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Report written October 10, 1947

Report issued October 2, 1953

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A method of measurement of resistivity of liquid NaK alloys has been developed by which data have been taken at temperatures above 600°C.

Although nonconducting materials such as glass, ceramics, etc., were tried, it was found necessary to employ a metal tube for these measurements at high temperature. The method, in short, consists of passing a measured current through a calibrated Inconel tube containing NaK alloy, heating the central portion to a uniform temperature over a length of 12", and measuring the potential drop across the heated length. The temperature of the tube is measured with thermocouples simultaneously with the potential measurement. The resistance of the NaK is then calculated from the formula for parallel resistors:

$$\frac{1}{R_T} = \frac{1}{R_C} + \frac{1}{R_N} \text{ or } R_N = \frac{R_C R_T}{R_C - R_T} \quad (I)$$

where R_T = Resistance of tube full of NaK

R_C = Calibration resistance of empty tube

R_N = Resistance of NaK

The resistivity of the NaK is derived as follows:

$$R = \frac{R_N A}{L} \quad (II)$$

where R = Resistivity

A = Cross-sectional area of NaK

L = Length of NaK

Experimental Method

The Inconel tube, 0.252" O.D., 0.008" wall and 3 feet long, was first cleaned with soap, then with nitric acid, then with water, acetone, and alcohol in succession. Kovar metal tubes were silver-soldered to the ends; glass was sealed to the Kovar. At one end of the tube the glass was sealed off, while at the other end the tube was evacuated and the liquid metal admitted through a branch tube. A small bulb, 3/4" in diameter, was left unfilled to permit thermal expansion of the NaK.

Leads for potential measurements were spot-welded to the tube at exactly 12" (30.48 cm) apart. To minimize errors due to thermoelectric effects, molybdenum was chosen for leads. Chromel-Alumel thermocouples were placed against the tube and were insulated (oxide coat) from the tube to prevent electrical contact. The tube with leads and thermocouples in place was packed in a powder inside of a heavy copper cylinder which provided heat uniformity. The powder chosen was boron mixed with asbestos fiber, which served to deoxidize the atmosphere around the tube as well as to insulate it electrically.

The copper cylinder was tubular, 3/4" I.D., 3" O.D., and 18" long. The Inconel tube was centered within the cylinder so that the points of potential measurement on the tube were 3" inside the ends of the cylinder. Asbestos cement was placed around the tube at the ends of the cylinder to retain the powder and to minimize air flow.

The tube and cylinder were heated inside of a 3" tube furnace which was three feet long. The heating power was regulated by Variacs and indicated by ammeters. The furnace had three windings - one over the whole length, the other two at the ends overlapping the main winding. The temperatures were regulated and a uniform temperature along the tube was maintained with this equipment. The degree of uniformity obtained was $\pm 0.2^{\circ}\text{C}$ at temperatures below 300°C and $\pm 0.6^{\circ}\text{C}$ at 600°C .

The current passed through the tube was obtained from two large storage batteries in parallel. All of the leads of the current circuit were of manganin, and a rheostat was used to adjust the current.

The current was determined by measuring the potential across a 0.01 ohm standard.

The potentials across the tube and that of the standard resistor were measured simultaneously on L. and N. Type K potentiometers. Thermocouple readings were also taken on a Type K potentiometer.

Calibration of Tube

The tube was calibrated by making resistance measurements with the inside evacuated. The calibration was found not to change significantly after the first heating (see Table I and Figure 1).

The cross-sectional area of the Inconel tube was calculated from expansion coefficient data supplied by the International Nickel Company. These data are given in Table II and plotted in Figure 2.

Table I

CALIBRATION OF INCONEL TUBE

First Heating		Second Heating		Third Heating	
Temp. (°C)	Resistance (Milliohms)	Temp. (°C)	Resistance (Milliohms)	Temp. (°C)	Resistance (Milliohms)
50.0	73.78	20	76.1	86	76.6
113	74.45	124	77.1	104	76.8
163	75.12	148	77.3	136	77.0
213	75.93	182	77.6	190	77.6
230	76.25	210	77.9	220	77.95
345	78.9	227	78.0	270	78.4
512.5	80.3	303	78.7	303	78.6
514	80.5	385	79.5	358	79.24
58.0*	76.5*	445	80.0	508	80.8
		478	80.4	517	81.0
		552	81.3	575	80.3
		580**	81.2**	600	80.0
		600	80.1	613	80.4
		610	80.2		
		625	80.4		

*After Cooling.

**Transition Temperature.

Table II

AREA OF INCONEL TUBE

Temp. (°C)	Area	
	(Sq.In.)	(Sq.Cm.)
20	0.0437	0.282
300	0.0439	0.283
400	0.04405	0.284
500	0.0442	0.285
600	0.0443	0.286

Results

Resistivity determinations were made on two sodium-potassium alloys containing 44.8% and 80% potassium by weight, respectively. The observed and calculated values of the resistivity are given in Tables III and IV. The measured resistance of the filled tube is given in column 2, the resistance of the empty Inconel tube (read from Figure 1) in column 3, and the resistance of the NaK alloy (calculated by equation I) in column 4. The resistivity of the alloy was calculated by equation II and is given in the last column. The resistivity values for these two compositions are plotted as a function of temperature in Figure 3. The curve for the 44.8 w/o K (32.3 a/o K) alloy appears to consist of two straight lines showing a break at 220°C.

There is some speculation that this break is associated with the existence of a compound in the liquid state.¹ The curve for the 80 w/o K (70.2 a/o K) alloy is uniformly curved.

¹ Kremann, R., Pestemer, Max, and Schreiner, Hellmut; Rec. Trav. Chim. 51, 557-563 (1932), "The Inner Friction of Liquid Sodium-Potassium Alloys."

Table III

RESISTANCE DATA - NaK ALLOY (44.8 w/o K)

Temperature (°C)	R _T (milliohms)	R _C (milliohms)	R _N (milliohms)	A (cm ²)	R (microhm cm)
22 *	3.38	76.1	3.54	0.282	32.8
47.2*	3.43	76.3	3.59	0.282	33.2
75.2	3.44				
84.0	3.48				
90.0	3.53	76.7	3.70	0.282	34.1
114.5*	3.61				
122 *	3.65				
150 *	3.78				
112 **	3.595	76.95	3.77	0.282	34.9
146	3.755	77.3	3.95	0.282	36.6
167	3.85	77.5	4.05	0.282	37.6
181	3.92	77.6	4.13	0.282	38.2
207	4.04	77.8	4.26	0.282	39.4
246	4.26	78.2	4.51	0.283	41.8
268	4.37	78.4	4.63	0.283	43.0
303	4.57	78.7	4.85	0.283	44.9
337	4.77	79.1	5.08	0.283	47.2
417	5.26	79.8	5.63	0.284	52.5
453	5.48	80.2	5.88	0.285	54.9
475	5.59	80.4	6.01	0.285	56.2
486	5.63	80.5	6.05	0.285	56.5

*Too high resistance.

**Repeated.

Table IV

RESISTANCE DATA - NaK ALLOY (80w/o K)

Tempera- ture (°C)	R _T (milliohms)	R _C (milliohms)	R _N (milliohms)	A (cm ²)	R (microhm cm)
30	3.62	76.2	3.80	0.282	35.2
36	3.65	76.2	3.83	0.282	35.5
102	3.99	76.8	4.21	0.282	39.0
136	4.17	77.2	4.41	0.282	40.7
174	4.37	77.5	4.63	0.282	43.0
219	4.64	78.0	4.93	0.282	45.6
243	4.79	78.2	5.10	0.283	47.4
273	4.98	78.5	5.32	0.283	49.4
302	5.17	78.7	5.54	0.283	51.3
333	5.37	79.0	5.76	0.283	53.5
368	5.62	79.4	6.05	0.284	56.3
399	5.84	79.6	6.30	0.284	58.7
438	6.13	80.0	6.64	0.284	61.9
469	6.37	80.3	6.92	0.285	64.6
480	6.44	80.4	7.00	0.285	65.4
500	6.62	80.6	7.21	0.285	67.5
518	6.75	80.8	7.37	0.285	69.0
553	7.06	81.1	7.74	0.285	72.4
600	7.48	80.1	8.25	0.286	77.4
650	7.95	80.6	8.83	0.286	82.8
712	8.65	81.2	9.67	0.287	91.0
720	8.77	81.3	9.83	0.287	92.5

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