Int. J. Heat Mass Transfer. Vol. 9, pp. 845–852. Pergamon Press 1966. Printed in Great Britain

THERMAL CONDUCTIVITIES OF SOME IRON ALLOYS HAVING UNUSUALLY HIGH LATTICE COMPONENTS

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(*Received* 9 *February* 1966)

Abstract—Results for the thermal conductivity and electrical resistivity of some twenty-two cast irons including five high nickel content materials are presented and discussed. The measurements cover the temperature range 20–200°C which has been extended up to 800°C for particular materials.

The transport property behaviour of these materials is complex and is certainly influenced by the amount and type of free carbon present coupled with the amounts of other alloy constituents. It does not seem possible to fit the results by any simple empirical relationship based upon the use of the derived Lorenz function. Pending accurate measurements an estimate of the thermal conductivity behaviour of a cast iron can, however, be obtained from considerations of the general pattern of the thermal conductivity–temperature relationships of these materials and a rough measurement at room temperature coupled with measurements of electrical resistivity and knowledge of its chemical composition and metallurgical state.

NOMENCLATURE

T, absolute temperature [°K];
λ, total thermal conductivity [$\text{Wcm}^{-1}\,\text{deg}^{-1}$];
λ_e, electronic component of thermal conductivity;
λ_g, lattice component of thermal conductivity;
ρ, total electrical resistivity [$\mu\Omega$ cm];
σ, electrical conductivity $1/\rho$ [$\mu\Omega^{-1}\,\text{cm}^{-1}$];
L, derived Lorenz function $\left(\frac{\lambda\rho}{T}\right)$[$\text{V}^2\,\text{deg}^{-2}$].

INTRODUCTION

FROM THE results of investigations of λ and σ of metals and alloy series, it has been shown [1, 2] that for absolute temperatures, normally above 300°K, simple correlations of the type first proposed by Smith and Palmer [3], namely

$$\lambda = AT\sigma + C,$$

often apply. With the appropriate values for the constants A and C for the different groups of alloys, λ can usually be predicted from the simpler measurement of ρ to within 5–10 per cent, an order of accuracy which is often sufficient for many practical purposes.

In an earlier paper [2] special treatment was found to be necessary for some materials such as beryllium and chromium, for which λ_g tended to be comparable with λ_e (where $\lambda = \lambda_e + \lambda_g$), and particularly for graphite for which λ_g was by far the predominant component. Reference was also made to the high lattice components of certain conducting compounds [4] such as the borides and carbides of titanium and zirconium, and the differences which occur in their temperature dependence. The need was then stressed for further work to be undertaken on such materials and certainly upon cast-irons for which some very high lattice components had been obtained [5–8]. Furthermore there was evidence of considerable dependence on heat treatment. In 1939 attention had been drawn [9] to some values of λ and ρ obtained by Masumoto [10] for some cast irons at 34°C. Before heat

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that the theoretical value of L is $2{\cdot}443 \times 10^{-8}$ $\mathrm{V}^2\,\mathrm{deg}^{-2}$ and

$$\lambda_e = 2{\cdot}443 \times 10^{-8}\frac{T}{\rho}$$

and

$$\lambda_g = \lambda - \lambda_e.$$

DISCUSSION

From the results of Table 3 it can be seen that many of these materials possess extremely high values of λ_g. In most cases λ_g is larger than λ_e, and for some it is up to seven times greater. This is unusual for metals and must be mainly attributed to the high carbon content, particularly when free carbon is present as graphite flakes. Depending on the orientation and inter-connection of these flakes, it is quite possible for such a material to have a high λ accompanied by a high value of ρ. This is in part due to the fact that the anisotropy of the graphite lattice is less marked for heat flow than for electrical flow, and to λ of graphite being greater than that of iron whereas the reverse is true for σ. Furthermore examination of Table 3 shows that λ_g decreases with increase in temperature. For about half of the materials studied this decrease is an approximately linear function of $1/T$. Where this is not so the rate of decrease usually tends to become greater than $1/T$ at higher temperatures.

Comparison of the percentage drop in λ_g between 50° and 200°C shows values ranging from 4 to 30 per cent with two thirds of these values between 9 and 20 per cent. A material with a drop of only 4 per cent is BALM for which λ_g is approximately equal to λ_e.

From Table 2 it would seem that the large difference between this material and sample SQJ has been brought about by the addition of less than 0·1 per cent of magnesium. This addition led to the formation of spheroidal graphite in BALM, whereas in SQJ the graphite was present in laminar flake form. This marked decrease of both λ and ρ due to the formation of spheroidal graphite is similar to the different behaviour of a "ductile iron" to that of a grey iron reported by Brophy and Sinnott [8]. The two Lepaz irons, with the graphite reported as in the nodular form, also have the lowest Lorenz function of the present group of materials. Palmer [17], although reporting only electrical resistivities of cast irons, also found that there was "a lowering of ρ as the flakes became finer". Figure 1 illustrates the behaviour of the λ vs. σT relationship for these present materials. This form of correlation has been found most satisfactory for several groups of alloys and the two lines

$$\lambda = 2{\cdot}43 \times 10^{-8}T\sigma + 0{\cdot}092$$

and

$$\lambda = 2{\cdot}39 \times 10^{-8}T\sigma + 0{\cdot}042$$

which have been proposed [18] for irons and steels in the alpha and gamma phases respectively are also included in the figure. Whilst the data for BALM lie between these two lines the figure emphasizes that no correlation based solely upon the use of the simple Lorenz function can be used for these cast irons.

The present results are found to be in general accord with the earlier work but since the differences in composition and condition of these materials can produce such large effects, it is not profitable to make direct comparison of the results in some cases, only one physical property has been discussed and in only a few instances are full details available of condition and structure, etc. The subject is clearly most complex. It is necessary not only to consider the effect on property due to a particular element but also its inter-related effects upon the structure of the graphite or the containing matrix, which in turn can have further effects upon the transport properties. However, earlier authors emphasized the effects of the relative total amounts of free carbon and of silicon which are present.

Table 4 contains the values at 50° and 200°C for L obtained using the appropriate data for λ and ρ in Table 3 for those materials for which

Table

Material	Total C	Combined C	Si	S	P	Mn	C Ni
HG 22	2·85–3·05	0·65–0·95	2·0–2·4	0·05	0·35–0·5	0·6–1·0	
HG 12	3·45	0·7	2·3	0·055	0·5	0·8	0·1
YHA "Loded Centricast"	3·0–3·4		2·6–3·1	0·1 max	0·7–0·9	0·6–1·2	
E 19-1A	3·1–3·4		1·75–2·2	0·12	0·15	0·6–0·9	
Ti–Va	2·92	1·07	0·97	0·063	0·47	0·79	0·17
Unnamed R	3·32	0·62	1·88	0·086	0·101	1·0	1·23
R–H	2·91	0·68	1·44	0·112	0·13	0·73	0·16
"Jenop"	3·16		1·42	0·148	0·068	0·54	4·62
Unnamed W	2·99		1·78	0·16	0·06	0·095	2·65
C 1	3·47	0·84	1·55	0·122	0·17	0·55	0·04
A 1	2·86	0·61	1·65	0·081	0·052	1·07	2·34
A 2	3·18	1·04	1·54	0·082	0·053	0·98	2·18
Ni–Cr	3·34	0·86	1·60	0·152	0·094	0·57	3·31
NM	2·92	0·74	2·0	0·130	0·094	0·45	2·51
NCM	3·35	1·22	1·53	0·136	0·078	0·55	4·08
Lepaz 30	2·30	0·4	1·0	0·10	0·04	0·75	
Lepaz 35	2·30	0·7	1·0	0·15	0·04	1·15	

Table 2. I

Material	Total	Chemical composition (%)						
	C	Si	S	P	Mn	Ni	Cr	Cu
KVD	2·9	1·6			1·1	13·5	2·6	7
SQJ	3·0	1·8			1·0	22·1	1·8	<0·1
BALM	3·0	1·75	0·010	0·020	1·05	21·5	1·65	<0·1
BAHT	3·0	1·8	0·007	0·026	0·83	14·5	2·6	7·25
BAHU	3·0	2·4	0·006	0·018	0·80	15·2	1·8	7·40

Details of low alloy cast irons studied

hemical composition (%)				Other details supplied
Cr	Mo	V	Ti	
0·55–0·85		0·2–0·40		Cast with white fracture, annealed at 1020°C and slowly cooled.
0·35	<0·1			Centrifugally cast in grey form and not subsequently heat treated.
0·6–1·0				
0·2–0·3				
0·12		0·17	0·05	
0·07				Stress relieved at 500–550°C for 6 h and furnace cooled.
0·02	0·05			Stated to be a sample conforming to B.S. 1452, grade 17 grey cast iron.
0·88	1·11			
0·7	0·98			Heat treated at 600°F for 48 h.
0·06	<0·02			Medium size flake graphite in fine pearlite matrix and small areas of randomly distributed phosphide eutectic.
0·04	0·98			Mixed coarse and short compacted flake graphite in matrix of pearlite with very fine pearlite associated with small isolated iron carbide areas.
0·02	1·08			Coarse but compacted flake graphite in matrix of pearlite with iron carbide.
0·48	0·06			Medium to coarse flake graphite in matrix of pearlite with iron carbide.
0·10	1·0			Medium size short compacted flake graphite in matrix of coarse and fine pearlite.
0·69	1·16			Medium size flake graphite in matrix of aciculated ferrite with fair amounts of fine pearlite associated with large areas of iron carbide.
				A pearlite malleable cast iron, graphite present in nodules of aggregate form in a mainly laminated pearlite matrix with ferrite lakes surrounding the nodules and a fine ferritic network round the pearlite grains.
				Similar to 30, graphite present in nodules of aggregate form in a wholly laminated pearlite matrix.

etails of high nickel content cast irons

Mg	Fe	Other details
	bal.	Flake graphite and 10–20% fine spikey undercooled graphite and 10–15% carbide in austenite matrix. As cast.
	bal.	Normal flake graphite and 5–7% fine carbide in austenite matrix. As cast.
0·095	bal.	Spheroidal graphite. As cast.
	bal.	Flake graphite with lower tendency to graphitise than BAHU. As cast.
	bal.	Flake graphite. As cast.

Table 3. Values of λ, λ_e, λ_g and ρ for 22 cas

Material	50°C				100°C				200°C				300°C				
	λ	λ_e	λ_g	ρ	λ	λ_e	λ_g	ρ	λ	λ_e	λ_g	ρ	λ	λ_e	λ_g	ρ	
HG 22	0·279	0·117	0·162	67·2	0·287	0·130	0·157	70·0	0·302	0·152	0·150	76·1					
HG 12	0·419	0·100	0·319	79·1	0·419	0·110	0·309	82·7	0·419	0·128	0·291	90·0					
YHA	0·410	0·086	0·324	91·6	0·406	0·097	0·309	94·3	0·398	0·113	0·285	102·1					
E19-1A	0·534	0·094	0·440	84·3	0·511	0·103	0·408	88·1	0·481	0·120	0·361	96·6	0·459	0·131	0·328	106·6	
Ti-Va	0·565	0·194	0·371	40·6	0·520	0·208	0·312	43·7	0·488	0·228	0·260	50·8					
Unnamed R	0·389	0·116	0·273	68·1	0·396	0·127	0·269	71·7	0·387	0·149	0·238	77·4					
R–H	0·477	0·129	0·348	61·0	0·472	0·142	0·330	64·3	0·448	0·160	0·288	72·0	0·410	0·173	0·237	81·0	0·
"Jenop"	0·320	0·115	0·205	68	0·324	0·126	0·198	72·3	0·332	0·144	0·188	80·1					
Unnamed W	0·364	0·128	0·236	61·4	0·370	0·141	0·229	64·7	0·380	0·161	0·219	71·6					
C1	0·513	0·105	0·408	74·8	0·498	0·115	0·383	79·1	0·471	0·132	0·339	87·4					
A1	0·384	0·140	0·244	56·3	0·382	0·153	0·229	59·5	0·378	0·175	0·203	66·1					
A2	0·372	0·143	0·229	55·3	0·369	0·156	0·213	58·3	0·363	0·180	0·183	64·2					
Ni Cr	0·470	0·102	0·368	77·1	0·459	0·112	0·347	81·3	0·440	0·129	0·311	89·6					
NM	0·293	0·122	0·171	64·6	0·300	0·132	0·168	68·9	0·310	0·155	0·155	74·4					
NCM	0·312	0·117	0·195	67·3	0·316	0·128	0·188	71·0	0·324	0·147	0·177	78·5					
Lepaz 30	0·385	0·224	0·161	35·2	0·394	0·236	0·158	38·7	0·394	0·249	0·145	46·5	0·394	0·251	0·143	55·7	0·
Lepaz 35	0·389	0·221	0·168	35·7	0·398	0·232	0·166	39·2	0·402	0·248	0·154	46·6	0·402	0·254	0·148	55·0	0·
SQJ	0·412	0·051	0·361	153·6	0·400	0·058	0·342	157·7	0·375	0·070	0·305	164·7	0·352	0·082	0·270	170·8	0·
BALM	0·159	0·079	0·080	100·5	0·168	0·088	0·080	103·9	0·182	0·105	0·077	110·0	0·194	0·121	0·073	115·6	0·
KVD(AR)	0·256	0·045	0·211	174·3	0·256	0·050	0·206	182·0	0·260	0·061	0·199	190·0	0·260	0·071	0·189	196·0	0·
KVD(HT)	0·277	0·052	0·225	151·2	0·278	0·059	0·219	155·0	0·279	0·071	0·208	162·3	0·279	0·083	0·196	169·6	0·
BAHT	0·364	0·057	0·307	139·5	0·356	0·064	0·292	142·8	0·339	0·077	0·262	149·6					
BAHU(AR)	0·419	0·049	0·370	159·5	0·406	0·056	0·350	161·8	0·383	0·069	0·314	166·5	0·368	0·082	0·286	171·5	0·
BAHU(HT)	0·419	0·053	0·366	148·0	0·406	0·060	0·346	151·5	0·383	0·074	0·309	157·5	0·368	0·086	0·282	162·5	0·

(AR) = as received; (HT) = heat treated to about 800°C.

irons studied

400°C				600°C				800°C				% drop in λ_g between 50°C and 200°C	Approximate $\lambda_g \propto 1/T$ relationship
λ	λ_e	λ_g	ρ	λ	λ_e	λ_g	ρ	λ	λ_e	λ_g	ρ		
												7	Yes
												9	Yes
												12	Yes
												18	Yes
												30	Yes
												13	No
372	0·176	0·196	93·5									17	No
												8	Yes
												8	Yes
												17	Fair
												17	Fair
												20	Fair
												15·5	Fair
												9	Fair
												9	Fair
385	0·252	0·133	65·2	0·335	0·226	0·109	94·6	0·234	0·207	0·027	12·7	10	Fair
398	0·251	0·147	65·5	0·356	0·232	0·124	92·0	0·251	0·225	0·026	116·5	8	Below 400°C
337	0·093	0·244	176·5	0·314	0·114	0·200	187·0	0·294	0·134	0·160	196·2	16	Below 400°C
205	0·136	0·069	120·6	0·225	0·164	0·061	129·8	0·249	0·191	0·058	137·5	4	No (almost constant)
262	0·082	0·180	200·0	0·274	0·104	0·170	206·0	0·287	0·126	0·161	208·5	6	Fair
282	0·093	0·189	177·0	0·284	0·111	0·173	192·0	0·287	0·126	0·161	208·5	7·5	Fair
												15	Fair
356	0·094	0·262	175·0	0·339	0·117	0·222	181·6	0·318	0·139	0·179	188·5	15	No
356	0·098	0·258	168·0	0·339	0·120	0·219	177·0	0·318	0·139	0·179	188·5	15	No

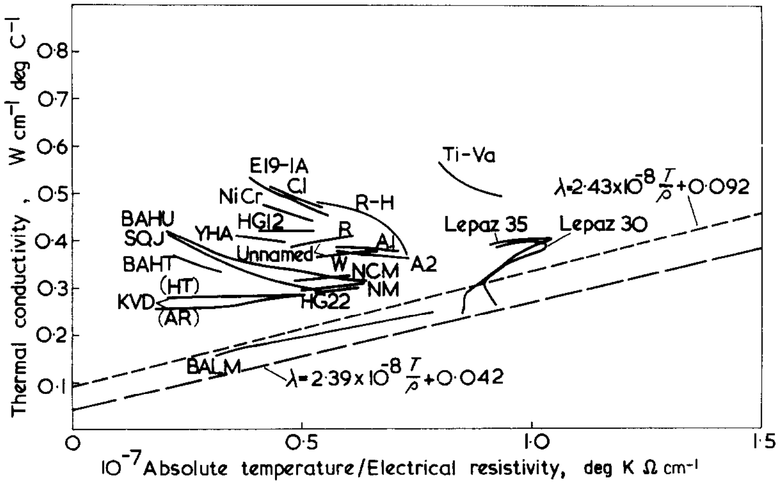

FIG. 1. Thermal conductivity vs. absolute temperature divided by electrical resistivity for cast irons studied.

Table 4. L for cast irons with various amounts of free carbon and silicon

Material	% C		% Si	*L*	
	Total	Free		50°C	200°C
HG 12	3·45	2·75	2·3	10·26	7·98
C 1	3·47	2·63	1·55	11·87	8·7
Ni–Cr	3·34	2·48	1·60	11·21	8·34
R–H	2·91	2·23	1·44	9·0	6·82
Unnamed R	3·32	2·70	1·88	8·21	6·34
A 1	2·86	2·25	1·65	6·7	5·29
A 2	3·18	2·14	1·54	6·26	4·93
NM	2·92	2·18	2·0	5·86	4·87
NCM	3·35	2·13	1·53	6·5	5·36
Ti–Va	2·92	1·85	0·97	7·1	5·24
Lepaz 30	2·30	1·90	1·0	4·2	3·87
Lepaz 35	2·30	1·60	1·0	4·3	3·96

the full analysis was supplied, and relates these values to the carbon and silicon contents.

These results support earlier work and indicate that in general, high λ is obtained with a material containing a high carbon content but with a low silicon content. However, a more definite point can be considered since it can be seen that the twelve materials in the table can be divided into two groups, having free carbon contents above and below 2·2 per cent respectively. For the materials in the latter group the values of L are considerably lower than those in the former. Thus a high value of λ is not necessarily accompanied by a low value of ρ. Furthermore, within the two groups high thermal conductivity in each is obtained with samples having low silicon contents. Whilst the absolute values of λ and ρ are also affected by the other added elements, it is the value of L which appears to be a more representative property to consider in relation to the carbon and silicon contents.

This somewhat limited pattern suggests that it may be possible to make a tentative empirical approach towards trying to calculate λ for a cast iron from the knowledge of ρ and its composition, if the present results are used in a relationship which involves L rather than λ. An attempt was made on these lines with an equation of the form

$$100L_\theta = aL'_{\theta\mathrm{Fe}} + bA + cB + dC + eD + fE + gF,$$

where (i) $L'_{\theta\mathrm{Fe}}$ is a representative value for the Lorenz function of pure iron at the temperature θ, for example $2{\cdot}77 \times 10^{-8}\ \mathrm{V}^2\ \mathrm{deg}^{-2}$ at 50°C;

(ii) a to g are the amounts (wt. %) of Fe, flake graphite, spheroidal graphite, combined C, Si, total S + P, and total of metallic elements respectively;

(iii) A to F are constants for each of these impurities;

and it was found that there is no one set of values for A to F which will fit the present results. Furthermore if allowance is made that F should have a value at 50°C somewhere in the range $2{\cdot}5$ to $3 \times 10^{-8}\ \mathrm{V}^2\ \mathrm{deg}^{-2}$, since all the elements are metallic, it is still not possible to obtain values for A to E which will fit the data. This is an obvious area for more work to be carried out but it seems clear that any approach must take into account the form of the free carbon which is present.

For the three Ni–Resist materials the main difference in chemical composition is in the nickel content. Figure 2 illustrates the linear variation which is found for the dependence of λ on nickel content for the three materials after heat treatment. Not only is the marked dependence on nickel content for this relatively highly alloyed state surprising, but the direction of the dependence is contrary to that expected [5, 9]. Here again it seems likely that there are metallurgical differences associated with other variants, possibly silicon content [5] as well as the nickel content which could account for these results. It is certainly a fact that two of these materials showed changes of one or both properties due to the heat treatment they received during the thermal conductivity determinations.

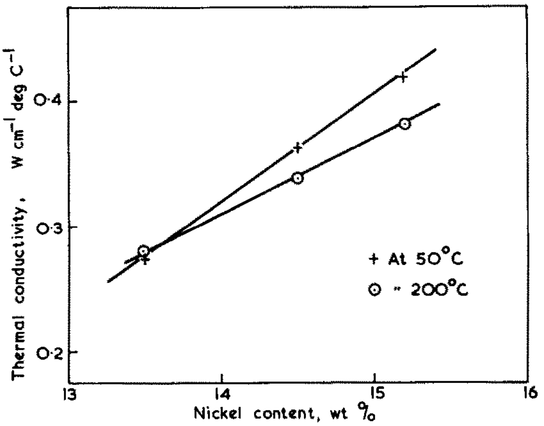

FIG. 2. Variation of thermal conductivity with nickel content for high nickel content cast irons.

A further surprising aspect of this whole subject of nickel content is that the manufacturer's specification allows this content to vary over quite wide limits for nominally one material. A final point in regard to these materials is that the sample BAHU contains a lower Cr and higher Si content than the other two and has therefore a greater graphitizing tendency. The fact that both λ and ρ for the material are higher is consistent with such a tendency.

The two rather outstanding findings discussed for the above materials, together with the rather random transport properties which can be obtained, serve to emphasize the intricacies of the problem and the real need for a systematic study to be made on the relationship between the λ and ρ of a cast iron and its metallurgical condition, chemical composition and heat treatment.

Whether such a study would ever enable λ to be predicted with any degree of certainty is open to question, but it should lead to a more complete understanding of the processes involved and of the extent to which λ_g depends upon the form of the carbon constituent or the matrix.

The NPL decision always to measure, rather than to attempt to estimate, λ for iron alloys with more than 1 per cent carbon content has been fully justified. However, Fig. 3 illustrates the variation of λ with temperature for most of the present materials, some having been excluded for the sake of clarity. It is seen that there is a tendency for them to conform in general to a somewhat similar pattern, at least up to 800°C, to that obtained for other irons and steels [20]. The extreme curves for pure iron and a highly alloyed austenitic steel are shown as broken lines roughly enveloping the present data. Hence if an approximate value can be obtained for λ of a material of this type at normal temperatures, together with a knowledge of ρ and its metallurgical history, it should be possible to form a fair estimate of its likely behaviour to higher temperatures.

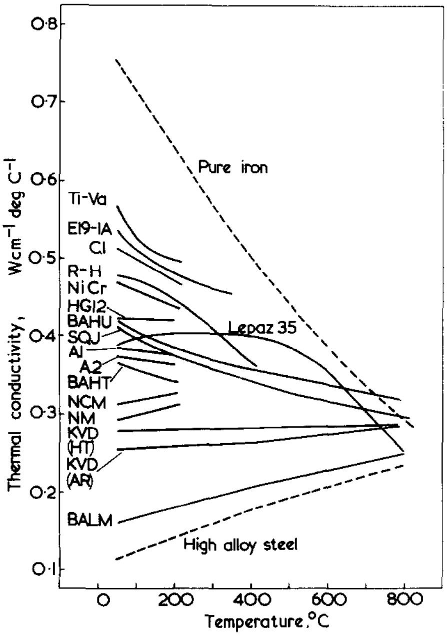

FIG. 3. Variation of thermal conductivity with temperature for cast irons studied.

The outstanding problem of determining λ at about room temperature can be solved by the use of the thermal comparator method [21–23]. This simple device enables a fairly accurate measurement to be made in a few seconds, providing the sample has a good surface finish and some materials of known thermal conductivity are available for calibration purposes. It is suggested that the above techniques should be used in the first instance if the data are required quickly or the accuracy does not justify the time-consuming standard methods which would normally have to be employed. Furthermore, measurements of λ made at room temperature by the thermal comparator method and of ρ made by a four-probe method, before and after various heat treatments, would provide a simple and rapid means of ascertaining the overall effect of such treatments on these properties.

ACKNOWLEDGEMENTS

The authors wish to thank the following organizations for their interest and for permission to publish the results of work undertaken on their behalf: British Cast Iron Research Association, Messrs. Ricardo & Co. Engineers (1927) Ltd., Hepworth & Grandage Ltd., Ruston & Hornsby Ltd., Walmsleys (Bury) Ltd., Leys Malleable Castings Co. Ltd. They also wish to thank the members of the International Nickel Co. Ltd., for their help and continued interest in the work on the high nickel content cast irons and finally their colleagues Margaret Woodman and A. E. Langton who assisted with some of the experimental work. The work on the nickel cast irons and the preparation of the account has formed part of the Research Programme of the National Physical Laboratory, and of the thermal conductivity studies of the Thermophysical Properties Research Centre. The paper is published by permission of the Director of the National Physical Laboratory.

REFERENCES

1. R. W. POWELL and R. P. TYE, The thermal and electrical conductivities of some nickel–chromium (Nimonic) alloys, *Engineer, Lond.* **209**, 729–732 (1960).
2. R. W. POWELL, Correlation of metallic thermal and electrical conductivities for both solid and liquid phases, *Int. J. Heat Mass Transfer* **8**, 1033–1045 (1965).
3. C. S. SMITH and E. W. PALMER, Thermal and electrical conductivities of copper alloys, *Trans. Am. Inst. Min. Metall. Engrs* **117**, 225–243 (1935).
4. R. W. POWELL and R. P. TYE, The thermal conductivities of some electrically conducting compounds, in *Special Ceramics 1964*, pp. 243–257. Academic Press, New York (1965).

5. E. Sohnchen, The electrical and thermal conductivity of cast iron, *Arch. Eisenhütt Wes.* **8**, 223–229 (1934).
6. J. Maréchal and J. Listray. A study of the thermal conductivity and the electrical resistivity of cast iron, *Révue Métall., Paris* **36**, 240–250 (1939).
7. C. H. Lorig and V. H. Schnee, Damping capacity, endurance, electrical and thermal conductivities of some grey cast irons, *Trans. Am. Fndrym. Ass.* **48**, 425–448 (1940).
8. J. H. Brophy and M. J. Sinnott, The thermal and electrical conductivities of ductile cast iron and several grey cast irons, *Trans. Am. Soc. Metals* **52**, 567–581 (1960).
9. R. W. Powell, A survey of existing data on the thermal and electrical conductivities of irons and steels, Iron and Steel Institute, Special Report No. 24, 253–268 (1939).
10. H. Masumoto, On the electrical and thermal conductivities of carbon steel and cast iron, *Sci. Rep. Tôhoku Univ.* **16**, 417–435 (1927).
11. J. R. Davis, H. W. Deem and H. W. Lownie, Service of the life of iron castings can be affected by thermal conductivity, *Trans. Am. Fndrym. Soc.* **64**, 223–225 (1956).
12. D. Fitzgeorge and J. A. Pope, The thermal and elastic properties of eight cast irons, *Trans. NE. Cst Instn Engrs Shipbldrs* **75**, 285–330 (1959).
13. K. B. Palmer, The thermal and electrical conductivities of ductile cast iron and several grey cast irons by J. H. Brophy and M. J. Sinnott—A critical review, *B.C.I.R.A. Jl* **8**, 266–272 (1960).
14. J. W. Donaldson, The thermal conductivities of grey cast irons, *Proc. Instn Mech. Engrs* **2**, 953–983 (1928).
15. J. W. Donaldson, The thermal conductivity of wrought iron, steel, malleable cast iron and cast iron, *J. Iron Steel Inst.* **128**, 255–276 (1933).
16. J. W. Donaldson, The thermal conductivity of high-duty and alloy cast irons, *Fndry Trade J.* **60**, 513–516 (1939); see also, *Engineering, Lond.* **148**, 26–28 (1939).
17. K. B. Palmer, The electrical resistivity of cast iron, *J. Res. Dev. Br. Cast Iron Res. Ass.* **4**, 571–585 (1953).
18. R. W. Powell, The thermal conductivities of some gas turbine materials, Iron and Steel Institute, Special Report No. 43, 315–318 (1952).
19. F. Bollenrath and W. Bungardt, The thermal conductivity of pure iron and commercial steels, *Arch. Eisenhütt Wes.* **9**, 253–262 (1935).
20. R. W. Powell, Thermal conductivities of solid materials at high temperatures, *Research, Lond.* **7**, 492–501 (1954).
21. R. W. Powell, Experiments using a simple thermal comparator for measurement of thermal conductivity, surface roughness and thickness of foils or of surface deposits, *J. Scient. Instrum.* **34**, 485–492 (1957).
22. R. W. Powell and R. P. Tye, Thermal conductivity of ceramic materials and measurements with a new form of thermal comparator, in *Special Ceramics, 1962*, pp. 261–280. Academic Press, New York (1963).
23. R. W. Powell and B. W. Jolliffe, The thermal conductivities of scandium and some rare earth metals, *Phys. Lett.* **14**, 171–172 (1965).

Résumé—Les résultats des conductivités thermiques et des résistivités électriques de vingt-deux sortes de fontes parmi lesquelles cinq contenant une quantité élevée de nickel sont présentés et discutés. Les mesures couvrent la gamme de températures de 20 à 200°C qui a été étendue jusqu'à 800°C pour certain matériaux.

Le comportement des propriétés de transport de ces matériaux est complex; il est certainement influencé par la quantité et le type de carbone libre présent associé aux quantités d'autres constituants de l'alliage. Il ne semble pas possible de représenter les résultats par une relation empirique simple employant la fonction de Lorenz. En attendant des mesures précises, une estimation du comportement de la conductivité thermique d'une fonte peut, cependant, être obtenue à partir de considérations sur la variation générale de la conductivité thermique de ces matériaux en fonction de la température et d'une mesure grossière à la température ambiante associée aux mesures de la résistivité électrique et à la connaissance de sa composition chimique et de son état métallurgique.

Zusammenfassung—Ergebnisse für die thermische Leitfähigkeit und den elektrischen Widerstand von zweiundzwanzig Gusseisensorten, worunter sich fünf mit hohem Nickelgehalt befinden, sind angegeben und diskutiert. Die Messungen erstrecken sich auf den Temperaturbereich von 20–200°C und sind für verschiedene Materialien auf 800°C ausgedehnt.

Das Verhalten der Transporteigenschaften dieser Materialien ist komplex und ist sicher beeinflusst vom Gehalt und von der Art des anwesenden freien Kohlenstoffes, gekoppelt mit den Anteilen anderer Legierungsbestandteile. Es erscheint nicht möglich, die Ergebnisse durch eine einfache empirische Beziehung, die auf der abgeleiteten Lorenzfuktion beruht, zur Übereinstimmung zu brigen. Bei noch anhängigen genauen Messungen kann eine Abschätzung des Verhaltens der thermischen Leitfähigkeit von Gusseisen durchgeführt werden unter Berücksichtigung des allgemeinen Verlaufs der Wärmeleitfähigkeit–Temperaturbeziehungen dieser Materialien und einer groben Messung bei Zimmertemperatur zusammen mit Messungen der elektrischen Leitfähigkeit und bei Kenntnis ihrer chemischen Zusammensetzung und ihres metallurgischen Zustands.

Аннотация—Представлены и анализированы результаты по исследованию теплопроводности и электрического сопротивления 22 чугунных отливок, включая 5, содержащих высокий процент никеля. Измерения проводились в диапазоне температур от

20 до 200°C, а для определенных материалов верхний предел температур составлял 800°C.

Характеристики переноса для этих материалов сложны и, несомненно, зависят от количества и вида свободного углерода в материале в сочетании с количеством других веществ составляющих сплав.

Не представляется возможным описать результаты какимлибо простым эмпирическим соотношением, основанным на использовании выведенной функции Лоренца. Однако до проведения тщательных измерений можно получить примерную оценку теплопроводности.