Joint Design Tests

SUB MINIATURE BOILERS

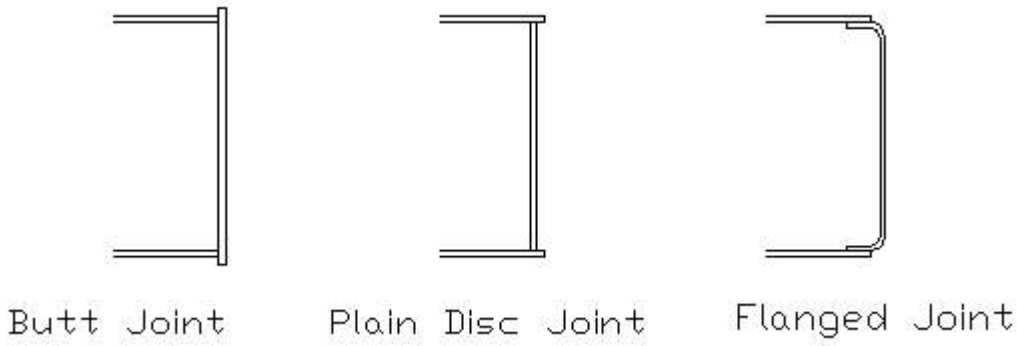
A paper in support of the application for the AMBSC Code Part 3 - SUB MINIATURE BOILERS at present being negotiated with the AMBSC and Workcover in NSW.

Joint Design Tests for Sub Miniature Boilers

By Paul Trevaskis

Introduction

This paper has been prepared to support the application for the (Australian Miniature Boiler Safety Committee) AMBSC Code Part 3 - SUB MINIATURE BOILERS at present being negotiated with the AMBSC and Workcover in NSW.
In Australia there has been some discussion about the various joint construction methods, which can be used in boilers smaller than 76mm diameter. In order to test these methods a series of test pieces were constructed, and tested to destruction. The three types of joints are shown below.



Drawing 1

Boiler Construction

- The test pieces ranged from 50.8mm to 76mm diameter.
- All models built from seamless copper tube to AS1432, Including the 1.2, 1.6 and 2mm end plates.
- The 3mm copper endplates to AS1566-110
- The 19 and 25.4 mm flues to AS1432.
- All joints silver soldered with 45% silver solder to AS1167.1
- The filling bushes were built to the AMBSC Code part 1 issue 7, some from brass and some from bronze.
- The 1.2mm flanged end plate was formed using a punch and die in a hydraulic press. These plates built with a 1.6mm radius on the flange, which is 5mm long. They were pushed into the barrel by hand.
- The plain disc endplates in all sizes were turned on a lathe to be a hand push fit into the barrel.
- The holes for the flues were made with a 19mm or a 25.4 mm drill.
- The discs for the butt joints were turned to 54mm dia, giving a 1.6 mm lip.
- The “T” boiler the 38 mm hole in the 50mm piece for the horizontal section was done in a lathe.
- Soldering was done with a propane torch and fire bricks arranged to shield the piece.
- The jobs were pickled in a sulphuric acid solution.
- Initial leak testing was to 100psi.

The Tables referred to are included in the appendix of this document.
The dimensions of the test pieces are shown in Table 1.

Testing

The testing was performed by:
Paul Trevaskis: manager of Rishon Locomotives, member of Rails in the Garden.
(Small scale live steam locomotive manufacturer)
Bill Dunn: FIEAust, CPEng,
[Registration No: #2574761] Engaged in the design, manufacture and installation of industrial package boilers since 1973.
John Rogers: An amateur locomotive builder.
All three gentlemen are members of AMRA QLD.

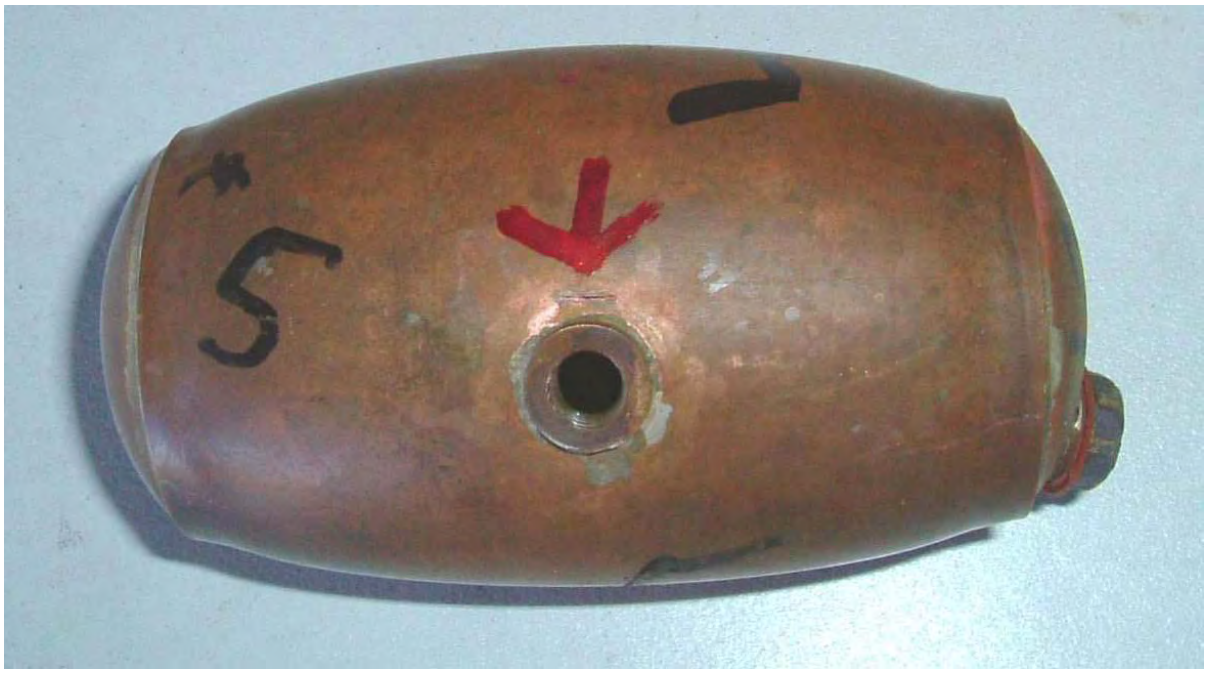
Mr Rogers and Mr Dunn were present for the testing shown in Table 2.
Due to time constraints the whole procedure was not completed in one day.
They were not present for the testing done in Table 3

The test pump used a ¼" bore pump fitted with 2 x O rings on the piston and O rings on the valves. A 25000kpa/ 3500psi liquid filled pressure gauge was fitted.

Testing Procedure.

- All pieces were filled to overflowing with clean tap water.
- The pump was filled with water and the pipes flushed.
- The boiler was then connected and pumping would begin.
- Dimensional readings were taken at 100psi intervals. The psi readings on the gauge are in red which was easier to read. Some people are more comfortable with the old measurement.

During the course of the procedure it became apparent that once the centre flues started to collapse then considerable pumping was required before the total collapse of the flue and the pressure in the piece started to rise again. The barrel and end plates would then start to expand. The end plates would be overtaken by the barrel in the expansion rate till something gave way and the piece was ruined. This is demonstrated in the following pictures.



No5 Showing spilt shell near bush

End View of No5 showing collapsed flue.

No11 Showing spilt shell near bush

Results

The full results are recorded in Tables 2 and 3

Results Summary

No 1	The piece failed at 1000psi when a pin hole appeared in the flue very near the inside edge of the joint with the endplate. This joint was very distorted by the collapse of the flue.
No 2	Failed at 1190 psi. The bush broke caused by the shell distorting. This bush was only 2mm thick.
No 3	At 1200 psi the shell split near the bush.
No 4	At 1000psi the joint failed on one end on top of the flue. This joint was very distorted by the collapse of the flue.
No 5	At 1500 psi the shell split near the bush.
No 6	At 1100 psi the end plate to outer joint split; this was contaminated by soft solder.
No 7	At 1100 psi the stay joint failed.
No 8	At 1600 psi the shell split beside the bush and the bush deformed.
No 9	At 1200 psi the bush had distorted too much to hold pressure.
No 10	At 1500 psi the shell split near the bush.
No 11	At 1500 psi the shell split near the bush.

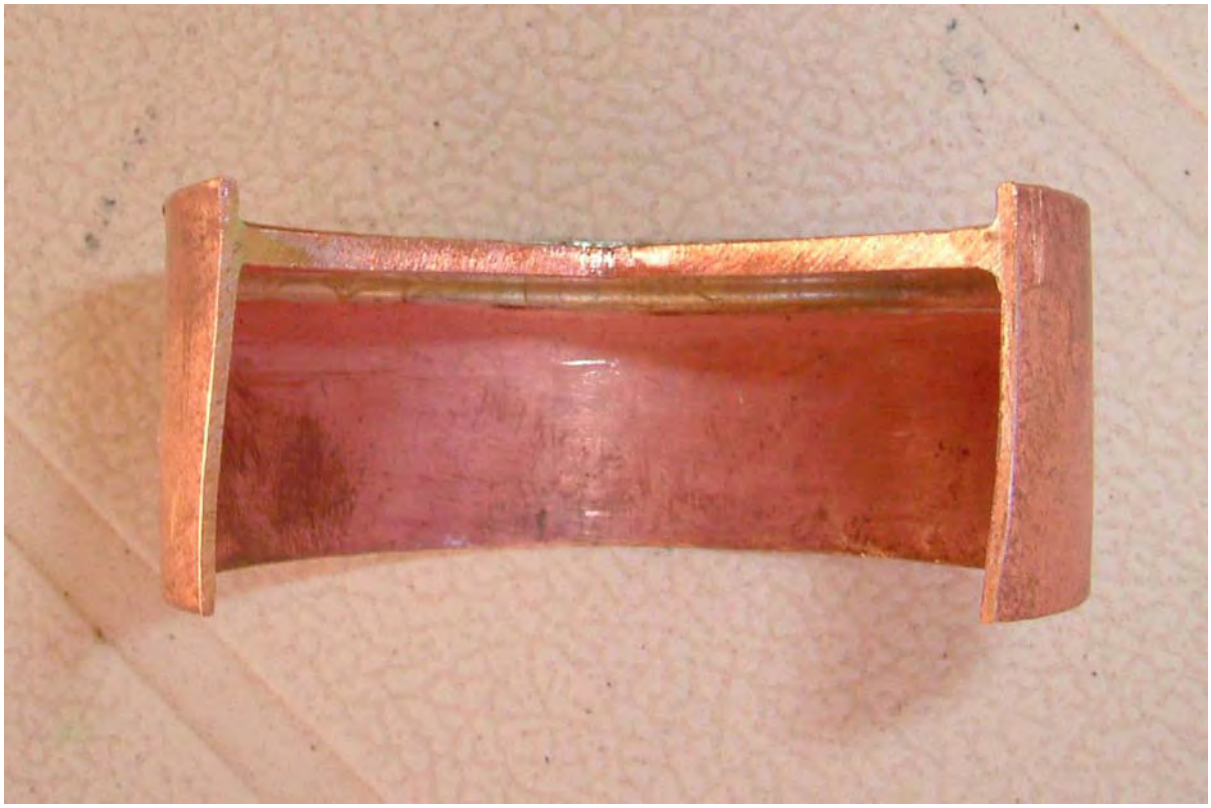
It was felt that Nos 6 and 9 were inconclusive in that the stay less boiler had not been tested properly as in No 6 and likewise the butt joint in No 9. Therefore No 11 was built. 2” dia stay less, 1/16 ends, one recessed and the other a butt joint.

The Aster boiler used has thick end plates. These are tapped to take a couple of flanged boiler fittings. A couple of brass plates were screwed in these places and soft soldered as well. This is where the piece failed at 700 psi.

The “T” boiler failed at 1100psi when the flue to the vertical barrel joint developed a pin hole. This joint was very distorted by the collapse of the flue.

When No 11 was sectioned it was found that because of the tight fit of the disc into the barrel the silver solder had not penetrated the full width of the joint for some of the circumference of the joint.
It is interesting to note that even without full penetration of the solder the joint had not failed. Refer to the photographs of No11.
A further test piece was constructed. This consisted of a short piece of 2” copper pipe and a disc of 1/6” copper turned on a lathe to be a loose fit into the pipe. Because the pipe is not a perfect circle there was daylight to be seen around the disc with it only touching in places. It could be made to drop out by finger touch. For silver soldering it was supported on a short pillar, leaving the short end up for soldering. After pickling, there could be seen a definite ring of solder on the inside of the joint. This is easily seen in the photographs.
Therefore a tight push fit is not recommended for this type of joint.

No11 Sectioned. The incomplete solder penetration can be seen on the right hand side of the piece.



Section of test piece with complete solder penetration.

Conclusions

In these sizes there is no difference between a flanged endplate joint and a plain disc thick enough to withstand the pressure without stays.

In the cases where the test piece failed on the endplate it was at the centre flue and endplate joint. This joint was always severely deformed by the collapse of the flue. This was nothing to do with whether or not the plate was flanged.

In some cases where the shell split there was a mark to be seen from the die used in manufacturing the pipe. The area would have been affected by soldering in the bush.

Even though some joints could be considered as being of poor quality, these joints where still stronger than the copper tubes used. It is recommended that joints are an easy fit to allow solder penetration.

This paper could not have been completed without the help of the following good people.
Bill Dunn and John Rogers from AMRA QLD for their help as observers, data recorders and input into the final draft.
People from Rails in the Garden and The Live Steam group from AMRA QLD.
Argyle Locomotives
Jim Greg from WA

Appendix

Table 1

Table 1 Boiler types all dimensions in mm

Number	OD	Thickness mm	Length mm	End plate thickness mm	End plate	type	Flue size mm
1	76	1.6	160	3	plain		25.4 x .8
2	63.5	1.2	150	3	plain		25.1 x 1.2
3	63.5	1.2	150	2	plain		25.1 x 1.2
4	63.5	1.2	150	1.6	plain		25.1 x 1.2
5	50.8	1.2	100	1.2	flanged		19 x 1
6	50.8	1.2	100	1.6	plain	flush recessed	19 x 1
7	50.8	1.2	100	1.2	plain	stayed 4.7 brass	19 x 1
8	50.8	1.2	100	1.6	plain	recessed	19 x 1
9	50.8	1.2	150	1.6	plain	recessed flat butt joint	19 x 1
10	50.8	1.2	150	1.6	plain	recessed flush	19 x 1
11	50.8	1.2	100	1.6	plain	recessed flat butt joint	nil

"T" boiler 50.8 x 1.2 vertical barrel 70mm high with a horizontal 38 x 1.2 section 115mm long all end plates flanged from 1.6mm sheet.

Aster Smithies type 38mm OD, .8mm thick, 190mm long
2mm plain end plates

Table 2

Testing started at 10.32am 30 July 04 — 30.7.04 ambient temp 22c water temp 19.8

No	PSI stepped	Kpa	diameter	flue collapse	end plate deflection	Time started	Notes
1	600	4132	78	started		10.32	
	750	5168	79.8				at 1000 psi the flue
	900	6201	81				failed on the inside
	950	6545	81.5				near the joint
	1000	6890	82.4				
2	500	3445	64	started		11.00	
	600	5168	65				
	700	4823	66	totally			
	800	5512	67				failed at 1190 psi
	900	6201	68				bush broken caused
	1000	6890	69				by shell deflection.
	1100	7579	72				
	1150	7924	73.5				
	1190	8199	74				
3	500	3445	64.5			11.20	
	600	5168	65				
	650	4271		started			
	750	5168	66.3	totally			Shell spilt at 8400mpa
	800	5512					near bush
	900	6201	67.5				
	1000	6890	68		started		
	1000	6890	69.5				
	1050	7234	70				
	1100	7579	71				
	1200	8268	73.5				
	1200	8268	74.9				
	1200	8268	76.1				
4	400	2756	64		started	12.10	
	600	5168	64.5	started			
	600	4823	65	totally			
	700	4823	66.1				at 1000 psi the joint at the top
	800	5512	67		bulging		of the flue on one end leaked.
	900	6201	67				Joint weakened by metal bending
	1000	6890	67.4				
5	400	2756	51.7	started	started	12.20	
	1000	6890	51.9		bulging		
	1200	8268	55				
	1200	8268	55.1				at 1500 psi the washer under the
	1300	8957	55.2		bulging		screw failed
	1400	9646	55.3				
	1400	9646	55.9				bush leaking
	1500	10335	55.9				bush leaking test stopped

Table 2 continued

No	PSI stepped		diameter	flue collapse	end plate deflection	Time started	Notes
6	200	1378			started	12.30	
	400	2756					
	500	3445	51.5				
	700	4823	52.5				
	900	6201	53		bulging		
	1000	6890	53.5			split end plate to outer joint	
	1100	7579	55			contaminated by soft solder	
					.		
7	300	2067	50.8			12.40	
	400	2756	51		started		
	500	3445	51.5				
	700	4823	52				
	800	5512	52.5		bulging		
	900	6201	53				
	1000	6890	53.5				
	1100	7579	53.5				failed joint on stay
8	400	2756	51.5	started		12.48	
	500	3445	51.7				
	600	5168	52				
	700	4823	52.5				
	800	5512	52.5	totally			
	800	5512					fitting failed
	900	6201					replaced fitting
	950	6545	54				
	1000	6890	56				
	1200	8268	56.7				
	1250	8612	57.7				
	1300	8957	58				
	1400	9646	59.5				
	1400	9646	60.1				
	1400	9646	62				
	1450	9990	62.5				
	1450	9990					fitting leaking, tightened
	1500	10335	62.9				shell split beside bush
	1600	11024	63				bush deformed

Table 2 continued

No	PSI stepped	Kpa	diameter	flue collapse	end plate deflection	Time started	
9	400	2756		started		13.10	
	500	3445			started		
	600	5168	51.5				
	700	4823	51.7				
	750	5167	52				
	800	5512	52.9	totally			
	900	6201	53		bulging		
	1000	6890	53.5				
	1100	7579	53.7				
	1100	7579	54		continued		
	1200	8268	56		deformation		
	1200	8268				fitting leaks, bush deformed	
10	400	2756	52			13.20	
	500	3445			started		
	600	5168	52.5				
	650	4478	53				
	700	4823		started		pump repair	
	750	5167					
	800	5512	52	totally			
	800	5512					
	1000	6890	52.5				
	1000	6890	53		bulging		
	1100	7579	54				
	1200	8268	54.5				
	1200	8268	55				
	1300	8957	57				
	1400	9646	58				
	1450	9990	58.5		continued		
	1450	9990	59.5		deformation		pump failure

Table 3

Testing started at 3pm 1 Aug 04

No	PSI stepped	Kpa	diameter	flue collapse	end plate deflection	Time started	Notes	
5	400	2756	51.7	started	started	12.20		30-Jul-04
	1000	6890	51.9		bulging			
	1200	8268	55					
	1200	8268	55.1			at 1500 psi the washer under the		
	1300	8957	55.2		bulging	screw failed		
	1400	9646	55.3					
	1400	9646	55.9		bush leaking			
	1500	10335	55.9		bush leaking		test stopped	
							washer replaced next day	
	1500	10335	63				testing resumed 1 Aug 04	
	1500	10335	63.5				shell burst near bush	
10	400	2756	52			13.20		30-Jul-04
	500	3445			started			
	600	5168	52.5					
	650	4478	53					
	700	4823		started		pump repair		
	750	5167						
	800	5512	52	totally				
	800	5512						
	1000	6890	52.5					
	1000	6890	53		bulging			
	1100	7579	54					
	1200	8268	54.5					
	1200	8268	55					
	1300	8957	57					
	1400	9646	58					
	1450	9990	58.5		continued			
	1450	9990	59.5		deformation		pump failure test stopped	
	1400	9646	60.8				test resumed 1Aug 04	
	1500	10335	61					
	1500	10335					shell burst near bush	
Aster	500	3445	37.8					
	600	5168	38					
	700	4823	43.5					
	700	4823	44				leak an backhead where fittings usually attach	

Table 3 2-Feb

	PSI stepped		diameter	flue collapse	end plate deflection	Time started	Notes
"T" boiler	200	1378			80		
	300	2067					
	400	2756		started			
	500	3445			85.5		
	600	5168			86		
	700	4823			87		
	800	5512	38.5	collapsed	87.4		
	900	6201	38.7		8		
	1000	6890	39		88.6		
	1100	7579	39.4		89.8		back flue joint fail
11	100	689	50.8		101.6		
	200	1378	51		106		
	400	2756	51.2		109		
	500	3445	51.5		110.5		
	600	5168	51.8		111.5		
	700	4823	52.2		112		
	800	5512	52.5		112.8		
	900	6201	53		113.3		
	1000	6890	53.7		114		
	1100	7579	54.5		114.5		
	1200	8268	55.3		115		
	1300	8957	56.7		115.4		
	1300	8957	57.5		15.5		
	1400	9646	58.3		115.5		
	1400	9646	59.5		115.5		
	1450	9990	60.3		115.5		
	1500	10335	60.5		115.5		barrel split near bush