SWIFT 2013 CONFERENCE and TRADE SHOW

DEVELOPING ANTI-ICING AIRFIELD RUNWAYS WITH SOLAR ENERGY

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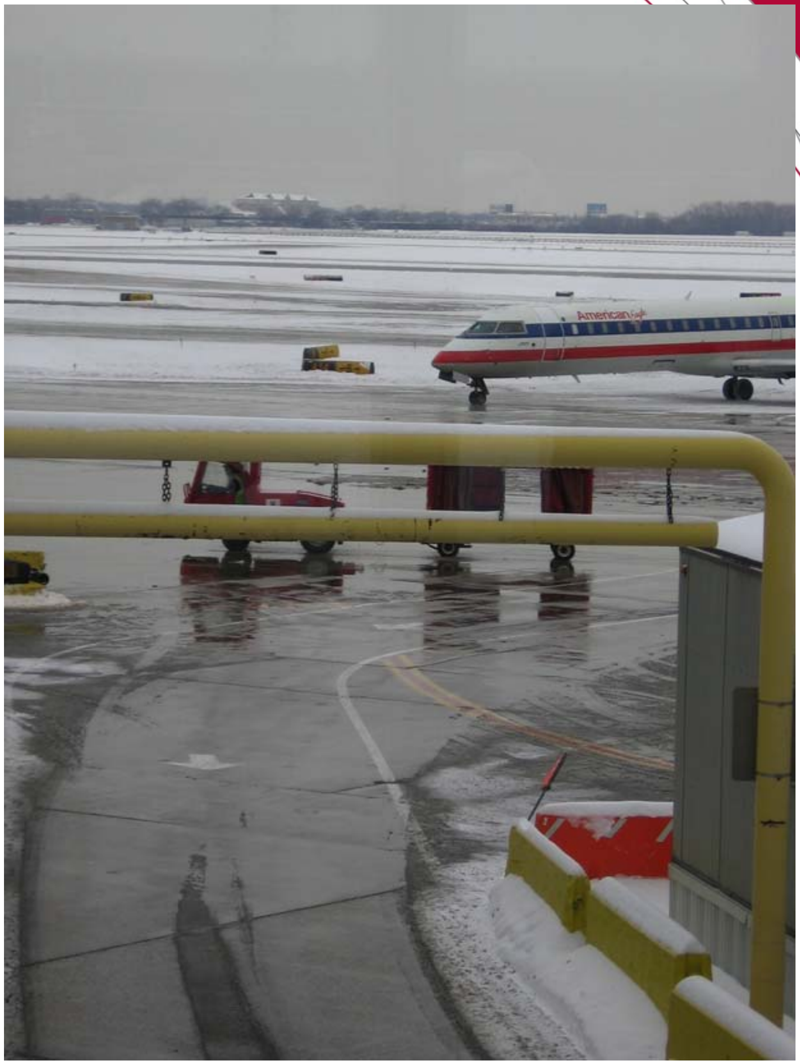
BACKGROUND
CHICAGO O'HARE



INCIDENTS / ACCIDENTS

JAN 1978 – JAN 2009

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

(2 engines GWT > 6,000 #)

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

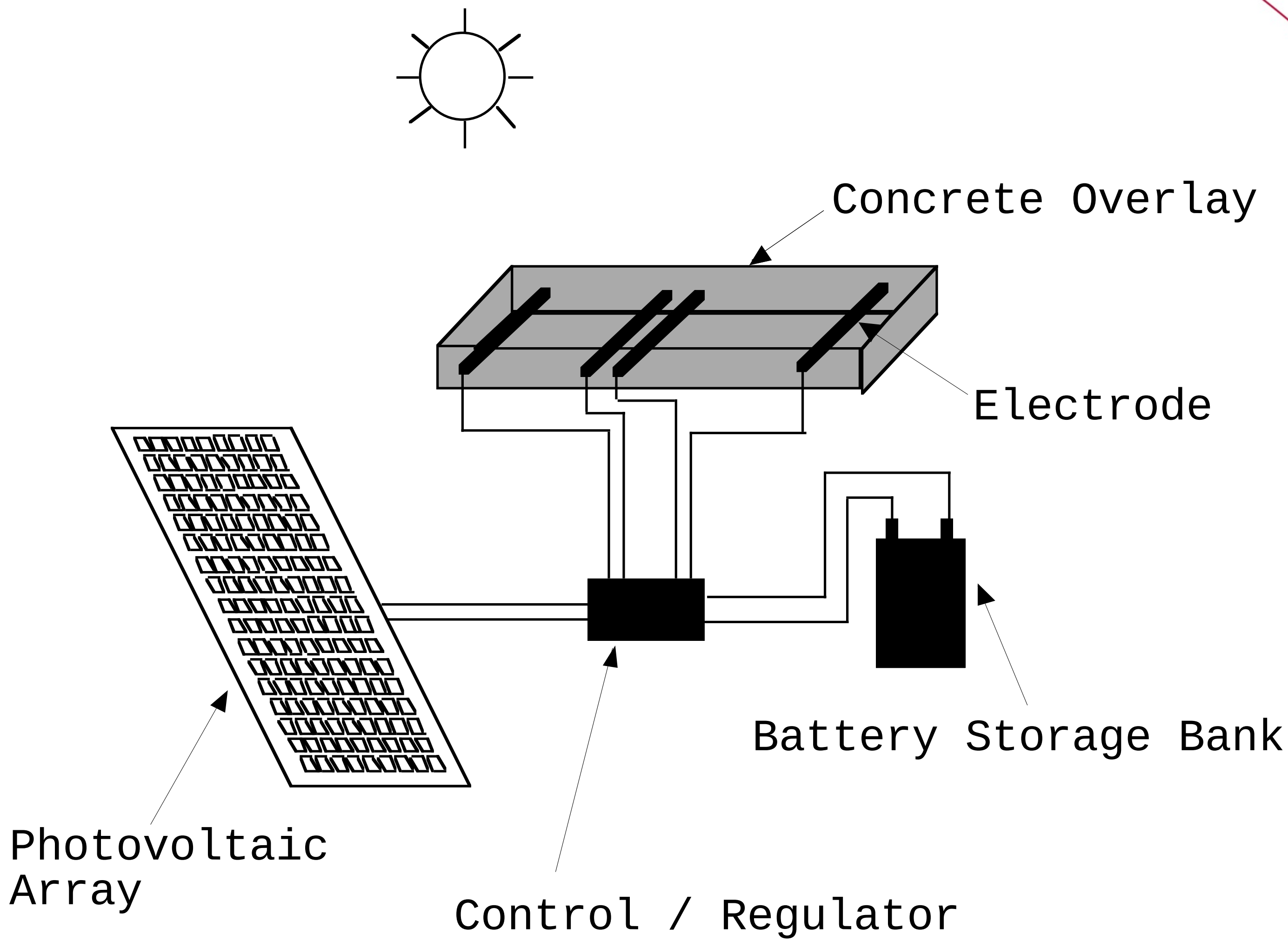
SNOW REMOVAL

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

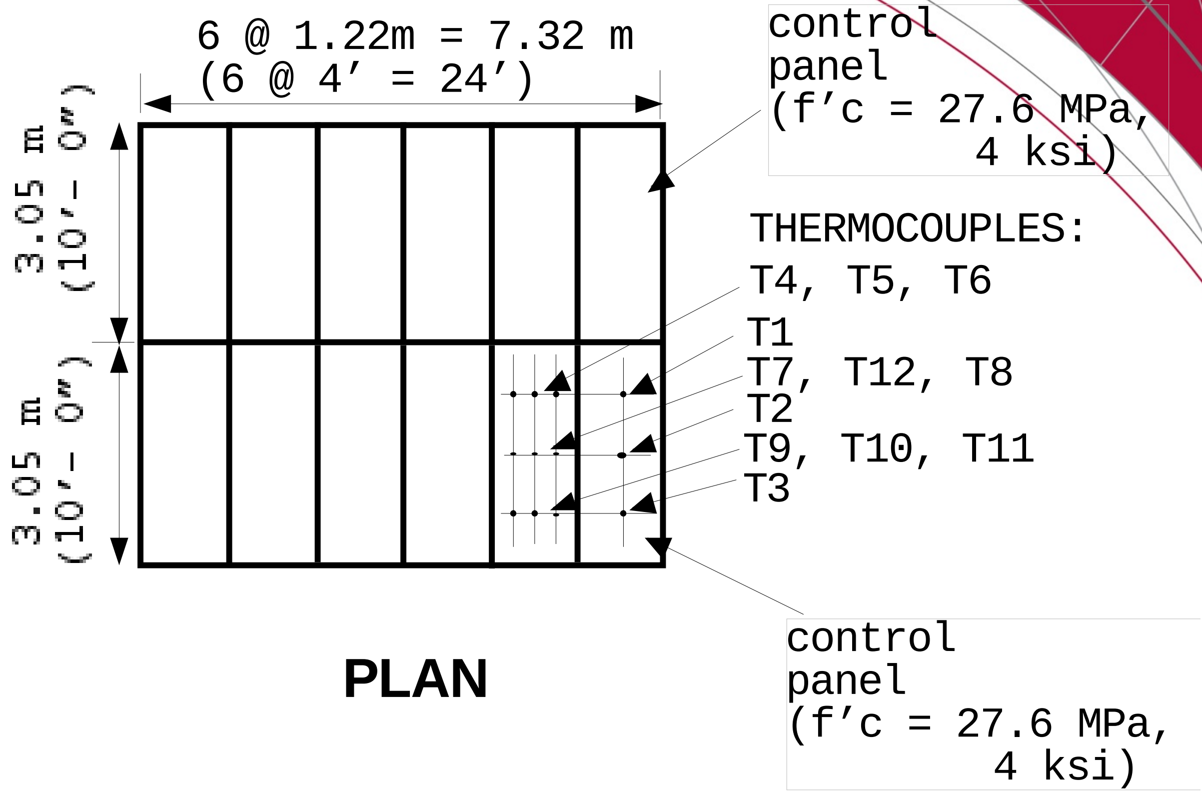
OBJECTIVES

- 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

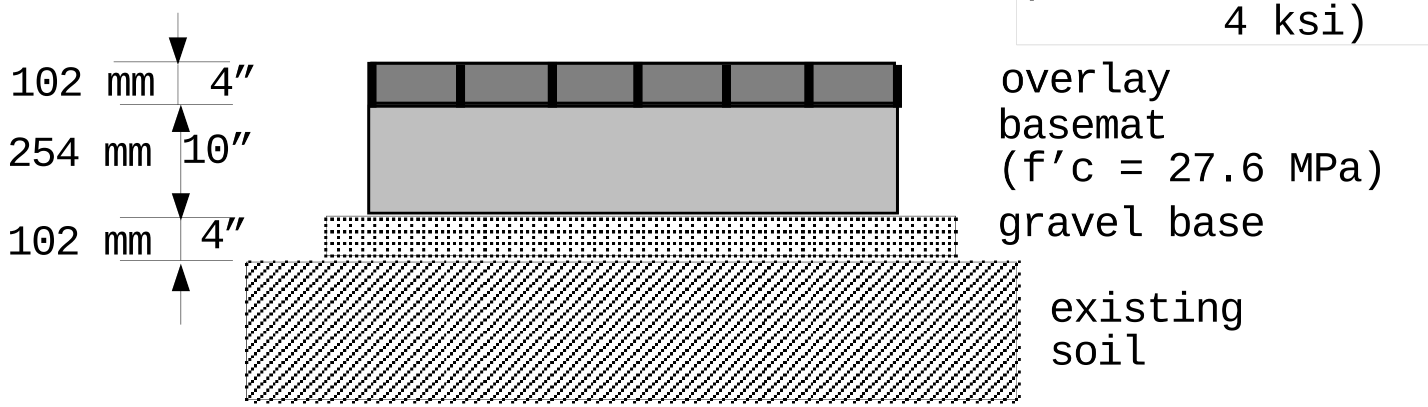
TEST SETUP


Concrete Overlay
Electrode
Battery Storage Bank
Photovoltaic
Array
Control / Regulator

TEST MAT LAYOUT



PLAN



ELEVATION

TESTING AREA

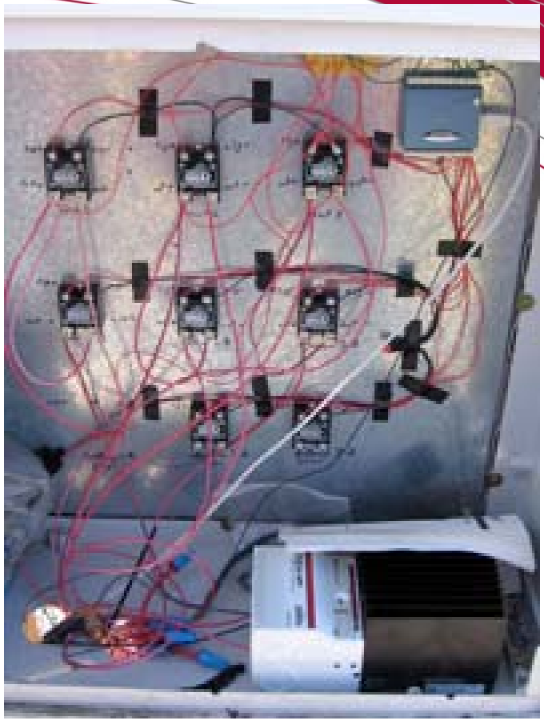
19.8m x 19.8m (65’ x 65’) Study Area)

ANTI-ICING SYSTEM

6.1m x 7.3m Test Mat (20’ x 24’)

32- 200 Watt SOLAR PANELS (7.2 kW / 20’x20’ = 162 W/m^2, 18W/ft^2)

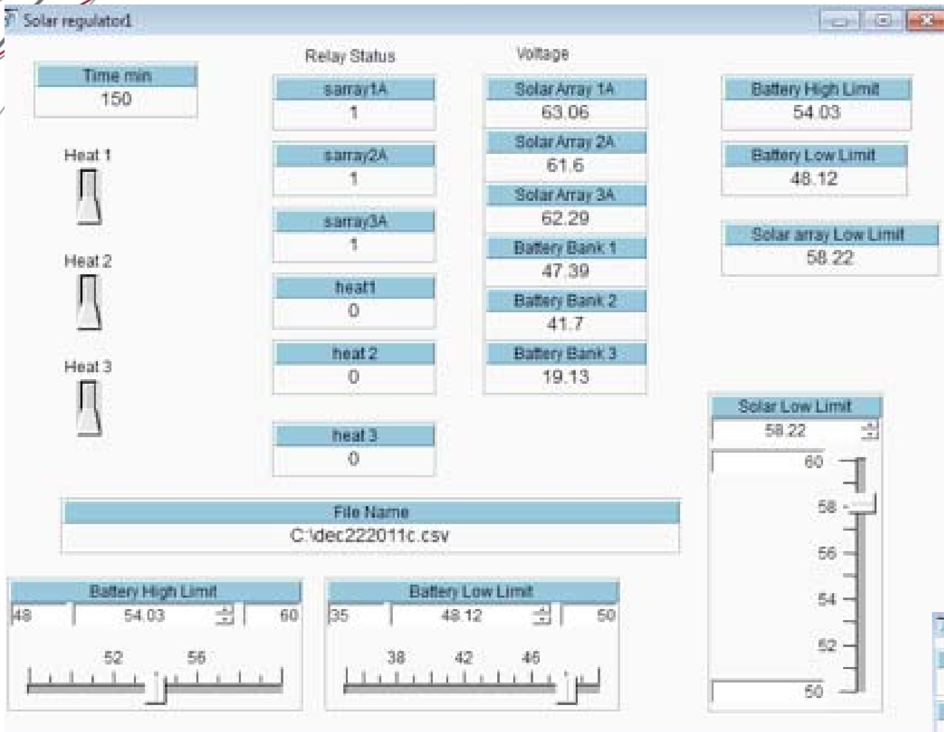
BATTERY STORAGE



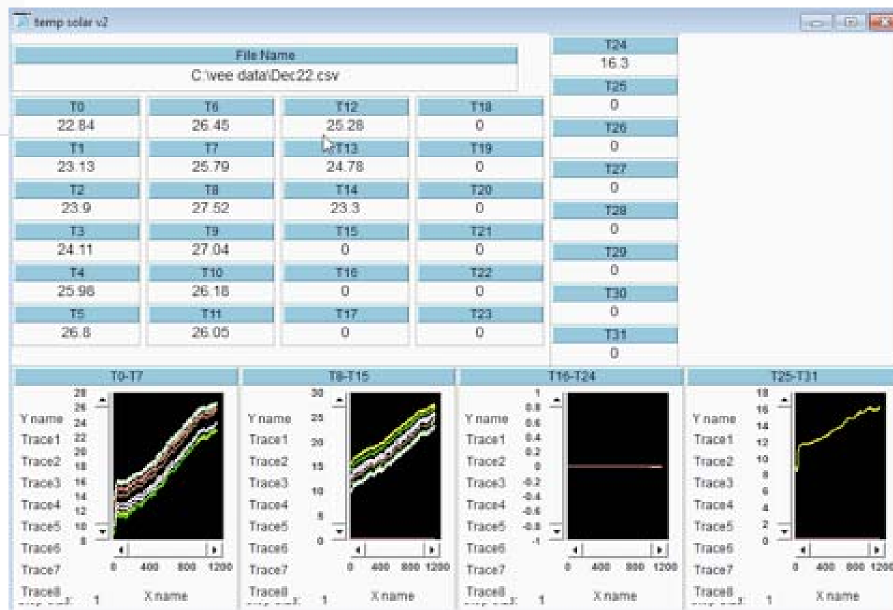
REGULATOR

DAQ SYSTEM

RECORDED MEASUREMENTS



VOLTAGE



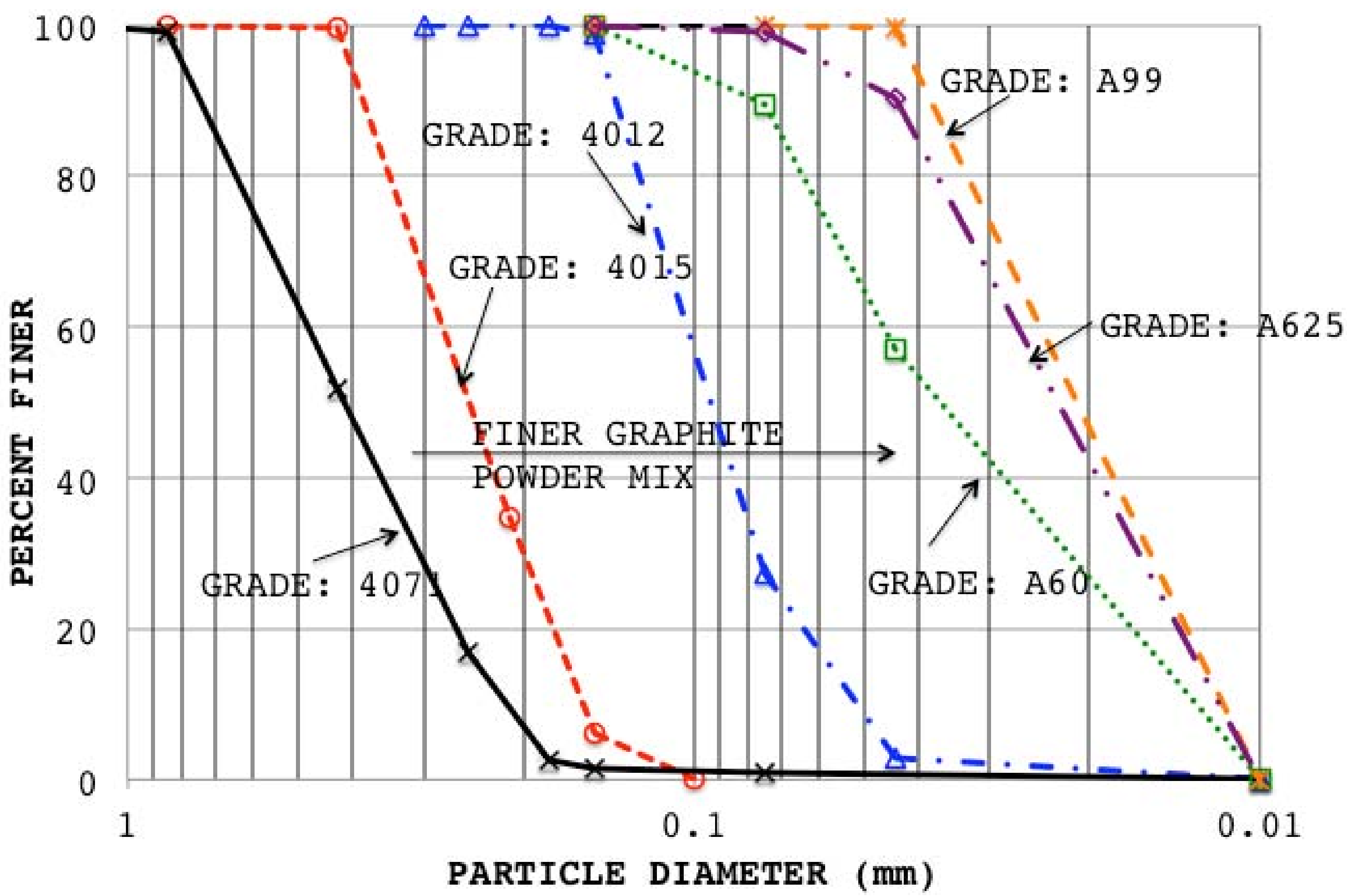
TEMPERATURE

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

- HEAT GENERATION = f(ELECTRICAL CONDUCTIVITY)
- κ (cond. conc) = 1500 * κ (normal conc.)
- $\kappa = $ f(temperature)
- STRENGTH, CONDUCTIVITY, & WORKABILITY

COND CONC MATERIALS

GRAPHITE POWDER GRADATION



TRIAL MIX BATCH

MIX	GRAPHITE POWDER (%)	RAPHITE POWDE 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

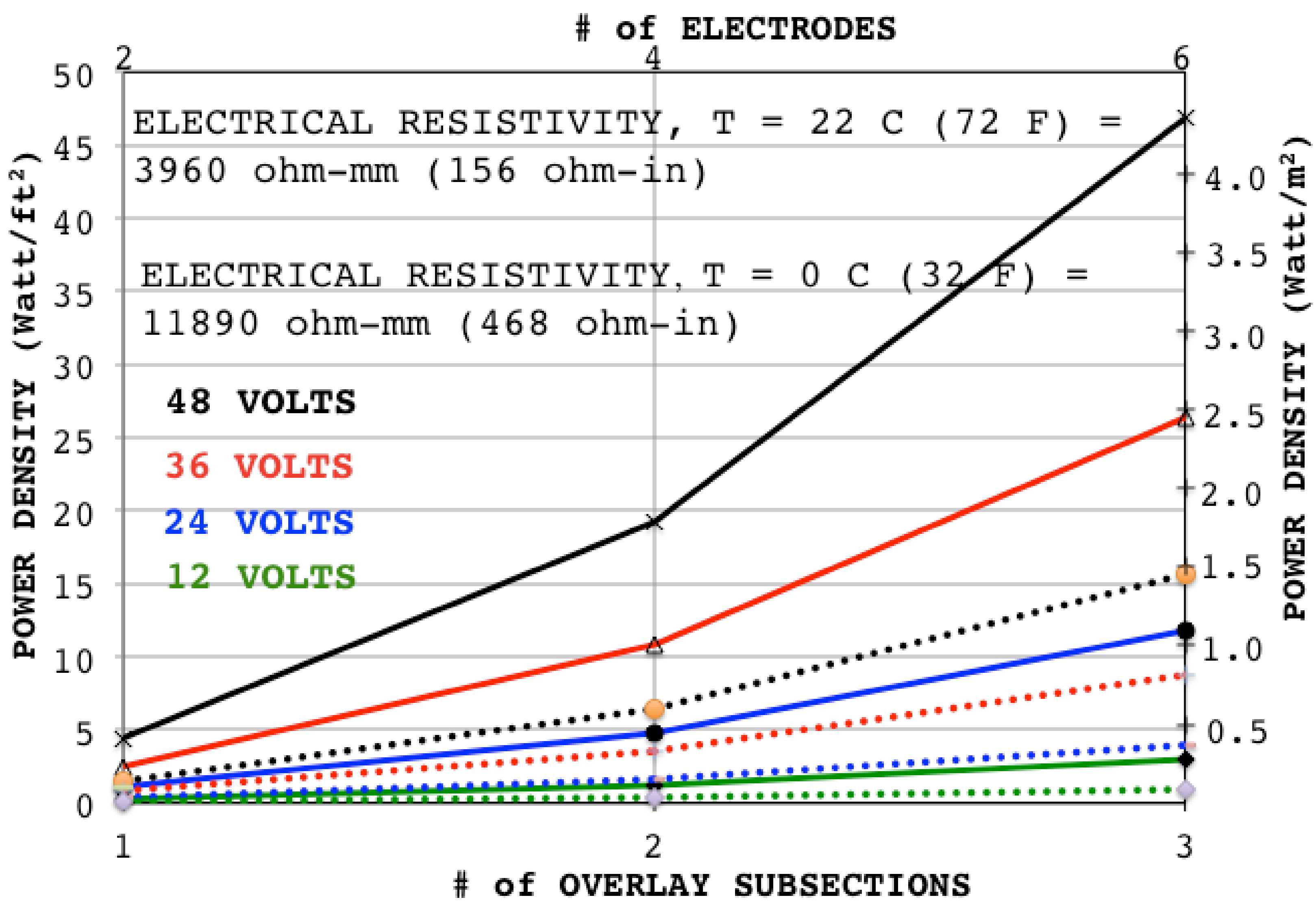
MIX	UnWt (pcf)	UnWt (kN/m^3)	f'c (ksi) 28 day	f'c (MPa) 28 day	El. Resistivity (ohm-in) 28 day	El. Resistivity (ohm-cm) 28 day
1	137.1	21.6	2.75	18.95		
2	137.1	21.6	3.10	21.36		
3	138.3	21.7	4.15	28.59		
4	138.3	21.7	5.60	38.58		
5	137.4	21.6	5.10	35.14		
6	136.4	21.4	na	na		
7	135.6	21.3	na	na		
8	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

CRITERIA:
STRENGTH
CONDUCTIVITY
WORKABILITY

CONDUCTIVE CONC. CYLINDER

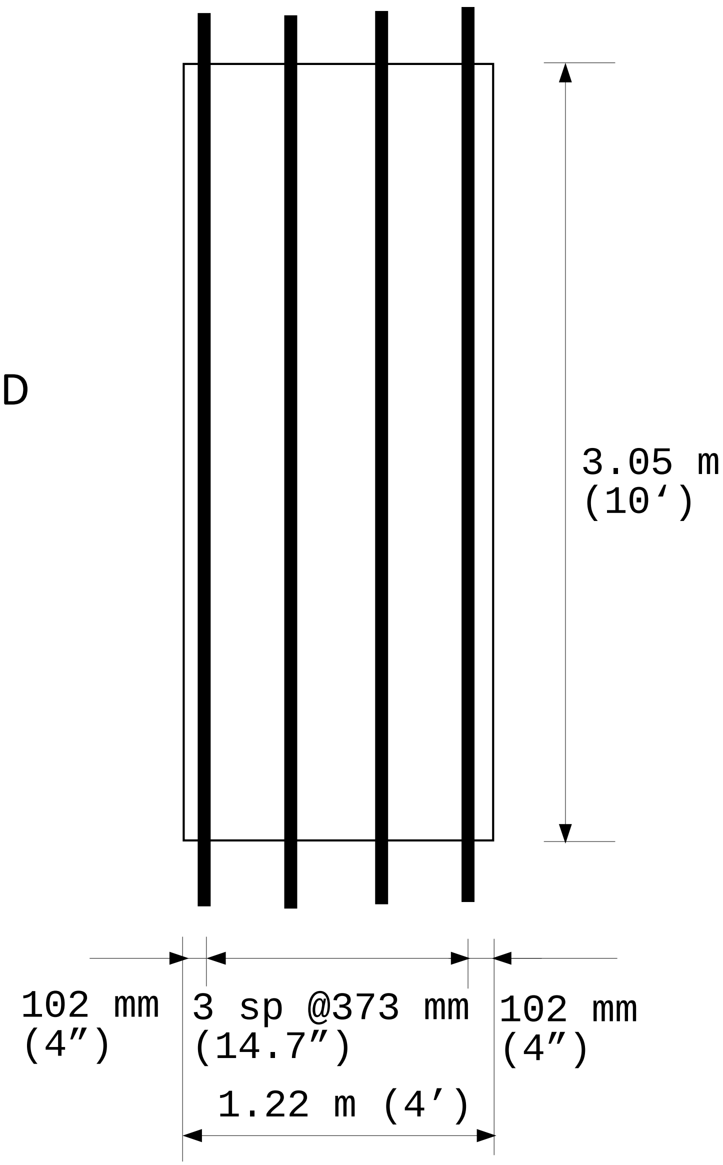
CONDUCTIVE CONC. CYLINDER

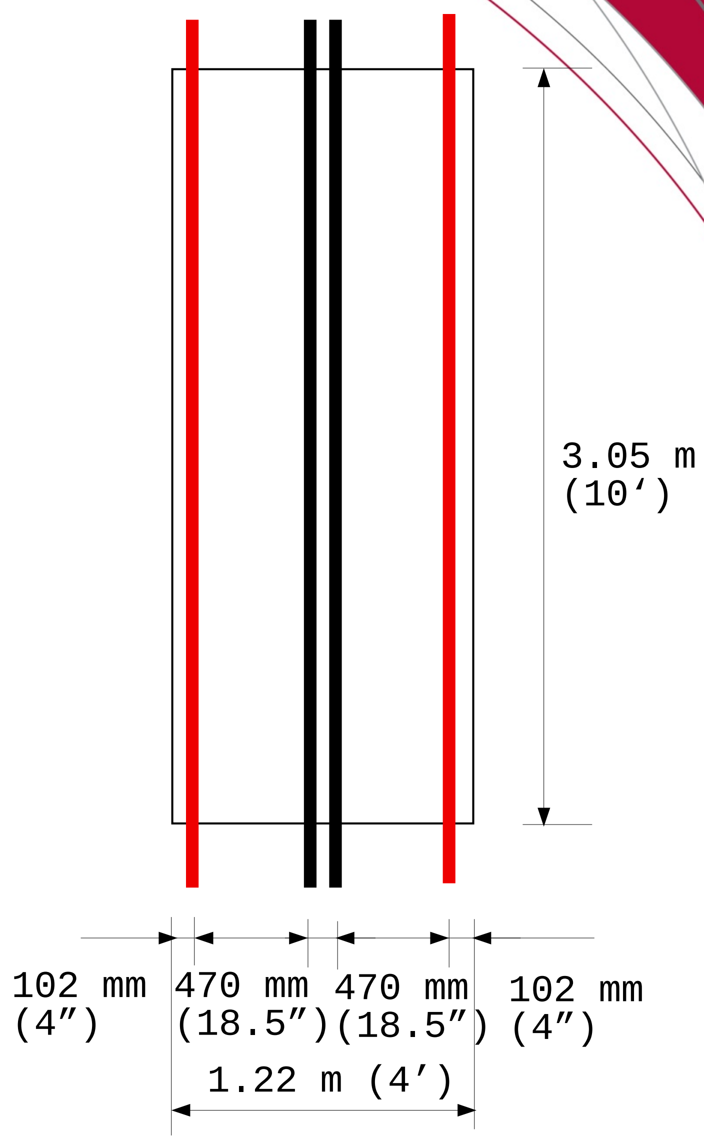
ELECTRODE CONFIGURATION



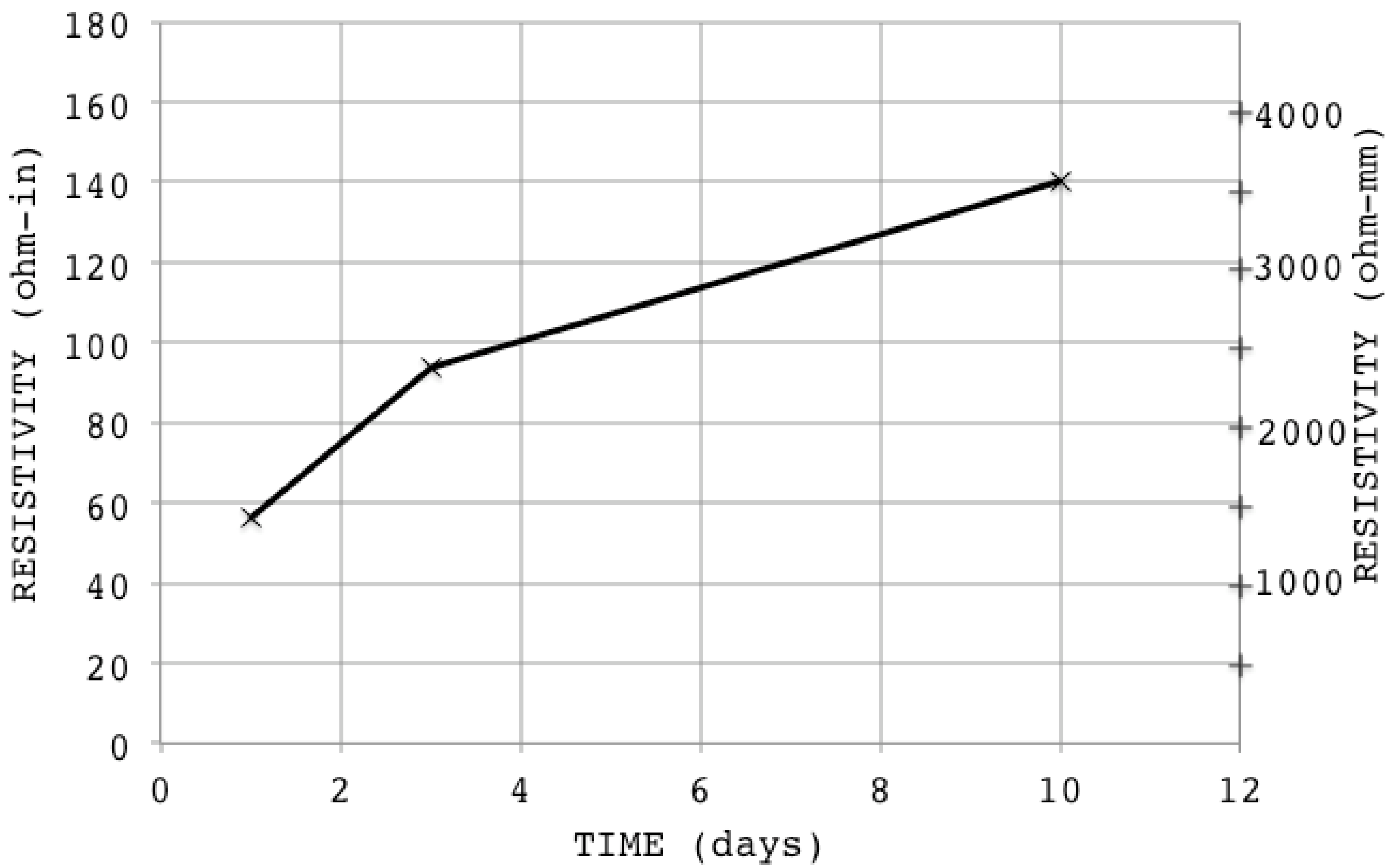
ELECTRODE LAYOUT

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





RESISTIVITY = f(TIME)



ICE TEST

ICE TEST

CONTROL TEST MAT

COND. CONC. TEST MAT

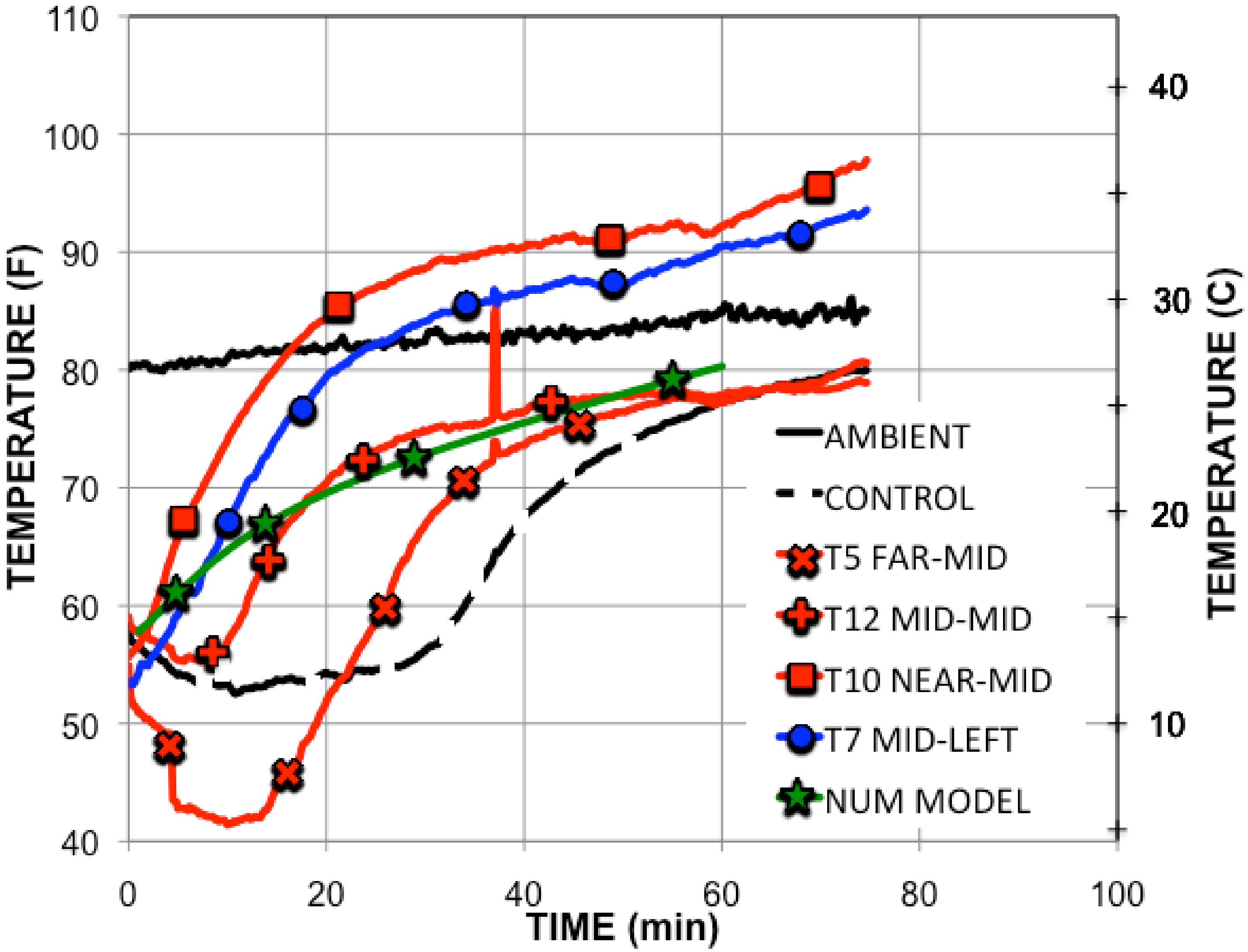
TIME = 0

CONTROL TEST MAT

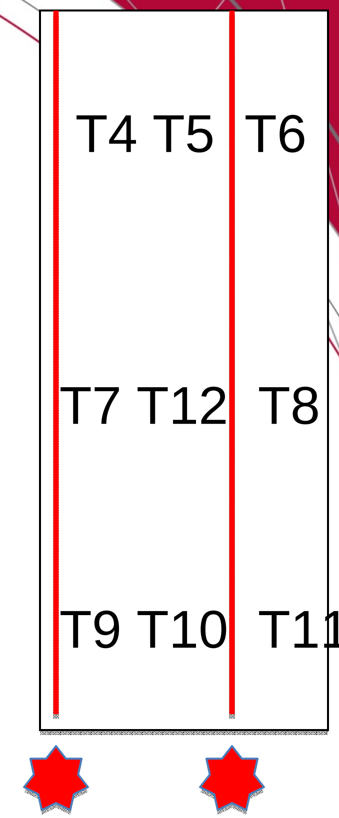
COND. CONC. TEST MAT

TIME = 25 MINUTES

ICE TEST



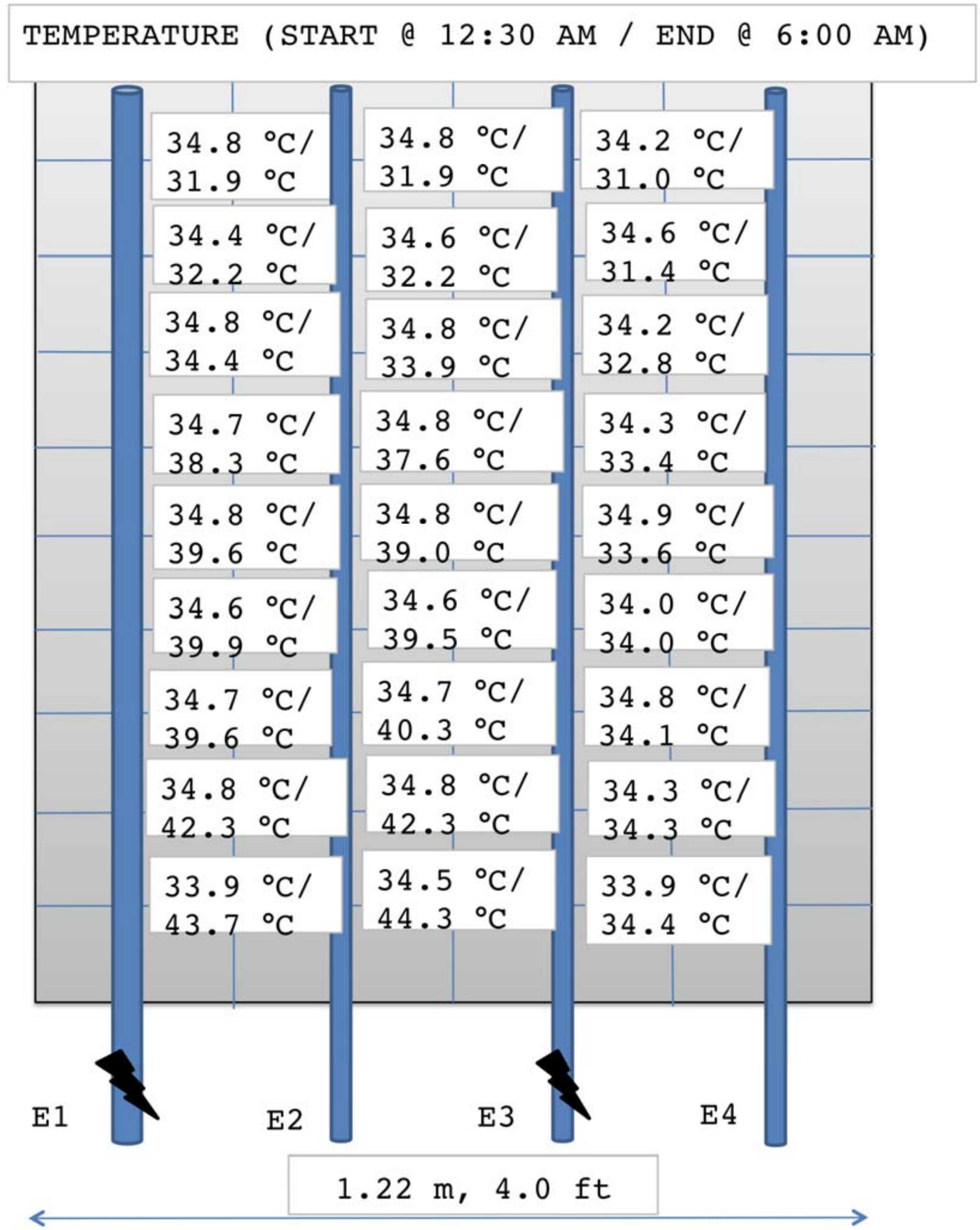
TEMPERATURE (F)
110
100
90
80
70
60
50
40
0
20
40
60
80
100
TIME (min)
40
30
20
10
TEMPERATURE (C)
AMBIENT
CONTROL
T5 FAR-MID
T12 MID-MID
T10 NEAR-MID
T7 MID-LEFT
NUM MODEL



T4 T5 T6
T7 T12 T8
T9 T10 T11

5 HOUR HEAT TEST

July 29, 2011	12:30 AM
AMBIENT TEMP	28.8 °C
CONTROL MAT TEMP	31.3 °C
VOLTAGE INPUT	50.2 V
	6:00 AM
AMBIENT TEMP	24.0 °C
CONTROL MAT TEMP	28.8 °C
VOLTAGE INPUT	32.7 V



HEAT TEST SUMMARY (initial / final) 12:30 AM / 6:30 AM

DATE (2011)	MAT #	AMBIENT T °C	VOLTAGE DC V	COND. CONC. °C	CONV. CONC. °C
		Tinitial / Tfinal	Vinitial / Vfinal	Tinitial / Tfinal	Tinitial / Tfinal
Jul 29	1	28.8 / 24.0	50.2 / 32.7	34.7 / 37.9	31.3 / 28.8
Aug 9	1	26.1 / 22.7	50.2 / 47.4	27.3 / 33.5	24.3 / 24.5
Aug 16	1	23.5 / 23.0	51.5 / 47.6	28.6 / 33.4	26.5 / 24.9
Sept 2	2	25.0 / 24.8	25.0 / 24.8	33.4/ 30.4	29.1 / 26.2
Oct 7	3	17.7 / 14.4	49.8 / 48.8	19.9 / 24.5	18.3 / 14.1
Oct 20	4	0.0 / -2.2	53.9 / -	8.1 / 8.4	4.7 / 1.6
Nov 28	4 & 7	1.1 / 0	52.2 / 49.3	0.8 / 5.9	0.6 / -2.1
Nov 29	3	-2.8 / -1.7	51.0 / 48.6	-0.2 / 1.4	-2.1 / -4.3

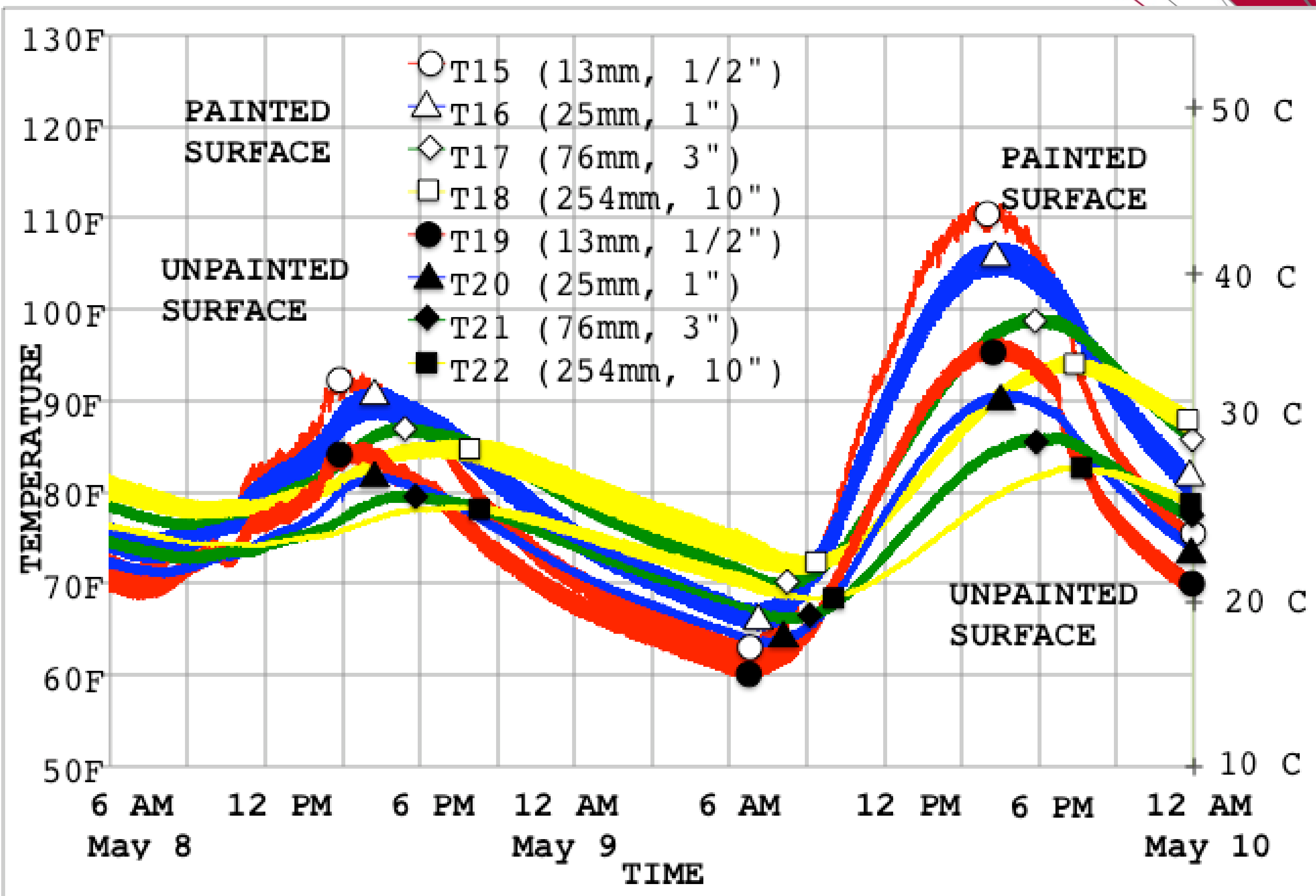
COST ANALYSIS

Material	Cost per unit	Amount of material needed per unit	Total Cost per 4-in thick, 4-ft x 10-ft overlay panel	Total Cost per ft^2 (4-in thick panel)
Carbon Powder, lb.	\$0.72	650 lb/yd^3	\$231.10	5.78
Steel Fibers, lb	\$0.40	50 lb/yd^3	\$9.88	0.25
Normal-weight concrete, yd^3	\$120	1 yd^3	\$59.25	1.48
Conductive Concrete			\$300.23	7.51
Steel Electrodes, ft.	\$5	48 ft / panel	\$240.00	6.00
Photovoltaic Panels, panel	\$400	2	\$800	20.00
Deep-Cycle Batteries, battery (12 V)	\$250	2	\$500	12.50
		Total Cost =	**\$1,840.23**	**\$46.01**

EACH 4-in THICK OVERLAY PANEL (4-ft x 10-ft) = 13.33 ft^3 = 0.494 yd^3

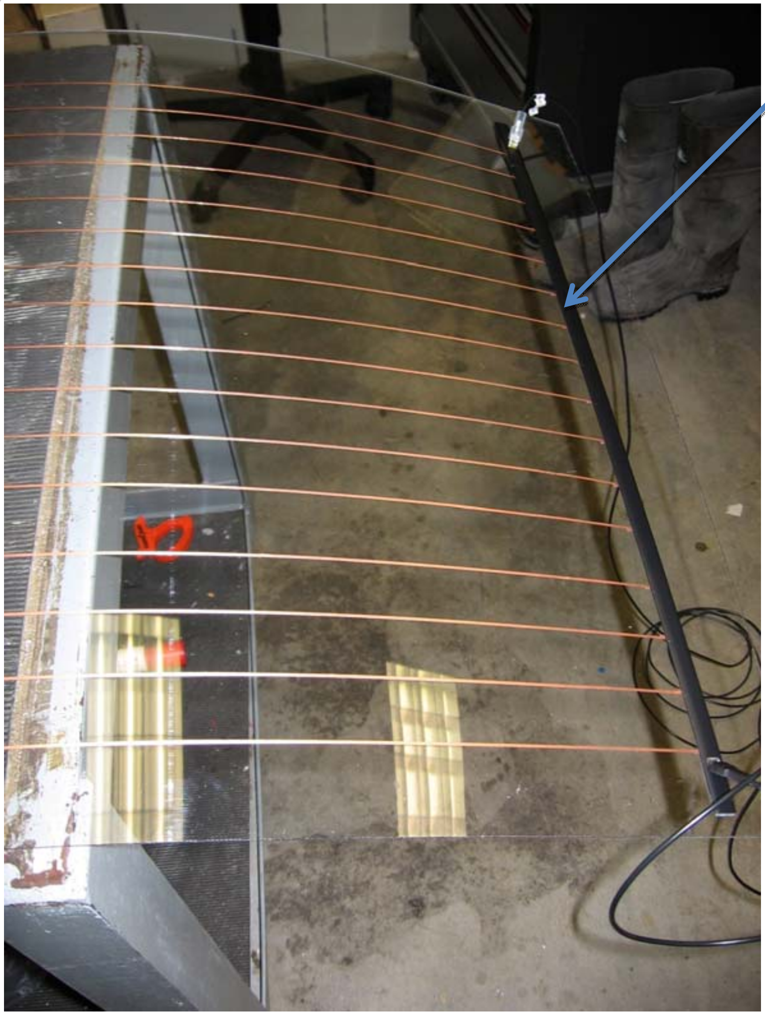
SURFACE PAINTING

PAINTED PAVEMENT
(time = 30 hrs; thermal mass)



FUTURE RESEARCH

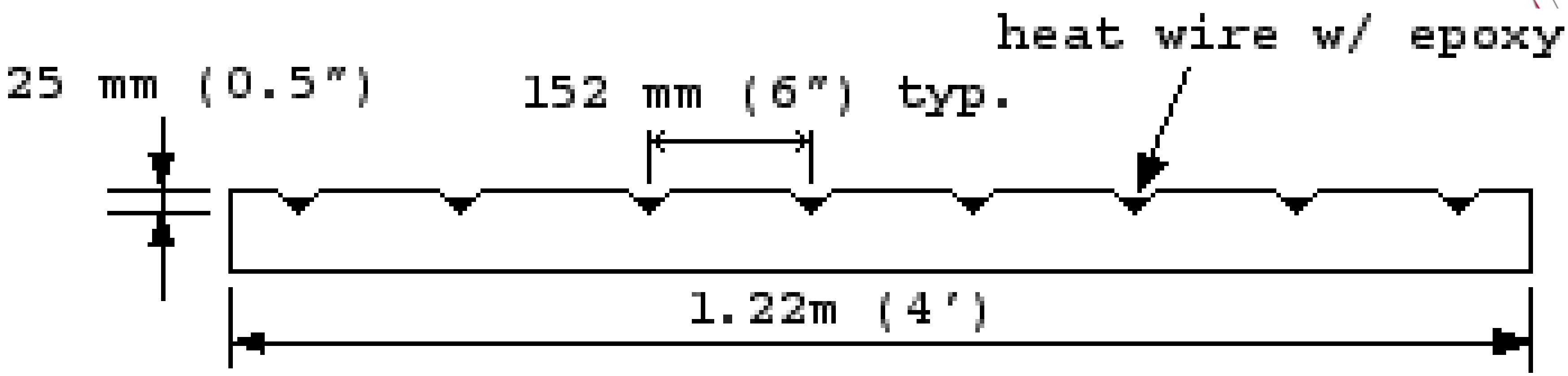
HEAT WIRE(0.6m x 1.5 m; 2' X 5' LEXAN)



COPPER WIRE HEATING ELEMENTS
32 mm (1.25 in) spacing

Start: 23 °C (72.5 °F)
1.5 minutes 30 °C (86 °F)
i = 8.6 amps

FUTURE RESEARCH
(grooved concrete surface)



CONCLUSIONS

- SNOW REMOVAL IS EXPENSIVE
- PLOWING & CHEMICAL TREATMENT
- ALTERNATIVE APPROACH- SOLAR ENERGY & CONDUCTIVE CONCRETE
- CONDUCTIVE CONCRETE UNIFORMITY
- FUTURE WORK- HEAT WIRE

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GO HOGS GO!

University of ARKANSAS RAZORBACKS

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