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F-15 Inlet/Engine Test Techniques and Distortion Methodologies Studies

Volume VII - Cross Correlation Functions

Contract Number NAS4-2364

NASA Contractor Report 144872

F-15 Inlet/Engine Test Techniques and Distortion Methodologies Studies

Volume VII - Cross Correlation Functions

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Prepared for
Dryden Flight Research Center
under Contract NAS4-2364

National Aeronautics
and Space Administration

June 1978

FOREWORD

This report was prepared by the McDonnell Aircraft Company (MCAIR), a division of the McDonnell Douglas Corporation, St. Louis, Missouri for the National Aeronautics and Space Administration, Dryden Flight Research Center, Edwards, California. The study was performed under NASA Contract NAS4-2364, "F-15 Inlet/Engine Test Techniques and Distortion Methodologies Study." The work was performed from March 1977 through February 1976 with Mr. Jack Nugent (NASA/Dryden) as Program Monitor and Mr. Harvey Neumann (NASA/Lewis) as Technical Monitor. Special acknowledgement is due Mr. T. Putnam (NASA/ Dryden) for his constructive criticisms and suggestions.

The effort at McDonnell Aircraft Company was conducted under the technical leadership of the Engineering Technology Division. In addition to the authors listed on the cover, other MCAIR personnel that made significant contributions to this program were Mr. Edward Smith, Mr. Lee Weltmer and Mr. Mark Sawyer. Special acknowledgement is due Mr. Hershel Sams for his reviews and suggestions.

Significant subcontract support was provided by Mr. Wayne Walter and Mr. Lew Hayward of Pratt & Whitney Aircraft (P&WA), Government Products Division, under the direction of Mr. Frank Thompson.

This report consists of nine volumes. Technical discussions of the program, results and Appendices A and B are presented in Volume I (NASA CR 144866). Appendices C through J are presented in Volume II through IX (NASA CR 144867-144874) which present the distortion analysis plots and the associated statistical functions used for the analyses.

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Program Monitor: Jack Nugent (NASA/Dryden)
Technical Monitor: Harvey Neumann (NASA/Lewis)

16. Abstract

The Cross Correlation Function plots contained in this volume of the F-15 Inlet/Engine Test Techniques and Distortion Methodologies Study were used in accomplishing the primary study goal of determining if peak distortion data taken from a subscale inlet model can be used to predict peak distortion levels for a full scale flight test vehicle. The results of this study are contained in the Technical Discussion, Volume I (NASA CR 144866).

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LIST OF ILLUSTRATIONS

SYMBOLS

	Description	Units
ALPHA	Aircraft angle of attack	degrees
ALT	Altitude	meters (feet)
AVG	Average.	
b, B	Radial Distortion Weighting factor	
BYPASS	Inlet bypass area.	sq. meters (sq. inches)
Beta	Aircraft angle of sideslip	degrees
CIVV	Compressor Inlet (Fan) Variable Vanes . . .	degrees
Deg	Degree	degree
ΔP_{t_2}	Fluctuating component of individual probe pressure at the engine face	
$(\Delta P_{t_2})_{rms}$	Root mean square of fluctuating pressure . .	kPa (PSIA)
DELTA3	Inlet third ramp angle relative to the Inlet Reference Line	degrees
$\Delta P_{t_{2.5H}}$	Fluctuating component of fan exit total pressure/engine stream	kPa (PSIA)
$\Delta P_{t_{2.5C}}$	Fluctuating component of fan exit total pressure/fan stream	kPa (PSIA)
$\frac{\Delta P}{P}$, D_2	Spatial Distortion = $[(P_{t_2})_{max} - (P_{t_2})_{min}]/\bar{P}_{t_2}$	
FLT, FLIGHT	Flight test data notation	
FSCP	Full Scale Cold Pipe (without engine) wind tunnel test data notation	
FSE	Full Scale with Engine wind tunnel test data notation	
HZ	Hertz.	hertz
I.D., IDENT	Identification	
K_{a_2}, KA2	Fan distortion descriptor = $K_\theta + b\, K_{r_{a_2}}$ . .	
K_θ, KTHETA	Circumferential distortion	
$K_{r_{a_2}}$, KRA2	Radial distortion.	

SYMBOLS (Continued)

	Description	Units
BKRA2	Radial distortion multiplied by radial distortion weighting factor.	
KC2	High compressor distortion descriptor. . . .	
KθSP	Circumferential distortion descriptor used to calculate the high compressor distortion descriptor.	
kPa	Pressure, Killopascals	Killopascals
M_o	Freestream Mach number	
MACH	Freestream Mach number	
MAX	Maximum.	
MIN	Minimum.	
No.	Number	
P_{t_2}	Individual probe engine face steady state pressure	kPa (PSIA)
$\overline{P_{t_2}}$	48 probe averaged engine face steady state pressure	kPa (PSIA)
$\overline{P}_{t_{25H}}$	Average high compressor face steady state pressure	kPa (PSIA)
P_{t_o}	Freestream total pressure.	kPa (PSIA)
PT2I	Individual probe time variant engine face pressure	kPa (PSIA)
$\overline{PT2I}$, $\overline{PI}$	48 probe averaged time variant engine face pressure	kPa (PSIA)
PI/PS	Ratio of time variant to steady state 48 probe averaged engine face pressure . . .	
PSIA	Pressure (Pounds per Square Inch Absolute) .	PSIA
Q, q	Dynamic pressure·	kPa (PSIA)
Re. No.	Reynolds number	
RHO	Inlet first ramp angle relative to the Inlet Reference Line	degrees
RMS, rms	Root mean square	
Sec	Second	second

SYMBOLS (Continued)

	Description	Units
Series VII	1/6th scale inlet wind tunnel test series data notation.	
Series VIII	1/6th scale inlet wind tunnel test series data notation	
T_{t_2}	Engine face total temperature	°K
$T_{t_{25H}}$	High compressor inlet (or fan exit) total temperature.	°K
Tu	Turbulence	
W2	Engine/Fan airflow	kg/sec (LB/sec)
WAT2	Corrected fan airflow = $W2\sqrt{\theta_{t_2}}/\delta_{t_2}$	kg/sec (LB/sec)
WAT2 Design	Design corrected fan airflow	98.43 kg/sec (217 LB/sec)
WAT2 Percent	WAT2 divided by WAT2 Design x 100	
W25H	High compressor airflow	kg/sec (LB/sec)
WAT25H	Corrected high compressor airflow $W25H\sqrt{\theta_{t_{25H}}}/\delta_{t_{25H}}$	kg/sec (LB/sec)
WAT25H Design	Design corrected high compressor airflow . .	24.69 kg/sec (54.44 LB/sec)
WAT25H Percent	WAT25H divided by WAT25H Design x 100. . . .	
α	Aircraft angle of attack	degrees
β	Aircraft angle of sideslip	degrees
Δ_3	Inlet third ramp angle relative to the Inlet Reference Line	degrees
δ_{t_2}	Corrected average engine face total pressure $\overline{P_{t_2}}/101$	
$\delta_{t_{25H}}$	Corrected average engine face total pressure $\overline{P_{t_{25H}}}/101$	
ρ	Inlet first ramp angle relative to the Inlet Reference Line	degrees
σ	Standard deviation of the instantaneous pressure	kPa (PSIA)

SYMBOLS (Concluded)

	Description	Units
$\sigma_{xy}(\tau)$	Covariance of pressure data from probes x and y at lag time τ	kPa (PSIA)
$\sigma_{xy}(\tau=0)$	Covariance of pressure data from probes x and y at lag time $\tau=0$	kPa (PSIA)
θ_{t_2}	Corrected average engine face total temperature $T_{t_2}/288.15$	
$\theta_{t_{25H}}$	Corrected average high compressor face total temperature $T_{t_{25H}}/288.15$	

SUMMARY

Recent emphasis on increased maneuverability requirements for fighter aircraft has necessitated an extensive engineering development effort be directed towards inlet/engine compatibility. Inlet/engine compatibility must be assessed early in the aircraft development program to allow necessary inlet and engine design modifications to be defined and implemented at minimum cost impact. This early assessment of inlet/engine compatibility is determined by engine stability audits computed using inlet distortion levels from subscale inlet model data and engine sensitivities to inlet distortion. Therefore, the accuracy with which subscale inlet model distortion levels predict flight test vehicle distortion levels is a crucial element in assessing inlet/engine compatibility.

The primary goal of this distortion methodologies study was to determine if time variant distortion data taken from a subscale inlet model can predict peak distortion levels for a full scale flight test vehicle. The data base used to accomplish this goal was collected in separate programs by MCAIR and NASA/Dryden. Subscale and full scale wind tunnel data were collected by MCAIR during the F-15 development program, and flight test data were collected by NASA/Dryden during the NASA F-15 inlet/engine compatibility flight test program. This data base has a Mach number range of 0.4 to 2.5 and an angle of attack range from -10 degrees to +12 degrees.

The primary objectives accomplished in meeting the overall program goal were to determine the effects on peak distortion of: (1) Reynolds Number/scale, (2) engine presence and (3) frequency content. In addition, the capability of the P&WA stability audit system to predict engine stalls was evaluated, and the capability of Melick's procedure, Reference (1), to predict peak time variant distortion levels was evaluated. Using the Pratt and Whitney Aircraft distortion descriptor, K_{a_2}, the data indicate the following significant results for the F-15/F100 inlet/engine propulsion system.

- Peak time variant distortion from subscale inlet model wind tunnel tests are representative of full scale flight test distortion.
- The time variant pressure data of this study are random stationary data, thereby allowing valid statistical analyses to be conducted.
- The effect of the engine presence on total pressure recovery, peak time variant distortion and turbulence level is small but favorable.
- The Reynolds number/scale evaluation indicates a general trend of increasing total pressure recovery, decreasing peak time variant fan distortion and decreasing turbulence with increasing Reynolds number/scale.
- The frequency content evaluation indicates that peak time variant fan distortion and turbulence increase with increasing filter cutoff frequency for all of the data evaluated in this study.
- The capability of the Pratt & Whitney Aircraft stability audit system to predict engine stalls has been verified for both stall and non-stall flight test conditions.

- Predictions of peak distortion values using Melick's procedure are accurate to 11.3 percent average error for fourteen data points having nominal turbulence levels and are accurate to 20 percent average error (the maximum error approaches 40 percent) for eight data points having high turbulence levels.

APPENDIX H

CROSS-CORRELATION FUNCTIONS

Presented herein are the cross-correlation function plots which have been generated for the same set of high response pressure probes as the cross spectral density (CSD) plots. The cross-correlation function plots and CSD plots are used in the evaluation of Malick's procedure which predicts most probable peak distortion values.

The cross correlation coefficients for the wind tunnel data have not been normalized in the traditional method, but have been normalized by the standard deviation at lag time equal to zero ($\tau = 0$). To obtain the unnormalized cross correlation function, multiply the plotted coefficient by the standard deviation at lag time equal to zero that is listed on each plot. To obtain the traditional normalized cross-correlation coefficient, divide the unnormalized cross correlation function by the square root of the product of the individual probe standard deviations listed on each plot.

The cross correlation functions for the flight test data have not been normalized. To compute the traditional cross-correlation coefficient, take the square root of the value from the plot and divide by the square root of the product of the individual probe standard deviations listed on each plot.

SUMMARY OF HIGH RESPONSE PROBES INVESTIGATED FOR CROSS-CORRELATION FUNCTION PLOTS

FIGURE NUMBER	DATA POINT IDENT. NO.	*PART-POINT	MODEL SCALE	PROBES ANALYZED		
1	5	164-1	1/6th	L3R2	L3R3	L3R5
2	7	421-10	FLT	L8R2	L8R3	L8R6
3	18	157-5	1/6th	L3R2	L3R3	L3R5
4	19	421-14	FLT	L1R2	L1R3	L1R6
5	42	206-9	1/6th	L6R2	L6R3	L6R6
6	44	414-2	FLT	L6R2	L6R3	L6R6
7	60	249-5	1/6th	L8R2	L8R3	L8R5
8	63	385-2	FSCP	L1R2	L1R3	L1R6
9	65	543-4	FSE	L8R2	L8R3	L8R5
10	66	184-7	1/6th	L8R2	L8R3	L8R5
11	69	413-12	FSCP	L8R2	L8R3	L8R5
12	70	425-1	FLT	L1R2	L1R3	L1R5
13	79	227-7	1/6th	L5R2	L5R3	L5R5
14	81	465-8	FSCP	L8R2	L8R3	L8R6

* FOR FLIGHT DATA, THESE ARE FLIGHT-RUN NUMBERS

DATA POINT I.D. NO.	MODEL SCALE	M_o	α (DEG)	β (DEG)	ρ (DEG)	$\Delta 3$ (DEG)	BYPASS*	% WAT2	RE NO. x 10^{-6}	ANALYSIS TIME (SEC)	PART–POINT**
1	FLT	0.4	16.4	−0.8	6.9	27.6	C	104.1	1.44	0.6	422-4
2	FLT	0.59	13.9	0.9	7.0	26.6	C	102.7	2.04	0.6	417-5
3	↓	0.52	10.0	0.7	↓	27.6	↓	107.1	1.33	0.6	417-4
4	↓	0.69	11.5	1.0	↓	26.5	↓	104.2	0.84	0.6	417-2
5	1/6th	0.60	−10.0	10.0	−3.0	10.6	C	97.2	0.43	0.144	164-1
6	1/6th	0.60	−10.0	10.0	−3.0	10.6	C	90.2	0.43	0.144	164-3
7	FLT	0.69	−8.4	10.6	0.6	10.5	C	101.2	1.40	0.88	421-10
8	1/6th	0.60	4.0	0	7.0	10.6	C	76.6	0.43	0.181	112-7
9	1/6th	0.60	4.0	0	7.0	10.6	C	108.6	0.43	0.181	112-5
10	FSE	0.60	4.0	0	5.2	10.0	C	97.7	3.41	1.110	116-2
11	FLT	0.67	4.3	0.7	6.9	11.1	C	94.4	3.58	0.72	424-2
12	↓	0.69	3.4	0.7	6.9	11.1	↓	74.1	3.68	0.76	425-6
13	↓	0.59	4.6	1.2	7.0	11.1	↓	107.9	1.74	0.62	412-2
14	↓	0.60	4.6	0.6	6.9	11.0	↓	76.2	1.66	1.11	424-11
15	FLT	0.85	8.8	−0.5	7.0	27.6	C	104.2	2.21	0.60	417-3
16	FLT	0.92	5.6	0.6	7.0	26.6	C	104.5	1.04	0.60	417-1
17	1/6th	0.90	−10.0	10.0	−3.0	10.6	C	70.2	0.34	0.113	157-7
18	1/6th	0.90	−10.0	10.0	−3.0	10.6	C	106.3	0.34	0.113	157-5
19	FLT	0.94	−8.9	10.2	1.0	10.5	C	107.1	1.6	0.69	421-14
20	FSE	0.90	−4.0	0	−1.0	8.2	C	97.8	3.64	1.990	102-2
21	FLT	0.90	−2.8	−0.2	−1.2	8.7	C	97.5	3.25	1.23	424-10
22	FLT	0.93	−3.3	0	−1.2	8.6	C	104.8	1.17	1.99	425-3
23	1/6th	0.90	4.0	0	7.0	10.6	C	76.8	0.34	0.369	67-9
24	1/6th	0.90	4.0	0	7.0	10.6	C	104.3	0.34	0.369	67-7
25	FSE	0.90	4.0	0	7.3	10.4	C	97.7	3.62	2.260	126-2
26	FLT	0.92	4.6	0.7	6.0	11.0	C	96.2	3.47	0.89	420-9
27	↓	0.91	5.2	0.5	6.9	11.1	↓	99.1	3.28	1.18	422-2
28	↓	0.92	4.2	0.1	7.0	11.0	↓	76.1	2.47	1.34	421-5
29	↓	0.90	4.1	0.5	6.9	11.1	↓	98.6	2.43	1.46	424-9
30	↓	0.90	5.1	0.1	7.0	11.0	↓	105.7	2.42	0.69	421-4
31	↓	0.90	3.5	0.2	7.0	11.0	↓	77.5	1.78	2.26	421-6
32	↓	0.90	5.2	−0.1	7.0	11.0	↓	100.1	1.79	0.70	421-7
33	↓	0.94	4.3	0.2	7.0	11.1	↓	105.6	1.89	1.06	421-8

QP78-0323-8

*C = Closed

**For flight test, these data are flight-run numbers

TABLE H-1
DATA MATRIX

DATA POINT I.D. NO.	MODEL SCALE	M_0	α (DEG)	β (DEG)	ρ (DEG)	$\Delta 3$ (DEG)	BYPASS*	% WAT2	RE NO. x 10^{-6}	ANALYSIS TIME (SEC)	PART–POINT**
34	FLT	1.21	1.5	0	6.0	27.6	C	98.3	2.97	0.60	423-4
35	FLT	1.24	3.0	0.8	6.7	27.6	C	96.4	1.52	0.60	423-3
36	1/6th	1.2	10.0	0	7.0	10.6	C	76.6	0.45	0.198	131-7
37	1/6th	1.2	10.0	0	7.0	10.6	C	107.9	0.45	0.198	131-5
38	FLT	1.18	7.7	0.3	7.0	11.0	C	74.0	3.22	1.21	424-12
39	↓	1.2	7.4	−0.1	7.1	11.1	↓	94.4	3.35	1.19	424-13
40	↓	1.17	10.6	0.0	7.0	11.0	↓	103.4	1.40	0.60	421-17
41	FLT	1.54	1.5	0	−1.4	27.0	Auto	95.4	2.17	0.60	424-6
42	1/6th	1.6	−4.0	0	−2.0	13.5	C	87.3	0.21	0.106	206-9
43	1/6th	1.6	−4.0	0	−2.0	13.5	C	96.9	0.21	0.106	206-5
44	FLT	1.57	−3.6	0.7	−2.3	13.7	C	83.3	1.46	0.65	414-2
45	1/6th	1.8	−2.0	0	−3.0	17.4	C	80.5	0.22	0.210	15-9
46	1/6th	1.8	−2.0	0	−3.0	17.4	C	91.0	0.22	0.201	15-5
47	FLT	1.75	−2.6	0.4	−2.2	16.7	C	80.7	1.41	1.23	415-1
48	FSCP	1.8	−2.0	0	−3.0	18.7	C	75.1	1.45	0.680	353-15
49	↓	↓	−2.0	↓	−3.0	↓	↓	82.2	1.45	0.680	353-5
50	↓	↓	−2.0	↓	−3.0	↓	↓	85.4	1.44	0.680	353-12
51	FSE	1.8	−2.0	0	−2.9	18.6	C	80.6	1.46	0.680	523-2
52	FSE	1.8	−2.0	0	−2.9	18.6	C	79.3	1.46	0.680	525-4
53	FLT	1.81	−2.3	0.2	−2.9	18.2	C	78.9	1.53	0.680	416-1
54	FSCP	1.8	4.0	0	2.5	18.7	C	79.9	1.45	2.800	355-8
55	FSE	1.8	4.0	0	2.5	18.7	C	80.8	1.46	2.800	528-2
56	FSE	1.8	4.0	0	2.5	18.7	C	79.7	1.46	2.800	529-4
57	FLT	2.0	2.5	0.2	2.3	20.9	Auto	77.0	1.72	2.800	425-2

GP78-0323-9

*C = Closed

**For flight test, these data are flight-run numbers

TABLE H-1 (Continued)
DATA MATRIX

DATA POINT I.D. NO.	MODEL SCALE	M_0	α (DEG)	β (DEG)	ρ (DEG)	$\Delta\vartheta$ (DEG)	BYPASS*	% WAT2	RE NO. x 10^{-6}	ANALYSIS TIME (SEC)	PART–POINT**
58	1/6th	2.2	−2.0	0	−4.0	22.5	C	68.6	0.22	0.100	250-7
59	FSCP	2.2	−2.0	0	−4.0	22.5	C	69.2	1.48	0.600	411-6
60	1/6th	2.2	−2.0	0	−4.0	25.0	O	65.0	0.22	0.100	249-5
61	1/6th	2.2	−2.0	0	−4.0	25.0	O	52.9	0.22	0.100	249-9
62	FSCP	2.2	−2.0	0	−4.0	25.0	O	61.7	1.48	0.600	385-5
63	FSCP	2.2	−2.0	0	−4.0	25.0	O	62.3	1.48	0.600	385-2
64	FSE	2.2	−2.0	0	−4.0	24.8	P	60.2	1.27	0.600	542-2
65	FSE	2.2	−2.0	0	−4.0	24.8	P	60.5	1.27	0.600	543-4
66	1/6th	2.2	0	0	−2.0	22.5	C	69.3	0.22	0.106	184-7
67	1/6th	2.2	0	0	−2.0	22.5	C	75.4	0.22	0.106	184-5
68	FSCP	2.2	0	0	−2.0	22.5	C	73.6	1.47	0.650	413-9
69	FSCP	2.2	0	0	−2.0	22.5	C	68.3	1.47	0.650	413-12
70	FLT	2.2	0.1	0.2	−2.2	22.9	C	73.0	2.34	0.650	425-1
71	FSCP	2.2	4.0	0	0.0	25.0	O	60.7	1.48	0.600	382-3
72	FSE	2.2	4.0	0	1.0	25.0	O	59.2	1.28	0.600	545-2
73	FSE	2.2	4.0	0	1.0	25.0	O	58.2	1.27	0.600	546-4
74	1/6th	2.2	12.0	0	6.0	25.0	O	47.3	0.22	0.100	252-9
75	1/6th	2.2	12.0	0	6.0	25.0	O	65.0	0.22	0.100	252-5
76	FSCP	2.2	12.0	0	6.8	25.0	O	60.8	1.48	0.600	384-2
77	FSE	2.2	11.0	0	6.8	24.8	O	59.0	1.28	0.600	548-3
78	FSE	2.2	11.0	0	6.8	24.8	P	59.8	1.27	0.600	549-8
79	1/6th	2.5	0	0	−4.0	26.0	O	63.1	0.21	0.100	227-7
80	1/6th	2.5	0	0	−4.0	26.0	O	68.2	0.21	0.100	227-5
81	FSCP	2.5	0	0	−4.0	26.0	O	62.8	1.28	0.600	465-8
82	FSCP	2.5	0	0	−4.0	26.0	O	68.9	1.28	0.600	465-5

*O = Open, C = Closed, P = Partial

GP78-0323-10

**For flight test, these data are flight-run numbers

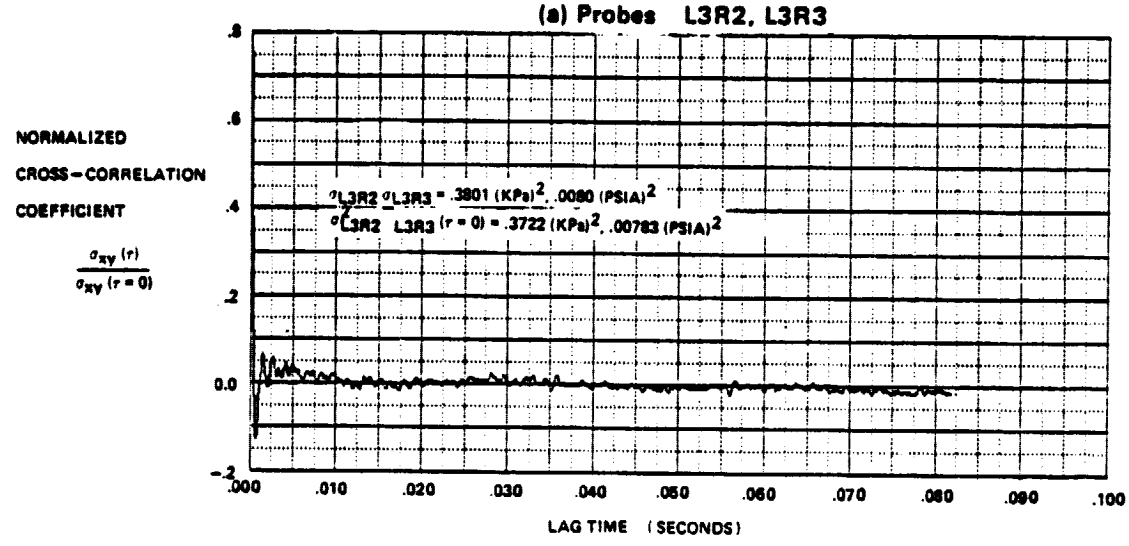
TABLE H-1 (Concluded)
DATA MATRIX

SERIES VII - NASA DATA STUDY

DATA PART/POINT 184/1 IDENT. 8 FREQUENCY RANGE = 6 — 12000 Hz
THE SEGMENT START TIME WAS AT 22:11:52.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
0.6	−10	10	−3.0	10.6	0.0	97.2%	−11.7

1 PSIA = 6.8948 kPa



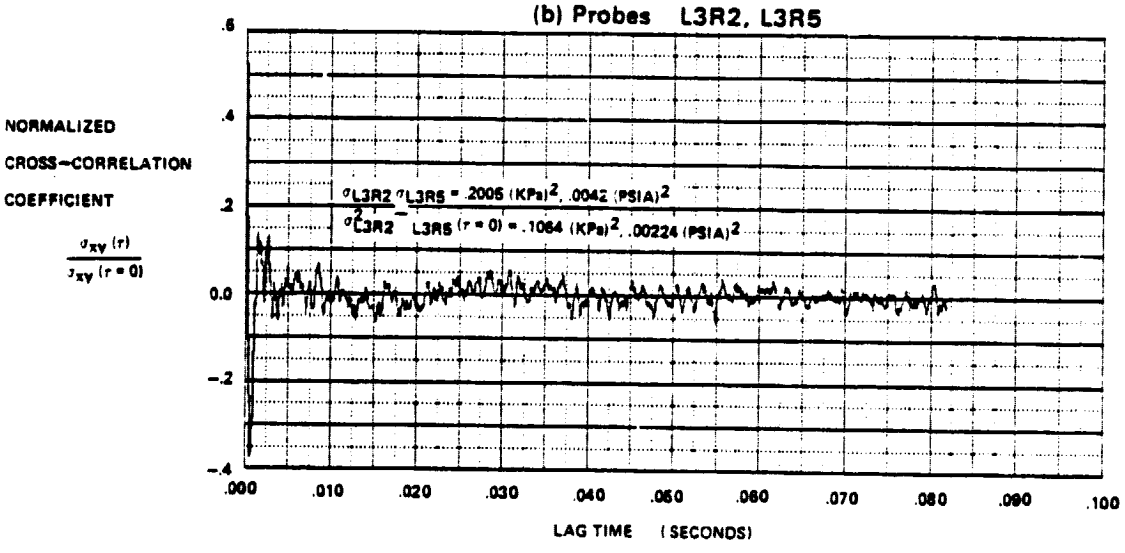


FIGURE H-1
CROSS-CORRELATION FUNCTIONS
$M_0 = 0.6$ $\alpha = -10$ $\beta = 10$ WAT2 = 97.2%

SERIES VII - NASA DATA STUDY

DATA PART/POINT 164/1 IDENT. 8 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 22:11:52.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
0.6	−10	10	−3.0	10.6	0.0	97.2%	−11.7

1 PSIA = 6.8948 kPa

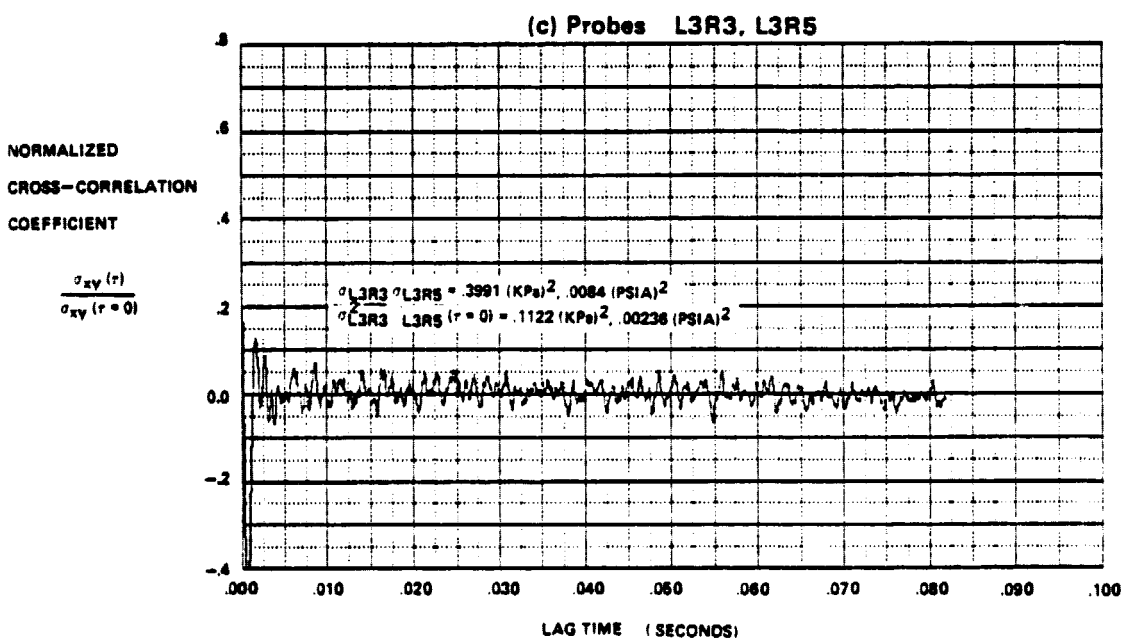
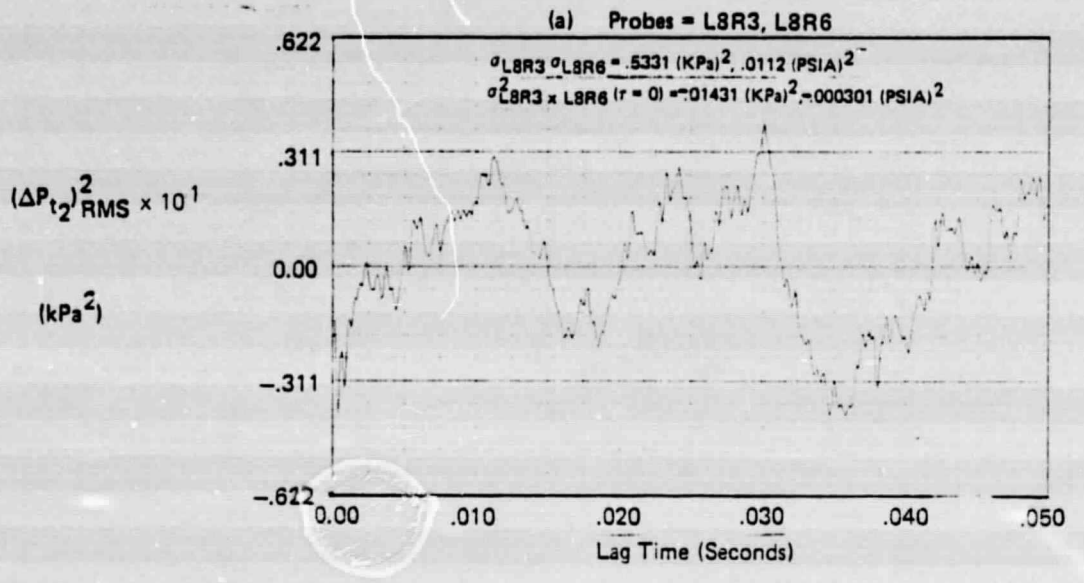


FIGURE H-1 (Continued)
CROSS-CORRELATION FUNCTIONS
$M_0 = 0.6$ $\alpha = -10$ $\beta = 10$ WAT2 = 97.2%

DATA FLIGHT/RUN 421/10 IDENT. 7 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:09:24.580
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.69	−8.5	10.5	12143 (39840)	0.6	10.5	0.0	101.2%	−8.513

1 psia = 6.8948 KPa



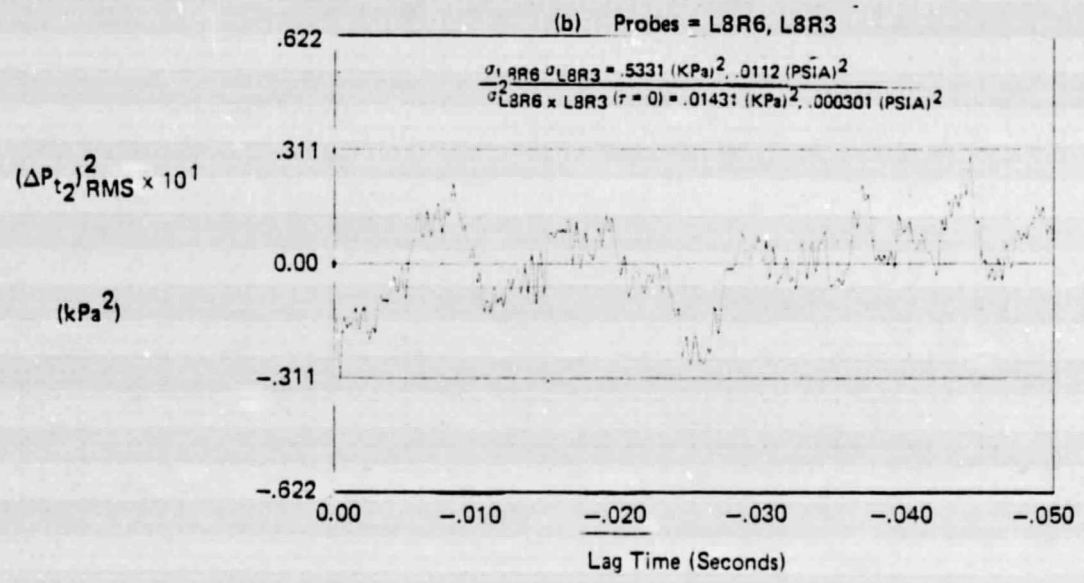


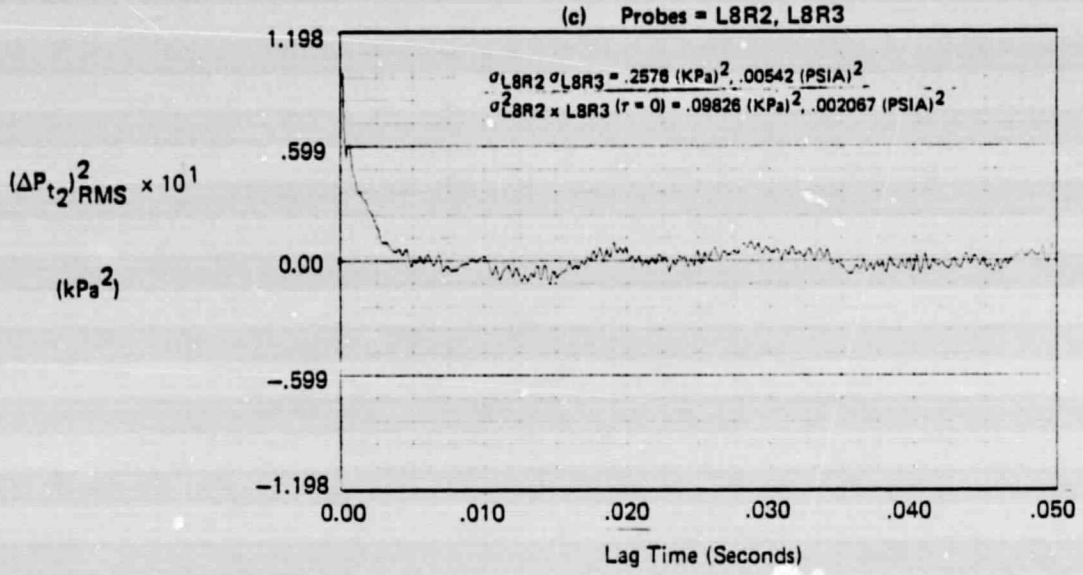
FIGURE H-2

CROSS-CORRELATION FUNCTIONS FOR
M_o = .69, α = −8.5, β = 10.5, WAT2 = 101.2%

DATA FLIGHT/RUN 421/10 IDENT. 7 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:09:24.580
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.69	−8.5	10.5	12143 (39840)	0.6	10.5	0.0	101.2%	−8.513

1 psia = 6.8948 KPa



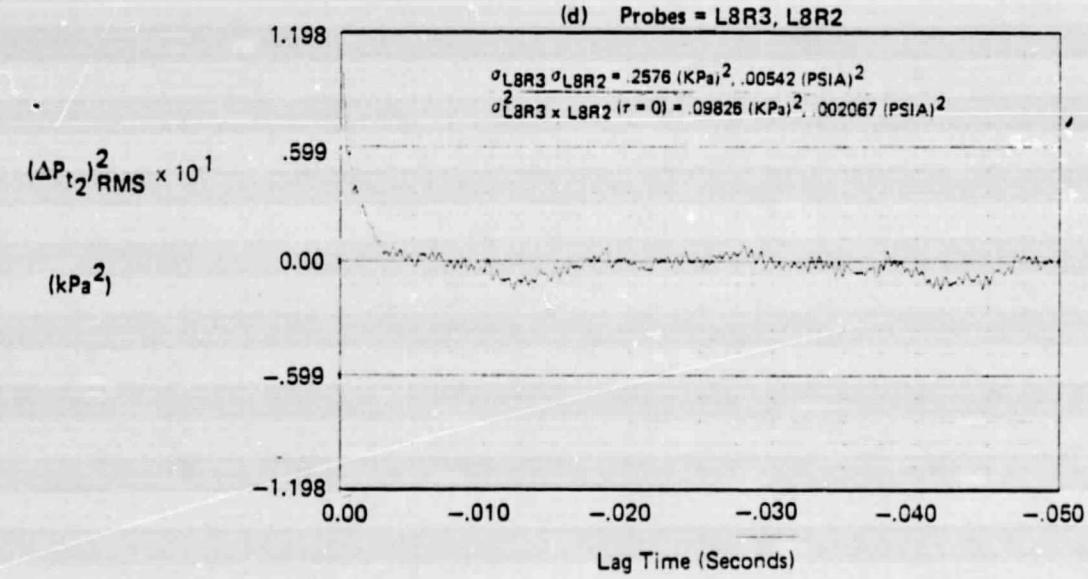


FIGURE H-2 (Continued)

CROSS-CORRELATION FUNCTIONS FOR

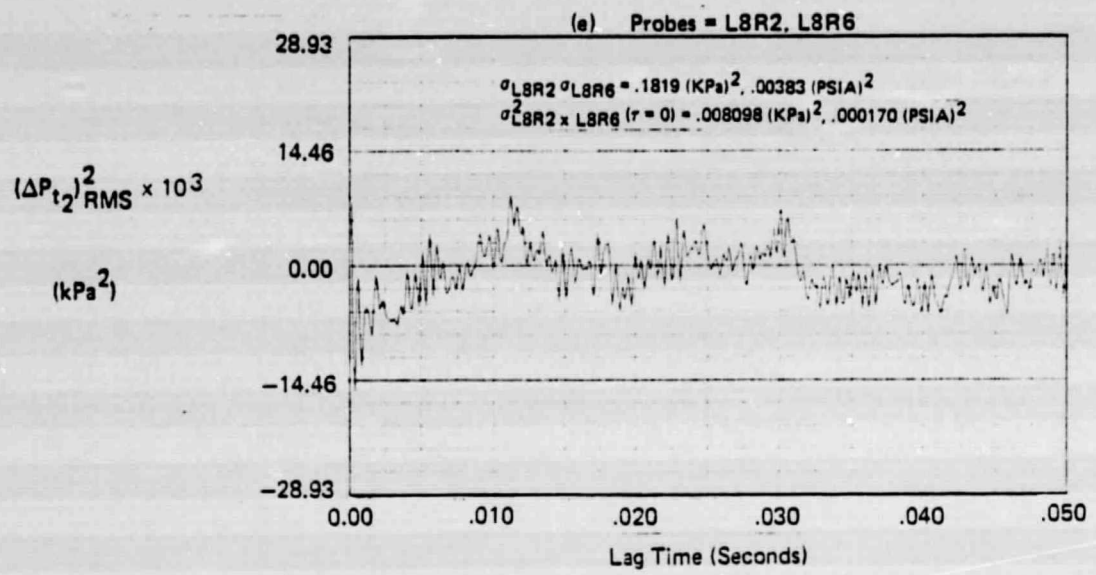
M_o = .69, α = −8.5, β = 10.5, WAT2 = 101.2%

FLIGHT - NASA DATA STUDY

DATA FLIGHT/RUN 421/10 IDENT. 7 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:09:24.580
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.69	−8.5	10.5	12143 (39840)	0.6	10.5	0.0	101.2%	−8.513

1 psia = 6.8948 KPa



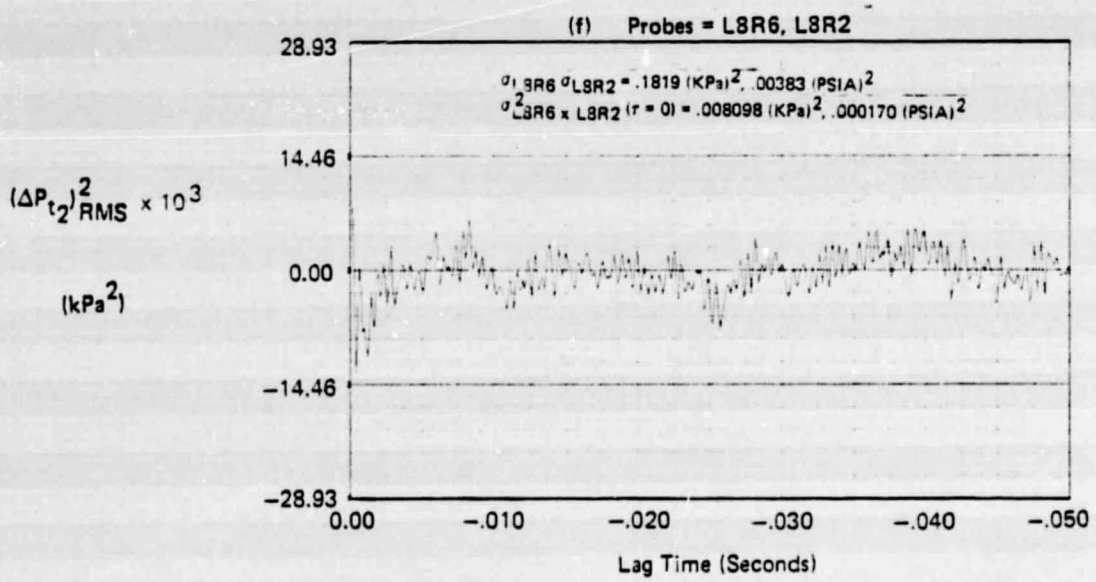


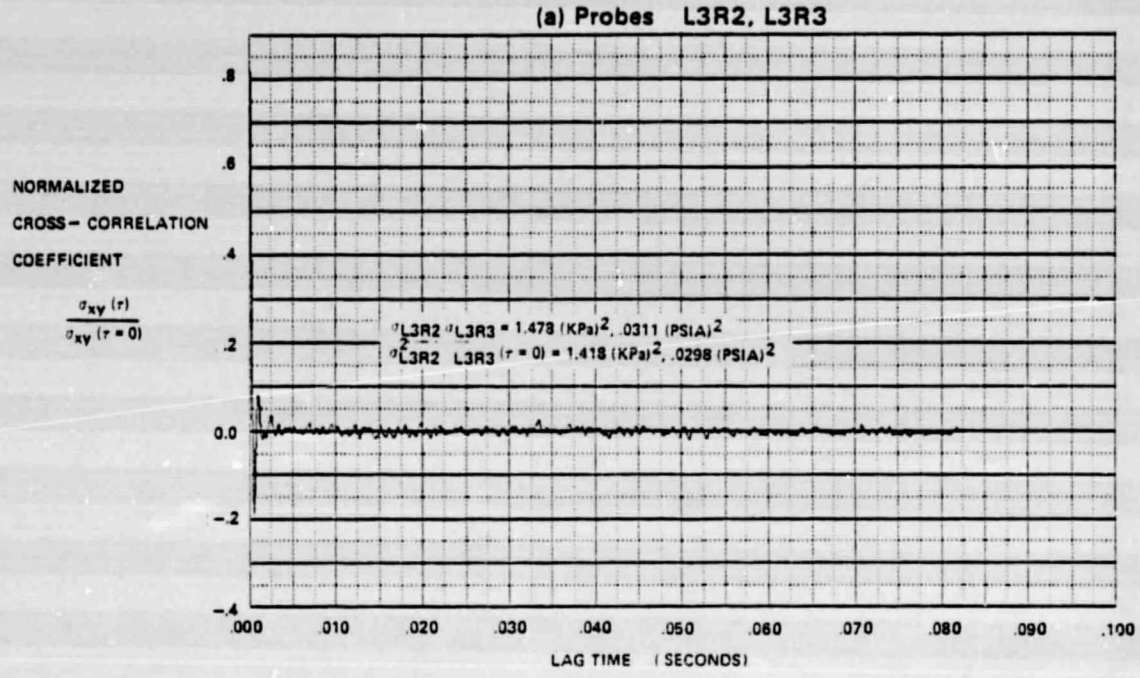
FIGURE H-2 (Concluded)
CROSS-CORRELATION FUNCTIONS FOR
M_o = .69, α = −8.5, β = 10.5, WAT2 = 101.2%

SERIES VII - NASA DATA STUDY

DATA PART/POINT 157/5 IDENT. 16 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 20:08:47.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
0.9	−10	10	−3.0	10.6	0.0	106.3%	−5.0

1 PSIA = 6.8948 kPa



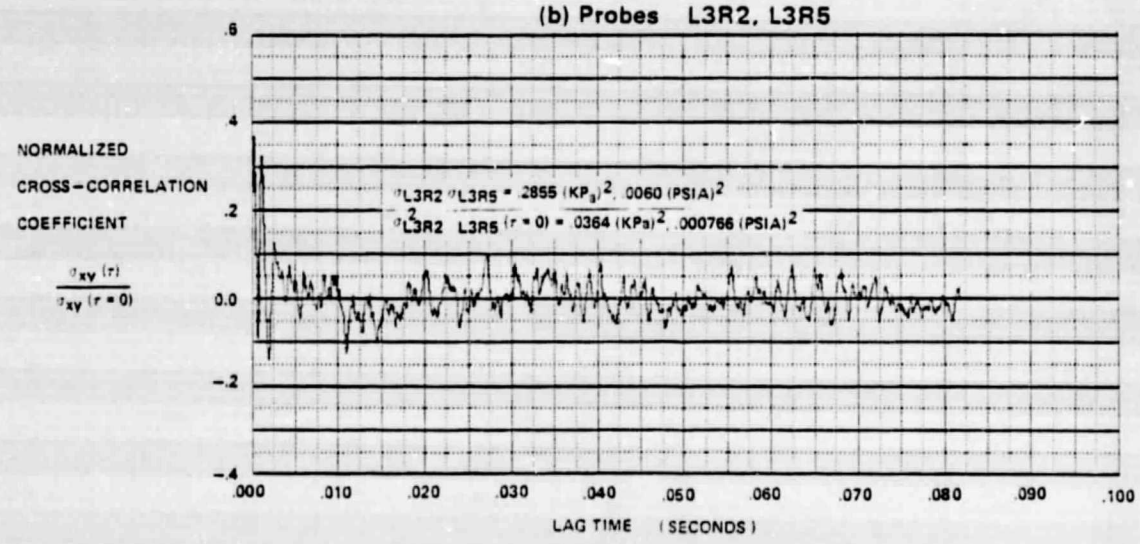


FIGURE H-3

CROSS−CORRELATION FUNCTIONS FOR
M_o = 0.9, α = −10, β = 10, WAT2 = 106.3%

SERIES VII - NASA DATA STUDY

DATA PART/POINT 157/5 IDENT. 18 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 20:08:47.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
0.9	−10	10	−3.0	10.6	0.0	106.3%	−5.0

1 PSIA = 6.8948 kPa

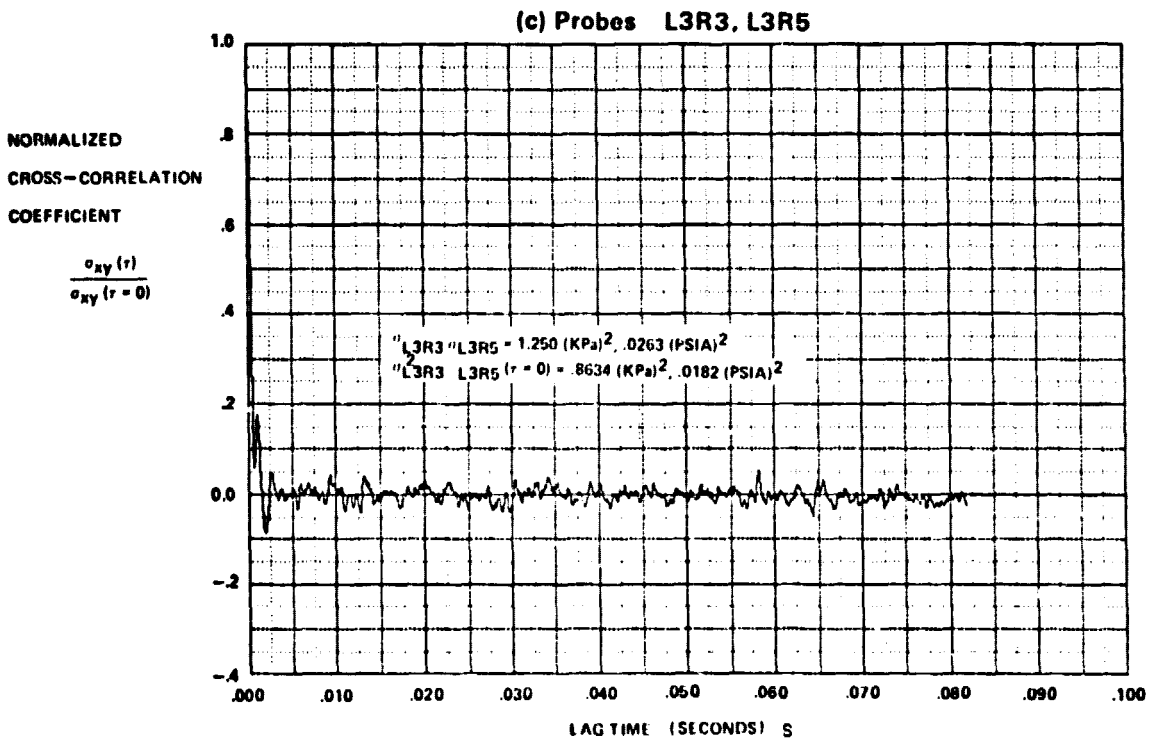


FIGURE H-3 (Continued)

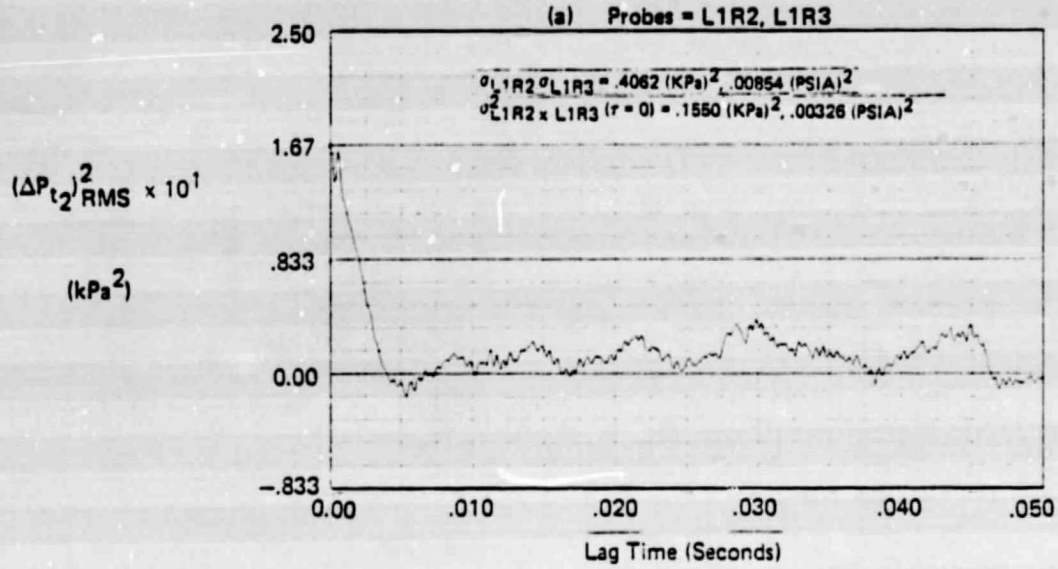
CROSS-CORRELATION FUNCTIONS FOR
M_O = 0.9, α = −10, β = 10, WAT2 = 106.3%

FLIGHT - NASA DATA STUDY

DATA FLIGHT/RUN 421/14 IDENT. 19 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:16:07.140
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.94	−8.9	10.2	13402 (43970)	1.0	10.5	0.0	107.1%	−5.000

1 psia = 6.8948 KPa



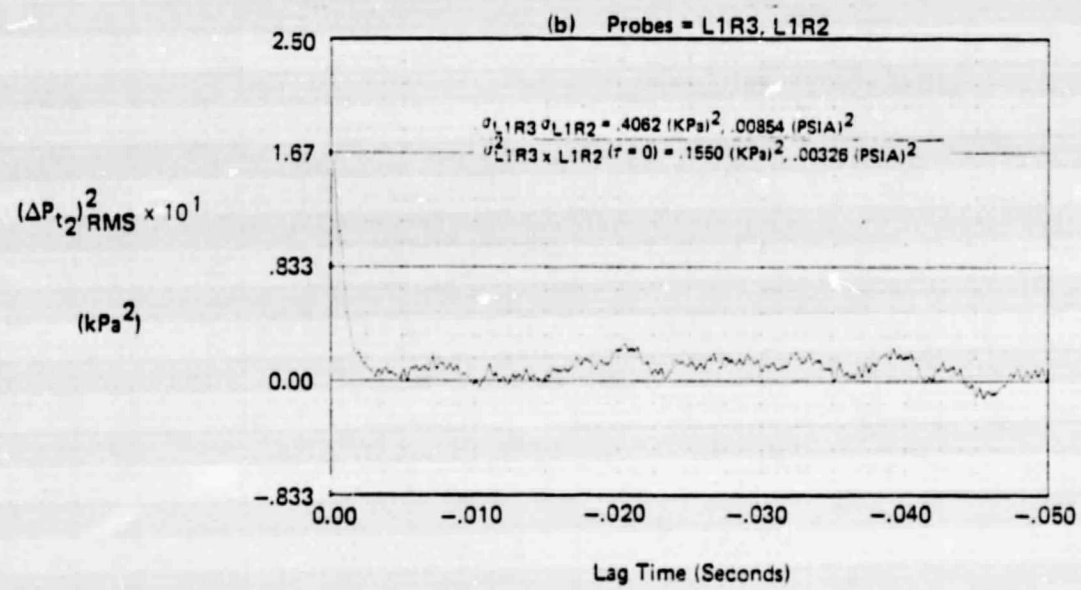


FIGURE H-4

CROSS-CORRELATION FUNCTIONS FOR

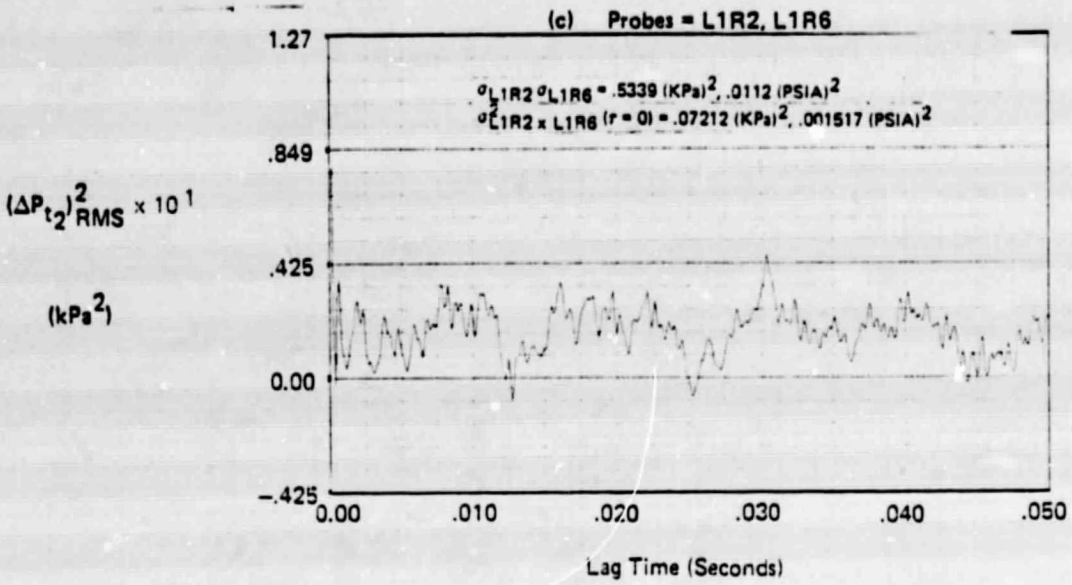
M_o = .94, α = −8.9, β = 10.2, WAT2 = 107.1%

FLIGHT - NASA DATA STUDY

DATA FLIGHT/RUN 421/14 IDENT. 19 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:16:07.140
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.94	−8.9	10.2	13402 (43970)	1.0	10.5	0.0	107.1%	−5.000

1 psia = 6.8948 KPa



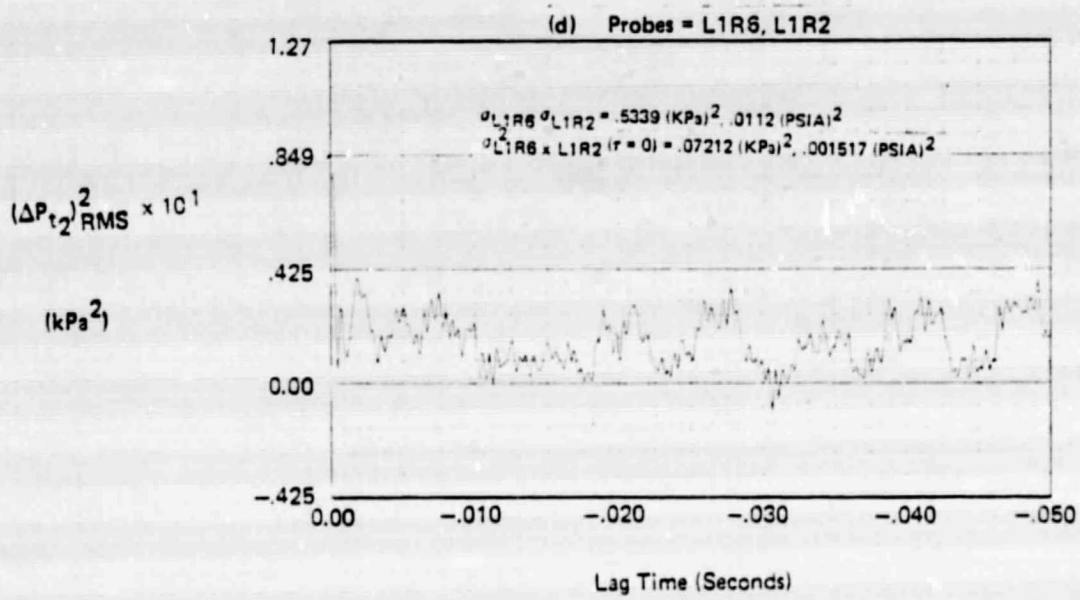


FIGURE H-4 (Continued)
CROSS-CORRELATION FUNCTIONS FOR
M_o = .94, α = −8.9, β = 10.2, WAT2 = 107.1%

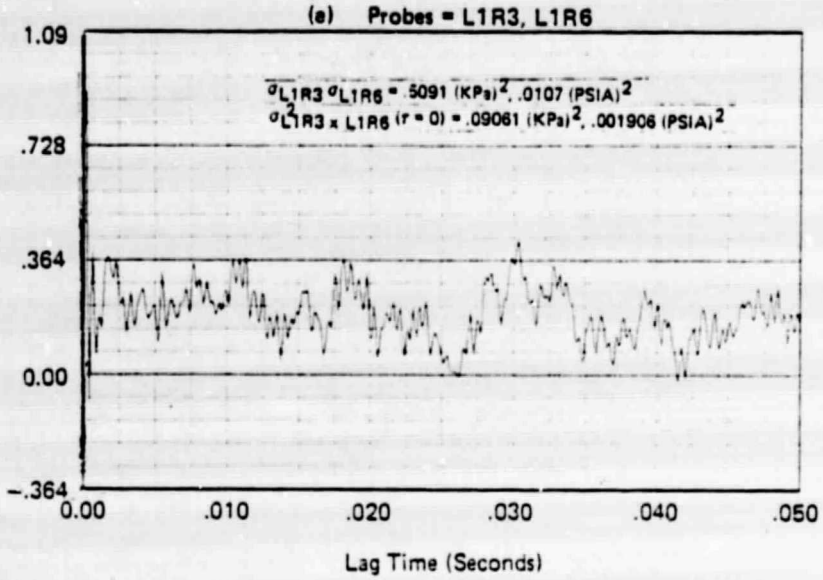
FLIGHT - NASA DATA STUDY

DATA FLIGHT/RUN 421/14 IDENT. 19 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 21:16:07.140
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
0.94	−8.9	10.2	13402 (43970)	1.0	10.5	0.0	107.1%	−5.000

1 psia = 6.8948 KPa

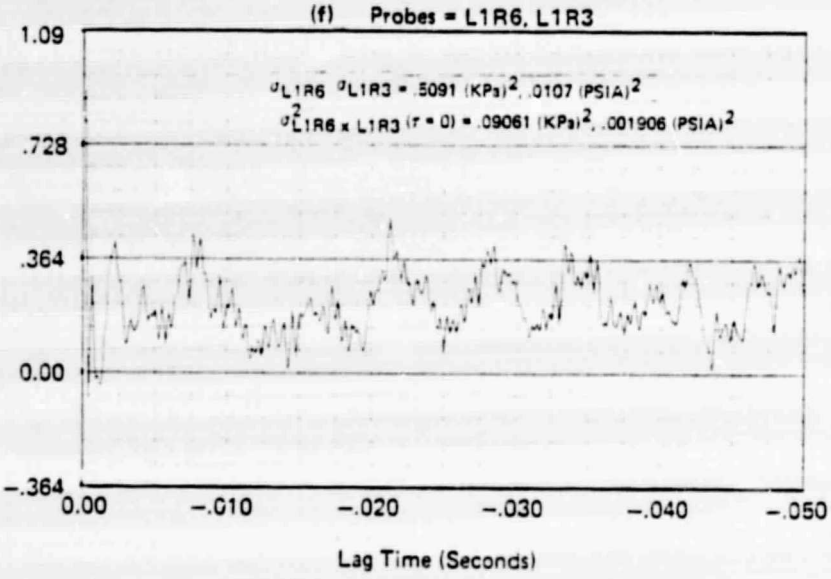
(e) Probes = L1R3, L1R6



$(\Delta P_{t_2})^2_{RMS} \times 10^1$

(kPa^2)

(f) Probes = L1R6, L1R3



$(\Delta P_{t_2})^2_{RMS} \times 10^1$

(kPa^2)

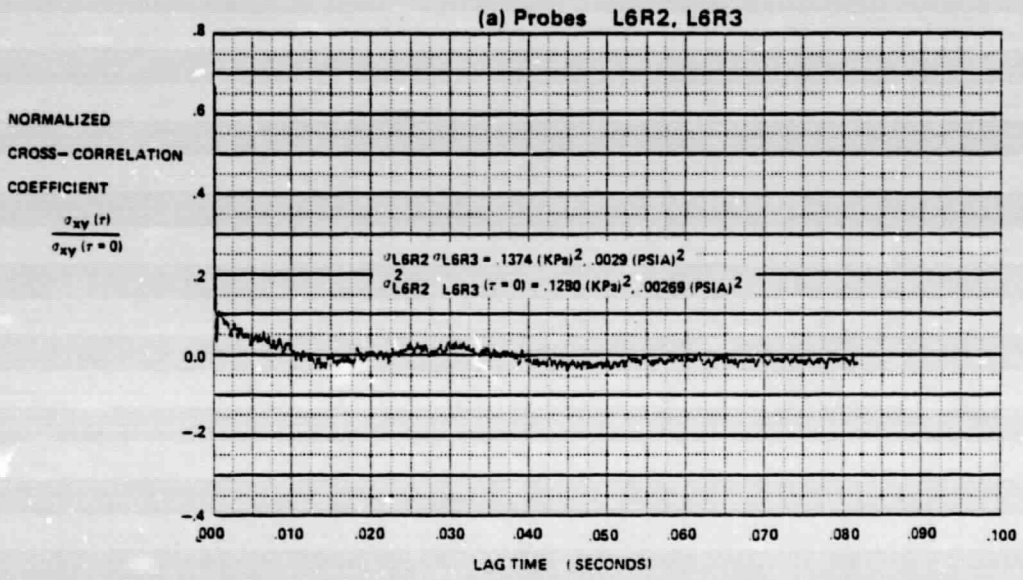
FIGURE H-4 (Concluded)
CROSS-CORRELATION FUNCTIONS FOR
M_o = .94, α = −8.9, β = 10.2, WAT2 = 107.1%

SERIES VIII - NASA DATA STUDY

DATA PART/POINT 206/5 IDENT. 43 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 03:30:06.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
1.6	−4	0	−2.0	13.5	0.0	96.9%	−12.0

1 PSIA = 6.8948 kPa



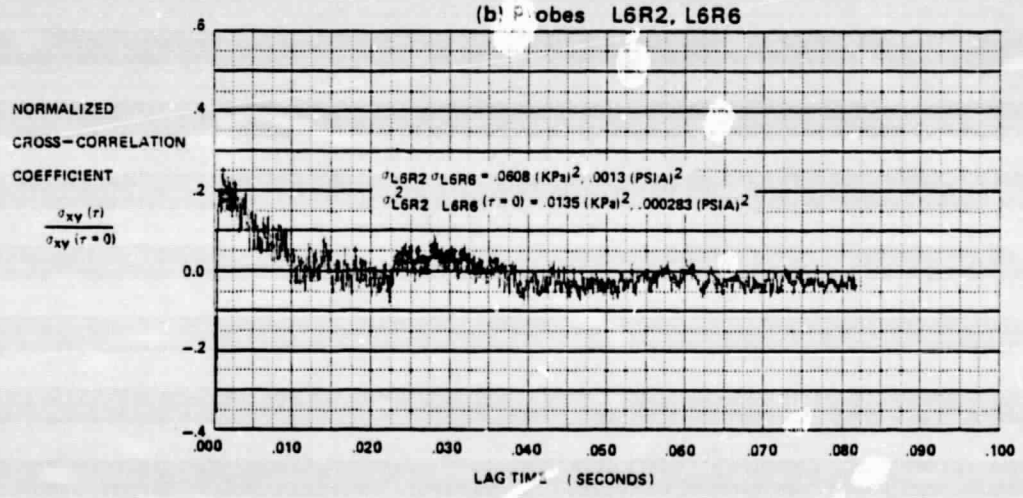


FIGURE H-5
CROSS-CORRELATION FUNCTIONS FOR
M_O = 1.6, α = −4, β = 0, WAT2 = 96.9%

SERIES VIII - NASA DATA STUDY

DATA PART/POINT 206/8 IDENT. 43 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 03:30:06.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
1.6	−4	0	−2.0	13.5	0.0	96.9%	−12.0

1 PSIA = 6.8948 kPa

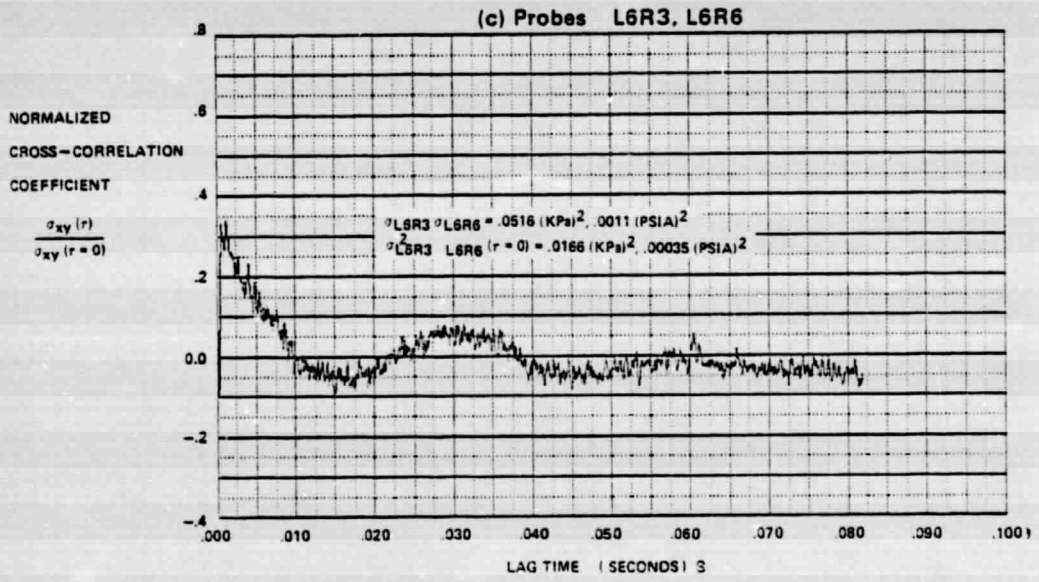


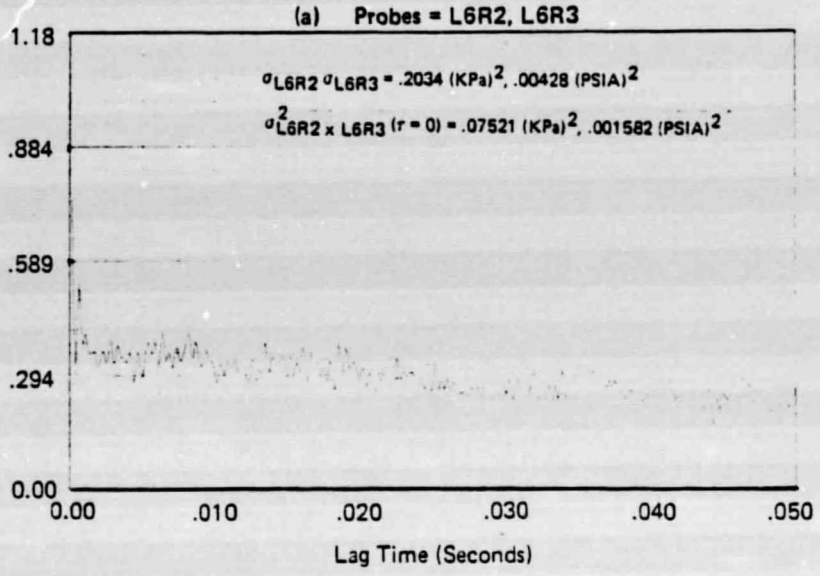
FIGURE H-5 (Continued)
CROSS−CORRELATION FUNCTIONS FOR
M_o = 1.6, α = −4, β = 0, WAT2 = 96.9%

DATA FLIGHT/RUN 414/2 IDENT. 44 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 20:16:46.820
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
1.57	−3.6	0.6	17157 (56290)	−2.3	13.7	0.0	89.3%	−20.60

1 psia = 6.8948 KPa

(a) Probes = L6R2, L6R3



(b) Probes = L6R3, L6R2

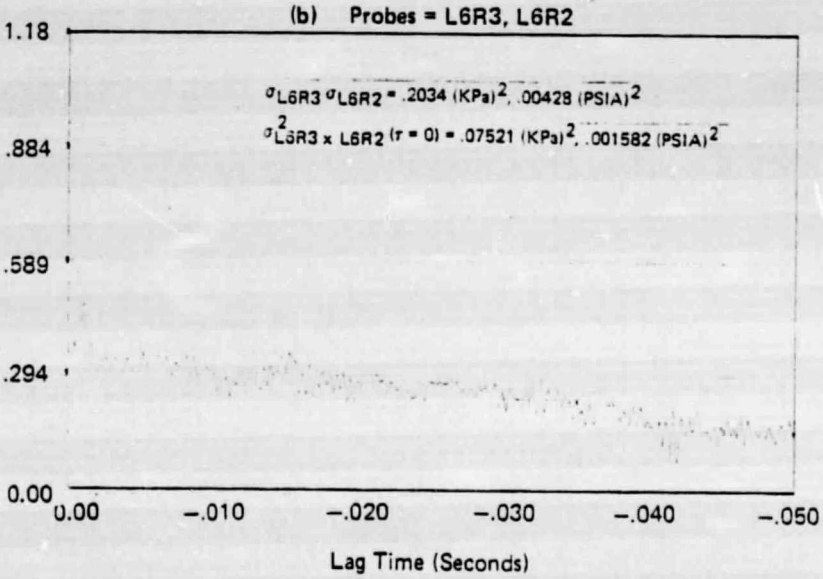


FIGURE H-6

CROSS-CORRELATION FUNCTIONS FOR

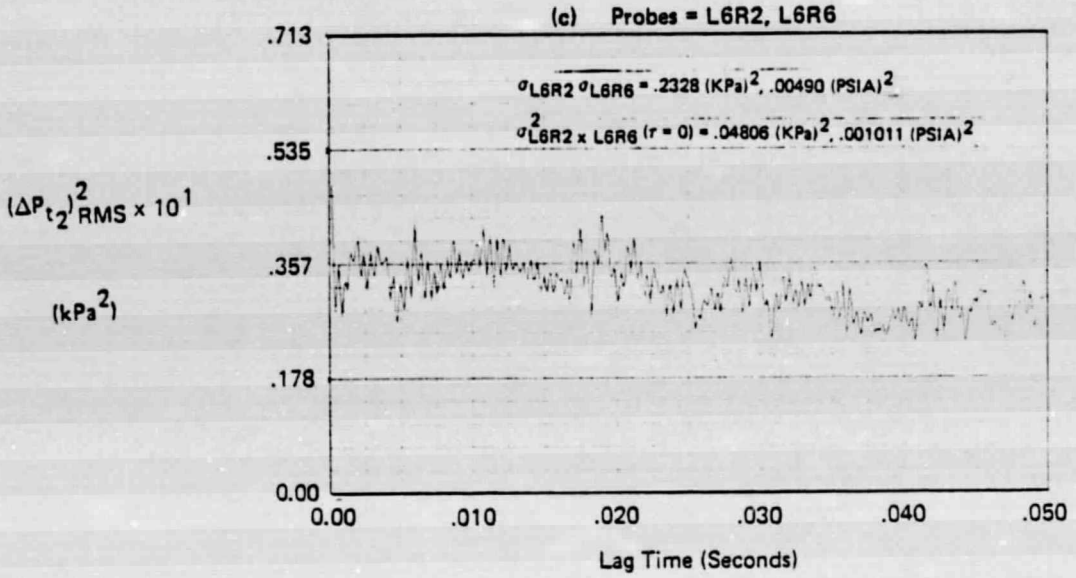
M_o = 1.57, α = −3.6, β = 0.6, WAT2 = 89.3%

DATA FLIGHT/RUN 414/2 IDENT. 44 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 20:16:46.820
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
1.57	−3.6	0.6	17157 (56290)	−2.3	13.7	0.0	89.3%	−20.60

1 psia = 6.8948 KPa

(c) Probes = L6R2, L6R6



(d) Probes = L6R6, L6R2

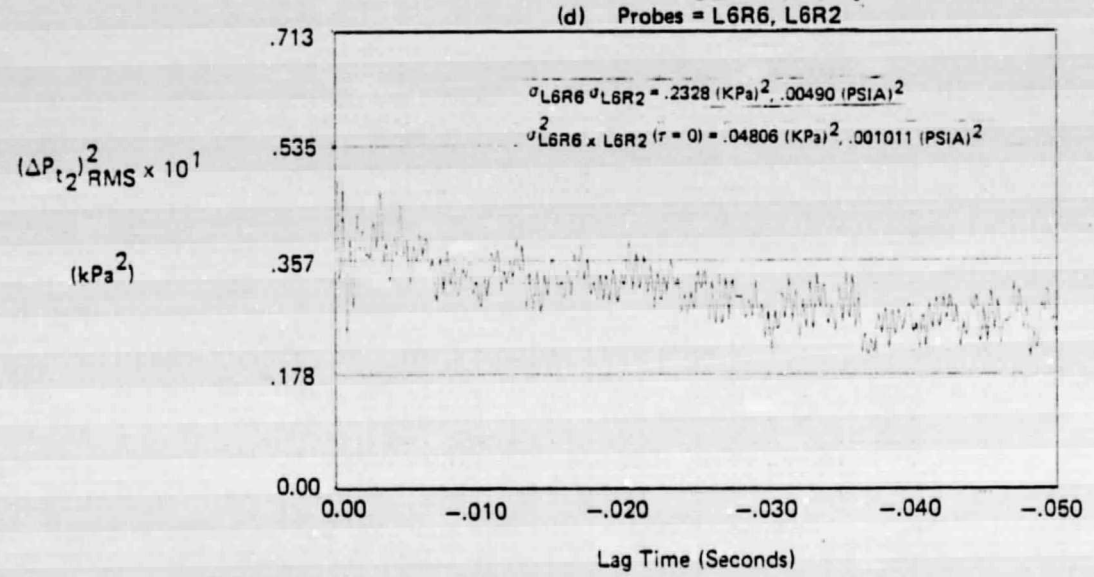


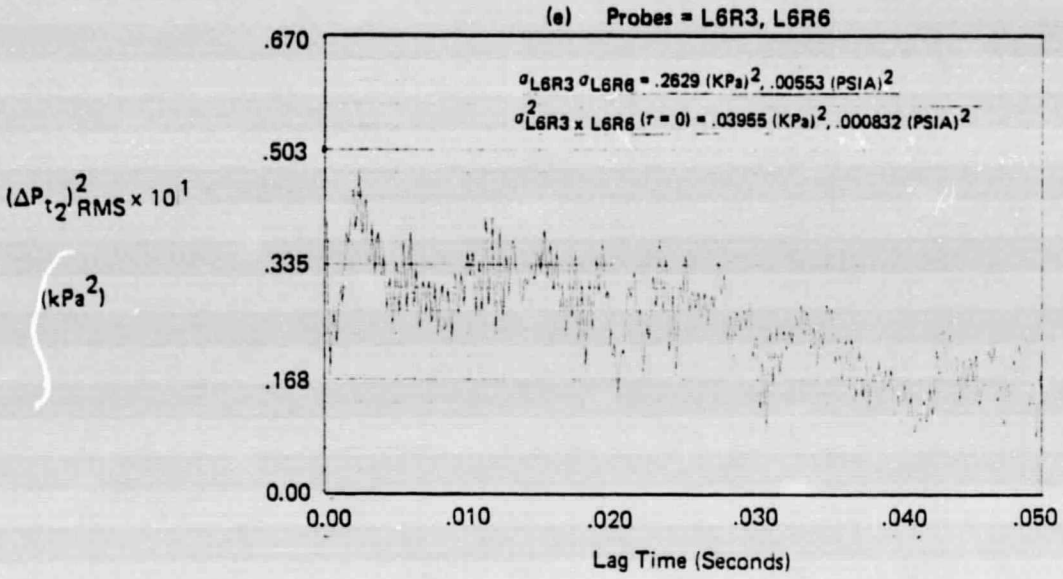
FIGURE H-6 (Continued)

CROSS-CORRELATION FUNCTIONS FOR
M_o = 1.57, α = −3.6, β = 0.6, WAT2 = 89.3%

DATA FLIGHT/RUN 414/2 IDENT. 44 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 20:16:46.820
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
1.57	−3.6	0.6	17157 (56290)	−2.3	13.7	0.0	89.3%	−20.60

1 psia = 6.8948 KPa



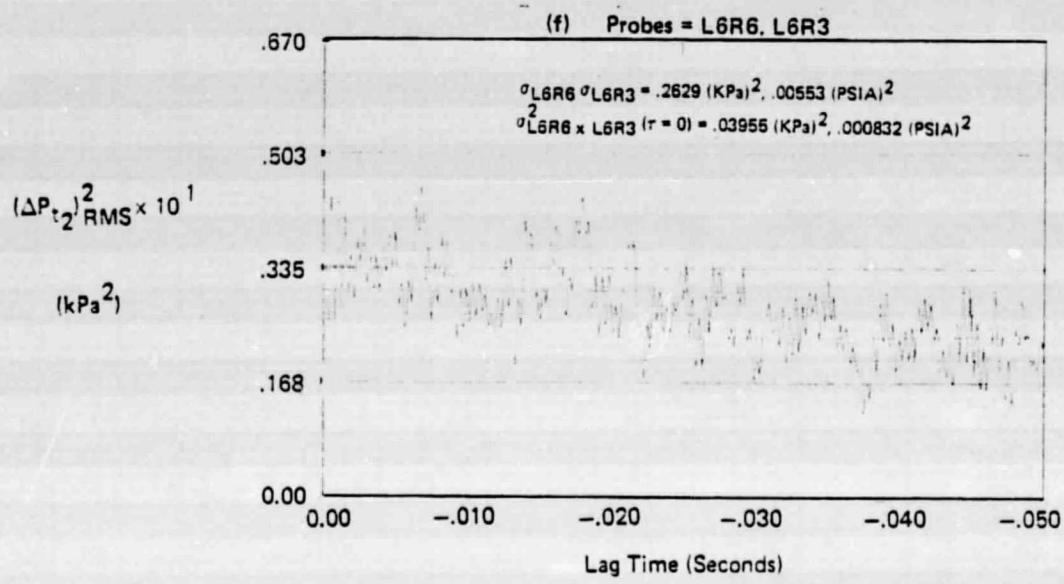


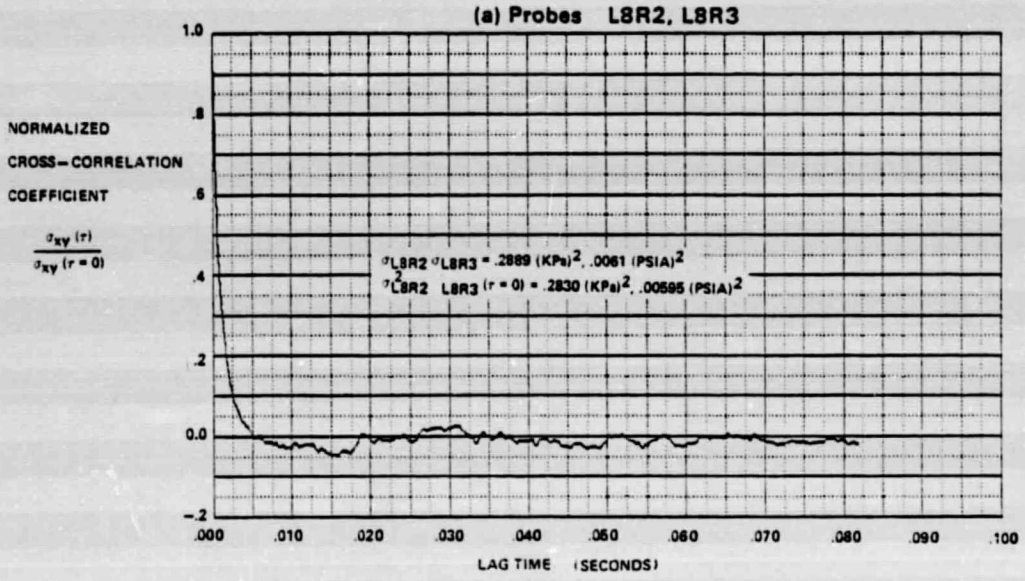
FIGURE H-6 (Concluded)
CROSS-CORRELATION FUNCTIONS FOR
M_o = 1.57, α = −3.6, β = 0.6, WAT2 = 89.3%

SERIES VIII - NASA DATA STUDY

DATA PART/POINT 249/5 IDENT. 60 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 06:15:59.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	25.0	.0774 (120.0)	65.0%	−25.0

1 PSIA = 6.8948 kPa



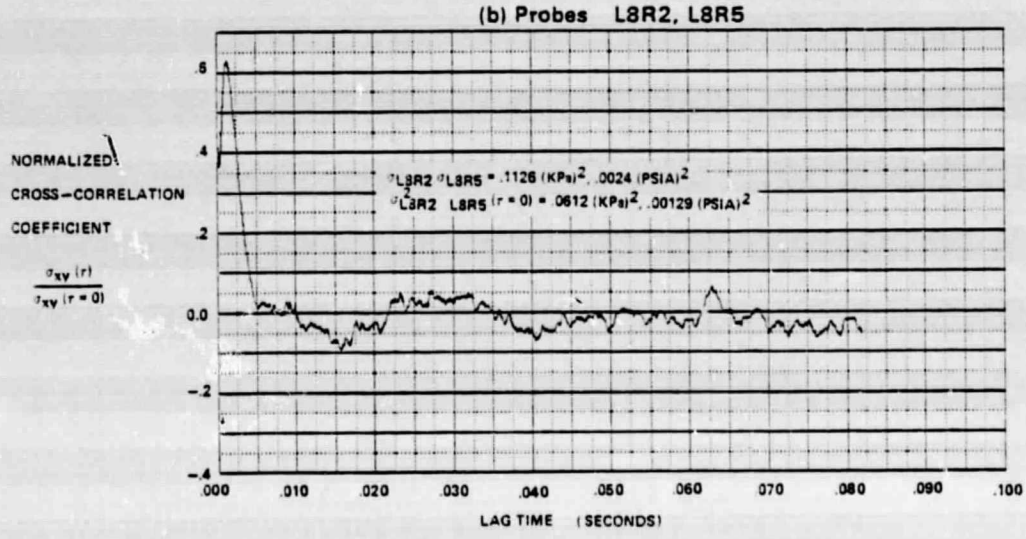


FIGURE H-7
CROSS − CORRELATION FUNCTIONS FOR
M_o = 2.2, α = −2, β = 0, WAT2 = 65.0%

SERIES VIII. - NASA DATA STUDY

DATA PART/POINT 249/5 IDENT. 60 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 06:16:59.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	25.0	.0774 (120.0)	65.0%	−25.0

1 PSIA = 6.8948 kPa

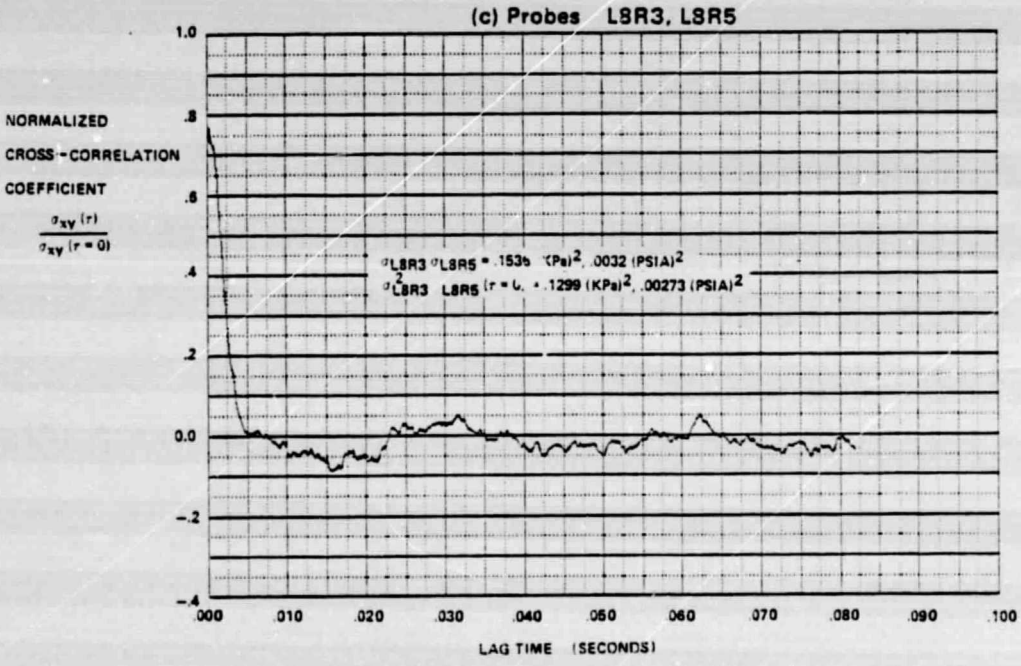


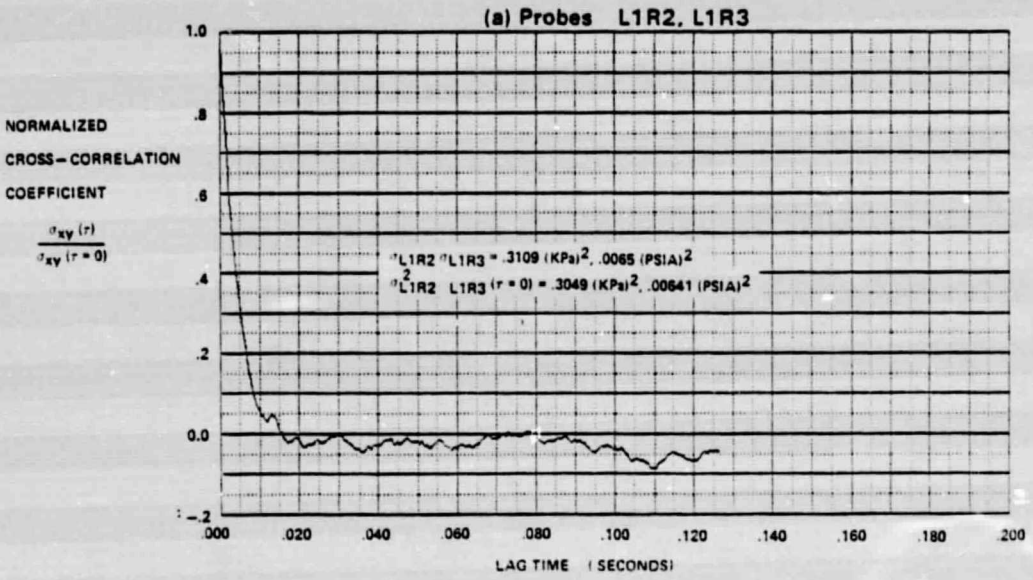
FIGURE H-7 (Continued)
CROSS−CORRELATION FUNCTIONS FOR
$M_o = 2.2$, $\alpha = -2$, $\beta = 0$, WAT2 = 65.0%

FSCP - NASA DATA STUDY

DATA PART/POINT 386/2 IDENT 63 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 01:29:15.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	25.0	.0775 (120.1)	62.3%	−25.0

1 PSIA = 6.8948 kPa



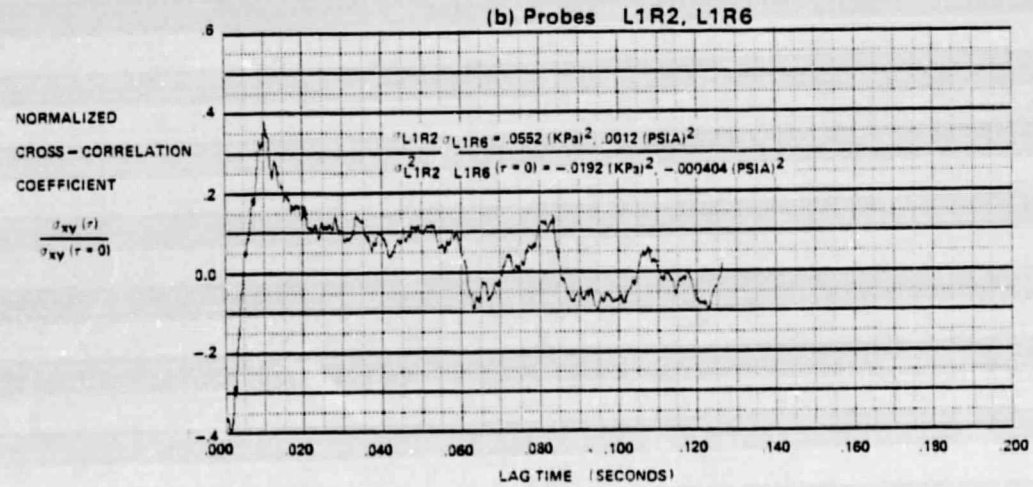


FIGURE H-8

CROSS−CORRELATION FUNCTIONS FOR $M_o = 2.2$, $\alpha = -2$, $\beta = 0$, WAT2 = 62.3%

FSCP - NASA DATA STUDY

DATA PART/POINT 386/2 IDENT. 63 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 01:29:15.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	25.0	.0775 (120.1)	62.3%	−25.0

1 PSIA = 6.8948 kPa

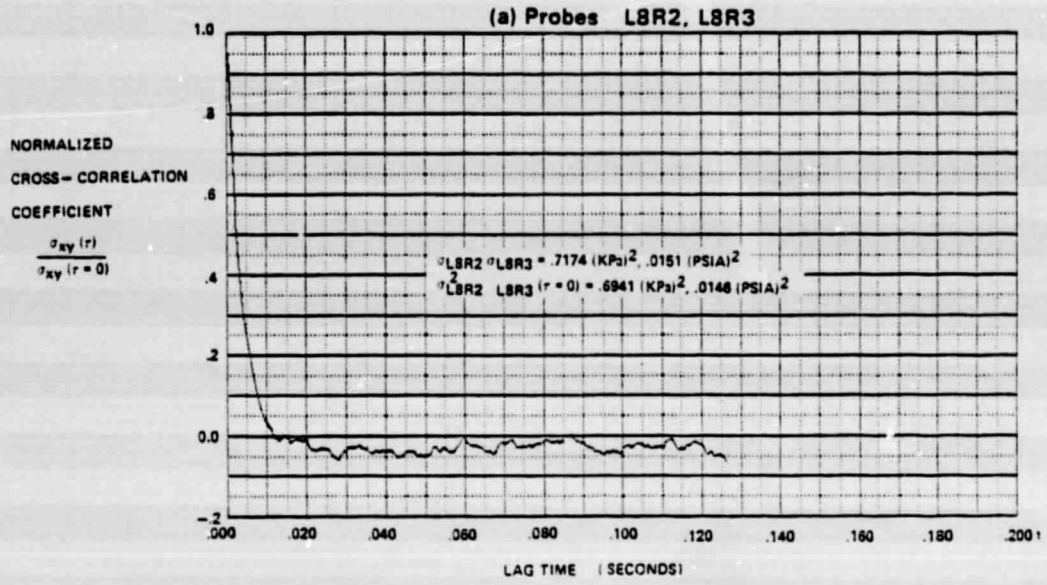
FIGURE H-8 (Continued)
CROSS−CORRELATION FUNCTIONS FOR
M_O = 2.2, α = −2, β = 0, WAT2 = 62.3%

FSE - NASA DATA STUDY

DATA PART/POINT 543/4 IDENT. 66 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 23:12:07.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	24.8	.0223 (34.5)	60.5%	−25.0

1 PSIA = 6.8948 kPa



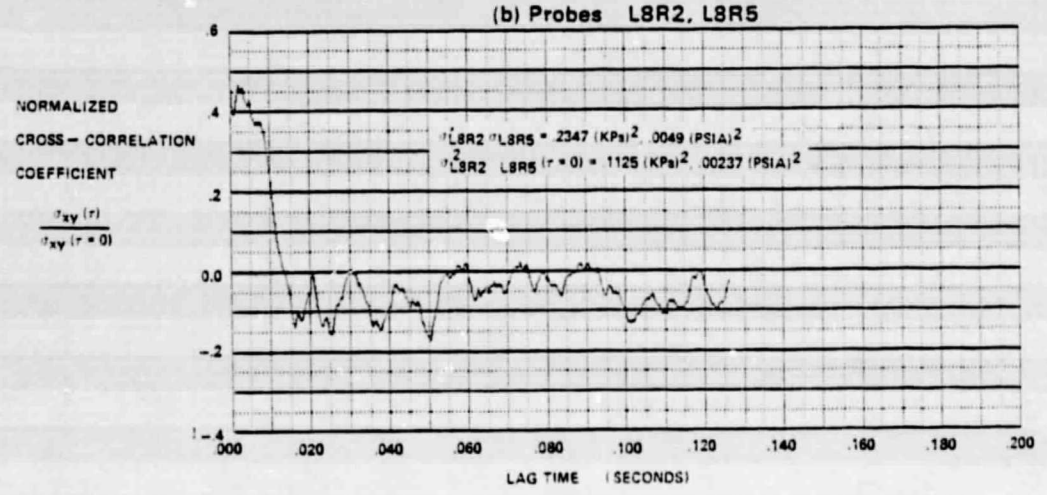


FIGURE H-9

CROSS—CORRELATION FUNCTIONS FOR
M_o = 2.2, α = −2, β = 0, WAT2 = 60.5%

FSE - NASA DATA STUDY

DATA PART/POINT 543/4 IDENT. 68 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 23:12:07.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	−2	0	−4.0	24.8	.0223 (34.5)	60.5%	−25.0

1 PSIA = 6.8948 kPa

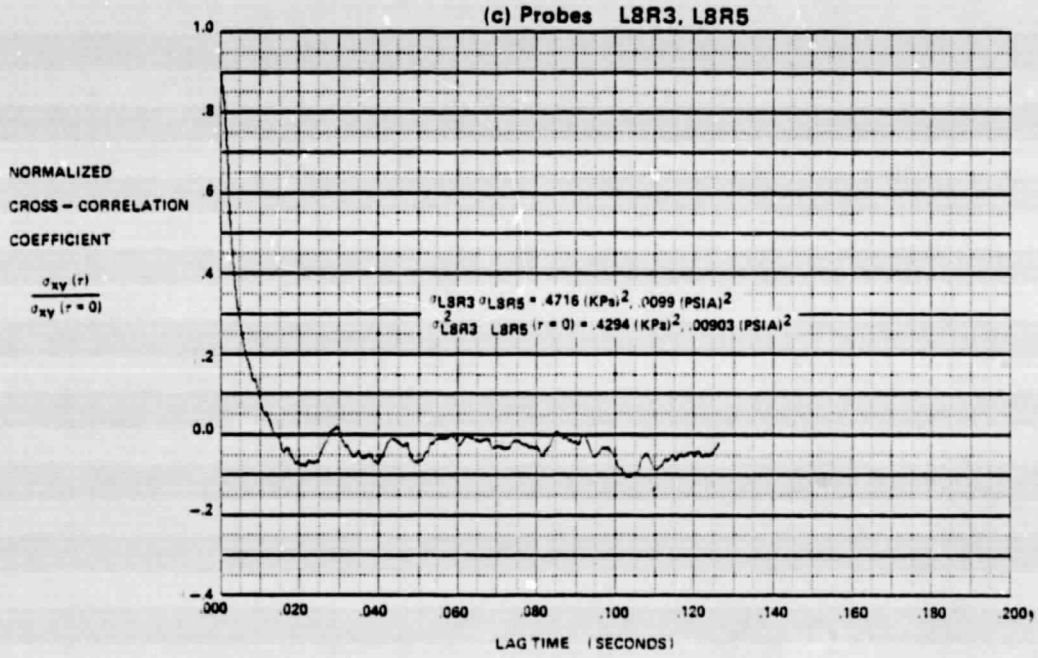


FIGURE H-9 (Continued)
CROSS–CORRELATION FUNCTIONS FOR
M_o = 2.2, α = −2, β = 0, WAT2 = 60.5%

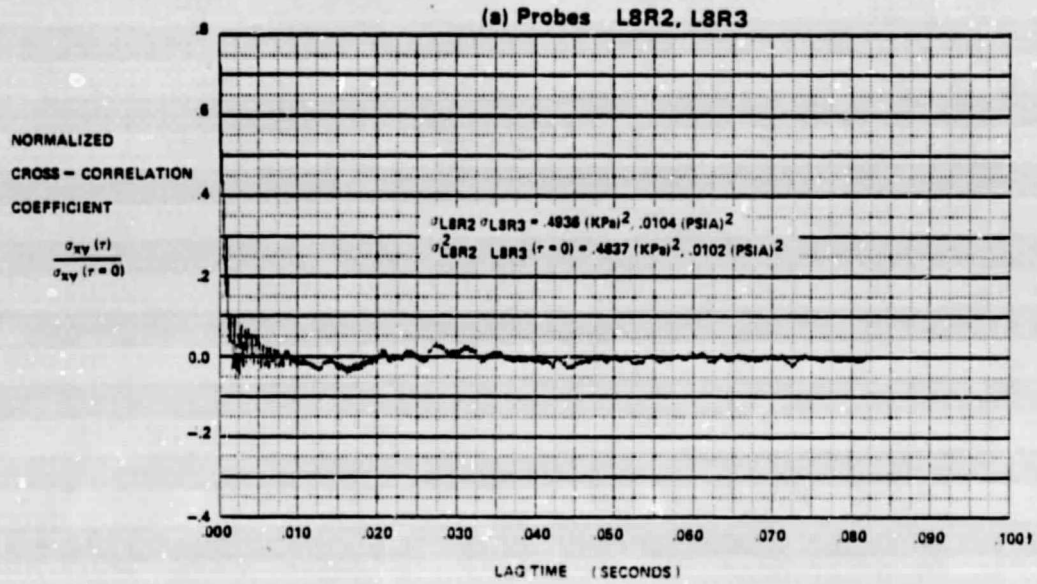
SERIES VIII - NASA DATA STUDY

DATA PART/POINT 184/7 IDENT. 66 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 20:22:12.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	0	0	−2.0	22.5	0.0	69.3%	− 25.0

1 PSIA = 6.8948 kPa

(a) Probes L8R2, L8R3



(b) Probes L8R2, L8R5

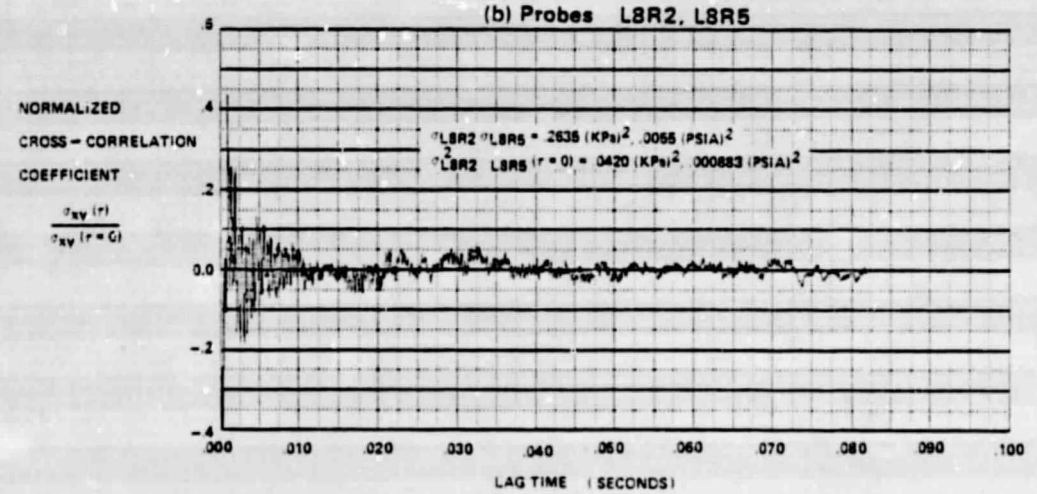


FIGURE H-10
CROSS − CORRELATION FUNCTIONS FOR
M_o = 2.2, α = 0, β = 0, WAT2 = 69.3%

SERIES VIII - NASA DATA STUDY

DATA PART/POINT 184/7 IDENT. 66 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 20:22:12.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	0	0	−2.0	22.5	0.0	69.3%	−25.0

1 PSIA = 6.8948 kPa

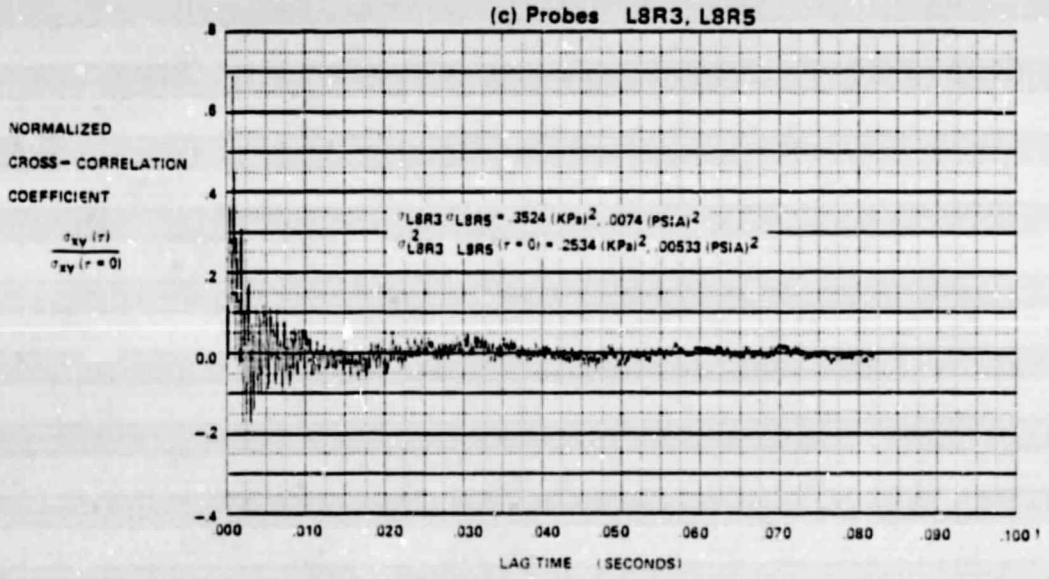


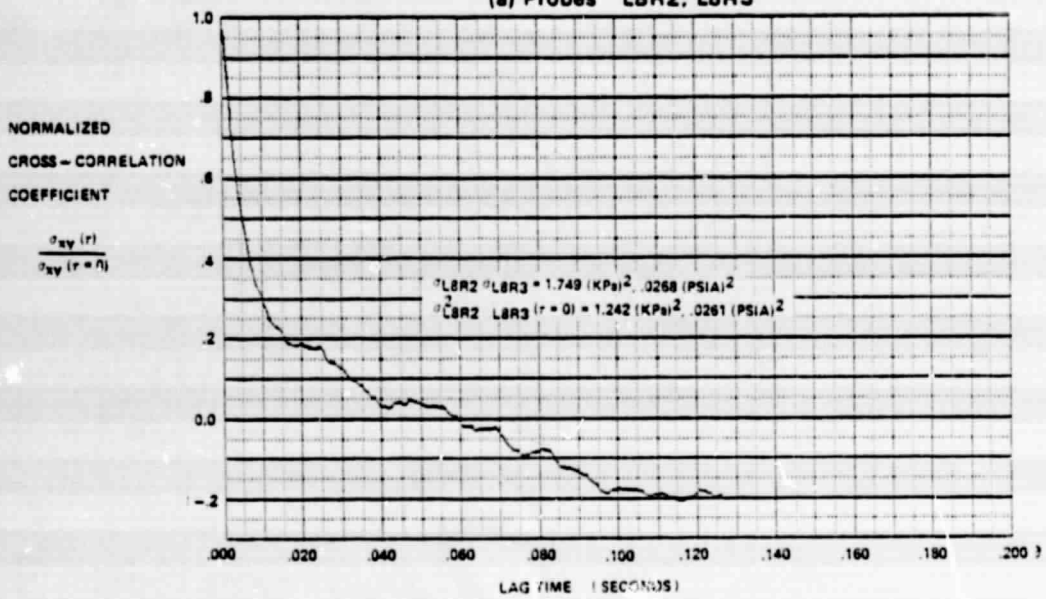
FIGURE H-10 (Continued)
CROSS – CORRELATION FUNCTIONS FOR
M_o = 2.2, α = 0, β = 0, WAT2 = 69.3%

DATA PART/POINT 413/12 IDENT. 69 FREQUENCY RANGE = 4 – 2024 Hz
THE SEGMENT START TIME WAS AT 22:34:15.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	0	0	−2.0	22.5	0.0	68.3%	−25.0

1 PSIA = 6.8948 kPa

(a) Probes L8R2, L8R3



(b) Probes L8R2, L8R5

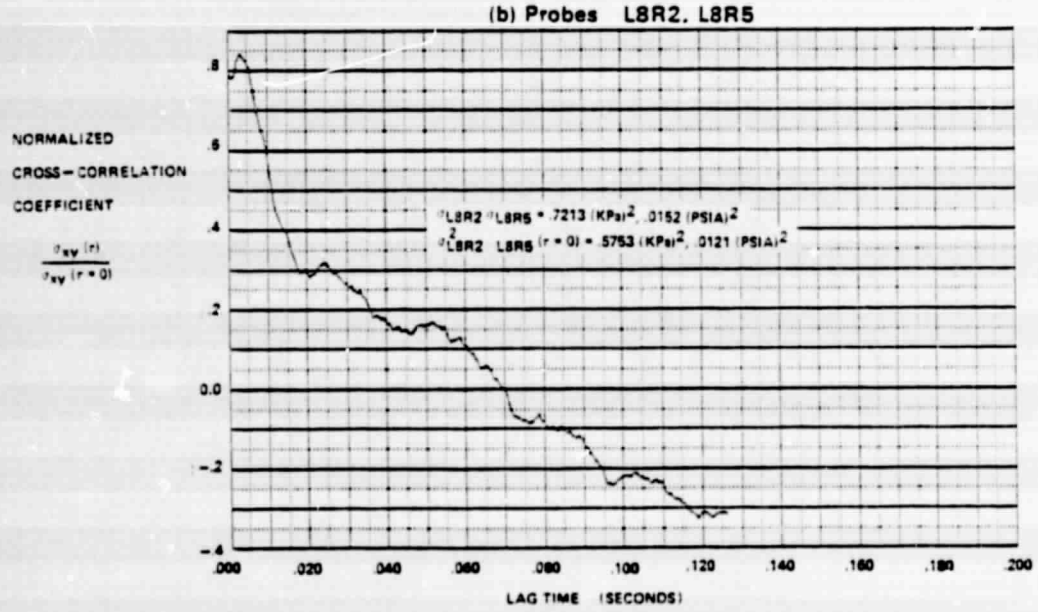


FIGURE H-11

CROSS–CORRELATION FUNCTIONS FOR
$M_o = 2.2$, $\alpha = 0$, $\beta = 0$, WAT2 = 68.3%

FSCP - NASA DATA STUDY

DATA PART/POINT 413/12 IDENT. 69 FREQUENCY RANGE = 4 — 2024 Hz
THE SEGMENT START TIME WAS AT 22:34:15.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.2	0	0	−2.0	22.5	0.0	68.3%	−25.0

1 PSIA = 6.8948 kPa

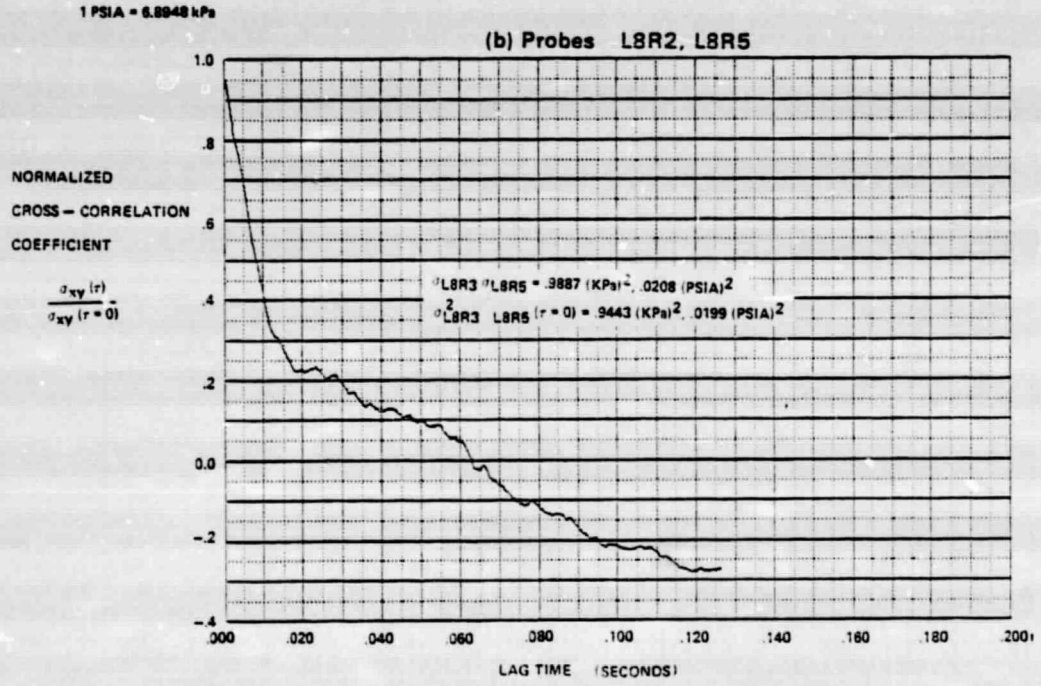
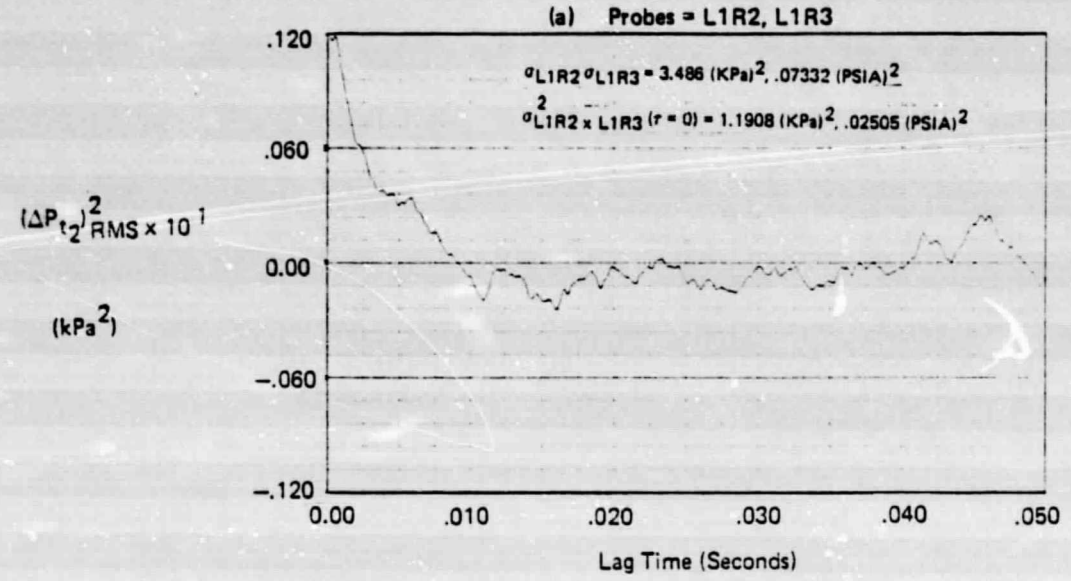


FIGURE H-11 (Continued)
CROSS—CORRELATION FUNCTIONS FOR
M_o = 2.2, α = 0, β = C, WAT2 = 68.3%

DATA FLIGHT/RUN 425/1 IDENT. 70 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 05:09:58.870
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
2.21	0.1	0.2	16523 (54210)	−2.2	22.9	0.0	73.0%	−25.000

1 psia = 6.8948 KPa



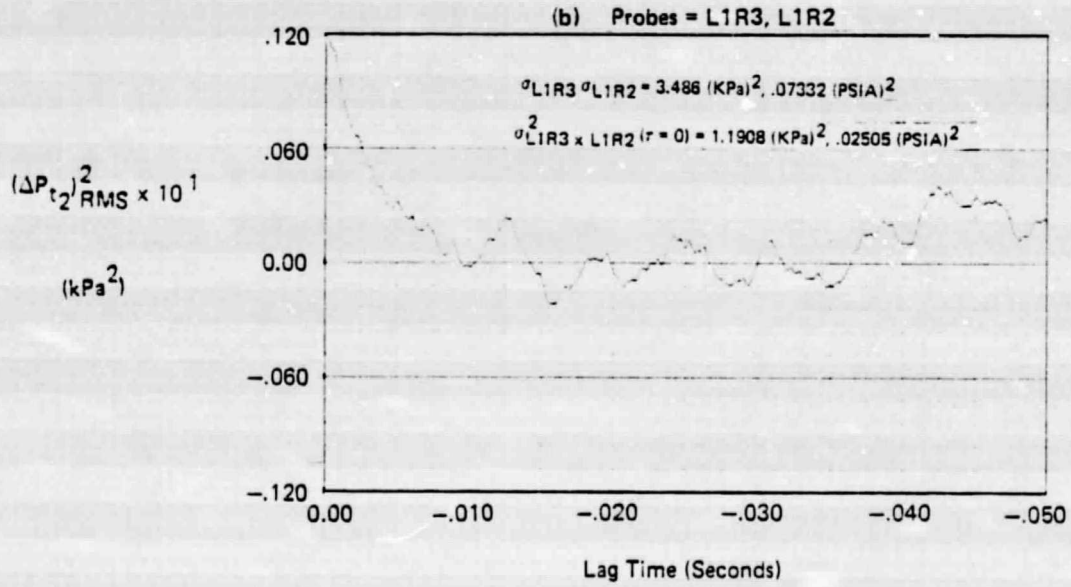
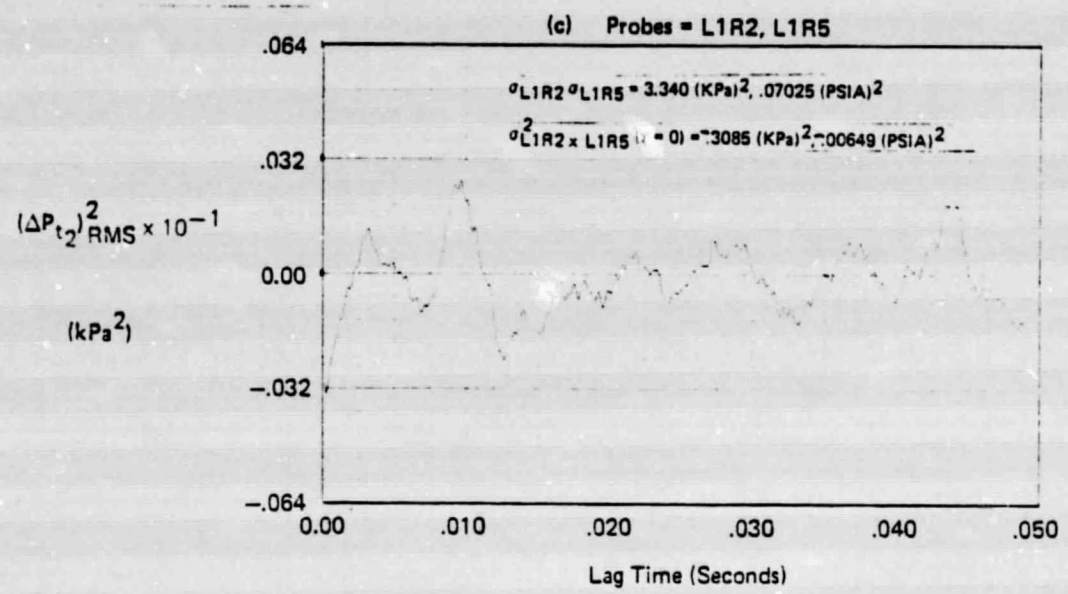


FIGURE H-12
CROSS-CORRELATION FUNCTIONS FOR
M_o = 2.21, α = 0.1, β = 0.2, WAT2 = 73.0%

DATA FLIGHT/RUN 425/1 IDENT. 70 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 05:09:58.870
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
2.21	0.1	0.2	16523 (54210)	−2.2	22.9	0.0	73.0%	−25.000

1 psia = 6.8948 KPa



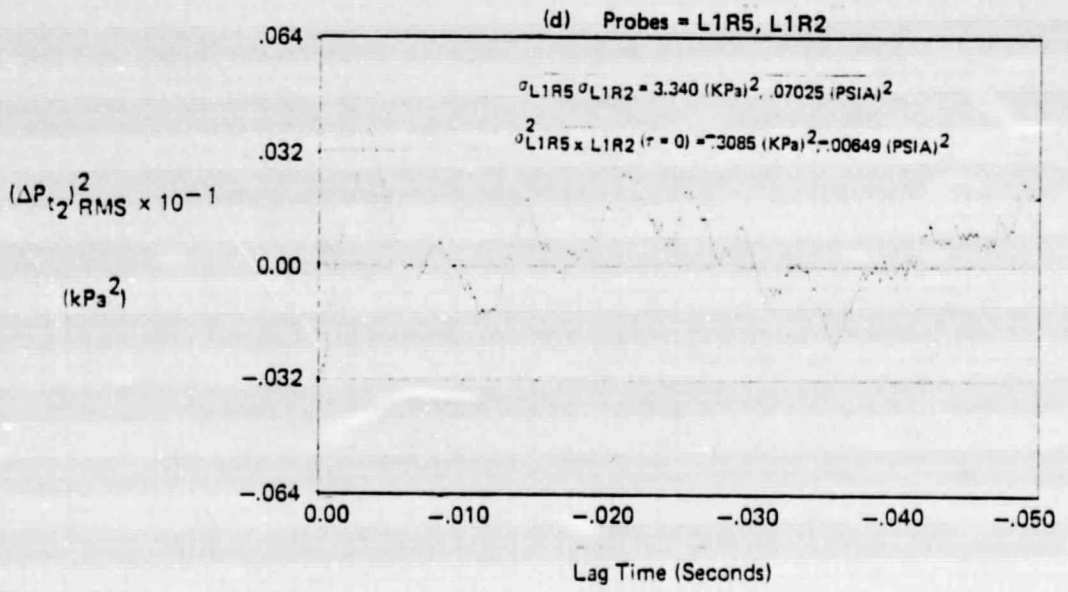


FIGURE H-12 (Continued)
CROSS-CORRELATION FUNCTIONS FOR
M_o = 2.21, α = 0.1, β = 0.2, WAT2 = 73.0%

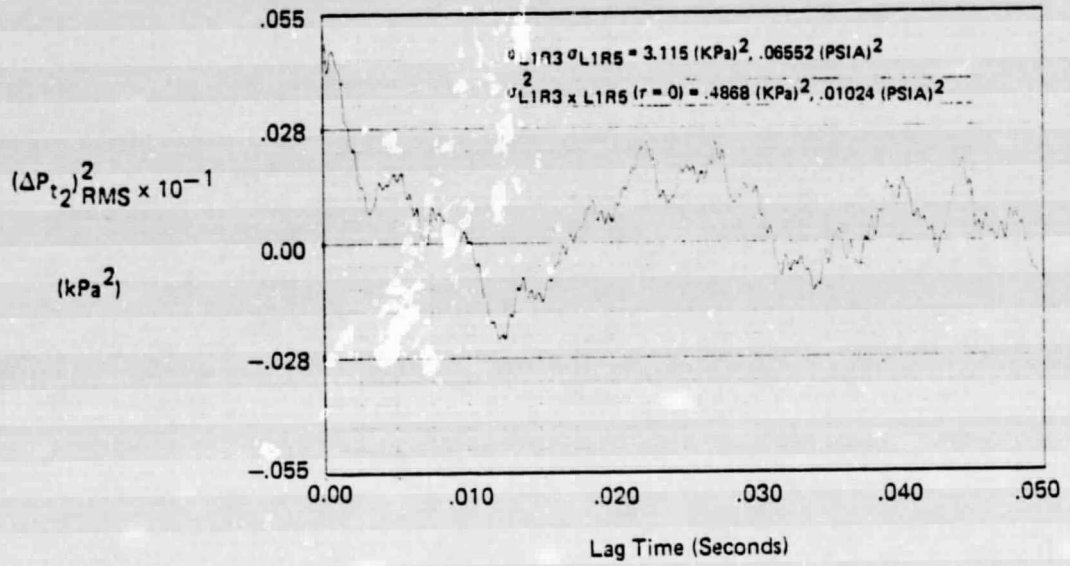
FLIGHT - NASA DATA STUDY

DATA FLIGHT/RUN 425/1 IDENT. 70 FREQUENCY RANGE = 4 — 2000 Hz
THE SEGMENT START TIME WAS AT 05:09:58.870
BANDWIDTH = 4.0 Hz RECORD LENGTH = 1.0 SECONDS

MACH	ALPHA	BETA	ALT	RHO	DELTA3	BYPASS	WAT2	CIVV
2.21	0.1	0.2	16523 (54210)	−2.2	22.9	0.0	73.0%	−25.000

1 psia = 6.8948 KPa

(e) Probes = L1R3, L1R5



(f) Probes = L1R5, L1R3

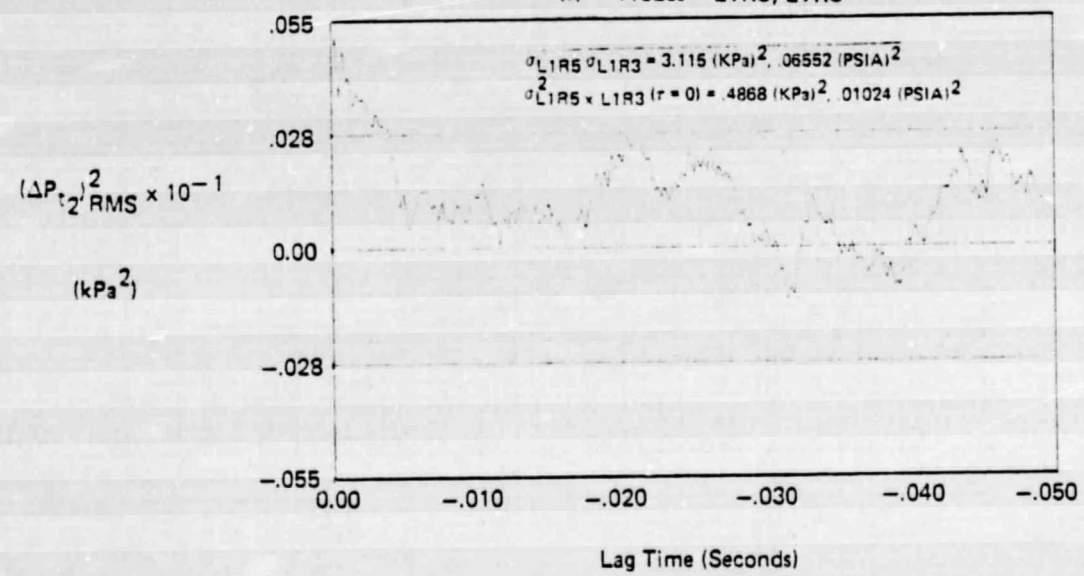


FIGURE H-12 (Concluded)
CROSS-CORRELATION FUNCTIONS FOR
$M_o = 2.21$, $\alpha = 0.1$, $\beta = 0.2$, WAT2 = 73.0%

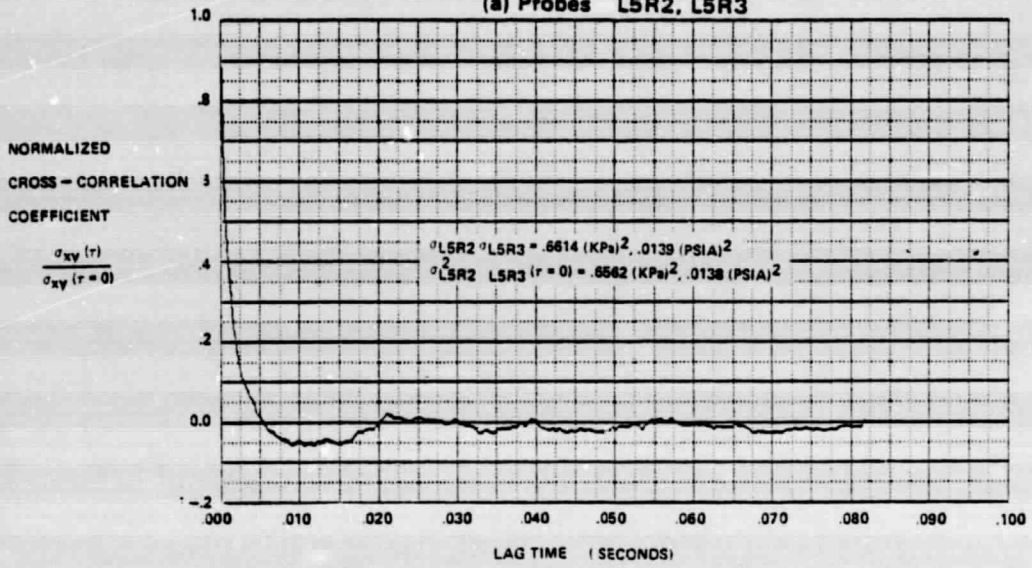
SERIES VIII - NASA DATA STUDY

DATA PART/POINT 227/7 IDENT. 79 FREQUENCY RANGE = 6-12000 Hz
THE SEGMENT START TIME WAS AT 20:27:47.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.5	0	0	−4.0	25.0	.0774 (120.0)	63.1%	−25.0

1 PSIA = 6.8948 kPa

(a) Probes L5R2, L5R3



(b) Probes L5R2, L5R5

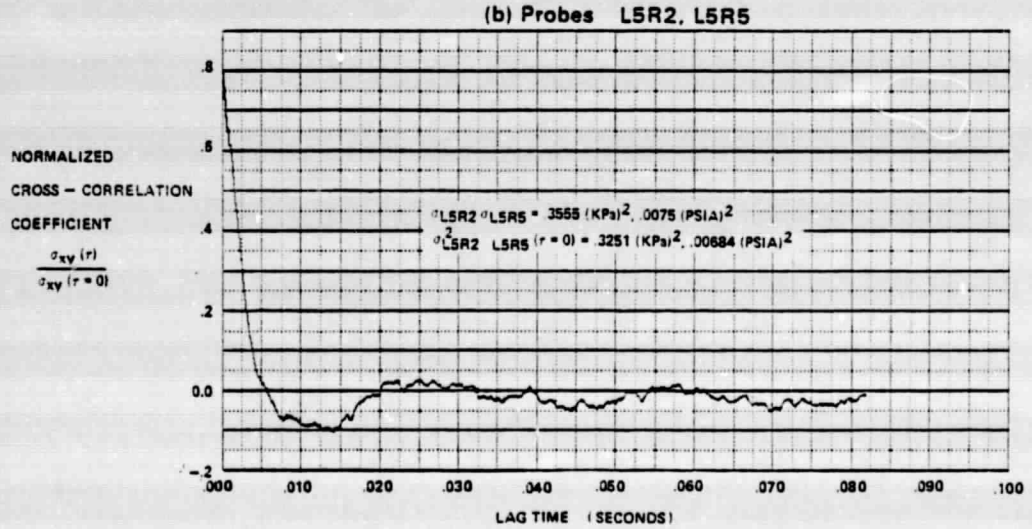


FIGURE H-13
CROSS—CORRELATION FUNCTIONS FOR
M_0 = 2.5, α = 0, β = 0, WAT2 = 63.1%

SERIES VIII - NASA DATA STUDY

DATA PART/POINT 227/7 IDENT. 79 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 20:27:47.000
BANDWIDTH = 12.2 Hz RECORD LENGTH = 10.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.5	0	0	−4.0	26.0	.0774 (120.0)	63.1%	−25.0

1 PSIA = 6.8948 kPa

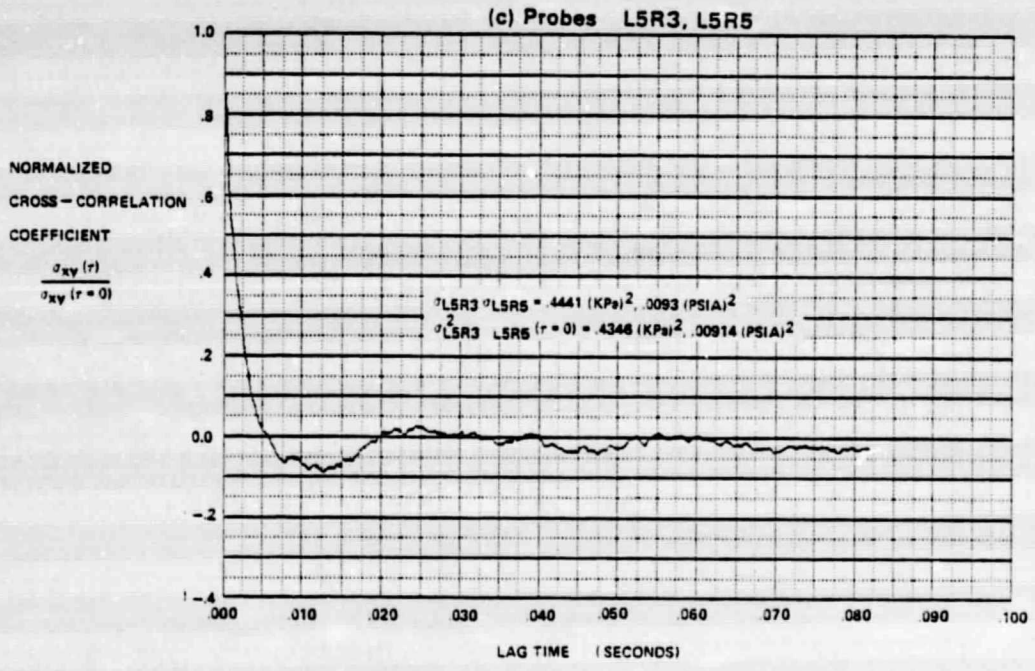


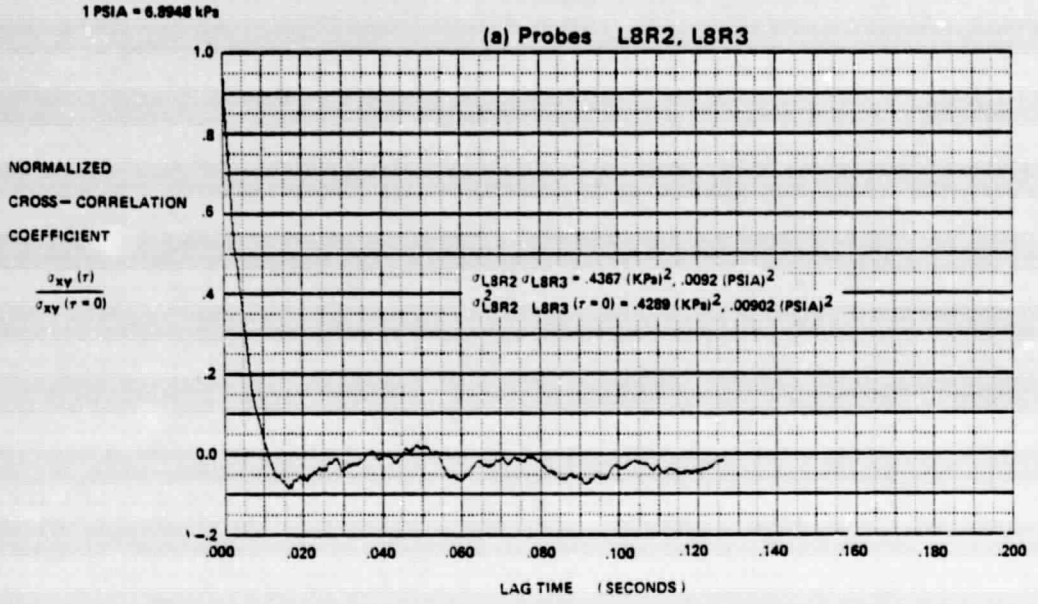
FIGURE H-13 (Continued)
CROSS—CORRELATION FUNCTIONS FOR
M_o = 2.5, α = 0, β = 0, WAT2 = 63.1%

FSCP - NASA DATA STUDY

DATA PART/POINT 465/8 IDENT. 81 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 03:23:40.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.5	0	0	−4.0	26.0	.0781 (121.0)	62.8%	−25.0

1 PSIA = 6.8948 kPa



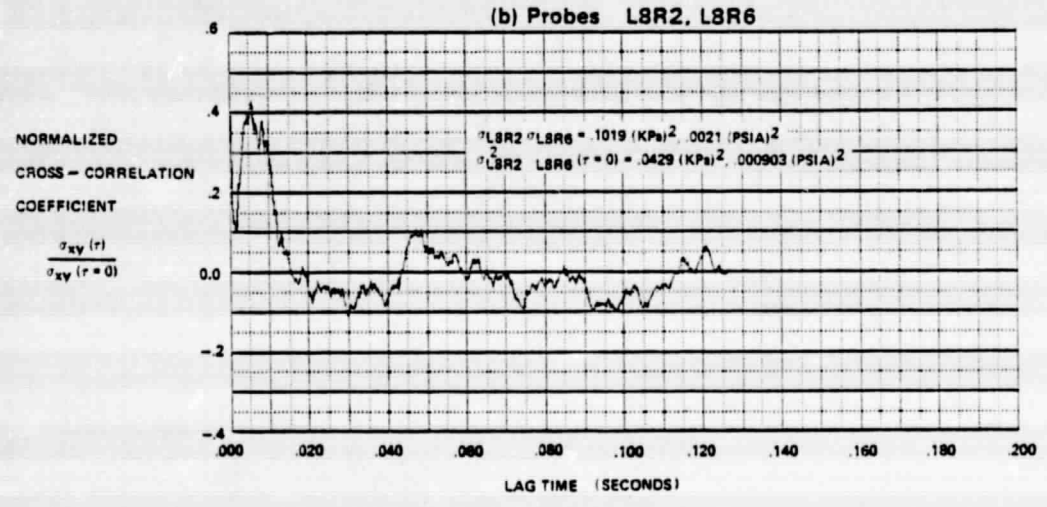


FIGURE H-14
CROSS—CORRELATION FUNCTIONS FOR M_o = 2.5, α = 0, β = 0, WAT2 = 62.8%

FSCP - NASA DATA STUDY

DATA PART/POINT 466/8 IDENT. 81 FREQUENCY RANGE = 4 - 2024 Hz
THE SEGMENT START TIME WAS AT 03:23:40.000
BANDWIDTH = 7.9 Hz RECORD LENGTH = 13.0 SECONDS

MACH	ALPHA	BETA	RHO	DELTA3	BYPASS	WAT2	CIVV
2.5	0	0	−4.0	26.0	.0781 (121.0)	62.8%	−25.0

1 PSIA = 6.8948 kPa

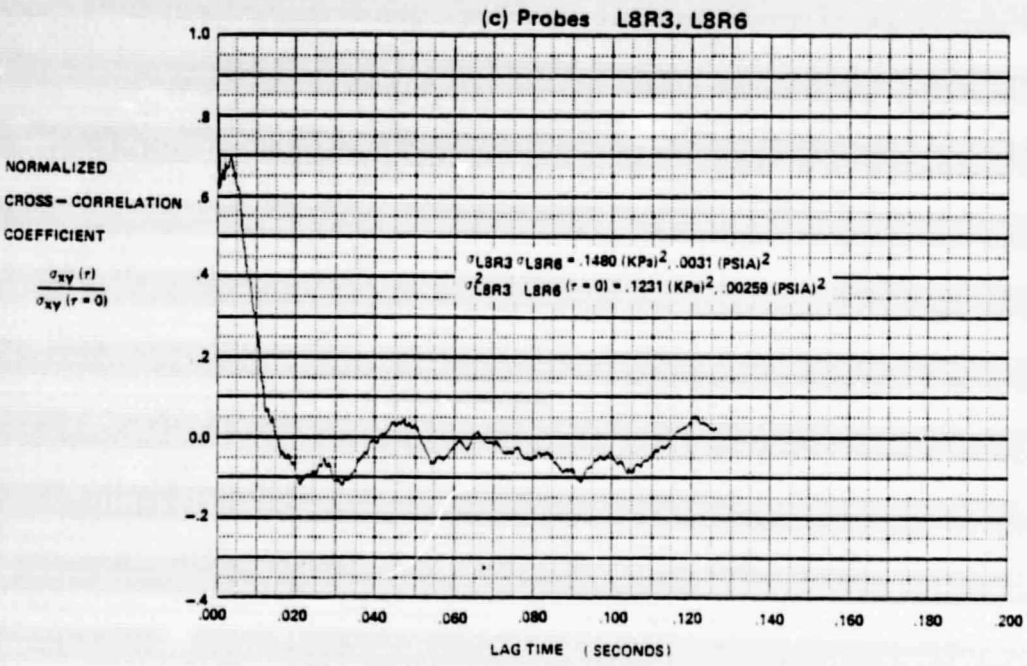


FIGURE H-14 (Continued)
CROSS—CORRELATION FUNCTIONS FOR
$M_O = 2.5$, $\alpha = 0$, $\beta = 0$, WAT2 = 62.8%