

Temperature Rise Tests

Centre for Power Transformer Monitoring, Diagnostics
and Life Management (transformerLIFE)

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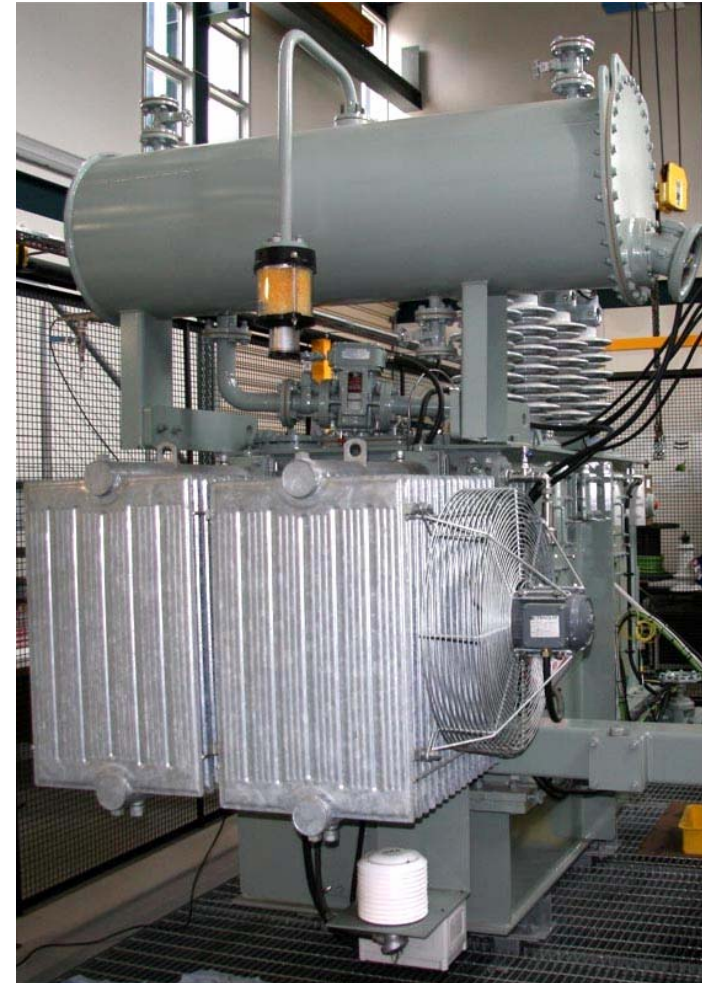
Spring 2009 IEEE Transformers Committee Meeting

Miami FL, 21 April 2009



Special Test Transformer Nameplate Data

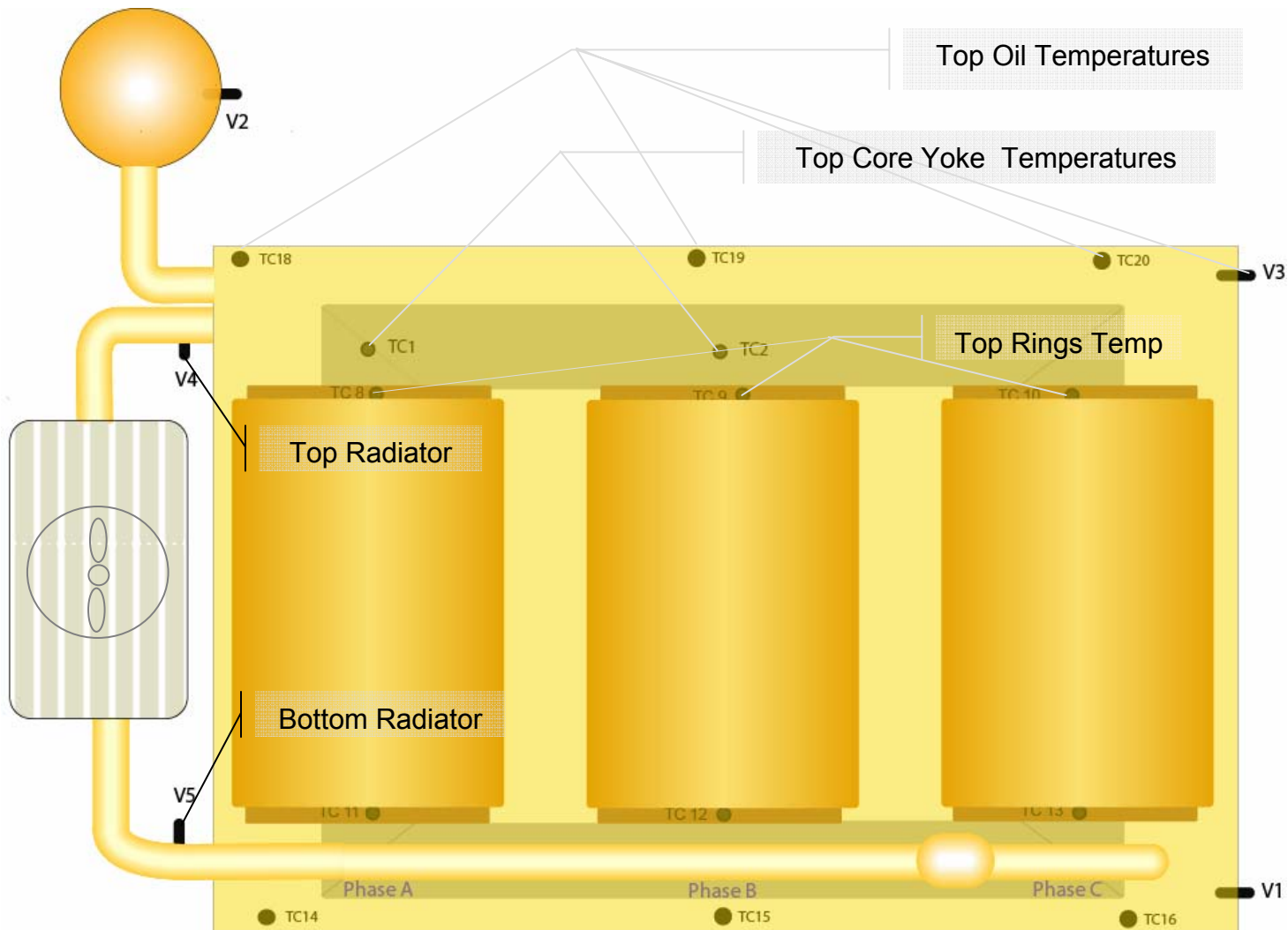
Year of Manufacture	2006
Rated Power HV/MV for ONAN, kVA	468/468
Rated Voltage HV/MV/LV, kV	22/4.5/0.415
Rated Current HV/MV Amp	12.3/60.0
Cooling Types	ONAN, ONAF, OFAF
Number of Phases	3
Vector Symbol	YNyn0yn0
Mass Untanking, kg	2420
Mass Each Cooler (excluding oil), kg	115
Mass Total (including oil), kg	6850
Insulating Oil Each Cooler, l	43
Insulating Oil Total, litre	2650
Oil Circulation, l/min	1200



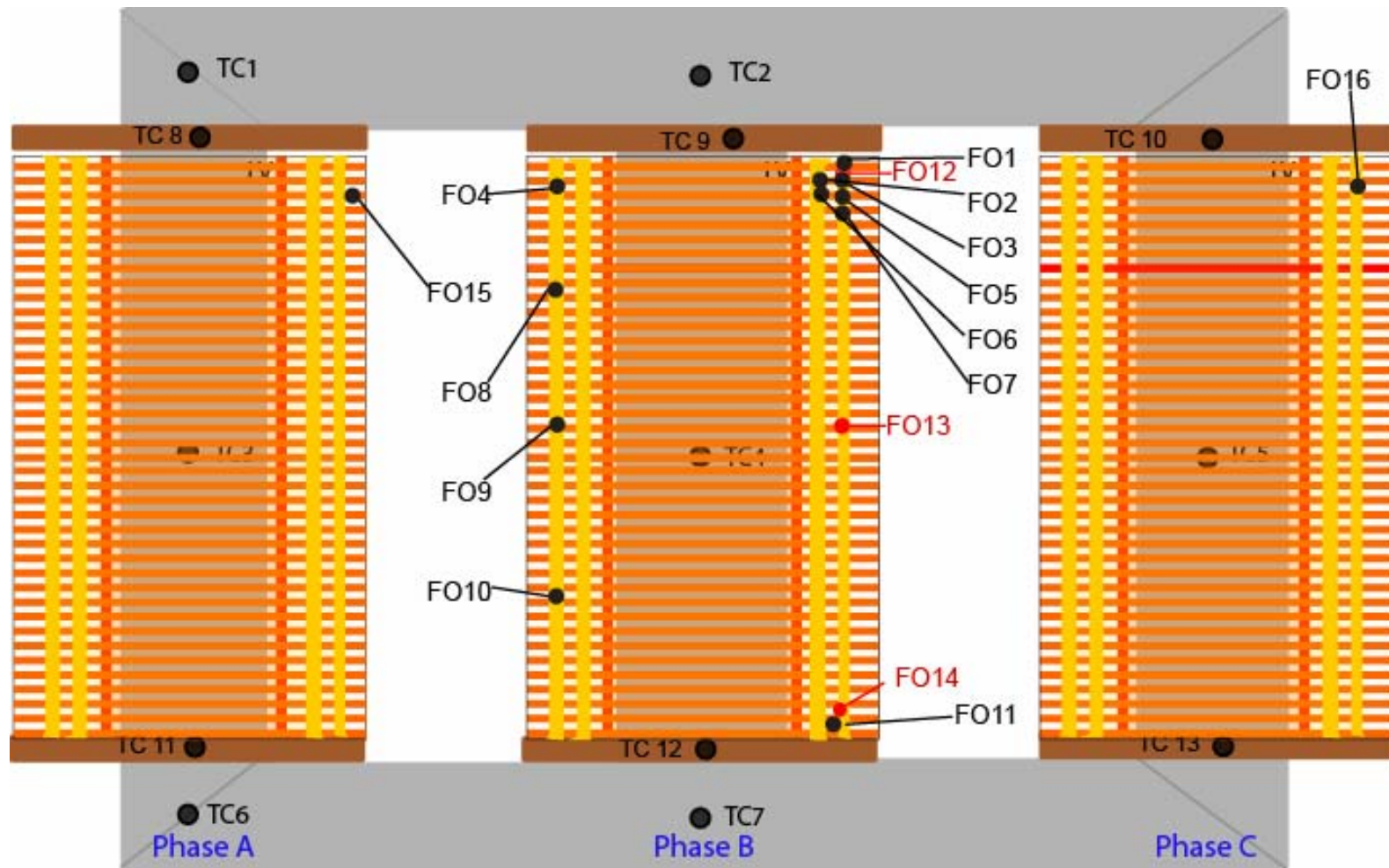
Temperature Sensors and DAQ System

- 16 Fiber Optic sensors
- 24 Thermocouples, including magnetic and thermal ribbon types
- 9 RTDs, including those of moisture/temperature transmitters
- More than 60 channels of information stored at 1 min interval

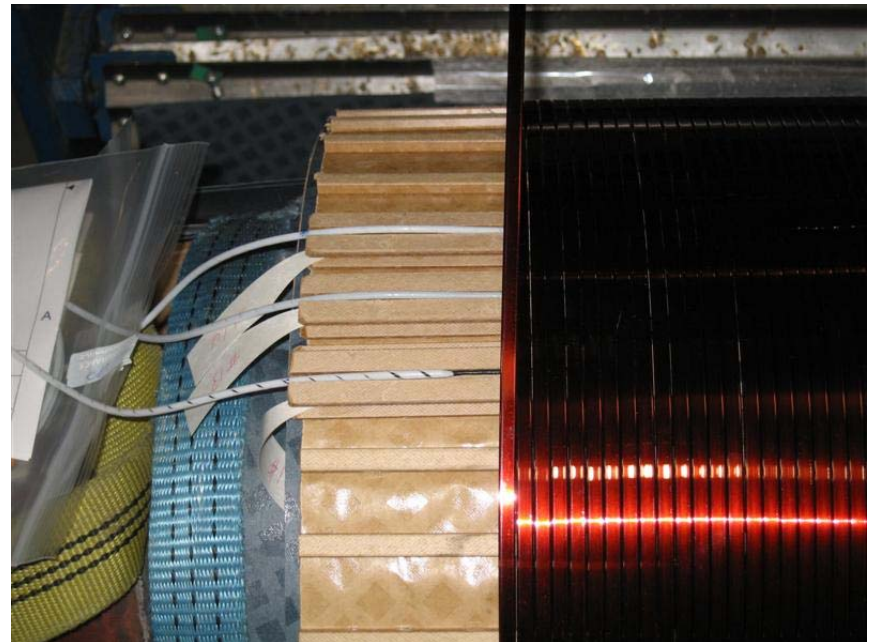
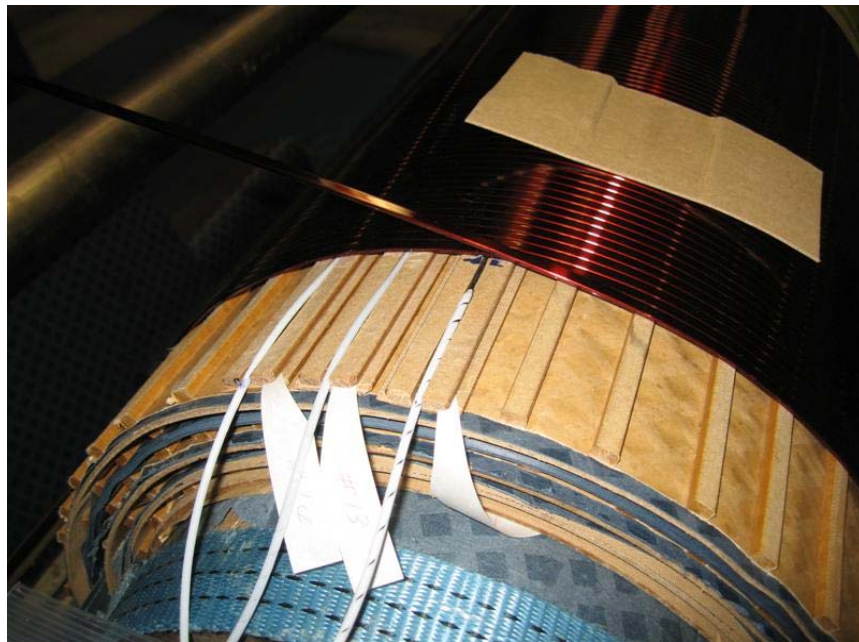
Location of Thermocouples and RTDs in Test Transformer



Location of Fibre Optic Probes and Core Thermocouples



Fibre Optic Probe Installation in MV Winding, Phase B



Fibre Optic Probe Installation in HV Winding

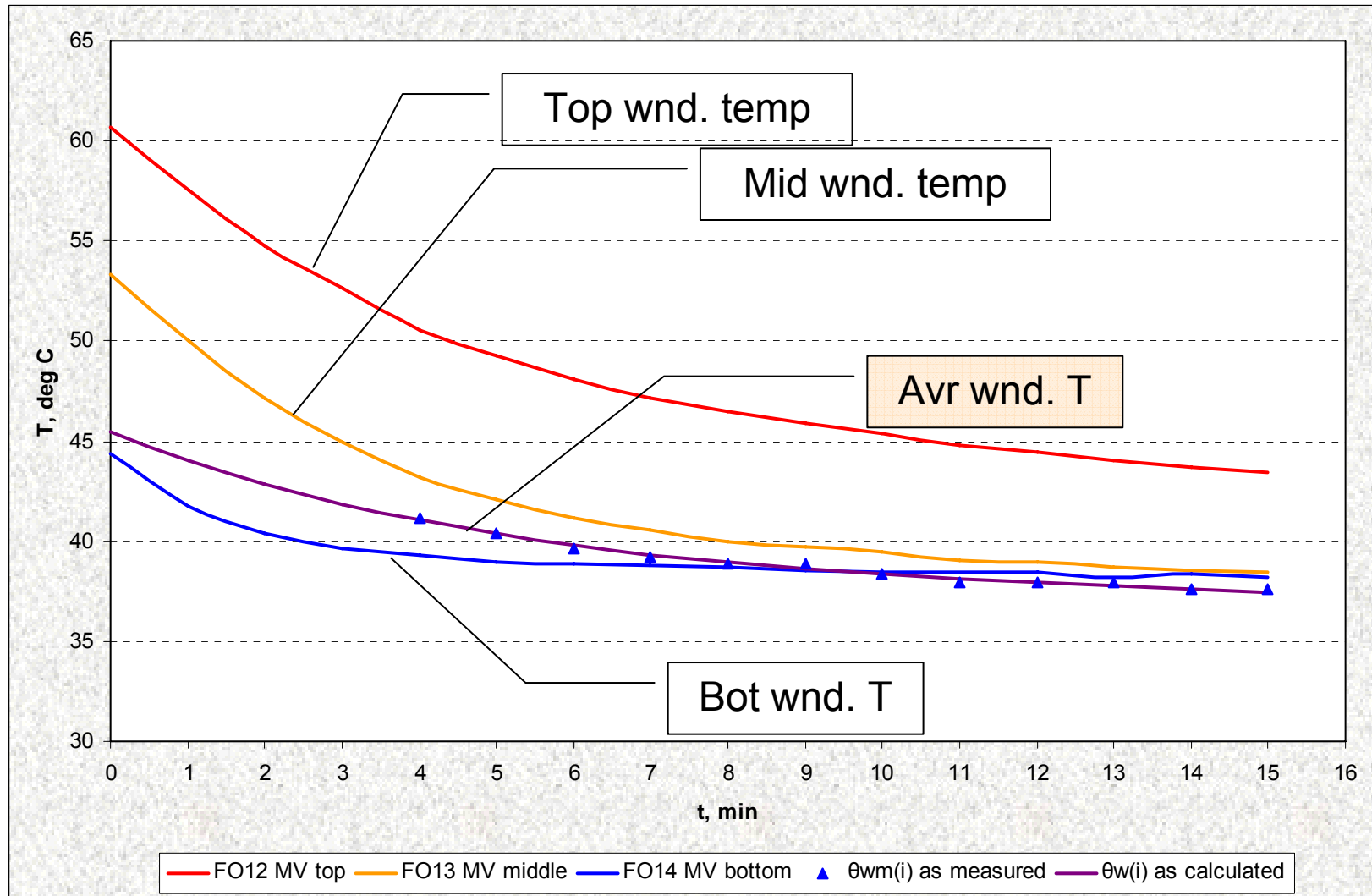


Effect of Measuring Instrumentation

- In the following 4 slides, comparisons are made for the two windings of Phase B (OF AF)
 - MV (layer type)
 - HV (disc type)
- The comparisons are made for results obtained during the Temperature Rise Tests conducted at Monash using two different instrumentation sets for winding resistance measurement

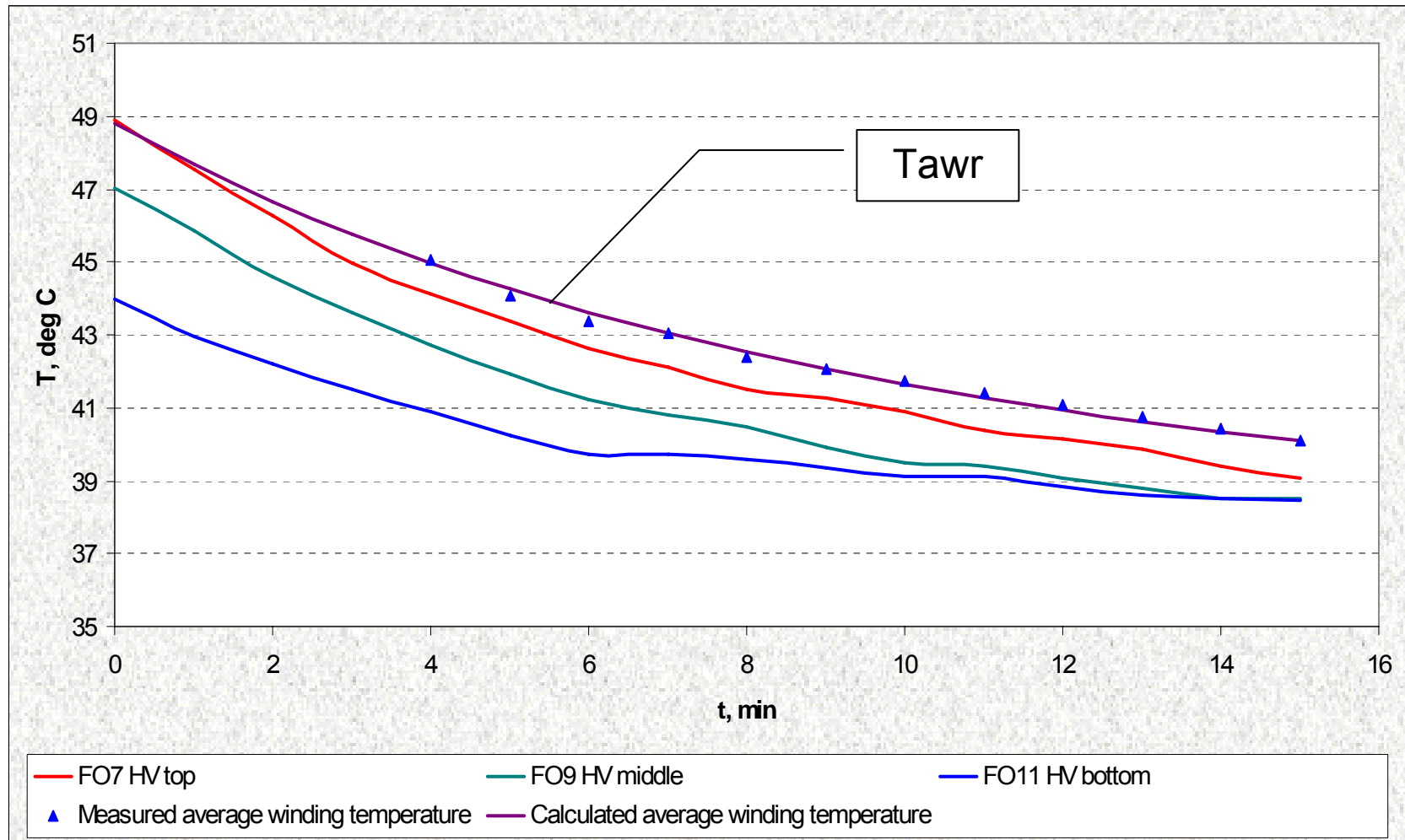
Comparison of Tavr and FO for MV OFAF Phase B, 100A

1st set of winding resistance measurement instrumentation was used



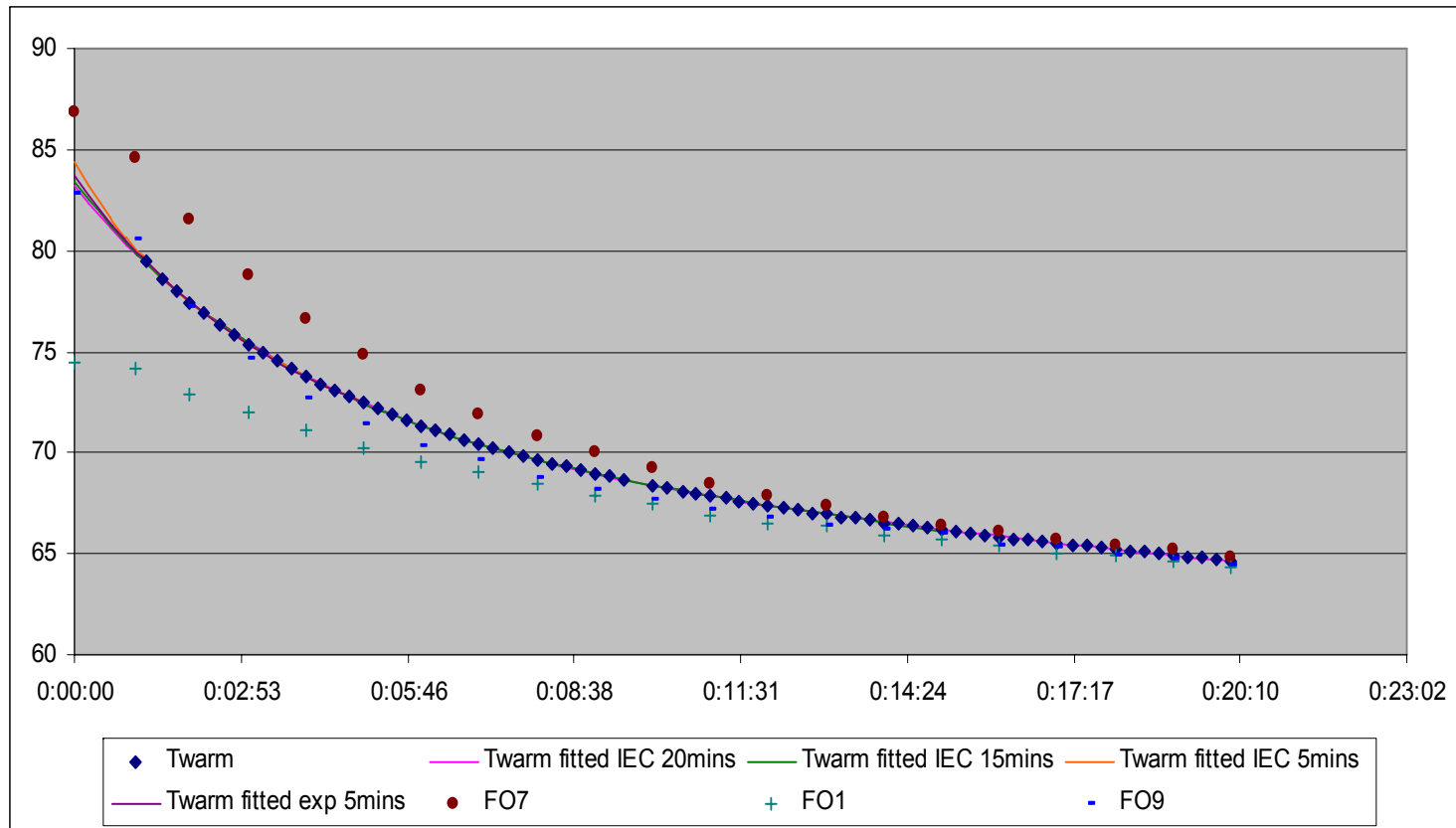
Comparison of Tavr and FO for HV OFAF Phase B, 100A

1st set of winding resistance measurement instrumentation was used



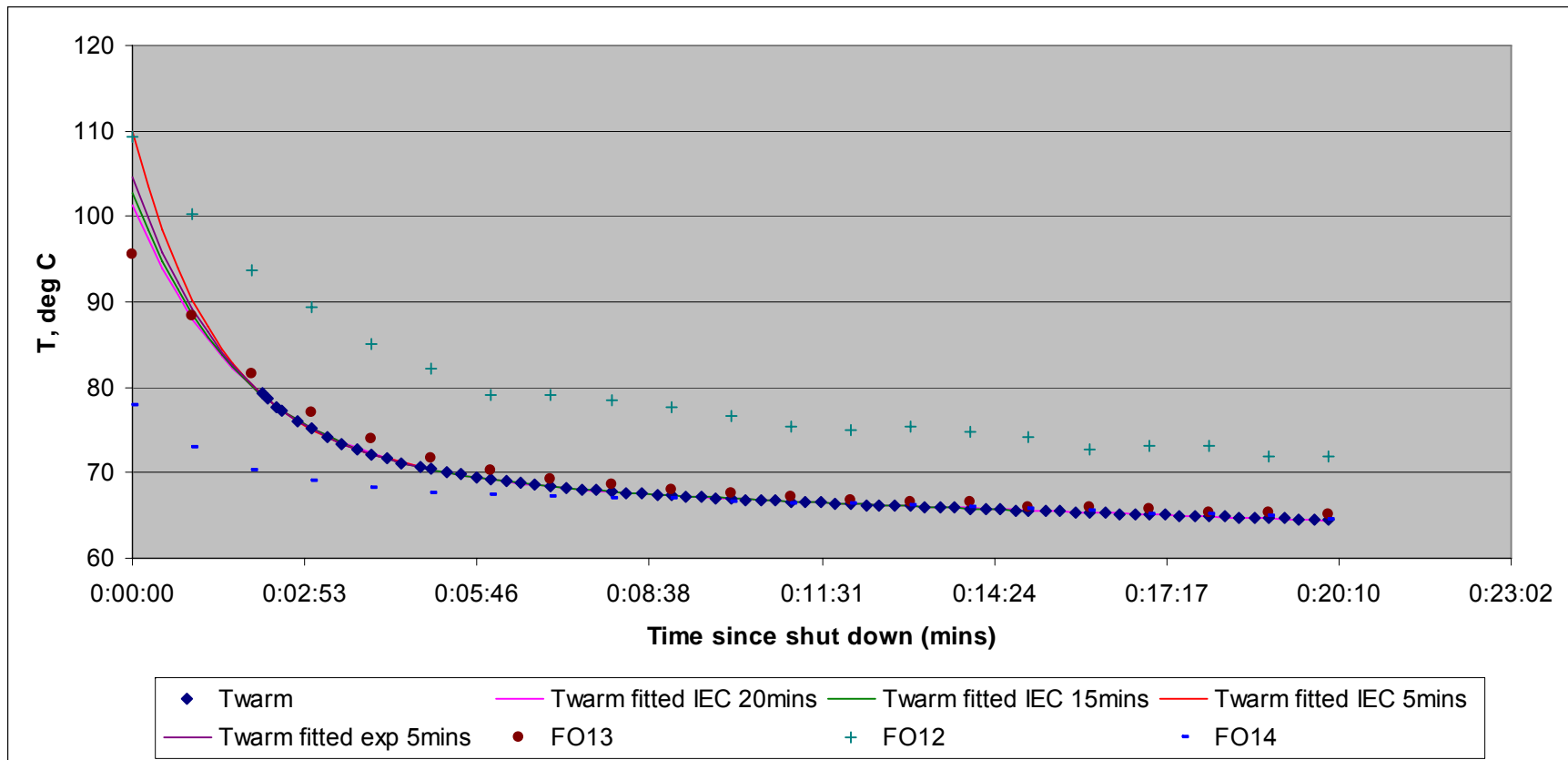
OFAF (100A) HV Phase B

2nd set of winding resistance measurement instrumentation was used



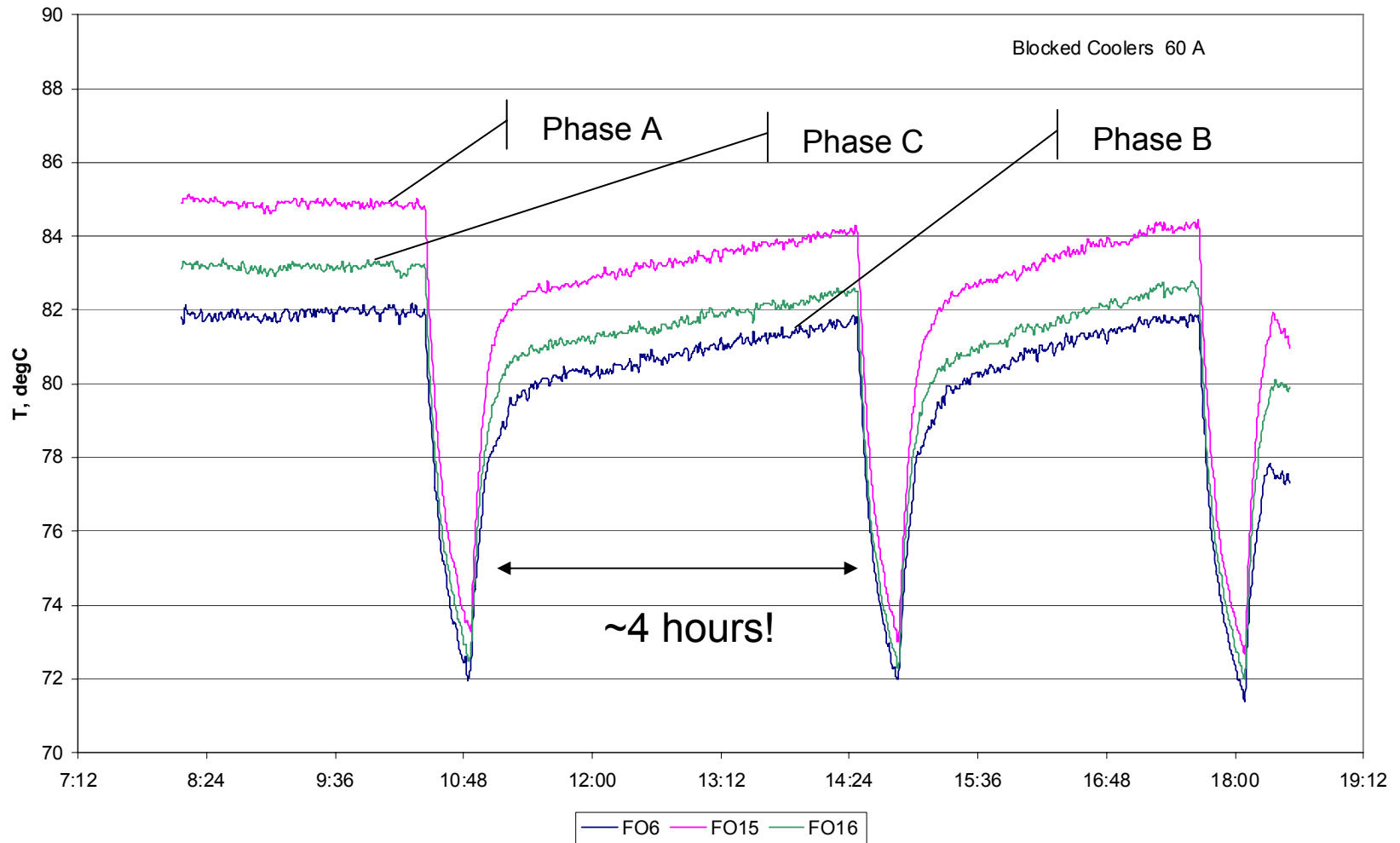
OFAF(100 A) MV Phase B

2nd set of winding resistance measurement instrumentation was used



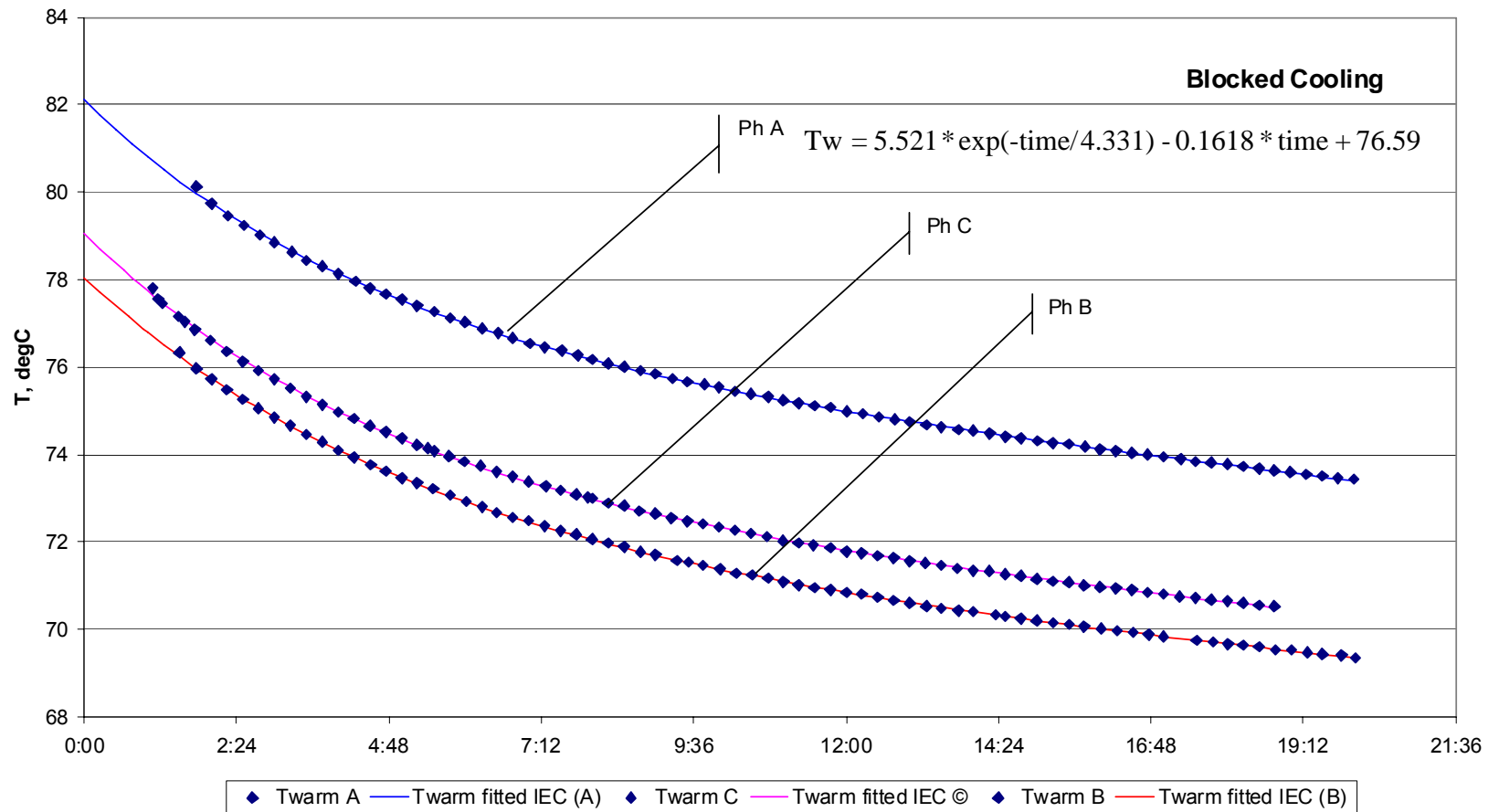
It could be seen that depending on duration of test variations in Twnd (R) is ~10 °C

Blocked Coolers: 60A

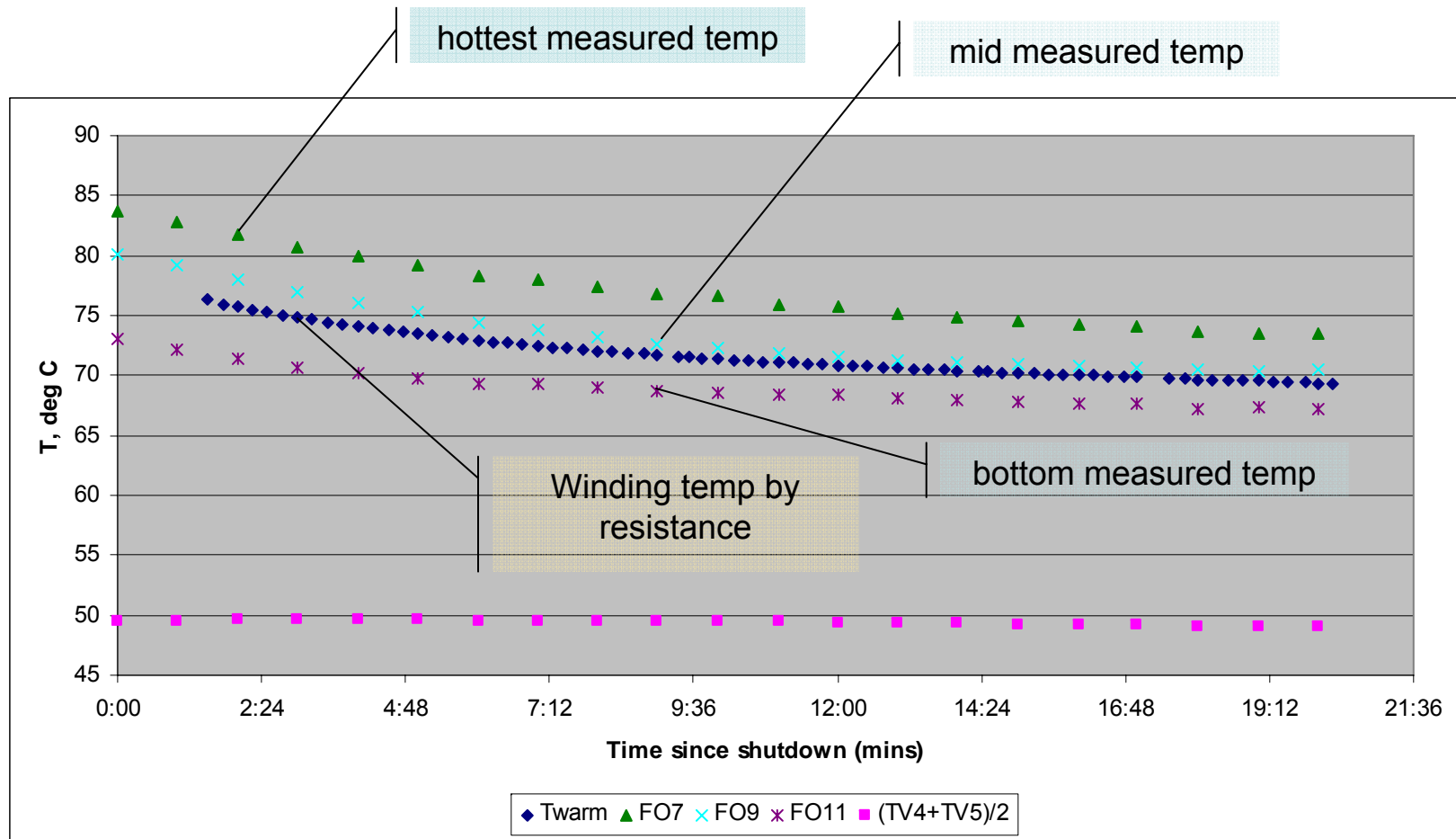


Blocked Coolers: 60 A

2nd set of winding resistance measurement instrumentation was used

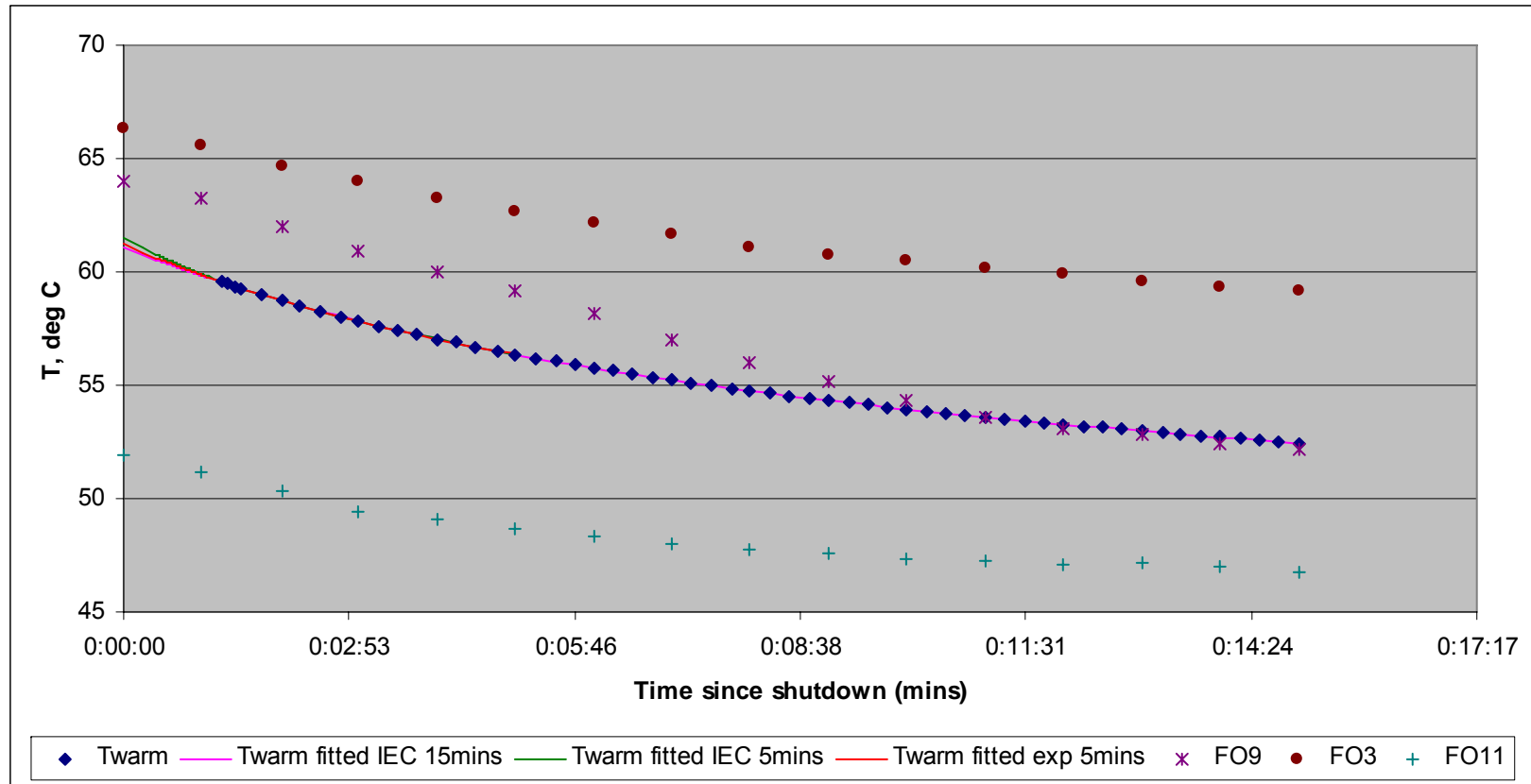


Blocked Coolers HV Phase B 60A



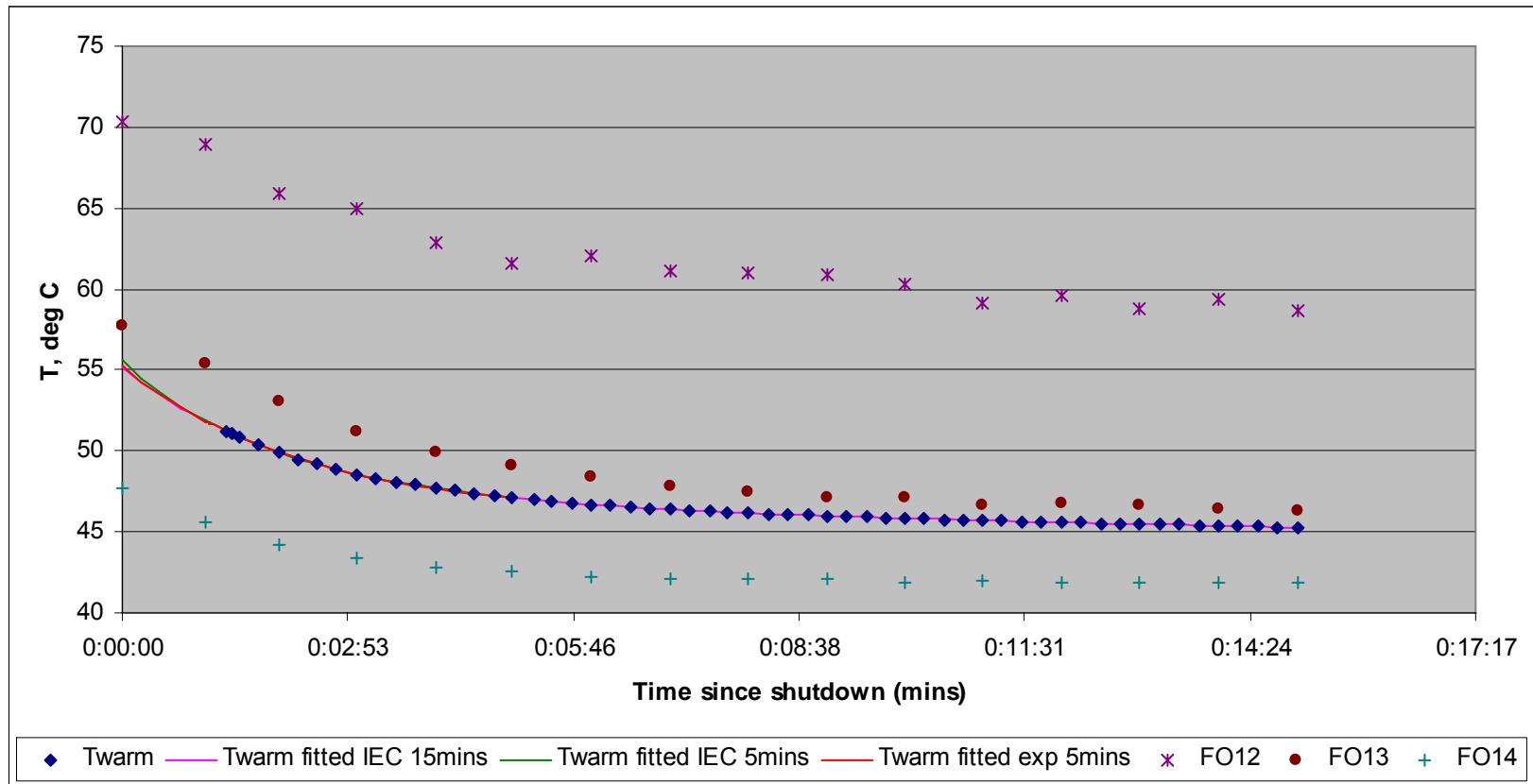
ONAN(60A) HV phase B

2nd set of winding resistance measurement instrumentation was used



ONAN(60A) MV phase B

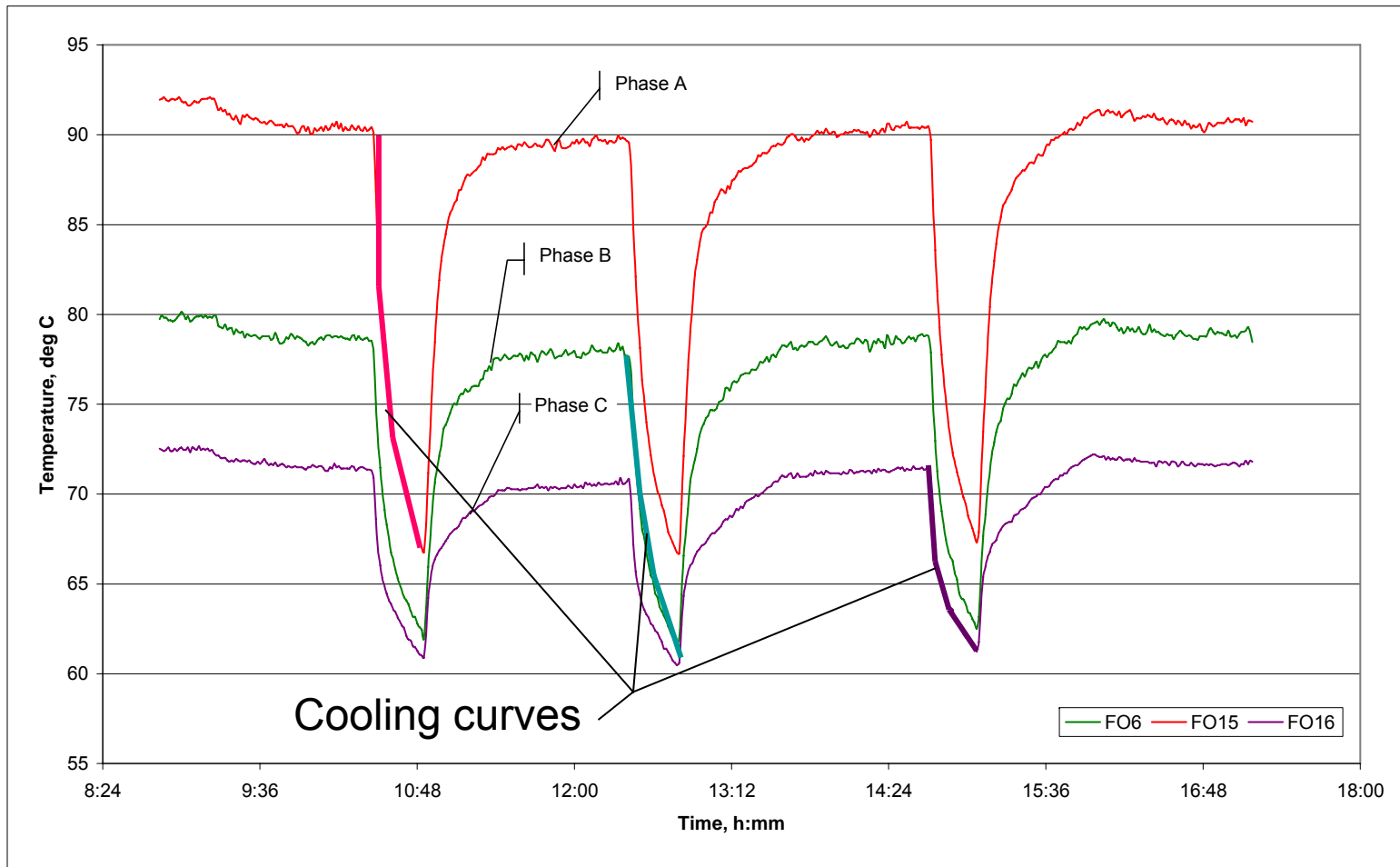
2nd set of winding resistance measurement instrumentation was used



Comparison of FO Data for Phases A, B & C

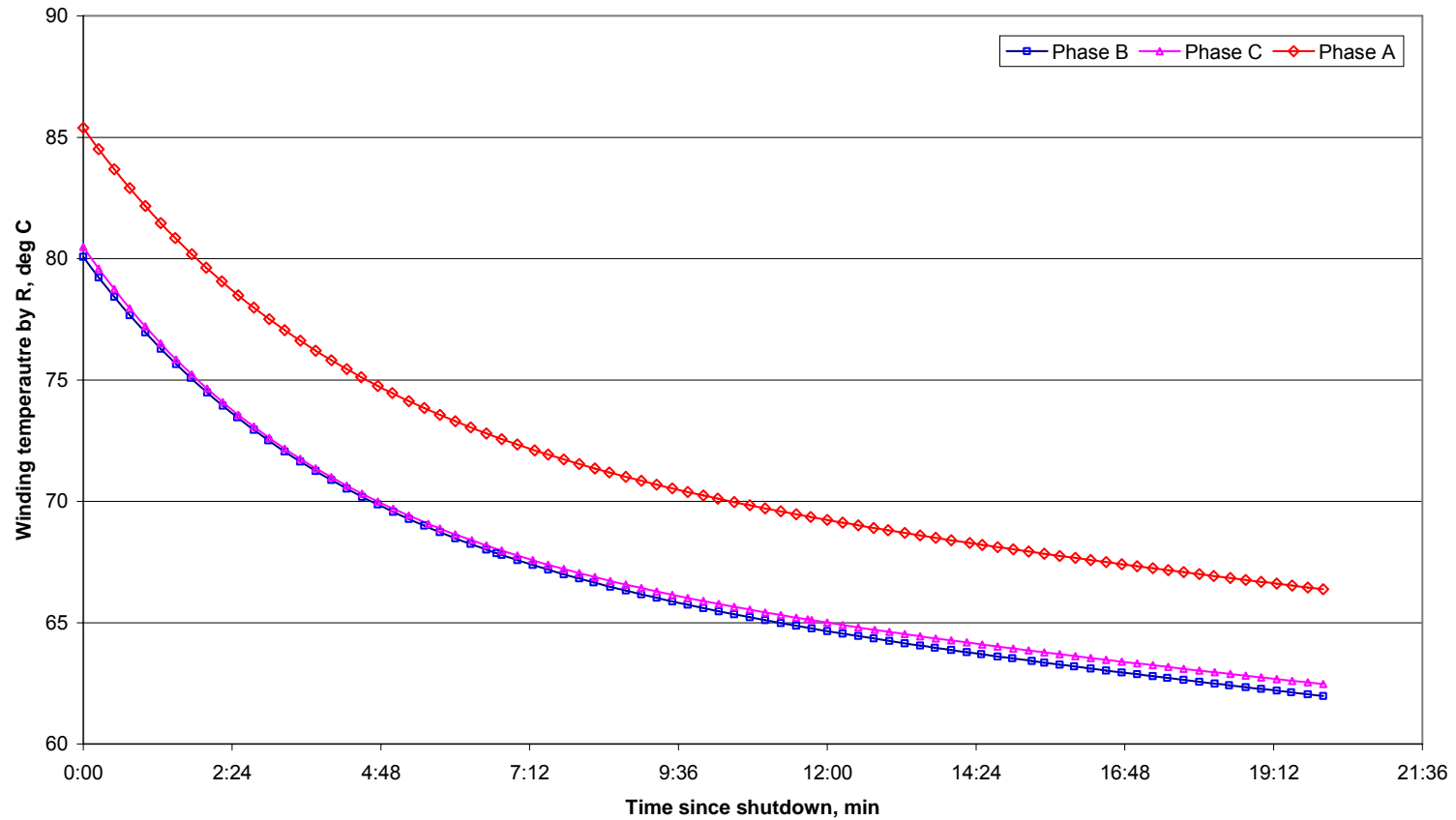
- In the following slide a comparison is made for Phases A, B and C for the HV (disc type) winding for the OFAF cooling mode
- The comparison is made for the measurements obtained during the Temperature Rise Tests conducted at Monash for the FO probes installed in the 2nd top disc of Phases A, B & C
- The differences in the FO measurement results were observed due to the following reasons:
 - Phase A is the most remote phase from the oil inlet pipe; the velocity of oil flow through the winding ducts of Phase A is the lowest
 - Phase C is the closest phase to the oil inlet pipe; the velocity of oil flow through the winding ducts of Phase C is the highest
 - Phase B is in the middle between the inlet pipe and Phase A

FO Sensors Data for Phases A, B and C OF AF (100A)

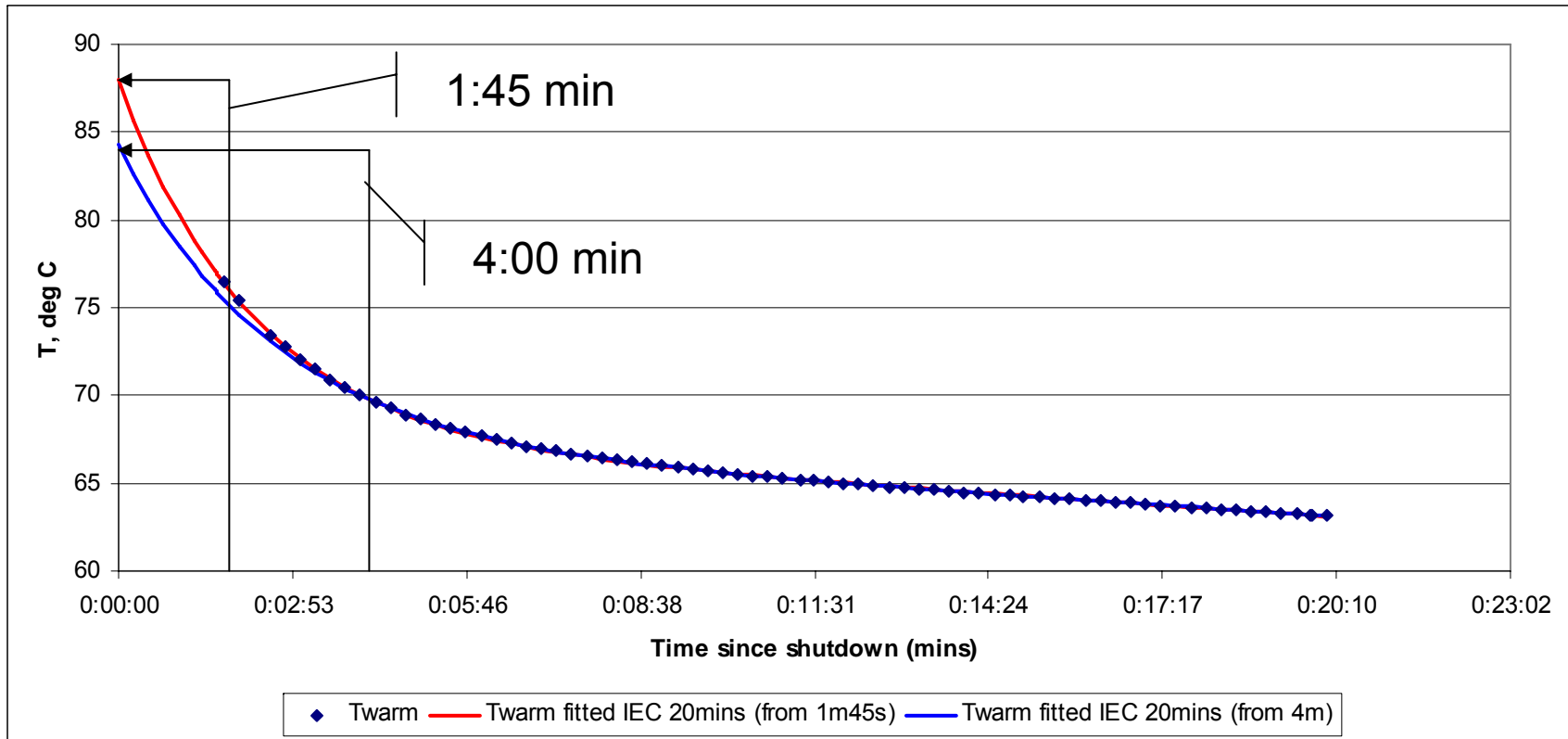


Cooling Curves for A, B and C Phases, OFAF (100A), HV

2nd set of winding resistance measurement instrumentation was used



Effect of first valid time point for MV in OFAF



Factors Affecting Winding Temperature Rise

- Winding resistance measuring equipment
- Ambient temperature determination
- Inadequate calculation of the average oil temperature (leads to wrong g factor)
- Accuracy of Load Loss measurement
- Assumed total loss as sum of NL + LL
- Effect of the Core temperature dynamics
- Cold resistance measurement errors
- Not reaching steady state before shutdown

Factors Affecting Winding Temperature Rise (cont'd)

- Connection circuit (two windings at a time)
- Time interval – first and last data point resistance measurement
- Fitting curve method
- Ambient oil temperature consideration

Conclusions

- Depending on winding time constant taking first resistance measurement at **4 min** may be too long wait and could lead to significant error in determination of winding temperature at shutdown
- **10 min cooling curve** period could be well justified for small and medium distribution transformers, but does not seem to be adequate for large power transformers, where **20 min** should be considered as more appropriate
- **15 sec** acquisition rate was found to be easily achievable with the modern acquisition systems and is recommended, especially for a winding with a short time constant

Conclusions (Cont'd)

- Considerations should be given to the following recommendations when FO sensors are used:
 - a. Number and locations of FO temperature probes should be determined on the basis of analysis of heat and mass transfer with assistance of numerical methods such as FEM and CFD;
 - b. Hot-spot temperature should be continuously measured by FO sensors installed **in each winding of each phase** and verified by calculations in accordance with the latest relevant standards and/or more detailed in-house thermo-hydraulic models;
 - c. Average winding temperature rise by resistance should be measured *only in the winding of the phase with the highest hot-spot temperature* found in b) unless the difference between that temperature and the average of all phases exceeds agreed value (e.g. 3 °C).