NAVSEA
WARFARE CENTERS
DAHLGREN

Gun and Electric Weapon Systems (E)

Comparing Fires Using Scaling

Jon J. Yagla, PhD.

Insensitive Munitions and Energetic Materials Technology Symposium

Portland, Oregon USA

April 2018

NSWCDD-PN-16-00187; Distribution Statement A: Approved for Public Release, distribution is unlimited

Fires Studied

Swedish JP5

~ 3ft x 4ft

(.9 x 1.1 m)

Swedish Sand Burner

~ 3ft x 4ft

(.9 x 1.1 m)

Swedish Torch

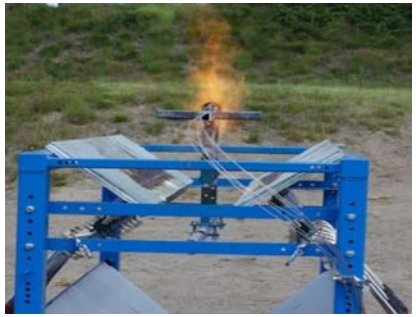
~ 1.5ft x 3ft

(.5 x.9 m)

Meppen Propane

~26ft x 16ft

7.9 x 4.9 m



Dutch Torch

~1.5ft x 3ft

(.5 x.9 m)

Dahlgren JP5

30ft x 30ft

(9.2 x 9.2 m)

Fires Studied, Cont.

Dutch Diesel
~6 ft diameter
(1.8 m)

Dahlgren JP5
12ft x 12ft
(3.8 x 3.8 m)

Dahlgren Propane
8ft x 8ft (2.4 x 2.4 m)
and 12ft x 12ft (3.6 x 3.6 m)

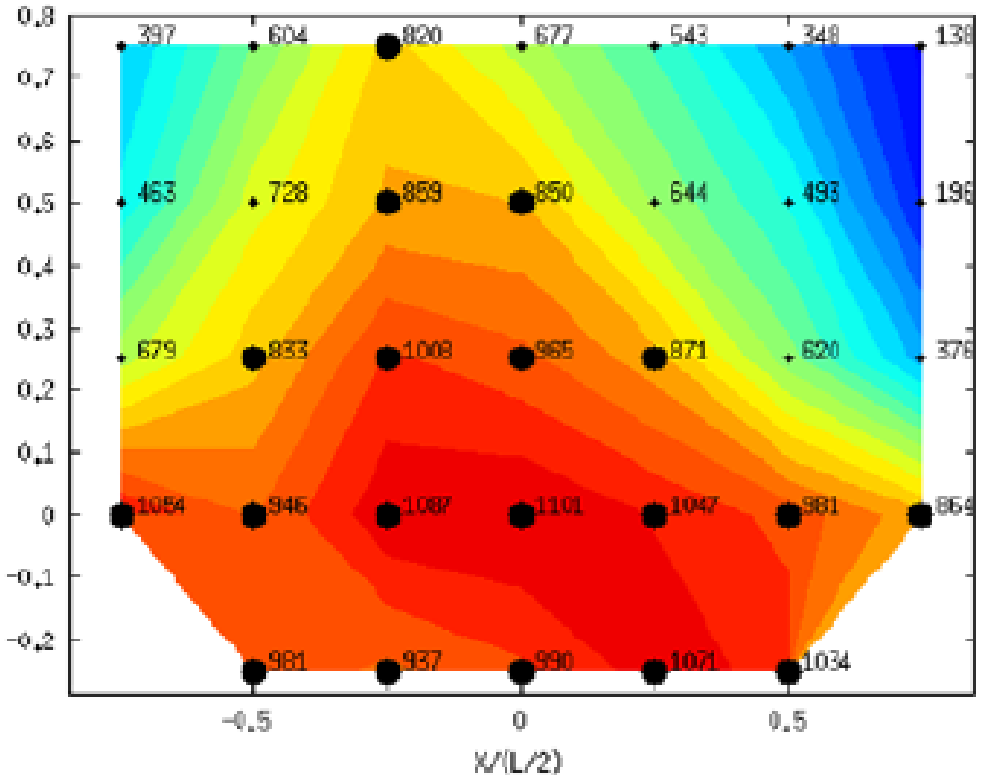
Fires Studied, Cont.

Sandia JP-4
62 f (19 m) Diameter

Meppen Propane
15 x 28 ft (5 x 8 m) Propane

Fires Studied, Final

Dahlgren .6 x 1.2 m propane demo burner



This is the smallest burner in the comparison using scaling study

Curves from Grizzo, Gill, and Nicolette, "Estimates of the Extent and Characterof the Oxygen Starved Interior in Large Pool Fires," in ASTM STP 1336, 1998

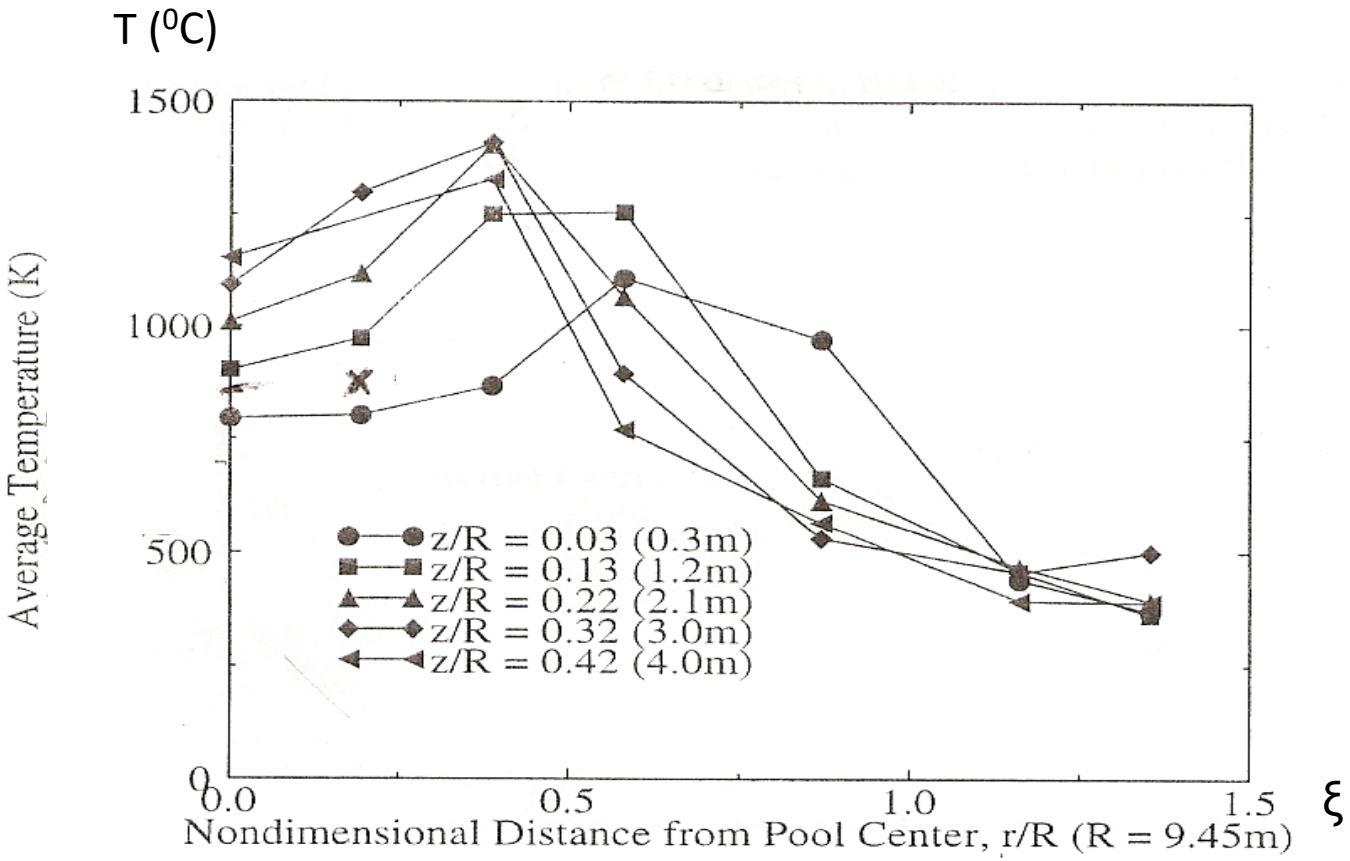


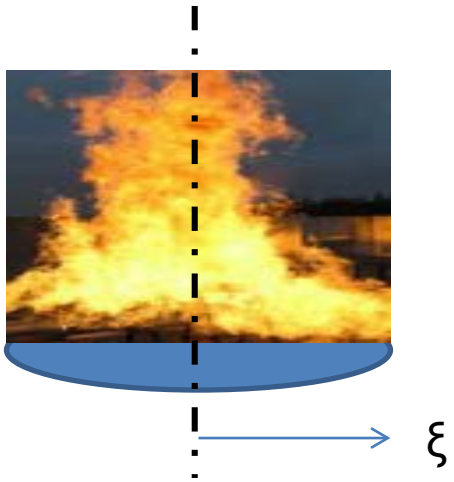
FIG. 1 -- Time-Averaged Thermocouple Temperature Profile for JP4 Pool Fire

This is the largest burner in the comparison using scaling study

Objective

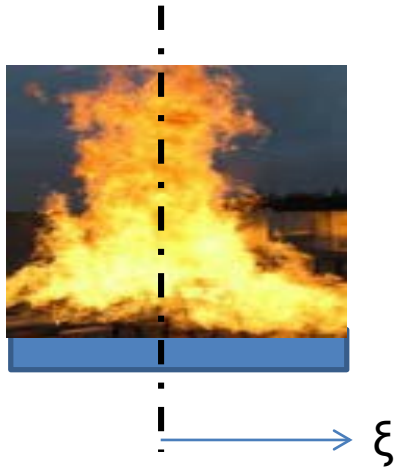
Compare fires at Dahlgren (Propane, Kerosene, and JP-5), with Propane fire at Meppen, and a JP-4 fire at Sandia

The approach is to compare fires by plotting temperature fields using non dimensional lengths



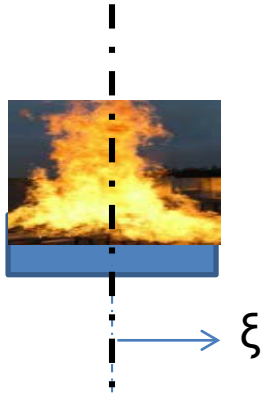
Round, ξ = r/R

Sandia ~19 m dia.



Square ξ = x/(W/2)

Dahlgren 9 x 9 (m)

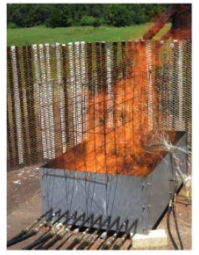


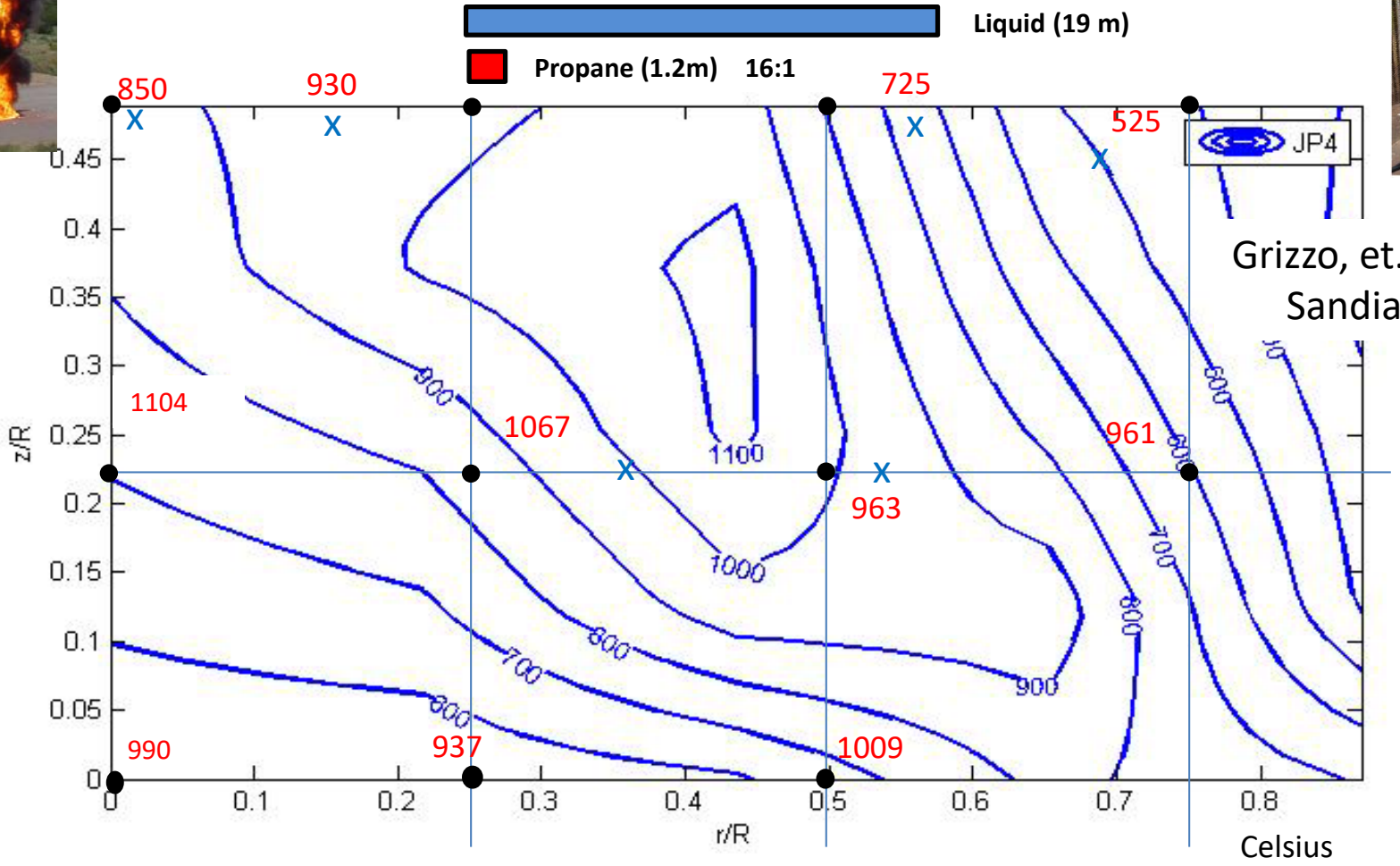
Rectangle ξ =x/(L/2)

Dahlgren 2.5 x 4 ft
(0.6 x 1.2 m)

Sandia 10m Radius JP4 Fire Temperature Contours with Dahlgren Demo .6m Wide Burner Temperature Contours

This is the most extreme scale factor:





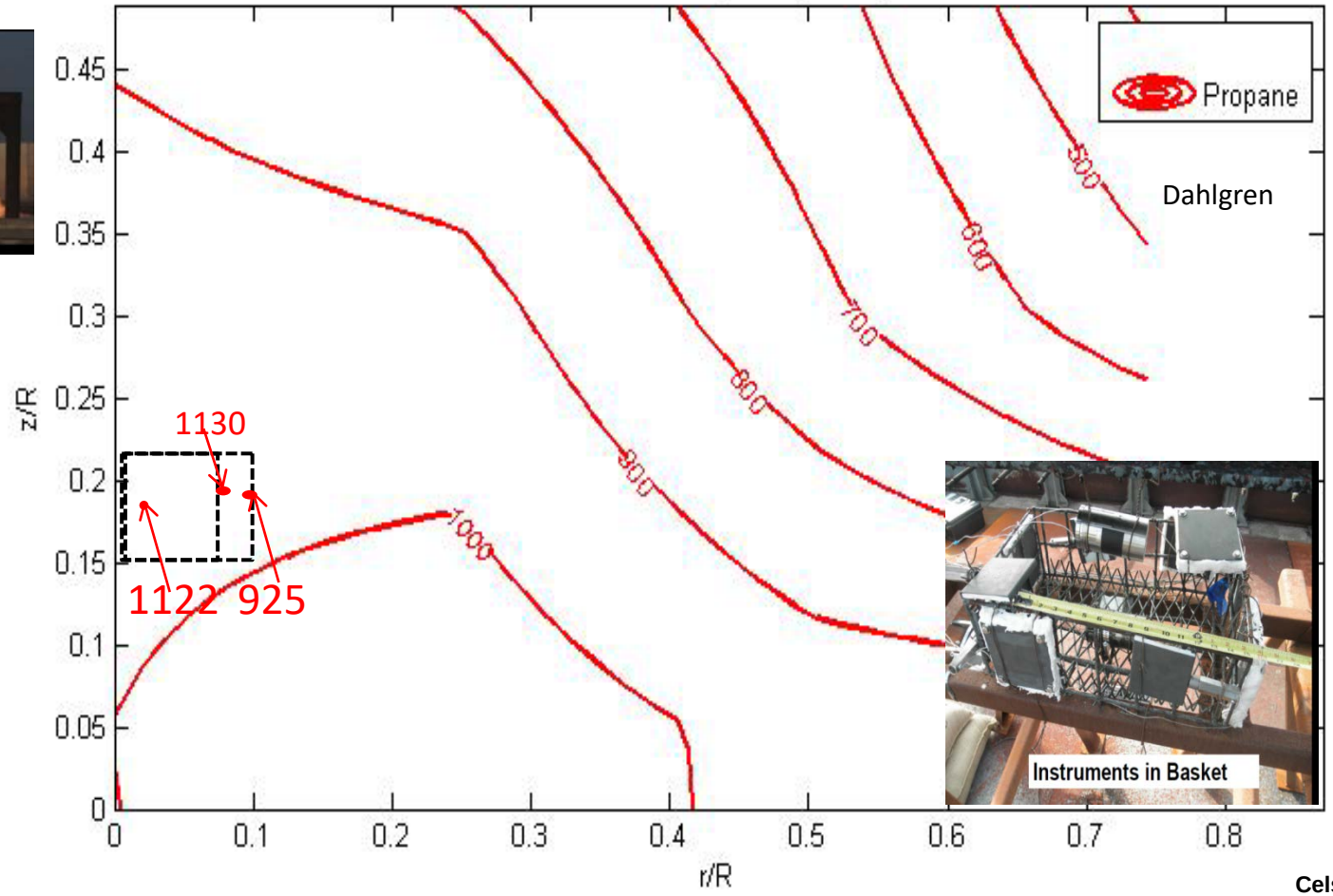
Grizzo, et. al.
Sandia

Celsius

And it is trying to work!

X denotes place where interpolated JP-4 data gives same value as propane

Dahlgren Scale Demo Propane Burner Temperature Contours with Data from Meppen Fire



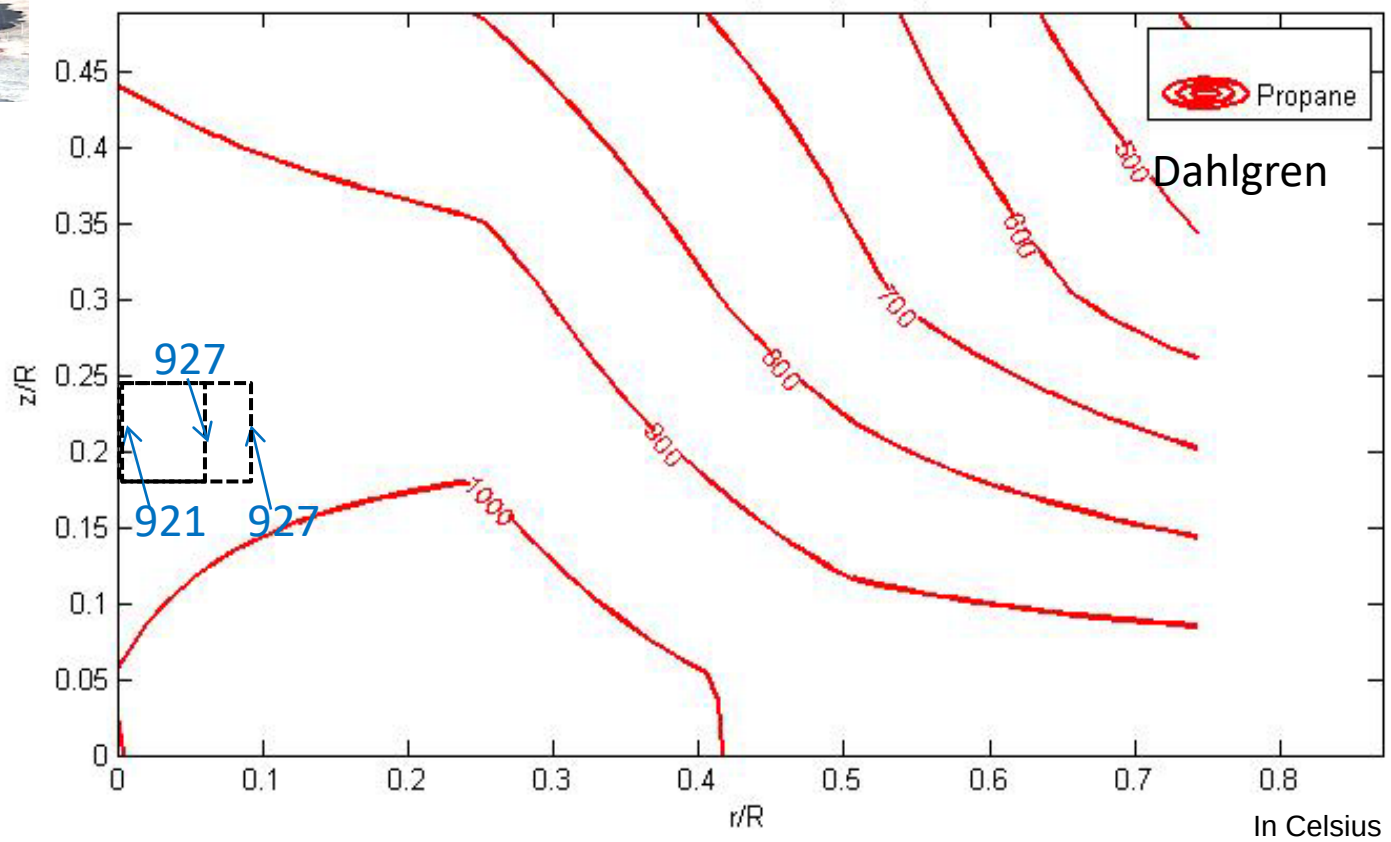
Basket of instru-ments

Celsius

This shows the Dahlgren demo burner temperatures are a little lower than the temperatures in the burner at Meppen.

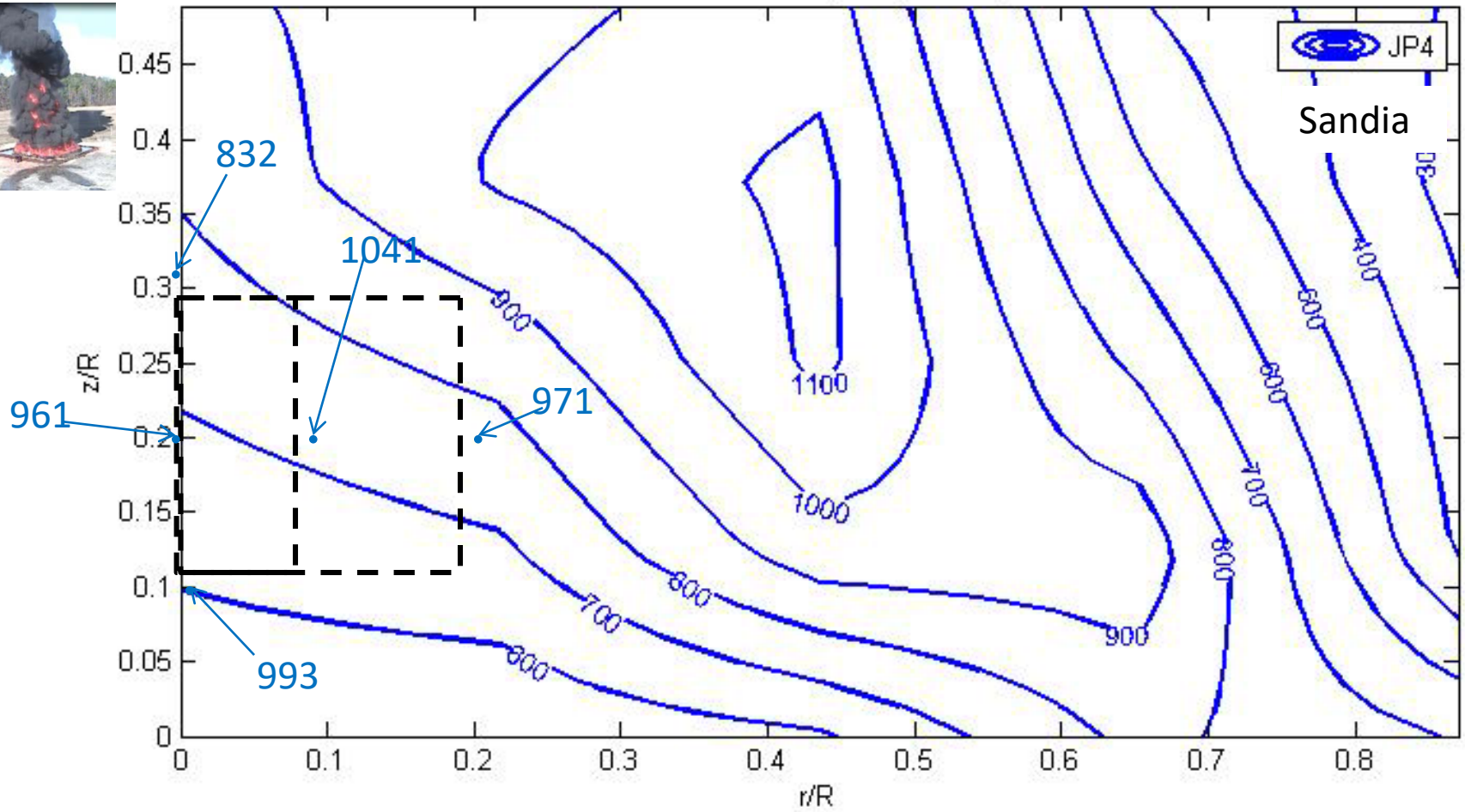
The Dahlgren fire temperatures have since been increased.

Dahlgren Scale Demo Propane Burner Temperature Contours with Data from Dahlgren JP-5 Fire



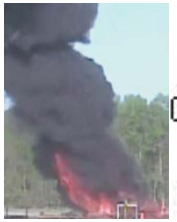
This shows the Dahlgren JP-5 fire was around the same temperature as the Demo Propane Burner

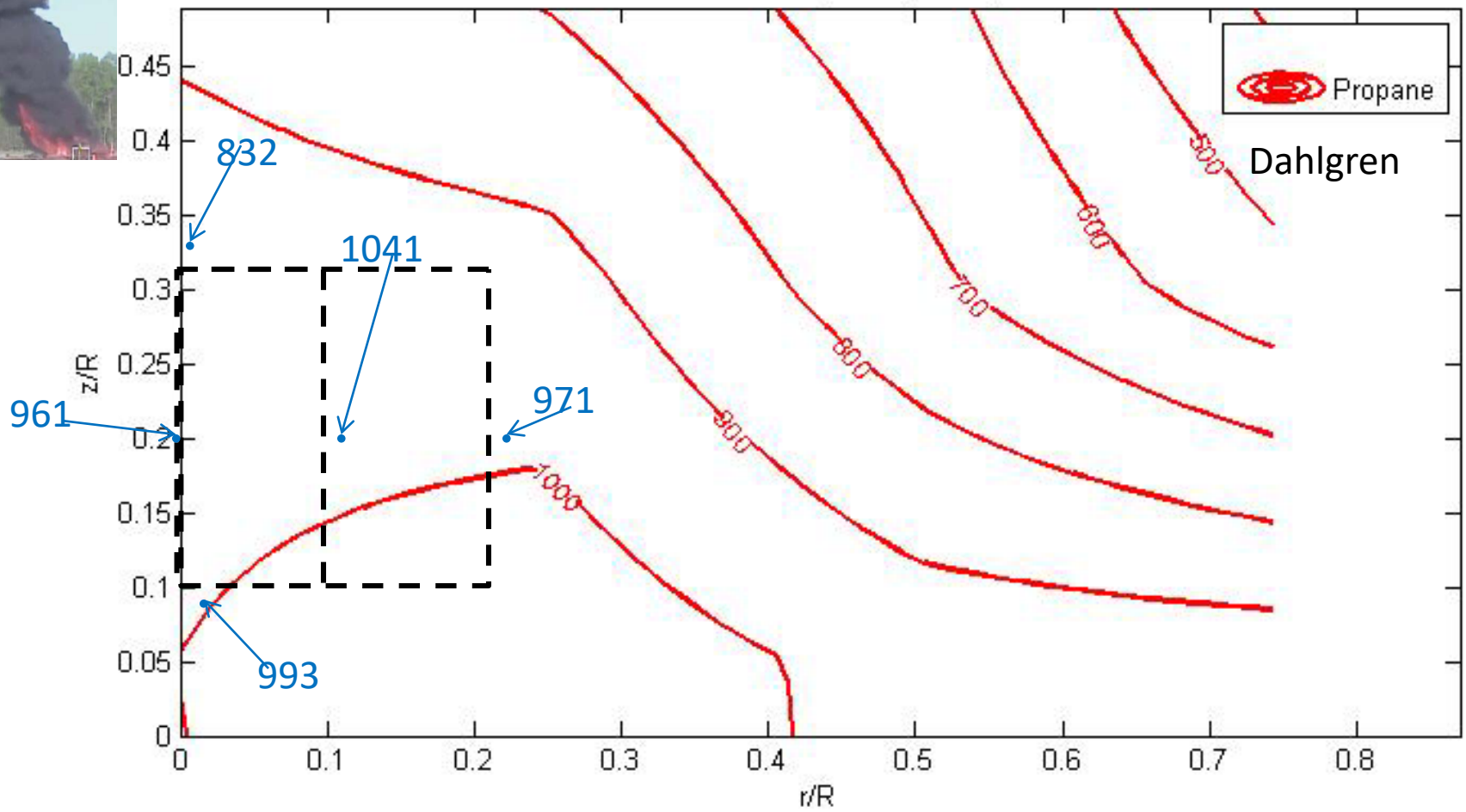
Sandia Round JP-4 Fire Data Temperature Contours with Data from SM-3 MK 21 Canister in Dahlgren SM-3 JP-5 fire



This shows the Dahlgren JP-5 fire was hotter than the Sandia JP-4 fire in the scaled location of the canister

Dahlgren Scale Demo Propane Burner Temperature Contours with Data from SM-3 MK21 Canister in Dahlgren SM-3 JP-5 fire

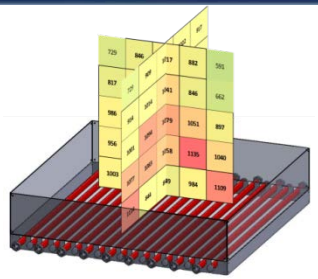




This shows the Dahlgren SM-3 fire was about the same temperature as the propane burner fire

8 ft x 8 ft Propane **Average Temperature Measurements**

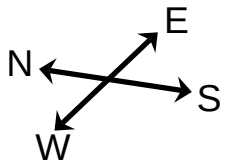
8 ft x 8 ft (2.4 m) burner
Instruments 5 ft x 5 ft (1.5m) cube



Ensemble Average	**999**
Standard dev.	**87**

729	**846**	**1017**	**882**	591
817	**909**	**1041**	**846**	662
986	**979**	**1079**	**1051**	**897**
956	**1054**	**1058**	**1135**	**1040**
1003	**1010**	**849**	**984**	**1109**

Looking West



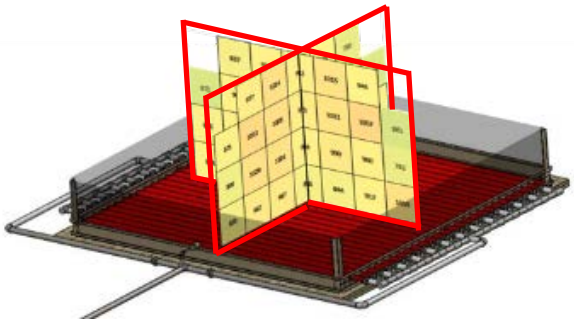
5’

729	**909**	**1017**	**1022**	**917**
914	**1014**	**1041**	**1037**	**1012**
1001	**1094**	**1079**	**1060**	**1064**
1077	**1083**	**1058**	**1092**	**1122**
1114	**844**	**849**	**950**	**1100**

5’

Looking North

12 ft x 12 ft (3.6 m) Propane Average Temperature Measurements



Average	907°C
Maximum	1047°C
Co. Var.	8%

8’

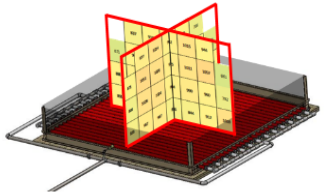
	801	894	897	938	938	
749	842	906	928	951	882	817
899	936	933	900	956	923	847
944	940	911	827	834	932	967

	870	920	897	997	1047	
658	929	990	928	961	987	952
910	1003	955	900	962	988	897
1012	871	903	827	850	859	814

6’

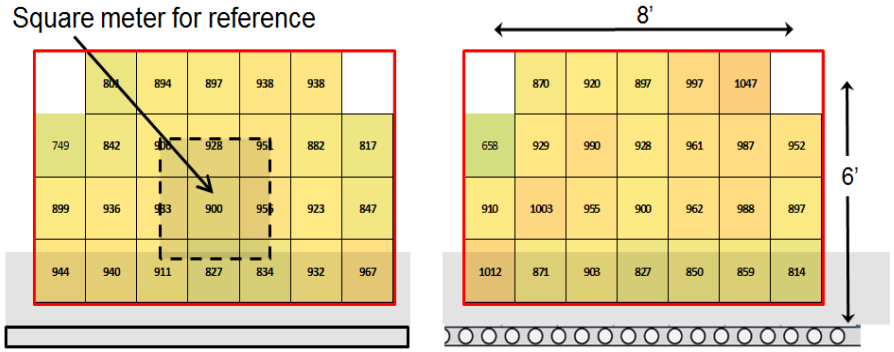
Side by Side Comparison of 8 x 8 and 12 x 12 Propane Burners

12 ft x 12 ft Propane Average Temperature Measurements (°C)



Average	907°C
Maximum	1047°C
Co. Var.	8%

Square meter for reference

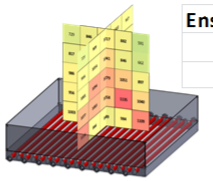


13

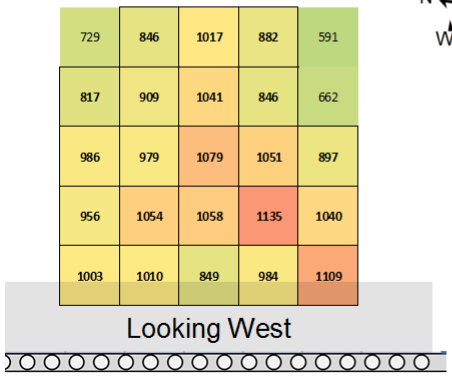
8 ft x 8 ft Propane Average Temperature Measurements (°C)

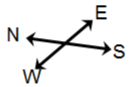
Ensemble Average	999
Standard dev.	87

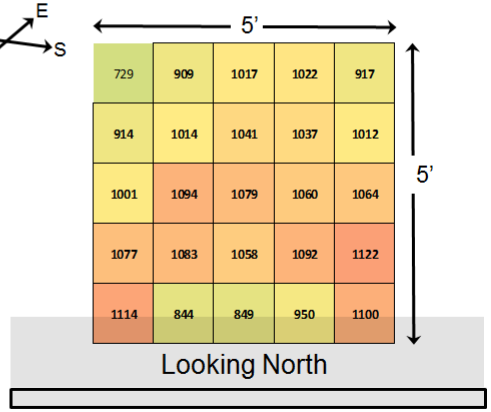
Calm wind conditions are needed for qualification testing



8ft x 8ft burner
Instruments 5Ft x 5ft cube



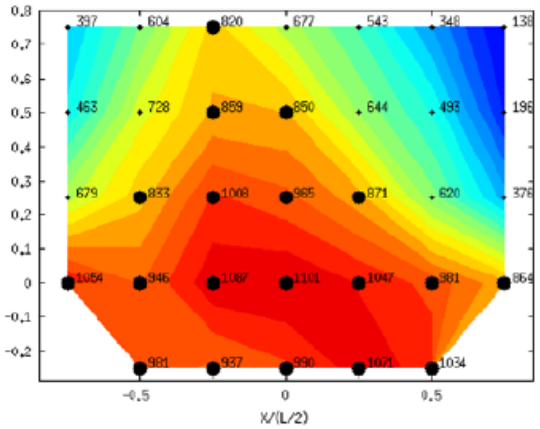




12

The propane fires nicely fill out the space above the burner and don't have much structure. There isn't much difference between these two fires in a statistical sense

Non Dimensional Propane Temperature Fields



1:1

2.5 x 4 rectangle

729	846	1017	882	591
817	909	1041	846	662
986	979	1079	1051	897
956	1054	1058	1135	1040
1003	1010	849	984	1109

1:2

8 x 8 square

	801	894	897	938	938	
749	842	906	928	951	882	817
899	936	933	900	956	923	847
944	940	911	827	834	932	967

1:3

12 x 12 square

Again, the propane fires nicely fill out the space above the burner and don't have much structure. There isn't much difference between these three fires in a statistical sense.

Aluminum Container Test in a Propane Fuel Fire

Value of Flame Filling Flame Space Above Burner:

The average temperature on 12 thermocouples surrounding container was 863°C (1585°F)

Summary

- Scaling the length axes shows temperature contours over a wide range of lengths (1.2 to 19 meters) and provides a means of comparing fires

- The JP-5 fire in Dahlgren and propane fires in Meppen and Dahlgren are reasonably the same at homologous positions near the test item

- Scaling may be used to predict the temperature field in large fire from temperature measurements in a small fire

Future Work

- The baseline liquid fuel fire at Sandia showed low temperatures in the inner core of the fire as compared to the other fires. Therefore a complete mapping of a liquid fuel fire in a large pit such as at Dahlgren is needed. This fire would become the baseline for scaling up or down, as much as 16:1 to 1:16. Pans for 12 ft. x 12 ft and 30 ft x 30 ft are readily available.
- Scaling for rectangular fires needs further development. This would facilitate developing modular fires consisting of arrays of basic modules.
- Square fires are prismatic near the pan, but quickly become cylindrical. Need to work out length scaling based on pan area$^{1/2}$.
- Estimate velocity fields from temperature fluctuations using signal processing techniques. Try to detect wave like motions and get group velocities as in acoustics.
- Apply turbulence methods to characterize time dependent fluctuations , <u,v,w>.
- Study vertical direction using momentum length scaling from buoyant plume theory.
- Attempt large eddy simulations to determine the unstable, nearly chaotic swirling motions seen in large fires. Also check limits of scaling.