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Validation of Aircraft Noise Prediction Program

C. Y. Kapper

Douglas Aircraft Company
McDonnell Douglas Corporation
Long Beach, California 90846

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A study to validate the NASA Noise Prediction Program (ANOPP) by comparing the predictions with flyover noise data was performed. A data base of six flyover noise runs for the DC-10-40/JT9D-59A configuration was used. It was shown that for all power settings ANOPP consistently underpredicted the low frequency spectral levels, overpredicted high frequency spectral levels and consequently overpredicted the inlet and aft PNLT time histories.

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CONTENTS

1.0 SUMMARY

A study to validate the NASA Aircraft Noise Prediction Program (ANOPP) by comparing the predictions with flyover noise data was carried out. A data base of six flyover noise runs for the DC-10-40/JT9D-59A airplane/engine configuration was used. The data consisted of the flyover noise measurements as well as flight path profile, propulsion characteristics and configuration characteristics such as wing area and flap deflection angle. Predicted and measured 1/3-octave band sound pressure levels at selected angles from the flight path were compared for all six runs. Predicted and measur-d PNLT histories were also compared. It was shown that for all power settings ANOPP consistently underpredicted the low frequency spectral levels, overpredicted high frequency spectral levels, and consequently overpredicted the inlet and aft PNLT time histories.

2.0 INTRODUCTION

Over the past several years there has been a continuing effort by the National Aeronautics and Space Administration (NASA) to develop a computer program for the prediction of aircraft noise. One of the capabilities of the Aircraft Noise Prediction Program (ANOPP) is to predict levels, spectra, and directivity of aircraft flyover noise and its component noise sources. The prediction methodologies incorporated into ANOPP by NASA are based on selected theoretical and empirical techniques for predicting aircraft noise sources currently deemed to be the best methods available. However, many of these prediction methods involve the use of model-scale data, empirical correction factors, and static test data bases. Flight effects include Doppler shift and convective amplification terms but omit the effects of installation and forward motion on engine noise. Verification of the ANOPP prediction procedures against actual flyover noise measurements for current commercial conventional takeoff and landing (CTOL) aircraft has been limited by the availability of flyover noise data bases. Since the DC-10 airplane represents a large portion of the United States commercial wide-body fleet, the Douglas Aircraft Company (DAC) has conducted, under contract to the NASA Langley Research Center (LaRC), a validation study of ANOPP. This report contains the results of that study.

Selected for the ANOPP validation was a flyover noise data base consisting of six flyovers for the DC-10-40/JT9D-59A airplane/engine configuration with fully treated engine nacelles. The data base contains flyovers at various approach and takeoff engine power settings (1800 through 3600 rpm) wach with constant glideslope and pitch angle during the flyover. Approach measurements are with the aircraft in a "dirty" configuration, i.e., large flap deflections and landing gear deployed. Takeoff measurements represent an aircraft in a similar configuration with samll flap deflections. The flyover noise measurements were made with tripod mounted microphones above sandy soil on the runway centerline at various distances from the end of the runway at the Douglas test facility in Yuma, Arizona.

The flyover noise predicted by ANOPP for the six runs are graphically compared to the measured flight data. The comparisons include perceived noise versus directivity and 1/3-octave-band spectra at selected angles from the inlet The ANOPP noise source breakdowns are also included in the spectral plots.

3.0 DESCRIPTION OF THE FLYOVER NOISE TEST

The flyover noise runs used in the ANOPP validation study were conducted at the Yuma International Airport, Yuma, Arizona in January 1976. The recordings of the flyover noise histories were made in compliance with requirements of FAR Part 36 (Reference 1) with the special equipment and procedures used as described in Reference 2. The various types of information recorded and means of recording each is presented below. Figure 1 depicts the airplane flyover noise measurement system.

3.1 Aircraft/Engine Performance Data

Aircraft/engine performance data were recorded by the Airborne Digital Data System (ADDS) to allow for merging with space/time histories of the flyovers determined by another system. All performance data were measured with production instrumentation or taken from flight card tabulations when such data remained constant during a run. Table I shows the measured or derived aircraft/engine performance data determined for each run.

3.2 Weather Data

The necessary meteorological information was determined by several means. A Mobile Atmospheric Recording Tower (MART) was used to continuously measure surface weather conditions consisting of wet and dry bulb temperatures and wind speed and direction at a height of ten meters above the ground. Upper air sounding data were taken during the flyover noise tests to define the vertical gradients of temperature, humidity, and wind. A meteorologically instrumented light plane airplane continuously flying a flight pattern from runway level ten meters above the ground to at least test airplane altitude was used to measure temperature and humidity. Upper air wind speed and direction were obtained by theodolite tracking of weather balloons. In addition, small portable weather stations were used to record weather data at selected locations.

3.3 Aircraft Position Data

For all flyovers, the airplane space position relative to the microphone locations was obtained as a function of time using a Mobile Automatic Laser Tracking (MALT) system. This system consists of an autotrack monopulse optical radar with a multipower laser as the ranging beam energy source. The airplane was equipped with a retroreflector positioned on the vertical stabilizer. The MALT system was displaced laterally from the flight path so no part of the fuselage or wing could interupt the beam path. During the data reduction process, the airplane reference point used in all space positioning was switched from the retroflector to the Instrument Landing System (ILS) glideslope antenna located in the nose of the airplane. The ILS position is shown in Figures 2 and 3.

3.4 Physical Site Data

The general topography of the area at the Yuma test site allowed for the microphone measuring positions to be located at the southwest corner of the Yuma airport in an agricultural area interlaced with irrigation canals at an elevation from about 36 to 65 meters above sea level. The terrain was nearly flat at all measuring points and consisted of sandy soil with various degrees of compaction. There were no obstructions to interfere with the acoustic measurements.

3.5 Flyover Noise Data

The flyover noise data selected to form the flight data base in the ANOPP validation study were measured using half-inch, tripod-mounted microphone cartridges with wind screens 1.2 meters above the ground. The microphones were oriented such that the sound path was at approximately grazing incidence throughout the recording. The flyover noise data were recorded in such a way so as to allow merging the performance and space/time positioning data with the noise data when the data were processed. High frequency pre-emphasis was utilized to record data during the takeoff and approach noise runs. For each noise recording, the gain setting on the signal conditioning amplifiers was set to obtain optimum signal-to-noise ratios for optimum dynamic recording range on the magnetic tape.

For takeoff flight runs, the microphone measuring position was located on the runway centerline 2225 meters beyond the end of the runway. For approach runs, the microphone was positioned 1684 meters beyond the end of the runway centerline.

4.0 FLYOVER DESCRIPTION

A McDonnell Douglas model DC-10-40 wide-bodied commercial transport powered by three Pratt and Whitney JT9D-59A high bypass-ratio turbofan engines with acoustically treated nacelles was flown and its noise characteristics in various attitudes and configurations were measured. Figures 2 and 3 are the top and side views of the Series 40 aircraft and show the gross dimensions, locations of the engines, and the positioning of the ILS glideslope antenna and the laser tracking target on the aircraft.

A total of six flyover runs were used for the validation study. The aircraft systems configuration for the flyover noise runs were with leading edge slats extended, flaps deflected, gear down and the auxiliary power unit off. The Series 40 aircraft landing gear consists of a two carriage nose gear, two four carriage sets of wing gear, and a two carriage landing gear located in the main fuselage between the wing gear. The slats and flaps are of one segment.

Table I lists all the aircraft configurations and the associated flight operations for the flyovers. For the purpose of this study, the acoustical treatment in the inlet cowl, fan cowl, fan reverser and aft cowl and primary nozzle are considered essentially the same for all three engines.

Tables II through VII describe the aircraft parameters necessary to predict flyover noise using ANOPP. The weather at various altitudes is presented in Table VIII.

5.0 ANOPP PROGRAM DESCRIPTION AND OPERATION

5.1 Overview of Program

The ANOPP computer program used in the validation study was the version stored on the NASA-Langley computer system at the time of contract execution. The ANOPP system contains several levels of increasingly more complex and detailed noise prediction methodologies. The level used in this study consisted of predicting levels, spectra, and directivity for an aircraft flyover. Using aerodynamic and propulsion characteristics which are functions of time (held constant for the selected flyovers), the spectral levels for the component noise sources consisting of airframe, fan inlet and exhaust, turbine, core, and jet noise were predicted at a constant distance from the aircraft using the appropriate ANOPP source noise modules. Based on inputs describing the space-time positioning of the aircraft for the measured flyovers, the component source noise for each time point desired was propagated to the observer location (microphone position) taking into account spherical attenuation, atmospheric absorption, and excess ground attenuation. For each specified time point, spectral, levels, and directivity for each noise source were output as well as corresponding values for the total noise. Perceived noise level angle histories were determined using another ANOPP module. A sample ANOPP input deck describing the procedure used to predict the flyover noise for the first approach run is listed in Appendix A.

5.2 Method of Operation

Execution of the ANOPP computer program on the NASA-Langley Control Data Corporation (CDC) computer system was accomplished by using a remote batch site facility located at the Douglas Long Beach plant. Once initial contact feasibility was established, card decks in the ANOPP executive system control statement language containing the necessary descriptive inputs were submitted and the printout received at the remote batch facility. The remote facility consisted of a computer terminal, and reader, line printer, and acoustic coupler.

Further detailed information regarding the capabilities and operational use of the ANOPP noise prediction system can be obtained from Dr. William Zorumski of Langley Research Center.

6.0 COMPARISON OF ANOPP PREDICTIONS WITH FLYOVER DATA

Comparisons of the ANOPP prediction and the flyover noise data for each of the six flyovers are presented in Figures 4 through 38. These graphical comparisons consist of PNLT versus directivity and spectra at selected angles. It should be noted that the version of ANOPP used for the validation study did not contain provisions to predict noise from an acoustically treated nacelle/engine combination. Since the aircraft used in the flyover noise data base was flown with three acoustically treated engines, i.e., treatment in the fan inlet, fan exhaust, and turbine ducts, the ANOPP levels predicted for these sources are higher than they should be. However, these differences are small with respect to the overall data trends that can be determined from the figures because the ANOPP option in the fan noise module for predicting noise for an unattenuated cut on tone was turned off. This resulted in a comparison of unattenuated predicted broadband noise with flyover levels containing an attenuated tone and broadband noise.

The PNLT directivity on approach shows that ANOPP overpredicted inlet turbomachinery noise from 1 to 6 PNdB with better agreement at the higher approach power settings. ANOPP likewise overpredicted the aft noise on approach from 1 to 3 PNdB. The aft noise was consistently higher up to 4 PNdB and agreed better at higher thrust settings.

The approach spectra at the inlet angles show ANOPP underpredicted the jet noise below 1250 Hz and overpredicted the fan inlet noise above 1250 Hz with a smooth shaped spectra. For the approach aft angles, ANOPP predicted a higher fan exhaust noise than the measured total noise and underpredicts jet and core noise. The airframe noise for the low frequencies seems to be too high.

The takeoff spectra for the inlet angles shows a consistent underprediction of jet and core noise at low frequencies and an overprediction of fan inlet noise by up to 15 PNdB. For these power settings, the fan exhaust noise for the last four third octave bands was also overpredicted. The aft takeoff spectra show a jet noise prediction too low at low frequencies and a fan exhaust noise overprediction at high frequencies.

Appendix B contains the necessary information needed to predict the attenuation spectra for the fan inlet, fan exhaust, and turbine tailpipe for each of the three engines. Specific acoustic impedance values were calculated using a method similar to the one found in Reference 3. This information is included so that more accurate flyover noise predictions can be made once the capability to predict attenuation spectra is included in ANOPP.

7.0 CONCLUDING REMARKS

ANOPP predictions were made and compared with flyover noise data obtained for a DC-10-40 airplane with acoustically treated nacelles. Since an ANOPP module to predict noise from a treated nacelle was not available, an approximation for this condition was made by eliminating the calculation of tones for a hardwall nacelle in the fan noise module.

ANOPP applied in this manner predicted EPNL values in excess of measured values within a three EPNdB margin at both the approach and takeoff conditions.

ANOPP predictions of the total noise on a spectral basis at low frequencies were consistently lower than the measured flyover noise. ANOPP predictions of the total noise at high frequencies were consistently higher than the measured noise.

Although measured data were not available for individual sources, some inferences were drawn regarding ANOPP prediction of individual sources. These inferences were made by comparing ANOPP source predictions with total measured noise in those regions of the spectra where individual sources dominated the total noise. The low frequency difference between predicted and measured noise may be due to an underprediction in those frequency bands of either jet or airframe noise or a combination of both. The high frequency differences showed that at inlet angles for all power settings, ANOPP overpredicted the fan inlet noise. Fan exhaust noise for all power settings at aft angles was also overpredicted. In addition, at takeoff power settings fan exhaust noise was overpredicted for the inlet angels.

The predicted hardwall broadband levels appeared higher than the measured broadband fan noise levels as expected. Whether the overprediction was of the right magnitude could not be determined since data on the attenuation of broadband noise for the treatment was unavailable. No inference could be drawn about the other sources because they fell so far below the total measured flyover noise. The PNLT directivity information showed higher levels at the inlet and aft angles for all power settings corresponding to the SPL differences.

8.0 RECOMMENDATIONS

It is recommended that the development of ANOPP be continued and that it include the incorporation of a method to predict noise from a treated nacelle. Once this modification is accomplished, the ANOPP validation done in this report should be repeated for a treated nacelle configuration and compared against the flyover noise data. It is further recommended that the development of ANOPP be continued by including in its prediction methodology ways to account for effects of multiple source locations, due to the distribution of engine locations on the airframe, airplane shielding, and wing- and jet-wake scattering.

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TABLE I

DC-10-40/JT9D-59A

ENGINE/AIRPLANE FLYOVER RUNS

AT OVERHEAD

(AZIMUTH ANGLE ϕ=0°)

RUN	CONDITION	PHYSICAL ENGINE SPEED	FLAPS	GEOMETRIC ALTITUDE	AIRCRAFT TRUE VELOCITY	GLIDESLOPE ANGLE*	PITCH ANGLE*	GROSS WEIGHT	AMBIENT TEMPERATURE AT ALTITUDE	RELATIVE HUMIDITY AT ALTITUDE
		RPM	deg	m	m/s	deg	DEG	deg	K	PERCENT
1	APPROACH	2530	53.4	119.3	84.22	-2.2	3.6	203,848	285.1	46
2	APPROACH	2380	52.1	120.4	78.61	-2.6	3.1	177,130	288.1	46
3	APPROACH	1959	36.7	115.5	76.25	-2.5	6.3	173,048	288.8	44
4	TAKEOFF	3511	10.9	363.1	100.53	7.1	16.8	245,443	285.4	66
5	TAKEOFF	3231	10.7	353.9	96.21	5.7	16.1	234.375	286.0	70
6	TAKEOFF	3408	10.3	345.5	97.03	7.3	16.5	230,610	286.3	71

*Positive above horizontal,negative below horizontal

TABLE II

ANOPP AIRFRAME NOISE PARAMETERS ,MODULE AFM

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
AW	Wing planform area	m^2	338.9	338.9	338.9	338.9	338.9	338.9
BW	Wing span	m	50.3	50.3	50.3	50.3	50.3	50.3
AH	Horizontal tail planform area	m^2	101.3	101.3	101.3	101.3	101.3	101.3
BH	Horizontal tail span	m	21.6	21.6	21.6	21.6	21.6	21.6
AV	Vertical tail planform area	m^2	56.2	56.2	56.2	56.2	56.2	56.2
BV	Vertical tail span	m	7.3	7.3	7.3	7.3	7.3	7.3
V	Aircraft velocity	m/s	84.22	78.61	76.25	100.53	96.21	97.03
N	Conventional construc.	-	1	1	1	1	1	1
AF	Flap planform area	m^2	62.0	62.0	62.0	62.0	62.0	62.0
CF	Trailing edge flap gross chord	m	4.7	4.7	4.7	4.7	4.7	4.7
GAMMA	Trailing edge flap	deg	53.4	52.1	36.7	10.9	10.7	10.3
NF	No. trailing edge slots	-	1	1	1	1	1	1
TDMG	Main landing gear tire diameter	m	1.32	1.32	1.32	1.32	1.32	1.32
CMG	Ratio main gear strut length to wheel dia.	-	1.92	1.92	1.92	1.92	1.92	1.92
NMGW	No. wheels per main gear	-	4	4	4	4	4	4
NMG	No. main landing gear	-	3	3	3	3	3	3
TDNG	Nose landing gear tire diameter	m	1.02	1.02	1.02	1.02	1.02	1.02
CNG	Ratio nose gear strut length to wheel dia.	-	1.79	1.79	1.79	1.79	1.79	1.79

TABLE II - Continued

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
NNGW	No. wheels per nose landing gear	-	2	2	2	2	2	2
NNG	No. nose landing gear	-	1	1	1	1	1	1
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
RHOA	Ambient air density	kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
MUA	Ambient coefficient of viscosity for air	kg/m-s	$1.7746x10^{-5}$	$1.7891x10^{-5}$	$1.7925x10^{-5}$	$1.7761x10^{-5}$	$1.7790x10^{-5}$	$1.7804x10^{-5}$
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0
REFL	Total source power ref. length	m	1.0	1.0	1.0	1.0	1.0	1.0
ITEWN	Trailing edge wing noise code	-	1	1	1	1	1	1
ITEHTN	Trailing edge horizontal tail noise	-	1	1	1	1	1	1
ITEVTN	Trailing edge vertical tail noise	-	1	1	1	1	1	1
ITEFN	Trailing edge flap noise	-	1	1	1	1	1	1
ILESN	Leading edge slat noise	-	1	1	1	1	1	1
IMGN	Main landing gear noise	-	1	1	1	1	1	1
INGN	Nose landing gear noise	-	1	1	1	1	1	1
ITYPW	Conventional wing	-	1	1	1	1	1	1
IPRINT	Print input-output	-	3	3	3	3	3	3
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3

TABLE II - Continued

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
PREF	Reference pressure	N/m^2	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$
POWREF	Reference power	W	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$

TABLE III

ANOPP FAN INLET NOISE PARAMETERS ,MODULE FAN

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
AREA	Fan duct cross sectional area	m^2	4.3	4.3	4.3	4.3	4.3	4.3
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
VO	Aircraft velocity	m/s	84.22	78.61	76.25	100.53	96.21	97.03
DELTA	Angle between flight vector and engine inlet axis	deg	6.8	6.7	9.8	10.7	11.4	10.2
DELT	Total temperature rise across fan	K	50.0	44.0	31.0	97.0	81.0	92.0
DIAM	Fan duct outer diameter	m	2.34	2.34	2.34	2.34	2.34	2.34
DIS	Inlet flow distortion factor	-	0.0	0.0	0.0	0.0	0.0	0.0
DM	Fan rotor tip relative Mach number at design point	-	1.36	1.36	1.36	1.36	1.36	1.36
DOTM	Mass flow rate fan	kg/s	556.57	509.85	414.59	758.42	701.27	739.37
IDBB	Discharge broad band code	-	0	0	0	0	0	0
IDRS	Discharge rotor stator code	-	0	0	0	0	0	0
IGV	Inlet guide vane option	-	0	0	0	0	0	0
INBB	Broad band inlet code	-	1	1	1	1	1	1
INCT	Inlet combination tone code	-	0	0	0	0	0	0
INDIS	Inlet distortion code	-	0	0	0	0	0	0
INRS	Inlet rotor stator code	-	0	0	0	0	0	0
IPRINT	Print output-input	-	3	3	3	3	3	3
NB	Number rotor blades	-	46	46	46	46	46	46
NV	Number stator blades	-	96	96	96	96	96	96
OMEGA	Fan rotor speed	rev/s	42.17	39.67	32.65	58.52	53.85	56.80

TABLE III - Continued

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0
RHOA	Ambient density	kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
RSS	Rotor stator spacing	Percent	26.0	26.0	26.0	26.0	26.0	26.0
TA	Ambient temperature	K	285.1	288.1	288.8	285.4	286.0	286.3
NENG	Number of engines	-	3	3	3	3	3	3
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3
PREF	Reference pressure	N/m^2	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$

TABLE IV

ANOPP FAN EXHAUST NOISE PARAMETERS ,MODULE FAN

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
AREA	Fan duct cross sectional area	m^2	1.74	1.74	1.74	1.74	1.74	1.74
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
VO	Aircraft velocity	m/s	84.22	78.61	76.25	100.53	96.21	97.03
DELTA	Angle between flight vector and engine inlet axis	deg	6.8	6.7	9.8	10.7	11.4	10.2
DELT	Total temperature rise across fan	K	50.0	44.0	31.0	97.0	81.0	92.0
DIAM	Fan duct outer diameter	m	1.49	1.49	1.49	1.49	1.49	1.49
DIS	Inlet flow distortion factor	-	0.0	0.0	0.0	0.0	0.0	0.0
DM	Fan rotor tip relative Mach number at design point	-	1.36	1.36	1.36	1.36	1.36	1.36
DOTM	Mass flow rate fan	kg/s	473.1	433.6	353.8	625.5	584.2	612.4
IDBB	Discharge broad band code	-	1	1	1	1	1	1
IDRS	Discharge rotor stator code	-	0	0	0	0	0	0
IGV	Inlet guide vane option	-	0	0	0	0	0	0
INBB	Broad band inlet code	-	0	0	0	0	0	0
INCT	Inlet combination tone code	-	0	0	0	0	0	0
INDIS	Inlet distortion code	-	0	0	0	0	0	0
INRS	Inlet rotor stator code	-	0	0	0	0	0	0
IPRINT	Print output-input	-	3	3	3	3	3	3
NB	Number rotor blades	-	46	46	46	46	46	46
NV	Number stator blades	-	96	96	96	96	96	96
OMEGA	Fan rotor speed	rev/s	42.17	39.67	32.65	58.52	53.85	56.80
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0

TABLE IV - Continued

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
RNOA	Ambient density	Kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
RSS	Rotor stator spacing	percent	26.0	26.0	26.0	26.0	26.0	26.0
TA	Ambient temperature	K	285.1	288.1	288.8	285.4	286.0	286.3
NENG	Number engines	-	3	3	3	3	3	3
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3
PREF	Reference pressure	N/m^2	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}

TABLE V

ANOPP JET NOISE PARAMETERS, MODULE JRSJET

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
TA	Ambient absolute temperature	K	285.1	288.1	288.8	285.4	286.0	286.3
RHOA	Ambient density	kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0
PREF	Reference pressure	N/m^2	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$	$2.0x10^{-5}$
POWREF	Reference power level	W	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$	$1.0x10^{-12}$
IOPT	Coaxial nozzle with subsonic primary and secondary jets	-	5	5	5	5	5	5
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3
IPRINT	Print output-input	-	3	3	3	3	3	3
VO	Aircraft velocity	m/s	84.22	78.61	76.25	100.53	96.21	97.03
A1	Fully expanded primary jet area	m^2	0.585	0.582	0.577	0.634	0.622	0.630
DE1	Equivalent circular nozzle dia.	m	0.863	0.861	0.857	0.899	0.890	0.896
DH1	Hydraulic dia. primary jet nozzle	m	0.863	0.861	0.857	0.899	0.890	0.896
V1	Primary jet relative velocity	m/s	293.9	265.3	199.8	482.4	417.0	458.2
RHO1	Fully expanded primary jet density	kg/m^3	0.491	0.496	0.525	0.445	0.458	0.448
T1	Fully expanded primary jet total temperature	K	760.0	744.6	688.9	873.7	821.6	855.9
MD1	Design Mach number for supersonic primary nozzle	-	1.0	1.0	1.0	1.0	1.0	1.0

TABLE V - Continued

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
A2	Fully expanded secondary jet area	m^2	1.792	1.795	1.794	1.772	1.786	1.776
V2	Secondary jet relative velocity	m/s	229.1	212.0	173.6	316.7	292.6	308.6
RHO2	Fully expanded secondary jet density	kg/m^3	1.207	1.194	1.196	1.149	1.156	1.151
T2	Fully expanded secondary jet total temperature	K	316.7	315.6	308.9	344.4	335.6	342.2
AE	Cascade exit area	m^2	1.0	1.0	1.0	1.0	1.0	1.0
AT	Tailpipe area	m^2	1.0	1.0	1.0	1.0	1.0	1.0
KC	Thrust reverser constant	-	0.0	0.0	0.0	0.0	0.0	0.0
KT	Reverser constant	-	149.0	149.0	149.0	149.0	149.0	149.0
NENG	Number engines	-	3	3	3	3	3	3

TABLE VI

ANOPP CORE NOISE PARAMETERS, MODULE COR

ANOPP SYMBOL	DESCRIPTION	UNITS	VALUES AT					
			RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
DOTM	Core mass flow	kg/s	83.46	76.20	60.78	132.90	117.03	120.01
T3	Combustor inlet total temperature	K	677.7	662.0	613.0	810.5	767.4	795.0
T4	Turbine inlet total temperature	°K	1232.3	1181.3	1048.3	1565.3	1444.3	1526.6
P3	Combustor inlet total pressure	N/m^2	10113.3	9011.6	6895.8	18358.1	15504.6	17273.1
VA	Aircraft velocity	m/s	84.22	78.61	76.25	100.53	96.21	97.03
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0
TA	Ambient temperature	°K	285.1	288.1	288.8	285.4	286.0	286.3
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
RHOA	Ambient density	kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
PA	Ambient pressure	N/m^2	0.976×10^5	1.013×10^5	1.021×10^5	0.979×10^5	0.987×10^5	0.991×10^5
PREF	Reference pressure	N/m^2	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}
POWREF	Reference power	W	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}	1.0×10^{-12}
IPRINT	Printed output-input	-	3	3	3	3	3	3
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3

TABLE VII

ANOPP TURBINE NOISE PARAMETERS, MODULE TUR

ANOPP SYMBOL	Description	UNITS	VALUES AT RUN 1	RUN 2	RUN 3	RUN 4	RUN 5	RUN 6
NB	No. blades last rotor stage	-	102	102	102	102	102	102
SRS	Rotor/stator spacing ratio	-	1.88	1.88	1.88	1.88	1.88	1.88
CL	Sound speed at turbine exit	m/s	522.7	547.1	526.3	592.6	574.7	586.6
CA	Ambient sound speed	m/s	338.54	340.32	340.73	338.72	339.02	339.25
VTR	Relative tip speed of last rotor	m/s	149.3	140.2	121.9	213.3	199.6	208.8
DOTM	Mass flow through turbine	kg/s	83.46	76.20	60.78	132.90	117.03	120.01
RHOA	Ambient density	kg/m^3	1.1928	1.2245	1.2319	1.1960	1.2023	1.2054
R	Radius sound sphere centered at source	m	1.0	1.0	1.0	1.0	1.0	1.0
MA	Aircraft Mach number	-	0.249	0.231	0.212	0.297	0.284	0.286
ITOPT	Turbofan correction code	-	2	2	2	2	2	2
OMEGA	Shaft speed	rev/s	42.17	39.67	32.65	58.52	53.85	56.80
IPRINT	Printed output-input	-	3	3	3	3	3	3
NENG	Number engines	-	3	3	3	3	3	3
IOUT	Output units (dB,dim.)	dB	3	3	3	3	3	3
PREF	Reference pressure		2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}	2.0×10^{-5}

TABLE VIII

FLYOVER WEATHER CONDITIONS

	ALTITUDE	TEMPERATURE	WIND SPEED	RELATIVE HUMIDITY
	m	K	m/s	%
RUN 1, approach	0	285.1	0.5	40
	100	285.1	1.0	46
	200	285.1	2.6	61
	300	285.1	3.1	63
	400	285.1	3.6	40
	500	285.1	4.6	33
RUN 2, approach	0	288.1	0.6	46
	100	288.1	1.0	46
	200	283.7	1.5	46
	300	283.1	2.0	51
	400	283.1	3.6	45
	500	283.1	4.6	41
RUN 3, approach	0	289.0	0.6	44
	100	288.8	1.2	44
	200	284.0	1.7	44
	300	283.2	2.1	43
	400	283.0	3.5	42
	500	283.0	4.5	41
RUN 4, takeoff	0	285.4	0.2	75
	100	285.4	0.5	73
	200	285.4	1.5	72
	300	285.4	1.5	66
	400	287.0	3.6	64
	500	287.0	6.2	60
RUN 5, takeoff	0	286.0	1.0	72
	100	286.0	1.0	71
	200	286.0	2.6	70
	300	286.0	4.1	70
	400	286.0	4.6	64
	500	286.0	3.6	64

TABLE VIII - Continued

	ALTITUDE	TEMPERATURE	WIND SPEED	RELATIVE HUMIDITY
	m	K	m/s	%
RUN 6, takeoff	0	286.3	2.0	71
	100	286.3	2.0	71
	200	286.3	2.0	71
	300	286.3	1.1	71
	400	286.3	1.8	70
	500	286.3	2.0	70

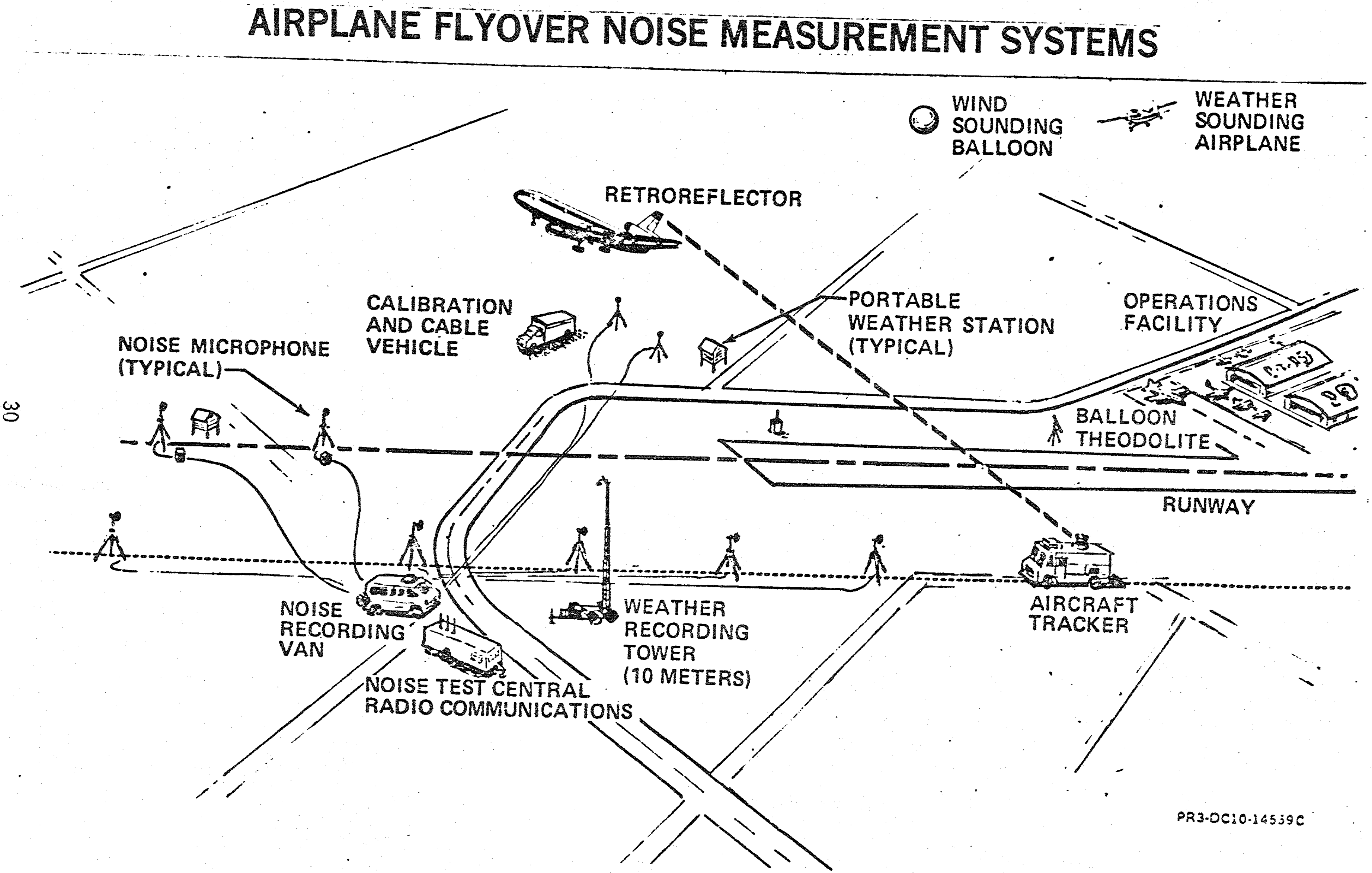

AIRPLANE FLYOVER NOISE MEASUREMENT SYSTEMS
WIND SOUNDING BALLOON
WEATHER SOUNDING AIRPLANE
RETROREFLECTOR
CALIBRATION AND CABLE VEHICLE
PORTABLE WEATHER STATION (TYPICAL)
OPERATIONS FACILITY
NOISE MICROPHONE (TYPICAL)
BALLOON THEODOLITE
RUNWAY
NOISE RECORDING VAN
WEATHER RECORDING TOWER (10 METERS)
AIRCRAFT TRACKER
NOISE TEST CENTRAL RADIO COMMUNICATIONS
PR3-DC10-14559C

FIGURE 1.

MODEL DC-10 SERIES 40 — TOP VIEW

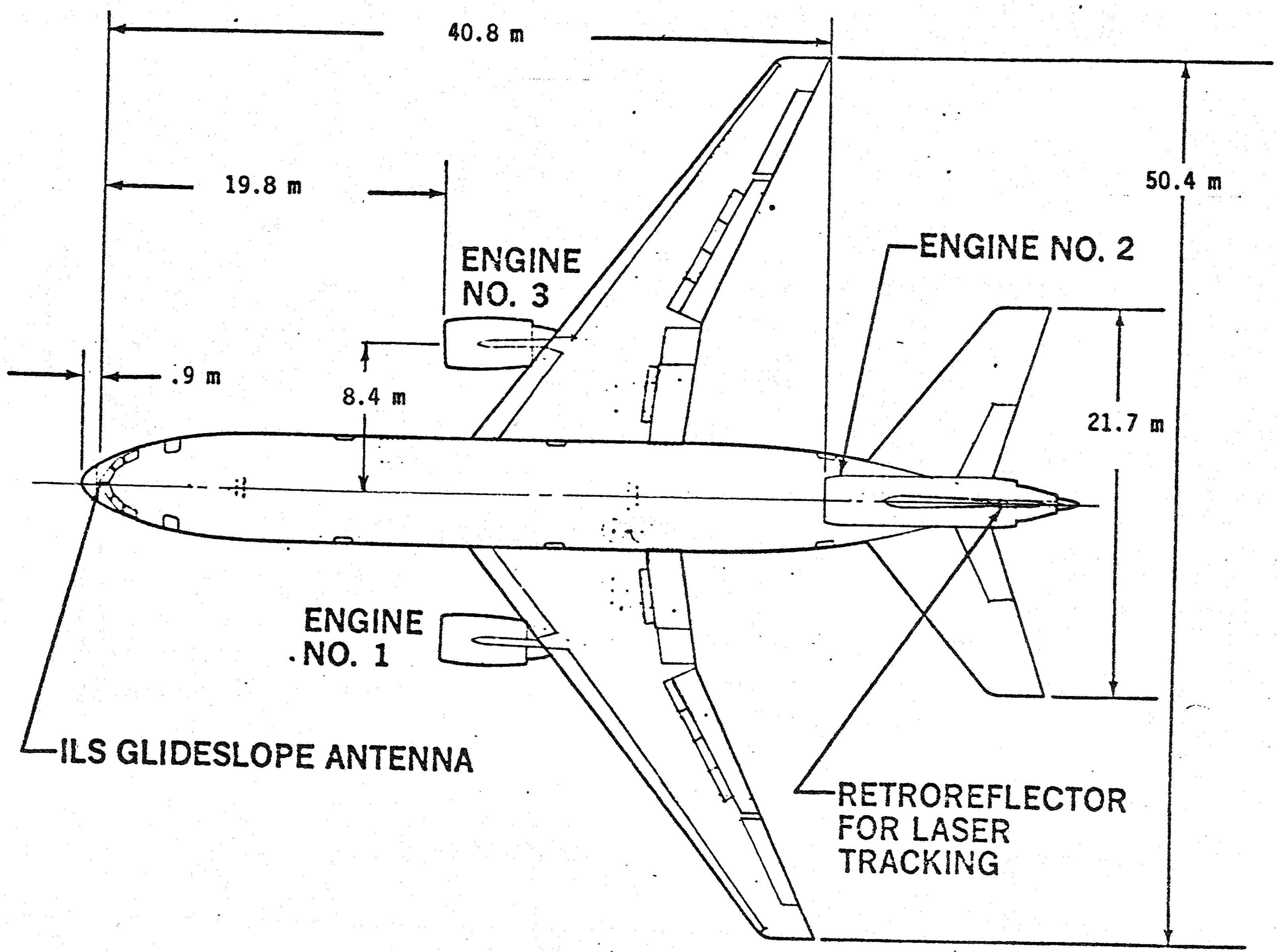


FIGURE 2.

MODEL DC-10 SERIES 40 — SIDE VIEW

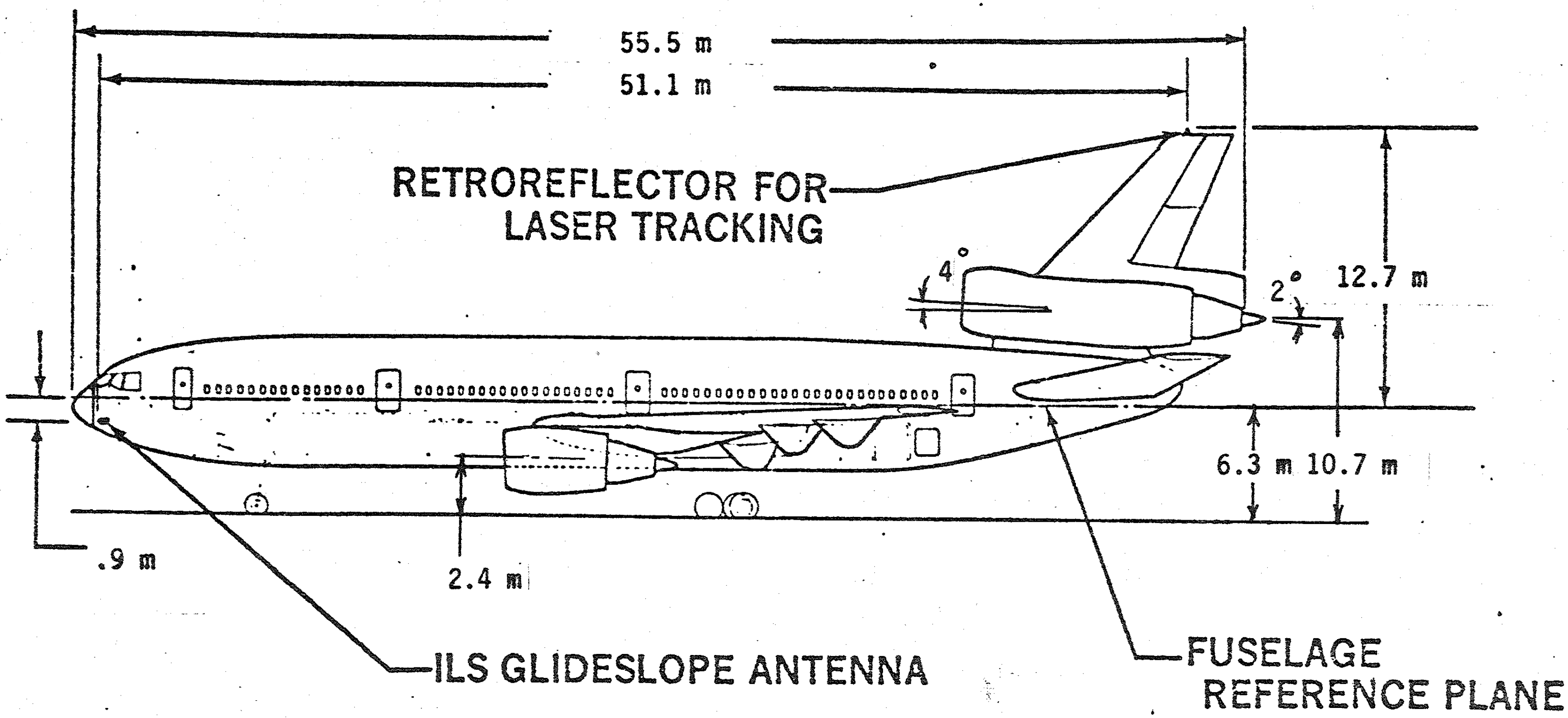


FIGURE 3.

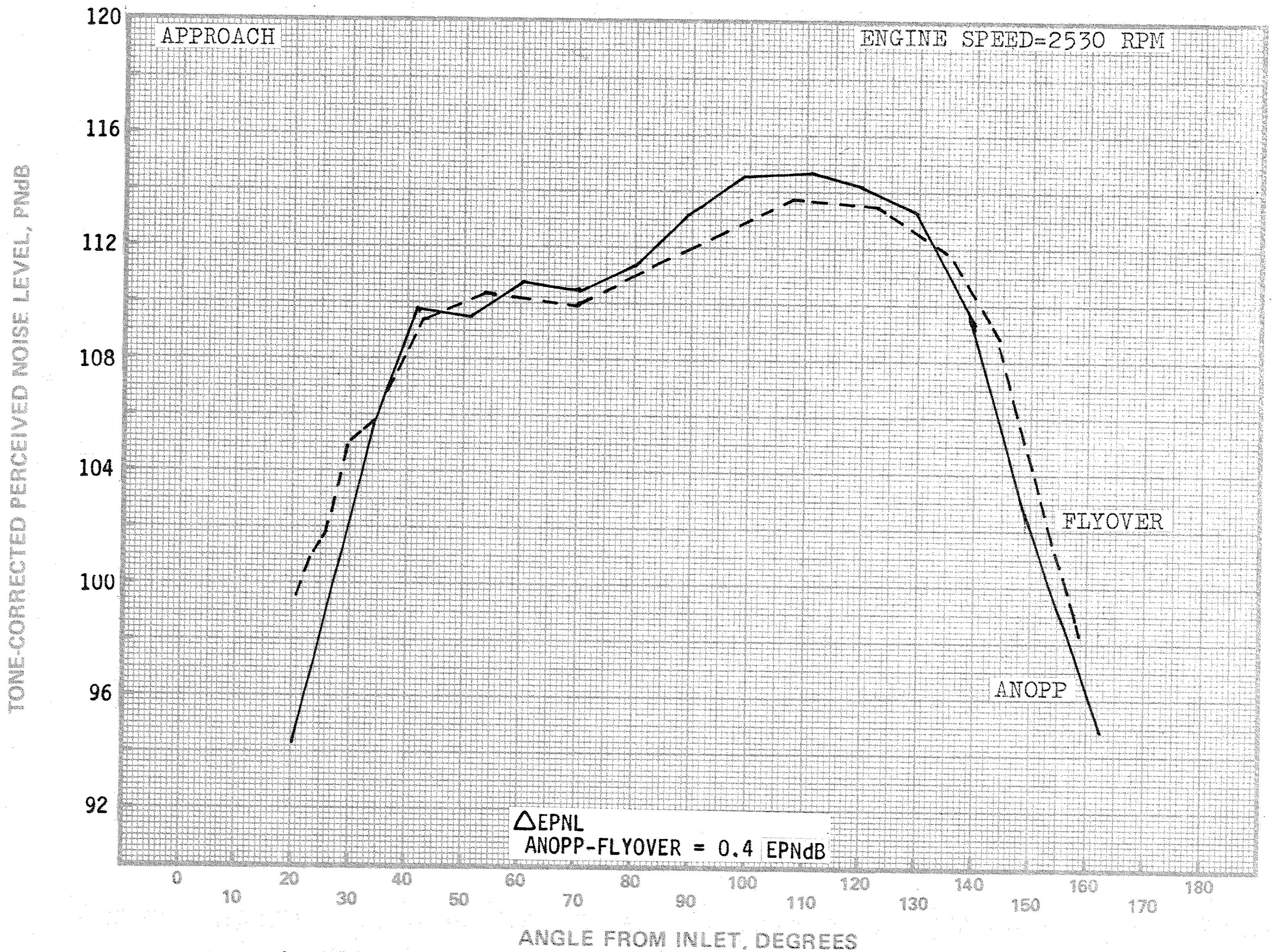


FIGURE 4. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 1

FIGURE 5. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 1, ANGLE FROM INLET=30°

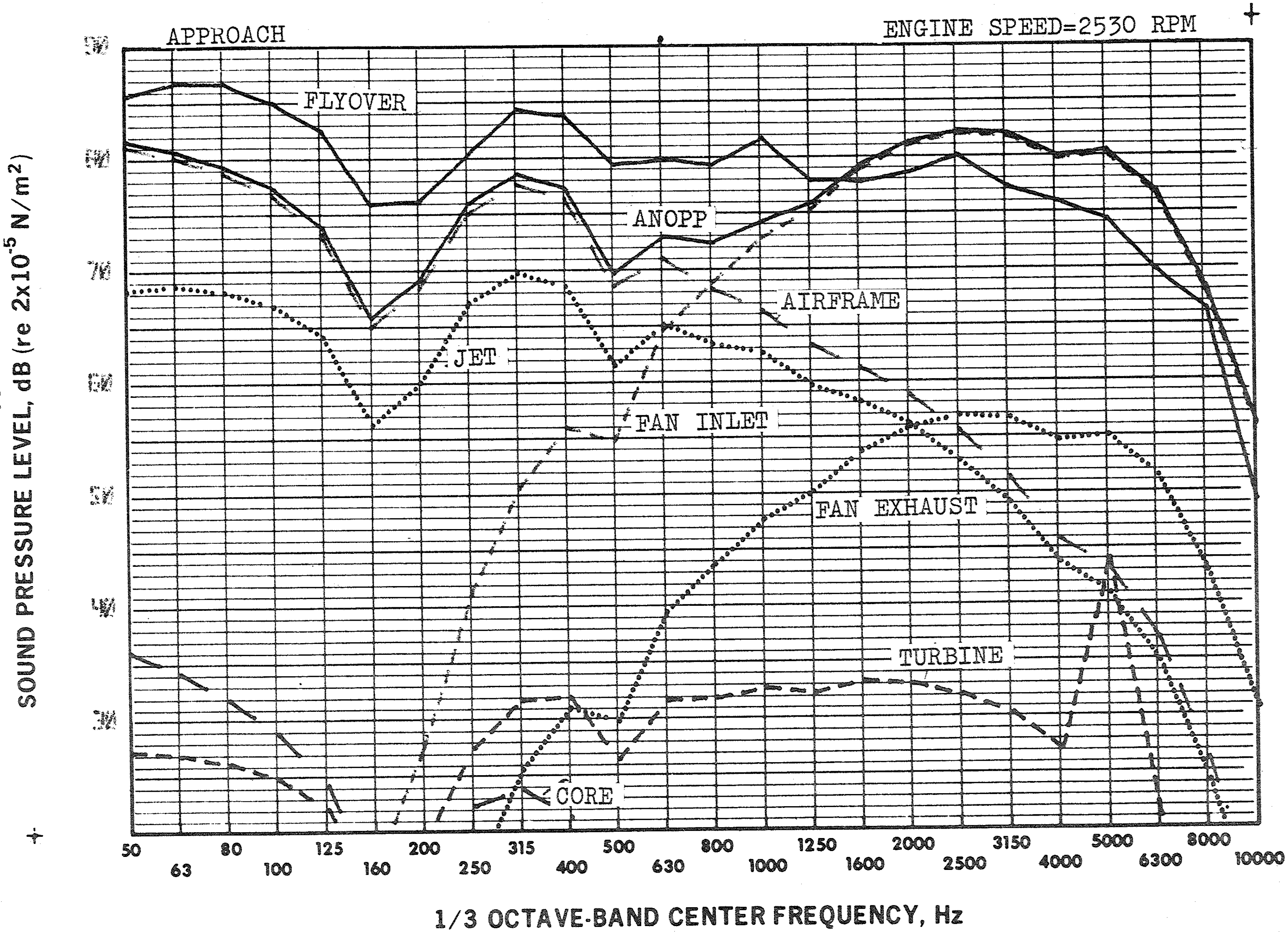


FIGURE 6. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 1, ANGLE FROM INLET=50°

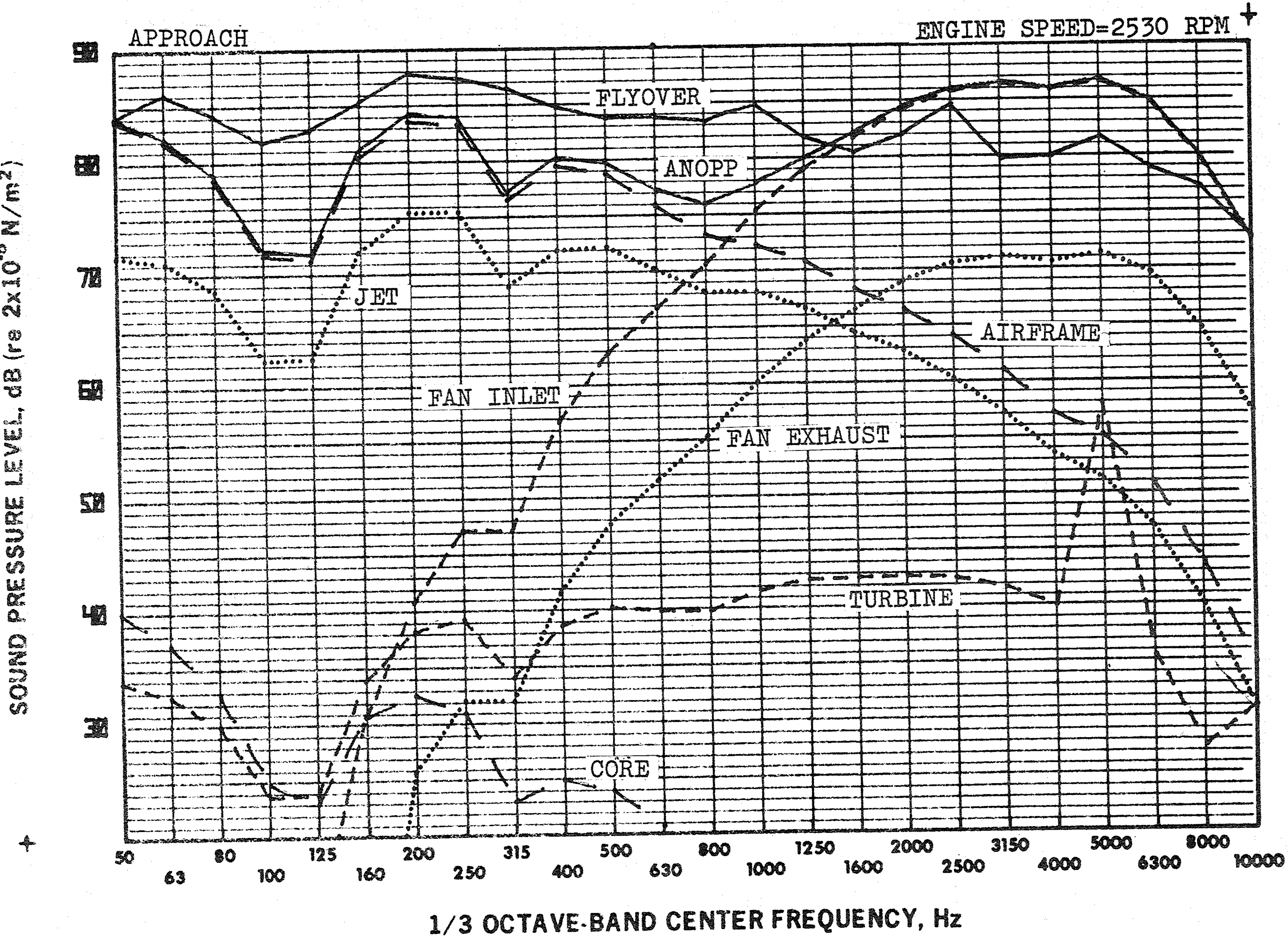


FIGURE 7. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 1, ANGLE FROM INLET=90°

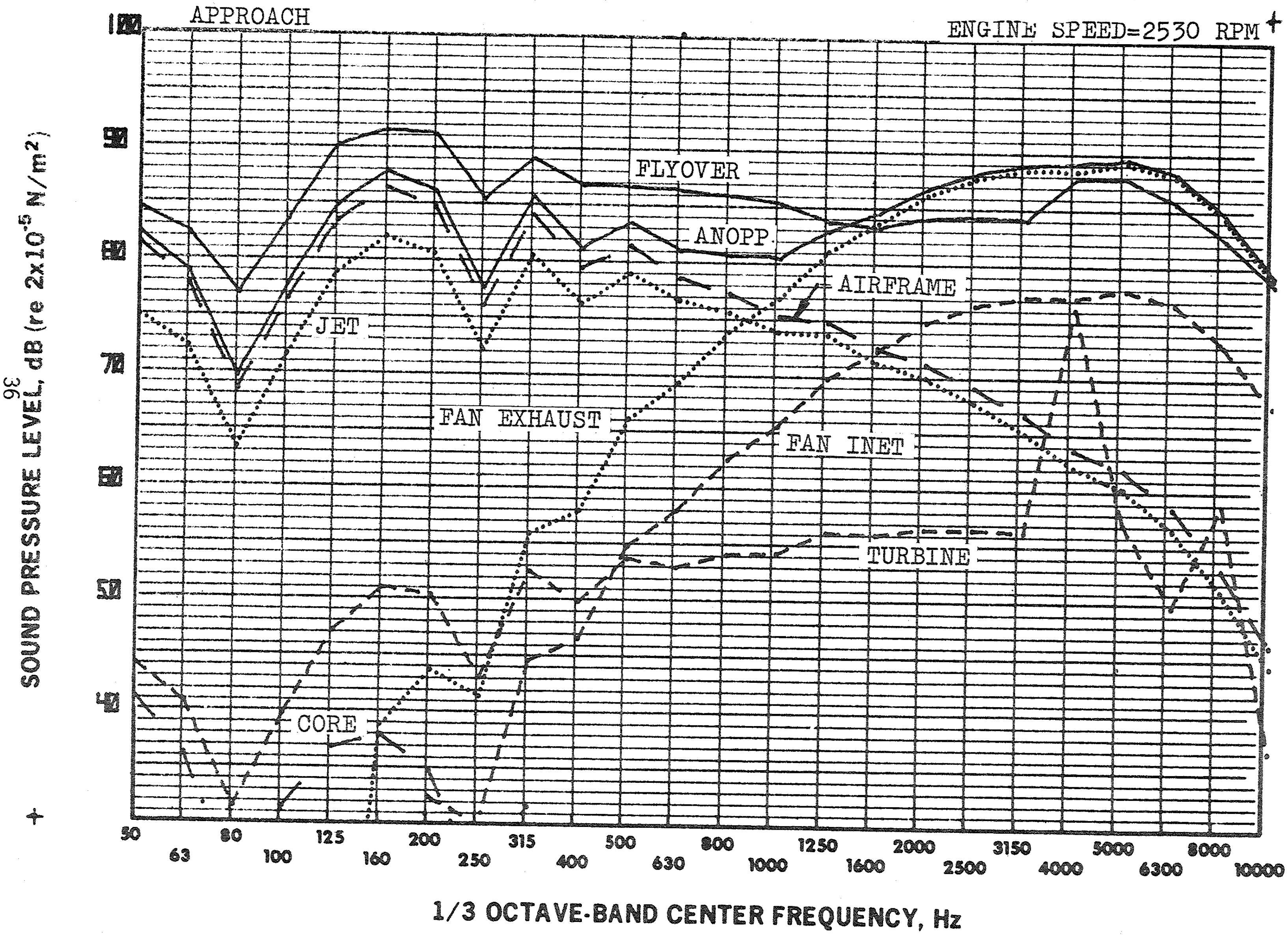


FIGURE 8. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 1, ANGLE FROM INLET=120°

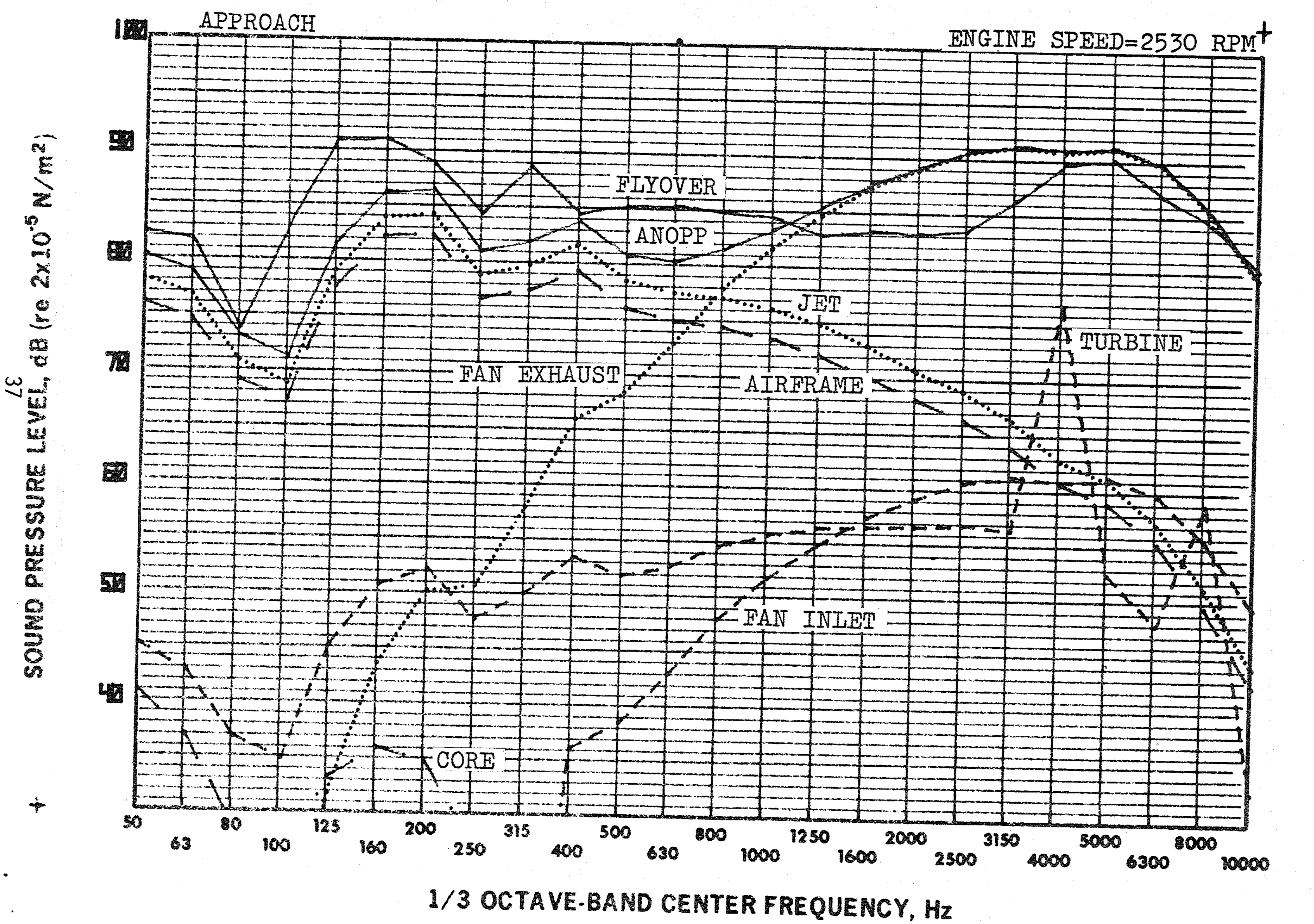
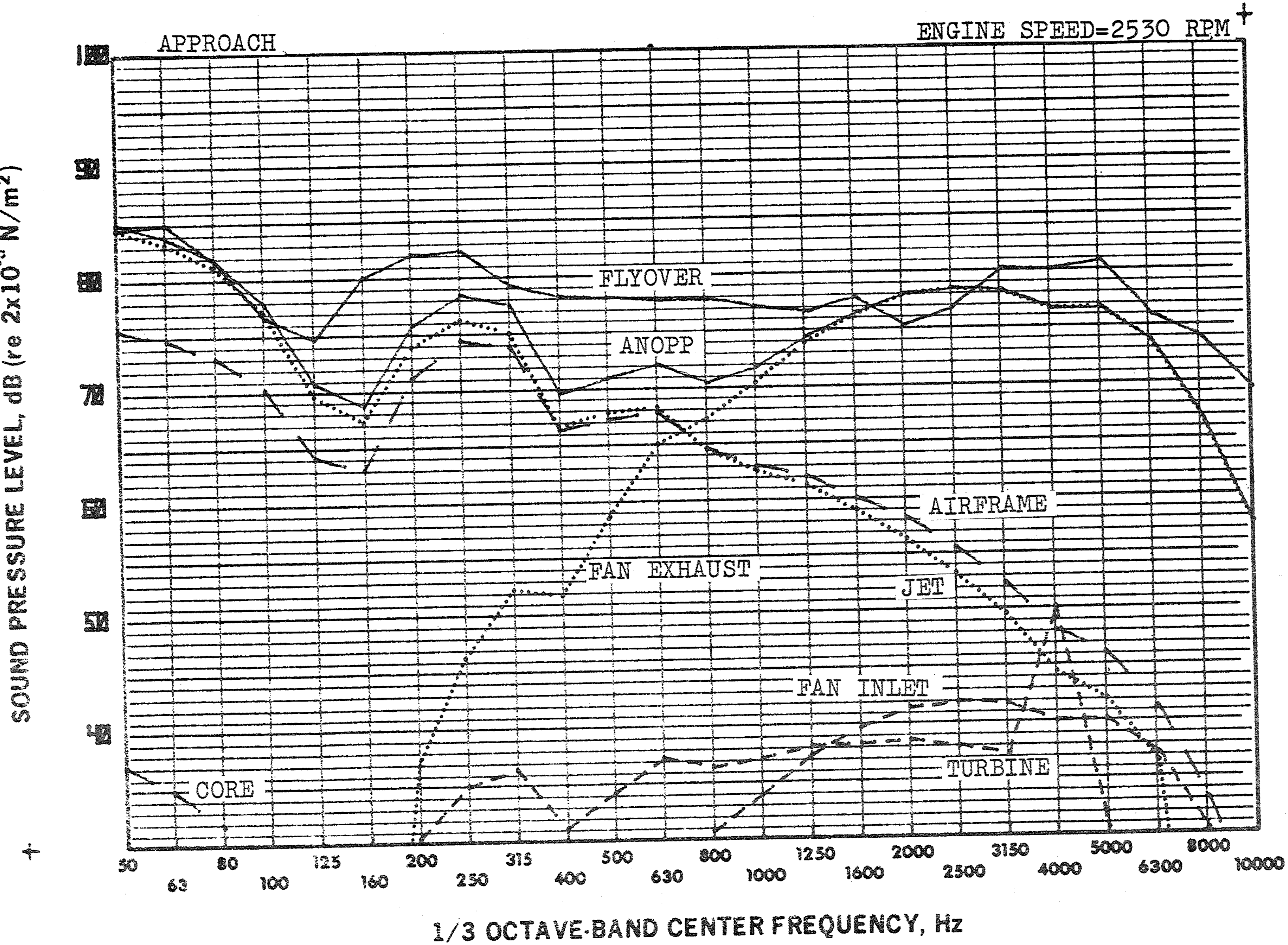


FIGURE 9. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 1, ANGLE FROM INLET=150°



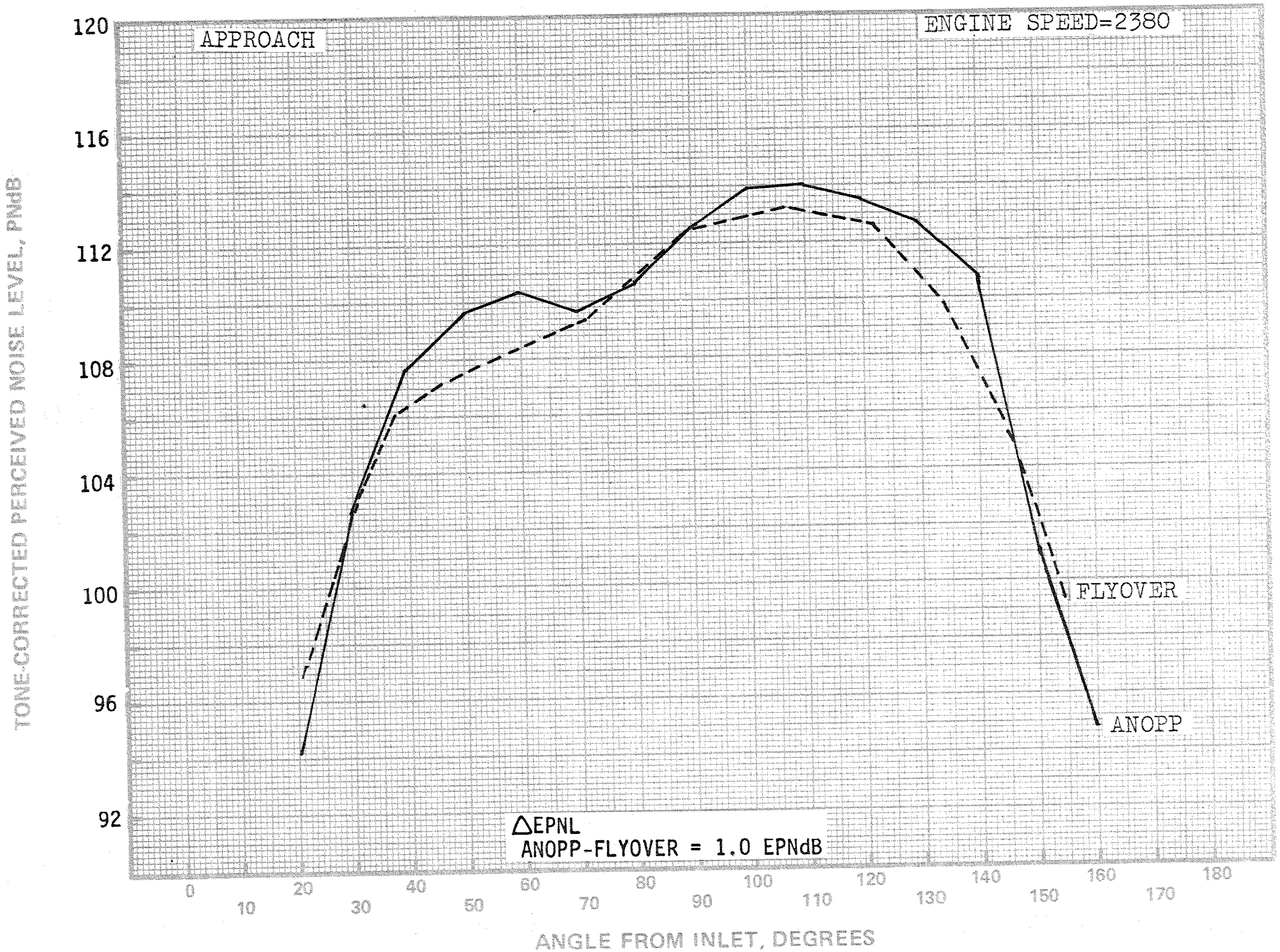


FIGURE 10. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 2

FIGURE 11. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 2, ANGLE FROM INLET=30°

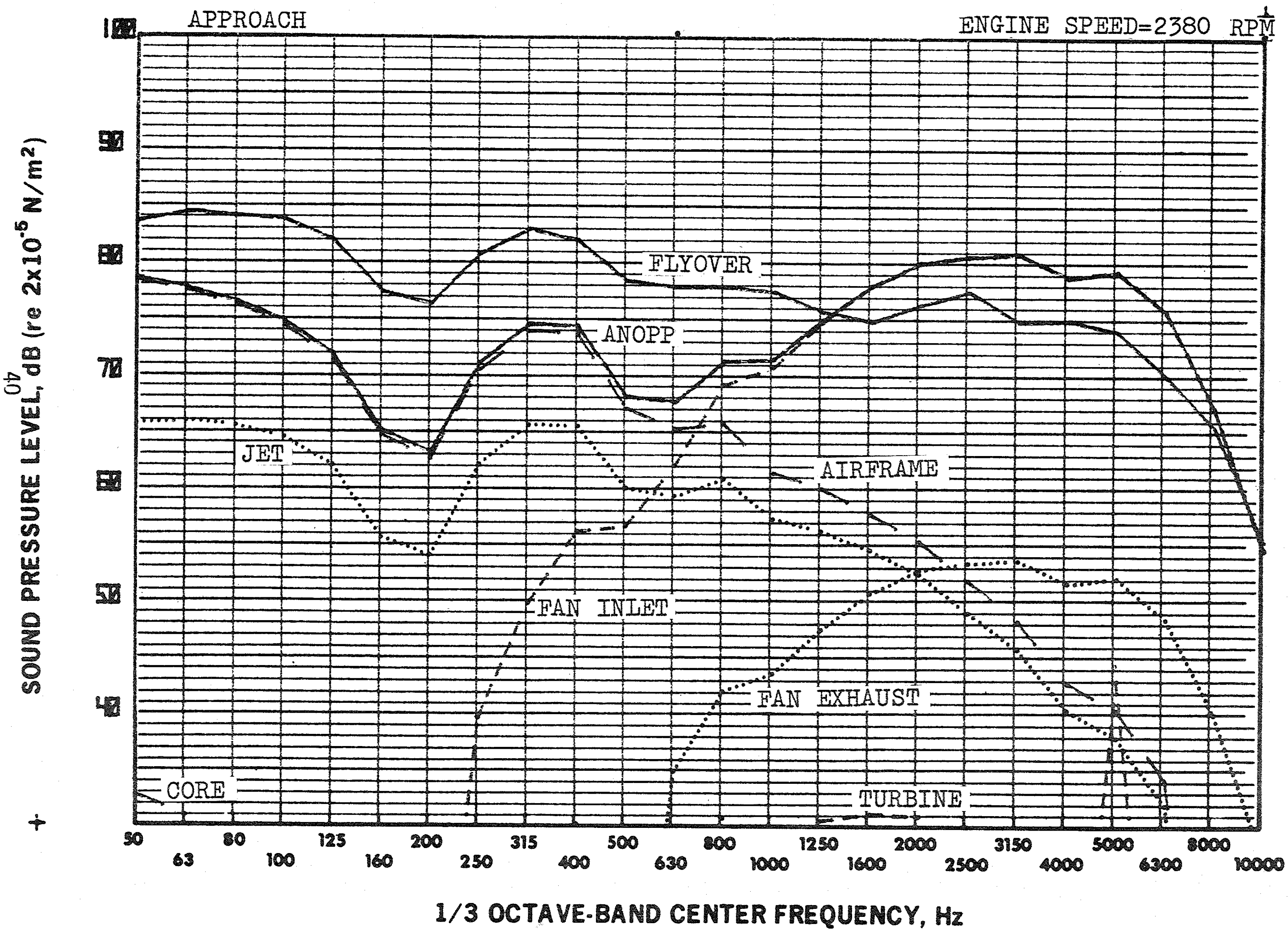


FIGURE 12. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 2, ANGLE FROM INLET=50°

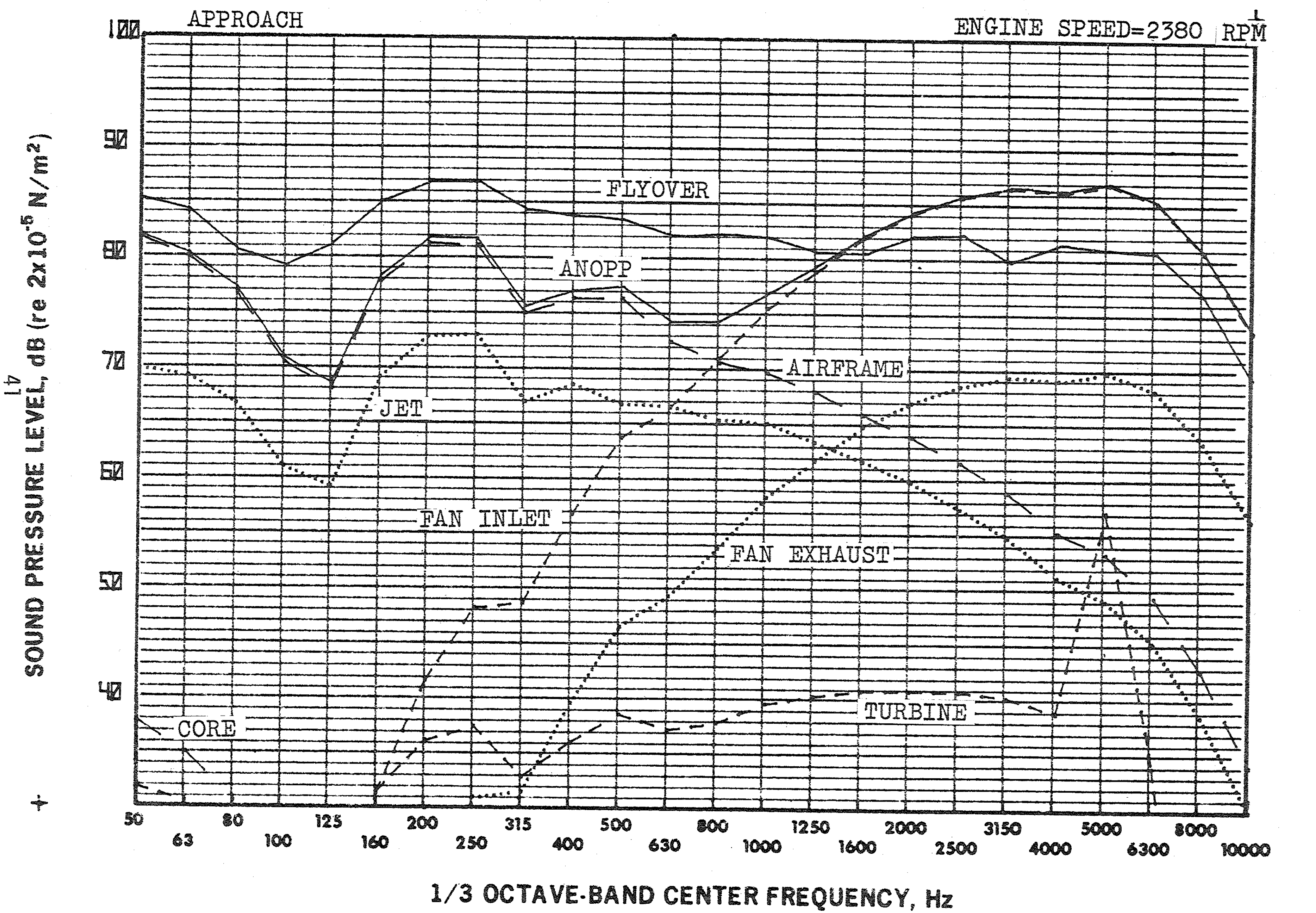


FIGURE 13. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 2, ANGLE FROM INLET=90°

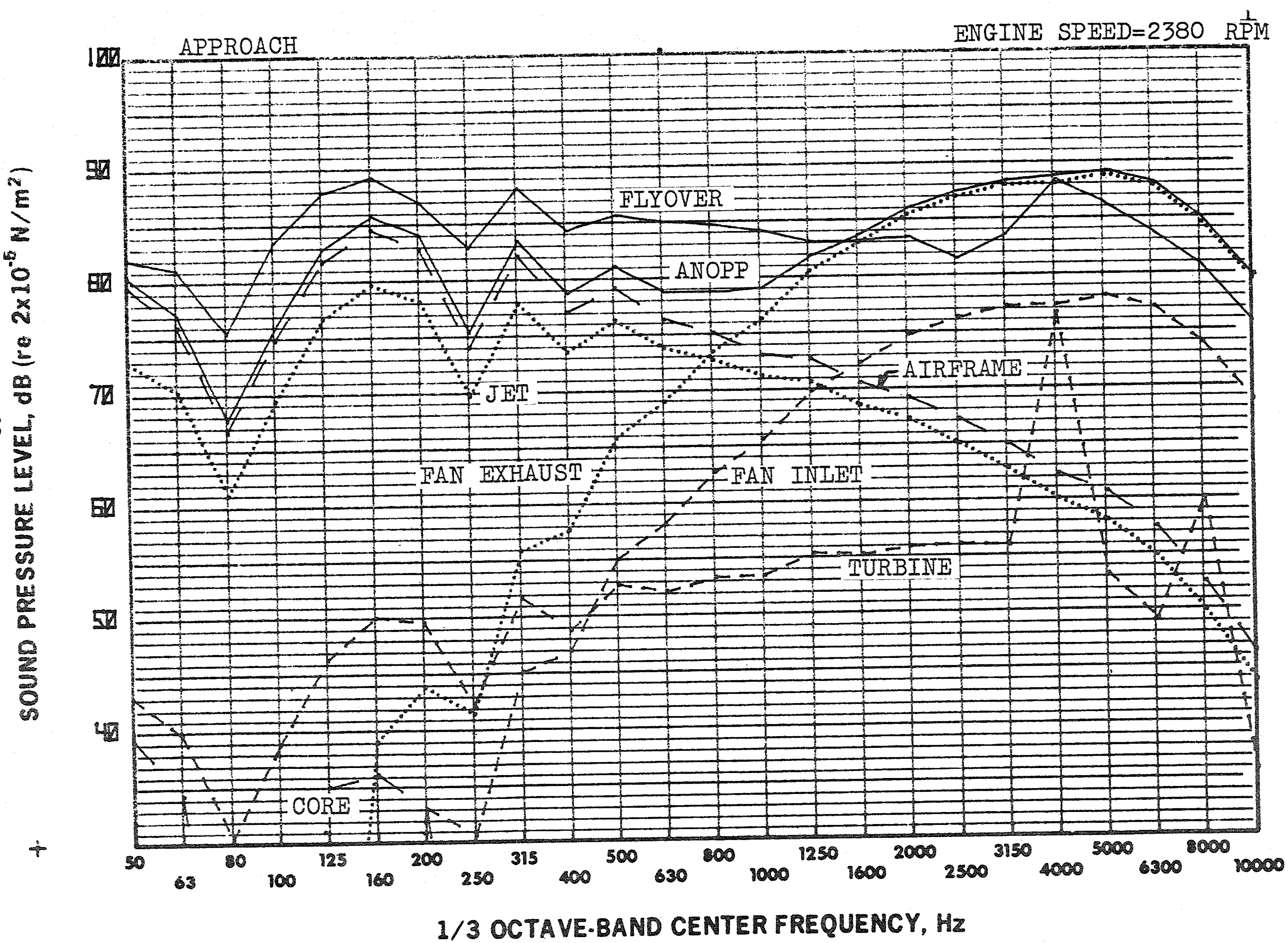


FIGURE 14. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 2, ANGLE FROM INLET=120°

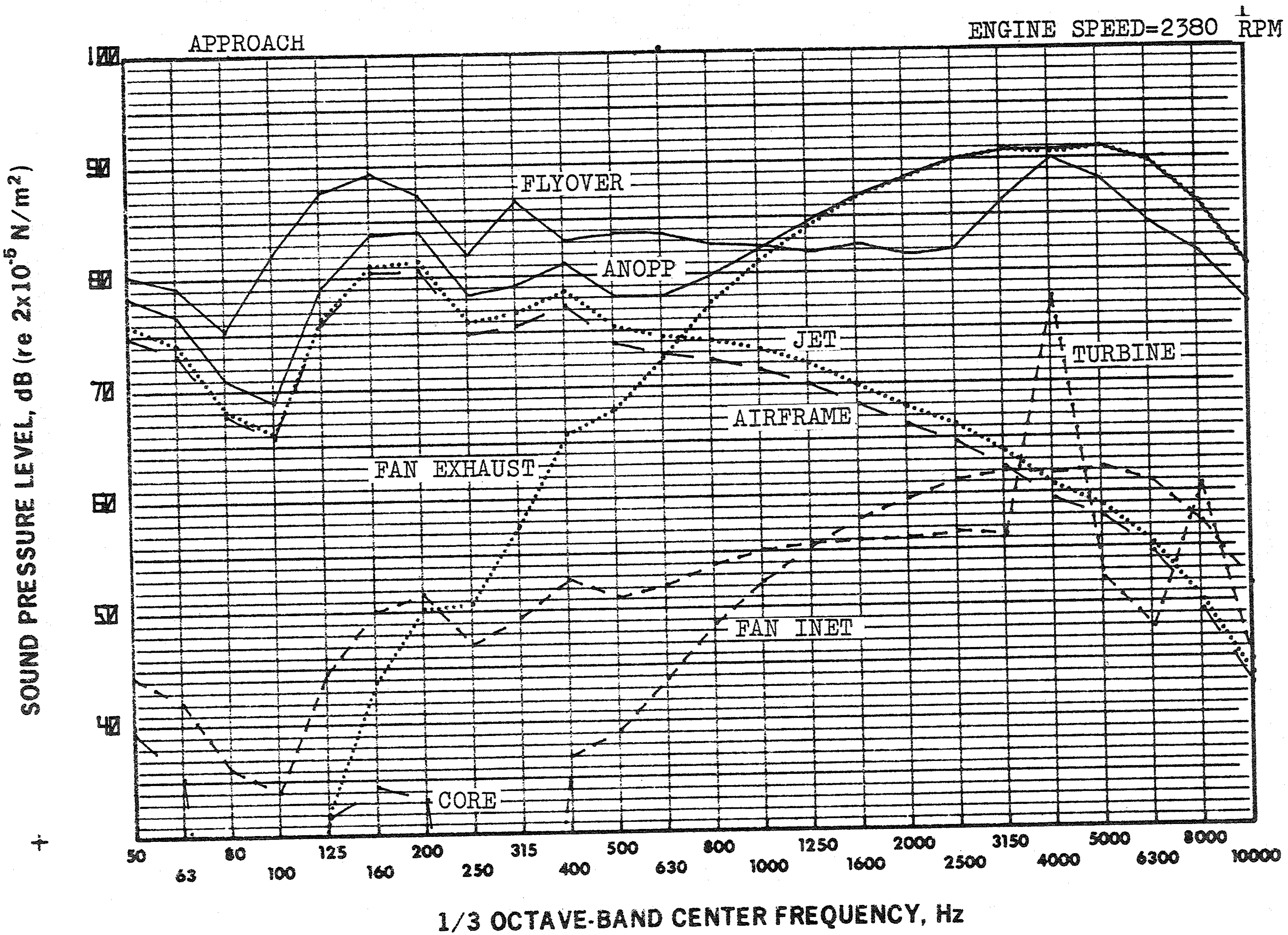
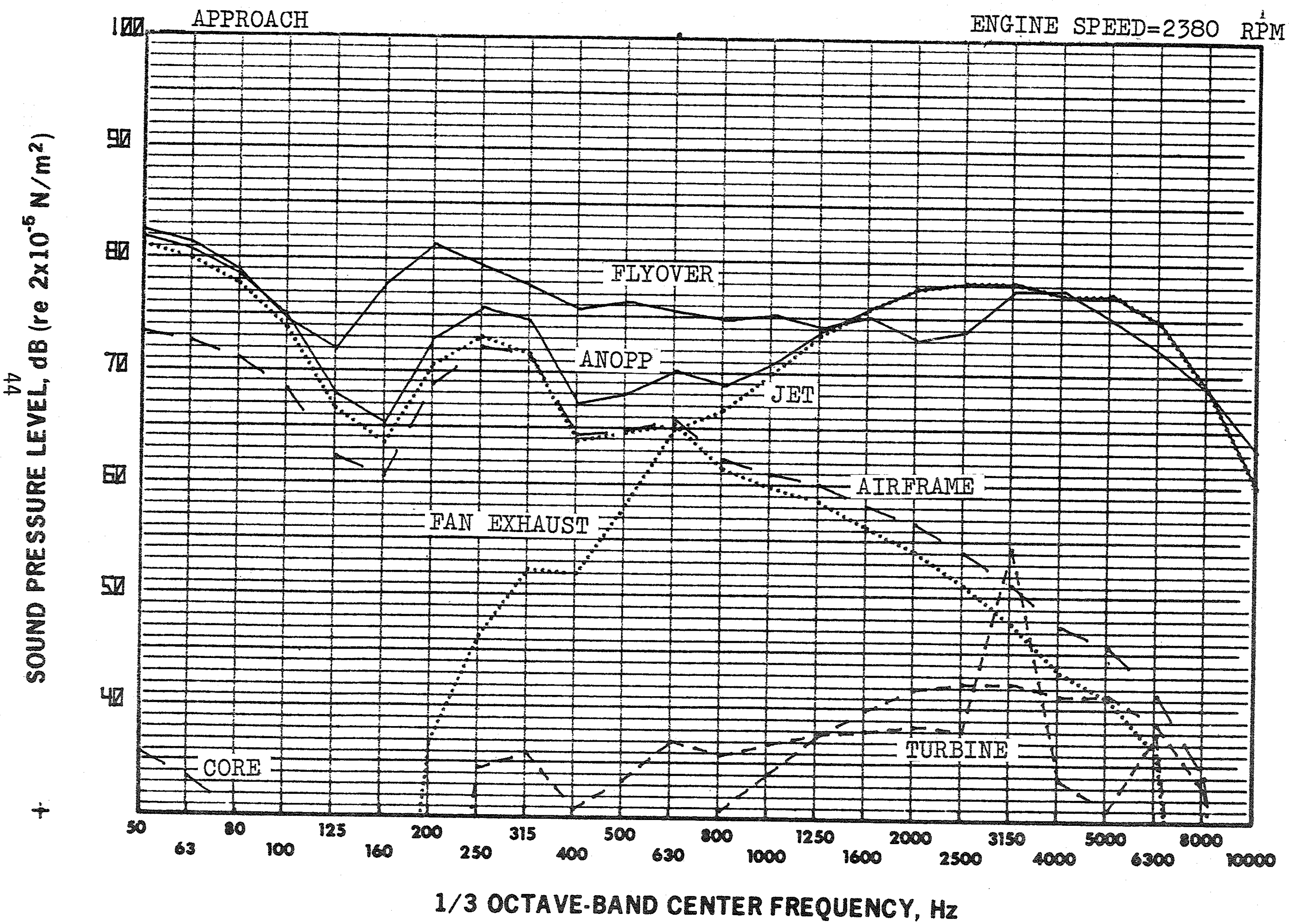


FIGURE 15. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 2, ANGLE FROM INLET=150°



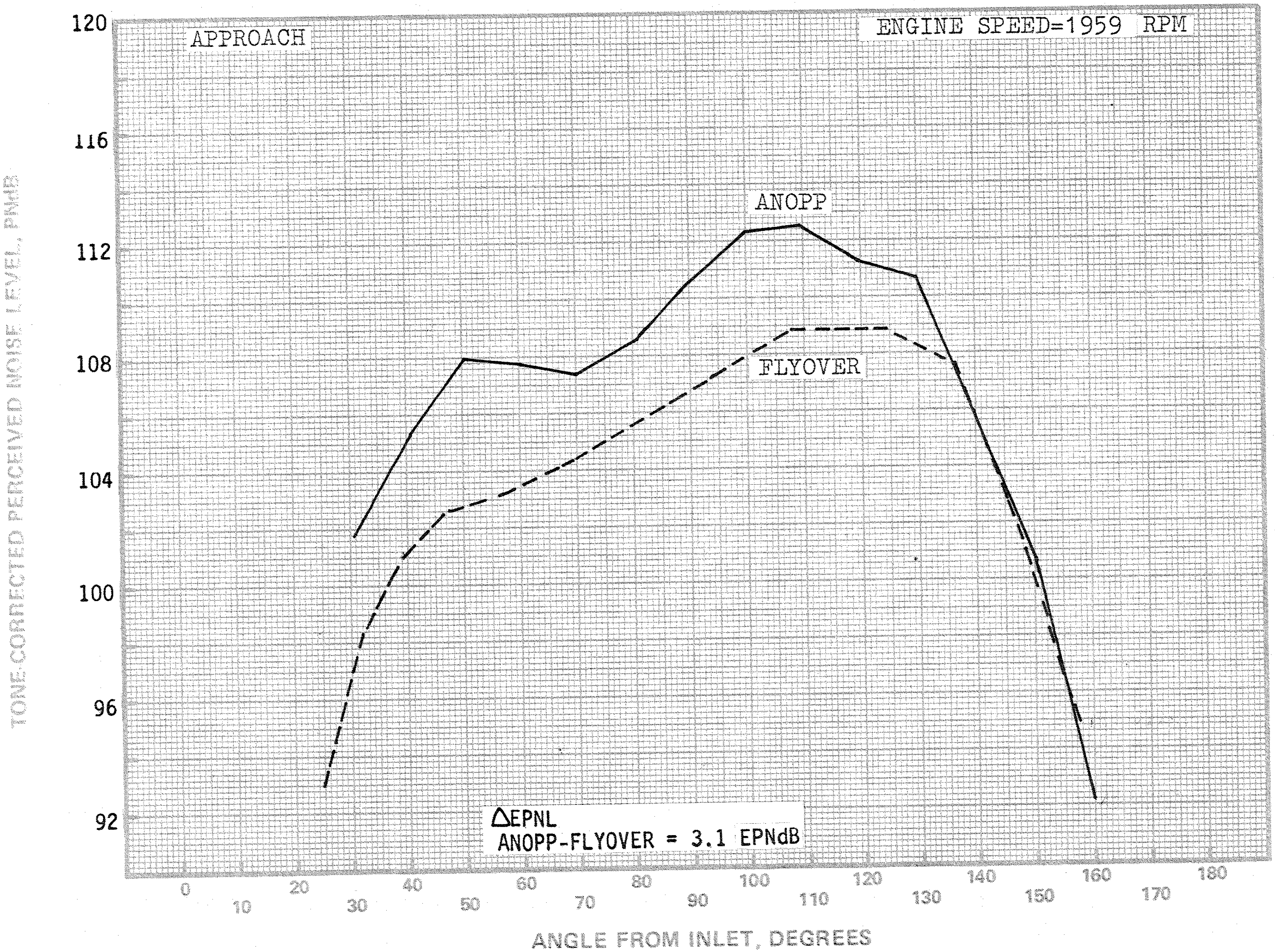


FIGURE 16. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 3

FIGURE 17. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 3, ANGLE FROM INLET=30°

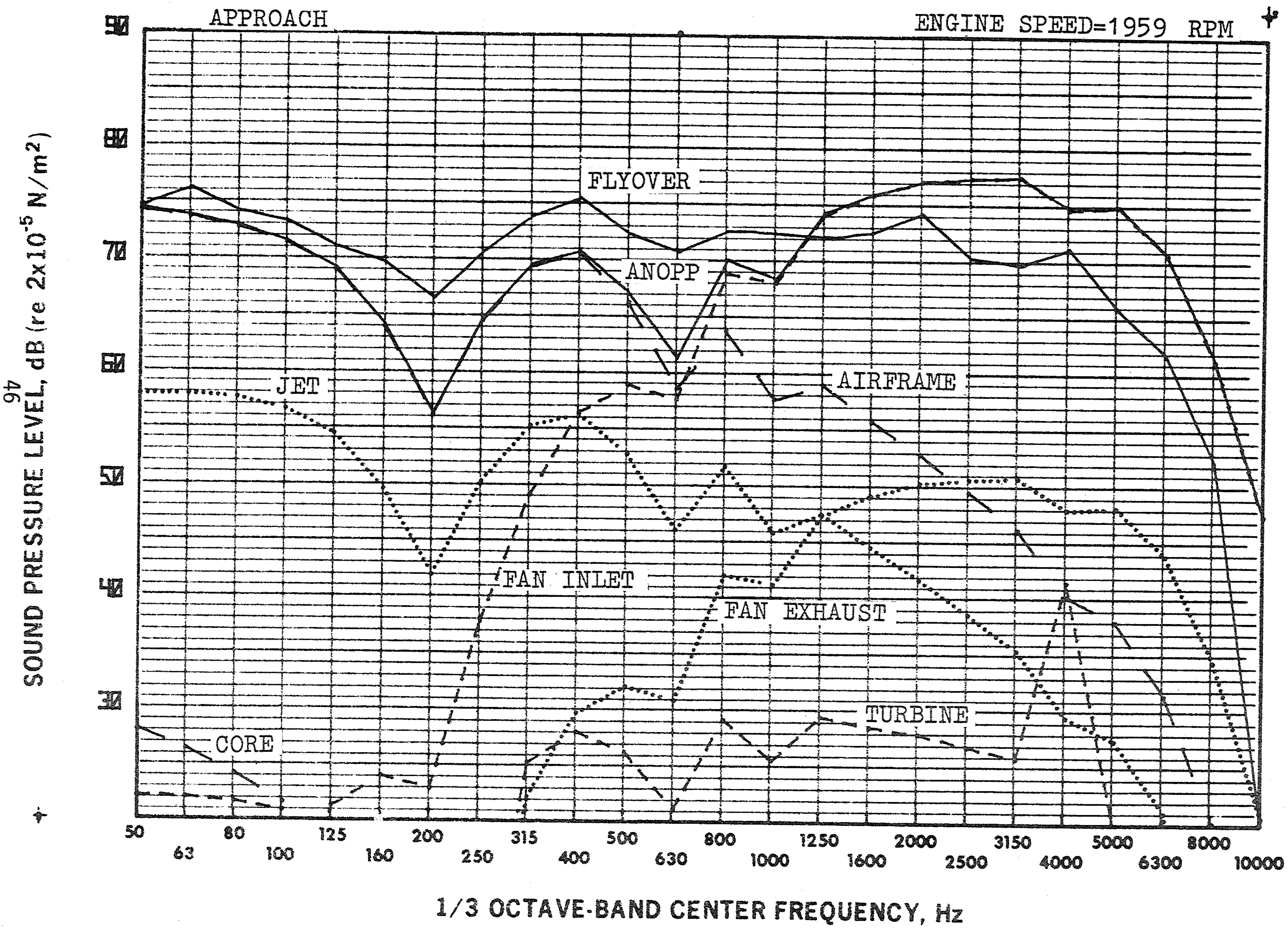


FIGURE 18. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 3, ANGLE FROM INLET=50°

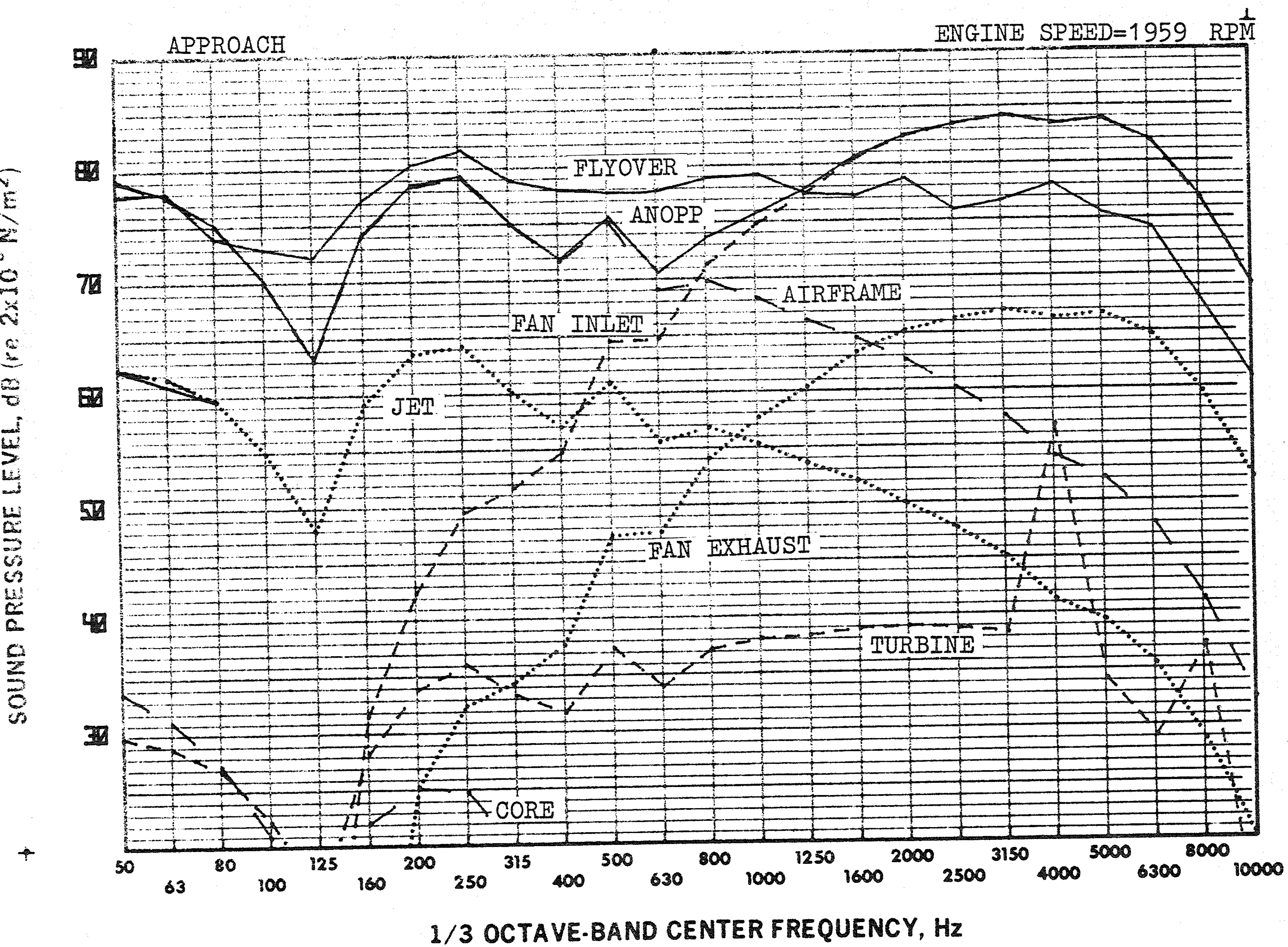


FIGURE 19. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 3, ANGLE FROM INLET=90°

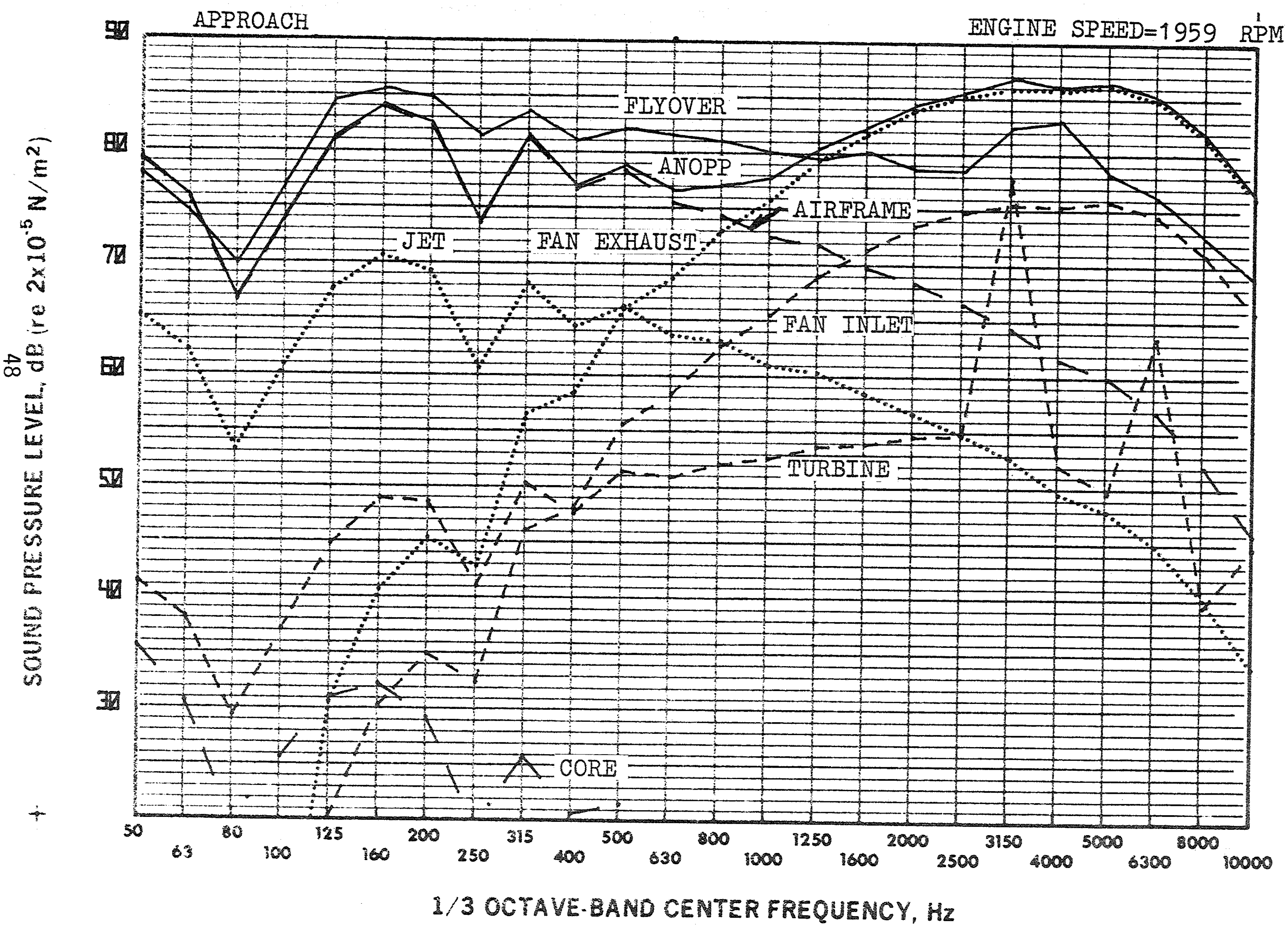


FIGURE 20. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 3, ANGLE FROM INLET=120°

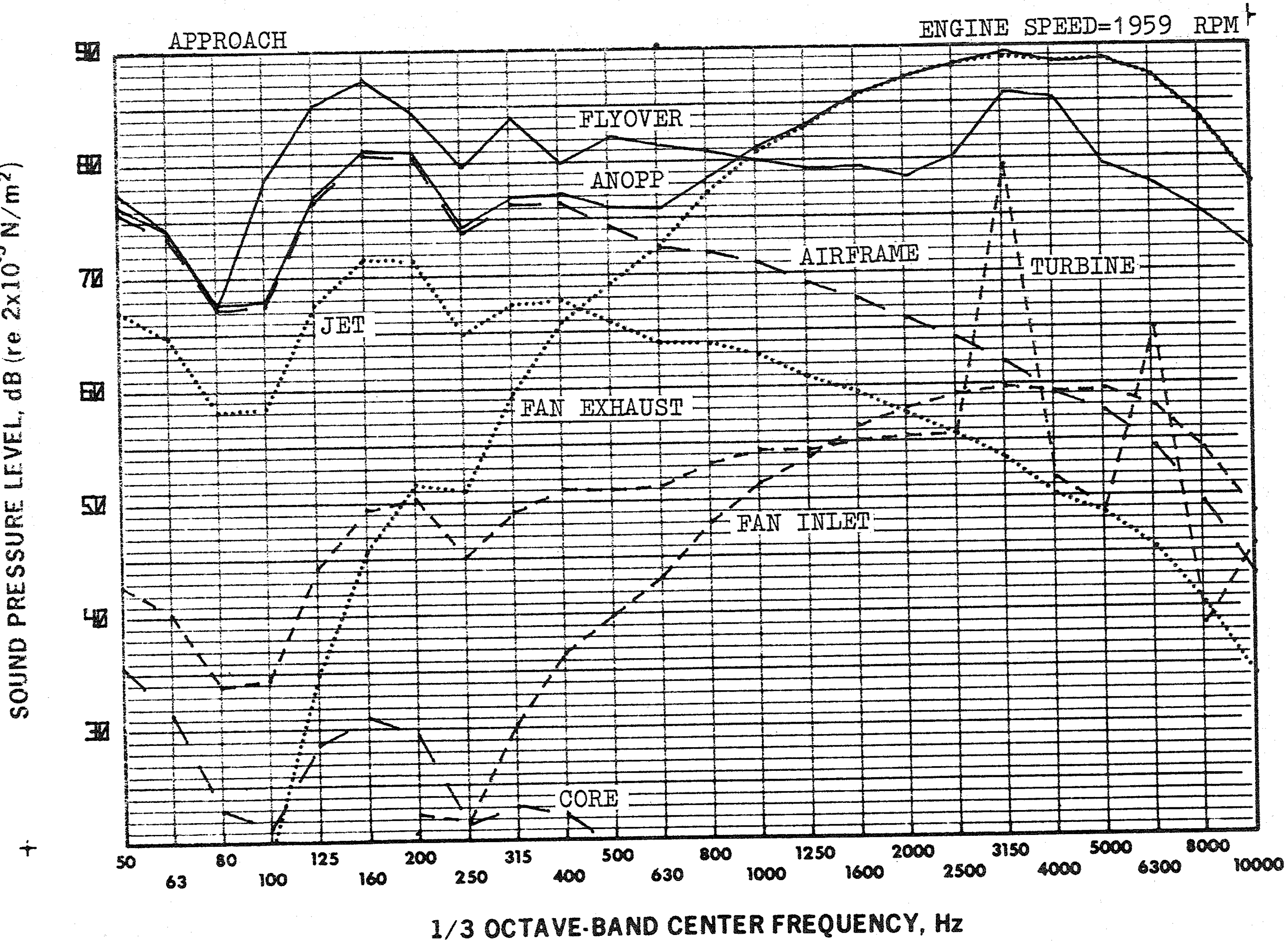
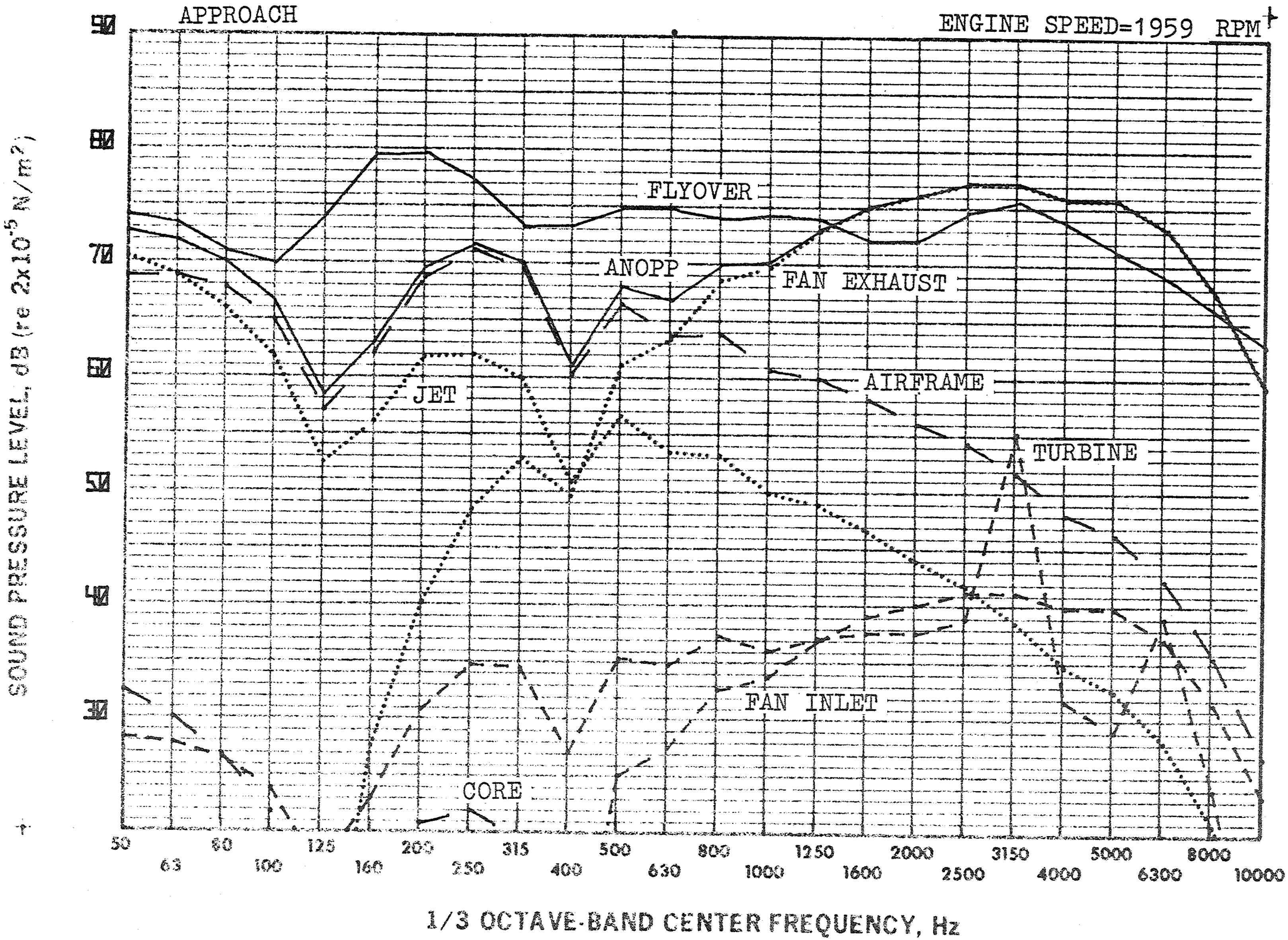


FIGURE 21. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 3, ANGLE FROM INLET=150°



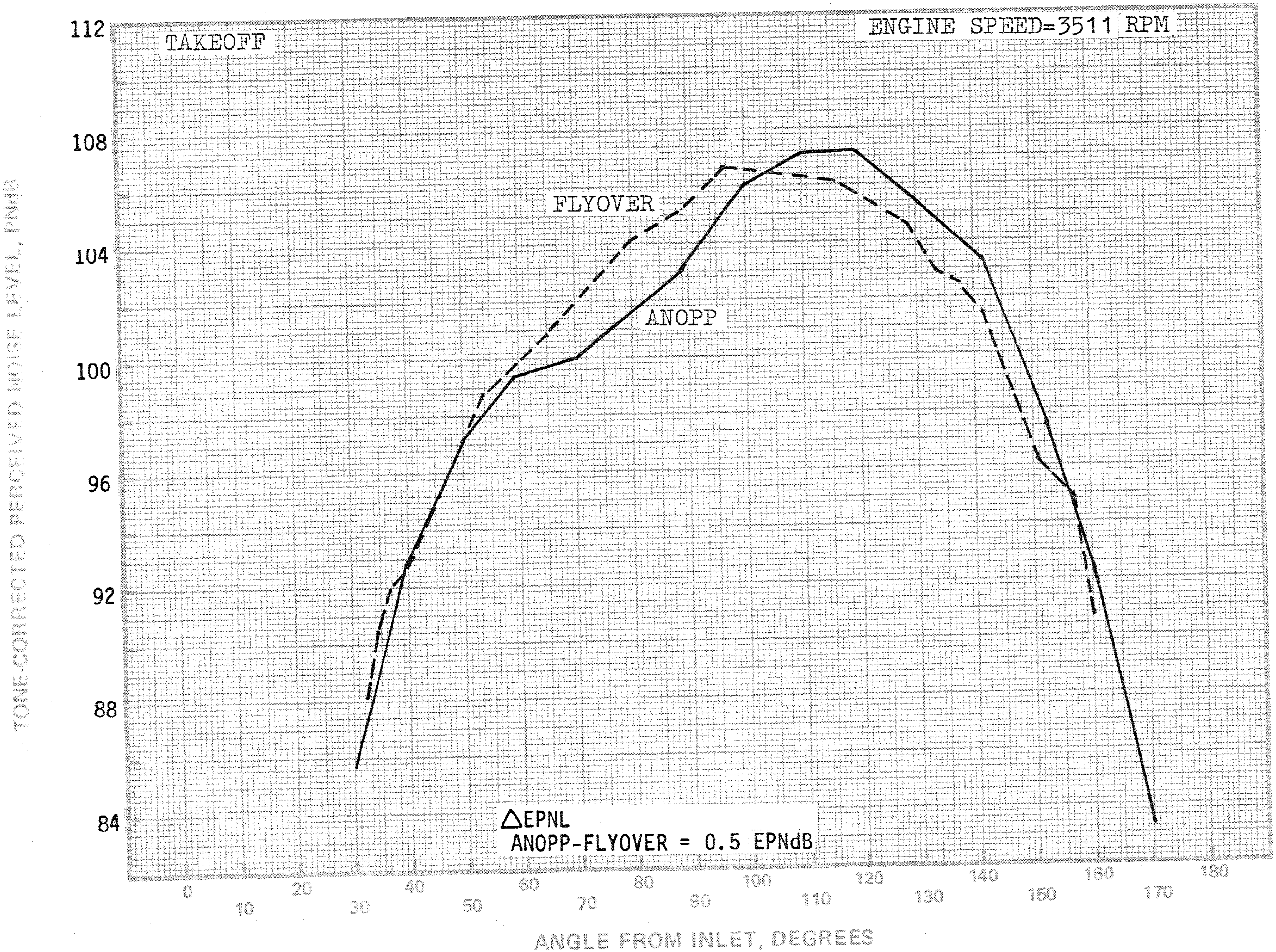


FIGURE 22. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 4

FIGURE 23. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 4, ANGLE FROM INLET=30°

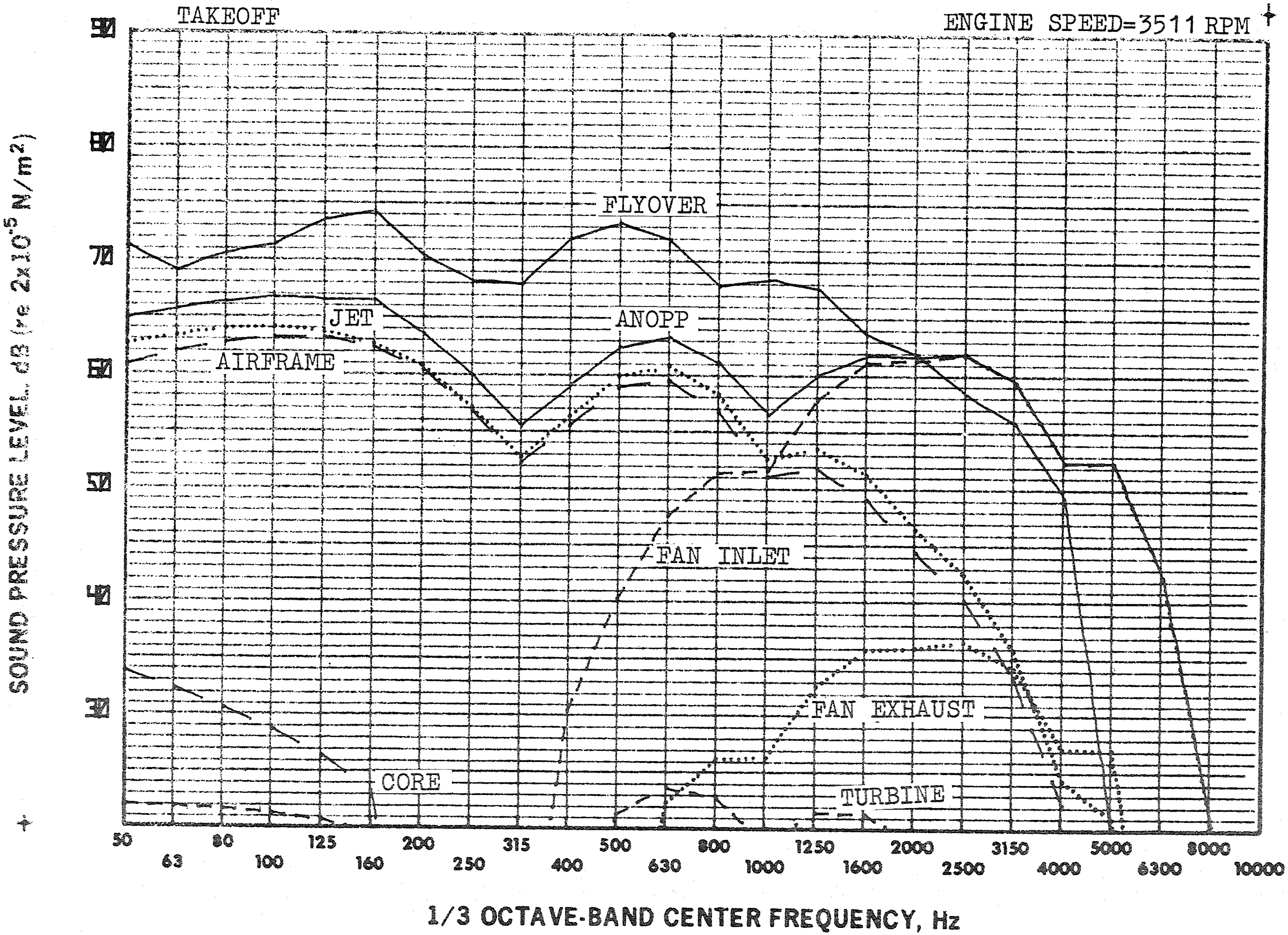


FIGURE 24. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 4, ANGLE FROM INLET=50°

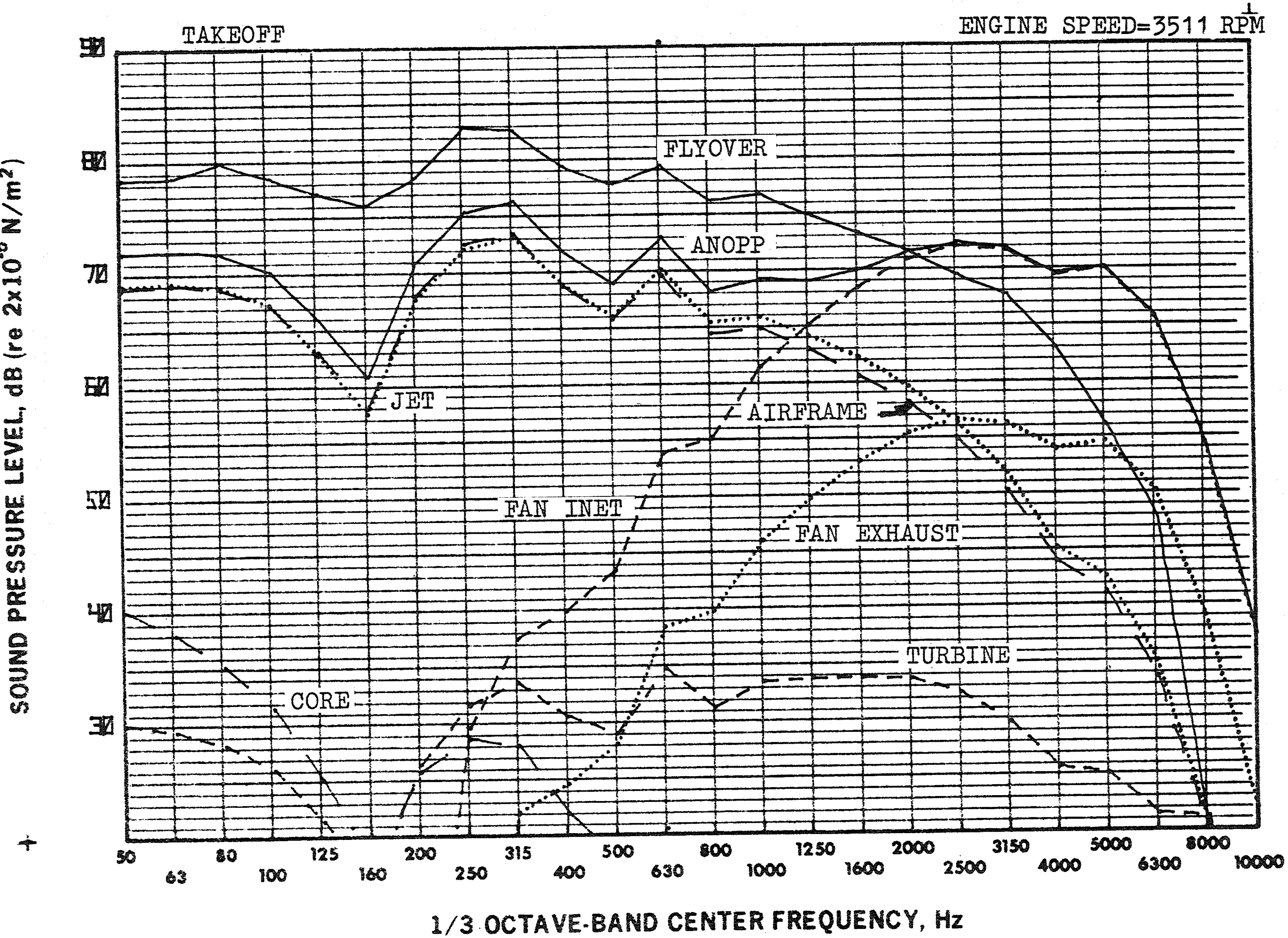


FIGURE 25. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 4, ANGLE FROM INLET=90°

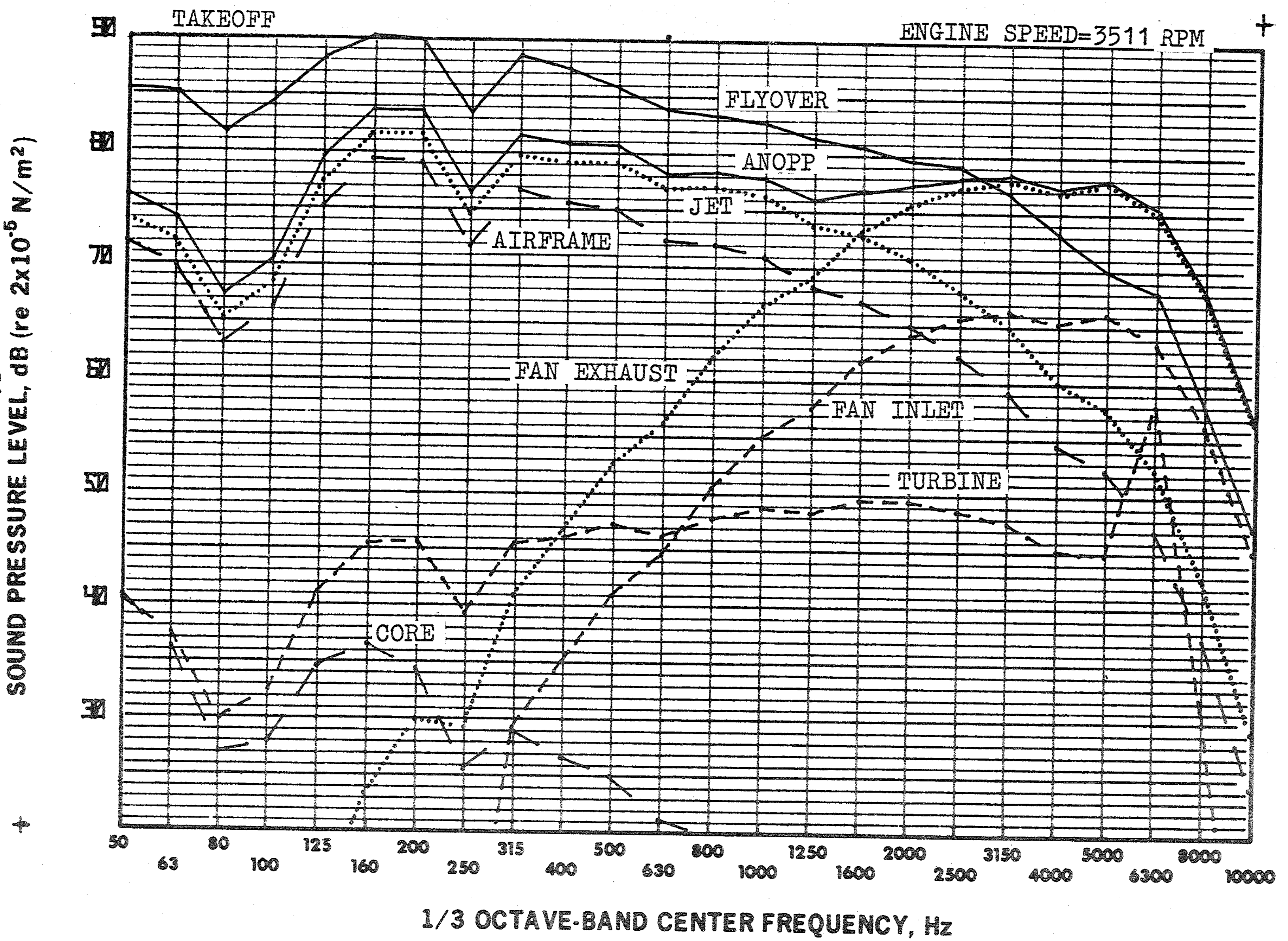


FIGURE 26. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 4, ANGLE FROM INLET=120°

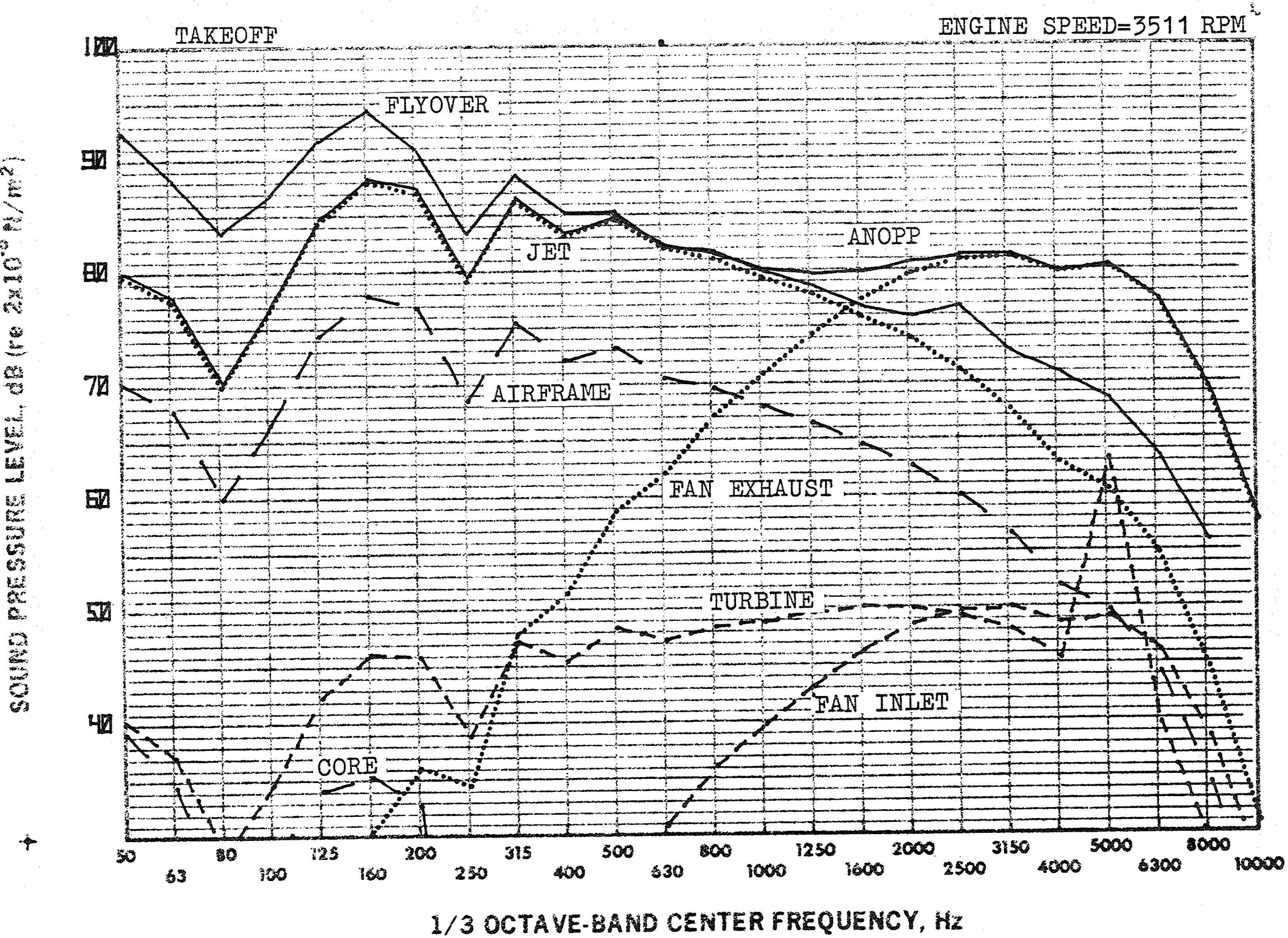
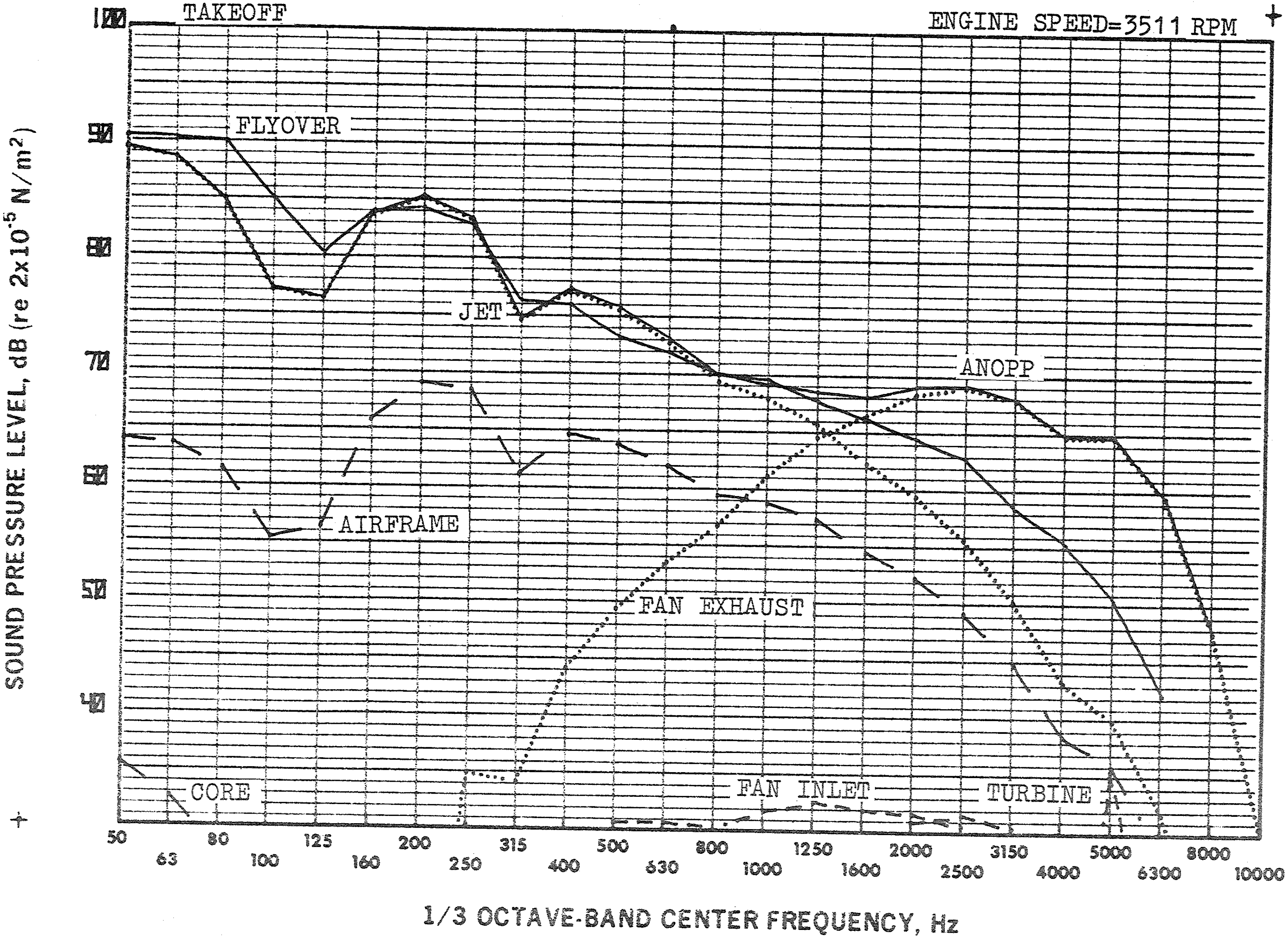


FIGURE 27. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 4, ANGLE FROM INLET=150°



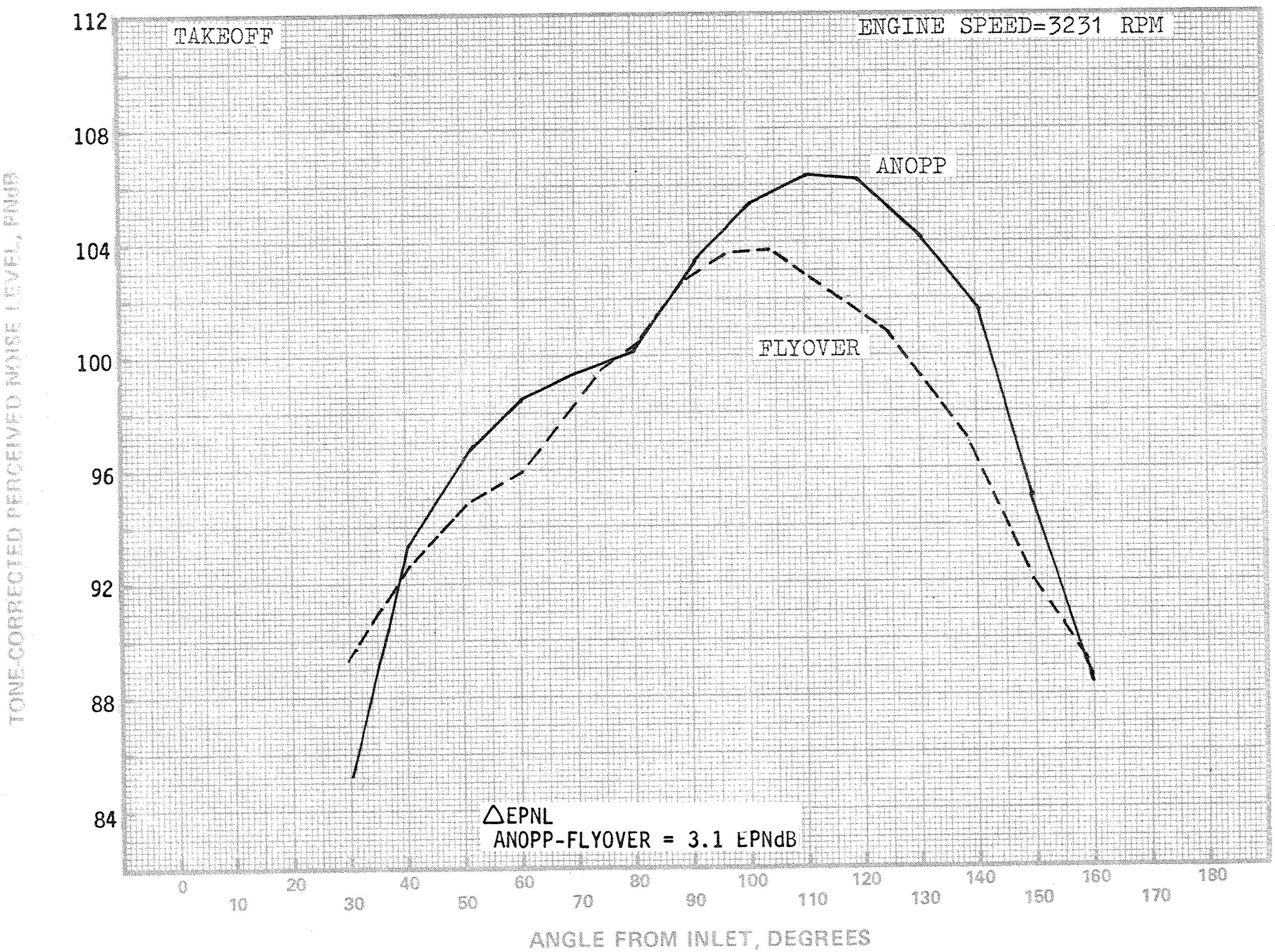


FIGURE 28. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 5

FIGURE 29. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 5, ANGLE FROM INLET=30°

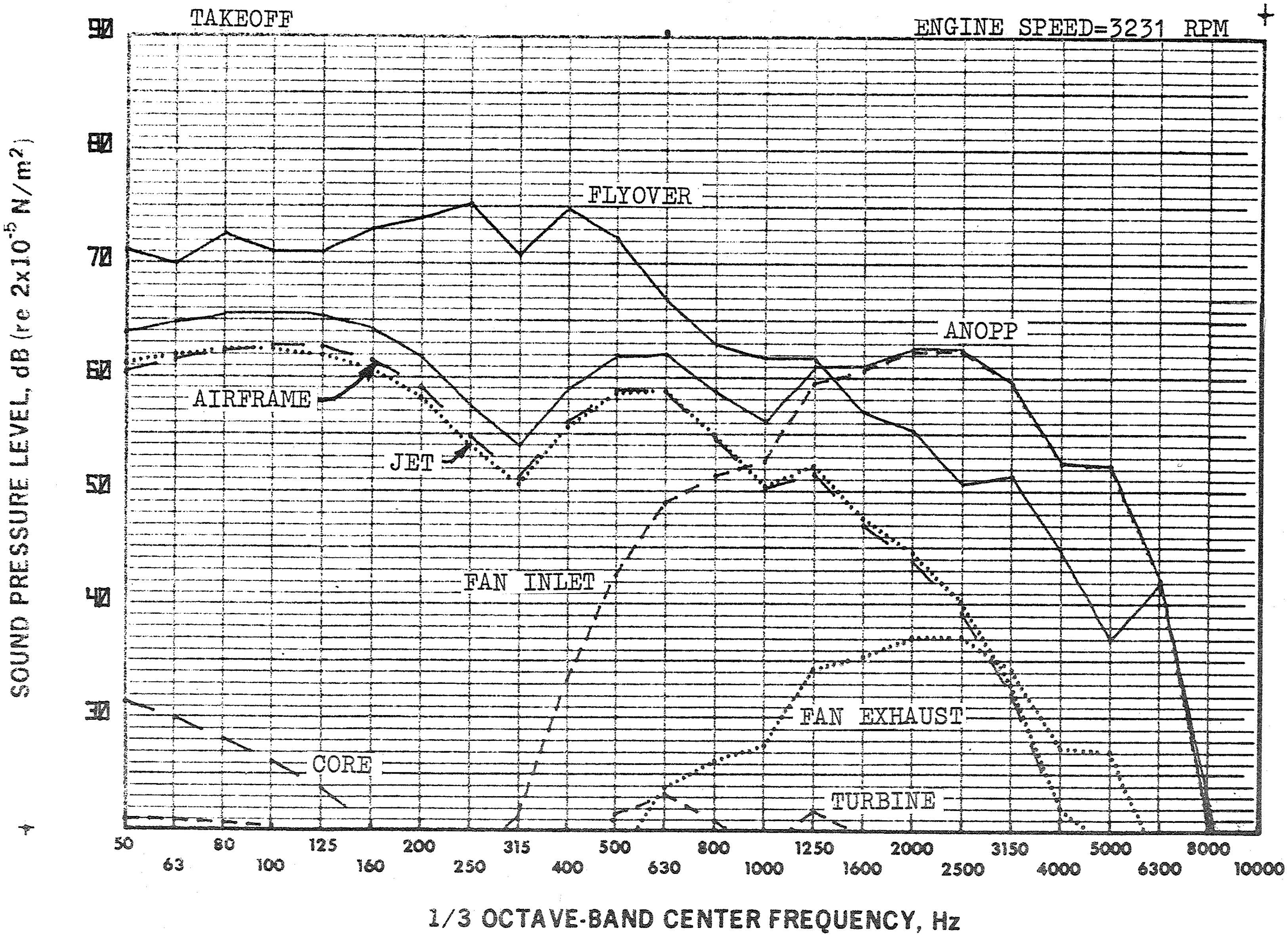


FIGURE 30. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 5, ANGLE FROM INLET=50°

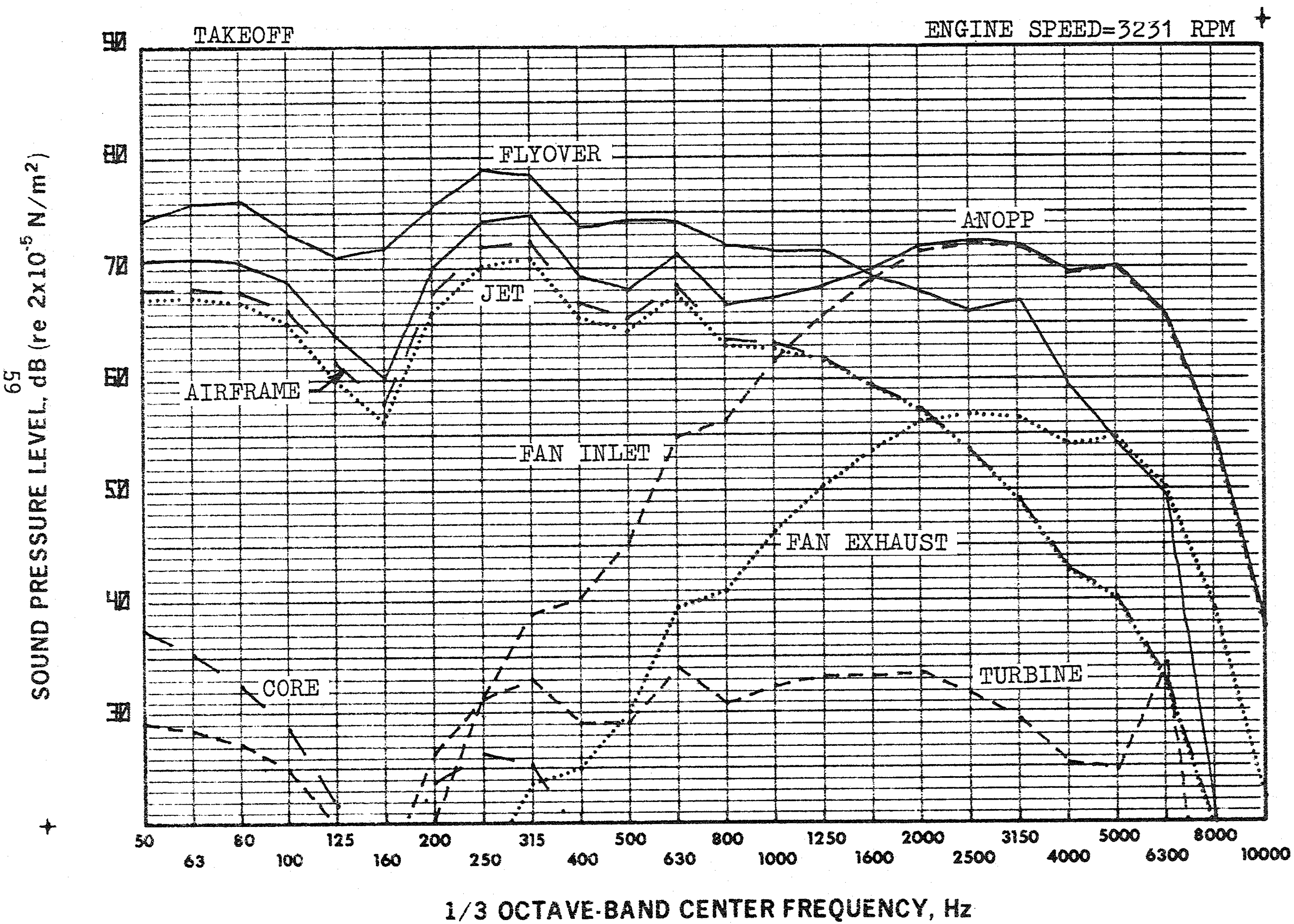


FIGURE 31. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 5, ANGLE FROM INLET=90°

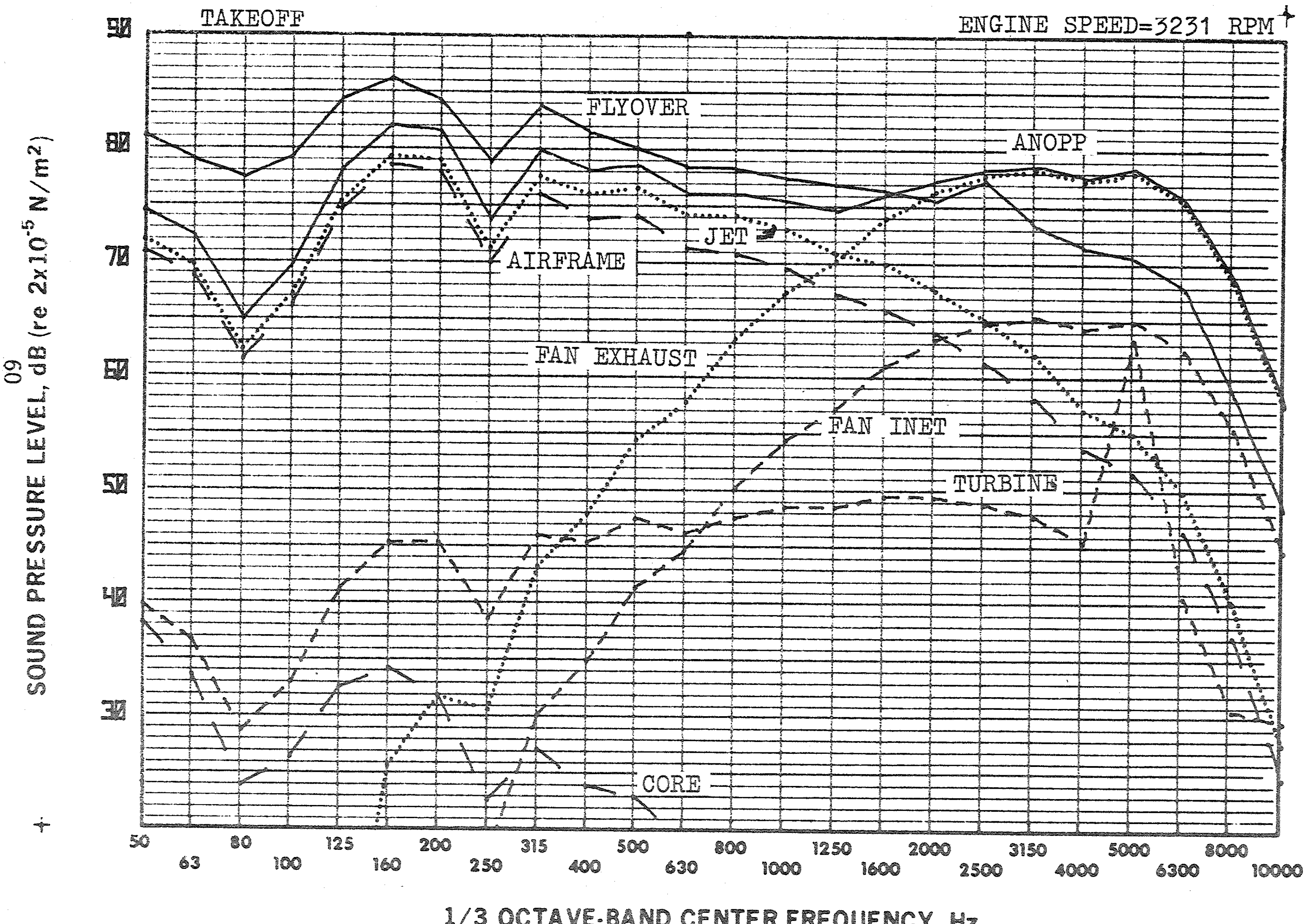


FIGURE 32. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 5, ANGLE FROM INLET=120°

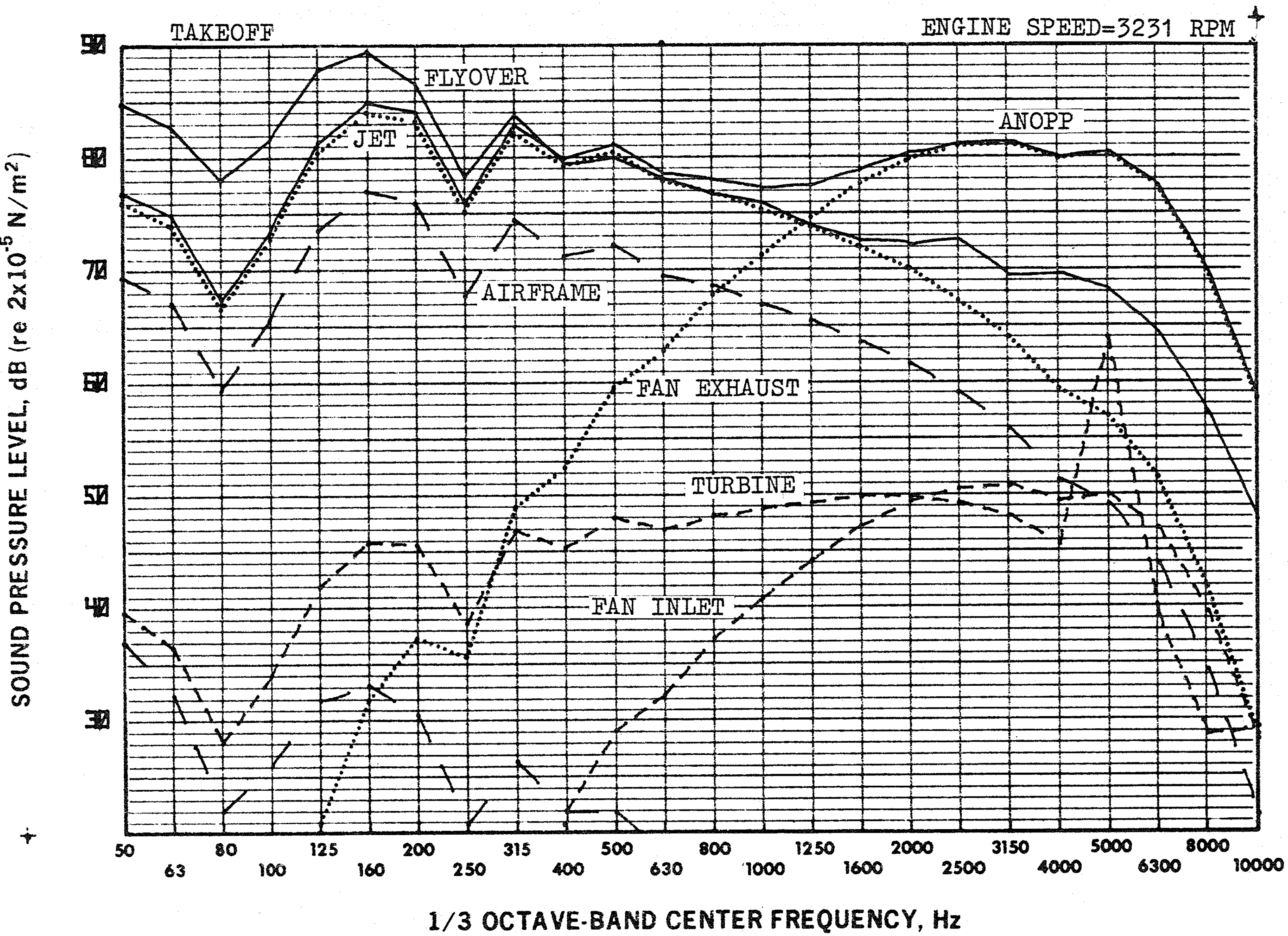
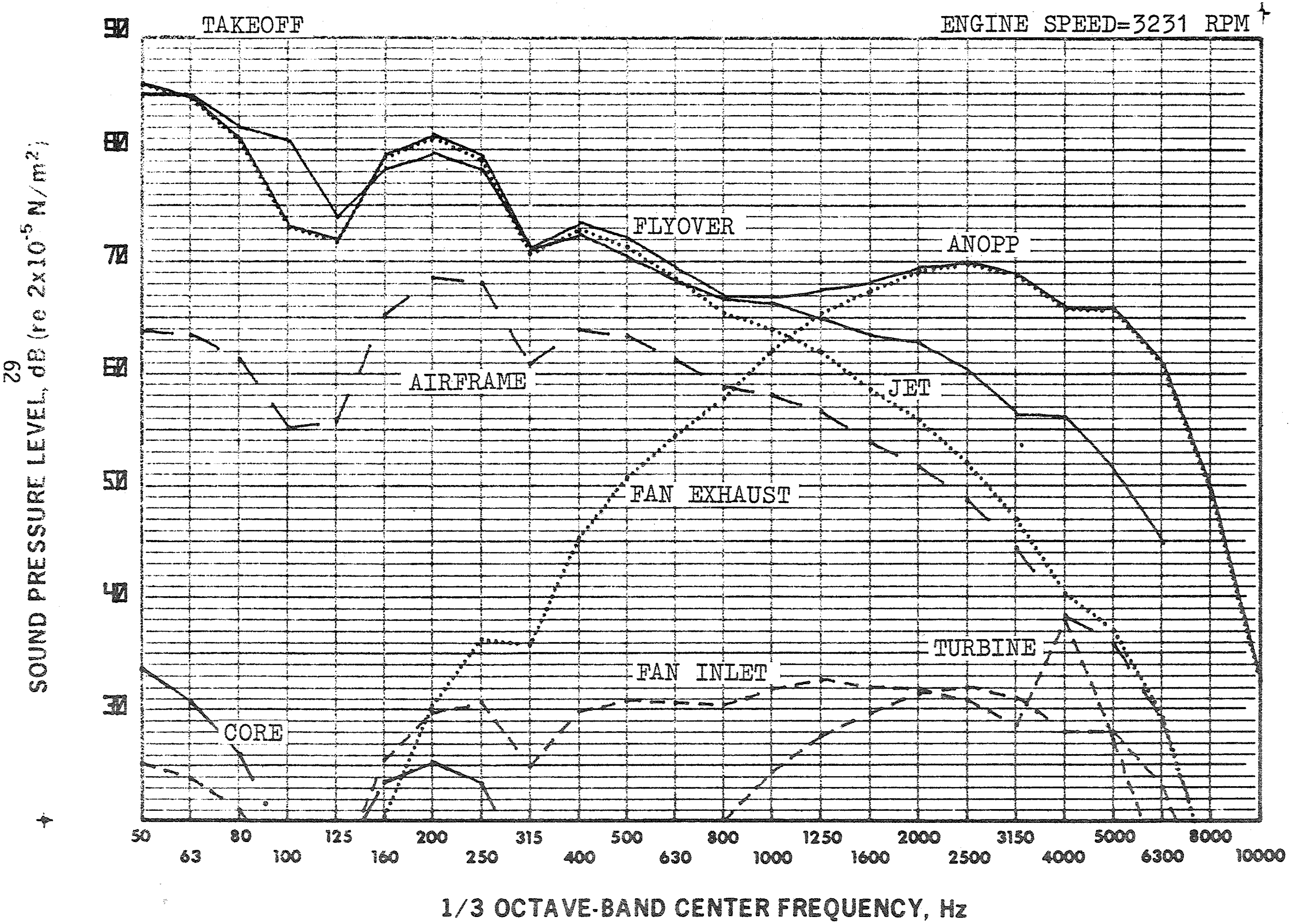


FIGURE 33. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 5, ANGLE FROM INLET=150°



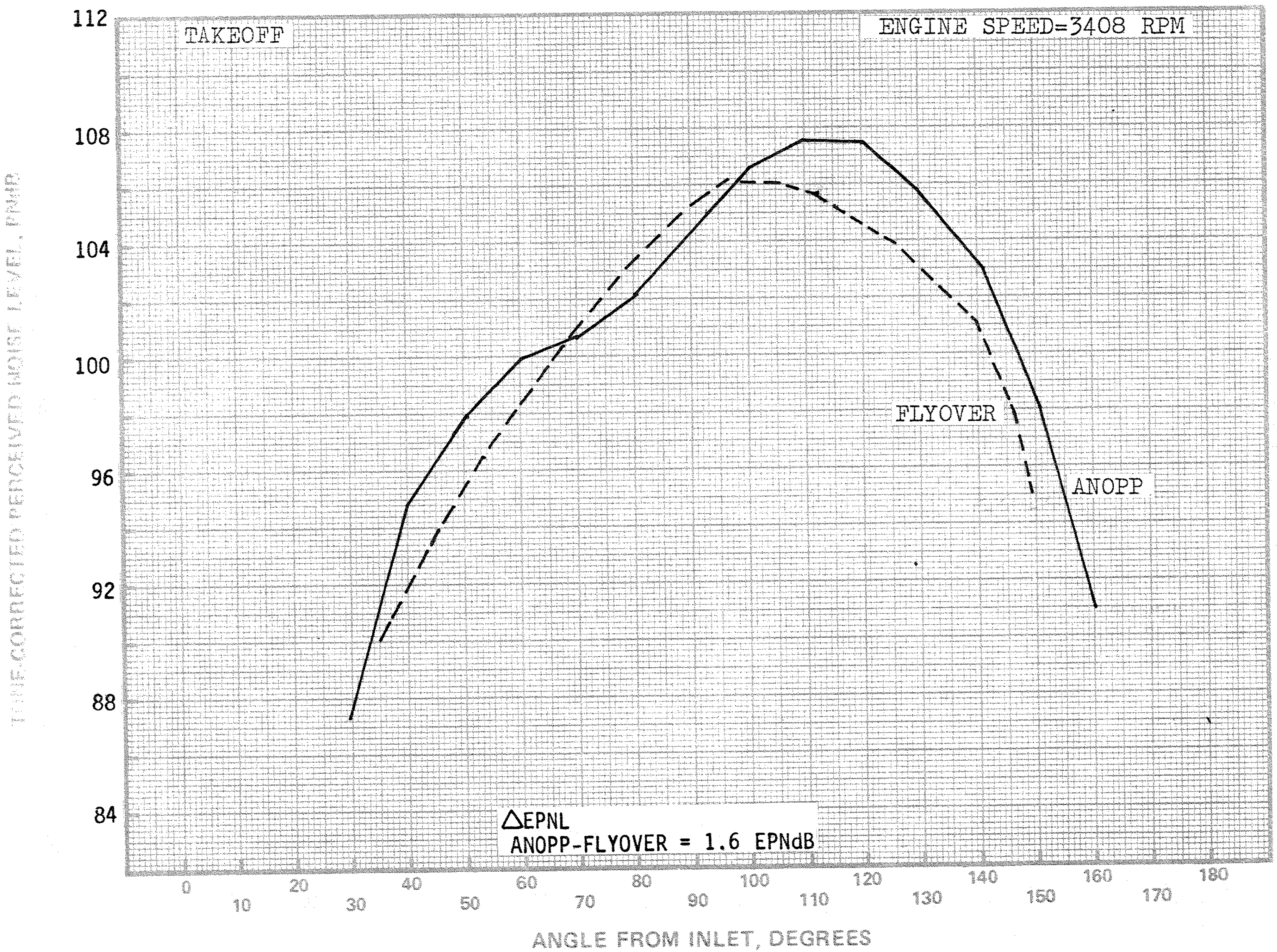


FIGURE 34. COMPARISON OF MEASURED AND PREDICTED PNLT DIRECTIVITY FOR RUN 6

FIGURE 35. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 6, ANGLE FROM INLET=50°

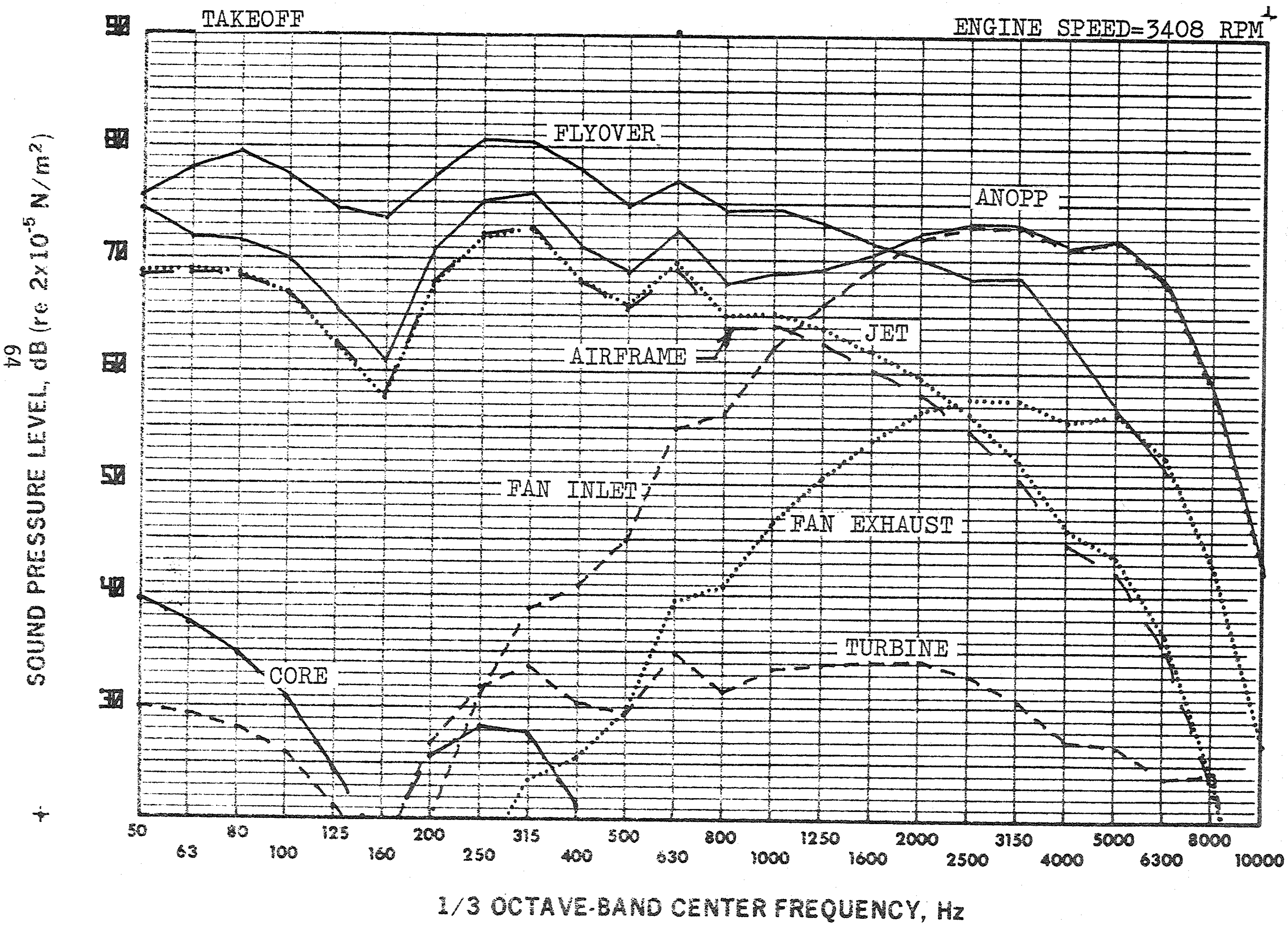


FIGURE 35. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 6, ANGLE FROM INLET=90°

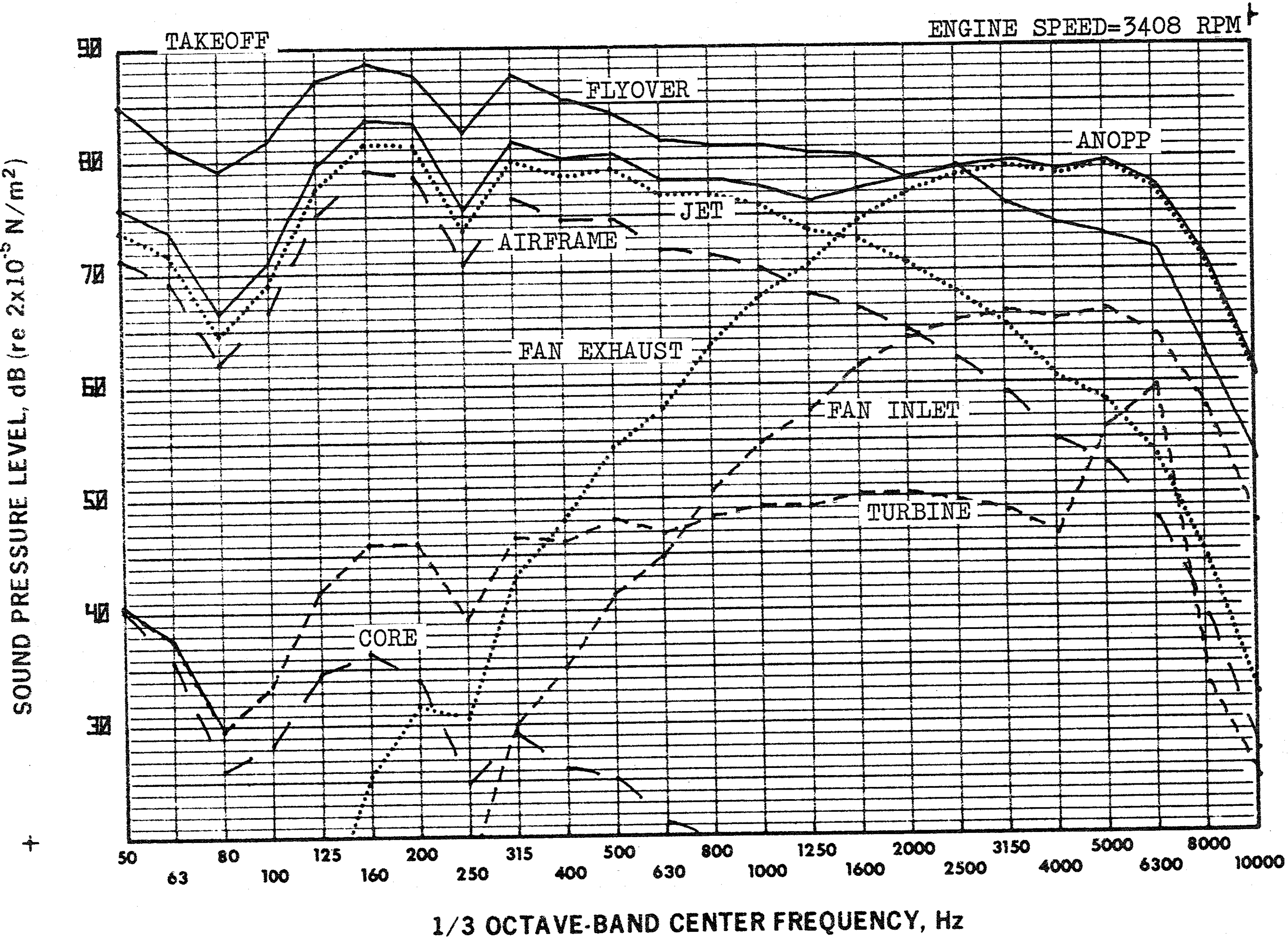


FIGURE 37. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 6, ANGLE FROM INLET=120°

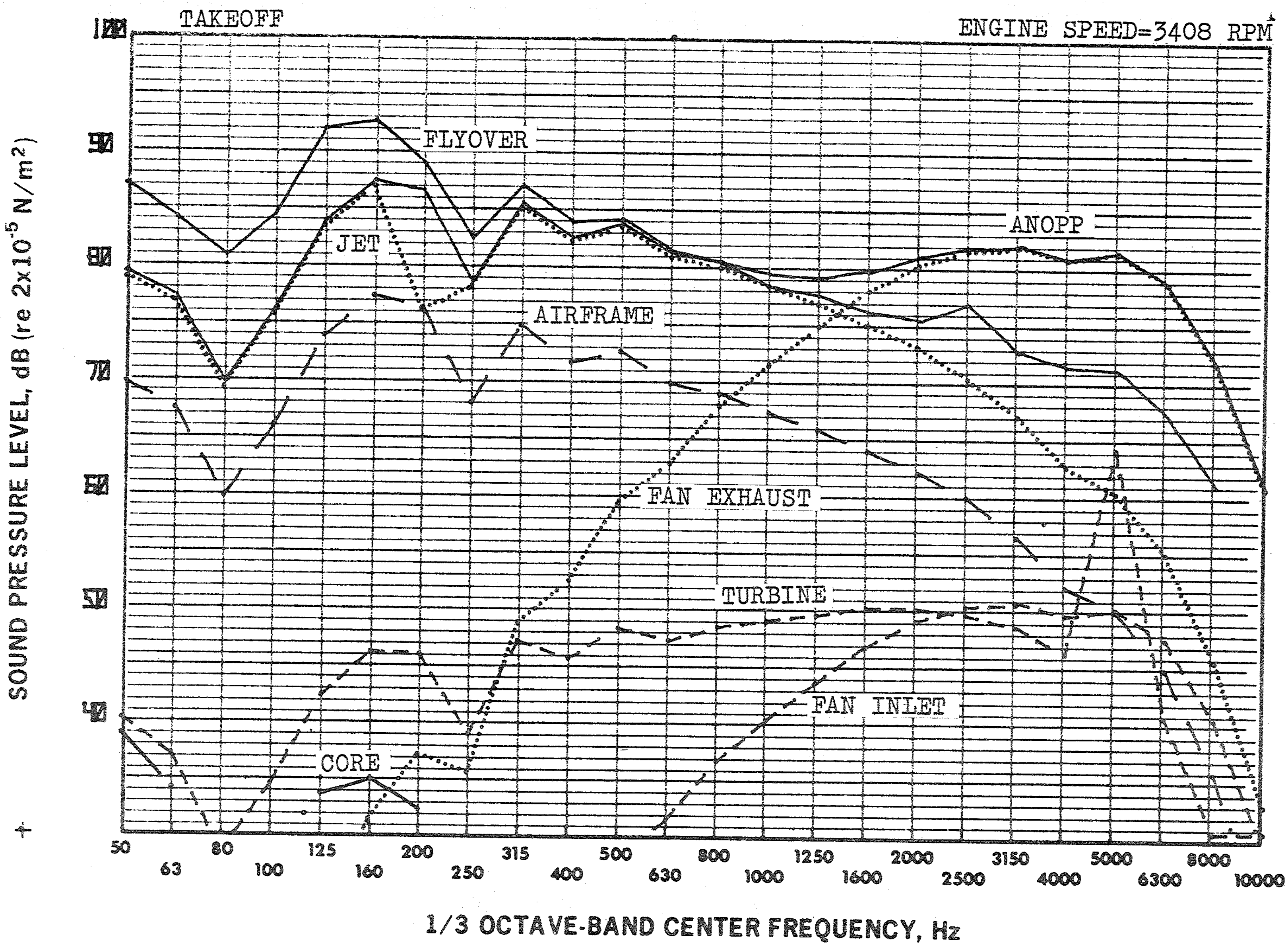
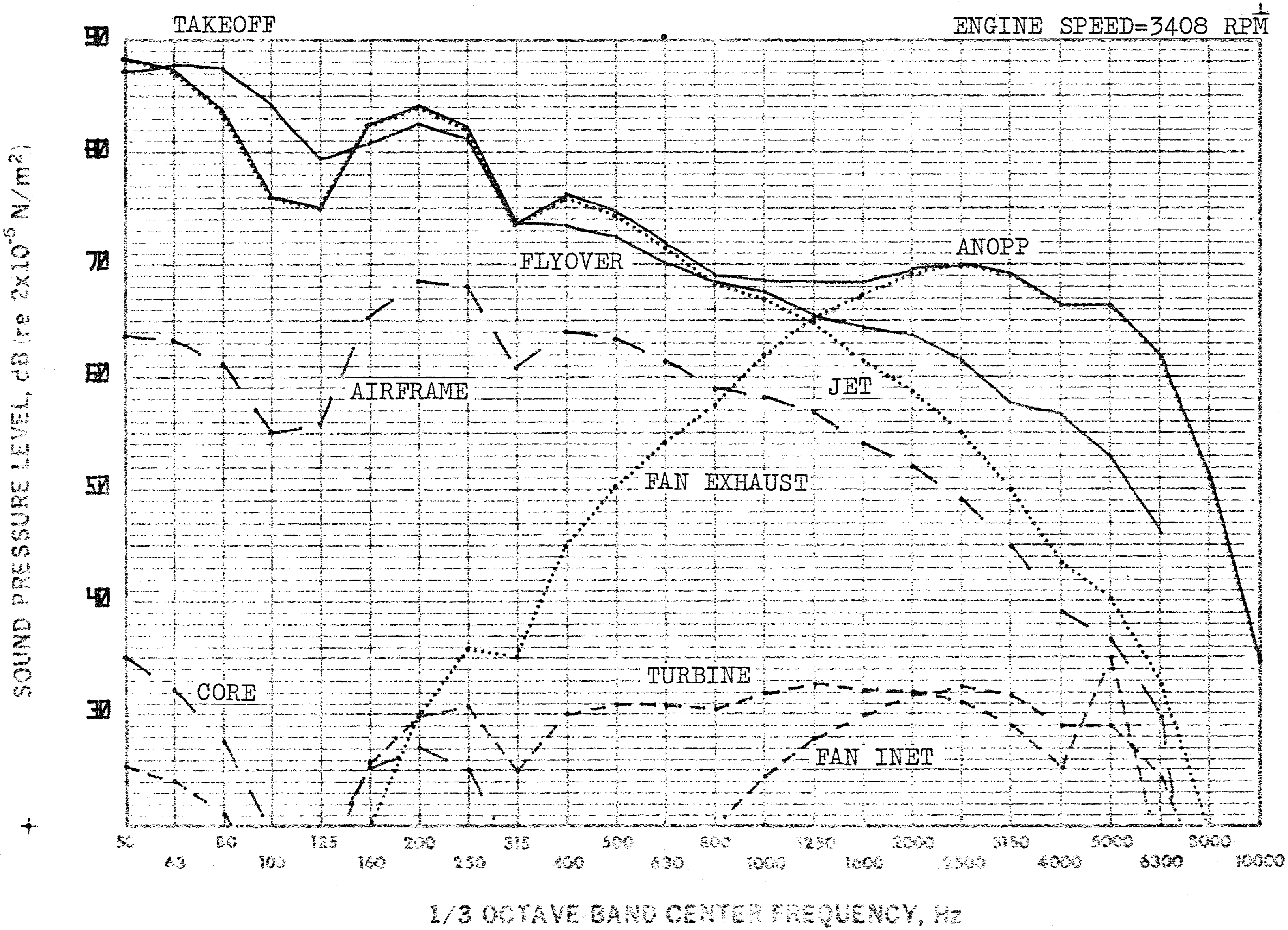


FIGURE 38. COMPARISON OF TOTAL MEASURED AND PREDICTED SPECTRA FOR RUN 6, ANGLE FROM INLET=150°



APPENDIX A

INPUT DECK LISTING FOR APPROACH RUN #1

```
$*****************************************************************************************
$*********                                                                      *********
$*********                         RUN 1 APPROACH                               *********
$*********                                                                      *********
$*****************************************************************************************
$
$     RETRIEVE JRS TABLES FROM LIBRARY FILE
$
      LOAD /ANOPDAT/ JRS $
$
      PARAM ZERO=0, ONE=1, TWO=2, THREE=3 $
      PARAM NREC=0 $
$             ELIMINATE PARAM MESSAGES
      PARAM ITHOUT=0, SHR=1.4, DELT2=0., DELT3=0.,DELT4=0.,
            DELT5=0., DELT6=0., DELT7=0., DELT8=0., DELT9=0., DELT10=0.,
            REFR=1., IGEF=1 $
      PARAM POWREF=1,OE=12,DIS=0.0,AE=1.0,AT=1.0,KE=0.0,KT=149.0 $
      PARAM YA=0.0,NINT=5,METHOD=2,CLC=.01,OH=1.0,
            SIGMA=250000.,NF=1,NNGH=2,REFL=1.0 $
      PARAM ITEWN=1,ITEMTN=1,IEVIN=1,ITYPW=1,RREF=1.0 $


            ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)
      PARAM RO1=4.6,R=1.0,DELT1=0.,FLTNUM=6HFLT001,PREF=2.E-5 $
      CREATE EXFAN,TOT1,TOT2,TOT3,TOT4,TOT5,TOT6 $
```

```
$
$              CREATE PROCEDURE FOR MOVING AND PROPAGATING THE SOURCE
$

      CREATE PROC $

      UPDATE NEWUFPROC, SOURCE** $

*ADDR OLDM**, NEWM=MOVE, MNR=200 $
$
$              CALCULATE TIME DEPENDENT GEOMETRY
$
      PARAM ALT=ZA $
      EXECUTE TDG $
$
$              CALCULATE AIRFRAME NOISE AND PROPAGATE TO OBSERVER
$
      EXECUTE AFM $
      EXECUTE SUM DU1=AFM, DM1=HSP, DU11=SCRATCH, NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SCA=NOISUM, IPRINT=THREE, OBSPECT=TOT1 $
$
$              CALCULATE FAN INLET NOISE AND PROPAGATE TO OBSERVER
$
      PARAM AREA=4.3,DIAM=2.34,DOTM=556.6,IGV=0,IDBB=0,IDRS=0,INBB=1,INCT=0,
            INDIS=0, INRS=0 $
      EXECUTE FAN VO=V $
      EXECUTE SUM DU1=FANOUT,DM1=HSP,DU11=SCRATCH,NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SCA=NOISUM, IPRINT=THREE, OBSPECT=TOT2 $
$
$              CALCULATE FAN EXHAUST NOISE AND PROPAGATE TO OBSERVER
$
      PARAM AREA=1.74,DIAM=1.49,DOTM=475.0,IDBB=1,IDRS=0,IGV=0,INBB=0,
            INCT=0, INDIS=0, INRS=0 $
      EXECUTE FAN VO=V,FANOUT=EXFAN $
      EXECUTE SUM DU1=EXFAN,DM1=HSP,DU11=SCRATCH,NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SCA=NOISUM, IPRINT=THREE, OBSPECT=TOT3 $
$



              ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)
$              CALCULATE JET NOISE AND PROPAGATE TO OBSERVER
$
      EXECUTE JRSJET VO=V $
      EXECUTE SUM DU1=JRSOUT,DM1=HSP,DU11=SCRATCH,NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SCA=NOISUM, IPRINT=THREE, OBSPECT=TOT4 $
$
$              CALCULATE CORE NOISE AND PROPAGATE TO OBSERVER
$
```

```
      PARAM DUTM=83.46 $
      EXECUTE COR VARV $
      EXECUTE SUM DU1=COROUT,DM1=MSP,DU11=SCRATCH,NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SLA=NOISUM, IPRINT=THREE, OBSPECT=TOT5 $
$
$             CALCULATE TURBINE NOISE AND PROPAGATE TO OBSERVER
$
      EXECUTE TUR $
      EXECUTE SUM DU1=TUROUT,DM1=MSP,DU11=SCRATCH,NSUM=ONE,IPRINT=ZERO $
      EXECUTE ASP SLA=NOISUM, IPRINT=THREE, OBSPECT=TOT6 $
$
$             CALCULATE TOTAL NOISE AND PROPAGATE TO OBSERVER
      PARAM NSUM = 6 $
$
      EXECUTE SUM DU1=AFM, DU2=FANOUT, DU3=EXFAN, DU4=JRSOUT, DU5=COROUT,
                  DU6=TUROUT, DM1=MSP, DM2=MSP, DM3=MSP, DM4=MSP, DM5=MSP,
                  DM6=MSP, DU11=SCRATCH $
      EXECUTE ASP SLA=NOISUM, IPRINT=THREE $
      PARAM NREC = NREC + 1 $
END* $
$

$             CREATE FREQUENCY,THETA,AND PHI DATA MEMBERS

$


      CREATE SFIELD $

      UPDATE NEWU=SFIELD, SOURCE=* $

-ADDR OLDM=*, NEWM=FREQ, FORMAT=4H*RS$, MNR=1 $
50.,63.,80.,100.,125.,160.,200.,250.,315.,400.,500.,630.,800.,1000.,1250.,
1600.,2000.,2500.,3150.,4000.,5000.,6300.,8000.,10000. $
-ADDR NEWM=THETA, OLDM=*, FORMAT=4H*RS$ MNR=1 $
10.,20.,30.,40.,50.,60.,70.,80.,90.,100.,110.,120.,130.,140.,150.,160.,170. $



                 ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)

-ADDR OLDM=*, NEWM=PHI, FORMAT=4H*RS$, MNR=1 $
0. $
END* $
$

$             CREATE INPUT FOR ATMOSPHERIC MODEL

$


      CREATE ATMO $

      UPDATE NEWU=ATMO, SOURCE=* $
```

```
*ADDR OLDM=*, NEWM=IN, FORMAT=0, MNR=100 $
100.0,10,325.0,6,1,1,6 $
0.0,285.,0.5,40.0 $
100.0,285.1,1.0,46.0 $
200.0,285.1,2.6,61.0 $
300.0,285.1,3.1,63.0 $
400.0,285.1,3.6,40.0 $
500.0,285.1,4.6,33.0 $
END* $
      TABLE ATMO(MOLABSOR) 1 SOURCE=* $

INT=1
IND1=RS,59,1,1,0.,.25,.50,.60,.70,.80,.90,1.0,1.1,1.2,1.3,
      1.5,1.7,2.0,2.3,2.5,2.8,3.0,3.3,3.6,4.15,4.45,4.8,5.25,
      5.70,6.05,6.50,7.0,10.0
DEP=RS,0.,.315,.70,.840,.930,.975,.996,1.0,.970,.900,.800,
     .750,.670,.570,.495,.450,.400,.370,.330,.300,.260,.245,
     .230,.220,.210,.205,.200,.200,.200
END* $
$

$              CREATE OBSERVER COORDINATES FOR OUTPUT DESIRED

$

      CREATE OBSERV $

      UPDATE NEWU=OBSERV, SOURCE=* $

*ADDR NEWM=COORD, OLDM=*, FORMAT=4H3R83, MNR=3 $



                 ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)

0.,0.,0. $
END* $
$

$              CREATE OUTPUT AND SCRATCH DATA UNITS

$

      CREATE OBSPECT,OBSLEV $

      CREATE NOISUM,SCRATCH,DU11,FANOUT,JRBOUT,COROUT,TUROUT,AFM $

$

$              AIRFRAME NOISE PARAMETERS

$
```

```
PARAM AW=338.9,BW=50.3,AM=101.3,BM=21.6,AV=56.2,BV=7.3,V=84.22,
      N=1,AF=62.0,CF=4.7,GAMMA=53.4,TDMG=1.32,CMG=1.92,NMGW=4,

      NMG=3,TDNG=1.02,CNG=1.79,NNG=1 $

PARAM CA=338.54,RHOA=1.19280,MUA=0.000017746,ITEFN=1,ILESN=1,
      IMGN=1,INGN=1,IOUT=3 $

$
$          FAN NOISE PARAMETERS (COMMON TO INLET AND EXHAUST)
$

PARAM DELTA=6.8,DELT=50.0,DM=1.36,NB=46,NV=90,
      OMEGA=42.17,RSS=26.0,TA=285.1,NENG=3 $

$
$          JET NOISE PARAMETERS
$

PARAM IOPT=5,A1=0.585,DE1=0.863,DM1=0.863,V1=293.9,RHO1=0.491,
      T1=760.0,A2=1.79,V2=229.1,RHO2=1.207,T2=310.7 $



                ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)
$
$          CORE NOISE PARAMETERS
$

PARAM T3=677.70,T4=1232.3,P3=10113.30,PA=97620.05 $

$          TURBINE NOISE PARAMETERS
$

PARAM NB=102,SRS=1.88,CL=552.7,VTR=149.30,MA=0.249,ITOPT=2 $
$
$          BEGIN FUNCTIONAL MODULE EXECUTION
$
```

```
PARAM IPRINT=0 $
EXECUTE ATMO $          BUILD ATMOSPHERIC DATA FUNCTIONS
EXECUTE ATT $           BUILD ATTENUATION DATA FUNCTIONS
PARAM IPRINT=3 $
$         PARAMETER VALUES FOR THETA=  10 DEGREES
PARAM XA=-2011.58,ZA=197.10,T=-25.90 $
CALL PROC(MOVE) $
SETSYS JECHO=.FALSE. $
PARAM IPRINT=0 $
$         PARAMETER VALUES FOR THETA=  20 DEGREES


              ANOPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)
PARAM XA=-482.0, ZA=138.32, T=-5.72 $
CALL PROC(MOVE) $
$         PARAMETER VALUES FOR THETA=  30 DEGREES
PARAM XA=-246.88, ZA=129.29, T=-2.93 $
CALL PROC(MOVE) $
$         PARAMETER VALUES FOR THETA=  40 DEGREES
PARAM XA=-166.41, ZA=126.19, T=-1.98 $
CALL PROC(MOVE) $
$         PARAMETER VALUES FOR THETA=  50 DEGREES
PARAM XA=-115.80, ZA=124.25, T=-1.58 $
CALL PROC(MOVE) $
$         PARAMETER VALUES FOR THETA=  60 DEGREES
PARAM XA=-81.58, ZA=122.93, T=-0.97 $
```

```
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 70 DEGREES
PARAM XA=-54.25, ZA=121.88, T=0.64 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 80 DEGREES
PARAM XA=-31.10, ZA=120.99, T=0.57 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 90 DEGREES
```

ANUPP INPUT STREAM EDIT PHASE (PRIMARY EDIT)

```
PARAM XA=-10.00, ZA=120.18, T=0.12 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 100 DEGREES
PARAM XA=10.97, ZA=119.38, T=0.13 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 110 DEGREES
PARAM XA=32.94, ZA=118.53, T=0.34 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 120 DEGREES
PARAM XA=55.47, ZA=117.67, T=0.60 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 130 DEGREES
PARAM XA=82.29, ZA=116.64, T=0.98 $
CALL PROC(MOVE) $
$          PARAMETER VALUES FOR THETA= 140 DEGREES
```

```
        PARAM XA=115,82, ZA=115,35, T=1,38 $
        CALL PROC(MOVE) $
$               PARAMETER VALUES FOR THETA= 150 DEGREES
        PARAM XA=165,10, ZA=113,46, T=1,90 $
        CALL PROC(MOVE) $
$               PARAMETER VALUES FOR THETA= 160 DEGREES
        PARAM XA=244,20, ZA=110,42, T=2,90 $
        CALL PROC(MOVE) $
$               PARAMETER VALUES FOR THETA= 170 DEGREES
        PARAM XA=408,30, ZA=104,11, T=4,84 $
        CALL PROC(MOVE) $
        PARAM IPRINT=3 $
$
$               CALCULATE THE TOTAL EPNL FOR THE OBSERVER
$
        EXECUTE SR1 NT=NREC, OBSPECT=TOT1 $
        EXECUTE SR1 NT=NREC, OBSPECT=TOT2 $
        EXECUTE SR1 NT=NREC, OBSPECT=TOT3 $
        EXECUTE SR1 NT=NREC, OBSPECT=TOT4 $
        EXECUTE SR1 NT=NREC, OBSPECT=TOT5 $
        EXECUTE SR1 NT=NREC, OBSPECT=TOT6 $
        EXECUTE SR1 NT=NREC $
$
        GOTO STOP $
        PROCEED $
        UPLIST $
        CATALOG $
```

APPENDIX B

IMPEDANCE VALUES FOR DC-10-40/JT9D-59A

APPROACH AND TAKEOFF FLYOVER RUNS

FAN INLET — NOSE COWL FORWARD (WING ENGINES)*

1/3-OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.8	-56.9	1.3	-56.9
63		-45.2		-45.2
80		-35.9		-35.9
100		-28.5		-28.5
125		-22.6		-22.6
160		-17.9		-17.9
200		-14.2		-14.2
250		-11.3		-11.3
315		- 8.9		- 8.9
400		- 7.1		- 7.1
500		- 5.6		- 5.6
630		- 4.4		- 4.4
800		- 3.4		- 3.4
1,000		- 2.6		- 2.6
1,250		- 2.0		- 2.0
1,600		- 1.5		- 1.5
2,000		- 1.0		- 1.0
2,500		- 0.6		- 0.6
3,150		- 0.3		- 0.3
4,000		1.4		0.0
5,000		0.4		0.4
6,300		1.1		1.1
8,000		3.1		3.1
10,000		- 2.1		- 2.0

*EFFECTIVE TREATMENT LENGTH = 0.46 m, DIAMETER d = 2.34 m

FAN INLET — NOSE COWL AFT (WING ENGINES)*

1/3-OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.4	-21.3	0.7	-21.3
63		-16.9		-16.9
80		-13.4		-13.4
100		-10.6		-10.6
125		- 8.4		- 8.4
160		- 6.7		- 6.7
200		- 5.3		- 5.3
250		- 4.1		- 4.1
315		- 3.2		- 3.2
400		- 2.5		- 2.5
500		- 1.9		- 1.9
630		- 1.4		- 1.4
800		- 1.0		- 1.0
1,000		- 0.7		- 0.7
1,250		- 0.3		- 0.3
1,600		- 0.0		- 0.0
2,000		0.3		0.3
2,500		1.0		1.0
3.150		5.2		5.3
4,000		- 1.4		- 1.4
5,000		0.1		0.1
6,300		2.5		2.5
8,000		- 0.2		- 0.2
10,000		10.9		11.6

*EFFECTIVE TREATMENT LENGTH = 0.72 m, DIAMETER d = 2.34 m

FAN INLET — NOSE COWL FORWARD (TAIL ENGINE)*

1/3 OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.9	-42.8	1.5	-42.8
63	↕	-33.9	↕	-33.9
80		-26.9		-26.9
100		-21.4		-21.4
125		-17.0		-17.0
160		-13.5		-13.5
200		-10.7		-10.7
250		- 8.5		- 8.5
315		- 6.7		- 6.7
400		- 5.3		- 5.3
500		- 4.2		- 4.2
630		- 3.3		- 3.3
800		- 2.5		- 2.5
1,000		- 1.9		- 1.9
1,250		- 1.4		- 1.4
1,600		- 1.0		- 1.0
2,000		- 0.6		- 0.6
2,500		- 0.3		- 0.3
3,150		1.0		0.0
4,000		0.0		0.5
5,000		1.2		1.2
6,300		5.3		5.3
8,000		- 1.2		- 1.2
10,000		0.0		0.5

*EFFECTIVE TREATMENT LENGTH = 0.6 m, DIAMETER d = 2.34 m

FAN INLET — NOSE COWL AFT (TAIL ENGINE)*

1/3 OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.8	-59.3	1.3	-59.3
63		-47.1		-47.1
80		-37.4		-37.4
100		-29.7		-29.7
125		-23.6		-23.6
160		-18.7		-18.7
200		-14.9		-14.9
250		-11.8		-11.8
315		- 9.4		- 9.4
400		- 7.4		- 7.4
500		- 5.9		- 5.9
630		- 4.6		- 4.6
800		- 3.6		- 3.6
1,000		- 2.8		- 2.8
1,250		- 2.1		- 2.1
1,600		- 1.6		- 1.6
2,000		- 1.1		- 1.1
2,500		- 0.7		- 0.7
3,150		- 0.4		- 0.4
4,000		0.0		0.0
5,000		0.4		0.4
6,300		1.0		1.0
8,000		2.4		2.4
10,000		- 3.9		- 3.9

*EFFECTIVE TREATMENT LENGTH = 0.3 m, DIAMETER d = 2.34 m

FAN EXHAUST DUCT (WING AND TAIL)*

1/3-OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.8	-58.7	1.1	-61.3
63		-46.6		-48.7
80		-37.0		-38.6
100		-29.4		-30.7
125		-23.3		-24.3
160		-18.5		-19.3
200		-14.7		-15.3
250		-11.6		-12.1
315		- 9.2		- 9.6
400		- 7.3		- 7.6
500		- 5.7		- 6.0
630		- 4.5		- 4.7
800		- 3.5		- 3.7
1,000		- 2.7		- 2.8
1,250		- 2.0		- 2.1
1,600		- 1.5		- 1.6
2,000		- 1.0		- 1.1
2,500		- 0.6		- 0.6
3,150		- 0.2		- 0.2
4,000		0.2		0.1
5,000		0.6		0.5
6,300		1.3		1.1
8,000		2.9		2.4
10,000		- 2.8		- 8.0

*EFFECTIVE TREATMENT LENGTH = 1.5 m, DIAMETER d = 0.5 m

TURBINE EXHAUST DUCT (WING AND TAIL)*

1/3-OCTAVE BAND CENTER FREQUENCY	SPECIFIC ACOUSTIC IMPEDANCE			
	APPROACH		TAKEOFF	
	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE	SPECIFIC ACOUSTIC RESISTANCE	SPECIFIC ACOUSTIC REACTANCE
50	0.7	-178.5	0.8	-192.3
63		-141.7		-152.8
80		-112.6		-121.3
100		- 89.4		- 96.4
125		- 71.0		- 76.5
160		- 56.4		- 60.8
200		- 44.8		- 48.3
250		- 35.6		- 38.3
315		- 28.2		- 30.4
400		- 22.4		- 24.1
500		- 17.8		- 19.2
630		- 14.1		- 15.2
800		- 11.1		- 12.0
1,000		- 8.8		- 9.5
1,250		- 6.9		- 7.5
1,600		- 5.5		- 5.9
2,000		- 4.3		- 4.6
2,500		- 3.3		- 3.6
3,150		- 2.5		- 2.7
4,000		- 1.8		- 2.0
5,000		- 1.3		- 1.4
6,300		- 0.8		- 0.9
8,000		- 0.3		- 0.5
10,000		0.0		- 0.0

*EFFECTIVE TREATMENT LENGTH = 0.9 m, DIAMETER d = 0.3 m

End of Document