

# ITS-90

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**Fluke Precision Measurement**

# Physical constants

 $c$  $\mu_0$  $G$  $\epsilon_0$  $h$  $L$  $e$

# The ITS-90

- ⦿ Specifies certain fixed points (the freezing points of seven metals, the melting point of gallium, the triple points of water, mercury and four cryogenic gases, and the boiling points of hydrogen at two pressures) as references for the calibration of thermometers. The temperature of these fixed points is precisely defined and internationally agreed.
- ⦿ Defines procedures by which certain practical thermometers of the required quality and precision can be calibrated in such a way that the values obtained from them can be precise and reproducible, while at the same time representing the corresponding thermodynamic temperatures as closely as possible.

# ITS-90

- ⦿ International Temperature Scale of 1990
  - designed by CCT – subcommittee of CIPM
  - adopted by CIPM in 1989
  - came in to force 1 January 1990
  - superseded IPTS-68
  
- ⦿ Thermodynamic Temperature Scale
  - is consistent with all known laws of thermodynamics
  - independent of physical properties of any substance
  - ITS-90 is an approximation to thermodynamic temperature scale

# Thermodynamic scale

- ⊙ William Thomson introduced absolute temperature scale in 1848

- derived from Carnot ideal heat engine

- defines absolute zero

- standard unit is the kelvin (K)

- defines 1K as 1/273.16 of TPW

- standard symbol is T

- ice point is 273.15K

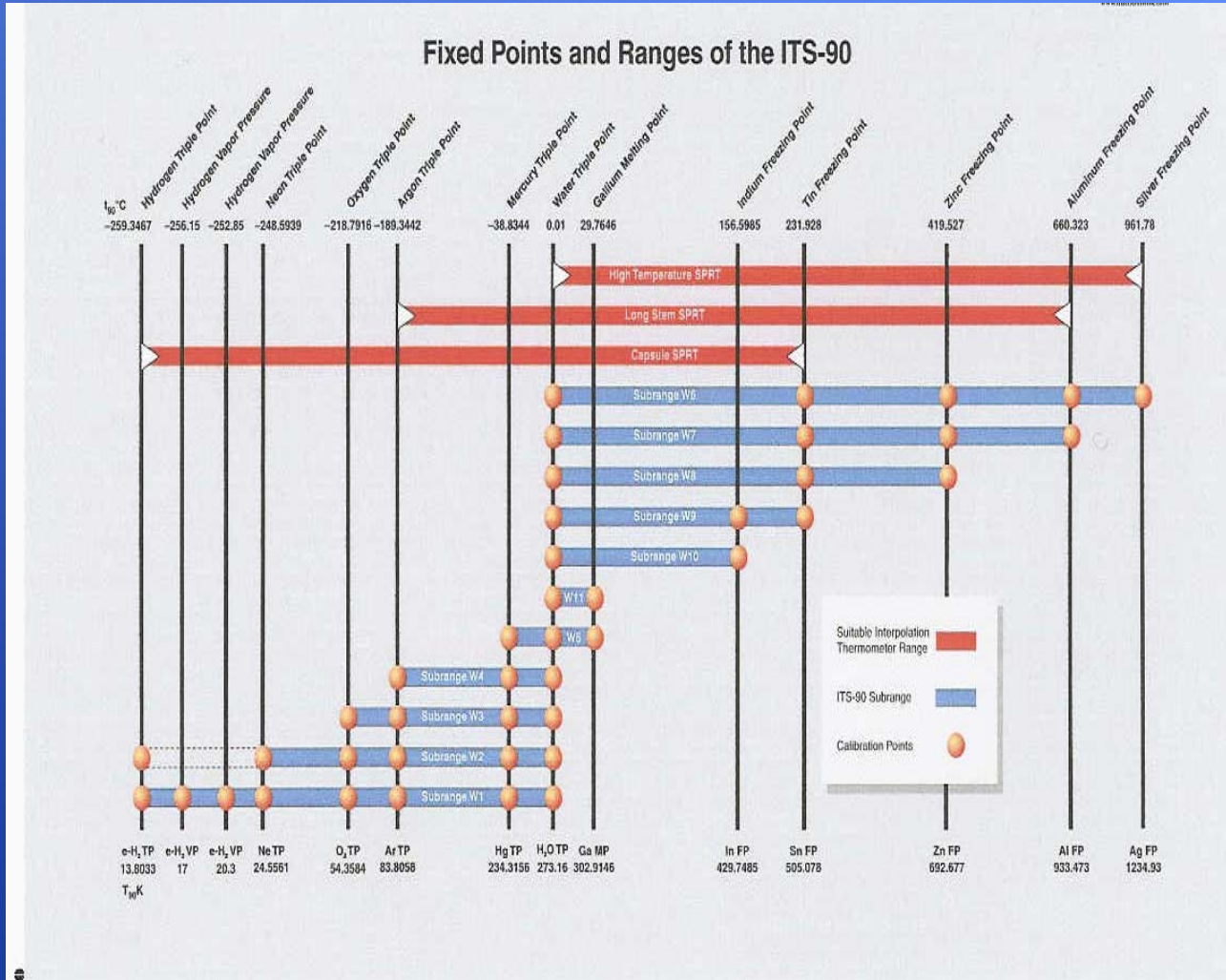
- steam point is 373.15K

- triple point of water is 273.16K (0.01°C)

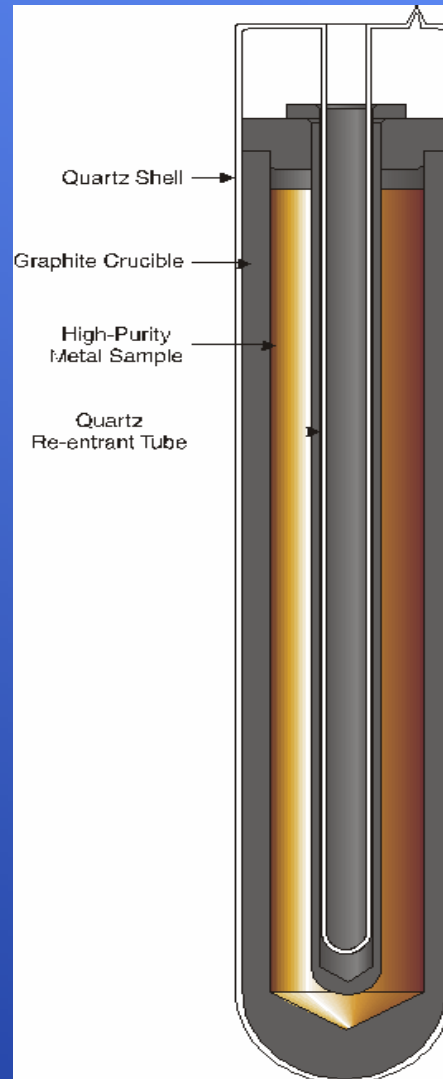
# ITS-90 fixed points

-189.3442°C	TP of Argon	83.8058 K
-38.8344°C	TP of Mercury	234.3156 K
0.01°C	TP of Water	273.16 K
29.7646°C	MP of Gallium	302.9146 K
156.5985°C	FP of Indium	429.7485 K
231.928°C	FP of Tin	505.078 K
419.527°C	FP of Zinc	692.677 K
660.323°C	FP of Aluminum	933.473 K
961.78°C	FP of Silver	1234.93 K

# ITS-90 ranges



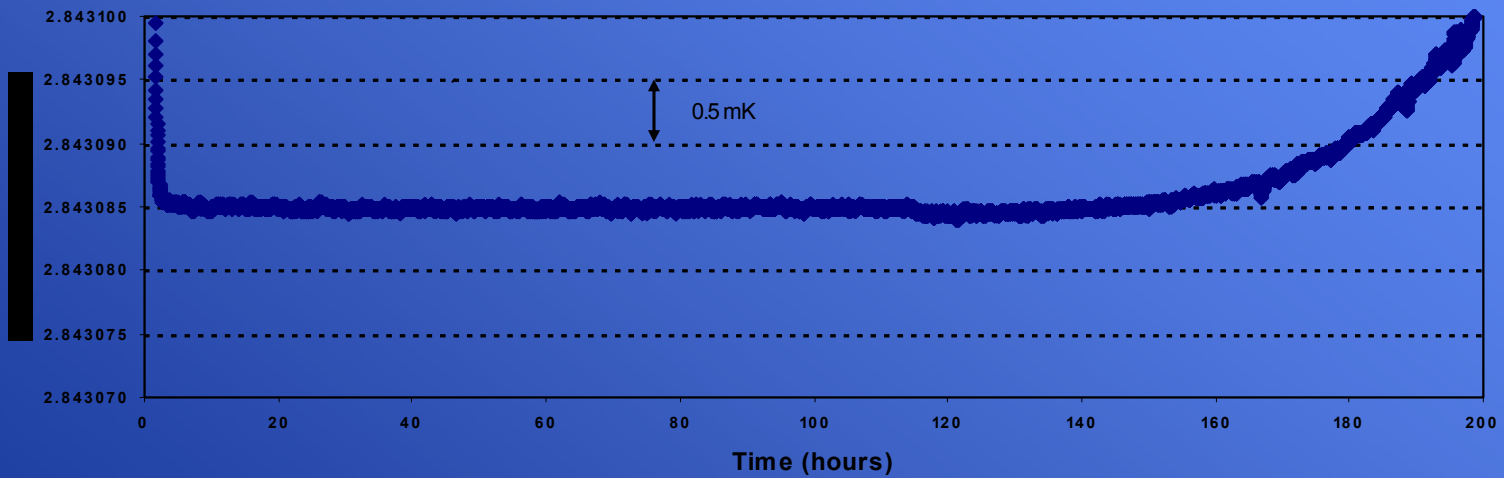
# Fixed point cell





# Melting curve - Ga

**A Melting Curve of Gallium in Model 9230  
Cell #43002, 12/28/2000 -1/8/2001**



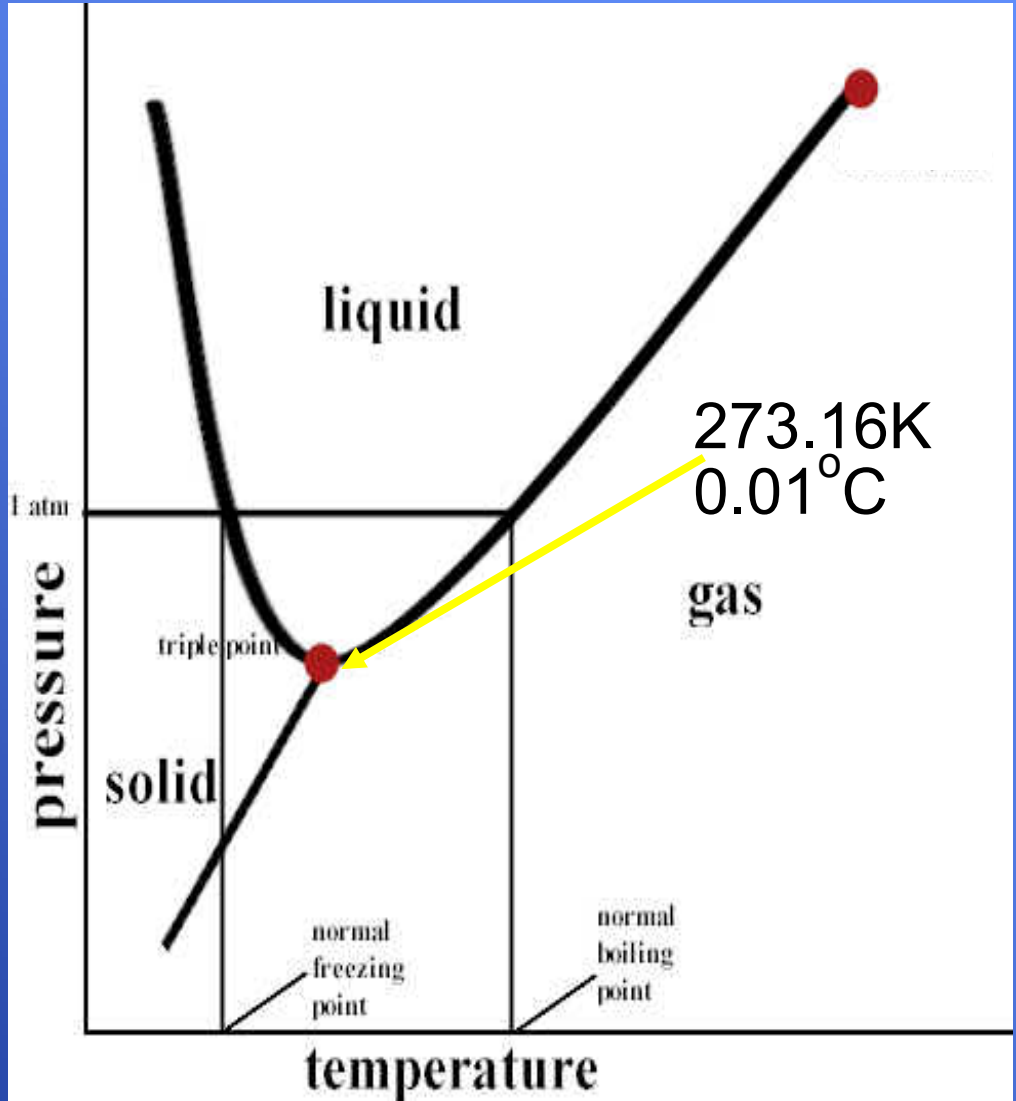
# SPRT a practical thermometer

## Standard Platinum Resistance Thermometer

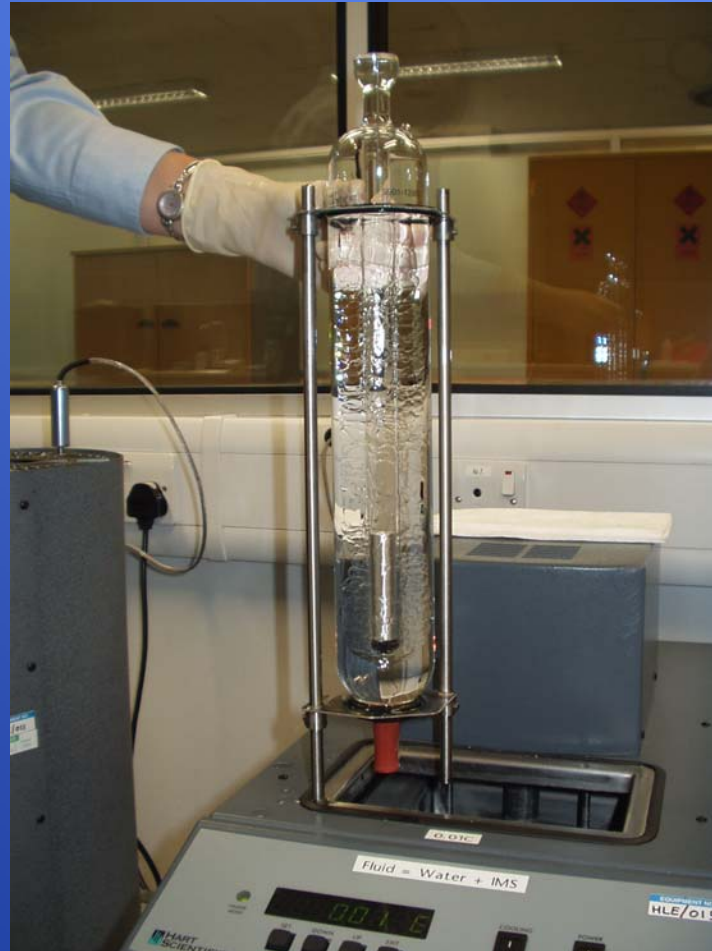
- Strain-free, well-annealed wire
- Pure platinum
- **Resistance ratios**
- $W_{(302.9146K)} \geq 1.11807 (Ga)$
- Protection from contamination
- **Four-lead construction**
- $W_{(273.15K)} \leq 0.844235 (Hg_{TP})$
- Standard dimensions
- Good electrical insulation



# Triple point of water



# TPW cell



# Automated TPW



- ⦿ Fully automated operation
- ⦿  $< 0.0005^{\circ}\text{C}$  uncertainty
- ⦿  $> 12$ -hour plateaus
- ⦿ Self-calibration via water triple point cell
- ⦿ Intrinsic standard

# Practical aspects of TPW

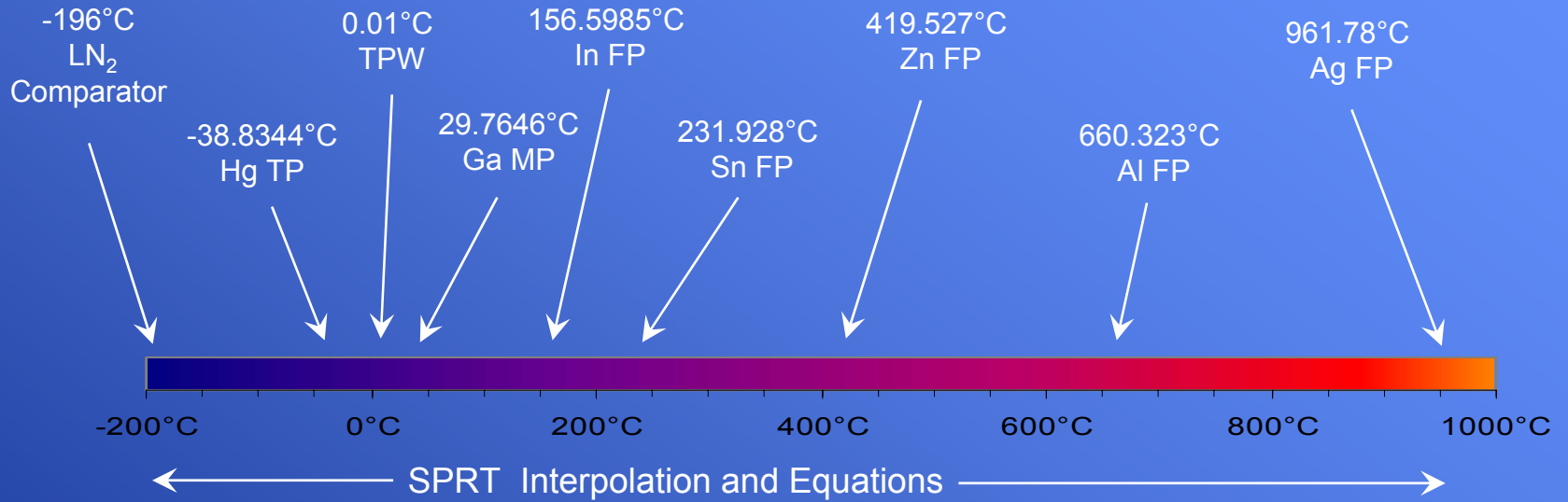
- ⦿ Does not need recalibration
- ⦿ Check reference probes for drift
- ⦿ Valuable history – record all TPW measurements
- ⦿ Most accurate temperature standard
- ⦿ Easy to realise
- ⦿ Check on return from calibration

**Every lab should have one !**

# Realisation of the ITS-90

- ⊙ Obtaining the equilibrium states as defined by the scale
- ⊙ Having thermometers in thermal equilibrium with those equilibrium states
- ⊙ Making accurate measurements and interpretation of the properties of those thermometers in terms of the ITS-90

# Realising the ITS-90





# Norwich uncertainties

TEMPERATURE				
Calibration at fixed points				
4-wire standard platinum resistance thermometers (SPRT)				
TP Water	0.01 °C	0.07 mK	Measurements of R(0.01°C)  Uncertainty in the determination of $W(t_{90})$ used to calculate ITS-90 coefficients.  Note: TP = Triple Point FP = Freezing Point MP = Melting Point BP = Boiling Point	
BP Nitrogen	-196 °C	1.6 mK		
TP Mercury	-38.8344 °C	0.27 mK		
MP Gallium	29.7646 °C	0.27 mK		
FP Indium	156.5985 °C	0.58 mK		
FP Tin	231.928 °C	0.72 mK		
FP Zinc	419.527 °C	1.0 mK		
FP Aluminium	660.323 °C	2.1 mK		
Calibration by comparison				
4-wire platinum resistance thermometers	-196 °C	9.3 mK		Comparison calibrations can also be carried out at other temperatures in the range -80°C to 500°C the uncertainties may be calculated on request and will lie between adjacent points.
	-80 °C	5.0 mK		
	-40 °C	4.0 mK		
	0 °C	2.6 mK		
	30 °C	2.8 mK		
	100 °C	5.6 mK		
	156 °C	6.5 mK		
	232 °C	6.1 mK		
	420 °C	8.8 mK		
	500 °C	12 mK		
Temperature indicators and recorders with temperature sensor(s)		as above with an allowance for display resolution and short-term stability		
Precision thermistors	0 °C to 100°C	2.1 to 2.7 mK		