Anomalous Heat Induced by Deuterium Flux in a Bunch of Long-Thin Palladium Tubes using PID Method for Calorimetry

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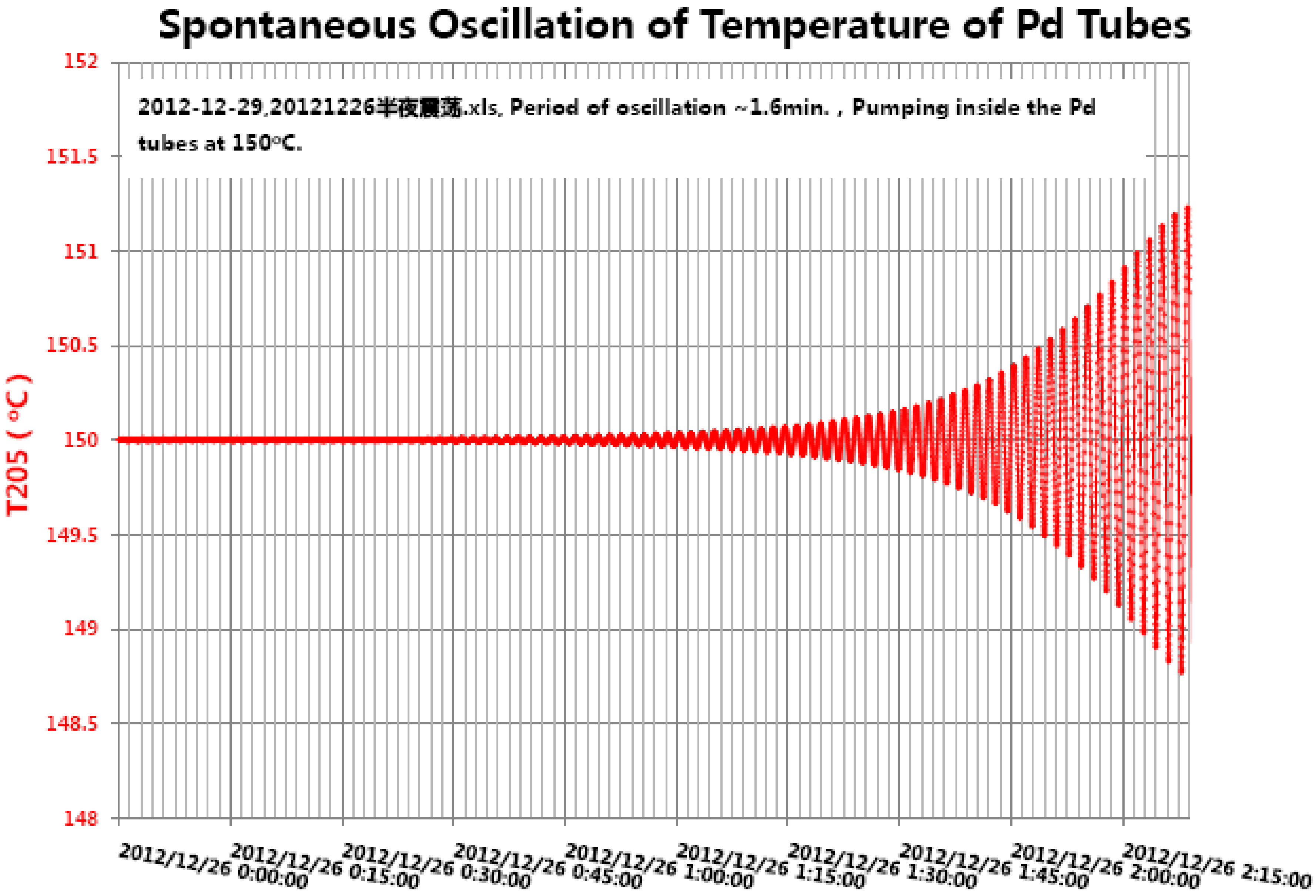
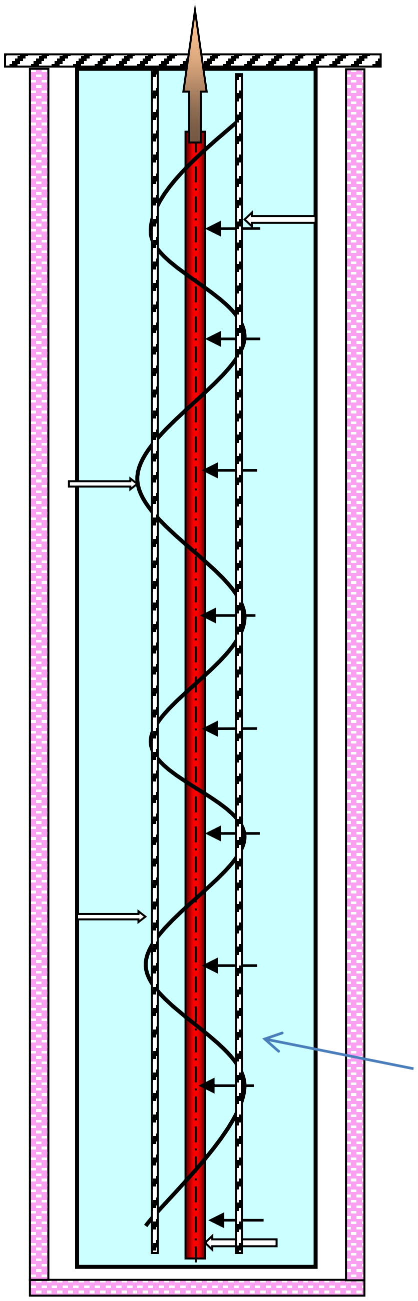
Growing Oscillation of Pd Temperature



Anomalous Temperature Coefficient of Ni-Cr Resistance



Helium Analysis

$$C * \frac{\partial T}{\partial t} = -k * (T - T_r) + P_{PID}$$

Dissipation Process

PID: Proportional, Integration, Differential

$$u = K_p * [(T_f - T) + \frac{1}{T_i} * \int_0^t (T_f - T) dt + T_d * \frac{\partial (T_f - T)}{\partial t}];$$

$$\frac{\partial u}{\partial t} = K_p [-\frac{\partial (T - T_f)}{\partial t} - \frac{T - T_f}{T_i} - T_d * \frac{\partial^2 (T - T_f)}{\partial t^2}];$$

$$\frac{\partial P_{PID}}{\partial t} = k_1 \frac{\partial u}{\partial t}$$

$$(C + k_1 K_p T_d) * \frac{\partial^2 T}{\partial t^2} + (k + k_1 K_p) * \frac{\partial T}{\partial t} + k_1 K_p [\frac{T - T_f}{T_i}] = 0;$$

$$\frac{\partial P_{PID}}{\partial t} = k_1 \frac{\partial u}{\partial t}$$

$$\mathrm{P}_{\mathrm{PID}} = \frac{V^2}{R} = \frac{(K_u u)^2}{R};$$

$$\Delta P_{PID} = \frac{2K_u^{\ 2} u\, \Delta u}{R} = \frac{2K_u^{\ 2} u^2}{R} \frac{\Delta u}{u} = 2P_{PID} \frac{\Delta u}{u}$$

$$\Delta P_{PID} = k_1\, \Delta u$$

$$k_1 = \frac{2K_u^2}{R} u = \frac{2K_u}{R} V = 2K_u I$$

$$(C + k_1 K_p T_d) * \frac{\partial^2 (T - T_f)}{\partial t^2} + (k + k_1 K_p) * \frac{\partial (T - T_f)}{\partial t} + k_1 K_p [\frac{T - T_f}{T_i}] = 0;$$

$$T(t) - T_f = A * Exp[-\varsigma \, \omega \, t] * Sin[\omega \sqrt{1 - \varsigma^2} \, t + \varphi_o]$$

$$\varsigma = \frac{(k + k_1 K_p)}{2} \sqrt{\frac{T_i}{k_1 K_p (C + k_1 K_p T_d)}} > 0,$$

Suppress Oscillation

$$\omega = \sqrt{\frac{k_1 K_p}{T_i (C + k_1 K_p T_d)}}$$

$$u = k_p e + k_i \int_0^t e(\tau)\,d\tau + k_d \frac{de}{dt} = k_p\left(e + \frac{1}{T_i}\int_0^t e(\tau)\,d\tau + T_d \frac{de}{dt}\right)$$

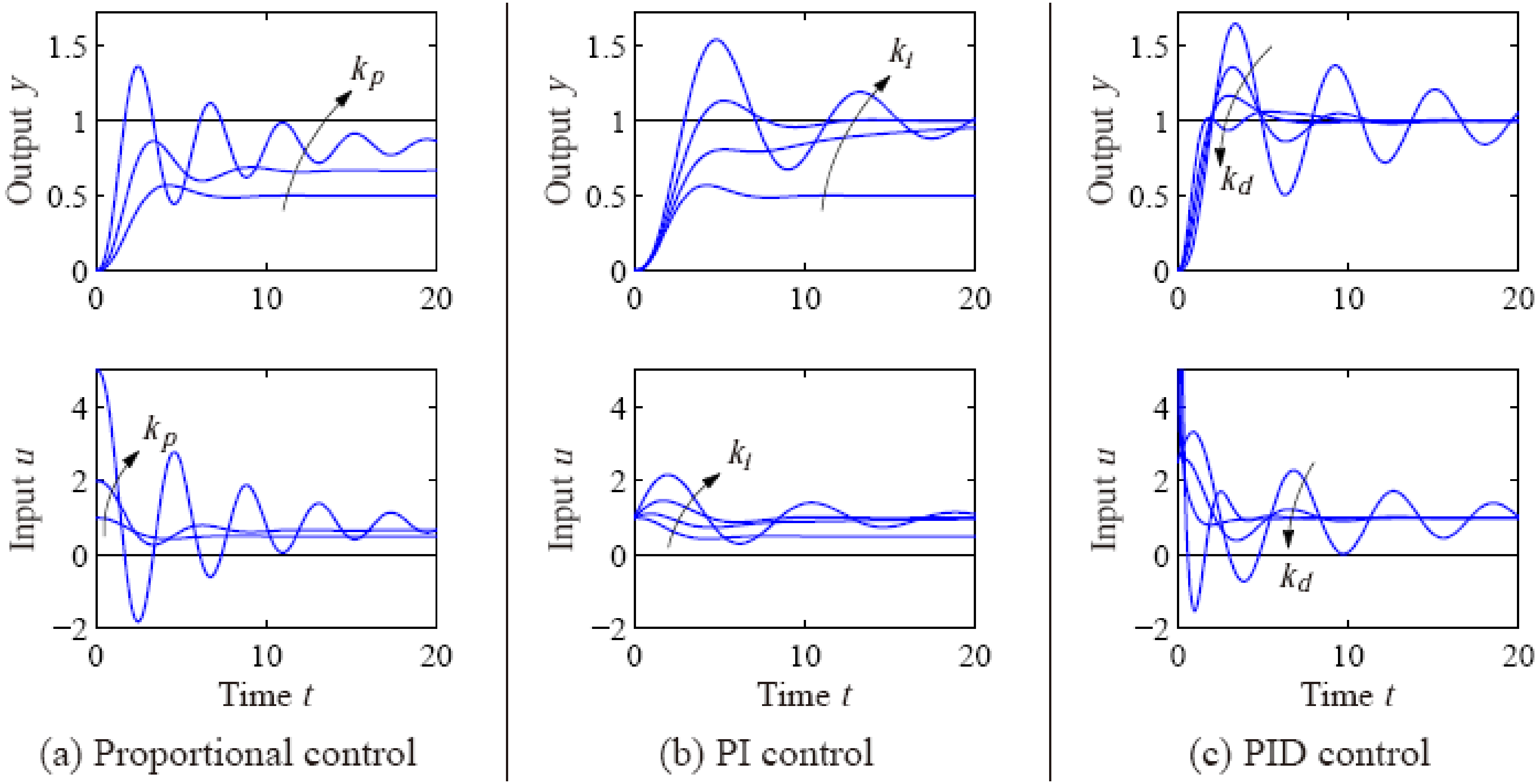


Figure 10.2: Responses to step changes in the reference value for a system with a proportional controller (a), PI controller (b) and PID controller (c). The process has the transfer function $P(s) = 1/(s+1)^3$, the proportional controller has parameters $k_p = 1, 2$ and 5, the PI controller has parameters $k_p = 1$, $k_i = 0, 0.2, 0.5$ and 1, and the PID controller has parameters $k_p = 2.5$, $k_i = 1.5$ and $k_d = 0, 1, 2$ and 4.

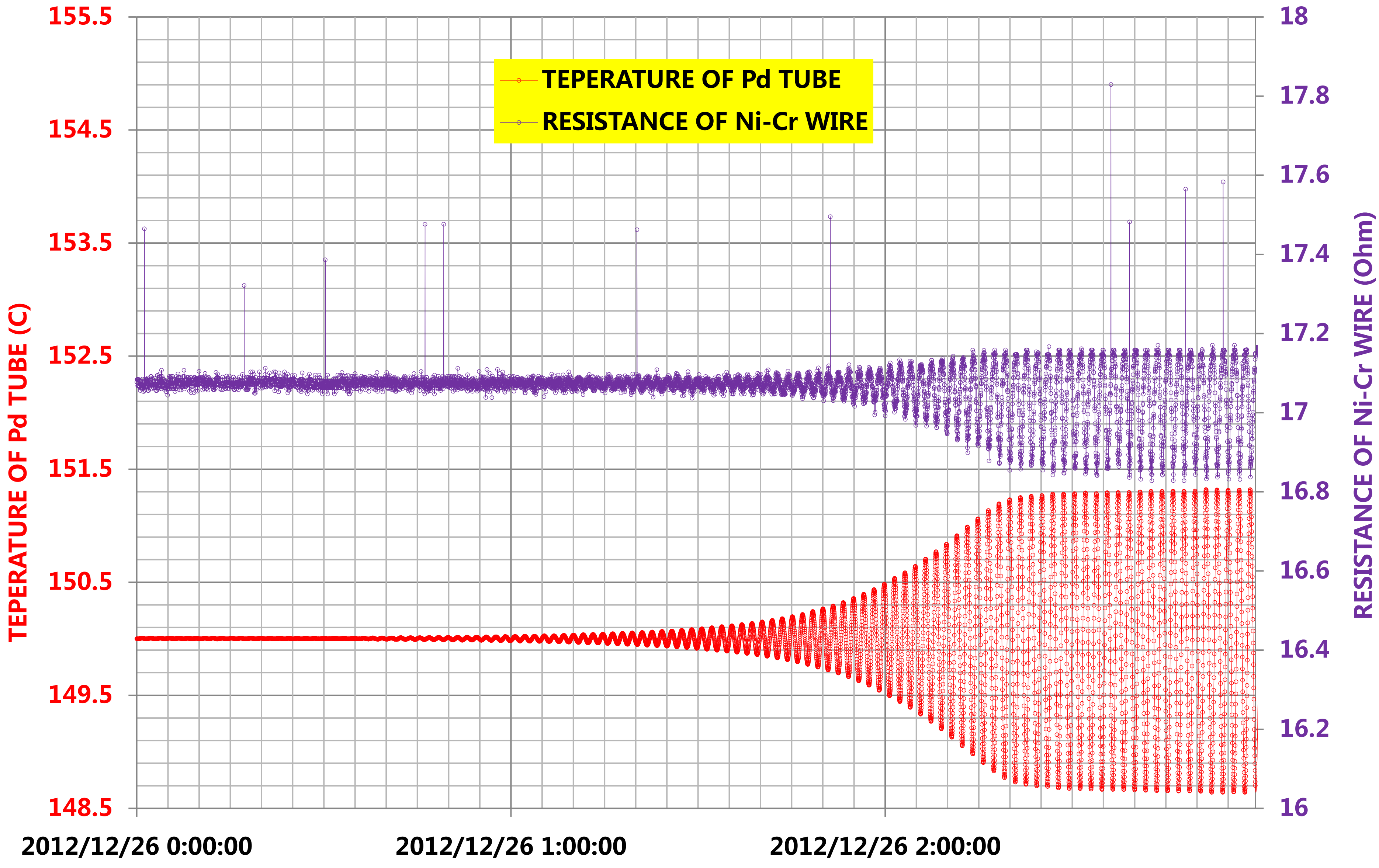
$$(C + k_1 K_p T_d) * \frac{\partial^2 (T - T_f)}{\partial t^2} + (k + k_1 K_p - \frac{\partial P_x}{\partial T}) * \frac{\partial (T - T_f)}{\partial t} + k_1 K_p [\frac{T - T_f}{T_i}] = 0;$$

$$T(t) - T_f = A * Exp[-\varsigma\, \omega\, t] * Sin[\omega \sqrt{1 - \varsigma^2}\, t + \varphi_o]$$

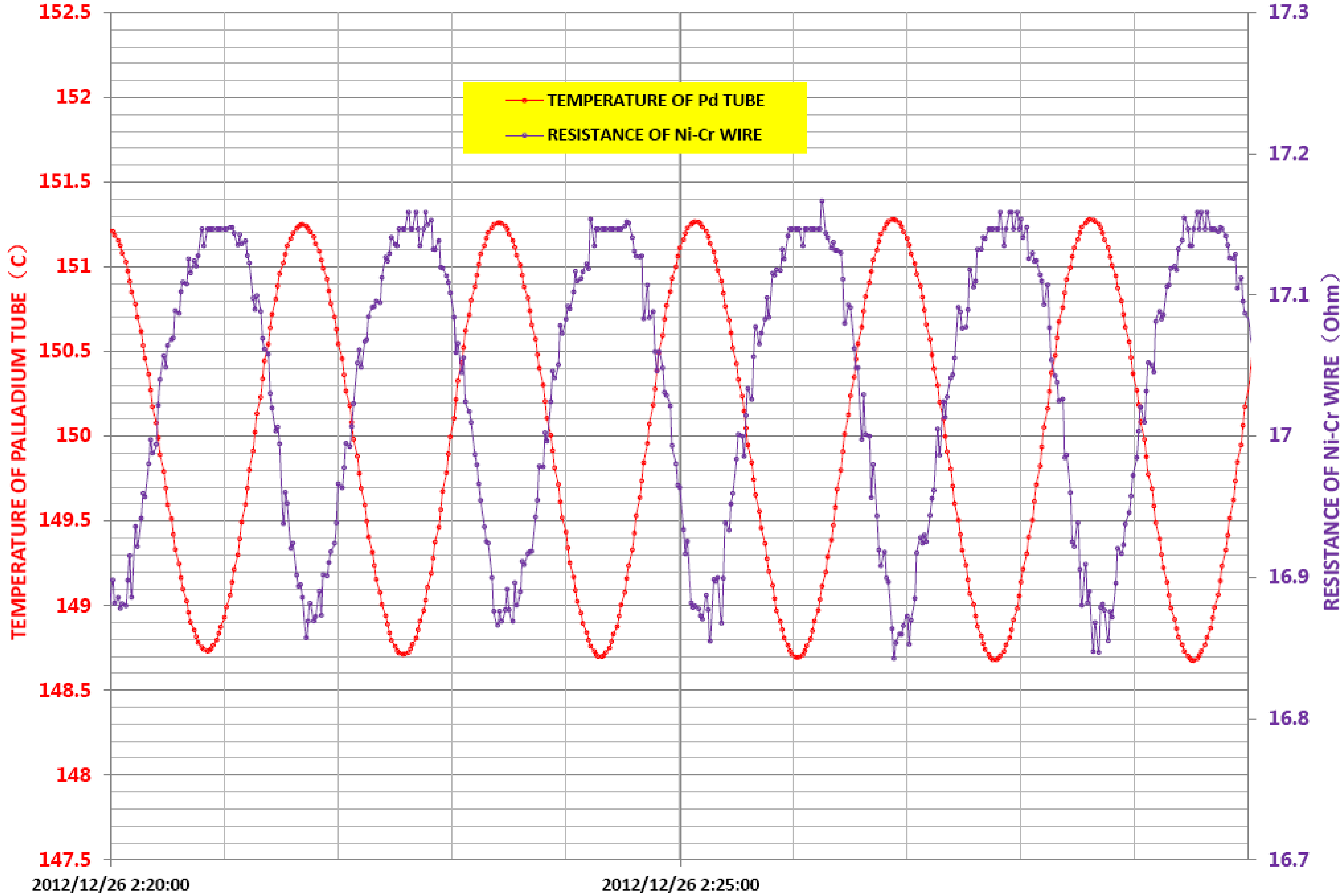
$$\varsigma = \frac{(k + k_1 K_p - \frac{\partial P_x}{\partial T})}{2} \sqrt{\frac{T_i}{k_1 K_p (C + k_1 K_p T_d)}} < 0, \text{Growing Oscillation}$$

$$\omega = \sqrt{\frac{k_1 K_p}{T_i (C + k_1 K_p T_d)}}$$

Anomalous Temperature Coefficient of Ni-Cr Resistance



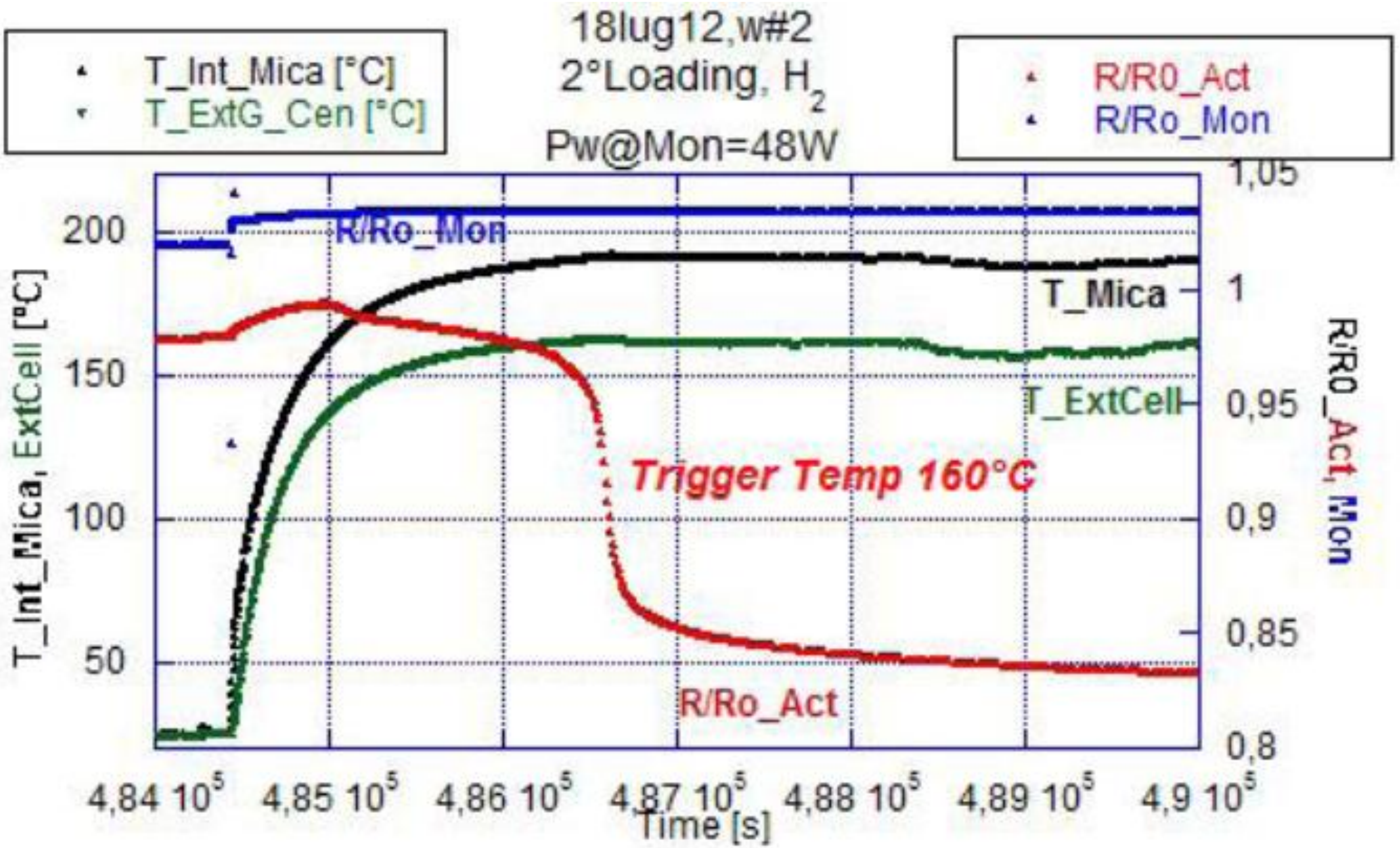
Anomalous Temperature Coefficient of Ni-Cr Resistance



Temperature Coefficient of Resistance~10^{-3}--10^{-4} 1/C

Material	Resistivity Coefficient [2)] - ρ - *(ohm m)*	Temperature Coefficient [2)] *per degree C*
Chromel (alloy of chromium and aluminum)		0.58×10^{-3}
Constantan	49×10^{-8}	3×10^{-5}
Copper	1.724×10^{-8}	4.29×10^{-3}
Iron	9.71×10^{-8}	6.41×10^{-3}
Manganese	185×10^{-8}	1.0×10^{-5}
Nickel	6.85×10^{-8}	6.41×10^{-3}
Nickeline	50×10^{-8}	2.3×10^{-4}
Nichrome (alloy of nickel and chromium)	$100 - 150 \times 10^{-8}$	0.40×10^{-3}
Silicon[1)]	0.1-60	-70×10^{-3}
Silver	1.59×10^{-8}	6.1×10^{-3}
Tungsten	5.65×10^{-8}	4.5×10^{-3}

Celani's Ni-Cr-Mn (Constante Wire) in H_2 Gas



Attenuated Oscillation To Growing Oscillation