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Attention: Robert C. Pierson, Director
Standardization and Non-Power Reactor Project Directorate

Subject: **GE Response to the Resolution of Outstanding Issues 140 and 144 of ABWR DSER SECY-91-355**

Enclosed are thirty-four (34) copies of the GE response to Outstanding Issues 140 and 144 both pertaining to the revision of Appendix 15E - ATWS analysis. Since the changes are so extensive, a complete Appendix 15E (including the unchanged pages) is included in this transmittal.

It is intended that GE will amend the SSAR with this revised Appendix 15E.

Sincerely,

R C Stirm

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APPENDIX 15E

ATWS PERFORMANCE EVALUATION

SECTION 15E

CONTENTS

15E.1 INTRODUCTION

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

The procedure and assumptions used in this analysis are consistent with those used in the analyses for the operating plants as documented in Section 15E.8, Reference 1.

15E.2 PERFORMANCE REQUIREMENTS

As identified in Section 15E.8, Reference 1, the design should meet the following requirements:

(1) Fuel Integrity - The long term core cooling capacity shall be assured by meeting the cladding temperature and oxidation criteria of 10CFR50.46 (i.e., peak cladding temperature not exceeding 1200° C or 2200° F, 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 (3.16 kg/cm^2g) of the containment structure. The suppression pool temperature shall be limited to values shown in Table 15E.2-1.

(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 a safe shutdown condition, and be cooled down and maintained in a cold shutdown condition.

These performance requirements are summarized in Table 15E.2-1.

Table 15E.2-1

PERFORMANCE REQUIREMENTS

	RPV Peak Pressure	Maximum Pool Temperature	Fuel Integrity	Maximum Containment Pressure
ARI/RPT	105.5 kg/cm^{2}g	97.2°C*	Coolable Geometry	3.16 kg/cm^{2}g
FMCRD/RPT	105.5 kg/cm^{2}g	97.2°C*	Coolable Geometry	3.16 kg/cm^{2}g
Boron/RPT	105.5 kg/cm^{2}g	Containment Design Pressure	Coolable Geometry	3.16 kg/cm^{2}g

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** 57.2 °C pool temperature should not be reached before the reactor reaches the hot shutdown condition.*

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 and also in Section 15E.8, Reference 1. Tables 15E.3-1 and 15E.3-2 list the initial conditions and equipment performance characteristics, which are used in the analysis.

Table 15E.3-1

INITIAL OPERATING CONDITIONS

Parameter	Value
Dome Pressure (kg/cm^2g)	72.1
Core Flow (Mkg/hr)/(%NBR)	52.2/100
Vessel Diameter (m)	7.06
Number of Fuel Bundles	872
Power (MWt)/(%NBR)	3926/100
Steam/Feed Flow (kg/sec)/(%NBR)	2123/100
Feedwater Temperature (°C)	215.6
Void Reactivity Coefficient (¢/%)	-9.7
Doppler Coefficient (¢/°C)	-0.504
ARI/FMCRD Reactivity Curve	D Curve
Suppression Pool Volume (m^3)/ (Full NBR FW Flow-Min)	3580/28.1
Initial Suppression Pool Temperature (°C)	37.7
Condensate Storage Temperature (°C)	48.9

Table 15E.3-2

EQUIPMENT PERFORMANCE CHARACTERISTICS

Parameters	Value
Nominal Closure Time of MSIV (sec)	3.0
Relief Valve System Capacity (% NBR Steam Flow)/No. of Valves	91.3 at 1st setpoint/ 18
Relief Valve Setpoint Range (kg/cm^2g)	80.5/84.0
Relief Valve Opening Time (sec)	0.15
Pressure Drop Below Setpoint for Relief Valve Closure (kg/cm^2)	5.3
Relief Valve Closure Time Delay (sec)	0.9
Relief Valve Closure Time Constant (sec)	0.2
RCIC Low Water Level Initiation Setpoint	Level 2
HPCF Low Water Level Initiation Setpoint	Level 1.5
HPCF Start Time (sec)	20
HPCF/RCIC High Water Level Shutoff Setpoint[1]	Level 8
Number of HPCF Pumps	2
HPCF Flow Rate per Pump[2] (kg/sec)/(% NBR Steam Flow)	50.4/2.37
RCIC Start Time (sec)	$\geq$ 29
RCIC Flow Rate (kg/sec)/(% NBR Steam Flow)	50.4/2.37
ATWS Dome Pressure Sensor Time Constant (sec)	0.5
ATWS Logic Time Delay (sec)	0.03

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[1] *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.*

[2] *The nominal flow versus pressure head curve is used. The value given for ABWR is at 82.7* kg/cm^2g.

Table 15E.3-2

EQUIPMENT PERFORMANCE CHARACTERISTICS (Continued)

Parameter	Value
Recirculation Pump System Inertia (Kg-m^2)	21.5
Delay before Start of Electro-Hydraulic Rod Insertion (with/without off-site power) (sec)	1.0/39.0
Electro-Hydraulic Control Rod Insertion Time (sec)	135
ARI Rod Insertion Time (sec)	25
RHR Pool Cooling Capacity (Kcal/sec/°C)/ (% NBR at 38°C ΔT)	265/1.57
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 (kg/cm^2g)	52.7
Setpoint for Automatic Pool Cooling (°C)	43.3
RHR Start Time (sec)	20

15E.4 ATWS LOGIC AND SETPOINTS

The mitigation of ATWS events is accomplished by multitude of equipment and procedures. These include ARI, FMCRD run-in, feedwater runback, RPT, recirculation runback, ADS inhibit, and SLCS. The logic of these ATWS mitigation is presented in Figures 15E.4-1. The followings are the initiation signals and setpoint for the above response:

(1) ARI and FMCRD run-in
- High pressure (1125 psig), or
- Level 2

(2) SLCS initiation
- High pressure (1125 psig), and SRNM not downscale for 3 minutes, or
- Level 2 and SRNM not downscale for 3 minutes, or
- Manual ARI/FMCRD run-in signals and SRNM not downscale for 3 minutes

(3) RPT (RIPs not connected to M/G set)*
- High pressure (1125 psig)

(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 (1125 psig), and SRNM not downscale for 2 minutes

(7) ADS inhibit
- High pressure (1125 psig), and SRNM not downscale for 2 minutes, or
- Level 2 and SRNM not downscale for 25 seconds

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

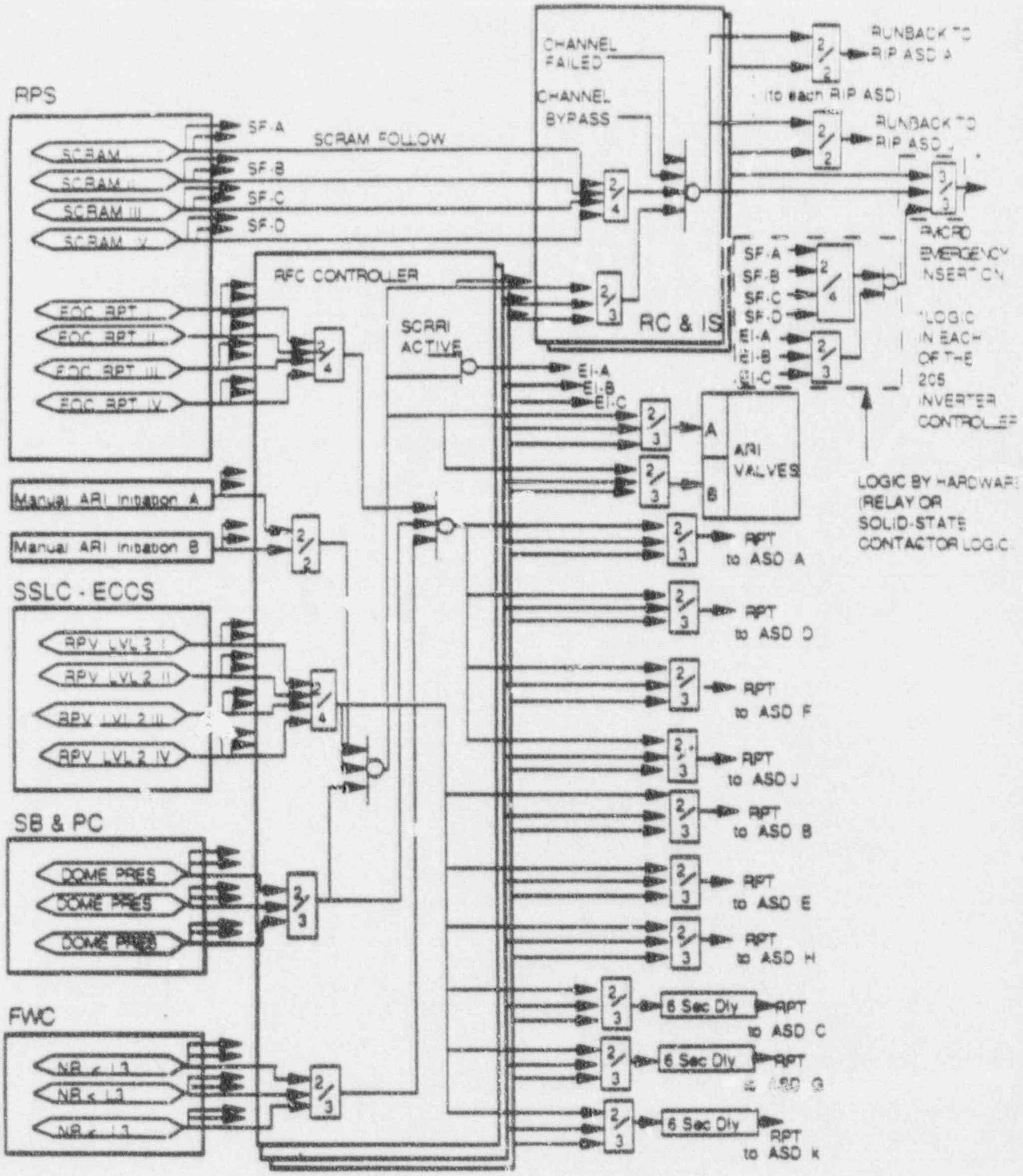


Figure 15E.4-1. ATWS Mitigation Logic

15E.5 SELECTION OF EVENTS

Based on conclusions from the evaluations for operating BWR plants as documented in Section 15E.8, Reference 1, 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 mitigation actions are assumed to occur on the appropriate signals. No operator action is assumed, unless specifically mentioned. The third category covers the cases has only minor impact to the reactor vessel and 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 produces 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 or FMCRD run-in initiated from the low level signals. Thus, this event is analyzed to show that the low level trips are capable to mitigate 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, heat flux, and vessel pressure than those from MSIV closure event due to the fast closure of the turbine stop valves. However, the availability of 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 turbine trip as the reduction of vacuum in the main condenser initiates turbine stop valves 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 turbine trip case. The availability of main condenser significantly reduces the load of suppression pool from steam discharge from S/RVs.

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 a 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 S/RV setpoint, steam flow discharge to the suppression pool does not take place.

Since the transient is not severe enough to trip the ATWS logic or initiate HPCF or RCIC flow as the feedwater and level control is maintained. Manual ARI/FMCRD run-in has to be initiated by operator in the case of 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 insertion after operator action, the boron injection would bring the reactor to below 1%.

(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 the 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 event. 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 steam line pressure. The characteristics of the remaining portion of this transient is 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 300 psig. In this condition, the reactor has almost no voids in it and therefore only little if any positive reactivity is increased. Hence, this event is not considered further.

All transient analyses, unless otherwise specified, were performed with the REDYA code. Other codes used in special analysis are ODYNA and PANACEA.

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 seconds delay, are 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 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 generate a 100 gpm 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 ARI and the electric insertion of the FMCRDs. The insertion of the control rods is successful in bringing the reactor to hot shutdown. Peak values of key parameters are shown in Table 15E.6.1-1 for the ARI case and Table 15E.6.1-2 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 19.4 minutes from the beginning of the event. The transient behavior of this case is listed in Table 15E.6.1-3. The reactor system response is presented by Figures 15E.6.1-1 to 15E.6.1-4 for ARI activated, Figures 15E.6.1-5 to 15E.6.1-8 for FMCRD run-in case and Figures 15E.6.1-9 to 15E.6.1-12 as SLCS operating, respectively. The normalized axial power shape change during FMCRD run-in are presented in Figure 15E.6.1-13. The increase of the local power density does not violate the performance criteria.

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.

Figures 15E.6.2-1 to 15E.6.2-4 show the transient behavior under ARI activation, Figures 15E.6.2-5 to 15E.6.2-8 for FMCRD run-in and Figures 15E.6.2-9 to 15E.6.2-12 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 pump 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 not-downscale signal for 3 minutes, the SLCS will be initiated. At 16.9 minutes, the reactor is brought to hot shutdown when enough boron concentration is built up in the reactor core.

Tables 15E.6.2-1 to 15E.6.2-3 show the 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 five seconds. Figures 15E.6.3-1 to 15E.6.3-4 show the transient behavior for ARI activated. Figures 15E.6.3-5 to 15E.6.3-8 represent FMCRD run-in event. The mitigation of this event by SLCS is illustrated in Figures 15E.6.3-9 to 15E.6.3-12.

After the loss of feedwater has taken place, the pressure, water level and neutron flux begin to fall. Around 6.5 seconds low water (L3) is reached. This trips four recirculation pumps. At about 22 seconds, low water (L2) is also reached. This trips remaining recirculation pumps, activates ARI, FMCRD run-in, starts SLCS clock, and initiated 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 SRNM signal is not downscale. AT about 16.9 minutes the reactor becomes hot shut down as the boron concentration reaches sufficient value. Tables 15E.6.3-1 to 15E.6.3-3 show the summary of peak values of key parameters for the three cases.

15E.6.4 Loss of Feedwater Heater

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. Figures 15E.6.4-1 to 15E.6.4-4 show the transient behavior for ARI, Figures 15E.6.4-5 to 15E.6.4-8 for FMCRD run-in and Figures 15E.6.4-9 to 15E.6.4-12 for SLCS case, respectively. Upon the failure of rod insertion, SLCS can bring the reactor to hot shutdown at about 33.3 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 re-establish quasi-steady axial power shape. The peak value of these new profiles, which were calculated by the PANACEA code, are shown in Figure 15E.6.4-13. The peak cladding temperature does not exceed the coolable geometry criteria Figure 15E.6.4-14 presents the normalized axial power shape change during the event. Table 15E.6.4-1 shows the peak values of the key parameters for FMCRD run-in case. The same 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 a rapid steam shutoff. Pressure and power increases which 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 after about 48 seconds. This terminates the steam discharge to the suppression pool. Figures 15E.6.5-1 to 15E.6-4 show the transient behavior for ARI, Figures 15E.6.5-5 to 15E.6-8 for FMCRD run-in and Figures 15E.6.5-9 to 15E.6-12 for SLCS cases, respectively.

The closur [illegible] he turbine stop valves causes a rapid inc [illegible] of pressure, the ATWS high pressure se [illegible] nt 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 SRNM not-downscale and the high pressure signal when the timer run up. In this case, the hot shutdown is reached at about 19 minutes. Tables 15E.6.5-1 to 15E.6.5-3 show the 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 (see section 15E5.4). However, the MSIVs and turbine bypass valves also close after the condenser vacuum has further dropped to their closure setpoints, relief valves 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 characteristic are concerned and similar to the MSIV closure case with respect to suppression pool temperature and pressure. Figures 15E.6.6-1 to 15E.6.6-4 show the transient behavior for ARI event, Figures 15E.6.6-5 to 15E.6.6-8 for FMCRD run-in case and Figures 15E.6.6-9 to 15E.6.6-12 for 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 not-downscale and high pressure signals. As the poison reaches sufficient concentration in the core, the reactor achieves hot shutdown in about 19.1 minutes. Tables 15E.6.6-1 to 15E.6.6-3 show the 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. Figures 15E.6.7-1 to 15E.6.7-4 show the transient behavior for ARI, Figures 15E.6.7-5 to 15E.6.7-8 in FMCRD run-in and Figures 15E.6.7-9 to 15E.6.7-12 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, 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 SRNM not-downscale and the hot shutdown is achieved at about 20 minutes. Tables 15E.6.7-1 to 15E.6.7-3 show the summary of peak values of key parameters for these events.

Table 15E.6.1-1

MSIV CLOSURE SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	451	1.7 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	91.3	4.6 sec
Maximum Average Heat Flux (%)	131	3.0 sec
Maximum Bulk Suppression Pool Temperature (°C)	59.9	303 min
Associated Containment Pressure (kg/cm^2g)	0.24	303 min
Peak Cladding Temperature (°C)	613	17.9 sec

Table 15E.6.1-2

MSIV CLOSURE SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	451	1.7 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	91.3	4.6 sec
Maximum Average Heat Flux (%)	131	3.0 sec
Maximum Bulk Suppression Pool Temperature (°C)	65.8	148 min
Associated Containment Pressure (kg/cm^{2}g)	0.32	148 min
Peak Cladding Temperature (°C)	536	8.5 sec

Table 15E.6.1-3

MSIV CLOSURE SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	451	1.7 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	91.3	4.6 sec
Maximum Average Heat Flux (%)	131	3.0 sec
Maximum Bulk Suppression Pool Temperature (°C)	81.6	33.4 min
Associated Containment Pressure (kg/cm^2g)	0.63	33.4 min
Peak Cladding Temperature (°C)	697	140.0 sec

Table 15E.6.2-[illegible]

LOSS OF AC POWER SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	170	0.69 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	84.9	3.0 sec
Maximum Average Heat Flux (%)	102	0.89 sec
Maximum Bulk Suppression Pool Temperature (°C)	58.5	351 min
Associated Containment Pressure (kg/cm^2g)	0.22	351 min

Table 15E.6.2-2

LOSS OF AC POWER SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	170	0.69 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	84.9	3.0 sec
Maximum Average Heat Flux (%)	102	0.89 sec
Maximum Bulk Suppression Pool Temperature (°C)	59.2	325 min
Associated Containment Pressure (kg/cm^2g)	0.23	325 min

Table 15E.6.2-3

LOSS OF AC POWER SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	453	371 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	84.9	3.0 sec
Maximum Average Heat Flux (%)	102	0.89 sec
Maximum Bulk Suppression Pool Temperature (°C)	65	163 min
Associated Containment Pressure (kg/cm^2g)	0.31	163 min

Table 15E.6.3-1

LOSS OF FEEDWATER SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	116	424 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	75.4	430 sec
Maximum Average Heat Flux (%)	116	430 sec
Maximum Bulk Suppression Pool Temperature (°C)	58.0	384 min
Associated Containment Pressure (kg/cm^{2}g)	0.22	384 min

Table 15E.6.3-2

LOSS OF FEEDWATER SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	116	424 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	75.4	430 sec
Maximum Average Heat Flux (%)	116	430 sec
Maximum Bulk Suppression Pool Temperature (°C)	57.9	383 min
Associated Containment Pressure (kg/cm^2g)	0.22	383 min

Table 15E.6.3-3

LOSS OF FEEDWATER SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	116	424 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	75.4	430 sec
Maximum Average Heat Flux (%)	116	430 sec
Maximum Bulk Suppression Pool Temperature (°C)	63.1	212 min
Associated Containment Pressure (kg/cm^{2}g)	0.28	212 min

Table 15E.6.4-1

LOSS ONE FEEDWATER HEATER SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	116	424 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	75.4	430 sec
Maximum Average Heat Flux (%)	116	430 sec
Maximum Bulk Suppression Pool Temperature* (°C)	**	**
Associated Containment Pressure (kg/cm^2g)	**	**

** Initial values

Table 15E.6.5-1

TURBINE TRIP WITH BYPASS SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	126.5	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	34.4	33 sec
Associated Containment Pressure (kg/cm^2g)	0.01	33 sec

Table 15E.6.5-2

TURBINE TRIP WITH BYPASS SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	126.5	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	34.7	90 sec
Associated Containment Pressure (kg/cm^{2}g)	0.02	90 sec

Table 15E.6.5-3

TURBINE TRIP WITH BYPASS SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	126.5	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	42.1	12 min
Associated Containment Pressure (kg/cm^2g)	0.07	12 min

Table 15E.6.6-1

LOSS OF CONDENSER VACUUM SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	127	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	59.4	316 min
Associated Containment Pressure (kg/cm^2g)	0.24	316 min

Table 15E.6.6-2

LOSS OF CONDENSER VACUUM SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	127	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	60.7	282 min
Associated Containment Pressure (kg/cm^{2}g)	0.25	282 min

Table 15E.6.6-3

LOSS OF CONDENSER VACUUM SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	757	0.79 sec
Maximum Vessel Bottom Pressure (kg/cm^{2}g)	87.1	2.46 sec
Maximum Average Heat Flux (%)	127	1.10 sec
Maximum Bulk Suppression Pool Temperature (°C)	80.1	49.5 min
Associated Containment Pressure (kg/cm^{2}g)	0.59	49.5 min

Table 15E.6.7-1

FEEDWATER CONTROLLER FAILURE SUMMARY (ARI)

	Value	Time
Maximum Neutron Flux (%)	647	19.9 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.0	21.6 sec
Maximum Average Heat Flux (%)	127.7	20.3 sec
Maximum Bulk Suppression Pool Temperature (°C)	34.6	48 sec
Associated Containment Pressure (kg/cm^2g)	0.01	48 sec

Table 15E.6.7-2

FEEDWATER CONTROLLER FAILURE SUMMARY (FMCRD RUN-IN)

	Value	Time
Maximum Neutron Flux (%)	647	19.9 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.0	21.6 sec
Maximum Average Heat Flux (%)	127.7	20.3 sec
Maximum Bulk Suppression Pool Temperature (°C)	34.6	60 sec
Associated Containment Pressure (kg/cm^2g)	0.01	60 sec

Table 15E.6.7-3

FEEDWATER CONTROLLER FAILURE SUMMARY (BORON INJECTION)

	Value	Time
Maximum Neutron Flux (%)	647	19.9 sec
Maximum Vessel Bottom Pressure (kg/cm^2g)	87.0	21.6 sec
Maximum Average Heat Flux (%)	127.7	20.3 sec
Maximum Bulk Suppression Pool Temperature (°C)	34.8	48 sec
Associated Containment Pressure (kg/cm^2g)	0.02	48 sec

Figure 15E.6.1-1. ABWR MSIV Closure, ARI

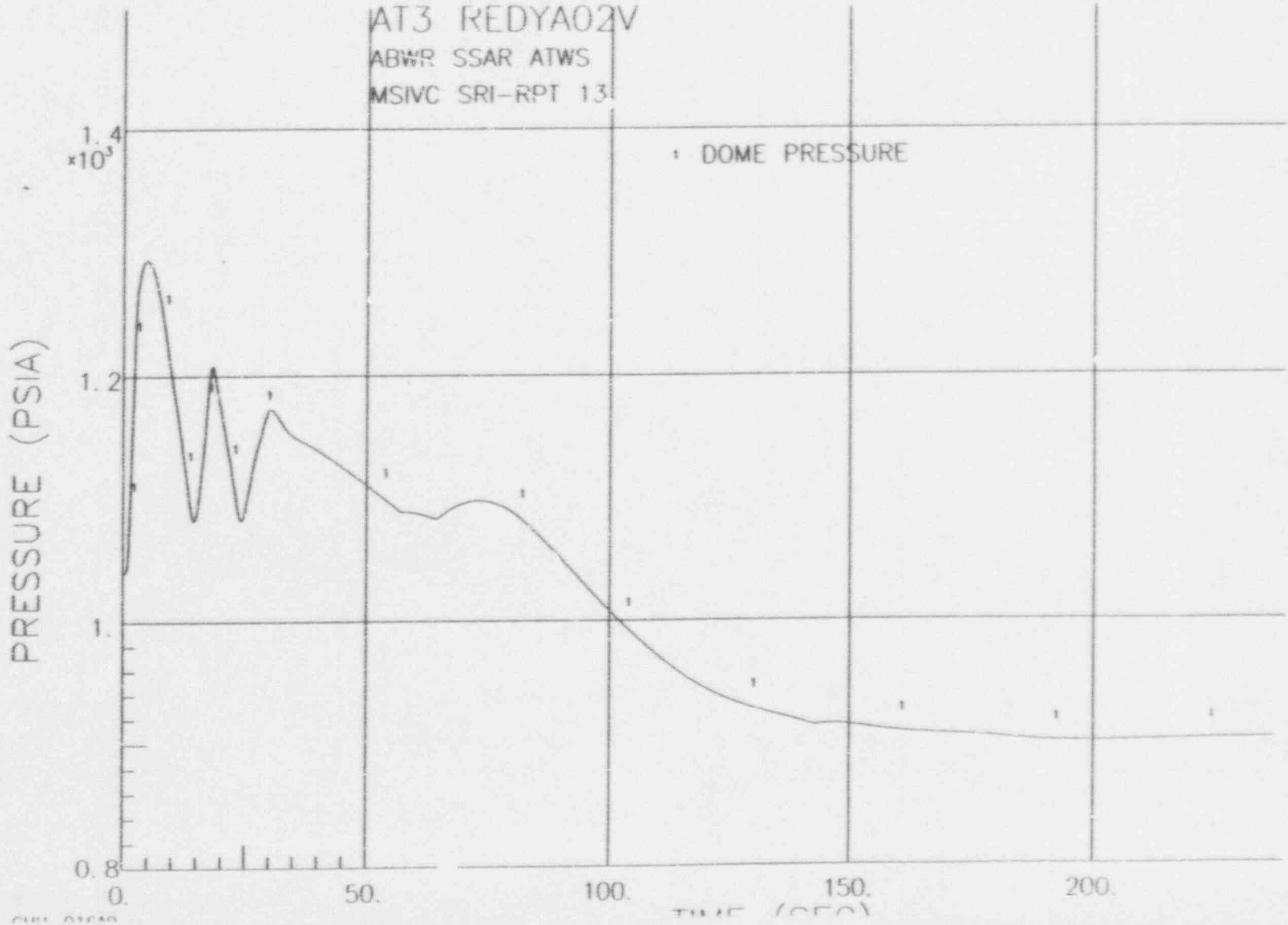


Figure 15E.6.1-2. ABWR MSIV Closure, ARI

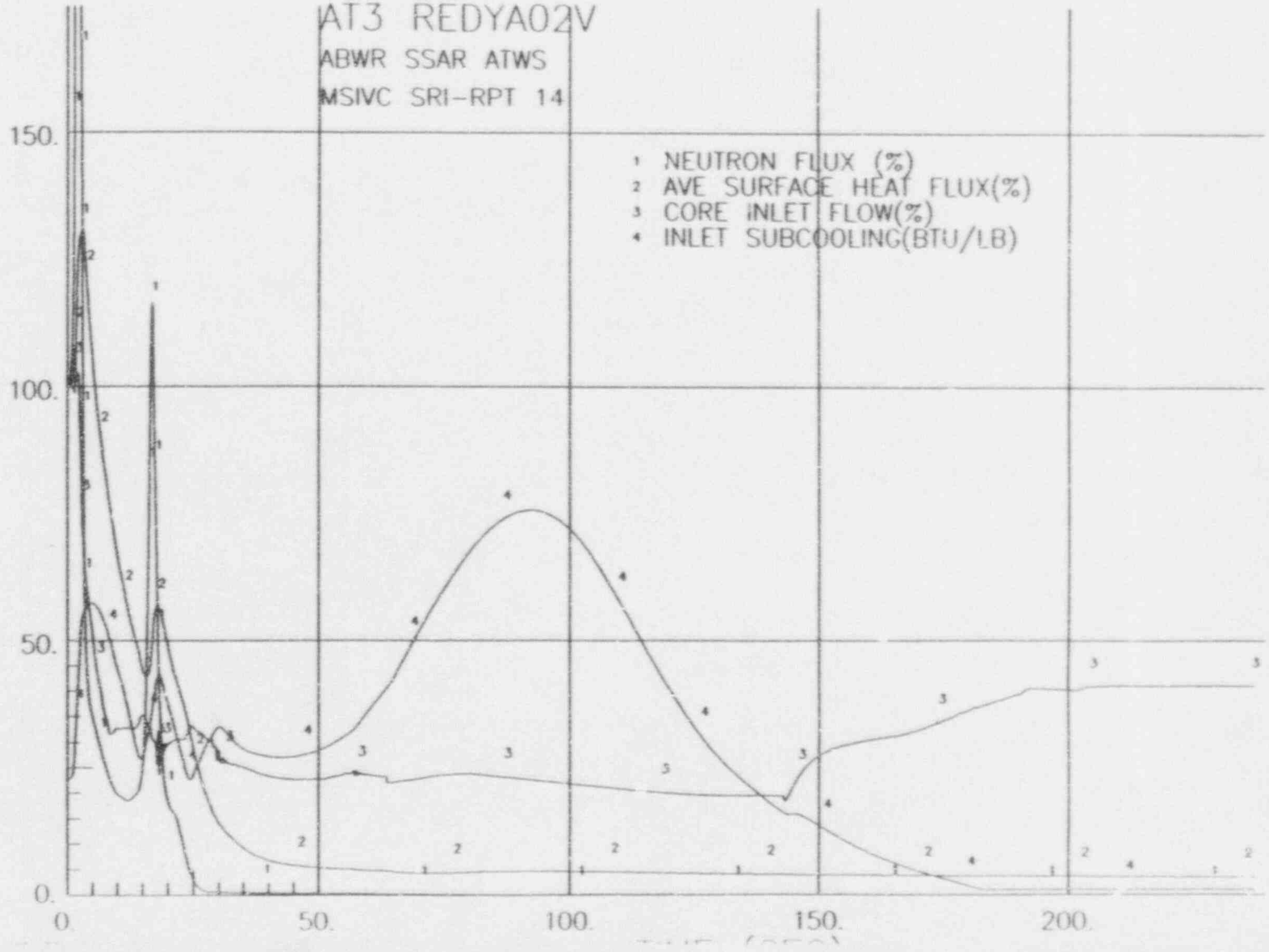


Figure 15E.6.1-3. ABWR MSIV Closure, ARI

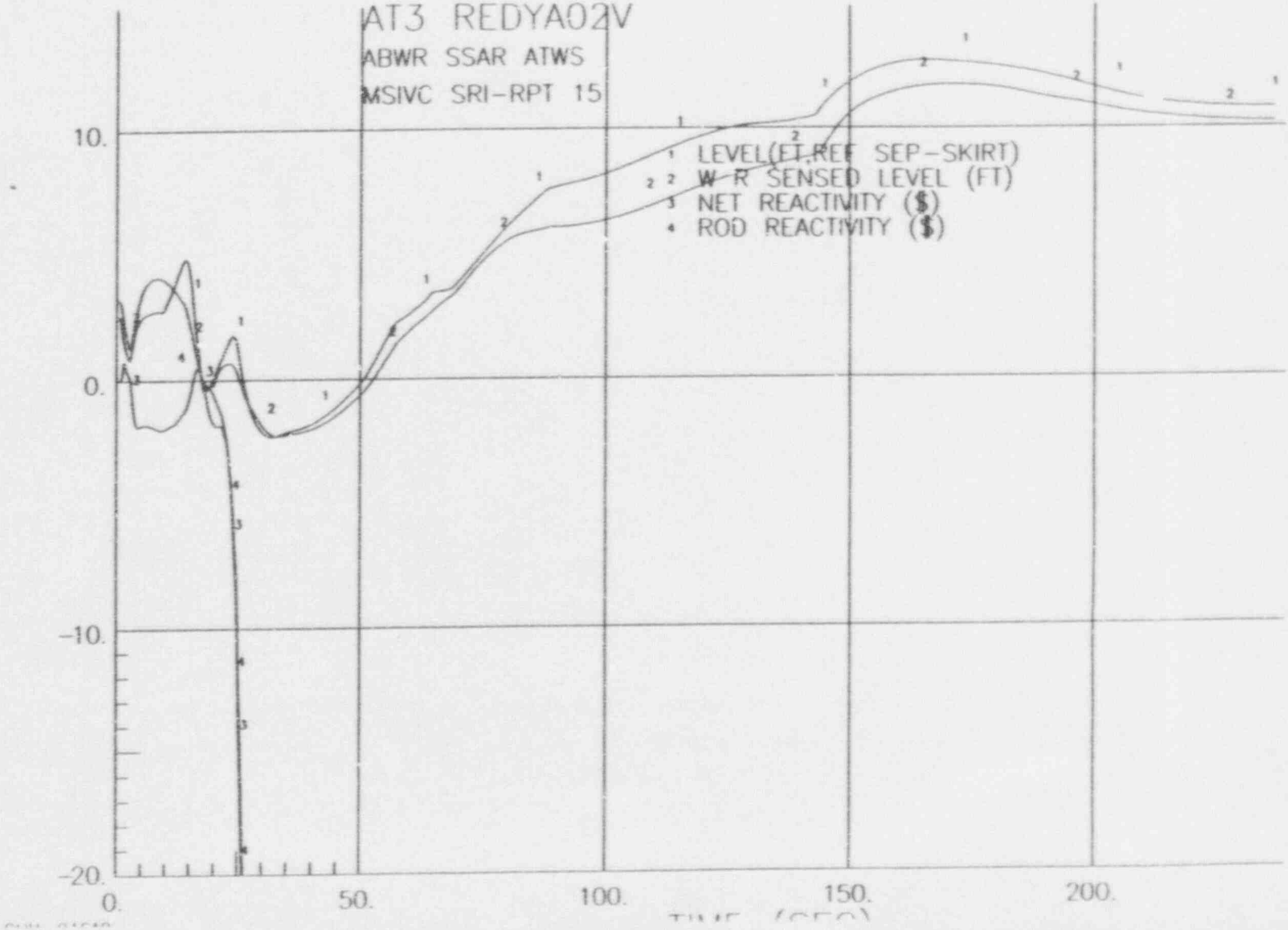


Figure 15E.6.1-4. ABWR MSIV Closure, ARI

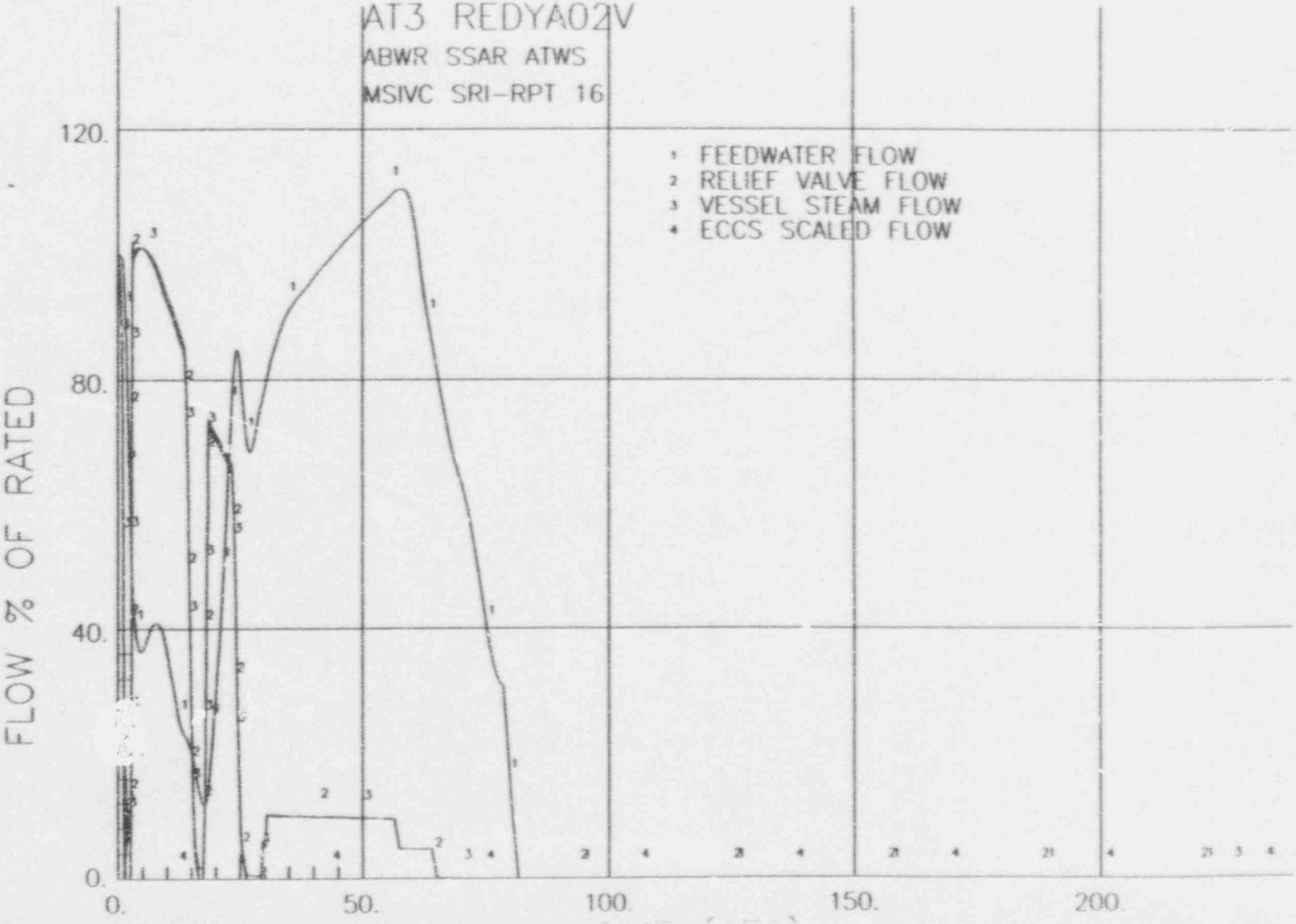
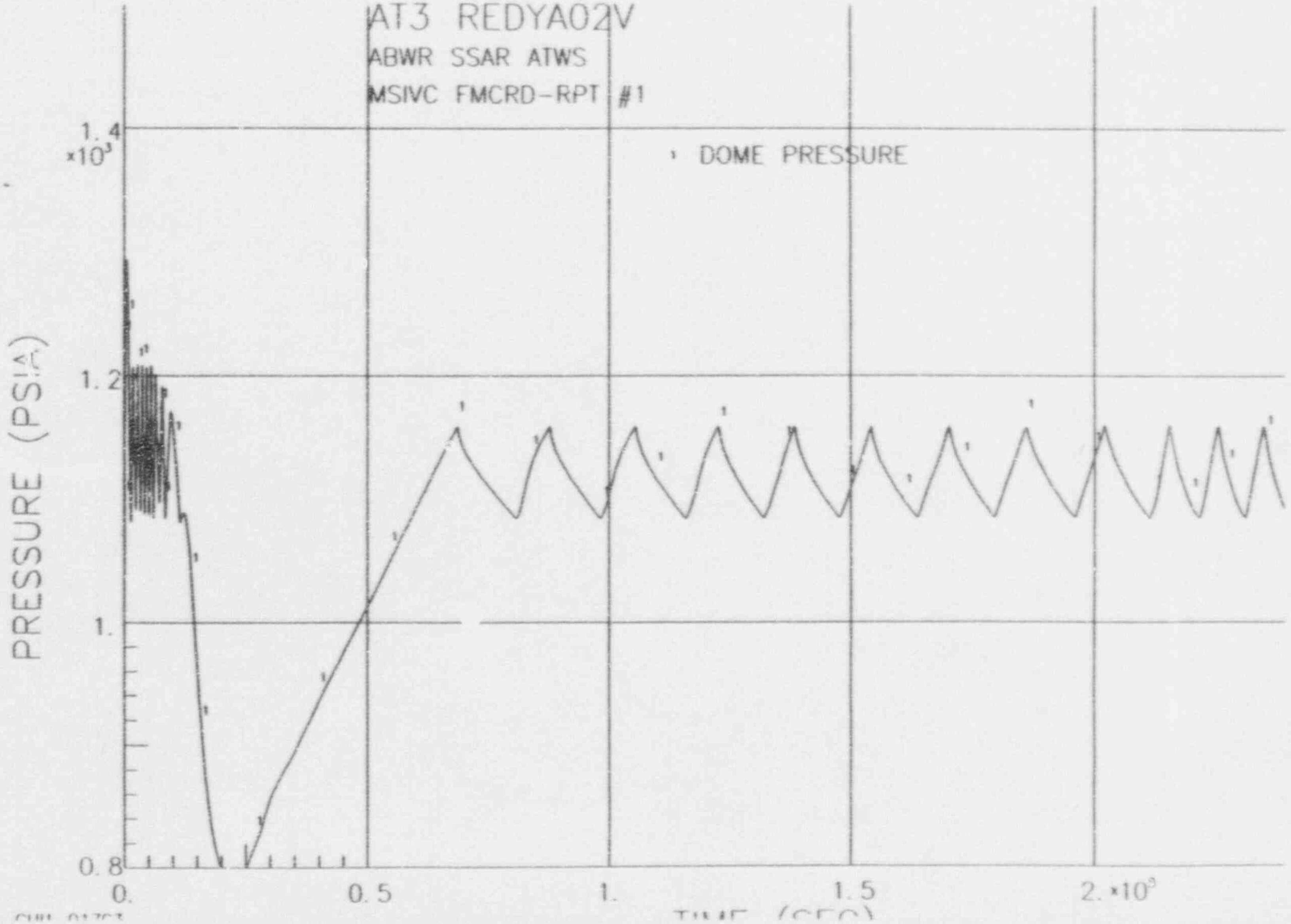


Figure 15E.6.1-5. ABWR MSIV Closure, FMCRD Run-in



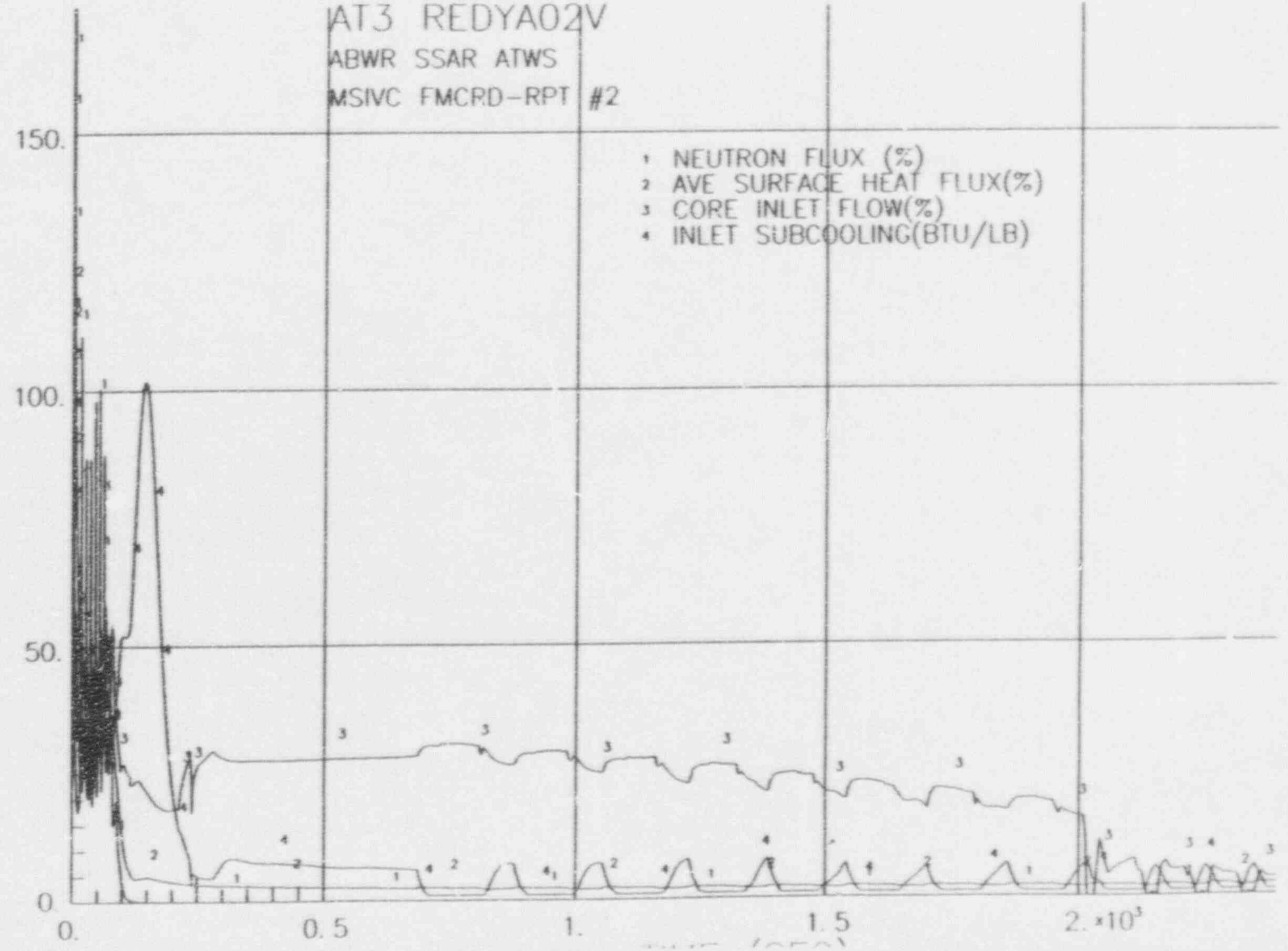


Figure 15E.6.1-6. ABWR MSIV Closure, FMCRD Run-in

Figure 15E.6.1-7. ABWR MSIV Closure, FMCRD Run-in

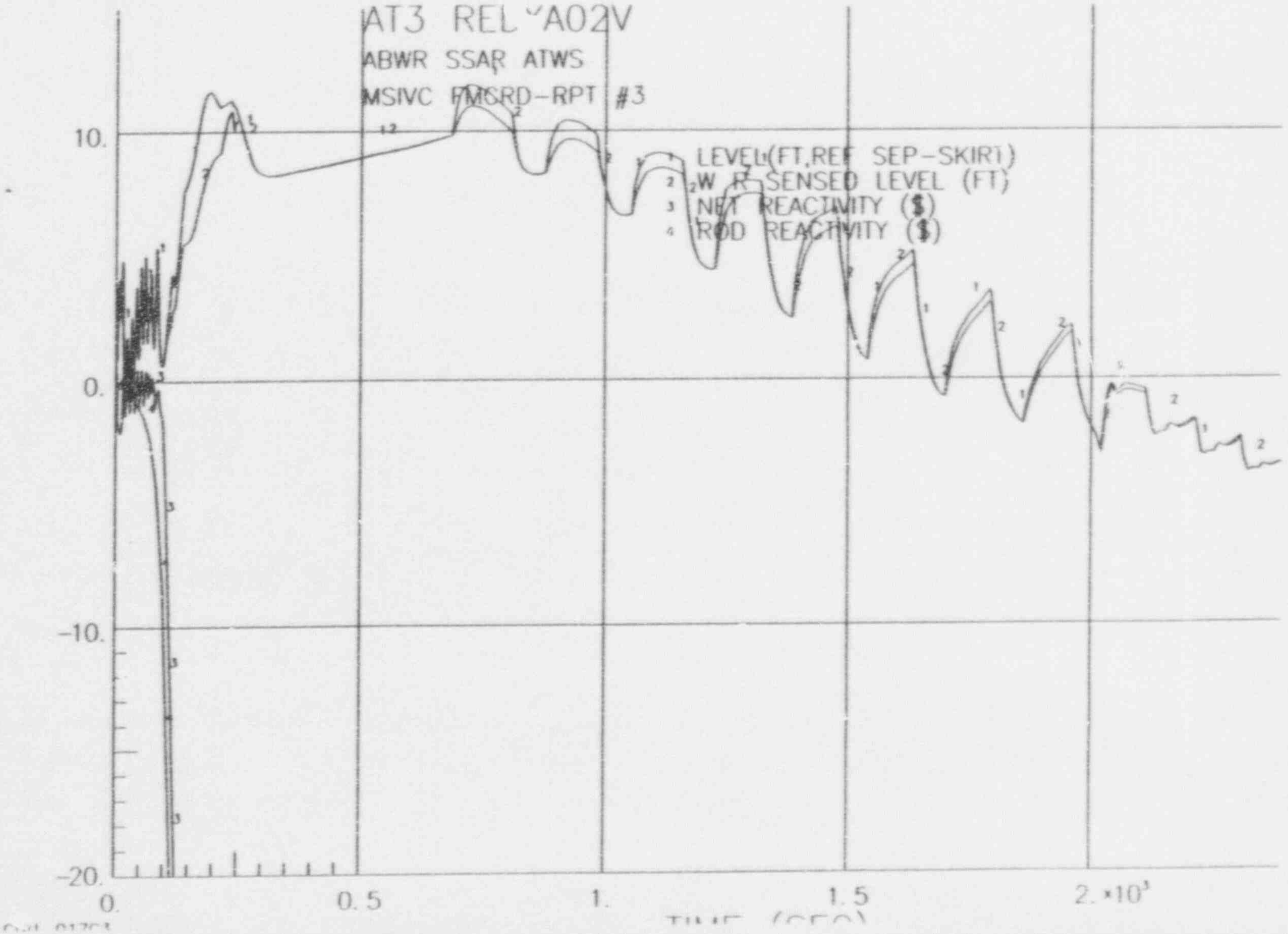


Figure 15E.6.1-8. ABWR MSIV Closure, FMCRD Run-in

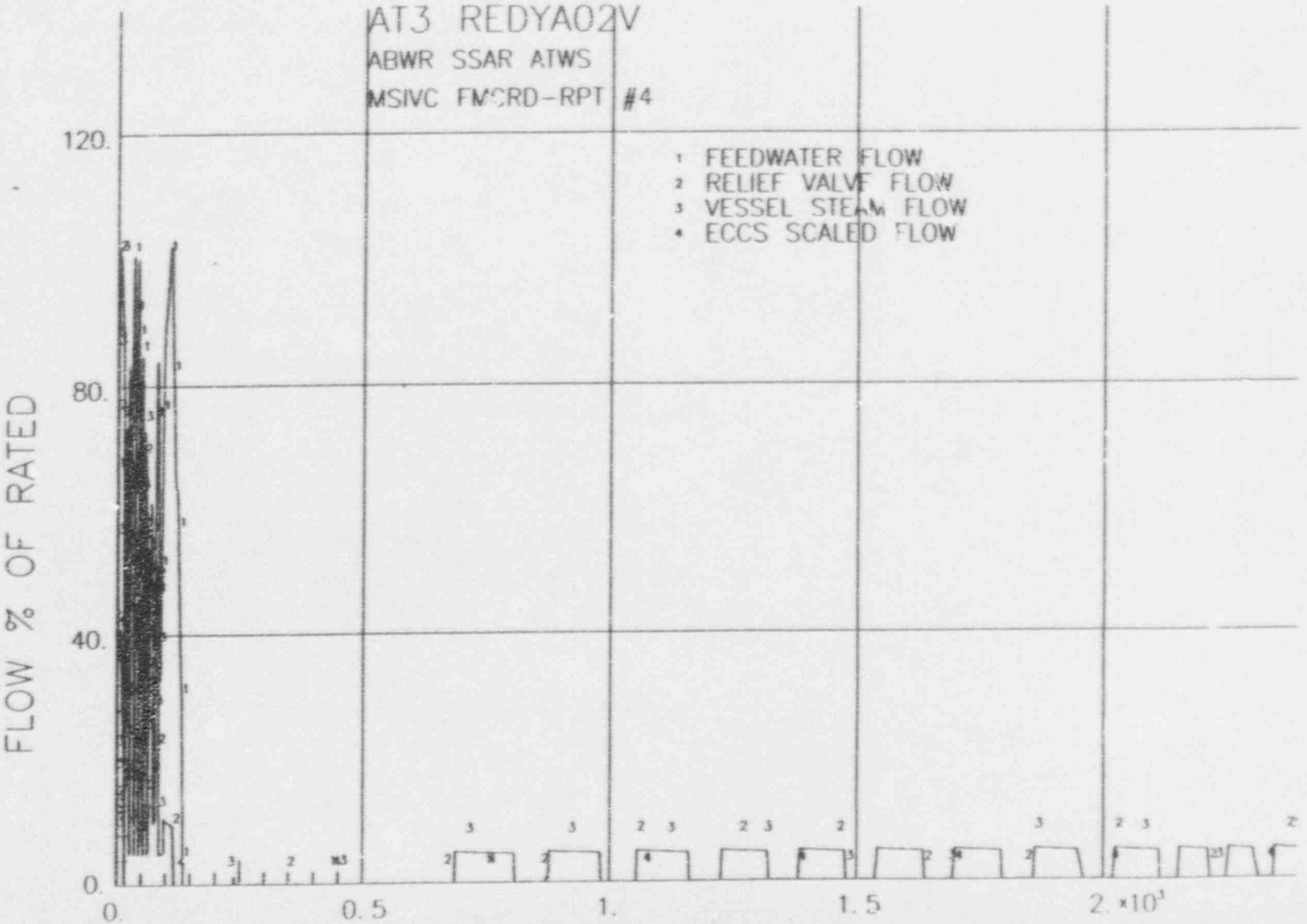


Figure 15E.6.1-9. ABWR MSIV Closure, SLCS

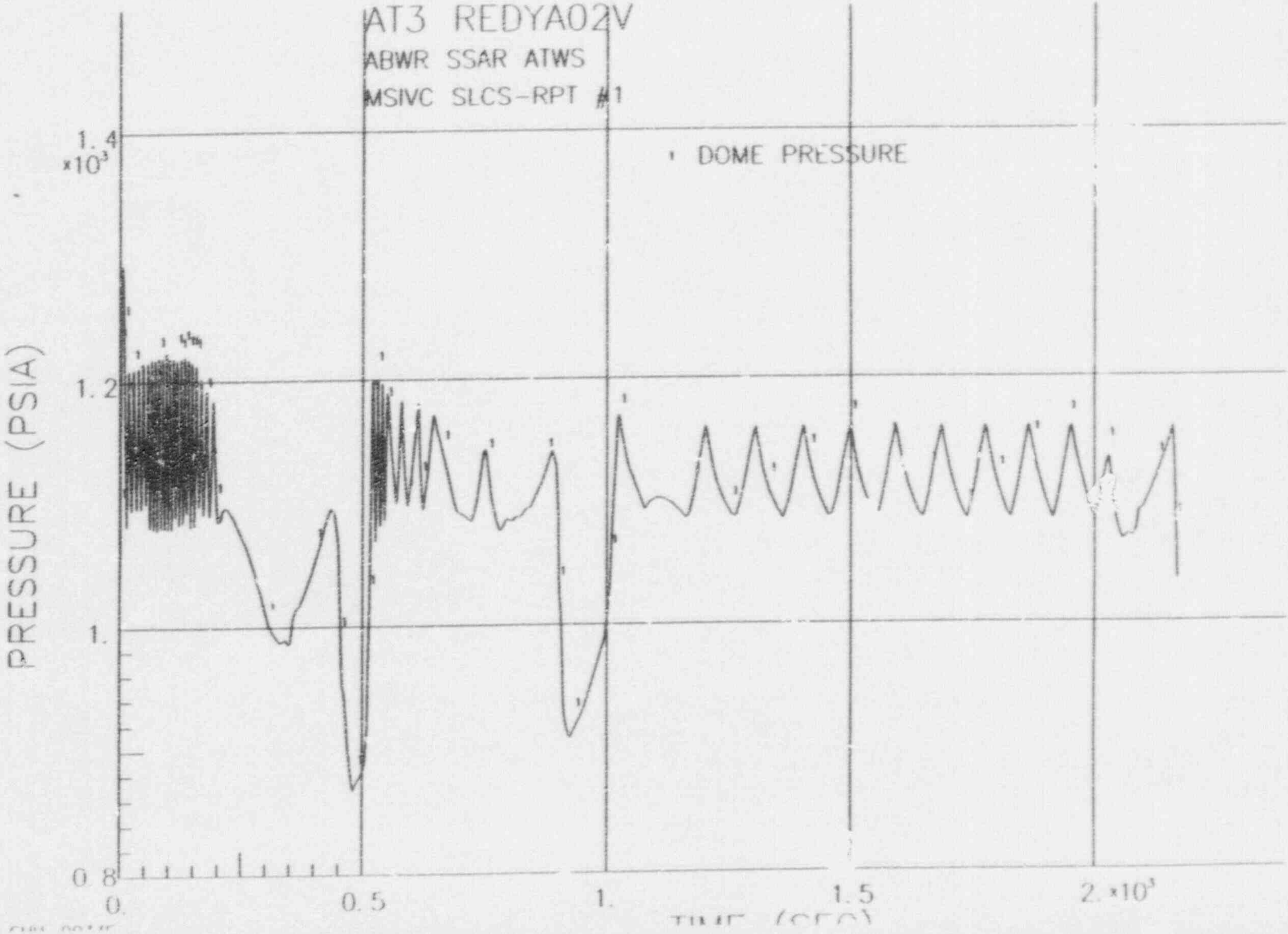


Figure 15E.6.1-10. ABWR MSIV Closure, SLCS

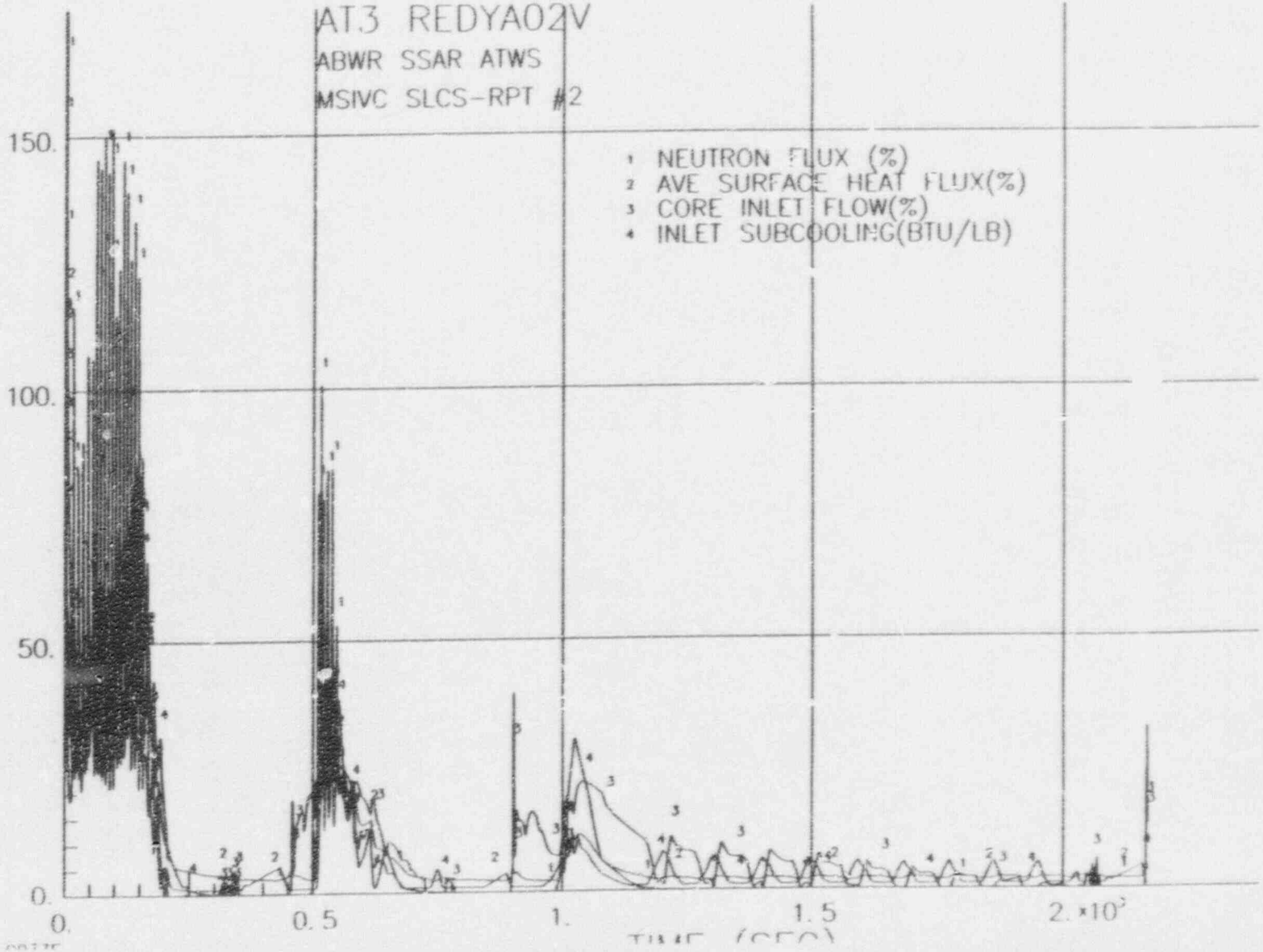
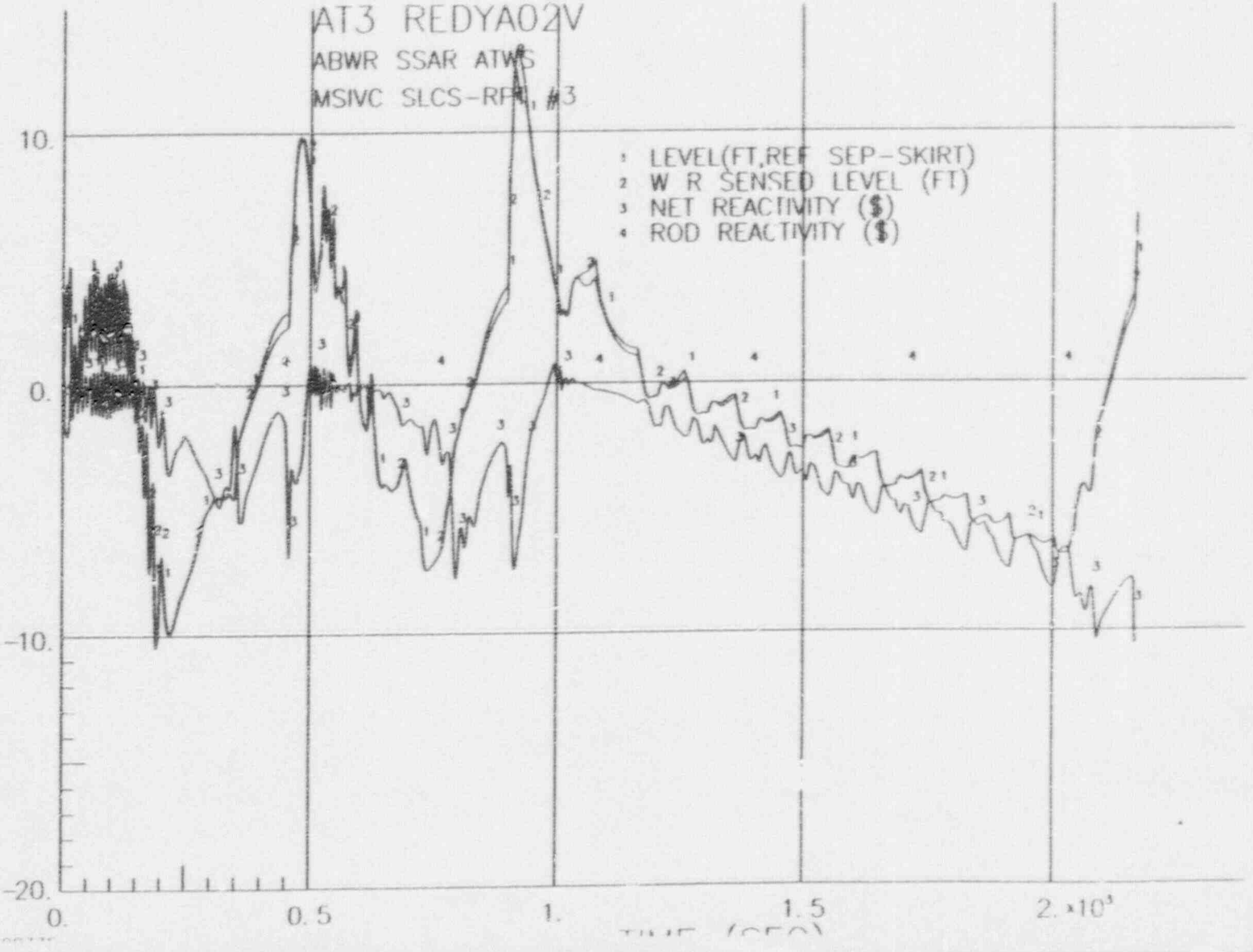


Figure 15E.6.1-11. ABWR MSIV Closure, SLC[illegible]



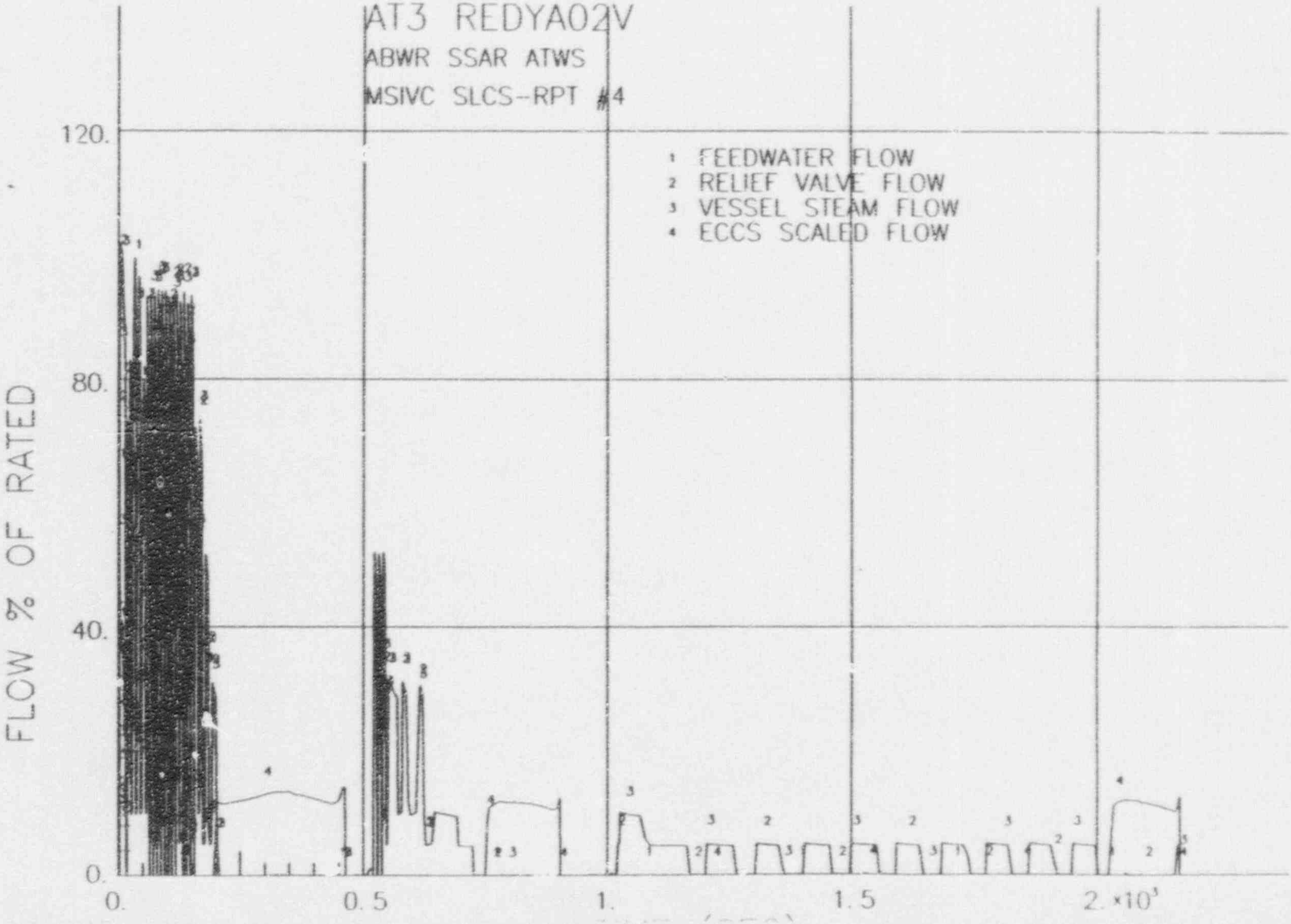


Figure 15E.6.1-12. ABWR MSIV Closure, SLCS

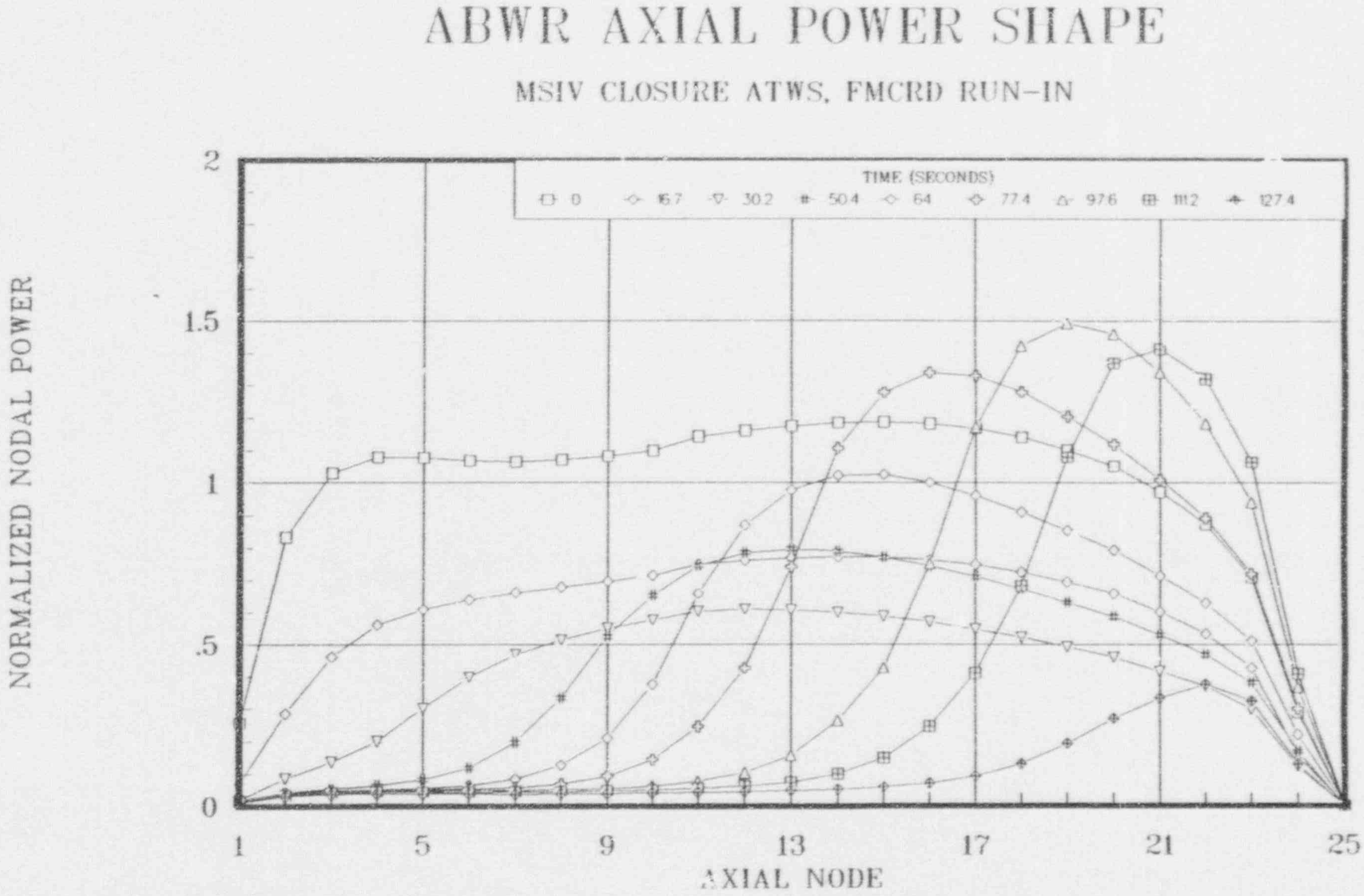


Figure 15E.6.1-13. ABWR MSIV Closure, FMCRD Run-in

Figure 15E.6.2-1. ABWR Loss of AC Power, ARI

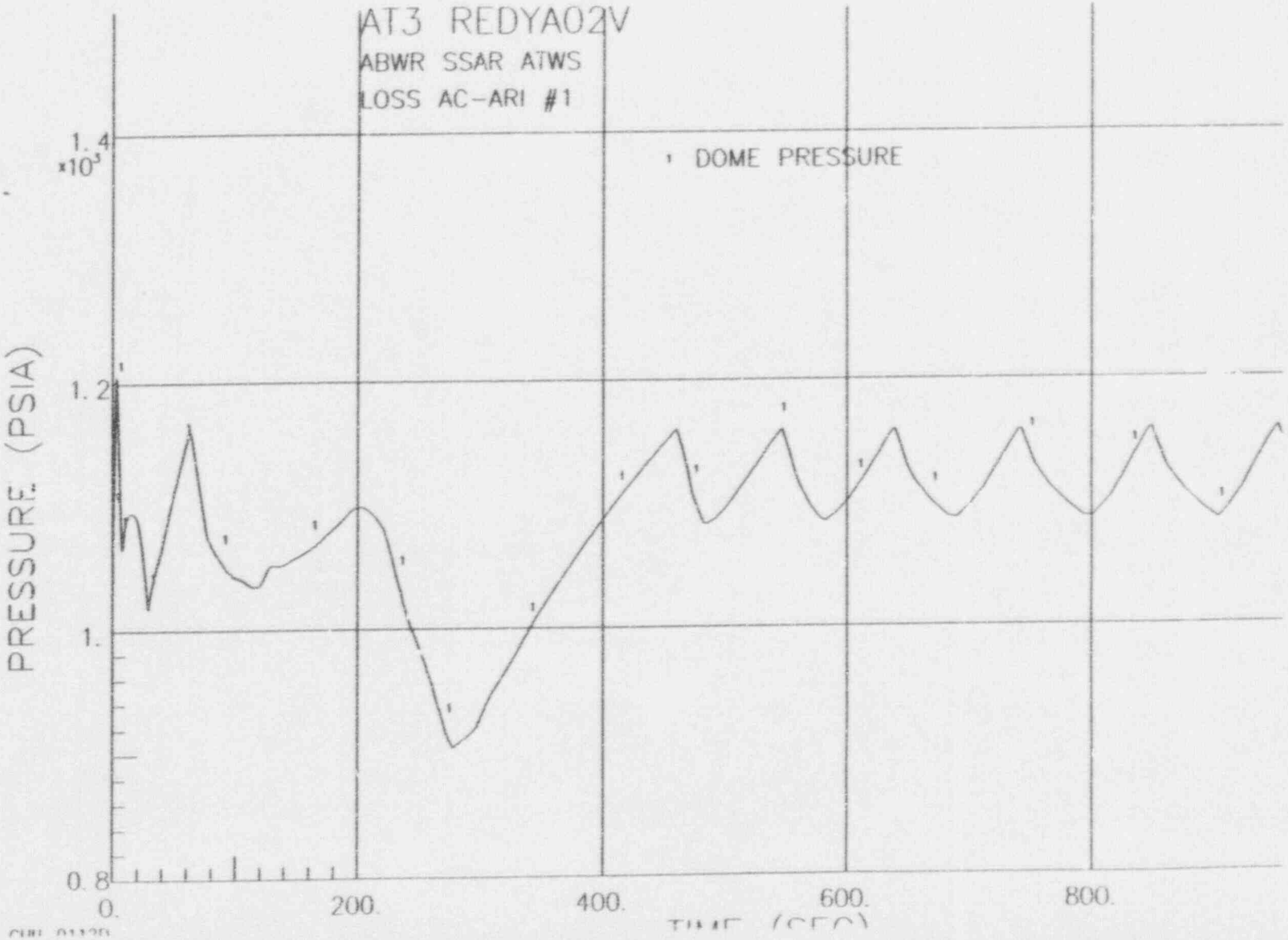


Figure 15E.6.2-2. ABWR Loss of AC Power, ARI

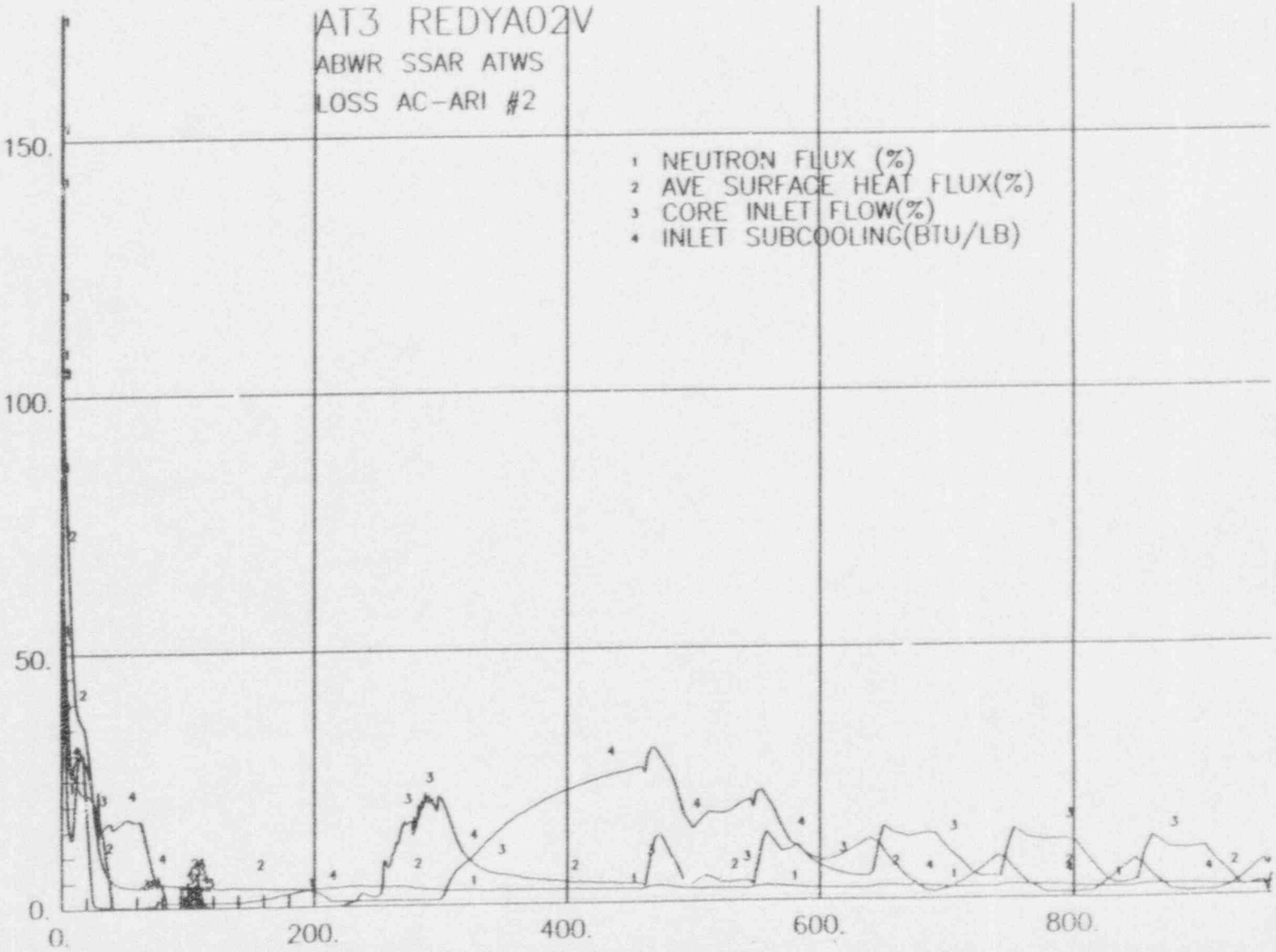


Figure E.6.2-3. ABWR Loss of AC Power, ARI

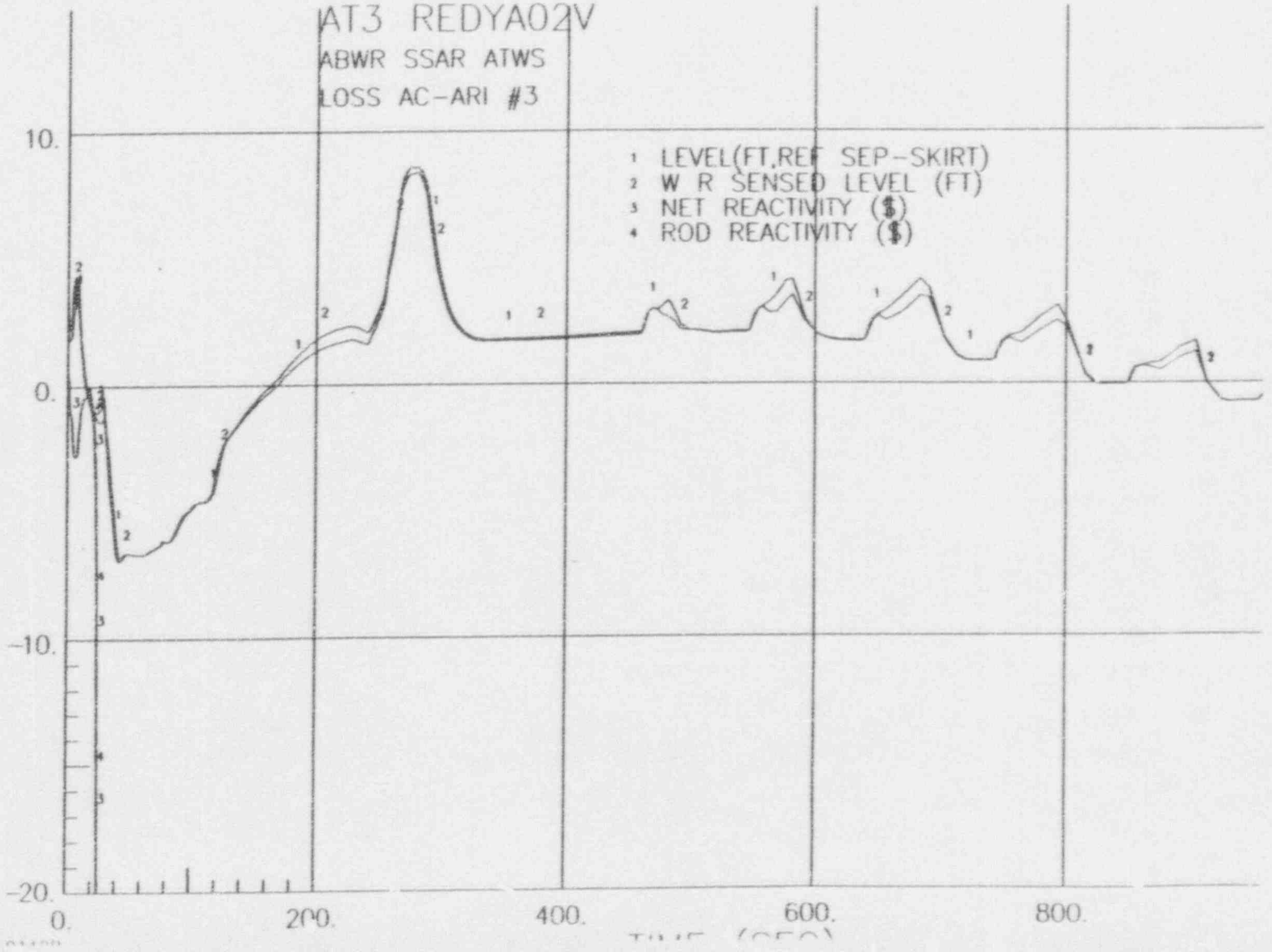


Figure 15E.6.2-4. ABWR Loss of AC Power, ARI

Figure 15E.6.2-5. ABWR Loss of AC Power, FMCRD Run-in

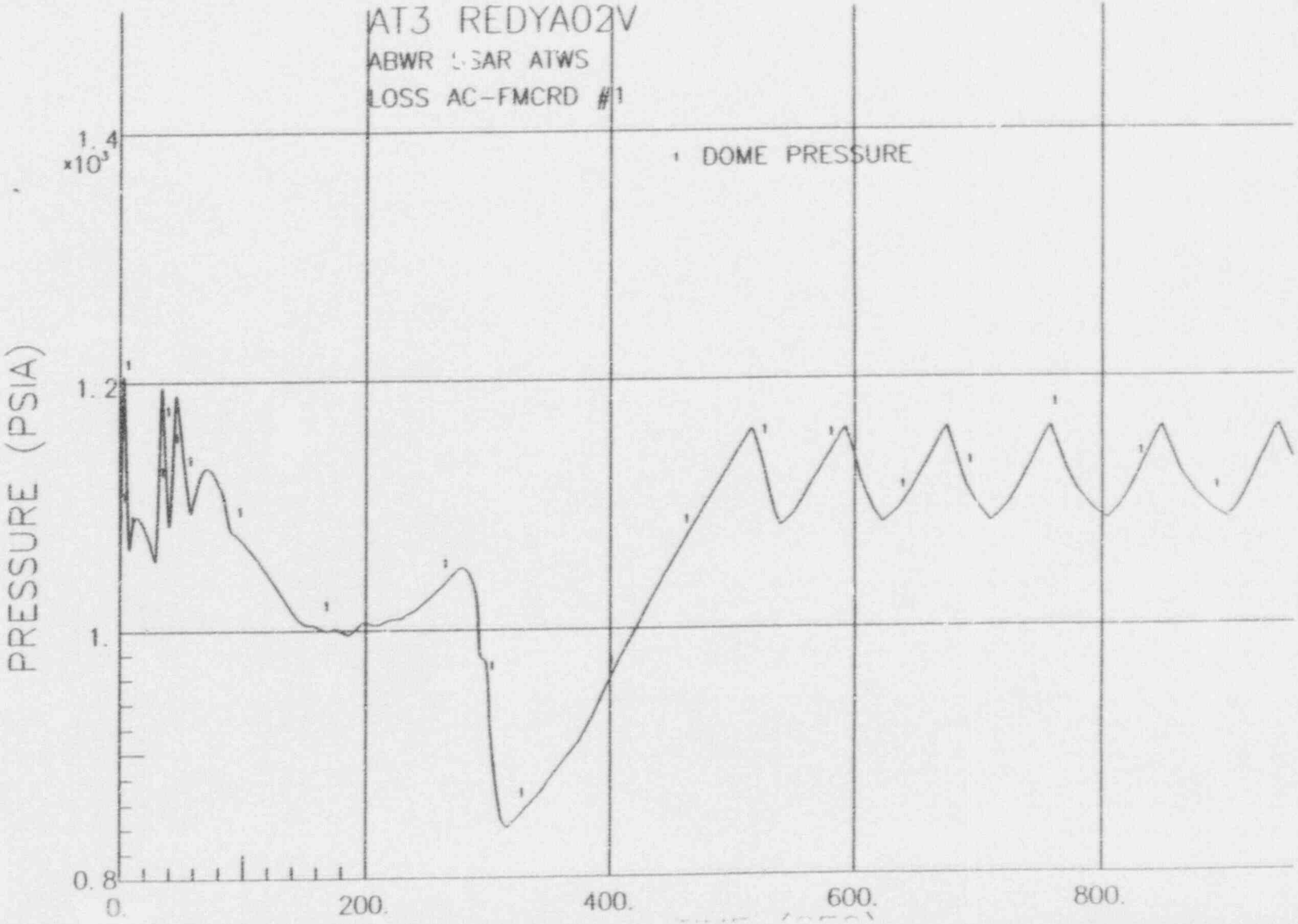
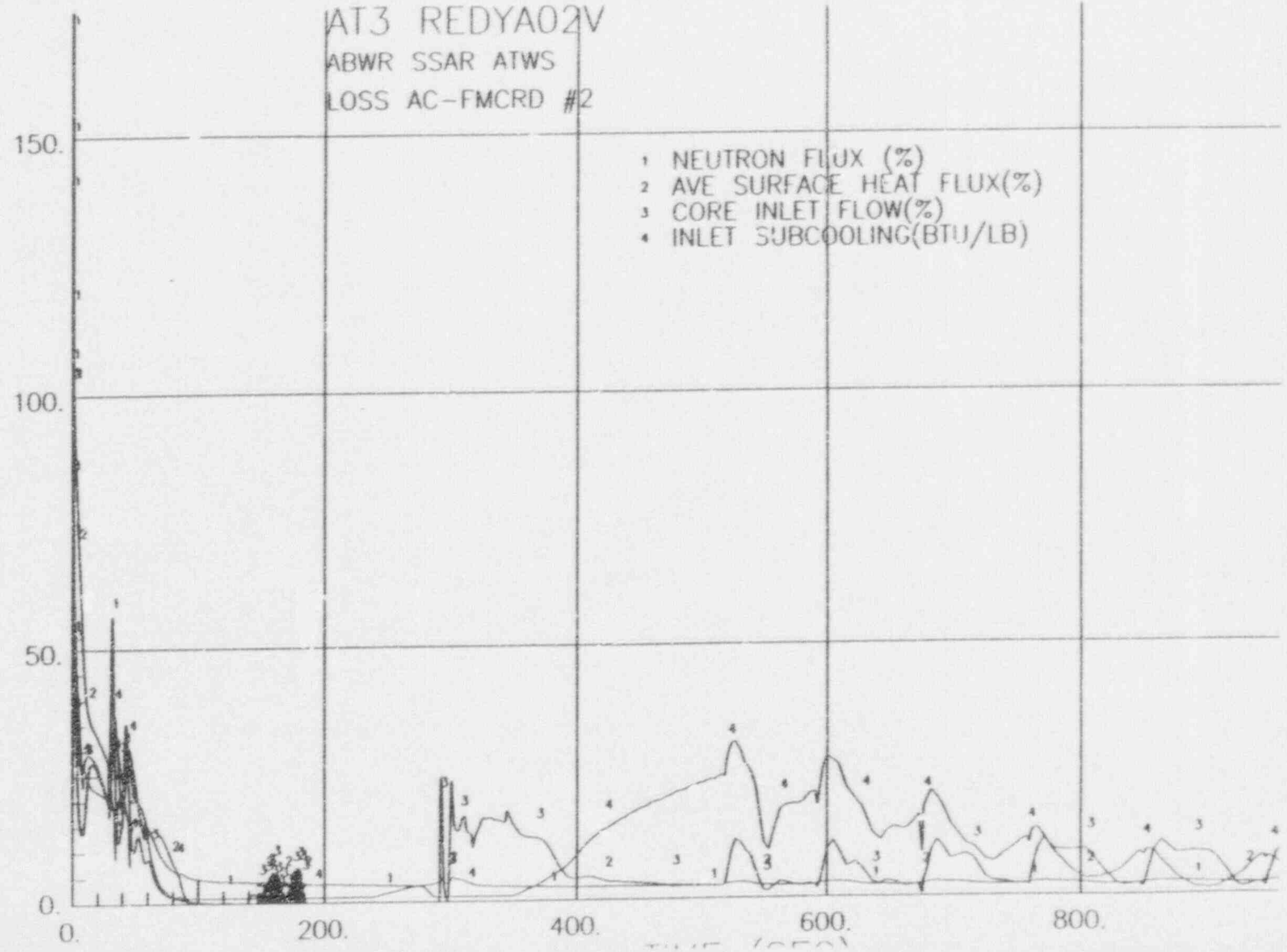


Figure 15E.6.2-6. ABWR Loss of AC Power, FMCRD Run-in



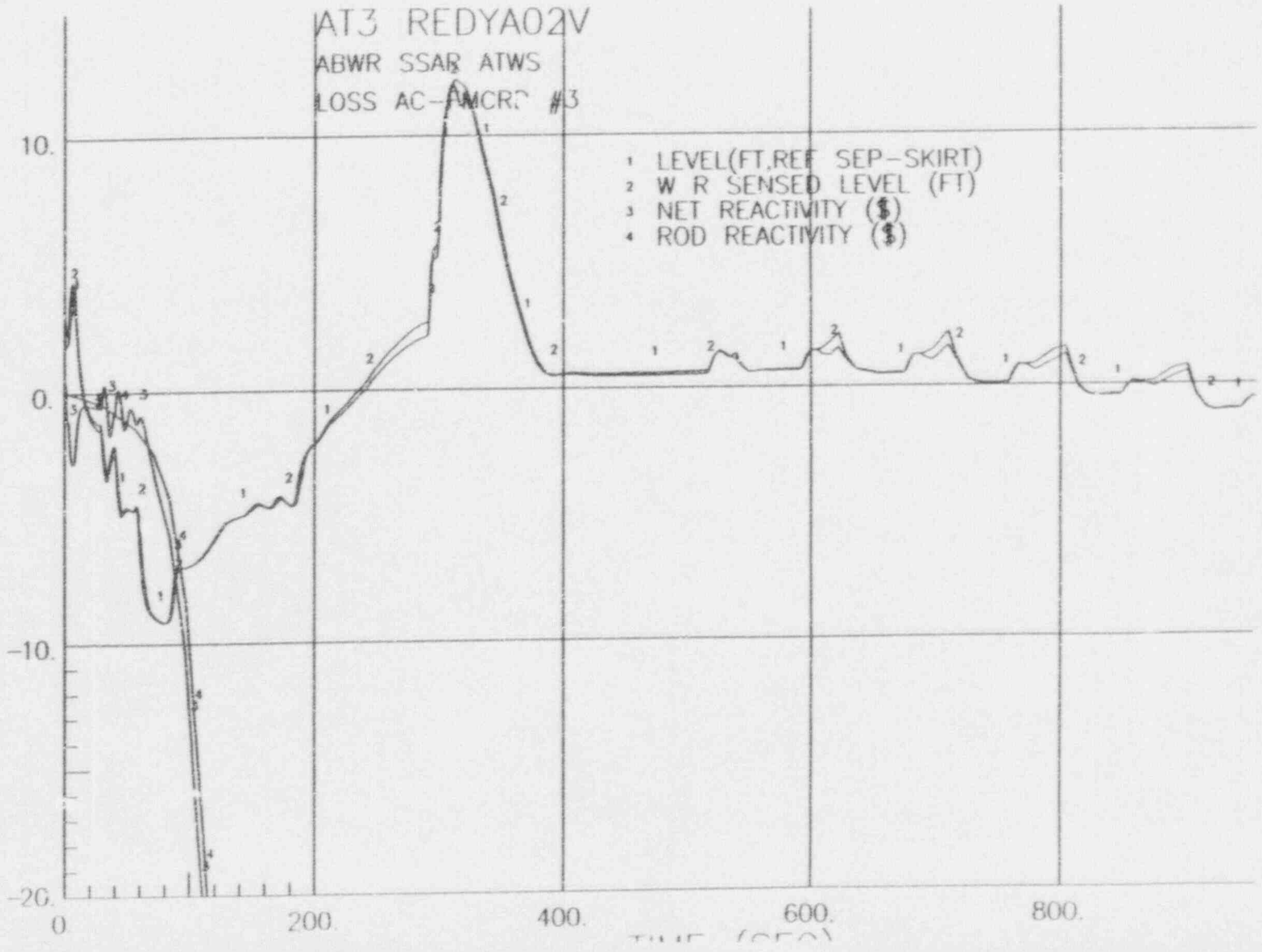


Figure 15E.6.2-7. ABWR Loss of AC Power, FMCRD Run-in

Figure 15E.6.2-8. ABWR Loss of AC Power, FMCRD Run-in

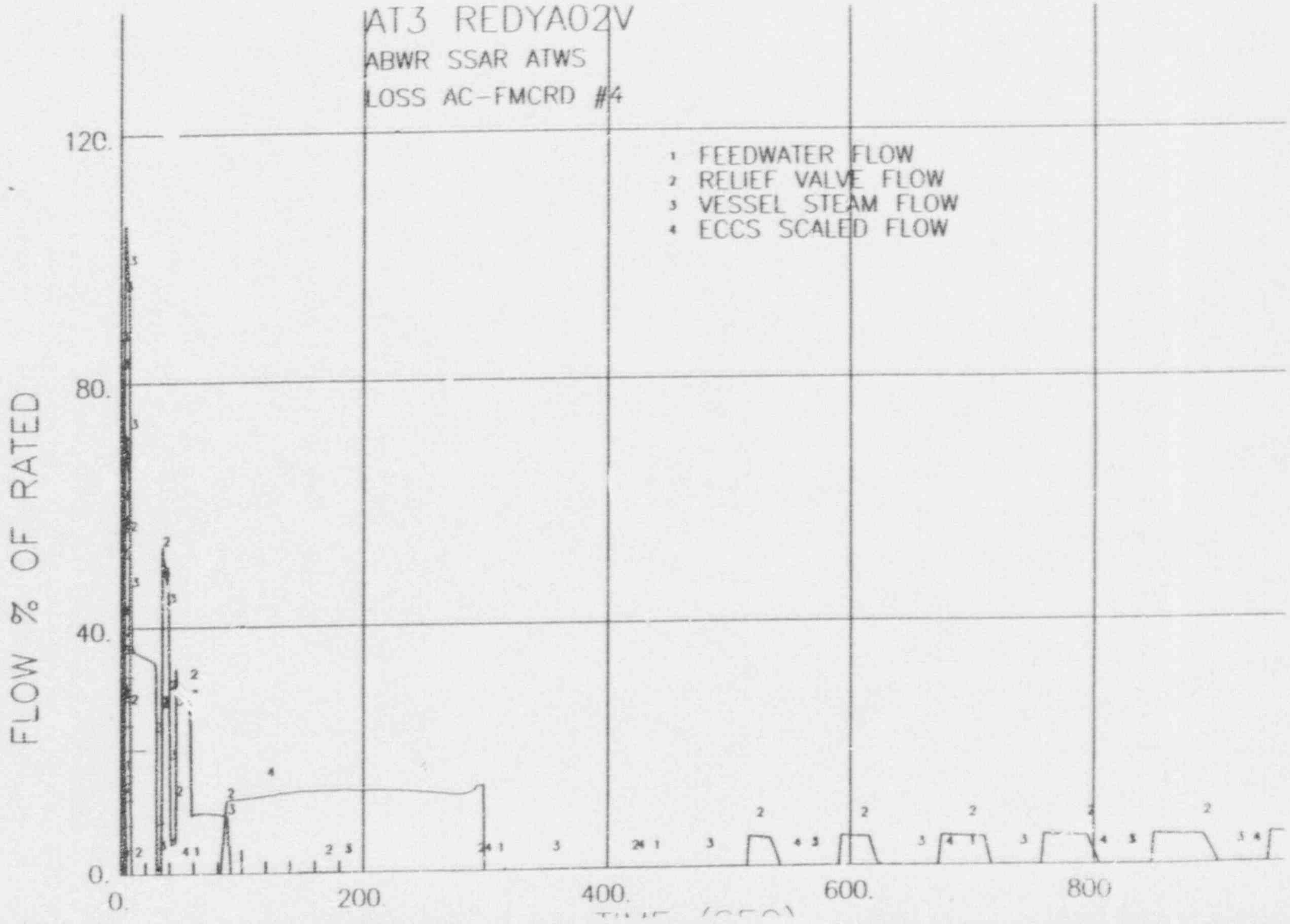


Figure 15E.6.2-9. ABWR Loss of AC Power, SLCS

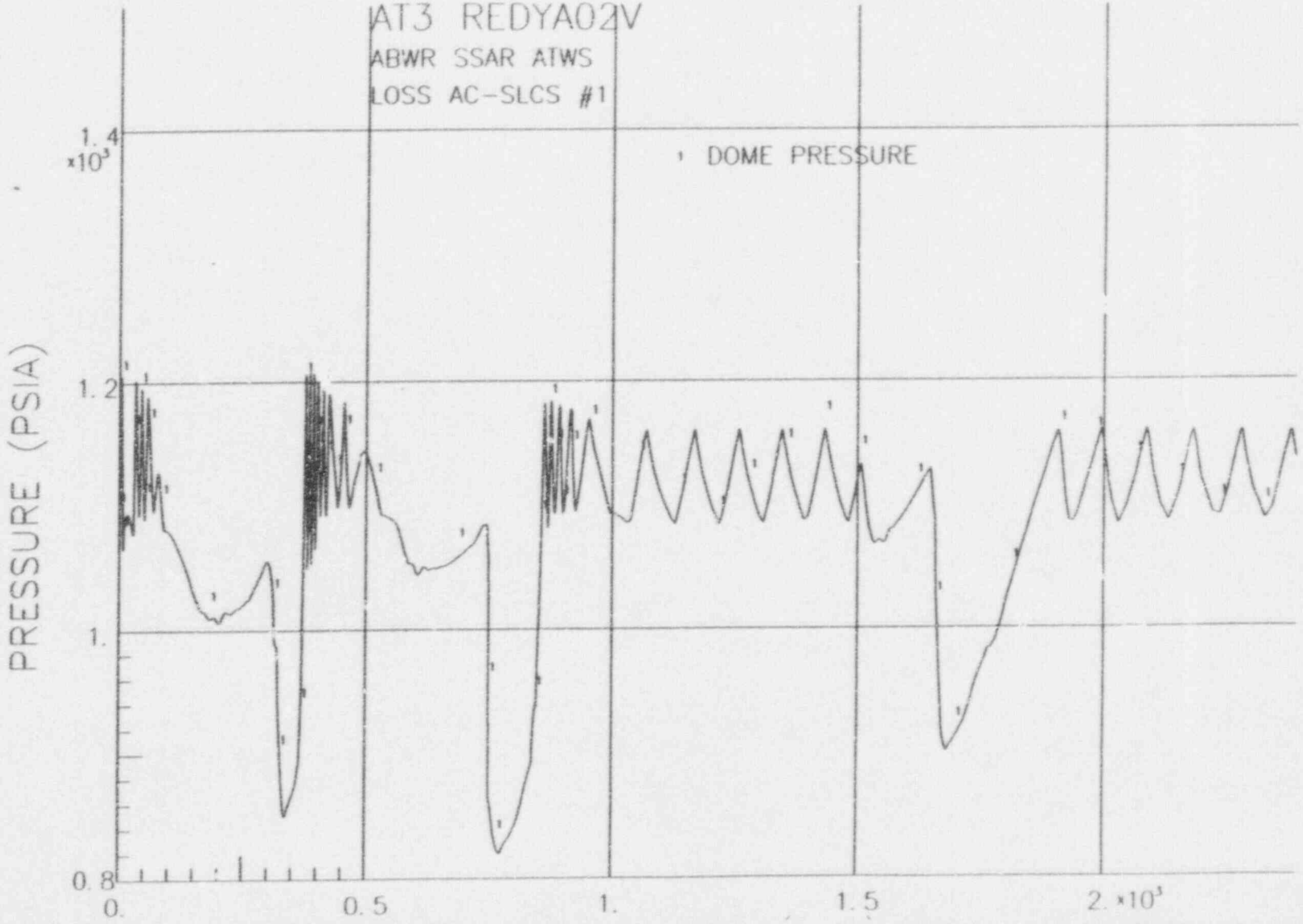


Figure 15E.6.2-10. ABWR Loss of AC Power, SLCS

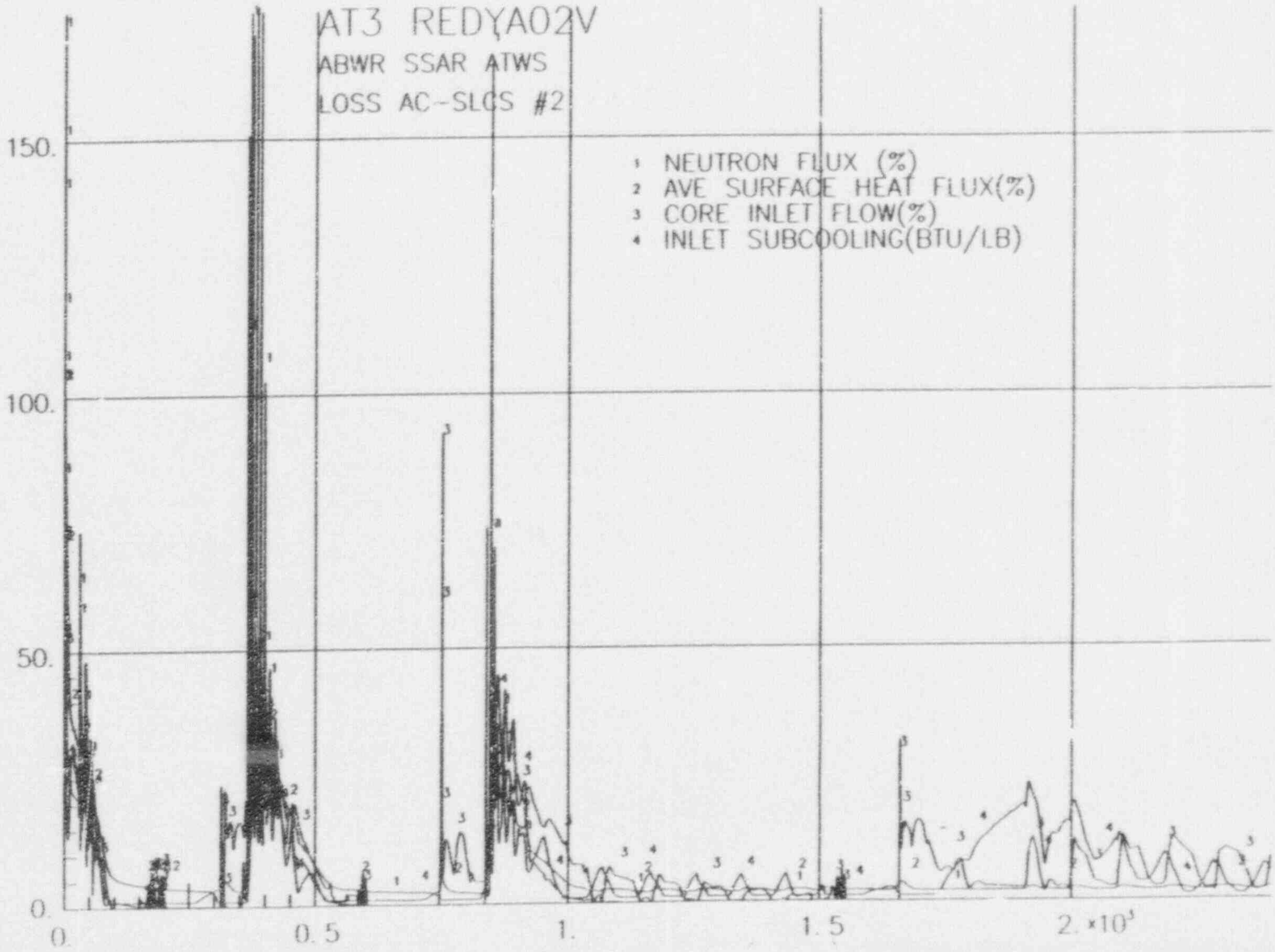


Figure 15E.6.2-11. ABWR Loss of AC Power, SLCS

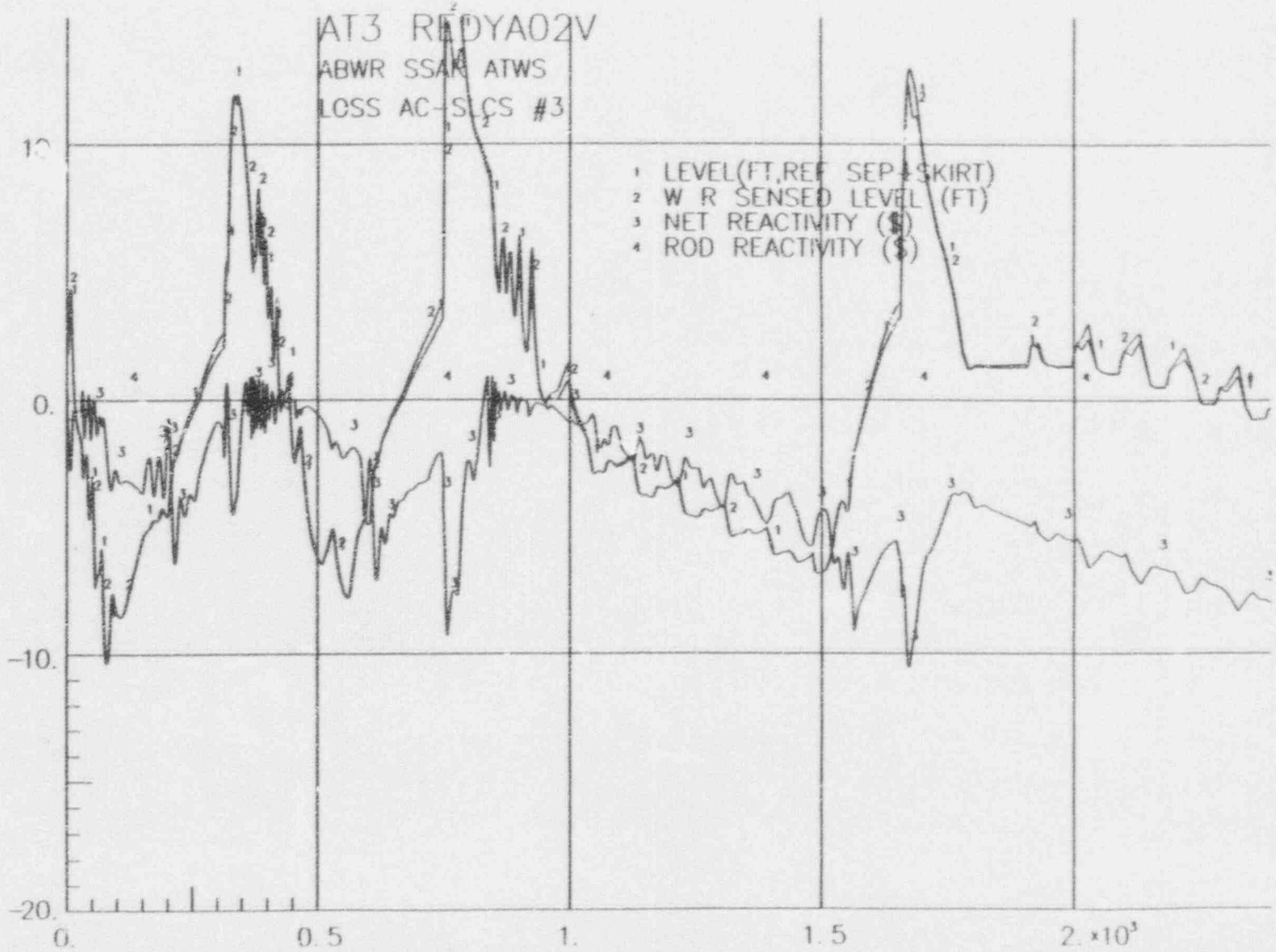


Figure 15E.6.2-12. ABWR Loss of AC Power, SLCS

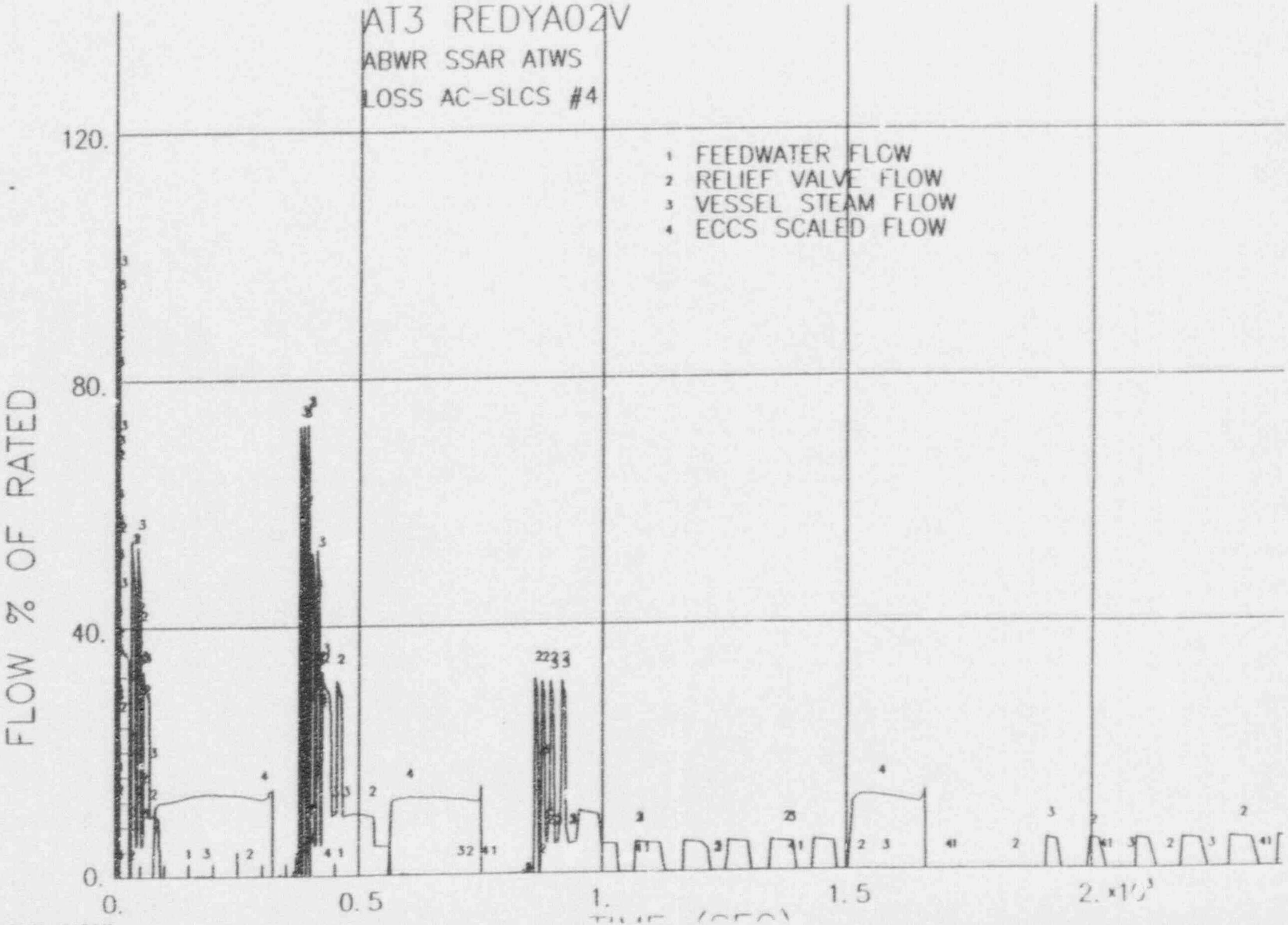


Figure 15E.6.3-1. ABWR Loss of Feedwater Flow, ARI

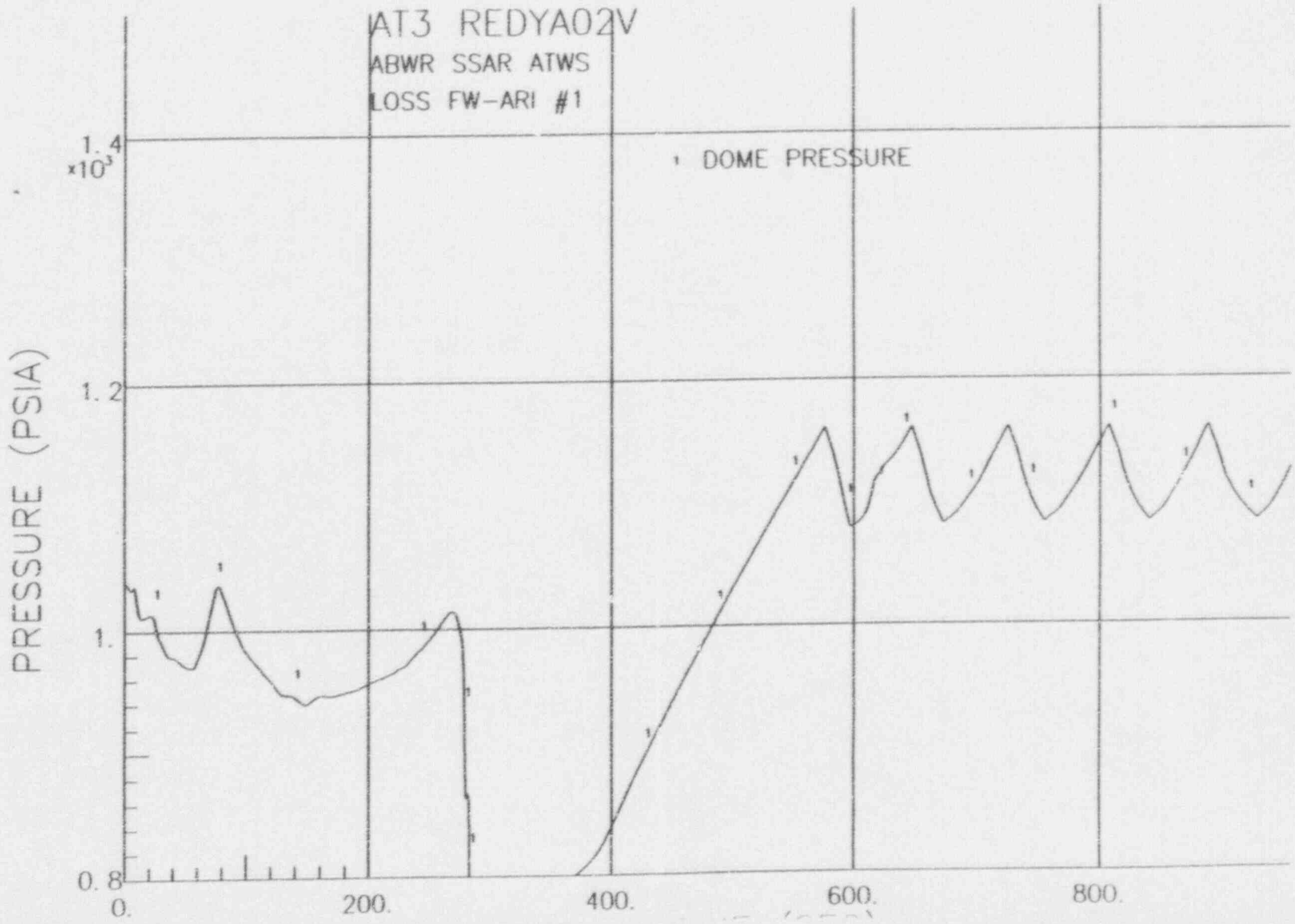


Figure 15E.6.3-2. ABWR Loss of Feedwater Flow, ARI

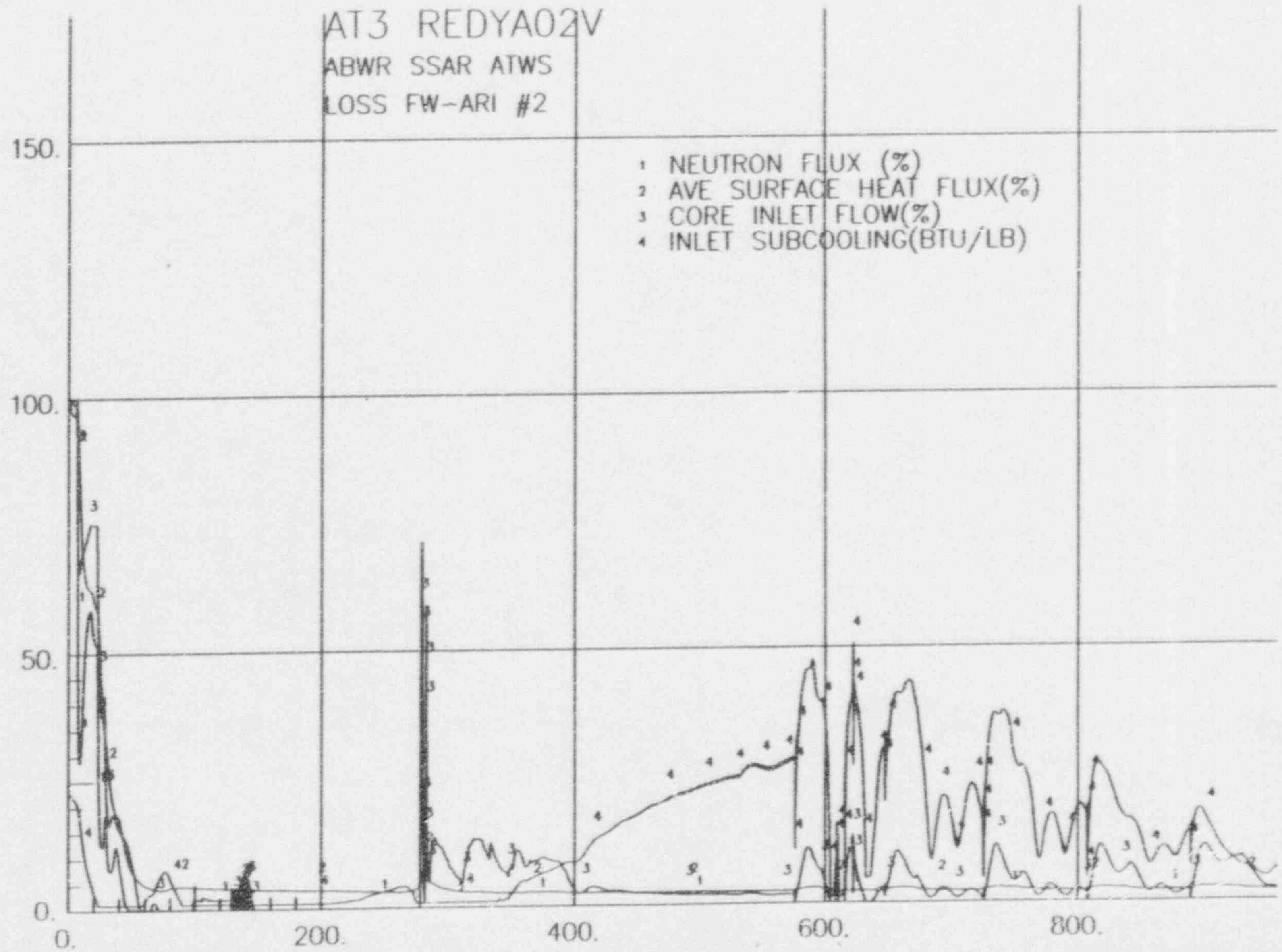


Figure 15E.6.3-3. ABWR Loss of Feedwater Flow, ARI

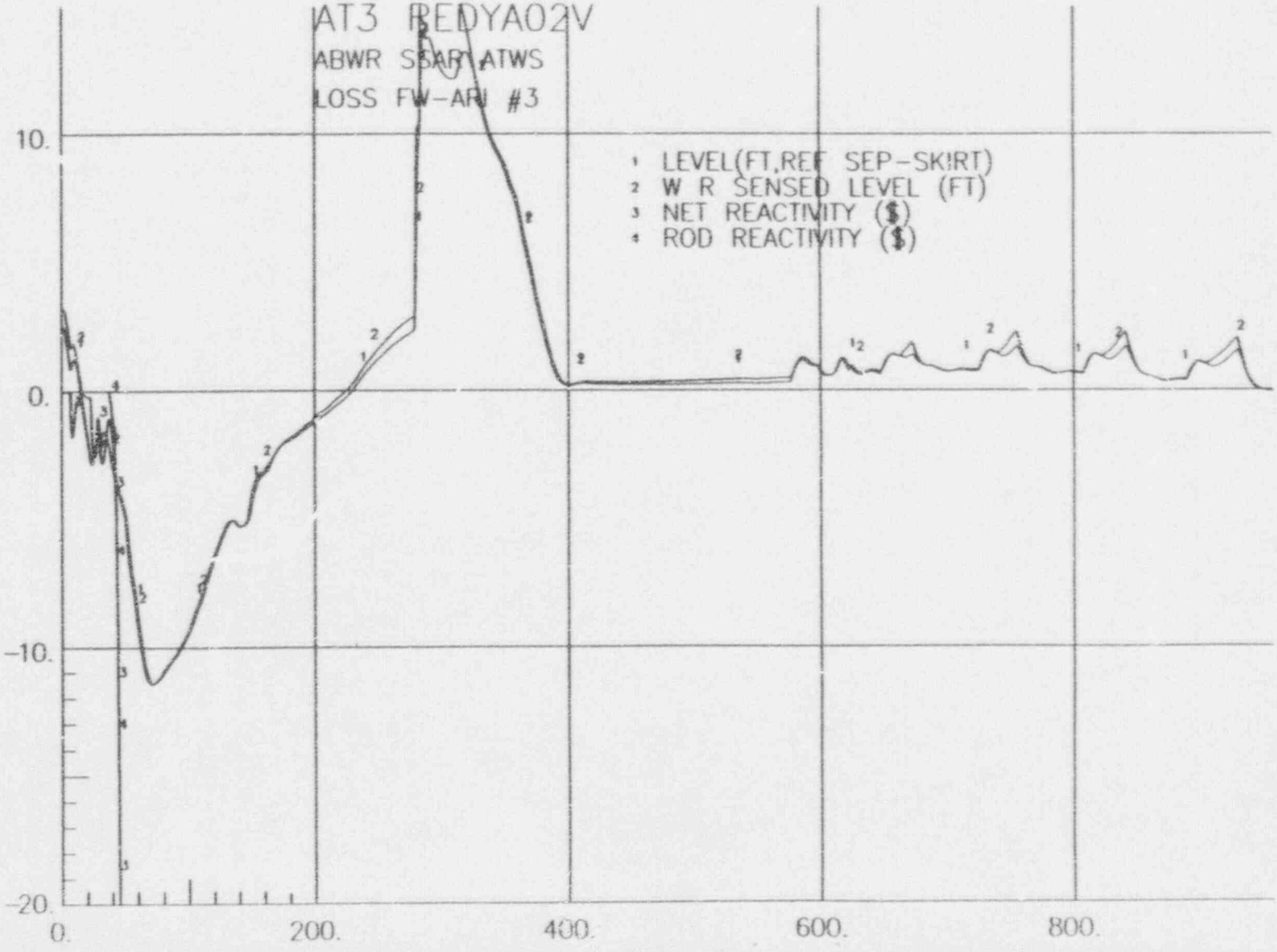


Figure 15E.6.3-4. ABWR Loss of Feedwater Flow, ARI

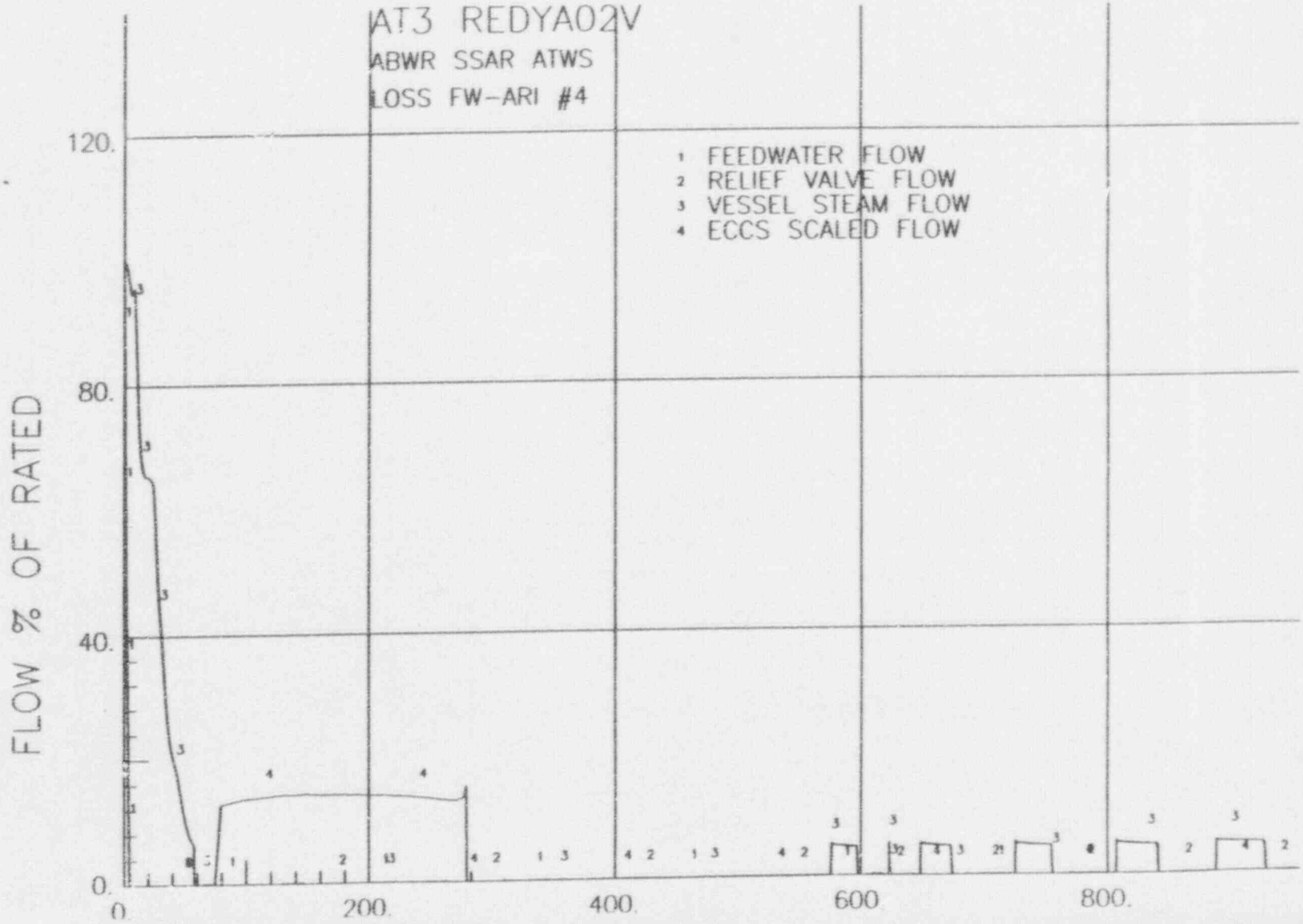


Figure 15E.6.3-5. ABWR Loss of Feedwater Flow, FMCRD Run-in

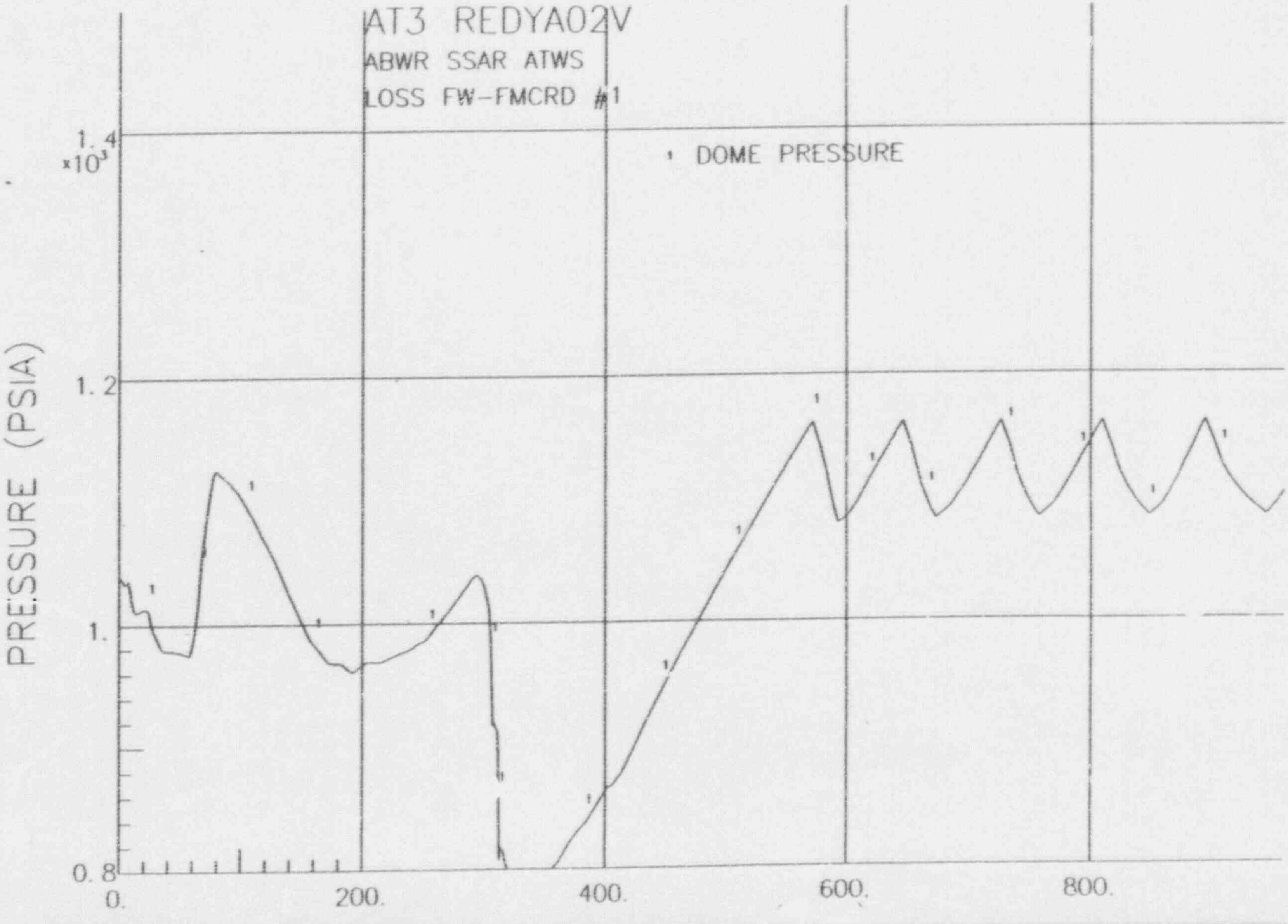


Figure 15E.6.3-6. ABWR Loss of Feedwater Flow, FMCRD Run-in

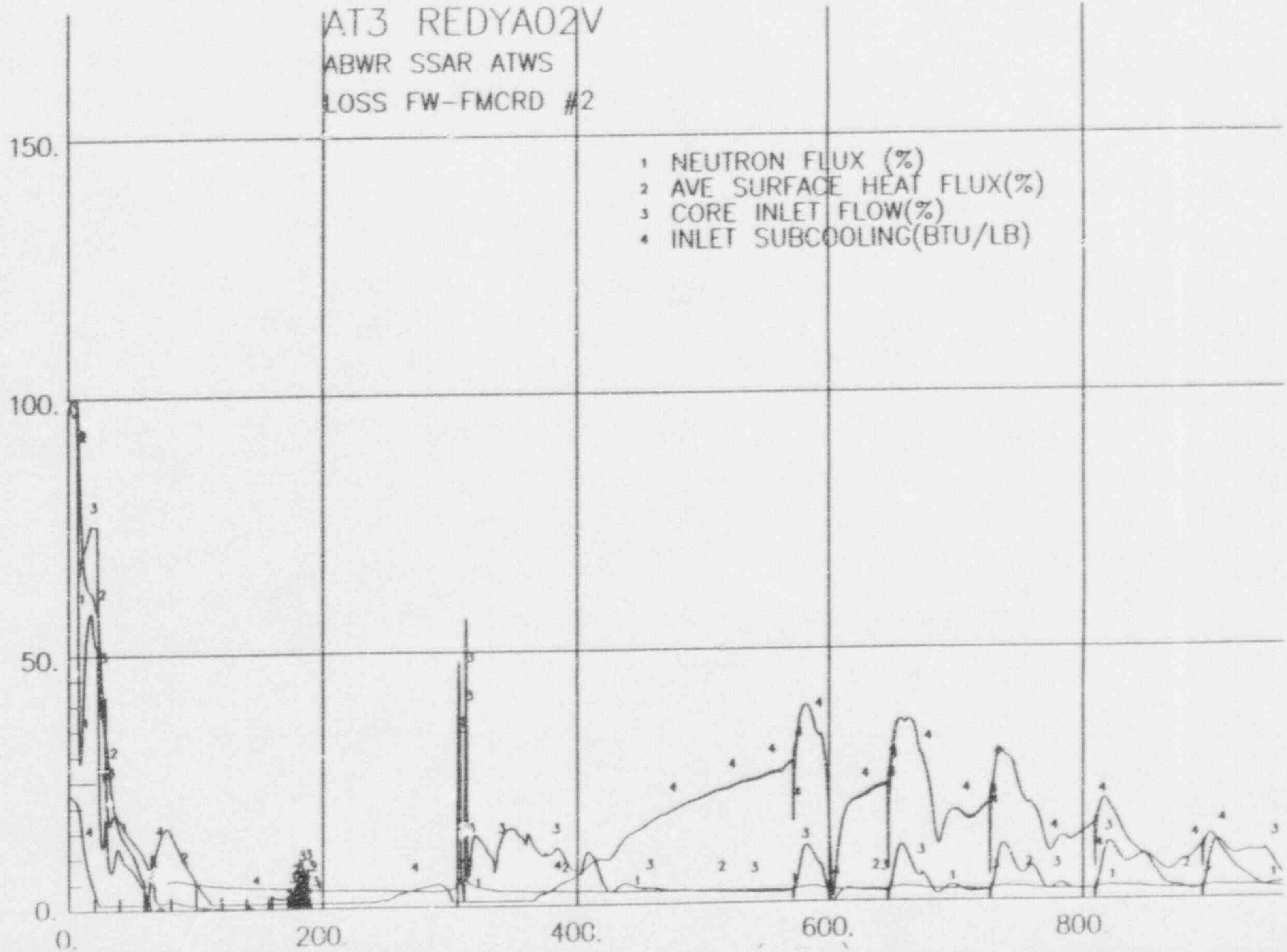


Figure 15E.6.3-7. ABWR Loss of Feedwater Flow, FMCRD Run-in

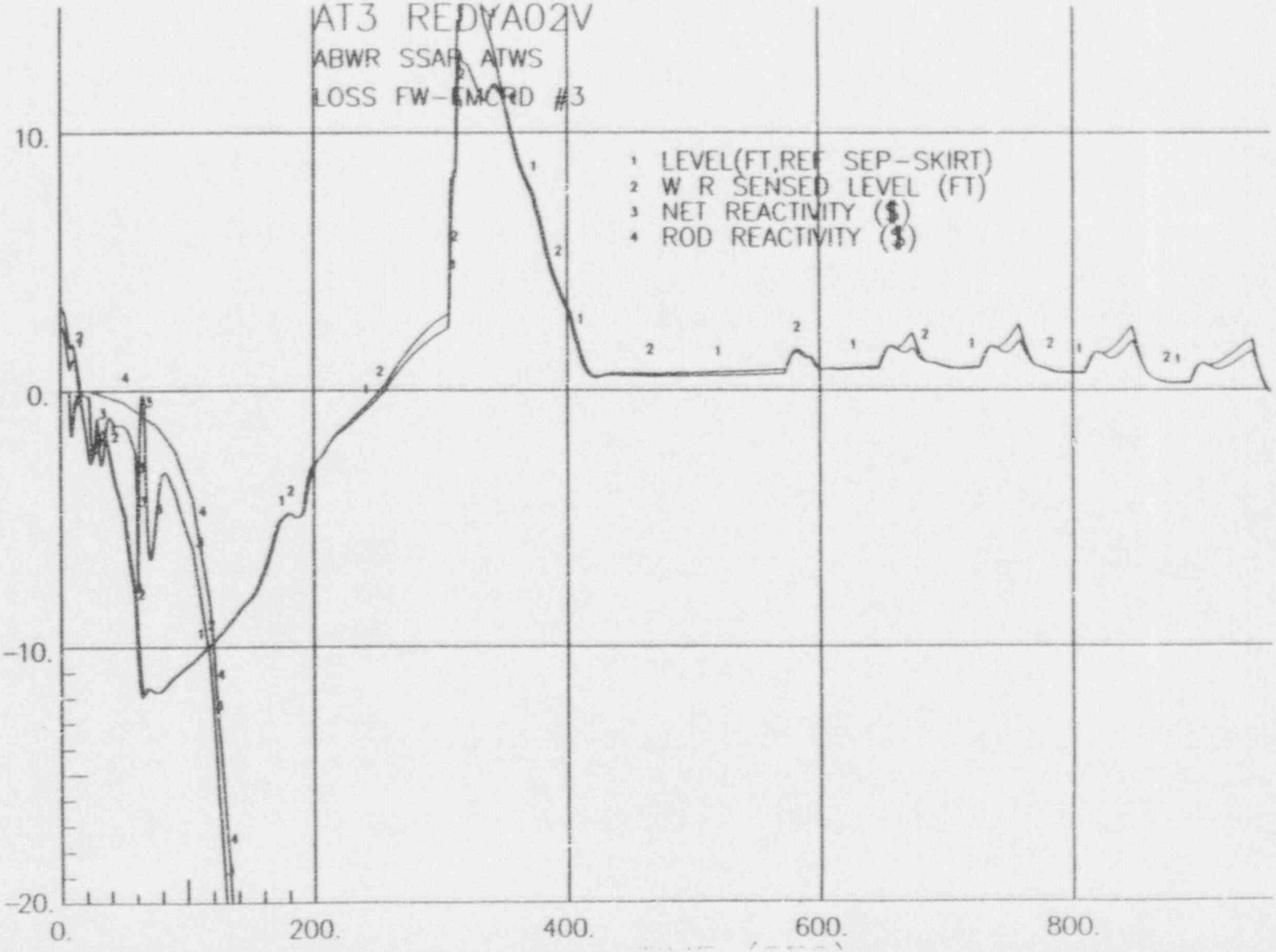


Figure 15E.6.3-8. ABWR Loss of Feedwater Flow, FMCRD Run-in

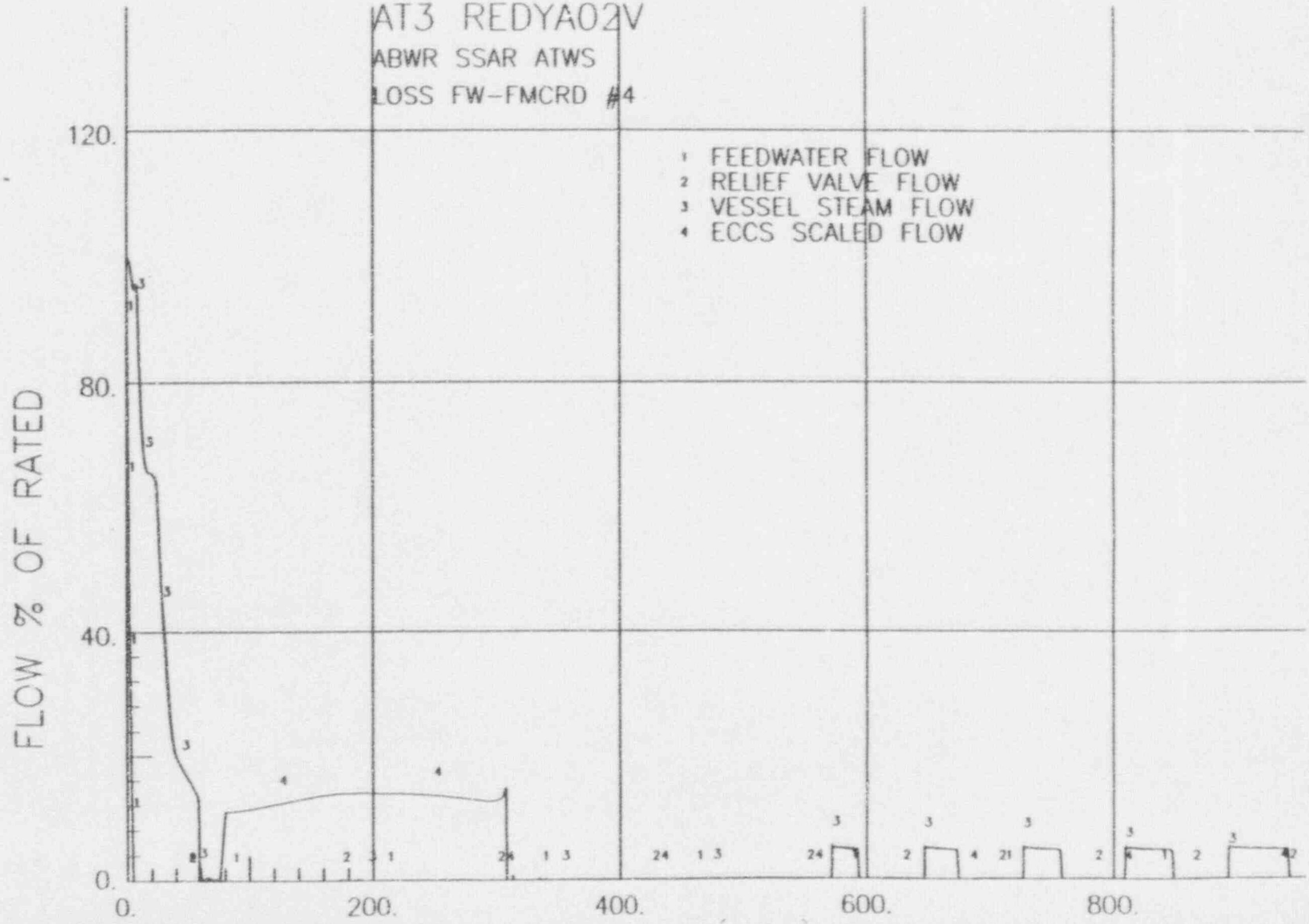


Figure 15E.6.3-9. ABWR Loss of Feedwater Flow, SLCS

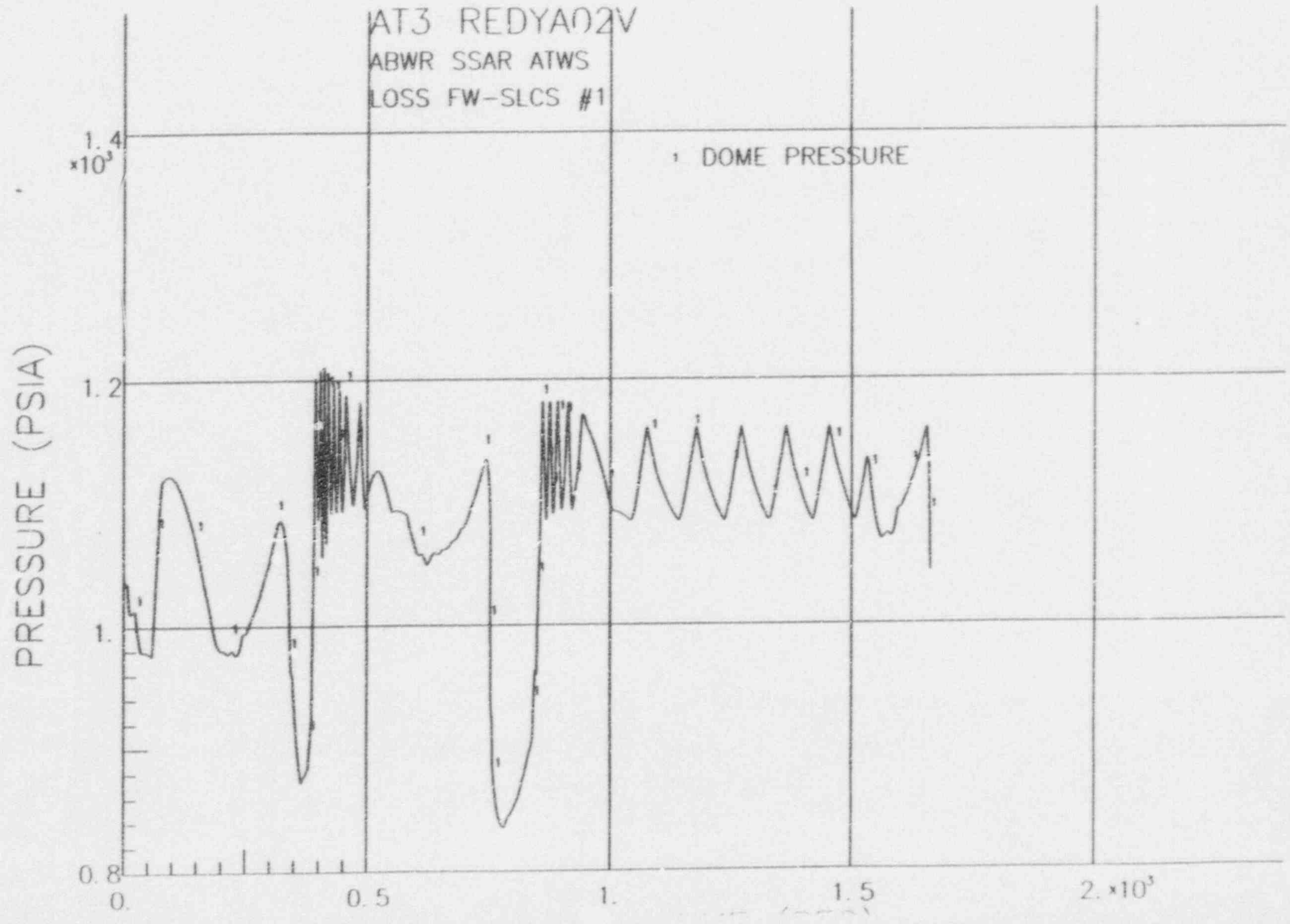


Figure 15E.6.3-10. ABWR Loss of Feedwater Flow, SLCS

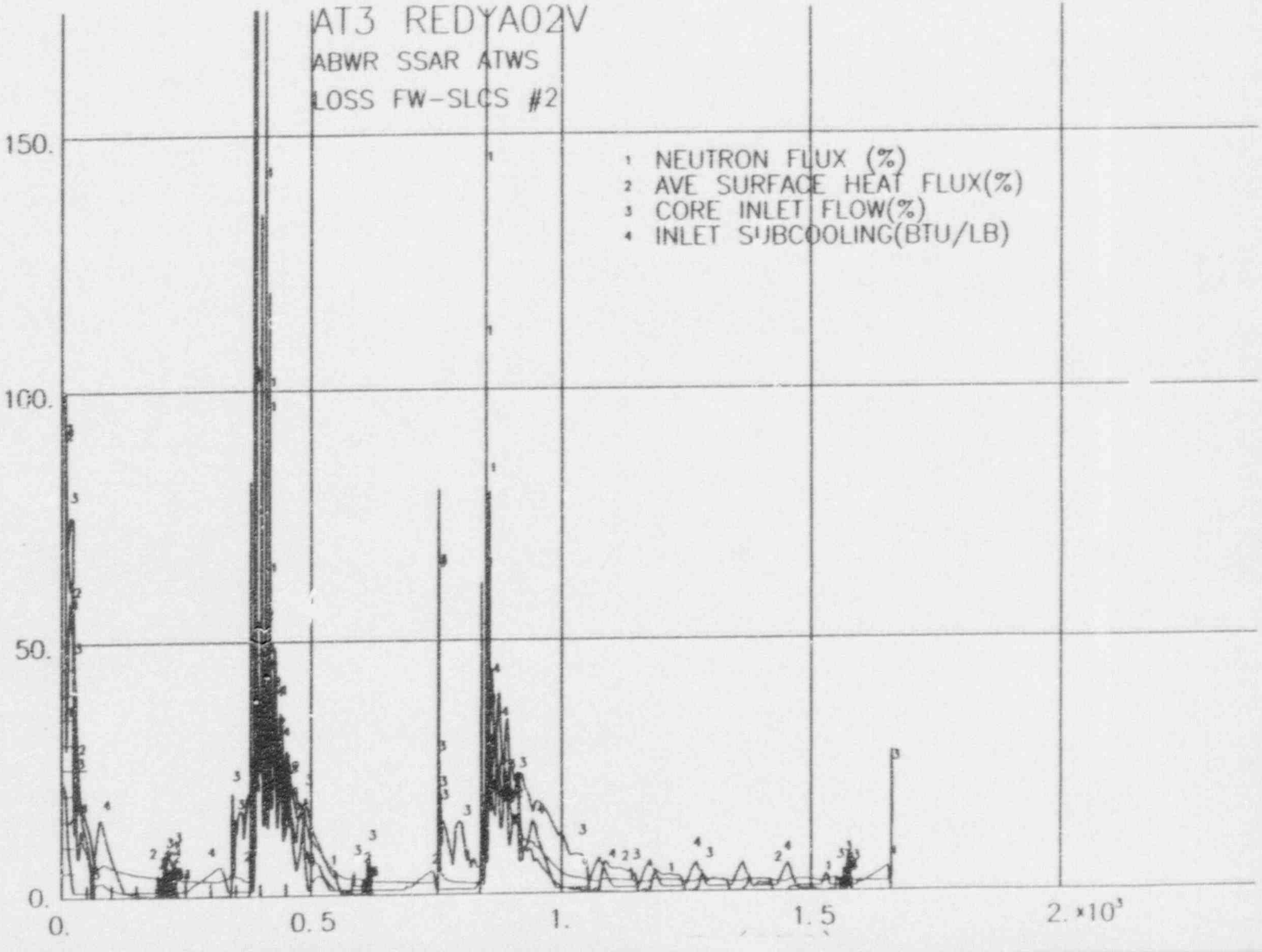


Figure 15E.6.3-11. ABWR Loss of Feedwater Flow, SLCS

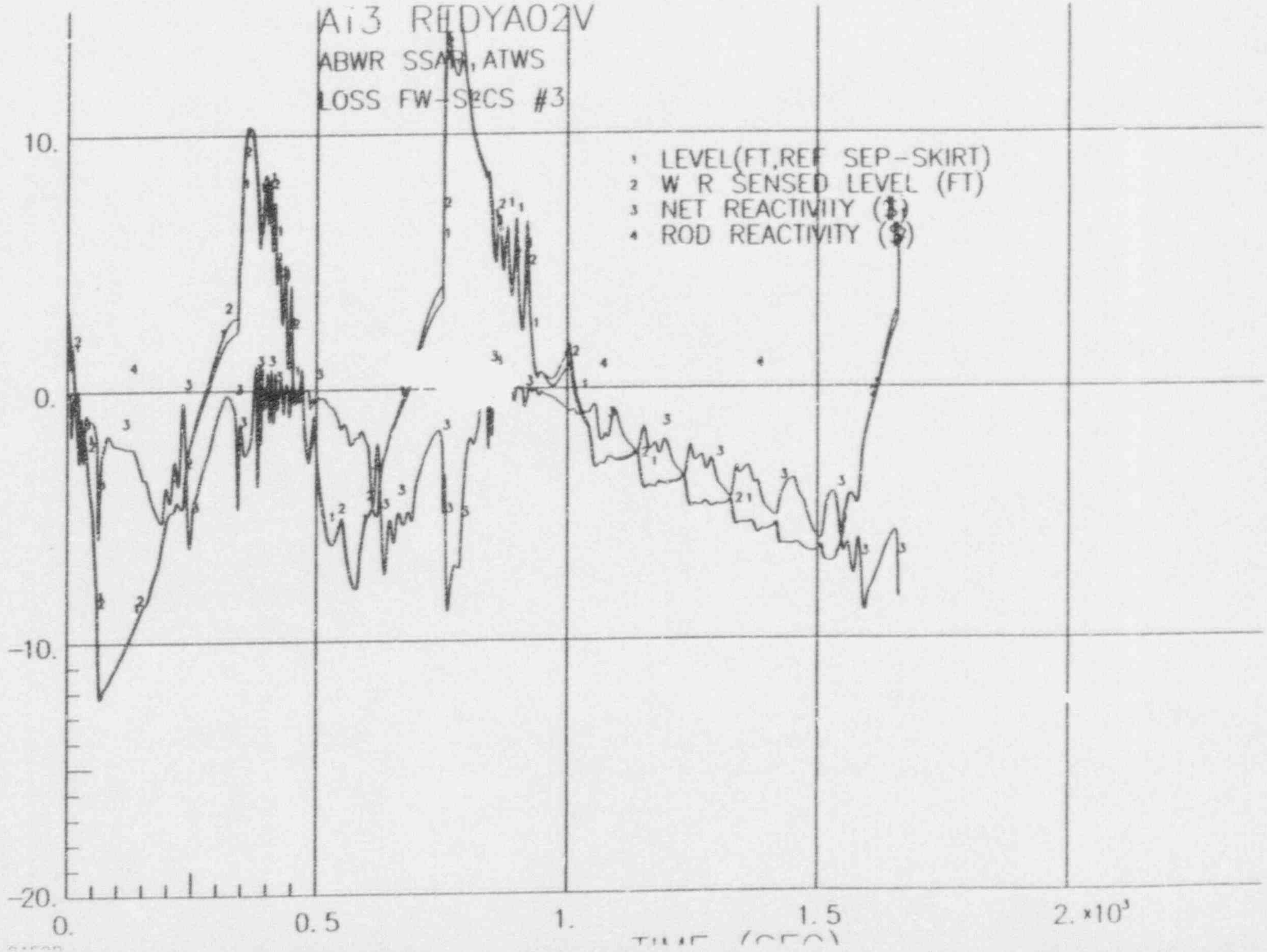


Figure 15E.6.3-12. ABWR Loss of Feedwater Flow, SLCS

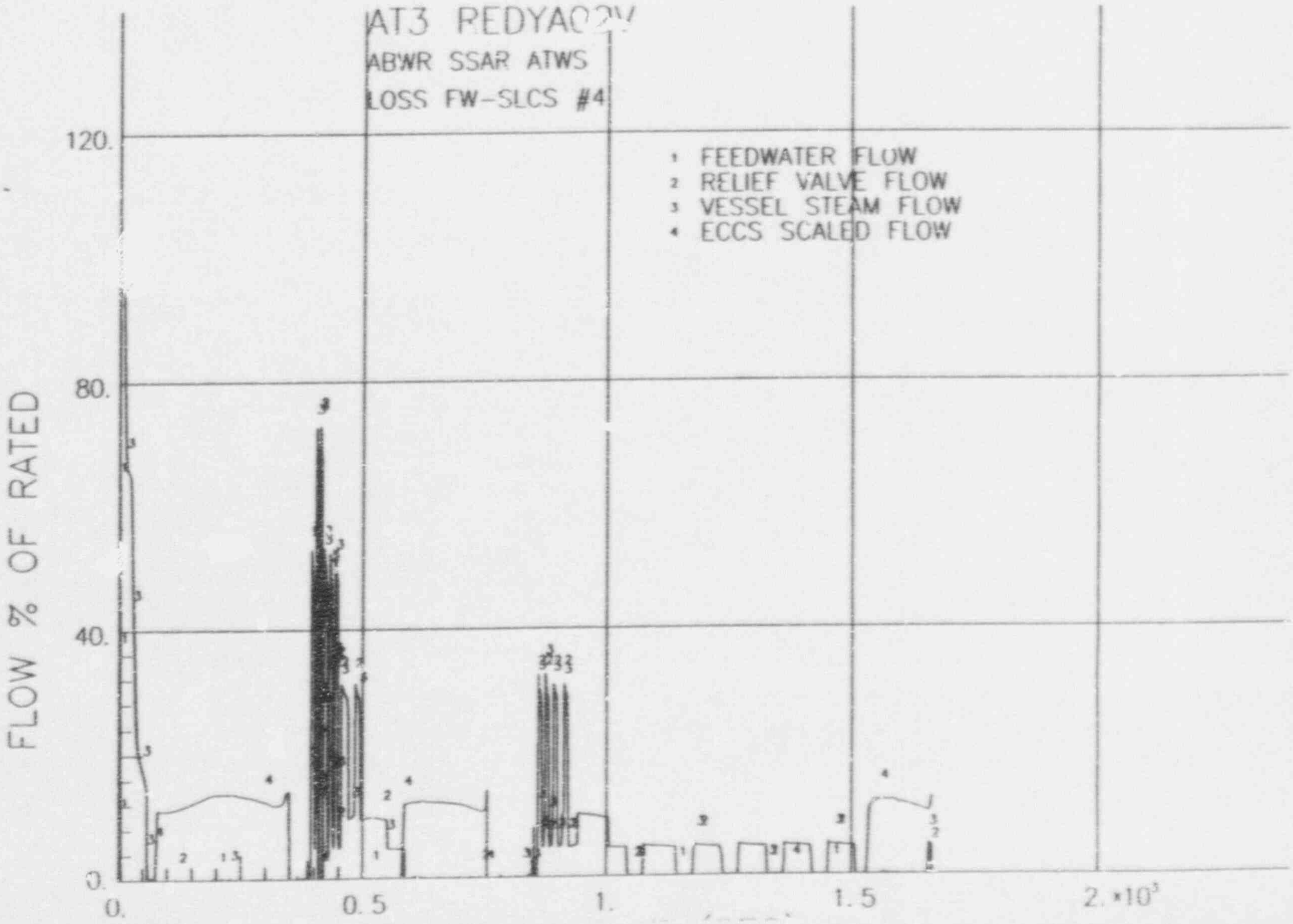


Figure 15E.6.4-1. ABWR Loss of Feedwater Heater, ARI

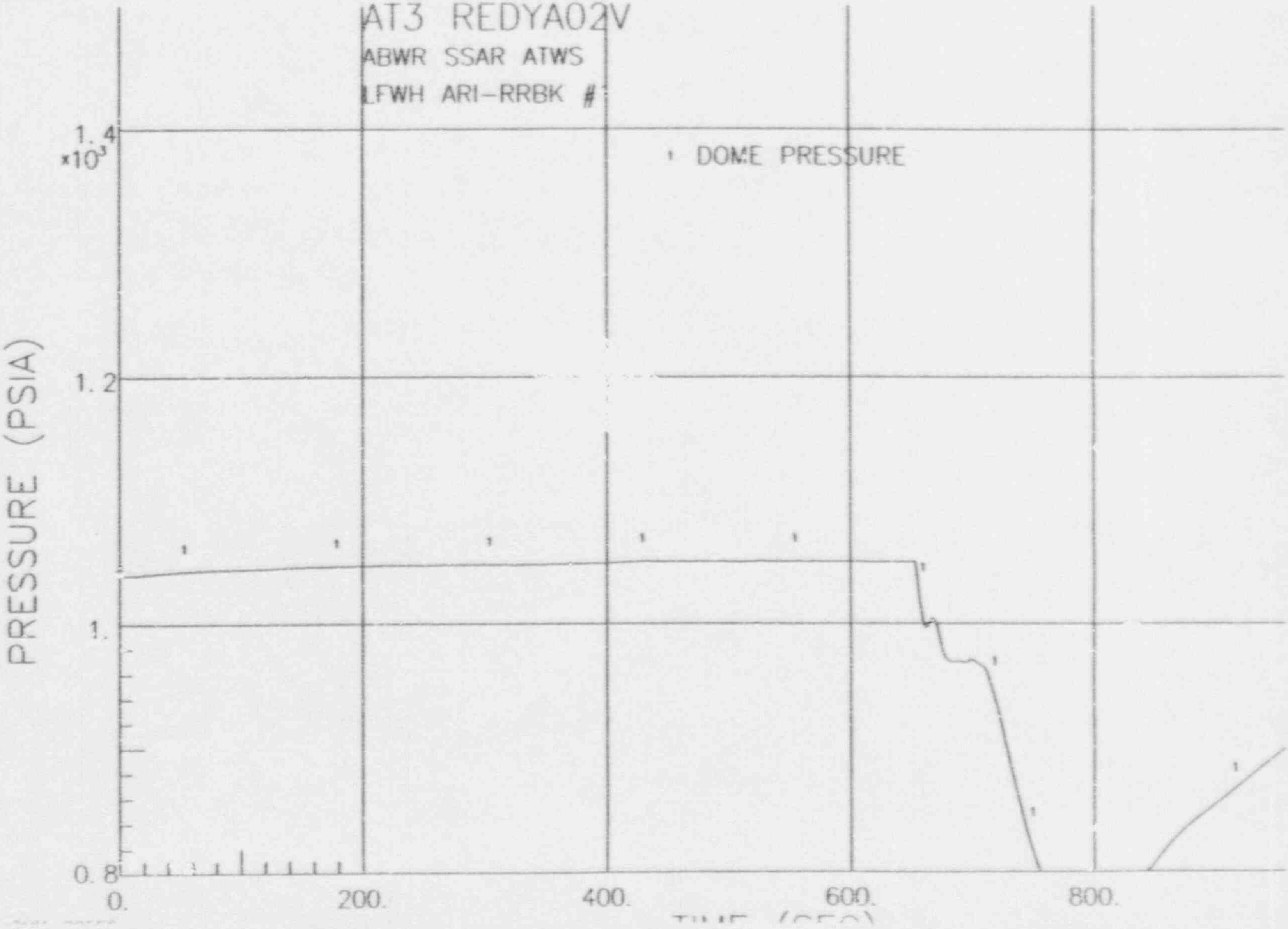


Figure 15E.6.4-2. ABWR Loss of Feedwater Heater, ARI

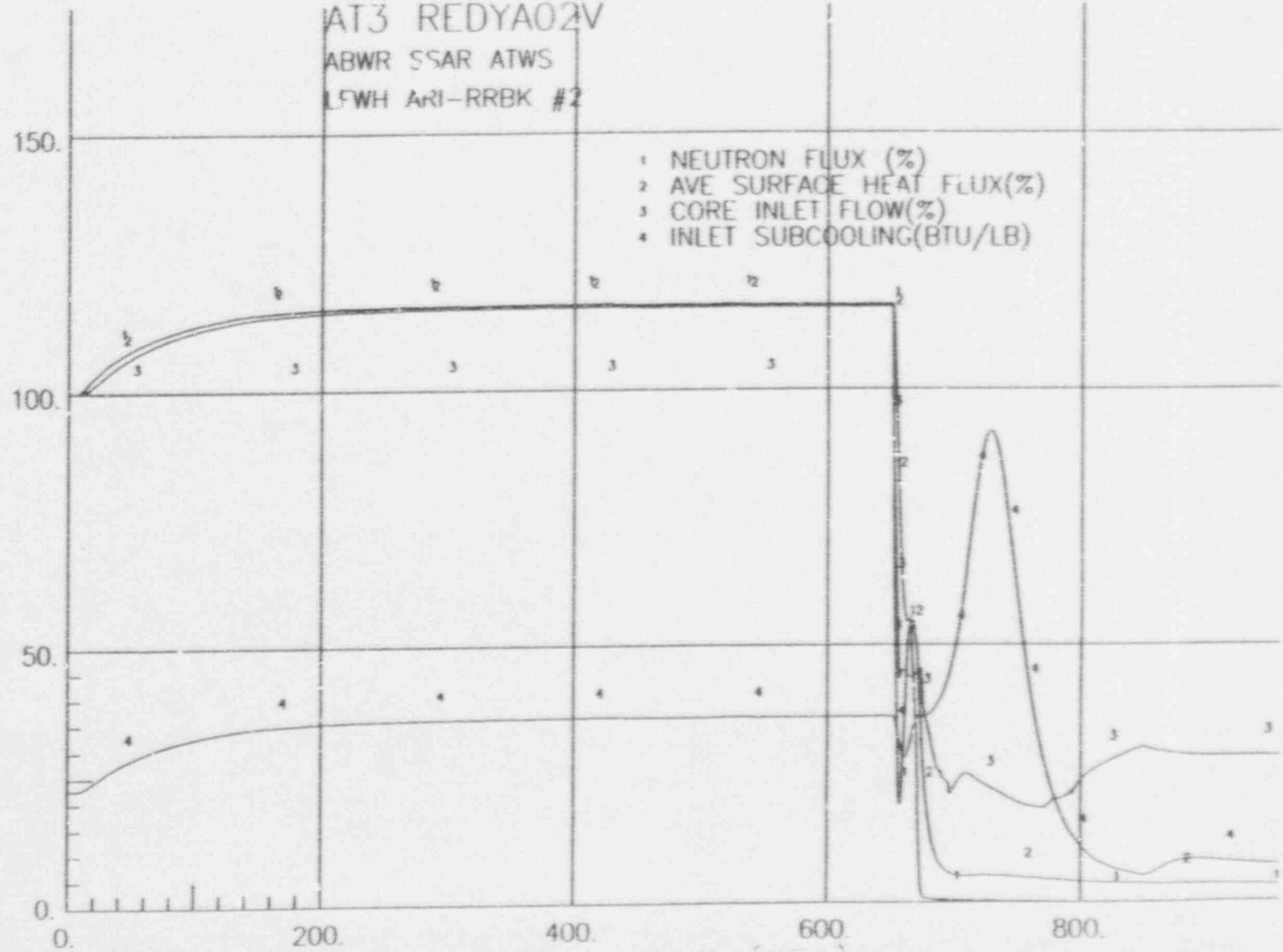


Figure 15E.6.4-3. ABWR Loss of Feedwater Heater, ARI

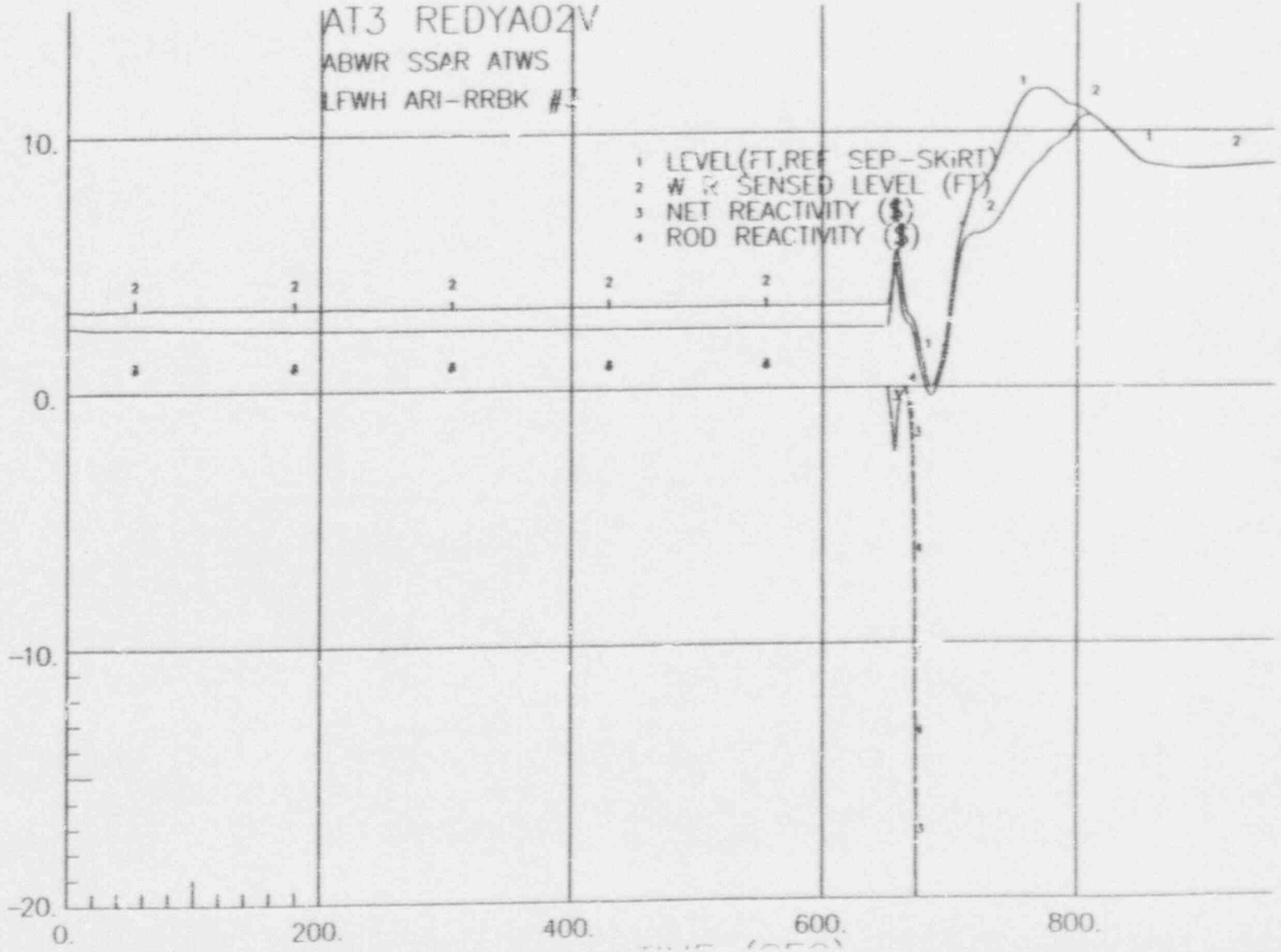


Figure 15E.6.4-4. ABWR Loss of Feedwater Heater, ARI

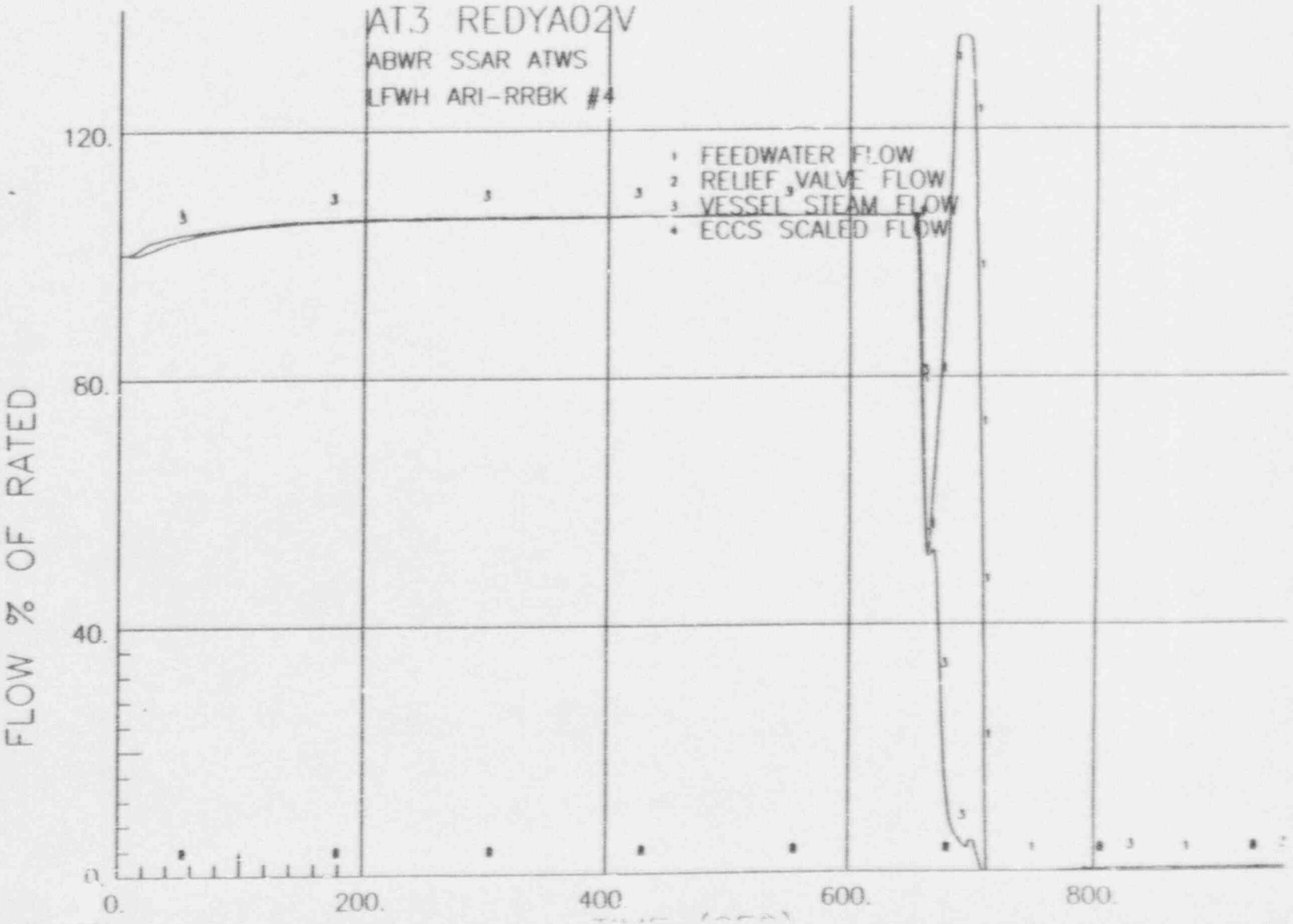


Figure 15E.6.4-5. ABWR Loss of Feedwater Heater, FMCRD Run-in

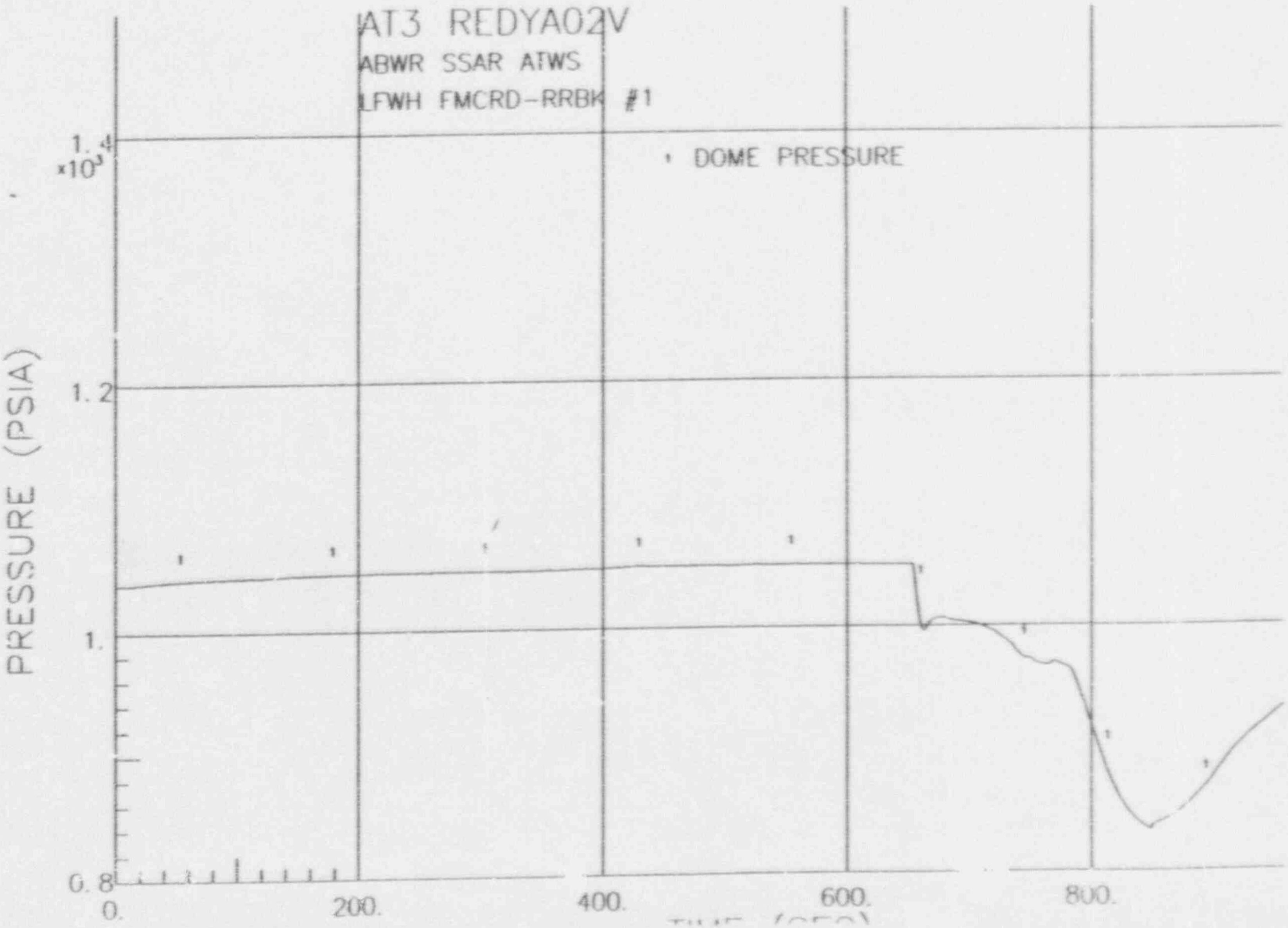


Figure 15E.6.4-6. ABWR Loss of Feedwater Heater, FMCRD Run-in

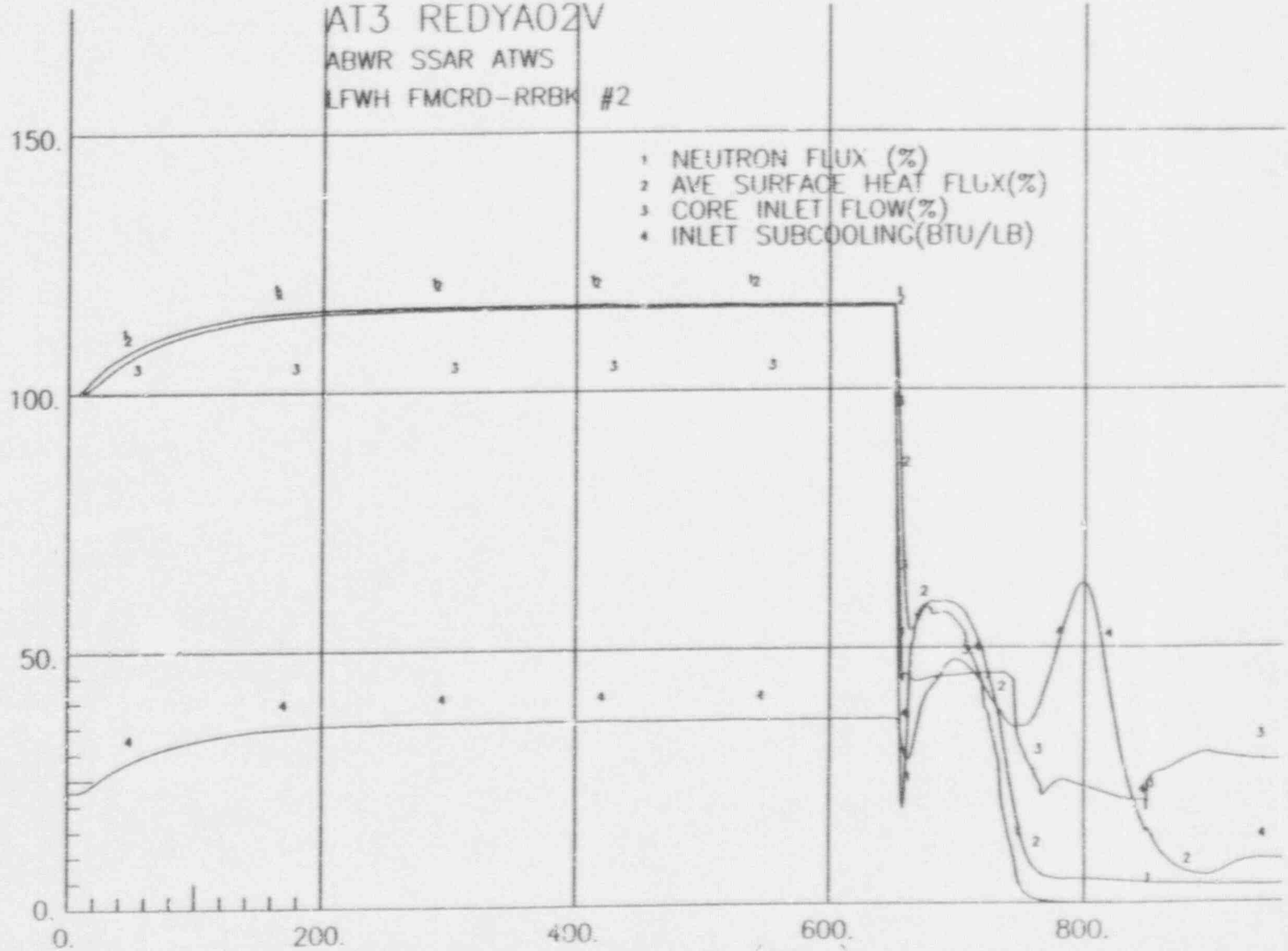


Figure 15E.6.4-7. ABWR Loss of Feedwater Heater, FMCRD Run-in

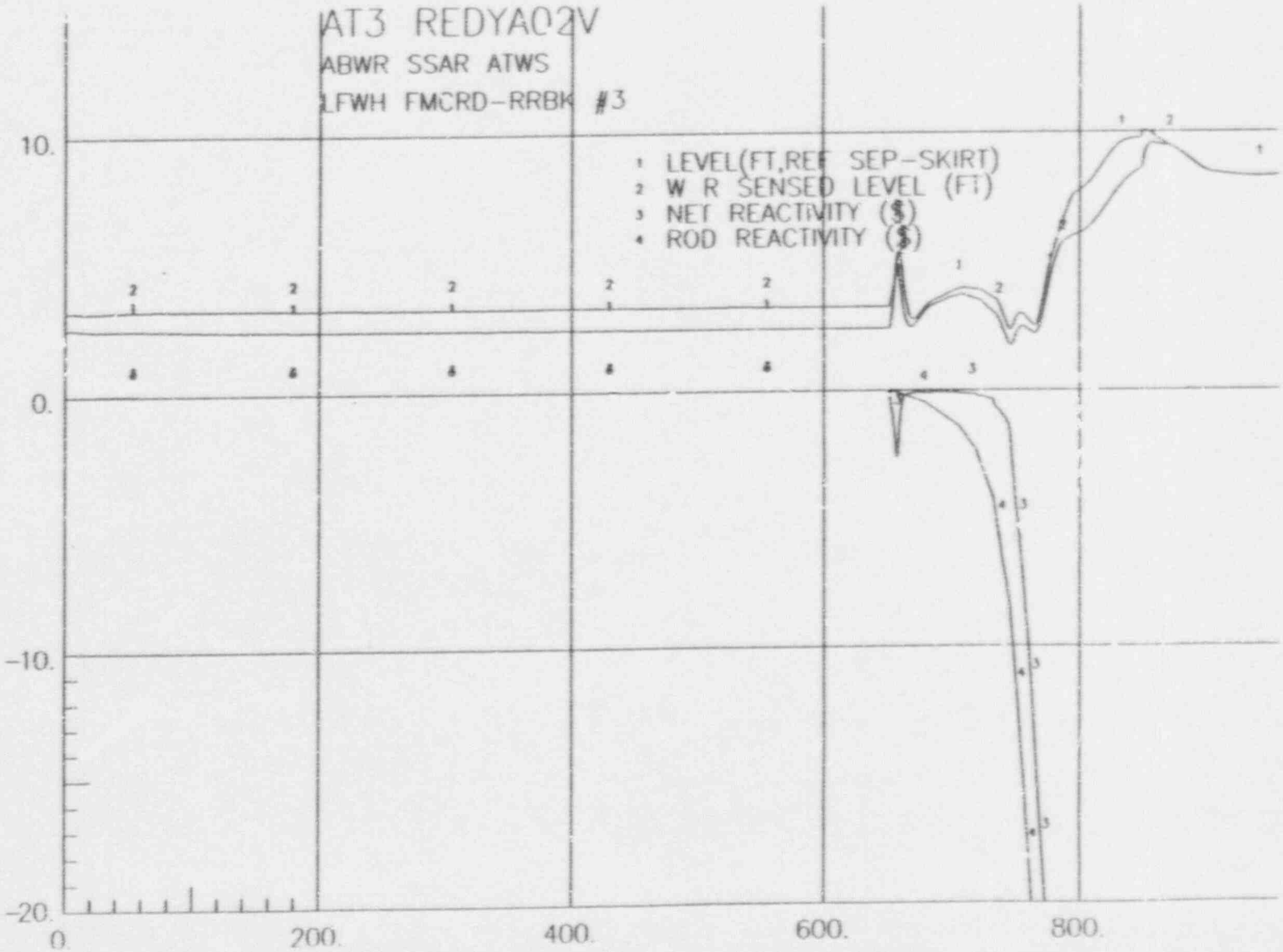


Figure 15E.6.4-8. ABWR Loss of Feedwater Heater, FMCRD Run-in

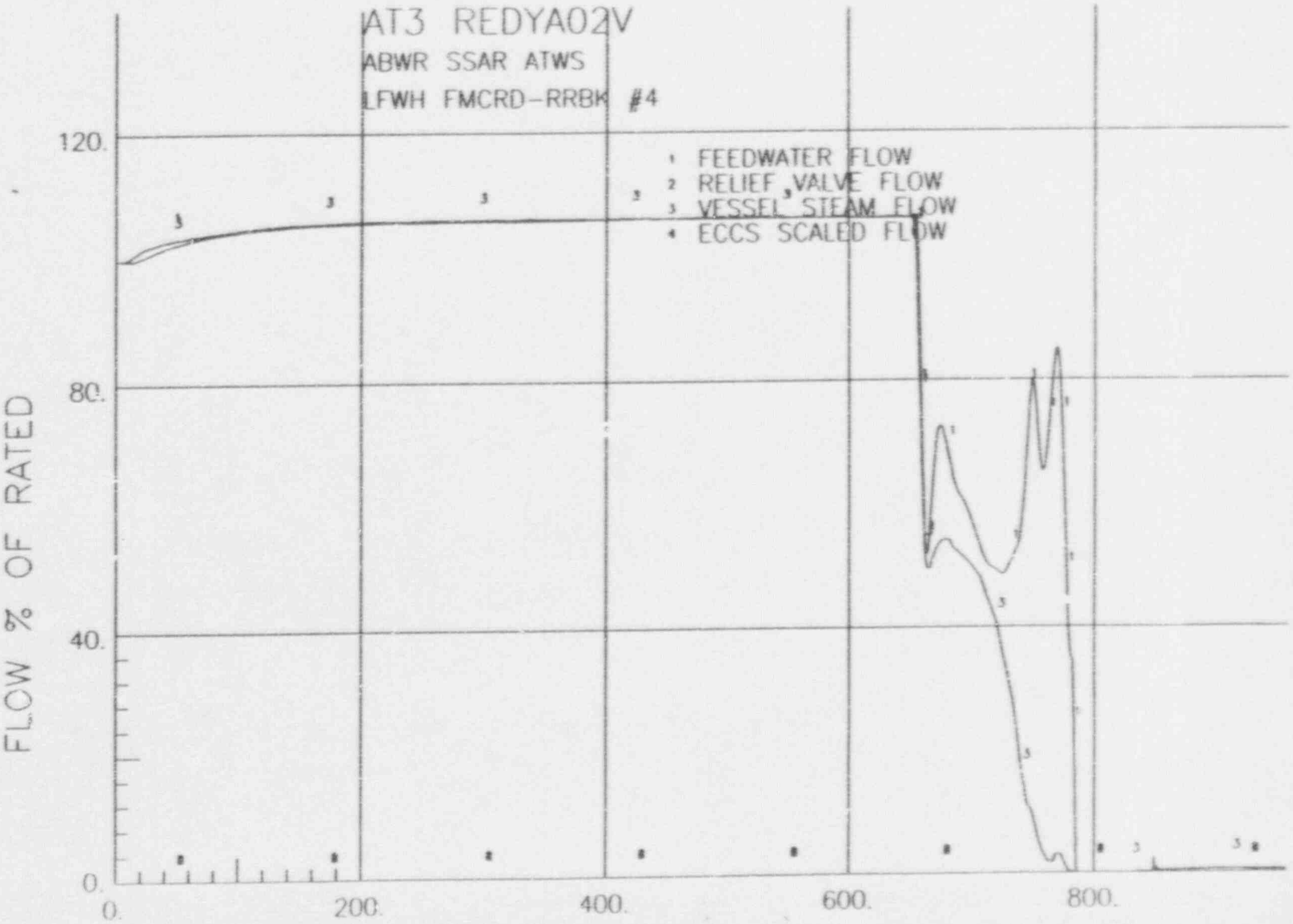


Figure 15E.6.4-9. ABWR Loss of Feedwater Heater, SLCS

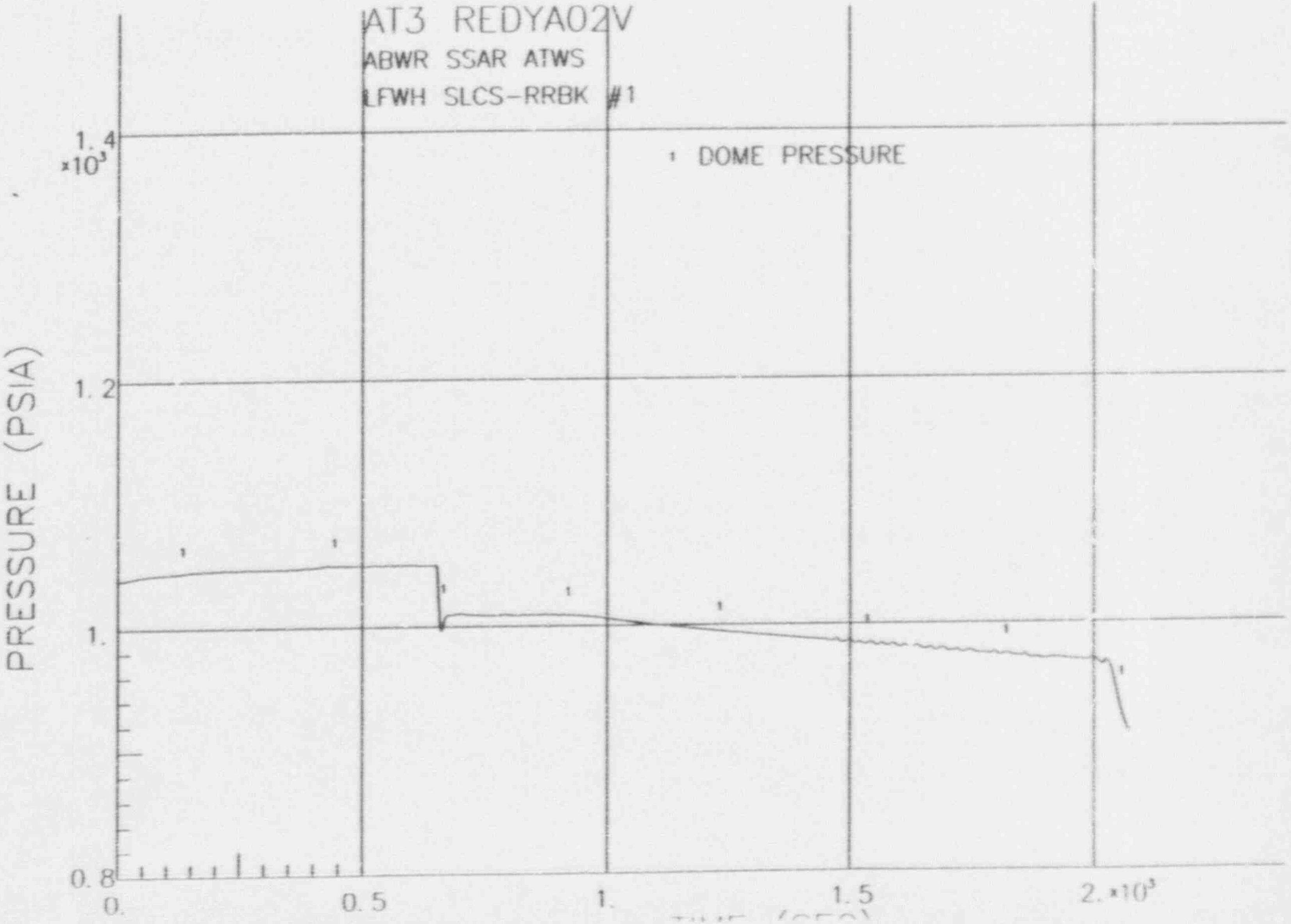


Figure 15E.6.4-10. ABWR Loss of Feedwater Heater, SLCS

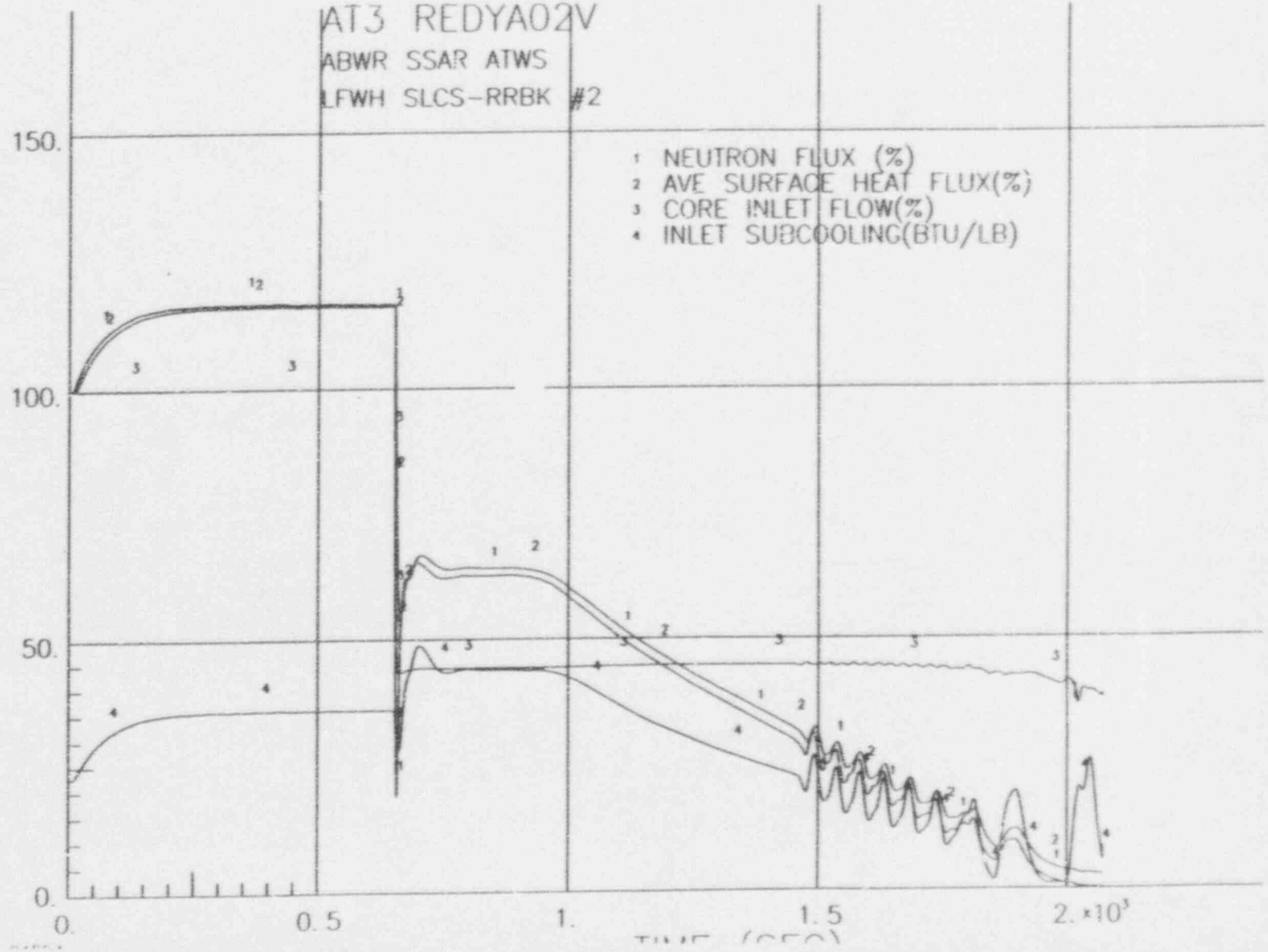
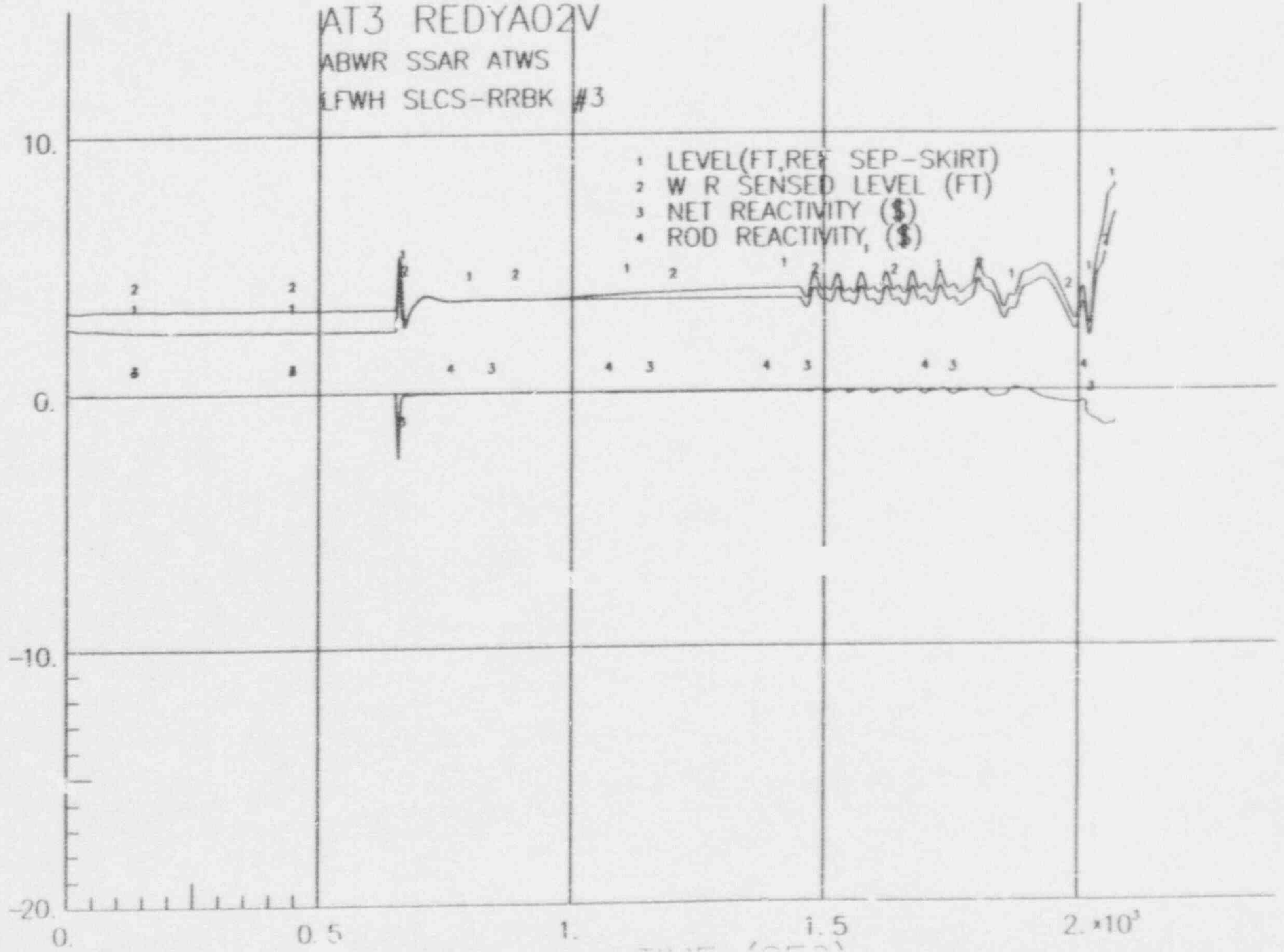


Figure 15E.6.4-11. ABWR Loss of Feedwater Heater, SLCS



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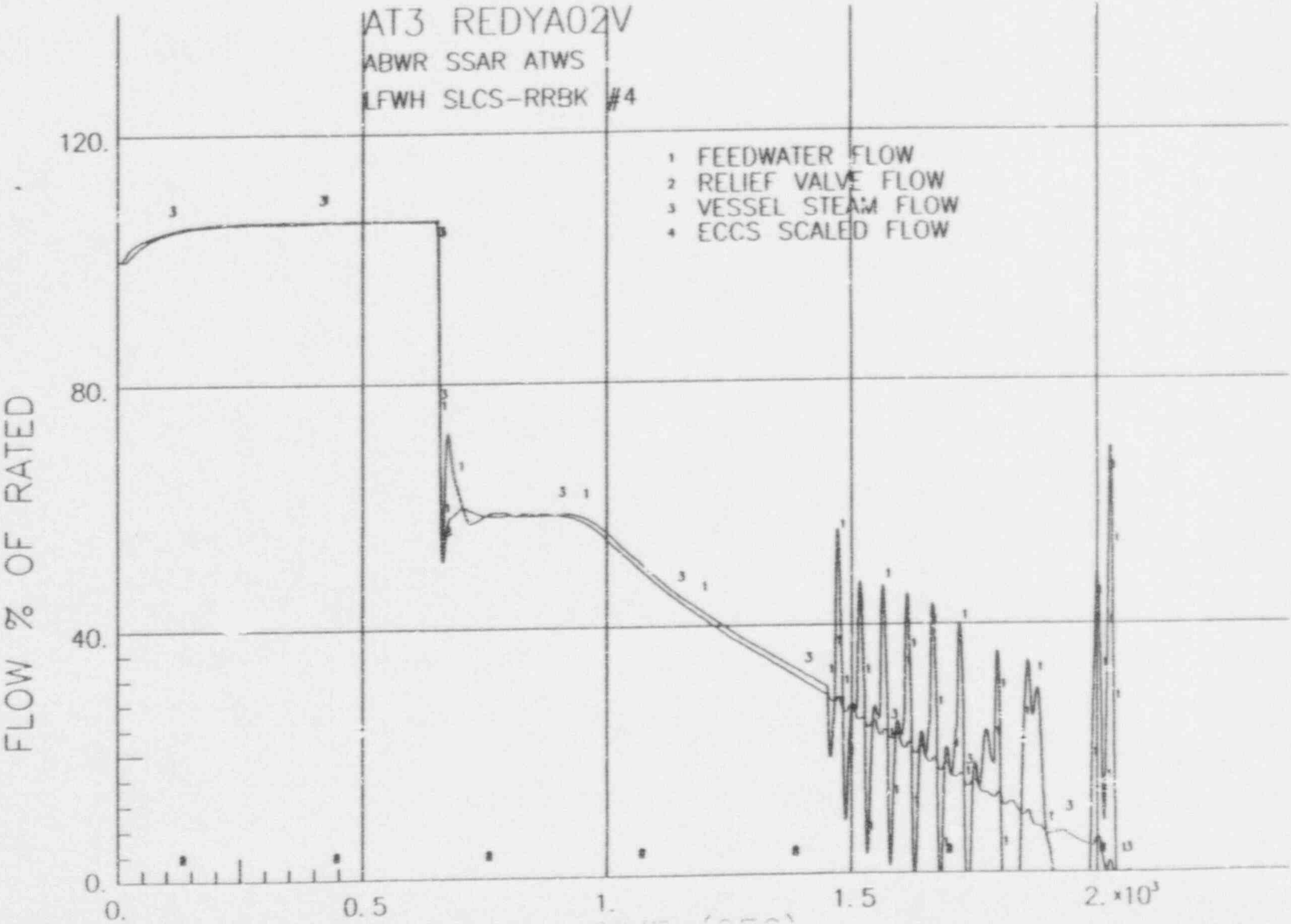


Figure 15E.6.4-12. ABWR Loss of Feedwater Heater, SLCS

Figure 15E.6.4-13. ABWR Loss of Feedwater Heater, Max. LHGR

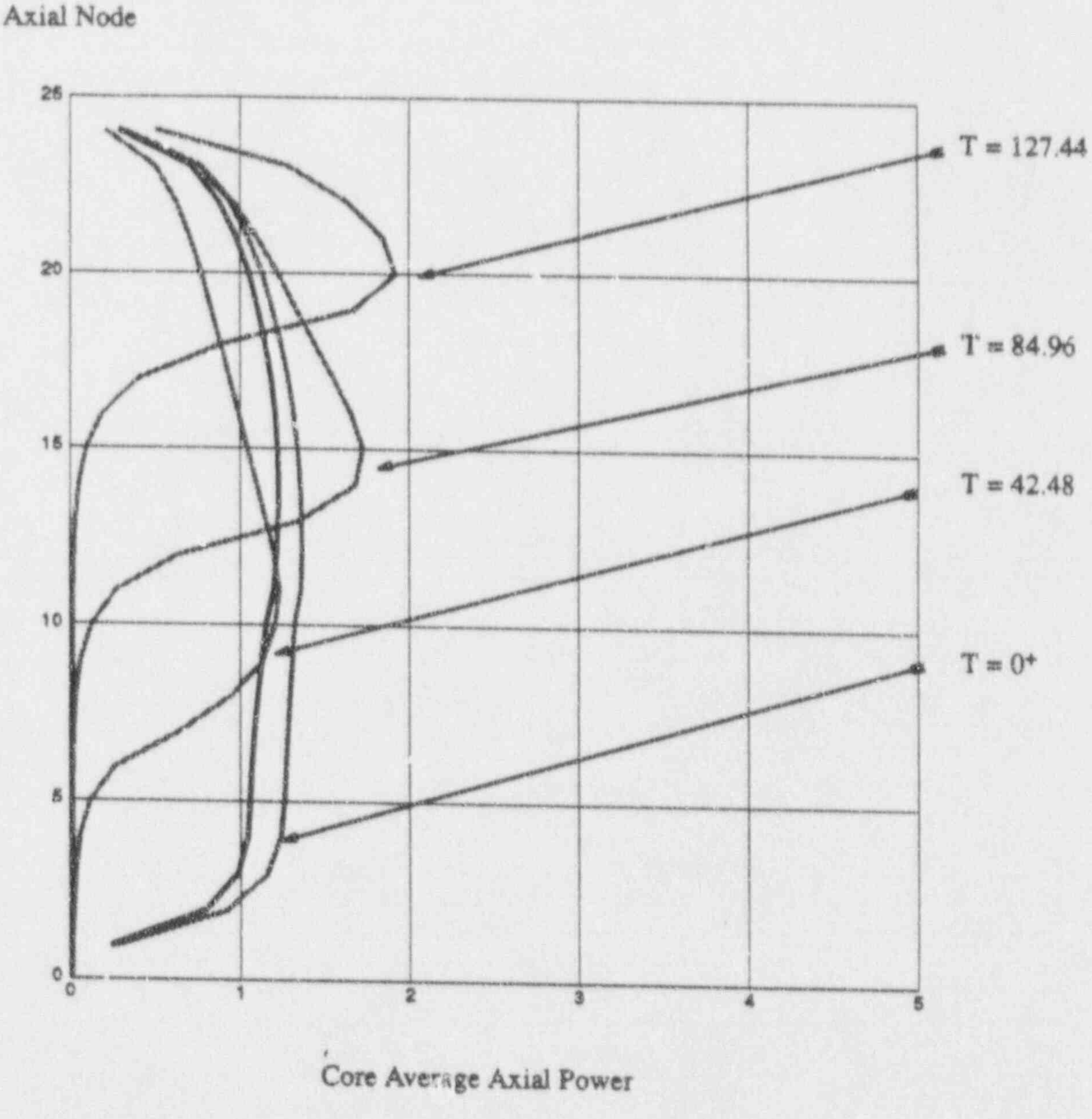


Figure 15E.6.4-14. ABWR Loss of Feedwater Heater, FMCRD Run-in

Figure 15E.6.5-1. ABWR Turbine Trip w/ Bypass, ARI

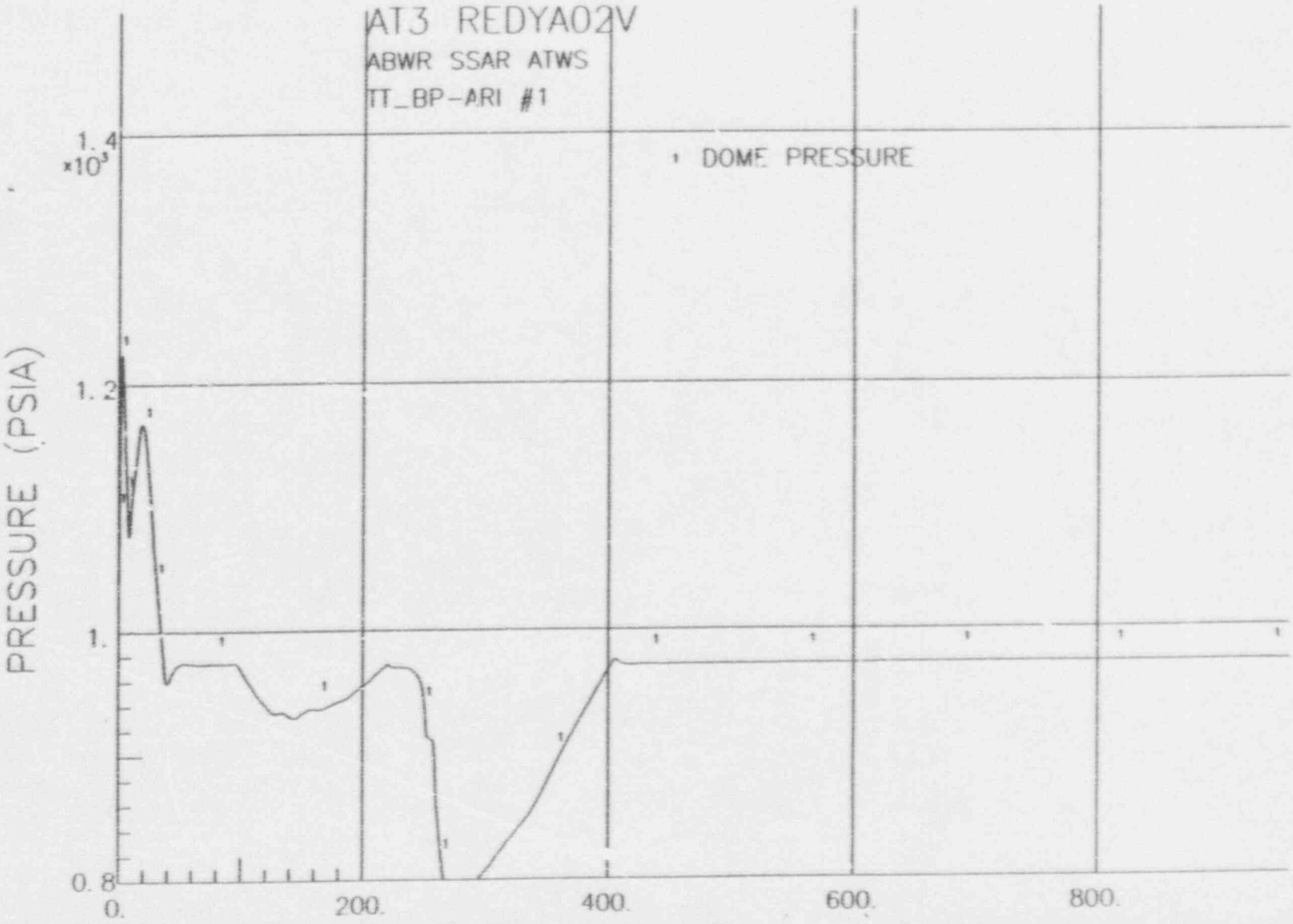


Figure 15E.6.5-2. ABWR Turbine Trip w/ Bypass, ARI

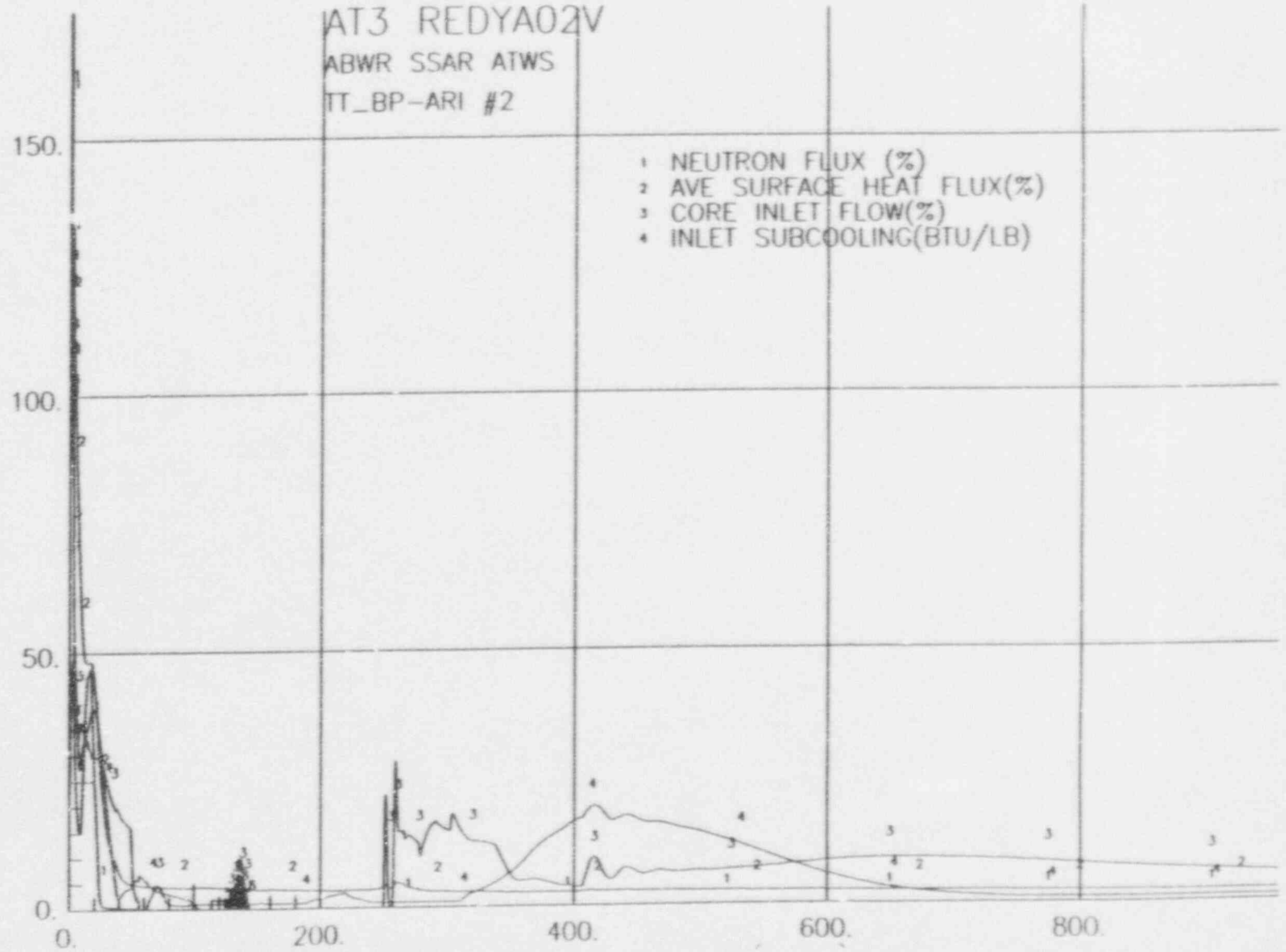


Figure 15E.6.5-3. ABWR Turbine Trip w/ Bypass, ARI

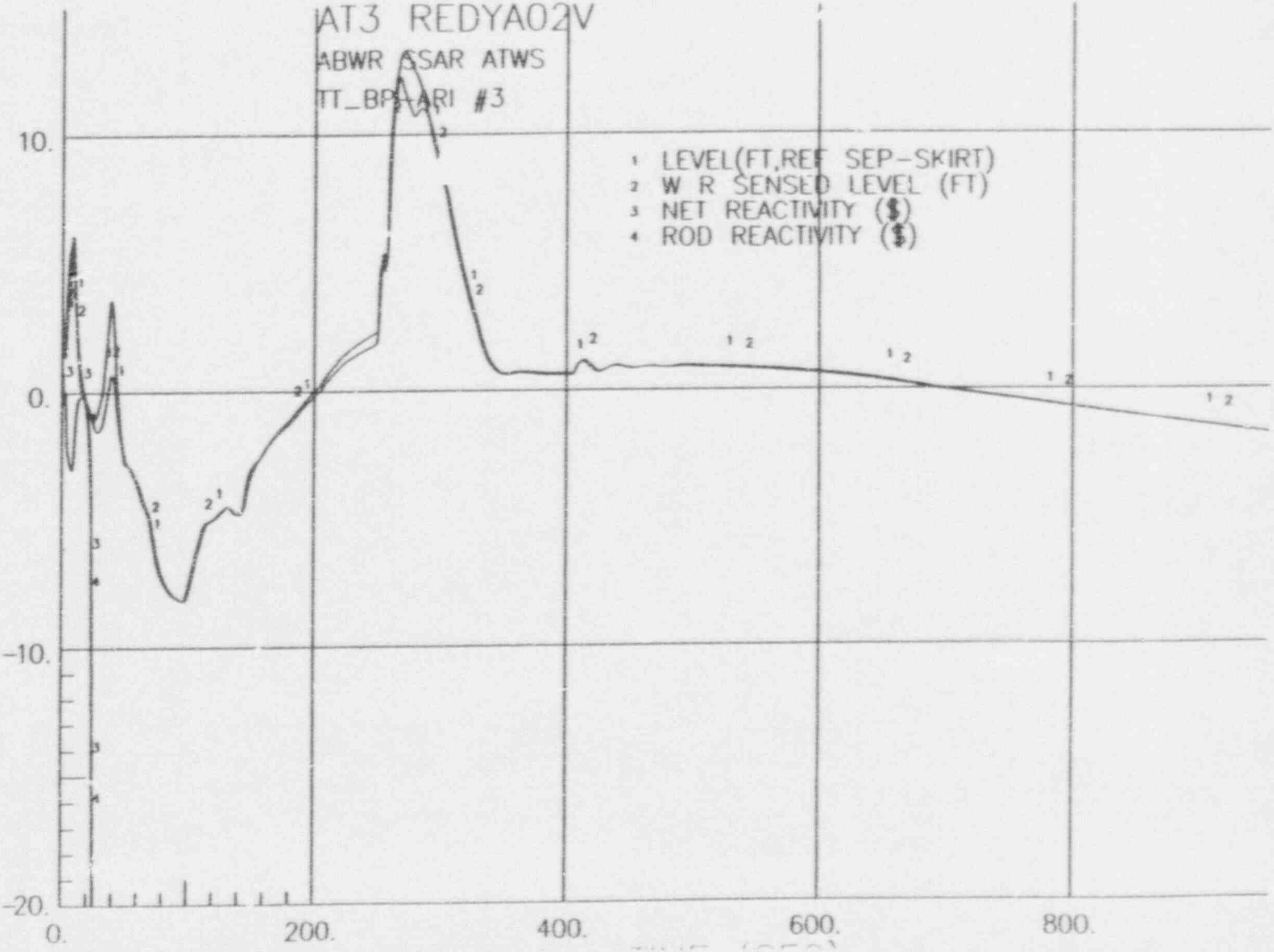


Figure 15E.6.5-4. ABWR Turbine Trip w/ Bypass, ARI

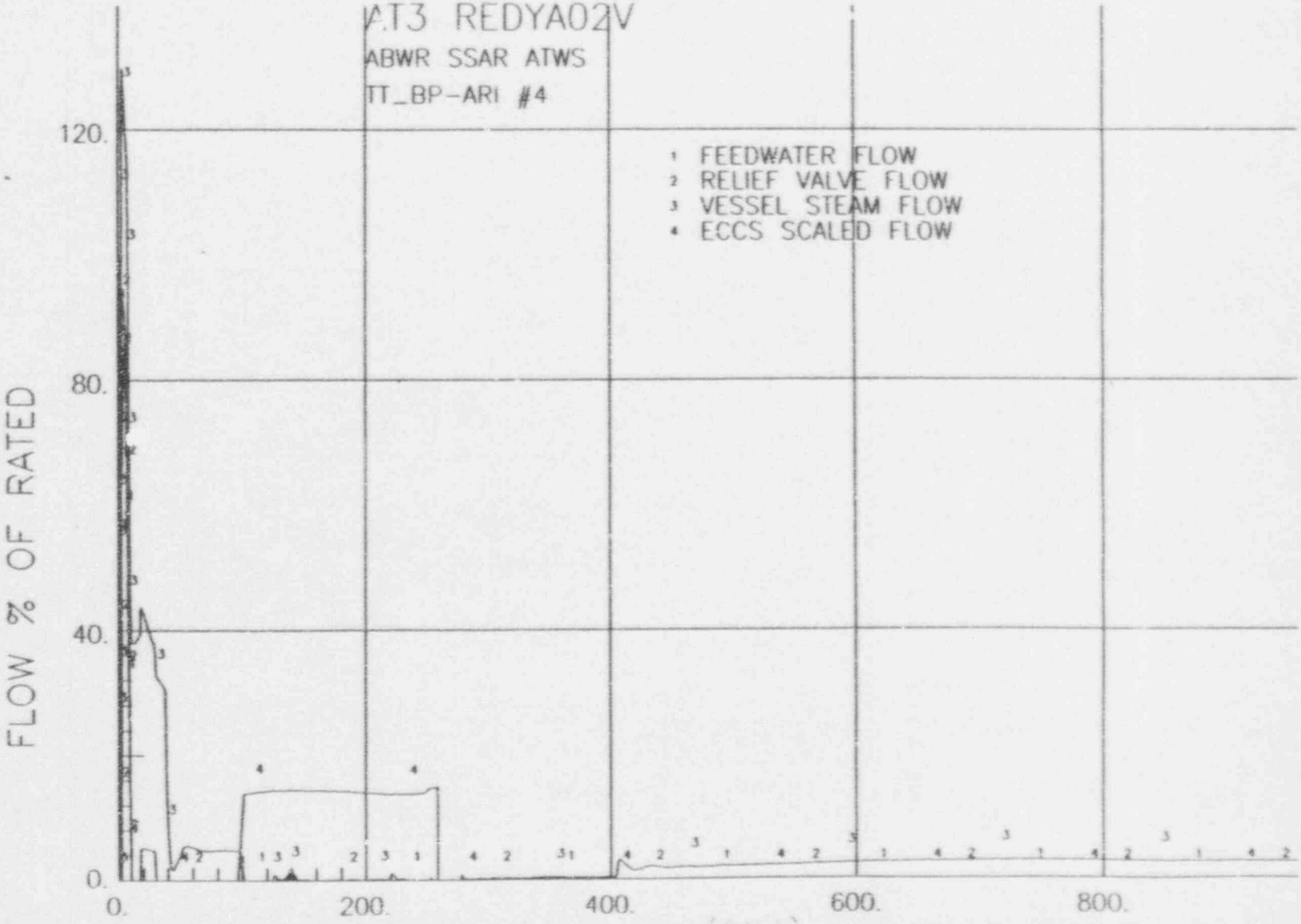


Figure 15E.6.5-5. ABWR Turbine Trip w/ Bypass, FMCRD Run-in

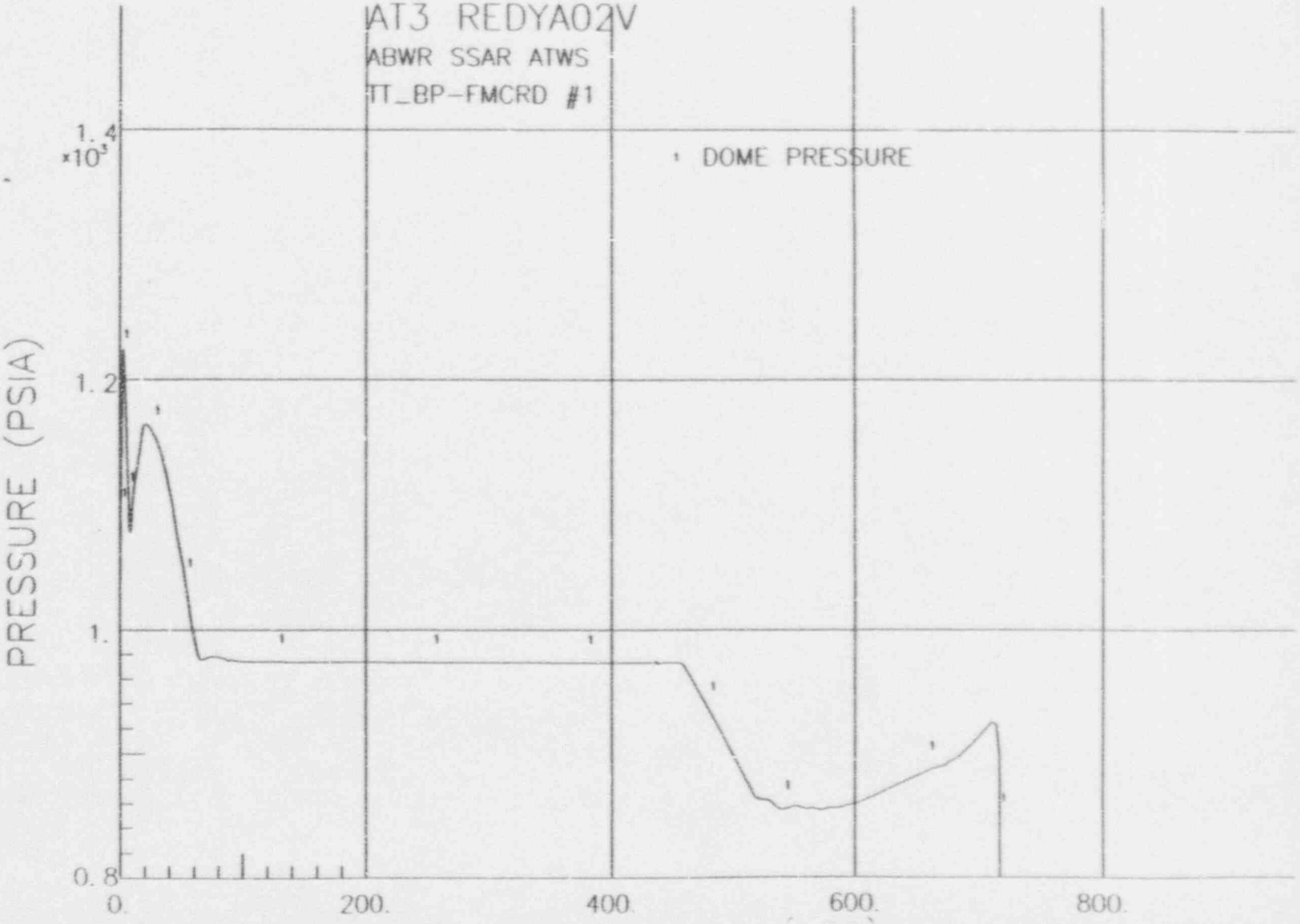


Figure 15E.6.5-6. ABWR Turbine Trip w/ Bypass, FMCRD Run-in

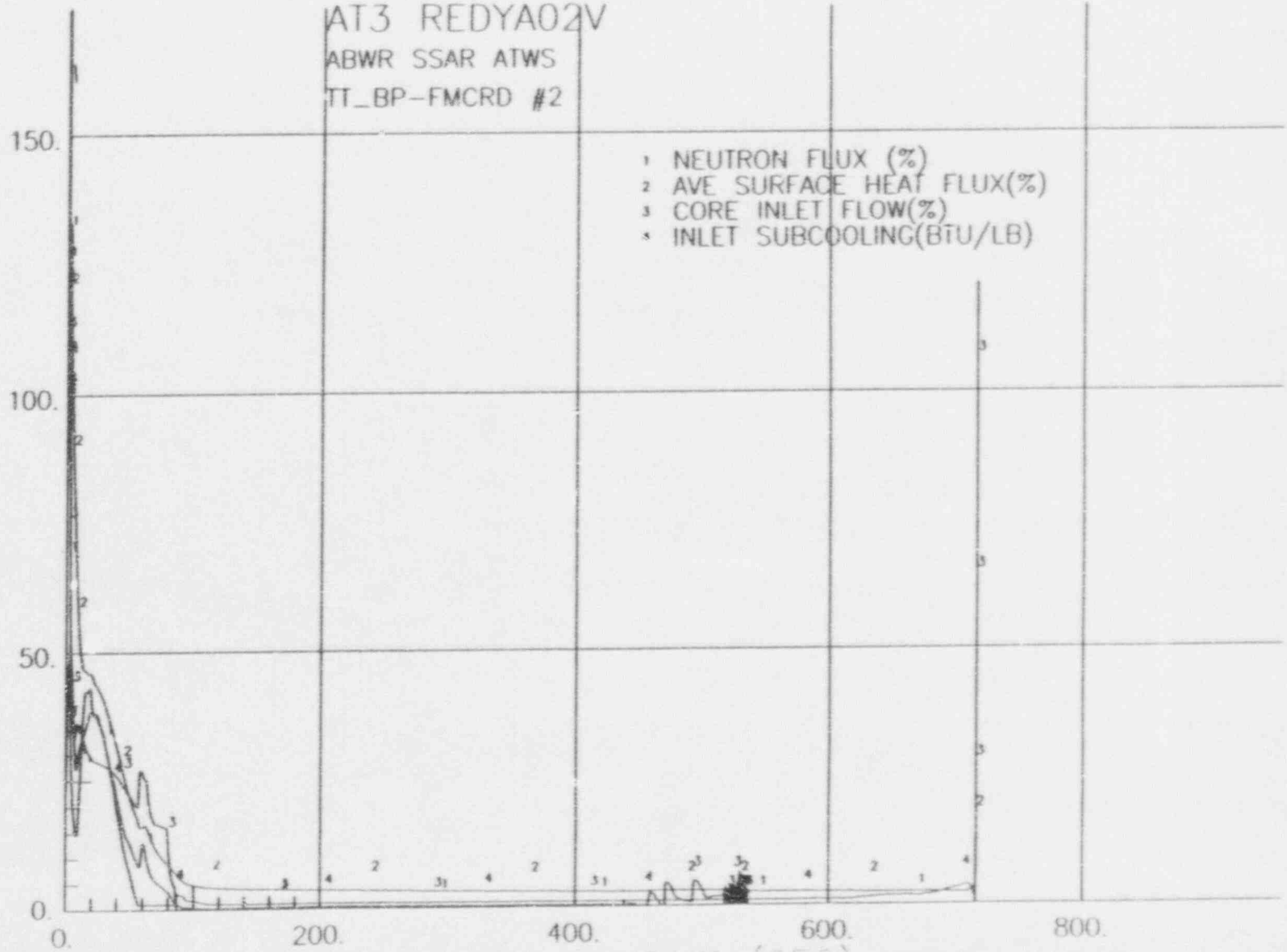


Figure 15E.6.5-7. ABWR Turbine Trip w/ Bypass, FMCRD Run-in

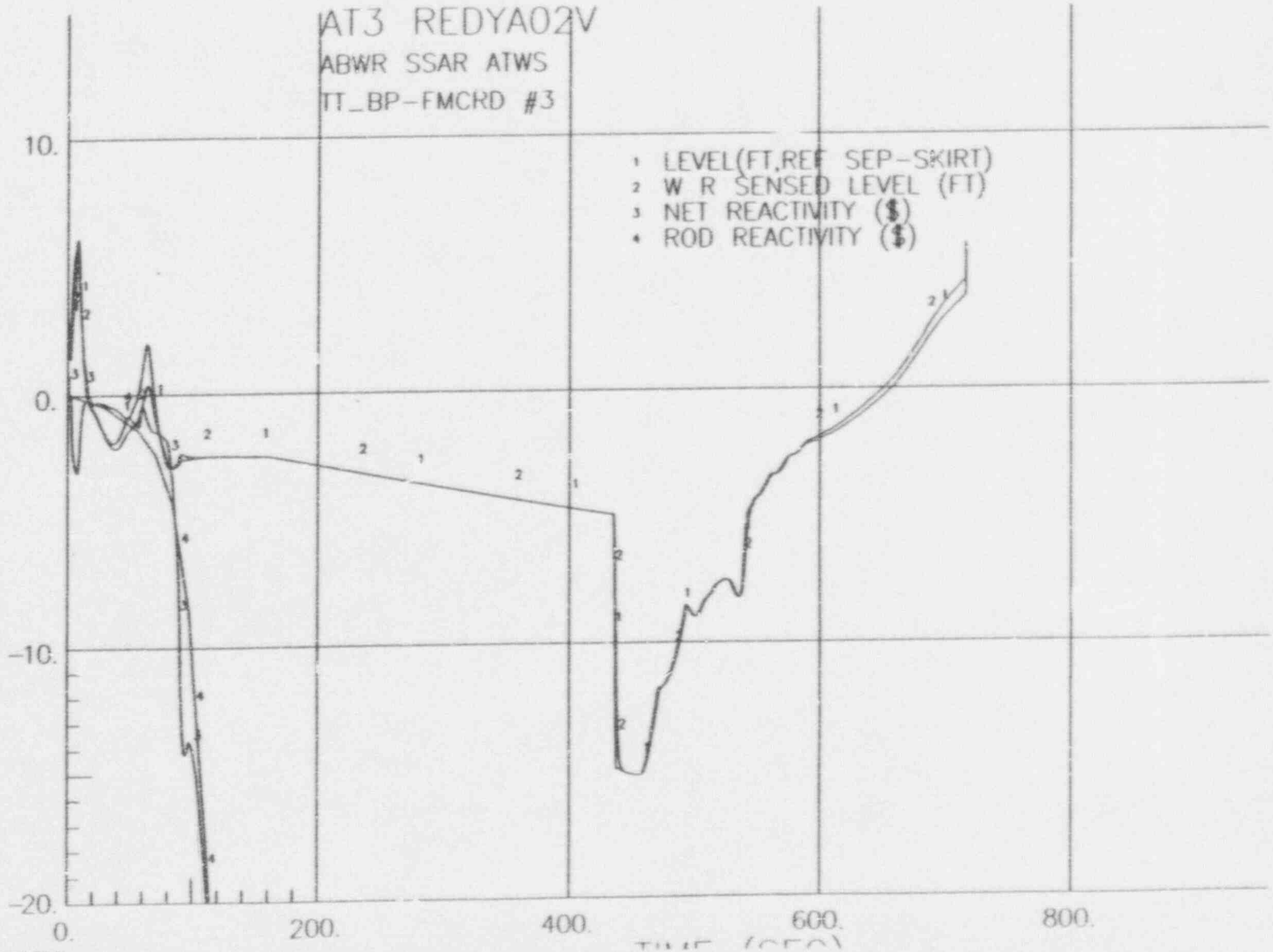


Figure 15E.6.5-8. ABWR Turbine Trip w/ Bypass, FMCRD Run-in

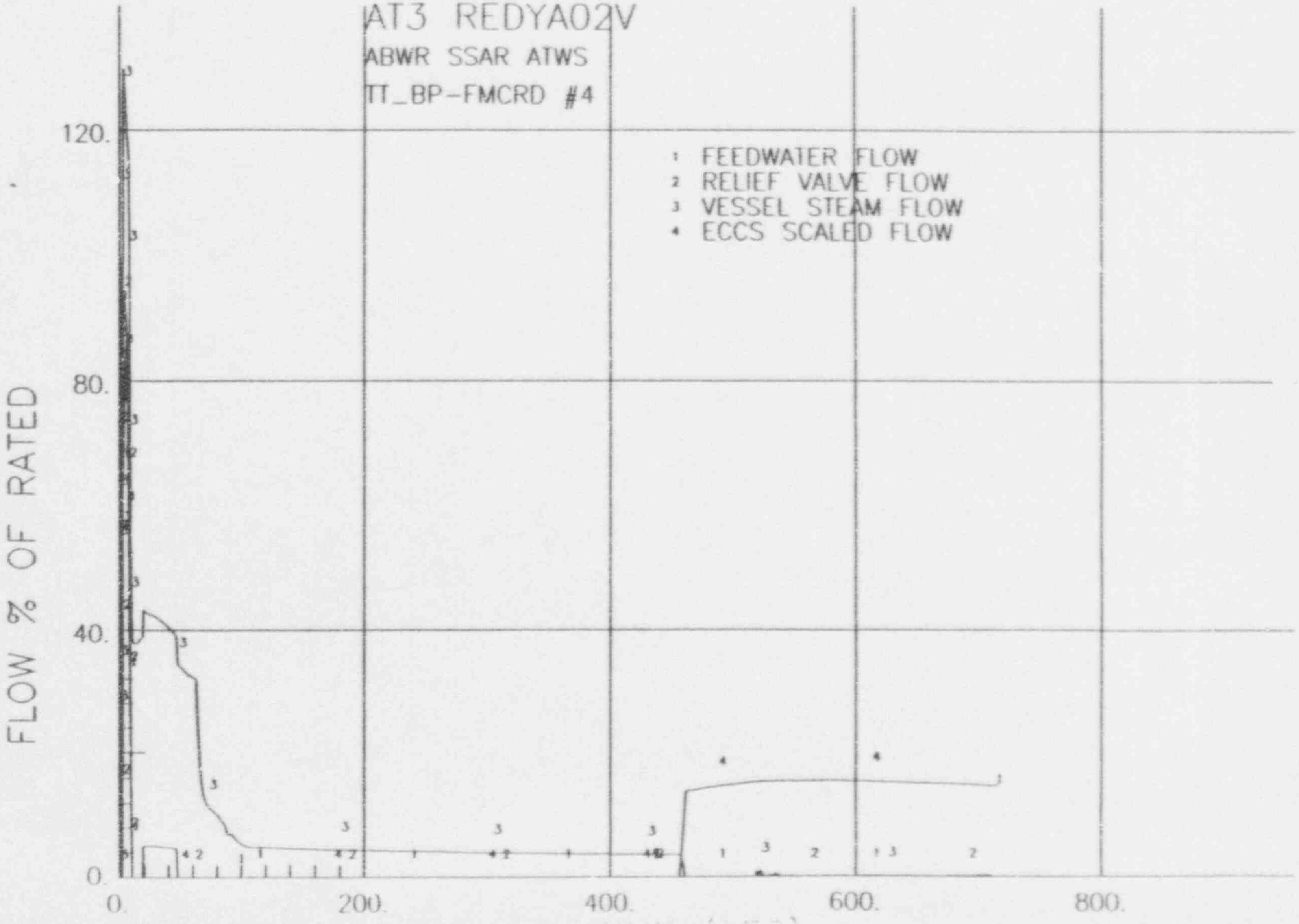


Figure 15E.6.5-9. ABWR Turbine Trip w/ Bypass, SLCS

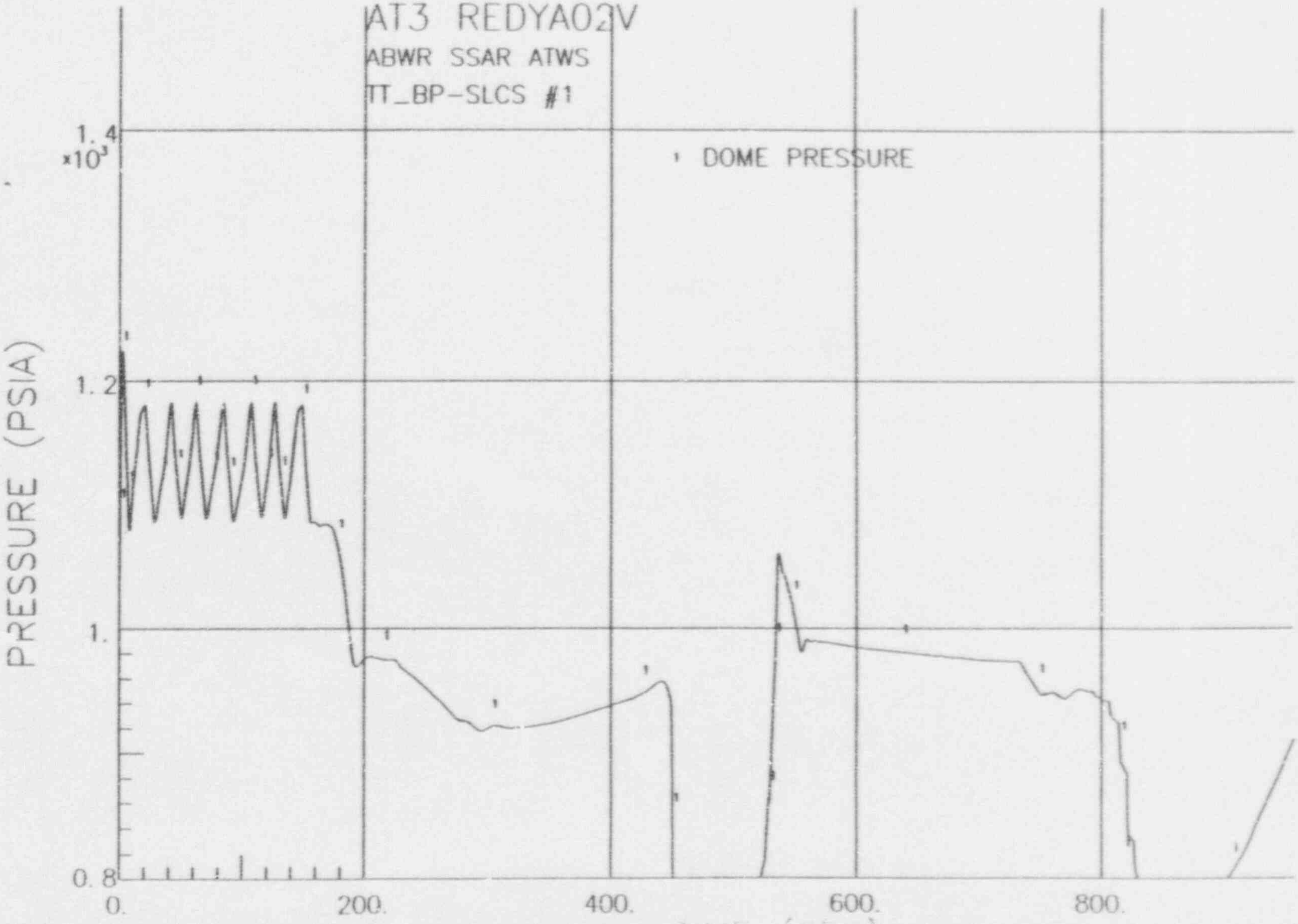


Figure 15E.6.5-10. ABWR Turbine Trip w/ Bypass, SLCS

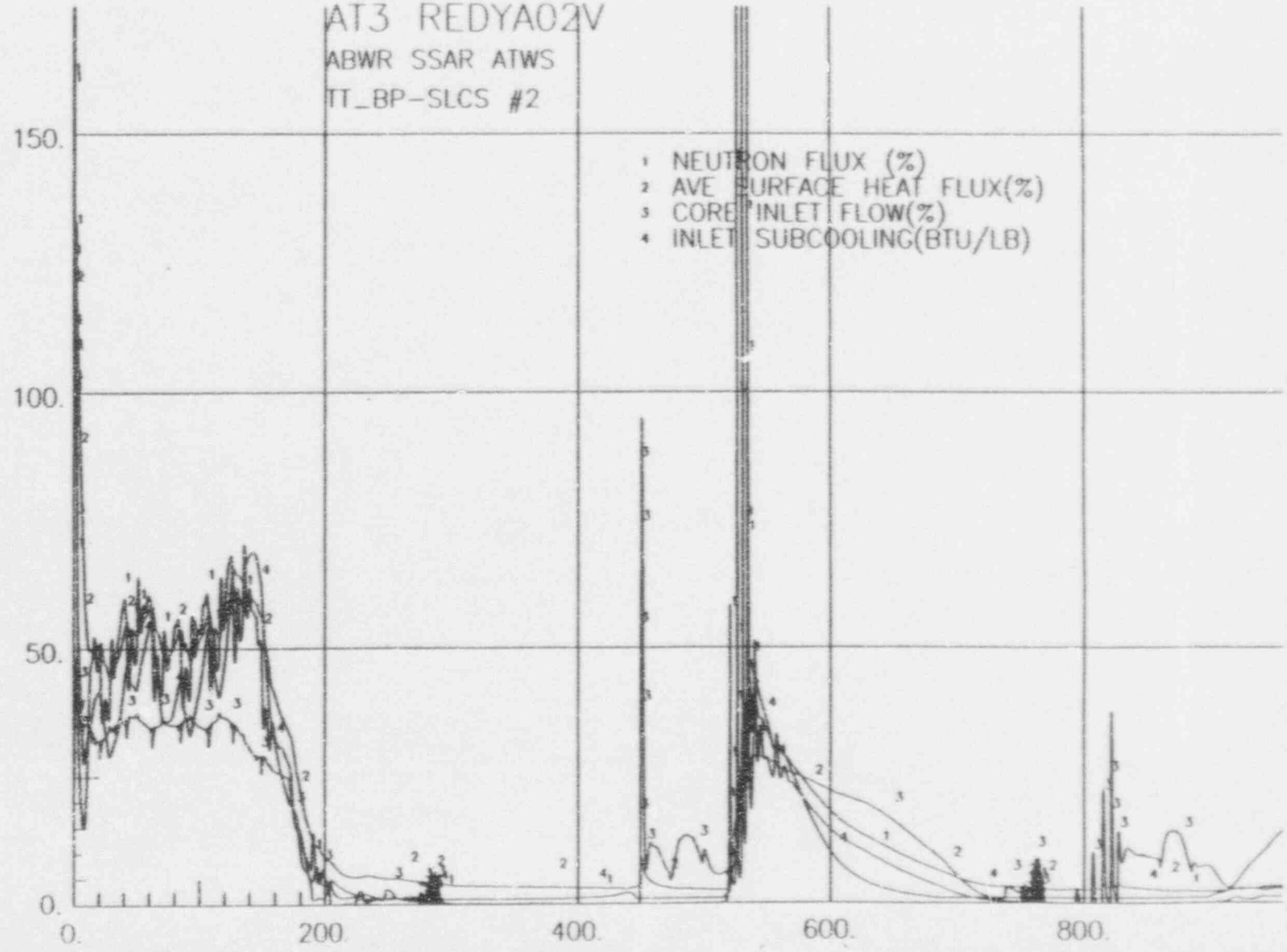


Figure 15E.6.5-11. ABWR Turbine Trip w/ Bypass, SLCS

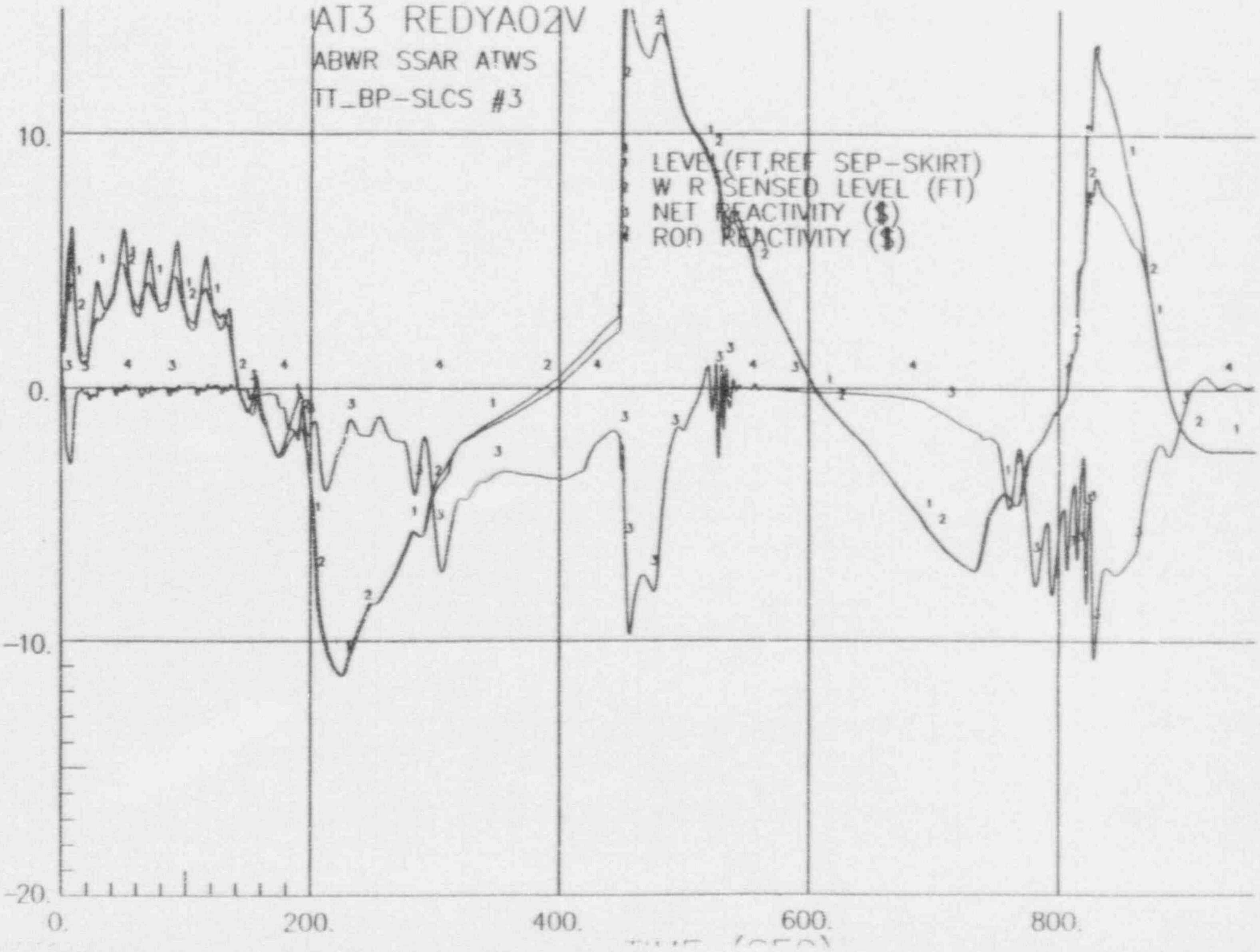


Figure 15E.6.5-12. ABWR Turbine Trip w/ Bypass, SLCS

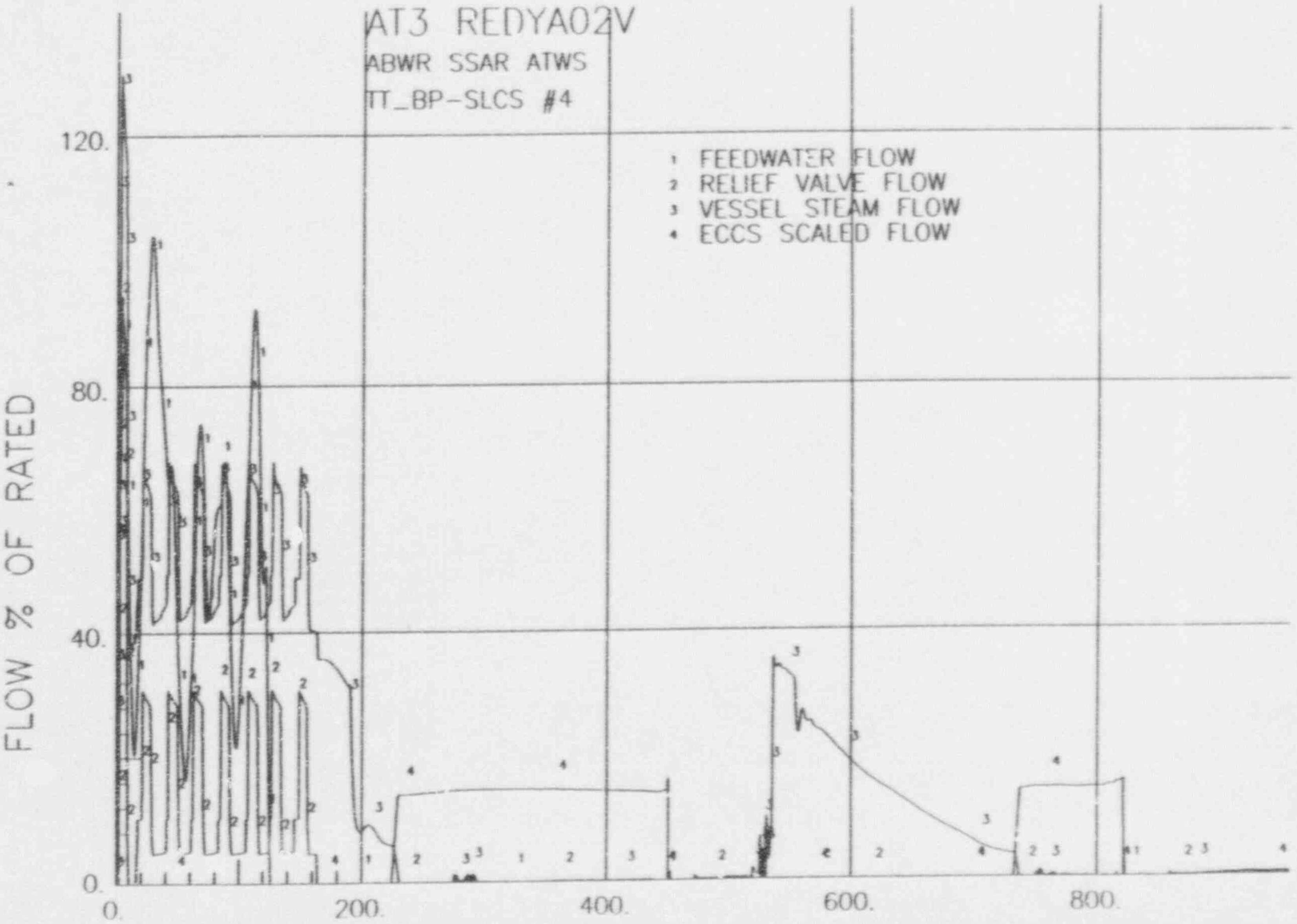


Figure 15E.6.6-1. ABWR Loss of Condenser Vacuum, ARI

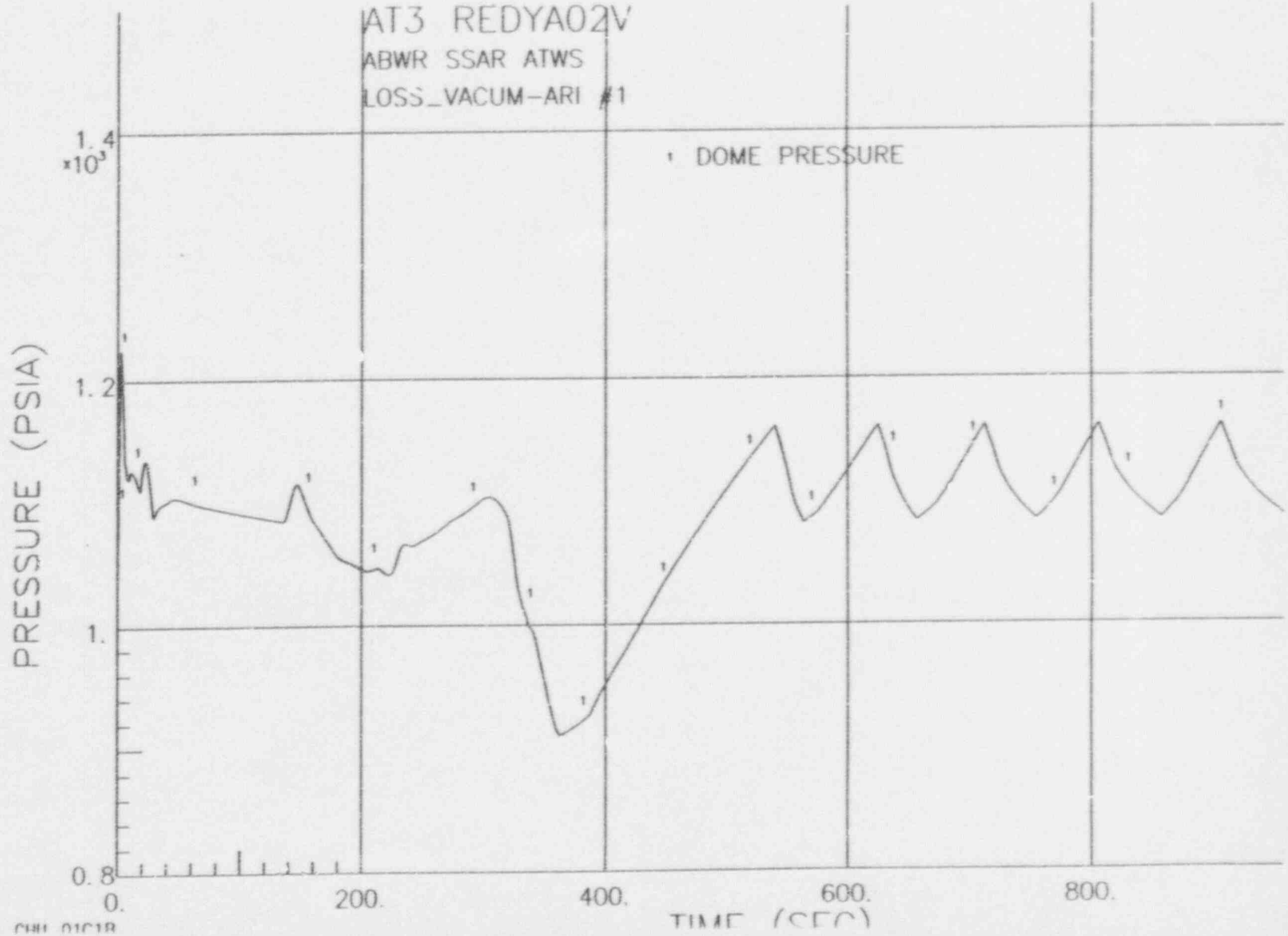


Figure 15E.6.6-2. ABWR Loss of Condenser Vacuum, ARI

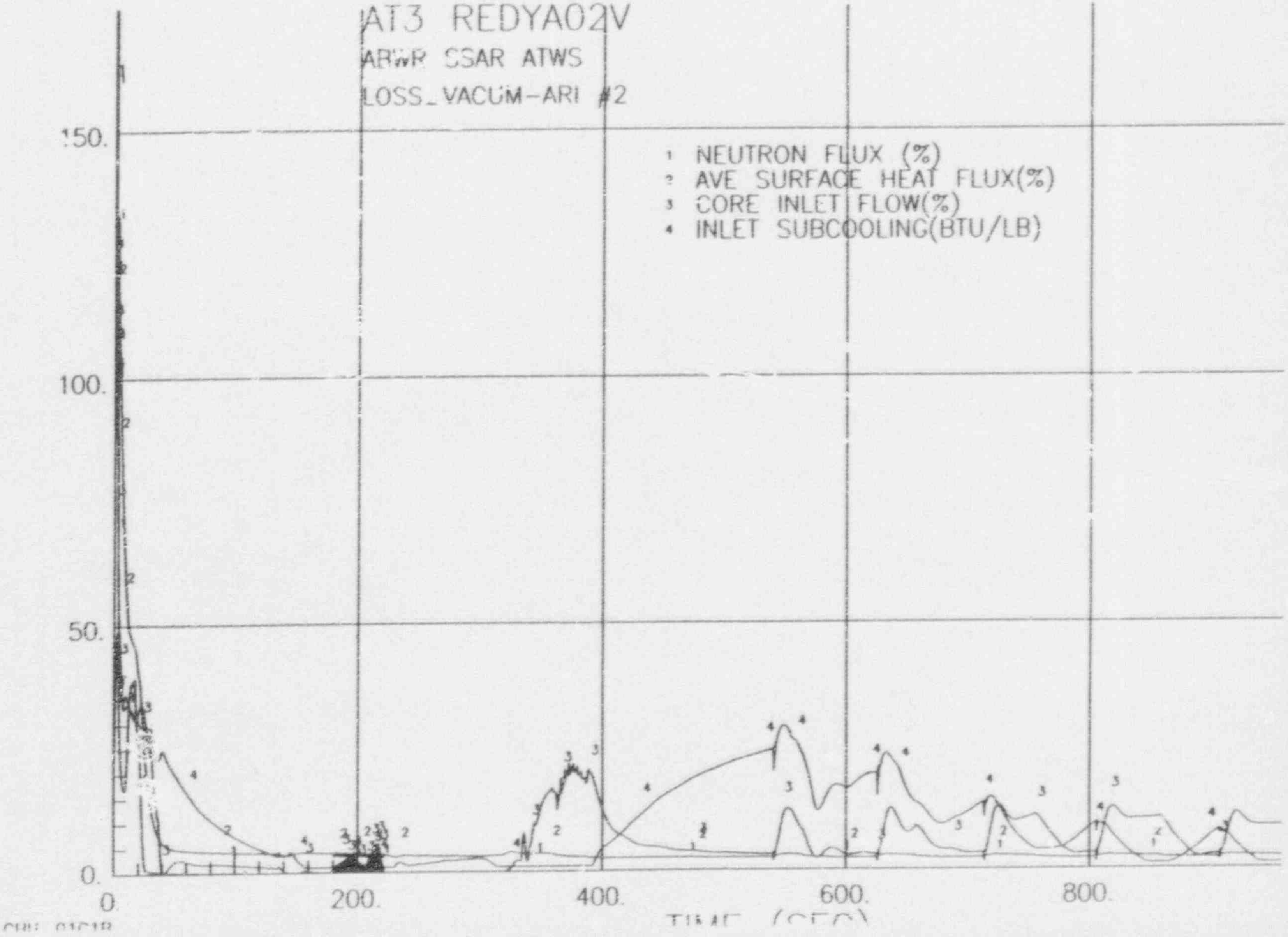


Figure 15E.6.6-3. ABWR Loss of Condenser Vacuum, ARI

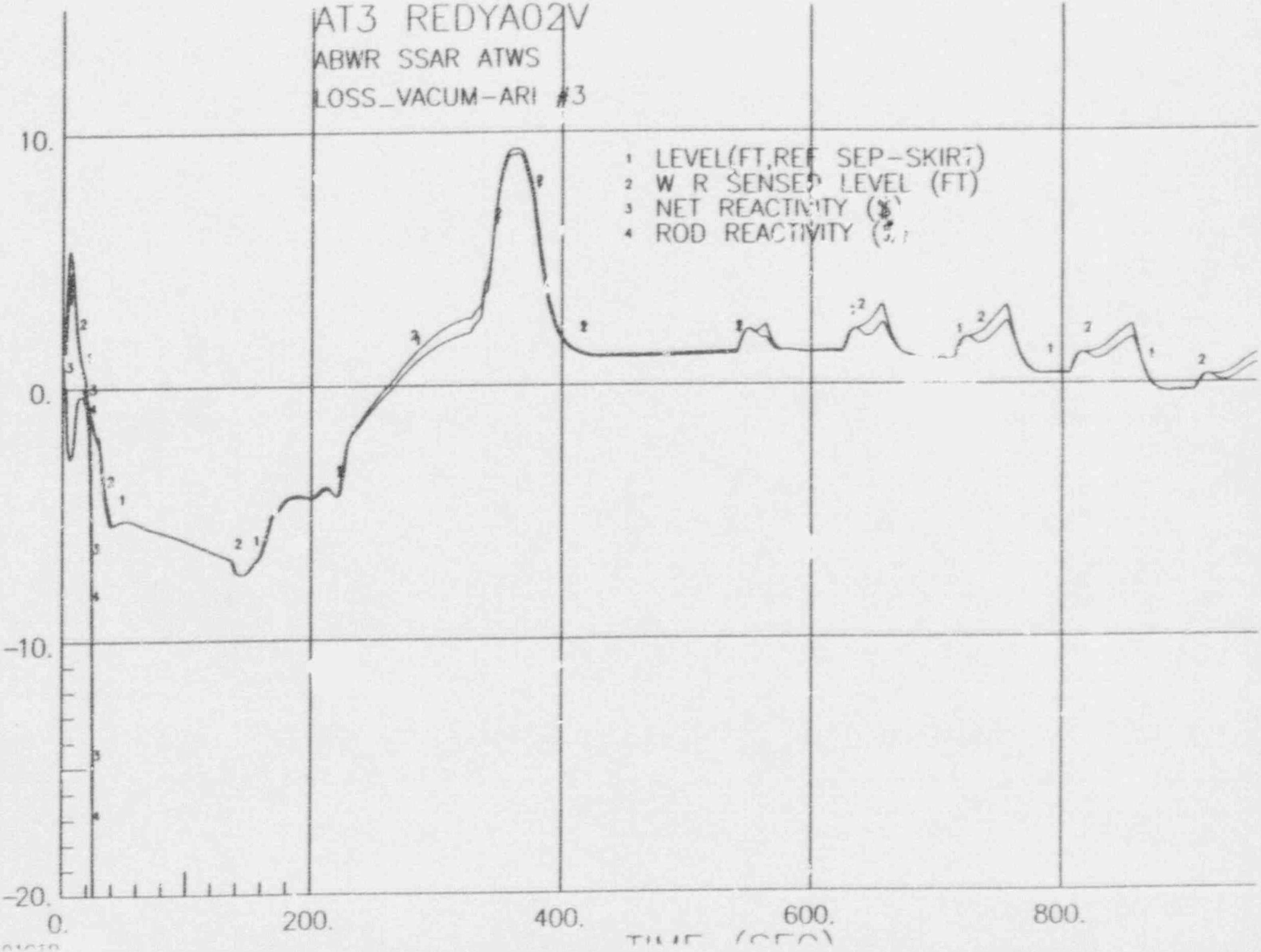


Figure 15E.6.6-4. ABWR Loss of Condenser Vacuum, ARI

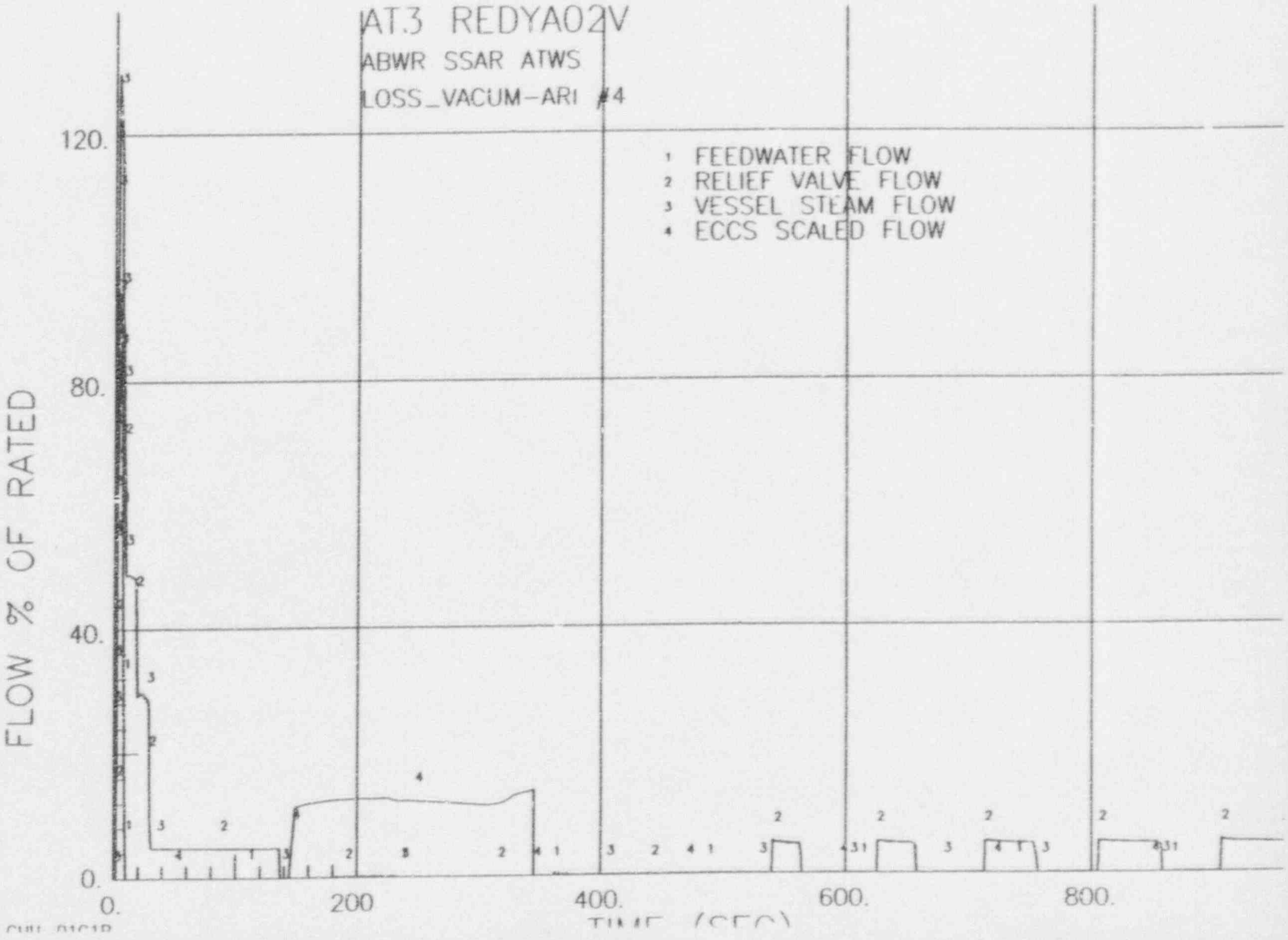


Figure 15E.6.6-5. ABWR Loss of Condenser Vacuum, FMCRD Run-in

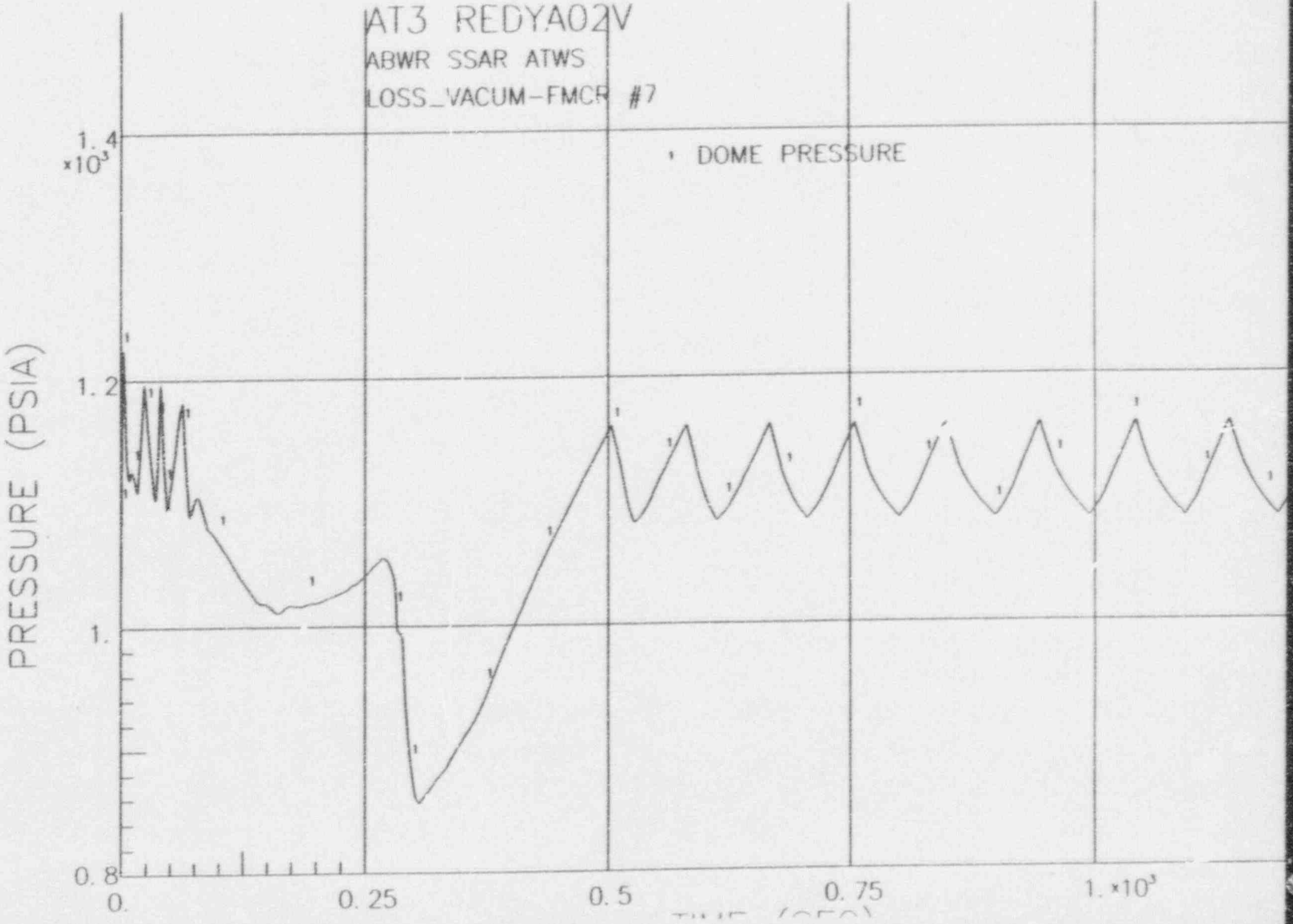


Figure 15E.6.6-6. ABWR Loss of Condenser Vacuum, FMCRD Run-in

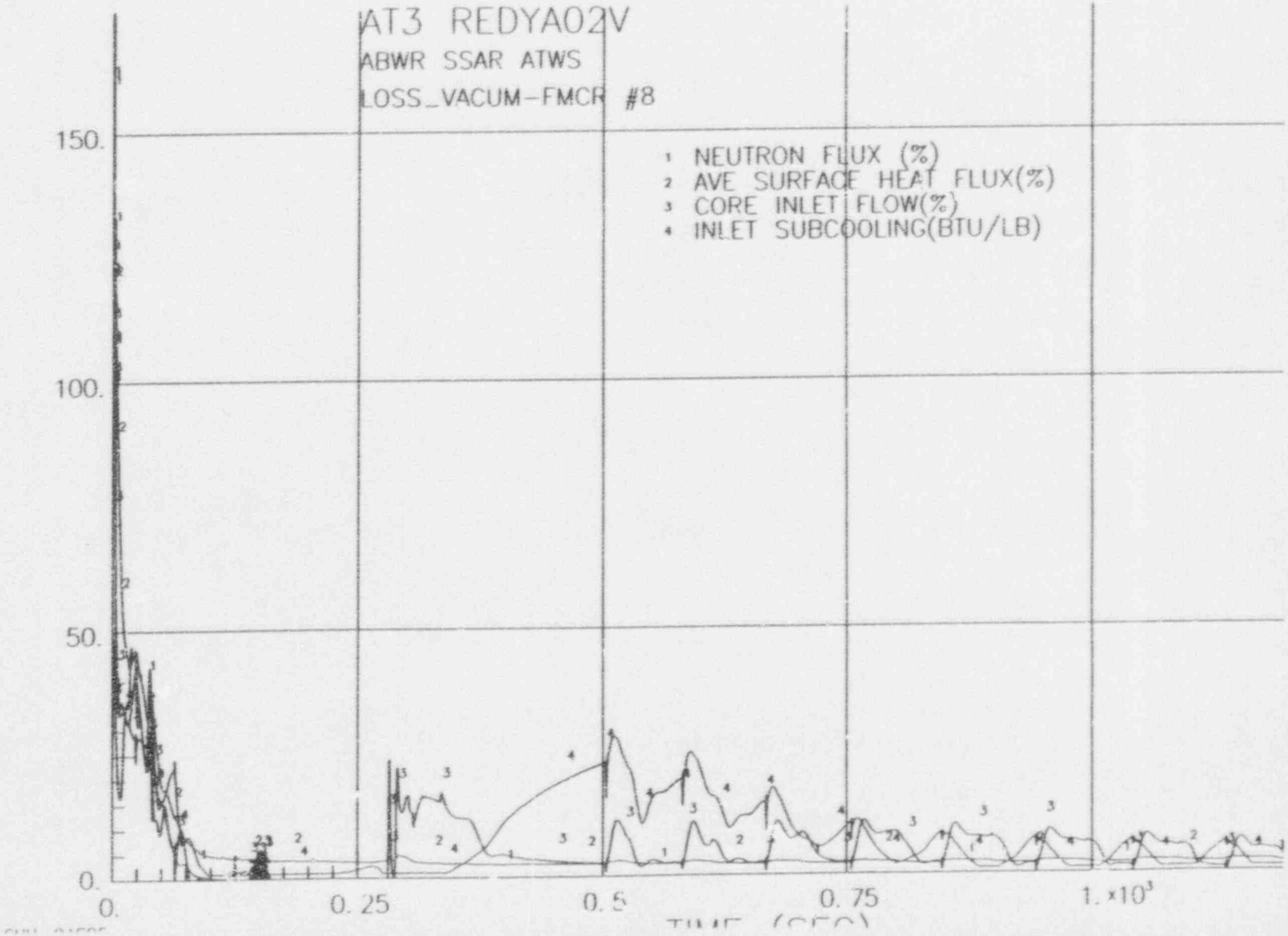


Figure 15E.6.6-7. ABWR Loss of Condenser Vacuum, FMCRD Run-in

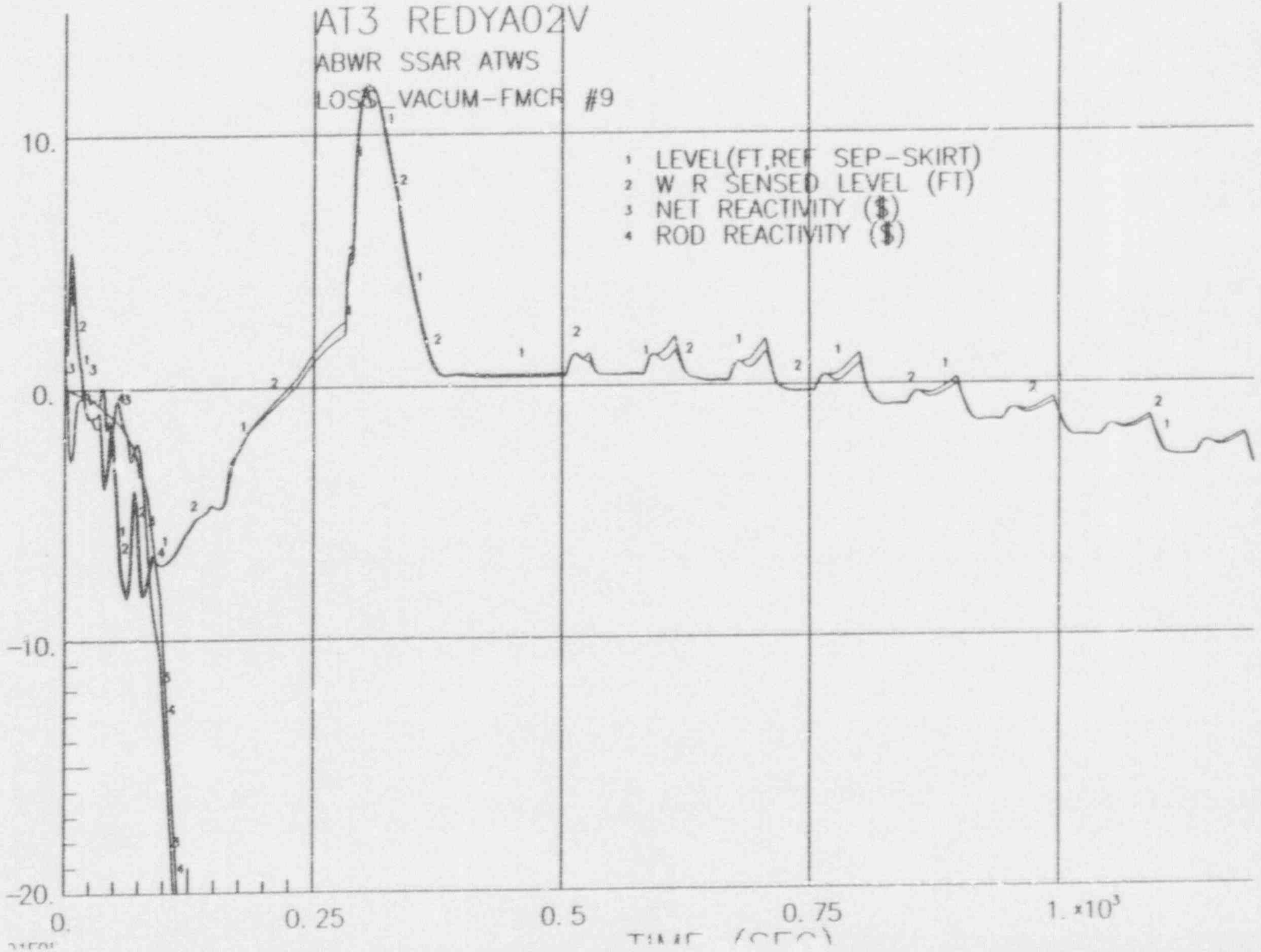


Figure 15E.6.6-8. ABWR Loss of Condenser Vacuum, FMCRD Run-in

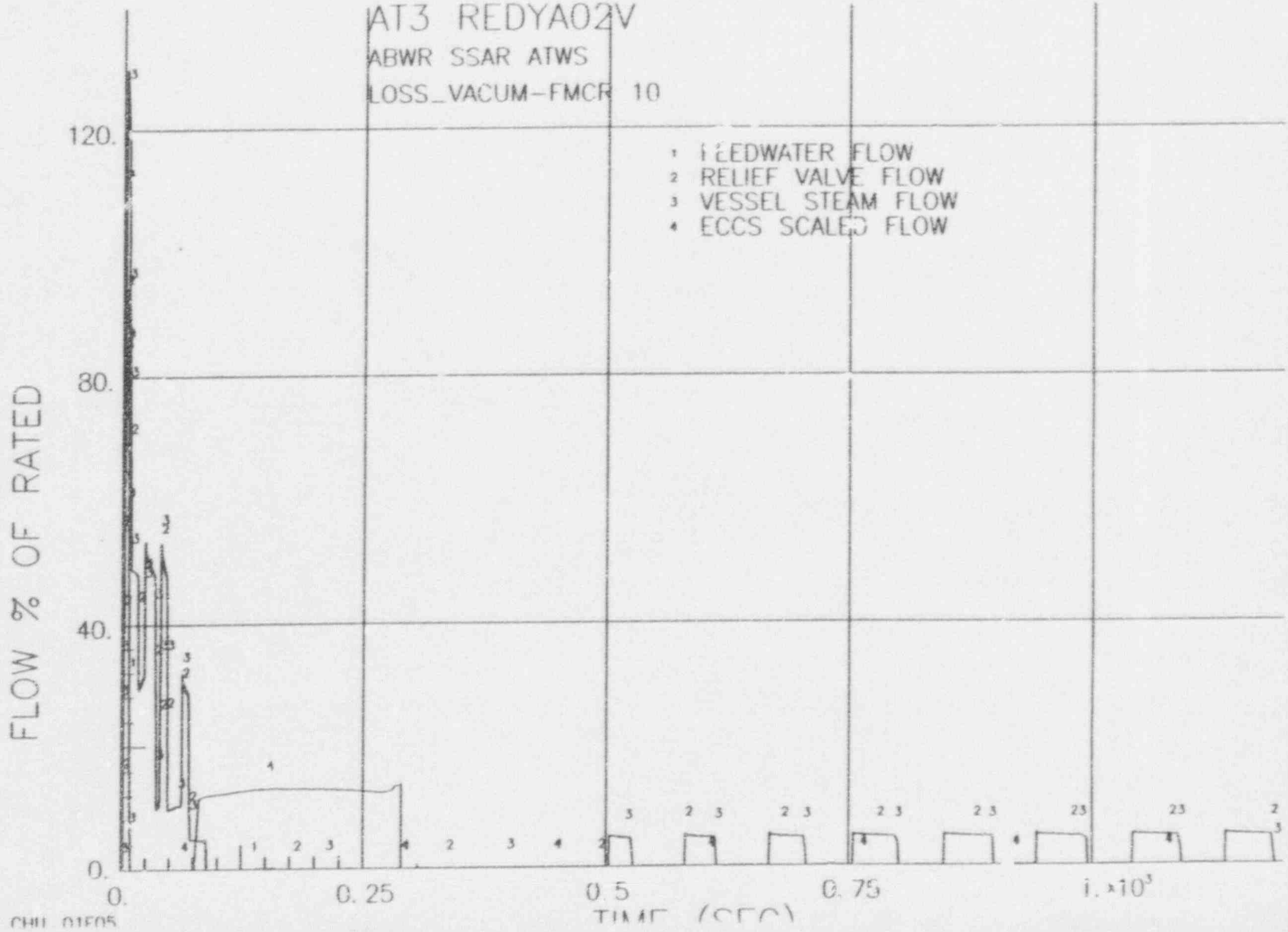


Figure 15E.6.6-9. ABWR Loss of Condenser Vacuum, SLCS

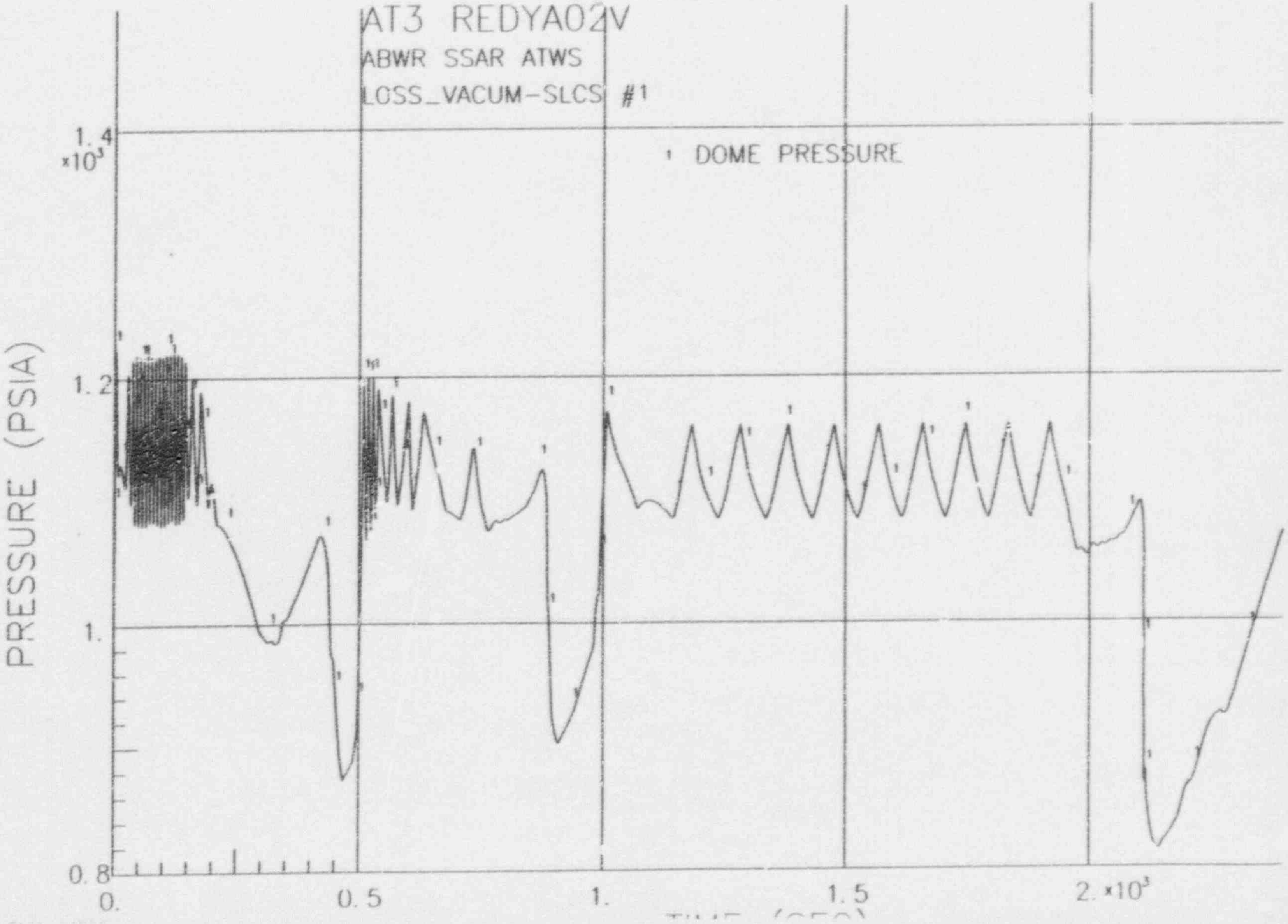


Figure 15E.6.6-10. ABWR Loss of Condenser Vacuum, SLCS

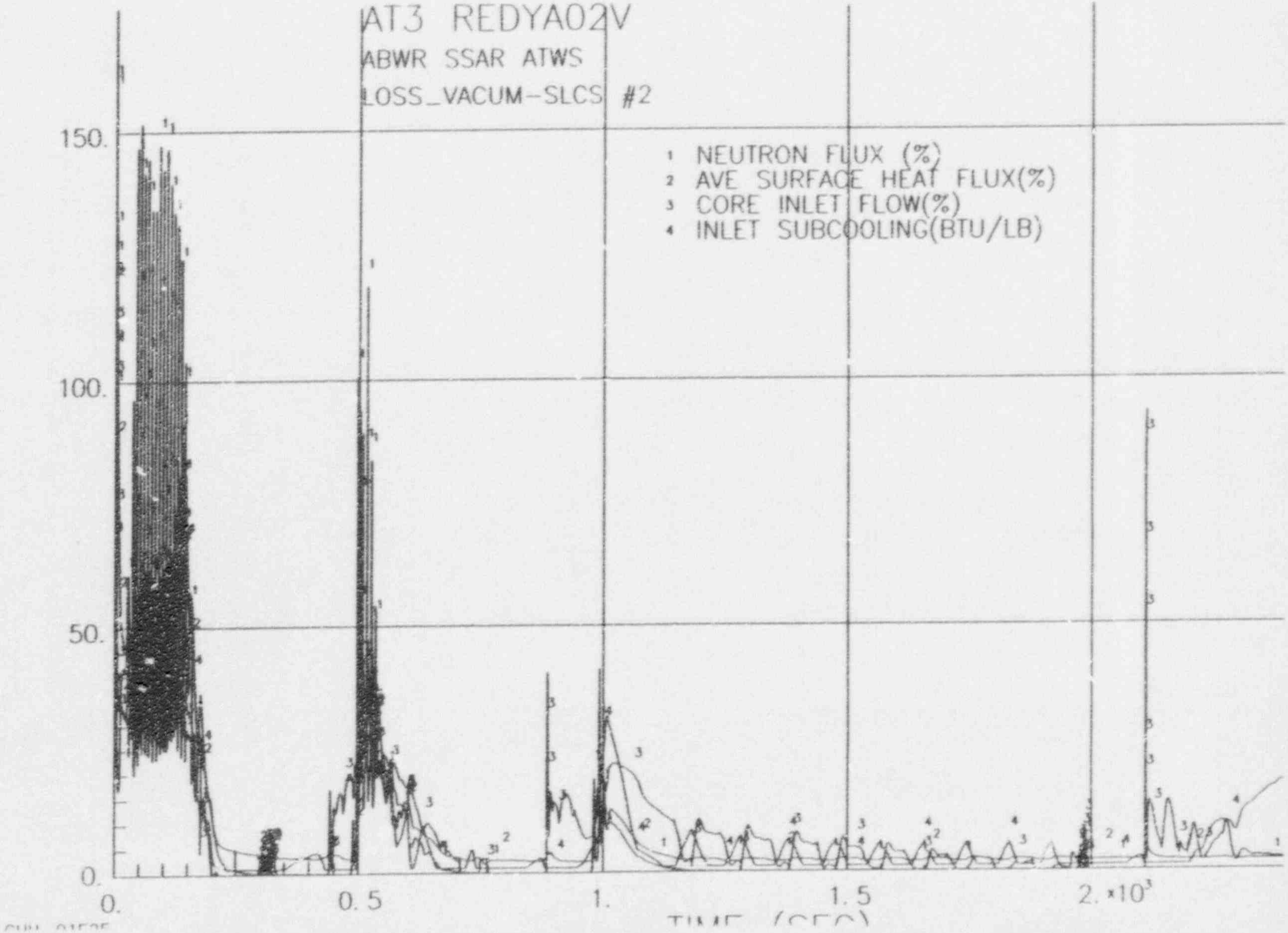


Figure 15E.6.6-11. ABWR Loss of Condenser Vacuum, SLCS

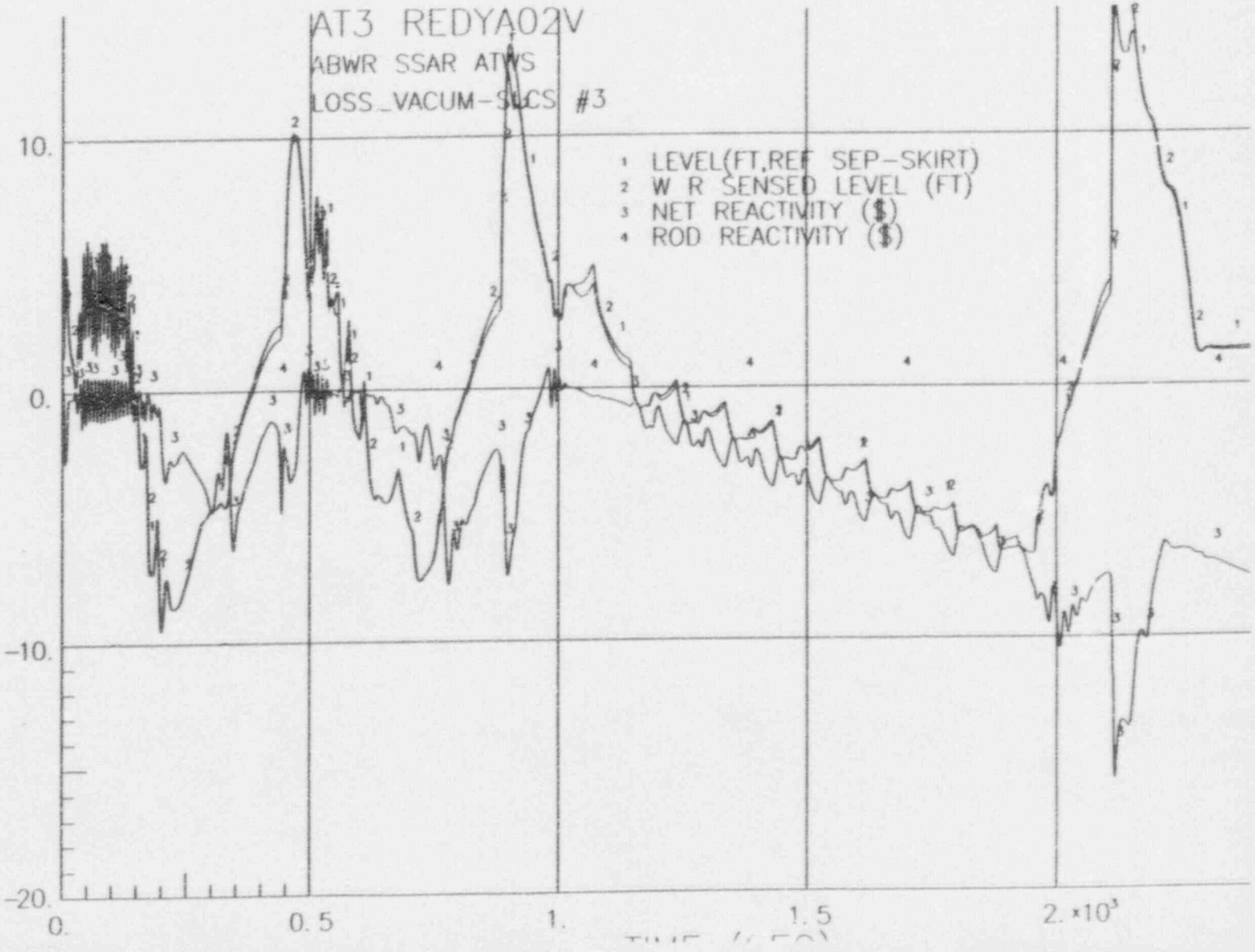


Figure 15E.6.6-12. ABWR Loss of Condenser Vacuum, SLCS

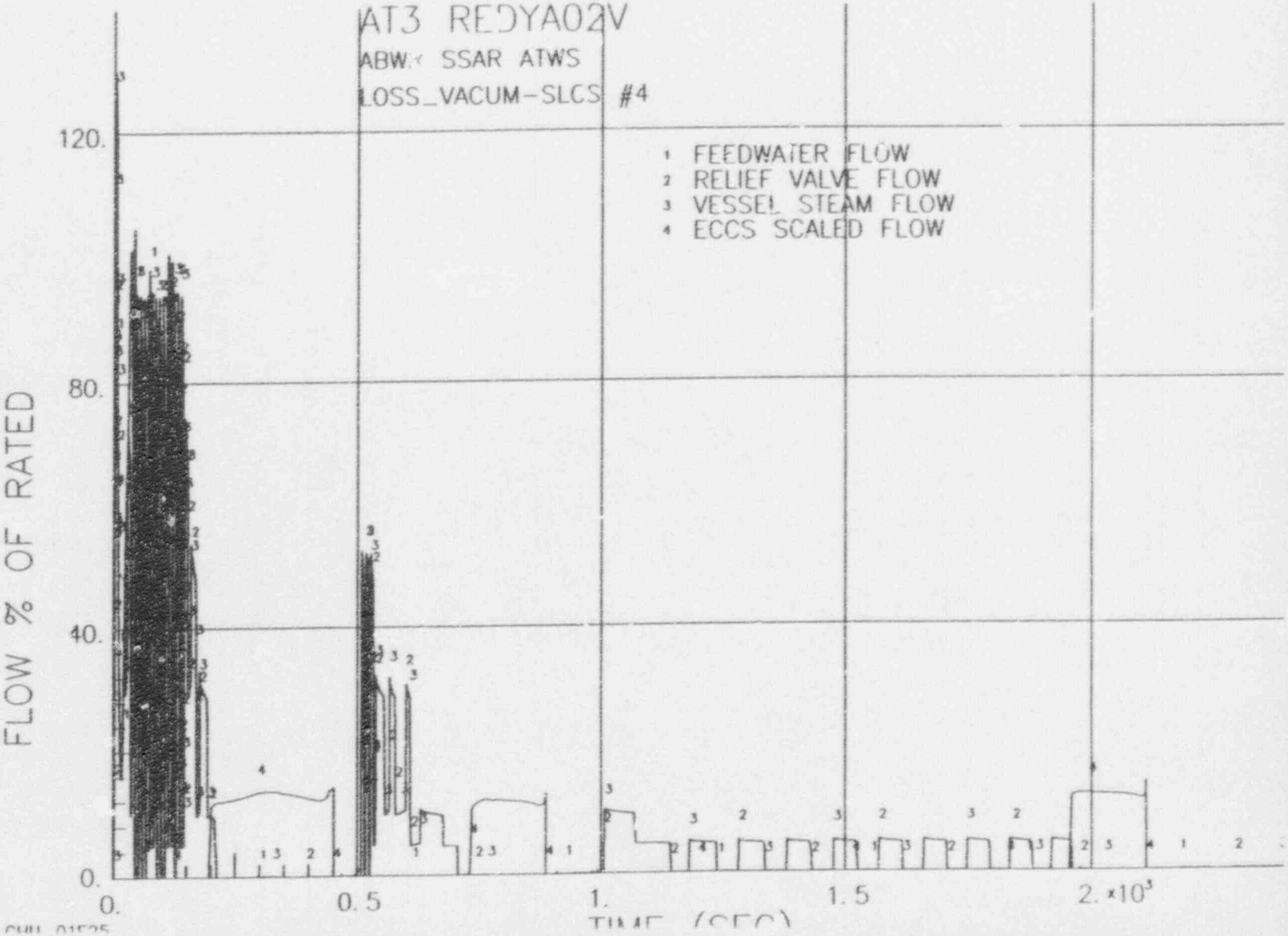


Figure 15E.6.7-1. Feedwater Controller Failure Maximum Demand, ARI

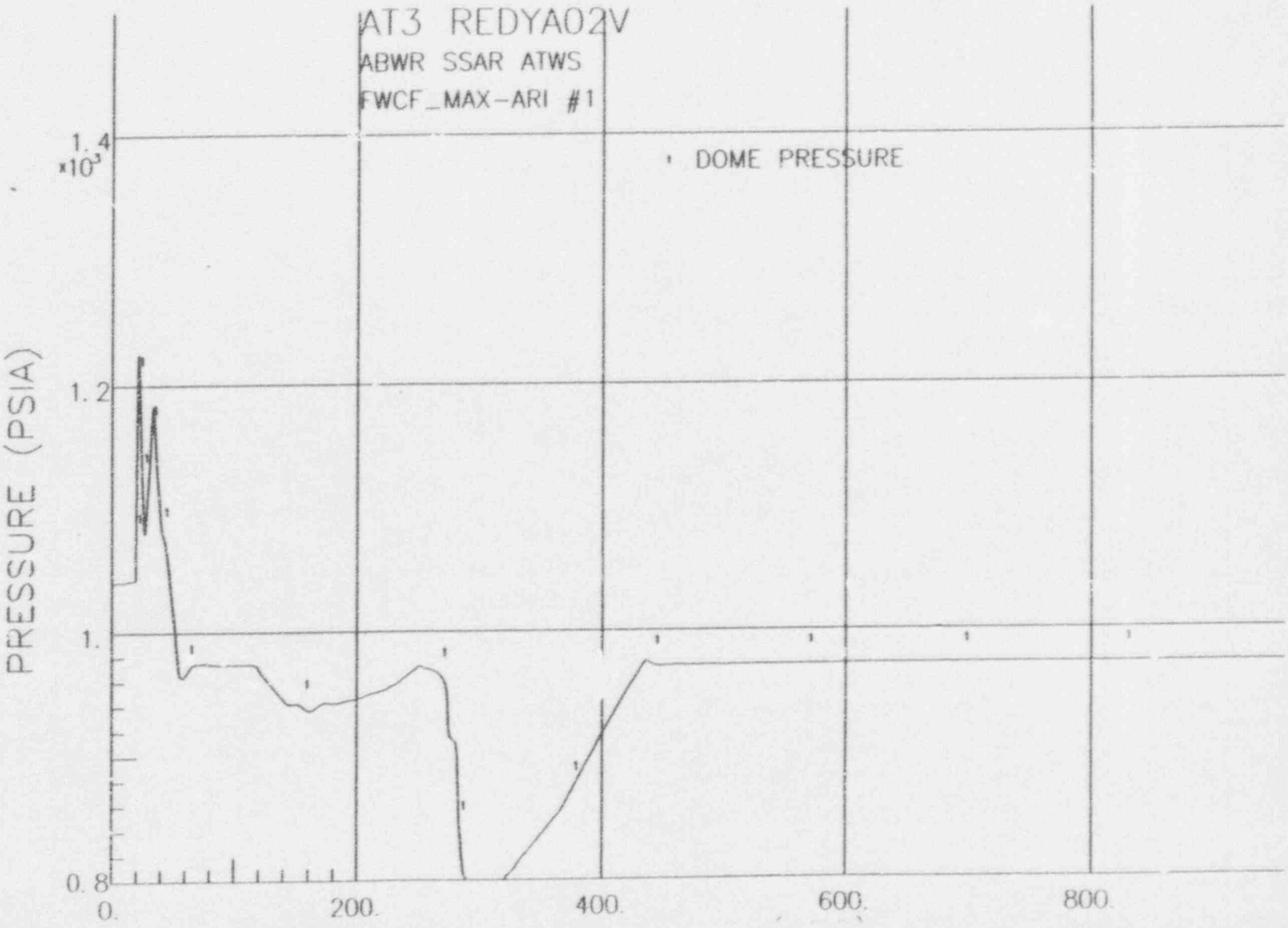


Figure 15E.6.7-2. Feedwater Controller Failure Maximum Demand, ARI

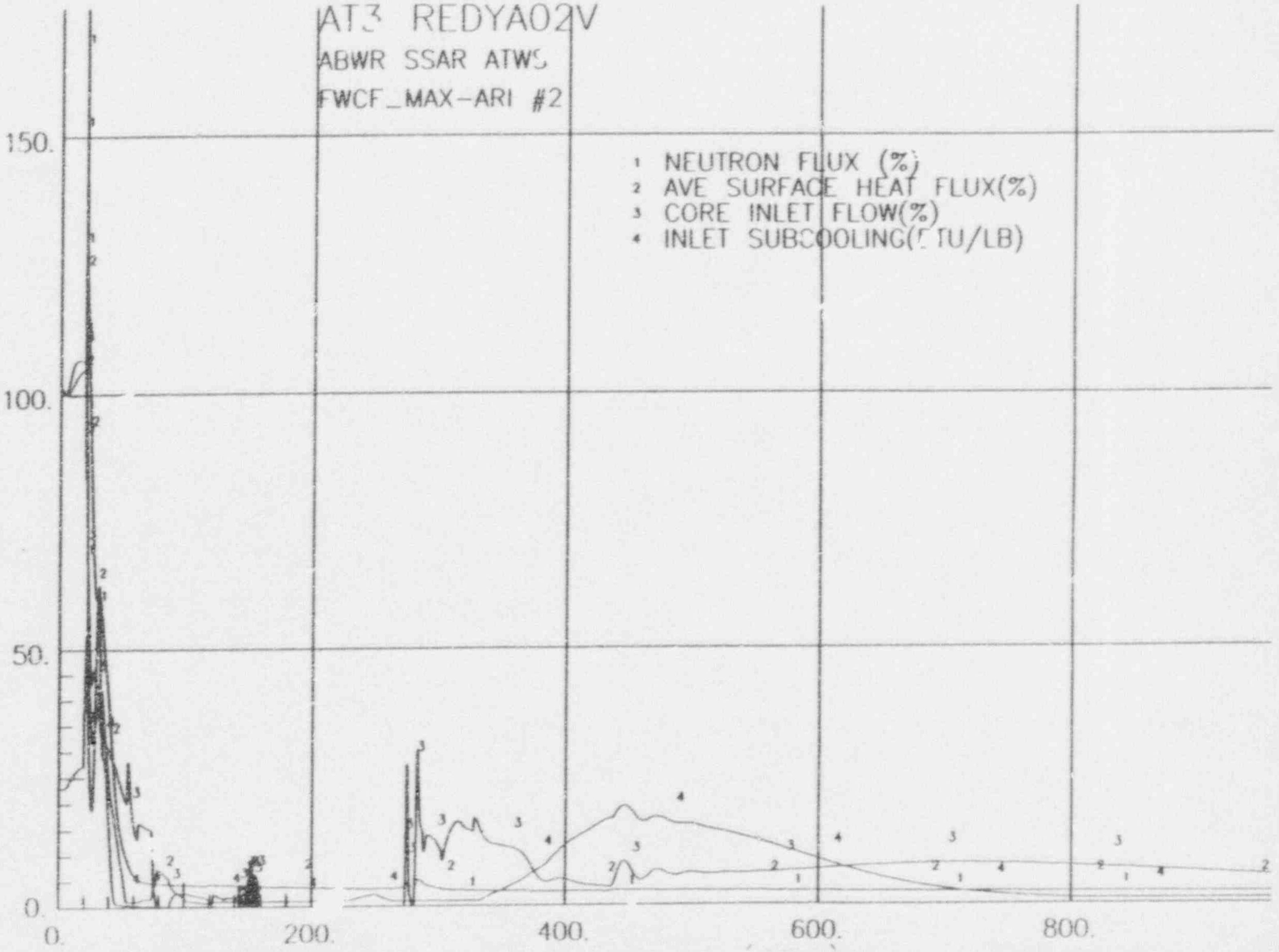


Figure 15E.6.7-3. Feedwater Controller Failure Maximum Demand, ARI

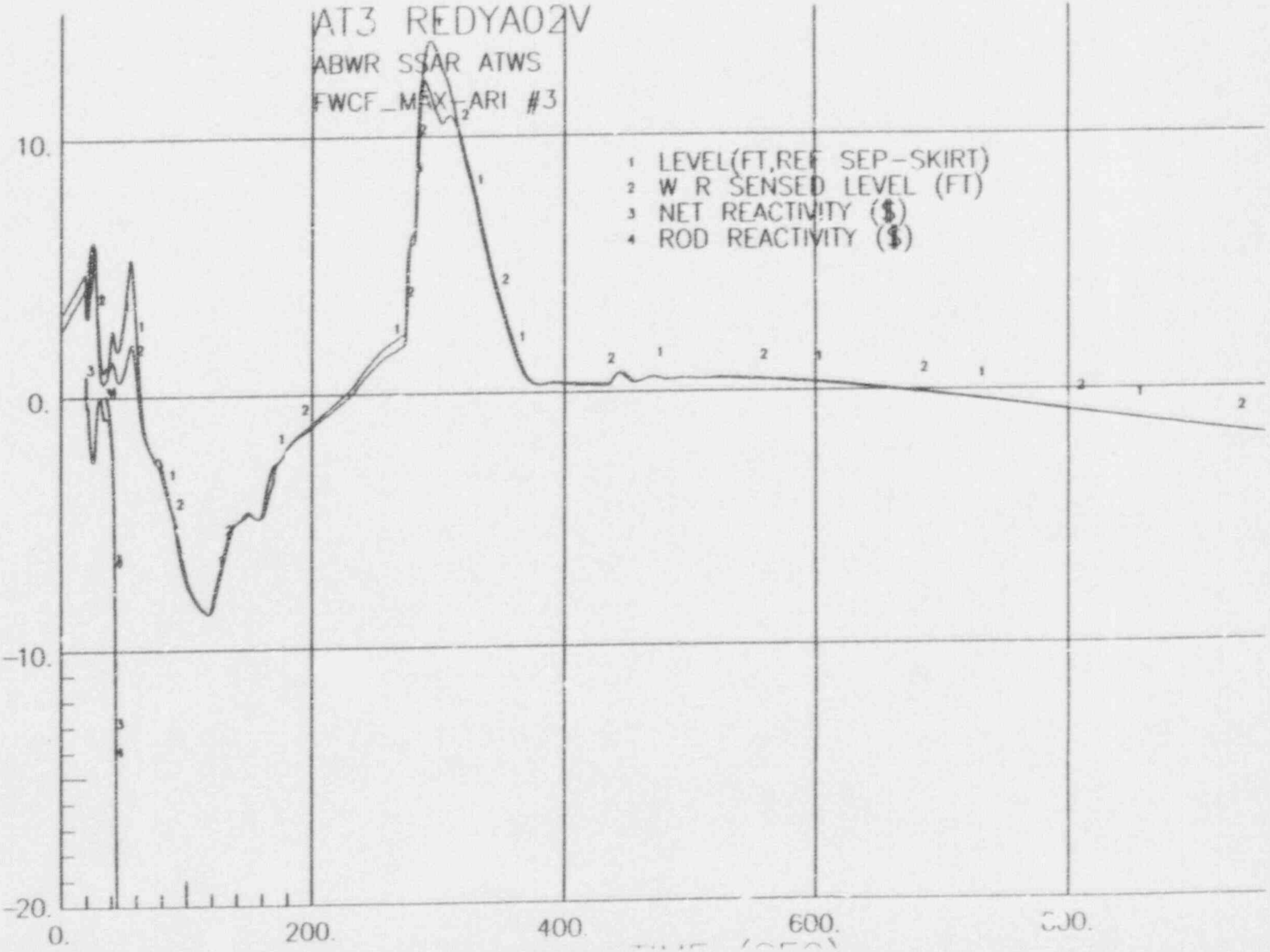


Figure 15E.6.7-4. Feedwater Controller Failure Maximum Demand, ARI

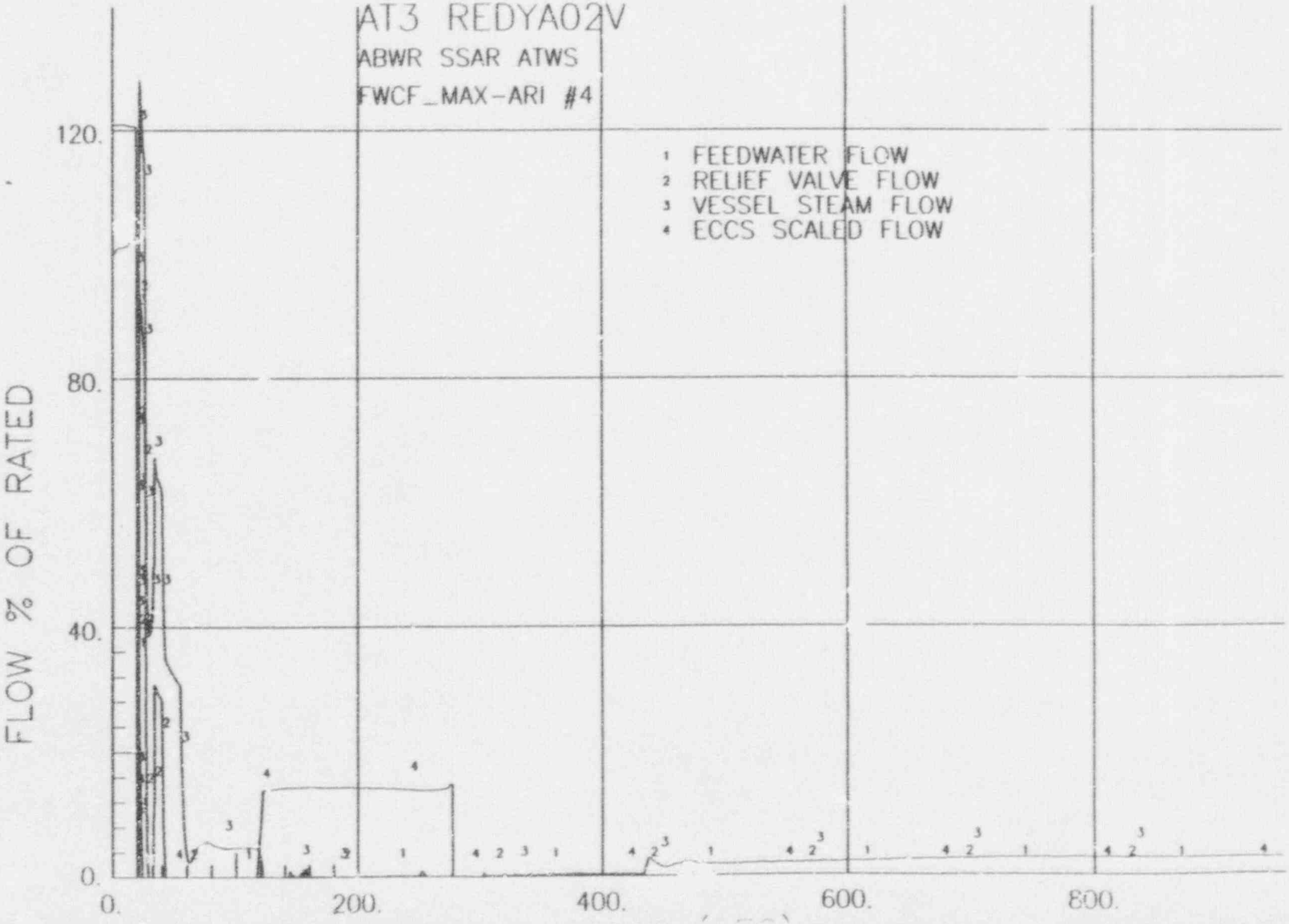


Figure 15E.6.7-5. Feedwater Controller Failure Maximum Demand, FMCRD Run-in

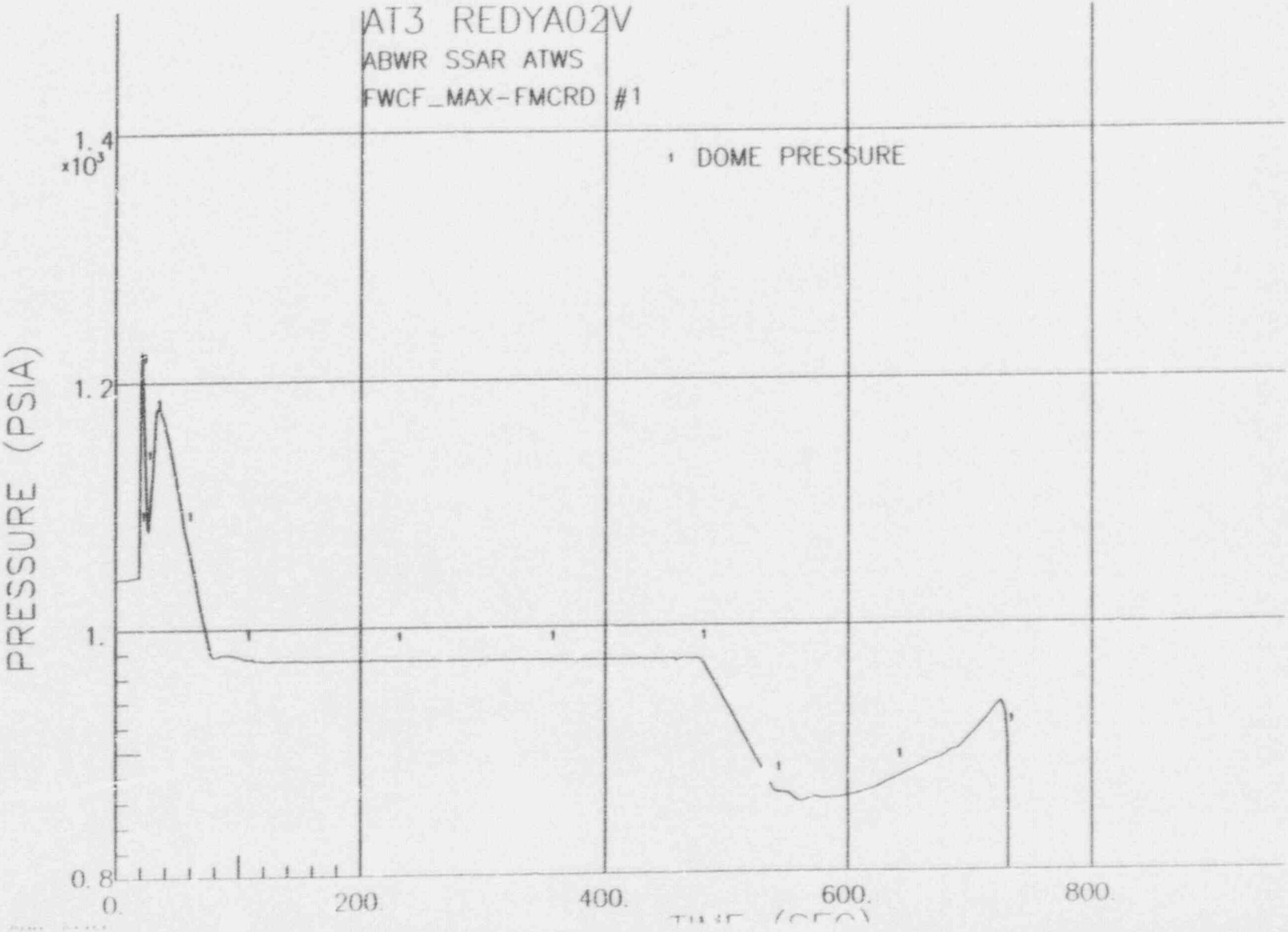


Figure 15E.6.7-6. Feedwater Controller Failure Maximum Demand, FMCRD Run-in

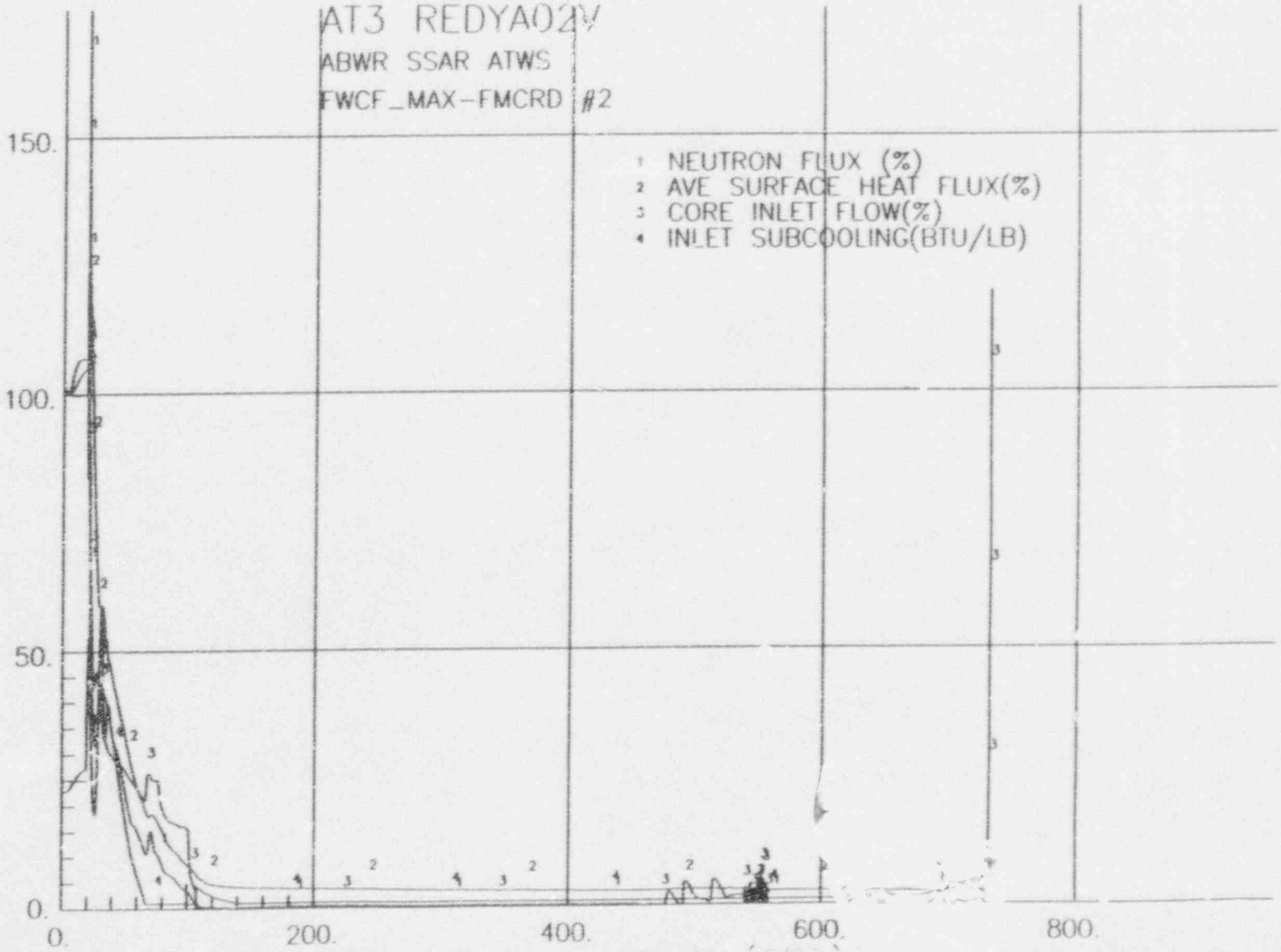


Figure 15E.6.7-7. Feedwater Controller Failure Maximum Demand, FMCRD Run-in

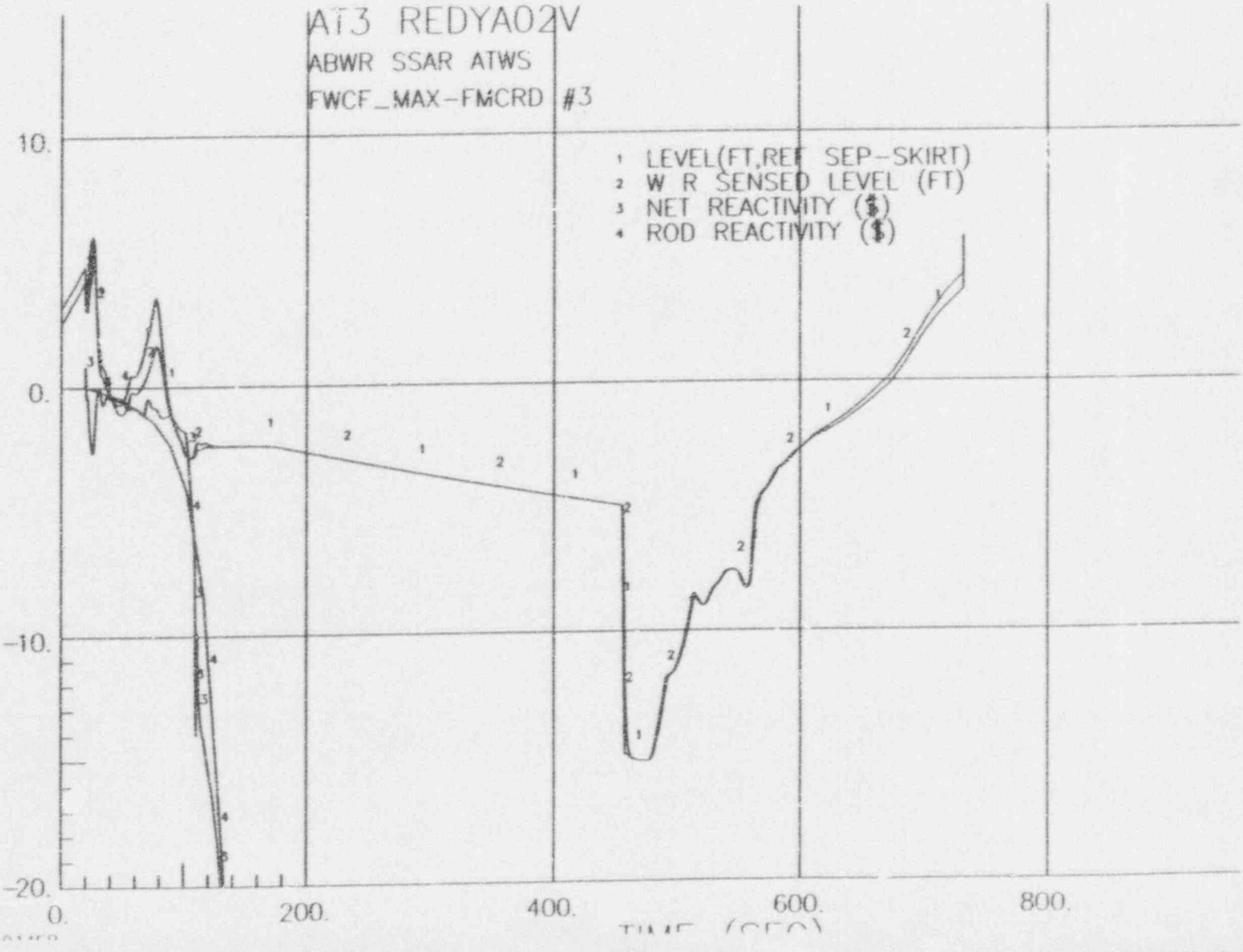


Figure 15E.6.7-8. Feedwater Controller Failure Maximum Demand, FMCRD Run-in

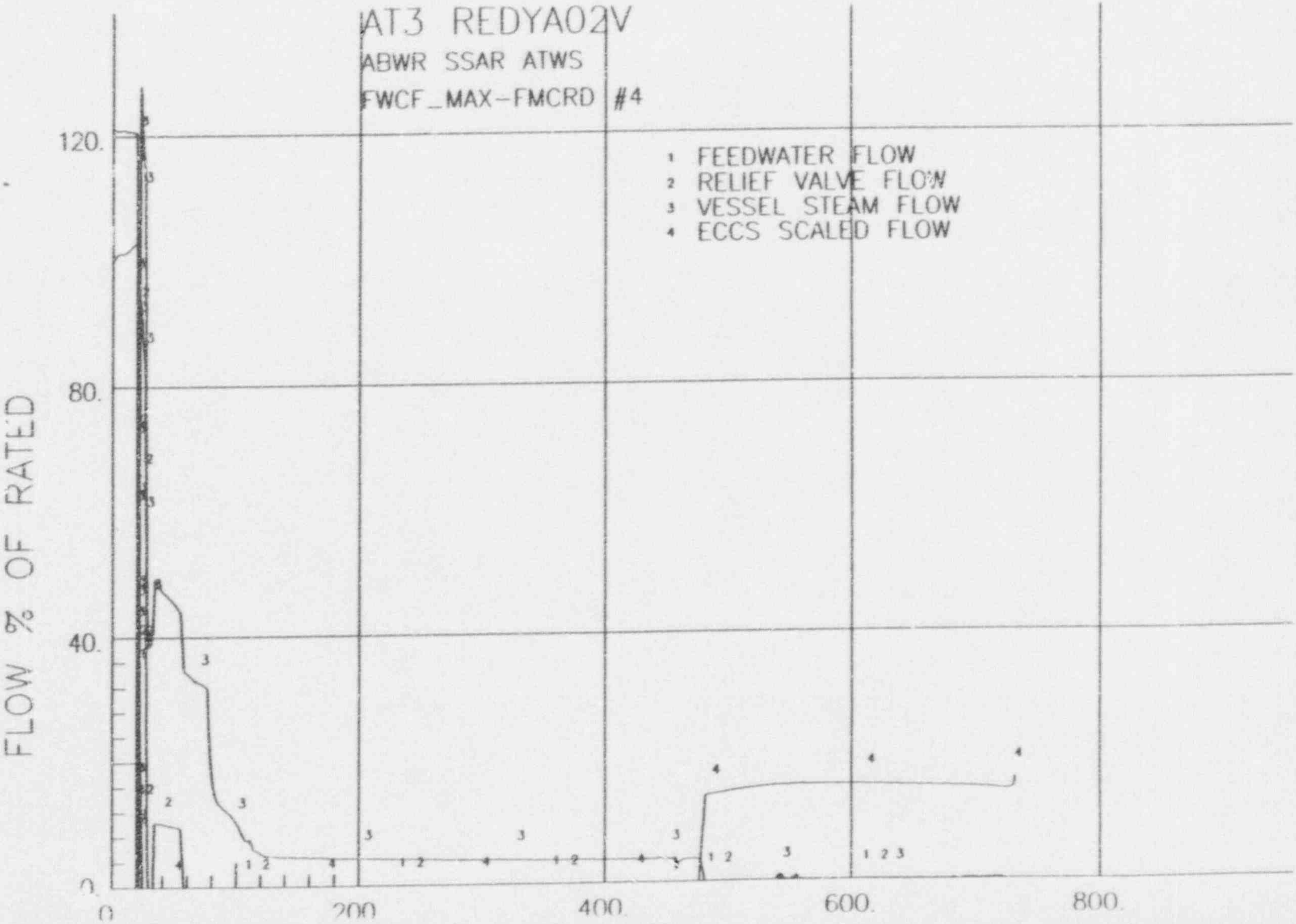


Figure 15E.6.7-9. Feedwater Controller Failure Maximum Demand, SLCS

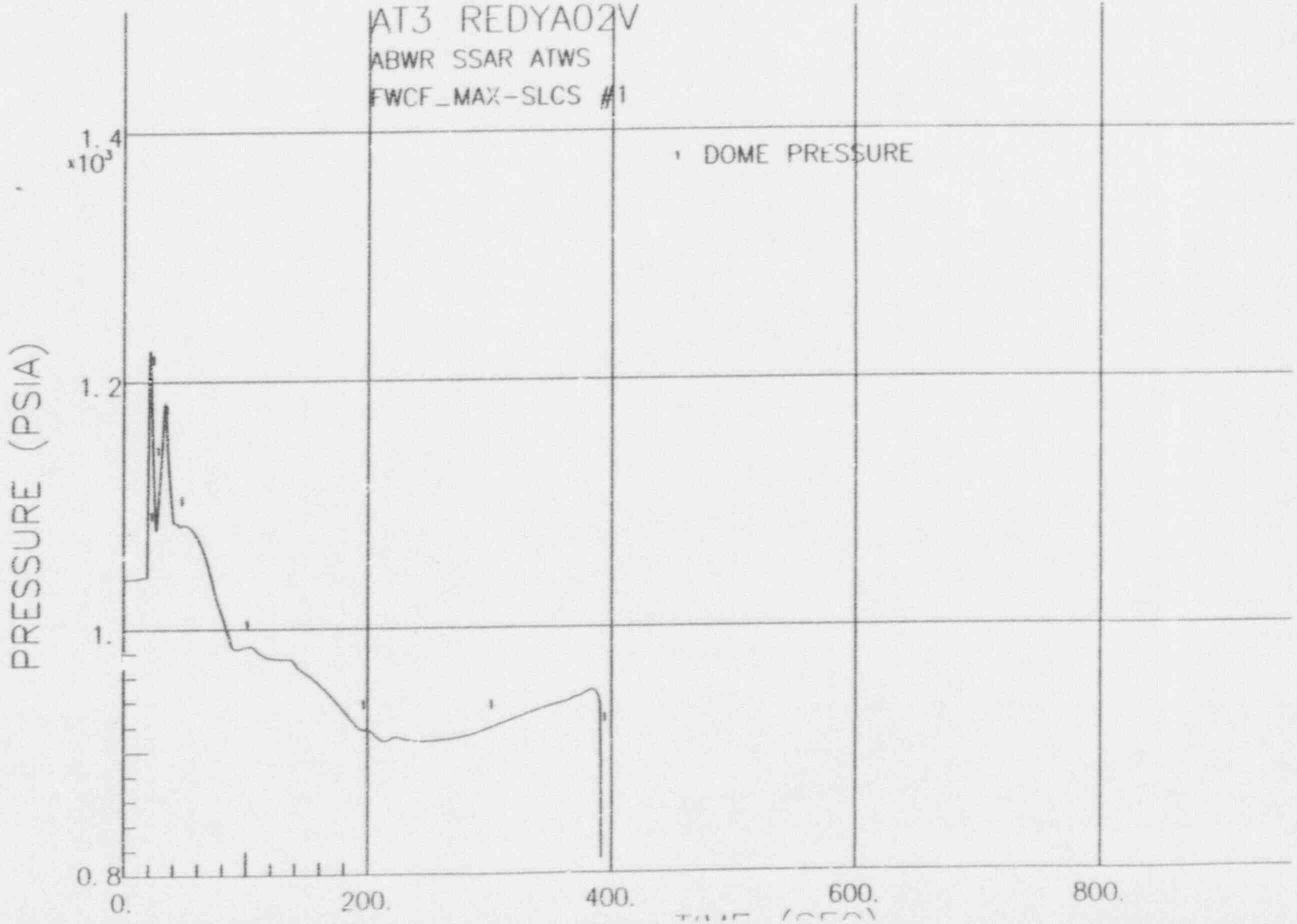


Figure 15E.6.7-10. Feedwater Controller Failure Maximum Demand, SLCS

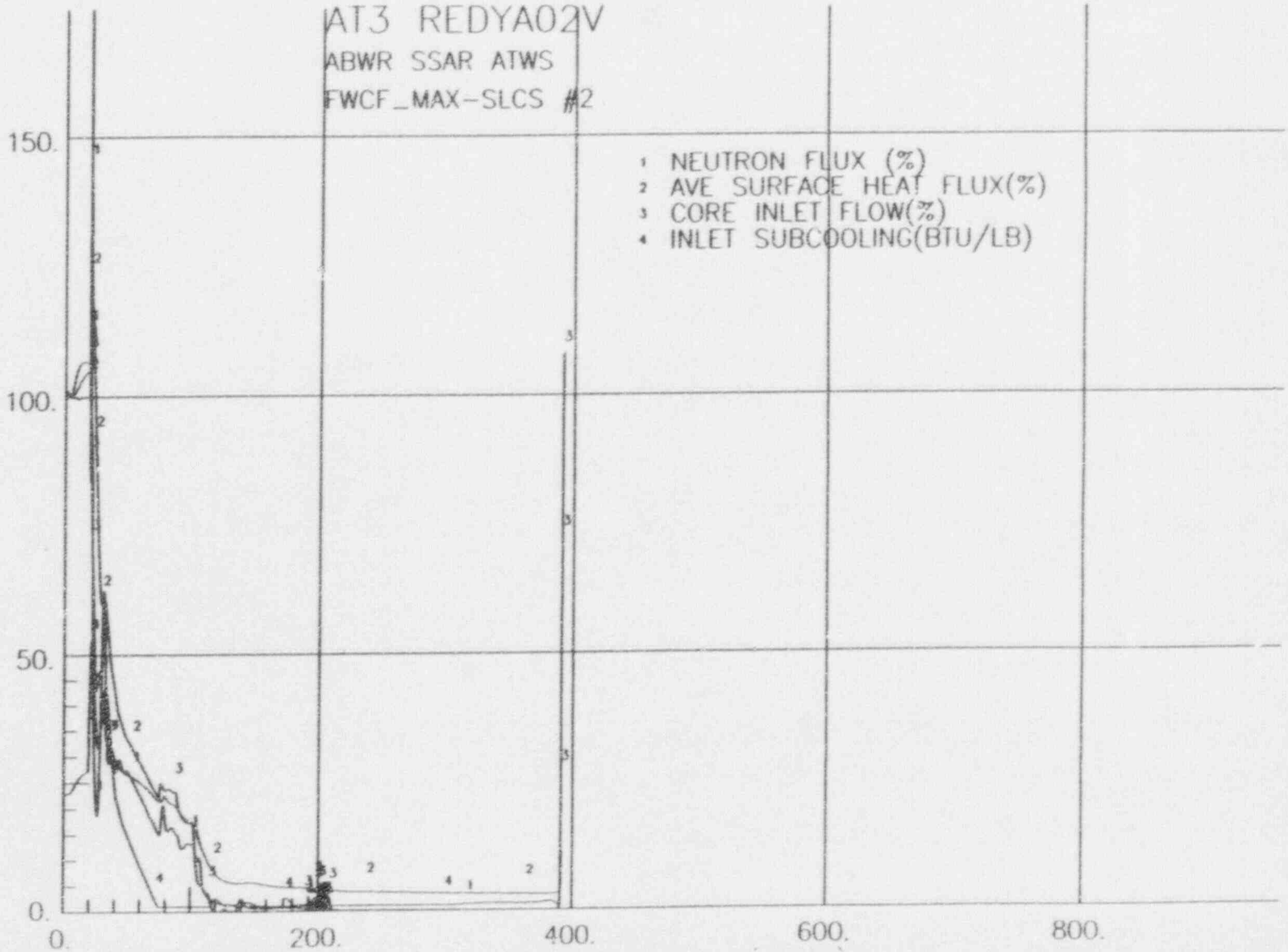


Figure 15E.6.7-11. Feedwater Controller Failure Maximum Demand, SLCS

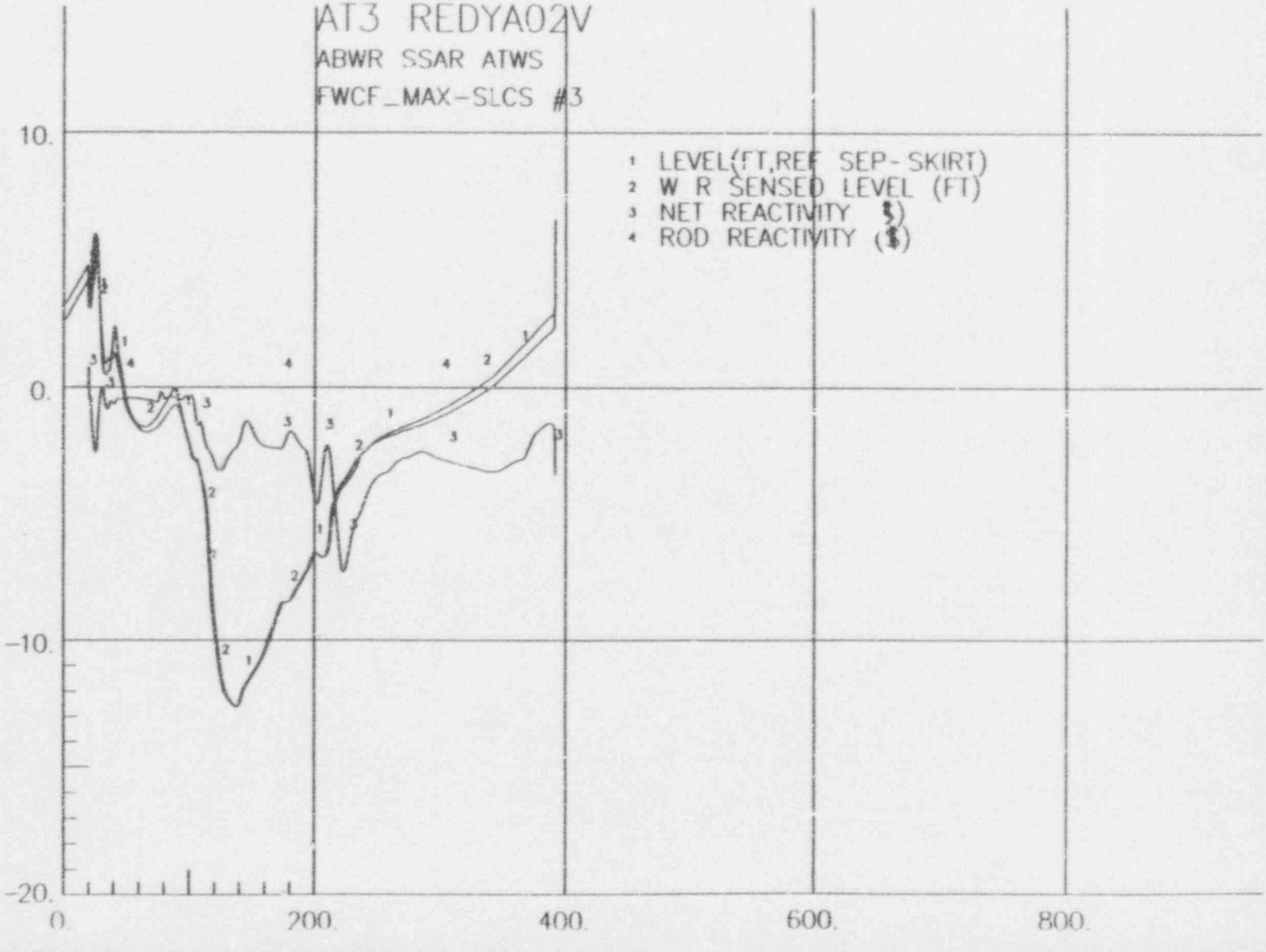
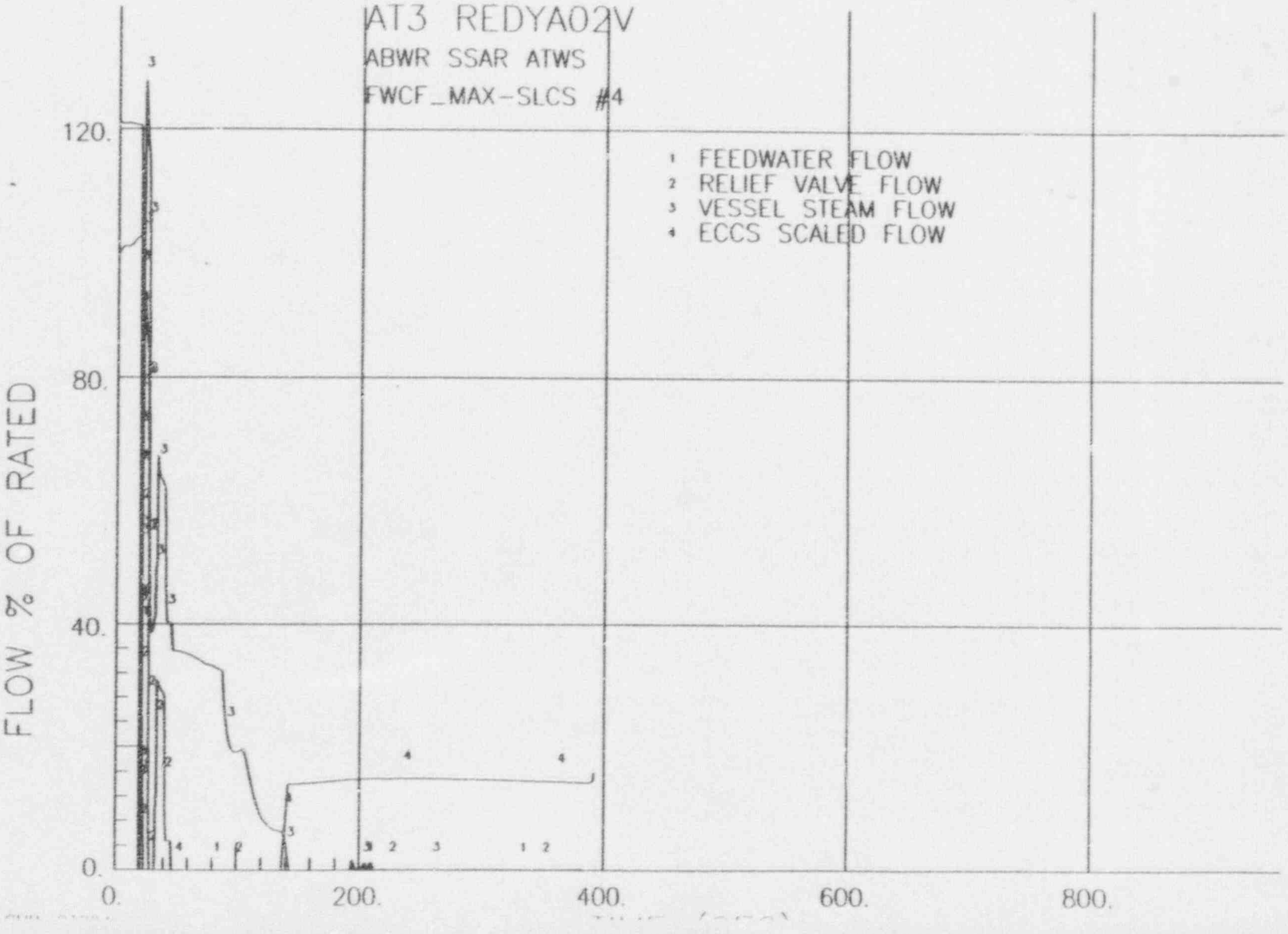


Figure 15E.6.7-12. Feedwater Controller Failure Maximum Demand, SLCS



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 1.1 kg/cm^2 margin in peak containment pressure). Therefore, an automatic SLCS injection as a backup for ATWS mitigation is acceptable.

15E.8 REFERENCE

1. *Assessment of BWR Mitigation of ATWS.* (NEDE-24222, September, 1979).