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MODERN HEAT TREATMENT TECHNOLOGY FOR OCTG PIPE INDUSTRY[1]

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Abstract

The increasingly stringent market requirements, generated by the API standards and ever more demanding OCTG customers, have pushed pipe producers towards heat treatment plants of superior performance. The main requirements of a higher quality and consistency in results, coupled with the ever present need to limit the environmental impact and minimize energy consumption, determined the development of a new generation of treatment plants. The heat treatment line supplied by SMS Meer to Pervouralsky Novotrubny Works, Russia is an example of such a modern approach.

Key words: Reheating furnace; Heat treatment furnace; OCTG pipes industry; Pipes/tubes heat treatment.

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1. INTRODUCTION

1.1 Plant data

The finishing plant is designed for the production of 80,000 t/year of pipes as per the following table.

Table 1 – Plant product basic data

Type of Pipes	Outside diameter (mm)	Wall Thickness (mm)	Standard
Tubing	60.3 to 88,9	4.83 to 6.45	API, GOST (upset)
	60.3 to 114.3	5 to 7	GOST (higher strength pipes)
Coupling stock	73 to 195	11 to 19	GOST, API5CT
Line pipes	89 to 219	6 to 25	TU - corrosion cold resistant pipes

The main equipment composing the plant are:

- Austenitizing Furnace – HT
- Quench sprayer – QS
- Quench tank – QT
- Tempering Furnace – LT
- Cooling bed #1 – CB#1
- Straightening machine – ST
- Cooling bed #2 – CB#2
- Quality Assurance Line – QAL

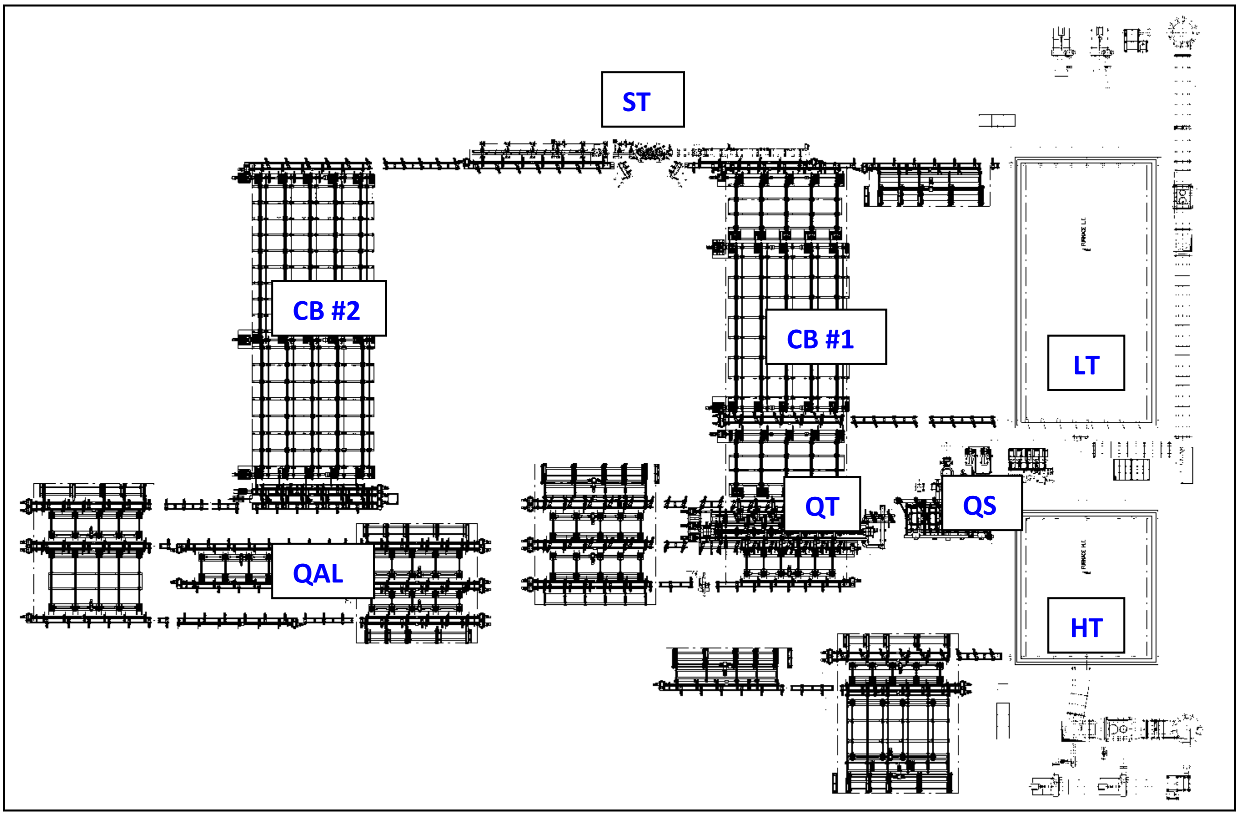

Figure 1: Finishing area layout.

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2 METHODS

Three main technological flows are possible.

2.1 Hardening and Tempering Cycle

Low wall thickness (<20mm)

Table 2 – Heat treatment cycle option 1

1.Austenitizing furnace 2.Descaling 3.Quenching sprayer 4.Tempering furnace 5.Straightener 6.Cooling bed	a. High-strength tubing and couplings as per: API 5CT (groups N80-Q, L80-1, P 110) and GOST 633 (groups E, L, M, R /in Russian letters E, Л, M, P) including upset pipes b. Line pipes (TU 14-3-1128, GOST 8731 with protocols etc.) c. Cold-resistant and corrosion resistant casing

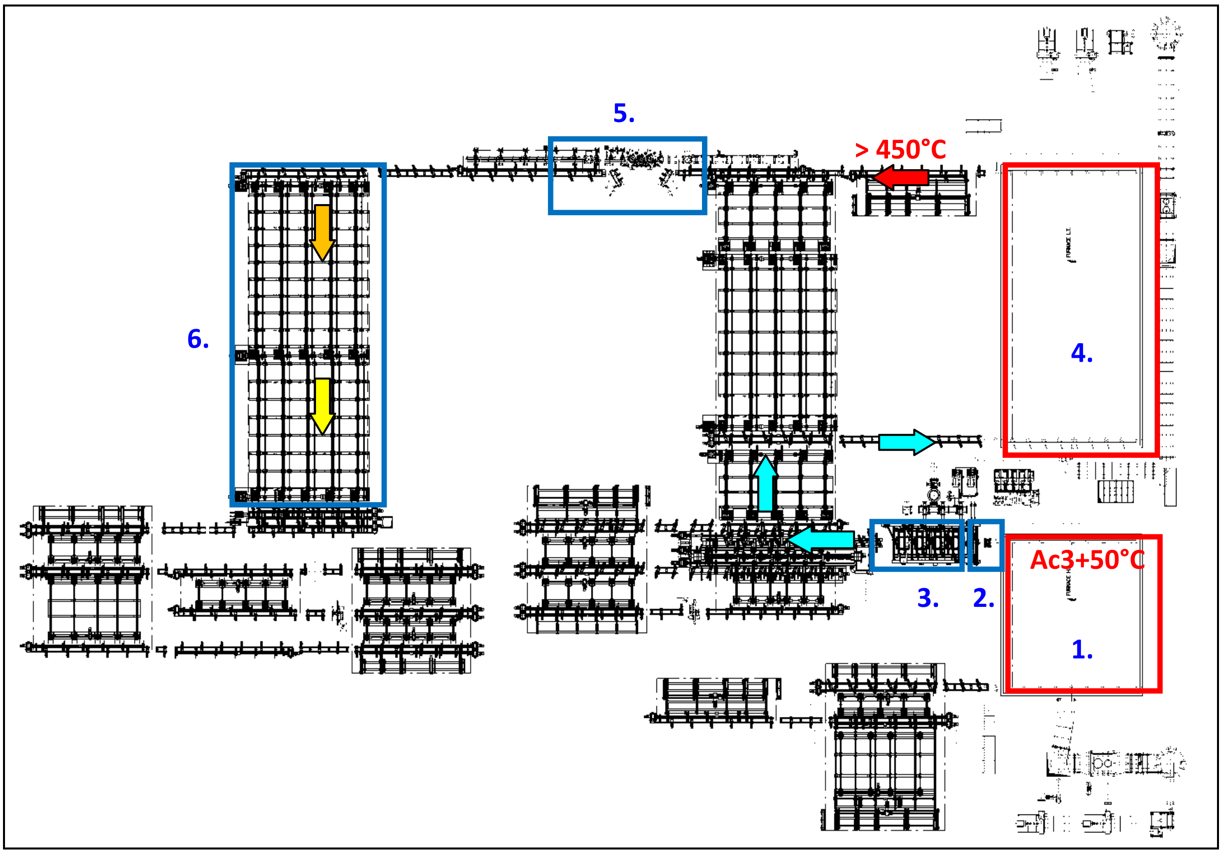

Figure 2: Technological flow: Hardening and Tempering of low wall thickness pipes.

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2.2 Hardening and Tempering Cycle

High wall thickness (>20mm)

Table 3 – Heat treatment cycle option 2

1.Austenitizing furnace 2.Descaling 3.Quenching tank 4.Tempering furnace 5.Straightener 6.Cooling bed	a. High strength couplings as per: API 5 CT (groups N80-Q, L80-1, P 110) and GOST 633(groups E, L, M, R /in Russian letters E, Л,M, P) b. Line pipes (TU 14-3-1128, GOST 8731 with protocols etc.) and coupling stock with cold-resistant and corrosion resistant performance

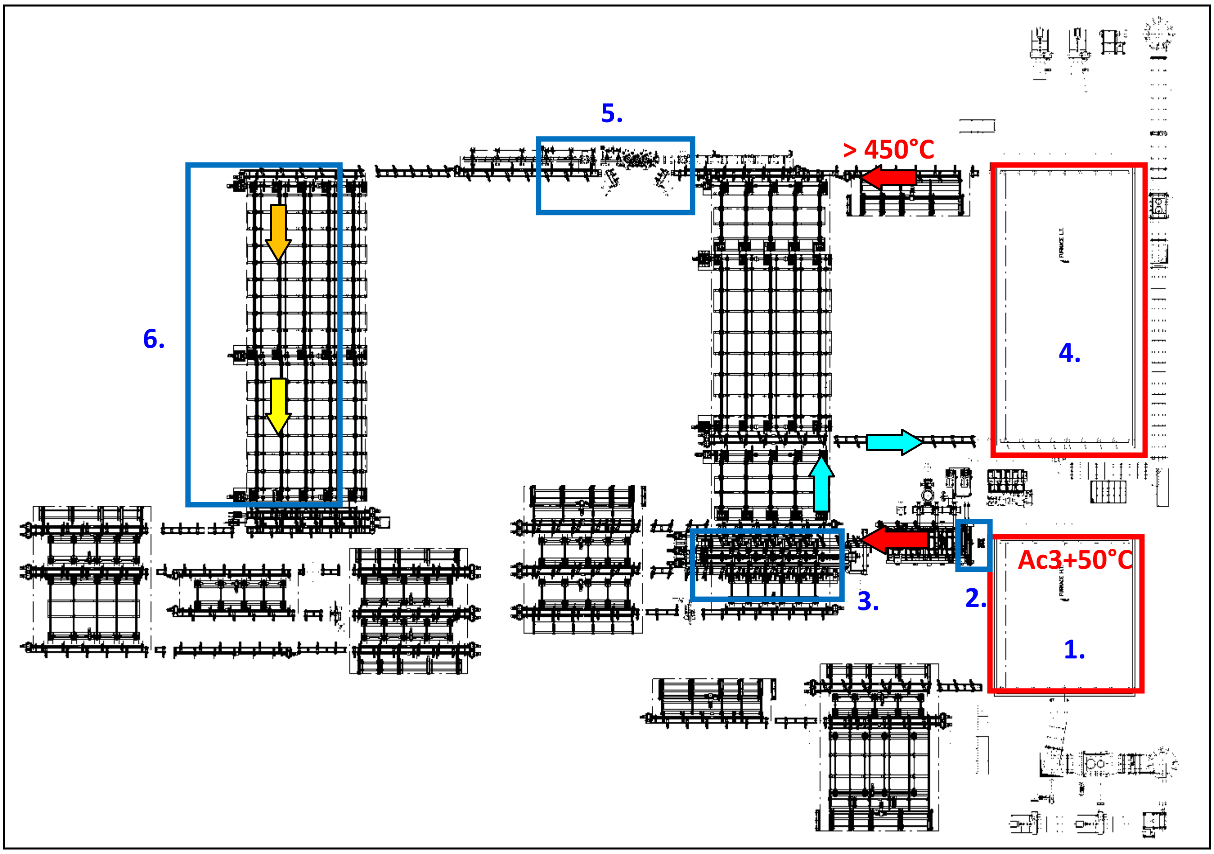

Figure 3: Technological flow: Hardening and Tempering of high wall thickness pipes.

Figure 4: Quenching tank area overview.

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2.3 Normalization

Table 3 – Heat treatment cycle option 3

1.Autenitizing furnace 2.Intermediate cooling bed 3.Straightener 4.Cooling bed	a. Pipes with upset ends as per API 5 CT group N80-1 as per GOST 633, for which the quenching is not required. b. Preliminary (pre-) normalization of line pipes and tubing with cold-resistant and corrosion resistant performance with further heat treatment according to variants 1 and 2.

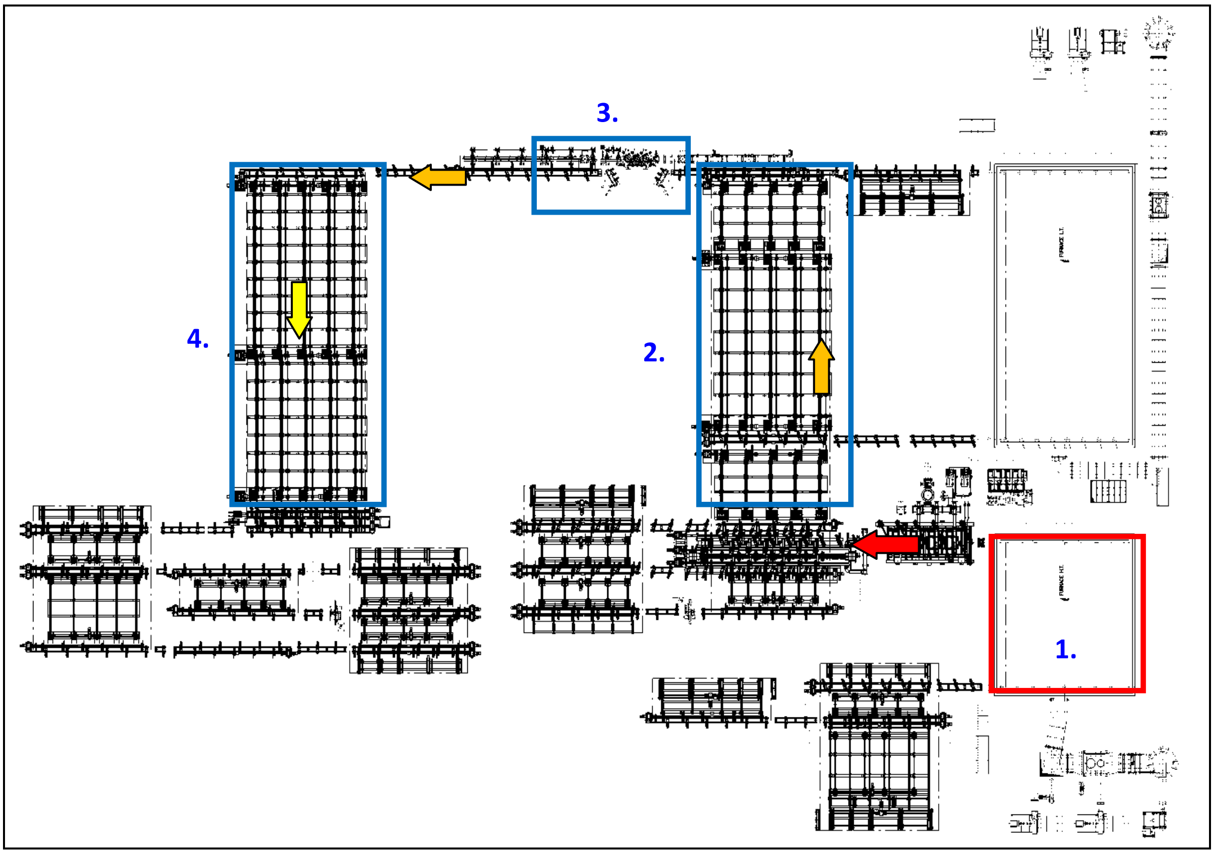

Figure 5: Technological flow: pipes normalization.

2.4 Furnaces

The Austenitizing (see Figure 8) and Tempering (see Figure 9) furnaces are of walking beam type with Chromium-Nickel alloyed beams. The lifting and transversal movements are achieved through hydraulic cylinders connected to a single power unit common for both furnaces.

Both furnaces have an unfired zone on the charging side to shield the cold pipe entering the furnace from the high heat coming from the fired zones. This allows for a gradual heating, avoiding pipe deformations and guaranteeing correct movements inside the furnace.

Burners are positioned orthogonally to the advancement flow of the pipes in the furnace. Such lay-out allows better and more uniform heating along the pipe length.

The discharge fumes are collected and exit the furnace through ducts located in the lower part of the charging area to maximize heat transfer to the pipes and utilize the entire furnace length.

Both furnaces are equipped with charging and discharging machinery to guarantee handling also in case of deformed pipes.

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The furnaces are equipped with high-speed burners with on/off control (see Figure 6 and Figure 7), divided in digitally controlled zones (see Table 4) to guarantee and optimal heating uniformity and flexibility of operation.

Figure 6: Austenitizing Furnace, digitally controlled burners battery

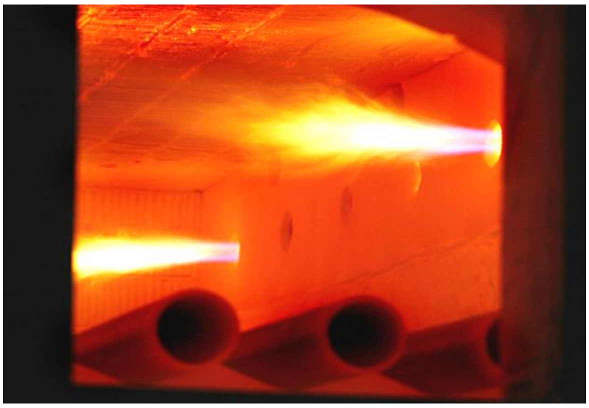

Figure 7: Tempering Furnace, digitally controlled burners from inside the furnace.

Table 4: table showing burners distribution in physically separated zones

	Physical zones	Digital zones	Number of burners
Austenitizing Furnace	heating I	4	12
	heating II	4	12
	soaking	4	12
Tempering Furnace	heating I	4	12
	heating II	4	12
	heating III	4	12
	soaking I	4	12
	soaking II	4	12

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Figure 8: Austenitizing Furnace, aerial view.

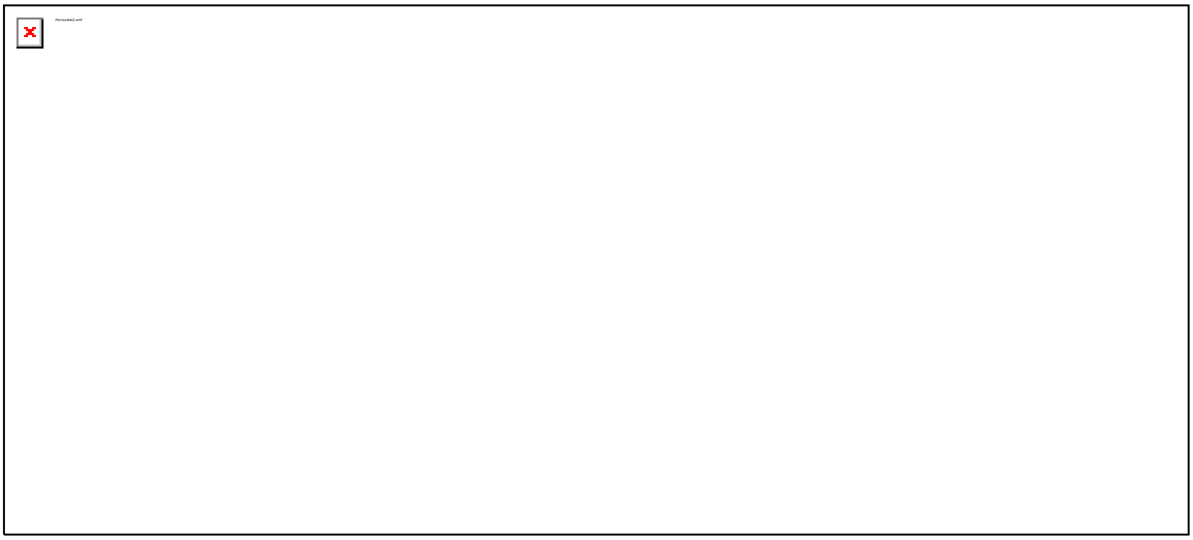

Figure 9: Tempering Furnace, side section.

2.5 Quenching Sprayer

The quenching sprayer is composed by a frame supporting the transport roller table, the descaling module and the three spraying modules (see Figure 10).
The frame is supported on screw jacks so that the centerline of the quenching heads corresponds with the pipe being treated independently from its diameter.
The descaling module is connected to a 200 l/min pump with 200 bar of feed pressure.
Each of the three quenching modules is equipped with approx. 1000 nozzles, connected to a movable lever system that can be adjusted to the different pipe diameters so that the flow direction is always tangential to the pipe surface (see Figure 11).

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The used water then flows to a scale pit from where it is recycled to the filtering and cooling plant.

Figure 10: Quenching sprayer 3-d modeling.

Figure 11: The water flow from the quenching head nozzles is always kept perfectly tangential to the pipe surface.

Quenching Tank

A rotating arm transfers the pipe from the furnace exit roller table into the quenching tank (see Figure 12).
Located in the tank is a supporting beam that can be hydraulically lifted and lowered. The actuating cylinder is located outside the tank.
The beam is fitted with wheels designed to allow the processed pipe rotation. A set of levers locks the pipe during immersion.
A nozzle located at one end allows the pressurized injection into the pipe of air/water mix.
At the end of the tempering process, a second rotating arm extracts the pipe from the tank.
The working sequence is as follows (refer also to Figure 13):

- The pipe is transferred from the roller table to the beam through the first rotating arm,
- Pipe is locked onto the beam,

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- Automatic positioning of the ID nozzle,
- Lowering of the pipe in the tank,
- Nozzle operation and injection of the air/water mix into the pipe,
- Lifting of the pipe from the tank,
- Transfer of the pipe out of the tempering tank through the second rotating arm.

Figure 12: Pipe entering the Quenching Tank

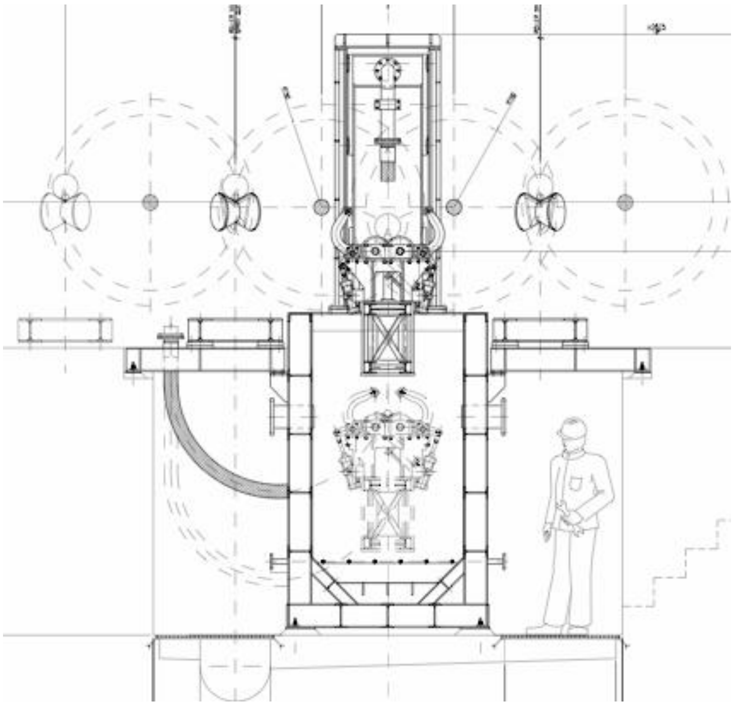

Figure 13: Quenching tank section.

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2.6 Straightener

The cross-roll straightening machine is of upright design. It is a 6-roll straightening machine (see Figure 14), with the 3 upper and the 3 lower rolls mounted in pairs, one above the other.
The straightening effect is achieved by the ovalising and/or bending of the material to be straightened between the rolls, the yield point of the material to be straightened being exceeded. The roll angularity forces the material to be straightened to rotate helically while passing through the machine. The helical movement makes the straightening force become effective in all points on the circumference along the longitudinal axis.
The open style of the straightening machine allows the operator to observe the material to be straightened exactly during the straightening operation.
The straightening machine is designed for processing tubes with upsetted ends. In order that the tubes can pass through the straightening triangle without colliding with the rolls and thus being damaged, the machine is equipped with quick-acting short-stroke hydraulic cylinders.

Figure 14: Straightening machine during testing.

2.7 Handling Equipment and Cooling Beds

These auxiliary components of the line have however a primary importance since they connect all processing steps together. Solidly engineered and equipped with reliable components, the handling equipment combines a very high production rate (one pipe every 24 seconds) with careful and precision handling.

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Figure 15: Cooling bed.

3 RESULTS

The following performance variables were monitored and collected:

- Furnace consumption levels
- NOx emissions
- Pipe discharge temperature uniformity
- Mechanical characteristics reached after heat treatment

The first three results refer to the acceptance test on a pipe 88,9 x 6,5, the product that was requiring the peak production of 150 pipes/hr.

3.1 Specific Consumption

The specific consumption of the furnaces is shown in the following table.

Table 5: Furnaces specific consumption

	Guarantee value	Measured value
Hardening furnace	-	**200 kcal/kg**
Tempering furnace	-	**98 kcal/kg**

3.2 NOx Emissions

During the acceptance test above we measured the following NOX emissions:

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Table 6: Furnaces NOx Emissions

	Guarantee value	Measured value
Hardening furnace	**280 mg/Nm3**	**<160 mg/Nm3**
Tempering furnace	**180 mg/Nm3**	**<100 mg/Nm3**

3.3 Temperature Uniformity

During the acceptance test we measured the variation on the surface temperature of the pipes by using optical pyrometers positioned immediately after the discharge doors. The results are shown in the following tables and on Figures 16 and 17.

Table 7: Hardening furnace temperature guarantee values

	Guarantee value	Measured value
Hardening furnace	**+/- 10°C**	**+/- 5°C (max)**

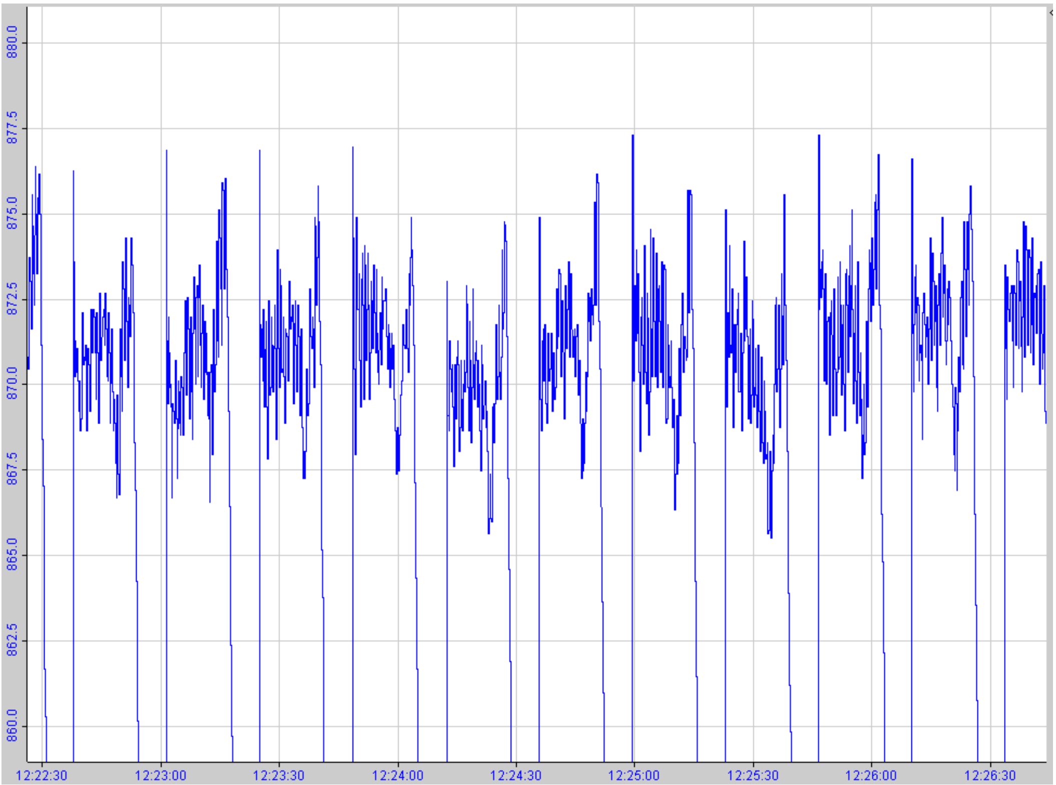

Figure 16: Detected temperature of tubes coming out from hardening furnace.

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Table 8: Tempering furnace guarantee values

	Guarantee value	Measured value
Tempering furnace	**+/- 5°C**	**+/- 4°C (max)**

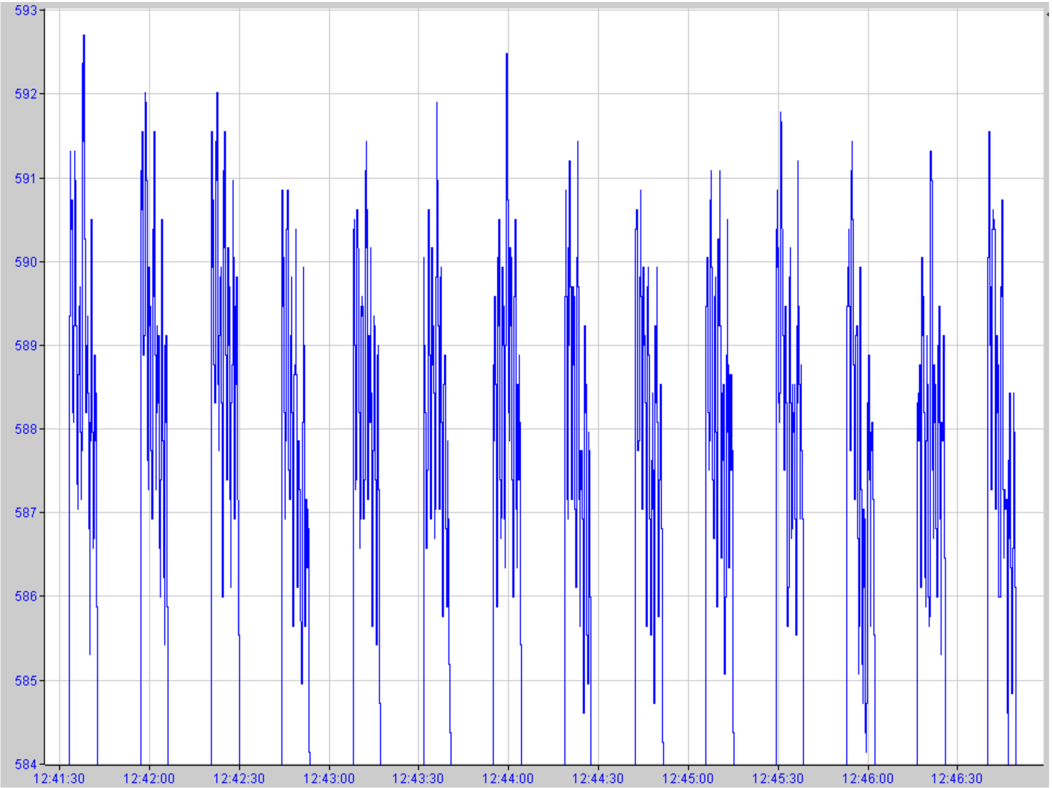

Figure 17: Detected temperature of tubes coming out from tempering furnace.

3.4 Mechanical Characteristics

Starting with relatively poor starting steel grades, we reached high mechanical properties, fulfilling all the performances trials (see summary on Table 9).

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Table 9: Performance trials results

Steel grade	GOST	API	Pipe	Production (p/h)	Mechanical charateristics											
					Rp0,2 (MPa)			Rm (MPa)			ε (%)		KCV (kgfxm/cm2)		KCU (kgfxm/cm2)	
					min	plant average results	max	min	plant average results	max	min	plant average results	min	plant average results	min	plant average results
13ХФА	ТУ 1317-233-00147016-02	KV -50	89x6	68	340	430	471	502	540	628	25	27	10 (-50°C)	33	10 (-60°C)	38
13ХФА	ТУ 1317-233-00147016-02	KV -50	89x8	68	340	451	471	502	570	628	25	28	10 (-50°C)	31	10 (-60°C)	36
13ХФА	ТУ 1317-233-00147016-02	KV -50	159x6	33	340	365	471	502	540	628	25	28	10 (-50°C)	33	10 (-60°C)	40
13ХФА	ТУ 1317-233-00147016-02	KV -50	159x8	33	340	422	471	502	540	628	25	27	10 (-50°C)	36	10 (-60°C)	41
13ХФА	ТУ 1317-233-00147016-02	KV -50	159x10	49	340	450	471	502	590	628	25	27	10 (-50°C)	35	10 (-60°C)	39
13ХФА	ТУ 1317-233-00147016-02	KV -50	219x16	39	340	355	471	502	550	628	25	27	10 (-50°C)	38	10 (-60°C)	47
15Х5МФБЧ	ТУ 14-158-124		73x5,5	104	520	580		650	720		18		10 (-50°C)	16		
20	ТУ 14-159-1128		114x12	91	245	560		412	353		21	28			3 (-60°C)	27
20	ПР 993-09 к ГОСТ 8731		168x16	41	245	550		412	402		21	32			4 (-60°C)	32
20A	ТУ 14-158-113-99		89x8	104	353	480		510	625	638	25	27	15 (20°C) 4 (-50°C)	24 (20°C) 22(-50°C)	4 (-60°C)	23
20A	ТУ 14-158-113-99		114x8	104	353	490		510	630	638	25	26	15 (20°C) 4 (-50°C)	22 (20°C) 21 (-50°C)	4 (-60°C)	24
20A	ТУ 14-158-113-99		114x14	86	353	470		510	625	638	25	27	15 (20°C) 4 (-50°C)	23 (20°C) 17 (-50°C)	4 (-60°C)	16
20A	ТУ 14-158-113-99		159x8	52	353	450		510	580	638	25	26	15 (20°C) 4 (-50°C)	20 (20°C) 15 (-50°C)	4 (-60°C)	20
20A	ТУ 14-158-113-99		159x12	46	353	385		510	560	638	25	28	15 (20°C) 4 (-50°C)	27 (20°C) 19 (-50°C)	4 (-60°C)	22
20A	ТУ 14-158-113-99		168x14	43	353	450		510	600	638	25	27	15 (20°C) 4 (-50°C)	20 (20°C) 14 (-50°C)	4 (-60°C)	18
20A	ТУ 14-158-113-99		219x16	39	353	360		510	530	638	25	28	15 (20°C) 4 (-50°C)	22 (20°C) 21 (-50°C)	4 (-60°C)	24
30ХМА	ГОСТ 633 под гр.пр. "М"		88,9x6,5	150	724	880	921	823	1000		11,3	16				
30ХМА	ГОСТ 633 под гр.пр. "Р"		60,3x5	150	930	950	1137	1000	1040		9,5	15				
30ХМА	ГОСТ 633 под гр.пр. "Р"		73x5,5	150	930	940	1137	1000	1100		9,5	18				
32Г2-6	ГОСТ 633 под гр.пр. "Е"	API 5CT N80Q	73x5,5	150	552	660	758	689	800		13	19				
32Г2-6	ГОСТ 633-80 под гр.пр. "Л"		73x7	133	654	735	862	758	850		13	20				
32Г2	ГОСТ 633 под гр.пр. "Л"		114,3x7	108	654	750	862	758	870		12,3	19				
32Г2	ГОСТ 633 под гр.пр. "Л"		88,9x12	120	654	760	862	758	860		12,3	23				
32Г2		API 5CT N80Q	88,9x13,5	100	552	600	758	689	780		14	20				
32Г2		API 5CT N80Q	93,17x13	100	552	630	758	689	790		14	23				
32Г2		API 5CT N80Q	93,2x12,5	120	552	600	758	689	746		14	26				
35ХГСА	ГОСТ 633 под гр.пр. "Л"		132,1x14,5	50	654	765	862	758	930		12,3	24				
37Г2Ф		API 5CT P110	107,95x15,5	92	758	800	965	862	920		12	13				
45		API 5CT N80Q	168,28x8,94	50	552	570	758	689	760		12	25				
Д		API 5CT N80Q	187,71x19,5	45	552	580	758	689	770		12	23				

4 CONCLUSIONS

With the successful commissioning of this plant, SMS Meer grew in confidence of having a winning package for the heat treatment of pipes. This product line binds high technological content to good profit pictures with the following advantages:

- Wide product mix obtained from limited number of starting steel-grades
- 100% of quality pipes obtained under high performance pacing (up to 150 pipes/hour)
- Full tracking control (pipe by pipe) on the line for maximum optimization of heats and production lots along the line.