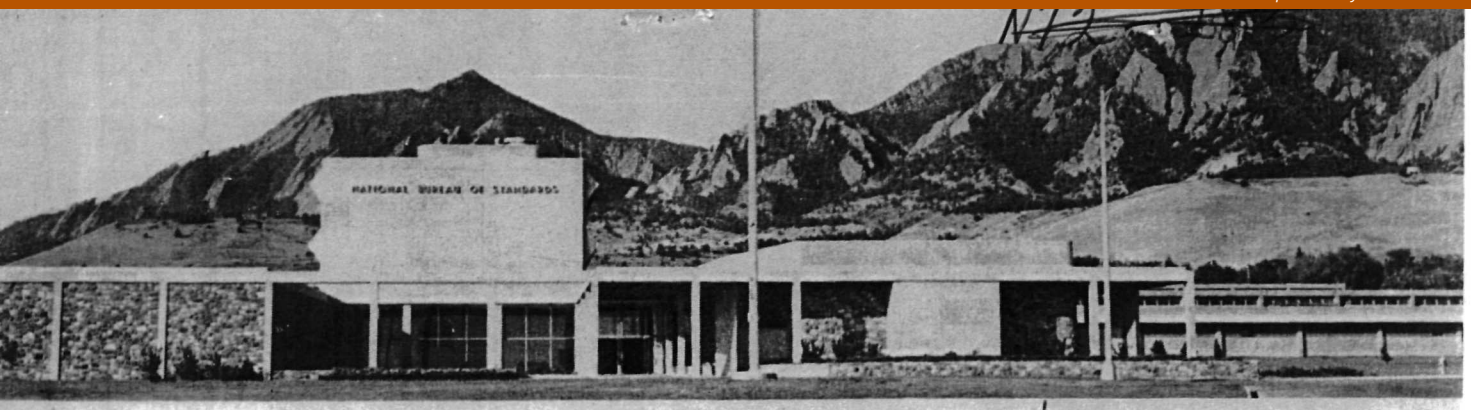

NBS REPORT

9799

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

NBS

U. S. DEPARTMENT OF COMMERCE
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Boulder, Colorado 80302

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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*

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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.

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* 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 occassionally 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:

$$\ell n\,\lambda = \sum_{i=1}^{n} a_i \,[\ell nT]^{i+1} \tag{1}$$

$$\rho = \sum_{i=1}^{m} b_i \,[\ell nT]^{i-1} \tag{2}$$

$$S = \sum_{i=1}^{\ell} c_i \,[\ell nT']/T'; \qquad T' = \frac{T}{10} + 1 \tag{3}$$

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^4 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 μV/K at 4 K, 0.2% + 0.5 μV/K at 30 K, and 0.1% + 0.3 μV/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 (°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 (°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 $Wm^{-1}\ K^{-1}$, 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          0
THERMOCOUPLE POSITIONS AND AVERAGE DIAMETERS (CM)
  0.00000   2.53924   5.07924   7.61822  10.15721  12.69670  15.23695  17.77695
  1.12787   1.12794   1.12798   1.12801   1.12802   1.12802   1.12801
-------------------------------------------------------------
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 12,71 1445  21
   24.57    30.28    35.50    40.94    45.65    50.54    55.34    59.53
     0.32    100.00    110.58
   293400    2.9700     -0.00      -0.0     643.9      24.1       1.0
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             4.038              1.1058-003
-------------------------------------------------------------
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
   509400    5.1580     -0.00      -0.0     643.9      24.2       1.0
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             4.038              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
   936150    9.4790     -0.00      -0.0     643.8      24.3       1.0
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             4.038              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
  533300   5.4000   220.03       2.0    642.7      23.0       2.0
THERMOCOUPLE TEMPERATURES
  21.570   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   306.45   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   538.73   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              1.1239-003
-------------------------------------------------------------
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      25.2       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              1.1462-003
-------------------------------------------------------------
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              1.1609-003
-------------------------------------------------------------
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
  4088150   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              1.1846-003
-------------------------------------------------------------
```

Table 2 (Continued)

```
THERMAL CONDUCTIVITY DATA FOR AGC STAINLESS STEEL MARCH 4,71 1005  11
  508.74   811.64  1031.38  1245.16  1454.64  1660.60  1864.35  2065.07
   -75.84    100.00    123.98
  6169900   62.1200   9435.86       2.0     642.8      22.8       3.0
THERMOCOUPLE TEMPERATURES
 107.524  119.315  130.355  140.938  151.175  161.122  170.865  180.373
HEATER POWER   REFERENCE TEMPERATURE   SPECIMEN RESISTANCE
 3.8527-001            76.624              1.2998-003
-------------------------------------------------------------
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
  188.30   299.45   410.92   521.00   630.55   739.32   848.18   956.28
   -63.27    100.00    134.94
  4710780   47.4400  34429.40       2.0      621.3      21.8       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      615.8      23.5       4.0
THERMOCOUPLE TEMPERATURES
 229.577  240.309  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
-5.07430396+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
1.19568464+000	2.46637135-006	1.41972570+002
-2.08587079-001	-7.15013025-007	-6.36076918+001
1.94161811-002	1.20466776-007	1.55317665+001
-7.49952257-004	-1.09160536-008	-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	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
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	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
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	TEMPERATURE DIFFERENCE	OBSERVED THERMAL CONDUCTIVITY	CALCULATED THERMAL CONDUCTIVITY	PERCENT DEVIATION
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 3,71 840 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	4.837	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 1

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
17.578	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	-105.80	0.15
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 $\times 10^{8}$ (V^2/K^2)	Thermo-power ($\mu V/K$)
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

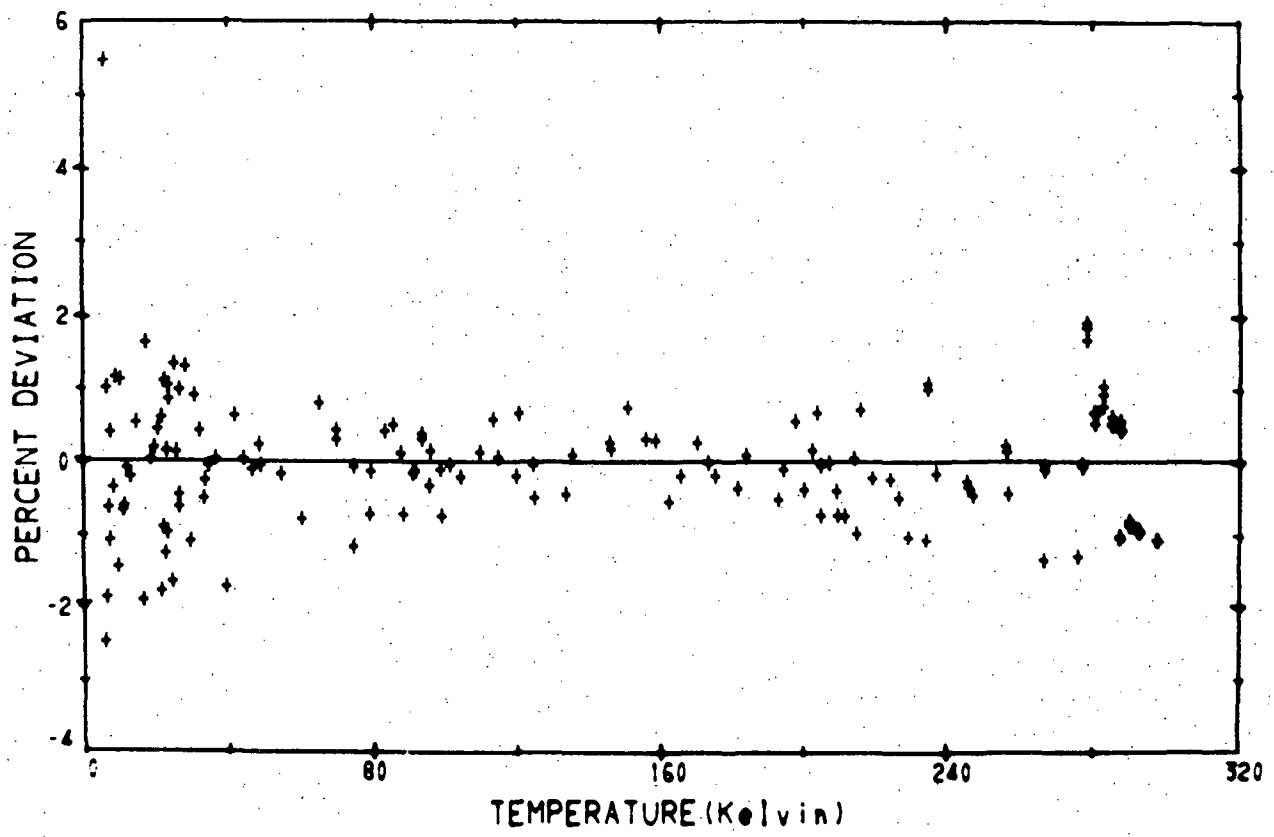

Figure 1. Thermal conductivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

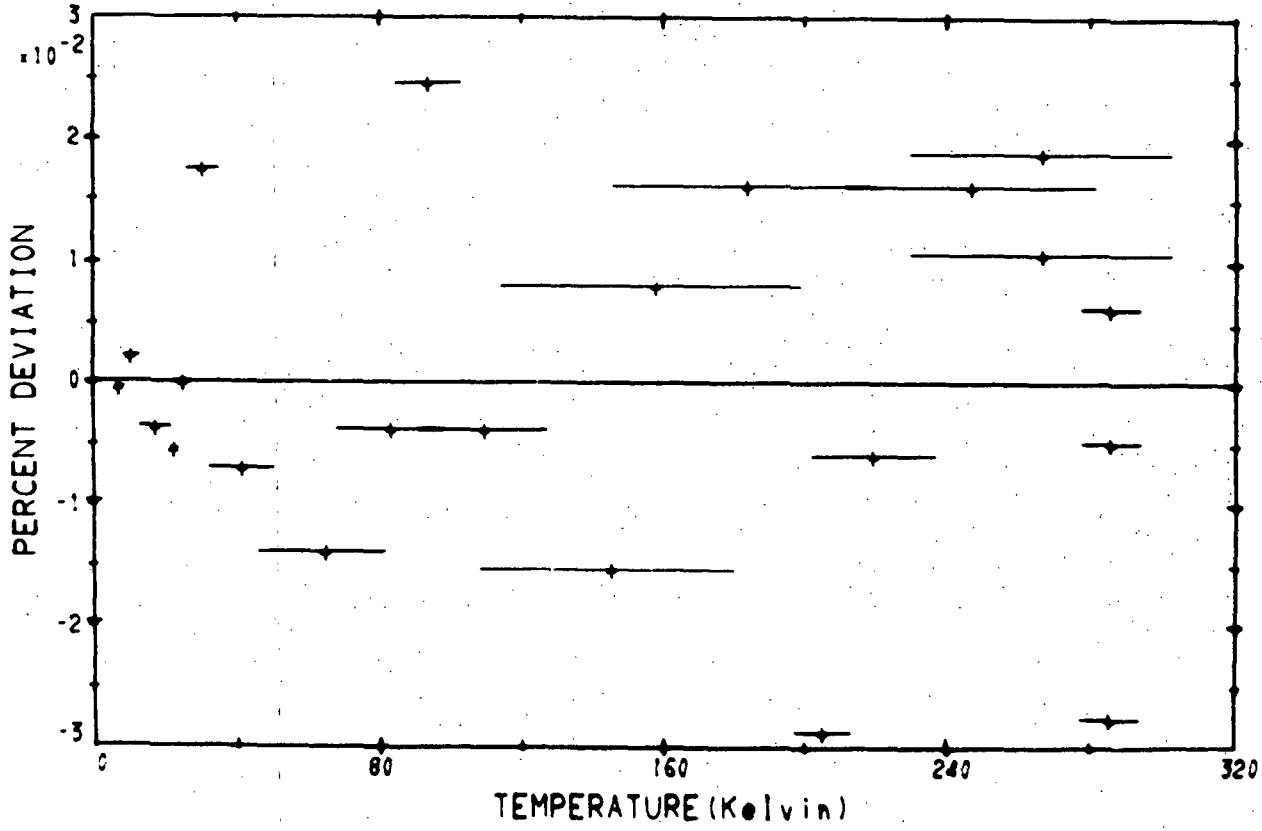

Figure 2. Electrical resistivity deviations for Fe-22Cr-13Ni-5Mn stainless steel

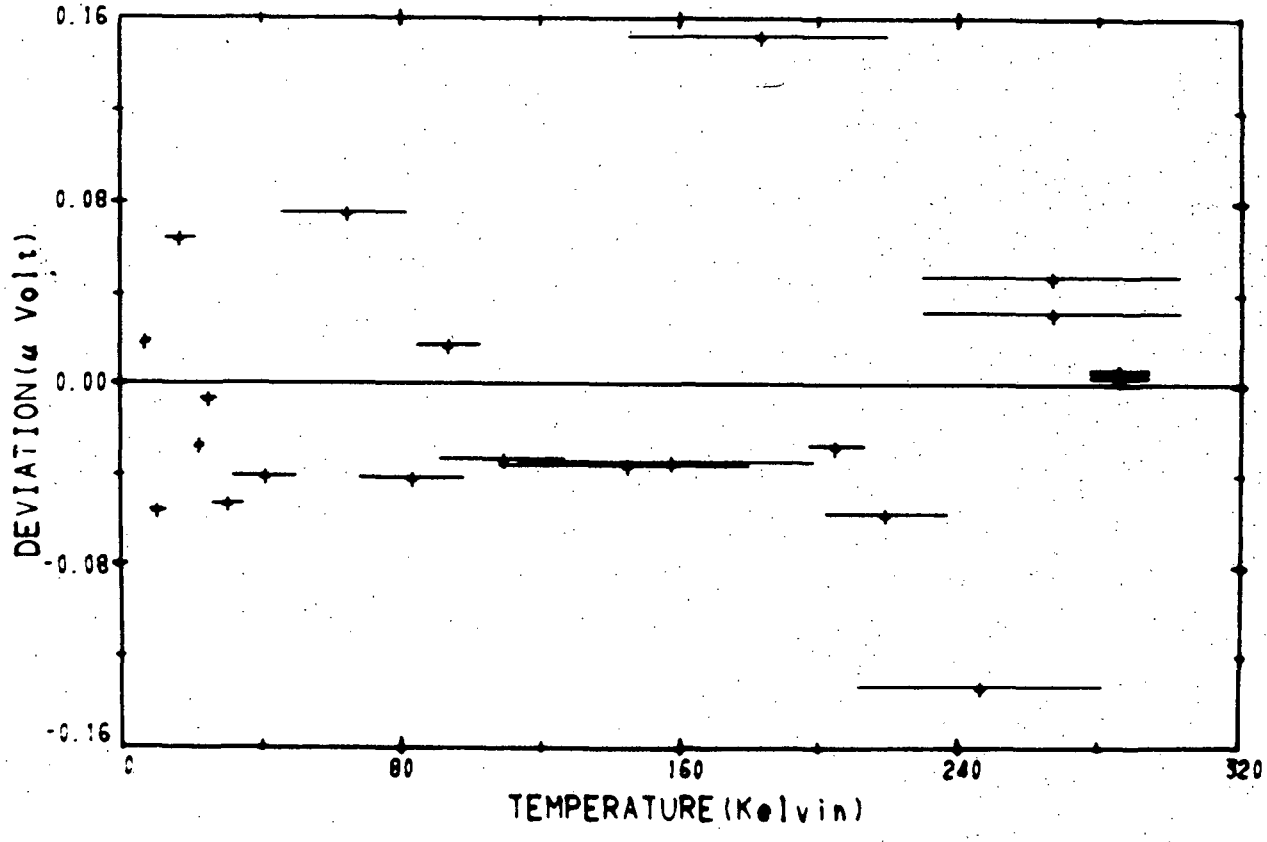

Figure 3. Thermovoltage deviations for Fe-22Cr-13Ni-5Mn stainless steel

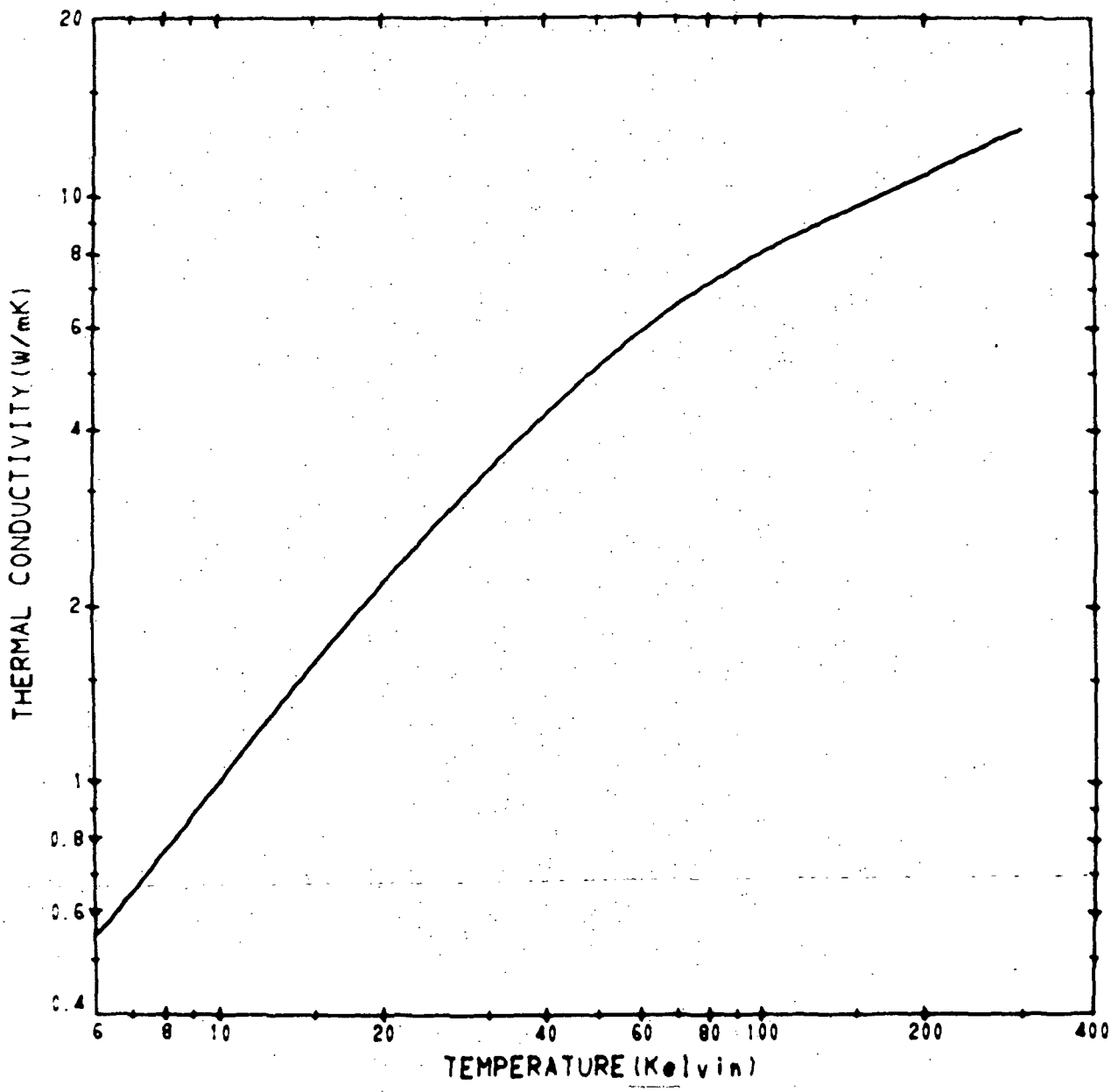

Figure 4. Thermal conductivity of Fe-22Cr-13Ni-5Mn stainless steel

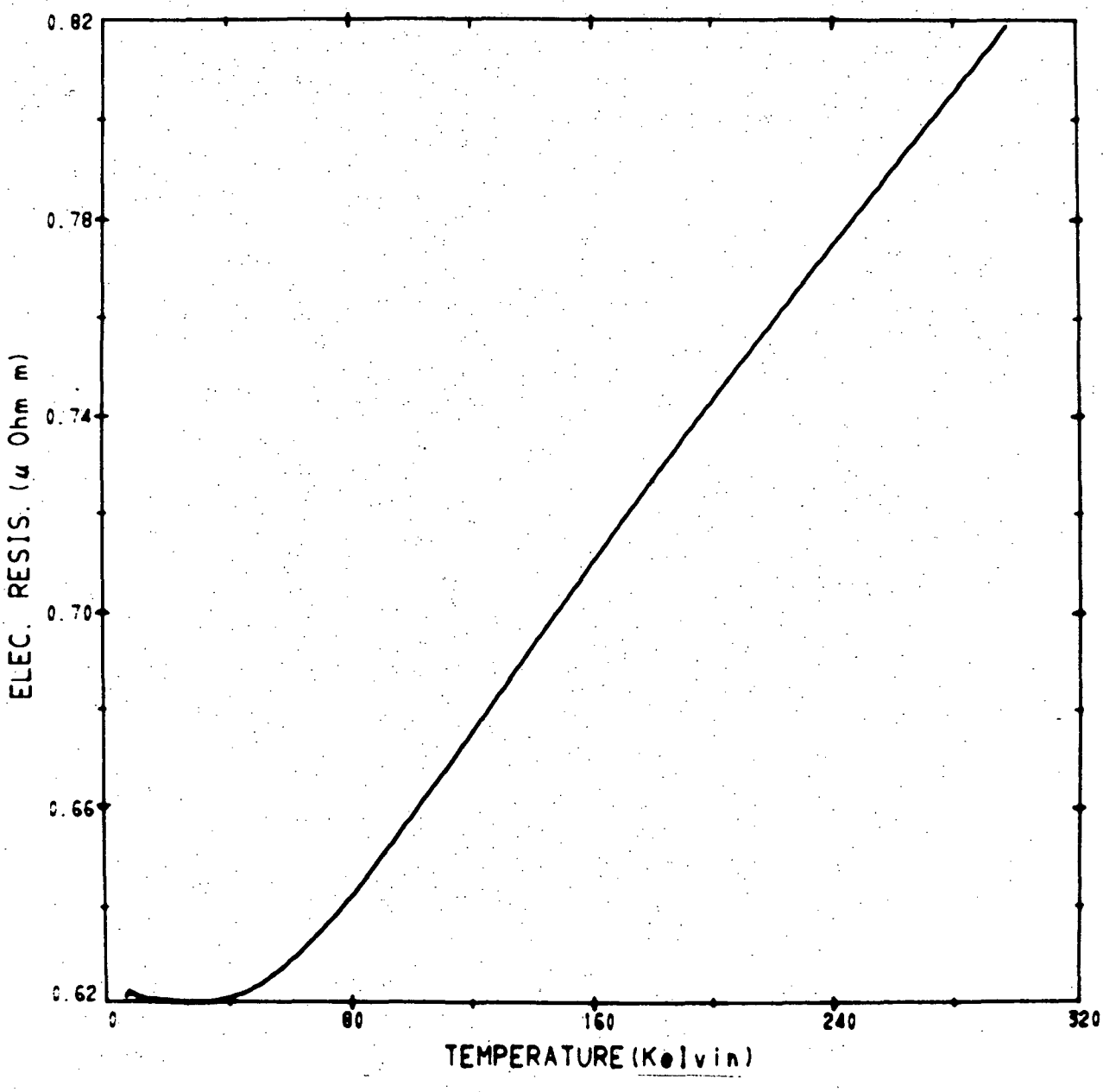

Figure 5. Electrical resistivity of Fe-22Cr-13Ni-5Mn stainless steel

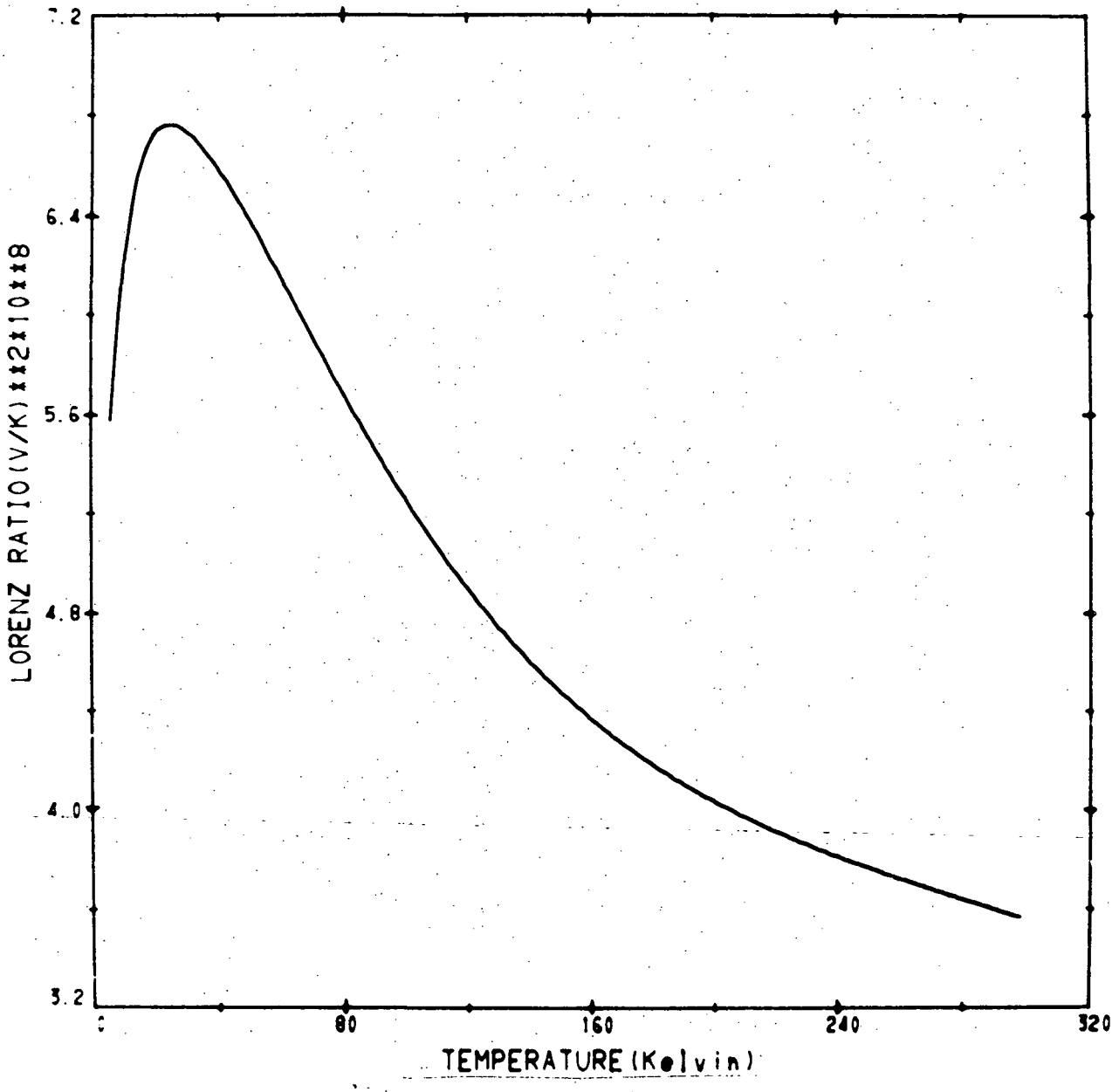

Figure 6. Lorenz ratio of Fe-22Cr-13Ni-5Mn stainless steel

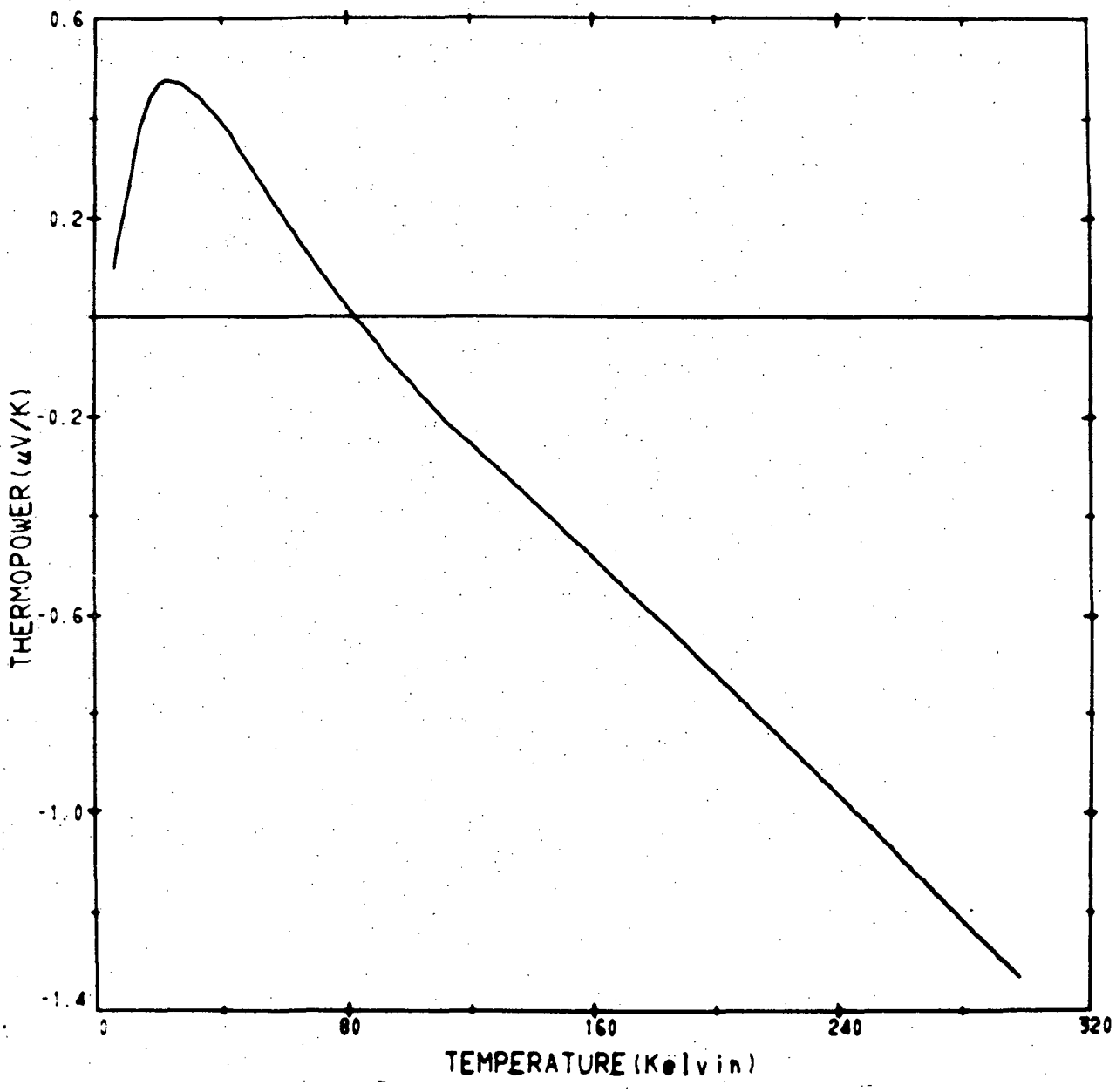

Figure 7. Thermopower of Fe-22Cr-13Ni-5Mn stainless steel

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