TURBULENCE MEASUREMENTS IN THE COMPRESSOR EXIT FLOW OF A GENERAL ELECTRIC CF6-50 ENGINE

by J. R. TAYLOR

The purpose of this program was to measure the turbulence intensity and scale in the compressor exit flow stream of an operating CF6-50 gas turbine engine. This program was conducted as an addendum to, and concurrently with, Phase III of the NASA/GE Experimental Clean Combustor Program (Contract NAS3-19736). Compressor exit turbulence data are required for the development of lean burning, premixed, prevaporized combustion systems that have low levels of nitrogen oxide (NO_x) emissions. The systematic development of very lean burning premixed, prevaporized combustion systems to the point of practical application to advanced gas turbine engines requires quantitative knowledge of compressor exit turbulence parameters and the effects of turbulence intensity and scale on fuel preparation, the premixing process and fuel droplet evaporation.

Prior to this program, compressor exit turbulence test data have not been available, probably because compressor exit flow conditions represent a very severe environment for turbulence measurement instrumentation. Flow velocities, temperatures and pressure levels are very high. Also, high vibration levels and solid particles in the air stream can destroy fragile instrumentation very quickly.

Ruggedized cooled film probes were used in this program to measure CF6-50 compressor exit turbulence properties at three different engine idle condition test points. Data were also obtained with this probe at the 30 percent and at the 85 percent engine power settings but, unfortunately, the quality of the data for these conditions was not acceptable. These measurements were made by using an electric motor-driven probe actuator to set three "equal area" radial immersions in the compressor exit diffuser flow stream at an axial location 15.5 cm downstream of the compressor exit plane. At each engine test condition, the sensing element of the probe was moved to three radial immersion points in the compressor exit flowpath. Each immersion point was located at the center of one-third of the flowpath cross-sectional area.

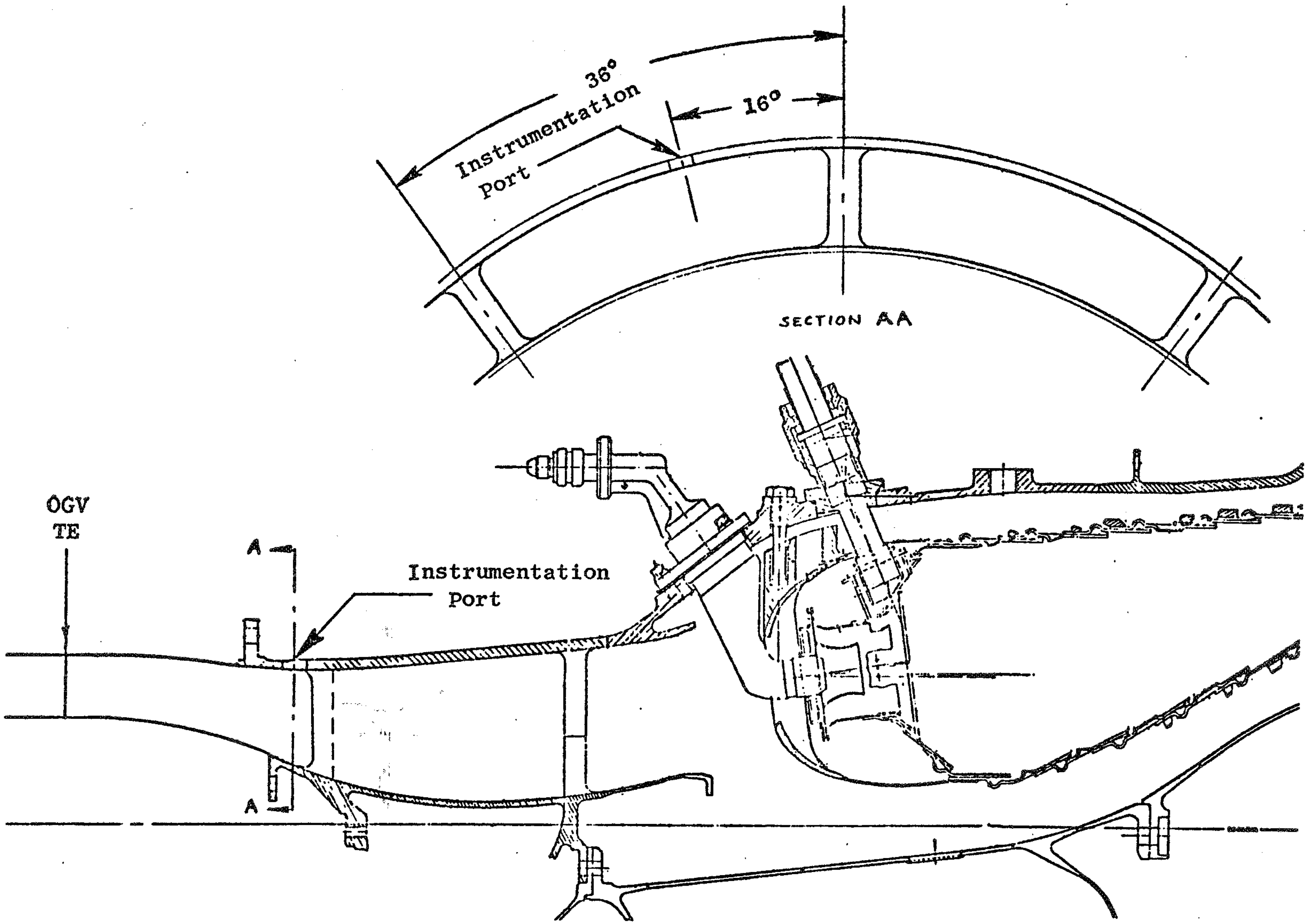
The turbulence probe was coupled to a constant temperature anemometer and signal conditioning system. An on-line readout system connected to the anemometer was used to check the data as it was acquired. A well calibrated digital voltmeter displayed the signal DC level, a true RMS meter measured the AC level and a small oscilloscope was used to visually observe the signal output. A magnetic tape recorder made a permanent record of the data which was used for the data reduction analysis. A Time-Data Fast Fourier Transform (FFT) system was used for the data reduction and curve plotting procedures.

At engine idle conditions, the turbulence intensity ranged from 4.8 percent to 5.6 percent and the length scale ranged from 5.64 cm to 6.95 cm. The length scale values are somewhat larger than the passage height at the measurement plane (5.54 cm), which indicates that the shape of the turbulent eddies are elongated in the axial direction. The microscale values range from about 0.73 cm to about 0.98 cm.

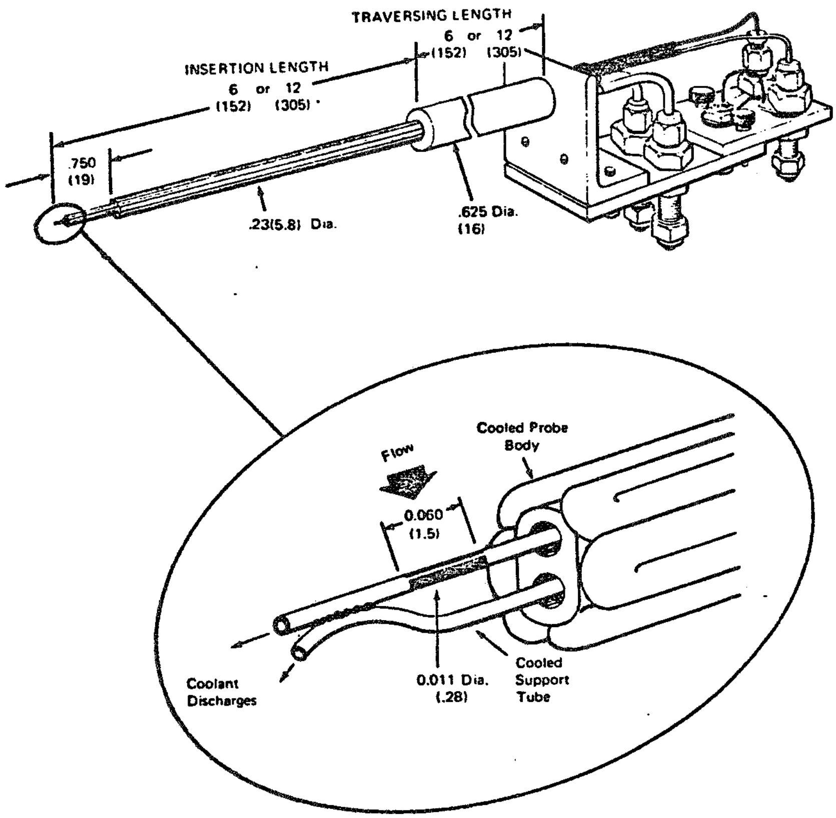
Power spectral density distributions show that a large proportion of the turbulent energy at the measurement plane is concentrated at frequencies below one kilohertz.

These turbulence data can be used to help simulate compressor exit flow conditions in development test programs for advanced combustion systems. These results also demonstrate the feasibility of using ruggedized cooled film probes to make turbulence measurements in the high pressure, high temperature and high velocity environment of an operating gas turbine engine.

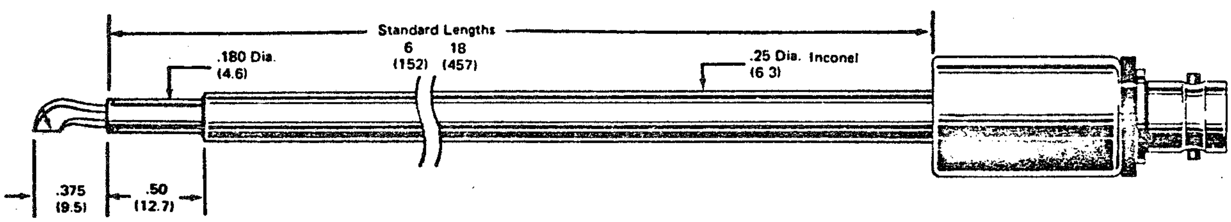
However, a considerable amount of probe development work will be required to develop turbulence measurement probes that can withstand the very severe environment encountered in the compressor exit flow of a gas turbine engine at high engine power operating conditions.



CF6-50 Frame Drawing Showing Instrumentation Port Location.

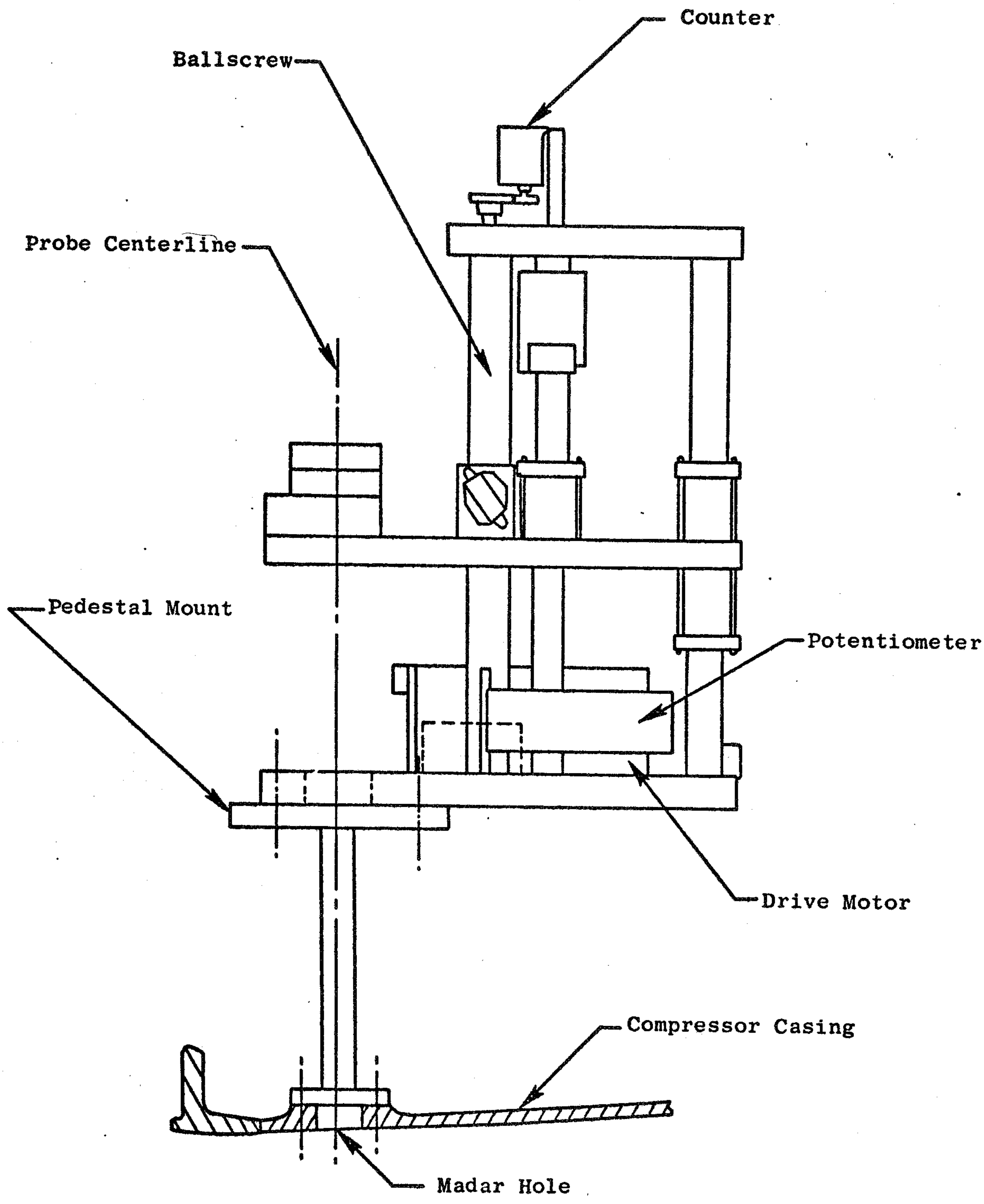


Water-Cooled Hot Film Probe

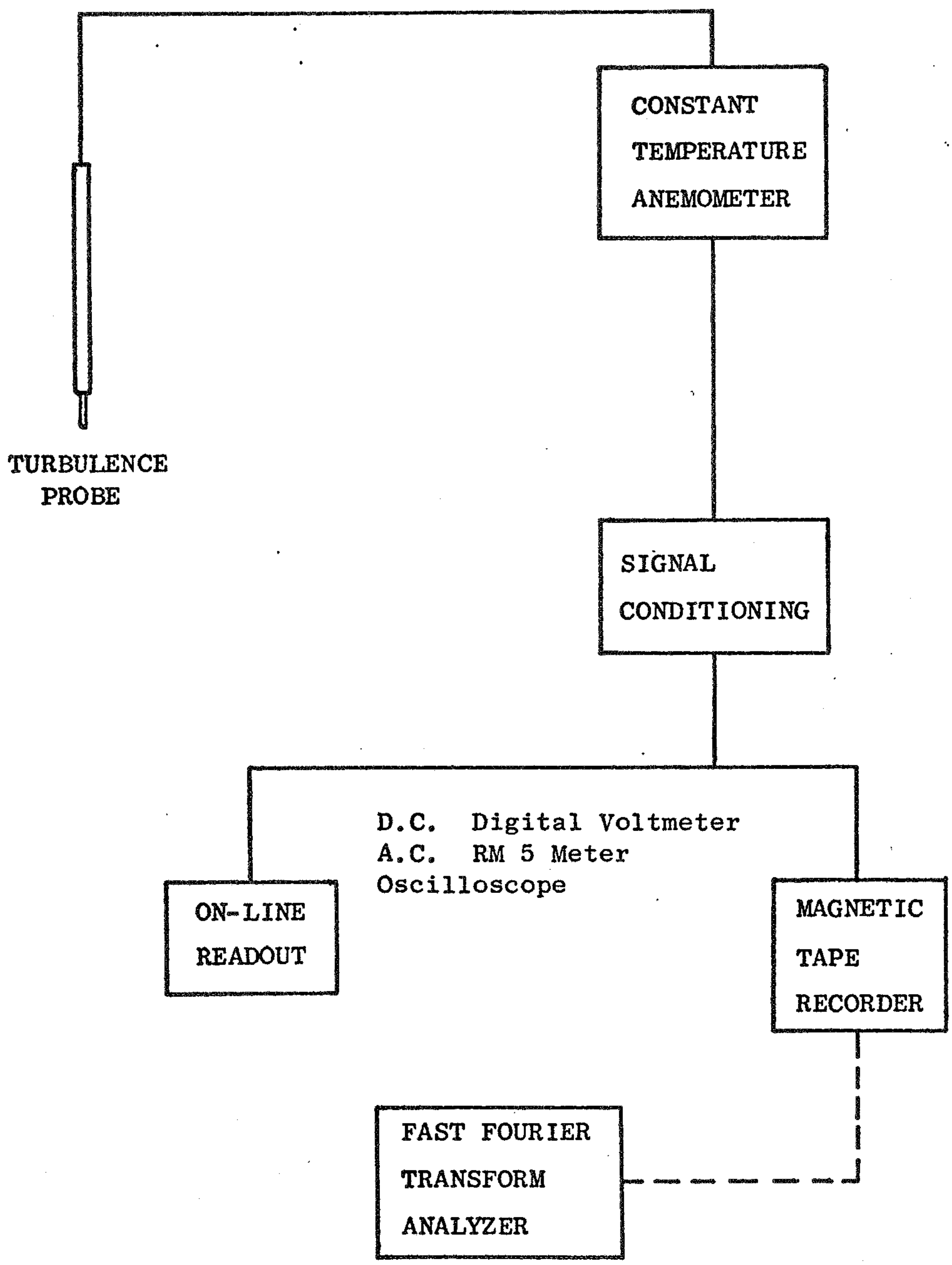


Hot Wire Probe

Turbulence Measurement Probes.



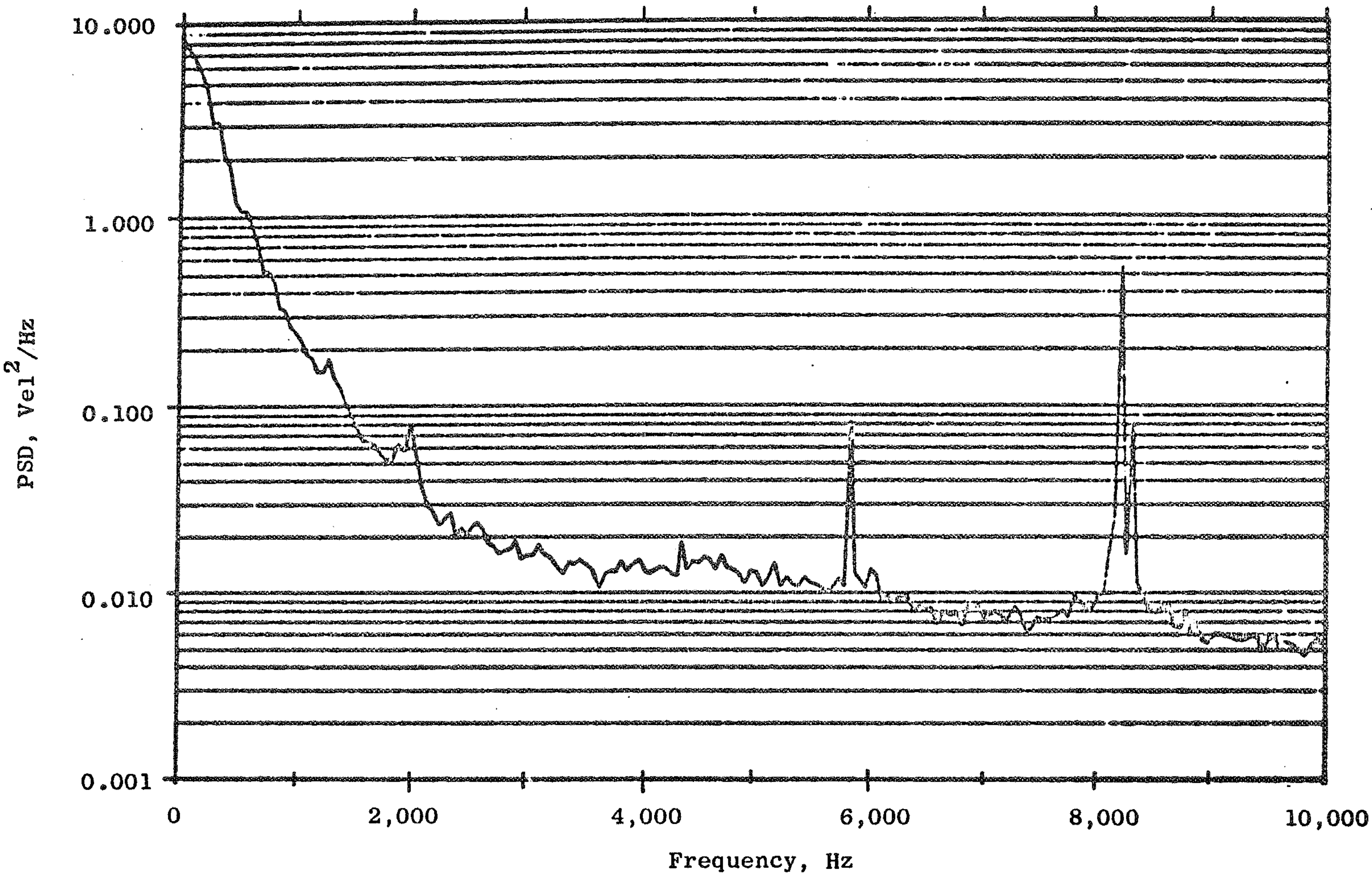
Turbulence Probe Actuator.



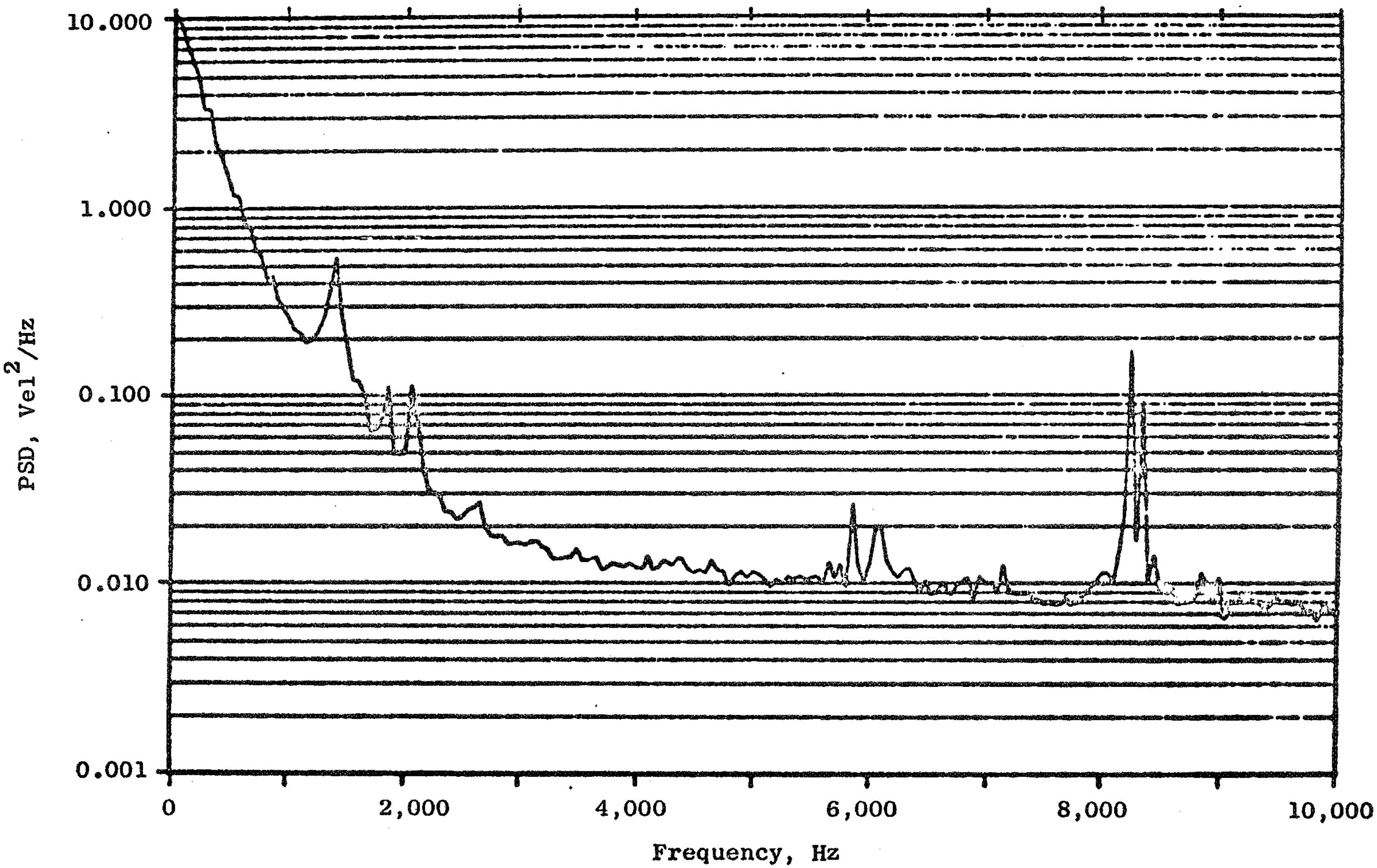
Data Acquisition and Reduction System.

TURBULENCE TEST DATA

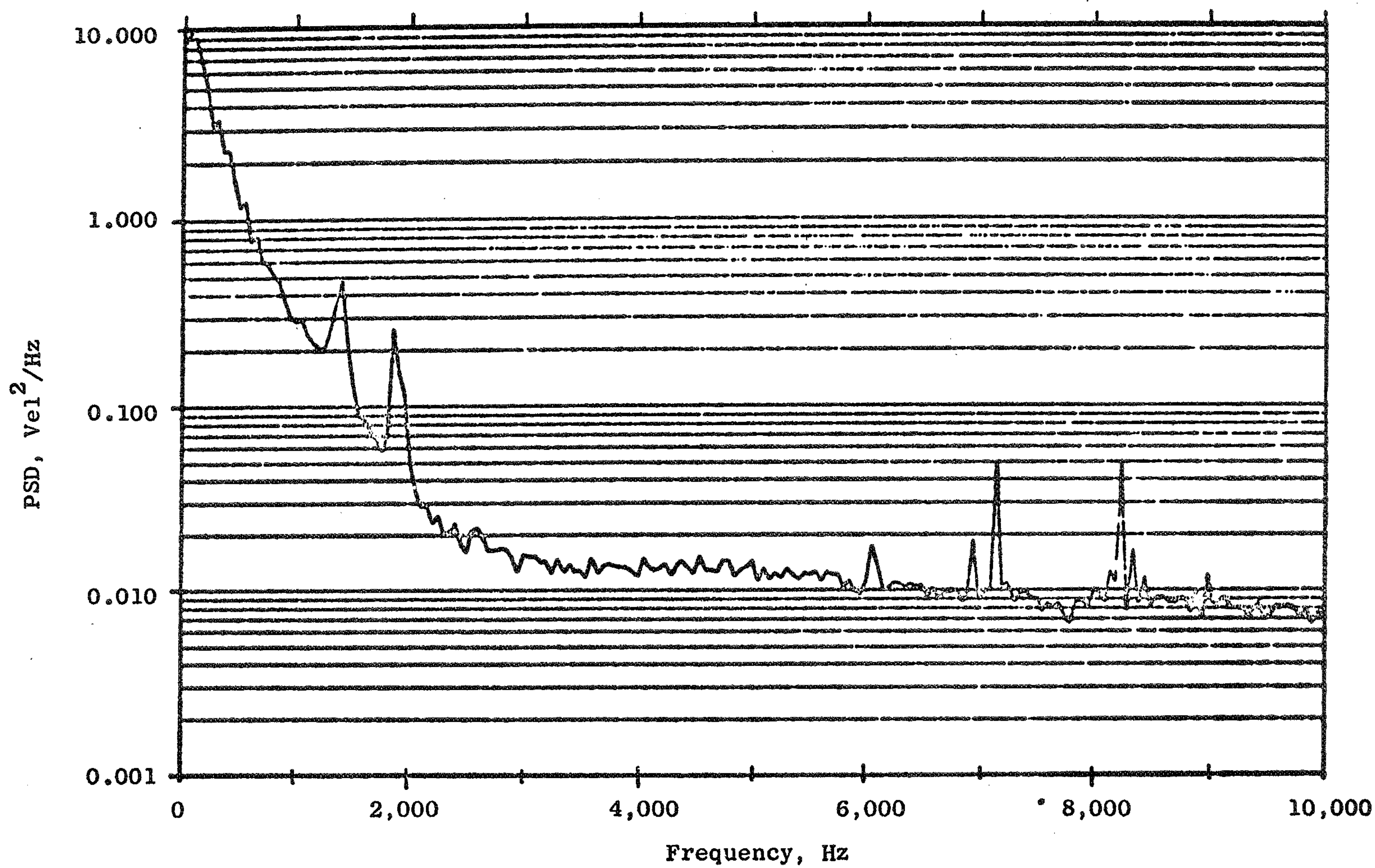
DATA POINT NUMBER	95	106	106	106A	106A	106A
PROBE POSITION	INNER	INNER	OUTER	INNER	CENTER	OUTER
CALCULATED VELOCITY - m/sec	68.3	69.2	69.2	68.6	76.2	68.6
TURBULENCE - m/sec	3.26	3.66	3.44	3.60	4.27	3.84
TURBULENT INTENSITY - %	4.8	5.3	5.0	5.2	5.6	5.6
TURBULENT MISCOSCALE - cm	0.73	0.94	0.85	0.79	0.98	0.91
TURBULENT LENGTH SCALE - cm	6.58	6.04	5.73	5.64	6.95	5.97



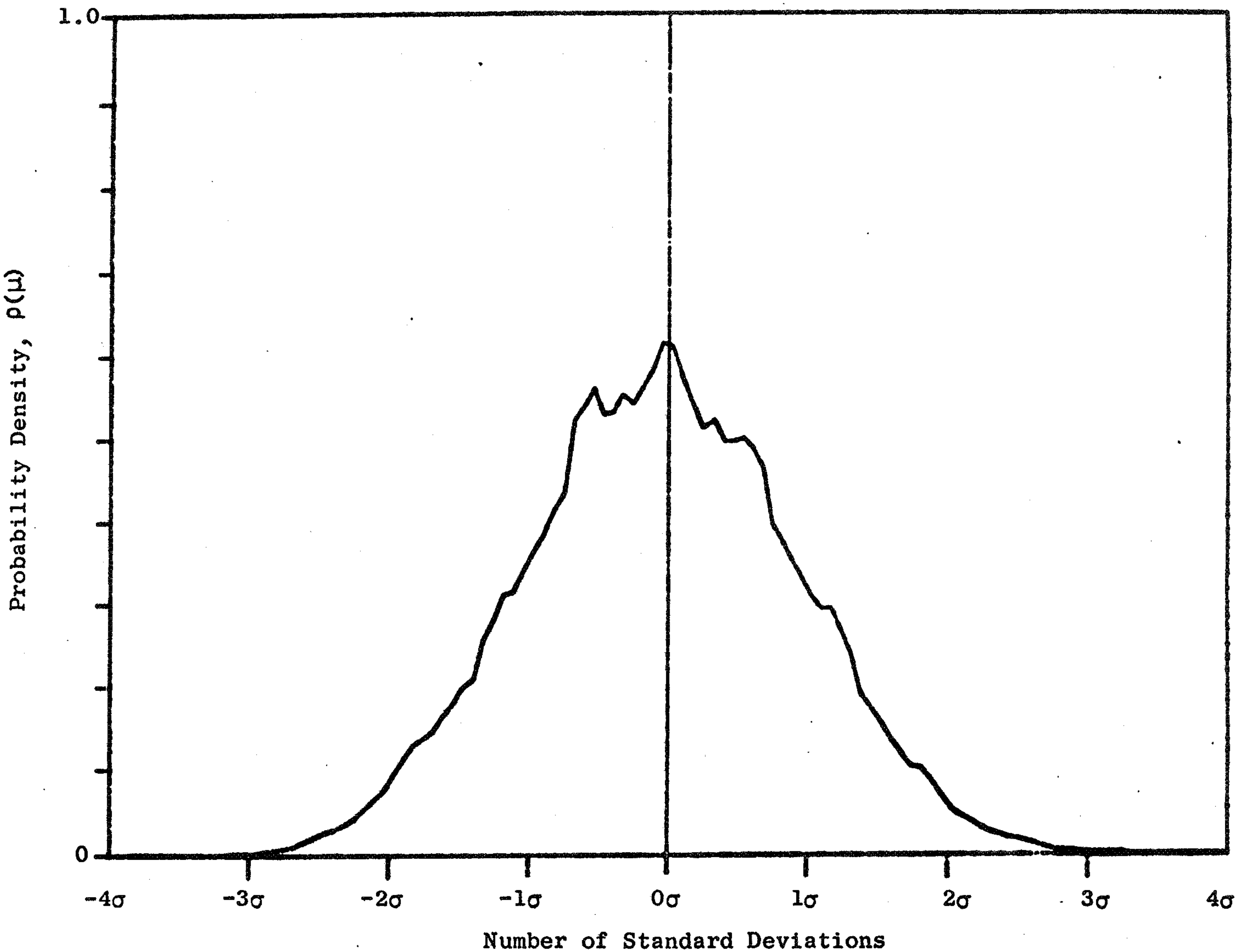
Power Spectral Density for Data Point 106A, Outer Probe Position.



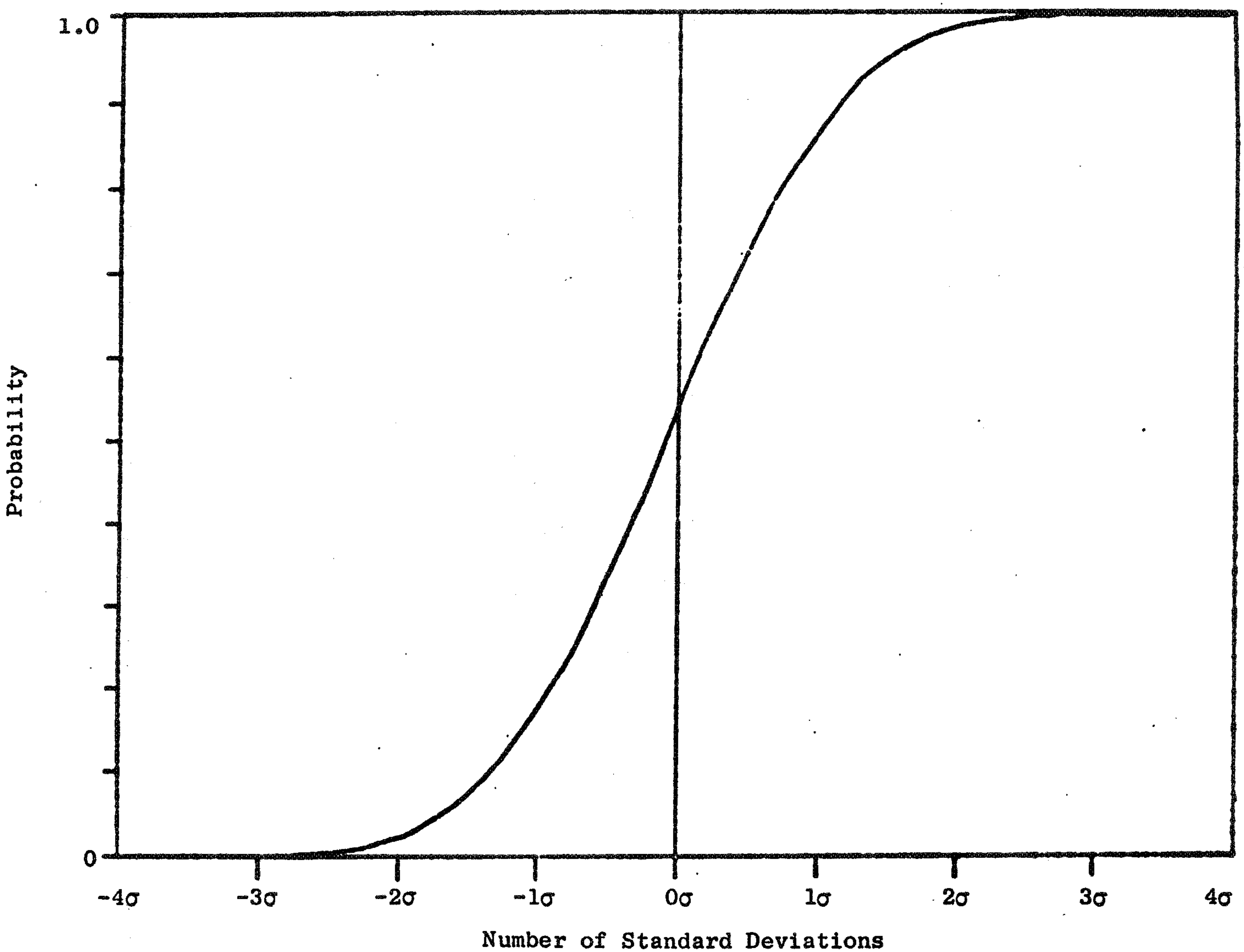
Power Spectral Density for Data Point 106A, Center Probe Position.



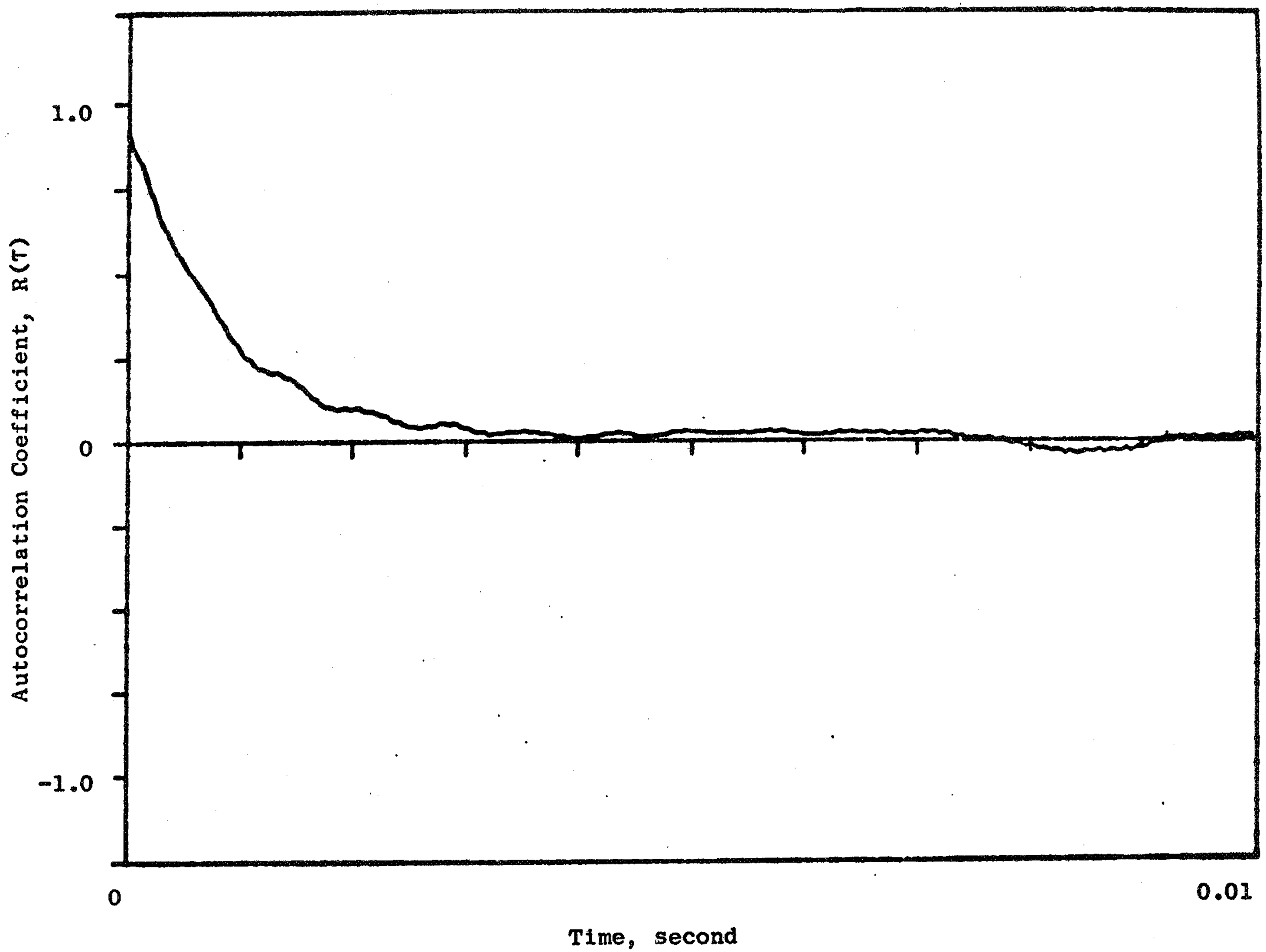
Power Spectral Density for Data Point 106A, Inner Probe Position.



Probability Density for Data Point 106A, Center Probe Position.



Probability Distribution for Data Point 106A, Center Probe Position.



Autocorrelation Coefficient for Data Point 106A, Center Probe Position.