Current Issues in BPV I

Dave Berger
PPL Generation – LLC
Chair, ASME BPV I Standards Committee
on Power Boilers
Three Recent Areas

- TG Modernization
- SG – Solar
- SG - Locomotives
BPV I – TG On Modernization of Section I

TG Proposals for Review

Date August 2011
Why Bother?

- Section I has been around a long time
- Serves us pretty well for a broad range of equipment
Projections

- Future Power Boilers
  - Ultrasupercriticals?
    - Higher Pressures (~5000 psig / 350 bar)
    - Higher Temperatures (~1400F / 760 C)
  - More Cycling
  - Need for Design by Analysis (DBA)
Benefits

- Increased Efficiency
- Environmental
- Designs Better Suited for Operational Needs
Challenges

- Transient Operation
  - Startup/Shutdown/Load-Following
- Construction Details
  - Branch Intersections
  - Flat Heads
- Creep-Fatigue Interaction
- High Temperature Corrosion
<table>
<thead>
<tr>
<th>Part</th>
<th>Title</th>
<th>Owner</th>
<th>Overview</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Requirements</td>
<td>Bob McLaughlin</td>
<td>based on current PG-1, PG-2, etc</td>
</tr>
</tbody>
</table>
| 2    | Responsibilities and Duties   | Jim Pillow       | Clearly define ‘overall responsibility’  
Care required with ‘Users design Specification’ |
| 3    | Materials                     | Jeff Henry       | Mainly PG-5 and PW-5, etc; refer to VIII Div 2 for bolting, flanges, etc; separate para for CSEF |
| 4    | Design By Rule                | Ed Ortman        | Mainly existing PG and PW items  
Possible cross reference to VIII Div 2 |
| 5    | Design by Analysis            | David Anderson   | Cross refer to VIII Div 2 for time independent  
Include creep/fatigue interaction in Section I |
| 6    | Fabrication                   | Stuart Cameron   | Existing PG and PW; incorporate relevant parts of VIII Div 2; specific section on CSEF |
| 7    | Inspection and Examination   | John Arnold      | Review scope of examination and acceptance criteria |
| 8    | Pressure Testing              | Dave Tuttle      | Transfer of existing                                                      |
| 9    | Over Pressure Protection      | Dave Tuttle      | Transfer of existing                                                      |
## Gap Analysis - Example

### Existing Rules in Section I

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG - 17</td>
<td>Fabrication by a combination of methods</td>
</tr>
<tr>
<td>PG - 19</td>
<td>Cold Forming of Austenitic Materials</td>
</tr>
<tr>
<td>PG - 75</td>
<td>Fabrication - General</td>
</tr>
<tr>
<td>PG - 76</td>
<td>Fabrication - General</td>
</tr>
</tbody>
</table>

### Relevant Rules in Section VIII Div 2

<table>
<thead>
<tr>
<th>Code</th>
<th>Paragraph</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASME VIII Div 2</td>
<td>6.1</td>
<td>General Fabrication Requirements - more detail on material identification, forming of shells and heads, base material preparation, cleaning of surfaces</td>
</tr>
<tr>
<td>ASME VIII Div 2</td>
<td>6.2</td>
<td>Welding Fabrication requirements - detail on precautions to be taken before welding, special requirements, repair of weld defects</td>
</tr>
</tbody>
</table>

### Relevant Rules from Other Codes

<table>
<thead>
<tr>
<th>Code</th>
<th>Paragraph</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN12952 - 5</td>
<td>7.3</td>
<td>Forming of tube bends - refers to appendix on production tests, tolerances on tube thinning, post bend heat treatment requirements</td>
</tr>
<tr>
<td>EN12952 - 5</td>
<td>8.8</td>
<td>Welding subsequent to final PWHT - rules / limitations for minor attachments, etc</td>
</tr>
<tr>
<td>EN12952 - 5</td>
<td>10.4.2.3</td>
<td>Rules for local PWHT</td>
</tr>
<tr>
<td>EN12952 - 5</td>
<td>App. C</td>
<td>Manufacture of welded tube walls - tolerances for fit up of membrane to tube welds</td>
</tr>
<tr>
<td>VIII Div 2</td>
<td>Potential Home in Section I</td>
<td>Existing Section I paragraph</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td><strong>6.1 General Fabrication Requirements</strong>&lt;br&gt;6.1.1 Materials&lt;br&gt;6.1.2 Forming&lt;br&gt;6.1.3 Base Metal Preparation&lt;br&gt;6.1.4 Fitting and Alignment&lt;br&gt;6.1.5 Cleaning of Surfaces to Be Welded&lt;br&gt;6.1.6 Alignment Tolerances for Edges to Be Butt Welded</td>
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<td>PG-17, PG-75, PW-26&lt;br&gt;PG-78(?)&lt;br&gt;PG-19&lt;br&gt;PG-76, PG-77, PW-29&lt;br&gt;PG-80, PG-81, PW-33, PW-34&lt;br&gt;PW-31</td>
</tr>
<tr>
<td><strong>6.2 Welding Fabrication Requirements</strong>&lt;br&gt;6.2.1 Welding Processes&lt;br&gt;6.2.2 Welding Qualifications and Records&lt;br&gt;6.2.3 Precautions to Be Taken Before Welding&lt;br&gt;6.2.4 Specific Requirements for Welded Joints&lt;br&gt;6.2.5 Miscellaneous Welding Requirements&lt;br&gt;6.2.6 Summary of Joints Permitted and Their Examination&lt;br&gt;6.2.7 Repair of Weld Defects&lt;br&gt;6.2.8 Special Requirements for Welding Test Plates</td>
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<td>PW-1&lt;br&gt;PW-27&lt;br&gt;PW-28&lt;br&gt;PW-35, PW-41&lt;br&gt;PW-36, PW-47&lt;br&gt;PW-9, PW-15, PW-16&lt;br&gt;PW-40&lt;br&gt;PW-53</td>
</tr>
</tbody>
</table>
Research Needs

Research Projects defined for the two major gaps:

- Creep-Fatigue interaction and allowable flaw size
- Erosion Corrosion, Oxidation

RFP by ASME ST LLC.

Contract awarded July 2011 to Structural Integrity Assoc. and EPRI for item 1
Implementation Alternatives

Three Options Assessed:

1. Re-Write of Section I
2. Creation of a Section I Division 2
3. Creation of Section I Appendices (Mandatory and non-mandatory)

Each option has pros and cons
TG Recommendation

- ASME Ballot 11-2072

Proposal:

“To proceed with the TG recommendation to prepare a document of alternative rules in the form such that either a Division 2 or Appendices may be formed following a further review by Section I.”
Next Steps (If authorized)

- Identify & Appoint Project Mgr.
- Develop Detailed Project Plan
- Select Professional “Code Writer”
- Ongoing Review – Cognizant SGs
- Steering by TG-Modernization
- Balloting by BPV I (eventually!)
Concentrated Solar to Electric Power
Introduction to Current Methods

August 11, 2011
ASME Section I
S. Torkildson, P.E.
Industry Jargon

- CSP = concentrated solar power
- PV = photo-voltaic
- Insolation = available solar radiation per unit area (watts/m²)
- Receiver = a device that receives solar radiation and converts it to another type of energy
- Heliostat = a mirror with a drive that allows it to track the sun
Parabolic Trough

- Linear parabolic reflectors
- Reflectors rotate to track sun.
- Tube at focal point heats a heat transfer fluid.
- Heat transfer fluid generates steam in a heat exchanger.
- Steam powers a steam turbine to generate electric power.
- Current status: operational
Parabolic Trough

http://www.nrel.gov/csp/troughnet/
Parabolic Trough Technology

Linear Fresnel Collector

- Similar to trough system
- Solar radiation focused on tube carrying water/steam
- Linear reflector elements track sun
- Stationary multi-tube or single tube receiver
- Steam powers turbine to produce electricity
- Essentially a once-through steam generator
- Current status: operational
Linear Fresnel Collector

Photo courtesy of Areva
Direct Steam Generation

- Tower mounted receiver (boiler)
- Solar flux is focused on a boiler that generates steam from water.
- Steam powers a turbine to generate electricity
- Cavity style receiver/boilers
- External style receiver/boilers
- Current status: operational
Direct Steam Generation

How The System Works

1. A field of sun-tracking heliostats reflects solar heat to a thermal receiver mounted atop a tower.

2. The focused heat boils water within the thermal receiver and produces steam.

3. The plant pipes the steam from each thermal receiver and aggregates it at the turbine.

4. The steam powers a standard turbine and generator to produce solar electricity.

5. The steam then reverts back to water through cooling, and the process repeats.

Courtesy of Victory Energy
Direct Steam Generation
External Receiver

Photos courtesy of eSolar
Direct Steam Generation
Cavity Receiver

Courtesy of Victory Energy
Parabolic Reflector/Stirling Engine

- Stirling engine located at focal point of parabolic reflector
- Gas heated in Stirling engine
- Stirling engine is a closed cycle
- Current status: operational
Brayton (gas turbine) Cycle

- A gas turbine compresses air that is heated in a tower mounted receiver.
- Two-axis tracking heliostats to place high solar intensity on receiver.
- Heated, expanded air powers gas turbine to generate electric power.
- Current status: A demo system has been operated in Spain but technology is still in R&D stage.
- Issues: high temperature material problems; control of variable flow.
Diurnal Solar Insolation

Chart courtesy of Areva
Diurnal Variation

- Solar peak is earlier in the day v. the power grid’s peak demand period
- Energy storage essential for an economically viable system
- Molten salt is the current leading storage method
Molten salt (combinations of sodium, potassium & calcium nitrates) is heated in tower-mounted receiver.
Receiver is heated by two-axis tracking heliostats.
Hot molten salt is stored in a tank
Salt drawn off the hot storage tank creates steam in a heat exchanger
The steam powers a turbine to generate electric power.
Spent molten salt is sent to a cold storage tank for re-cycling through the loop.
Current status: operational
Molten Salt

### Quiz

Which systems fall within the scope of Section I? (i.e., Which systems are boilers?)

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parabolic trough</td>
<td>Yes - thermal fluid heater</td>
</tr>
<tr>
<td>Linear Fresnel collector</td>
<td>Yes - makes steam</td>
</tr>
<tr>
<td>Direct steam generation</td>
<td>Yes - makes steam</td>
</tr>
<tr>
<td>Brayton cycle</td>
<td>? Heats air, but no phase change. Pressure is produced on the same shaft as the power generation turbine.</td>
</tr>
<tr>
<td>Molten Salt</td>
<td>? No vapor. No phase change. But a fluid is heated.</td>
</tr>
<tr>
<td>Dish/Stirling Engine</td>
<td>? Self contained system. Power is not used external to system.</td>
</tr>
</tbody>
</table>
Definition of “boiler” is ultimately by jurisdictional law or regulation. Some of the new technologies do not easily fit within the classic definitions. Jurisdictions will vary in interpretation.
The Definition Problem

- The various definitions of boiler include many different solar technologies under the same “boiler” umbrella.

- Some solar technologies are clearly not subject to the same safety concerns as a more “traditional” steam boiler.

- Application of steam boiler regulations to some solar technologies is inappropriate in some cases.
## Code Issues

<table>
<thead>
<tr>
<th>System</th>
<th>Is it a boiler?</th>
<th>Code problems?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parabolic trough</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
| Linear Fresnel collector | Yes           | 1. Need relief on dual feedwater pump requirement.  
|                      |                 | 2. Austenitic stainless prohibition makes process thermocouples impossible. |
| Direct steam generation | Yes             | No                                                       |
| Brayton cycle        | Probably Not    | 1. Pressure relief and isolation valves  
|                      |                 | 2. Creep fatigue interaction  
|                      |                 | 3. High temp materials |
| Molten Salt          | Probably Not    | Pressure relief and valves                               |
| Dish/Stirling Engine | No              | No                                                       |
Linear Fresnel Code Needs

- Seeking relief from redundant feedwater pump requirement. Inquiry expected soon.
- Seeking relief from austenitic stainless prohibition in wetted service.
  - Stainless steel thermowells needed for temperature monitoring in wet sections.
Molten Salt Issues

- Historically systems were designed to Section I as “boilers”
- Molten salt does not vaporize – at excess temperatures, it decomposes to a solid with reduced volume compared to liquid (opposite from water to ice)
- No explosion or over-pressure hazard
- Safety valve needed?
- Are stop and check valves required for boilers appropriate? Are the same locations appropriate?
Molten Salt Code Needs

- Different failure modes than a steam boiler
- Needs a unique definition
- Solar TG to initiate dialog with National Board regarding a definition.
Brayton Cycle Issues

- Classified as a “boiler” in most jurisdictions
- Working fluid is air, no phase change
- System will need a pressure regulating valve that dumps excess pressure to control turbine speed.
- Does it also need a pressure relief valve?
  - Redundant to regulating valve
  - Rupture disk not an option for Section I construction
- Block and check valves needed?
  - Lock-out of turbine eliminates pressure source
Brayton Cycle Issues

- Requires high temperature materials
  - 1600°F (870°C) today; 1800°F (980°C) in future
- Lack of code approved materials
- Creep-fatigue interaction
SG - Locomotive

- Experienced, active & dedicated
  - Strong membership overlap with NBIC and FRA ESC
- A few tough issues
  - Parts available “back in the day” no longer readily obtainable
Issues with Pressure Relief Devices in Multiple Media Applications

Prepared by: J. F. Ball, P. E.
October, 2011
Pressure Relief Devices in Multiple Media Applications

- Current Code requirements related to multiple fluid applications
  - Section I
  - Section IV
  - Section VIII

- Potential Code updates
Section 1

- All applications considered as steam
  - Valves tested on steam
  - Nameplate ratings based on steam flow
  - Installation rules and practices based around steam service
Section I – Liquid problems

1. Startup problems

- Boiler is filled with water, and water is relieved until sufficient heat content is developed
- Probability of this occurring over time is low
- Liquid capacity will probably be adequate
Section I – Liquid problems

- 2 ring steam valves will chatter on water
- Valve damage may occur on extended openings
  - Seat leakage
  - Damage of guiding surfaces
Section I – High temperature hot water boiler application

- Hot water at valve seat – percentage will flash to steam during valve actuation, alleviates chatter problem

- Valves designed for this application should be used
  - Marked “HTHW”
  - Single ring designs with 10% blowdown
  - Packed lift lever and closed bonnet designs required
Section I – High temperature hot water boiler application

- Discharge piping should be suitable for partial liquid service
Economizer Application

- Units that can be isolated require pressure relief valve
- Water during upset condition may be below 212 deg. F
  - Upsets often occur on cold water
  - Pump overspeed
  - Incorrect valve line-up
Economizer Application

- Standard valves have proven problematic
  - Chatter problems
  - Seat tightness issues

- Code Case 2446 developed to allow pilot operated pressure relief valves to be used
Economizer Application

- Pilot valve operation well suited to multiple fluids
  - Modulating pilot design suited for water
  - Code Case required testing or both steam and water with the same adjustments
  - Seat loading increases with increasing pressure
Code Case 2446 Incorporation

Code Case 2446 was incorporated into Section I

PG-69.1.6

“Pressure relief valves for economizer service shall also be capacity certified with water…”
- No current valves for lower pressure economizers have been certified
- High pressure pilot designs are not economically feasible
- Code Case 2640-1 has delayed implementation of PG-69.1.6 for 2 years
- Task group looking at problem
Section IV

- Applications
  - Hot water boilers
  - Potable hot water heaters

- Pressure relief valve serves several functions
  - Thermal expansion
    - Low capacity requirement, valve will “crack” open only
Section IV

- Runaway overpressure condition
  - Steam or water hot enough to flash to steam will be generated
  - ASME/NB certified valves are flow tested on steam – assures performance on worst case condition
Section IV

- Temperature and Pressure (T&P) valves for hot water heaters
  - Set pressure established on water, and verified on water during certification
  - Pop and flow tested on steam to determine ASME capacity
Section IV

- Temperature and Pressure (T&P) valves for hot water heaters
  - Flow tested on hot water to establish capacity for CGA certification (demonstrates hot water capacity on thermal element activation)
Section VIII

- Contains few references to multiple fluid applications

*UG-125(f)* Vessels that are to operate completely filled with liquid shall be equipped with pressure relief devices designed for liquid service...
Section VIII Installation

- **UG-134 (a)**

  Pressure relief devices intended for relief of compressible fluids shall be connected to the vessel in the vapor space above any contained liquid or to piping connected to the vapor space in the vessel which is to be protected. Pressure relief devices intended for relief of liquids shall be connected below the liquid level. Alternative connection locations are permitted, depending on the potential vessel overpressure scenarios and the type of relief device selected, provided the requirements of UG-125(a)(2) and UG-125(c) are met.
Section VIII

- Valve certification rules consider valve for one service only
- Overpressure design assigned to owner/user
Section VIII – Rupture Disks

- Rupture disk rule development started to consider multiple fluids

- Performance testing on both fluid types required on compressible and/or incompressible fluids for suitable designs
  - Applicable fluid can be told by $K_R$ markings
Section VIII – Rupture Disks

- $K_{RG}$ indicates disk design is suitable for gas service
- $K_{RL}$ indicates design is suitable for liquid
- $K_{RGL}$ indicates design is good for both applications and will have the same flow resistance
Section VIII – Rupture Disks

- Some designs are marked with separate $K_{RG}$ and $K_{RL}$ values
  - Indicates design has been tested on both fluid types but achieved different flow resistance
- $K_{RL}$ disk will probably work on gas
- $K_{RG}$ disk may not work on liquid!
  - “Solid” liquid system application will be covered
Section VIII – PRV’s

- Current valve rules do not address multiple fluids
  - Some manufacturers have developed designs claimed to be good for both without adjustment – no certifications issued on this basis
  - Most process valve designs have variations in design from gas to liquid
Section VIII – PRV’s

- Proposed code case for true dual stamping for steam, air, and/or liquid currently under review
Multiple Marking of Certified Capacities for Pressure Relief Valves

Inquiry: Under what conditions may a Manufacturer or Assembler of a pressure relief valve place more than one certified capacity on the pressure relief valve or the nameplate and comply with UG-129?

Reply: It is the opinion of the Committee that a Manufacturer or Assembler of a pressure relief valve may place more than one certified capacity on the valve or nameplate providing:

(a) The pressure relief valve has been capacity certified by the Manufacturer per the requirements of UG-131 for each of the medias with the following additional requirements:

(1) during the certification of capacity testing required per UG-131, the pressure relief valve shall be tested first on one of the certified medias (steam, air, gas or water) and then tested on all other medias requested by the Manufacturer;

(2) there shall be no adjustments to any of the pressure relief valves after completion of the testing on the first media;

(3) using the set pressure determined in the first media testing for each valve, the measured set pressure for the valve tested on the additional medias shall meet the tolerance requirements of UG-134(d)(1).
(b) The pressure relief valve shall meet all the requirements of UG-136 for all of the certified capacities stamped on the valve or nameplate except:
(1) for sample valves selected for production certification and recertification per UG-136(c)(3)(a) the same requirements per (a) above shall apply;
(2) production testing per UG-136(d)(4) shall require testing with steam for pressure relief valves having steam as one of the certified medias. Pressure relief valves for air and water certification may be tested with either air or water.
(c) This Code Case number shall be on a plate permanently attached to the pressure relief valve.
Section VIII – PRV’s

- Some recommended practices
  - User should determine capacity for all applicable fluids
  - Specify PRV type based on most probable fluid
    - Liquid valve on gas will function – probably will have long blowdown
    - Gas valve on liquid may require additional overpressure to achieve full lift
Section VIII – PRV’s

- Specify capacity based upon largest possible flow rate
- Consider modulating pilot valve design
  - Good choice where function on dual fluids is important
Section VIII – PRV’s

- Two phase applications not considered
  - Valve function will be acceptable based upon gas type design
  - Application problem is determining required capacity and true relief capacity
  - DIERS work on this complex problem
Pictures Courtesy of:

(“borrowed” from)

- Cleaver Brooks
- Babcock & Wilcox Company
- Anderson Greenwood
- Watts
Questions?