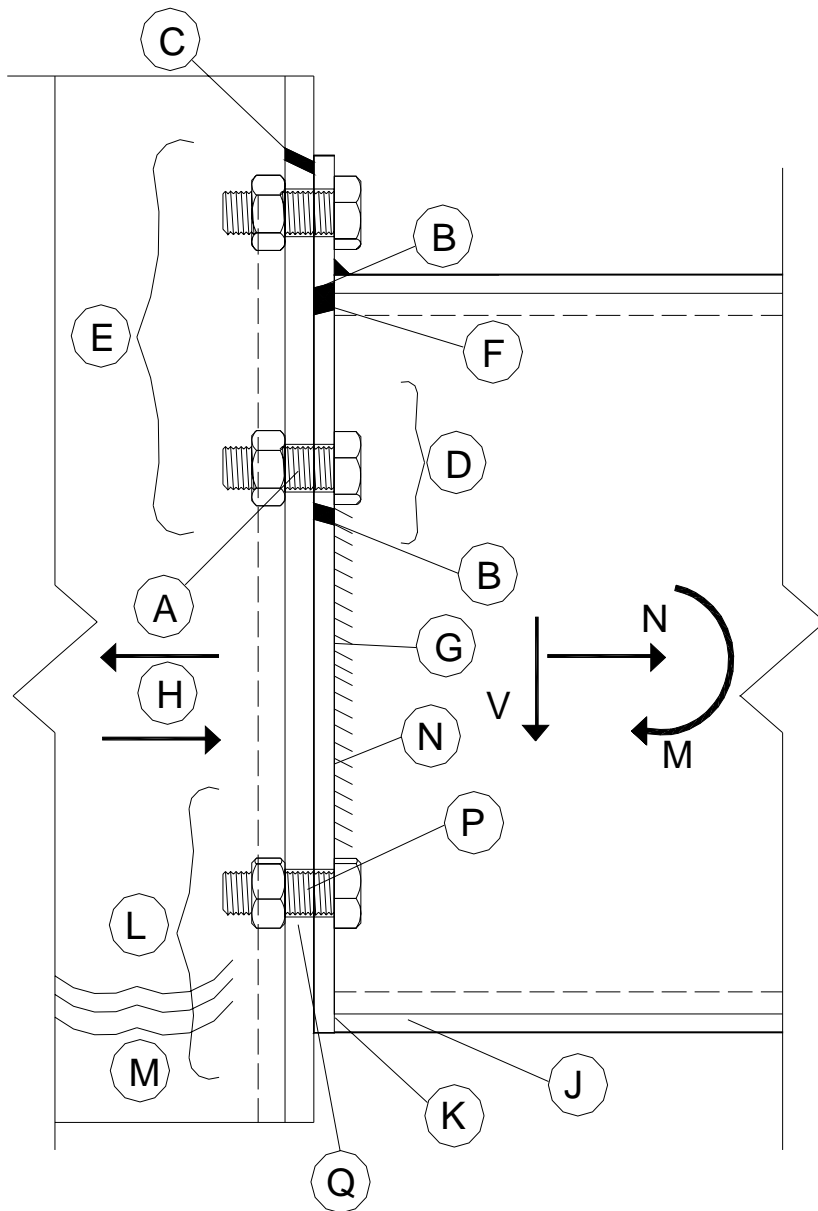


***Mechanical Properties
of Grade 8.8 Bolts
at Elevated Temperatures***

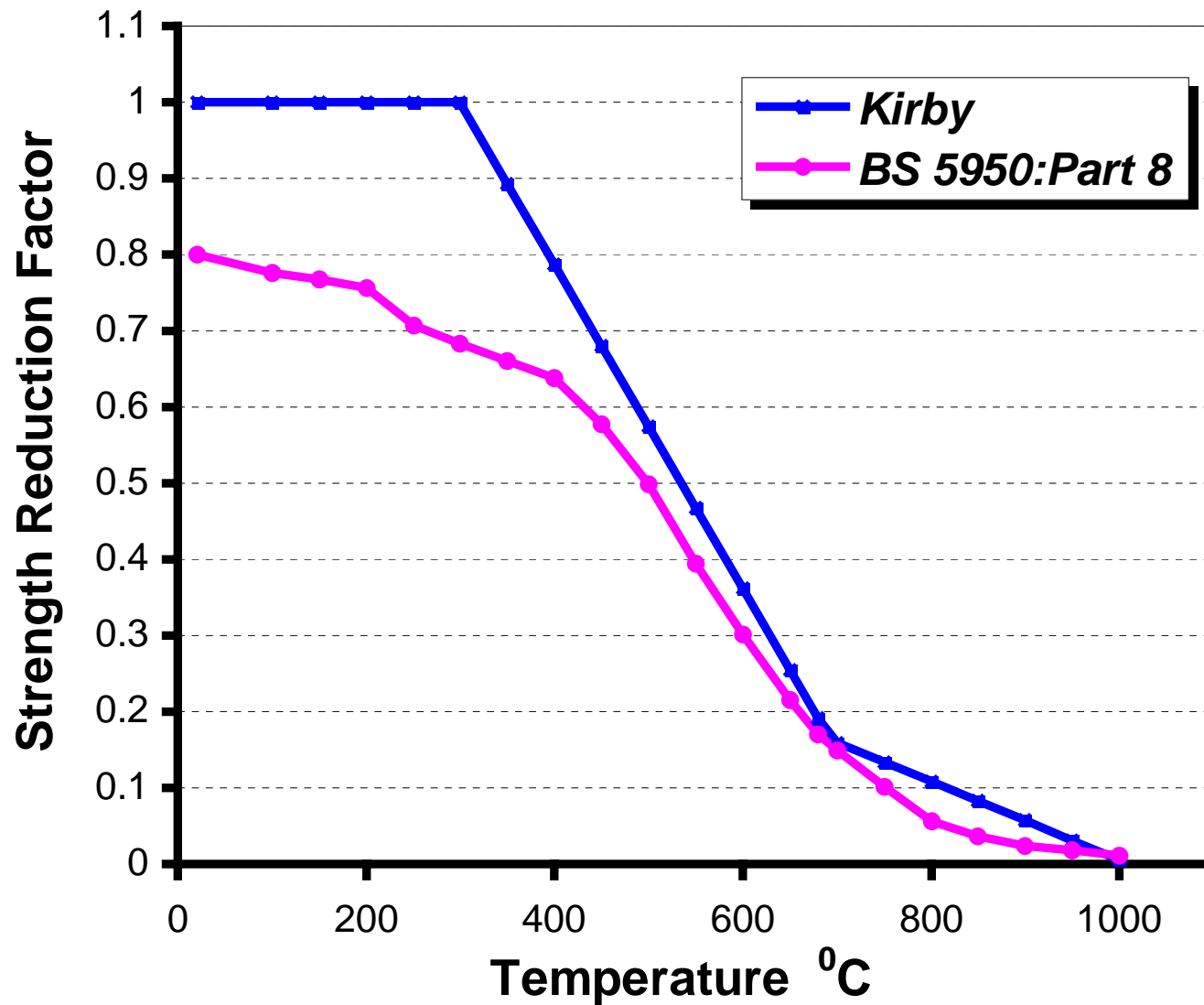
MSc project
Yiannis Theodorou

Component approach to joint design

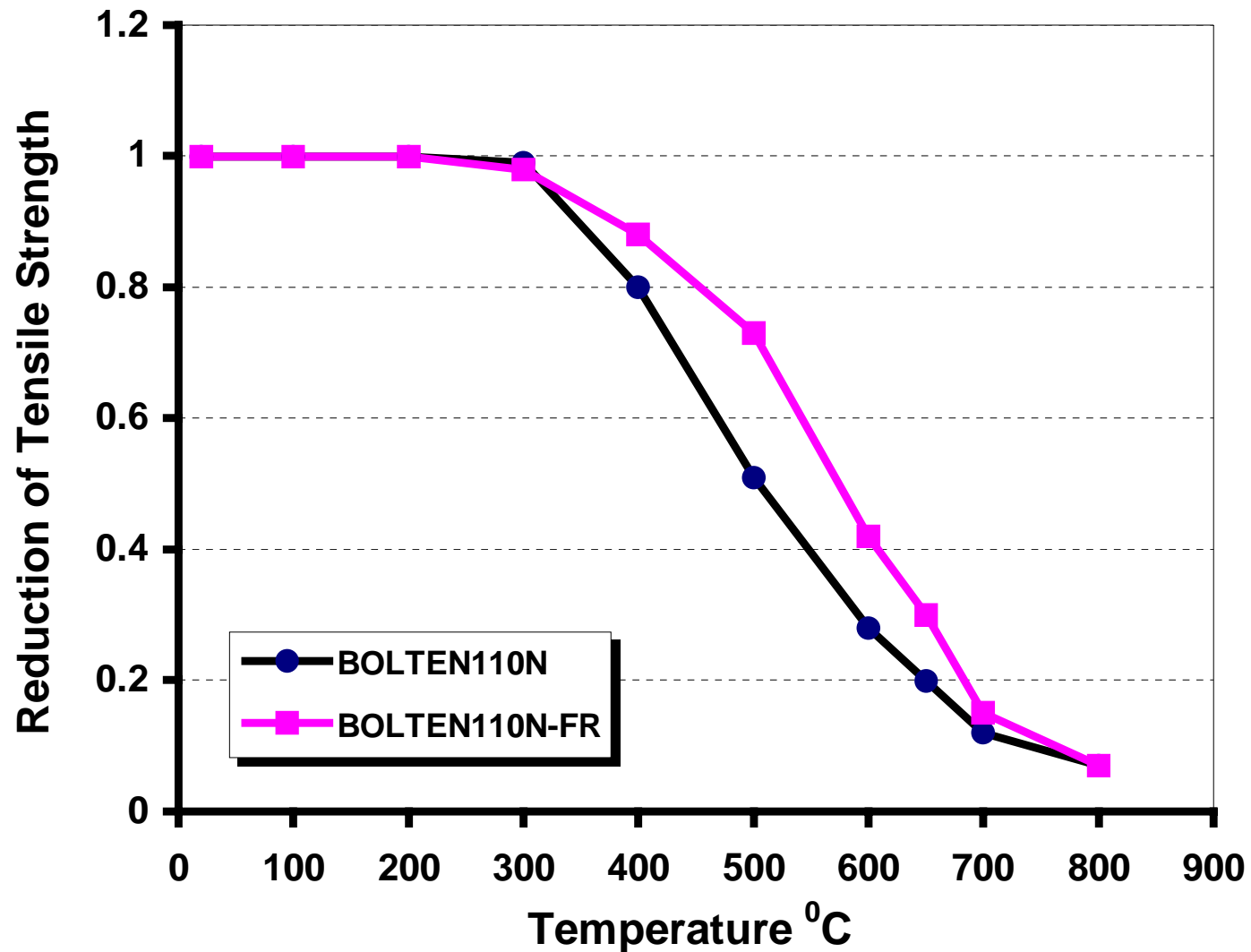


Zone	REF	Checklist item
Tension	A	Bolt Tension
	B	End Plate Bending
	C	Column Flange Bending
	D	Beam Web Tension
	E	Column Web Tension
	F	Flange to End Plate Weld
	G	Web to End Plate Weld
Horizontal Zone	H	Column Web Panel Shear
Compression	J	Beam Flange Compression
	K	Beam Flange Weld
	L	Column Web Crushing
	M	Column Web Buckling
	N	Web to End Plate Weld
Vertical Shear	P	Bolt Shear
	Q	Bolt Bearing(Plate or Flange)

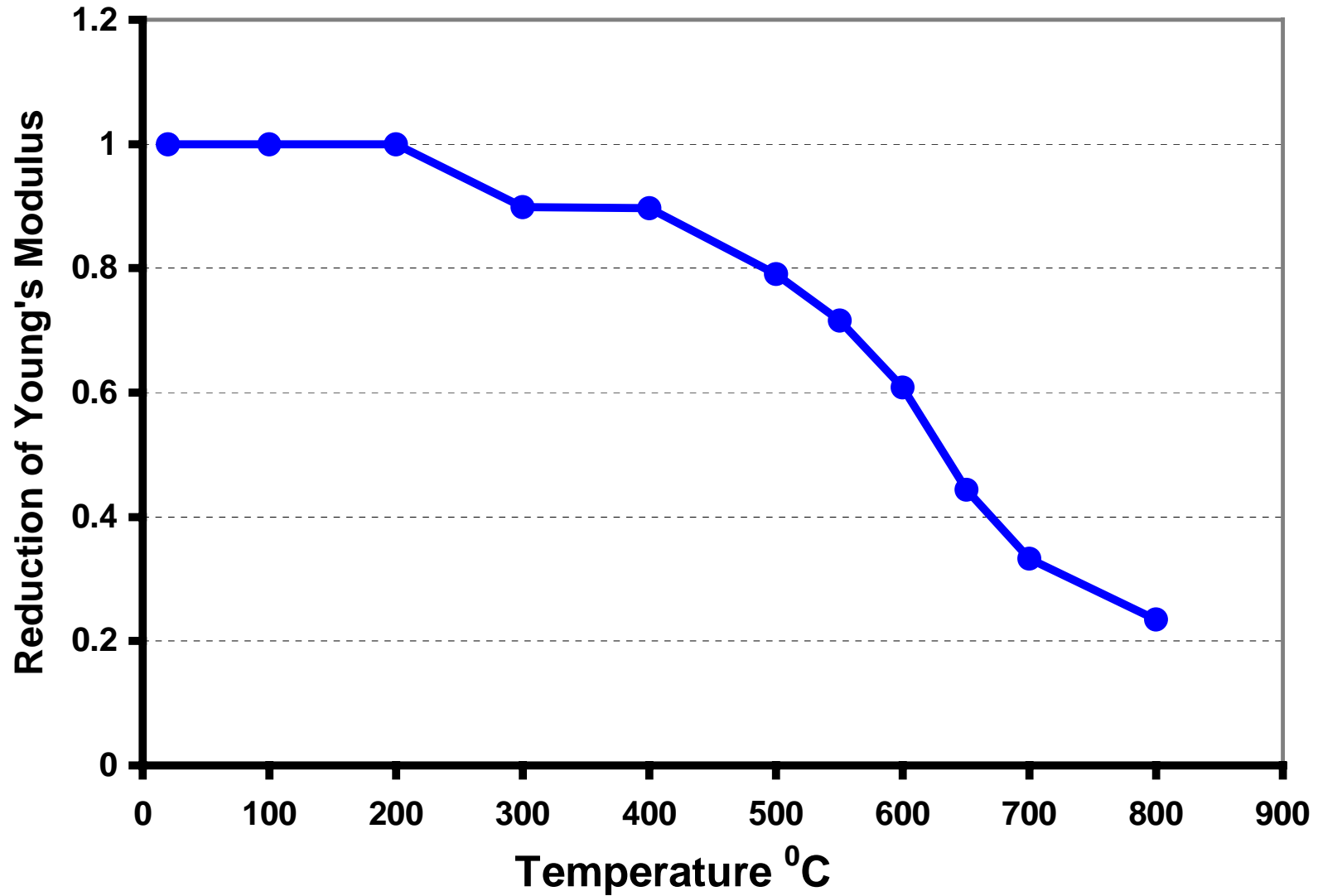
Strength reduction factors measured by Kirby



Comparison of tensile strength of FR and ordinary bolts at elevated temperatures



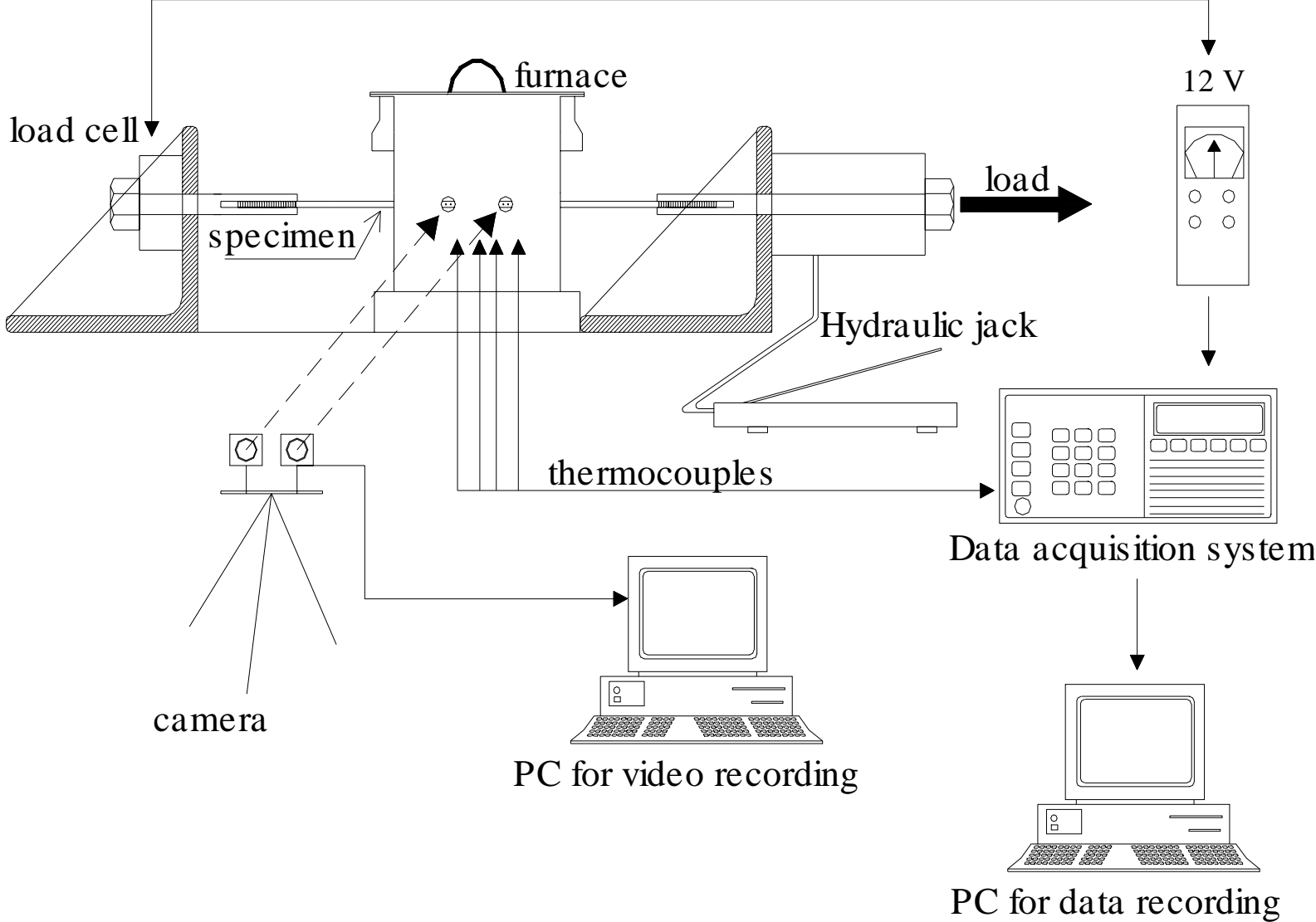
Temperature Dependency of Young's Modulus of FR Bolts



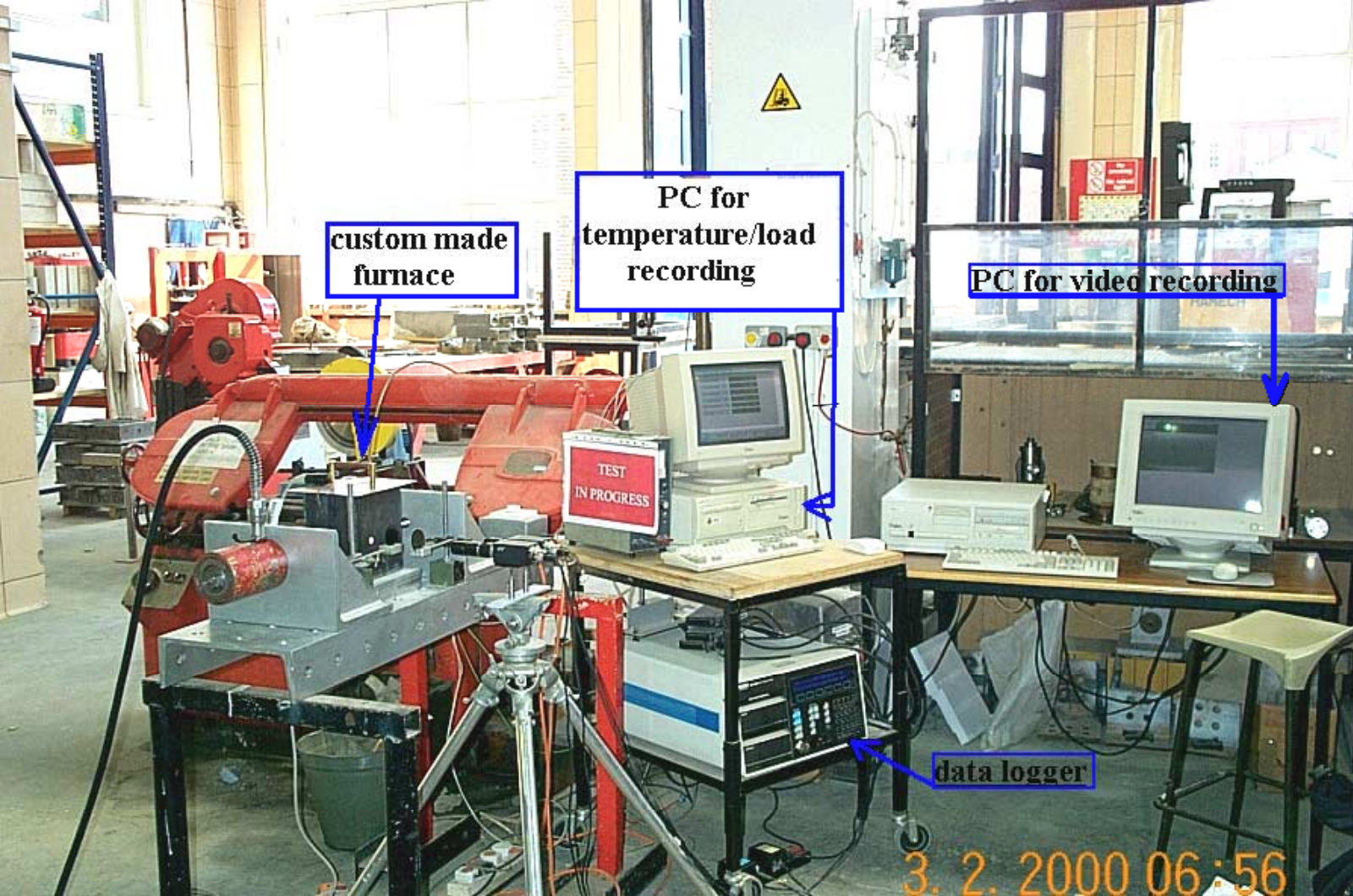
Aim of study

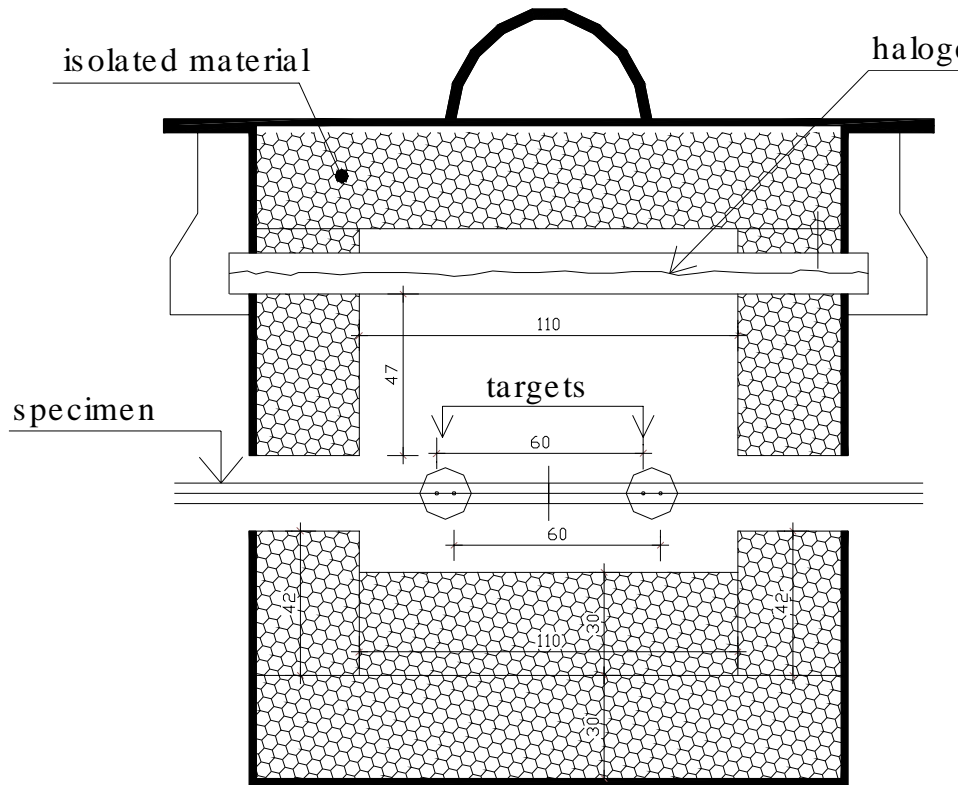
- ❑ To measure the mechanical properties (strength, stiffness, expansion) of grade 8.8 bolts across a range of temperatures
- ❑ Project Involved
 - Designing and building furnace
 - Devising instrumentation

Schematic diagram of apparatus

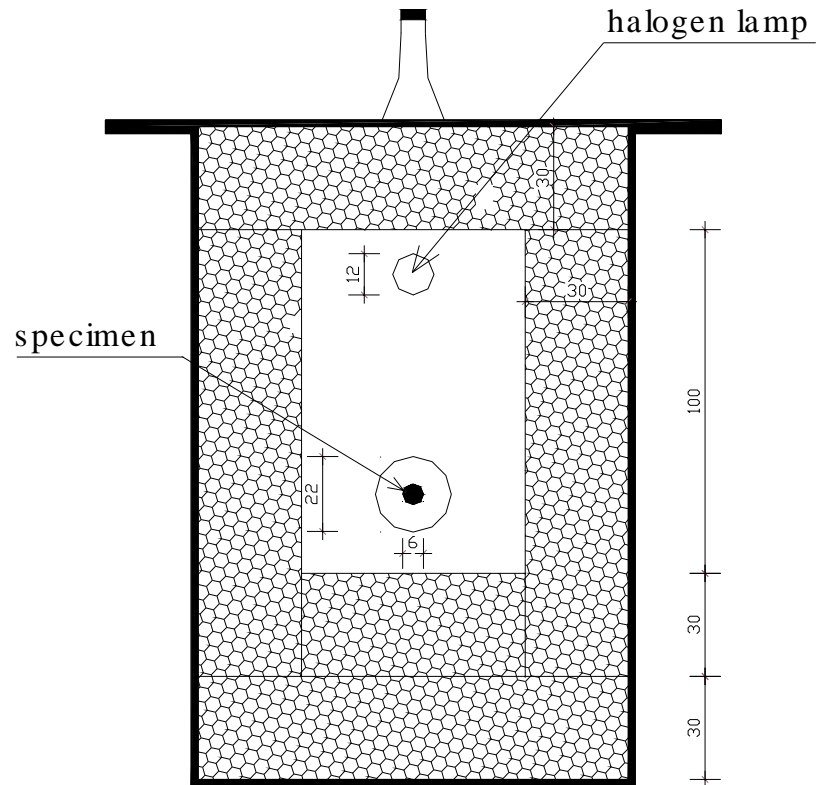


Experimental apparatus





Cross-Section of Furnace

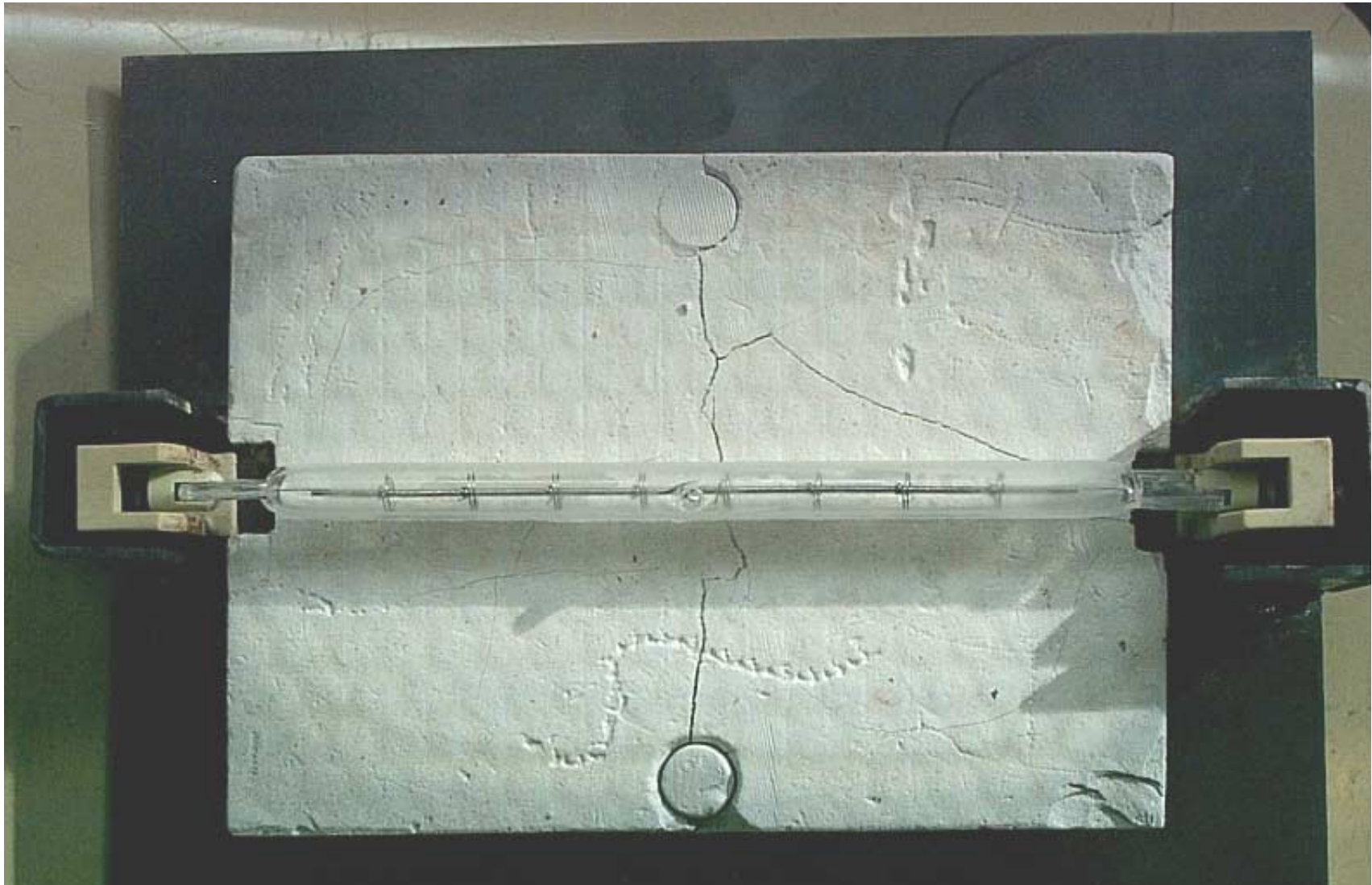


Cross-Section of Furnace

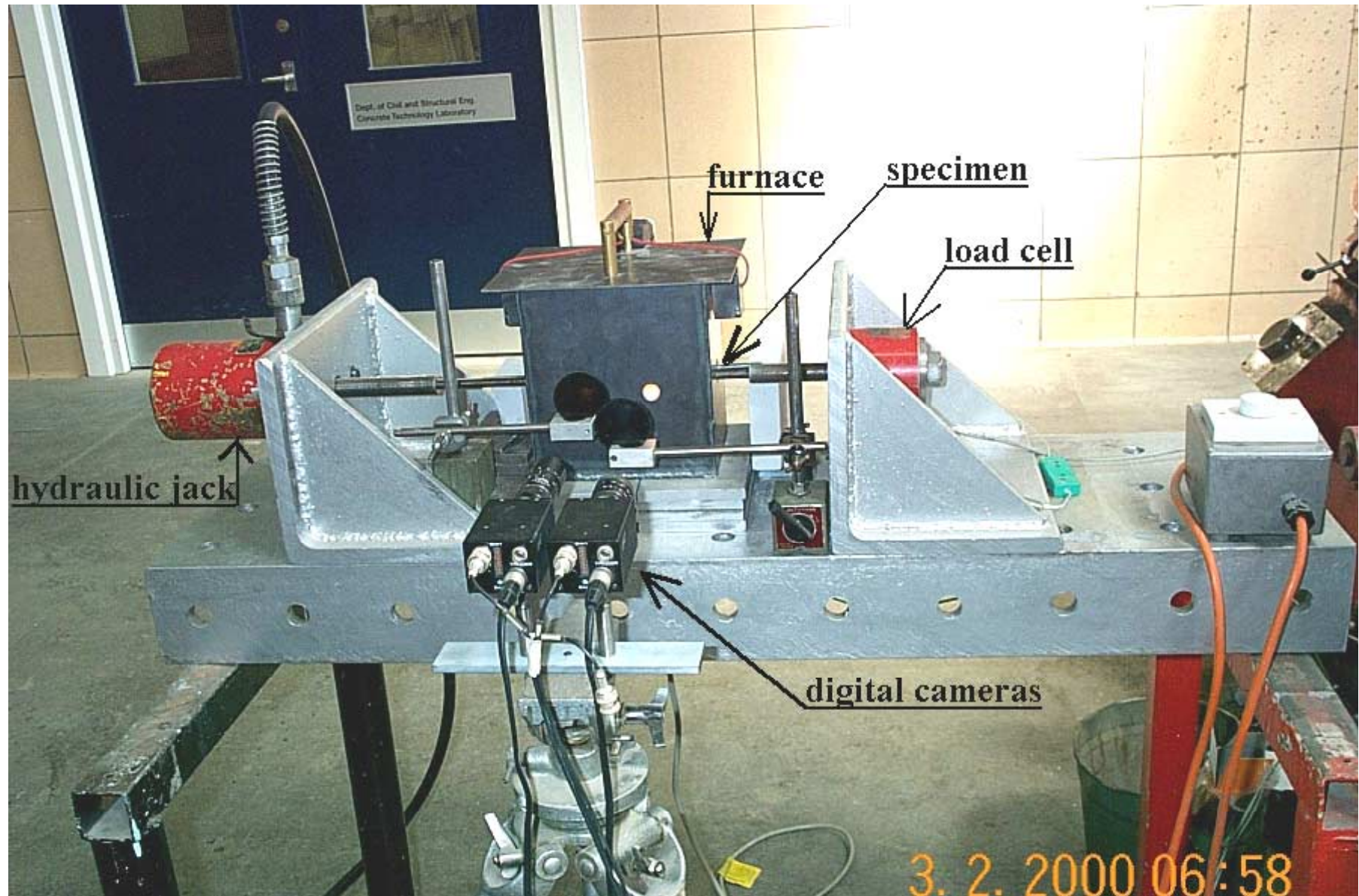
View into furnace



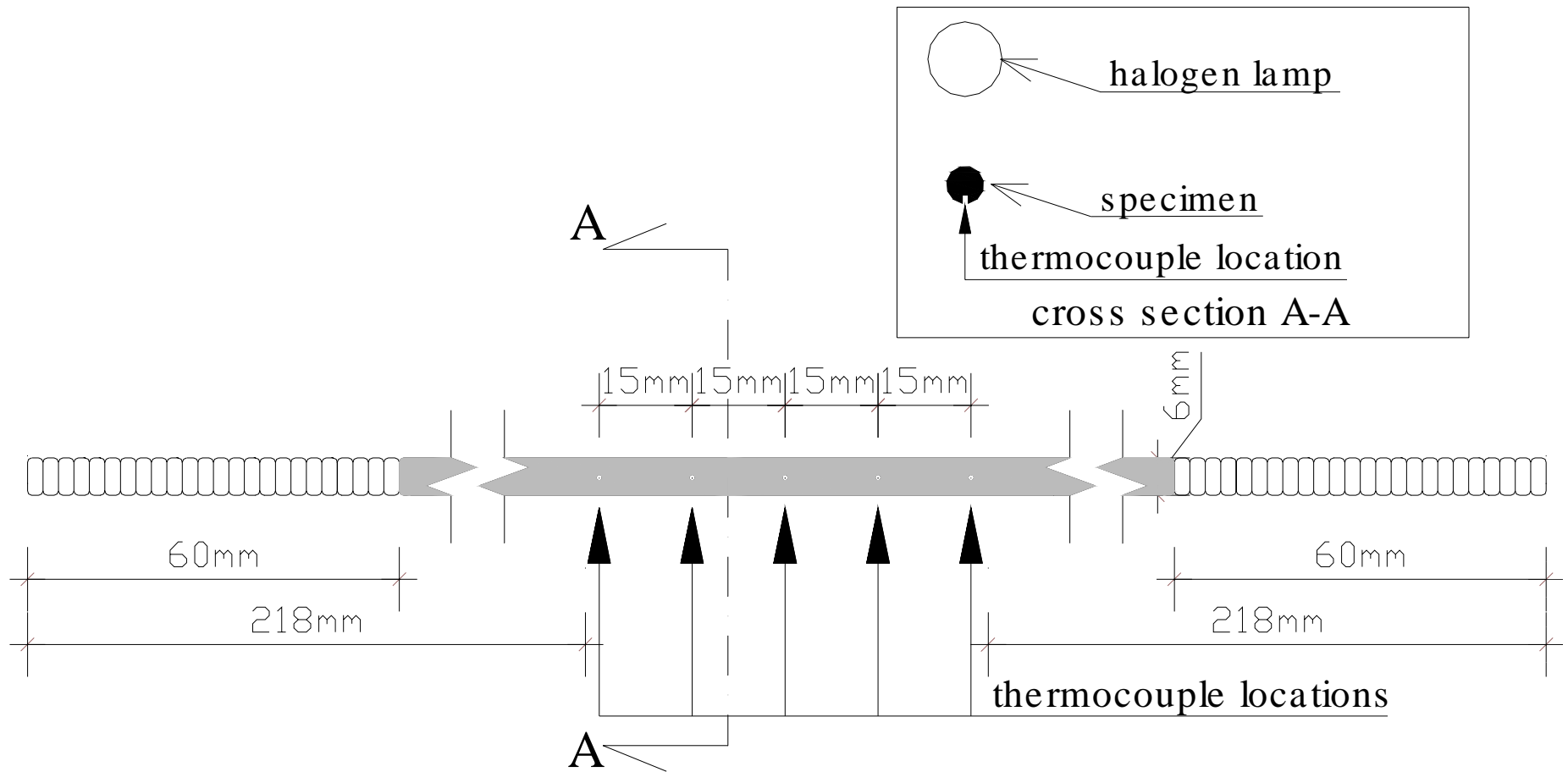
Underside of lid showing halogen lamp



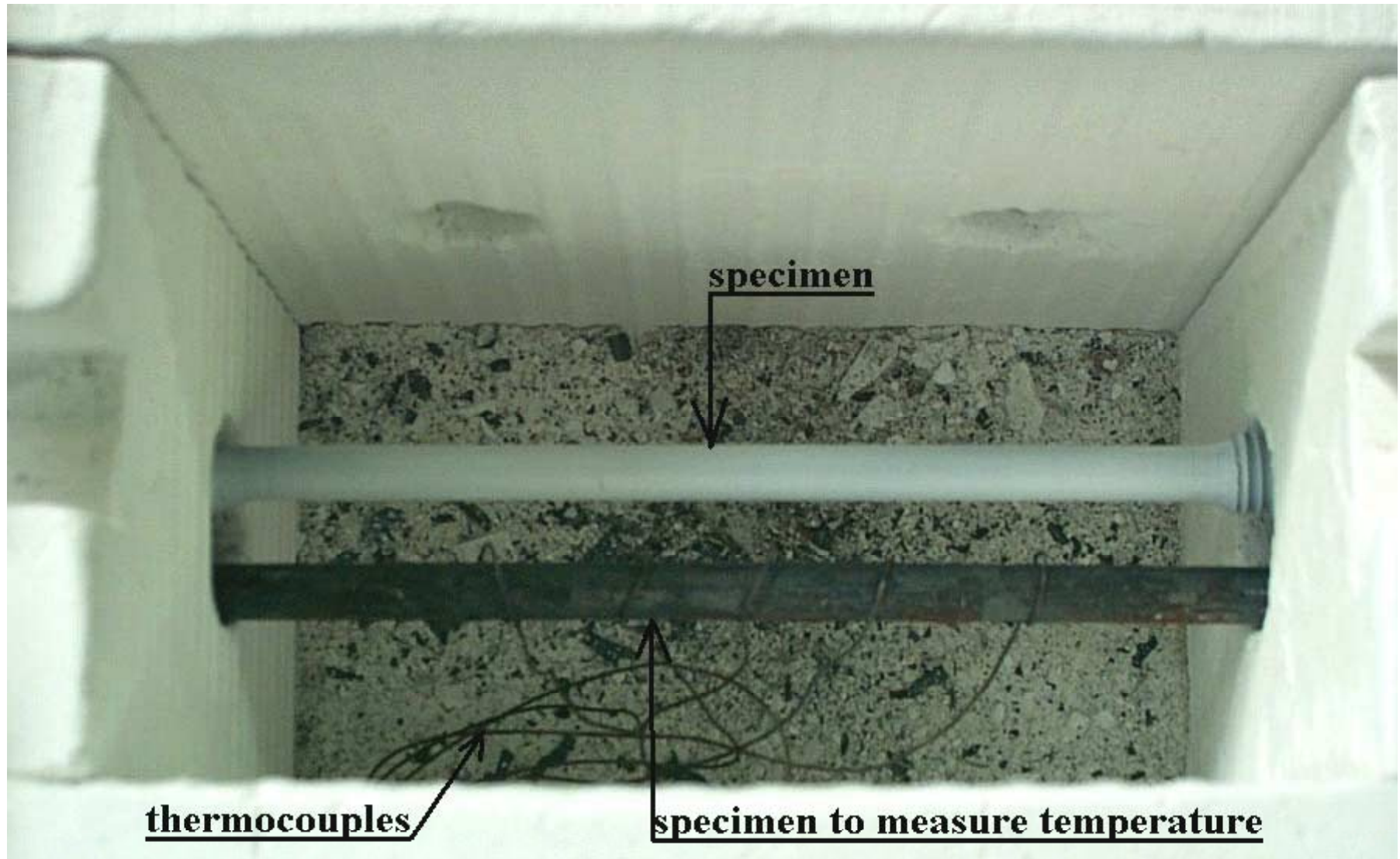
Location of cameras

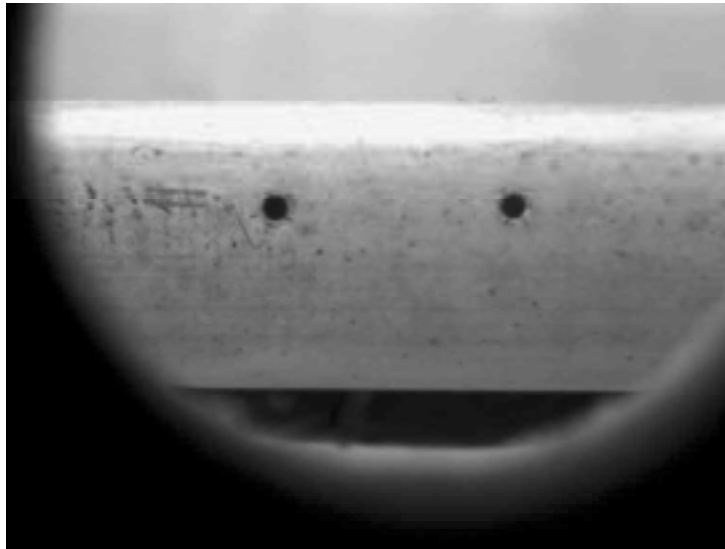
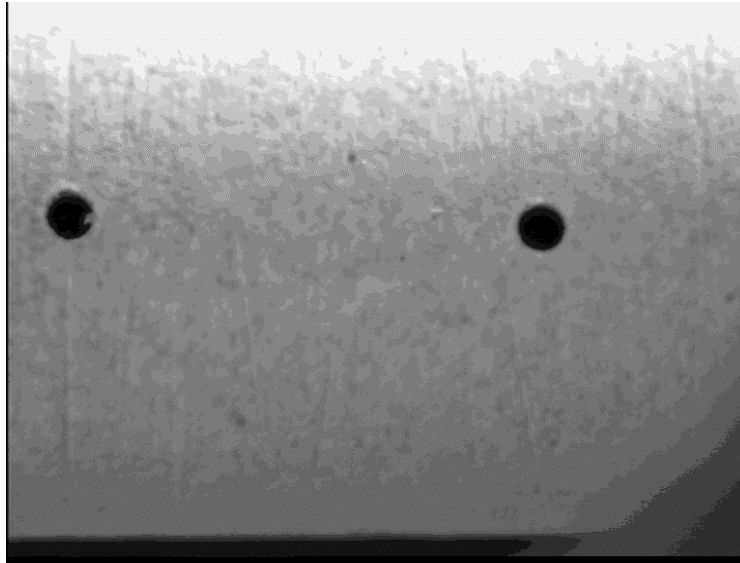


Thermocouples

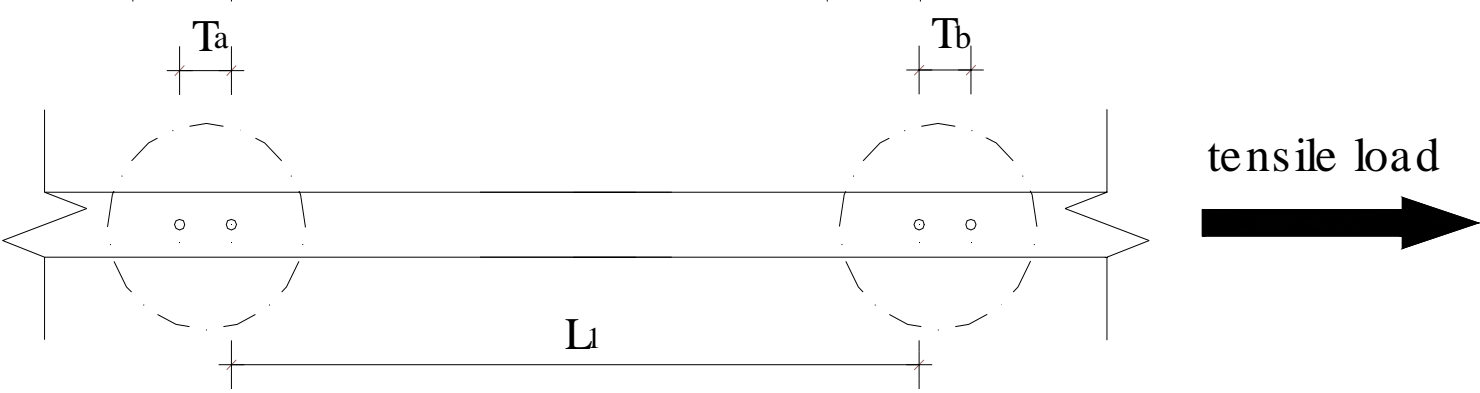
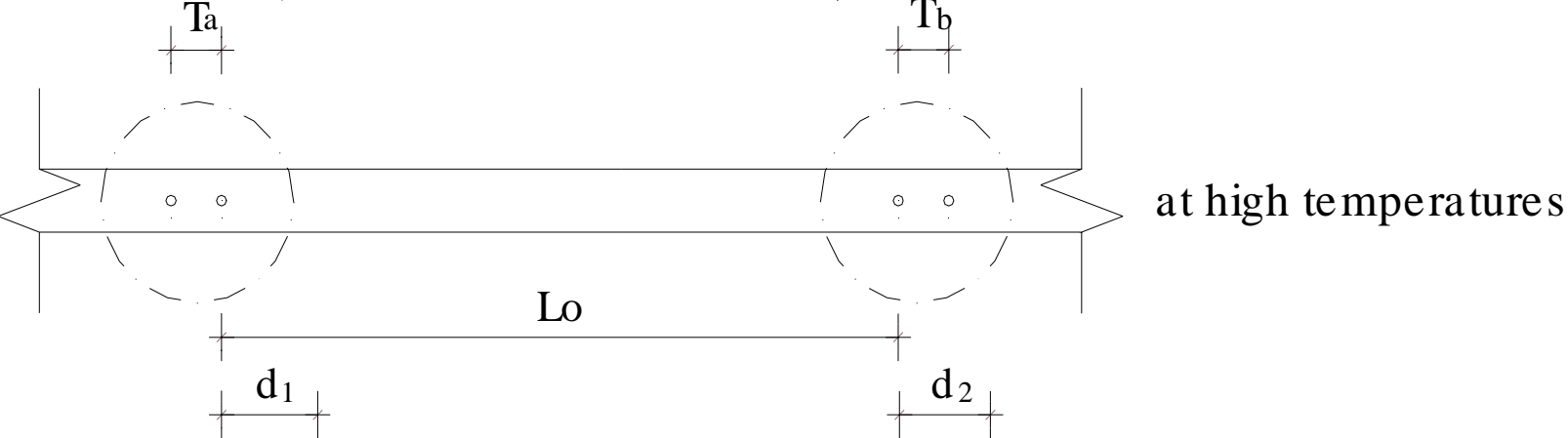
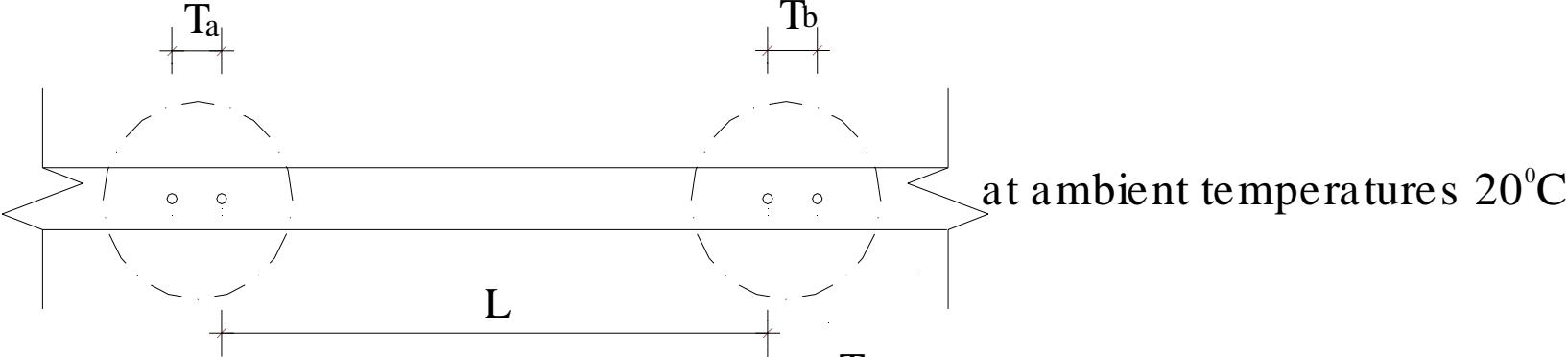


Temperature control specimen

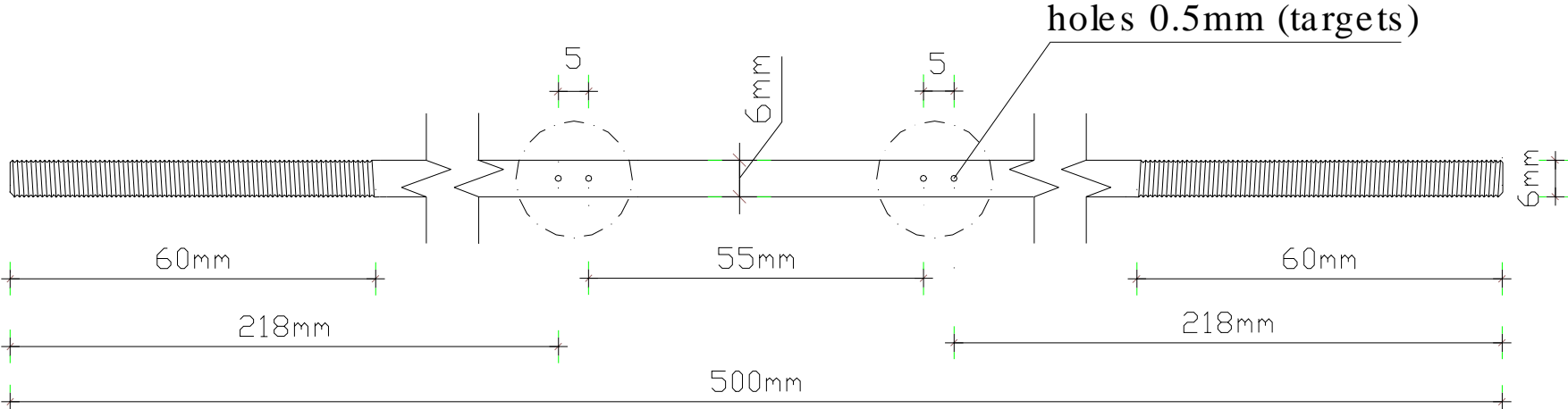




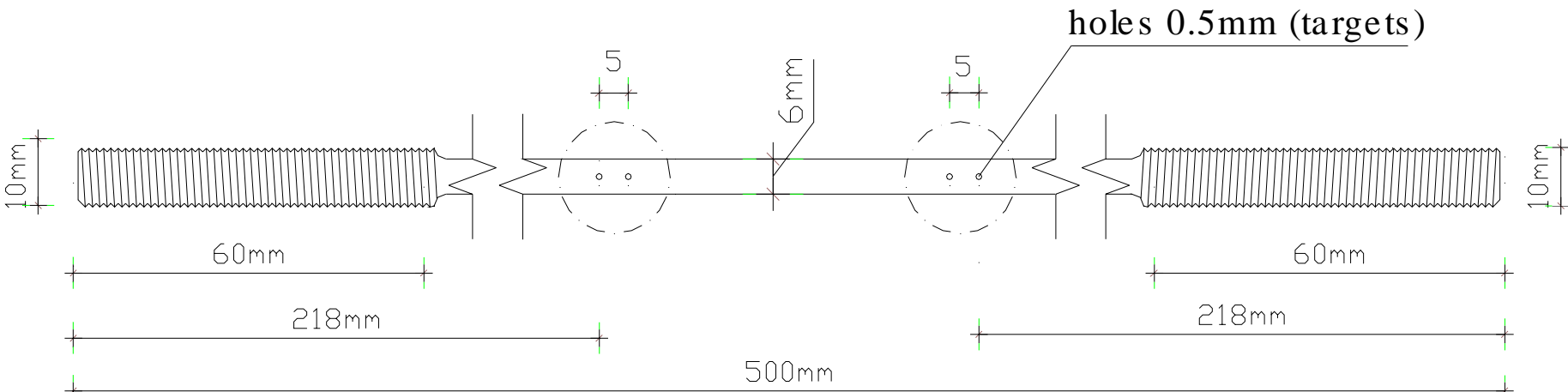
Measuring strain



Specimens

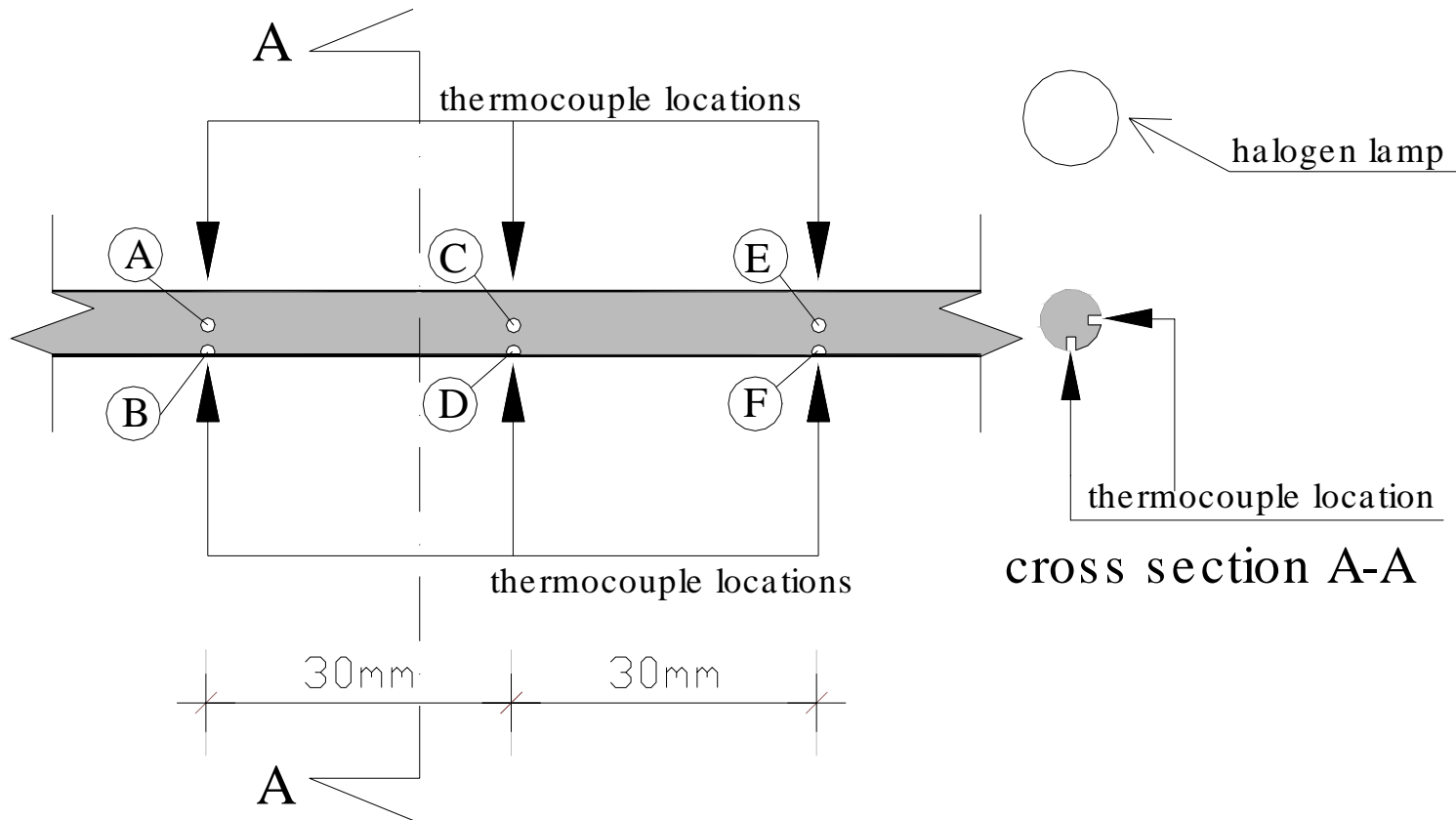


Group A



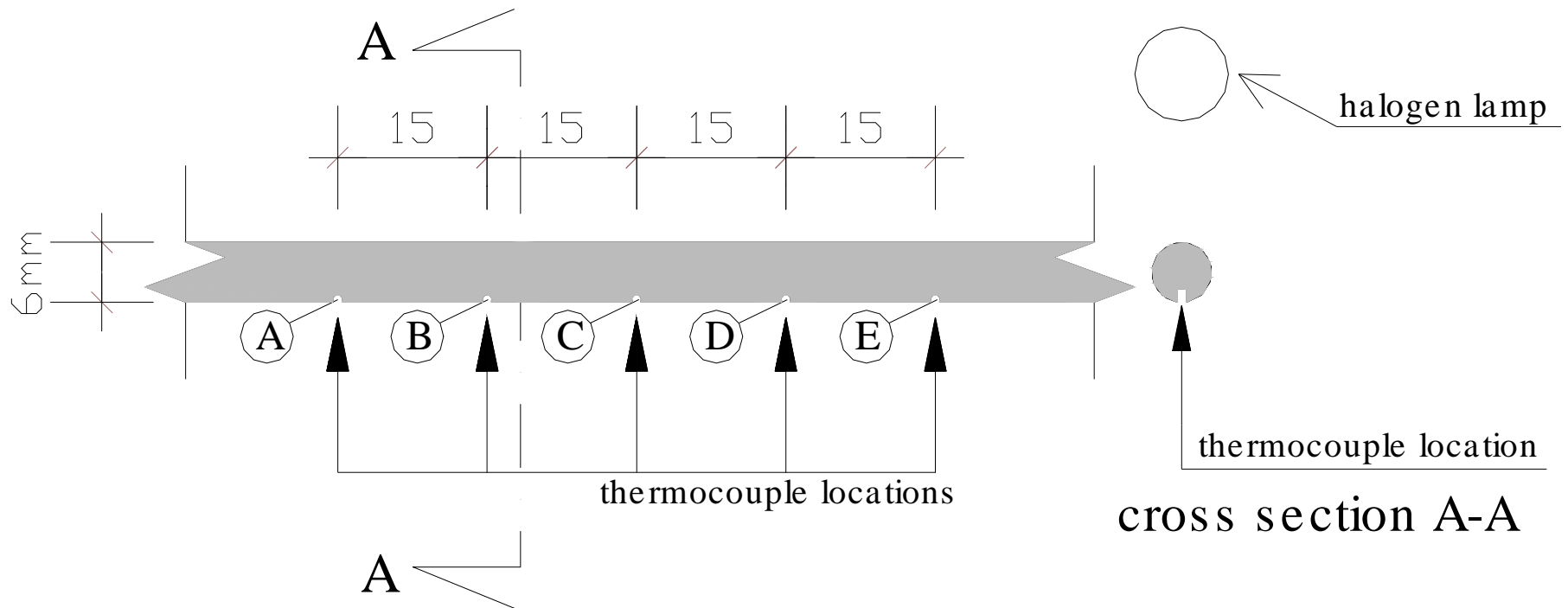
Group B

Pilot test



- ❑ Little difference between side and bottom
- ❑ As much as 30C along length

Thermocouple arrangement



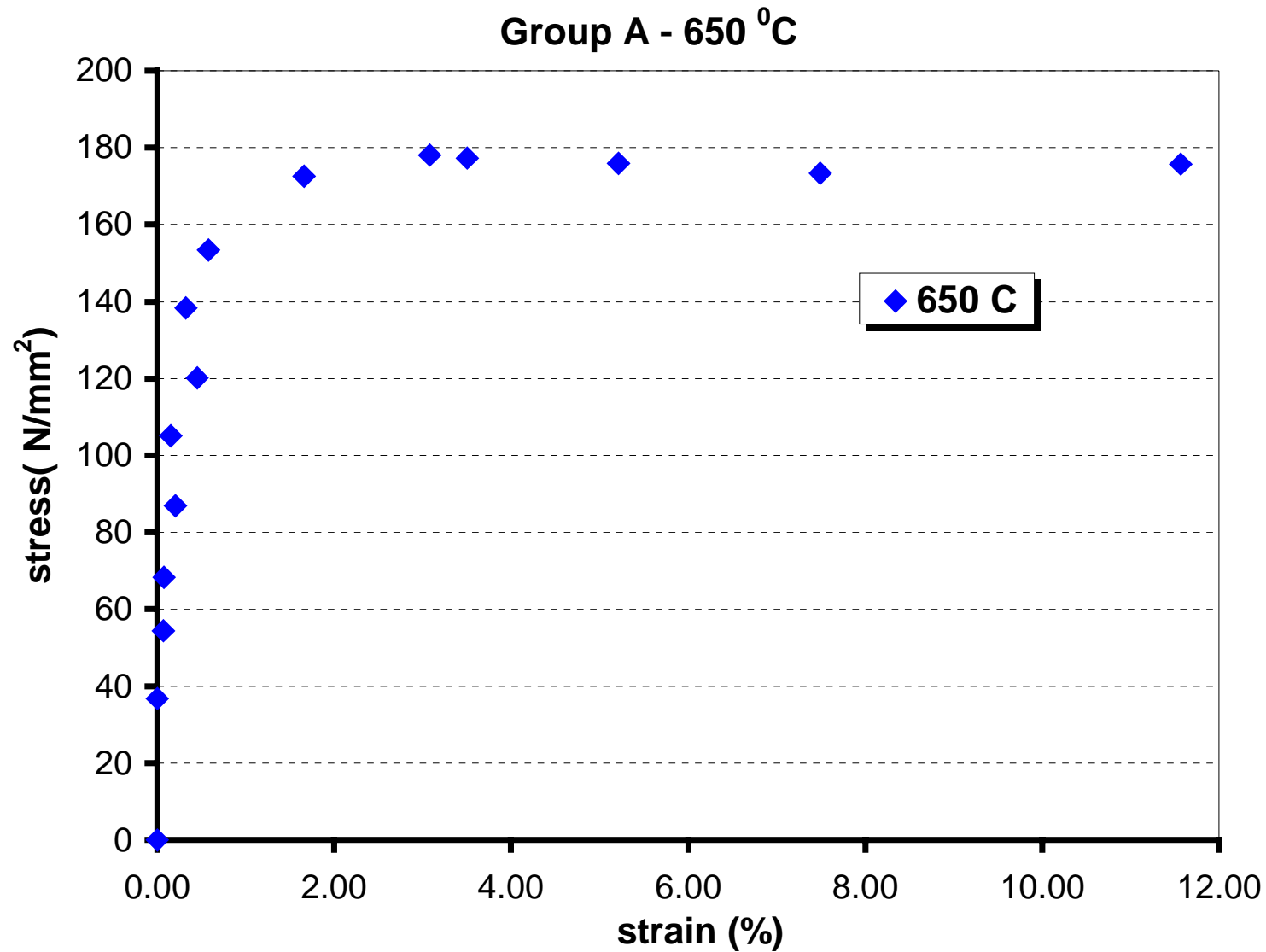
❑ C hottest

❑ Average value used to present results

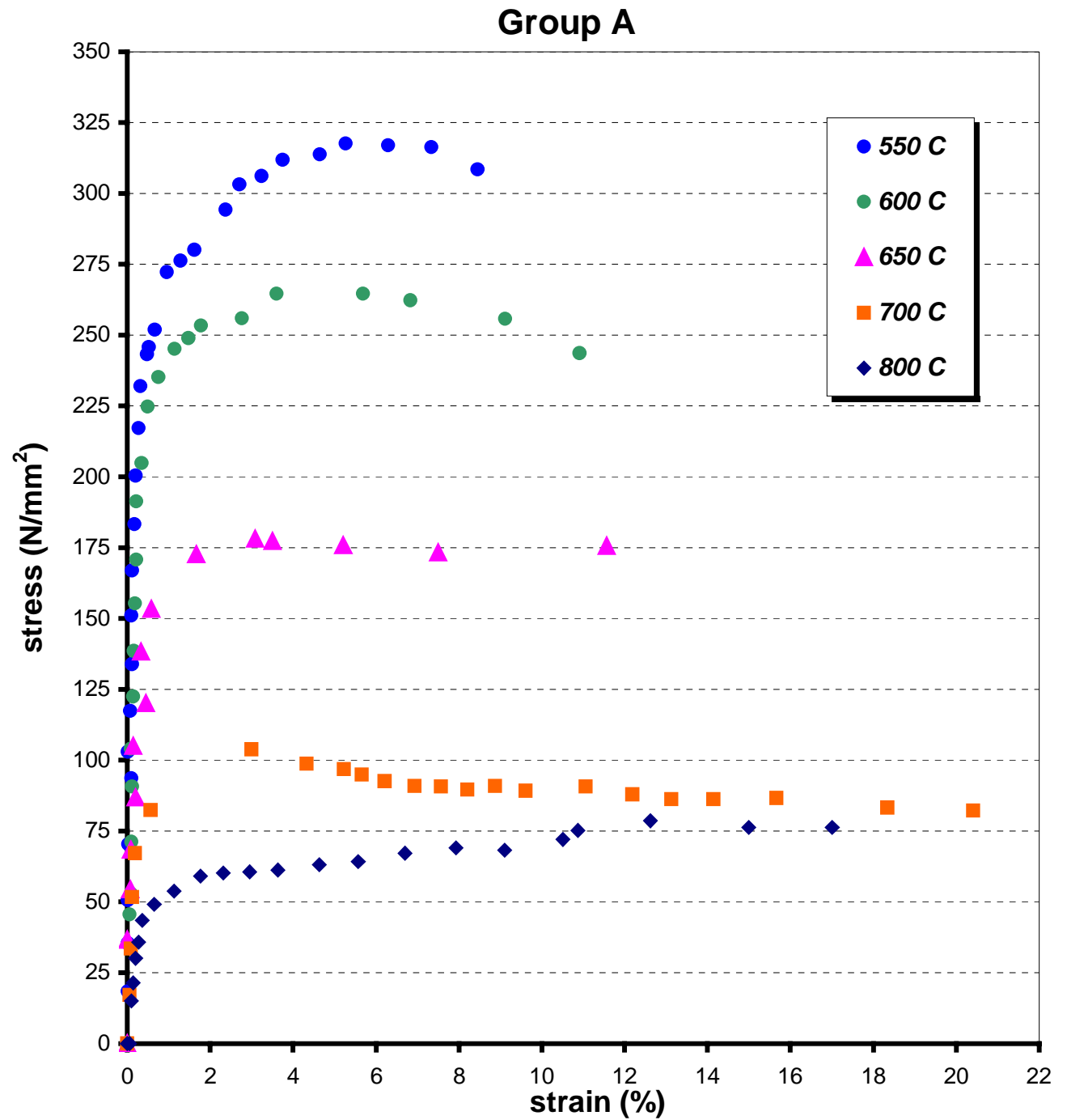
Range of temperatures recorded

Test	A	B	C	D	E	Ave.
550 °C	536	555	563	555	337	549
600 °C	582	605	613	606	582	598
650 °C	633	658	663	656	632	649
700 °C	684	711	715	710	686	701
800 °C	787	807	812	807	786	800

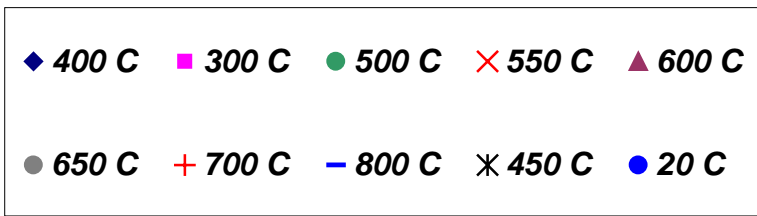
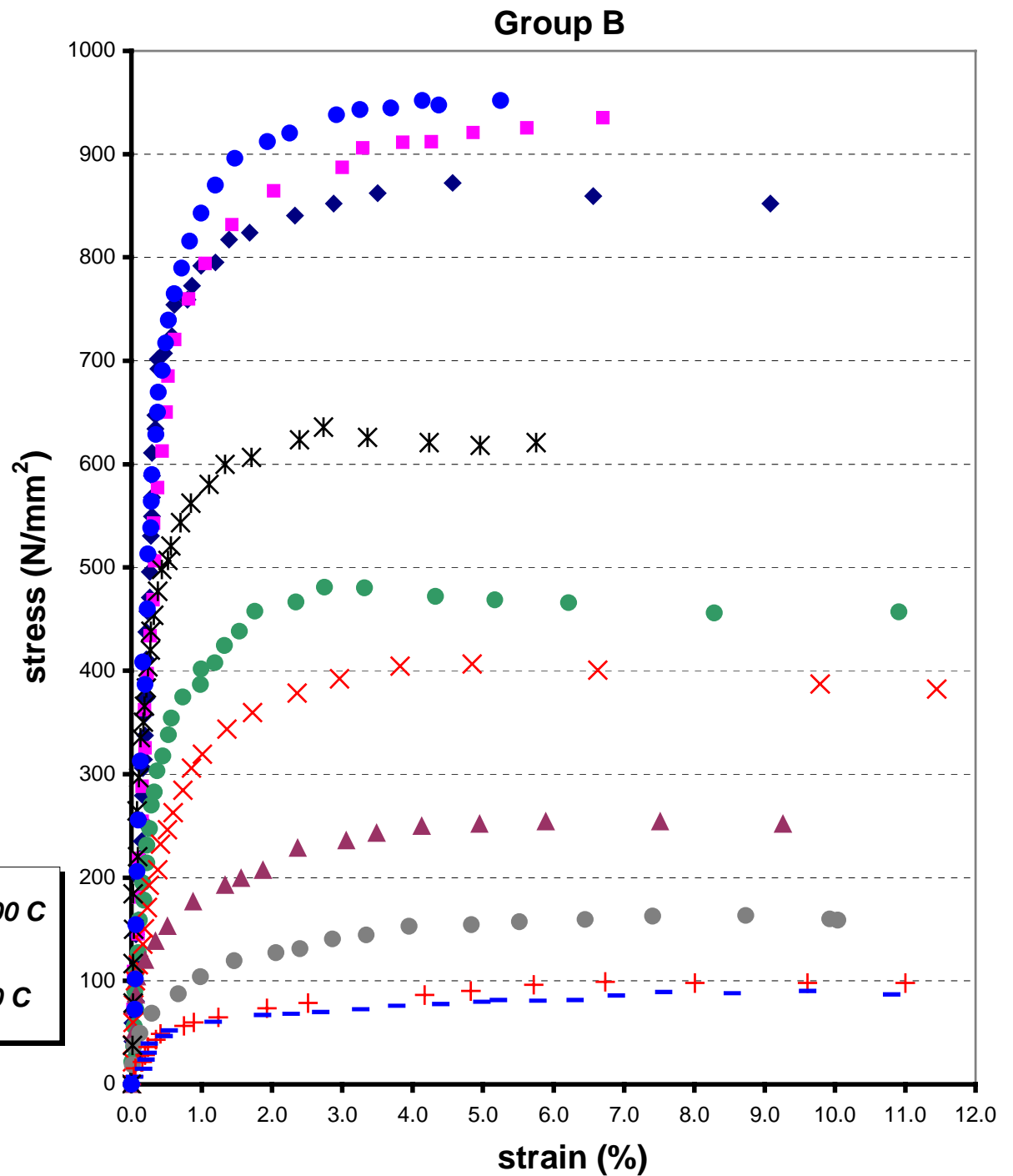
Variation of stress-strain relationship at 650 °C



Summary Group A

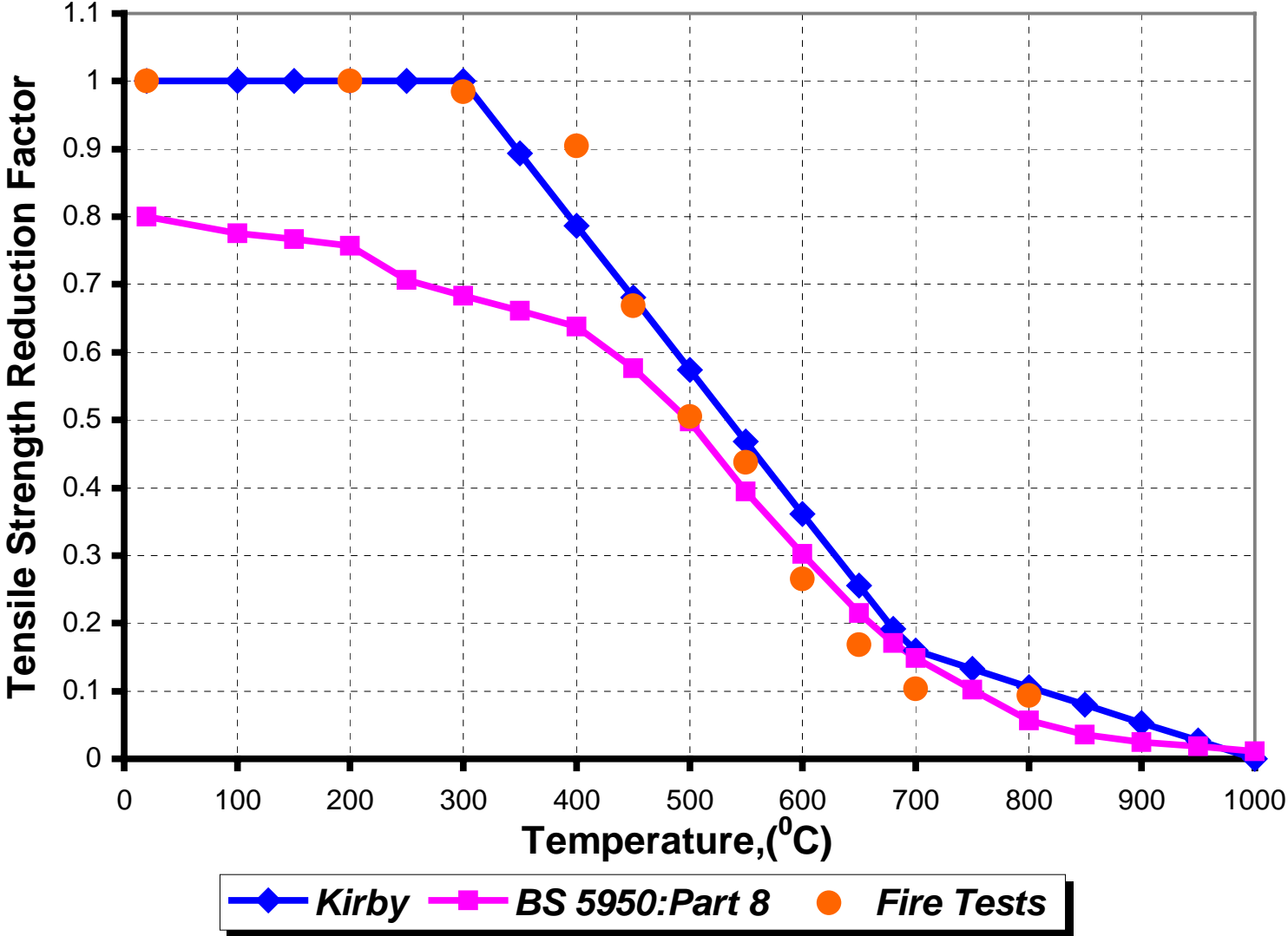


Summary Group B

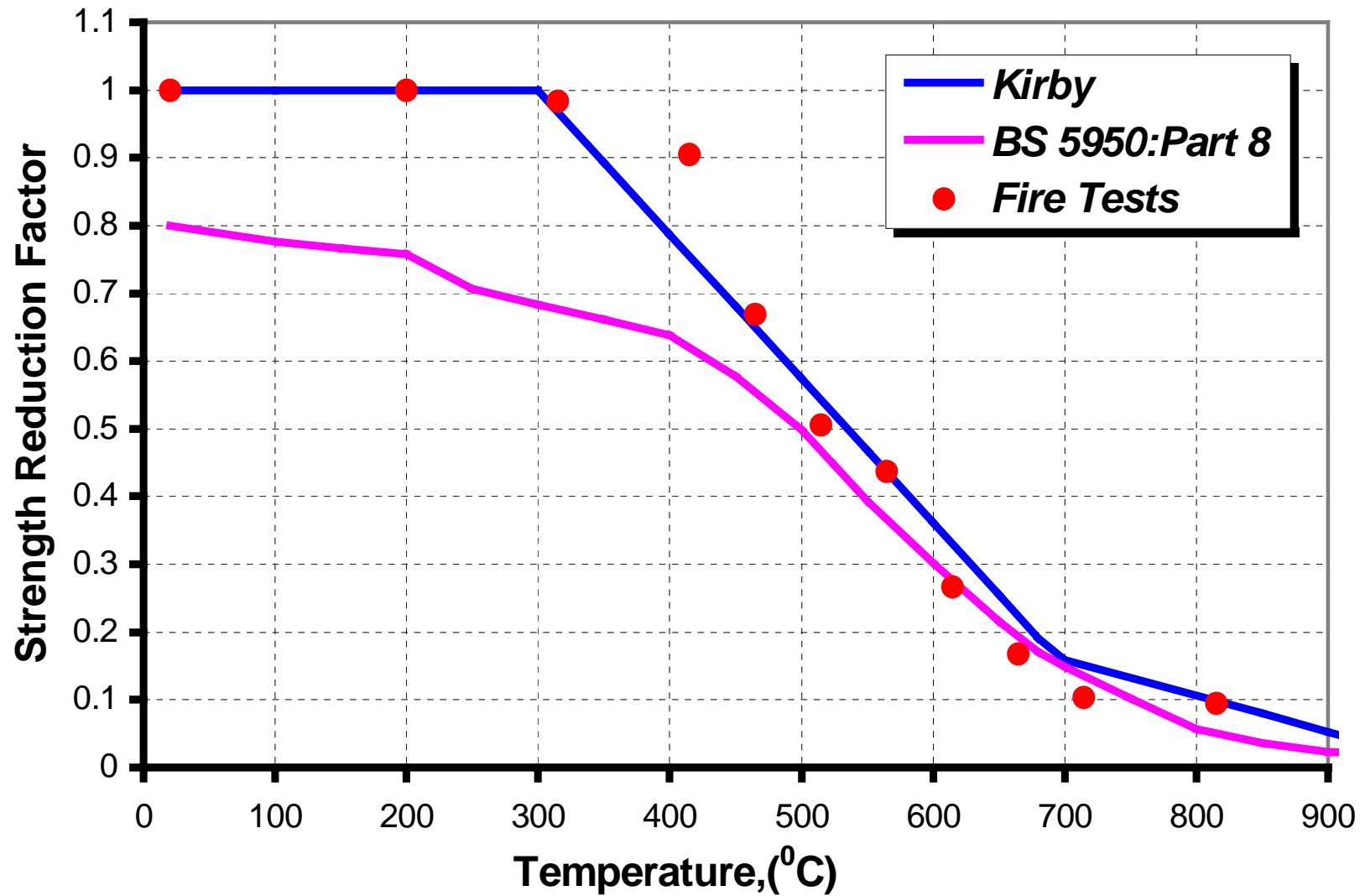




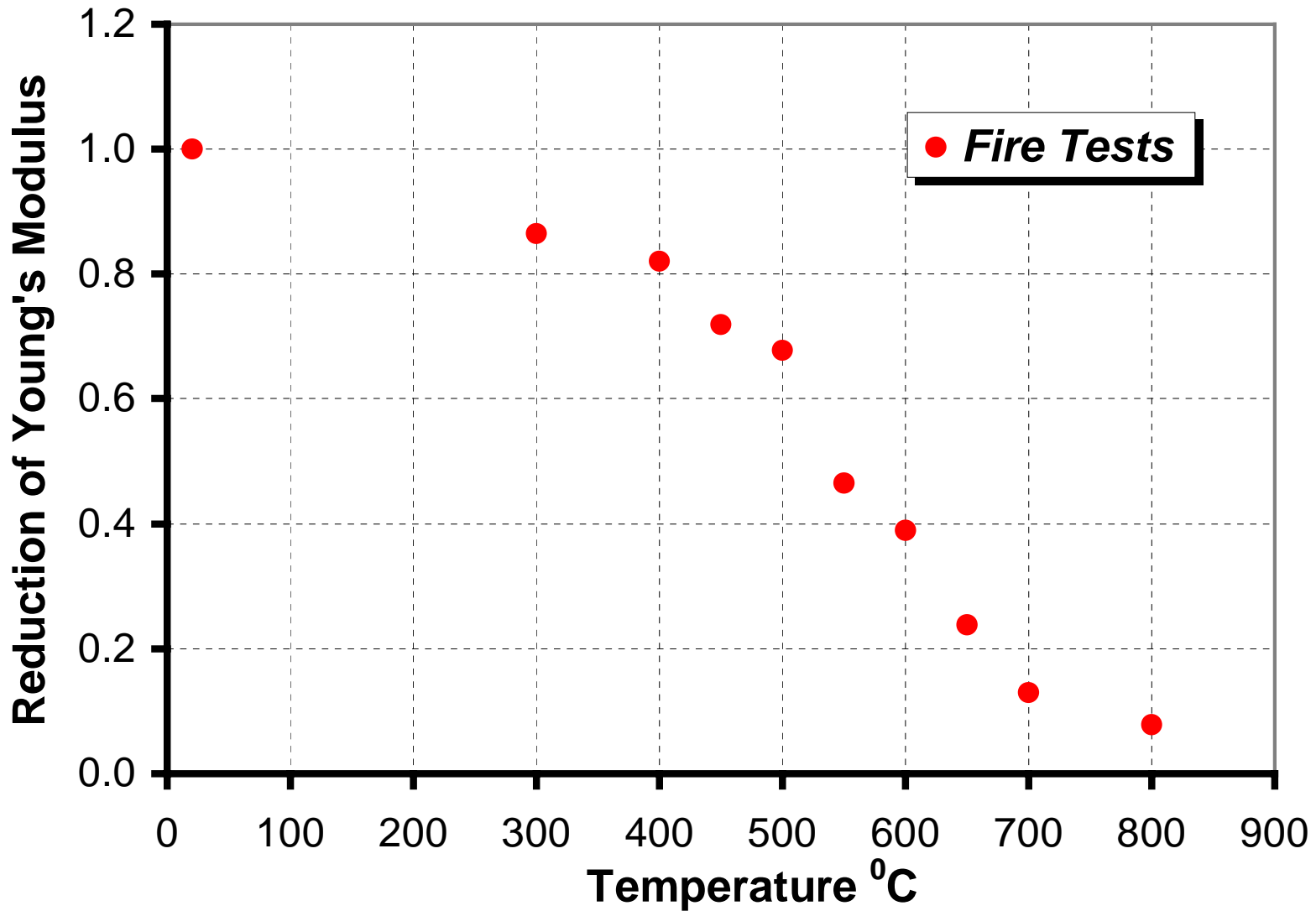
Comparison – tests, Kirby, BS5950



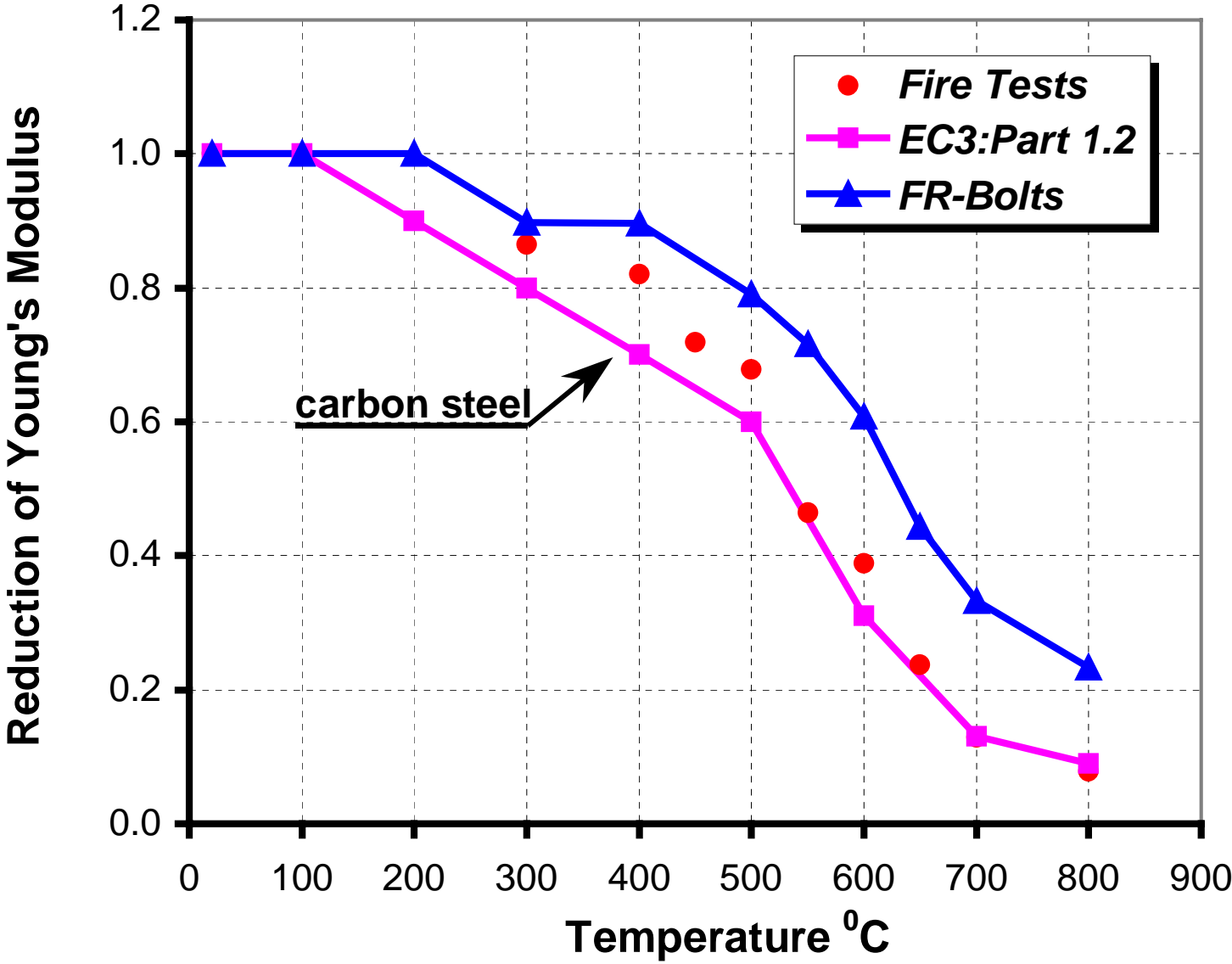
Comparison: temp + 15C



Variation of Young's Modulus with temperature



Comparison of variation of E with EC3





800 C

700 C

650 C

600 C

550 C

500 C

450 C

400 C

300 C

20 C

Conclusions

- ❑ Halogen furnace worked well
- ❑ Cameras reasonably accurate for strain measured
- ❑ Temperature variation along bolt length not ideal
- ❑ Strength reduction
 - BS5950 conservative
 - Kirby recommendations verified
- ❑ Stiffness reduction
 - EC3 Part 1.2 formula for structural steel applicable to bolts