

1 DR. SANJOY: That was the clad
2 temperature.

3 CHAIRMAN WALLIS: No, this is the steam.
4 It is the other way around, it is getting cooled as it
5 goes through the grid?

6 DR. HOCHREITER: Right. This is the steam
7 temperature, 93 inches, again I should have drawn an
8 arrow here, but the flow is up this way.

9 CHAIRMAN WALLIS: So what cools it?

10 DR. HOCHREITER: The droplet breakup here.
11 The turbulent mixing, droplet breakup.

12 CHAIRMAN WALLIS: Now, these droplets --

13 DR. HOCHREITER: Increased convection.

14 CHAIRMAN WALLIS: These droplets are
15 hitting your probe, then?

16 DR. HOCHREITER: The droplets are hitting
17 the grid.

18 CHAIRMAN WALLIS: Not hitting the probe?

19 DR. KRESS: What was bothering me is that
20 this supposes that every grid you hit the droplets get
21 smaller, and then they get smaller again. I could
22 never rationalize this.

23 DR. HOCHREITER: That may not be true,
24 because you may reach a minimum size where most of the
25 drops can pass through the grid. Where most of the

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1 drops can pass through the grid.

2 DR. KRESS: But then you wouldn't see the
3 effect.

4 DR. HOCHREITER: There is still a
5 convective enhancement that is caused by the spacer,
6 particularly a spacer like this. So you are going to
7 get a higher interfacial heat transfer between the
8 vapor and the drop.

9 MR. SCHROCK: Do you have thermacouples on
10 the grids?

11 DR. HOCHREITER: Yes.

12 MR. SCHROCK: You are not showing us
13 those?

14 DR. HOCHREITER: I'm not. Most of these
15 grids will end up being quenched.

16 MR. SCHROCK: Yes, that is what I was
17 going to suggest, that your cooling occurs between the
18 grid and the steam going through and not in a change
19 in mixing conditions downstream of that.

20 DR. HOCHREITER: Well, I know there is a
21 change in the mixing conditions downstream, I know
22 that from single phase tests.

23 MR. SCHROCK: But you can't convince me
24 that the predominant effect is in the region
25 downstream of the grid, without showing me the

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1 temperature on the grid.

2 DR. HOCHREITER: Well, for most of these
3 tests --

4 MR. SCHROCK: They are quenched.

5 DR. HOCHREITER: For most of these tests
6 the grid --

7 MR. SCHROCK: But that is a lot of
8 surface area compared to the drop surface area.

9 DR. HOCHREITER: I know, I agree, I agree.
10 And that is something that we are going to have to
11 sort out from the data. And, really, we've talked
12 about this with the NRC.

13 We have purposely kept these tests at a
14 low temperature, because it is the beginning of a test
15 period, a long test period, one very large expensive
16 rod bundle.

17 What we planned to do, and Steve had it on
18 his slide, is go back after we run our separate
19 effects decomposition of disperse flow film boiling,
20 and run higher temperature tests, because there we
21 will definitely have the grids hot.

22 And we do have some data, but it is
23 limited, where the grids are hot. And I can't
24 honestly answer whether you see exactly the same
25 effect, or not, without going back and looking

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1 specifically at that data.

2 MR. SCHROCK: But you are convinced that
3 the predominant effect is the enhanced heat transfer
4 between drops and steam downstream from the grid, not
5 enhanced heat transfer in the grid, from wall to
6 steam?

7 DR. HOCHREITER: Well, actually, liquid
8 film is --

9 MR. SCHROCK: Well, the liquid film is the
10 wall to the vapor.

11 DR. HOCHREITER: Yes. Right now, yes, I
12 am.

13 DR. KRESS: Larry, I conclude that in
14 order to get that enhanced heat transfer, that you
15 have to have more droplet surface area, which means
16 you have to break them up.

17 Actually the heat transfer of a given drop
18 between the steam and drop wasn't much, when I tried
19 to make the calculations. So that is, once again, I
20 come back to I never figured out how we kept making
21 the droplets smaller each time.

22 DR. HOCHREITER: Well, Dr. Schrock has a
23 very valid point.

24 DR. KRESS: Yes, it could have something
25 to do with that grid, yes.

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1 DR. HOCHREITER: And the amount of surface
2 area. You get two benefits, if you would, in that
3 case. One, the surface area benefit, because the grid
4 does have a huge surface area.

5 The second benefit is that the relative
6 velocity is much higher for the interfacial heat
7 transfer, because the grid is not moving.

8 MR. SCHROCK: And the third is that you
9 are in a thermal entry region.

10 DR. HOCHREITER: Right.

11 MR. SCHROCK: Very close to the beginning
12 of it.

13 DR. HOCHREITER: That is right.

14 MR. SCHROCK: All at a very high heat
15 transfer coefficient.

16 DR. HOCHREITER: That is right.

17 CHAIRMAN WALLIS: What does your grid
18 thermocouple show?

19 DR. HOCHREITER: For most of the tests the
20 grid thermocouple, once you start to get water through
21 here, will quench. So it will come down --

22 CHAIRMAN WALLIS: The grid thermocouple is
23 way down there.

24 DR. RANSOM: Larry, have you modeled these
25 using COBRA/TRAC, or --

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1 DR. HOCHREITER: Yes.

2 DR. RANSOM: What does it show in terms of
3 these temperatures?

4 DR. HOCHREITER: We get a behavior like
5 this.

6 DR. RANSOM: It would be very instructive
7 to see some comparisons.

8 DR. HOCHREITER: We have done those, we do
9 get a behavior that is like this.

10 DR. RANSOM: You do get that kind of
11 superheat being predicted?

12 DR. HOCHREITER: Yes. If anything we tend
13 to overpredict the superheat.

14 DR. RANSOM: How about other NRC codes?
15 Like RELAP-5, what does it show?

16 DR. HOCHREITER: I cannot answer that, I
17 don't know. But in this case, at this higher
18 elevation, you do see more of an effect on the grid,
19 even on the vapor temperature, including the rod
20 temperatures.

21 The higher you go, of course the power
22 gets higher. This is around the peak power location.
23 Again, this is a thermocouple downstream of the grid,
24 thermocouple upstream of the grid.

25 And when I said these tests are quasi-

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1 steady, I mean, these temperatures are really fairly
2 steady for hundreds of seconds. And you don't see
3 that in a normal reflood test.

4 Again, the reason for it is because we've
5 been running these at a constant power. But here is
6 almost 200 degrees C difference, upstream and
7 downstream.

8 And you see the same picture for the
9 vapor. The vapor is almost constant. This is almost
10 a steady state test, that starts to drop off sooner
11 because it is at a lower elevation.

12 CHAIRMAN WALLIS: And no one has tried to
13 analyze these?

14 DR. HOCHREITER: We are analyzing these,
15 the NRC is going to be analyzing these.

16 CHAIRMAN WALLIS: I really don't think
17 that is the way to do it, they should be analyzing
18 them right now, not waiting.

19 DR. HOCHREITER: This is at the -- past
20 the peak power location, almost at the exit of the
21 bundle. And, again, this is the temperature
22 downstream of the grid, and this is the temperature
23 upstream.

24 The temperatures, of course, are lower now
25 because the power has dropped off.

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1 DR. KRESS: You have cosine type
2 distribution?

3 DR. HOCHREITER: No, it is two straight
4 lines.

5 DR. KRESS: Two straight lines?

6 DR. HOCHREITER: From .5 to 1.5 peaking
7 factor, and 1.5 occurs at about 108 inches, and then
8 from 1.5 down to .5 at 144 inches.

9 DR. KRESS: Yes, that would be easier to
10 analyze, anyway.

11 DR. HOCHREITER: And that is one of the
12 reasons it was chosen.

13 DR. SANJOY: If you take the precursory
14 cooling into account, does the advance of the quench
15 front follow any sort of conduction quench front
16 advance? You would have to work out the entrainment,
17 and all this sort of stuff.

18 DR. HOCHREITER: We had a student that
19 just finished at Penn State, that made improvements to
20 the COBRA/TF inverted annular, annular, and
21 entrainment models. We had him run his calculations
22 against FLECHT test, which have a cosine power shape,
23 and these rod bundle tests.

24 And he got excellent agreement with these
25 five bundle tests. There still are issues with the

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1 code. One of the issues is what do you choose for T-
2 min, minimal film boiling temperature.

3 These tests indicate that it should be
4 lower than the models that are typically in the code.
5 If you make that adjustment you could match the quench
6 fronts very well.

7 So it was actually a combination of both
8 of those things.

9 CHAIRMAN WALLIS: How much water is being
10 drained out the top of the hole?

11 DR. HOCHREITER: Quite a bit. The
12 qualities, if I remember correctly, are around 50
13 percent.

14 CHAIRMAN WALLIS: So half the flow coming
15 out of the top is water?

16 DR. SANJOY: T-min would also depend on
17 the material?

18 DR. HOCHREITER: Yes.

19 DR. SANJOY: That is the problem.

20 CHAIRMAN WALLIS: It depends on the
21 velocity, too. It is not just a magic number.

22 DR. HOCHREITER: We have run experiments,
23 again, as part of the program, on different cladding
24 materials. We built a small furnace and we took
25 inconnel, built a four foot heater rods, basically,

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1 and basically oxidized the inconel. And we got T-min
2 values, basically, with a dunk test.

3 And then we took zircaloy, fresh zircaloy,
4 and zircaloy with different oxidation thicknesses,
5 which we could characterize, did the same thing. Yes,
6 there is quite a bit of difference.

7 We took the inconel samples, we roughened
8 them, and again you get a higher T-min value. So this
9 is something that is going to have to be nailed down.

10 CHAIRMAN WALLIS: Which means that all
11 fuel elements which have an oxide layer are going to
12 be different?

13 DR. HOCHREITER: That is right. But those
14 are usually low power fuel elements, not limine.

15 Again, what I'm ecstatic about with this
16 data is the steam temperature measurements that just
17 slowly, slowly come down towards saturation. We never
18 saw that in any previous test, ever, anywhere in the
19 world.

20 DR. RANSOM: Never saw what?

21 DR. HOCHREITER: Steam temperatures
22 remaining superheated and then slowly coming down to
23 a saturation temperature like this. Usually it goes
24 plunk.

25 DR. RANSOM: You don't see any quench, you

1 don't think?

2 DR. HOCHREITER: That is right. Now, this
3 is at the very top of the bundle, the flow is most
4 highly dispersed.

5 MR. SCHROCK: It looks almost like it sort
6 of tries to quench, and then hesitates, and then tries
7 again.

8 DR. HOCHREITER: Yes, in here.

9 MR. SCHROCK: Right, those shelves.

10 DR. HOCHREITER: Yes. And so, again, my
11 interpretation of the data is take the tops.

12 DR. RANSOM: You have the same number on
13 that 1096, is that a run number?

14 DR. HOCHREITER: Yes.

15 DR. RANSOM: But when I look at the
16 printed version it looks different out here where
17 these, near the tail end.

18 DR. HOCHREITER: I don't know what you
19 mean.

20 DR. RANSOM: I guess you've gone over it
21 with a pen, and smeared it up, that is what it looks
22 like.

23 DR. HOCHREITER: With the green, you mean?

24 DR. RANSOM: Right, the green.

25 DR. HOCHREITER: Yes, I did, to make it

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1 more dramatic.

2 DR. RANSOM: But when you look at the
3 printed one there are more distinct shelves.

4 DR. HOCHREITER: Yes.

5 DR. RANSOM: There, as it comes down.

6 DR. HOCHREITER: That is very true, that
7 is very true. You can see them in through here.

8 DR. RANSOM: Yes.

9 CHAIRMAN WALLIS: I don't think your model
10 is going to predict those shelves.

11 DR. HOCHREITER: I don't think so either.

12 MR. BOEHNERT: What are you attributing
13 this to, Larry?

14 DR. HOCHREITER: What am I attributing
15 what to?

16 MR. BOEHNERT: This fall off of superheat
17 cooling?

18 DR. HOCHREITER: The quench front is
19 coming up but it is so highly dispersed that there is
20 just not a lot of liquid there, okay? There is
21 obviously liquid in the flow, that is really what
22 causes this, okay?

23 MR. BOEHNERT: But you are saying you've
24 never seen these many tests before?

25 DR. HOCHREITER: But I've never seen it

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1 persist for as long a period of time. Because we
2 always use these aspirating steam probes and, you
3 know, so you are sucking steam, hopefully steam, into
4 the thimble, where you have a shielded thermocouple.
5 And you provide a torturous path, hopefully, to
6 separate out the liquid.

7 Well, hopefully doesn't cut it. Now, a
8 couple of reasons. One, you do get liquid in there,
9 when you get it in there, it hits the probe, it
10 quenches. These were larger thermacouples, which is
11 probably part of the problem. These are much smaller
12 thermacouples.

13 Again, the other thing is you have a decay
14 power, so the whole transient is compressed. And you
15 get a lot more liquid up there, sooner, than you do in
16 these tests.

17 CHAIRMAN WALLIS: Did you do separate
18 effects tests on your probes to see what they actually
19 measure in a controlled flow?

20 DR. HOCHREITER: We have not, no. I think
21 we did something like this in the FLECHT SEASET
22 program. We used bare thermacouples in the FLECHT
23 SEASET program, but it was at the very end of the
24 particular, in a small 21 rod bundle.

25 And we had, Ralph and I designed a lot of

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1 steam probes that didn't work, okay? So it is rare
2 that you find one that does. And we had shielded
3 thermacouples, we had self-aspirating thermacouples,
4 and then we had bare thermacouples.

5 Now, bare thermacouples worked the best.
6 I think it is just a question of providing the
7 smallest target to the drops.

8 DR. SANJOY: There was some CARS
9 measurements made at Lehigh, John Chen made them?

10 DR. HOCHREITER: Yes. So he basically
11 took what we had done in FLECHT and did it in a
12 smaller rod bundle where, again, he was aspirating,
13 pulling a vacuum and sucking --

14 DR. SANJOY: No, I meant he was also using
15 random scattering to look at temperatures.

16 DR. HOCHREITER: That I'm not aware of.

17 DR. SANJOY: I don't know if he ever got
18 it to work.

19 DR. HOCHREITER: I really can't answer
20 that, I don't know.

21 DR. SANJOY: Then he had an independent
22 measurement, completely.

23 DR. HOCHREITER: Right.

24 DR. SANJOY: NRC funded it, so we should
25 be able to dig up what --

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1 DR. HOCHREITER: No, we have the reports,
2 and I looked at those reports, I just don't remember
3 that being reported.

4 DR. SANJOY: Okay.

5 DR. MOODY: What is the one inch per
6 second?

7 DR. HOCHREITER: It is one inch cold
8 flooding rate into the bottom of the bundle.

9 Now, we have the laser illuminated camera.
10 And this was positioned at the 93 inch elevation. And
11 this is plotting the mean diameter versus time after
12 reflow. This gives you an indication of where the
13 quench front is, okay?

14 And as the quench front is moving up along
15 these elevations, the mean diameter from the
16 distribution of the drops that we measured with the
17 camera, is slowly increasing.

18 And then as the quench front gets very
19 close to this 93 inch elevation, this basically falls
20 off. So we are measuring drops, entrained drops,
21 roughly four to six inches below the quench front,
22 with this camera system. We have never been able to
23 dot and plot it.

24 And you get a whole history of these
25 drops. When we did these, tried these types of

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1 measurements in the FLECHT SEASET program, as Steve
2 indicated, we would maybe get 50 drops.

3 DR. KRESS: Where would you locate a grid
4 along that?

5 DR. HOCHREITER: This is above a grid, if
6 I remember correctly.

7 CHAIRMAN WALLIS: So one location?

8 DR. HOCHREITER: Yes, one location. I'm
9 going to show you above and below in a minute.

10 DR. RANSOM: Larry, what Webber number do
11 those correspond to?

12 DR. HOCHREITER: I can't tell you that, I
13 have not calculated that.

14 DR. RANSOM: You really need to extract
15 some of that data out of this.

16 DR. HOCHREITER: Well, we will, we will.
17 We will be able to do that because we will do the --
18 at least it is going to be a bundle average steam
19 velocity, and we can calculate that.

20 DR. KRESS: By looking at that change in
21 droplet size you could probably extract how much
22 turned into steam.

23 DR. HOCHREITER: Exactly. But you have to
24 remember --

25 DR. SANJOY: There is not much change.

1 DR. HOCHREITER: You have to remember --

2 DR. KRESS: That is what I was thinking,
3 there is not much of a slope there.

4 DR. HOCHREITER: You have to remember that
5 these, the measuring system tends to bias you towards
6 smaller sizes.

7 DR. KRESS: It probably does, yes.

8 DR. HOCHREITER: Because we cannot see the
9 drops that are behind the rod, and we are looking
10 through the gap. And the gap, I think, is 122 mils.
11 And in the camera system you have to put boundaries,
12 you put into the software boundaries. So it is
13 actually less than 122 mils.

14 And then the software package with the
15 system basically rejects parts of drops, or any drop
16 that touches the boundary. So you tend to get a bias
17 here, probably, of smaller drops.

18 DR. SANJOY: These are about 15 thou,
19 right?

20 DR. HOCHREITER: Right.

21 DR. SANJOY: What is 122 mils?

22 DR. HOCHREITER: Well, roughly eight times
23 this.

24 DR. SANJOY: This is a Sauter mean?

25 DR. HOCHREITER: This is just mean, I'm

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1 going to show you Sauter mean next. Sauter mean is a
2 little larger. There is more scatter, too, which I
3 cannot explain right now.

4 DR. RANSOM: Sauter mean is the diameter
5 that gibes you the same surface area?

6 DR. HOCHREITER: It is a surface area --

7 CHAIRMAN WALLIS: Actually it is a volume
8 to surface.

9 DR. HOCHREITER: A volume to surface, so
10 it comes out with a D, yes.

11 These are the number of counts. This is
12 just to show you that we had a lot of counts.

13 CHAIRMAN WALLIS: This is counts per
14 second?

15 DR. HOCHREITER: This is counts for each
16 diameter size that we got, okay? And we -- I don't
17 have the total number of counts, but it is typically
18 like 5,000.

19 So the number, we threw anything of 20 or
20 less. So to calculate this diameter, whether it is a
21 Sauter mean, or the average diameter, where you are
22 using data that has about 51 counts.

23 CHAIRMAN WALLIS: Presumably over a period
24 of time?

25 DR. HOCHREITER: It is, but it is rather

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1 short. Total counts, total, for that window.

2 DR. SANJOY: But there is seconds after
3 reflood?

4 DR. HOCHREITER: Yes, these are seconds
5 after reflood.

6 DR. SANJOY: How big are your windows?

7 DR. HOCHREITER: THE time window? I think
8 it was about, I'm guessing, 20 seconds.

9 CHAIRMAN WALLIS: So there are very few
10 counts per second.

11 DR. HOCHREITER: Yes. I don't really know
12 the exact number.

13 DR. SANJOY: But it is off that order,
14 because you go one, two, three, four, five, six, six
15 in 100 seconds, roughly, of those.

16 DR. HOCHREITER: Yes. Now, if we look at
17 the distribution, and you should correct your slide,
18 this is below the 110 inch grid, this is the
19 distribution we are getting, this was the mean, okay?
20 And the mean was 18 mils.

21 CHAIRMAN WALLIS: That is a log scale?

22 DR. HOCHREITER: Yes. Actually we found
23 most of this fits a log normal distribution.

24 CHAIRMAN WALLIS: What are these weird
25 ones which are off scale?

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1 DR. HOCHREITER: They are weird. They are
2 weird data, which I cannot explain at this time.

3 DR. SANJOY: So these are log normal
4 distribution, really?

5 DR. HOCHREITER: Yes.

6 CHAIRMAN WALLIS: Except for the weird
7 ones.

8 DR. HOCHREITER: Except for the weird
9 ones. This is above the grid, the one below the grid
10 was 0.18 something. This is the size above the grid,
11 the size has decreased.

12 The other thing, at least it seems to me,
13 that this distribution is tighter than the one below
14 the grid.

15 DR. SANJOY: But, you know, as you said,
16 you may be biasing your data because of the window.

17 DR. HOCHREITER: I know, I know. You have
18 to consider that.

19 MR. SCHROCK: There is a huge resonance of
20 10 to the minus 2 inches. Resonance.

21 CHAIRMAN WALLIS: Those are the weird
22 ones.

23 MR. SCHROCK: It looks like a neutron
24 scattering.

25 CHAIRMAN WALLIS: Well, it is not a log

1 scale, is it?

2 DR. SANJOY: Well, it could be that there
3 is a preferred size.

4 MR. SCHROCK: It could be.

5 DR. HOCHREITER: I don't have an
6 explanation for these points.

7 DR. SANJOY: If you look at this data set
8 there is also that little bump.

9 DR. HOCHREITER: The next plot just is
10 axial plots of the vapor temperature. So the green is
11 at the beginning of the test. The solid squares are
12 at 350 seconds. So, I mean, I just drew a colored
13 line through here, so you can see it better.

14 And this is a turn-around, so you have
15 some data here, you have point that is low here, these
16 points are high here, points in here. Some of the
17 thermacouples in the steam probes do behave
18 differently, because this one is low, these two are
19 basically together, these three are basically
20 together.

21 By and large you don't see a large radial
22 temperature gradient across the bundle, because you
23 are sampling three different subchannels here, in the
24 bundle.

25 Each one of these thermacouples is in the

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1 center of a different subchannel. They come in from
2 the side.

3 DR. SANJOY: So now this is by axial
4 location?

5 DR. HOCHREITER: That is right, this is
6 temperature versus axial position.

7 DR. SANJOY: And the temperature --

8 DR. HOCHREITER: Or three different times.

9 MR. SCHROCK: Okay.

10 DR. HOCHREITER: This is at the beginning
11 of the test, this is at 350 seconds, this is at turn-
12 around. Now, this is my drawing of --

13 MR. SCHROCK: I don't understand how you
14 are showing turn-around on temperature versus
15 location.

16 DR. HOCHREITER: This is the clad
17 temperature turn-around, this is the steam temperature
18 distribution at the time that the clad temperature
19 turns around.

20 CHAIRMAN WALLIS: Where does it turn
21 around?

22 DR. HOCHREITER: At the upper elevations,
23 up in here. And I don't remember what the time is, I
24 would have to go back and look at the time.

25 DR. BAJOREK: It is about 800 seconds or

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1 so.

2 DR. HOCHREITER: Yes, something like that.

3 DR. SANJOY: 350 seconds, when you say
4 350, is 350 from the start of reflood?

5 DR. HOCHREITER: Right.

6 DR. SANJOY: But when you say turn-around,
7 what do you mean, is that something like 800 seconds?

8 DR. HOCHREITER: Yes, I should have put a
9 time in here.

10 Now, the plot that Dr. Kress was talking
11 about looks something like this. Again, this is
12 temperature versus elevation. These are the heater
13 rod temperatures, these are the spacer grids, these
14 are vapor temperature measurements.

15 CHAIRMAN WALLIS: So the zigzag is used as
16 spacer?

17 DR. HOCHREITER: Yes. You get cooling,
18 and then you get recovery, cooling, recovery, I'm not
19 too sure why this drops down, and then and so forth.
20 Then you have --

21 DR. SANJOY: Where is your flux peak?

22 DR. HOCHREITER: It's in here, very close
23 to this. Yes, I don't know why this is --

24 CHAIRMAN WALLIS: What are the
25 expectations of the code, Steve? Are you going to

1 model these mountains?

2 DR. BAJOREK: Yes, we think that in the
3 long run this code has to be able to get the cladding
4 profile, and be able to get the dips following each of
5 these grids. And that is going to require us not only
6 to get the rod to the fluid heat transfer correct, the
7 interfacial heat transfer correct, and be able to get
8 what I will call the delta D, or the change in the
9 droplet sizes it encounters one grid to the next.

10 DR. KRESS: We'll need that, because there
11 is 150 degree difference there.

12 DR. SANJOY: What time is it?

13 DR. HOCHREITER: This is at the peak
14 temperature turnaround time. This is around 800
15 seconds. It is actually -- I can tell you that more
16 accurately.

17 DR. RANSOM: Larry, the turn-around time
18 is when the peak clad temperature starts to go back
19 down?

20 DR. HOCHREITER: Yes. It is more like 400
21 seconds.

22 DR. SANJOY: Four hundred seconds?

23 DR. HOCHREITER: I'm just going based on
24 this.

25 DR. SANJOY: And where does the peak clad

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1 temperature occur, is it at the maximum flux point?

2 DR. HOCHREITER: Yes, it is up in here.

3 DR. SANJOY: Somewhere there. So I don't
4 understand this, Larry. The peak temperature there,
5 that you are showing, is about 850, 870, or something.

6 DR. HOCHREITER: I see what you are
7 saying, yes.

8 DR. SANJOY: So wouldn't you expect that
9 unless the turn-around is just before the peak?

10 DR. HOCHREITER: Ralph, do you remember
11 the exact location of the peak power?

12 DR. ROSAL: 108.

13 DR. HOCHREITER: 108 inches?

14 DR. ROSAL: Yes, we have it.

15 DR. HOCHREITER: All right, I would have
16 to convert that to meters, because this was in -- I
17 don't really know, it is before this grid.

18 CHAIRMAN WALLIS: This initial
19 temperature, what is that? The initial temperature of
20 everything?

21 DR. HOCHREITER: This was the initial
22 temperature of the test.

23 CHAIRMAN WALLIS: Everything is at that
24 temperature, it must be just the peak?

25 DR. HOCHREITER: It is the peak. There

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1 was a 20 PSI test, I've got a similar set of plots for
2 40. Do you want me to walk through those plots?

3 CHAIRMAN WALLIS: Is there anything new?

4 DR. HOCHREITER: Not so much, no.

5 CHAIRMAN WALLIS: So are you going to,
6 then, show us some predictions, or something?

7 DR. HOCHREITER: No.

8 CHAIRMAN WALLIS: There is a COBRA/TF
9 here, on one of these.

10 DR. HOCHREITER: I don't think so, there
11 shouldn't be. If there is, I screwed up.

12 I do want to show you, if you go ahead in
13 the package, this is the steam probe behavior. When
14 you are at the center of a subchannel, and when you
15 are in the gap.

16 This experiment has a vapor temperature
17 measured in the gap, versus this experiment, same
18 conditions as the vapor temperature measured in the
19 center of the subchannel.

20 CHAIRMAN WALLIS: So you are going to show
21 that, too, in the code? It is going to be a two
22 dimensional code, a three dimensional code?

23 DR. BAJOREK: No.

24 CHAIRMAN WALLIS: There is a big
25 difference.

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1 DR. SANJOY: What is the vapor velocity?

2 DR. HOCHREITER: I cannot give you an
3 accurate number on that.

4 DR. SANJOY: It is most likely, though,
5 that things are fairly well mixed, aren't they?

6 DR. HOCHREITER: Well, your vapor
7 velocities are going to be the highest in here.

8 DR. SANJOY: Right.

9 DR. HOCHREITER: Okay? Vapor velocities
10 are the highest in here, and they are going to be the
11 lowest right in here.

12 DR. SANJOY: That could be just the
13 radiation effect, or something.

14 DR. HOCHREITER: I don't think so. I
15 really don't.

16 CHAIRMAN WALLIS: So it is much more
17 readily quenched in the one position than the other?

18 DR. HOCHREITER: Well, you have more
19 liquid here than you do here.

20 CHAIRMAN WALLIS: And the one that is
21 quenched, I'm trying to figure out which is which.
22 The center line is --

23 DR. HOCHREITER: The one that is quenched
24 is the one that is in the center. You have a non-
25 uniform temperature distribution within the

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1 subchannel.

2 The temperatures are going to be higher in
3 the gaps than they are in the center of the
4 subchannel. CFD calculations show that, because the
5 velocity distribution is highest in the center of the
6 subchannel, lowest in the gap region.

7 So if nothing else changes, the vapor in
8 here is going to be at a higher temperature than here,
9 simply because of velocity. It is lower in the gap
10 region compared to the center.

11 Now, should a computer code like TRAC-M
12 account for this? No, I don't think so.

13 CHAIRMAN WALLIS: Well, if it is
14 averaging, it is going to average over a pretty wide
15 range of --

16 DR. HOCHREITER: Well, there is more area
17 here than there is here.

18 CHAIRMAN WALLIS: What is it going to say
19 the temperature is?

20 DR. HOCHREITER: What TRAC-M is going to
21 say the temperature is?

22 CHAIRMAN WALLIS: So 600 or something,
23 between --

24 DR. HOCHREITER: TRAC-M is going to give
25 you a more accurate estimate of the temperature in

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1 here.

2 DR. SANJOY: It would be an area average.

3 CHAIRMAN WALLIS: I guess it doesn't
4 matter, there would be enough coefficients in the code
5 that it will correct for it, anyway.

6 DR. HOCHREITER: Well, I wouldn't even
7 try, but this is just something that people should
8 know about.

9 DR. BAJOREK: Larry, I think what you are
10 pointing out is, the TRAC-M, we would be shooting at
11 getting like a mass weighted average across the
12 bundle, and that is about the best we will do with
13 that.

14 What the tests are pointing out is the
15 potential need, in the future, for looking at
16 subchannel effects. In something like that we would
17 want to start looking at coupling TRAC-M with the
18 COBRA/TF, or something like a VIPER, if it is
19 important for the Staff to be able to predict the
20 differences across the bundle, like that.

21 DR. SANJOY: Are the clad temperatures
22 higher in the gaps, too?

23 DR. HOCHREITER: We don't know, because we
24 have a single thermocouple at some position. We don't
25 know the azimuthal position of the thermacouples.

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1 Also the interior of the rod is boron nitride-filled.
2 So you tend to smear out azimuthal differences.

3 DR. SANJOY: But you are getting the
4 inconnel temperature, right?

5 DR. HOCHREITER: The inside temperature of
6 the cladding is measured.

7 DR. SANJOY: So some of it is --

8 MR. SCHROCK: Larry, how did you explain
9 this quench that occurs and persists for 20 odd
10 seconds down here?

11 DR. HOCHREITER: Big drop, big drop.

12 MR. SCHROCK: Well, I can see it is a big
13 drop, but what is going on there, how does the steam
14 suddenly go to saturation well --

15 DR. HOCHREITER: The steam doesn't, the
16 steam doesn't.

17 MR. SCHROCK: What is that?

18 DR. HOCHREITER: The thermocouple does.
19 A drop hits the thermocouple and quenches it. The
20 steam temperature is up here.

21 CHAIRMAN WALLIS: Is there one drop for
22 that whole period?

23 DR. HOCHREITER: It could be more than
24 one.

25 DR. RANSOM: What it looks like is an

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1 inverted annular flow, almost, over the mass
2 concentration of liquids more in this channel.

3 DR. HOCHREITER: No, you just got hammered
4 by a bunch of drops.

5 DR. RANSOM: Well, that is what I said.
6 But essentially inverted annular flow, where you have
7 a higher concentration of liquid in the center of the
8 channel.

9 DR. HOCHREITER: Right, you have more
10 drops.

11 DR. RANSOM: That is right.

12 DR. SANJOY: But it could be ligaments, it
13 could be anything.

14 DR. HOCHREITER: I don't think so, not at
15 this time.

16 CHAIRMAN WALLIS: Is this just downstream
17 of a spacer?

18 DR. HOCHREITER: This is at 100 inches, so
19 this is downstream of a spacer.

20 CHAIRMAN WALLIS: So you've got drops
21 coming off the spacer, preferential streaks?

22 DR. HOCHREITER: Yes, but it is pretty far
23 downstream of the spacer.

24 MR. SCHROCK: So it looks as though there
25 is not much liquid getting to that level until a

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1 little bit after 200 seconds. Then all of a sudden --

2 DR. HOCHREITER: Well, this I think, the
3 fine hash, here, I think is liquid.

4 DR. RANSOM: 25 seconds is a long time.

5 DR. HOCHREITER: That is liquid coming.

6 DR. RANSOM: But there is a precipitous
7 change at 210 seconds, or something like that.

8 DR. HOCHREITER: Right. Well, there is
9 one here, too.

10 DR. RANSOM: Well, that one is short.

11 DR. HOCHREITER: Yes, but this is liquid.

12 DR. RANSOM: Sure.

13 DR. HOCHREITER: All of this is liquid,
14 liquid, but whammo, you got hit, you try to recover,
15 you got hit again. You try to recover, you got hit
16 again.

17 CHAIRMAN WALLIS: It got really soaked for
18 a long time.

19 DR. HOCHREITER: Yes, try to recover, got
20 hit again, and slowly dried out, okay? Almost got
21 here, but you got hit again. And, finally, you dried
22 up.

23 Now, the steam temperature, what we are
24 concerned about is the steam temperature. This is not
25 the steam temperature. The steam temperature is up

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1 here.

2 That is what I said, you draw an envelope
3 over these spikes, that is about the best you can do,
4 okay? That is the best you can do.

5 So if your code comes along and predicts
6 the tops of these, down to here, you are doing a real
7 good job.

8 DR. SANJOY: But you don't even know if
9 the top is the steam temperature.

10 DR. HOCHREITER: No, but it is the closest
11 thing to the steam temperature.

12 DR. SANJOY: Yes, but the code doesn't
13 have to predict it because, in fact, it may be halfway
14 to the steam temperature, it could be the full way,
15 you don't know.

16 DR. HOCHREITER: If the code is predicting
17 a temperature down here, it is wrong.

18 DR. SANJOY: That is wrong, yes.

19 DR. HOCHREITER: But if the code is
20 predicting a temperature here, it is wrong. If it is
21 predicting a temperature up here it is wrong.

22 DR. SANJOY: Maybe.

23 DR. HOCHREITER: No, it is wrong. I mean,
24 this is probably hotter than the rods.

25 DR. SANJOY: Well, we don't want to do

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1 that.

2 DR. RANSOM: Larry, if I --

3 DR. HOCHREITER: It has to be in the
4 vicinity of this data.

5 DR. RANSOM: Larry, other investigators
6 have used a shielded thermocouple that more or less
7 kept the liquid away from the thermocouple so you more
8 or less measure the steam temperature. Would that be
9 worth trying?

10 DR. HOCHREITER: I did try that, and what
11 happens is you have a larger target, because it is
12 shielded. So you get more liquid hitting it.

13 DR. RANSOM: In a cold shield?

14 DR. HOCHREITER: That is right. I tried
15 aspirating these things, where you cut holes in the
16 sides so the steam magically flows through, and it
17 flows out the top. The steam didn't know that, and
18 the water just hit it.

19 So, really, I really think the best thing
20 are as small as you can get them, the thermacouples.

21 CHAIRMAN WALLIS: Well, let's let the
22 radiation now, when the guy is in the gap, you've
23 actually got more rods than you show there. It is
24 looking sideways, it sees a lot more view factor of
25 rods than it does in the other cases, more heat leak

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1 by radiation in the single light case.

2 DR. HOCHREITER: I, think the argument
3 would be, I mean, this sees nothing but a sea of rods.

4 CHAIRMAN WALLIS: Does it? It sees the
5 outside world looking straight down, and straight up,
6 and straight sideways. More southeast and west, it
7 sees space.

8 MR. SCHROCK: But his scale is misleading,
9 because the actual clearance between the rods is quite
10 small.

11 CHAIRMAN WALLIS: At least it would
12 explain the quenching.

13 DR. HOCHREITER: This is very true, we
14 have not done that, that is one of the things that we
15 have to do with this data. Because this actually goes
16 back to -- I don't think I wanted to do that.

17 CHAIRMAN WALLIS: I think if you look at
18 a lot of details you are going to find so many of
19 these anomalies.

20 DR. HOCHREITER: Yes, but this goes back
21 to, I think, what Dr. Schrock was saying, in terms of
22 the accuracy of the data. You have the accuracy of the
23 instrumentation, but you have a large uncertainty,
24 which is really imposed on the data.

25 And the radiation effects in here are one

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1 of them. This behavior is another.

2 CHAIRMAN WALLIS: Is this consistent at
3 different locations? I mean, if you went to 125
4 inches you might find the story was reversed.

5 DR. HOCHREITER: We only ran this one
6 test. We did not run other tests. We talked about
7 this and decided the most representative place for the
8 thermacouples for these steam temperature measurements
9 was more into the center of the subchannel because you
10 are, in effect, sampling a larger fraction.

11 CHAIRMAN WALLIS: If that is true of all
12 locations of the probe.

13 DR. HOCHREITER: I can't answer that.

14 MR. SCHROCK: You've got some apparent
15 recovery times that are almost unbelievable, I think.

16 DR. HOCHREITER: Well, the scale, though,
17 is -- look at the scale.

18 MR. SCHROCK: Yes.

19 DR. HOCHREITER: The sampling time is --

20 MR. SCHROCK: Have you calculated what the
21 recovery time ought to be?

22 CHAIRMAN WALLIS: The trouble is swept
23 away very quickly.

24 DR. HOCHREITER: Well, it is also followed
25 by a burst of superheated steam.

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1 CHAIRMAN WALLIS: But it is swept away,
2 right?

3 DR. HOCHREITER: Yes. Again, looking at
4 the drop -- I'm skipping ahead. This is the drop
5 data. Again, this is a 40 PSI test. This is below
6 the grid, and you have a mean of .025 inches.

7 DR. SANJOY: Why is there so much more
8 scatter here, than the other one?

9 DR. HOCHREITER: I don't know. And this
10 is above the grid. I think the grids are shaping the
11 drop distribution. Now, I did not think about drops
12 agglomerating downstream of a grid, okay?

13 I don't know if that is happening at all,
14 or not. But, clearly, when you are passing through a
15 grid, you are tending to, I think, to shape the
16 distribution.

17 CHAIRMAN WALLIS: That is a very big drop
18 on the right-hand tail, there.

19 DR. HOCHREITER: Over here?

20 CHAIRMAN WALLIS: Yes.

21 DR. HOCHREITER: It is probably too big.

22 DR. SANJOY: The camera didn't reject that
23 one?

24 DR. HOCHREITER: No, but it probably
25 should have.

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1 DR. SANJOY: Ten to the minus one inches,
2 one-tenth of an inch.

3 DR. HOCHREITER: This would still be
4 within the subchannel.

5 DR. SANJOY: I thought you said it was
6 .122 inches, your subchannel? I mean, your camera
7 would reject anything --

8 DR. HOCHREITER: So this is .01, this is
9 .1.

10 DR. SANJOY: Oh, okay.

11 CHAIRMAN WALLIS: But still a .05 inch
12 drop is pretty big.

13 DR. HOCHREITER: Fifty mils, yes.

14 DR. SANJOY: How many millimeters is that?

15 DR. HOCHREITER: A little more than one,
16 one and a quarter.

17 Now, one of the questions that was asked,
18 I think by Dr. Banerjee, what are we learning that is
19 new? This is the kind of data we got in FLECHT
20 SEASET, okay?

21 This was taken with high speed movie
22 cameras, which mostly failed, because we ripped the
23 film apart. You take 400 feet of this film at 2000
24 frames a second. This was a successful test, we got
25 101 drops.

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1 We then paid an employee to basically go
2 frame by frame, shining this on a wall, paying for the
3 changes in his eye prescription, as he would count the
4 drop sizes, and we would get distributions that are
5 something like this.

6 CHAIRMAN WALLIS: Not so different from
7 what you got now.

8 DR. HOCHREITER: No, it is really not that
9 different. Except now we get a lot more data for a
10 long period of time. This is only for six seconds,
11 okay?

12 DR. BAJOREK: Yes, but we are also going
13 to be able to get it above and below a grid for
14 comparable flows.

15 DR. HOCHREITER: I think that was a little
16 bit out of order. But here were, again, the axial
17 profiles for this test. Again, these are the grids.
18 I have the grid wall temperatures plotted here.

19 Here is one of the grid wall temperature.
20 So this is indicating that part of the grid is still
21 hot, part of the grid is wetted. Most of the time,
22 particularly at this time, when the quench runs at
23 this elevation, the grids have wetted.

24 And then you see the saw-toothed curve
25 that you get from the heat transfer performance of the

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1 grid.

2 CHAIRMAN WALLIS: Again, that is reversing
3 steam probe in certain locations, it is really cold.

4 DR. HOCHREITER: Yes, you have one
5 thermocouple quenched here, the other two are okay.
6 These are all together, together, together, this one
7 is quenched, this is at the end of the bundle, these
8 are all together.

9 DR. SANJOY: That is a snapshot it time,
10 right?

11 DR. HOCHREITER: That is correct.

12 DR. SANJOY: So one could be quenched.

13 CHAIRMAN WALLIS: So explaining this may
14 be harder than getting the data.

15 DR. HOCHREITER: Boy, I hope not. Now,
16 contrast that to an axial temperature distribution
17 from FLECHT SEASET. This is temperature versus
18 elevation, this is the behavior. And you don't really
19 see a spacer grid effect.

20 Now, the bundle was not instrumented
21 specifically to look for it. So it is really not too
22 surprising that you don't see it. But the spacer
23 grids that are in these tests are very simple grids.
24 Half the blockage that these grids are.

25 But you have to instrument it to find it,

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1 and that was not done, because it wasn't considered
2 that important.

3 CHAIRMAN WALLIS: The agency is going to
4 have to decide what kind of code assessment is
5 appropriate for this sort of data.

6 DR. HOCHREITER: Well, what would be very
7 interesting to me would be, if someone predicts these
8 tests very well, okay, with the codes. And then
9 predicts these tests very well.

10 DR. BAJOREK: And predicts FEBA Test 223
11 and 234, which were comparable tests, where they took
12 a grid in and out.

13 DR. HOCHREITER: With or without a center
14 grid. If you are going to predict this test, you are
15 going to have to have a spacer grid model in there,
16 that is going to somehow recognize this geometry.

17 And then to predict these tests, you are
18 going to have to have a spacer grid model in there
19 that somehow recognizes the FLECHT grid geometry.

20 DR. SANJOY: You'd have to do that for the
21 pressure drop, anyway, it is for some loss factor, or
22 something, right?

23 DR. HOCHREITER: Yes.

24 DR. SANJOY: So, I mean, it could be
25 related to that.

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1 CHAIRMAN WALLIS: Who is going to do this
2 work?

3 DR. HOCHREITER: Look at all those hands
4 flying.

5 DR. BAJOREK: We will be doing that, that
6 will be the staff.

7 CHAIRMAN WALLIS: Will I still be on the
8 ACRS when you finish?

9 DR. BAJOREK: How many more years are you
10 going to be doing this?

11 (Laughter.)

12 DR. HOCHREITER: Now, what Steve
13 indicated, currently what is planned to do in the
14 program, is do some interfacial drag experiments over
15 a range of flows and powers, and pressures.

16 This is to be used to aid in the model
17 development for advance plant audits that the Staff is
18 doing right now. We are presently installing a steam
19 boiler, actually Penn State is doing this for the
20 program, and then we will run steam cooling
21 experiments with and without droplet injection, to
22 create, basically, steady state dispersed flow of film
23 boiling tests, where we can decouple the problem from
24 the quench front.

25 The steam cooling tests will also give us

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1 a reference convective heat transfer.

2 CHAIRMAN WALLIS: It will be interesting
3 to see how steady your steady state is.

4 DR. HOCHREITER: Well, that is true, that
5 is true, because this is not going to be
6 straightforward.

7 Once these are done we will also be
8 looking at more severe reflood tests with variable
9 flow rates, higher temperatures. Again, the higher
10 temperatures are primarily to drive the grids to a
11 higher superheat temperature for a longer period of
12 time. Really, to address the point that Dr. Schrock
13 brought up.

14 And then there has also been talk about
15 doing top down film boiling experiences. But this
16 part of the plan is pretty much agreed upon.

17 CHAIRMAN WALLIS: What is a top down film
18 boiling experiment?

19 DR. HOCHREITER: These are tests where you
20 would actually bring the flow in from the top, and it
21 would simulate the reverse flow period at the end of
22 blowdown. It is still dispersed film flow boiling, but
23 you now have a reverse flow.

24 And this is typical of, certainly, most
25 four-loop plants, where you get a reverse flow as the

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1 pressure is coming down during blowdown. Now, we
2 can't go to really high pressures, we can only go up
3 to maybe 60, 70 feet, but at least we can capture the
4 effect.

5 DR. SANJOY: That is at fairly high
6 pressure, that happens?

7 DR. HOCHREITER: Well, it is typically 100
8 PSI, and we are not going to be able to get to 100
9 PSI.

10 DR. MOODY: You would do those on the same
11 geometry?

12 DR. HOCHREITER: Yes.

13 DR. RANSOM: Larry, what do you expect to
14 get out of the droplet injection test? You want to
15 get a steady state, is that the idea?

16 DR. HOCHREITER: Yes. And I specifically
17 want to get very detailed subchannel vapor temperature
18 measurements.

19 It is doubtful that we can move the camera
20 around during a test, because this -- it is very, very
21 delicate. You have to set this thing up very -- I'm
22 not going to say, set it up and fix it very hard.

23 And we've observed that as you heat the
24 facility up the bundle can twist. And, remember, you
25 are only looking through the gap. So the area, the

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1 viewing area can change.

2 So we've had to come up with an
3 arrangement, basically, lets the camera flow to move
4 with the housing as much as possible. But if we could
5 get somebody to give us some more money, we could put
6 more of these cameras in different positions.

7 But it is a very expensive system. When
8 we purchased it, it was approximately 70 to 100,000
9 dollars. But it has really given very good data.

10 DR. RANSOM: So you just have one window,
11 where you can take --

12 DR. HOCHREITER: No, we have windows -- we
13 have a total of six --

14 DR. RANSOM: You only have a camera at one
15 of the windows?

16 DR. HOCHREITER: We only have a camera at
17 one of the windows. Now, what we did in the reflood
18 test is we moved the camera, repeated the test
19 conditions, and we would do the same thing here.

20 So what you are relying on is the ability
21 to reproduce the conditions test to test, and then you
22 move the camera at different elevations.

23 MR. SCHROCK: Is your camera working full
24 frame? Is the image on the film occupying the whole
25 frame?

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1 DR. HOCHREITER: Yes. In fact you get two
2 subchannels, or two gaps. So you have -- it sees a
3 rod, and then sees a gap on either side of the rod.
4 And that is about as much as we can open it up, and
5 still get the resolution we want to get.

6 CHAIRMAN WALLIS: How many drops does it
7 see at a time, is it just one?

8 DR. HOCHREITER: No.

9 CHAIRMAN WALLIS: Several, none?

10 DR. HOCHREITER: I don't know what you
11 mean.

12 CHAIRMAN WALLIS: Well, you've got an
13 exposure, once you get an exposure and the thing zaps.

14 DR. HOCHREITER: It will take a scan. You
15 will basically put it in a thousand by a thousand
16 pixel plate, if you think about it as a plate. And
17 then it counts all the drops.

18 CHAIRMAN WALLIS: But isn't it like a
19 flash photograph in digital form?

20 DR. HOCHREITER: In a sense, yes.

21 CHAIRMAN WALLIS: But the short exposure,
22 and zap --

23 DR. HOCHREITER: Yes, very short, yes.

24 CHAIRMAN WALLIS: -- and then you get some
25 blobs here and there?

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1 DR. HOCHREITER: And you count them, and
2 you reject some, and you count them, and they go into
3 a bin, you've a bunch of bins that are set up. Then
4 you just keep counting, and you keep filling the bins.

5 CHAIRMAN WALLIS: The machine can count
6 them?

7 DR. HOCHREITER: Yes.

8 DR. BAJOREK: Larry, isn't it that it
9 takes two frames very close together --

10 DR. HOCHREITER: That is for velocity.

11 DR. BAJOREK: Yes, to get the velocity,
12 but it also gauges whether the droplet is coming at
13 you, because based on the blurb between the two
14 photographs, or whether you have one that is moving
15 with the stream, that is how it is screeding those
16 out?

17 DR. HOCHREITER: Well, but that is for
18 velocity mode. When you do exactly what Steve said,
19 for getting the droplet velocity, we've gotten some
20 velocity measurements, but we found that there was a
21 problem.

22 We were not getting accurate drop size
23 measurements when we put the camera into the velocity
24 mode. So we opted for getting accurate drop sizes.
25 When we looked at the droplet velocity data that we

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1 were getting, it was actually all over the place.

2 CHAIRMAN WALLIS: All over the place?

3 DR. HOCHREITER: Yes, there was no rhyme
4 or reason.

5 CHAIRMAN WALLIS: Velocity is an important
6 variable in the code.

7 DR. HOCHREITER: I understand that, but it
8 was a cloud. This may have been because we were
9 downstream of a grid.

10 DR. SANJOY: You weren't getting enough
11 separation?

12 DR. HOCHREITER: No, I think we were just
13 getting a wide range of velocities.

14 CHAIRMAN WALLIS: That is that true? rue.

15 DR. HOCHREITER: A very wide range of
16 velocities.

17 DR. SANJOY: Well, it would be turbulent.

18 DR. HOCHREITER: It could be. But I think
19 downstream of grid accented that problem, okay? And
20 then we had this, again, problem with the software.

21 CHAIRMAN WALLIS: It was telling you
22 something very important.

23 DR. HOCHREITER: I agree. And one of the
24 things that we are going to do is fix the system so we
25 can get better velocity data, as well as drop size

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1 data.

2 MR. SCHROCK: You get kind of density
3 waves, you have wetting on the thing that sweeps the
4 batch of water off, and --

5 DR. HOCHREITER: Yes.

6 MR. SCHROCK: -- high density two phase
7 mixture goes sweeping downstream. You see that go by
8 rather left to chance as to what you are
9 photographing.

10 Are you getting -- and then the drops in
11 this time period between those sweeps probably
12 smaller, and moving at lower velocity.

13 DR. HOCHREITER: That could be.

14 MR. SCHROCK: But I think that the
15 pulsating nature of it is probably important.

16 DR. HOCHREITER: Well, like I said --

17 MR. SCHROCK: -- heat transfer
18 characteristics.

19 DR. HOCHREITER: Well, it depends on the
20 frequency. But the flow is unsteady. I mean, you
21 can, you set up steady boundary conditions, but the
22 flow is still unsteady, okay? And that is not going to
23 change.

24 Some of the problems we had was that we
25 would get oscillations that were superimposed on,

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1 again, this unsteady flow. And they were really due
2 to the facility. So we had to, basically, figure out
3 why. And we threw a lot of data away because of that.

4 Now, what I'm hoping here, when we do
5 these droplet injection tests, we have to be careful
6 because I don't want flashing to occur in these
7 injectors. But I also don't want condensation to
8 occur, such as the pressure takes a dive.

9 So these are going to be pretty delicate
10 to set up. You would like the water to come out of
11 these injectors saturated at the system pressure.

12 DR. MOODY: You made quite an argument
13 about that, and I thought liquid jets breaking up into
14 the range of droplet size. You also said some
15 intriguing things about this camera you used.

16 It takes pictures on a regular
17 photographic film?

18 DR. HOCHREITER: It is a digital camera.

19 DR. MOODY: It is a digital camera, I
20 mean, you are getting --

21 DR. HOCHREITER: This stuff gets stored in
22 the software, and you are probably asking for more
23 detail than I can answer.

24 DR. MOODY: It was just a curiosity point.

25 So you get a really fine resolution?

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1 DR. HOCHREITER: It does.

2 MR. SCHROCK: It gives you a very clear
3 picture, 1000 by 1000.

4 DR. HOCHREITER: And we calibrated this,
5 like I said, on a milling machine, and we had, I think
6 they are called rectals, they are like pieces of glass
7 that have known images machined in them, of different
8 sizes, so we could get a calibration curve for the
9 camera system.

10 DR. MOODY: Which one threw the film
11 apart? You mentioned something about --

12 DR. HOCHREITER: Those were high speed
13 movies that we took 20 some odd years ago, as part of
14 the FLECHT SEASET program.

15 DR. MOODY: Okay.

16 DR. HOCHREITER: And you could only put
17 400 foot roll of film into these. These are high cam
18 cameras, and most of the time you basically destroyed
19 the film.

20 DR. SANJOY: That is not always true.

21 DR. HOCHREITER: Most of the times we
22 always destroyed the films, because we didn't do a
23 very good job.

24 CHAIRMAN WALLIS: Because it is going so
25 fast, it is the mechanical forces on the film.

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1 DR. HOCHREITER: It rips it apart.

2 MR. SCHROCK: Well, that is the design.
3 I mean, the film is a tape that rotates the prism. I
4 mean, it is like a belt drive.

5 DR. HOCHREITER: Well --

6 DR. SANJOY: If you get it up too fast it
7 rips.

8 CHAIRMAN WALLIS: So you are going to go
9 through your conclusions now?

10 DR. HOCHREITER: Yes, sorry. We think we
11 have constructed a facility which is flexible. It is
12 low pressure. We've added seven new features to the
13 facility. We've tried to take advantage of,
14 basically, the lessons learned in previous reflood and
15 other two-phased flow experiments, and enhanced the
16 instrumentation in the facility, and the data that we
17 can generate from the facility.

18 And the tests have been basically designed
19 to provide answers for code model development, as
20 opposed to address licensing questions.

21 The FLECHT SEASET program was really
22 designed to address licensing issues. So you would
23 run tests up to 2,200 degrees fahrenheit and, of
24 course, you destroyed your heater rods doing that.

25 We are not doing that in this test

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1 program. We are specifically designing experiments to
2 give us data that can be used to either verify or
3 develop component models which would go into an
4 advanced code, like TRAC-M.

5 And we have been working hand in hand with
6 the NRC. In fact, the conditions for our experiments
7 basically come from the NRC. So the idea here is
8 basically to improve the models in the NRC codes, and
9 then the NRC codes will be used for audit
10 calculations.

11 And I think there really is a need for
12 this, because these days, again, the vendors are
13 pushing the envelope in terms of allowable peak
14 cladding temperatures, and kilowatts per foot.

15 CHAIRMAN WALLIS: What is the measurement
16 of improvement, reflood models?

17 DR. HOCHREITER: If they can match this
18 data and previous data.

19 CHAIRMAN WALLIS: They measure this in
20 terms of less uncertainty, or less scatter, or some
21 measure of deviation within the experiment?

22 DR. HOCHREITER: Yes, less uncertainty.

23 DR. SANJOY: The answer to the question is
24 that you are getting better droplet data, that is one
25 of the main things, compared to previous experiments?

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1 DR. HOCHREITER: Better steam temperature
2 data, better void fraction data. Well, consider what
3 is there. Better mass flow and mass balance data.

4 CHAIRMAN WALLIS: It may make you more
5 confused about the theory, so the theory could,
6 eventually, end up being --

7 DR. HOCHREITER: Well, clearly, I don't
8 know if we've done it a disservice, or what, but these
9 have an effect, and most codes don't model it.

10 MR. SCHROCK: Well, I think there is no
11 question that you've proven that those things have an
12 effect. I worry about the fact that the data are
13 still being collected from the viewpoint of being able
14 to get some kind of time averaged information about
15 drop size and distribution.

16 Whereas what you see in the movie that you
17 showed us, is a pulsating flow. And the effect of the
18 pulsation is not being addressed.

19 DR. HOCHREITER: Not trivial.

20 MR. SCHROCK: And I think it is important.

21 DR. HOCHREITER: These flows are unsteady.
22 I mean, like I said, you run the tests as being steady
23 state, or quasi-steady state. But the flow itself is
24 unsteady. That is not going to change.

25 DR. KRESS: It doesn't look like it is

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1 high, near your --

2 DR. HOCHREITER: It is steadier as you go
3 up the bundle.

4 DR. KRESS: Yes.

5 DR. HOCHREITER: The most unsteady portion
6 is going to be right at the quench front, I would
7 agree with that.

8 DR. KRESS: But that would be important to
9 determine the drops.

10 DR. HOCHREITER: Because it determines the
11 liquid fractions carried up.

12 DR. MOODY: The spacers are terribly
13 significant, you mentioned. And as far as something
14 you said, several times, that the droplets really
15 break up as they go through the spacers. What is your
16 current thinking of the mechanisms, causes of breakup?

17 DR. HOCHREITER: Well, there is separate
18 effects data that we looked at. And, again, this is
19 roughly 20 years ago, because we put in droplet
20 breakup models in the COBRA/TF.

21 We did this as part of the FLECHT SEASET
22 program. And we ran little bench tests at Carnegie
23 Mellon, where we took a blow torch and heated up a
24 grid strap, and we dropped drops on it, and measured
25 the chattering of the drops, and we measured the drop

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1 sizes.

2 And we ran tests for different thicknesses
3 of the strap, different diameters of the drops. And
4 we developed, basically, a correlation for this. And
5 it was in terms like Dr. Ransom said, the Webber
6 number, droplet Webber number.

7 And that model went in the COBRA/TF, and
8 that was used as part of the FLECHT SEASET program
9 when we looked at evaluating the effect of full
10 blockages, and spacer grids. But these were simple
11 grids, because there was no data on this type of a
12 geometry.

13 DR. MOODY: That is primarily a velocity
14 effect then, isn't it, that causes a breakup?

15 DR. HOCHREITER: If you get droplet Webber
16 numbers, I think, greater than 80, you would start to
17 shatter drops. And this was consistent with
18 measurements that people had taken where they would
19 drop drops on a heated surface, and then photograph
20 what would happen.

21 If the droplet Webber number was smaller
22 than that, you would basically bounce, the surface
23 tension could hold the drop together. But when you
24 had a sufficient inertia, the drop had sufficient
25 inertia, you would hit the surface, the drop would

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1 shatter into a population of small droplets.

2 DR. MOODY: Thank you.

3 MR. SCHROCK: I would like to ask you to
4 calculate HA over MC for your thermacouples, and tell
5 us what it is, some time.

6 DR. HOCHREITER: Okay.

7 DR. RANSOM: I have a couple of quick
8 questions. What are your plans for preserving this
9 data for future use? And the reason I ask that
10 question is a lot of the reactor safety data is
11 starting to disappear because of the way it was
12 stored, and preserved in the past.

13 The second one, is this gravity-fed?

14 DR. HOCHREITER: No, these are forced flow
15 tests.

16 DR. RANSOM: Forced flow with a positive
17 displacement pump, or --

18 DR. HOCHREITER: Actually what we did was
19 we had a pressurized tank that we would inject the
20 flow, using a pressurized tank.

21 DR. RANSOM: But how do you maintain a
22 constant flow rate?

23 DR. HOCHREITER: We have a flow control
24 valve.

25 DR. SANJOY: But that brings up the point

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1 of --

2 DR. HOCHREITER: Let me go back and answer
3 his first question. In the contract we have to
4 supply, to the NRC, this data on CDs, which they will
5 put into the data bank.

6 DR. SANJOY: But that brings up the
7 question that many situations you have, essentially,
8 gravity fed systems, where you do get strong
9 oscillations.

10 DR. HOCHREITER: Right.

11 DR. SANJOY: And a lot of the phenomena
12 change with the oscillations, because you -- there is
13 ligaments of liquid behind --

14 DR. HOCHREITER: It goes all the way up.

15 DR. SANJOY: -- and then it goes whoosh,
16 out. The entrainment completely changes with the
17 oscillation.

18 DR. RANSOM: Well, I notice you have a
19 downcomer, well you have a downcomer in the diagram
20 you have in this report. I was wondering if you plan
21 to use that? Yes, short an external downcomer?

22 DR. HOCHREITER: Not at the present time.

23 DR. KRESS: These oscillations that you
24 see always tend to delay the time in which you have
25 the peak clad, and actually lower it. So if you had

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1 correlations that didn't have those in it, you would
2 still be somewhat conservative, I think, in terms of
3 regulatory space.

4 So I don't know how important it is to
5 actually get those kinds of oscillations.

6 DR. HOCHREITER: I've seen mixed bag on
7 these. The oscillations can help you, the
8 oscillations can hurt you.

9 CHAIRMAN WALLIS: I can see some
10 sophisticated vendor coming in and saying, we've
11 designed our system to have oscillations at much lower
12 peak clad temperature.

13 MR. SCHROCK: Therefore we are
14 conservative, and therefore okay.

15 CHAIRMAN WALLIS: Maybe it is time to go
16 back to Steve? Thank you, Larry, that was very
17 interesting, indeed.

18 DR. SANJOY: We should really visit some
19 of -- why didn't we visit the facility?

20 DR. HOCHREITER: More than welcome to
21 come. I would not come on a home football weekend
22 unless you want to stay here and then drive up.

23 DR. BAJOREK: Well, originally that was
24 our plan, to have this meeting up at Penn State. But
25 the problem there was budgetary. The Staff wasn't

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1 able to continue the program at the end of the year.

2 There is a continuing resolution now that
3 is preventing us from continuing some of these
4 programs and initiating new ones.

5 MR. BOEHNERT: And it is also impacting
6 our travel budget, too.

7 MR. SCHROCK: Well, is it planned to do it
8 in the future?

9 DR. BAJOREK: I hope so, yes. I think it
10 is a lot better to see the facility, rather than
11 looking at the movie, and the confusion, is that a
12 light, or is that a rod? You know, seeing it first-
13 hand.

14 And also, you know, I thought it was very
15 informative to look at the output from the laser
16 camera, and the output from an optical camera at the
17 same time.

18 And what was very interesting is that the
19 laser camera seemed to be picking up a lot more. And
20 you can watch that, and when somebody says, the
21 carryover for action is about 75 percent, yes, you
22 almost see that in the movies itself, even though you
23 look at a meter, or Ralph can help us out with that
24 and show us, yes, you are still sitting up there well
25 above anybody's estimate of T-min, while you are

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1 seeing all of these droplets.

2 CHAIRMAN WALLIS: Now, if you could
3 measure velocity, as well as population, you could
4 then calculate flow rate, and compare it with the flow
5 rate, and --

6 DR. BAJOREK: Right, we are getting
7 carryover, you are getting the carryover from that,
8 you know what you are putting in, you are separating
9 it, so you are getting a steam flow rate coming out.

10 Now, if you get to the droplet velocities
11 above the grid, okay, we are going to get the relative
12 velocities, and that is going to help us get at the
13 interfacial heat transfer part of this.

14 DR. HOCHREITER: We are going to try to
15 get that software fixed. But we've discovered this
16 during the testing. And the vendor said, yes, you
17 should have these upgrades, which only cost umpteen
18 dollars, which of course we did not have, and we have
19 to send back a camera, and the computer system, which
20 meant we would have to stop testing. So we opted to
21 test.

22 DR. SANJOY: Were Those Oxford lasers?

23 DR. HOCHREITER: Yes, you are familiar
24 with the same spiel?

25 DR. KRESS: As I remember the calculation,

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1 those droplets reached terminal velocity very fast.
2 So that if you know the steam velocity, and the
3 droplet size distribution, you could make a pretty
4 good estimate of the distribution of velocities.

5 And that may be a mechanism for
6 agglomeration. They have different velocities, the
7 droplets did.

8 DR. BAJOREK: I think the question a
9 couple of hours ago, what have I learned here today?
10 First, there is still a lot of work to do.

11 Most of this data that Larry was talking
12 about were obtained June, July, and August. And there
13 hasn't been a tremendous opportunity to compare these
14 to previous results, compare it to one test to the
15 other, and a lot of it has been sorting out are these
16 tests valid, I mean, are they good, of the type of
17 quality that we expect to get?

18 And our conclusion right now is yes. We
19 are seeing a lot of interesting things in the data
20 that we don't have an explanation for, at this point.
21 But that is where kind of the fun begins.

22 Now, I think in terms of things that we've
23 talked about today, that we need to incorporate, and
24 work into this overall project, the first one I would
25 characterize as bias and uncertainty.

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1 I think the questions that we've had a few
2 times now, if we change a reflood model, how do we
3 know we are getting any better? I think we owe it to
4 you to define, in much better terms, what models we
5 are focusing our attention on, and as we start to
6 tinker with some of these knobs in the code, are we
7 having an effect?

8 And I think the only way of doing that is
9 taking the models we have now, obtaining a bias and
10 uncertainty from some preliminary assessments, making
11 the changes, and hopefully you are going in the right
12 direction, and then bias is becoming smaller, and the
13 uncertainty likewise dropping.

14 I think we --

15 DR. MOODY: Can you make copies of this
16 for us?

17 DR. BAJOREK: I guess. We think it is
18 very clear that the spacer grids, their design
19 differences, and their effect on the transient, are
20 key. This is really what is dominating the vapor
21 temperatures, the clad temperatures.

22 And in terms of model development, my
23 suggestion is that this be given one of the top
24 priorities. TRAC-M does not have spacer grid models
25 at this time. And it is clear that we've got to take

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1 this data, the egg crate data from FLECHT, where you
2 can see a little bit more of the dips downstream of
3 the rods.

4 So 318.05, I think, was too high a
5 temperature to see some of those. But that in FEBA it
6 tried to develop spacer grid models that will help
7 give us this change in droplet size, as we go up the
8 bundle.

9 CHAIRMAN WALLIS: What do the vendors have
10 for spacer grid models?

11 DR. BAJOREK: The Westinghouse model, I'm
12 just trying, I want to make sure I'm not giving away,
13 this is an open meeting, and I don't want to give away
14 proprietary models.

15 CHAIRMAN WALLIS: But they do have spacer
16 grid models?

17 DR. BAJOREK: Yes. I put that into the
18 COBRA TRAC. It was based on the Carnegie Mellon data,
19 it does take a look at the droplet size coming to the
20 grid, and how it would break up as it passes the grid.

21 But we need to get that capability in
22 TRAC-M. Now, one of the things that I also was
23 thinking about, as we went through the presentation
24 today, we are getting a lot of very good information
25 on the dispersed droplet film boiling type of regime,

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1 what the grids are doing to things.

2 We are going to get better information
3 down near the quench front, and that is where these
4 more detailed DP cells are going to help us quite a
5 bit.

6 We've got to think and be fairly clever,
7 as we are going through additional tests, and
8 evaluating these, on how we can identify inverted
9 annular flow, and what is the flow, excuse me, the
10 heat flux split near the quench front.

11 That has been a nagging problem in some of
12 the reflood models. Because what we need, in order to
13 get our model correct at the PCT location, we have to
14 know how quickly we eat up the vapor very close to the
15 quench front.

16 MR. SCHROCK: What does IVA mean?

17 DR. BAJOREK: Inverted annular.

18 MR. SCHROCK: And q-double-prime split,
19 you are talking about --

20 DR. BAJOREK: Heat flux.

21 MR. SCHROCK: -- heat flux to liquid, and
22 heat flux to vapor?

23 DR. BAJOREK: Yes.

24 CHAIRMAN WALLIS: There was very little
25 that Larry said that helped me with the inverted

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1 annular, he is talking about droplets and all that,
2 that has nothing to do with inverted annular,
3 supposedly the liquid is in the middle, and the film
4 is on the wall.

5 This is only a very short length of the --

6 DR. HOCHREITER: Yes, but we ran tests at
7 six inches a second.

8 CHAIRMAN WALLIS: Right.

9 DR. HOCHREITER: So we do have that data.

10 CHAIRMAN WALLIS: Okay.

11 DR. BAJOREK: So that data is in there.

12 We need to think more in terms of how we --

13 CHAIRMAN WALLIS: You didn't show us that
14 today?

15 DR. HOCHREITER: No.

16 CHAIRMAN WALLIS: Why?

17 DR. HOCHREITER: Why didn't I show you
18 that?

19 CHAIRMAN WALLIS: I'm assuming because it
20 wasn't any good.

21 DR. HOCHREITER: No, that is the wrong
22 assumption.

23 DR. KRESS: It was too good to be true.

24 DR. BAJOREK: Actually they are very good
25 in that you get the inverted annular flow regime, and

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1 it is persistent over a very long period of time.
2 FLECHT 317-01, which is the one a lot of people use,
3 get crunched in the 20 seconds.

4 But I think in your test, Larry, it stayed
5 inverted annular for a couple hundred seconds?

6 DR. HOCHREITER: That is correct.

7 DR. BAJOREK: So they aren't as fun as the
8 dispersed droplet because with all that water, those
9 probes quench right away. And we haven't gotten to
10 the point of trying to evaluate the DP cells, and what
11 there might be some type of a void distribution.

12 Just, you know, to elaborate on a couple
13 of points. When, and we owe you this, I mean, we have
14 to develop this. When I say bias and uncertainty, one
15 of the things that I want to recognize is that
16 previous reflood experiments had the idea that, hey,
17 if you knew VIN, your flooding rate, you would
18 essentially be interested in what would be the heat
19 flux from the rod, because in your code assessment you
20 would look at the predicted versus measured.

21 And in some cases you see vendors say,
22 well, my bias is in terms of a delta PCT. And I think
23 as Larry mentioned, if you do it that way, you really
24 cover over all the processes. You may get the PC
25 right, but you haven't a clue whether it was because

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1 there were compensating errors through your
2 calculation.

3 As we go through the development of what
4 we are going to call these mechanistic reflood models,
5 what we need to do is to break these into as many
6 individual components as we can, look at the models we
7 have now, look at the ones we intend to develop, and
8 try to determine bias and uncertainties for things
9 like components of the heat flux below the quench
10 front; components of the film boiling heat flux up
11 near the PCT location, how much was convective, how
12 much was due to a convected enhancement with the
13 droplets, if there is any drop to wall impaction try
14 to characterize that.

15 I think a very, very important aspect, as
16 Larry pointed out, is what is the entrainment rate at
17 the quench front, and how much of that, eventually,
18 gets carried over out of the bundle.

19 Very small deltas in how you predict that
20 can have a very drastic impact on your steam
21 temperatures higher up in the bundle. And I think as
22 we saw from the spacer grids, we need to be able to
23 characterize what is the variation of droplet size, as
24 it approaches and passes through a grid.

25 CHAIRMAN WALLIS: It seems to me that you

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1 need a full time analyst at NRC doing all this?

2 DR. BAJOREK: In fact we do have one
3 person right now, his mission is to start putting
4 these interim reflood models into the code. But it is
5 a full time job just putting those in.

6 And over the course of, probably, the next
7 year characterizing these in setting things up,
8 hopefully, in an automated way that we can get some
9 quantified measures.

10 CHAIRMAN WALLIS: So you are short of
11 hoping that the mechanistic model is going to be a
12 fair representation of what is going on. And that is
13 something we don't really know yet.

14 There may be mechanisms which we don't
15 know how to model yet, that should be in the code. It
16 is not just building on someone's fantasy of what
17 happened there 20 years ago. There is a lot more
18 information now. So you may have to change your
19 thinking about some of the models.

20 DR. BAJOREK: I think that is why we need
21 to look at the data, and develop some new fantasies on
22 what we see in there.

23 And I think, as I mentioned, we think in
24 terms of what we've seen, the tests that spacer grid
25 models have to be at the higher priority. I think, as

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1 we mentioned earlier, what do we do now if a vendor,
2 or somebody comes in with a different type of model,
3 which has different mixing veins, different blockage.

4 This may be reason, in the future, where
5 we might want to start working in some other types of
6 small scale separate effects test, to where we might
7 be able to more easily vary things like the mixing
8 vein geometry blockage, and things like that, that I
9 mentioned, the inverted annular flow split.

10 MR. SCHROCK: What is the subscript R,
11 there, radiation?

12 DR. BAJOREK: Radiation.

13 MR. SCHROCK: Radiation to what, drops, or
14 radiation to --

15 DR. BAJOREK: To the film. At least in my
16 simplistic way of looking at it, right now, heat flux
17 is split between something that goes to the liquid --

18 MR. SCHROCK: I see, it is just for that
19 term, there, you are talking about. Yes, inverted
20 annular.

21 DR. BAJOREK: Radiation, perhaps some
22 contact of the waves, and the rest going into the
23 vapor phase. But one, how do you characterize that,
24 and what is the split.

25 DR. SANJOY: You don't think the flow

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1 oscillations should be taken into account during
2 gravity reflood?

3 DR. BAJOREK: Right now I'm not convinced
4 that the oscillations that we saw in those movies are
5 necessarily something that is an artifact of what
6 would happen if you had a constant reflood, versus
7 what is going on in that facility, where you know that
8 for those early tests, the controller was trying to
9 keep up, and it was pulsating at the inlet. Larry?

10 DR. HOCHREITER: Well, I think for the
11 movie we showed, I don't think there was strong
12 pulsations.

13 DR. SANJOY: No, I'm talking about the
14 real reactor situation, the code has to handle a
15 situation where everybody understands that there are
16 large oscillations. And everything you said here
17 could be of much less important than those
18 oscillations.

19 So how are we going to account for that?

20 DR. HOCHREITER: It is not clear that the
21 reactor does oscillate, it is not clear to me. There
22 have been some large scale tests, and you don't see a
23 lot of oscillations.

24 DR. BAJOREK: I thought they did see them
25 in CCTF, Larry?

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1 DR. HOCHREITER: For selected tests, not
2 every test.

3 DR. SANJOY: Well, maybe there should have
4 been an assessment of that problem, then. I thought
5 that there were oscillations, but maybe there are some
6 that --

7 DR. BAJOREK: I think there were in some
8 of those CCTF experiments.

9 DR. HOCHREITER: In some, not in all.

10 DR. BAJOREK: And I think in terms of how
11 we would approach that, first try to get models that
12 work good under very well established boundary
13 conditions. And I think we are getting out of this an
14 easy power shape, you know the inlet conditions.

15 If we get models that work good there, try
16 them out on CCTF, and SETF, other tests where you --
17 ACHILLES would be another good one, tests with a
18 downcomer, where you can see if they are doing
19 adequately for gravity reflood.

20 DR. SANJOY: Did they see oscillations in
21 the WINFRED experiments? We will have to look at
22 those. They were done, what, about ten years ago?

23 DR. BAJOREK: About that. I guess I'm not
24 real familiar with that, except for the test that was
25 the international standard problem, where they got a

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1 large burst of the non-condensibles.

2 DR. SANJOY: I know that early '80s,
3 anyway, there was quite a bit of concern about these
4 oscillations, and the modeling of them. And the
5 reason was that they strongly affected entrainment.

6 And to first order the main thing that
7 matters is how much is entrained, it is the balance
8 between what is carried out, and what you put in. And
9 that depends, really, it determines how fast the front
10 goes.

11 Now, since that time the problem seems to
12 have sort of vanished, I don't know why. Whether that
13 was just neglect, or there was a reason to say it
14 wasn't important.

15 But I think it would be worthwhile, at
16 least, having an assessment as to whether it is
17 important or not. Because it could have an effect on
18 the test program, also.

19 I agree with you that first you should be
20 able to handle the steady state. But the phenomena
21 during oscillations could be quite different, because
22 you tend to leave a lot of liquid up there, where it
23 gets caught in the vapor, and it gets carried out.

24 So the entrainment correlations,
25 everything change. Maybe not, but --

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1 DR. BAJOREK: Well, let me see if I can
2 try to find out what --

3 DR. SANJOY: What is known bout it.

4 DR. BAJOREK: -- why the problem has gone
5 away. I thought I heard, at one point, that the heat
6 transfer was improved when you had the gravity
7 reflood, and the oscillations. So maybe that --

8 DR. SANJOY: But entrainment got worse.
9 At least I remember in some cases.

10 CHAIRMAN WALLIS: So you will have to
11 respond to this oscillation issue, it is not going to
12 go away.

13 DR. BAJOREK: That is all I have.

14 CHAIRMAN WALLIS: I think it has been very
15 good to get results from this experiment. We have
16 been looking forward to getting some results, for some
17 time.

18 Also hearing that the Staff has ideas
19 about how to use them. And I believe what is going to
20 happen here is that there won't be any letter from the
21 ACRS, or anything like that. But I will give a report
22 to the full Committee at the December meeting.

23 So I would need input, then, from you
24 folks by the end of November. Is that a reasonable
25 thing, go back and write up comments which I can then

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1 -- your comments will actually be handed out to the
2 full Committee. They are for publication, which I'm
3 sure they will be.

4 MR. SCHROCK: Would you ask him to give us
5 copies?

6 CHAIRMAN WALLIS: Yes, I would like copies
7 of your --

8 Are there final remarks that members of
9 the subcommittee would like to make at this time,
10 before we recess?

11 DR. MOODY: I was just going to mention,
12 on page --

13 CHAIRMAN WALLIS: I think you need to
14 bring your mike up.

15 DR. MOODY: This is in the PSU ARL report,
16 rod bundle heat transfer, that we all got a copy of.
17 I just want to say, I think you are a little too
18 restrictive on page 29, when you make a statement in
19 the middle of the page.

20 From this point forward temperatures must
21 be in absolute units. I don't think you have to say
22 that. I think you can take whatever units. Do you
23 recall anything like that? Okay, you have some heat
24 transfer equations, conduction and convection, getting
25 a temperature. Probably one of your students.

1 DR. HOCHREITER: No, we are having an
2 endless battle on units, temps, and so forth.

3 DR. MOODY: Well, I think the thought was
4 you had to use absolute, and you don't have to.

5 DR. HOCHREITER: No, I agree.

6 CHAIRMAN WALLIS: Radiation expression?

7 DR. MOODY: There wasn't a radiation
8 expression in there.

9 DR. HOCHREITER: Let us check that out.

10 CHAIRMAN WALLIS: There is a lot to be
11 said for having agreement on units. When you come to
12 a massive code, which -- we have a great deal of
13 difficulty with vendors who come here with mixed
14 units, and you can never be clear on what units are
15 actually encoded in the code itself, or whether or not
16 they have mixed them up, and whether the conversion
17 factors are all right.

18 If you have a consistent set of units all
19 the way through it is much more reassuring. You will
20 get the NASA problem with Mars.

21 Anyone else?

22 DR. RANSOM: One thing I didn't hear
23 anything about today, but was the single phase
24 pressure drop analysis that they have in the report,
25 which seemed to bring up a number of issues that I

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1 think ought to be resolved, in a way.

2 Why it doesn't approximate the velocity
3 situation very closely, and I know at one point they
4 talk about frictional pressure drop, but don't mention
5 entrance effects, which clearly would have an effect
6 of increasing the frictional pressure drop.

7 But I guess my conclusions, in general, I
8 sure would like to see a little more analysis, you
9 know, to go along with this data. I'm not -- I know
10 you've said that is what you plan, and I hope you will
11 do it.

12 DR. HOCHREITER: We've actually done some
13 more, particularly on the pressure drop. We had a
14 student that just is completing his thesis, where he
15 set up a CFD model. They modeled a fraction of the
16 model, plus the spacer. And he actually got very good
17 agreement with the measured pressure drop data.

18 He is now comparing it to some of the
19 single phase transfer data that we got from the
20 facility. He did find a pressure drop relationship
21 in, I think, Tong and Wiseman's book, that gave a
22 better agreement for the bare rod bundle pressure drop
23 than what we were seeing when we would go to the Moody
24 chart.

25 So I think -- I haven't had a chance to go

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1 back and look at that particular correlation, but I
2 know it gives higher friction factors. And this is
3 really what we are seeing when we reduce the data.

4 And I do think it is due to exactly what
5 you said, which is entrance region downstream of the
6 spacer grid. Because the upstream tap is going to be
7 in that region.

8 CHAIRMAN WALLIS: Ready to recess? All
9 right, we will now recess until 8:30 tomorrow morning.
10 Thank you all very much.

11 (Whereupon, at 5:10 p.m. the above-
12 entitled matter was recessed.)

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CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on
Reactor Safeguards Thermal-
Hydraulic Subcommittee

Docket Number: N/A

Location: Rockville, Maryland

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

15 Rebecca Davis
Rebecca Davis
Official Reporter
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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
THERMAL-HYDRAULIC PHENOMENA SUBCOMMITTEE MEETING:
NRC-RES ROD BUNDLE HEAT TRANSFER TEST PROGRAM/
FRAMATOME ANP-RICHLAND S-RELAP5 LB LOCA CODE
NOVEMBER 12-14, 2002
ROCKVILLE, MARYLAND

DRAFT PRESENTATION SCHEDULE

Contact: P. Boehnert (301/415-8065) ("pab2@nrc.gov")

<u>TOPIC</u>	<u>PRESENTER</u>	<u>TIME</u>
November 12, 2002		
I. <u>Introduction</u>	G. Wallis, Chairman	1:00 p.m.
II. <u>NRC-RES Rod Bundle Heat Transfer Test Program - Status</u>		
A. Introduction	S. Bajorek, RES	1:10 p.m.
B. Rod Bundle Heat Transfer Program Status	L. Hochreiter, Penn. State U.	1:30 p.m.
	BREAK	3:00 p.m.
C. Concluding Remarks	S. Bajorek	5:00 p.m.
III. <u>Recess</u>		5:15 p.m.

November 13, 2002

<u>TOPIC</u>	<u>PRESENTER</u>	<u>TIME</u>
IV. <u>Reconvene Open</u>	G. Wallis, Chairman	8:30 a.m.
V. <u>Framatome-ANP Richland</u> <u>S-RELAP5 Realistic LB</u> <u>LOCA Code Closed</u>		
A. Introduction	Mr. Holm	8:40 a.m.
B. Momentum Equation <ul style="list-style-type: none"> ● Straight Pipe ● Bends/Elbows ● Area Changes ● Multi-Junctions ● Cross-Flow ● 2-D Model ● Cold Leg/Downcomer Connection ● Downcomer/Lower Plenum Connection ● Pump ● Added Mass 	Mr. Carlson	
	LUNCH	12:00 p.m.
B. Momentum Equation (Cont.) Closed		1:00 p.m.
C. General RELAP-5 Questions Open	Mr. Martin	2:45 p.m.
D. Selection of Node Size Open	Mr. Martin	
E. Critical Flow Open	Mr. O'Dell	
F. Statistical Analyses Open/Closed (as necessary)	Mr. O'Dell	
VI. Recess		6:00 p.m.

November 14, 2002

<u>TOPIC</u>	<u>PRESENTER</u>	<u>TIME</u>
VII. <u>Reconvene Open</u>	G. Wallis, Chairman	8:30 a.m.
VIII. <u>Framatome-ANP Richland S-RELAP5 Realistic LB-LOCA Code - Summary of Methodology Closed</u>		
A. Requirements & Capabilities		
B. Changes to RELAP5 to Create S-RELAP5		
C. Assessment & Ranging of Parameters		
D. Sensitivity & Uncertainty Analyses		
	LUNCH	12:00 p.m.
IX. <u>NRR Presentation - Safety Evaluation Report for S-RELAP5 Realistic LB LOCA Code</u>		1:00 p.m.
A. Code Review Results	R. Landry, NRR	
B. Uncertainty Analysis Methodology	Y. Orechwa, NRR	
C. Staff Parametric Studies	S. Colpo, NRR	
D. SER Conclusions	R. Landry, NRR	
X. <u>Framatome Response to NRR Presentations Open/Closed (as necessary)</u>		4:00 p.m.
XI. <u>Subcommittee Caucus Open</u>		4:45 p.m.
1. Comments on Meeting Presentations		
2. Follow-on Actions		
3. Decision to Bring Review to ACRS/ Instructions to Presenters		
XII. Adjourn		5:00 p.m.

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Penn State/US NRC Rod Bundle Test Facility and Reflood Heat Transfer Program (RBHT)

L.E. Hochreiter

Mechanical and Nuclear Engineering Department

The Pennsylvania State University

(814)-865-6198

lehnuc@engr.psu.edu



Program Background

- RBHT Contract was initiated in November 1997 with the Nuclear Regulatory Commission Office of Research.
- Is a joint program between the College of Engineering and the Applied Research Laboratory (ARL).
- Principal Investigators
 - Dr. L.E. Hochreiter
 - Dr. F-B. Cheung
 - Dr. T.F. Lin



Background

- Loss of Coolant Accident (LOCA) is the most limiting design basis accident for PWRs.
- LOCA can limit the peak kW/ft values as well as the allowable power shapes for the plant operation.
- LOCA is a 'calculated' accident, the performance of the safety systems in mitigating the accident depends on the computer models used.



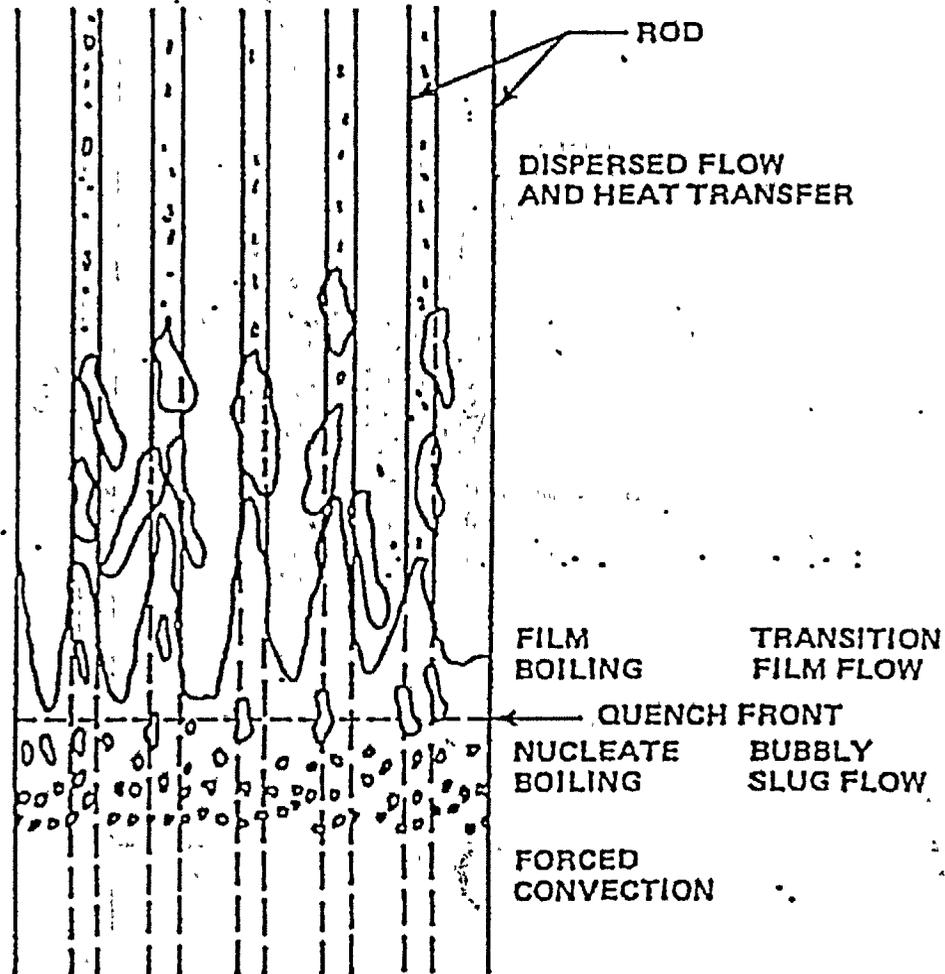
Peak Cladding Temperature (PCT) is calculated to occur during the Reflood period of the transient.

- Heat transfer rates are the smallest.
- Several different heat transfer mechanisms control the heat transfer.
- Flow is highly dispersed and non-equilibrium with superheated steam and liquid droplets.
- Quench front progresses up the fuel rods as the core quenches.
- Reflood is also the most limiting LOCA period with Best-Estimate codes.

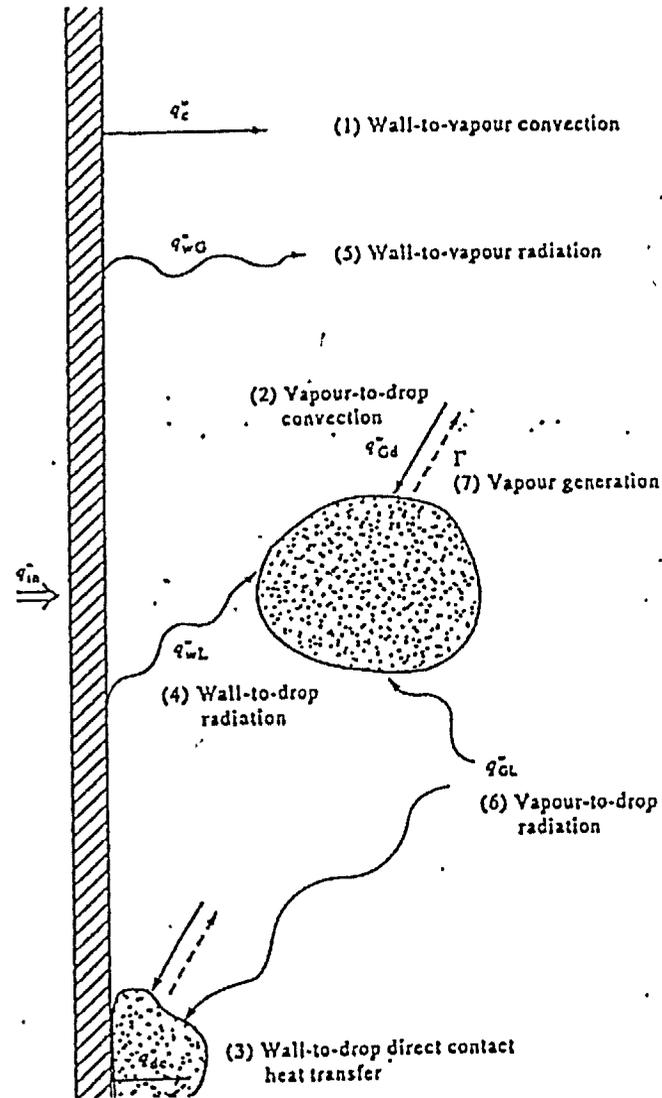
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Flow Regimes During Reflood



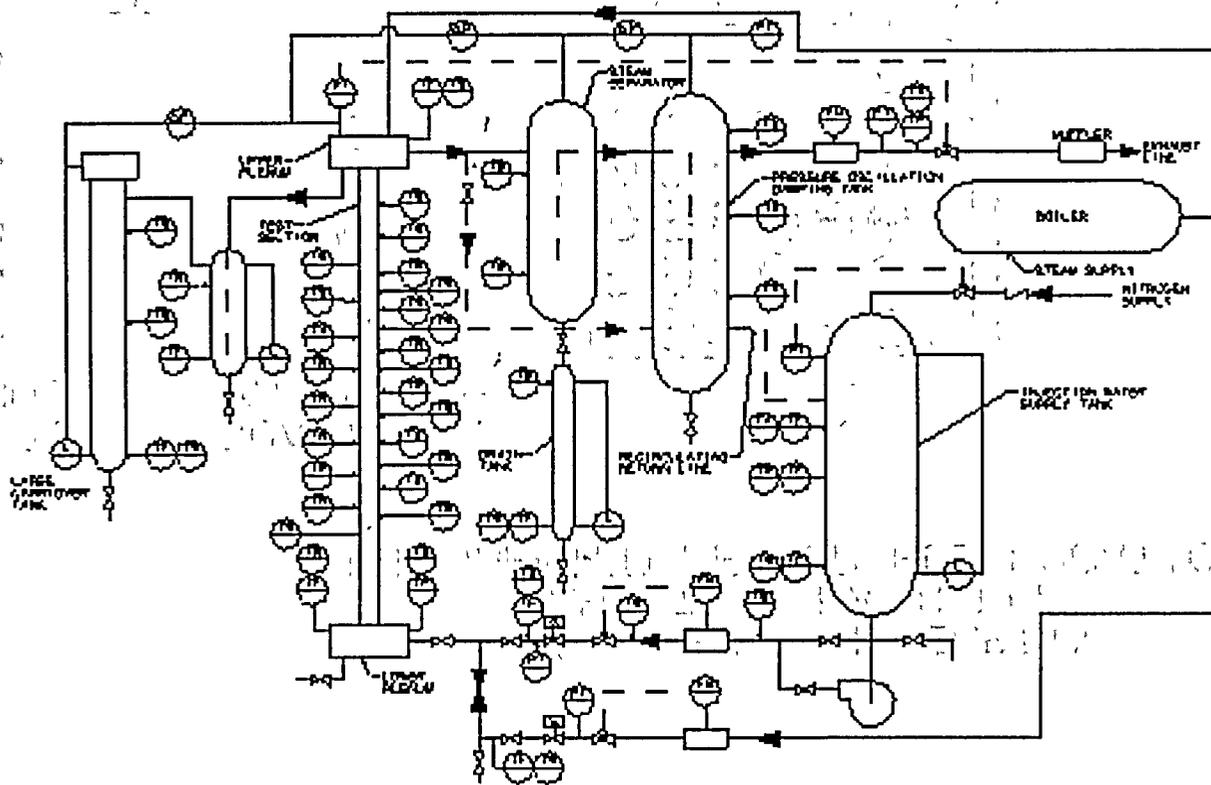
Reflood Heat Transfer Phenomena





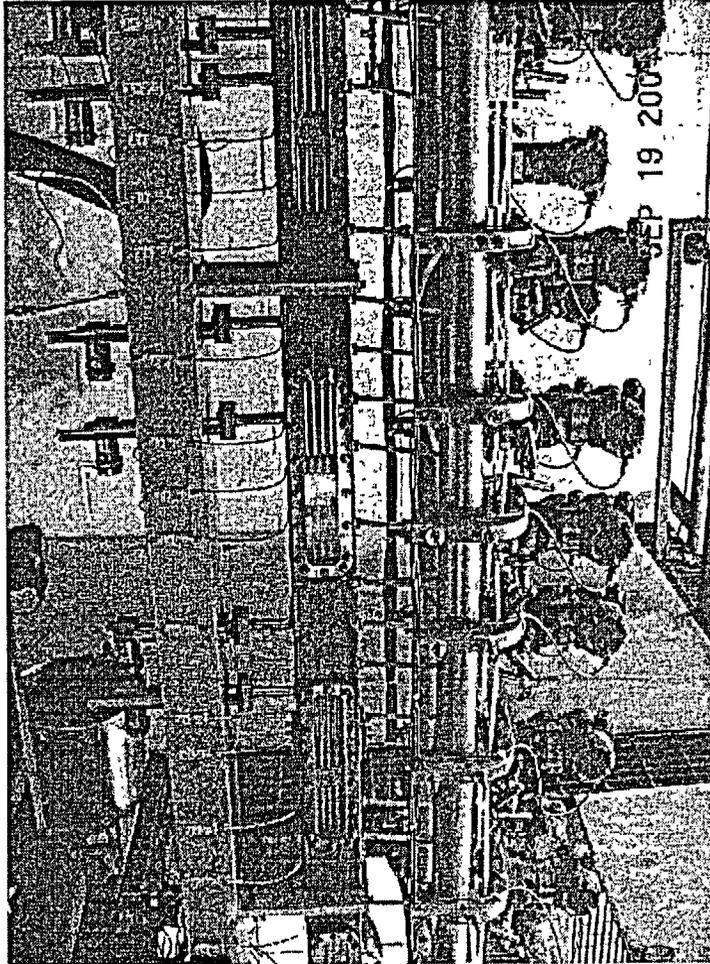
System Schematic with Instrumentation

PENN STATE UNIVERSITY
RSH-T-TEST FACILITY
INSTRUMENTATION
SCHEMATIC



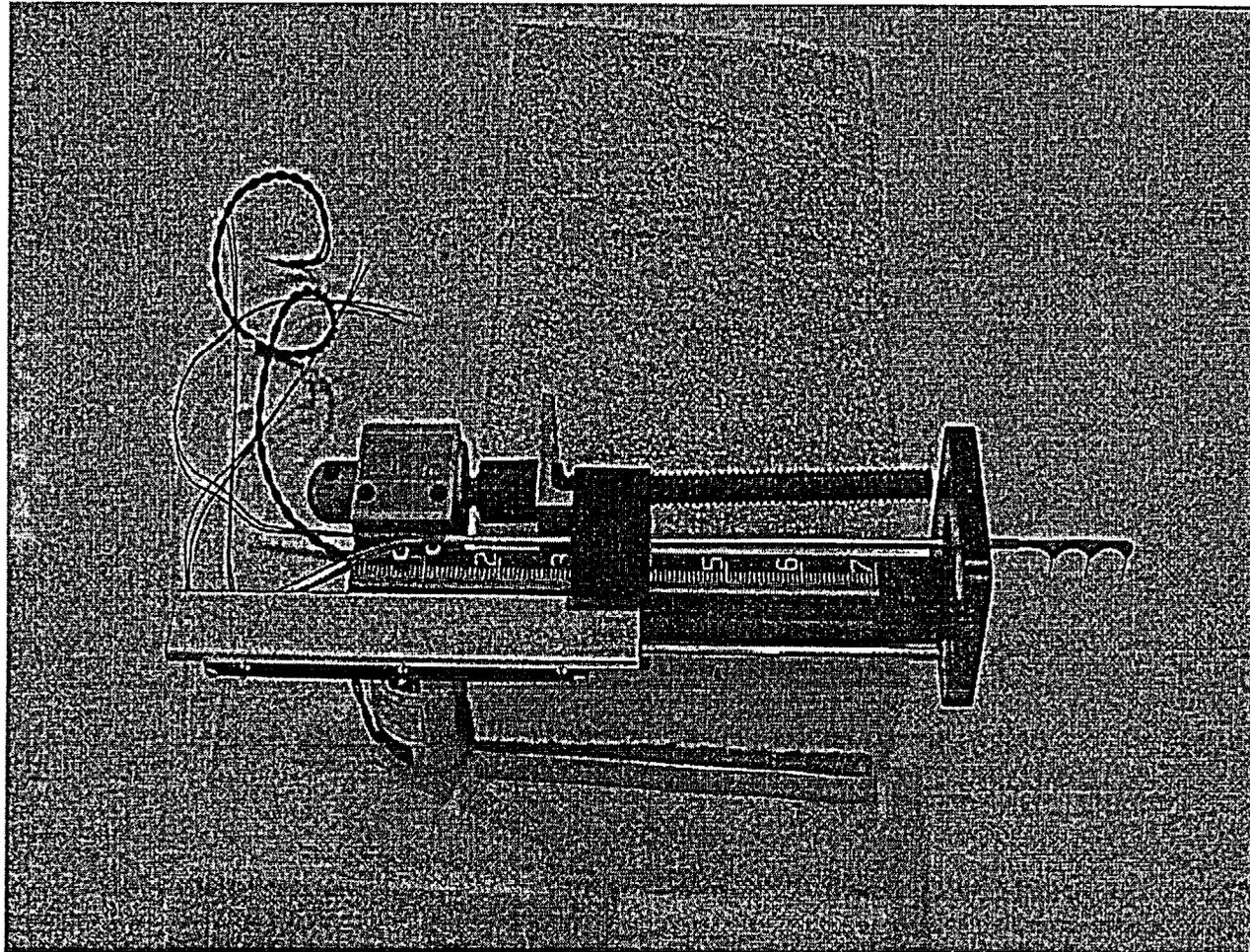


RBHT



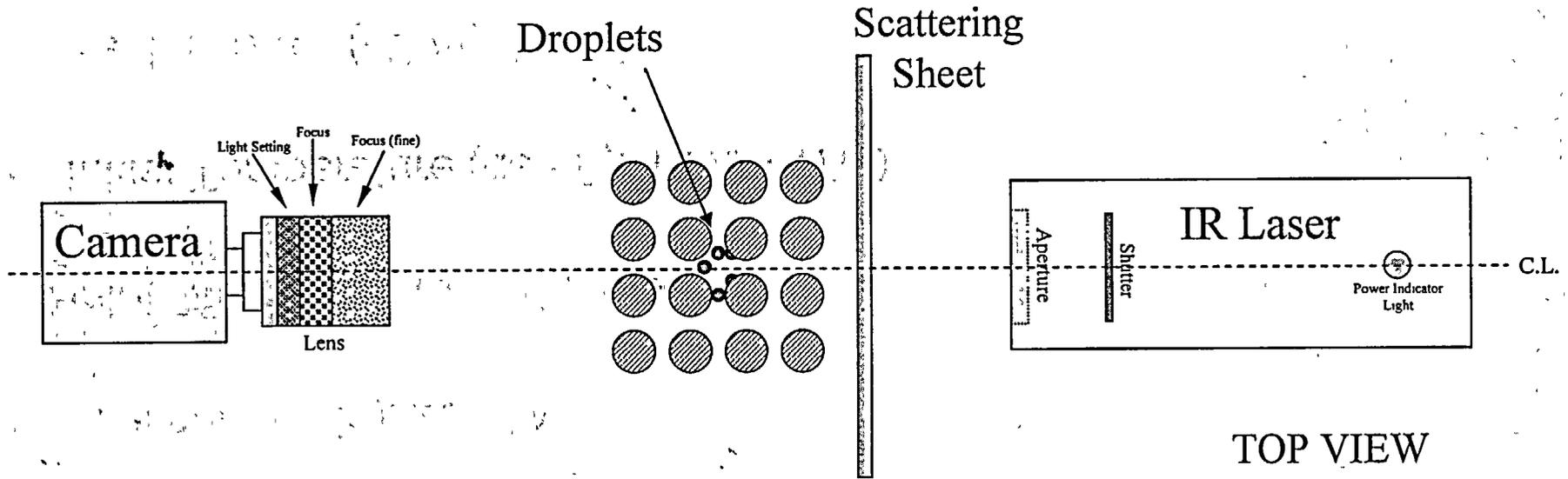
Flow Housing
Instrumentation

RBHT – Steam Probe Rake





Laser Illuminated Digital Imaging System Setup



TOP VIEW
NOT TO SCALE



RBHT Matrix

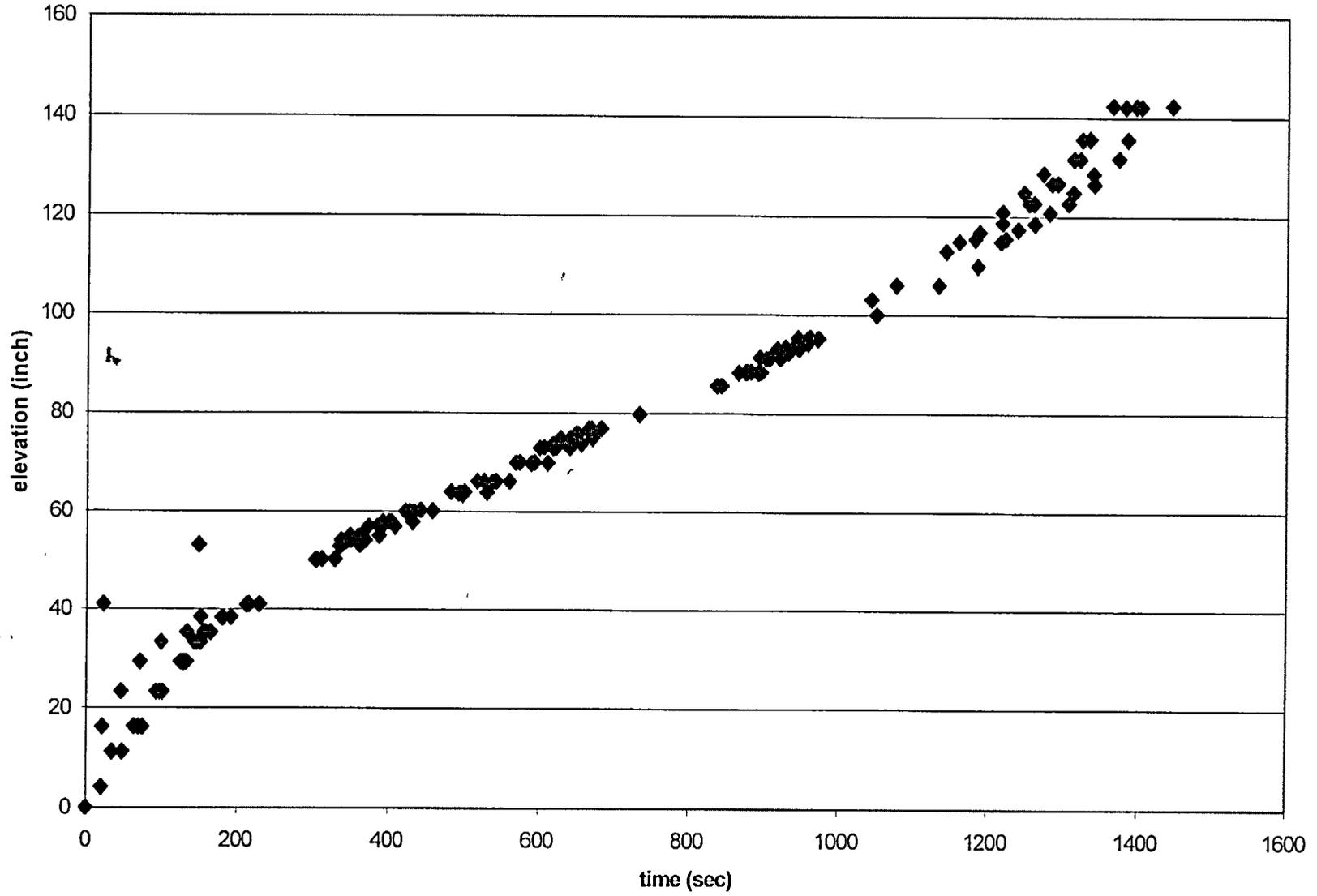
- Flooding Rate (inch/s): 0.54 - 10
- Pressure (psia): 20 - 60
- Inlet Subcooling (deg F): 20 - 150
- Initial Temperature (deg F): 1200 - 1700
- Peak Power* (kW/ft): 0.4 - 0.7

* *Power was held constant, did not decay.*

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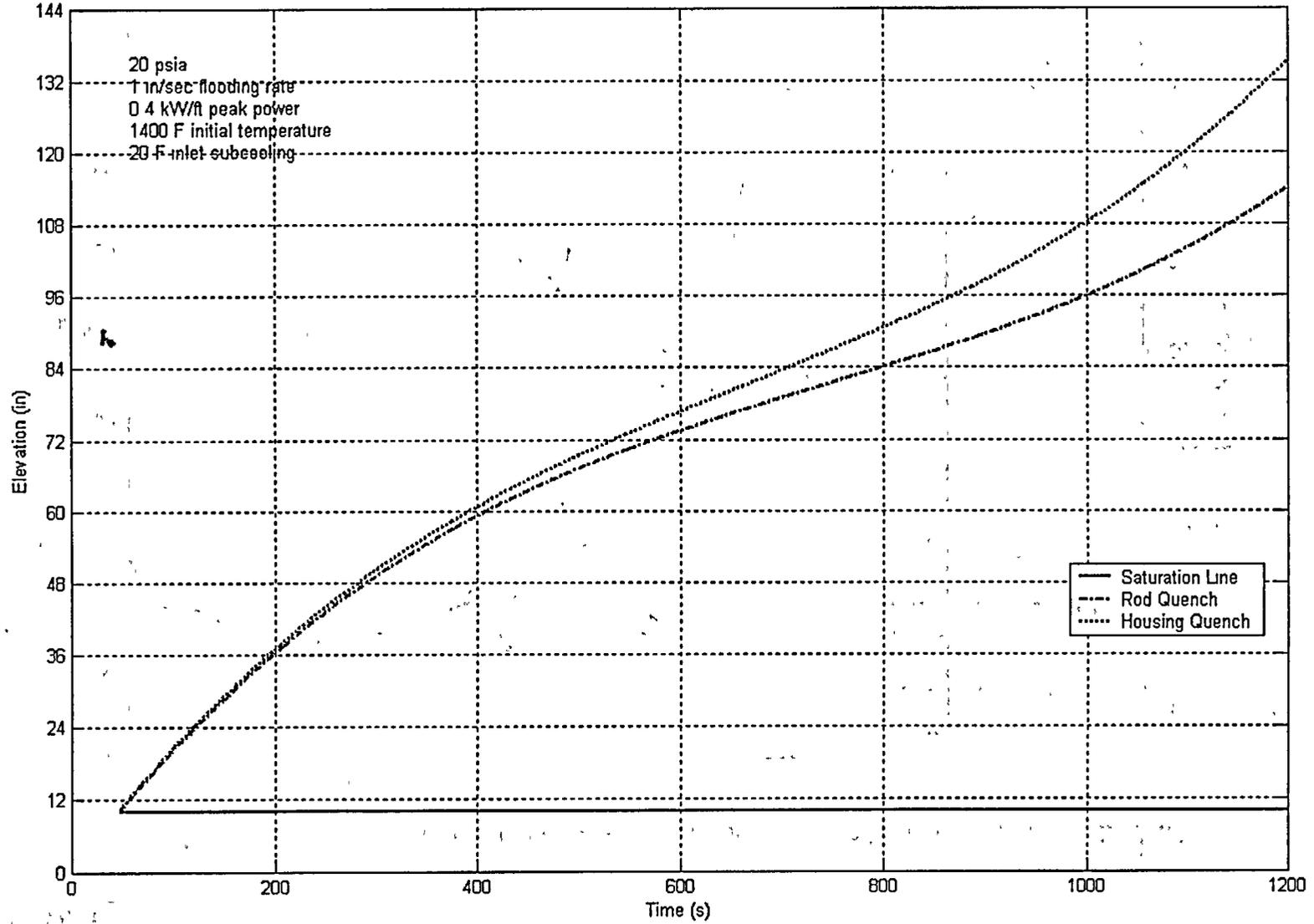
- Spacer grids can have a significant effect on the heat transfer due to
 - convective enhancement
 - grid quenching
 - entrained droplet break-up



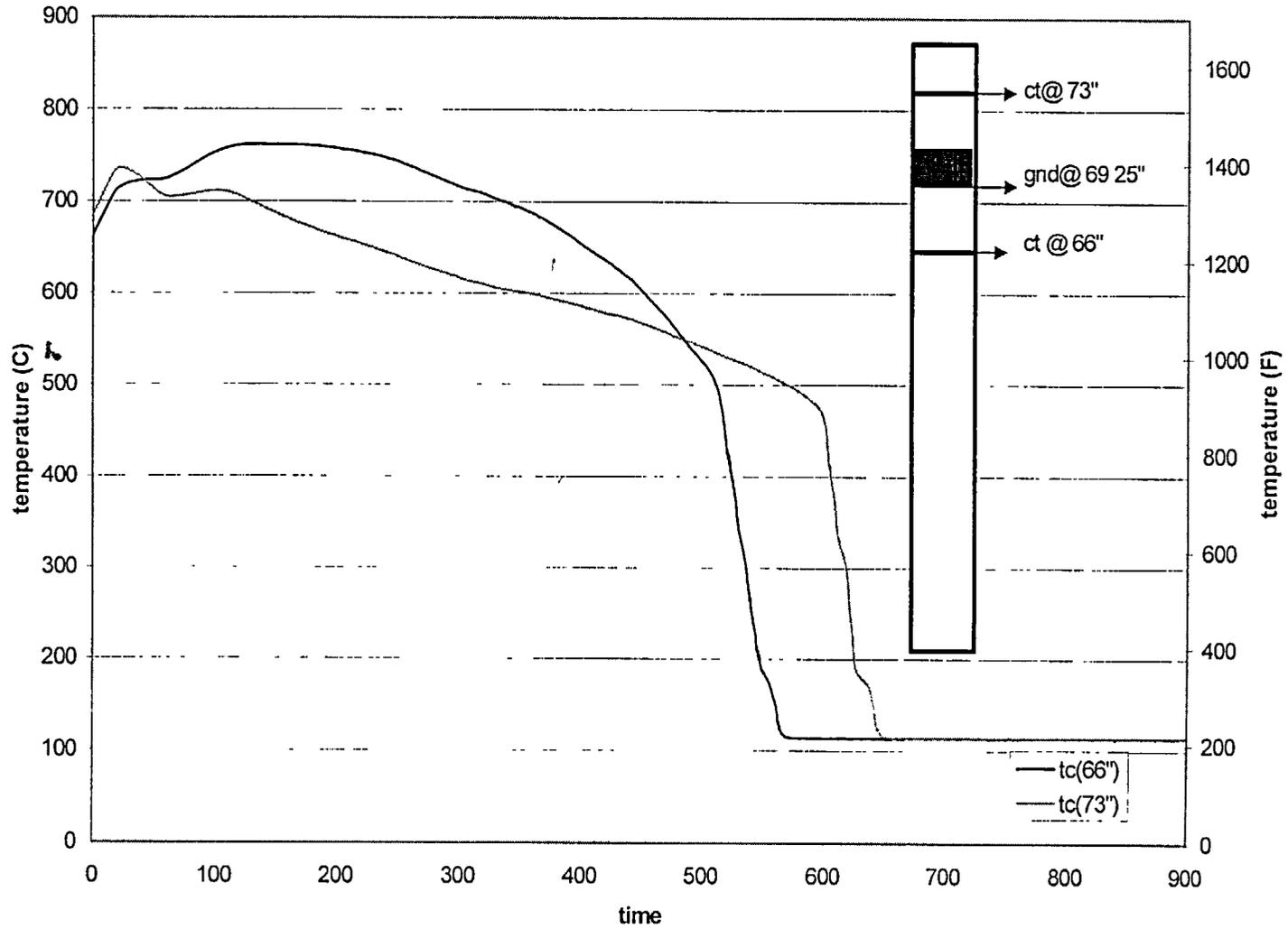
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Fronts and Saturation Line Locations - Exp 1096

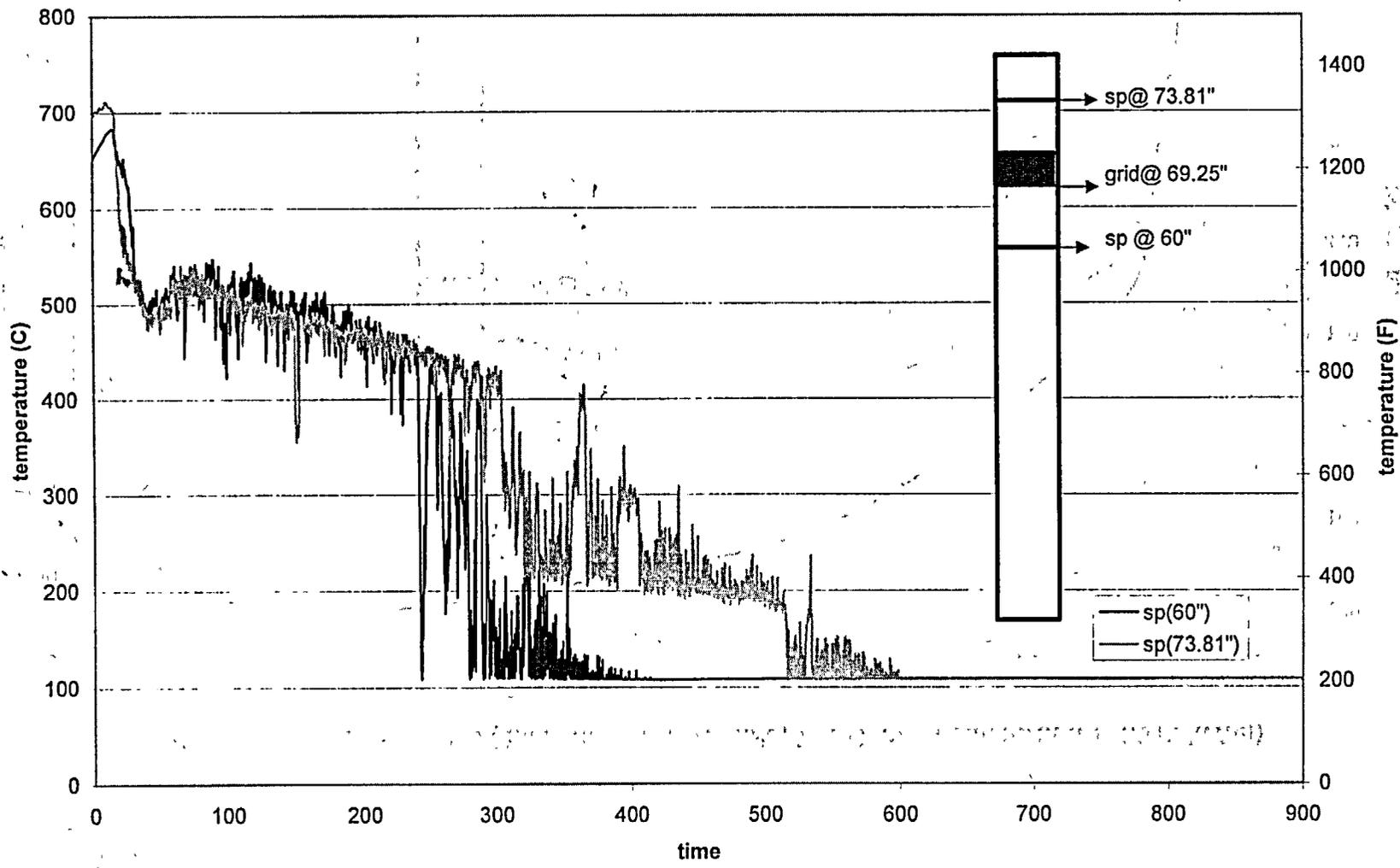


Clad Temperature, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)

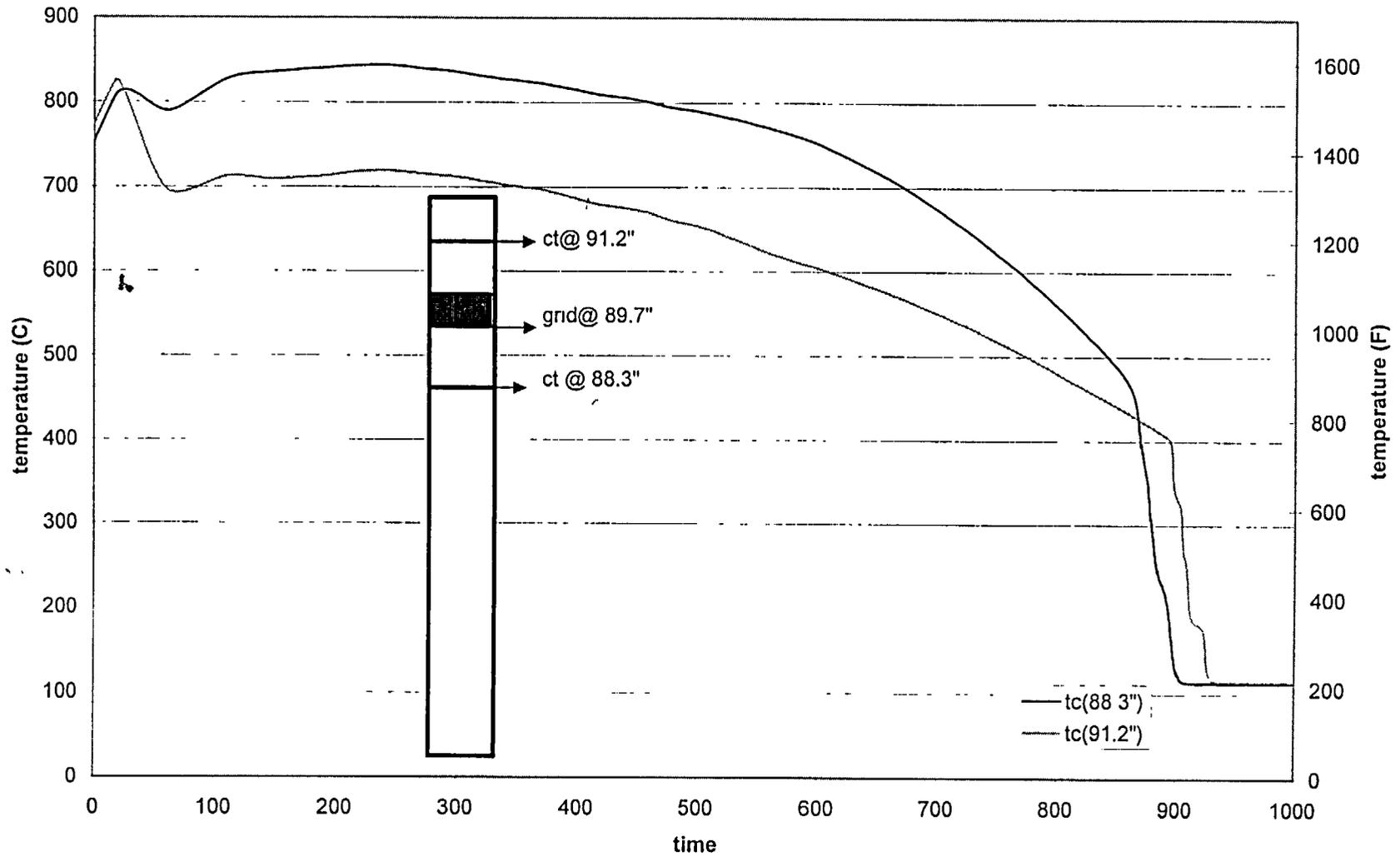




Steam Temp, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)



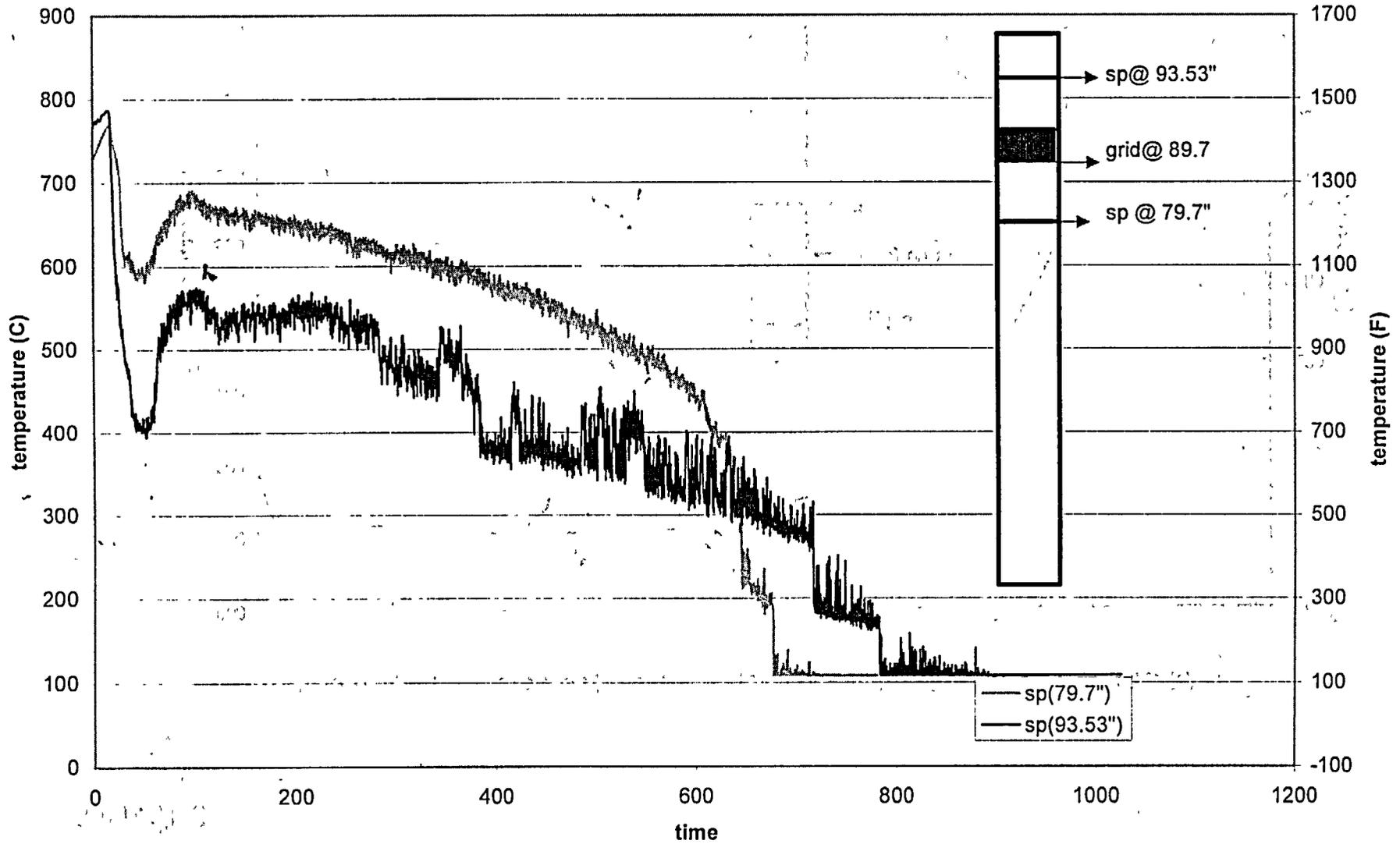
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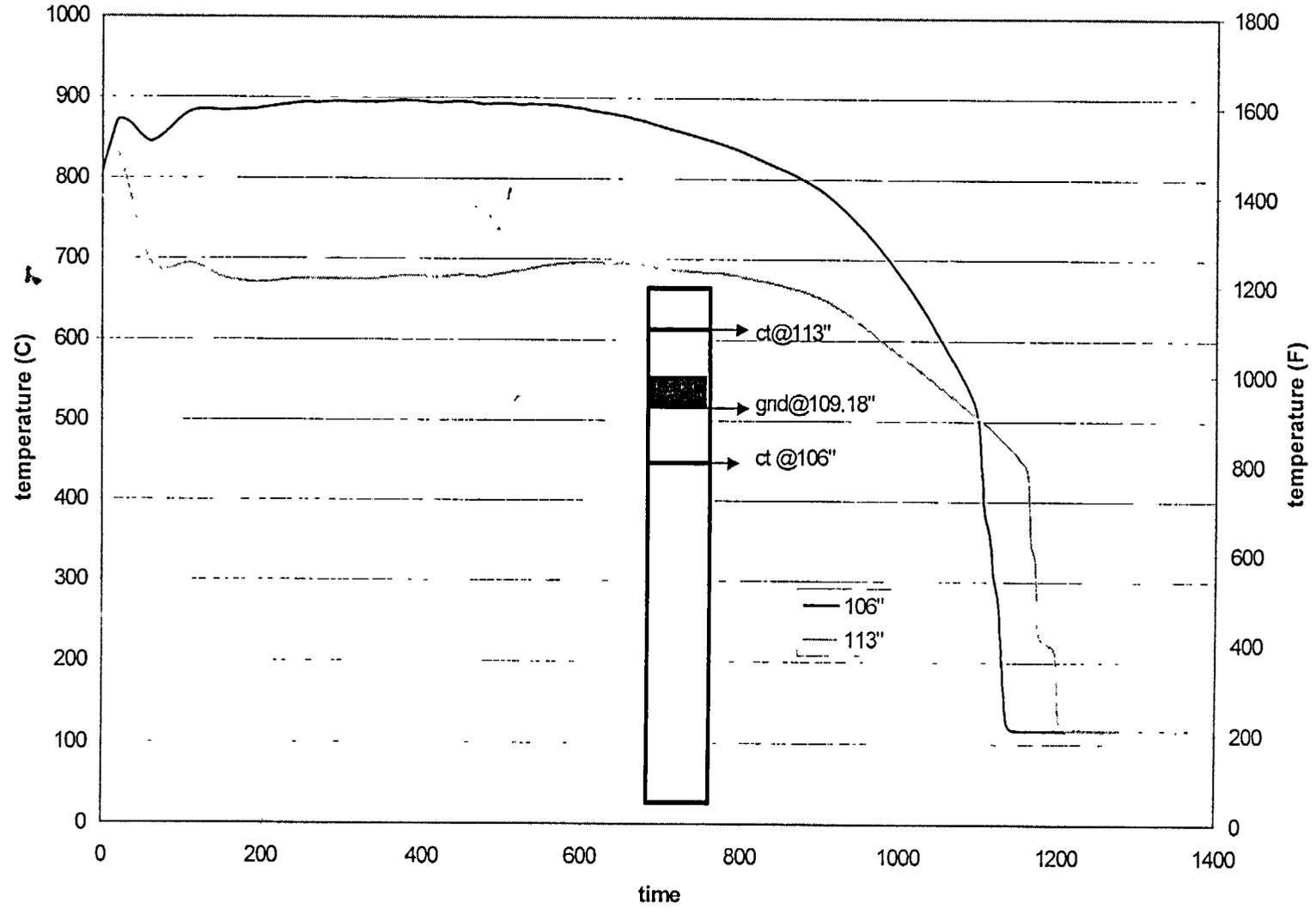


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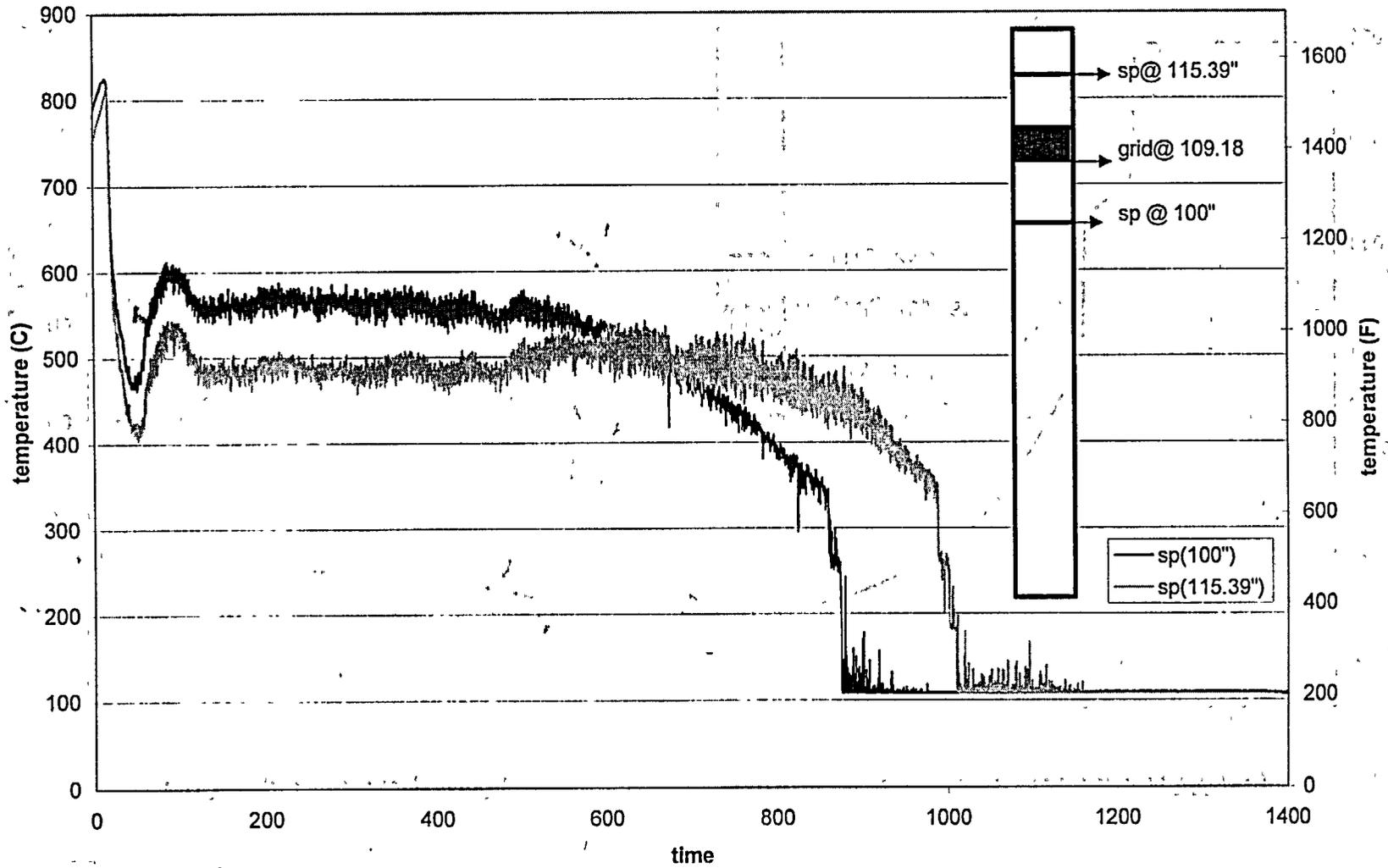
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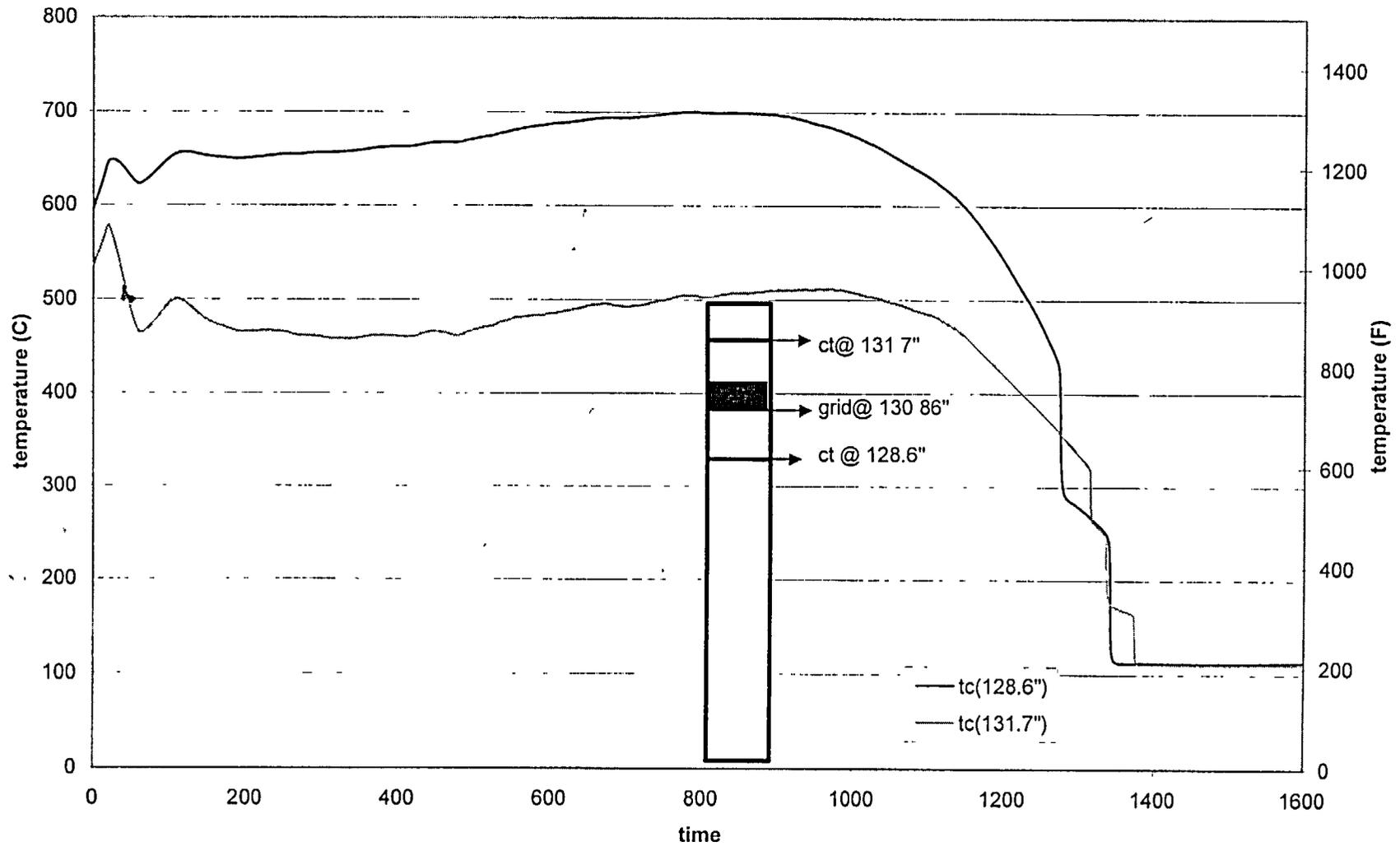
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Steam Temp, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)



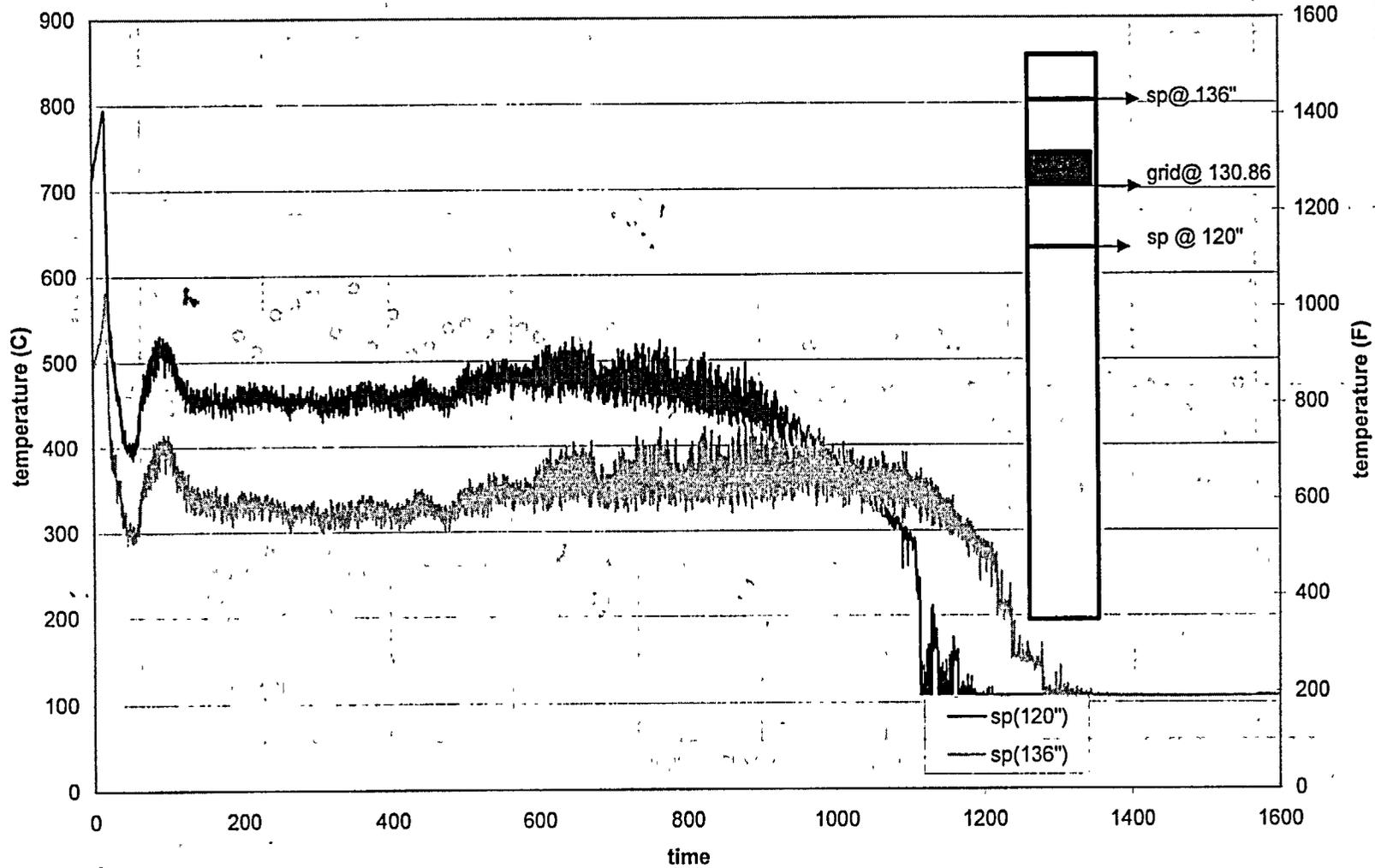
Clad Temperature, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)



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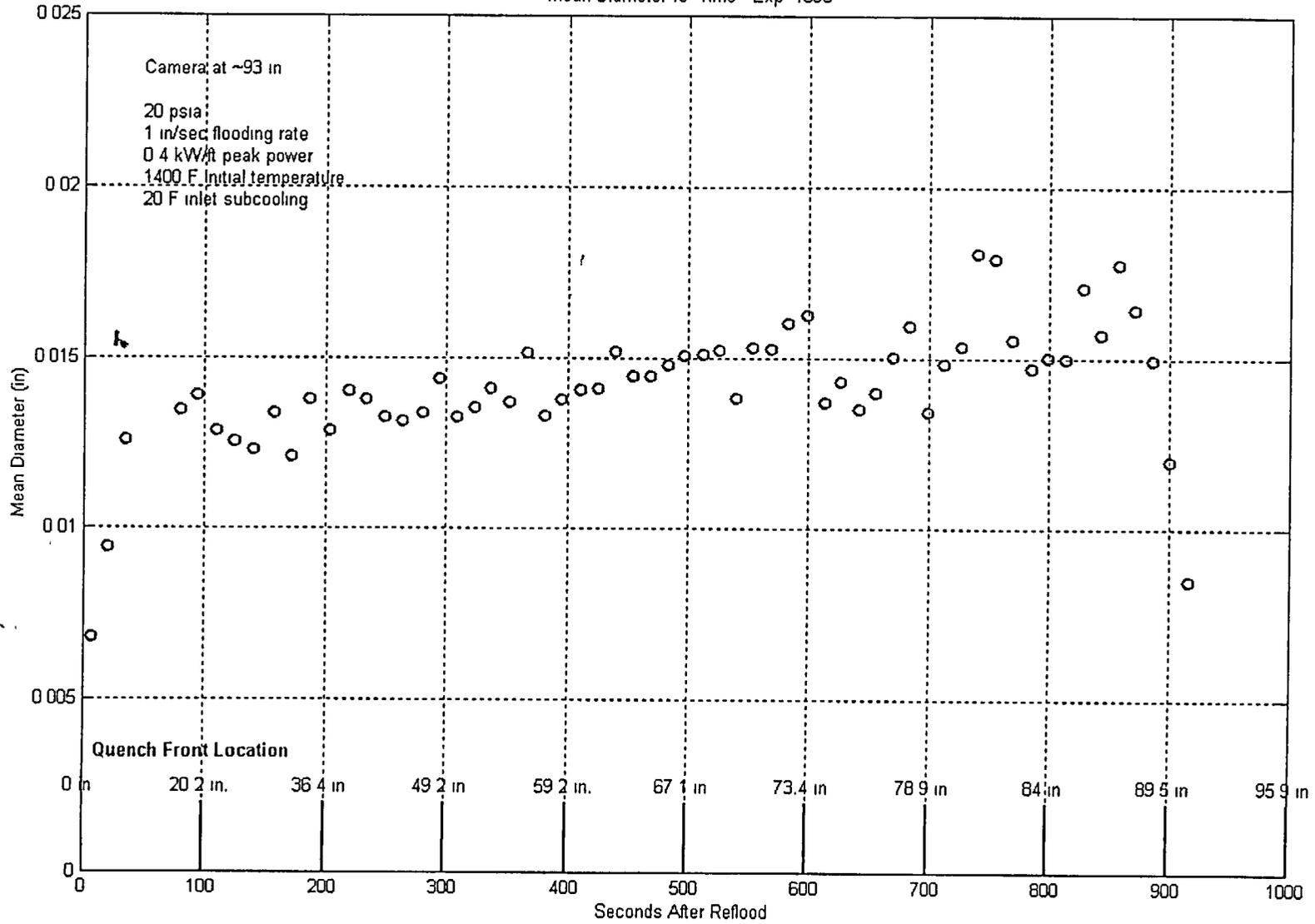


Steam Temp, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)





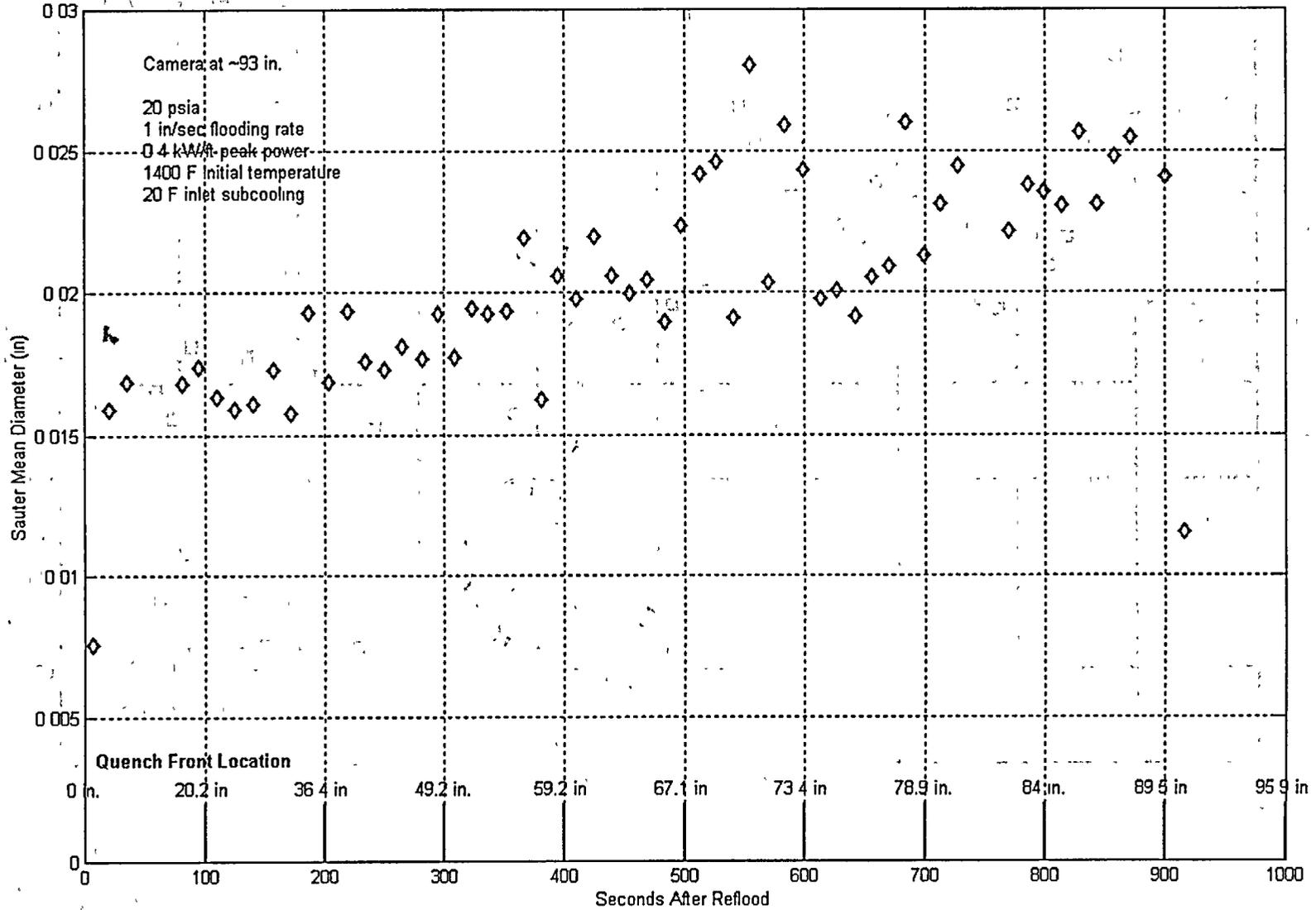
Mean Diameter vs Time - Exp 1096

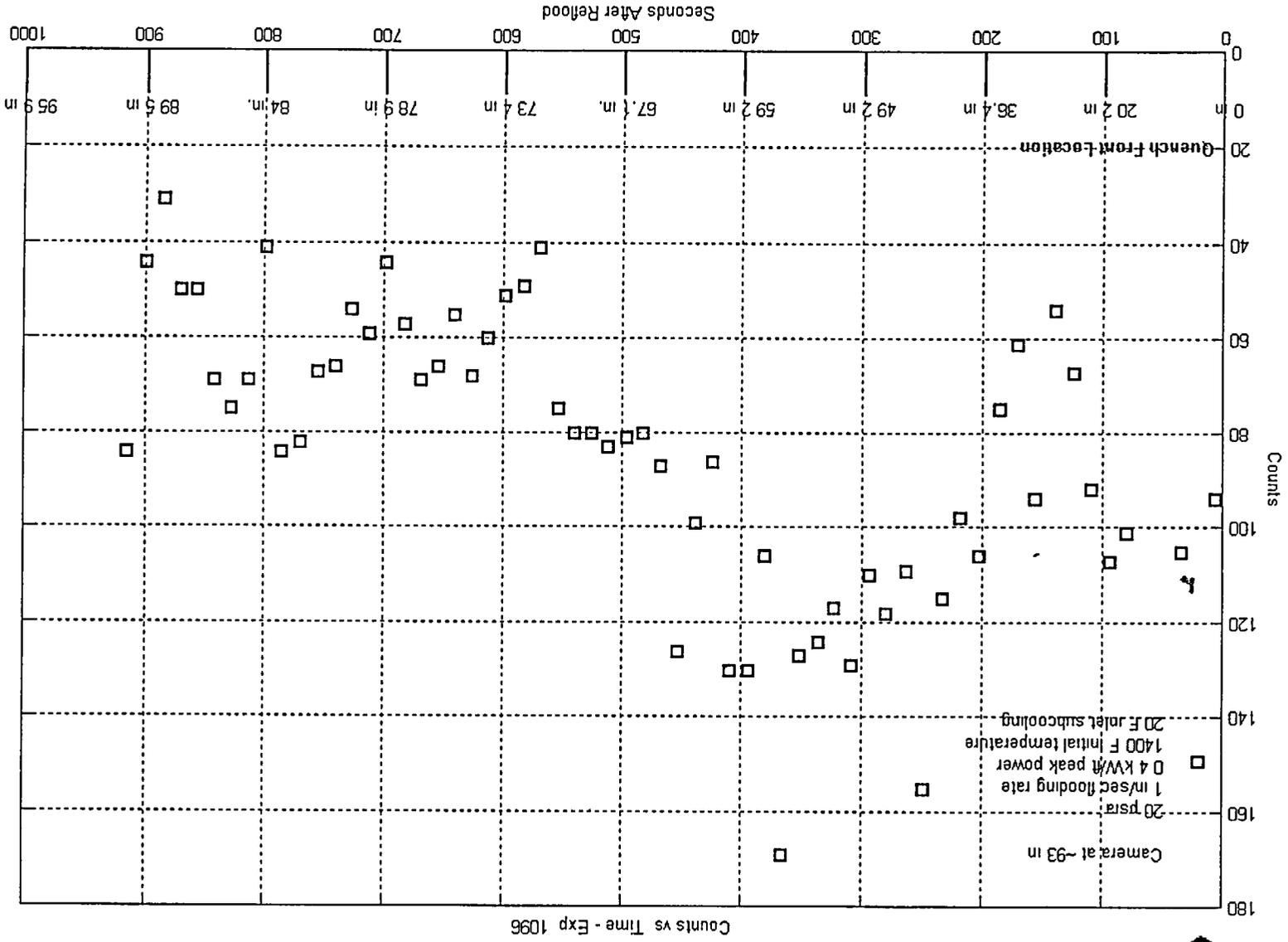


PENNSTATE



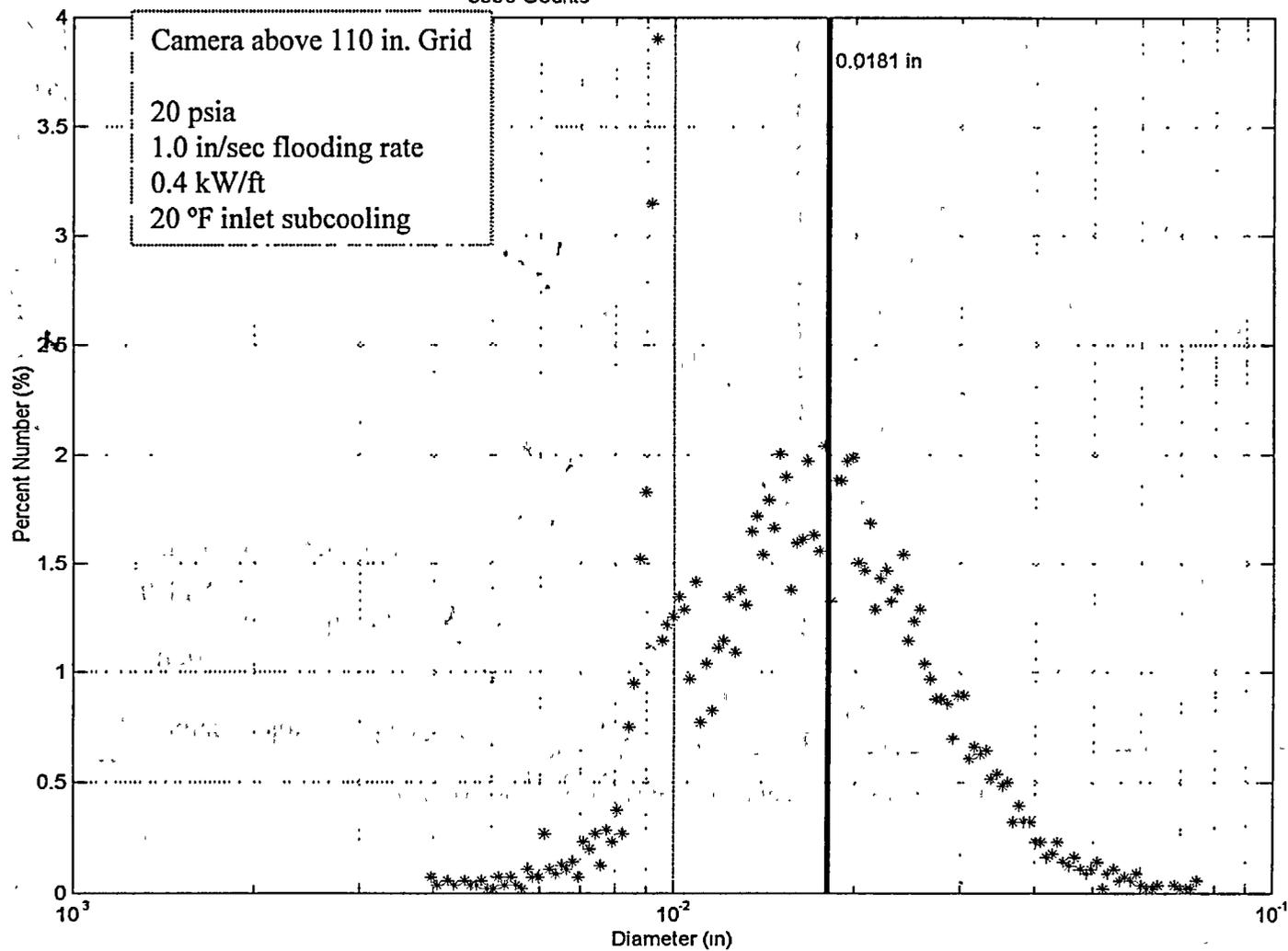
Sauter Mean Diameter vs. Time - Exp 1096





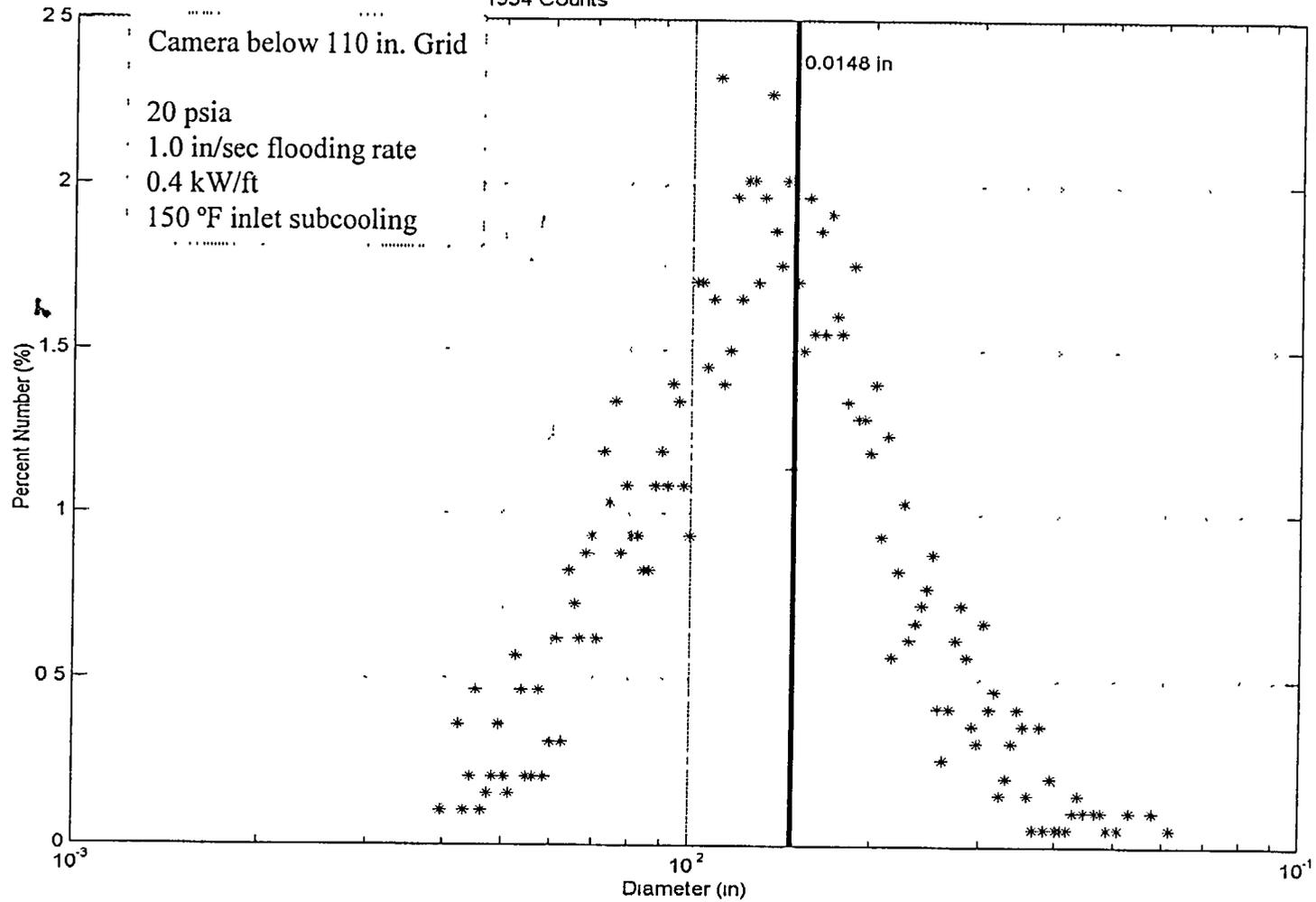


Percent Number Distribution - Exp 1096 - Below 110 in. Grid
5590 Counts

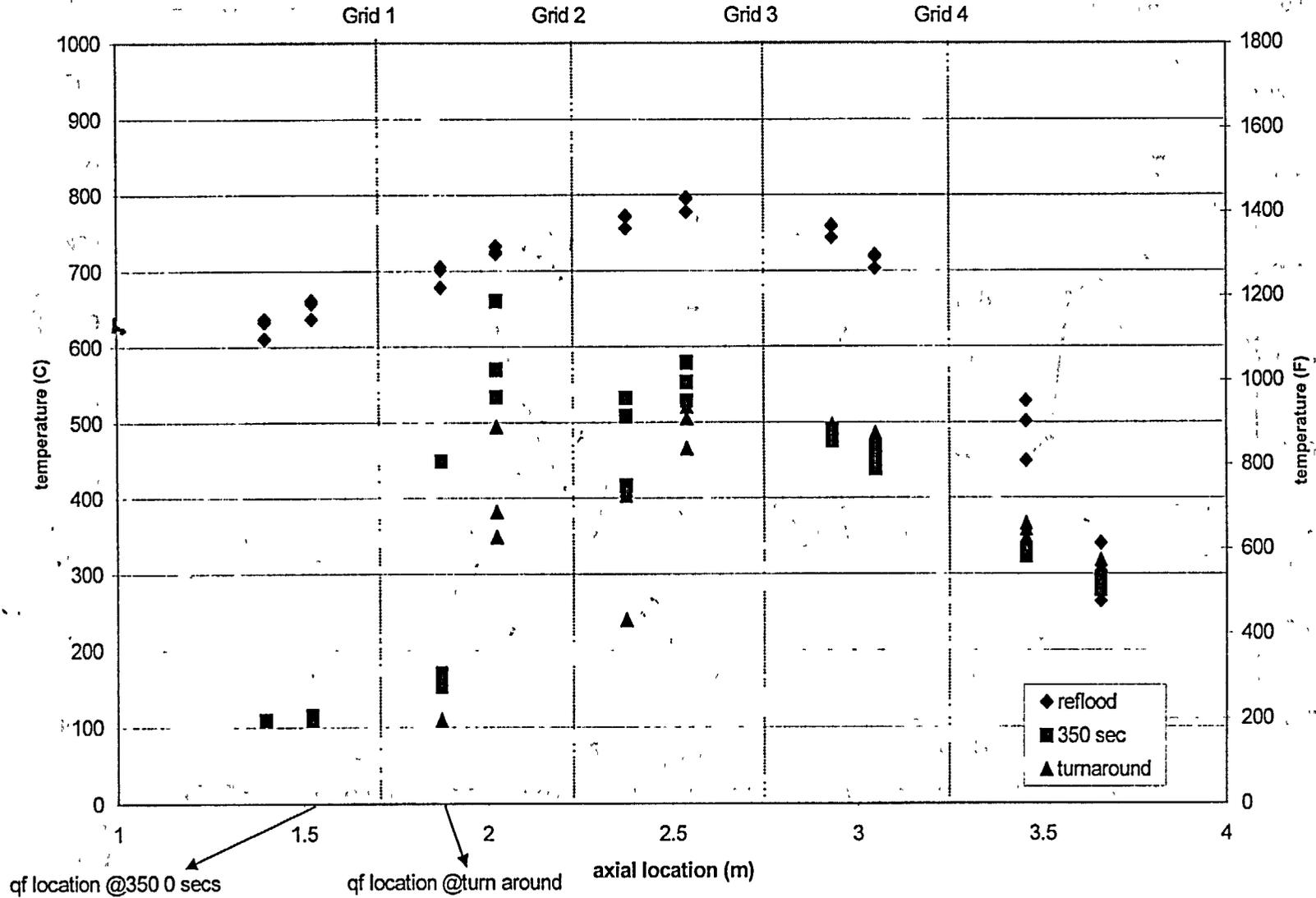




Percent Number Distribution - Exp. 1103 - Above 110 in Grid
1934 Counts

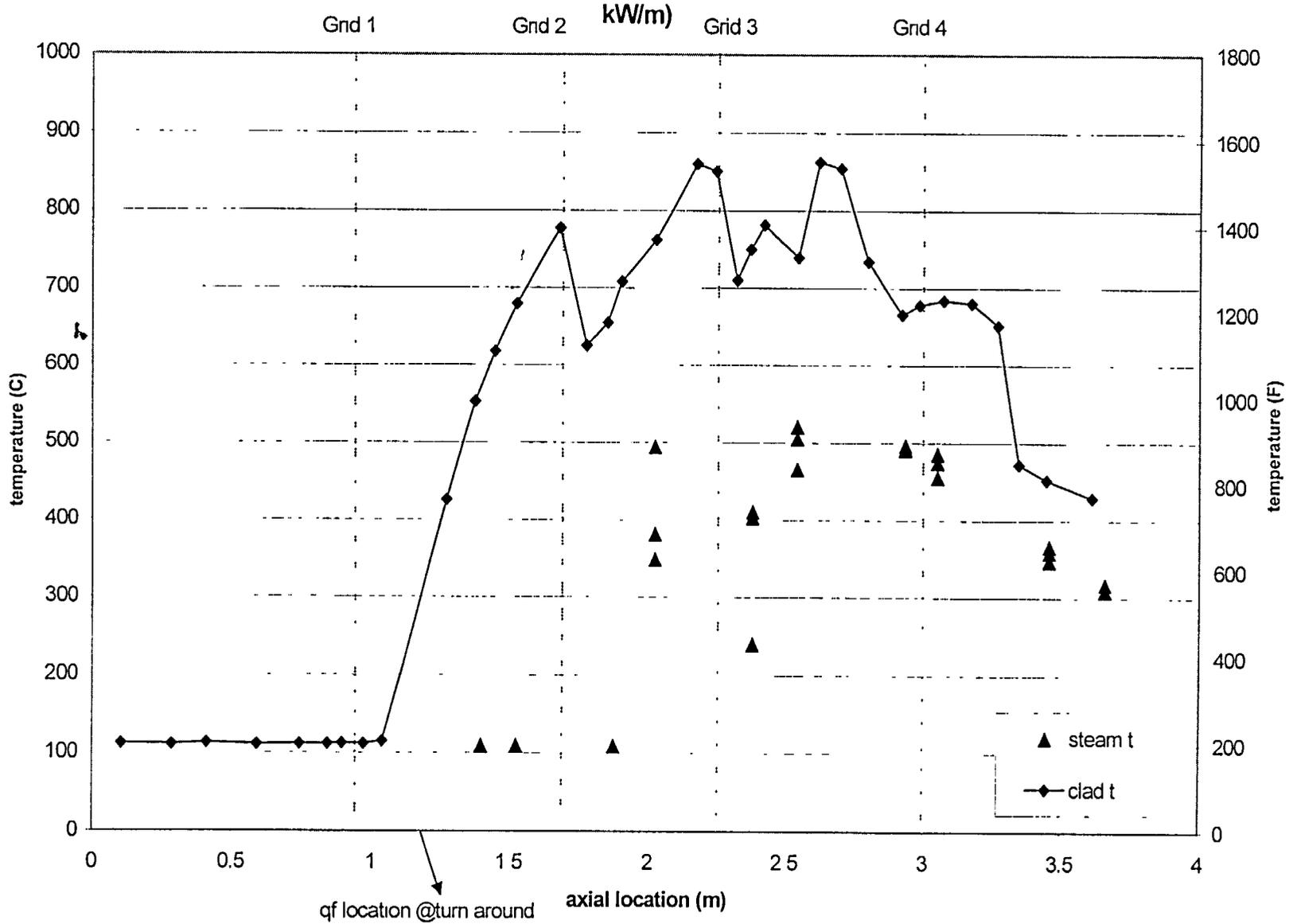


Steam Temperature, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312 kW/m)





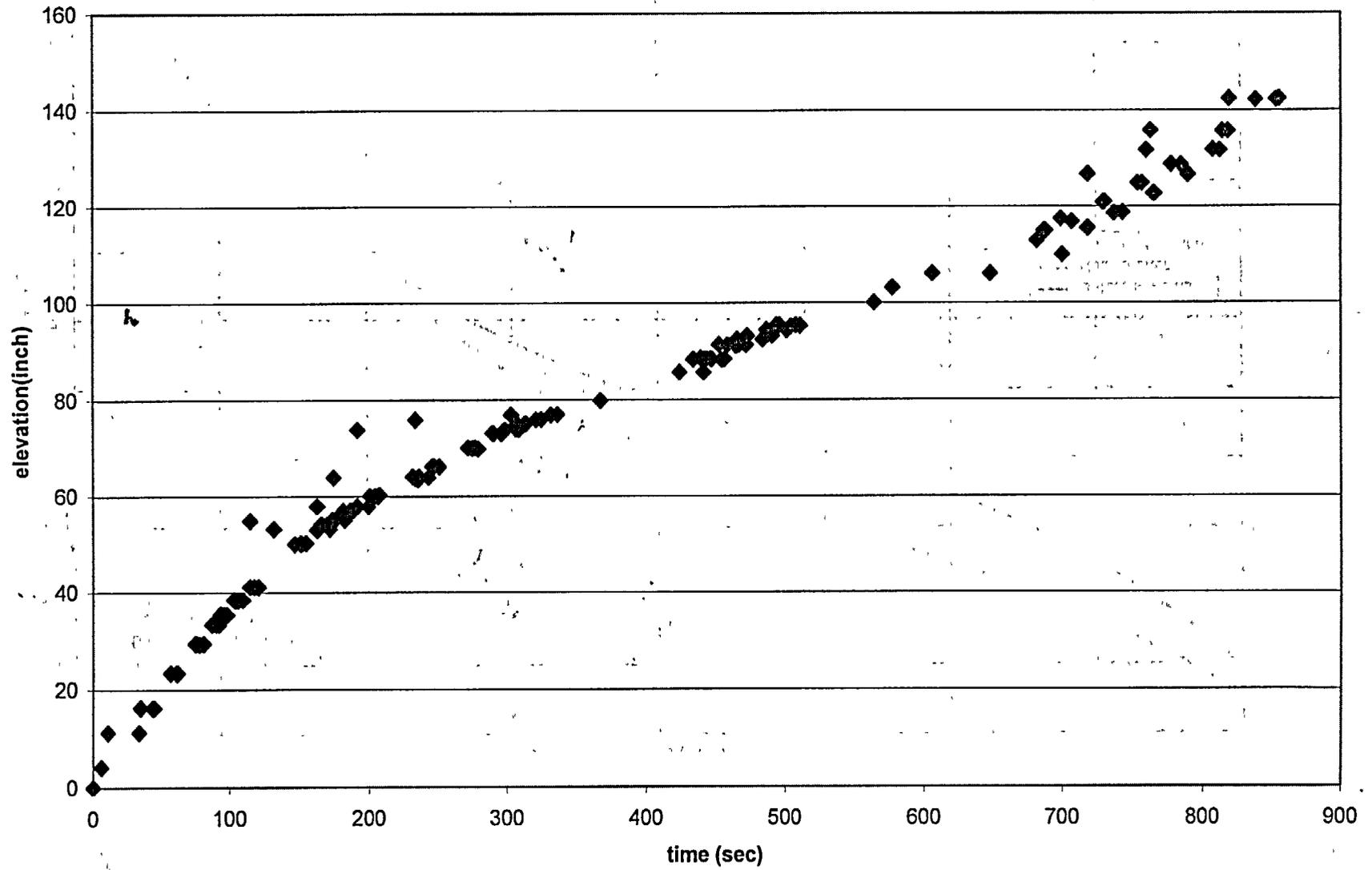
Temp@ turnaround time, Exp 1096 (2.54 cm/sec, 137.9 kPa, 760 C initial temperature, 1.312

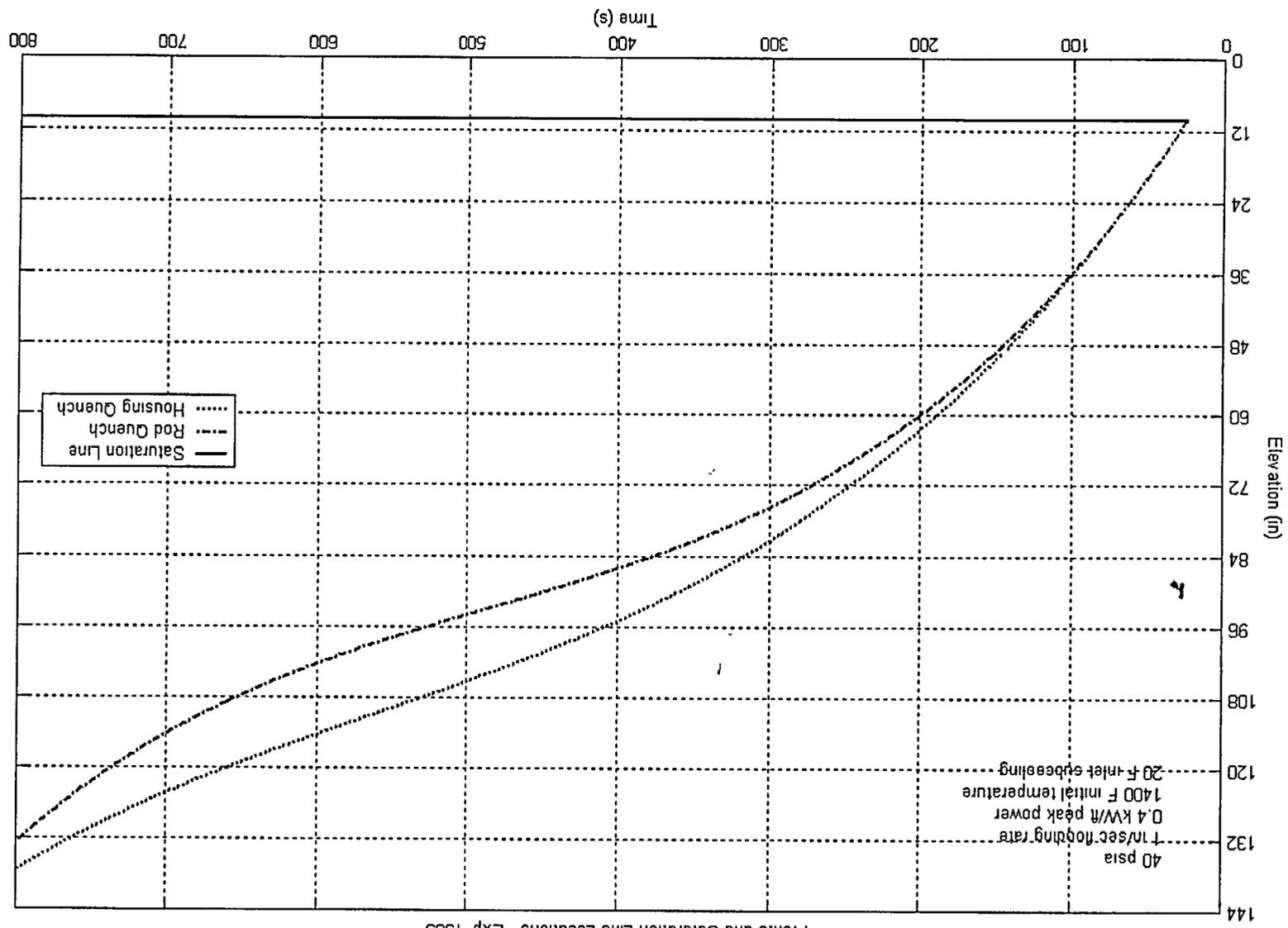


PENNSTATE



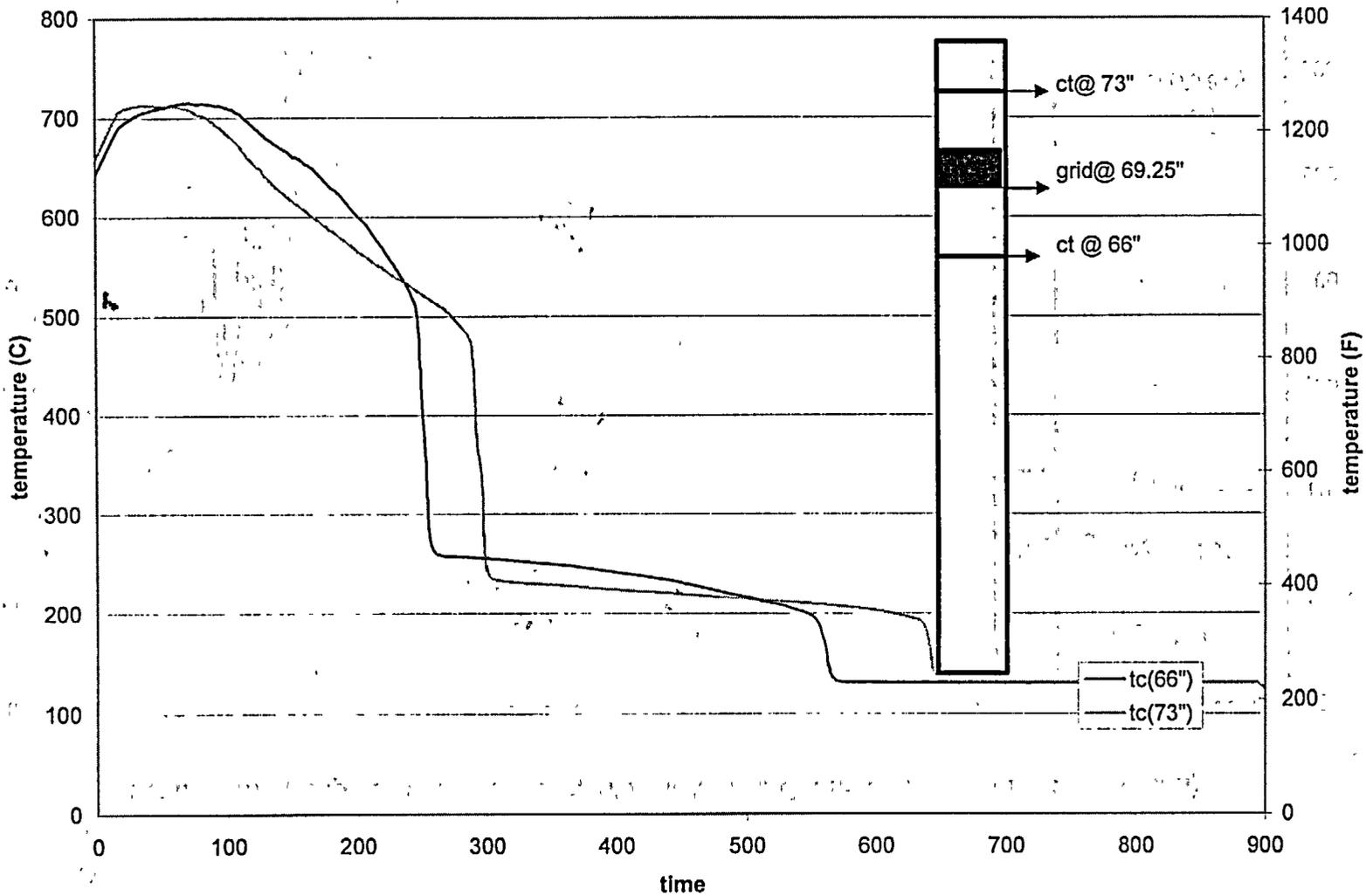
RBHT, Experiment 1383, 40 psia, 1.0 in/sec, 1400 F initial temperature, 20 F subcooling





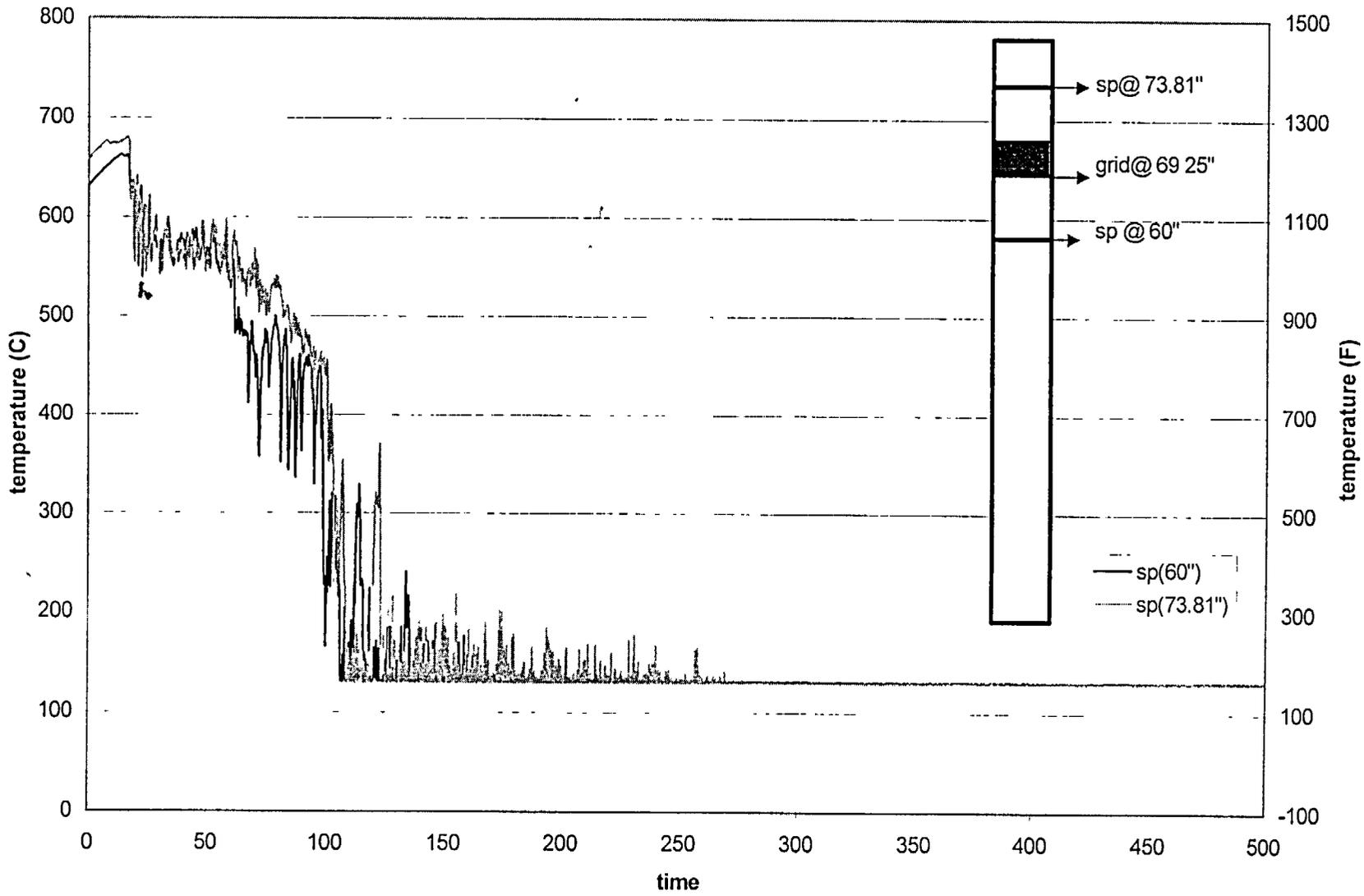


Clad Temperatures, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



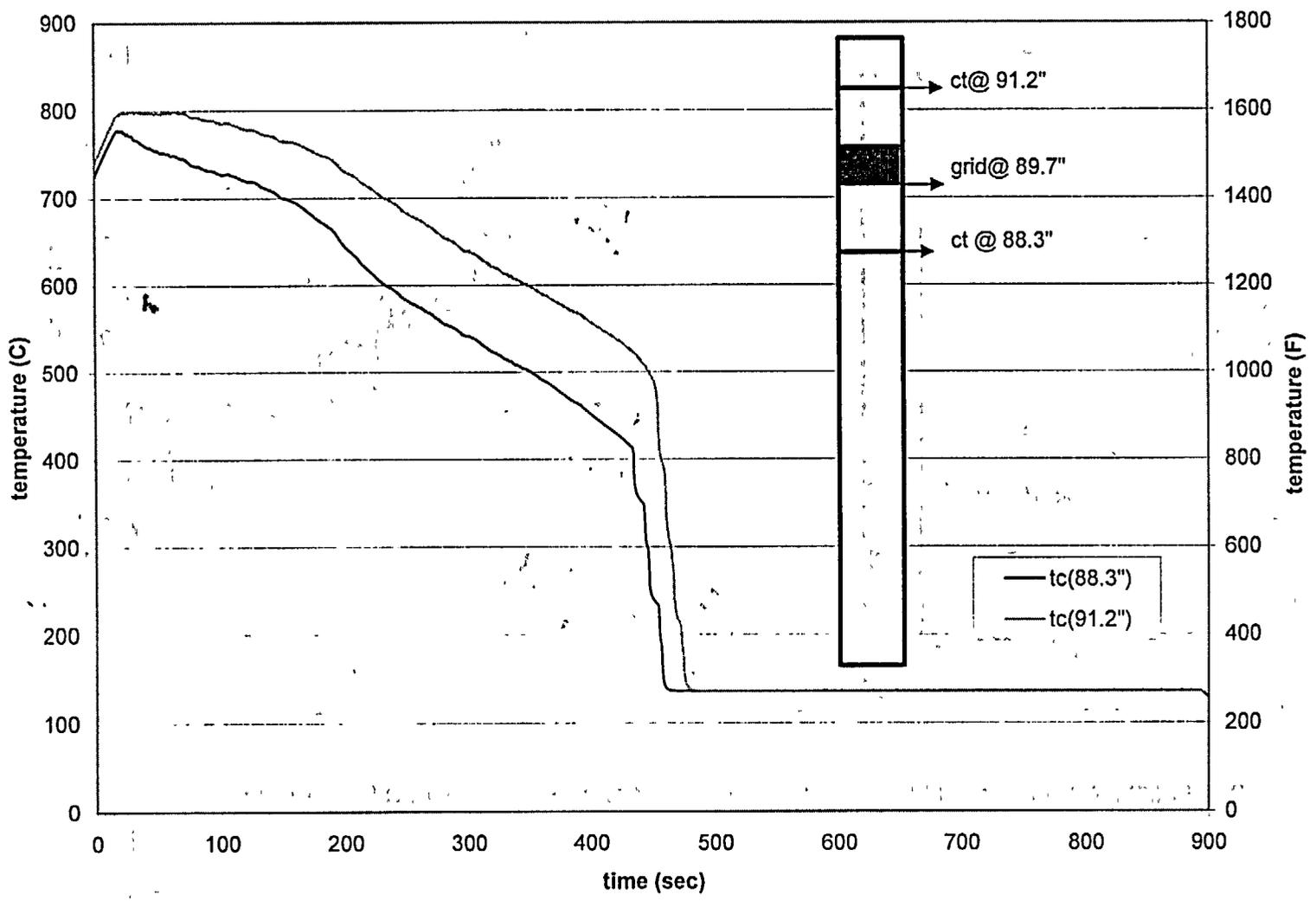


Steam Temp, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



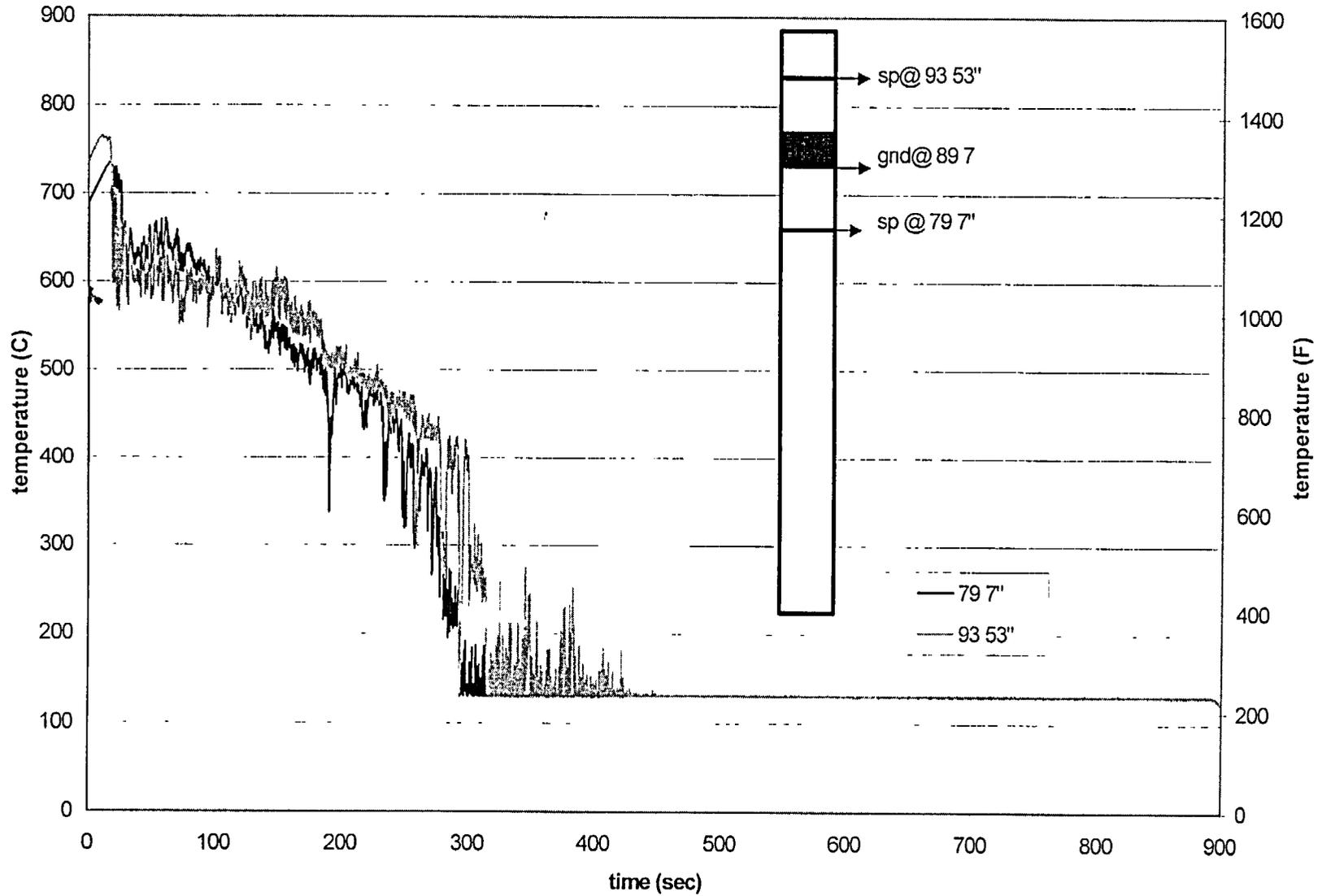


Clad Temperatures, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)





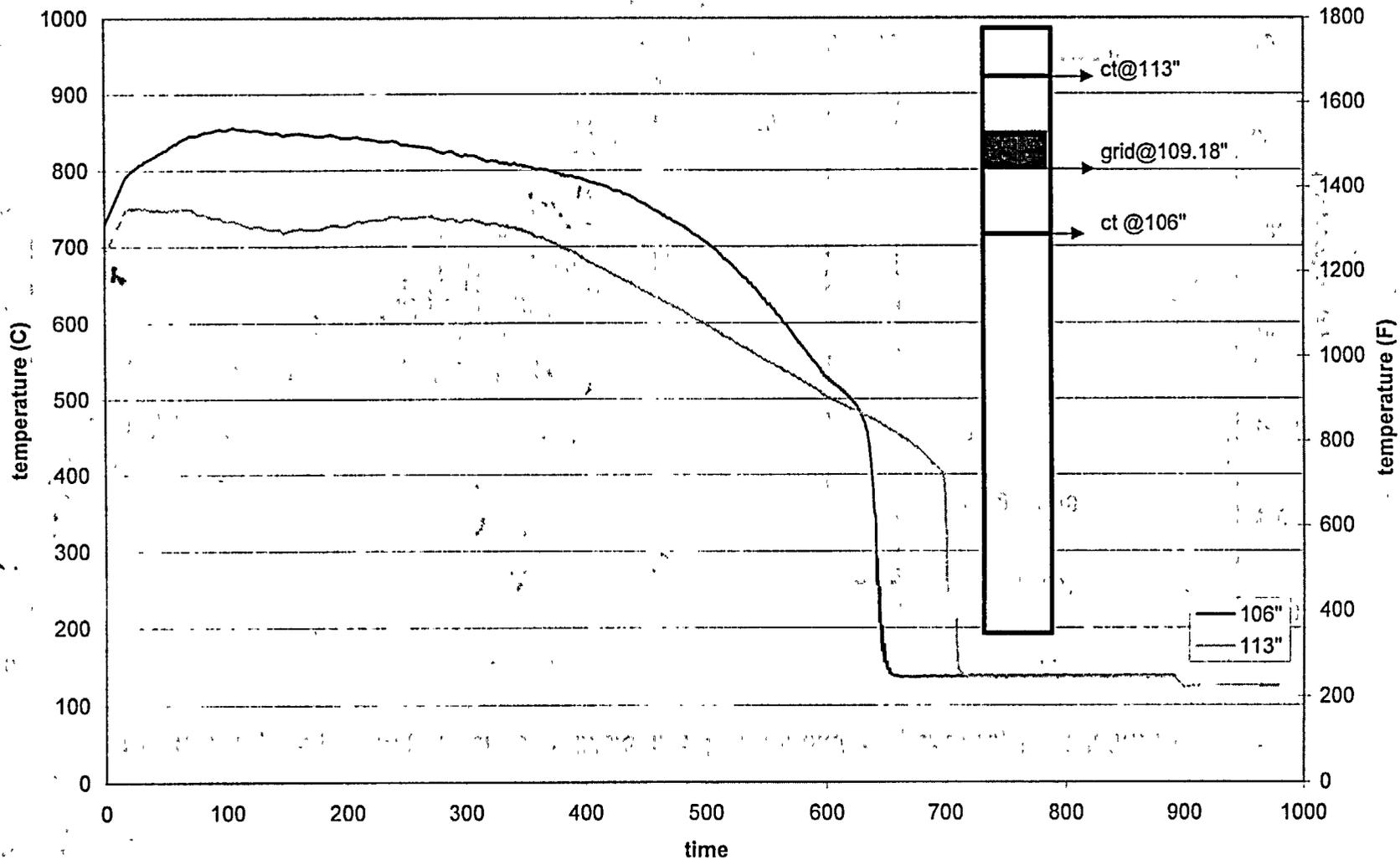
Steam Temp, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



PENNSTATE

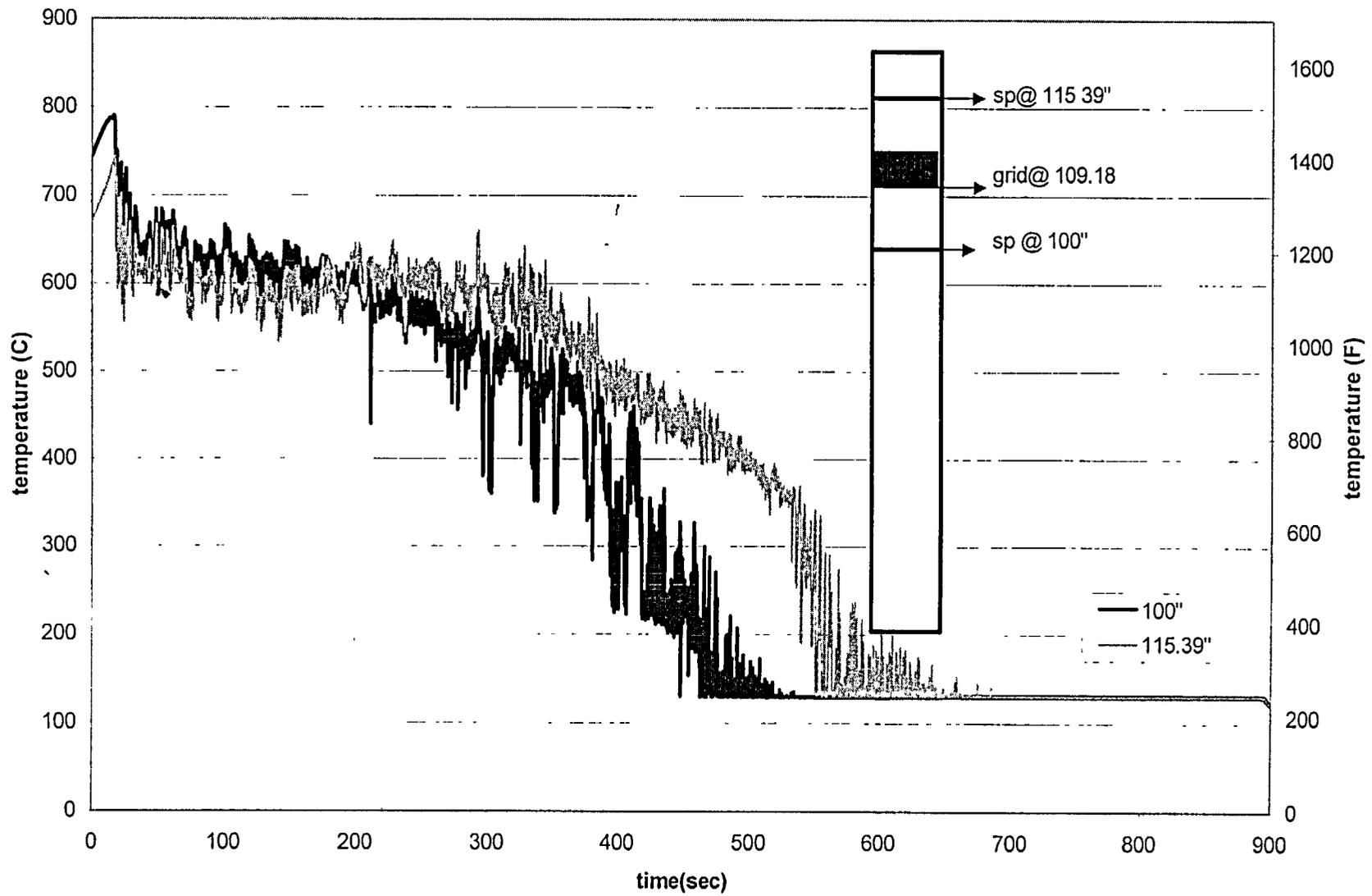


Clad Temperatures, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



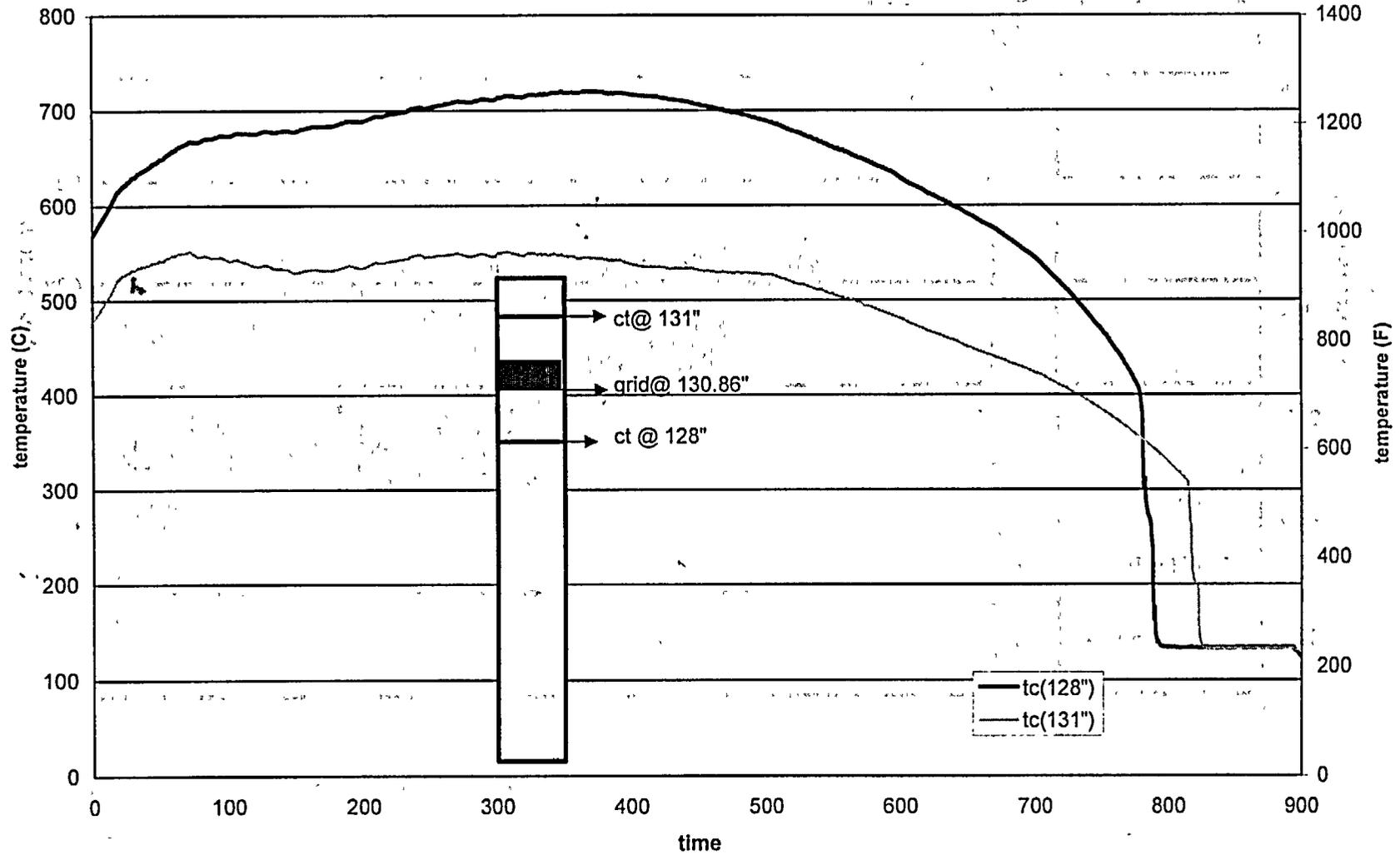


Steam Temp, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



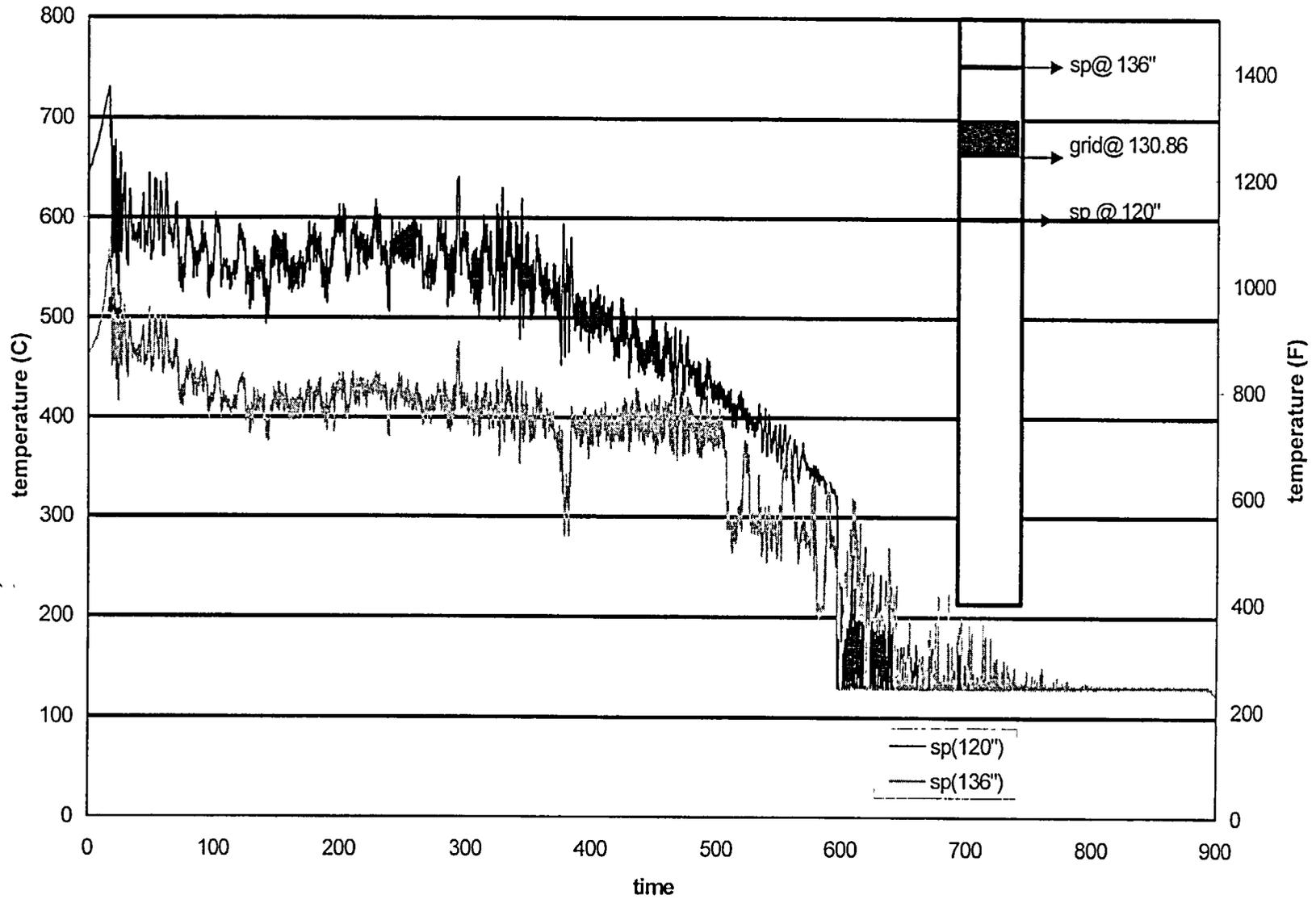


Clad Temperatures, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



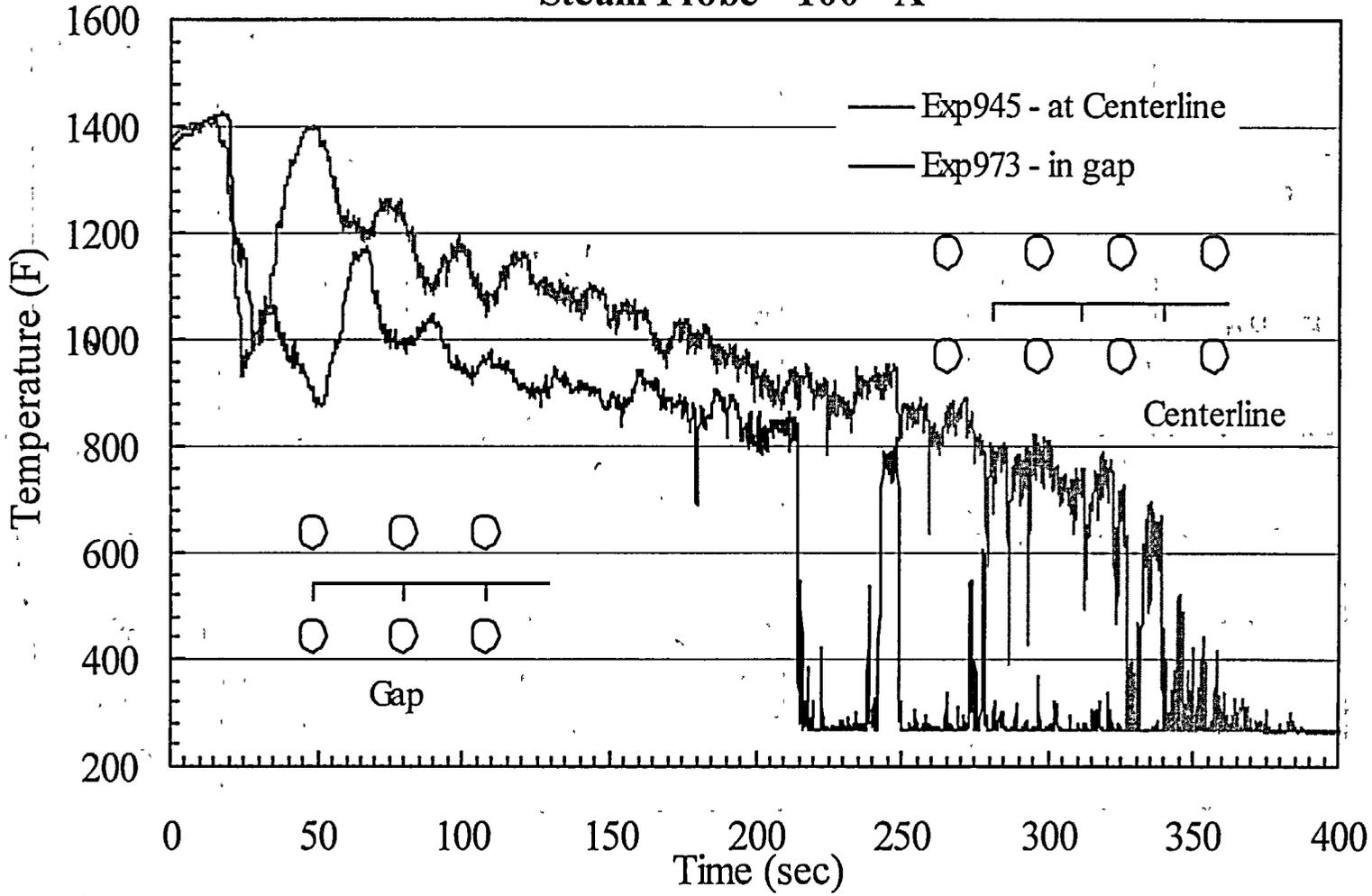


Steam Temp, Exp 1383 (2.54 cm/sec, 275.8 kPa, 760 C initial temperature, 1.312 kW/m)



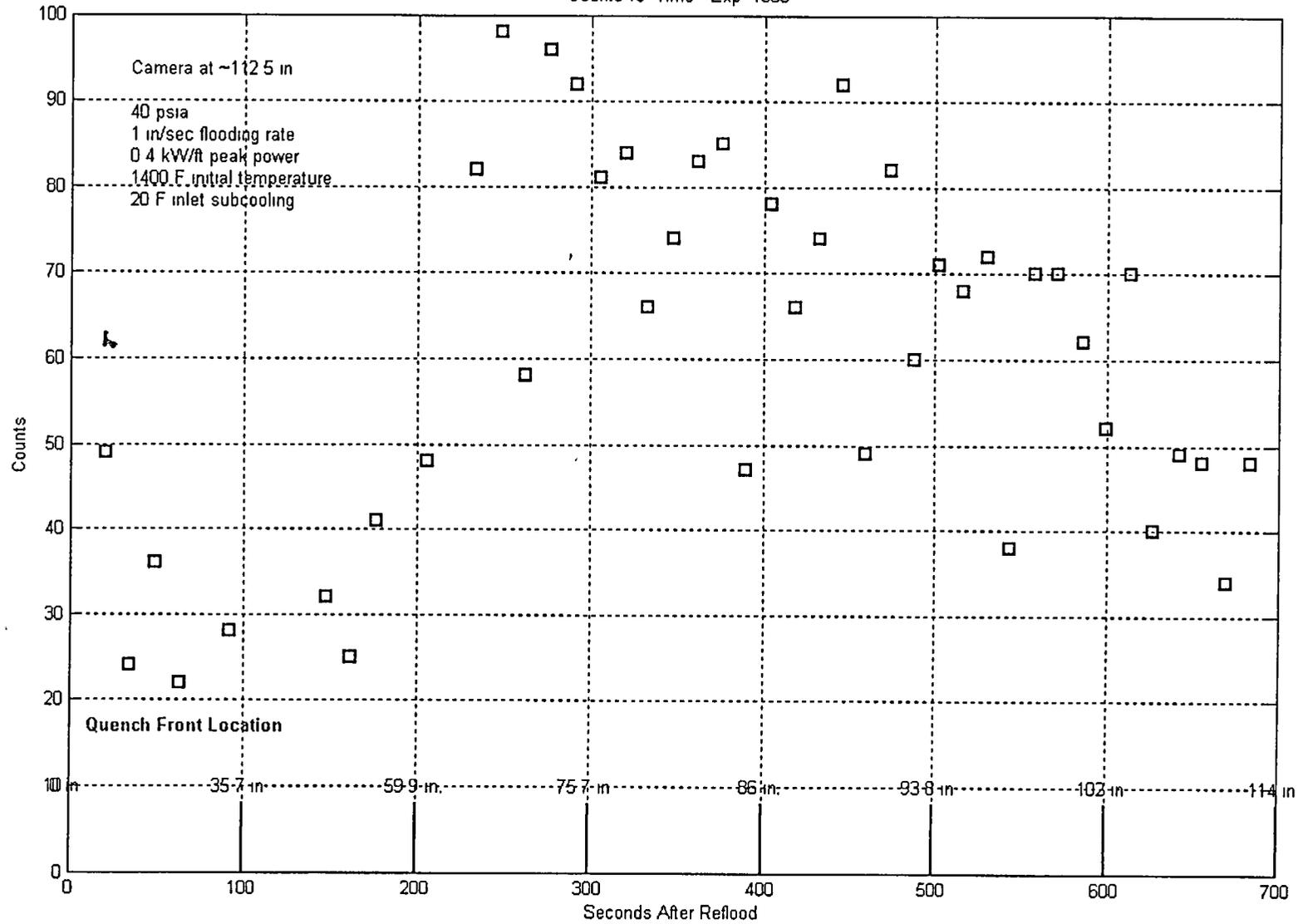


Steam Probe - 100"-A



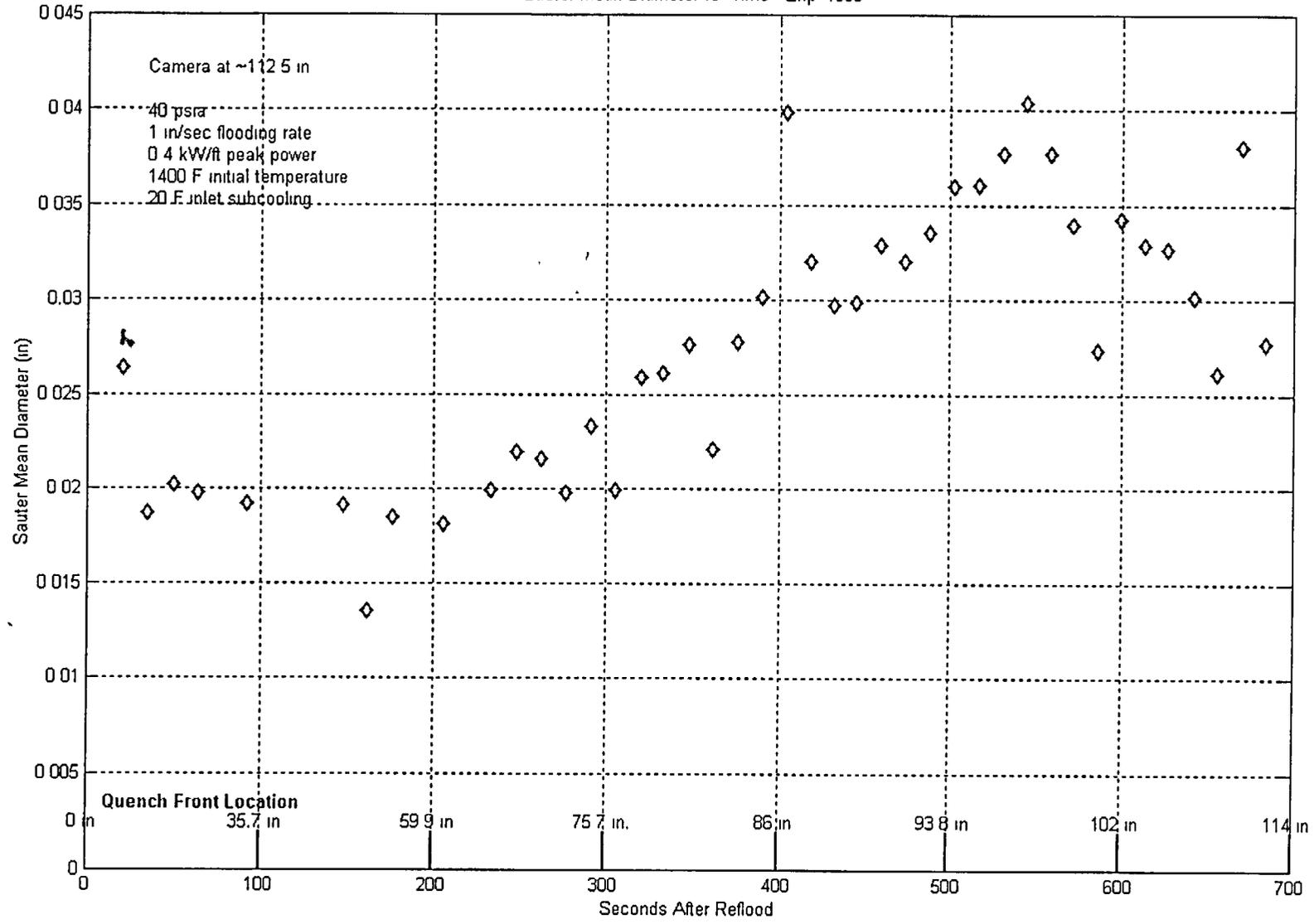


Counts vs Time - Exp 1383



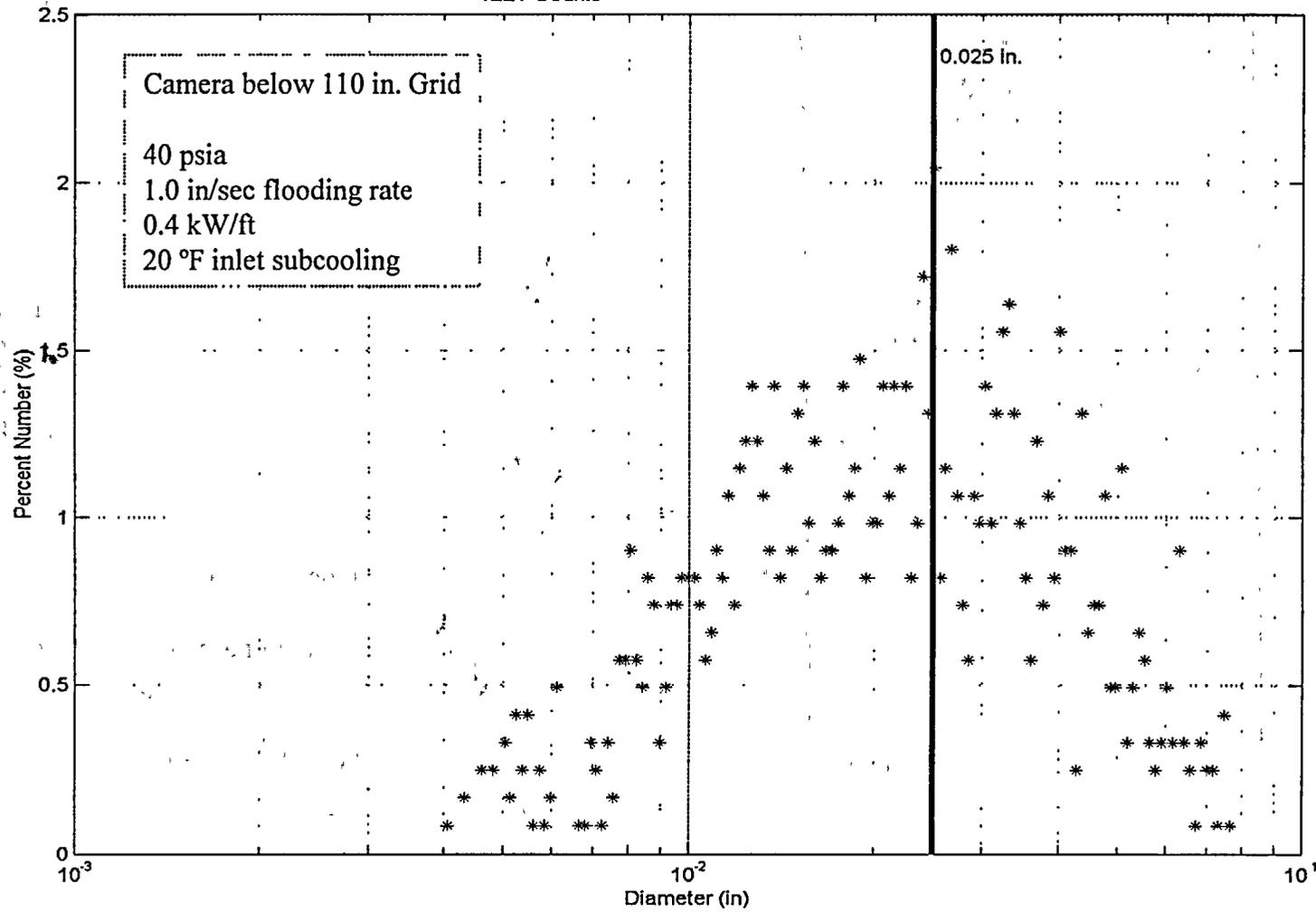


Sauter Mean Diameter vs Time - Exp 1383

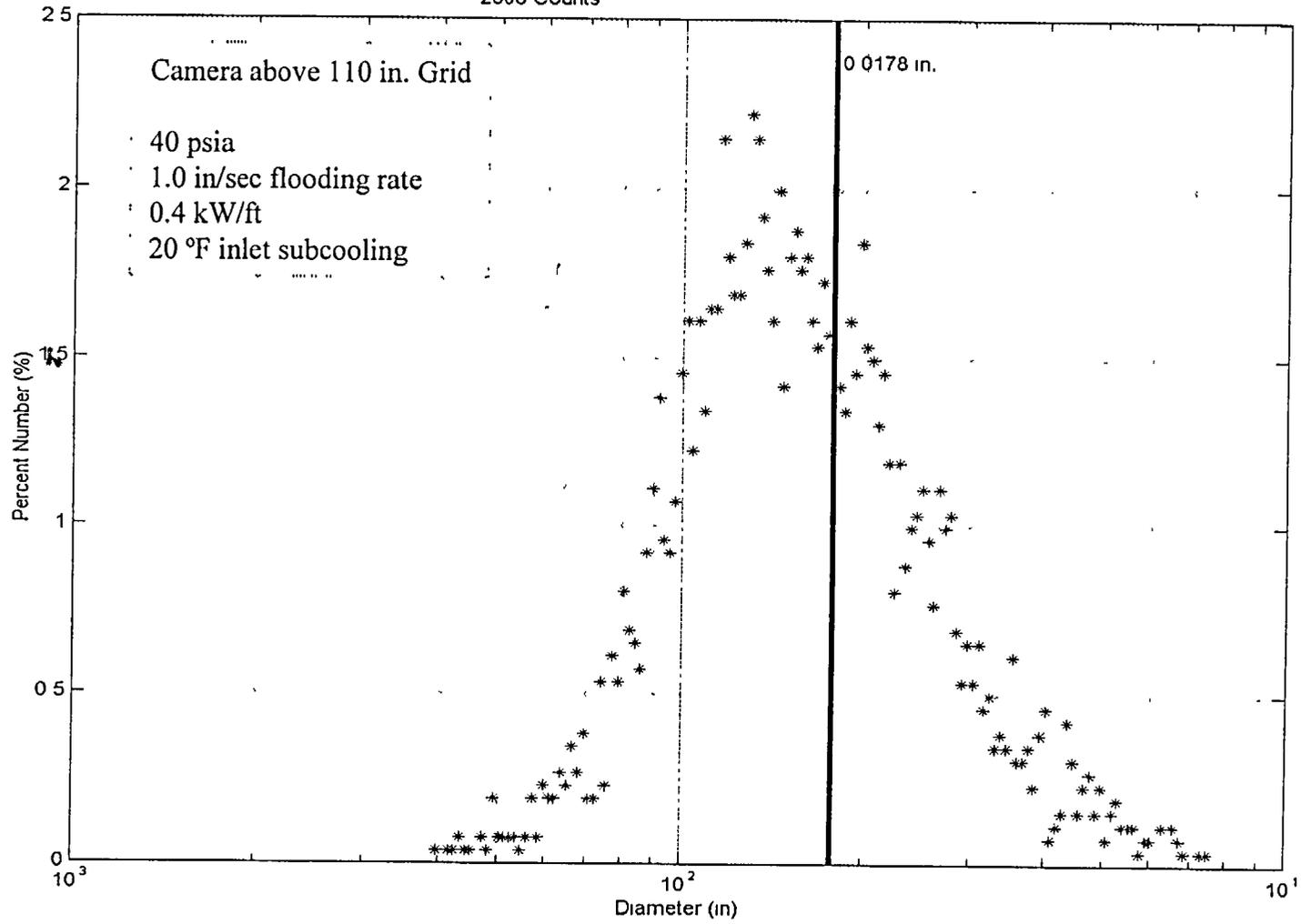




Percent Number Distribution - Exp. 1088 - Below 110 in. Grid
1221 Counts



Percent Number Distribution - Exp 1383 - Above 110 in. Grid
2608 Counts



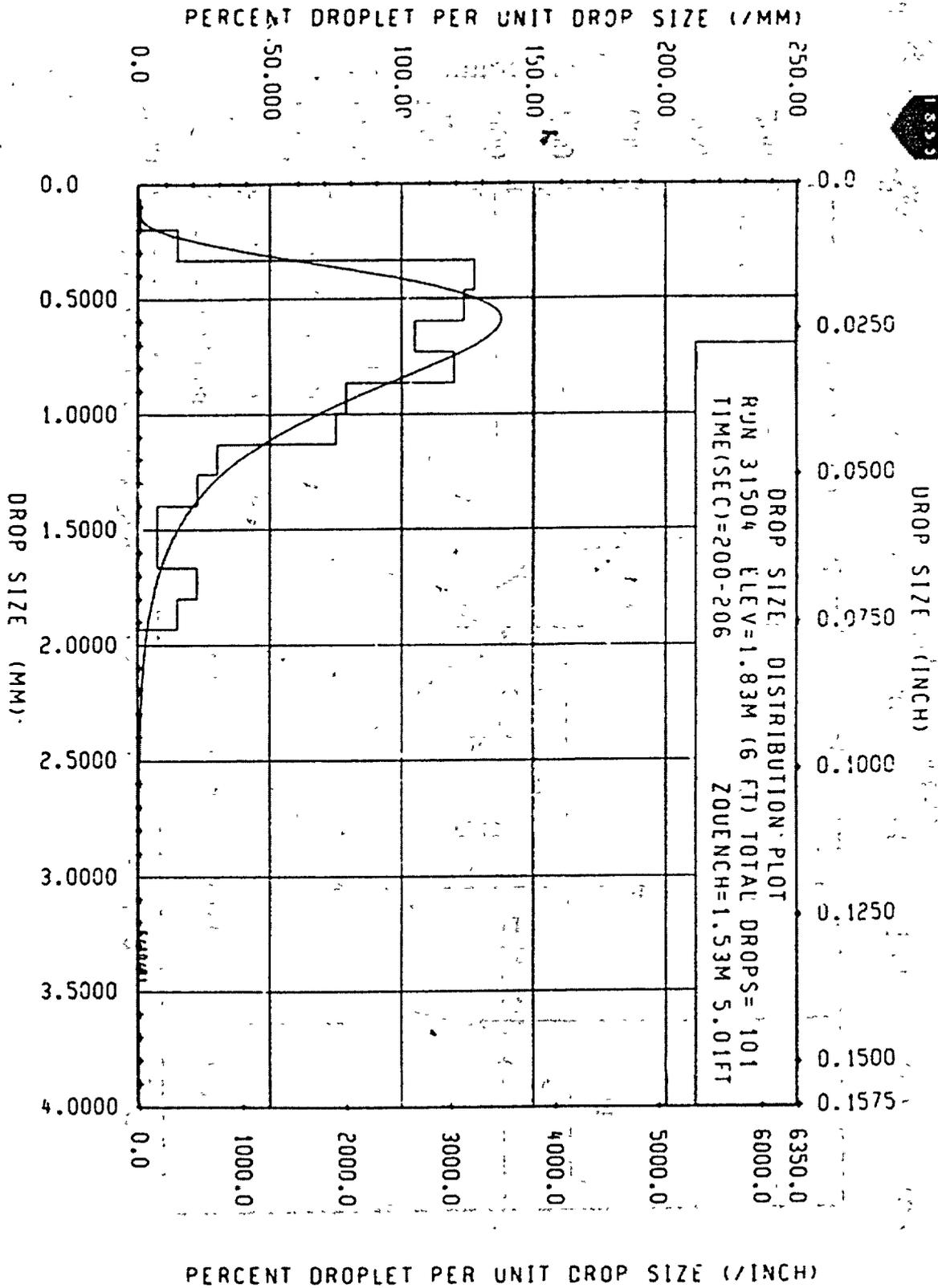
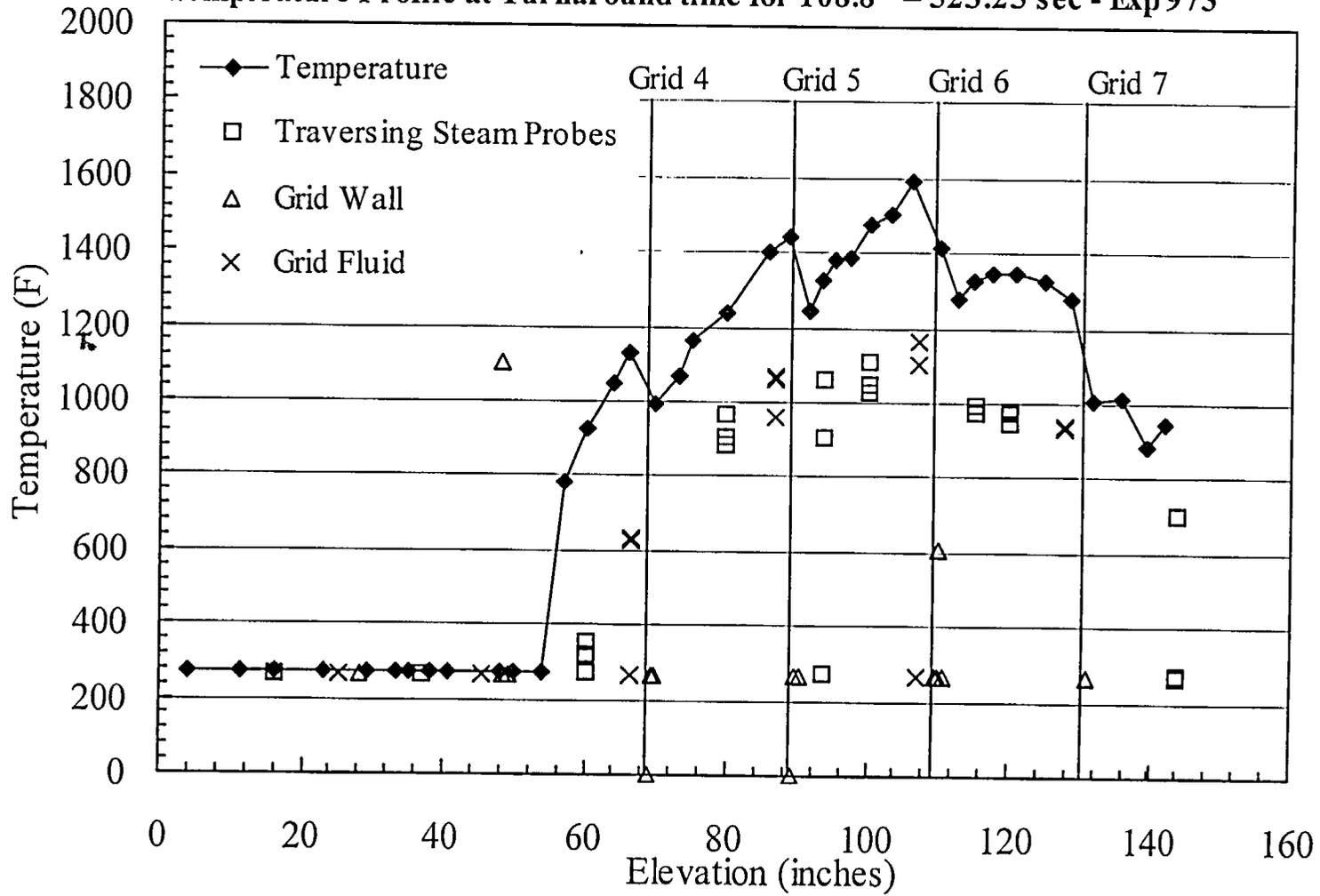
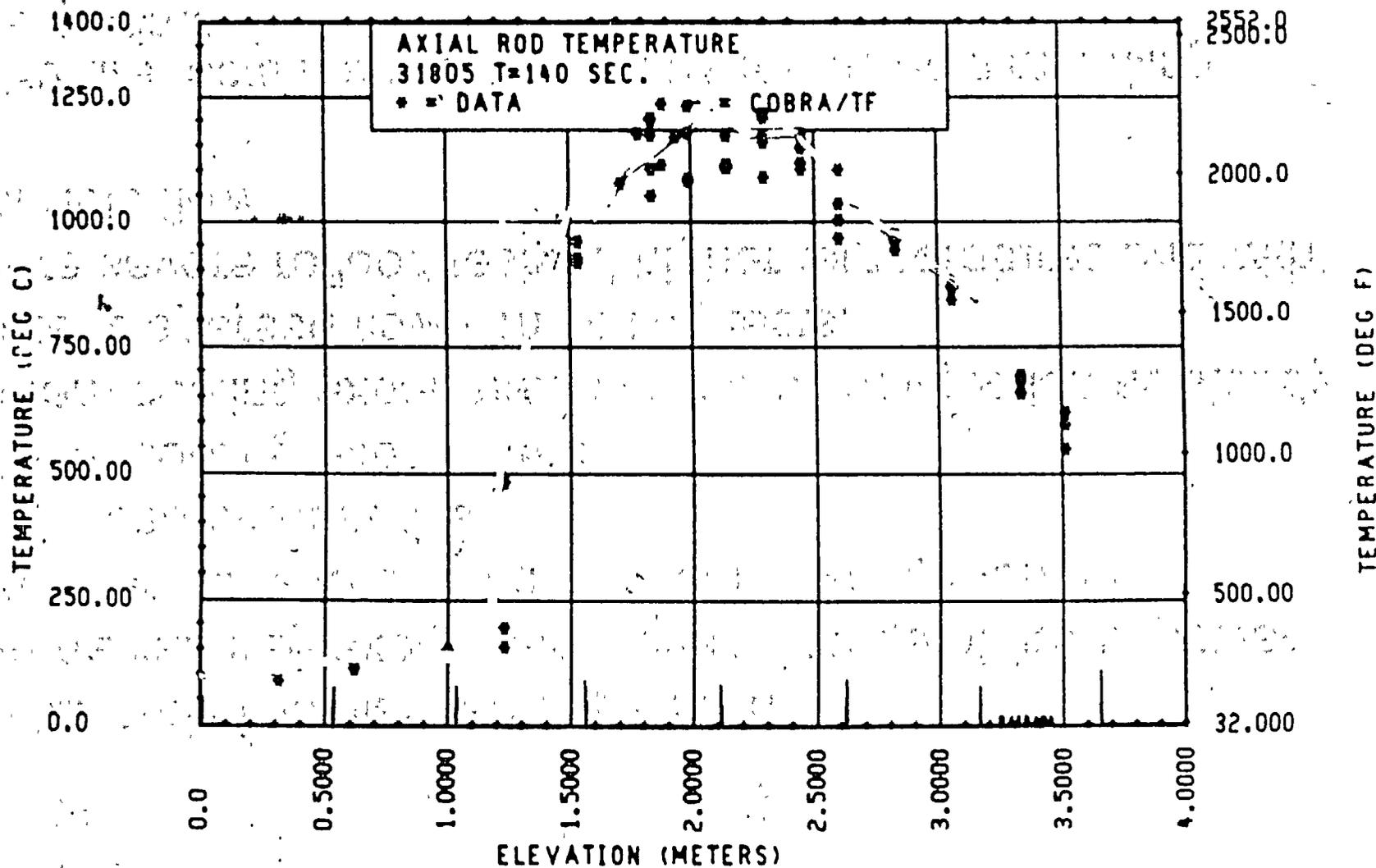


Figure E-8. Drop Size Distribution Plot, Run 31504

Temperature Profile at Turnaround time for 108.8" = 523.25 sec - Exp 973





Steam Probe Location



Future Program

- Currently it is planned to perform:
 - Interfacial drag experiments over a range of flows, power and pressures to aid in the model development for advanced plant audits.
 - Steam cooling experiments.
 - Steam cooling experiments with droplet injection as steady state" dispersed flow film boiling tests.
 - More severe reflood tests at higher temperatures and with variable flow.
- Future tests may also examine top down film boiling experiments.



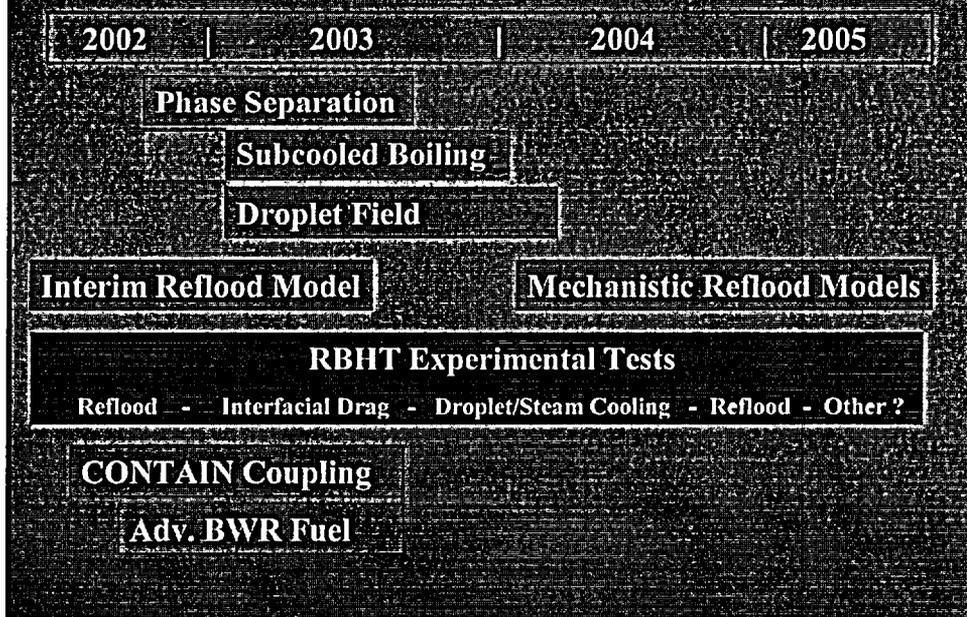
Conclusions

- RBHT has been constructed as a flexible, low pressure, rod bundle test facility.
- Several new features have been added to the RBHT facility to provide additional detailed thermal-hydraulic data.
- Experiments have been performed in a separate effects test mode to isolate particular phenomena.
- RBHT Program is structured to improve the reflood models in the NRC safety analysis codes.
- Improved NRC codes will aid them in audit calculations and risk informed regulation.

Major Test Series

- Transient forced reflood tests (complete)
- Interfacial drag tests
- Steam cooling / droplet injection tests
- Transient (high temperature) forced reflood tests

TRAC-M Model Development



NRC/RES Rod Bundle Heat Transfer Program Status

Stephen M. Bajorek

Division of Systems Analysis and Regulatory Effectiveness
Office of Nuclear Regulatory Research

Meeting of the Advisory Committee on Reactor Safeguards
Thermal-Hydraulic Phenomena Subcommittee

November 12, 2002

INTRODUCTION

- The Rod Bundle Heat Transfer (RBHT) test program was initiated in 1998 to provide detailed information to enable development of mechanistic thermal-hydraulic models for the reflood period of a LOCA.
- Processes of interest:
 - Dispersed droplet film boiling
 - Entrainment at quench front
 - Inverted annular film boiling & transition boiling
 - Spacer grid effects
 - Drop size, break up, and evaporation rates

Q. What have I learned?

A. Three issues need
to be addressed w.r.t
RBHT in model dev.

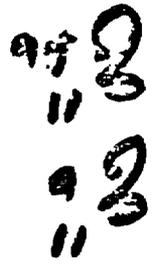
→ Bias & Uncertainty
of indiv. models!

→ Spacer grid models,
design differences
are key!

→ IVA & " split ?

①

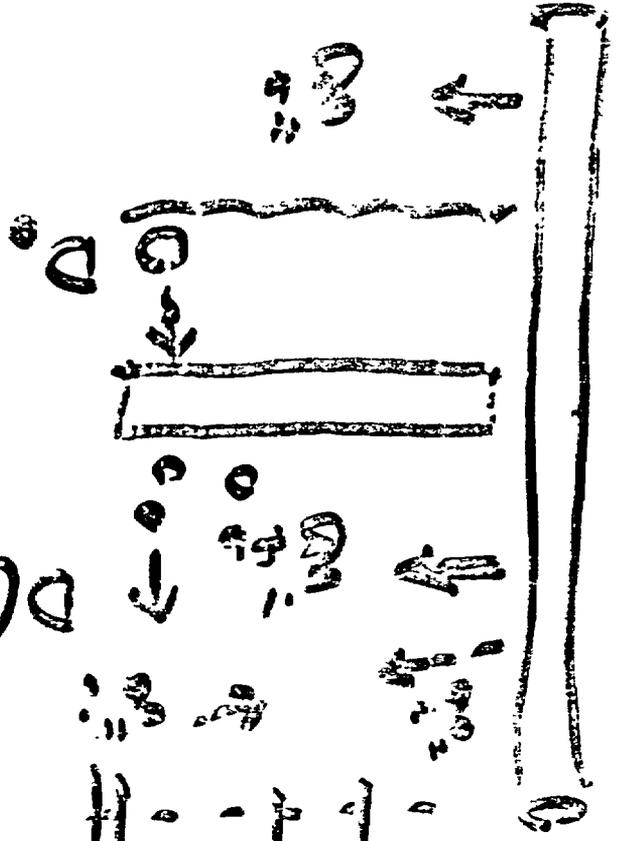
etc.
D (a)



etc.

etc.

etc.
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etc.



D (a)



etc.

etc.

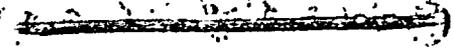


etc.



etc.

etc.



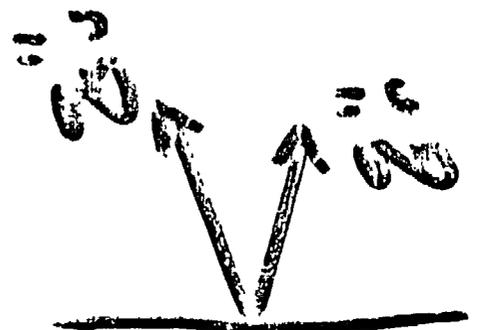
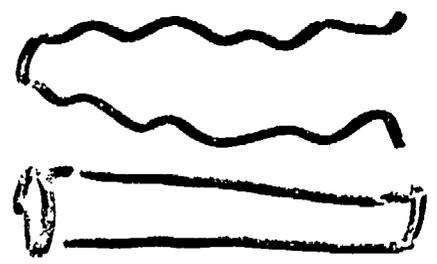
Spencer's Guide

* First order, says it
be high priority

* What is AD(?)
and how does it
relate to priority?



TVR Film Reviewing



T(?)

new

is it?



INTRODUCTORY STATEMENT BY THE CHAIRMAN OF THE
SUBCOMMITTEE ON THERMAL-HYDRAULIC PHENOMENA
11545 ROCKVILLE PIKE, ROOM T-2B1
ROCKVILLE, MARYLAND
NOVEMBER 12, 2002

The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Thermal-Hydraulic Phenomena. I am, Graham Wallis, Chairman of the Subcommittee. The other ACRS Members in attendance are: Tom Kress, and Victor Ransom. ACRS Consultants in attendance are: Sanjoy Banerjee, Fred Moody, and Virgil Schrock.

For today's meeting, the Subcommittee will discuss the status of the NRC Office of Nuclear Regulatory Research's (RES) Rod Bundle Heat Transfer (RBHT) Program underway at Pennsylvania State University. Tomorrow, we will continue review of the Framatome ANP-Richland S-RELAP5 realistic code version and its application to PWR large-break LOCA analyses. Portions of this meeting will be closed to the public for discussion of information considered proprietary to Framatome ANP-Richland Incorporated.

Mr. Paul Boehnert is the Cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the *Federal Register* on October 23, 2002.

A transcript of this meeting is being kept, and the transcript will be made available as stated in the Federal Register Notice. It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

We have received no written comments or requests for time to make oral statements from members of the public.

(Chairman's Comments-if any)

We will now proceed with the meeting and I call upon Dr. Stephen Bajorek, from the NRC's Office of Nuclear Regulatory Research, to begin.