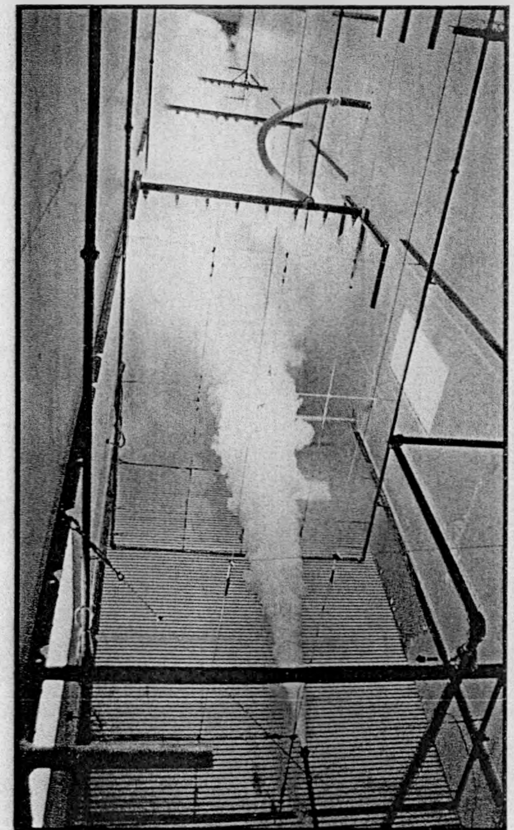
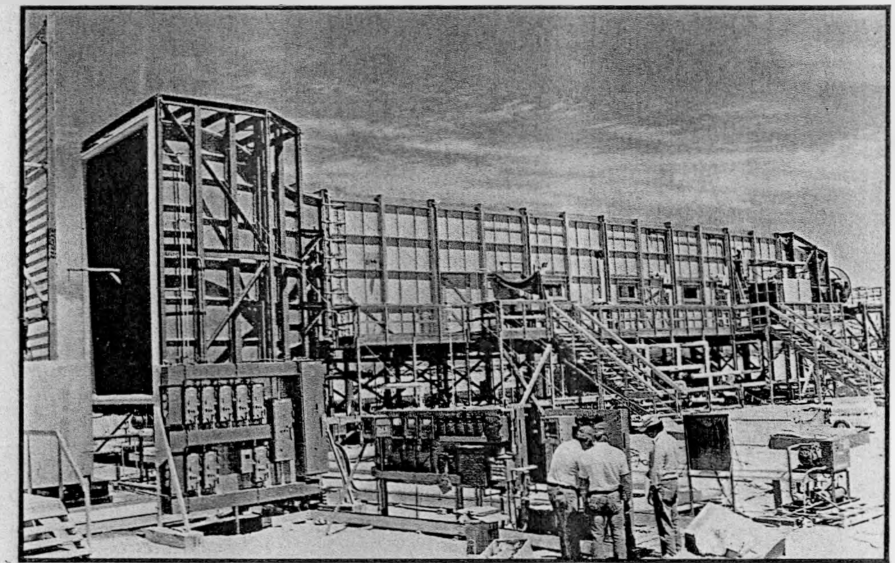




5-31-90 JT

Effectiveness of Water Spray Mitigation Systems for Accidental Releases of Hydrogen Flouride

Volume IV
Appendix F
Flow Chamber Evaluation

Prepared by:

D.E. Neff, Colorado State University
Fluid Mechanics & Wind Engineering
Laboratory - Fort Collins, CO 80524

for:

The Industry Cooperative HF
Mitigation / Assessment Program
Water Spray Subcommittee

June, 1989

UCRL-21214
VOLUME IV

UCRL--21214-Vol.4

DE90 001103

PREFACE

This report is one of several work products generated by the Industry Cooperative HF Mitigation/Assessment Program. This ad hoc industry program began in late 1987 to study and test techniques for mitigating accidental releases of hydrogen fluoride (HF) and alkylation unit acid (AUA) and to better estimate ambient impacts from such releases.

The hazards of HF have long been recognized. Standard operating practices focused on minimizing the possibility of a release and mitigating the effects if a release should occur. These practices are continually monitored and improved to maximize safety protection based on the available technical data. This recent program targeted further improvements based on new technical data.

Twenty companies from the chemical and petroleum industries sponsored and funded this program. These include:

Allied-Signal	Elf Aquitaine	Shell Internationale
Amoco	Exxon	Sun/Suncor
Ashland	Kerr-McGee	Tenneco
BP	Marathon	Texaco
Chevron	Mobil	Unocal
Conoco/Dupont	Phillips	3M
Dow	Saras	

K. W. Schatz, Mobil Research and Development Corporation (MRDC) and R. P. Koopman, Lawrence Livermore National Laboratories (LLNL) prepared this document as part of the work for the Water Spray Subcommittee.

The cooperation of the members of the following groups is gratefully acknowledged:

1. Allied-Signal for providing anhydrous hydrogen fluoride, analytical equipment and personnel.

2. Chevron for providing personnel.

3. Colorado State University, for consulting on scale-up, flow chamber design and flow chamber testing.

4. Conoco/DuPont, for providing personnel, safety training and data modeling.

5. Dow Chemical for providing personnel.

6. Exxon R&E for providing personnel.

7. Industry cooperative HF Mitigation/Assessment program sponsors for funding the program.

8. Insitec for conducting the aerosol measurements.

9. Lawrence Livermore National Laboratories for providing personnel and services.

10. Mobil Central Research Laboratories for providing laboratory space and consulting on experiments.

11. Mobil Refineries, Paulsboro, NJ, and Joliet, IL, for providing alkylation unit acid.

12. Mobil R&D Corp., for providing personnel and services.

13. Phillips for providing personnel.

14. United Engineers & Constructors, Stearns Roger Division, Denver, for engineering, procurement and construction of the flow chamber.

15. U. S. Department of Energy and contractors EG&G and ReeCo for providing the test site and services.

The results of this study are being published with the intent of making them available to any interested party. The deliverables of the program consist of a report with several appendices, a supplementary report (with a planned release date of third quarter 1989), a volume of still pictures, video tapes and magnetic data tapes. These can be obtained through the U.S. Department of Commerce, National Technical Information Services (NTIS), Springfield, Virginia 22161. Anyone may use these results, subject to the rights of others, to contribute to the further maximization of safety protection. However, neither the sponsors for this work, nor their contractors, accept any legal liability or responsibility whatsoever for the consequences of its use or misuse.

Flow Chamber Evaluation

David E. Neff

Colorado State University

25 August, 1988

Table of Contents

I) VELOCITY PROFILE MEASUREMENTS

Documentation

Vertical mean velocity and turbulent intensity profiles were obtained at five different wind tunnel locations for low and high speed tunnel settings. These profiles are listed and plotted in this section. The profiles file name describes the tunnel wind speed and position. The first character indicates tunnel speed setting, L for low speed, H for high speed. The second character indicates tunnel longitudinal position, U for upwind (10 ft downwind of entrance grid), D for downwind (65 ft downwind of entrance grid). The third character indicates tunnel lateral position, 1 for -2 ft, 2 for -1 ft, 3 for 0 ft, 4 for +1 ft, 5 for +2 ft from tunnel centerline respectively.

Experimental Technique

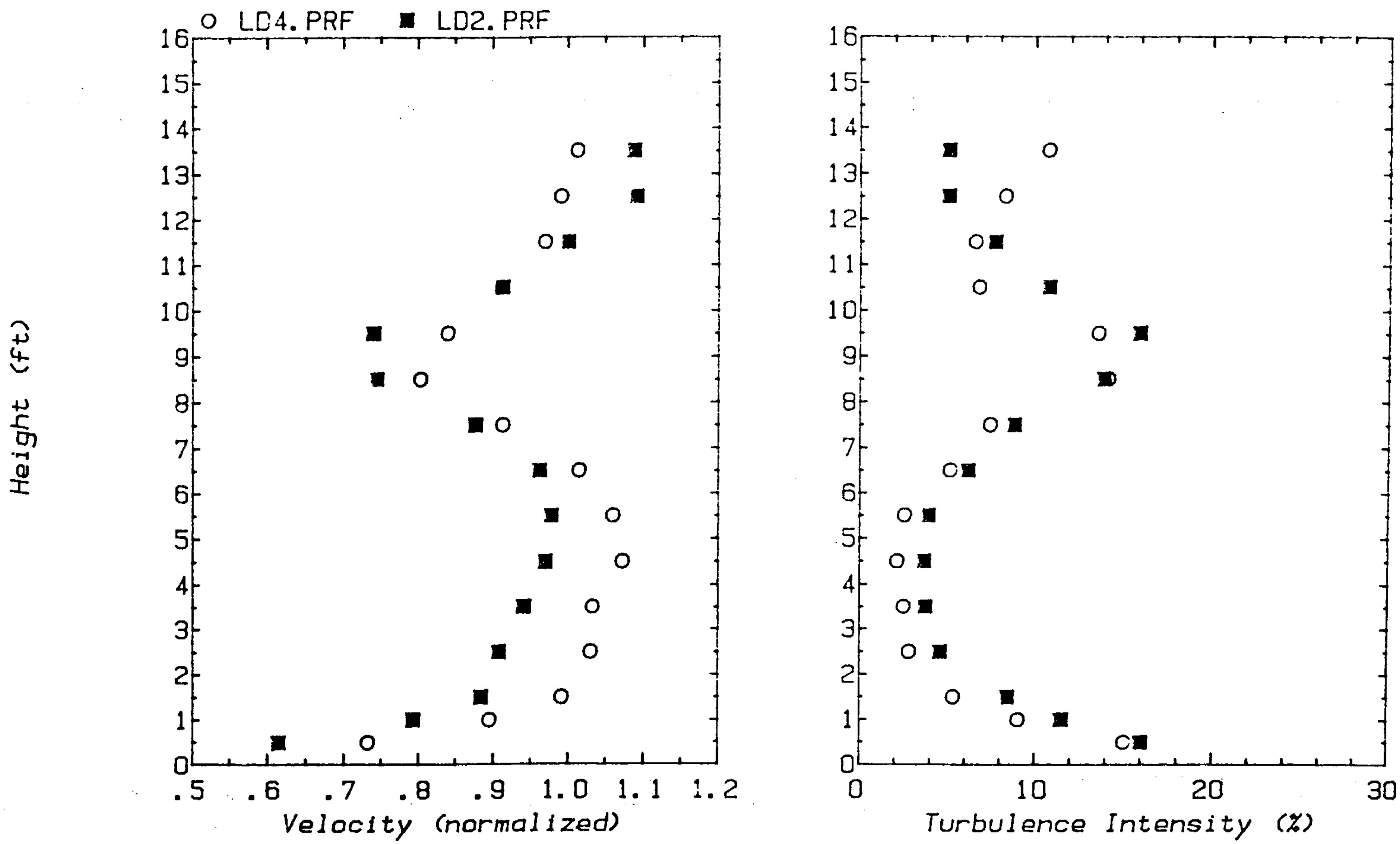
Velocity measurements were made with a TSI 1050 hot film anemometer system capable of responding to the highest frequency velocity fluctuations present within the NTS wind tunnel. The hot film was calibrated in a custom made calibrator similar to the TSI 1125 air speed calibrator. This calibrator was tested at Colorado State University against pitot probe measurements in a low turbulence wind tunnel and against a TSI 1125 calibrator. For a velocity range of 2.5 to 10 m/s the calibrator was accurate to ± 1.5 percent. The hot film was calibrated each day before and after the velocity profile measurements to help minimize errors associated with calibration drift for which hot films are susceptible. On one day the drift between the two calibrations was as great as 8 percent. The data presented here has been corrected for this drift by the experimenters perception as to when and how the drift most likely occurred. The mean and turbulent velocity measurements should be considered accurate to within ± 6 percent.

Comments

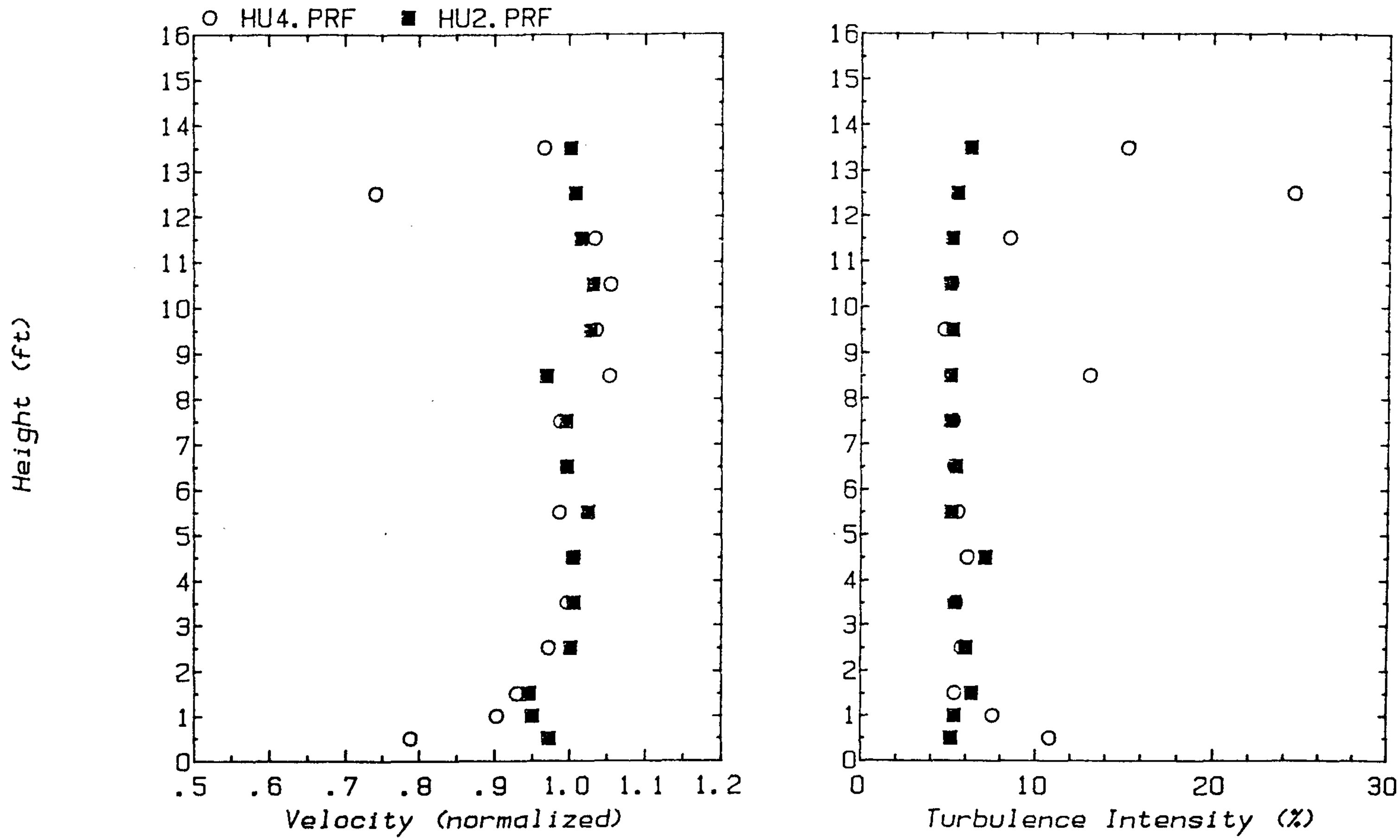
Velocity profile plots at the upwind cross section for both low and high wind speed cases indicate a fairly uniform ± 5 percent mean velocity variation except where velocity deficits are expected, i.e. near the floor, behind a cross bar, near the camera box. The turbulent intensity over this upwind section is generally 5 to 6 percent except near the previously mentioned obstacles where it is much higher.

Velocity profile plots at the downwind cross section for both low and high wind speed cases indicate that:

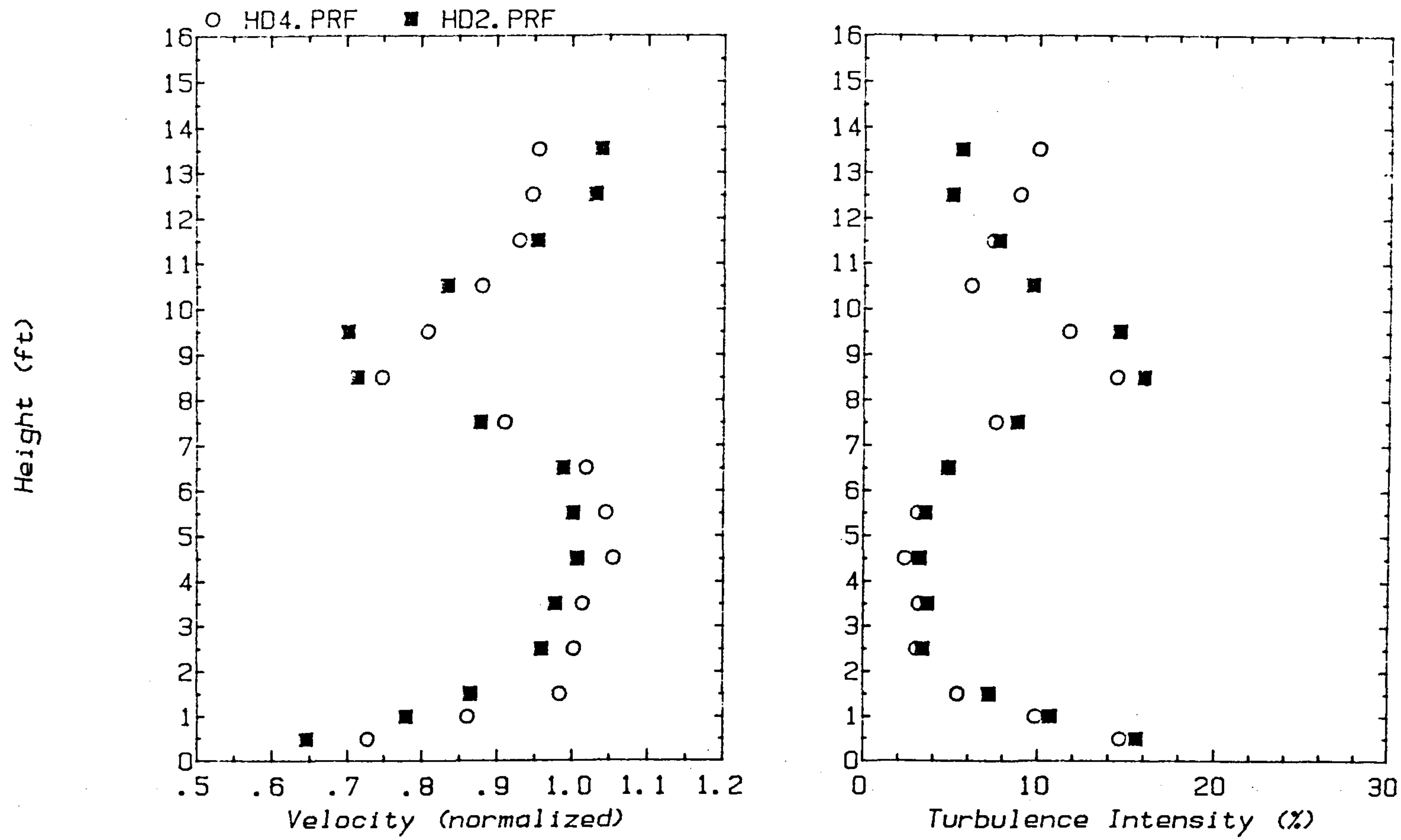
1) The floor boundary layer has grown to about 2 feet.
2) The water spray header pipes located 8.5 ft. above the floor generate a 3 to 4 foot wide turbulent wake with a maximum velocity deficit of 30 percent.
3) The background turbulence level generated form the entrance grid appears to be 1 to 2 percent.
4) The camera boxes wake has caused a 5 to 10 percent asymmetry in the mean flow for both high and low wind speed cases. The profile on the camera box side of the tunnel shows an accelerated flow in the lower half and an deficit flow in the upper half when compared to the profile on the other side. The turbulent intensity is higher in those profile points nearest the camera box wake.



Velocity and Local Turbulence Intensity Profiles



Velocity and Local Turbulence Intensity Profiles



Velocity and Local Turbulence Intensity Profiles

FILE NAME = LU2.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.98	5.08
2	1.00	.95	5.12
3	1.50	.97	6.03
4	2.50	.99	5.82
5	3.50	.99	5.36
6	4.50	1.01	5.35
7	5.50	.99	5.15
8	6.50	1.01	5.27
9	7.50	.96	5.22
10	8.50	.99	12.86
11	9.50	1.06	4.63
12	10.50	1.04	5.14
13	11.50	1.02	5.68
14	12.50	1.00	6.04
15	13.50	.99	6.66

REFERENCE VELOCITY = 4.61 m/s

FILE NAME = LU4.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.97	10.25
2	1.00	.98	6.61
3	1.50	.96	5.18
4	2.50	.91	7.04
5	3.50	1.05	6.26
6	4.50	1.03	7.66
7	5.50	1.04	5.77
8	6.50	1.05	5.71
9	7.50	1.03	6.59
10	8.50	1.07	11.20
11	9.50	1.04	4.64
12	10.50	1.04	4.85
13	11.50	1.02	10.27
14	12.50	.72	26.09
15	13.50	.98	14.04

REFERENCE VELOCITY = 4.61 m/s

FILE NAME = HU2.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.97	5.15
2	1.00	.95	5.35
3	1.50	.94	6.34
4	2.50	1.00	6.01
5	3.50	1.01	5.34
6	4.50	1.00	7.11
7	5.50	1.02	5.15
8	6.50	1.00	5.42
9	7.50	1.00	5.09
10	8.50	.97	5.09
11	9.50	1.03	5.21
12	10.50	1.03	5.06
13	11.50	1.02	5.18
14	12.50	1.01	5.50
15	13.50	1.00	6.23

REFERENCE VELOCITY = 7.86 m/s

FILE NAME = HU4.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.79	10.84
2	1.00	.90	7.58
3	1.50	.93	5.36
4	2.50	.97	5.75
5	3.50	1.00	5.46
6	4.50	1.01	6.08
7	5.50	.99	5.55
8	6.50	1.00	5.29
9	7.50	.99	5.25
10	8.50	1.05	13.08
11	9.50	1.04	4.76
12	10.50	1.05	5.14
13	11.50	1.03	8.51
14	12.50	.74	24.58
15	13.50	.97	15.19

REFERENCE VELOCITY = 7.86 m/s

FILE NAME = LD2.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.61	15.97
2	1.00	.79	11.48
3	1.50	.88	8.44
4	2.50	.91	4.57
5	3.50	.94	3.72
6	4.50	.97	3.65
7	5.50	.98	3.89
8	6.50	.96	6.16
9	7.50	.88	8.81
10	8.50	.74	13.86
11	9.50	.74	15.90
12	10.50	.91	10.75
13	11.50	1.00	7.68
14	12.50	1.09	5.00
15	13.50	1.09	5.02

REFERENCE VELOCITY = 4.61 m/s

FILE NAME = LD4.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.73	15.04
2	1.00	.90	9.06
3	1.50	.99	5.34
4	2.50	1.03	2.81
5	3.50	1.03	2.50
6	4.50	1.07	2.13
7	5.50	1.06	2.55
8	6.50	1.01	5.14
9	7.50	.91	7.41
10	8.50	.80	14.14
11	9.50	.84	13.57
12	10.50	.91	6.76
13	11.50	.97	6.54
14	12.50	.99	8.27
15	13.50	1.01	10.73

REFERENCE VELOCITY = 4.61 m/s

FILE NAME = HD2.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.64	15.58
2	1.00	.78	10.71
3	1.50	.86	7.22
4	2.50	.96	3.39
5	3.50	.98	3.64
6	4.50	1.01	3.18
7	5.50	1.00	3.53
8	6.50	.99	4.83
9	7.50	.88	8.77
10	8.50	.71	15.97
11	9.50	.70	14.59
12	10.50	.83	9.64
13	11.50	.95	7.70
14	12.50	1.03	5.00
15	13.50	1.04	5.54

REFERENCE VELOCITY = 7.86 m/s

FILE NAME = HD4.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.73	14.64
2	1.00	.86	9.87
3	1.50	.98	5.39
4	2.50	1.00	3.05
5	3.50	1.01	3.17
6	4.50	1.06	2.35
7	5.50	1.05	3.10
8	6.50	1.02	4.80
9	7.50	.91	7.56
10	8.50	.75	14.44
11	9.50	.81	11.73
12	10.50	.88	6.12
13	11.50	.93	7.38
14	12.50	.95	8.93
15	13.50	.95	9.99

REFERENCE VELOCITY = 7.86 m/s

FILE NAME = LU1.PRF

RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	.50	.95	5.21
2	1.00	.94	5.45
3	1.50	.94	5.45
4	2.50	.98	5.46
5	3.50	.97	5.27
6	4.50	.99	4.99
7	5.50	1.01	5.20
8	6.50	.99	6.05
9	7.50	.96	5.53
10	8.50	1.04	13.24

REFERENCE VELOCITY = 4.61 m/s

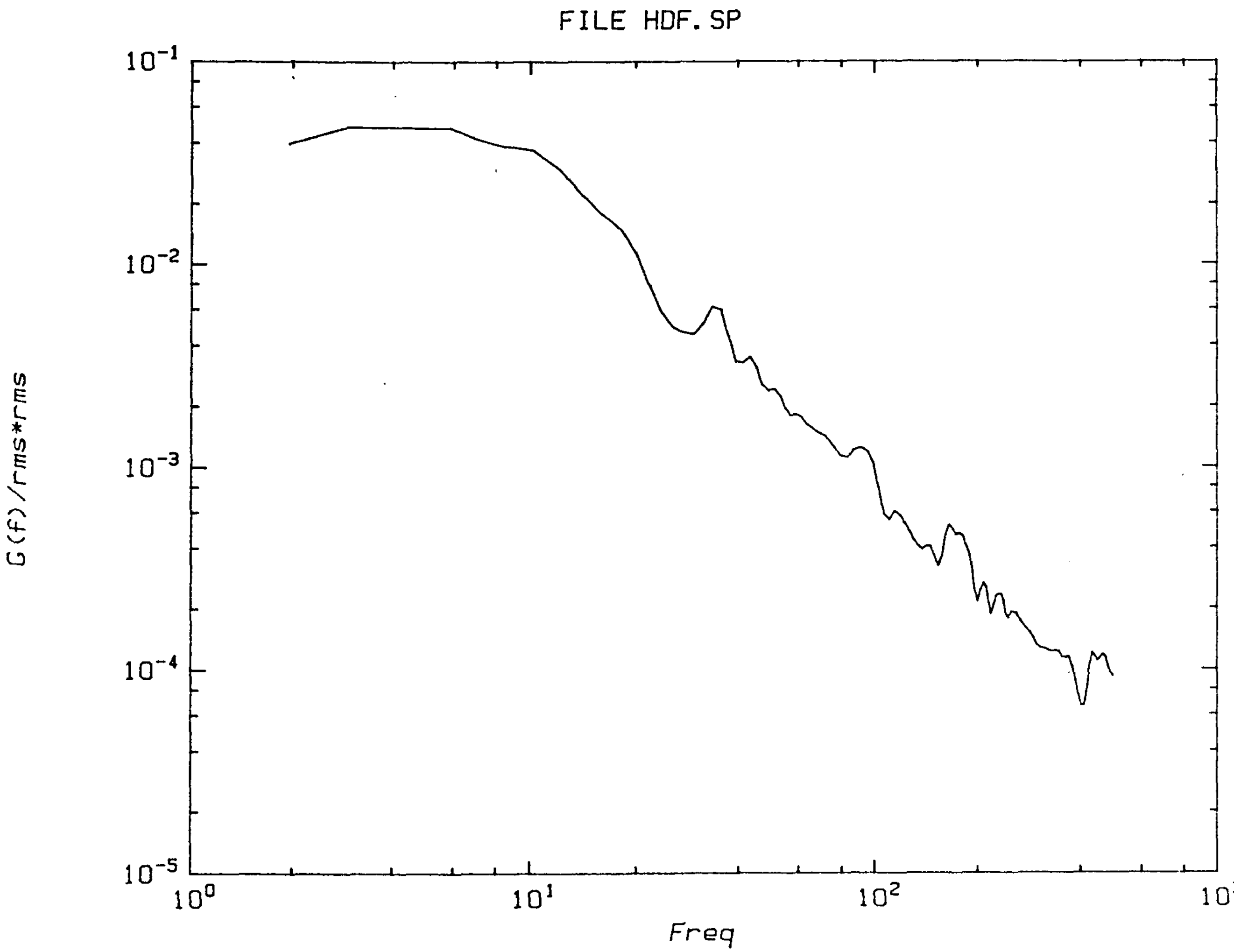
FILE NAME = HU1.PRF

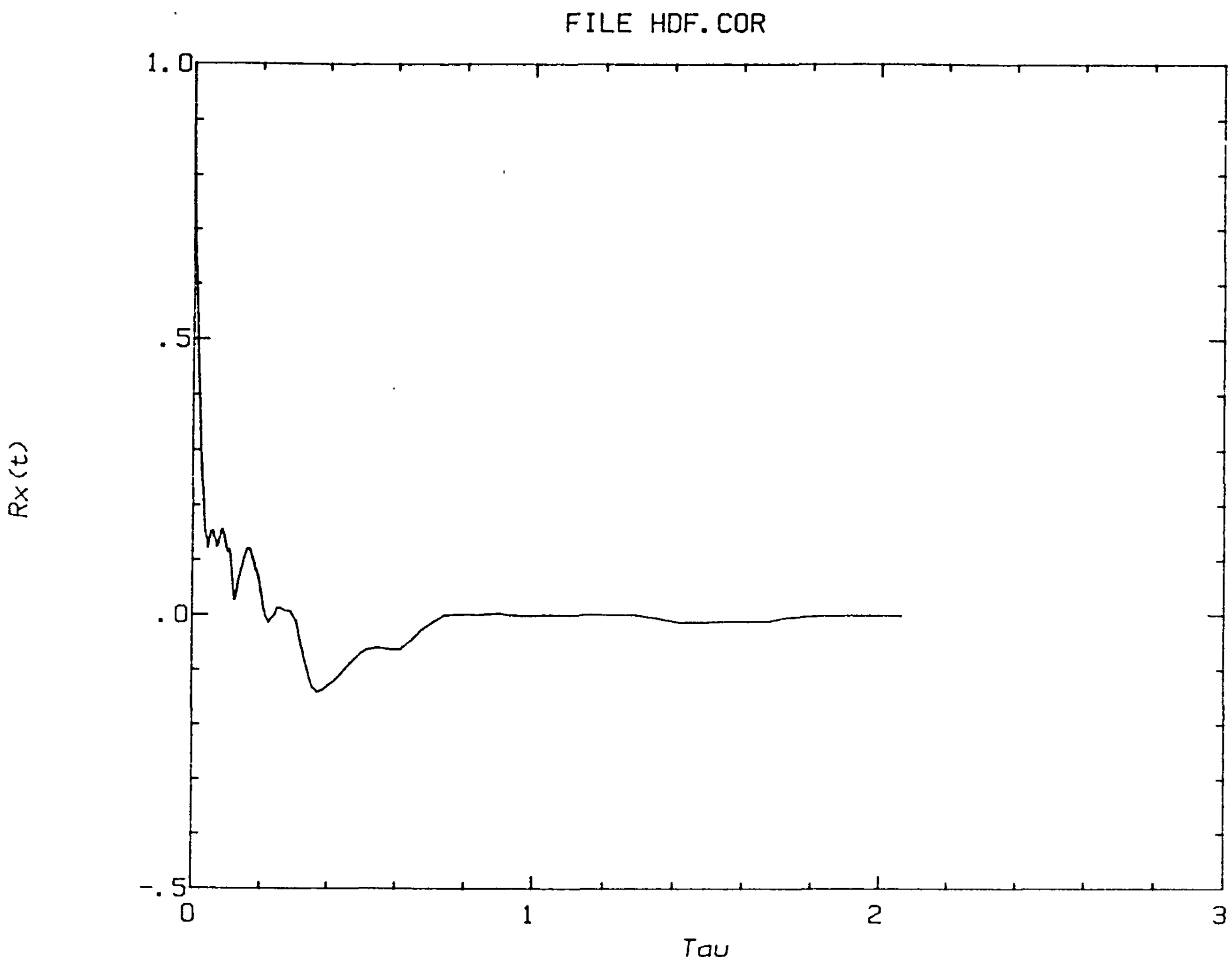
RECORD NO.	HEIGHT ft	VELOCITY norm	TURBULENCE (%)
1	2.50	.97	6.57
2	3.50	1.01	5.34
3	4.50	1.01	5.39
4	5.50	1.03	5.55
5	6.50	1.02	5.09
6	7.50	.98	5.17
7	8.50	.96	4.94

REFERENCE VELOCITY = 7.86 m/s

II) SPECTRAL VELOCITY MEASUREMENTS

A velocity time series was obtained for the higher wind speed setting at the tunnel position (65′,1′,5′). The right handed coordinate systems origin was entrance grid, tunnel centerline, floor level. This velocity time series consisted of 5 segments of 1024 points per segment acquired at 1000 Hz. The mean and rms velocity were 7.95 and 0.25 m/s respectively. Thus the local turbulent intensity was 3.14 percent. This time series was analyzed and the normalized power spectral density versus frequency and the autocorrelation coefficient versus time lag were plotted. The integral time scale was calculated to be 0.02 seconds, thus the integral length scale was 0.16 meters.


FILE HDF.SP
G(f)/rms*rms
Freq
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{0}
10^{1}
10^{2}
10^{3}


FILE HDF.COR
1.0
.5
.0
-.5
Rx(t)
0
1
2
3
Tau

III) PITOT PROBE VELOCITY MEASUREMENTS

Pitot probe measurements are an accurate and reliable method for obtaining mean velocity within a wind tunnel. These probes measure the static and total pressure at a point within a flowing fluid. The static and total pressure difference are related to the local fluid velocity via the general equation :

$V = \sqrt{2g(P_t - P_s)/d}$ where V is velocity,
g is gravitational constant,
P_t is total pressure,
P_s is static pressure,
d is local fluid density.

Rewriting this equation into specific units and assuming the local pressure and temperature = 680 mmHg, 37 C respectively yields :

$V = 22\sqrt{(P_t - P_s)}$ where V is m/s
$(P_t - P_s)$ is inches H_2O

The accuracy of a pitot probes measure of mean velocity is dependent on;

1) the pitot probes accuracy in obtaining the flows true static and total pressure and
2) the differential pressure measurement accuracy.

The pitot probes accuracy is generally within ± 1 % providing that the probe Reynolds no. is greater than 30 (V>0.5m/s), velocity is less than a Mach no. of 0.7, the yaw and pitch angles are within ± 5 degrees of the mean velocity vector and the flow is homogeneous (i.e. no water spray present).

The differential pressure transducer used at the N.T.S. wind tunnel was calibrated against an N.B.S. traceable Micro-manometer (Dwyer model no. 1430). These calibrations indicate that the pressure measurements were accurate to within ± 1.5 % of full scale (F.S.=0.10 in H_2O).

Summarizing these accuracy statements for pitot probe velocity measurements at the NTS wind tunnel yields a mean velocity measure in the range of 0.5 to 7.75 m/s accurate to ± 0.1 m/s.

Validyne Pressure Transducer Calibration
Date 07-26-88

Model DP851V-P10 S/N 44366
Range 0.100"H2O 0-5 VDC output

Micro-Manometer ("H2O) (+-.0006)	Pressure Transducer (volts)	Pressure Transducer ("H2O) (+-.0010)	Percent Full Scale Error
0.0000	0.000	0.0000	0.00
0.0096	0.524	0.0105	0.88
0.0100	0.543	0.0109	0.86
0.0396	1.933	0.0387	-0.94
0.0724	3.576	0.0715	-0.88
0.1004	4.963	0.0993	-1.14
0.1010	4.993	0.0999	-1.14
0.1020	5.015	0.1003	-1.70
0.1188	5.878	0.1176	-1.24
0.0000	0.006	0.0001	0.12

Validyne Pressure Transducer Calibration
Date 08-05-88

Model DP851V-P10 S/N 44366
Range 0.100"H2O 0-5 VDC output

Micro-Manometer ("H2O) (+-.0006)	Pressure Transducer (volts)	Pressure Transducer ("H2O) (+-.0010)	Percent Full Scale Error
0.0000	0.000	0.0000	0.00
0.0024	0.114	0.0023	-0.12
0.0106	0.530	0.0106	0.00
0.0360	1.770	0.0354	-0.60
0.0586	2.950	0.0590	0.40
0.1040	5.134	0.1027	-1.32
0.1198	5.942	0.1188	-0.96
0.1250	6.190	0.1238	-1.20
0.0000	0.000	0.0000	0.00

note > transducer response was linear up to
its upper limit of 6.267 volts output