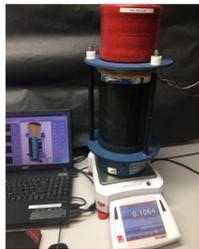


Introduction to the Macroflash

- The next generation of advanced instrumentation for the measurement of heat transmission through materials developed by NASA is now commercially available.
- Hundreds of materials tested over the last decade not only prove the accuracy of the device but to optimize the testing methodology and the associated software.
- The Macroflash is a flat plate boiloff calorimeter that provides effective thermal conductivity (k_e) data for a wide range of materials from thermal insulation to structural composites to ceramics.

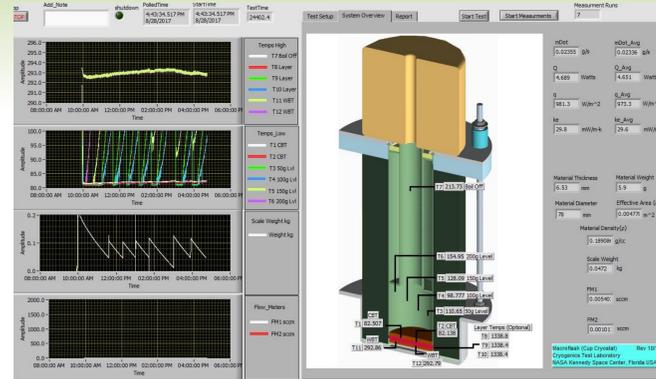
KEY BENEFITS:

1. Provides outstanding thermal conductivity data for below-ambient temperatures and under more realistic conditions (large ΔT)
2. Multiple tests can be completed in one day
3. Convenient size for test specimens (solids, foams, or powders)
4. Simple training; easy to use
5. No costly vacuum chamber set up required
6. Cost-effective to own and operate



Methodology

- **Principle of heat flow measurement:** boiloff calorimetry (ASTM C1774, Annex A4).
- **Test specimen:** single material or specialized combination of different materials.
- **Thickness:** critical measurement for k_e calculation. Fit-up for good thermal contact is also crucial for rigid materials.
- **Steady-state condition:** between 50 g and 100 g LN₂



Macroflash in operation during cooldown

Multiple data points can be obtained from a single test by using intermediately placed temperature sensors through the thickness of the test specimen. Any two temperatures between 78 K and about 403 K can be set up.

Example Test Data

- **Proven:** 500+ material test specimens to date
- **Comprehensive library:** Calibrated material data included with each device
- **Specimen material/type:** Non-isotropic, layered, asymmetrical, inhomogeneous types are acceptable; solids or powders; foams, aerogels, wood, metals, ceramics, glass, composites

Test Series	Matl Code	Test Specimen Description Material Type	Manufacturer	Test Runs	Density g/cm ³	Load psi	Grease Y or N	Q W	q W/m ²	Std dev	k_e mW/m-K	Cal L, S, H	Comp. Strength	F _{ST}
Z1-155	A	Ultra Low Density (ULD) Aerogel composite	Aspen Aerogels	7	0.118	0	N	4.651	1020	1.0	18.6	L	0.8	365
Z1-149	A	Cryogel x201 #3 (1 Layer)	Aspen Aerogels	5	0.166	0	N	5.970	1309	0.6	12.4	L	1.6	426
Z1-118	A	X-aerogel Yellow Disk GRC (ref. Z315)	GRC	4	0.150	5	N	6.760	1482	0.8	25.0	L	1.6	385
Z1-115	A	X-aerogel EXP Tan Disk #1 (Flexcon)	Blueshift	3	0.148	5	N	7.299	1601	0.5	28.1	L	1.6	385
Z1-094a	A	Primaloft Thin Aerogel	Primaloft	4	0.247	2	N	4.933	1082	0.4	12.8	L	1.72	799
Z1-158b	B	Glass Bubbles, nominal tap density	3M	5	0.073	0	N	7.070	1550	0.1	29.7	L		
Z1-021	B	Perlite Powder		5	0.080	0	N	7.622	1671	0.1	33.4	L		
Z1-039	B	JSC Mars 1A regolith	JSC	4	0.783	2	N	15.411	3379	0.1	125	S		
Z1-188a	C	Ultem 2300 #1 (after sanding flat)	Sabic	7	1.507	5	Y	25.591	5612	0.4	225	S		
Z1-162e	C	G-10 CR composite (cal)		7	1.939	5	Y	47.959	10516	0.4	464	S		
Z1-017	C	G-10CR (warp direction)		7	1.929	5	Y	47.550	10492	0.2	624	S		
Z1-130	E	DGEBF-005 #8 Epoxy Resin	South Dakota	7	1.256	5	Y	20.117	4411	0.8	187	S		
Z1-095	E	Epon862-04 (ref. Z325)	South Dakota	6	1.260	5	Y	22.666	4970	0.8	232	S		
Z1-157a	F	FoamGlass #3	Pittsburgh Corning	6	0.118	5	N	7.455	1635	0.4	32.3	L	0.8	210
Z1-153	F	Polyimide Foam Solimide AC-550	Evonik	5	0.008	0	N	8.119	1780	0.4	36.6	L	0.01	34
Z1-150a	F	SOH BX-265 #2	NCH	3	0.037	2	N	5.916	1297	0.2	22.6	L	0.4	483
Z1-129	F	Rohacell WF-300 stack #3/#4	Evonik	4	0.319	2	N	8.592	1884	0.3	42.4	L	17.8	1317
Z1-125	F	Divinycell Foam H45 #5	Evonik	4	0.051	2	N	6.024	1321	0.1	23.9	L	0.6	493
Z1-018	F	Ceriflex-25 Extruded Polystyrene	Diversifoam	4	0.032	2	N	5.630	1232	0.1	22.0	L	0.3	392
Z1-177	G	Plain Glass Sample #3		7	2.475	5	N	57.696	12652	0.5	872	S	50	23
Z1-120	L	Cabot Corp. Thermal Wrap	Cabot	5	0.074	2	N	5.604	1229	0.2	16.3	L		
Z1-032	L	Reflectix R5B3 Single Bubble	Reflectix	5	0.066	0	N	8.026	1760	0.1	33.3	L		
Z1-145	P	Aerogastic Versify Sample-A 22-stack	KSC	5	0.896	5	Y	18.883	4141	0.2	153	S		
Z1-015	P	Ultem PEI #1 (w/ grease)	Sabic	7	1.027	5	Y	18.889	4142	0.4	157	S		
Z1-002	P	Teflon TFE	DuPont	7	2.120	5	Y	28.375	6222	0.2	253	S	24	45
Z1-151	W	Balsa (in-plane) 7.3mm		5	0.166	5	N	8.264	1812	0.6	46.0	L	7	916
Z1-020	W	Balsa Wood (with the grain; warp direction)		4	0.160	5	N	15.548	3409	0.4	133	S	7	328
Z1-014	X	Pine Wood #1		4	0.515	5	N	15.695	3442	0.0	128	S	7	106
Z1-182	X	Ceramic resin post-fire (U Mich)	Formlabs	7	1.412	5	Y	79.335	17397	0.0	370	S	72.2	138

Thermophysical data for structural-thermal materials

Material	σ MPa	ρ kg/m ³	k_e mW/m ² -K	F_{ST} K-m ² /g
G-10 (transverse direction)	448	1.939	467	495
Ultem™ 2300 Glass Filled PEI	221	1.500	212	695
Ultem™ 9185 PEI (3-D printed)	100	1.199	145	575
Teflon™ PTFE	24.1	2.120	253	45
Rohacell™ WF-300 PMI foam (14 kPa)	17.8	324	42.1	1,305
Balsa Wood (transverse direction)	7.0	166	45.9	919
Aerogel™ polyimide aerogel	1.6	150	28.1	380
Foamglas™ Cellular Glass Foam	0.8	118	32.3	210
Divinycell™ H45 PVC Foam (14 kPa)	0.6	50	23.8	504
Spray Foam Polyio BX-265 (14 kPa)	0.4	37	22.6	483

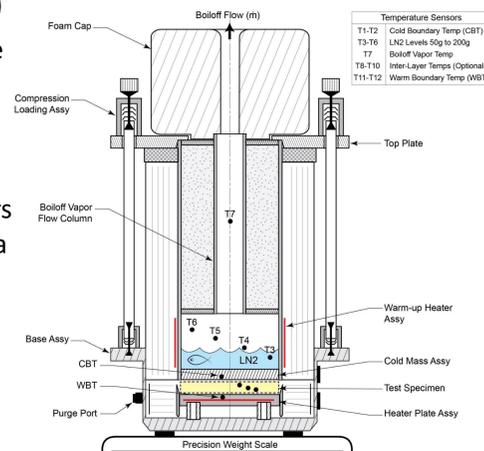
Boundary temperatures 293 K / 78 K

Practical, standardized way to measure heat transmission through materials under steady-state conditions at below-ambient temperatures and under different compressive loads.

Design

- **Temperature range:** from 77 K to 403 K
- **Calculation values:** effective thermal conductivity (k_e), heat flux (q), and heat flow rate (Q)
- **Test specimen dimensions:** 76-mm diameter by 6.4-mm thickness (calibration standard)
- Any thickness from 1 mm to 10 mm can be tested for comparative data
- **Compression loading of test specimen:** 0, 2, or 5 psi [standard settings]
- Optional intermediate temperature sensors for calculating thermal conductivity (λ) as a function of mean temperature (T_m)

ASTM C1774, Annex A4
(Flat Plate, Comparative)



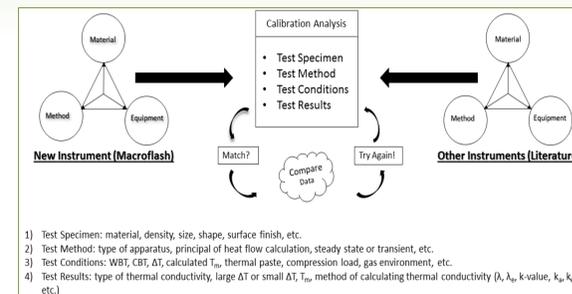
Structural-Thermal Figure-of-Merit (F_{ST}) where:
 σ = compressive strength [MPa]
 k_e = effective thermal conductivity [mW/mK]
 ρ = bulk density [kg/m³]

$$F_{ST} = \frac{\sigma}{\rho k_e} \times 10^6 \left[\frac{K \cdot m \cdot s}{g} \right]$$

Calibration & Analysis

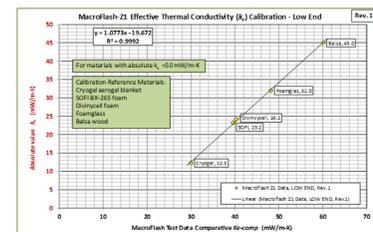
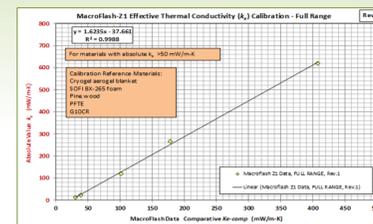
- Total uncertainty in k_e is calculated to be 4.8 % for the Macroflash
- Repeatability between test runs is typically < 1%
- Test specimen compression loading at 0, 2 or 5 psi; with or without thermal grease

Overall repeatability for most test series is demonstrated to be within 0.5%.



- 1) Test Specimen: material, density, size, shape, surface finish, etc.
- 2) Test Method: type of apparatus, principal of heat flow calculation, steady state or transient, etc.
- 3) Test Conditions: WBT, CBT, ΔT , calculated T_m , thermal paste, compression load, gas environment, etc.
- 4) Test Results: type of thermal conductivity, large ΔT or small ΔT , T_m , method of calculating thermal conductivity (k_e , k_a , k_p , k_g , etc.)

$$Q = V_{STP} \Gamma_{STP} h_{fg} \frac{\partial \Gamma_{fg}}{\partial t} \quad k_e = \frac{Qx}{A_e DT} = \frac{4Qx}{pd_e^2 DT} \quad q = \frac{Q}{A_e}$$



Conclusion

- The Macroflash instrument, an easy-to-use flat-plate boiloff calorimeter, has been developed to provide effective thermal conductivity (k_e) data for a wide range of materials from thermal insulation to structural composites.
- The Macroflash follows the guidelines of standard ASTM C1774 (Annex A4), providing a cost-effective, field-representative methodology to test any material for below-ambient temperature applications to moderately elevated temperature conditions.

From engineered materials development, to research testing, to quality control in manufacturing, this standardized device provides utility for the fields of energy, transportation, aerospace, construction, medical, and environment.

