ATTACHMENT II TO IPN-98-023

GENERATION OF ALL CURVES ASSOCIATED WITH THE PRESSURE-TEMPERATURE LIMITS REPORT (PTLR)

NEW YORK POWER AUTHORITY
INDIAN POINT 3 NUCLEAR POWER PLANT
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Nuclear Engineering
CALCULATION CONTROL SHEET

Nuclear Plant: IP3 ☑ JAF ☐

CALC. NO. IP3-CALC-RCS-02444 REVISION 1
CALCULATION IS: PRELIMINARY ___ FINAL x

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PROBLEM/OBJECTIVE/METHOD
Based on approved analyses and documents, generate the curves that would be required to support Heatup/Cooldown/OPS Tech Specs for 13.3 EFPY or for a proposed PTLR

DESIGN BASIS/ASSUMPTION
See Sections 1.0 and 2.0.
The results of this calculation are valid for operation up through 13.3 EFPY only.

SUMMARY/CONCLUSIONS
Curves are generated and shown on the enclosed figures.

THIS CALC SUPERSEDES OR VOIDS CALC.# IP3-CALC-RCS-02444 Rev 0

DISTRIBUTION: C= CONTROLLED I= INFO

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CALCULATION SHEET

New York Power Authority
CALCULATION NO. IP3-CALC-RCS-02444 REVISION 1

Project N/A Page 1 of 42
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1.0 BACKGROUND AND PURPOSE

The Pressure-Temperature Limits Report (PTLR) is a document that extracts information relevant to thermal-hydraulic operation of the Reactor Coolant System (RCS) out of the Technical Specifications. Similar to the Core Operating Limits Report (COLR), the PTLR is routinely updated by NYPA personnel without requiring a Technical Specifications (Tech Specs) amendment.

There are seven (7) curves in the PTLR that represent limits on RCS temperature and pressure. This calculation creates these curves for a cumulative reactor vessel service life up to 13.3 Effective Full-Power Years (EFPY).

Revision 1 to this calculation adds instrument uncertainty to all curves except the OPS setpoint and revises the OPS setpoint curve per NRC recommendations (1997-1998). This revision identifies the source of the 13.3 EFPY curves (Reference 6.13).

2.0 ASSUMPTIONS

All calculations are based on approved documents, with the exception of ASME Code Case N-514, which has been generically approved by the NRC (the NRC does, however, require an exemption request on a case-by-case basis to use it). In order to make use of this Code Case, the licensing amendment associated with the PTLR includes an exemption request to apply it to IP3.

The heatup-cooldown analysis of record (Reference 6.1) assumes isothermal conditions in the RCS. For conservative purposes, all references to temperature in this calculation will refer to Average T-Inlet. This is colder than Tavg and is therefore conservative for low-temperature pressure calculations.

Except for the OPS setpoint curve, all of the curves calculated in this document include allowance for instrument uncertainties. The uncertainties used in this calculation, along with the curves to which they apply, are shown on the following page. **For future revisions to these curves, it is important to note and reverify the applicability of instrument uncertainties assumed in the calculation of the curves.**

SUMMARY OF INSTRUMENT UNCERTAINTIES USED IN THIS DOCUMENT

Parameter and Affected Instruments	Uncertainty Assumed in This Calc	Applicable Section(s)
Wide Range RCS Temperature	30°F	3.1, 3.2, 3.3.3.3
RCS Pressure: Lower Narrow Range (PT-413,-433,-443)	43 psi (See Note below)	3.1, 3.2, 3.5, 3.6
RCS Pressure: Upper Narrow Range (PT-455, 456, 457, 474)	30 psi (See Note below)	3.1, 3.2
RCS Pressure: Wide Range (PT-402, 403)	108 psi (See Note below)	3.1, 3.2
OPS Enable Temperature	30°F	3.3.3, 3.4
Pressurizer Level	7%	3.5, 3.6
Primary-to-Secondary ΔT	36°F	3.4

Note: The RCS Lower Narrow Range pressure instrument uncertainty is based upon a 75 psi instrument uncertainty reduced by the square root of three (i.e., 1.73), which allows for multiple indication from the three independent pressure instruments PT-413, -433 and -443. Because all three measure RCS pressure, which should be the same value for all, it is acceptable statistically to reduce the uncertainty by a factor of 1.73.

By the same token, the RCS Wide Range pressure uncertainty is based on a 153 psi uncertainty reduced by the square root of two (1.414), allowing for multiple indication from PT-402 and PT-403. Similar to the case of RCS Lower Narrow Range pressure, the uncertainty can be reduced statistically from 153 psi to 108 psi. By comparison, no statistical correction is applied to RCS Upper Narrow Range pressure instruments, which have an uncertainty of less than 30 psi. However, since 30 psi is historically the minimum allowance maintained for pressure uncertainty, it will be retained here.

Temperature uncertainty cannot be similarly reduced for multiple indication, since temperature may vary throughout the Reactor Coolant System. One cannot expect all temperature indicators to be reading the same value. However, there are other sources of conservatism in the use of temperature indication. For example, all the curves generated in this calculation (and as applied in the Technical Specifications) use the coldest T_{cold} for temperature indication, but the analyses (Reference 6.1) are based on average temperature. This alone provides for several degrees of margin. Also, the expected deviation in temperature from line to line is small compared to the total indicator uncertainty. For these reasons, the temperature uncertainty has been rounded from 31.5 degF to 30 degF. This is a very small reduction (approximately the thickness of the line on most of the curves), and use of the round number facilitates the calculation.

Instrument uncertainties are derived in References 6.15 through 6.19.

It should also be noted that this document refers to T_{inlet} as the temperature of water entering the reactor vessel. For purposes of application to the Technical Specification amendments, T_{inlet} will for this calculation be considered as equivalent to T_{cold}.

Finally, it is important to note that all curves are based on the Reference 6.1 tables for 15 EFPY, not 13 EFPY. This is because the NRC has requested that NYPA impose an additional 15% penalty on reactor vessel neutron fluence, which has been accommodated by taking the 15 EFPY data and reducing the effective service period to 13.3 EFPY (Reference 6.13).

It should also be noted that this document refers to T_{inlet} as the temperature of water entering the reactor vessel. For purposes of application to the Technical Specification amendments, T_{inlet} will for this calculation be considered as equivalent to T_{cold}.

Finally, it is important to note that all curves are based on the Reference 6.1 tables for 15 EFPY, not 13 EFPY. This is because the NRC has imposed a 15% penalty on reactor vessel neutron fluence, which has been accommodated by taking the 15 EFPY data and reducing the effective service period to 13.3 EFPY (Reference 6.13).

3.0 CALCULATIONS

The seven curves in the PTLR are:

Limitations for RCS Heatup
Limitations for RCS Cooldown
OPS Setpoint
Secondary Side Limitations for RCP Start with Secondary Side Hotter Than Primary
Pressurizer Limitations for OPS Inoperable (Up to 1 Charging Pump Operable)
Pressurizer Limitations for OPS Inoperable (Up to 3 Charging Pumps and/or 1 SI Pump Operable)
RCS Pressure Limitations for Hydrostatic Testing

The values for these curves are developed one at a time in the sections that follow.

3.1 Limitations for RCS Heatup

The heatup curves for 13.3 EFPY are taken directly from Tables 31, 32 and 33 of Reference 6.1 for heatup rates of 20 degF/hr, 40 degF/hr and 60 degF/hr. These data are shown on Table 1 of this calculation.

The attached table includes no allowance for instrument uncertainty. Therefore, in order to create the applicable figure, the data must be increased by 30 degF and reduced by a pressure margin appropriate for the instrument (See note on Section 2.0). In addition, a penalty is imposed to allow for Reactor Coolant Pump and Residual Heat Removal Pump operation at low temperatures, similar to that which has been applied historically to the OPS curve (See Section 3.3.3.4 and Table 3B). The resultant curve is shown on Figure 1. In accordance with NRC requirements, the applicable reactor vessel service life, material specs, procedural limits on heatup rate and limiting RT_{NDT} are included on the figure.

3.2 Limitations for RCS Cooldown

The cooldown curves for 13.3 EFPY are taken directly from Table 30 of Reference 6.1 for cooldown rates of 0 degF/hr (isothermal), 20 degF/hr, 50 degF/hr, 60 degF/hr, 80 degF/hr and 100 degF/hr. These data are shown on Table 2.

The attached table includes no allowance for instrument uncertainty. Therefore, in order to create the applicable figure, the data must be increased by 30 degF and reduced by a pressure margin appropriate for the instrument (See note on Section 2.0). In addition, a penalty is imposed to allow for Reactor Coolant Pump and Residual Heat Removal Pump operation at low temperatures, similar to that which has been applied historically to the OPS curve (See Section 3.3.3.4 and Table 3B). The resultant curve is shown on Figure 2. In accordance with NRC requirements, the applicable reactor vessel service life, material specs, procedural limits on heatup rate and limiting RT_{NDT} are included on the figure.

3.3 OPS Setpoint Curve

This figure provides several pieces of information:

- the limiting pressure as a function of temperature for OPS actuation (i.e., OPS setpoint);
- the OPS enable temperature;
- the temperature limitations for Reactor Coolant Pump (RCP) operation, and;
- the temperature to which the RCS must be heated per (proposed) Tech Spec 3.1.A.8.c.(2) if the OPS is inoperable.

This figure also verifies that the OPS protects the Residual Heat Removal (RHR) System from overpressurization at cold shutdown conditions.

The intent and function of the OPS (Low Temperature Overpressurization Protection System, also known as the LTOPS) is to prevent potential damage to the reactor vessel that might occur during RCS pressure excursions at low temperatures.

The OPS setpoint is determined (per ASME Code Case N-514, Reference 6.2 and the existing NYPA OPS analysis, Reference 6.3) by:

1. starting with the 10CFR50 Appendix G curve;
2. increasing the limiting pressure on this curve by 10%;
3. adding a 50 degF penalty to allow for temperature differences between the vessel and the instrumentation (this is also used to support RCP start with secondary side hotter than primary);
4. adding a 44 psi penalty to compensate for pressure overshoot;

5. adding an additional pressure penalty to compensate for the static and dynamic head from RHR and Reactor Coolant Pump operation; and then

6. identifying an absolute upper limit for the OPS setpoint, regardless of temperature.

Finally, the curve must be evaluated to identify the temperature(s) for:

- the minimum temperatures for allowable operation of 1, 2, 3 or 4 RCPs;
- the OPS enable temperature, and;
- the temperature to which the RCS must be heated with OPS inoperable.
- Also, it is necessary to confirm that the OPS, when functional, will also protect Residual Heat Removal (RHR) system piping from overpressure when the RCS and RHR systems are below 200°F.

IN SUMMARY, THE OPS CURVE IS A BASIC PRESSURE/TEMPERATURE LIMIT CURVE MODELED ON THE APPENDIX G CURVE AND ADJUSTED TO ALLOW FOR THE DESIGN BASIS HEAT INPUT EVENT AND MASS INPUT EVENT .

The complex calculational process that generates this curve is shown in detail in Sections **3.3.1** through **3.3.3,** which follow:

3.3.1 Establishment of the App. G Curve

The Appendix G curve upon which the OPS curve is based is found on Table 2 and consists of the isothermal cooldown curve. This curve is then adjusted to incorporate pressure and temperature penalties as identified in the following sections.

NOTE: The lowest RCS temperature used in this analysis is 50 degF. This is because of the limitation in Reference 6.14 requiring a minimum boltup temperature of 60 degF. The 50 degF temperature limit bounds the boltup temperature requirement and is therefore valid for all conditions at which the RCS could be at pressure.

The limiting Heatup/Cooldown Curve generated above is increased by 10% as specified in ASME Code Case N-514 to establish a basic OPS setpoint curve.

Note: This is done by taking each pressure in psig and multiplying it by 1.10. This is slightly more conservative than the more rigorous method of converting pressure to psia, increasing it by 10% (i.e., multiplying by 1.10) and then converting back to psig.

3.3.2 Overshoot and Temperature Lag Penalties

A pressure penalty of 44 psi is now applied to the curve, since 44 psi is the maximum amount of "overshoot" (i.e., pressure surge subsequent to generation of an OPS overpressure signal and relief by the opening PORV) that would be encountered in an overpressure event (Reference 6.3).

In addition to the overshoot penalty, a temperature penalty of 50 degF is applied to allow for temperature lag between vessel metal temperature and RCS fluid temperature. This is applied by increasing all temperatures on the OPS curve by 50 degF.

The steps on this page are shown in tabular fashion on Table 3A.

3.3.3 Other Considerations Affecting OPS Setpoint Curve

So far we have calculated an OPS setpoint curve that allows for the effects of mass input and heat input events. In order to finish the job, there are a few more considerations that have to be included.

3.3.3.1 OPS Enable Temperature

For the first 11 EFPY of service life, the OPS enable temperature has been defined as the limiting RT_{NDT} for heatup or cooldown plus 90°F, in accordance with the requirements of Reg Guide 1.99, Rev. 2. ASME Code Case N-514 revises this setpoint to RT_{NDT} + 50°F. ABB-Combustion Engineering has performed an evaluation of the Heatup/Cooldown analysis of record (Reference 6.1) in light of the ASME Code Case. This is appropriate, since ABB-CE was the original author of the HU/CD analysis and the manufacturer of the IP3 reactor vessel.

The results of this evaluation (Reference 6.8) define the OPS enable temperature for 13.3 EFPY (i.e., 15 EFPY reduced to 13.3) of service to be no less than 289°F. Adding an allowance for instrument error of 30°F increases the OPS enable temperature to 319°F.

3.3.3.2 Absolute Maximum for OPS Pressure

ASME Code Case N-514 allows for the establishment of higher OPS setpoints than have been used in the past. Because of this, it is worth evaluating whether there is an "absolute maximum" or a "ceiling" for OPS setpoints. In other words, is there a pressure that the OPS setpoint can **never** exceed, regardless of temperature?

In fact, there is such a maximum pressure, and it stems from the heat-input scenario. As noted in Section 3.3.2 above, the heat-input analysis of record assumes a maximum ΔT of 100°F between primary and secondary systems.

For a heat-input scenario, the most limiting case comes, logically enough, at the highest temperature and pressure. For OPS, this is the **enable** temperature, defined in Section 3.3.3.1 as 319°F. The maximum allowable OPS setpoint is that pressure that limits the overshoot on a heat-input event to a maximum of 44 psi, which is the original design basis for the OPS (Reference 6.3). A supplemental report was prepared by TM Engineering (Reference 6.10) calculating maximum OPS setpoint as a function of enable temperature. That curve, which conservatively includes no instrument uncertainty, is shown on Figure 3A (increasing temperature by 30°F would raise the maximum allowable pressure. By eliminating the uncertainty allowance, the curve is by definition more limiting).

Review of this figure establishes a maximum OPS pressure setpoint of 1851 psig, for an OPS enable temperature of 319°F.

Reviewer's Note: The curve in Reference 6.10 was prepared assuming a different OPS methodology than that currently under review. Therefore the individual OPS enable temperatures selected for evaluation are different than the ones identified in Reference 6.10. The curve, however, is quite linear across the range of enable temperatures and is therefore valid for all OPS enable temperatures between 308°F and 352°F.

3.3.3.3 Heatup Requirements for OPS Inoperable

In the current OPS Technical Specifications (Section 3.1.A.8), the operators are given a choice of actions in the event the OPS becomes inoperable. One of these options is "the RCS must be heated in accordance with Specification 3.1.A.1.h(3) and maintained above 370°F." The Basis for Section 3.1.A goes on to explain why: "This temperature is that value for which the the RCS heatup and cooldown curves...permit pressurization to the setting of the pressurizer safety valves. Accordingly, with an inoperable OPS and an RCS temperature (of) 370°F, the pressurizer safety valves will preclude violation of the 10CFR50, Appendix G, curves."

According to the RCS Design Basis Document (Reference 6.11), the pressurizer safety valves open at a pressure of no greater than 2485 psig. Allowing a +3% tolerance on valve setting raises this pressure to 2560 psig. This pressure corresponds to a temperature of 381°F on the 60°F/hr heatup curve (Table 1). An additional 30°F is added for temperature instrument uncertainty.

Therefore, in the event of OPS inoperability, the heatup option shall be: "the RCS must be heated in accordance with Specification 3.1.A.1.h(3) and maintained above 411°F."

3.3.3.4 Limitations for RCP and RHR Pump Operation

The operation of Reactor Coolant Pumps (RCPs) and Residual Heat Removal (RHR) Pumps adds a pressure penalty to the RCS, caused by static head due to elevation differences and dynamic head due to pump operation. For the RCP's, this effect has been evaluated in the OPS design (Reference 6.3), and these penalties are as follows:

Number of Operating RCPs	Static/Dynamic Pressure Head
0	3.2 psi
1	8.0 psi
2	13.0 psi
3	21.4 psi
4	30.3 psi

The pressure head from the two RHR pumps (which have significantly lower flow than the RCP's) is bounded by that of 2 operating RCP's. Therefore, the presence of two operating RHR pumps is assumed to add a total of 13.0 psi to the pressure in the reactor vessel.

There are a number of ways to implement these penalties. One would be to lower the OPS setpoint curve by 30.3 psi to compensate for the pressure head resulting from four RCP's in operation, and increase this penalty by another 13.0 psi to account for two operating RHR pumps. This action would be the most conservative but is very onerous at low RCS temperatures, particularly when one considers that there is usually no more than one RCP operating at low temperatures.

A better plan (and the one currently in use at IP3) is to limit the maximum number of operating RCPs to a temperature at which there is adequate pressure margin to allow for their operation. In other words, there is a minimum temperature required for operation of one RCP, a slightly higher temperature for operation of two RCPs and so on.

Operating procedures at Indian Point Unit 3 restrict RCP operation to the following temperatures:

Number of RCPs in Operation	**Minimum Required Temperature**
1	90
2	100
3	110
4	120

There is no procedural restriction for RHR pump operation. Therefore, penalties for pump operation are applied to the OPS Curve as follows: RCP penalties are added as a function of the maximum allowable number of RCP's for a given temperature, and an additional penalty of 13.0 psi for RHR pump operation is also applied. These penalties and their effects on the OPS Curve are shown on Table 3B.

3.3.3.5 Verification of RHR Piping Overpressure Protection

The OPS was originally designed to protect the RCS and reactor vessel, but the Residual Heat Removal (RHR) System is also subject to overpressure. For this reason, no Safety Injection (SI) pumps are permitted to be capable of injecting into the RCS when the RHR is in service. However, at cold shutdown conditions (RCS below 200°F), one SI pump may be returned to service to provide an alternate cooling or boration path, or to support mid-loop operation. Therefore, whenever the OPS setpoint curve is updated, it is necessary to demonstrate that the OPS protects the RHR System at RCS temperatures of 200°F and below.

According to Table 3B, the OPS limits the maximum RCS pressure to 562.2 psig at a temperature of 200°F. The OPS design limits the overshoot on an overpressure event to 44 psi. Therefore, in a mass-input or heat-input event at 200°F, the maximum RCS pressure will be 562.2 + 44 = 606.2 psig. Allowing for a temperature instrument uncertainty of 30°F, we assume that the RCS temperature is really 230°F instead of 200°F. The OPS pressure setpoint at 230°F is 617.1 psig, which with overshoot now results in a maximum pressure of 617.1 + 44 = 661.1 psig.

The design basis RHR piping pressure is 737 psig. Therefore, the OPS will protect the RHR System from overpressurization at cold shutdown.

3.3.4 The OPS curve, showing all aspects calculated in this section, is shown in tabular form on Table 3B and graphically on Figure 3. Note that the curve has been "levelled off" at the low temperature end to ensure that its slope is always zero or positive. The curve has also been "clipped" at the high end to incorporate the maximum allowable pressure from Section 3.3.3.2.

3.4 Curve for RCP Start with Secondary Side Hotter Than Primary Side

For cases in which the secondary side is hotter than the primary side, certain restrictions are applied by Tech Specs before an RCP can be started. For example, the Operators are required to maintain a pressurizer level of no more than 73% indicated (i.e., 80% with uncertainty of 7%). This allows for an anticipated surge when the RCS is heated by the secondary side subsequent to RCP start.

The Tech Specs also impose a limitation on maximum T_{inlet} as a function of the ΔT between primary and secondary sides. This is to prevent the heat input resulting from RCP start increasing the RCS temperature to the extent that the OPS enable temperature is exceeded, and the system is automatically disabled.

This is most easily explained by example. In the paragraphs that follow, the derivation of the Secondary Side Temperature Limitations (SSTL) Curve is established.

- For a service life of 13.3 EFPY, we have identified the OPS enable temperature as 319°F, which includes an 30°F allowance for instrument uncertainty.

- The original OPS analysis (Reference 6.3) is based on a maximum error of 36°F in ΔT measurement. In other words, an indicated primary-to-secondary ΔT of 64°F could be as great as 100°F. Similarly, an indicated primary-to-secondary ΔT of 0°F (isothermal) could be as great as 36°F.

- The OPS is analyzed for a maximum actual primary-to-secondary ΔT of 100°F.

- The SSTL Curve consists essentially of two lines, defined by three points (P_1, P_2, P_3).

  P_1 is the maximum allowable indicated ΔT between primary and secondary sides. This is equal to 100°F (ΔT limit) - 36°F (uncertainty) = 64°F.

P_2 is the T_{inlet} limit for "isothermal" primary-to-secondary conditions. In other words, for an indicated ΔT of 0°F, the analysis assumes a "true" primary-to-secondary ΔT of 36°F. Therefore, when the RCP is started the RCS will heat up by half the value of ΔT, or 18°F. That means the maximum allowable T_{inlet} for an **indicated** ΔT of 0°F is the OPS enable temperature minus 18°F, or 319°F - 18°F = 301°F.

P_3 is just like P_2, only it applies to an indicated ΔT of 64°F, which corresponds to a "true" ΔT of 100°F. So the start of an RCP would result in an RCS heatup of no more than one-half of 100°F, or 50°F. The OPS enable temperature less 50°F is 269°F, so P_3 is set at T_{inlet} = 269°F for an indicated ΔT of 64°F.

The locations of the three points (and the completed curve) are presented on Figure 4.

3.5 Pressurizer Limitations for OPS Inoperable (Up to One Charging Pump Operable)

The figures derived in this section (Figure 5) and the next section (Figure 6) refer to another operator option allowed by the Tech Specs in response to OPS inoperability. It protects the RCS from overpressurization by establishing a large pressurizer bubble. The basis of this bubble (as per Reference 6.3) is to provide enough of a cushion to keep RCS pressure below the OPS setpoint for a full ten minutes. Ten minutes is defined in Reference 6.3 as a reasonable amount of time for operator response in the event of a mass input scenario.

The only difference between Figures 5 and 6 is the magnitude of the potential mass input. If only a single charging pump is capable of feeding the RCS, then the maximum mass input to the RCS on an inadvertant pump start is about 80 gpm (the analysis conservatively assumes 100 gpm). On the other hand, if all three charging pumps are capable of delivering mass to the RCS, or if one SI pump is capable of feeding the RCS, the mass input is much greater, and a larger pressurizer bubble is required.

3.5.1 Calculation of Curves

As noted above, this figure consists of a series of curves which define a pressurizer bubble size adequately large to compensate for ten minutes of mass injection without exceeding OPS setpoints. This is done by defining maximum pressurizer level as a function of T_{inlet} for a series of limiting RCS pressures.

The applicable assumptions are as follows:

- Maximum mass input = 100 gpm, which equals 13.37 ft^3/min (or 133.7 ft^3 in ten minutes)
- Initial pressures used: $\leq$400, $\leq$450, $\leq$500 and $\leq$550 psig

- Pressurizer level uncertainty of 7%

- Pressure / temperature uncertainties of 43 psi and 30 degF, respectively (See Section 2)

The equations that generate these curves are taken directly from Reference 6.3, which has been submitted to the NRC and approved per Tech Spec amendment 67:

$L(PZR) = (1730.65\ ft^3 - V_g(0)) / 16.613$

where L(PZR) = the limiting pressurizer level;
1730.65 ft^3 = available pressurizer volume;
16.613 = ft^3 / percent PRZR level, and;

$V_g(0) = \Delta V / [1-P_0/P_f]^{(1/1.4)}$

where ΔV = Increase in liquid volume due to 10 minute mass input

P_0 = Initial RCS pressure in PSIA (e.g., if the initial RCS pressure is $\leq$100 psig and the pressure instrument uncertainty is 43 psi, then P_0 is 100 + 14.7 + 43 = 157.7 psia

P_f = LTOPS allowable maximum pressure at the chosen RCS temperature + 30 degF uncertainty

1/1.4 = the inverse gamma expansion term for the steam space in the pressurizer (which is conservative for a nitrogen atmosphere in lieu of steam)

The final pressurizer level is reduced by 7% to allow for instrument uncertainty, and the maximum pressurizer level under ANY circumstances is no greater than 73% indicated (i.e., 80% required, less 7% allowance for level uncertainty).

For illustrative purposes, here is a sample calculation:

At an indicated RCS temperature of 250 degF and indicated pressure no greater than 450 psig):

$V_g(0) = 133.7\ ft^3 / [1- (450+43+14.7)/(669.5+14.7)]**1/1.4$
$= 351.92\ ft^3$

L(PZR) = (1730.65 - 351.92) / 16.613 - 7% = 76.0%

By the same token, an indicated RCS temperature of 150 degF and indicated pressure no greater than 500 psig results in $V_g(0) > 1730.65$, and therefore off the curve.

Table 5 presents the results of the calculations required to create the curve, which is shown on Figure 5.

3.6 Pressurizer Limitations for OPS Inoperable (Up to Three Charging Pumps and/or One SI Pump Operable)

This is essentially the same as Section 3.5, with the following changes in assumptions:

- The initial pressures used are ≤100, ≤200, ≤300, ≤400 and ≤500 psig
- The limiting mass input is all three charging pumps available and/or one safety injection pump available.
- Instrument uncertainties remain the same.

The single failure associated with mass-input accident initiation here is either inadvertant start of one SI pump (the other two must be incapable of feeding the RCS when OPS is required to be operational) or an Appendix-R fire in the charging pump control box that causes all three charging pumps to start. The analysis does **not** assume simultaneous operation of three charging pumps and one SI pump. It **does**, however, consider inadvertant SI pump start while normal charging is in service, since RCS pressure would be maintained using the normal letdown path.

The original OPS analysis (Reference 6.3) used the following values for SI pump injection against RCS pressure:

RCS Pressure (psig)	**SI Pump Flow (gpm)**	**ΔV After Ten Minutes (ft^3)**
100	630	842.2
200	608	812.8
300	583	779.4
400	558	745.9
500	533	712.5

The SI flows have decreased slightly, based on the 1992 SI flow balance work done at IP3 (Reference 6.12) and as reflected in FSAR Table 14.2-8 (which shows the flow for **two** pumps). However, the values in the above table will be retained for conservative purposes.

Table 6 presents the results of the calculations required to create the curve, which is shown on Figure 6.

3.7 RCS Pressure Limitations for Hydrostatic Testing

Hydrostatic test pressure limits are taken directly from Tables 31, 32 and 33 of Reference 6.1. The philosophy behind the generation of the hydrostatic testing pressure limits is that the normal heatup curves shall be used up to the minimum allowable temperature for testing (this is defined in Reference 6.14 as 318 degF, which we have increased by 30 degF uncertainty to get 348 degF), at which point the curve steps up to the limits calculated for hydrostatic testing and remains consistent with this curve, eventually peaking at a maximum testing pressure of 2485 psig.

Table 7 shows the derivation of this curve, given the limitations of the three heatup rates from Table 1, the transition to the hydrostatic curve at 347.9°F and the levelling off at 2485 psig.

The curve is shown graphically in Figure 7, with instrument uncertainty allowances and pump operation penalties added as in Figures 3.1 and 3.2.

3.8 Verification of Pressurizer Bubble for Two SI Pumps Operating

Finally, a verification is provided for the special case in which two SI pumps may be operable. This is the case in which pressurizer level is at zero (indicated). For such a case, the available volume in the pressurizer, assuming a 7% level uncertainty is:

[(1471.8 cu ft x 0.93) + (0.5 x (1800 - 1471.8))] x 7.45 g/cu ft = 11,420 gal

where 1471.8 cu ft is the volume of the pressurizer between the instrument taps, and the total volume is 1800 cu ft. Therefore, the above equation represents the span of the pressurizer level instrument plus the dome at the top, with no credit taken for displacement due to heaters or for piping volume. (See Reference 6.9 for details)

According to Reference 6.12, the maximum expected flow of two SI pumps against zero pressure is 1060 gpm. Increasing this by 7% for conservatism gives us 1134gpm (Note: a 7% increase in SI flow is the difference between degraded and expected SI flow, per Reference 6.12). Multiplying the result by 10 gives us 11,340

gallons in ten minutes, which is less than the available 11,420 gallons. Therefore, two SI pumps starting inadvertantly will not fill the pressurizer in ten minutes, which is adequate time for operators to respond. This is consistent with the (proposed) basis to Tech Spec 3.3.

4.0 SUMMARY AND CONCLUSION

The PTLR curves are listed in Tables 1 through 7 and shown graphically in Figures 1, 2, 3, 4, 5, 6 and 7.

5.0 PROCEDURES AFFECTED BY THIS CALCULATION

5.1 Graphs Book Figure RCS-1A

5.2 Graphs Book Figure RCS-1B

5.3 Graphs Book Figure RCS-1D

5.4 Graphs Book Figure RCS-1F

5.5 Graphs Book Figure RCS-1G

5.6 Procedure 3PT-SA11

5.7 Operations Procedures POP-1.1 and POP 3.1 (for OPS arming temperature).

Note that the Graphs Book figures CANNOT be revised until appropriate allowance for instrument error is added to the OPS setpoint curve in Figure 3. Therefore, ACTS Item 29757 has been opened to calculate and apply instrument uncertainties to the affected graph and procedures.

6.0 REFERENCES

6.1 "MISC-MPS-ER-005 - Indian Point Unit 3 Final Report on Appendix G Reactor Vessel Pressure-Temperature Limits," ABB-Combustion Engineering, July 1991

6.2 ASME Code Case N-514

6.3 "Indian Point Unit No. 3 Low Temperature Overpressurization Protection System Analysis Final Report," D. Speyer and M. Feltus, August 24, 1984

6.4 Memorandum REC-093-093, Gumble to distribution, "Potential Nonconservatisms in LTOPS Setpoints," June 10, 1993

6.5 IP3 Operations Procedure POP-1.1, Rev 40, "Plant Heatup from Cold Shutdown Condition"

6.6 IP3 Operations Procedure POP-3.3, Rev 31, "Plant Cooldown, Hot to Cold Shutdown"

6.7 NSE 95-3-329-RCS, "Reactor Coolant System Cooldown Rate of 40 degF/hr," Rev. 0, Nov. 21, 1995

6.8 Post Project Report for Contract Order C 97 Z0064, "NYPA IP3 PT Curve/Code Case N-514 Review," ABB-Combustion Engineering, PENG-97-163, 8/19/97

6.9 Pressurizer Outline Drawing 9321-05-2292, Rev. 0

6.10 "Evaluation of Indian Point Unit 3 Low Temperature Overpressurization Protection System," Agreement No S-90-01811, D. Speyer, October 1982

6.11 Reactor Coolant System Design Basis Document , IP3-DBD-314, Rev. 0

6.12 SECL 92-131, "High Head Safety Injection Flow Changes Safety Evaluation," Westinghouse Electric Corp, June 1992

6.13 Letter PENG 98-014, Hoffman to Ghergurovich, "Revised ART Determination for Indian Point Unit 3," ABB-Combustion Engineering, Jan 23, 1998

6.14 WCAP-15024, "Indian Point Unit 3 Heatup and Cooldown Limit Curves for Normal Operation," Westinghouse Energy Systems, February 1998

6.15 Calculation IP3-CALC-RPC-00318 Rev. 1

6.16 EQ Calculation EQ-GC-99.141 P-455, Rev. 1

6.17 Calculation IP3-RPT-UNSPEC-02006, Rev. 3

6.18 Calculation IP3-CALC-RCS-00404 Rev 2A

6.19 Calculation EQ-GC-99.141 T-423B Rev. 2

CALCULATION SHEET

New York Power Authority
CALCULATION NO. IP3-CALC-RCS-02444 REVISION 1

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Title Generation of All PTLR Curves Date Feb 13, 1998
Preliminary ____ Prepared by F. Gumble Date 2/13/98
Final X Checked by G. Canavan Date 2/12/98

Table 1
Data for Heatup Curves, 13.3 EFPY
(From Reference 6.1)

RCS TEMP DEG F	20 F/ HOUR
50	520.4
60	523.7
70	527.6
80	532.1
90	537.2
100	543.2
110	550.2
120	558.2
130	567.4
140	578.1
150	590.5
160	604.8
170	621.3
180	640.4
190	662.5
200	688.0
210	717.5
220	751.6
230	791.0
240	836.6
250	889.3
260	950.2
270	1020.7
280	1102.1
290	1196.2
300	1293.6
310	1405.4
320	1534.6
330	1684.0
335.8	-
335.8	-
336.72	-
340	1856.7
350	2056.3
360	2287.2
367.98	2500.0
370	2554.0
380	2862.4
390	3000.0

RCS TEMP DEG F	40 F/ HOUR
50	520.4
60	523.7
70	527.6
80	532.1
90	537.2
100	543.2
110	529.7
120	524.1
130	525.2
140	531.6
150	542.5
160	557.4
170	576.4
180	599.4
190	626.8
200	659.0
210	696.6
220	740.4
230	791.0
240	836.6
250	889.3
260	950.2
270	1020.7
280	1102.1
290	1196.2
300	1292.1
310	1391.5
320	1506.3
330	1639.1
335.8	-
335.8	-
336.72	-
340	1792.5
350	1970.0
360	2175.1
370	2412.2
373.2	2500.0
380	2686.3
390	3000.0

RCS TEMP DEG F	60 F/ HOUR
50	520.4
60	523.7
70	527.6
80	532.1
90	537.2
100	540.5
110	516.6
120	500.7
130	491.7
140	488.4
150	490.0
160	496.2
170	506.7
180	521.4
190	540.3
200	563.8
210	592.1
220	625.9
230	665.6
240	712.2
250	766.4
260	829.6
270	902.8
280	987.8
290	1086.2
300	1200.1
310	1331.9
320	1484.3
330	1607.9
335.8	-
335.8	-
336.72	-
340	1744.3
350	1902.0
360	2084.3
370	2295.1
378.41	2500.0
380	2538.7
390	2820.3
400	3000.0

Table 2
Data for Cooldown Curves, 13.3 EFPY
(From Reference 6.1)

RCS TEMP DEG F	COOLDOWN P-ALLOWABLE (PSIG) ISO THERMAL	20 F/ HOUR	50 F/ HOUR	60 F/ HOUR	80 F/ HOUR	100 F/ HOUR
50	520.4	444.8	332.0	294.6	220.1	146.3
60	523.7	448.5	336.5	299.4	225.6	152.4
70	527.6	452.9	341.7	304.9	231.7	159.5
80	532.1	457.9	347.7	311.3	239.0	167.6
90	537.2	463.8	354.7	318.7	247.2	177.0
100	543.2	470.5	362.7	327.2	256.9	187.7
110	550.2	478.3	372.0	337.0	267.9	200.4
120	558.2	487.3	382.8	348.4	280.9	214.9
130	567.4	497.7	395.2	361.6	295.6	231.7
140	578.1	509.7	409.6	376.9	312.9	251.0
150	590.5	523.6	426.1	394.5	332.6	273.2
160	604.8	539.7	445.4	414.8	355.8	299.3
170	621.3	558.3	467.6	438.4	382.1	329.3
180	640.4	579.8	493.2	465.6	413.0	363.9
190	662.5	604.6	522.9	497.1	448.1	403.7
200	688.0	633.4	557.1	533.4	489.4	449.5
210	717.5	666.6	596.9	575.5	536.4	503.2
220	751.6	705.0	642.7	624.1	591.6	565.1
230	791.0	749.3	695.7	680.3	654.3	636.2
240	836.6	800.6	757.0	745.2	728.0	718.1
250	889.3	859.9	827.6	820.3	811.9	812.1
260	950.2	928.5	909.7	907.1	910.3	922.4
270	1020.7	1007.7	1004.2	1007.5	1020.7	1020.7
280	1102.1	1099.4	1102.1	1102.1	1102.1	1102.1
290	1196.2	1196.2	1196.2	1196.2	1196.2	1196.2
300	1305.0	1305.0	1305.0	1305.0	1305.0	1305.0
310	1430.8	1430.8	1430.8	1430.8	1430.8	1430.8
320	1576.2	1576.2	1576.2	1576.2	1576.2	1576.2
330	1744.3	1744.3	1744.3	1744.3	1744.3	1744.3
340	1938.7	1938.7	1938.7	1938.7	1938.7	1938.7
350	2163.3	2163.3	2163.3	2163.3	2163.3	2163.3
360	2423.1	2423.1	2423.1	2423.1	2423.1	2423.1
362.56	2500.0	2500.0	2500.0	2500.0	2500.0	2500.0
370	2723.3	2723.3	2723.3	2723.3	2723.3	2723.3
380	3000.0	3000.0	3000.0	3000.0	3000.0	3000.0

Table 3A (Page 1 of 2)
Appendix G Curve and Pressure/Temperature Penalties

RCS Temperature (degF)	RCS Temperature + 50 degF	Appendix G Curve Pressure (psig)	Appendix G Curve Pressure x 110%	App. G Press. Reduced by 44 psi Overshoot
50	**100**	520.4	572.44	528.44
60	**110**	523.7	576.07	532.07
70	**120**	527.6	580.36	536.36
80	**130**	532.1	585.31	541.31
90	**140**	537.2	590.92	546.92
100	**150**	543.2	597.52	553.52
110	**160**	550.2	605.22	561.22
120	**170**	558.2	614.02	570.02
130	**180**	567.4	624.14	580.14
140	**190**	578.1	635.91	591.91
150	**200**	590.5	649.55	605.55
160	**210**	604.8	665.28	621.28
170	**220**	621.3	683.43	639.43
180	**230**	640.4	704.44	660.44
190	**240**	662.5	728.75	684.75
200	**250**	688.0	756.80	712.80
210	**260**	717.5	789.25	745.25
220	**270**	751.6	826.76	782.76
230	**280**	791.0	870.10	826.10
240	**290**	836.6	920.26	876.26
250	**300**	889.3	978.23	934.23

Table continued on next page

Table 3A (Page 2 of 2)
Appendix G Curve and Pressure/Temperature Penalties

RCS Temperature (degF)	RCS Temperature + 50 degF	Appendix G Curve Pressure (psig)	Appendix G Curve Pressure x 110%	App. G Press. Reduced by 44 psi Overshoot
260	**310**	950.2	1045.22	1001.22
270	**320**	1020.7	1122.77	1078.77
280	**330**	1102.1	1212.31	1168.31
290	**340**	1196.2	1315.82	1271.82
300	**350**	1305.0	1435.50	1391.50
310	**360**	1430.8	1573.88	1529.88
320	**370**	1576.2	1733.82	1689.82
330	**380**	1744.3	1918.73	1874.73
340	**390**	1938.7	2132.57	2088.57
350	**400**	2163.3	2379.63	2335.63
360	**410**	2423.1	2665.41	2621.41
370	**420**	2723.3	2995.63	2951.63

Table 3B (Page 1 of 2)
Determination of OPS Setpoint Curve
(Input Data fromTable 3A)

RCS Temperature + 50 degF	Penalty due to RCP and RHR Pump Operation (psi)	App G Press. Reduced by 44 psi for Overshoot and Pump Penalties (psig)	OPS Setpoint Curve (psig)
90	21.0 (i.e., 13.0 + 8.0)	507.44	**493.1**
100	26.0 (i.e., 13.0 + 13.0)	502.44	**493.1**
110	34.4 (i.e., 13.0 + 21.4)	497.67	**493.1**
120	43.3 (i.e., 13.0 + 30.3)	493.06	**493.1**
130	43.3	498.01	**498.0**
140	43.3	503.62	**503.6**
150	43.3	510.22	**510.2**
160	43.3	517.92	**517.9**
170	43.3	526.72	**526.7**
180	43.3	536.84	**536.8**
190	43.3	548.61	**548.6**
200	43.3	562.25	**562.2**
210	43.3	577.98	**578.0**
220	43.3	596.13	**596.1**
230	43.3	617.14	**617.1**
240	43.3	641.45	**641.4**
250	43.3	669.50	**669.5**
260	43.3	701.95	**701.9**

Table continued on next page

Table 3B (Page 2 of 2)

Determination of OPS Setpoint Curve

(Input Data fromTable 3A)

RCS Temperature + 50 degF	Penalty due to RCP and RHR Pump Operation (psi)	App G Press. Reduced by 44 psi for Overshoot and Pump Penalties (psig)	OPS Setpoint Curve (psig)
270	43.3	739.46	**739.5**
280	43.3	782.60	**782.6**
290	43.3	832.96	**833.0**
300	43.3	890.93	**890.9**
310	43.3	957.92	**957.9**
320	43.3	1035.47	**1035.5**
330	43.3	1125.01	**1125.0**
340	43.3	1228.52	**1228.5**
350	43.3	1348.20	**1348.2**
360	43.3	1486.58	**1486.6**
370	43.3	1646.52	**1646.5**
380	43.3	1831.43	**1831.4**
390	43.3	2045.27	**1851.0**
400	43.3	2292.33	**1851.0**
410	43.3	2578.11	**1851.0**
420	43.3	2908.33	**1851.0**

Table 4

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Table 5
Pressurizer Level and RCS Pressure Restrictions for OPS Inoperable and up to One Charging Pump Operable (Applicable to Service Life of ≤ 13.3 EFPY)

Max. PZR Level (%) for RCS Indicated Pressure of:

RCS Temp (degF)	OPS Max Press. (psig)	400 psig	450 psig	500 psig	550 psig
≤100	493.1	55.09			
110	493.1	55.09			
130	498.0	57.53	>0 (-122.6)		
150	510.2	62.23	4.69		
170	526.7	66.64	38.69		
190	548.6	70.57	55.10	>0 (-119.6)	
210	578.0	74.02	64.95	36.45	>0 (-253.3 @220 degF)
230	617.1	76.97	71.44	59.98	14.20
250	669.5	79.45	75.99	70.30	58.68
270	739.5	81.50	79.29	76.14	71.23
290	833.0	83.16	81.72	79.86	77.35
310	957.9	84.50	83.54	82.38	80.96
330	1125.0	85.56	84.91	84.17	83.31
≥350	1348.2	86.39	85.95	85.45	84.90

Note: All PZR levels > 73% will be truncated to 73%

Table 6
Pressurizer Level and RCS Pressure Restrictions for OPS Inoperable and up to 3 Charging Pumps and/or 1 Safety Injection Pump Operable (Applicable to Service Life of ≤ 13.3 EFPY)

Max. PZR Level (%) for RCS Indicated Pressure of:

RCS Temp (degF)	OPS Max Press. (psig)	100 psig	200 psig	300 psig	400 psig	500 psig
≤100	493.1	31.06	16.03			
110	493.1	31.06	16.03			
130	498.0	31.26	16.60			
150	510.2	31.74	17.93			
170	526.7	32.34	19.55	<0(-4.4)		
190	548.6	33.07	21.45	0.80		
210	578.0	33.94	23.63	6.33		
230	617.1	34.94	26.03	11.99		
250	669.5	36.05	28.60	17.59	<0(-1.7)	
270	739.5	37.23	31.22	22.91	9.71	<0(-14.9)
290	833.0	38.45	33.79	27.78	19.00	4.90
310	957.9	39.65	36.22	32.08	26.46	18.36
330	1125.0	40.79	38.42	35.78	32.38	27.86
350	1348.2	41.82	40.35	38.86	37.03	34.72
≥370	1646.5	42.74	41.99	41.39	40.65	39.73

Table 7
RCS Temperature/Pressure Restrictions for Hydrostatic Testing

RCS TEMP DEG F	HYDRO STATIC
50	693.8
60	698.3
70	703.4
80	709.4
90	716.3
100	724.3
110	733.5
120	744.2
130	756.5
140	770.8
150	787.3
160	806.3
170	828.4
180	853.8
190	883.3
200	917.3
210	956.6
220	1002.1
230	1054.7
240	1115.5
250	1185.7
260	1267.0
270	1360.9
280	1469.4
290	1594.9
300	1740.0
310	1907.7
320	2101.6
330	2325.8
335.8	-
335.8	-
336.72	2500.0
340	2584.9
350	2884.5
360	3000.0
370	-
378.41	-
380	-
390	-
400	-
410	-
418.41	-
420	-
430	-
440	-

CALCULATION SHEET

New York Power Authority
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Final X Checked by G. Canavan Date 2/17/98

Figure 1
Reactor Coolant System Heatup Limitations, 13.3 EFPY
Including Limiting Temperatures for RCP Operation

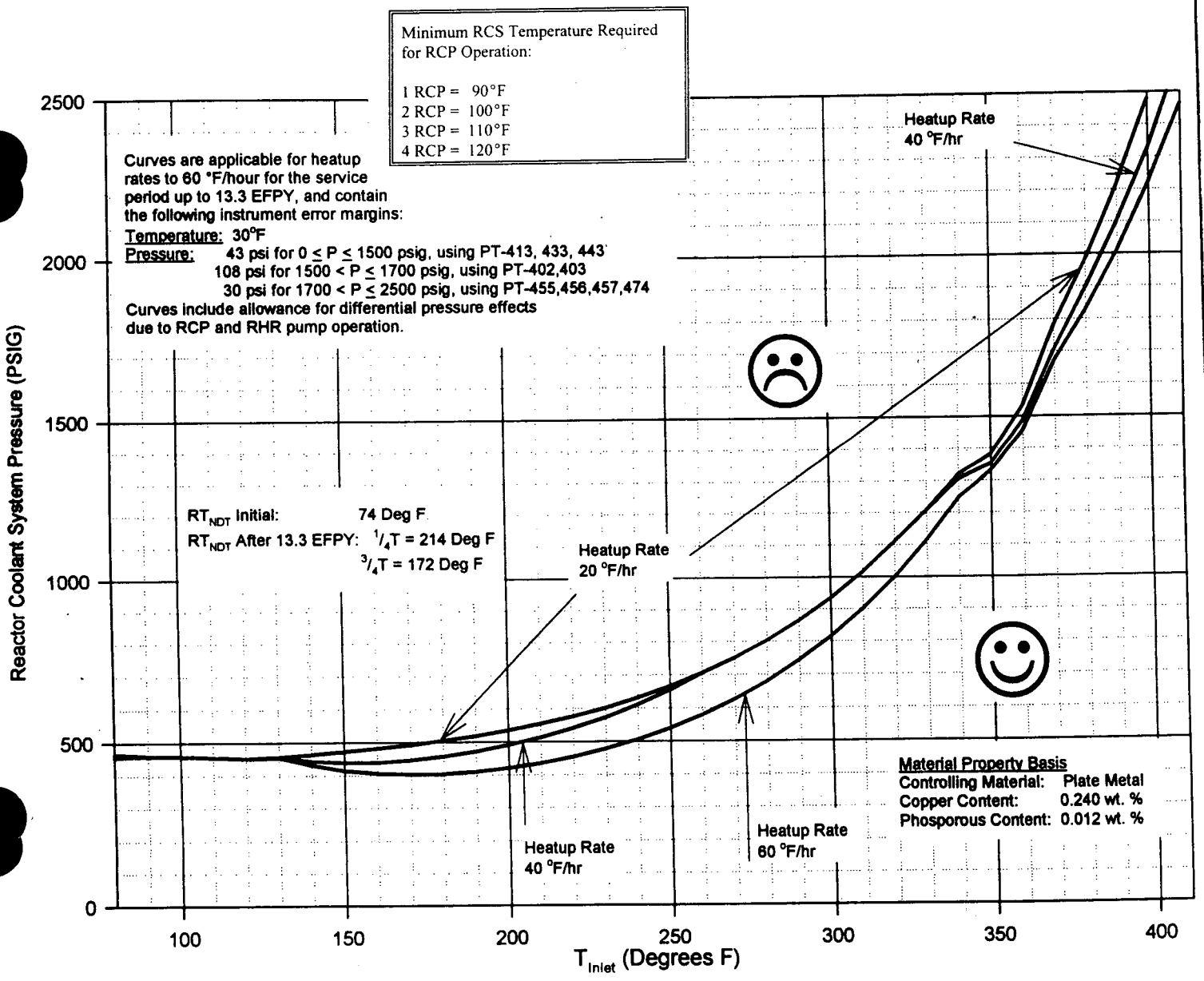

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Figure 2
Reactor Coolant System Cooldown Limitations, 13.3 EFPY
Including Limiting Temperatures for RCP Operation

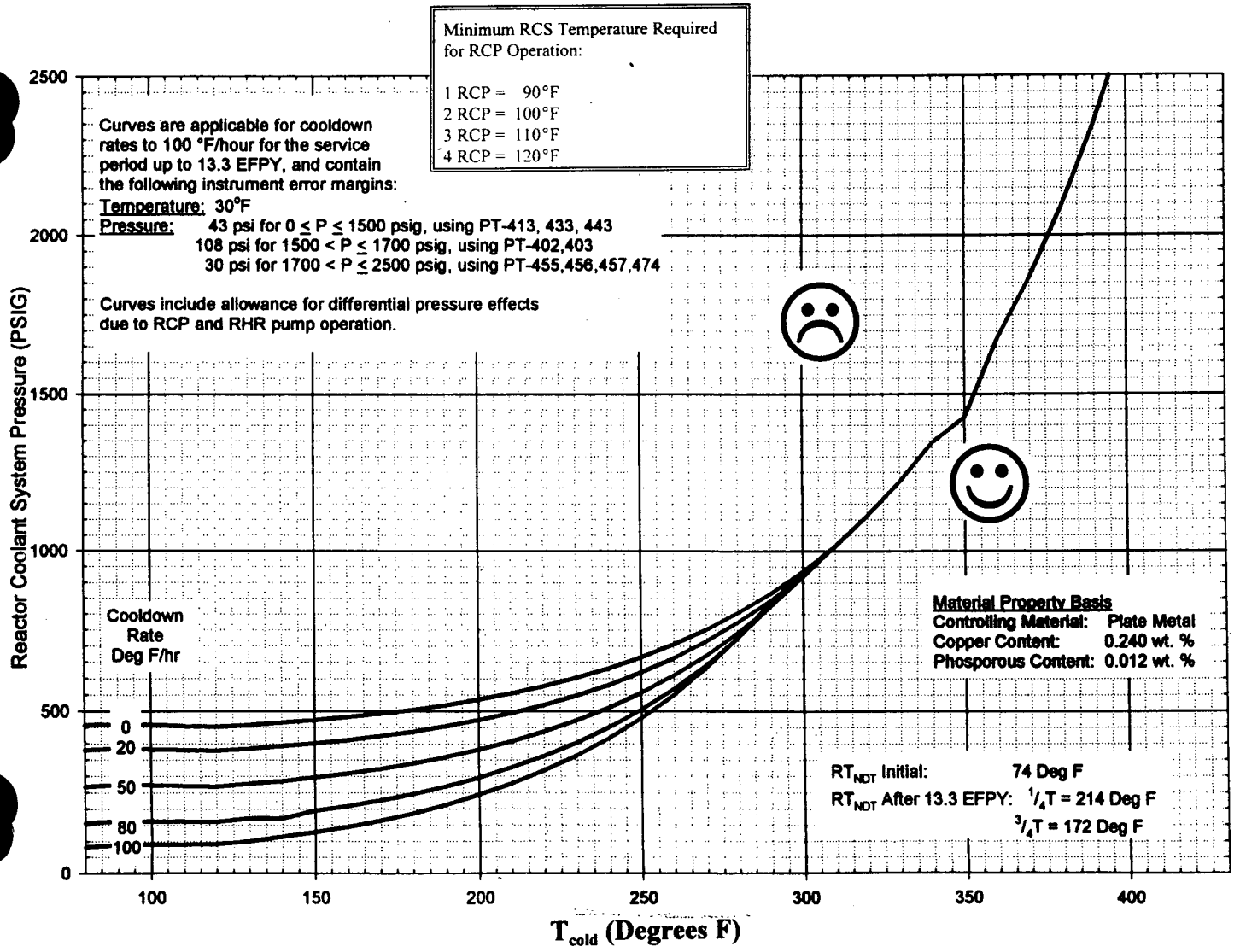

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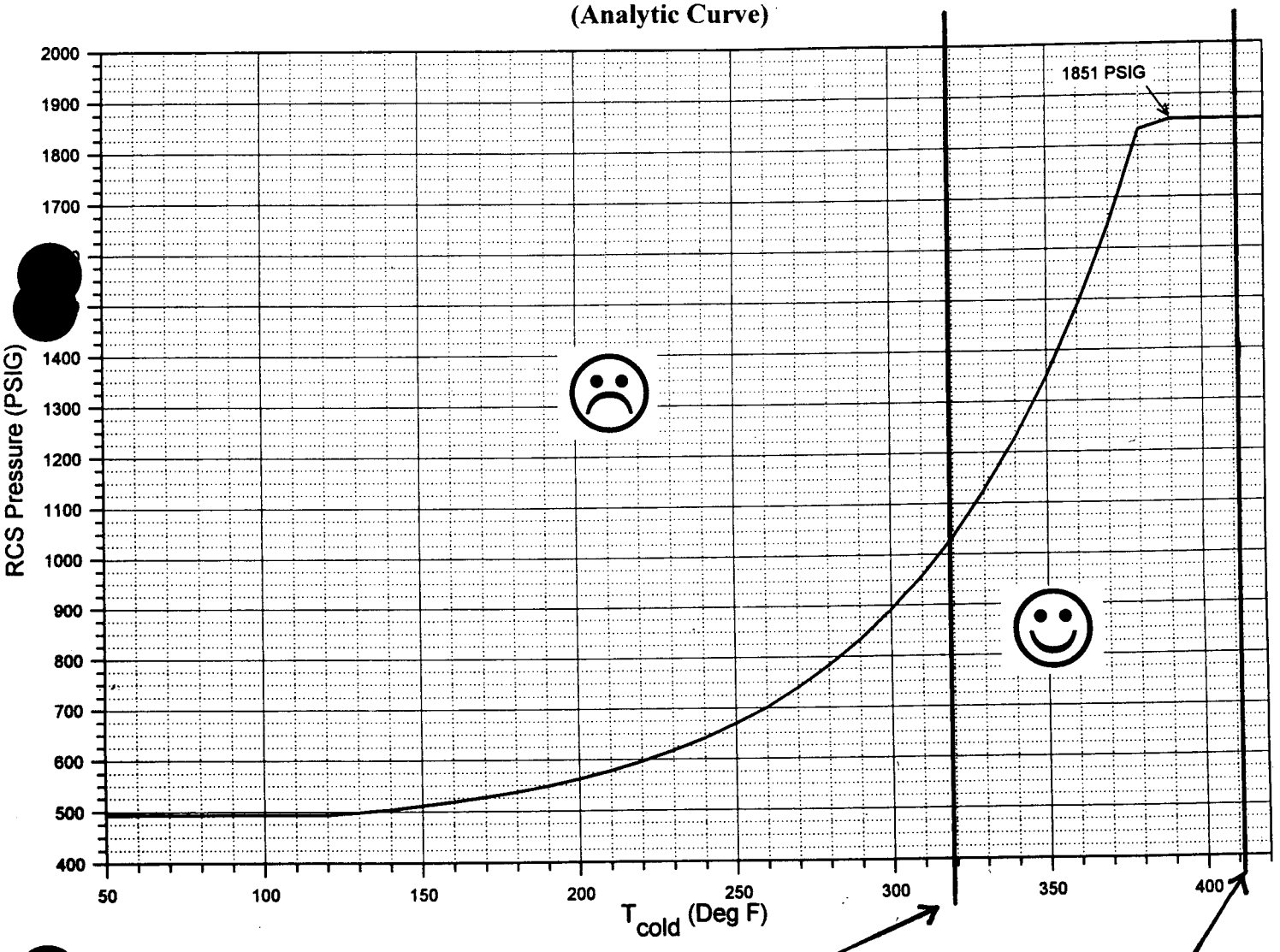
Figure 3
OPS Setpoint, Including OPS Arming Temperature and Heatup Requirements for OPS Inoperable
13.3 EFPY
(Analytic Curve)



OPS Arming Temperature (319degF)

Heat to this temperature if OPS is inoperable (411 degF)

CALCULATION SHEET

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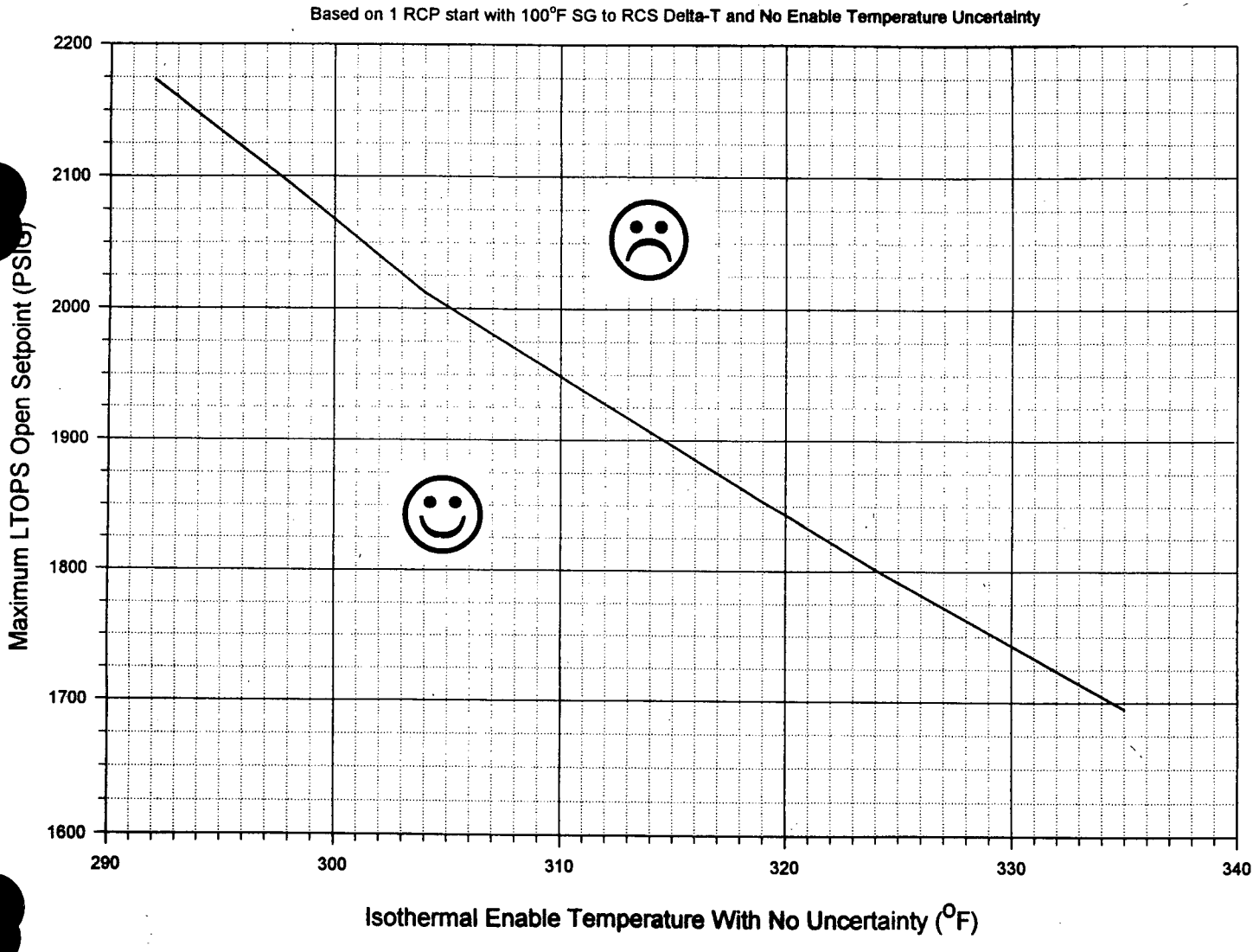
Figure 3A
Maximum Permissible RCS Pressure vs. OPS Enable Temperature
(Reference 6.10)



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Title Generation of All PTLR Curves Date Feb 13, 1998
Preliminary ____ Prepared by F. Gumble Date 2/12/98
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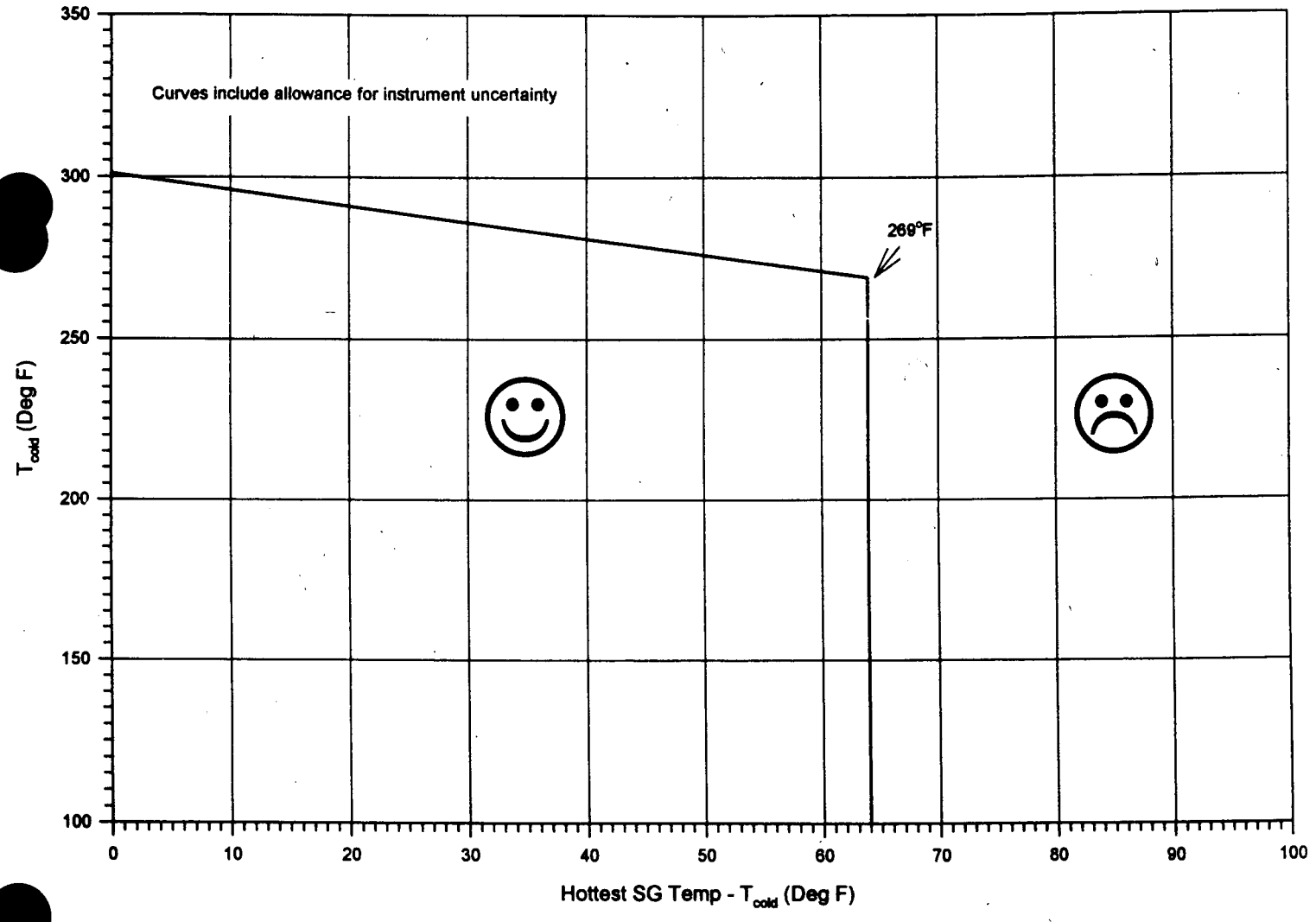
Figure 4
Secondary Side Limitations for RCP Start With Secondary Side Hotter Than Primary
13.3 EFPY



CALCULATION SHEET

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Final X Checked by G. Canavan Date 2/12/98

Figure 5
Pressurizer Limitations for OPS Inoperable
(Up to One Charging Pump Capable of Feeding RCS)
13.3 EFPY

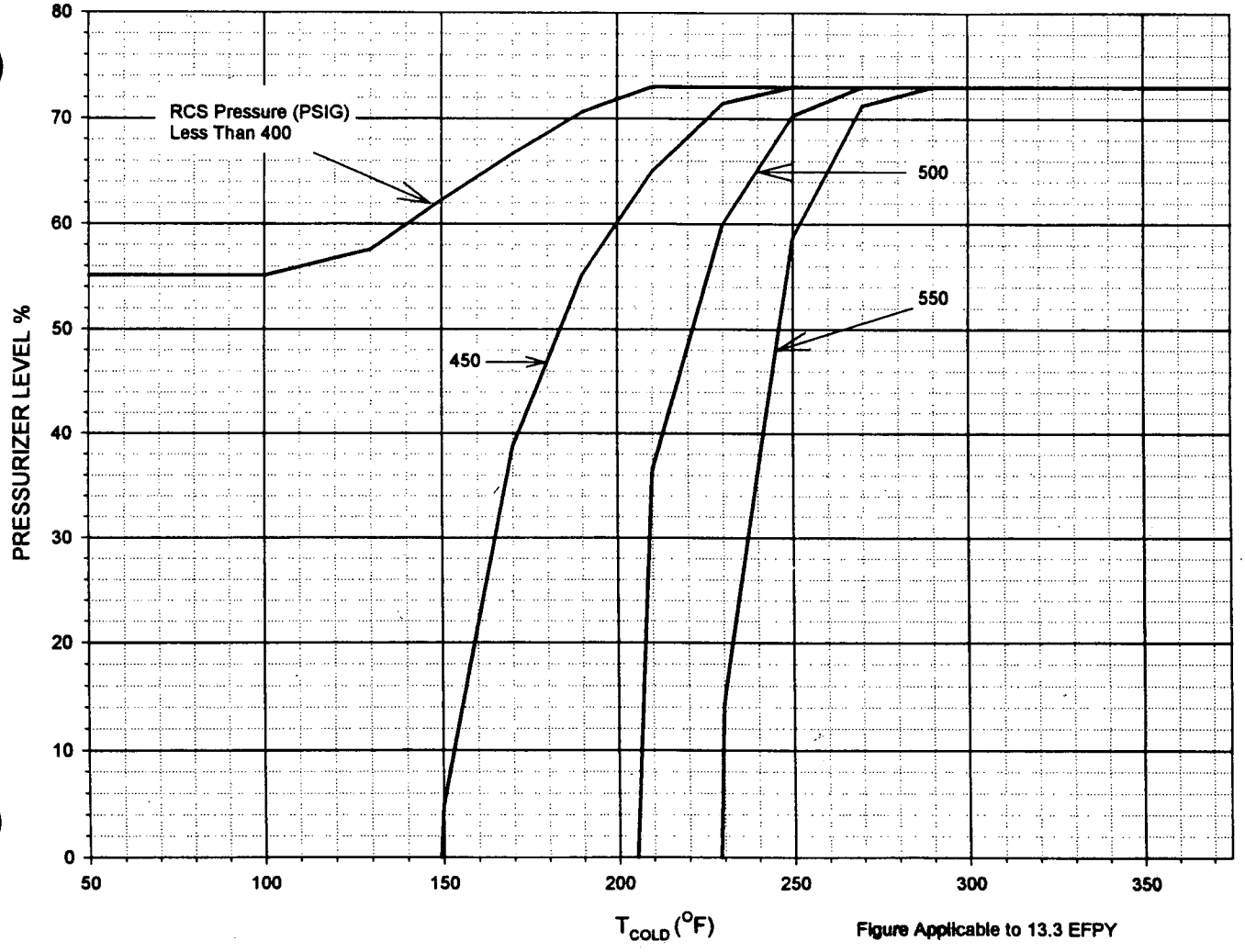

Figure Applicable to 13.3 EFPY

CALCULATION SHEET

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Final X Checked by G. Canavan Date 2/17/98

Figure 6
Pressurizer Limitations for OPS Inoperable
(Up to Three Charging Pumps and/or One Safety Injection Pump Capable of Feeding RCS)
13.3 EFPY

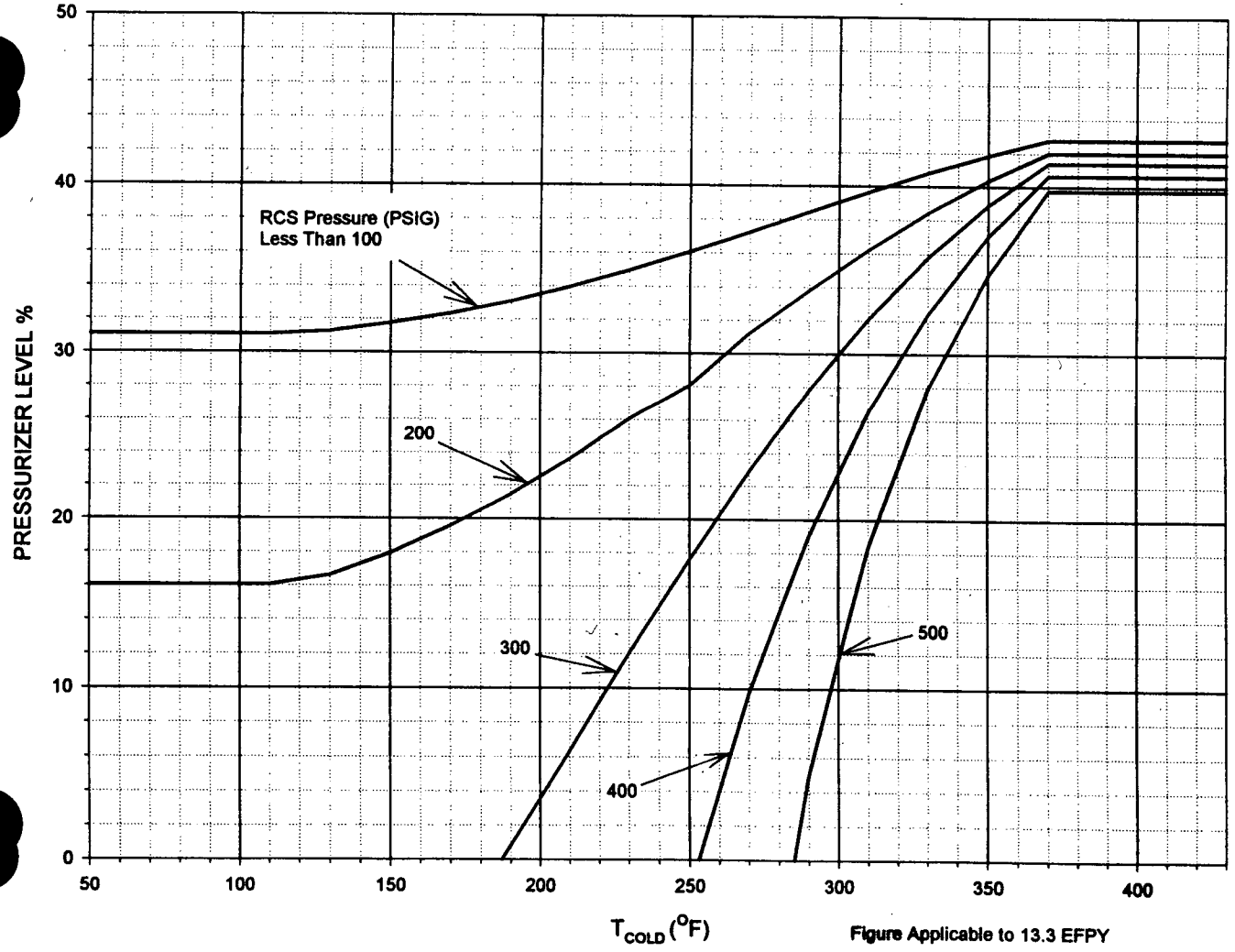

Figure Applicable to 13.3 EFPY

CALCULATION SHEET

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Title Generation of All PTLR Curves Date Feb 13, 1998
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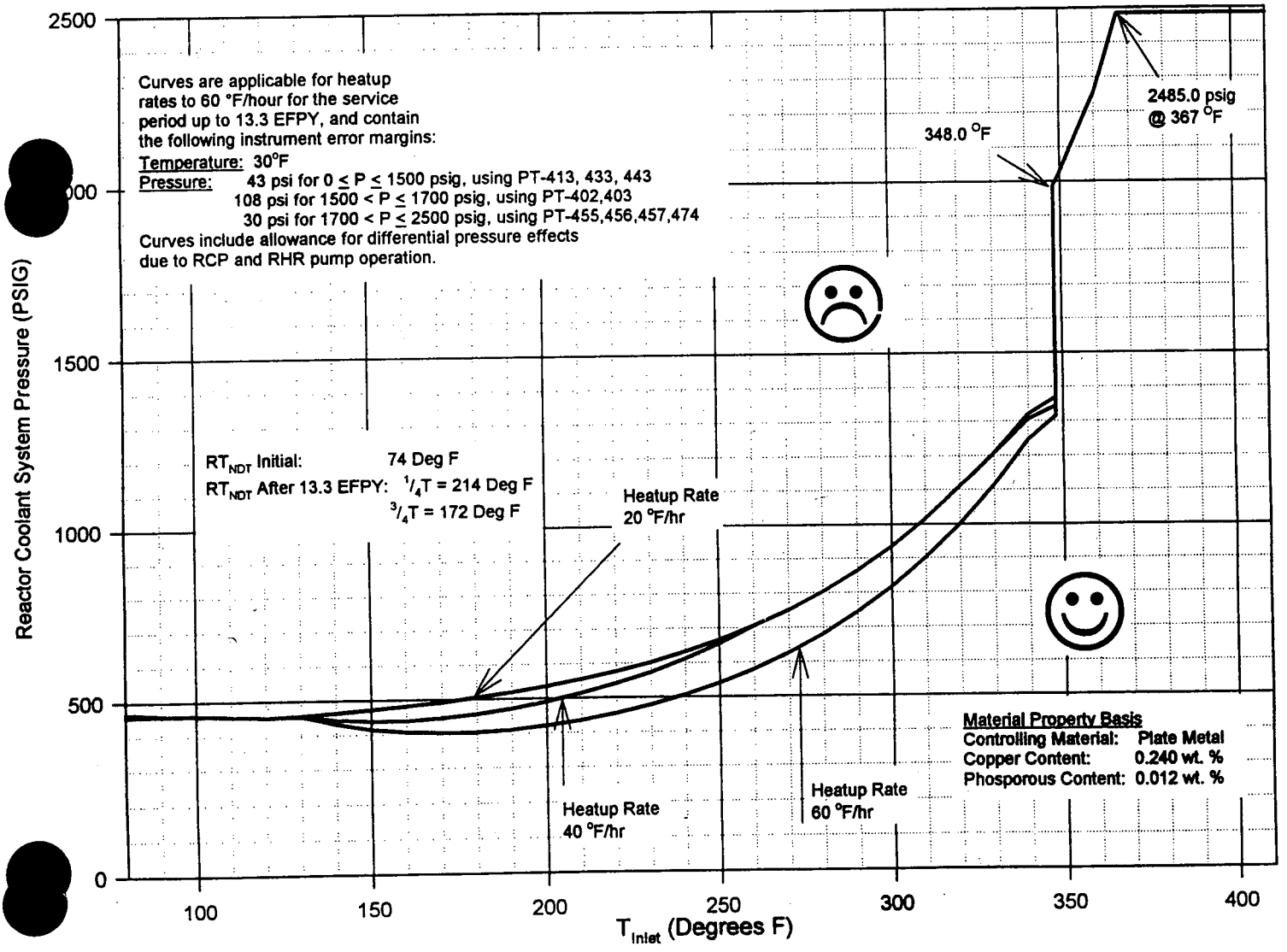
Figure 7
RCS Pressure Limitations for Hydrostatic Testing
13.3 EFPY