Becht Nuclear Services Newsletter

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Time Limited Aging Analyses (TLAA) for Plant License Renewal

We have recently completed supporting of a client's license renewal analyses and submittals, for plant life extension. Of particular importance was the updated assessment of the fatigue qualification of ASME Class 1 components for a longer plant operating life, including the effects of the reactor coolant environment on fatigue life. As part of the activity we supported the client at the hearing with the ACRS and during the NRC audits of environmental fatigue analyses.

For the license renewal of operating plants, ASME Class 1 components that were designed for cyclic operation must be re-evaluated to determine if margins to fatigue failure will be maintained over the extended plant life. Original plant fatigue analyses were completed based on the ASME Bopiler and Pressure Vessel Section III (ASME III) Class 1 fatigue curves that were developed from experimental cyclic fatigue data in air. Mean fit of the failure data curve with added design margins on stress and cycles were utilized to provide desired margins in the design fatigue curves for carbon and stainless steels. Ongoing fatigue research has shown that the design margin safety factors of 2 on stress and 20 on cycles used in the ASME III fatigue curves may be non-conservative when the effects of reactor water environments are considered. Therefore, for life extension analyses the current ASME III fatigue analyses of Class 1 lines are re-evaluated using recommendations from NRC NUREG publications. This article is an overview of the approach used to account for the environmental effects in the life extension fatigue evaluation of Class 1 components.

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New Team Member

Jack Cole, PE joined the Becht Nuclear Services team in July after a thirty three year career at the Columbia Generating Station Boiling Water Reactor. Jack started at Columbia during initial construction, working first as a piping field engineer and then moving on to installation of large mechanical equipment. He ultimately moved from construction into operational design support.

Jack left Columbia as the Design Authority for the Civil/Structural discipline. His activities for Columbia included:

- Design and modification of ASME Class 1, 2, 3, and B31.1 piping and support systems
- Operability Determinations for degraded safety related components evaluations
- Support of License Renewal Time Limited Aging Analyses
- Broke/Fix Repairs for Mechanical Equipment
- Risk Informed ISI Consulting on over 20 foreign and domestic plants
- Overall Design Basis compliance review for all plant design changes.
- Plant fatigue monitoring program manager.
- Fitness for service evaluations for Section VIII tanks and vessels.
- Utility RPE for ASME Design Specifications.

In addition to his utility work activities Jack has served on various ASME Section III Codes and Standards committees for the last 29 years. His current committee memberships include the Section III Working Group on Piping, the Subgroup on Component Design, the BPV III Strategy and Project Management Committee (Chair), the BPV III standards committee (Vice Chair), and the BPV III Special Committee on Interpretations (Chair). Jack also is the project manager for ASME activities related to incorporation of design rules to address reactor water environmental effects on fatigue life.

In addition to his design background, Jack brings an understanding of commercial reactor operations and licensing knowledge to supplement the Becht Nuclear Services team. ■

Seismic Evaluation of Fire Protection Piping Systems

A 1-DAY COURSE OFFERED
AT YOUR FACILITY

- Unique seismic aspects of fire protection (FP) systems
- Codes and standards for the seismic design of fire protection
- Concurrent loads and load combinations
- Seismic evaluation procedure for FP piping
- Analysis and span tables approach
- Static and dynamic analysis approach
- Stress and other limits
- Seismic capacity of FP grooved couplings
- Seismic capacity of FP threaded joints
- NFPA-13 seismic sway bracing vs. seismic supports
- Attachment to plant structures

High Energy Line Breaks

Nuclear power plants are designed, constructed, operated and inspected to prevent pipe ruptures. Despite these preventive measures, plants are designed to mitigate the effects of hypothetical pipe ruptures. The hypothetical ruptures are in the form of leakage cracks and, for high energy lines (operating temperatures in excess of 200oF or operating pressures in excess of 275 psig), full circumferential and longitudinal breaks. Nuclear power plants are designed to achieve a safe shutdown if such a postulated high energy line break (HELB) was to occur.

The methods and criteria for HELB analysis are defined in Section 3.6 of the NRC Standard Review Plan (NUREG 0800). There are basically two consequences to the postulated HELB:

(1) Dynamic effects in the form of pipe whip, jet impingement on surrounding targets, in-pipe fluid transients (waterhammer) caused by the sudden break, and sub-compartment pressurization due to the discharge of hot pressurized fluid inside rooms and compartments, and

(2) Environmental effects in the form of flooding and spray wetting from fluid discharge from the break, and harsh ambient temperatures and humidity. Challenged by these effects, plant systems and components must be designed to operate to bring the plant to a safe shutdown.

To limit and confine the dynamic effects of postulated HELB, plants install whip restraints, bumpers, jet shields and barriers. These protective structures are designed using energy methods or dynamic analysis techniques, including finite element analysis, such as illustrated in the figure.

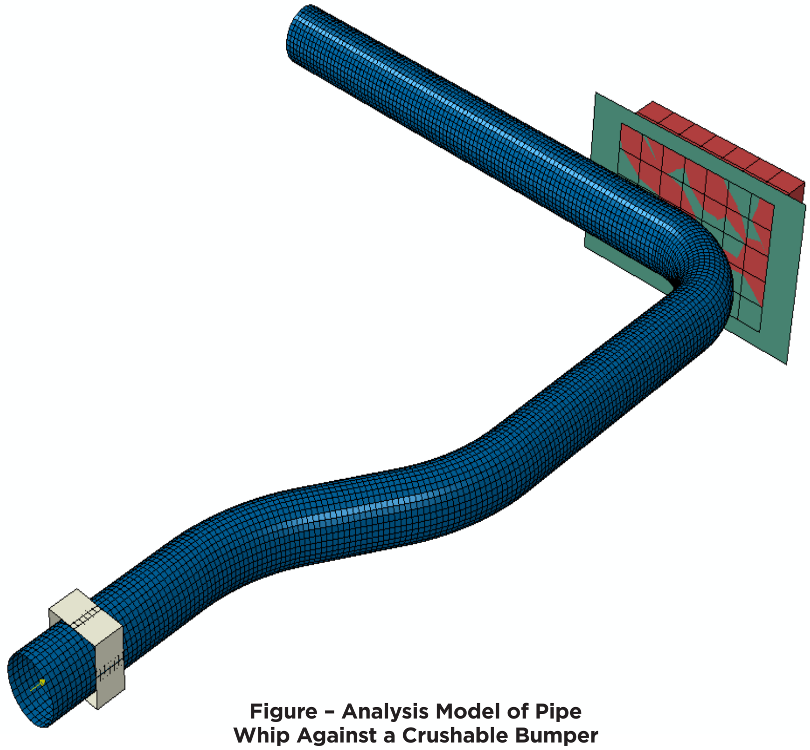

Figure – Analysis Model of Pipe Whip Against a Crushable Bumper

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Time Limited Aging Analysis (continued from page 1)

Regulatory Requirements

One major aspect of plant license renewal is the review, update, or regeneration of plant analyses that depend on the system operating time or cycles. These are commonly referred to as time-limited aging analyses (TLAAs). 10CFR54 defines TLAAs as those licensed calculations that:

1. Involve systems, structures, and components within the scope of license renewals as delineated in 54.4(a);
2. Consider the effects of aging;
3. Involve time-limited assumptions defined by the current operating term, for example years;
4. Are determined to be relevant by the licensee in making a safety determination;
5. Involve conclusions or provide the basis for conclusions related to the capability of the system structure, and component to perform its intended functions, as delineated in 54.4 (b);
6. Are contained or incorporated by reference in the current licensing basis (CLB).

The NRC staff approach to review TLAA analyses is documented in NUREG-1800 Revision 2, "Standard Review Plan for Review of License Renewal Applications for Nuclear Power Plants", Section 4.3.

Transients Review

The actual plant operating transient history is first reviewed, as input to the updated fatigue analyses. This review is to ensure that the projected transient cycles used in the TLAA will envelope the number of cycles expected over the projected new operating life. The review may also reveal that some projected transient events occur less often or are less severe than previously estimated for the original plant life, providing a basis for reduction of excessive conservatism, if needed. To complete the transient reviews, ongoing cycle counting must be evaluated. If cycle counting for Class 1 components has not been done in the past, then operator logs going back to plant startup are reviewed for an accurate assessment of the stress cycles that have occurred at the plant.

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Buried Pipe Design and Integrity

A ONE-DAY COURSE OFFERED
AT YOUR FACILITY

Historical Overview
Early waterworks developments
Early nuclear designs
Current expectations

Codes and Standards
AWWA Standards
ASME B31.1 Appendix VII
ASME III BPVC-III
ASCE References
Pipeline codes
Bibliography

Regulatory Requirements
US NRC Standard Review Plan
Buried Pipe Initiative

Design Equations and Example
Internal Pressure
Soil loads
Surface loads
Constrained expansion
Ground settlement
Groundwater
Frost heave
Fluid transient (waterhammer)
Seismic wave passage
Seismic anchor movement

Considerations for non-Metallic Pipe
Fiberglass
PVC
High Density Polyethylene

Design Analysis Process
Geotechnical-civil input
Mechanical and system input
Output
Qualification

Integrity Assessment
Assessment of wall thinning
Assessment of pitting
Assessment of crack-like flaws
Assessment of mechanical damage
Run-or-repair decision

Instructor

Mr. George Antaki, Vice-chairman of ASME B31 Mechanical Design Committee, past Chair of the joint ASME-ASCE task group on buried pipe, co-author of buried pipe reports for the American Lifelines Alliance and EPRI, co-author of draft code cases on buried pipe design and integrity.

Please contact George Antaki at 803-979-1340 or gantaki@becht.com

Time Limited Aging Analysis (continued from page 3)

Selection of Locations for Environmental Fatigue Evaluations

The next step is to determine the specific locations in Class 1 systems and components that govern fatigue life. Original plant license renewal applications focused on locations identified as typical fatigue sensitive locations for each type of LWR plant. NUREG-1800 rev. 2 has expanded the number of locations for fatigue evaluation, stating "Critical components should include as a minimum, those selected in NUREG/CR-6260. Applicants should consider adding additional component locations if they are considered to be more limiting than those considered in NUREG/CR-6260." The industry is currently working through the process to be followed to determine the selection process for the limiting locations.

In selecting limiting locations for TLAA several factors must be accounted for: the magnitude and number of transients, the stresses in the system, and the environmental effects. Limiting locations can be determined based upon an understanding of the plant operation and identification of fatigue sensitive locations in the current design-basis fatigue analyses. These fatigue sensitive locations are typically at vessel nozzles, piping tees and branch connections, reducers, tapered transitions, and dissimilar metal weld joints. These will tend to have high fatigue usage factors in the existing analyses. The applicant will have to thoroughly and clearly document the basis for the selected TLAA controlling locations.

Update of Class 1 Fatigue Analyses for Revised Transients

Next is the update of existing fatigue analyses, adjusted for increased or reduced transient cycles. In this step stress ranges previously determined in the design basis analysis remain unchanged, but the adjustment of expected cycles will impact load pair combinations. The new cumulative usage factors (CUFs) are calculated and must remain below the ASME III limit of 1.0. In-air CUFs greater than about 0.3 will be difficult to qualify when introducing the environmental penalties.

To complete the environmental fatigue evaluation and achieve CUFs below 1.0 it may be necessary to refine the original design basis fatigue analysis to remove excessive conservatism. Areas of improvement would be to refine the grouping of transients, to evaluate of controlling load cases for analysis insight, to improve the design transients based upon a proven record of operation, or consideration of event/load timing for refinement of stresses. This effort may range from adjustments ot existing design analyses to the generation of complete new analyses. Depending upon complexity and cost, a determination may be made to monitor fatigue at key locations.

Evaluation of Reactor Water Coolant Environment

NUREG-1800 recognizes NUREG/CR-6909 to evaluate the effects of the reactor water environment on fatigue life, through the application of an environmental fatigue penalty factor, the Fen, applied to the in-air usage factor. Fen is defined as the ratio of the fatigue life in LWR environment divided by the fatigue life in air, Uenv/Uair.

To complete the environmental fatigue evaluations following NRC accepted methods, data on parameters such as oxygen content, sulfur content for carbon steel, temperatures, and strain rates must be determined. Default bounding values may be utilized for a first level evaluation of the Fen. Other approaches using average temperatures, or more detailed analyses are available for optimizing the Fen values.

The Fen penalty factors are applicable to the wetted surfaces of components in contact with the reactor coolant. For piping systems, due to the conservative rules of NB-3600, Fen penalties are applied without determination of peak stress location. When multiple load sets are evaluated to determine partial usage factors, an appropriate environmental penalty factor for each load pair must be determined and new environmental usage factors determined. The partial usages are combined using Miner's rule.

At this time, if the cumulative environmental fatigue usage exceeds 1.0, the alternative beyond more analytical refinement is to monitor the location and manage fatigue over the component life. If the usage factor approaches 1.0 the component must be replaced.

ASME Code Activities in Support of Environmental Fatigue

ASME is actively engaged with the industry to provide environmental fatigue evaluation methods in Section III of the Code. Two Code Cases, N-761 for environmental fatigue curves and N-792 for Fen, have been published. A revision to N-792 to simplify the assessment procedure is in progress.

ASME has teamed with EPRI to create a fatigue expert panel to address issues in the application of the Fen factor methodology and to evaluate other methods to address component fitness for service if usage exceeds 1.0. Current activities include developing sample problem solutions for environmental fatigue analyses, development of a Code Case for flaw tolerance evaluation, development of a Code Case to provide methods for determining strain rate as required by the Fen method, and update of the piping stress indices to reduce conservatism in the determination of peak stresses. Becht Engineering is actively involved resolving the on-going issues with environmental fatigue determination and providing methods for establishing acceptable safety margins. Becht engineers lead the responsible committees and are project managers for the applicable changes. ■

High Energy Line Break (continued from page2)

The interest in pipe breaks originated with the need to size the emergency core cooling systems (ECCS), when it became important to understand break size, shape, opening area and opening time. The analysis of high energy line breaks then evolved to encompass dynamic effects such as pipe whip and jet impingement, and the regulatory expectations were spelled-out in 1974, in Regulatory Guide 1.46, later to be replaced by Standard Review Plan Section 3.6.

The nuclear power industry has studied the dynamic effects of postulated HELB for the past 45 years. These studies have included theoretical, experimental, and numerical research. The pioneering works in the field included a 1965 study on two-phase blowdown from pipes and a 1969 report on blowdown and jet forces, both by Dr. Moody, and the early experimental work by Faletti and Moulton in 1969. This was to be followed by more experiments aimed at improving our understanding of the transient phenomena that take place when a break occurs in a high pressure and high temperature pipe. Following is a quick overview of some of the experimental work conducted since the early 1970s.

In 1975 Tractionel (Belgium) conducted tests on the energy absorbing capabilities of stainless steel U-bars, compression copper bumpers, and cellular concrete.

From 1974 through 1986 the Japan Atomic Energy Research Institute (JAERI) conducted a series of jet discharge tests and studies on 4 inch, 6 inch, and 8 inch pipe under PWR and BWR primary loop pressures and temperatures. The tests were also instrumented to measure target temperature.

In 1979, Westinghouse conducts tests on pipes used as elements of pipe whip restraints.

In 1980 and 1981, Studsvik conducts large scale jet impingement tests at the Marviken power plant in Sweden. The pipe sizes tested ranged from 8 inch to 20 inch, with pressures up to 700 psi, and fluid ranging from subcooled water to steam.

In the mid-1980s JAERI also conducted tests of pipe whip with U-bar whip restraints. The whipping pipes were 4 inch and 6 inch, pressurized at BWR as well as PWR pressures and temperatures. The tests investigated the dynamics of the whipping pipe and the formation of a hinge at the whip restraint.

In the mid-1980s the Atomic Energy of Canada and the Electric Power Development Company of Japan conducted pipe-on-pipe tests to investigate the effect of 3 inch and larger pipe on 2 inch pipe targets at 1300 psi and 550°F.

In 1981-1984, the CEA-CEN (France) conducted tests and studies on the effects of pipe-on-pipe impact using 4 inch whipping pipe on 4 inch and 2 inch pipe targets. The testing program also included pipe whip impact against steel plates and concrete slabs. The test conditions were those of a PWR at 2400 psi and 600°F.

In 1983, Combustion Engineering performs tests on energy absorbing stainless steel honeycomb material.

In 1984-1987, the Pacific Northwest Laboratory conducted for the NRC a series of tests were 6 inch pipes were catapulted against 3 inch to 12 inch pipe targets, to investigate the potential for propagation of breaks by pipe-to-pipe impact.

In 1985 the CEGB and Magnox Electric plc (UK) conducted pipe whip tests on cantilevered pipe to determine the influence of several factors on the zone of influence swept by the whipping pipe. Factors investigated included the direction of the thrust force at the broken end, strain-hardening of the pipe material, whipping pipe with multiple bends, the difference in behavior between opening and closing bends.

In 1986, in an EPRI-sponsored study, the experimental results for two-phase jets from the Marviken tests were compared to numerical simulation (EPRI-NP-4362).

In 1988 a revised ANS 58.2 is issued, replacing the 1980 issue, introducing several changes including the use of the leak-before-break method.

In 1990, Siemens conducted tests to investigate what happens at the hinge section of a whipping pipe. The hinge section was also tested with a circumferential crack, to investigate the highly unlikely case of a pipe break occurring in a pipe that had a pre-existing crack at the buckle section.

In the mid-1990s the University of Manchester (UK) conducted experimental and numerical studies of the plastic behavior, ovalization of the cross-section, and buckling of whipping pipes as a function of D/t (the ratio of their diameter to their thickness). The flow restriction caused by ovalization is also addressed in the study.

In summary, a number of experimental studies have been conducted in the last 35 years, which are used today to benchmark the simple energy-balance analytical, and more complex (finite element analysis) numerical methods for the analysis of the dynamic effects of postulated high energy pipe breaks. ■

Figure - Recent FEA Benchmarked Against the JAERI tests

BECHT ENGINEERING AND BECHT NUCLEAR STAFF ARE ACTIVE IN NATIONAL CODES AND STANDARDS COMMITEES

ASME Committees

Board of Governors – *member and former member*
Board on New Development – *member and current Chair*
Council on Standards– member and two *former Chairs*
Board on Hearings and Appeals – *past Chair*
Board on Nuclear Codes and Standards – *member*
Board on Pressure Technology Codes and Standards – *five past members*
Board on International Standards – *past member*

Boiler and Pressure Vessel Code Committees

Technical Oversight Committee (former Main Committee) - *member*
Committee on Pressure Vessels (BVC VIII) – *member and current Chair*
Subgroup on High Pressure Vessels (Section VIII, Div 3) – *member and former Chair*
Subgroup on Design (BPV VIII) – *member and past Chair*
Subgroup on General Requirements (BPV VIII) – *member and past Chair*
Subgroup on Heat Transfer Equipment (BPV VIII) – *member and past Chair*
Subgroup on Toughness (BPV II & VIII) – *member*
Task Group on Impulsively Loaded Vessels (SC VIII) - *member*
Special Interpretations Committee (SC-VIII) -*member*
Committee on Transport Tanks – *former member*
Design and Analysis Committee – *current Chair*
Subgroup on Elevated Temperature Design – *member and former Chair*
Subgroup on Design/Analysis (BPV III & VIII) – *member and current Chair*
Project Team on Hydrogen Tanks - *member*
Subcommittee on Accreditation - *member*
Working Group on Piping (SG-D) (BPV III) – *member*
Subgroup on General Requirements (BPV III) - *member*
Special Working Group on High Density Polyethylene Piping (SC III) – *member*
Standards Committee on Qualification of Mechanical Equipment - *member*
Executive Committee on Strategy and Project Management – BPV III - *Chair*
Special Committee on Interpretations - *BPV III Chair*
Subgroup on Component Design – (BPV III) - *Member*
Working Group on Piping (BPV III) – *Member and Past Chair (George is Current Chair)*

Piping and Component Codes and Standards

B31, Code for Pressure Piping, Standards Committee – *two members and former Chair*
B31, Code for Pressure Piping, Executive Committee – *two members*
B31.3, Process Piping Section Committee – *two members and current Chair and former Chair*
B31.3 SG on High Pressure Piping – *past Chair*
B31.3 SG on Design – *member*
B31 Code for Pressure Piping, Mechanical Design Committee – *three members and former Vice-Chair*
B31.12 Hydrogen Piping and Pipelines Section Committee - *member*
B16 Standardization of Valves, Flanges, Fittings, and Gaskets Standards Committee – *member*

Post Construction Standards

Post Construction Standards Committee – *three members, current Vice Chair, former Chairs*
Post Construction Executive Committee – *three members*
SC on Repair and Testing – *member and current/founding Chair*
SC on Inspection Planning – *two members*
SC on Flange Joint Assembly – *current Chair*
SC on Flaw Evaluation – *former member*

ASME/API

ASME/API Joint Fitness-For-Service Committee (API 579/ASME FFS-1)– *member and Current Vice Chair*

API

Committee on Refining Equipment - *past member*
Task Group on API 580 – *past member*
Subcommittee on Materials and Corrosion – *past member*
Task Group on Materials for Heavy Wall Vessels – *past Chair*
Subcommittee on Heat Transfer Equipment – *past Chair*
Task Group on Shell & Tube Heat Exchangers –*past member*
Task Group on Air Cooled Heat Exchangers – *past member*
Subcommittee on Above Ground Storage Tanks – *past member*
Subcommittee on Piping – *past Vice Chair*
API 582 – Welding Guidelines for the Chemical, Oil and Gas Industries – *past Chair*

Other

MTI - Chair of the Knowledge Management Project Development Committee – *Current Chair*
AWS A5 (Filler Metals) Committee Member- Source for ASME IIC - *member*
ASTM Committee F-17, Plastic Piping Systems Main Committee - *member*
ASTM Standards and Certification Board of Directors Member - *former Chairman*
ASTM Committees C03, C-16, and D-20.23 – *member*
ISA - The International Society for Measurement and Control, SP 93, Sealing Technologies Committee Member
Materials Technology Institute's Technical Advisory Council Committee - *member*
Materials Technology Institute, Evaluation of Gaskets Committee - *member*
US TAG for ISO/TC 153/SC 1 – Valve Design, Manufacturing, Marking and Testing - *member*
US TAG for ISO/TC 5/SC 10 - Metallic Flanges and Their Joints - *member*
US TAG for ISO/TC 197 – Hydrogen Technologies - *member*
Joint ASME – IEEE Seismic Qualification Committee – *former member*
ASME-ASCE Joint Task Group on Buried Pipe – *founding Chair*
Process/Industry Practices (PIP): Coatings and Insulation, *former Function Team Leader*
Society for Protective Coatings (SSPC): Standards Review Committee, *former Co-Leader of Maint Painting Comm*