Analysis of Inlet Sprays

Dr. T.W. Lee

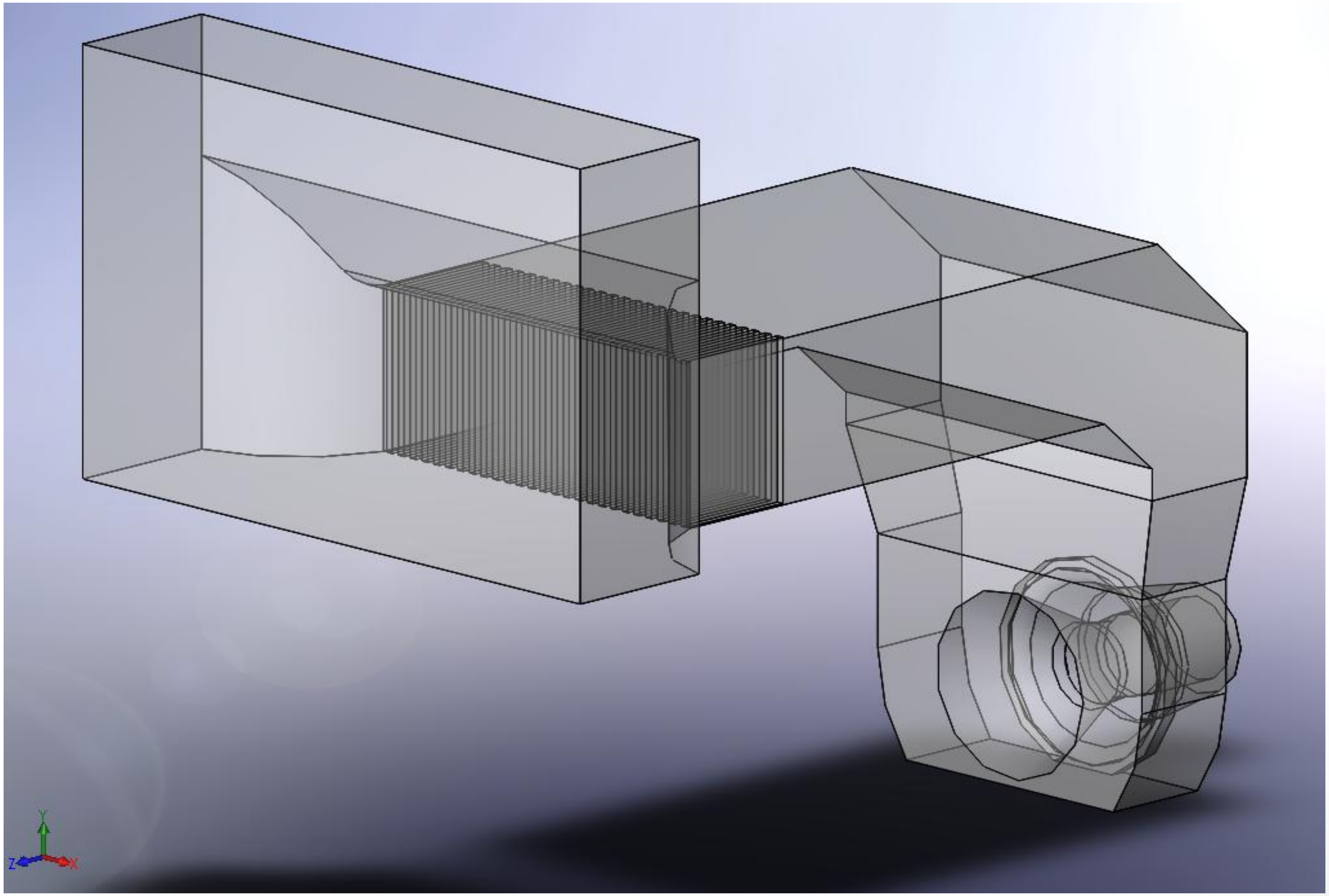
Akshay Batra, Kevin Hargrave

Introduction

- The purpose of this study was to determine the possible damage that may be done to the compressor blades of a gas powered turbine.
- The scope of this study was to investigate the behavior of water droplets injected into the inlet to a gas powered turbine, along with how many of these droplets travelled through the exit of the inlet along with their size.
- It was first decided to observe the behavior of the droplets at four different temperatures and four different relative humidities with all of the grids on, and FLUENT was chosen as the CFD solver.
- Then it was decided to perform a study where the grids were varied while the temperature was held constant and the relative humidity varied.
- An average droplet diameter was determined from data obtained from Parker-Hannefin, along with the operating pressures.
- The average droplet diameter was determined to be 7.25 microns.

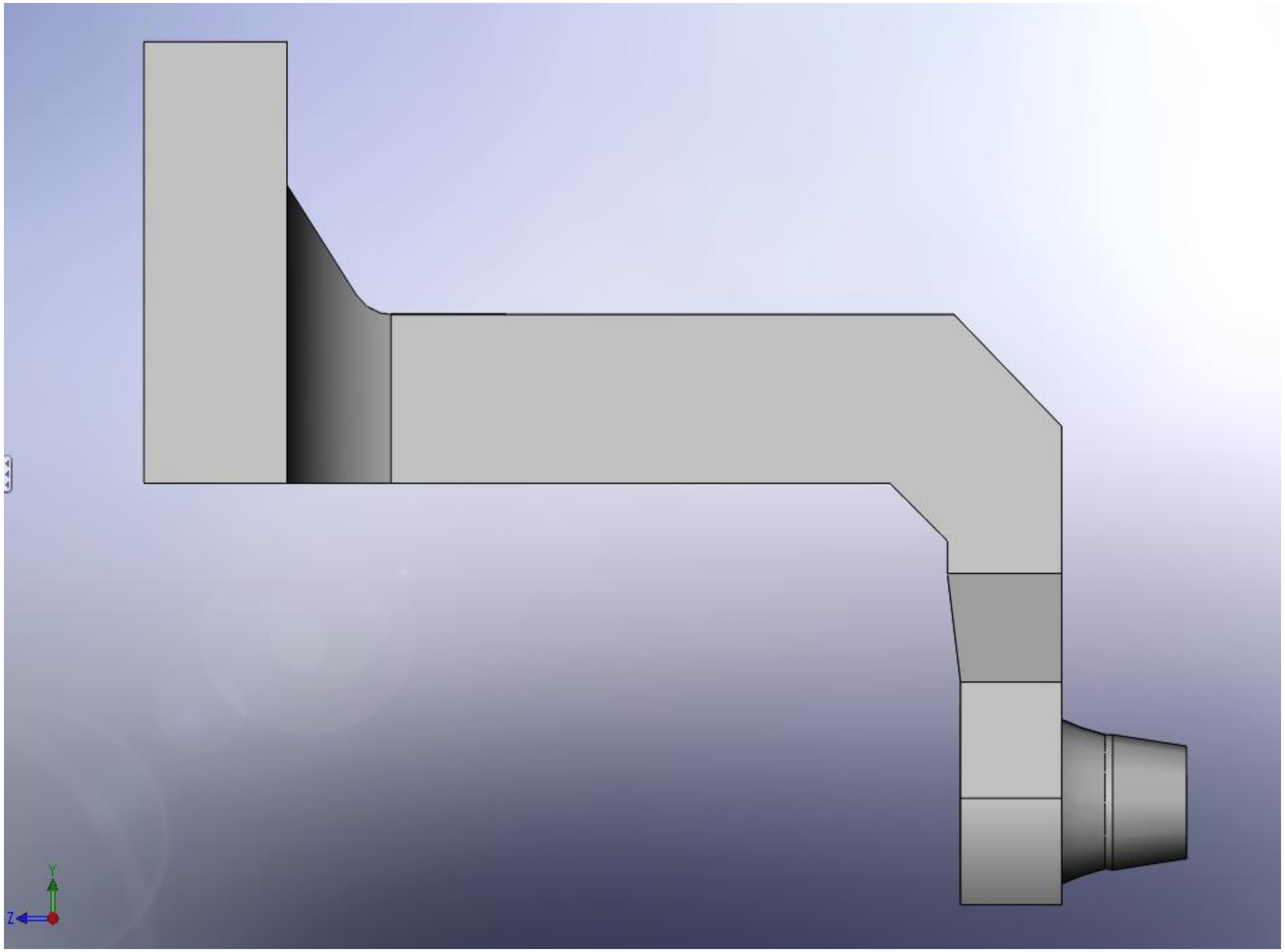
Final Geometry

- Displayed here is the final geometry of the inlet to the turbine.



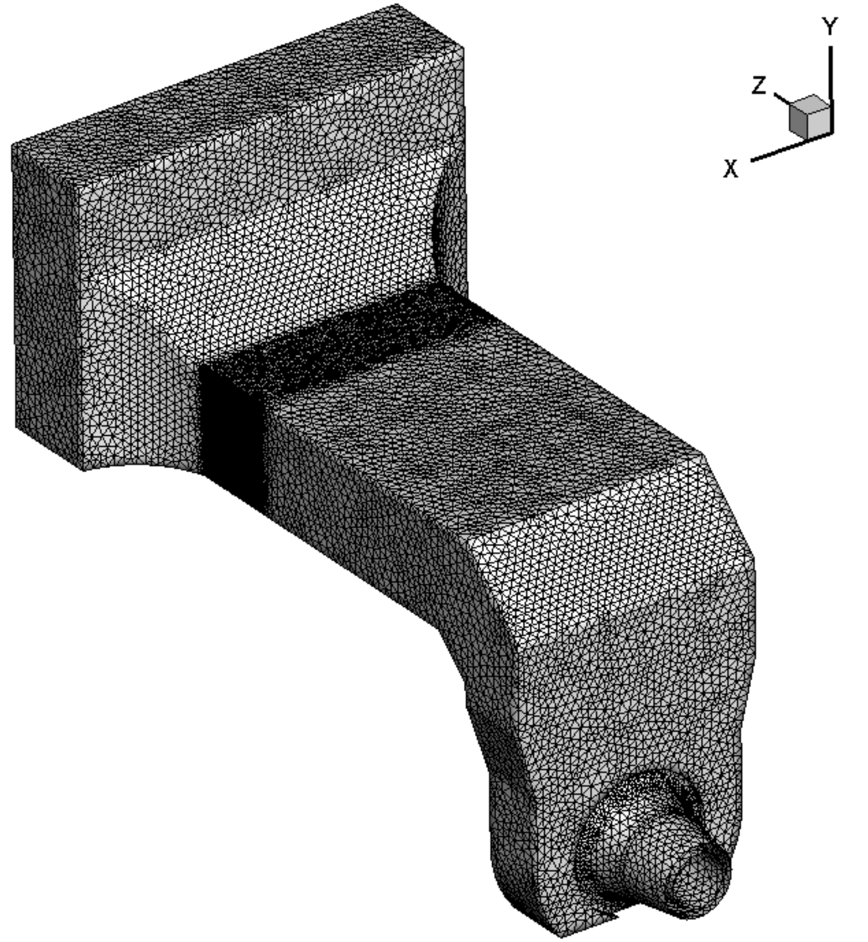
Geometry Cont.

- Right hand view of the model.



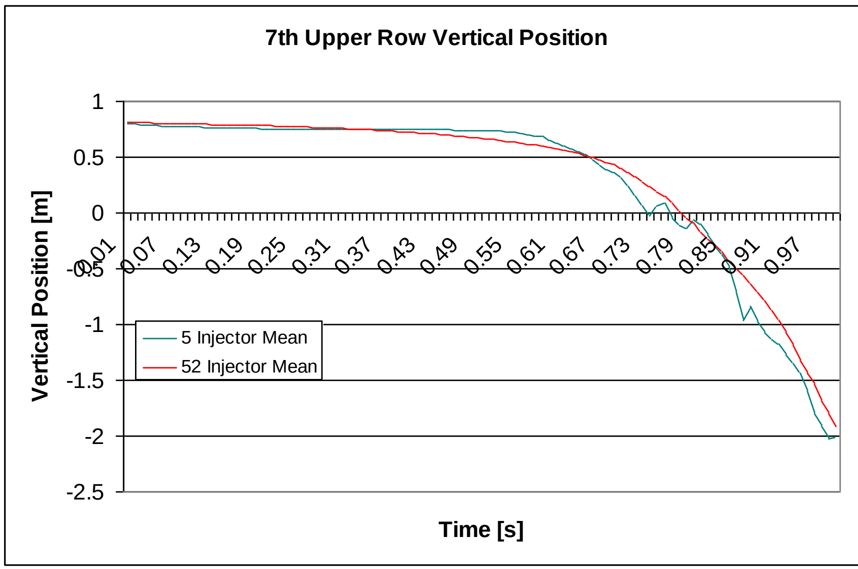
Fluent Meshed Geometry

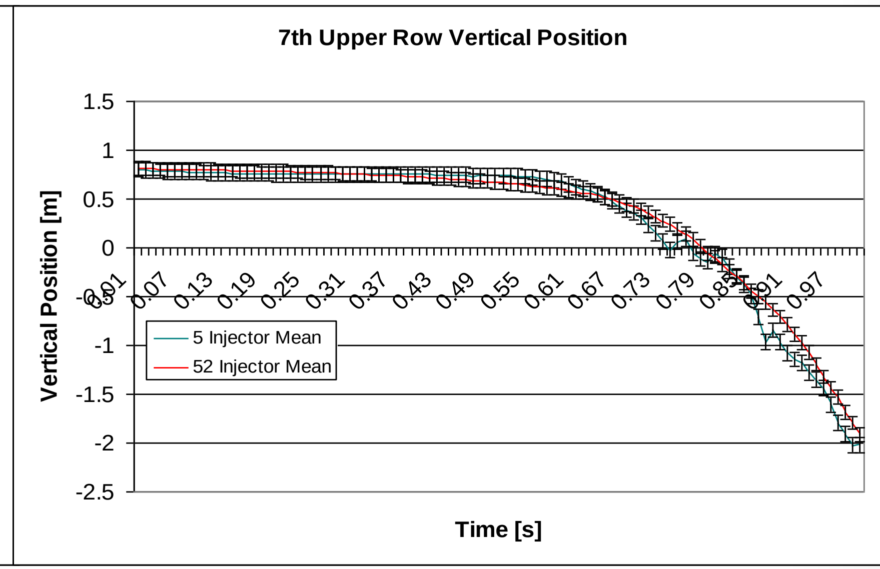
- This figure shows the meshed geometry as seen in Fluent and displayed in Techplot.



Number of Injectors Validation

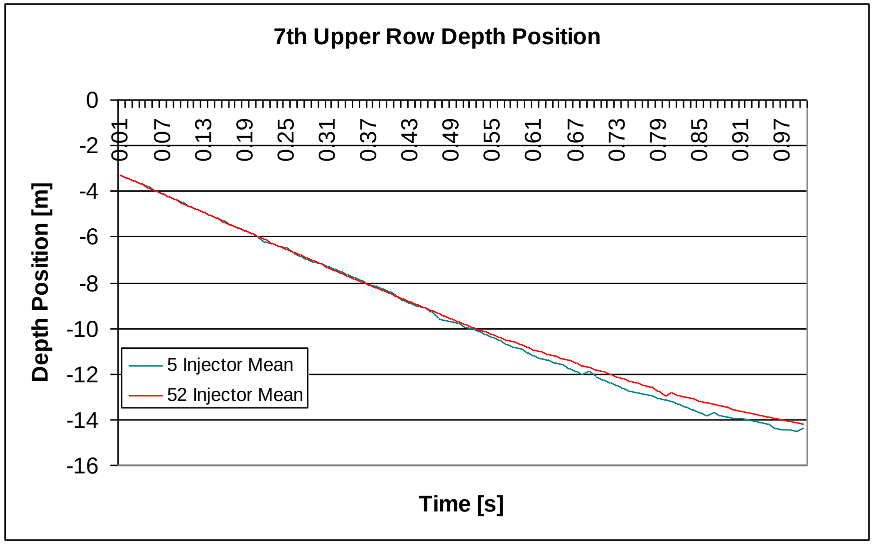
- Plots showing the average position of the water droplets over time for both the 5 injector case and the 52 injector case.

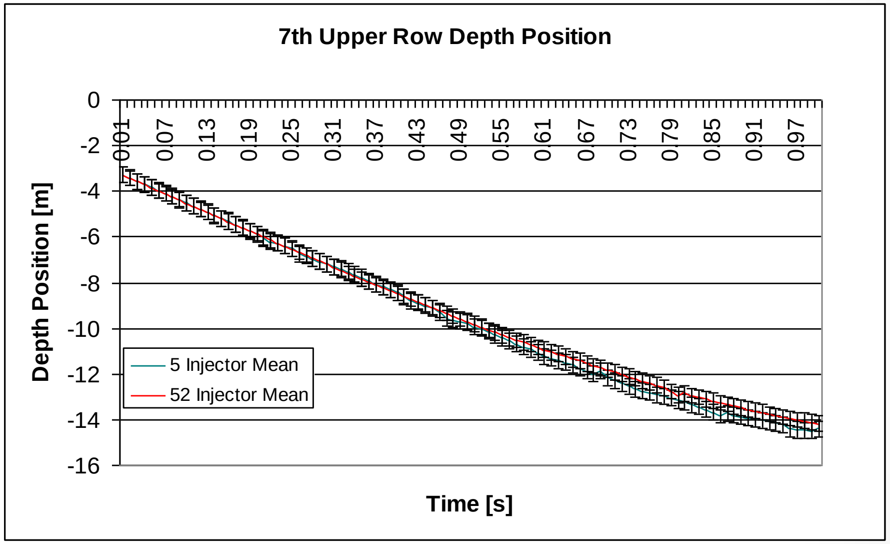




Injector Validation Cont.

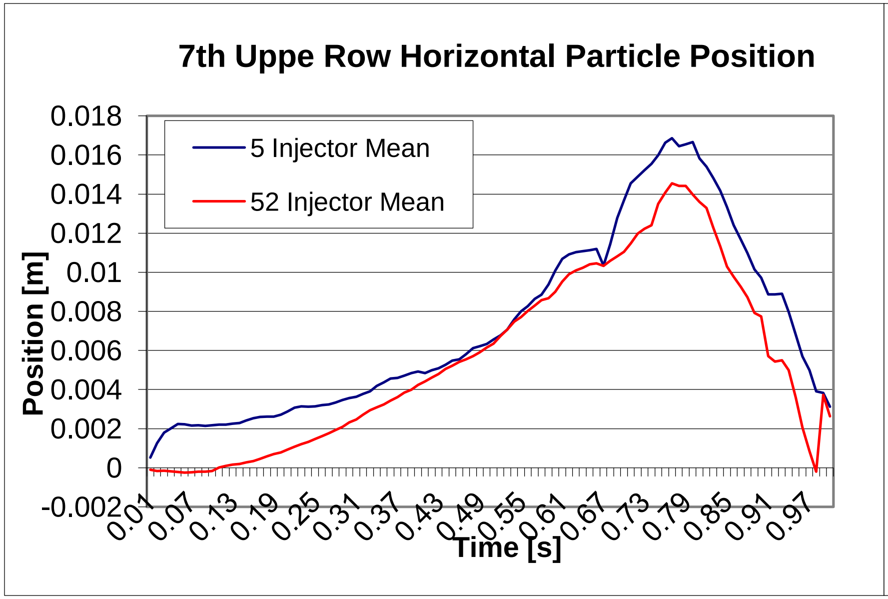
- These plots show the average position of the droplets along the length of the inlet.

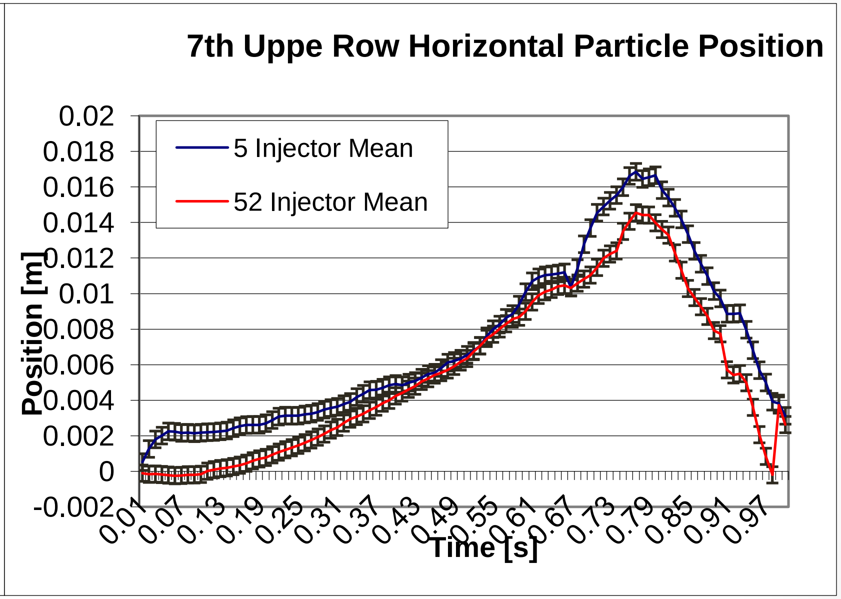




Injector Validation Cont.

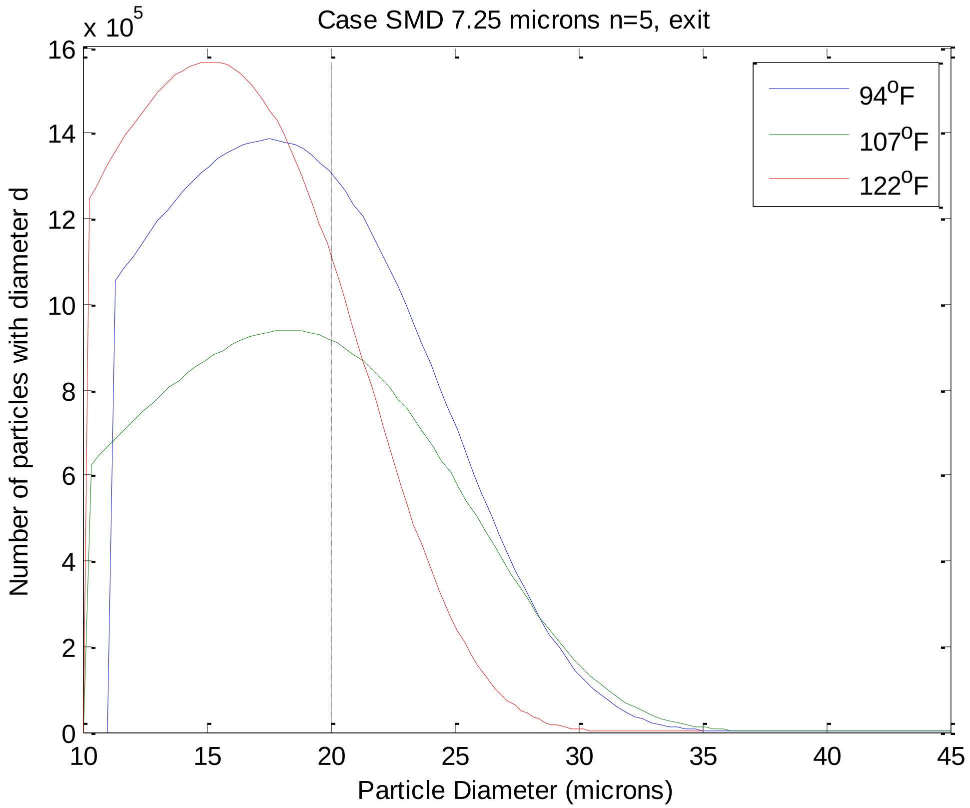
- These images show the average droplet position along the width of the inlet.





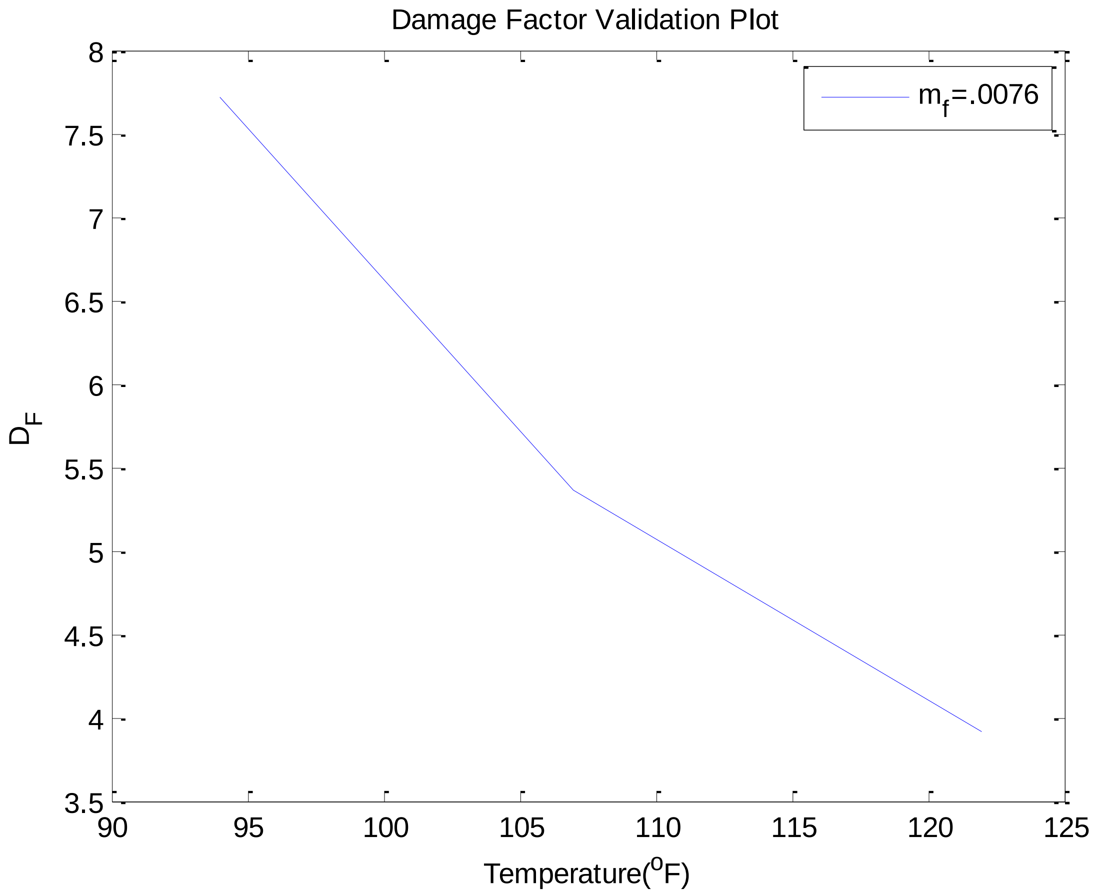
Evaporation Validation

- The following image shows the number of particles diameter distribution for the evaporation validation case.



Evaporation Validation

- This plot shows the validation of the evaporation model used in the FLUENT simulations.



Temperature Validation Case Studies

- Four temperature validation case studies were performed, each with its own unique conditions.
- The purpose behind these case studies is to determine if the FLUENT model results matched those found in the physical model.
- It can be seen from the following tables that the results form FLUENT are nearly identical to those obtained by SRP's physical plant.
- These results show that the FLUENT model closely simulates what is happening within the real world model, as far as the change in temperature is concerned. This means that there is a high probability that the simulations also closely match the droplet behavior within the physical model.

Parameters for the Validation Case Studies

- Spreadsheet data taken from the SRP experimental data collection for July. The first case study data taken from July 1st at 11:00AM is shown as an example.

FLUENT key Parameters from the temperature values given from SRP for the first validation case study

T exit is 88ºF = 304K
(T inlet to SRP compressor)

T inlet is 99ºF = 310K

Only grid E is turned on

Water mass fraction (m_{-f})
for 30.18% is 0.011499.

SMD = 7.25 microns.

Steady state simulation run until convergence at 200 iterations.

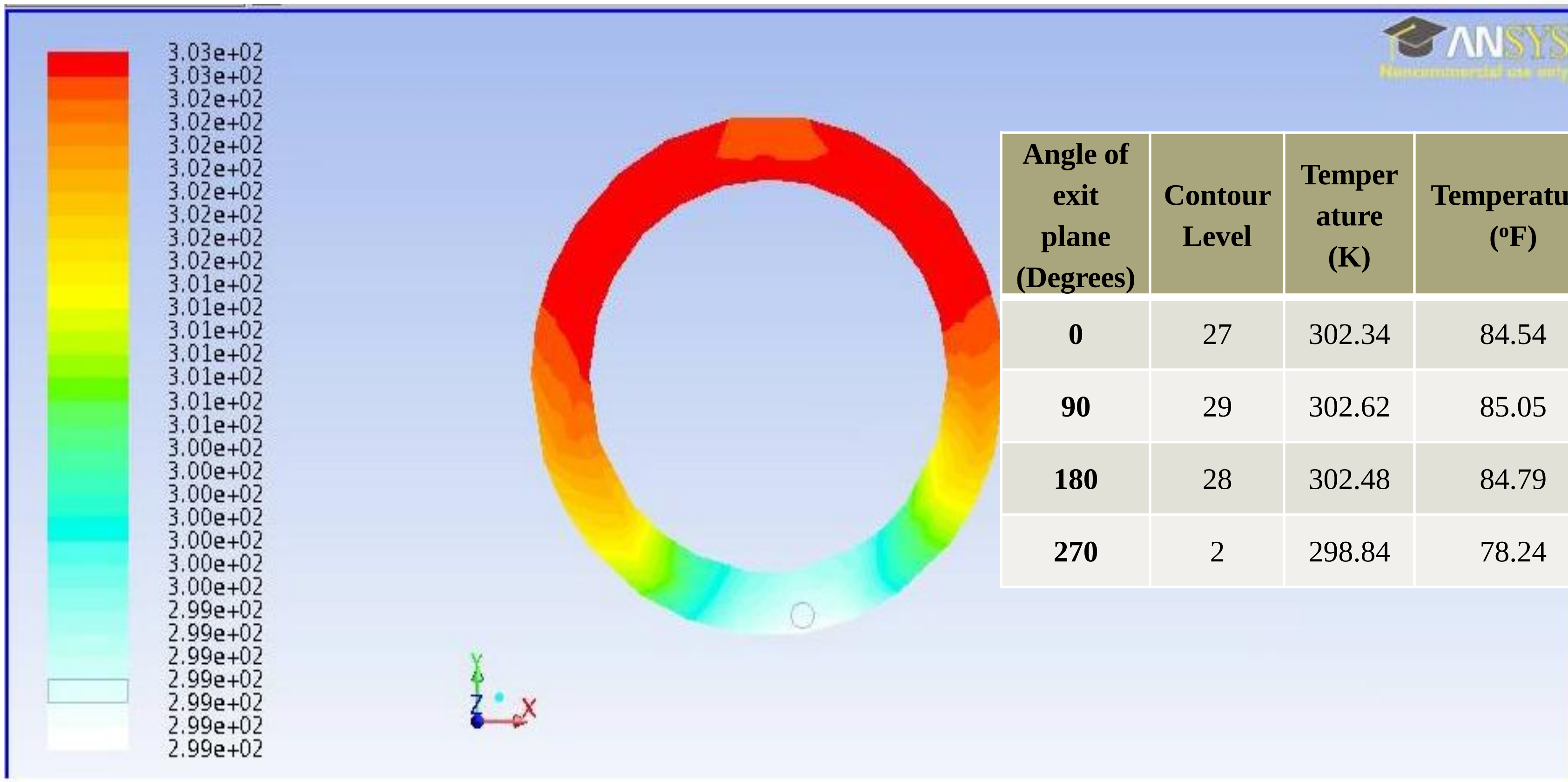
A1 | Start

	A	B	C	D	E	F	G	H	I	J
1	Start	7/1/12 0:00								
2	End	8/1/12 0:00								
3	Interval	5 m								
4										
5	Timestamp	Load	Ambient dry bulb T	CT comp inlet T	Sprits on	Grid AB on	Grid C on	Grid D on	Grid E on	Total flow
6		MW	F	F	binary	binary	binary	binary	binary	gpm
7		SG5A:DWATT	SG5A:ATDB	SG5A:CTIM	SG5A:L4DF_RUN	SG5A:LAC51_EN	SG5A:LAC52_EN	SG5A:LAC53_EN	SG5A:LAC54_EN	SG5A:IFQ_T
8	7/1/12 0:00	131.59883	91.026451	91.805099	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0145495

J140 | 28.5232944488525

	A	B	C	D	E	F	G	H	I	J
31	7/1/12 10:15	95.142746	96.53885651	100.47168	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0144426
32	7/1/12 10:20	95.139046	96.75518799	100.68875	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0141978
33	7/1/12 10:25	95.135338	96.97151947	100.90583	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0139222
34	7/1/12 10:30	95.131638	97.18785095	101.1229	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0136467
35	7/1/12 10:35	95.12793	97.4041748	101.33998	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0133712
36	7/1/12 10:40	95.124229	97.61768341	101.55705	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0130957
37	7/1/12 10:45	95.484962	97.80690002	101.77413	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0128202
38	7/1/12 10:50	113.11028	97.99612427	100.32713	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0125446
39	7/1/12 10:55	130.02196	98.50839996	98.03112	FALSE	FALSE	FALSE	FALSE	FALSE	-0.0122691
40	7/1/12 11:00	148.85818	99.11042786	88.162834	TRUE	FALSE	FALSE	FALSE	TRUE	28.523294
41	7/1/12 11:05	153.34581	99.53716278	75.981537	TRUE	FALSE	FALSE	TRUE	TRUE	47.76609
42	7/1/12 11:10	152.96574	99.08987427	75.773758	TRUE	FALSE	FALSE	TRUE	TRUE	46.884266

Contours of Temperature at the Exit of the Inlet from FLUENT



Angle of exit plane (Degrees)	Contour Level	Temperature (K)	Temperature (°F)
0	27	302.34	84.54
90	29	302.62	85.05
180	28	302.48	84.79
270	2	298.84	78.24

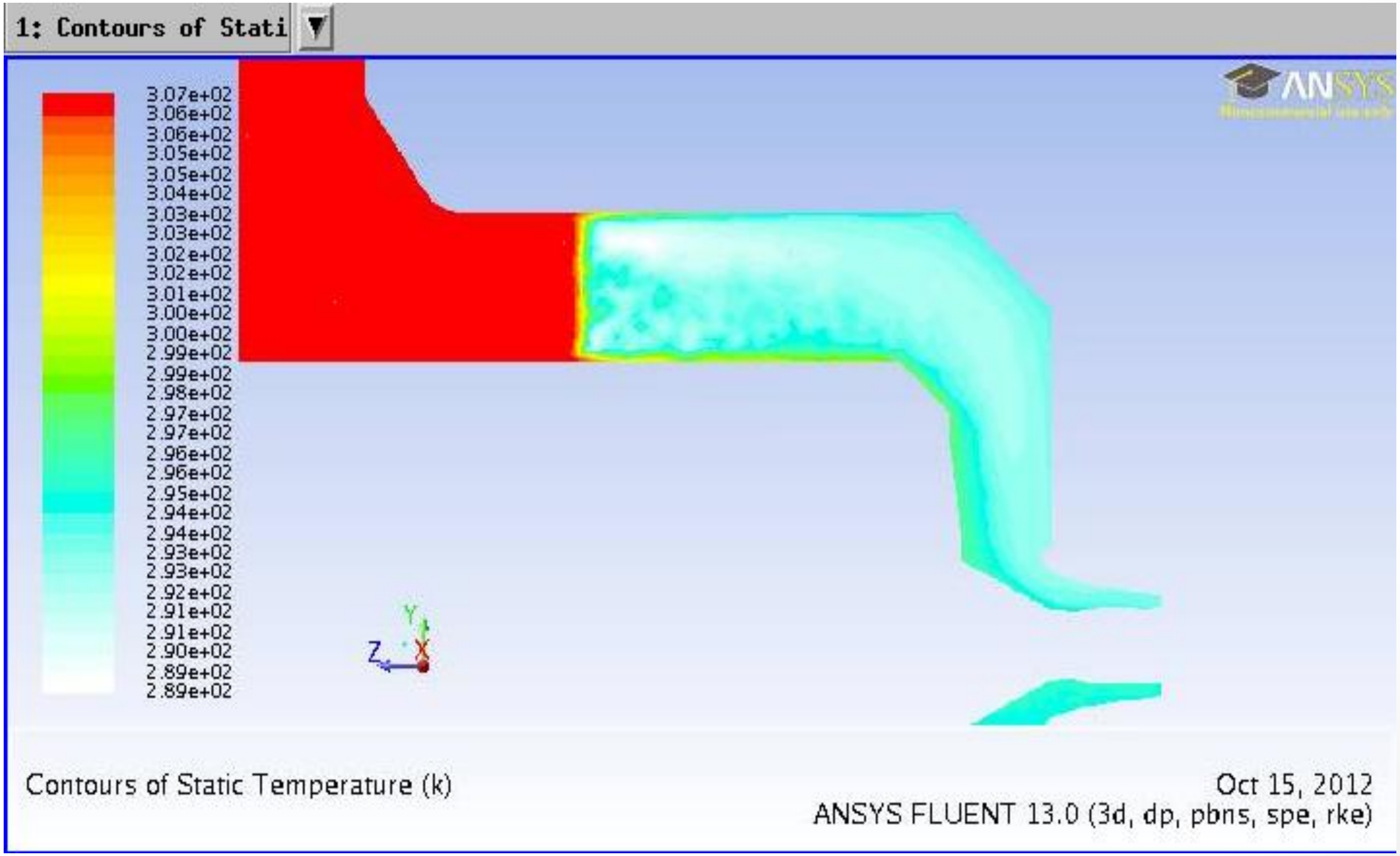
Results

SRP temperature values at the inlet to the compressor		
Case Number	Temperature (K)	Temperature (^oF)
1	304.35	**88.16**
2	298.07	**76.86**
3	300.01	**80.35**
4	300.06	**80.43**

Fluent temperature values at the exit of the inlet.						
Case Number	Min. Temp. (K)	**Min. Temp. (^oF)**	Max. Temp. (K)	**Max. Temp. (^oF)**	Ave. Temp. (K)	**Ave. Temp. (^oF)**
1	299	**78.5**	303	**85.7**	301.57	**83.16**
2	293	**67.7**	298	**76.7**	296.22	**73.53**
3	300	**80.3**	302	**83.9**	300.97	**82.07**
4	299	**78.5**	301	**82.1**	299.9	**80.15**

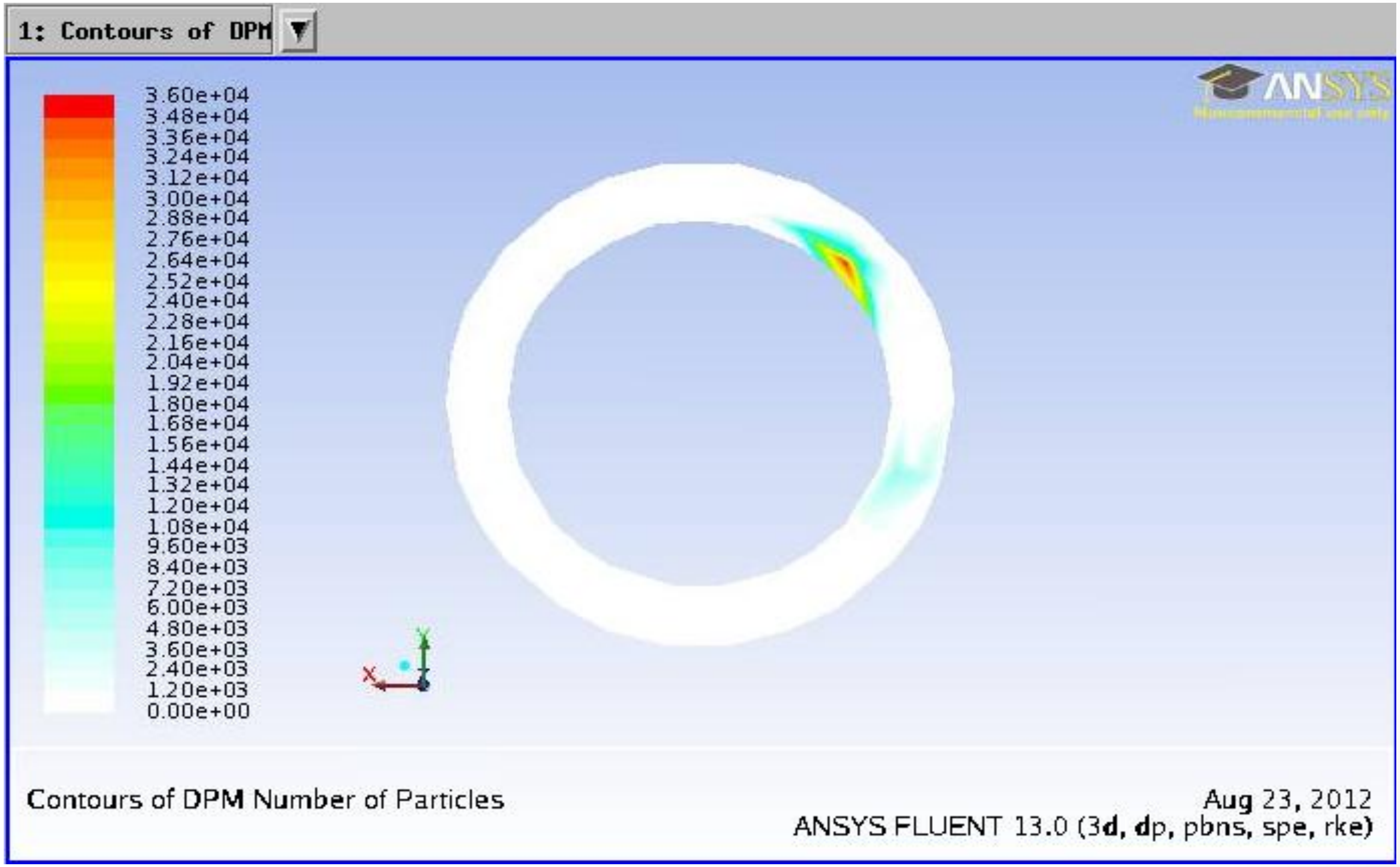
Simulation Case Example

- This is the temperature contour for 20% relative humidity at 94^{o}F



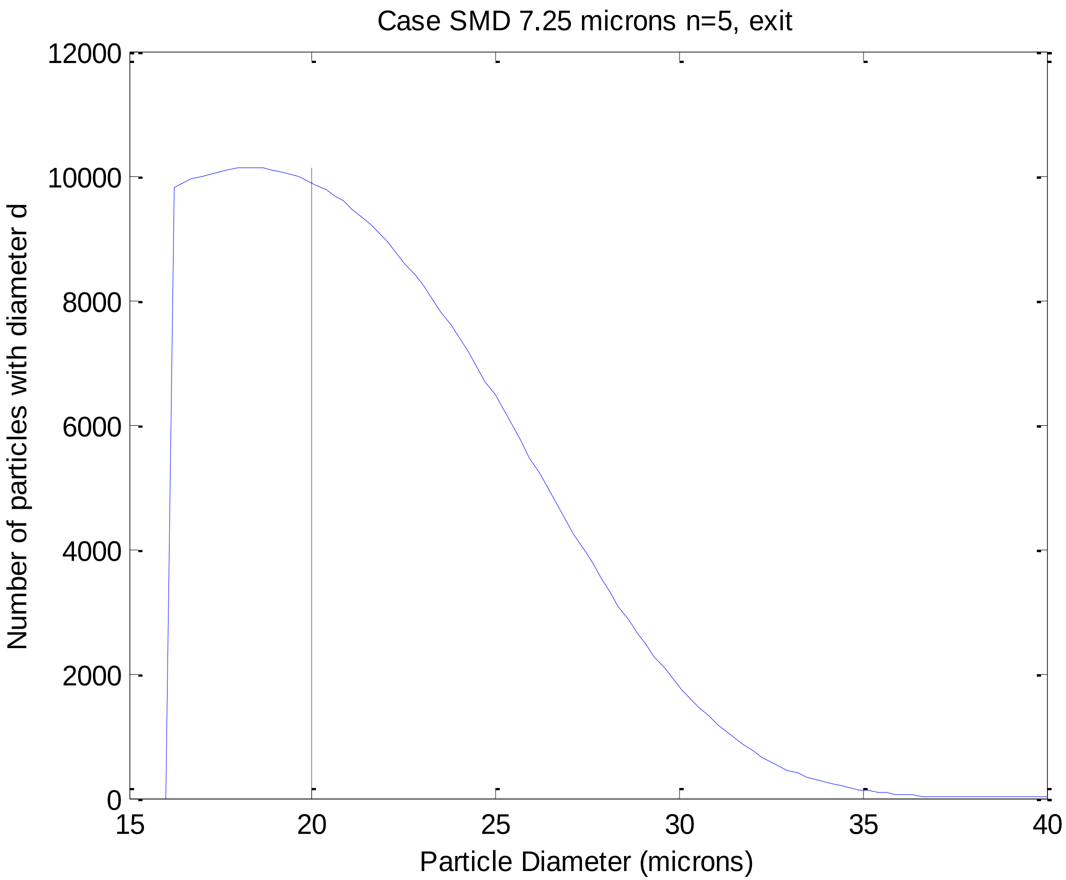
Example Case Cont.

- This image shows the contour for the number of particles exiting the inlet.



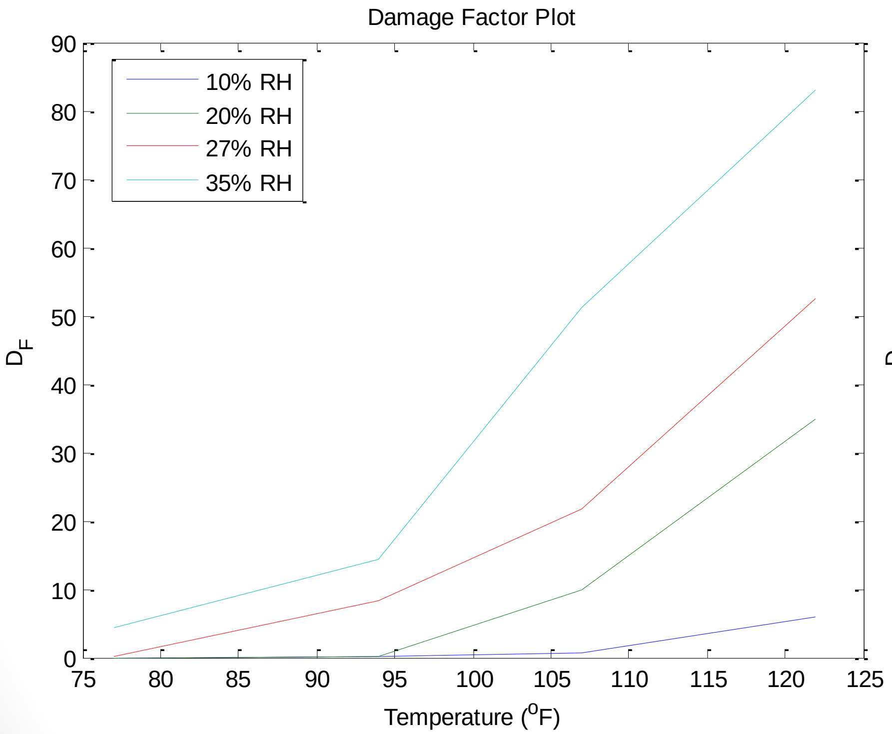
Example Case Cont.

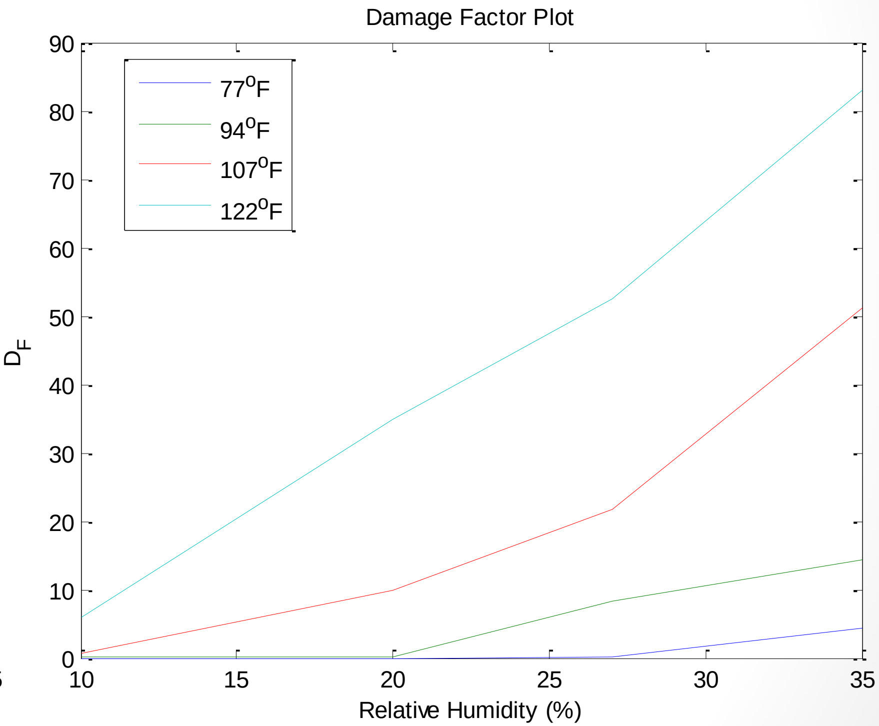
- This plot displays the diameter distribution with respect to the number of particles of a given diameter.



Damage Factor Plot

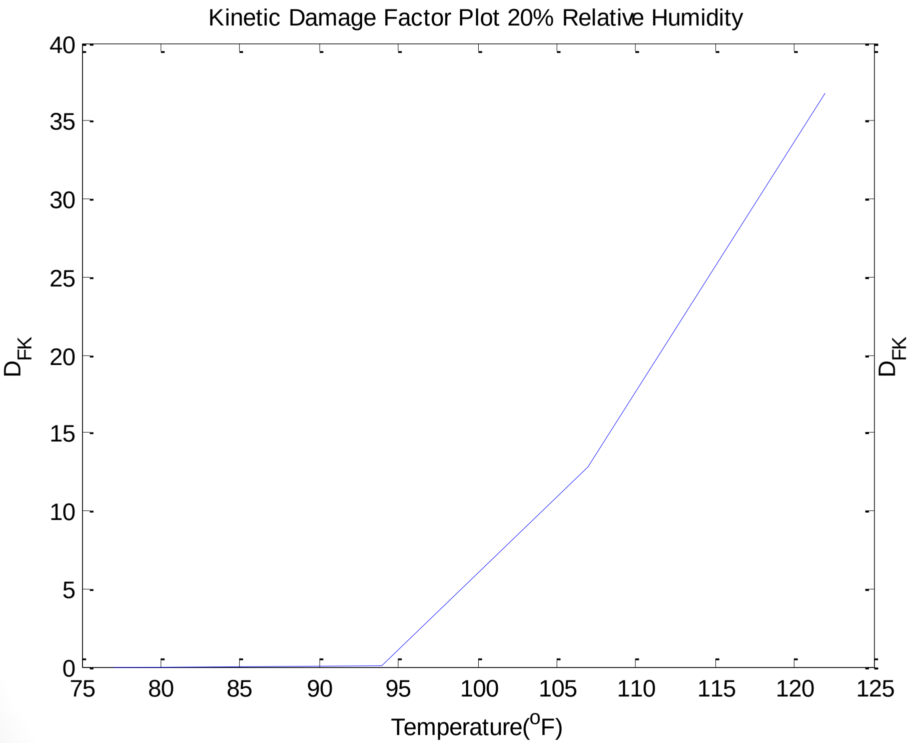
- The following two plots show the damage factor as calculated from the individual diameter distribution plots. Two variations of the plot are shown.

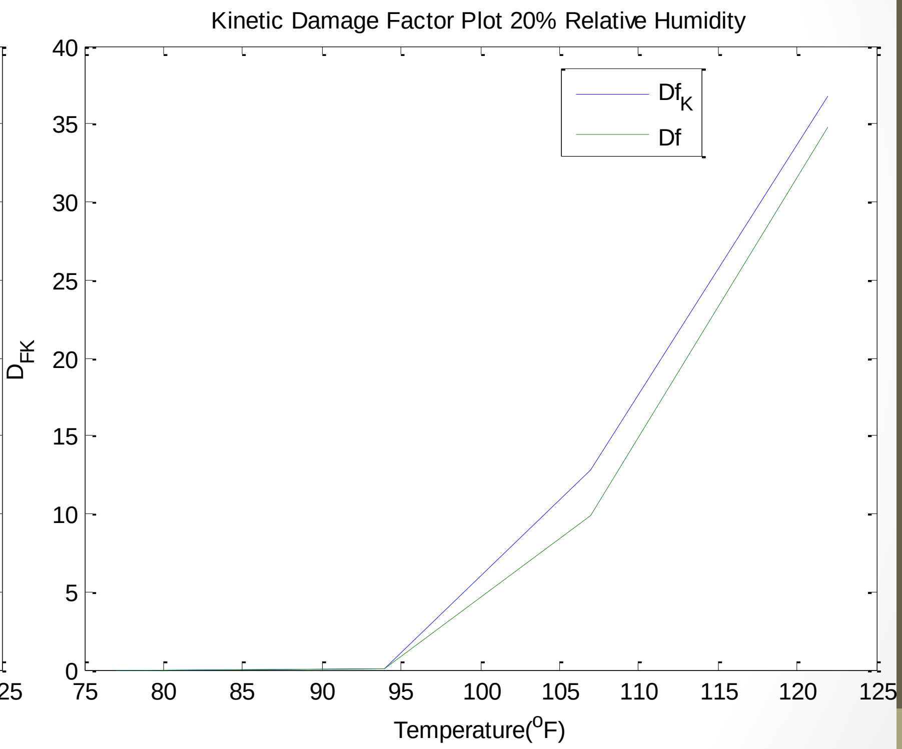




Damage Factor Continued

- This damage factor plot takes into account the velocity of the particles and relates them to kinetic energy.





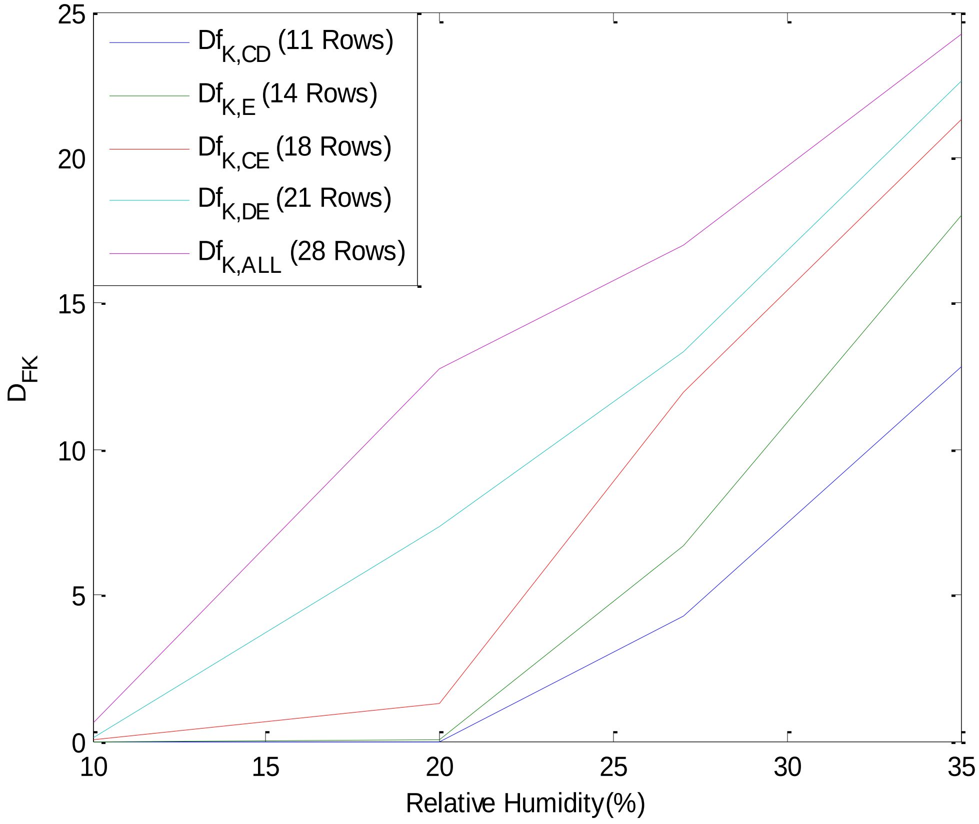
Grid Variation Simulations

- Four different sets of grids were examined; grids C & D, grids C & E, grids D & E, and grid E.
- Only one temperature was looked at and it was 107°F, while the same four relative humidities were utilized.

Grid	Number of Rows	Mass Flow (Gal/min)	Mass Flow (kg/s)
C & D	11	24	1.514157
E	14	26	1.640345
C & E	18	32	2.018878
D & E	21	44	2.775968

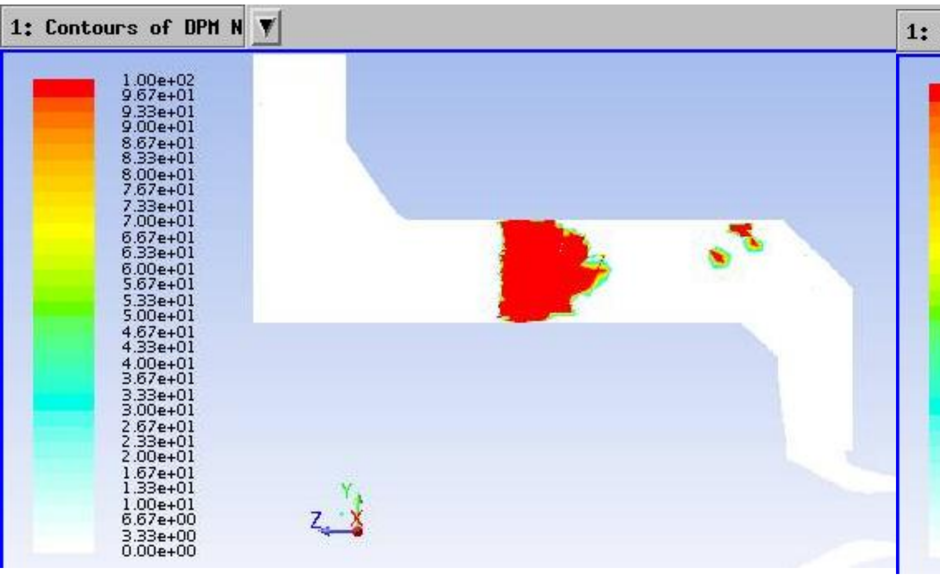
Grid Variation Kinetic Damage Factor Plot

- Here you can see the kinetic damage factor plot for the grid variation simulations along with the matching ALL grids simulation.

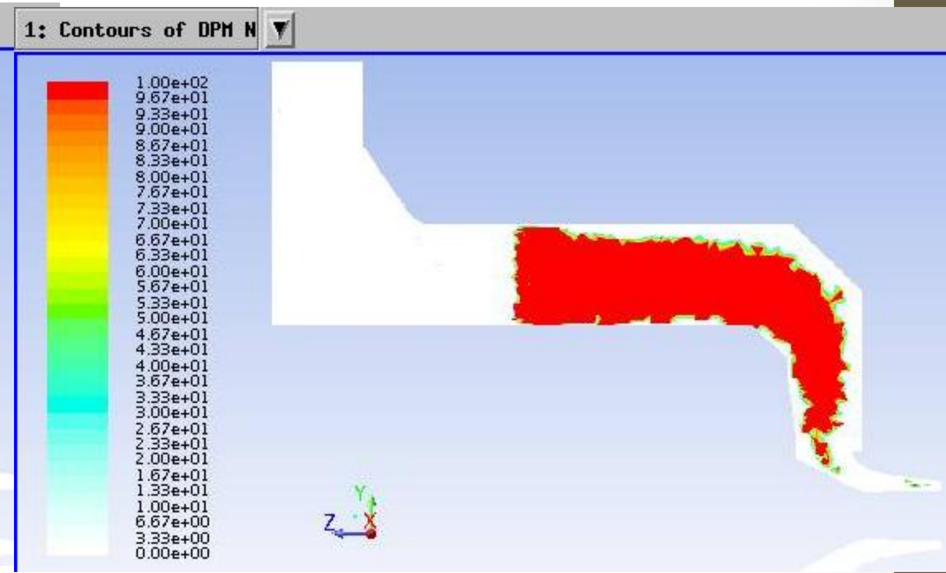


New Number of Injectors Validation

- Performed a new number of injectors validation study where the evaporation of the droplets was examined to see the difference between 5 and 52 injectors.



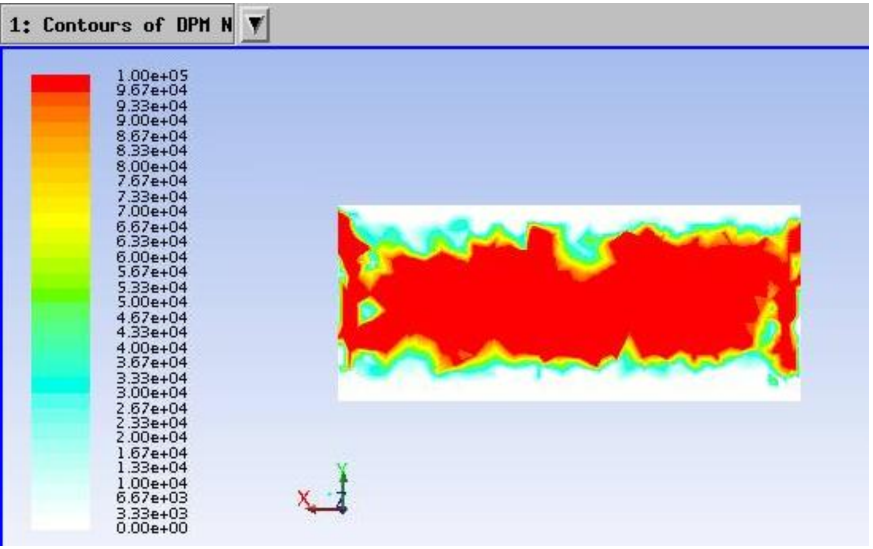
77^{o}F, 20% relative humidity 52 injectors



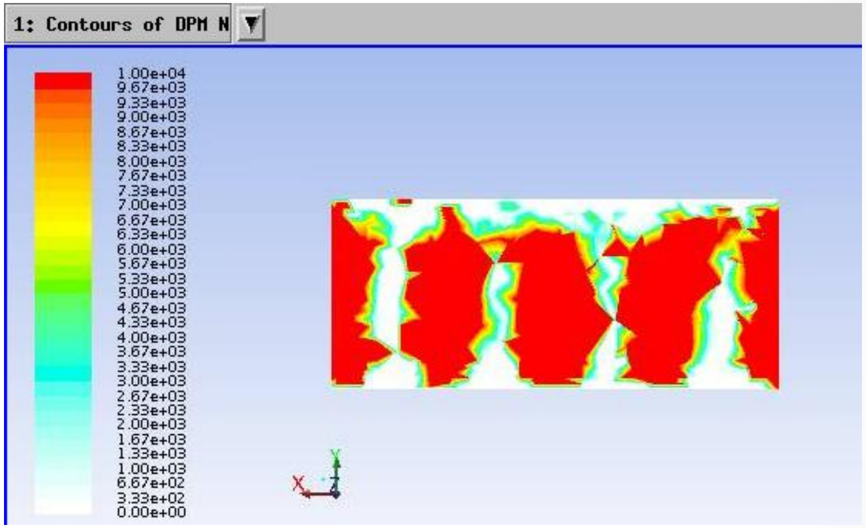
77^{o}F, 20% relative humidity 5 injectors

New Number of Injectors Validation Cont.

- These images show the diffusion of droplets 2m after the point of injection.



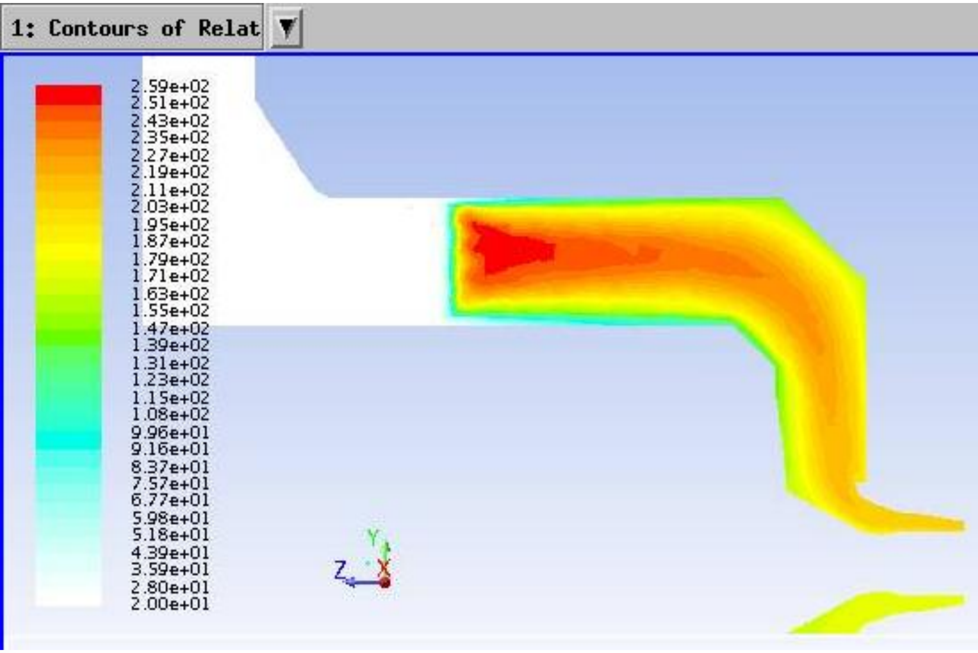
77^{o}F, 20% relative humidity 52 injectors



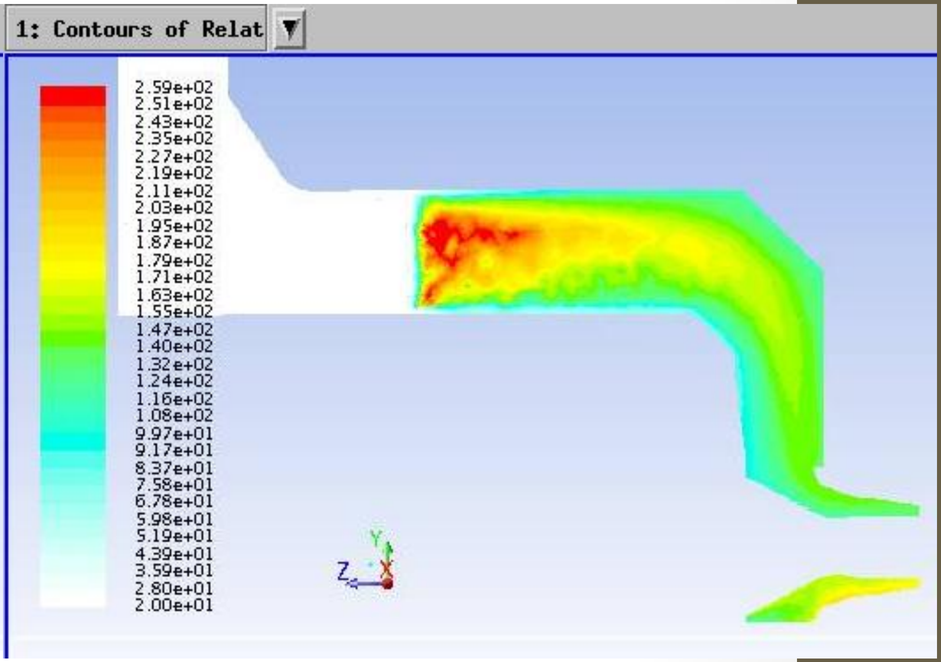
77^{o}F, 20% relative humidity 5 injectors

New Number of Injectors Validation Cont.

- These images show contours of relative humidity throughout the inlet.



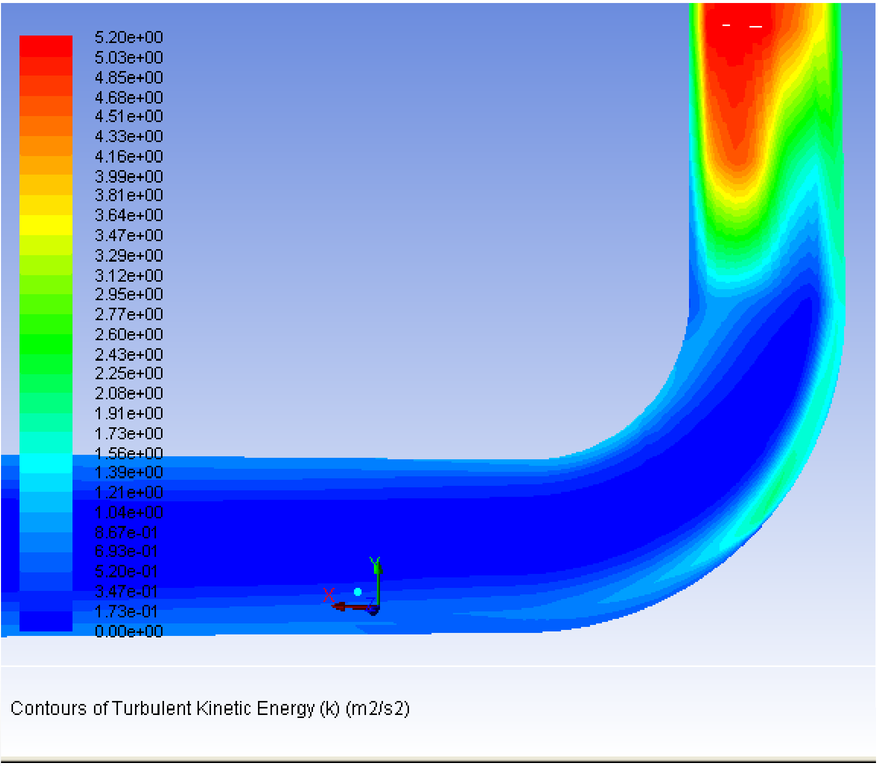
77ºF, 20% relative humidity 52 injectors

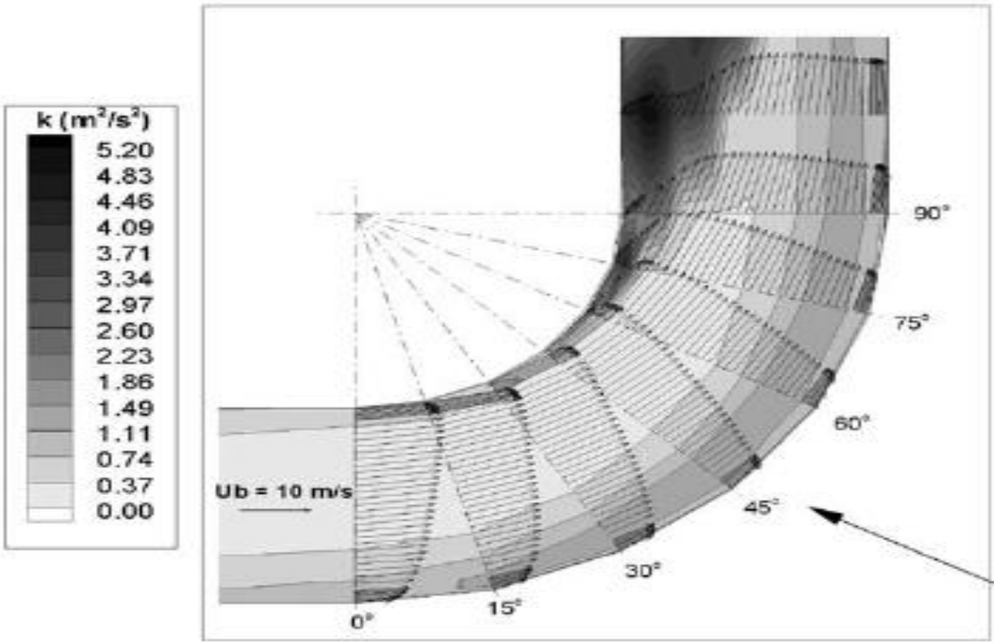


77ºF, 20% relative humidity 5 injectors

Turbulent Kinetic Energy Validation

- A turbulent kinetic energy validation was also performed to ensure that the simulations would give correct energy results.





Future Work Cont.

- Grid refinement study to ensure that the flow is analyzed in an expedient manner, and accurately as possible.
- Finish the new number of injectors validation study to determine the optimum number of injectors for obtaining the same results as the 52 cases while achieving a faster run time.
- Create plots of the average relative humidity at the exit of the inlet for the different cases.