FURUKAWA ELECTRIC

FURUKAWA ELECTRIC GROUP

Al-Stabilized NbTi Conductor for Detector Solenoid at Furukawa

Sep. 13th, 2022

Hisaki Sakamoto

SuperPower Inc. (SPI)

Furukawa Electric Co. Ltd. (FEC)

Outline

- Al-stabilized NbTi conductor
- History of Al-stabilized NbTi conductor production at FEC
- Challenge in Al-stabilized NbTi conductor Production
- Brief explanation on Al-stabilized NbTi conductor production
- Difficulty in Al-stabilized superconductor production
- Summary

Acknowledgement

Many thanks to Mr. Akira Takagi, FEC and Mr. Kota Katayama, SPI for the preparation of this talk and Prof. Akira Yamamoto and Prof. Toru Ogitsu, KEK for helpful suggestions.

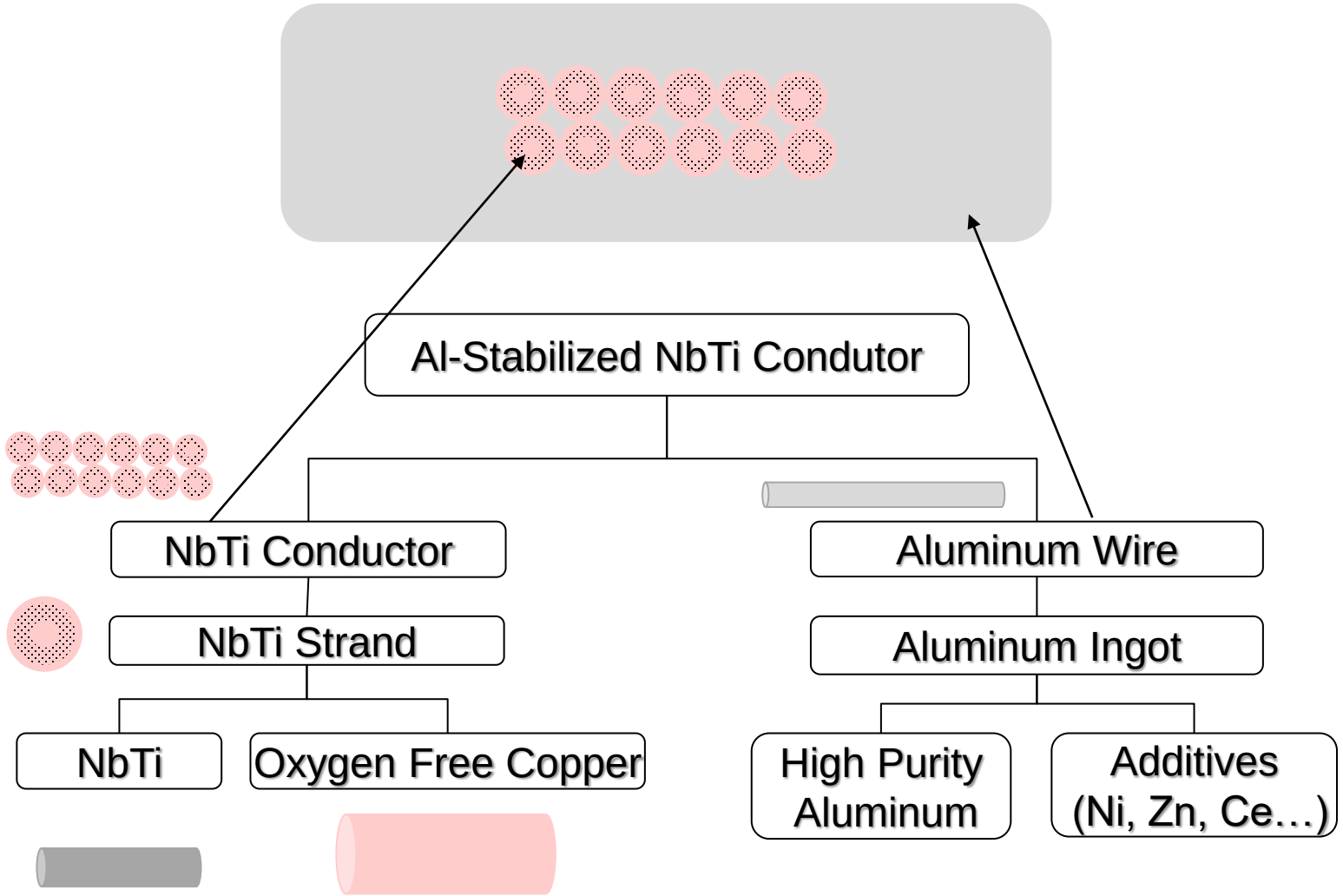
Currently, FEC said to our customer that we could not produce Al-stabilized NbTi conductor.

This means that we could not find a way to produce large amount of Al-stabilized conductor comply with the specification with foreseeable cost and lead time because of instability in the co-extrusion process which is currently usable.

Al-Stabilized NbTi conductor

Requirement：

- Ic
- RRR
- Strength
- Bonding between Al and NbTi conductor
- Dimension
- Defect
- Piece length



History of Al-stabilized NbTi conductor at FEC

FURUKAWA ELECTRIC

- FEC has many experiences for producing Al-stabilized NbTi conductors.
- FEC had contributed many detector solenoid projects.

Project	Lab.	Completion	Dim. of NbTi Strand (mm)	No. of strands	Stranded Cable	Stabilizer	Conductor	Quantity (m)
Mu2e PS	FNAL	2016	1.47	30	2.3*23.7	Ali-Ni	5.6*30	10,720
Mu2e DS	FNAL	2015	1.47	12	2.3*7.9	Al	5.3*20.1	9,900
SMES R&D Coil	NIFS	2004	0.823	8	1.55*	Al	5.8	14,000
SRC Main Coil	RIKEN	2000	1.15	10	2.15*	Al-Ni	8*15	77,680
ATLAS Thin Solenoid for LHC	KEK	1998	1.22	12	2.3*7.4	Al-Ni	4.2*30	6,500
SRC Trim Model Coil	RIKEN	1997	1.25			Al-Zn	2.9*3.6	4,600
SRC Main Model Coil	RIKEN	1997	1.25	10	2.35*	Al-Zn	8*15	15,400
BESS	KEK	1996	0.77			Al	1.2*1.8	7,000
SDC Prototype SSC	KEK	1993	1.277	10		Al-Zn-Si	4.37*43.8	6,000
TOPAZ	KEK	1983	1.8*3.3			Al	3.6*18	2,300

Subsidiary

In house

Challenge in Al-stabilized NbTi conductor Production

Al-stabilized NbTi conductor is the unique product dedicated to Detector Solenoid Magnet.

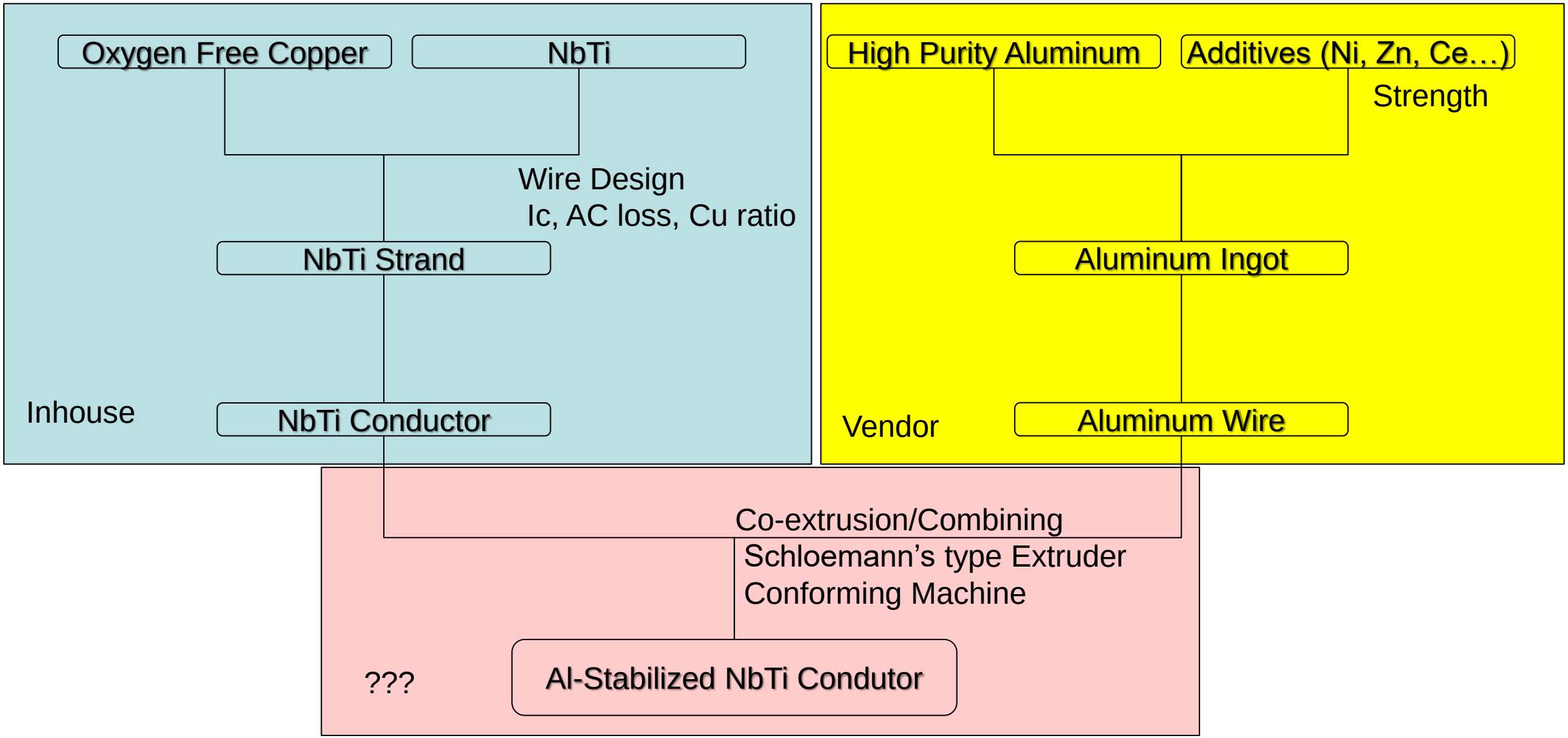
- Demand is not stable, by project.
- Specification will be changed by project.

Superconductor manufacturer can retain Superconductor production line, but could NOT hold the production line for the Al-stabilized NbTi conductor.

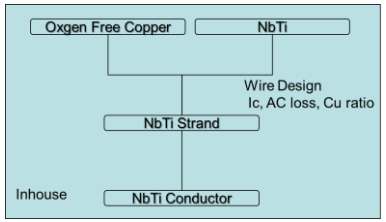
Machines that used for former Al-stabilized NbTi conductor became decrepit and were scrapped.

Where can we produce the Al-stabilized NbTi conductor ?

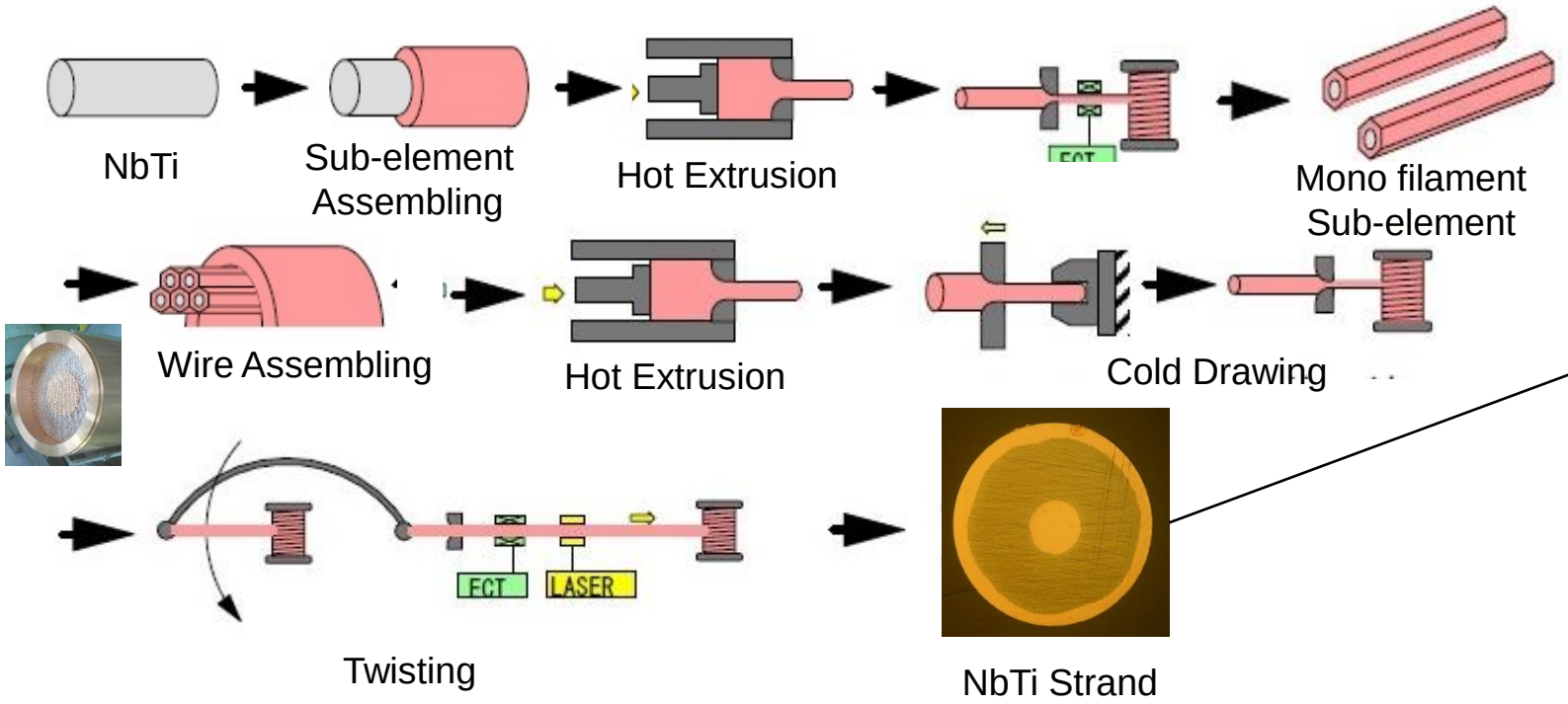
Al-stabilized NbTi conductor production scheme



NbTi superconductor Production

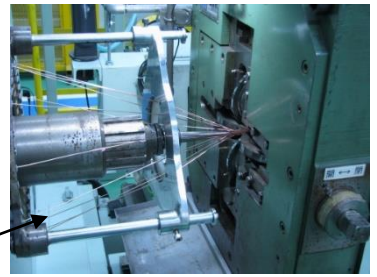


NbTi Strand Fabrication



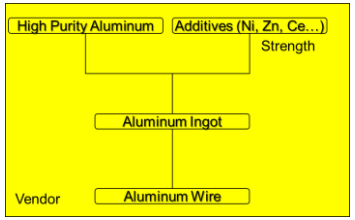
NbTi Conductor Fabrication

Stranding

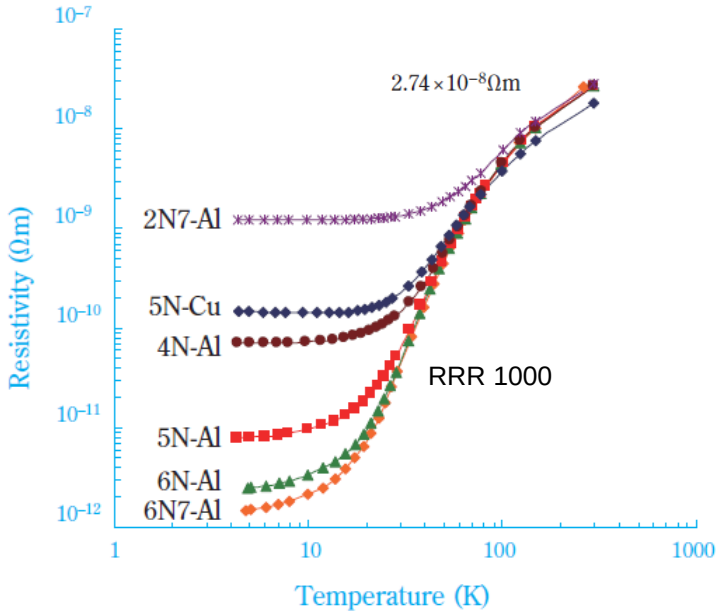


NbTi Stranded Conductor

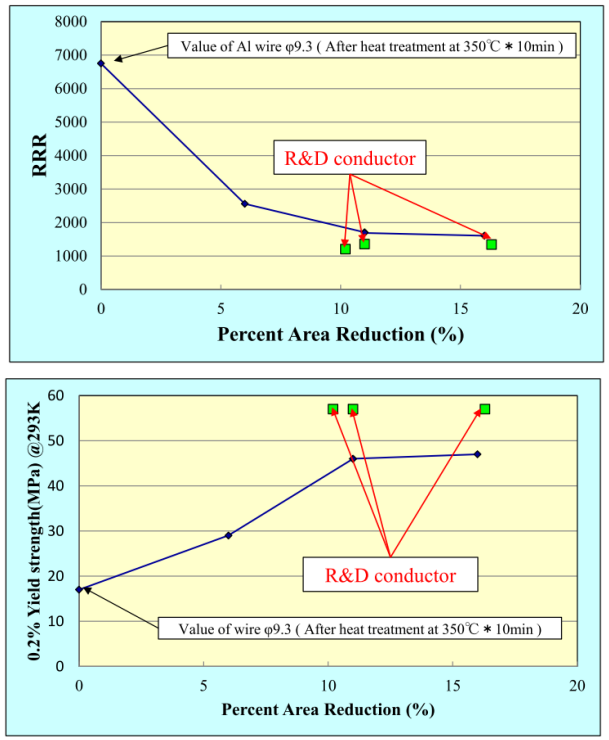
Al alloy stabilizer development



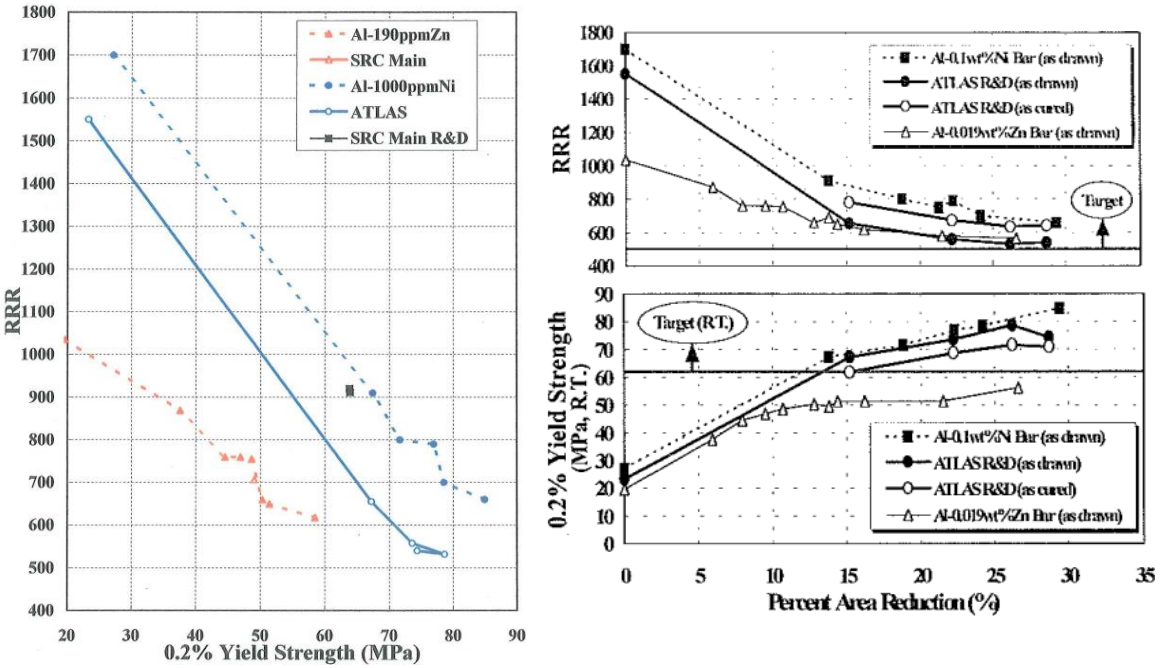
Hi-purity Aluminum shows very high RRR, but strength is very low.
Alloying a small element to hi-purity Aluminum, to balance RRR and strength.



Resistivity of Aluminum



RRR and Yield Strength of 5N-Al at various cold work condition



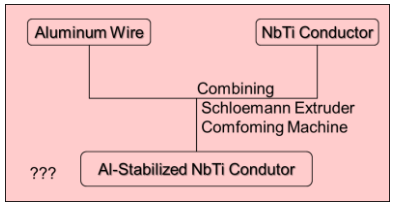
Relationship between RRR and Yield Strength of Al-Alloys

H. Hoshikawa *et al.*, *SUMITOMOKAGAKU* P.13-19, 2013

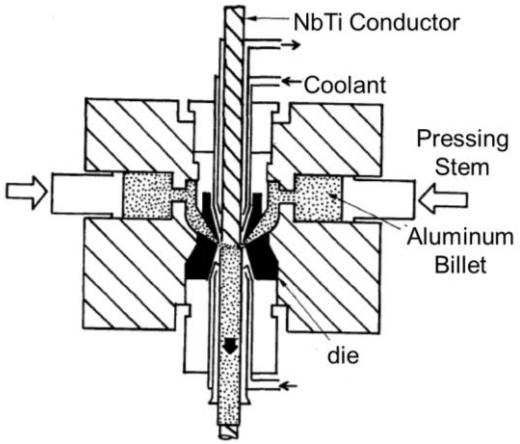
K. Katayama *et al.*, *IEEE Trans. Appl. Supercond.*, Vol.26, No.3, 801204, 2016

K. Wada *et al.*, *IEEE Trans. Appl. Supercond.*, Vol.10, No.1, pp.373-376 2000

Combining NbTi conductor and Al Stabilizer



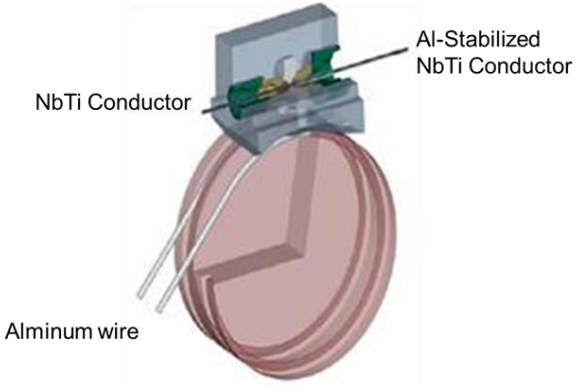
Historically, two types of machines are used for combining NbTi conductor and Al stabilizer. One is Schloemann's cable claddig press and the other is conforming (conklad) machine.



Schematic view of Schloemann's cable cladding press

K.Saito et al.,
J. JILM, Vol. 35, No. 5 (2020), 297-303
in Japanese

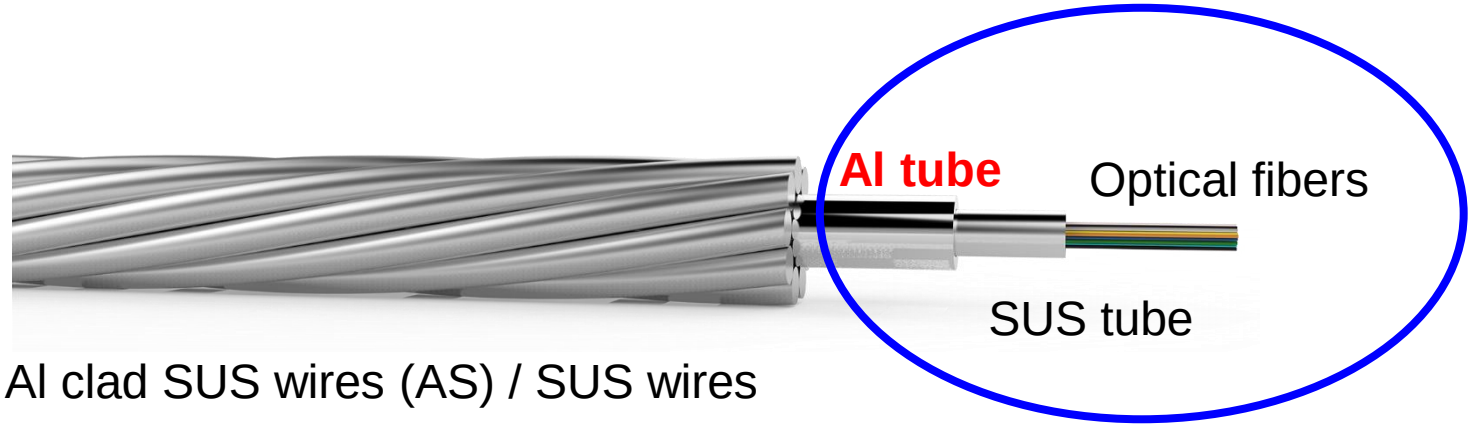
Item	Schloemann	Conforming
Al Source	Billet	Wire
Machine Size	Large	Small
Application	Clad wires	OPGW, AS
Al-stabilized NbTi conductor		
Cross Section of Al	Large	Small -170mm^2 (Max 300mm^2)
Length	Limited by Billet	Continuous



Schematic view of conforming machine
https://bwe.co.uk/conklad/

OPGW (OPtical Grounded Wire)

At the tops of high-voltage electricity pylons
Combining the functions of grounding and communications
Optical fiber : communications (data transmission)
Grounded wire : shielding high-voltage cables from lightning strikes



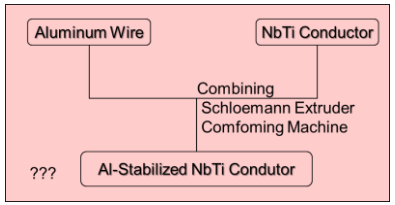
Al clad SUS wires (AS) / SUS wires

by Conforming process

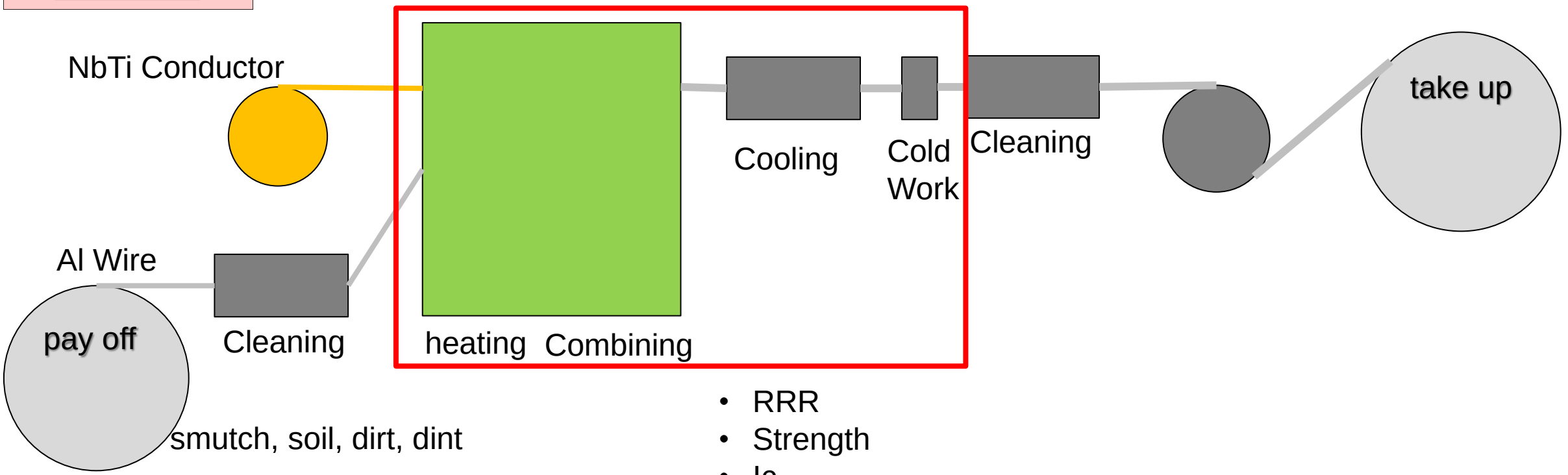
https://www.furukawalatam.com/en-us/products-catalog-details/opgw-cable-dual-dg1030133---101mm2

OPGW does not need precise dimension control as superconductor.

Al-stabilized NbTi conductor production



Typical production Lines is as follows,

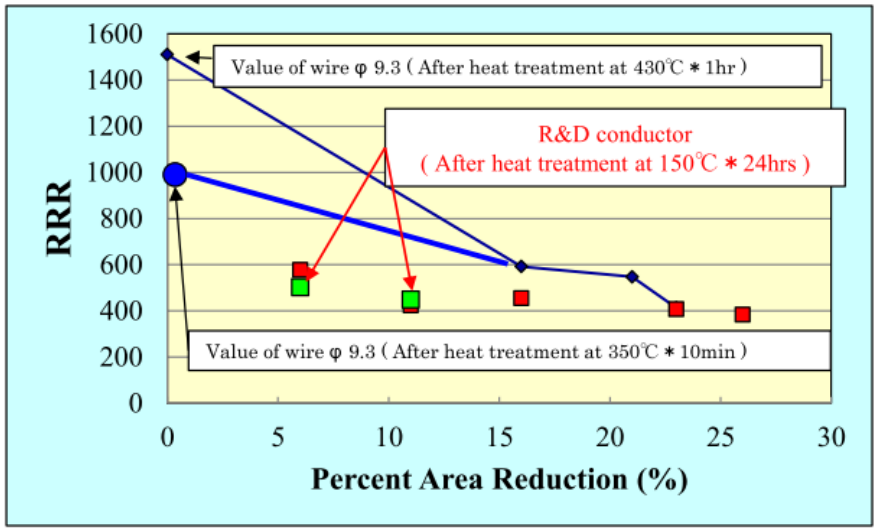


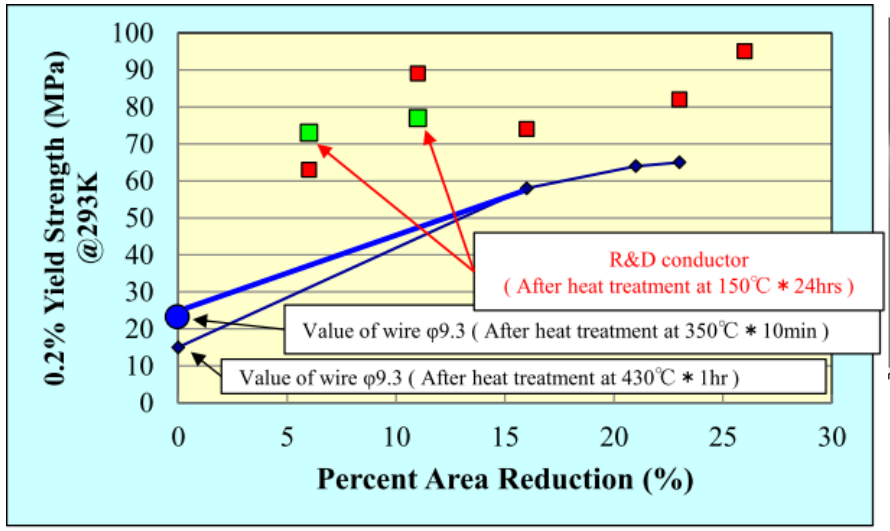
smutch, soil, dirt, dint

Temp. Line speed (duration),
Cold work ratio

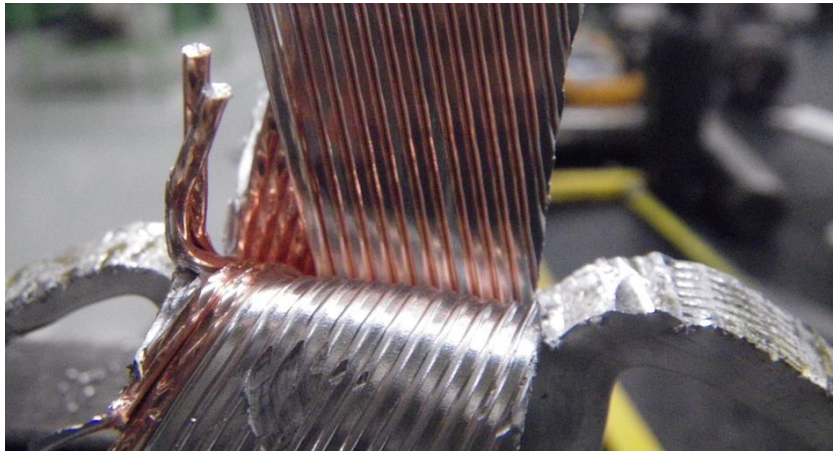
- RRR
- Strength
- Ic
- Bonding between Al Stabilizer and NbTi Conductor
- Dimensional Accuracy
- Surface quality (Defect free : burr, blister, scratch...)
- NbTi conductor displacement in the conductor (tilt, position)

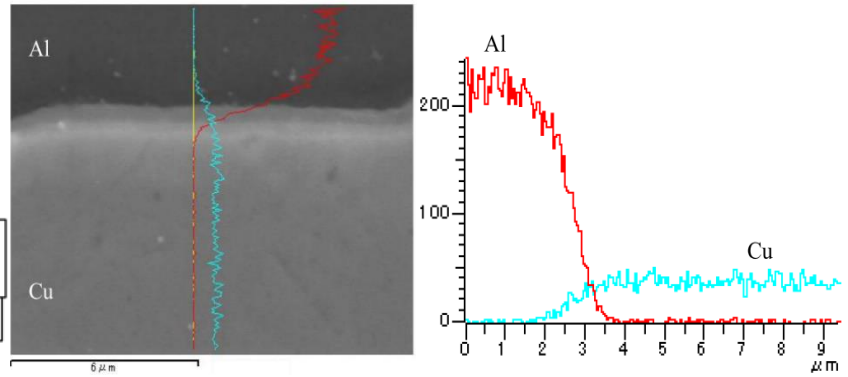
Al-stabillized NbTi superconductor



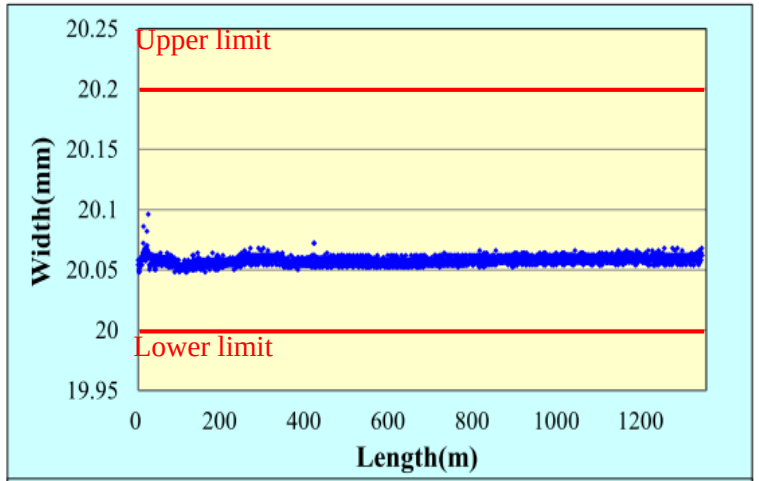


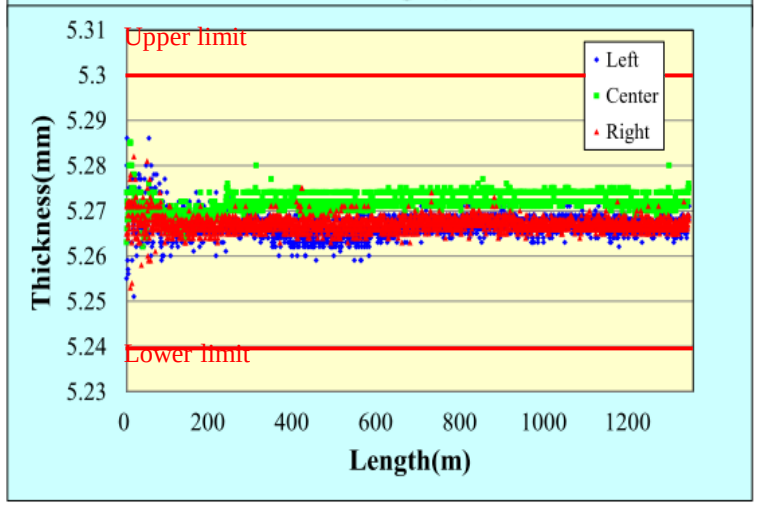
Relationship between RRR, 0.2% yield strength and cold work, respectively.





The results of SEM and EDX analysis on the boundary between Superconductor and Aluminum



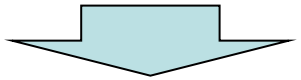


Width and Thickness variations along with length.

K. Katayama *et al.*, *IEEE Trans. Appl. Supercond.*,Vol.26, No.3, 801204, 2016

Difficulty in Al-stabilized NbTi conductor production

- Al-Ni alloy is dedicated to the Al-stabilized conductor, not standard material. Needs long LT.
- It seems that the conforming line used for recent production is not fit for Al-stabilized NbTI conductor production.
  Quality and Repeatability issue in actual production.
  Human resources are as well.
- Conforming machine (conklad) could not be applied for larger size conductor.



- If we succeed to develop stable production condition with existing conforming machine, will the machine be able to survive for next project ?
- Need combining line and human resources dedicated to future Al-stabilized NbTi conductor.

Summary

- FEC produced many types of Al-stabilized NbTi conductor for Detector Solenoid Magnet.

- Sporadic demand of Al-stabilized NbTi conductor makes it inviable business.

- Combining machines used for former Al-stabilized NbTi conductor production became decrepit and were scrapped.

- It seems that it is the time to re-construct the structure of Al-stabilized NbTi conductor production. Is it possible to secure the combining machine at Detector Solenoid Community ?

Thank you for your attention !

Bound to Innovate