15E ATWS Performance Evaluation

15E.1 Introduction

Typical ATWS events are analyzed for ABWR to confirm the design for ABWR.

15E.2 Performance Requirements

The design should meet the following requirements:

(1) **Fuel Integrity—**The long-term core cooling capability shall be assured by meeting the cladding temperature and oxidation criteria of 10CFR50.46 (i.e., peak cladding temperature not exceeding 1204°C, and the local oxidation of the cladding not exceeding 17% of the total cladding thickness).

(2) **Containment Integrity—**The long-term containment capability shall be maintained. The maximum containment pressure shall not exceed the design pressure (0.310 MPaG) of the containment structure. The suppression pool temperature shall be limited to values shown in Table 15E-1.

(3) **Primary System—**The system transient pressure shall be limited such that the maximum primary stress within the reactor coolant pressure boundary (RCPB) does not exceed the emergency limits as defined in the ASME Code, Section III. If practical, the peak pressure should be limited to the upset limits in order to allow for more economical equipment design.

(4) **Long-Term Shutdown Cooling—**Subsequent to an ATWS event, the reactor shall be brought to a safe shutdown condition, and be cooled down and maintained in a cold shutdown condition.

These performance requirements are summarized in Table 15E-1.

15E.3 Analysis Conditions

Due to the extremely low probability of the occurrence of an ATWS, nominal parameters and initial conditions have been used in this analysis. Tables 15E-2 and 15E-3 list the initial conditions and equipment performance characteristics which are used in the analysis.

15E.4 ATWS Logic and Setpoints

The mitigation of ATWS events is accomplished by a multitude of equipment and procedures. These include ARI, FMCRD run-in, feedwater runback, RPT, recirculation runback, ADS inhibit, and SLCS. The logic of this ATWS mitigation is presented in Figures 15E-1a, 15E-1b and 15E-1c. The following are the initiation signals and setpoints for the above equipment responses:

(1) ARI and FMCRD run-in

- High pressure (7.76 MPaG), or
- Level 2

(2) SLCS initiation

- High pressure (7.76 MPaG), and SRNM ATWS permissive for 3 minutes, or
- Level 2 and SRNM ATWS permissive for 3 minutes, or
- Manual ARI/FMCRD run-in signals and SRNM ATWS permissive for 3 minutes.

(3) RPT (RIPs not connected to M/G set)*

- High pressure (7.76 MPaG)

(4) RPT (RIPs connected to M/G set)

- Level 2

(5) Recirculation runback (10%/second)

- Any scram signals, or
- Any ARI/FMCRD run-in signals

(6) Feedwater runback

- High pressure (7.76 MPaG), and SRNM ATWS permissive for 2 minutes

(7) ADS inhibit

- The APRM ATWS permissive signal is combined with a reactor water level signal (Level 1.5) such that ADS automatic initiation is inhibited unless both power and level are below their setpoints.

15E.5 Selection of Events

The following limiting events were selected to demonstrate the performance of the ATWS capabilities. They are grouped into three categories. The first category includes events which demonstrate ATWS mitigation on the most severe and limiting cases. The second category has events which are generally less severe for ATWS analysis but are analyzed to show the sensitivity of key ATWS parameters to these events. In each above case, the recirculation pump trip, ARI, electrical insertion of the control rod drives, boron injection and other ATWS

* Also tripped at Level 3, which is not a part of ATWS mitigation.

mitigation actions are assumed to occur on the appropriate signals. No operator action is assumed, unless specifically mentioned. The third category covers the cases which have only minor impact to the reactor vessel containment. They are discussed briefly to support the assumption that they do not significantly influence the design of ATWS mitigation. No analysis was performed for events in the third category.

Category 1. Limiting Events

(1) Main Steam Isolation Valve (MSIV) Closure

Generic studies have shown that this transient produced high neutron flux, heat flux, vessel pressure, and suppression pool temperature. The maximum values from this event are, in most cases, bounding of all events considered.

(2) Loss of Normal AC Power

This transient is less severe than the MSIV closure in terms of vessel pressure, heat flux, neutron flux, and suppression pool temperature. However, because the loss of power to the condensate and feedwater pumps causes the feedwater flow to cease, very low vessel water levels are expected. Thus, the capability of the ECCS to recover the water level will be tested.

(3) Loss of Feedwater

This transient is less severe than the above two events. However, it is the only event which is mitigated by ARI, FMCRD run-in, or boron injection, initiated from the low level signals. Thus, this event is analyzed to show that the low level trips are capable of mitigating the event.

(4) Loss of Feedwater Heater

This transient is very mild, as the increase of neutron flux never reaches the scram setpoint. The reactor shutdown is initiated by operator action. The main concern is that peak linear heat generation rate may exceed performance criteria when FMCRD run-in is initiated. The analysis is to show that the recirculation runback can mitigate this event.

Category 2. Moderate Impact Events

(5) Turbine Trip with Bypass Valves Open

This transient usually produces higher neutron flux than the MSIV closure event due to the fast closure of the turbine stop valves. However, the availability of the main condenser significantly reduces the amount of steam discharged into the suppression pool.

(6) Loss of Condenser Vacuum

The initial transient behavior of this event is similar to that of a turbine trip, as the reduction of vacuum in the main condenser initiates turbine stop valve closure. When the isolation setpoint is reached, the MSIVs start to close. The event follows the pattern of MSIV closure in suppression pool temperature and containment pressure.

(7) Feedwater Controller Failure at Maximum Demand

This transient produces peak values of key parameters similar to those of a turbine trip case. The availability of the main condenser significantly reduces the load of suppression pool from steam discharge from SRVs.

Category 3. Minimum Impact Events

(8) Recirculation Flow Controller Failure at Maximum Demand

This transient is not severe enough to trip any ATWS logic nor initiate HPCF or RCIC flow. It is considerably milder than the MSIV closure or turbine trip ATWS cases. This is a short-term transient with sudden power rise and relatively small pressure increase. The entire transient is over within 30 seconds, by which time the reactor settles out to a new equilibrium condition of less than 100% rated power. Since the peak pressure stays below the lowest SRV setpoint, steam flow discharge to the suppression pool does not take place.

The transient is not severe enough to trip the ATWS logic or initiate HPCF or RCIC flow, because the feedwater and level control is maintained. Manual ARI/FMCRD run-in has to be initiated by operator in case manual scram fails. The success of ARI or FMCRD run-in with recirculation runback can bring the reactor to hot shutdown just like normal scram. If control rods fail to insert after operator action, the boron injection would bring the reactor to hot shutdown.

(9) Startup of the Idle Recirculation Pump

The abnormal startup of an idle recirculation pump requires the inverter to provide electric current much higher than normal to counter the much higher reverse flow. This overcurrent requirement activates the overcurrent protection logic of the electric bus which supplies the power to the idle RIP. This electric bus is tripped by the protection logic. Consequently, the other RIPs powered by this electric bus are also tripped. Therefore, this event is similar to the trip of three recirculation pump events. Since the scram is never initiated and there is no steam discharged into the suppression pool, there is no impact to the ATWS mitigation design. Therefore, further transient-specific analyses have not been done.

(10) Inadvertent Opening of All Bypass Valves

This event initiates a gradual decrease of the vessel pressure and power. It is followed by a rapid rise of pressure and power after the closure of MSIV on low steamline pressure. The characteristics of the remaining portion of this transient are very much the same as the MSIV closure event, except it starts at a much lower initial power level. The steam discharged into the containment is much less than that in the MSIV closure event. The same conclusion is also true for other key parameters.

(11) Shutdown Cooling (RHR) Malfunction–Decreasing Temperature

This event can only occur at very low pressure. The shutoff head of the shutdown cooling pumps is less than 2.07 MPaG. In this condition, the reactor has almost no voids in it and therefore little, if any, positive reactivity is inserted. Hence, this event is not considered further.

All transient analyses, unless otherwise specified, were performed with the BISON code.

15E.6 Transient Responses

For every event selected for analysis, three cases were analyzed. The first one shows the ATWS performance with ARI. This case is intended to show the effectiveness of the ARI design. The second case, which uses FMCRD run-in, assuming a total failure of ARI, was performed to show the backup capability of FMCRD run-in. The third case was analyzed to show the in-depth ATWS mitigation capability of the ABWR. In this case, both ARI and FMCRD run-in are assumed to fail. Automatic boron injection with a 180-second delay is relied upon to mitigate the transient event.

If the ARI and FMCRD run-in fail at the same time, which has extremely low probability of occurrence, the peak reactor pressure would still be controlled by the recirculation runback and relief valves. However, the nuclear shutdown will then rely on the automatic SLCS injection. The boron would reach the core 60 seconds after the initiation. The operation of both SLCS pumps generates a 6.31 E-3 m^3/s volumetric flow rate of sodium pentaborate. The nuclear shutdown would begin when boron reaches the core.

15E.6.1 Main Steam Isolation Valve Closure

This transient is considered an initiating event caused by either operator action or instrument failure. Scram signal paths that are assumed to fail include valve position, high neutron flux high vessel pressure, and all manual attempts. A short time after the MSIVs have closed completely, the ATWS high pressure setpoint is reached, which initiates four of the ten recirculation pumps to trip and the rest start to runback. The combined effect of the trip and runback reduces the core flow and increases core voids, thereby reducing power generation which limits pressure increase and steam discharge to the suppression pool. The ATWS high pressure signal causes the actuation of the ARI and the electric insertion of the FMCRD. The insertion of the control rods is successful in bringing the reactor to hot shutdown. Key timeline events and peak values of key parameters are shown in Table 15E-4 for the ARI case and Table

15E-5 for the FMCRD run-in case. In the case that control rods fail to insert, the reactor will be brought to hot shutdown by automatic boron injection in about 17 minutes from the beginning of the event. The transient behavior of this case is listed in Table 15E-6. The reactor system response is presented by Figure 15E-2 for ARI activated, Figure 15E-3 for FMCRD run-in case and Figure 15E-4 as SLCS operating, respectively. The increase of the local power is not expected to damage the fuel. Therefore, the performance criteria are met.

15E.6.2 Loss of AC Power

In this event, all scram signal paths, including valve position, high flux, high pressure, low level, and all manual attempts have been assumed to fail.

The loss of AC power has the following effects:

(1) An immediate load rejection will occur. This will cause the turbine control valves to close.

(2) As a result of the load rejection, four of the ten recirculation pumps will trip.

(3) Due to the loss of power to the condensate pumps, feedwater will be lost.

(4) The reactor will be isolated after loss of main condenser vacuum.

Figure 15E-6 shows the transient behavior under ARI activation, Figure 15E-7 for FMCRD run-in and Figure 15E-8 for automatic SLCS, respectively.

The fast closure of the turbine control valves causes a rapid increase of pressure, and the ATWS high pressure setpoint is reached shortly after the control valves have closed. Because the four pumps have already tripped at this time on the load rejection signal, only six remaining pumps will start runback. The ATWS high pressure signal initiates the rod insertion. The rod insertions are successful in bringing the reactor to hot shutdown. If both modes of rod insertion fail, the ATWS high pressure signal also initiates the timer for SLCS. After confirming the rod insertion failure by monitoring the high pressure and SRNM ATWS permissive signal for 3 minutes, the reactor is brought to hot shutdown when enough boron concentration is built up in the reactor core.

Tables 15E-7 to 15E-9 show the key timeline events and a summary of peak values of key parameters for the three events.

15E.6.3 Loss of Feedwater

This event does not have rapid excursions, as in some of the other events, but is a long-term power reduction and depressurization. Since the pressure begins to fall at the onset of the transient, the need for relief valves does not arise until isolation occurs very late in the event and only single valve cycling is expected to handle decay heat. The containment limits are not approached.

In this event all feedwater flow is assumed to be lost in about six seconds.
Figure 15E-9 shows the transient behavior for ARI activated. Figure 15E-10 represents FMCRD run-in event. The mitigation of this event by SLCS is illustrated in Figure 15E-11.

After the loss of feedwater has taken place, the pressure, water level and neutron flux begin to fall. At around 10 seconds, low water (L3) is reached. This trips four recirculation pumps. At about 29 seconds, low water (L2) is also reached. This trips remaining recirculation pumps, activates ARI, FMCRD run-in, starts SLCS clock, and initiates RCIC. Successful insertion of control rods brings the reactor to hot shutdown. Failure of rod insertion will initiate SLCS upon the timer run-up while the SRNM ATWS permissive signal is present. At about 17 minutes, the reactor becomes hot shutdown as the boron concentration reaches sufficient value.
Tables 15E-10 to 15E-12 show the key timeline events and a summary of peak values of key parameters for the three cases.

15E.6.4 Loss of Feedwater Heating

This transient does not trip any automatic ATWS logic. ARI, FMCRD run-in, and SLCS timer are assumed to be initiated by operator at about 10 minutes after the beginning of this event. At this time, the reactor has settled in a new steady state at a higher power level. There is no steam discharge to the suppression pool because of the relatively low vessel pressure. Figure 15E-12 shows the transient behavior for ARI, Figure 15E-13 for FMCRD run-in and Figure 15E-14 for SLCS case, respectively. Upon the failure of rod insertion, the SLCS can bring the reactor to hot shutdown at about 27 minutes.

The mild nature of this transient forestalls any significant peak values for the key parameters normally associated with ATWS study. However, the slow insertion rate of FMCRD run-in allows the reactor to reestablish quasi-steady axial power shape. The peak value of these new profiles, which were calculated by the POLCA code, are shown in Figure 15E-15. The peak cladding temperature does not exceed the coolable geometry criteria. Figure 15E-16 presents the normalized axial power shape change during the event. Table 15E-13 shows the key timeline events and a summary of the peak values of the key parameters for FMCRD run-in case. The same peak values apply to ARI and SLCS cases as well.

15E.6.5 Turbine Trip with Bypass

The initial characteristics of this transient are much like the MSIV closure described in Section 15E.6.1 with rapid steam shutoff. Pressure and power increases are limited by the action of the relief valves and RPT/recirculation runback. As this event progresses, however, the availability of the main condenser makes it possible for the relief valves to be closed sooner, which terminates the steam discharge to the suppression pool. Figure 15E-17 shows the transient behavior for ARI, Figure 15E-18 for FMCRD run-in and Figure 15E-19 for SLCS cases, respectively.

The closure of the turbine stop valves causes a rapid increase of pressure; the ATWS high pressure setpoint is reached shortly after the closure. The high pressure initiates four of the

recirculation pumps to trip and the rest to start runback, initiates ARI, FMCRD run-in and SLCS timer. Upon successful insertion of the control rods, the reactor achieves hot shutdown. If the rods fail to insert into the core, the SLCS will be initiated by the SRNM ATWS permissive signal and the high pressure signal when the timer runs up. In this case, the hot shutdown is reached at about 17 minutes after the start of the event. Tables 15E-14 to 15E-16 show key timeline events and summary of peak values of key parameters for these events.

15E.6.6 Loss of Condenser Vacuum

This transient starts with a turbine trip because of the low condenser vacuum; therefore, the beginning is the same as the turbine trip event (Section 15E.6.5). However, the MSIVs and turbine bypass valves also close after the condenser vacuum has further dropped to their closure setpoints, and relief valve cycling increases considerably compared to the original turbine trip case. Hence, this event is similar to the turbine trip event as far as the peak power and pressure characteristics are concerned and similar to the MSIV closure case with respect to suppression pool temperature and pressure. Figure 15E-20 shows the transient behavior for ARI event, Figures 15E-21 for FMCRD run-in case and Figure 15E-22f or SLCS condition, respectively. The high pressure ATWS setpoint is reached shortly after the closure of turbine stop valves. The high pressure initiates trip for four of the ten RIPs and runback of the other six. It starts ARI, FMCRD run-in and SLCS timer. A successful insertion of control rods brings the reactor to hot shutdown. Otherwise, the injection of boron is initiated upon SRNM ATWS permissive and high pressure signals. As the poison reaches sufficient concentration in the core, the reactor achieves hot shutdown in about 17 minutes after the start of the event. Tables 15E-17 to 15E-19 show the key timeline and a summary of peak values of key parameters for these events.

15E.6.7 Feedwater Controller Failure

The initial portion of this transient results in a gradual power increase, then a sharp pressure rise and power peak as the turbine stop valves close at high water level. The long-term segment of this transient is similar to that of turbine trip with bypass valves operating. The discharge of steam into the suppression pool is minimized by the availability of the main condenser and turbine bypass valves. Figure 15E-23 shows the transient behavior for ARI, Figure 15E-24 in FMCRD run-in and Figures 15E-25 for SLCS case, respectively.

The closure of the turbine stop valves starts a rapid increase of pressure. The ATWS high pressure setpoint is reached shortly after the valve closure. The high pressure trips four of the ten recirculation pumps and starts runback of the other six, and initiates ARI, FMCRD run-in, and SLCS timer. The reactor reaches hot shutdown once the control rods complete the insertion into the core. If the rod insertion fails, the initiation of SLCS is confirmed by the SRNM ATWS permissive signal and the hot shutdown is achieved at about 17 minutes after the start of the event. Tables 15E-20 to 15E-22 show the key timeline events and a summary of peak values of key parameters for these events.

15E.7 Conclusion

Based upon the results of this analysis, the proposed ATWS design for the ABWR is satisfactory in mitigating the consequences of an ATWS. All performance criteria specified in Section 15E.2 are met.

It is also concluded from results of the above analysis that automatic boron injection could mitigate the most limiting ATWS event with margin (at least 0.108 MPa margin in peak containment pressure). Therefore, an automatic SLCS injection as a backup for ATWS mitigation is acceptable.

15E.8 Reference

None

Table 15E-1 Performance Requirements

	RPV Peak Pressure	Maximum Pool Temperature	Fuel Integrity	Maximum Containment Pressure
ARI/RPT	10.34 MPaG	100°C*	Coolable Geometry	0.310 MPaG
FMCRD/RPT	10.34 MPaG	100°C*	Coolable Geometry	0.310 MPaG
Boron/RPT	10.34 MPaG	Containment Design Pressure	Coolable Geometry	0.310 MPaG

* 100°C pool temperature should not be reached before the reactor reaches the hot shutdown condition.

Table 15E-2 Initial Operating Conditions

Parameters	Value
Dome Pressure (MPaG)	7.07
Core Flow (Mkg/hr)/(% NBR)	47/90
Vessel Diameter (m)	7.06
Numbers of Fuel Bundles	872
Power (MWt)/(% NBR)	3926/100
Steam/Feed Flow (kg/sec)/(% NBR)	2124/100
Feedwater Temperature (°C)	215.6
Suppression Pool Volume (m^3)/ (Full NBR FW Flow-Min)	3580/27.9
Initial Suppression Pool Temperature (°C)	35
Condensate Storage Temperature (°C)	48.9

Table 15E-3 Equipment Performance Characteristics

Parameters	Value
Closure Time of MSIV (s)	3.0
Relief Valve System Capacity (% NBR Steam Flow)/No. of Valves	89.7 at 1st setpoint/18
Relief Valve Setpoint Range (MPaG)	7.89/8.24
Relief Valve Opening Time (s)	0.15
Relief Valve Closure Setpoint (% of setpoint)	98
Relief Valve Closure Time Delay (s)	0.0
Relief Valve Closure Time Constant (s)	0.0
RCIC Low Water Level Initiation Setpoint	Level 2
HPCF Low Water Level Initiation Setpoint	Level 1.5
HPCF Start Time (s)	20
HPCF/RCIC High Water Level Shutoff Setpoint*	Level 8
Number of HPCF Pumps	2
HPCF Flow Rate per Pump† (kg/s)/(% NBR Steam Flow)	50.4/2.37
RCIC Start Time (s)	≥ 29
RCIC Flow Rate (kg/s)/(% NBR Steam Flow)	50.4/2.37
ATWS Dome Pressure Sensor Time Constant (s)	0.5
ATWS Logic Time Delay (s)	0.3
Recirculation Pump System Inertia (kg-m^2)	21.5
Delay Before Start of Electrohydraulic Rod Insertion (with/without offsite power)(s)	1.0/39.0
Electrohydraulic Control Rod Insertion Time (s)	135
ARI Rod Insertion Time (s)	25
RHR Pool Cooling Capacity (MJ/s/°C)/(NBR at 38°C ΔT)	1.28/1.24
RHR SP Cooling Auto Start Temperature (°C)	37.7
Water Level Setpoint Above Which RHR Pool Cooling Is Allowed	Level 1
Setpoint for Low Water Level Closure of MSIV	Level 1.5
Setpoint for Low Steamline Pressure Closure of MSIV (MPaG)	5.17

* HPCF and RCIC high level shutoff is independent of drywell pressure for ATWS mitigation. Automatic reset is required so restart will automatically occur if level returns below the level setpoint. Manual action to control level in the normal range is preferred rather than automatic cycling between L8/L2 during the post-hot shutdown phase of any ATWS event.

† The nominal flow versus pressure head curve is used. The value given for ABWR is at 8.12 MPaG.

Table 15E-4a MSIV Closure Summary (ARI)

Time (s)	Event
0.00	Simulation starts
1.00	MSIVs start to close
3.03	Maximum APRM (193 %)
3.46	RPT of 4 RIPs activated on low water level L3
3.47	Opening of Relief and Safety valves at the setpoints
3.82	ARI activated on high pressure (7.86 MPaA)
4.00	MSIVs are fully closed
4.82	Recirculation runback of 6 RIPs activated on ARI signal
4.90	Maximum Vessel Bottom Pressure (8.96 MPaA)
28.8	Control rods are fully inserted

Table 15E-4b MSIV Closure Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	193	3.0 s
Maximum Vessel Bottom Pressure (MPaG)	8.86	4.9 s
Maximum Average Heat Flux (%)	131	3.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	73.0	230 min
Associated Containment Pressure (MPaG)	0.027	230 min
Peak Cladding Temperature (°C)	566	7.7 s

Table 15E-5a MSIV Closure Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
1.00	MSIVs start to close
3.05	Maximum APRM (193 %)
3.46	RPT of 4 RIPs activated on low water level L3
3.47	Opening of Relief and Safety valves at the setpoints
4.00	MSIVs are fully closed
4.82	FMCRD Run-in activated on high pressure (7.86 MPaA)
5.05	Maximum Vessel Bottom Pressure (8.96 MPaA)
5.82	Recirculation runback of 6 RIPs activated on FMCRD Run-in signal
124	Feedwater pumps are tripped on high pressure and SRNM ATWS permissive for 2 minutes
140	Control rods are fully inserted

Table 15E-5b MSIV Closure Summary (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	193	3.0 s
Maximum Vessel Bottom Pressure (MPaG)	8.86	5.1 s
Maximum Average Heat Flux (%)	133	3.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	76.5	190 min
Associated Containment Pressure (MPaG)	0.032	190 min
Peak Cladding Temperature (°C)	566	5.4 s

Table 15E-6a MSIV Closure Summary (Boron Injection)

Time (s)	Event
0.00	Simulation starts
1.00	MSIVs start to close
3.05	Maximum APRM (193 %)
3.46	RPT of 4 RIPs activated on low water level L3
3.47	Opening of Relief and Safety valves at the setpoints
4.00	MSIVs are fully closed
5.05	Maximum Vessel Bottom Pressure (8.96 MPaA)
124	Feedwater pumps are tripped on high pressure and SRNM ATWS permissive for 2 minutes
161	RPT of 6 RIPs activated on low water level L2
190	RCIC starts to inject water due to low water level L2 after a delay of 29 s
204	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
244	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-6b MSIV Closure Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	193	3.0 s
Maximum Vessel Bottom Pressure (MPaG)	8.86	5.1 s
Maximum Average Heat Flux (%)	131	3.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	88.6	60 min
Associated Containment Pressure (MPaG)	0.042	60 min
Peak Cladding Temperature (°C)	566	5.4 s

Table 15E-7a Loss of AC Power Summary (ARI)

Time (s)	Event
0.00	Simulation starts
1.00	Postulated Loss of AC power
1.00	Feedwater lost due to loss of AC power to condensate pumps
1.00	Load Rejection occurs on loss of AC power (fast TCV closure)
1.00	All RIPs are tripped due to Loss of AC power: - 6 RIPs are connected M/G sets - 4 RIPs are tripped instantaneously due to loss of AC power
1.08	TCVs are fully closed
1.54	Maximum APRM (118 %)
3.26	ARI activated on high pressure (7.86 MPaA)
3.34	Opening of Relief and Safety valves at the setpoints
7.00	TBVs close after 6 seconds from the loss of AC power
8.34	Maximum Vessel Bottom Pressure (8.52 MPaA)
28.3	Control rods are fully inserted
29.0	MSIV closure due to loss of main condenser vacuum
32.0	MSIVs are fully closed

Table 15E-7b Loss of AC Power Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	118	1.5 s
Maximum Vessel Bottom Pressure (MPaG)	8.42	8.3 s
Maximum Average Heat Flux (%)	101	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	69.3	310 min
Associated Containment Pressure (MPaG)	0.023	310 min
Peak Cladding Temperature (°C)	466	6.2 s

Table 15E-8a Loss of AC Power Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
1.00	Postulated Loss of AC power
1.00	Feedwater lost due to loss of AC power to condensate pumps
1.00	Load Rejection occurs on loss of AC power (fast TCV closure)
1.00	All RIPs are tripped due to Loss of AC power: - 6 RIPs are connected M/G sets - 4 RIPs are tripped instantaneously due to loss of AC power
1.08	TCVs are fully closed
1.54	Maximum APRM (118 %)
3.26	FMCRD Run-in activated on high pressure (7.86 MPaA)
3.34	Opening of Relief and Safety valves at the setpoints
7.00	TBVs close after 6 seconds from the loss of AC power
8.34	Maximum Vessel Bottom Pressure (8.52 MPaA)
29.0	MSIV closure due to loss of main condenser vacuum
32.0	MSIVs are fully closed
42.3	Control rods start to move after the delay of 39 s due to the unavailable AC power
60.9	RCIC starts to inject water due to low water level L2 after a delay of 29 s
75.5	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
177	Control rods are fully inserted

Table 15E-8b Loss of AC Power Summary (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	118	1.5 s
Maximum Vessel Bottom Pressure (MPaG)	8.42	8.38 s
Maximum Average Heat Flux (%)	101	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	70.0	300 min
Associated Containment Pressure (MPaG)	0.023	300 min
Peak Cladding Temperature (°C)	466	6.2 s

Table 15E-9a Loss of AC Power Summary (Boron Injection)

Time (s)	Event
0.00	Simulation starts
1.00	Postulated Loss of AC power
1.00	Feedwater lost due to loss of AC power to condensate pumps
1.00	Load Rejection occurs on loss of AC power (fast TCV closure)
1.00	All RIPs are tripped due to Loss of AC power: - 6 RIPs are connected M/G sets - 4 RIPs are tripped instantaneously due to loss of AC power
1.08	TCVs are fully closed
1.53	Maximum APRM (117 %)
3.38	Opening of Relief and Safety valves at the setpoints
8.34	Maximum Vessel Bottom Pressure (8.53 MPaA)
29.0	MSIV closure due to loss of main condenser vacuum
56.7	RCIC starts to inject water due to low water level L2 after a delay of 29 s
66.4	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
243	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-9b Loss of AC Power Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	117	1.5 s
Maximum Vessel Bottom Pressure (MPaG)	8.63	3.8 s
Maximum Average Heat Flux (%)	101	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	73.1	220 min
Associated Containment Pressure (MPaG)	0.027	220 min
Peak Cladding Temperature (°C)	545	21.3 s

Table 15E-10a Loss of Feedwater Summary (ARI)

Time (s)	Event
0.00	Simulation starts
0.00	Maximum Vessel Bottom Pressure (7.41 MPaA) (The Vessel bottom pressure is decreasing during the transient due to the decreased steam flow and the trip of RIPs)
1.00	Loss of Feedwater
5.14	Runback of all RIPs on low water level L4
5.31	Maximum APRM (101 %)
10.4	RPT of 4 RIPs activated on low water level L3
29.4	RPT of 6 RIPs activated on low water level L2
29.5	ARI activated on low water level L2
54.6	Control rods are fully inserted

Table 15E-10b Loss of Feedwater Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	101	5.3 s
Maximum Vessel Bottom Pressure (MPaG)	7.31	0.0 s
Maximum Average Heat Flux (%)	100	5.4 s
Maximum Bulk Suppression Pool Temperature, (°C)	*	*
Associated Containment Pressure (MPaG)	*	*
Peak Cladding Temperature (°C)	†	

* Initial values

† Minimum CPR stayed above SLMCPR

Table 15E-11a Loss of Feedwater Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
0.00	Maximum Vessel Bottom Pressure (7.41 MPaA) (The Vessel bottom pressure is decreasing during the transient due to the decreased steam flow and the trip of RIPs)
1.00	Loss of Feedwater
5.14	Runback of all RIPs on low water level L4
5.31	Maximum APRM (101 %)
10.4	RPT of 4 RIPs activated on low water level L3
29.4	RPT of 6 RIPs activated on low water level L2
30.5	FMCRD Run-in activated on low water level L2
58.2	RCIC starts to inject water due to low water level L2 after a delay of 29 s
75.0	MSIVs start to close on low water level L1.5
90.5	Opening of Relief and Safety valves at the setpoints
91.9	Maximum Vessel Bottom Pressure (8.23 MPaA)
94.2	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
166	Control rods are fully inserted

Table 15E-11b Loss of Feedwater Summary (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	101	5.3 s
Maximum Vessel Bottom Pressure (MPaG)	8.13	91.9 s
Maximum Average Heat Flux (%)	100	5.4 s
Maximum Bulk Suppression Pool Temperature, (°C)	68.6	400 min
Associated Containment Pressure (MPaG)	0.022	400 min
Peak Cladding Temperature (°C)	*	

* Minimum CPR stayed above SLMCPR

Table 15E-12a Loss of Feedwater Summary (Boron Injection)

Time (s)	Event
0.00	Simulation starts
1.00	Loss of Feedwater
4.78	Runback of all RIPs on low water level L4
4.90	Maximum APRM (101 %)
10.3	RPT of 4 RIPs activated on low water level L3
23.2	RPT of 6 RIPs activated on low water level L2
49.4	MSIVs start to close on low water level L1.5
52.0	RCIC starts to inject water due to low water level L2 after a delay of 29 s
60.6	Opening of Relief and Safety valves at the setpoints
61.3	Maximum Vessel Bottom Pressure (8.32 MPaA)
69.2	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
263	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-12b Loss of Feedwater Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	101	4.9 s
Maximum Vessel Bottom Pressure (MPaG)	8.22	61.3 s
Maximum Average Heat Flux (%)	100	4.9 s
Maximum Bulk Suppression Pool Temperature, (°C)	71.4	290 min
Associated Containment Pressure (MPaG)	0.025	290 min
Peak Cladding Temperature (°C)	350	0.0

Table 15E-13a Loss of Feedwater Heating Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
1.00	Loss of Feedwater heating (Feedwater temperature decreases by 55.6 ºC)
600	The Feedwater reaches the minimum temperature (159.5 ºC) during the transient
600	Maximum APRM (114 %)
600	FMCRD Run-in activated manually by operator
601	Recirculation runback of 10 RIPs activated on FMCRD Run-in signal
735	Control rods are fully inserted

Table 15E-13b Loss of Feedwater Heating Summary (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	114	600
Maximum Vessel Bottom Pressure (MPaG)	7.32	0.0 s
Maximum Average Heat Flux (%)	113	600 s
Maximum Bulk Suppression Pool Temperature, (°C)	*	*
Associated Containment Pressure (MPaG)	*	*
Peak Cladding Temperature (°C)	542	661 s

* Initial values

Table 15E-14a Turbine Trip with Bypass Summary (ARI)

Time (s)	Event
0.00	Simulation starts
1.00	TSVs start to close
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.22	ARI activated on high pressure (7.86 MPaA)
3.28	Opening of Relief and Safety valves at the setpoints
4.04	Maximum Vessel Bottom Pressure (8.53 MPaA)
4.22	Recirculation runback of 6 RIPs on ARI signal
28.2	Control rods are fully inserted

Table 15E-14b Turbine Trip with Bypass Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	4.0 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	43.3	300 min
Associated Containment Pressure (MPaG)	0.010	300 min
Peak Cladding Temperature (°C)	429	3.0 s

Table 15E-15a Turbine Trip with Bypass Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
1.00	TSVs start to close
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.28	Opening of Relief and Safety valves at the setpoints
4.04	Maximum Vessel Bottom Pressure (8.53 MPaA)
4.22	FMCRD Run-in activated on high pressure (7.86 MPaA)
5.22	Recirculation runback of 6 RIPs on FMCRD Run-in
139	Control rods are fully inserted

Table 15E-15b Turbine Trip with Bypass Summary (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	4.0 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	43.3	17 min
Associated Containment Pressure (MPaG)	0.010	17 min
Peak Cladding Temperature (°C)	527	60.7 s

Table 15E-16a Turbine Trip with Bypass Summary (Boron Injection)

Time (s)	Event
0.00	Simulation starts
1.00	TSVs start to close
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.28	Opening of Relief and Safety valves at the setpoints
4.04	Maximum Vessel Bottom Pressure (8.53 MPaA)
120	Feedwater pumps are tripped upon high pressure (7.86 MPaA) and SRNM ATWS permissive for 2 minutes
162	Remaining 6 RIPs are tripped on low water level L2
191	RCIC starts to inject water due to low water level L2 after a delay of 29 s
222	MSIV closure activated on low water level L1.5
241	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
243	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-16b Turbine Trip with Bypass Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	4.1 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	75.3	160 min
Associated Containment Pressure (MPaG)	0.030	160 min
Peak Cladding Temperature (°C)	577	128 s

Table 15E-17a Loss of Condenser Vacuum Summary (ARI)

Time (s)	Event
~ -2.5	Loss of Condenser vacuum
0.00	Simulation starts
1.00	Turbine trip actuated due to Loss of Condenser vacuum
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.22	ARI activated on high pressure (7.86 MPaA)
3.27	Opening of Relief and Safety valves at the setpoints
4.22	Recirculation runback of 6 RIPs on ARI signal
7.48	MSIV closure and bypass valves closure due to condenser vacuum has dropped to their closure setpoints
8.68	Maximum Vessel Bottom Pressure (8.54 MPaA)
9.48	Feedwater is lost due to the trip of condensate pumps on Loss of Condenser vacuum
28.2	Control rods are fully inserted

Table 15E-17b Loss of Condenser Vacuum Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.44	8.7 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	69.6	320 min
Associated Containment Pressure (MPaG)	0.023	320 min
Peak Cladding Temperature (°C)	429	3.0 s

Table 15E-18a Loss of Condenser Vacuum (FMCRD Run-In)

Time (s)	Event
~ -2.5	Loss of Condenser vacuum
0.00	Simulation starts
1.00	Turbine trip actuated due to Loss of Condenser vacuum
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.27	Opening of Relief and Safety valves at the setpoints
4.04	Maximum Vessel Bottom Pressure (8.53 MPaA)
4.22	FMCRD Run-in activated on high pressure (7.86 MPaA)
5.22	Recirculation runback of 6 RIPs on FMCRD Run-in signal
7.48	MSIV closure and bypass valves closure due to condenser vacuum has dropped to their closure setpoints
9.48	Feedwater is lost due to the trip of condensate pumps on Loss of Condenser vacuum
44.0	RPT of 6 RIPs activated on low water level L2
72.8	RCIC starts to inject water due to low water level L2 after a delay of 29 s
90.5	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
139	Control rods are fully inserted

Table 15E-18b Loss of Condenser Vacuum (FMCRD Run-In)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	4.0 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	70.3	300 min
Associated Containment Pressure (MPaG)	0.024	300 min
Peak Cladding Temperature (°C)	450	11.5 s

Table 15E-19a Loss of Condenser Vacuum Summary (Boron Injection)

Time (s)	Event
~ -2.5	Loss of Condenser vacuum
0.00	Simulation starts
1.00	Turbine trip actuated due to Loss of Condenser vacuum
1.10	TSVs are fully closed
1.16	RPT of 4 RIPs activated on TSV closure
1.55	Maximum APRM (136 %)
3.27	Opening of Relief and Safety valves at the setpoints
7.48	MSIV closure and bypass valves closure due to condenser vacuum has dropped to their closure setpoints
9.48	Feedwater is lost due to the trip of condensate pumps on Loss of Condenser vacuum
11.8	Maximum Vessel Bottom Pressure (8.75 MPaA)
35.7	RPT of 6 RIPs activated on low water level L2
64.5	RCIC starts to inject water due to low water level L2 after a delay of 29 s
82.3	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
243	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-19b Loss of Condenser Vacuum Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	136	1.6 s
Maximum Vessel Bottom Pressure (MPaG)	8.65	11.8 s
Maximum Average Heat Flux (%)	106	1.7 s
Maximum Bulk Suppression Pool Temperature, (°C)	74.1	210 min
Associated Containment Pressure (MPaG)	0.028	210 min
Peak Cladding Temperature (°C)	458	10.1 s

Table 15E-20a Feedwater Controller Failure Summary (ARI)

Time (s)	Event
0.00	Simulation starts
1.00	Feedwater flow starts to increase
1.00	Feedwater flow reaches the maximum flow of 2761 kg/s
15.8	High water level L8
15.9	Feedwater pumps tripped on high water level L8
16.0	TSV closure initiated on high water level L8
16.0	RPT of 4 RIPs activated on TSV closure
16.4	Maximum APRM (142 %)
18.1	ARI activated on high pressure (7.86 MPaA)
18.1	Opening of Relief and Safety valves at the setpoints
18.8	Maximum Vessel Bottom Pressure (8.53 MPaA)
18.8	Recirculation runback of 6 RIPs activated on ARI signal
43.1	Control rods are fully inserted

Table 15E-20b Feedwater Controller Failure Summary (ARI)

	Value	time
Maximum Neutron Flux (%)	142	16.4 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	18.8 s
Maximum Average Heat Flux (%)	109	16.6 s
Maximum Bulk Suppression Pool Temperature, (°C)	43.3	320 min
Associated Containment Pressure (MPaG)	0.010	320 min
Peak Cladding Temperature (°C)	448	18.0 s

Table 15E-21a Feedwater Controller Failure Summary (FMCRD Run-In)

Time (s)	Event
0.00	Simulation starts
1.00	Feedwater flow starts to increase
1.00	Feedwater flow reaches the maximum flow of 2931 kg/s
15.8	High water level L8
15.9	Feedwater pumps tripped on high water level L8
16.0	TSV closure initiated on high water level L8
16.0	RPT of 4 RIPs activated on TSV closure
16.4	Maximum APRM (142 %)
18.1	Opening of Relief and Safety valves at the setpoints
18.8	Maximum Vessel Bottom Pressure (8.53 MPaA)
18.8	FMCRD Run-in activated on high pressure (7.86 MPaA)
19.8	Recirculation runback of 6 RIPs on FMCRD Run-in signal
82.8	RCIC starts to inject water due to low water level L2 after a delay of 29 s
117	MSIVs start to close on low water level 1.5
137	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
154	Control rods are fully inserted

Table 15E-21b Feedwater Controller Failure Summary (FMCRD Run-In)

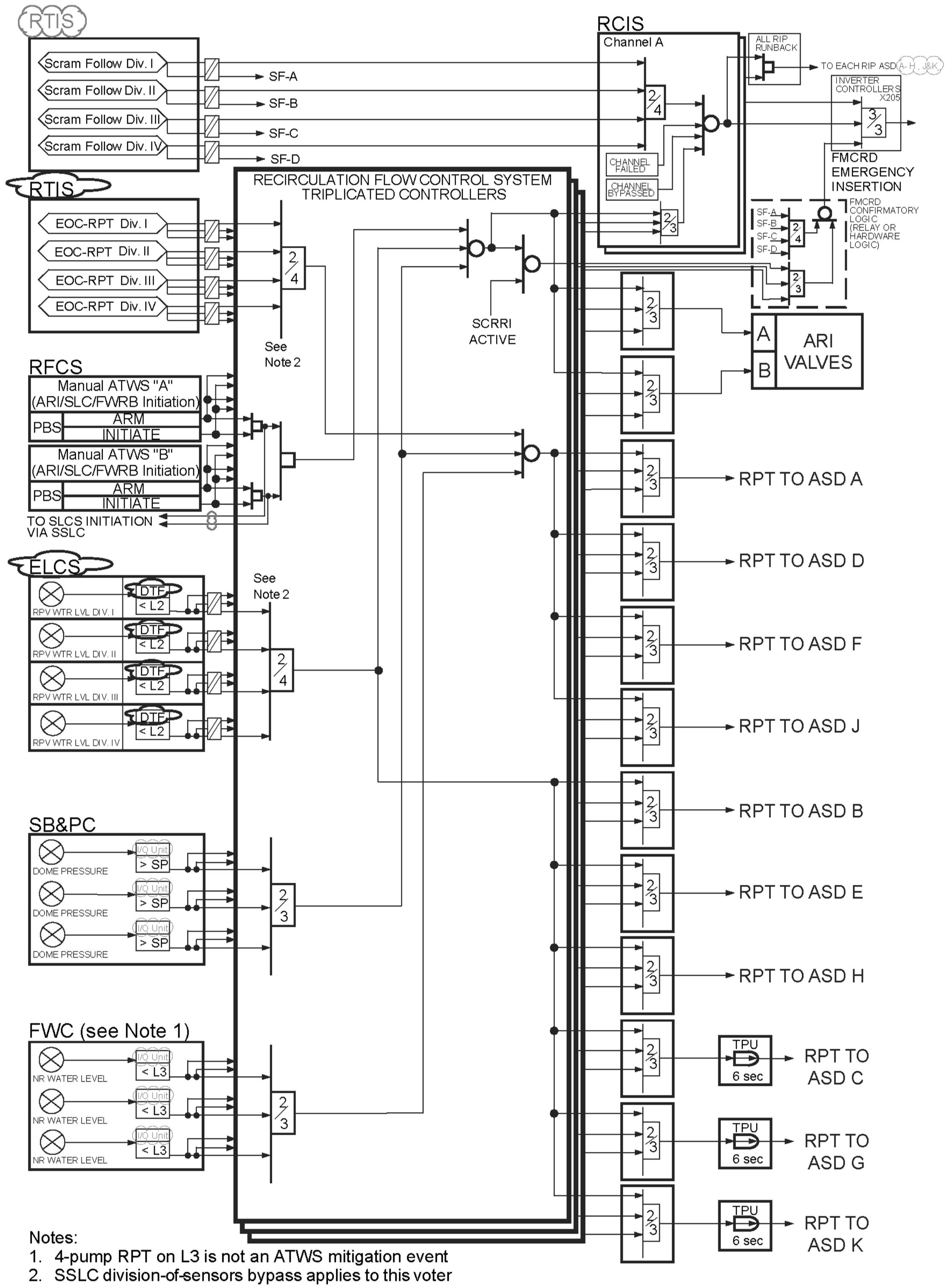
	Value	time
Maximum Neutron Flux (%)	142	16.4 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	18.8 s
Maximum Average Heat Flux (%)	109	16.6 s
Maximum Bulk Suppression Pool Temperature, (°C)	68.8	410 min
Associated Containment Pressure (MPaG)	0.023	410 min
Peak Cladding Temperature (°C)	448	18.0 s

Table 15E-22a Feedwater Controller Failure Summary (Boron Injection)

Time (s)	Event
0.00	Simulation starts
1.00	Feedwater flow starts to increase
1.00	Feedwater flow reaches the maximum flow of 2761 kg/s
15.8	High water level L8
15.9	Feedwater pumps tripped on high water level L8
16.0	TSV closure initiated on high water level L8
16.0	RPT of 4 RIPs activated on TSV closure
16.4	Maximum APRM (142 %)
18.1	Opening of Relief and Safety valves at the setpoints
18.8	Maximum Vessel Bottom Pressure (8.53 MPaA)
43.0	RPT of 6 RIPs activated on low water level L2
75.4	RCIC starts to inject water due to low water level L2 after a delay of 29 s
107	MSIVs start to close on low water level 1.5
126	HPCF starts to inject water due to low water level L1.5 after a delay of 20 s
258	SLCS starts to inject Boron solution in the upper plenum due to high pressure (7.86 MPaA) and SRNM ATWS permissive for 3 minutes and after a transport delay of 60 s
1000	Simulation is terminated since the reactor is brought to hot shutdown due to enough boron concentration has been built up

Table 15E-22b Feedwater Controller Failure Summary (Boron Injection)

	Value	time
Maximum Neutron Flux (%)	142	16.4 s
Maximum Vessel Bottom Pressure (MPaG)	8.43	18.8 s
Maximum Average Heat Flux (%)	109	16.6 s
Maximum Bulk Suppression Pool Temperature, (°C)	72.3	280 min
Associated Containment Pressure (MPaG)	0.027	280 min
Peak Cladding Temperature (°C)	448	18.0 s



Notes:
1. 4-pump RPT on L3 is not an ATWS mitigation event
2. SSLC division-of-sensors bypass applies to this voter

Figure 15E-1a ATWS Mitigation Logic (ARI, FMCRD Run-In, RPT, Manual Initiation)

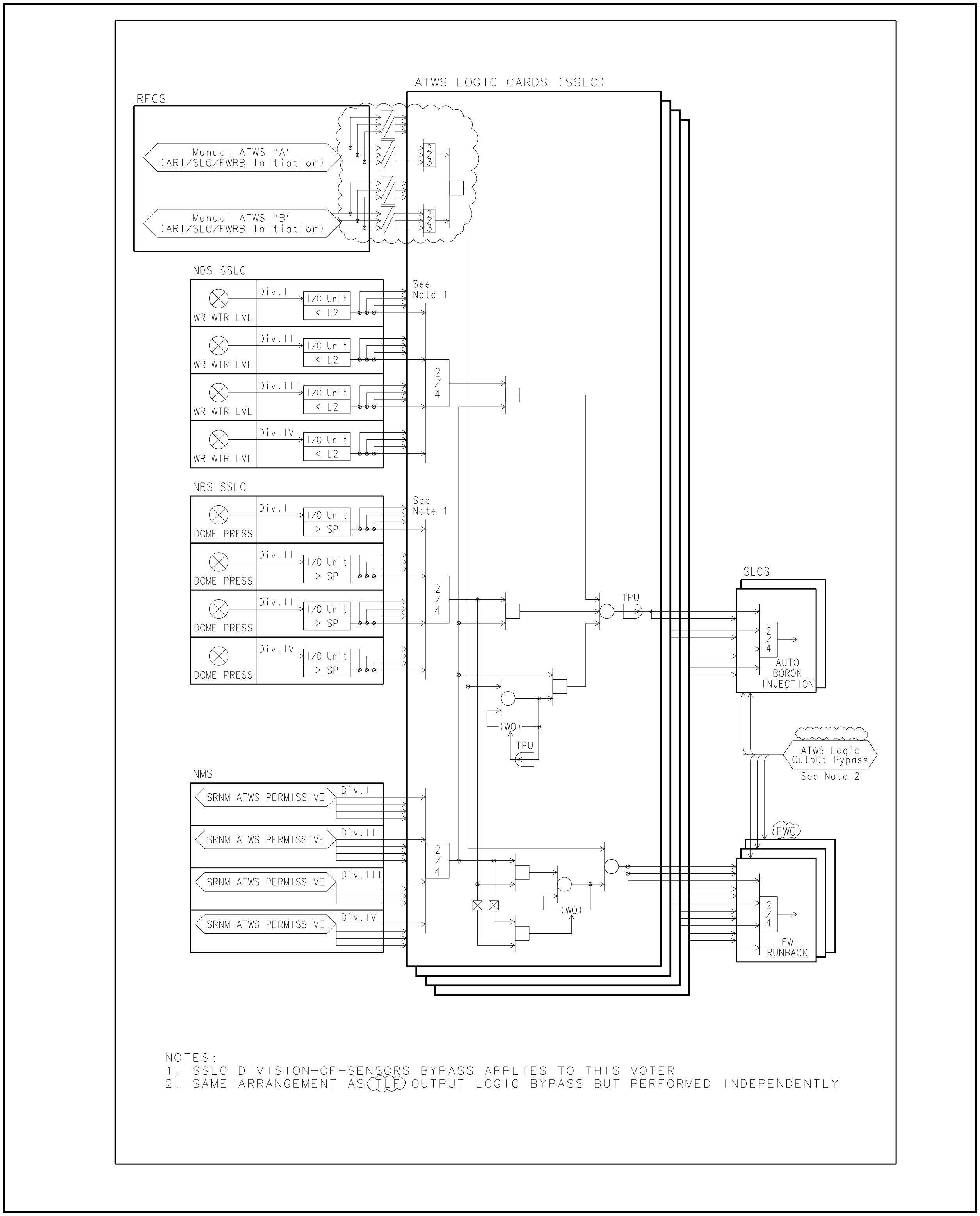


Figure 15E-1b ATWS Mitigation Logic (SLCS Initiation, Feedwater Runback)

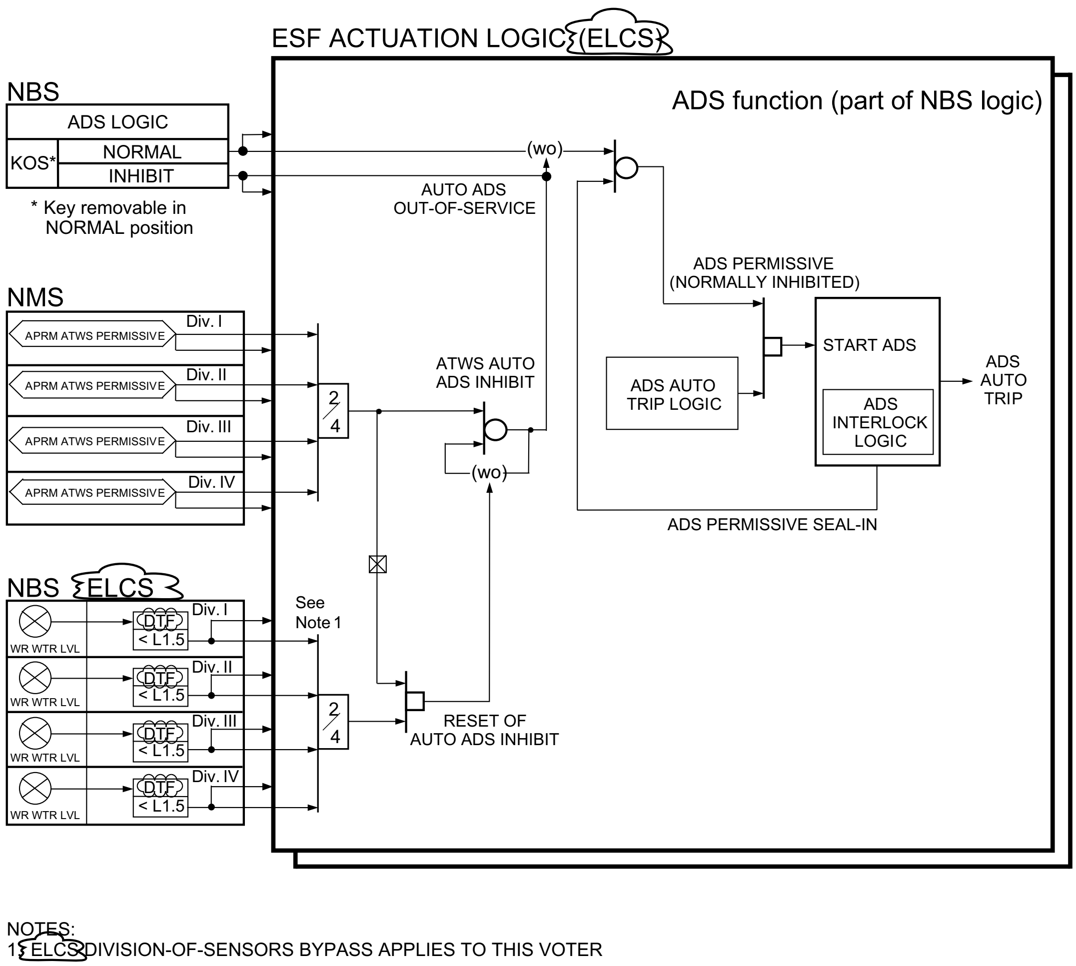


Figure 15E-1c ATWS Mitigation Logic (SLCS Initiation, Feedwater Runback)

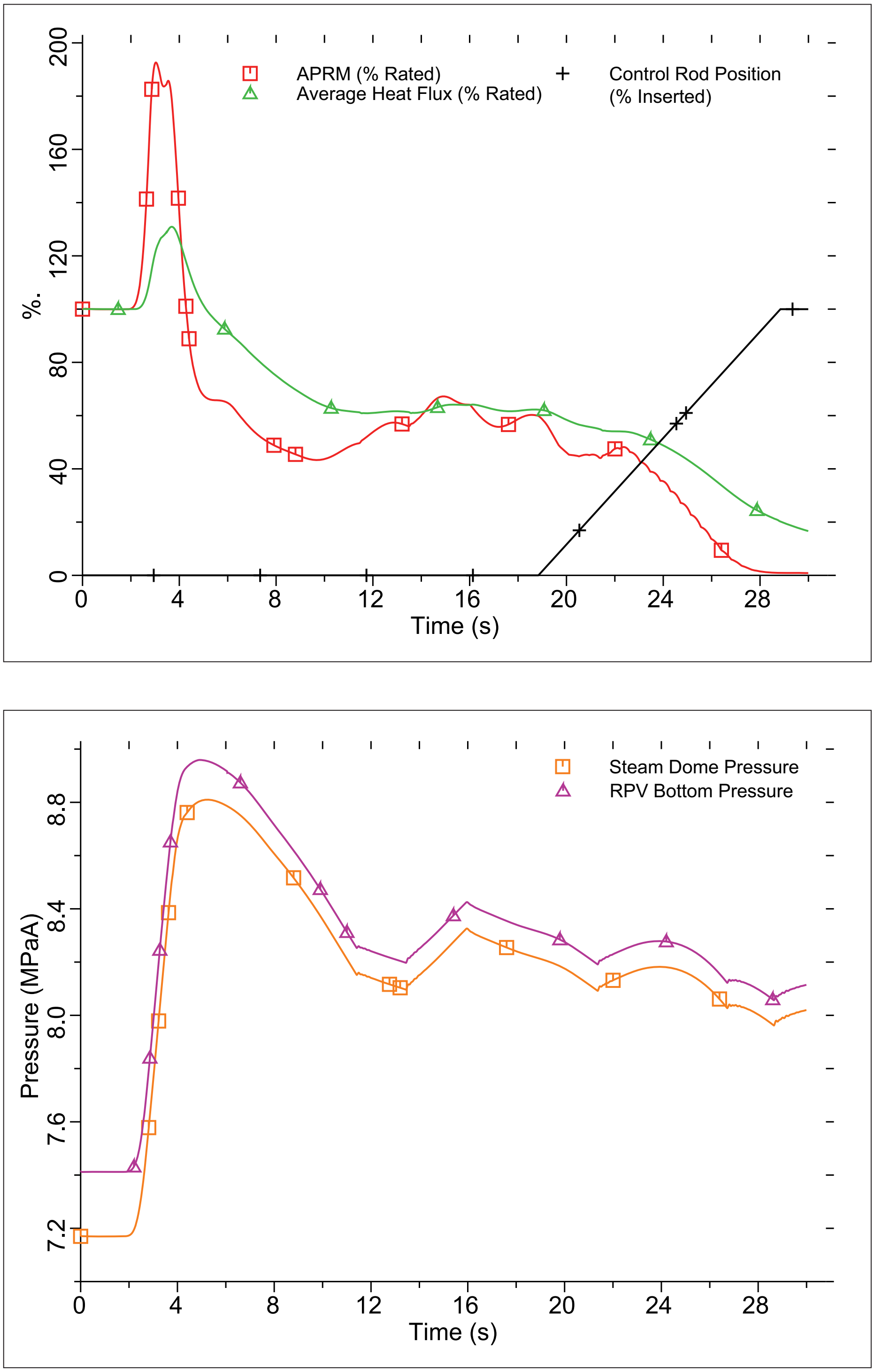


Figure 15E-2a ABWR MSIV Closure, ARI

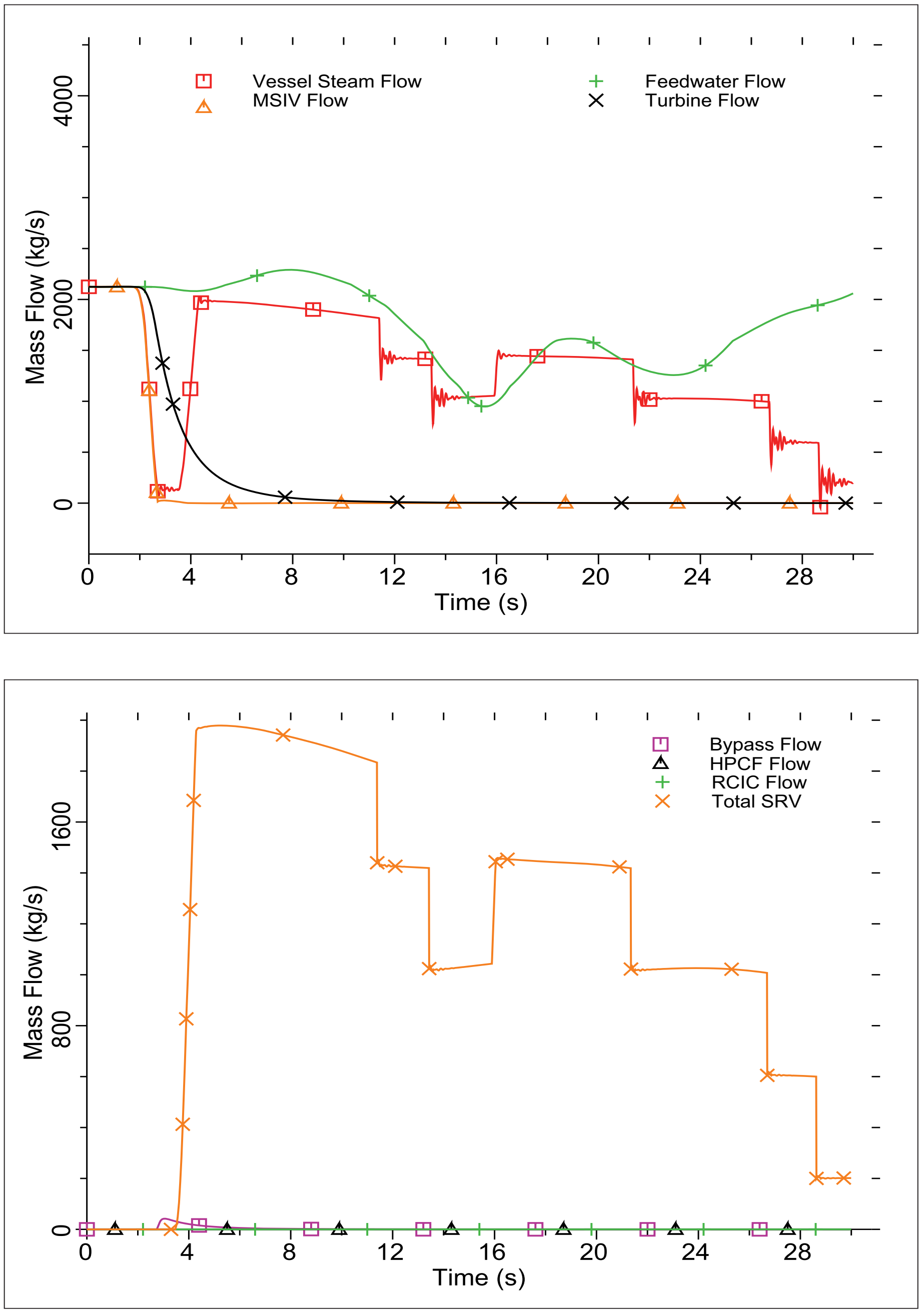


Figure 15E-2b ABWR MSIV Closure, ARI

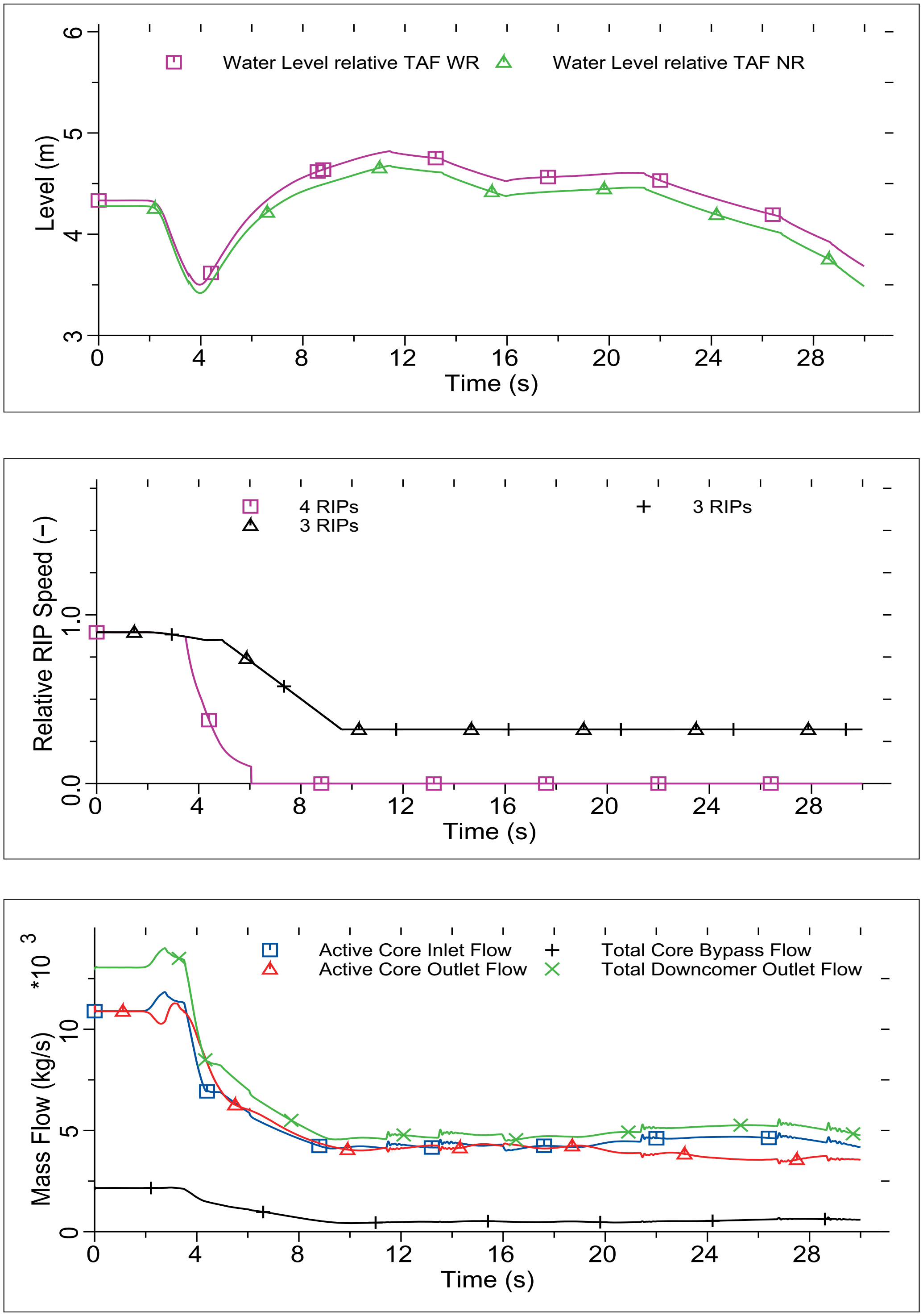


Figure 15E-2c ABWR MSIV Closure, ARI

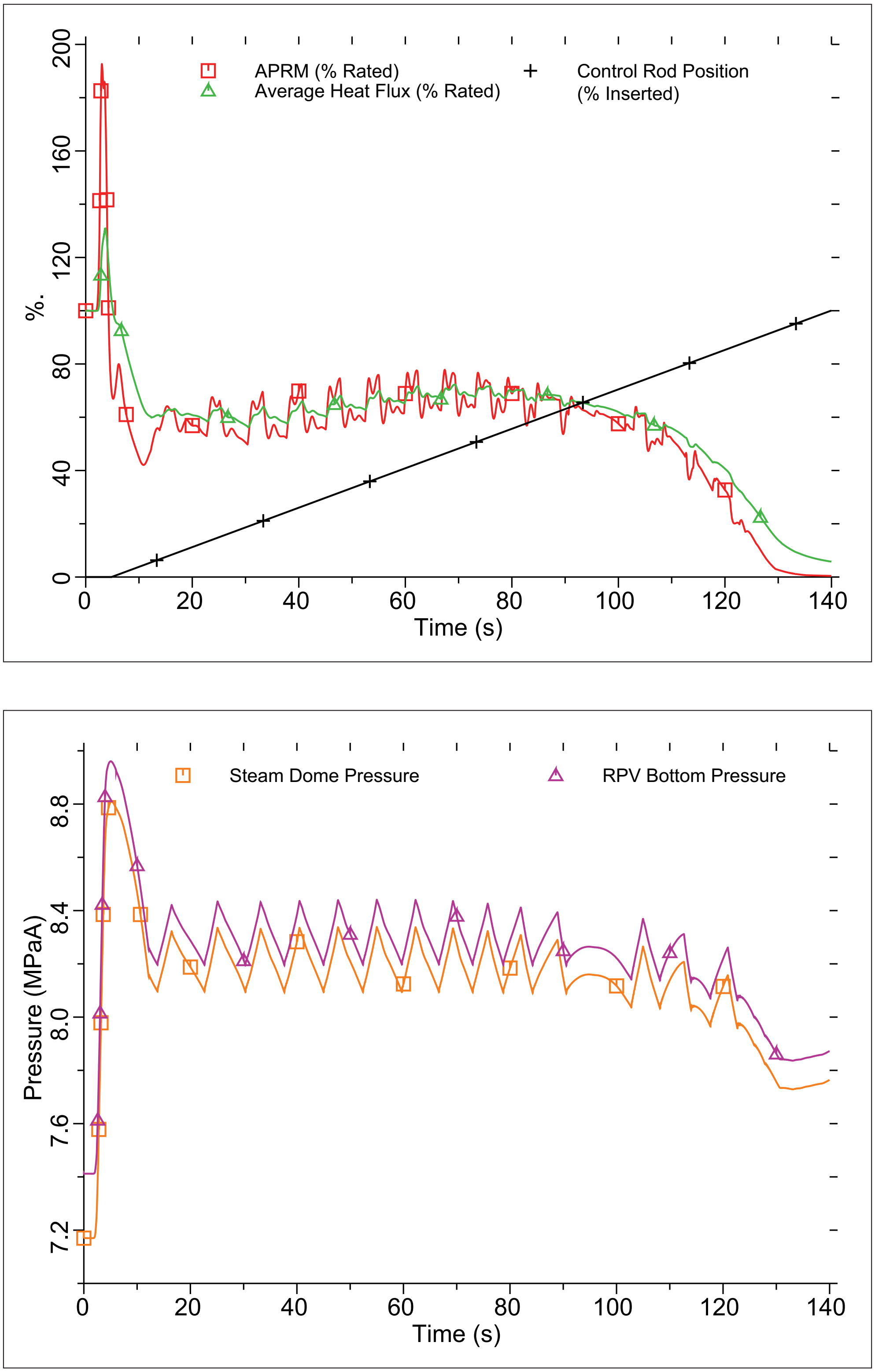


Figure 15E-3a ABWR MSIV Closure, FMCRD Run–in

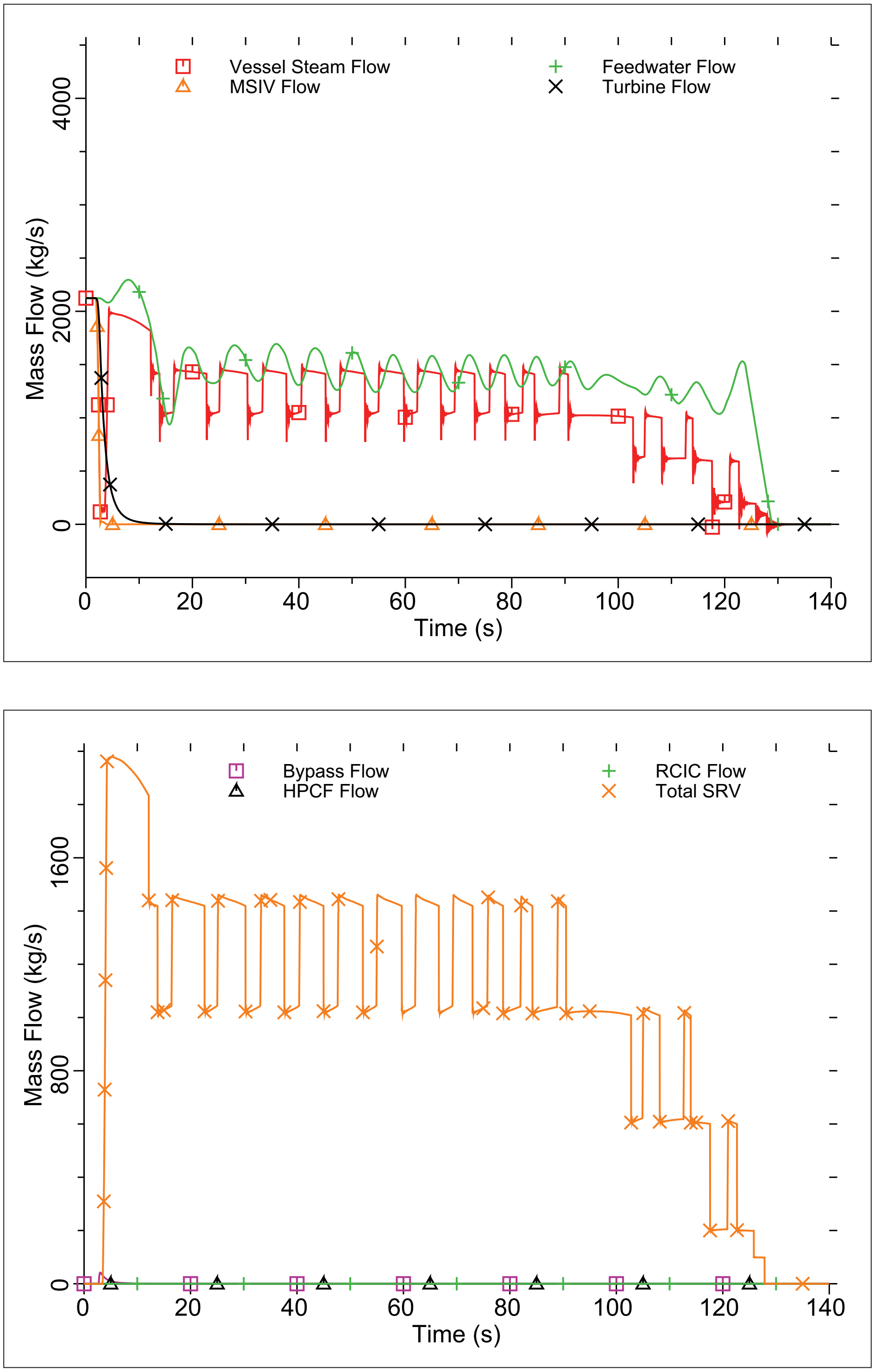


Figure 15E-3b ABWR MSIV Closure, FMCRD Run-in

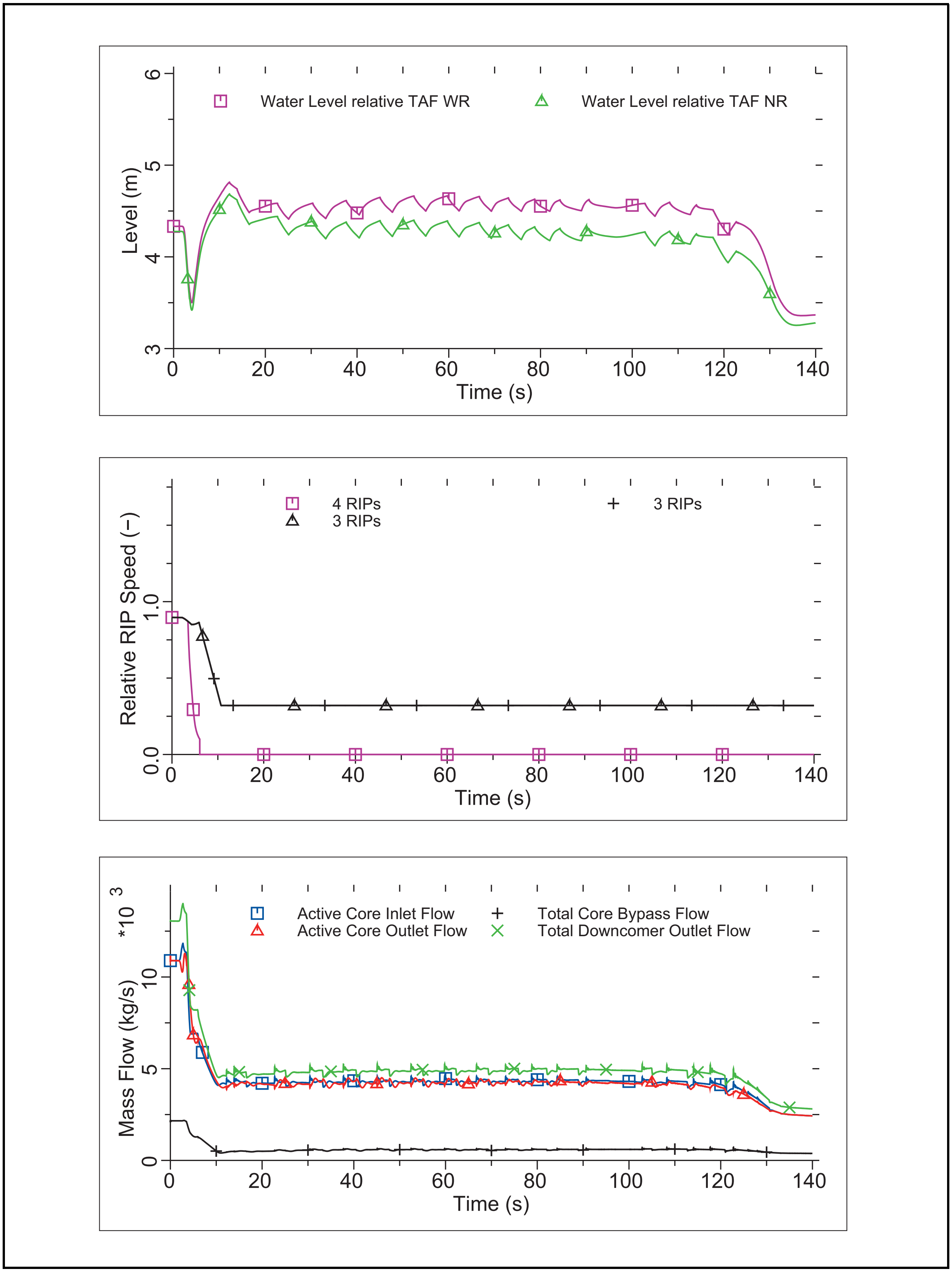
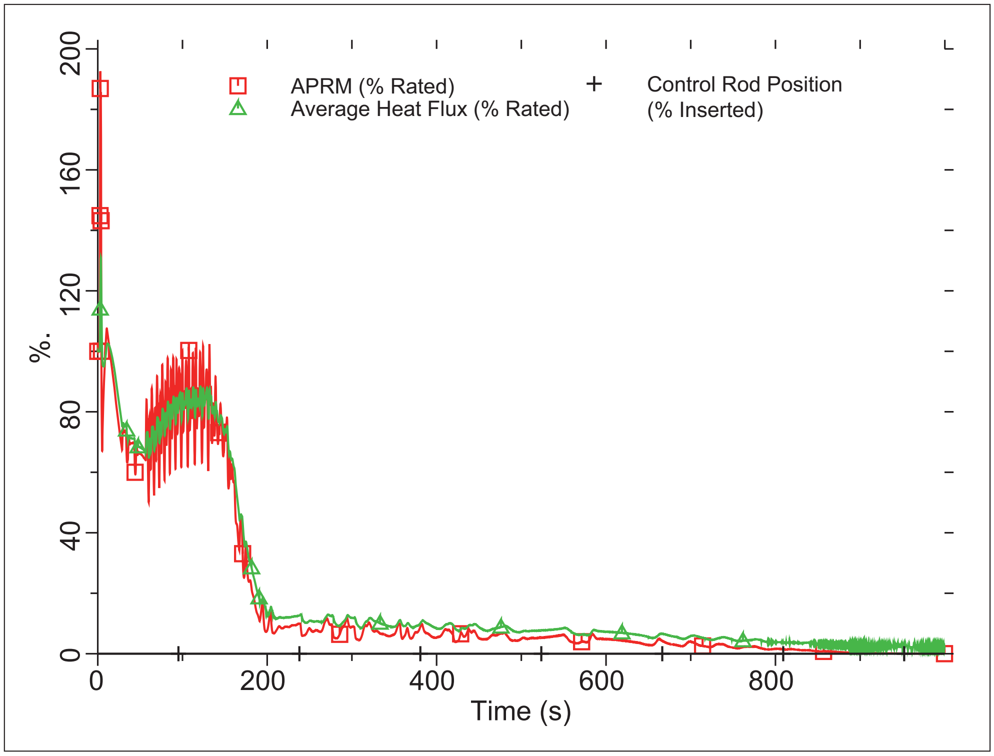


Figure 15E-3c ABWR MSIV Closure, FMCRD Run-in



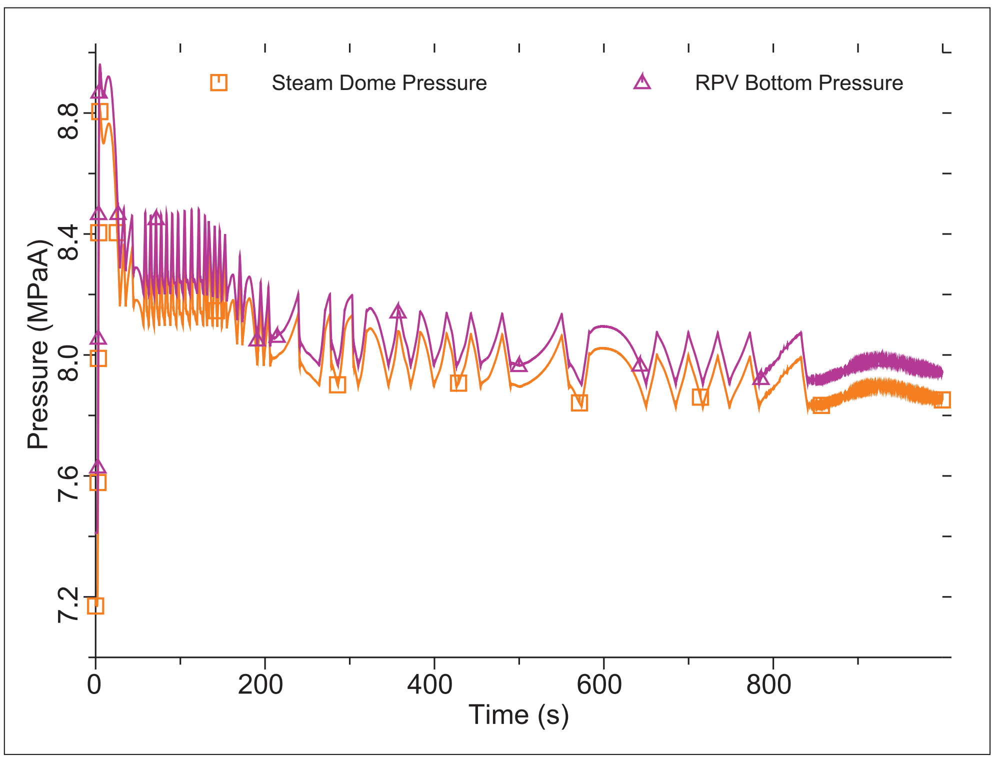


Figure 15E-4a ABWR MSIV Closure, SLCS

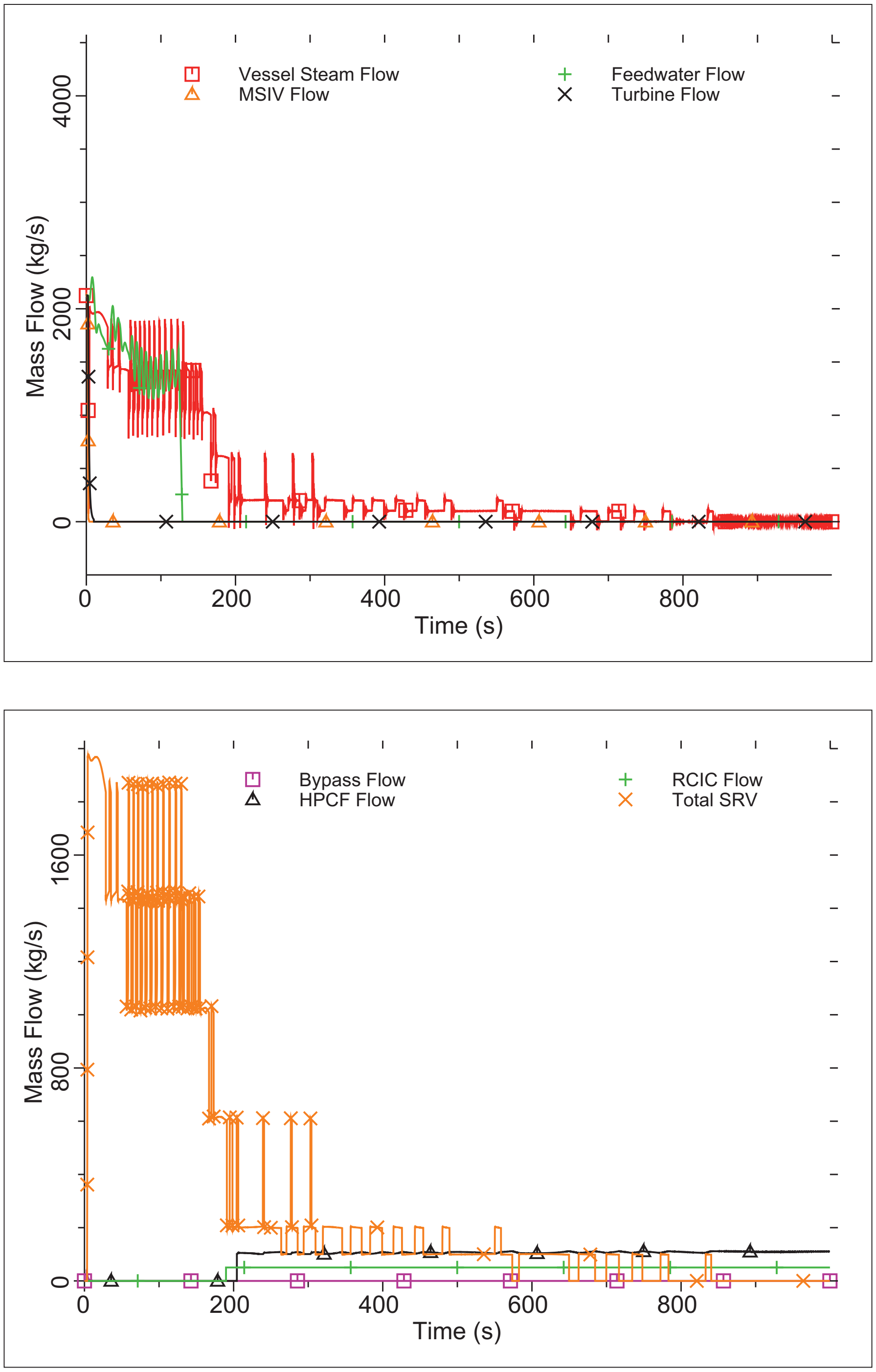


Figure 15E-4b ABWR MSIV Closure, SLCS

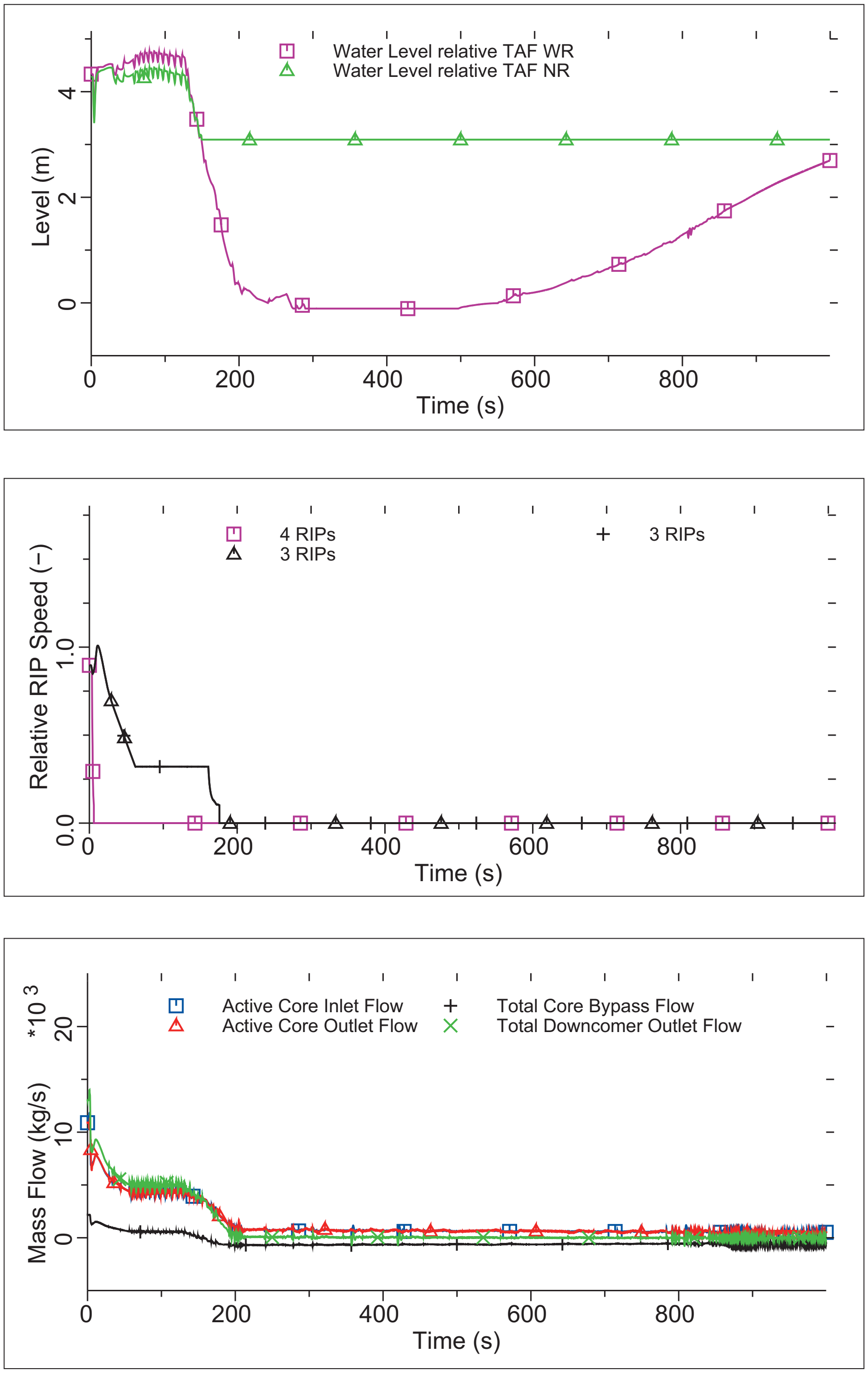


Figure 15E-4c ABWR MSIV Closure, SLCS

Figure 15E-5 Not Used

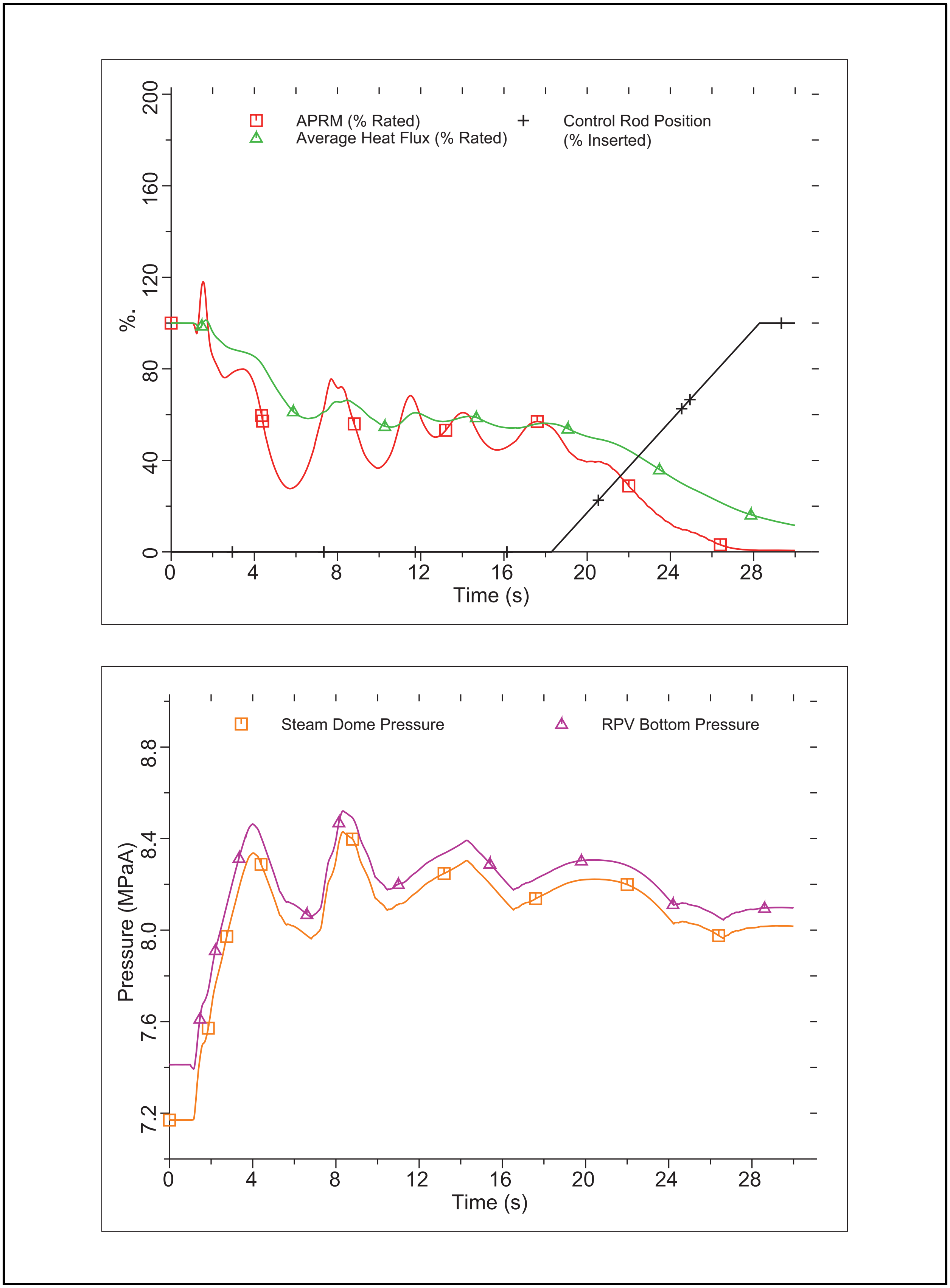


Figure 15E-6a ABWR Loss of AC Power, ARI

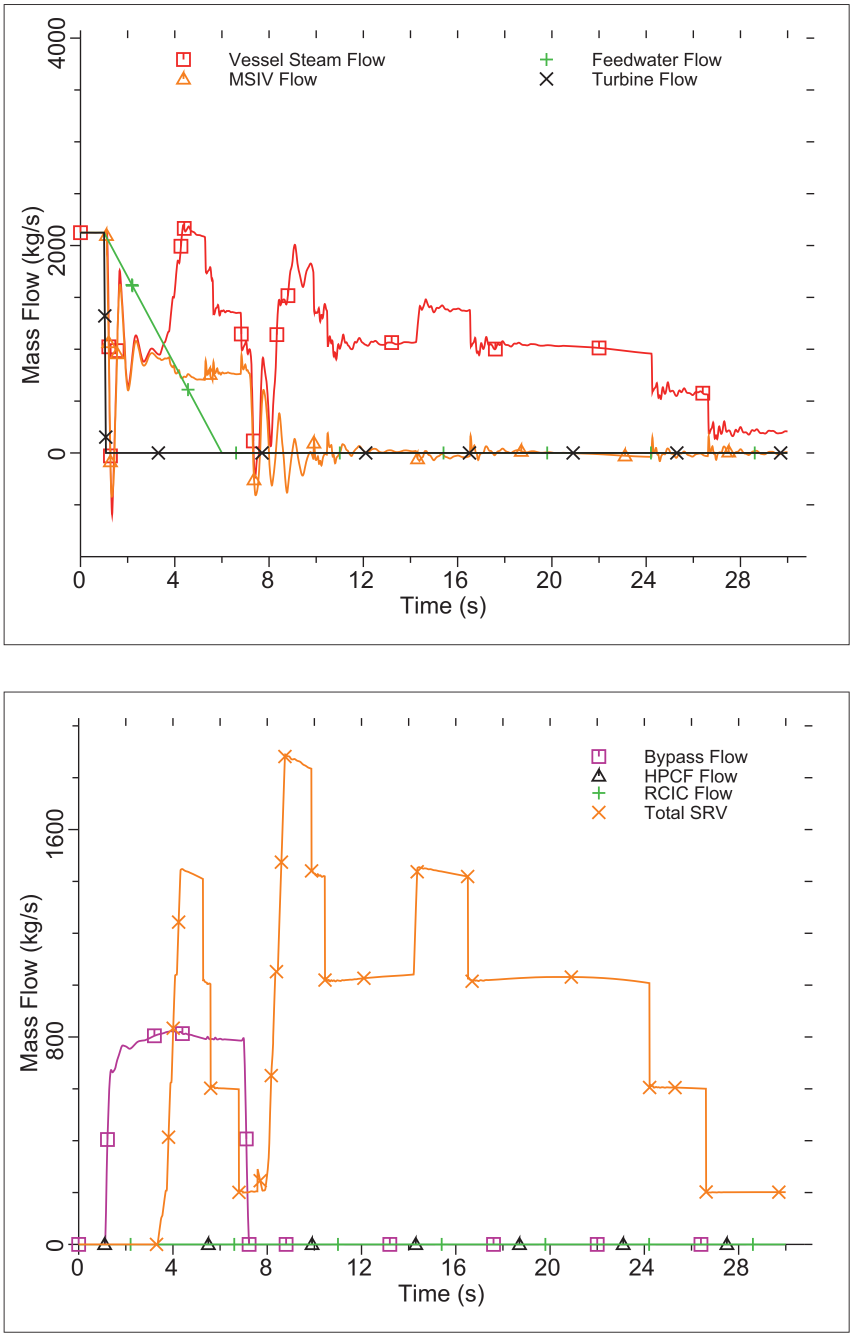


Figure 15E-6b ABWR Loss of AC Power, ARI

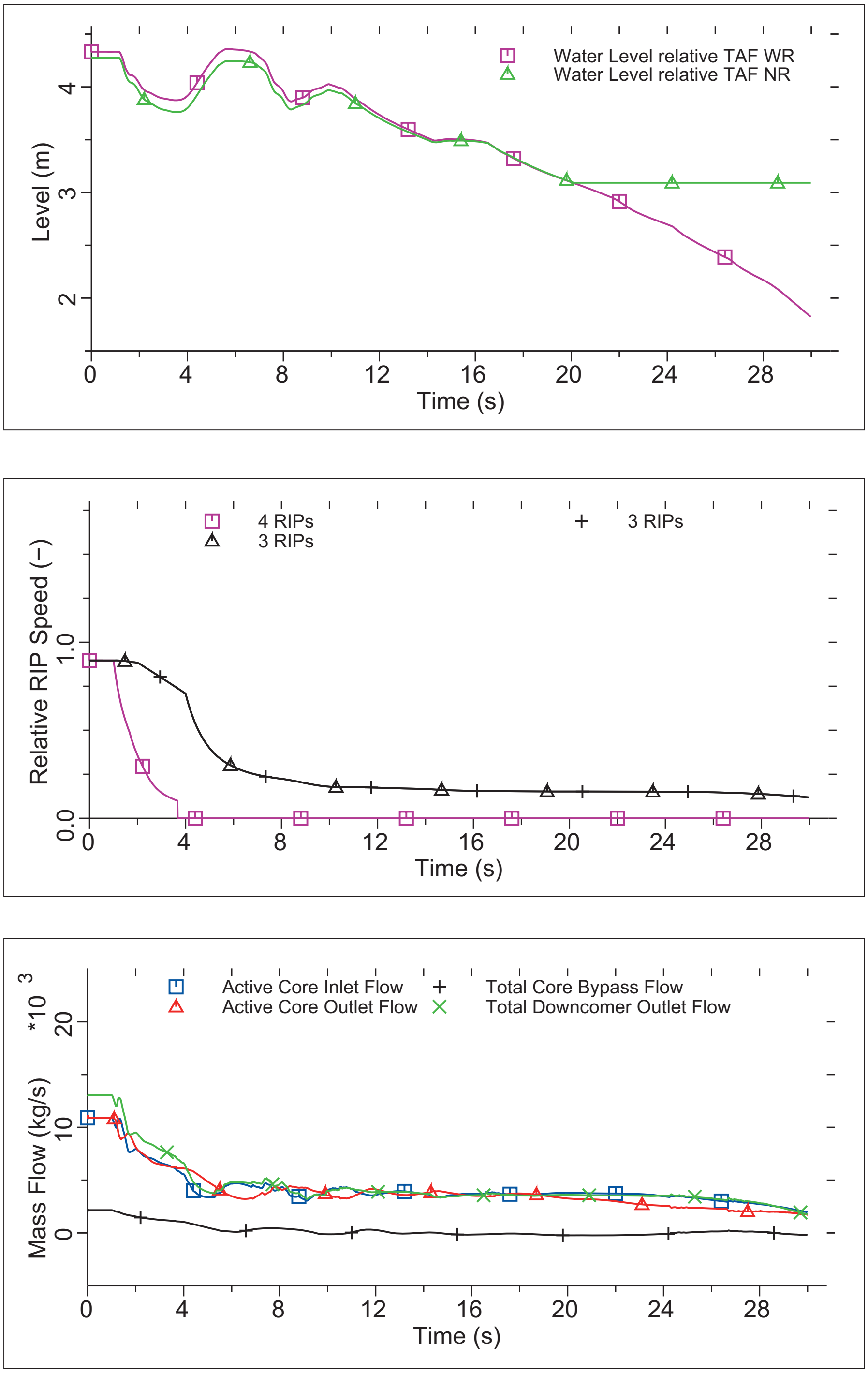


Figure 15E-6c ABWR Loss of AC Power, ARI

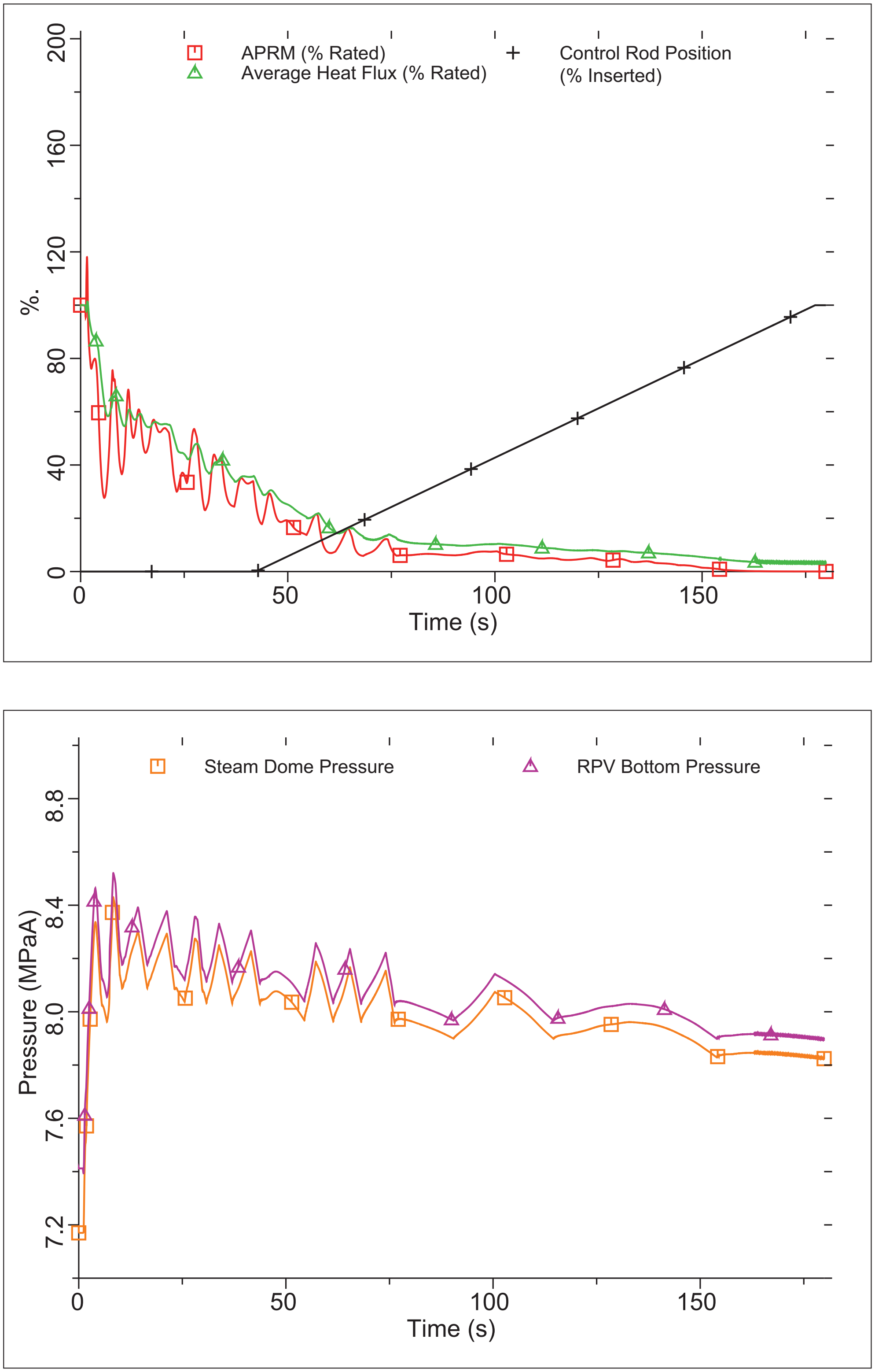


Figure 15E-7a ABWR Loss of AC Power, FMCRD Run–in

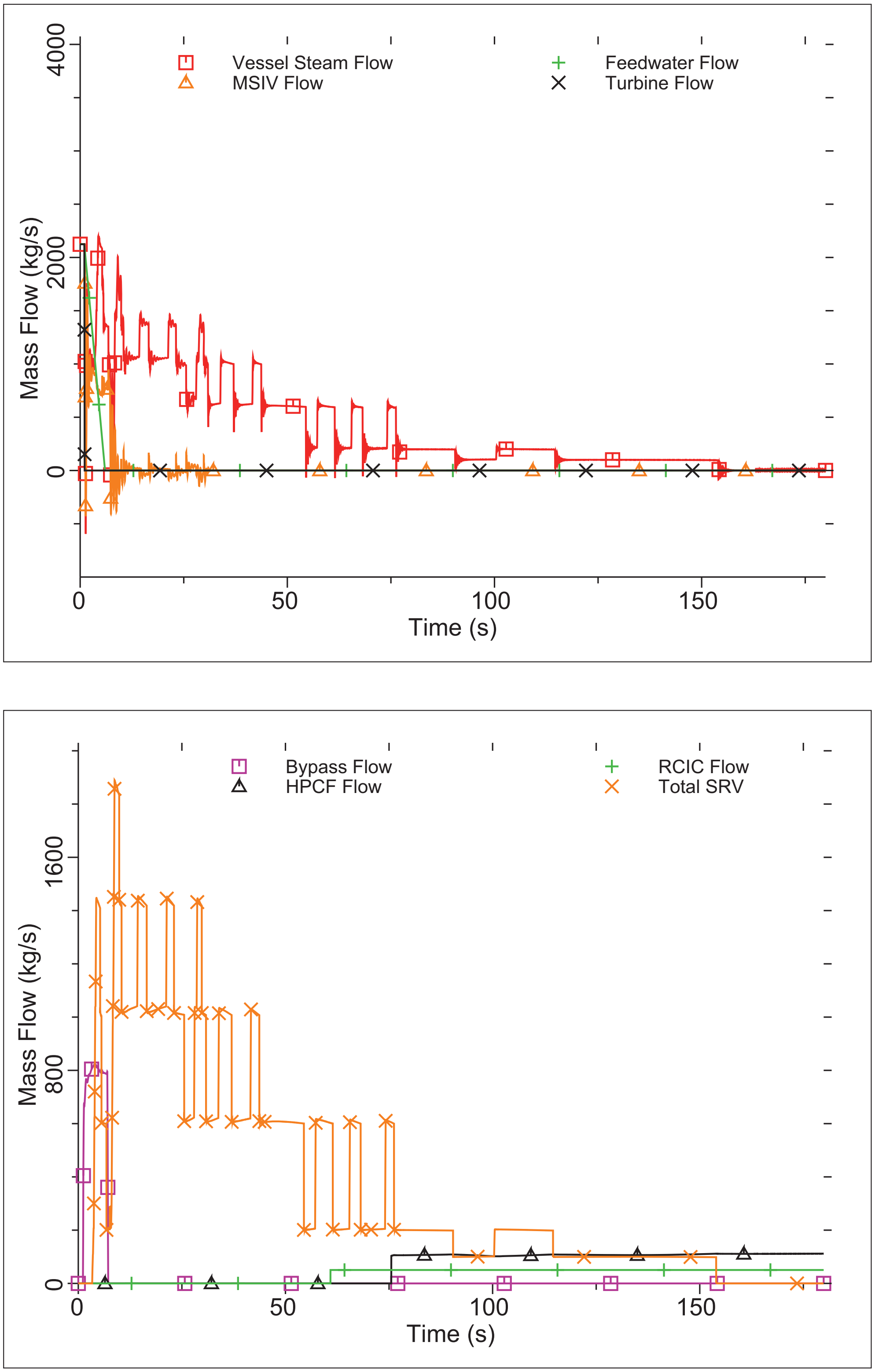


Figure 15E-7b ABWR Loss of AC Power, FMCRD Run–in

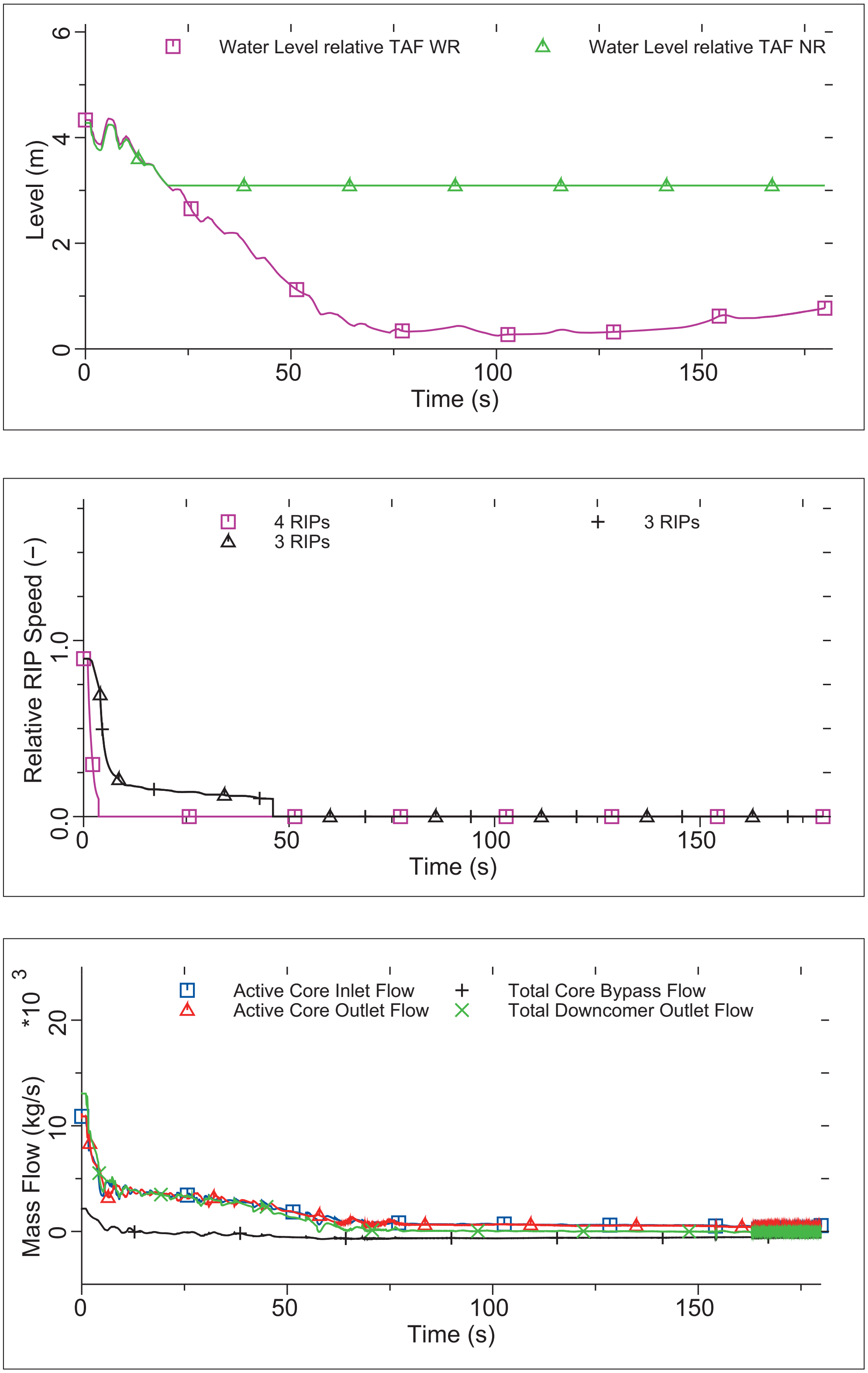


Figure 15E-7c ABWR Loss of AC Power, FMCRD Run–in

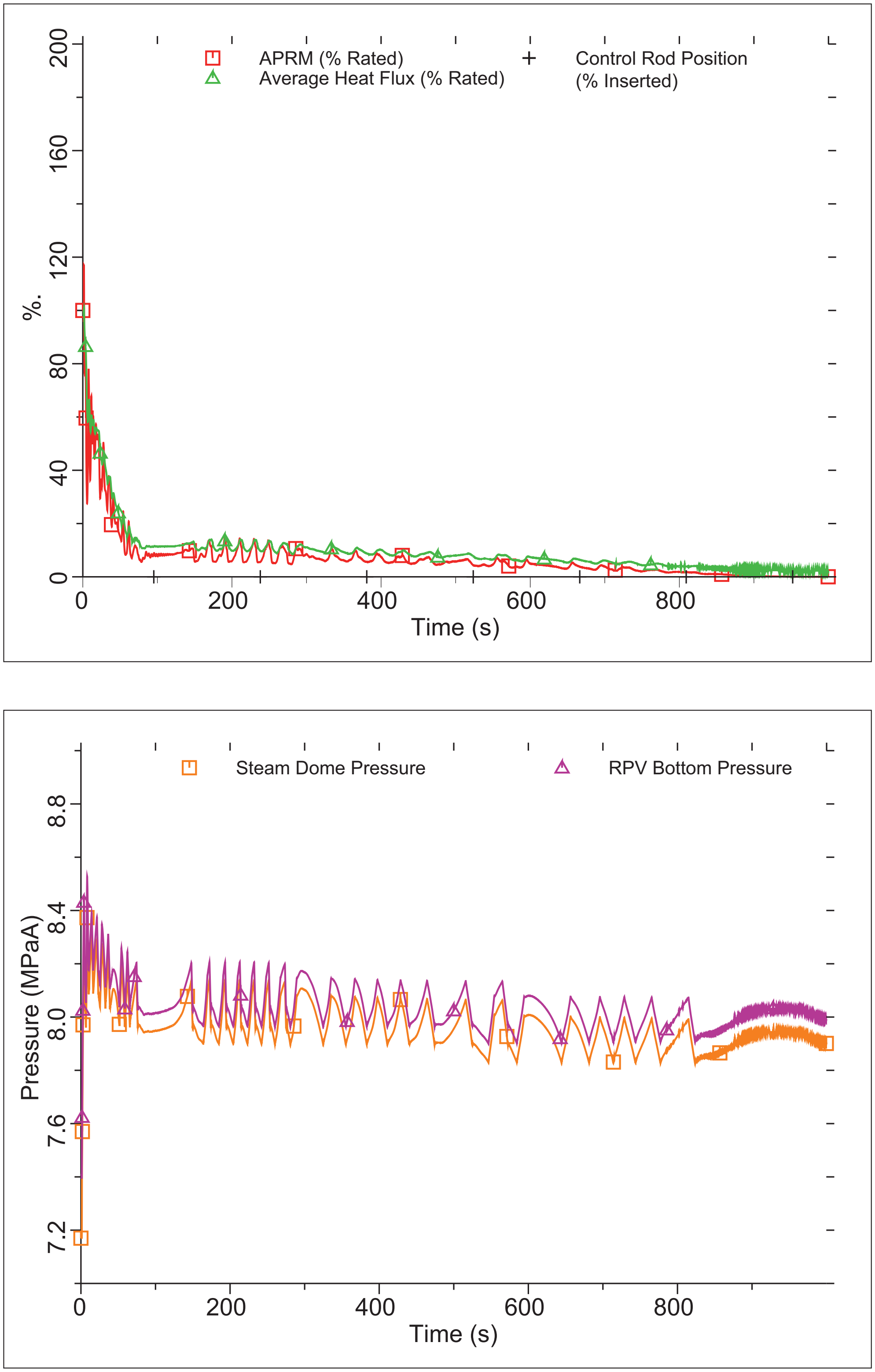


Figure 15E-8a ABWR Loss of AC Power, SLCS

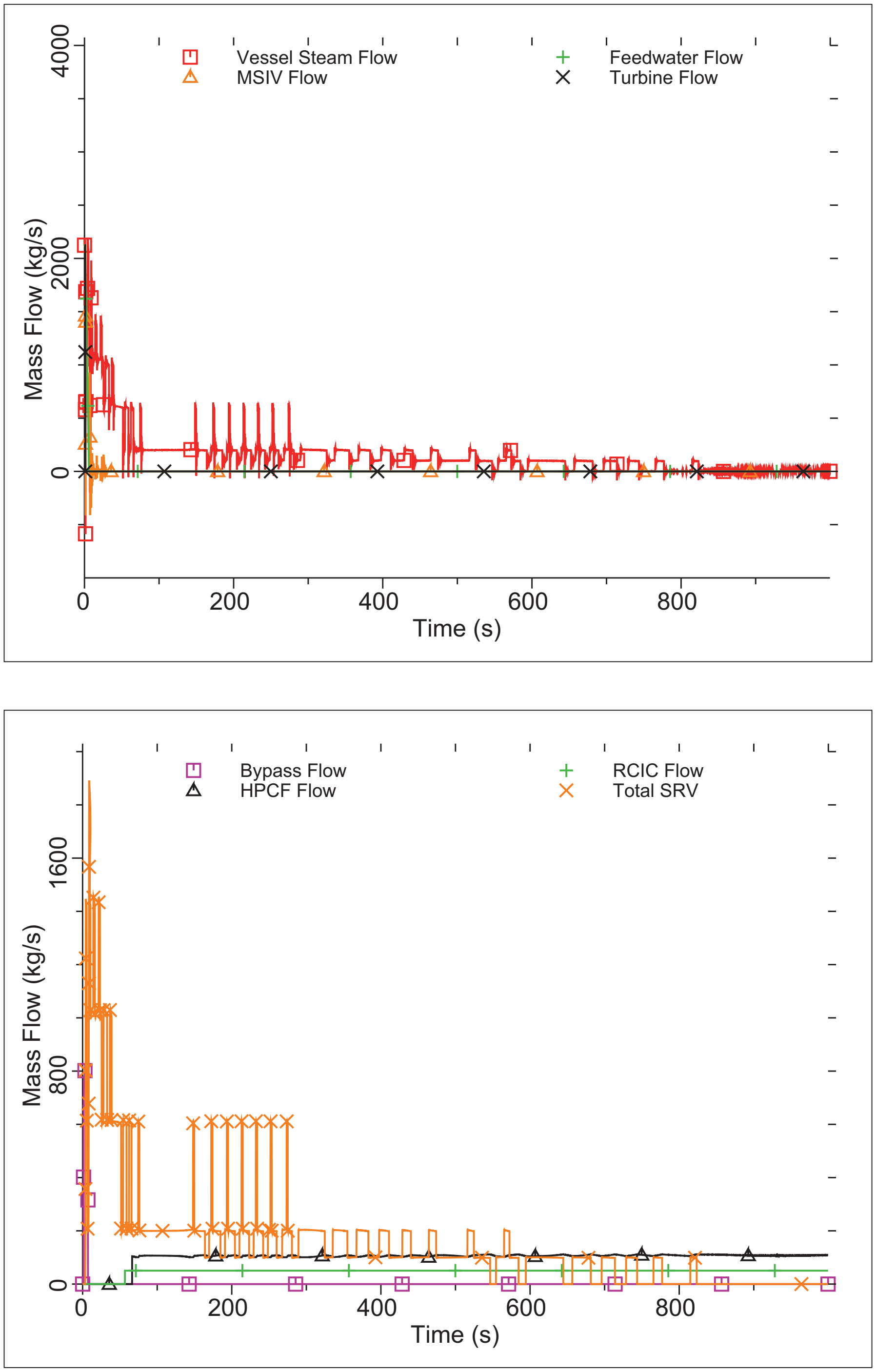


Figure 15E-8b ABWR Loss of AC Power, SLCS

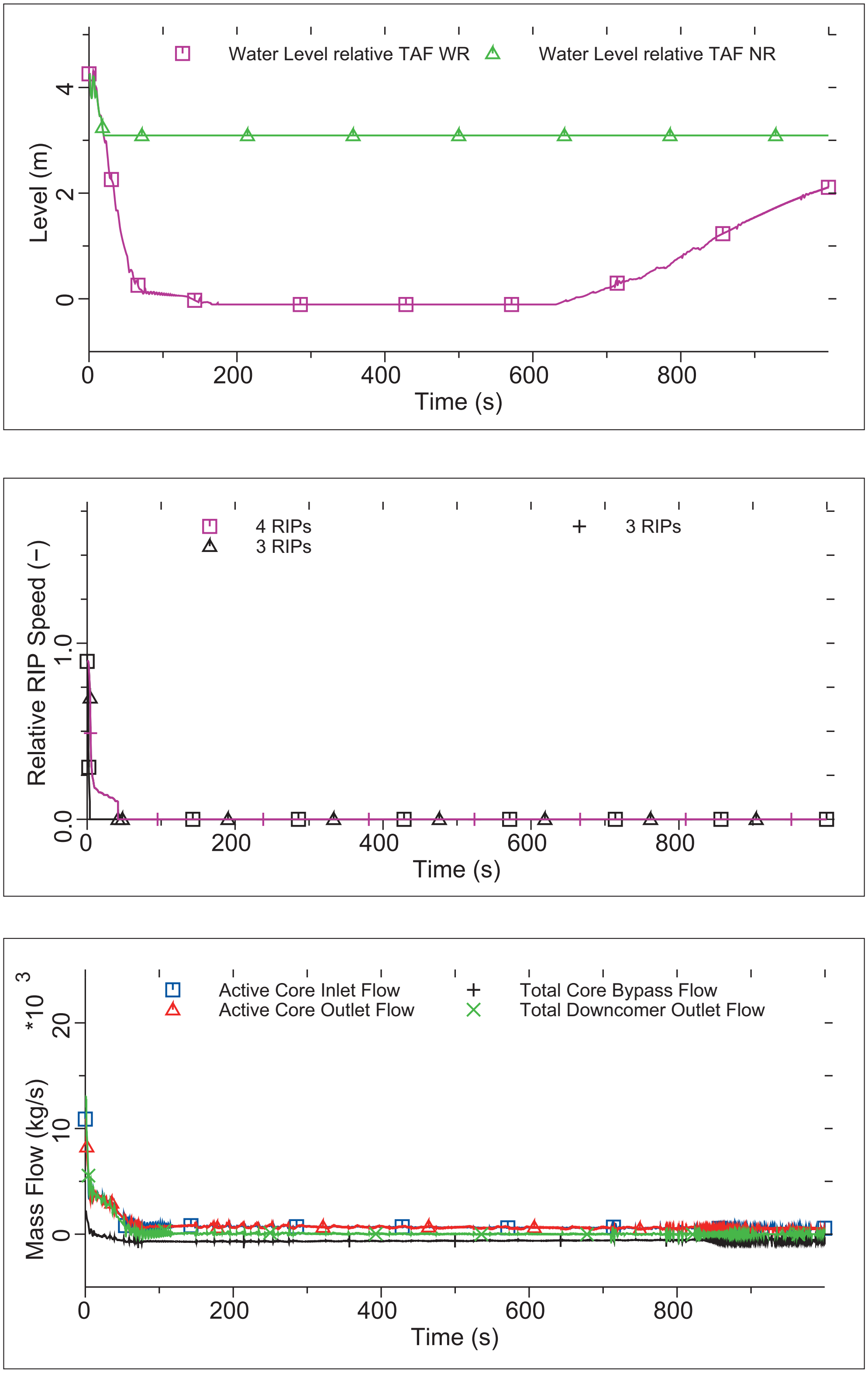


Figure 15E-8c ABWR Loss of AC Power, SLCS

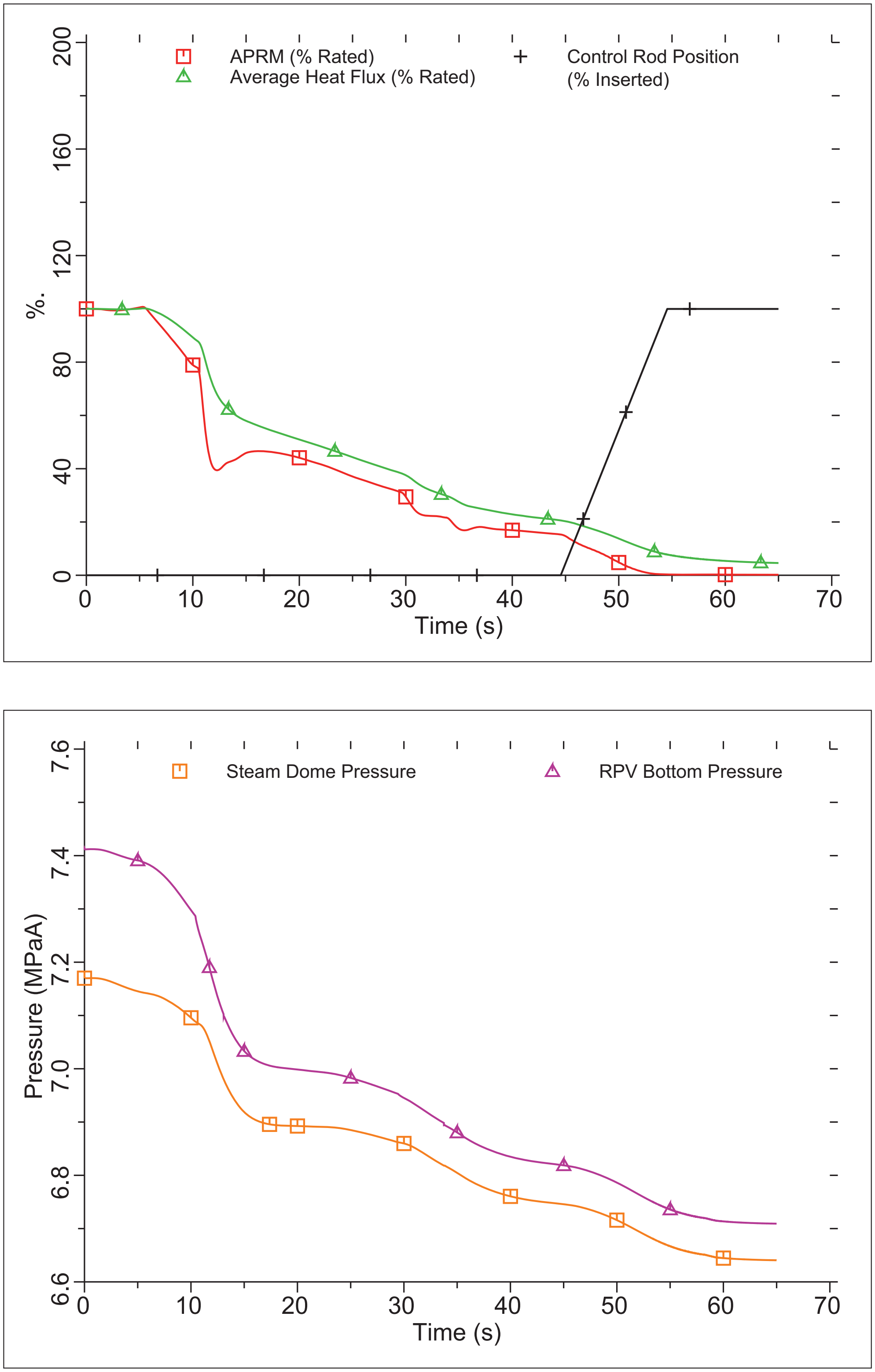


Figure 15E-9a ABWR Loss of Feedwater Flow, ARI

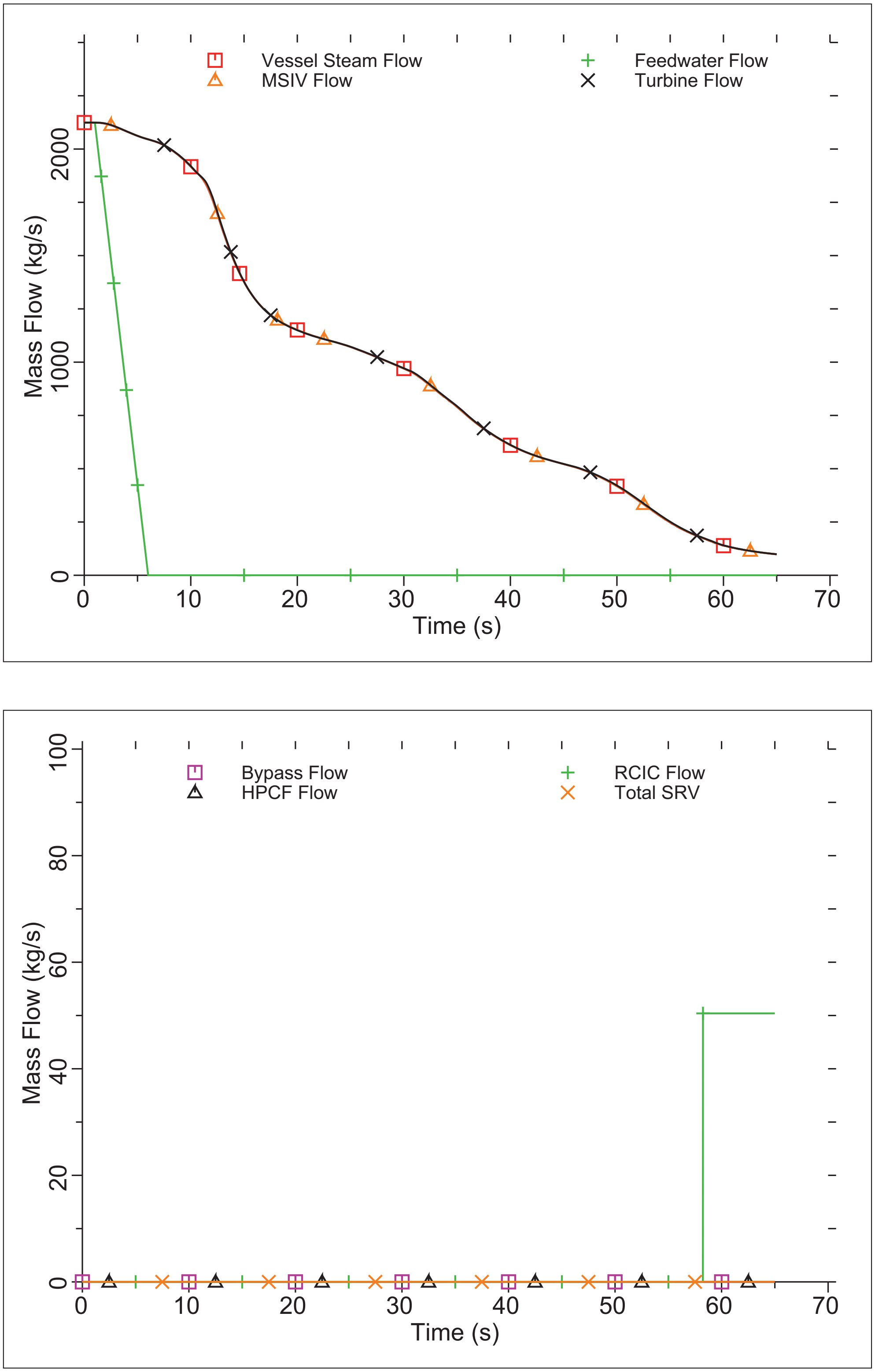


Figure 15E-9b ABWR Loss of Feedwater Flow, ARI

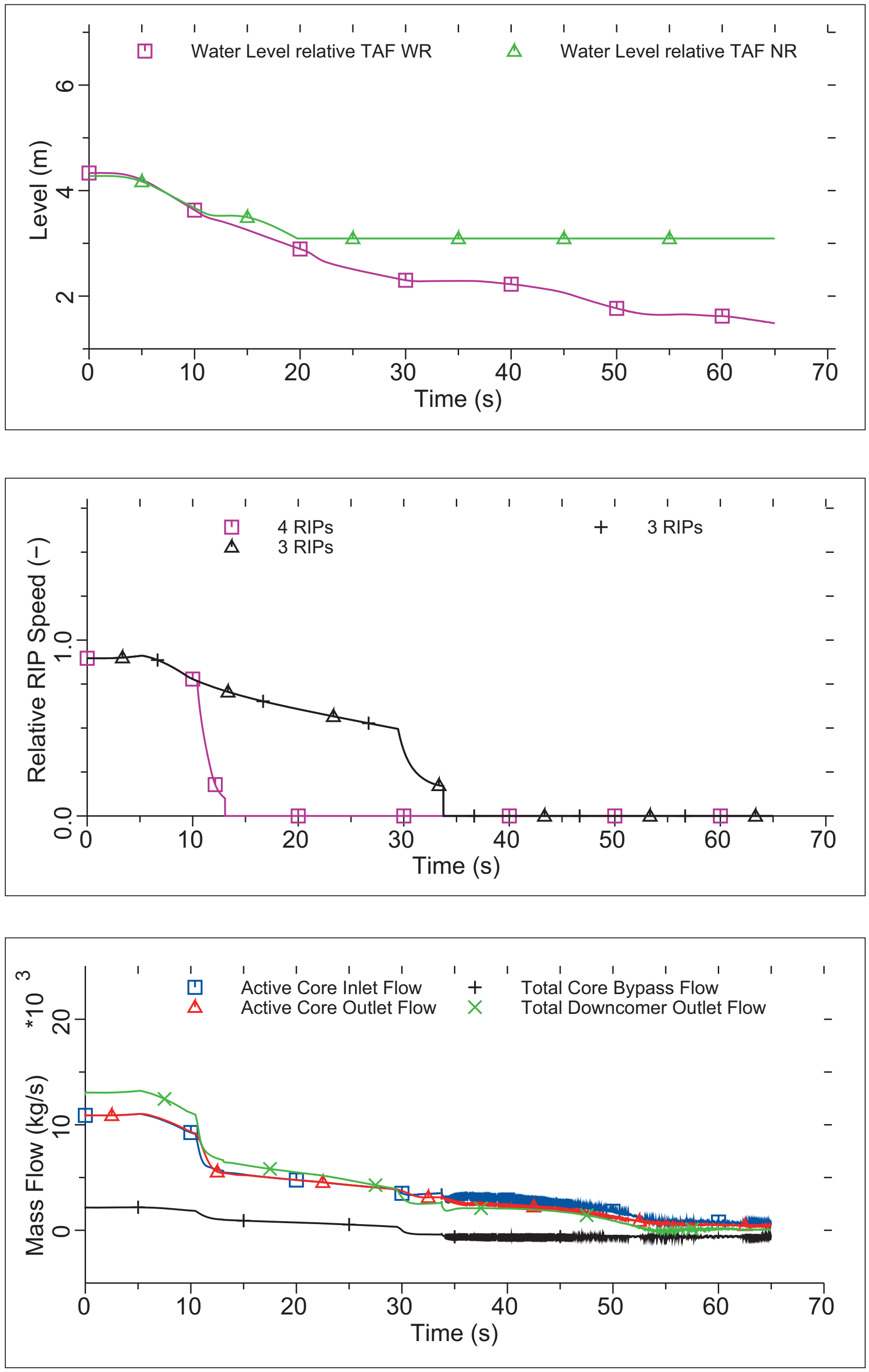


Figure 15E-9c ABWR Loss of Feedwater Flow, ARI

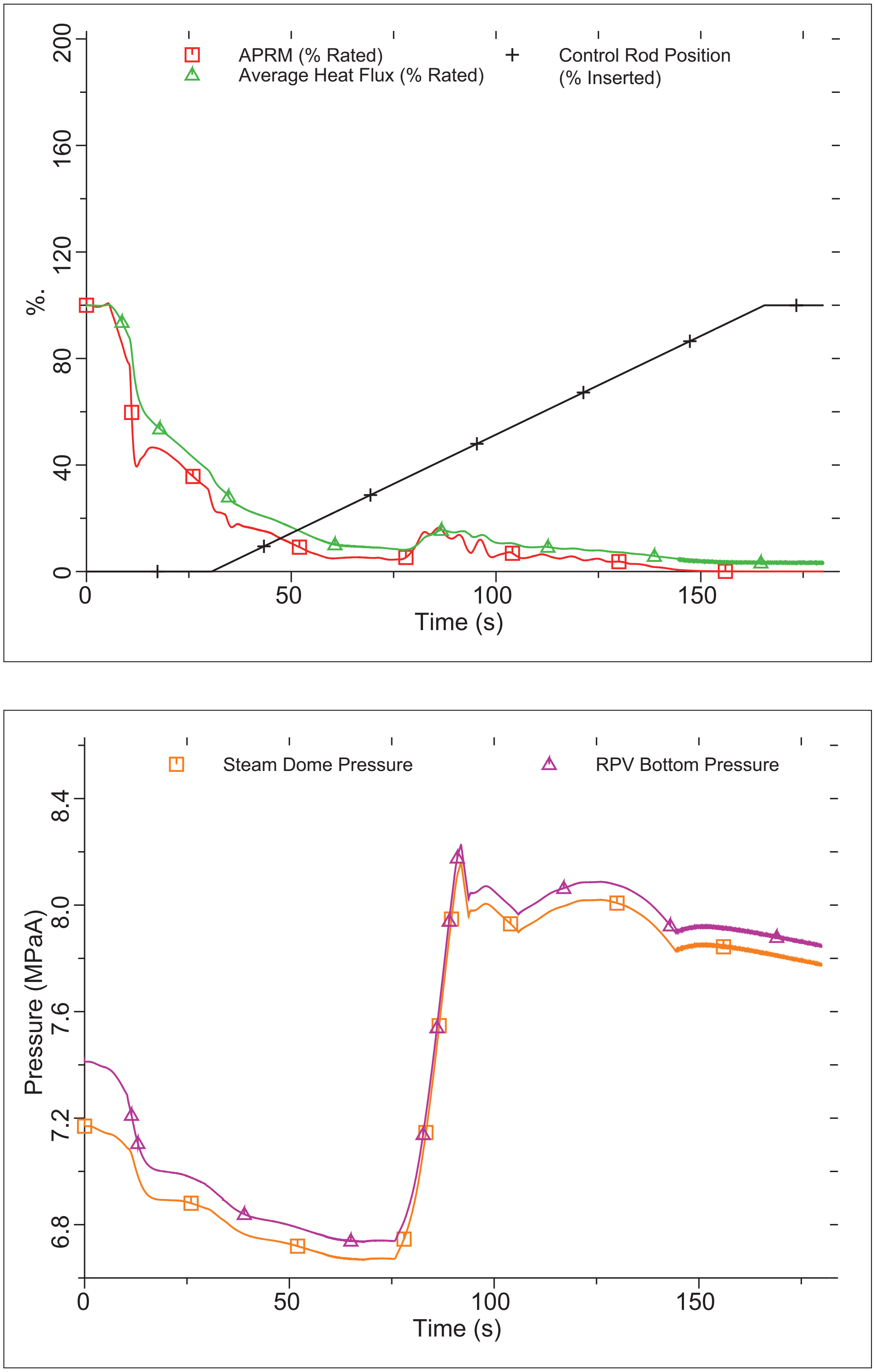


Figure 15E-10a ABWR Loss of Feedwater Flow, FMCRD Run–in

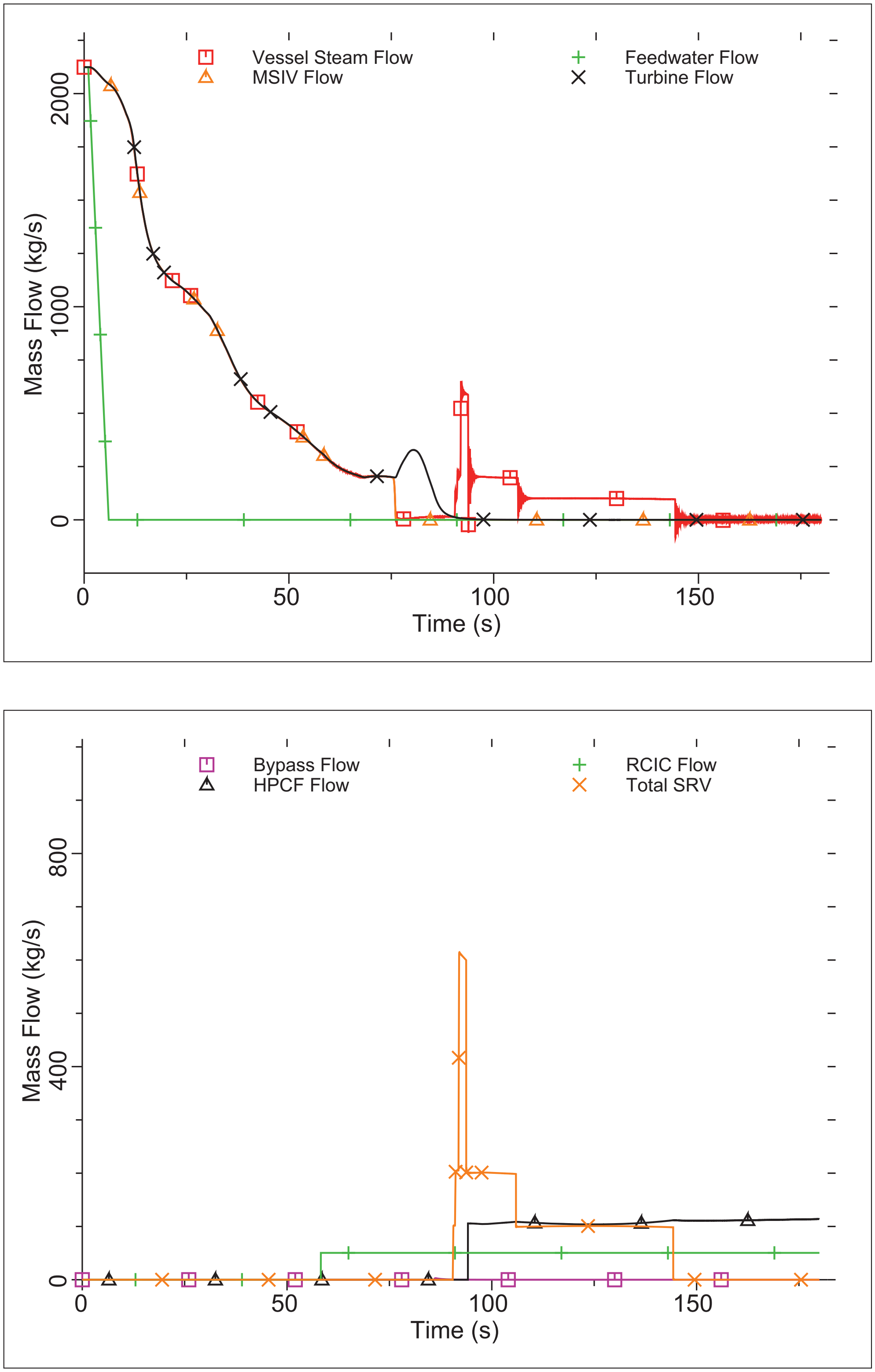


Figure 15E-10b ABWR Loss of Feedwater Flow, FMCRD Run–in

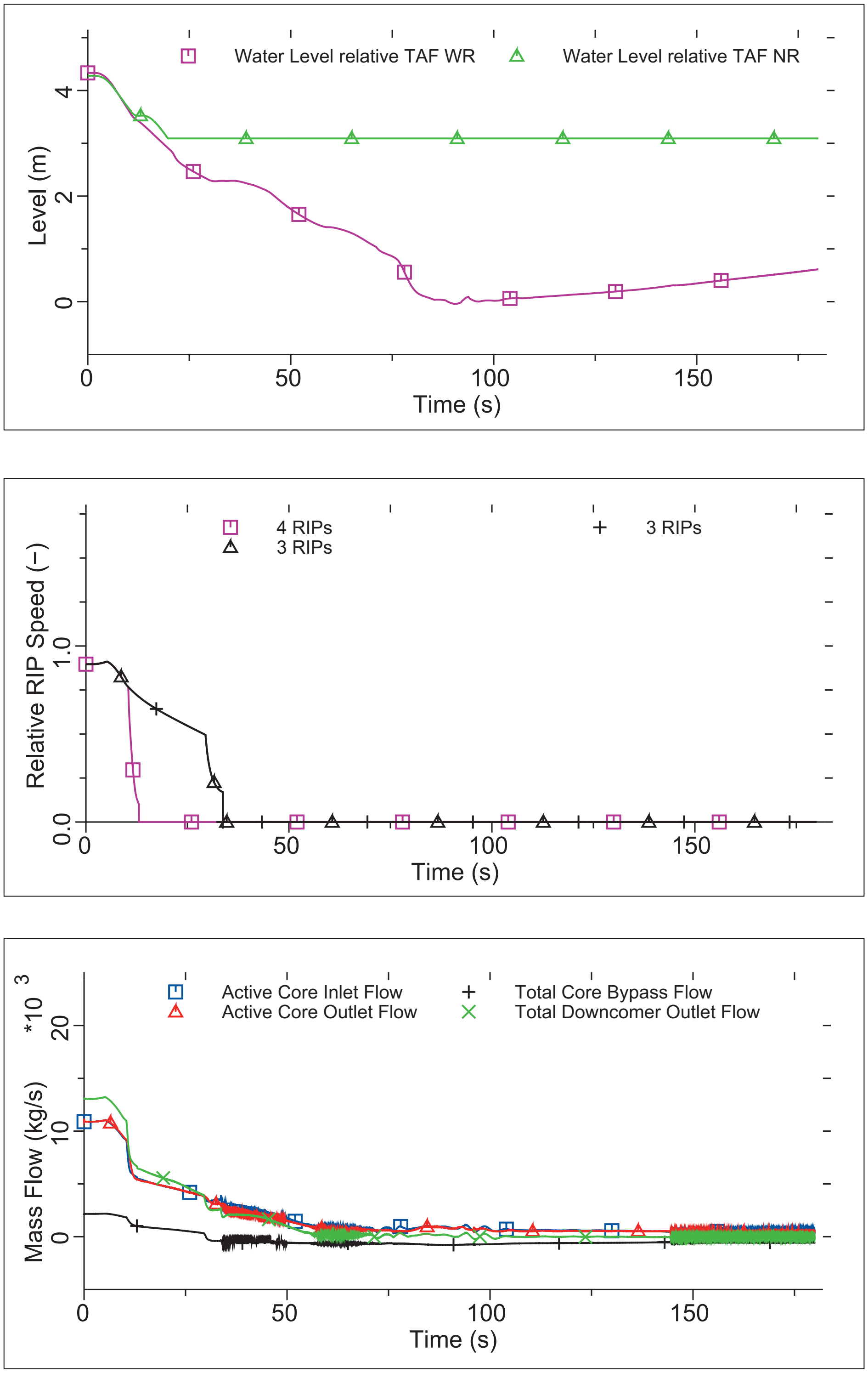


Figure 15E-10c ABWR Loss of Feedwater Flow, FMCRD Run–in

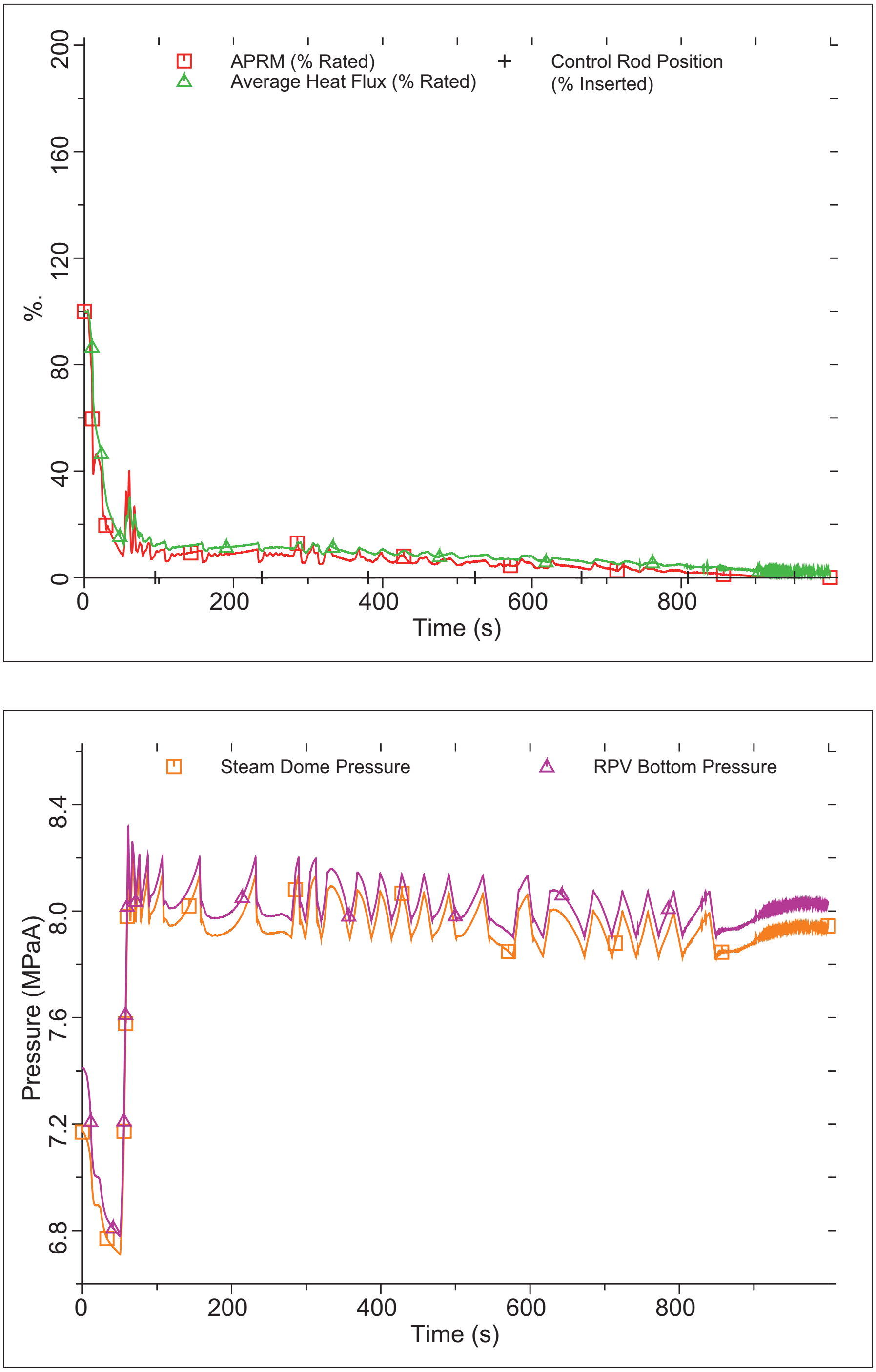


Figure 15E-11a ABWR Loss of Feedwater Flow, SLCS

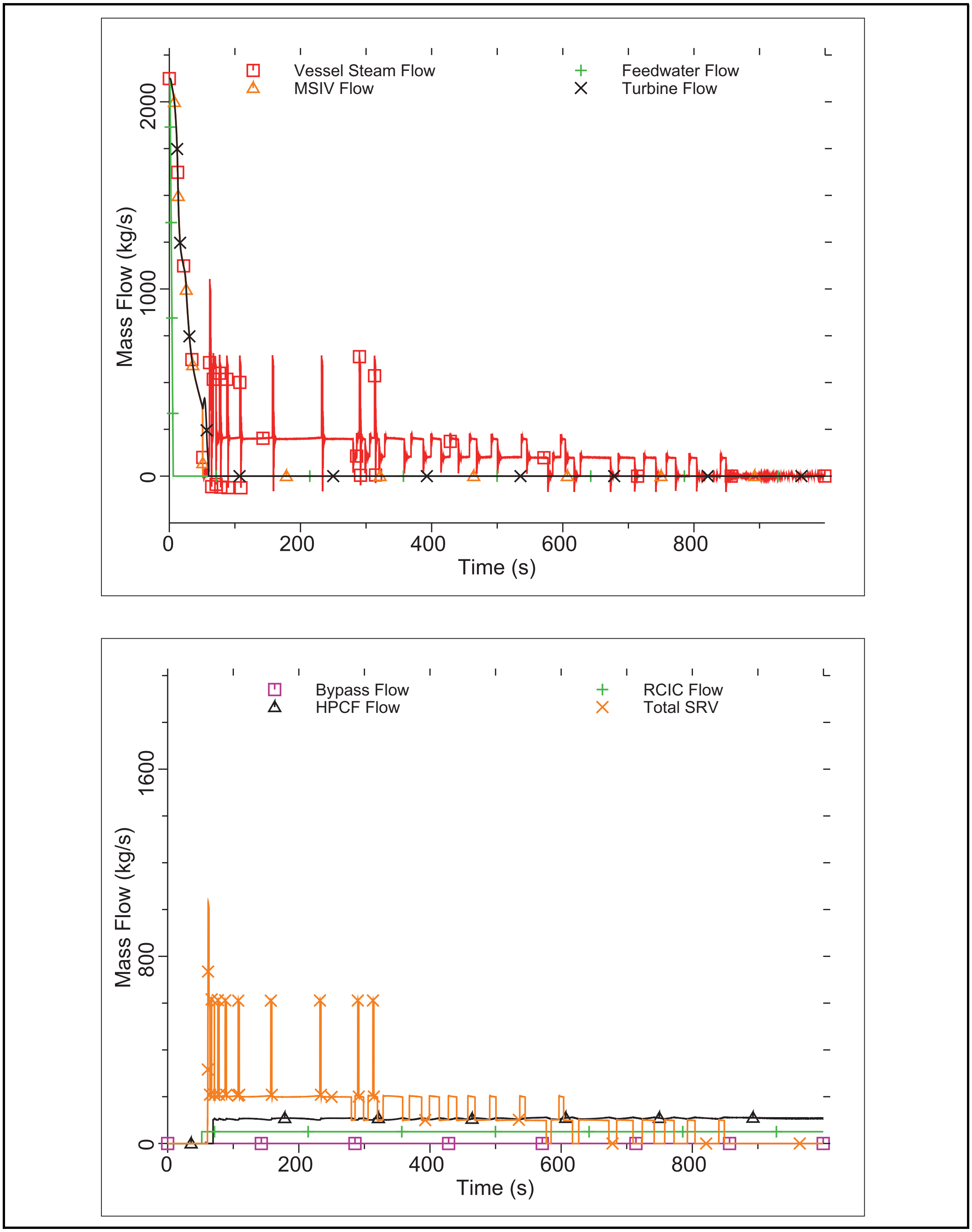


Figure 15E-11b ABWR Loss of Feedwater Flow, SLCS

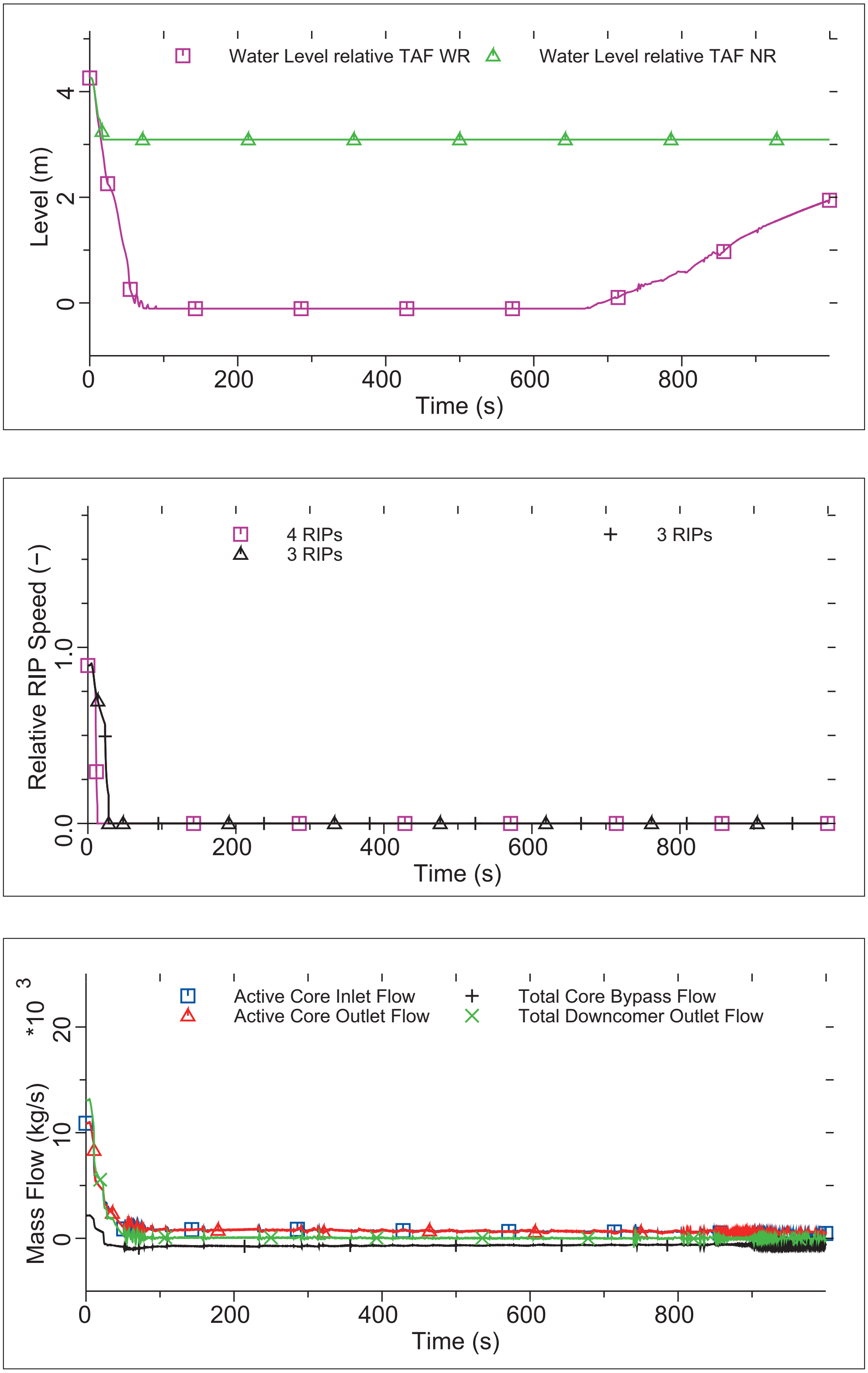


Figure 15E-11c ABWR Loss of Feedwater Flow, SLCS

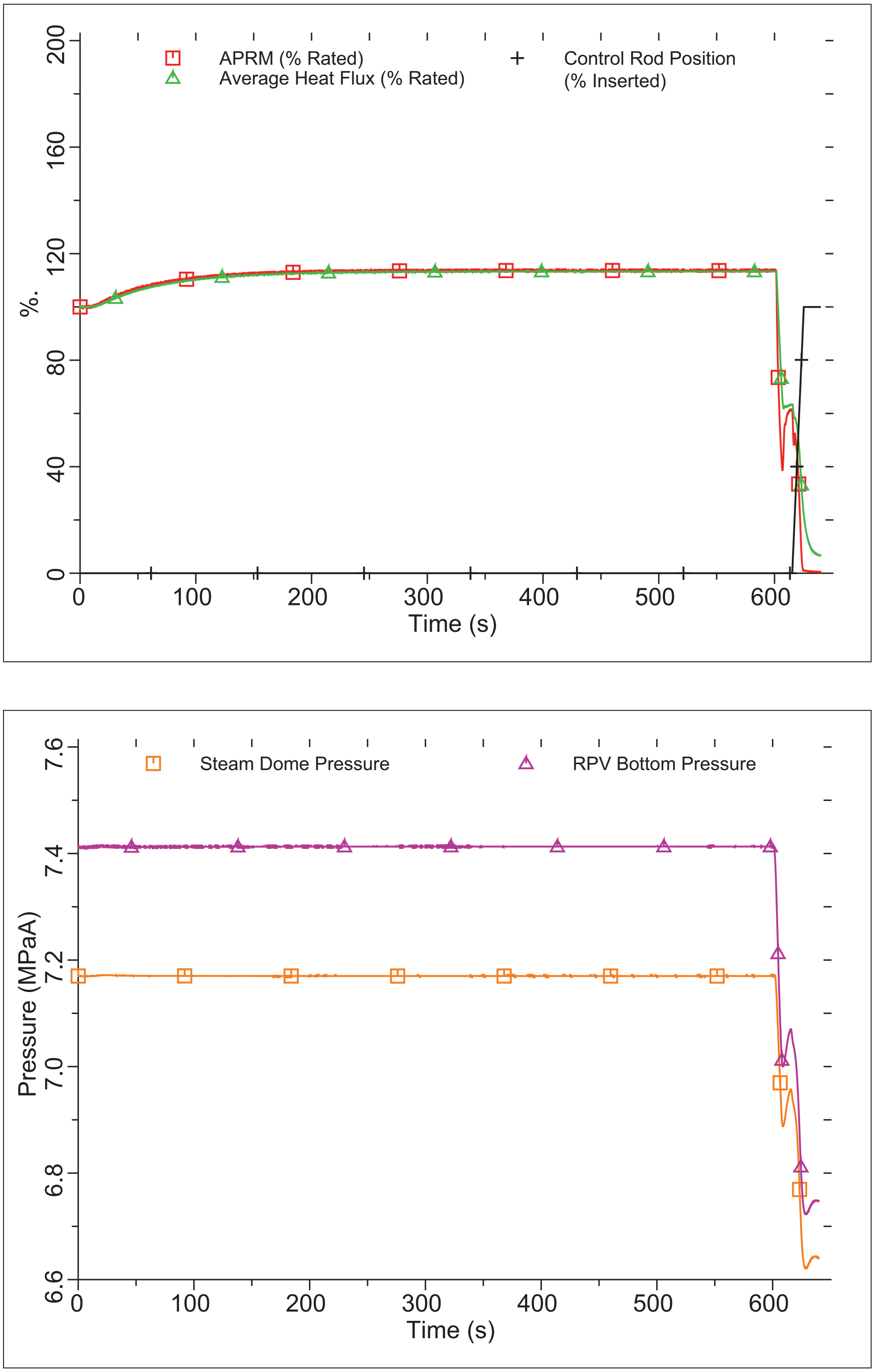


Figure 15E-12a ABWR Loss of Feedwater Heating, ARI

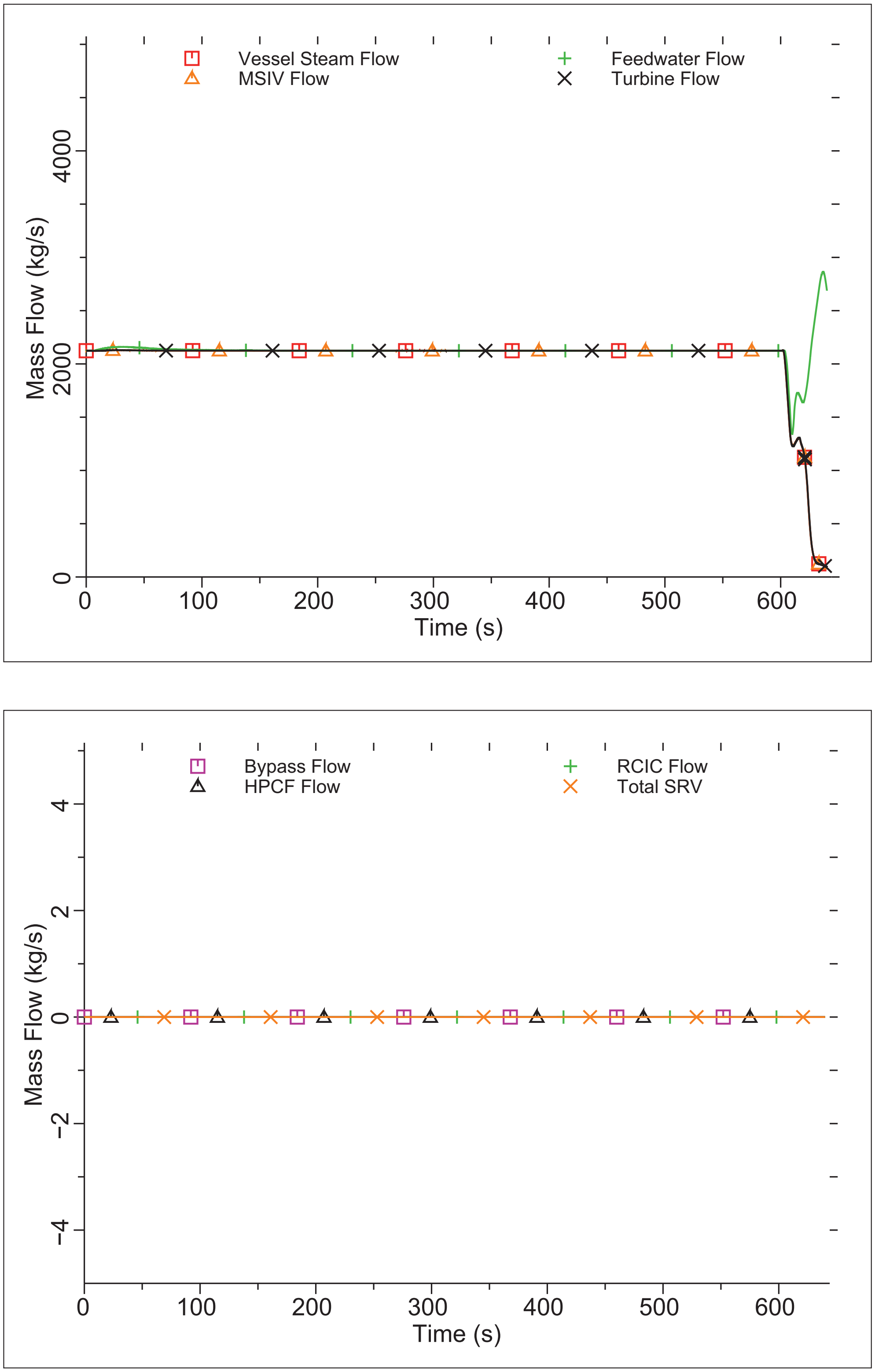


Figure 15E-12b ABWR Loss of Feedwater Heating, ARI

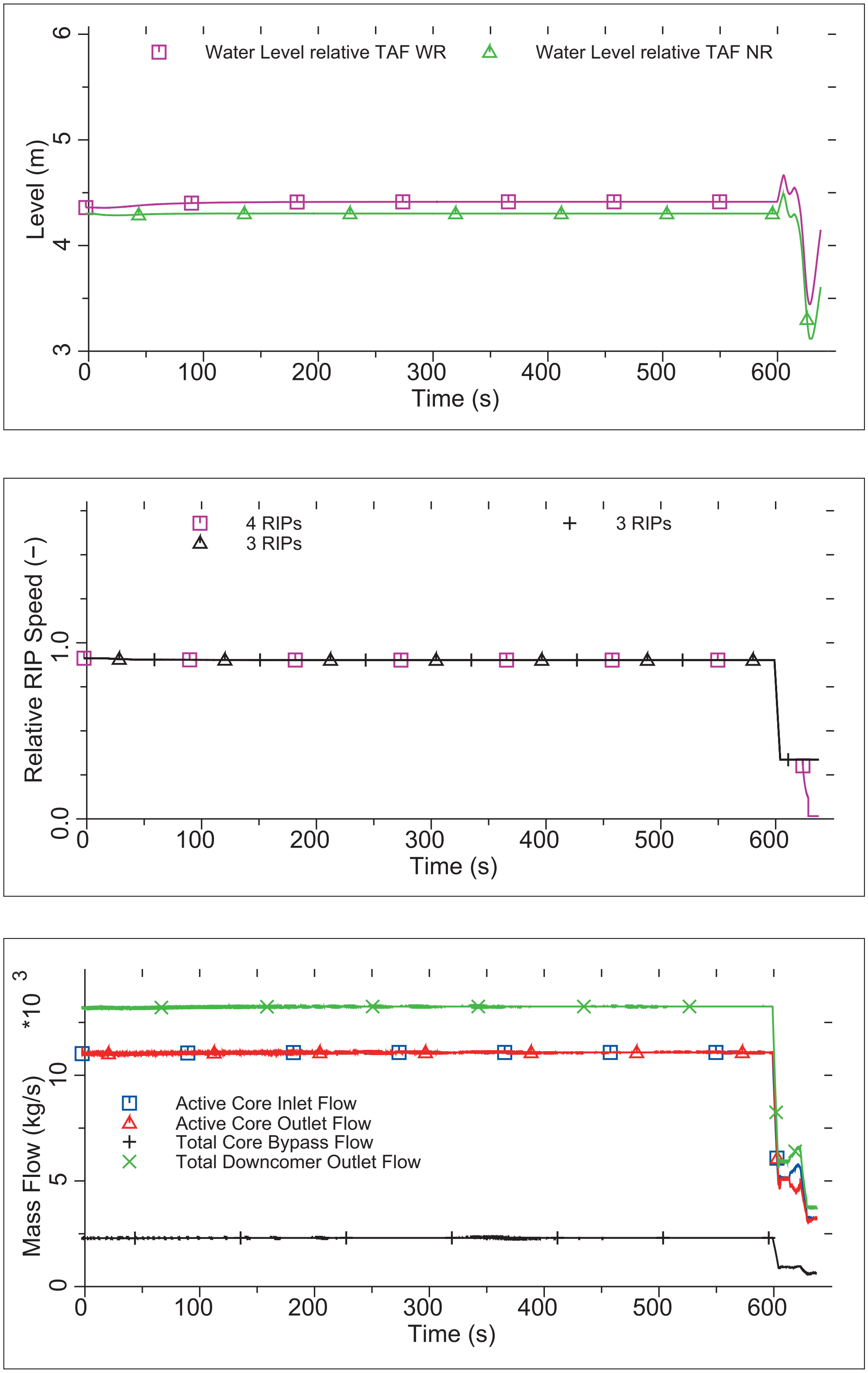


Figure 15E-12c ABWR Loss of Feedwater Heating, ARI

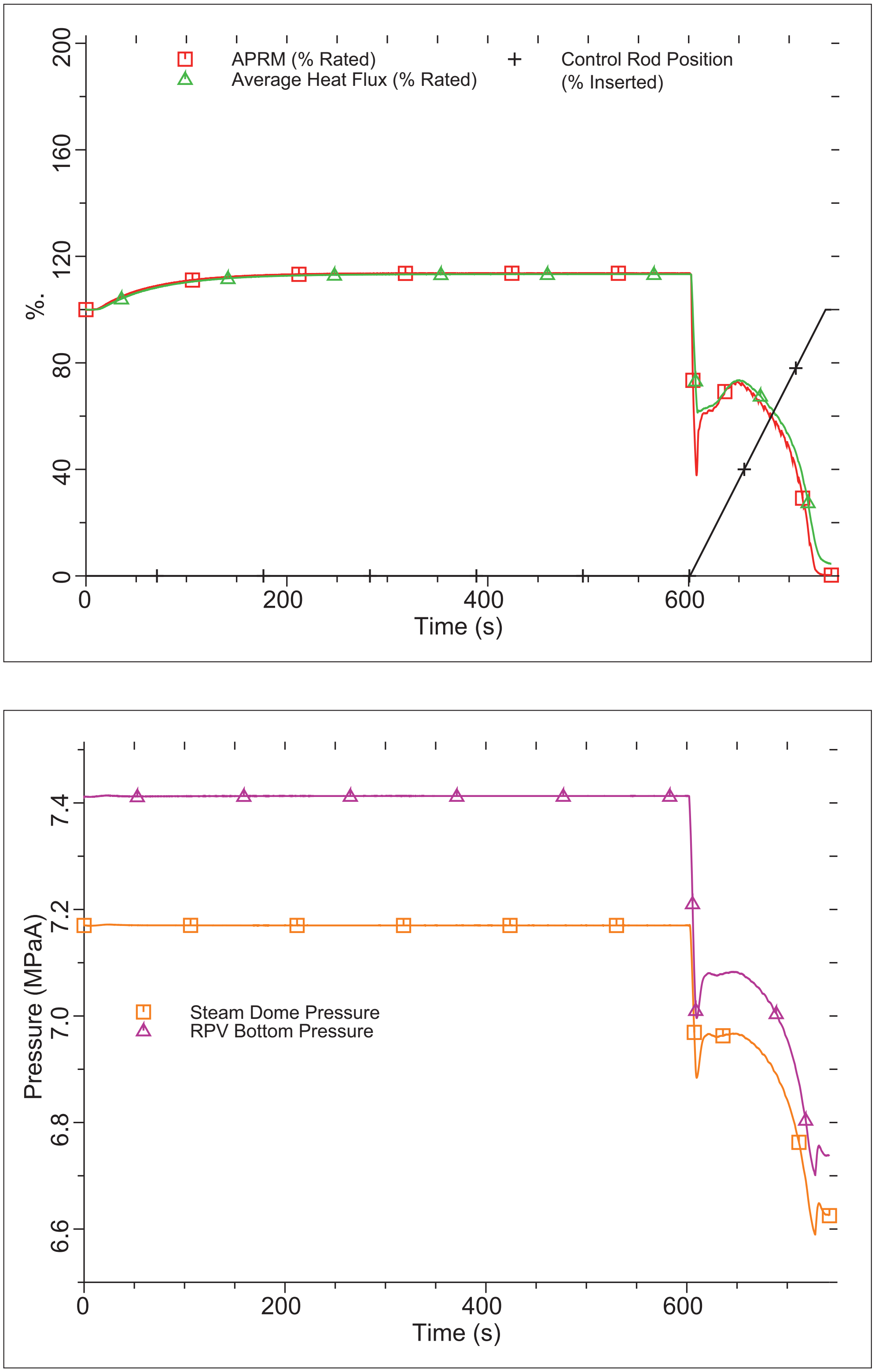


Figure 15E-13a ABWR Loss of Feedwater Heating, FMCRD Run–in

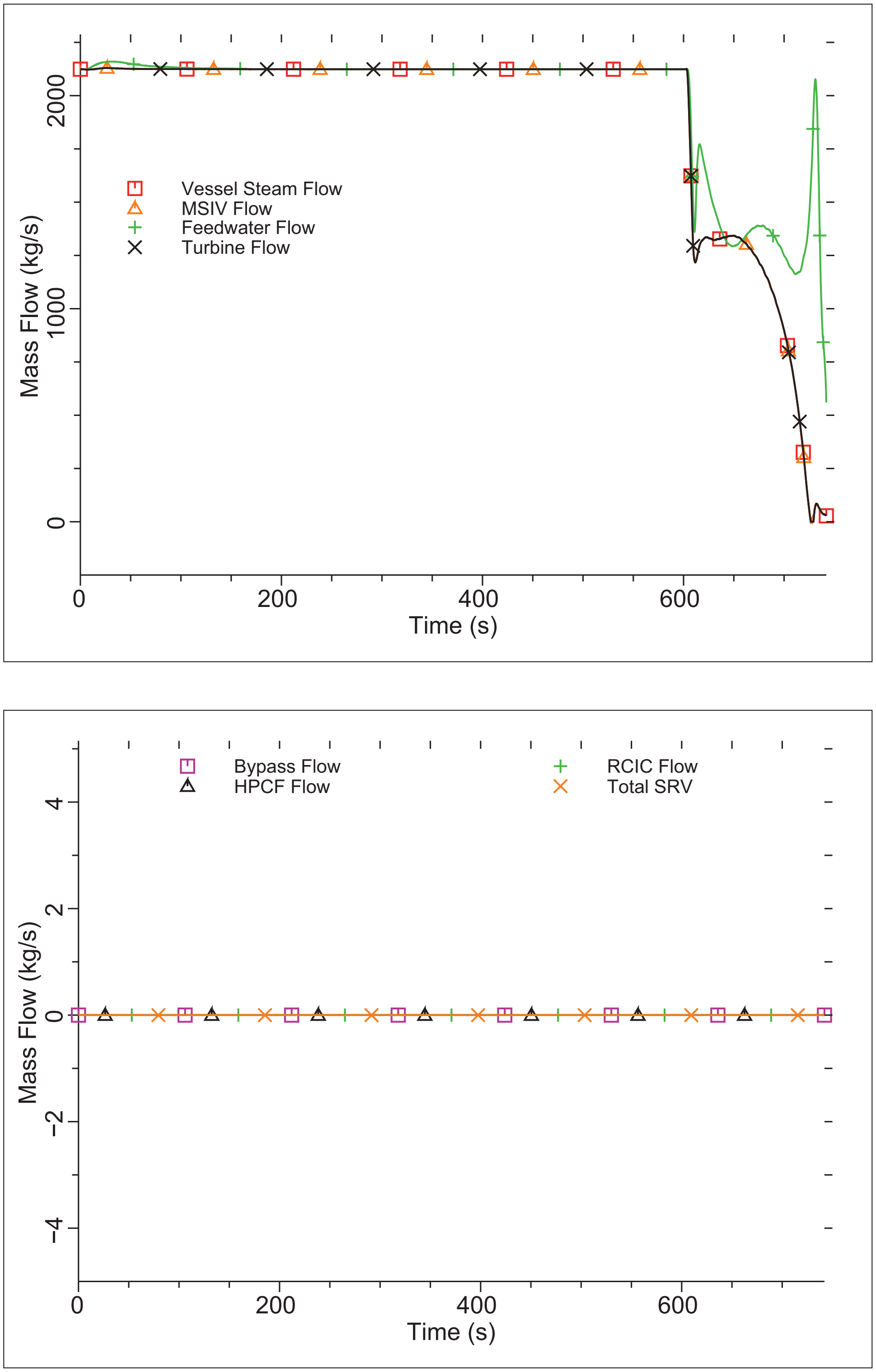


Figure 15E-13b ABWR Loss of Feedwater Heating, FMCRD Run–in

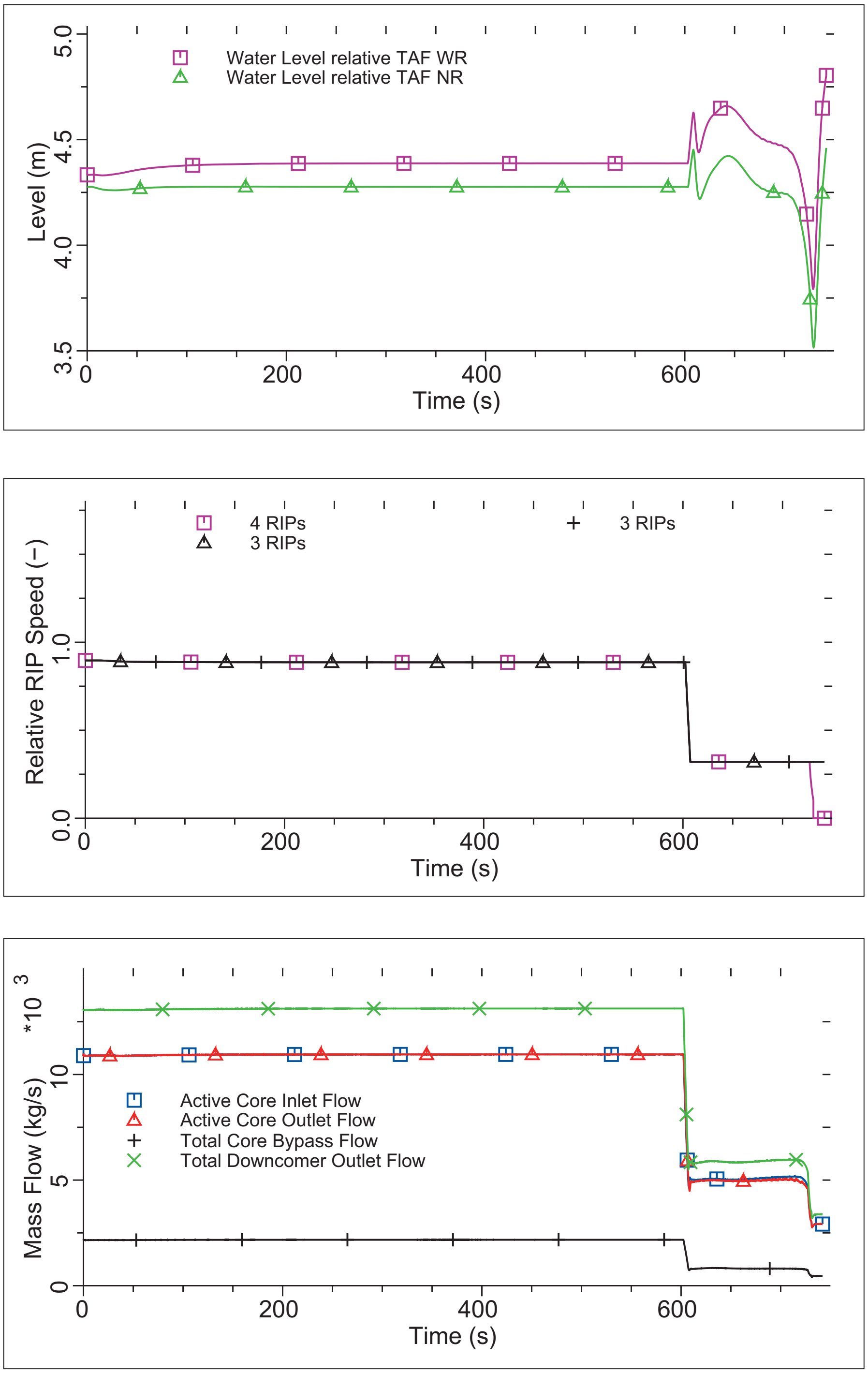


Figure 15E-13c ABWR Loss of Feedwater Heating, FMCRD Run–in

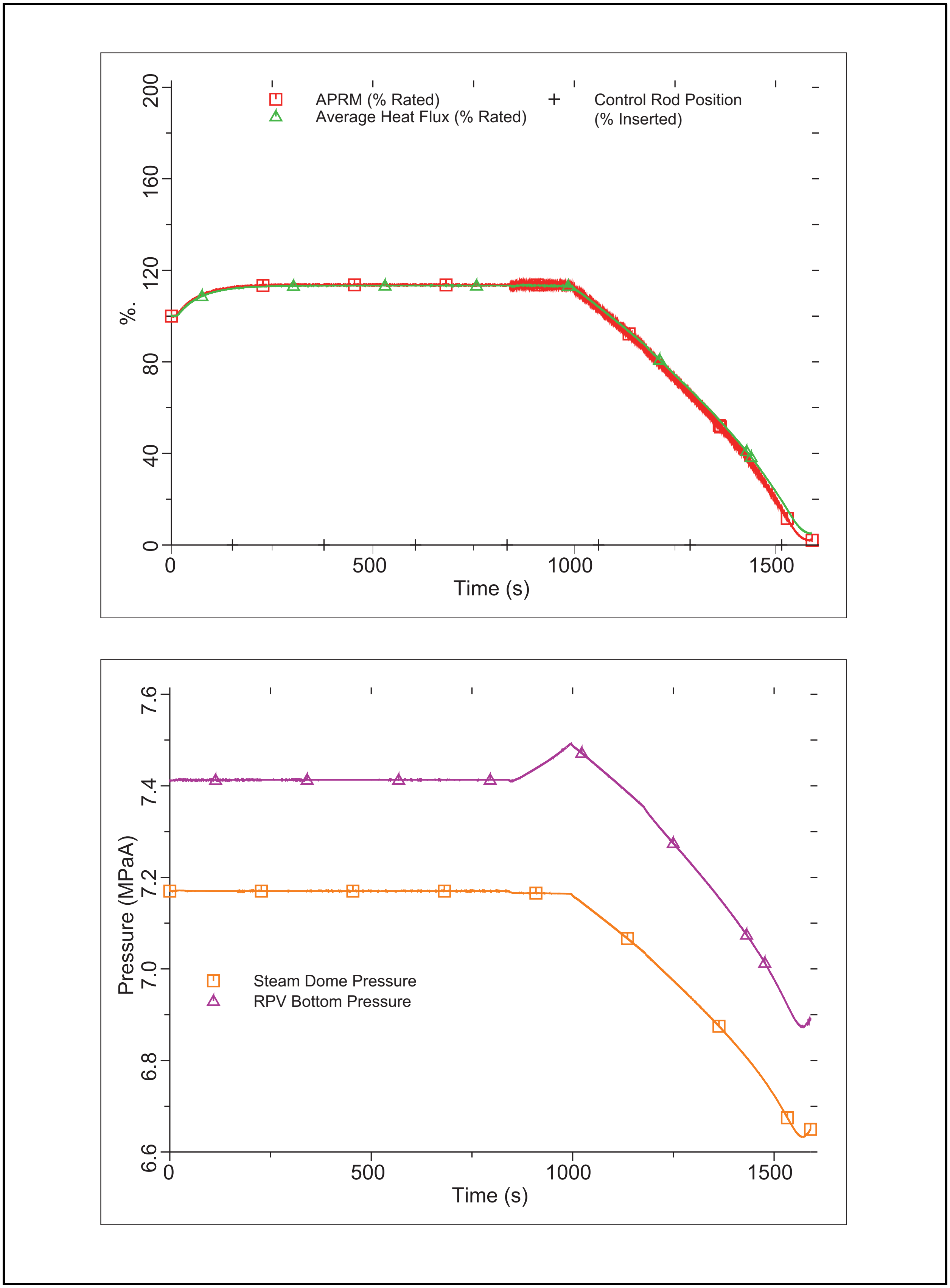


Figure 15E-14a ABWR Loss of Feedwater Heating, SLCS

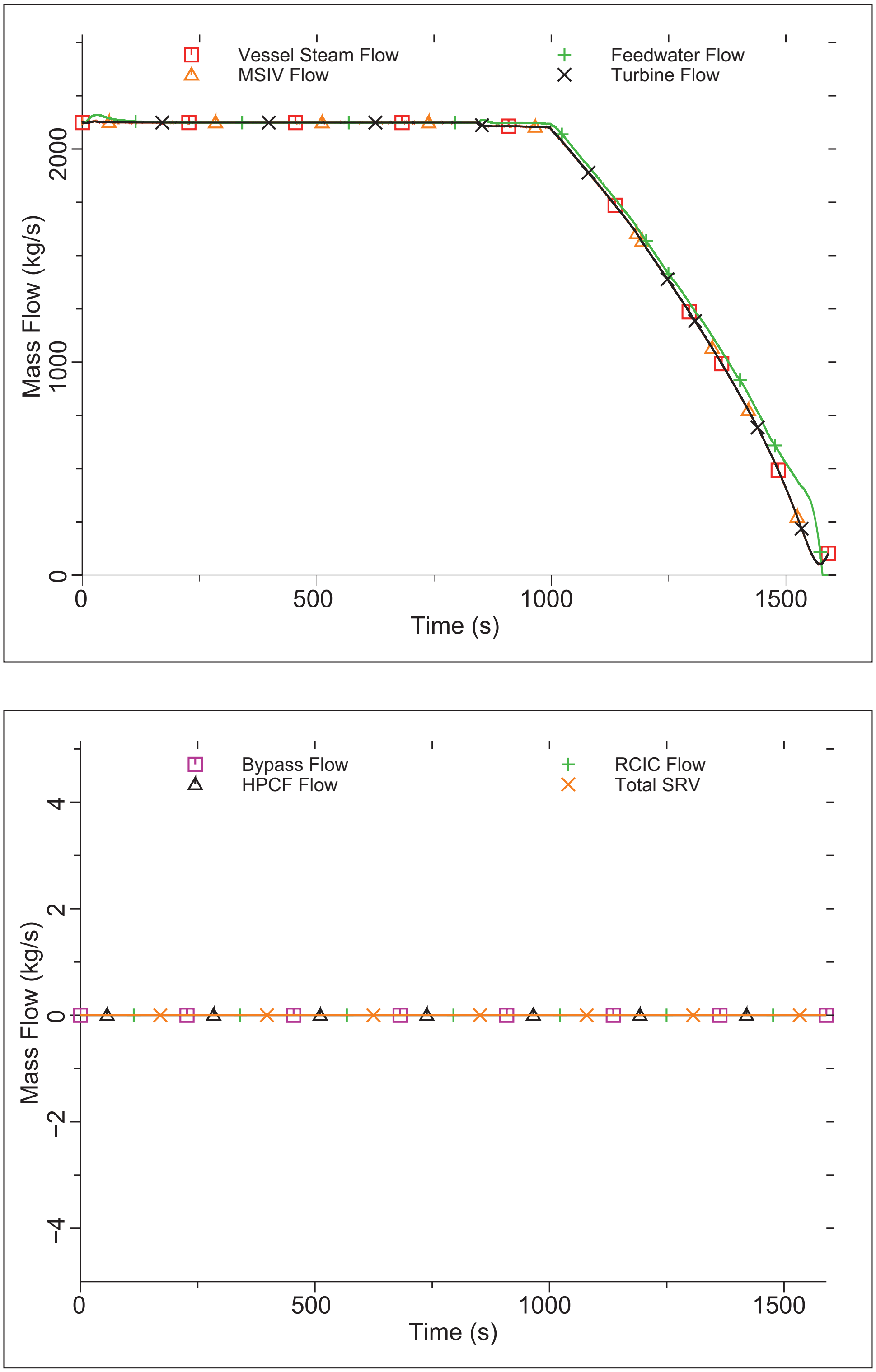


Figure 15E-14b ABWR Loss of Feedwater Heating, SLCS

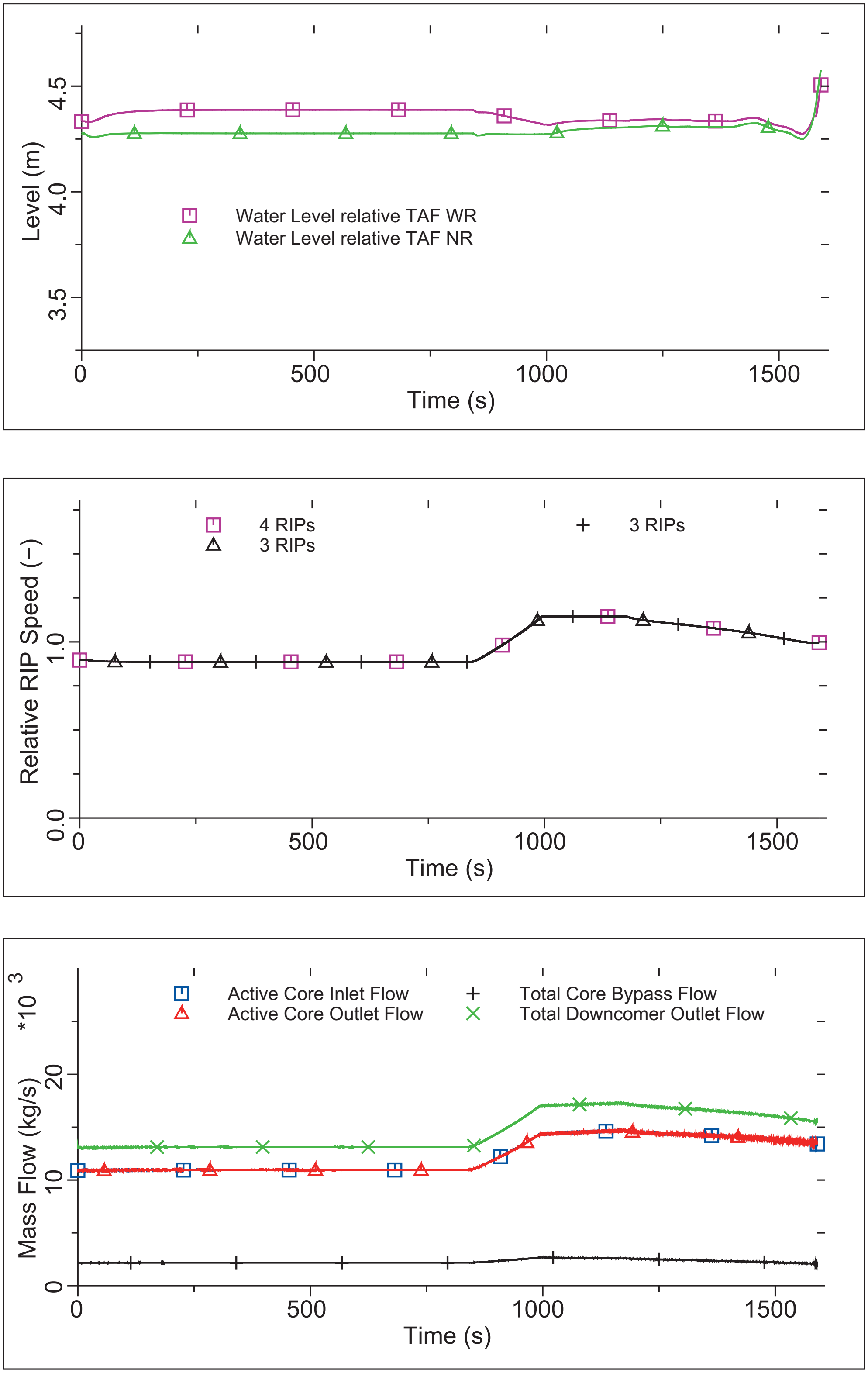


Figure 15E-14c ABWR Loss of Feedwater Heating, SLCS

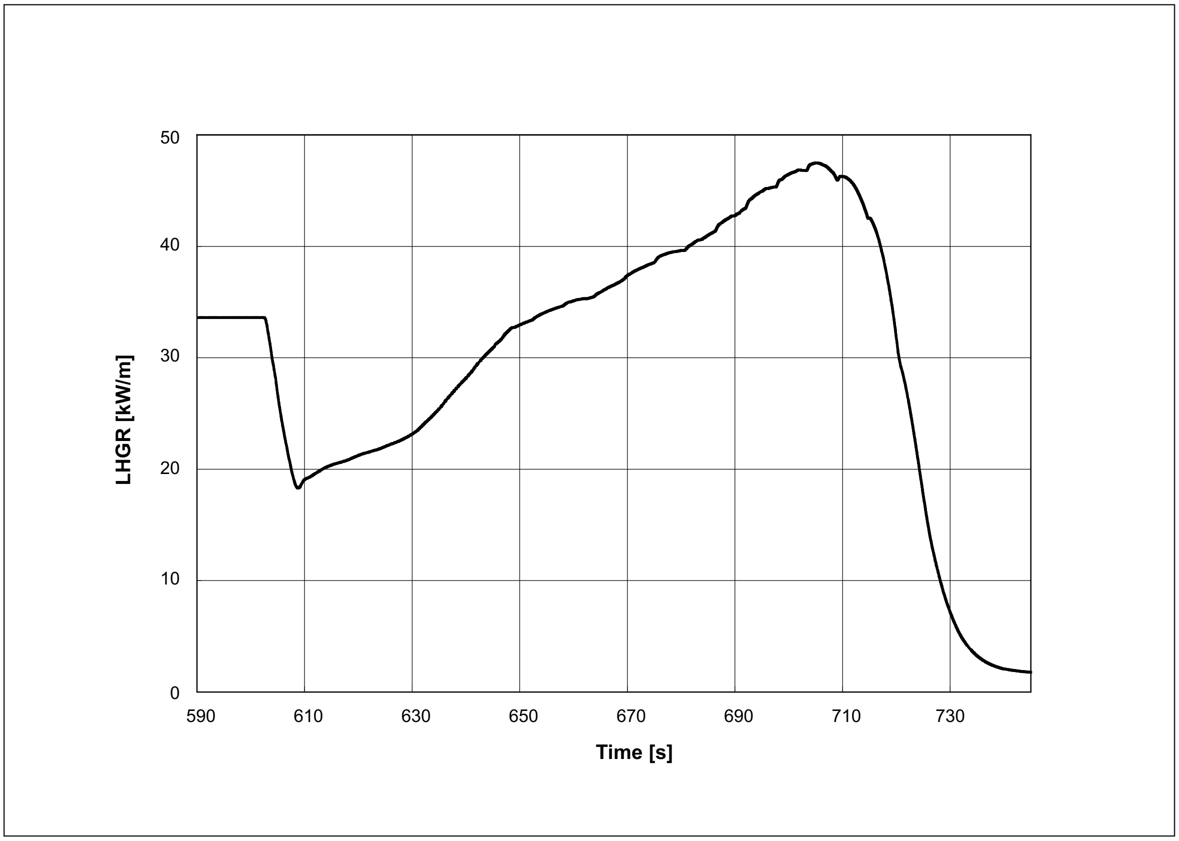


Figure 15E-15 ABWR Loss of Feedwater Heating, Max. LHGR

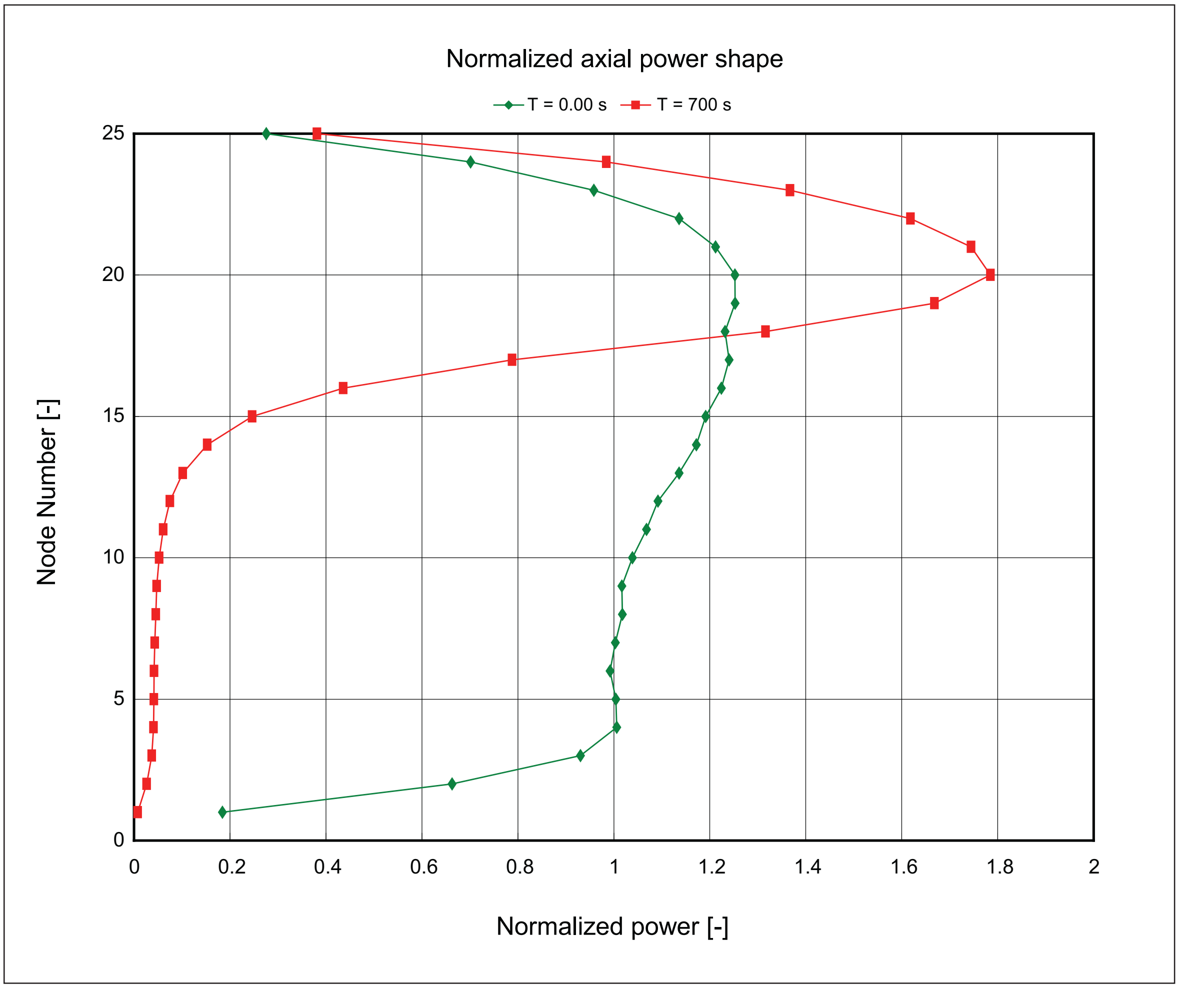


Figure 15E-16 ABWR Loss of Feedwater Heating, FMCRD Run–in, Axial Power Shape

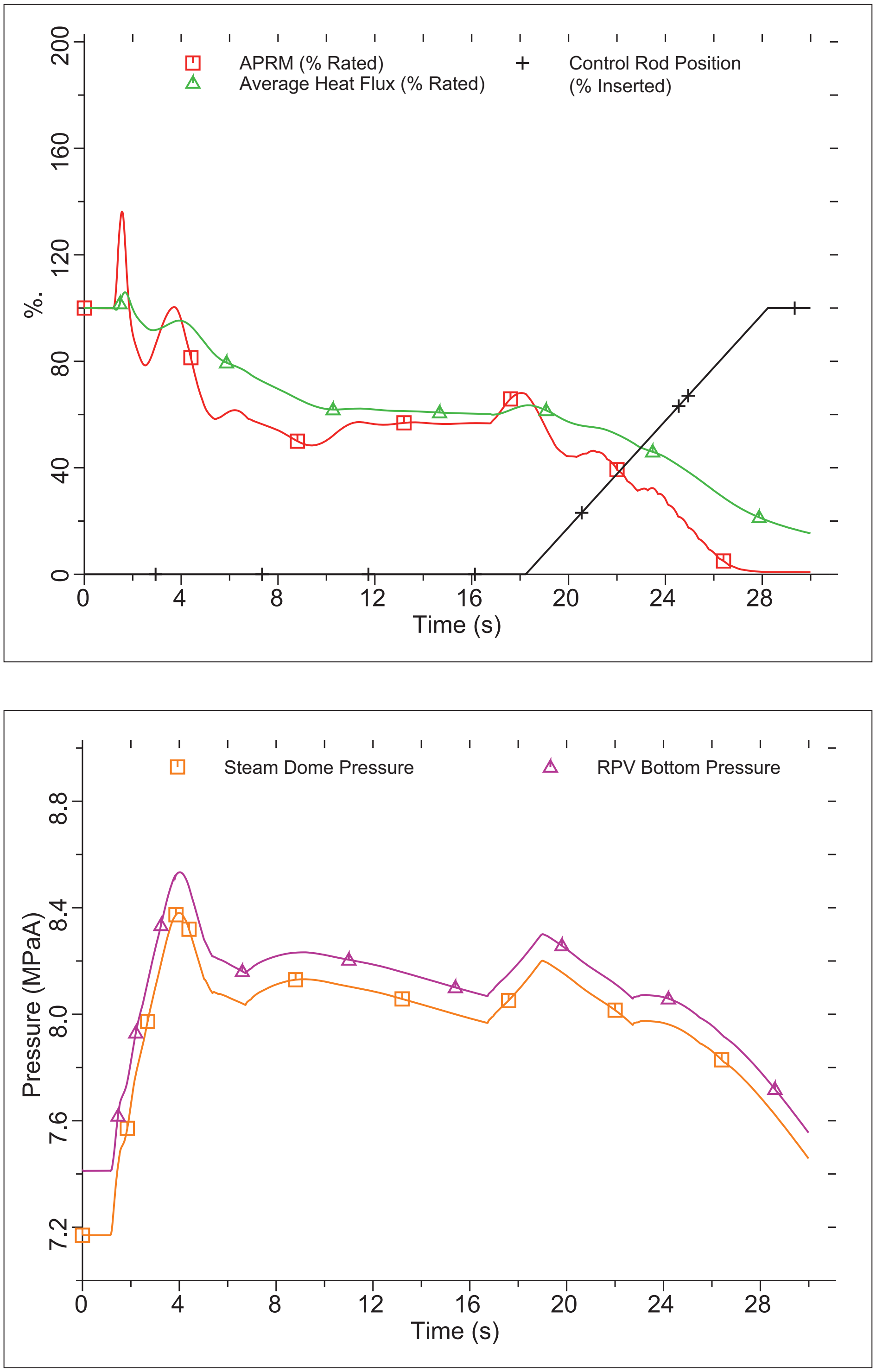
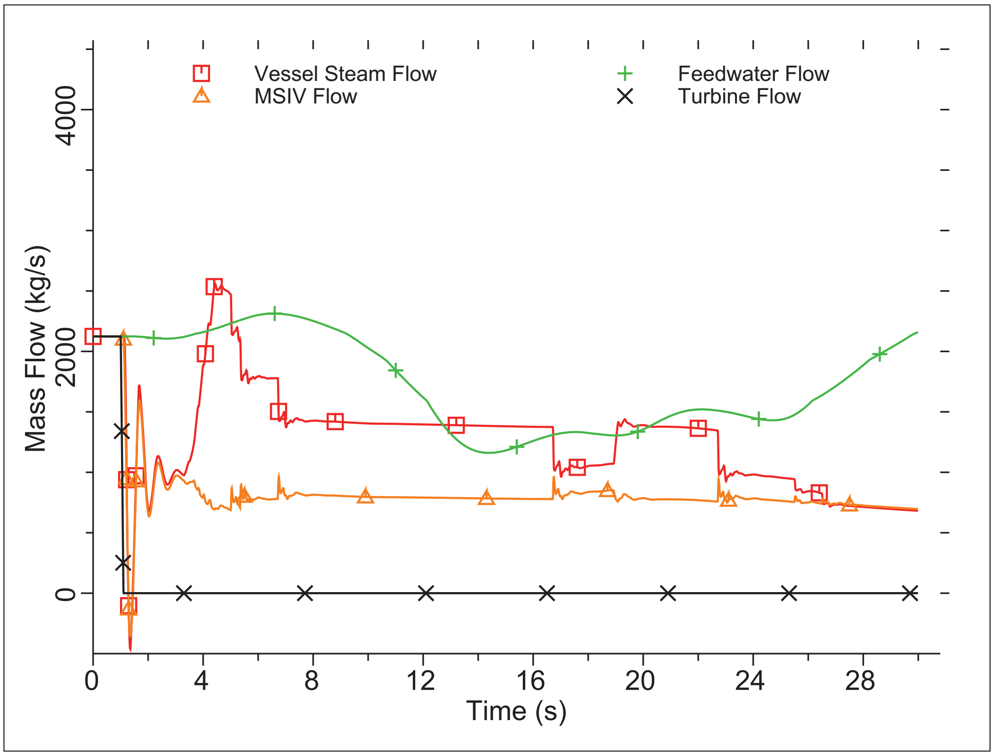


Figure 15E-17a ABWR Turbine Trip w/ Bypass, ARI



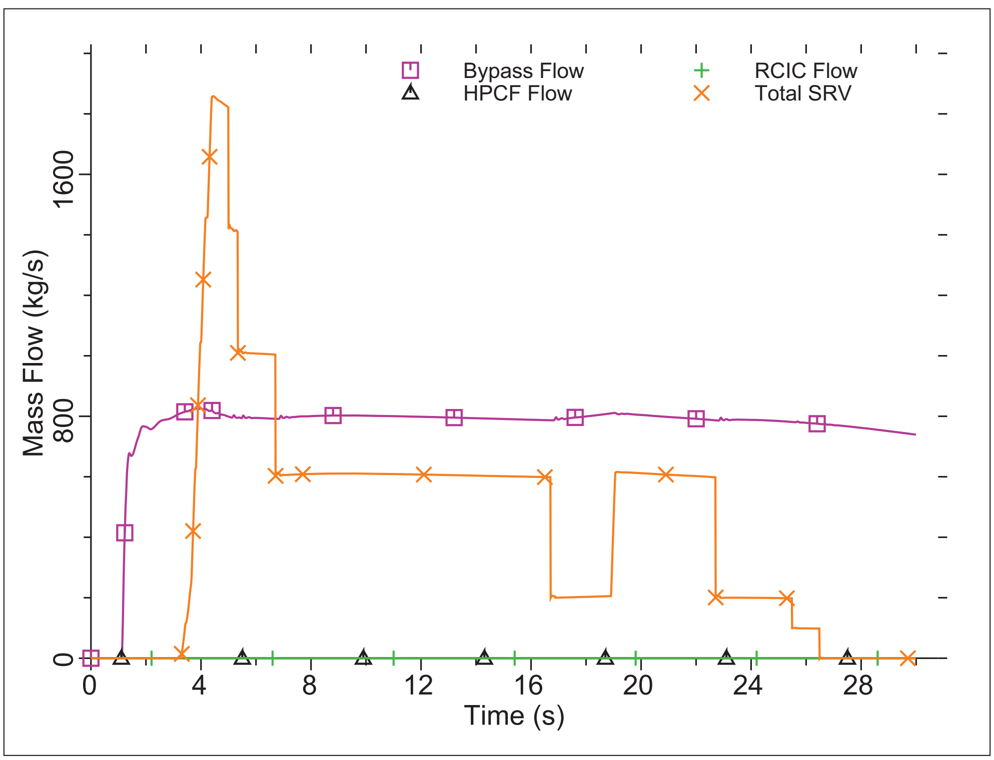


Figure 15E-17b ABWR Turbine Trip w/ Bypass, ARI

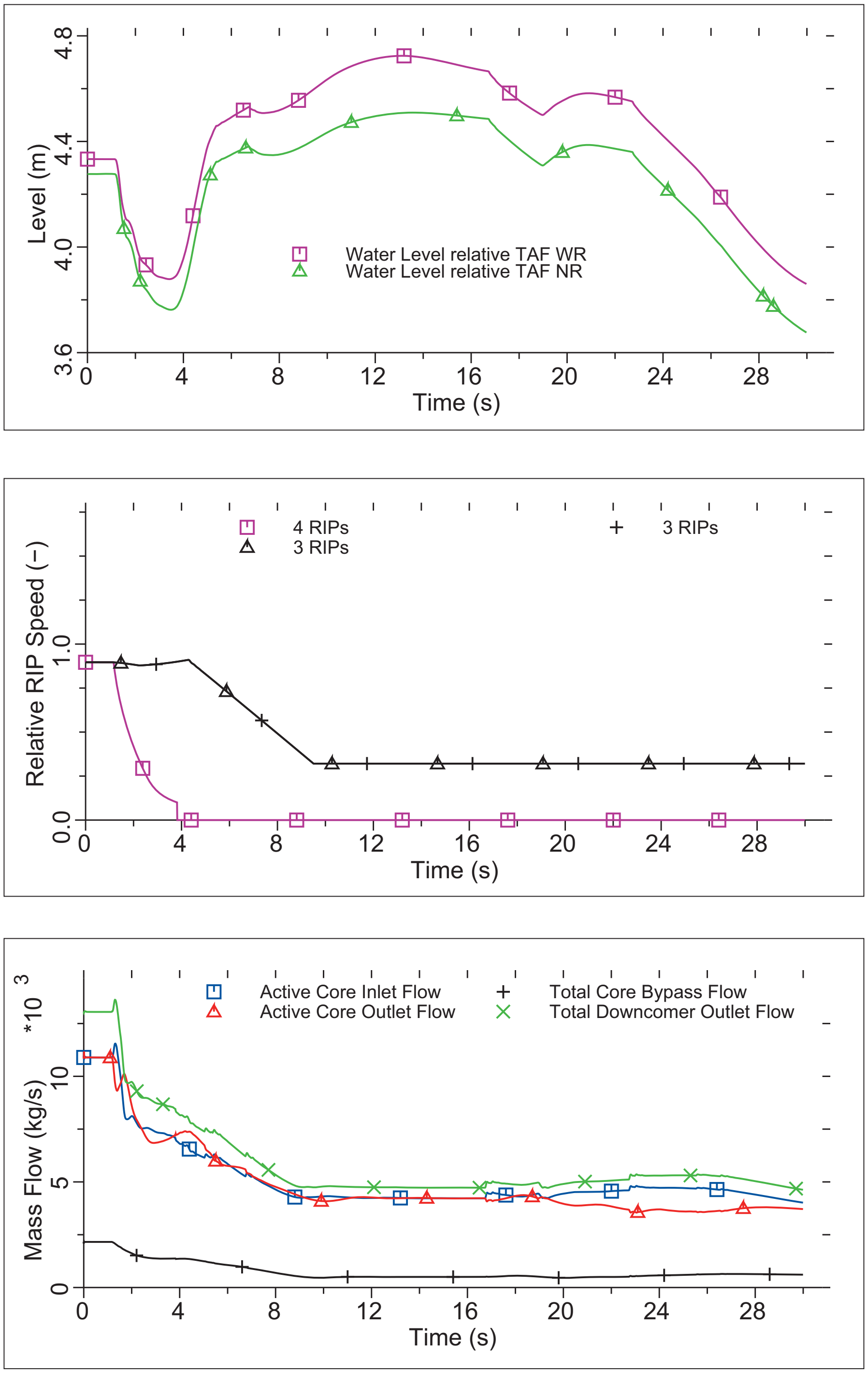


Figure 15E-17c ABWR Turbine Trip w/ Bypass, ARI

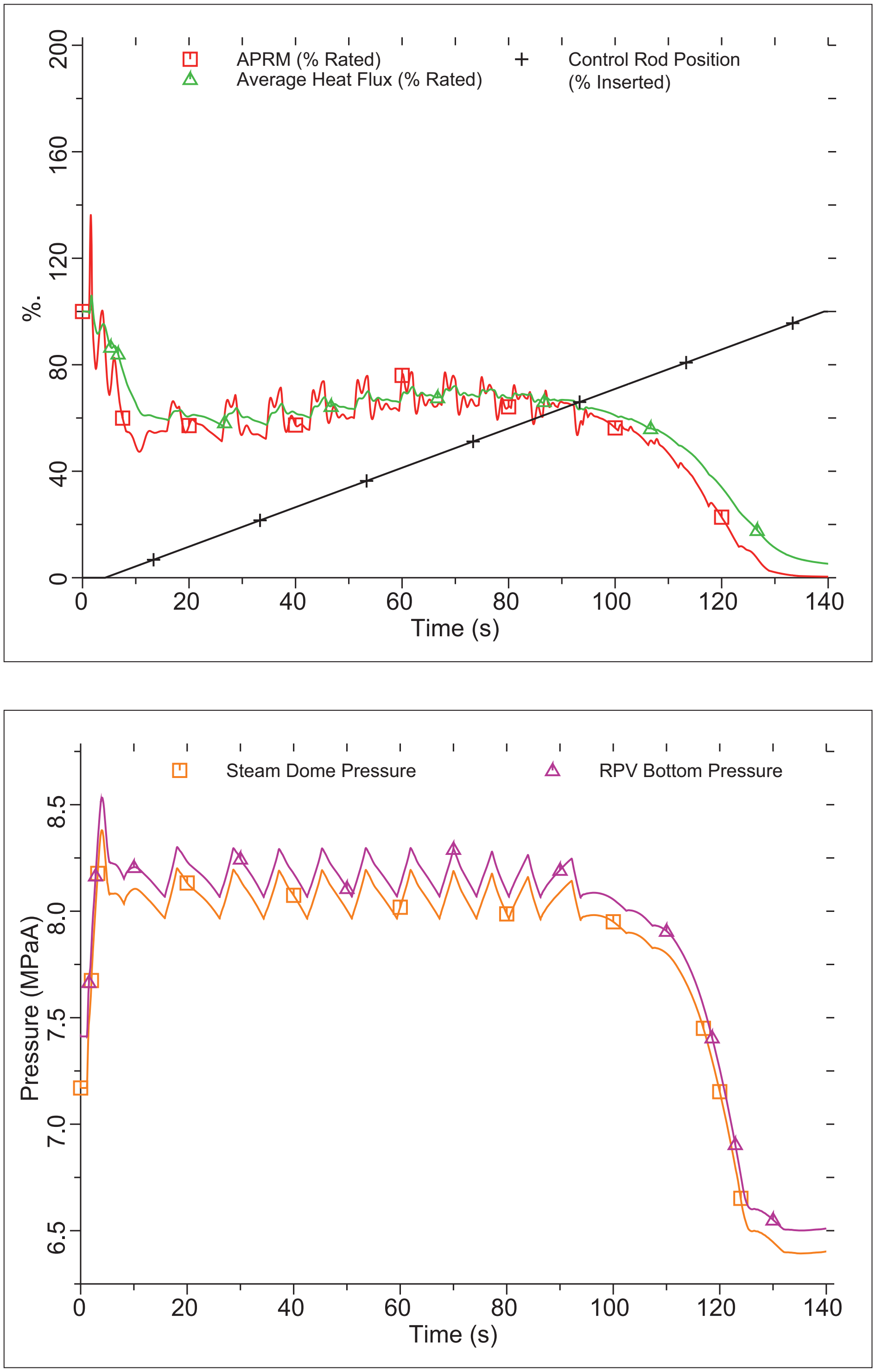


Figure 15E-18a ABWR Turbine Trip w/ Bypass, FMCRD Run–in

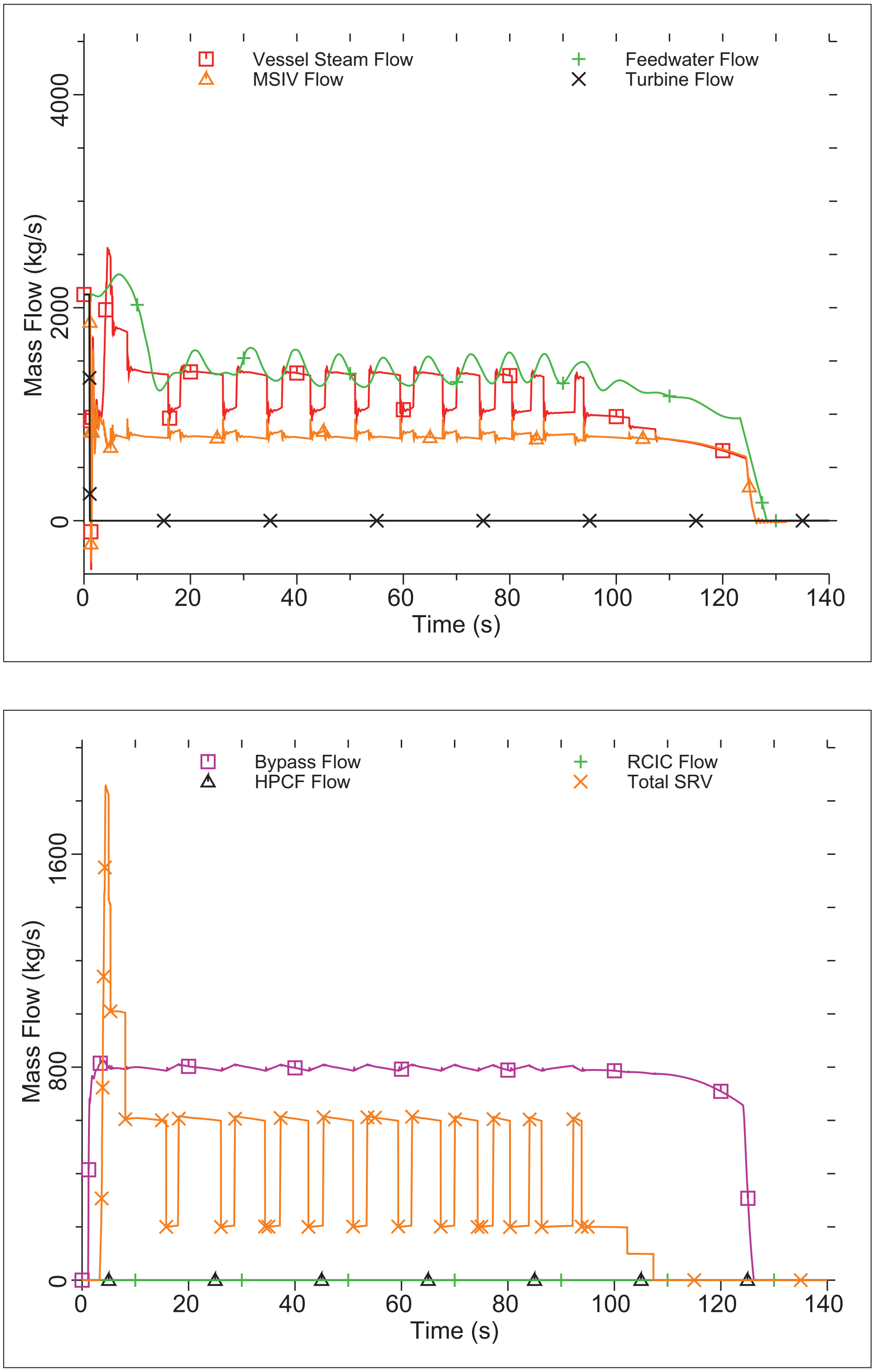


Figure 15E-18b ABWR Turbine Trip w/ Bypass, FMCRD Run–in

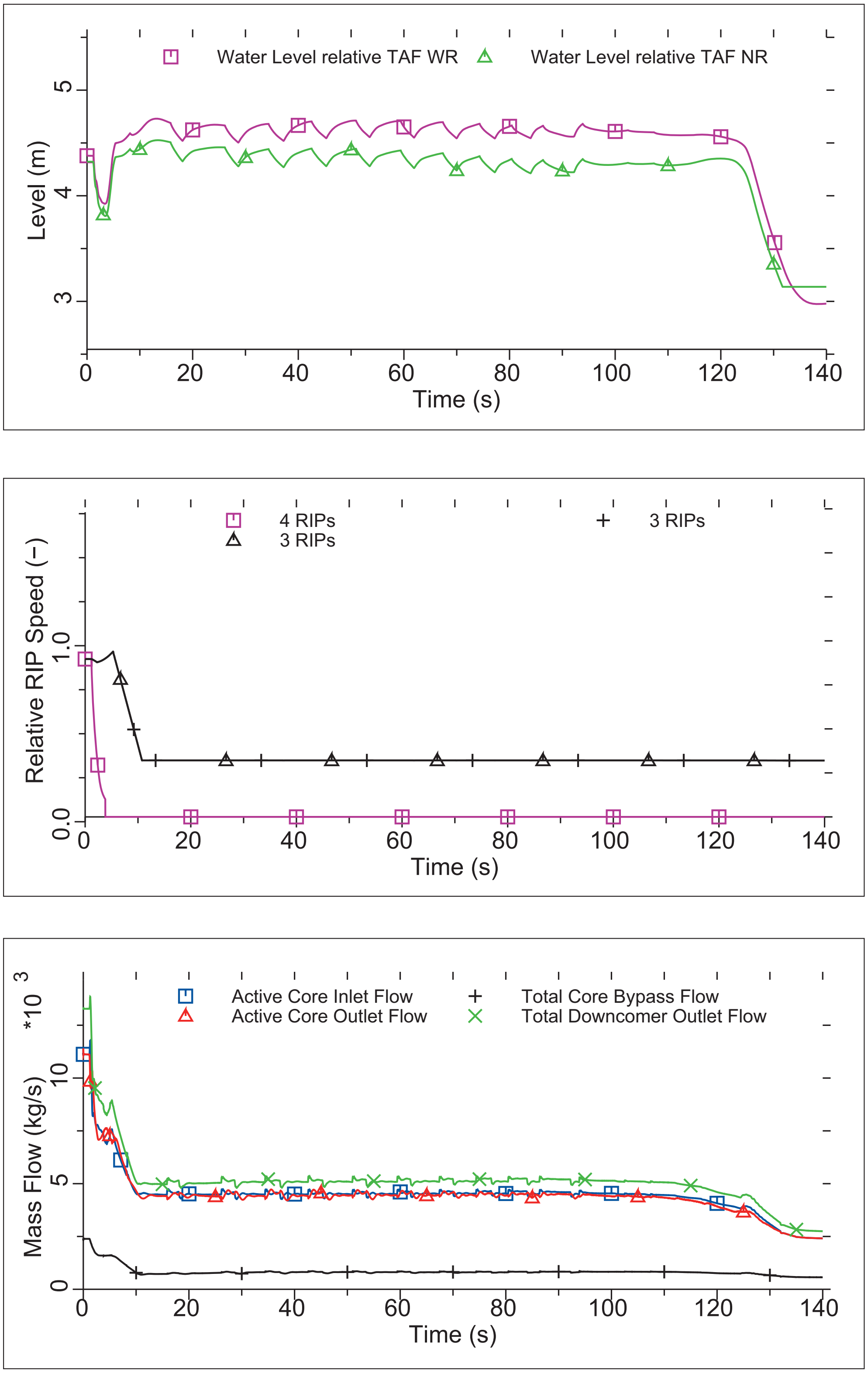
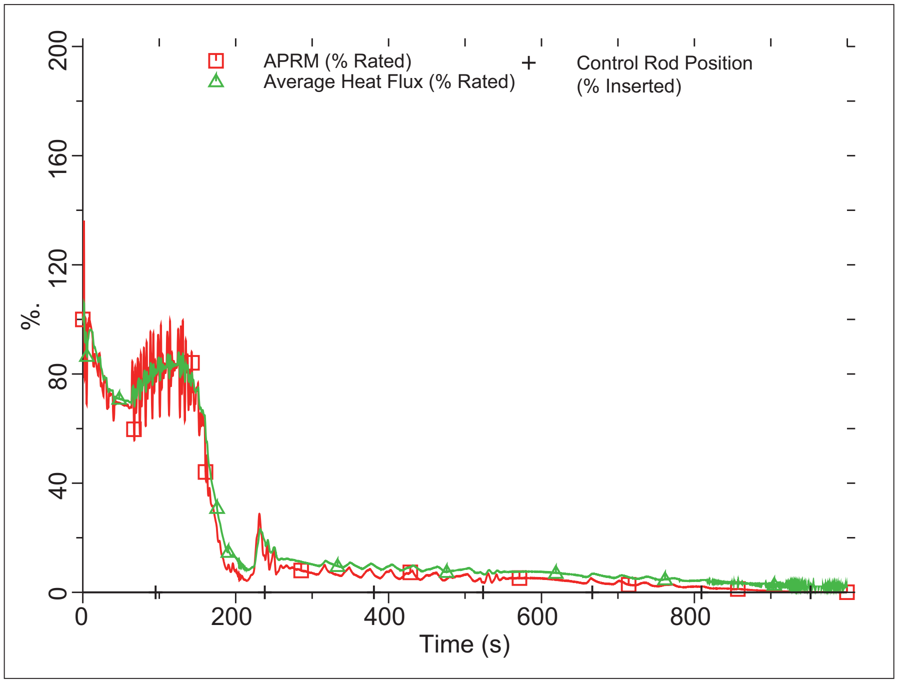


Figure 15E-18c ABWR Turbine Trip w/ Bypass, FMCRD Run–in



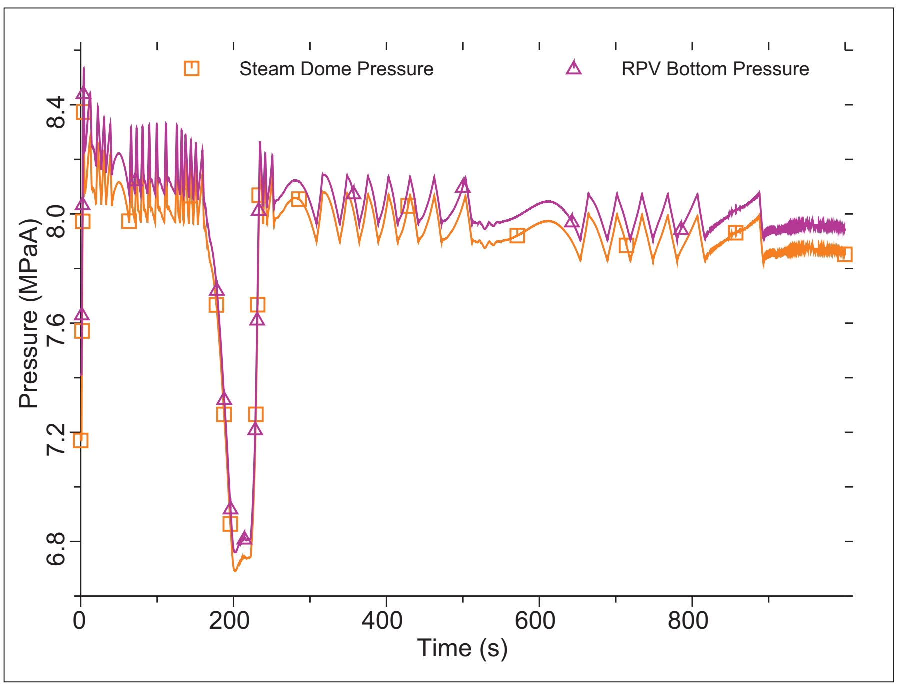


Figure 15E-19a ABWR Turbine Trip w/ Bypass, SLCS

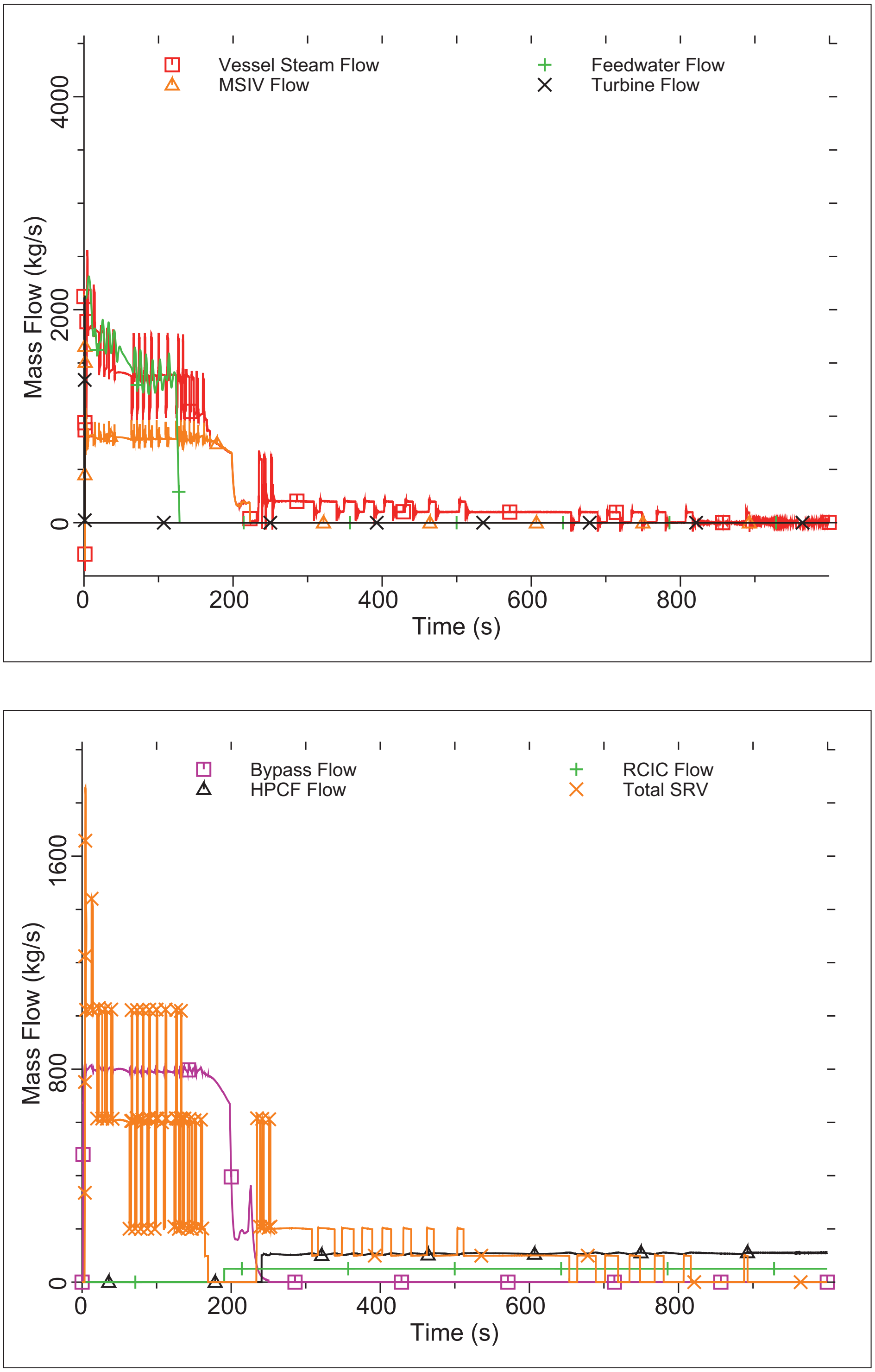


Figure 15E-19b ABWR Turbine Trip w/ Bypass, SLCS

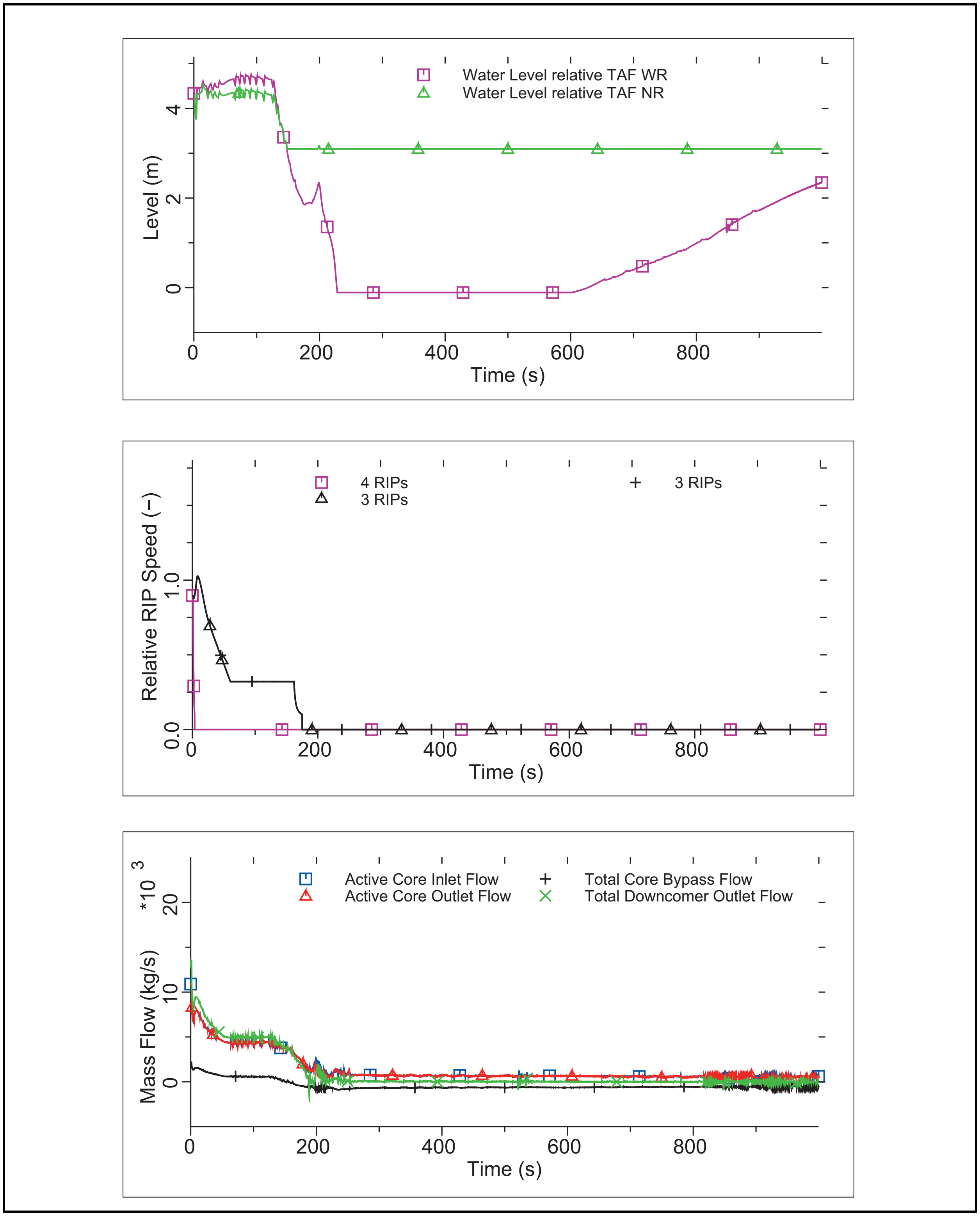
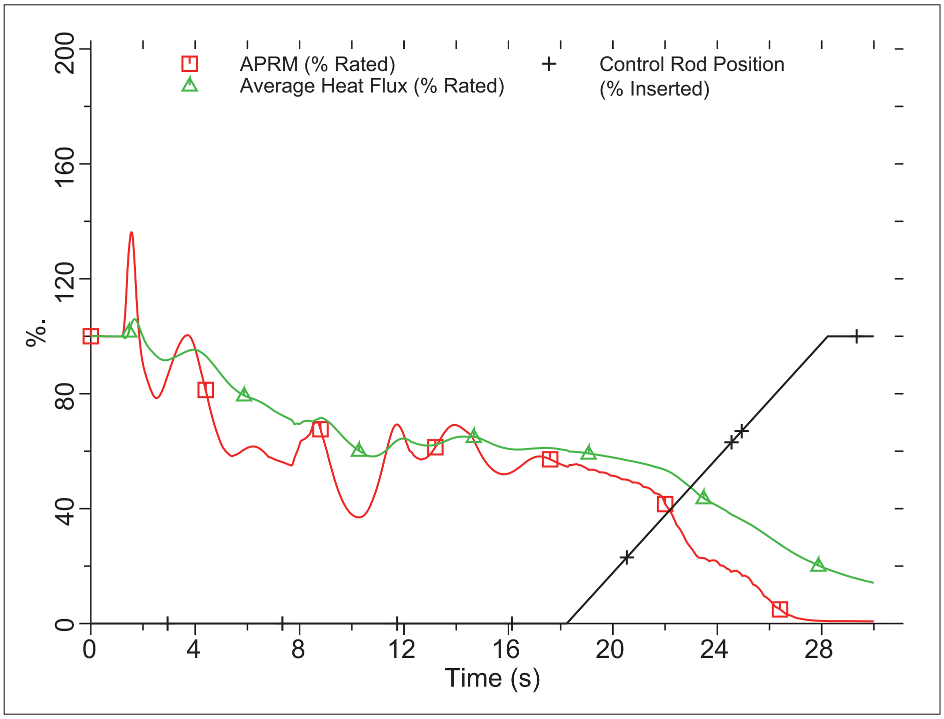


Figure 15E-19c ABWR Turbine Trip w/ Bypass, SLCS



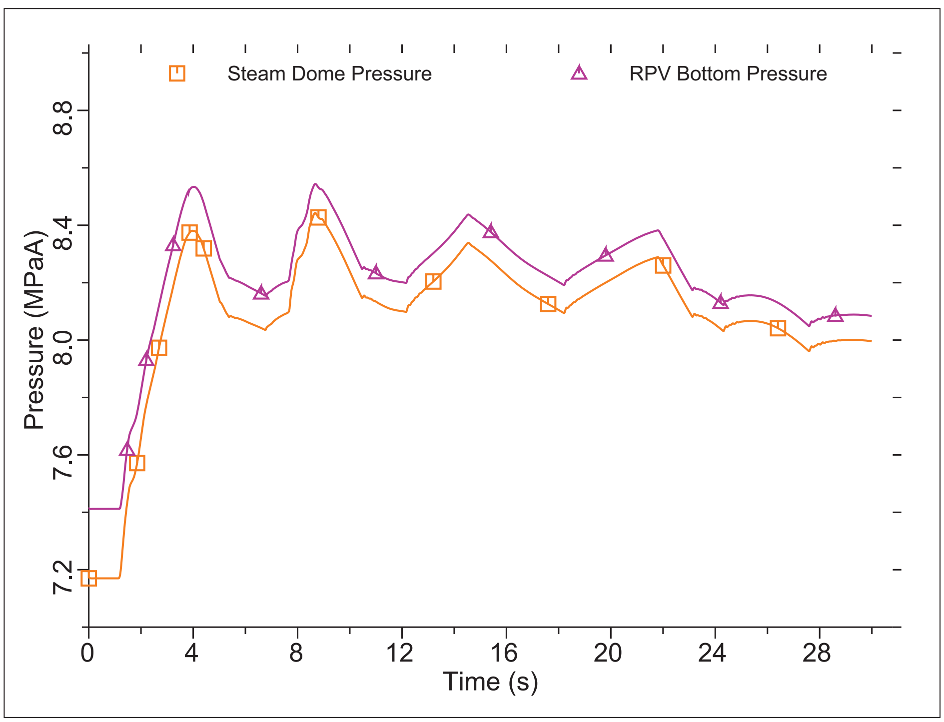


Figure 15E-20a ABWR Loss of Condenser Vacuum, ARI

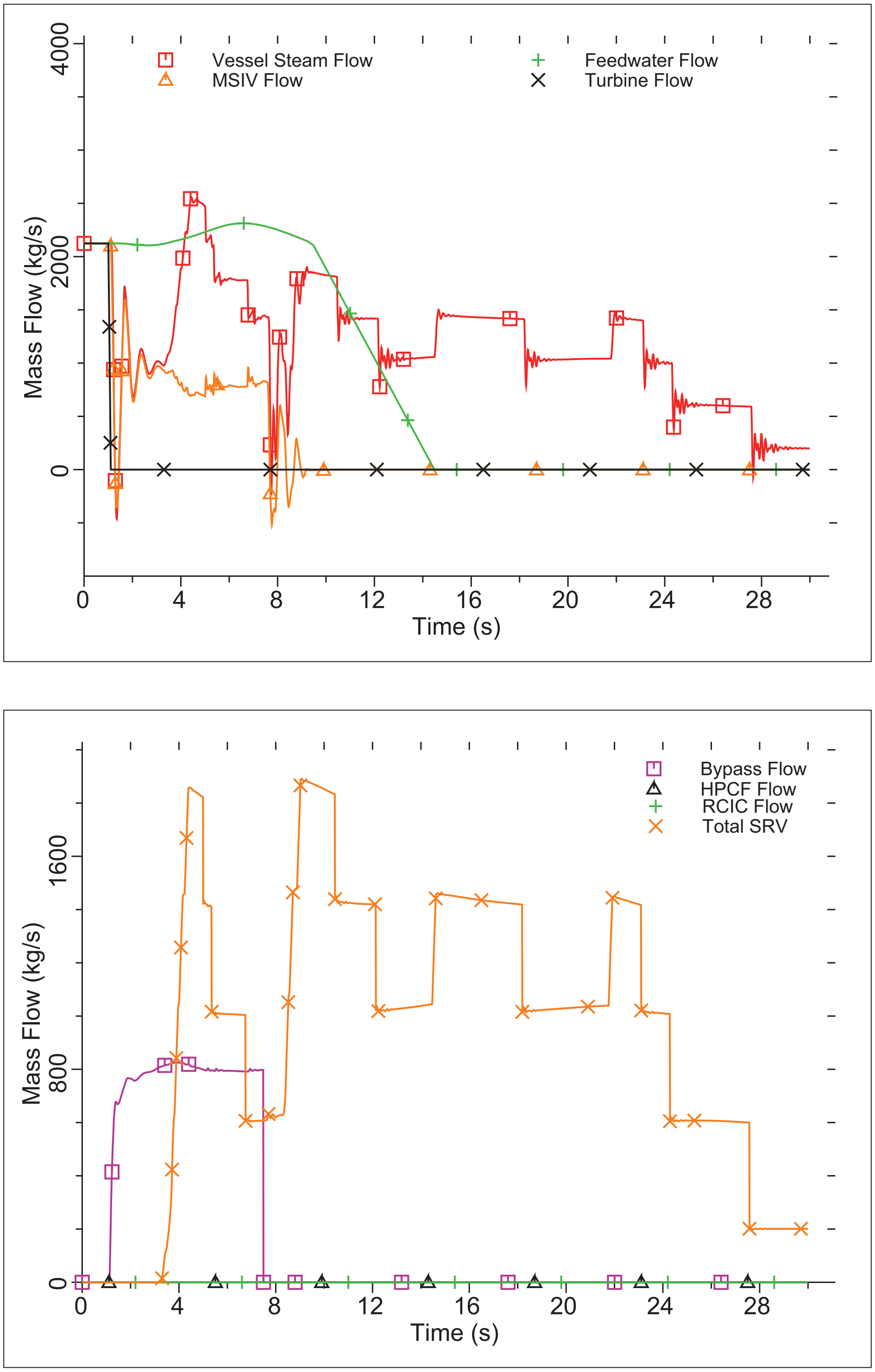


Figure 15E-20b ABWR Loss of Condenser Vacuum, ARI

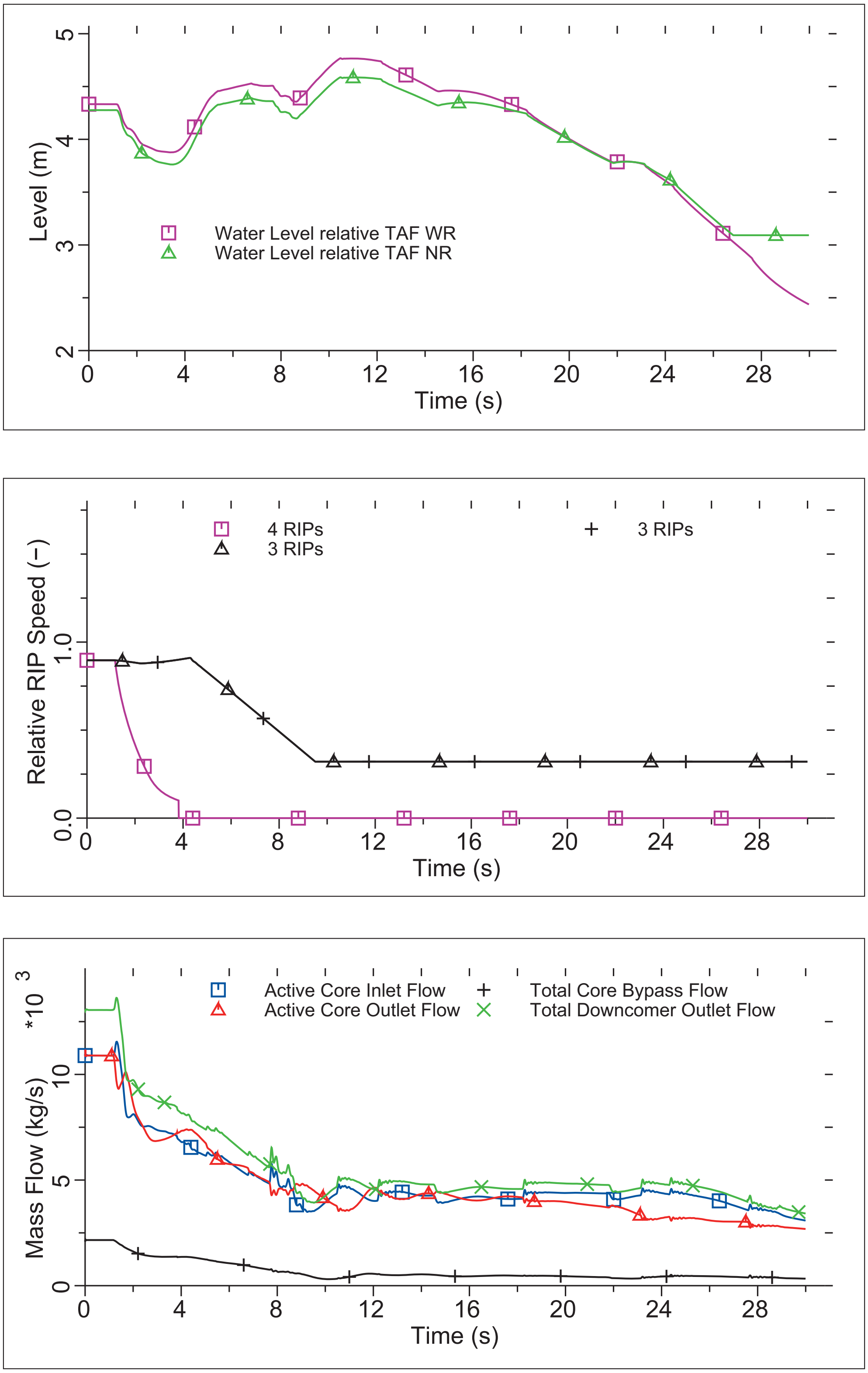


Figure 15E-20c ABWR Loss of Condenser Vacuum, ARI

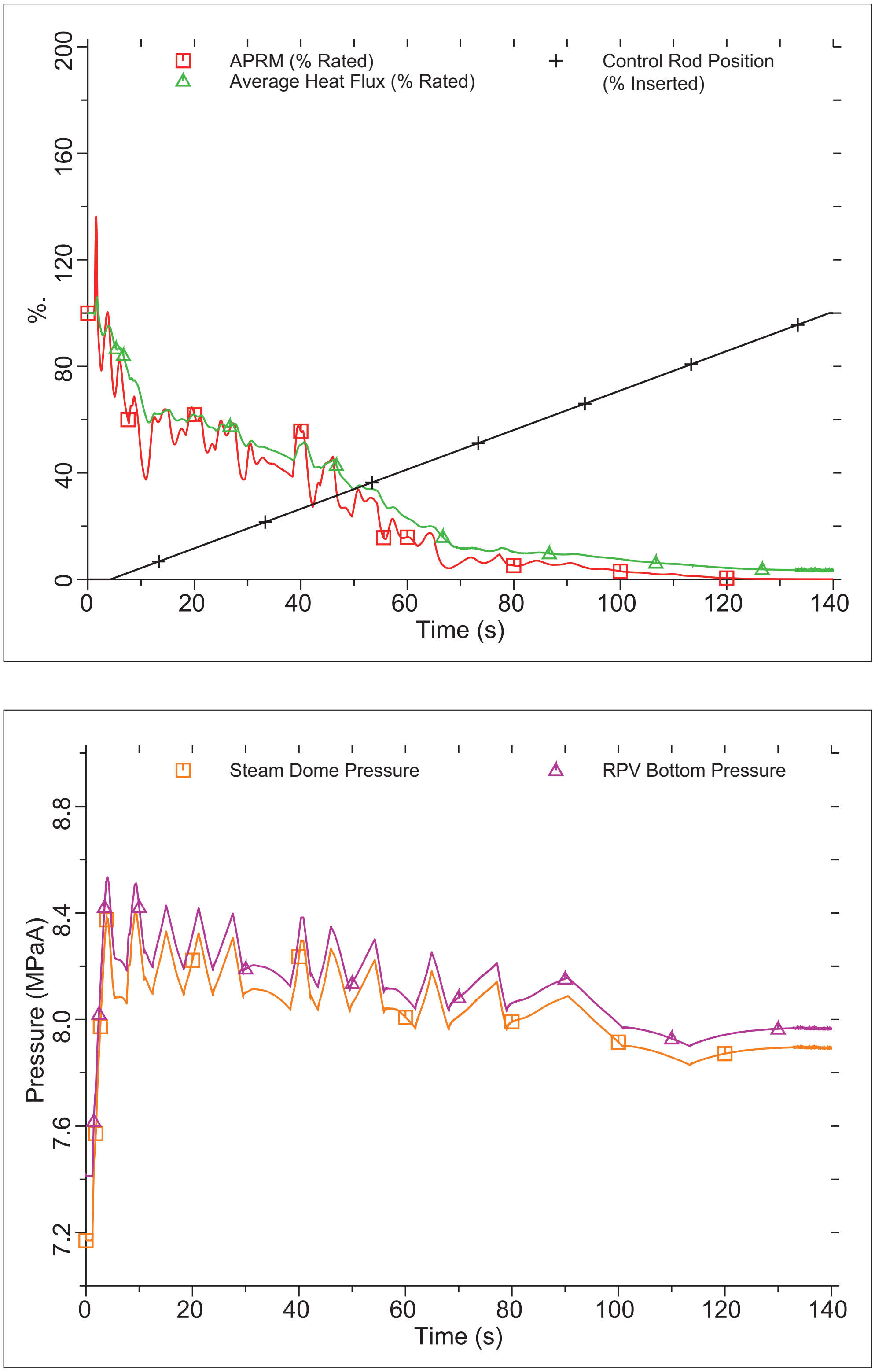


Figure 15E-21a ABWR Loss of Condenser Vacuum, FMCRD Run–in

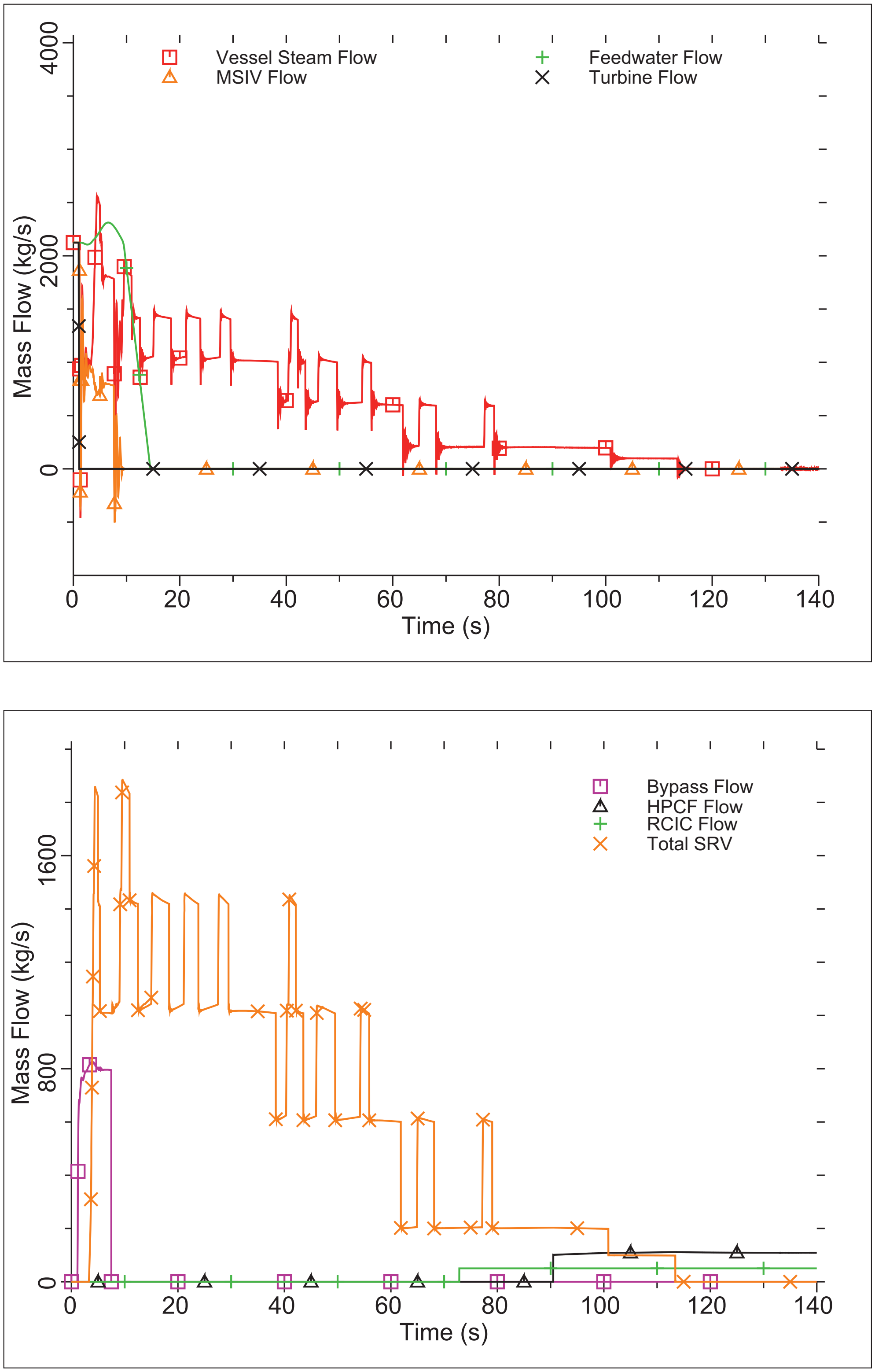


Figure 15E-21b ABWR Loss of Condenser Vacuum, FMCRD Run–in

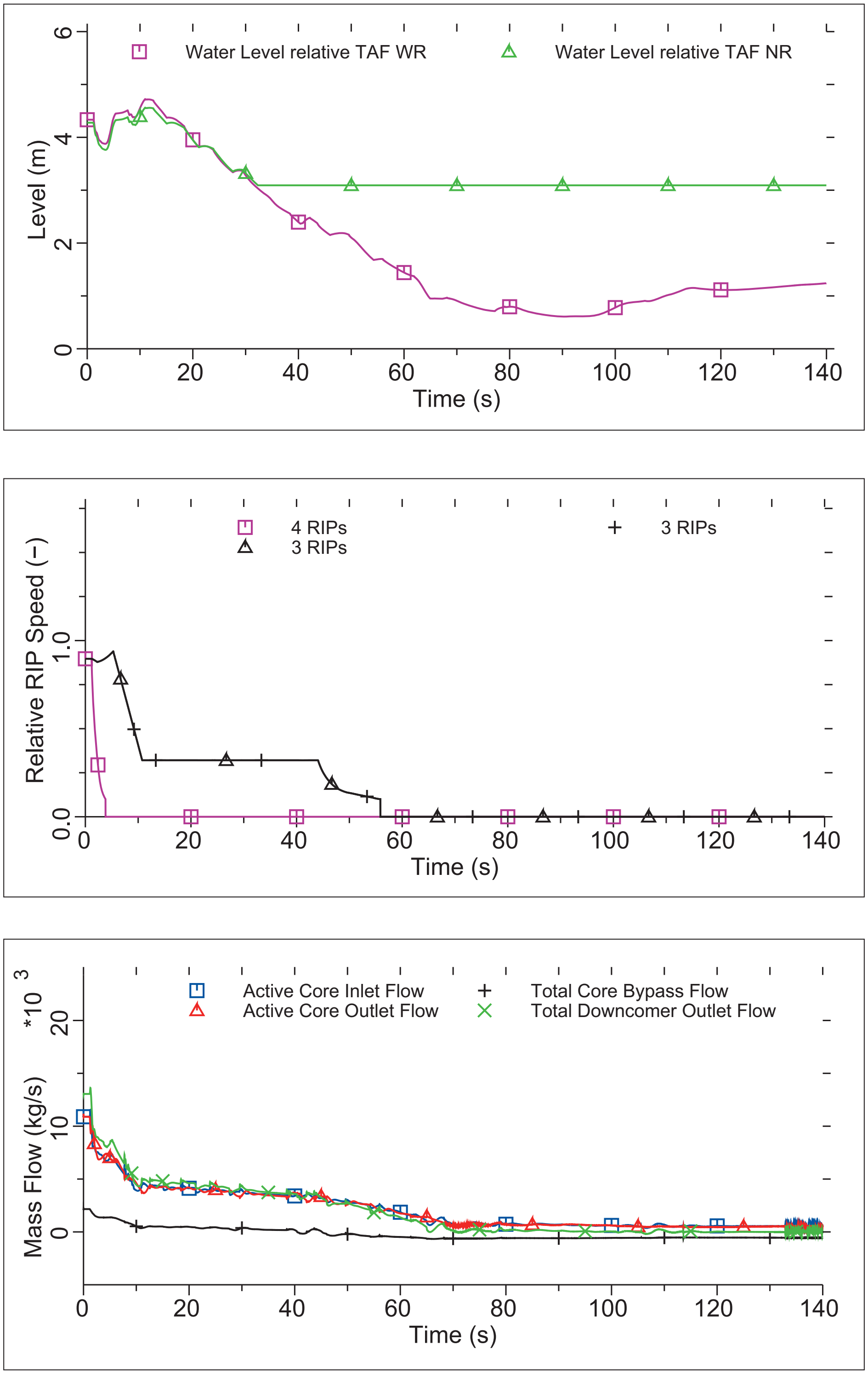


Figure 15E-21c ABWR Loss of Condenser Vacuum, FMCRD Run–in

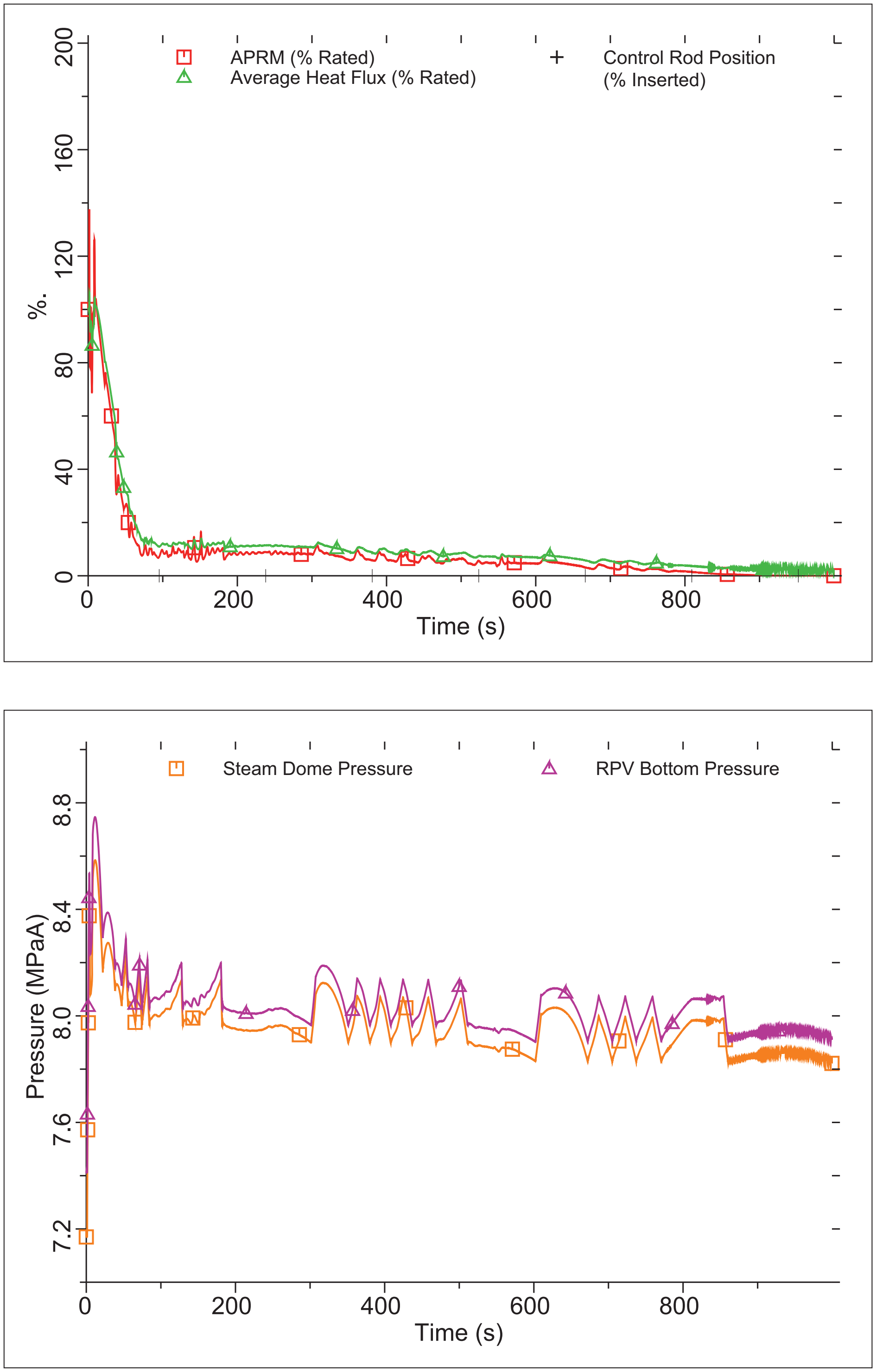


Figure 15E-22a ABWR Loss of Condenser Vacuum, SLCS

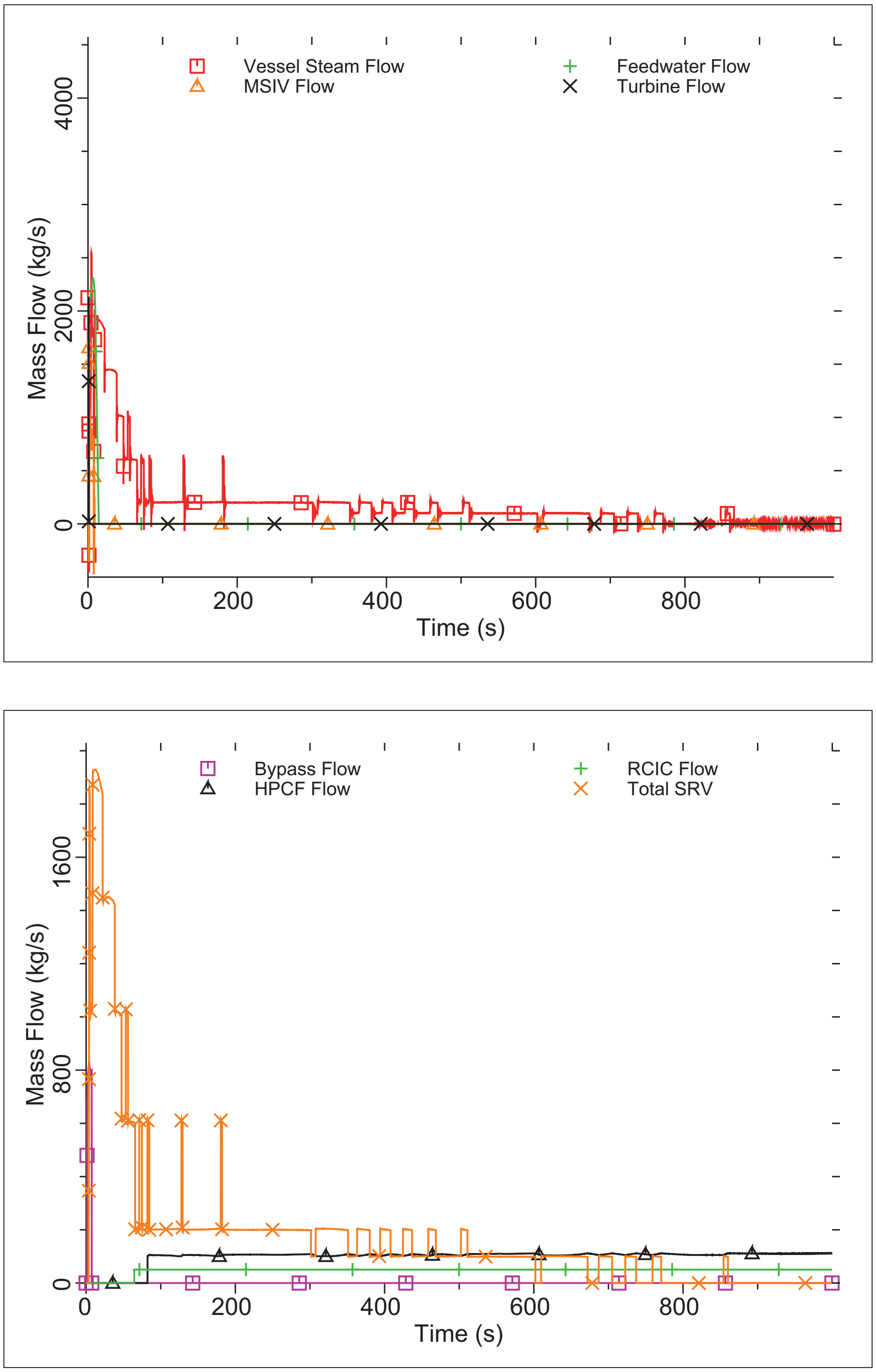


Figure 15E-22b ABWR Loss of Condenser Vacuum, SLCS

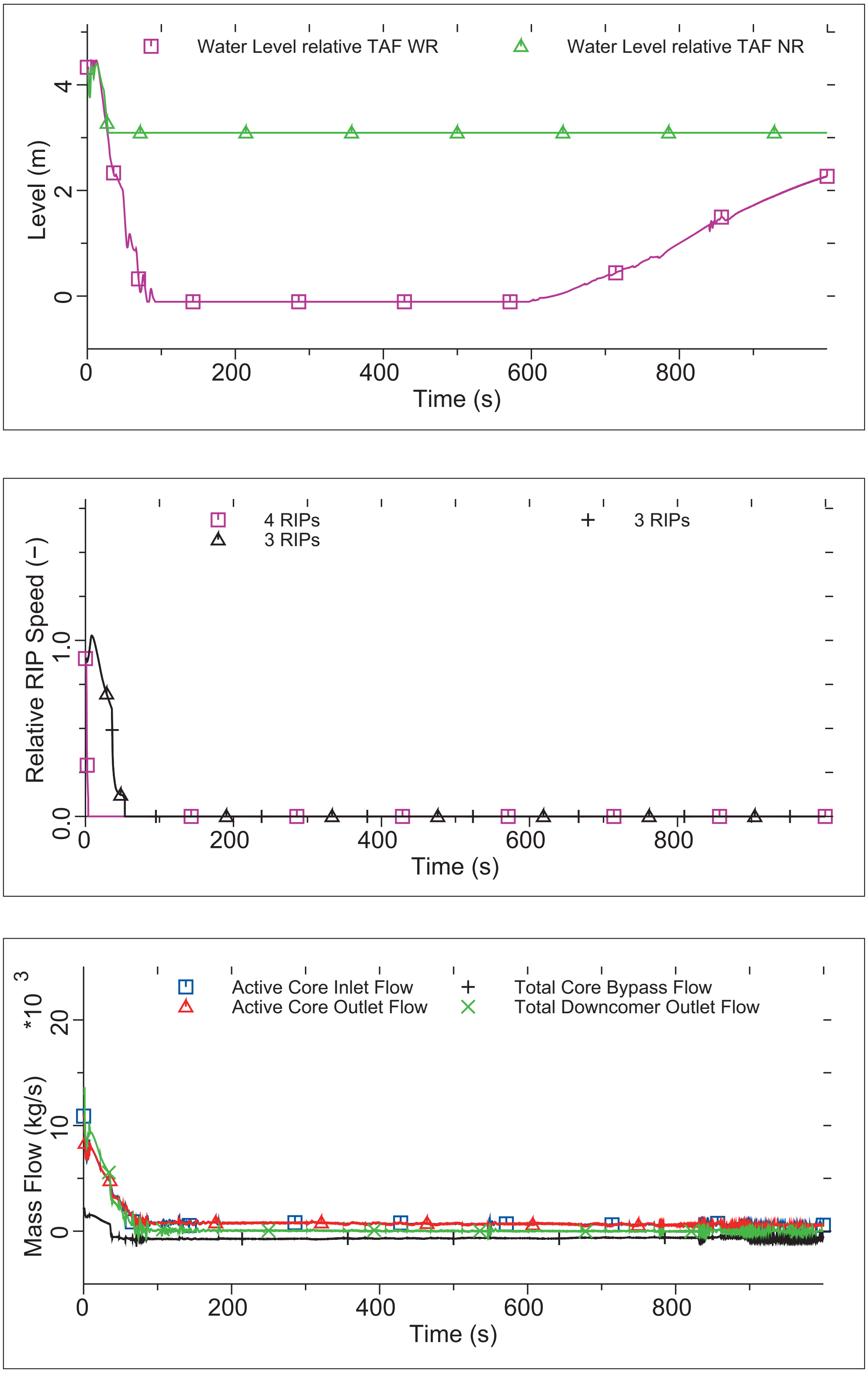
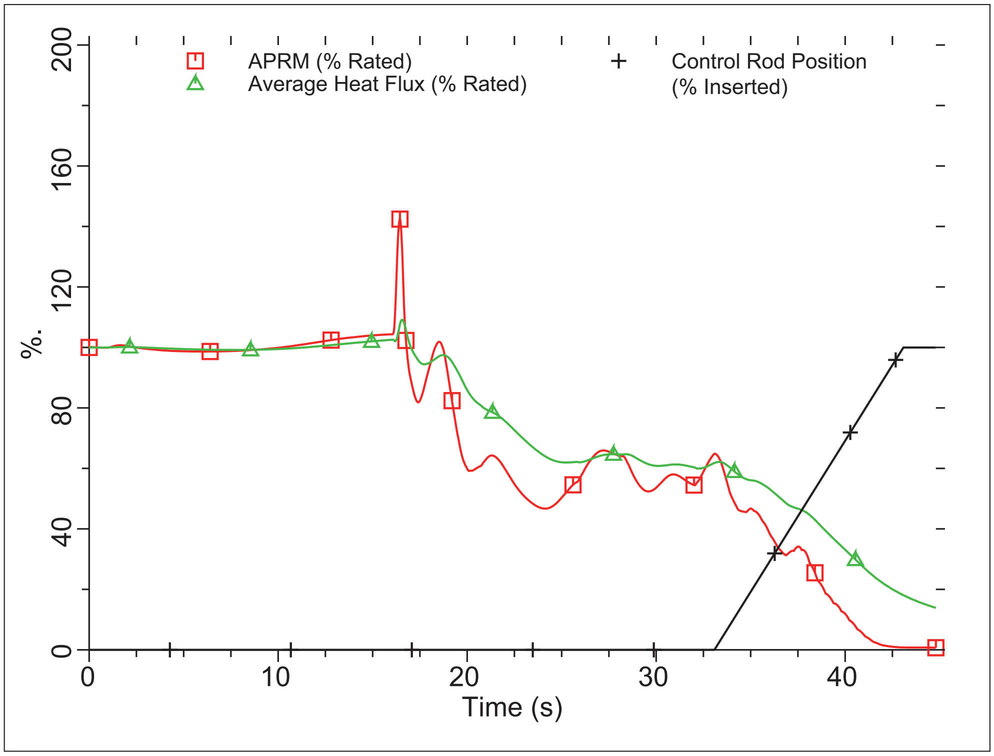


Figure 15E-22c ABWR Loss of Condenser Vacuum, SLCS



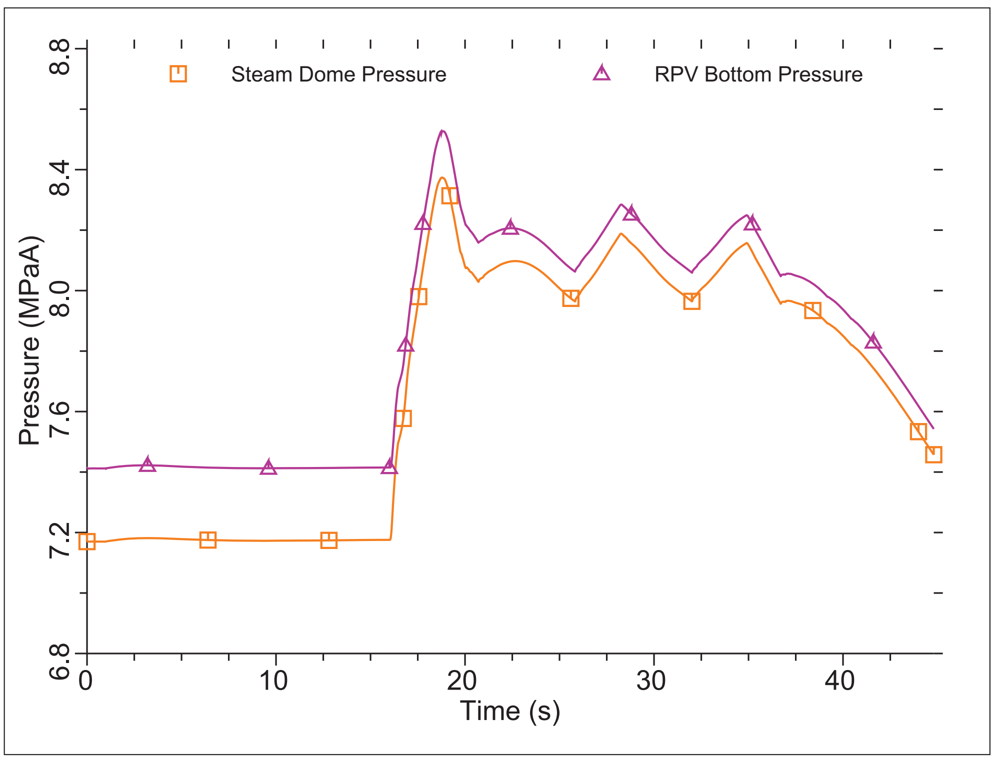


Figure 15E-23a ABWR Feedwater Controller Failure Maximum Demand, ARI

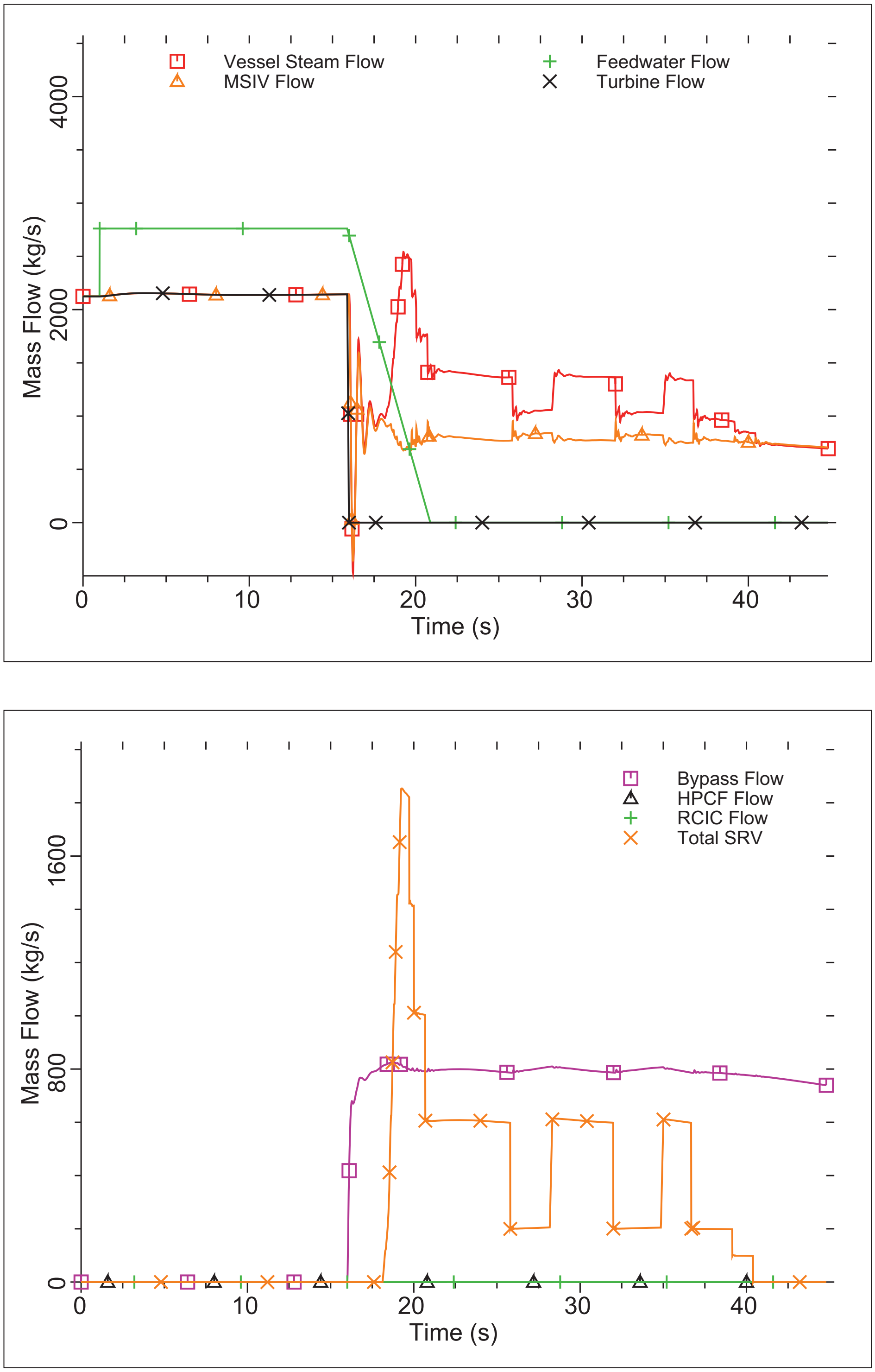


Figure 15E-23b ABWR Feedwater Controller Failure Maximum Demand, ARI

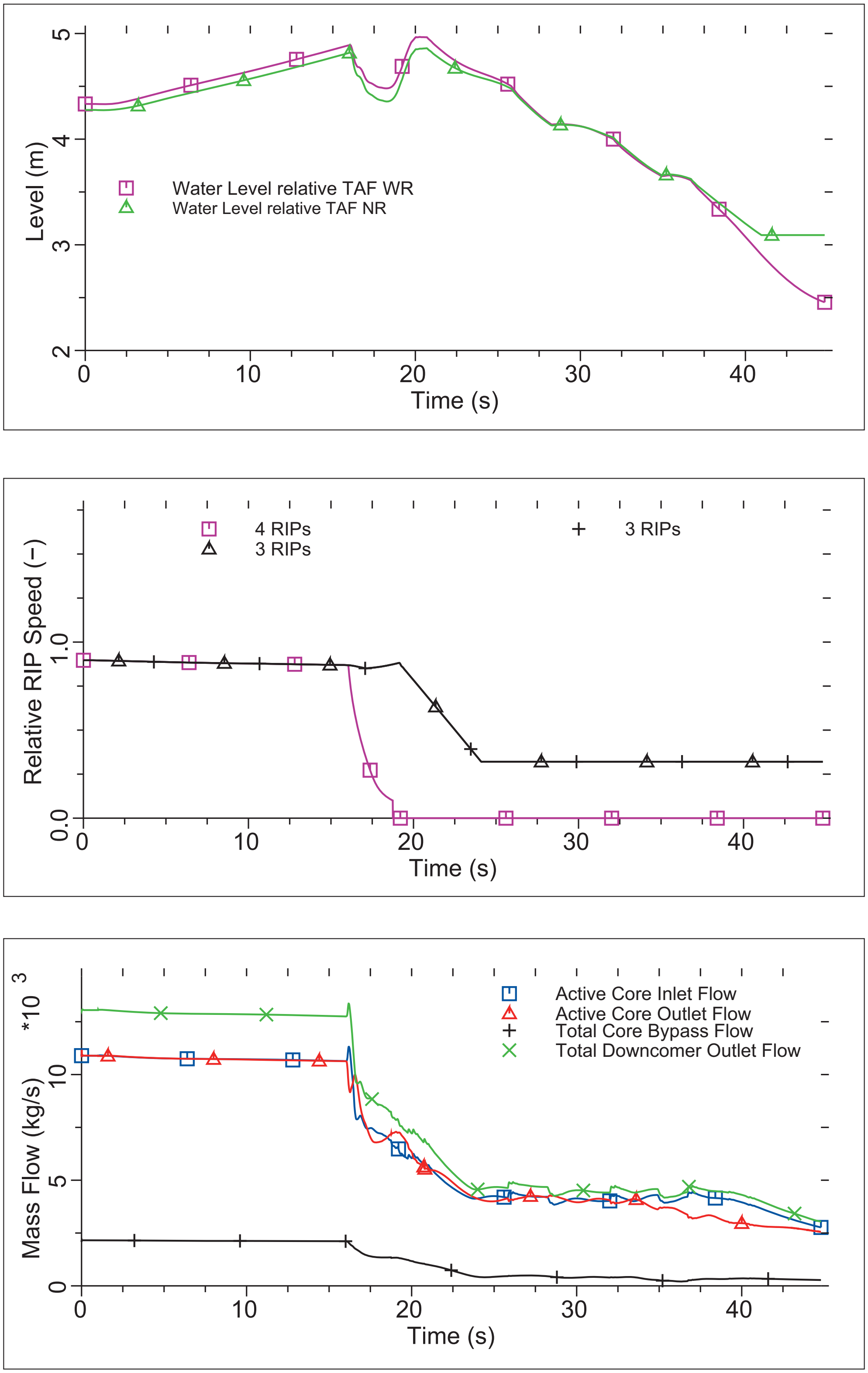


Figure 15E-23c ABWR Feedwater Controller Failure Maximum Demand, ARI

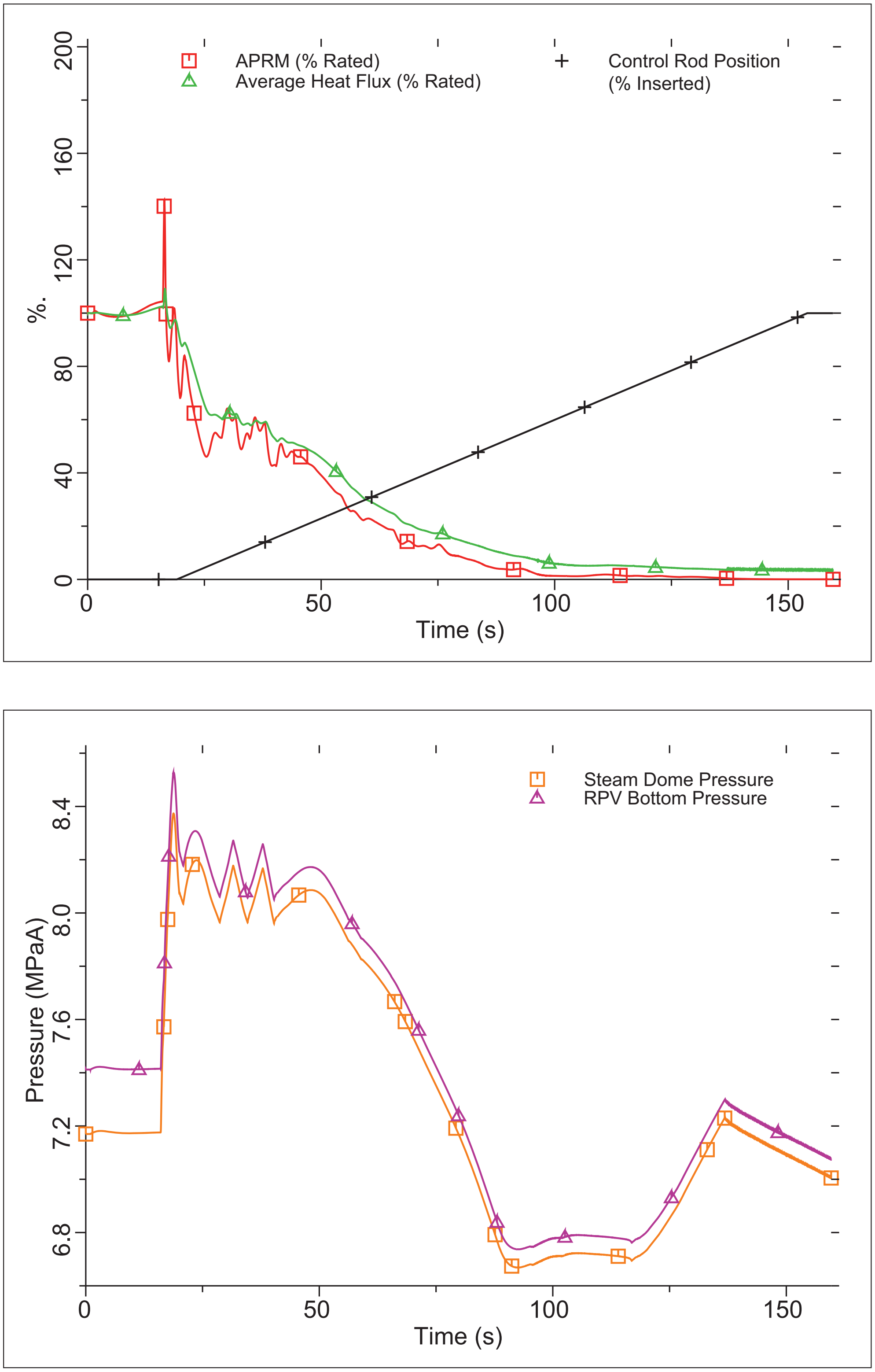
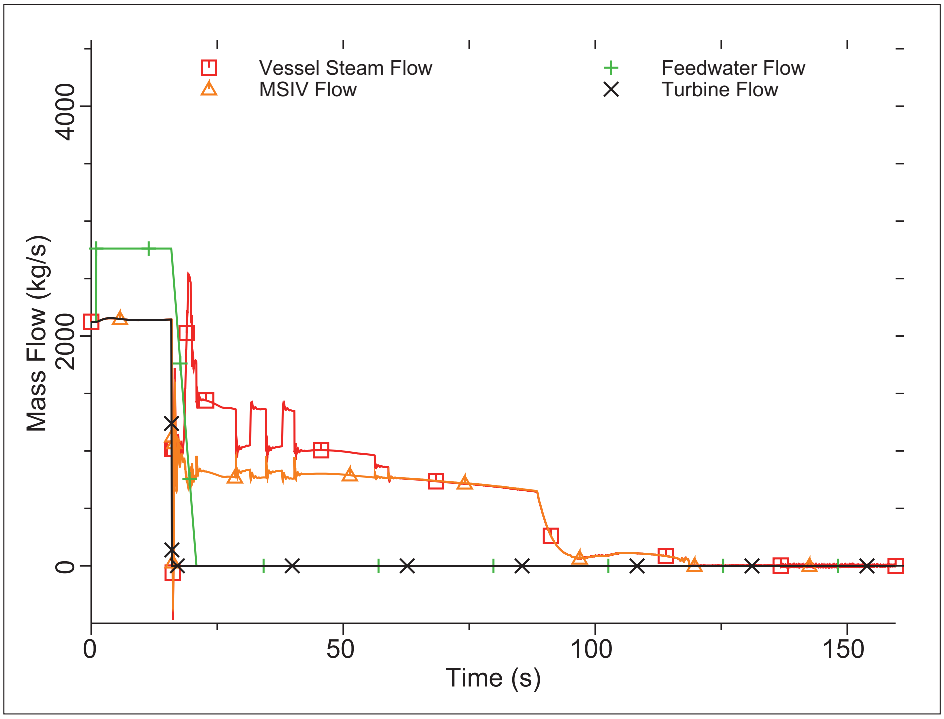


Figure 15E-24a ABWR Feedwater Controller Failure Maximum Demand, FMCRD Run–in



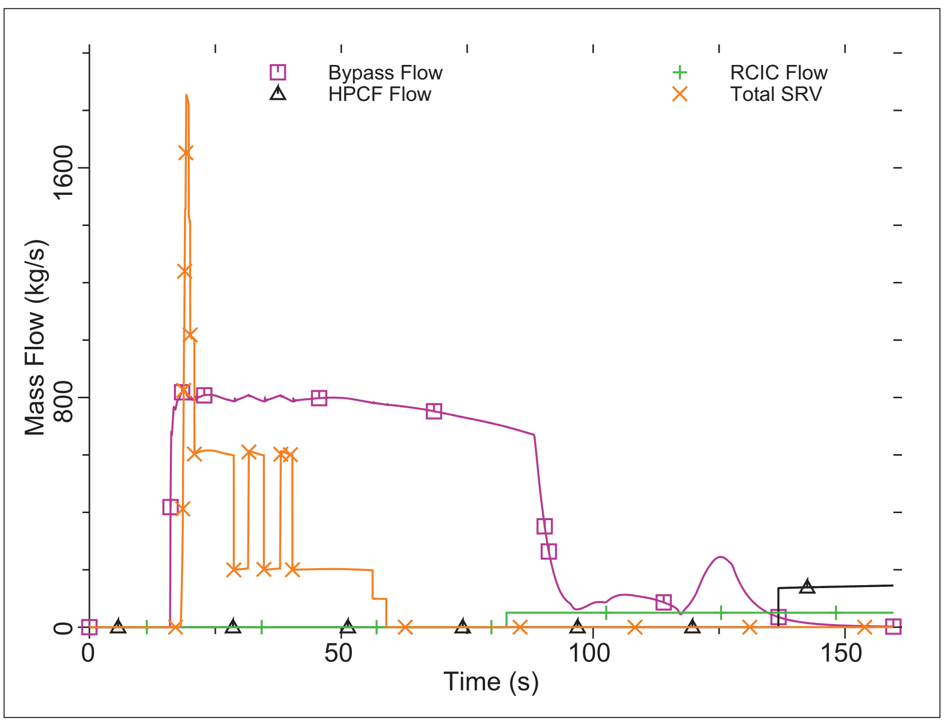


Figure 15E-24b ABWR Feedwater Controller Failure Maximum Demand, FMCRD Run–in

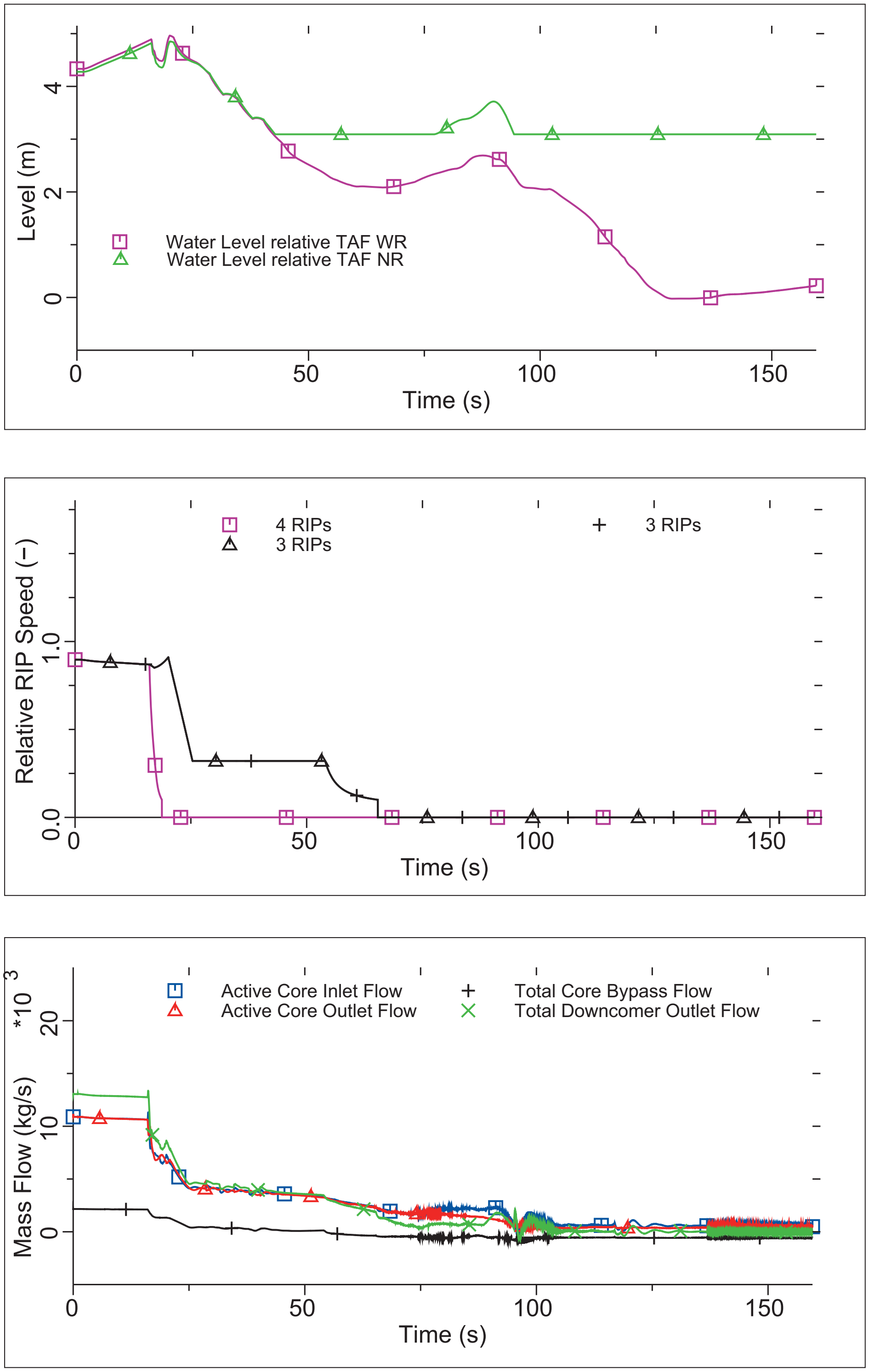


Figure 15E-24c ABWR Feedwater Controller Failure Maximum Demand, FMCRD Run–in

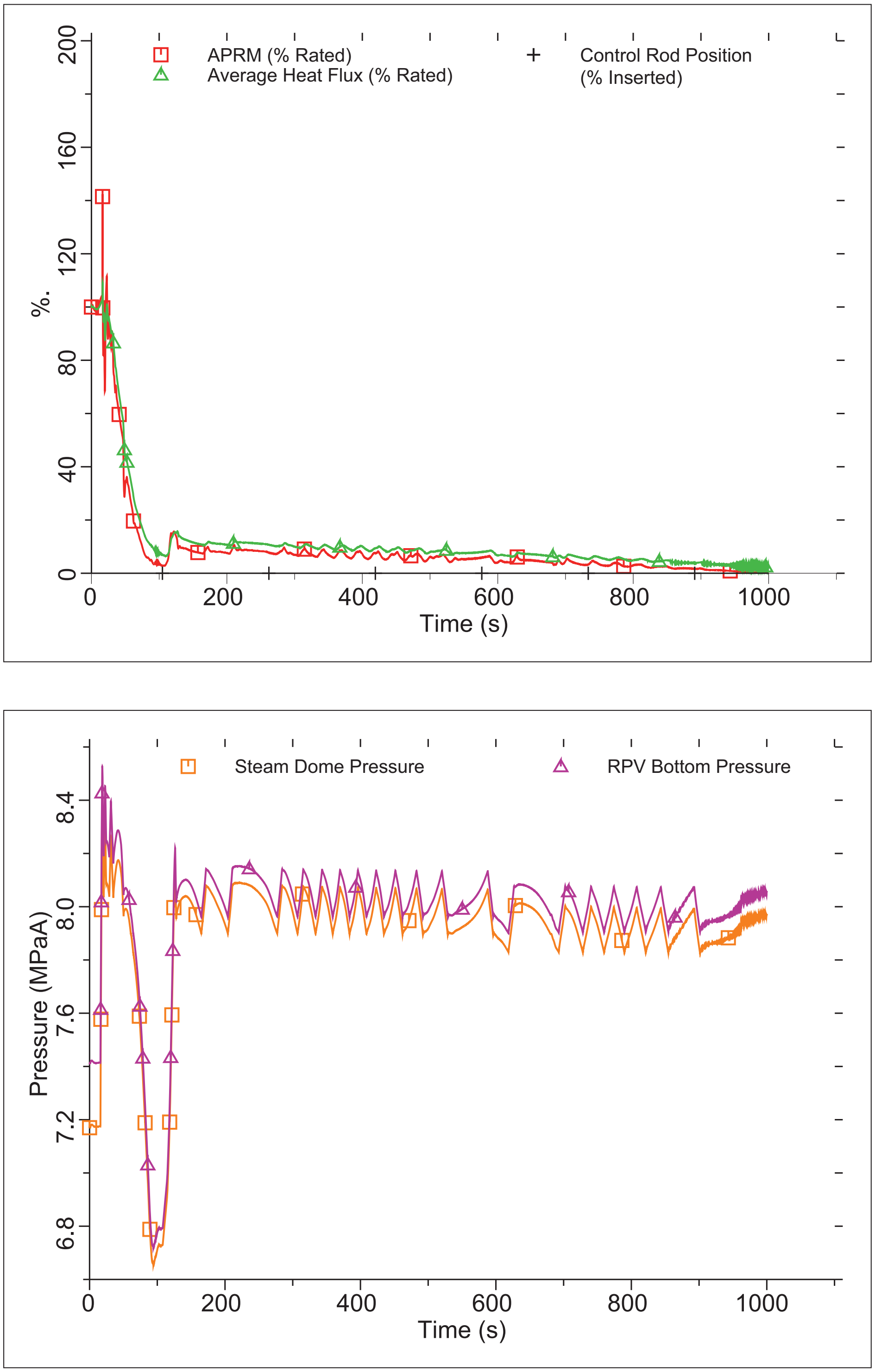
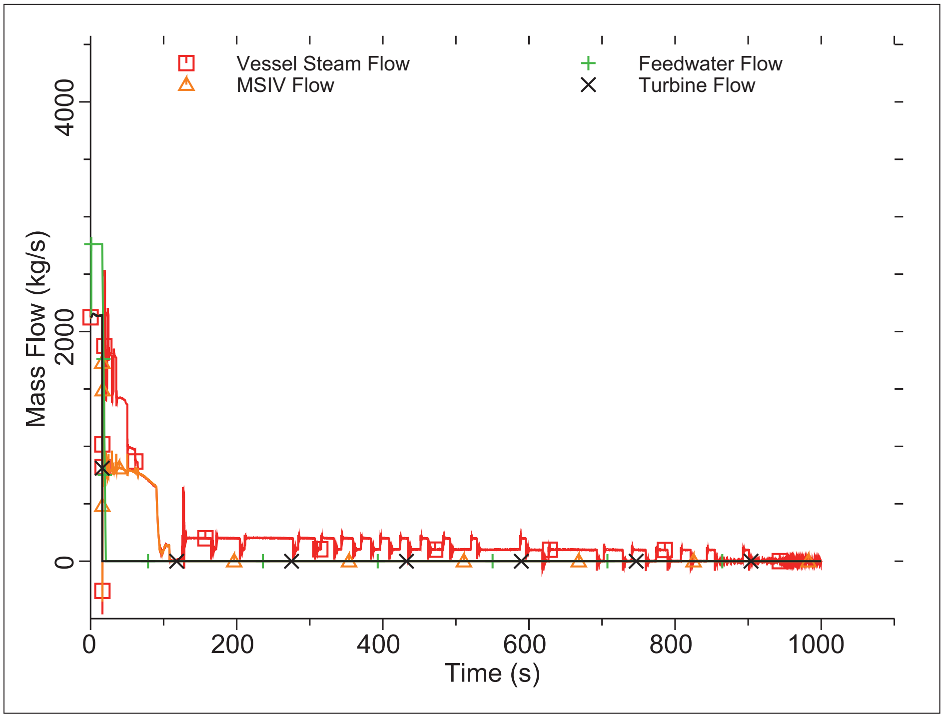


Figure 15E-25a ABWR Feedwater Controller Failure Maximum Demand, SLCS



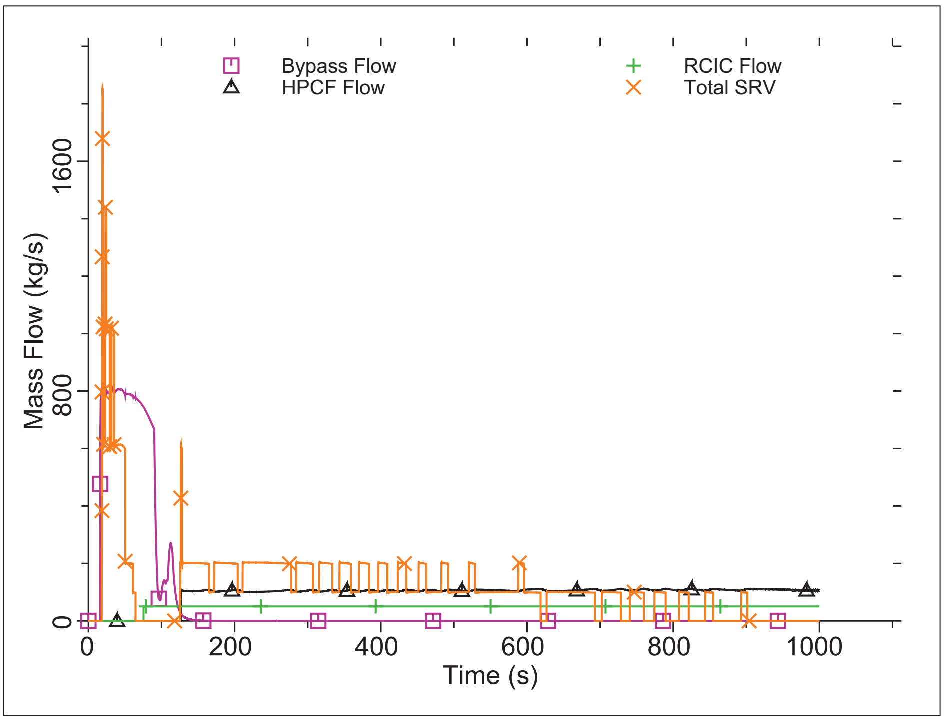


Figure 15E-25b ABWR Feedwater Controller Failure Maximum Demand, SLCS

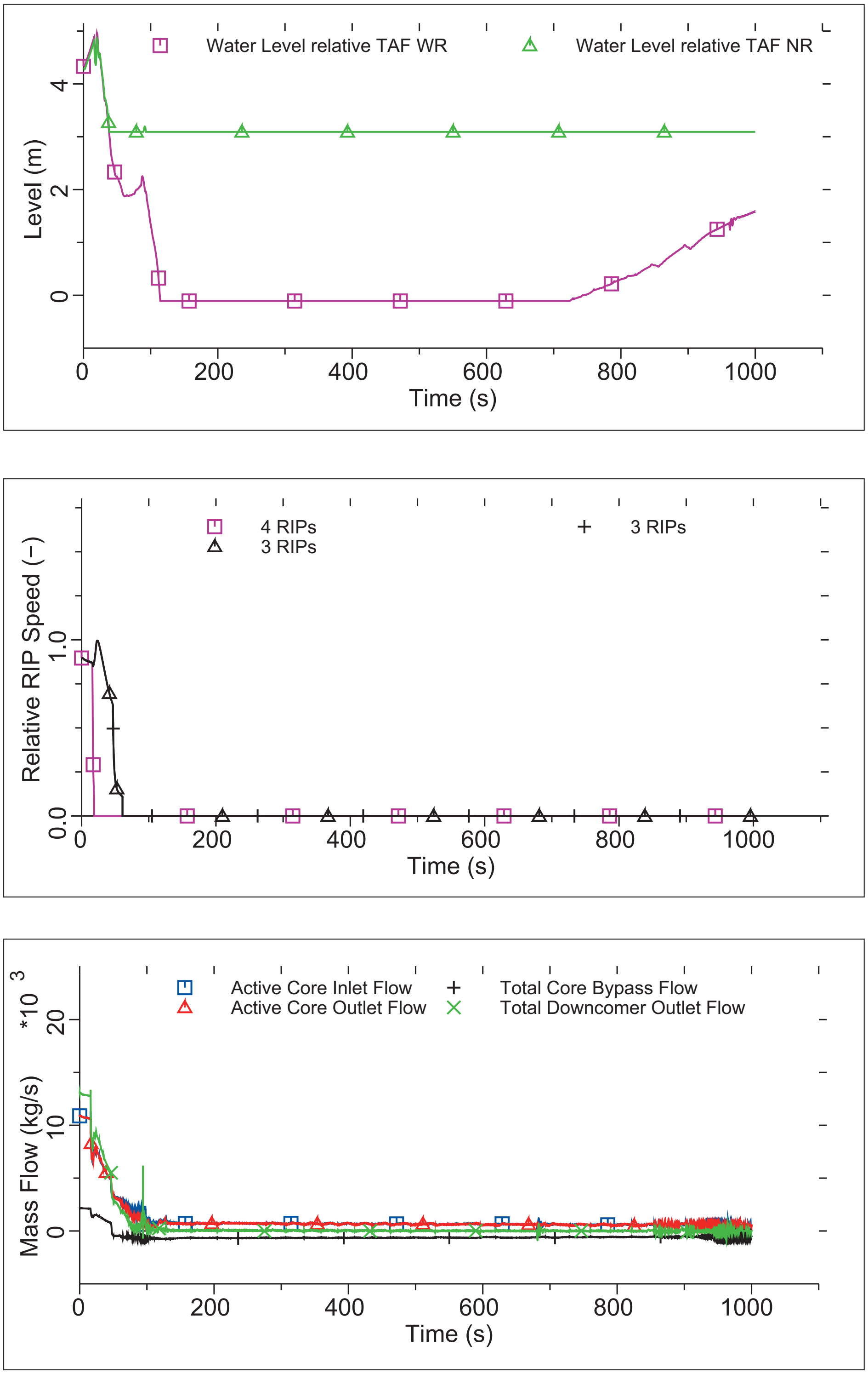


Figure 15E-25c ABWR Feedwater Controller Failure Maximum Demand, SLCS