What I learned in 30 years of Nuclear Piping Design Part II – How to Finish well

D.H.Creates[1)]

1) Senior Piping Design Engineer, Ontario Power Generation Inc.

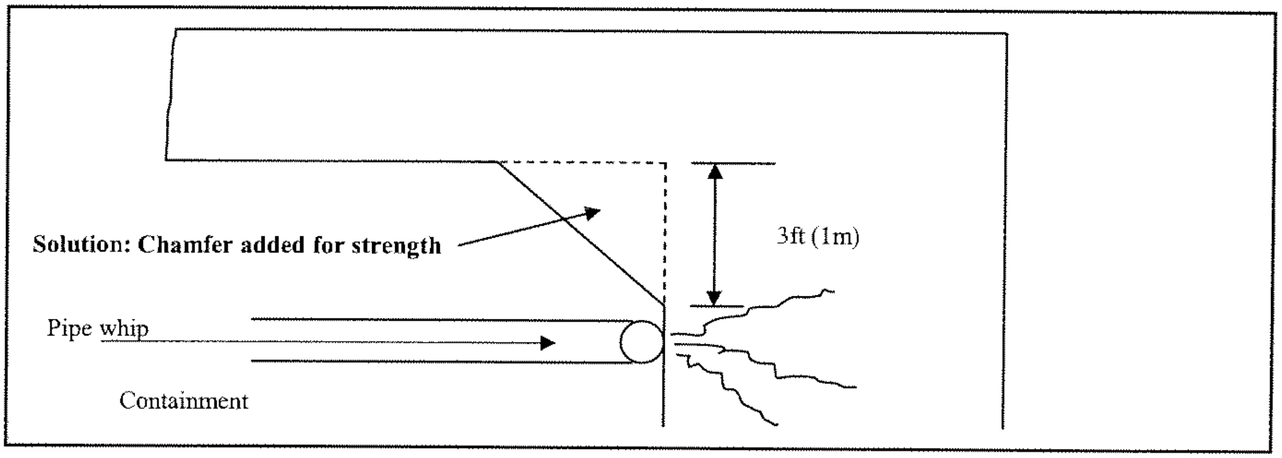
ABSTRACT

Over a period of 30 years in the job of piping design on one Station, there was time to be involved in the design from scratch and to live into the operation phase of the piping systems I had helped design. Here the design was tested and the feedback began. This feedback loop has been a wealth of further experience to sharpen the piping designers' skills and is perhaps not available to many piping designers given the length of nuclear projects in the past and the job market conditions. Knowing the design history and the design basis intimately, uniquely prepares the piping designer to address discovery issues and provide design guidance to solve operational problems: Effect on others, Further Changes, Grief and Grace.

EFFECT ON OTHER STAKEHOLDERS

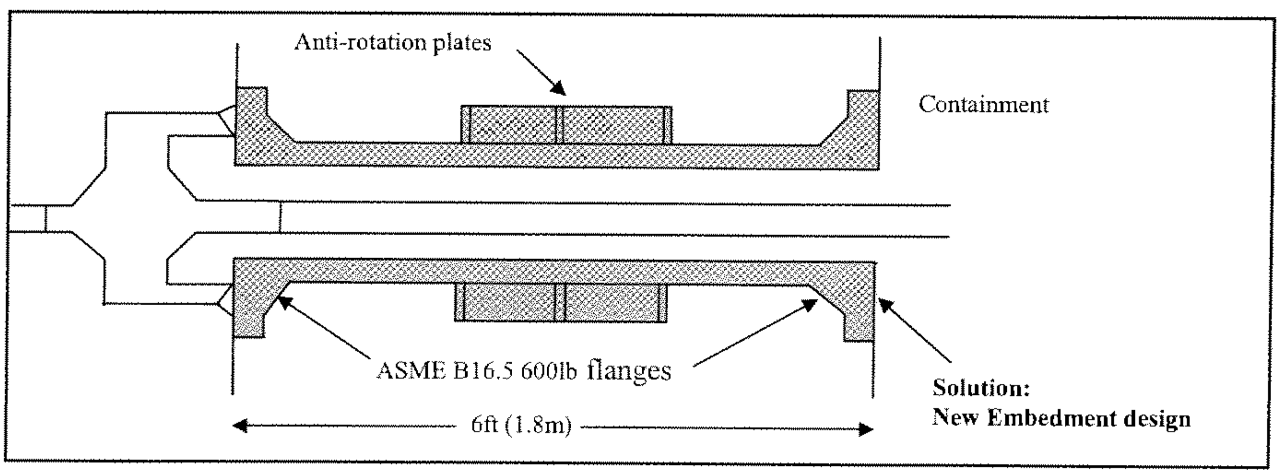
E.1(a) Pipe Whip Impact Loadings

Because of the huge impact forces of a postulated break in the largest Heat Transport pipe, structural modification were required to the containment design.

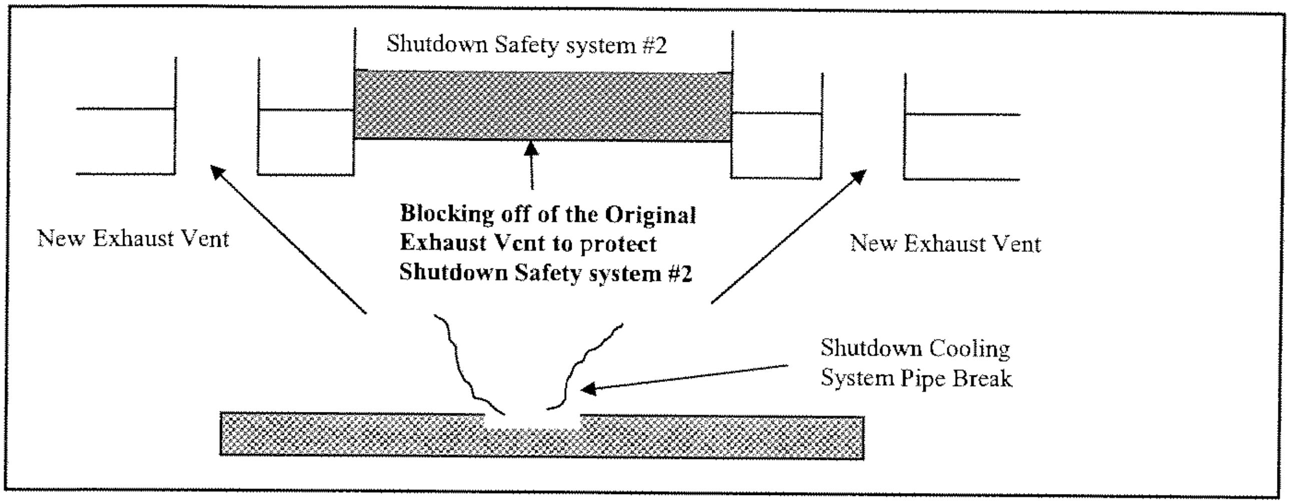


E.1(b) Pipe Whip Anchor Loading

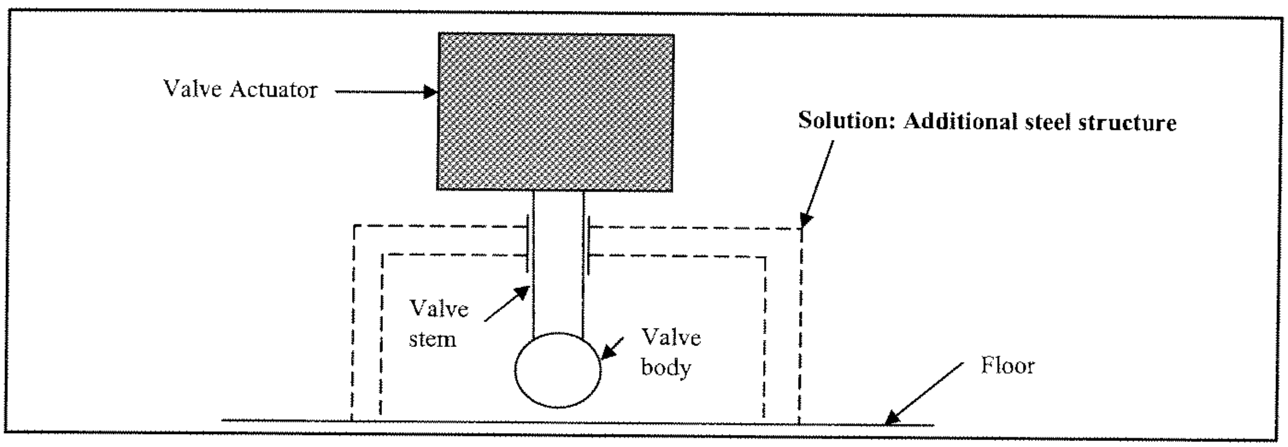
Huge moment loadings due to pipe whip challenged the old embedment design with a plate welded to the ends of a pipe.



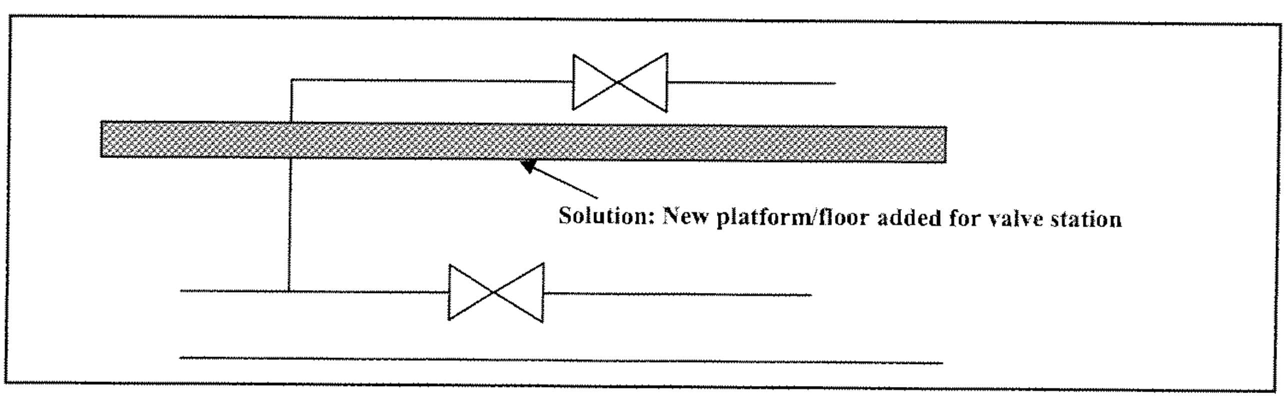
E.1(c) Pipe Break Pressure/Debris Loading
To protect the Shutdown Safety system, a Containment internal modification was required.



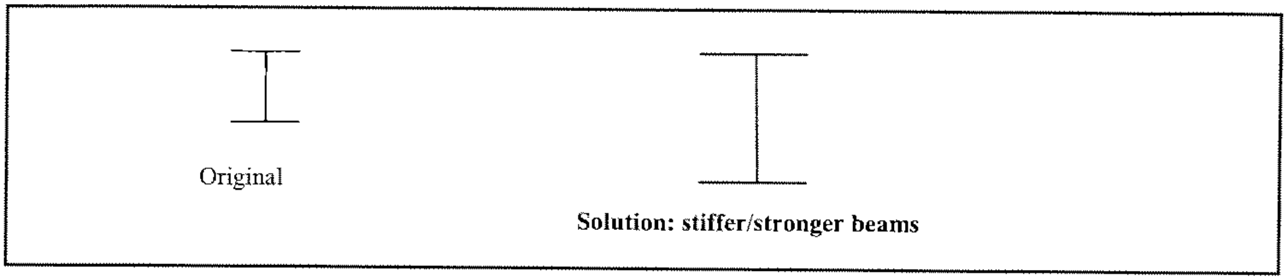
E.2 Massive Valve Actuators:
Piping could not survive the seismic loads and required addition of structural steel for support of valves.



E.3 New structural platform/floors
When the piping designer ran out of space, the structural engineer designed a new platform for piping and valves. Hollow steel structures were some of the members used to meet stiffness requirements.

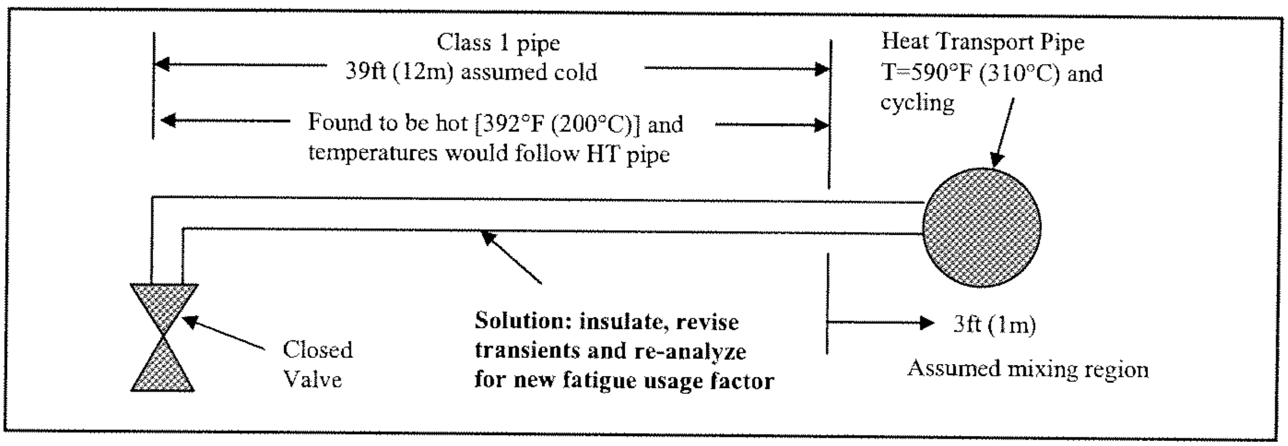


E.4 Stiffer/stronger Steel beams required inside containment
When the initial steel drawings were reviewed, the steel was to be too weak for the anticipated piping requirements and stiffer stronger beams were employed.

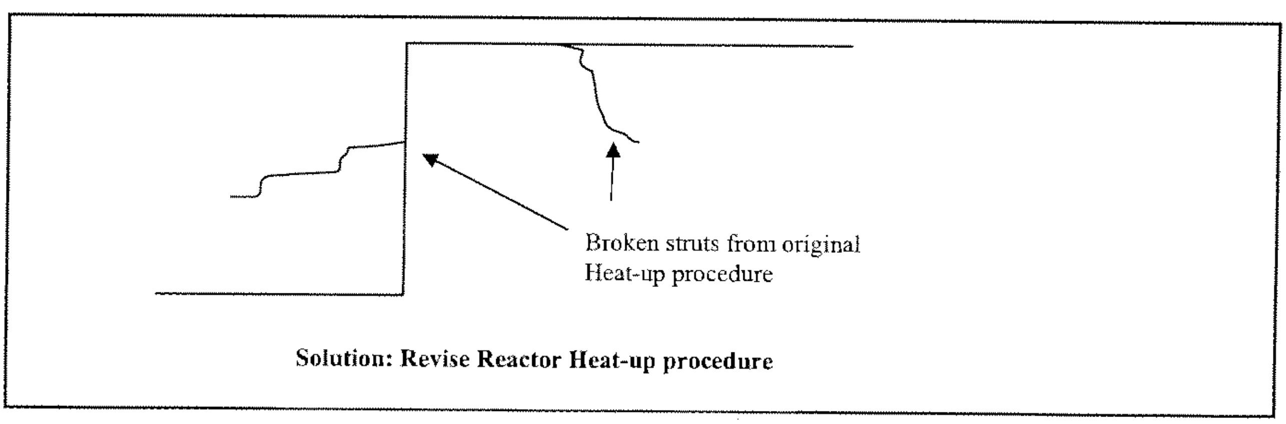


FURTHER CHANGES? YES!
The rubber hits the road when operation starts, and there are more things to learn.

F.1 Cold Pipe in theory actually followed temperature changes in attached pipe
The 8 long stagnant horizontal Emergency Cooling Injection (ECI) pipes connected to the Heat Transport (HT) system were assumed to be cold except for a length of 1 meter (3ft) where mixing was assumed to take place close to the hot flowing fluid. It was discovered the lines were hot along their whole length due to this thermal mixing and temperature started to drop at 100°F/ft (180°C/m) only in the vertical pipe down to the normally closed valve. This meant the ECI pipes would follow the HT temperatures and have higher fatigue usage factors.

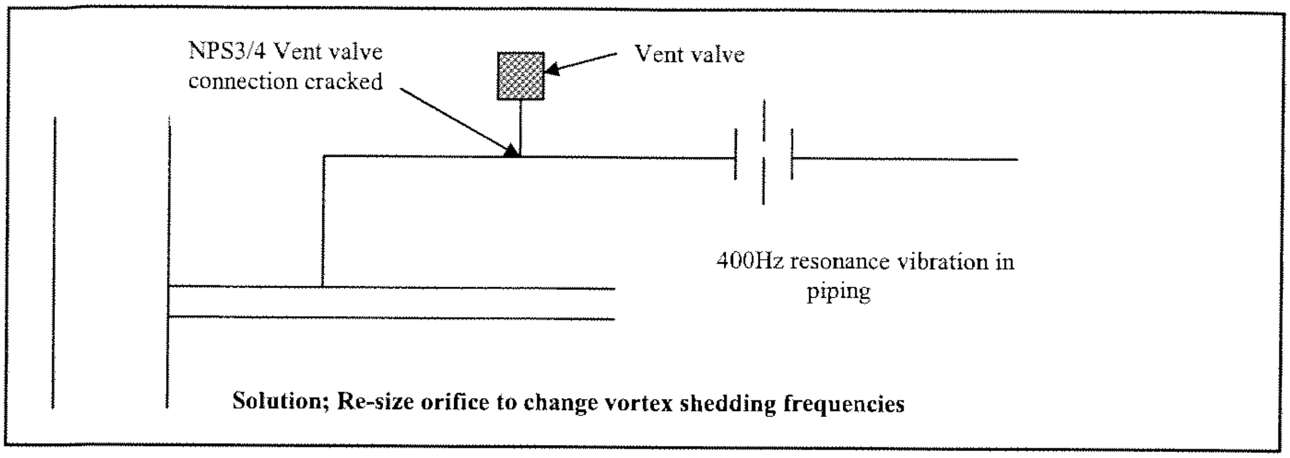


F.2 Original Reactor Heat-up procednre caused water/steam hammer
Inspections after some running time identified a problem with some Class 1 pipe supports. This led to reconsidering the heat-up procedure and how it contributed to the phenomenon of steam generation and void collapse in equipment/piping.



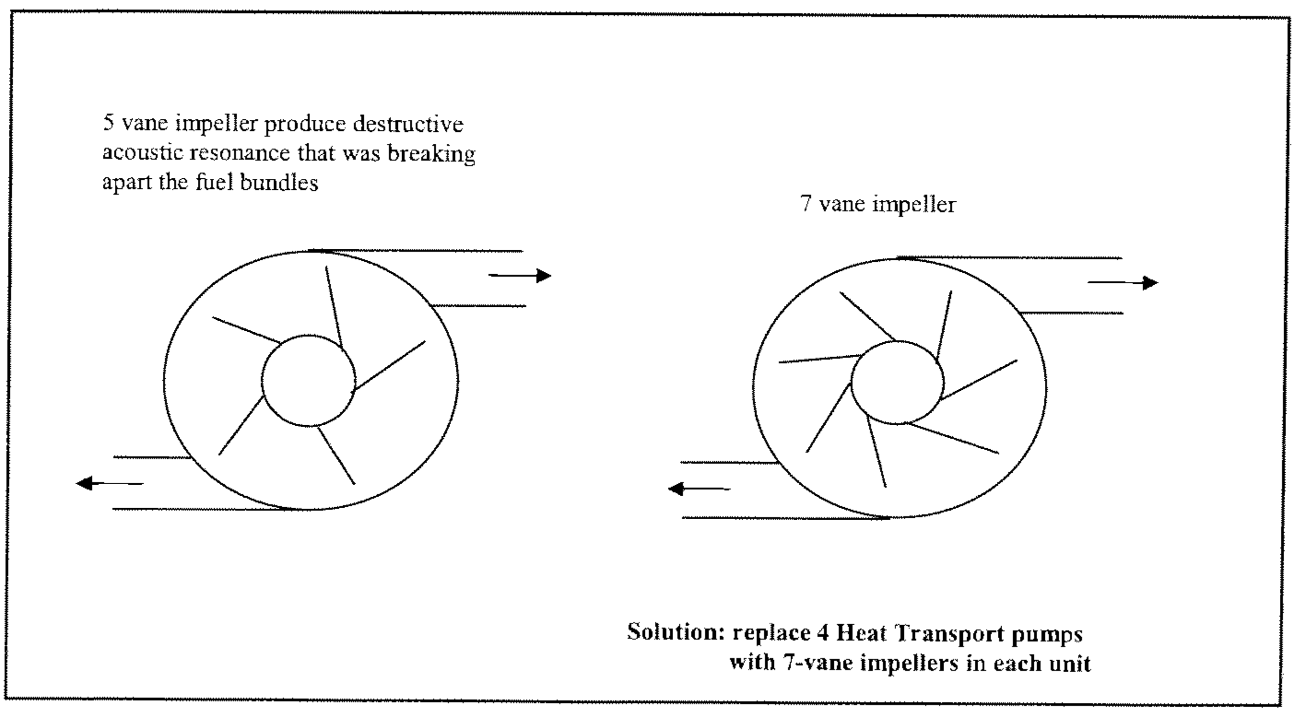
F.3(a) Destructive Resonance in piping from flow through Orifice

On start-up of the first unit, a high pitched sound was heard coming from inside the vault under certain operating configurations. Leaks of D2O into containment were soon identified and an investigation was initiated. The tuning of three major pipe segments were found to be involved to support this resonance phenomenon. (If we had planned it, we probably would have failed). Reconfiguring the Class 1 piping was not an option.

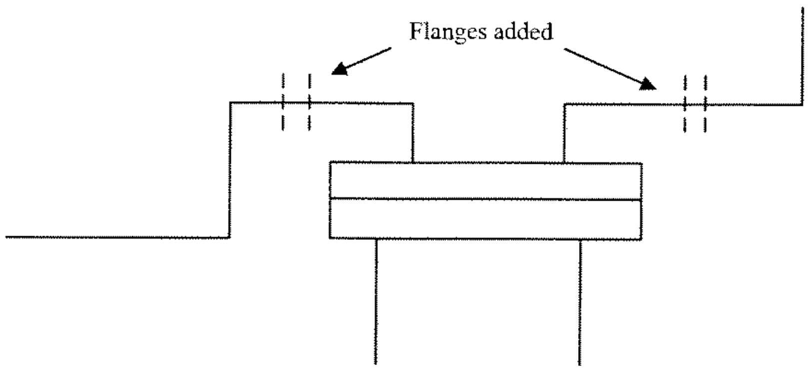


F.3(b) Destructive Resonance from Pump Vane passing frequency

After a short time of operating the new unit, the fueling machine got stuck on a channel while fueling online. Of the 32 pencils in a fuel bnndle (each about 2ft (600mm) long), some had broken free after the end plate that was holding them together had become cracked due to the resonance with the vane-passing frequency of the double discharge Heat Transport pumps.

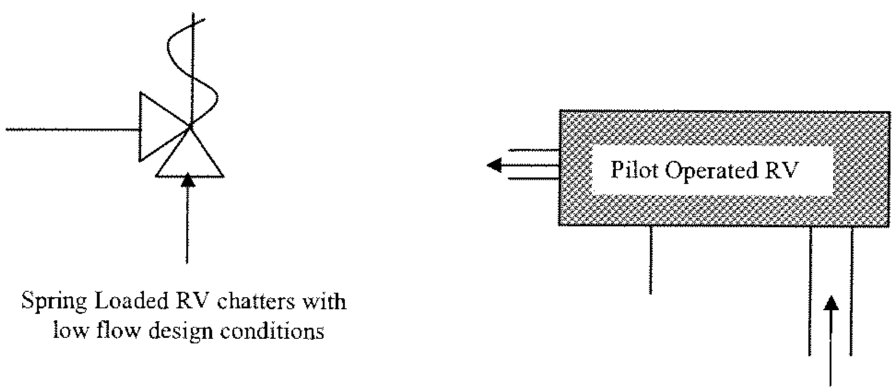


F.4 Piping Layout Blocks Heat Exchanger Tube Bundle Removal
How could this happen? In the design stage, there was no plan to remove the tube bundle before the end-of-life of the equipment. Then it became known that the tube bundle had a shorter life than the shell and provision had to be made to replace it.



Solution: Add flanges into piping and re-analyze

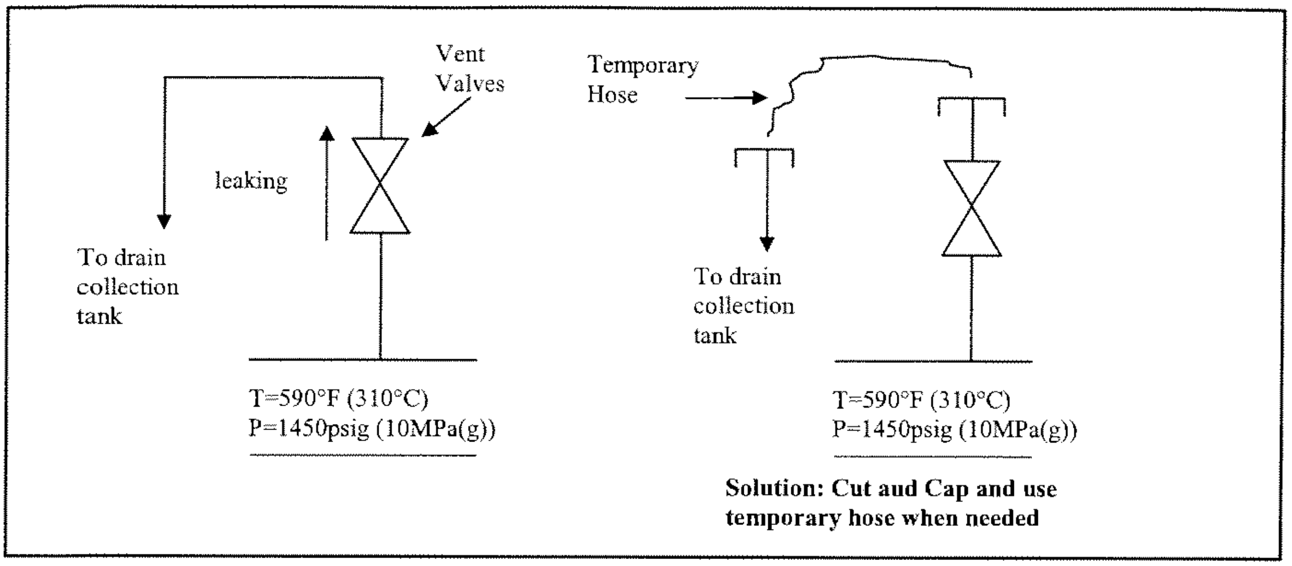
F.5 Spring-loaded Relief Valve (RV) chatters in low flow conditions
Multiple design conditions proved impossible for the spring-loaded Relief valve to handle. Designing for high flow conditions as per system overpressure relief requirements left the spring-loaded relief valve vulnerable to chattering, that could lead to destructive waterhammer, in the more probable low flow design conditions.



Solution: Replace with adequate component

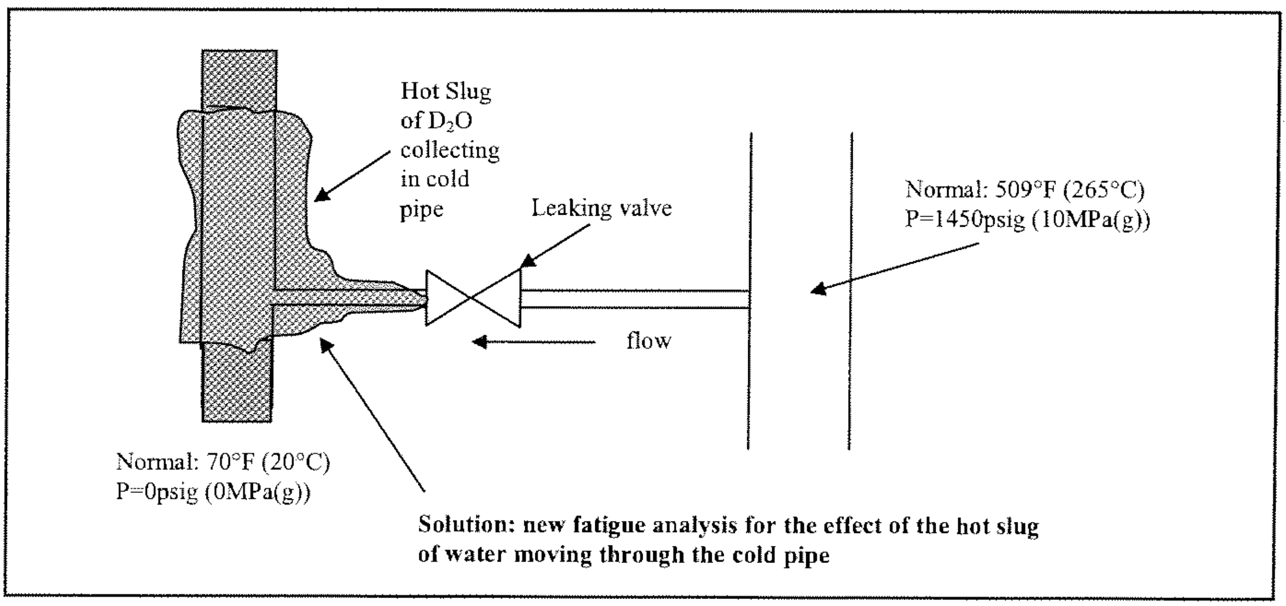
F.6 Heat transport Vent valves leaking

When Heat Transport vent valves started leaking with 1450psig (10MPa(g)) pressure differential, the D_2O collected tank was filling up too quickly. The valves were in an awkward location for replacement. A positive isolation was required. This modification affected 2 design specifications, and 10 stress reports that had to be npdated.



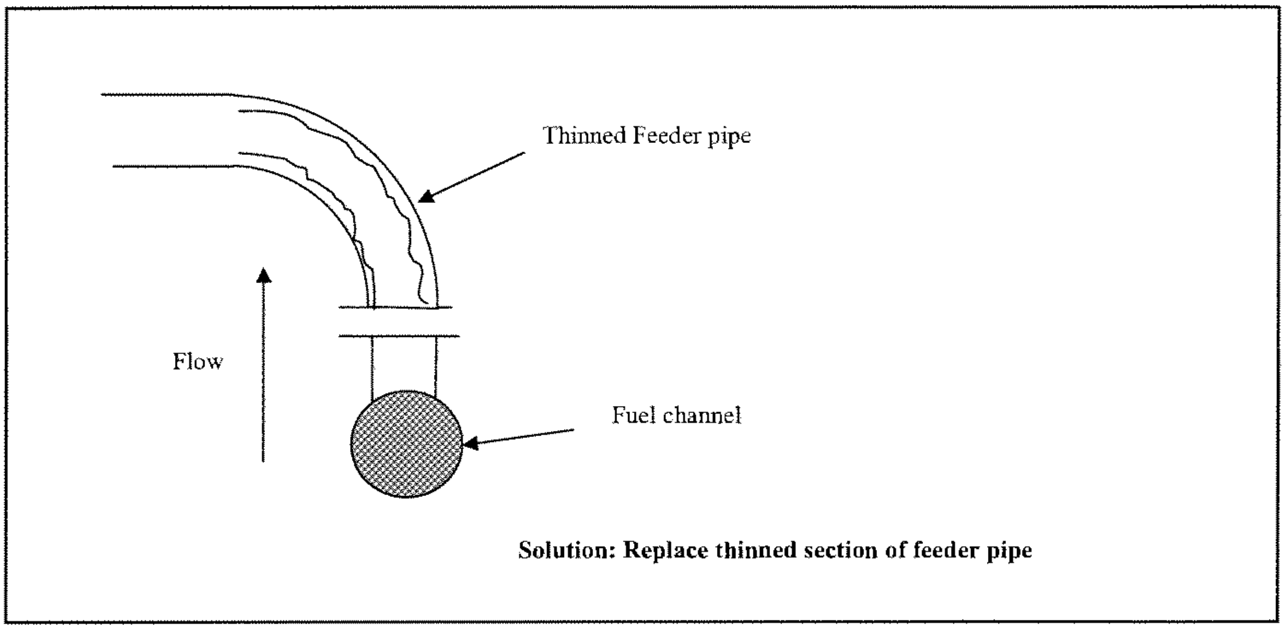
F.7 Isolation Valve leaking hot fluid iuto cold standby system

When the isolation valve began to leak, high pressnre hot D_2O was pushed into the connected standby cooling system which was normally cold and de-pressurized. This created a slng of hot water in the normally cold pipe that was circnlated when the cooling system was subsequently started np.



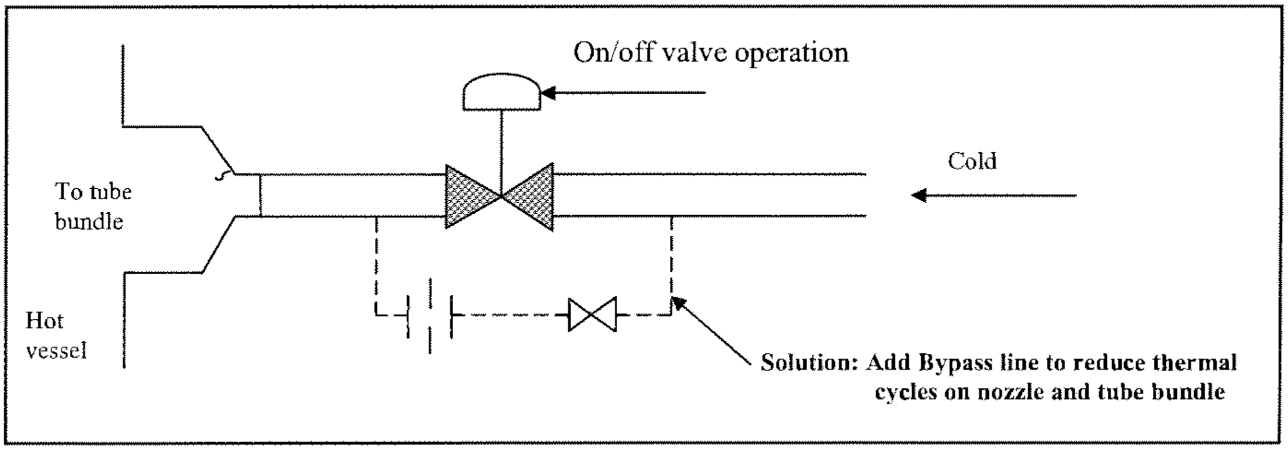
F.8 Flow Accelerated Corrosion (FAC) thinning of Class 1 Outlet Feeder piping

Due to a variable chromium content, fluid velocities and 2-phase flow conditions, some outlet feeder pipes were vulnerable to FAC at the first and second bends downstream of the ontlet from fuel channel. Stress analysis was used to reduce the number of feeders that needed section replacement, but there were still some that would need replacement before the end-of-life of the fuel channel.



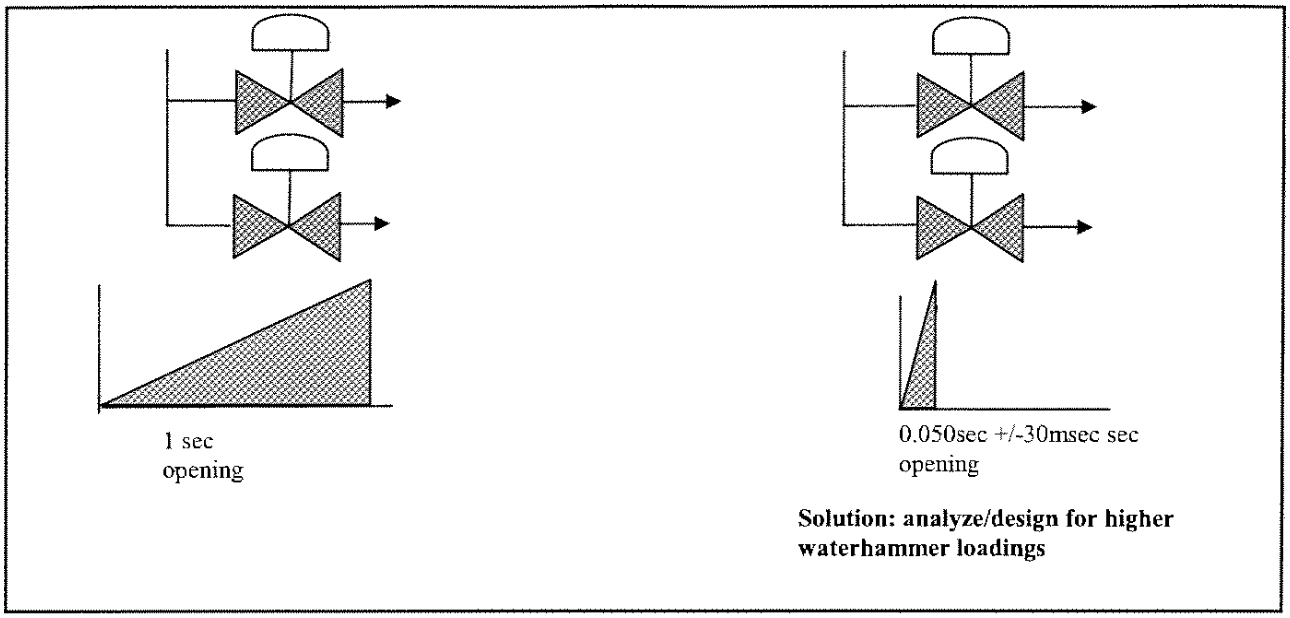
F.9 Intermittent Valve Operation fatigues Vessel Nozzle

An on/off valve operation put the tube bundle and nozzle through thermal cycles that resulted in cracks in the nozzle.



F.10 Shortening of Valve Opening Time changes Waterhammer loadings

When the Heat Transport pilot operated Liquid Relief Valve opening times were shortened, a new waterhammer analysis was required. This analysis was complicated by the valves operating in pairs, slight variation in signal times to open (milliseconds), and phasing due to variation in internal mechanics of the valves (some slower and some faster).



GRIEF AND GRACE

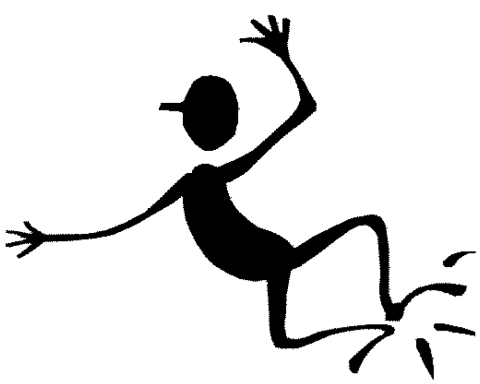
Grief: records system is hard to manage
Grace: pipes are forgiving (and so are people)

Keeping track of the design via records is sometimes grievous, bnt in all this, the pipe is forgiving, and we need to be also.

SUMMARY

After designing the piping system, the piping designer needs the continned cooperation of various stakeholders to accommodate varions needs that arise. Dealing with discoveries during initial operation is a wealth of additional information. This can to lead to further changes which provide an opportunity for the piping designer to provide a variety of different design solntions involving other stakeholders as well.

To finish well involves recognizing the <u>E</u>ffect on other stakeholders, dealing effectively with <u>F</u>urther changes, enduring the <u>G</u>rief of records and enjoying the benefits of <u>G</u>race.



Finish Well