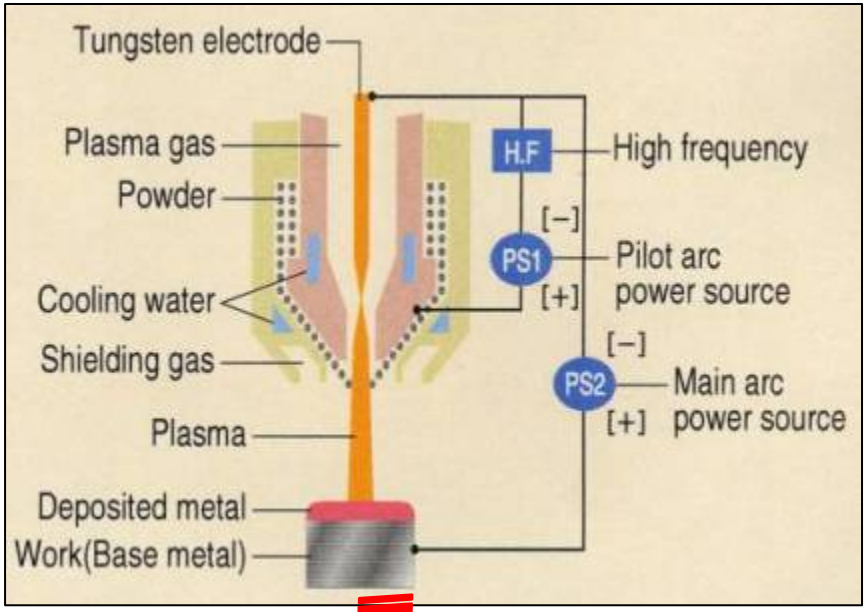
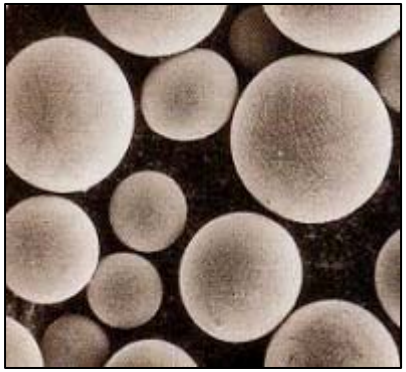
Daido Boiler Super Tube

PPW Overlaid Boiler Tubes for Higher Efficiency Waste to Energy Plants

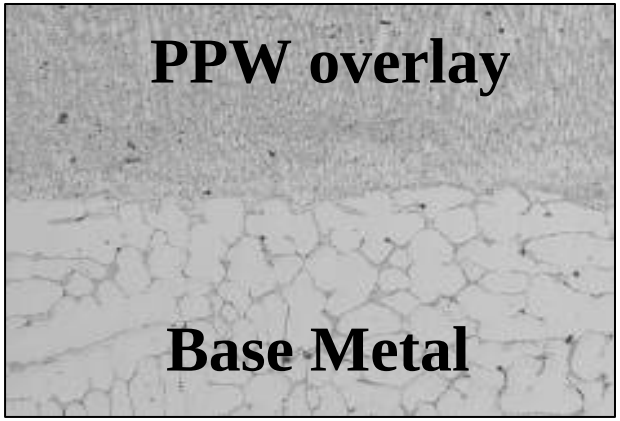
Daido Steel Co., Ltd.
Ethylene Super Tube Department
February 16, 2010

PPW Plasma Powder Welding





Gas atomized
High Ni-Cr powder developed and produced by Daido



Applications of PPW

Demand	Applications	Daido Original Powder
High temp. corrosion resistance	Boiler tube	21Cr-13Mo-2Co-3W-Ni (BST276) 22Cr-9Mo-2Co-Ni (BST625) 27Cr-Si-Al-W (BST1)
Anti-coking and carburization	Ethylene cracking	45Cr-50Ni-1Mo
High temp. erosion Resistance	FCC nozzle	2C-21.5Cr-4.3Mo-9V-Co (KV10)
Anti-metal dusting	GTL, CTL	50Cr-Ni

The History of PPW

PPW: Plasma Powder Welding

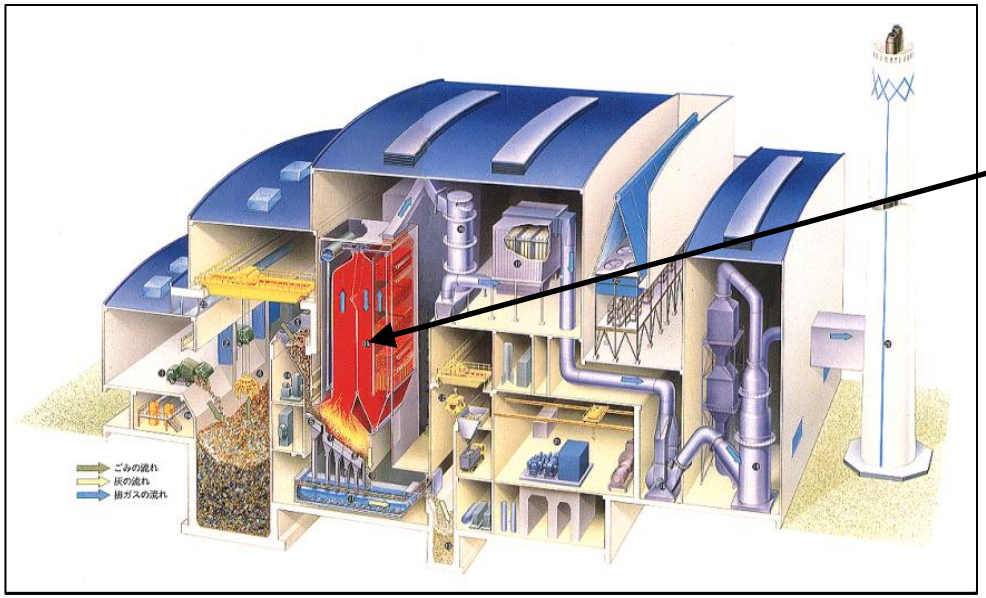
1960-1964 Union Carbide Co. in USA developed welding application of plasma energy and powder metallurgy.

1973-1991 Daido Steel developed automatic Plasma Powder Welding (PPW) machine for engine valve. Plasma arc generator, gas controller, powder metal feeder, and particle size controlling were patented by Daido.

1992- More than 150 PPW machines for engine valve have been shipped to auto motive engine valve companies.

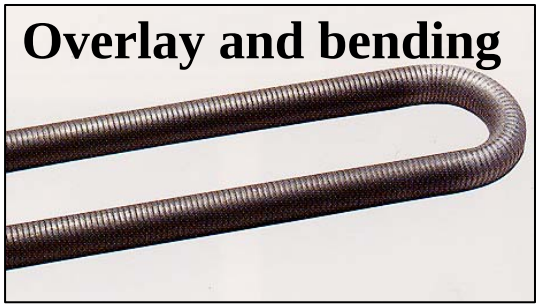
The History of Boiler Super Tube

1994-	Daido developed Boiler tubes with PPW overlay for the waste to energy plant with the Japan national project.
1998-	Daido started commercial manufacturing of Boiler Super Tube (BST276, BST625) for Japanese waste to energy plants.
2009-	Daido developed New BST1 for higher Temperature.



Waste to Energy Plant

Boiler Super Tube BST276 & BST625



Production Process of BST

Base Tube

Carbon Steel ,low alloy steel:
STB340
Stainless Steel : SUS310SJ1

Powder

Ni Base Material : BST625, BST276
Fe Base Material : BST310S

PPW

Dimension
- PPW thickness : Min. 1.5mm
- PPW length : Max. 8.4M
- Tube Diameter : OD31.8
-114.3mm

Inspection

Macro and Micro test - PPW thickness - Luck of fusion
Chemical Analysis - PPW layer composition

Benefits of BST Boiler Super Tube

(1) Control of the chemistry of PPW overlay by the original metal powders

(2) New grade of PPW overlay BST1 for higher temperature or longer tube life

(3) PPW overlay on the inner surface of boiler tubes also available (Min. ID:2”, Max length:5m)

Existing Generation Materials
BST 276 & BST 625

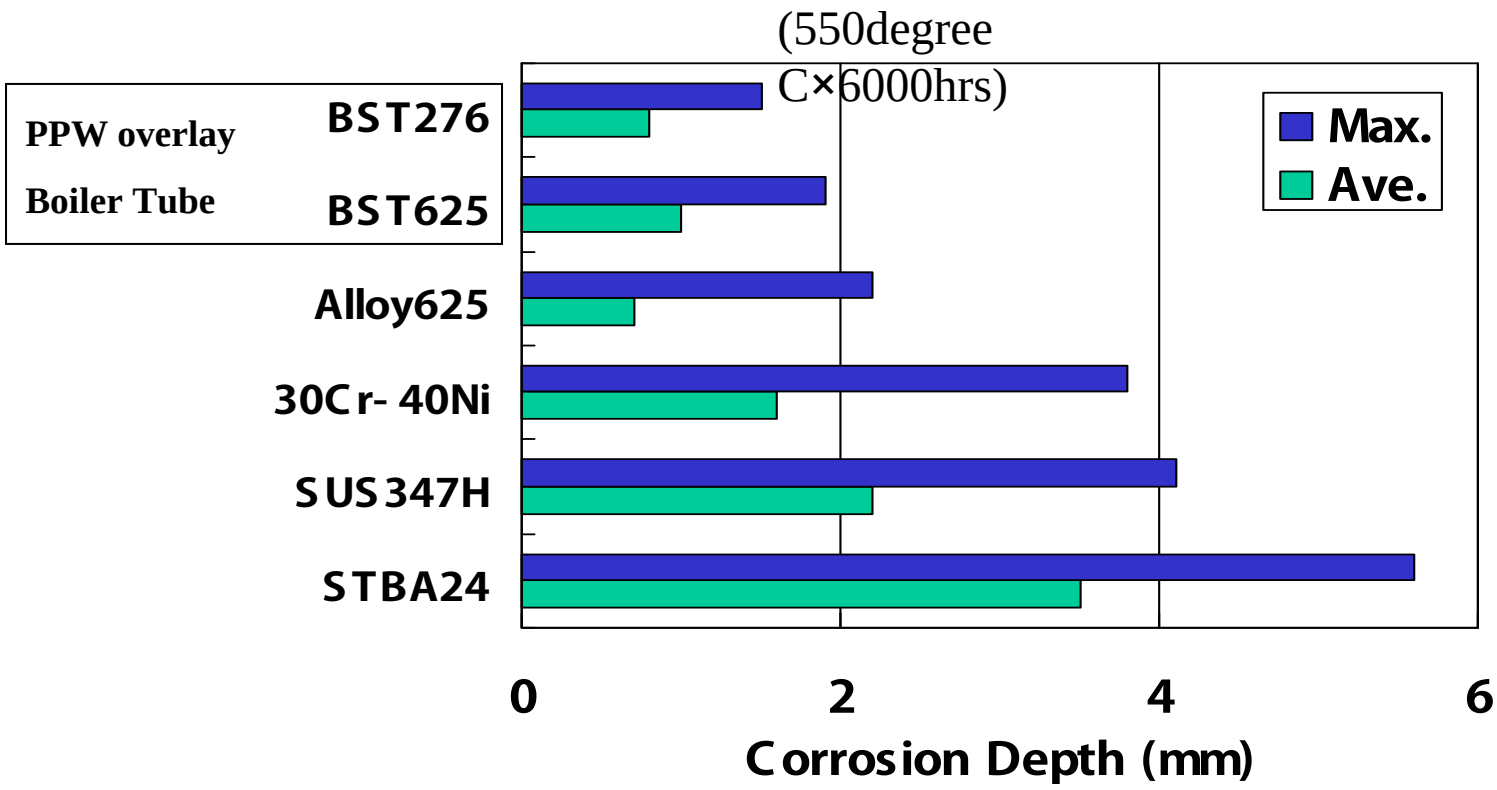
Steam Temperature: Max. 500 degree C

Chemistry of Weld overlay (Typical)

Unit: WT%

	C	Si	Mn	Ni	Cr	Mo	Co	W	Fe
BST276	.01	.8	.2	Bal	20.8	13.2	2.2	3.1	1.0
BST625	.01	.2	.1	Bal	21.8	9.2	2.0	-	1.2

Actual corrosion depth in the waste to energy plant



(Ref.) Mechanical Properties of Boiler tubes

(Base 5m/m + PPW 2m/m)

STB340 + BST276(PPW)		
R.T.		
	T/S	El
Base tube	620	28.8
With PPW	601	41.2

Application of BST276 & BST625

Base tube	Size	OD: 31.8-114.3mmφ, Thickness: 3.5-6.0mm, L(Shipping length): 0.9-8.2M
	Grade	STB340, STB410, SUS310J1
PPW overlay	Thickness	1.5-3.5mm (Single pass)
	Grade	BST276, BST625, BST310S
Plants	24 waste to Energy Plants in Japan (Location: Tokyo, Osaka, Nagoya, Hokkaido, Tochigi, Kyoto, Kagawa, Toyama, Chiba, etc)	
Quantity	Over 8000P's are on operation now. Maximum years in operation is 10 years. (2010)	

New Generation Material “BST1”
for higher temperature and longer tube life

Steam Temperature: Over 500 degree C

(1) Chemistry of PPW overlay

(WT%)

	C	Si	Ni	Cr	Mo	Co	W	Al
BST1	Ad.	Ad.	BAL	27	-	-	Ad.	Ad.
BST625	0.01	0.8	BAL	22	9	2	-	
BST276	0.01	0.2	BAL	21	13	2	3	

(2) Concept of BST1 Chemistry

- Chemistry of BST1 is originally developed and applied for commercial Air-heater for Gasification and Ash Melting System.
(Steam temperature: over 500^{o}C (932^{o}F))

-Higher corrosion resistance with higher Cr than BST625 or BST276.

-Higher W than BST276 prevents the formation of Cr-depleted zones.

-Added Si, Al prevent corrosion by Cl through grain boundaries.

- Adequate C makes fine grains to protect against corrosion through grain boundaries.

(3) Results by Corrosion test in molten Salts

Corrosion Test

JIS Z 2293

Methods for high temperature corrosion test of metallic materials by dipping and embedding in molten salts

Salts

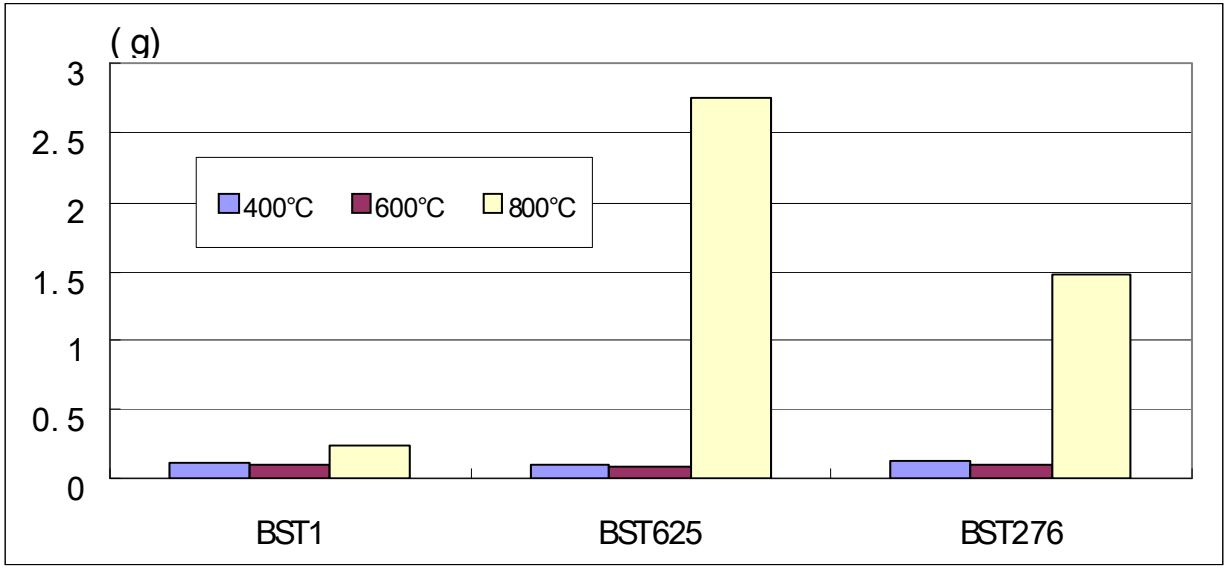
	Mol. %	Wt. %
Na_2SO_4	3	16.8
K_2SO_4	3	20.6
Fe_2O_3	2	12.6
$PbCl_2$	3	28.15
$FeCl_2$	3	12.85
NaCl	2	3.95
KCl	2	5.05

Dipping temperature and time

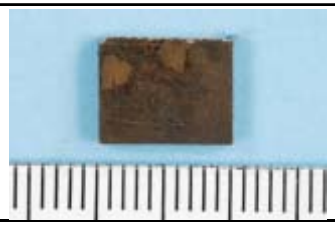
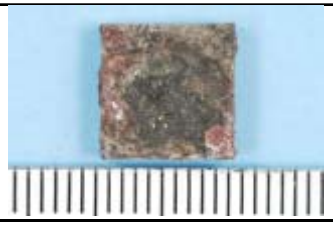
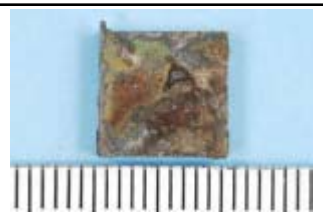
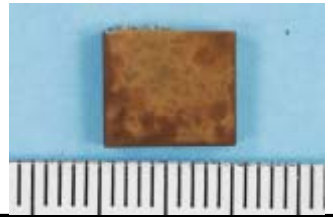
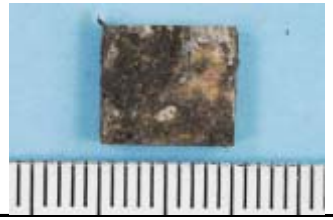
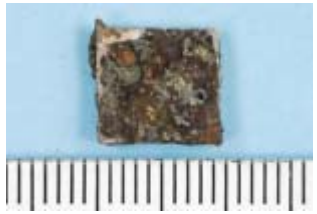
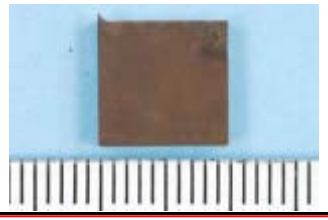
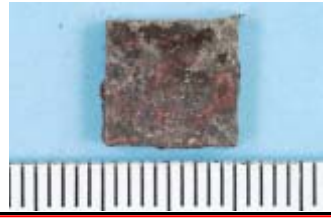
°C	400	600	800
°F	752	1,112	1,472
time	100 hours		

(4) Weight loss

Weight loss of BST1 at 800°C is remarkably smaller than BST276 or 625



(5) Appearance after the test

	400°C x 100 h	600°C x 100 h	800°C x 100 h
BST1			
BST625			
BST276			

Consistent with the above data - almost no corrosion of BST1 even at 800°C

(6) Microstructure of cross section

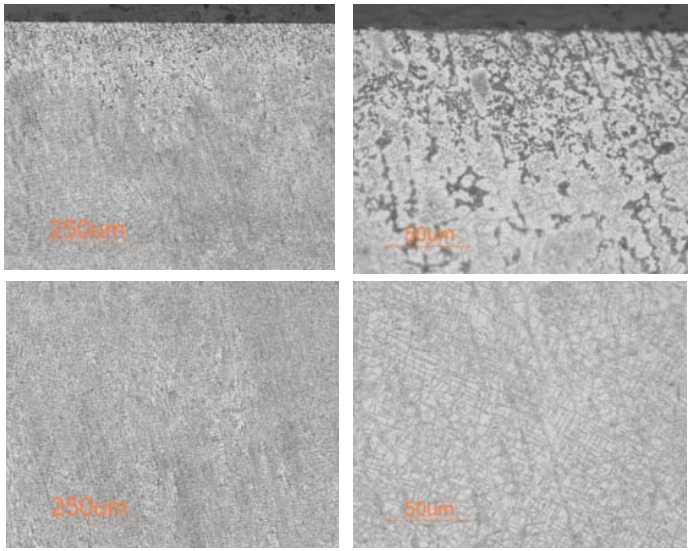
800°C x 100 hrs

Surface of BST1 is almost flat without corrosion.

Surfaces of BST276 and BST625 are heavily damaged.

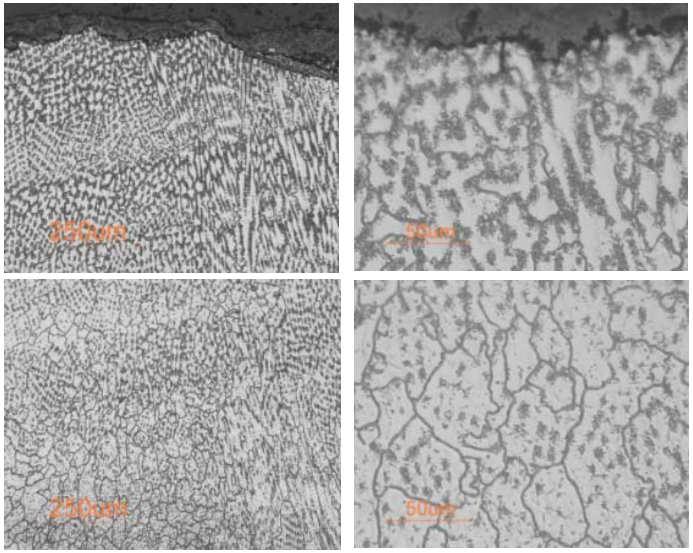
BST1 (800°C x 100 hrs)

Surface



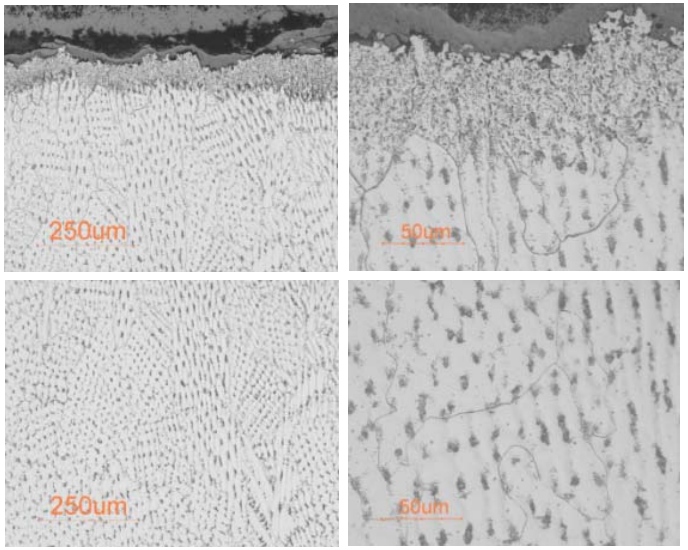
BST276 (800°C x 100 hrs)

Surface



BST625 (800°C x 100 hrs)

Surface



Conclusions

- Boiler Super tube BST276 and 625 have been applied in the Japanese Waste to Energy plants since 1998 without any troubles.

- A new generation Boiler Super Tube BST1 has been developed by higher contents of Cr, W, Al, and Si, without Mo and Co.

- A high temperature (800^{o}C or 1,472^{o}F) molten salt test revealed higher corrosion resistance of BST1 as compared with BST276 or BST625 against oxide and chloride formations.

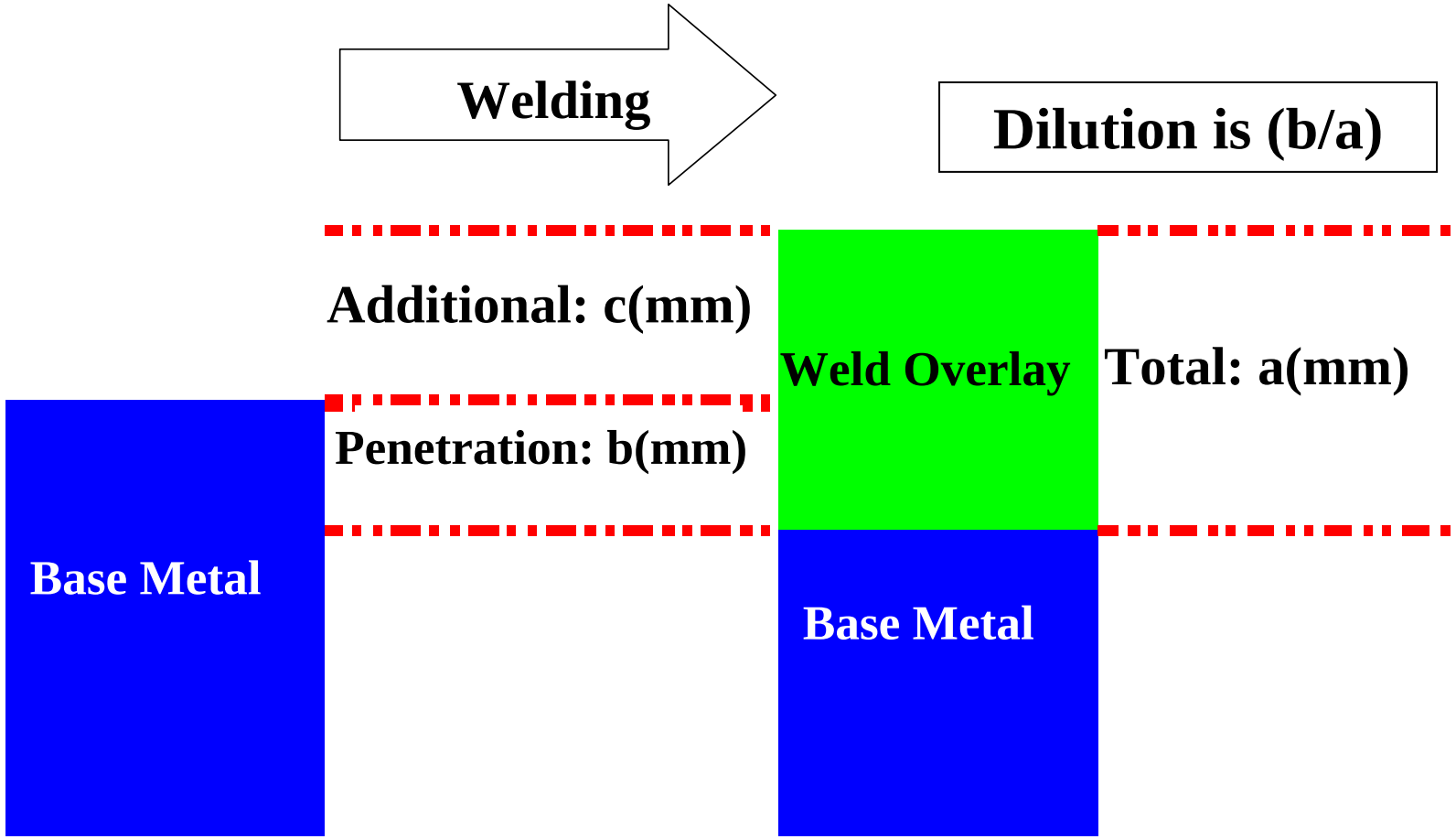
- BST1 is expected to enable higher steam temperatures with longer tube life, resulting in higher efficiency for waste to energy plant operation.

Thank you so much for your attention

ARIGATO GOZAI MASHITA ! !

Control of the chemistry of PPW overlay

Case of Inconel 625 overlay



Case1: Conventional Weld overlay of Inco 625 by Mig with 9% dilution

(WT%)

Thickness		
a	Total overlay(mm)	2.3
b	Penetration(mm)	0.20
c	Additional(mm)	2.1
	Dilution(%)	8.7

			C	Si	Mn	Ni	Cr	Mo	Nb+Ta	Co	Fe
Base Metal	STB		0.10	0.20	0.50	0.00	0.00	0.00	0.00	0.00	99.00
Mig filler metal	Inco625		0.02	0.30	0.07	61.00	22.20	9.20	3.50	0.00	3.10
Overlay			0.03	0.29	0.11	55.70	20.27	8.40	3.20	0.00	11.44
Spec	Inco625	Min					20.00	8.00	3.15		
		Max	0.10	0.50	0.50	Bal.	23.00	10.00	4.15		5.00

Case2: BST625: PPW weld overlay with original powdfer by PPW with 15% dilution

Thickness		
a	Total overlay(mm)	2.3
b	Penetration(mm)	0.35
c	Additional(mm)	2.0
	Dilution(%)	15.2

			C	Si	Mn	Ni	Cr	Mo	Nb+Ta	Co	Fe
Base Metal	STB		0.10	0.20	0.50	0.00	0.00	0.00	0.00	0.00	99.00
PPW powder	Original		0.02	0.30	0.30	59.00	25.50	10.50	4.00	0.00	0.00
Overlay			0.03	0.28	0.33	50.02	21.62	8.90	3.39	0.00	15.07
Spec	Inco625	Min					20.00	8.00	3.15		
		Max	0.10	0.50	0.50	Bal.	23.00	10.00	4.15		5.00