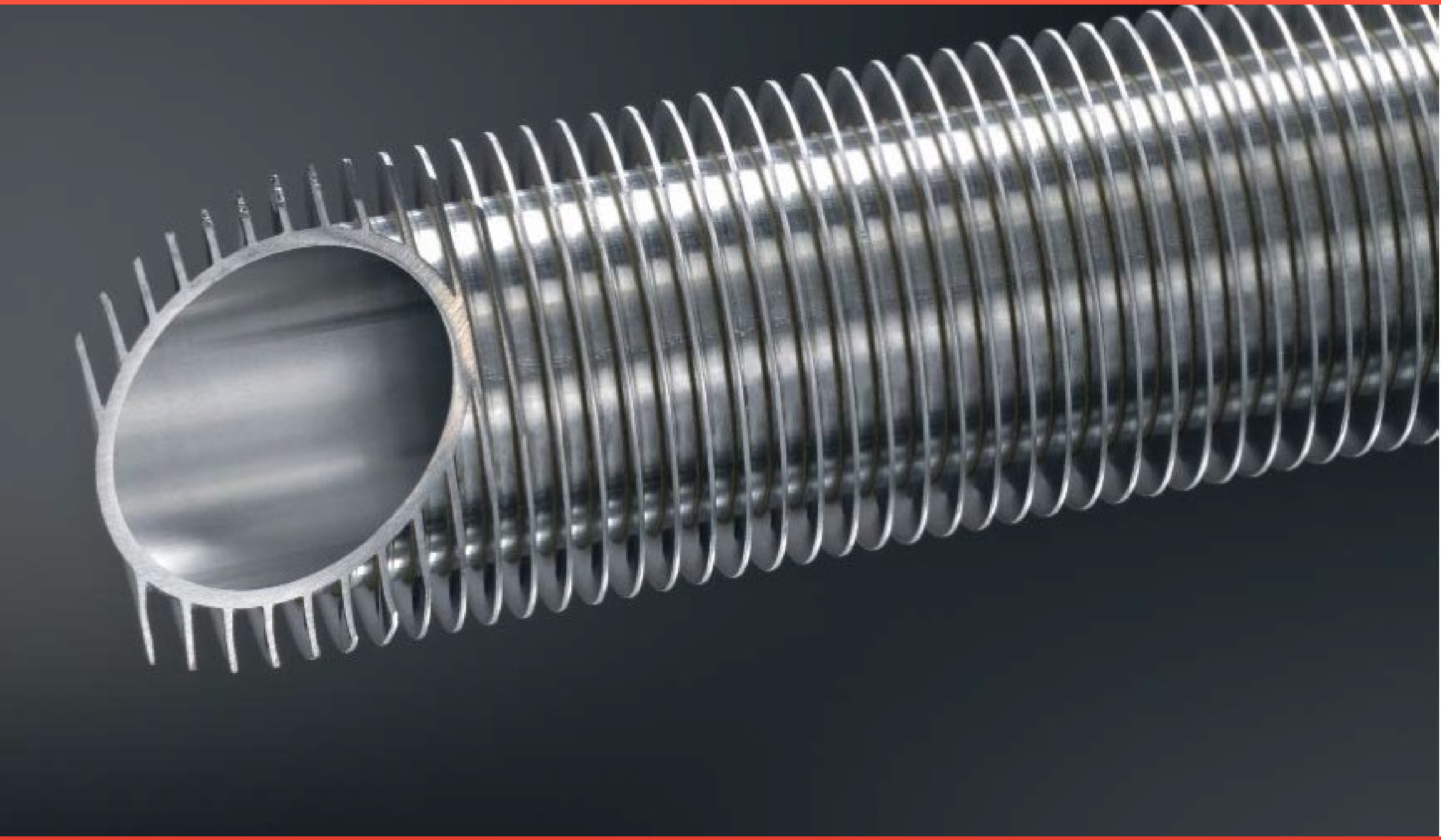
SCHMOELE



LASERFIN® - Finned Tubes

The most flexible finned tube family in the world

- 100 % flexibility - freely combinable of tube and fin material
- 100 % welding - highest heat conductivity from fin to tube
- 100 % gap free - because of 100 % laser welding of fin and tube
- High corrosion resistance against aggressive media based on different material combinations
- Easy shaping of the finned tubes thanks to optimal bending and coilability of the finned tubes
- Compact design of the heat exchanger thanks to the large heat exchange surfaces of the finned tubes
- Low weight of the heat exchangers because of reduced tube numbers
- Standard tube materials stainless steel 1.4301 (TP304), 1.4404 (TP316L), 1.4571 (TP316Ti)
- Standard fin materials stainless steel 1.4301 (TP304), 1.4404 (TP316L), 1.4571 (TP316Ti)
- Copper (Cu-DHP), Aluminium (Al99,5 EN AW-1050A) and more materials on request

LASERFIN®-Finned Tubes

Application

The Laserfin finned tubes, manufactured exclusively by Schmöle, are suitable for all types of heat exchangers for cooling and heating gases and liquids. The many years of successful series and project deliveries of Laserfin finned tubes show that this product, manufactured using state-of-the-art laser technology, is particularly suitable for the following areas of application:

Power Plants

- Cooling towers or cooling water recooling plants with dry, dry / wet or wet operation
- Sodium coolers for Fast Breeder power plants
- Flue gas cooling and heating in flue gas desulfurisation scrubbers (FGD) and nitrogen removing plants (DENOX)

Chemical Industry

- Heat exchangers of all kinds for cooling and heating of liquids and gases
- Heat exchangers tor nitric acid (HNO3) plants, e.g. for the fertilizer industry

Heat Recovery Plants

- Flue gas coolers

Heating Industry

- Primary heat exchangers in gas heating boilers
- Secondary heat exchangers for domestic water heating in condensing boilers

General Engineering

- Heat exchangers for gas cooling of industrial furnaces
- Heat exchangers for tank heating
- Oil coolers for vacuum plants, ship plants, pumps etc
- Heat exchangers for oil preheating

Description

Within the large field of use of heat exchangers there are a great number of applications in which the use of finned tubes results in an optimized heat exchanger design, such as the dry cooling lowers in power plant construction and heat exchangers in the chemical industry for direct process applications.

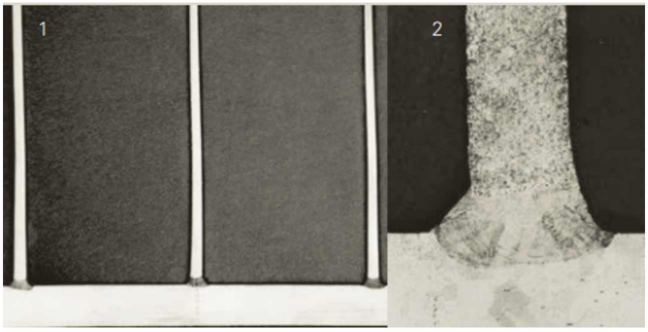
Based on many years of experience in the manufacture of finned tubes at Schmöle and in view of additional require ments we could present the Laserfin finned tube as completely unprecedented in the finned tube technology twenty years ago.

Schmöle Laserfin finned tubes are manufactured by helically winding strip onto tubes, both from standard and special stainless steel grades. The laser welding technique without filler metal developed by Schmöle allows a crevice-free weld between the strip edge and the tube.

The use of the laser technique for the welding of finned tubes offers a number of advantages due to the ability of beam to be very accurately focussed, allowing full use of the beam's high thermal capacity. These advantages are in particular:

- thin, continuous weld seam
- small heat-affected zone
- short heating time
- only slight microstructural change in tube and fin
- high utilization of heat for forming the seam
- high welding speed
- no impurity of the weld seam, as the laser welding is carried out under a protective atmosphere
- no material deformation

Advantages



Laserfin-Finned Tube Code 05 50 25

Figures 1 and 2 show cross section of Laserfin-Finned Tubes.

- Figure 1 - Dimension
  - Tube all thickness = 1,5 mm
  - Fin thickness = 0,4 mm
  - Fin height = 12,5 mm
  - Fin pitch = 5 fins/inch
- Figure 2 - Ratio of dimensions between tube wall thickness, fin thickness and heat affected zone having a depth of 0.2 mm only.

- Small heat-affected zone of the laser welding process; because of this material savings of tube and fin compared to traditional welding processes are possible
- Possibility of welding different materials for fin and tube
- Economic manufacture of high finned tubes from standard and special stainless steel grades as well as nickel-base alloys
- Increased safety because of the avoidance of crevice corrosion due to the high weld integrity between tube and fin
- Only slight discolouration at weld site

Materials

Usually we use same or similar materials for tube and strip. Manufacture of finned tubes from different materials of tube and strip on request.

This is only a selection of materials. Other materials (e.g. carbon steel or special stainless steel) on request.

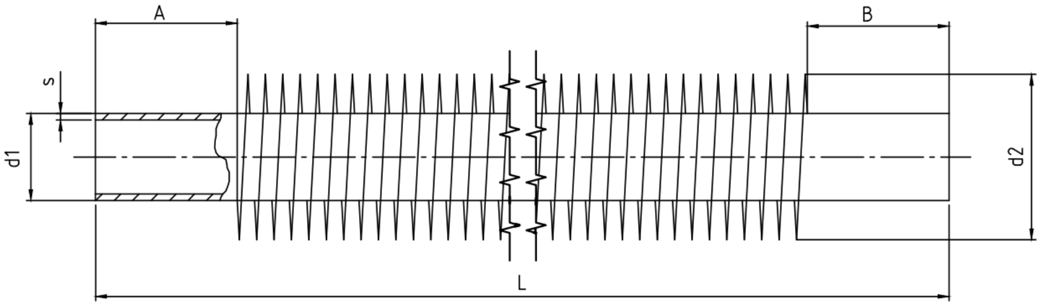
Laserfin-Finned Tubes of Schmöle are at present manufactured from the following malerials:

Material designation DIN	**Material-number DIN**	**Tube**					**Strip**
		Product standard	**Comparable US-materials**				**Product standard**
Chrom-Nickel-Steel Grades			**AISI/ SAE**	**UNS**	**ASTM standard**		
					welded	**seamless**	
X5CrNi18-10	1.4301	DIN EN 10217-7	TP304	S30400	A249	A213	DIN EN 10088
X2CrNiMo17-12-2	1.4404	DIN EN 10217-7	TP316L	S31603	A249	A213	DIN EN 10088
X2CrMoTi18-2	1.4521	DIN EN 10296-2	AISI444	S44400	-	A213	DIN EN 10088
X6CrNiMoTi17-12-2	1.4571	DIN EN 10217-7	TP316Ti	S31635	A249	A213	DIN EN 10088

LASERFIN®-Finned Tubes

Dimensions*

Schmöle Code-No.	Base tube		Finned Tube								
	Outside-Ø d1 mm	Wall thickness s1 mm	Outside-Ø d2 mm	Fin height hr mm	Mean fin thickness δr mm	Inside area qi cm2	Fin pitch		Outside surface area Aa m2 /m	Surface area ratio Aa/Ai -	ca. weight G kg/m
							1/Zoll	mm			
13 18 08	8	0,75	18	5,0	0,5	0,33	13	1,95	0,248	10,8	0,55
13 25 15	15	1,2	25	5,0	0,5	1,25	13	1,95	0,389	8,9	1,06
13 33 15	15	1,2	33	9,0	0,6	1,25	13	1,95	0,773	18,2	2,08
09 38 18	18	1,5	38	10,0	0,4	1,77	9	2,82	0,697	13,9	1,62
11 38 18	18	1,5	38	10,0	0,4	1,77	11	2,31	0,839	16,7	1,84
11 30 20	20	1,2	30	5,0	0,5	2,43	11	2,31	0,423	6,9	1,24
13 30 20	20	1,2	30	5,0	0,5	2,43	13	1,95	0,489	8,0	1,37
09 38 20	20	1,5	38	9,0	0,6	2,27	9	2,82	0,669	11,7	2,09
11 38 20	20	1,5	38	9,0	0,6	2,27	11	2,31	0,804	14,1	2,40
11 40 20	20	1,5	40	10,0	0,4	2,27	11	2,31	0,901	15,9	2,00
11 35 25	25	1,5	35	5,0	0,5	3,80	11	2,31	0,510	6,74	1,70
13 35 25	25	1,5	35	5,0	0,5	3,80	13	1,95	0,589	7,76	1,85
11 43 25	25	1,5	43	9,0	0,6	3,80	11	2,31	0,946	12,8	2,88
13 43 25	25	1,5	43	9,0	0,6	3,80	13	1,95	1,104	15,0	3,24
09 45 25	25	1,5	45	10,0	0,4	3,80	9	2,82	0,878	12,0	2,13
11 45 25	25	1,5	45	10,0	0,4	3,80	11	2,31	1,055	14,4	2,40
09 50 25	25	1,5	50	12,5	0,4	3,80	9	2,82	1,144	15,7	2,55
11 50 25	25	1,5	50	12,5	0,4	3,80	11	2,31	1,381	19,0	2,92
13 40 30	30	1,5	40	5,0	0,5	5,73	13	1,95	0,689	7,4	2,19
13 48 30	30	1,5	48	9,0	0,6	5,73	13	1,95	1,269	14,1	3,77
11 50 30	30	1,5	50	10,0	0,4	5,73	11	2,31	1,210	13,5	2,81
11 55 30	30	1,5	55	12,5	0,4	5,73	11	2,31	1,570	17,6	3,38



*Fin pitch is possible from 5 - 13 fins/inch, on request < 5 fins/inch

Forms of supply

- in straight lengths up to 12.0 m
- with unfinned ends
- with unfinned intermediate sections
- in bent form
- in coil shape

Material combinations

Tube	Fin strip
Stainless steel	Stainless steel
Stainless steel	Aluminium
Stainless steel	Copper
Carbon steel	Carbon steel
Carbon steel	Aluminium
Copper	Copper
Copper	Aluminium
Copper nickel	Copper
Copper nickel	Aluminium
Titanium	Titanium
Titanium	Copper

Dimensions

• Tube outside diameter	8 - 50 mm
• Finned tube outside diameter	18 - 80 mm
• Fin pitch	5 - 13 fins/inch
• Fin height	5 - 17 mm
• Fin thickness	0,4 - 1,0 mm
• Maximum finned tube lengths	12,000 mm

Execution of finning

Fin and tube are continuously welded. The fin pitch can vary on the tube length, for example from 9 to 13 fins/inch.

In the case of interruption of strip (e.g. change of strip coil) the tube may have one unfinned intermediate part of ≤ 6 fin pitches per 2 m finning length, i.e. a maximum of 2% of the finning length may be unfinned.

Heat transfer

The heat transfer function $Nu/Pr^{0.333}$, reffered to the outer heat transfer coefficient αa for forced gas flow through Laserfin finned tube bundles with staggered tube arrangement, can be determined according to graph 1 and equation 4.

The curve in graph 1 corresponds to the following equation for Laserfin finned tubes having a tube outside diameter of 20 mm, a fin outside diameter of 40 mm and a fin thickness of 0.4 mm:

$$Nu/Pr^{0.333} = 1.013\ Re^{0.382} \qquad [-] \qquad (1)$$

The outer heat transfer coefficient αa for air as function of the Reynolds number can be taken directly from graph 2.

The flow velocity Ve is referred to the smallest flow cross section fa in the Laserfin finned tube bundle.

The influence of the fin efficiency η on the outer heat transfer coefficient αa is already considered in the graphs 1 and 2 and in the equations 1 to 6.

Radiation coefficient

The influence of the heat radiation on the heat transfer has not been taken into account in the outer heat transfer coefficient αa. As shown in graph 3 the heat radiation is insignificant for gas temperatures below 100°C, however it is not negligible at bigger temperature differences. In this case the radiation coefficient αa may be added to the outer heat transfer coefficient αs.

Pressure drop

The pressure Δp for cross flow of gases through Laserfin finned tube bundles with staggered tube arrangement is calculated according to the following equation:

$$\Delta p = \zeta * \rho /_2 * ve^2 * n \qquad [Pa] \qquad (7)$$

The resistance coefficient ζ may be taken from graph 4.

Fin efficiency

Graph 5 shows the fin efficiency η of stainless steel being a function of the outer heat transfer coefficient αa with the fin thickness ζR as parameter.

From graph 5 it follows that for an operating point αa = 60 W/m2K halving the fin thickness from 0.8 to 0.4 mm reduces the fin efficiency η by only 17 %.

The utilization of the material savings possible with Laserfin finned tubes, e.g. using a fin thickness of 0.4 mm, will result in a considerably more favourable price/performance ratio compared with traditionally welded finned tubes having fin thicknesses of 0.8 mm or more.

Nomenclature		
a	m^2/s	Temperature coefficient
d1	mm; m	Tube outside diameter
fe	cm^3	Smallest flow cross section
hR	mm	Fin height
m	1/"; mm	Fin pitch
n	-	Number of tube rows
s	mm	Tube wall thickness
t	s	Point of time
ve	m/s	Flow velocity at smallest section
αa	W/m^2K	Outer heat transfer coefficient
αs	W/m^2K	Radiation coefficient
δr	mm	Fin thickness
Δp	Pa	Pressure drop
ζ	-	Resistance coefficient
η	-	Fin efficiency
ϑg	°C	Gas temperature
ϑg	°C	Tube temperature
ϑg	°C	Water temperature
λ	W/mK	Thermal conductivity
ν	m^2/s	Cinematic viscosity
ρ	kg/m^3	Density

The curve correspond to the following equations:

- **Fin thickness 0.8 mm**

$\alpha a = 1.624 * Re^{0.362}$ $[W/m^2 K]$ (2)

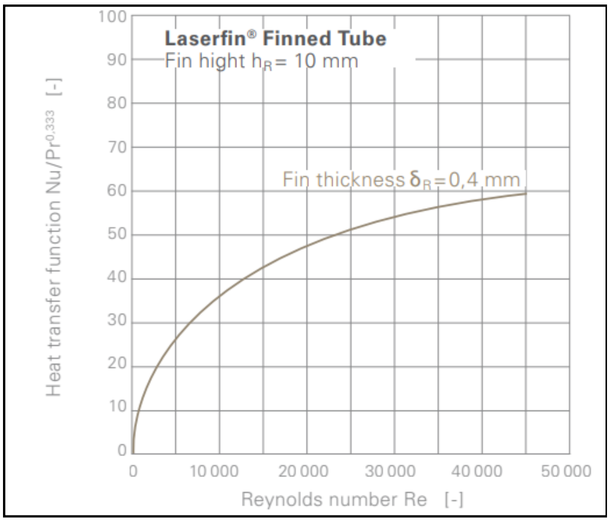
- **Fin thickness 0,4 mm**

$\alpha a = 1.374 * Re^{0,363}$ $[W/m^2 K]$ (3)

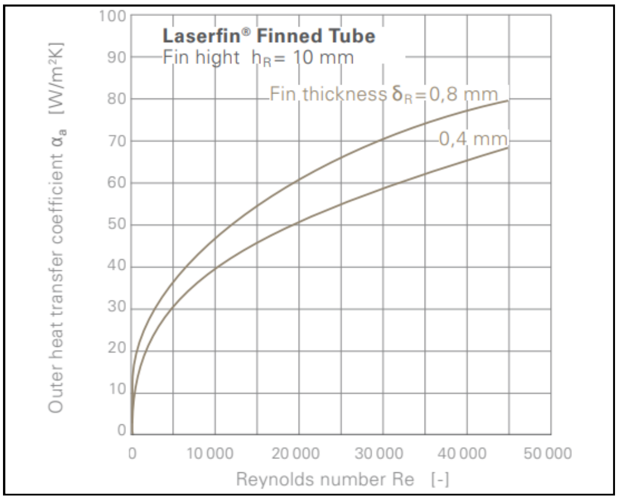
- **Definitions**

$Nu = \alpha a * d1 / \lambda$	Nußelt number	(4)
$Pr = \nu / a$	Prandlt number	(5)
$Re = Ve * d1 / \nu$	Reynolds number	(6)

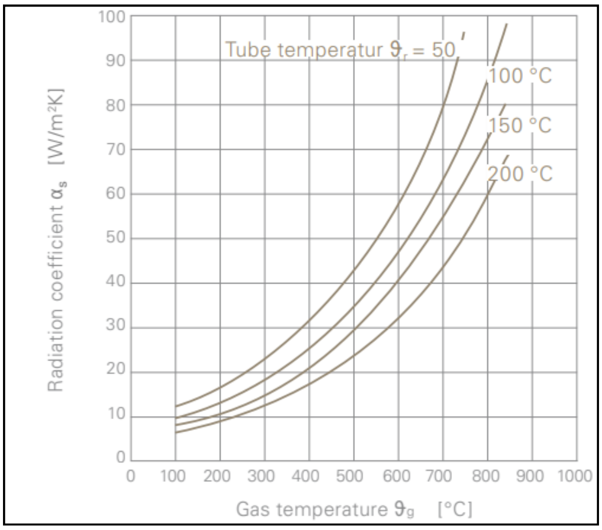
Graph 1:
Heat transfer of forced gas flow through Laserfin finned tube bundles with staggered tube arrangement



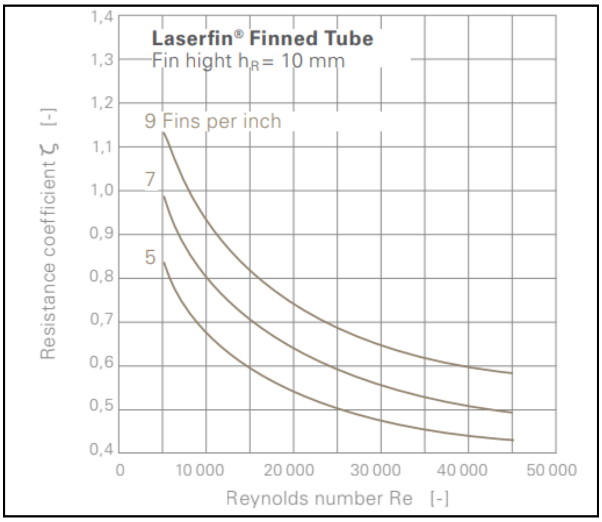
Graph 2:
Outer heat transfer coefficient αa for forced air flow through Laserfin finned tube bundles with staggered tube arrangement



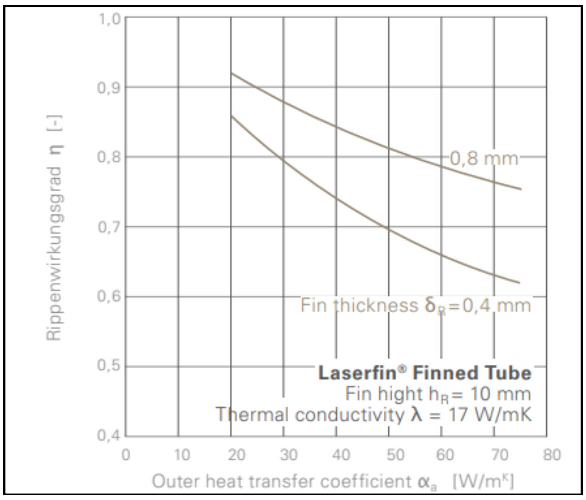
Graph 3:
Influence of heat radiation on the heat transfer



Graph 4:
Pressure drop ΔP for cross flow of gases through Laserfin finned tube bundles with staggered tube arrangement



Graph 5:
Fin efficiency η of stainless steel as a function of the outer heat transfer coefficient αa



Presentation of the heat flow by means of finite element analysis

The 100 % weld integrity between tube and fin strip results in a considerably better heat flow for Laserfin finned tubes compared with tradilionally welded finned tubes. In order to make, in this respect, both a qualitative and a quantitative statement, a comparative study by means of finite element analysis had to be conducted.

The heat flow for finned tubes having an air gap of 0.05 mm between tube and fin root (weld integrity 0 %) has been compared with the heat flow of crevice·free welded Laserfin® Finned Tubes (weld integrity 100 %).

The march of temperature, starting with 250 °C at the fin tip is shown as a comparison of graphs 6 and 7 (weld integrily 0%) with 8 and 9 (weld integrily 100 %).

Graph 10 shows the ideal march of temperature in a Laserfin finned tubes compared with an unwelded finned tube.

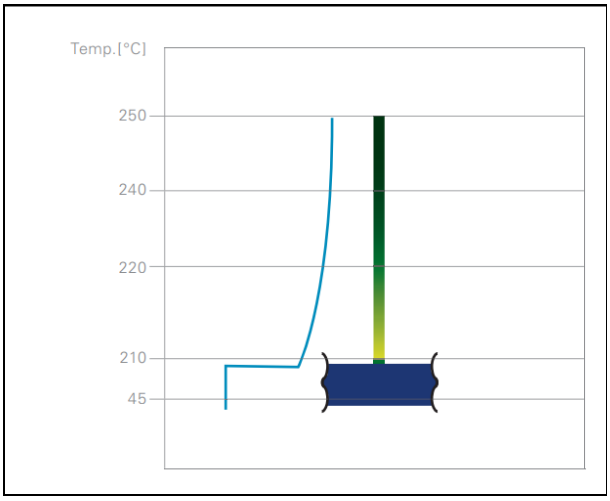
The considerably reduced material thickness of fin and tube wall as well as the 100 % weld integrity made possible by the laser welding procedure result in substantial material and weight savings when using Laserfin finned tubes compared with traditionally welded finned tubes.

These material savings do not only lead to reduced heat exchanger costs but also to further advantages as a result of smaller and cheaper total installations.

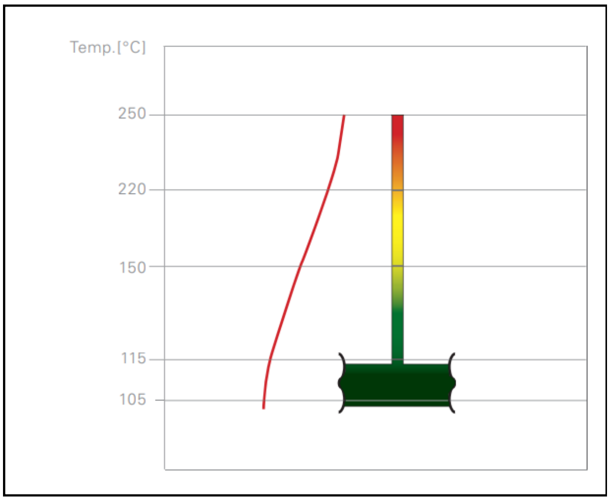
The following data has been used as a basis for the finite element analysis:

• Tube outside diameter	d1	25 mm
• Tube wall thickness	s	1.5 mm
• Fin height	h	10 mm
• Fin thickness	δr	0.4 mm
• Inner medium		water of turbulent flow
• Starting temperature		20°C
• Point of time of the temp. start	t	57 s after start of energy input

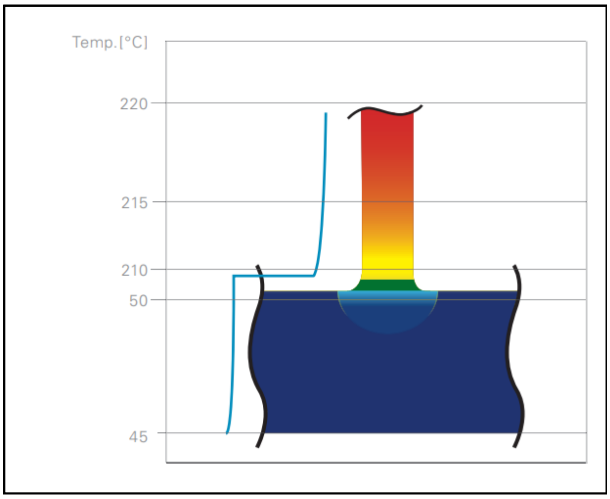
Graph 6:
Heat flow through finned tubes:
Weld integritiy 0%



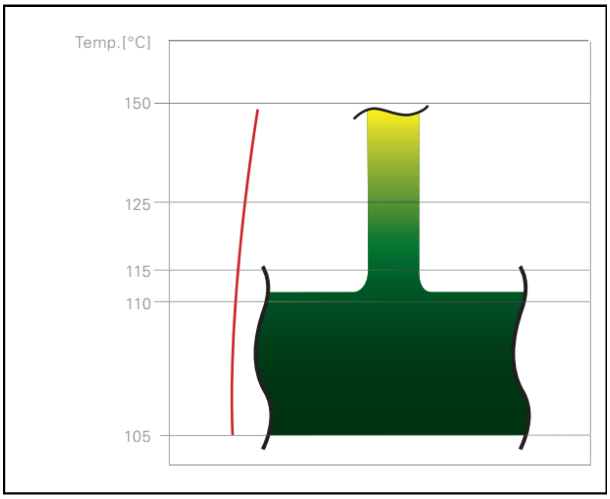
Graph 7:
Heat flow through Laserfin finned tubes:
Weld integritiy 100%



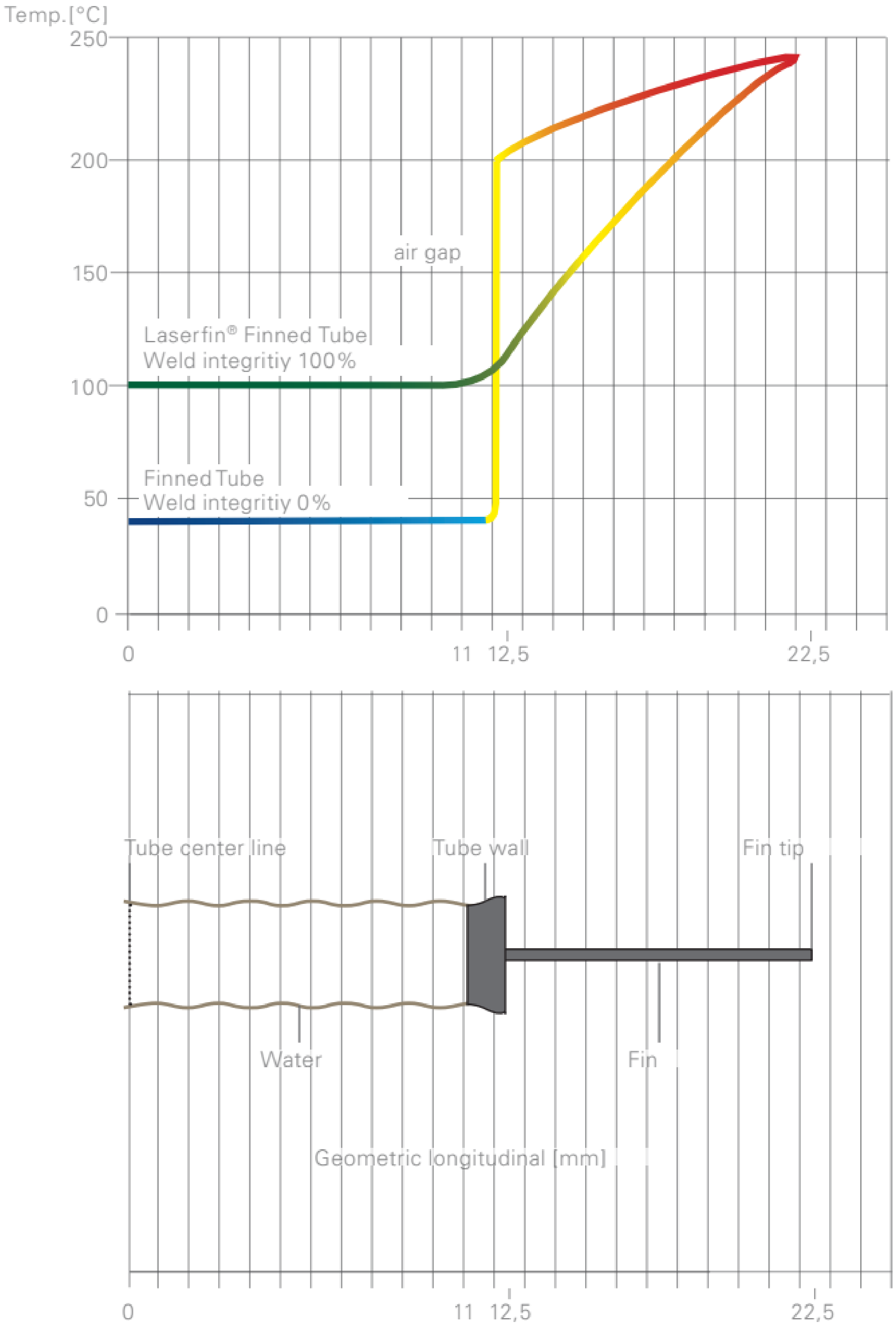
Graph 8:
Heat flow through finned tubes:
Weld integritiy 0%



Graph 9:
Heat flow through Laserfin finned tubes:
Weld integritiy 100%



Graph 10:
March of temperature in finned tubes:
Weld integrity 100% to 0%



Inspections

Base tubes
- Inspections to base standrad
- Certificate APZ 3.1 acc. EN 10204

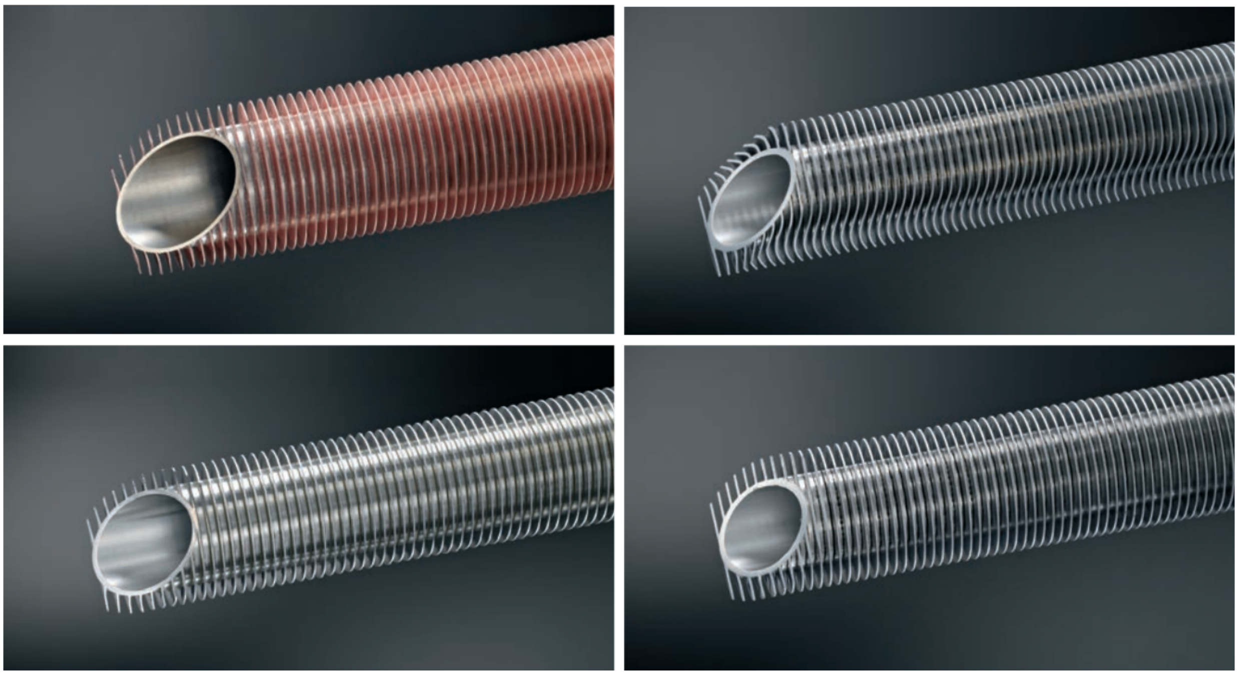
Finned tubes
- Inspections after agreement
- Certificate APZ 3.1 acc. EN 10204

Certification

TÜV Certificate for a welding procedure qualification record (WPQR)
- On customer request, a TÜV WPQR can be done
- WPQR according DIN EN ISO 15614-11, AD 2000 HP 2/1

Tube codification

Schmöle-Code-No. 5 40 20
- Fin pitch 5 fins/inch
- Fin outside diameter 40 mm
- Tube outside diameter 20 mm



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