ISABELLENHÜTTE

Technical Information

The following chapter contains practical information on the behaviour, during and after subsequent treatment, of the alloys delivered by us. This information is intended to assist in selecting the correct alloy for the appropriate application.
It cannot, of course, deal with all imaginable applications in the smallest detail. We are, however, at any time prepared to answer your questions and to help solve any problems.
A collection of the most important and most often used conversion tables concludes this chapter.

A. The Electrical Resistance and its Temperature Coefficient

Resistivity

In accordance with the equation

$$R_t = \frac{\rho_t \cdot l}{q}$$

the electrical resistance of a conductor at temperature t is proportional to its length and inversely proportional to its cross-sectional area on the condition that there is a constant cross-section over the whole test length.

R_t = Resistance in Ω at Temperature t
l = Length in m
q = Cross-Sectional area in mm²
ρ_t = Resistivity in Ω · mm²· m^{-1} at temperature t

In order to calculate

$$\rho_t = R_t \cdot \frac{q}{l}$$

R_t, q and l are determined. If

q = 1 mm² and
l = 1 m

are given, one calculates the resistivity in Ω · mm² · m^{-1}, i.e. the resistance of a conductor of 1m length and 1 mm² cross-sectional area.

The resistivity can also be defined as to be the electrical resistance of a cube with 1cm edge length; then it is expressed in units of Ω · cm. Since for base metals and alloys the resistance of such a cube is very low, the resistance values are expressed in µΩ · cm, i. e. in millionths of an Ω · cm.

The values for e.g. ISOTAN® would then be either

0.49 Ω · mm² · m^{-1}

or

49 µΩ · cm.

The practical determination of the resistivity can be difficult, since determination of the cross-sectional area of e.g. wires with non-circular cross-section or very thin wires is difficult. In such cases, the cross-sectional area is determined on the basis of weight and length.

The resistivity of a wire can then be determined in accordance with the equation:

$$\rho_t = \frac{R_t \cdot g}{\gamma} \cdot \frac{1}{l^2}$$

R_t = Resistance in Ω at Temperature *t*
ρ_t = Resistivity in Ω · mm²· m^{-1} at temperature *t*
g = Weight in g
γ = Density in γ /cm³
l = Length in m

For countries using a different system of meaurement the resistivity is expressed in units which must be converted when changing over from one system to another (see Annex “Conversion Values”):

Resistance per Meter

The resistance per meter of a conductor is determined by the quotient of its resistivity and cross-sectional values.

The Temperature Coefficient (α) of Resistivity

Metals and their alloys exhibit a dependence of the resistivity on temperature. In general the resistivity increases with temperature dependence of resistivity can be expressed by the equotion:

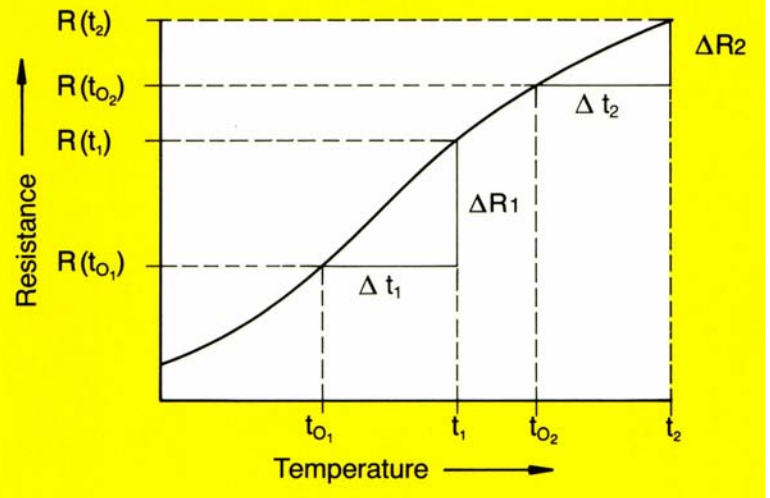
$$R_t = R_o [1 + \alpha (t - t_o)]$$

This equation applies only if resistance and temperature expose a linear relationship in the test temperature expose a linear relationship in the test temperature range from t_o to t. For most alloys and metals this is not the case, especially as regards large temperature intervals. In order to deliver an exact description of the temperature dependence of the resistivity, complicated equations are required.

In spite of this temperature coefficient is defined from the equation above as being:

$$\alpha = \frac{R_t - R_o}{R_o (t - t_o)} [K^{-1}]$$

$$\text{Resistance per Meter} = \frac{\text{Resistivity } (\Omega \cdot mm^2 . m^{-1})}{\text{Cross-sectional area } (mm^2)} = \Omega \cdot m^{-1}$$



$\Delta t_1 = \Delta t_2$
$\Delta R_1 > \Delta R_2$

It thus indicates the average variation of the resistivity per degree Kelvin in the temperature range from t_o to t, referred to the resistance value R at t_o.

When experimentally determining the temperature coefficient as well as during communication between supplier and customer two points must be observed:

1. As already mentioned, the temperature dependence of the resistivity in general does not show a linear, but a curved form. This applies particularly to certain resistance alloys and is the reason why differing temperature coefficients result from the calculations, because they depend on the part of the curve which corresponds to a certain Δ t (see the figure on page 2).

2. Due to the fact that the temperature dependent resistance variation is referred to the resistance value R_o when defining the temperature coefficient values result for different values of R_o, even if the temperature intervals chosen are of equal width.

This means that together with the value of the temperature coefficient the temperature interval from °C to °C must always be quoted. Comparison of test results is possible only if the test conditions are the same.

In some alloys the temperature coefficient can be controlled by combining certain alloy components. It can then achieve negative values or values around 0 between room temperature and appr. 100°C.

Dependence of Resistivity in $\Omega \cdot mm^2 \cdot m^{-1}$ on Temperature for Various Alloys

Alloy	20°C	100°C	200°C	300°C	400°C	500°C	600°C	700°C	800°C	900°C	1000°C	1100°C	1200°C
ISAOHM	1,32	1,32	1,32	—	—	—	—	—	—	—	—	—	—
ISA-CHROM 60	1,13[1]	1,14	1,16	1,18	1,20	1,22	1,21	1,21	1,22	1,23	1,24	1,26	1,28
	(1,11)[2]	(1,12)	(1,14)	(1,16)	(1,18)	(1,22)	—	—	—	—	—	—	—
ISA-CHROM 80	1,12[1]	1,13	1,13	1,14	1,15	1,16	1,15	1,14	1,14	1,14	1,15	1,16	1,17
	(1,08)[2]	(1,09)	(1,10)	(1,12)	(1,14)	(1,16)	—	—	—	—	—	—	—
ISA-CHROM 30	1,04	1,07	1,11	1,14	1,17	1,20	1,22	1,24	1,26	1,28	1,30	1,32	—
ISOTAN	0,49	0,49	0,49	0,49	0,49	0,49	—	—	—	—	—	—	—
ISA-NICKEL	0,45	0,48	0,49	0,51	0,52	0,53	0,55	0,56	—	—	—	—	—
MANGANIN	0,43	0,43	—	—	—	—	—	—	—	—	—	—	—
NICKELIN W	0,40	0,404	0,41	0,417	0,424	0,432	—	—	—	—	—	—	—
RESISTHERM	0,33	0,41	0,52	0,64	0,76	0,89	1,02	—	—	—	—	—	—
ISAZIN	0,30	0,304	0,31	0,315	0,321	0,326	—	—	—	—	—	—	—
ZERANIN 30	0,29	0,29	—	—	—	—	—	—	—	—	—	—	—
Alloy 127	0,21	0,215	0,221	0,228	0,234	—	—	—	—	—	—	—	—
Alloy 90	0,15	0,156	0,162	0,169	0,175	—	—	—	—	—	—	—	—
ISA 13	0,125	0,129	0,133	—	—	—	—	—	—	—	—	—	—
Alloy 60	0,10	0,107	0,114	0,123	—	—	—	—	—	—	—	—	—
Pure Nickel	0,09	0,13	0,19	0,25	0,32	0,38	0,41	—	—	—	—	—	—
Special Nickel	0,077	0,11	0,17	—	—	—	—	—	—	—	—	—	—
Alloy 30	0,05	0,057	0,064	—	—	—	—	—	—	—	—	—	—
A-Copper	0,025	0,031	0,039	—	—	—	—	—	—	—	—	—	—
Pure-Copper	0,0172	0,023	0,031	—	—	—	—	—	—	—	—	—	—

1) These values apply to a state of equilibrium.
2) These values apply to a state after rapid cooling; see also **B. "Special Characteristics of Nickel-Chromium-Alloys".**

B. Special Characteristics of Nickel-Chromium Alloys

The resistivity of nickel-chromium alloys shows a special characteristic. At temperatures below 500°C it is affected by the rate with which the alloy has been cooled from high temperatures, e.g. after annealing, and it decreases with increasing cooling rate. This behaviour is shown schematically in the graph on the right.

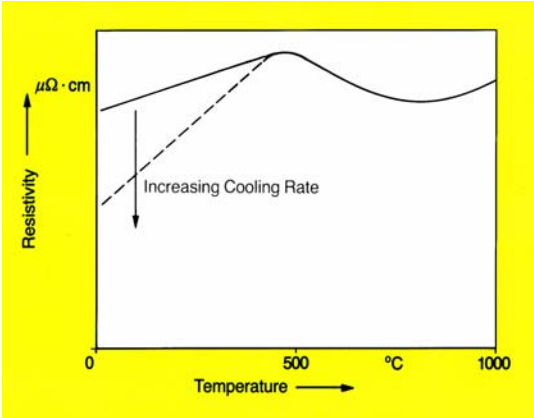
The solid line represents the so-called state of equilibrium, i.e. the resistivity of an annealed wire after slow cooling. The dotted line indicates how the resistivity below 500°C changes for lower values by rapid cooling. Rapid cooling takes place e.g. with thin wires after strand annealing.

This effect is strongest for wires of nonferrous nickel-chromium alloys, like NiCr8020. It is weaker for nickel-chromium NiCr6015 and can be neglected for nickel-chromium NiCr3020.

In addition, since with normal strand annealing the cooling rate increases with decreasing wire diameter, this effect will become stronger, too, as the wire diameter becomes smaller.

For NiCr8020 and NiCr6015, assuming normal annealing conditions, the resistance decrease between 1 and 0.01mm diam. amounts to appr. 1.3 resp. 0.5%. For ISAOHM® the decrease amounts to appr. 5% because of a varying composition.

For resistance wires of NiCr alloys no sliding resistivity has been standardized; instead an average resistivity is quoted (see also DIN 17471). It should be born in mind, however, that this value for NiCr8020 and NiCr6015 is lower than the value quoted in DIN 17470 for heating resistors.



Effect of Pre-Treatment on the Temperature Dependence of the Resistance on ISA-CHROM 80®.

C. Surface Loading Capacity

Generation of heat has great importance in electrical engineering, no matter whether it should be controlled as far as possible or whether it is intended to be used.

The main questions to be answered in this connection is what temperature a current-carrying wire, ribbon, sheet etc. will reach during operation.

Answering this question is somewhat difficult, since the determining factors, like type of insulation and shape of the resistive conductor, cooling conditions, surface deterioration during operation and other properties of the material, which for their part again depend on the temperature, can often only be a matter for conjecture.

Current-Carrying Capacity of Wires

In order to make things easier to control, simple models, suitable to be converted into practical solutions, are chosen for tests and measurements. Such a model is formed e.g. by a straight bare wire, stretched in still air of 20°C, whereby the natural movement of the air is in no way impeded, and which is loaded by current. This model has the advantage that the temperature of the wire can be determined on the basis of its thermal expansion in addition to other methods.

If a current i flows through a conductor with the length l and the resistance R, then the electrical power P, converted into heat, is calculated as follows:

$P = i^2 \cdot R$

Inserting

$$R = \rho \cdot \frac{l}{q}$$

the following results:

$$P = \frac{i^2 \cdot \rho \cdot l \cdot 4}{\pi \cdot d^2}$$

The amount of heat created per cm² of wire surface is called the surface load n of the wire; it is expressed in watts (W) per square centimeter (cm^{-2}).
Using the above formula, then after inserting the determining values for the surface in the following results:

$$n = \frac{i^2 \cdot \rho_t \cdot 0.04053}{d^3}$$

i = Current in Amps
ρ_t = Resistivity in Ω x mm" x m^{-1}
at temperature t (°C)
d = Wire diameter in mm

The surface load is a measure of the temperature the wire will achieve under given environmental conditions. It is not a material-dependent quality, but must be chosen in accordance with the respective conductor material and application.

The upper limit should, of course, be determined on the basis of the maximum working temperature of the conductor in order to ensure adequate scale and corrosion resistance etc.

Fig.1 shows the relationships between surface load and wire operating temperature for wires of different materials with 0.5mm diam.

In general, a current-carrying wire very quickly achieves, after switching-on the current, a stationary state, in which the amount of heat produced within a unit of time equals the amount of heat dissipated. When using the model mentioned above: “Streched wire in still air of 20°C”, then the heat is dissipated by convection – removal through air flow – and radiation. Under the conditions quoted the heat is removed mainly by convection, while heat removal by radiation is worth mentioning only at temperatures >400 – 600°C. The share of heat radition, however, increases with temperature by a factor of T^4.

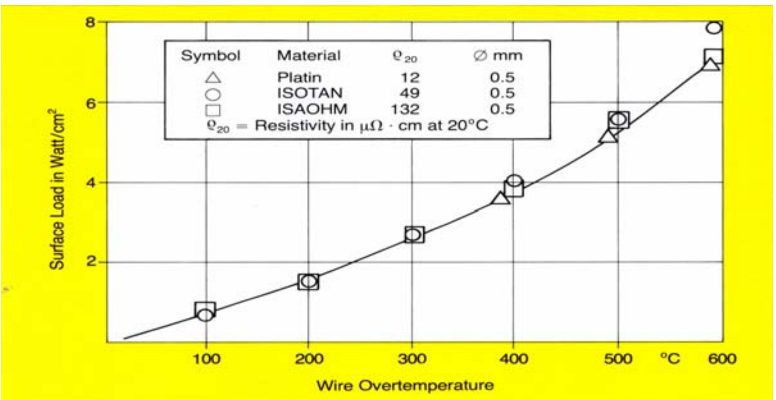
The diameter of the conductor, too, affects the kind of heat dissipation. Fig. 2 shows the interaction of convection and radiation in dependence on the wire diameter. In the area of the hatched border line heat removal by convection equals that by radiation. At lower temperatures and smaller wire diameters heat removal by convection prevails; at higher temperatures and larger wire diameters heat removal by radiation is in excess.

Fig. 2 shows also that the share of convection in heat dissipation grows with decreasing wire diameter. This is due to the fact that for thinner wires the heat transfer from wire to air improves considerably. In practice this means that, for the same operating temperature, thin wires can be loaded more heavily than thick wires.

By suppressing convection, e.g. by lowering the atmospheric pressure, the curve is shifted to the left; this means that the share of radiation increases. On the other hand the curve can be shifted to the right e.g. by using a fan. Provided the electrical power is kept constant, in the latter case the wire temperature would be substantially lower.

The diagrams mentioned above – Figs. 1 and 2 – apply to horizontally arranged straight wires in still air. In practice this arrangement is very rarely chosen, especially for thin wires. Wires wound on cores or

Fig. 1: Overtemperature of Wire against Air in Dependence on the Surface Load in Watt/cm² and on Different Materials.



arranged in the form of a spiral permit much smaller surface loads since the heat dissipating wire surface is strongly reduced as compared with freely stretched wires.

In case of a bobbin being densely wound with resistance wire, the surface of this structure can be taken as the reference quantity for the value "Watt per cm²". This means that the diameter of the wound bobbin can be taken as "wire diameter". The result is that for such a structure at a given surface load in W/cm² the surface temperature will be considerably higher than for a single wire.

Fig. 3 shows the possible current-carrying capacity in Watt/cm² for different temperatures dependent on the "wire" diameter. Bobbins should be referred to in this diagram by the bobbin diameter. Since the current-carrying capacity in Watt per cm² is given, this diagram applies to all Isabellenhütte alloys. The interrelationship between current loads (Amps) and resulting temperature for an ISOTAN® wire of 0.5mm diam. can be seen from Fig. 4. It must be kept in mind, however, that for this type of presentation the curves for materials with different resistivities are also different, unlike the previous figures.

As shown in Fig. 1, a given surface load – expressed in Watt per cm² - causes equal wire temperatures for every alloy. Therefore the current load values for equal wire diameters can be converted by the following formula:

P = constant, thus $i_1^2 \cdot R_1 = i_2^2 \cdot R_2$

Thus : $i_1 = i_2 \cdot \sqrt{\frac{R_2}{R_1}}$

and : : $i_1 = i_2 \cdot \sqrt{\frac{\rho_2}{\rho_1}}$

The following tables show, with ISOTAN® as an example, the geometrical data between 0.02 and 6.3mm diam. as well as the current-carrying capacity values in Amps for 40/60/80/100/200/300/400/500 and 600°C. In accordance with the above formula, the current values are converted in accordance with:

$$i_x = i_{ISOTAN} \cdot \sqrt{\frac{0.49}{\rho_x}}$$

where i_x refers to the current for a wire of an alloy with the resistivity ρ. It must be kept in mind that for ρ the values valid for ρ the respective temperature must be used (see the tables on pages 7 + 8).

The current-carrying capacity tables all refer to bare wire; due to better heat dissipation, oxidized wires (only possible for the alloys ISA-CHROM60®, ISA-CHROM80® and ISOTAN®) can withstand a load increase of up to 20%, expressed in Watt per cm², mainly at higher temperatures.

The current-carrying capacities of enamelled wires are about the same as those of bare wires are about the same as those of bare wires. The heat insulation effect of the enamel is compensated by the increase of the effective diameter and good heat dissipation properties. Silk-covered wires exhibit strongly varying loading capacities, depending on the kind of manufacturing process and type; the respective value must be determined individually.

Fig. 4

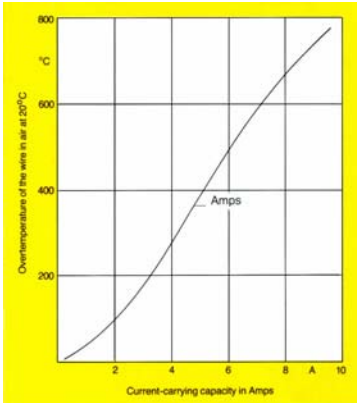
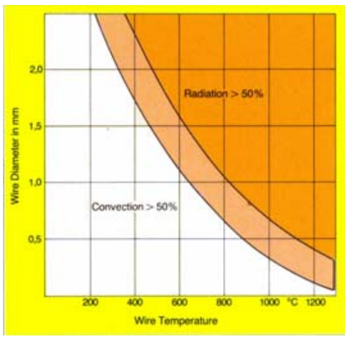


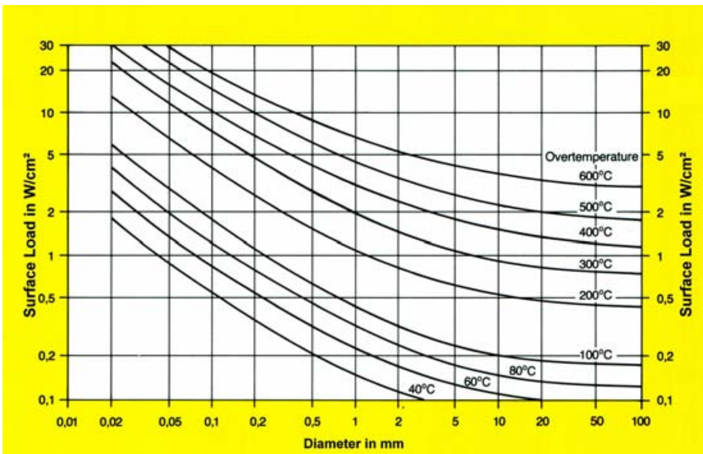
Fig. 4: Current-carrying capacity of ISOTAN® wire of 0.5mm diam. in dependence on overtemperature of the wire against air at 20°C (100°C overtemperature correspond to a real temperature of 120°C).

Fig. 2



Comparison of the share of radiation and convection effects in heat dissipation of resistance wires in air at 20°C. In the dark boundary area heat dissipation by convection about equals that by radiation. On the right of the boundary area radiation prevails; on the left convection has the larger share.

Fig. 3



Diameter in mm	ISOTAN® Resistance in Ω/m	Amps for an Overtemperature of: 40°C		60°C		80°C		100°C		200°C	
		I in A	Surface Load in W/cm^2	I in A	Surface Load in W/cm^2	I in A	Surface Load in W/cm^2	I in A	Surface Load in W/cm^2	I in A	Surface Load in W/cm^2
0,020	1560	0,0270	1,82	0,0342	2,92	0,0410	4,20	0,0479	5,69	0,0724	13,0
0,022	1290	0,0305	1,75	0,0381	2,74	0,0450	3,82	0,0534	5,31	0,0807	12,1
0,025	998	0,0353	1,60	0,0441	2,49	0,0520	3,47	0,0617	4,84	0,0933	11,1
0,028	796	0,0402	1,48	0,0502	2,30	0,0600	3,29	0,0703	4,46	0,106	10,2
(0,030)	693	0,0437	1,41	0,0546	2,21	0,0650	3,13	0,0764	4,29	0,115	9,70
0,032	609	0,0467	1,33	0,0584	2,08	0,0690	2,90	0,0818	4,05	0,124	9,26
0,036	481	0,0534	1,22	0,0668	1,92	0,0790	2,68	0,0935	3,72	0,140	8,51
0,040	390	0,0606	1,15	0,0757	1,79	0,0900	2,53	0,106	3,45	0,160	7,89
0,045	308	0,0691	1,05	0,0864	1,64	0,102	2,28	0,121	3,17	0,183	7,26
0,050	249	0,0777	0,966	0,0971	1,51	0,115	2,12	0,136	2,94	0,206	6,74
0,056	199	0,0880	0,880	0,110	1,38	0,130	1,92	0,154	2,68	0,235	6,22
(0,060)	173	0,0960	0,853	0,120	1,33	0,142	1,87	0,168	2,58	0,254	5,93
0,063	157	0,101	0,816	0,126	1,27	0,150	1,80	0,177	2,49	0,269	5,73
(0,070)	127	0,114	0,758	0,143	1,19	0,169	1,67	0,200	2,32	0,303	5,33
0,071	124	0,116	0,752	0,145	1,17	0,172	1,65	0,203	2,29	0,308	5,27
0,080	97,5	0,133	0,691	0,166	1,08	0,197	1,52	0,233	2,11	0,354	4,86
0,090	77,0	0,153	0,642	0,191	1,00	0,226	1,40	0,267	1,94	0,406	4,48
0,100	62,4	0,173	0,600	0,216	0,933	0,254	1,29	0,302	1,81	0,458	4,17
(0,110)	51,6	0,193	0,560	0,241	0,873	0,286	1,23	0,337	1,69	0,512	3,91
0,112	49,7	0,197	0,554	0,246	0,865	0,292	1,22	0,345	1,68	0,523	3,86
(0,120)	43,3	0,213	0,524	0,266	0,818	0,315	1,15	0,372	1,59	0,567	3,69
0,125	39,9	0,223	0,510	0,279	0,798	0,331	1,12	0,391	1,55	0,594	3,59
(0,130)	36,9	0,234	0,498	0,292	0,775	0,347	1,09	0,409	1,51	0,622	3,50
0,140	31,8	0,255	0,475	0,319	0,742	0,378	1,04	0,446	1,44	0,679	3,33
(0,150)	27,7	0,276	0,452	0,345	0,706	0,409	0,993	0,483	1,37	0,736	3,18
0,160	24,4	0,297	0,430	0,371	0,671	0,441	0,949	0,520	1,31	0,794	3,05
0,180	19,3	0,342	0,401	0,428	0,628	0,508	0,885	0,599	1,22	0,911	2,83
0,200	15,6	0,386	0,372	0,482	0,581	0,572	0,818	0,675	1,13	1,03	2,64
(0,220)	12,9	0,433	0,354	0,541	0,552	0,642	0,778	0,758	1,07	1,16	2,49
0,224	12,4	0,441	0,347	0,551	0,542	0,653	0,761	0,771	1,05	1,18	2,46
0,250	9,98	0,503	0,324	0,629	0,507	0,746	0,713	0,880	0,982	1,35	2,30
0,280	7,96	0,577	0,303	0,721	0,473	0,856	0,666	1,01	0,914	1,54	2,14
(0,300)	6,93	0,623	0,287	0,778	0,448	0,924	0,632	1,12	0,875	1,67	2,06
0,315	6,29	0,663	0,281	0,828	0,438	0,983	0,612	1,16	0,849	1,77	2,00
(0,320)	6,09	0,672	0,275	0,843	0,433	1,00	0,609	1,18	0,841	1,81	1,98
(0,350)	5,09	0,748	0,261	0,936	0,406	1,11	0,574	1,31	0,796	2,01	1,87
0,355	4,95	0,760	0,258	0,950	0,404	1,13	0,571	1,33	0,789	2,05	1,86
0,40	3,90	0,880	0,242	1,10	0,378	1,31	0,536	1,54	0,734	2,37	1,73
0,45	3,08	1,01	0,224	1,26	0,349	1,50	0,494	1,77	0,684	2,73	1,62
0,50	2,49	1,15	0,212	1,44	0,332	1,70	0,462	2,01	0,644	3,10	1,53
(0,55)	2,06	1,29	0,200	1,61	0,315	1,92	0,444	2,26	0,609	3,49	1,45
0,56	1,99	1,32	0,198	1,65	0,309	1,95	0,432	2,31	0,603	3,57	1,44
(0,60)	1,73	1,43	0,189	1,79	0,297	2,13	0,420	2,51	0,580	3,88	1,39
0,63	1,57	1,53	0,187	1,91	0,292	2,26	0,409	2,67	0,565	4,12	1,35
(0,65)	1,48	1,58	0,182	1,98	0,285	2,35	0,402	2,77	0,555	4,29	1,33
(0,70)	1,27	1,74	0,177	2,17	0,275	2,58	0,388	3,04	0,533	4,70	1,28
0,71	1,24	1,77	0,175	2,21	0,273	2,62	0,383	3,09	0,529	4,78	1,27
0,75	1,11	1,89	0,169	2,36	0,264	2,81	0,374	3,31	0,514	5,12	1,23
0,80	0,975	2,05	0,164	2,56	0,256	3,03	0,359	3,58	0,496	5,55	1,19
0,85	0,864	2,21	0,159	2,76	0,248	3,27	0,348	3,86	0,481	5,99	1,16
0,90	0,770	2,37	0,154	2,96	0,240	3,51	0,338	4,14	0,467	6,43	1,13
0,95	0,691	2,53	0,149	3,16	0,233	3,75	0,328	4,43	0,454	6,89	1,10
1,00	0,624	2,70	0,146	3,37	0,227	4,00	0,320	4,72	0,442	7,35	1,07
(1,10)	0,516	3,04	0,139	3,80	0,217	4,51	0,306	5,32	0,422	8,30	1,03
1,12	0,497	3,11	0,138	3,88	0,215	4,61	0,304	5,44	0,418	8,49	1,02
(1,20)	0,433	3,39	0,133	4,24	0,208	5,03	0,292	5,94	0,405	9,27	0,986
1,25	0,399	3,57	0,131	4,46	0,204	5,30	0,288	6,25	0,397	9,77	0,969
1,40	0,318	4,12	0,124	5,16	0,194	6,12	0,273	7,22	0,377	11,3	0,923
1,50	0,277	4,50	0,120	5,63	0,188	6,68	0,265	7,88	0,365	12,3	0,896
1,60	0,244	4,89	0,117	6,11	0,182	7,25	0,256	8,56	0,355	13,4	0,873
1,80	0,193	5,69	0,110	7,12	0,174	8,43	0,244	9,95	0,337	15,7	0,833
2,00	0,156	6,50	0,106	8,14	0,166	9,66	0,233	11,4	0,323	17,9	0,800
(2,20)	0,129	7,37	0,102	9,21	0,160	10,9	0,224	12,9	0,311	20,4	0,773
2,24	0,124	7,54	0,101	9,43	0,159	11,2	0,222	13,2	0,307	20,9	0,768
2,50	0,0998	8,74	0,098	10,9	0,152	13,0	0,217	15,3	0,296	24,1	0,739
2,80	0,0796	10,1	0,094	12,6	0,144	15,0	0,205	17,7	0,284	28,1	0,712
3,00	0,0693	11,1	0,092	13,9	0,143	16,4	0,199	19,4	0,277	30,7	0,696
3,15	0,0629	11,8	0,089	14,8	0,140	17,5	0,198	20,7	0,272	32,9	0,685
(3,20)	0,0609	12,1	0,089	15,1	0,139	18,0	0,197	21,2	0,271	33,6	0,682
(3,50)	0,0509	13,6	0,086	17,1	0,137	20,2	0,190	23,8	0,263	37,9	0,664
3,55	0,0495	13,9	0,086	17,4	0,135	20,6	0,189	24,3	0,262	38,6	0,661
4,00	0,0390	16,3	0,083	20,4	0,130	24,1	0,181	28,5	0,252	45,4	0,639
4,50	0,0308	19,1	0,080	23,8	0,124	28,3	0,176	33,4	0,243	53,3	0,619
5,00	0,0249	22,0	0,077	27,6	0,122	32,7	0,171	38,6	0,236	61,6	0,602
5,50	0,0206	25,0	0,075	31,3	0,118	37,1	0,166	43,8	0,229	70,3	0,589
5,60	0,0199	25,7	0,075	32,1	0,117	38,1	0,165	44,9	0,228	72,0	0,586
6,00	0,0173	28,2	0,074	35,3	0,115	41,9	0,162	49,4	0,224	79,2	0,577
6,30	0,0157	30,2	0,073	37,8	0,114	44,8	0,161	52,9	0,222	84,8	0,571

Diameter in mm	ISOTAN® Resistance in Ω/m	Amps for an Overtemperature of: 300°C		400°C		500°C		600°C	
		I in A	Surface Load in W/cm²	I in A	Surface Load in W/cm²	I in A	Surface Load in W/cm²	I in A	Surface Load in W/cm²
0,020	1560	0,0964	23,0	0,110	30,1	0,133	44,2	0,144	51,3
0,022	1290	0,109	22,2	0,123	28,3	0,149	41,4	0,161	48,3
0,025	998	0,124	19,6	0,143	25,9	0,173	38,0	0,188	44,7
0,028	796	0,138	18,1	0,163	24,0	0,197	35,2	0,215	41,7
(0,030)	693	0,153	17,2	0,177	23,0	0,214	33,7	0,233	40,0
0,032	609	0,165	16,4	0,191	22,0	0,231	32,3	0,252	38,5
0,036	481	0,188	15,1	0,219	20,3	0,265	29,8	0,290	35,8
0,040	390	0,212	14,0	0,247	19,0	0,300	27,8	0,329	33,6
0,045	308	0,243	12,9	0,284	17,6	0,344	25,8	0,379	31,4
0,050	249	0,274	11,9	0,321	16,4	0,389	24,0	0,431	29,5
0,056	199	0,312	11,0	0,367	15,2	0,445	22,3	0,494	27,6
(0,060)	173	0,338	10,5	0,398	14,6	0,482	21,4	0,537	26,5
0,063	157	0,358	10,2	0,422	14,1	0,511	20,7	0,569	25,7
(0,070)	127	0,404	9,43	0,478	13,2	0,578	19,3	0,646	24,1
0,071	124	0,411	9,34	0,486	13,1	0,588	19,2	0,658	24,0
0,080	97,5	0,471	8,60	0,559	12,1	0,677	17,8	0,760	22,4
0,090	77,0	0,540	7,94	0,648	11,4	0,785	16,8	0,877	21,0
0,100	62,4	0,610	7,39	0,728	10,5	0,882	15,4	0,966	19,7
(0,110)	51,6	0,682	6,93	0,816	9,92	0,985	14,5	1,12	18,7
0,112	49,7	0,696	6,84	0,833	9,81	1,01	14,4	1,15	18,5
(0,120)	43,3	0,754	6,53	0,905	9,40	1,10	13,8	1,25	17,8
0,125	39,9	0,791	6,36	0,950	9,16	1,15	13,4	1,31	17,4
(0,130)	36,9	0,828	6,20	0,995	8,95	1,21	13,1	1,37	17,1
0,140	31,8	0,903	5,90	1,09	8,55	1,32	12,5	1,51	16,4
(0,150)	27,7	0,979	5,64	1,18	8,20	1,43	12,0	1,64	15,8
0,160	24,4	1,06	5,40	1,28	7,89	1,55	11,6	1,77	15,3
0,180	19,3	1,21	5,01	1,47	7,35	1,78	10,8	2,05	14,3
0,200	15,6	1,37	4,68	1,67	6,91	2,02	10,1	2,34	13,6
(0,220)	12,9	1,54	4,41	1,87	6,54	2,27	9,59	2,63	12,9
0,224	12,4	1,57	4,36	1,91	6,47	2,32	9,49	2,69	12,8
0,250	9,98	1,79	4,07	2,19	6,07	2,65	8,91	3,08	12,1
0,280	7,96	2,05	3,80	2,51	5,70	3,04	8,35	3,55	11,4
(0,300)	6,93	2,23	3,64	2,73	5,48	3,31	8,04	3,87	11,0
0,315	6,29	2,36	3,54	2,90	5,33	3,51	7,82	4,12	10,8
(0,320)	6,09	2,41	3,50	2,96	5,29	3,58	7,76	4,20	10,7
(0,350)	5,09	2,68	3,32	3,30	5,04	4,00	7,39	4,70	10,2
0,355	4,95	2,72	3,29	3,36	5,00	4,07	7,33	4,79	10,2
0,40	3,90	3,15	3,07	3,89	4,69	4,71	6,87	5,57	9,60
0,45	3,08	3,63	2,87	4,50	4,40	5,45	6,46	6,46	9,09
0,50	2,49	4,13	2,71	5,13	4,17	6,21	6,12	7,39	8,69
(0,55)	2,06	4,64	2,57	5,77	3,97	6,99	5,83	8,35	8,31
0,56	1,99	4,75	2,55	5,91	3,94	7,15	5,78	8,54	8,24
(0,60)	1,73	5,17	2,45	6,44	3,81	7,80	5,58	9,33	8,00
0,63	1,57	5,49	2,39	6,84	3,72	8,29	5,45	9,94	7,83
(0,65)	1,48	5,70	2,35	7,18	3,66	8,62	5,37	10,3	7,73
(0,70)	1,27	6,26	2,26	7,81	3,53	9,46	5,18	11,4	7,49
0,71	1,24	6,37	2,25	7,96	3,51	9,63	5,15	11,6	7,45
0,75	1,11	6,82	2,19	8,53	3,42	10,3	5,10	12,4	7,28
0,80	0,975	7,39	2,12	9,25	3,32	11,2	4,87	13,5	7,09
0,85	0,864	7,97	2,05	9,99	3,23	12,1	4,73	14,6	6,92
0,90	0,770	8,57	2,00	10,7	3,14	13,0	4,61	15,8	6,77
0,95	0,691	9,17	1,95	11,5	3,07	13,9	4,50	16,9	6,62
1,00	0,624	9,78	1,90	12,3	3,00	14,9	4,40	18,1	6,50
(1,10)	0,516	11,0	1,82	13,9	2,88	16,8	4,22	20,5	6,27
1,12	0,497	11,3	1,80	14,2	2,86	17,2	4,19	21,0	6,22
(1,20)	0,433	12,3	1,75	15,5	2,78	18,8	4,07	23,0	6,07
1,25	0,399	13,0	1,72	16,4	2,73	19,8	4,00	24,3	5,98
1,40	0,318	15,0	1,63	19,0	2,61	23,0	3,82	28,2	5,74
1,50	0,277	16,4	1,59	20,8	2,54	25,2	3,72	30,9	5,61
1,60	0,244	17,9	1,55	22,6	2,47	27,4	3,63	33,7	5,49
1,80	0,193	20,8	1,48	26,4	2,37	32,0	3,47	39,4	5,28
2,00	0,156	23,9	1,42	30,3	2,28	36,7	3,34	45,4	5,11
(2,20)	0,129	27,1	1,37	34,4	2,21	41,7	3,23	51,6	4,96
2,24	0,124	27,8	1,36	35,2	2,19	42,7	3,21	52,9	4,94
2,50	0,0998	32,1	1,31	40,8	2,11	49,4	3,10	61,4	4,78
2,80	0,0796	37,4	1,26	47,5	2,04	57,4	2,99	71,6	4,63
3,00	0,0693	41,0	1,23	52,1	1,99	63,1	2,93	78,6	4,54
3,15	0,0629	43,7	1,21	55,6	1,97	67,4	2,88	84,1	4,49
(3,20)	0,0609	44,7	1,21	56,8	1,96	68,8	2,87	85,9	4,47
(3,50)	0,0509	50,4	1,18	64,2	1,91	77,7	2,79	97,1	4,37
3,55	0,0495	51,4	1,17	65,4	1,90	79,2	2,78	99,1	4,35
4,00	0,0390	60,4	1,13	76,9	1,84	93,2	2,69	117	4,23
4,50	0,0308	71,0	1,10	90,4	1,78	109	2,61	137	4,11
5,00	0,0249	82,0	1,07	104	1,73	127	2,54	159	4,02
5,50	0,0206	93,7	1,05	119	1,69	144	2,48	182	3,94
5,60	0,0199	95,9	1,04	122	1,69	148	2,47	186	3,92
6,00	0,0173	105	1,02	134	1,60	163	2,44	205	3,87
6,30	0,0157	113	1,01	144	1,64	174	2,41	220	3,83

In the following some examples are given:

Example 1

Problem:
What current is required to increase the temperature by 200°C of ISA13® wire with a diameter of 0.20mm?

Solution:

a) From the table can be seen that the value for ISOTAN® wire with equal diameter is 1.03 Amps.

b) This value must be converted for ISA 13® in accordance with the previously quoted formula; this results in

$$i_X = 1.03 \cdot \sqrt{\frac{0.49}{0.13}} = \begin{array}{l} 1.03 \cdot 1.94 \\ \cong 2 Amps \end{array}$$

where 0.49 is the resistivity of ISOTAN® and 0.13 the resistivity of ISA13®, at 200°C, resprectively.

Result:
An ISA13® wire with a diameter of 0.20mm must be loaded with a current of 2 Amps in order to increase its temperature by 200°C.

Example 2

Problem:
What is the temperature increase of ISA-CHROM 60® wire with a diameter of 1.0mm, if it is loaded with a current of 8 Amps?

Solution:

a) In accordance with the previously quoted formula, for 20°C the conversion factor for ISA-CHROM 60® alloy is calculated to be

$$\sqrt{\frac{0.49}{1.11^{1)}}} = 0.664$$

b) In order to get the load value for ISOTAN® wire with equal diameter, the value for ISA-CHROM 60® must be divided by this value, thus

$$i_{ISOTAN} = \frac{8 Amps}{0.664} = 12 Amps$$

This results in a value of 12 Amps for ISOTAN® alloy.

If an ISOTAN® wire of equal diameter is loaded with the calculated 12 Amps, its temperature will increase by somewhat less than 400°C. As can be seen from the table on page 8, an overtemperature of 400°C is achieved by applying a current of 12.3 Amps.

The conversion factor determined as per a) applies to 20°C; it must now be re-determinded for 400°C. It is 0.644, resulting from

$$\sqrt{\frac{0.49}{1.18^{1)}}}$$

where 0.49 is the resistivity of ISOTAN® and 1.18 that of ISA-CHROM 60®, at 400°C, respectively.

Now if the load current of 8 Amps for ISA-CHROM 60® at 400°C is re-calculated for ISOTAN® , a value of 12.4 Amps for ISOTAN® wire with equal diameter will result. Since for 400°C a value of 12.3 Amps applies, one gets the following:

Result:
If an ISA-CHROM 60® wire with a diameter of 1.0mm is loaded with a current of 8 Amps, its temperature will increase by somewhat more than 400°C.

.

1) These values apply to a state after rapid cooling

Current-Carrying Capacity of Flat Wires

For round wires the diameter is sufficient to determine the data previously quoted. For ribbons the thickness and above all, the width must be taken into consideration.

When making comparisons, the table containing the cross-sectional values of standard ribbons with rounded-off edges vs. those of round wires should be consulted.

At high temperature (600°C) or if for other reasons the proportion of heat dissipation by radiation exceeds the dissipation by convection, flat wires and ribbons of any dimension have a current-carrying capacity greater than that of round wires with an equal cross-sectional area, due to their larger surface area.

In the event that the heat dissipation takes place mainly by convection - generally at low temperatures -, then the current carrying capacity of flat wires and ribbons will exceed that of flat wires of an equal cross-sectional area only for ratios between width and thickness of more than 15 : 1.

If flat wires are wound around a carrier there will be a larger contact area available for heat transfer to the carrier by heat conductance as compares with round wires, but no generally valid data can be given as to a possibly higher current-carrying capacity. For heat dissipation to the outside, of course, only a part i. e. one half of the surface of the ribbon is available; this must be kept in mind when making calculations.

The following tables give information on the resistance, surface and weight of flat ISOTAN® wires, referenced at 1 m. In addition they contain data as to the load currents for ribbons of ISOTAN® at overtemperatures of 100/200/300 and 400°C.

The following should be mentioned:

Since the edges are rounded-off, the cross-sectional area and resistance of flat wires are calculated by the formula below.

Calculation of the Cross-Sectional Area and Resistance of Flat Wires

R = $\frac{\rho \cdot l \cdot 10^{-3}}{a(b - a \cdot 0.215)}$

Q = $a(b - a \cdot 0.215)$

O = $[a(\pi - 2) + 2b] \cdot l$

a = Thickness in mm
b = Width in mm
l = Length in mm
R = Resistance in Ω
Q = Cross-sectional area in mm"
O = Surface in mm²
ρ = Resistivity in Ω ·mm · m^{-1}

The values in the current-carrying capacity tables refer to bare wired or bare ribbon. Oxidized wire and ribbon can, due to improved heat dissipation, withstand a load increase of up to 20 %, expressed in Watt per cm^2.

The current-carrying capacity of ribbons of other alloys can be using the same method as described for wires.

Diameter of Round Wires of Equal Cross-Sectional Area in mm

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	0,25	0,36	0,44	0,50	0,56	0,62	0,67	0,71	0,76	0,80
0,06	0,27	0,39	0,48	0,55	0,62	0,68	0,73	0,78	0,83	0,87
0,07	0,30	0,42	0,52	0,60	0,67	0,73	0,79	0,84	0,89	0,94
0,08	0,32	0,45	0,55	0,64	0,71	0,78	0,84	0,90	0,96	1,01
0,09	0,34	0,48	0,58	0,68	0,76	0,83	0,89	0,96	1,01	1,07
0,10	0,35	0,50	0,62	0,71	0,80	0,87	0,94	1,01	1,07	1,13
0,12	0,39	0,55	0,67	0,78	0,87	0,96	1,03	1,10	1,17	1,23
0,14	0,42	0,59	0,73	0,84	0,94	1,03	1,11	1,19	1,26	1,33
0,16	0,44	0,63	0,78	0,90	1,01	1,10	1,19	1,27	1,35	1,42
0,18	0,47	0,67	0,82	0,95	1,07	1,17	1,26	1,35	1,43	1,51
0,20	0,49	0,71	0,87	1,00	1,12	1,23	1,33	1,42	1,51	1,59
0,22	0,52	0,74	0,91	1,05	1,18	1,29	1,40	1,49	1,58	1,67
0,24	0,54	0,77	0,95	1,10	1,23	1,35	1,46	1,56	1,65	1,74
0,26	0,56	0,80	0,99	1,14	1,28	1,40	1,52	1,62	1,72	1,81
0,28	0,58	0,83	1,02	1,19	1,33	1,46	1,57	1,68	1,79	1,88
0,30	0,60	0,86	1,06	1,23	1,37	1,51	1,63	1,74	1,85	1,95
0,35	0,64	0,93	1,14	1,32	1,48	1,62	1,76	1,88	1,99	2,10
0,40	0,68	0,99	1,22	1,41	1,58	1,74	1,88	2,01	2,13	2,25
0,45	0,72	1,04	1,29	1,50	1,68	1,84	1,99	2,13	2,26	2,38
0,50	0,75	1,10	1,36	1,57	1,76	1,94	2,09	2,24	2,38	2,51
0,60		1,20	1,48	1,72	1,93	2,12	2,29	2,45	2,60	2,75
0,70		1,28	1,59	1,85	2,08	2,28	2,47	2,64	2,81	2,96
0,80		1,36	1,70	1,97	2,22	2,44	2,64	2,82	3,00	3,16
0,90		1,44	1,79	2,09	2,35	2,58	2,79	2,99	3,18	3,35
1,00		1,51	1,88	2,20	2,47	2,71	2,94	3,15	3,34	3,53
1,20			2,05	2,39	2,69	2,96	3,21	3,44	3,65	3,86
1,40			2,19	2,57	2,89	3,19	3,46	3,70	3,94	4,16
1,60			2,33	2,73	3,08	3,39	3,68	3,95	4,20	4,44
1,80			2,45	2,88	3,25	3,59	3,89	4,18	4,44	4,69
2,00			2,56	3,02	3,41	3,77	4,09	4,39	4,67	4,94

A = Thickness, b = Width

Surface of Flat Wires in cm² · m⁻¹

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
	20,6	40,6	60,6	80,6	101	121	141	161	181	201
0,06	20,7	40,7	60,7	80,7	101	121	141	161	181	201
0,07	20,8	40,8	60,8	80,8	101	121	141	161	181	201
0,08	20,9	40,9	60,9	80,9	101	121	141	161	181	201
0,09	21,0	41,0	61,0	81,0	101	121	141	161	181	201
0,10	21,1	41,1	61,1	81,1	101	121	141	161	181	201
0,12	21,4	41,4	61,4	81,4	101	121	141	161	181	201
0,14	21,6	41,6	61,6	81,6	102	122	142	162	182	202
0,16	21,8	41,8	61,8	81,8	102	122	142	162	182	202
0,18	22,1	42,1	62,1	82,1	102	122	142	162	182	202
0,20	22,3	42,3	62,3	82,3	102	122	142	162	182	202
0,22	22,5	42,5	62,5	82,5	103	123	143	163	183	203
0,24	22,7	42,7	62,7	82,7	103	123	143	163	183	203
0,26	23,0	43,0	63,0	83,0	103	123	143	163	183	203
0,28	23,2	43,2	63,2	83,2	103	123	143	163	183	203
0,30	23,4	43,4	63,4	83,4	103	123	143	163	183	203
0,35	24,0	44,0	64,0	84,0	104	124	144	164	184	204
0,40	24,6	44,6	64,6	84,6	105	125	145	165	185	205
0,45	25,1	45,1	65,1	85,1	105	125	145	165	185	205
0,50	25,7	45,7	65,7	85,7	106	126	146	166	186	206
0,60		46,8	66,8	86,8	107	127	147	167	187	207
0,70		48,0	68,0	88,0	108	128	148	168	188	208
0,80		49,1	69,1	89,1	109	129	149	169	189	209
0,90		50,3	70,3	90,3	110	130	150	170	190	210
1,00		51,4	71,4	91,4	111	131	151	171	191	211
1,20			73,7	93,7	114	134	154	174	194	214
1,40			76,0	96,0	116	136	156	176	196	216
1,60			78,3	98,3	118	138	158	178	198	218
1,80			80,5	101	121	141	161	181	201	221
2,00			82,8	103	123	143	163	183	203	223

a = Thickness, b = Width

Flat Wires of ISOTAN® - Grams per Meter (g · m⁻¹)

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	0,44	0,89	1,3	1,8	2,2	2,7	3,1	3,6	4,0	4,4
0,06	0,53	1,1	1,6	2,1	2,7	3,2	3,7	4,3	4,8	5,3
0,07	0,61	1,2	1,9	2,5	3,1	3,7	4,4	5,0	5,6	6,2
0,08	0,70	1,4	2,1	2,8	3,5	4,3	5,0	5,7	6,4	7,1
0,09	0,79	1,6	2,4	3,2	4,0	4,8	5,6	6,4	7,2	8,0
0,10	0,87	1,8	2,7	3,5	4,4	5,3	6,2	7,1	8,0	8,9
0,12	1,0	2,1	3,2	4,2	5,3	6,4	7,4	8,5	9,6	10,7
0,14	1,2	2,5	3,7	4,9	6,2	7,4	8,7	9,9	11,2	12,4
0,16	1,4	2,8	4,2	5,6	7,1	8,5	9,9	11,3	12,8	14,2
0,18	1,5	3,1	4,7	6,3	7,9	9,6	11,2	12,8	14,4	16,0
0,20	1,7	3,5	5,3	7,0	8,8	10,6	12,4	14,2	15,9	17,7
0,22	1,9	3,8	5,8	7,7	9,7	11,7	13,6	15,6	17,5	19,5
0,24	2,0	4,2	6,3	8,4	10,6	12,7	14,8	17,0	19,1	21,2
0,26	2,2	4,5	6,8	9,1	11,4	13,8	16,1	18,4	20,7	23,0
0,28	2,3	4,8	7,3	9,8	12,3	14,8	17,3	19,8	22,3	24,8
0,30	2,5	5,2	7,8	10,5	13,2	15,8	18,5	21,2	23,9	26,5
0,35	2,9	6,0	9,1	12,2	15,3	18,5	21,6	24,7	27,8	30,9
0,40	3,3	6,8	10,4	13,9	17,5	21,1	24,6	28,2	31,7	35,3
0,45	3,6	7,6	11,6	15,6	19,6	23,6	27,6	31,7	35,7	39,7
0,50	4,0	8,4	12,9	17,3	21,8	26,2	30,7	35,1	39,6	44,0
0,60		10,0	15,3	20,7	26,0	31,4	36,7	42,0	47,4	52,7
0,70		11,5	17,8	24,0	30,2	36,4	42,7	48,9	55,1	61,4
0,80		13,0	20,1	27,3	34,4	41,5	48,6	55,7	62,9	70,0
0,90		14,5	22,5	30,5	38,5	46,5	54,5	62,5	70,5	78,6
1,00		15,9	24,8	33,7	42,6	51,5	60,4	69,3	78,2	87,1
1,20			29,3	40,0	50,6	61,3	72,0	82,7	93,4	104
1,40			33,6	46,1	58,5	71,0	83,5	95,9	108	121
1,60			37,8	52,1	66,3	80,5	94,8	109	123	138
1,80			41,9	57,9	73,9	89,9	106	122	138	154
2,00			45,7	63,5	81,3	99,1	117	135	153	170

a = Thickness, b = Width

Current-Carrying Capacity of Flat Wires of ISOTAN®
in Amps for an Overtemperature of 100°C
Horizontally stretched in still air of 20°C

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	0,93	1,60	2,13	2,66	3,20	3,64	4,12	4,56	5,03	5,51
0,06	1,02	1,75	2,33	2,91	3,50	3,98	4,50	4,99	5,51	6,03
0,07	1,10	1,89	2,52	3,15	3,78	4,31	4,87	5,40	5,96	6,52
0,08	1,17	2,02	2,69	3,36	4,04	4,60	5,20	5,77	6,36	6,96
0,09	1,25	2,14	2,85	3,56	4,28	4,88	5,51	6,11	6,74	7,38
0,10	1,31	2,25	3,00	3,75	4,51	5,14	5,80	6,43	7,10	7,77
0,12	1,44	2,45	3,29	4,11	4,94	5,63	6,35	7,04	7,78	8,51
0,14	1,55	2,67	3,55	4,44	5,34	6,08	6,87	7,61	8,41	9,20
0,16	1,66	2,85	3,80	4,75	5,71	6,50	7,35	8,14	9,00	9,84
0,18	1,76	3,02	4,03	5,04	6,05	6,89	7,79	8,63	9,53	10,4
0,20	1,85	3,19	4,25	5,31	6,38	7,27	8,22	9,10	10,0	11,0
0,22	1,95	3,34	4,46	5,57	6,70	7,63	8,62	9,55	10,5	11,5
0,24	2,03	3,49	4,66	5,82	7,00	7,97	9,00	10,0	11,0	12,0
0,26	2,12	3,64	4,84	6,06	7,28	8,29	9,37	10,4	11,5	12,5
0,28	2,20	3,77	5,03	6,28	7,55	8,60	9,72	10,8	11,9	13,0
0,30	2,27	3,91	5,21	6,51	7,82	8,91	10,1	11,2	12,3	13,5
0,35	2,46	4,22	5,62	7,03	8,45	9,63	10,9	12,1	13,3	14,6
0,40	2,62	4,51	6,00	7,51	9,02	10,3	11,6	12,9	14,2	15,5
0,45	2,78	4,78	6,37	7,97	9,58	10,9	12,3	13,7	15,1	16,5
0,50	2,93	5,04	6,72	8,40	10,1	11,5	13,0	14,4	15,9	17,4
0,60		5,52	7,36	9,21	11,1	12,6	14,2	15,8	17,4	19,1
0,70		5,97	7,95	9,94	12,0	13,6	15,4	17,0	18,8	20,6
0,80		6,37	8,49	10,6	12,8	14,5	16,4	18,2	20,1	22,0
0,90		6,77	9,02	11,3	13,6	15,4	17,4	19,3	21,3	23,3
1,00		7,13	9,50	11,9	14,3	16,3	18,4	20,4	22,5	24,6
1,20			10,4	12,9	15,6	17,7	20,0	22,2	24,5	26,8
1,40			11,2	14,0	16,9	19,2	21,7	24,0	26,5	29,0
1,60			12,0	15,0	18,0	20,5	23,2	25,7	28,3	31,0
1,80			12,8	15,9	19,1	21,8	24,6	27,3	30,1	33,0
2,00			13,5	16,8	20,1	22,9	25,9	28,7	31,7	34,7

a = Thickness, b = Width

Current-Carrying Capacity of Flat Wires of ISOTAN®
in Amps for an Overtemperature of 200°C
Horizontally stretched in still air of 20°C

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	1,40	2,26	3,11	3,94	4,75	5,53	6,29	7,06	7,86	8,60
0,06	1,53	2,47	3,41	4,31	5,19	6,05	6,88	7,72	8,60	9,38
0,07	1,66	2,68	3,68	4,66	5,62	6,55	7,45	8,35	9,30	10,1
0,08	1,77	2,86	3,93	4,98	6,00	7,00	7,95	8,91	9,93	10,8
0,09	1,88	3,03	4,17	5,28	6,36	7,41	8,43	9,45	10,5	11,5
0,10	1,98	3,19	4,39	5,56	6,70	7,81	8,88	9,95	11,1	12,1
0,12	2,17	3,49	4,81	6,09	7,34	8,55	9,72	10,9	12,1	13,3
0,14	2,34	3,78	5,20	6,58	7,93	9,24	10,5	11,8	13,1	14,3
0,16	2,50	4,04	5,56	7,04	8,48	9,88	11,2	12,6	14,0	15,3
0,18	2,65	4,28	5,89	7,46	8,99	10,5	11,9	13,4	14,9	16,2
0,20	2,80	4,51	6,21	7,87	9,48	11,0	12,6	14,1	15,7	17,1
0,22	2,94	4,74	6,52	8,25	9,94	11,6	13,2	14,8	16,5	18,0
0,24	3,07	4,95	6,81	8,62	10,40	12,1	13,8	15,4	17,2	18,8
0,26	3,19	5,15	7,09	8,98	10,8	12,6	14,3	16,1	17,9	19,5
0,28	3,31	5,34	7,35	9,31	11,2	13,1	14,9	16,7	18,6	20,3
0,30	3,43	5,53	7,62	9,64	11,6	13,5	15,4	17,3	19,2	21,0
0,35	3,71	5,98	8,23	10,4	12,6	14,6	16,6	18,6	20,7	22,7
0,40	3,96	6,38	8,78	11,1	13,4	15,6	17,8	19,9	22,2	24,2
0,45	4,20	6,78	9,33	11,8	14,2	16,6	18,9	21,1	23,6	25,7
0,50	4,43	7,17	9,85	12,4	15,0	17,5	19,9	22,3	24,8	27,1
0,60		7,75	10,8	13,6	16,4	19,1	21,8	24,4	27,2	29,7
0,70		8,45	11,6	14,7	17,7	20,8	23,5	26,4	29,4	32,1
0,80		9,03	12,4	15,7	19,0	22,1	25,1	28,2	31,4	34,2
0,90		9,58	13,2	16,7	20,1	23,4	26,7	29,9	33,3	36,3
1,00		10,10	13,9	17,6	21,2	24,7	28,1	31,5	35,1	38,3
1,20			15,2	19,2	23,1	26,9	30,6	34,3	38,3	41,7
1,40			16,4	20,8	25,0	29,1	33,2	37,2	41,4	45,2
1,60			17,5	22,2	26,7	31,1	35,4	39,7	44,2	48,3
1,80			18,6	23,6	28,4	33,1	37,7	42,2	47,0	51,3
2,00			19,6	24,8	29,9	34,8	39,6	44,4	49,5	54,0

a = Thickness, b = Width

Current-Carrying Capacity of Flat Wires of ISOTAN®
in Amps for an Overtemperature of 300°C
Horizontally stretched in still air of 20°C

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	1,94	3,09	4,19	5,33	6,43	7,55	8,62	9,70	10,7	11,8
0,06	2,12	3,38	4,58	5,83	7,03	8,26	9,43	10,6	11,7	12,9
0,07	2,29	3,66	4,96	6,31	7,61	8,93	10,2	11,5	12,7	13,9
0,08	2,45	3,91	5,29	6,73	8,12	9,54	10,9	12,3	13,5	14,9
0,09	2,59	4,14	5,61	7,14	8,61	10,1	11,6	13,0	14,3	15,8
0,10	2,73	4,36	5,91	7,52	9,07	10,6	12,2	13,7	15,1	16,6
0,12	2,99	4,77	6,47	8,24	9,93	11,7	13,3	15,0	16,5	18,1
0,14	3,23	5,16	7,00	8,90	10,7	12,6	14,4	16,2	17,9	19,6
0,16	3,46	5,52	7,48	9,52	11,5	13,5	15,4	17,3	19,1	21,0
0,18	3,66	5,85	7,93	10,1	12,2	14,3	16,3	18,4	20,3	22,3
0,20	3,86	6,17	8,36	10,6	12,8	15,1	17,2	19,4	21,4	23,5
0,22	4,05	6,47	8,77	11,2	13,5	15,8	18,1	20,3	22,4	24,6
0,24	4,23	6,76	9,16	11,7	14,1	16,5	18,9	21,2	23,4	25,7
0,26	4,41	7,04	9,54	12,1	14,6	17,2	19,6	22,1	24,4	26,8
0,28	4,57	7,30	9,89	12,6	15,2	17,8	20,4	22,9	25,3	27,8
0,30	4,73	7,56	10,2	13,0	15,7	18,5	21,1	23,7	26,2	28,8
0,35	5,11	8,17	11,1	14,1	17,0	20,0	22,8	25,6	28,3	31,3
0,40	5,46	8,72	11,8	15,0	18,1	21,3	24,3	27,4	30,2	33,2
0,45	5,80	9,26	12,5	15,9	19,3	22,6	25,8	29,1	32,1	35,2
0,50	6,11	9,72	13,2	16,8	20,3	23,8	27,2	30,6	33,8	37,1
0,60		10,7	14,5	18,4	22,2	26,1	29,8	33,6	37,2	40,7
0,70		11,6	15,7	19,9	24,0	28,2	32,2	36,2	40,0	43,9
0,80		12,3	16,7	21,3	25,7	30,1	34,4	38,7	42,7	46,9
0,90		13,1	17,7	22,6	27,2	32,0	36,5	41,1	45,4	49,8
1,00		13,8	18,7	23,8	28,7	33,7	38,5	43,3	47,8	52,5
1,20			20,4	25,9	31,3	36,7	42,0	47,2	52,1	57,2
1,40			22,1	28,1	33,9	39,8	45,5	51,1	56,4	61,9
1,60			23,6	30,0	36,2	42,5	48,5	54,6	60,2	66,1
1,80			25,1	31,9	38,5	45,2	51,6	58,0	64,1	70,3
2,00			26,4	33,6	40,5	47,5	54,3	61,1	67,4	74,0

a = Thickness, b = Width

Current-Carrying Capacity of Flat Wires of ISOTAN®
in Amps for an Overtemperature of 400°C
Horizontally stretched in still air of 20°C

thickness	width / b in mm									
a in mm	1	2	3	4	5	6	7	8	9	10
0,05	2,44	3,88	5,3	6,7	8,1	9,5	10,9	12,3	13,6	15,0
0,06	2,67	4,2	5,8	7,3	8,8	10,4	11,9	13,4	14,9	16,4
0,07	2,89	4,6	6,3	7,9	9,6	11,2	12,9	14,5	16,1	17,7
0,08	3,08	4,9	6,7	8,4	10,2	12,0	13,8	15,5	17,2	18,9
0,09	3,27	5,2	7,1	8,9	10,8	12,7	14,6	16,4	18,2	20,0
0,10	3,44	5,5	7,5	9,4	11,4	13,4	15,4	17,3	19,2	21,1
0,12	3,8	6,0	8,2	10,3	12,5	14,7	16,8	18,9	21,0	23,1
0,14	4,1	6,5	8,8	11,1	13,5	15,9	18,2	20,5	22,7	25,0
0,16	4,4	6,9	9,5	11,9	14,4	17,0	19,4	21,9	24,3	26,7
0,18	4,6	7,3	10,0	12,6	15,3	18,0	20,6	23,3	25,8	28,3
0,20	4,9	7,7	10,5	13,3	16,1	19,0	21,7	24,5	27,2	29,9
0,22	5,1	8,1	11,1	14,0	16,9	19,9	22,8	25,7	28,5	31,3
0,24	5,3	8,5	11,6	14,6	17,7	20,8	23,8	26,8	29,8	32,7
0,26	5,6	8,8	12,0	15,2	18,4	21,6	24,8	27,9	31,0	34,1
0,28	5,8	9,2	12,5	15,8	19,1	22,4	25,7	28,9	32,2	35,4
0,30	6,0	9,5	12,9	16,3	19,8	23,2	26,6	30,0	33,3	36,6
0,35	6,5	10,2	14,0	17,6	21,4	25,1	28,8	32,4	36,0	39,5
0,40	6,9	10,9	14,9	18,8	22,8	26,8	30,7	34,6	38,4	42,2
0,45	7,3	11,6	15,8	20,0	24,2	28,5	32,6	36,7	40,8	44,8
0,50	7,7	12,2	16,7	21,1	25,5	30,0	34,4	38,7	43,0	47,2
0,60		13,4	18,3	23,1	28,0	32,9	37,7	42,4	47,1	51,8
0,70		14,5	19,6	24,9	30,2	35,5	40,7	45,8	50,9	55,9
0,80		15,5	21,1	26,6	32,3	37,9	43,4	48,9	54,4	59,7
0,90		16,4	22,4	28,3	34,3	40,2	46,1	51,9	57,7	63,4
1,00		17,3	23,6	29,8	36,1	42,4	48,6	54,7	60,8	66,8
1,20			25,7	32,5	39,3	46,2	53,0	59,6	66,3	72,8
1,40			27,8	35,2	42,6	50,0	57,3	64,5	71,7	78,8
1,60			29,7	37,5	45,5	53,4	61,2	68,9	76,6	84,2
1,80			31,6	40,0	48,4	56,8	65,1	73,3	81,5	89,5
2,00			33,3	42,0	50,9	59,8	68,5	77,1	85,7	94,2

a = Thickness, b = Width

D. Technical Terms of Delivery and Tolerances

Availables Types

Our alloys are available in the form of

- annealed bare wires; on request ISOTAN®, ISA-CHROM 60® and ISA-CHROM 80® can be manufactured with an insulation oxide film;
- enamelled wires with or without synthetic (rayon) or silk or glass fibre cover;
- annealed flat wires with rounded-off edges (calculation of cross-sectional area see page 10);
- annealed ribbons, also in sheet or panel form;
- foils;
- stranded wires.

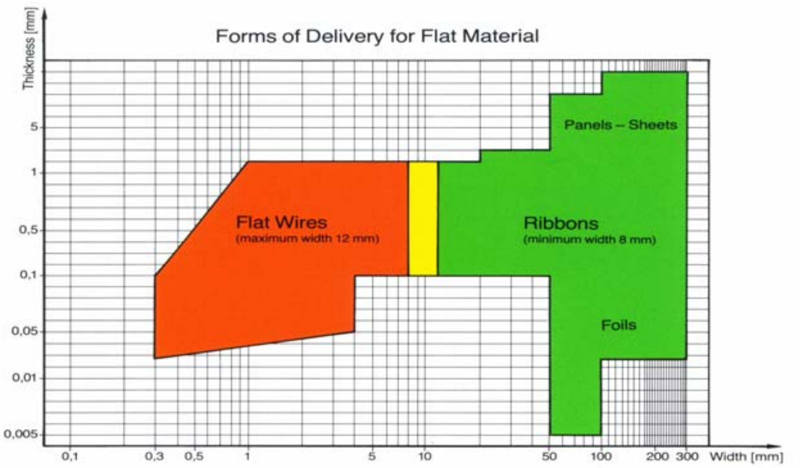
On request our alloys can also be delivered with special hardnesses.

Dimensional Range

- Bare wires 0.01 – 8mm ∅
- Insulated wires 0.01 – 2mm ∅
- Flat wires 0.05 – 1mm ∅ thickness
- Metal sheets and panels 0.10 – 10mm ∅ thickness
- Foils 0.005 – 0.10 mm ∅ thickness

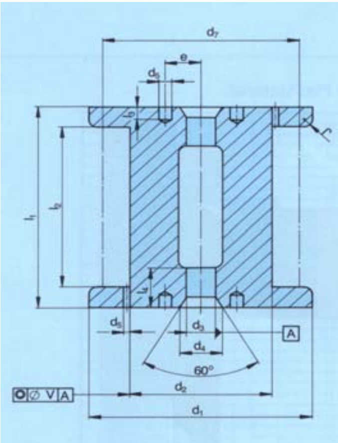
The dimensional ranges are illustrated in the following diagram; details are given on request.

- Strands up to a cross-sectional area of 4.0mm² with up to 48 single wires.



Packing

Wires of less than 1mm diam. and flat wires of less than 0.80mm thickness and a maximum width of 5mm are delivered on plastic spools according to DIN IEC 264 resp. on American standard spools in accordance with the tables on the right.



Insulated wires are delivered on plastic spools as for bare wires.
Stranded wires are delivered on special spools holding up to 100kg per spool in one length.
Ribbon with a maximum width of 10mm can be delivered on special spools; ribbon of more than 10mm width is delivered spirally wound in the form of disks with an inner diameter of 100mm and an outer diameter of 300mm maximum.
Wires with a diameter of more than 1mm can be delivered on spools or wound in coils as per the table on the right.

Spools according to DIN IEC264

Spool Dimensions (mm)					Weight of Wound-Up Wire	On Plastic Spools Round Wires up to 1.0 Diam. Flat Wires up to 5.0mm Width and 0.8mm Thickness			
Spool Diameter			Spool Width			</= 0.10	> 0.10	> 0.40	> 0,70
d_1	d_2	d_3	l_1	l_2	kg appr.		</= 0.40	</= 0.70	</= 1.00
50	32	11	50	38	0.1	+			
63	40	11	63	49	0.4	+			
80	50	16	80	64	0.7	+	+		
100	63	16	100	80	1.5		+		
125	80	16	125	100	3.0		+	+	
160	100	22	160	128	7.0		+	+	+
200	125	22	200	160	13.0		+	+	+
250	160	22	200	160	23.0		+	+	+
355	224	36	200	160	45.0			+	+
500	315	36	250	180	80.0				+

American Spools

63	44.3	16	61	51	0.25	Designation 060 "Half-Cut"
63	44.3	16	86	76	0.45	Designation 065 "1 lb Spool"

Special spool

for wires > 0.8mm diam. with reference to DIN IEC 264

560	315	127	400	300	200	>0.8mm

Coils

Round Wires > 1mm diam.			Flat Wires > 5.0mm Width > 0.8mm Thickness
Wire Diameter resp. Width (mm)	Inner Diameter of Coil (mm) appr.	Outer Diameter of Coil (mm) appr.	Weight of Coil (kg) appr.
> 1.0 - 2.5	300	400	20
> 2.5 - 6.0	550	700	60

Technical Terms of Delivery

For bare wires the terms of delivery of DIN 46460, part 1, apply; dimensions and resistance values are standardized in DIN 46461 and 46463.
In general for linear resistance a tolerance of ±5% from the nominal value applies; this may increase to ±10% maximum for thin wires and low resistance alloys. Within one wire length the tolerance is appr. ±1% maximum from the actual resistance per meter.
The wire diameter may deviate from the nominal value by appr. ± 2.4% maximum. For oxidized wires the technical terms of delivery are summarized in DIN 46464.

Wires insulated by an oxide layer can be used at temperatures up to the maximum working temperature for bare wires. The break-down voltage is more than 10V for ISOTAN® and more than 3 V for the nickel-chromium alloys ISA-CHROM 80® and ISA-CHROM 60®. For enamelled and silk-covered wires the terms of delivery of DIN 46460, Parts 2 – 4, and DIN 46462 apply.

Enamelled wires are treated with a so-called solderable enamel (DIN designation Type V); the wires may be directly tinned if the alloys permits. On request a high-temperature resistant enamel (DIN designation Type W200), usable at temperatures of up to 200°C, or even more for short periods, is available.

The break-down voltage for both types ranges from 700 to more than 2.500V, depending on the diameter. The wires can also be covered with rayon, natural silk or glass fibre. Subsequent impregnation with silicone varnish for improved adhesion is possible. The break-down voltage is several hundred volts.

For certain applications, especially if insulated wires are used for heating bimetals, a combination of several insulation types is recommended.

Flat wires of resistance alloys are standardized in DIN 46465. It should be noted that the nominal dimensions quoted there often will not meet the requirements of our customers and that for this reason we have chosen a different gradation.

For resistance alloys supplied as ribbon or sheet, no special standard exists. Here we apply the permissible values stated in DIN 1791 for copper and wrought copper alloys, as regards thickness and width tolerances.

For stranded wires of resistance alloys, too, no special standards exist. The technical terms of delivery must be negotiated individually. If stranded wires are used for heating cables, however, the regulations of VDE 0253 must be observed.

On request special tolerance values can be offered.

E. Corrosion Resistance

At room temperature the alloys manufactured by us exhibit good corrosion resistance in the bare condition. In order to avoid corrosion during storage, it is recommended that the environment should be as dry as possible.
Alloys with a high copper content have a tendency to surface corrosion after long periods of storage.

It should be kept in mind that oxidized wires of nickel-chromium alloys can be destroyed when stored in a moist environment. The alloy MANGANIN® is susceptible to stress crack corrosion; it also requires to be stored at a dry place.

The corrosion resistance characteristics at maximum working temperature can be seen from the table on the right.

On completion of soldering, brazing or welding work the flux must be removed very thoroughly, since it can contribute to corrosion, especially at higher temperatures.

Designation	Corrosion Resistant up to Maximum Working Temperature Against					
	Atmospheric Corrosion at 20°C	air and other oxygen containing gases	nitrogen containing gases with little oxygen content	Sulphur-Containing Gases: Oxi-dizing	Sulphur-Containing Gases: Reductive	carbu-riza-tion
ISAOHM	high	high	high	high	high	high
ISA-CHROM 60	high	high	high	medium	medium	high
ISA-CHROM 80	high	high	high	medium	medium	high
ISA-CHROM 30	high	high	high	medium	medium	high
ISOTAN	high	high	high	high	low	high
ISA-NICKEL	high	high	high	high	low	high
MANGANIN	high	medium	medium	medium	low	high
NICKELIN	high	high	high	high	low	high
RESISTHERM	high	high	high	medium	low	high
ISAZIN	high	medium	medium	medium	low	high
ZERANIN 30	high	medium	medium	medium	low	high
ALLOY 127	high	medium	medium	medium	low	high
ALLOY 90	high	medium	medium	medium	low	high
ISA 13	high	low	low	low	low	high
ALLOY 60	high	low	low	low	low	high
NICKEL	high	high	high	low	high	high
ALLOY 30	high	low	low	low	low	high
CuNi1	medium	low	low	low	low	high
E-Copper	medium	low	low	low	low	high

F. Instructions for Treatment

The alloys delivered by Isabellenhütte have good working characteristics.

The following instructions should be observed:

Winding

All wires should be treated as carefully as possible, with a tension below the yield point. The yield point can be taken as being appr. 50% below tensile strength in annealed condition.

Aging

Even when winding a resistance wire with little tension deformation can take place. By simple bending, mechanical stresses are built up in the wire. They affect the electrical resistance and should be minimized by heat treatment.

Copper alloys can increase their resistivity by deformation; for ISOTAN® e.g. this increase can achieve up to 7%. As regards nickel-chromium alloys, deformation reduces the resistivity, for ISAOHM® e.g. up to 10%.

Heat treatment – which is also called artificial aging – is especially required when precision resistors are manufactured.

Aging is a stabilization process; it can be accelerated considerably by applying temperature well above ambient temperature is determined by the material and especially by the insulation used.

In some cases artificial aging by temperature cycling is an advantage. Here temperature cycles between 20°C and maximum aging temperature are repeatedly run.

The aging temperature should not exceed 140°C because of the sensitivity to heat of the wire insulation. Bare wires slightly begin to oxidize above 100°C; this oxide layer can be removed by pickling.

Pickling

The type of pickling bath is mainly determined by the nature of the alloy. For MANGANIN® e. g. sulphuric chromic acid, for ZERANIN® nitric acid, for ISOTAN® also nitric acid or persulphate pickle is used; for nickel-chromium alloys pickling in phosphoric acid has proven its value. The immersion period lasts for 1 to 10 minutes depending on the alloy.

Soldering, Brazing and Welding of Resistance Alloys

<u>Soldering</u>
The copper alloys manufactured by Isabellenhuette can be soldered like pure copper, using normal solders and fluxes. Light abrasion of the areas to be soldered is recommended.

When soldering precision resistors a leadfree solder (e.g. L-SnAg5 according to preferrably pure colophony) should be used. Even the smallest residual of aggressive fluxes causes corrosion of the wire thus alternation to the resistance. Solders containing lead may be subject to metallic alternations. The melting point of the solder must be such as to prevent softening over time. In general, however, brazing should be preferred.

ISAOHM® alloy can only be soldered by using particularly aggressive fluxes, as used for soldering stainless steels (e.g. Soldaflux Z by Degussa). In addition the surfaces must be roughened beforehand. But even then the bond does not have the quality as with copper alloys.

In all cases the flux must be carefully removed.

<u>Brazing</u>
The soundest and most reliable bonds are made by brazing. Since the temperature coefficient and resistivity of the alloys for precision resistors are affected by heating, it is recommended to use low melting point brazing solders (L-Ag40Cd DIN 1707, e.g. “Degussa 4003”) and to keep the brazing time as short as possible. Flux “h” of Degussa has proved useful.

<u>Welding</u>
The alloys can be welded. It must be kept in mind, however, that the electrical and heat conductivities as well as the melding points often greatly differ from the respective values of other materials.

<u>General</u>
Besides those mentioned above normally no other peculiarities need to be taken into consideration. It is not possible to define “ideal” conditions for soldering, brazing or welding, since experience has shown that the skill of the worker plays a more important role than the selection of components.

Cutting

While with copper-nickel alloys no problems arise, nickel-Chromium alloys and pure nickel are tough and show high strength at high temperatures; they thus tend to “weld together” with the tools. This must be taken into consideration when drilling, threading or sawing. Under certain circumstances it may be more favourable to use hard, i.e. un-annealed, alloys.