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

June 13, 1991

NRC INFORMATION NOTICE NO. 91-38: THERMAL STRATIFICATION IN FEEDWATER SYSTEM PIPING

Addressees:

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose:

This information notice is intended to alert addressees to feedwater system (FWS) piping that could be subjected to thermal stratification and cause unacceptable pipe movement. 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 do not constitute NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On December 12, 1990, the Duquesne Light Company (the licensee) discovered global thermal stratification over a long stretch of horizontal FWS piping inside containment at the Beaver Valley Power Station, Unit 1 (BV-1) during followup activities related to NRC Bulletin No. 79-13, "Cracking in Feedwater System Piping." Global thermal stratification results in low-cycle fatigue, pipe movement, and stresses that might not have been considered in the design of the piping system (as opposed to cyclic thermal stratification and thermal striping which result in high-cycle fatigue and pipe cracks.) The licensee detected global thermal stratification at BV-1 using instrumentation installed to monitor the behavior of the feedwater line following unexpected movement of the feedwater piping in November 1989 (see Figure 1). This instrumentation detected feedwater temperatures at the top and bottom of the feedwater line that varied as much as 200°F. The licensee attributed this thermal stratification to inadequate mixing of feedwater along a 90-foot section of horizontal piping inside the containment. Although a vertical section of piping might be expected to provide sufficient mixing to prevent stratification, the horizontal section at BV-1 is preceded by a 20-foot vertical section that apparently did not provide adequate mixing to prevent stratification. This global thermal stratification phenomenon was not previously considered in the design of the main feedwater piping system for BV-1.

IDTR-11C

Discussion:

BV-1 is a 3-loop pressurized water reactor (PWR) designed by the Westinghouse Electric Corporation. The three-loop design may be particularly susceptible to global thermal stratification in the FWS piping because it typically includes a long section of horizontal piping just inside containment. However, other plant designs, including boiling water reactors (BWRs), may be susceptible to this phenomenon. For instance, a similar FWS event occurred on August 22, 1984, at the Washington Nuclear Plant, Unit 2, (WNP-2) and is discussed in NRC Information Notice (IN) 84-87, "Piping Thermal Deflection Induced by Stratified Flow." In this event, the BWR was operating at about 1 percent power when the introduction of cold feedwater into hot feedwater piping, heated by the reactor water cleanup system, caused the pipe to deflect and damage the hangers and snubbers.

Thermal stratification of the feedwater line may occur while a plant is starting up or cooling down, or when auxiliary feedwater (AFW) is being injected into the steam generator through the feedwater line. While a BWR plant is starting up, stratified flow can be introduced when cold feedwater is added to hot FWS piping (as was the case at WNP-2). While a BWR or PWR plant is cooling down, especially from full-power operation (Mode 1) to hot standby (Mode 3), the significant decrease in the FWS flow rate and temperature make the FWS piping susceptible to stratification. For a PWR, AFW injection probably introduces the greatest potential for thermal stratification. When cold AFW is injected just after the full flow of hot feedwater, the temperature differential across the pipe can become as large as 200°F.

In long, horizontal lengths of piping, 2 (or more) streams of fluid of different temperatures can flow in separate layers without appreciable mixing, making long sections of pipe susceptible to thermal stratification. This piping may be subjected to stresses that were not previously accounted for in the piping design. The BV-1 event also demonstrates that a vertical section of pipe just upstream of a long section of horizontal pipe offers little (if any) protection from stratification.

Another concern resulting from the BV-1 event is the adequacy of the design of supports for piping that may undergo thermal stratification. Supports located along such piping may restrict pipe movement and contribute to pipe deformation or support damage. A similar concern existed at Trojan during an event in 1988 (see NRC Bulletin 88-11, "Pressurizer Surge Line Thermal Stratification").

These concerns are similar to those described in NRC Bulletin 79-13 (Revision 2, October 16, 1979) and NRC IN 84-87. However, this NRC information notice addresses primarily the effects of thermal stratification on feedwater system piping, whereas NRC Bulletin 79-13 addressed primarily the effects of thermal stratification on the steam generator nozzles. IN 84-87 addresses thermal stratification in the feedwater system at BWRs.

The staff addressed thermal stratification in other systems important to safety in NRC Bulletins 88-08; 88-08, Supplement 1; and 88-08, Supplement 3; "Thermal Stress in Piping Connected to Reactor Coolant Systems," and in NRC INs 88-01, "Safety Injection Pipe Failure," and 88-80, "Unexpected Piping Movement Attributed to Thermal Stratification."

Although thermal stratification is not a new problem, the most recent event demonstrates that mechanisms for thermal stratification continue to be identified. This most recent finding indicates that stresses produced by stratification in systems with long sections of horizontal piping may result in an unanalyzed condition which can affect the integrity of piping and supports.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate NRR project manager.

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

Technical Contacts: Angie P. Young, NRR
(301) 492-1167

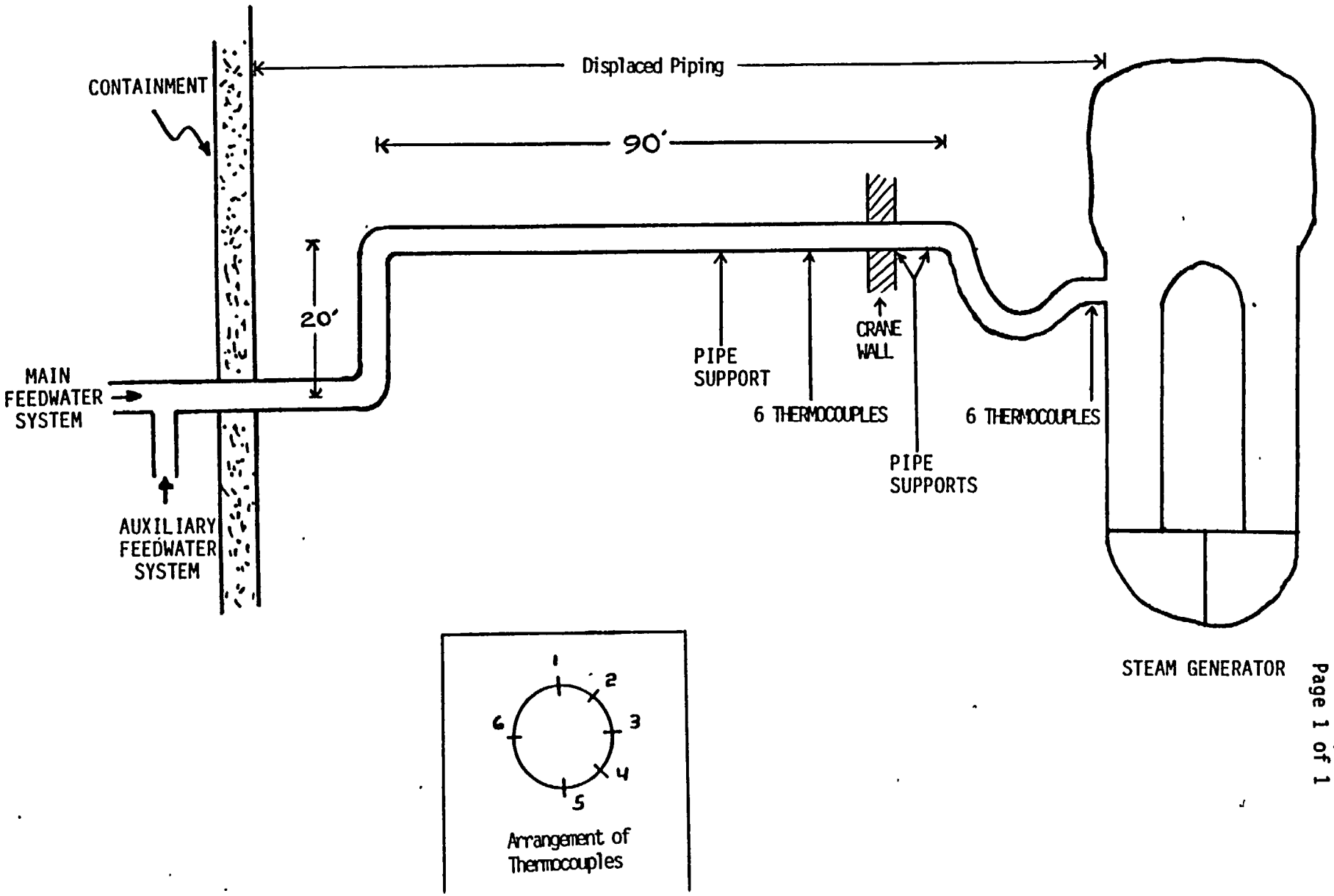
James E. Beall, RI
(412) 643-2000

Andrew J. Kugler, NRR
(301) 492-0834

Shou-Nien Hou, NRR
(301) 492-0793

Attachments:
1. Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment
2. List of Recently Issued NRC Information Notices

Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment



LIST OF RECENTLY ISSUED
NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
91-37	Compressed Gas Cylinder Missile Hazards	06/10/91	All holders of OLs or CPs for nuclear power reactors.
91-36	Nuclear Plant Staff Working Hours	06/10/91	All holders of OLs or CPs for nuclear power reactors.
91-35	Labeling Requirements for Transporting Multi-Hazard Radioactive Materials	06/07/91	All U.S. Nuclear Regulatory Commission (NRC) licensees.
91-34	Potential Problems in Identifying Causes of Emergency Diesel Generator Malfunctions	06/03/91	All holders of OLs or CPs for nuclear power reactors.
91-33	Reactor Safety Information for States During Exercises and Emergencies	05/31/91	All holders of OLs or CPs for nuclear power reactors.
91-32	Possible Flaws in Certain Piping Systems Fabricated by Associated Piping and Engineering	05/15/91	All holders of OLs or CPs for nuclear power reactors.
91-31	Nonconforming Magnaflux Magnetic Particle (14AM) Prepared Bath	05/09/91	All holders of OLs or CPs for nuclear power reactors.
91-30	Inadequate Calibration of Thermoluminescent Dosimeters Utilized to Monitor Extremity Dose at Uranium Processing and Fabrication Facilities	04/23/91	All fuel cycle licensees and other licensees routinely handling unshielded uranium materials.

OL = Operating License
CP = Construction Permit

The staff addressed thermal stratification in other systems important to safety in NRC Bulletins 88-08; 88-08, Supplement 1; and 88-08, Supplement 3; "Thermal Stress in Piping Connected to Reactor Coolant Systems," and in NRC INs 88-01, "Safety Injection Pipe Failure," and 88-80, "Unexpected Piping Movement Attributed to Thermal Stratification."

Although thermal stratification is not a new problem, the most recent event demonstrates that mechanisms for thermal stratification continue to be identified. This most recent finding indicates that stresses produced by stratification in systems with long sections of horizontal piping may result in an unanalyzed condition which can affect the integrity of piping and supports.

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate NRR project manager.

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

Technical Contacts: Angie P. Young, NRR
(301) 492-1167

James E. Beall, RI
(412) 643-2000

Andrew J. Kugler, NRR
(301) 492-0834

Shou-Nien Hou, NRR
(301) 492-0793

Attachments:
1. Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment
2. List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCE

OFC	*DOEA:EAB	*SC:DOEA:EAB	*C:DOEA:EAB	*Tech Ed	*DOEA:OGCB	*NRR:EMEB	*RI
NAME	AYoung:atb	DFischer	AChaffee		AKugler	SNHou	JBeall
DATE	04/25/91	05/20/91	05/20/91	/ /91	06/ /91	06/ /91	04/24/91

OFC	C:DOEA:OGCB	D:DOEA					
NAME	CBerlinger	CERossi					
DATE	06/04/91	06/7/91					

OFFICIAL RECORD COPY
Document Name: IN 9138

The staff addressed thermal stratification in other systems important to safety in NRC Bulletins 88-08, 88-08 Supplement 1, and 88-08 Supplement 3, "Thermal Stress in Piping Connected to Reactor Coolant Systems," and in NRC INs 88-01, "Safety Injection Pipe Failure," and 88-80, "Unexpected Piping Movement Attributed to Thermal Stratification."

Although thermal stratification is not a new problem, the most recent event demonstrates that mechanisms for thermal stratification continue to be identified. This most recent finding indicates that stresses produced by stratification in systems with long sections of horizontal piping may result in an unanalyzed condition which can pose a threat to the integrity of piping and supports.

This information notice requires no specific action or written response. If you have any questions about this matter, please contact one of the technical contacts listed below or the appropriate NRR project manager.

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

Technical Contacts: Angie P. Young, NRR
(301) 492-1167

James E. Beall, RI
(412) 643-2000

Andrew J. Kugler, NRR
(301) 492-0834

Shou-Nien Hou, NRR
(301) 492-0793

Attachments:
1. Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment
2. List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCE

OFC	*DOEA:EAB	*SC:DOEA:EAB	*C:DOEA:EAB	*Tech Ed	*DOEA:OGCB	*NRR:EMEB	*RI
NAME	AYoung:atb	DFischer	AChaffee		AKugler	SNHou	JBeall
DATE	/ /91	/ /91	/ /91	/ /91	/ /91	/ /91	/ /91

OFC	C:DOEA:OGCB	D:DOEA					
NAME	CBerlinger	CERossi					
DATE	6/4/91	/ /91					

OFFICIAL RECORD COPY
Document Name: STRAT

Thermal stratification in other systems important to safety has been addressed in NRC Bulletins 88-08, 88-08 Supplement 1, and 88-08 Supplement 3, "Thermal Stress in Piping Connected to Reactor Coolant Systems," and in NRC Information Notices 88-01, "Safety Injection Pipe Failure," and 88-80, "Unexpected Piping Movement Attributed to Thermal Stratification."

Although thermal stratification is not a new problem, the most recent event demonstrates that mechanisms for thermal stratification continue to surface and can pose a threat to the integrity of piping and supports.

This information notice requires no specific action or written response. If you have any questions about this matter, please contact one of the technical contacts listed below or the appropriate NRR project manager.

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

Technical Contacts:

Angie P. Young, NRR
(301) 492-1167

James E. Beall, RI
(412) 643-2000

Andrew J. Kugler, NRR
(301) 492-0834

Shou-Nien Hou, NRR
(301) 492-0793

Attachments:
1. Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment
2. List of Recently Issued NRC Information Notices

*SEE PREVIOUS CONCURRENCE

OFC	*DOEA:EAB	*SC:DOEA:EAB	*C:DOEA:EAB	Tech Ed	DOEA:OGCB	NRR:EMEB	*RI
NAME	AYoung:atb	DFischer	AChaffee	JMain	AKugler	SNHou	JBeall
DATE	/ /91	/ /91	/ /91	6/29/91	5/23/91	5/30/91	/ /91

OFC	C:DOEA:OGCB	D:DOEA					
NAME	CBerlinger	CERossi					
DATE	/ /91	/ /91					

OFFICIAL RECORD COPY
Document Name: STRAT

Thermal stratification in other systems important to safety has been addressed in NRC Bulletins 88-08, 88-08 Supplement 1, and 88-08 Supplement 3, "Thermal Stress in Piping Connected to Reactor Coolant Systems," and NRC Information Notices 88-01, "Safety Injection Pipe Failure," and 88-80, "Unexpected Piping Movement Attributed to Thermal Stratification."

This information notice requires no specific action or written response. If you have any questions about this matter, please contact one of the technical contacts listed below or the appropriate NRR project manager.

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

Technical Contacts: Angie P. Young, NRR
(301) 492-1167

James E. Beall, RI
(412) 643-2000

Andrew J. Kugler, NRR
(301) 492-0834

Shou-Nien Hou, NRR
(301) 492-0793

Attachments:
1. Figure 1. Beaver Valley Unit 1 Main Feedwater System Piping Configuration Inside Containment
2. List of Recently Issued NRC Information Notices

OFC	:DOEA:EAB	:SC:DOEA:EAB	:C:DOEA:EAB	:Tech Ed	:DOEA:OGCB	:NRR	:RI
NAME	:AYoung:atb	:DFischer	:AChaffee	:	:AKugler	:SNHou	:JBeall (via FAX)
DATE	: 4/25/91	: 5/10/91	: 5/20/91	: / /91	: / /91	: / /91	: 4/24/91

OFC	:C:DOEA:OGCB	:D:DOEA	:	:	:	:	:
NAME	:CBerlinger	:CERossi	:	:	:	:	:
DATE	: / /91	: / /91	:	:	:	:	:

OFFICIAL RECORD COPY
Document Name: STRAT