



**THE NATIONAL BOARD
OF BOILER AND PRESSURE VESSEL INSPECTORS**

Date Distributed: 1/25/2023

NATIONAL BOARD INSPECTION CODE TASK GROUP HISTORICAL BOILERS

MINUTES

Meeting of January 9, 2023
Charleston, SC

*These minutes are subject to approval and are for the committee use only.
They are not to be duplicated or quoted for other than committee use.*

The National Board of Boiler & Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, Ohio 43229-1183
Phone: (614)888-8320
FAX: (614)847-1828

1. Call to Order

Chair, Mr. Trevor Seime called the Historical Task Group (TG) meeting to order at 8:02 am EST.

2. Introduction of Members and Visitors

Secretary, Ms. Jodi Metzmaier, did a roll call of all TG members in person and online. The visitors in person stated their name and their company. Ms. Metzmaier then called on all visitors online, who then said their name and their company. All members and visitors are noted on the attendance sheet. (Attachment 1)

3. Check for a Quorum

With 13 of 14 members in attendance, both in person and online, a quorum was established.

4. Awards/Special Recognition

Jon Wolf – 5 Years as a member of TG Historical

Matt Sansone – 5 Years as a member of TG Historical

Mr. Seime presented Mr. Jon Wolf with a pin for 5 years of service as a member of the Historical TG.

Mr. Seime acknowledged Mr. Sansone for 5 years of service as a member of the Historical TG. Mr.

Sansone joined the meeting online; he will be presented with his pin at the next meeting he attends in person.

5. Announcements

Ms. Metzmaier gave announcements to the TG. (Attachment 2)

6. Adoption of the Agenda

A motion as made and seconded to adopt the agenda.

- Add presentation on Additive Manufacturing using Weld Metal Build Up by Teresa Melfi.
- Add July 2023 future meeting as St. Louis, MO
- Add discussion item regarding Safety Valve replacement.

The above items were added to the agenda. The motion was then revised to adopt the revised agenda. The motion was seconded and unanimously approved.

7. Approval of the Minutes of the July 11, 2022, Meeting

A motion was made to approve the minutes from the July 2022 Historical TG meeting. The motion was seconded and unanimously approved.

8. Review of Rosters

- **Membership Reappointments**

There are no membership reappointments for this meeting.

- **Membership Nominations**

Mr. Jon Ferreira (AIA) is interested in becoming a member of the Historical TG.

Mr. Ferreira spoke on his behalf, stating his history with his employer, HSB, and his position with them now. He then reviewed his resume with the TG, and let the group know why he would like to become a member and how he would be an asset. Mr. Ferreira left the room while the TG discussed his nomination. Many group members believe Mr. Ferreira would be a good addition to the group, and he would be a great replacement for Mr. Robert Underwood. A motion was made to accept Mr. Ferreira as a member of the Historical TG. The motion was seconded and **unanimously approved.**

- **Officer Nominations**

None.

9. **Presentation on Additive Manufacturing using Weld Metal Build Up by Teresa Melfi.**
 Ms. Teresa Melfi gave a presentation to the Historical TG on Manufacturing using Weld Build Up. (Attachment 3) After the presentation the group had a discussion with Ms. Melfi which included many questions.

10. **Action Items**

Item Number: 20-25	NBIC Location: Part 3, S2.13	No Attachment
<p>General Description: Repair Procedure for Fire Boxes</p> <p>Subgroup: SG Historical Task Group: M. Wahl (PM), R. Forbes, T. Dillon, L. Moedinger & F. Johnson</p> <p>Explanation of Need: In NBIC Part 3, S2.13.10.3, S2.13.11 do not define what to do at a riveted joint. On the tubesheet, or firedoor sheet, where it is flanged to rivet to the firebox, the repairs are silent on what to do at the riveted joint.</p>		
<p>January 2023 Action: PROGRESS REPORT: Mr. Wahl presented this item to the group, and asked Mr. Moedinger for an update on where the Locomotive TG stands on this topic. Mr. Moedinger stated locomotive has not addressed this topic. The group then asked if it would be better if the Historical TG moved forward on their own without working with the Locomotive TG. After discussion Mr. Wahl stated he will move forward working with the task group assigned to this item to try and come up with a proposal. Mr. Moedinger stated Locomotive TG has a meeting in March 2023 and they are working to create a diagram, and he would like for the Historical TG to hold off on creating anything until Locomotive TG meets. Mr. Moedinger will contact Mr. Wahl with information on the Locomotive TG item so he can see where they are and try to work with them to create a proposal for the July 2023 meeting.</p>		

Item Number: 20-26	NBIC Location: Part 2, S2	No Attachment
<p>General Description: Concern for Historical Boiler Inspections Nationwide</p> <p>Subgroup: SG Historical Task Group: T. Dillon (PM), M. Horton, L. Moedinger, M. Wahl, D. Rupert, K. Anderson, M. Sansone, & J. Wolf</p> <p>Explanation of Need: Currently Jurisdictions are not uniform in adoption of how and when inspections are performed.</p>		
<p>January 2023 Action: Mr. Tom Dillon spoke on this item, stating there hasn't been any movement on this topic other than Mr. Seime is keeping in contact with the NB Training Department, but nothing has been able to be created yet. Mr. Sansone also stated he brought this topic up to BOT and Training and they were both very receptive to the idea. The group then decided this item should be closed as an action item, and it will be changed to an ongoing discussion item that will be kept on future agendas for updates to be reported/discussed. Mr. Tom Hall joined the discussion talking about a training course they provide for operation of historical boilers. A motion was made to close this item and make it an <u>ongoing discussion item</u>. The motion was seconded, and unanimously approved.</p>		

Item Number: 21-03	NBIC Location: Part 2, S2	Attachment 4
<p>General Description: Inspection of through stays and diagonal stays</p> <p>Subgroup: Historical Task Group: D. Rose (PM), R. Bryce, R. Forbes, C. Jowett Submitted by: David Rose</p> <p>Explanation of Need: The code is silent on the inspection of through stays and diagonal stays. Additionally, new repair methods are available from ASME that can be incorporated.</p>		
<p>January 2023 Action: Mr. Rose presented a proposal to the Historical TG and reviewed the proposed text. A motion was made to accept the proposal as presented. The motion was seconded. The group then had a lot of discussion, regarding the proposed wording, and Mr. Seime stated he believes this item should be passed as presented as a starting point and then action items can be opened at a later date to manipulate or change the wording as needed. Much of the discussion was regarding the wording “Sagging beyond 3x the original diameter”. Many members thought this needed to be more vague and not so exact. The wording was slightly revised, the motioner and seconder changed their motion to accept the revised proposal. The motion was unanimously approved.</p>		

Item Number: 21-09	NBIC Location: Part 3, S2	Attachment 5
<p>General Description: Incorporate new repair methods for through and diagonal stays</p> <p>Subgroup: Historical Task Group: D. Rose (PM), R. Bryce, R. Forbes, C. Jowett Submitted by: David Rose</p> <p>Explanation of Need: The code is silent on the inspection of through stays and diagonal stays. Additionally, new repair methods are available from ASME that can be incorporated.</p>		
<p>January 2023 Action: Mr. Rose reviewed the proposal with the TG. A motion was made and seconded to accept the proposal. After much discussion, a title was added to the proposal for the paragraph and a few other small changes were made to the proposal. The motioner and seconder revised their motion to accept the revised proposal. The motion was unanimously approved.</p>		

Item Number: 21-34	NBIC Location: Part 2, S2	Attachment 6
<p>General Description: Working Pressure Calculations for Curved Stayed Surfaces</p> <p>Subgroup: Historical Task Group: Mike Wahl (PM), R. Bryce, & T. Dillon</p> <p>Background: In January 2021, Dr. Bryce initiated the conversation with the group for this topic. He is proposing the group open an item to address working pressure calculations for curved stayed surfaces. After discussion, a task group was formed</p>		
<p>January 2023 Action: Dr. Robert Bryce presented a proposal to the TG. During discussion the group made a few changes to the proposal. A motion was made to accept the revised proposal. The motion was seconded and unanimously approved.</p>		

11. New Items

None.

12. Discussion

- Safety Valve Replacement

Dr. Bryce discussed this topic with the TG. The group reviewed Part 3, 3.2.6 and 3.2.6.2c). Dr. Bryce would like the group to consider adding text to 3.2.6. It was then noted that this section is a guideline and not mandatory. Mr. Seime suggested opening an action item to address safety valves and how they are taken care of on historical boilers. Mr. Kevin Anderson will be sending Mr. Jon Wolf information to discuss in the Part 4 meeting. Mr. Wolf & Mr. Wahl will work together to submit an action item. Mr. Anderson would also like to work with Mr. Wolf and Mr. Wahl on the new item. Mr. Dennis Rupert noted that the historical valves are “Relief Valves” and not “Safety Relief Valves”.

13. Future Meetings

- July 2023 – St. Louis, MO
- January 2024 – Charlotte, NC

Mr. Seime discussed the future meetings with the TG.

14. Adjournment

A motion was made to adjourn the meeting at 11:03 am EST. The motion was seconded and unanimously approved.

Respectfully submitted,



Jodi Metzmaier
Historical Task Group Secretary

Taskgroup Historical Attendees - January 2023

MEMBERS:	Interest Category	Registered For	In Person	Remote	Not In Attendance
Trevor Seime - Chair	Jurisdictional Authorities	In Person	x		
Tom Dillon - Vice Chair	General Interest	In Person	x		
Jodi Metzmaier	NBIC Secretary	In Person	x		
Kevin Anderson	Users	Remote		x	
Michael Carlson	Jurisdictional Authorities	In Person	x		
Jim Getter	Manufacturers	In Person	x		
Michael Horton	General Interest	Remote		x	
Frank Johnson	Users	In Person	x		
Chris Jowett	National Board Certificate Holder	Remote		x	
Don Kinney	Jurisdictional Authorities	In Person			x
David Rose	Users	Remote		x	
Dennis Rupert	General Interest	Remote		x	
Matt Sansone	Jurisdictional Authorities			x	
Mike Wahl	General Interest		x		
Jon Wolf	Authorized Inspection Agencies	In Person	x		

VISITORS:	Company/Title/Interest	Registered For	In Person	Remote
Greg Goossens	NBBI	In Person	x	
Luis Ponce	NBBI	In Person	x	
Gary Scribner	NBBI	In Person	x	
Melissa Wadkinson	Fulton Thermal Corp	In Person	x	
Robert Derby	United Association ITF	In Person	x	
Jon Ferreira	HSB	In Person	x	
Ken Misiewicz	Pleune Service Company	In Person	x	
Kim Black	American Boiler Manufacturers Association	In Person	x	
Teresa Melfi	Lincoln	In Person	x	
James Roberts	Arcosa Tank, LLC	In Person	x	
Ron Spiker	State of SC	In Person	x	
Kathy Moore	Joe Moore & Company, Inc.		x	
Vinny Scarcella	CNA		x	
Linn Moedinger	Strasburg Rail Road	Remote		x
Robert Bryce	Heartland Software	Remote		x
Robin Forbes	Heartland Software	Remote		x
Jeremy Smith	NC Department of Labor Boiler Safety Bureau	Remote		x
Richard Smith	Owner of Software Engineering	Remote		x
KR Hough	Traction Engineering			x
Jeffrey Detwiler	Oklahoma Threshing Association			x
Ken Griffis	Larson Welding Machine		x	
Ernest Brantley	XL Insurance America, Inc.		x	
Harrington Henry	Arise		x	
Don Patton	Bay City Boiler		x	
Craig Bierl	Chubb Insurance			x
John King	Chubb Insurance			x
Tom Hall	General Interest - Steam School Instructor in Canada			x

TGH Announcements

- Zoom Notes:
 - Make sure your actual name is on your zoom account.
 - Please add an “M” for Member, “V” for Visitor, or “S” for Staff at the end of your name. Example: Jodi Metzmaier - S
 - Click “Participants”, click “more” next to your name, click “rename,” and add the applicable letter.
 - Please stay muted during the meeting. If you would like to speak, please use the “raise hand” feature, and then you can unmute as you are called on.

• For the July meeting we will begin using MS Teams instead of Zoom.

- The National Board will be hosting a reception on Wednesday evening from 5:30pm to 7:30pm in the Colonial Ballroom at the hotel. We will also host a breakfast and lunch on Thursday. Breakfast will be served from 7:00am to 8:00am, and lunch will be served from 11:30am to 12:30pm. Both meals will be served at the hotel in the Colonial Ballroom. Members, visitors, and guests are all welcome.

Please register now if you have not already done so.

- Meeting schedules, meeting room layouts, and other helpful information can be found on the National Board website under the **Inspection Code** tab → NBIC Meeting Information.
- We now have a review and comment Letter Ballot type. When we send out a LB for review and comment, the layout of the ballot will look different, as it will not have any voting options.
- Remember to add any attachments that you’d like to show during the meeting (proposals, reference documents, power point, etc.) to the cloud **prior to the meeting**.
 - If needed, we can go over how to do this.
 - ALL power point attachments/presentations **must be sent to Jonathan prior to the meeting** for approval.
- Always submit attachments in word format showing “strike through/underline”
 - Please contact me if you need any help with this.
- If you’d like to open a new Interpretation or Action item, this should be done on the National Board Business Center.
 - Anyone, member or not, can open a new item.
- As a reminder, anyone who would like to become a member of a group or committee:
 - Should attend at least 2 meetings prior to being put on the agenda for membership consideration. The nominee will be on the agenda for voting during their 3rd meeting.
 - The nominee must submit the formal request along with their resume to Jonathan **PRIOR TO** the meeting. nbicsecretary@nbbi.org
 - If needed, we can also create a ballot for voting on a new member between meetings. To do this, you will need to contact Jonathan.
- Thank you to everyone who registered online for this meeting. The online registration is very helpful for planning our reception, meals, the room set up, etc. Please continue to use the online registration for each meeting. If you are here in person, and did not register, please visit the National Board website to register now. Registering will make sure we have an accurate count for the reception, breakfast, and lunch. It also is a good way to make sure we have the most up-to-date contact information.

Weld Metal Additive Manufacturing

Using weld metal as a replacement material

Teresa Melfi
NBIC Meeting
Historical Boilers
January 2023

Outline

- Case Study: weld metal as a replacement for historic parts
- Recent high temperature pressure retaining application
- Current projects and trends in weld metal manufacture
- How codes treat weld metal as a replacement material
- NBIC approach
 - Interpretation
 - Code change
 - Wait for ASME rules

3D welding for replacement parts

- Old machinery
- Initially a casting, a forging, or even an assembly
 - Very long lead times
 - Very expensive
 - Downtime . . .
- Often no drawings

<https://www.youtube.com/watch?v=E2B0JUP7e8c>

Case Study – Bearing Housing

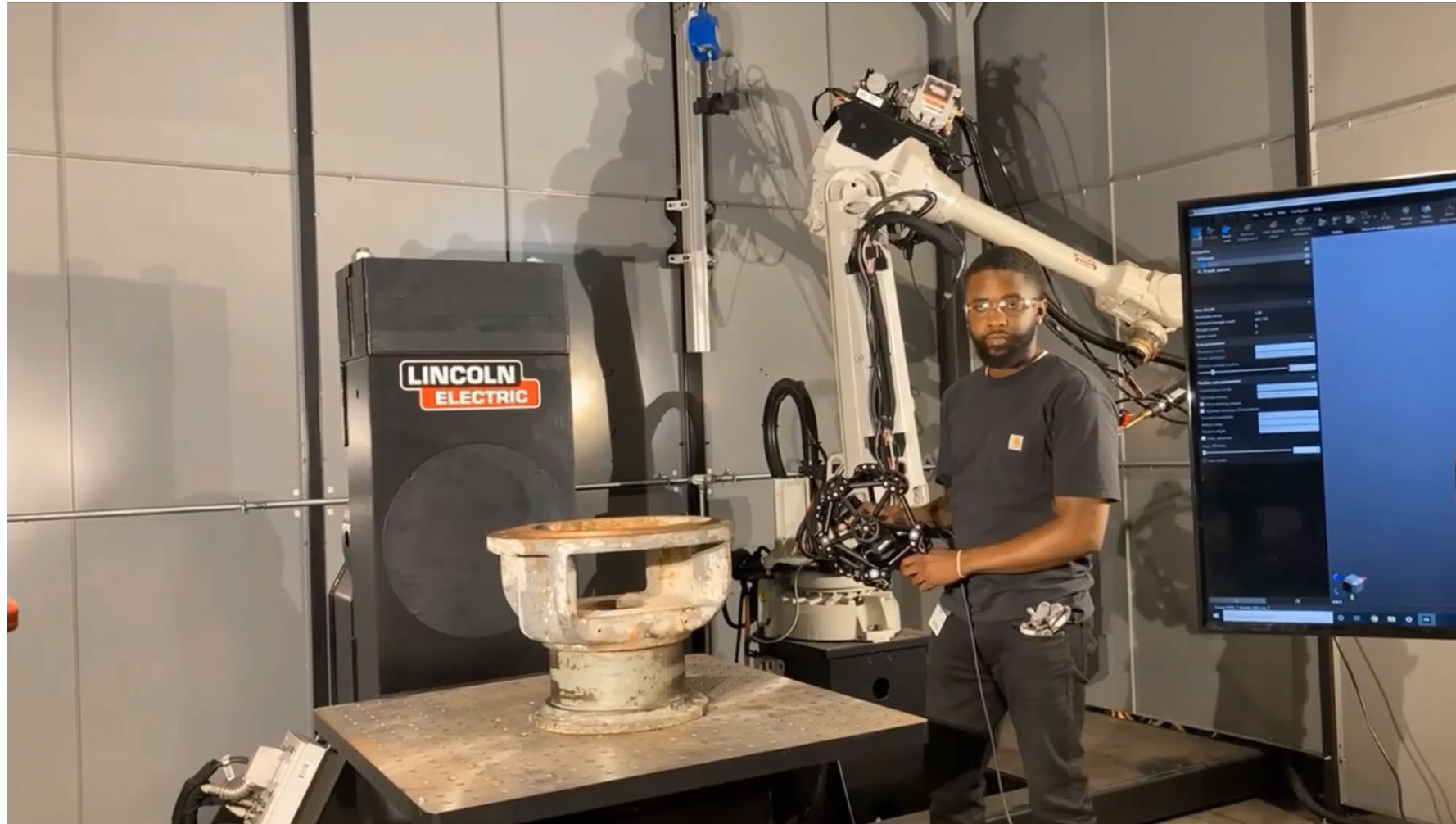
- Cracked Flange
- Pre-WWII Part
- No Prints
- Reverse Engineered
- Printed
- Machined
- Put into service



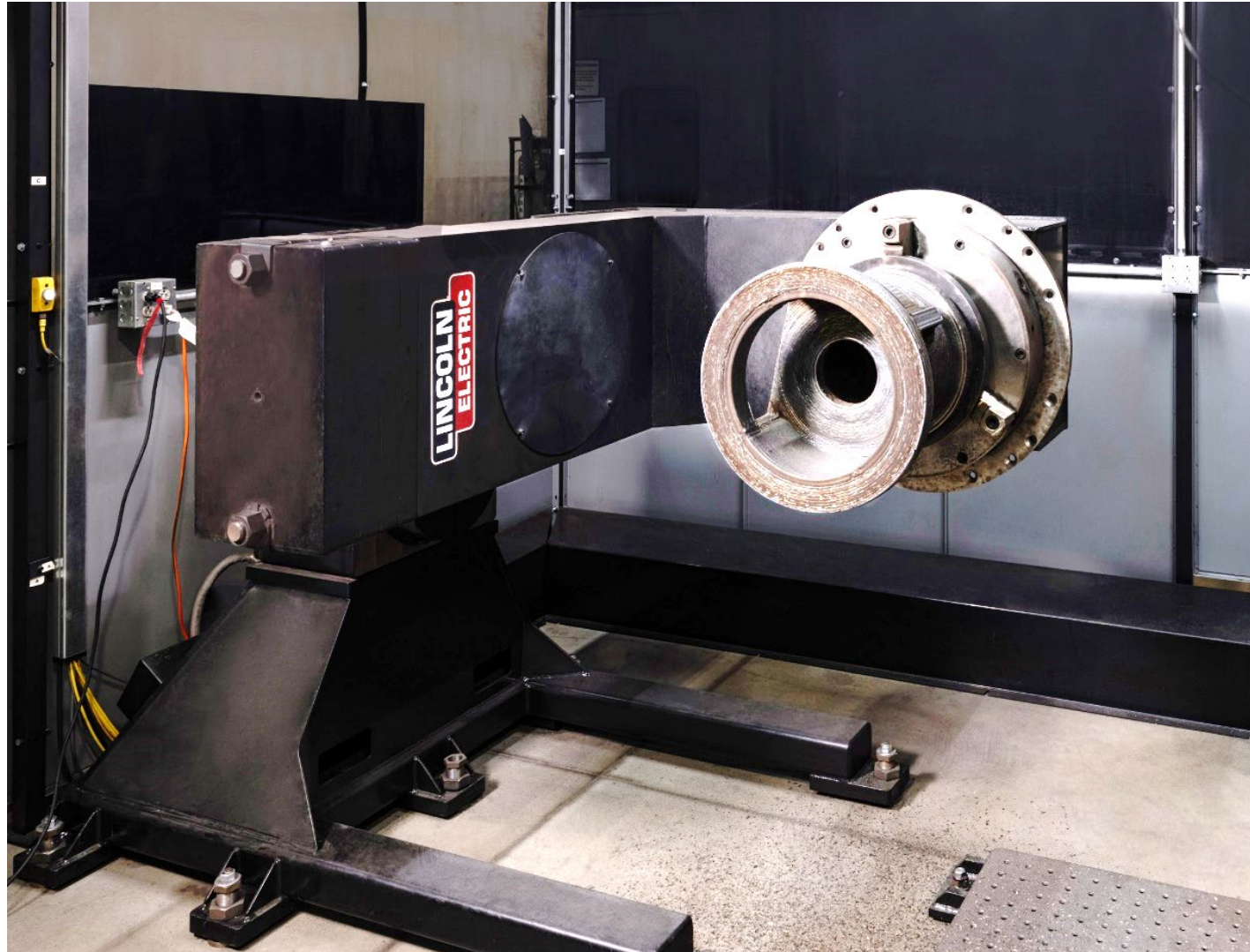
As-received Part (actually, an assembly)



Create 3D CAD File (Model)



Printed Part





Machine only Critical Surfaces



As-received Part



Weld Metal Part





ICAM 2022

ASTM INTERNATIONAL
Helping our world work better

API and ASME Qualification of a Printed Pressure Component

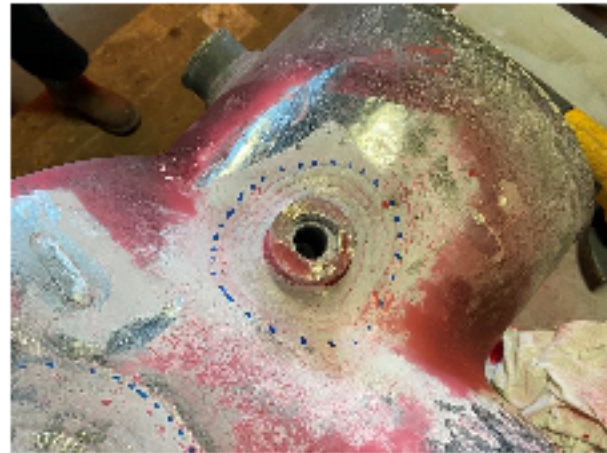
Robert Rettew, Chevron
Teresa Melfi, Lincoln Electric
Matt Sanders, Stress Engineering

www.amcoe.org

**Selected slides are shown in this presentation.
The entire Chevron ICAM presentation will be
attached to the meeting minutes.**

A Refinery 3D Printing Success Story

- In early 2022, a facility turnaround needed replacements for several components in hydrogen furnace service. These components were critical path to restart the facility.
- Service requirements were 1500F and 300psi, with a design lifetime of 20 years.
- Application was for a furnace header. Previous installation was Alloy 800H with Alloy 617 weldments.
- Existing components were damaged and unusable. Replacement using traditional methods estimated ~3 months.
- 3D printing was used to deliver replacements in just under 4 weeks, avoiding a significant shutdown.



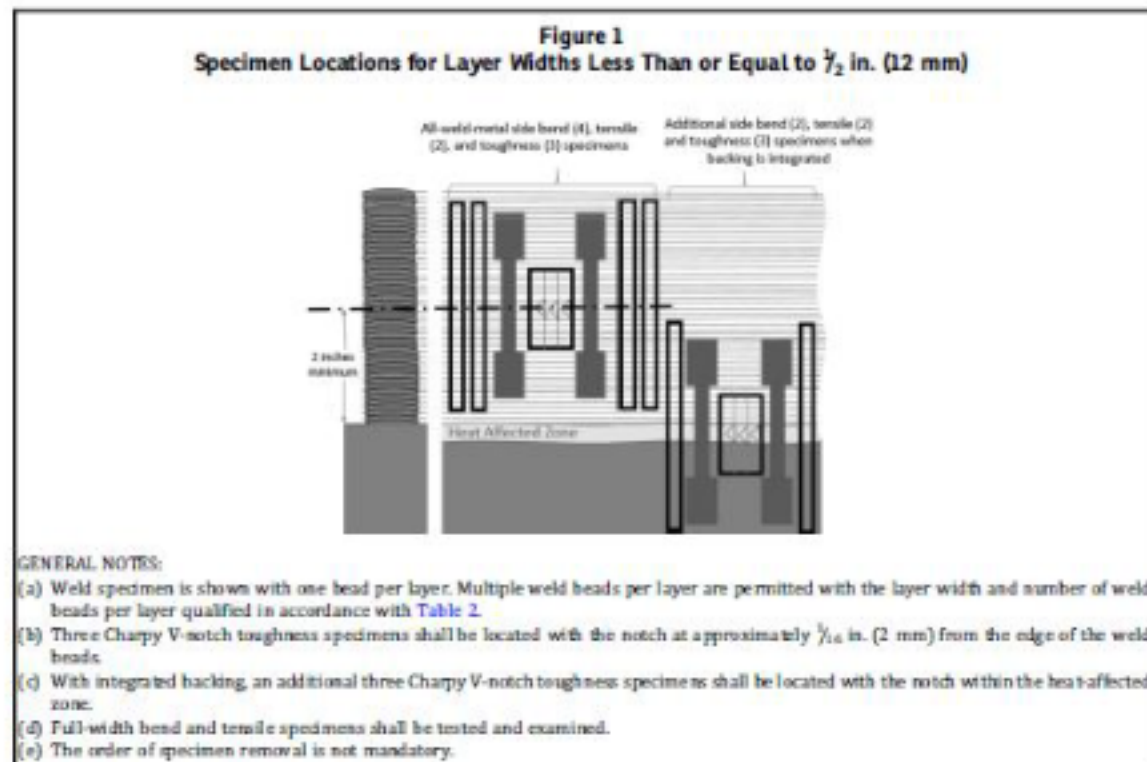
Piping components being printed at Lincoln Electric Additive Services



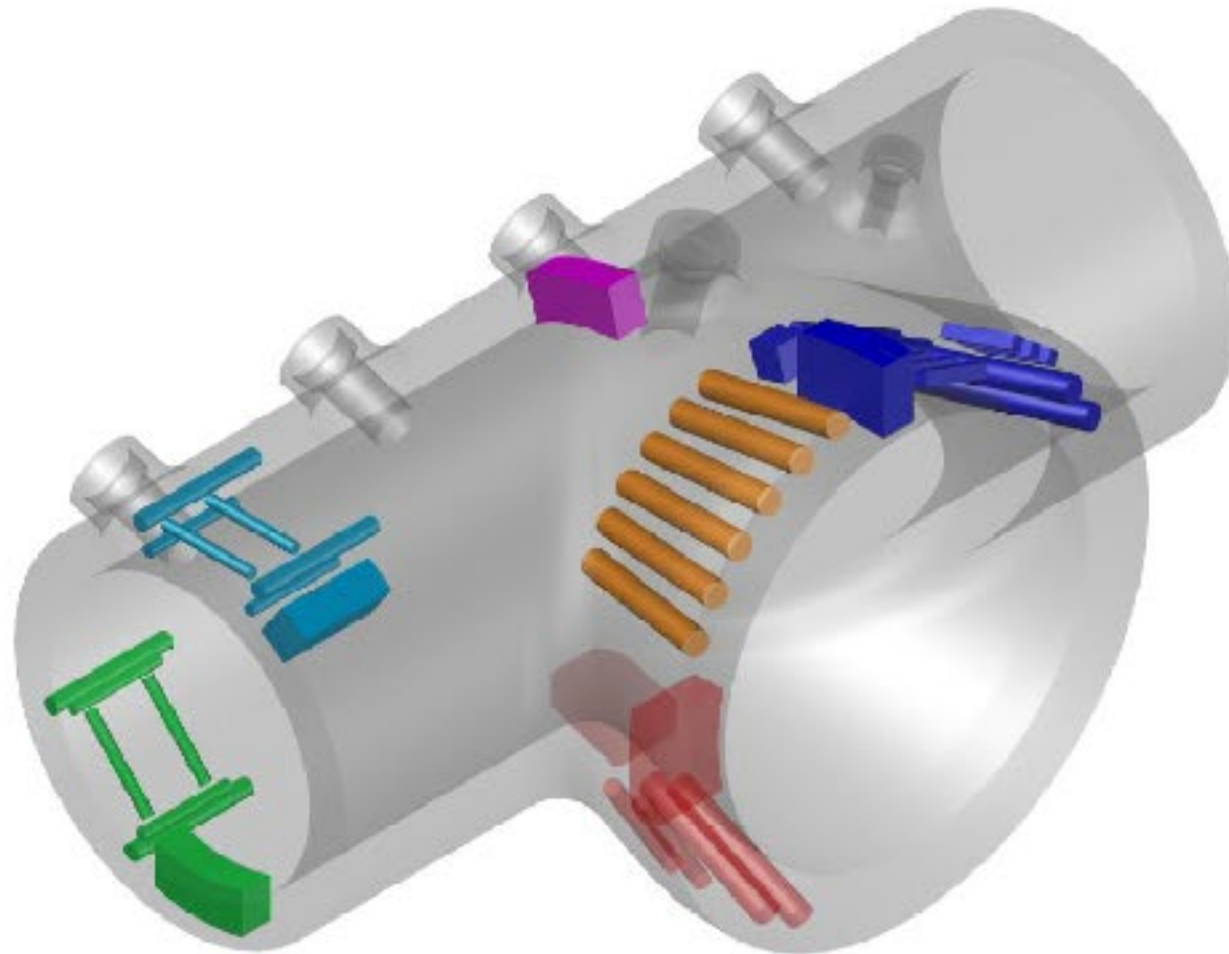
(left) Digital part verification, (right) Final Installation

ASME 3020 Qualification

Cooling Rate	Wall Thickness	Yield Strength	Ultimate Strength
<i>(type)</i>	<i>(type)</i>	<i>(ksi)</i>	<i>(ksi)</i>
Slow <i>High Heat Input & High Interpass</i>	Thin	49.9	99.0
		51.0	100.0
	Thick	59.0	103.0
		60.5	102.0
		58.0	103.0
		58.0	102.0
		61.5	104.0
Fast <i>Low Heat Input & Low Interpass</i>	Thin	57.0	96.5
		56.0	96.5
	Thick	63.5	107.0
		63.5	98.0



Specimen Locations from Sacrificial Article



Tensile Testing from Sacrificial Part

Section	Orientation	Location	Yield Strength (ksi)	Tensile Strength (ksi)	Elongation (%)	Reduction of Area (%)
Light Blue	Longitudinal	ID	57.6	107.5	44.8	53.7
			55.4	99.9	40.1	52.6
	Longitudinal	OD	65.5	108.7	40.4	55.0
			66.4	108.7	40.5	51.0
	Transverse	Mid wall	60.9	106.1	45.5	42.5
			59.0	102.7	34.9	31.1
Transverse	Mid-wall	63.0	107.0	39.9	51.4	
		61.6	107.9	37.4	44.0	
Green	Longitudinal	ID	58.0	101.8	43.1	49.4
			58.3	102.2	44.9	57.2
	Longitudinal	OD	64.3	109.4	42.1	44.7
			66.7	108.6	42.5	45.8
Red	Longitudinal	Mid-wall	60.9	101.8	47.0	55.2
			60.4	102.4	48.6	55.7
	Transverse		61.0	104.2	44.4	58.7
			61.5	104.7	43.7	51.0
Dark Blue	Longitudinal	Mid wall	60.6	101.1	46.5	59.2
			60.5	101.1	46.8	59.2
	Transverse		61.4	103.5	40.3	48.7
			62.5	105.4	40.5	54.0

Timeframe Recap

- **Week One**
 - First Inquiry
 - Meetings & Printability Assessment with Lincoln Electric
 - Determined code case and API guidance
- **Week Two**
 - Risk Assessment, supported by review of Lincoln and Industry Data
 - Visit to Lincoln, review QA/QC and manufacturing
 - Initial Mechanical Results, Surface Roughness, and FEA model
- **Week Three**
 - Hydrotest, PAUT, and RT on test piece
 - Grinding & photography of surface indications
- **Week Four**
 - Delivery of subsequent parts for final machining, inspection, & installation

Weld Metal Manufacture Today ... and trends

- Huge use in repair – due to supply chain constraints on large forgings, castings and specialty metals
- Still used in prototyping and in tooling (no code rules)
- Significant work on multi-metal and functionally gradient parts – pups for dissimilar metal joining, moving field welds outside of critical zones, corrosion and heat resistance, etc.
- Significant work on redesigns to remove excess thickness required for metal flow (castings, forgings)

Weld Metal AM Code Rules

- Code case 3020 is incorporated into 2023 Section IX as QW-600 series – bracketed qualifications required
- Scattered specific BPV code cases allow use of additive materials
- Broad code case has been balloted by ASME BPV AM group.
 - Will go on to VIII and III quickly. Possibly to B31, B16, I – as they choose.
 - Limited materials including mild, low alloy, stainless and nickel-alloy steels.
 - Limited to time-independent use.
- AM has been applied in BPV using weld metal buildup rules
- API 20S, AWS D20, DNV and others have use rules in place

NBIC Possible Approaches

- Don't add or subtract any rules
 - Let repairs and alterations language cover this, along with jurisdictions/Ais
 - Wait for rules to be adopted into BPV codes (2025-2027 for III and VIII)
- Add specific rules for repair or alteration using weld metal
- Issue interpretation(s) to address how this is covered
 - See B31.3 interpretation on the next slide

Dr. Amir Farzadfar
Emerson Process Management
301 S. 1st Avenue
Marshalltown, IA 50158
Email: amir.farzadfar@emerson.com

Subject: B31.3-2014, Interpretation of Paras. 302.3.2(f), 304.7.2, 323.1.2 Additive Manufacturing Materials

Reference: Your September 9, 2015 Request for Interpretation; ASME C&S File #15-2052

Dear Dr. Farzadfar:

Your request for interpretation has been reviewed by the B31.3 Process Piping Committee. Following is the Committee's understanding of your question and official response:

Question: Does ASME B31.3 permit the use of an unlisted piping component manufactured using the additive manufacturing process?

Reply: Yes, provided it meets all of the requirements of the Code including material being qualified in accordance with the requirements of para. 323.1.2, and the component meeting the requirements of paras. 326.1.2 and 326.2.2.

Sincerely,



Riad Mohamed
Secretary, B31.3 Process Piping Committee
212-591-8528
mohamedr@asme.org

Item 21-03 Inspection of through stays and diagonal stays

David Rose

S2.10.4.1 STAYBOLTS

The maximum allowable working pressure for symmetrically spaced corroded staybolts will be calculated using the formula provided in either of the two following paragraphs or the accompanying tables. Equations calculate MAWP based on measuring the staybolt spacing on the stayed surface and the minimum diameter of the corroded staybolt.

Through stays shall be visually examined for damage or failure such as corrosion, sagging or cracks.

1. Sagging beyond 3x the original diameter of the stay shall be replaced.
2. Cracked through stays shall be replaced.
3. Corroded through stays shall be measured where accessible and if the measured diameter has been reduced by more than 20% of the original the through stay shall be replaced.

Alternatively, the acceptable loading may be calculated in accordance with the relevant sections of the 1971 ASME BPVC.

Diagonal braces shall be visually examined for damage or failure such as corrosion, deformation or cracks.

1. Cracks shall be cause for repair.
2. Deformation should be carefully monitored for changes indicating movement.
3. Corroded braces shall be measured where accessible and if the measured diameter has been reduced by more than 20% of the original or the cross-sectional area has been reduced by 30% the brace shall be replaced.

Alternatively, the acceptable loading may be calculated in accordance with the relevant sections of the 1971 ASME BPVC.

a) Iron Staybolt

Staybolts which are of iron or of unknown material shall be calculated using the following formula or Table S2.10.4.1-a. The table is based on a stress value of 7,500 psi (51.7 MPa) for staybolts. Refer to ASME Section 1, 1971 Edition, Table PG-23.3, for allowable loads for all staybolts.

FORMULA HERE

b) Steel Staybolts

Staybolts of known, steel material shall be calculated using the following formula or Table S2.10.4.1-b. The table is based on a stress value of 11,300 psi (78.0 MPa) for staybolts. Refer to ASME Section 1, 1971 Addenda for allowable loads for all staybolts.

FORMULA HERE

Item 21-09 Repair of through stays
David Rose

Rationale:

ASME PL-27 provides a construction method applicable to through stays that would be useful in repairs. Using PL-27 as a guide we can add these methods in to assist in the replacement of corroded or excessively sagged through stays.

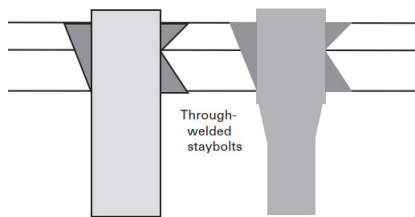
Part 3 – Repair

Suggested addition:

S2.13.4.1 REPLACEMENT OF THROUGH STAYS

- a) Threaded through stays may be replaced in kind in accordance with the original design. The threaded portion of the stay may be upsized to permit new threads to be cut in the shell. The new threads may be Unified National Fine thread.
- b) Threaded through stays may be replaced by welded-in stays provided that, in the judgement of the Inspector or Jurisdiction, the material adjacent to the through stay has not been materially weakened by deterioration or wasting away.
- c) Reduced section through stays shall be replaced with stays of similar design.
- d) Stays shall be removed by threading out or drilling.
- e) Welded stays shall be inserted into countersunk holes through the sheet and attached by full penetration welds to plate of no less than 3/8" (10mm) thickness.
- f) The ends of the stays shall not be covered by weld metal and the face of the welds shall not be below the outside surface of the plates.
- g) Minimum diameter of the reduced section of the stay shall be no less than the greater of 1" or stay bolt length divided by 120.
- h) Material will be in accordance with Table S2.7.1 for Boiler Braces.
- i) Original nuts and washers may be reinstalled on a welded stay for cosmetic purposes only.

Figure S2.13.4.1



After beveling, and prior to the installation of the stay, the two plates should be welded and ground back to match the bevel prep. To facilitate installation, heating the through stay will aid in tensioning the stay and prevent sag. Excessive preload applied to the stay should be taken into consideration.

S2.10.4.1 STAYBOLTS

The maximum allowable working pressure for symmetrically spaced corroded staybolts will be calculated using the formula provided in either of the two following paragraphs or the accompanying tables. Equations calculate MAWP based on measuring the staybolt spacing on the stayed surface and the minimum diameter of the corroded staybolt.

a) Iron Staybolt

Staybolts which are of iron or of unknown material shall be calculated using the following formula or Table S2.10.4.1-a. The table is based on a stress value of 7,500 psi (51.7 MPa) for staybolts. Refer to ASME Section 1, 1971 Edition, Table PG-23.3, for allowable loads for all staybolts.

$$p = \frac{\pi \left[\frac{d}{2}\right]^2 s}{p^2} \quad S = 7,500 \text{ psi (51.7 MPa)}$$

b) Steel Staybolts

Staybolts of known, steel material shall be calculated using the following formula or Table S2.10.4.1-b. The table is based on a stress value of 11,300 psi (78.0 MPa) for staybolts. Refer to ASME Section 1, 1971 Addenda for allowable loads for all staybolts.

$$p = \frac{\pi \left[\frac{d}{2}\right]^2 s}{1.1xp^2} \quad S = 11,300 \text{ psi (78.0 MPa)}$$

c) For curved stayed surface subjected to external pressure, equations to calculate MAWP of staybolts on curved stayed surfaces shall use the longitudinal and circumferential pitches. Use (l × w) in place of p² in equations S2.10.4.1.a and S2.10.4.1.b.

S2.10.4.3 CURVED STAYED SURFACES SUBJECTED TO INTERNAL PRESSURE

The maximum allowable pressure for stayed curved plates and those parts, which require staying with stays or staybolts of uniform diameter, uniformly longitudinally spaced, shall be calculated using the following formula.

$$P = \frac{TS \times t \times E}{H \times FS}$$

where

$$E = \frac{p_l - d_s}{p_l}$$

p_l is longitudinal staybolt pitch

d_s is the outside diameter of the staybolt

If E is not known, then 80% may be used

TS = tensile strength; if not known then 55,000 shall be used

FS = 5 for curved stayed surfaces subjected to internal pressure

H for locomotive style boilers = height of crown sheet of firebox to wrapper sheet measured through the hole for the fusible plug

H for boilers with circular fireboxes = inside radius of the course of shell or drum

S2.10.4.4 CURVED STAYED SURFACES SUBJECTED TO EXTERNAL PRESSURE

The maximum allowable pressure for stayed curved plates and those parts, which require staying with stays or staybolts of uniform diameter, uniformly longitudinally spaced, and subjected to pressure on the convex side, shall be calculated using the following formula.

$$\begin{array}{l} \text{If } (d_o \leq 42 \text{ inches}) \\ \\ \text{If } (d_o > 42 \text{ inches}) \end{array} \quad P = P_s + \frac{8000t}{d_o}$$
$$P = P_s$$

where

P_s is stayed surface equation from S2.10.4 STAYED SURFACES

d_o is outside diameter of firetube, if tapered use the largest outside diameter