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THERMAL CONDUCTIVITY, ELECTRICAL RESISTIVITY, AND
THERMOPOWER OF AEROSPACE ALLOYS FROM 4 TO 300 K:

VI. Fe-22Cr-13Ni-5Mn STAINLESS STEEL

J. G. Hust and L. L. Sparks



**U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS**

Institute for Basic Standards
Boulder, Colorado 80302

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Cryogenics Division, NBS-Institute for
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ABSTRACT

Thermal conductivity, electrical resistivity, Lorenz ratio, and the thermopower data are reported for a specimen of Fe-22Cr-13Ni-5Mn stainless steel in the furnace brazed condition for temperatures from 4 to 300 K.

KEY WORDS

Cryogenics, electrical resistivity, Lorenz ratio, Seebeck effect, stainless steel, thermal conductivity, transport properties.

* This work was carried out at the National Bureau of Standards under the sponsorship of the NASA-Space Nuclear Systems Office, Cleveland.

1. Introduction

Design and development engineers in the aerospace industry continue to have urgent need for thermal and mechanical property data for new materials. For most materials, especially new or uncommon alloys, measured values of thermal conductivity are not available and predictions cannot be made with adequate confidence. To help satisfy these needs, we have constructed an apparatus for the simultaneous measurement of thermal conductivity, electrical resistivity, and thermopower. Measurements have been conducted on several aerospace alloys, Hust, et al. [1] Another phase of this program, to establish standard reference data on several standard reference materials, has begun. We intend to measure several specimens of materials which appear to be useful as standards. Also we plan to occasionally measure other aerospace alloys, as we have done here, to satisfy specific need in the industry. This paper contains the results of our measurements on the transport properties of Fe-22Cr-13Ni-5Mn stainless steel.

2. Apparatus and Data Analysis

The apparatus is based on the axial one-dimensional heat flow method. The specimen is a cylindrical rod 11.3 mm in diameter and 23 cm long with an electric heater at one end and a temperature controlled sink at the other. The specimen is surrounded by glass fiber and a temperature controlled shield. Eight thermocouples are mounted at equally spaced points along the length of the specimen to determine temperature gradients in the range 4 to 300 K.

The experimental data are represented by arbitrary functions over the entire range and smooth tables are generated from these functions. The number of terms used to represent each of the data sets is optimized, through the use of orthonormal functions, so that none of the

precision of the data is lost by underfitting nor are any unnecessary oscillations introduced by overfitting. A detailed description of this apparatus and the methods of data analysis was given by Hust, et al. [1]

3. Specimen Characterization

The specimen was cut from a nozzle in the triple brazed condition. The furnace brazing cycles are given in table 1. The hardness is Rockwell B55. The grain size varied from 0.01 mm at the center of the rod radially to 0.07 mm at the outside surface. The composition in weight percent of this material is as follows:

Cr = 21.48, Ni = 12.36, Mn = 5.44, Mo = 2.12, Si = 0.42, N = 0.27, V = 0.20, Nb = 0.19, C = 0.05, S = 0.01, and Fe = balance.

4. Results

The transport properties of a specimen of Fe-22Cr-13Ni-5Mn stainless steel were measured in the thermal conductivity apparatus. These data are presented in tables 2 and 3.

The experimental data were functionally represented with the following equations:

$$\ln \lambda = \sum_{i=1}^n a_i [\ln T]^{i+1} \quad (1)$$

$$\rho = \sum_{i=1}^m b_i [\ln T]^{i-1} \quad (2)$$

$$S = \sum_{i=1}^{\ell} c_i [\ln T'] / T'; \quad T' = \frac{T}{10} + 1 \quad (3)$$

where λ = thermal conductivity, ρ = electrical resistivity, S = thermopower, and T = temperature. Temperatures are based on the IPTS-68

scale above 20 K and the NBS P2-20 (1965) scale below 20 K. The parameters, a_i , b_i , and c_i , determined by least squares, are presented in table 4. The deviations of the experimental data from these equations are given in tables 5 through 7 and in figures 1 through 3. The horizontal bars in figures 2 and 3 indicate the temperature span across the specimen for each run. The "observed" thermal conductivities are computed from the mean temperature gradients indicated by adjacent thermocouples. Calculated values of λ , ρ , and S , and $L = \rho\lambda/T$ (Lorenz ratio) are presented in table 8 and in figures 4 through 7.

A detailed error analysis for this system has been presented previously by Hust, et al. [1] Based on this analysis of systematic and random errors the uncertainty estimates (with 95% confidence) are as follows:

thermal conductivity:	2.5% at 300 K, decreasing as $T^{\frac{1}{2}}$ to 0.70% at 200 K, 0.70% from 200 K to 50 K, increasing inversely with temperature to 1.5% at 4 K.
electrical resistivity:	0.25%
thermopower:	0.5% + 0.2 μ V/K at 4 K, 0.2% + 0.5 μ V/K at 30 K, and 0.1% + 0.3 μ V/K above 76 K.

The thermopower values given here are absolute values although our measurements were carried out with respect to normal silver wire. The absolute thermopowers of normal silver reported by Borelius, et al. [2] were used to convert the experimental data to the absolute scale.

5. Discussion

This aerospace alloy is primarily a lattice conductor similar to other alloys measured by Hust, et al. [1]. The lattice component

for this steel is about twice the electronic component near the peak in the Lorenz ratio. A component separation as described by Hust, et al. [3] to determine the lattice conductivity has been done. The resulting lattice conductivity will be compared to other alloys in a subsequent report.

6. References

1. J. G. Hust, R. L. Powell, and D. H. Weitzel, "Thermal Conductivity, Electrical Resistivity, and Thermopower of Aerospace Alloys from 4 to 300 K," NBS Report 9732 (1969).
2. G. Borelius, W. H. Keesom, C. H. Johansson, and J. O. Linde, "Establishment of an Absolute Scale for the Thermoelectric Force," *Proc. Kon. Akad. Amsterdam* 35, 10 (1932).
3. J. G. Hust and Robert L. Powell, "Thermal Conductivity of Aerospace Alloys at Cryogenic Temperatures," Thermal Conductivity, Proceedings of the Eighth Conference (Purdue Univ., West Lafayette, Indiana, Oct. 7-10, 1968) Ed. by C. Y. Ho and R. E. Taylor, Plenum Press, N. Y., 1969.

TABLE 1. FURNACE BRAZING CYCLES
FOR Fe-22Cr-13Ni-5Mn STAINLESS STEEL

CYCLE NUMBER 1

A.	Total Time Above 531°C:	9 Hours
B.	Approximate Heating Rate from 38°C to 980°C:	111°C/Hour
C.	Total Time Above 980°C:	2 Hours
D.	Maximum Temperature:	1070°C
E.	Approximate Cooling Rate from 1070°C to 531°C:	167°C/Hour

CYCLE NUMBER 2

A.	Total Time Above 531°C:	6 Hours
B.	Approximate Heating Rate from 531°C to 930°C	167°C/Hour
C.	Total Time Above 930°C:	1 Hour
D.	Maximum Temperature:	995°C
E.	Approximate Cooling Rate from 995°C to 531°C:	167°C/Hour

CYCLE NUMBER 3

A.	Total Time Above 531°C:	6 Hours
B.	Approximate Heating Rate from 531°C to 870°C:	167°C/Hour
C.	Total Time Above 870°C:	2 Hours
D.	Maximum Temperature:	970°C
E.	Approximate Cooling Rate from 970°C to 531°C:	139°C/Hour

Note: All times and temperatures approximate.

Bar is initially solution annealed at 1120°C.

Notes Relating to Tables

Table 2

The data listed are, in part, card images of experimental data as read into the computer for data processing. These data are not clearly labelled. The following is a line by line explanation of these tables:

- 1st line - Data identification.
- 2nd line - Thermocouple emfs (μV).
- 3rd line - Seebeck emf (μV), specimen current (mA), specimen voltage drop (μV).
- 4th line - Sample heater voltage (μV), current (mA), platinum resistance thermometer voltage (μV), platinum resistance thermometer current (mA), cryogenic bath pressure (mm of Hg), room temperature ($^{\circ}\text{C}$), code indicating type of cryogenic bath (1 = liquid helium, 2 = liquid hydrogen, 3 = liquid nitrogen, 4 = dry ice-alcohol, 5 = ice-water).
- 5th line - Thermocouple temperatures (K).
- 6th line - Heater power (W), reference temperature (K), specimen resistance (Ω).

Table 3

The data listed are, in part, card images of experimental data as read into the computer for data processing. These data are not labelled clearly. The following is a line by line explanation of these tables:

- 1st line - Data identification.
- 2nd line - Platinum resistance thermometer voltage (μV), cryogenic bath pressure (mm of Hg), room temperature ($^{\circ}\text{C}$), platinum resistance thermometer current (mA), code indicating type of cryogenic bath (1 = liquid helium, 2 = liquid hydrogen, 3 = liquid nitrogen, 4 = dry ice-alcohol, 5 = ice-water), specimen current (mA), specimen voltage (μV), mean emf of eight thermocouples (μV).

3rd line - Reference temperature (K), specimen resistance (Ω),
specimen temperature (K).

Tables 5 through 7

These data are semi-processed computer output. Temperature is Kelvin, thermal conductivity is in $\text{Wm}^{-1} \text{K}^{-1}$, electrical resistance is in ohms, and thermovoltage is in μV .

Table 2. Basic semi-processed temperature gradient data for Fe-22Cr-13Ni-5Mn stainless steel

NO. OF GRADIENT AND ISOTHERMAL RUNS AGC STAINLESS STEEL									
22									
THERMOCOUPLE POSITIONS AND AVERAGE DIAMETERS (CM)									
0.0000	2.53924	5.07924	7.61022	10.15721	12.69670	15.23695	17.77695		
1.12707	1.12794	1.12790	1.12801	1.12802	1.12802	1.12802	1.12801		
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1445 21									
24.57	30.20	35.50	40.94	45.65	50.54	55.34	59.53		
0.32	100.00	110.50	-0.00	-0.0	643.9	24.1	1.0		
293400	2.9700	-0.00							
THERMOCOUPLE TEMPERATURES									
5.810	6.231	6.592	6.956	7.290	7.611	7.919	8.208		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
8.7140-004			4.030		1.1050-003				
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1600 22									
59.84	72.26	83.75	94.81	104.60	114.33	123.66	132.16		
0.82	100.00	110.51	-0.00	-0.0	643.9	24.2	1.0		
509400	5.1580	-0.00							
THERMOCOUPLE TEMPERATURES									
8.208	9.018	9.738	10.415	11.028	11.612	12.164	12.686		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
2.6275-003			4.030		1.1051-003				
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1715 23									
131.77	158.80	183.06	205.82	225.81	245.10	263.32	280.17		
1.66	100.00	110.41	-0.00	-0.0	643.8	24.3	1.0		
936150	9.4790	-0.00							
THERMOCOUPLE TEMPERATURES									
12.644	14.253	15.669	16.986	18.159	19.274	20.323	21.315		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
8.8738-003			4.030		1.1041-003				

Table 2 (continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10.71 1115 17									
26.82	32.09	37.41	42.77	47.66	52.84	57.96	62.62		
0.24	100.00	110.37							
53300	5.4000	220.03	2.0	642.7	23.0	2.0			
THERMOCOUPLE TEMPERATURES									
21.370	21.688	21.994	22.300	22.596	22.895	23.186	23.471		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
2.8798-003		19.835		1.1037-003					
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10.71 1355 18									
51.53	63.10	74.37	85.63	95.98	106.43	116.77	126.38		
0.43	100.00	110.35							
816900	8.2700	220.54	2.0	642.8	23.2	2.0			
THERMOCOUPLE TEMPERATURES									
22.822	23.509	24.164	24.818	25.436	26.046	26.647	27.226		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
6.7558-003		19.849		1.1035-003					
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10.71 1650 19									
102.76	128.00	151.67	174.77	196.13	216.98	237.34	256.58		
0.24	100.00	110.35							
1295450	13.1100	221.87	2.0	642.9	23.2	2.0			
THERMOCOUPLE TEMPERATURES									
25.857	27.355	28.749	30.113	31.394	32.634	33.842	35.006		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
1.6983-002		19.885		1.1035-003					
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 9.71 1330 15									
206.80	258.60	306.43	351.96	393.81	434.32	473.46	510.95		
-1.64	100.00	110.57							
2088150	21.1200	219.39	2.0	643.4	23.1	2.0			
THERMOCOUPLE TEMPERATURES									
31.946	35.053	37.917	40.645	43.164	45.578	47.893	50.120		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
4.4102-002		19.817		1.1057-003					

Table 2 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 9.71 1730 16									
433.79	558.73	636.72	729.91	817.42	902.47	985.59	1066.39		
-11.19	100.00	112.39							
3486250	35.2200	221.62	2.0	643.1	23.0	2.0			
THERMOCOUPLE TEMPERATURES									
45.598	51.811	57.510	62.849	67.811	72.561	77.146	81.575		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
1.2279-001	19.879								

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 11.71 1400 20									
816.30	900.54	983.84	1064.73	1142.75	1219.86	1296.03	1370.94		
-14.75	100.00	114.62							
3471100	35.0500	218.60	2.0	643.8	23.2	2.0			
THERMOCOUPLE TEMPERATURES									
67.655	72.376	76.976	81.394	85.629	89.764	93.808	97.772		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
1.2166-001	19.796								

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 3.71 840 9									
148.36	199.03	249.76	299.68	348.82	397.69	446.22	494.41		
-10.69	100.00	116.09							
2808000	28.3500	9335.12	2.0	643.0	23.0	3.0			
THERMOCOUPLE TEMPERATURES									
84.254	86.986	89.704	92.362	94.966	97.541	100.088	102.602		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
7.9607-002	76.166								

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 3.71 1435 10									
272.85	377.00	480.39	581.59	681.01	779.32	876.71	973.00		
-26.10	100.00	118.46							
4080150	41.2400	9353.10	2.0	641.9	22.5	3.0			
THERMOCOUPLE TEMPERATURES									
91.014	96.532	101.951	107.201	112.314	117.326	122.257	127.094		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
1.6860-001	76.248								

Table 2 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 4.71 1005 11					
568.74	811.64	1031.38	1245.16	1454.64	1660.60 1864.35 2065.07
-75.84	100.00	123.98			
616900	62.1200	9435.86	2.0	642.8	22.8 3.0
THERMOCOUPLE TEMPERATURES					
107.924	119.315	130.355	140.938	151.175	161.122 170.865 180.373
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE					
3.8327-001		76.624		1.2398-003	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 5.71 1005 13					
701.57	967.77	1229.83	1484.31	1733.38	1977.99 2219.65 2457.52
-98.93	100.00	125.90			
6801350	68.4400	9449.02	2.0	642.7	22.3 3.0
THERMOCOUPLE TEMPERATURES					
113.772	127.231	140.238	152.667	164.666	176.308 187.696 198.803
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE					
4.6548-001		76.684		1.2590-003	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 5.71 1645 14					
1319.96	1555.02	1788.89	2017.39	2241.77	2462.99 2682.14 2898.61
-105.64	100.00	129.79			
6583000	66.2000	9641.26	2.0	643.8	21.6 3.0
THERMOCOUPLE TEMPERATURES					
145.440	156.859	168.080	178.924	189.478	199.796 209.946 219.901
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE					
4.3579-001		77.558		1.2979-003	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 23.71 1215 4					
89.30	139.48	189.96	239.97	289.90	339.65 389.60 439.37
-26.68	100.00	132.87			
3152770	31.7200	34395.90	2.0	621.8	22.9 4.0
THERMOCOUPLE TEMPERATURES					
196.813	199.148	201.493	203.812	206.124	208.424 210.729 213.023
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE					
1.0001-001		192.647		1.3287-003	

Table 2 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 24, 71 5									
188.50	299.45	410.92	521.00	630.55	739.32	848.18	956.28		
-63.27	100.00	134.94							
4718780	47.4400	34429.40	2.0	621.3	21.0	4.0			
THERMOCOUPLE TEMPERATURES									
201.575	206.724	211.870	216.935	221.959	226.933	231.897	236.815		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
2.2386-001		192.808							
				1.3494-003					

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 25, 71 848 6									
387.79	616.93	845.29	1069.30	1290.75	1509.21	1726.77	1941.52		
-146.68	100.00	138.78							
6843910	68.7100	34464.20	2.0	614.4	22.9	4.0			
THERMOCOUPLE TEMPERATURES									
210.969	221.499	231.928	242.105	252.119	261.955	271.719	281.329		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
4.7025-001		192.974							
				1.3878-003					

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 26, 71 1106 8									
768.41	1008.56	1248.23	1483.17	1715.34	1944.45	2172.95	2398.51		
-168.43	100.00	141.48							
7119850	71.4400	34665.00	2.0	618.8	22.9	4.0			
THERMOCOUPLE TEMPERATURES									
229.365	240.286	251.131	261.711	272.131	282.381	292.583	302.653		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
5.0864-001		193.937							
				1.4149-003					

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 25, 71 1700 7									
768.68	1009.05	1248.96	1484.06	1716.37	1945.56	2174.12	2399.72		
-168.57	100.00	141.50							
7120175	71.4400	34665.10	2.0	615.0	23.5	4.0			
THERMOCOUPLE TEMPERATURES									
229.577	240.509	251.164	261.752	272.178	282.431	292.635	302.708		
HEATER POWER REFERENCE TEMPERATURE SPECIMEN RESISTANCE									
5.0867-001		193.938							
				1.4150-003					

Table 2 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 19, 71 1000 2						
81.24	134.38	187.97	241.13	294.33	347.40	401.00 454.48
-41.84	100.00	143.99				
3456787	34.7000	51001.40	2.0	621.9	22.6	5.0
THERMOCOUPLE TEMPERATURES						
277.074	279.447	281.839	284.213	286.588	288.957	291.350 293.738
HEATER POWER		REFERENCE TEMPERATURE	SPECIMEN RESISTANCE			
1.1995-001		273.431	1.4399-003			

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 19, 71 1730 3						
82.99	136.01	189.53	242.78	295.97	349.04	402.66 456.14
-41.83	100.00	144.02				
3456810	34.7000	50983.60	2.0	621.8	22.7	5.0
THERMOCOUPLE TEMPERATURES						
277.065	279.432	281.821	284.199	286.574	288.943	291.337 293.725
HEATER POWER		REFERENCE TEMPERATURE	SPECIMEN RESISTANCE			
1.1995-001		273.344	1.4402-003			

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 18, 71 1615 1						
83.96	137.01	190.52	243.62	296.77	349.78	403.36 456.83
-41.79	100.00	144.03				
3456776	34.7000	50974.40	2.0	619.9	23.5	5.0
THERMOCOUPLE TEMPERATURES						
277.063	279.431	281.820	284.191	286.564	288.931	291.323 293.710
HEATER POWER		REFERENCE TEMPERATURE	SPECIMEN RESISTANCE			
1.1995-001		273.298	1.4403-003			

Table 3. Basic semi-processed isothermal electrical resistivity data for Fe-22Cr-13Ni-5Mn stainless steel

No isothermal electrical resistivity data recorded.

Table 4. Parameters in equations 1, 2, and 3 for Fe-22Cr-13Ni-5Mn stainless steel

COEFFICIENTS FOR		
THERMAL CONDUCTIVITY	ELECTRICAL RESISTIVITY	THERMOPOWER
-5.07438396+000	-1.80350320-006	-2.71839867+001
6.86126136+000	5.36698495-006	1.25699585+002
-3.88271546+000	-4.95206039-006	-1.85664400+002
1.19368464+000	2.46637135-006	1.41972570+002
-2.08387079-001	-7.15013025-007	-6.36076918+001
1.94161811-002	1.20466776-007	1.55317665+001
-7.49952257-004	-1.09168536-008	-1.69357672+000
	4.11823823-010	

Table 5. Thermal conductivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1445 21						
MEAN	TEMPERATURE	OBSERVED	CALCULATED	PERCENT		
TEMPERATURE	DIFFERENCE	THERMAL	THERMAL	DEVIATION		
		CONDUCTIVITY	CONDUCTIVITY			
6.021	0.421	5.27-001	5.40-001	-2.5		
6.411	0.361	6.14-001	5.80-001	5.5		
6.774	0.365	6.07-001	6.19-001	-1.9		
7.123	0.334	6.64-001	6.57-001	1.0		
7.451	0.321	6.89-001	6.93-001	-0.6		
7.765	0.307	7.21-001	7.29-001	-1.1		
8.063	0.289	7.66-001	7.63-001	0.4		

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1600 22						
MEAN	TEMPERATURE	OBSERVED	CALCULATED	PERCENT		
TEMPERATURE	DIFFERENCE	THERMAL	THERMAL	DEVIATION		
		CONDUCTIVITY	CONDUCTIVITY			
8.613	0.810	8.24-001	8.27-001	-0.3		
9.378	0.720	9.28-001	9.17-001	1.2		
10.076	0.677	9.86-001	1.00+000	-1.4		
10.721	0.613	1.09+000	1.08+000	1.2		
11.320	0.585	1.14+000	1.15+000	-0.6		
11.888	0.552	1.21+000	1.22+000	-0.6		
12.425	0.521	1.28+000	1.28+000	-0.1		

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12.71 1715 23						
MEAN	TEMPERATURE	OBSERVED	CALCULATED	PERCENT		
TEMPERATURE	DIFFERENCE	THERMAL	THERMAL	DEVIATION		
		CONDUCTIVITY	CONDUCTIVITY			
13.448	1.609	1.40+000	1.40+000	-0.2		
14.961	1.416	1.59+000	1.58+000	0.6		
16.328	1.317	1.71+000	1.74+000	-1.9		
17.573	1.173	1.92+000	1.89+000	1.7		
18.716	1.114	2.02+000	2.02+000	0.1		
19.798	1.049	2.15+000	2.15+000	0.2		
20.819	0.993	2.27+000	2.26+000	0.5		

Table 5 (continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10, 71 1115 17					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
21.529	0.318	2.30+000	2.34+000	-1.8	
21.841	0.306	2.39+000	2.38+000	0.6	
22.147	0.306	2.39+000	2.41+000	-0.9	
22.448	0.296	2.47+000	2.44+000	1.1	
22.746	0.299	2.45+000	2.48+000	-1.2	
23.041	0.291	2.51+000	2.51+000	0.2	
23.329	0.285	2.57+000	2.54+000	1.1	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10, 71 1355 18					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
23.166	0.687	2.50+000	2.52+000	-1.0	
23.837	0.655	2.62+000	2.60+000	0.9	
24.491	0.653	2.63+000	2.67+000	-1.6	
25.127	0.618	2.78+000	2.74+000	1.4	
25.741	0.611	2.81+000	2.81+000	0.2	
26.347	0.601	2.86+000	2.87+000	-0.4	
26.937	0.579	2.97+000	2.93+000	1.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 10, 71 1650 19					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
26.606	1.497	2.88+000	2.90+000	-0.6	
28.052	1.395	3.09+000	3.05+000	1.3	
29.431	1.363	3.16+000	3.20+000	-1.1	
30.753	1.281	3.37+000	3.34+000	0.9	
32.014	1.240	3.48+000	3.47+000	0.5	
33.238	1.208	3.57+000	3.59+000	-0.5	
34.424	1.164	3.71+000	3.71+000	-0.0	

Table 5 (continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 9, 71 1330 15					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
33.500	3.107	3.61+000	3.62+000	-0.2	
36.485	2.864	3.91+000	3.91+000	0.1	
39.281	2.728	4.11+000	4.18+000	-1.7	
41.905	2.518	4.45+000	4.42+000	0.7	
44.371	2.414	4.64+000	4.64+000	0.1	
46.735	2.316	4.84+000	4.84+000	-0.1	
49.007	2.227	5.03+000	5.03+000	-0.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 9, 71 1730 16					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
48.704	6.212	5.02+000	5.01+000	0.3	
54.661	5.700	5.48+000	5.48+000	-0.1	
60.180	5.339	5.84+000	5.89+000	-0.7	
65.330	4.962	6.29+000	6.23+000	0.8	
70.186	4.750	6.57+000	6.54+000	0.5	
74.854	4.585	6.81+000	6.81+000	-0.0	
79.361	4.429	7.05+000	7.05+000	-0.1	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 11, 71 1400 20					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
70.015	4.721	6.55+000	6.53+000	0.3	
74.676	4.601	6.72+000	6.80+000	-1.1	
79.185	4.418	7.00+000	7.04+000	-0.7	
83.512	4.235	7.30+000	7.27+000	0.5	
87.696	4.135	7.48+000	7.47+000	0.2	
91.786	4.045	7.65+000	7.65+000	-0.1	
95.790	3.964	7.80+000	7.82+000	-0.3	

Table 5 (continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 3, 71 040 9					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
85.620	2.731	7.41+000	7.37+000	0.5	
88.345	2.718	7.45+000	7.50+000	-0.7	
91.033	2.658	7.61+000	7.62+000	-0.1	
93.664	2.604	7.77+000	7.73+000	0.4	
96.253	2.574	7.86+000	7.84+000	0.2	
98.814	2.548	7.94+000	7.95+000	-0.1	
101.345	2.514	8.05+000	8.05+000	0.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 3, 71 1435 10					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
93.773	5.518	7.77+000	7.74+000	0.3	
99.242	5.418	7.91+000	7.97+000	-0.7	
104.576	5.250	8.16+000	8.17+000	-0.2	
109.757	5.113	8.38+000	8.36+000	0.2	
114.820	5.012	8.55+000	8.54+000	0.1	
119.792	4.931	8.69+000	8.70+000	-0.1	
124.676	4.857	8.86+000	8.86+000	-0.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 4, 71 1005 11					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
113.620	11.391	8.55+000	8.50+000	0.6	
124.835	11.040	8.83+000	8.86+000	-0.4	
135.646	10.582	9.20+000	9.19+000	0.1	
146.056	10.238	9.51+000	9.48+000	0.3	
156.149	9.947	9.79+000	9.76+000	0.4	
165.994	9.743	1.00+001	1.00+001	-0.1	
175.619	9.508	1.02+001	1.03+001	-0.1	

Table 5 (continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 5, 71 1005 13					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
120.501	13.460	8.79+000	8.73+000	0.7	
133.735	13.007	9.10+000	9.13+000	-0.4	
146.453	12.429	9.52+000	9.49+000	0.2	
158.667	11.999	9.86+000	9.82+000	0.3	
170.487	11.642	1.02+001	1.01+001	0.3	
182.002	11.388	1.04+001	1.04+001	-0.3	
193.250	11.107	1.07+001	1.07+001	-0.5	
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 5, 71 1645 14					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
151.149	11.419	9.70+000	9.62+000	0.8	
162.469	11.221	9.87+000	9.92+000	-0.5	
173.502	10.845	1.02+001	1.02+001	0.0	
184.201	10.553	1.05+001	1.05+001	0.1	
194.637	10.319	1.07+001	1.07+001	-0.0	
204.871	10.150	1.09+001	1.10+001	-0.7	
214.923	9.955	1.11+001	1.12+001	-0.9	
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 23, 71 1215 4					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
197.980	2.335	1.09+001	1.08+001	0.6	
200.320	2.345	1.08+001	1.09+001	-0.3	
202.652	2.319	1.10+001	1.09+001	0.2	
204.968	2.312	1.10+001	1.10+001	0.0	
207.274	2.300	1.10+001	1.10+001	0.0	
209.576	2.305	1.10+001	1.11+001	-0.7	
211.876	2.294	1.11+001	1.12+001	-0.7	

Table 5 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 24, 71 5					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
204.149	5.148	1.11+001	1.10+001	0.7	
209.297	5.147	1.11+001	1.11+001	-0.4	
214.403	5.065	1.12+001	1.12+001	0.1	
219.447	5.024	1.13+001	1.13+001	-0.2	
224.446	4.974	1.14+001	1.15+001	-0.2	
229.415	4.964	1.15+001	1.16+001	-1.0	
234.356	4.917	1.16+001	1.17+001	-1.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 25, 71 848 6					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
216.234	10.530	1.13+001	1.13+001	0.8	
226.714	10.429	1.15+001	1.15+001	-0.4	
237.017	10.177	1.17+001	1.18+001	-0.1	
247.112	10.014	1.19+001	1.20+001	-0.4	
257.037	9.836	1.21+001	1.22+001	-0.4	
266.837	9.764	1.22+001	1.24+001	-1.3	
276.524	9.610	1.24+001	1.26+001	-1.3	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 26, 71 1106 8					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
234.825	10.922	1.18+001	1.17+001	1.1	
245.709	10.844	1.19+001	1.19+001	-0.2	
256.421	10.581	1.22+001	1.22+001	0.3	
266.921	10.420	1.24+001	1.24+001	-0.0	
277.256	10.250	1.26+001	1.26+001	0.0	
287.482	10.202	1.27+001	1.28+001	-1.0	
297.618	10.071	1.28+001	1.30+001	-1.0	

Table 5 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 25, 71 1700 7					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
234.843	10.932	1.18+001	1.17+001	1.1	
245.737	10.855	1.19+001	1.19+001	-0.3	
256.458	10.588	1.22+001	1.22+001	0.2	
266.965	10.426	1.24+001	1.24+001	-0.1	
277.304	10.253	1.26+001	1.26+001	-0.0	
287.533	10.204	1.27+001	1.28+001	-1.0	
297.672	10.072	1.28+001	1.30+001	-1.0	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 19, 71 1000 2					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
278.260	2.373	1.28+001	1.26+001	1.7	
280.643	2.393	1.27+001	1.27+001	0.6	
283.026	2.373	1.28+001	1.27+001	1.0	
285.400	2.375	1.28+001	1.28+001	0.6	
287.773	2.369	1.29+001	1.28+001	0.5	
290.154	2.393	1.27+001	1.28+001	-0.8	
292.544	2.388	1.28+001	1.29+001	-0.9	

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB. 19, 71 1730 3					
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION	
278.248	2.367	1.29+001	1.26+001	2.0	
280.627	2.389	1.28+001	1.27+001	0.7	
283.010	2.377	1.28+001	1.27+001	0.8	
285.386	2.375	1.28+001	1.28+001	0.6	
287.758	2.369	1.29+001	1.28+001	0.5	
290.140	2.394	1.27+001	1.28+001	-0.8	
292.531	2.388	1.28+001	1.29+001	-0.9	

Table 5 (Continued)

THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL FEB 18, 71 1615						
MEAN TEMPERATURE	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION		
278.247	2.369	1.29+001	1.26+001	1.9		
280.626	2.389	1.28+001	1.27+001	0.7		
283.006	2.371	1.29+001	1.27+001	1.1		
285.378	2.373	1.28+001	1.28+001	0.7		
287.748	2.367	1.29+001	1.28+001	0.6		
290.127	2.392	1.27+001	1.28+001	-0.8		
292.517	2.387	1.28+001	1.29+001	-0.9		

Table 6. Electrical resistivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

MEAN TEMPERATURE	TEMPERATURE RANGE	OBSERVED RESISTANCE	CALCULATED RESISTANCE	PERCENT DEVIATION
7.087	2.397	1.106-003	1.106-003	-0.00
10.632	4.478	1.105-003	1.105-003	0.00
17.378	8.671	1.104-003	1.104-003	-0.00
22.440	2.101	1.104-003	1.104-003	-0.01
25.092	4.404	1.103-003	1.104-003	-0.00
30.646	9.149	1.103-003	1.103-003	0.02
41.612	18.174	1.106-003	1.106-003	-0.01
64.755	35.977	1.124-003	1.124-003	-0.01
83.238	30.117	1.146-003	1.146-003	-0.00
93.583	18.348	1.161-003	1.161-003	0.02
109.520	36.080	1.185-003	1.185-003	-0.00
145.419	72.449	1.240-003	1.240-003	-0.02
157.873	85.032	1.259-003	1.259-003	0.01
183.681	74.461	1.298-003	1.298-003	0.02
204.950	16.210	1.329-003	1.329-003	-0.03
219.360	35.240	1.349-003	1.350-003	-0.01
246.784	70.360	1.388-003	1.388-003	0.02
266.607	73.289	1.415-003	1.415-003	0.01
266.646	73.330	1.415-003	1.415-003	0.02
285.400	16.664	1.440-003	1.440-003	-0.03
285.386	16.660	1.440-003	1.440-003	-0.00
285.379	16.647	1.440-003	1.440-003	0.01

Table 7. Thermovoltage deviations for Fe-22Cr-13Ni-5Mn stainless steel

UPPER TEMPERATURE	LOWER TEMPERATURE	OBSERVED THERMOVOLTAGE	CALCULATED THERMOVOLTAGE	DEVIATION
8.208	5.810	0.32	0.30	0.02
12.686	8.208	0.82	0.86	-0.06
21.315	12.644	1.66	1.60	0.06
23.471	21.370	0.24	0.27	-0.03
27.226	22.822	0.43	0.43	-0.01
35.006	25.857	0.24	0.30	-0.05
50.120	31.946	-1.64	-1.60	-0.04
81.575	45.598	-11.19	-11.27	0.08
97.772	67.655	-14.75	-14.71	-0.04
102.602	84.254	-10.69	-10.71	0.02
127.094	91.014	-26.10	-26.07	-0.03
180.373	107.924	-75.84	-75.80	-0.03
198.803	113.772	-98.93	-98.90	-0.03
219.901	145.440	-105.64	-105.60	0.05
213.023	196.813	-26.68	-26.65	-0.03
236.815	201.575	-63.27	-63.22	-0.06
281.329	210.969	-146.68	-146.55	-0.13
302.653	229.365	-168.43	-168.47	0.05
302.708	229.377	-168.57	-168.60	0.03
293.738	277.074	-41.84	-41.85	0.01
293.725	277.065	-41.83	-41.83	0.00
293.710	277.063	-41.79	-41.80	0.01

Table 8. Transport properties of Fe-22Cr-13Ni-5Mn stainless steel

Temp (K)	Thermal Conductivity (Wm ⁻¹ K ⁻¹)	Electrical Resistivity (nohm m)	Lorenz ratio $\times 10^3$ (V ² /K ²)	Thermo- power (μ V/K)
7	0.643	621.9	5.71	0.14
8	0.756	621.9	5.87	0.17
9	0.872	621.6	6.02	0.20
10	0.991	621.3	6.16	0.23
12	1.23	620.9	6.37	0.30
14	1.47	620.8	6.52	0.36
16	1.71	620.7	6.62	0.41
18	1.94	620.7	6.69	0.45
20	2.17	620.6	6.73	0.46
25	2.73	620.3	6.76	0.47
30	3.26	620.1	6.73	0.46
35	3.76	620.3	6.67	0.43
40	4.24	621.0	6.59	0.39
45	4.69	622.2	6.49	0.35
50	5.12	623.8	6.38	0.30
55	5.51	626.0	6.27	0.25
60	5.87	628.5	6.15	0.20
65	6.21	631.4	6.03	0.15
70	6.53	634.5	5.92	0.11
75	6.82	638.0	5.80	0.06
80	7.09	641.6	5.68	0.02
85	7.34	645.5	5.57	-0.02
90	7.57	649.4	5.46	-0.06
95	7.79	653.5	5.36	-0.09
100	8.00	657.7	5.26	-0.13
110	8.37	666.2	5.07	-0.20
120	8.71	674.9	4.90	-0.26
130	9.02	683.7	4.75	-0.31
140	9.31	692.4	4.61	-0.37
150	9.59	701.1	4.48	-0.43
160	9.86	709.7	4.37	-0.49
170	10.1	718.3	4.27	-0.54
180	10.4	726.6	4.19	-0.60
190	10.6	734.9	4.11	-0.66
200	10.9	743.1	4.04	-0.72
220	11.4	759.2	3.92	-0.84
240	11.8	774.8	3.82	-0.96
260	12.3	790.3	3.73	-1.09
280	12.7	805.5	3.64	-1.22

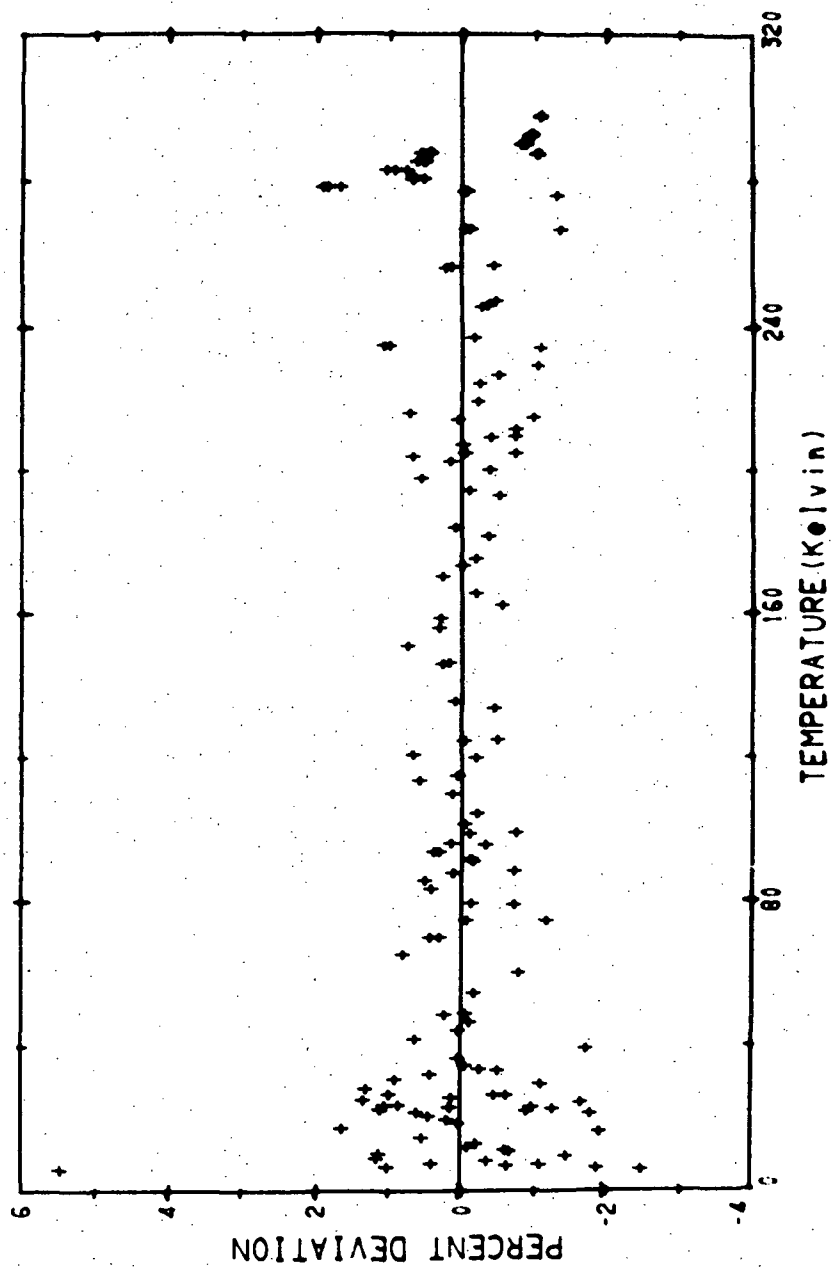


Figure 1. Thermal conductivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

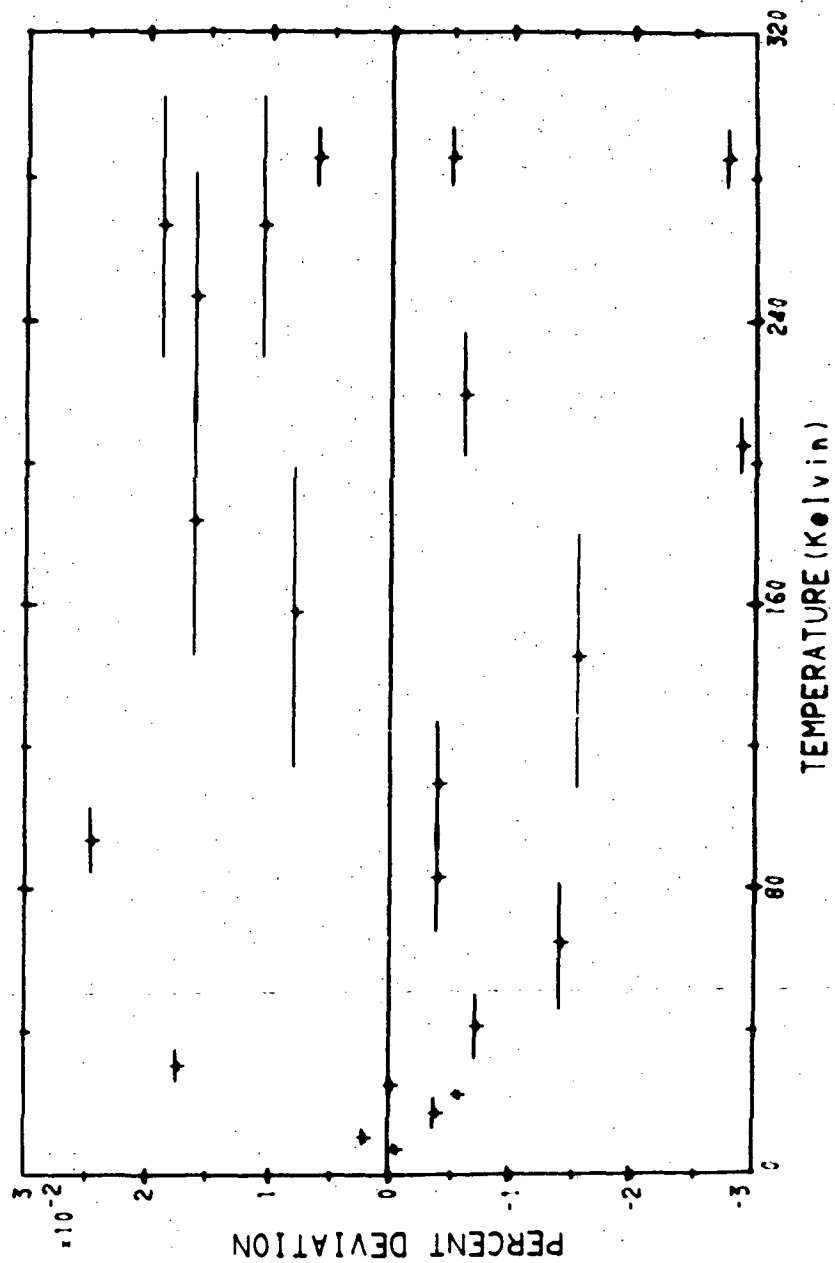


Figure 2. Electrical resistivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

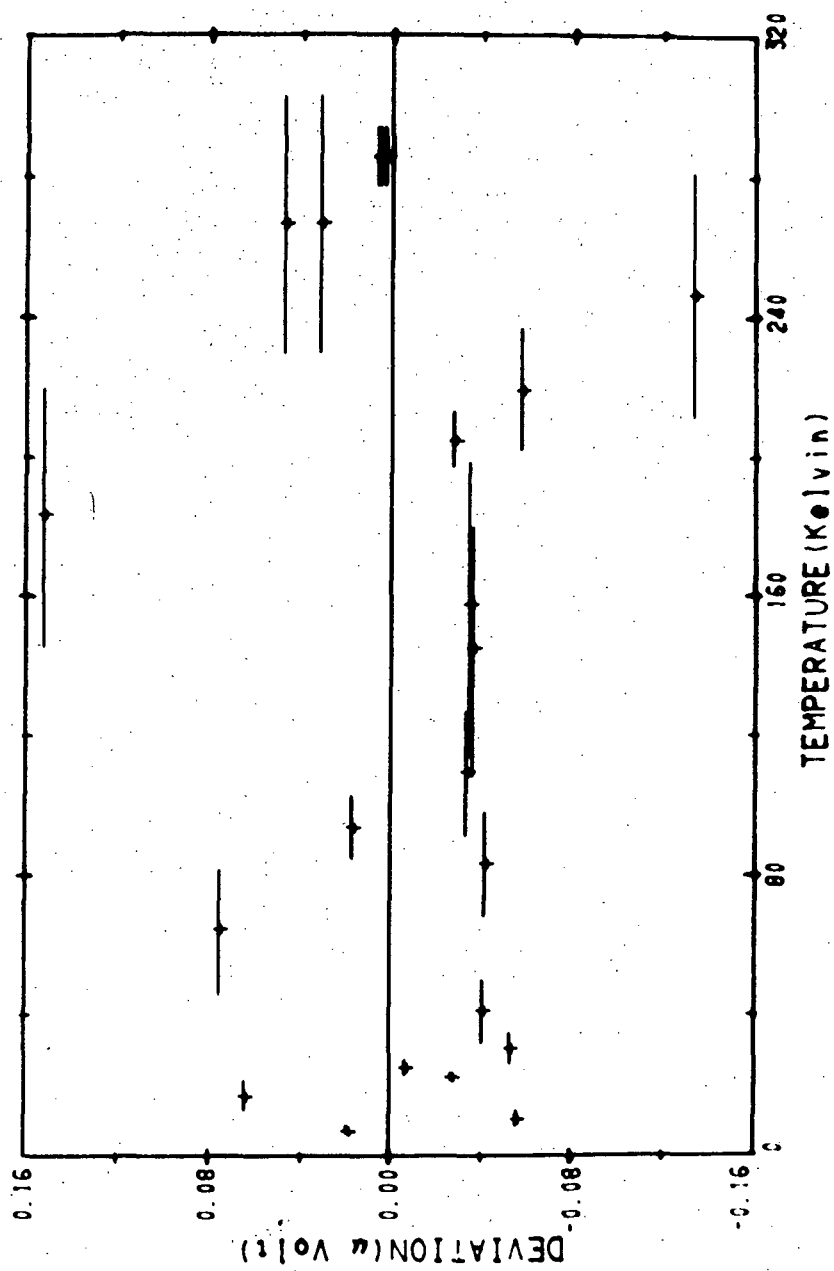


Figure 3. Thermovoltage deviations for Fe-22Cr-13Ni-5Mn stainless steel

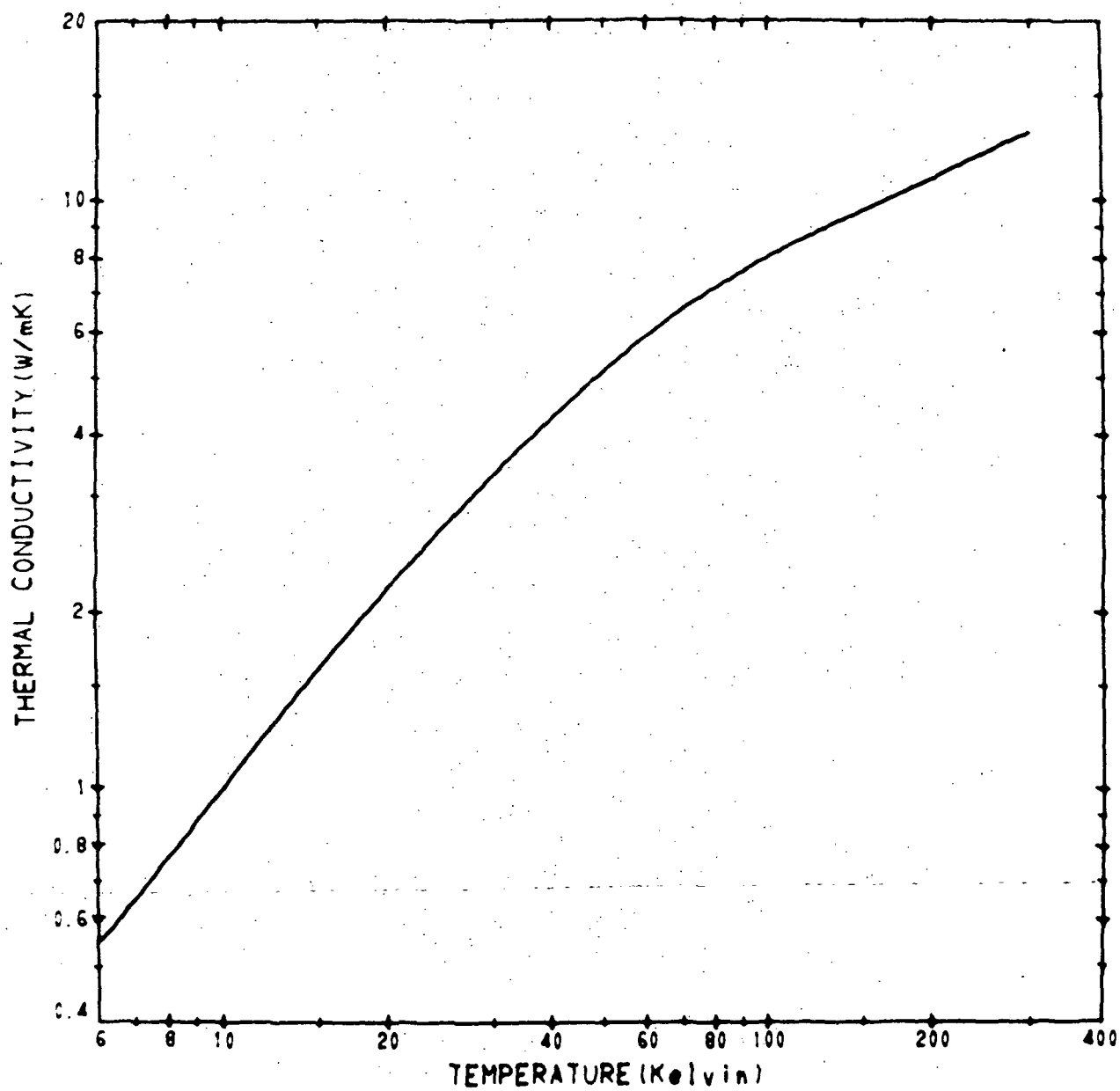


Figure 4. Thermal conductivity of Fe-22Cr-13Ni-5Mn stainless steel

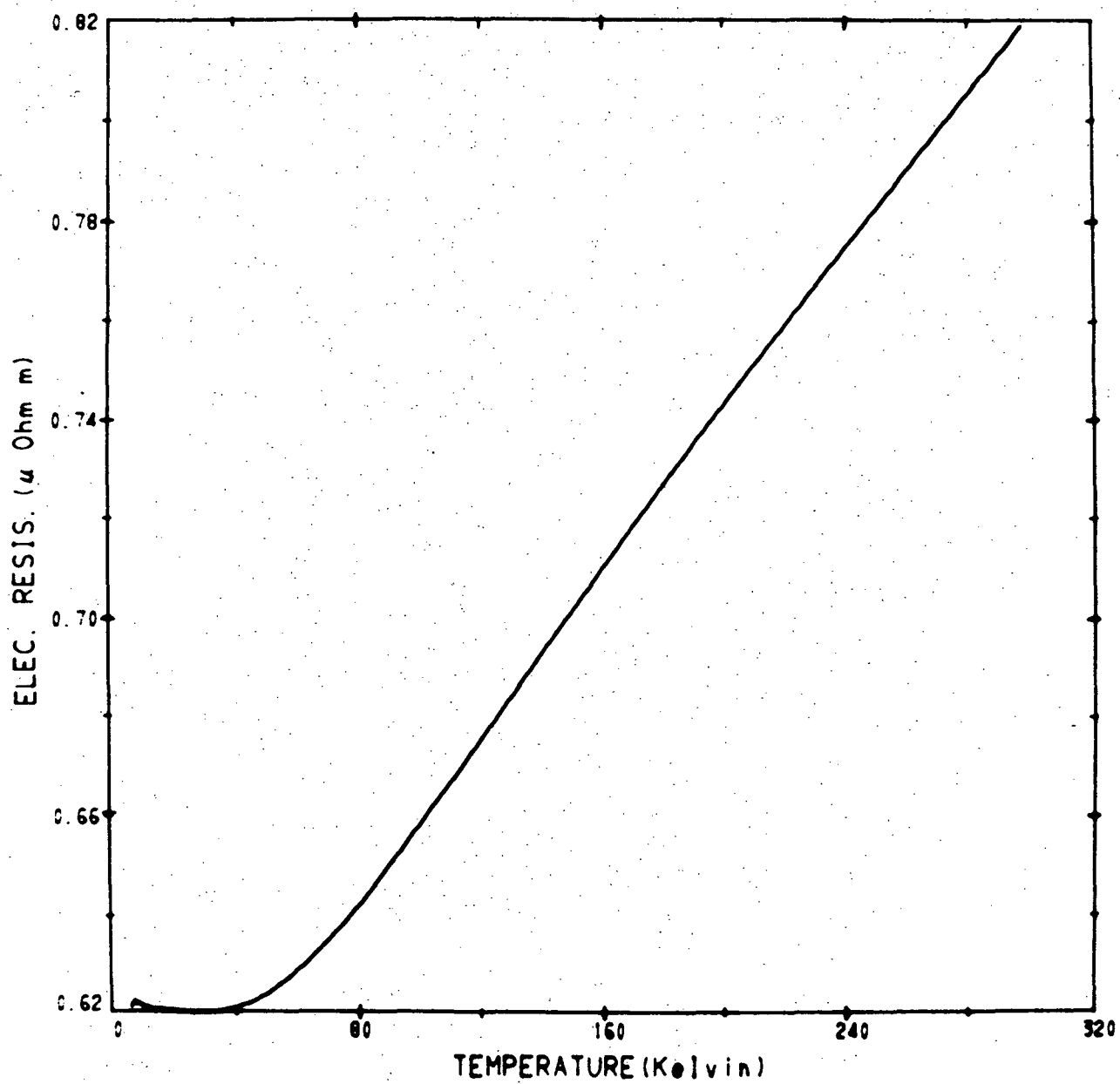


Figure 5. Electrical resistivity of Fe-22Cr-13Ni-5Mn stainless steel

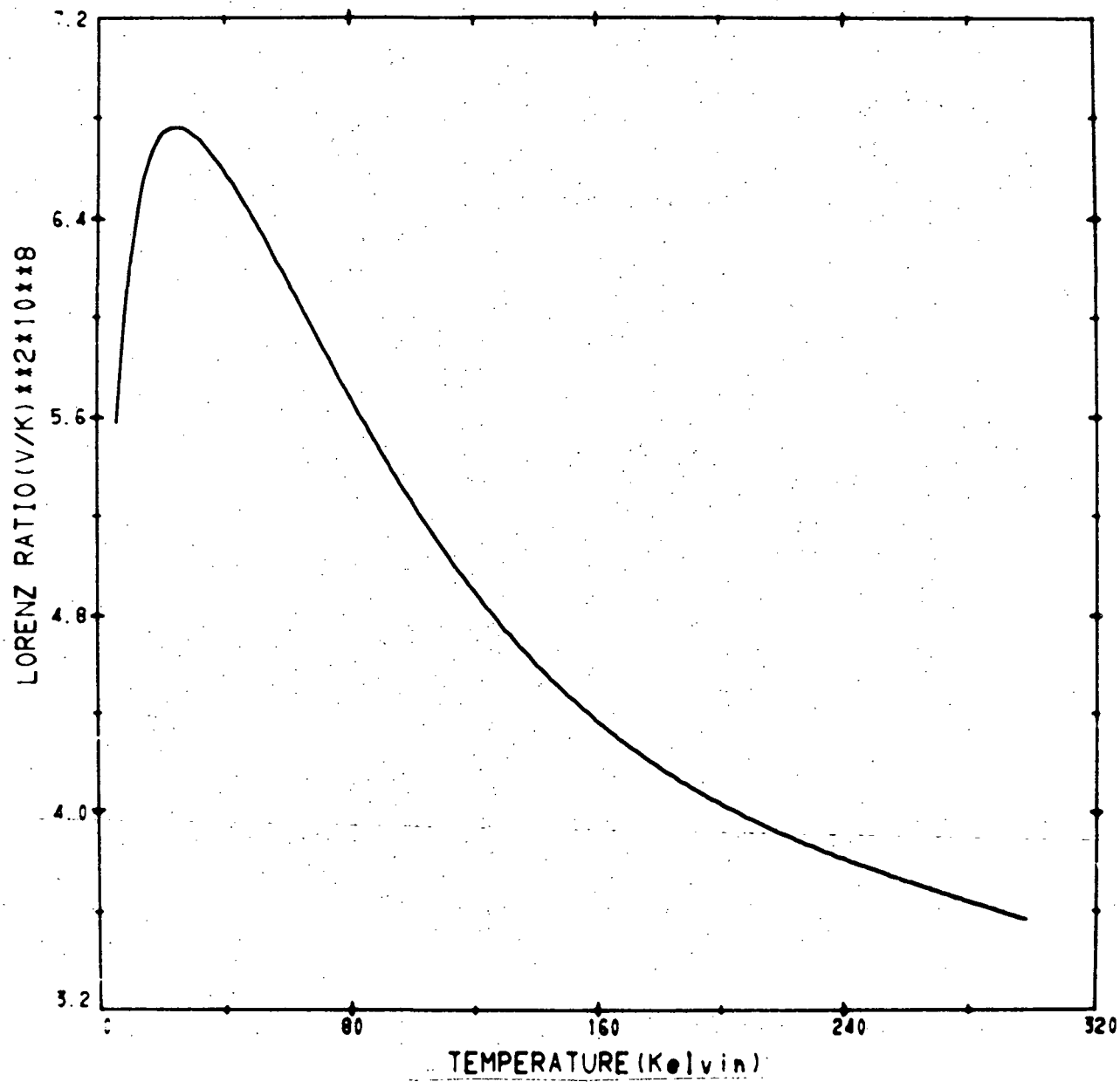


Figure 6. Lorenz ratio of Fe-22Cr-13Ni-5Mn stainless steel

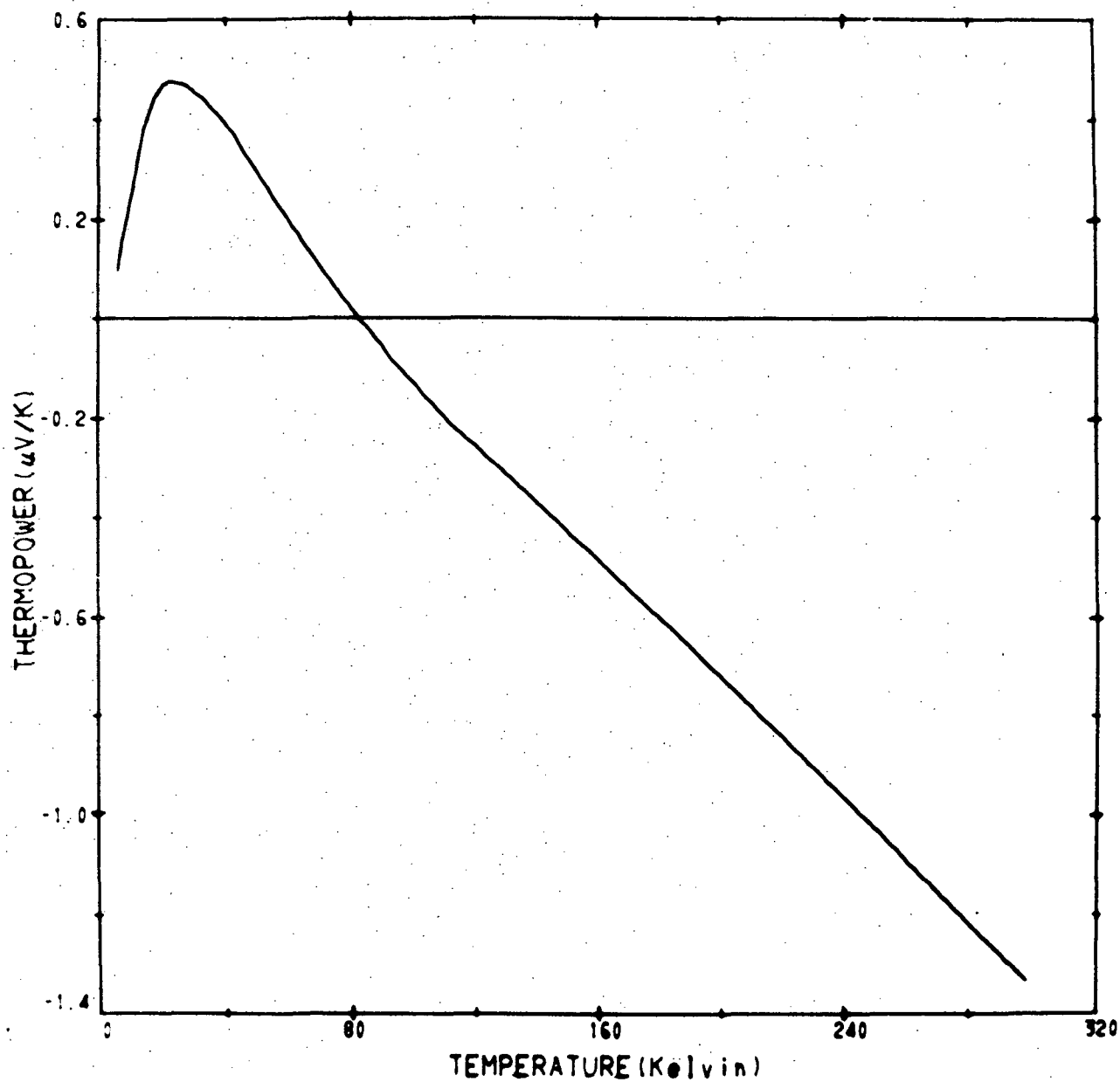


Figure 7. Thermopower of Fe-22Cr-13Ni-5Mn stainless steel

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