Airflow and Oxygen Concentration Effects in Dust Layer Hot Surface Ignition Temperature Tests

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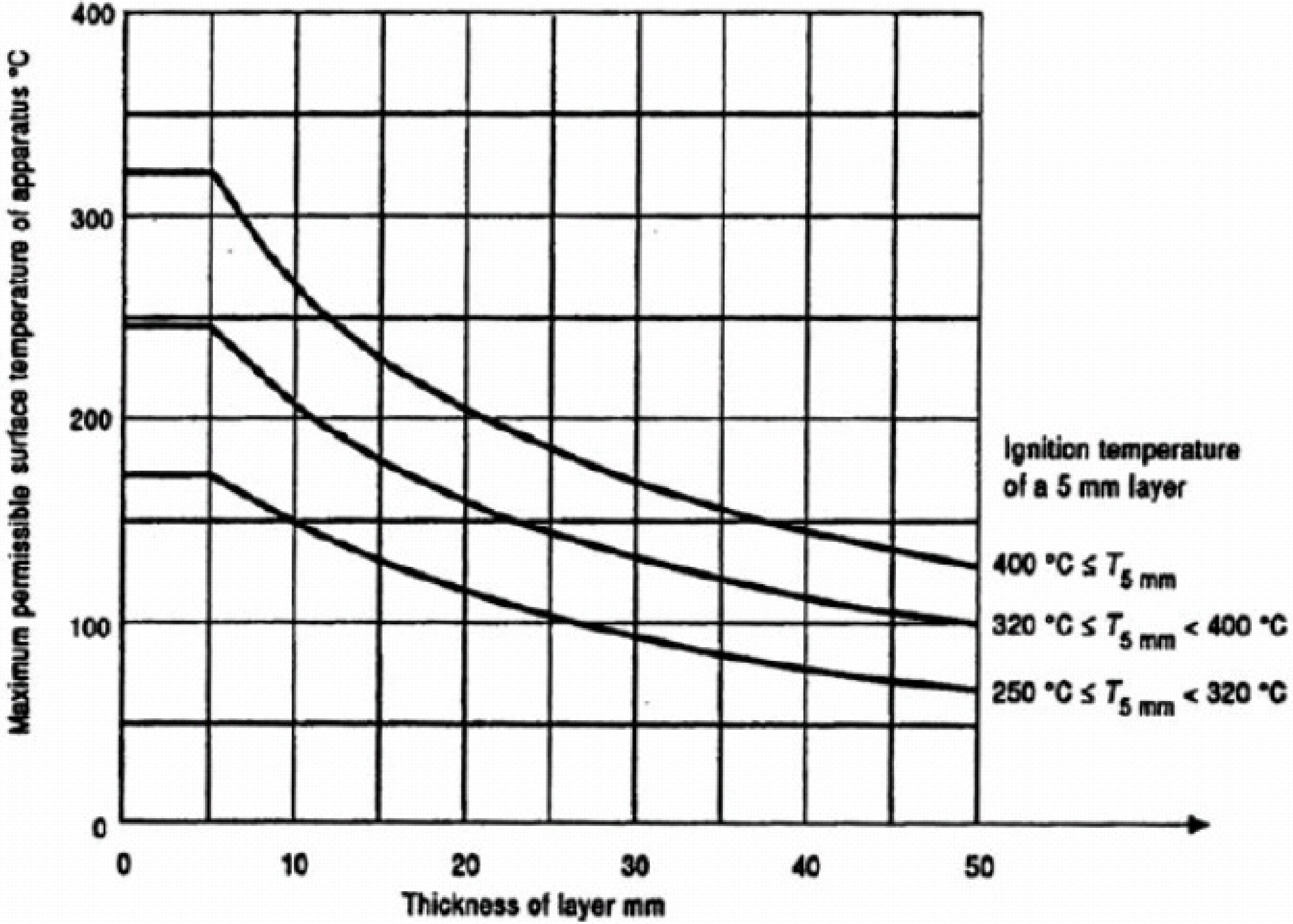
Background:
ASTM E 2021 and IEC 61241-2-1 Tests for Measuring Hot Surface Layer Ignition Temperature

	ASTM	IEC
Particle size	< 75 ㎛	< 200 ㎛
Layer thickness	12.7mm	5mm in priority
Ignition criteria	50℃ above the hot plate	250℃ above the hot plate or 450℃ of dust layer

Thermocouple located at mid-elevation of dust layer in both standards.

Visible glowing or flaming is another ignition criterion.

Dust Layer Thickness Effects in IEC 61241-2-1

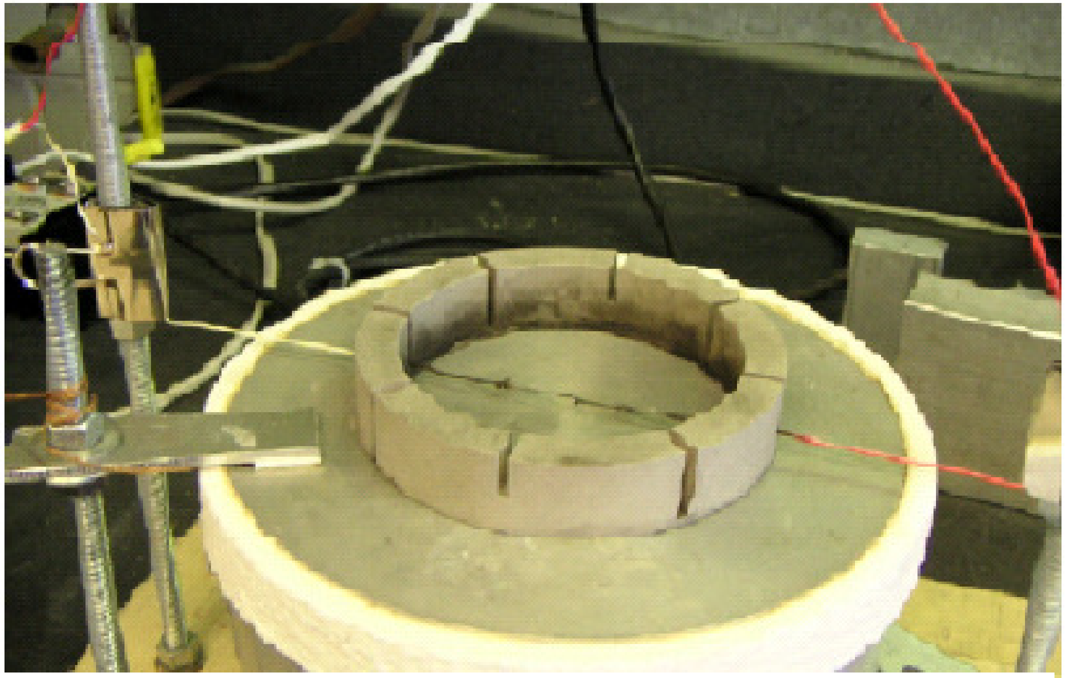


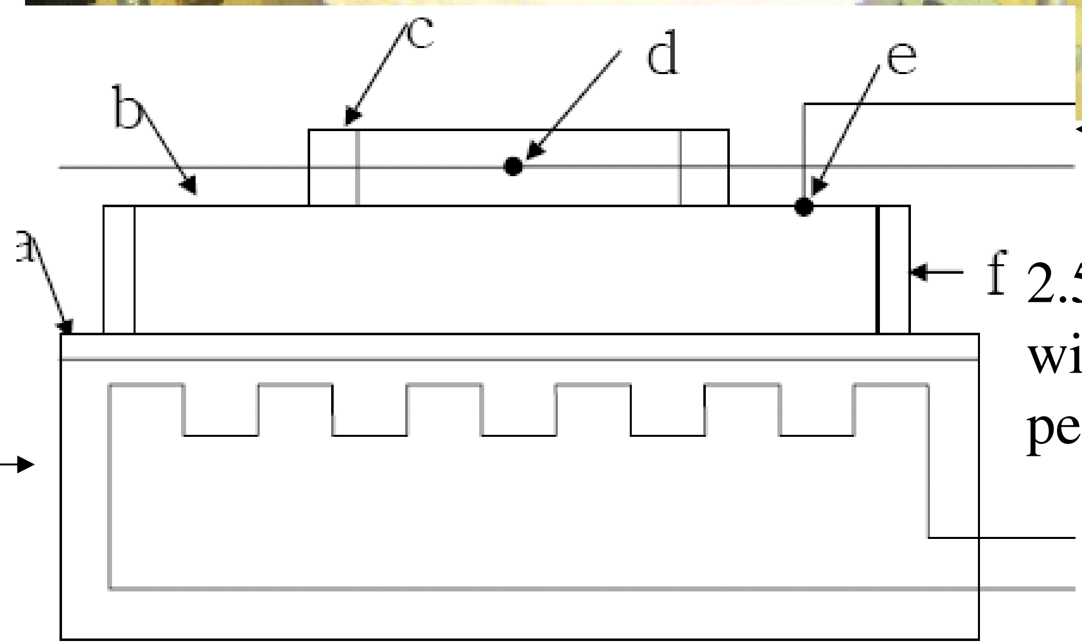
OBJECTIVES of this Paper

1. to explore the possibility of a more objective layer temperature rise criterion for layer ignition;
2. to determine the effects of material additives on minimum hot surface ignition temperatures;
3. to determine the effects of specific ambient air flow rates and velocities on measured values of T_{si}.

Hot Plate and Dust Layer Ring

10 cm ID, 2.5 cm high ring for dust layer





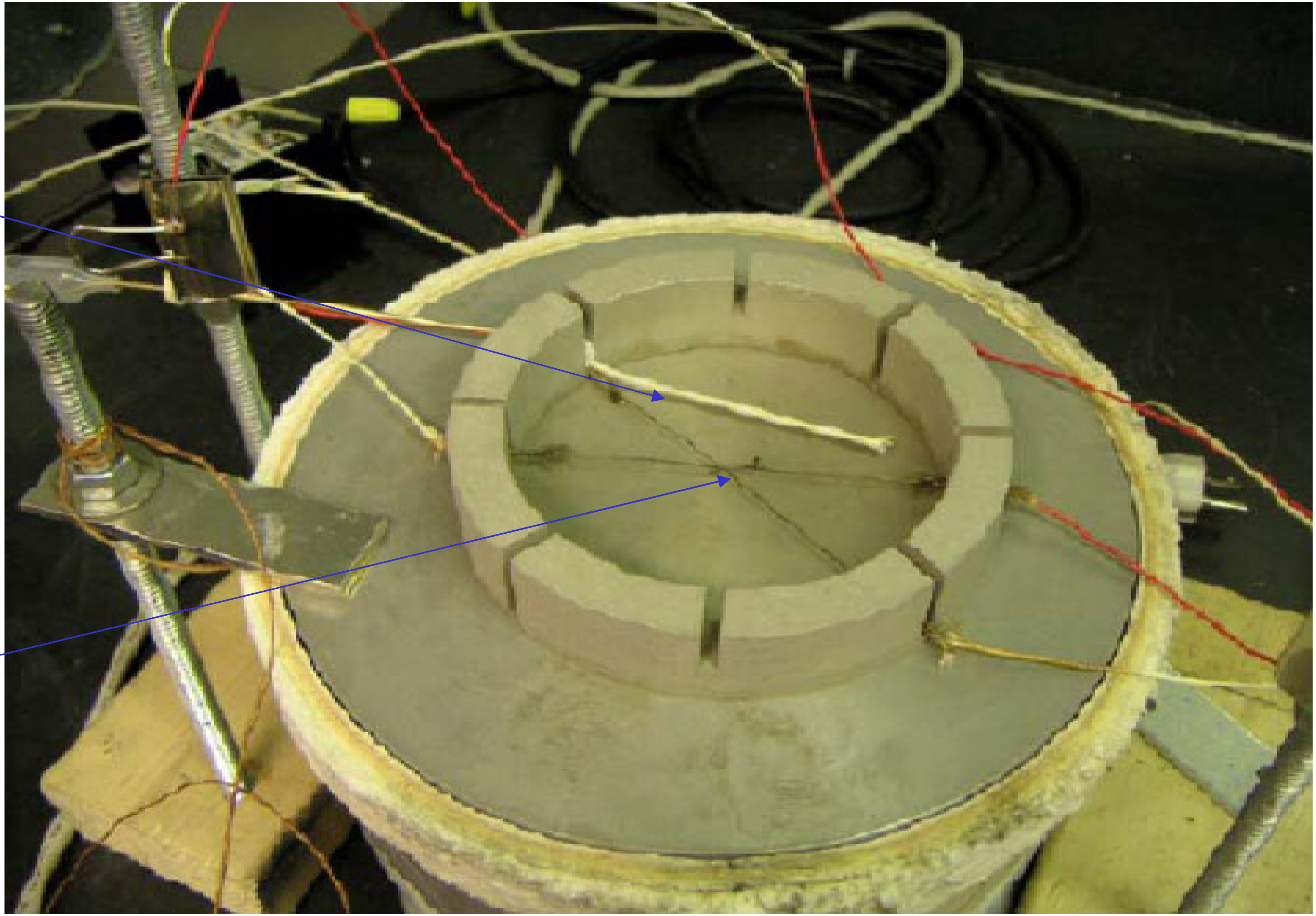
Added Instrumentation for These Tests

- Second thermocouple situated at ¼ elevation (3 mm) of layer
- Air sample in layer connected to Oxygen concentration analyzer in some tests
- Air velocity monitor above dust layer free surface to measure velocity induced by lab fume hood.

Additional Instrumentation

O_2 Sample Probe for some tests

2nd thermo-couple

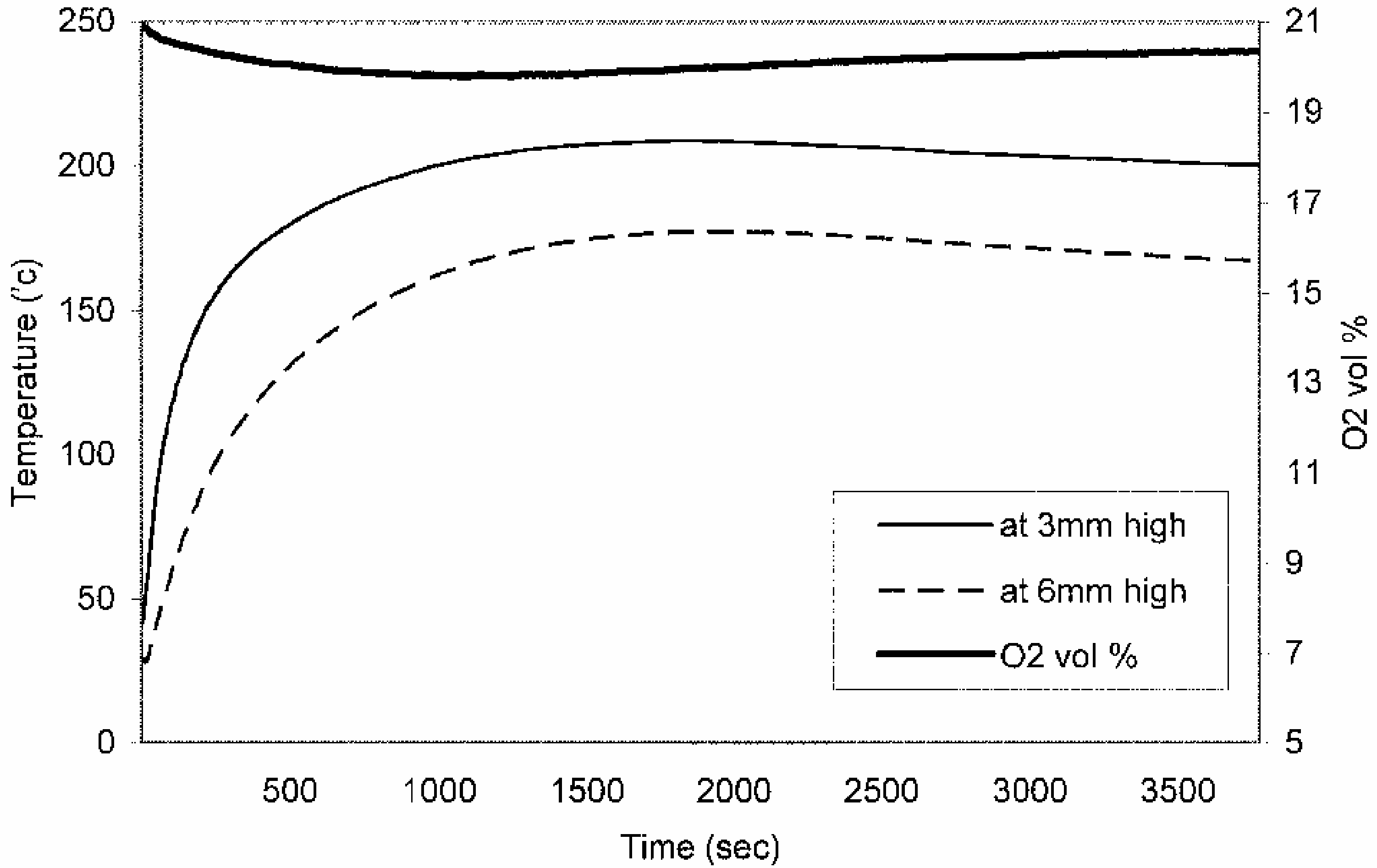


Dust Materials Tested

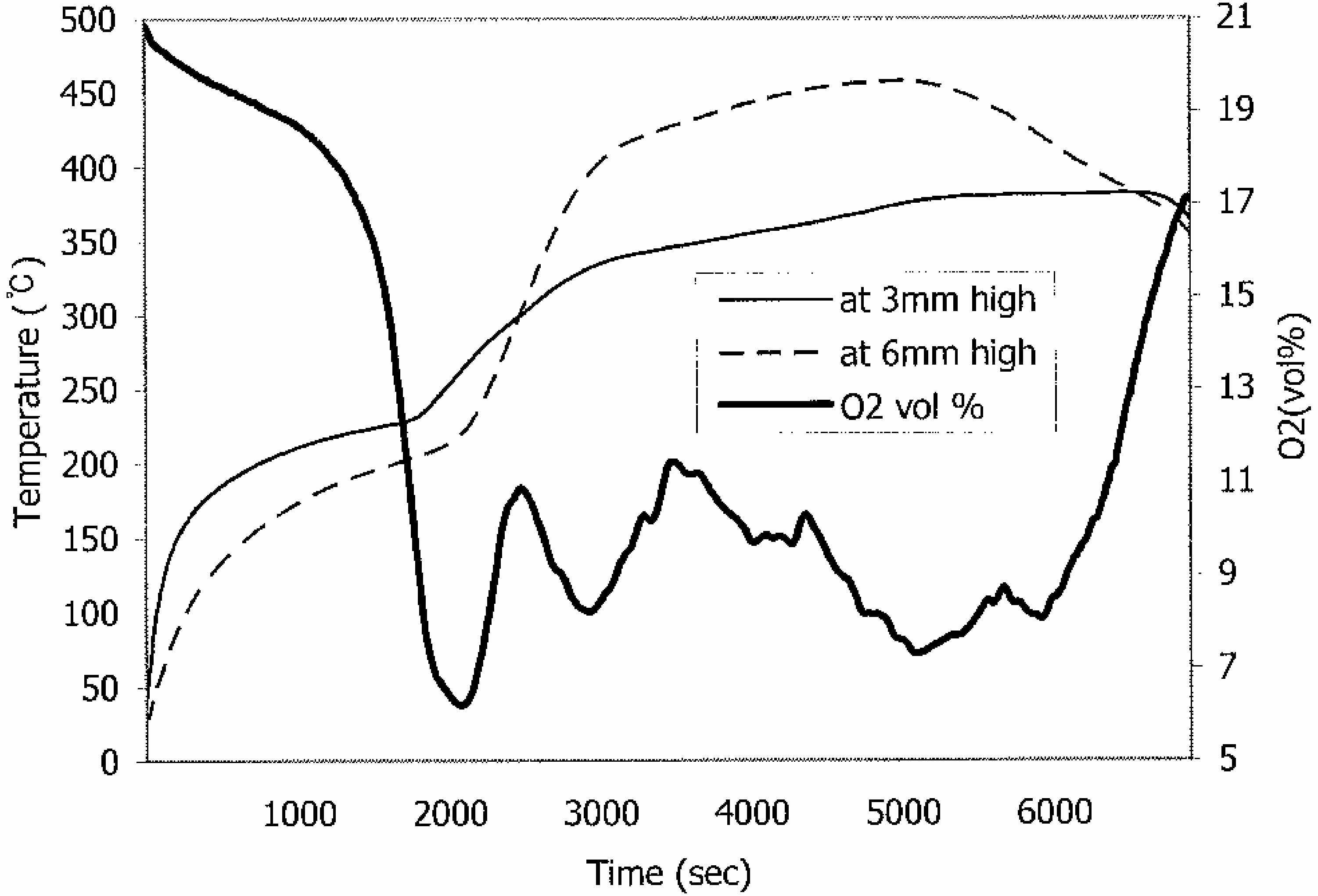
	Bulk density (g/cm^3)	Particle size (μm)	Material supplier
Pittsburgh seam coal	0.553	<75	NIOSH Pittsbugh research Laboratory
Gum Arabic powder	0.388	80% <105	Anonymous
Paper dust from printing press	0.029	<850, >425	Local newspaper company
Brass powder	0.320	<45	NEI-group

Various amounts of stearic acid were added to the brass powder in some tests.

Temperatures and oxygen concentration measured in coal dust layer at a surface temperature of 220°C (no ignition)



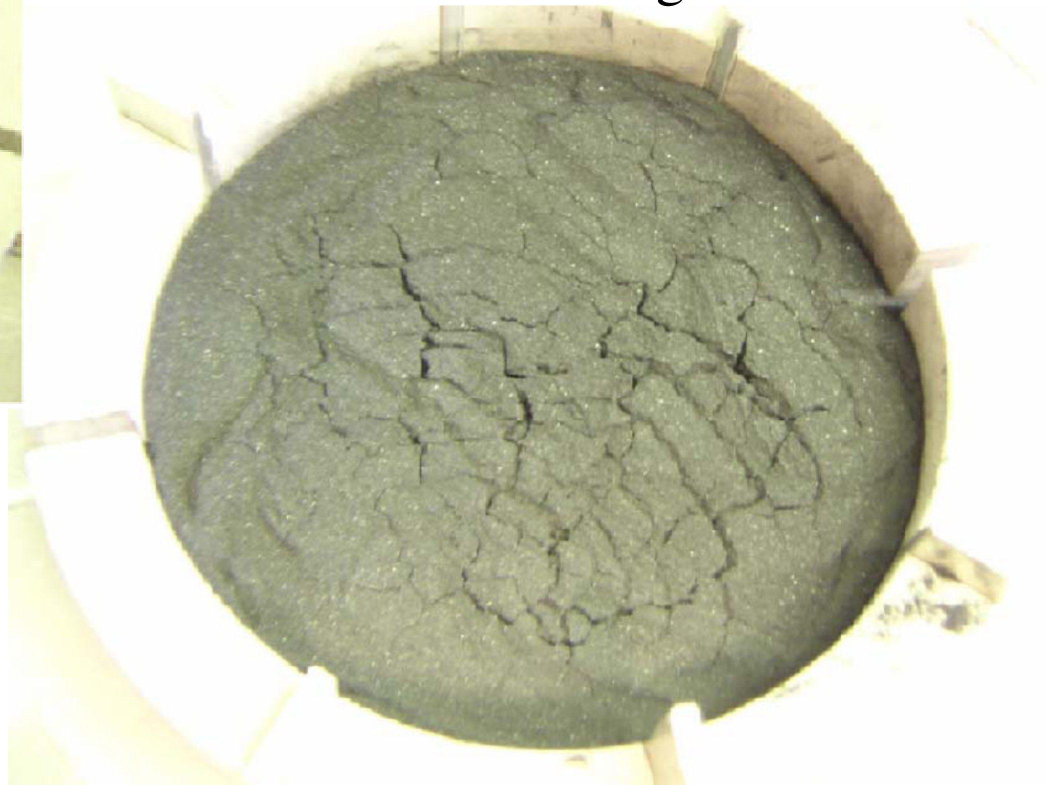
Temperatures measured in coal dust layer at surface temperature of 230^{o}C (ignition)



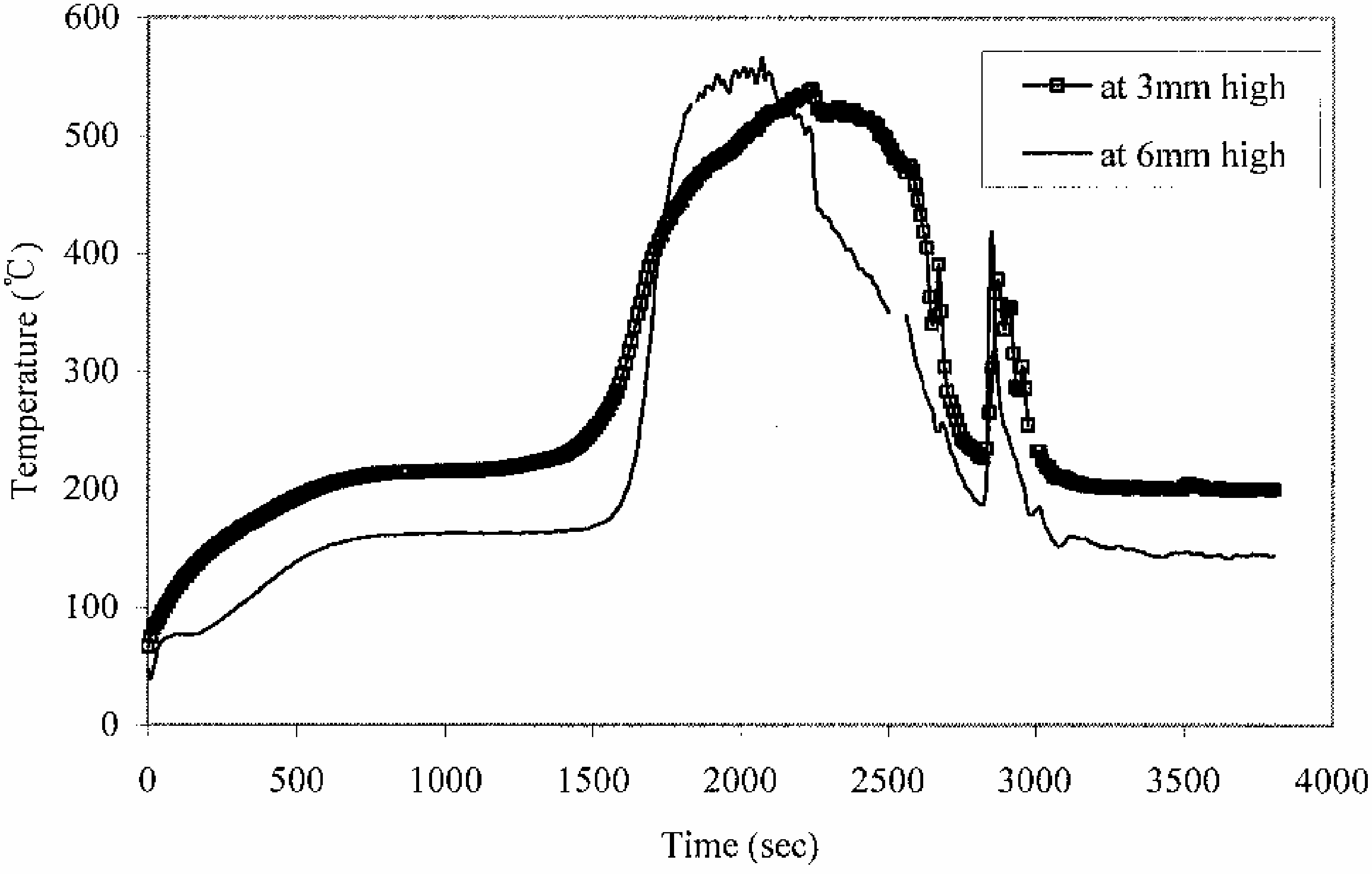
Pittsburgh coal dust at ignition and after burning for > 1 hour

At Ignition

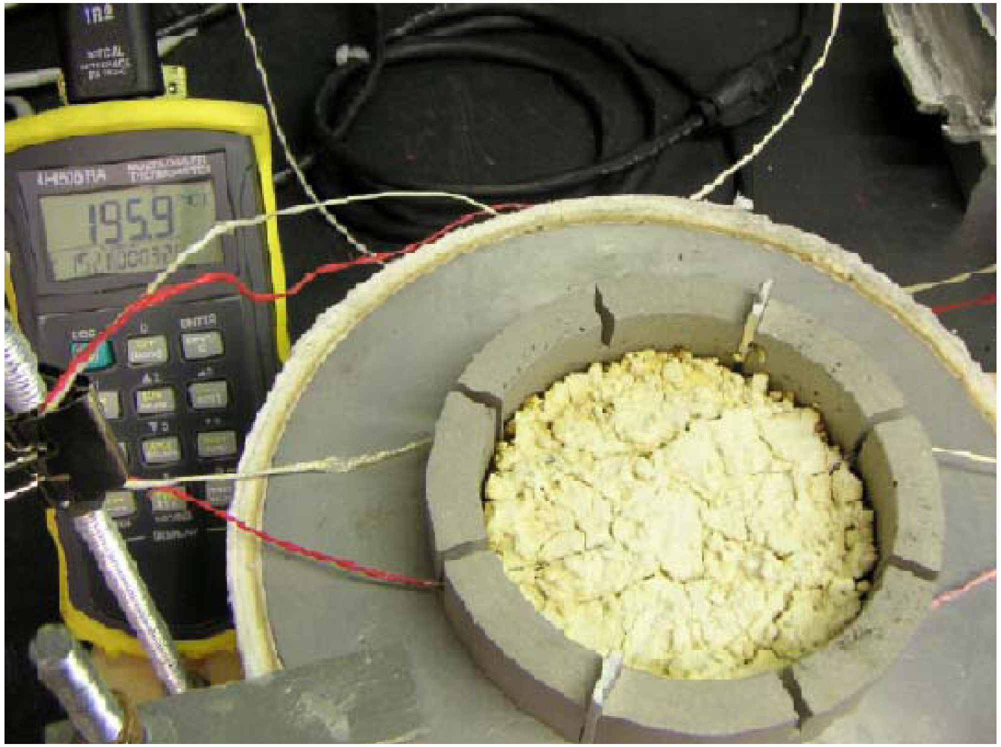
After burning



Temperatures measured in gum powder layer at a surface temperature of 270^{o}C (ignition)



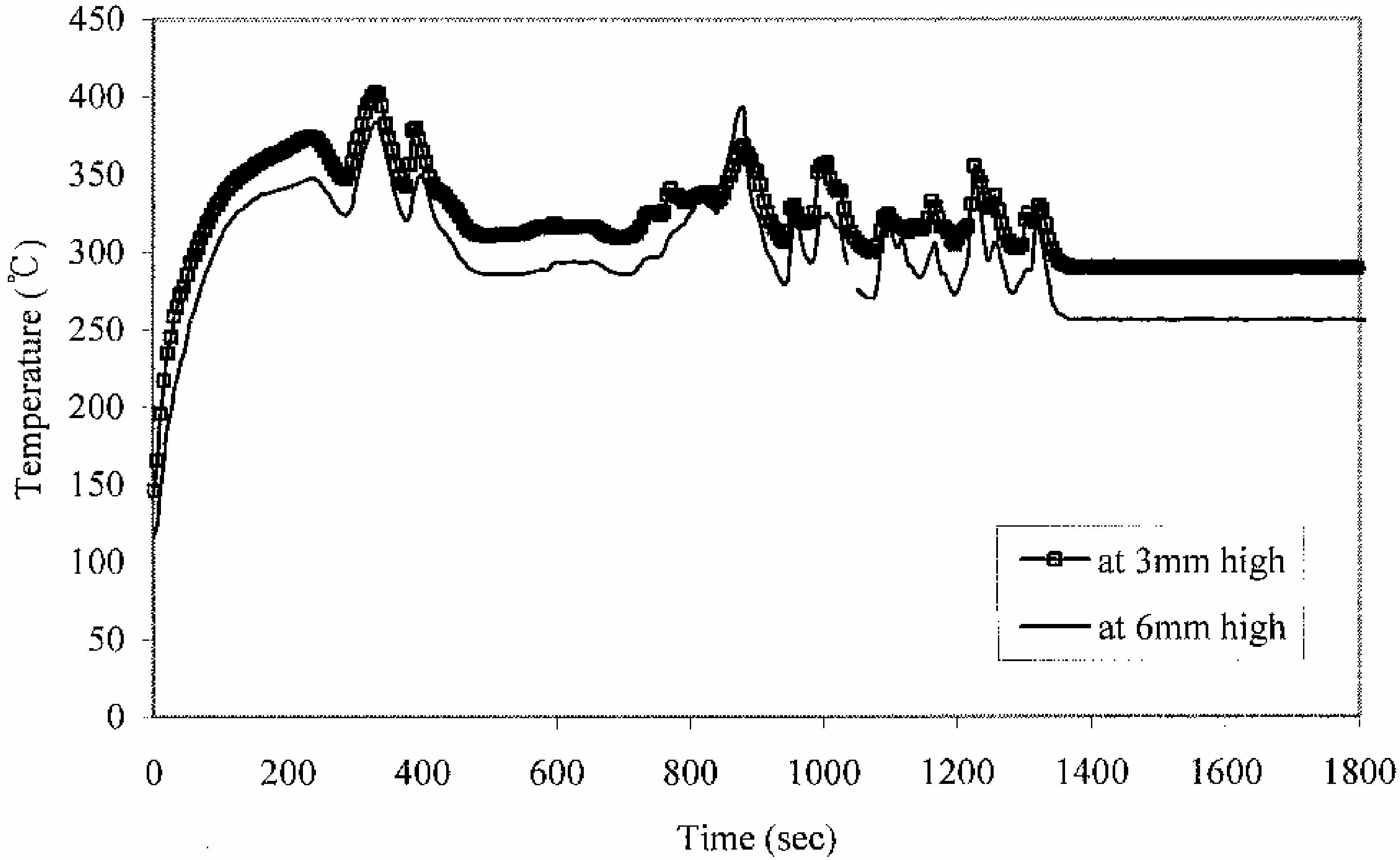
Gum Arabic Powder Before and After Burning



During Heating

After Burning

Temperatures measured in paper dust layer at a surface temperature of 360°C (ignition)

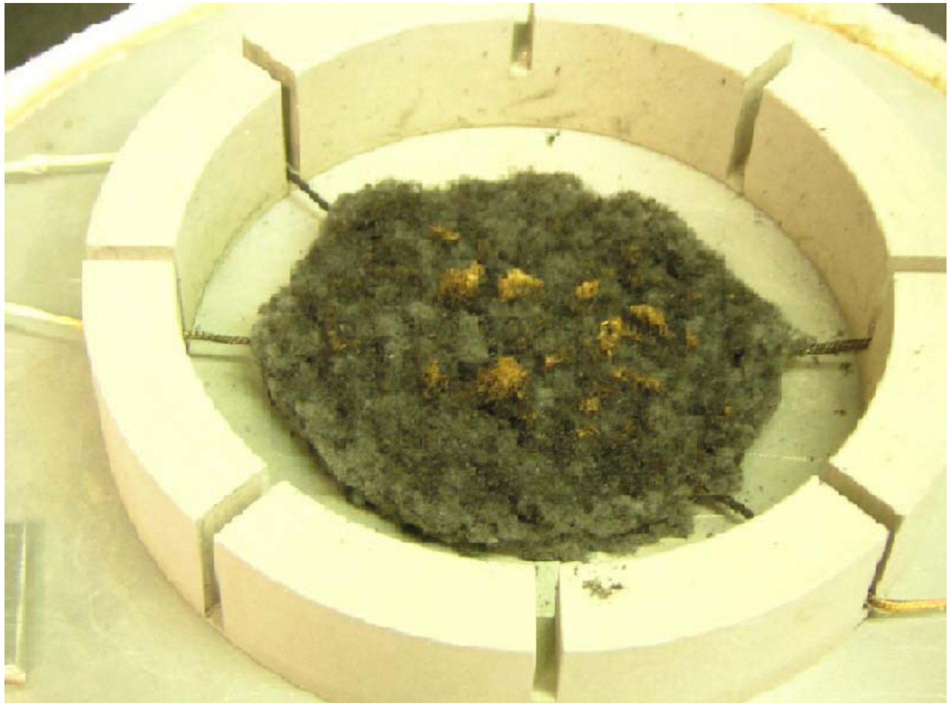


Paper Dust Before and During Burning

Before Test

Void Fraction = 0.95

During Test with surface temperature of 360^{o}C.



Minimum Surface Ignition Temperatures

Coal Dust	220 ^oC
Gum Arabic Powder	270 ^oC
Paper Dust	360 ^oC
Brass Powder alone and with 2% and 4 wt% stearic acid	$>$ 400 ^oC
Brass Powder with 6 wt% stearic acid	$\leq$ 400 ^oC
Brass Powder with 10 wt% stearic acid	180 ^oC

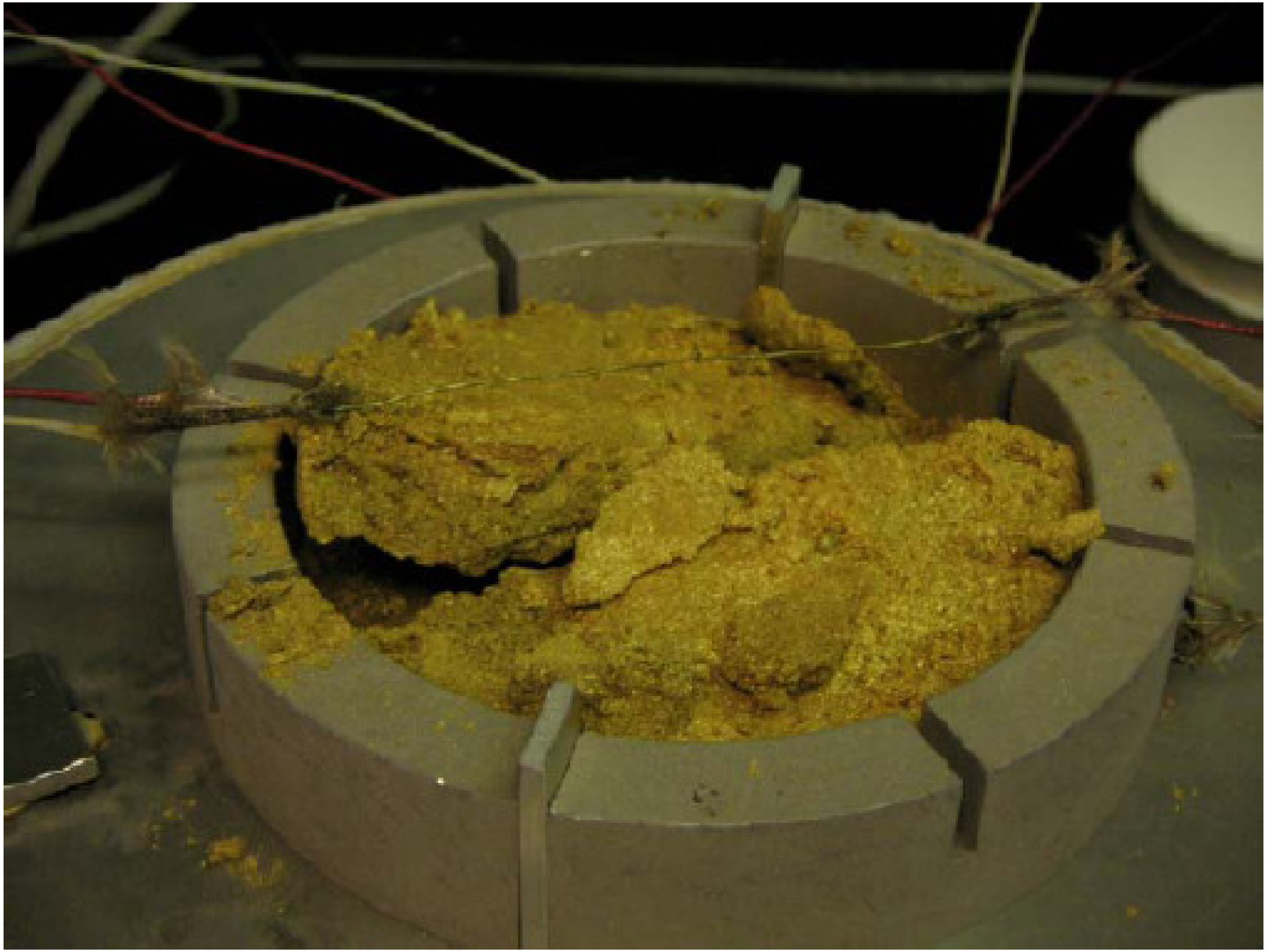
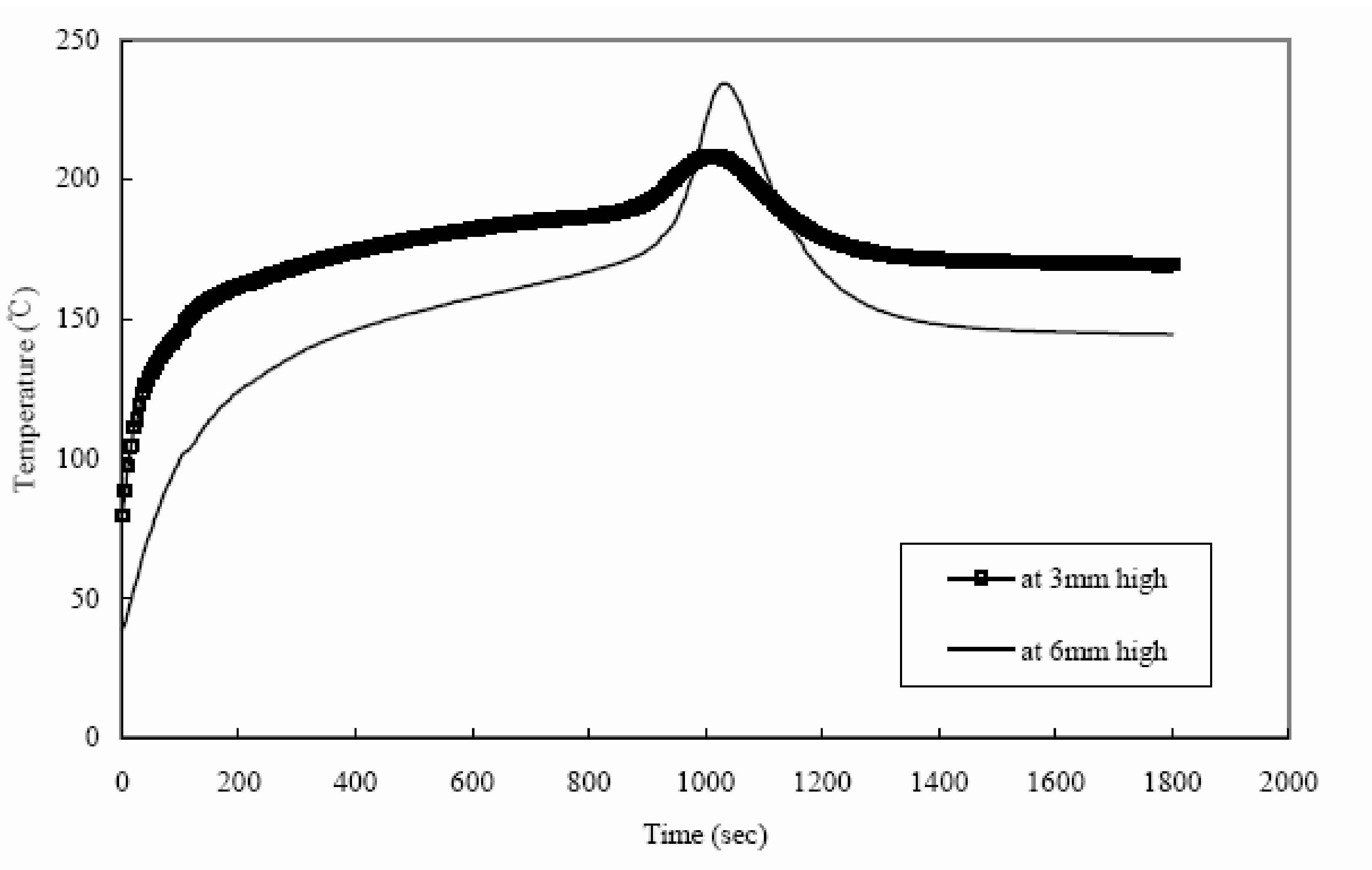


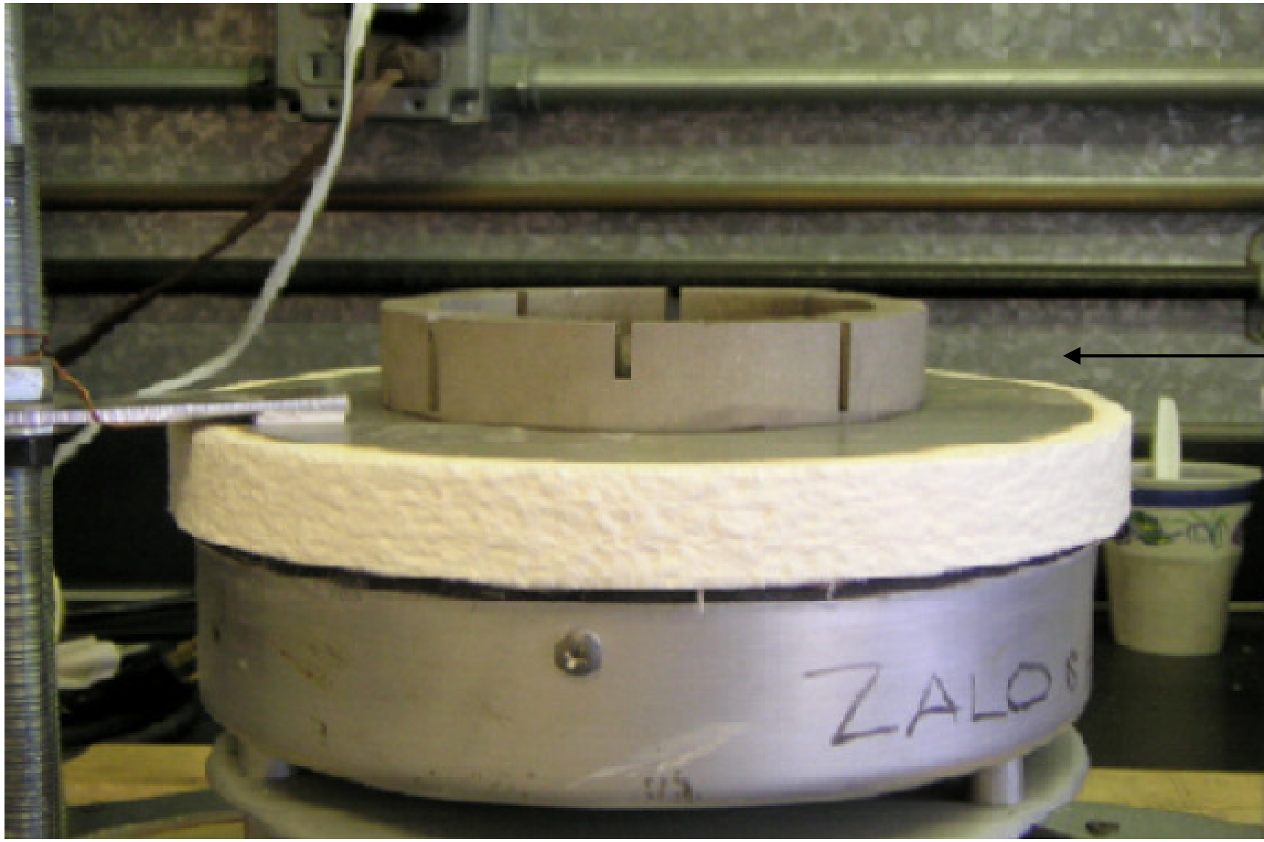
Figure 70 : At the end of test of brass powder with 4% stearic acid at 400℃

Temperatures in Brass Powder + 10% Stearic Acid at a Surface Temperature of 180 ^oC



Lab Hood Induced Air Velocity at Dust Layer Elevation

As measured with hot wire anemometer velocity probe



0.5 cm/s
horizontal
velocity
at 6 mm
elevation

0.5 cm/s Horizontal Air Velocity Effect: Delays ignition but does not change min hot surf temperature

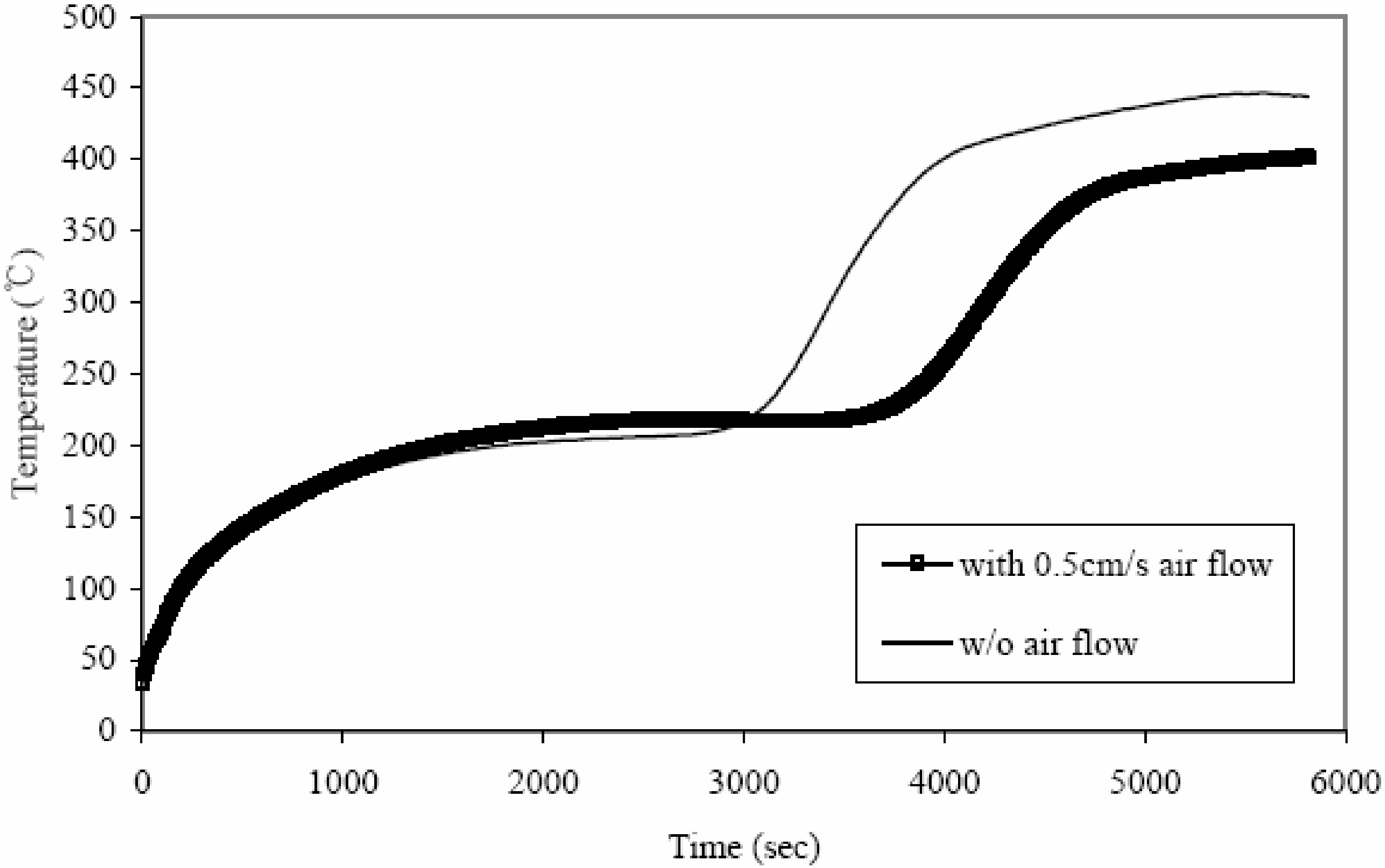
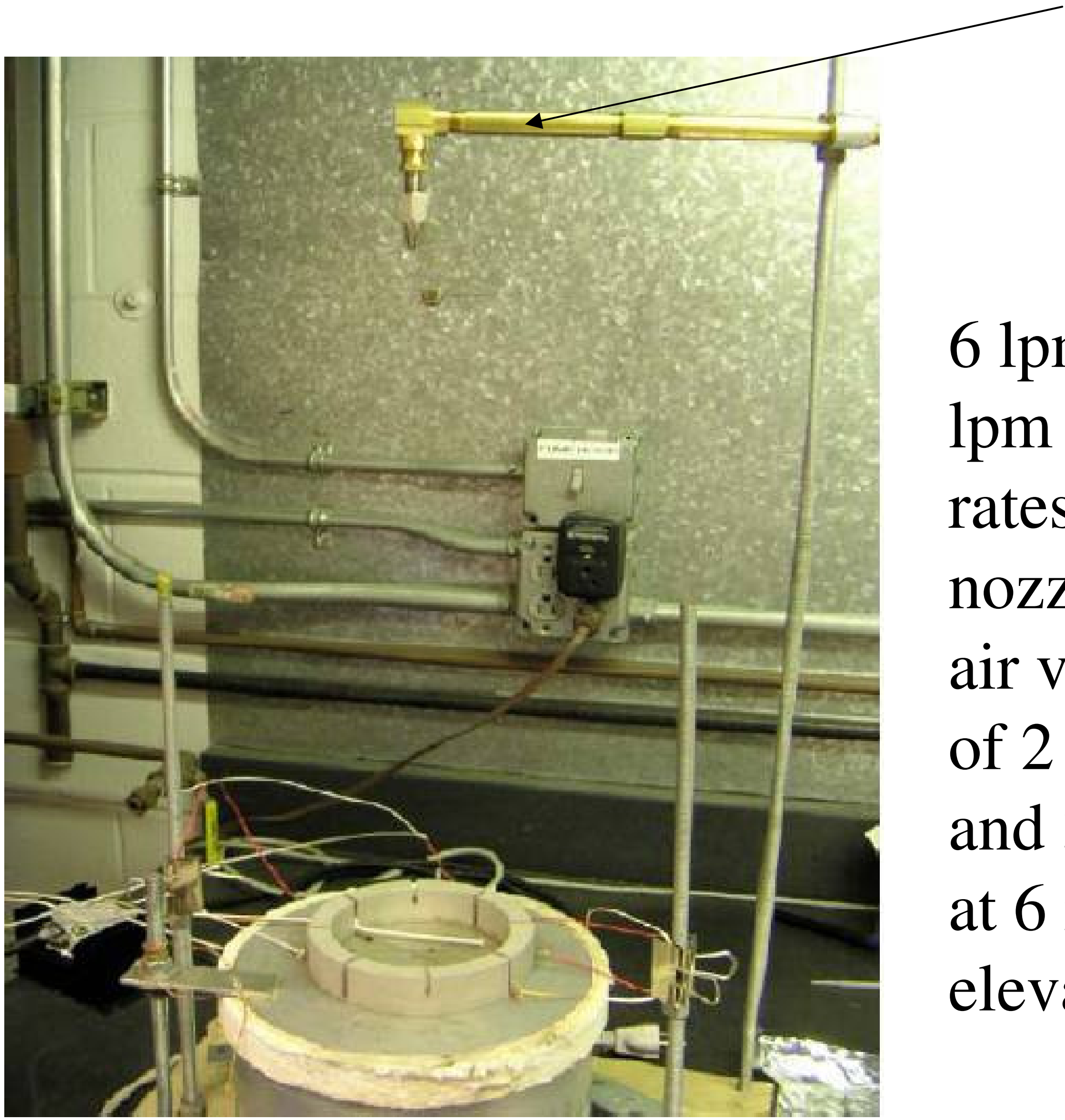


Figure 81 : Pittsburgh seam coal temperatures at 6mm high with and w/o air flow at 220℃

Larger Downward Air Velocities Induced by Air Nozzle



Velocity Probe

6 lpm and 15 lpm air flow rates through nozzle create air velocities of 2 cm/s and 33 cm/s at 6 mm elevation.

Air Flow Effects

- Air velocity of 2.5 cm/s did not affect minimum hot surface ignition temperature measured for Pittsburgh coal. It did delay time of ignition as in case with 0.5 cm/s horizontal air velocity.
- Air velocity of 15 cm/s did increase minimum hot surface ignition temperature of coal from 220 ^{o}C to over 230 ^{o}C.

Other Conclusions

- Dust layer ignition is preceded by the higher elevation (6 mm) thermocouple showing an increase in temperature over the lower elevation (3 mm) thermocouple.
- The crossover of temperatures at the two elevations provide a more meaningful and objective indication of dust layer ignition.
- Dust layer ignition is accompanied by a dramatic decrease in oxygen concentration within the dust layer. This decrease seems to be due to O_2-limited smoldering in dust layer.

Hot Wire Anemometer for Air Velocity Measurement

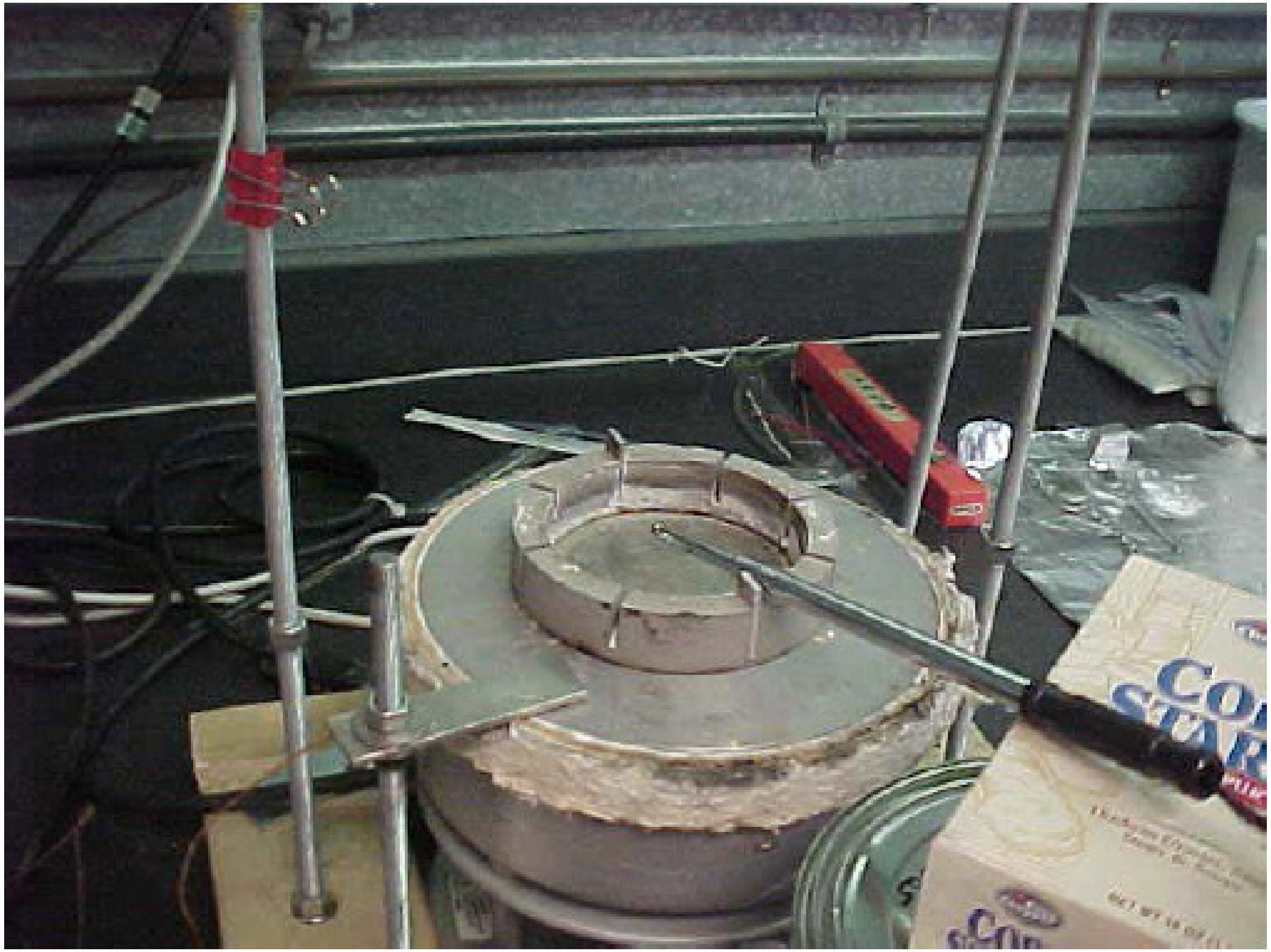


Figure 79 : Air flow velocity measurement