SWIFT 2011 CONFERENCE & TRADE SHOW

DEVELOPING ANTI-ICING AIRFIELD RUNWAYS USING SOLAR ENERGY & CONDUCTIVE CONCRETE

By Ernie Heymsfield, Panneer Selvam, Mark Kuss, and Adam Osweiler

University of Arkansas / Dept. of Civil Engineering

INCIDENTS / ACCIDENTS

- 1958-1993 RUNWAY WATER, ICE, OR SNOW CONTRIBUTED TO 100 AIRPLANE ACCIDENTS
- JAN 1978 – JAN 2009

    100 OVERRUN ACCIDENTS / INCIDENTS @ US RUNWAYS WITH SLUSH, ICE, OR SNOW

OVERRUN TYPE	INCIDENT	ACCIDENT
LANDING	67	21
TAKEOFF	4	8
TOTAL	71	29

SNOW REMOVAL

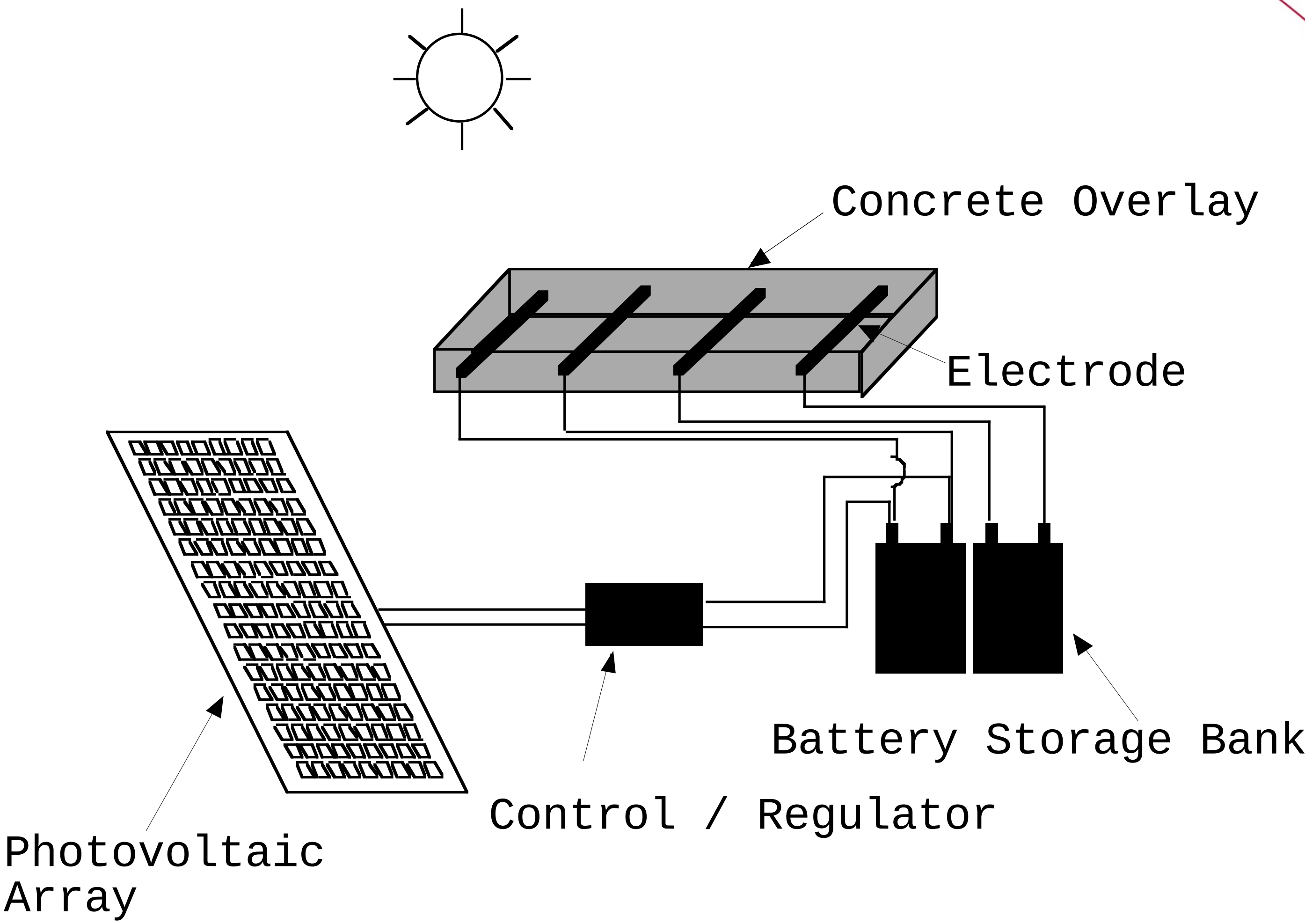
- PLOWING AND CHEMICAL TREATMENT
- EXPENSIVE: $4M BUDGETED FOR AIRSIDE/RUNWAY SNOW REMOVAL AT MSP (Paul Sichko)

OBJECTIVES

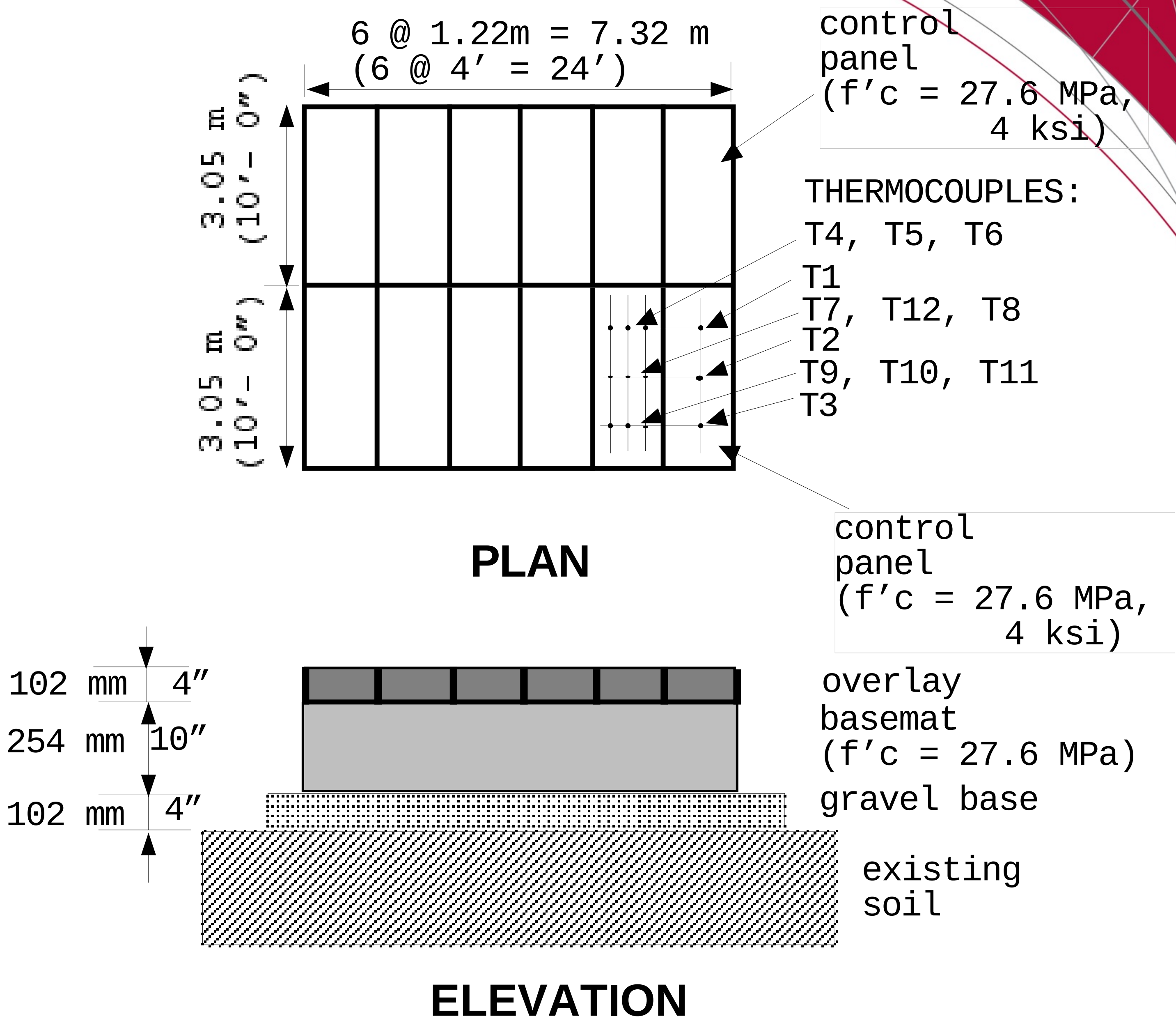
- DEVELOP AN ANTI-ICING RUNWAY PAVEMENT
  - USE SOLAR ENERGY (photovoltaic cells to produce DC current)
  - CONDUCTIVE CONCRETE PAVEMENT
  - CONCRETE AS A HEAT MASS
  - CONTINUALLY KEEP SLAB AT ABOVE FREEZING TEMPERATURE

TEST SETUP

TEST SETUP

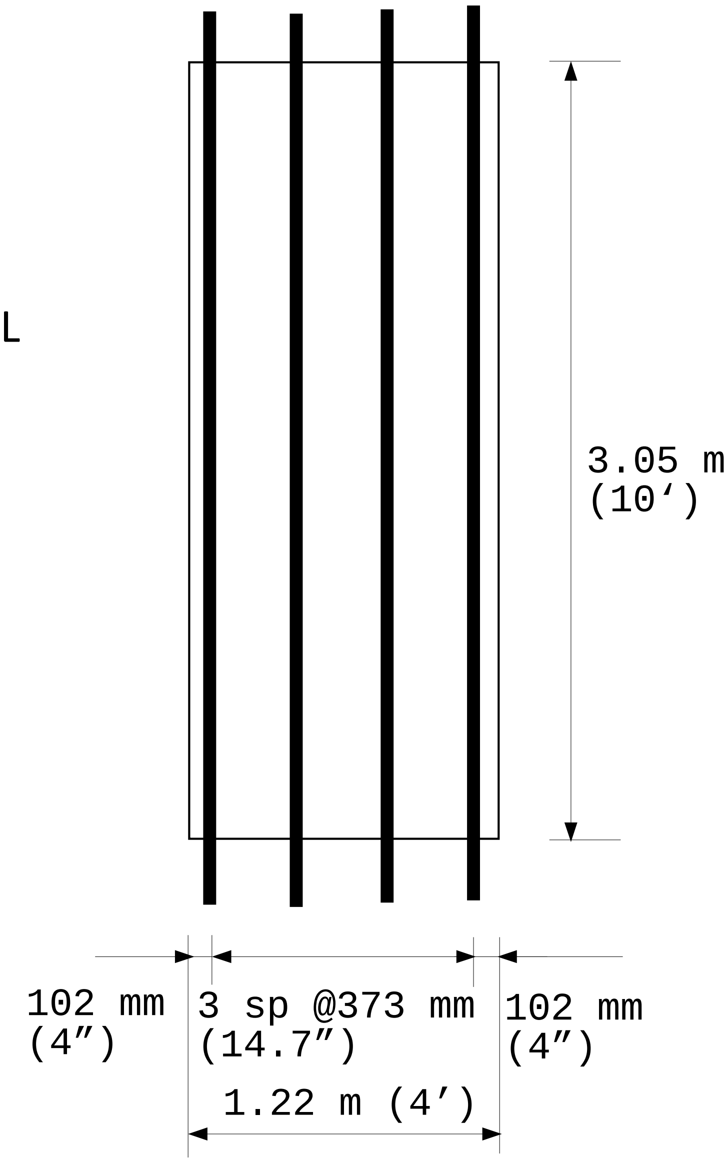

Concrete Overlay
Electrode
Battery Storage Bank
Control / Regulator
Photovoltaic
Array

TEST MAT LAYOUT



ELECTRODE LAYOUT

25 mm (1”) DIAM.
GALVANIZED STEEL
THREADED BARS



TESTING AREA
(19.8m x 19.8m, 65ft x 65ft)

ANTI-ICING SYSTEM

TEST MAT

DAQ SYSTEM

BATTERY STORAGE (4 - 12V)

SOLAR PANELS
(8- 200 Watts)

TESTING AREA

CONDUCTIVE CONCRETE

CONDUCTIVE CONCRETE (CONDUCTIVITY, κ = 1/ELECTRICAL RESIST.)

- ELECTRICAL CONDUCTIVITY & THERMAL CONDUCTIVITY
- NORMAL WEIGHT CONCRETE (6-11 kΩ*m, 236 – 433 kΩ*in)
- CONDUCTIVE CONCRETE (0.00114 kΩ*m, 0.045 kΩ*in)
- κ (cond. conc) = 5260 * κ (normal conc.)
- STRENGTH, CONDUCTIVITY, & WORKABILITY

GOVERNING EQUATIONS

- HEAT CONDUCTION

TEMPERATURE

HEAT GENERATION RATE

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+\frac{\partial Q}{\partial t}-\rho c_p\frac{\partial T}{\partial t}=0$$

THERMAL CONDUC.

SPECIFIC HEAT

- ELECTRIC FIELD

VOLTAGE

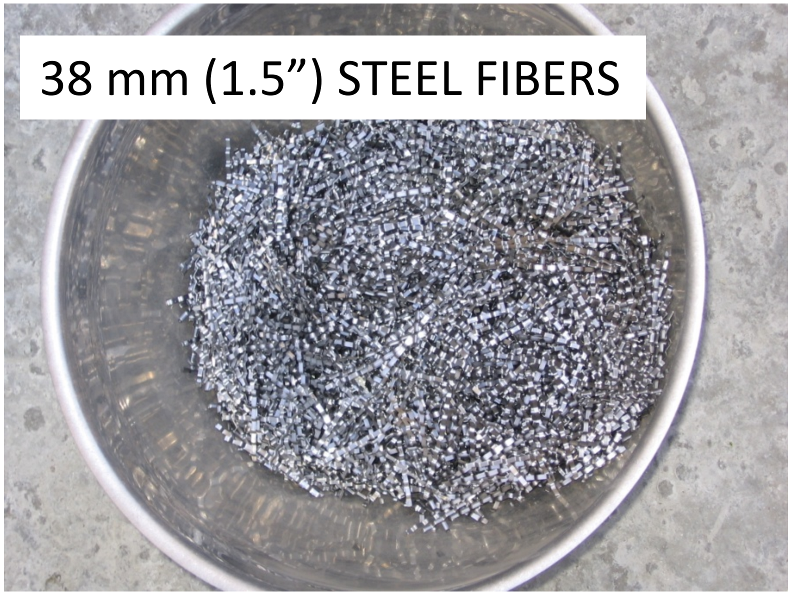
ELEC. CONDUC. = f(T)

$$\frac{\partial}{\partial x}\left(\kappa\frac{\partial V}{\partial x}\right)+\frac{\partial}{\partial y}\left(\kappa\frac{\partial V}{\partial y}\right)+\frac{\partial}{\partial z}\left(\kappa\frac{\partial V}{\partial z}\right)=0$$

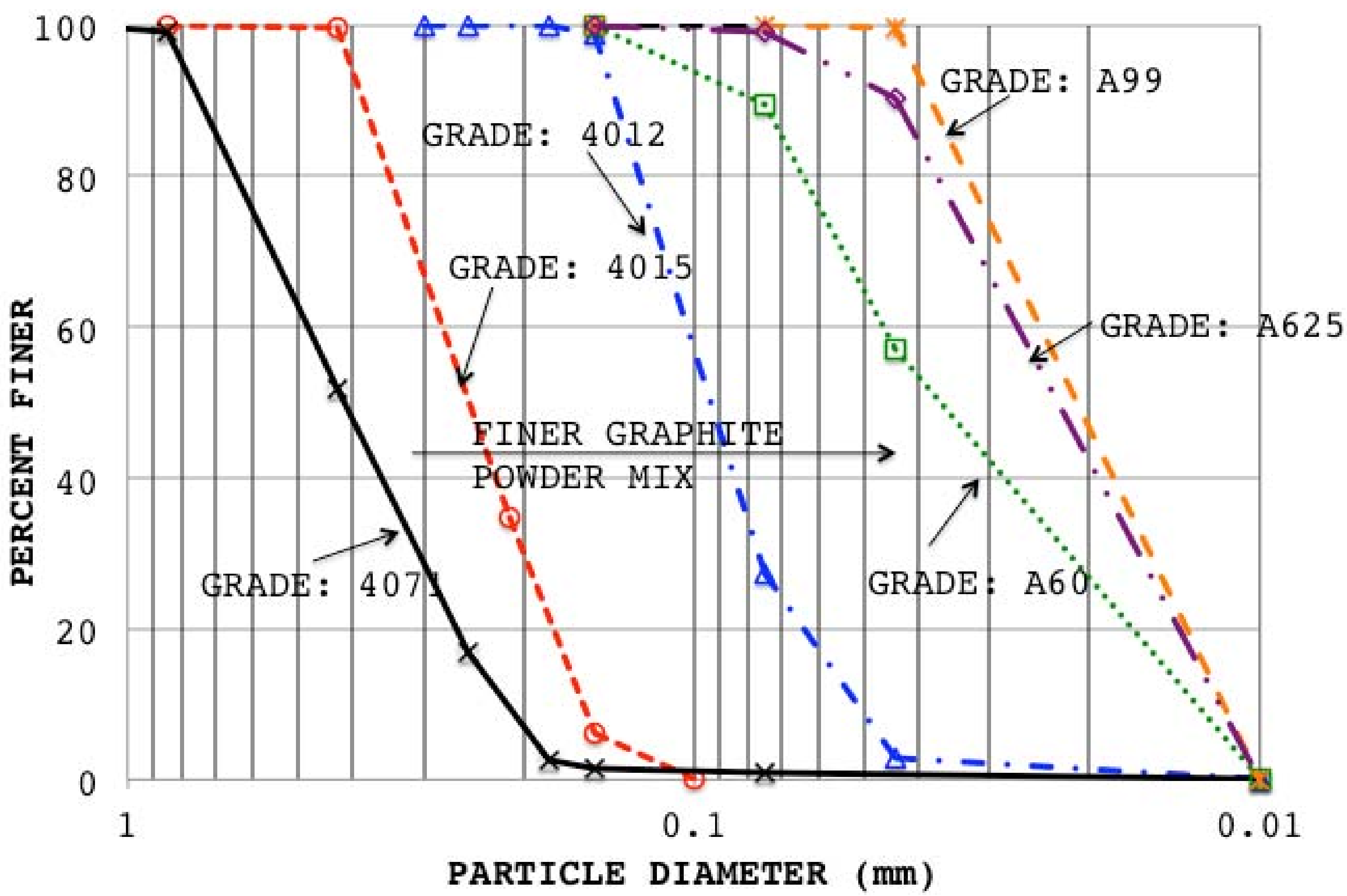
- JOULE HEATING (HEATING AND ELECTRIC FIELD)

$$\kappa\left(\left(\frac{\partial V}{\partial x}\right)^2+\left(\frac{\partial V}{\partial y}\right)^2+\left(\frac{\partial V}{\partial z}\right)^2\right)-\frac{\partial Q}{\partial t}=0$$

COND CONC MATERIALS



GRAPHITE POWDER GRADATION



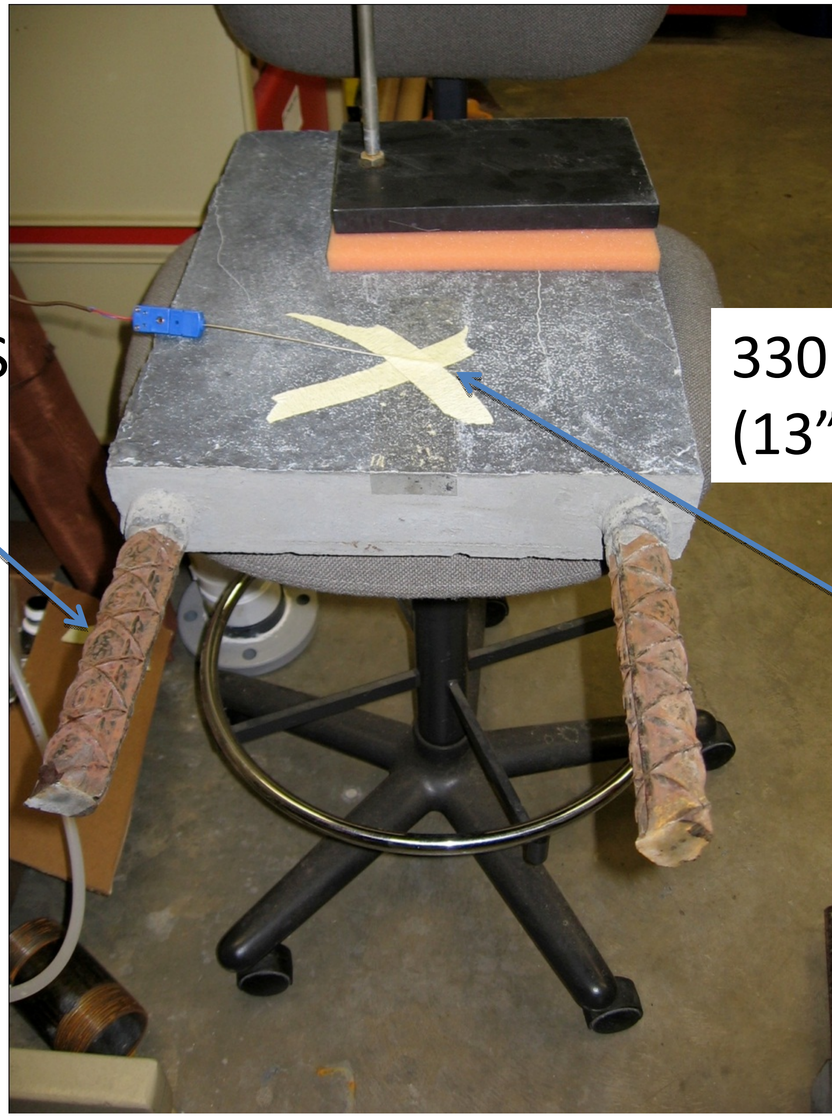
TRIAL MIX BATCH

MIX	GRAPHITE POWDER (%)	GRAPHITE POWDER DESIGNATION	STEEL FIBER 38 mm (1.5") (%)	CEMENT (TYPE 1) (%)	FLY ASH (%)	COARSE AGGREGATE (%)	FINE AGGREGATE (%)	WATER (%)	AIR (%)	w/c
1	24.9	A60,A99,A625	1.5	15.1	5.4	26.6	0.8	23.7	2.0	0.40
2	24.9	A4012	1.5	15.1	5.4	26.6	0.8	23.7	2.0	0.40
3	19.9	A4015	1.5	15.1	5.4	26.6	5.8	23.7	2.0	0.40
4	19.9	A4071	1.5	15.1	5.4	26.6	5.8	23.7	2.0	0.40
5	19.9	A4071	2.5	15.1	5.4	26.6	4.8	23.7	2.0	0.40
6	19.9	A4071	3.5	15.1	5.4	26.6	3.8	23.7	2.0	0.40
7	17.2	A4071	5.0	15.1	5.4	26.6	5.0	23.7	2.0	0.40
8	17.2	A4071	2.7	15.1	5.4	26.6	7.2	23.7	2.0	0.40
9 BFS	7.2	A4071	2.7	11.9	0.0	36.1	21.4	18.7	2.0	0.35
10 BFS	17.2	A4071	2.7	18.8	0.0	31.0	4.5	23.7	2.0	0.40
11	17.2	A4071	2.7	15.1	5.4	26.6	7.2	23.7	2.0	0.40

MIX	UnWt (pcf)	UnWt (kN/m^3)	f'c (ksi) 28 day	f'c (MPa) 28 day	El. Resistivity (ohm-in) 28 day	El. Resistivity (ohm-cm) 28 day
1	137.1	21.6	2.75	18.95		
2	137.1	21.6	3.10	21.36		
3	138.3	21.7	4.15	28.59		
4	138.3	21.7	5.60	38.58		
5	137.4	21.6	5.10	35.14		
6	136.4	21.4	na	na		
7	135.6	21.3	na	na		
8	137.8	21.7	5.85	40.31	253	643
9 BFS	133.8	21.0	4.80	33.07	1778	4516
10 BFS	129.6	20.4	5.70	39.27	711	1806
11	137.8	21.7	6.15	42.37	156	396

HEAT RATE TESTING

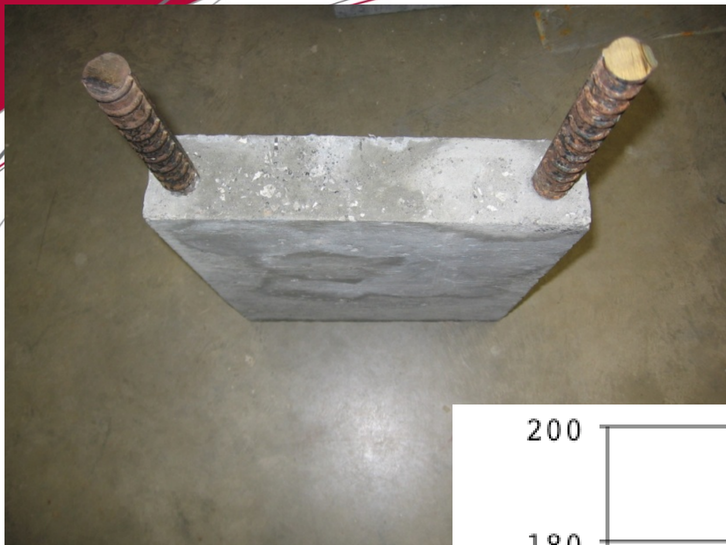
#10 REINF. BARS
(32 mm)

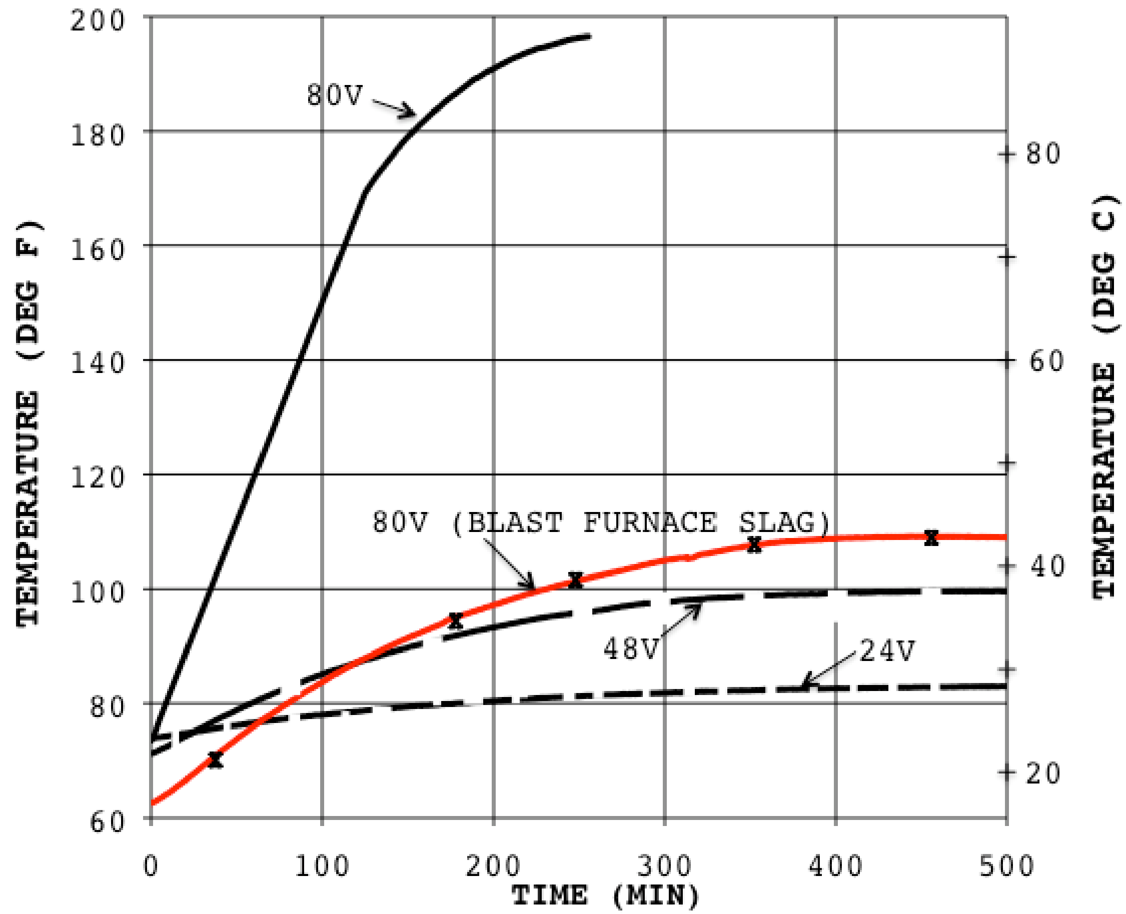


330 mm x 457 mm x 64 mm
(13” x 18” x 2.5”)

THERMOCOUPLE

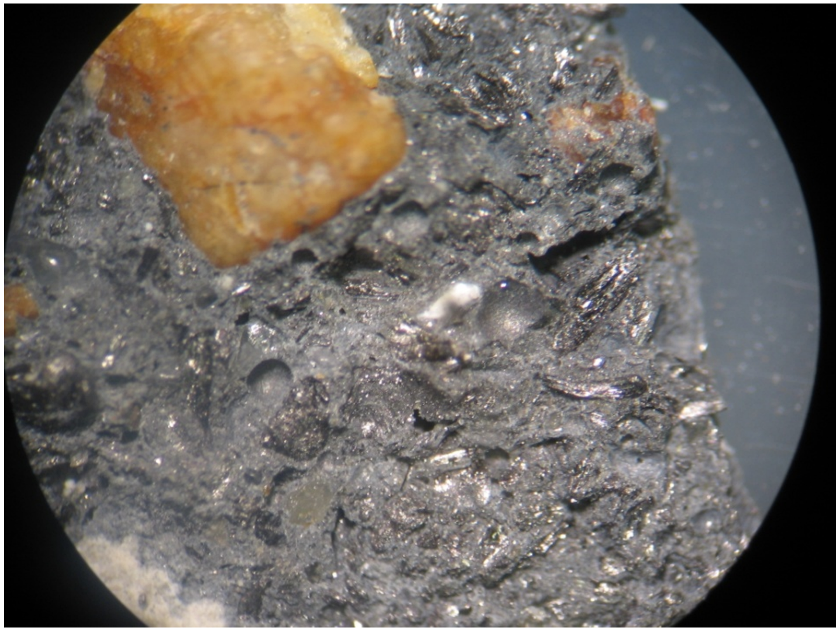
TEMPERATURE GRADIENT



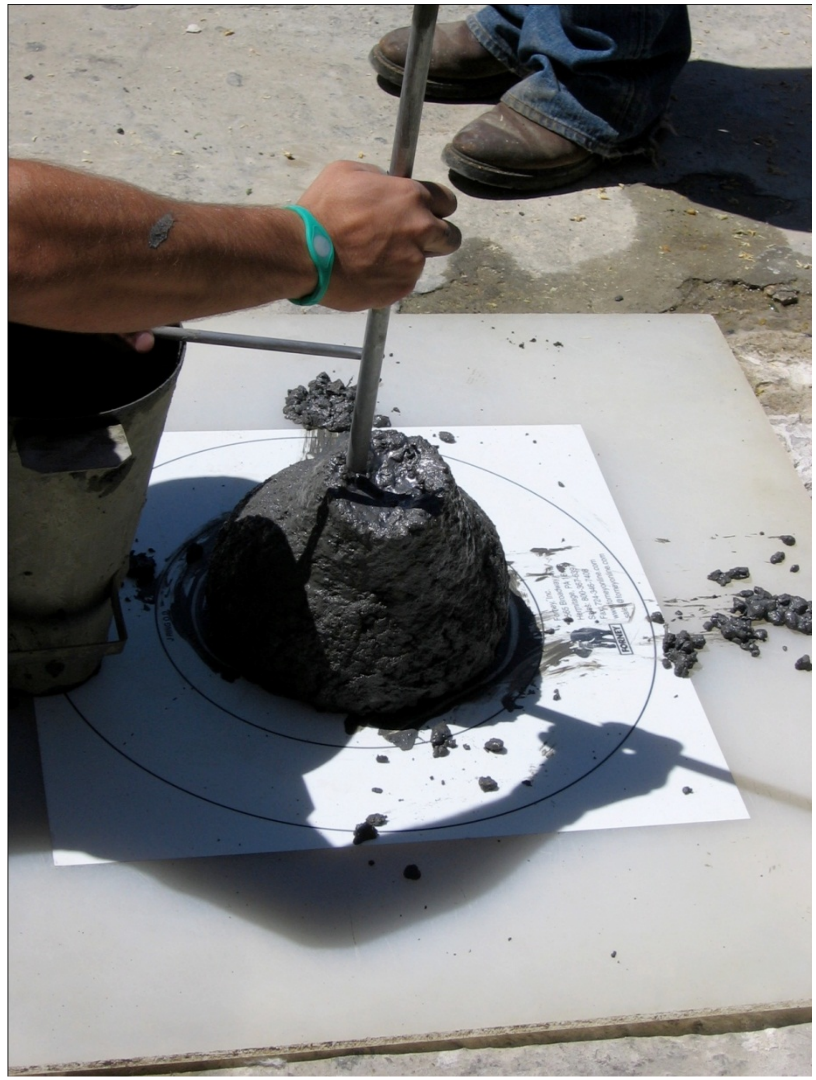


CONDUCTIVE CONC. CYLINDER

CONDUCTIVE CONC. CYLINDER



WORKABILITY (SLUMP TEST)

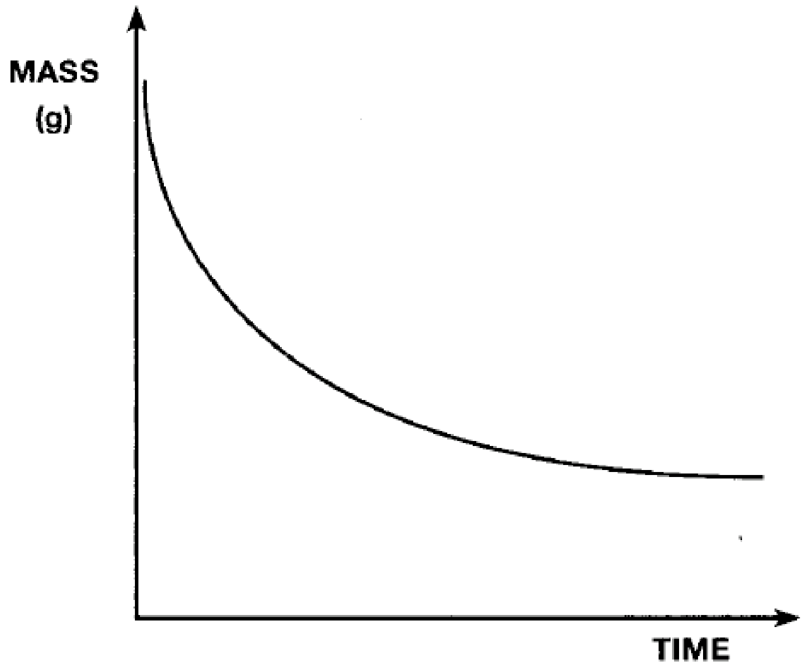


140 mm
(5.5in)

WORKABILITY

OVERLAY MAT TESTING (48 VOLTS)

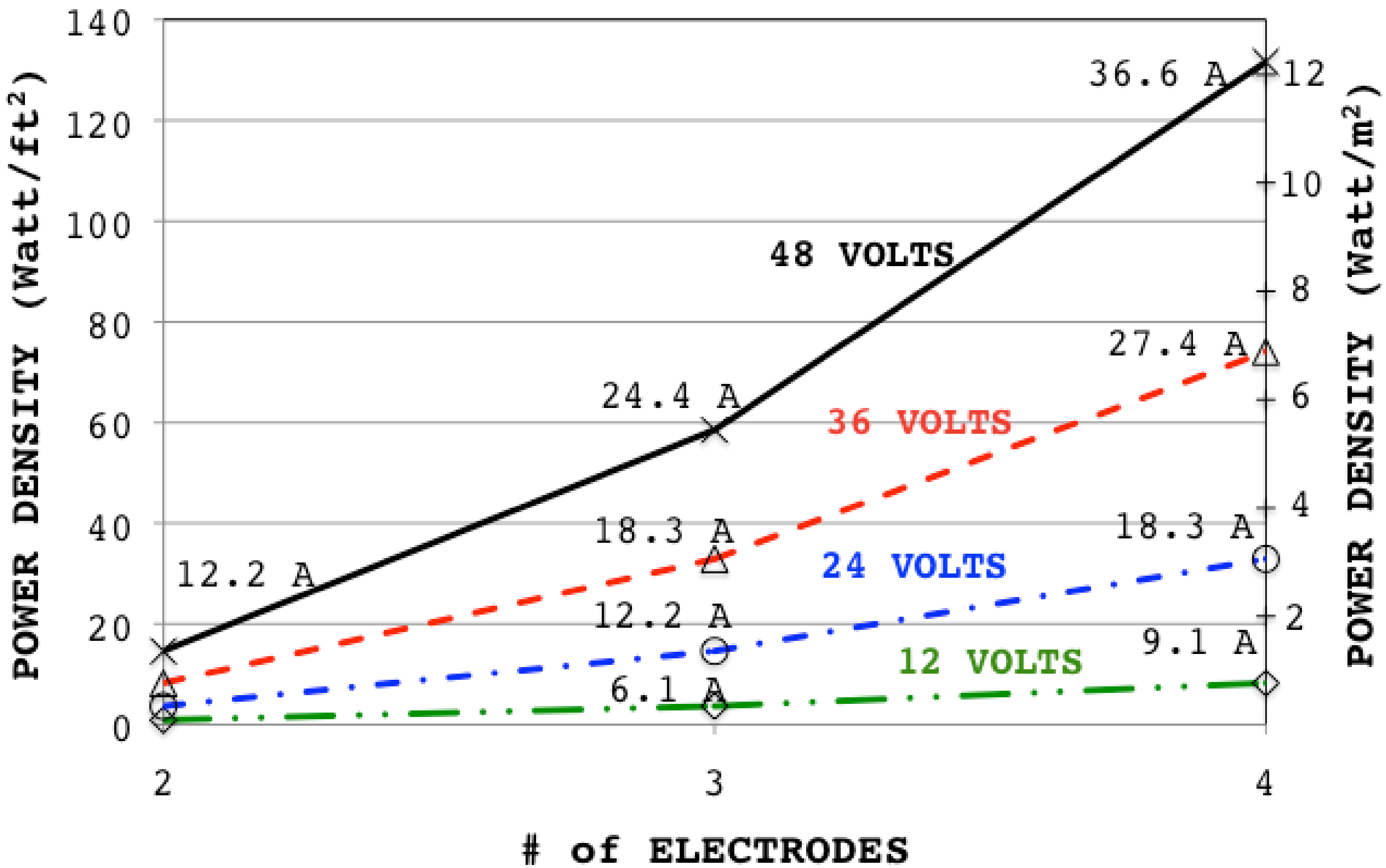
Explain the shape of the graph.



It curves, with a higher bit at the end and a rather aesthetically pleasing slope downwards towards a pretty flat straight bit. The actual graph itself consists of 2 straight lines meeting at the long left hard corner of the graph and moving away at a 90° angle. Each line has an arrow head on the end.

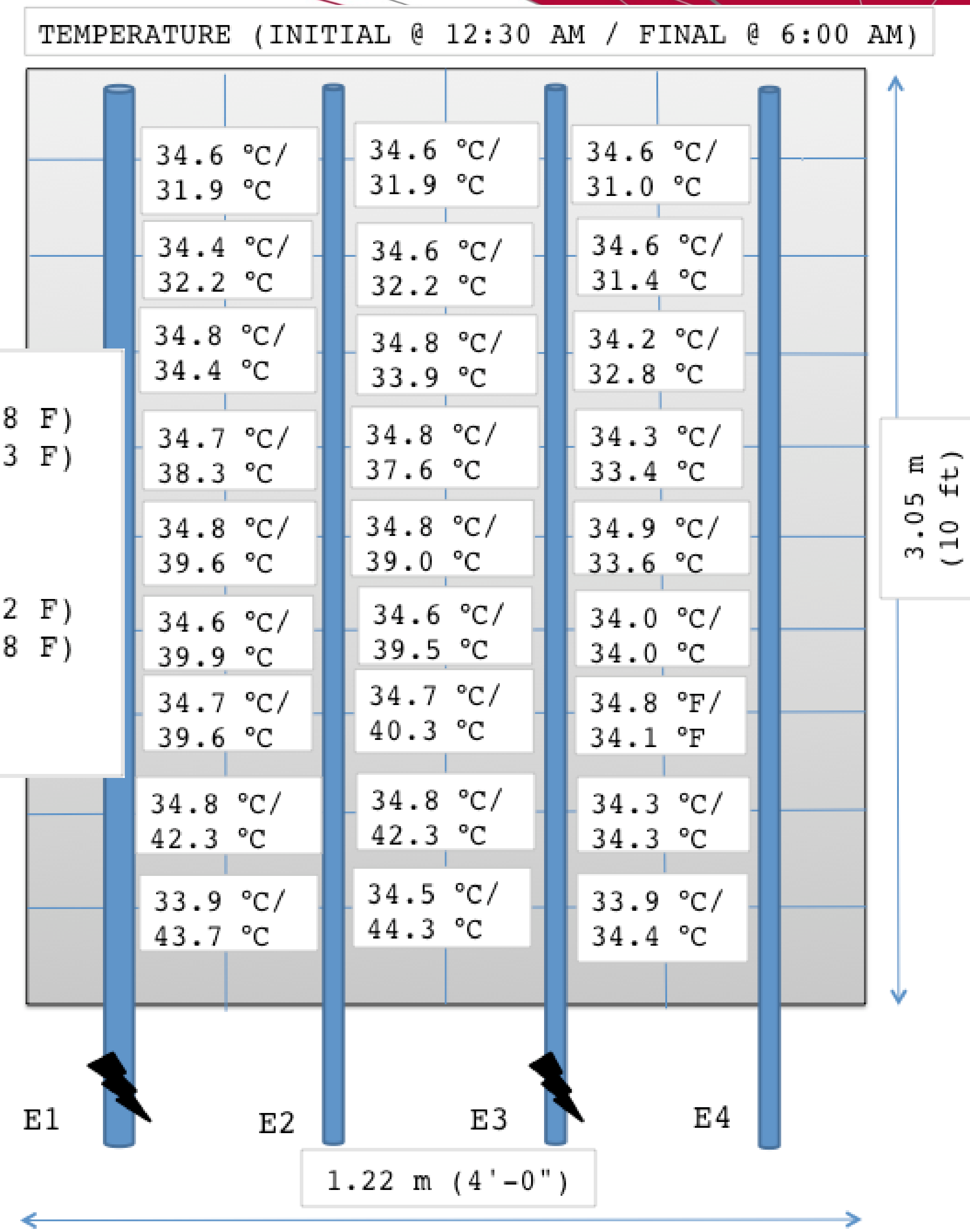
Ref: F IN EXAMS
By R. Benson

POWER DENSITY (ρ = 45 ohm-in)



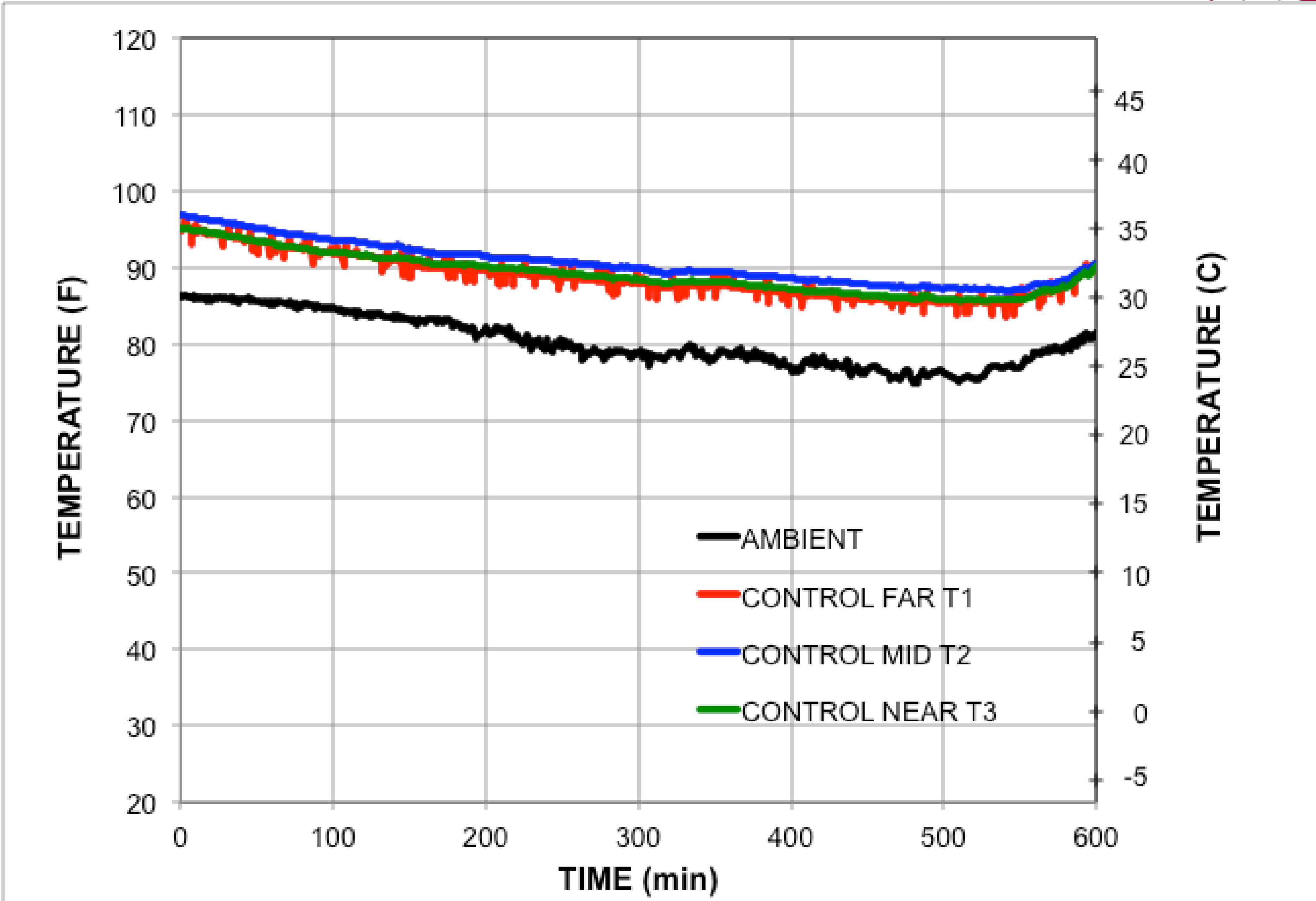
5 HOUR HEAT TEST

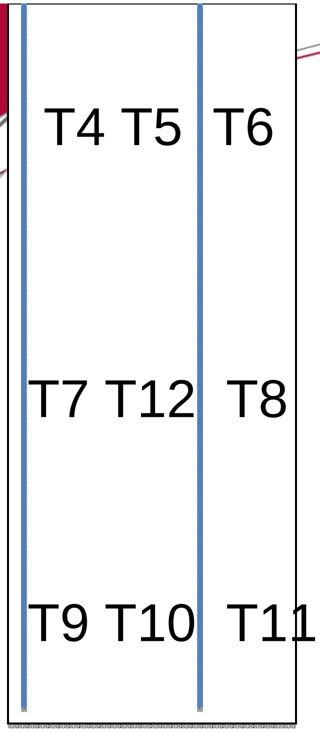
TIME	12:30 AM
AMBIENT TEMP	28.8 C (83.8 F)
CONTROL MAT TEMP	31.3 C (88.3 F)
VOLTAGE INPUT	50.2 V
TIME	6:00 AM
AMBIENT TEMP	24.0 C (75.2 F)
CONTROL MAT TEMP	28.8 C (83.8 F)
VOLTAGE INPUT	32.7 V

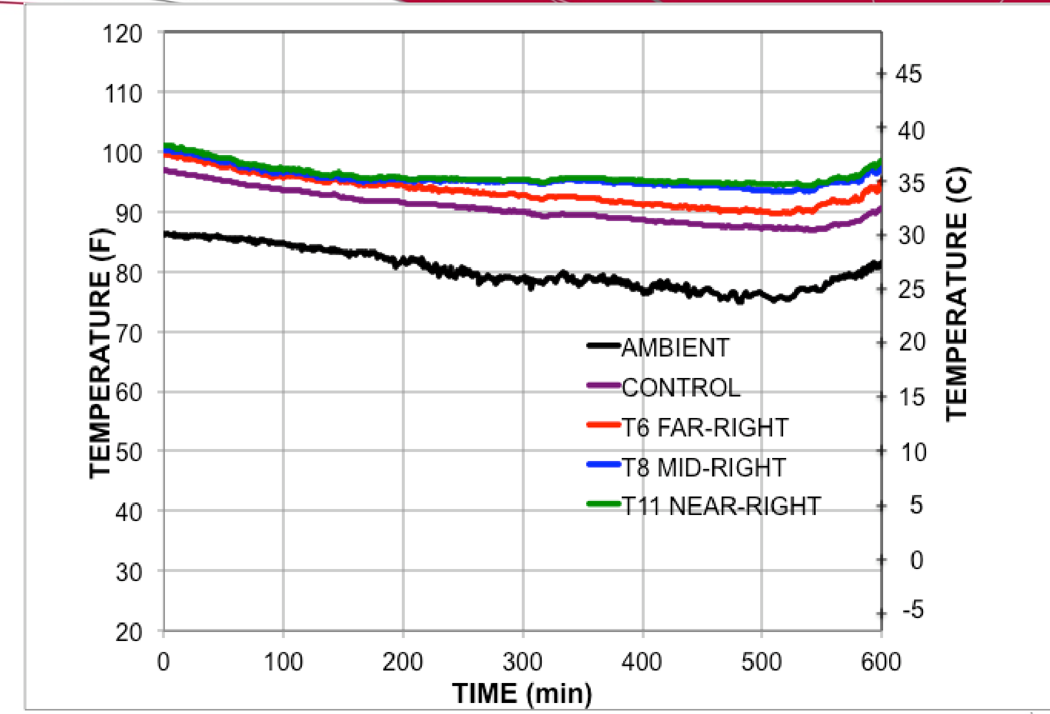


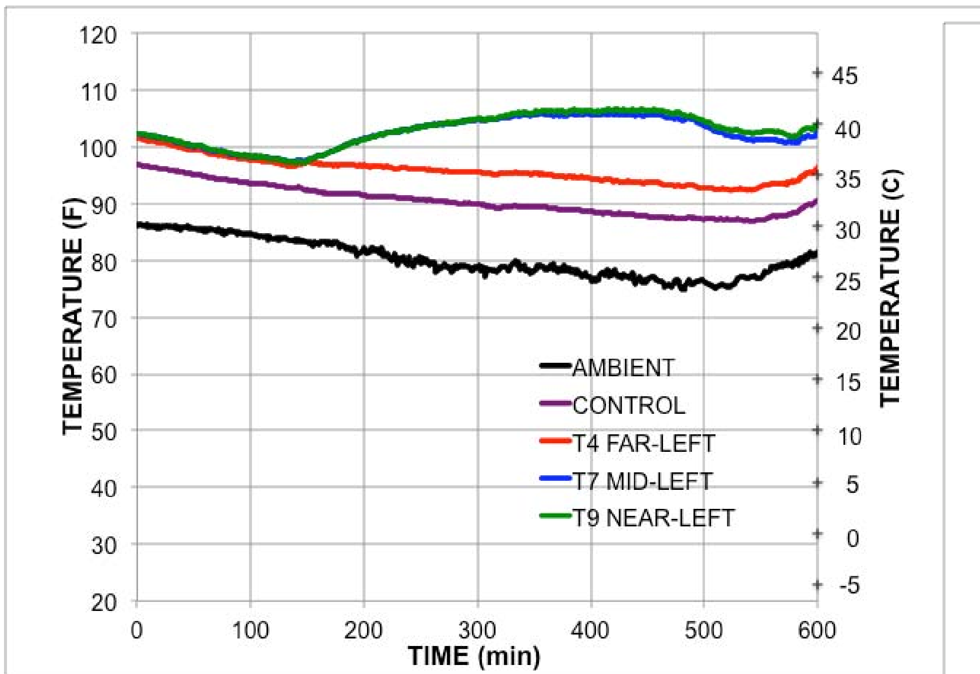
FAR END CONC-ELECTRODE INTERFACE

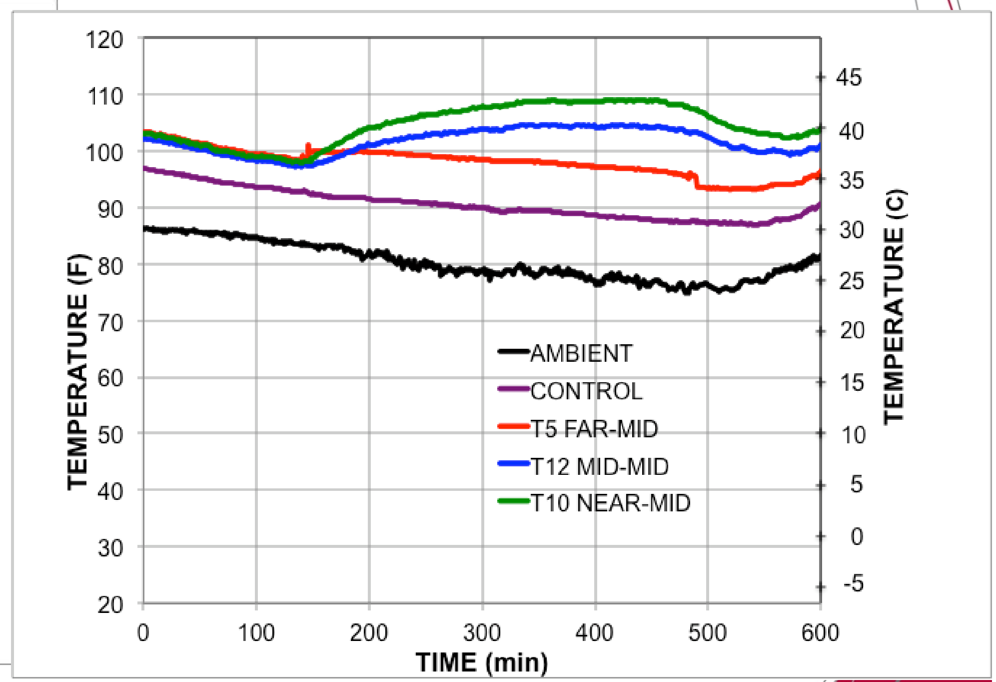
5 HOUR HEAT TEST (CONTROL MAT TEMPERATURE)




T4 T5 T6
T7 T12 T8
T9 T10 T11


TEMPERATURE (F)
TEMPERATURE (C)
TIME (min)
AMBIENT
CONTROL
T6 FAR-RIGHT
T8 MID-RIGHT
T11 NEAR-RIGHT

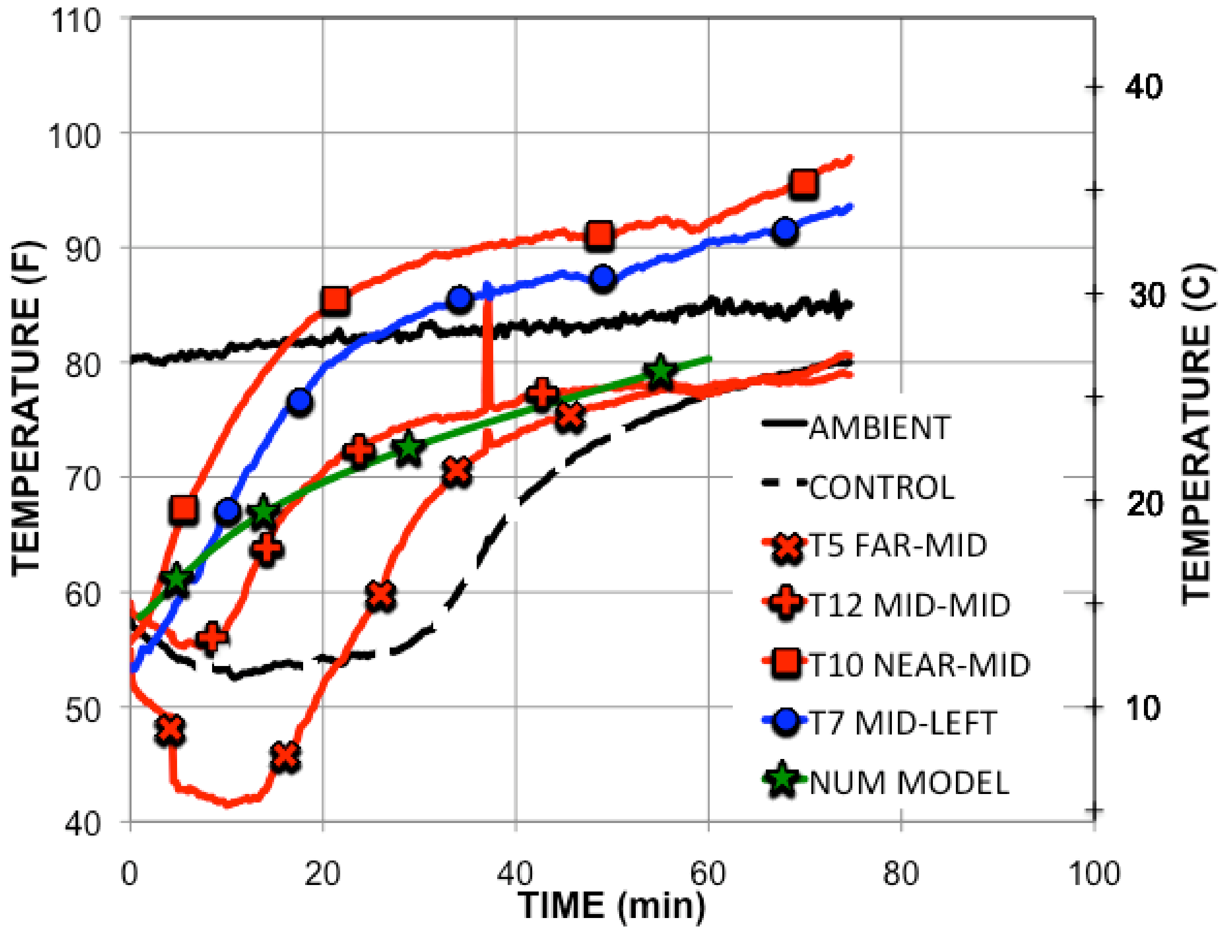

TEMPERATURE (F)
TEMPERATURE (C)
TIME (min)
AMBIENT
CONTROL
T4 FAR-LEFT
T7 MID-LEFT
T9 NEAR-LEFT


TEMPERATURE (F)
TEMPERATURE (C)
TIME (min)
AMBIENT
CONTROL
T5 FAR-MID
T12 MID-MID
T10 NEAR-MID

ICE TEST (25 MINUTES)

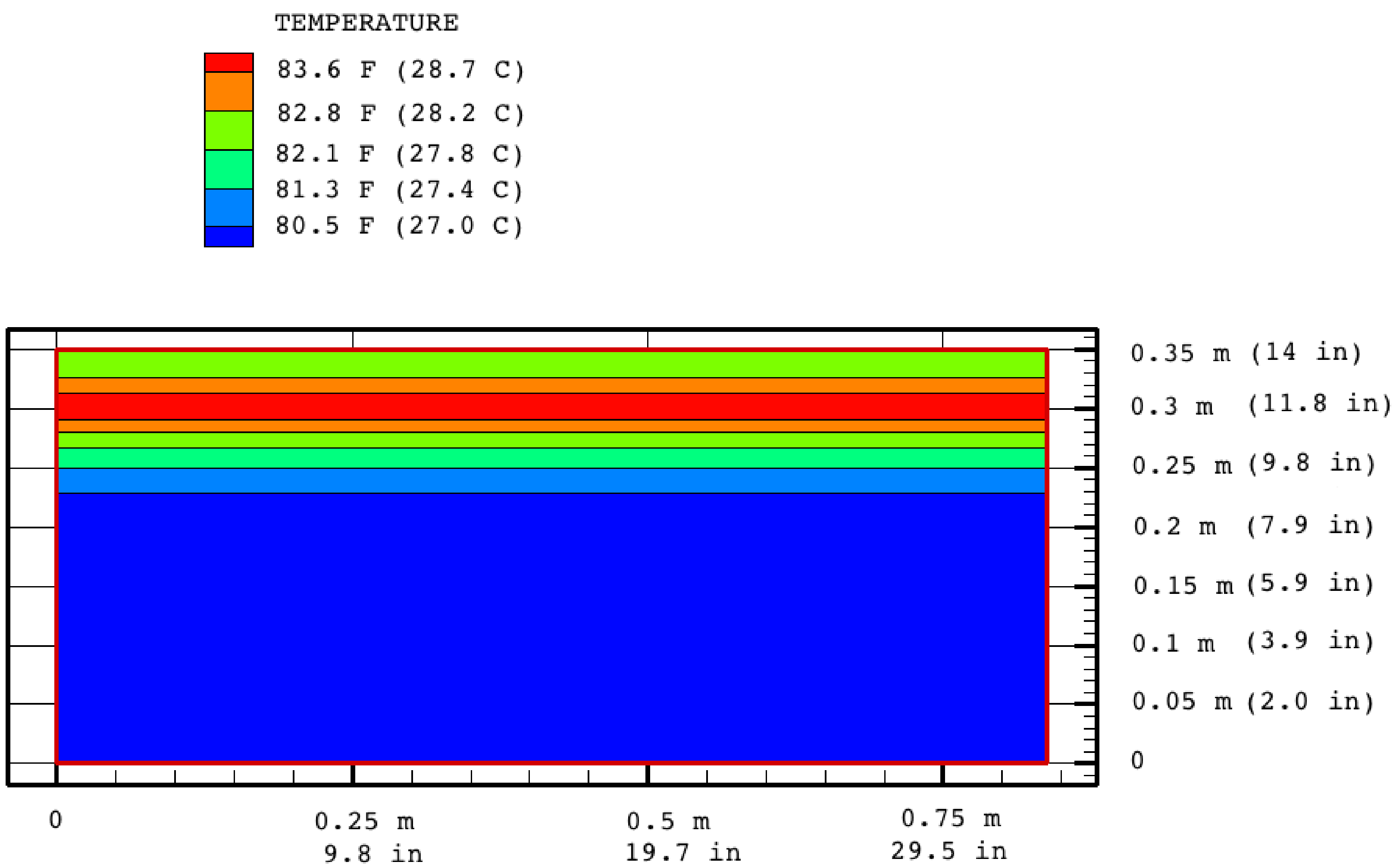
ICE TEST

ICE TEST



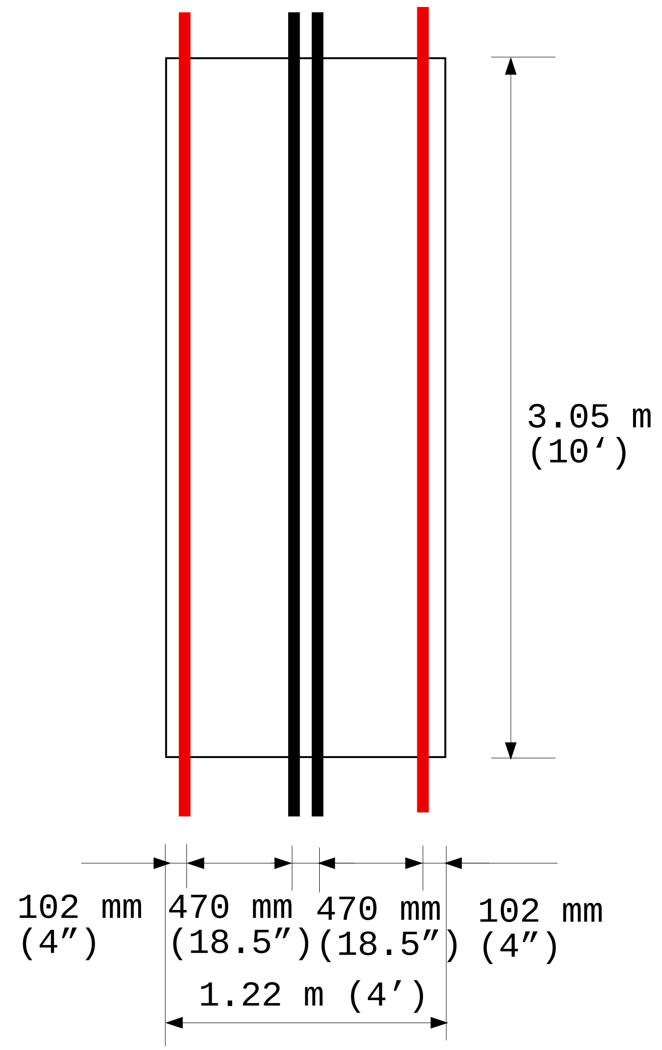
TEMPERATURE (F)
110
100
90
80
70
60
50
40
0
20
40
60
80
100
TIME (min)
TEMPERATURE (C)
40
30
20
10
AMBIENT
CONTROL
T5 FAR-MID
T12 MID-MID
T10 NEAR-MID
T7 MID-LEFT
NUM MODEL

FINITE DIFFERENCE MODEL

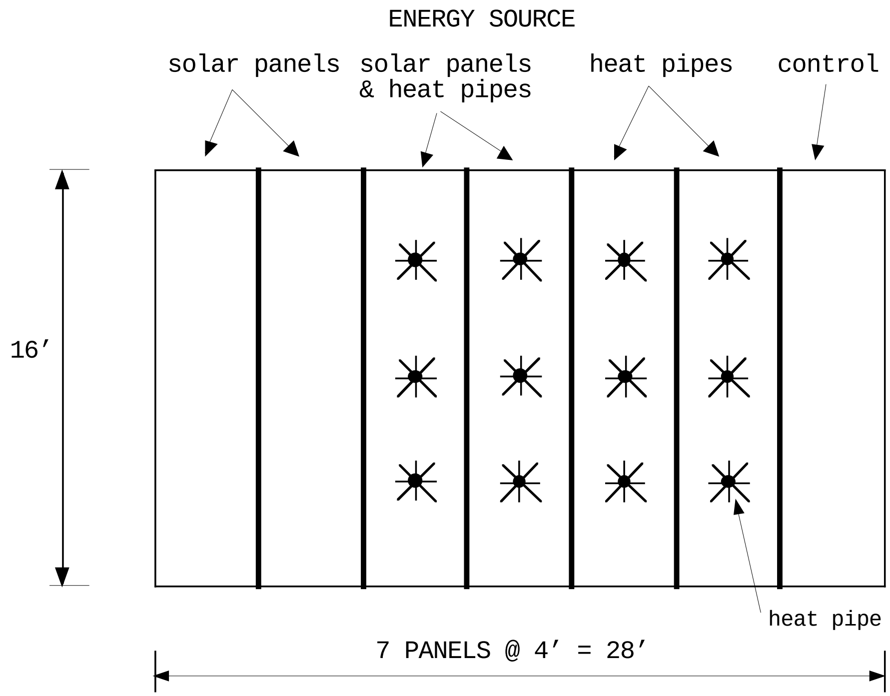


FUTURE WORK

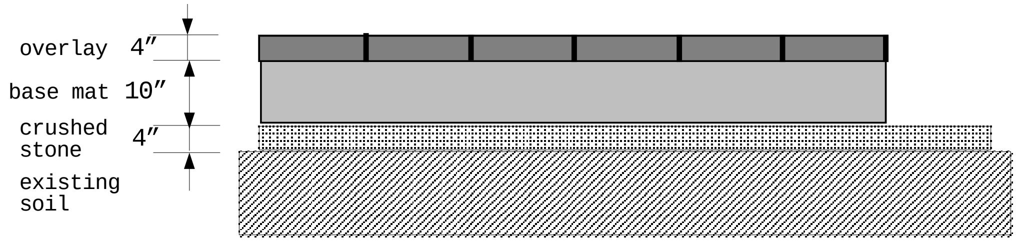
ELECTRODE LAYOUT



FUTURE WORK



PLAN VIEW



ELEVATION

CONCLUSIONS

- SNOW REMOVAL IS EXPENSIVE
- ENTAILS PLOWING & CHEMICAL TREATMENT
- ALTERNATIVE APPROACH- SOLAR ENERGY & CONDUCTIVE CONCRETE
- CONDUCTIVE CONCRETE UNIFORMITY
- MONITOR TEMPERATURES DURING 2011-2012 WINTER SEASON.

ACKNOWLEDEMENTS

- US FEDERAL AVIATION ADMINISTRATION
- Joe Breen, FAA Project Manager
- Albert Tamashausky, Asbury Graphite Mills, Inc.

GO RAZORBACKS!

University of ARKANSAS
RAZORBACKS

ernie@uark.edu