16. Industrial Platinum Resistance Thermometers

Industrial platinum resistance thermometers (IPRTs) are constructed from platinum of a lower quality than is used for SPRTs; typically, values of W(H_2O b.p.) range from 1.385 to 1.3925 and values of residual resistance from 10^{-3} to 2 x 10^{-2}. Since IPRT design must provide sufficient reproducibility in the presence of shocks, vibration, high pressure and other hostile environments such as are found in industrial applications, it does not comply with some requirements of the ITS-90, such as strain-free mounting of the wire. Therefore IPRTs are less reproducible than SPRTs. Nevertheless, it is possible to select IPRTs that are only an order of magnitude less reproducible than SPRTs and in a restricted temperature range this difference might be even smaller. In particular environments an IPRT can be even more reproducible than an SPRT where, of course, an SPRT would not be considered for use anyway. Although this chapter delineates many of the drawbacks of IPRTs, we must emphasize that they are among the most-commonly-used thermometers. It is possible to purchase IPRT elements of a selected design or configuration at relatively low cost, to assemble them into sheaths with a minimum of laboratory practice, to anneal them at 450 °C, and finally to calibrate them according to one of the proposed schemes and so obtain an approximation to the ITS-90 to within about ± 50 mK between -180 to 0 °C, and within about ± 10 mK between 0 and 420 °C [Actis and Crovini (1982), Bass and Connolly (1980), and Connolly (1982)].

16.1 Quality of Industrial Platinum Resistance Thermometers

IPRTs are manufactured in a great variety of models and the actual fabrication has a definite influence on their metrological quality. The accuracies discussed in Section 16.2 for IPRTs can be achieved only with thermometers that are suitably stable. This variability led to the specifications codes discussed in Section 16.3 which allow a minimum level of uniformity in the thermometer characteristics. The tolerances allowed are wide (~ 0.2 °C to 2 °C), however, so they are satisfactory only for the more common industrial uses.

A wide variety of techniques have been devised for winding the platinum wire (Fig. 16.1 a). Many thermometers are formed by winding a fine wire or coil on a glass support and imbedding the winding in glass. This can introduce strain into the wires and cause contamination of the wires at higher operating temperatures. The configuration so far introduced that offers the best stability [Actis and Crovini (1982)] and the lowest hysteresis [Curtis (1982)] is that in which a platinum coil is supported inside the

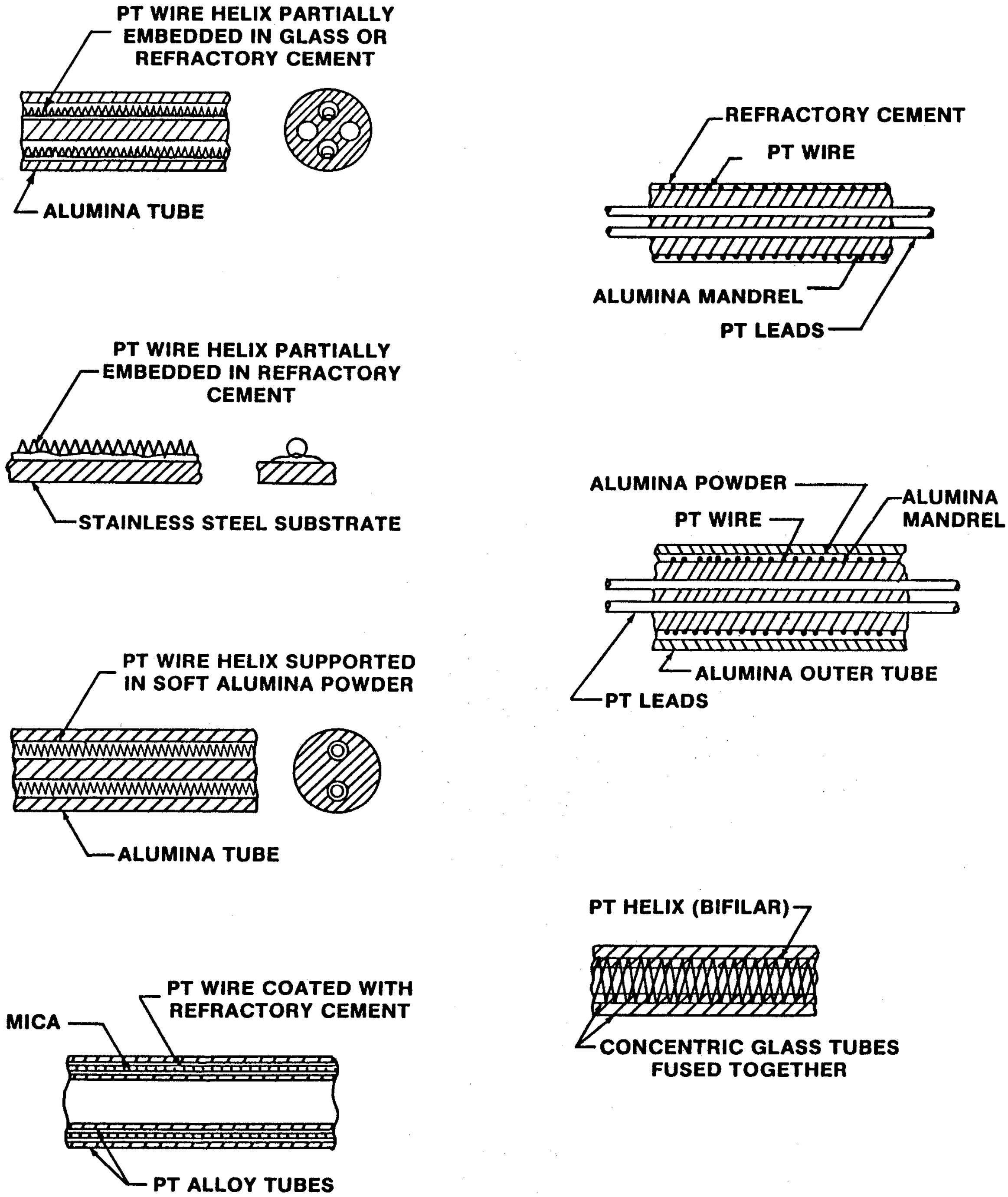

Fig. 16.1: (a) Fabrication of IPRTs: wire-wound;

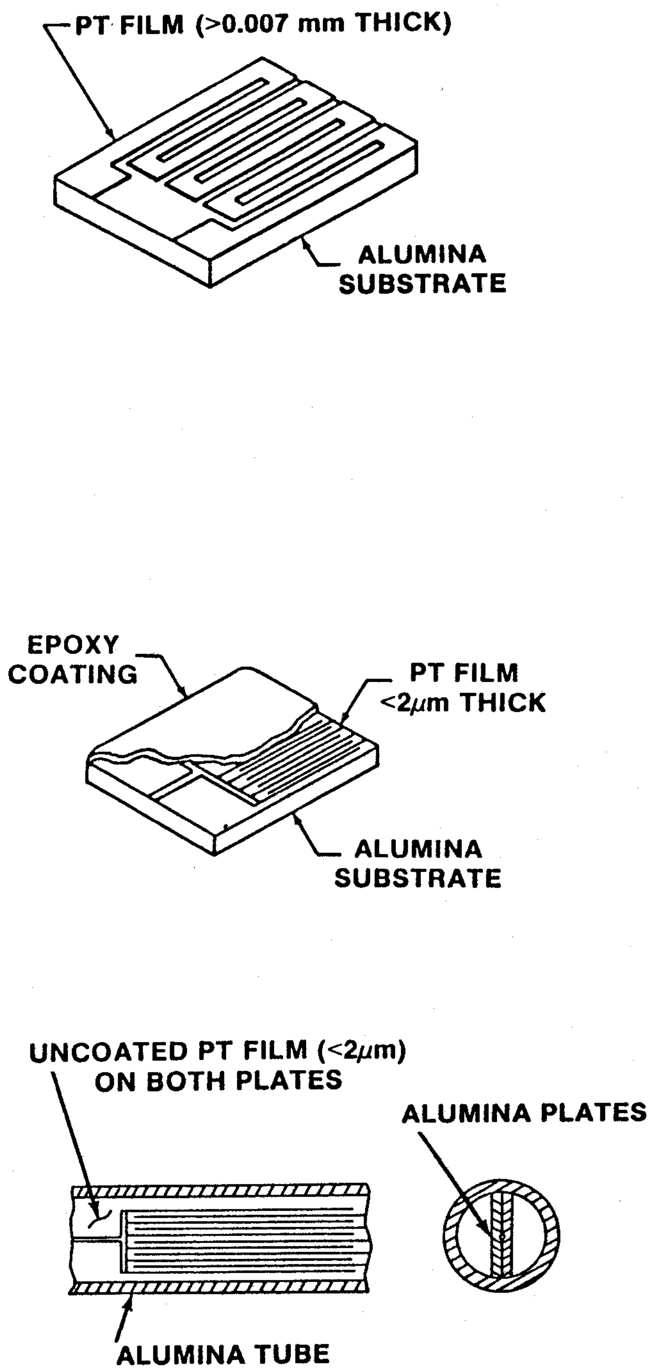

Fig. 16.1: (b) Fabrication of IPRTs: thick film [Curtis (1982)].

capillaries of a twin- (or four-) bore, high-purity-alumina insulator. Either the use of a cement to clamp one side of the coil to the capillary wall or, preferably, the insertion of soft alumina powder prevents the platinum coil from vibrating freely and helps in achieving good reproducibility in industrial applications. IPRTs having the platinum wire fully embedded in cement or hard glass (as above) and thick-film IPRTs (as below) do not afford a comparable reproducibility. Advances in thick film technology led to the development of resistance thermometers having a deposited platinum ink as the detecting element, rather than a platinum wire. These films are deposited on ceramic wafers in a variety of forms (Fig. 16.1 b), including the standard detector size of 3 mm diameter by 25 mm long. They also match the specifications of the national and international codes. One advantage of film sensors appears to be that they are less susceptible to mechanical shock and so are more rugged than conventional wire-wound detectors. However, they can suffer from strain due to differential thermal expansion.

16.1.1 Stability

A wire-wound thermometer is a delicate instrument since strain in the platinum wire causes a change in electrical resistance and so a shift of the W(T) versus T relationship. Also, change in impurity concentration (such as oxidation) affects the thermometric properties [Berry (1982a), (1982b)]. Therefore PRTs should be tested for stability with time on thermal cycling between extreme temperatures in the expected range of operation. For example, Mangum and Evans (1982) investigated the stability upon thermal cycling and handling of 60 IPRTs from 5 manufacturers. Most of them exhibited calibration drifts, instability caused by moisture, and hysteresis. After cycling to 235 °C, one-half of the thermometers showed changes in R(0 °C) larger than the equivalent of 15 mK and one-quarter larger than 50 mK. Comparable results were obtained in other experiments [Sinclair et al. (1972), Curtis (1982)]. Actis and Crovini (1982), Connolly (1982) and Bass and Connolly (1980), on the other hand, found rather better behaviour. Most of the national codes give tolerances for the permitted variation in resistance after a given number of thermal cycles.

IPRTs exhibit *hysteresis* on thermal cycling; this means that the IPRT may have different but reproducible R vs T relationships depending upon the thermal history of the thermometer and on whether a given temperature is being approached from lower or higher temperatures [Curtis (1982)]. A typical example is shown in Fig. 16.2. The span or width of the hysteresis loop can be correlated with W(H_2O b.p.) as shown in Fig. 16.3. For different thermometer constructions the hysteresis effect can be different. The user is

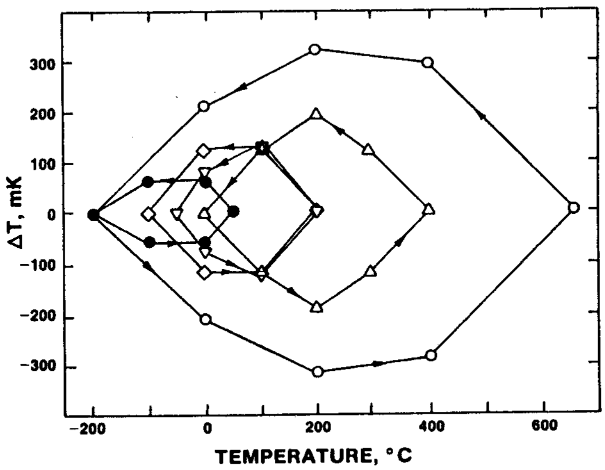

Fig. 16.2: A typical example of hysteresis in an IPRT [Curtis (1982)].

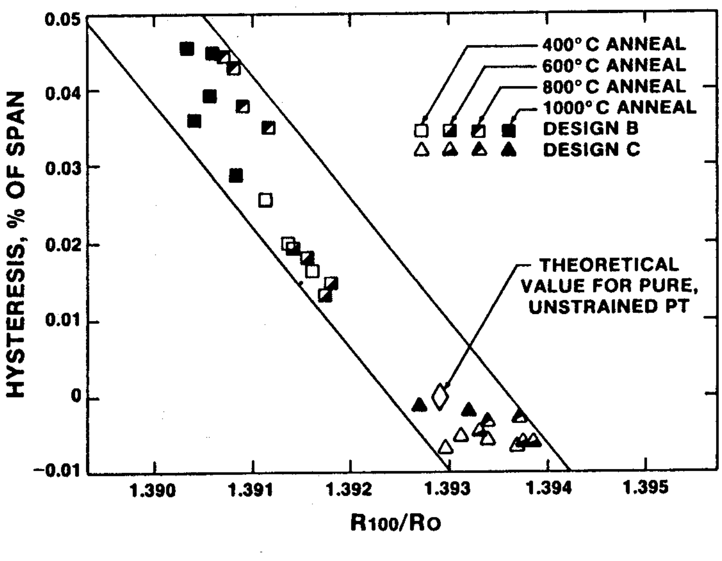

Fig. 16.3: Correlation between width of hysteresis loop and R($H_2$0 b.p.)/R(0 °C) for industrial platinum resistance thermometers cycled between -200 °C and : 200 °C [after Curtis (1982)].

advised to choose the thermometer type that exhibits the smallest hysteresis span. Similar effects have been observed by Besley and Kemp (1983) and Chattle (1977) on cycling between 100 °C and -200 °C.

It follows then that a procedure should be developed to bring the IPRTs into a stable state that is needed for accurate measurements. Since the hysteresis behaviour is caused by reversible changes in resistance from annealed to strained conditions in the platinum (at least below the temperature range where hysteresis due to reversible oxidation of the platinum can also occur), this means that the IPRT must be strained for work below room temperature and annealed for work above room temperature and, subsequently, all thermal cycling must never exceed the limits of this stabilization thermal cycle. Consequently, since the thermometer is almost always stored at room temperature, this temperature must not be substantially crossed after stabilization at any temperature below 100 K (strained) or at 200 °C to 450 °C (annealed).

Another reason for hysteresis is connected with moisture inside the encapsulation (most of the IPRTs are not hermetically sealed) [Mangum (1984)] which acts as a shunting resistance on the platinum wire. Moisture was observed to produce changes as large as 35 mK on sensor cycling between 0 °C and 40 °C. Moisture (69% of the cases) rather than strain (19% of the cases) was believed to account for most of the drift in IPRTs as a result of tests on 94 IPRTs in the range 0°-100 °C (and with annealing up to 235 °C).

IPRTs are generally produced to match the (inter-) national codes but the production is not 100% reliable [Chattle (1975)]. Tests are therefore necessary to select thermometers that match within closer tolerances.

Many experiments have been done, especially below 650 °C, to evaluate the *stability* of IPRTs (the distinction between instability and hysteresis is slight, but the latter is considered to be reversible). These have involved, in total, about 250 thermometers in about 80 batches and models from most of the manufacturers. Most of the thermometers had R(0 °C) = 100 Ω, and most of the tests were in the range -50 °C to 250 °C. There was not much uniformity in the results. Some thermometers were stable to within 5 mK, many to within 10 mK, and most to within 50 mK. Increasing the test range to 420 °C did not affect the results much. Instability increases rapidly at higher temperatures; drifts in R(0 °C) equivalent to from 0.2 K to several kelvins can be expected. Figures 16.4-16.7 show examples of instability in tests of various batches of thermometers.

16.1.2 Self-heating

In measuring the electrical resistance of the thermometer it is impossible not to dissipate thermal energy by Joule heating. Consequently there exists a difference between

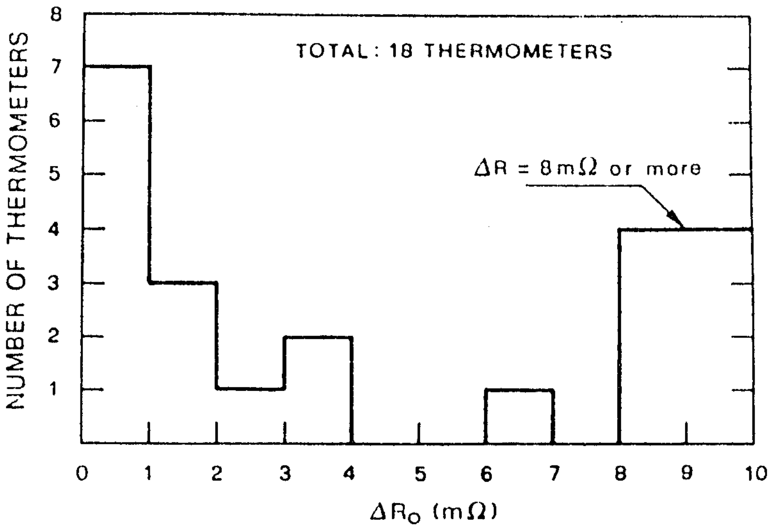

Fig. 16.4: Histogram showing the amount of the shift in R(0 °C) after a single exposure to liquid oxygen following stabilization at 450 °C for a group of 18 industrial platinum resistance thermometers having R(0 °C) = 100 Ω [Actis and Crovini (1982)].

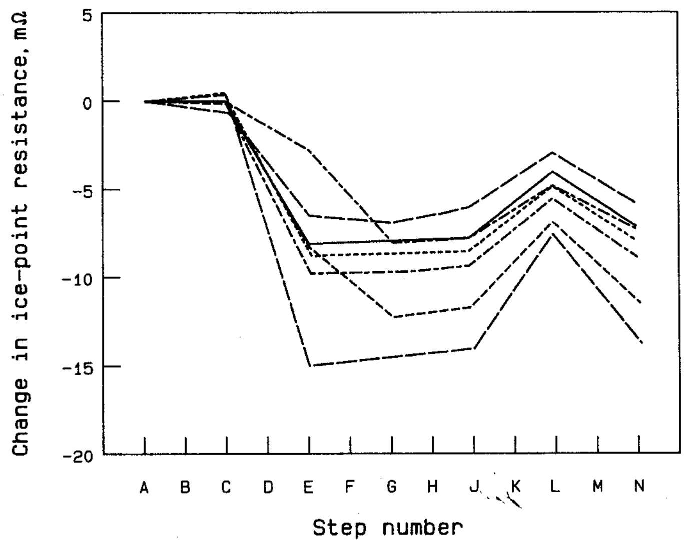

Fig. 16.5: Changes in R(0 °C) for seven industrial platinum resistance thermometers after 10 cycles between 20 °C and -196 °C (with occasional measurement also of R(100 °C): A, measurement of R(0 °C); B, measurement of R(100 °C); C, measurement of R(0 °C); D, ten cycles between 293 K and 77 K; E, measurement of R(0 °C); F, ten cycles between 293 K and 77 K; G, measurement of R(0 °C); H, ten cycles between 293 K and 77 K; J, measurement of R(0 °C); K, measurement of R(100 °C); L, measurement of R(0 °C); M, ten cycles between 293 K and 77 K; N, measurement of R(0 °C); [after Besley and Kemp (1983)].

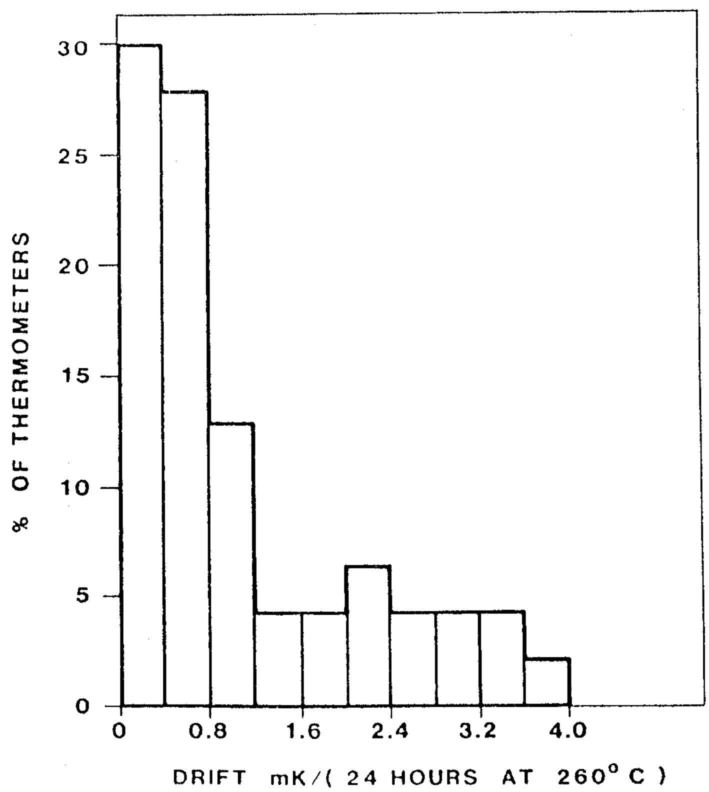

Fig. 16.6: Distribution of the rate of drift of R(0 °C) due to exposure to 260 °C for up to 100 hours for a group of 87 IPRTs [Connolly (1982)].

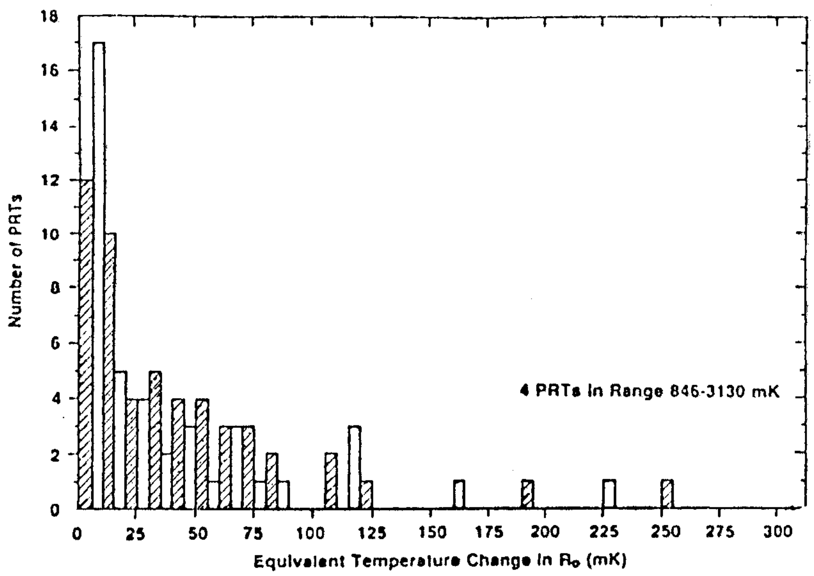

Fig. 16.7: Histogram of the maximum equivalent temperature change in R(0 °C) during ten 24 hour exposures to 235 °C for a group of 98 IPRTs [Mangum (1984)].

the temperature of the thermometer and that of the medium being measured. This difference is a function of the thermal characteristics of the thermometer and its coefficient of thermal exchange with the medium. It is proportional to the square of the thermometer current (i). Commonly, the PRT resistance is measured at 1 mA and $\sqrt{2}$ mA, plotted as a function of i^2, and extrapolated linearly to 0 mA. One can therefore evaluate the influence of the self-heating by measuring the variation of thermometer resistance with measuring current.

16.1.3 Response Time

Just as with self-heating, the response time of a thermometer depends upon both the characteristics of the thermometer and of the medium in which it is immersed. There are two methods to determine the response time. The first consists of immersing the thermometer in a fluid, measuring the response time under these conditions, and then by similarity deducing the response time in the medium to be used. The second method consists of studying, in situ, the response of the thermometer by using the thermometer resistance itself as a heating element. Then, by analyzing this response one can obtain the response time through the use of an algorithm [e.g. Kerlin et al. (1982)].

16.2 Interpolation Equations for Industrial Platinum Resistance Thermometers*

In principle, any of the approximations of Section 8.2 can also be used with IPRTs, although within some (generally unknown) broader limits of accuracy, but in practice few of them have been. Recall also that the techniques described here have been tested for sensors mounted by the experimenters in suitable glass or metal sheaths and not in the manufacturers' rugged sheaths meant for industrial applications. It is not known if the same accuracies apply in the latter case. No simple approximation for use above about 200 °C is yet available. The two most-used techniques are:

(a) Polynomials for $W(t_{68})$ versus t_{68}:

For secondary realizations extending above 0 °C it is possible to interpolate between fixed-point measurements with polynomials relating $W(t_{68})$ to t_{68} similar to the defining equations of the IPTS-68. There are two distinctly different aspects that limit the accuracy of such realizations: one is the inherent irreproducibility of the IPRTs themselves, both repeatedly with one thermometer

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* As in Section 8.2, these approximations were originally devised with reference to the IPTS-68, and so many of the equations in this section still carry an IPTS-68 designation. Generalization to the ITS-90 is straightforward.

and between different thermometers; the other is the indifferent agreement of the interpolating equation with the IPTS-68. There are not many data available on the accuracy that may be obtained. Actis and Crovini (1982) use the equations

$$W(t') = 1 + At' + Bt'^2 \qquad (16.1)$$

and $$t = t' + \gamma\left(\frac{t}{100\,°C}\right)\left(\frac{t}{t_1} - 1\right)\left(\frac{t}{t_2} - 1\right)\left(\frac{t}{630.74\,°C} - 1\right) \qquad (16.2)$$

where t_1 and t_2 are the temperatures of the fixed points used to evaluate A and B, and γ is a constant determined by calibration at a third fixed point. They tested these equations with 20 IPRTs from 6 manufacturers over the temperature ranges 0 °C to 420 °C or 0 °C to 330 °C, depending upon the particular IPRT. They found rather close agreement between the calibration constants of all thermometers but one, although two had to be calibrated in a restricted range. For a sub-group of 15 IPRTs from 5 manufacturers, all having the same configuration (sensing element diameter between 2.5 and 3.5 mm, length between 15 and 30 mm, multi-bore alumina insulator containing a minimally constrained platinum coil, operation up to 500 °C) the agreement provided by Equations 16.1 and 16.2 was better. In the range from 0 °C to 420 °C, with A, B and γ determined from calibrations at the steam, zinc, and tin points respectively, the 15 thermometers showed a mean difference with respect to the IPTS-68 of (3.6 ± 2.7) mK at 327 °C and of (-4.2 ± 1.5) mK at 150 °C (one-standard-deviation estimates). The stability of R(0 °C) for these IPRTs upon repeated cycles between 0 °C and 450 °C and 0 °C and -190 °C was always inside ± 5 mK, and for 13 of them better than ± 2 mK. If Eq. (16.2) was omitted, the differences with respect to the IPTS-68 at 327 °C and 150 °C were (45 ± 5.9) mK and (16 ± 1.8) mK respectively. In this latter case, a maximum difference of about 50 mK was reached between 250 °C and 300 °C. Using both equations with different calibration points, provided they were reasonably spaced, produced equivalent results.

(b) Besley and Kemp (1983) investigated a group of 27 IPRTs having W(H_20 b.p.) in the range 1.3912 to 1.3923. They first stabilized the ice-point resistance of the thermometers by thermal cycling between 77 K and 273 K. They then used the ice point and the oxygen boiling point as the reference temperatures in a Z-function (Eq. 8.5) related to T by

$$Z(T) = \sum_{i=0}^{8} a_i T^i \qquad (16.3)$$

and found an inaccuracy of ± 0.035 K from 70 K to 273 K.

(c) A simple polynomial fit of degree 2 to 4 for W(t) against t is frequently a good approximation depending upon the range and the number of calibration points. Calibrations accurate to within ± 20 mK can usually be obtained with a quadratic fit to 5 to 10 points in the range -50 °C to 200 °C. Connolly (1982) and Bass and Connolly (1980) found that a cubic equation

$$W(t) = 1 + at + bt^2 + ct^3 \qquad (16.4)$$

fitted 87 wire-wound IPRTs (that came largely from one manufacturer) from 0 °C to 250 °C to within ± 10 mK. Selected thermometers were better than this. However, with thick film sensors the uncertainty was as high as ± 35 mK.

(d) Above 100 K the Callendar and Callendar-Van Dusen equations can be used with IPRTs with the coefficients determined from least-squares fits to calibrations at from 5 to 15 temperatures, depending upon the range. Such fits are typically uncertain to a few tens of millikelvins.

16.3 National and International Specifications for IPRTs*

Various organizations, including the International Electrotechnical Commission (IEC) and the International Organization of Legal Metrology (OIML), have promulgated specifications and manufacturing tolerances for IPRTs*. The relationship between R and t_{68} is generated from the Callendar and Callendar-Van Dusen equations

$$R(t_{68})/R(0\ °C) = 1 + At_{68} + Bt_{68}^2 \qquad t_{68} \geq 0\ °C \qquad (16.5)$$

and $$R(t_{68})/R(0\ °C) = 1 + At_{68} + Bt_{68}^2 + Ct_{68}^3\,(t_{68} - 100\ °C) \qquad t_{68} < 0\ °C\ . \qquad (16.6)$$

Two sets of values of the coefficients A, B, C typical of IPRTs with W(H_2O b.p.) = 1.385 and 1.391 respectively are used (Tables 16.2, 16.3). The equation (or tables derived

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* Since these international specifications and tolerances have not yet been reformulated to refer directly to the ITS-90, they are summarized here with their IPTS-68 designations.

therefrom) can then be used with any IPRT that has the specified R(0 °C) and W(H_20 b.p.) to give temperatures accurate to within specified tolerances. These tolerances (the ones specified by IEC (1983) are shown in Fig. 16.8) vary with the temperature, having minimum values of a few tenths of a °C at 0 °C, rising to about ± 0.5 °C (Class A) and ± 1.3 °C (Class B) at -200 °C and to several °C above 600 °C. These, naturally, are much larger than the uncertainty that results with a *calibrated* thermometer. The thermometer specifications currently and formerly issued by various standards organizations are summarized in Table 16.1. If one IPRT is interchanged for another nominally the same, temperature readings can differ by up to several degrees, depending upon the value of temperature. The tables issued by OIML (1985) for platinum with values of W(H_20 b.p.) = 1.385 and 1.391 are reproduced here as Tables 16.2 (the same numerically as the equivalent table of IEC (1983)) and 16.3 respectively. The tables are in the form of R(t_{68})/R(0 °C) as a function of temperature.

Table 16.1: Summary of Current and Past IPRT Specifications

	International Agreed Specifications		Former National Specifications				
Organization*	IEC Publ. 751 (1983)	OIML 1985	BS 1904:1984	DIN 43760	GOST 6651-84	JEMIMA	SAMA RC-4-1966
R(0°C) (Ω)	100	5 to 1000	100	100	10, 46, 100	100	100
tolerance:**							
Class A	± 0.06		± 0.075	± 0.06	± 0.15	~ 0.03	special standard
Class B	± 0.12		± 0.1	± 0.12	± 0.3	~ 0.5	
α ($°C^{-1}$)	3.85×10^{-3}	3.85×10^{-3} and 3.91×10^{-3}	3.85×10^{-3}	3.85×10^{-3}	3.85×10^{-3} and 3.91×10^{-3}	3.916×10^{-3}	3.923×10^{-3}
tolerance:**							
Class A	$\pm 1.3\times10^{-5}$	$\pm 0.7\times10^{-5}$	$\pm 0.7\times10^{-5}$	$\pm 1.3\times10^{-5}$	$\pm 0.7\times10^{-5}$		
Class B	$\pm 3.0\times10^{-5}$	$\pm 1.2\times10^{-5}$	$\pm 2 \times10^{-5}$	$\pm 3.0\times10^{-5}$	$\pm 1.1\times10^{-5}$		
ranges (°C)							
Class A	-200 to 650		-183 to 630		-200 to 600	-200 to 600	-200 to 600
Class B	-200 to 850	-200 to 850	(-220 to 1050)	-200 to 850	-200 to 850		
coefficients:		(Type I)			(Type I)		
A ($°C^{-1}$)	$3.908\ 02 \times10^{-3}$	$3.908\ 02\times10^{-3}$	$3.968\ 35\times10^{-3}$	$3.908\ 02\times10^{-3}$	$3.908\ 02\times10^{-3}$	$3.974\ 78\times10^{-3}$	$3.981\ 53\times10^{-3}$
B ($°C^{-2}$)	-5.802×10^{-7}	-5.802×10^{-7}	-5.8349×10^{-7}	$-5.801\ 95\times10^{-7}$	-5.802×10^{-7}	-5.8775×10^{-7}	-5.8531×10^{-7}
C ($°C^{-4}$)	$-4.273\ 50 \times10^{-12}$	-4.274×10^{-12}	-4.3557×10^{-12}	-4.2735×10^{-12}	$-4.273\ 50\times10^{-12}$	-3.4813×10^{-12}	-4.3545×10^{-12}
		(Type II)			(Type II)		
A ($°C^{-1}$)		$3.968\ 68\times10^{-3}$			$3.968\ 47\times10^{-3}$		
B ($°C^{-2}$)		-5.8677×10^{-7}			-5.847×10^{-7}		
C ($°C^{-3}$)		-4.141×10^{-12}			-4.3558×10^{-12}		

* BS = British Standard
DIN = Deutschen Institut für Normung
GOST = (All-Union State Standard, USSR)
JEMIMA = Japanese Standard
SAMA = Scientific Apparatus Makers of America
IEC = International Electrotechnical Commission
OIML = International Organization for Legal Metrology

** Type I refers to thermometers with $\alpha = 3.85 \times 10^{-3}\ °C^{-1}$ and Type II to thermometers with $\alpha = 3.91 \times 10^{-3}\ °C^{-1}$.
Class A and Class B refer to accuracy tolerances, A being the higher.

Table 16.2

RESISTANCE RATIOS FOR INDUSTRIAL PLATINUM RESISTANCE THERMOMETERS WITH $R(100\ ^{0}C)/R(0\ ^{0}C) = 1.3850$

Interpolation equation for the temperature range from − 200 to 0 ^{0}C : $R(t_{68})/R(0\ ^{0}C) = 1 + At_{68} + Bt_{68}^{2} + C(t_{68} - 100)t_{68}^{3}$

from 0 to 850 ^{0}C : $R(t_{68})/R(0\ ^{0}C) = 1 + At_{68} + Bt_{68}^{2}$

where

$A = 3.90802 . 10^{-3}\ ^{0}C^{-1}$

$B = -5.8020 . 10^{-7}\ ^{0}C^{-2}$

$C = -4.274 . 10^{-12}\ ^{0}C^{-4}$

t_{68} (^{0}C)	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60	-65	-70	-75	-80	-85	-90	-95	-100
-100	0.6025	0.5822	0.5619	0.5415	0.5211	0.5006	0.4800	0.4594	0.4387	0.4179	0.3971	0.3763	0.3553	0.3343	0.3132	0.2920	0.2708	0.2494	0.2280	0.2065	0.1849
0	1.0000	0.9804	0.9609	0.9412	0.9216	0.9019	0.8822	0.8625	0.8427	0.8229	0.8031	0.7832	0.7633	0.7433	0.7233	0.7033	0.6833	0.6631	0.6430	0.6228	0.6025

t_{68} (^{0}C)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0	1.0000	1.0195	1.0390	1.0585	1.0779	1.0973	1.1167	1.1361	1.1554	1.1747	1.1940	1.2132	1.2324	1.2516	1.2707	1.2898	1.3089	1.3280	1.3470	1.3660	1.3850
100	1.3850	1.4039	1.4229	1.4417	1.4606	1.4794	1.4982	1.5170	1.5358	1.5545	1.5731	1.5918	1.6104	1.6290	1.6476	1.6661	1.6846	1.7031	1.7216	1.7400	1.7584
200	1.7584	1.7768	1.7951	1.8134	1.8317	1.8499	1.8682	1.8863	1.9045	1.9226	1.9407	1.9588	1.9769	1.9949	2.0129	2.0308	2.0488	2.0667	2.0845	2.1024	2.1202
300	2.1202	2.1380	2.1557	2.1735	2.1912	2.2088	2.2265	2.2441	2.2617	2.2792	2.2967	2.3142	2.3317	2.3491	2.3665	2.3839	2.4013	2.4186	2.4359	2.4531	2.4704
400	2.4704	2.4876	2.5048	2.5219	2.5390	2.5561	2.5732	2.5902	2.6072	2.6242	2.6411	2.6580	2.6749	2.6918	2.7086	2.7254	2.7422	2.7589	2.7756	2.7923	2.8090
500	2.8090	2.8256	2.8422	2.8587	2.8753	2.8918	2.9083	2.9247	2.9411	2.9575	2.9739	2.9902	3.0065	3.0228	3.0391	3.0553	3.0715	3.0876	3.1038	3.1199	3.1359
600	3.1359	3.1520	3.1680	3.1840	3.1999	3.2159	3.2318	3.2476	3.2635	3.2793	3.2951	3.3108	3.3266	3.3423	3.3579	3.3736	3.3892	3.4047	3.4203	3.4358	3.4513
700	3.4513	3.4668	3.4822	3.4976	3.5130	3.5283	3.5437	3.5590	3.5742	3.5894	3.6047	3.6198	3.6350	3.6501	3.6652	3.6802	3.6953	3.7103	3.7252	3.7402	3.7551
800	3.7551	3.7700	3.7848	3.7997	3.8144	3.8292	3.8440	3.8587	3.8733	3.8880	3.9026	-	-	-	-	-	-	-	-	-	-

Tables corresponding to various national specifications can be generated using the coefficients given in Table 16.1

Table 16.3

RESISTANCE RATIOS FOR PLATINUM RESISTANCE THERMOMETERS WITH $R(100\ ^0C)/R(0\ ^0C) = 1.3910$

Interpolation equation for the temperature range from − 200 to 0 ^0C : $R(t_{68})/R(0\ ^0C) = 1 + At_{68} + Bt_{68}^2 + C(t_{68} - 100)t_{68}^3$

from 0 to 850 ^0C : $R(t_{68})/R(0\ ^0C) = 1 + At_{68} + Bt_{68}^2$

where $A = 3.96868.10^{-3}\ ^0C^{-1}$

$B = -5.8677\ .10^{-7}\ ^0C^{-2}$

$C = -4.141\ .10^{-12}\ ^0C^{-4}$

t_{68} (^0C)	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60	-65	-70	-75	-80	-85	-90	-95	-100
-100	0.5964	0.5758	0.5552	0.5345	0.5137	0.4929	0.4721	0.4511	0.4302	0.4091	0.3880	0.3668	0.3456	0.3243	0.3029	0.2814	0.2599	0.2382	0.2165	0.1947	0.1729
0	1.0000	0.9801	0.9603	0.9403	0.9204	0.9004	0.8804	0.8604	0.8403	0.8202	0.8000	0.7798	0.7596	0.7394	0.7191	0.6987	0.6784	0.6580	0.6375	0.6170	0.5964

t_{68} (^0C)	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0	1.0000	1.0198	1.0396	1.0594	1.0791	1.0989	1.1185	1.1382	1.1578	1.1774	1.1970	1.2165	1.2360	1.2555	1.2749	1.2944	1.3137	1.3331	1.3524	1.3717	1.3910
100	1.3910	1.4102	1.4295	1.4486	1.4678	1.4869	1.5060	1.5251	1.5441	1.5631	1.5821	1.6010	1.6200	1.6389	1.6577	1.6765	1.6954	1.7141	1.7329	1.7516	1.7703
200	1.7703	1.7889	1.8075	1.8261	1.8447	1.8632	1.8818	1.9002	1.9187	1.9371	1.9555	1.9739	1.9922	2.0105	2.0288	2.0470	2.0652	2.0834	2.1016	2.1197	2.1378
300	2.1378	2.1559	2.1739	2.1919	2.2099	2.2278	2.2458	2.2637	2.2815	2.2994	2.3172	2.3349	2.3527	2.3704	2.3881	2.4057	2.4234	2.4410	2.4585	2.4761	2.4936
400	2.4936	2.5111	2.5285	2.5459	2.5633	2.5807	2.5980	2.6153	2.6326	2.6499	2.6671	2.6843	2.7014	2.7186	2.7357	2.7527	2.7698	2.7868	2.8038	2.8207	2.8376
500	2.8376	2.8545	2.8714	2.8882	2.9051	2.9218	2.9386	2.9553	2.9720	2.9886	3.0053	3.0219	3.0384	3.0550	3.0715	3.0880	3.1044	3.1209	3.1373	3.1536	3.1700
600	3.1700	3.1863	3.2026	3.2188	3.2350	3.2512	3.2674	3.2835	3.2996	3.3157	3.3317	3.3477	3.3637	3.3797	3.3956	3.4115	3.4274	3.4432	3.4590	3.4748	3.4906
700	3.4906	3.5063	3.5220	3.5376	3.5533	3.5689	3.5844	3.6000	3.6155	3.6310	3.6465	3.6619	3.6773	3.6926	3.7080	3.7233	3.7386	3.7538	3.7691	3.7842	3.7994
800	3.7994	3.8145	3.8297	3.8447	3.8598	3.8748	3.8898	3.9047	3.9197	3.9346	3.9494	-	-	-	-	-	-	-	-	-	-

Tables corresponding to various national specifications can be generated using the coefficients given in Table 16.1

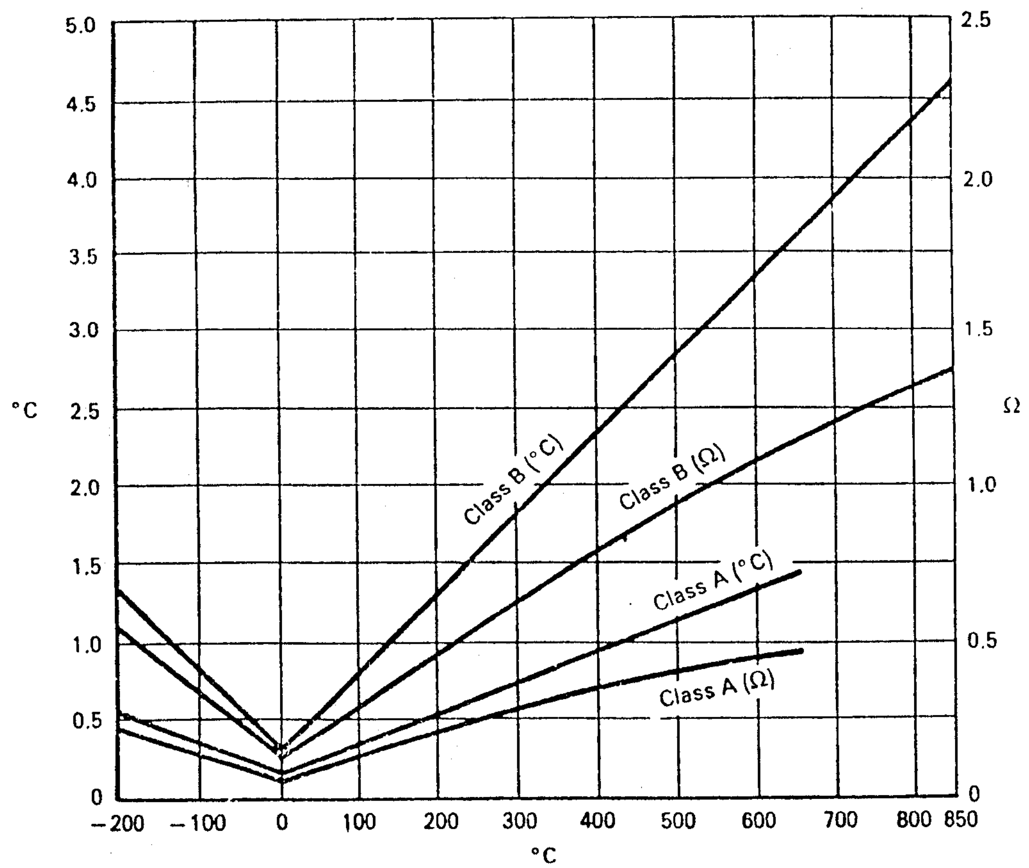

Fig. 16.8: Tolerances for industrial platinum resistance thermometers as specified by IEC (1983).