UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

July 16, 1992

NRC INFORMATION NOTICE 91-52, SUPPLEMENT 1: NONCONSERVATIVE ERRORS IN OVERTEMPERATURE DELTA-TEMPERATURE (OTΔT) SETPOINT CAUSED BY IMPROPER GAIN SETTINGS

Addressees

All holders of operating licenses or construction permits for Westinghouse (W)-designed nuclear power reactors.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to supplement information provided in the original information notice regarding errors in OTΔT settings and to alert addressees to new information on this problem. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

The Commonwealth Edison Company and the Duke Power Company recently notified the NRC of a problem with the saturation of the OTΔT reactor trip function of the Westinghouse Type 7300 Plant Protection System (PPS) at the Byron, Braidwood, McGuire and Catawba nuclear power plants. The problem was that the OTΔT reactor trip setpoint was not being automatically reduced to the extent required in response to a rising Tavg. The NRC alerted the industry to the problem in Information Notice (IN) 91-52, dated August 29, 1991.

In response to IN 91-52, the Westinghouse Nuclear and Advanced Technology Division (WNATD) prepared Westinghouse Technical Bulletin NSD-TB-91-08-R0, which was issued by the Westinghouse Nuclear Services Division on December 13, 1991. This bulletin (Attachment 1): (1) addressed the effect of the rate of increase of Tavg in transient situations, (2) revealed that Westinghouse Type 7100 and Foxboro analog PPS equipment can also be affected, and (3) provided a recommended scaling method to ensure that the OTΔT setpoint reaches its minimum design value before the Tavg channel becomes saturated under "worst case" transient conditions.

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PDR I&E Notice 91-052

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In this analysis WNATD concluded that even though the DNB ratio dropped below the design value of 1.3, it could not go beyond 1.0. However, the WNATD generic safety analysis may not envelope the worst case conditions at all affected plants.

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Charles E. Rossi

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical contact: S. D. Alexander, NRR
(301) 504-2995

Attachments:
1. WNSD Technical Bulletin NSD-TB-91-08-RO
2. List of Recently Issued NRC Information Notices

NSD Nuclear Services Division

Westinghouse Technical Bulletin

An advisory notice of a recent technical development pertaining to the installation or operation of Westinghouse-supplied Nuclear Plant equipment. Recipients should evaluate the information and recommendation, and initiate action where appropriate.

P.O. BOX 355, Pittsburgh, PA 15230

Subject: OVER TEMPERATURE DELTA-T (OTDT) SCALING			Number: NSD-TB- 91-06-RO
System(s): WESTINGHOUSE NSSS PROCESS CONTROL SYSTEM			Date: 12/13/91
Affected Plants: ALL PLANTS WITH W OTDT REACTOR TRIP FUNCTION			S.O.(s): 492/320
References: PLANT TECH SPECS, PLAS, SCALING MANUALS, NRC INFO NOTICE 91-52	Affects Safety Related Equipment	Yes ☒ No ☐	Sheet: 1 of 8

INTRODUCTION

NRC Information Notice 91-52 discusses recent events where improper scaling of the Over Temperature Delta-T (OTDT) protection channel allowed the average temperature (T-Avg) lead/lag compensation module to saturate before the T-Avg input reached the upper limit of its range. Saturation of this module prevented further reduction in the OTDT setpoint as T-Avg continued to increase. This channel was, therefore, ineffective in performing its intended safety function.

Although all reported incidents involved 7300 series process equipment, the potential for a similar situation also exists for 7100 and Foxboro equipment. For 7300 equipment, the T-Avg saturation condition was eliminated by redistributing the gains on the OTDT setpoint summing amplifier and the lead/lag compensation module. The input resistor of the OTDT summator was changed from 50k ohms to 24.9k ohms and the gain of T-Avg lead/lag module was reduced by a factor of 50k/24.9k = 2.008. These changes ensured that the OTDT setpoint would reach the trip setpoint before the T-Avg module output saturated.

This Technical Bulletin addresses these modifications and identifies a potential transient concern, solution and recommendations.

BACKGROUND

The OTDT Trip is designed to provide primary protection against departure from nucleate boiling (DNB) during postulated condition II events in Westinghouse reactors. The trip function operates by comparing the temperature difference (DT) between the hot leg and the cold leg of each loop to a calculated

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J. S. Srinivasan, Control Systems Analysis

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N. P. Mueller, Mgr. Control Systems Design Analysis

Approval: L. R. Benson
L. R. Benson
Domestic Customer Projects

setpoint (OTDT). A reactor trip is initiated when two or more loop DTs exceed their setpoint. Several terms such as, loop average temperature (T-Avg), pressurizer pressure, and axial neutron flux distribution in the core (F-DELTA I), are factored into the OTDT trip setpoint calculation (Equation-1).

The setpoint is typically expressed by the following equation:

$$OTDT_{sp} = [K_1 - K_2 (1 + Tau_1 s)/(1 + Tau_2 s) (T_{Avg} - T_{Ref}) + K_3(P - P_{Ref}) - F(Delta\text{-}I)]^*[DELTA\text{-}T] \quad \text{(Equation-1)}$$

where:

K_1, K_2, K_3 : are gains,

$Tau_1 s$, $Tau_2 s$: are the lead/lag time constants on T-Avg,

T_{Ref} : is the reference T-Avg, typically nominal full power T-Avg

P_{Ref} : is the reference pressurizer pressure, typically nominal pressurizer pressure

F(Delta-I) : is the Delta-I penalty

DELTA-T : is the full power DT

T_{Avg} : is the measured Average temperature

P : is the measured Pressurizer pressure.

When considering implementation of the OTDT setpoint in the protection system, Equation-1 can be reduced and written in the voltage form as follows:

$$V_{OTDT} = G_s \cdot [B_s - G_t \cdot V_t + G_p \cdot V_p - V_{F(Delta\text{-}I)}] \quad \text{(Equation-2)}$$

where:

V_{OTDT} = OTDT setpoint in volts

G_s = gain on the OTDT summer

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To illustrate this saturation effect, consider a temperature transient superimposed on the initial steady state conditions (580°F) used in the previous example. Figure 2 gives the output of the T-Avg module, with the lead/lag compensation, to a 2°F/sec temperature increase (postulated rod withdrawal event) for a typical equipment setup (G_1 = 0.8, L/L = 28/4). Note that even though the lead/lag module gain is less than 1, the T-Avg module saturates after about 19 seconds (t_0 = 5 sec). At this time the input T-Avg has only reached 608°F (580°F + 14 sec times 2°F/sec), which is only about 80% of its possible range.

Even though, the T-Avg module saturation during transients may be unavoidable, the gains can always be redistributed such that the OTDT setpoint reaches a minimum to ensure a trip, i.e., OTDT setpoint reaches the minimum of its range (0 volt, or 1 volt), before the T-Avg module saturates (refer to Figure 3). A technique for achieving this is outlined in the following section.

SOLUTION

The nonconservative impact on the OTDT setpoint calculation caused by steady state or transient saturation of the T-Avg lead/lag module can be avoided as follows:

1. Set the gain on the T-Avg lead/lag module to be less than unity. This will keep the T-Avg module from saturating over the entire input range of T-Avg in steady state.

2. Evaluate Equation-2 to determine the Bias (B_s) and OTDT summer gain (G_s) such that the summer output reaches a minimum to ensure a trip condition (output equal to 0 v, or 1 v) before or as the T-Avg lead/lag module output reaches saturation (output equal to 10 v, or 5 v). This is done with the pressure and Delta-I inputs to the Summer acting, to the maximum extent, to keep the setpoint above the trip value.

The second step is illustrated in the following example using the 7300 equipment voltage ranges (0 to 10 v).

Initial conditions (referenced to Equation-2):

a) The output of the OTDT Summer is at the minimum, $V_{OTDT} \leq 0$

b) There is no Delta-I penalty, $V_{F(Delta\text{-}I)} = 0$ v

c) The T_{Avg} lead/lag module reaches saturation, $G_1 \cdot V_1 = 10$ v

d) $G_p \cdot V_p$ is evaluated at the maximum pressure (usually 2500 psig)

Solving Equation-2 under these conditions will give a value of G_s.

$$G_s \bullet [B_s \cdot 10 + G_p \bullet 10] \leq 0 \qquad \text{(Equation-3)}$$

or,

$$G_s \geq [G_s \bullet B_s + (G_s \bullet G_p)\ 10] / 10 \qquad \text{(Equation-4)}$$

The value of products $G_s \bullet B_s$, $G_s \bullet G_p$ and $G_s \bullet G_t$ can be determined by comparing Equation-2 to Equation-1 reduced to voltage form, using plant specific parameter ranges and equipment type (7300 in this example). Once G_s is calculated, the bias B_s and the gains G_t and G_p and $F_{Delta(I)}$ need to be calculated based on Equation-2 and the products $G_s \bullet B_s$, $G_s \bullet G_p$ and $G_s \bullet G_t$.

RECOMMENDATIONS

Scaling of the OTDT channel should be examined to confirm that saturation of the T-Avg lead/lag module will not occur in the steady state and that the channel gains are distributed such that, during transient conditions, saturation of this module would occur only after the channel has developed a trip setpoint.

Proper operation of the steady state is assured if the gain of the T-Avg lead/lag module is less than unity.

Equation-2 can be used to verify the proper functionality of the OTDT channel under transient conditions. V_{OTDT} is calculated using the plant specific values for the terms, G_s, B_s, and $G_p \bullet V_p$ (under maximum pressure condition) and assuming the maximum value at the output of the T-Avg lead/lag module (10 v or 5 v) and the minimum value (0 v or 1 v) of $V_{F(Delta-I)}$. If the value of "V_{OTDT}" is equal to or less than the minimum of the equipment (0 v for 7300, or 1 v for 7100 or Foxboro) then the OTDT scaling is done properly. If the value of "V_{OTDT}" does not meet this criteria, then the gain G_s and bias B_s must be adjusted as outlined in the solution section. Once G_s is calculated, the gains G_t, G_p and $F_{Delta(I)}$ need to be calculated based on Equation-2.

OTDT CIRCUIT BLOCK DIAGRAM

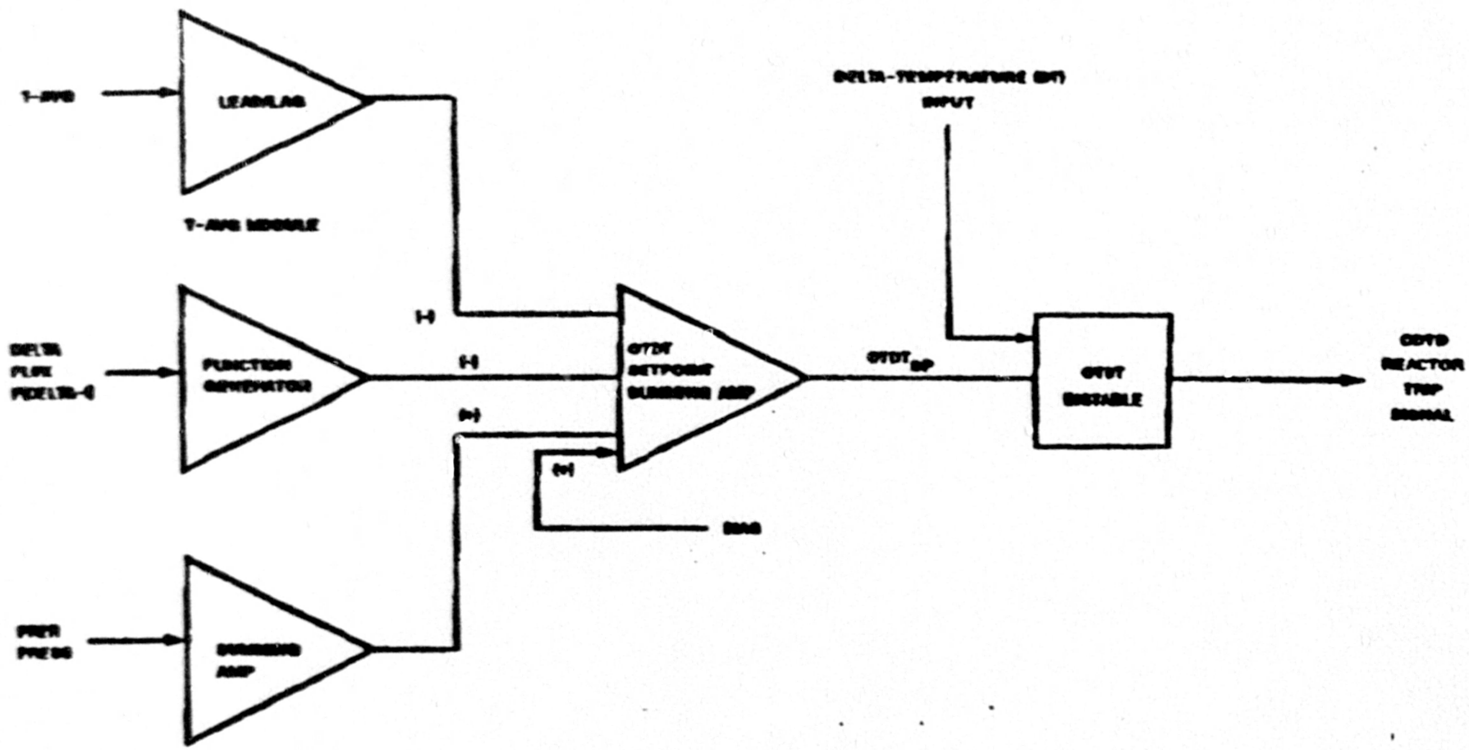

FIGURE 1

OTDT Temperature Lead/Lag Compensation

Gt = 0.8, dT/dt = 2°F/sec, L/L = 28/4

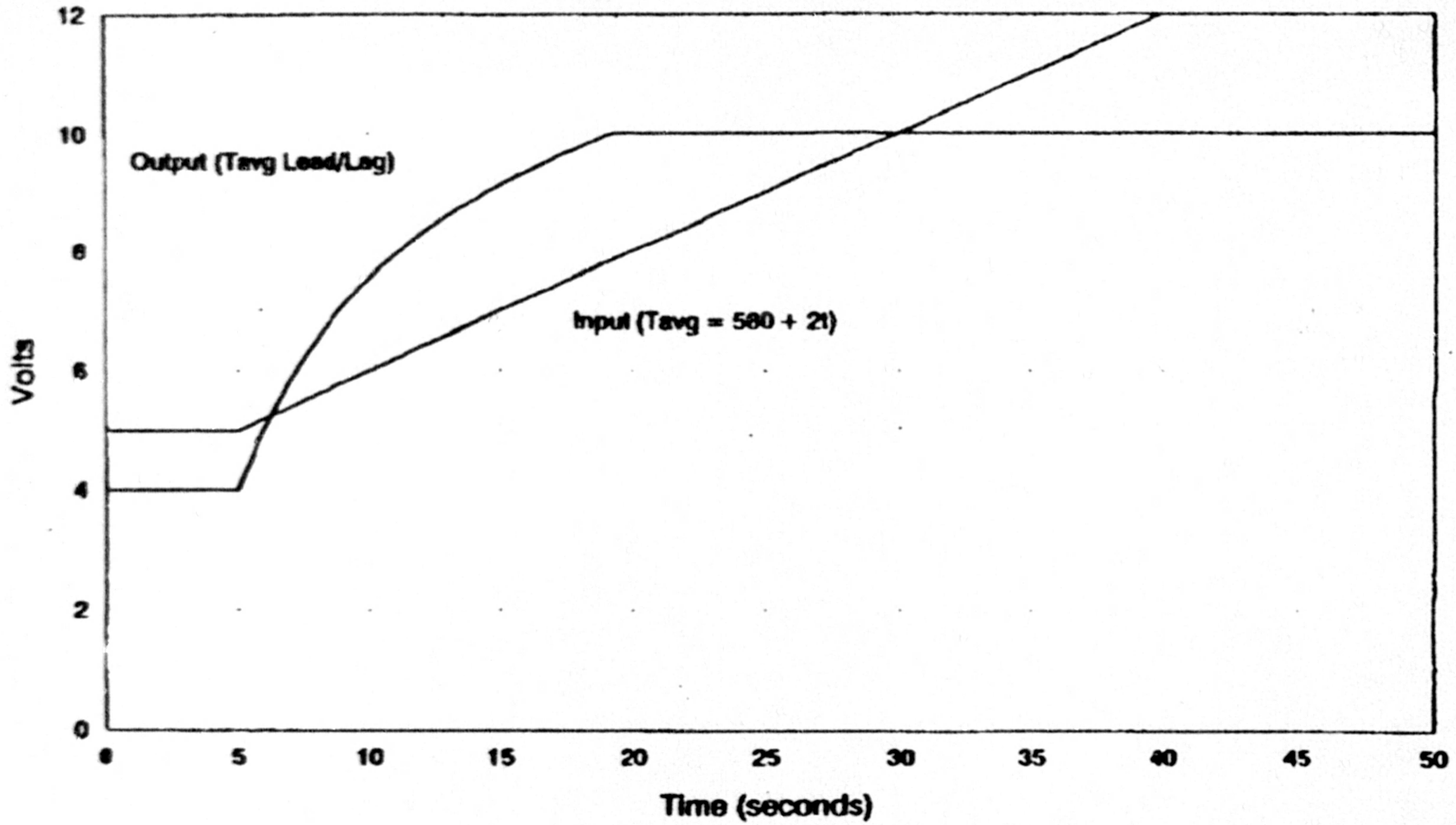

FIGURE 2: OTDT LEAD/LAG MODULE SATURATION

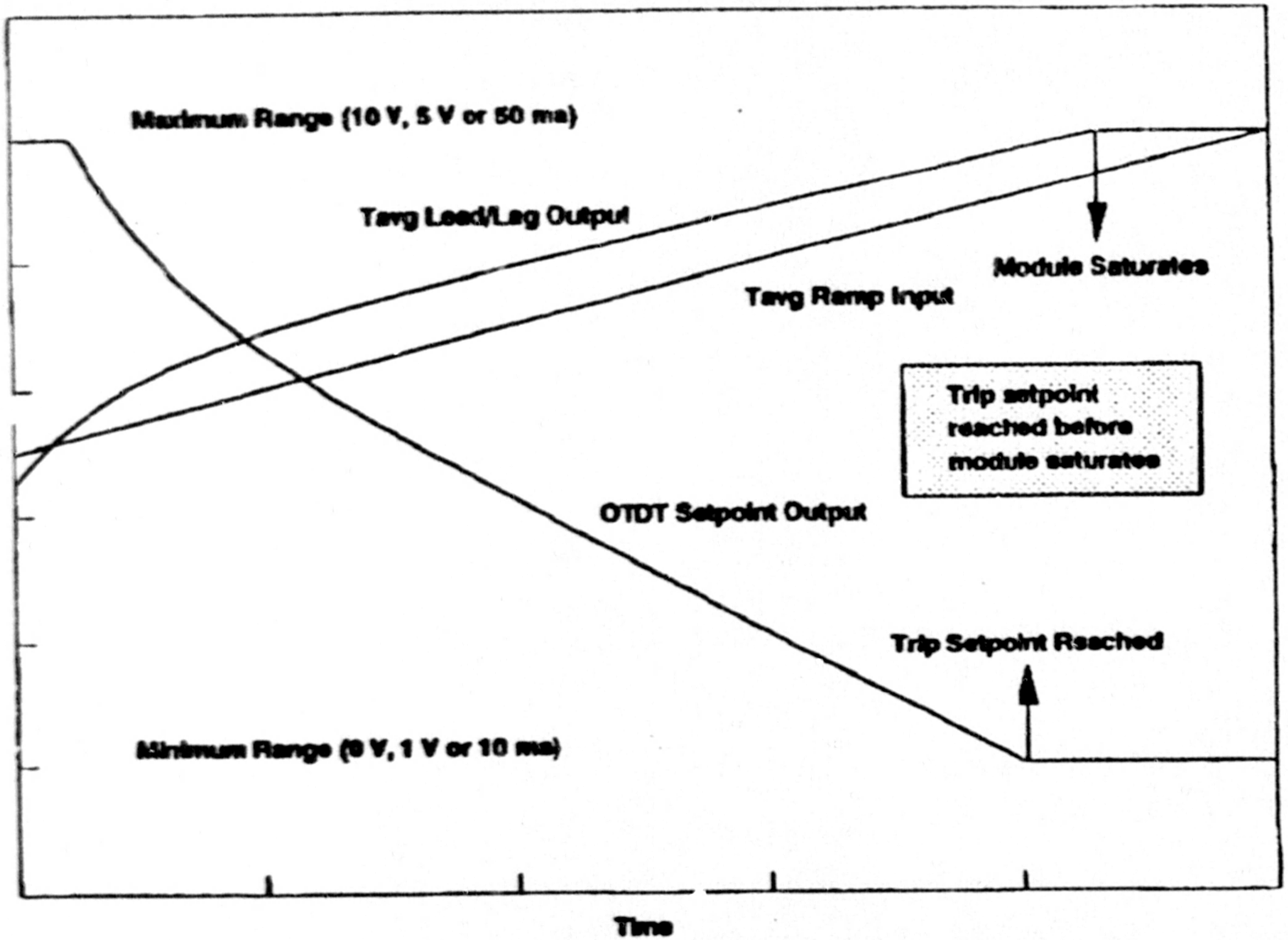

FIGURE 3: ILLUSTRATION OF SOLUTION

LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
92-52	Barriers and Seals Between Mild and Harsh Environments	07/15/92	All holders of OLs or CPs for nuclear power reactors.
92-51	Misapplication and Inadequate Testing of Molded-Case Circuit Breakers	07/09/92	All holders of OLs or CPs for nuclear power reactors.
92-50	Cracking of Valves in the Condensate Return Lines of A BWR Emergency Condenser System	07/02/92	All holders of OLs or CPs for BWRs.
92-49	Recent Loss or Severe Degradation of Service Water Systems	07/02/92	All holders of OLs or CPs for nuclear power reactors.
92-48	Failure of Exide Batteries	07/02/92	All holders of OLs or CPs for nuclear power reactors.
92-47	Intentional Bypassing of Automatic Actuation of Plant Protective Features	06/29/92	All holders of OLs or CPs for nuclear power reactors.
92-46	Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Tests, and Ampacity Calculation Errors	06/23/92	All holders of OLs or CPs for nuclear power reactors.
92-45	Incorrect Relay Used in Emergency Diesel Generator Output Breaker Control Circuitry	06/22/92	All holders of OLs or CPs for nuclear power reactors.
92-44	Problems with Westinghouse DS-206 and DSL-206 Type Circuit Breakers	06/18/92	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit

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Original Signed by
Charles E. Rossi

Charles E. Rossi, Director
Division of Operational Events Assessment
Office of Nuclear Reactor Regulation

Technical contact: S. D. Alexander, NRR
(301) 504-2995

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CHANGES TO FINAL DRAFT WERE DISCUSSED W/ S ALEXANDER ON 7/9/92
David Lanning 7/10/92

*See previous concurrence.

OFFICE:	RIS2:VIB:DRIS	TECHED	ASC:VIB:DRIS	BC:VIB:DRIS	NAME:
NAME:	SAlexander:sda*	JMain*	RWilson*	LJNorrholm*	DATE:
	04/15/92	04/16/92	05/06/92	05/07/92	

OFFICE:	D:DRIS:NRR	EAB:DOEA:NRR	BC:EAB:DOEA
NAME:	BKGrimes*	TKoshy*	*AChaffee
DATE:	05/08/92	05/08/92	07/10/92

OFFICE:	BC:OGCB:DOEA	D:DOEA:NRR
NAME:	CBerlinger*	CERossi
DATE:	06/10/92	07/1/92

DOCUMENT NAME: 91-52.SP1

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NAME:	SAlexander:sda*	JMain*	RWilson*	LJNorrholm*	DATE:
	04/15/92	04/16/92	05/06/92	05/07/92	

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DATE:	05/08/92	05/08/92	07/10/92

OFFICE:	BC:OGCB:DOEA	D:DOEA:NRR
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NAME:	TKoshy*	CBerlinger	CERossi		
DATE:	05/08/92	05/ /92	05/ /92	/ /92	/ /92

OFFICIAL RECORD COPY DOCUMENT NAME: "OTDTNATD" (WP5.1)

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DATE:	04/15/92	04/16/92	05/6/92	05/7/92	05/8/92

OFFICE:	EAB:DOEA:NRR	BC:OGCB:DOEA	D:DOEA:NRR		
NAME:	TKoshy	CBerlinger	CERossi		
DATE:	05/08/92	05/ /92	05/ /92	/ /92	/ /92

OFFICIAL RECORD COPY DOCUMENT NAME: "OTDTANIL" (WP5.1)

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NAME:	TKoshy	CBerlinger	CERossi		
DATE:	04/ /92	04/ /92	04/ /92	/ /92	/ /92

OFFICIAL RECORD COPY DOCUMENT NAME: "OTDTINS1" (WP5.0)

UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555

July 16, 1992

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System(s): WESTINGHOUSE NSSS PROCESS CONTROL SYSTEM		Date	12/13/91
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N. P. Mueller
N. P. Mueller, Mgr. Control Systems Design Analysis

Approval: L. R. Benson
L. R. Benson
Domestic Customer Projects

NSD 3087 B 03/89

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$Tau_1 s$, $Tau_2 s$: are the lead/lag time constants on T-Avg,

T_{Ref} : is the reference T-Avg, typically nominal full power T-Avg

P_{Ref} : is the reference pressurizer pressure, typically nominal pressurizer pressure

F(Delta-I) : is the Delta-I penalty

DELTA-T : is the full power DT

T_{Avg} : is the measured Average temperature

P : is the measured Pressurizer pressure.

When considering implementation of the OTDT setpoint in the protection system, Equation-1 can be reduced and written in the voltage form as follows:

$$V_{OTDT} = G_s \cdot [B_s - G_t \cdot V_t + G_p \cdot V_p - V_{F(Delta\text{-}I)}] \qquad \text{(Equation-2)}$$

where:

V_{OTDT} = OTDT setpoint in volts

G_s = gain on the OTDT summer

B_s = bias on the OTDT summer

G_t = gain on the T-Avg module

$G_t \cdot V_t$ = voltage output of the T-Avg lead/lag module

G_p = gain on the pressurizer module

V_p = voltage equivalent of the pressurizer pressure

$V_{F(Delta-I)}$ = voltage equivalent of the F(Delta-I) penalty

The setpoint calculation in its simple form is shown in Figure-1. As can be seen from the above equations and from Figure-1, as the T-Avg increases, the $OTDT_{sp}$ decreases; as the pressurizer pressure increases the $OTDT_{sp}$ increases and the Delta-I penalty always decreases the setpoint.

DISCUSSION

If the gains and biases in Equation-2 are not distributed properly some of the terms in Equation-2 could reach their maximum (saturate), before the OTDT setpoint reaches its tripped condition. As an example, consider the typical case where the input range of T-Avg is 530°F to 630°F. This corresponds to 0 to 10 volts for 7300, or 1 to 5 volts for 7100 or Foxboro equipment. If the plant is operating at a reduced power level and is at the middle of its T-Avg range (580°F) and the gain G_t on the T-Avg module is 1.6 (i.e., greater than one), then for the 7300 equipment the output of the T-Avg module in steady state will be 5 times 1.6 = 8.0 volts. If the power level is then increased and T-Avg increases to 595°F (65% of its range) the T-Avg module output at this new steady state should be 6.5 times 1.6 = 10.4 volts. However, due to the hardware limitation the output will reach its maximum of 10 volts and its overall contribution to the setpoint will not change for any further temperature increases.

This condition can be resolved by distributing the gains in the Equation-2, i.e., decrease the G_t and correspondingly increase the gain G_s. The bias B_s, gain G_p and gain on $V_{F(Delta-I)}$ also need to be reduced accordingly.

Transient response situations must also be considered to assure proper operation of the hardware. Specifically, during a transient the amplification associated with the lead/lag compensation unit, (used to anticipate the temperature response of the Reactor Coolant System) could cause saturation preventing further OTDT setpoint decreases on additional temperature (T-Avg) increases.

To illustrate this saturation effect, consider a temperature transient superimposed on the initial steady state conditions (580°F) used in the previous example. Figure 2 gives the output of the T-Avg module, with the lead/lag compensation, to a 2°F/sec temperature increase (postulated rod withdrawal event) for a typical equipment setup (G_1 = 0.8, L/L = 28/4). Note that even though the lead/lag module gain is less than 1, the T-Avg module saturates after about 19 seconds (t_0 = 5 sec). At this time the input T-Avg has only reached 608°F (580°F + 14 sec times 2°F/sec), which is only about 80% of its possible range.

Even though, the T-Avg module saturation during transients may be unavoidable, the gains can always be redistributed such that the OTDT setpoint reaches a minimum to ensure a trip, i.e., OTDT setpoint reaches the minimum of its range (0 volt, or 1 volt), before the T-Avg module saturates (refer to Figure 3). A technique for achieving this is outlined in the following section.

SOLUTION

The nonconservative impact on the OTDT setpoint calculation caused by steady state or transient saturation of the T-Avg lead/lag module can be avoided as follows:

1. Set the gain on the T-Avg lead/lag module to be less than unity. This will keep the T-Avg module from saturating over the entire input range of T-Avg in steady state.

2. Evaluate Equation-2 to determine the Bias (B_s) and OTDT summer gain (G_s) such that the summer output reaches a minimum to ensure a trip condition (output equal to 0 v, or 1 v) before or as the T-Avg lead/lag module output reaches saturation (output equal to 10 v, or 5 v). This is done with the pressure and Delta-I inputs to the Summer acting, to the maximum extent, to keep the setpoint above the trip value.

The second step is illustrated in the following example using the 7300 equipment voltage ranges (0 to 10 v).

Initial conditions (referenced to Equation-2):

a) The output of the OTDT Summer is at the minimum, $V_{OTDT} \leq 0$

b) There is no Delta-I penalty, $V_{F(Delta-I)} = 0$ v

c) The T_{Avg} lead/lag module reaches saturation, $G_1 \cdot V_1 = 10$ v

d) $G_p \cdot V_p$ is evaluated at the maximum pressure (usually 2500 psig)

Solving Equation-2 under these conditions will give a value of G_s.

$$G_s \cdot [B_s - 10 + G_p \cdot 10] \leq 0 \qquad \text{(Equation-3)}$$

or,

$$G_s \geq [G_s \cdot B_s + (G_s \cdot G_p)\ 10] / 10 \qquad \text{(Equation-4)}$$

The value of products $G_s \cdot B_s$, $G_s \cdot G_p$ and $G_s \cdot G_t$ can be determined by comparing Equation-2 to Equation-1 reduced to voltage form, using plant specific parameter ranges and equipment type (7300 in this example). Once G_s is calculated, the bias B_s and the gains G_t and G_p and $F_{Delta(f)}$ need to be calculated based on Equation-2 and the products $G_s \cdot B_s$, $G_s \cdot G_p$ and $G_s \cdot G_t$.

RECOMMENDATIONS

Scaling of the OTDT channel should be examined to confirm that saturation of the T-Avg lead/lag module will not occur in the steady state and that the channel gains are distributed such that, during transient conditions, saturation of this module would occur only after the channel has developed a trip setpoint.

Proper operation of the steady state is assured if the gain of the T-Avg lead/lag module is less than unity.

Equation-2 can be used to verify the proper functionality of the OTDT channel under transient conditions. V_{OTDT} is calculated using the plant specific values for the terms, G_s, B_s, and $G_p \cdot V_p$ (under maximum pressure condition) and assuming the maximum value at the output of the T-Avg lead/lag module (10 v or 5 v) and the minimum value (0 v or 1 v) of $V_{F(Delta-I)}$. If the value of "V_{OTDT}" is equal to or less than the minimum of the equipment (0 v for 7300, or 1 v for 7100 or Foxboro) then the OTDT scaling is done properly. If the value of "V_{OTDT}" does not meet this criteria, then the gain G_s and bias B_s must be adjusted as outlined in the solution section. Once G_s is calculated, the gains G_t, G_p and $F_{Delta(f)}$ need to be calculated based on Equation-2.

OTDT CIRCUIT BLOCK DIAGRAM

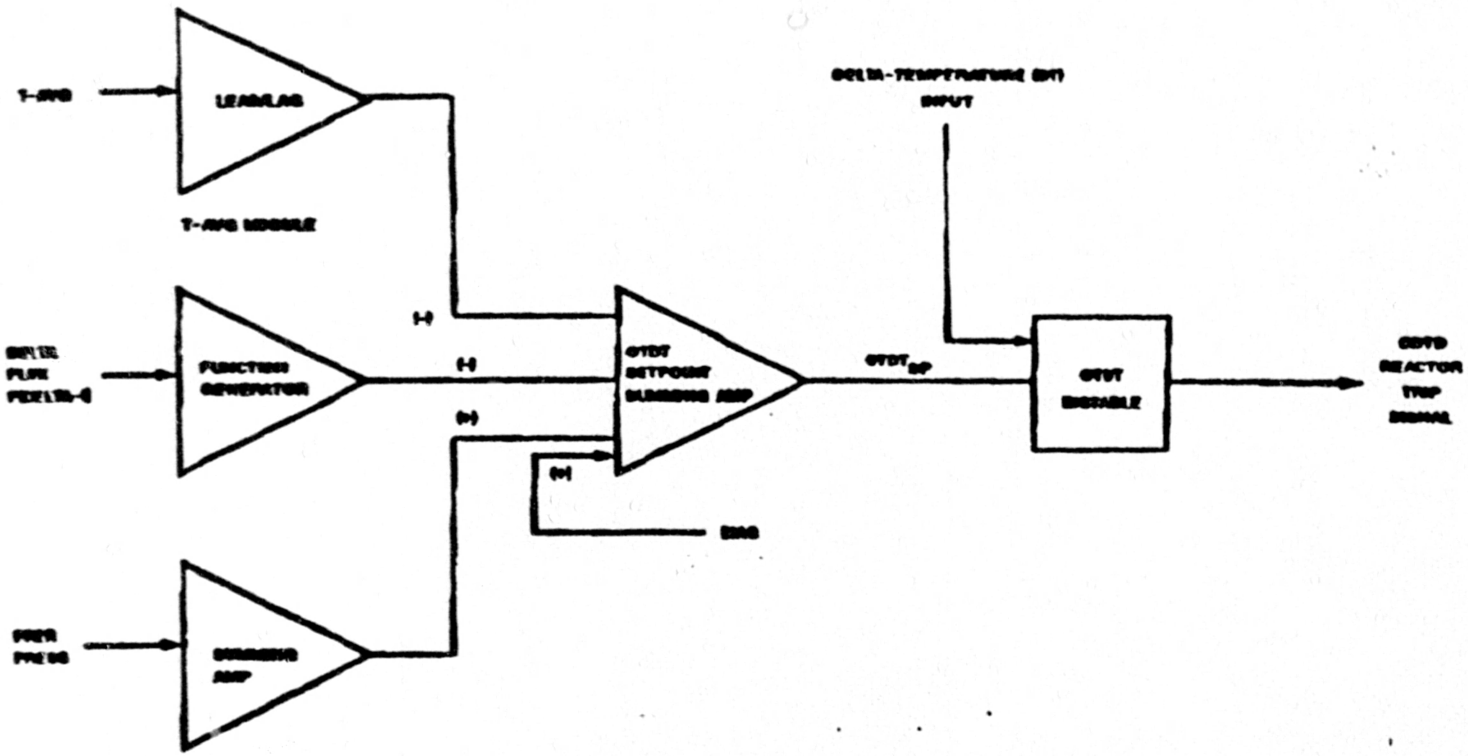

FIGURE 1

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OTDT Temperature Lead/Lag Compensation

Gt = 0.8, dT/dt = 2°F/sec, L/L = 28/4

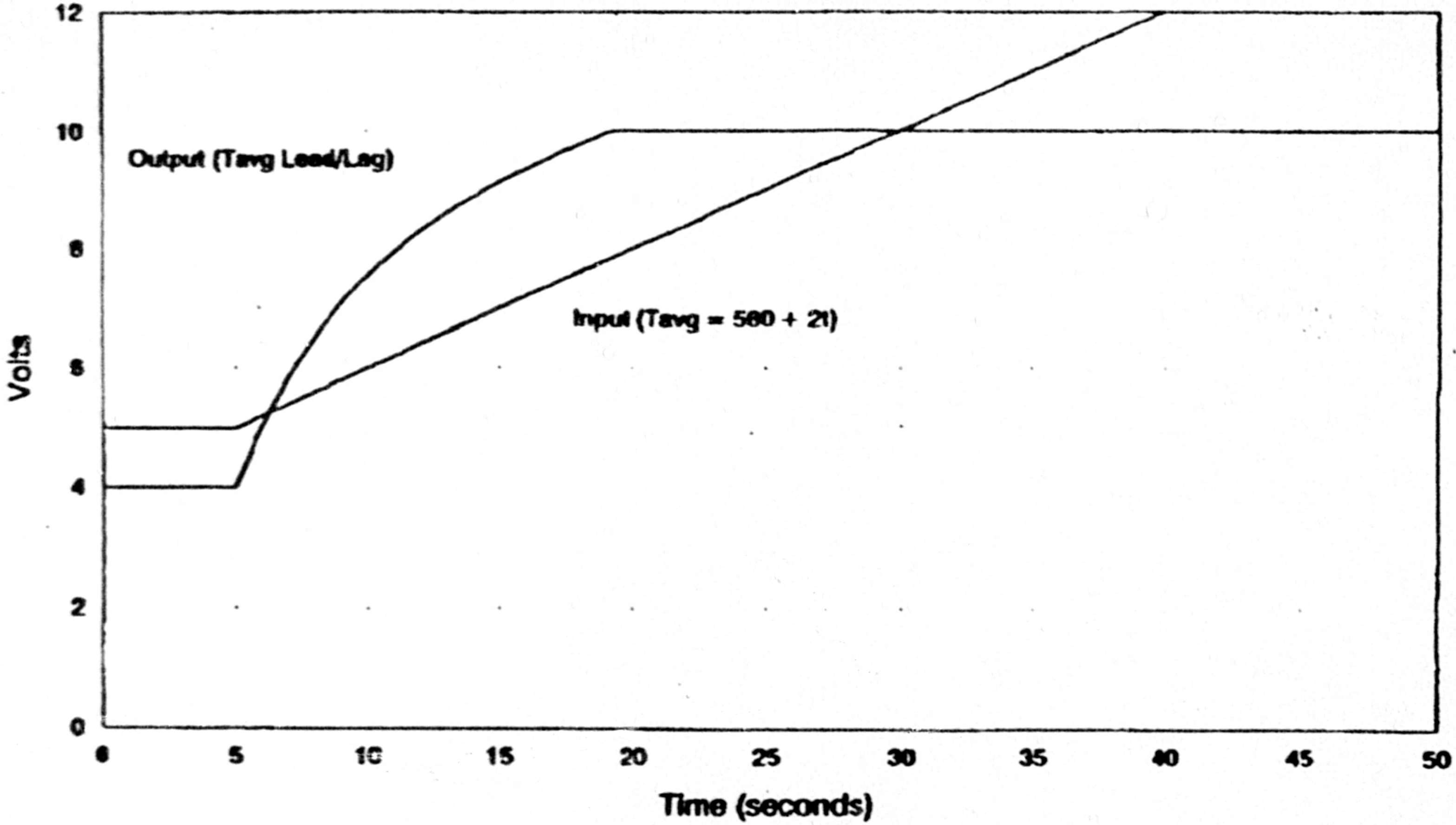

FIGURE 2: OTDT LEAD/LAG MODULE SATURATION

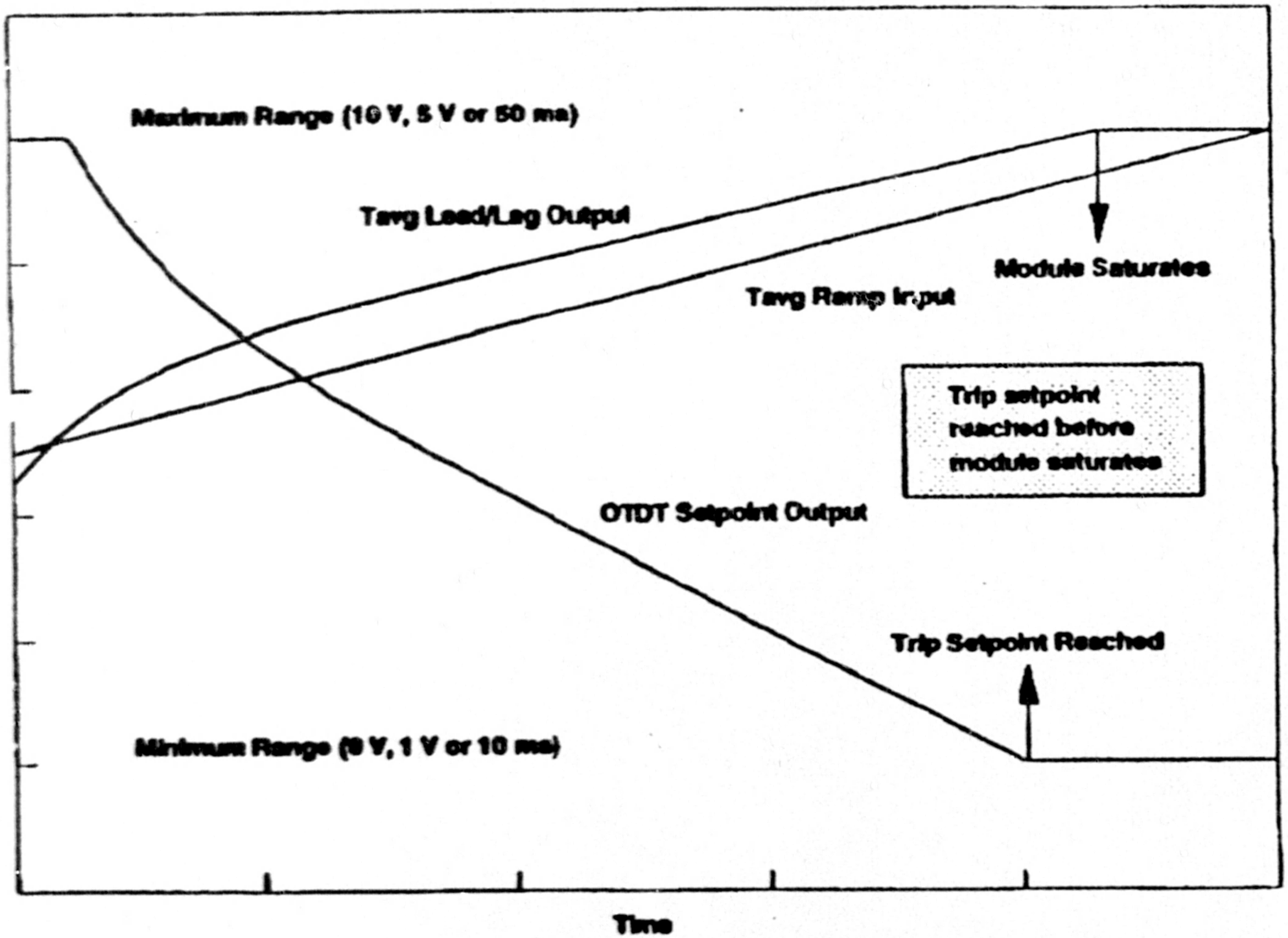

FIGURE 3: ILLUSTRATION OF SOLUTION

LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
92-52	Barriers and Seals Between Mild and Harsh Environments	07/15/92	All holders of OLs or CPs for nuclear power reactors.
92-51	Misapplication and Inadequate Testing of Molded-Case Circuit Breakers	07/09/92	All holders of OLs or CPs for nuclear power reactors.
92-50	Cracking of Valves in the Condensate Return Lines of A BWR Emergency Condenser System	07/02/92	All holders of OLs or CPs for BWRs.
92-49	Recent Loss or Severe Degradation of Service Water Systems	07/02/92	All holders of OLs or CPs for nuclear power reactors.
92-48	Failure of Exide Batteries	07/02/92	All holders of OLs or CPs for nuclear power reactors.
92-47	Intentional Bypassing of Automatic Actuation of Plant Protective Features	06/29/92	All holders of OLs or CPs for nuclear power reactors.
92-46	Thermo-Lag Fire Barrier Material Special Review Team Final Report Findings, Current Fire Endurance Tests, and Ampacity Calculation Errors	06/23/92	All holders of OLs or CPs for nuclear power reactors.
92-45	Incorrect Relay Used in Emergency Diesel Generator Output Breaker Control Circuitry	06/22/92	All holders of OLs or CPs for nuclear power reactors.
92-44	Problems with Westinghouse DS-206 and DSL-206 Type Circuit Breakers	06/18/92	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit