

## Sample Research Plan / Final Paper No. 1

Initial Research Plan – 3-5 pages, double spaced, including Working Title, Statement of Problem or Question, Background Research, Hypothesis, Bibliography. (All items indicated in sample are blue)

Once initial research plan has been submitted, reviewed, and approved, students should continue developing their experiment.

Experiment – Resubmit Initial Research Plan, now including: Proposed Step by Step Procedure and Complete Materials List. (Added items indicated in sample in green)

Once procedure has been submitted, reviewed and approved, students can begin data collection.

Data – collect and record experimental data. Analyze results and use to create appropriate tables, graphs, and/or statement of results. Resubmit Research Plan (blue & green items) and include data/results. (Added items indicated in sample in red)

Now student should write up a discussion of the results and their conclusions, including whether the experiment proved or disproved their hypothesis. (Added items indicated in sample in black) In this sample paper, the student should have included more discussion in both the results and the conclusions. He did so in his oral presentations, but that information should be in the written work as well.

Student should proof their entire paper, then have a teacher, parent, or mentor also proof the paper. Using the information from the final completed research paper, write an abstract of 250 words or less. Instructions may be found on the UMVSD website.

Submit the abstract before the stated deadline.

## **Sample Research Plan / Final Paper No. 1**

**Date:**

**Student(s) Name:** Thomas Chaney

**School & Grade:** Tippecanoe High School, Grade 9

**Title:** Pyrogel, the Future of Fire Defense (You can start with a working title and change it as project develops)

### **Question**

What Material is best suited for use in a firefighter's jacket? (You can narrow the question during background research)

### **Hypothesis**

The pyrogel fabric will have the lowest heat conductivity and flame resistance compared to the other materials. ( Do not declare a hypothesis until after you complete background research)

### **Research**

#### **Fires**

In 30 seconds or less a small flame can get out of control and turn into a house fire. It takes less than 5 minutes for the flames to spread and heat up the entire house. Heat from fires is more dangerous than the actual flames. Temperatures in a house fire can be 100 degrees at floor level and 600 degrees at eye level. This amount of heat can char and melt clothes and scorch your lungs. In some cases after a burning room is vented a flashover will occur where everything ignites at once.

The science of how chemistry, heat transfer, fluid mechanics, and fire science work together to effect fire behavior is Fire Dynamics. Webster’s dictionary defines fire as, “an exothermic chemical reaction that emits heat and light.” Fire is quantified in heat energy, which is a type of energy categorized by the shaking of molecules. Heat energy is measured in Joules (J), Calories (1 Calorie=4.18 J), or BTU’s (1 BTU =1055 J). Temperature is a measure of heat based on a scale and a reference point. It can be measured in degrees Fahrenheit or degrees Celsius. Temperature references from the national institute of standards and technology:

<u>°C</u>	<u>°F</u>	<u>Response</u>
37	98.6	Normal human oral/body temperature
44	111	Human skin begins to feel pain
48	118	Human skin receives a first degree burn injury
55	131	Human skin receives a second degree burn injury
62	140	A phase where burned human tissue becomes numb
72	162	Human skin is instantly destroyed
100	212	Water boils and produces steam
140	284	Glass transition temperature of polycarbonate
230	446	Melting temperature of polycarbonate
250	482	Charring of natural cotton begins
>300	>572	Charring of modern protective clothing fabrics begins
>600	>1112	Temperatures inside a post-flashover room fire

Heat transfer is how the heat from a fire moves. As the second law of thermodynamics state, hot moves towards cold. There are three ways it accomplishes this. Conduction is the transfer of heat within solids or between touching solids for example a pot being heated up on a stovetop. Convection is heat transfer by the movement of liquids or gasses. And finally Radiation is heat moving by electromagnetic waves which in most cases is light.

## **Firefighter's Injuries**

About 100 firefighters are killed each year and tens of thousands are injured. A large numbers of these injuries unsurprisingly are burns and might be prevented through better protective equipment. Right now Firefighters PPE or personal protective equipment consists of their turnout gear and SCBA (self-contained breathing apparatus). Their turnout gear which protects their body from the fire is made up of 3 layers. First is the Kevlar/ Nomex outer layer for direct flame protection, the vapor barrier to prevent steam burns, and the in thermal barrier insulates the firefighter from the heat of the fire.

## **Procedures**

### **Heat Test**

1. Cut material into a 12.7 cm by 12.7 cm square and 0.508 cm thick.
2. Place first material centered on the testing door window and bolt on the other side snug.
3. Put both thermocouples into a cup of water and note the temperature difference if any.
4. Attach thermocouples to both sides of the material.
5. Place test door in the open toaster over and set the toaster oven to 232 Degrees Celsius.
6. Turn on oven and record outside and inside temperature every 15 seconds for 3 minutes, 30 seconds and any observations.
7. Turn off oven remove door and turn on fan to cool.
8. Wait until the oven reaches room temperature and repeat 5 times for each material.

## Flame test

1. Use Already cut material and place onto burn apparatus
2. Attach Thermocouple to outside of material and record initial temp.
3. Fill metal dish with 1 ml of 91% isopropyl alcohol
4. Place metal dish between the lines
5. Light the dish of alcohol and start timer
6. Record observations and temperature every 10 seconds for 50 seconds
7. Repeat 3 times for each material

## Materials

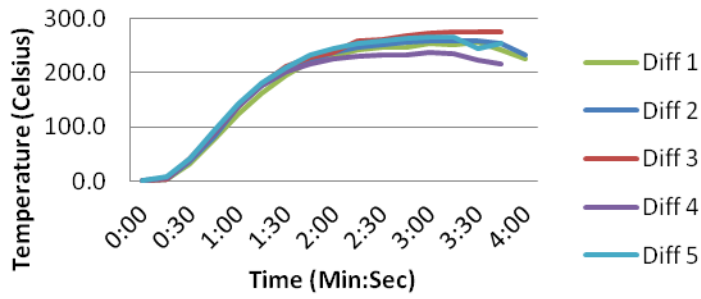
- 2 voltmeters
- 2 thermocouples
- 1 toaster oven
- Heat test apparatus
- Flame test apparatus
- 91% isopropyl alcohol
- Small metal dish
- lighter
- Fire extinguisher
- Safety goggles
- Timer
- Fiberglass insulation
- Rock Wool insulation
- Pyrogel
- Aerogel
- Fire suit insulation material

# Data

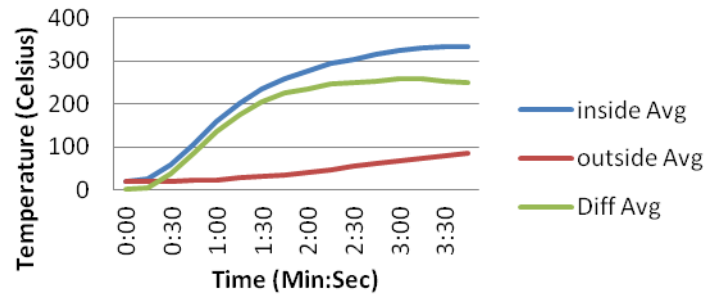
## Aerogel

Min:Sec	in 1	out 1	Diff 1	in 2	out 2	Diff 2	in 3	out 3	Diff 3	in 4	out 4	Diff 4	in 5	out 5	Diff 5
0:00	19	19	0.0	18	18	0.0	18	18	0.0	21	21	0.0	22	21	1.0
0:15	23	20	3.0	22	18	4.0	23	19	4.0	26	21	5.0	28	21	7.0
0:30	53	21	32.0	54	18	36.0	60	19	41.0	61	21	40.0	62	21	41.0
0:45	99	22	77.0	101	20	81.0	109	21	88.0	111	23	88.0	115	22	93.0
1:00	150	25	125.0	160	22	138.0	161	22	139.0	163	25	138.0	168	24	144.0
1:15	191	28	163.0	200	25	175.0	203	24	179.0	205	30	175.0	210	28	182.0
1:30	228	32	196.0	229	28	201.0	237	26	211.0	236	35	201.0	238	29	209.0
1:45	257	35	222.0	253	31	222.0	260	31	229.0	258	41	217.0	264	32	232.0
2:00	271	40	231.0	274	36	238.0	283	45	238.0	276	50	226.0	280	36	244.0
2:15	289	46	243.0	291	43	248.0	300	41	259.0	291	60	231.0	295	41	254.0
2:30	302	54	248.0	303	52	251.0	309	48	261.0	302	69	233.0	304	46	258.0
2:45	310	62	248.0	315	59	256.0	321	53	268.0	311	78	233.0	315	52	263.0
3:00	323	68	255.0	325	66	259.0	330	58	272.0	323	86	237.0	324	57	267.0
3:15	328	75	253.0	333	74	259.0	338	62	276.0	329	94	235.0	330	63	267.0
3:30	340	83	257.0	340	81	259.0	345	70	275.0	323	99	224.0	312	67	245.0

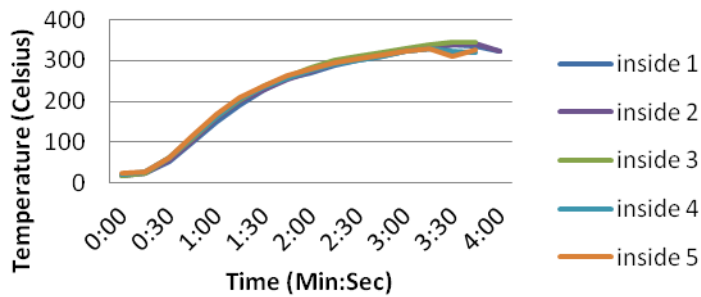
### Aerogel Difference



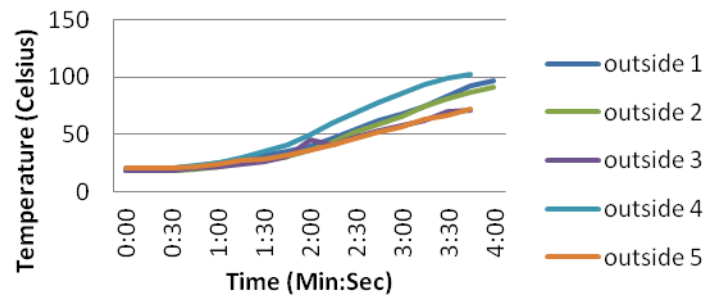
### Aerogel Average



### Aerogel Inside

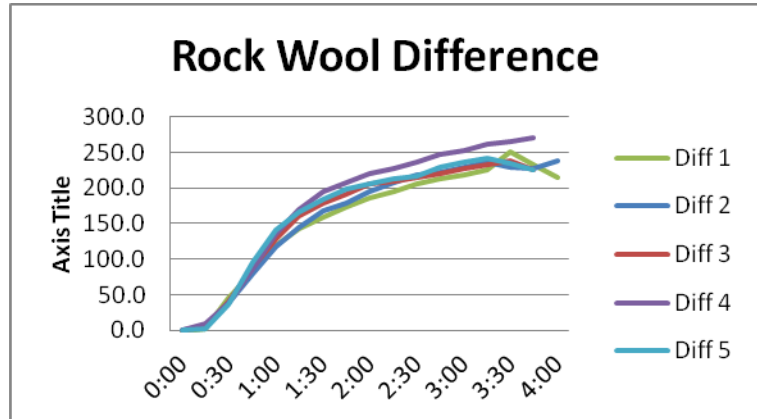
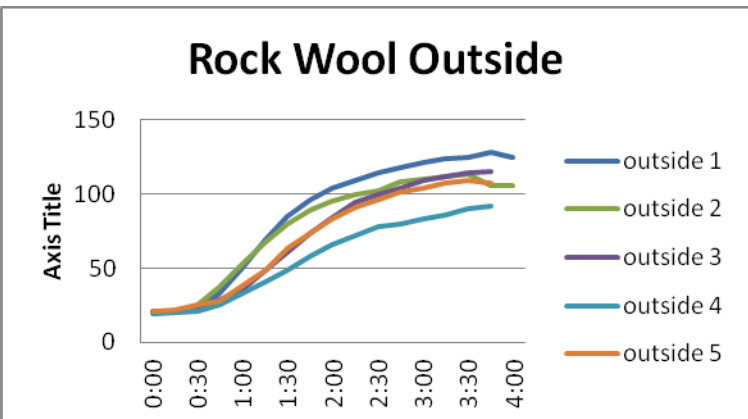
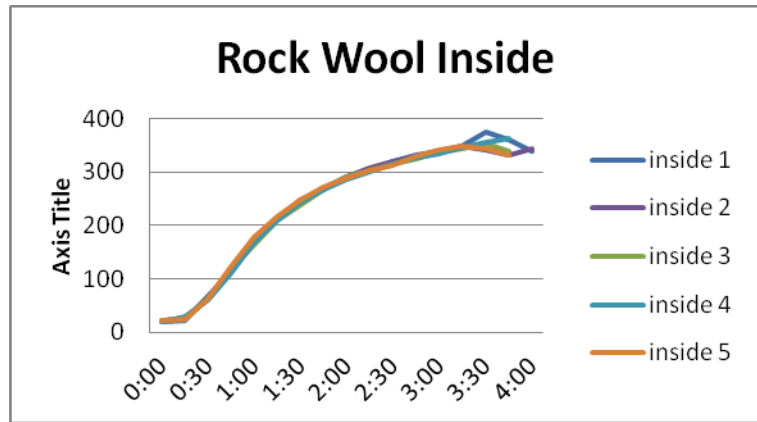
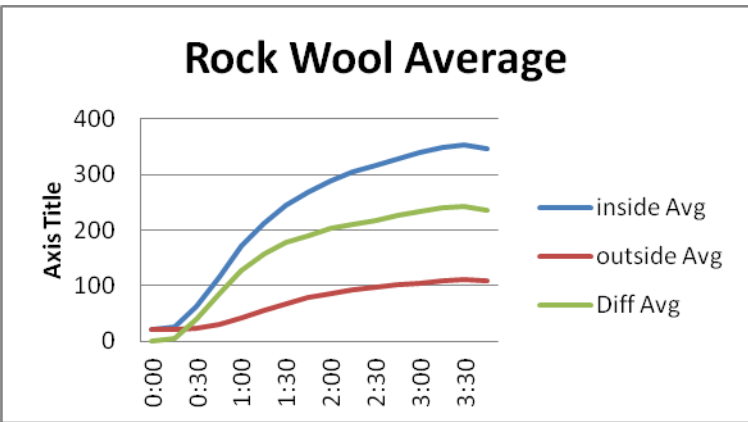


### Aerogel Outside



## Rock Wool

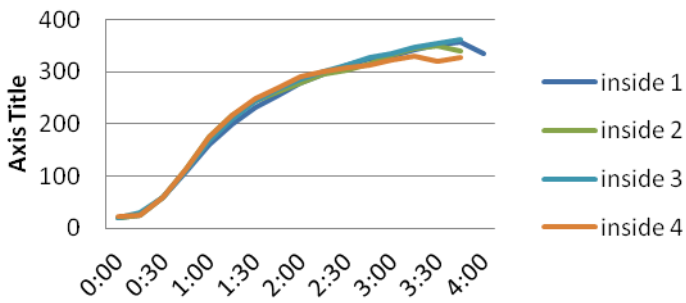
Min:Sec	In 1	out 1	Diff 1	in 2	out 2	Diff 2	In 3	out 3	Diff 3	in 4	out 4	Diff 4	In 5	Out 5	Diff 5
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0:15	23	20	3.0	26	21	5.0	25	21	4.0	30	20	10.0	25	22	3.0
0:30	68	23	45.0	63	25	38.0	63	23	40.0	60	21	39.0	62	25	37.0
0:45	114	33	81.0	117	37	80.0	118	29	89.0	111	25	86.0	123	28	95.0
1:00	170	50	120.0	170	53	117.0	165	36	129.0	168	33	135.0	178	38	140.0
1:15	212	69	143.0	212	68	144.0	209	49	160.0	210	41	169.0	216	49	167.0
1:30	244	85	159.0	248	80	168.0	239	61	178.0	244	49	195.0	248	63	185.0
1:45	270	96	174.0	268	89	179.0	266	74	192.0	266	58	208.0	273	74	199.0
2:00	290	104	186.0	290	95	195.0	290	84	206.0	286	66	220.0	289	83	206.0
2:15	304	109	195.0	307	100	207.0	304	94	210.0	300	72	228.0	304	91	213.0
2:30	319	114	205.0	320	102	218.0	315	100	215.0	314	78	236.0	313	96	217.0
2:45	331	118	213.0	330	108	222.0	325	104	221.0	327	80	247.0	330	101	229.0
3:00	340	121	219.0	339	110	229.0	336	109	227.0	335	83	252.0	341	104	237.0
3:15	349	124	225.0	348	112	236.0	345	112	233.0	347	86	261.0	349	107	242.0
3:30	375	125	250.0	342	113	229.0	353	114	239.0	356	90	266.0	343	109	234.0



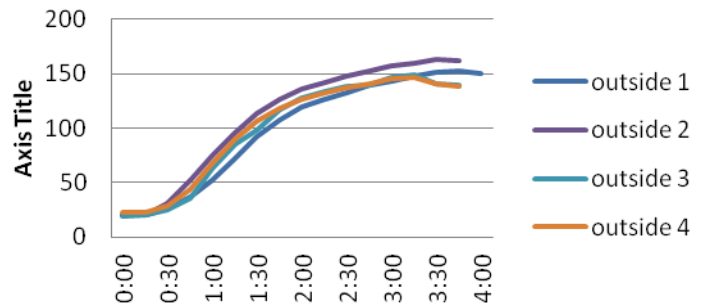
## Fiberglass

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0:00	20	20	0.0	20	20	0.0	20	19	1.0	23	23	0.0	23	25	-2.0
0:15	25	21	4.0	25	21	4.0	30	20	10.0	26	23	3.0	26	25	1.0
0:30	60	26	34.0	60	31	29.0	60	25	35.0	60	29	31.0	60	31	29.0
0:45	110	37	73.0	114	52	62.0	111	36	75.0	115	44	71.0	115	46	69.0
1:00	161	52	109.0	176	75	101.0	168	63	105.0	175	68	107.0	175	70	105.0
1:15	200	72	128.0	216	96	120.0	210	85	125.0	218	90	128.0	218	92	126.0
1:30	231	92	139.0	244	114	130.0	244	98	146.0	248	106	142.0	248	108	140.0
1:45	255	108	147.0	261	127	134.0	266	117	149.0	268	118	150.0	268	120	148.0
2:00	278	119	159.0	279	136	143.0	286	128	158.0	291	127	164.0	291	129	162.0
2:15	295	127	168.0	296	142	154.0	300	134	166.0	301	133	168.0	301	135	166.0
2:30	312	133	179.0	303	148	155.0	314	138	176.0	308	137	171.0	308	139	169.0
2:45	325	140	185.0	316	153	163.0	327	140	187.0	312	141	171.0	312	143	169.0
3:00	331	143	188.0	333	157	176.0	335	146	189.0	323	145	178.0	323	147	176.0
3:15	343	148	195.0	345	160	185.0	347	149	198.0	330	147	183.0	330	149	181.0
3:30	352	151	201.0	350	163	187.0	356	141	215.0	320	141	179.0	320	143	177.0

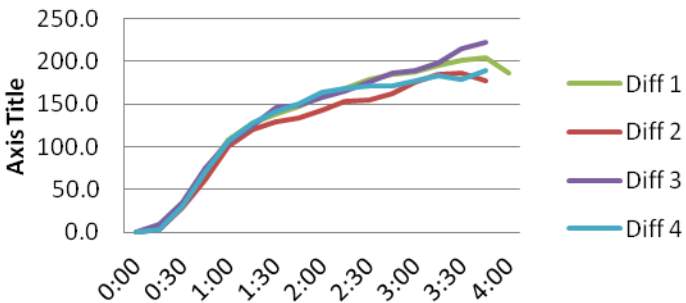
### Fiberglass Inside



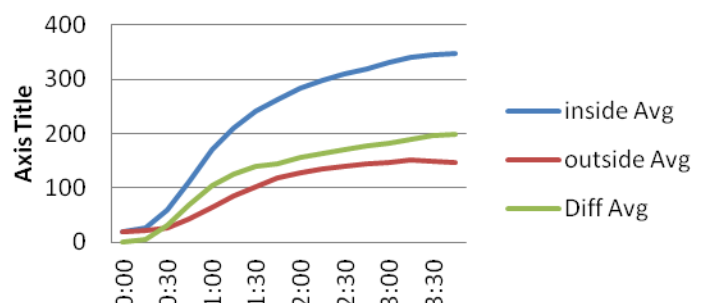
### Fiberglass Outside



### Fiberglass Difference



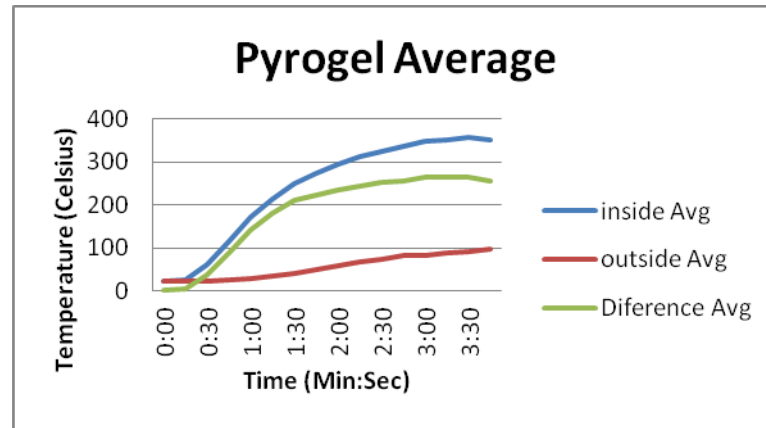
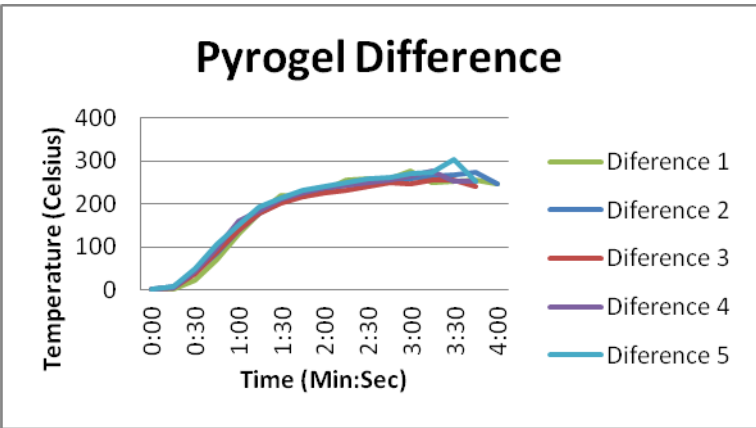
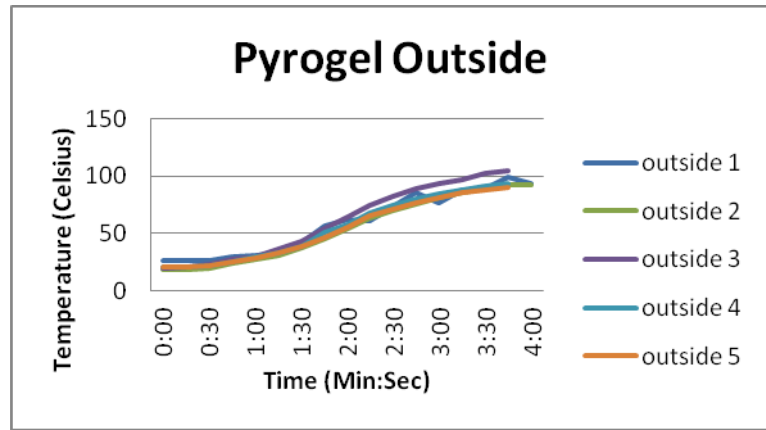
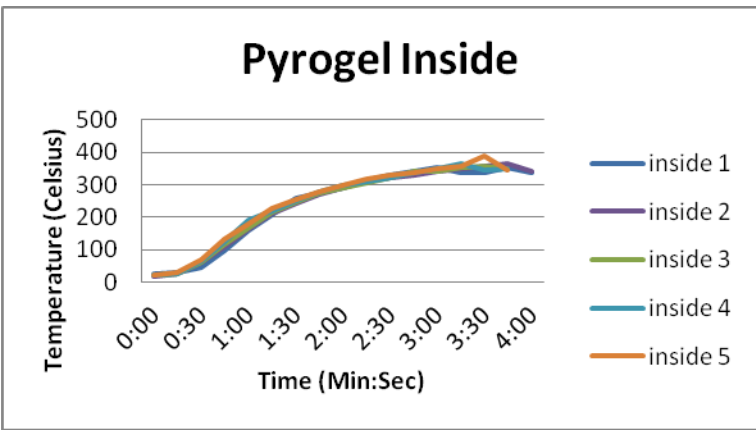
### Fiberglass Average





## Pyrogel

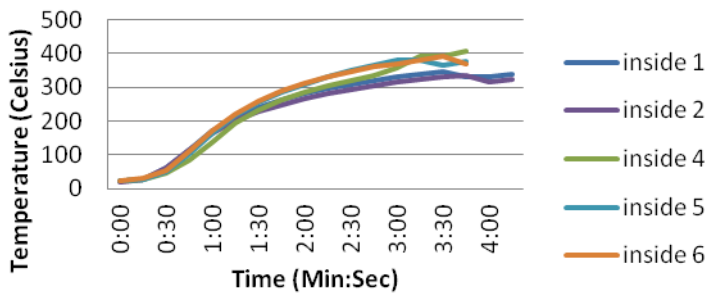
Min:Sec	in 1	out 1	Diff 1	in 2	out 2	Diff 2	in 3	out 3	Diff 3	in 4	out 4	Diff 4	in 5	out 5	Diff 5
0:00	26	27	2	19	19	0	20	20	0	21	21	0	21	21	0
0:15	27	27	3	26	19	7	24	21	3	26	21	5	29	21	8
0:30	47	27	22	59	20	39	60	23	37	64	22	42	70	22	48
0:45	97	30	69	110	24	86	115	27	88	122	25	97	130	25	105
1:00	158	31	129	165	27	138	168	30	138	190	30	160	180	29	151
1:15	208	33	177	210	31	179	213	36	177	218	33	185	225	33	192
1:30	258	42	218	243	37	206	245	43	202	249	39	210	253	39	214
1:45	272	56	218	270	45	225	272	54	218	278	51	227	278	47	231
2:00	291	62	231	290	54	236	291	64	227	296	58	238	298	56	242
2:15	314	61	254	308	63	245	307	75	232	311	68	243	316	66	250
2:30	329	73	257	321	70	251	322	82	240	323	74	249	329	71	258
2:45	341	86	258	331	76	255	339	89	250	337	80	257	338	77	261
3:00	352	77	278	340	81	259	342	94	248	350	85	265	350	81	269
3:15	336	88	250	350	86	264	352	97	255	363	88	275	358	86	272
3:30	338	89	251	357	89	268	358	102	256	343	91	252	390	88	302



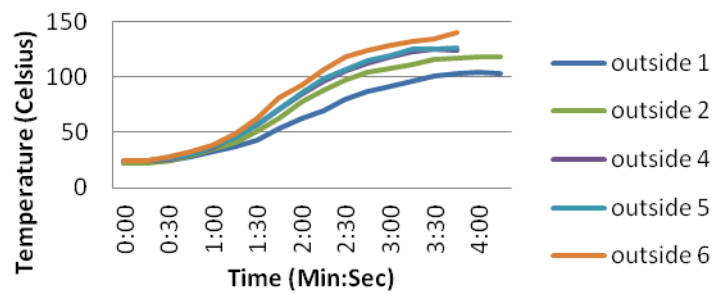
## Fire Suit

Min:Sec	In 1	out 1	Diff 1	in 2	out 2	Diff 2	in 3	out 3	Diff 3	in 4	out 4	Diff 4	in 5	out 5	Diff 5
0:00	22	22	0	21	22	-1	25	25	0	24	24	-1	25	25	0
0:15	26	23	3	26	22	3	27	25	2	27	25	2	29	25	4
0:30	60	24	36	62	24	37	46	26	21	49	27	22	54	28	26
0:45	116	28	87	116	29	87	82	31	52	102	31	71	110	32	78
1:00	171	32	139	166	34	131	138	36	102	166	38	128	171	38	133
1:15	204	37	167	202	41	161	193	46	147	216	46	171	221	49	172
1:30	241	43	198	229	51	178	232	57	175	254	57	197	260	63	197
1:45	264	54	211	249	63	186	264	71	193	286	71	215	291	81	210
2:00	281	63	218	267	78	189	286	84	201	310	86	224	313	93	219
2:15	297	70	227	281	88	193	303	97	207	332	99	233	332	107	225
2:30	309	80	229	293	97	196	321	106	214	349	107	242	346	118	228
2:45	320	87	233	304	104	201	335	113	222	367	115	252	360	124	236
3:00	329	92	237	316	108	207	357	119	238	379	119	260	371	129	242
3:15	338	97	241	322	112	211	393	123	269	382	125	257	382	132	250
3:30	346	101	245	329	116	214	393	125	268	365	126	239	391	135	256

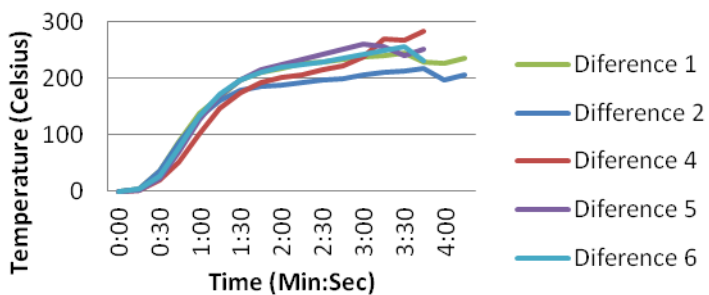
### Fire Suit Inside



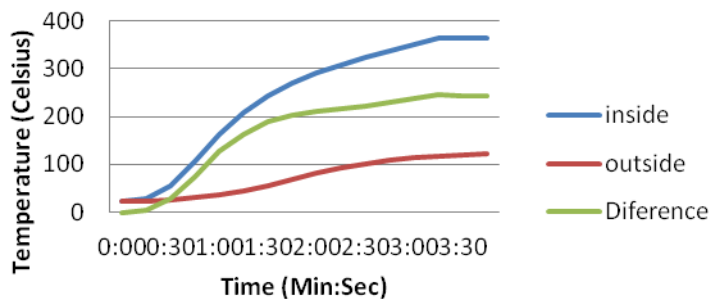
### Fire Suit Outside



### Fire Suit Difference



### Fire Suit Average



## Flame Test Averages

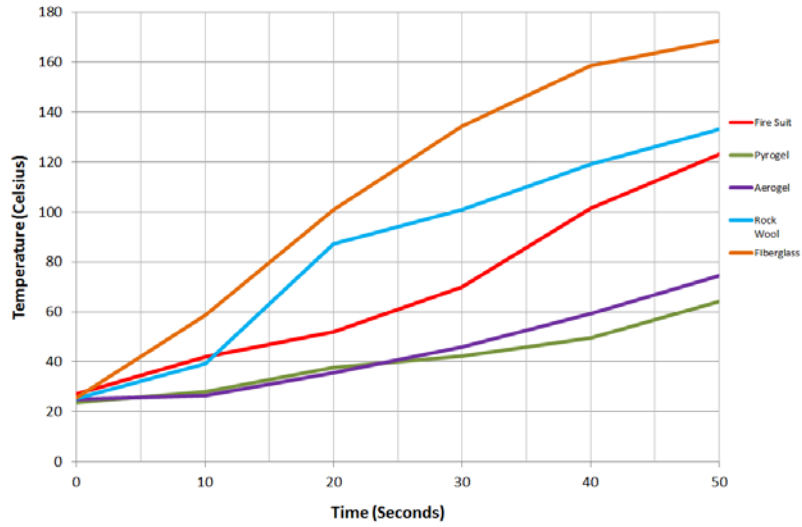
Time (sec)	Pyrogel (°C)	Rock wool (°C)	Fiberglass (°C)	Fire suit (°C)	Aerogel (°C)	Control (°C)
0	23.7	25.3	25.7	27.0	25.0	890
10	28.0	39.3	58.7	42.0	26.3	903
20	37.7	87.3	101.0	52.0	35.7	915
30	42.3	101.0	134.3	70.0	46.0	903
40	49.7	119.0	158.7	101.3	59.3	900
50	64.0	133.0	168.7	123.0	74.3	912

## Observations



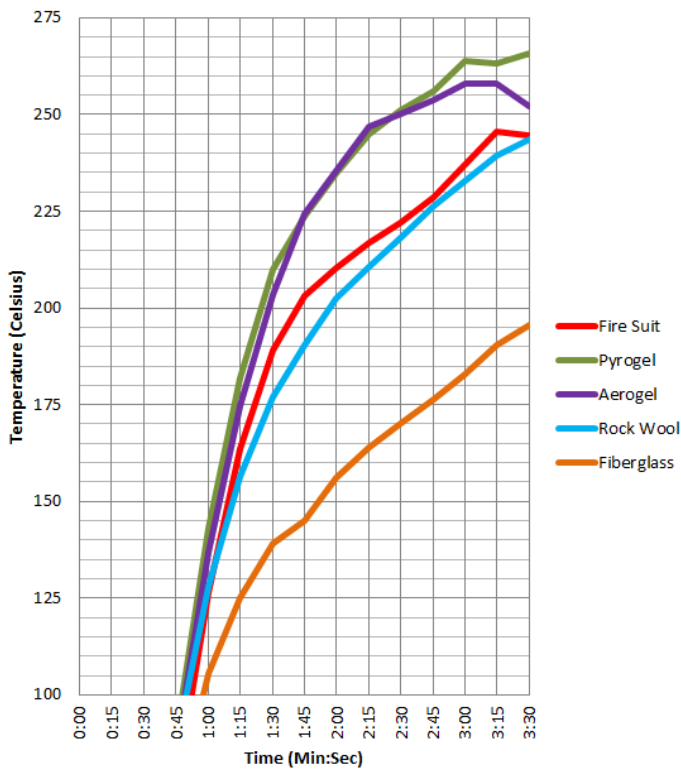
Pyrogel	Rock wool	Fiberglass	Firesuit	Aerogel	Control
Soot Formed on back of sample	Slightly discolored and some charring	Melted where flame was in contact and discolored	Charred and shrank where in contact with flame	Kevlar packet was slightly charred.	N/A

# Flame Test Results

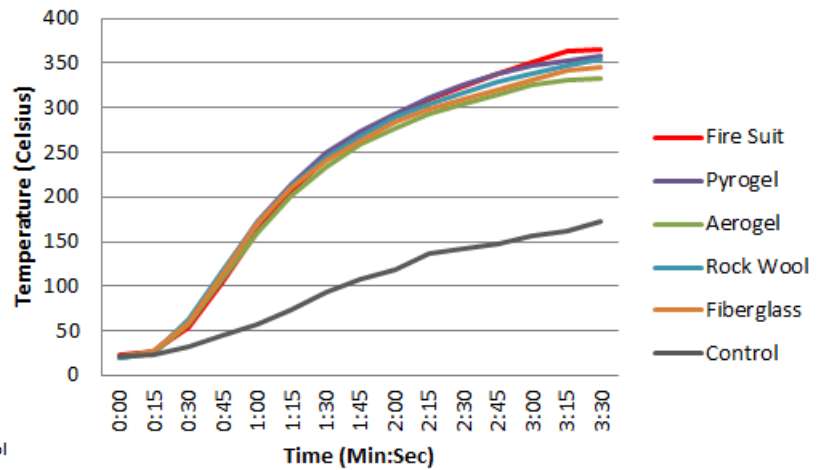


## Heat Test Summary

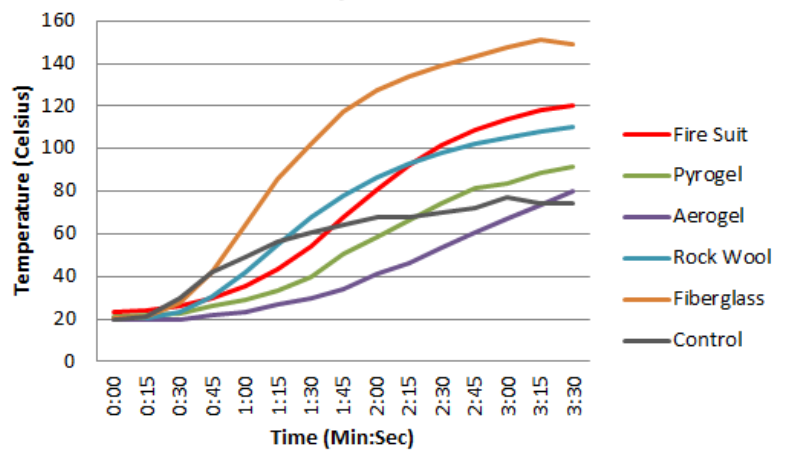
### Temperature Difference



### Material Temperature Inside



### Material Temperature Outside



## Conclusion

In conclusion my hypothesis was correct because the Pyrogel performed the best on both of the tests. I think Pyrogel performed the best because of its low density and high melting temperature.

I Plan to continue this experiment by building a complete sleeve out of Pyrogel to get a more realistic test.



## Works Cited

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