The resistance ratio criteria of PRTs as interpolating instruments for ITS-90

K. Yamazawa, J. V. Widiatmo, J. Tamba and M. Arai
National Metrology Institute of Japan
National Institute of Advanced Industrial Science and Technology (NMIJ, AIST)

Introduction

In the text of the ITS-90 [1,2], it is stated as follows for the requirement criteria of a PRT.

> **An acceptable platinum resistance thermometer must be made from pure, strain-free platinum, and it must satisfy at least one of the following two relations:**
>
> $W(29.7646\ °C) \geq 1.118\ 07$ (8a)
>
> $W(-38.8344°C) \leq 0.844235$ (8b)
>
> **An acceptable platinum resistance thermometer that is to be used up to the freezing point of silver must also satisfy the relation:**
>
> $W(961.78°C) \geq 4.2844$ (8c)

The basis of the requirements (8a) and (8b) originally comes from adopting the requirements of the previous temperature IPTS-68 scale, with converting the notation from the resistance ratio at 100 °C to that of the Ga and Hg point. Criterion (8c) was added to give an index for the insulating resistance. The origin of the technical basis for these requirements seems to be fading out from history, which might cause blind belief upon implicit (or even forgotten) restrictions.

The S_i value

In the research of sub-range inconsistencies of the ITS-90 by White and Strouse, a new index, $S_i = (W-1)/(W_{r,i}-1)$, has been introduced [3]. In their paper visiting the mathematics as well as dealing with actual data of 60 PRTs, they have elucidated that when the S_i values are constant along the temperature range, sub-range inconsistencies among the various sub-ranges of the ITS-90 would be minimal. Furthermore, they mention about a possibility to express the criteria using S_i for the interpolating PRTs in ITS-90 to give a more appropriate limitation compared to the existing criteria.

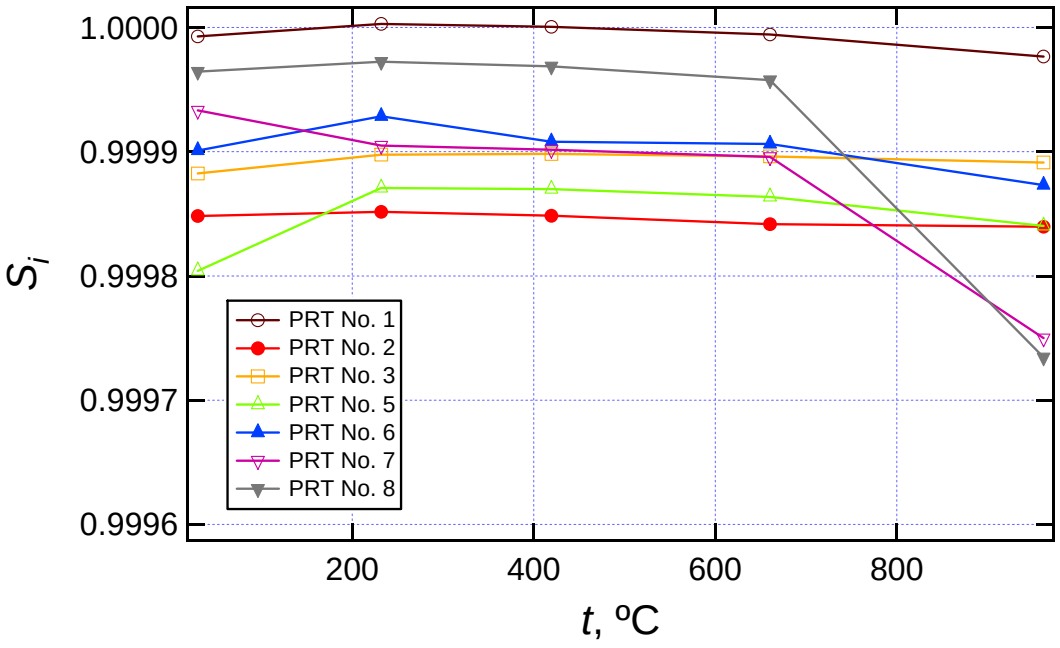
Results at NMIJ

NMIJ has been conducting the comparison measurements aimed to develop the high temperature scale for platinum resistance thermometers. To discuss the scale above the currents higher temperature limit of PRTs, between the Ag freezing point (961.78 ºC), up to the Cu freezing point (1084.62 ºC), a comparison measurement between a radiation thermometer and a PRT has been undertaken and the results will be reported at the next TEMPMEKO [4].

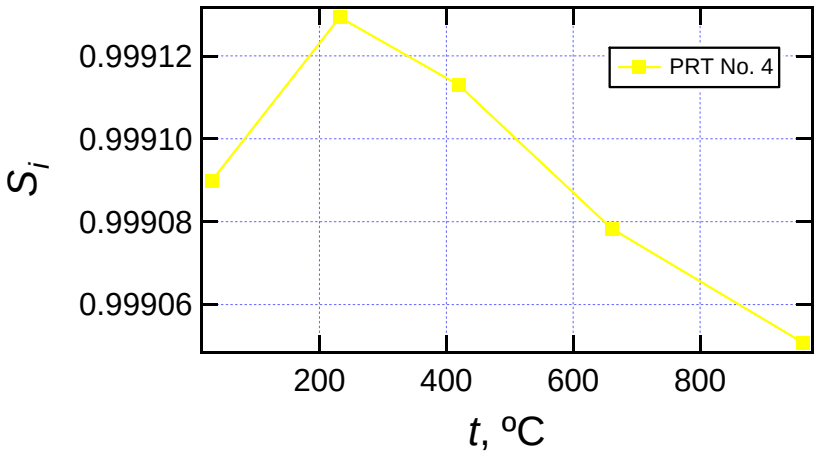
The figure presented below shows the S_i values for the PRTs investigated in reference 4. In Fig. (a), we can see that an obvious difference in the S_{Ag} for PRTs No. 7 and 8, compared to the S_i values at other fixed point temperatures. From the other figures presented in ref. 4, we can see that the obvious change of the S_{Ag} might detect the illness of the thermometer due to leakage, even when the W_{Ag} criteria in the current ITS-90 definition is even fulfilled.

On the other hand, the PRT shown in Fig. (b) does not fulfil any of the criteria for the resistance ratio specified as requirements to the PRT upon ITS-90, in specific, the W_{Ga} is 1.118 031 4. As a result, the S_i values are remarkably lower compared to those fulfilling the requirements. However, the variance of the S_i values among each fixed point for this PRT (labeled No. 4) is smaller compared to that for PRTs No. 7 and 8, and no such vast depression of the S_i value is found at the Ag point. In the comparison measurements to be reported in reference 4, we have found that when applying the interpolation for the TPW-Ag sub-range as defined in the ITS-90, the results show that the measured temperature coincides with those PRTs that fulfill the ITS-90, even at elevated temperatures near the Ag point [4].

These result shows that further discussion upon the criteria itself is demanded, and the criteria on the ITS-90 should be revised.



(a)



(b)

Fig. S_i values [3] calculated for the 8 PRTs investigated in reference 4 (origin: Fig. 5 of the submitted paper of [4]). The Ga, Sn, Zn, Al and Ag points are shown.

(a) S_i values of PRTs fulfilling the criteria for ITS-90.

(b) S_i values of a PRT not meeting the criteria.

Proposal to the CCT-WG3

As a summary, in the investigation at NMIJ reported in detail in reference [4], we have found two extraordinary cases;

(1) Two PRTs fulfilling both the criteria for Ga and Ag of ITS-90, however, indicating evidence of apparent insulation leakage error above the Al.

(2) One PRT NOT fulfilling both the criteria for Ga and Ag of ITS-90, however, its interpolation characteristics up to the higher temperatures coincide with those that do fulfill, and the ITS-90 interpolation function seems to be applicable.

Facing these two irregular cases, and upon respect to the vast data of White and Strouse [3], we consider that it might give a good opportunity to form a joint program among the members of WG3 to investigate the interpolation characteristics for the current ITS-90 sub-ranges for the PRT (or even up to higher temperatures), to review and revise those requirements specified in the ITS-90.

Such investigation is demanded since the calibration uncertainties (CMCs) at the Ag freezing point at various NMIs are remarkably smaller (at the level of few mKs) than that expected upon the definition of the ITS-90, especially for the criterion (8c) of reference [1]. The customers using the calibrated PRTs might seriously under estimate their uncertainties upon interpolation, when standing on a blind belief that their PRT fulfills the ITS-90 criteria.

Remark

The data underpinning this proposal is based upon the paper submitted to TEMPMEKO [4]. More details about the data will be presented at the conference.

References

1. H. Preston-Thomas: Metrologia **27**, 3 (1990)

2. Supplementary information for the international temperature scale of 1990, BIPM

3. D. R. White and G. F. Strouse: Observations on sub-range inconsistency in the SPRT interpolations of ITS-90, Metrologia **46**, 101/108 (2009)

4. K. Yamazawa, J. Widiatmo, J. Tamba and M. Arai : Comparison measurement for the development of high temperature platinum resistance scale, presented at the TEMPMEKO & ISHM 2010 and submitted to the International Journal of Thermophysics.