data. They're not synchronized in time, I'm not saying that, but it looks more like the phenomenon is more adequately described by the code in those comparisons than it is here.

And, I guess what we're hearing is that the phenomena are well described here and these data show it. And, we don't see that -- I don't see that -- in these traces. And, it does seem to me that I have seen it in traces that have been presented for PWR TRAC.

And, so I would think that it's worth looking at the differences in the handling of this particular phenomena in the two. I wouldn't be totally satisfied with this until you understand why it happens.

DR. ANDERSEN: I think I can give a little additional explanation.

I remember seeing some plots late yesterday afternoon. In some cases it was exactly as you said, where all the thermocouples quenched at exactly the same time and in that case the PWR version of the TRAC picked it up very well.

But, I also remember seeing cases where there was a large variation in when the thermocouple quenched and in that case the PWR version of the TRAC did virtually the same as we see here. It was kind of in the middle of the data.

And, what you see is that when you have pronounced multi-dimensional effects in the bundle that sometimes one thermocouple is wetted and sometimes it's not. TRAC does not predict the individual behavior.

If you see an effect like where you have a rising level and suddenly you quench all the thermocouples at the same time at that elevation -- that was obviously in some of the plots that were shown yesterday for the PWR version of TRAC -- then the code picks it up very well.

What you see at the second plot there is you see quenching due to a rising level from below. And, obviously what is happening is that TRAC is somewhat overpredicting the time when this level rises up to the thermocouple.

But, I'm confident that you would see the same type of behavior in the calculation, you get a quite sudden rewet.

DR. TIEN: Jens, I think the key point is -- you know, not to argue as to how it goes through the average of the curve --

DR. ANDERSEN: Yes.

DR. TIEN: In the model we built in -- you built in -- say, in the TRAC code for the rewet, how does that represent the average of all this multi-dimension that you mentioned? Or, is it simply just a correlation, or the best you can get? And, so that's the end of it.

You cannot argue really. I think, perhaps, it is wrong to argue it's a average of experimental data and so on.

(Pause.)

MR. SOZZI: This is Gary Sozzi from General Electric.

I'd like to make an overall comment about what you're seeing here. The TLTA is a large integral test. You're looking at very,very fine details inside of a rod bundle that contains sixty-four rods.

Unless you have precise boundary conditions predicted precisely across that bundle I would caution you to not draw any too strong interpretation from this example. If you're trying to make conclusions about whether a rewet model adequately predicts the phenomenon or not I would caution you in looking at this.

This is not a very well controlled bundle experiment from the standpoint of drawing those kinds of conclusions. So, please keep that in mind in picking apart the differences here.

DR. CATTON: In other words, you may not know void fraction very well, you may not know the level very well, so as a result you may not be able to predict heat transfer very well?

MR. SOZZI: If you are not precisely predicting the inlet conditions to this channel compared to what was actually physically there, then drawing a fine interpretation and details about the wiggles, I think, you might be misled a little bit.

DR. TIEN: Gary, I agree with you completely. That was my last comment.

I think the question really is not to compare that, but, "How do you justify that?" We're trying to say the code is sound, right?

MR. SOZZI: Yes.

DR. TIEN: And say, "How do you justify the model you use in the code really represents an overall picture?" But, that cannot be justified simply saying, "Well, this is in a relative good agreement with all this data." That's my point.

MR. SOZZI: Yes.

DR. SCHROCK: That was the point I made initially --

DR. TIEN: Yes, yes.

DR. SCHORCK: -- and that's where we started.

DR. CATTON: It could be that your experiment was a little on the weak side for this sort of a use.

MR. SOZZI: But, I think the challenging one that he showed a little earlier on the Oakridge Bundle Test is a better place to draw those kinds of conclusions regarding heat transfer modeling.

DR. CATTON: Certainly.

What this demonstrates is a weakness in other parts of both the experiment and the code.

DR. PLESSET: Well, I think we should go on.

(Slide.)

MR. ALAMGIR: The other TLTA case, now, the case very similar to the previous one, except --

DR. PLESSET: I wonder if you could pass over the data and go directly to the conclusions of this particular --

MR. ALAMGIR: Okay.

DR. PLESSET: I don't think there's anything that will stimulate a lot of argument in those data.

(Slide.)

MR. ALAMGIR: The system response was very similar to the ECC case. There was, however, a difference in calculated pressures between the ECC and no ECC. And, we also observed that difference in the data. The temperature, heat up rates, agree well in the long term.

(Slide.)

Let's now move onto multi-dimensional facility SSTF. We will try to look at a case where we address the TRAC upper plenum model.

This is an experiment in the SSTF which is a quality study in nature ran at constant pressure. What I'm showing you is a modelization input model for the SSTF for this case. The conditions were such that we had initially a two-phase mixture level in the upper plenum below the location of the ECC spray jets.

And, at the initiation of the test HPCS was injected. There was no injection of steam from the lower plenum, but there was injection of steam into the core for each of the fifty-eight bundles.

The measurements we have are like delta-P in the upper plenum and temperatures through the tie plates. This is a measure, measurements. What we will try to see is whether or not the TRAC model for the ECC distribution can predict --

MR. THEOFANOUS: Can you point directly exactly where the temperatures were measured?

MR. ALAMGIR: Those were measured above and below the tie plate for each of the fifty-eight bundles.

MR. THEOFANOUS: How far above?

(Pause.)

MR. ALAMGIR: Bill Sutherland.

MR. THEOFANOUS: In the bottom of the machinery how were the thermocouples located as compared to where the steam was coming out.

MR. SUTHERLAND: The center of the bundle.

MR. THEOFANOUS: So, we're seeing the steam really coming out, right? You don't have any temperatures in the pool itself?

MR. SUTHERLAND: There are.

MR. THEOFANOUS: So you want to talk about them?

MR. ALAMGIR: What was the question?

MR. THEOFANOUS: I just if you have temperatures in other places in the plenum above the plate, are you going to talk about them?

MR. ALAMGIR: I have compared temperatures above the tie plate with the data.

MR. THEOFANOUS: So, you want to look at those. Those are really seeing the steam coming out. I'm saying: Do you have --

MR. ALAMGIR: I have not compared TRAC calculation with anything really in the plenum.

MR. THEOFANOUS: You haven't done any of that?

MR. ALAMGIR: No.

MR. THEOFANOUS: Okay.

(Pause.)

What are you trying to get out of those comparisons?

MR. ALAMGIR: Well, see the distribution of the subcooling, see if TRAC didn't calculate that.

MR. THEOFANOUS: How do you see the distribution so clearly if you haven't done any comparisons with the temperatures in the pool?

MR. ALAMGIR: Okay --

(Pause.)

It is a controversial question, I think. You are asserting that --

MR. THEOFANOUS: I'm not asserting anything, I'm asking a question.

MR. ALAMGIR: Okay, you assert -- if I take your word, are you asserting that there is predominant steam flow through the center of the bundles so it will distort the measurement?

MR. THEOFANOUS: Well, no.

All I'm saying is that there is certainly the -- if you are injecting cold water there certainly you aren't going to have a uniform temperature in pool itself.

Now, what is going to be happening on the top of those bundles will depend on how the fluid is distributing and mixing in the pool itself.

MR. ALAMGIR: That's right.

MR. THEOFANOUS: It seems to me that's the primary area of interest for comparisons, and you are saying that you do not compare that, but you will compare with the temperatures at the exit of the bundles. And, I guess I can see there was --

MR. ALAMGIR: There is a reason why. The TRAC upper plenum model calculates a distribution of subcooling at the tie plate only.

MR. THEOFANOUS: Only?

MR. ALAMGIR: Yes.

DR. ANDERSEN: Well, what TRAC does, it calculates the subcooling in every node in the upper plenum. But, what is important when you look at the system response is: what is is the subcooling in the nodes right above the upper tie plate, because that is what is available for liquid inflow into the bundle and that is what will control the subcool CCFL breakdown.

Sure, it would be interesting to compare the subcooling in the rest of the bundle but we have not done -- in the rest of the upper plenum -- but we have not done that. We have concentrated on what controls the system behavior.

MR. THEOFANOUS: Okay, well I would like to suggest that you are trying to understand the phenomena of a very difficult situation, and you should really look at everything and not only one location.

DR. TIEN: Jens, is that correct? You only calculate the ring temperatures in the upper plenum? You know, after you divide that into different node, right? You calculate only the subcore rings nodal temperatures. Do you have upper plenum temperature distribution calculations?

DR. ANDERSEN: We calculate the temperatures and the void fractions and the pressures for every node in the upper plenum.

DR. TIEN: So there you should have those information, what, you know --

DR. ANDERSEN: We have the information available but we have not spent an awful lot of time comparing them with data. We have concentrated on the one set of nodes right above the upper tie plate because, as I said before, that's what controls the CCFL.

MR. THEOFANOUS: Maybe in that next meeting, together with everything else, we can see that.

DR. CATTON: It seems to me in that location nodalization would be very important. If you have finer nodes you can get the temperature closer to where the CCFL is occuring.

MR. ALAMGIR: That is volume dependent, yes.

DR. CATTON: Have you done those -- are you doing those kinds of studies?

MR. ALAMGIR: No, not at this point.

DR. CATTON: Then what did you do, just sort of, "Gee, I've got ten nodes and ten volumes left"?

MR. ALAMGIR: No, we -- as far as the hydraulics is concerned we take care of the large node -- take care of the small node by using the Level Tracking Model. We can use a large node and --

DR. CATTON: But, using a large node you have to extrapolate to the tie plate to get a temperature somehow, particularly if there's stratification. Because at the top of the -- where you're tracking the level you're sure that it's saturated, if there's subcooling around then you've got an average temperature --

MR. ALAMGIR: What I'm comparing is measured temperature at the tie plate -- above and below the tie plate -- with the calculated temperatures in the TRAC node centers.

I do not see anyway else extrapolating that information unless the node sizes are infinitesimally small.

DR. CATTON: I think you need to fool around with volume size to come to some sort of a conclusion about the goodness of your results.

MR. ALAMGIR: True.

(Slide.)

We'll go through this quickly.

We have modelled the three types of nozzles in the

SSTF. And, in the bottom picture we look at the overall response of the upper plenum inventory. Here we're showing a colapsed level. And, the solid line is TRAC.

So, when HPCS comes on, which comes on at an elevation above that two-phase level, it is predominantly spray. And, then we'll be seeing the level position in the next slide, but it comes on in a predominantly steam environment. And, later on the level swells and at times covers the sponges.

(Slide.)

Here we see the inventory is only about eight inches out of a total height of the upper plenum, which is seventy-five inches. And, it seems to be steady at that position.

DR. SCHROCK: Excuse me.

Did you tell us yesterday the exact form of this correlation that you're using at the upper tie plate in terms of subcooling dependence?

MR. ALAMGIR: I think Jens was here yesterday.

DR. ANDERSEN: You're talking about the CCFL correlation?

DR. SCHROCK: Right, yes.

DR. ANDERSEN: Okay, CCFL correlation is Cootat(ph) Elastic-type correlation. What controls the --

DR. SCHROCK: But, how are you introducing the subcooling? You're subtracting off the steam flow subseded with condensation, or what?

DR. ANDERSEN: No, we're not really using -- TRAC calculates local subcooling of the liquid above the upper tie plate. So, we're using the local condition. The amount of liquid coming through the upper tie plate is based on what is available above the upper tie plate. The water with subcooling is there.

Now, what we find is that we have a lot of steam coming up which condenses in the upper plenum such that the liquid there is saturated. Then essentially the liquid that would enter into the bundle would be saturated and we relied on the saturated CCFL code.

Now, what happens when the liquid becomes subcooled, we're still following the CCFL code but at some point we get so much subcooling penetrating through the upper tie plate that it quenches the steam going up through the upper tie plate and essentially shuts it off.

And, that's when we get the CCFL breakdown. But, we are still applying the Cootat(ph) Elastic Correlation throughout the entire event.

DR. SCHROCK: So that the subcooling influences only the breakdown but not the flooding relationship while it is in CCFL?

DR. ANDERSEN: That is correct.

DR. SCHROCK: Yes.

DR. TIEN: This is what I mentioned yesterday, you know. This is a slightly different model, however I recently saw some data, actual -- again, a bundle test with steam and water subcooled they show different from the test, you know, you show. And, it's much more closer to the model like Wallace and myself proposed before.

So, that's highly interesting, but put everything again in the other side of this state.

DR. SCHROCK: I have an experiment underway now on flooding in debris beds in which the first data sets have shown extreme insensitivity to the the subcooling in the churn turbulent pool above the debris bed.

But, the liquid injection rates up to this point have been limited. We need a larger pump, which we're not installing. But, we have not yet seen this -- the breakdown phenomena.

So, it will be interesting to see how that compares with your result. I want to look more closely at what you have there. But, I think the point is that the thing really is insensitive in CCFL to the amount of subcooling in that pool. The flooding correlation is insensitive to that.

(Pause.)

MR. ALAMGIR: Okay.

(Slide.)

Here we're looking at the two-phase level calculations in TRAC in relation to the location of the ECC injection. You see that initially the two-phase level is here, which is below this bar joint, so the ECC injection is in the form of a spray.

(Slide.)

And, we can relate that to the subcooling as we define here. In the upper plenum just above the tie plate this solid line here is the subcooling calculated in the node above the upper tie plate and the peripheral region.

And, we compared that with --

(Slide.)

-- upper tie plate temperatures in the experiment. And, these are again -- we found that measured very close to the tie plate.

We see that when it's spray there is not much subcooling because that spray is -- a lot of steam condenses in the spray, so subsequently cannot accumulate. And, when we see that the sponger is almost covered we have what we call a submerged jet. And, all of the subcooling can be localized and subsequently can build up.

So, if we look at that location and the corresponding location here we see that there is a build-up of subcooling leading to a CCFL, more liquid drainage due to large CCFL breakdown, and the level comes down again. It's again a spray mode, subcooling decreases, two-phase level goes up, and the cycle repeats.

So, we'll see that the two-phase level will oscillate near the ECC sponges, which is phenomenoligically, I think, correct.

DR. PLESSET: Let me suggest you go to your conclusions on this particular point. I'm trying to keep you from getting too far behind time.

It's not your fault.

(Slide.)

MR. ALAMGIR: The conclusion is that, looking at the comparison of the system -- upper plenum inventory -- you see a very good agreement. We also see a distribution of subcooling in the context of the present definition predicted quite well.

I think the end upper plenum model is doing an acceptable job.

(Slide.)

In this next test we'll be looking at parallel channel phenomena in the SSTF in this particular test, which is a side entry orifice CCFL-type test.

ECC is injected in combination with the steam injection in the core and lower plenum. The injected ECC is obstructed from flowing down into the CCFL at the upper tie plate and the side entry orifice, but it can leak through into the bundle through these holes.

And, as a result most of the bundles are in counter-current flow, but a time comes when a transition occurs and we get more than one mode, instead of more than one mode.

(Slide.)

We'll go to the results directly. Before that let me just flip this.

(Slide.)

This shows the three modes, one with predominant liquid column, another with a level, and a third occuring for dispersed flow. This is a limiting case. There can be a combination of these two in some sense if there is quite a bit of leakage through these holes.

(Slide.)

What we saw in the experiment is that out of the fifty-eight bundles the six major bundles showed that the peripheral ones were in downflow; there were two upflow bundles, one near the apex, another here; and the other two central region bundles showed countercurrent flow.

(Slide.)

We modelled the TRAC case by grouping fifty-eight bundles into thirteen groups and dividing the vessel core region into five radial regions, the sixth one being the downcomer.

We found that we have upflow in the apex bundles, downflow in the peripheral bundles, and a combination in the next row; D standing for downflow, C for countercurrent flow.

So, we found that the predominant modes occuring at the two extreme regions and the central regions showing totally countercurrent flow in the experiment.

(Slide.)

Just to show that it was so we plotted the velocities in the TRAC calculation, and we see that it's different for the three modes. We see downflow of zero velocity here, it's negative; for the peripheral bundles smaller vapor velocity for the countercurrent flow bundles; and very high vapor velocity for co-current upflow bundles.

(Slide.)

The next plot substantiates this plot by showing that the liquid velocity at the side entry orifice for the upflow bundle is positive. We also calculated the overall core pressure drop closely enough.

(Slide.)

This slide, which is not included there, shows the difference between the mass flow rates for the co-current upflow bundle at the side entry orifice and the upper tie plate. The difference is the leakage from the bypass.

(Slide.)

And, the pressure drops in the three types of bundles, as we call them, are also closely matched. This one not as much as good as this liquid downflow bundle and the countercurrent flow bundles. But, the trend is there.

(Slide.)

I think in this test we have seen that TRAC can handle multiple-bundle interaction. And, we saw parallel channel four modes and they keep this whole section dry.

What's going on is that we are monitoring sensitivity study as to how many radial regions are needed in the bundle and how we should group the bundles, bor example, in the BWR.

DR. TIEN: This five each in core model for the upper plenum, do you have for each region measurements, different locations, different, you know --

(Pause.)

Perhaps one of the slides you have.

(A previous slide.)

Here it shows the instrument locations in the upper plenum.

DR. TIEN: I mean the different channels where you come down. Do you have any measurements? You have six regions here.

MR. ALAMGIR: Within each region how many measurements do you have , say, at different locations?

MR. ALAMGIR: Okay, let me get --

DR TIEN: What I'm trying to see is whether you have some kind of oscillating pattern.

MR. ALAMGIR: The measurement bundles are the ones marked "M".

DR. TIEN: Oh.

MR. ALAMGIR: There are six of those.

DR. TIEN: For those measured bundles you see a consistent pattern. There's no, say, oscillating pattern in the sense that sometimes, you know, change behavior with time.

MR. ALAMGIR: Dumping.

DR. TIEN: Dumping, yes.

MR. ALAMGIR: In the interaction?

DR. TIEN: No, not interaction, do they change with time. Just like, we did some tests at Berkeley, the Metti(ph) channel as supported by EPI. We have many, many different channels -- parallel channels -- we see the act altering.

Sometimes they got CCFL, sometimes they get CCFL breakdown. But, on the other hand, where you average out they follow quite well with the Cuta-Palatsa(ph) correlation type.

What I'm trying to see is whether the bundle test you have here you have any behavior of that type. Can you say anything?

(Pause.)

MR. SUTHERLAND: This is Bill Sutherland from General Electric.

This test he's comparing is a steady state test, and under those conditions the bundles stay in the same condition. We do see transitions as we get into a test mode or changing test conditions. Like, a draining core will then eventually switch into all countercurrent flow regions.

But, in the steady state condition he's in here now each bundle stays in the condition it's in.

DR. TIEN: Yes, okay.

I guess, in your case you have a bundle you already averaged out, so you get some pretty much steady-kind-of-state behavior.

MR. SUTHERLAND: Yes.

DR. TIEN: We have actual detailed channel, we find actually they vary a lot, although on the average they behave like a steady state type.

MR. ALAMGIR: That's all for the TRAC code case, then, today. We have some more new results but it will take some time to dig into the comparisons.

(Slide.)

What we see from these early results is that we have favorable prediction for interfacial shear for a pretty low flow two-phase tracking performance of the jet pump; the heat transfer models, except the film boiling which shows a glitch at higher mass flux; the upper plenum model. And, we identify the areas for improvement as droplet field and the liquid entrainment near pool.

DR. SHROCK: I'd like to comment on the overall conclusions. They're, I guess in my view, rather typical of what I've heard over the years as codes have been developed. The conclusion is always at any given moment been that the predictions are just fine. And, in specific areas, as you've outlined specific areas here.

But, then we subsequently find that the tests were for conditions that do not adequately cover the tests that are found in actual accident scenarios, they produce different results ahd put a greater burden on the code and then the code fails. And, then we have a panic follow-on effort to figure out what it is that is wrong about that specific component.

I'd just like to say at this point that I think we should have matured beyond this level by 1982, and I just hate to see these presentations continue with global conclusions of this nature which are based upon essentially superficial examination, or exposition at least, of detailed comparisons.

When you cite critical flow as one which is adequate in the code I can't argue that it may be adequate for characterizing the kinds of test facilities in which the geometries are relatively simple and multi-dimensional influences are not great in evaluating critical flow, and so forth.

There are situations, such as those described in Zuber's report that you cited, in which our knowledge is totally lacking as to what to do with critical flow calculations under those circumstances. If we're ingesting two-phase fluid out of a stratified large channel into a smaller diameter critical flow section the predictions of that critical flow are at this stage totally inadequate.

And, we shouldn't be afraid to say that if that is the case. I know that your purpose here is something different. But, in the long range reactor safety is not served by this procedure, okay?

And, more than that we inhibit the research efforts which are necessary to gain the knowledge that will improve reactor safety.

MR. ALAMGIR: These conclusions were made with application in mind, for example, for a BWR where applications typical to what we have seen --

DR. PLESSET: Well, let me make a general comment also.

Dr. Schrock has made a good point. But, I'd like to take this opportunity to indicate something different in this situation. If we compare the development of TRAC for Pressurized Watter Reactors and the development of TRAC for Boiling Water Reactors, so far as I know this is the only case where a vendor is really making a strong effort to improve the code, the TRAC code, for his type of machine.

And, I think that's most commendable. And, I don't think that there is any vendor of a Pressurized Water Reactor that is doing this kind of work at all. I'd like to give you a little pat on the head in this respect, that I think it's very worthwhile and will only contribute to the benefits of the whole program.

Now, there are areas where work needs to be done, but I think it's very worthwhile that the vendor is doing this and is cooperating with the general code development for BWRs which is going on at INEL. I think that's very good, Mr. Quirk, and you can carry my message to your people. I think it's very worthwhile.

Now, I don't object to your having a real good reason for doing it, it might be very worthwhile for the people who use your type of machine and will help them. That's all right, and I think it's very good that you are making an effort to make the advanced code better for the use in your machine.

With that kind of sermon I will call for a ten minute break.

(Whereupon, at 10:15 a.m., a ten minute break was taken.)

DR. PLESSET: Let's reconvene.

Virgil, did you have a comment to make?

DR. SCHROCK: Yes.

I feel that, while I stand on the general statement that I made in the more global picture of the historical approach to code development and how that has related to reactor safety research, I think that my statement in the context of Alamgir's presentation may have been -- not may have been, certainly was -- unfair to him.

I think that it may have also conveyed an incorrect impression of my interpretation of the quality of the work done by the GE people and the contributions that you're making to the TRAC program. I'm quite familiar with those contributions through what I've seen at INEL and, in fact, I think that major improvements for BWR applications of the TRAC code have come out of the GE part in this partnership.

And, so I certainly wouldn't want to leave for the record an incorrect impression. I do, however, feel that the statement that the whole community should have matured by this time to the point where we no longer follow the practices that we saw got us into difficulties time after time through the 60's and early 70's where people thought a technical question was really laid to rest, and then it was discovered that, gee, it wasn't really laid to rest.

And, how did we get the impressions? We got the impressions because time after time after time we'd heard presentations, people become essentially convinced that the technical position is correct because they've heard it so many times.

And, I think we have to be more objective than that in looking at whether we are or are not satisfied with specific aspects of these complicated systems that we're dealing with.

So, for critical flow I would say the technology is by no means laid to rest. I think the interfacial phenomena for multi-fluid two-phase systems is not one that's laid to rest. And, so I don't want to leave the record showing that, in fact, yes, these are things which we don't need to do additional research on because our large system codes are showing that, in fact, we can calculate these things with a high level of assurance and that's that.

So, my apologies to all concerned if I was too hard on GE, I didn't mean it in that spirit at all. But, I do think that we need to avoid having a situation where we inhibit the necessary research by our zeal in arguing that the codes that we're now producing are really very good.

They are really good, but they're not perfect, and they may not be adequate in some situations that we have not yet examined. And, we have to be cautious about that.

DR. PLESSET: Did anyone else have any comments before we move on?

DR. CATTON: I think that I've probably been most critical of GE's EM model in the past, and I think it's time that the industry forges forward with best estimate methods.

So, even though I may sound quite critical of what you're doing, I really feel that it's time that everybody get on the bandwagon for the best estimate code.

DR. PLESSET: Well, in general I would say that there are some favorable crumbs that come out of this.

MR. QUIRK: Well, I wouldn't refer to them as crumbs at all. And, I would very much like to thank the subcommittee for their comments and observations, the compliments and the criticisms and the suggestions.

And, believe me, GE will evaluate each and every one of these and consider them further. So, thank you.

DR. PLESSET: Well, I'm sure that you would.

Now, I'd like it if you could get your speakers to kind of be a little bit aware of the time. Some of us have departure times and that's why I'm a little worried about the schedule. So, why don't we go on with that in mind.

MR. QUIRK: Along that note, we're planning to conclude our presentations by two-thirty this afternoon.

DR. PLESSET: Oh, that's very good then, because the NRC Staff is going to make a brief statement, I think, after you're finished.

MR. QUIRK: Okay.

DR. PLESSET: Very good, thank you.

MR. QUIRK: At this time I would like to introduce the next speaker.

Late yesterday afternoon Bharat Shiralkar gave us a description of the SAFER model. At this time he'll go in and talk about the qualification test results.

MR. SHIRALKAR: Good morning.

I'd like to continue with the assessment studies that you have been looking at, but now switch to the SAFER code. We've looked at TRAC earlier this morning.

(Slide.)

We have looked at SAFER predictions of data primarily for various experiments of the Two-Loop Test Apparatus, or the TLTA. And, there were five tests that we looked at to cover various conditions of large breaks for different ECC systems, degraded situations, small break, and a boil-off test.

And, those are the ones I'll be showing you today.

(Slide.)

There have been comparisons that have been ongoing and almost complete on the ROSA III Test Facility. This is a Japanese facility with four parallel heated bundles. And, the small and large break tests have been looked at. I do not have detailed comparisons to show you on those, I'll give a verbal summary of what we see on those at the end.

(Slide.)

I'm going to come up at the end and show you conclusions that substantiate that the results of the comparisons show good agreement and we believe the significant phenomena and trends have generally been captured.

(Slide.)

I'm sure by now all of you are familiar with the Two-Loop Test Apparatus. Very briefly, it's a single channel full scale facility with the representative hardware for the BWR like jet pumps, the separator, and two recirculation loops.

The tests are typically done by blowing down through one of the recirculation lines into a suppression tank.

(Slide.)

For the SAFER calculations, just to clarify, the inputs or the initial conditions are pressure, power, recirculation flow, feedwater, steam line flow, and initial downcomer level. The power, feedwater and steam line flow versus time. The ECC flow and temperatur versus time. The recirculation pump flow decay time constant and the time of transition boiling, which we discussed yesterday, comes from a LAMB/SCAT analysis of the TLTA.

(Slide.)

This is a summary of the test we looked at. If I may go briefly through a description of those.

The first one which I'll be looking at is what we call the Reference Test, and this is a test which is a BWR-6 type simulacion. We took an average central power bundle and an average ECC flow corresponding to 1 HPCS, 1 LPCS and 1 LPCI.

So, it is effectively a 2 LPCI failure.

(Slide.)

The next one is a similar test but without any ECC flow at all.

(Slide.)

The third one is a peak power test with a low ECC flow and a high ECC temperature. This is a bounding degraded kind of condition.

(Slide.)

We have a small break test that was done without any high pressure systems, so there was an ADS activiation and LPCS and 2 LPCA activated later.

(Slide.)

And, finally there is what we call a boil-off test, which is essentially a quasi steady state without depressurization at a fixed pressure where you let the system just boil-off dry with essentially assuming absolutely no ECC at all.

(Slide.)

Now, unlike TRAC in which we have a fairly detailed break flow model, in a simpler evaluation-type code we have essentially a prescription for the break flow. And, we can use like a Moody slip flow or a homogeneous flow model with an appropriate multiplier, or fl/D, to match the facility characteristics.

(Slide.)

Now, based on pre/ious predictions off the TLTA with the SAFER code and the geometry we have come up with this, which is admittedly a description, for the homogeneous flow times .8 to account for the lines and the friction pressure drops in the lines; initial subcooling multiplier of 1.2 on the break flow; and, as I said, these are derived from TLTA geometry and previous experience with the code.

(Slide.)

The results we'll be looking at are the pressure transients, the mixture levels in the different regions -- two-phase mixture levels -- the regional mass distribution, and rod temperatures.

(Slide.)

For the Reference Test this summarizes the initial conditions. And just to touch on a couple of those, the initial bundle power is about 5.0 megawatts, the initial pressure is 1044 psi. The recirculation flow is specified by this number here, which is the total bundle inlet flow. The jet pump flows are measured also at steady state. This is the steam flow leaving initially.

(Slide.)

So, with these initial conditions we initiate the transient by initiating a break in the recirculation line. The pressure response is very close as calculated using the prescription that we followed off the appointed multiplier and the homogeneous flow and the initial subcool break flow multiplier.

(Slide.)

The next chart is rather busy. It shows the mixture levels at different parts of the system. These are two-phase mixture levels inferred from -- in the experiment, from the conductivity probes or delta-P measurements. And, they're compared with calculated levels.

(Slide.)

If I start from the top, all the dashed lines are the data, the calculations are the solid lines. If you come down you can see the upper plenum level which starts off at this point; the lower plenum flashing, which produces an upsurge in the level; eventually a drainage; and in the long term transient at TLTA the experiment is showing that the upper plenum is essentially empty, and we are calculating some accumulation of mass late in the transient. And, I'll get to that in a little bit.

(Slide.)

Of some interest is the core level, and you can see that the core level in the experiment dropped -- this is number 3 -- to the bottom of the bundle and then refilled again due to side entry orifice CCFL and the leakage flow.

(Slide.)

SAFER calculates similar behavior. It did calculate a fairly high void fraction early in the transient when the flow stagnates early in the transient. It went up to the top again during lower plenum flashing, when the flashing subsides the level starts dropping and dropped to about two feet, I guess, from the bottom of the core. And, then due to side entry orifice CCFL it fills up again. This is the curve that's tracking through the data.

MR. EBERSOLE: May I ask you a question?

MR. SHIRALKAR: Yes.

MR. EBERSOLE: Some of these transient circumstances, can you define for me what you mean by a level in the context of the two-phase mix?

MR. SHIRALKAR: When you have a situation such as a draining situation the level is -- there's a fairly clear transition. Because the vapor separates from the level surface and you have a fairly good discontinuity between the void fraction below and above.

MR. EBERSOLE: Are you telling me to believe that it's water, it's solid water?

MR. SHIRALKAR: No, it's not.

MR. EBERSOLE: What sort of void fraction does it have?

MR. SHIRALKAR: It varies in the transient, but it could be as high as .7, .8, .9 below. If it gets to .9 what we do, particularly for heat transfer purposes, we will assume that it's no longer a continuous liquid regime.

MR. EBERSOLE: At .9?

MR. SHIRALKAR: At .9.

But, in most of these cases -- particularly in this region -- the void fraction below the level is lower, there's a fairly sharp demarcation between what it is below and what it is above.

MR. EBERSOLE: Thank you.

(Slide.)

MR. SHIRALKAR: The bypass is number four and you can see the bypass level fall and then fill up again when the ECC systems come on. And, the SAFER calculation again is predicting a somewhat earlier fall in the level and refilling at about the right time. And, after about a hundred seconds it stays full.

The lower plenum, which is region one, you can see that because of the side entry orifice CCFL you are not able to make up the water that is evaporating. And, so the level starts falling in the lower plenum. It eventually gets to the bottom of the jet pumps, and when it does it pretty much stays there because then it's able to divert most of the steam through the jet pumps.

And, we are picking up that trend very well until very late in the transient where the pressure is fairly low.

And, here what we find is that we get some subcooling of the lower plenum and the result is that the steam in the lower plenum is very small and you're able to dump the core into the lower plenum and fill it up. So, in these spikes it's showing up.

(Slide.)

And, turning back to the upper plenum, this again is where the upper plenum starts to accumulate some inventory and this is because, now that we filled up the lower plenum, you need more driving head to drive that flow out of the jet pumps. And, you accumulate some water in the upper plenum for that purpose. And, it's hanging around the spawler(ph) elevation or a little higher than that.

DR. CATTON: So, is this CCFL again?

MR.SHIRALKAR: This one here?

DR. CATTON: Yes.

MR.SHIRALKAR This is CCFL breakdown, yes.

DR. CATTON: Yes.

MR.SHIRALKAR: And, at very low pressures what happens is that the vapor density is very low and it doesn't take very much of a difference, for example, in the heat transfer from the wall to create slight differences in the vapor production.

And, that can contribute to some of these phenomena late in the transient.

(Slide.)

In the TLTA we had a particular problem in this regard because they put some insulation in the bottom of the lower plenum and we are not quite sure how effective it is.

DR. TIEN: Could I ask, your correlation you use for CCFL and the CCFL breakdown, do you have the same correlation with the same constants?

MR. SHIRALKAR: The same correlation --

DR. TIEN: Same constants?

MR. SHIRALKAR: -- it's just that the amount of steam is reduced by condensation.

DR. TIEN: So, you use the same T-1 heat to boiling?

MR. SHIRALKAR: Yes.

DR. TIEN: Okay.

DR. ZUDANS: Could I ask a question?

When you discussed this lower plenum situation from the very beginning, as you proceeded you said the level went down and reached the pump exit level?

MR. SHIRALKAR: The jet pump, yes.

DR. ZUDANS: And, continued boiling from that point on?

MR. SHIRALKAR: I'm sorry.

DR. ZUDANS: It continued boiling from that point on?

MR. SHIRALKAR: Yes, it's flashing.

DR. ZUDANS: Where would the steam go, in the side orifices?

MR. SHIRALKAR: It's now able to split based on the resistances of the two paths.

DR. ZUDANS: Okay, through the jet pumps --

MR. SHIRALKAR: Through the jet pumps, the larger part now is going through the jet pumps.

DR. ZUDANS: Now, why would the level stay, where would the water come from to supplement that inventory?

MR. SHIRALKAR: Oh, it's coming from the core and the bypass regions.

DR. ZUDANS: I see.

MR. SHIRALKAR: We're getting now a situation -- it's like a regulator almost, because a little water comes down and if you cover the exit a little bit that means that the resistance path changes and you put more steam up the side entry orifice, taht decreases the water coming down until it drops again.

DR. ZUDANS: Okay.

MR. SHIRALKAR: So, it kind of hangs around that elevation.

DR. ZUDANS: You answered my question. I didn't know where the water came from, now I see it.

Thank you.

DR. SCHROCK: Bharat, could I pursue Dr. Tien's question a little further?

MR. SHIRALKAR: Yes.

DR. SCHROCK. I was really the same question, I think, that I posed to Dr. Alamgir earlier. And, I understood then that you were doing something other than just reducing the steam flow in the flooding correlation to get the CCFL breakdown.

MR. SHIRALKAR: Well, in TRAC what effectively happens is that interfacial heat transfer takes care -- there is no difference in the correlation. Interfacial heat transfer effectively accounts for how much condensation you're getting of the steam, and then the effective steam flow is then again used.

We just calculate the vapor and liquid velocities and void fraction and temperatures in TRAC. So, it's effectively the same thing.

(Pause.)

DR. SCHROCK: Your reduction in the steam flow relates to the condensation potential of the liquid which is coming down then, not the condensation potential in this churn turbulent mixture above the tie plate, is that the picture?

MR. SHIRALKAR: Yes, both actually.

You know, in both -- in TRAC or SAFER?

DR. SCHROCK: Well, but the steam which has passed through the orifice and condensing in the two-phase level above no longer -- that is, the condensation that occurs above the constriction should no longer be important in the correlation for countercurrent flow.

MR. SHIRALKAR: That's true.

But, it feeds back because then it determines how much subcool water is coming down and it has a rapid feedback then on condensing it. It effectively condensation from above the restriction to below the restriction.

Once we get this region above subcooled and you've got subcooled water --

DR. SCHROCK: I'm trying to relate it to a simple experimental device in which you'd be measuring flooding with injection of subcooled water.

Would you calculate that condensation rate on the basis of the injected water rate, or would you calculate some other water rate and calculate condensation from that?

(Pause.)

MR. SHIRALKAR: Again, in SAFER what we would do is we would mix the water coming in, water we had above the restriction.

DR. SCHROCK: Yes.

MR. SHIRALKAR: And, the inventory of the water going down is based on that. So, once that gets subcooled it triggers the breakdown.

DR. SCHROCK: No, it's the flow rate of the liquid

I'm asking about.

MR. SHIRALKAR: It's CCFL correlation based on the steam rate coming in --

DR. SCHROCK: So, you interrate on that?

(Pause.)

You don't know the liquid flowing down until you've applied the correlation?

MR. SHIRALKAR: Yes.

DR. SCHROCK: Okay.

So, you have interrate on that, then.

DR. TIEN: I'd like to come back to this again very short, but you can make a comment just for my, maybe, knowledge also.

In the CCFL correlation it's well known that for CCFL and CCFL breakdown you might have different coefficients However, perhaps in your case -- especially based on some of the experiments -- you are more interested in the CCFL breakdown.

You know, using those coefficients related to CCFL breakdown, that's okay. Is my statement generally correct, or do you have other comments?

(Pause.)

MR. SHIRALKAR: When you say it's well known, I'm not sure what exactly you're referring to.

DR. TIEN: Oh, I mean for the CCFL correlation for start to have CCFL or a breakdown of CCFL, you know, we find -- as well as some other people find -- the coefficient should be different. Maybe not very different, but should be different. And, there is some kind of fact there.

MR. SHIRALKAR: When you say that are you accounting for the fact that some of the steam is being condensed?

DR. TIEN: Not necessarily.

There are many other factors: the upper plenum geometry, or the entry conditions, and build-up of the water level, or different kinds of delta-P. So, all of this enters the picture.

I just want to make that comment.

MR. SHIRALKAR: Yes.

What we're using is the steady state CCFL operating characteristics.

DR. TIEN: I think that may, you know, need some improvement in that case.

(Slide.)

MR. SHIRALKAR: I have some plots on the regional masses to show some detail. This is, after all, an inventory code. I'd like to show you how it does on some of the regional masses.

What we're doing here is comparing different regions, the mass history that is measure or inferred from delta-P measurements versus what we calculate to SAFER. This is for the lower plenum region.

You see that the initial part is captured very well, the drop. But, when we get to the bottom of the jet pumps the SAFER is calculating a somewhat higher mass than TLTA. And, since the level is the same effectively I think this means is that we have somewhat lower void fraction in SAFER than what is seen in the TLTA.

(Slide.)

There's a divergence late in the transient, and this is because -- as I mentioned earlier -- we're calculating a breakdown of CCFL at the side entry orifice resulting dumping of liquid into the lower plenum. And, from that point on the lower plenum is filled up.

In the experiment, for 350 seconds at least, this had not happened.

(Slide.)

This is a comparison of the core mass. The blue line is SAFER and the experiment is shown in black. You can see it's doing about as well it could be expected to do, pretty much following the drop, the filling, and general refilling process.

We're getting a couple of -- 1, 2, 3 here -- fairly large downflow rates and those are the CCFL breakdowns that you see.

(Slide.)

This is a comparison of the masses in the bypass region. And, you can see that we're predicting the draining and the filling process fairly well. This large spike we didn't catch, and this is in the data. And, it's showing --

DR. CATTON: Do you suppose that is a CCFL that you missed?

(Pause.)

MR. SHIRALKAR: It could be related to CCFL, a sudden increase of flow from the bypass to the core or to the guide tubes, the restriction between the guide tube and the bypass.

And, we may have gotten a sudden increase in the flow rate down there. I don't have a very good explanation for that right now.

(Slide.)

The upper plenum, you see again that the masses are well-predicted way into the late part of the transient. And, this is where the upper plenum in SAFER starts accumulating mass because the lower plenum is full and you need to have some higher driving head(ph) to drive the same flow out of the jet pumps.

(Slide.)

The comparison of the masses in the downcomer. And, again they look pretty good almost all the way to the end. And, here TLTA has accumulated some more mass than SAFER does, at the very end.

(Slide.)

Now, if you look at the temperature plot this will put this in somewhat of a perspective. You see that most of the action is over by about 150 seconds a. this is a long term kind of refilling process but the quenching of the bundles we're filling up has been long since over.

Now, what we tried to plot is -- if you just look at the envelope here, that's the envelope for the PCT, that's the drop curve. And, I think there are also some experimental points shown at 90 inches and 79 inches, there are these curves under the envelope.

And, we've shown nodal temperatures for those five nodes in SAFER. And, you can see that the slopes are predicted fairly well. We start heating up in SAFER a little bit earlier and we don't get the benefit of the top downquench that we discussed earlier.

And, so we go a little further until you get a filling from below and then the temperatures turn over. And, beyond that time everything is quenched.

(Slide.)

For all your comparisons -- the previous slides -- everything looks very impressive, except that the bypass level mass flow, you couldn't get -- there's a big dip.

MR. SHIRALKAR: Yes.

DR. TIEN: That looks like a --

MR. SHIRALKAR: It indicates a breakdown.

DR. TIEN: Breakdown, exactly.

MR. SHIRALKAR: Probably at the top of the guide tubes.

DR. TIEN: And, also I think it's reasonable to think that the bypass case, the geometries are much more complicated as compared to other regions.

MR. SHIRALKAR: Yes.

DR. TIEN: So, I think it's --

MR. SHIRALKAR: The TLTA, I believe it's four tubes.

DR. TIEN: Yes.

MR. SHIRALKAR: I have a number of other tests. I'm going to be showing you essentially the same kind of information. So, now that I've spent some time on the first one maybe I can go a little faster on the others.

(Slide.)

This one is the average power case again but with no ECC at all. And, so this basically a heat-up calculation and the power was turned off at a certain point when the temperature had reached what we felt was a safe value for the heaters, or unsafe value.

I'll skip the next slide on the detailed conditions and go directly to the results.

(Slide.)

The pressure, again, the same prescription that we had -- the same prescription for all the tests. You see that the pressure prediction is almost right on in this case.

(Slide.)

If we go to the levels, the upper plenum level starts dropping, lower plenum flashing increases, and the upper plenum stays empty. No ECC in this case. The core level drops in SAFER and you get lower plenum flashing which knocks it up again.

In the calculation we did not get, apparently, a high enough void fraction region to be called a two-phase level. So, in the experiment the level stays up to the top all the time then drops. In the calculation the level, you can see, is dropping here.

There's a slight hold-up of the level because this is when the upper plenum starts dumping into the core and then it continues to drop until it's all drained. The lower plenum level is also dropping. This time there is no ECC flow and it can drop below the jet pumps and keep going.

Number two is the level in the guide tubes and we see that SAFER is predicting the level in the guide tubes to be fairly constant for the first 80 seconds and then it starts dropping, whereas in the TLTA the reduction in the level of the guide tubes starts earlier.

(Slide.)

If I go again to my regional mass comparisons, this is the lower plenum region and you see the initial slope compares fairly well. The slope here, again, is the same but we are retaining a little bit more liquid in the lower plenum than the experiment shows.

(Slide.)

This is a comparison of mass in the core region and you can see again it's a very good comparison. We are slightly high here where we calculate water coming down from the upper plenum, but then we drain again and essentially drain the whole core at about 90 seconds.

(Slide.)

The bypass region in this case compares very favorably between the prediction and the experiment.

(Slide.)

The upper plenum region shows very similar trends but there is somewhat higher mass retention in SAFER as compared to the experiment.

(Slide.)

In the downcomer region the trend looks very favorable again.

(Slide.)

So, the final comparison for this test is a comparison of peak clad temperatures. Now, as I mentioned earlier, this was a test with no ECC. The power was reduced at this point, so anything beyond that -- the reason for these reductions, I want to clarify, is because the power was reduced up here.

But, you can see the general trend is that you get an early boiling transition and rewet in the calculation followed by a dryout and an increase in temperature. And, this happens successively at lower elevations.

Now, what we've compared is the highest temperature that we got in the TLTA, which happened to be at 79 inches. And, the curve to compare that against is curve number three, which happens to be close to that region. And, you can see that we're doing a fairly good job up to here, and beyond that time we are overpredicting the heat-up to some degree.

(Slide.)

The next test was a test with very low ECC and a very high power bundle, and this turned out to be the most difficult test for SAFER to predict the temperatures on, and I'll get into that in a minute.

(Slide.)

The prediction of pressure is fairly good compared to the data.

(Slide.)

The prediction of the mixture levels, the trends again are captured. You can see the upper plenum and the core draining. And, in this case we have a special situation because we have very low ECC fluid and we had in the experiment very low jet pumps.

So, with that experimental set-up it's not possible to flood the core up to the top very easily. And, so what happens is the core level kind of settles out at about this elevation, as you can see, in both the experiment and the calculation. The core level settles out at about this elevation, which is about a little less than midway to the top of the core.

And, what's happening above that region is that we're getting some liquid periodically coming down, and again we have this top quenching phenomena which is not handled very well in SAFER.

So, for this particular case, though we do quite well on the mass predictions, our temperature predictions tend to be pessimistic.

MR. THEOFANOUS: Could I go back to the previous slide?

(Previous slide.)

You should have a pressure difference between the predicted and the measured which is pretty steady over -- up to 100 seconds.

What does that mean? Do you have the wrong loss coefficients, or do you have the wrong heat transfer, metal heat coming in and therefore steaming it harder(ph)?

MR. SHIRALKAR: I think it's a little of both. I think it's the breakflow probably partly. We have essentially an equilibrium situation where the energy leaving is effectively equal to the energy being added to the system.

MR. THEOFANOUS: Yes.

MR. SHIRALKAR: And, I think we are probably not taking out the right amount of energy, out of the break.

MR. THEOFANOUS: And, then in view of that how are you then to interpret the levels since now you are driving everything with your own pressure?

MR. SHIRALKAR: Well, it's not the pressure, I think, that's so important as the pressure rate typically for --

MR. THEOFANOUS: Well, no, no.

I mean, you know, if you look at the levels after 100 seconds -- and that's where you begin to deviate -- or 80 seconds, from then on all the levels inside and how the different regions are going to drain or not is going to depend on the actual pressure level in the lower plenum.

MR. SHIRALKAR: The CCFL characteristics will be affected by that.

MR. THEOFANOUS: Sure.

And, now I'm saying: Is there any bearing there on the story that you were giving us in the next slide, or not?

MR. SHIRALKAR: I think it will have some effect but I don't think it's the major one.

DR. SCHROCK: I'm interested in your comparison of your SAFER comparison with the calculation and the TRAC calculation with the TTLT data. In the case of this run 6425, your prediction of the pressure as presented in Alangir's graphs shows that you have substantially lower prediction in TRAC. We discusse that earlier, and now in this case it appears to me that you're -- I'm sorry. I'm misinterpreting the comparison. This is TLTA against SAFER. No, I'm not misinterpreting it, excuse me. So it cloos as though SAFER predicts for the same run the pressure in the long term better than TRAC does.

DR. SHIRALKAR: Yes, but you've got to be careful because TRAC is calculating it from a first principle equation. In SAFER, we're applying a prescription for a particular experiment or set up which we believe to be good so we have applied some prior knowledge to obtaining these results. It's not a first principles calculation by any means.

DR. CATTON: You've tuned SAFER more?

DR. SHIRALKAR: Yes.

DR. SCHROCK: But still you've succeeded through your tuning in retaining the early time correspondence which it has in common with TRAC but you've eliminated the long term discrepancy which you had with TRAC.

DR. SHIRALKAR: Yes.

DR. SCHROCK: I don't understand exactly how you've done that with tuning. That's interesting.

DR. SHIRALKAR: Well, the prescription we chose is what I described to you. We have some entrainment as calculated in SAFER, two jet pumps and combined with the prescription that we chose it does a good job.

DR. SCHROCK: That may suggest something for the TRAC development, I suppose?

MR. EBERSOLE: I'd like to get your comment, your reaction to it. In the meantime, out in the boondocks we are requiring that the diesel plants at these reactors be crash started once a week without benefit of pre-oiling such that they're up to and available for pumping in ten seconds. Do you think that makes sense?

DR. SHIRALKAR: The question makes sense to have the pumps available early?

MR. EBERSOLE: Yes, with a potential cost of degrading their liability a great deal.

DR. SHIRALKAR: I'm not sure I can make a --

DR. PLESSET: I think you'd better say you're not an expert in this field.

DR. SHIRALKAR: I'm not an expert.

DR. CATTON: But Milt, this is a --

DR. PLESSET: It's a good point.

DR. CATTON: It's a big point for a best esimate as contrasted with EM.

DR. PLESSET: Mr. Shiralkar may not even know about this terrible thing.

MR. EBERSOLE: Well, that's why I mentioned it.

DR. CATTON: Give him a little more incentive.

DR. TIEN: Let me ask you a question. You are an expert.

DR. SHIRALKAR: Let me say one thing though. If we do find that you get early injection of a high pressure system going it does have a fairly significant effect.

MR. EBERSOLE: Well, you can't get it above 400 PSI. That's why I picked this curve to make the observation because the machines can't develop it. So I see, do you see where 400 pounds is? It's way out, 60, 70 seconds but we crash start these things without pre-oiling or whatever. Do it once a week. Just tear them up. And the real hazard, of course, is that we're damaging them so that they won't run in the long term and we've got to cover for that. That's all.

DR. PLESSET: You should tell him he has a very good point.

DR. SHIRALKAR: No comment.

DR. TIEN: Now, I come back to the SAFER code. It appears to me that you could take everything except when you get to bypass level.

DR. SHIRALKAR: That was that one case.

DR. TIEN: The next slide after this also --

DR. SHIRALKAR: Yes, yes.

DR. TIEN: So that's for two cases, the relative big discrepancy. Can you improve somehow?

DR. SHIRALKAR: This one, I really don't know what the cause is. I think you're referring to this plot which shows a regional comparison of mass in the bypass region.

DR. TIEN: Mixture level also.

DR. SHIRALKAR: Mixture level also. And I'm frankly at a little bit of a loss in this case to know why our how we could have a situation where the level in the bypass is so high compared to the core because normally you would expect that the density in the bypass would be higher and the level and equilibrium will be lower so I would like to take another shot at looking at the data also.

DR. CATTON: Maybe CCFL again?

DR. SHIRALKAR: It shouldn't affect the mass because the leakage path which equilizes between the bypass and the core -- you have a big Delta-P in the bypass and a small one in the core. It should have equalized the leakage flow.

DR. CATTON: Maybe the Delta-P in the core is higher than you think.

DR. SHIRALKAR: I don't believe so.

DR. CATTON: Something's got to hold the water in there.

DR. SHIRALKAR: Because you can see that there is water coming down from the top and the CCFL situation so I don't believe the pressure drops very high in the core but there is a point in which I don't have a clear resolution on it.

MR. THEOFANOUS: In your previous slide, again, isn't there a different trend between the bypass and the core? I see that they are in the experiment, the one that was draining and the other was more and the calculation was the other way around. Is there some explanation for that?

DR. SHIRALKAR: Come again?

MR. THEOFANOUS: Was it again --

DR. SHIRALKAR: This block?

MR. THEOFANOUS: No, the previous one.

DR. SHIRALKAR: The levels?

MR. THEOFANOUS: Yes, the different levels or is it a table? Maybe it's a table. Look at 3 and 4. It looks like it's just totally opposite.

DR. SHIRALKAR: You're saying that four is calculated to be higher than three?

MR. THEOFANOUS: Look at between, around 70 seconds. 70 seconds where you're draining and filling again. Do you find that the experiment and the calculation are exactly

180° apart.

DR. SHIRALKAR: The experiment you're saying drains earlier in the core.

MR. THEOFANOUS: Look at the experiment. 3 is under 4, okay? The calculation 3 is over 4. It's a complete reversal.

DR. SHIRALKAR: I would say that they are pretty close in the calculation.

MR. THEOFANOUS: No, no, no. Look at the trends. In the experiment the three is draining a hell of a lot more than 4. In the calculation, three is hanging up there while four is draining. It's an opposite trend.

DR. SHIRALKAR: That's partly also because of the two phase level that you calculate in SAFER. This has much more void than this one does so it shows up that way. Look at the masses. I believe it will not be the same way.

MR. THEOFANOUS: So it's in effect a void fraction, then?

DR. SHIRALKAR: I believe so.

If you look at the Regional mass in the core, it is true that they're showing holding up a somewhat higher mass in the core in SAFER beyond this time, but during this time it's planing at about the same rate. In the lower plenum mass, an excellent prediction earlier in the transient, the same problem very late in the transient.

The upper plenum masses --- we're predicting a higher increase during the lower plenum flashing period than is seen in the TLTA. The downcomer region, the predictions are pretty good. So, we end up then with this peak clad temperature plot and here you see what I indicated earlier. Again the jet pumps in the TLTA contribute to the situation, the very sharp jet pumps so that the core level hangs up around the middle. Under those situations, the heat transfer above the level is primarily from steam cooling or from liquid falling from above. They can see that in the experiment, if you look at the PCT which is really the envelope of all the temperatures, you can see a periodic rewetting phenomena going on because of liquid coming from the top. The SAFER calculation does not have the benefit of the high heat transfer to the liquid downflow and it basically is going to a much higher temperature than what is is seen. So in this case we are conservative.

The small break test, this is a test with the HPCS, not available, degraded (ph) situation, small break in the recirculation line. I'll skip over the details of the initial conditions. I'll show you the results. This is the vessel pressure. You can see that you have an initial small drop in the pressure and it stays fairly constant because you're not removing much energy through the break. The level will drop to a point to activate ADS. I'm sorry. First you get a -- activate ADS and MSIV closure.

MR. EBERSOLE: Could you interpret for me what that level means since that has to be a discernible level rather than a calculated level. It's got to be the gadget that trips the ADS.

DR. SHIRALKAR: That's correct. That is the --

MR. EBERSOLE: So at what quality --

DR. SHIRALKAR: That is the collapsed level in the downcomer, now, not in the core.

So at this point we have reached level one in the downcomer which has triggered the MSIV closure and you can see the effect of the MSIV closure is to pressurize. We over-predict the effect of the closure as compared to the data. The ADS comes on at this point and can blow the system down to a fairly low pressure. The LPCS and LPCI systems come on at about this time and have to fill up the system. Now, this is a case where I won't show you a temperature comparison because the temperature now gets about saturation, because the ADS is effective in keeping the core covered and there's no temperature rise at all but I will show you the regional masses and levels because I think they are still of interest.

DR. CATTON: To calculate things in your code, you calculate the collapsed level in the downcomer from the information you have at hand to determine when the ADS should, or did you just decide?

DR. SHIRALKAR: From the experiment, I think we simulated what we've done in the experiment.

DR. CATTON: You picked a time rather than calculate a collapsed level.

DR. SHIRALKAR: That's right.

DR. CATTON: Okay.

DR. SHIRALKAR: In this case, you can see that the predictions of levels are pretty good. You can see the upper plenum level is dropping, you get ADS actuation, you get a level swell and then slow drop in the level as you keep on getting flashing coming up from the core. The core level stays at the top all the time in the calculation and the prediction and the experiment.

DR. CATTON: Could you point to 7? I can't find 7.

DR. SHIRALKAR: Seven and eight are --

DR. CATTON: On top of one another?

DR. SHIRALKAR: I think they are overlaid, yes. The bypass level though does drop quite a bit and then refill is then when the low pressure systems come on and fills up again to the top. We get a slight CCFL phenomena when the ADS action has almost terminated with the result that you get some level formation calculated in the transient as well as seen in the transient experimentally. The regional mass comparison for the lower plenum -- up to this time the lower plenum is full. Then you have the ADS flashing off some liquid. We are over-predicting the mass held in the SAFER by some amount and then follow the train in terms of decrease and then eventual fill.

The bundle mass agreement is excellent so you can see that even though the level has stayed up to the top, the mass in the bundle did drop quite a bit and filled up again.

The bypass response again, very well predicted.

DR. CATTON: Do you have a figure for the downcomer m[illegible]?

DR. SHIRALKAR: I don't have a figure. Basically, what happened, the downcomer mass was that prediction was excellent up to the time of the ADS and beyond ADS we under-predicted the mass.

DR. CATTON: The reason I'm interested in it should be kind of obvious. That's what you have information about in the control room. If one of the eventual uses as you indicated earlier was to, for plant control.

DR. SHIRALKAR: Yes.

DR. CATTON: So I think that in the future when you present these kinds of things I'd like to see the downcomer mass.

DR. SHIRALKAR: Okay. This is the upper plenum mass and you can see the boil-off in the core leading to a drop in the upper plenum mass and then an increase due to the ADS and then picking up the trends very well in terms of transients.

DR. SCHROCK: In making these comparisons, it looks as though you've chosen the point value from the data corresponding to the time step that was used in SAFER and that gives rise to some sort of saw tooth funny business on the data as well as the prediction. Is there any important noise in the data that gets them scared in any of these comparisons?

DR. SHIRALKAR: Not as a result of this plot I think, because you notice --

DR. SCHROCK: Not this one so much as some of the others.

DR. SHIRALKAR: The time scales are very large. I'm talking about several hundred seconds time scale here.

DR. SCHROCK: Am I incorrect in supposing that some of the saw tooth intervals on SAFER calculations is an indication of the time step that you've used?

DR. SHIRALKAR: In SAFER, obviously we're not plotting every time step so we're plotting every so many time steps so I don't think it's this time step oscillation that you see.

DR. SCHROCK: Well, I'm looking at one which I guess I would have a hard time identifying it's region for bypass around 6432 run 1. It's a mass plot and what I see is that the jogs in SAFER correspond identically to the jogs in TLTA and I don't think that's a comparison of predicted and actual system response in a real sense. I think it's the way you presented the experimental data.

DR. SHIRALKAR: I will check into it further with the people who actually plotted it but I believe that you know, since the time steps, time scales are fairly large, I don't think we're doing that --

DR. SCHROCK: Could you back up just about three slides? Maybe you'd find out that looks like what I'm talking about and you'll see what I mean.

DR. SHIRALKAR: Is this the one?

DR. SCHROCK: Yes, exactly. See, on that rising section is there something other than coincidence leading to the little nick in both of those curves?

DR. SHIRALKAR: I cannot answer to the little nick.

DR. SCHROCK: Yes, but it's surprising that the experimental trace would show that and that and that the SAFER predictions shows it at exactly the same time. There are other places where I've seen similar things to what you've shown so I think it's the way you're making the comparison and what I'm asking is, is there anything important in the experimental data that's getting obscured by choosing point values out of the data and then plotting it as a straight line linking of points that are selected from the experimental data.

DR. SHIRALKAR: I don't believe this. I don't believe so but I can confirm it, you know. I will make sure that --

The final test I have is the so-called boil off test and this is a test in which the pressure was maintained at about 400PSI. There were several test runs. We chose this particular one. A bundle power is maintained at 250 Kilowatts and the bundle is just allowed to boil dry and htis is a check on the void fraction and the temperature, the heat up for the rods.

The first plot I have is a comparison of mixture levels and the way the test is run, we have to go to some initial transient period where we set up the SAFER code and the TLTA with some conditions such that there is some mixture level in the upper plenum, so the core in the upper plenum are full, then we start boiling off slowing the water and eventually the level will drop to the top of the core and progress further, so we're picking up the transients here. We are at the level as it dropped from the top of the core.

DR. CATTON: Why is the bypass different then? If this is just a boil down process, why is the bypass at a different level?

DR. SHIRALKAR: Because of void fraction differences. The bypass is essentially saturated.

You can see that the boil off rate is of course, fixed by the heat input but you can see that the level prediction which corresponds to the change in the void fraction as we progressively boil the water off is predicted very well.

We are predicting the bypass level somewhat lower, the parallel to the experiment. The reason for that is because the void fraction in the bottom node of the core is not being predicted absolutely correctly and I will show you that in the next slide.

MR. THEOFANOUS: What is the matter with the Wilson rise or the drift flux, this printing or calculations? (ph)

DR. SHIRALKAR: What the code does is that at very low flow rates it switches automatically to the Wilson so may guess would be --

MR. THEOFANOUS: So that's Wilson then.

DR. SHIRALKAR: I guess it would be Wilson, yes. You can see the comparison of void fractions -- void fractions in the experiment are inferred from Delta-P measurements basically. These are the void fractions that were measured along the height of the channel and this is a curve that SAFER puts through it's five notes. You can see that while the void fraction in this region are very well predicted, we tend to under predict the void fraction at the very bottom region. That is whether we have a very large slope in the void fraction curve and this results in, does not effect the total level here that is dominated by the swell in this region but it does effect to some degree the pressure drop, therefore the bypass level which is, has the same pressure dropped and should be slightly different compared to the data. This is a comparison of temperatures. What happened in the test was that we boiled off liquid up to what would correspond to the fourth node in SAFER from the bottom so the top one, fifth was boiled off and then the feed water was turned on to turn the temperatures off and refill the core again. What you're seeing here is a comparison of one SAFER plot which is number 5, the fifth node as compared to individual thermocouples which all lie within that node, so here is where we have a fairly large node which is averaging temperatures and you can see that the temperature in fact is being treated (ph) quite well. It's averaging the temperatures within that node.

I have a summary slide on the peak clad temperature predictions. If we were to look at all the five tests that I have discussed in terms of the peak clad temperatures, this is what we do. This is the predicted peak clad temperature versus the experimental peak clad temperature. 6432 is a small break and that remains at saturation and we predict it to remain at saturation so that one was right on. 6425 is the reference case and we are slightly over-predicting the temperature because of again the top down rewet phenomenon being not there in SAFER. We tend to be slightly low on the boil off tests and this is because of the averaging or the node of the temperatures within that node. 6426 is the average power, no ECC case and we over-predicted the temperature rise in the late part of the transient there. 6423 is the one that gave us the most trouble and this is because the top half of the core and the experiment was cooled slowly by liquid falling down and did not predict very well.

This summarizes the five experiments that we have seen. Now, I said that I did not have anything on the ROSA experiment to present to you. If you run this, got results from the small break and the large break. The small break again is right on, though we do get a temperature rise in that case but prediction is excellent. With a large break we are in a similar situation to this case. We have been over-predicting the temperature by 200° to 300°. Those are just numbers that I am giving you orally. I do not have the material in a format that I can hand out to you.

DR. CATTON: One of the ROSA III tests has become a standard problem.

DR. SHIRALKAR: That's a small break. That is excellent.

DR. CATTON: Are you going to use it?

DR. SHIRALKAR: Use it for what?

DR. CATTON: For part of the checking out of SAFER?

DR. SHIRALKAR: We have already.

DR. CATTON: Oh, good. I guess I wasn't listening.

DR. PLESSET: ROSA III has a short core.

DR. SHIRALKAR: That's correct.

DR. PLESSET: Can you tell what the effect of that is in the behavior of a system compared to a full scale, full length -- you'd be able to tell what the effect would be of having a reduced length.

DR. SHIRALKAR: I'm not sure I can summarize those in a --

DR. PLESSET: Not in one line, I guess.

DR. SHIRALKAR: Or just compare them with the full length at this stage. The temperatures that it calculate -- peak clad temperature wise, we are coming out reasonably close toward, to calculate for a BWR with SAFER so from that point of view, probably it's not too far off but there are obviously compromises in the calculation of various parameters, the CCFL and the vapor generation rates and so forth, though the tried to scale them the best they could.

DR. SCHROCK: I think your ROSA comparisons are very important because you've tuned the code with TLTA data and now you've shown us comparisons largely or exclusively to that same facility which was used for the data tuning, for the code tuning. But, are you prepared to make a prediction on how well the presently tuned version of SAFER is going to stand up against FIST data?

DR. SHIRALKAR: First of all, I don't agree with you that we tuned the code for the TLTA.

DR. SCHROCK: No?

DR. SHIRALKAR: The only thing I think we tried to predict as well as we could was a pressure response but given the pressure response I believe it calculated quite well the mass distributions and the heat up so I don't agree that we're tuning the model there. On ROSA we do have some results.

DR. SCHROCK: You did tune something you told us in order to get that pressure to curve in shape.

DR. SHIRALKAR: The break multiplier.

DR. SCHROCK: And do you think that will influence nothing but pressure?

DR. SHIRALKAR: No, effectively it shows that if you can do a reasonable job on the pressure that SAFER will predict quite well the distribution of masses and heat up.

DR. SCHROCK: I guess the break flow adjustment is the most popular one to make in making pressure curves fit and it tends to mask an awful lot of other things which -- I guess I come back to my same question. When you go now to the FIST facility --

DR. SHIRALKAR: Could I interrupt one second though? I agree, the break flow tuning is the most common thing but I hope that we've shown that the masses and the levels in different regions feel quite reasonable so I think it's beyond the first level of just saying tune the break and look at the end products. We've looked at various intermediate things.

DR. SCHROCK: Okay, but then the last question is how comfortable are you with your ability at this stage to say that you think this code without further tuning is going to do well against FIST data?

DR. SHIRALKAR: I think we should do well against FIST, I feel.

DR. SCHROCK: So we'll simply have to wait and see.

DR. PLESSET: Let me go back to the half height question. Do you feel you'll be able to say what the effect of the reduced height is compared to a full scale height?

DR. SHIRALKAR: I don't have a one to one comparison to give you an answer to that and we have not run ROSA with full height or half height. The only thing we do have is maybe a comparison of a typical BWR calculation versus what ROSA might do.

DR. PLESSET: What does that indicate? Have you done that yet?

DR. SHIRALKAR: I think we're going to end up with just the temperature is in the same range. That's not to say that there are various things in between that may be different.

DR. CATTON: Isn't it a matter that if you use a half height facility and you understand the physical processes and you build them into a code, there should be no problem with it being half height. On the other hand, if you're using a lot of engineering judgement in putting together your code then you better worry about it being half height. I think that's where TRAC is probably going to be very helpful for them in putting together a code that's more based on eingeering judgement with one that has more of the detailed physics in it.

DR. PLESSET: I think that's an important question, really. Maybe not for the boiler but, well, there's been a lot of use made of loft. This is a half height facility and the question is well, how meaningful is this in detail for a full scale full height plant? Do you see what I'm getting at?

DR. SHIRALKAR: Yes.

DR. PLESSET: Now, that's not your concern but it's of interest to us.

DR. CATTON: The measured peak temperature that comes out of a half scale facility doesn't have meaning except through analysis for a full-scale facility.

DR. PLESSET: The question is, how good is that extrapolation? Let me state it that way.

DR. CATTON: Sometimes I wonder.

DR. SHIRALKAR: I think the only way to get at it really or use the data is to simulate the facility with the model.

DR. PLESSET: Yes.

DR. SHIRALKAR: And see what it does.

DR. CATTON: But that means you need to be involved in some of these blind type standard problem exercises and I think both Dr. Plesset and I were at the International Standard Problem Program in Japan and we saw very few vendors. As a matter of fact, I don't believe we saw any other than the Japanese.

DR. PLESSET: We didn't see any there.

DR. CATTON: And that is I think where you prove that your half scale is okay to represent full scale because they're requiring the blind predictions. People come in and give it a shot and I think one of the conclusions at the last meeting we were at was that given a little bit of tuning, most of these codes will do a fine job and it gets down to how skilled are you and where are you going to demonstrate that skill but with a blind standard problem. That's a plug for the Standard Problem Program in case it wasn't very obvious.

DR. PLESSET: Yes.

MR. EBERSOLE: May I ask a question?

DR. PLESSET: Yes. Let me make just one final comment, Jesse. You're in a good position to make a comparison of half height with full height tests, I should think particularly when FIST is finished, don't you agree? And you have ROSA III data?

DR. SHIRALKAR: Yes.

DR. PLESSET: Well, I think it would be interesting if you did get some ideas from such comparison.

DR. CATTON: By the way, that's another standard problem based on a, I think it's Swedish BWR integral facility. I believe it will be a blind, but I'm not sure. That might be a good problem for you to exercise your code on and demonstrate it's ability to and your skill to predict what's going on.

DR. PLESSET: What kind of facility is that?

DR. CATTON: I don't recollect the details but there was an effort to try to locate and I think the word they used was Virgin BWR facility for testing the code.

DR. PLESSET: I think they have an interesting capability here.

DR. CATTON: I'd like to see it tested and proved against one of these facilities. That would really give a great deal of comfort.

DR. PLESSET: Well, fine. Jesse?

MR. EBERSOLE: Because of the relative higher probability of the small break, I think there's a test that's not up there that might be there and that's why I would call it an inhibited blowdown test and the reason I say that is is because of the peculiar way in which a small break is handled. Thereis a period of attempting to detect the presence of a small break and then an attempt to determine whether high pressure core injection is working or not. The end result of it is there is 90 second interval as I recall wherein the operator can assert himself and by a very simple action stop the blowdown. The consequences of his stopping blow down is of great interest when he needs blowdown so if you took 6432 and progressively delayed the time of blow down, it might produce some very interesting results. Do you follow me?

DR. SHIRALKAR: Yes.

DR. PLESSET: Does that complete your presentation for this morning?

DR. SHIRALKAR: I have a summary slide, I think.

DR. PLESSET: Let's let him finish. He's got one more slide he wants to show, I think.

DR. SHIRALKAR: The pressure prediction is controlled by the break in the ADS flow and with the model that they used we got excellent predictions for all the cases. The mixture levels is controlled by the depressurization, the CCFL particularly and I think the predictions are generally good.

The core level is sometimes difficult to define, particularly in the bottom flooding kind of situation at low pressure but the definition of 90% void for triggering the heat transfer seems to work fairly well. The regional mass distribution we are well protected. There was a problem in the lower plenum mass prediction at the end of the transient and we attribute that to accurate calculation of the vapor production of the lower plenum and subcool CCFL breakdown. The peak clad temperature heat up was well predicted. The PCT tended to be over-predicted particularly because of the top quench phenomenon which is not modeled very accurately and overall, I believe the predictions are good and we demonstrate that we have the correct phenomena and trends, particularly when you compare them with the data and also what I showed you yesterday with respect to the current evaluation model. I think this is a big step forward in achieving much more reasonable predictions.

DR. PLESSET: I think we have another question.

DR. ZUDANS: Yes, my question relates to the integration method that I read the report which describes it and I see that for the post part explicit oiler method is used except for pressure rate which is computed implicitly.

DR. SHIRALKAR: That is correct.

DR. ZUDANS: On a couple of occasions yesterday and today, I asked you whether or not there was any iteration of the state from time -- within a time step and I don't find in your flow chart any iteration although someone said there was some iteration. Could you explain it to me and if you don't have an iteration, how do you control the stability of your explicit solution algorhythm.

DR. SHIRALKAR: I think there are some iterations within loops but on the whole the scheme of the method, it is an explicit oiler method and we checked the stability primarily by wearing time step size and looking at what time step size give us, kind of an assimtotic (ph) behavior.

DR. ZUDANS: I guess that particular aspect is not shown in the flow charts that you put in the report but you do vary the time steps and repeat the process of computation to see whether or not you match the previous solution, that's what you're saying?

DR. SHIRALKAR: No, we don't do that.

DR. ZUDANS: Oh, then you don't vary the time steps.

DR. SHIRALKAR: Not within the given calculation. What I'm saying is that we've made sensitivity studies that establish if the time steps are reasonable.

DR. ZUDANS: Oh, before you make a specific run you kind of take a trial around and see what time steps would be acceptable.

DR. SHIRALKAR: Not for every one.

DR. ZUDANS: For a title run, for a group of runs but you don't have any explicit stability control criteria within the computational scheme itself?

DR. SHIRALKAR: I think what we do is we check on the -- Maybe I shouldn't say more than I'm familiar with the details but I believe what we do is we check on the -- an estimate of the second derivative to estimate what the error is but by and large there is a criteria which tells me what the time step should be based on that.

DR. ZUDANS: Let me tell you why I asked this question. It's a highly non-linear problem. Of course, you can only solve it by some iterative scheme completely. You use an explicit solution, algorhythm. That means that unless you iterate to correct solution at each time step you're solution does not have to be unique. In other-words you can get good looking curves but they don't mean anything. They could mean nothing. I'm not saying that they don't mean anything, so I'm concerned that unless you iterate within each time step to complete conversions of you or all (ph) the questions, you may not have a unique solution so I'd like to see how you handled that some time. Next presentation.

DR. SHIRALKAR: All right.

DR. PLESSET: Any other question?

DR. SCHROCK: I have just one additional point concerning Ivan's plea to use the standard problems and make pre-predictions. I would certainly heartily endorse this idea.

There is an aspect of the user choices in all of the codes which will influence any pre-prediction which is extremely important. An example of that that I'd cite was the RELAP-5 pre-predition of the loft, a specific loft test, I don't remember which one it was but the prediction was quite poor and the reason that the reason was poor was quickly diagnosed as poor modeling. That is, it was inadeqquate heat slabs. You may recall that one and so it emphasized the fact that the setting up of the code involved some user choses and that hasn't been discussed much in connection with the presentations we have heard about, SAFER, or for that matter the BWR TRAC developments and I would like to ask that also we have some discussion of these aspects when we go into further detail in a future meeting. I think this is extremely important in gaining overall confidence that the codes are really you know, becoming more or less fool proof so that they can be used by a variety of users and expect to get the same results.

DR. SHIRALKAR: I agree.

DR. CATTON: I might just mention the Standard Problem Program again. I think one of the things that they found was that the worst, what we considered the poorest codes sometimes predicted things the best and the best of codes soometimes did the worst job when they were comparee with one another. I don't think we're ever going to sort that our, Virgil unless you go to a really true first principle description and we just don't have that in front of us. We're always going to depend on the skill of the program user and we're really going to have to develop some means of making a measure of that.

DR. PLESSET: Well, that sounds like a good thought and maybe a discouraging one to recess for lunch.

(Whereupon, at 11:55 a.m., the hearing was adjourned, to recovene at 1:00 p.m. in the same place.

A F T E R N O O N   S E S S I O N

DR. PLESSET: We'll reconvene.

(Pause)

DR. SHIRALKAR: This is Bernard Shiralkar again and the topic of my talk now is results for some typical BWR LOCA calculations that we are in the process of performing. For this purpose, the analytical tool that we're losing is the TRAC B02 model which we've talked about earlier. The plant we're looking at is a typical BWR 6218 from the 624 bundles and the rated (ph) 2894 megawatts and looking at a break spectrum calculation, we're looking at these transients, the main steam line break, the high pressure code spray line break, a 100% recirculation line break, that's a failure of the recirculation line and some scaled down recirculation line breaks, an 80% break and a one foot square which turns out to be about a 47% break for this plant.

The basis of the calculations are nominal conditions. We are assuming a single failure in the calculations of an ECC system and that is the HPCS system for all of these calculations and we're doing these calculations at fairly high tech spec type linear heat generation rates. Now, we have completed three of these calculations. The other two are ongoing but I hope I can give you a flavor of the results as I go along.

This is a summary of the calculations we are doing. For the recirculation line breaks, I have listed the areas of the break. For all those breaks the ECC systems available are three low pressure coolant injection systems which come into the bypass region, a low pressure core spray system and we've triggered MSIV closure at times zero based on high driving pressure. The ECC system not available is the high pressure core stress system. For the main steam line break case, again we have three LPCI's and LPCS system and MSIV closure at times zero. Failure is the HPCS system. For the HPCS line break which is a fairly small break we lose one HPCS due to the break and we lose the other one due to the assumption of an HPCS failure. I need to check on that. Excuse me for a minute. Are you sure, Jens, whether we had the HPCS failure in this case or the LPCI plus LPCS failure?

DR. ANDERSEN: My name is Jens Andersen. You're talking about the HPCS line break?

DR. SHIRALKAR: Yes.

DR. ANDERSEN: Okay, in that one, of course, we lose the HPCS system and we assume the failure in the LPCS system so we lost that one, too.

DR. SHIRALKAR: Okay, so what I have there is correct?

DR. ANDERSEN: Yes.

DR. SHIRALKAR: So we are left with two LPCI's and the ADS system and we've lost the diesel generator which gives us the LPCS and LPCI systems.

The calculations that are done with these assumptions, that the LPCI, LPCS systems are activated on 500 PSI plus a delay of nine seconds. The MSIV closure is triggered for a .5 second delay and a 5 second stroke time. The recirculation pumps are tripped at times zero and the scram occurs at times zero. We also assume a loss of feedwater, at zero with the feedwater linearly shutting off in five seconds. The ADS is available, tripped on the other one with a 105 second delay.

This is the nodalization that was used for the calculation. We're using TRAC, the B02 code and the nodalization that we have here shows, I believe 11 axial levels -- 11 axial levels corresponding to the various levels shown here. We are modeling four rings radially, the outermost ring being the downcomer wall, the shroud wall and three rings inside the shroud and we have a number of channels, types, groups of channels connected between the lower and upper plenums and in this case we are modeling three regions of channels representing a high power channel and an average, a lower power channel.

The HPCS, LPCS, LPCI systems are simulated, though I believe in none of these calculations was the HPCS activated and an ADS capability exists in the -- to relieve pressure if needed.

This is just a summary of the nodalization. There are 11 axial rings, axial levels, four radial rings. We modeled just one theta sector, making for a total of 44 vessel cells. The total number of components in the simulation is 33 and the core is represented by three groups of channels which have 11 axial cells within each channel.

DR. SCHROCK: Excuse me. Does that high power channel correspond to the maximum power channel or is it just an average in a high power region.

DR. SHIRALKAR: For this calculation we are taking a fairly high limit in the sense that we have taken the highest power channel but we have taken quite a few off them, more than would exist in area (ph) plant.

For the main steam line break, I just show here a schematic at the bottom. There are four steam lines coming out of the reactor vessel and there are isolation valves on either side of the containment barrier, barrier wall and beyond that they joined together for the proceed to the turbine. The break we're considering is one which is inside the containment. This is a break in one line. Now, there are flow restrictors on each of these lines so that for the first few seconds before the MISV's close, we're getting a break corresponding to the restrictor area on this side and then the flow coming out of all these three steam lines is available to come out to this end. When the MSIV is closed then we have essentially a single inner break because now all these have been isolated. This happens in about five seconds.

So we have one steam line with a double inner break initially. We have three impact lines which are closed off at 5.5 seconds.. The result from the calculation was, we ran the plan for 20 seconds following a break. There was no boiling transition. At 20 seconds the core floor settled down into a natural circulation type mode and there was no heat up of any kind.

DR. TIEN: Do you get a natural circulation mode -- you mentioned that found from your calcul[illegible]on?

DR. SHIRALKAR: Yes.

DR. TIEN: And you only have three rings, right?

DR. SHIRALKAR: We have three rings inside the shroud and one outside.

DR. TIEN: I mean core flow; natural recirculation?

DR. SHIRALKAR: Yes.

DR. TIEN: What types of; say, is the nodalization is good enough to demonstrate a natural circulation?

DR. SHIRALKAR: Yes, I believe so. The natural circulation I'm referring to is coming from the downcomer into the core so it's the density head difference.

This is a sequence of events for the main steam line break. We postulate a steam line break at times zero with a scram, feedwater trip and recirculation line trip. The MSIV closure is initiated at times zero and it starts affecting it at .5 seconds. The feedwater is completely off at 5 seconds. The MSIV is completely closed at 5.5 seconds.

This chart shows the pressure response following the postulated break. You can see that initially we have a somewhat larger slope because the MSIV's are not closed and we have a larger break area. At about this time now, the MSIV's are closed and the pressure is continuing to fall but at a lower rate.

This shows the plot of the break flow versus time. The core flow decays because we have tripped the pumps and we're in mode of decaying floor flow until we reach eventually a fairly steady flow at a decay heat type level and that the circulation flows in about 15 seconds, even earlier. It's a very benign transient and it does not produce any heat up. Look at the peak clad temperature in the high power bundle. It's pretty much following the saturation curve with of course the temperature drop across the film.

The -- I show the temperatures now in the three different regions of bundles. Again, they all fall in the saturation curve and are displaced slightly because of the power level.

So the steam line break results in a very benign transient and it does not result in any heat up.

Let me go to the next one which is the high pressure core spray line. This transient was run for 330 seconds, The first part of the transient, we have a scram but nothing else has happened so the water is slowly boiling off. The pressure regulator is trying to hold the pressure and the downcomer level slowly drops. The level drops to the level one set point. That would initiate MSIV closure and ADS. So the ADS depressurizes the system at 200 seconds. There are no high pressure systems available because they've lost HPCS through the brick. At the end of the depressurization, we have lost water out of the core because of the blowdown process and when the depressurization subsides, we develop a higher wide fraction region near the top of the bundle and we start getting some dry out and temperature heat up but shortly after that, the low pressure systems come on and quench the core. It turns out that we do get a temperature rise if peak clad temperature is close to the initial steady state cladding temperature because it's happening so late in time.

I have a chronology of event for this case. We postulated the break at times zero accompanied by a scram, feedwater trip and recirculation line trip, circulation pump trip, sorry. The feedwater is completely shut off in five seconds. The level drops until at 91 seconds it reaches L-1 tripping the ADS and MSIV closures. MSIV's start closing a half a second later. They are completely closed in five seconds. After a delay of 105 seconds from the signal to the ADS, the ADS occurs, blowing down the system, allowing the low pressure system to come on about 300 seconds and shortly after that at 325 seconds you get a quenching of the core.

This plot shows the pressure response. As you can see, after a small initial depressurization, the pressure essentially is constant, and although the MSIV's are not closed, the pressure regulator is essentially shutting off the steam flow to maintain the pressure.

When it can no longer do so, then you see that the pressure starts dropping because of the break flow leaving now through the HPCS line. At this point, we have reached a level, one in the downcomer which results in the automatic repressurization system activation and we blow down the system.

This is a plot of the break flow and the break is now in the upper plenum region. It's right on the HPCS line so we're getting periodically, we're getting liquid going through the break acting as sort of a regulator and you get liquid going through the break, the depressurization drops a little bit, liquid level drops, depressurization increases slightly, you get more liquid through the break and progressively we go through that phenomena and eventually we've exhausted essentially the liquid in the upper plenum. This is the flow through the steam line and this is basically the pressure regulator which is responding and shutting off the flow that's going to the turbine and shutting it off to essentially zero. Later on, the MSIV closure would occur and completely stop any flow leaving the steam lines.

This shows the total discharge flow to the jet pumps. There is a drop in the flow because of the recirculation pump trip and go to essentially zero flow, going through the jet pumps -- the lower plenum flashing at about this point responding to the depressurization, produces an increase in the flow that's leaving. The flow is essentially at very low values throughout the transient.

This shows the inlet flow to the high power bundle again showing the similar characteristics to the jet pump discharge flow, early decay and a small amount of flow through the core until finally the system comes on and refloods the entire core region. This chart shows the peak clad temperatures for the three different power regions and you can see that they are following the saturation curve all the way down here through the depressurization. The pressure is dropping here to a lower level. When the depressurization is coming to a -- is slowing down and you can see a dry out occurs and the temperatures start climbing, the LPCI comes on and you get a quench a few seconds later. The peak clad temperature you have here is lower than your initial temperature that you had so it's once again a very low temperature.

DR. TIEN: The quenching time was calculated, correct?

DR. SHIRALKAR: That's correct.

DR. TIEN: 325 seconds and then you stop all your computations? Is that correct? All your computation carried may be 330 seconds?

DR. SHIRALKAR: That's right.

DR. TIEN: To that point. So you just, how the machine know, you just say any time when you have the PCT dropped a little bit, you just stop?

DR. SHIRALKAR: They way we run TRAC, there's no way we can run this transient in one shot, so we probably run it in several increments evaluating the results before we see how far we need to go.

Let me come now to the recirculation line breaks. We are in the process of completing these calculations so I do not have all the results to show you at this time. But let me describe the trends. I will be showing you the smallest of the breaks which is a one foot squared break. The behavior system response is very similar for the three breaks. It's just shifted in time. The smallest breaks, the smaller breaks depressurize later-the sequence of events is very similar.

You get an early boiling transition in the high power bundles followed by rewet. Later on the lost inventory results in cladding heat up, mostly in the area (ph) and high power channels. Occasionally we have seen it in the low power channel also.

The ECCS activation subcools the bypass and upper plenum regions with drainage to the lower plenum, so we're getting liquid that's coming through the core, helping the heat transfer. It's also helping to reflect the lower plenum. And the fuel is cooled by inventory accumulation as well as cocurrent upflow. There are periods where you have upflows through the channels. There is periodic drainage of liquid and the overall heat transfer is fairly high.

So with that, let me go to the results for the one foot square recirculation line break.

DR. SCHROCK: Can I ask a question before you leave this? As I understand it, activating the ADS system is extremely undesirable and the operator as Jesse has told us can't override it. Your peak clad temperatures calculated now for the small break indicate that there is no difficulty until the ADS is activated. It doesn't create a problem vis a vis peak clad temperature but it certainly creates a problem for the pressure vessel so is there any thinking to modify operational procedures in view of this as the activation of the ADS system, indeed desirable at this point?

DR. SHIRALKAR: Well, yes, because there is no other source of water at this time and high pressure, at least the calculation we have assumed so in order to -- if you did not have any water coming in then ultimately you would get heat up so this allows you to get down to lower pressures where the low pressure systems will be available.

DR. SCHROCK: But is it not possible to get there at a rate that doesn't jeopardize the pressure vessel?

DR. SHIRALKAR: There has been some thinking going into that in terms of control blow down, and so on, yes.

DR. SCHROCK: But that's something for the future.

DR. SHIRALKAR: The recirculation line break we ran was a one foot square break. That's the one we have the results for today. The -- again, the break was postulated to happen at times zero. We also had a scram, a feedwater trip and the circulation pump trip. Again, a similar sequence of events. The isolation valves start to close at about .5 seconds. We see a boiling transition in the high power bundles very early in the transient at about 1.1 seconds.

DR. WARD: What triggers the MSIV valves to close at half a second?

DR. SHIRALKAR: I believe it's the dry well pressure.

DR. WARD: The dry well pressure?

DR. SHIRALKAR: Yes. The peak cladding temperature for this transient happened very early in the transient at about 3 seconds, 3.2 seconds which is the time it rewet and reached about 687°Kelvin or 777°Fahrenheit. The feedwater shuts off at five seconds, the MSIV is closed completely at 5.5. Later in the transient there is a progressive evaporation of water in the bundles leading to a dry out. The temperature starts rising again. The LPCS and LPCI come on as shown here at 99 and 107 seconds and you get a quenching of the bundle eventually but the peak clad temperature in the second rise of temperature turns out to be lower in this case than the first one so the peak clad temperature in fact is the one that -- three seconds for this case.

This plot shows a typical steam dome pressure response. You get the early small depressurization when you first get the break and the MSIV is closed. You actually pressurize the system above initial operating pressure. At some point, the level in the downcomer will have dropped to uncover the break line, the recirculation line, which allows steam discharge instead of the water discharge that speeds up now the depressurization rate here until at some point slightly later at about ten seconds the initially subcooled water in the lower plenum and downcomer flashes. You can see the change in the depressurization rate. Following that, the system continues to blow down to near atmospheric pressure.

MR. EBERSOLE: May I ask you a question? Which of these breaks maximizes the gradient differential between the pressure in the fuel channel per se and that in the bypass area? And the reason I ask that is, there's an old flap that goes on forever about the square can distortions and the implications of impeding the control rod insertion process. Does your ca[illegible]ion develop the pressure gradient between the i[illegible]f the box enclosure and the exterior?

DR. SHIRALKAR: Yes. I don't have an answer as to which is the worst case. I haven't looked at it.

MR. EBERSOLE: Does your new results coincide with the older calculations and is that aspect of your design evaluation being looked at anew?

DR. SHIRALKAR: Do you want to take that, Dave?

MR. HAMMOND: I'm Dave Hammond from General Electric. On the -- for these transients we don't get any significant depressurization until you uncover the recirculation line which usually is on the order of about 8 to 10 seconds and by that time you've already inserted the control rods. So, there shouldn't be any major pressure gradients prior to insertion of the control rod or until after they have been inserted.

MR. EBERSOLE: For no depressurizations of any sort? All right.

MR. HAMMOND: Yes.

MR. EBERSOLE: You said for this kind of depressurization?

MR. HAMMOND: Well, for the DBA LOCA which is the most severe event as far as what you would get a rapid depressurization for, you'll have the rods in --

MR. EBERSOLE: Before you develop the differential?

MR. HAMMOND: Before you develop any large differentials, yes.

MR. EBERSOLE: Thank you.

DR. PLESSET: What does that 15.649 hours refer to on that?

DR. SHIRALKAR: It's probably the time.

DR. PLESSET: It must be a time, it's hours, but time of what?

DR. SHIRALKAR: Either the time the computer did something or the plotting or the execution of the run, probably.

DR. PLESSET: It doesn't mean anything then?

DR. SHIRALKAR: No, not as far as information that I intend to convey.

This shows where the break we're talking about, the in tact jet pump suction flow which drops as the pumps are coasting down -- you have an increase when you have the flashing due to the lower plenum flashing and then steadies out essentially zero flow.

This shows the same plot for the discharge flow from jet pumps.

Looking now at the broken side of the recirculation loop and this is the jet pump suction flow in the broken side and see a very rapid reversal in flow as the break occurs, eventually sending down to essentially very low flows.

This is a plot for the discharge flow transient from the broken jet pump.

I show here the inlet mass flow versus time for the high power region of bundles. Again the early coast down followed by some lower plenum flashing. We have essentially steam inflow into these channels for most of the period until you have -- in this period we are beginning to see large amounts of liquids, liquid comingdown through the average channel as well as some from the high power channel and the lower power channels filling up the lower plenum rapidly and the final spikes you see are due to the refilling process where now the liquid is going up into the hot channels and that's going to turn the transient around.and quench the temperatures.

This is the flow in the inlet of the average power bundle and the same characteristics again. If you look at the details you'll see that the steam flows going in here are smaller than those going into the high power bundles. Down here we are beginning to get a break down at the lower end of the average power bundle and that results in a fairly rapid filling of the lower plenum followed by complete reflood.

The lower power bundles behave in much the same way until you get here at about 100 seconds into the transient and now we are getting the effects of down flow into the low power bundles. You are beginning to see fairly large amounts of liquid down flow coming down here and in the process of subcooling the peripheral bundles. You have a fairly large downflow at this point which helps to refill the lower plenum and now here we have turned around and leaving to reflood the core.

This line here is just a plotting aberration when we put two plots together.

This plot shows the high power bundle peak clad temperature. This is really an envelope of the temperatures showing the highest temperature at any given point in time so if we go through this transient we see the early boiling transition at about one second getting to a temperature of about 680° Kelvin, a rewet in the well cooled region until we start getting a dry out here due to lack of inventory. Temperatures start increasing and there are periodic liquid downflow in the channels which tends to cool the channels. Now this particular downward spike here is due to the fact that we shifted from one node to another. In otherwords, the -- initially, node five out of the 11 nodes were the highest temperature node. That quenced and we pick up the trend then for the lower node, for node four and continue here. We start seeing large amounts of water coming in periodically resulting in quenching. It's trying to quench here. It doesn't quite make it. It heats up a little bit more and then finally quenches when you get the reflooding envelope so the peak clad temperature still is this value here initially at 680° Kelvin.

DR. TIEN: You mentioned that periodic PCT is due to the liquid flow, kind of periodic flow into that but in that flow before, it didn't show anything. Last flow. It's very sensitive.

DR. SHIRALKAR: It's small because of the scale and it's quite small compared to the initial flow but basically it's giving you a higher liquid content inside the bundle and it's getting you more cooling.

DR. TIEN: I see. So there's no inconsistency between your previous --

DR. SHIRALKAR: No.

DR. PLESSET: That peak clad temperature was Kelvin?

DR. SHIRALKAR: It's Kelvin on the lefthand and there's also Fahrenheit on the righthand side.

DR. PLESSET: Okay.

DR. SHIRALKAR: The highest temperature in the average power bundles -- as you can see there's no early transition here so we are pretty much following the saturation line until we get a dry out and mild increase in temperature fairly well cooled and the final quench at 200 seconds.

This is a temperature in the lowest power bundles. It's the peak clad temperature in the lower power bundles and you can see that this essentially follows the saturation curve. You do see in this case a small amount of deterioration of heat transfer at about 100 seconds but again that's quenched fairly rapidly and you keep following the saturation curve.

So to summarize the results we have to date in terms of peak clad temperatures for the main steam line break there was no heat up at all so this temperature is at 566° initial temperature. The HPCS line break, 584°. For the one foot square break, 782°. So these temperatures represent our best shot today of what we would expect in these kind of LOCA calculations. These calculations have been done with nominal conditions and with our best calculation in TRAC B02. The other two breaks, the calculations are ongoing and we are somewhere in the transient now in terms of calculation of time. We see similar behavior to this but we expect some higher temperature than that because of the larger breaks but we would expect to bound them between say 800° to 1000°.

DR. ZUDANS: I have one question to the model. You said that this was just one single ring and wasn't subdivided circumferentially, right? So you're assuming that the core acts in axisymmetric configuration. Is that the correct statement?

DR. SHIRALKAR: That is correct. There is one theta cell.

DR. ZUDANS: Under those conditions you assume that there's an instant mixing wherever the cold water comes in out the ring, the entire circumference ceases --

DR. SHIRALKAR: Circumferentially that is true.

DR. ZUDANS: How would the fact that the pipe only comes in one of these sectors and it doesn't see the rest of the circumference for some delayed time. Would these results be representative results or is this an optimistic picture?

DR. SHIRALKAR: In the bypass region, you're talking about the ECCS injection now coming in?

DR. ZUDANS: Yes.

DR. SHIRALKAR: We believe it's a reasonable representation but we do have calculations which are performed earlier with more than one theta cell.

DR. PLESSET: Has there been any effort at G.E. -- these are low probability events?

DR. SHIRALKAR: Yes.

DR. PLESSET: To scale them as a relative probability? Any effort in that direction? Do you see what I'm after?

DR. SHIRALKAR: Not exactly, no.

DR. PLESSET: Well, these are low probability but as a recirc. line break more probable than an HPCS line break or less probable or a main steam line break? Just relative. I know they're all supposedly very small. Has there been any thought in that direction?

DR. SHIRALKAR: I don't know of any. I'm not an expert on the data.

DR. PLESSET: Well, that's all right.

MR. DENNISON: We don't have the right people here to answer that. We have a PRA and safety people that I'm sure -- I'm not sure if they're in doing that or not but

I'm sure they're involved with something like that.

DR. PLESSET: They've thought about it, you think?

MR. DENNISON: I think.

DR. PLESSET: Well, it would be of some interest to have your views on this. If you have any idea of any absolute probabilities, I know they're terribly small and that would be interesting also. I've been thinking about the swedish design with the recirc. line and the pumps are inside the vessel if that's really worth the trouble or not. You have no opinion on that, I gather?

DR. QUIRK: Let me address that, Dr. Plesset. We do have a probablistic risk assessment people and we have evaluated our BWR-6 Mark III design with a PRA and to be honest with you, the design basis accident did not dominate the risks that come out of a PRA so --

DR. PLESSET: I'm not surprised really. I guess you aren't either?

DR. QUIRK: No, we're not. It's the -- what I call the end of spectrum events where you have say, a stationblack-out, total loss of off-sight AC power, total loss of on-sight AC power and you just lose availability of a lot of make up systems and you follow those all the way out and those tend to dominate the risk.

DR. PLESSET: Very good. Well, I think we shouldn't forget this kind of thing. I mean, it's very nice to have these very beautiful calculations and I guess you have to do it the way things are and so on, but we have to keep in mind what the real world is trying to tell us. Well, thank you very much.

DR. SHIRALKAR: That concludes this section. I do have another one to make on the approach we are proposing. Should we take a couple of minutes break and resume?

DR. PLESSET: Do you need a break?

DR. SHIRALKAR: No, I can go on if you like.

DR. PLESSET: Well, we don't need it. If you don't need it, we don't need it.

DR. SHIRALKAR: Just enough to get my slides.

DR. PLESSET: That's all right.

(Pause)

DR. SHIRALKAR: Along with the development of our evaluation methodology we've been also working on an application methodology that we have proposed to the NRC Staff and this is something that's under evaluation by the NRC Staff now and I'd like to give you what our thoughts are on how we think we should use the information we have.

What we are proposing is that loss of coolant accident events be analyzed with nominal input values in SAFER/GESTR. We proposed that the nominal peak clad temperature is then increased by an "adder" to obtain an upper bound PCT for design evaluation. This "adder" has to encompass in some way the Appendix K specified values as well as other uncertainties combined in some statistical manner and reference is made here to a January '82 meeting between G.E. and the NRC Staff where we discussed some ways to do this.

The method that we're proposing is basically the following: calibrate SAFER -- first of all, let us divide the uncertainties into two groups, uncertainties in the model itself and uncertainties inherent in some plan parameters. Now, the modeling uncertainties we propose we calibrate against of course, the BWR LOCA experiment and the way we propose to do that, it is a TRAC calculation for a BWR and that would be corrected to account for the bias and uncertainty in the TRAC calculation itself in some way. And secondly, quantify the effects on the peak clad temperature due to plant parameter uncertainties and this we would handle then by performing sensitivity studies with the SAFER model about the nominal case. So the basis for the adder is test data, TRAC predictions off the test data, TRAC benchmark calculations for plants and the SAFER/GESTR calculations for plants and we're trying to integrate the technology through the experiments, TRAC and SAFER to make -- to develop a methodology for reactor application.

What we have proposed is that the adder explicitly account for a bias and the uncertainty of these quantities, so the upper bound peak clad temperature that you apply for design use might be a nominal calculation augmented by an adder -- that adder is formulated in this way. It's Delta-1 which is a bias, an average bias of experiment minus TRAC values for the peak clad temperature and this is assumed to apply in the plant because TRAC is the best way we have today of extrapolating from experiments to plants. Delta-2 is the average bias of the TRAC plant value of PCT relative to SAFER/GESTR plant values for the same LOCA so you calibrate SAFER with the spectra TRAC or the spectrum of breaks which -- and we are in the process of doing that now.

DR. WARD: So would those be negative numbers?

DR. SHIRALKAR: They could be.

DR. SCHROCK: Would you apply them as negative numbers?

DR. SHIRALKAR: We propose to, yes. Well, these account for model bias. Now, we also have to account in some way for uncertainties in the model and again, what we've done is to evaluate and add a contribution due to the variance of TRAC minus experiment values which goes along with Delta-1 and the contribution due the variance of SAFER/GESTR TRAC values. So through these, what we're hoping to do is to account for the modeling part of the bias uncertainty. The last term here is to account for things that are not in the model, the plant uncertainties, the uncertainties in the plant parameters. So that last term, is a contribution to the adder due to the variance of the distribution of uncertainty in SAFER/GESTR plant values. This reflects uncertainty in these groups of variables. One, variables whose values are conservatively specified in Appendix K. Now, if you live within the rules of Appendix K, we have to have some way of accounting for these uncertainties and there are four, I believe, which are explicitly in the letter of the law of Appendix K and they specify the use of the decay heat model, the maximum temperature of transition boiling, break flow models, the slip flow, Moody model, and the megawatt reaction, red (ph) coefficients, the breaker just (ph). So that's one group of variables with which we are to deal in some way.

The second group are variables whose values are much better known in the experiments, controlled in the experiments, than they are in the plant. These are things like core power, peak linear heat generation rate, bypass leakage coefficients.

DR. WARD: Let me ask you a question about that one. That one strikes me as one where there might be a lot of variation even within a plant from bundle to bundle. I mean, that's not a design flow path in which their quality assurance practices make sure it's of a certain size and shape but those are just sort of clearances as I understand which are more or less accidental.

DR. SHIRALKAR: There are both kinds.

DR. WARD: Pardon?

DR. SHIRALKAR: There are both kinds.

DR. WARD: There are both kinds.

DR. SHIRALKAR: There are specific codes in the tie plate which are definitely quality control and which contribute to almost 50% of the leakage flow. There are others which result from clearances.

DR. WARD: And those clearances could be -- there could be a spectrum of clearances in a given plant from bundle to bundle, right?

DR. SHIRALKAR: They could be and what we've done is to kind of average them over a large number of components and that would be a nominal value. We will somehow have to get an estimate of what the variation is for this study.

The initial minimum critical power ratio which dominates the initial boiling transition and ECCS water temperatures and initiation signals which we included but which we feel are out of lower importance than the others and the last group are variables which are not involved in the experiments at all, in the hydraulic experiments that we've seen and they are basically the stored energy which derives from the pellet-clad gap conductors and the fuel rod internal pressure so these variables are not modeled in any of the experiments we've seen. So we need a method, a procedure for accounting for these variations. And this part of the adder which we are calling the plant uncertainty adder, what we've proposed is that we will evaluate -- we will look at the number of nominal conditions around the worst nominal conditions and we might do this for example, for a large break and a small break separately. But for each variable we will establish a nominal value and an upper bound value of some probability and for variables specified in Appendix K, this upper value will correspond to the specified value. Then we will perform sensitivity studies by perturbing each of these variables above the nominal value in SAFER/GESTR calculations and then combine them and what we're proposing is that we combine them in independent or RMS manner.

DR. TIEN: Did you say why the fuel rod internal pressure is also -- were a factor of PCT as an uncertainty?

DR. SHIRALKAR: I don't believe it's a very important parameter in this case. The way it does effect it is through possible perforation of the cladding which results in increased megawatt reaction.

DR. TIEN: But then that would offset the whole thing, right, in terms of lumping all these variables together?

DR. SHIRALKAR: Well, we'll find that the effect of that is very small, the sensitivity studies, so effectively yes. We'll put it in for what it's worth and evaluate what it's worth is.

DR. SCHROCK: Can I ask a question about the way in which you would make this adder determination on the break flow? As I understand Appendix K you are required to do a series of calculations using different break flow multipliers in order to discover which of those produces the most adverse peak clad temperature. That sequence of calculations isn't being made here, is it? So how do you determine an adder that's associated with the peak clad temperature variations which are associated with the Moody model in contrast to the --

DR. SHIRALKAR: That's a very good point and I must confess I haven't given it a lot of thought. I have not, because what we've thought so far would be primarily to take the largest which is the multiplier of one on the slip flow as being representative of Appendix K. Now, we do cover the whole break spectrum and any changes in the multiplier will be caught just at maybe a slightly lower break size.

DR. SCHROCK: It has the effect of saying it's a smaller break size?

DR. SHIRALKAR: Yes.

DR. SCHROCK: So there is a problem in coming up with a single number, I guess for that one, isn't there? I don't see how to do it offhand. It's a good idea.

DR. SHIRALKAR: What we propose to do is evaluate these adders at different conditions and then we will have to determine exactly how we apply them and this is something we are still in the process of talking with the NRC Staff on what a good approach might be and we could take the highest value of the adder at different points. We could make it function off -- at least have one or two values and correspond to different break sizes, perhaps.

MR. EBERSOLE: Maybe at this time I could step into what -- my real world and I mention a very small break indeed which may produce very embarrassing circumstances. I have in hand a little study done by one of our fellows. It says that some of your older plants, and I hope maybe they are older ones and only older ones and this is on a plant specific basis -- every potential for having impulse or header line breaks which simultaneously produce a very small loss of fluid, yet they blind the response systems because all the response systems are headered (ph) into that one instrument tap take off which usually is about a one inch line -- do you go so far as the implications of losing -- that's sort of, you understand, the Achilles heel of this system. It's the keystone which, if you pluck it out, all this rationale falls apart. Do you look at these aspects of your design problems and see by what means the operator could hope to recoop safety in the event one of these things fails? I can tell you these lines do fail, they are socket wells and they do come apart. As a matter of fact, the last shut down at Brown's ferry was do to socket failure, socket well failure on the first stage turbine, turbine first stage. Do you look at these degradations of the rather pure logic that you're always going to get the required response?

DR. SHIRALKAR: I think basically you're talking about very small breaks?

MR. EBERSOLE: Oh, yes.

DR. SHIRALKAR: And the response to those breaks. Now, I think the whole break spectrum ought to be covered in a procedure like this, but however, not further degradation. Here we are trying to work out a procedure that's in conformance with Appendix K. I believe that if we need to look at some more severe degraded conditions we should take our best shot at it with our best models.

MR. EBERSOLE: Well, in a way what I guess I could see here is, you could develop some times which would be quite long within which something could be done to recover the situation. I don't know how long those times are.

DR. SHIRALKAR: I think you're talking about operator guidelines.

MR. EBERSOLE: Whatever. Yes. I don't know what he can do because I don't know what he's got left. He in essence has been blinded and so has his equipment.

DR. SHIRALKAR: My understanding is that these events are covered in the emergency guideline procedures but I am not the expert --

MR. EBERSOLE: They are not covered because that hypothetical break has not been introduced as conceivable. It has been called incredible, even though it's far more probable than the ones you are discussing.

DR. QUIRK: Mr. Ebersole, are you referring to, let's be specific, water level instrument line break and one, say, ticket two division plant, you fail one side and then you then single fail the other side such that the initiation of safety systems is blocked because this has a false --

MR. EBERSOLE: Yes, that sort of thing. I don't know to what degree these combinational sets are organized. The effect is, there's been no regulatory control over the hydraulic plan designs. The regulatory control began at the electrical transducers region. In the early stages there was nothing in the regulatory controls that expressed a requirement that a hydraulic contact system to the primary process has certain configurations. As a result, there's a random configuration in the field.

DR. QUIRK: I was going to agree with you that this is very specific to plants. The later plants have much more tolerance to these types of things as do the early ones, not quite as much. We have not overlooked these in the way of EPG's. In fact, EPG's have been developed recently, have included a step where if the operator is confused he's getting high dry well readings and pressure readings and he's not sure what his levels are, he's instructed to ADS and depressurize and bring on low pressure systems so your concern has been identified and is being discussed.

DR. SHIRALKAR: We are right now in the process of determining these elements that go into this adder and I think I identified them before. The first element is to obtain a TRAC BWR calculation calibration with respect to experiments. The second element is to get a SAFER versus TRAC one on one comparisons for a spectrum of breaks. And thirdly, to perform SAFER/GESTR sensitivity studies to quantify the effect of these parameters we lumped into plant uncertainties so all these activities are ongoing and we expect to discuss them in more detail with the Staff when we meet them early next year. On the TRAC calibration versus experiments, the objective is to assess the TRAC bias and uncertainty in some rational manner. And the experiments we plan to utilize are primarily the TLTA and Oakridge tests which are available now. The code versions utilized are going to be TRAC B02 which is, as I point out close to the TRAC BD-1 version 12 at Idaho plus the G.E. models and TRAC B01 which is the G.E. version close to version 12. And we may choose later on to add more experimental comparisons to this base as they become available and -- okay.

The second element is the SAFER TRAC comparisons and the objective of these is to calibrate SAFER bias and uncertainty for BWR calculations. The results I showed you a little earlier are a part of the study. We're going to simulate the BWR/6-218, a representative plant and the BWR/4-218. The main difference between the two is that in the BWR/4 the ECCS systems come into the lower plenum through the jet pumps and you get a flooding from below. The transients that are being simulated are the main steam line break, the core spray line break and the circulation line breaks. For the BWR/4, at present our plan is to do the large break to get a calibration of SAFER performance for the bottom flooding events.

The final element is the sensitivity study. The objective of that is to quantify PCT changes due to plant parameter uncertainties and Appendix K requirements which are sort of upper bounds on some of the parameters we have to use. And for this we would establish the most limiting break and ECC combinations for typical 6's and 4's and then perform these sensitivity studies around these nominal cases as I explained earlier.

Here's a summary status. The TRAC BWR calibration studies -- we've done some B01 studies and they were shown to you today and yesterday. The B02 studies are in progress. We expect to get most of the ones we plan to do now by the end of the year. The SAFER TRAC comparisons are under way. The SAFER sensitivity studies -- right now we are -- the base calculation of break spectrum are under way and sensitivity studies are to be performed. So I think we are proposing a way -- I think we're making a serious approach to this problem of how to use a nominal kind of model within the Appendix K guidelines and that's the approach we have proposed.

DR. PLESSET: Well, thank you. Any questions?

DR. ZUDANS: Yes, just one. Do you intend to use the same model you showed us today for TRAC BWR calibration with the walk (ph) sector?

DR. SHIRALKAR: Yes.

DR. PLESSET: Go ahead.

DR. WARD: Let me make just one comment. I think this is really an excellent approach, your adder, best estimate and your adder approach and I think you're leaving yourself open to people picking at the details. I mean, you're putting everything out on the table and everybody can look at all the details but I think that's the way it ought to be done. In the past, all these same considerations have been buried in big black boxes or big black guesses, conservative assumptions and so forth and I guess I congratulate you on taking this rational approach.

DR. SHIRALKAR: Thank you.

DR. PLESSET: Any other comment? Well, thank you again. It was a very good presentation and we did appreciate it. As Mr. Ward has said, you evidently got it across very well.

DR. SHIRALKAR: Thank you.

DR. QUIRK: Dr. Ebersole, that concludes our presentations that we have planned for you over these two days, recognizing that we have given you an awful lot of information. I would like to just summarize some of the key messages.

Yesterday, Dr. Gary Dix identified some of the extensive tests that we have conducted to date, the TLTA and the Lynn Steam Sector Tests and other tests conducted in Japan. These tests provide an extensive data base which is the foundation of our analytical effort. And our analytical effort is really two steps. The first step is to develop sophisticated best estimate mo lel TRAC which we'll use for benchmark calculations. The second effort that I alluded to is to develop a more efficient engineering production code, SAFER, which we intend to be the workhorse of our analytical effort and TRAC, of course, is calibrated to the extensive data base described by Dr. Gary Dix and SAFER is calibrated to TRAC so we feel that there is a clcse coupling between our analytical effort and the extensive data that exists. We feel quite good about that tie and we wanted to assure you that as in the past maybe when we were less mature in the industry we produced some models and codes that predicted everything and maybe were over sold in some instances. We think the difference today in this maturing technology is that we have conducted tests that are aimed at simulating some very complex thermohydraulic phenomena that occur in BWR's and then we develop analytical models that predict those quite well, so we feel that this effort is extensive and it's on the right TRAC and is a basis for proceeding in licensing.

DR. PLESSET: Well, thank you. I think that the feeling up here is similar, that this is a very reasonable way to proceed within the confines of the present requirements and the like and we're sure to go into it more with you again as you know and it seems like a very worthwhile engineering analysis which you're undertaking. It should be very useful, and I again want to compliment you for trying and the way you're doing it.

Yes, another question?

DR. WARD: Yes, let me just ask one question. Given completion of this SAFER/GESTR system, what sort of -- just give me some estimate of the effort that it will take to qualify a new reactor core. I mean what sort of -- using this system, what will the cost of the analytically qualifying the new reactor core for Appendix K be?

(Pause)

MR. TOWNSEND: I'm Hal Townsend from General Electric. Obviously we're starting something really knew here that we haven't much experience with, but from the early experiences we've had, I would say to reanalyze the new core, the first ones will probably take on the order of six man months to a year of effort and probably in the order of six months calendar time. I would expect after that first pass that they would be somewhat faster but I think we're in that ballpark of half a year to a year manpower.

DR. PLESSET: Let me ask another question while you're there. Do you have any estimate of what gain you might get regarding core utilizability, load following capability? Is there any estimate? You must have a rough idea of what you might expect.

(Pause)

DR. PLESSET: I appreciate that this will be a guess at this point.

(Pause)

MR. TOWNSEND: That's again a very difficult question for us because we haven't had the opportunity to really evaluate how to use this. We are anticipating some relaxation in the core parameters so that we can get better fuel utilization. I think the other question is with so much margin relative to the 2200° today is just how do we use that? I think Dr. Ebersole alluded to something earlier that we have gotten into through design with our older codes of testing our diesels for early start, 10 second type starts. We really need to relook at those things with these kinds of models and maybe get rid of some of that kind of stuff and probably improve safety i the process, but we're so early in this cycle that I don't think we've had the chance to think of just how we will utilize this.

DR. PLESSET: I appreciate that. That's all right. Well, I guess that concludes this part of the program and we'll look forward to having a meeting with you later on to go into some of the details that we couldn't go into at this meeting. Thank you again and we'll be seeing you.

We have one other item on our program. Mr. Collins is going to make a brief comment from the point of view of the Staff.

(Pause)

MR. COLLINS: I'm Tim Collins from the Reactor Systems Branch of NRR. I've got really two brief presentations to make, one prepared by the branch reviewing the GESTR part of this code and the other branch which is reviewing the SAFER part. Our review is not something that is brand new. GESTR was originally submitted to us for review back in March of '78 and a separate report on the Urania/Gadolinia properties was submitted to us in January of '77. We essentially completed review of these two reports. As far as the draft SER is concerned, we sent that to G.E. and they elected to work on a revision and that's where the GESTR-LOCA model comes in with the Gadolinia/Urania properties model as an appendix to that and SAFER was the second volume, SAFER just being a modified version of SAFE and REFLOOD.

The GESTR part for volume 1 is being reviewed in two parts, Oakridge doing the review of the Urania/Gadolinia report which is Appendix B. Oakridge has completed their review and the results are in the hands of the postal service right now but it's our understanding that their evaluation is very favorable. The balance of volume 1 of

GESTR is being done in conjunction with Battelle and we have received an evaluation from them which again is favorable with a few outstanding issues. The outstanding questions have to do basically with comparisons of some experimental data and details on those outstanding issues I think are more easily found by just referring to Staff questions which were issued back in October in GESTR-LOCA. I think the Subcommittee was provided copies of those issues. I don't want to really go through this whole chronology here of submittals and questions. The only thing I'd like to point to is the schedule here of January '83. The people doing the review of the GESTR portion believe that if the responses are provided to us before Christmas time, that they can complete their review of GESTR in January.

As far as the SAFER portion goes, we see it as basically four parts to the review, the first one being to simply find out what the changes are from the evaluation model we have in hand and to evaluate the uncertainties and conservatisms in the new model and determine the sensitivities and then finally compare against what Appendix K requires.

Basically, the first one is complete and the rest are still in progress and require inputs from G.E. The major changes that we see -- the same thing that's pretty much been discussed in the last two days -- the expanded CCFL model, most importantly CCFL at the site entry orifice, the additional backflow leakage which is primarily leakage to the lower tie plate holes and past the finger springs and then the enhanced steam transfer models. The steam cooling -- there is no credit for steam cooling in the current modèl. We think that that will make a big difference depending on what model we finally find acceptable. Bromley film boiling correlation would replace an Alian correlation which is currently used. G.E. is also requesting an increase in core spray heat transfer based on fluid conditions that result from CCFL and there's also an increased transition boiling heat transfer.

We have questions on just about all of the areas. The single most important one that we see is how uncertainties are going to be treated in the application of the model. We have seen what was just presented in the last presentation but we have not received a formal proposal from G.E. as to how the adder is going to be used and we are not really at this time doing a review of the adder methodology simply because we don't have a formal proposal on it. It's in the treatment of uncertainties that things like decay heat and stored energy need to be addressed. At this point, we're not sure how they're going to be addressed. We think that could be the major area of the entire review.

We also have not received the qualification runs against TLTA or other experiments. We've asked for break spectrum calculations and a comparison of those calculations with the current evaluation model. What we're looking for there is really an understanding of where the conservatism is being chopped away. We've also asked for additional justification for coefficients used in the CCFL correlation at constrictions other than the upper tie plate. Once again, the key one is at the site entry orifice and we really don't have in hand a justification for the coefficient that they're going to use there and that again is a very important part of the entire model. The steam cooling model as the way it has been presented to us, we understand that they'd like to use a Dittus-Boelter relation but there is really no justification for that particular model that has been provided yet. We're waiting to see that. And the same with the improved core heat transfer and transition boiling. Really, what we think we have is a statement of what G.E. would like to use. We're missing a lot of the meat which makes for the justification for using the models. We've also asked for more discussion of a sensitivity of what we considered to be the minor model changes. Things like changes in the noding, the use of a drift flux model as opposed to the Wilson bubble rise model. There are several other changes which we think are minor but we'd like to have a better feel for, the impact that they have on the overall calculation.

And assuming that General Electric answers all our questions, by the 26th of January we think that we can finish our evaluation about 6 weeks after that which would make it about the middle of March. That's really all I have to say.

DR. PLESSET: Thank you, Mr. Collins.

DR. SCHROCK: I have one -- I'm a little confused as to why you say that Decay Heat is something that falls under the category of uncertainties. Did I understand that correctly?

MR. COLLINS: Yes.

DR. SCHROCK: Well, it's a model which, I mean a calculation procedure which is being proposed that is different than the one that's stated in Appendix K.

MR. COLLINS: That's right.

DR. SCHROCK: So it's a different model. It's not just a question of uncertainty.

MR. COLLINS: Well, that hasn't been proposed to us yet. Not formally.

DR. SCHROCK: We heard an Idaho Falls presentation from the Staff as well as G.E., that there was a proposal. Yesterday, I raised some questions recalling that meeting about whether or not the Staff has raised questions now with

G.E. pertaining to exactly what it is they are requesting in that regard. Out of that discussion, I understand that no, G.E. has not or the Staff has not asked G.E. for clarification of that submission so at this stage I must say I'm quite confused about what you're saying.

MR. COLLINS: I think we need to separate -- my concern is how the decay heat comes into play in SAFER and I think there's a different question which has to do with changes to Appendix K as a whole. Now, the way I see it right now, we have a rule and things have to be applied as the rule states. Unless there's a change to that rule, then we use it as it is. I think there are separate issues, but decay heat plays such an important role in the overall calculations that I don't want to just leave the fact that it's not addressed in SAFER out altogether. All I want to do is surface the fact that it's an important consideration. Now, if it's handled separately as a change to the rule, that's fine. If it's handled as part of a SAFER package, then that's something that we have to be aware of. I'm not sure how it's going to be handled.

DR. SCHROCK: I guess you've answered part of the question that I've raised but the part of it pertaining to the relationship between what we're hearing today and what we heard in previous Subcommittee meetings is still missing. Previously on two occasions we've had Staff tell us that it looks like a proposal for an exemption to Appendix K requirement on Decay Heat is likely to be approved. That's in the record.

MR. COLLINS: Well, an exemption -- I think an exemption is a third case, actually. Does the rule change? Does an exempt -- if you take an exemption and apply it to -- you have to apply it to a specific case, I believe.

DR. SCHROCK: I guess I'm not getting through to you with my point. I spent a good deal of time in two previous meetings -- a total of four days as I recall and what I hear you saying is that you don't acknowledge that there was any information transferred in that meeting that pertains to the meeting that we've been engaged in here and I find that a little bit unacceptable. Am I missing the point here, Mr. Chairman?

DR. PLESSET: No, that's the way I recall things, too. Well, we may be pressing Mr. Collins beyond what he is aware of because there have been indications to the Staff along the lines of what you're saying. They are talking about a two step change in Appendix K for example, along the lines of what we were told or at least what was indicated to us in our previous meetings. They may be backing away from that now with a new submittal or a more filled out submittal from G.E.

DR. TIEN: Mr. Chairman, could I make one short general comment, one suggestion. Regarding the data base justification, I think point out as CCFL coefficients, steam cooling model and the improved spray heat transfer, I think -- including also the film boiling, heat transfer, I think the CCFL coefficient is very crucial as you mentioned in the last two days, the side entry but that problem seems to also, is less low and also compared to the other data base problem, however, it is a relatively clear cut problem. I don't know whether -- I'd like to make a suggestion, whether it's out of place or not, but maybe NRC or EPRI and so on should, perhaps a little more make further studies on this because considering it is crucial importance and relative unknown situation, maybe you'd like to have some comparatory data base and so on but I think perhaps some independent study should be made in that particular area. It is relatively clear cut and also may be very profitable in terms of overall situations.

DR. PLESSET: Well, thank you again, Mr. Collins. I think that we're in a very fluid and developing situation and the next couple of months may tell us quite a bit about what's going to happen. Any other comments? If not, we'll adjourn the meeting and for me it's a real adjournment. Thank you.

(Whereupon, at 2:35 p.m., the meeting was adjourned.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

Advi v Committee on Reactor Safeguards

in the matter of: Emergency Core COoling Systems

Date of Proceeding: December 3, 1982

Docket Number: n/a

Place of Proceeding: San Jose, California

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Mike Connolly

Official Reporter (Typed)

Mike Connolly

Official Reporter (Signature)

ACRS ECCS SUBCOMMITTEE MEETING
DECEMBER 2-3, 1982
SAN JOSE, CA

- Tentative Schedule of Presentations -

December 2, 1982	Actual Time
I. Introduction	8:30 am
° M. Plesset, Chairman	
II. General Electric Presentation	
A. Introduction	8:45 am
J. F. Quirk	
B. GE ECCS Philosophy	9:15 am
J. E. Wood	
** BREAK **	10:15 am
C. Overview of BWR LOCA Technology	10:25 am
B. S. Shiralkar	
D. SAFER Model Description	11:25 am
B. S. Shiralkar	
** LUNCH **	12:30 pm
E. GESTER-LOCA Model Description and Qualification	1:30 pm
G. A. Potts	
F. TRAC-BWR Model Description	2:30 pm
B. S. Shiralkar	
** BREAK **	3:45 pm
III. Use of Electrical vs Nuclear Heater Rods for LOCA Experiments	4:00 pm
T. Knight (LANL)/W. G. Craddick (ORNL)	
IV. Recess	5:15 pm

- Tentative Schedule of Presentations -

December 3, 1982	Actual Time
V. Reconvene	8:30 am
VI. GE Presentation (Continued)	
A. Introduction	8:40 am
J. F. Quirk	
B. SAFER and TRAC Qualification	9:00 am
B. S. Shiralkar/W.A. Sutherland	
** Break **	10:15 am
C. ECCS Evaluation Methodology (Application Adder)	10:25 am
B. S. Shiralkar	
** Lunch **	12:00 Noon
D. Results for BWR LOCA Calculation	1:00 pm
H. E. Townsend/D. A. Hamond	
E. NRC Comments on the SAFER/GESTER Submittal	2:00 pm
T. Collins	
F. Decay Heat Exemption - Licensing Overview	2:30 pm
D. K. Dennison	
G. Conclusion	3:00 pm
J. Quirk	
VIII. Closing Remarks and Adjourn	3:15 pm

M.D. Alamgir

TRAC-BWR QUALIFICATION AT GE

Mohammed Alamgir
12/3/82

TRAC-BWR QUALIFICATION AT GE (1982)

- CODE: TRACB02
- QUALIFICATION DATA BASE
  - -SIMPLE VESSEL BLOWDOWN (PSTF/NORTH VESSEL)
  - -ORNL SINGLE BUNDLE LOOP
  - -TLTA (SINGLE BUNDLE BWR/6 SIMULATOR)
  - -SSTF (30° SECTOR REPRESENTATION OF BWR/4, BWR/6; 58 BUNDLES, CORE STEAM INJECTION)
  - -REACTOR DATA (PEACH BOTTOM TURBINE TRIP TESTS)
- QUALIFICATION STATUS: WILL BE COMPLETED DEC. '82
- TRAC RESULTS VS. EXPERIMENTAL DATA

Md. A
12/3/82

TRAC QUALIFICATION ACTIVITIES

Activity/ Facility	Test
TLTA	6425/2 (DBA,ECC)* 6426/1 (DBA,NO ECC)* 6441/6-1 (BOILOFF) 6424 (DBA,PEAKPOWER, ECC)
SSTF	SE3-1A (UPPER PLENUM (MIXING)* SE5-1A (SEO CCFL, 4 SENSITIVITY STUDY CASES)* SRT-3 (DBA SYSTEM RESPONSE) EA2-2 (LOWER PLENUM MIXING)
BWR TRANSIENTS	PEACH BOTTOM TURBINE TRIP TESTS, TT1, TT2, AND TT3.
VESSEL BLOWDOWN	PSTF 57-2-16 (LARGE VESSEL)* NV 8-21-1 (SMALL VESSEL)
ORNL (OAKRIDGE)	THTF 3.08.6C (FILM BOILING)*

*TRAC vs. DATA COMPARISON FOLLOWS

Md.A
12/3/82

TRACB02 QUALIFICATION

ASSESSMENT OBJECTIVE

- VESSEL BLOWDOWN
  - FLASHING/LEVEL SWELL IN A "FREE" POOL
  - VOID DISTRIBUTION

- OAKRIDGE SINGLE BUNDLE TEST
  - FILM BOILING (MEASURED ROD TEMP ~ 1500°F)

- TLTA LOCA TESTS (AVG. POWER, DBA, WITH & WITHOUT ECC)
  - OVERALL SYSTEM RESPONSE (KEY PHENOMENA, SEQUENCE OF EVENTS)
  - CRITICAL FLOW
  - CCFL/CCFL BREAKDOWN
  - HYDRAULICS IN A "COMPLEX" POOL (E.G., LOWER PLENUM)
  - JET PUMP PERFORMANCE
  - BUNDLE THERMAL RESPONSE

    BOILING TRANSITION/REWET

    TEMP. & HEAT UP RATE (FLOW/H.T. REGIME)

- SSTF (3D - EFFECTS)

  ECC MIXING IN UPPER PLENUM
  - SUBCOOLING DISTRIBUTION (UP. PLENUM INVENTORY)
  - SPRAY/SUBMERGED JET PERFORMANCE

  MULTIPLE BUNDLE CCFL
  - PARALLEL CHANNEL HYDRAULICS

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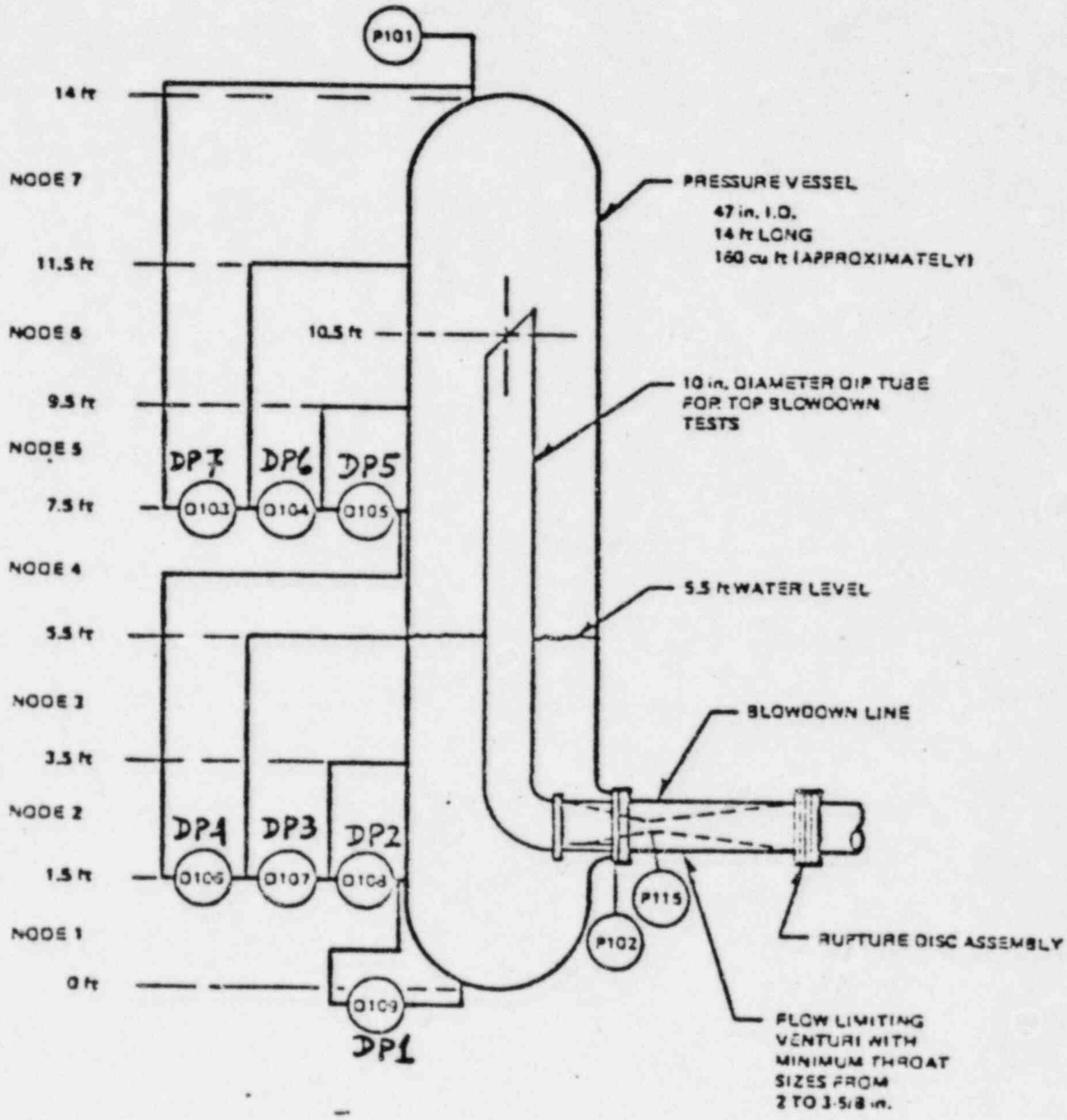
12/3/82

TRAC PREDICTION OF A
VESSEL BLOWDOWN EXPERIMENT
(PSTF 5702-16)

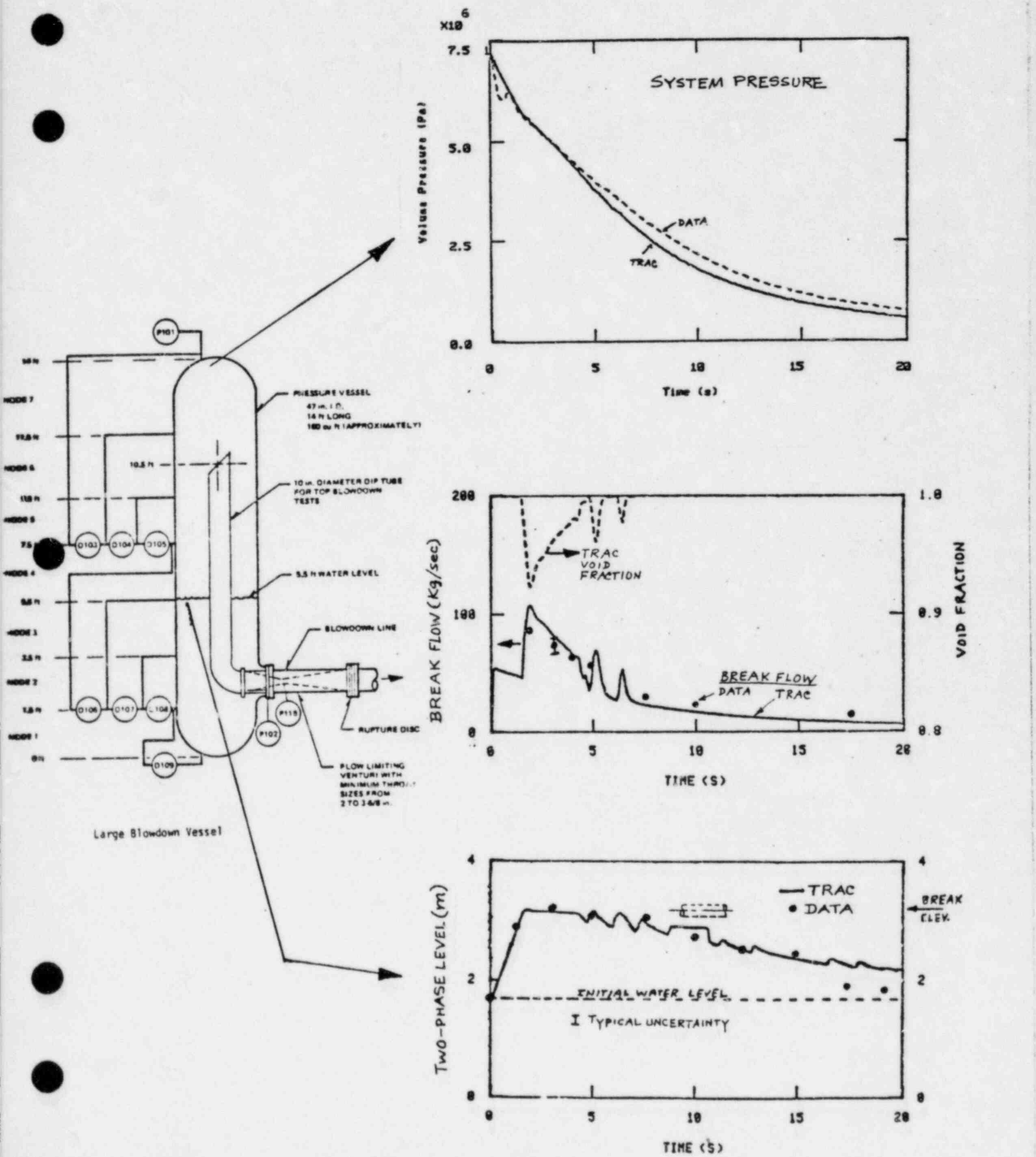
Md. A
12/3/82



LARGE BLOWDOWN VESSEL
(PSTF)

Md.A

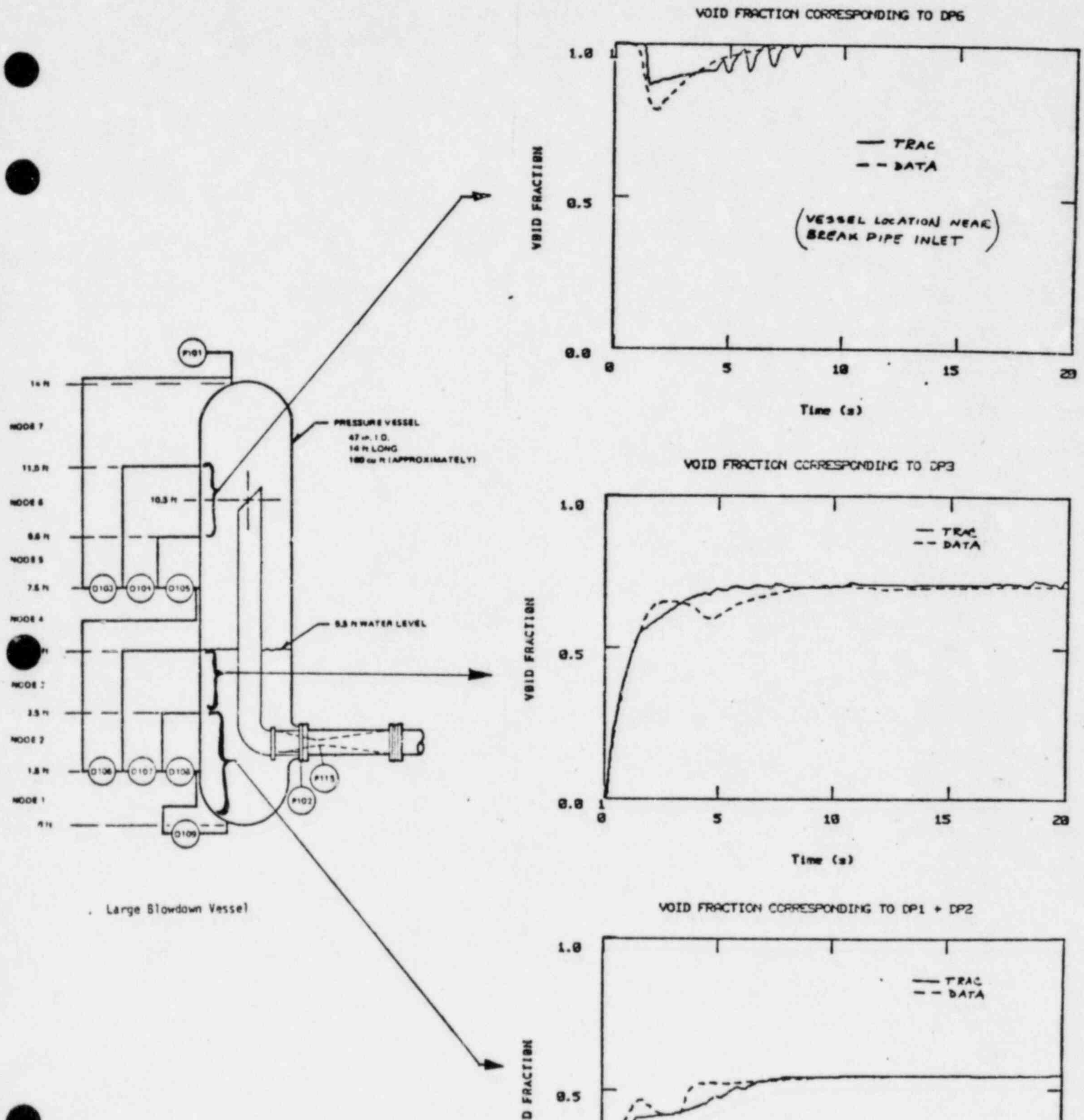
12/3/82



SYSTEM PRESSURE
Volume Pressure (Pa)
X10^6
7.5
5.0
2.5
0.0
DATA
TRAC
0
5
10
15
20
Time (s)
PRESSURE VESSEL
47 in. I.D.
14 ft LONG
160 cu ft (APPROXIMATELY)
10 in. DIAMETER DIP TUBE
FOR TOP BLOWDOWN
TESTS
5.5 ft WATER LEVEL
BLOWDOWN LINE
RUPTURE DISC
FLOW LIMITING
VENTURI WITH
MINIMUM THROAT
SIZES FROM
2 TO 3 4/8 in.
Large Blowdown Vessel
BREAK FLOW (Kg/sec)
VOID FRACTION
TRAC
VOID
FRACTION
BREAK FLOW
DATA
TRAC
200
100
0
1.0
0.9
0.8
TIME (S)
TWO-PHASE LEVEL (m)
TRAC
DATA
BREAK
ELEV.
INITIAL WATER LEVEL
I TYPICAL UNCERTAINTY
4
2
0
TIME (S)

PSTF 5702-16

TRAC PREDICTION OF VOID FRACTION IN THE PSTF



. Large Blowdown Vessel

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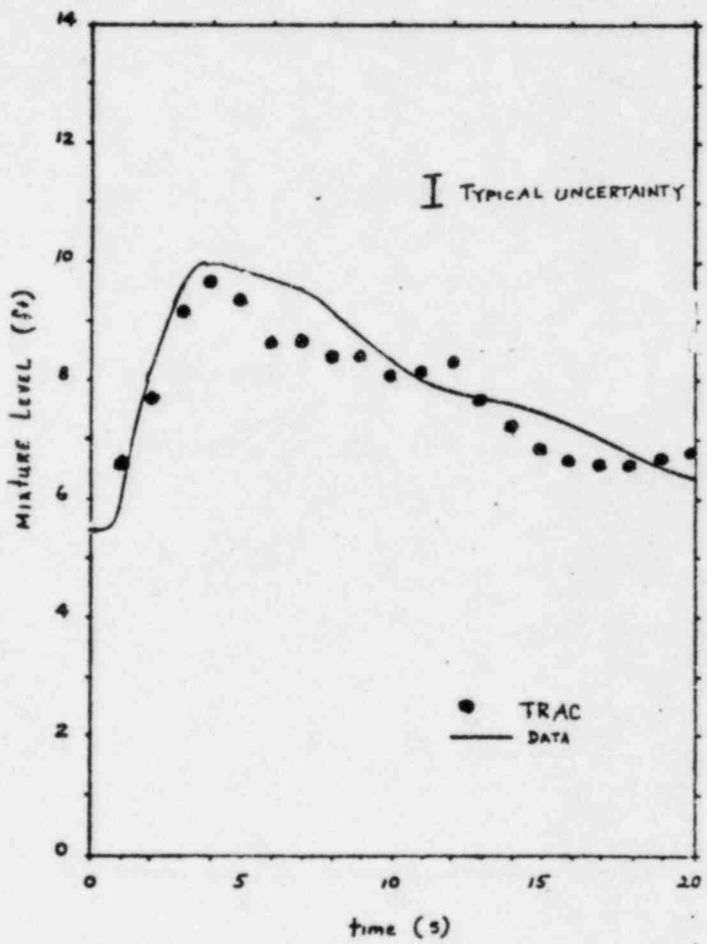
PSTF (5801-15) LEVEL SWELL
(DEVELOPMENTAL ASSESSMENT TEST CASE)



TRAC PREDICTION OF TWO-PHASE LEVEL IN PSTF 5801-15
(MEASURED SYSTEM PRESSURE IMPOSED AS A BOUNDARY CONDITION)

CONCLUSION

- TRACB02 INTERFACIAL SHEAR MODEL ADEQUACY CONFIRMED
  - ACCURATE PREDICTION OF VOID DISTRIBUTION/LEVEL SWELL IN A SIMPLE BLOWDOWN EXPERIMENT
  - FLOW REGIMES COVERED

    BUBBLY/CHURN FLOW
    ANNULAR/DISPERSED FLOW
    COCURRENT/COUNTERCURRENT FLOW

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TRAC PREDICTION OF OAKRIDGE
FILM BOILING TEST
(THTF 3.08.6C)

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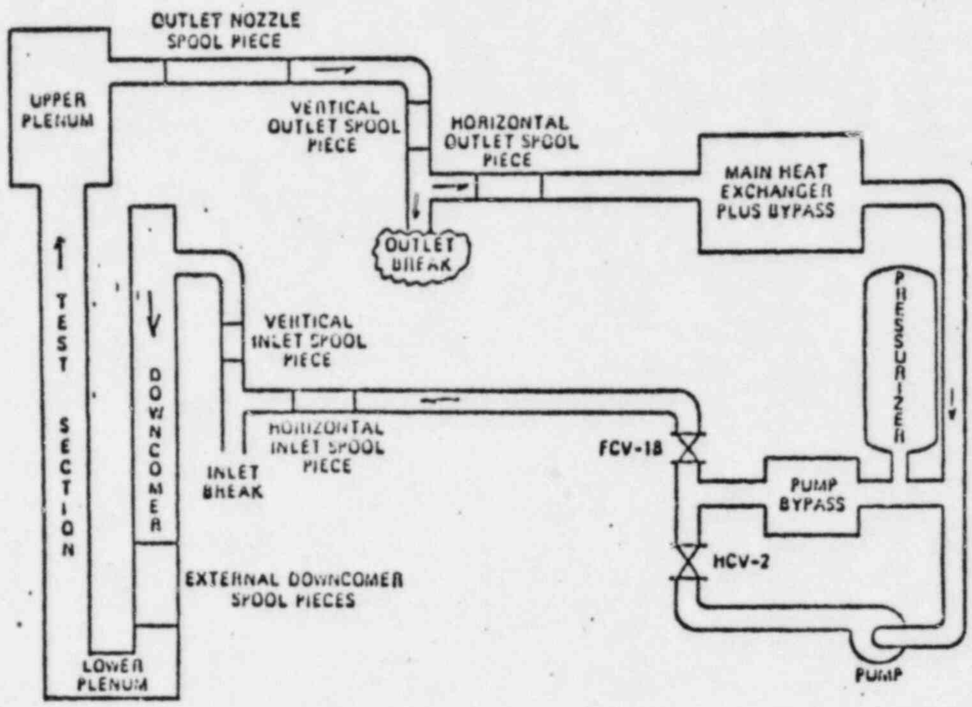
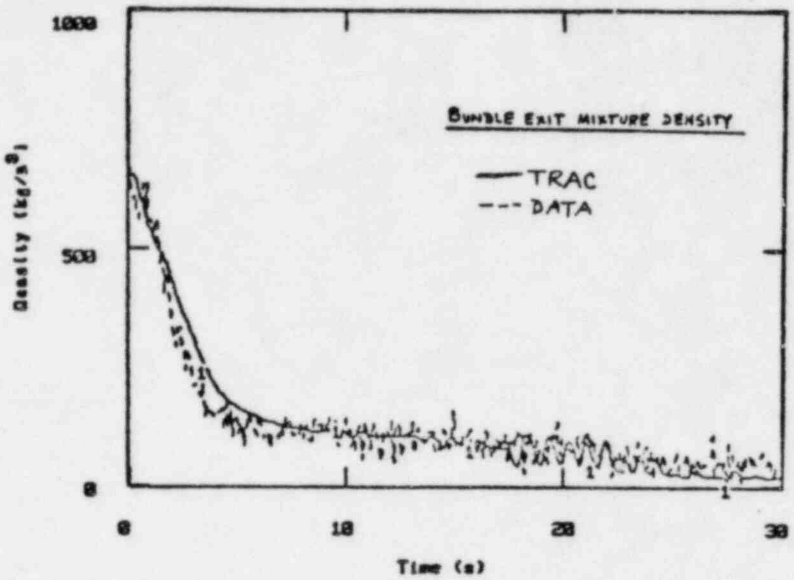
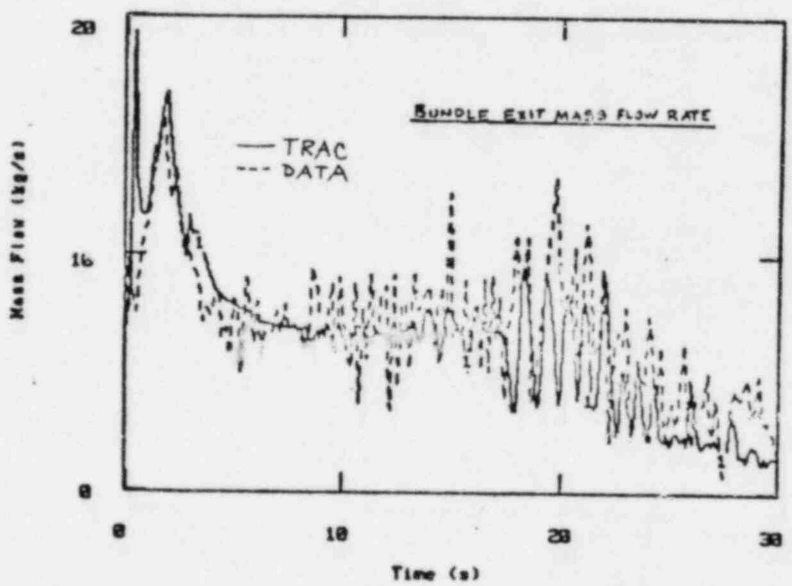
12/3/82



Simplified Drawing of THTF (ORNL)

TRAC / ORNL THTF 3.08.6C





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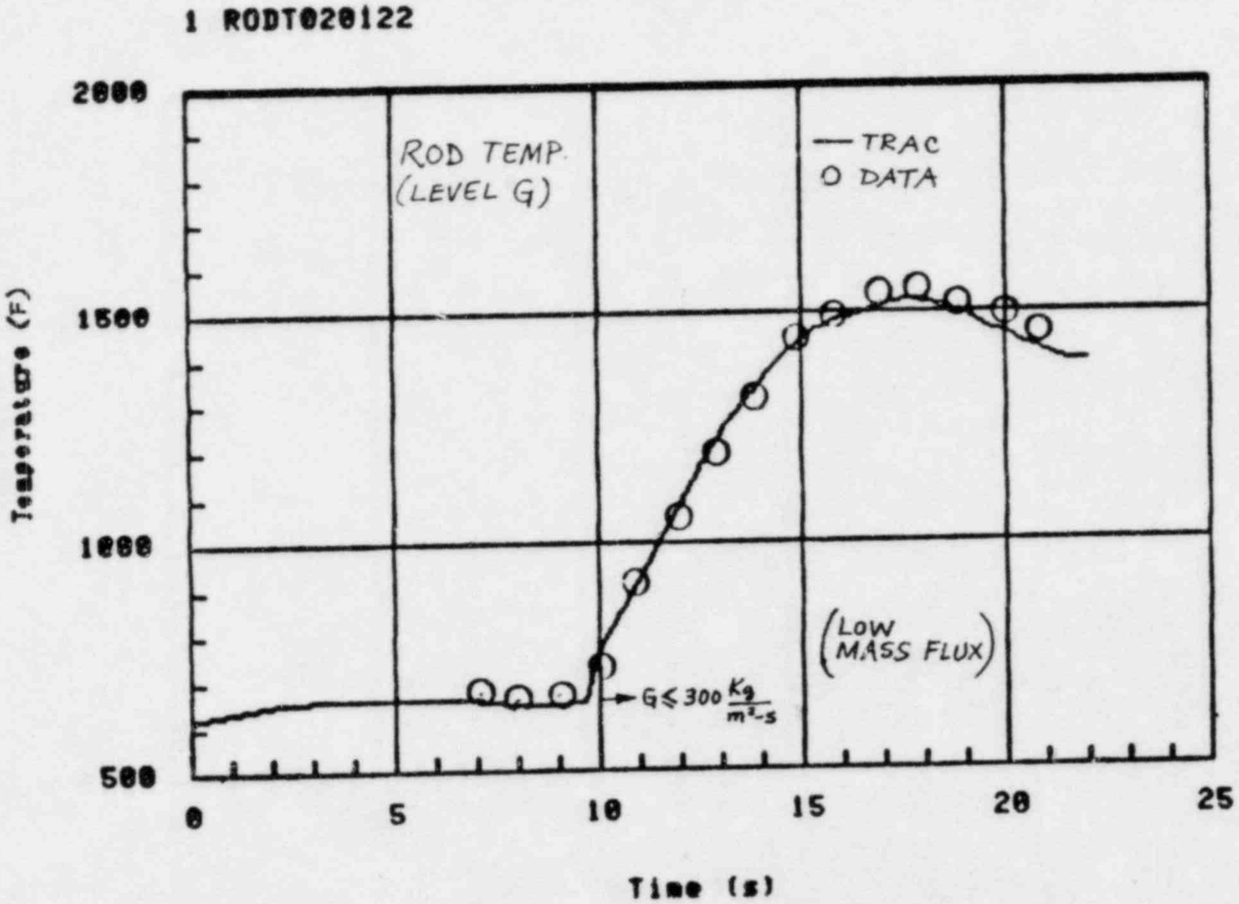
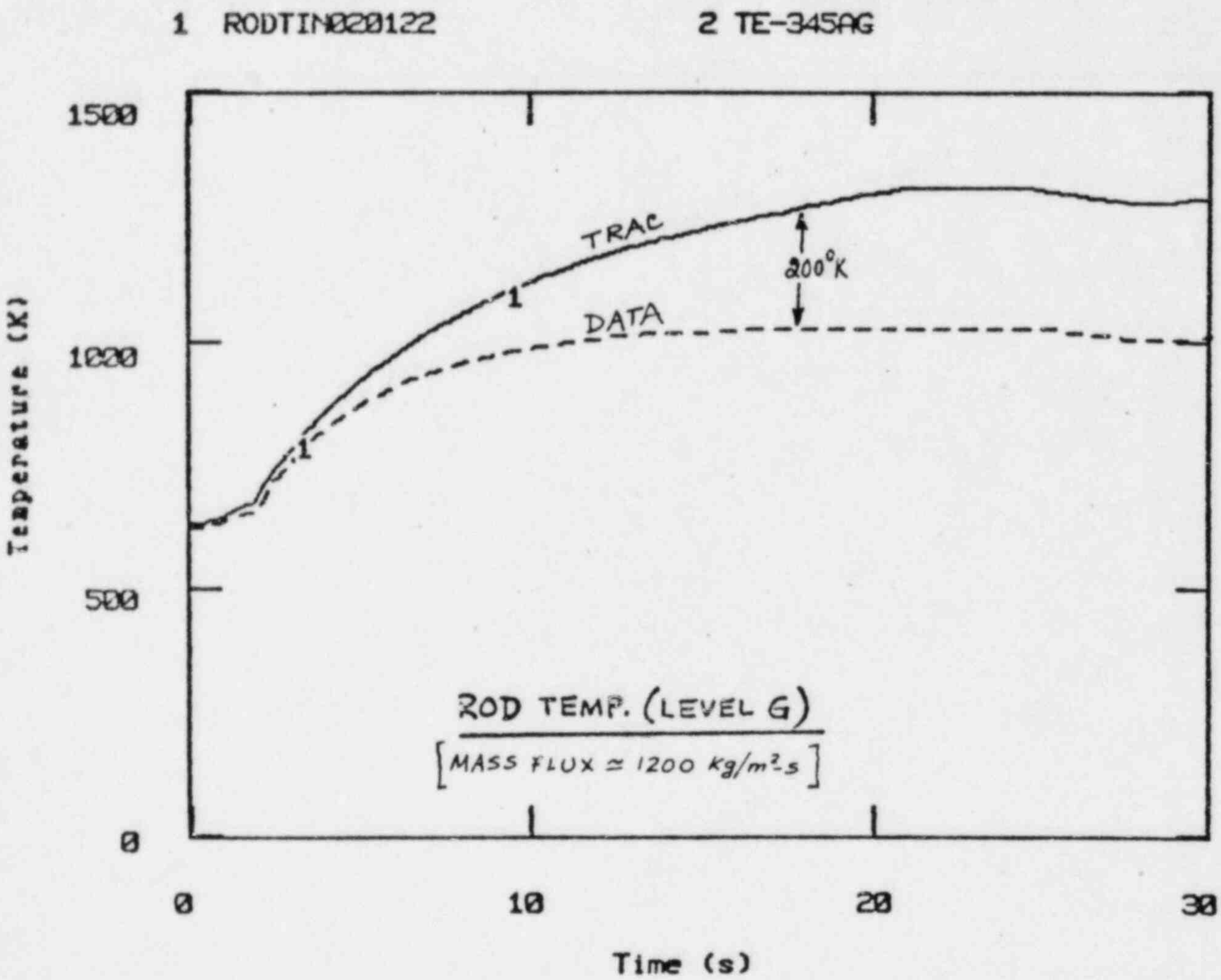
TRACB02/ORNL THTF 3.06.6B
(DEVELOPMENTAL ASSESSMENT TEST CASE)



B02 ORNL GE3KCC3

TRAC/ORNL THTF 3.08.6C



Md. A
12/3/82

CONCLUSION

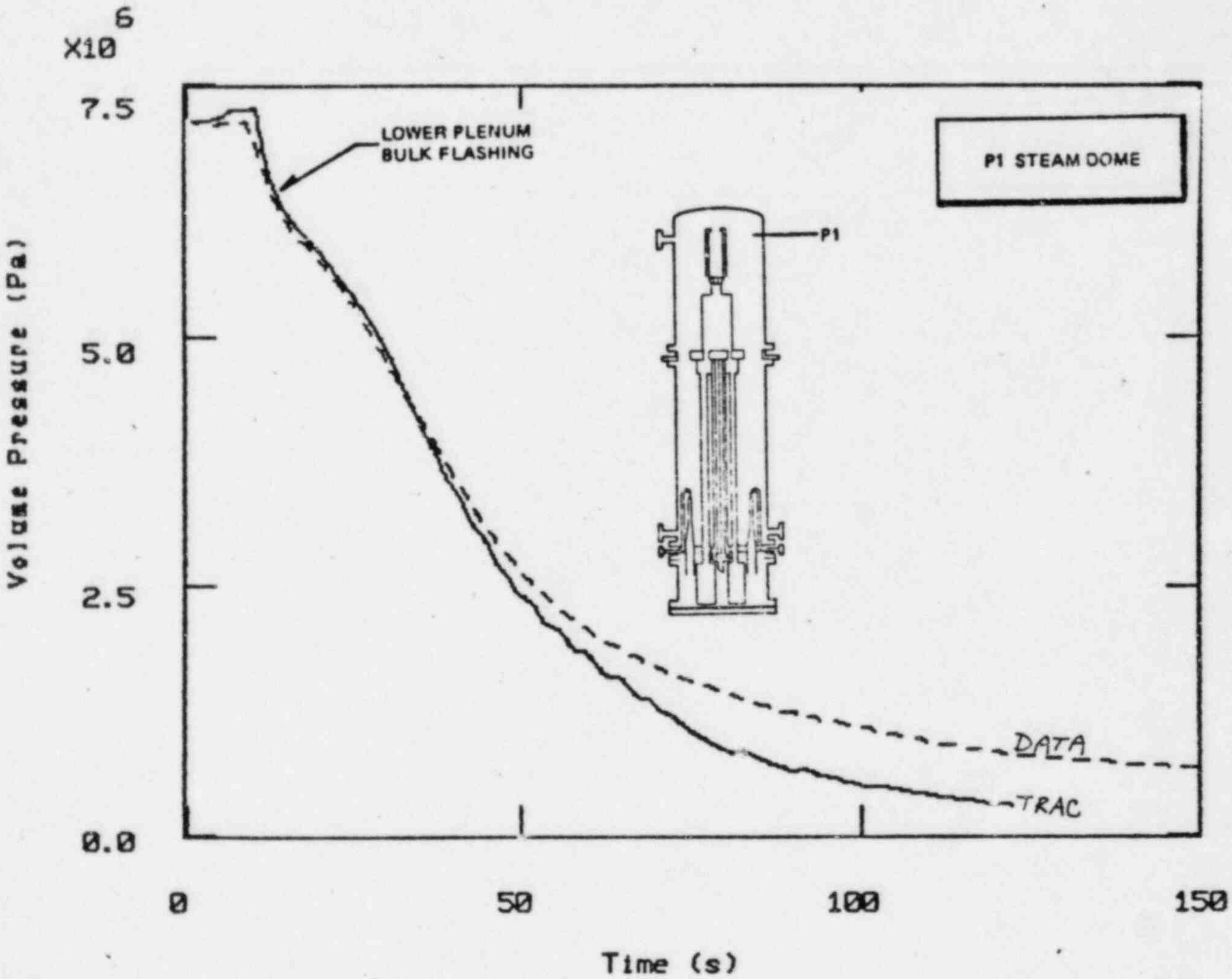
- ROD TEMPERATURES IN FILM BOILING
  - ACCURATELY PREDICTED FOR A LOW MASS FLUX CASE
  - OVERPREDICTED BY 200°K FOR HIGH MASS FLUX CASE (D_{min})
- A SEPARATE DROPLET FIELD REQUIRED TO ACCURATELY CAPTURE BROAD RANGE DISPERSED DROPLET FILM BOILING SITUATIONS
  - CONSERVATION OF NUMBER OF DROPLETS
  - ALTERATION OF DROPLET SIZE ALONG THE FLOW PATH

Md.A
12/3/82

TRAC PREDICTION OF
TLTA 6425 RUN 2
(AVG. POWER, DBA, ECC)

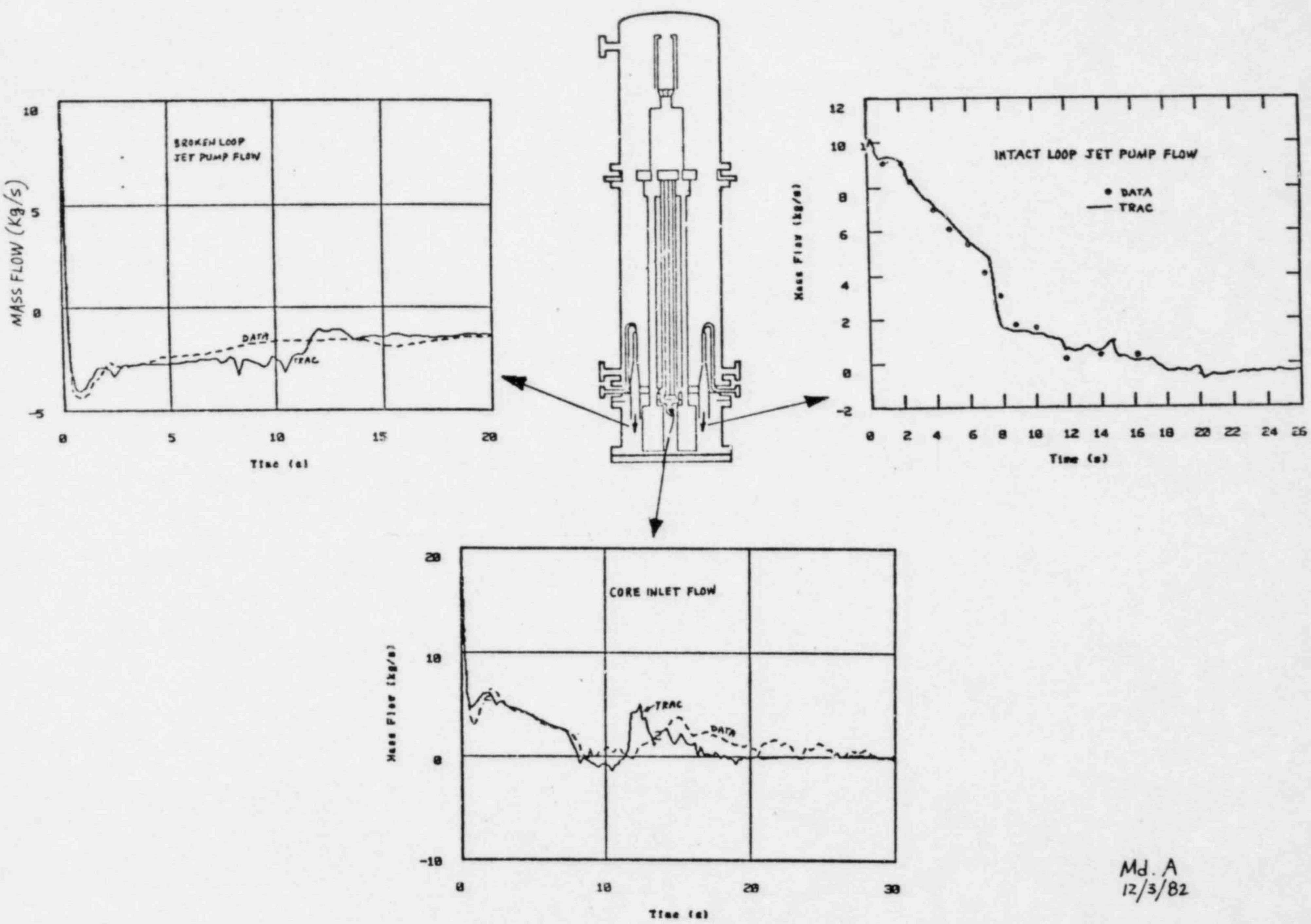
Md. A.
12/3/82

TRAC / TLTA 6425 RUN 2



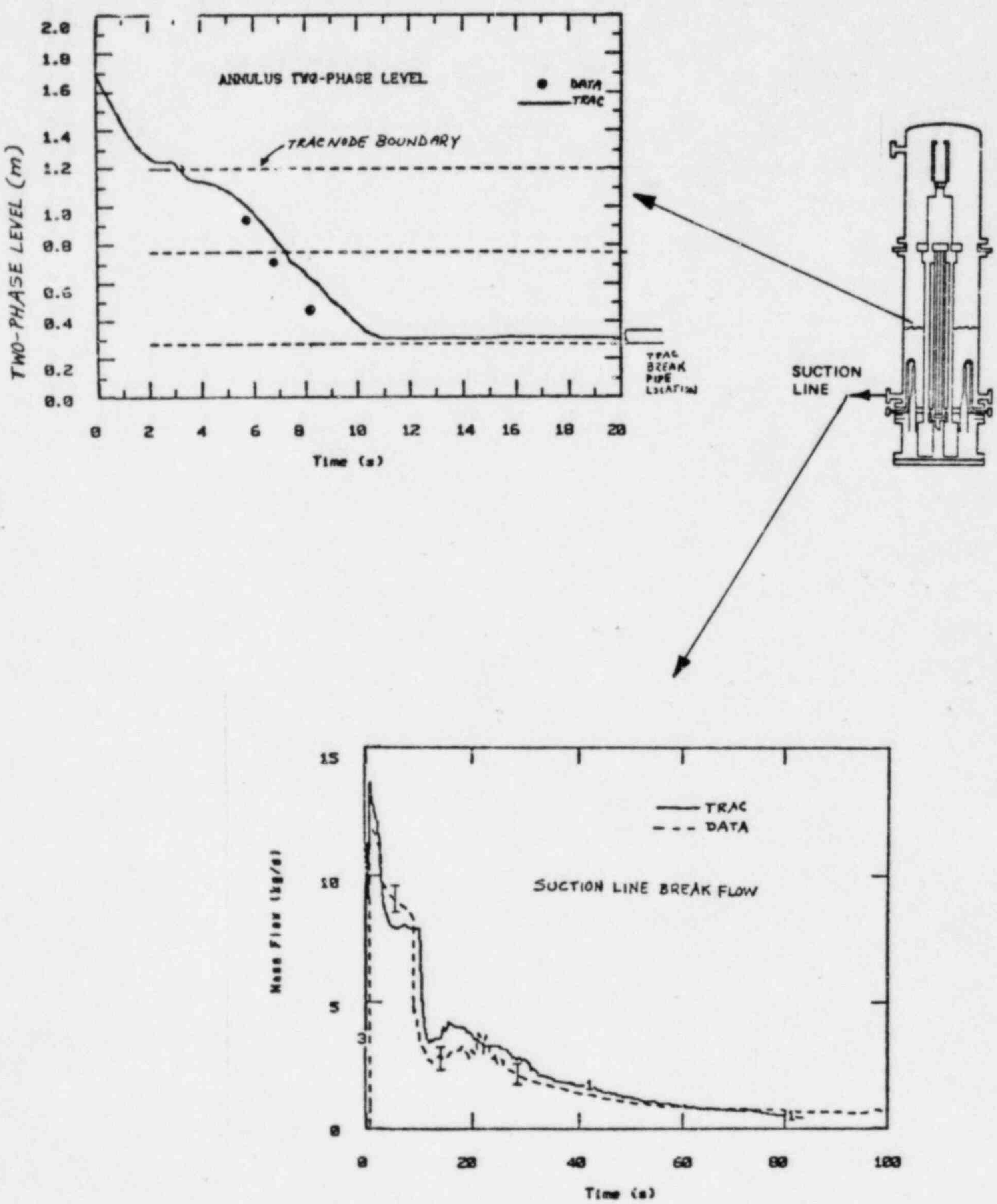
Md. A
12/3/82

TRAC / TLTA [illegible]25 RUN 2



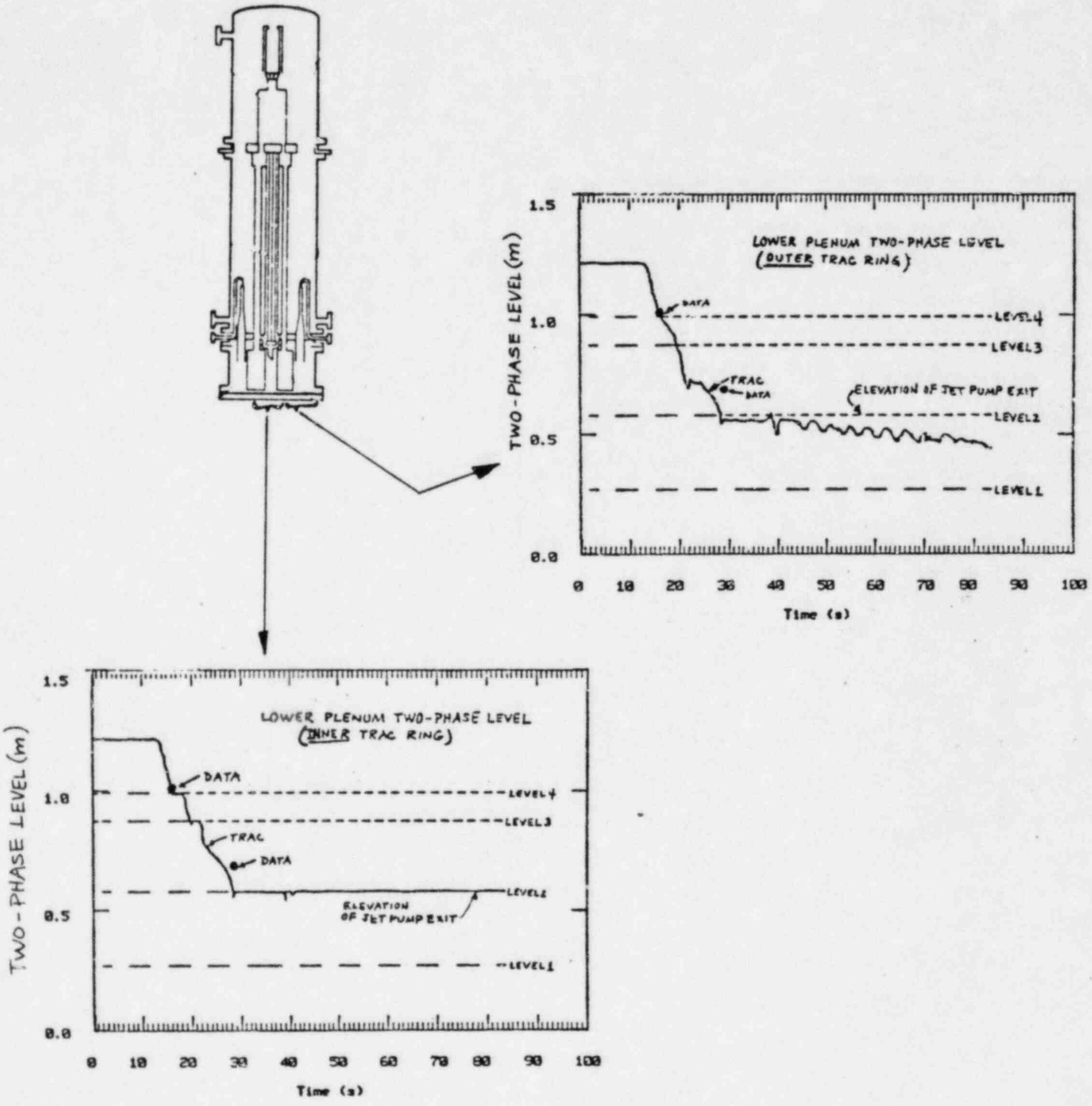
Md. A
12/3/82

TRAC/TLTA 6425 RUN 2



Md. A
12/3/82

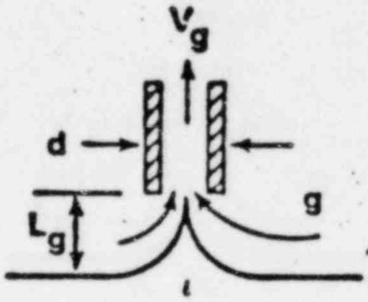
TRAC/ TLTA 6425 RUN 2



Md. A
12/3/82

TAKEN FROM:

"PROBLEMS IN MODELING OF SMALL BREAK LOCA" – N. ZUBER
NUREG–0724
(SECTION 3: LIQUID ENTRAINMENT IN BREAK FLOW, pp 18-24)
OCTOBER, 1980



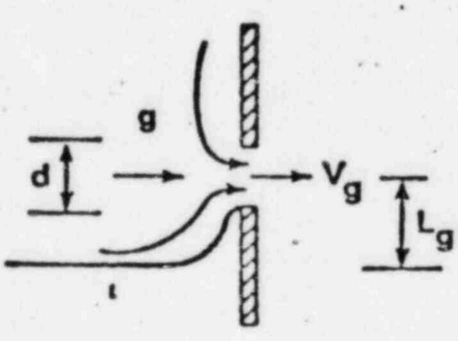
$$\underbrace{\frac{V_g\sqrt{\varrho_g}}{\sqrt{g\Delta\varrho L_g}}}_{A\,\equiv\,\text{FROUDE NUMBER}} \geqslant \underbrace{5.7\left(\frac{L_g}{d}\right)^{3/2}}_{B}$$

or

$$\frac{A}{B} \geqslant 1.0$$

(ENTRAINMENT FACTOR)

a. Liquid withdrawal through vertical pipe.
Correlation for incipient withdrawal - Ref. 9



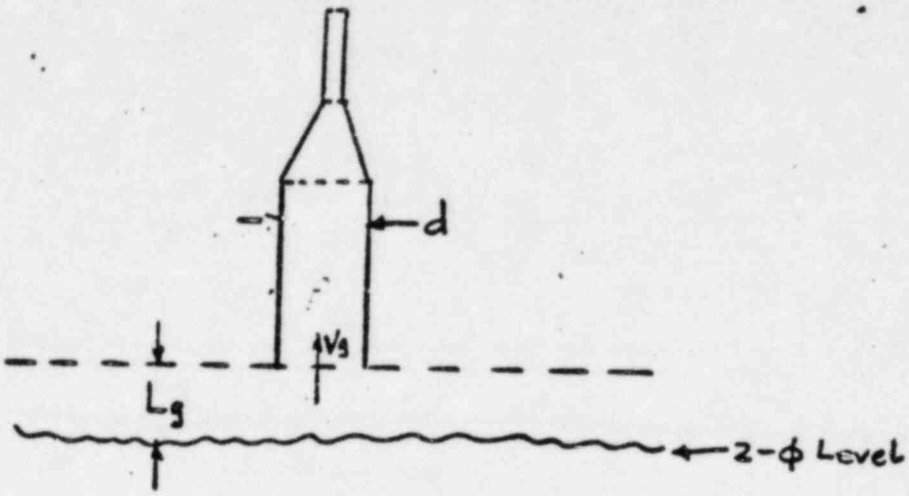
Orifice: $$\frac{V_g\sqrt{\varrho_g}}{\sqrt{g\Delta\varrho L_g}} \geqslant 3.25\left(\frac{L_g}{d}\right)^2$$

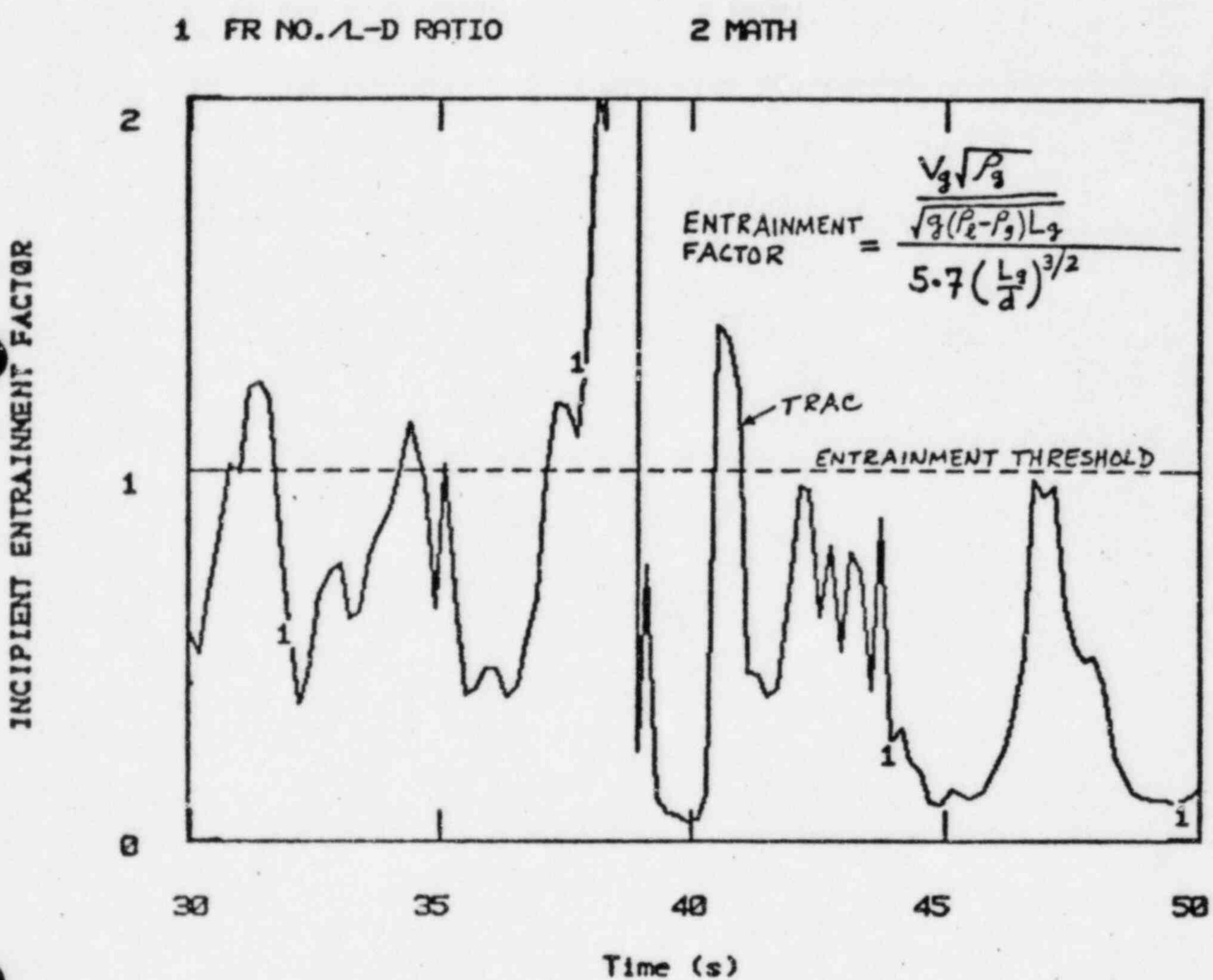
Slot: $$\frac{V_g\sqrt{\varrho_g}}{\sqrt{g\Delta\varrho L_g}} \geqslant 1.52\left(\frac{L_g}{d}\right)$$

b. Liquid withdrawal through side orifice and/or slot.
Correlations for incipient withdrawal - Ref. 7 and Ref. 8

FIG. 3-2 LIQUID WITHDRAWAL DUE TO BERNOULLI EFFECT

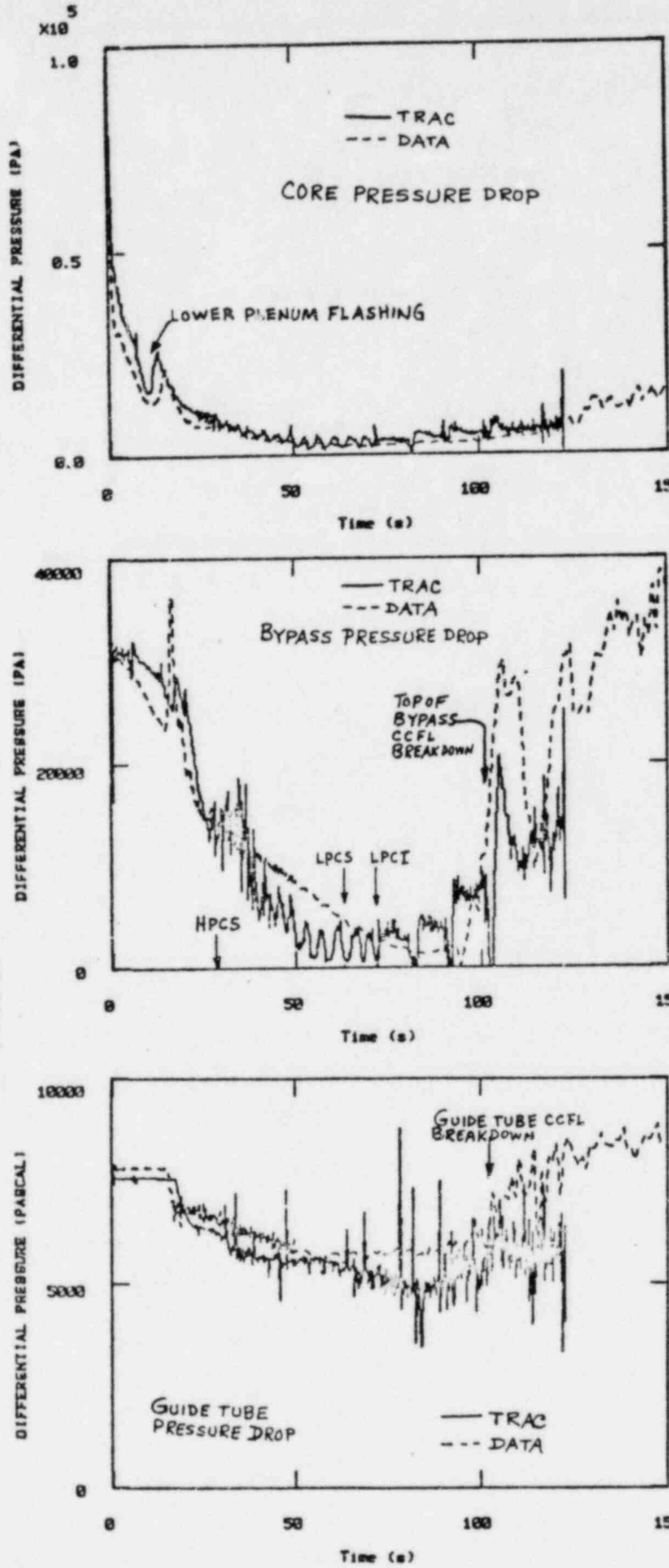
MDA
12/3/82





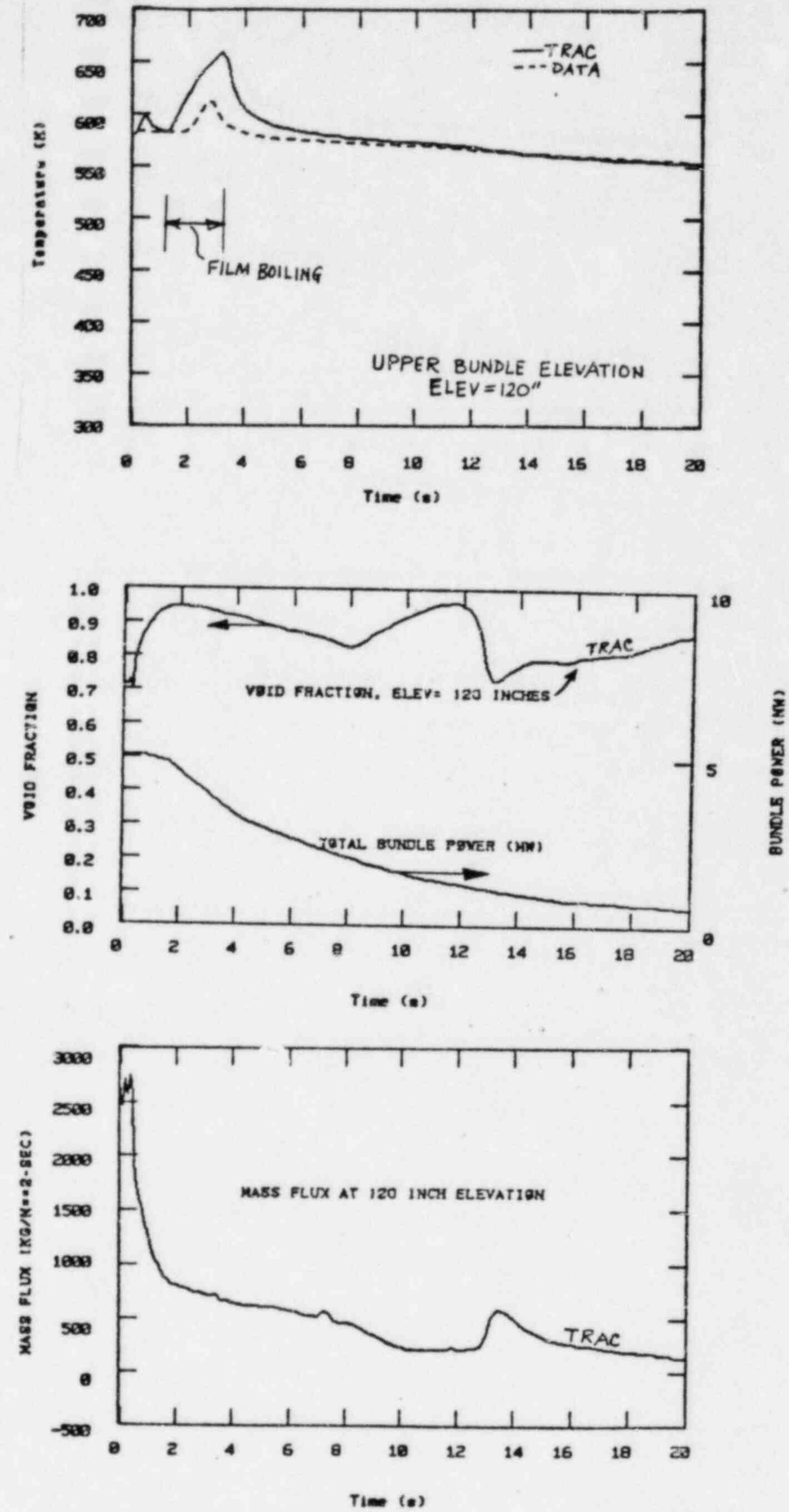
TLTA 6425/2

MDA
12/3/82



TRAC/ TLTA 6425 RUN 2

Md. A
12/3/82



TLTA 6425/2 (DBA, ECC)

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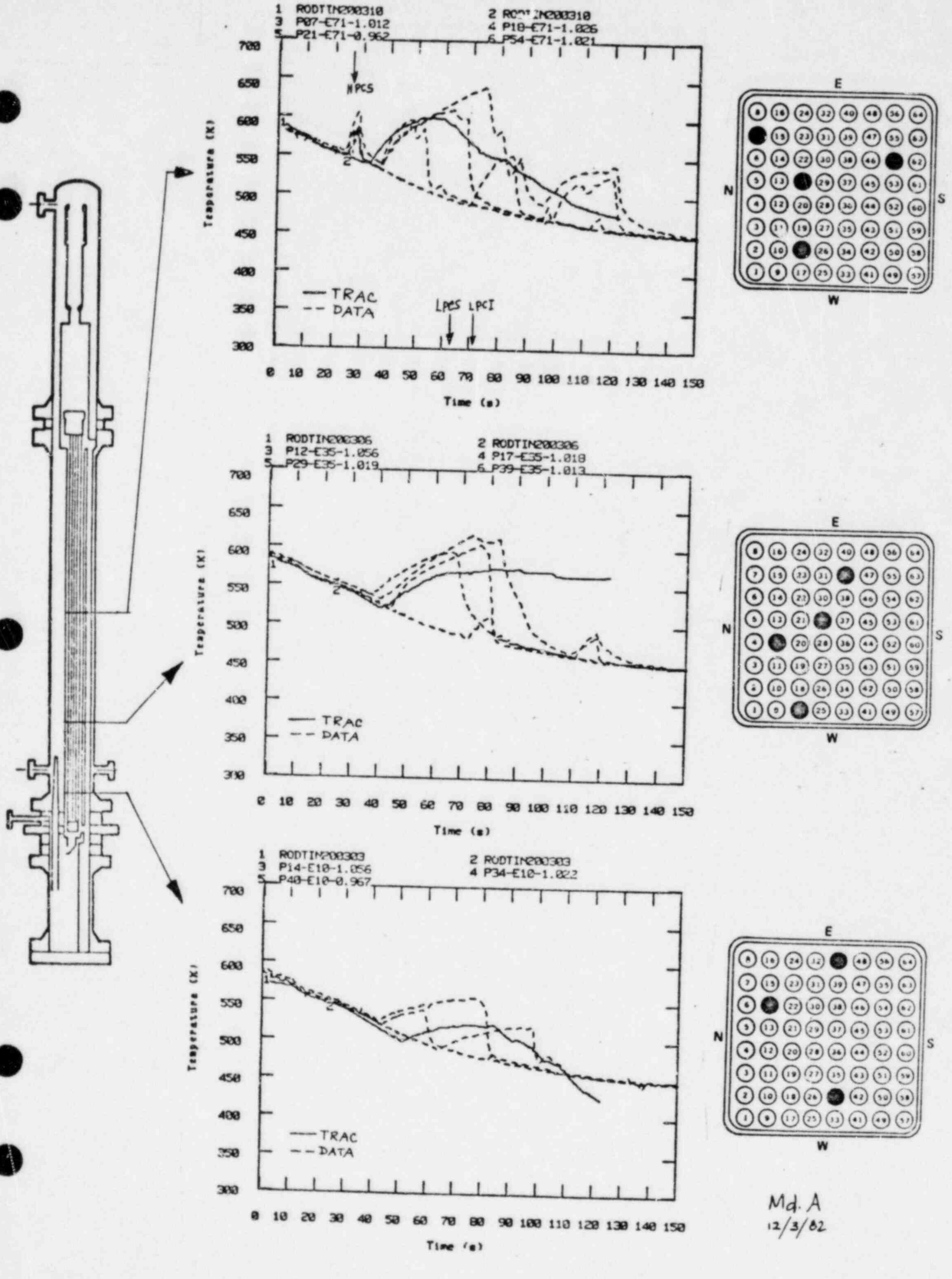
12/3/82

TRAC/TLTA 6425 RUN 2



Md. A
12/3/82

CONCLUSIONS

- GLOBAL RESPONSE (SEQUENCE OF EVENTS/KEY PHENOMENA) WELL PREDICTED FOR TLTA SYSTEM BLOWDOWN TEST WITH ECC

- GOOD AGREEMENT OF
  - FLOWS
  - REGIONAL PRESSURE DROPS (MASS INVENTORY)
  - TIME/AXIAL LOCATION OF ROD DRYOUT/REWET

- TLTA/TRAC PREDICTION-DATA COMPARISON CONFIRMS ADEQUACY OF
  - CRITICAL FLOW MODEL
  - TWO-PHASE LEVEL TRACKING MODEL
  - JET PUMP PERFORMANCE (NORMAL/REVERSE FLOW)
  - CCFL CORRELATION
  - HEAT TRANSFER CORRELATIONS/MODELS IN NUCLEATE/ TRANSITION BOILING
  - REWET CRITERIA IN FILM BOILING

- TLTA SYSTEM PRESSURE UNDERPREDICTED IN THE LATER TRANSIENT
  - LIQUID ENTRAINMENT FROM A POOL DUE TO BERNOULLI EFFECT (CORRELATION FOR AMOUNT OF ENTRAINMENT NOT AVAILABLE IN LITERATURE)

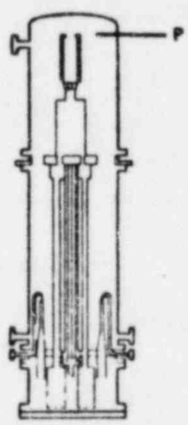
Md. A.
12/3/82

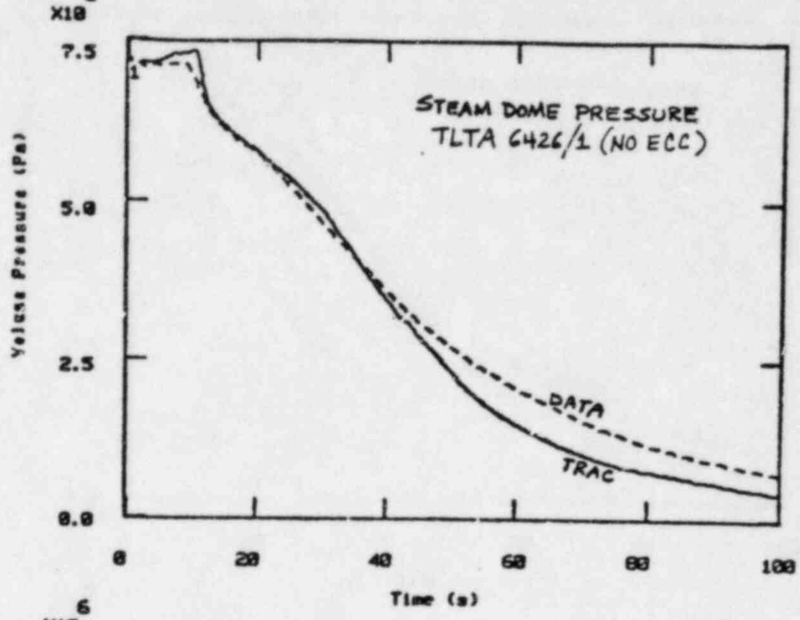
TRAC SIMULATION OF

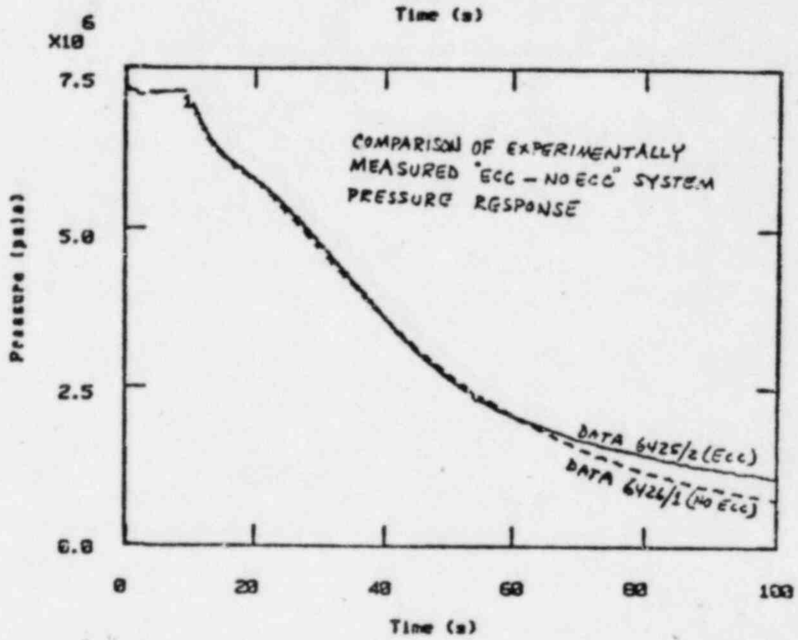
TLTA 6426 RUN 1

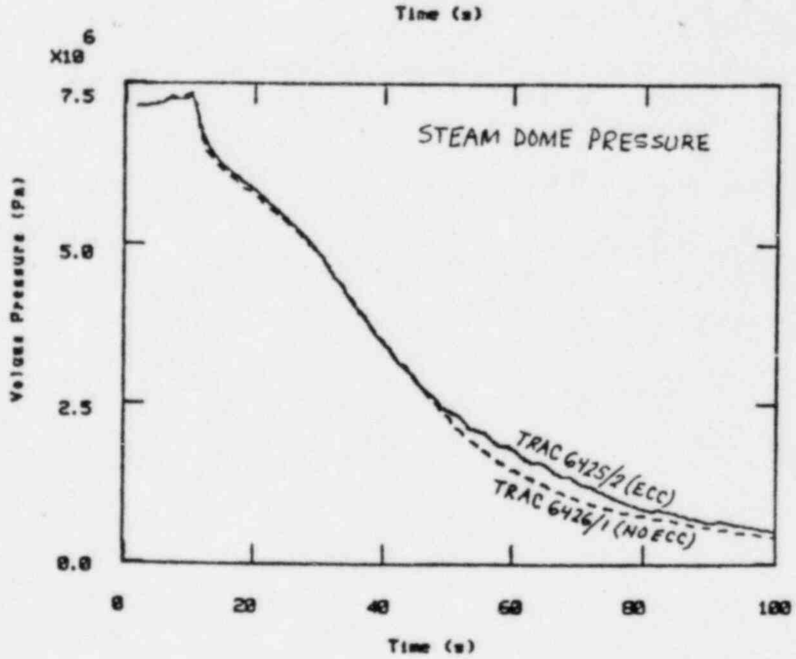
(AVG. POWER, DBA, NO ECC)

Md. A.
12/3/82

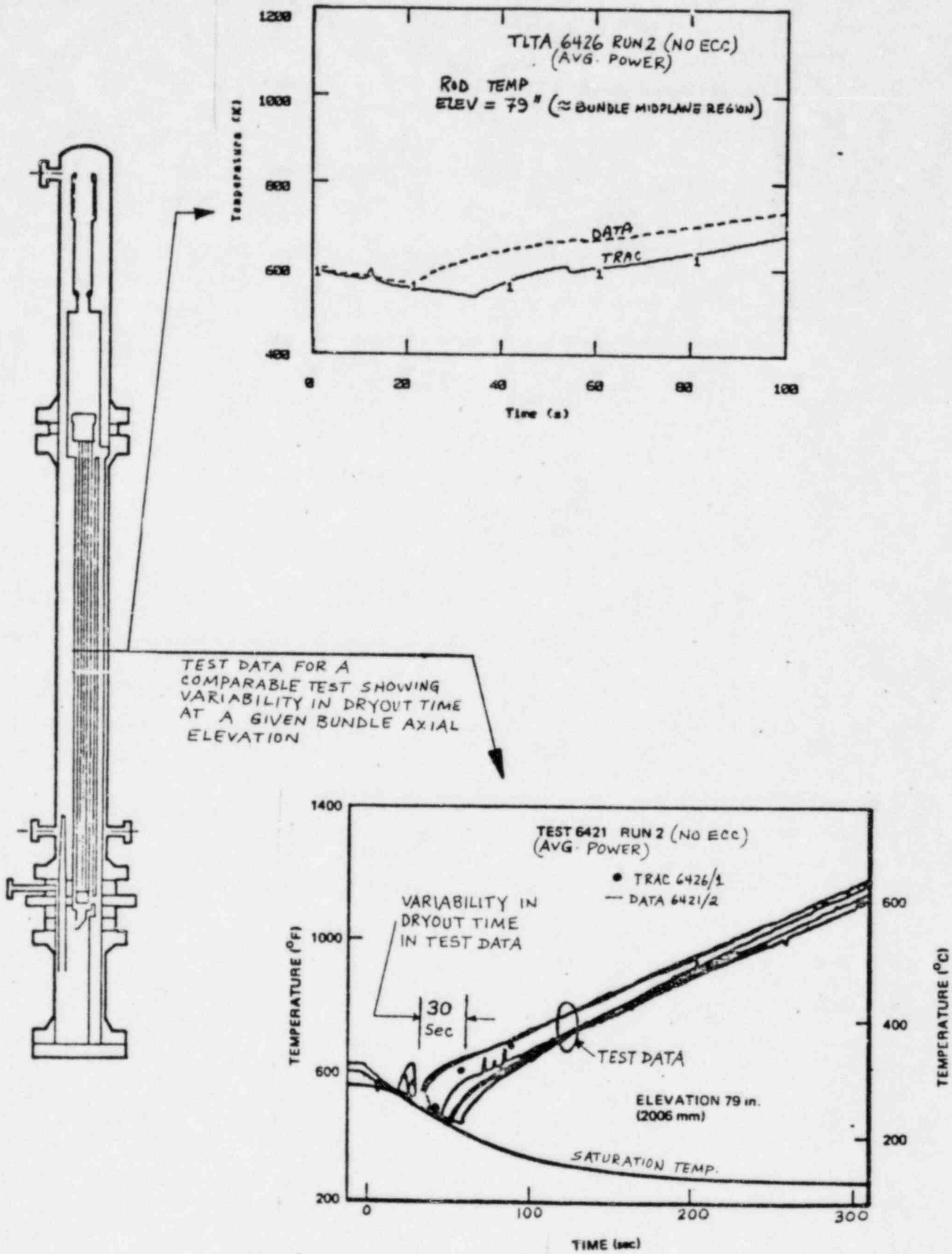

P


X10^6
7.5
5.0
2.5
0.0
Volume Pressure (Pa)
0
20
40
60
80
100
Time (s)
STEAM DOME PRESSURE
TLTA 6426/1 (NO ECC)
DATA
TRAC

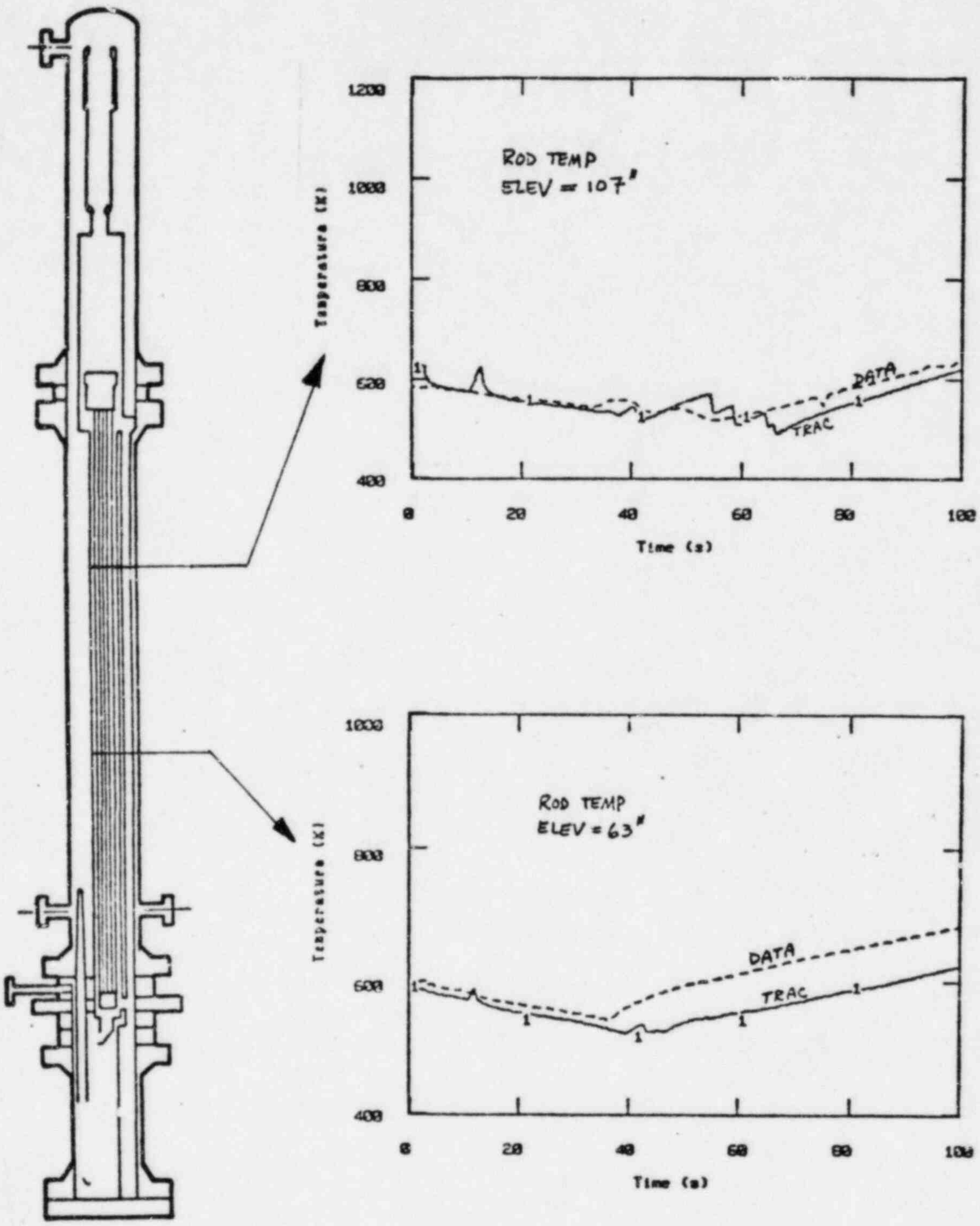

X10^6
7.5
5.0
2.5
0.0
Pressure (psia)
0
20
40
60
80
100
Time (s)
COMPARISON OF EXPERIMENTALLY
MEASURED "ECC – NO ECC" SYSTEM
PRESSURE RESPONSE
DATA 6425/2 (ECC)
DATA 6426/1 (NO ECC)


X10^6
7.5
5.0
2.5
0.0
Volume Pressure (Pa)
0
20
40
60
80
100
Time (s)
STEAM DOME PRESSURE
TRAC 6425/2 (ECC)
TRAC 6426/1 (NO ECC)

Md. A
12/3/82


TLTA 6426 RUN 2 (NO ECC)
(AVG. POWER)
ROD TEMP
ELEV = 79" (≈ BUNDLE MIDPLANE REGION)
Temperature (K)
1200
1000
800
600
400
DATA
TRAC
0
20
40
60
80
100
Time (s)
TEST DATA FOR A COMPARABLE TEST SHOWING VARIABILITY IN DRYOUT TIME AT A GIVEN BUNDLE AXIAL ELEVATION
TEST 6421 RUN 2 (NO ECC)
(AVG. POWER)
TRAC 6426/1
DATA 6421/2
VARIABILITY IN DRYOUT TIME IN TEST DATA
30 Sec
TEST DATA
ELEVATION 79 in.
(2006 mm)
SATURATION TEMP.
TEMPERATURE (°F)
1400
1000
600
200
TEMPERATURE (°C)
600
400
200
0
100
200
300
TIME (sec)

TRAC / TLTA 6426 RUN 2 (NO ECC)



Md. A
12/3/82

CONCLUSIONS

- GOOD AGREEMENT OF SYSTEM RESPONSE PREDICTION WITH DATA IN TLTA BLOWDOWN TEST WITHOUT ECC
- PREDICTS OBSERVED DIFFERENCES IN TLTA ECC-NO ECC SYSTEM PRESSURE RESPONSE
- LONG TERM ROD HEAT UP RATES COMPARE WELL WITH DATA
  - CONFIRMS ADEQUACY OF TRAC FORCED CONVECTION HEAT TRANSFER

Md. A.
12/3/82

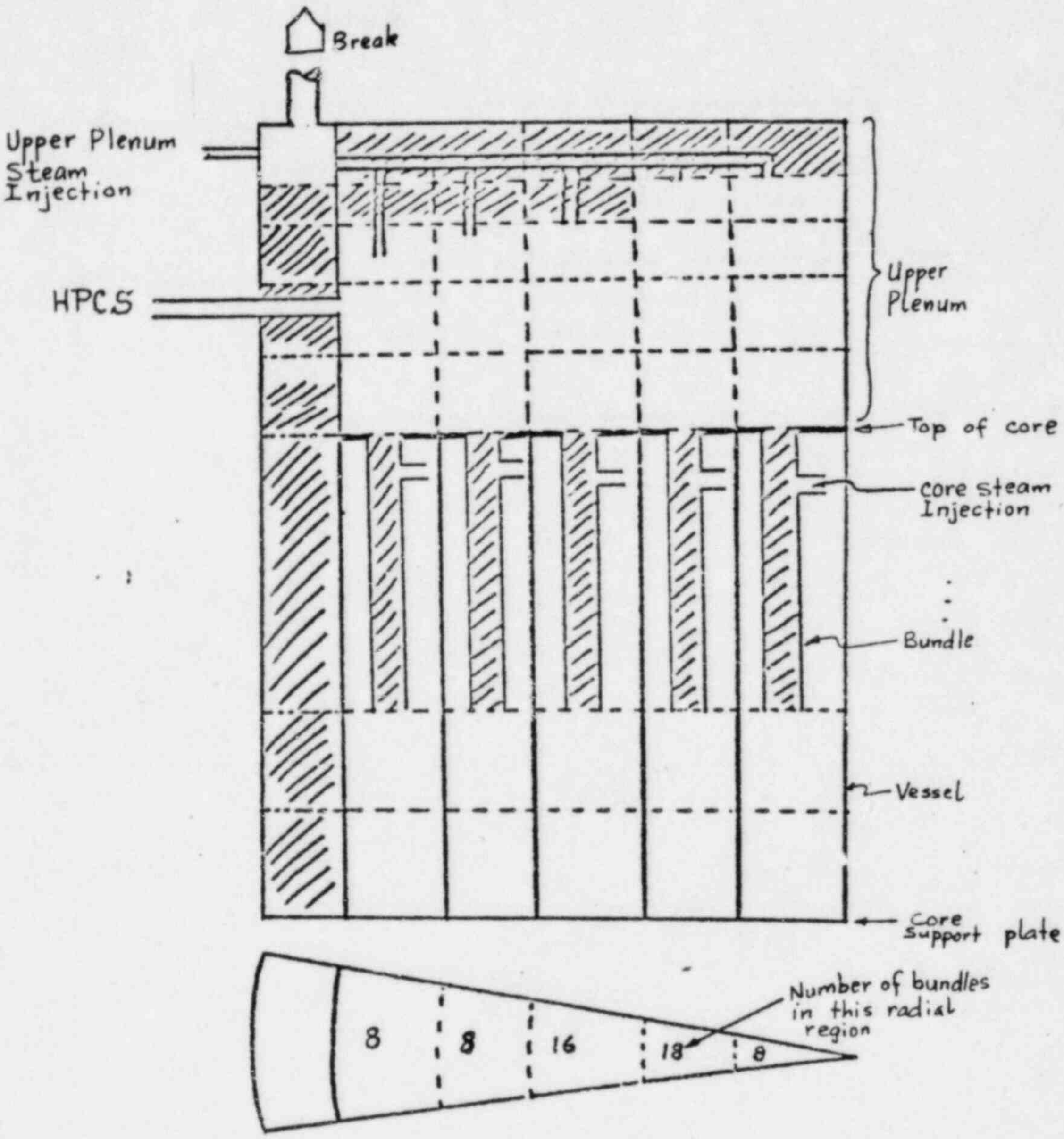
TRAC SIMULATION

OF

SSTF UPPER PLENUM MIXING TEST

(SE3-1A)

Md. A.
12/3/82

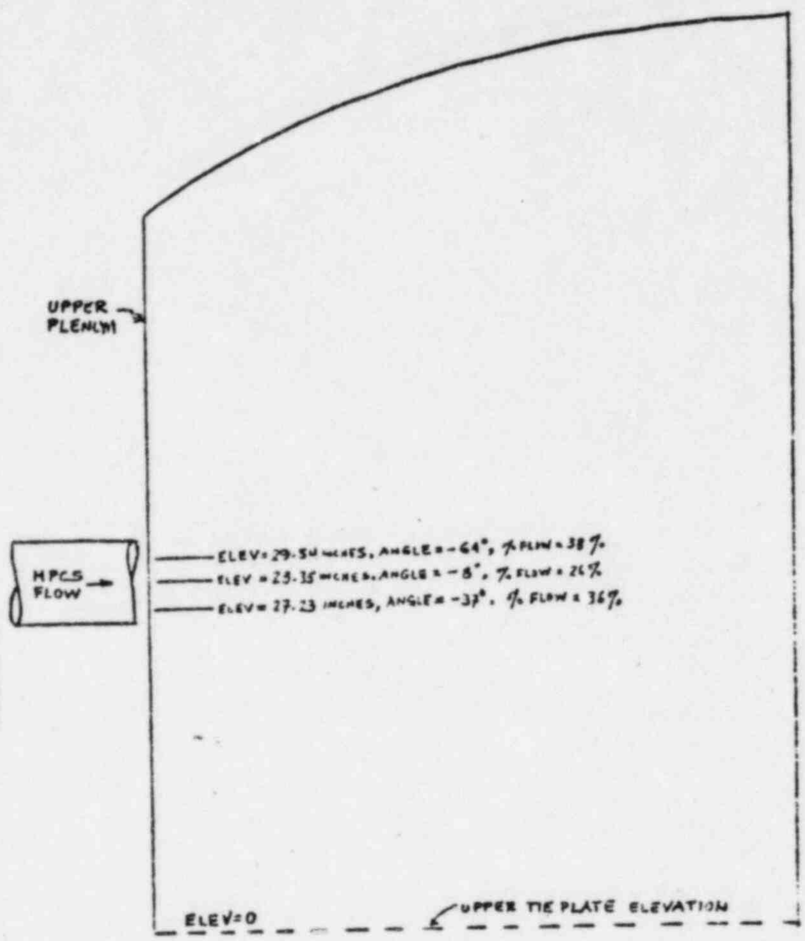


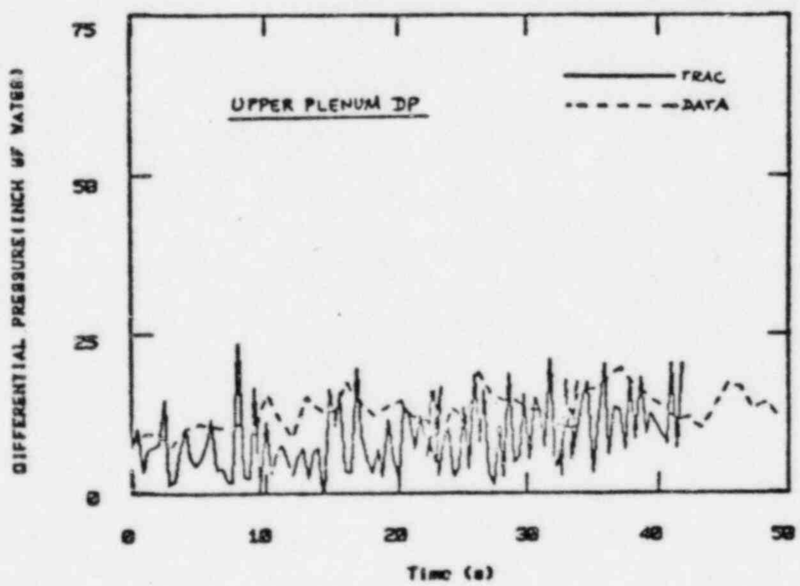
TRAC INPUT MODEL FOR SSTF TEST SE3-1A

Md. A
12/3/82

TRAC/SSTF UPPER PLENUM MIXING TEST SE3-1A

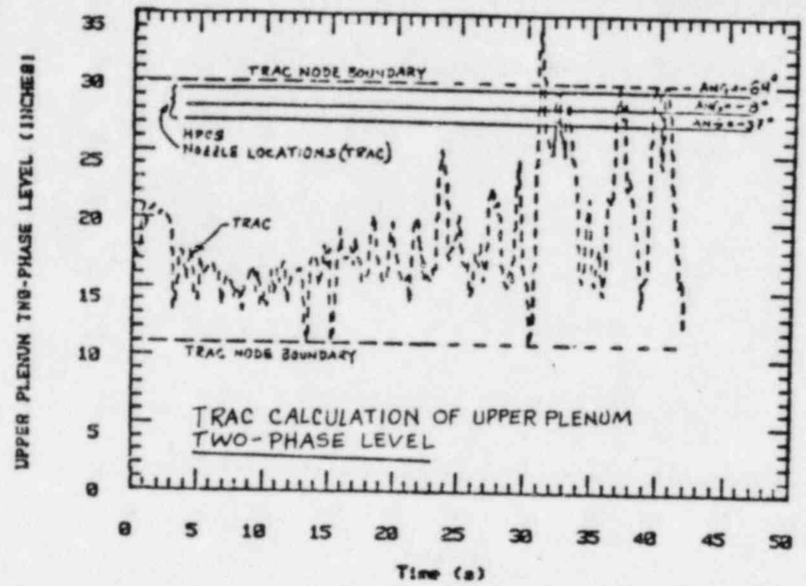
SSTF HPCS NOZZLES/TRAC



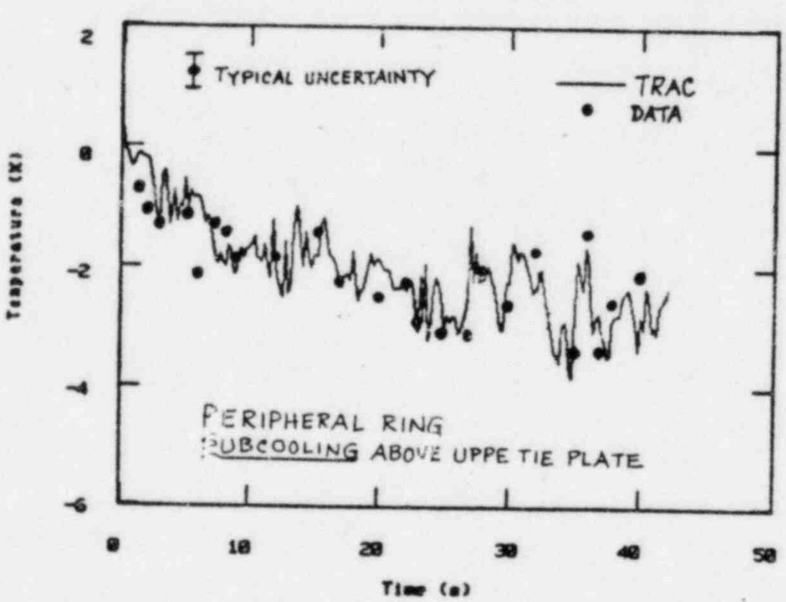


Md. A
12/3/82

SSTF UPPER PLENUM MIXING TEST SE3-1A

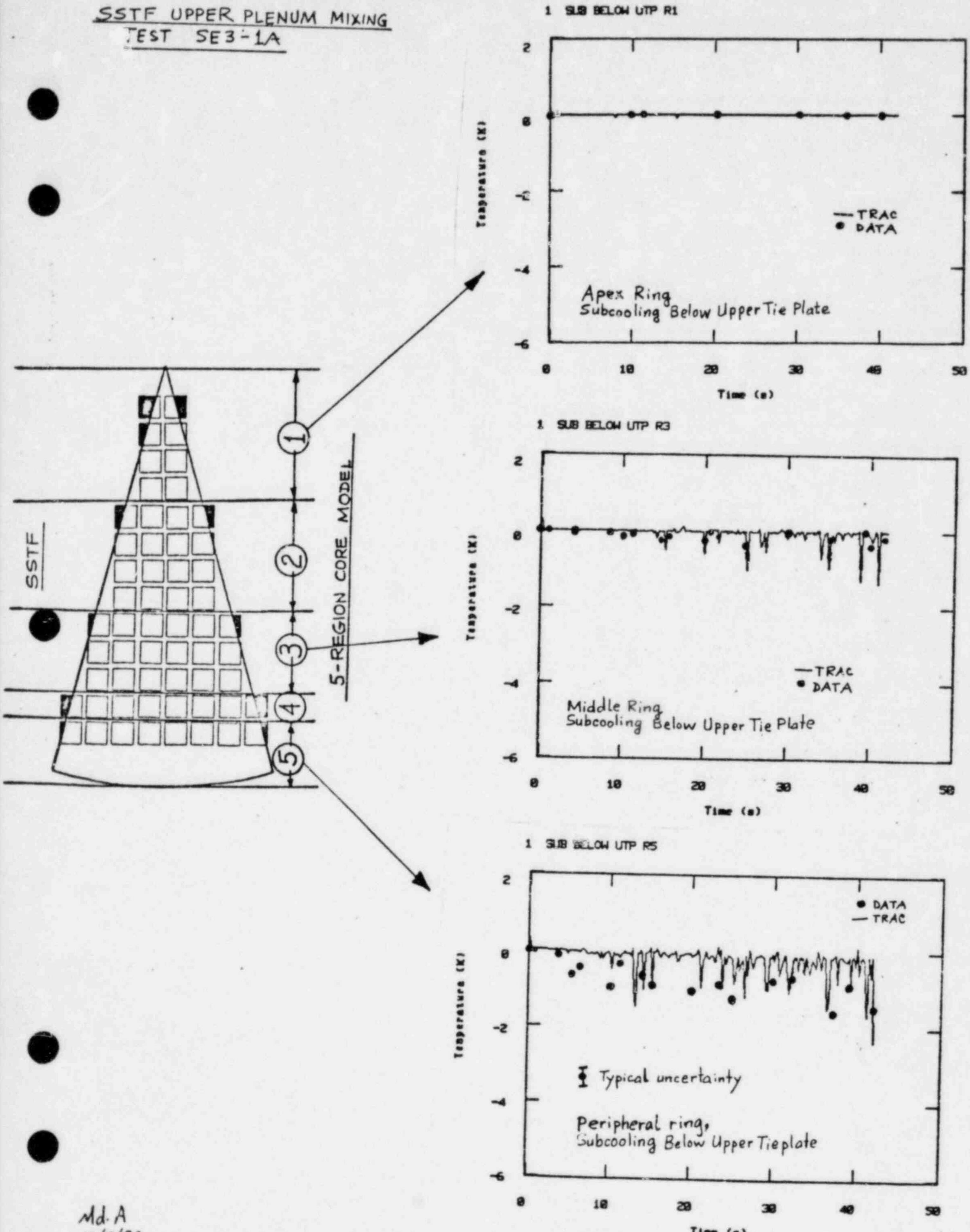


1 SUB ABOVE UTP R5



Md. A
3/12/82

SSTF UPPER PLENUM MIXING
TEST SE3-1A



Md. A
12/3/82

CONCLUSIONS

- TRAC CAPTURES MULTIDIMENSIONAL EFFECTS IN THE SSTF UPPER PLENUM MIXING TEST
  - GOOD AGREEMENT OF UPPER PLENUM INVENTORY
  - PREDICTS OBSERVED SUBCOOLING DISTRIBUTION
  - TRACB02 UPPER PLENUM MODEL DOES A GOOD JOB IN PREDICTING ECC MIXING

Md. A.

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TRAC SIMULATION

OF

SSTF MULTIPLE BUNDLE SEO CCFL TEST (SE1-5A)

(PARALLEL CHANNEL PHENOMENA)

Md. A.
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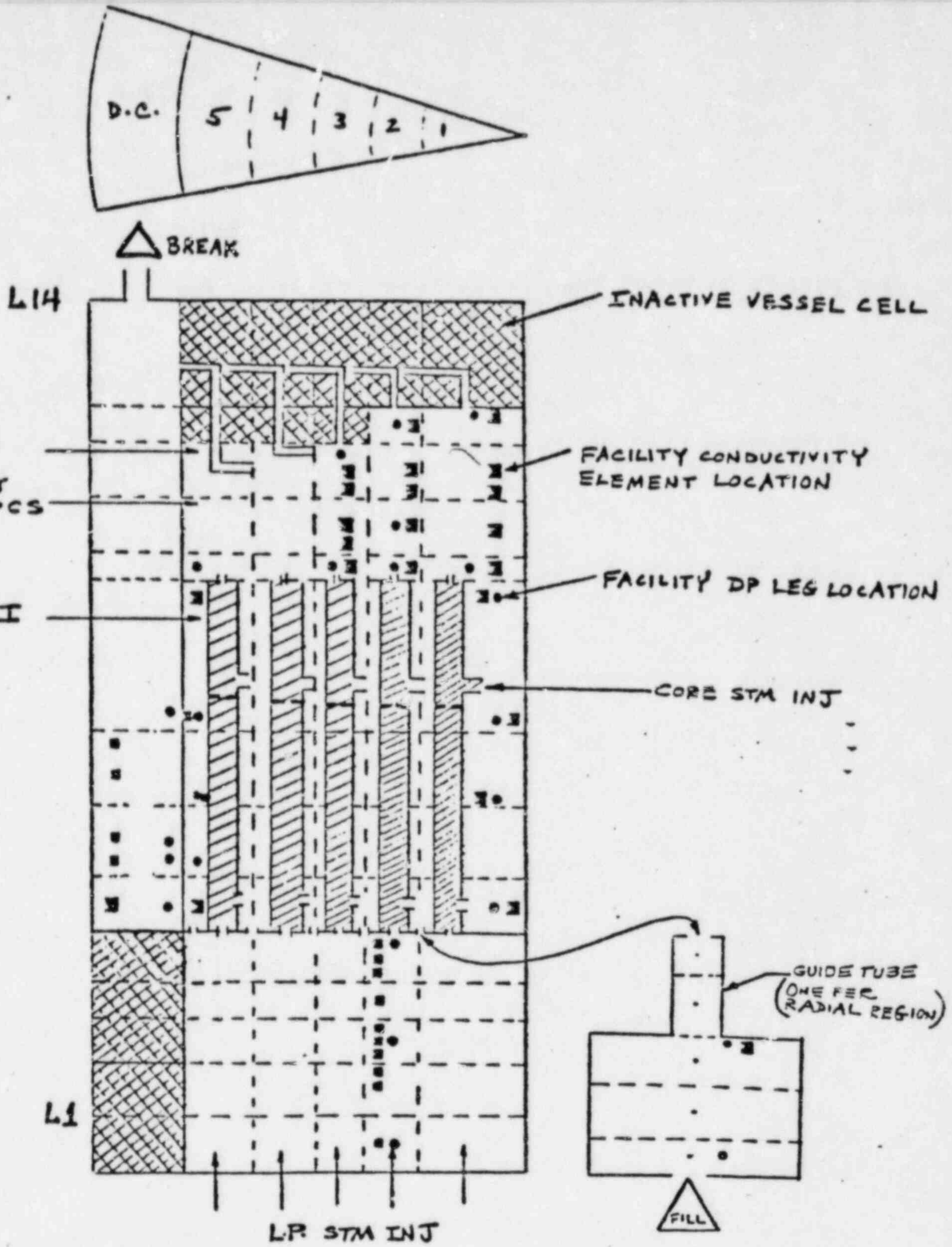


SSTF/TRAC AXIAL NODALIZATION

71 VESSEL CELLS

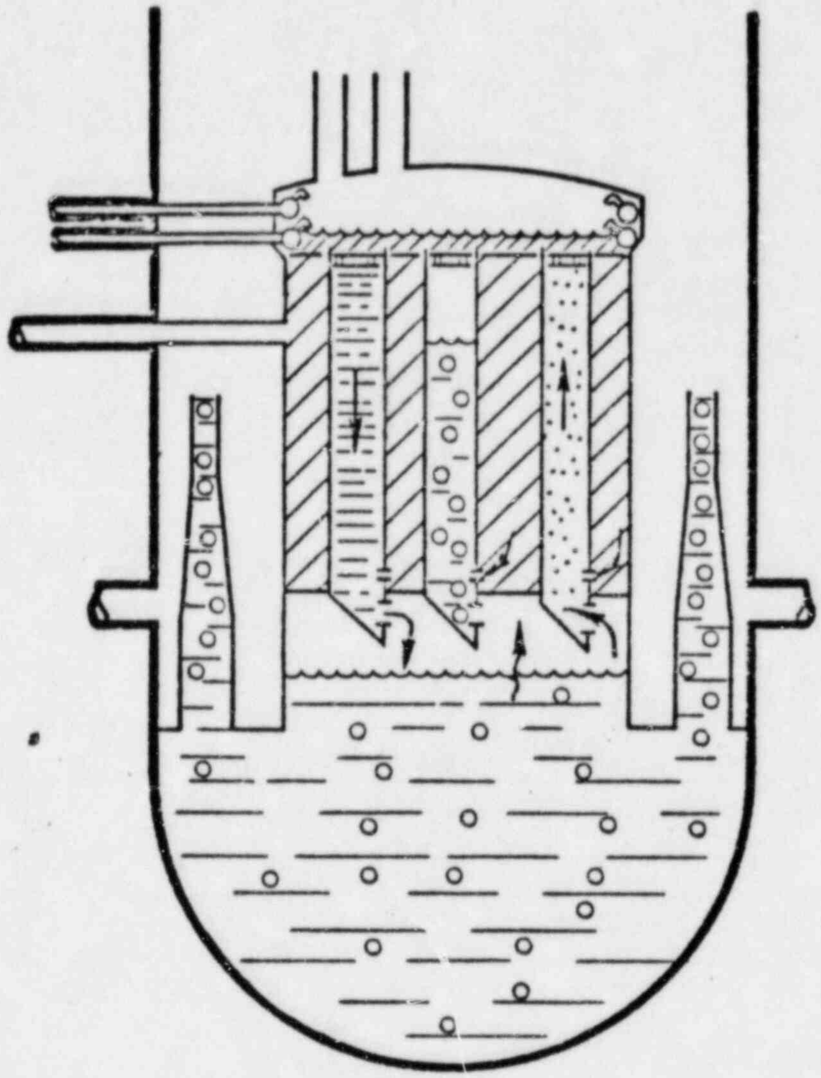
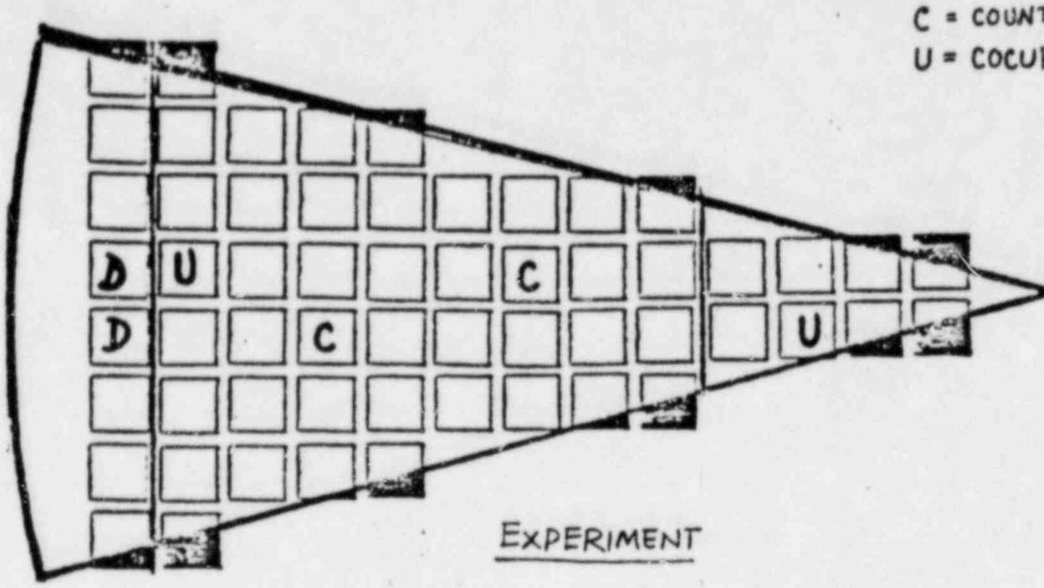


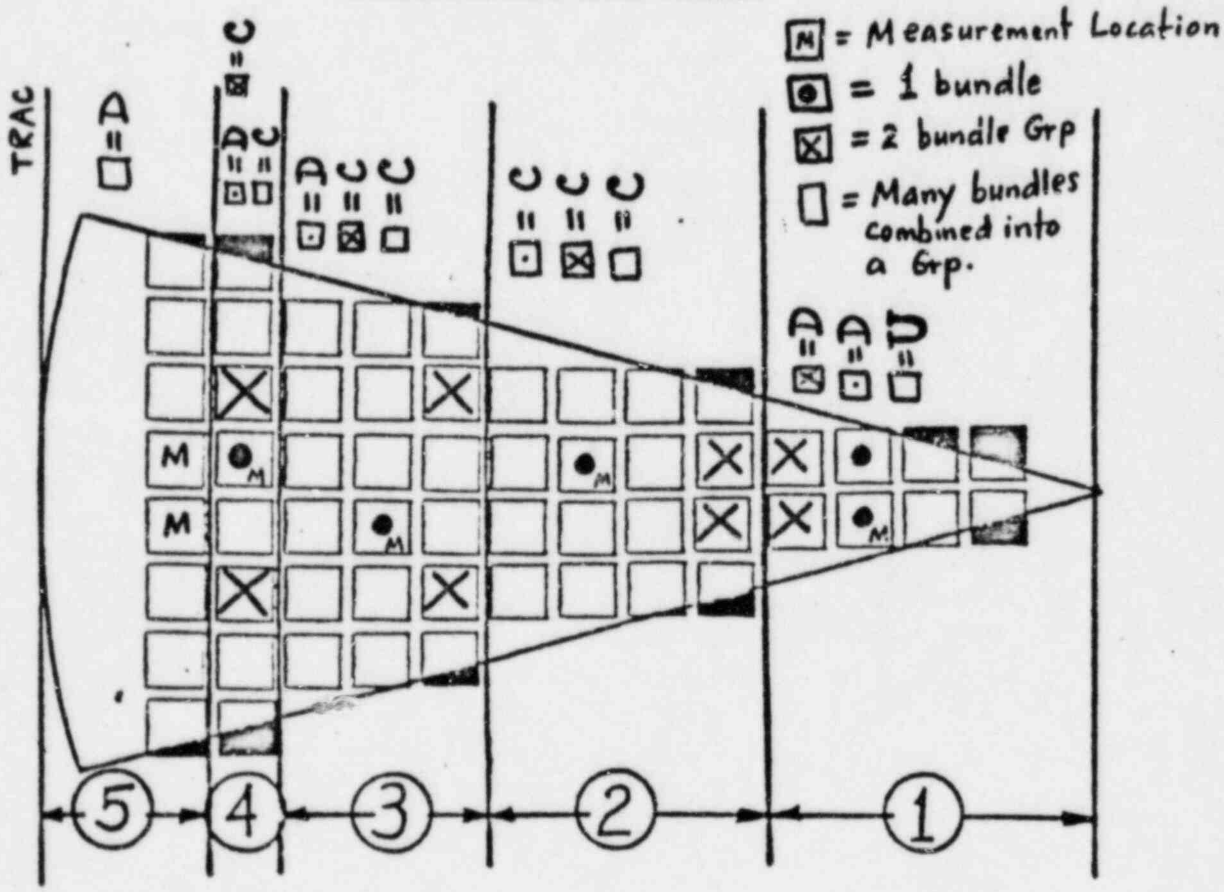
Figure 5. Typical Multi-channel Conditions

SSTF/TRAC

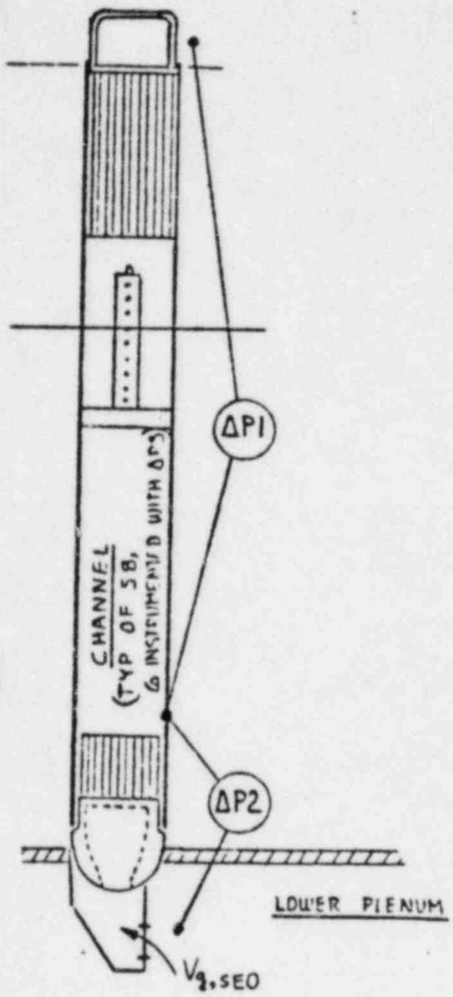
D = DOWNFLOW
C = COUNTERCURRENT FLOW
U = COCURRENT UPFLOW

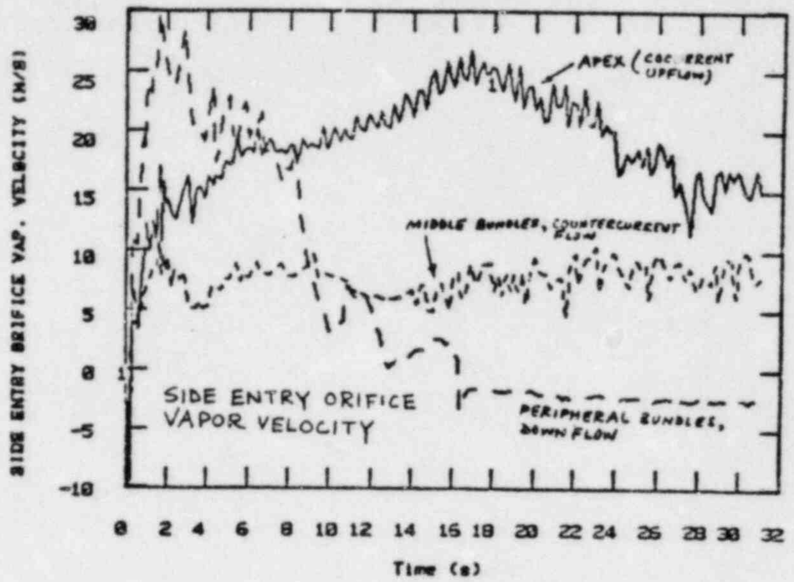


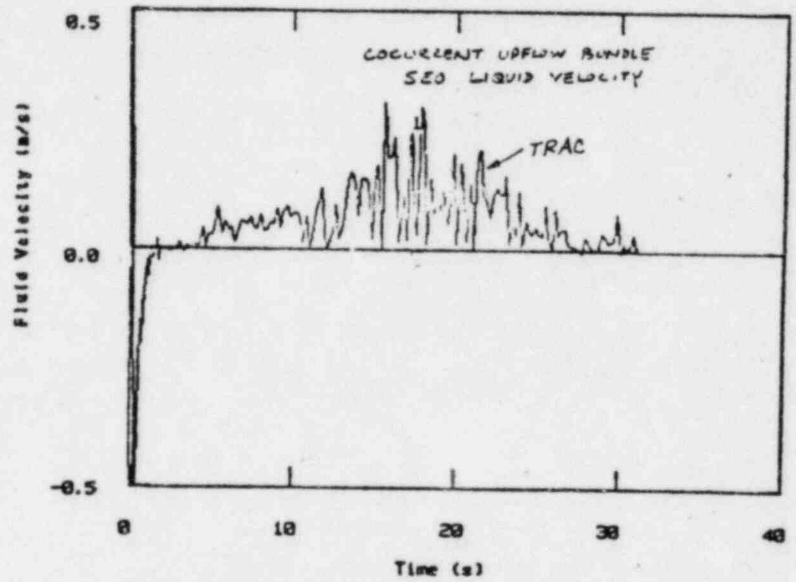
EXPERIMENT



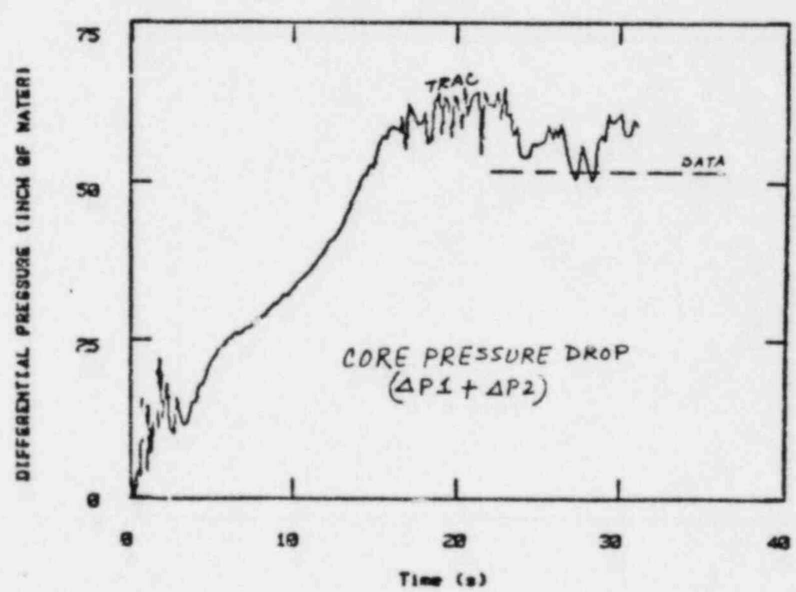
5-REGION CORE MODEL (TRAC)







1 RING 3 CORE DP



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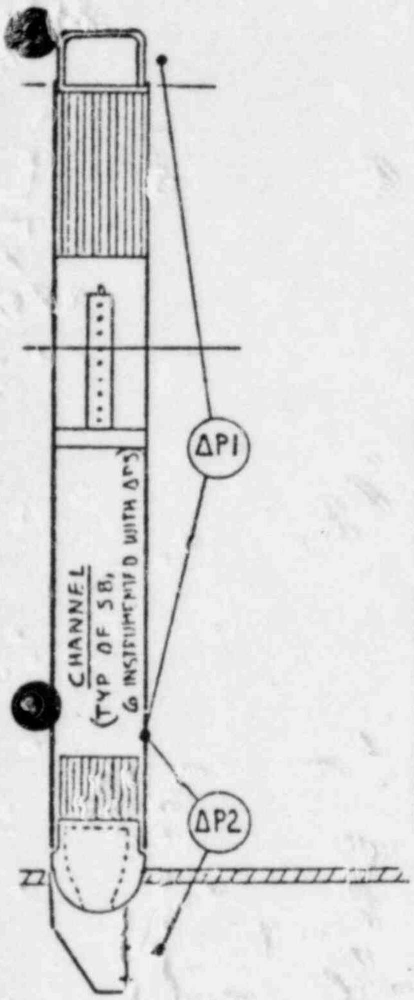
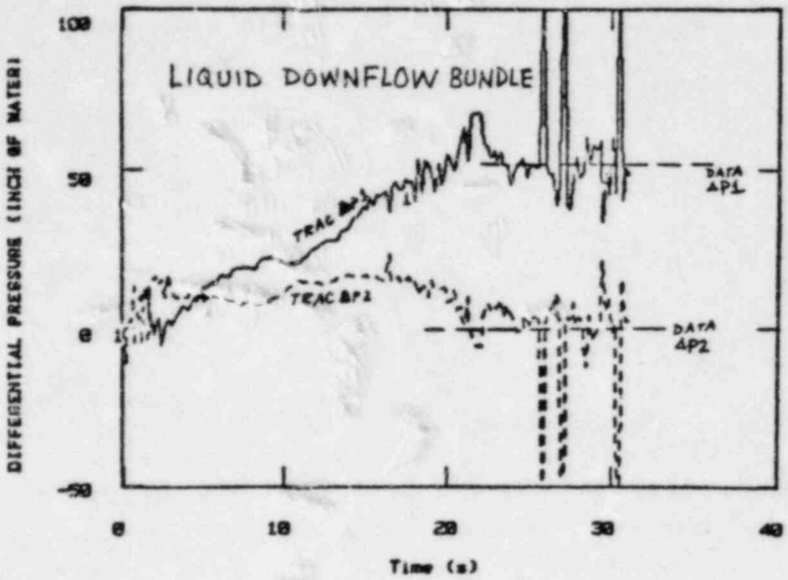
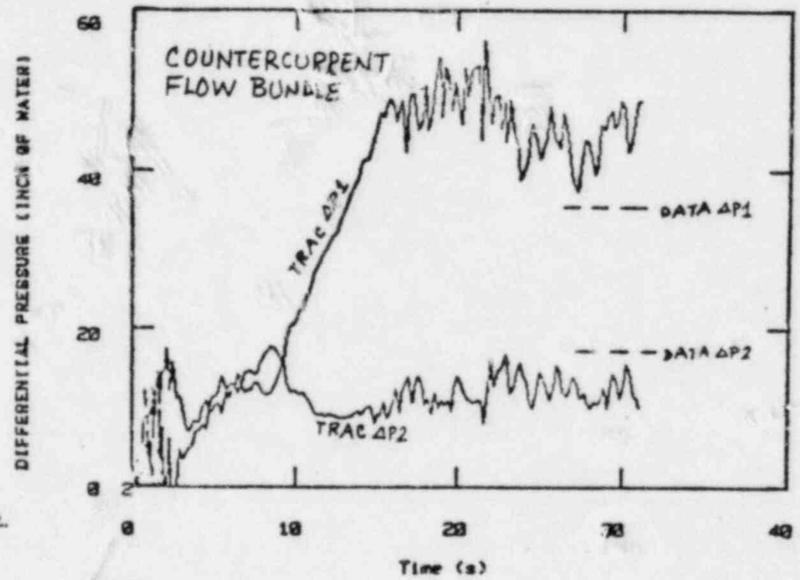
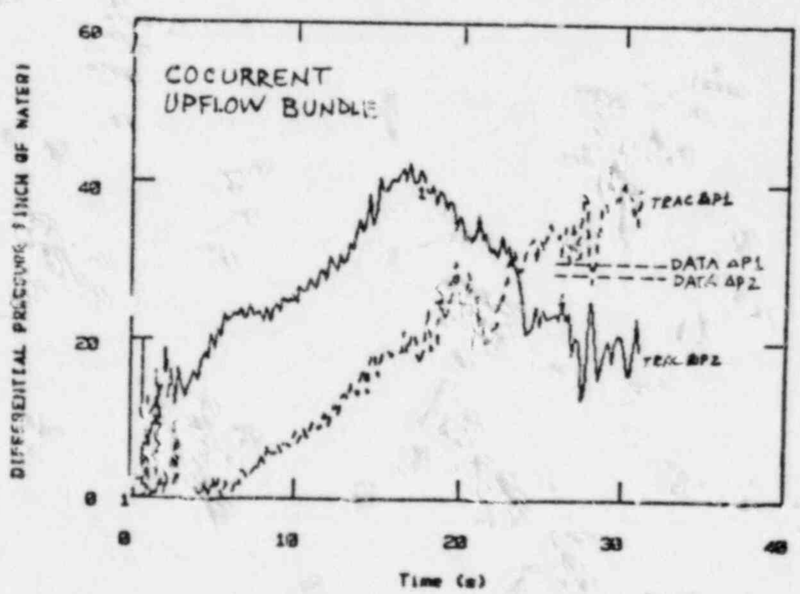

CHANNEL
(TYP OF 5B, 6 INSTRUMENTED WITH ΔP'S)
ΔP1
ΔP2


LIQUID DOWNFLOW BUNDLE
TRAC ΔP1
TRAC ΔP2
DATA ΔP1
DATA ΔP2
DIFFERENTIAL PRESSURE (INCH OF WATER)
Time (s)


COUNTERCURRENT FLOW BUNDLE
TRAC ΔP1
TRAC ΔP2
DATA ΔP1
DATA ΔP2
DIFFERENTIAL PRESSURE (INCH OF WATER)
Time (s)


COCURRENT UPFLOW BUNDLE
TRAC ΔP1
TRAC ΔP2
DATA ΔP1
DATA ΔP2
DIFFERENTIAL PRESSURE (INCH OF WATER)
Time (s)

Md. A
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CONCLUSIONS

- MULTIPLE BUNDLE CCFL TEST
  - TRAC CAPTURES MULTIPLE BUNDLE HYDRAULIC INTERACTION
  - PREDICTS OBSERVED PARALLEL CHANNEL FLOW MODES
  - CORE PRESSURE DROP WELL-PREDICTED
- FURTHER SENSITIVITY STUDIES ONGOING
  - NUMBER OF RADIAL REGIONS IN THE VESSEL
  - DISTRIBUTION OF BUNDLES

Md. A.

12/3/82

OVERALL CONCLUSIONS

- TRACB02 PREDICTIONS COMPARE WELL WITH EXPERIMENTAL DATA FROM SIMPLE 1-D EXPERIMENTS TO COMPLEX 3-D TESTS

- QUALIFICATION STUDY ONGOING

- TRACB02 ANALYTICAL MODEL ADEQUACY DEMONSTRATED THROUGH PREDICTION-DATA COMPARISON
  - INTERFACIAL SHEAR
  - CRITICAL FLOW
  - TWO-PHASE LEVEL TRACKING
  - JET PUMP COMPONENT

  - HEAT TRANSFER CORRELATIONS/MODELS
  - UPPER PLENUM MODEL

- AREAS FOR IMPROVEMENT
  - DROPLET FIELD FOR DISPERSED FLOW
  - LIQUID WITHDRAWAL NEAR A POOL DUE TO BERNOULLI EFFECT

Md. A.

12/3/82

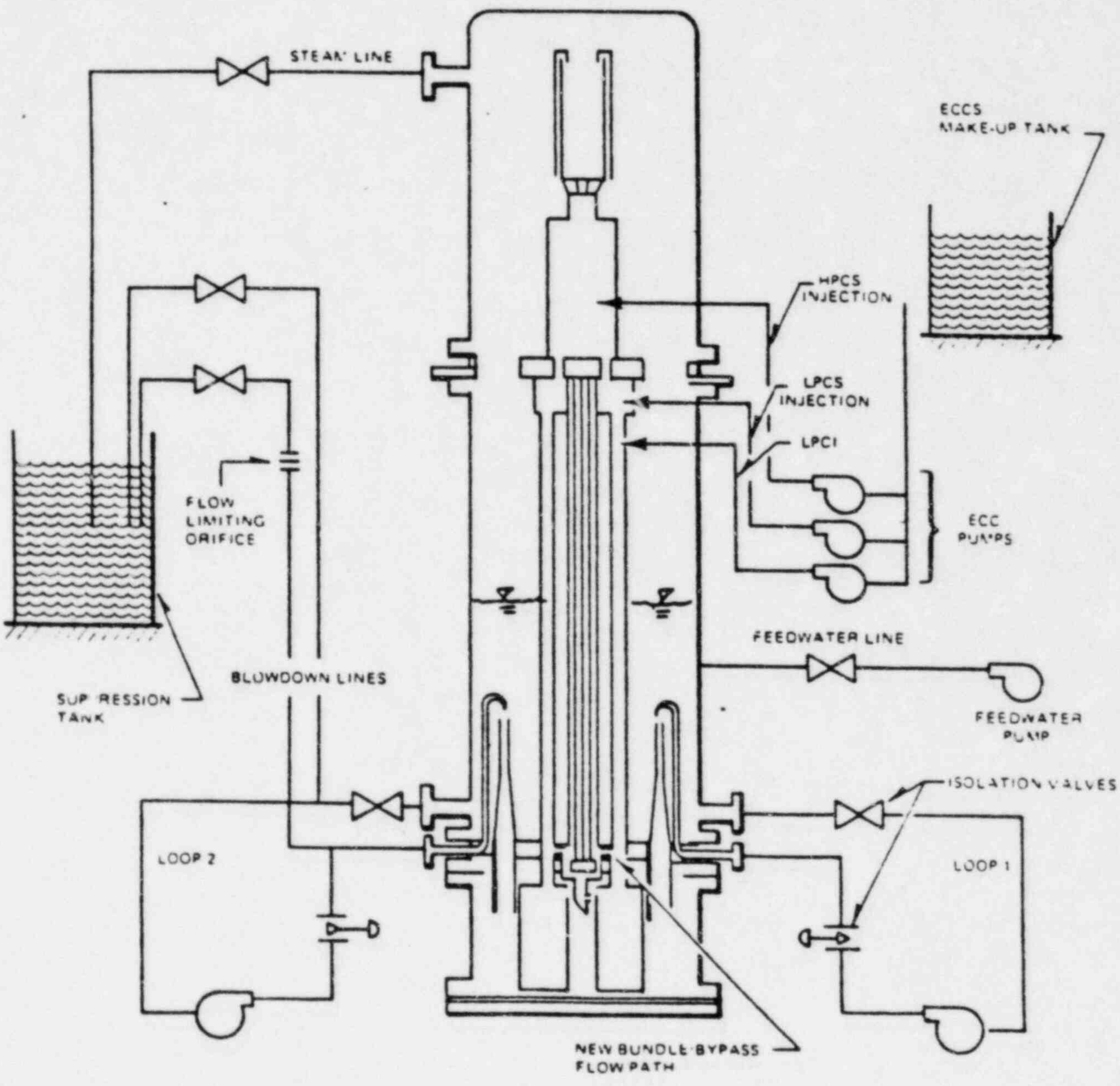
B. S. Shiralkar

SAFER ASSESSMENT STUDIES

- Two-Loop Test Apparatus (TLTA)
  - 5 Tests
  - Comparisons Completed
- ROSA III
  - Small and Large Break Tests
  - Preliminary Comparisons

RESULTS SHOW GOOD PREDICTIONS
SIGNIFICANT PHENOMENA AND TRENDS CAPTURED

BS Shiralkar
12/3/82



Two-Looo Test Apparatus Configuration 5A (TLTA 5A) with Emergency Core Cooling Systems

SAFER CALCULATIONS

INPUTS

- Initial Conditions - Pressure, Power, Recirculation Flow,
  Feedwater, Steam Line Flow

- Power, Feedwater, Steam Line Flow vs. Time

- ECCS Flow and Temperature vs. Time

- Recirculation Pump Flow Decay Time Constant

- Time of Transition Boiling.

TABLE 1 TLTA TESTS SELECTED FOR SAFER QUALIFICATION

Test No.	Break	BWR Simulation	TLTA Configuration	Test Condition	Basis For Candidate	Documentation Test
6426/R1	DBA	BWR/6	TLTA-5A	Average Central Power No ECC	Baseline data for BWR/6 Simulation without ECC	GEAP-24962-1
6425/R2	DBA	BWR-6	TLTA-5A	Average Central power Average ECC (1 HPCS/1LPCS/1LPCI)	Reference test for BWR/6 Simulation. ECC effects on system responses	GEAP-24962-1
6423/R3	DBA	BWR-6	TLTA-5A	Peak Power Low ECC flow rate high ECC flow temperature	Bounding case, High PCT	GEAP-24962-1
6432/R1	SBA	BWR-6	TLTA-5C	Average Central Power, No HPCS and FW, ADS Tripped, 1 LPCS/~2 LPCI	Degraded ECCS Small break test	GEAP-NUREG 23977-18
~~6441/3-7~~ 6441/6	No break, Separate Effects (boiloff)	BWR-6	TLTA-5A	Steady power 250kw Steady system pressure 400 psia, No forced coolant flow	TMI-like test. Steam cooling/bundle heat transfer evaluation	GEAP-24964

BREAK FLOW MODEL

- Homogeneous Flow * 0.8 ($\frac{fL}{D}$ = 2.0)

- Subcooled Multiplier of 1.2

- Based on TLTA Geometry, Previous Experience with 'SAFE' code.

SAFER RESULTS

PARAMETERS COMPARED

- Pressure Transients
- Mixture Levels
- Regional Mass Distribution
- Rod Temperatures.

TLTA TEST 6425/R2

REFERENCE DBA TEST

INITIAL CONDITIONS OF THE BD/ECC 1A REFERENCE TEST (6425 Run 2)

Initial Conditions	TLTA	
Bundle power	5.05[a] ± 0.03 MW	
Steam dome pressure	1044 ± 5 psia	(7198 kPa)
Lower plenum pressure	1071 ± 5 psia	(7384 kPa)
Lower plenum enthalpy	528 ± 5 Btu/lbm	(1228 Kj/Kg)
Initial water level[b]	73 ± 6 in. El	(1.85m)
Feedwater enthalpy	41 ± 2 Btu/lbm	(95 Kj/Kg)
Bundle inlet to outlet DP	17 ± 2 psi	(117 Pa)
Steam flow	6 ± 1 lbm/sec	(2.7 Kg/s)
Feedwater flow	1.4 ± 0.3 lbm/sec	(0.5 Kg/s)
Drive Pump 1 flow	9.1 ± 1 lbm/sec	(4.1 Kg/s)
Drive Pump 2 flow	8.4 ± 1 lbm/sec	(3.8 Kg/s)
Jet Pump 1 flow	22 ± 2 lbm/sec	(10 Kg/s)
Jet Pump 2 flow	20 ± 2 lbm/sec	(9 Kg/s)
Bundle inlet flow	39 ± 5 lbm/sec	(18 Kg/s)

All uncertainty bands are judged from the maximum of data fluctuation and/ or absolute uncertainties of the measurements.

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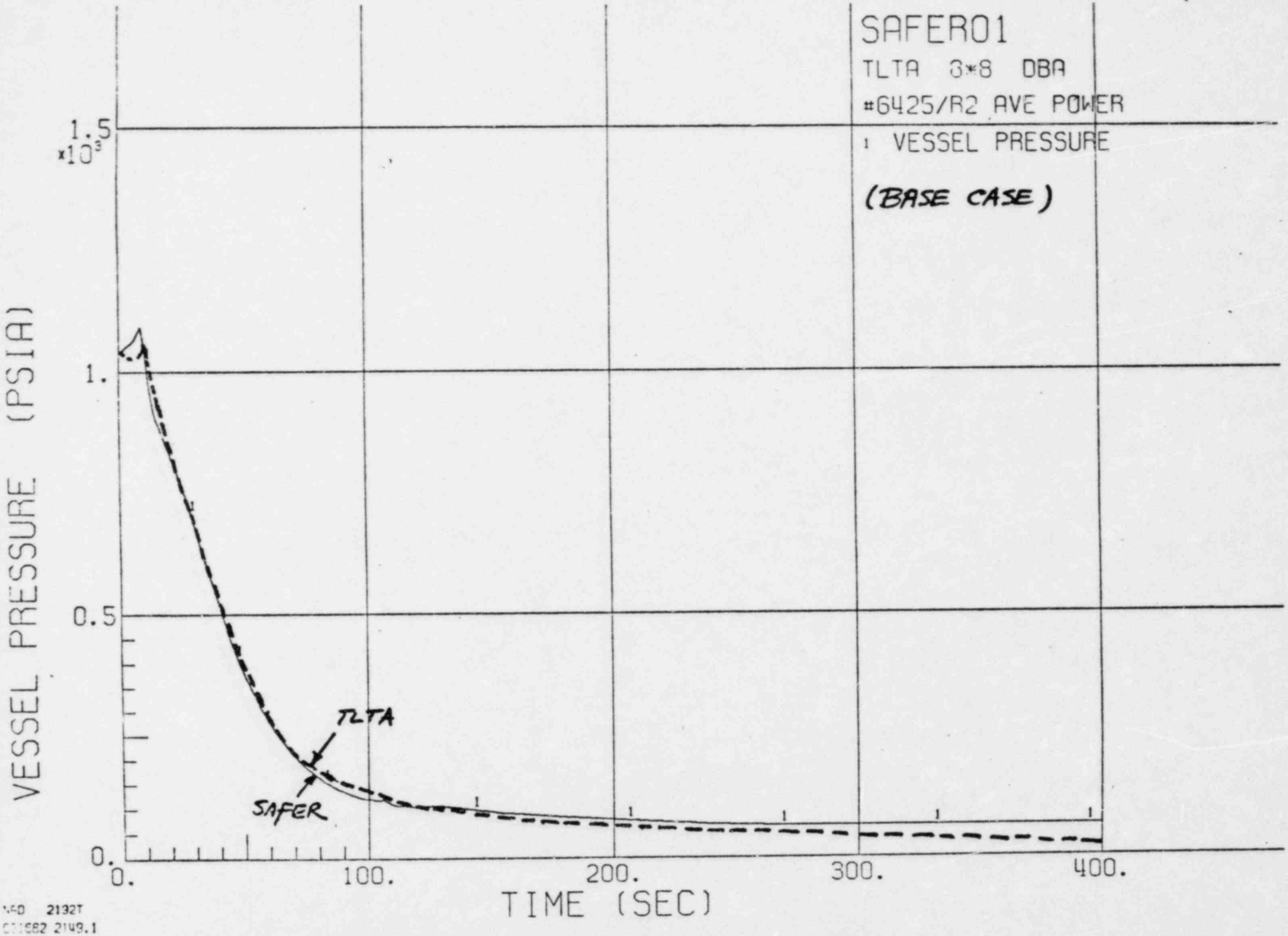
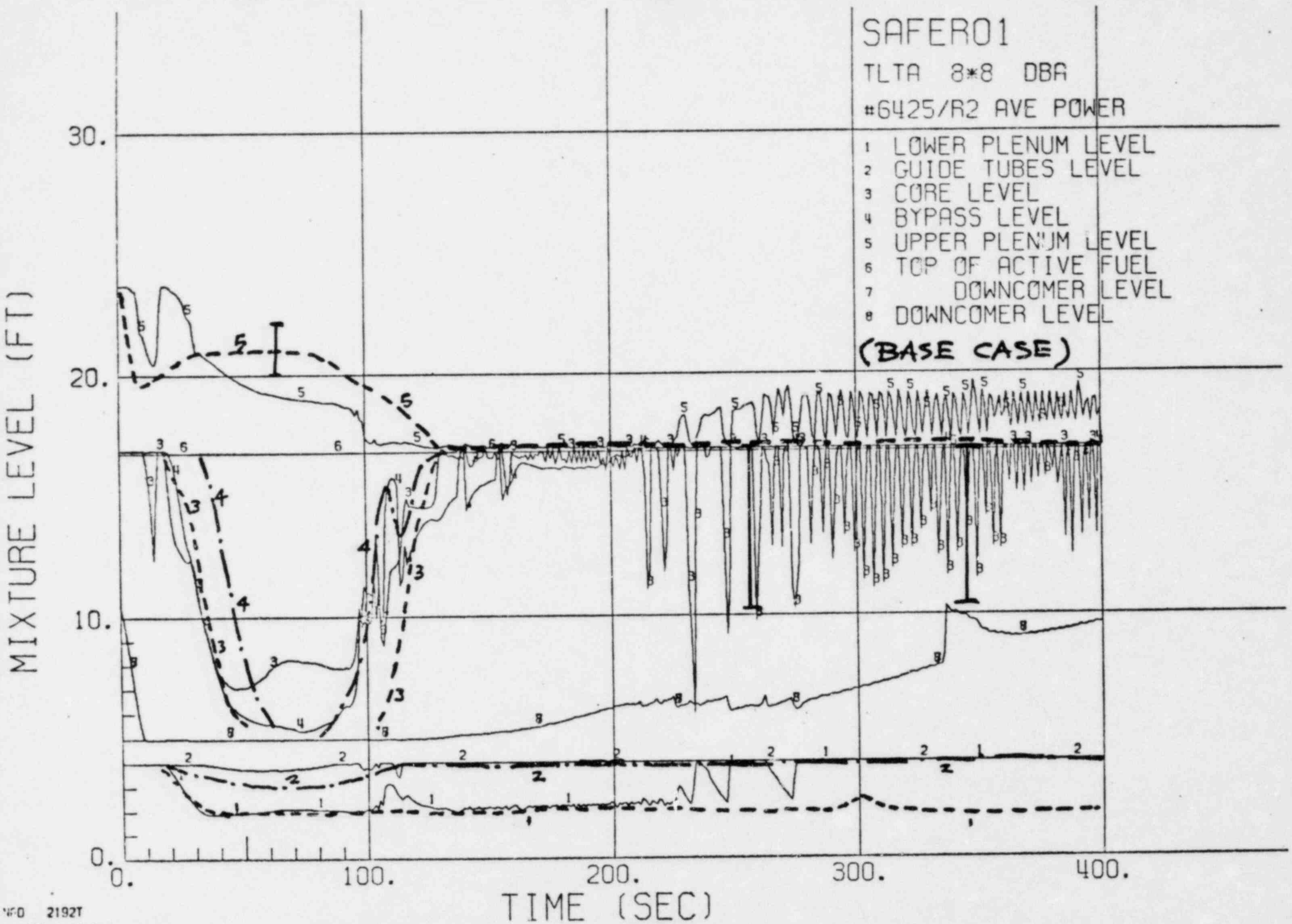
[a]NOTE: 5.05 MW is central average bundle power; core average power is 4.60 MW for BWR/6.

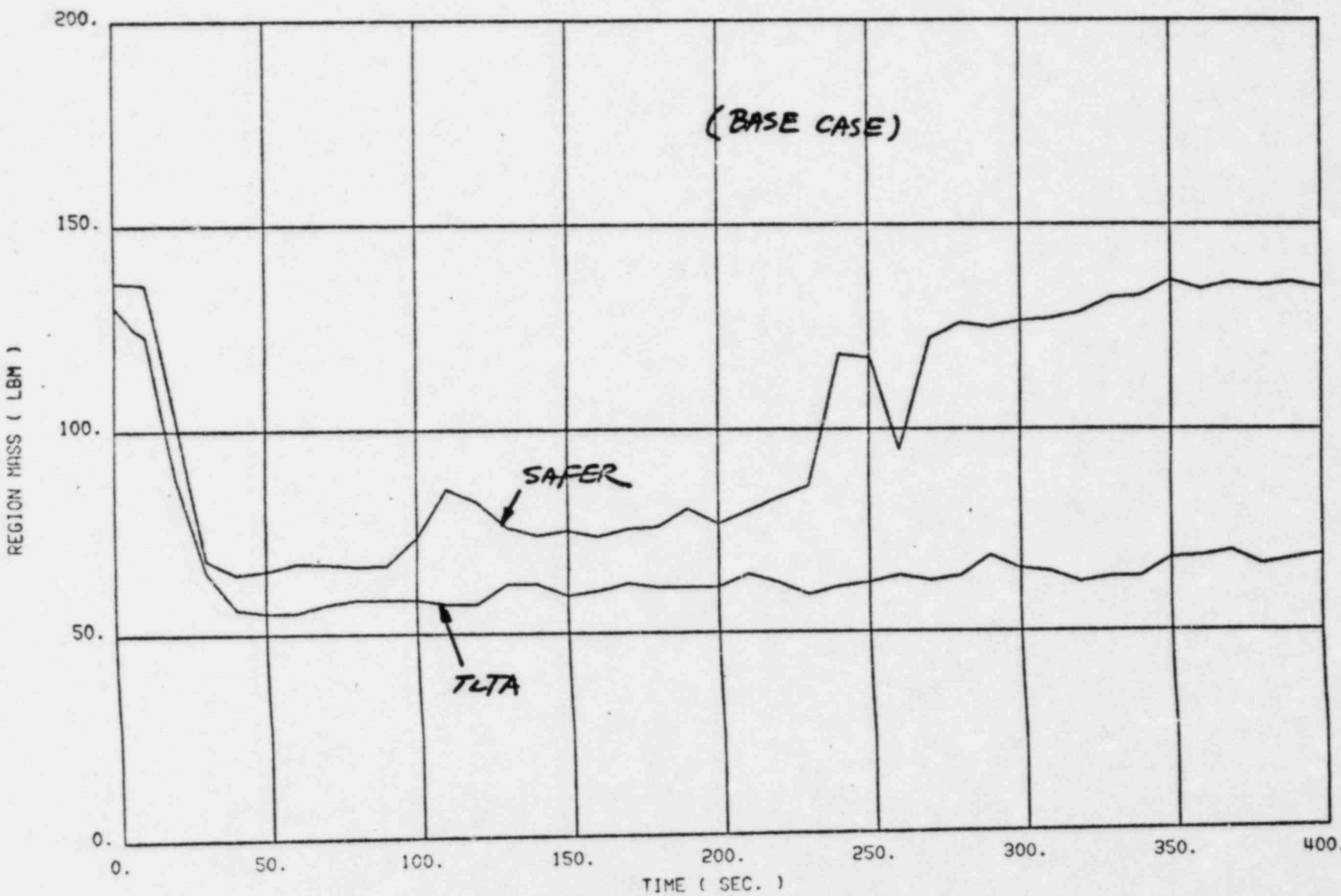
[b]NOTE: Relative to jet pump support plate.



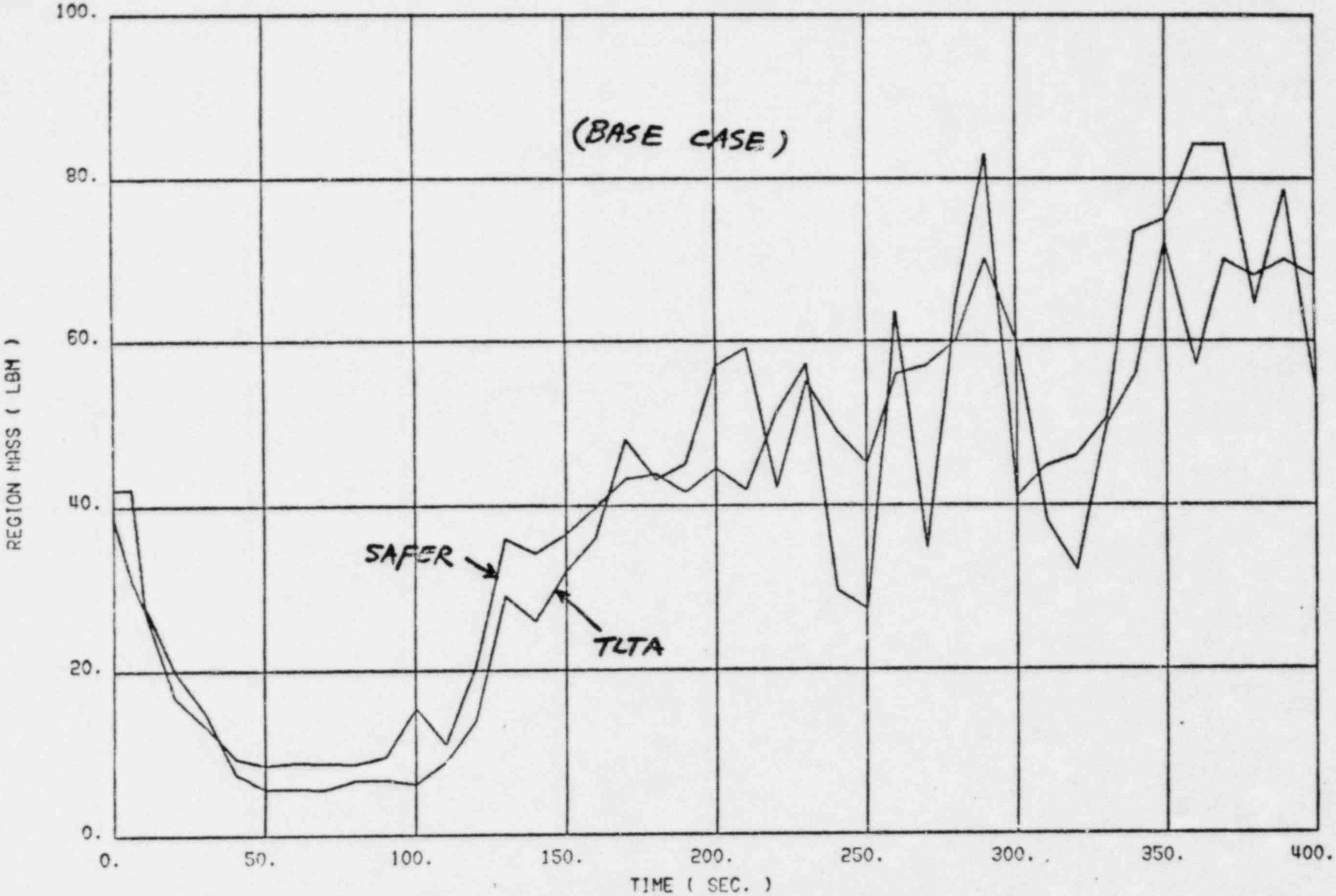
NED 2132T
C11682 2149.1



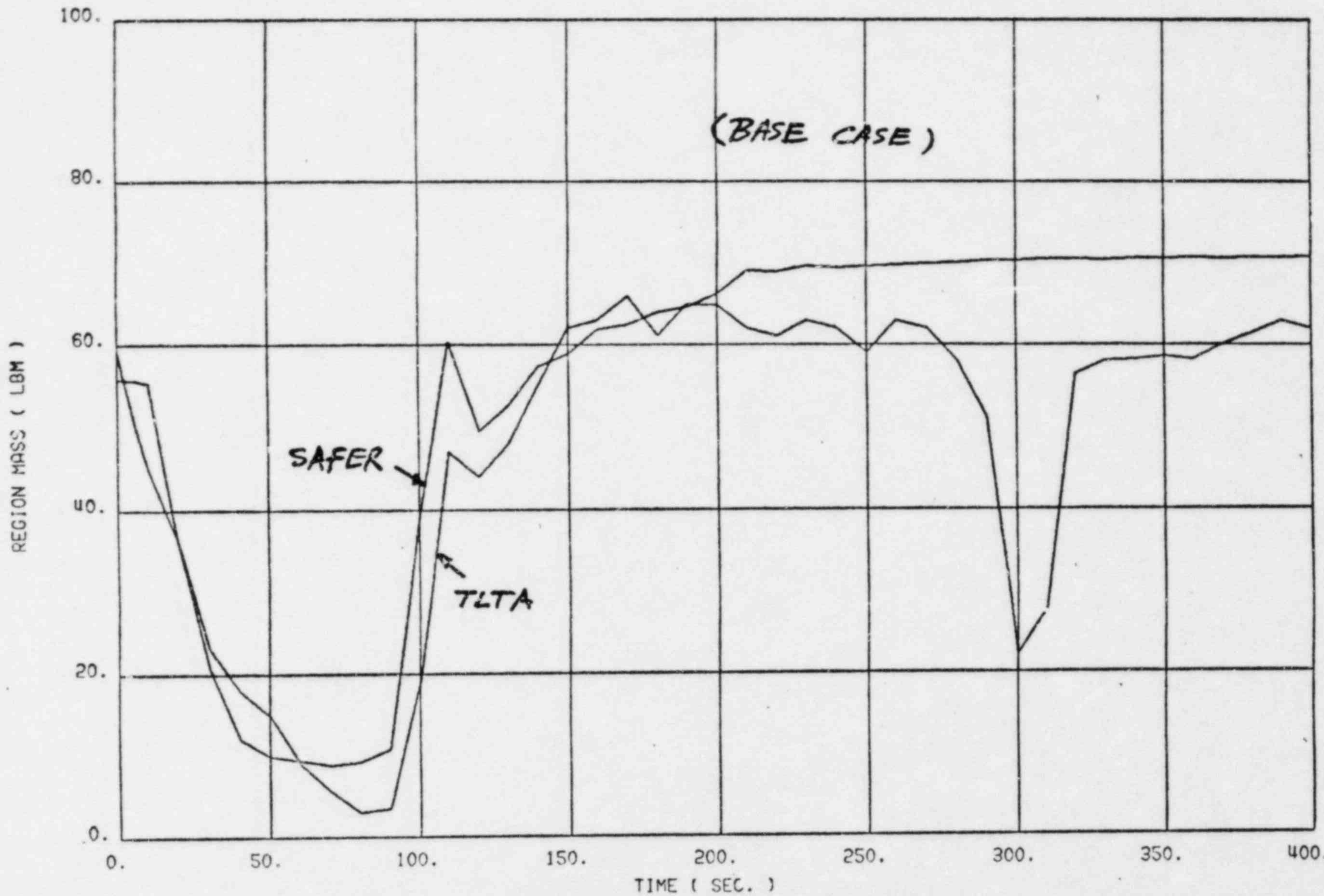
NED 2192T
001682 2143.1



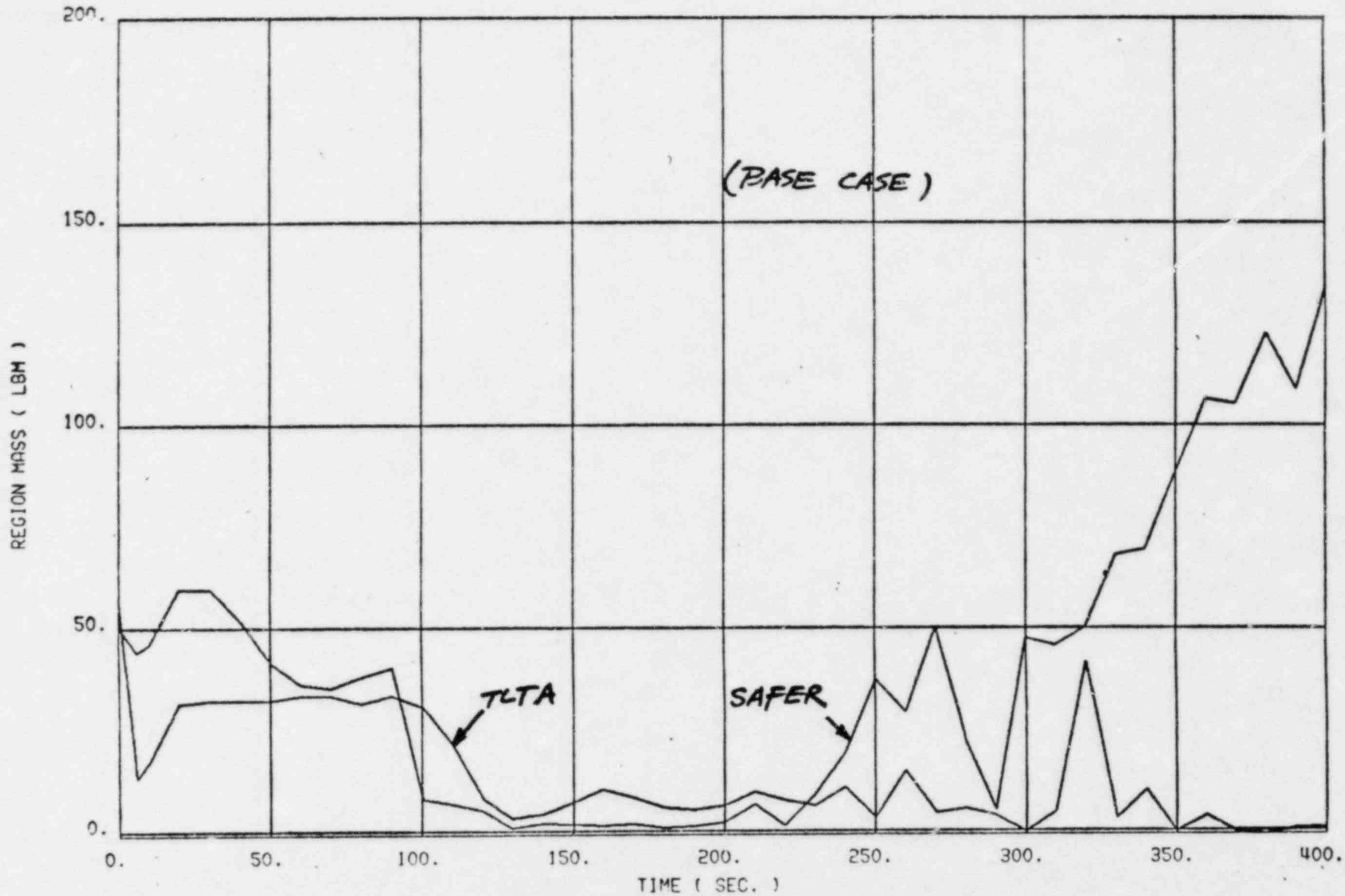
REGION 1 LOWER PLENUM (6425 R2)



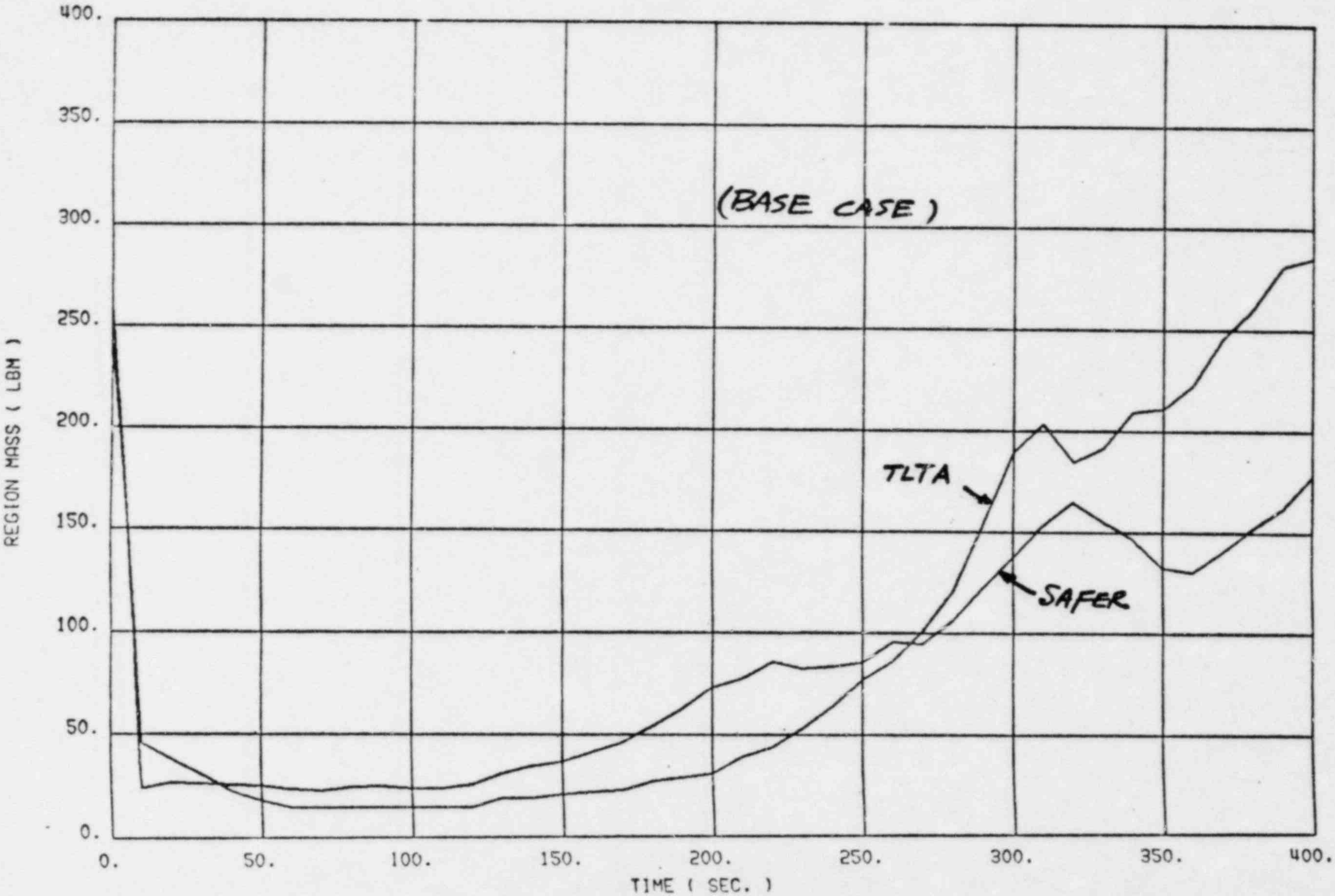
REGION 3 BUNDLE (6425 R2)



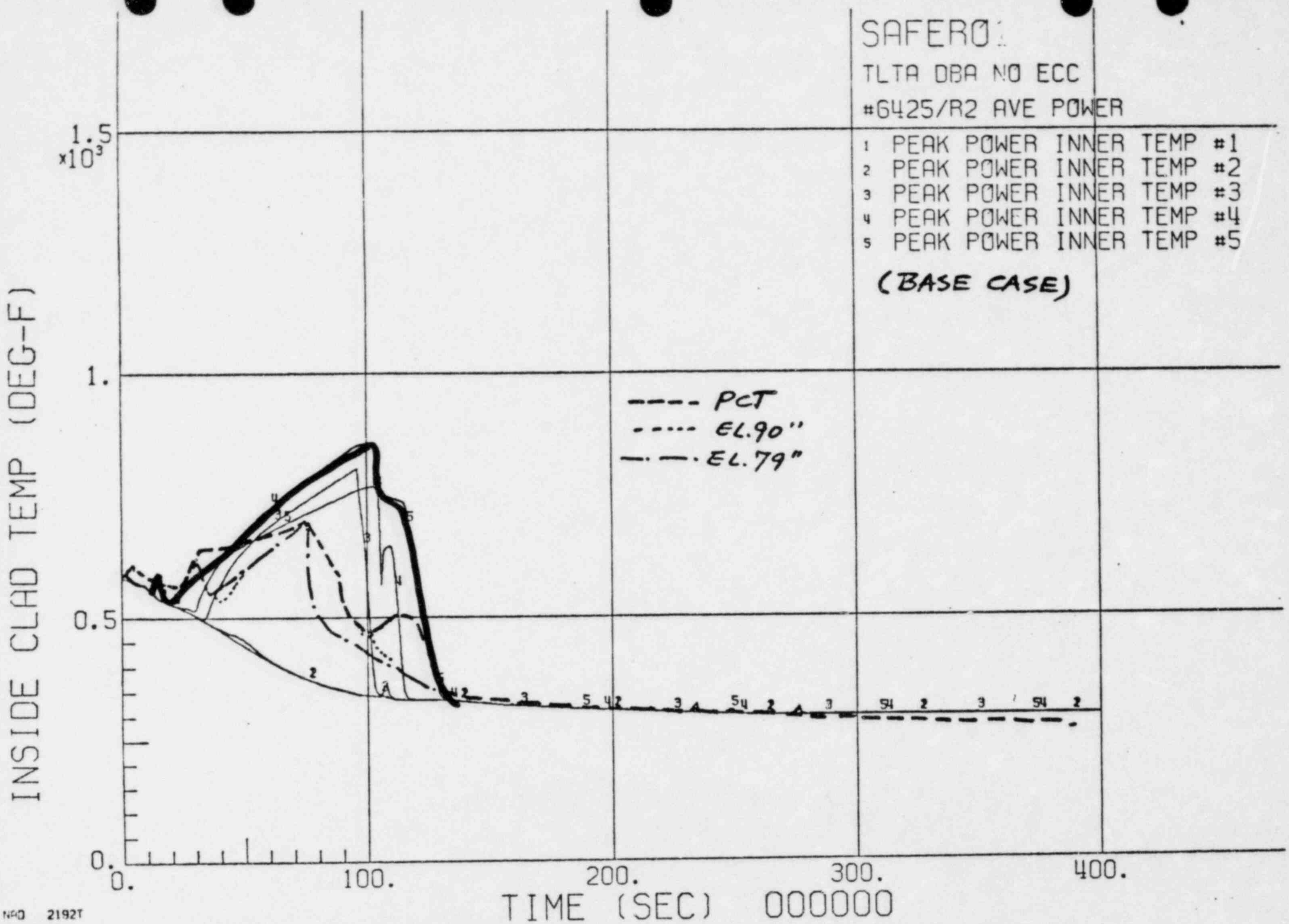
REGION 4 BYPASS (6425 R2)



REGION 5 UPPER PLENUM (6425 R2)



REGION 6&7 DOWNCOMMER (6425 R2)



NRO 2192T
061682 2149.1

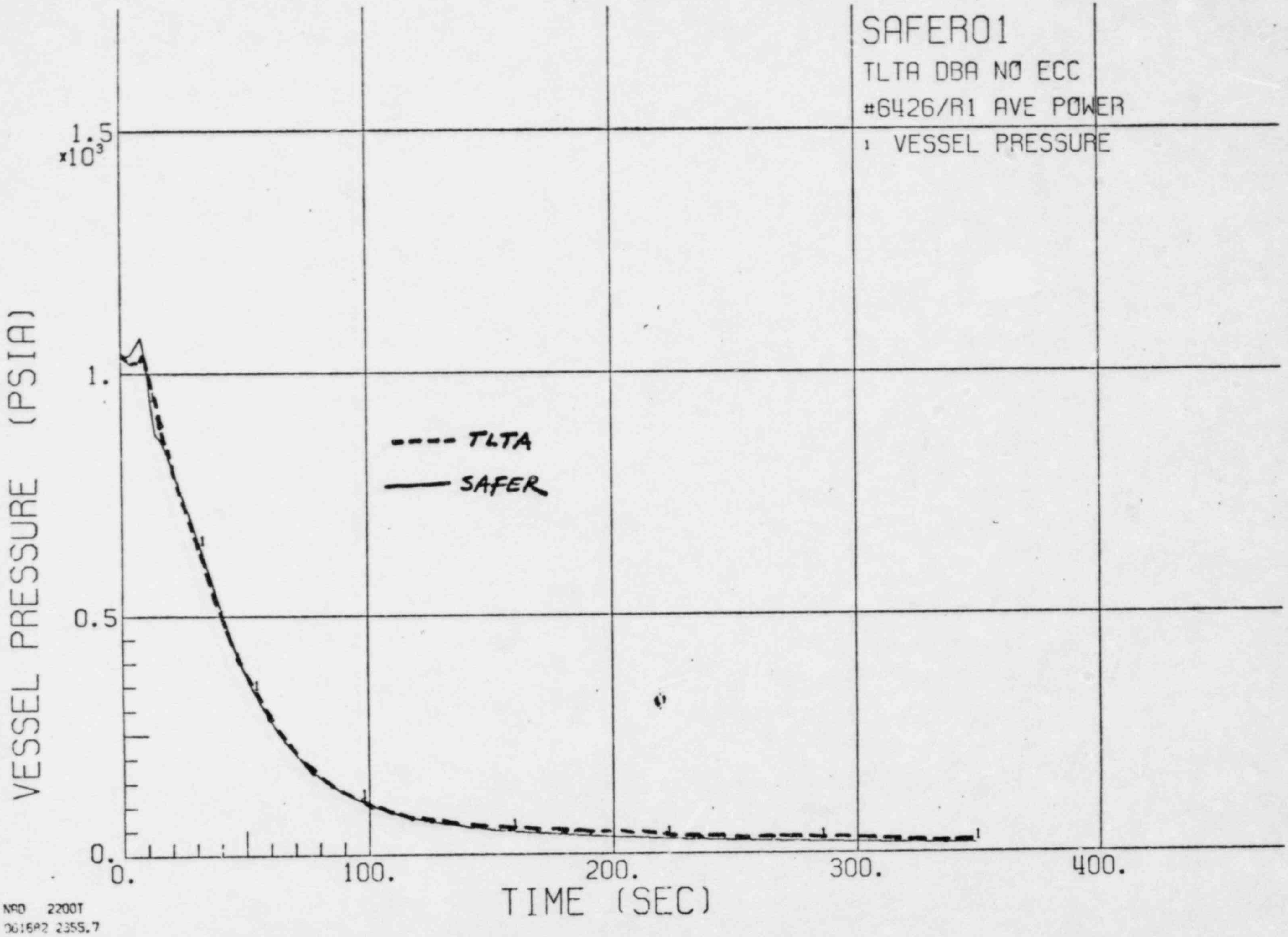
TLTA TEST 6426/R1

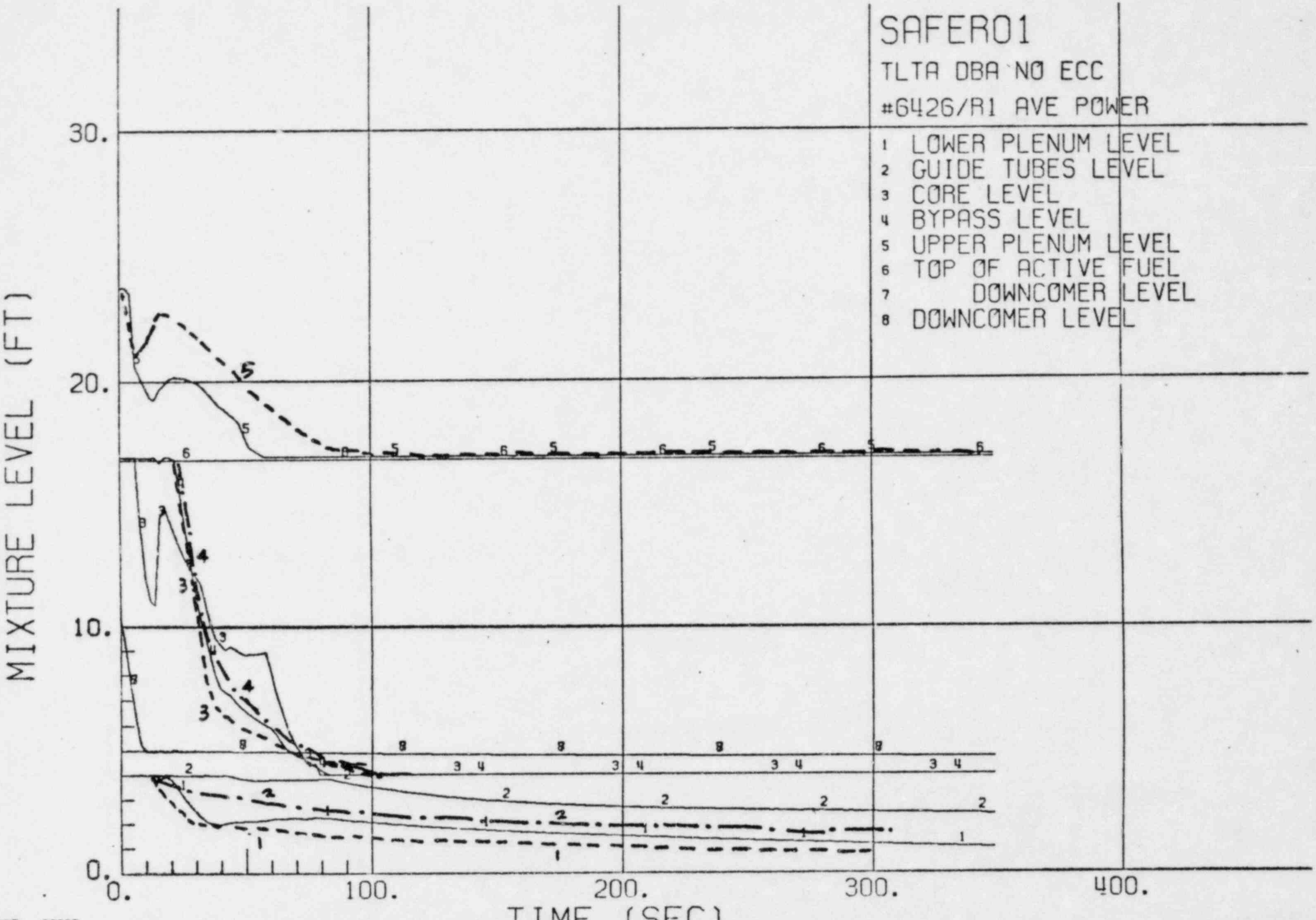
AVERAGE POWER, NO ECC

BD/ECC 1A TEST 6426 RUN 1 INITIAL CONDITIONS
(Avg. Power, No ECC)

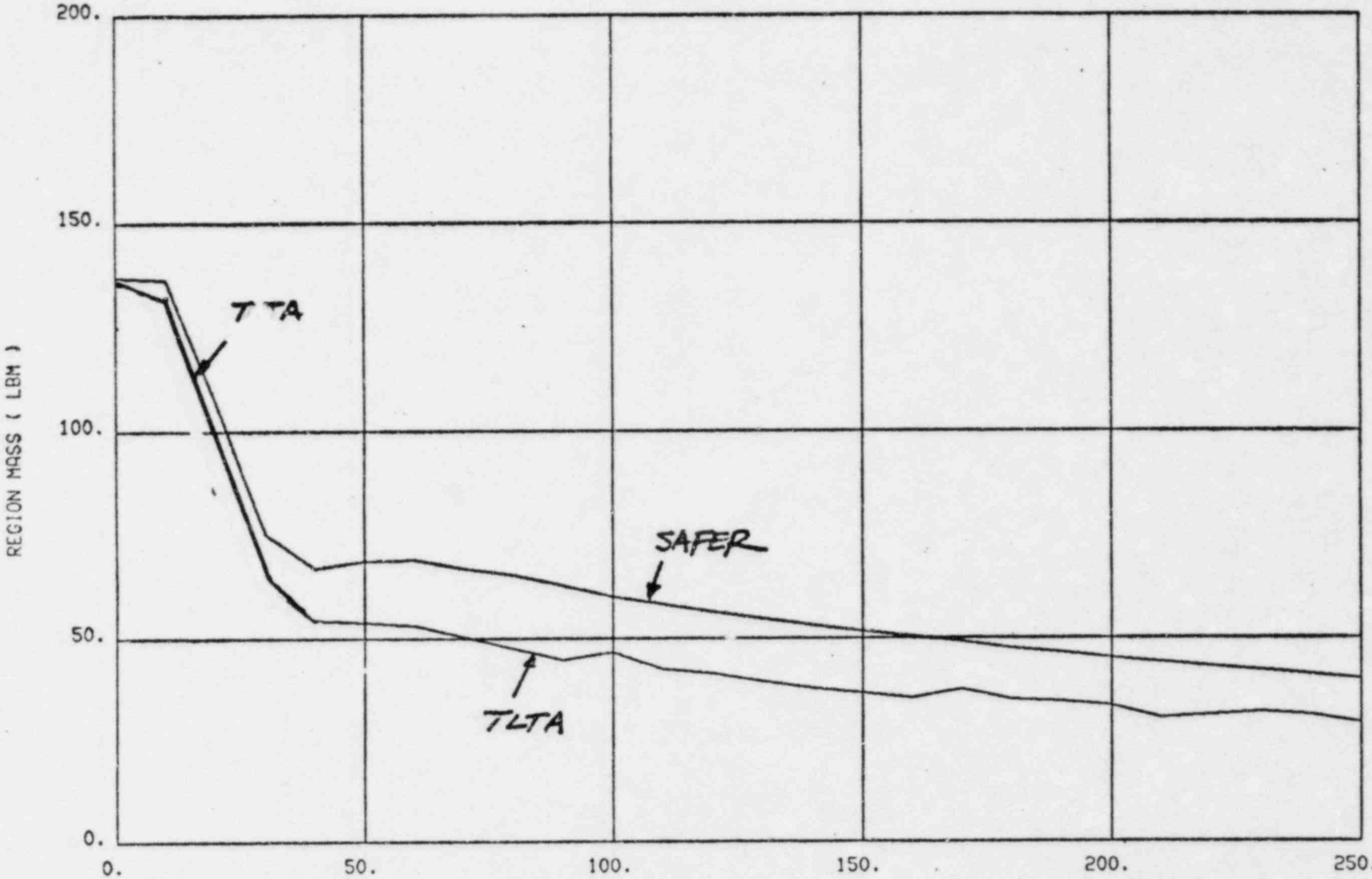
Initial Conditions	
Bundle power	5.05 ± 0.03 MW
Steam dome pressure	1044 ± 5 psia
Lower plenum pressure	1068 ± 5 psia
Lower plenum enthalpy	526 ± 5 Btu/lbm
Initial water level	123 ± 6 in. El
Feedwater enthalpy	66 ± 2 Btu/lbm
Bundle inlet to outlet DP	15 ± 2 psi
Steam flow	6 ± 1 lbm/sec
Feedwater flow	1.3 ± 0.3 lbm/sec
Drive Pump 1 flow	8.2 ± 1 lbm/sec
Drive Pump 2 flow	8.4 ± 1 lbm/sec
Jet Pump 1 flow	16 ± 2 lbm/sec
Jet Pump 2 flow	20 ± 2 lbm/sec
Bundle inlet flow	33 ± 5 lbm/sec

All uncertainty bands are judged from the maximum of data fluctuation and/or absolute uncertainties of the measurements.

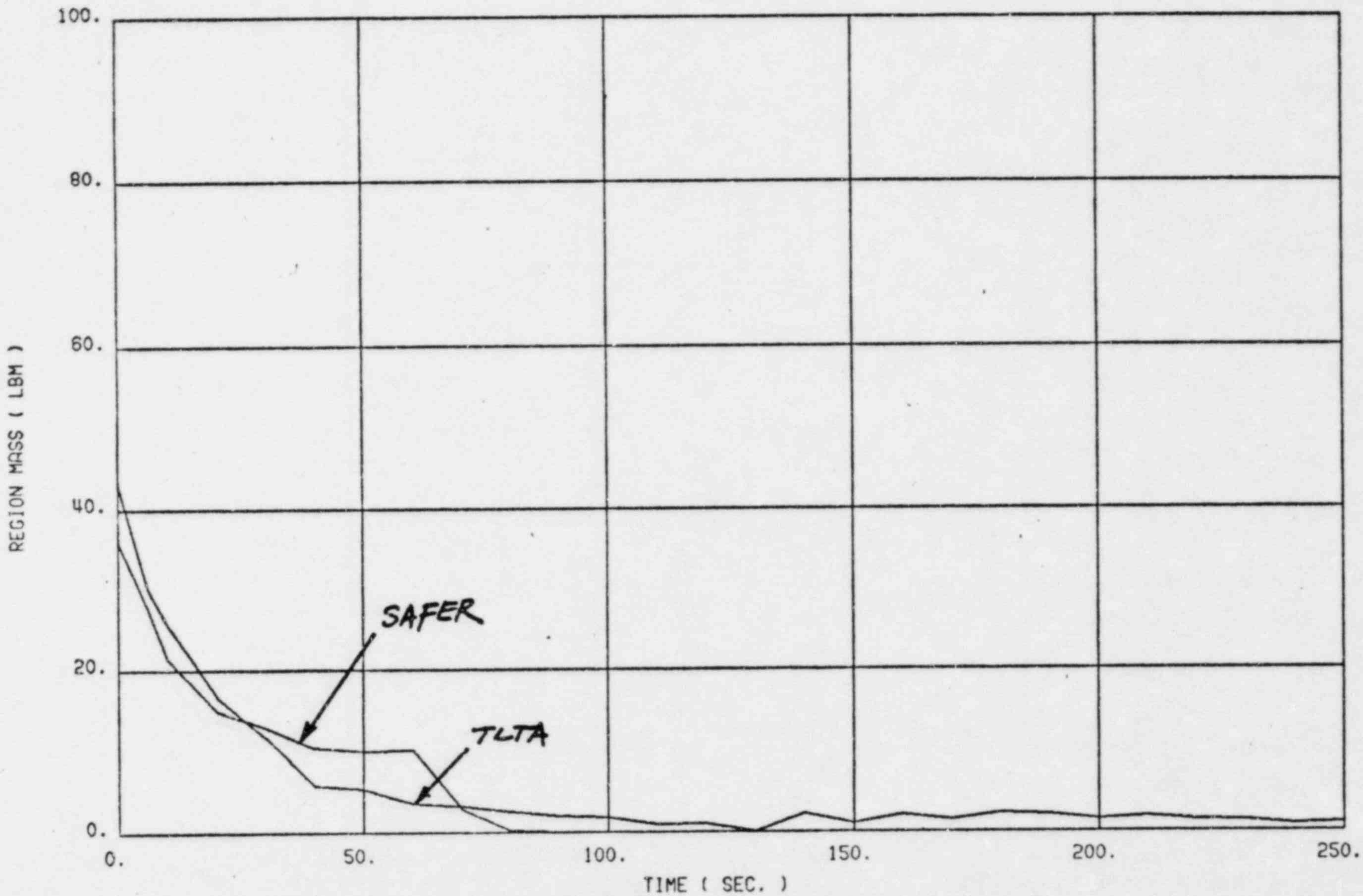

SAFER01
TLTA DBA NO ECC
#6426/R1 AVE POWER
1 VESSEL PRESSURE
TLTA
SAFER
VESSEL PRESSURE (PSIA)
x10³
1.5
1.
0.5
0.
0.
100.
200.
300.
400.
TIME (SEC)
NRD 2200T
061682 2355.7



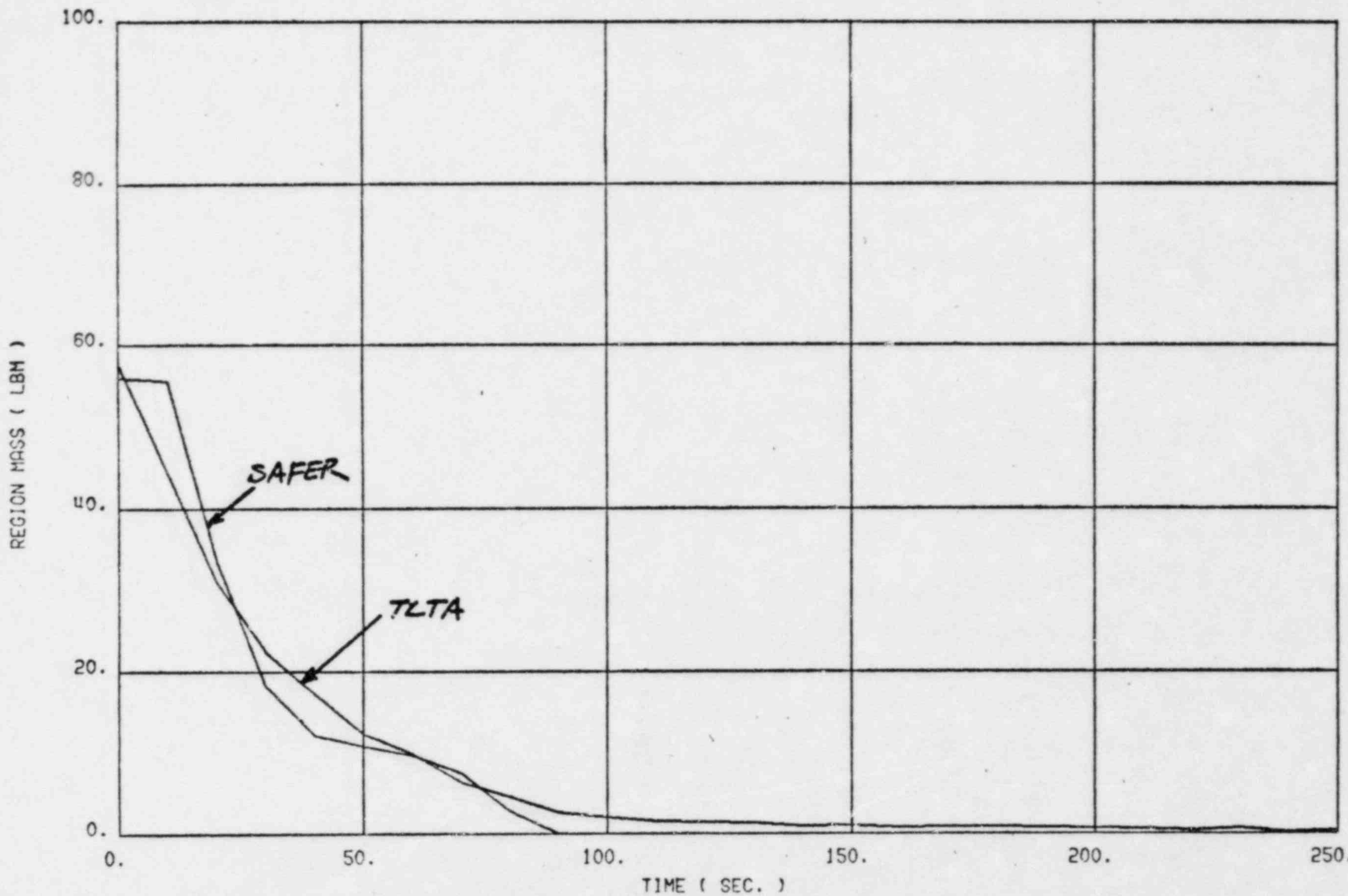
NRD 2200T
061682 2355.7



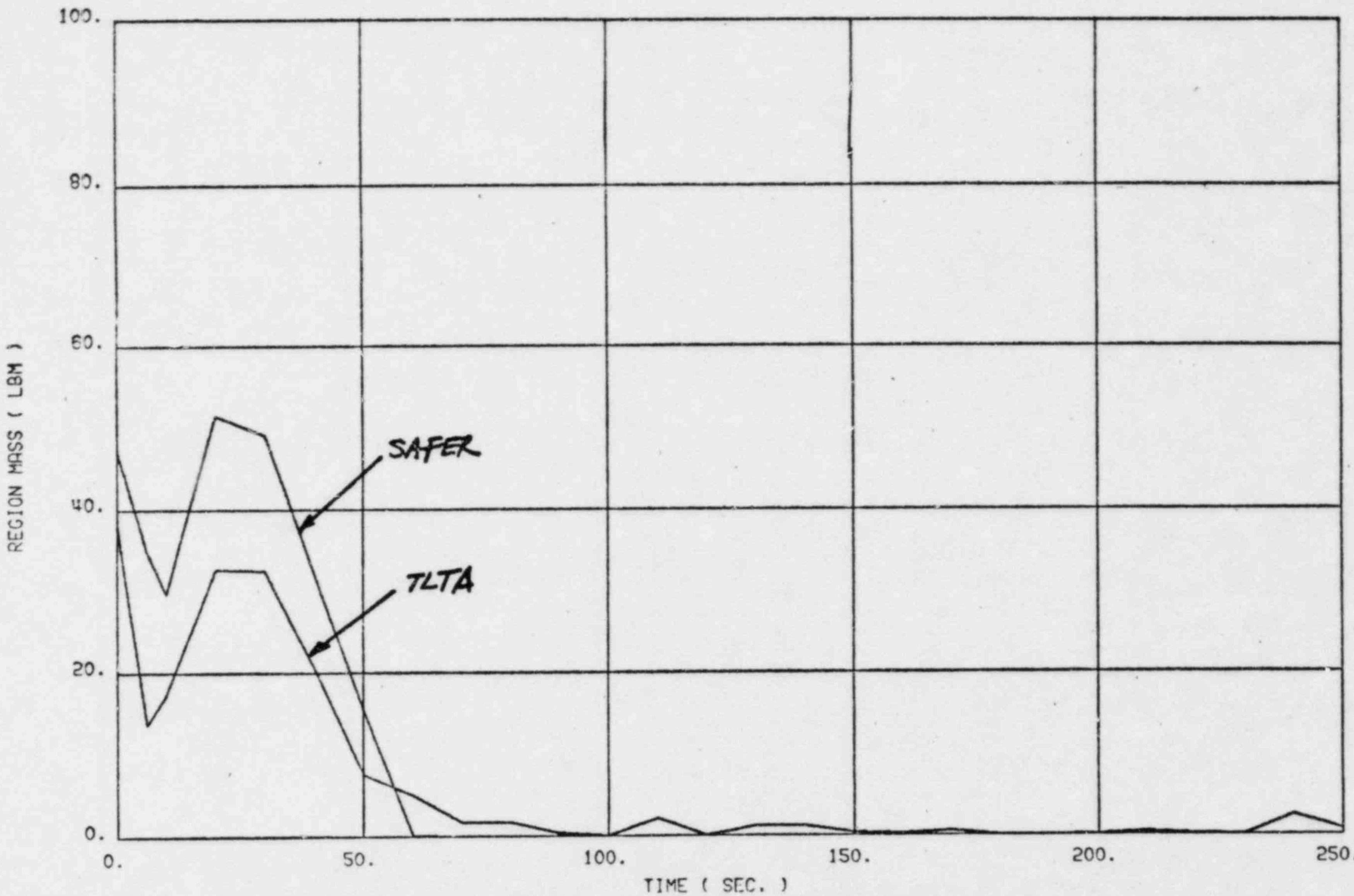
REGION 1 LOWER PLENUM (6426 R1) 2391T



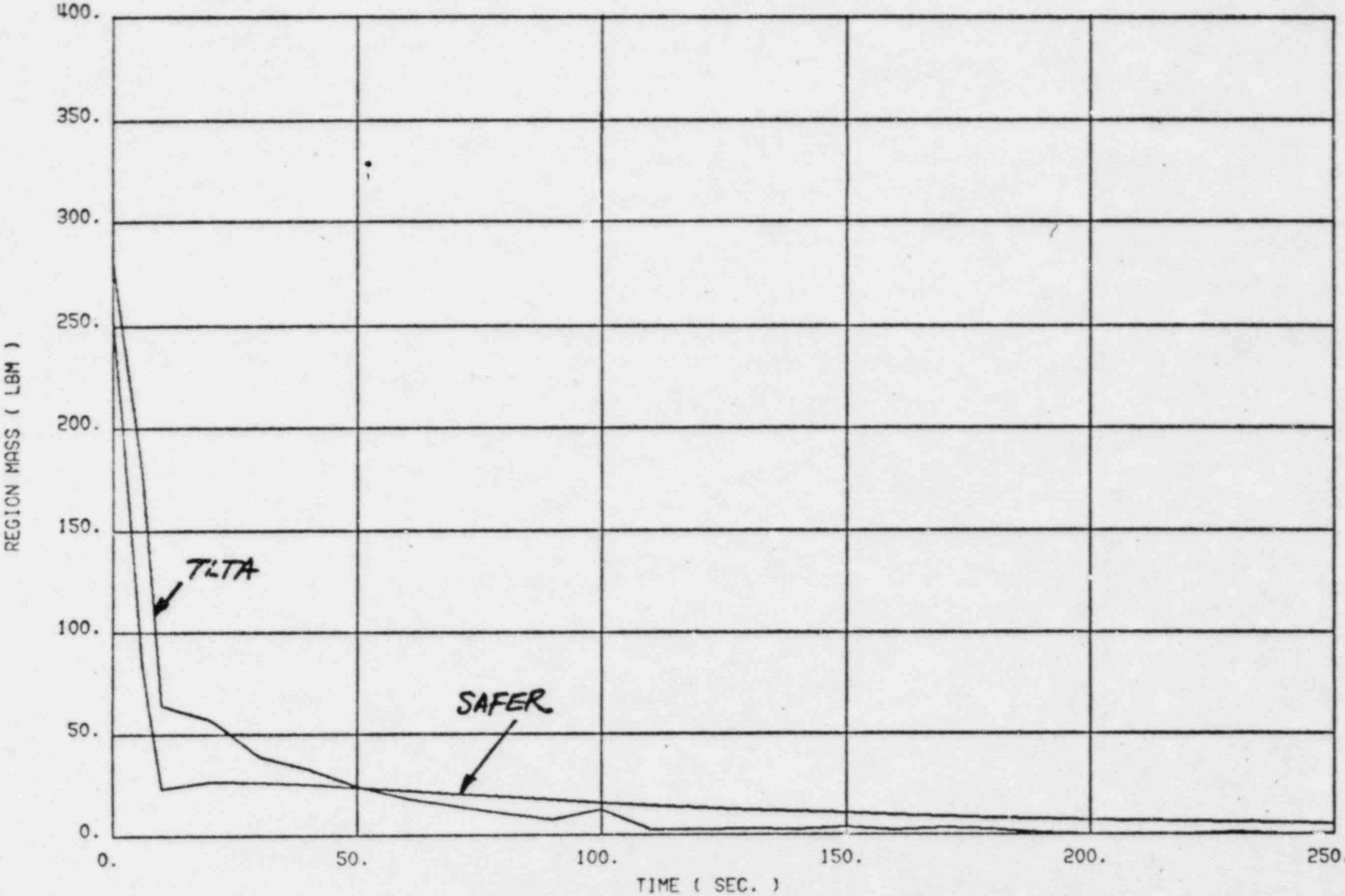
REGION 3 BUNDLE (6426 R1) 2391T



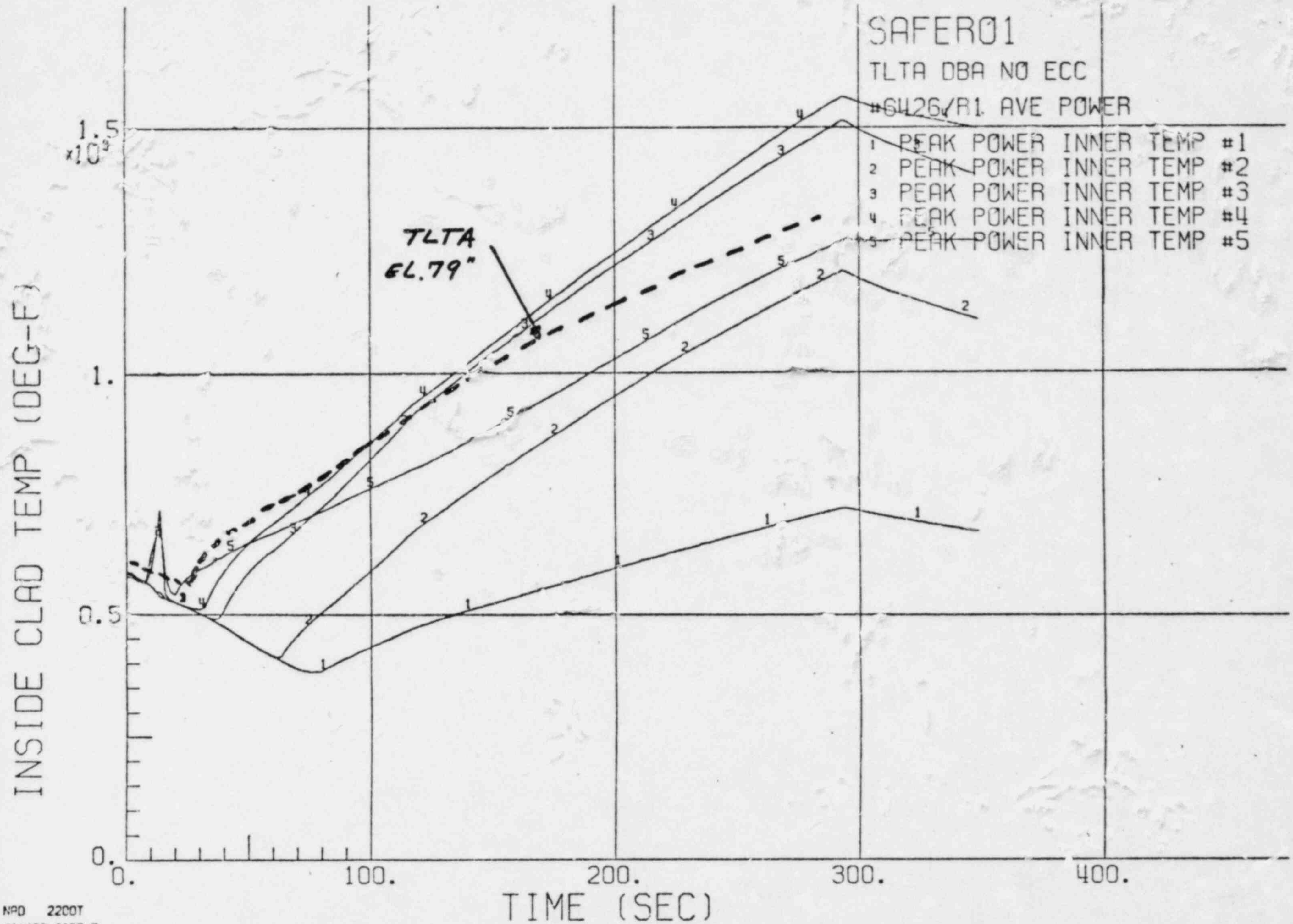
REGION 4 BYPASS (6426 R1) 2391T



REGION 5 UPPER PLENUM (6426 R1) 2391T



REGION 6&7 DOWNCOMMER (6426 R1) 2391T



NPD 2200T
CS1882 2355.7

TLTA TEST 6423/R3

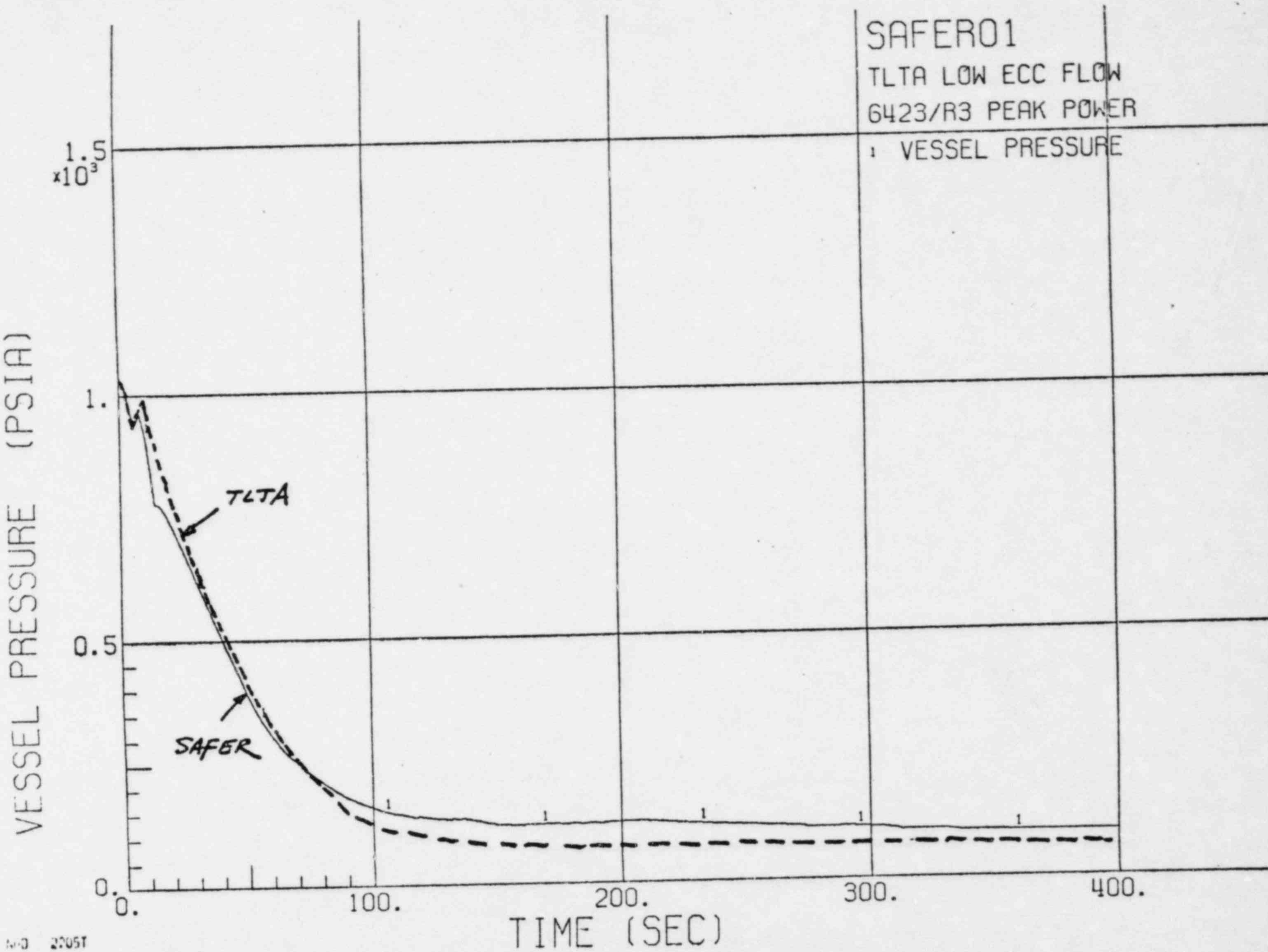
PEAK POWER BUNDLE, LOW ECC

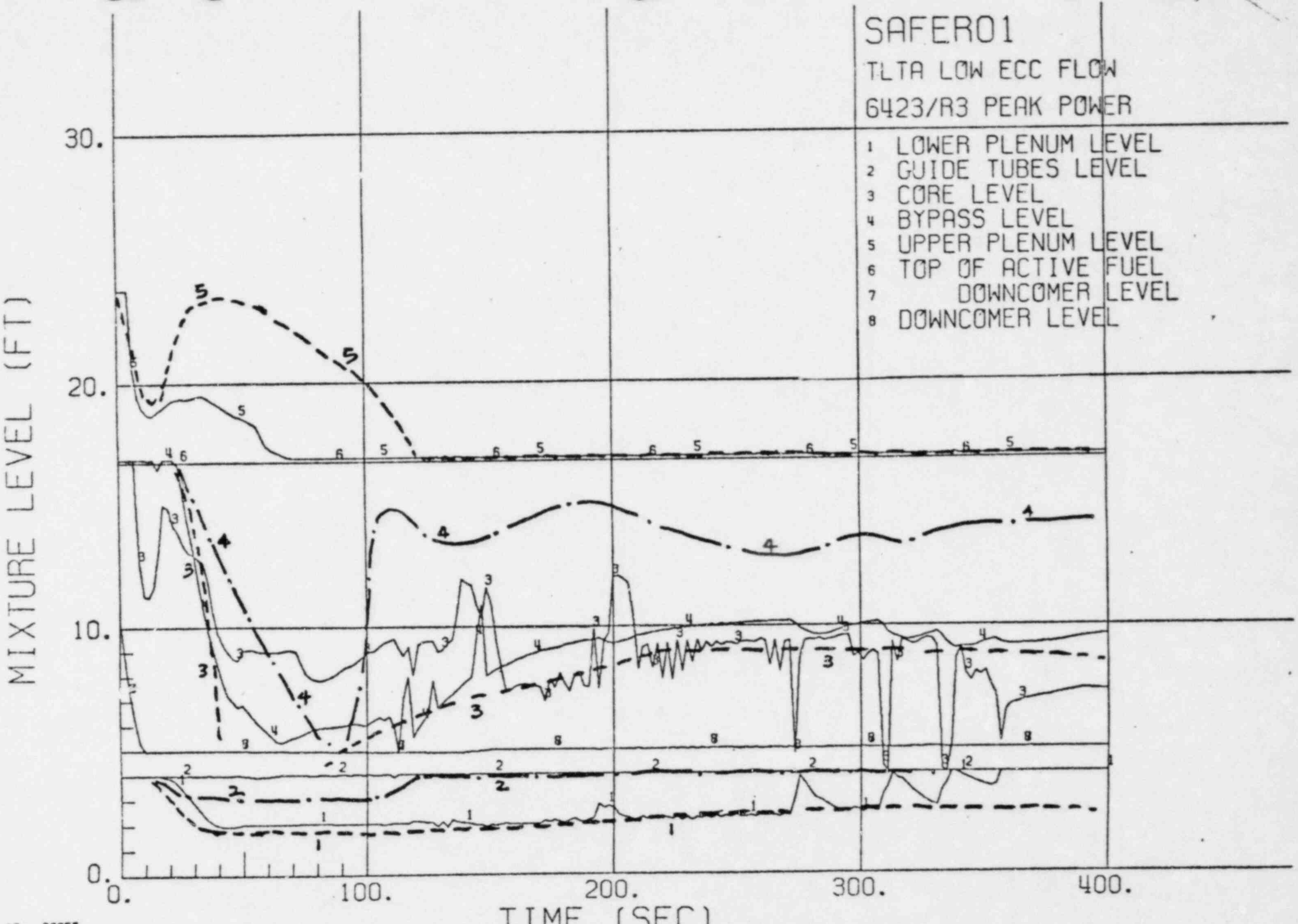
Table ..

TEST 6423 RUN 3 INITIAL CONDITIONS
(Peak Power, Low Rate/High Temperature ECC)

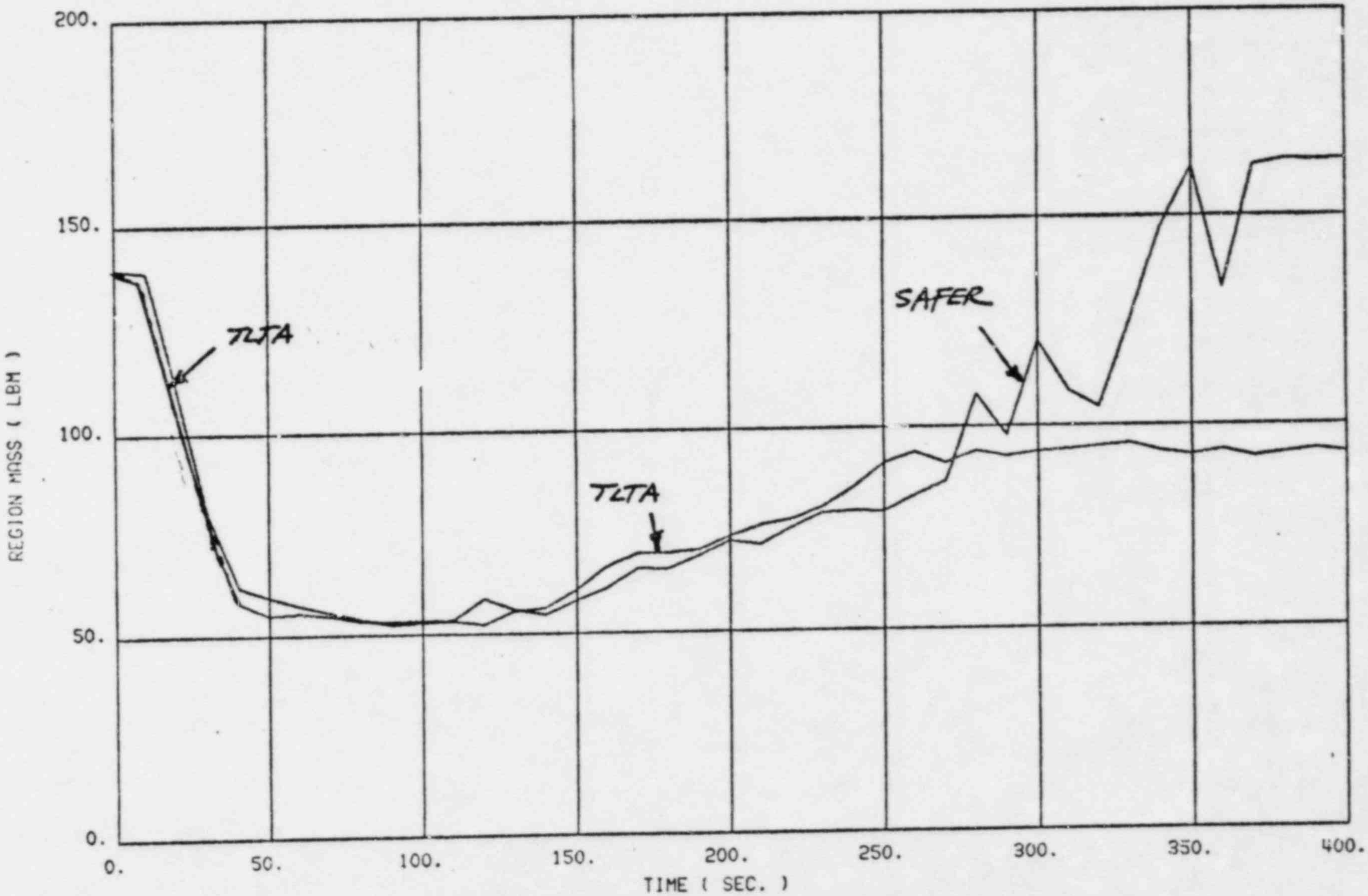
Initial Conditions	
Bundle power	6.46 ± 0.03 MW
Steam dome pressure	1037 ± 5 psia
Lower plenum pressure	1065 ± 5 psia
Lower plenum enthalpy	518 ± 5 Btu/lbm
Initial water level	123 ± 6 in. El
Feedwater enthalpy	41 ± 2 Btu/lbm
Bundle inlet to outlet DP	16 ± 2 psi
Steam flow	7 ± 1 lbm/sec
Feedwater flow	1.0 ± 0.3 lbm/sec
Drive Pump 1 flow	8.1 ± 1 lbm/sec
Drive Pump 2 flow	8.3 ± 1 lbm/sec
Jet Pump 1 flow	17 ± 2 lbm/sec
Jet Pump 2 flow	19 ± 2 lbm/sec
Bundle inlet flow	33 ± 5 lbm/sec
ECC fluid temperature	200 ± 15°F

All uncertainty bands are judged from the maximum of data fluctuation and/or absolute uncertainties of the measurements.

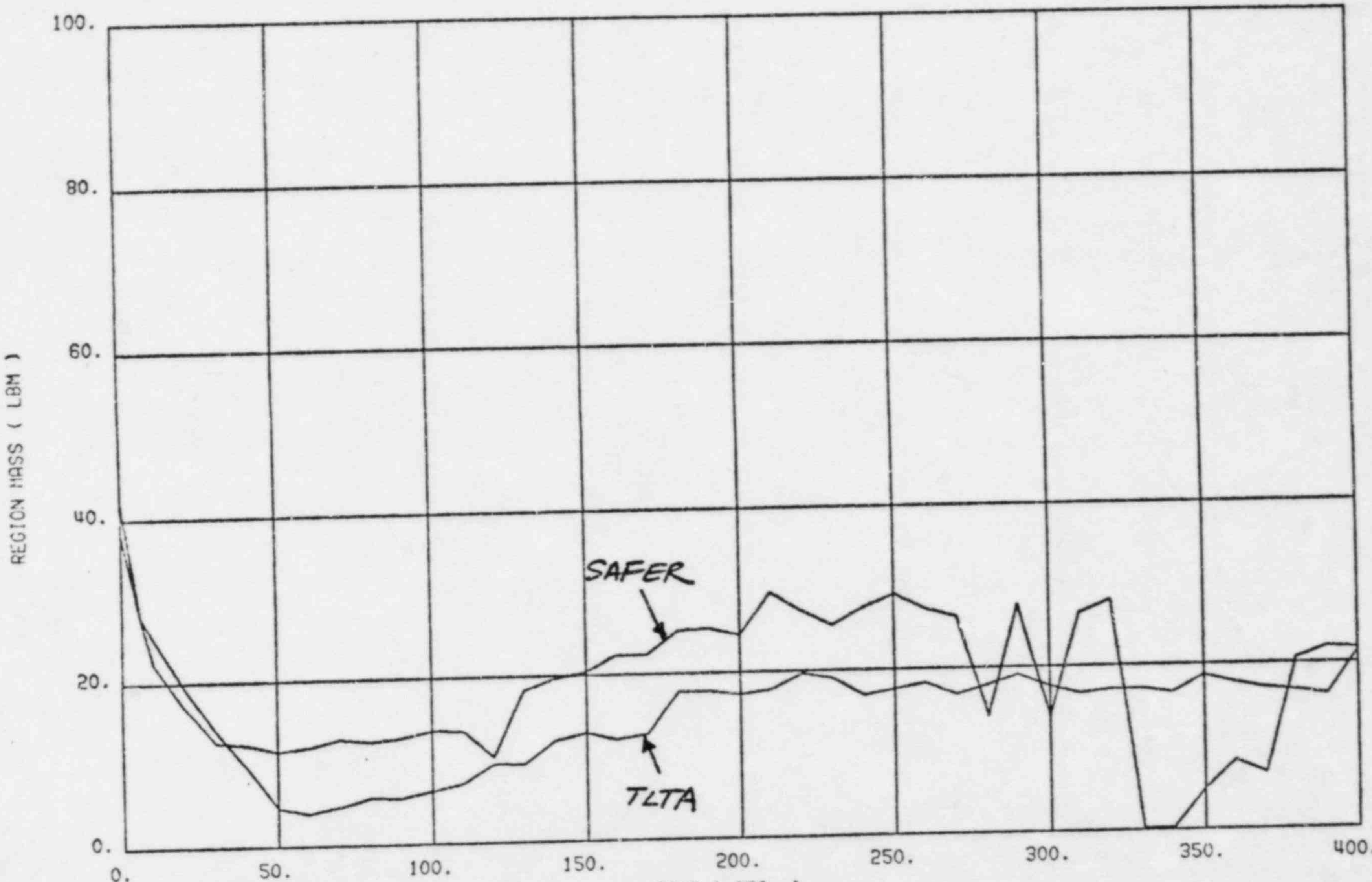

SAFER01
TLTA LOW ECC FLOW
6423/R3 PEAK POWER
1 VESSEL PRESSURE
VESSEL PRESSURE (PSIA)
1.5
x10³
1.
0.5
0.
TLTA
SAFER
0.
100.
200.
300.
400.
TIME (SEC)



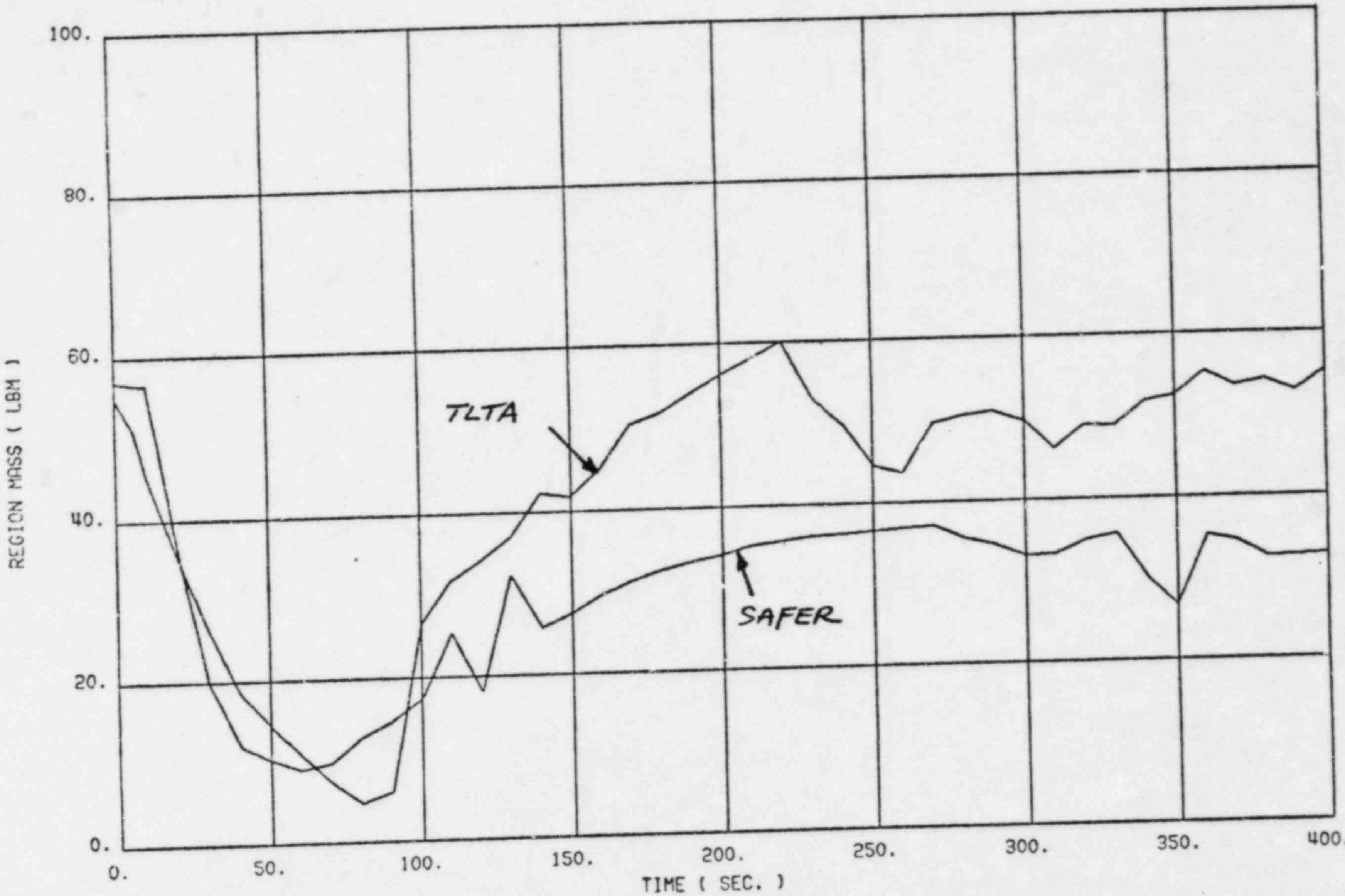
SAFER01
TLTA LOW ECC FLOW
6423/R3 PEAK POWER
1 LOWER PLENUM LEVEL
2 GUIDE TUBES LEVEL
3 CORE LEVEL
4 BYPASS LEVEL
5 UPPER PLENUM LEVEL
6 TOP OF ACTIVE FUEL
7 DOWNCOMER LEVEL
8 DOWNCOMER LEVEL
MIXTURE LEVEL (FT)
30.
20.
10.
0.
0.
100.
200.
300.
400.
TIME (SEC)



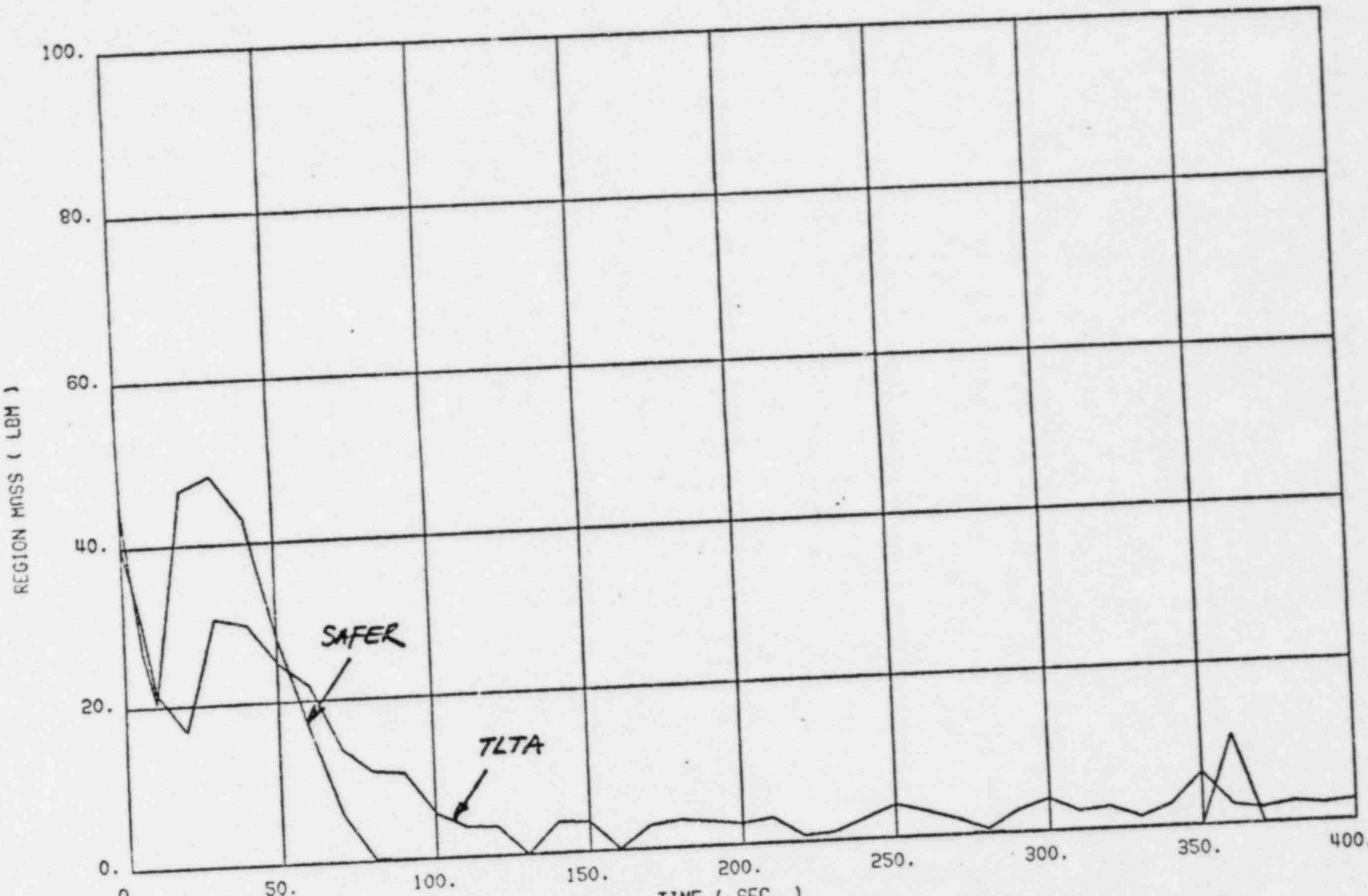
REGION 1 LOWER PLENUM (6423 R3)



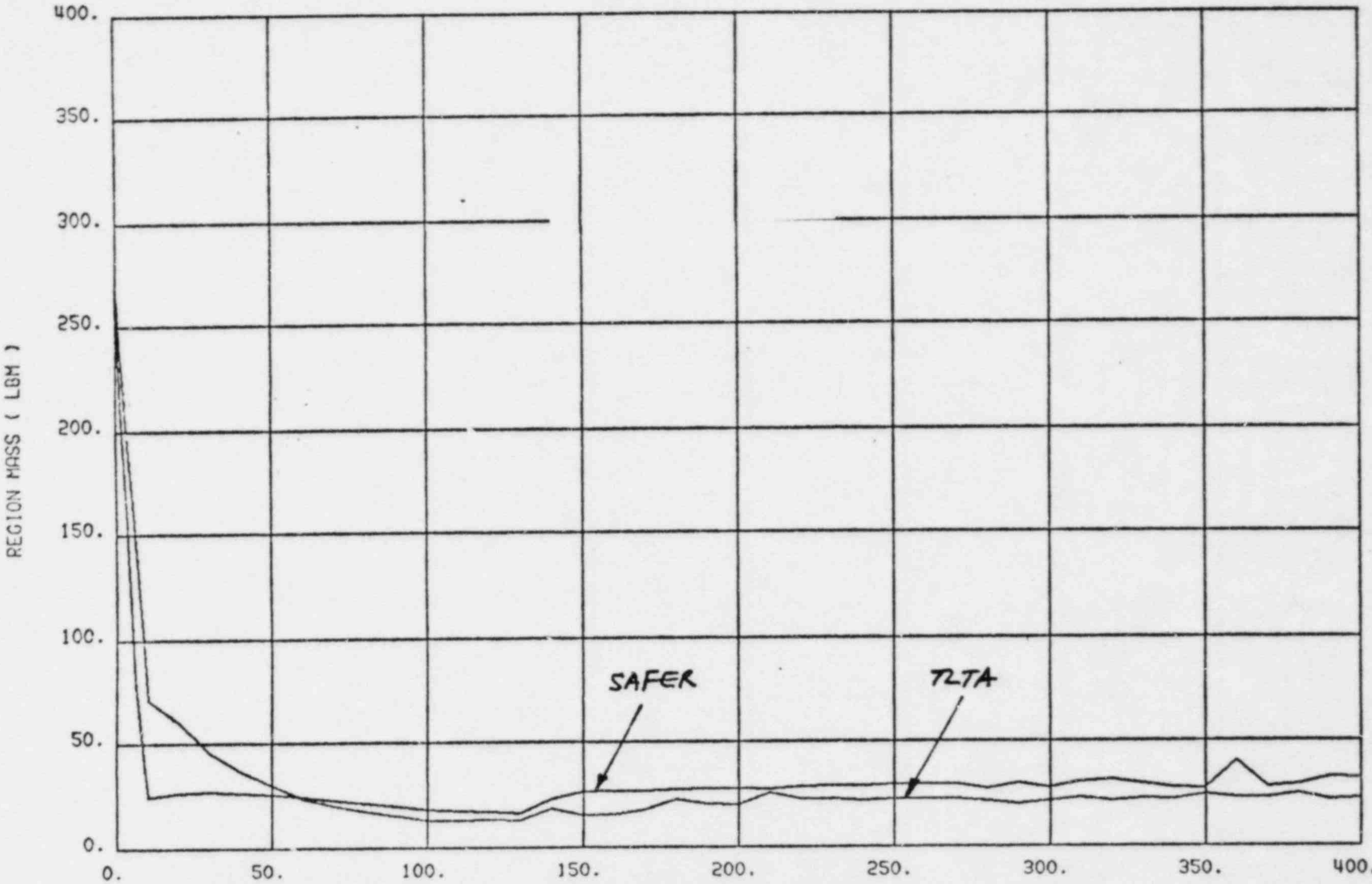
REGION 3 BUNDLE (6423 R3)



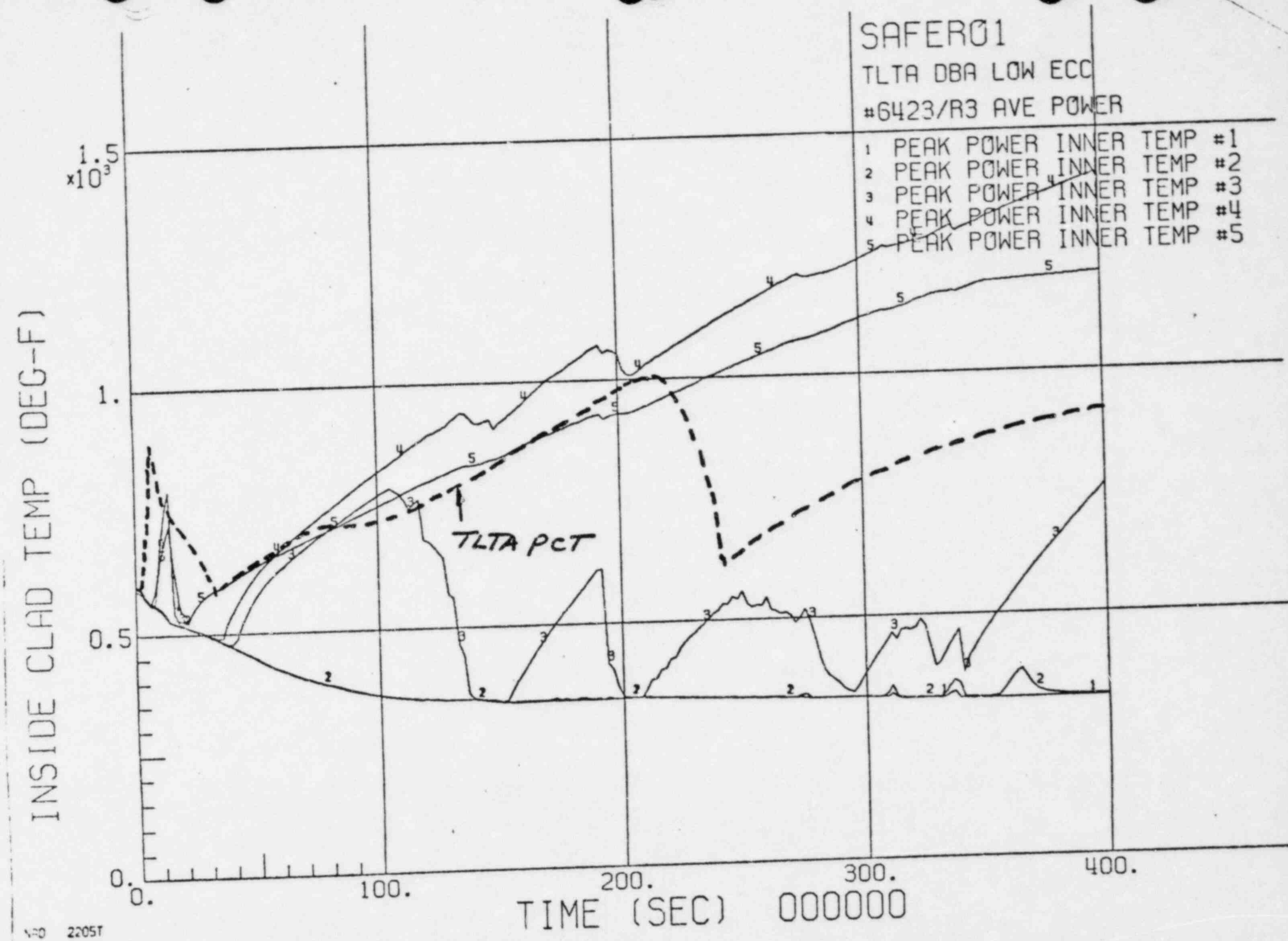
REGION 4 BYPASS (6423 R3)



REGION 5 UPPER PLENUM (6423 R3)



REGION 6&7 DOWNCOMMER (6423 R3)



SAFER01
TLTA DBA LOW ECC
#6423/R3 AVE POWER
1 PEAK POWER INNER TEMP #1
2 PEAK POWER INNER TEMP #2
3 PEAK POWER INNER TEMP #3
4 PEAK POWER INNER TEMP #4
5 PEAK POWER INNER TEMP #5
TLTA PCT
INSIDE CLAD TEMP (DEG-F)
x10³
1.5
1.
0.5
0.
0.
100.
200.
300.
400.
TIME (SEC) 000000

NEO 2205T

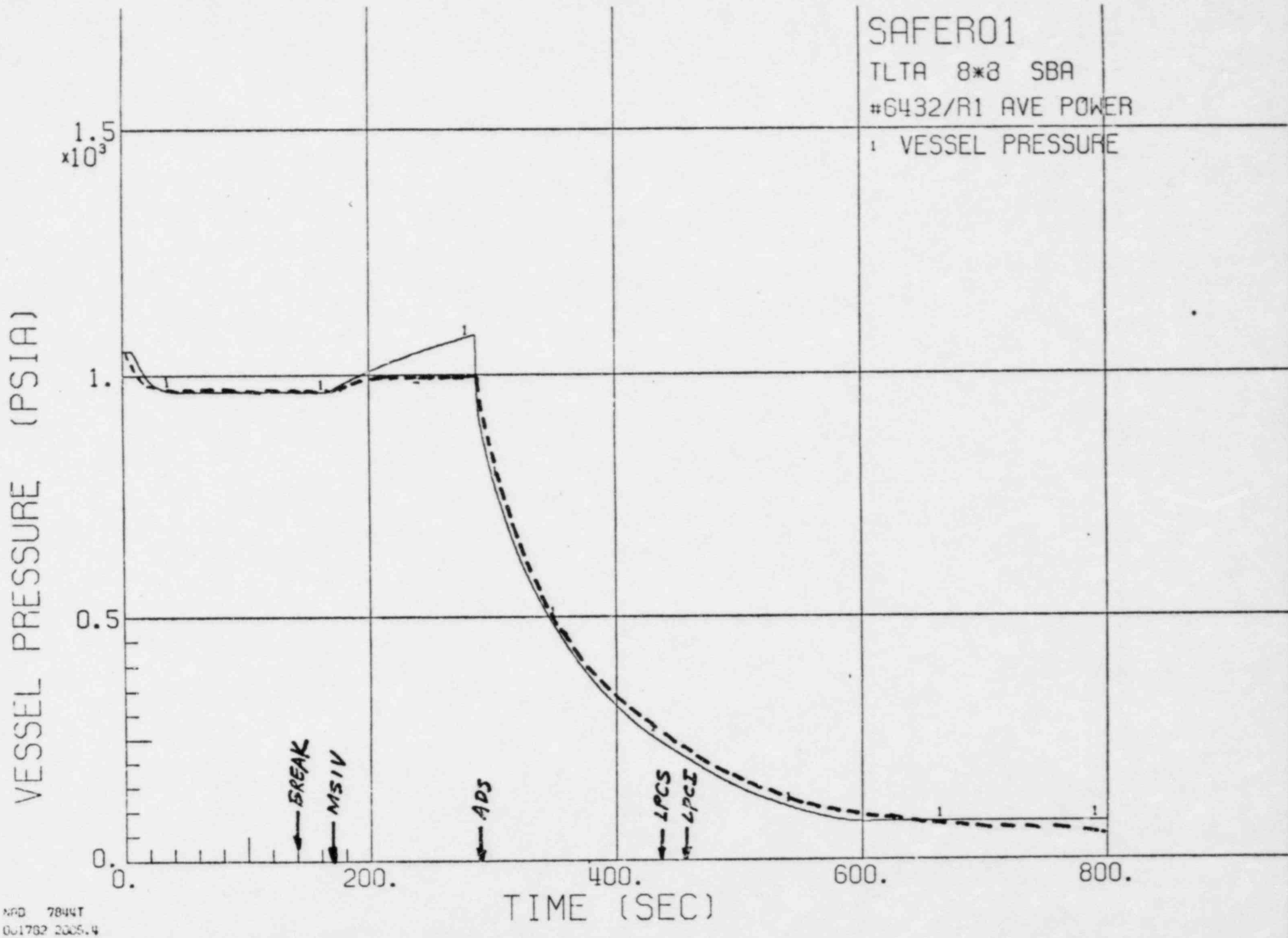
TLTA TEST 6432/R1

SMALL BREAK TEST

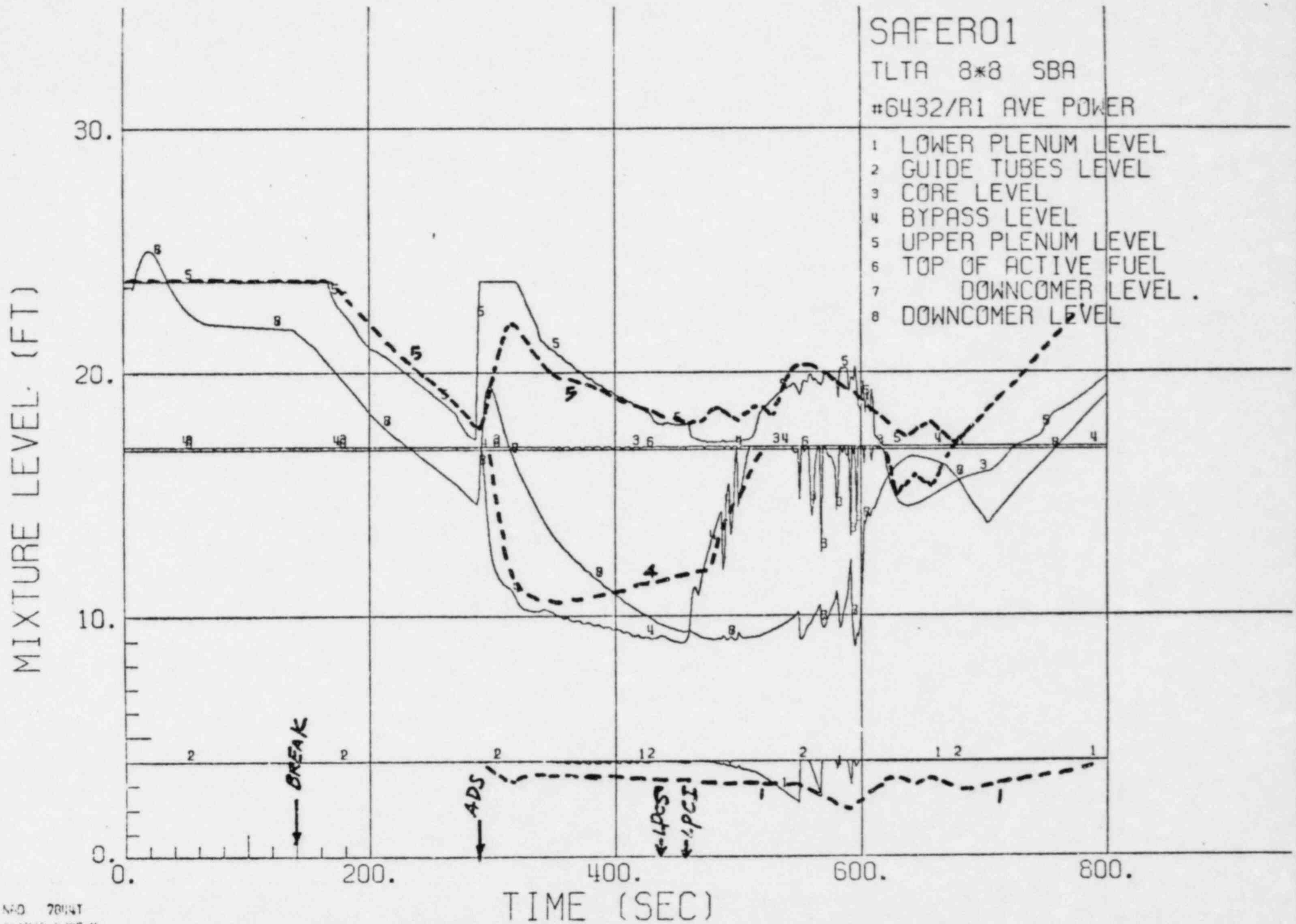
COMPARISON OF TEST CONDITIONS

(TLTA Small Break Test No. II, 6432/Run 1)

Break Size	Specified	Measured
Line No. 1	0.125±0.001 in. diameter	0.125±0.001 in. diameter
Line No. 2	0.153±0.001 in. diameter	0.153±0.001 in. diameter
ADS Orifice Size	0.677±0.001 in. diameter	0.677±0.001 in. diameter
ECCS		
Inlet Fluid Temperature	80±15°F	90±4°F
HPCS	HPCS deactivated	deactivated
LPCS (see Figure 2-6)	activated	activated
LPCI (see Figure 2-7)	activated	activated
Initial Condition		
Steam Dome Pressure	1050±20 psia	1048±5 psia
Water Level (Outside Shroud)	283±6 in. EL	283±3 in. EL
Bundle Flow (Core Flow)	34±5 lbm/sec.	34±5 lbm/sec.
Bypass Flow, Total	1.5±0.5 lbm/sec.	2.1±0.5 lbm/sec.
Steam Flow	1.4±0.5 lbm/sec.	1.6±0.5 lbm/sec.
Bundle Inlet Subcooling	23±5°F	21±4°F
Downcomer Temperature		
Above F.W. Sparger	T sat	553±4°F
Below F.W. Sparger	(T sat-23°F)±5°F	532±4°F
Timings		
Pump No. 1 Trip	0.0±0.2 sec.	0.0±0.1 sec.
Pump No. 2 Trip	4.0±1.0 sec.	4.0±0.2 sec.
Feed Water Trip	0.0±0.5 sec.	0.1±0.5 sec.
Break Open Line No. 1	$t \geq 140$ sec.±1 sec.	$t \geq 138 \pm 1$ sec.
Break Open Line No. 2	$140 \leq t \leq 286$ sec.	$138 \pm 1 \leq t \leq 286 \pm 1$ sec.
ADS Opening	286±2 sec.	286±1 sec.
MSIV (Steam Valve) Closure	166±2 sec.	165±1 sec.
ECCS Activated	37±1 sec.	37±1 sec.
Intact Recirculation Loop (No. 1 Isolated)	20±1 sec.	20±0.5 sec.

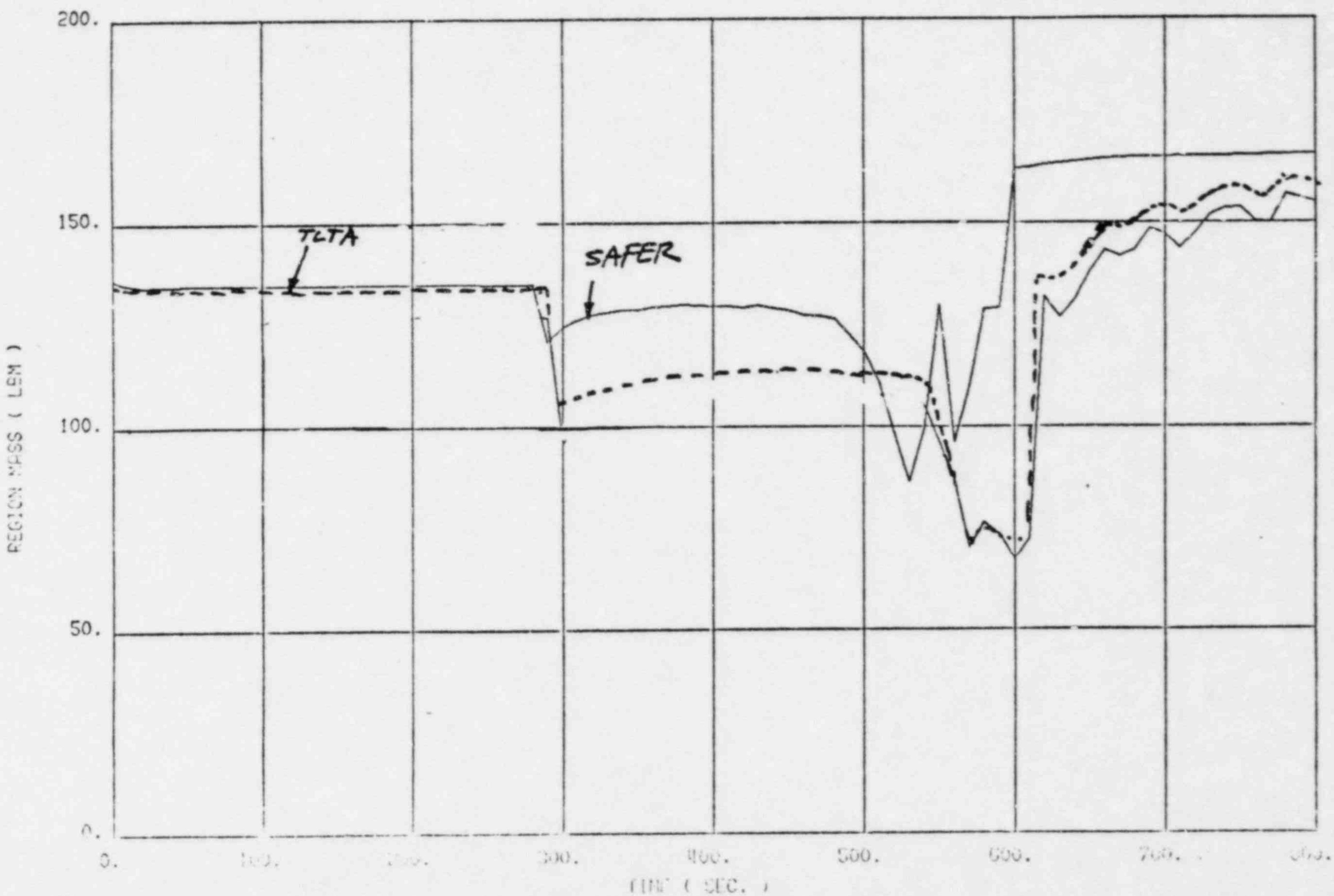


NRD 7844T
001782 2005.4

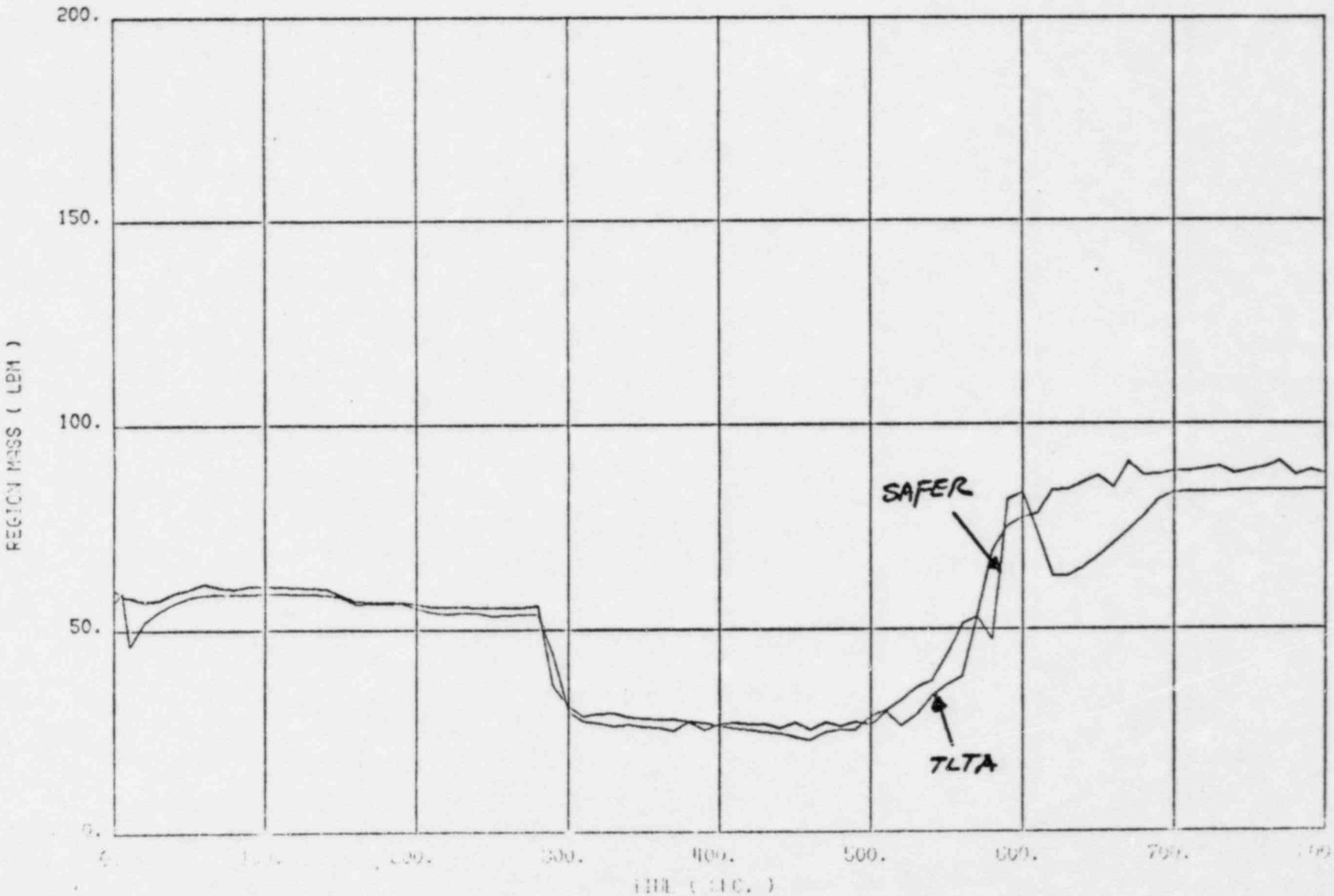


SAFER01
TLTA 8*8 SBA
#6432/R1 AVE POWER
1 LOWER PLENUM LEVEL
2 GUIDE TUBES LEVEL
3 CORE LEVEL
4 BYPASS LEVEL
5 UPPER PLENUM LEVEL
6 TOP OF ACTIVE FUEL
7 DOWNCOMER LEVEL.
8 DOWNCOMER LEVEL
MIXTURE LEVEL (FT)
TIME (SEC)
30.
20.
10.
0.
0.
200.
400.
600.
800.
BREAK
ADS
LPCS
HPCI

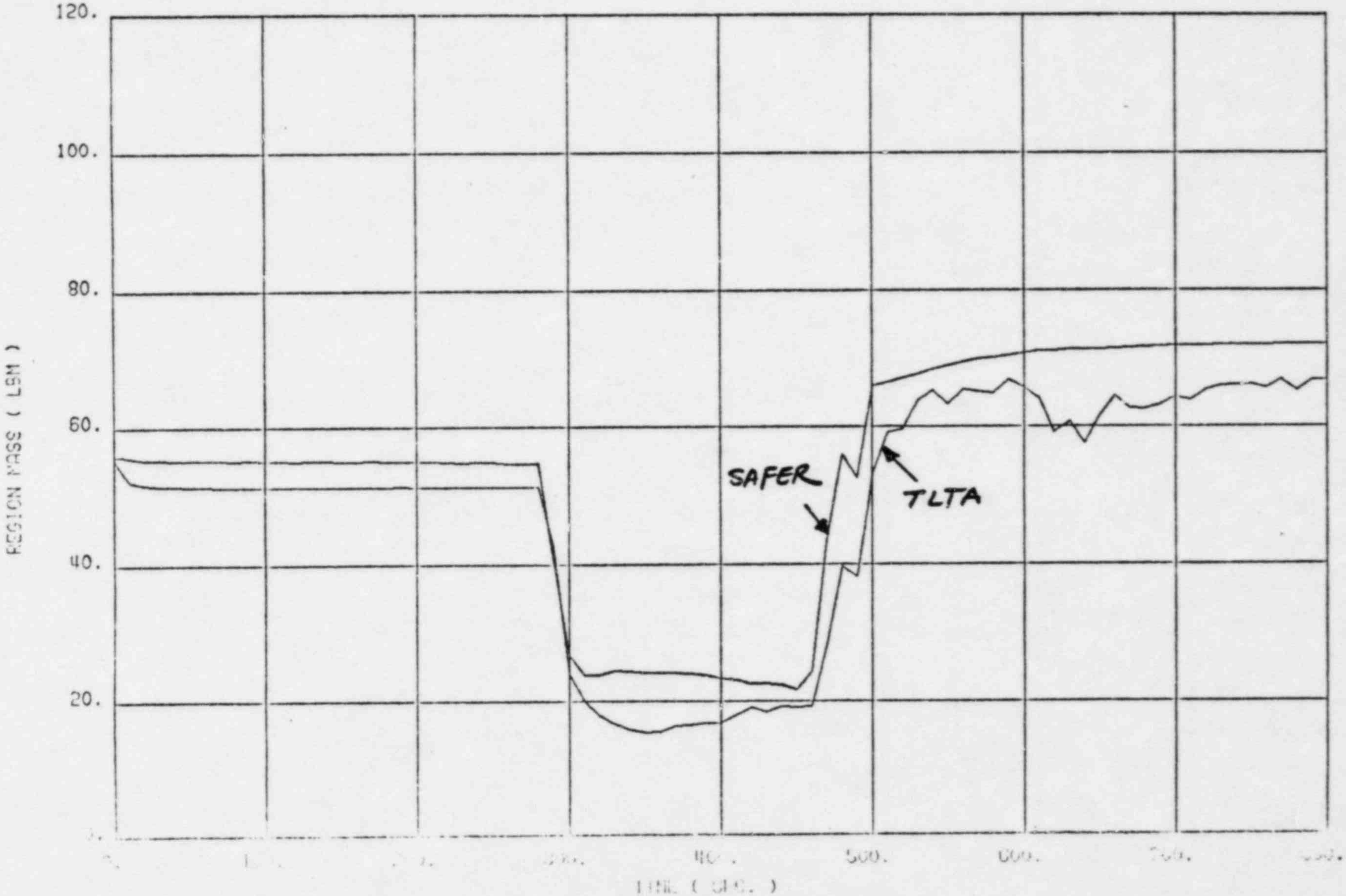
NAO 78441



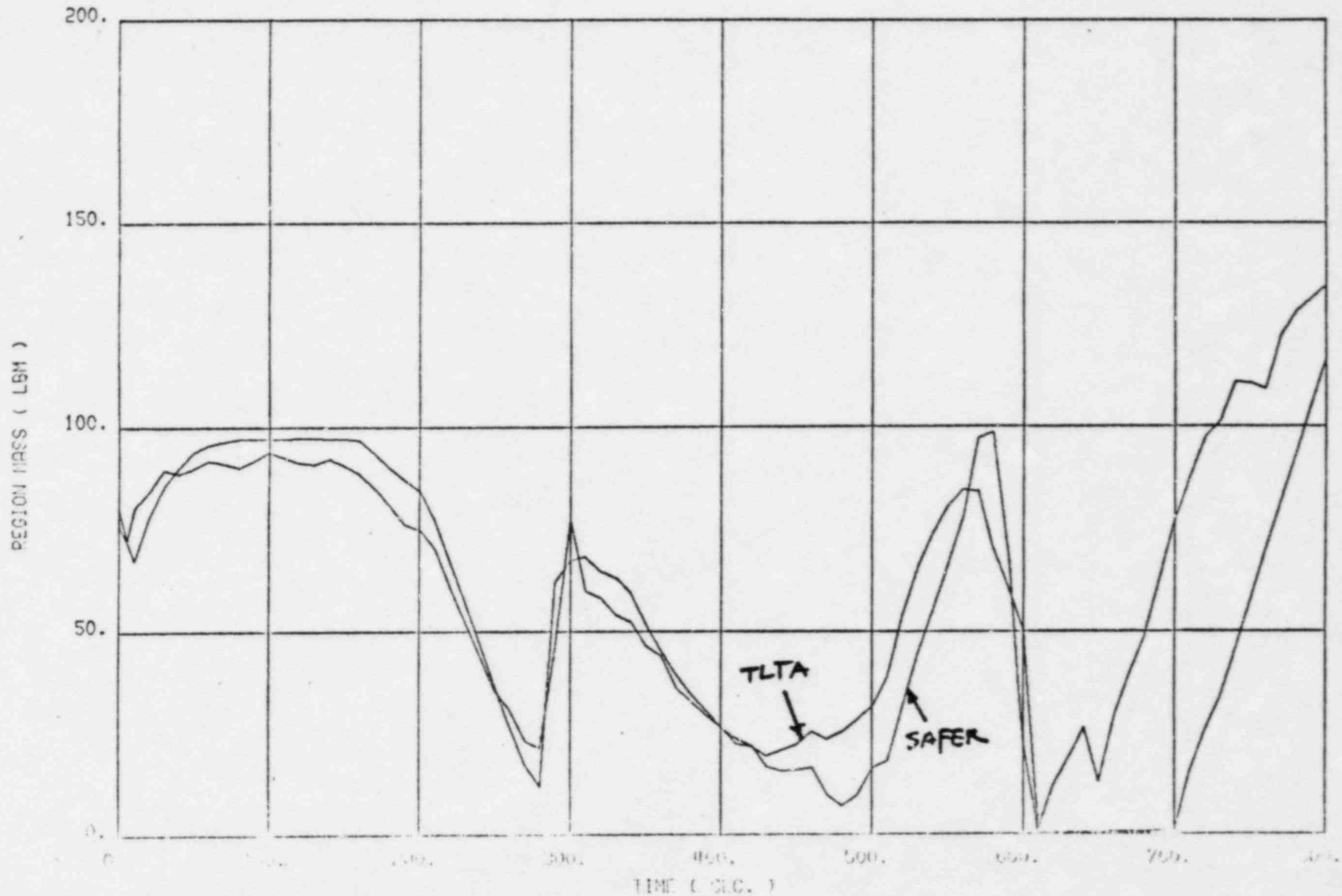
REGION 1 LOWER PLENUM (6432 R1) 7467T



REGION 3 BUNDLE (6432 R1) 74677



REGION 4 BYPASS (6432 R1) 7467T



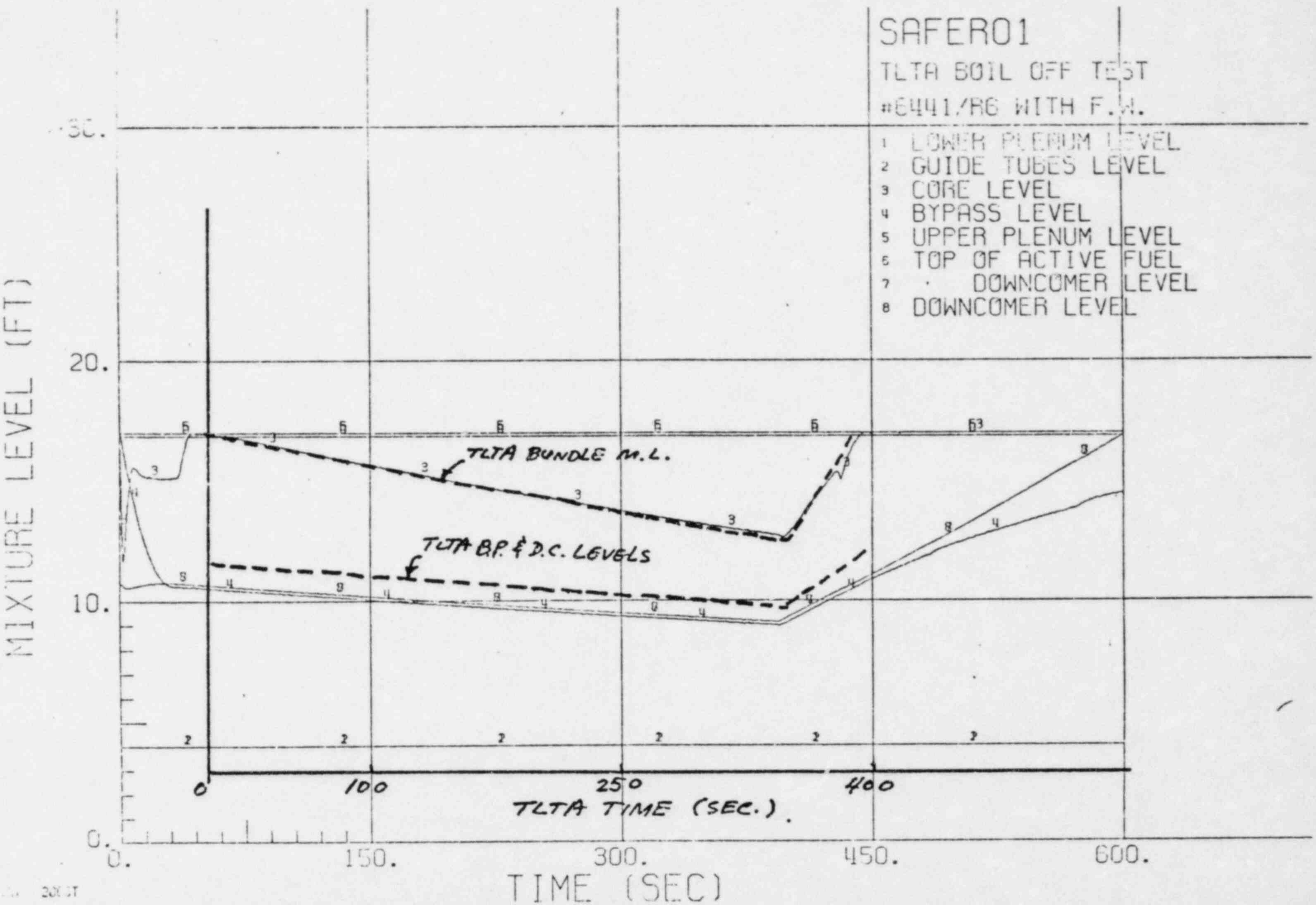
REGION 5 UPPER PLENUM (G432 R1) 7467T

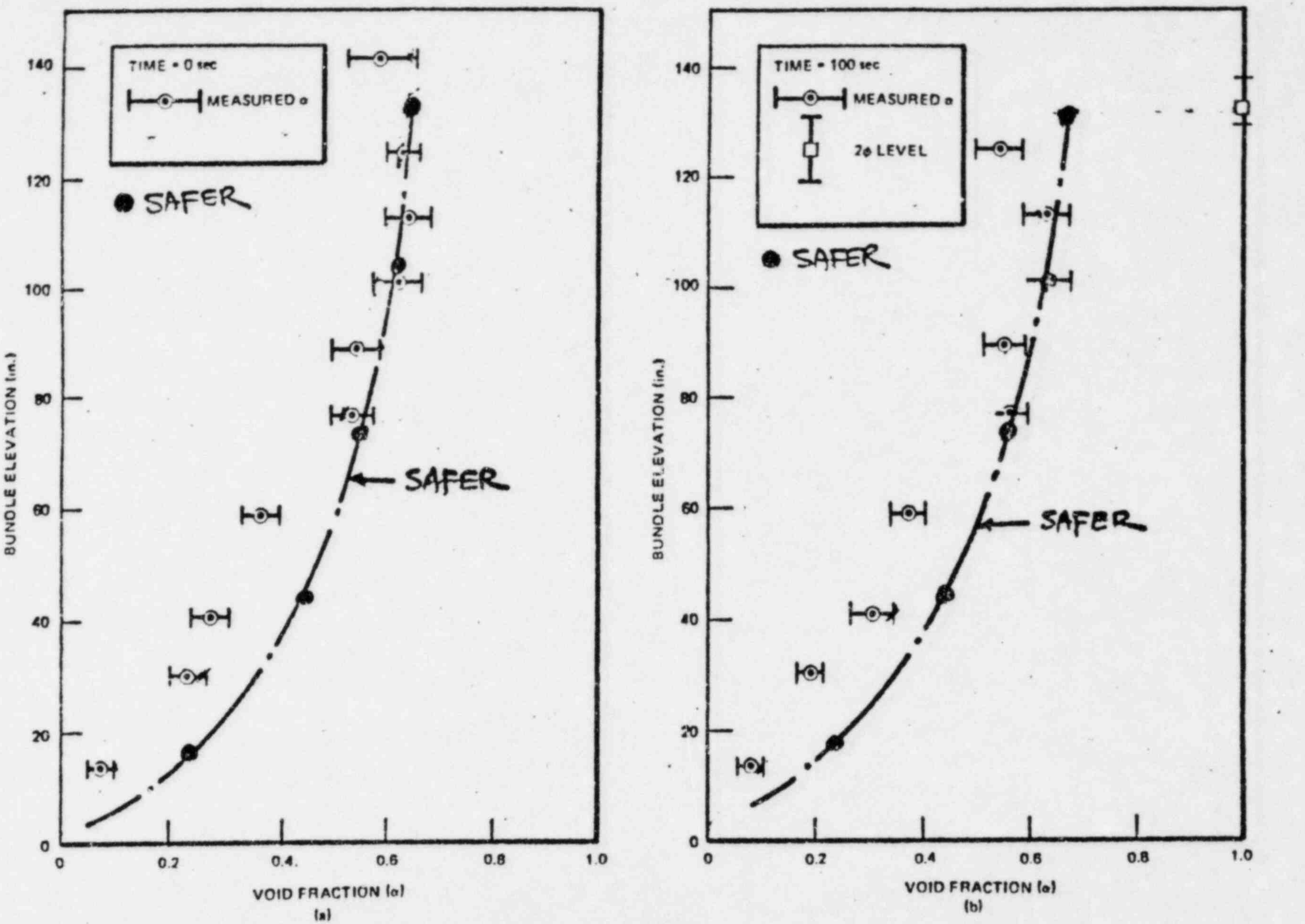
TLTA TEST 6441/R6

(BOIL-OFF TEST)

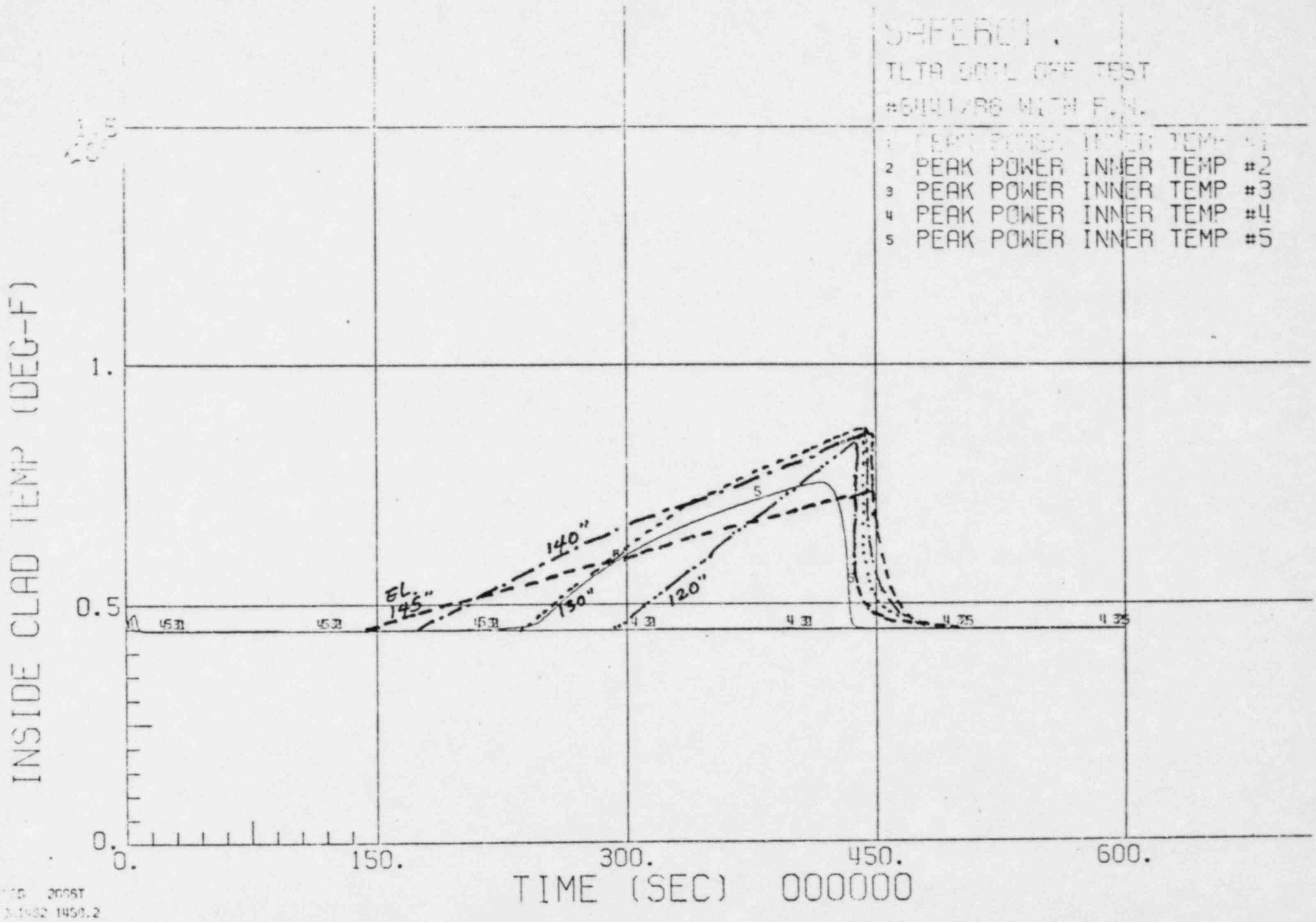
PRESSURE : 400 PSIA

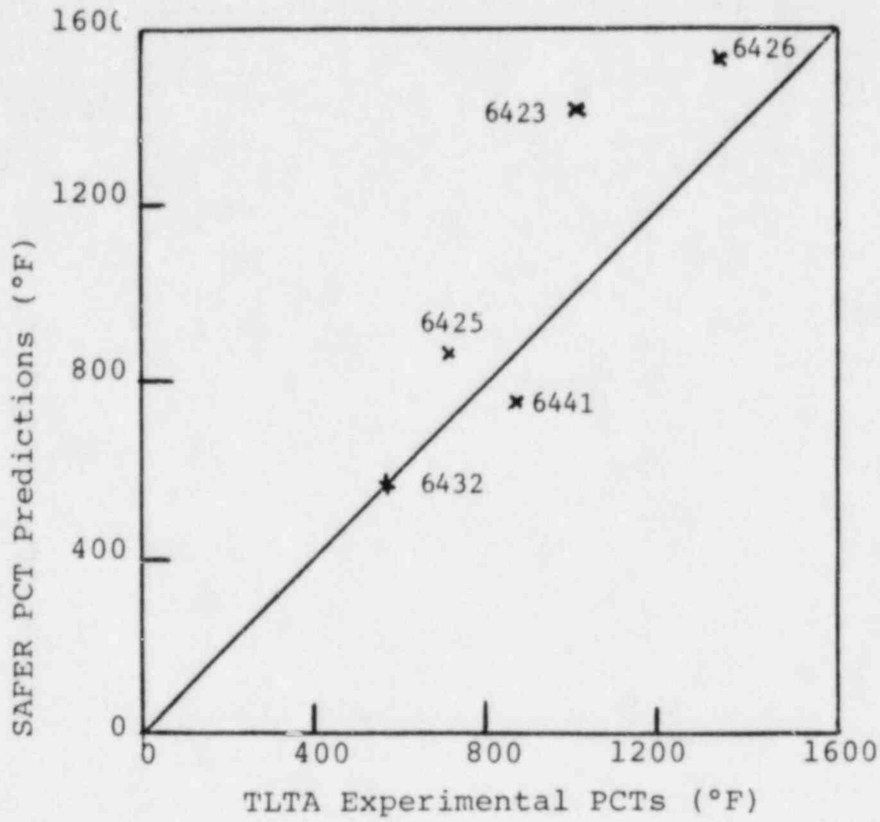
BUNDLE POWER : 250 KW


SAFER01
TLTA BOIL OFF TEST
#6441/R6 WITH F.W.
1 LOWER PLENUM LEVEL
2 GUIDE TUBES LEVEL
3 CORE LEVEL
4 BYPASS LEVEL
5 UPPER PLENUM LEVEL
6 TOP OF ACTIVE FUEL
7 DOWNCOMER LEVEL
8 DOWNCOMER LEVEL
TLTA BUNDLE M.L.
TLTA B.P. & D.C. LEVELS
MIXTURE LEVEL (FT)
30.
20.
10.
0.
0.
150.
300.
450.
600.
TIME (SEC)
0
100
250
400
TLTA TIME (SEC.)



Bundle Axial Void Distribution - 250 kW/400 psia Test (Run 6, Test Point 1)


SAFER01.
TLTA BOIL OFF TEST
#6441/R6 WITH F.N.
2 PEAK POWER INNER TEMP #2
3 PEAK POWER INNER TEMP #3
4 PEAK POWER INNER TEMP #4
5 PEAK POWER INNER TEMP #5
INSIDE CLAD TEMP (DEG-F)
TIME (SEC) 000000
0.
0.5
1.
150.
300.
450.
600.
EL. 145"
140"
130"
120"



Comparisons of SAFER Predictions with Experiments for TLTA Tests:

6425 - DBA, average power, average ECC

6423 - DBA, peak power, low ECC

6426 - DBA average power, no ECC

6432 - Small break

6441 - Boiloff

SUMMARY OF TLTA COMPARISONS

- Pressure
  - Controlled by Break (ADS) Flow
  - Excellent Prediction
- Mixture Levels
  - Controlled by Depressurization Rate, CCFL, Recirculation Flow
  - Good Predictions
  - Core Level Difficult to Define at Low Pressure (Defined by Location of 90% Void)
- Regional Mass Distribution
  - Core and Downcomer Masses Well Predicted
  - Lower Plenum Mass Overpredicted at end of Transient (Subcooled CCFL Breakdown at SEO)
- Peak Clad Temperature
  - Heatup Behavior Well Predicted
  - PCT Generally Overpredicted (Top Quench Phenomenon not Modeled)

OVERALL GOOD PREDICTION DEMONSTRATING CORRECT SIGNIFICANT PHENOMENA AND TRENDS

B S Shiralkar

RESULTS FOR BWR LOCA CALCULATIONS

- Analysis Tool: TRACB02
- Plant

  BWR/6-218

  624 Bundles

  2894 MW
- Transients Analysed:
  1. Main Steam Line Break
  2. HPCS Line Break
  3. 100% Recirculation Line Break (DBA)*
  4. 80% Recirculation Line Break*
  5. 1 ft^2 (47%) Recirculation Line Break
- Basis: Nominal Conditions

  Single Failure

  Maximum LHGR

---

* Not yet complete.

BS Shiralkar

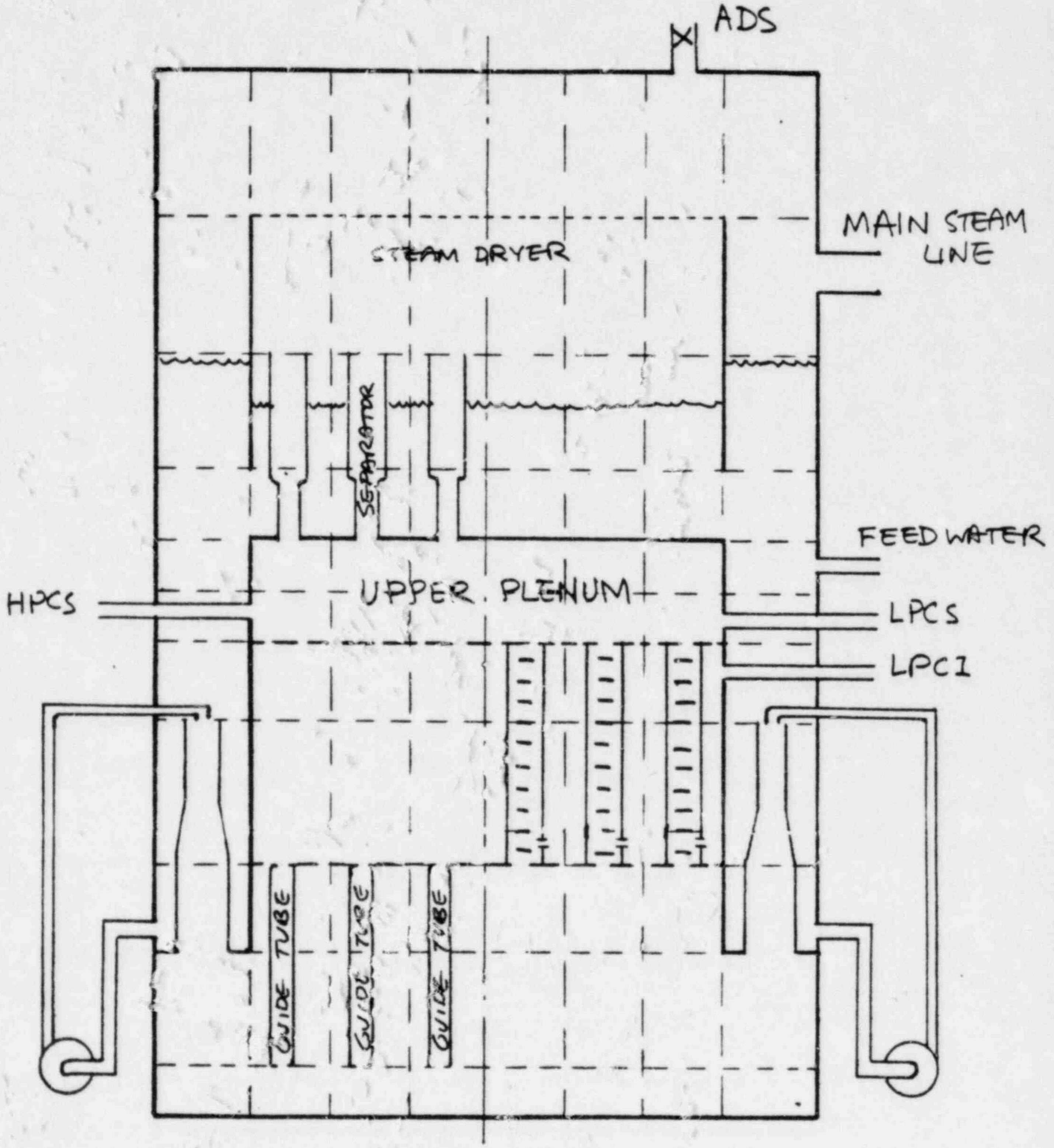
12/3/82

SUMMARY OF ASSUMPTIONS

Transient	Break Size (ft^2)	ECC Systems Available	ECC System Not Available
Recirc Break			
DBA	2.143	3 LPCI	
80%	1.714	LPCS	HPCS
47%	1.000	MSIV Closure begins at time 0.0	
Main Steam Line Break	2.536	3 LPCI LPCS MSIV Closure begins at time 0.0	HPCS
HPCS Line	0.230	2 LPCI ADS MSIV Closure on L1	LPCS + 1 LPCI

TRIPS ACTIVIATED

LPCI LPCS:	500 PSI + 9 seconds
MSIV:	0.5 second delay; 5 second stroke time
RECIRCULATION PUMP:	Tripped at Time 0.0
POWER:	Scram at Time 0.0
FEEDWATER:	Tripped at Time 0.0; linearly closed in 5 seconds
ADS:	Tripped on L1, 105. second delay time.



TRAC BWR/6 NODALIZATION

TRAC NODALIZATION

VESSEL:	11 Axial Levels 4 Radial Rings 1 θ Sector	44 Vessel Cells

Total Number of Components = 33

CORE: 3 groups of Channels (11 cells, 9 heated)

MAIN STEAM LINE BREAK

1 Steam Line: Double-Ended Guillotine Break

3 Intact Lines: MSIV Closed at 5.5 seconds

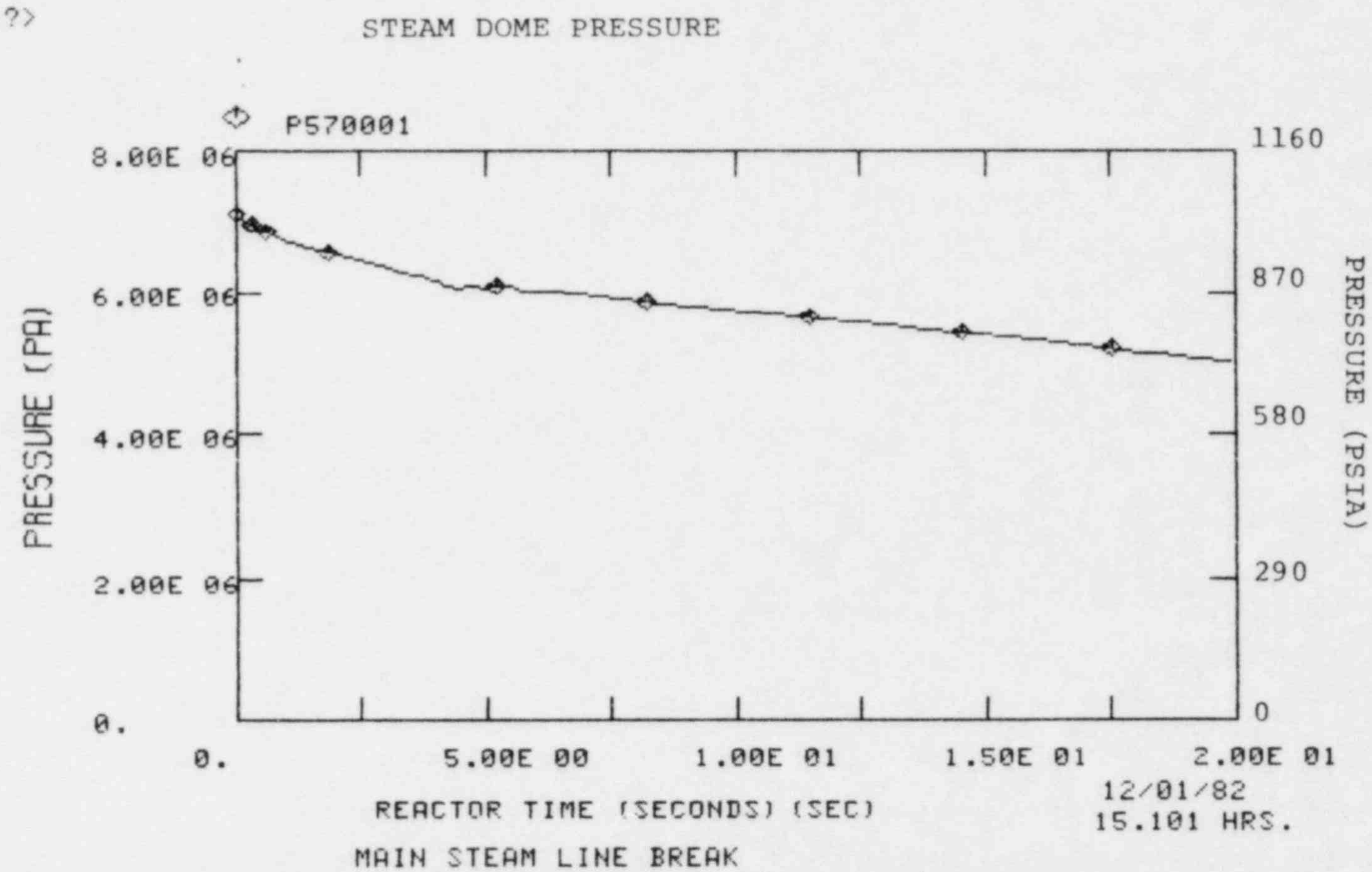
Result:

- Transient Time = 20. seconds after break
- No Boiling Transition
- At 20. seconds, core flow = 10% Initial Value (Natural circulation)

SEQUENCE OF EVENTS FOR MAIN STEAM LINE BREAK

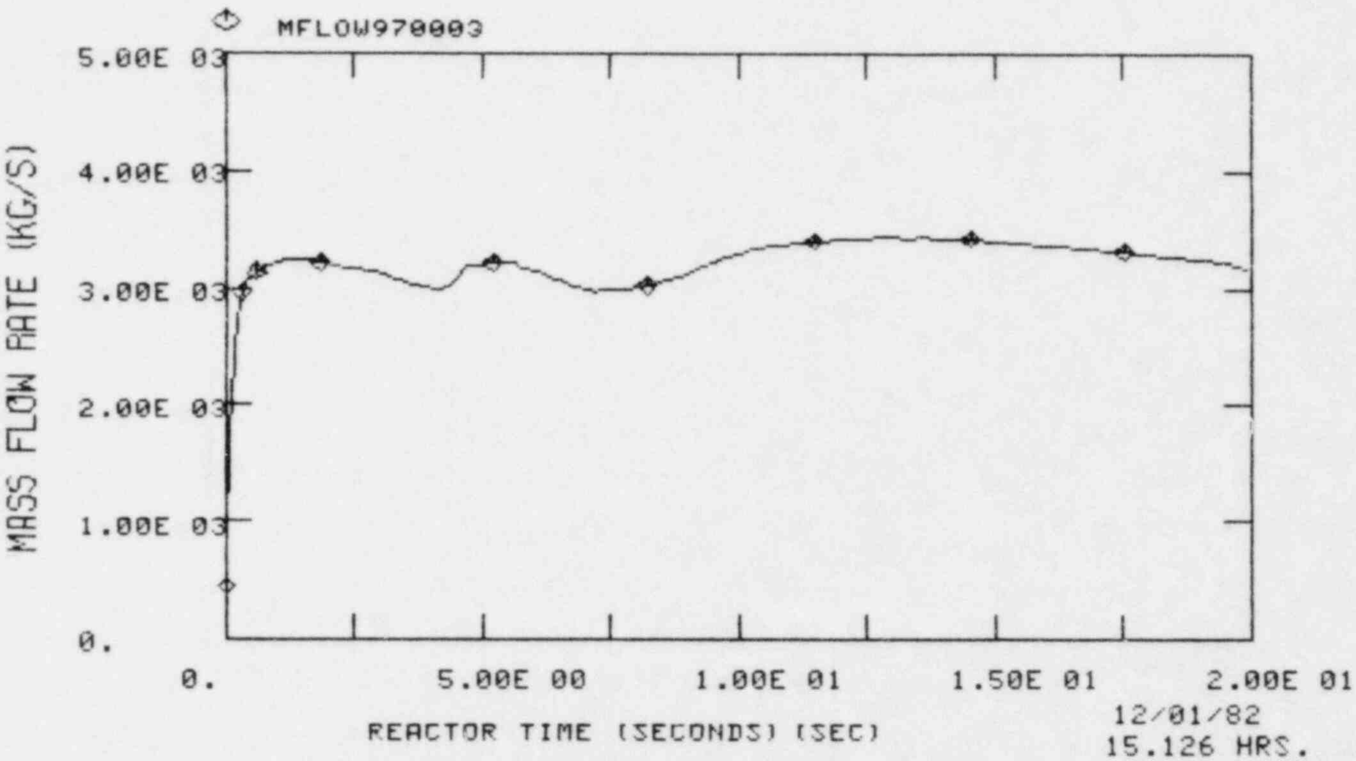
EVENT	TIME (sec)
Main Steam Line Break; Power Scram; Feedwater Trip; Recirculation pump trip	0.0
MSIV Closure Initiated in intact Main Steam Lines	0.5
Feedwater Off	5.0
MSIV Closed	5.5

<?>

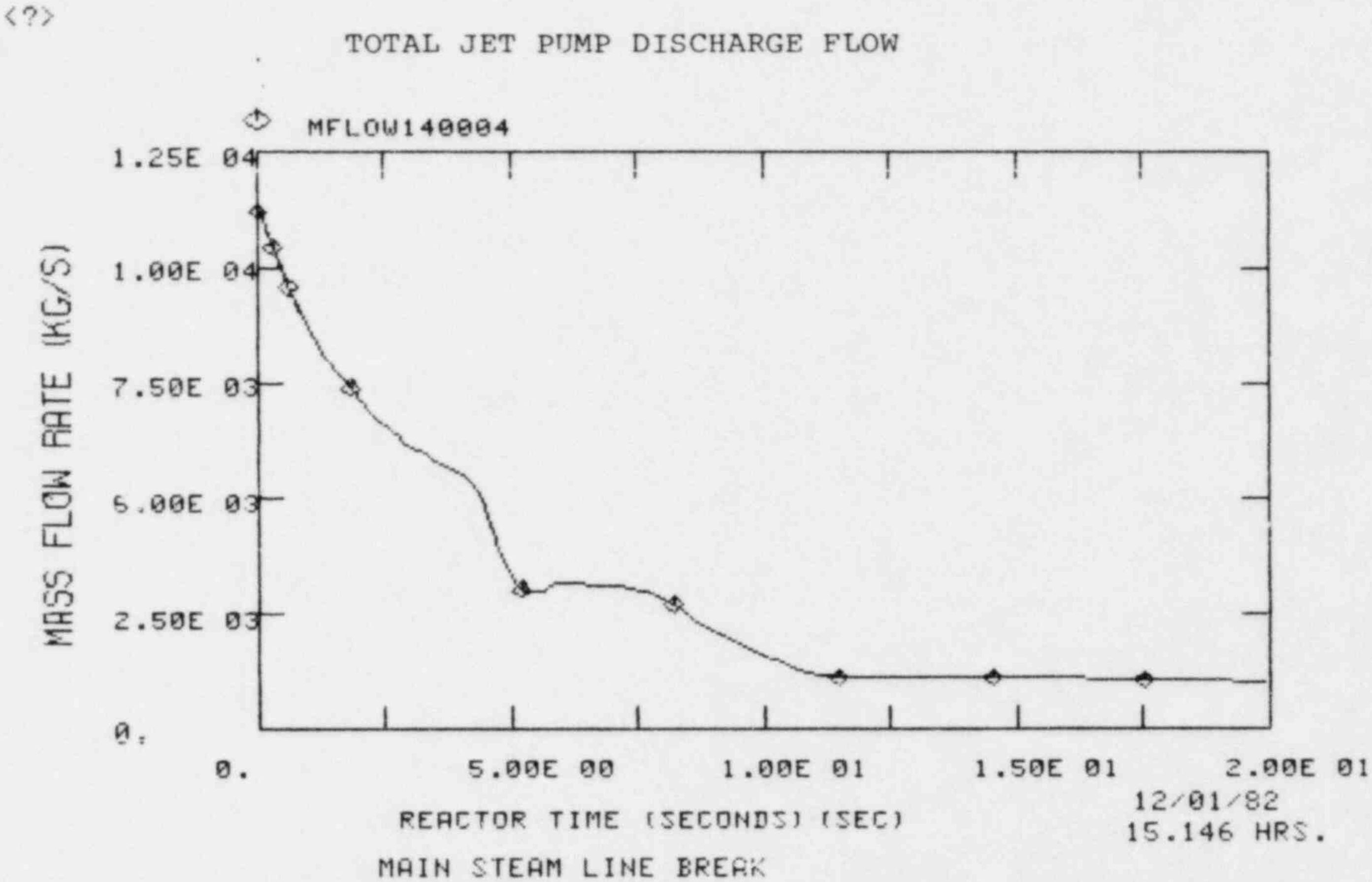

STEAM DOME PRESSURE
P570001
PRESSURE (PA)
8.00E 06
6.00E 06
4.00E 06
2.00E 06
0.
PRESSURE (PSIA)
1160
870
580
290
0
0.
5.00E 00
1.00E 01
1.50E 01
2.00E 01
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.101 HRS.
MAIN STEAM LINE BREAK

<?>

STEAM LINE BREAK FLOW



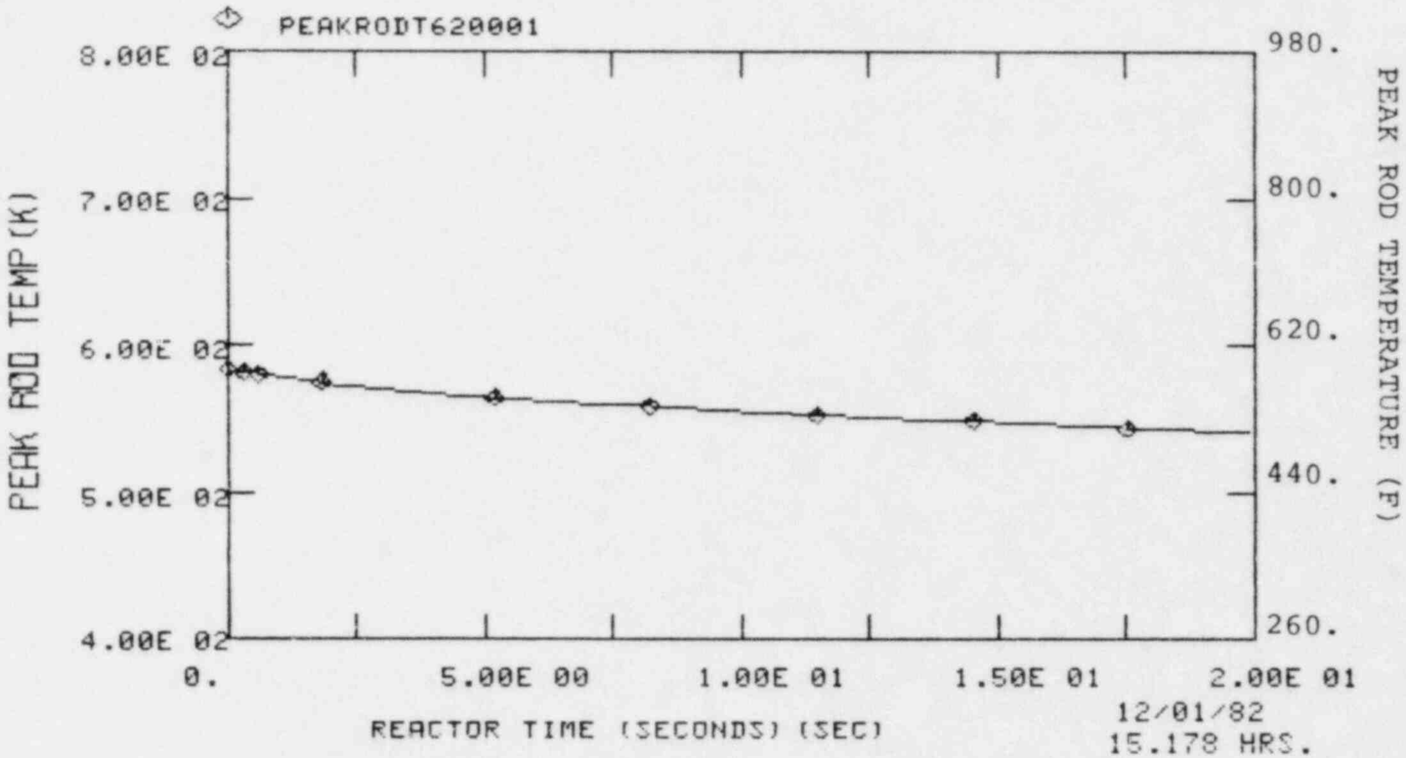
MAIN STEAM LINE BREAK



<?>
TOTAL JET PUMP DISCHARGE FLOW
MFLOW140004
MASS FLOW RATE (KG/S)
1.25E 04
1.00E 04
7.50E 03
5.00E 03
2.50E 03
0.
0.
5.00E 00
1.00E 01
1.50E 01
2.00E 01
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.146 HRS.
MAIN STEAM LINE BREAK

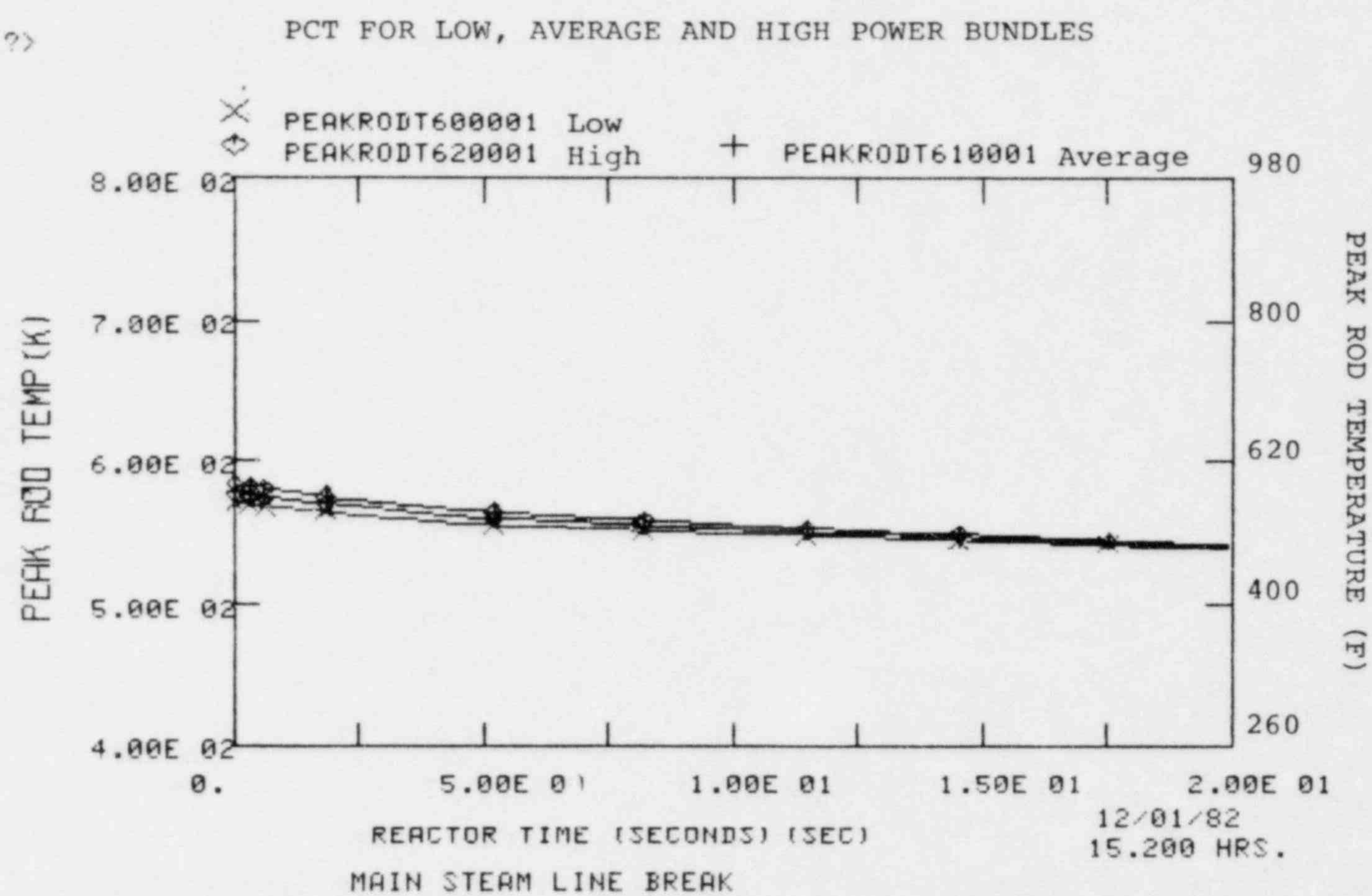
<?>

HIGH POWER BUNDLE PCT



MAIN STEAM LINE BREAK

<?>



PCT FOR LOW, AVERAGE AND HIGH POWER BUNDLES
PEAKRODT600001 Low
PEAKRODT620001 High
PEAKRODT610001 Average
8.00E 02
7.00E 02
6.00E 02
5.00E 02
4.00E 02
PEAK ROD TEMP(K)
980
800
620
400
260
PEAK ROD TEMPERATURE (F)
0.
5.00E 0)
1.00E 01
1.50E 01
2.00E 01
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.200 HRS.
MAIN STEAM LINE BREAK

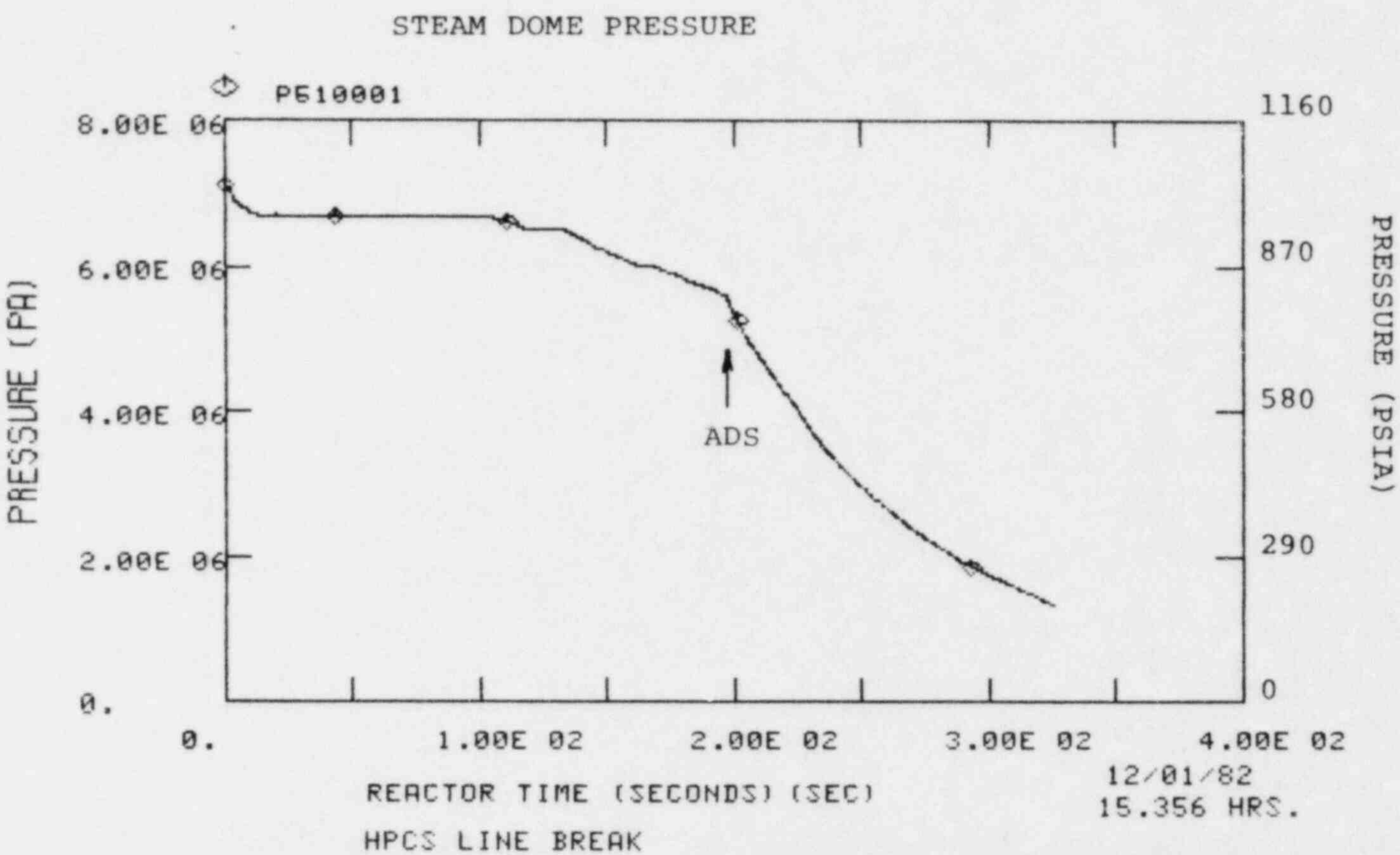
HPCS LINE BREAK

- Transient Time = 330 seconds after break.
- Pressure Regulator holds pressure as downcomer level slowly drops.
- ADS depressurizes system at ~200 seconds.
- Dryout occurs after end of depressurization.
- LPCI quenches core.
- PCT close to initial steady state cladding temperature.

SEQUENCE OF EVENTS FOR HPCS LINE BREAK

EVENT	TIME (sec)
HPCS Line Break; Power Scram; Feedwater Trip; Recirculation Pump Trip	0.0
Feedwater Off	5.0
L1 Trips ADS, MSIV	91.5
MSIV Start Closing	92.0
MSIV Closed Completely	97.0
ADS Opens	196.5
LPCI On	306.4
PCT, Followed by Quenching	325.0

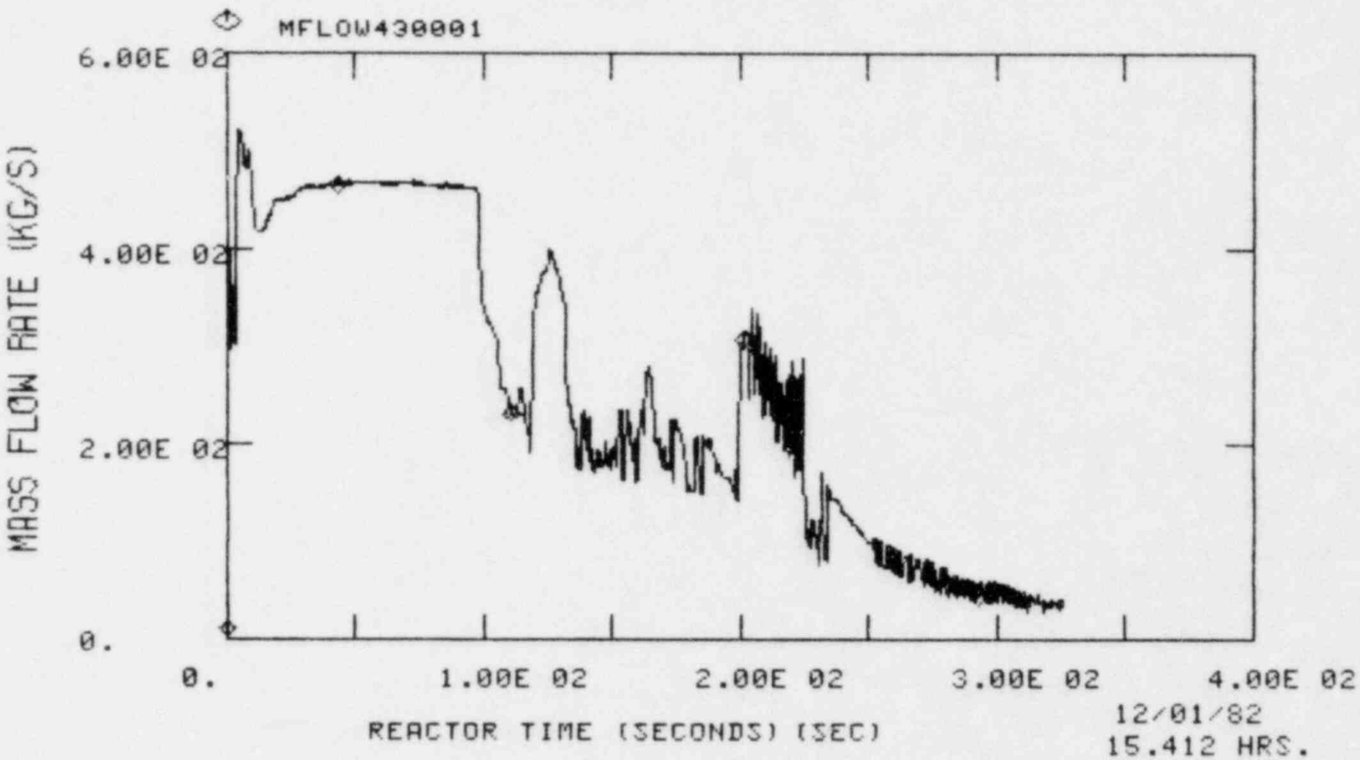
<?>



STEAM DOME PRESSURE
P510001
8.00E 06
6.00E 06
4.00E 06
2.00E 06
0.
1160
870
580
290
0
PRESSURE (PA)
PRESSURE (PSIA)
ADS
0.
1.00E 02
2.00E 02
3.00E 02
4.00E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.356 HRS.
HPCS LINE BREAK

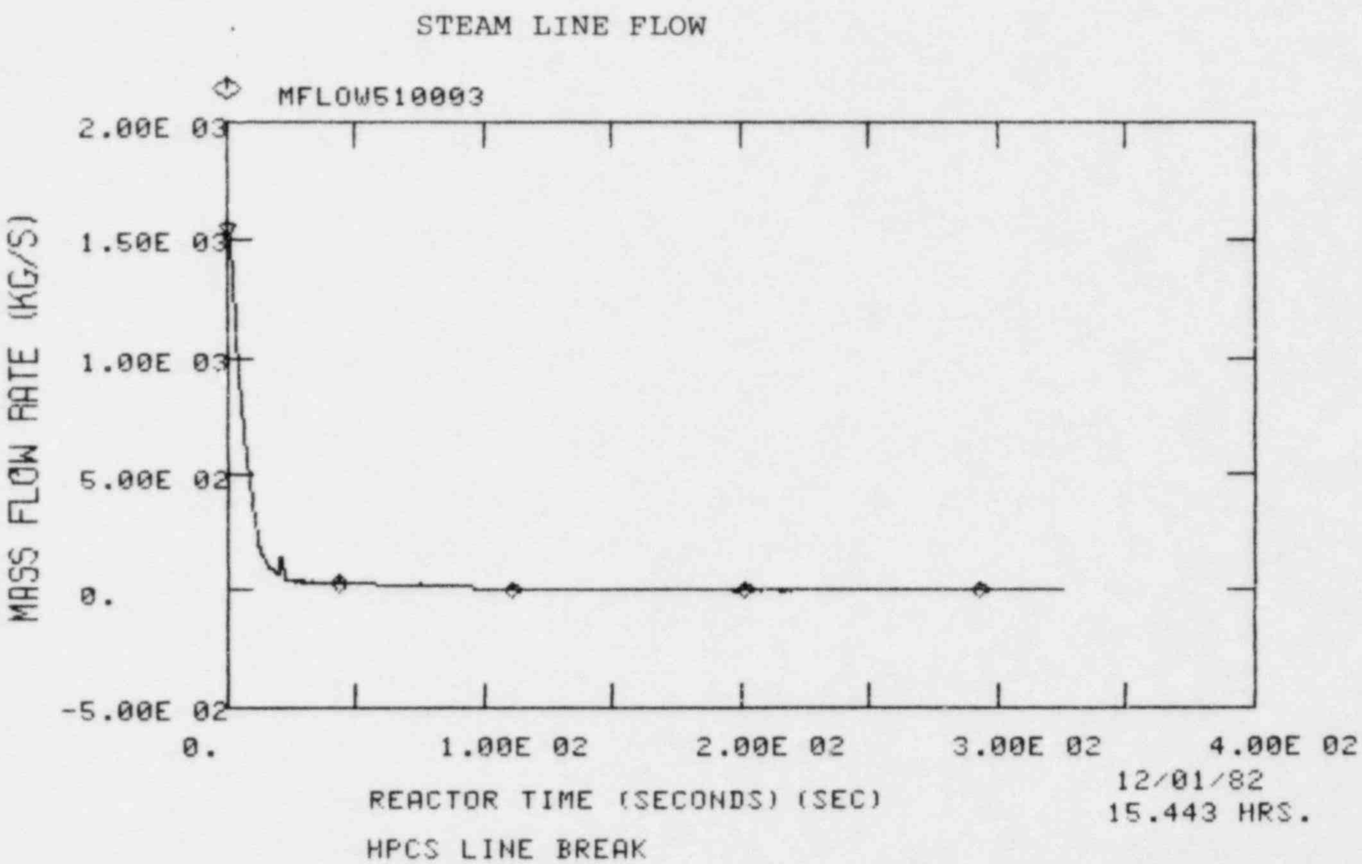
<?>

HPCS LINE BREAK FLOW

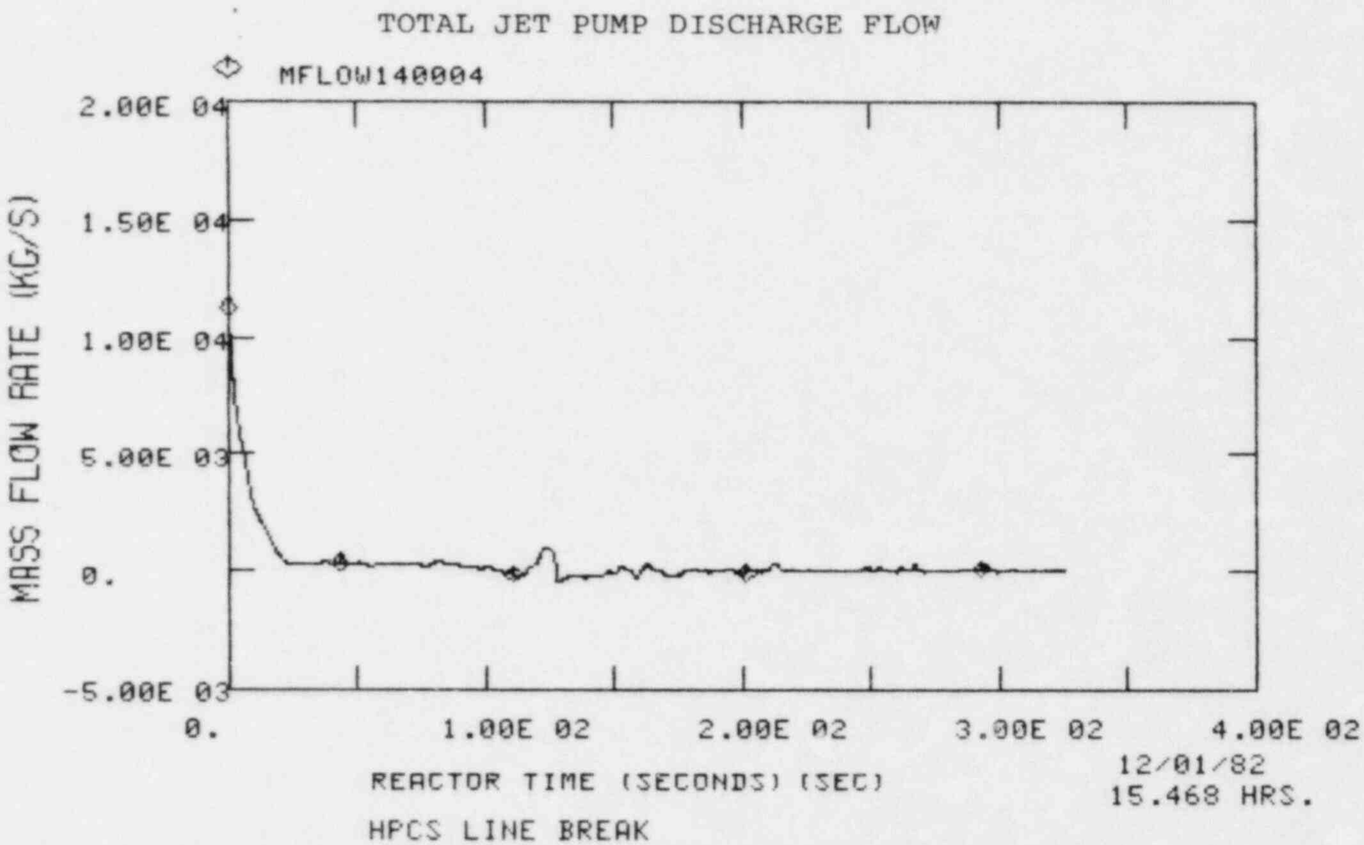


HPCS LINE BREAK

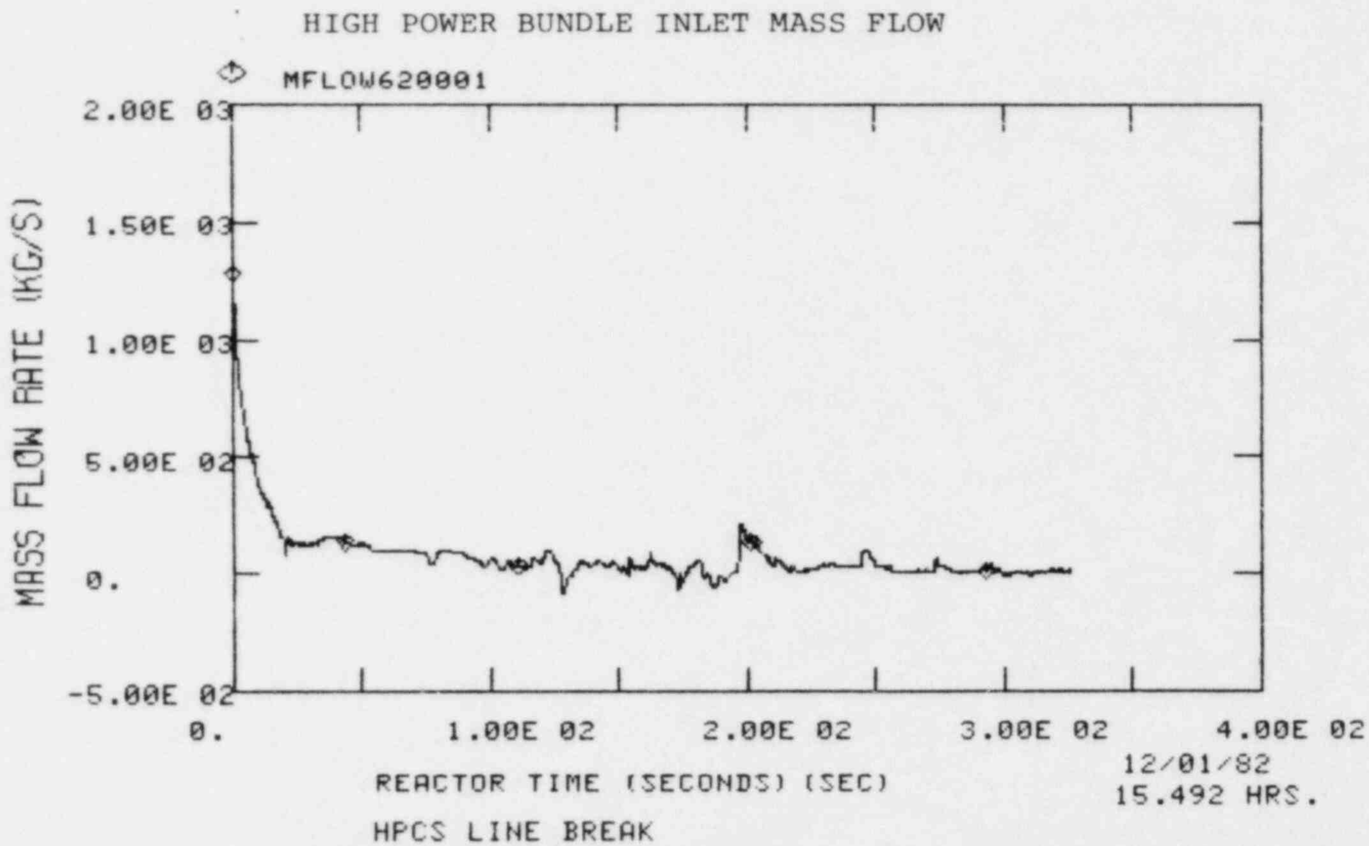
<?>


STEAM LINE FLOW
MFLOW510003
MASS FLOW RATE (KG/S)
2.00E 03
1.50E 03
1.00E 03
5.00E 02
0.
-5.00E 02
0.
1.00E 02
2.00E 02
3.00E 02
4.00E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.443 HRS.
HPCS LINE BREAK

<?>

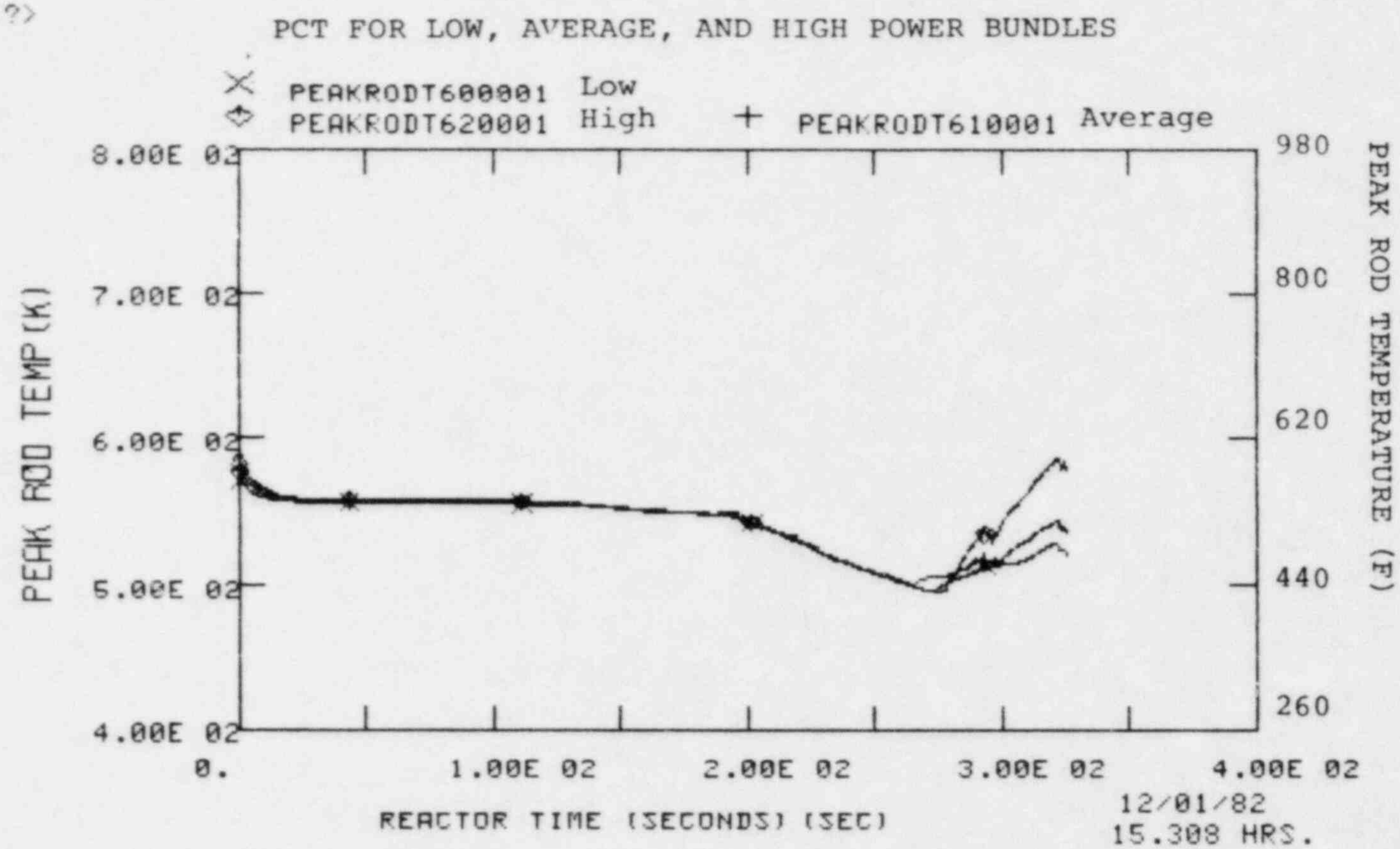

TOTAL JET PUMP DISCHARGE FLOW
MFLOW140004
2.00E 04
1.50E 04
1.00E 04
5.00E 03
0.
-5.00E 03
MASS FLOW RATE (KG/S)
0.
1.00E 02
2.00E 02
3.00E 02
4.00E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.468 HRS.
HPCS LINE BREAK

<?>



HIGH POWER BUNDLE INLET MASS FLOW
MFLOW620001
2.00E 03
1.50E 03
1.00E 03
5.00E 02
0.
-5.00E 02
MASS FLOW RATE (KG/S)
0.
1.00E 02
2.00E 02
3.00E 02
4.00E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.492 HRS.
HPCS LINE BREAK

<?>



HPCS LINE BREAK

RECIRCULATION LINE BREAKS

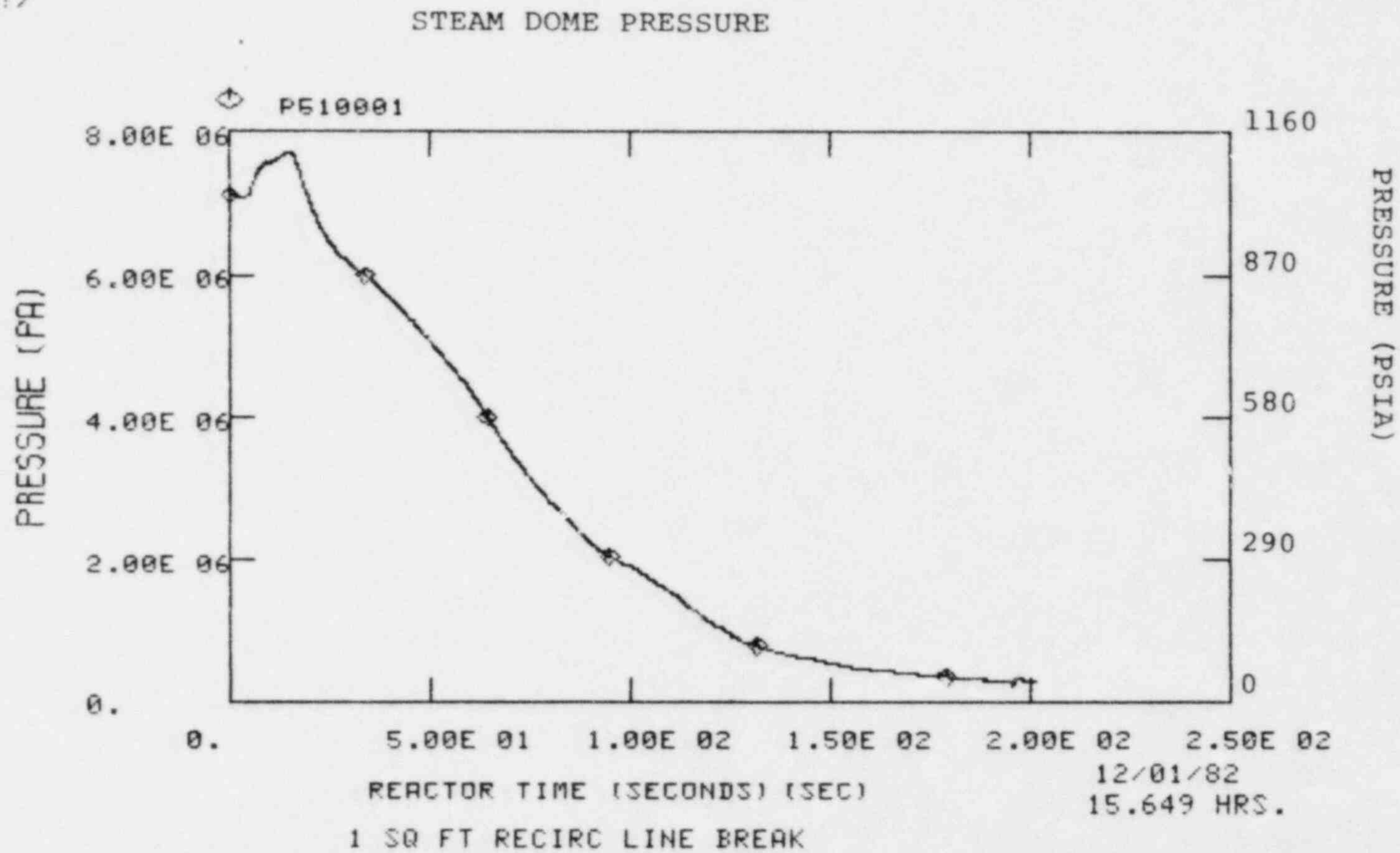
- Similar behavior for the three breaks, shifted in time.
- Early boiling transition occurs in high power channels, followed by rewet.
- Loss of inventory results in cladding heatup in average and high power channels.
- ECC activation subcools bypass, upper plenum regions with drainage to lower plenum.
- Fuel cooled by inventory accumulation in average power channels, co-current upflow in high power channels.

1 ft^2 (47%) RECIRCULATION BREAK

SEQUENCE OF EVENTS FOR 1 ft^2 RECIRCULATION BREAK

EVENT	TIME (sec)
Recirculation Line Break Power Scram Feedwater Trip Recirculation Pump Trip	0.0
MSIV Starts to Close	0.5
Boiling Transition in High Power Bundle	1.1
Peak Cladding Temperature (687°K) (777°F)	3.2
Feedwater Off	5.0
MSIV Closed Completely	5.5
Dryout in High Power Bundles	60.
LPCS On	99.5
LPCI On	107.0

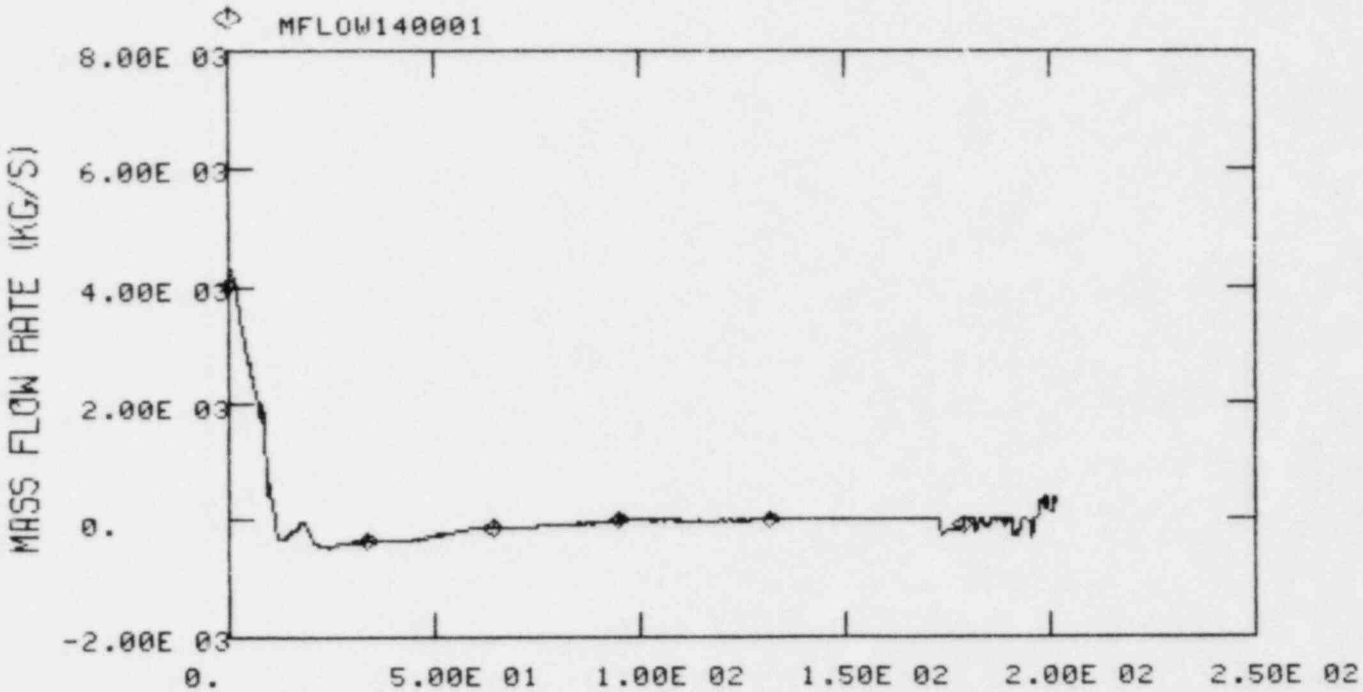
<?>



STEAM DOME PRESSURE
P510001
8.00E 06
6.00E 06
4.00E 06
2.00E 06
0.
PRESSURE (PA)
1160
870
580
290
0
PRESSURE (PSIA)
0.
5.00E 01
1.00E 02
1.50E 02
2.00E 02
2.50E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.649 HRS.
1 SQ FT RECIRC LINE BREAK

<?>

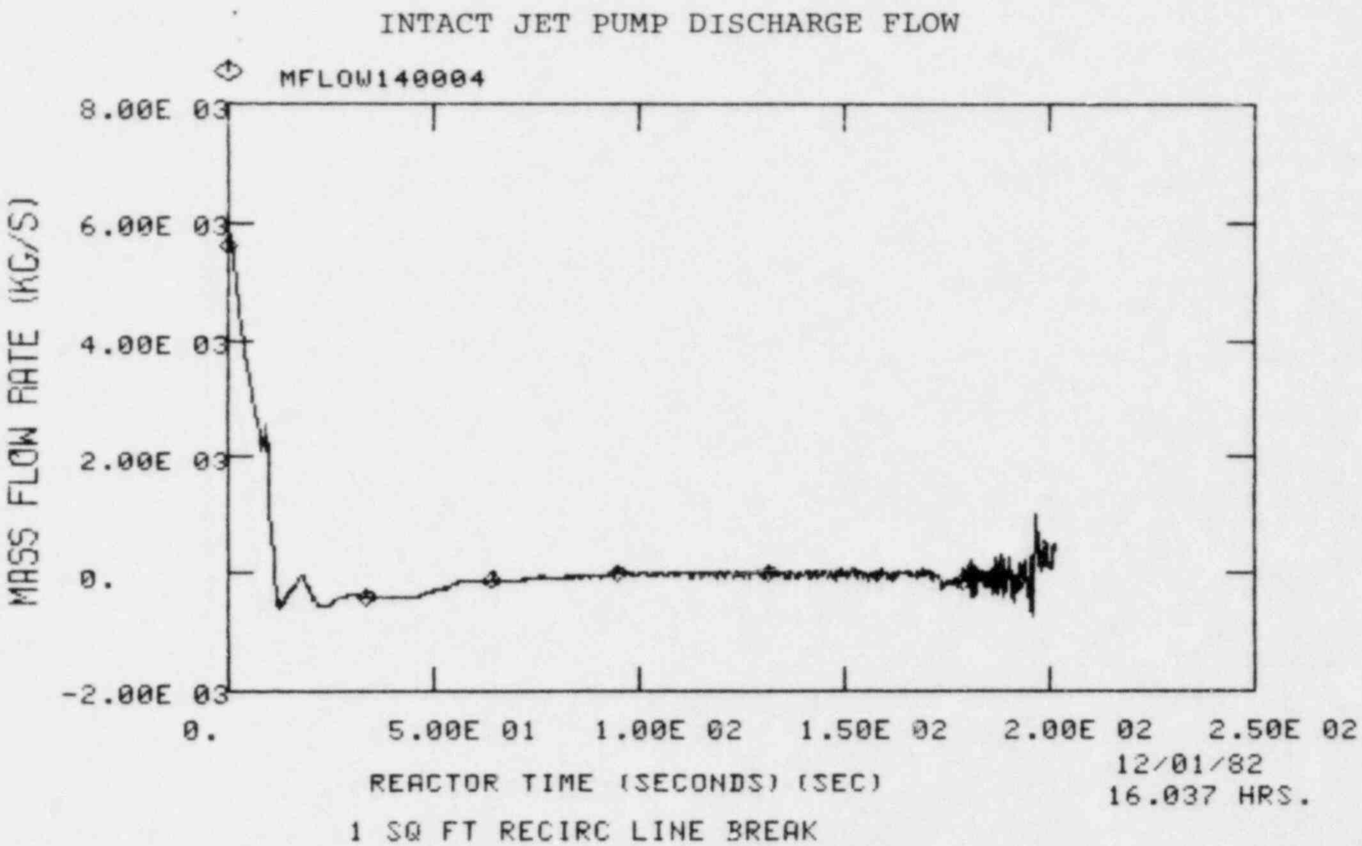
INTACT JET PUMP SUCTION FLOW



12/01/82
15.961 HRS.

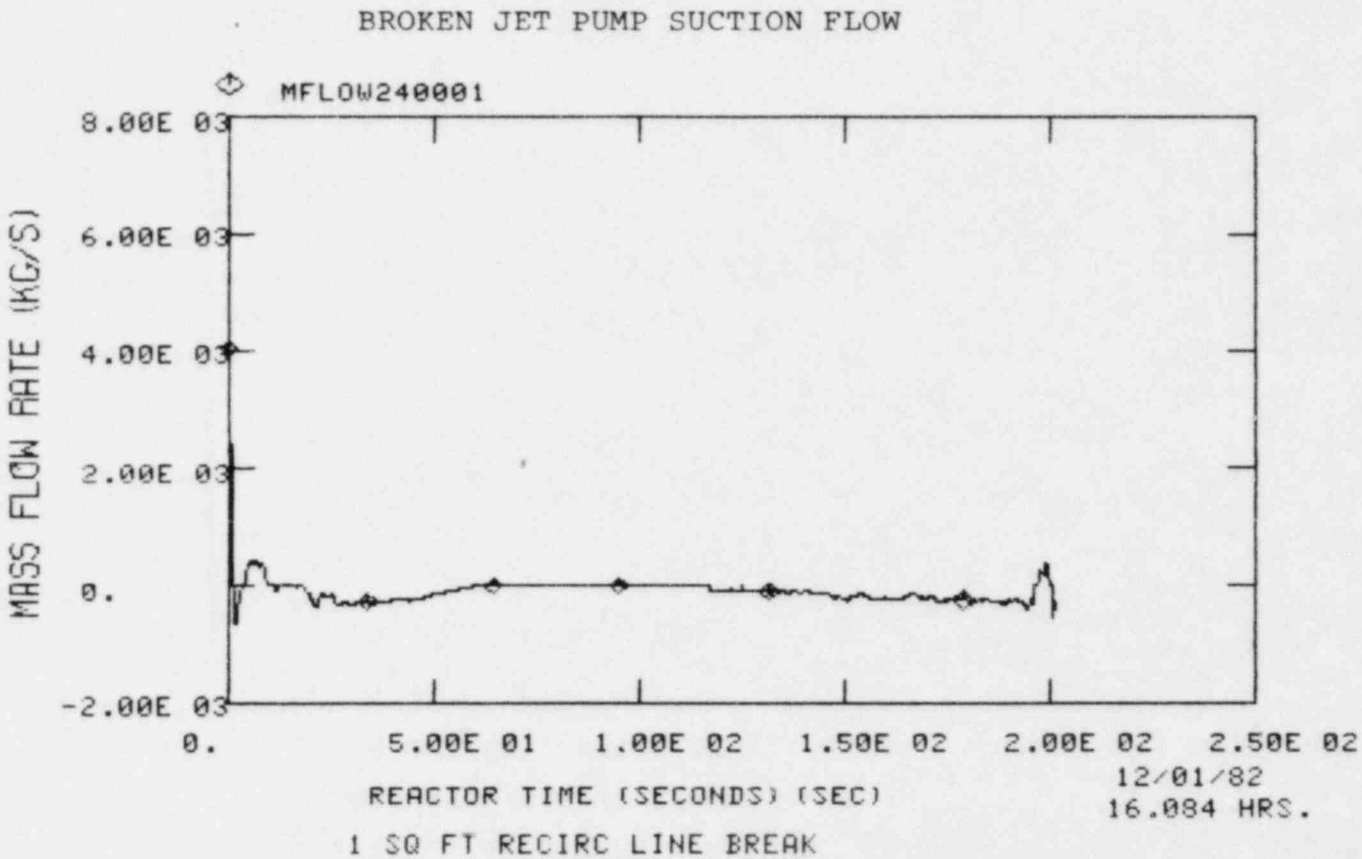
1 SQ FT RECIRC LINE BREAK

<?>



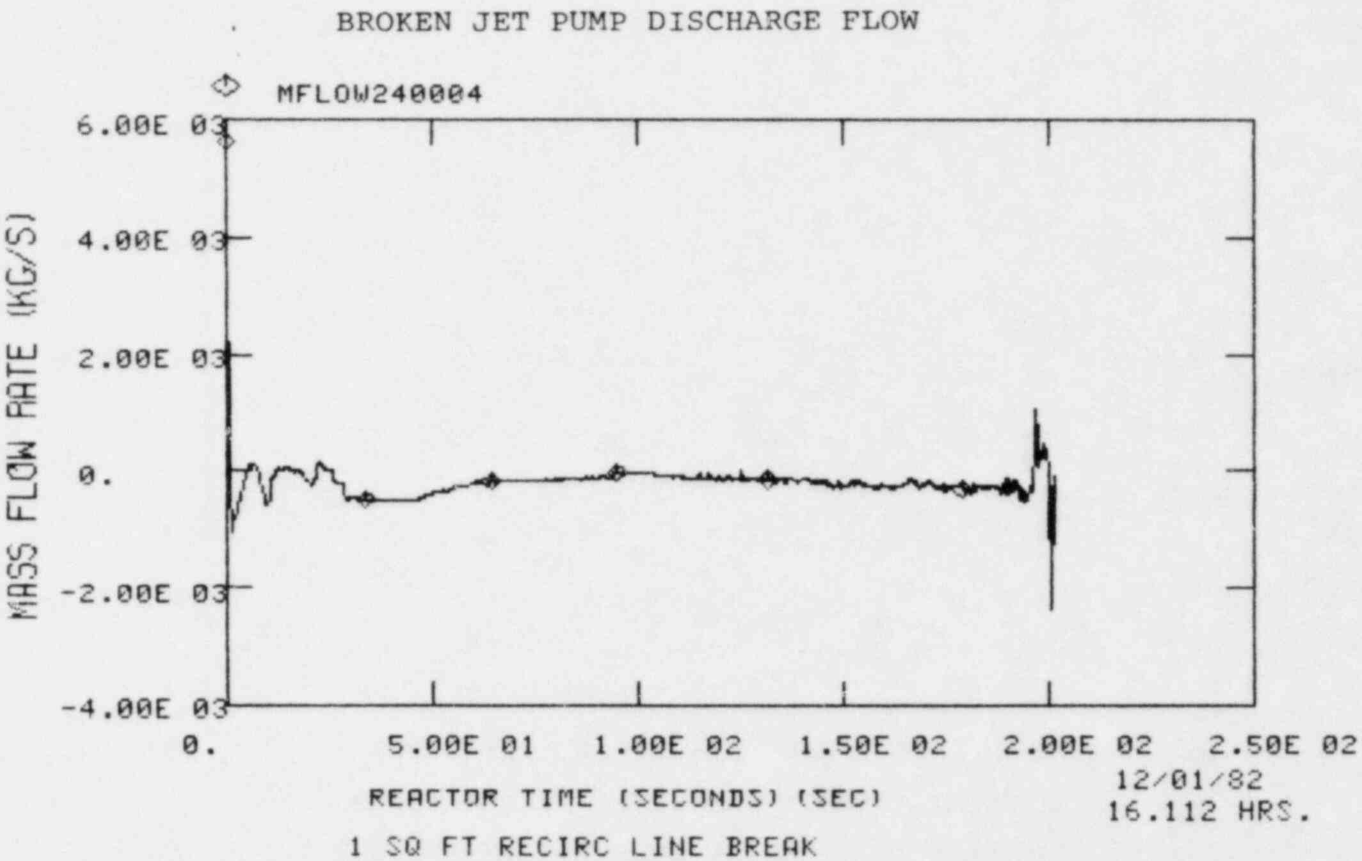
INTACT JET PUMP DISCHARGE FLOW
MFLOW140004
8.00E 03
6.00E 03
4.00E 03
2.00E 03
0.
-2.00E 03
MASS FLOW RATE (KG/S)
0.
5.00E 01
1.00E 02
1.50E 02
2.00E 02
2.50E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
16.037 HRS.
1 SQ FT RECIRC LINE BREAK

<?>



BROKEN JET PUMP SUCTION FLOW
MFLOW240001
8.00E 03
6.00E 03
4.00E 03
2.00E 03
0.
-2.00E 03
MASS FLOW RATE (KG/S)
0.
5.00E 01
1.00E 02
1.50E 02
2.00E 02
2.50E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
16.084 HRS.
1 SQ FT RECIRC LINE BREAK

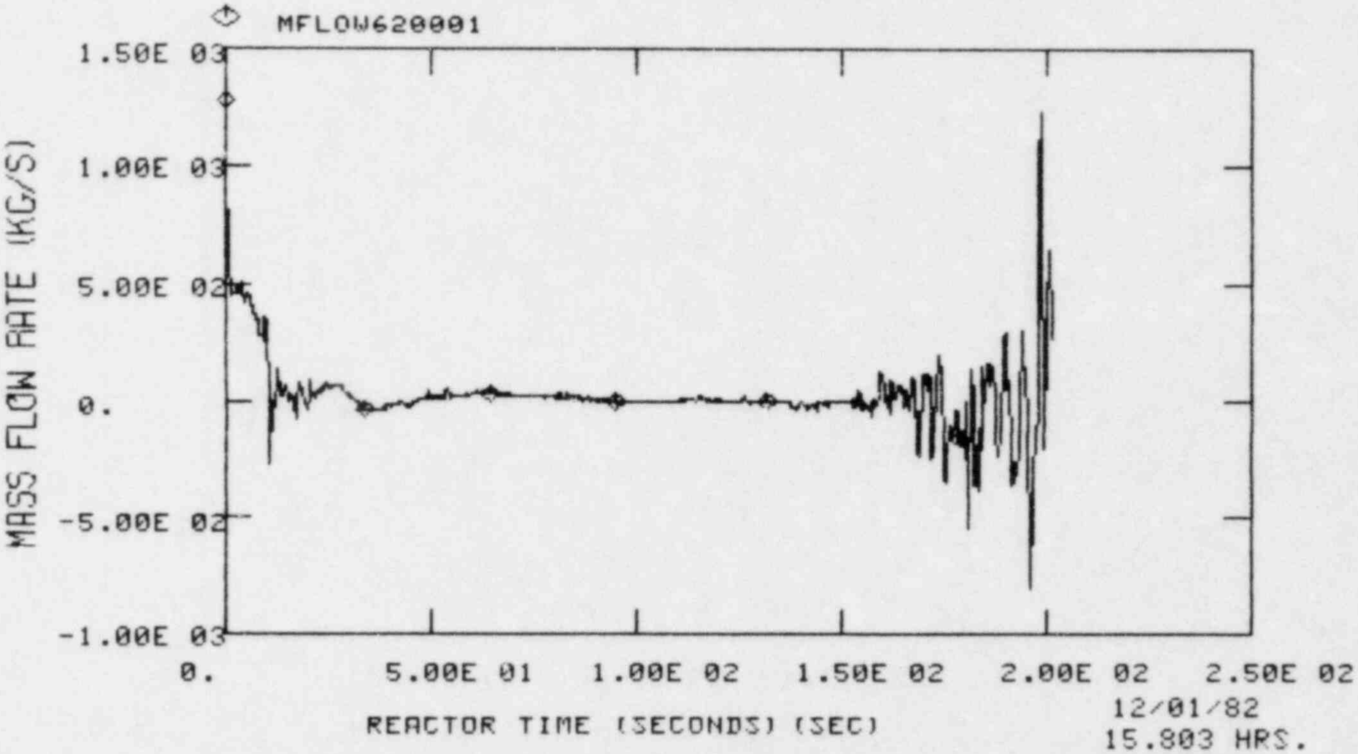
<?>



BROKEN JET PUMP DISCHARGE FLOW
MFLOW240004
6.00E 03
4.00E 03
2.00E 03
0.
-2.00E 03
-4.00E 03
MASS FLOW RATE (KG/S)
0.
5.00E 01
1.00E 02
1.50E 02
2.00E 02
2.50E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
16.112 HRS.
1 SQ FT RECIRC LINE BREAK

<?>

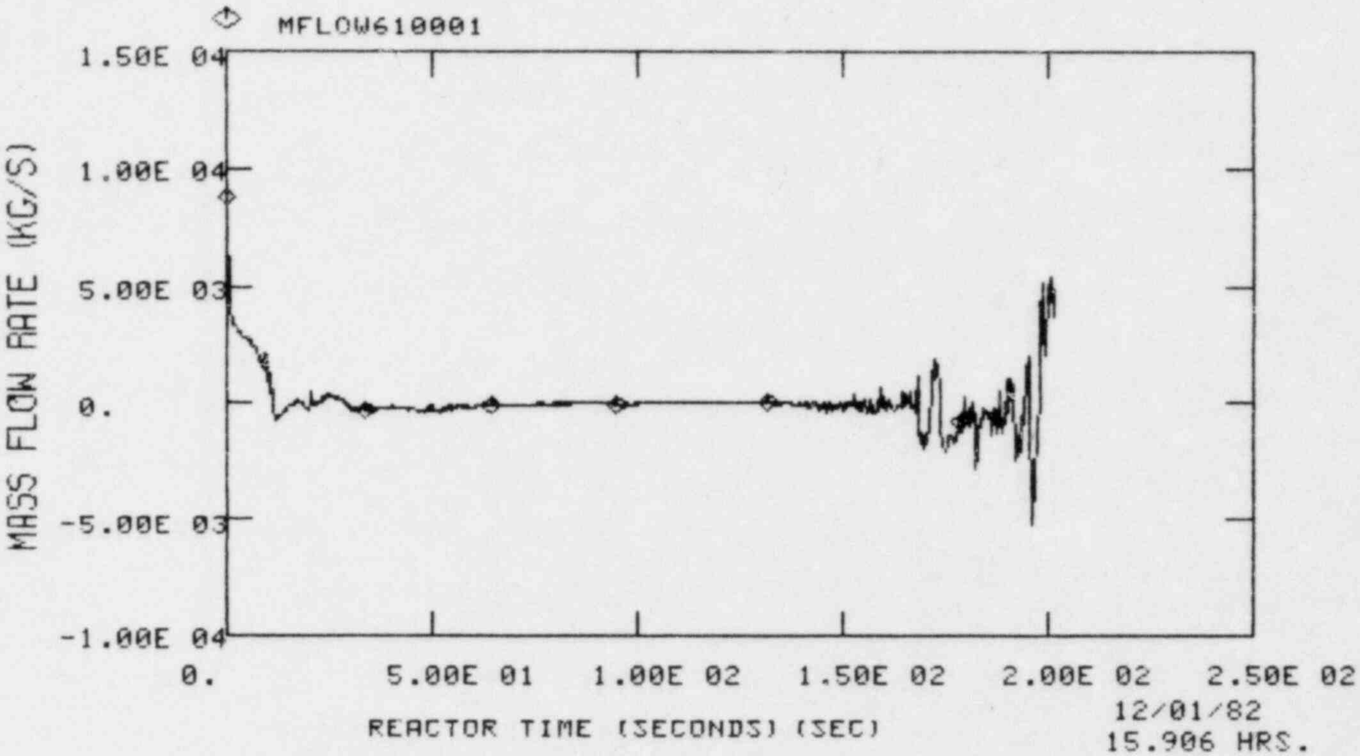
HIGH POWER BUNDLE INLET MASS FLOW



1 SQ FT RECIRC LINE BREAK

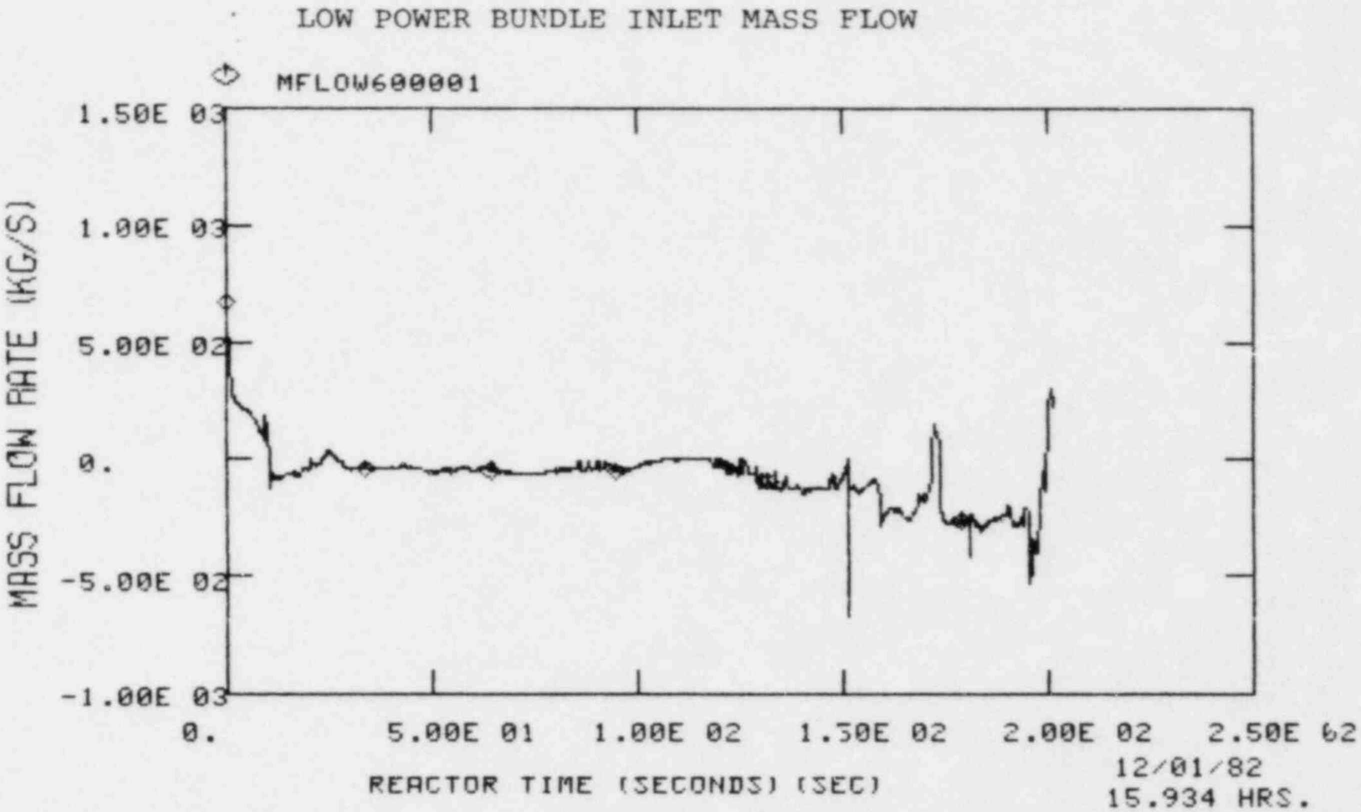
<?>

AVERAGE POWER BUNDLE INLET MASS FLOW



1 SQ FT RECIRC LINE BREAK

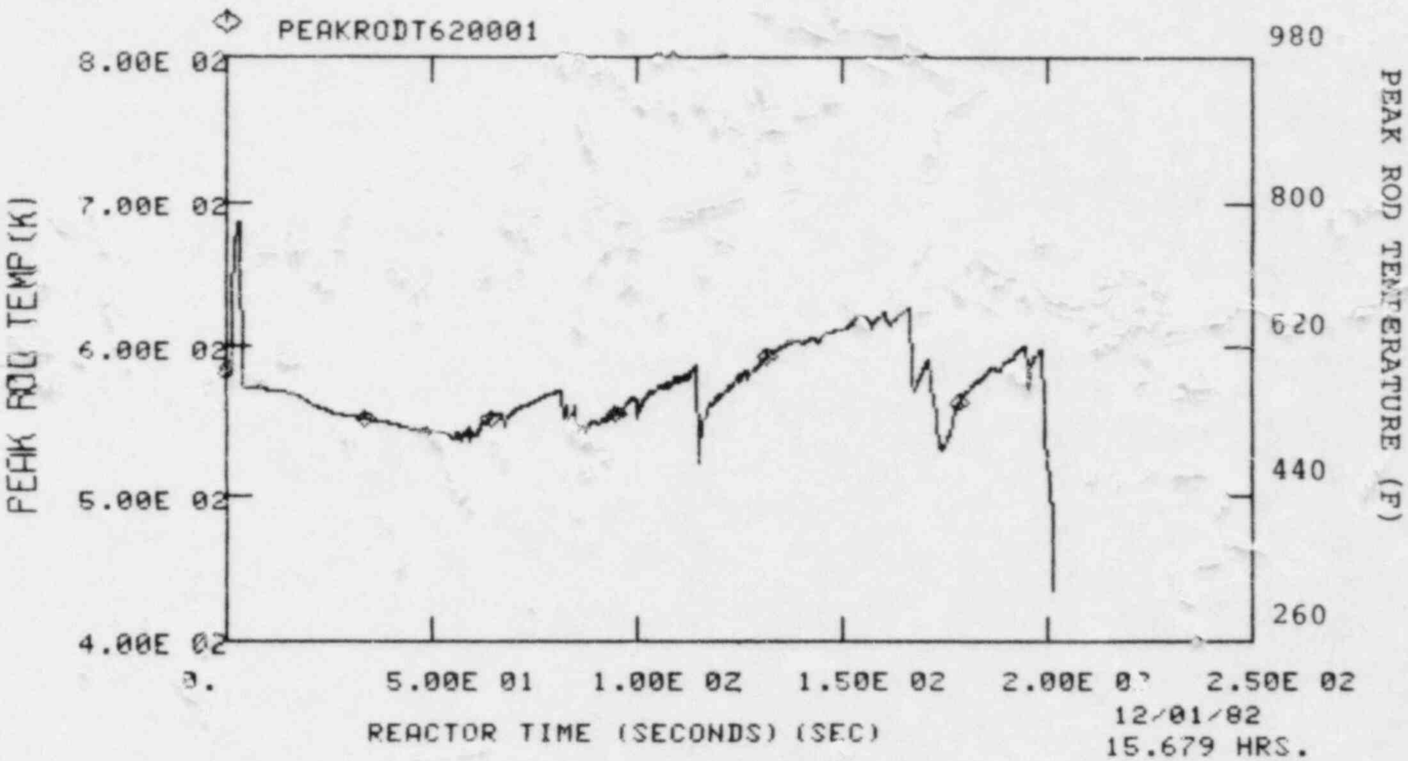
<?>



1 SQ FT RECIRC LINE BREAK

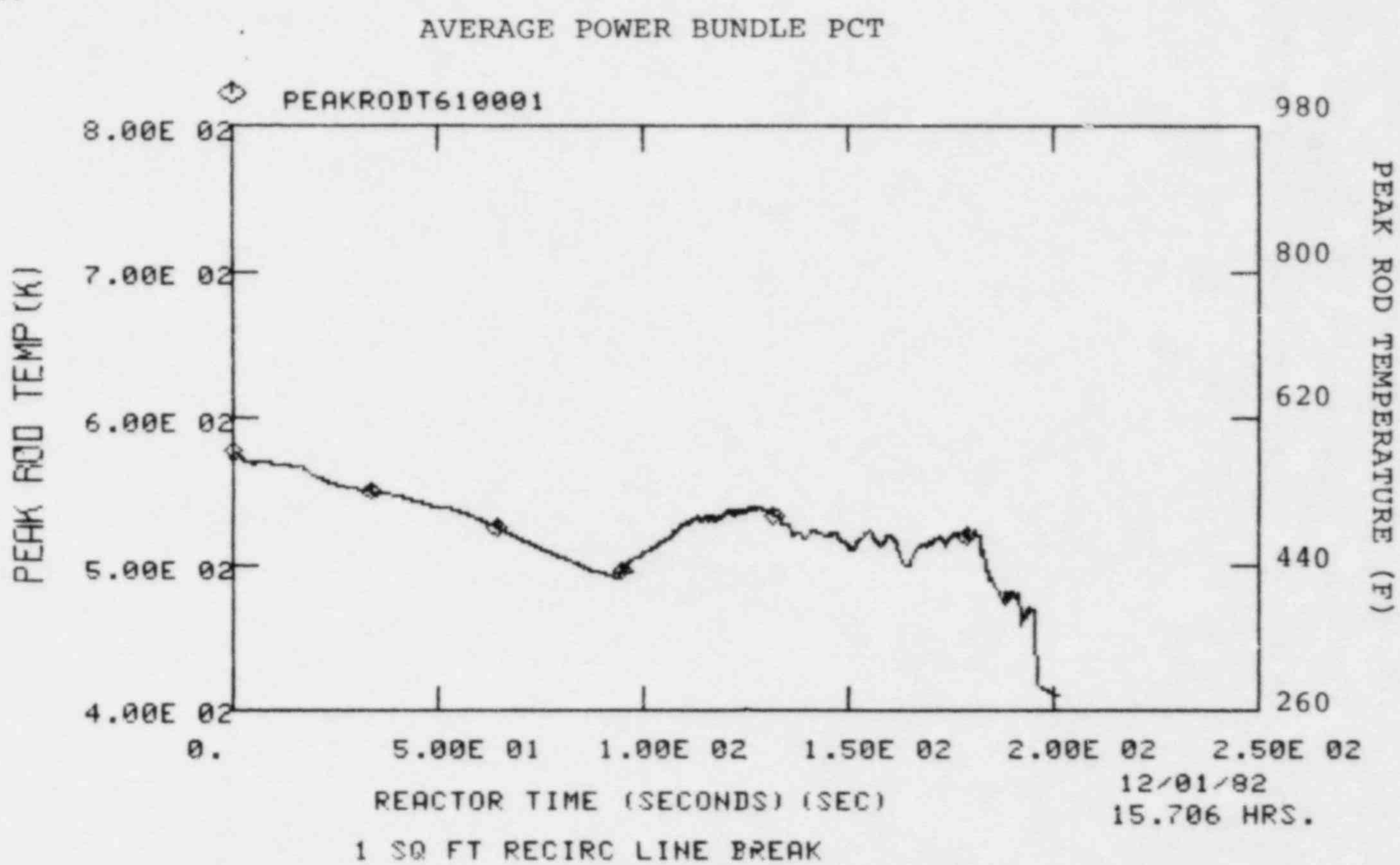
(1)

HIGH POWER BUNDLE PCT



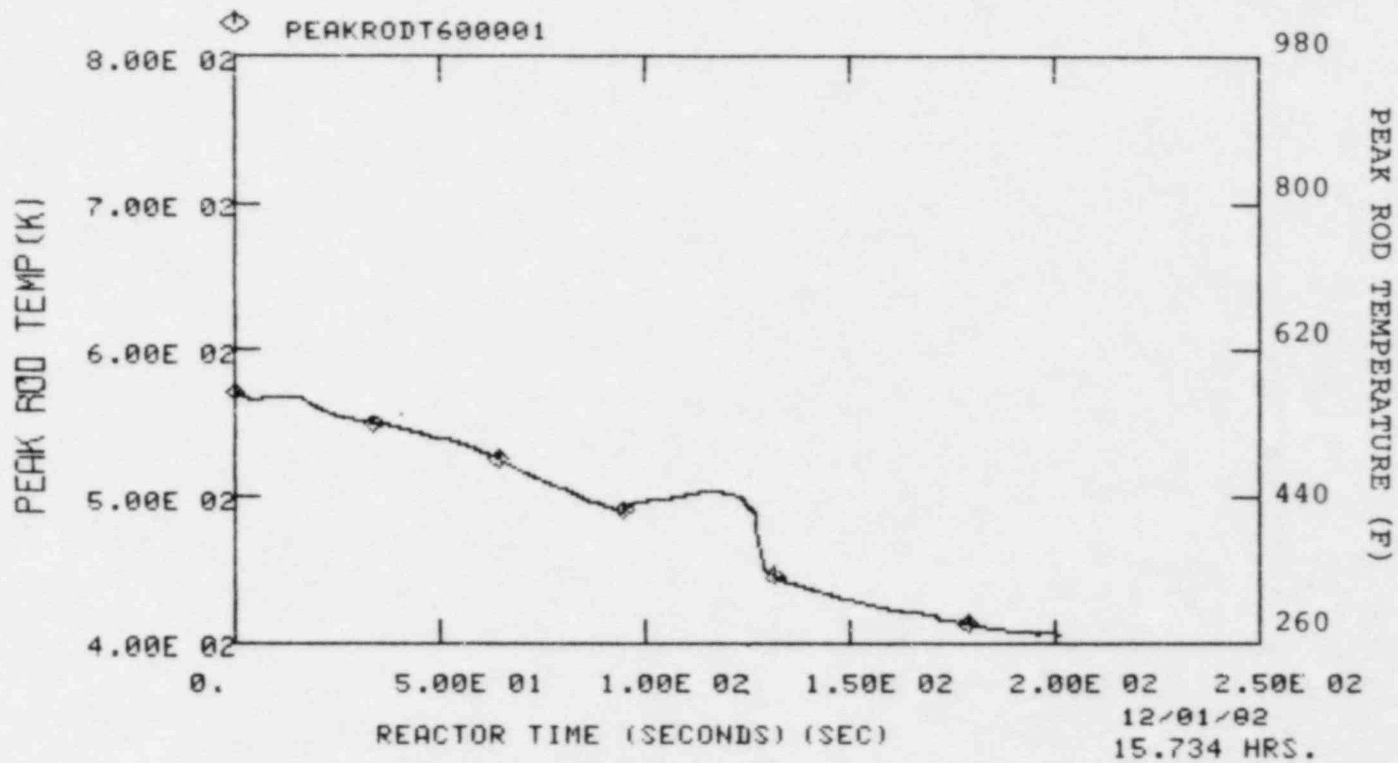
1 SQ FT RECIRC LINE BREAK

<?>


AVERAGE POWER BUNDLE PCT
PEAKRODT610001
PEAK ROD TEMP (K)
8.00E 02
7.00E 02
6.00E 02
5.00E 02
4.00E 02
PEAK ROD TEMPERATURE (F)
980
800
620
440
260
0.
5.00E 01
1.00E 02
1.50E 02
2.00E 02
2.50E 02
REACTOR TIME (SECONDS) (SEC)
12/01/82
15.706 HRS.
1 SQ FT RECIRC LINE BREAK

<?>

LOW POWER BUNDLE PCT



1 SQ FT RECIRC LINE BREAK

SUMMARY OF PCT

	PCT (^{o}F)
Main Steam Line Break	566
HPCS Line Break	584
1-ft^2 Recirculation Line Break	782

B.S Shiralkar

SAFER/GESTR APPLICATION METHODOLOGY

- LOCA events are analysed with nominal input values in SAFER/GESTR.
- Nominal PCT is increased by an "adder" to obtain an upper bound PCT for design evaluation.
- The "adder" encompasses Appendix K specified values as well as other uncertainties combined in a statistical manner (Reference January 1982 GE-NRC Meeting).

BS Shiralkar

12/3/82

METHOD

- Calibrate SAFER Modeling Uncertainties vs. "BWR-LOCA Experiments"
  - "BWR-LOCA Experiment" = TRAC-BWR Prediction for BWR Corrected to Account for TRAC-BWR Bias and Uncertainty.

- Quantify effects on PCT due to Plant Parameter Uncertainties by Performing Sensitivity Studies with SAFER.

BASIS FOR ADDER

- Test Data

- TRAC Predictions of Test Data

- TRAC Benchmark Calculations for Plants

- SAFER/GESTR Calculations for Plants

ADDER CALCULATION

$$PCT_{\text{Upper Bound}} = PCT_{\text{SAFER/GESTR}_{\text{NOMINAL}}} + \text{ADDER}$$

$$\text{Adder} = \Delta_1 + \Delta_2 + (r_1^2 + r_2^2 + r_3^2)^{1/2}$$

Δ_1 = Average Bias of Experiment-TRAC values of PCT. Assumed to apply in plant.

Δ_2 = Average Bias of (TRAC) plant values of PCT relative to SAFER/GESTR Plant values for the same LOCA. Accounts for simplified models in SAFER/GESTR.

Account for Model Bias

r_1^2 = Adder contribution due to variance of TRAC - Experiment Values.

r_2^2 = Adder contribution due to variance of SAFER/GESTR TRAC values.

Account for Model Uncertainties.

r_3^2 = Adder contribution due to variance of distribution of uncertainty of SAFER/GESTR Plant values. This reflects uncertainty in:

a) Variables whose values are conservatively specified in Appendix K

- Decay Heat
- Maximum Temperature for Transition Boiling
- Break Flow Model
- Metal Water Reaction Rate Coefficients

b) Variables whose values were much better known in the experiments than in a plant

- Core Power
- Peak Linear Heat Generation Rate
- Bypass Leakage Coefficients
- Minimum Critical Power Ratio
- ECCS Water Temperature
- ECCS Initiation Signals

c) Variables which were not involved in the experiments

- Pellet-Clad Gap Conductance
- Fuel Rod Internal Pressure.

EVALUATION OF PLANT UNCERTAINTY ADDER

r_3^2 will be evaluated at several break sizes and ECCS failure combinations.

1. For each variable, a value representing an upper bound probability will be established. For variables specified in Appendix K, this upper value will correspond to the specified value.

2. Sensitivity studies will be performed by perturbing these variables to the upper bound value in a SAFER/GESTR calculation.

ADDER ELEMENTS

1. TRAC-BWR Calibration vs. Experiments

2. SAFER/GESTR Comparisons vs. TRAC BWR for BWR Transients

3. SAFER/GESTR Sensitivity Studies to Quantify Plant Uncertainties.

TRAC-BWR CALIBRATION vs. EXPERIMENTS

- Objective: Assess TRAC-BWR bias and uncertainty

- Experiments Utilized

  - TLTA

  - ORNL Film Boiling Test

- Code Versions Utilized

  - TRACB02 (BD1/Version 12 +
    GE Models)

  - TRACB01 (GE Version close to
    Version 12)

SAFER vs. TRAC COMPARISONS

- Objective: Calibrate SAFER bias and uncertainty for BWR calculations

- Plant Simulated

BWR/6-218	BWR/4-218
624 Bundles	
2894 MW Initial Power	

- Transients Simulated

1. Main Steam Line Break	
2. HPCS Line Break	
3. 100% Recirculation Line Break	100% Recirculation Break
4. 80% Recirculation Line Break	
5. 1 ft^2 (47%) Recirculation Line Break.	

SAFER/GESTR SENSITIVITY STUDIES

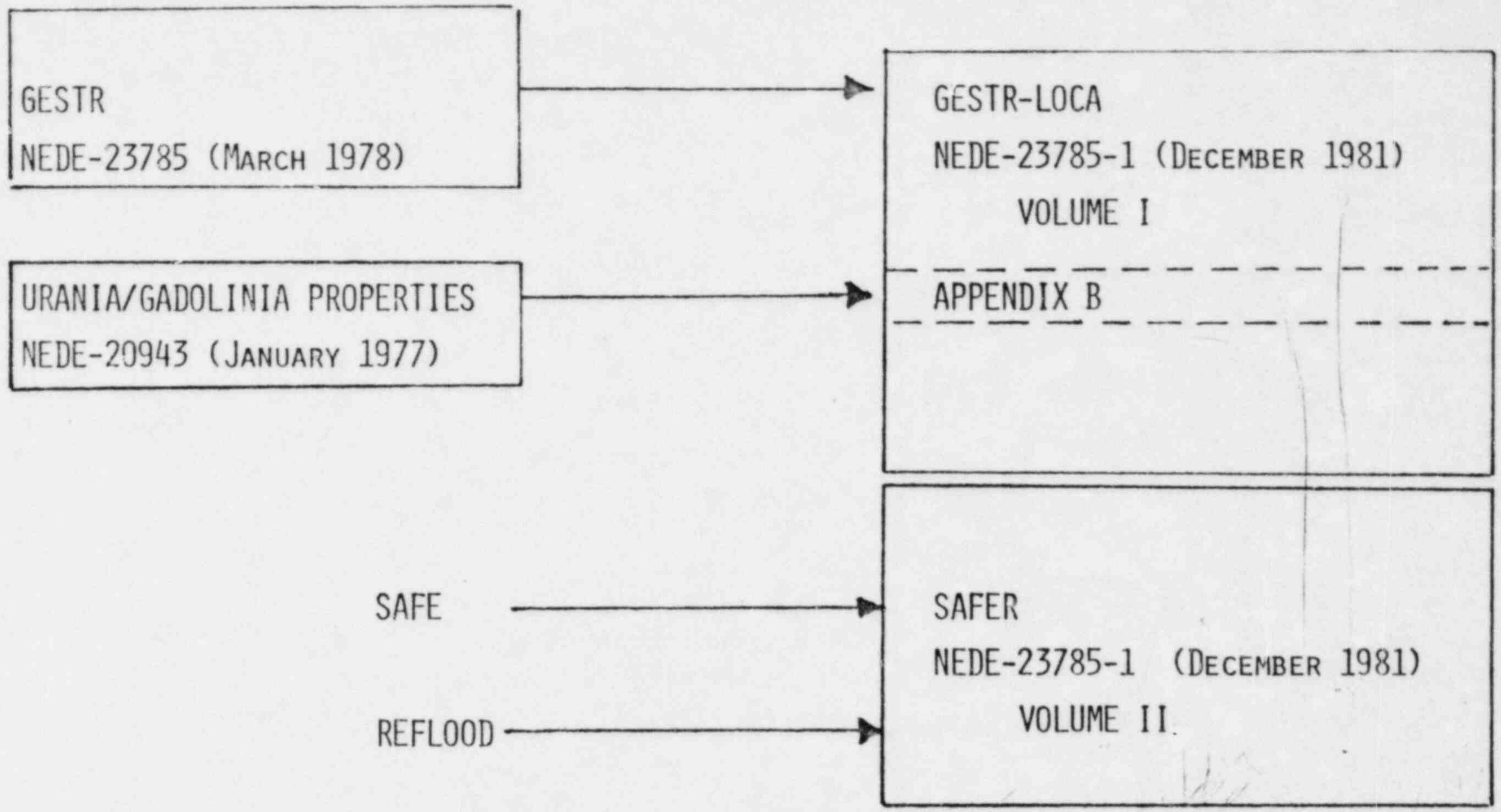
Objective: Quantify PCT changes due to Plant Parameters Uncertainties and Appendix K Requirements.

- Establish most limiting break and ECC failure combination for typical BWR/6 and BWR/4 plants.

- Perform sensitivity studies to account for plant parameter variations around limiting cases.

STATUS

- TRAC-BWR Calibration
  - TRACB01 studies completed
  - TRACB02 studies in progress
- SAFER-TRAC Comparisons
  - TRAC calculations almost completed for BWR/6, underway for BWR/4
  - SAFER calculations underway
- SAFER Sensitivity Studies
  - Base calculations of break spectrum underway
  - Sensitivity studies to be performed.


GESTR
NEDE-23785 (MARCH 1978)
URANIA/GADOLINIA PROPERTIES
NEDE-20943 (JANUARY 1977)
GESTR-LOCA
NEDE-23785-1 (DECEMBER 1981)
VOLUME I
APPENDIX B
SAFE
REFLOOD
SAFER
NEDE-23785-1 (DECEMBER 1981)
VOLUME II

APPENDIX B OF NEDE-23785-1 VOLUME 1, WHICH DEALS WITH URANIA/GADOLINIA PROPERTIES, WAS REVIEWED UNDER CONTRACT WITH OAK RIDGE NATIONAL LABORATORY. THE RESULTS OF THAT EVALUATION ARE BEING SENT TO THE NRC STAFF.

VOLUME 1 OF NEDE-23785-1, LESS APPENDIX B, IS BEING REVIEWED BY THE NRC STAFF WITH THE SUPPORT OF BATTELLE PACIFIC NORTHWEST LABORATORY. A TECHNICAL EVALUATION OF THE BASE DOCUMENT BY BATTELLE HAS BEEN RECEIVED BY THE STAFF.

GESTR-LOCA CHRONOLOGY

12/30/81 & 1/18/82	NEDE-23785-1 VOLUME 1 SUBMITTED.
1/21/82	GE/NRC STAFF MEETING ON GESTR-LOCA.
6/10/82	ERRATA AND ADDENDA TO NEDE-23785-1 VOLUME 1 ISSUED.
9/8/82	STAFF QUESTIONS ON APPENDIX B ISSUED.
10/7/82 REVISED 11/12/82	GE RESPONSES TO STAFF QUESTIONS ON APPENDIX B.
10/20/82	STAFF QUESTIONS ON GESTR-LOCA ISSUED.
10/22/82	PNL ISSUES TECHNICAL EVALUATION OF GESTR-LOCA.
?	GE RESPONSES TO STAFF QUESTIONS ON GESTR-LOCA.
JANUARY 1983	SAFETY EVALUATION OF GESTR-LOCA COMPLETED.

SAFER REVIEW PROCESS

- IDENTIFY CHANGES FROM CURRENT EM
- EVALUATE UNCERTAINTIES AND CONSERVATISMS
- DETERMINE SENSITIVITIES
- COMPARE AGAINST APPENDIX K REQUIREMENTS

MAJOR MODEL CHANGES

- EXPANDED CCFL MODEL
- ADDITIONAL BACKFLOW LEAKAGE
- ENHANCED HEAT TRANSFER
  - STEAM COOLING
  - BROMLEY FILM BOILING
  - INCREASED CORE SPRAY HT

AWAITED INFORMATION

- TREATMENT OF UNCERTAINTIES
- QUALIFICATION vs. TLTA
- BREAK SPECTRUM CALCULATIONS vs. EM
- DATA BASE/JUSTIFICATIONS FOR:
  - CCFL COEFFICIENTS
  - STEAM COOLING MODEL
  - IMPROVED CORE SPRAY HT
- SENSITIVITY vs. "MINOR" MODEL CHANGES

SCHEDULE

. RECEIVE ADDITIONAL INFORMATION - JANUARY 26, 1983

. COMPLETE EVALUATION - MARCH 11, 1983