July 9, 2014

MEMORANDUM TO: File

FROM: John Lehning, Reactor Engineer **/RA/**
Electrical and Reactor Systems Branch
Japan Lessons Learned Division
Office of Nuclear Reactor Regulation

SUBJECT: PRELIMINARY RESULTS FROM NRC STAFF ANALYSIS OF EXTENDED LOSS OF ALL ALTERNATING CURRENT POWER EVENT FOR A WESTINGHOUSE 4-LOOP REACTOR

In its review of power reactor licensees' strategies for mitigating an extended loss of all alternating current power (ELAP) event in response to Order EA-12-049, the NRC staff has been performing independent confirmatory analysis of the ELAP event using the NRC's thermal-hydraulic code TRACE. The primary objectives of this analysis are to assess the mitigating strategies' capabilities with regard to reactor core cooling, reactor coolant system inventory, and in some cases, shutdown margin.

Differences have been observed between the preliminary results of the NRC staff's confirmatory analysis for Westinghouse pressurized-water reactors (PWRs) and the results of industry calculations performed with the NOTRUMP code (e.g., the calculations documented in proprietary technical reports WCAP-17601-P and WCAP-17792-P). The observed differences are important because they impact the time at which providing makeup to the reactor coolant system is necessary to avoid a departure from natural circulation in the reactor coolant system loops and to ensure sufficient mixing of boric acid throughout the reactor coolant system. One apparent cause of the observed differences is associated with the modeling of reactor coolant pump seal leakage following depressurization of the reactor coolant system. However, additional factors may be involved.

In an effort to expedite mutual understanding of the differences between the two analyses, via this memorandum the NRC staff is making publicly available certain information from its preliminary confirmatory analysis that has been requested by the Pressurized Water Reactor Owners Group (PWROG). The specific information requested by the PWROG is included as Enclosure 1 to this memorandum, and the requested information provided by the NRC staff in response to the request is provided in Enclosure 2.

It should be emphasized that the information presented in Enclosure 2 is preliminary and, due to the importance of resolving the observed differences in a timely manner, the results have not received a full internal review by the NRC staff. To the extent necessary to fulfill its obligation to review power reactor licensees' mitigating strategies to ensure compliance with Order EA -12-049, the NRC staff will further review and refine the preliminary results in Enclosure 2.

Enclosures: As stated

Contact: John Lehning, NRR/JLD
415-1015

July 9, 2014

MEMORANDUM TO: File

FROM: John Lehning, Reactor Engineer **/RA/**
Electrical and Reactor Systems Branch
Japan Lessons Learned Division
Office of Nuclear Reactor Regulation

SUBJECT: PRELIMINARY RESULTS FROM NRC STAFF ANALYSIS OF EXTENDED LOSS OF ALL ALTERNATING CURRENT POWER EVENT FOR A WESTINGHOUSE 4-LOOP REACTOR

In its review of power reactor licensees' strategies for mitigating an extended loss of all alternating current power (ELAP) event in response to Order EA-12-049, the NRC staff has been performing independent confirmatory analysis of the ELAP event using the NRC's thermal-hydraulic code TRACE. The primary objectives of this analysis are to assess the mitigating strategies' capabilities with regard to reactor core cooling, reactor coolant system inventory, and in some cases, shutdown margin.

Differences have been observed between the preliminary results of the NRC staff's confirmatory analysis for Westinghouse pressurized-water reactors (PWRs) and the results of industry calculations performed with the NOTRUMP code (e.g., the calculations documented in proprietary technical reports WCAP-17601-P and WCAP-17792-P). The observed differences are important because they impact the time at which providing makeup to the reactor coolant system is necessary to avoid a departure from natural circulation in the reactor coolant system loops and to ensure sufficient mixing of boric acid throughout the reactor coolant system. One apparent cause of the observed differences is associated with the modeling of reactor coolant pump seal leakage following depressurization of the reactor coolant system. However, additional factors may be involved.

In an effort to expedite mutual understanding of the differences between the two analyses, via this memorandum the NRC staff is making publicly available certain information from its preliminary confirmatory analysis that has been requested by the Pressurized Water Reactor Owners Group (PWROG). The specific information requested by the PWROG is included as Enclosure 1 to this memorandum, and the requested information provided by the NRC staff in response to the request is provided in Enclosure 2.

It should be emphasized that the information presented in Enclosure 2 is preliminary and, due to the importance of resolving the observed differences in a timely manner, the results have not received a full internal review by the NRC staff. To the extent necessary to fulfill its obligation to review power reactor licensees' mitigating strategies to ensure compliance with Order EA -12-049, the NRC staff will further review and refine the preliminary results in Enclosure 2.

Enclosures: As stated

Contact: John Lehning, NRR/JLD
415-1015

DISTRIBUTION:
JLD R/F SPhilpott JLehning SWhaley SSun DWoodyatt JMiller

ADAMS Accession Number: ML14199A595 NRR-106

OFFICE	NRR/JLD/JERB	NRR/JLD/JERB:BC
NAME	JLehning	SWhaley
DATE	07/08/13	07/09/13

OFFICIAL RECORD COPY

INFORMATION REGARDING NRC STAFF CONFIRMATORY ANALYSIS
REQUESTED BY PRESSURIZED WATER REACTOR OWNERS GROUP

The following request was transmitted on July 1, 2014, via email from J. Hartz, Westinghouse, to the NRC staff:

Information requested from the TRACE run simulating RCS response to extended loss of AC power for the Westinghouse Standard 4 loop design (412).

- Overall RCS mass vs time
- RCS pressure vs. time
- Absolute break flow vs time
- Integrated break flow vs time
- Integrated accumulator flow vs time
- Initial accumulator volume (water and tank)
- Initial accumulator gas pressure and water temperature
- Is SG tube plugging assumed? If so, how much?
- Do the RCPs assume a stopped rotor after the initial coastdown or are local pressure losses based of forward, free-spin of the pump impeller?
- Overall model volume or volumes of the individual components (more preferable)

ENCLOSURE 1

NRC STAFF RESPONSE TO INFORMATION REQUEST BY PRESSURIZED WATER REACTOR OWNERS GROUP

As exemplified by the preliminary results below, the NRC staff's independent confirmatory analysis for Westinghouse pressurized-water reactors (PWRs) has focused on a four-loop input deck model that is based on a combination of plant-specific and generic information. As such, the analysis is not intended to correspond to a specific operating reactor, but rather, to provide general insight into the behavior and event progression that may be expected for an extended loss of all alternating current power (ELAP) affecting Westinghouse PWRs of various designs.

Based upon insights offered by the Pressurized Water Reactor Owners Group (PWROG), the NRC staff is currently developing parametric cases to simulate three categories of Westinghouse PWRs that are distinguished based on their reactor pressure vessel upper head leakage path configuration: (1) T_{hot} plants, (2) standard T_{cold} plants, and (3) T_{cold} plants that formerly had upper head injection systems. Because the analysis for the T_{hot} configuration is furthest along, most results presented below will represent this parametric case. However, two plots will be included to illustrate corresponding results for the T_{cold} configuration. These preliminary results suggest the potential influence of the upper head leakage path configuration on the calculated coping times without reactor coolant system makeup for avoiding a transition to reflux cooling and for ensuring sufficient mixing of boric acid in the reactor coolant system.

General information regarding the NRC staff's confirmatory analysis is provided below. This is followed by the staff's response to the specific information requested by the PWROG. Finally, additional figures are provided for the one-hour centered-moving-averages of the flow quality and mass flow rate over the steam generator U-bends.

I. General Information

Parameter	TRACE Analysis Value
Initial reactor coolant system mass (klbm)	499.3 (T_{hot} upper head configuration)
	502.3 (T_{cold} upper head configuration)
Initial T_{hot}, °F	621
Initial T_{cold}, °F	557
Decay heat model	ANS-5.1-1994 with U^{239}/Np^{239} decay
Cooldown assumptions	As per WCAP-17601-P, Section 5.2.1
Leakage assumptions	Nominal leakage rates and initiation times per WCAP-17601-P, Section 5.2.1; however, seal leakage rate at depressurized condition benchmarked to test data in WCAP-10541-P, R2

II. Responses to PWROG Information Request

1. Overall RCS mass vs time
   Provided in Figure 1, below.

2. RCS pressure vs. time
   Provided in Figure 2, below.

3. Absolute break flow vs time
   Provided in Figure 3, below.

4. Integrated break flow vs time
   Provided in Figure 4, below.

5. Integrated accumulator flow vs time
   Accumulator mass remaining provided in Figure 5, below.

6. Initial accumulator volume (water and tank)
   Total volume: 1349 ft^3
   Initial liquid volume: 850 ft^3

7. Initial accumulator gas pressure and water temperature
   Initial gas pressure: 639.5 psia
   Initial liquid temperature: 120°F

8. Is SG tube plugging assumed? If so, how much?
   Assumption of 8% of tubes plugged.

9. Do the RCPs assume a stopped rotor after the initial coastdown or are local pressure losses based of forward, free-spin of the pump impeller?
   Stopped impeller is not assumed. A plot of RCP impeller rotation is provided in Figure 6, below.

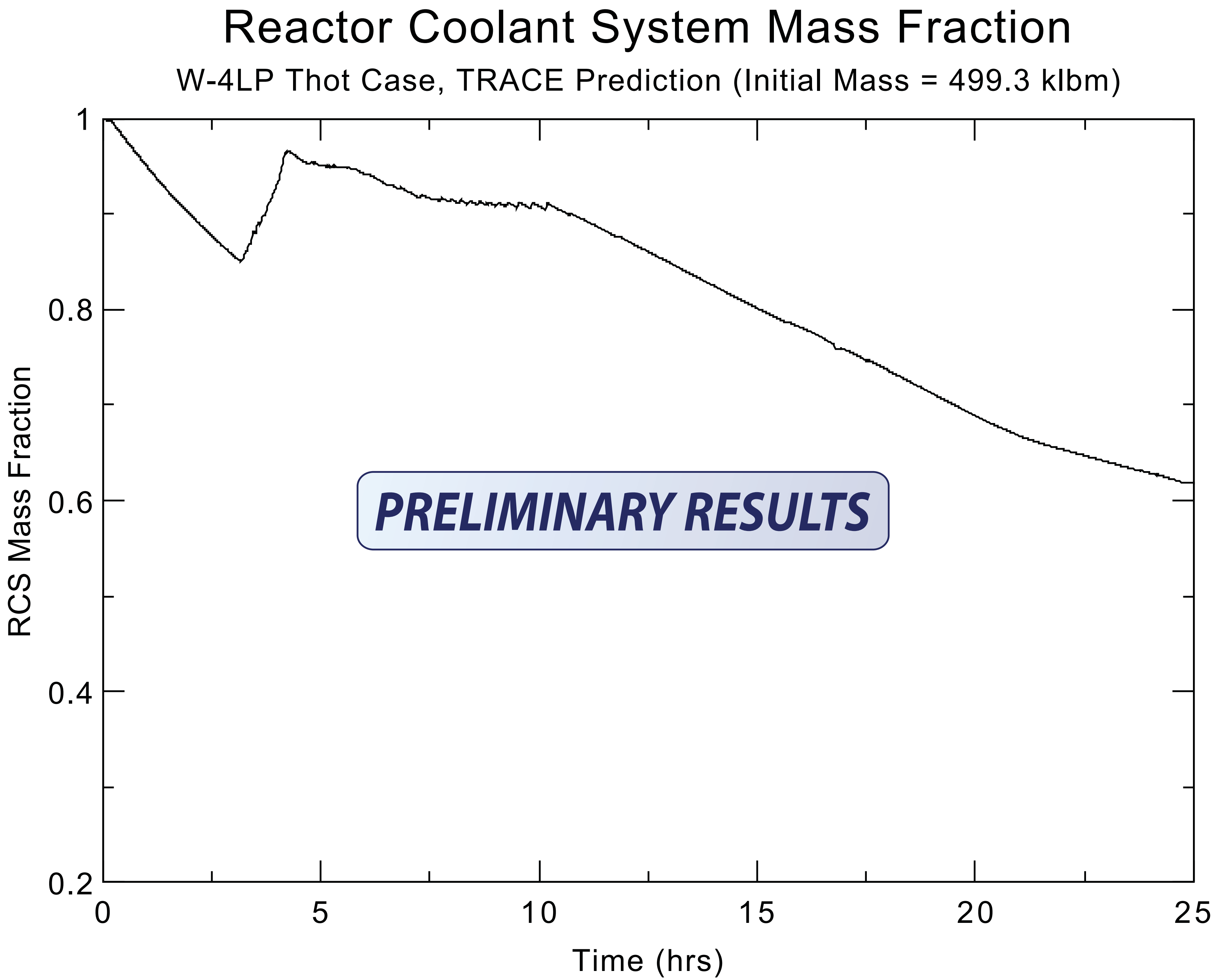
10. Overall model volume or volumes of the individual components (more preferable)
   Model component volumes applicable to preliminary results are tabulated below:

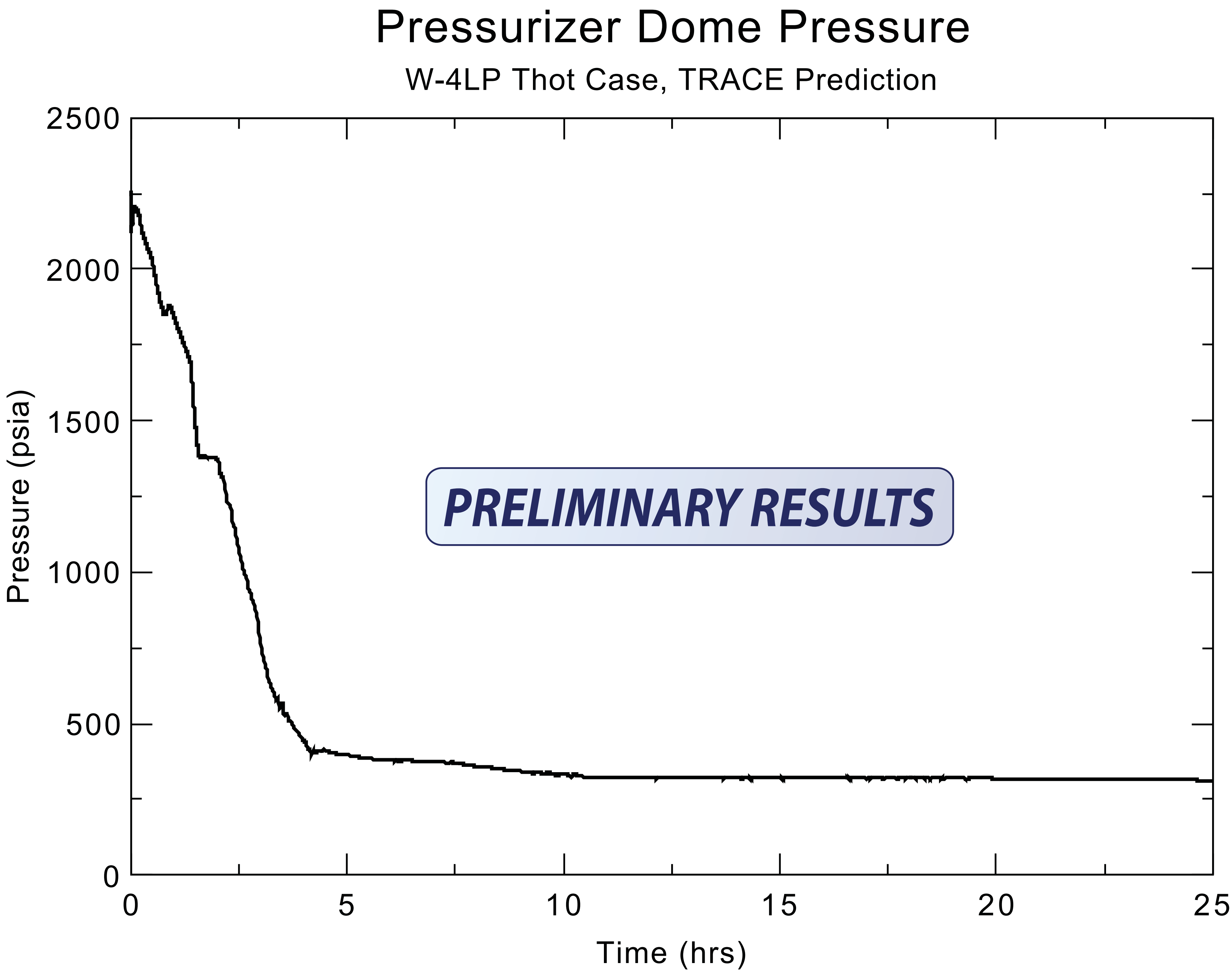
Component	*Volume (ft^3)*
Reactor pressure vessel, total	*4691*
RPV, above TAF	*2332*
RPV, core elevation	*1285*
RPV, below BAF	*1075*
Guide tubes	*261*
Pressurizer	*1800*
Surge line	*53*
The following component volumes are per loop:	
Hot leg	*100*
Steam Generator, inlet plenum	*142*
Steam Generator, tubes	*602*
Steam generator, outlet plenum	*142*
Intermediate leg	*145*
Reactor coolant pump	*80*
Cold leg	*98*
Accumulator piping downstream of check valve	*10*
Total reactor coolant system volume	*12088*

III. Figures

Figures 1 through 10, which plot key preliminary results from the NRC staff’s confirmatory analysis, are provided on the following pages.

Figures 1 through 6 respond to the PWROG’s information request. Figures 7 through 10 provide additional preliminary results showing the one-hour centered-time-average flow quality and liquid mass flow rate over the steam generator U-bend for the T_{hot} and T_{cold} simulations.


Reactor Coolant System Mass Fraction
W-4LP Thot Case, TRACE Prediction (Initial Mass = 499.3 klbm)
RCS Mass Fraction
1
0.8
0.6
0.4
0.2
0
5
10
15
20
25
Time (hrs)
PRELIMINARY RESULTS
Figure 1



Pressurizer Dome Pressure
W-4LP Thot Case, TRACE Prediction
2500
2000
1500
1000
500
0
Pressure (psia)
PRELIMINARY RESULTS
0
5
10
15
20
25
Time (hrs)

Figure 2

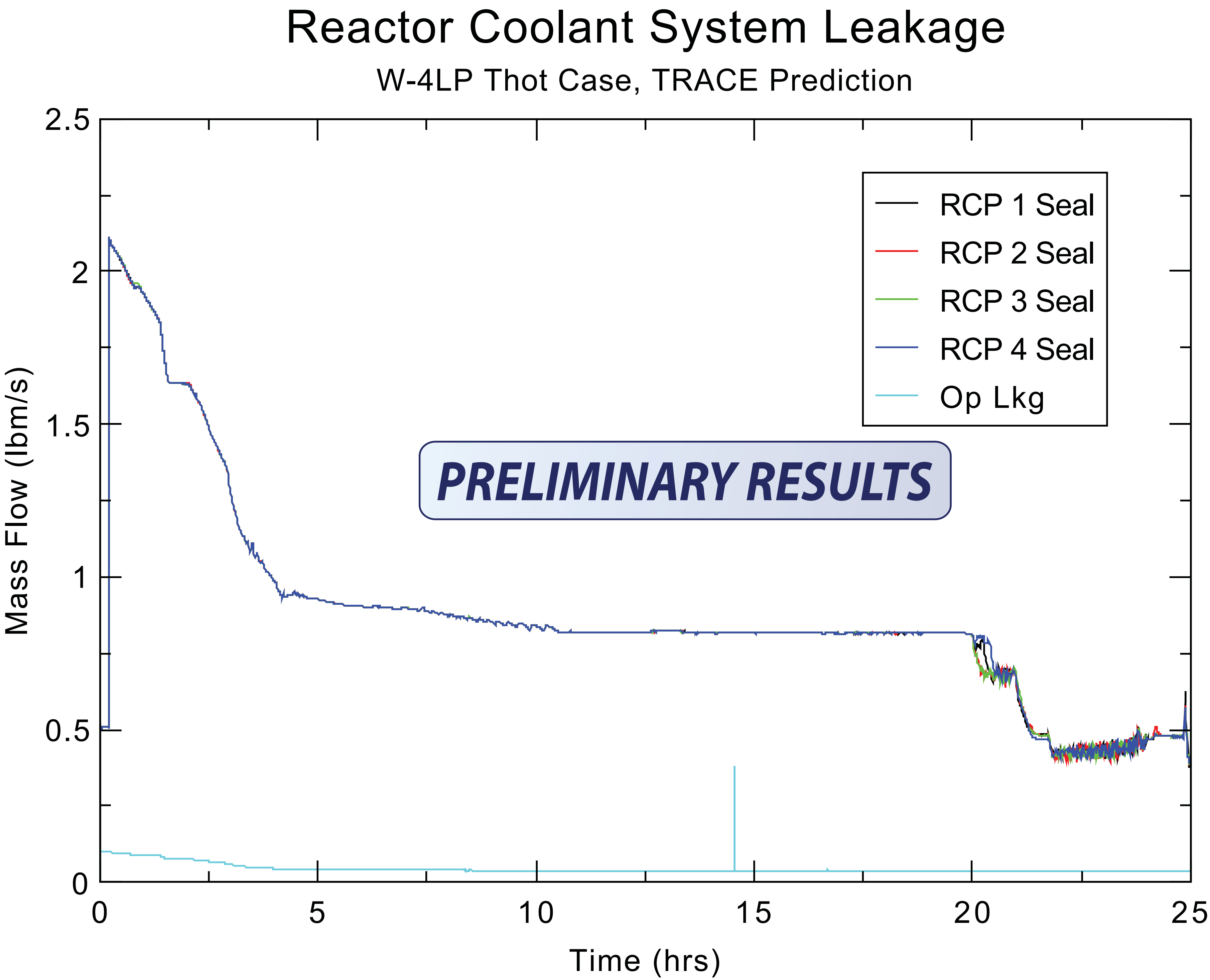

Reactor Coolant System Leakage
W-4LP Thot Case, TRACE Prediction
2.5
2
1.5
1
0.5
0
0
5
10
15
20
25
Mass Flow (lbm/s)
Time (hrs)
RCP 1 Seal
RCP 2 Seal
RCP 3 Seal
RCP 4 Seal
Op Lkg
PRELIMINARY RESULTS

Figure 3

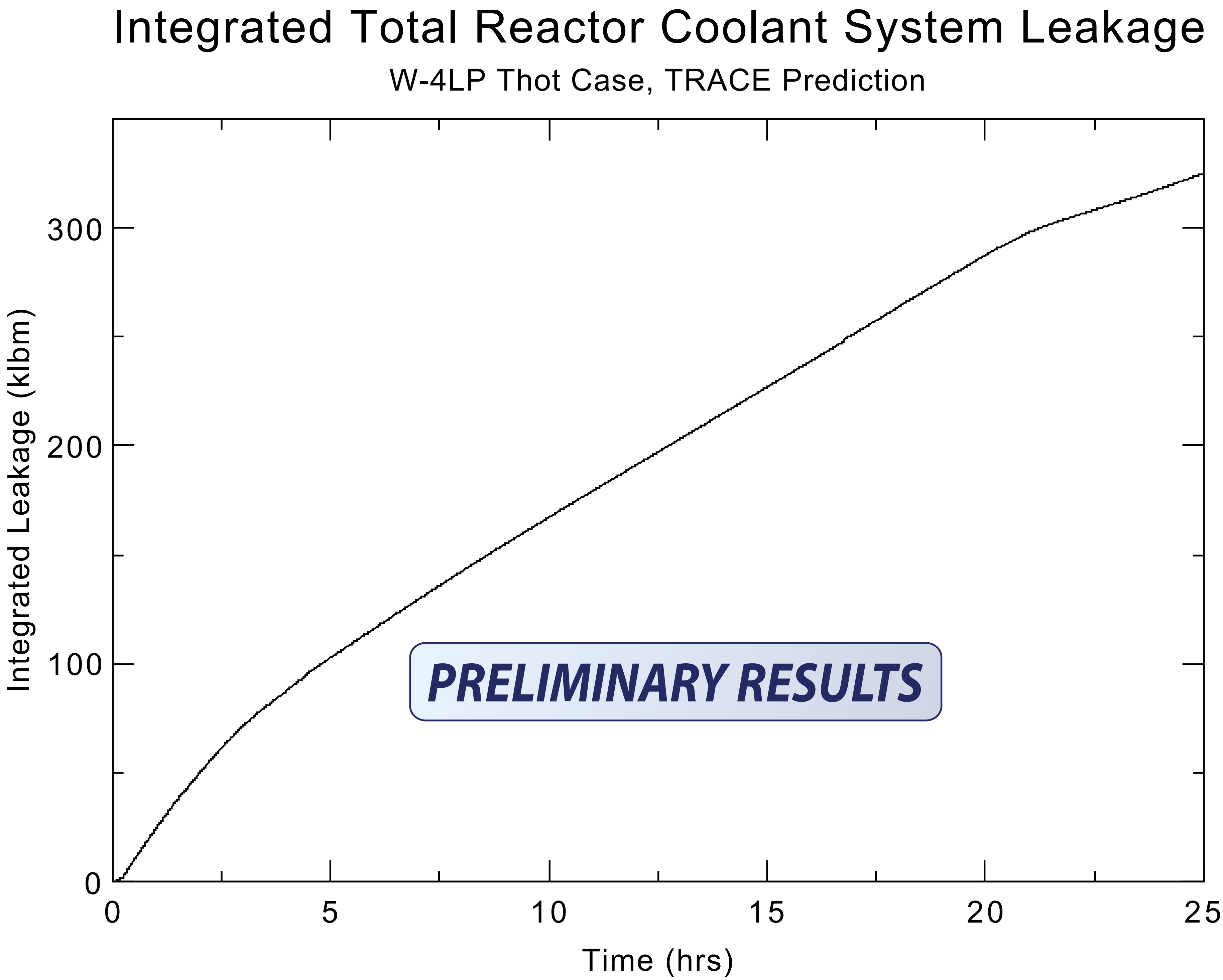

Integrated Total Reactor Coolant System Leakage
W-4LP Thot Case, TRACE Prediction
Integrated Leakage (klbm)
300
200
100
0
0
5
10
15
20
25
Time (hrs)
PRELIMINARY RESULTS

Figure 4

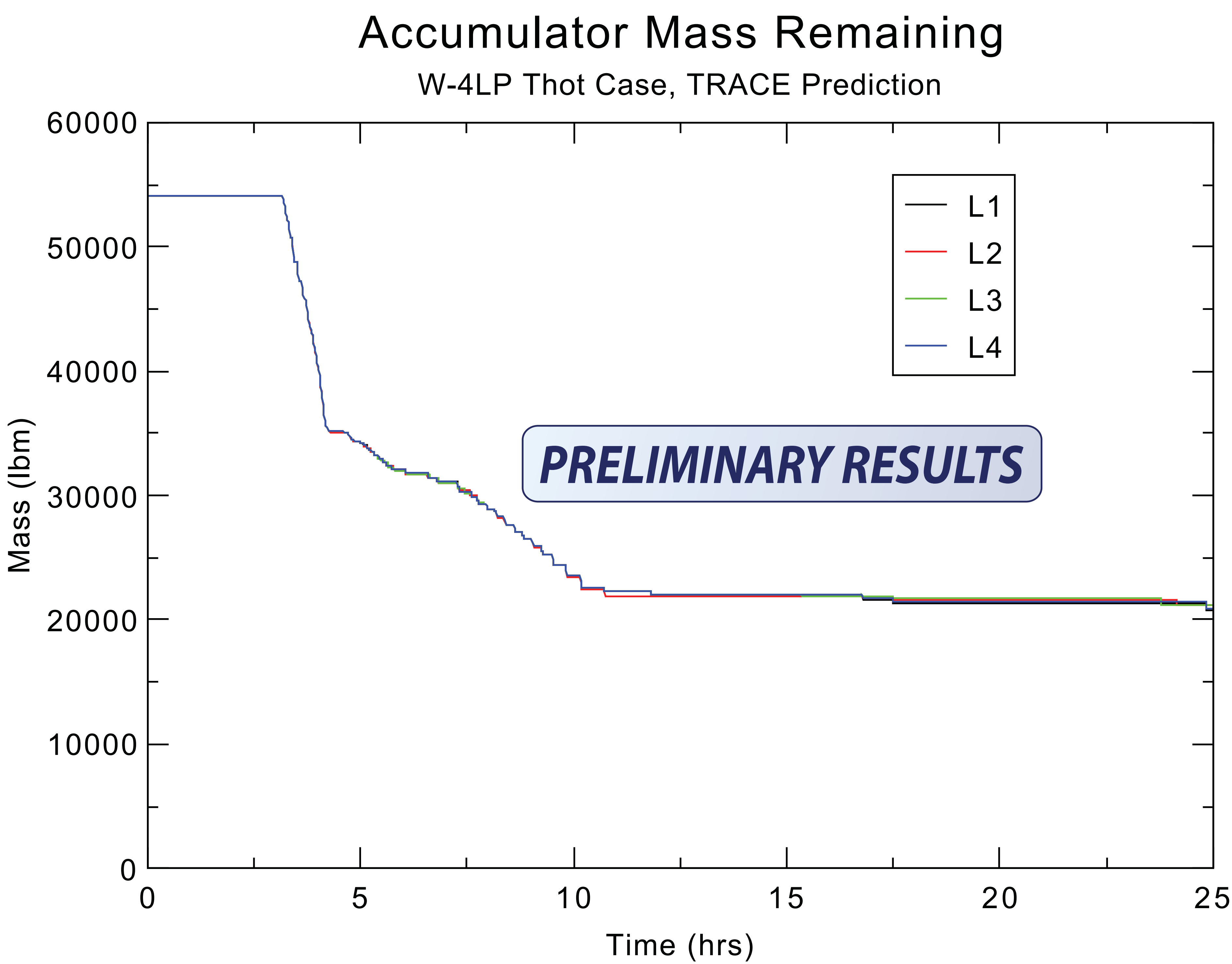

Accumulator Mass Remaining
W-4LP Thot Case, TRACE Prediction
60000
50000
40000
30000
20000
10000
0
0
5
10
15
20
25
Time (hrs)
Mass (lbm)
L1
L2
L3
L4
PRELIMINARY RESULTS

Figure 5

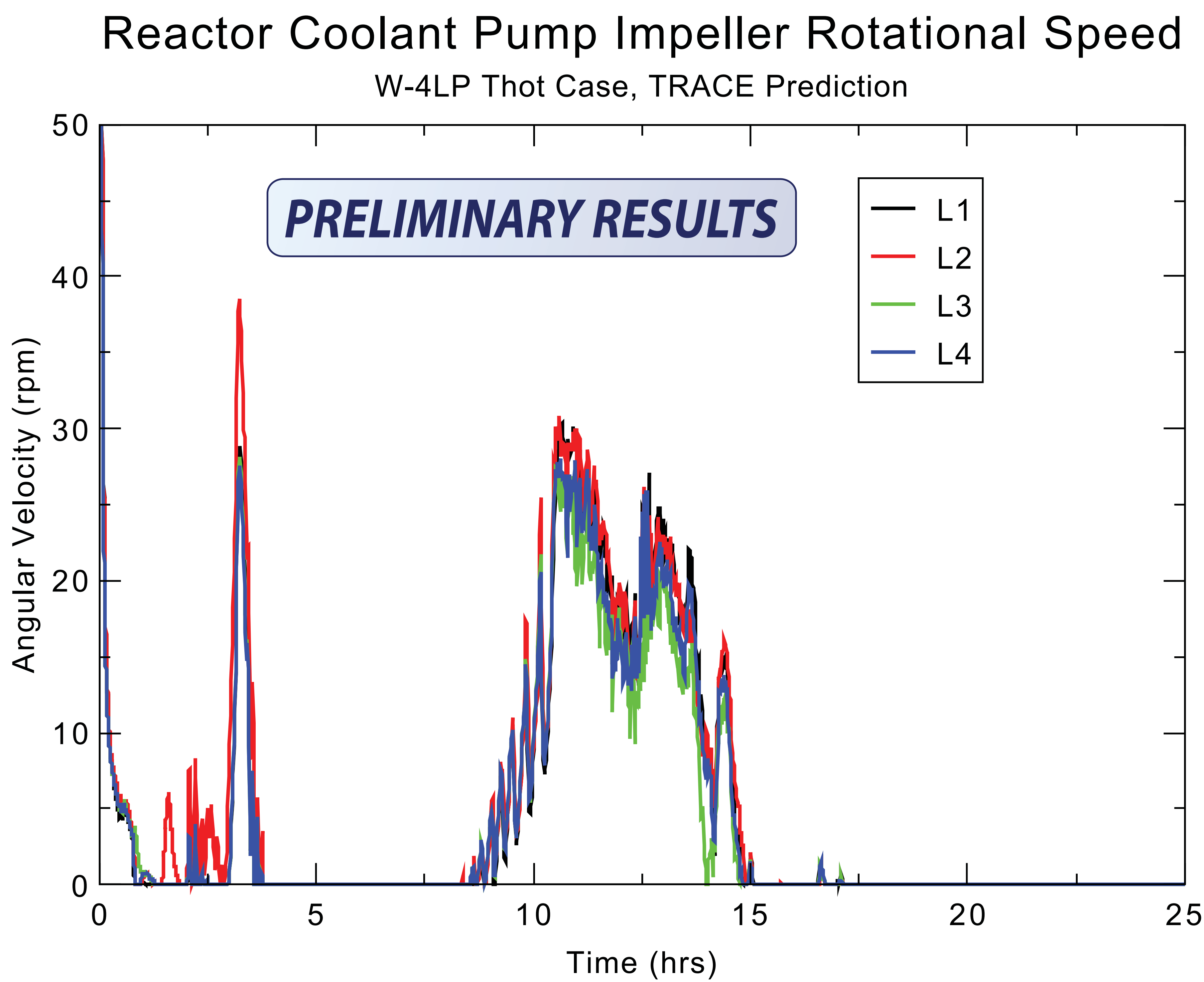

Reactor Coolant Pump Impeller Rotational Speed
W-4LP Thot Case, TRACE Prediction
PRELIMINARY RESULTS
L1
L2
L3
L4
Angular Velocity (rpm)
Time (hrs)
0
10
20
30
40
50
0
5
10
15
20
25

Figure 6

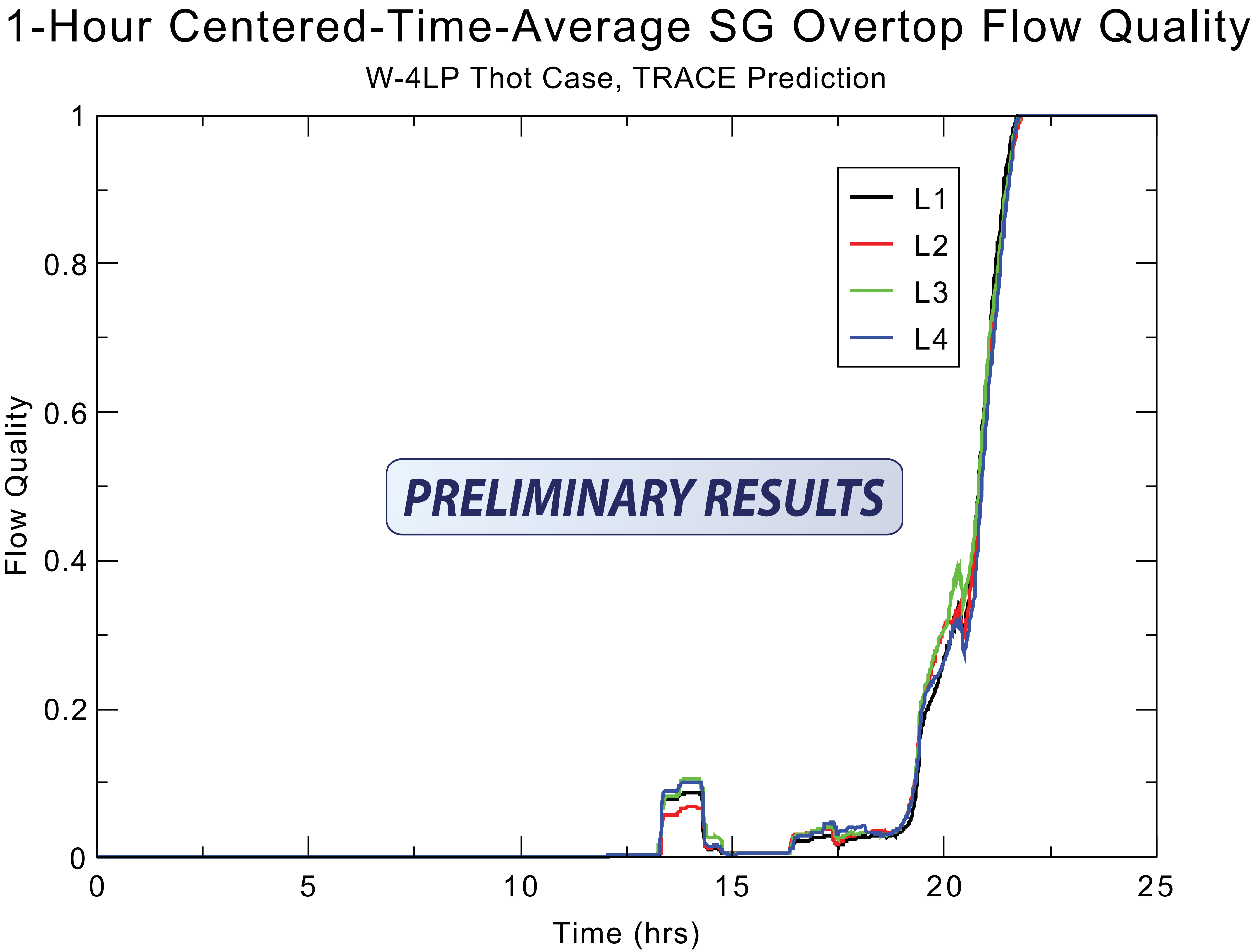

1-Hour Centered-Time-Average SG Overtop Flow Quality
W-4LP Thot Case, TRACE Prediction
L1
L2
L3
L4
PRELIMINARY RESULTS
Flow Quality
Time (hrs)
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25

Figure 7

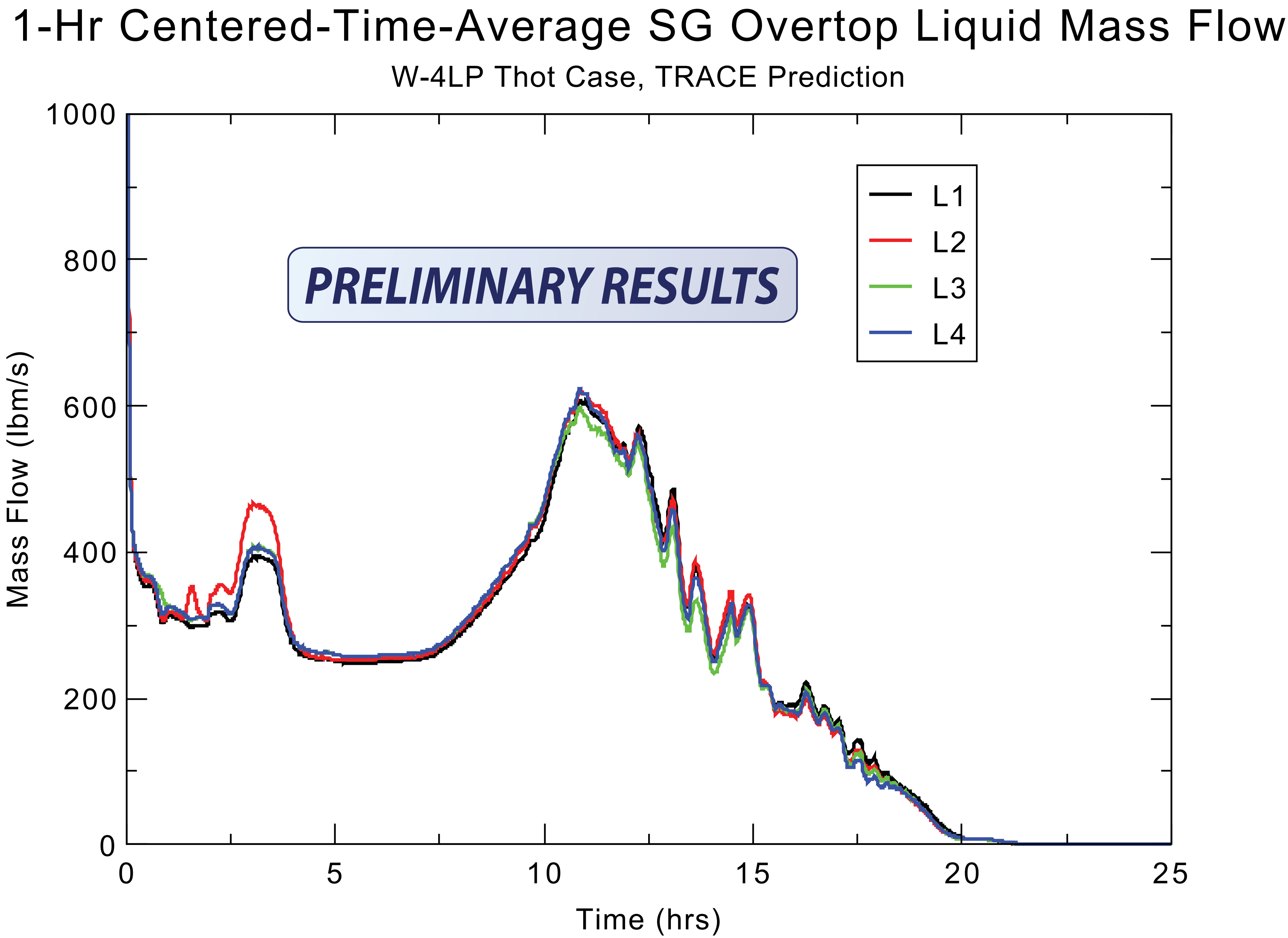
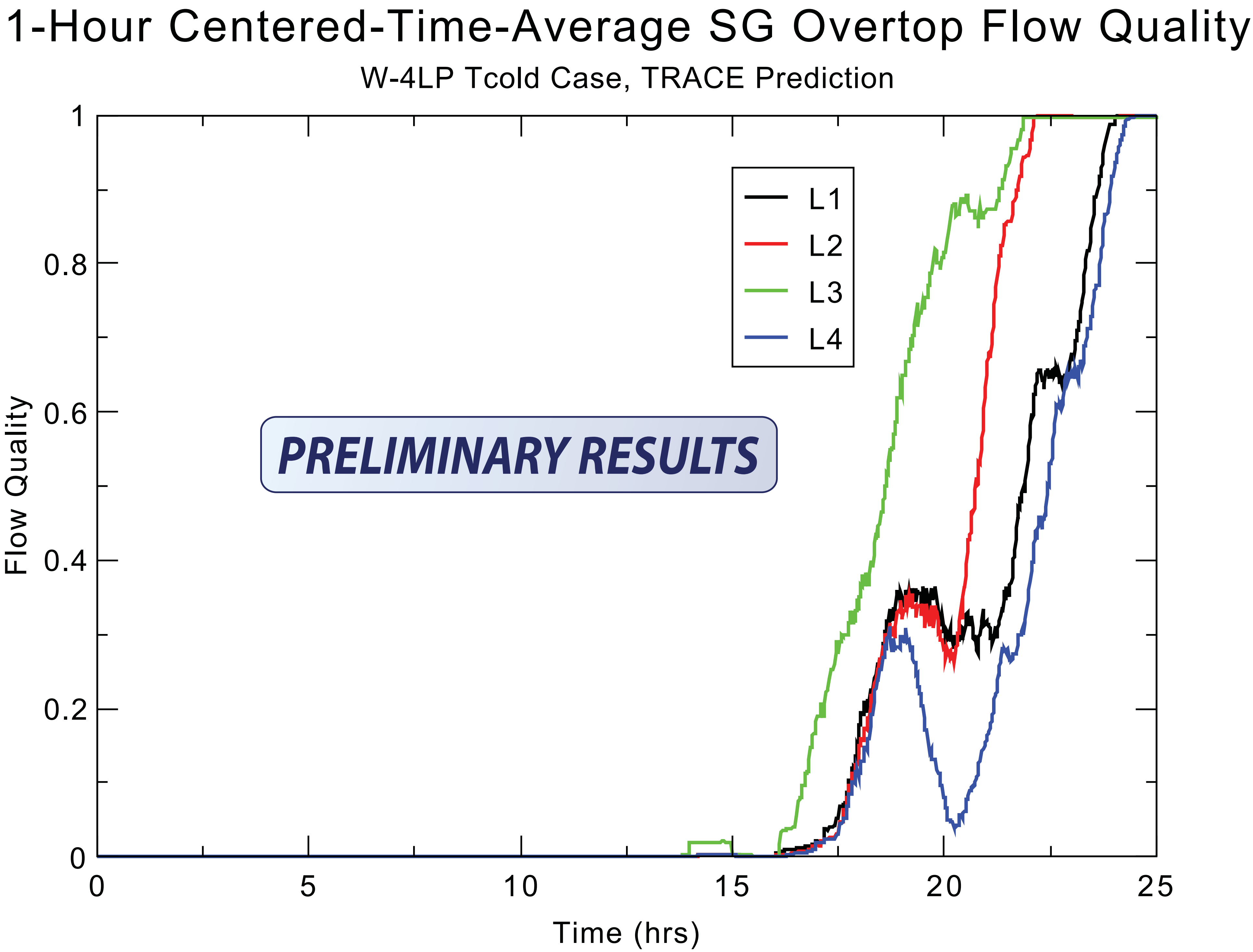
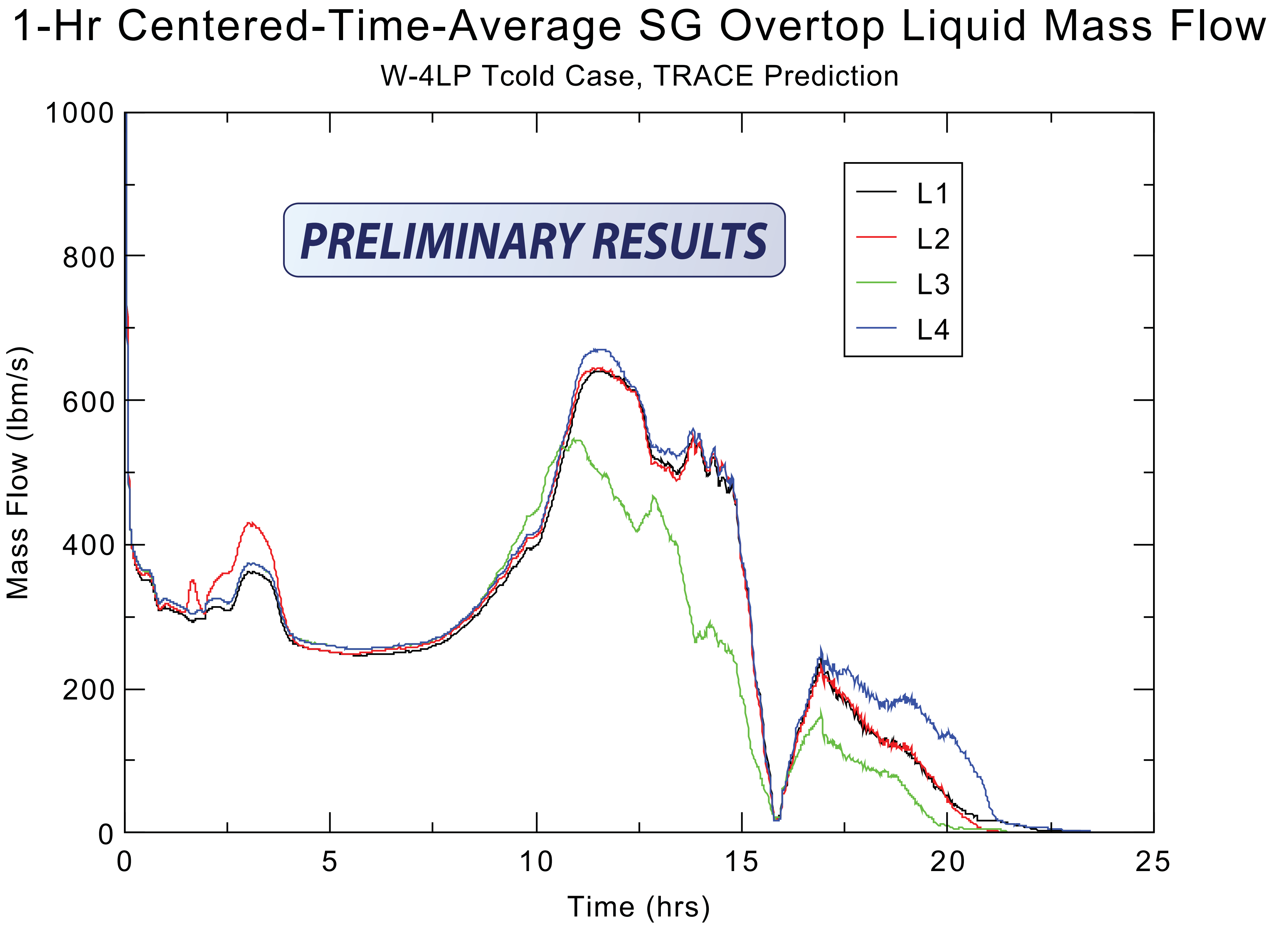

1-Hr Centered-Time-Average SG Overtop Liquid Mass Flow
W-4LP Thot Case, TRACE Prediction
PRELIMINARY RESULTS
L1
L2
L3
L4
Mass Flow (lbm/s)
Time (hrs)
0
200
400
600
800
1000
0
5
10
15
20
25

Figure 8



1-Hour Centered-Time-Average SG Overtop Flow Quality
W-4LP Tcold Case, TRACE Prediction
Flow Quality
Time (hrs)
L1
L2
L3
L4
PRELIMINARY RESULTS
0
0.2
0.4
0.6
0.8
1
0
5
10
15
20
25

Figure 9



1-Hr Centered-Time-Average SG Overtop Liquid Mass Flow
W-4LP Tcold Case, TRACE Prediction
PRELIMINARY RESULTS
L1
L2
L3
L4
Mass Flow (lbm/s)
Time (hrs)
0
200
400
600
800
1000
0
5
10
15
20
25

Figure 10