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Maraging Suspension wire oven construction

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Introduction

The KAGRA suspension wires are longer than the maximum acceptable dimension of the large oven available. They need to be processed at 450°C for 100 hours in neutral atmosphere. We designed a three meter long Argon atmosphere oven and G&M built it. .

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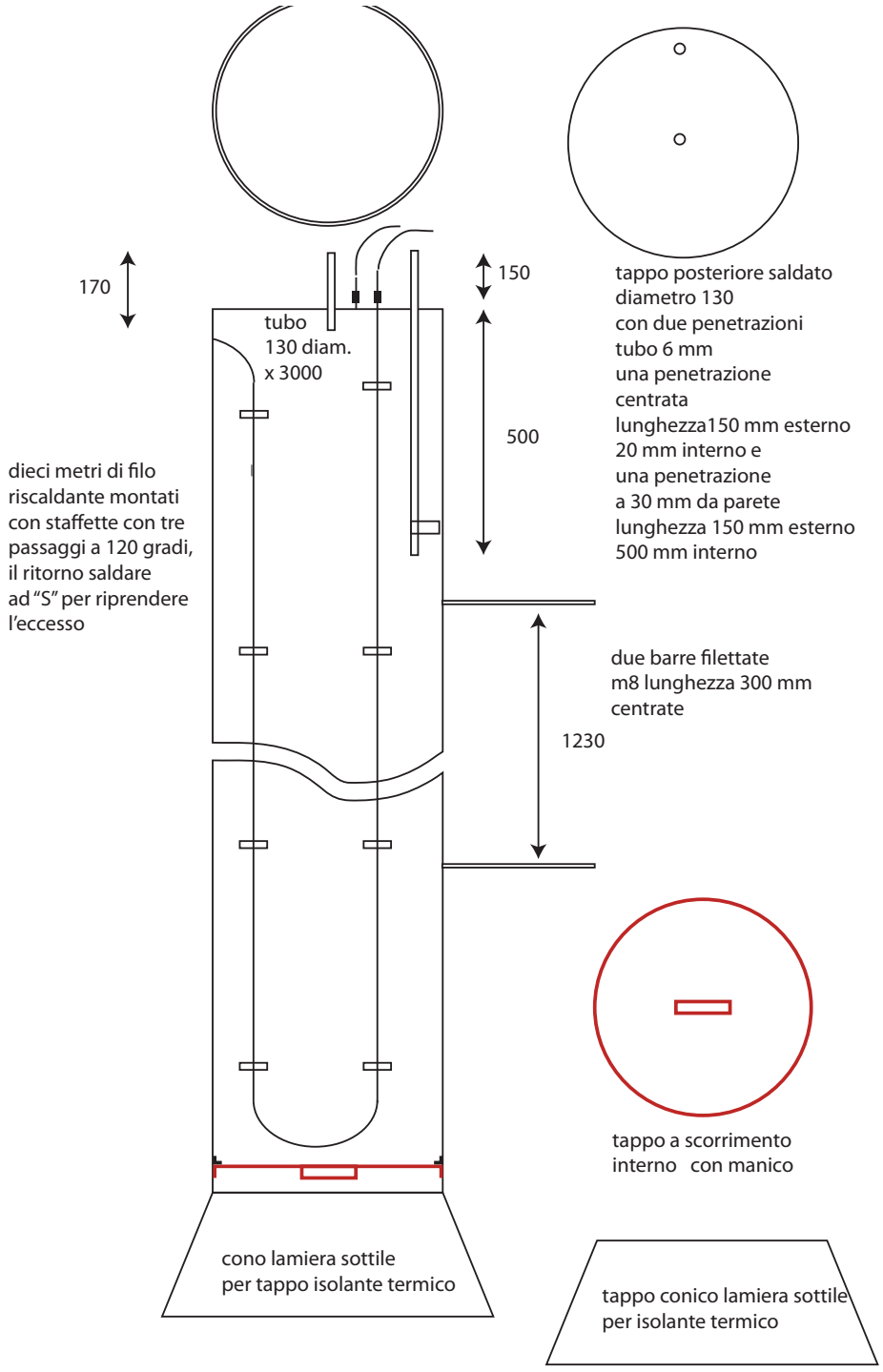
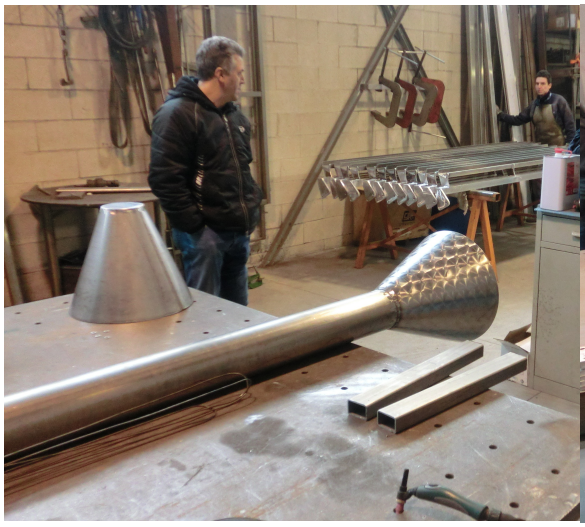
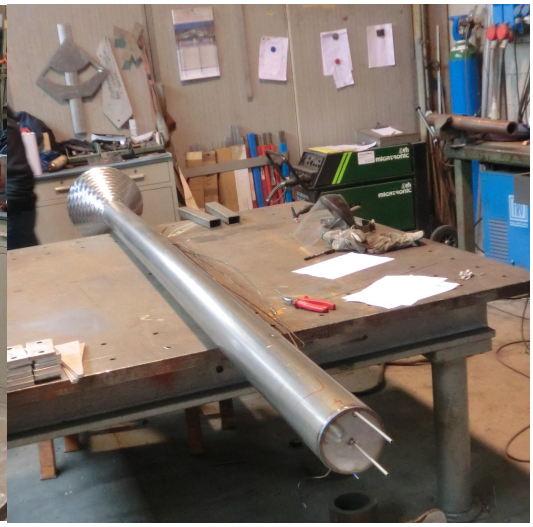
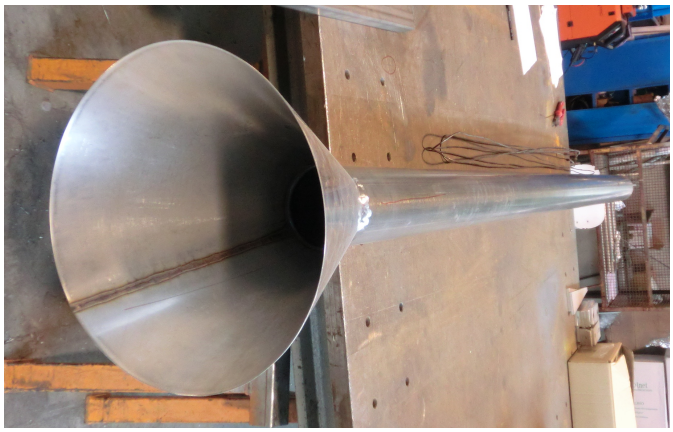


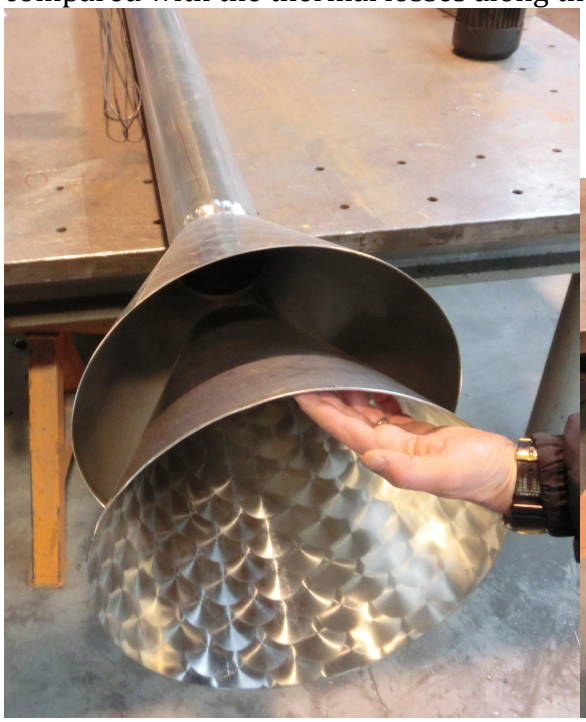
The oven is built around a 130 mm diameter stainless steel pipe, closed at one end, and with a conical end for the access port. A matching cone contains the plug thermal insulation.

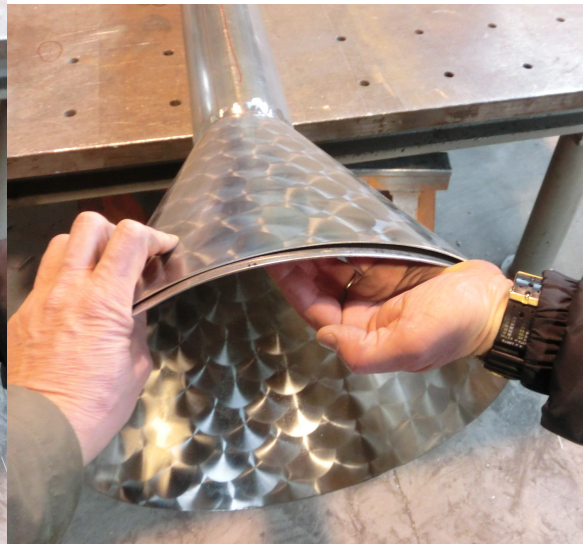



At the closed end, two 6 mm tubes allow the insertion of the type-K thermocouple for feedback, and of the purge Argon gas. The purge gas flows through the pipe and leaks through the two cones of the access port.



The conical end angle is designed with a sufficiently small angle to allow proper temperature degrading for the access port so that the thermal loss at the end is small compared with the thermal losses along the pipe. .





The thermal heating cable capable or heating up to 800°C, is then welded on the outer skin of the tube.

In this step, we made a mistake, because we used an available 10 m heating cable, which is not a multiple of the 3 m oven length. We assumed that the radiating heat would sufficiently uniformize the temperature. This wrong assumption caused some trouble in the 2013 production run. New heating cables, with length multiple of the oven length, will be replaced, in time for the 2014 production run.
As thermal insulation, eight layers of iisholnet ceramic fiber pads, alternated with aluminum foil were wrapped around the pipe.

Isholnet
ISOLANTI HOLDING NETWORK

ISHOLBIO - FELTRI IN FIBRA BIOSOLUBILE PER ALTA TEMPERATURA

I feltri ISHOLBIO a biopersistenza, sono in grado di fornire elevate prestazioni ad alta temperatura in alternativa alle fibre ceramiche refrattarie. Le fibre che costituiscono ISHOLBIO possiedono una formulazione brevettata con alta resistenza alla temperatura, bassi ritiri e grande sicurezza d'impiego sia dal punto di vista sanitario (sono fibre sbiosolubili ecologiche a bassa bio persistenza) sia per l'alta refrattarietà. La composizione chimica di ISHOLBIO rietra nella definizione di fibre vetrose artificiali (silicati) aventi un contenuto in ossidi alcalini ed alcalino terrosi superiore al 18% in conformemente alla Nota Q della Direttiva 97/69/EC. I feltri ISHOLBIO sono pertanto materiali biosolubili e non richiedono alcun tipo di avviso sanitario tossicilogico sulle confezioni. Per l'utilizzo del materiale, consultare la relativa Scheda di Sicurezza.

SPECIFICHE TECNICHE		
Densità kg/m^3	96; 128	
Temperatura di lavoro continua °C	1.000	
Temperatura massima di esposizione °C	1.200	
Temperatura di fusione °C	1.275	
Composizione chimica %:		
SiO_2	62 -67	
CaO	28 - 33	
MgO	1 - 6	
Altri	0 - 1	
Conduttività termica (W/m °K)		
temperatura	densità 96	densità 128
260°	0,07	0,06
540°	0,14	0,12
820°	0,23	0,22
980°	0,29	0,24
1100°	0,33	0,28
Ritiro lineare (dopo 24 ore a 1.100°)	1,20%	
Resistenza alla trazione		
	densità 96	densità 128
	kPa 50	kPa 70
Colore	bianco con riflessi azzurri	
Dimensioni standard (mm)		

spessore	larghezza	lunghezza
13	610	14.640
10	610	9.640
25	610	7.320
38	610	4.800
50	610	3.660

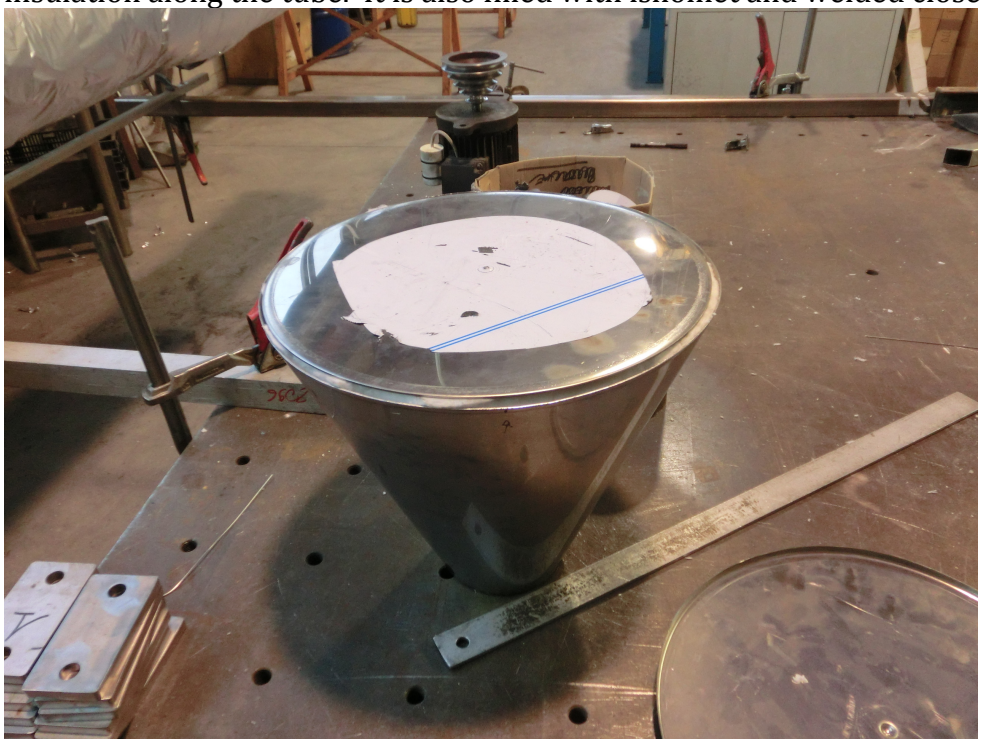
Il feltro ISHOLBIO viene prodotto utilizzando una speciale tecnologia
e presenta le seguenti caratteristiche principali:
- conduttività termica molto bassa
- alta resilienza
- alta resistenza alla trazione
- alta resistenza agli shock termici
- basso peso
- eccellente resistenza alla corrosione

heater and insulation power requirement evaluation:

number of layers	diameter [mm]	length of tape [m]	length of tape used	Number of rolls	Layer area [m2]	conductivity W/oK	Thermal drop for 1 kW [oK]	Integrated thermal drop [oK]	temperature [oK]	Thermal conductivity (from table)
1	156	2.45	2.45	0.16	1.5	15.8	63.157	63.157	386.84	0.14
2	182	2.86	5.31	0.34	1.7	18.5	54.134	117.29	332.71	0.14
3	208	3.27	8.58	0.55	2.0	21.1	47.368	164.66	285.34	0.14
4	234	3.68	12.3	0.79	2.2	11.9	84.209	248.87	201.13	0.07
5	260	4.08	16.3	1.1	2.5	13.2	75.788	324.66	125.34	0.07
6	286	4.49	20.8	1.3	2.7	14.5	68.898	393.55	56.446	0.07
7	312	4.90	25.7	1.7	2.9	15.8	63.157	456.71	-6.7106	0.07
8	338	5.31	31.0	2.0	3.2	17.2	58.299	515.01	-65.009	0.07
9	364	5.72	36.8	2.4	3.4	18.5	54.134	569.14	-119.14	0.07
10	390	6.13	42.9	2.8	3.7	19.8	50.525	619.67	-169.67	0.07

The eight insulating layers proved capable to heat the oven to the required temperature using half of the heater power.
On the access port side the isholnet payers were stepped to progressively wrap the port cone.

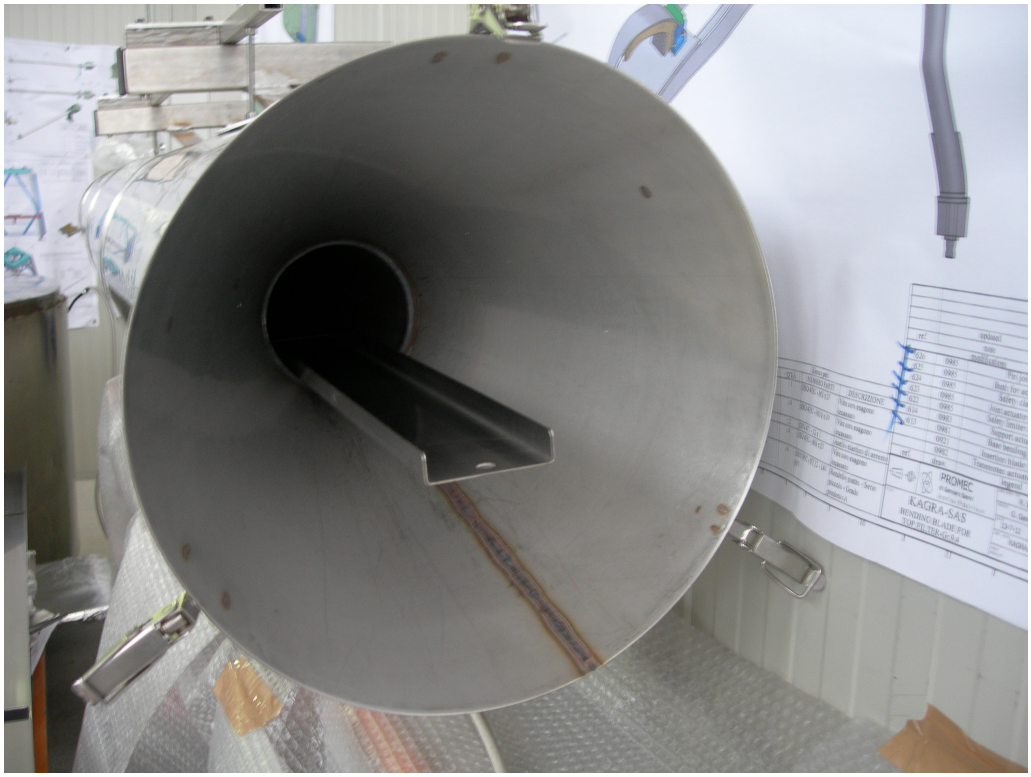
The conical plug fitting in the port cone is four time as long as the thickness of the insulation along the tube. It is also filled with isholnet and welded closed with a cap.



The thermal shield layers are protected with an outer skin, then the oven is suspended on a wall near the clean chamber. Proper latches hold the access port plug..

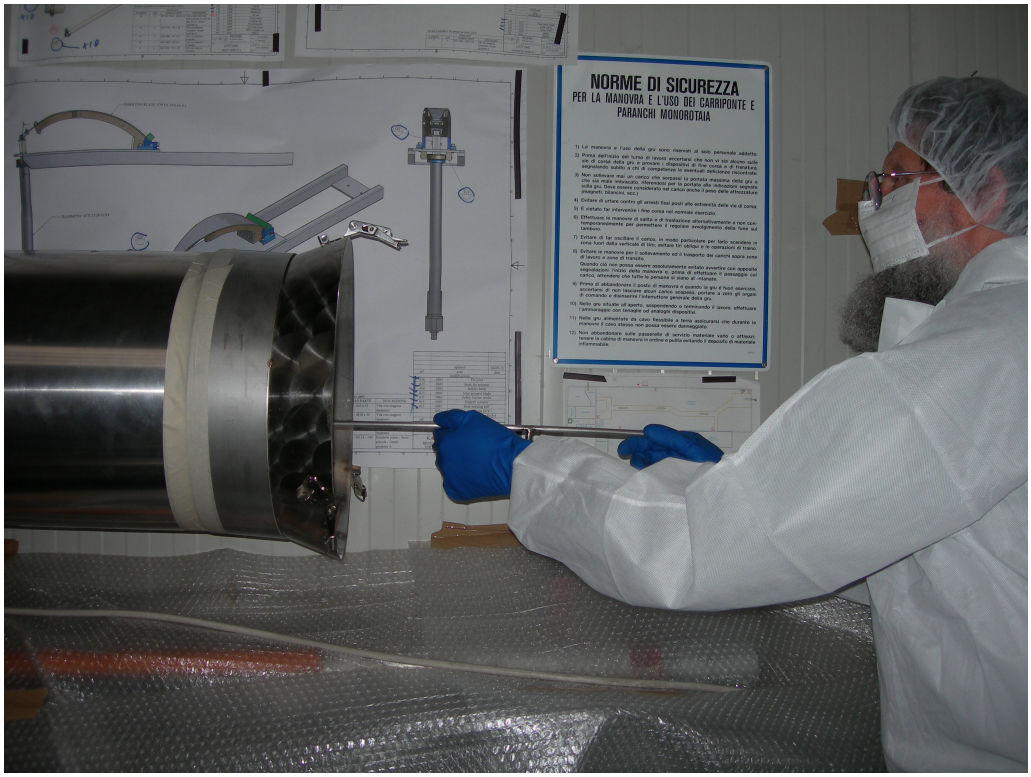
The gas flowmeter, the thermocouple and the control panel are installed.

The wires need to be supported along the length, to keep them from warping. For this a set of trays fitting inside the oven were designed as well.



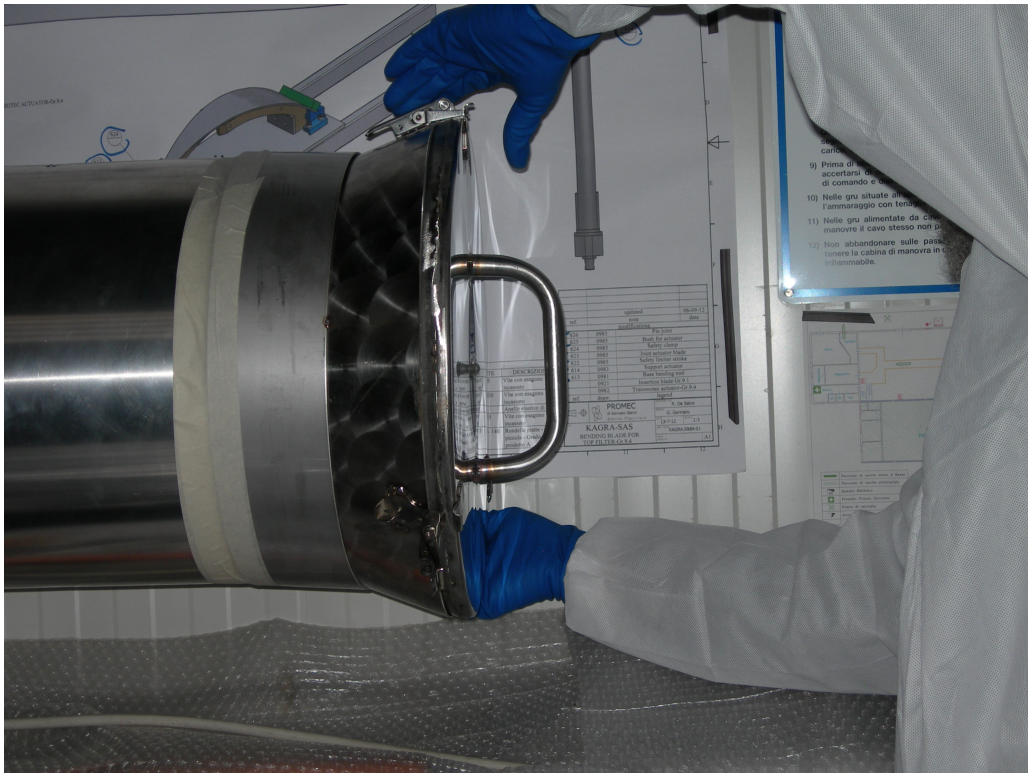
Five trays fit tight in the oven.

A special tool is designed to push and/or extract the trays from the oven.

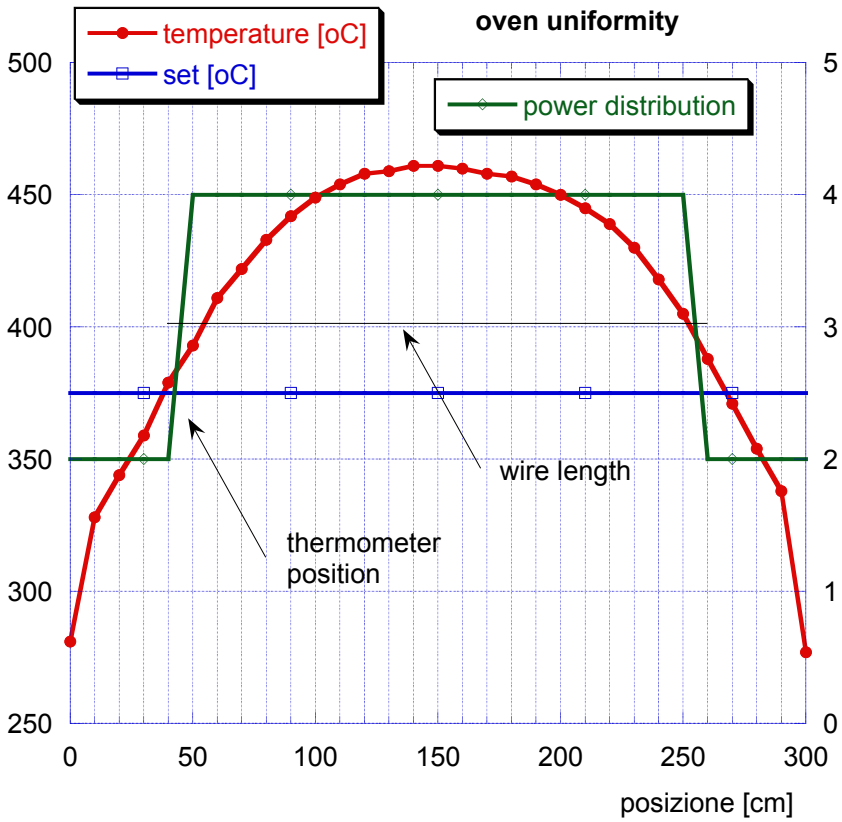


A gas restriction plug is inserted in the pipe before the conical plug, it is designed to generate a small intermediate chamber before the conical plug and impede oxygen back flow.

Finally the conical plug is inserted and latched.

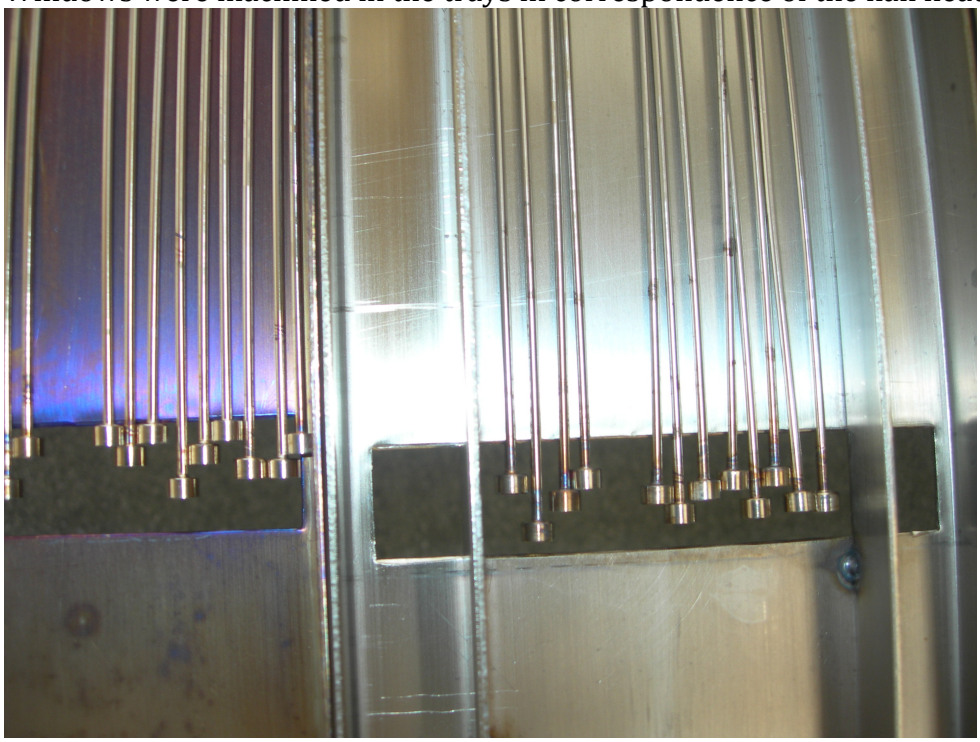


As mentioned, the heating cables available were not a multiple of the oven length, during the oven test run we measured a thermal uniformity much worse than desired.

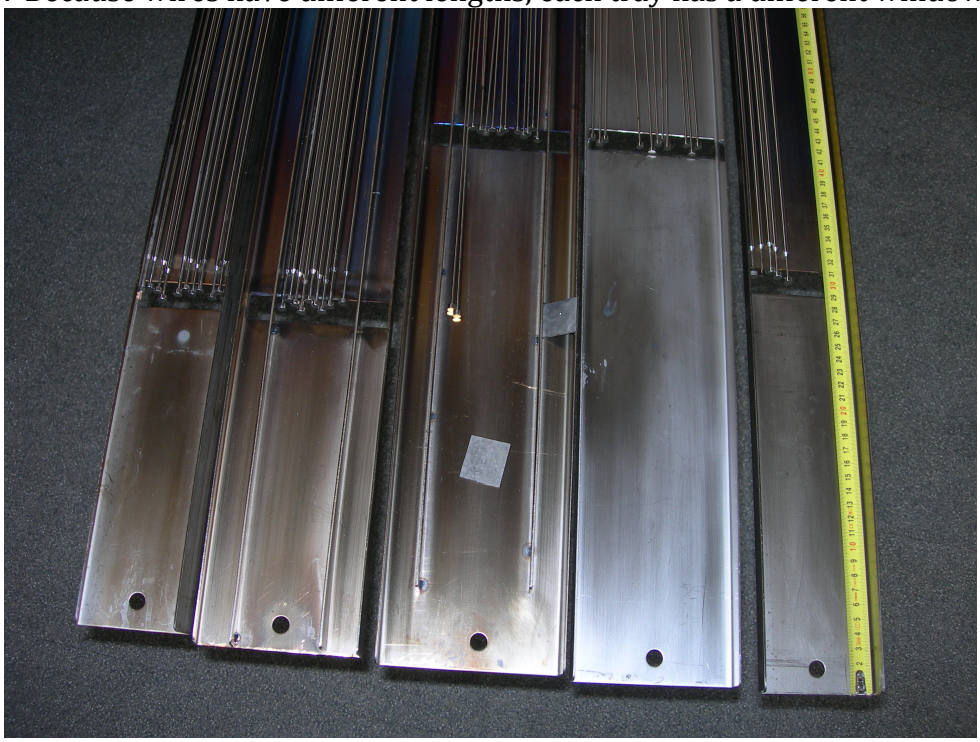


Because of the urgency to deliver the ongoing production run before the end of the Japanese fiscal year, no immediate fix was applied to the oven. A staged maraging hardening procedure was implemented instead to guarantee proper wire processing and wire hardening.
Heating cables of proper length will be installed before the next production run

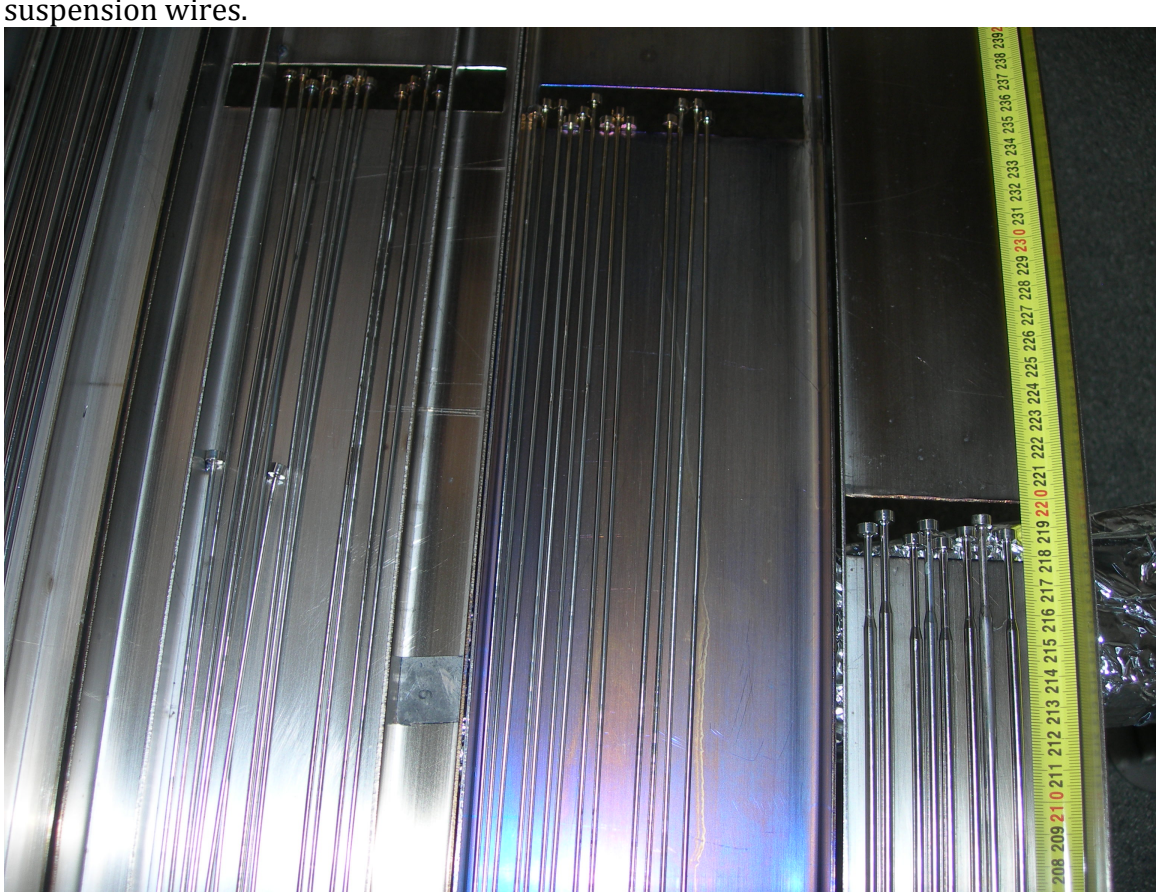
The wires need to be sustained along most of their length, otherwise they get bent. Still the wires have nail heads. It the nails heads sit on a flat surface, the weight of the wire would bend the neck of the nail head, just where it is most vulnerable. Windows were machined in the trays in correspondence of the nail heads



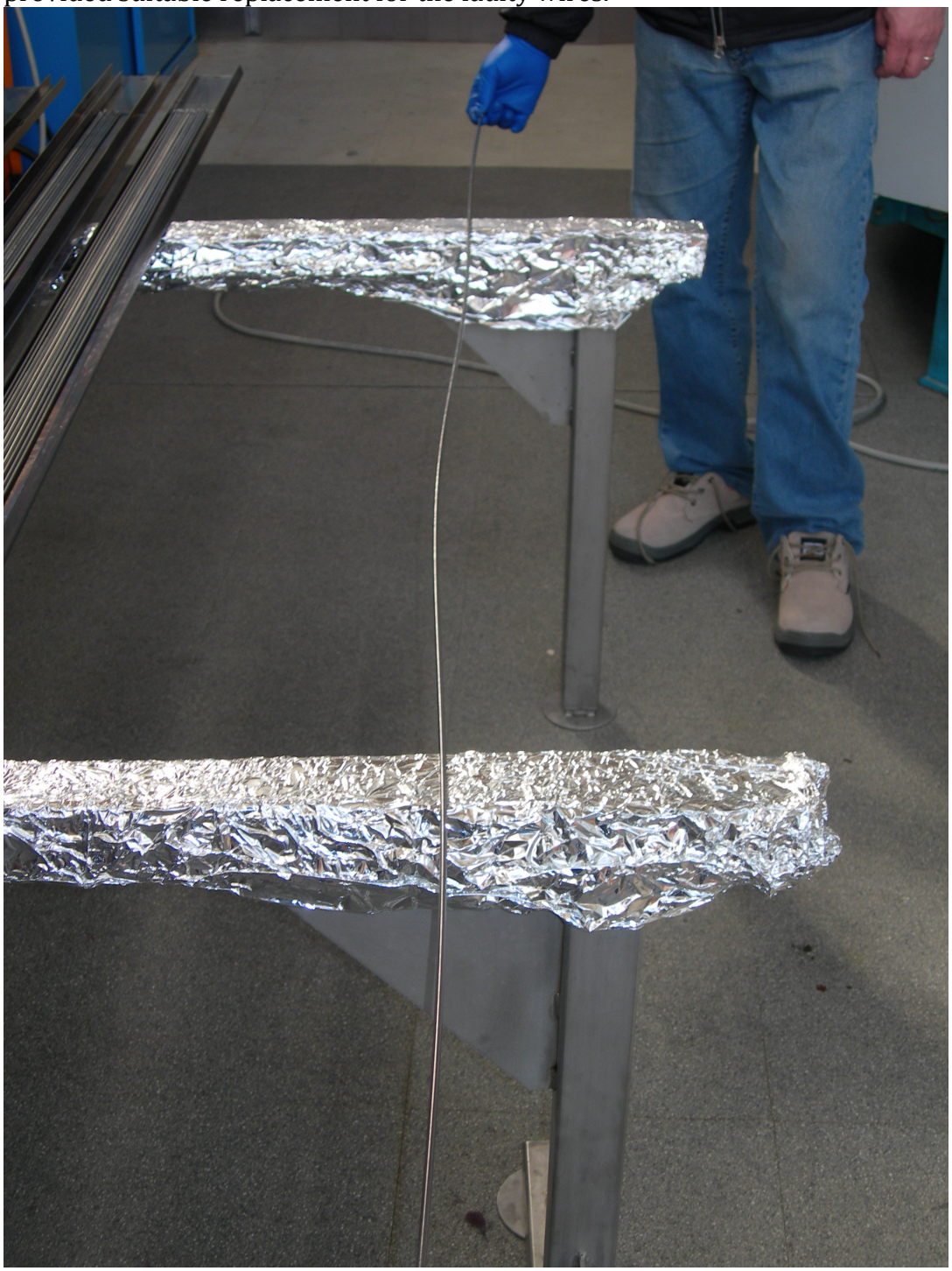
. Because wires have different lengths, each tray has a different window pattern.s



Having found the problem of the oven non uniformity in a test run, we devised the following solution.
The shorter wires were baked in the old round oven, which is known to be very uniform in temperature. The longer filter suspension wires are thin only in the 50 mm neck close to the nail heads, because that is the thinnest point, the rest of the wire length has twice the diameter and is therefore subject to ¼ of the stress, and is not worrysome.
We positioned the longer wires centered in the oven profile, used the measured oven profile to predict the baking temperature at the necks and tuned the oven to provide the required 435°C in that region. Along the wire length, the maraging is subject to higher temperature, which will produce over-aging and some reformed austenite.
To make sure that the wire necks reach the proper amount of hardening, we places small control stamps of maraging sheet near all critical parts of the wires, and along the wires themselves. Stamps are visible in the images above and below.
After the hardening process, we tested the stamps with a certified hardness meter.
The magnetic damper suspension wires are not subject to large stress and are no problem. They were nevertheless hardened and monitored together with the chain suspension wires.



Strangely enough all wires came out straight, except one, which during the process took a very anomalous twisted shape, shown below. Also one additional wire came out with a twisted head. Happily the additional spare wires foreseen (one per kind) provided suitable replacement for the faulty wires.



About the hardness, the stamps were measured and certified by a specialized company. The results are reported below.

centro tecnologico sperimentale s.r.l.
Via Puccini, 9 - Ceparana (SP)

RAPPORTO DI PROVA DI ANALISI E CARATTERISTICHE MECCANICHE
CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES TEST REPORT

COMPANY WITH QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV =ISO 9001:2008=

RAPPORTO N° 76313
Test Report n°
COMMESSA N° 504/13
CTS Job n°
PAG. 1 / 2

CLIENTE / Customer: GALLI & MORELLI s.r.l. LOC. ACQUACALDA - LUCCA
ORDINE CLIENTE / Customer order:
COMMESSA CLIENTE / Customer Job:

RIFERIMENTO - Item: Verbal request

N° PEZZI / N° Pieces	DESCRIZIONE / Description	DIMENSIONI / Dimension	MATERIALE / Material	COLATA N° / Heat n°	N° PROVA / Test n°
21	SAMPLES	Thk 1,5 mm	MARAGING	-	SEE BELOW

CARATTERISTICHE MECCANICHE - *Mechanical properties*

METODO DI PROVA - Test method: UNI EN ISO 6508-1
NOTE - Notes

Test n°	Dimens. Provette / Sample dimension			Rottura / Tensile strength		Snervam. / Yield point		Allung. / Elong.	Striz. / Reduct. of Area	Resilienza / Impact test		Piega / Bend	Durezza / Hardness
	larg. x spes. width x thk.	L_o	Area (S_o)										HRC
	mm	mm	mm^2	kN	N/mm^2	kN	N/mm^2	%	%	JOULE	Average	Result	Result
0													57-56-54
1													55-55-56
2													52-53-51
3													50-49-49
4													50-50-47
5													49-50-50
6													52-52-53
7													54-56-56
8													55-56-56
11													54-56-54
17													55-54-54
M													34-34-34
VALORI RICHIESTI			min										
Required values			max										

ANALISI CHIMICA - Chemical analysis

METODO DI PROVA - Test method
NOTE - Notes

N° provino e/o colata / Sample and/or heat n°														
VALORI RICHIESTI	min													
Required values	max													

ALLEGATI / Attachments

NOTE/ Notes HARDNESS TESTS CARRIED OUT ON THE NUMBERED SIDE OF THE SAMPLES

OPERATORE / Operator	ISPETTORE / Inspector	ISPETTORE / Inspector	IL DIRETTORE / The Director	DATA / Date
Paolo DEL CHIARO			Dott. Ing. C. DELLABIANCIA Federico BONDI	13/03/2013

centro tecnologico sperimentale s.r.l.
Via Puccini, 9 - Ceparana (SP)

RAPPORTO DI PROVA DI ANALISI E CARATTERISTICHE MECCANICHE
CHEMICAL ANALYSIS AND MECHANICAL PROPERTIES TEST REPORT

COMPANY WITH QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV =ISO 9001:2008=

RAPPORTO N° 76313
Test Report n°
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PAG. 1 / 2

CLIENTE Customer	ORDINE CLIENTE Customer order	COMMESSA CLIENTE Customer Job
GALLI & MORELLI s.r.l. LOC. ACQUACALDA - LUCCA		

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Verbal request

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21	SAMPLES	Thk 1,5 mm	MARAGING	-	SEE BELOW

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	larg. x spes. width x thk.	L_o	Area (S_o)										HRC
	mm	mm	mm^2	kN	N/mm^2	kN	N/mm^2	%	%	JOULE	Average	Result	Result
0													57-56-54
1													55-55-56
2													52-53-51
3													50-49-49
4													50-50-47
5													49-50-50
6													52-52-53
7													54-56-56
8													55-56-56
11													54-56-54
17													55-54-54
M													34-34-34
VALORI RICHIESTI			min										
Required values			max										

ANALISI CHIMICA - Chemical analysis

METODO DI PROVA - Test method
NOTE - Notes

N° provino e/o colata Sample and/or heat n°														
VALORI RICHIESTI	min													
Required values	max													

ALLEGATI / Attachments

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OPERATORE Operator	ISPETTORE Inspector	ISPETTORE Inspector	IL DIRETTORE The Director	DATA Date
Paolo DEL CHIARO			Dott. Ing. C. DELLABIANCIA Federico BONDI	13/03/2013

The explanation of the sample labels is the following:
The sample M is non hardened maraging, and correctly reads Rockwell Hardness 34.
The samples 0 to 17 belong the long suspension wires. The only really relevant are 1, 11, 7 and 17, which were placed next to the necks of the wires, they are all about 54. 0 and 8 are beyond the wires at the two edges, they also read good hardening.
The samples 2 to 6 are along the thick part of the wires, even if they are not as hard (they have been over-precipitated and likely have some reformed Austenite) they are still quite hard and retain the strength of a good structural steel, which is plenty good in the thick section of the wire.
The samples 21 to 42 are for the shorter wires, baked in the large oven, and all are in the good range.

All wires required were accepted for delivery.

Although the results were already acceptable, the oven is being refurbished for good thermal uniformity, and baking of wires as long as 2800 mm. The refurbished oven will be ready in the next several weeks, certainly well in advance of the next production runs.