QUESTION 87

Given the following conditions:

- The plant is recovering from a reactor trip that occurred 5 days ago
- Burnup is 1000 MWD/MTU
- Boron concentration 2 hours ago, prior to commencing the startup was 1300 ppm

A manual VCT makeup has just been completed. When the makeup was completed, unknown to the crew, PMW flow continued at 100 gpm. CEAs have since been withdrawn to a position that is at 0.07% $\Delta\rho$ less than the critical rod position on the ECP when criticality is declared at a SUR of 0.3 dpm with no rod motion.

Approximately how much time elapsed from the onset of dilution until criticality AND what action is required per OP 2202, Reactor Startup ICCE?

A. 4 minutes. ICCE termination criteria are NOT met. Send criticality data to RE.

B. 8 minutes. ICCE termination criteria are NOT met. Send criticality data to RE.

C. 4 minutes. ICCE termination criteria ARE met. Trip the reactor.

D. 8 minutes. ICCE termination criteria ARE met. Trip the reactor.

K&A Rating: 004A2.10 (4.2)

K&A Statement: Ability to predict the impact of the following malf and use procedures to mitigate: Inadvertent boration/dilution.

Key Answer: **A**

Justification (Question 87):

A. **CORRECT:**

(1) The boron concentration at criticality is equal to sample concentration (1300 ppm) plus the product of the given reactivity offset (-0.07% Δρ) and the inverse boron worth (118.7 ppm/%Δρ). [Crit Boron (**1291.691**) = Sample Boron (1300) + (negative 0.07%Δρ * IBW 118.7 ppm/%Δρ)].

(2) The quantity of water to effect the concentration change is given by OP 2208 formula, VOL = 62,490 * Ln(Ci/Cf). [62,490 * Ln(1300/1291.691) = **401 gallons**].

(3) The time to effect the necessary concentration change is given by dividing the volume of water by the volumetric flow rate of water addition. [401 gals / 100 gals/min = **4 min**].

None of the actions in OP 2202 Attachment 5 Conditional Actions are required. Criticality occurred well within the + 0.5% Δρ band. This is not a direct lookup. The calculations require use of multiple references and the calculation methodology is not provided in the references. While an inadvertent dilution during startup is a serious reactivity management concern, it does not meet criteria for ICCE termination as listed in OP 2202 Attachment 8.

B. **Incorrect:** Wrong time.
Plausible: Applicant may make a calculation error.

C. **Incorrect:** Wrong action. The action listed is not consistent with that associated with meeting ICCE termination criteria.
Plausible: Applicant may think ICCE criteria are met and that the given action is required.

D. **Incorrect:** Wrong time, wrong action. The action listed is not consistent with that associated with meeting ICCE termination criteria.
Plausible: Applicant may make a calculation error. Applicant may think ICCE criteria are met and that the given action is required.

SRO Only Justification: This question is SRO only as it requires assessing plant conditions and then selecting a procedure or section of a procedure to mitigate, recover or with which to proceed. The question cannot be answered by solely knowing systems knowledge, immediate operator actions, AOP or EOP entry conditions, or the purpose, overall sequence of events, or overall mitigative strategy of a procedure.

References: OP2202 Rev 022-01 Att 5
OP2208 Rev 015-01Att 4
RE Curve Book Cycle 23 Rev 000

Student Ref: OP2208 Attachment 4
RE Curve Book RE-F-02 (Pg 41 of 42 only)

Learning Objective:

Question Source: New

Question History: New

Cognitive Level: Memory/Fundamental Knowledge:
Comprehensive/Analysis: X

10CFR55: 43(b)(6) Procedures and limitations involved in initial core loading, alterations in core configuration, control rod programming, and determination of various internal and external effects on core reactivity

Comments (Question 87):
The key assumption made in calculating the duration of the inadvertent dilution in this question, is that the PMW sent to the VCT at 100 gpm is immediately injected into the RCS at that same rate. Although it is possible to dilute to the VCT at a flow rate of over 100 gpm, in order for any water in the VCT to get into the RCS, it must be pumped there using the system's Charging Pumps. The water can only leave the VCT for injection into the RCS at a rate conducive to the number of Charging Pumps running at the time. Each positive displacement Charging Pump is capable of injecting at a rate of 44 gpm, regardless of VCT or RCS conditions. Although the system has three Charging Pumps, by procedure no more than two are allowed to be running at any one time unless abnormal plant conditions exist, which they do not in this question. Therefore, assuming two Charging Pumps are operating, the diluted water in the VCT can only be pumped into the RCS at a maximum flow rate of 88 gpm.
Further delaying the impact of this dilution is the initial boron concentration of the water presently flowing through the VCT. If two Charging Pumps are operating pumping 88 gpm into the RCS, then to maintain the volume in the RCS constant, approximately 84 gpm must be flowing from the RCS to the VCT through Letdown (4 gpm enters the VCT as RCP seal bleedoff flow). The 100 gpm of pure water entering the VCT will first mix with the 88 gpm of RCS flow, which is at the RCS boron concentration of 1300 ppm. For this reason, any affect on RCS boron concentration by a blended makeup to the VCT is substantially dampened by the constant flow of RCS into the VCT. That is precisely why the VCT is the preferred destination for any RCS makeup requirements. The effect is delayed over a long period of time to allow the operators to take corrective action should a problem occur. Letdown flow will not change until the VCT reaches a level of approximately 88%, when Letdown flow is then diverted from the VCT to the Radioactive Clean Waste System. From this point until the dilution is complete, the only water entering the VCT will be the PMW flow. The delay caused by Letdown and makeup water mixing in the VCT also substantially complicates any attempt to calculate the time it will take for the RCS to be impacted by water injected into the VCT.
The attached graphs are plots taken from the simulator for two evolutions. The first involved injecting 400 gallons of PMW into the VCT at approximately 100 gpm (it actually went in a little faster, taking only about 3.5 minutes to complete). Graph #1 is a plot of VCT boron concentration changing as the PMW is injected, and continuing to show the effect of Letdown flow once the dilution has stopped at 400 gallons. The second graph depicts the effect on the RCS boron concentration as the VCT mixture begins to enter the RCS. To get a better comparison of the time delay, both data points were plotted together on Graph #3. Note that the RCS boron concentration does not start to drop until the 400 gallon dilution is almost complete, and even after over 20 minutes, RCS boron has only dropped about 5 ppm. The question assumes it would drop 9 ppm in four minutes, with an 8 minute time frame being used as a distracter. Both choices are clearly not even close to the actual time it would take for the 400 gallons to drop the RCS 9 ppm.
To further prove this point, a dilution of 800 gallons was performed and plotted in the identical manner. As shown in Graph #6, after approximately 16 minutes the RCS has only dropped about 5 ppm. This time frame was a little shorter than that required for a 400 gallon dilution because with an 800 gallon addition the VCT overfilled and Letdown flow was temporarily diverted. During that time only pure water was entering the VCT, causing a delay in VCT boron concentration recovery and a slightly faster drop in RCS boron concentration.
In conclusion, even if the VCT were to somehow be instantaneously filled with pure water (well beyond any procedure, design analysis, or question basis), it would still enter the RCS at a maximum rate of 88 gpm. Therefore, question #87 as given to the candidates has no valid answer and should be disregarded in any and all grading of the exam. - Bob Cimmino (Millstone Unit 2 NRC Exam Developer)

MILLSTONE POWER STATION
SYSTEM OPERATING PROCEDURE

Charging Pumps

OP 2304E

Rev. 018-03

STOP THINK ACT REVIEW

Approval Date: 8/28/14

Effective Date: 8/28/14

Level of Use
Continuous

1. PURPOSE

1.1 **Objective**

This procedure provides instructions for operation of charging pumps.

1.2 **Discussion**

During normal operating conditions, one charging pump is running to provide makeup water to the RCS. Following an outage, one or more charging pumps may be used to refill the RCS.

Additional charging pumps are placed in operation when any of the following conditions exist:

- Higher purification flow is desired
- Significant changes in RCS boron concentration are to be performed
- Specific operating conditions dictate

A charging pump operating and maintenance philosophy to be followed under normal operating conditions has been developed to support PM frequencies tailored specifically for each pump. "C" charging pump will be the lead pump, accruing the vast majority of run hours. It will be in service at all times, unless deficiencies preclude its operation or surveillance activities require another pump to be operated. "A" charging pump will be the first backup pump and will be run preferentially when "C" charging pump is not available, when two charging pump operation is required, or when surveillance activities require. "B" charging pump will be the second backup pump and maintained in "PULL–TO LOCK." It will be run when three charging pump operation is required, when two pump operation is required and "A" or "C" charging pump is not available, or when surveillance activities require.

A packing leakage strategy has also been established. Charging pumps with primary or secondary packing leakage less than 0.125 gpm are acceptable for continued use. When packing leakage exceeds 0.125 gpm but is less than 0.25 GPM the pump may continue to be operated, but a Condition Report shall be written to repair the leakage within seven days. A pump with packing leakage exceeding 0.25 gpm shall not be operated unless no other pumps are available, and isolation to minimize radwaste production should be considered until such time as packing can be replaced.

The "Normal After Close" position is when the pump switch is placed to "START" and allowed to spring return to neutral (red flag).

The "Normal After Trip" position is when the pump switch is placed to "STOP" and allowed to spring return to neutral (black flag).

4.2 **Normal Charging Pump Operation**

4.2.1 IF abnormal plant conditions call for the operation of all three charging pumps, AND RCS pressure is greater than 2,100 psia, THEN OBTAIN SM concurrence.. ② ③

CAUTION

1. Any longer than momentary interruption in charging flow through the regenerative HX results in letdown flow being isolated on high letdown temperature at the outlet of regenerative HX.
2. This section is written with the assumption that charging and letdown are in service in a normal configuration with one charging pump operating.

4.2.2 IF aligning or starting "A" or "C" charging pump AND WHEN possible, PERFORM the following (−25′6″ Aux Bldg):

a. Manually START associated plunger flush pump and ALLOW to operate for at least 1 minute.

b. OBSERVE the following for running flush pump:

- *No* abnormal noise or vibration
- Normal seal lube tank level (greater than $^1/_2$ full) and pump pressure (6 to 12 psig) (PI−234X or PI−234Z)
- Seal lube flow indicated in sightglass (FI−234X or FI−234Z)

4.2.3 As required, Refer To the following to ENSURE charging pump to be started has a suction and discharge flow path.

- OP 2304C−002, "Boric Acid Valve Lineup"
- OP 2304E−002, "Establishing a Flowpath From VCT to HPSI System"

4.2.4 IF manually starting charging pump, REMOVE desired charging pump from "PULL−TO−LOCK" and PLACE in "START" ("Normal After Close" position) (C−02).

NOTE

When "CHG PP BACK–UP CNTL" switch position is changed, the running charging pump stops and another pump automatically starts.

4.2.5 As desired, Refer To Table– 2 and ALIGN charging pump(s) as desired (C–02):

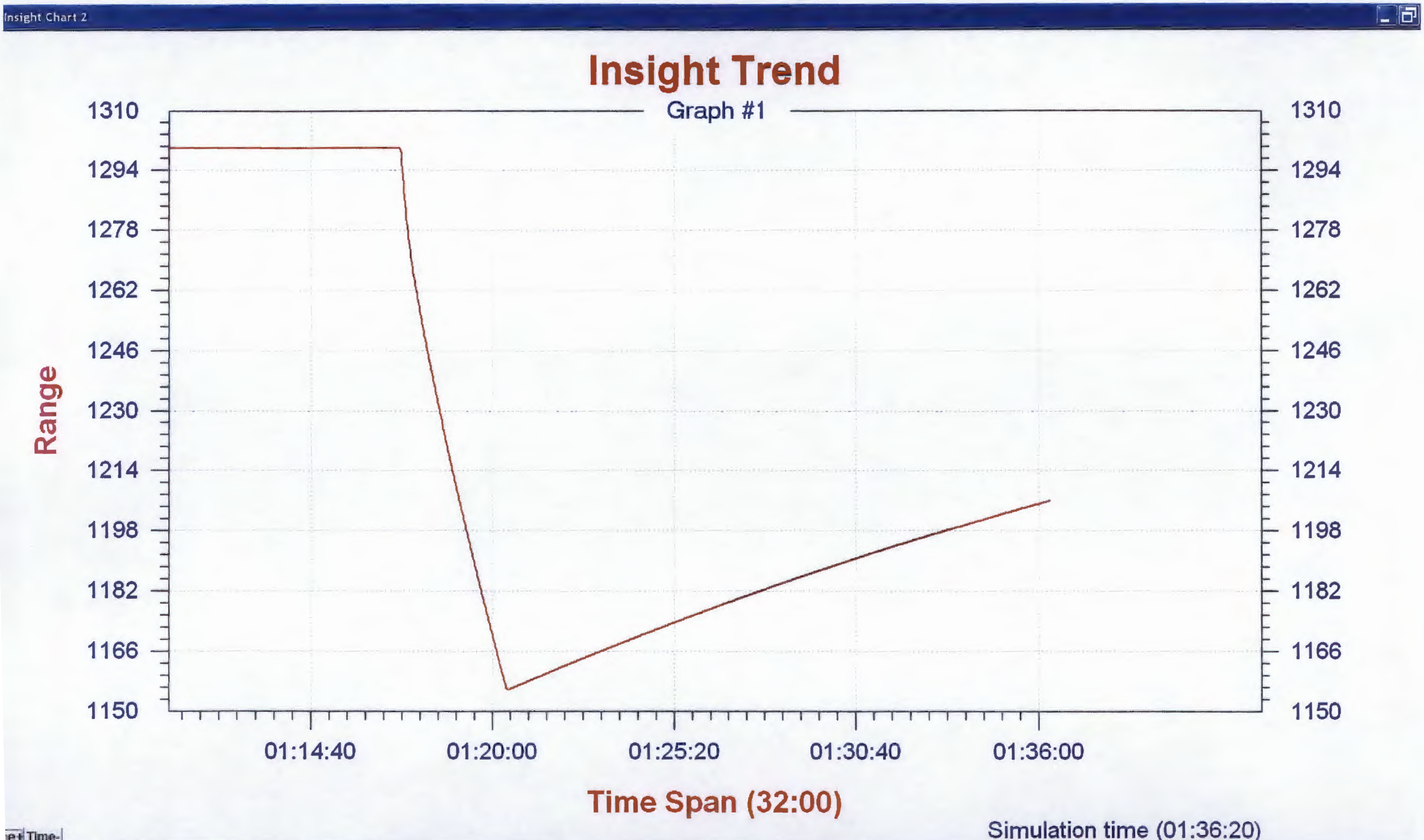
Table– 2, Charging Pump Combinations		
IF desired to shift to the following charging pump(s) operating,	**POSITION "CHG PP BACK–UP CNTL" switch to:**	**and PLACE "CHG PP OVERRIDE" switch to:**
"A"	"2 & 3"	"AUTO"
"B"	"3 & 1"	
"C"	"1 & 2"	
"A" and "B"	"2 & 3"	"LEV 1"
"B" and "C"	"3 & 1"	
"A" and "C"	"1 & 2"	
"A," "B," and "C"	"1 & 2"	"LEV 2"

NOTE

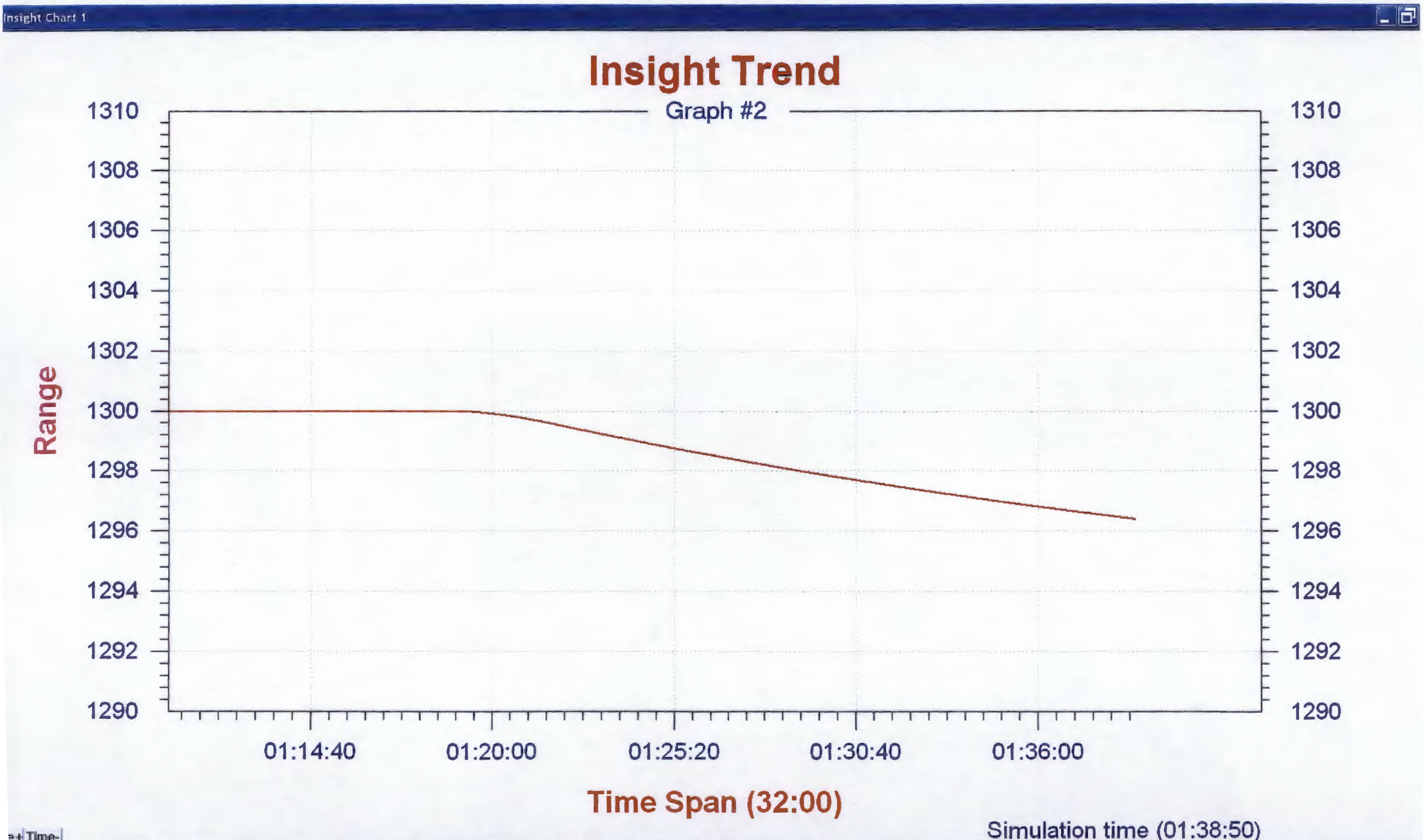
If RCS pressure is less than 1,000 psia, a portable flowmeter installed at FP–9869 must be used for an accurate measurement of charging header flow.

4.2.6 ENSURE the following:

- Desired charging pump(s) stop(s) (as applicable) and selected charging pump(s) automatically start(s) (C–02)
- "CHG HDR PRES, PI–212" (C–02) is above RCS pressure
- "CHG HDR FLOW, FI–212" (C–02) or local flow indicator stabilizes at appropriate flow (44 gpm for each pump operating)
- *No* respective operating charging pump alarms remain lit (C–02).



Color	Name	Description	Value	Units	Minimum	Maximum
	cvbvct	24.25 VCT BORON CON...	1206	PPM	1150	1310



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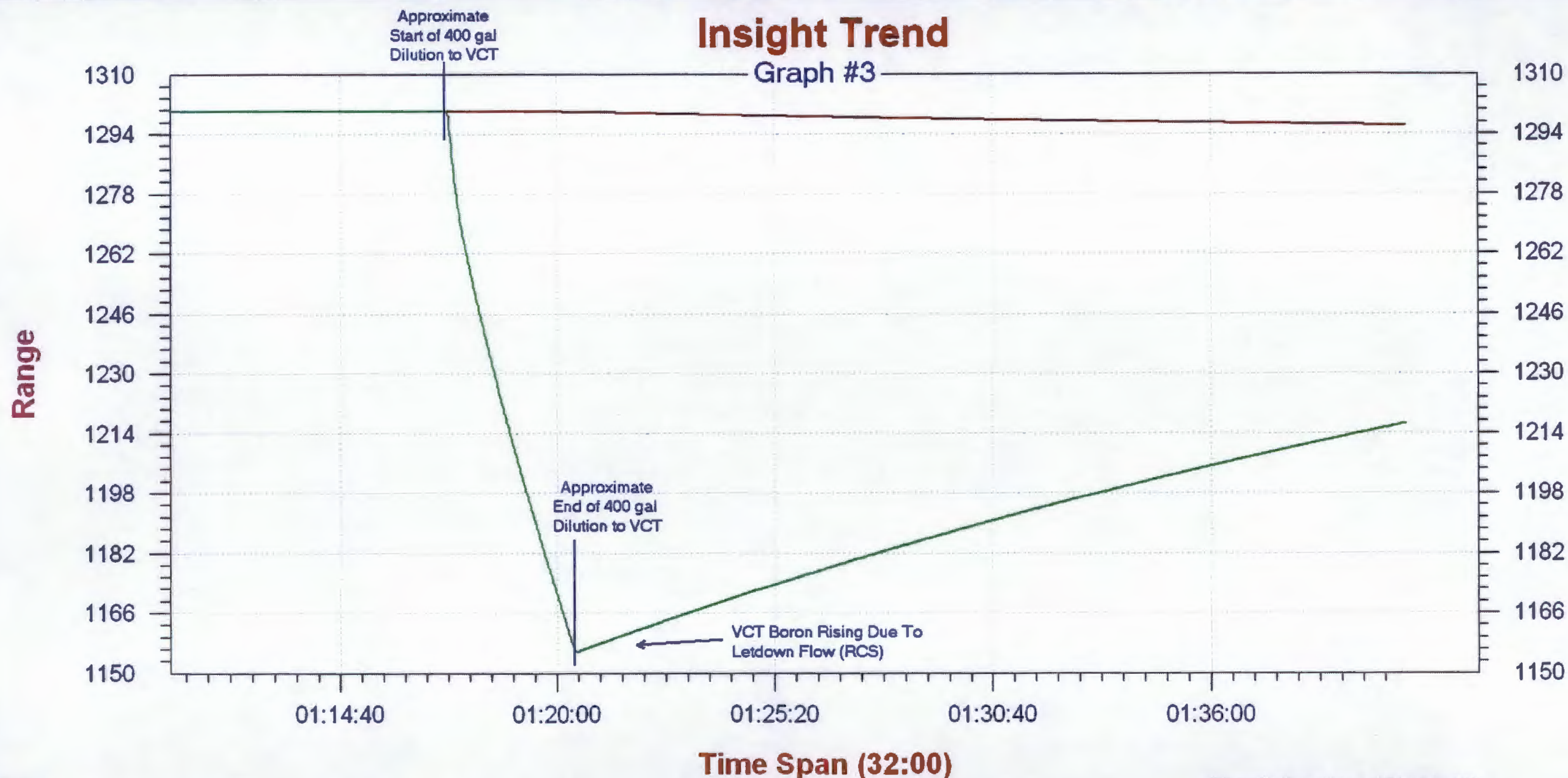
r	Name	Description	Value	Units	Minimum	Maximur
	rbcore	RCS Boron	1296	PPM	1290	1310

nsight Chart 3



ne+ Time-

or	Name	Description	Value	Units	Minimum	Maximur
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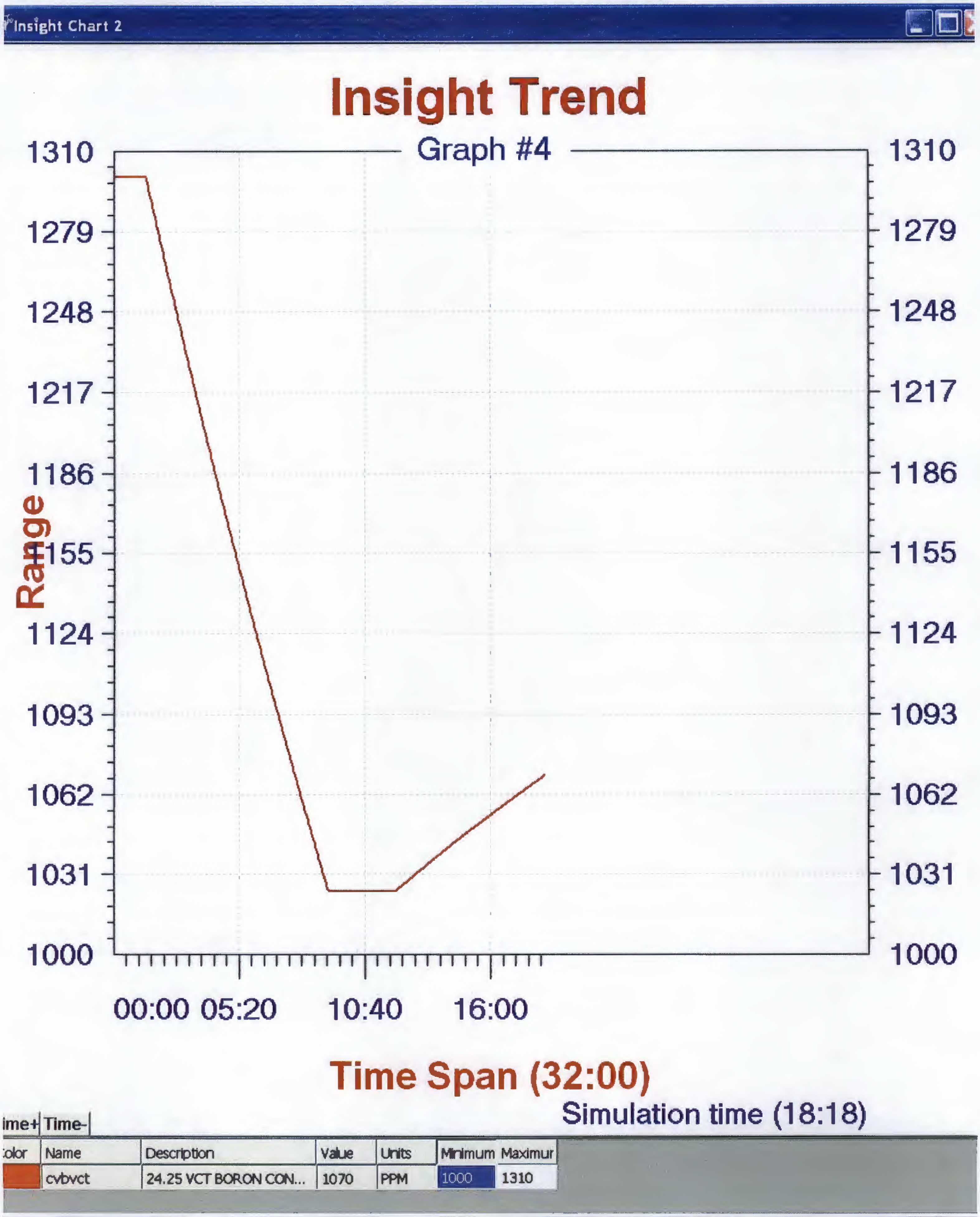
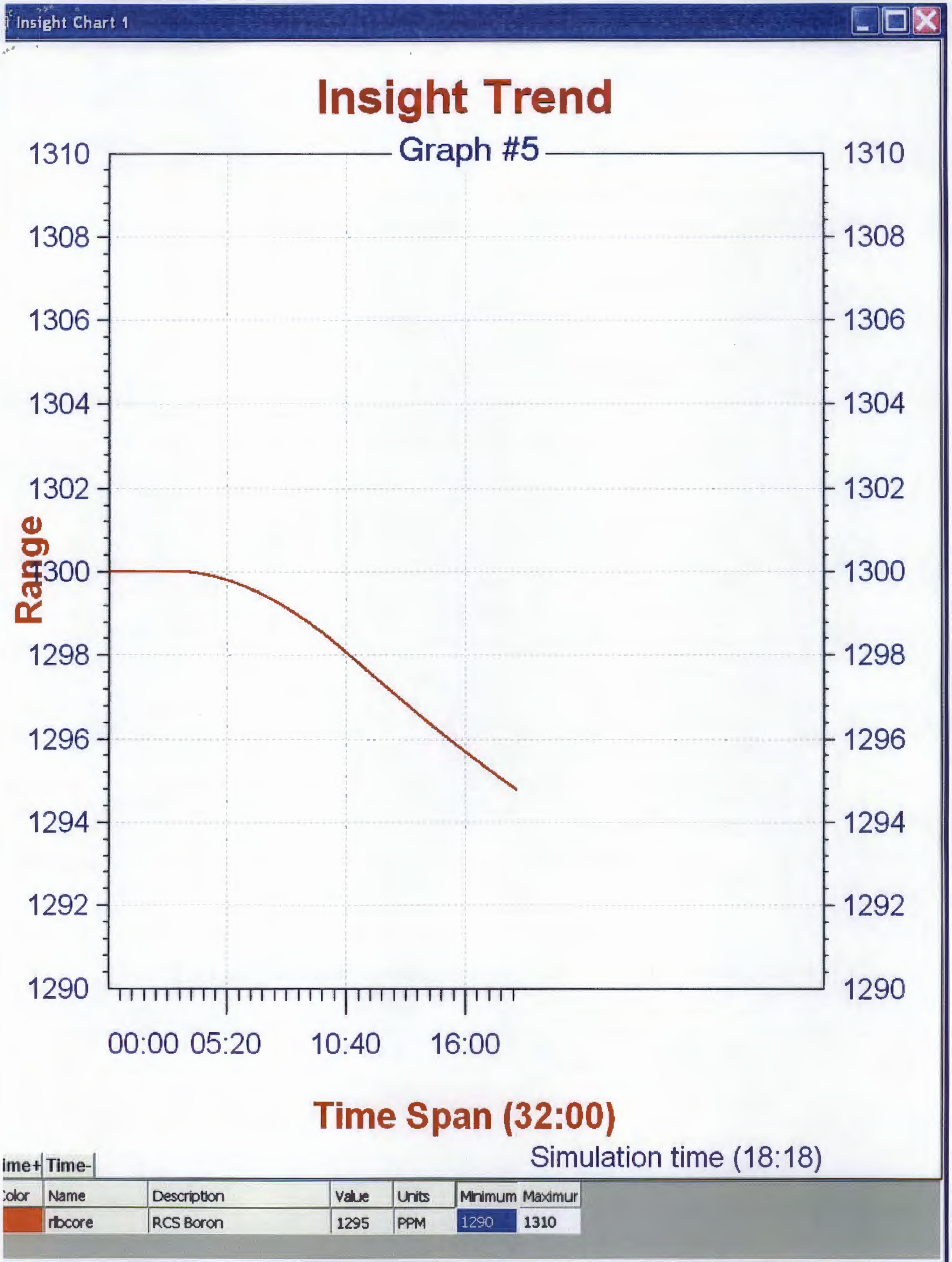
	cvbvct	24.25 VCT BORON CON...	1217	PPM	1150	1310



:olor	Name	Description	Value	Units	Minimum	Maximur
	cvbvct	24.25 VCT BORON CON...	1070	PPM	1000	1310


Insight Chart 1
Insight Trend
Graph #5
1310
1308
1306
1304
1302
1300
1298
1296
1294
1292
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Range
00:00 05:20 10:40 16:00
Time Span (32:00)
Simulation time (18:18)
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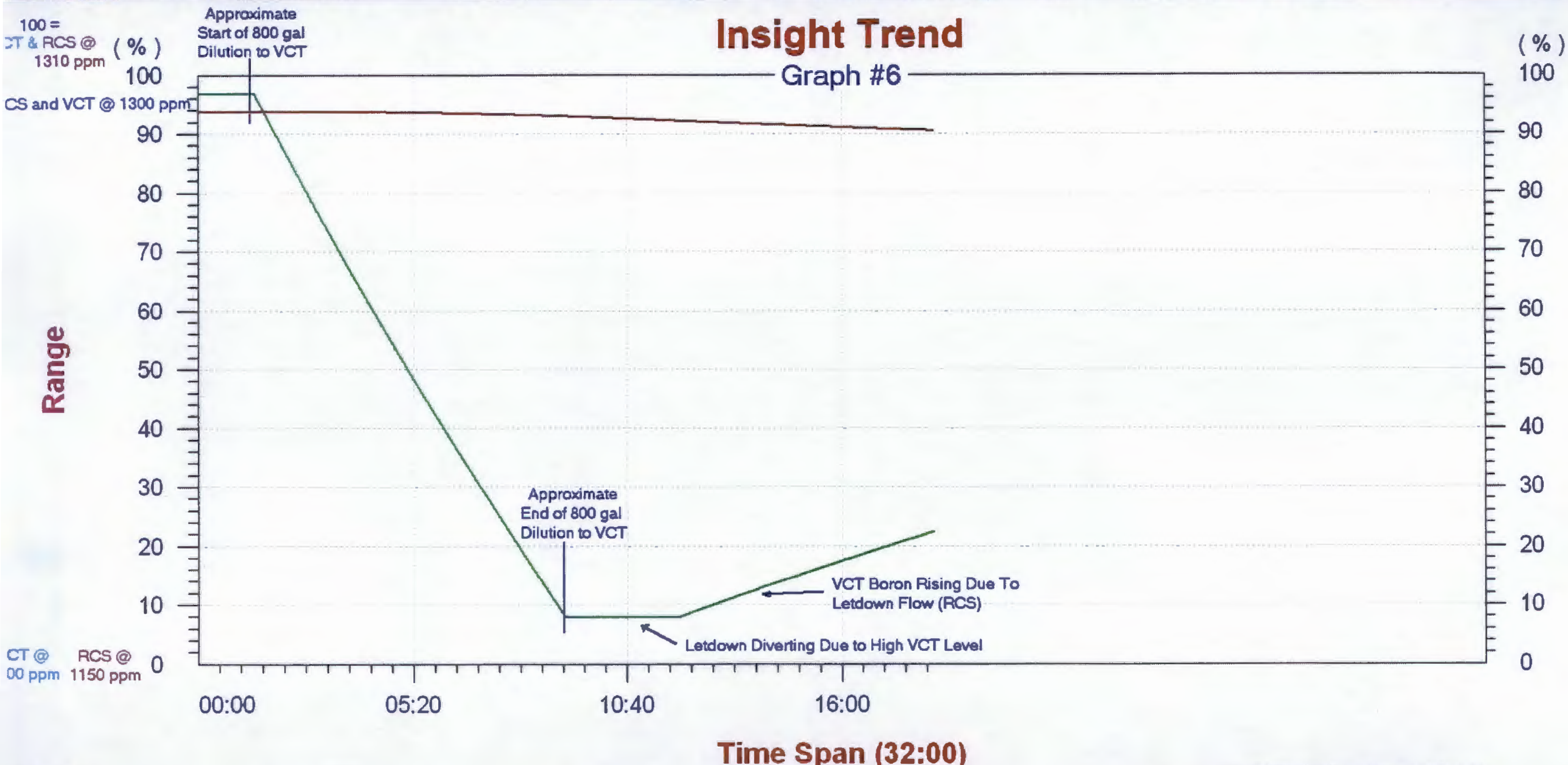
rbcore RCS Boron 1295 PPM 1290 1310

nsight Chart 3



Simulation time (18:18)

ie+ Time-

or	Name	Description	Value	Units	Minimum	Maximum
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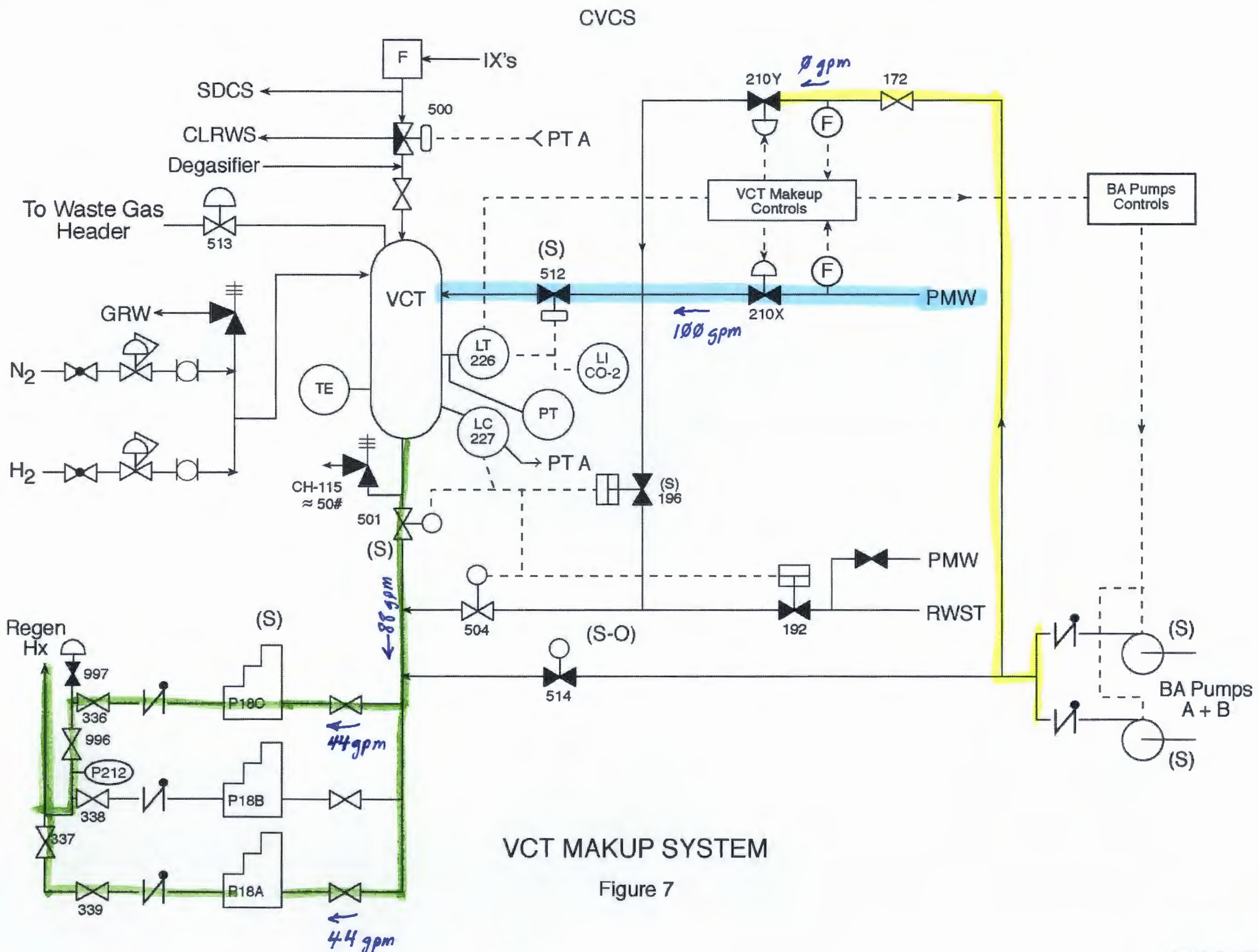
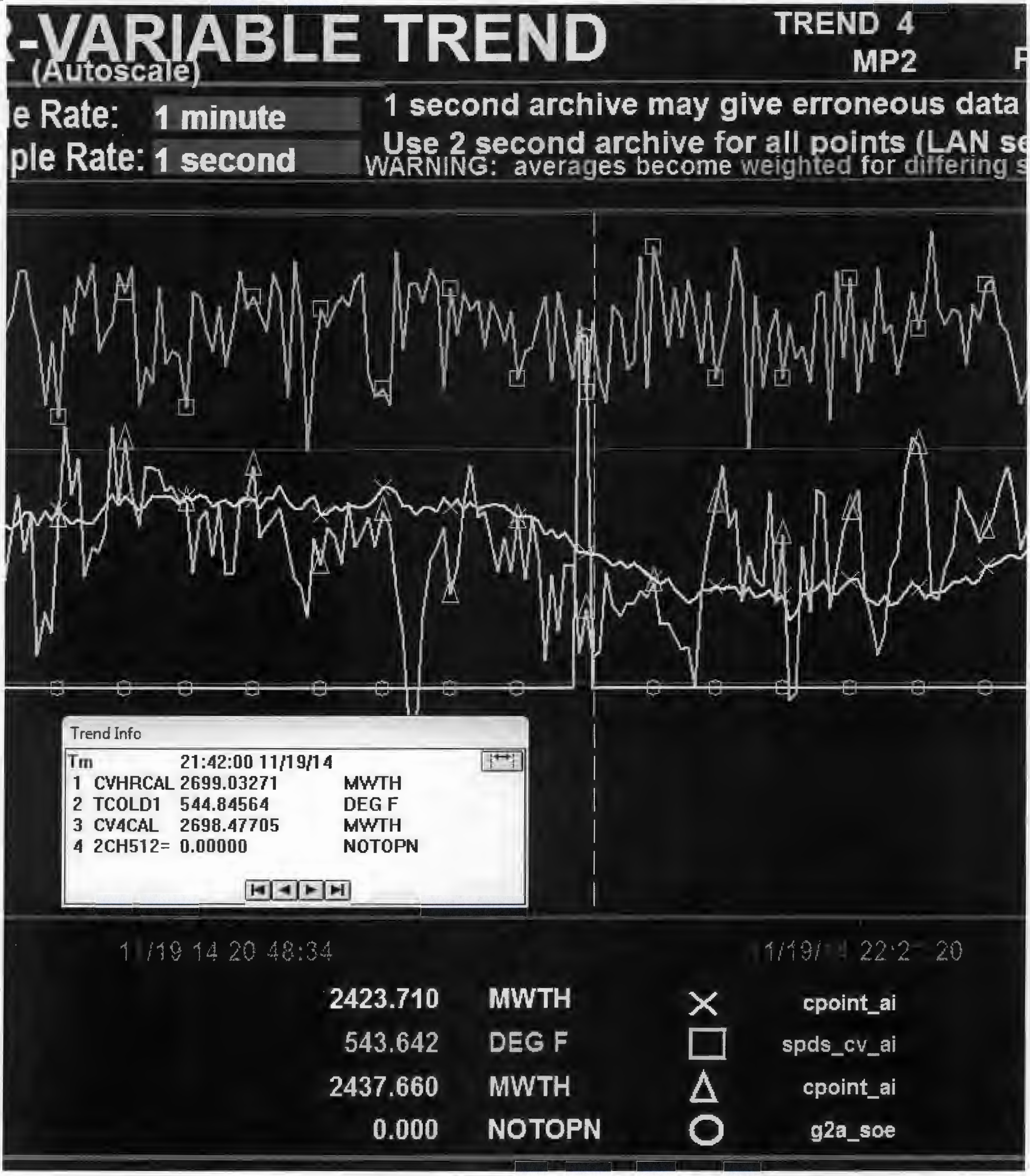
	cvbvct	24.25 VCT BORON CON...	1070	PPM	1000	1310



VCT MAKUP SYSTEM

Figure 7

Graphics No.: JB060A


-VARIABLE TREND
(Autoscale)
TREND 4
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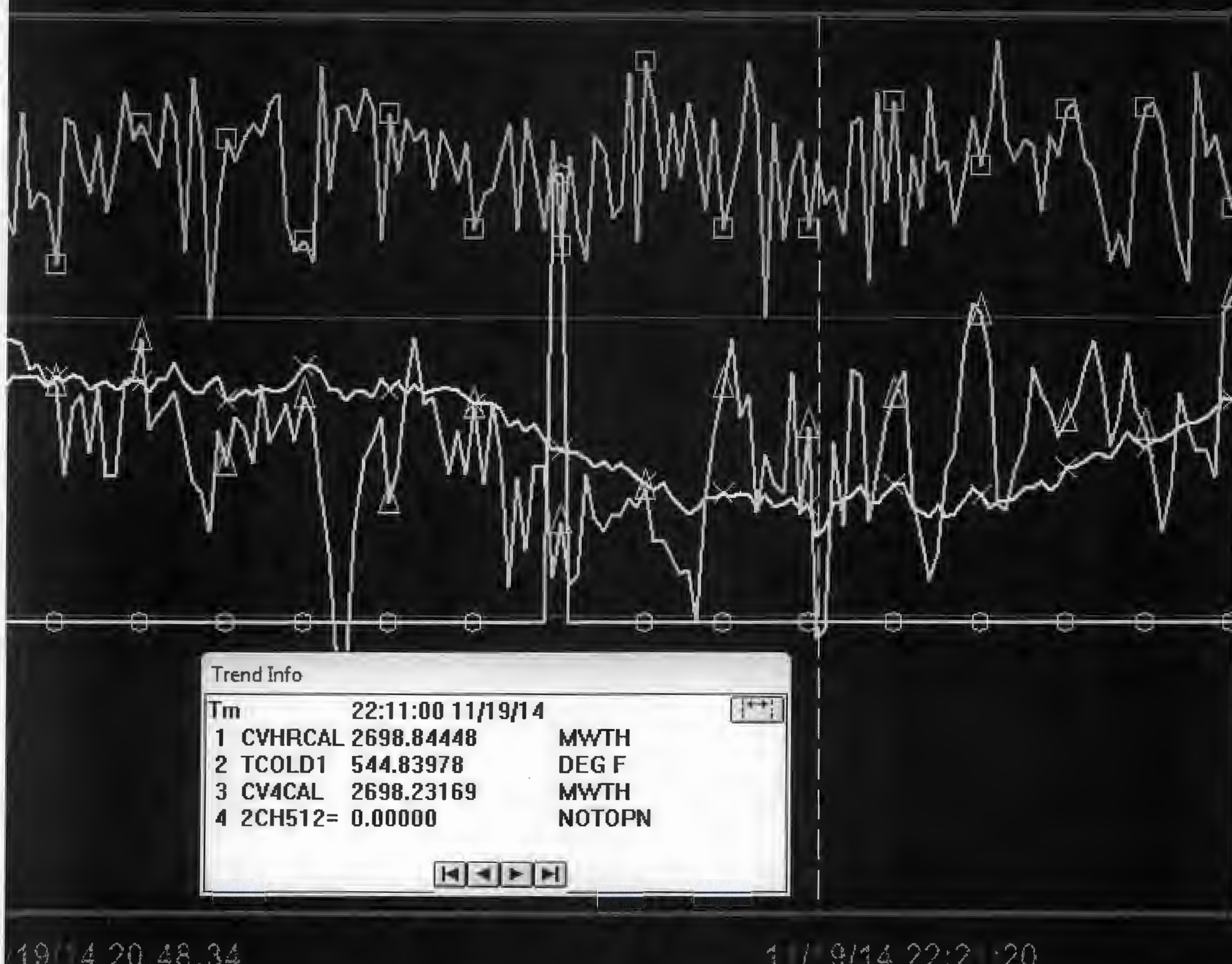
le Rate: 1 minute
ple Rate: 1 second
1 second archive may give erroneous data
Use 2 second archive for all points (LAN se
WARNING: averages become weighted for differing s
Trend Info
Tm 21:42:00 11/19/14
1 CVHRCAL 2699.03271 MWTH
2 TCOLD1 544.84564 DEG F
3 CV4CAL 2698.47705 MWTH
4 2CH512= 0.00000 NOTOPN
2423.710 MWTH cpoint_ai
543.642 DEG F spds_cv_ai
2437.660 MWTH cpoint_ai
0.000 NOTOPN g2a_soe

RIABLE TREND | TREND 4 | 21-NOV-14
ale) | MP2 | Page 1 of 1

1 minute | 1 second archive may give erroneous data
1 minute | Use 2 second archive for all points (LAN server)

WARNING: averages become weighted for differing sample rates



2428.334	MWTH	×	cpoint_ai
543.611	DEG F	□	spds_cv_ai
2441.067	MWTH	△	cpoint_ai
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NRC Response:

The comment is accepted. Delete Q87 from the SRO exam.

The key answer assumes that a 100 gpm dilution injection rate was established directly into the RCS. However, the question stated that the inadvertent dilution was the result of a manual volume control tank (VCT) makeup. Per OP-2304C, "Make Up (Boration and Dilution) Portion of CVCS", a manual makeup to the VCT aligns makeup directly to the VCT through CH-512. As stated in the licensee's post-exam comment, the dilution flow would mix with the tank contents and then the dilute mixture would be pumped from the tank via positive displacement charging pumps to the RCS at a maximum rate of 88 gpm. This flow rate is based on the maximum normal charging configuration of 2 pumps in operation, as described OP-2304E, "Charging Pumps", Revision 018-03. Because of the location of the tank outside containment and the piping volume between the tank and the RCS, there would be a time lag before any reactivity effect could be observed.

Choices A and C (4 minutes) are incorrect. It is clear that 4 minutes is too short a time period for the stated reactivity effect to occur since it would require the entire 400 gallon dilution to enter the RCS within that time when charging pumps are pumping into the RCS at no more than 88 gpm.

Distractor Choices B and D are also incorrect. These choices state 8 minutes as the time required to see the given reactivity effect from an inadvertent 100 gallon per minute dilution into the VCT. Assuming the maximum charging flow rate for the given plant condition of 88 gpm from the VCT, a total of 704 gallons of charging flow would enter the RCS over the time period. Some of this volume (the capacity of the piping from the tank to the RCS) would be at the same boron concentration as the RCS. The remaining volume would be at a varying boron concentration less than RCS concentration because the incoming primary makeup water dilution flow will mix with tank contents before it reaches the charging pump suction.

The licensee used the Millstone Unit 2 full scope simulator to demonstrate the effect on RCS boron concentration over time from an 800 gallon dilution to the VCT, performed at a rate of 100 gallons per minute. Graphs 5 and 6 of the post exam comment submittal show that approximately 2 minutes and 45 seconds elapse from the onset of the dilution before the RCS concentration begins to vary. That corresponds to an approximate volume of 240 gallons contained within the system piping from the VCT through the charging pumps and to the RCS boundary. The 240 gallons would be at equal concentration with the RCS and would have to be displaced into the RCS before any RCS dilution begins. During the remaining 5 minutes and 15 seconds (of the presumed 8 minute continuous water makeup to the VCT given in two of the answer choices), the charging pumps would deliver no more than 462 gallons of solution from the VCT to the RCS and this solution would be at a boron concentration less than 1300 ppm but considerably greater than 0 ppm. Graph 4 shows 1025 ppm as the lowest calculated VCT boron concentration during the dilution. Graph 6 shows that the RCS concentration has only dropped by 5 ppm at approximately 16 minutes after onset of the VCT dilution. The rate of RCS concentration change shown on Graph 6 (~2 ppm every 5 minutes for the 800 gallon dilution to the VCT) indicates that the reactivity effect given in the question stem would be observed somewhere greater than 10 and less than 26 minutes

after onset of the dilution event. This time exceeds the longest time (8 minutes) provided in any of the answer choices.

On 11/21/2014 the licensee provided information from plant design documents on system piping and volume control tank geometry and information from the plant process computer on actual plant response to a recent dilution water batch makeup to the volume control tank. This information provides additional assurance, based on real plant data, that the given reactivity response would take longer than 8 minutes.

Prints show the makeup line enters the volume control tank above the mid-plane of the tank, at an elevation such that there would be approximately 2300 gallons of borated water in the tank below the makeup penetration. Graphs were provided from the plant process computer showing the response of calculated plant thermal output and of RCS temperature to a 10 gallon dilution to the VCT performed on 11/21/14. The graphs indicate at least 15 minutes elapse from the completion of a 10 gallon dilution to the VCT until the first observed core response. The dilution was performed with only one charging pump (44 gpm) in operation. The response time delay is the result of the volume of borated water already in the charging system piping combined with the mixing of the dilution flow with the contents of the VCT. Extrapolating to estimate plant time response under a two charging pump in operation (88 gpm) configuration, it would take at least 7 minutes before seeing the first core response from the dilution proposed by Q87. Two pump operation is the most limiting condition that could be assumed. Based on the design of the VCT and the associated piping, it would not be possible to dilute the RCS sufficiently under the conditions given in the question stem to effect the necessary RCS boron concentration change within 8 minutes.

Complex calculations that are well beyond those anticipated by the question authors would be required to determine the exact time at which the given reactivity effects would be observed. Further, neither operators nor license applicants are expected to have the the information and computational skills necessary to calculate this exact time.

This question will be deleted from the exam on the basis that neither of the times given in the answer choices is correct.