Performance Evaluation of Underground Mine Diesel Engine Exhaust Insulation Products

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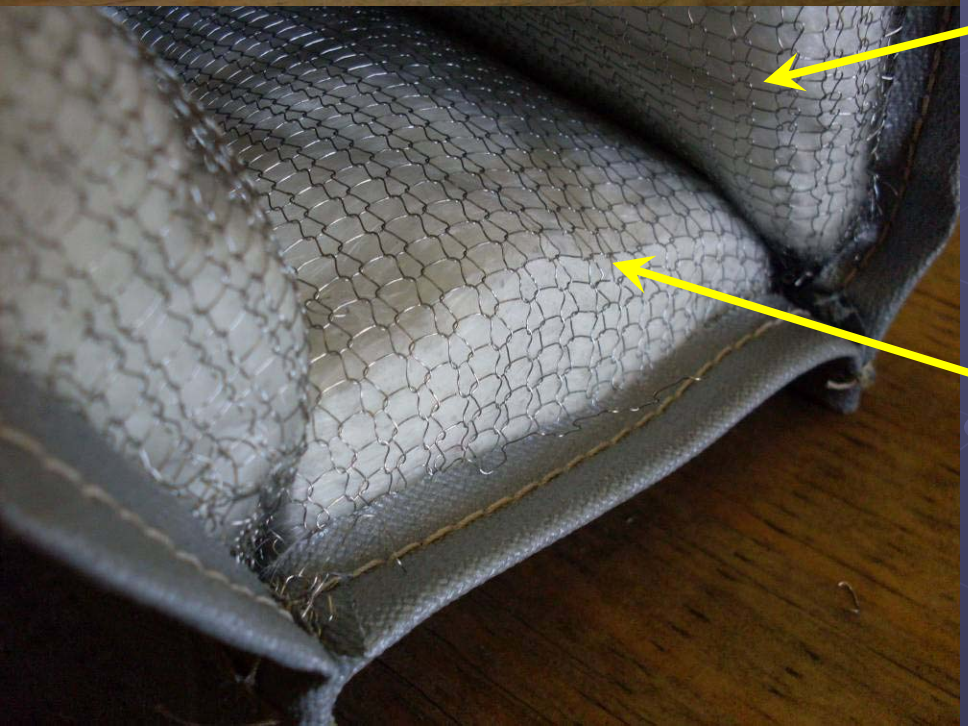
Abstract

The use of diesel engine exhaust insulation products are widespread and increasing in mobile underground mining equipment applications. Diesel engine exhaust insulation products minimize engine exhaust heat energy loss which can improve the oxidation performance of diesel oxidation catalysts and diesel particulate filters. In addition the passive regeneration performance of diesel particulate filters can also be improved through the use of diesel engine exhaust insulation products. Several types of diesel engine exhaust insulation products are currently offered by a variety of manufacturers. Very little published information is available concerning the thermal properties and performance of diesel engine exhaust insulation products.

In this technical paper 4 different types of diesel engine exhaust insulation products provided by the same vendor are installed onto a 33 kW diesel generator set and are evaluated based on ISO 8497. Each diesel engine exhaust insulation product was installed onto an identical engine exhaust pipe which was instrumented with 6 thermocouples attached to an 8 channel Omega TC-08 datalogger. The thermal insulation performance, heat transfer, insulation surface temperatures and rock impact damage to the surface of insulation are tested and reported. In addition the sound attenuation of each type of diesel engine exhaust insulation was tested and evaluated.

Product Description

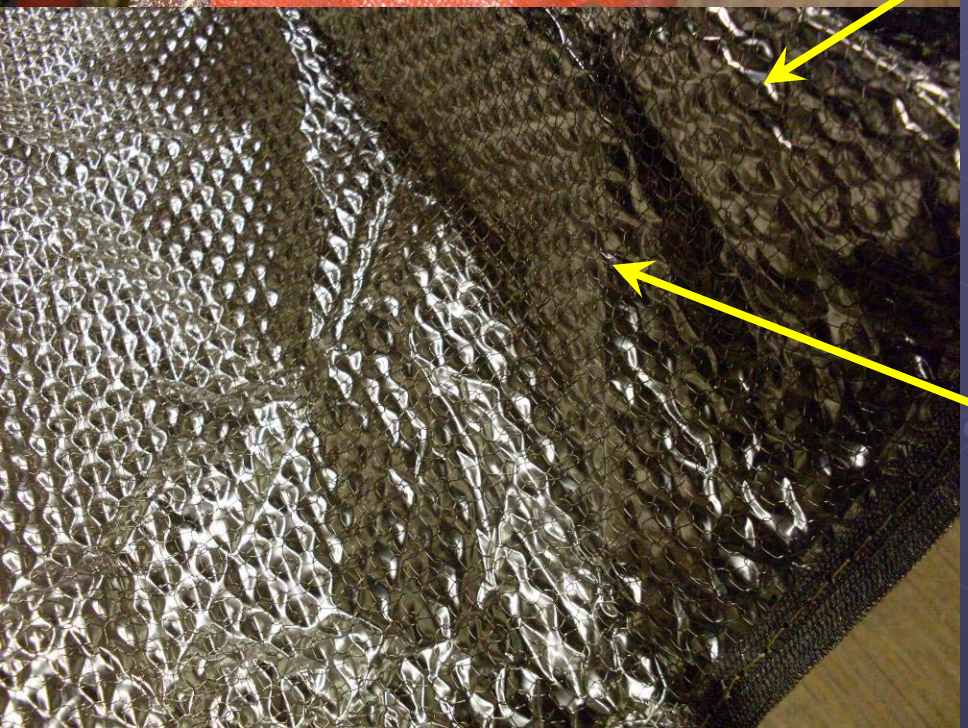


- Insulation type CEP STD:

- Outer layer
- Gray color
- silicone impregnated fiberglass outer cover
- Temperature limit of 500 ºF (260 ºC).

- Middle layer
- Fiberglass
- Temperature limit of 1200 ºF (649 ºC).

- Inner layer
- Steel mesh (304)
- Temperature limit of 1200 ºF (649 ºC).

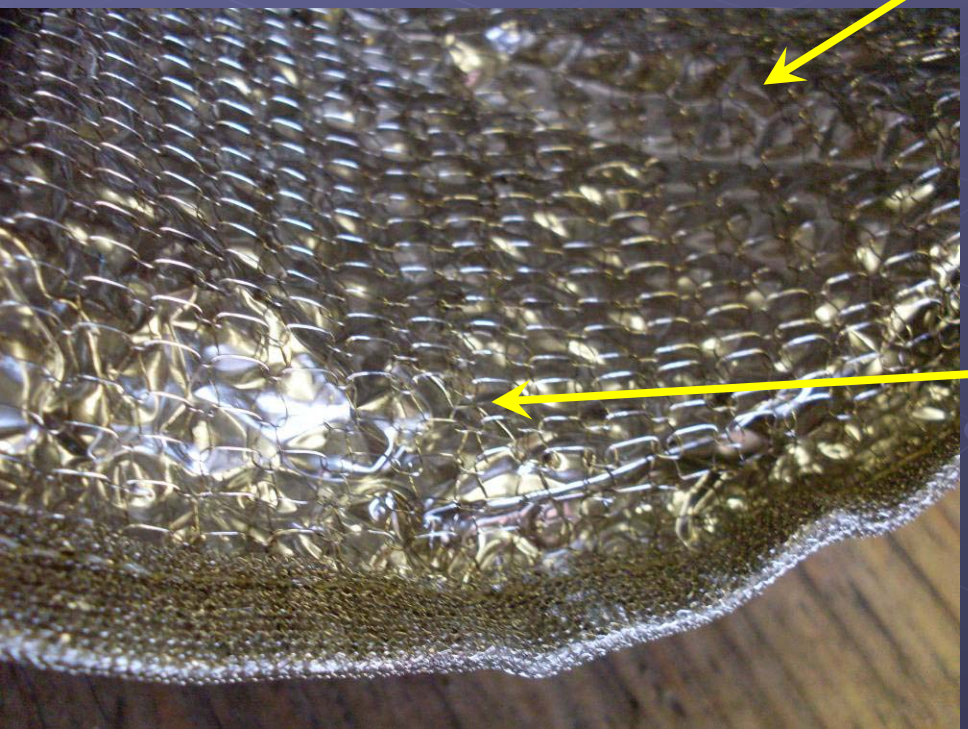


- Insulation type CEP II:

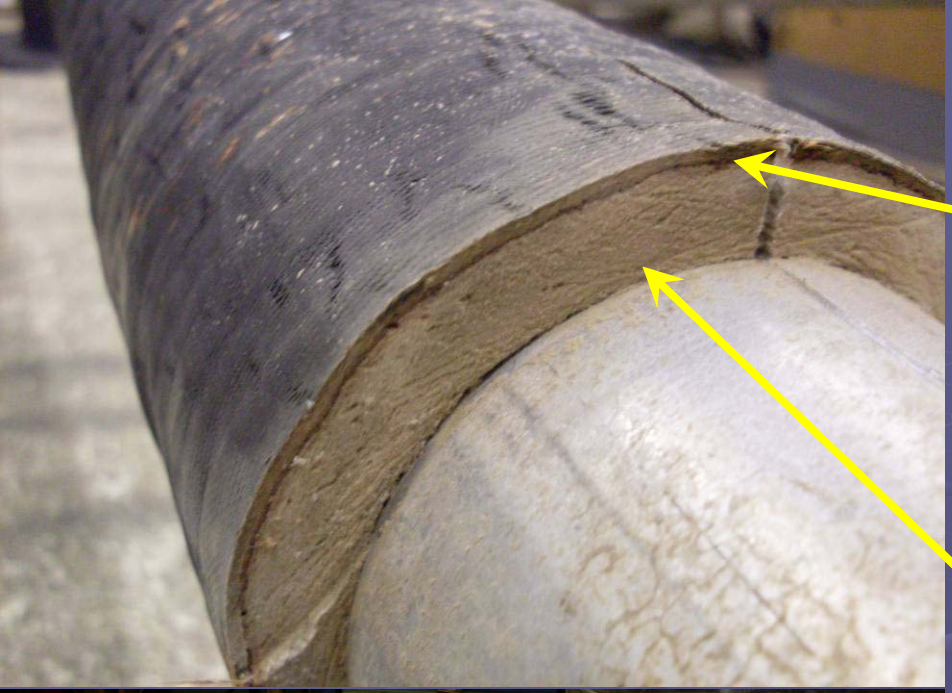
- Outer layer
- Red color
- Silicone impregnated fiberglass
- Temperature limit of 600 ºF (316 ºC).

- Middle layer
- Calcium-Magnesium-Silicate (CMS) wool
- Temperature limit of 1800 ºF (982 ºC).
- Thin sheet of stainless steel 321

- Inner layer
- Steel mesh (304)
- Temperature limit of 1200 ºF (649 ºC).



- Insulation type CEP III:
- Outer layer
- 304 stainless steel knitted wire mesh
- Stainless steel laminated fiberglass
- Temperature limit of 932 ºF (500 ºC).
- Middle layer
- Calcium-Magnesium-Silicate (CMS) wool
- Temperature limit of 1800 ºF (982 ºC).
- Thin sheet of stainless steel 321
- Inner layer
- 304 Stainless steel knitted mesh
- Temperature limit of 1200 ºF (649 ºC).

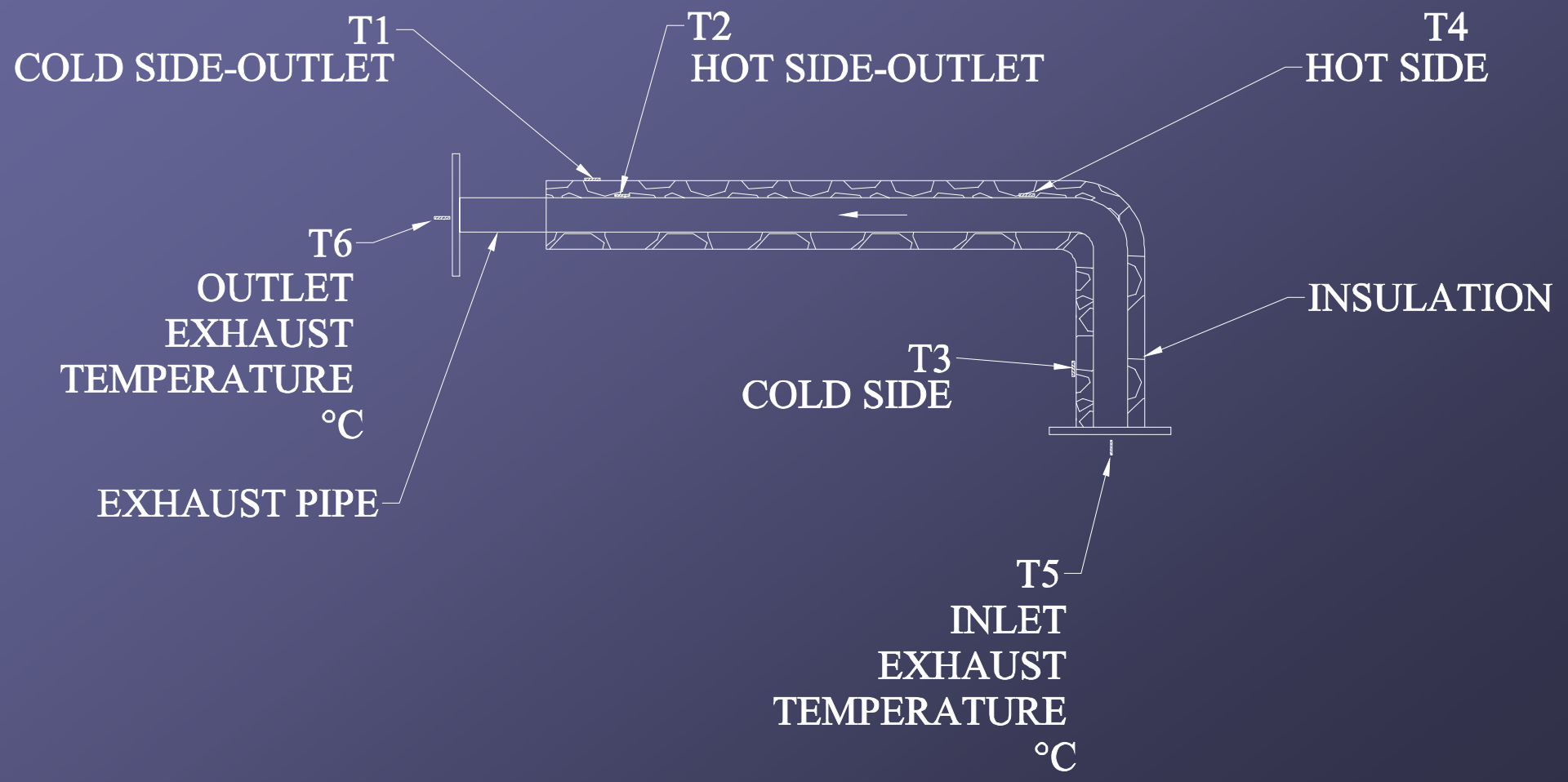


- Insulation type CEP Hard Coated (HC):

- Outer layer
- Black color
- Composite fiber

- Inner layer
- High alumina ceramic fiber
- Temperature limit of 2300 ºF (1260 ºC).

Exhaust Pipe Insulation Test Layout



Procedure

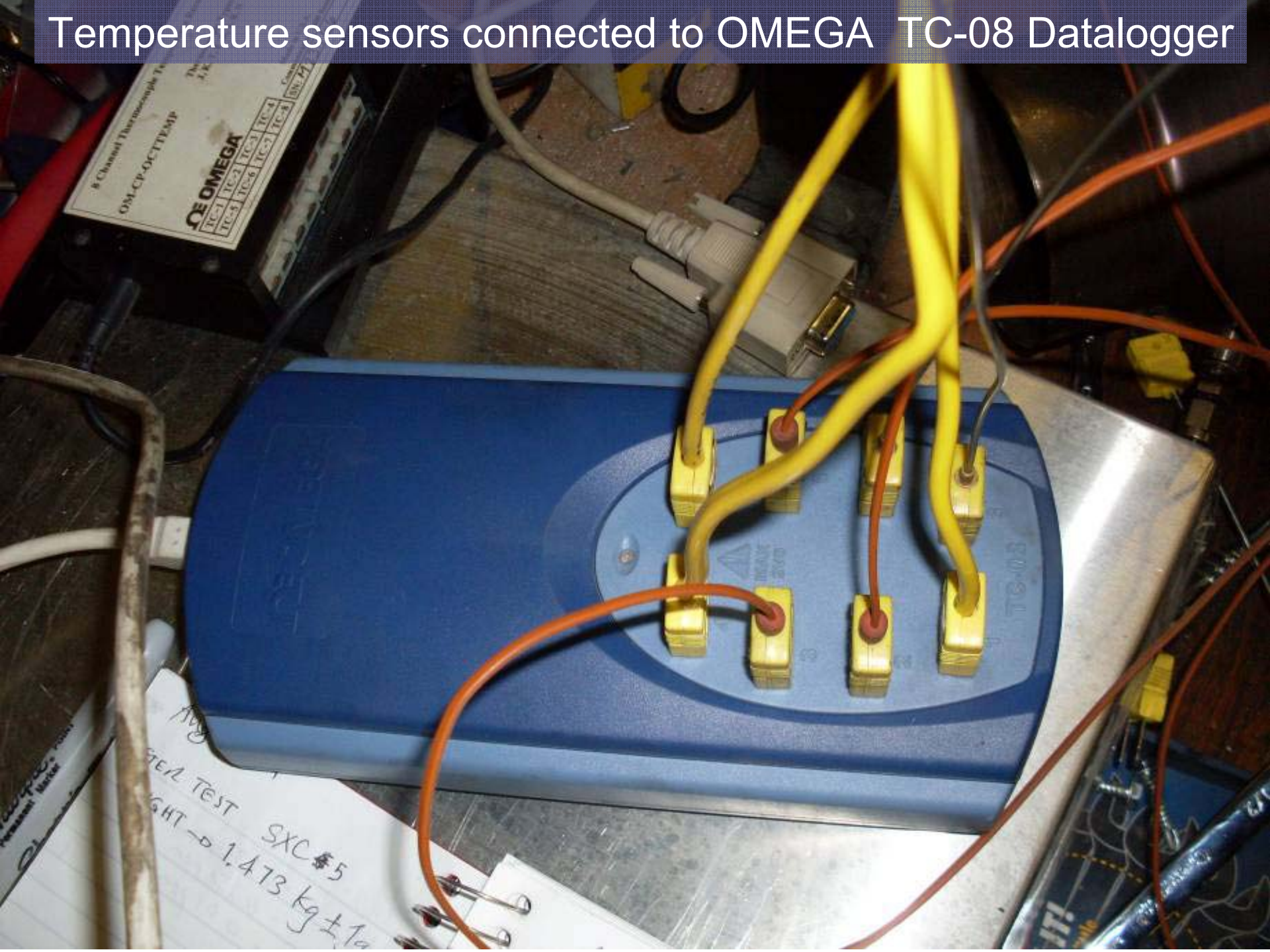
The exhaust pipe of a diesel genset was wrapped with 4 different types of removable insulation blanket.

Six sensors were installed on an exhaust pipe insulation as shown in the previous slides.

Two extra sensors (T7 &T8) were set to measure ambient temperature.

Temperatures measured in following steps: with engine off, while engine running with zero load, load increased to 36%, then 72% and back to 36%, zero load, and finally measurement continued for the last stage after engine turned off. The temperature of exhaust gas inside the pipe was measured at Inlet (T5) and outlet (T6) and subtracted to find the heat loss. The temperature of insulation inner layer (T2 , hot side) and outer layer (T1, cold side) were measured and subtracted to evaluate heat retention.

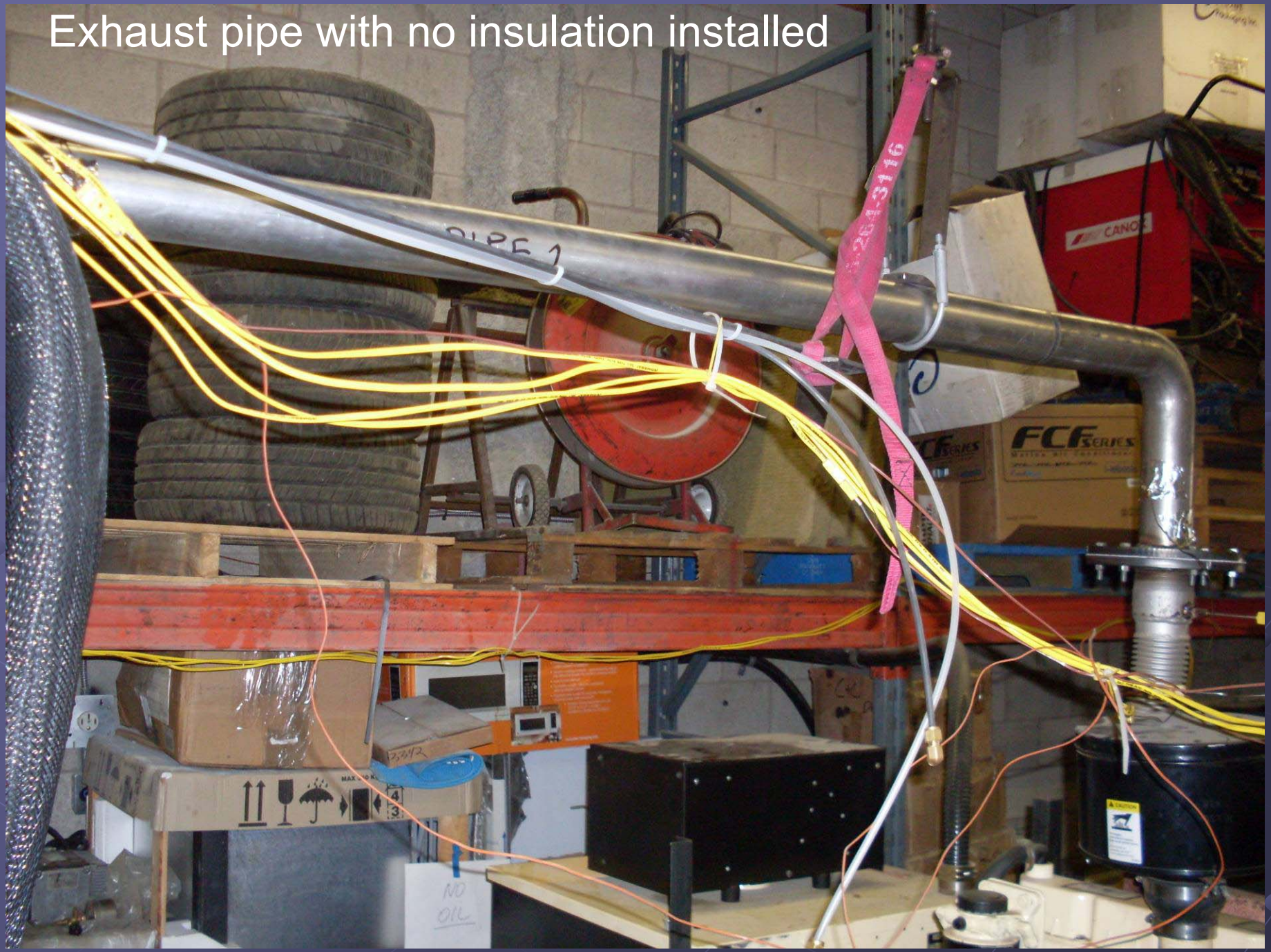
Temperature sensors connected to OMEGA TC-08 Datalogger



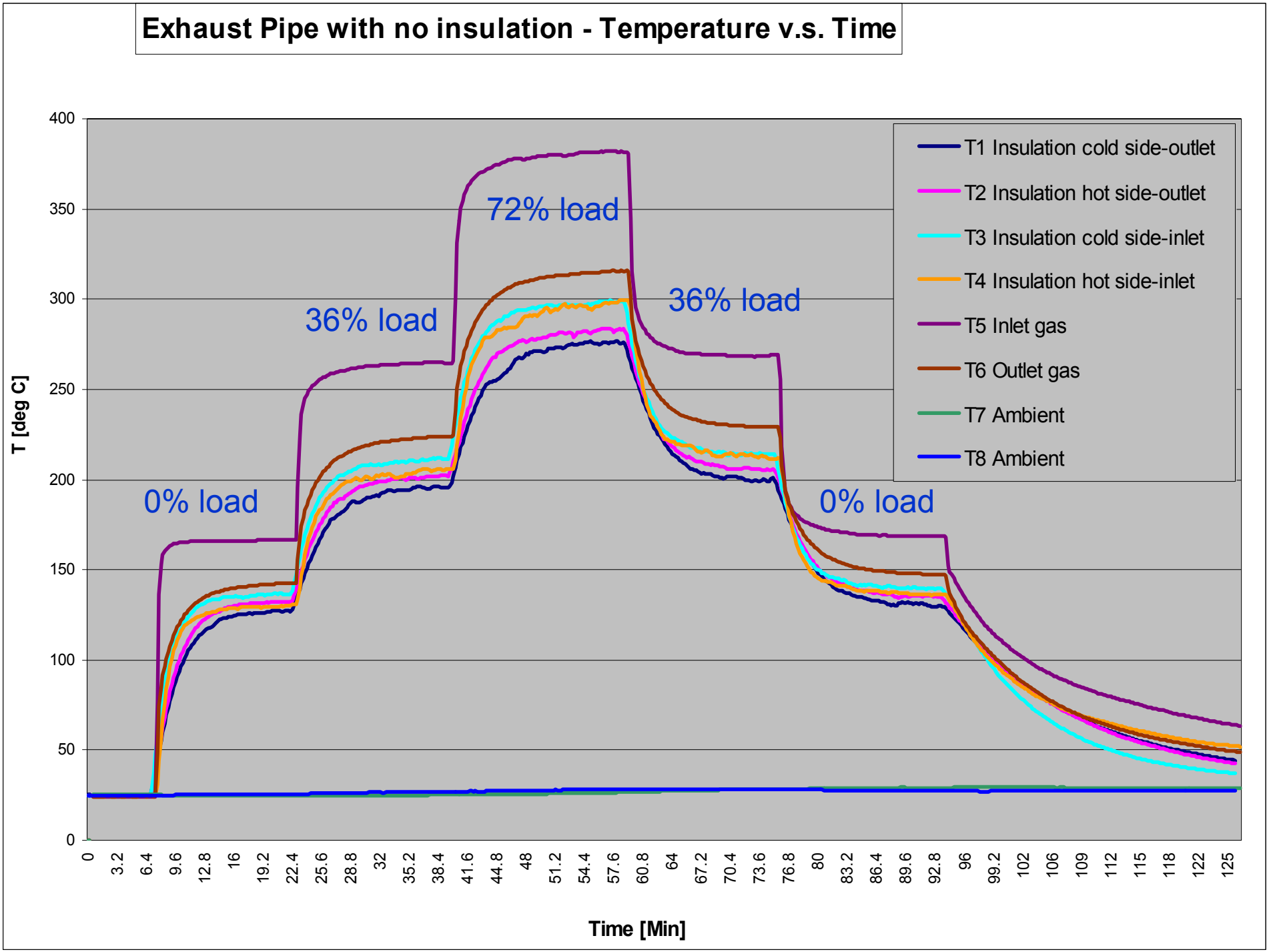
Load Bank


3KW
6KW
ON
OFF
6KW
6KW
ON
OFF
6KW
LOAD STEP SWITCHES
BYPASS
ON
LOAD
APPLIED
INTERLOCK
BYPASS
SWITCH
MASTER
LOAD
SWITCH
MANUAL STORAGE

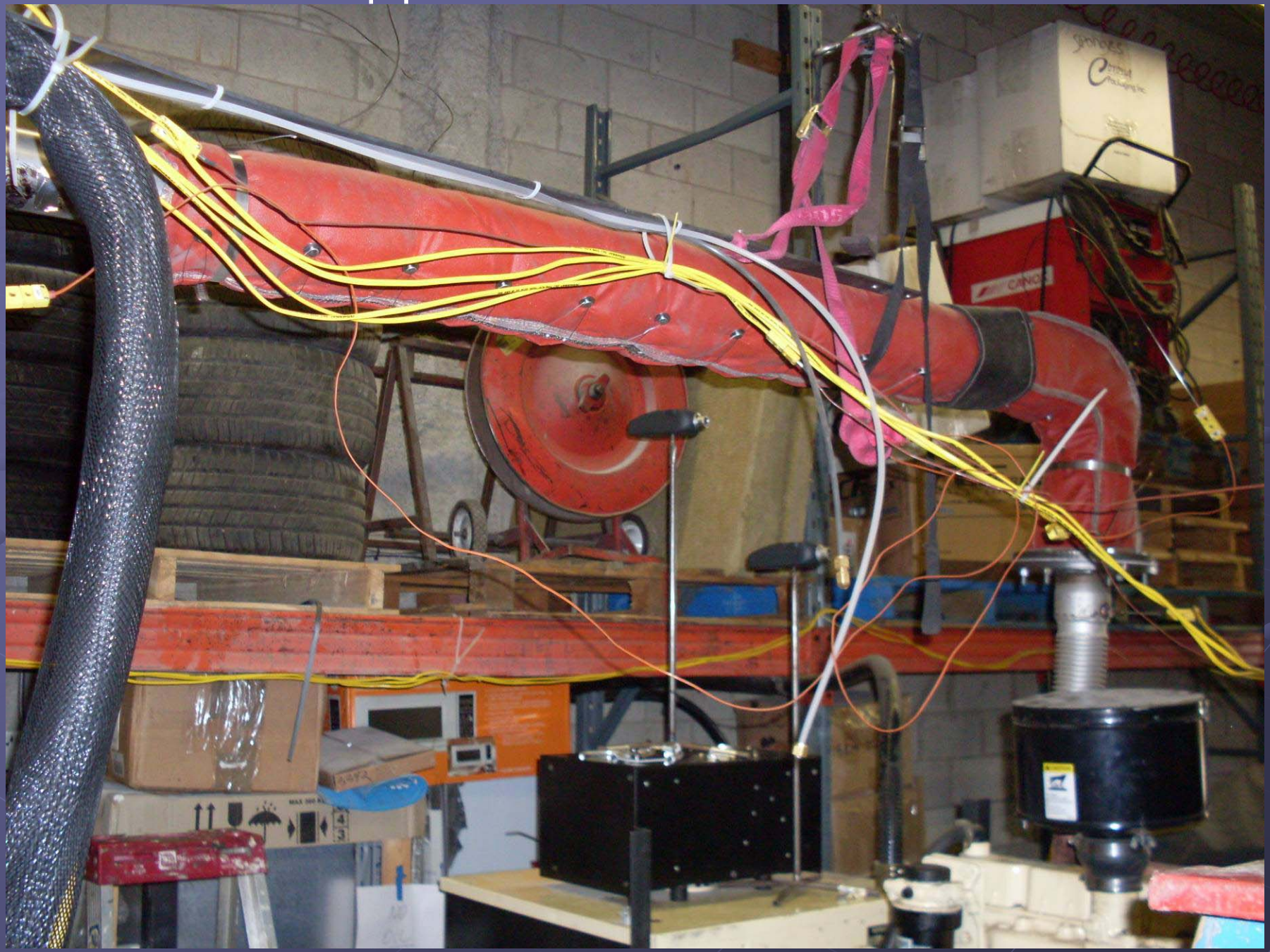
Exhaust pipe with no insulation installed

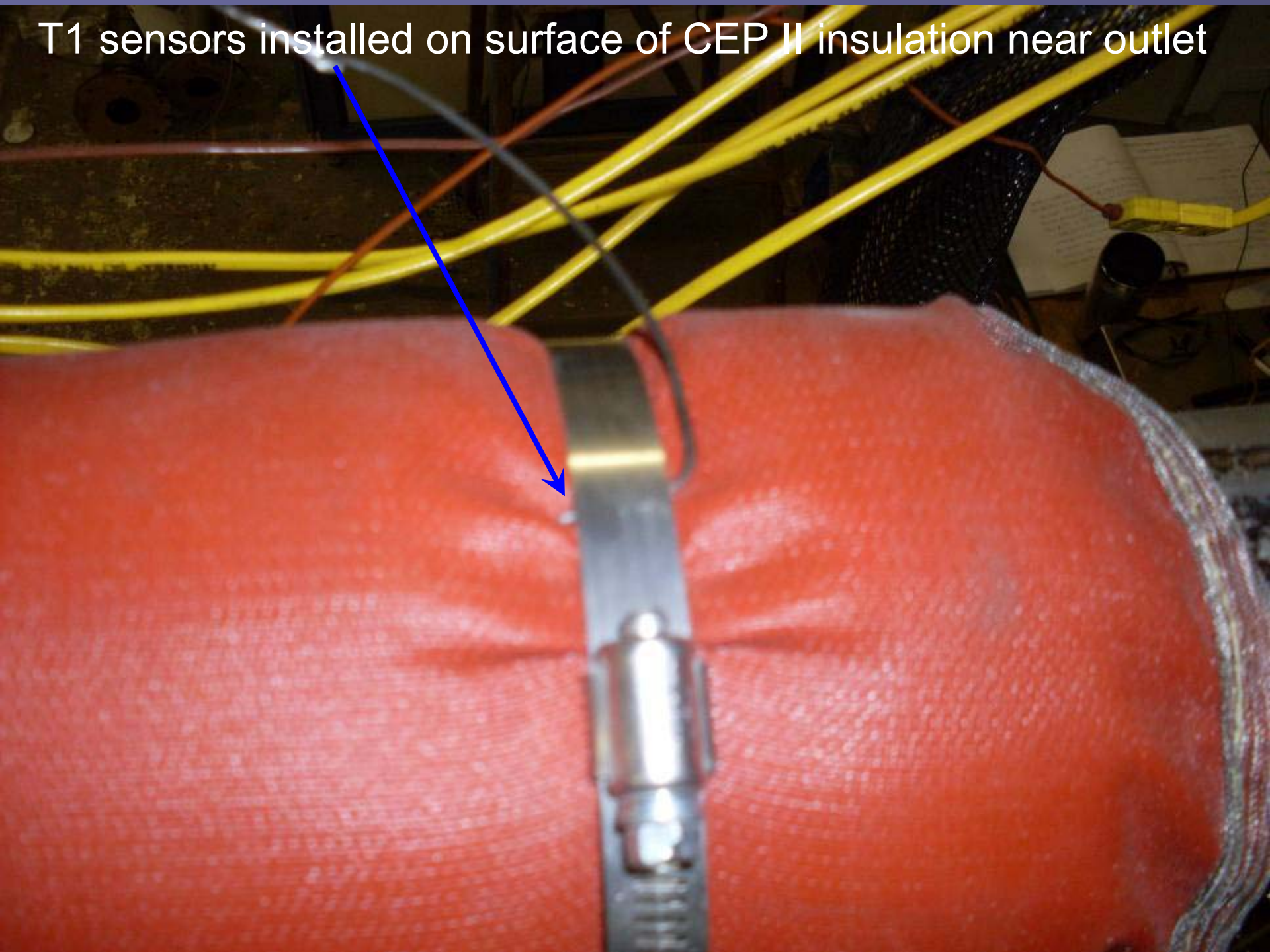



Exhaust gas temperature measurement at outlet (T6)

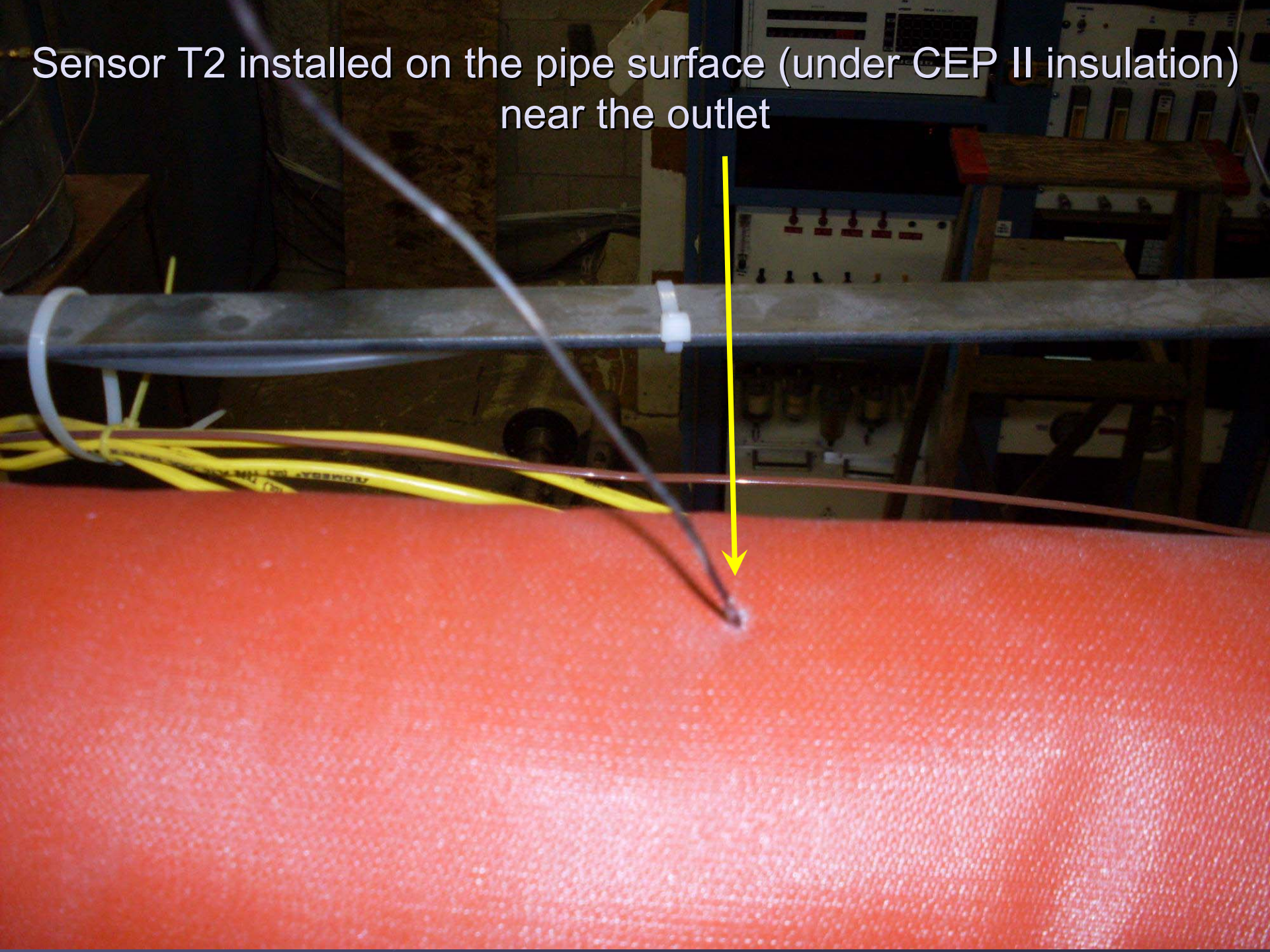

Exhaust Pipe with no insulation - Temperature v.s. Time
T [deg C]
Time [Min]
0% load
36% load
72% load
36% load
0% load
T1 Insulation cold side-outlet
T2 Insulation hot side-outlet
T3 Insulation cold side-inlet
T4 Insulation hot side-inlet
T5 Inlet gas
T6 Outlet gas
T7 Ambient
T8 Ambient

Exhaust pipe installed with CEP II insulation



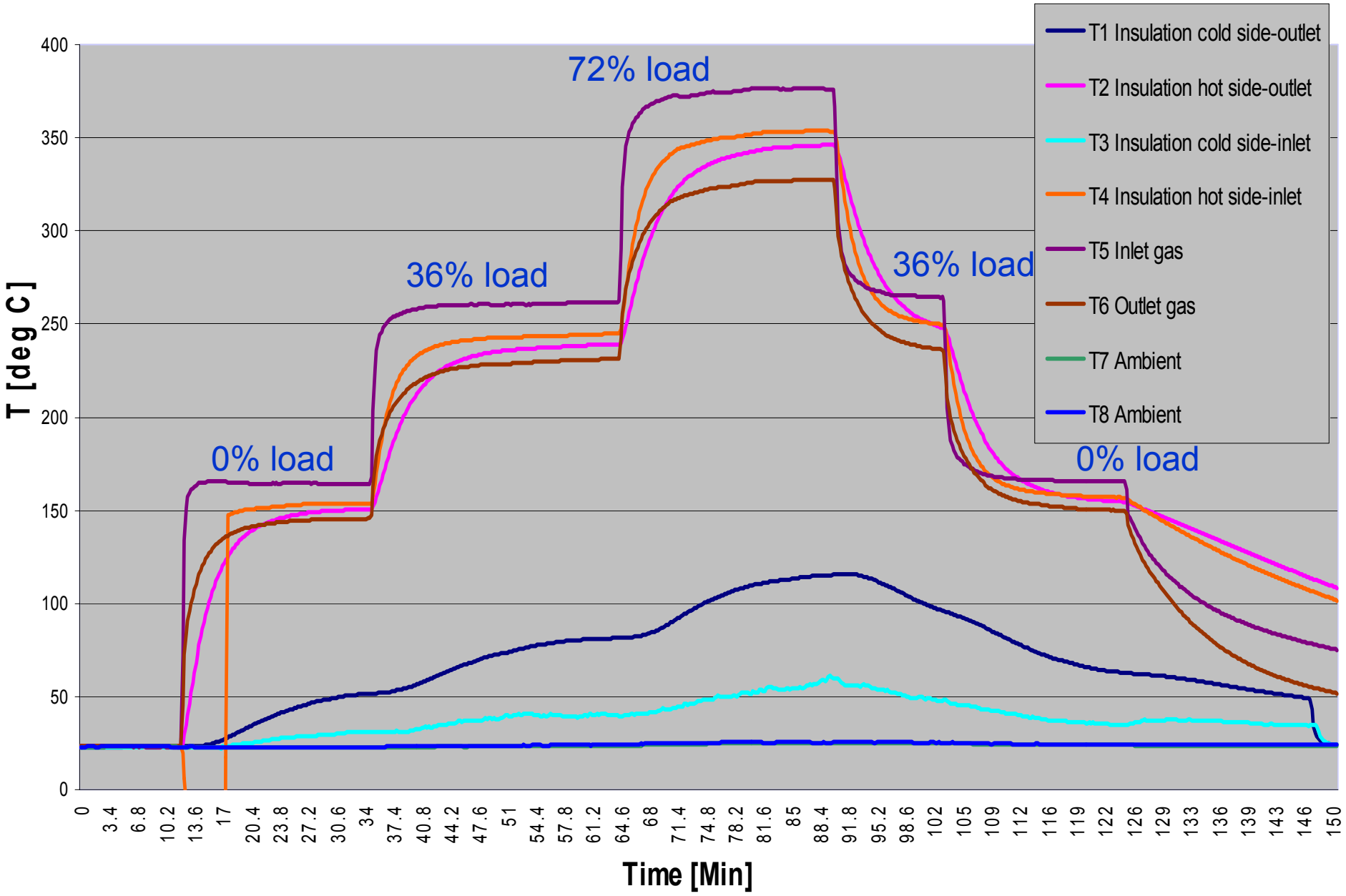

T1 sensors installed on surface of CEP II insulation near outlet

Pictures showing sensor T3 installed on the surface of CEP II

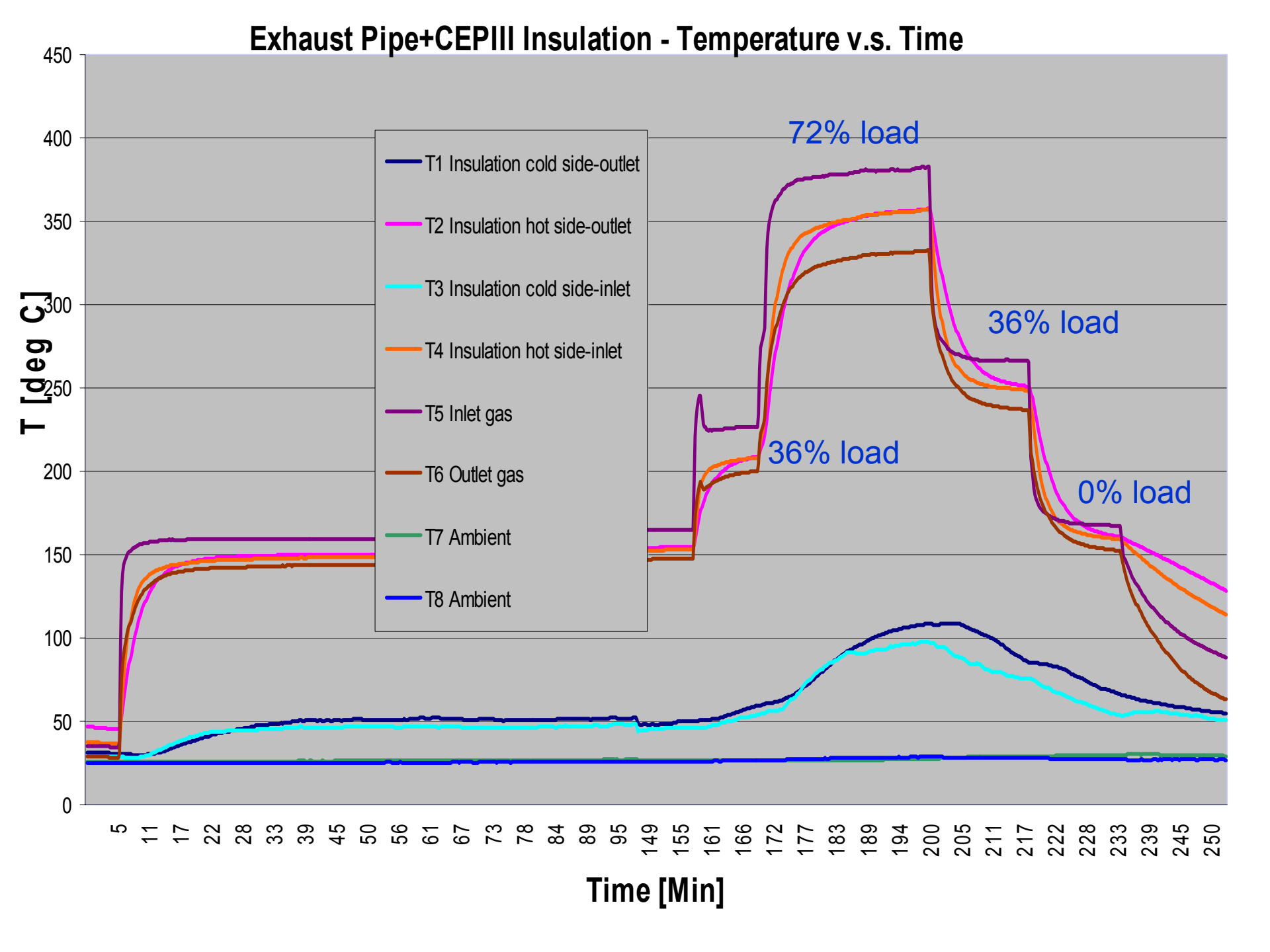

Sensor T2 installed on the pipe surface (under CEP II insulation) near the outlet


Sound level measurement, CEP II insulation, near the inlet

Exhaust Pipe+CEPII Insulation - Temperature v.s. Time

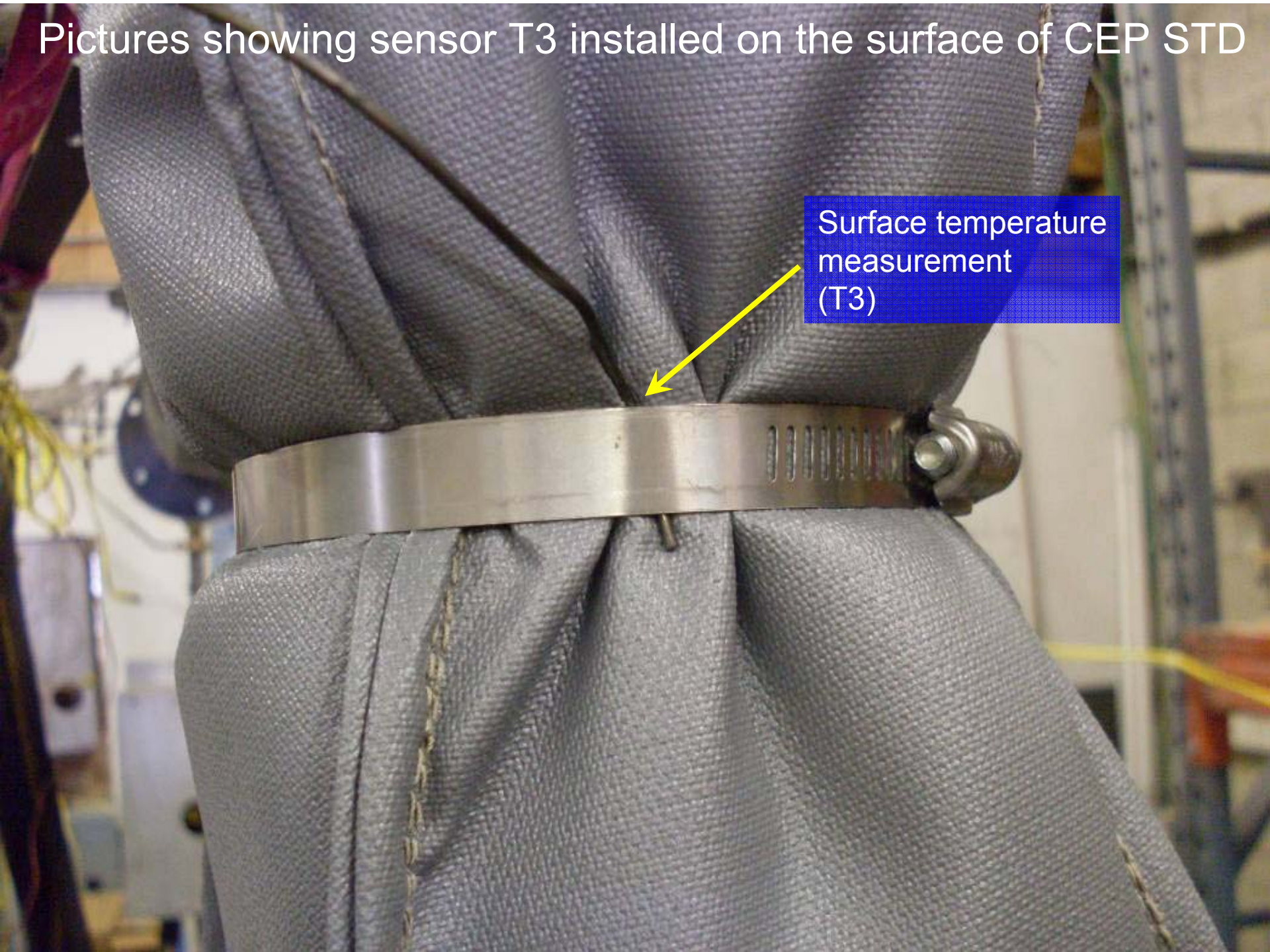


Picture of exhaust pipe installed with CEP III insulation

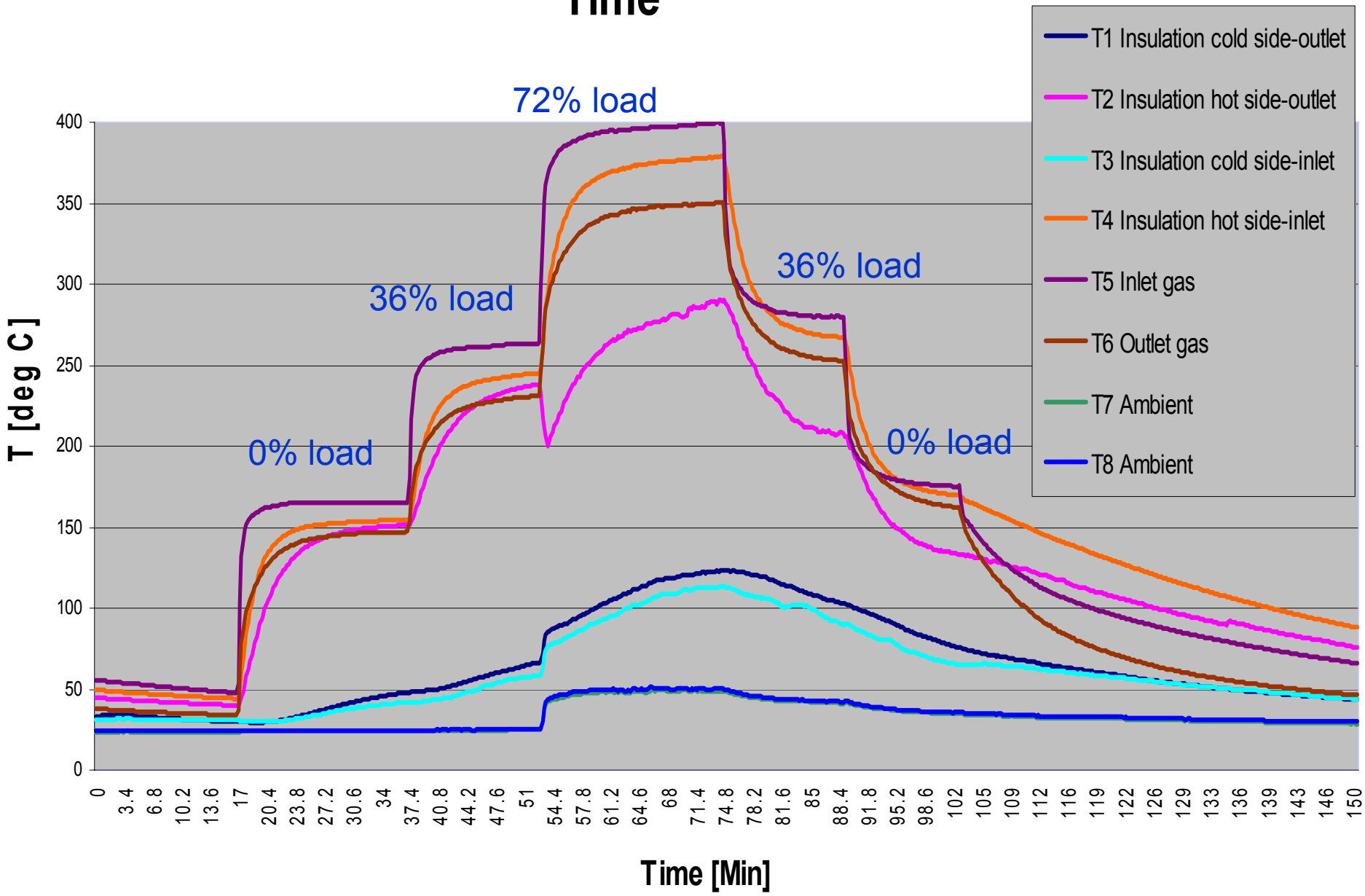

Exhaust Pipe+CEPIII Insulation - Temperature v.s. Time
T [deg C]
Time [Min]
T1 Insulation cold side-outlet
T2 Insulation hot side-outlet
T3 Insulation cold side-inlet
T4 Insulation hot side-inlet
T5 Inlet gas
T6 Outlet gas
T7 Ambient
T8 Ambient
72% load
36% load
36% load
0% load
0
50
100
150
200
250
300
350
400
450
5
11
17
22
28
33
39
45
50
56
61
67
73
78
84
89
95
149
155
161
166
172
177
183
189
194
200
205
211
217
222
228
233
239
245
250

Picture of exhaust pipe installed with CEP STD insulation

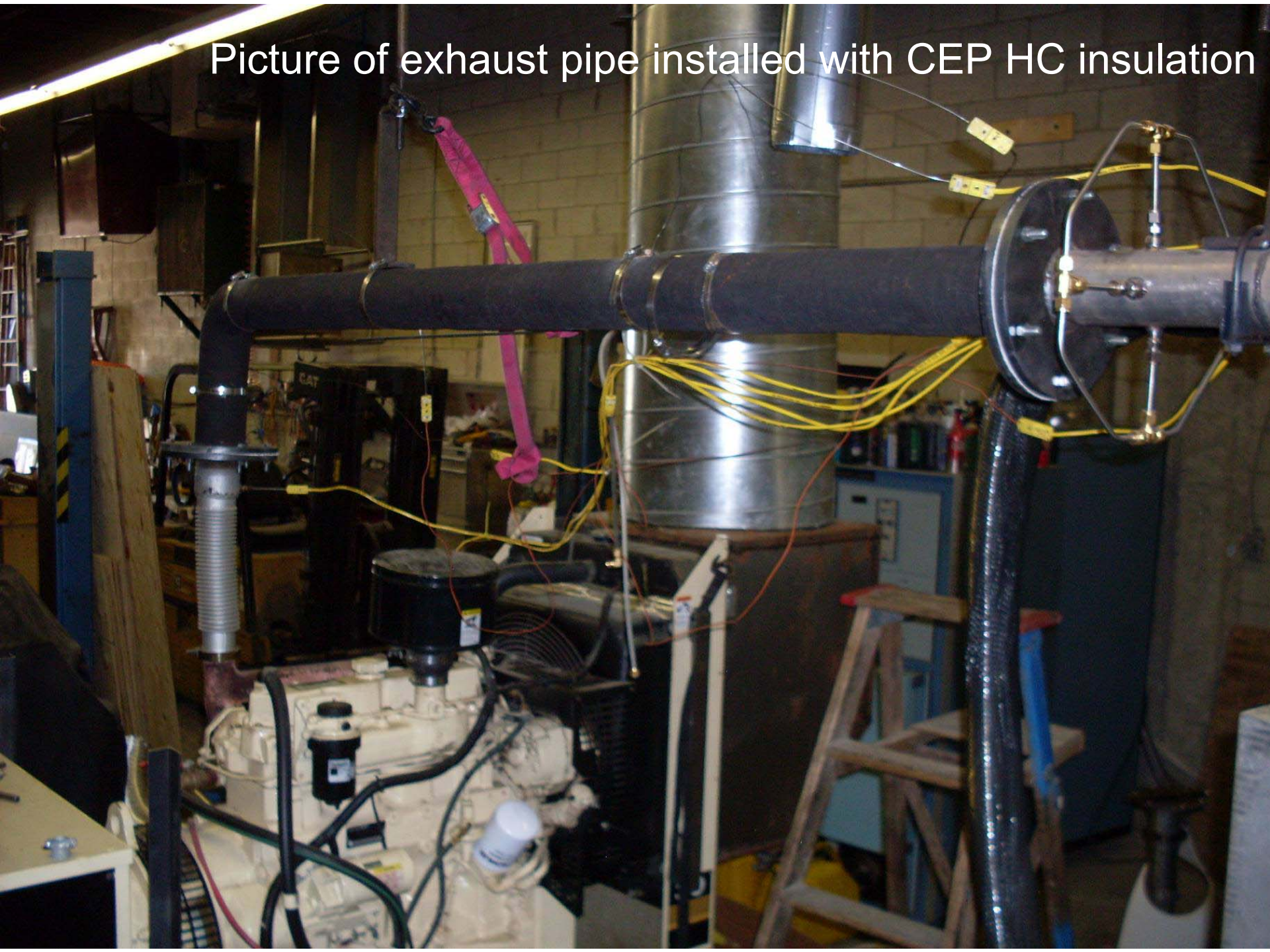
Pictures showing sensor T3 installed on the surface of CEP STD



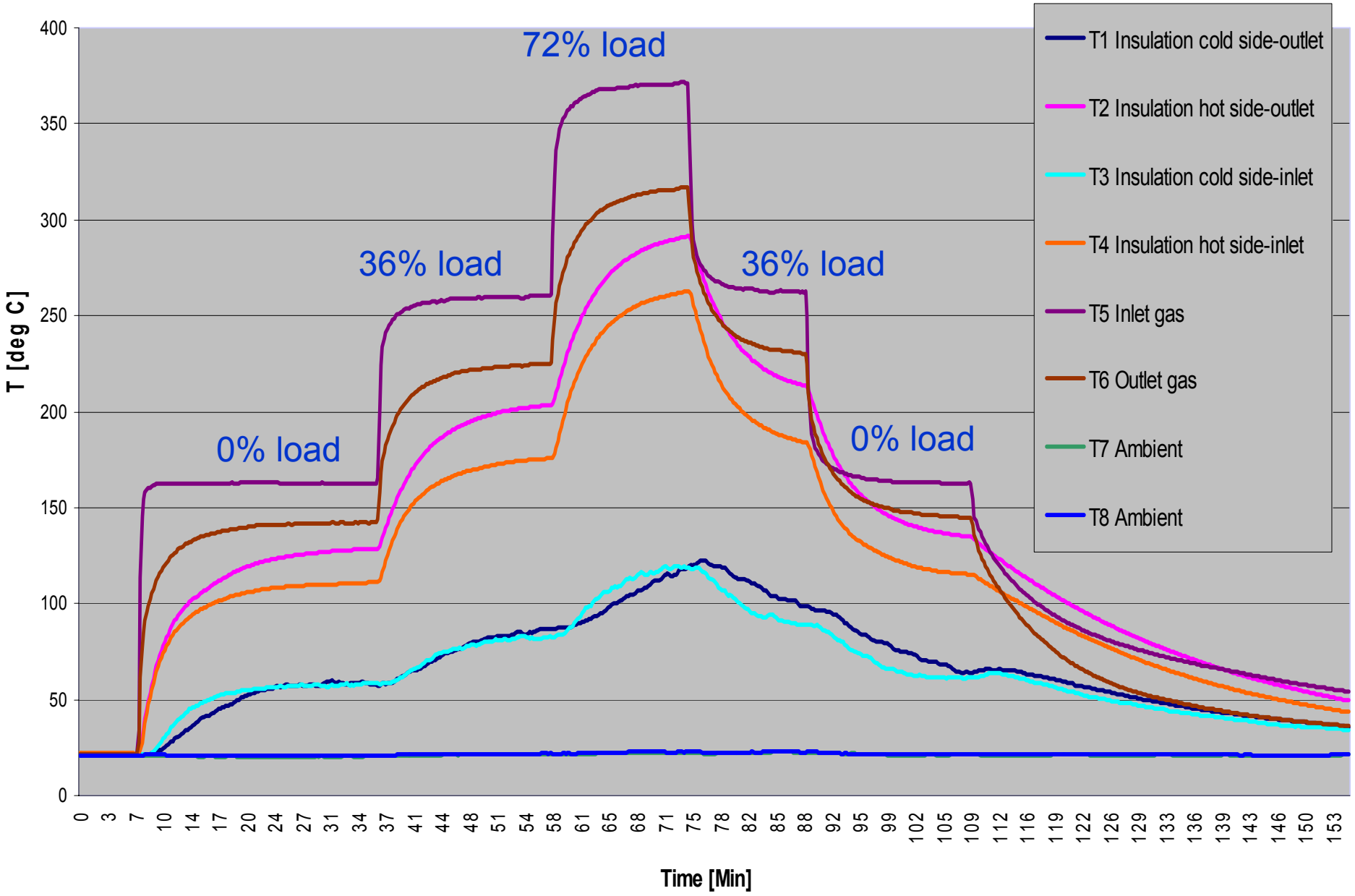
Exhaust Pipe+CEP STD Insulation - Temperature v.s. Time



Picture of exhaust pipe installed with CEP HC insulation

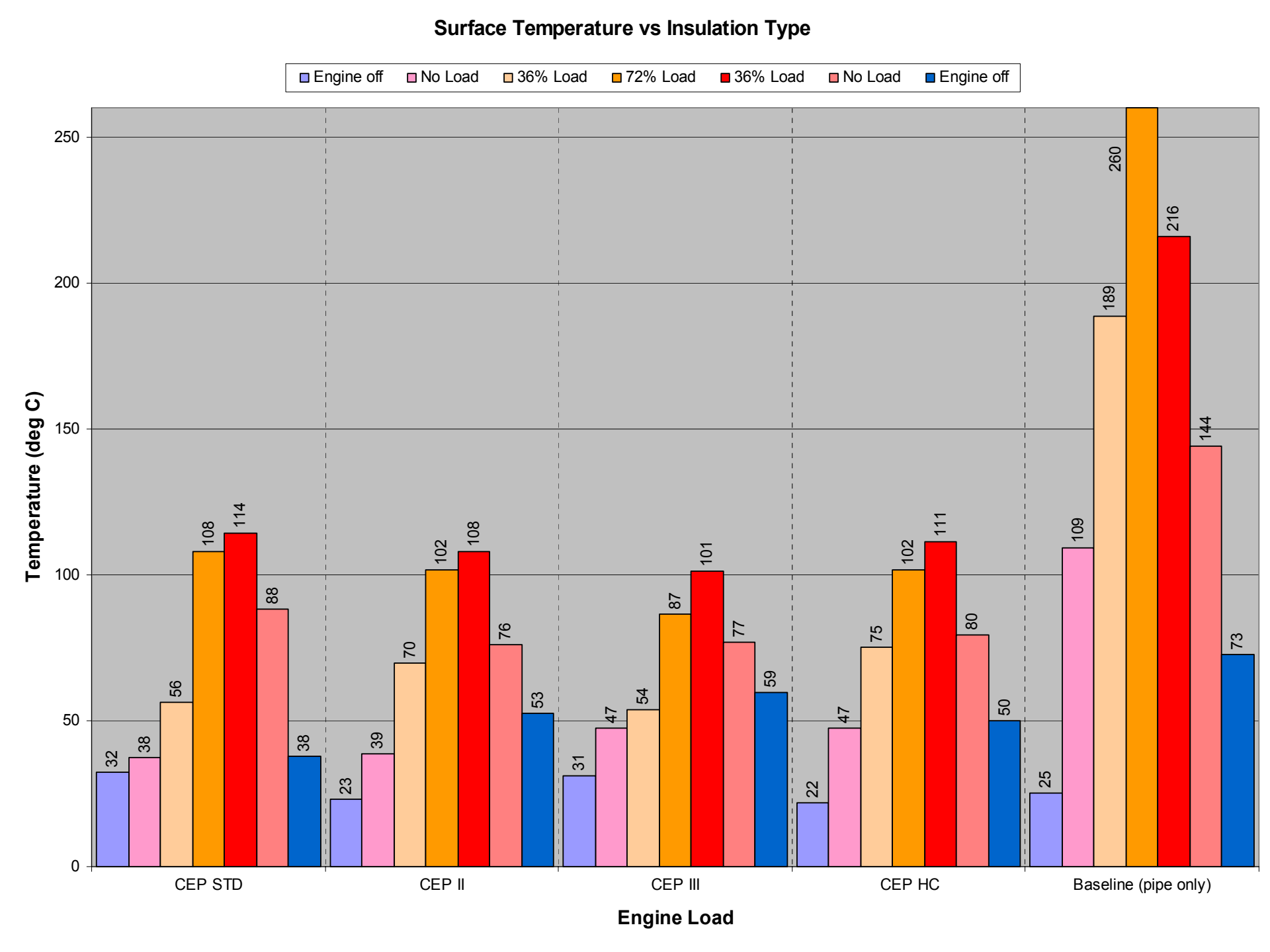


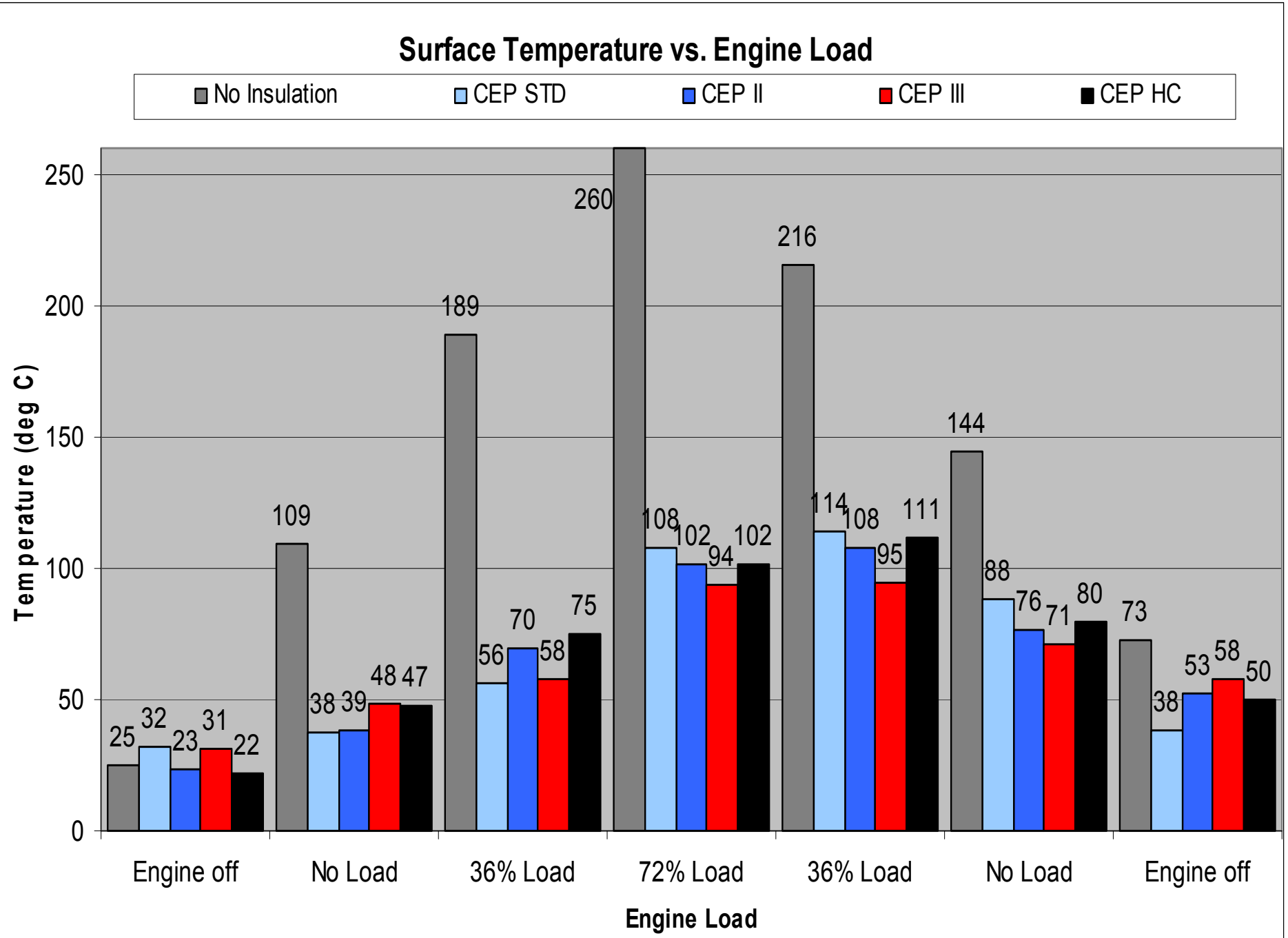
Exhaust Pipe+CEP HC Insulation - Temperature v.s. Time



Surface temperature Insulation evaluation

The chart for surface temperature (measured with T1 sensor) vs. insulation type shown on the next two slides. The chart shows that the skin (cold side) temperature of CEP III has the lowest value (101 ºC) compare to the other types of insulation (108 to 114 ºC). Therefore CEP III is the best insulation in terms of surface temperature and safety. Note that the Values lag behind load change due to insulation resistance. It has a delay in reaching to the maximum temperature during loading of the engine, and it has a delay in cooling off during unloading of the engine, therefore as shown in the chart 36% load shows higher heat than 72%.

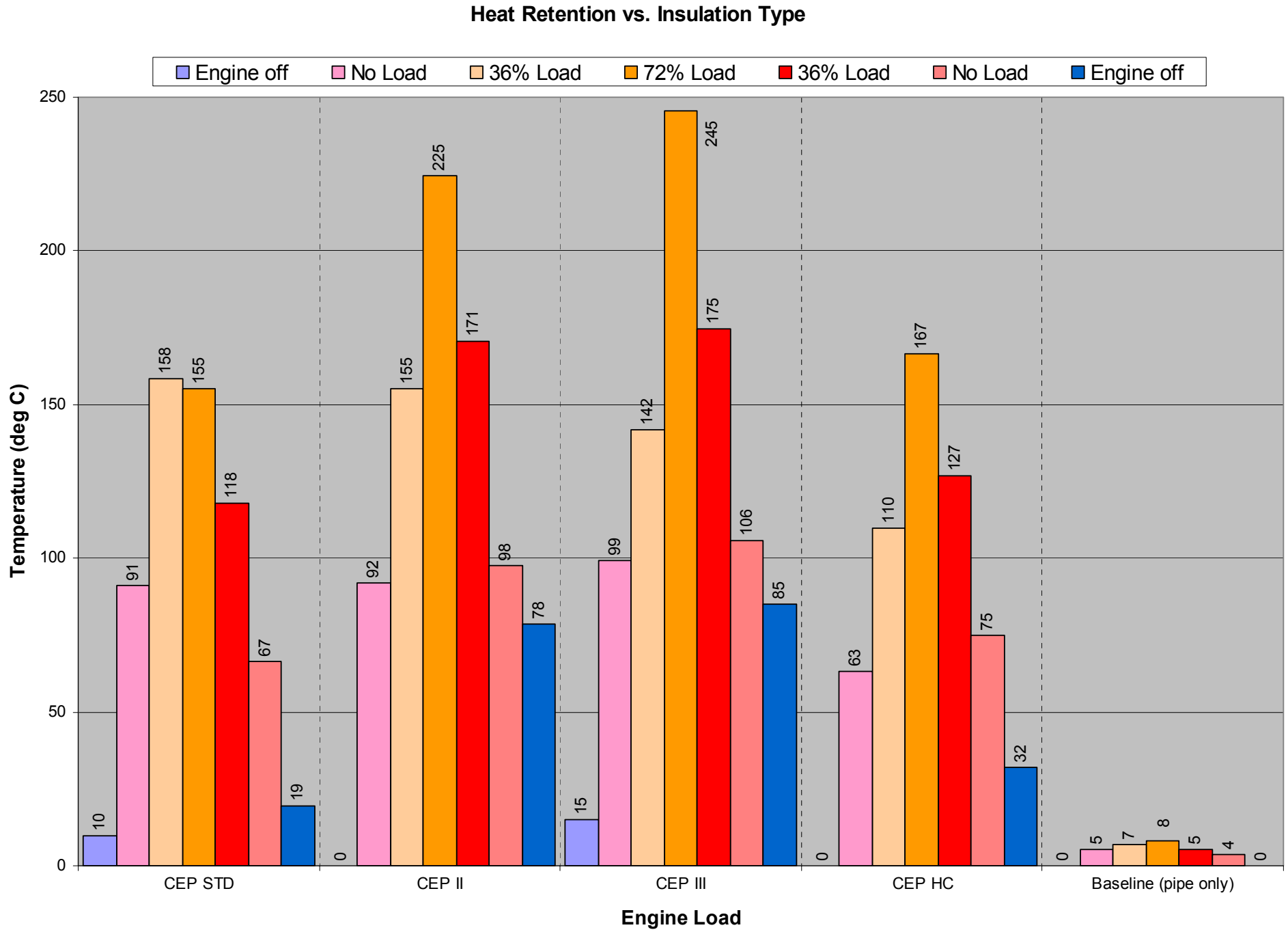

Surface Temperature vs Insulation Type
Engine off
No Load
36% Load
72% Load
36% Load
No Load
Engine off
Temperature (deg C)
0
50
100
150
200
250
32
38
56
108
114
88
38
23
39
70
102
108
76
53
31
47
54
87
101
77
59
22
47
75
102
111
80
50
25
109
189
260
216
144
73
CEP STD
CEP II
CEP III
CEP HC
Baseline (pipe only)
Engine Load

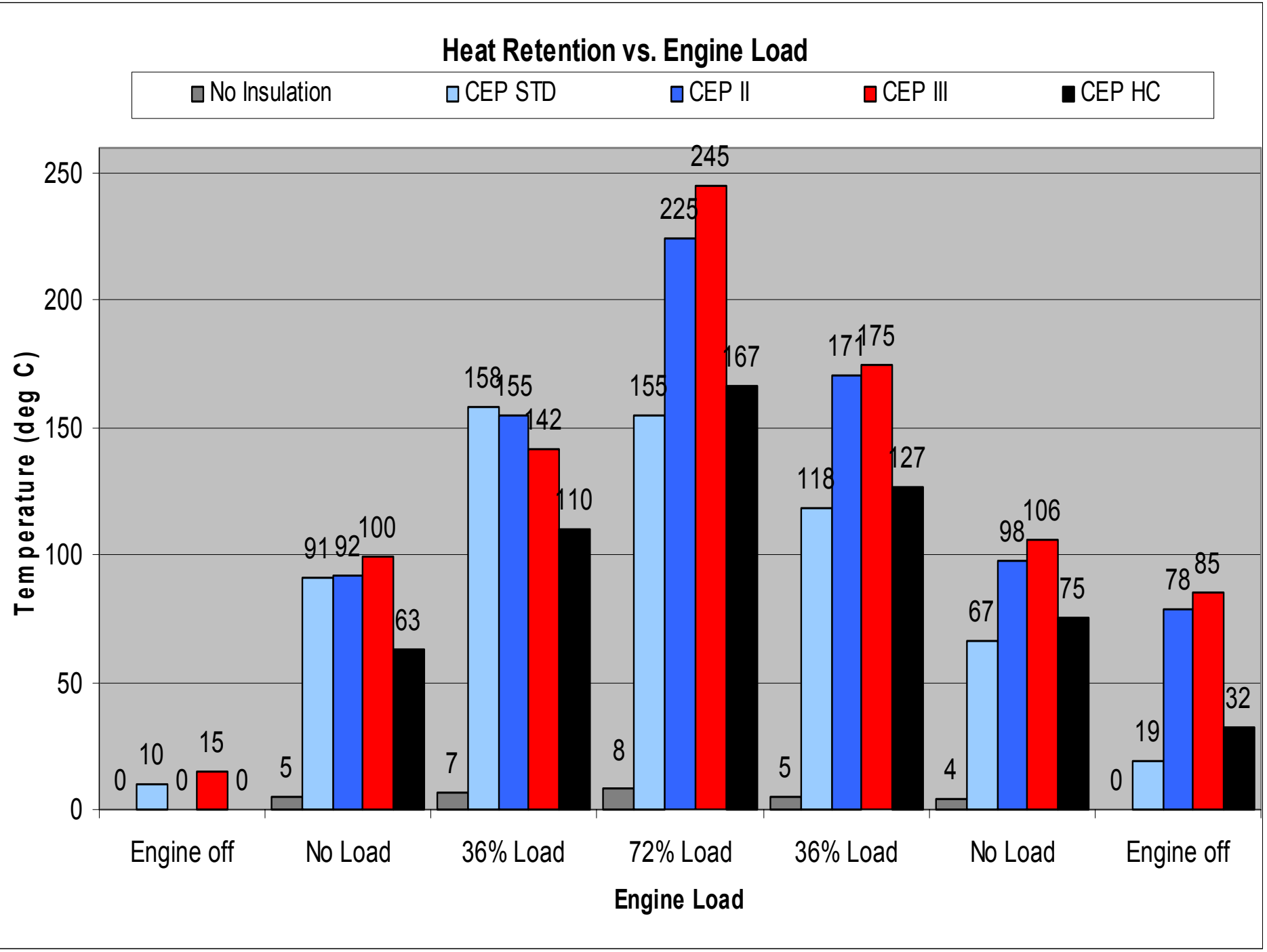

Surface Temperature vs. Engine Load
No Insulation
CEP STD
CEP II
CEP III
CEP HC
Temperature (deg C)
0
50
100
150
200
250
25
32
23
31
22
109
38
39
48
47
189
56
70
58
75
260
108
102
94
102
216
114
108
95
111
144
88
76
71
80
73
38
53
58
50
Engine off
No Load
36% Load
72% Load
36% Load
No Load
Engine off
Engine Load

Insulation Heat Retention Evaluation

On the next two slides, the heat retention was calculated by subtracting T1 from T2.

It represents pipe surface temperature (hot side) minus insulation surface (cold side) temperature. As shown in next slide, CEP III has the highest heat retention (245 ºC), than CEP II, CEP HC, and CEP STD.

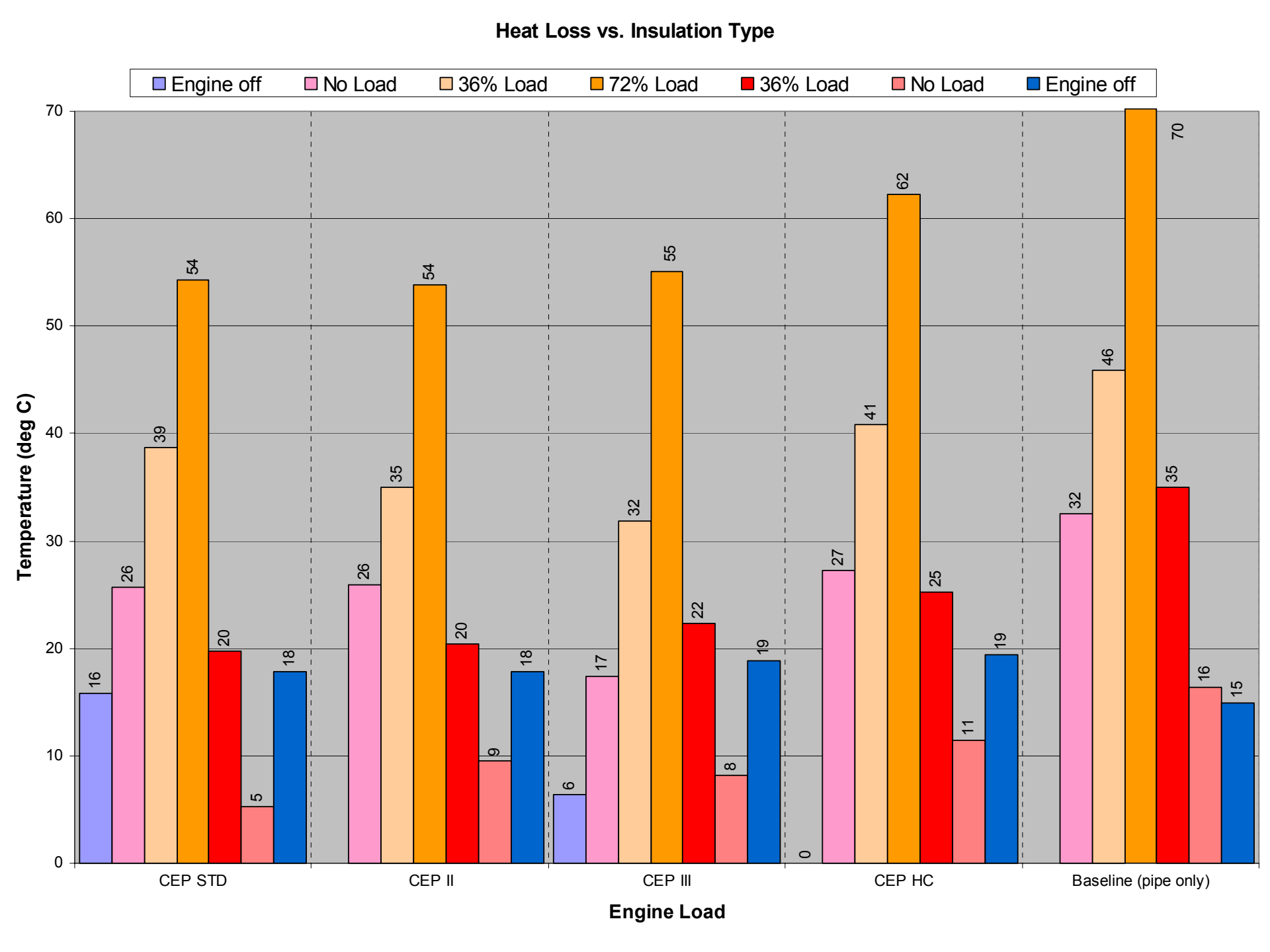

Heat Retention vs. Insulation Type
Engine off
No Load
36% Load
72% Load
36% Load
No Load
Engine off
Temperature (deg C)
250
200
150
100
50
0
10
91
158
155
118
67
19
0
92
155
225
171
98
78
15
99
142
245
175
106
85
0
63
110
167
127
75
32
0
5
7
8
5
4
0
CEP STD
CEP II
CEP III
CEP HC
Baseline (pipe only)
Engine Load


Heat Retention vs. Engine Load
No Insulation
CEP STD
CEP II
CEP III
CEP HC
Temperature (deg C)
250
200
150
100
50
0
0
10
0
15
0
5
91
92
100
63
7
158
155
142
110
8
155
225
245
167
5
118
171
175
127
4
67
98
106
75
0
19
78
85
32
Engine off
No Load
36% Load
72% Load
36% Load
No Load
Engine off
Engine Load

Heat loss inside exhaust pipe

On the next slide the heat lost was calculated by subtracting exhaust gas temperature inside the pipe at inlet from the value at the outlet side, or T5 minus T6.

The lower the value, means lower heat loss, and therefore a better insulation. CEP III, CEP II and CEP STD are almost performed similar and show lower values compare to CEP HC. Therefore all three are acceptable in terms of heat loss prevention.


Heat Loss vs. Insulation Type
Engine off
No Load
36% Load
72% Load
36% Load
No Load
Engine off
Temperature (deg C)
0
10
20
30
40
50
60
70
16
26
39
54
20
5
18
26
35
54
20
9
18
6
17
32
55
22
8
19
0
27
41
62
25
11
19
32
46
70
35
16
15
CEP STD
CEP II
CEP III
CEP HC
Baseline (pipe only)
Engine Load

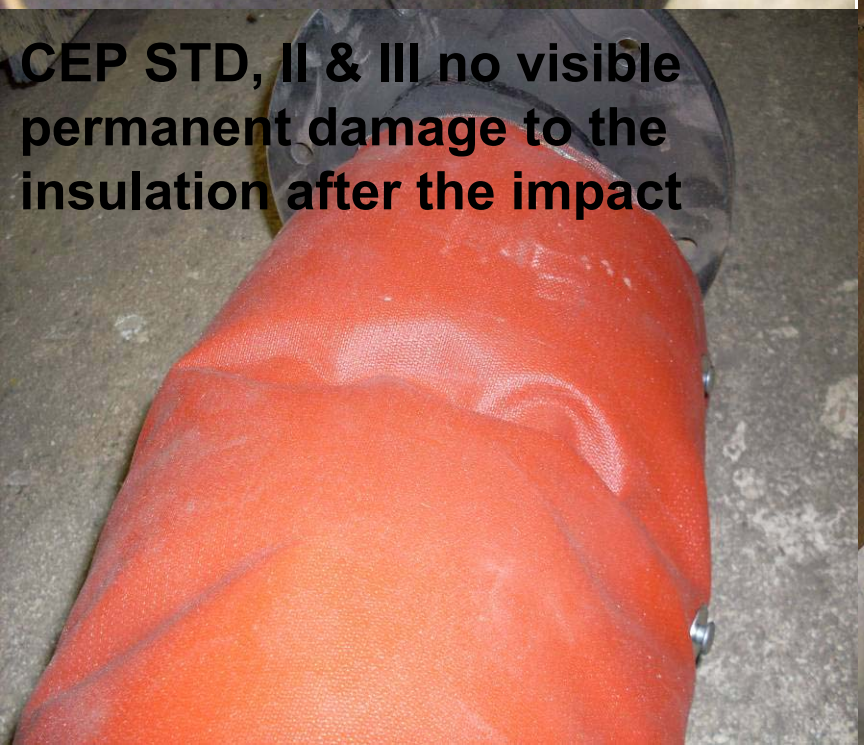
Impact Test

In this test 15.87 kg weight was dropped from a height of 4 feet on each insulation while strapped to the exhaust pipe.

CEP III, CEP II and CEP STD shows no visible damage to the surface of the insulation after the drop test. CEP HC was dented (about 0.25” deep).

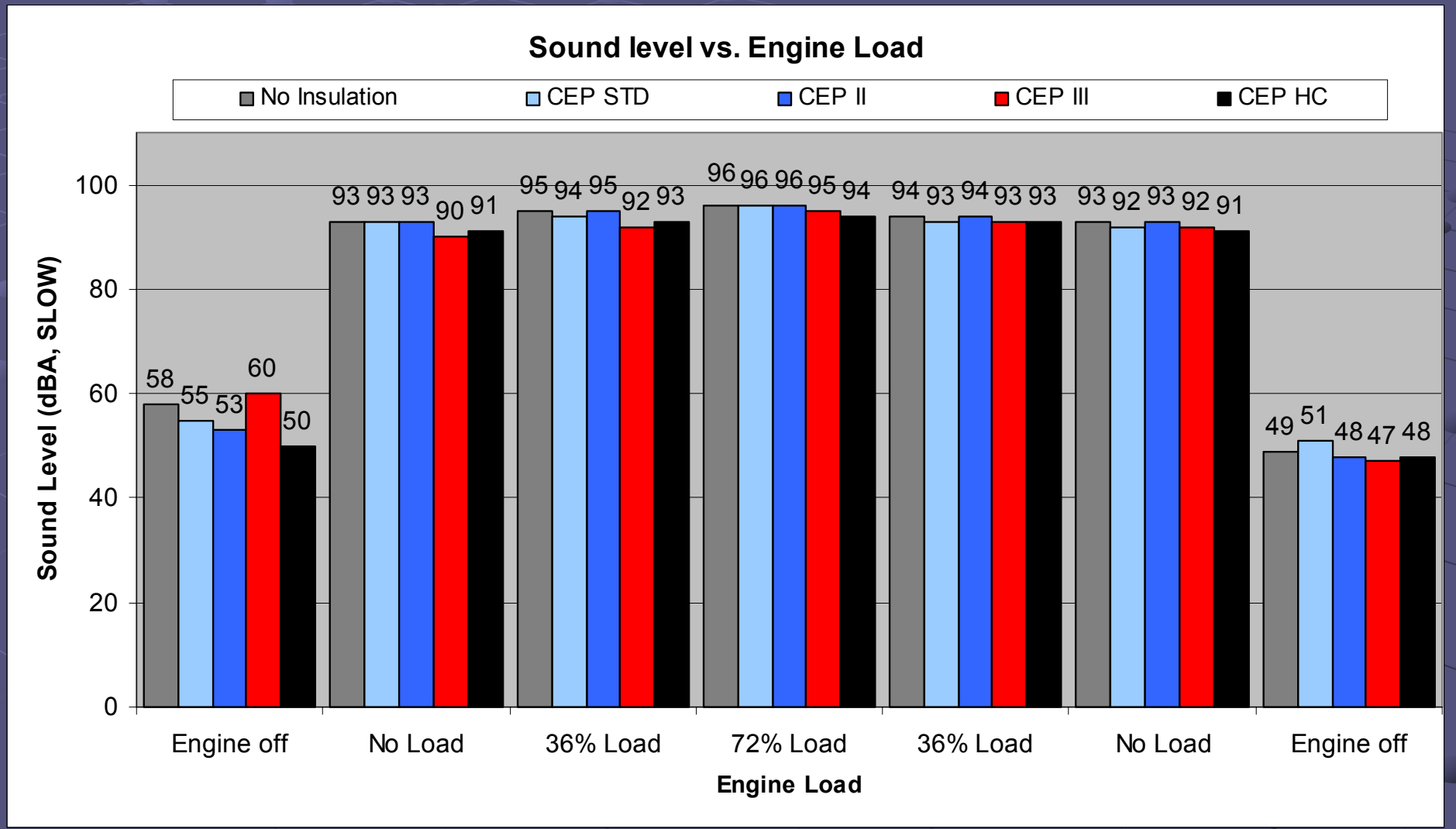
CEP HC with dent after the impact

CEP STD, II & III no visible permanent damage to the insulation after the impact



Sound Level Measurement

Sound level measured 26” away from the insulated exhaust pipe. It shows 1-3 dBA Improvement compare to pipe with no insulation. The sound measurement device was exposed to direct engine and other environmental noise.



Oil Absorption Test

- Each insulation was submerged in oil for an hour and weight before and after, the result is shown as % gain over the original weight:
- CEP STD 75% (highest oil absorption)
- CEP II 71%
- CEP III 64%
- CEP HC 33% (lowest oil absorption)