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ULTRASONIC TEMPERATURE MEASURING DEVICE

by

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ABSTRACT

Rhenium wires, previously irradiated to 8.7×10^{19} integrated thermal flux and 2.6×10^{19} integrated fast flux, were annealed and ultrasonically tested in vacuum up to ~4000°R, together with nonirradiated rhenium control wires. Sound velocities were measured during heating and cooling. These control wire and irradiated wire velocity data exhibited no significant systematic differences. From this it was concluded that structural or compositional radiation effects due to the above radiation levels were negligibly small with respect to the present ultrasonic thermometry application. The scatter in these velocity data corresponds to uncertainties in ultrasonically determined temperatures as follows: near 2000°R, ±2%; near 3000°R, ±1%; near 4000°R, less than ±1%. In addition to comparing these control and irradiated wires up to ~4000°R, two nonirradiated rhenium wires, one annealed and one not annealed, were tested while being heated up to ~5500°R. Up to 4000°R, i.e., before the second wire became annealed, the two ultrasonically indicated temperatures differed as follows: near 2000°R, 10%; near 3000°R, 8.5%; near 4000°R, 2.5%. Above 4000°R, annealing brought the two ultrasonically indicated temperatures into closer agreement: near 5000°R, 1/2%; near 5350°R, better than 1/2%.

Table 1

Pyrometer Calibration

Filament Current	Scale	Temperature Reading Dec. 19, 1966		Brightness Temperature (traceable to NBS)
Amperes		°C	°K	°K
6.5	L	935	1208	1160
7.0	L	1060	1333	1290
7.5	L	1185	1458	1410
8.0	H	1260	1533	1510
8.5	H	1325	1598	1600
9.0	H	1385	1658	1685
9.5	H	1455	1728	1755
10.0	H	1510	1783	1820
10.5	H	1565	1838	1880
11.0	H	1595	1868	1930
11.5	XH	1710	1983	1990
12.0	XH	1750	2023	2035
12.5	XH	1800	2073	2090
13.0	XH	1850	2123	2130
13.5	XH	1900	2173	2175
14.0	XH	1945	2218	2220
14.5	XH	2005	2278	2260
15.0	XH	2040	2313	2300
15.5	XH	2085	2358	2340
16.0	XH	2130	2403	2380
16.5	XH	2155	2428	2410
17.0	XH	2200	2473	2450
17.5	XH	2230	2503	2490
18.0	XH	2300	2573	2520

Typical oscillograms are shown in Figures 1a and 1b. Figure 1a oscillograms correspond to a first pair of control and irradiated Re specimens. Figure 1b oscillograms correspond to a second pair of specimens. It is seen that as temperature increases, the transit time increases in the sensor. Also important, the echoes obtained from the front and rear of the sensor remained at substantially constant amplitude. Transit times can be estimated from the oscillograms, but are more easily obtained automatically with the Ultrasonometer (NASA CR-72101, October 1966, Figure 9). Data are shown in Tables 2 and 3, comparing control and irradiated wires. The tabulated transit times are rounded off to the nearest 0.1 μ sec. Normalized sound velocity vs temperature is plotted in Figures 2 and 3. These graphs show that there are no significant systematic differences between the control and irradiated wires, all of which are from the same parent wire. Superposition of these graphs shows the excellent reproducibility of the Re data.

Having verified predictions that the radiation effects on structure or composition would not significantly influence sound velocity, it was decided to test nonirradiated Re wires to the maximum temperature capability of the oven. Two Re sensors, 0.020" diameter x 2" long, were flash butt-welded to 0.030" diameter Re lead-in wires. One of the sensors (specimen A) had previously been a control wire and so was annealed, while the other sensor (specimen B) had not been previously tested at high temperature. Data are tabulated in Table 4, and plotted in Figure 4. Data were obtained on heating only, as the tungsten element failed at ~5500°R on rising temperature. It was observed that both sensors followed the rapid cooling in the furnace following heater failure. The good agreement between both sensors, and between these data and the data obtained earlier (Figures 2 and 3) again shows that Re exhibits a substantially reproducible velocity vs temperature characteristic. Reliable thermometry accuracy of $\pm$ 50°R at a temperature up to ~5000°R therefore appears attainable in a 2" sensor.

Table 2

Extensional Wave Transit
Time in Rhenium Sensors
vs Temperature

Time	Temperature		Measured Transit Time, μ sec		Normalized Velocity	
hrs	°C	°R	Control	Irradiated	Control	Irradiated
(12/12/66)						
1030	25	536	22.0	22.1	1.0000	1.0000
1055	810	1949	23.6	23.6	.9321	.9363
1110	1050	2381	24.4	24.5	.9014	.9018
1125	1225	2696	24.9	25.0	.8833	.8838
1135	1375	2966	25.4	25.5	.8659	.8664
1153	1530	3245	25.8	26.0	.8524	.8497
1213	1625	3416	26.4	26.5	.8330	.8336
1230	1730	3605	26.8	26.9	.8206	.8212
1243	1850	3821	27.5	27.6	.7996	.8004
1250	1850	3821	27.5	27.6	.7996	.8004
1320	1750	3641	26.9	27.1	.8175	.8152
1330	1630	3425	26.4	26.6	.8330	.8305
1350	1520	3227	25.9	26.1	.8491	.8464
1405	1405	3020	25.5	25.7	.8625	.8596
1420	1205	2660	24.9	25.2	.8833	.8767
1435	1060	2399	24.4	24.6	.9014	.8982
1450	770	1880	23.5	23.6	.9360	.9363
(12/13/66)						
0845	25	536	22.0	22.1	1.0000	1.0000

Table 3

Extensional Wave Transit Time in Rhenium Sensors vs Temperature

Time	Temperature		Measured Transit Time, μ sec		Normalized Velocity	
hrs	°C	°R	Control	Irradiated	Control	Irradiated
(12/15/66)						
0900	25	536	22.1	22.1	1.0000	1.0000
0930	825	1976	23.6	23.6	0.9363	0.9363
1125	1070	2417	24.4	24.4	0.9055	0.9037
1135	1380	2975	25.4	25.5	0.8681	0.8664
1145	1650	3461	26.3	26.3	0.8384	0.8400
1155	1910	3929	27.7	27.6	0.7975	0.8004
1205	2090	4253	29.0	28.8	0.7617	0.7670
1215	1920	3947	27.6	27.5	0.8004	0.8018
1222	1640	3443	26.3	26.3	0.8384	0.8400
1230	1430	3065	25.6	25.6	0.8601	0.8601
1240	1070	2417	24.5	24.4	0.9018	0.9055
1255	800	1931	23.6	23.5	0.9363	0.9403
1500	25	536	22.1	22.0	1.0000	0.9955

Table 4

Extensional Wave Transit Time in Rhenium Sensors vs Temperature

Time	Temperature		Measured Transit Time, μ sec		Normalized Velocity	
hrs	°C	°R	Specimen A	Specimen B	Specimen A	Specimen B
(12/16/66)						
1120	25	536	22.1	22.3	1.0000	0.9910
1140	900	2111	24.1	24.4	0.9168	0.9055
1155	1150	2561	24.8	25.2	0.8909	0.8767
1210	1415	3038	25.6	26.1	0.8630	0.8464
1225	1640	3443	26.4	26.9	0.8368	0.8212
1240	1920	3947	27.5	27.8	0.8033	0.7946
1255	2100	4271	28.9	28.8	0.7643	0.7670
1305	2270	4577	30.2	30.2	0.7314	0.7313
1317	2490	4973	31.2	31.2	0.7079	0.7079
1334	2505	5000	31.2	31.3	0.7079	0.7045
1340	2580	5135	31.7	31.7	0.6967	0.6967
1345	2625	5216	32.3	32.3	0.6837	0.6837
1356	2700	5351	32.8	32.8	0.6733	0.6733
1400	2800	5531	--	--	--	--

Specimen A previously annealed.

Specimen B not previously annealed (note agreement in transit times above 4000°R).

Neither specimen irradiated.

Normalized velocity: values shown are normalized to the room temperature annealed value of Specimen A. Data were obtained on heating only.

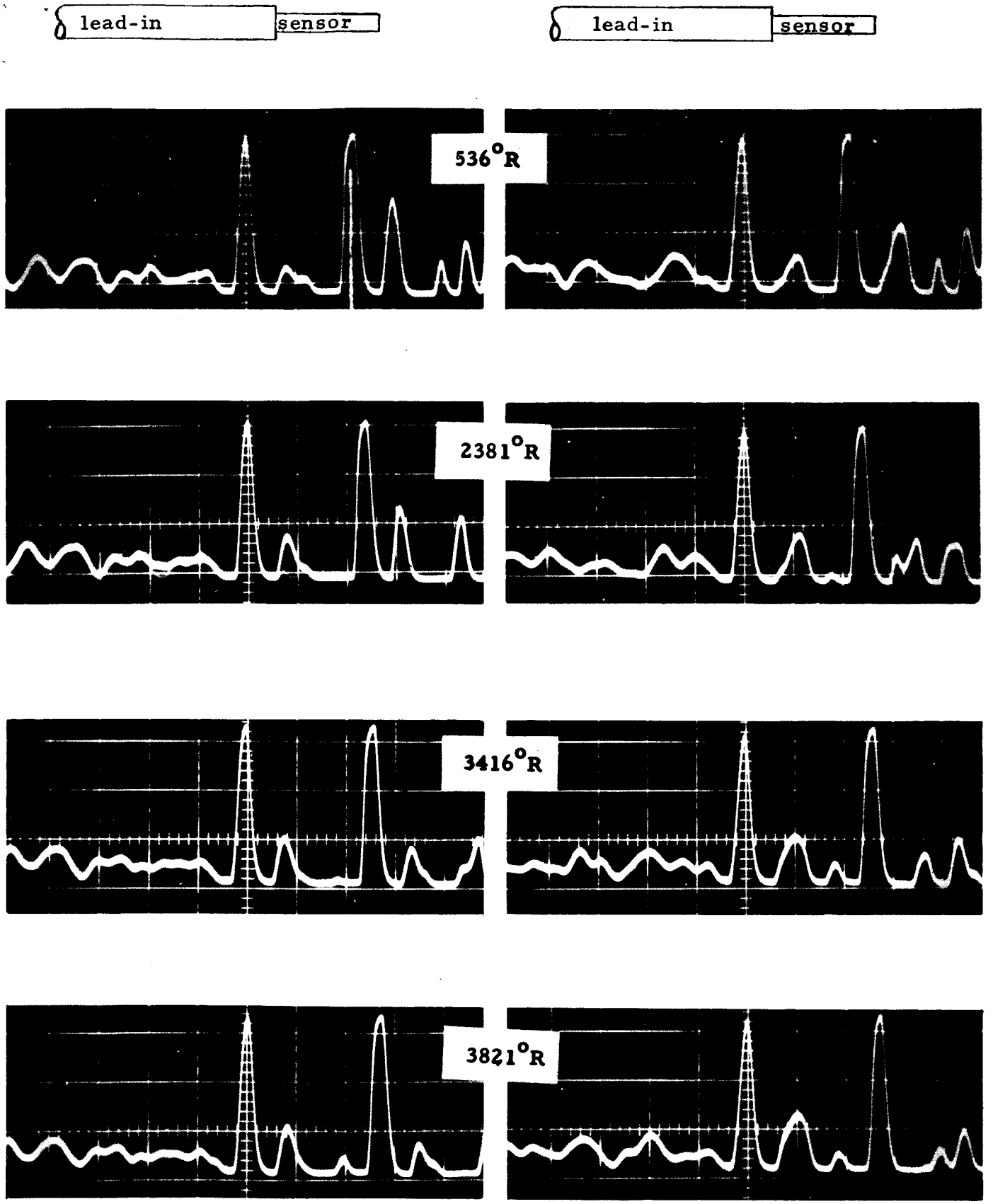

Figure 1a. Representative oscillograms show echoes from front and rear of control and irradiated rhenium sensors. Sweep speed, 10 μs/cm. Sensor dimensions: 0.02" (0.5 mm) dia x 2" (50 mm) long. Date of test: Dec. 12, 1966.

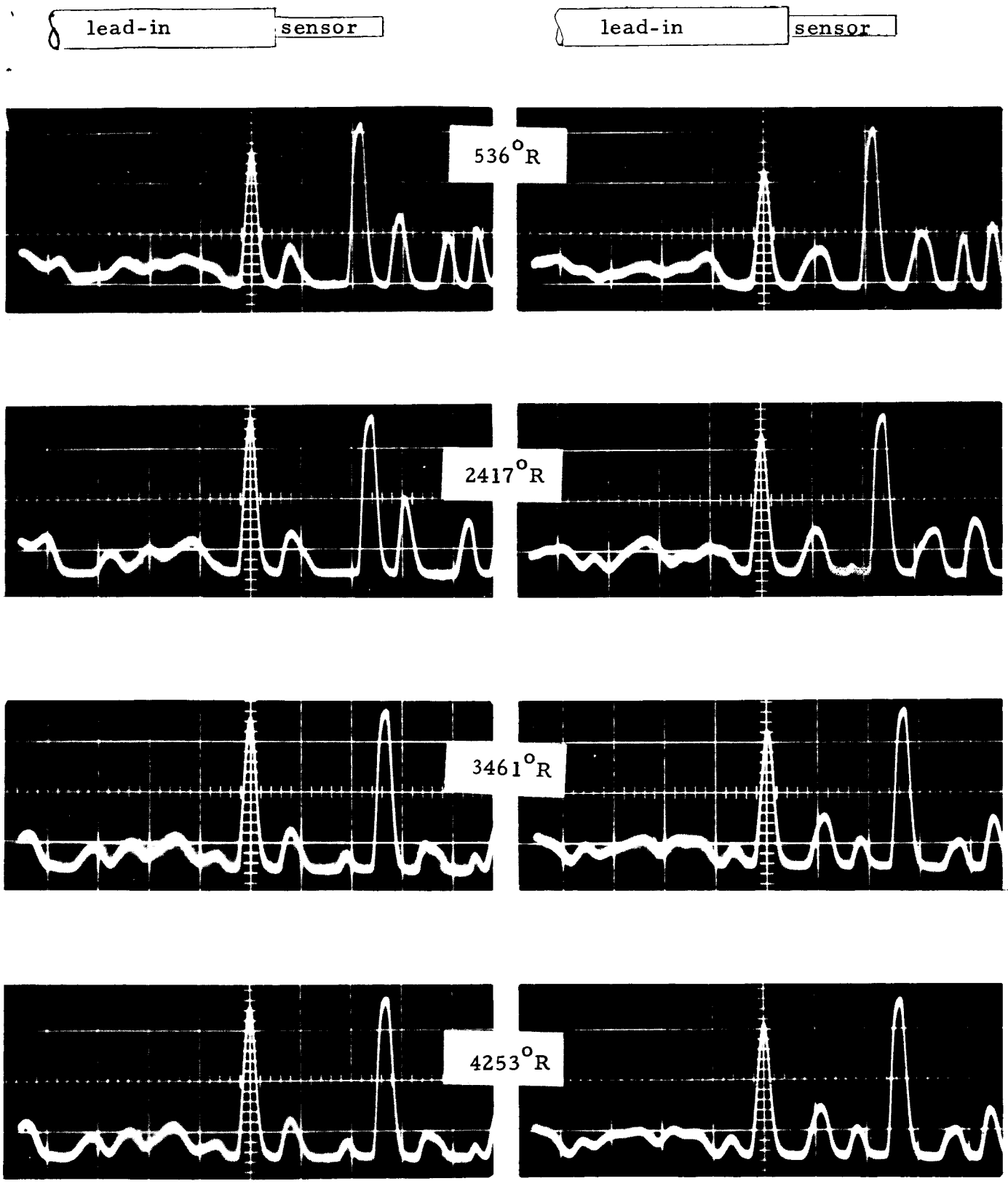

Figure 1b. Confirming tests in second pair of control and irradiated rhenium sensors show reproducibility obtained in ultrasonic experiment. Sweep speed, 10 μs/cm. Sensor dimensions: 0.02" (0.5 mm) dia x 2" (50 mm) long. Date of test: Dec. 15, 1966.

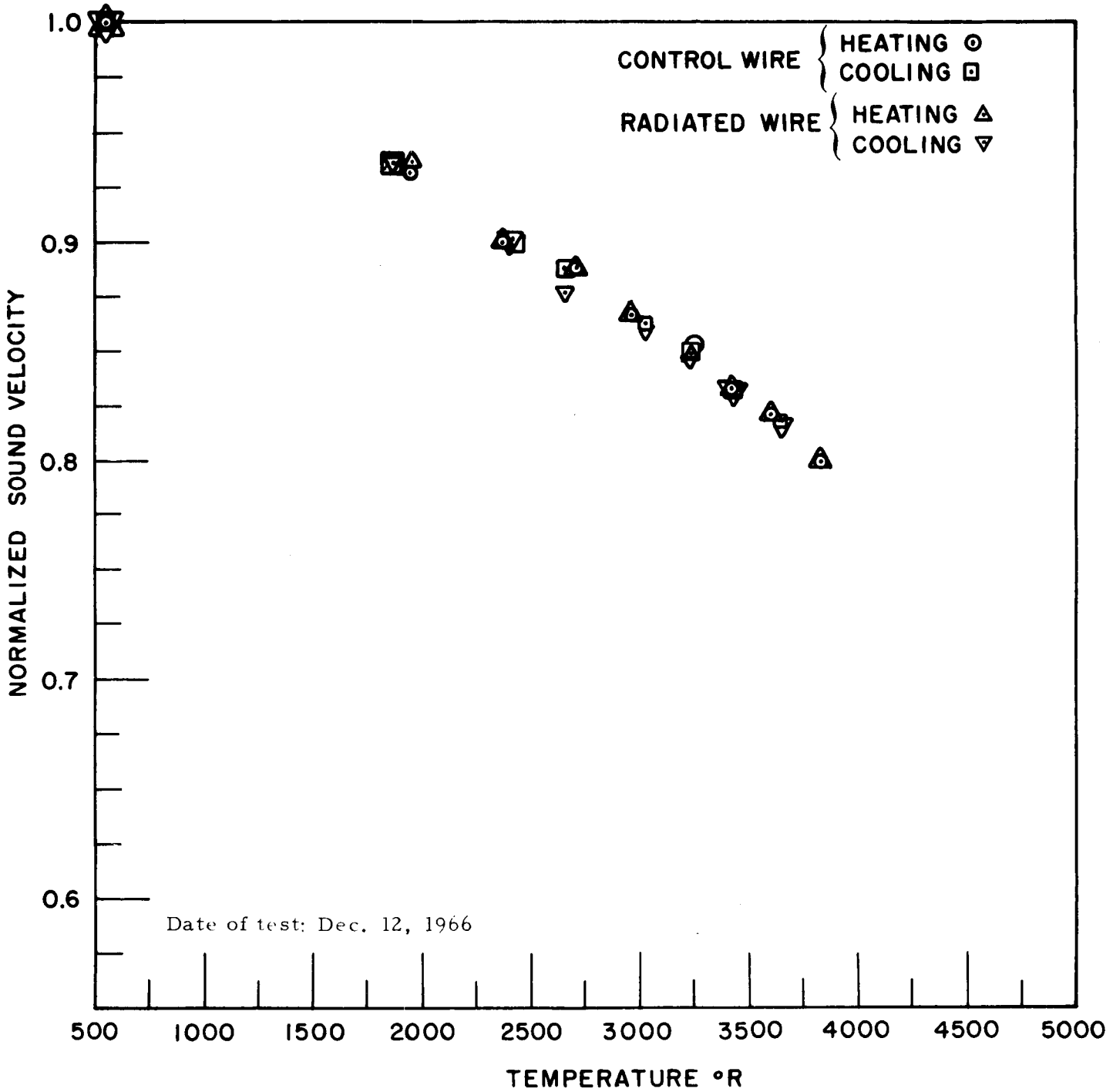

Figure 2. Normalized velocity vs temperature in control and irradiated rhenium specimens.

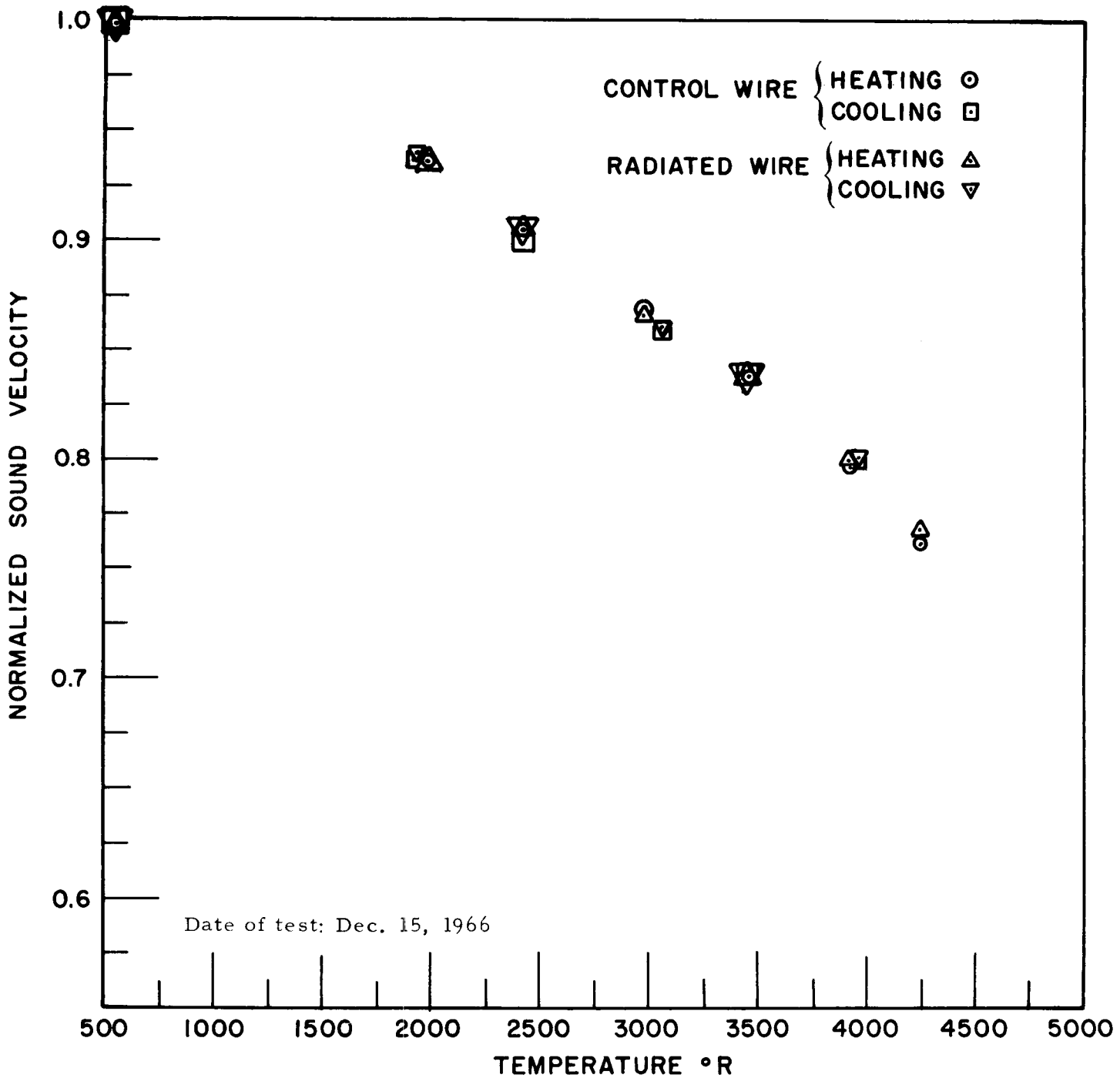

Figure 3. Normalized velocity vs temperature in control and irradiated rhenium specimens.

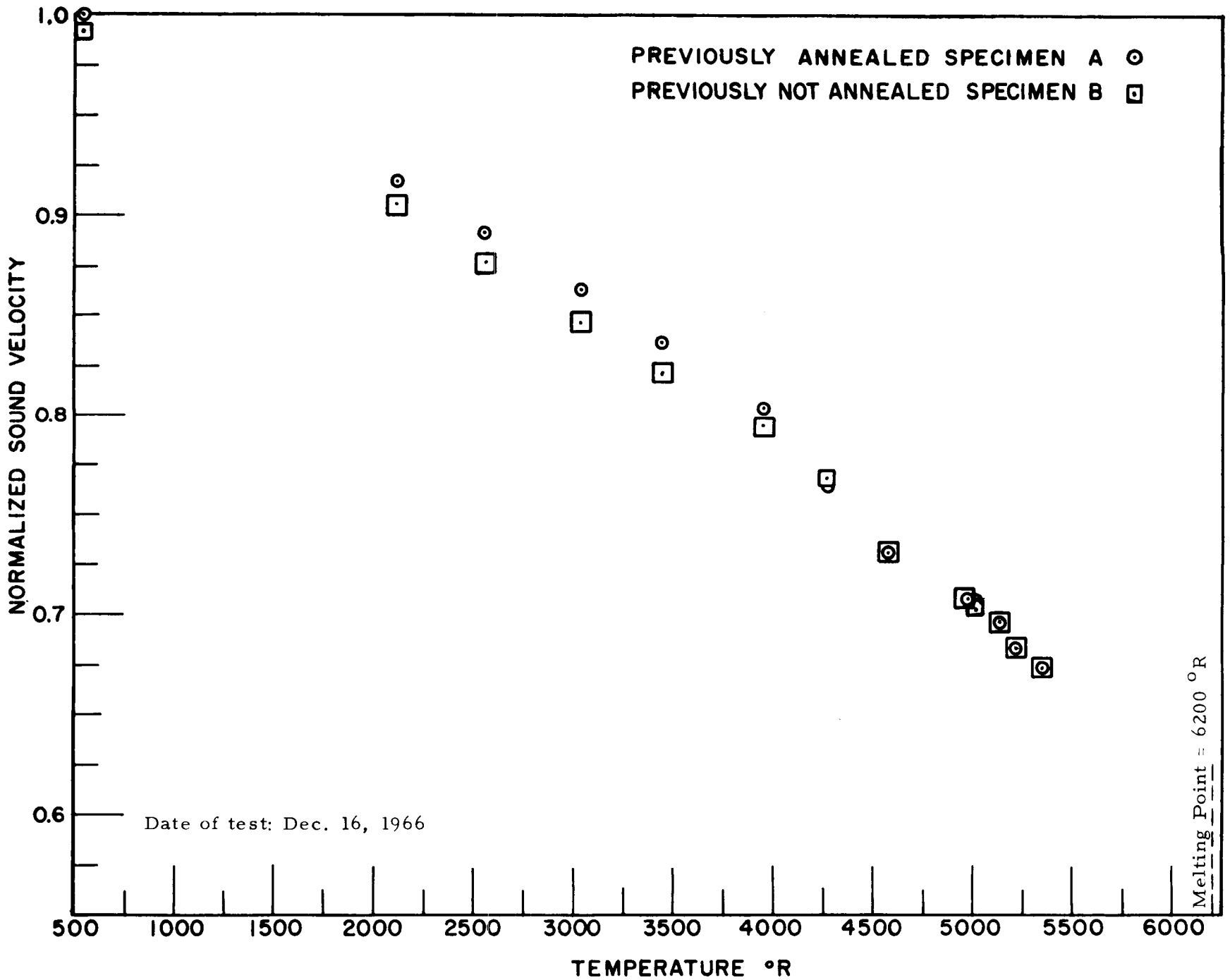

Figure 4. Normalized velocity vs temperature in two nonirradiated rhenium specimens.