RESULTS OF THE SHORT-TERM METEOROLOGICAL STUDY CONDUCTED TO DETERMINE THE EFFECT OF LAKE ERIE ON PLUME TRANSPORT CHARACTERISTICS AT THE FERMI 2 SITE

Based on Detroit Edison
Engineering Report 83C52-2,
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SUMMARY

Transport of a radiological release at a coastal plant site can be influenced by the presence of a large body of water adjacent to the site. As a result, the review of the Fermi 2 Radiological Emergency Response Preparedness (RERP) Plan by the NRR staff, NUREG-0798, Supplement No. 3 (p. 13-15) included a request to perform a short-term meteorological study at the Fermi 2 Site to determine the effect of Lake Erie on plume transport. Further, if the results of the study indicate that the effect is significant on the offsite dose assessment model, modification would be incorporated in the model.

Detroit Edison conducted a short-term meteorological study at the Fermi 2 Site during the summer of 1983. Supplemental temporary meteorological monitoring instrumentation was installed onsite at the Lake Erie shoreline and at an inland site approximately 5.5 miles west-northwest. Monostatic acoustic radar units at both locations provided actual measurements of the Thermal Internal Boundary Layer (TIBL) heights. The TIBL measured by the acoustic radar was compared with that predicted by the equations proposed by Raynor, Venkatram, and Weisman.

The data base established to test the performance of the published equations was selected such that a clearly defined TIBL height could be measured from the acoustic radar records and the meteorological parameters necessary to test each equation were available. Once the data base was developed, TIBL height was predicted for each of the available hours for each equation. Equation performance was evaluated using statistical techniques. Scatter diagrams, correlation coefficients, and mean deviations were developed for each set of predicted and measured values.

Statistical analysis of the results indicate that none of the three equations adequately predict TIBL height at the Fermi 2 Site. For example, the mean TIBL height measured at the Fermi 2 Site using acoustic radar data was 134 meters. The mean predicted heights ranged from 76 meters using the Raynor equation to 119 meters using the Weisman equation. The measured TIBL heights ranged from 52 to 261 meters; the predicted values from 6 to 307 meters. Scatter diagrams and correlation coefficients further support the above statements.

The results of the 1983 study indicate that the influence of Lake Erie on plume transport at the Fermi 2 site is not adequately characterized by the more well known equations currently published in the literature. Continuing analyses will be performed on the 1983 data base to determine whether the predictive capability of the equations used in the study can be improved or a site specific relationship can be established to predict the TIBL height. If the results of this ongoing analysis establish a relationship and there is a significant effect on the

offsite dose assessment model used during an emergency, a modification to the model will be implemented.

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1.0 INTRODUCTION

1.1 THERMAL INTERNAL BOUNDARY LAYER

A Thermal Internal Boundary Layer (TIBL) is an interface that forms as an air mass moves from a cool, smooth water surface to a warm, rough land surface. The lower layer of the air mass gradually assumes overland dispersion characteristics while the upper layer retains the overwater traits.

TIBL formation at a coastal site is associated with two types of air flow regimes when the water is cooler than the land

- o Onshore gradient flow is characterized by onshore winds driven by synoptic scale pressure gradients generally associated with early spring and fall.
- o Lake breeze phenomenon is characterized as a wind shift from offshore to onshore during daylight hours generally associated with the warmer months of the year (summer) when clear skies and light synoptic winds occur.

Releases that occur below the TIBL encounter an unstable air mass and vertical dispersion of the plume becomes restricted by the more stable air aloft. This is known as plume trapping and results in higher ground level concentrations near the source. Releases above the TIBL encounter a more stable air mass that restricts plume spread. However, when the plume impacts the deepening TIBL while progressing inland, it is fumigated quite rapidly to the ground. This results in higher concentrations at greater distances from the source. These characteristics are shown in Figure 1.1.

At Fermi 2, the unscheduled radiological release associated with accident-type offsite dose assessment is considered a ground level source. Therefore, plume trapping is most likely to occur if a TIBL is present during periods of onshore flow. A key element in estimating the magnitude and location of resultant doses is the height of the TIBL as a function of inland distance. A number of investigators have developed equations to simulate TIBL growth. However, these equations require meteorological parameters that were not available at the Fermi 2 site. Thus, the 1983 study was designed to provide the missing variables and investigate the lake effect phenomenon.

1.2 FERMI 2 SITE DESCRIPTION AND LOCAL CLIMATOLOGY

The Fermi 2 site is located on the western shore of the western basin of Lake Erie in Frenchtown Township, Michigan.

The site consists of about 1,120 acres located approximately 6 miles northeast of Monroe, Michigan, 35 miles southwest of Detroit, Michigan, and 25 miles northeast of Toledo, Ohio. Reactor centerline coordinates are 41° 57' 48" north latitude and 83° 15' 31" west longitude. Figure 1.2, illustrates the general region surrounding the Site; Figure 1.3 identifies the significant onsite features.

The predominant wind direction in the region is from the southwest. A higher percentage of easterly winds (onshore) is observed during spring and summer than in the fall and winter months. Wind speeds average 10 miles per hour on an annual basis and tend to be higher during spring, fall, and winter than during the summer. This is discussed in detail in Chapter 2 of the Fermi 2 FSAR.

FIGURE 1.1 PLUME DISPERSION INTO AND WITHIN A TIBL

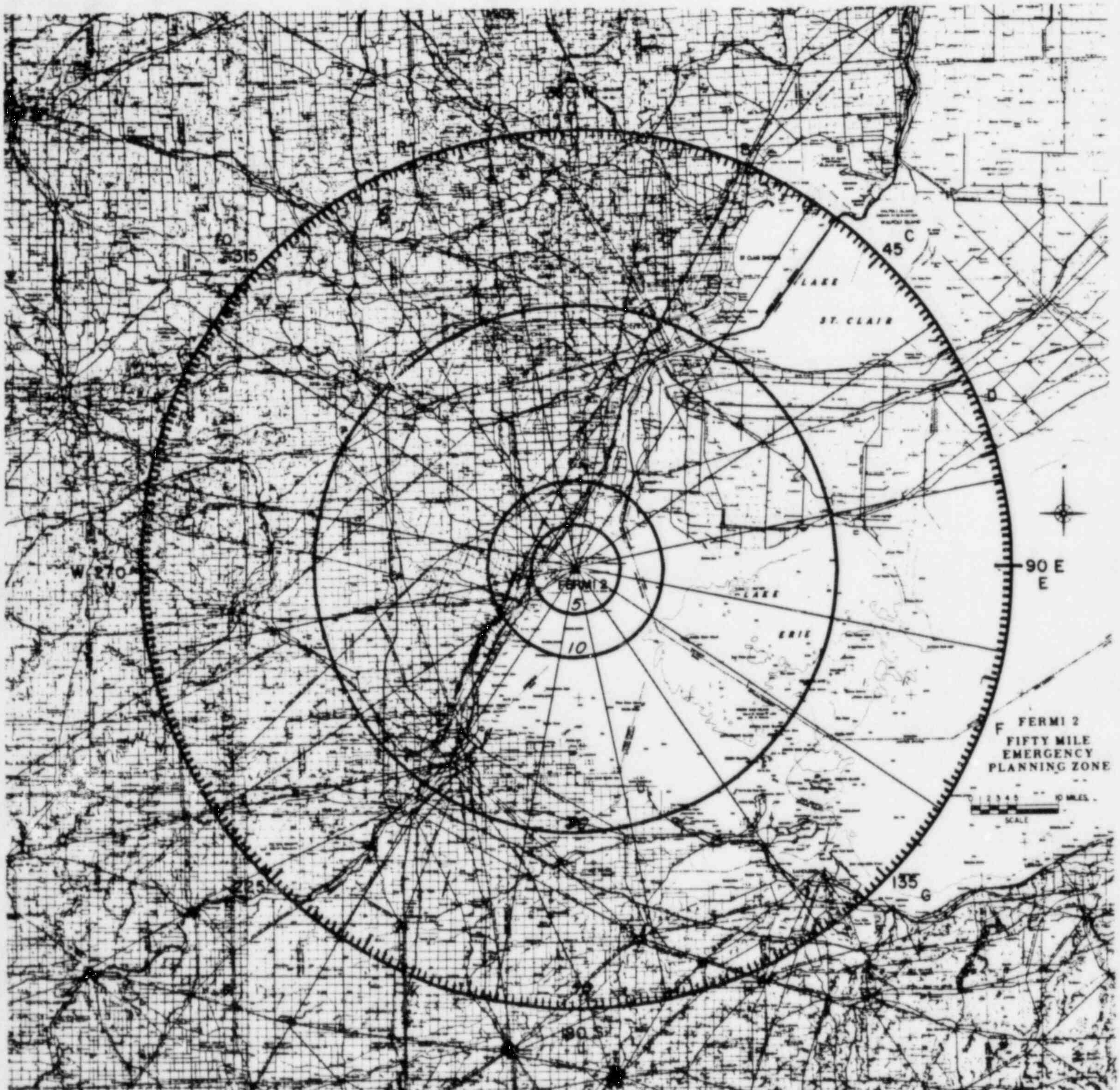
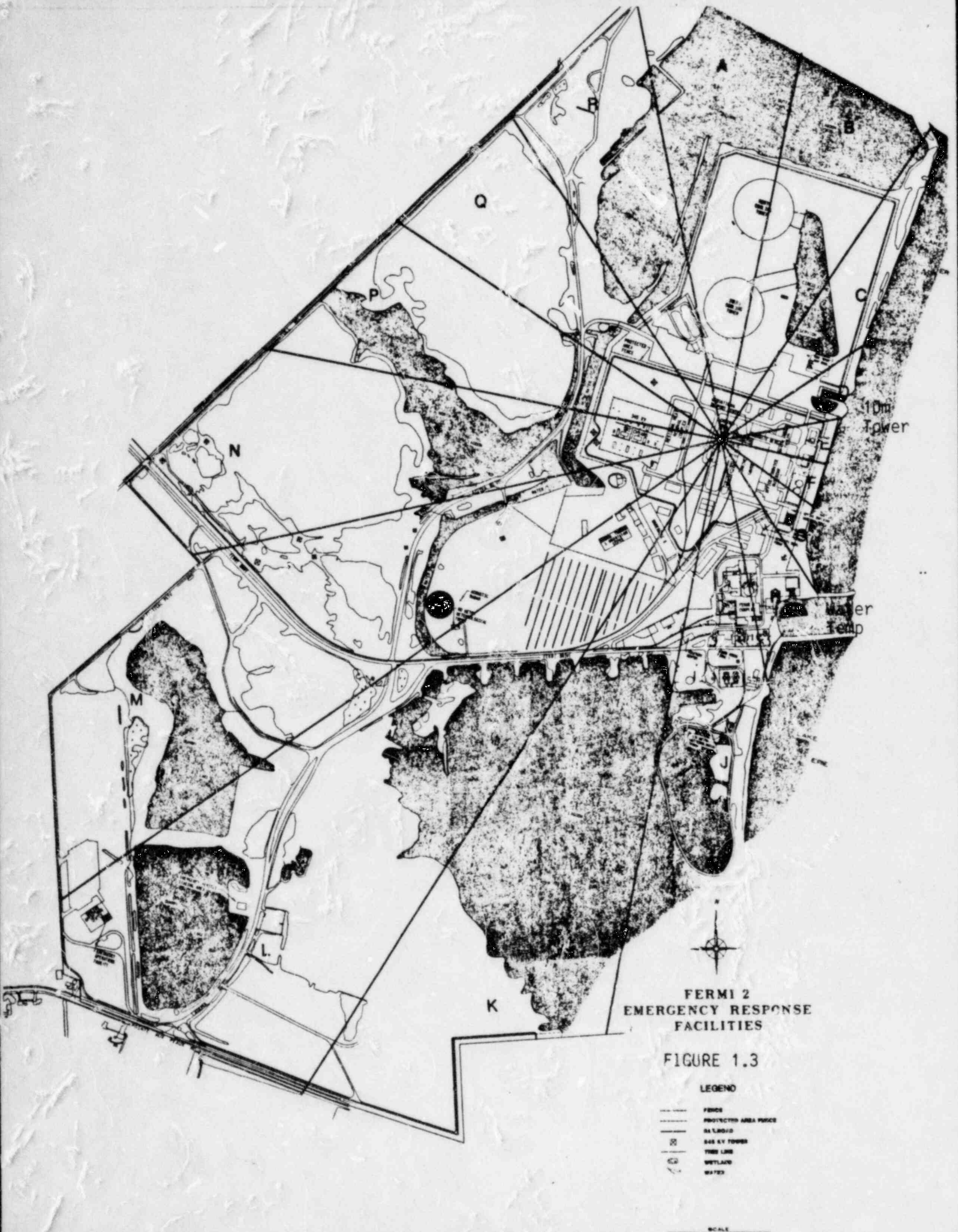


FIGURE 1.2 GENERAL REGION OF THE FERMI-2 SITE



FERMI 2
EMERGENCY RESPONSE
FACILITIES

FIGURE 1.3

2.0 DESCRIPTION OF THE STUDY

2.1 METEOROLOGICAL PARAMETERS

The data required to support the comparison between observed (measured) and predicted TIBL height was reviewed to determine the need for installation of any supplemental instrumentation at temporary sites. The parameters required for the study and their location are listed in Table 2.1.

Two sources of meteorological data were readily available: The 60-meter tower and monostatic acoustic radar unit at the Fermi 2 Site (Figure 1.3) and the Monroe Air Quality Network (MAQN), which is maintained by Edison's Engineering Research Department in association with the coal-fired Monroe Power Plant. The MAQN acquires its data from the Fermi 2 60-meter tower and supplemental 10-meter towers located at various inland sites represented by the squares in Figure 2.1.

As a result of the review, supplemental instrumentation was installed at two temporary sites. A 10-meter tower and instrument shelter were installed at the Lake Erie shoreline on the Fermi 2 Site (Figure 1.3). A second acoustic radar, 10-meter tower, and instrument shelter were installed at Edison's Newport Service Center, approximately 5.5 miles west-northwest of the Site. The relationship of these two sites is shown in Figure 2.2.

2.2 DATA COLLECTION

The Fermi 2 60-meter tower is operated and maintained in accordance with Regulatory Guide 1.23. The hourly average data from the MAQN data aquisition system was used as the data base for meteorological parameters from the 60-meter tower.* The 10-meter towers associated with the MAQN provided the data for characterizing onshore flow.

The Fermi 2 Site lakeshore and Newport Service Center sites were operated from May 10 through October 3, 1983. Stripchart data was collected from May 10 through June 17; operation of the data acquisition system began on June 17 and continued through October 3, 1983. All instrumentation at the supplemental sites was calibrated before and after the study period and weekly site visits were made to assess overall operation and perform periodic instrument checks.

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*The preoperational meteorological data acquisition system for Fermi 2 calculates a 15-minute average once per hour. The hourly averages from the MAQN provided a better data base.

Water temperature data was based on daily grab samples taken at the Fermi 2 intake. Acoustic radar data was recorded on strip charts for future interpretation.

TABLE 2.1 - METEOROLOGICAL PARAMETERS MEASURED FOR TIBL HEIGHT STUDY

PARAMETER	MEASUREMENT	LOCATION
oTemperature - Water	Grab Sample Lake Erie	Fermi-2 General Service Water Pump House Intake
- Land	ΔT (60m-10m)	60m Tower
	10m	60m Tower
	10m	10m Tower (LS)*
	5m	Newport Service Center*
oWind Speed Wind Direction	10m	10m Tower (LS)*
	10m	60m Tower
	10m	Newport Service Center*
oStability Class	Sigma Theta	10m Lake Shore*
	ΔT (60m-10m)	60m Tower
oTIBL Height	Acoustic Radar	60m Tower
	Acoustic Radar	Newport Service Center*
oSolar Radiation	Pyranometer	MAQN (Near 60m Tower)

*Parameters derived from supplemental system.

FIGURE 2.1

MONROE AIR QUALITY NETWORK

▲ SO_2 MONITORING STATION

■ SO_2 & 10M MET STATION

⬢ SO_2 STATION & 60M MET TOWER

● MONROE POWER PLANT

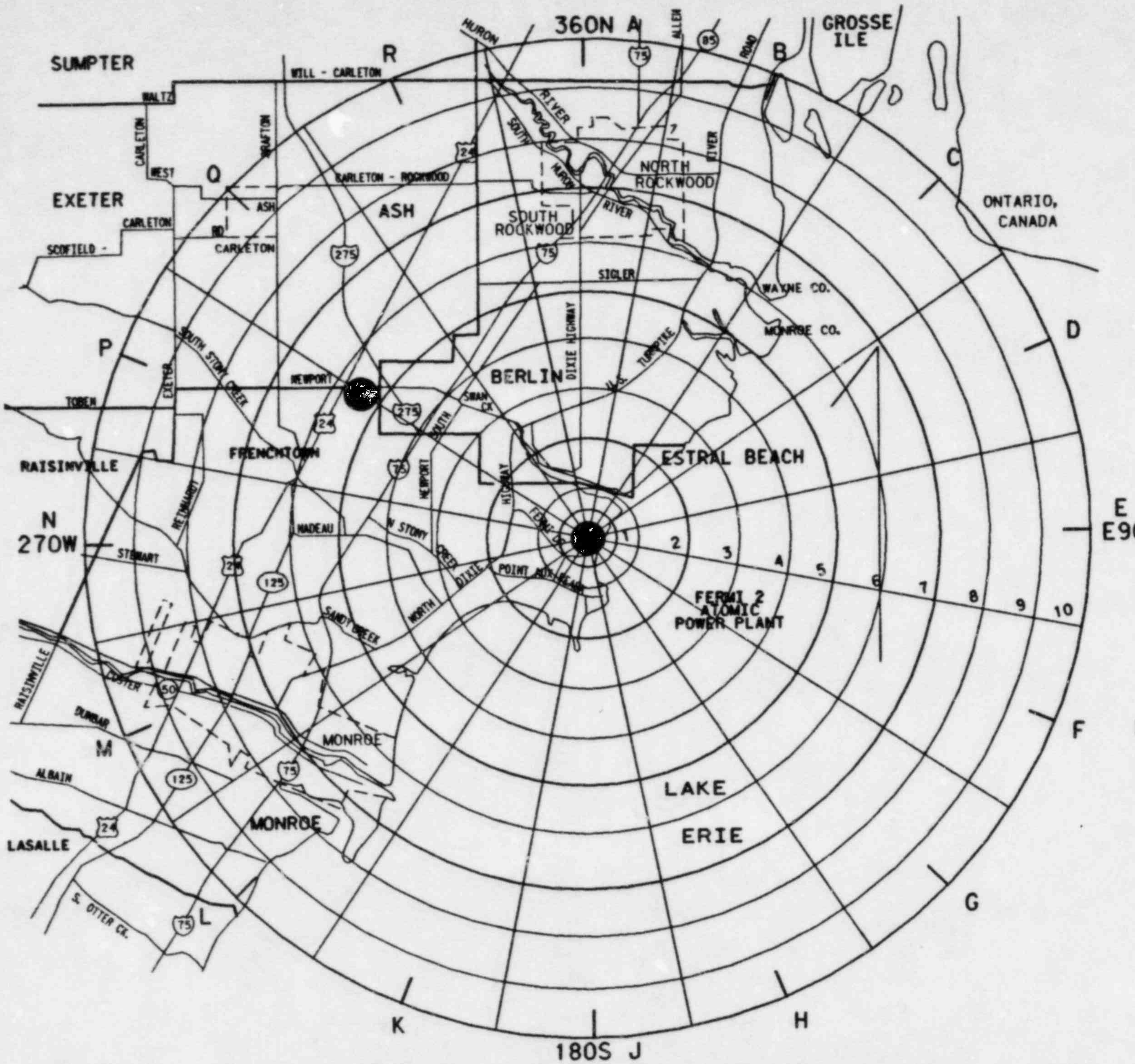

FIGURE 2.2 - LOCATION OF SUPPLEMENTAL MONITORING SITES FOR THE 1983 FERMI-2 LAKE EFFECT STUDY

3.0 DATA BASE DEVELOPMENT

The data base used for the analysis of observed (measured) versus predicted TIBL height was selected in three stages using predefined criteria as described in this Section.

3.1 POTENTIAL TIBL HOURS

The meteorological data from the Fermi 2 60-meter tower were reviewed to identify potential TIBL hours. The period March through October 1983 was selected to encompass the expected "lake effect" season. TIBL hours were identified according to the following selection criteria:

- o Onshore winds (57 degrees to 213 degrees at the Fermi Site)
- o Daylight hours
- o Sunny skies
- o Land temperature greater than water temperature

TIBL hours were further classified as onshore gradient flow, lake breeze, or lake influence.

- o Onshore gradient flow - onshore flow begins prior to sunrise or inland direction shift prior to shift at Fermi 2 Site
- o Lake Breeze - offshore to onshore wind direction shift 30° or greater, inland direction shift after Fermi shift, and wind speed less than 10 mph prior to shift
- o Lake Influence - similar to lake breeze, but wind direction shift less than 30°

The summary of the potential TIBL hours from March through October 1983 for the Fermi 2 Site is presented in Table 3.1.

3.2 OBSERVED (MEASURED) TIBL HEIGHT

TIBL heights were measured by monostatic acoustic radar units located at the 60-meter tower and the Newport site. The acoustic radar emits a 1600 Hertz sound pulse then "listens" for the return echoes that correspond to density fluctuations in the atmosphere. The output is a strip chart with gradations in color density from light gray to almost black. The radar typically "sees" and records return layer echoes, thermal echoes, precipitation echoes, high ambient

noise, and a malfunctioning instrument. Each echo produces a somewhat characteristic trace or pattern on the chart which can become quite complex and at times indistinguishable. Figure 3.1 shows a typical trace generated by the return signals.

The major difficulty associated with using acoustic radar data to identify measured TIBLs or mixing height is related to the interpretation criteria used since it is based on visual inspection of the chart. The initial interpretation was done by a Consultant. These results were then carefully reviewed by Edison personnel. Complicated patterns were discussed with other individuals with interpretive experience and a consensus opinion was derived.

Interpreted mixing height values were assigned a data quality indicator - good, poor, indistinguishable - that was associated with the confidence level of the interpreted number derived for a particular hour. Good values were easily identified from the charts; poor values were associated with mixing heights that were unclear or extrapolated from good data hours; and indistinguishable was associated with precipitation echoes or when the instrument was inoperable. Figure 3.1 is representative of a "good" trace from which good values can be read. Only data classified as good was used in the comparisons of measured versus predicted values. Table 3.2 presents the TIBL hours selected based on acoustic radar data.

3.3 PREDICTED TIBL HEIGHT

There are numerous equations available to predict boundary layers in the atmosphere and a large number for predicting the interface height between lake and land air under lake breeze or onshore gradient flow conditions. For the purposes of the study at Fermi 2, three standard approaches demonstrated in the literature were selected that represent some of the most widely accepted methods for calculating TIBL heights. The Raynor, Venkatram, and Weisman methods were evaluated using the data base created during the Fermi 2 study.

Table 3.3 presents the TIBL hours selected for the data base to be analyzed. This data base represents a clearly defined measured TIBL with all meteorological parameters required for the predictive equations. Section 3.3.4 provides the details for the final selection of the data base.

3.3.1 RAYNOR METHOD

Raynor et al. (1975)[2] demonstrated a method based on physical and dimensional considerations. The basic formulation is:

$$h = \frac{U_*}{\bar{U}} \left[\frac{|T_w - T_l| X}{|\Delta T / \Delta z|} \right]^{0.5}$$

Where

h = Raynor TIBL height (m)

U_* = Frictional velocity (m/s)

$\bar{U}$ = Mean wind speed (m/s)

T_w = Potent'al temperature over the water (K)

T_l = Potential temperature over the land surface (K)

X = Overland fetch (m)

$\Delta T / \Delta z$ = Atmospheric lapse rate over the water (K/m)

Use of this method was limited to "case days" when meteorological conditions were favorable and a "complete" data set was available. The measured values used to represent these parameters are as follows:

U_* = Frictional velocity calculated from the Businger (1971)[1] routine and the Log-law approximation if the 60-meter level wind speed measurements were unavailable.

$\bar{U}$ = Wind speed from the Fermi 60m tower at the 10m level.

T_w = Potential temperature over the water was approximated by using the daily grab sample water temperature.

T_l = Potential temperature over the land was taken from the 10m temperature at the Fermi 60m tower in the base case.

X = Overland fetch for the two acoustic radar sites was developed from USGS maps for each "lake effect" wind direction sector.

$\Delta T/\Delta z$ = Atmospheric lapse rate over the water was approximated using measured atmospheric stability based on sigma theta at the shoreline.

Each of these parameters had to be available to calculate Raynor TIBL heights.

3.3.2 VENKATRAM METHOD

Venkatram (1977)[4] used an approach similar to Raynor by solving two-dimensional mixed-layer energy equations and a simplified entrainment theory with one slight modification. This modification in the TIBL equation was found to be a non-dimensional quantity dependent upon the TIBL strength. The Venkatram formulation is given as:

$$h = \frac{U_*}{\overline{U}} \left[\frac{2\,(T_1 - T_w)\,X}{(\Delta\theta/\Delta z)(1 - 2F)} \right]^{0.5}$$

Where

h = Venkatram TIBL height (m)

U_* = Frictional velocity (m/s)

$\overline{U}$ = Average wind speed of the mixed layer (m/s)

T_w = Potential temperature of the water (K)

T_1 = Potential temperature of the land surface (K)

X = Overland fetch (m)

$\Delta\Theta/\Delta z$ = Atmospheric vertical potential temperature gradient over the water (K/m)

F = Fraction dependent upon the temperature variation across the TIBL

Use of the Venkatram method was limited to "case days" when meteorological conditions were favorable and a "complete" data set was available. The measured values used to represent these parameters are as follows:

U_* = Frictional velocity calculated from the Businger (1971)[1] routine and the Log-law approximation if the 60-meter level wind speed measurements were unavailable.

$\bar{U}$ = Average wind speed from the Fermi 60m tower at the 10m level.

T_w = Potential temperature over the water was approximated by using the daily grab sample water temperature.

T_l = Potential temperature over the land was taken from the 10m temperature at the Fermi 60m tower in the base case.

X = Overland fetch for the two acoustic radar sites was developed from USGS maps for each "lake effect" wind direction sector.

$\Delta\theta/\Delta z$ = Atmospheric potential temperature gradient over the water was approximated using measured atmospheric stability based on sigma theta at the shoreline.

F = Fraction assumed to be 0.22 based upon the work of Venkatram (1977).

3.3.3 WEISMAN METHOD

Weisman (1976)[5] developed a routine based upon a totally different approach using the surface heat flux for the site as the underlying force in TIBL development. This approach is given as:

$$h = \left[\frac{2\, Q_h\, X}{(\Delta\theta/\Delta z)\,\rho\, C_p \bar{U}} \right]^{0.5}$$

Where

h = Weisman TIBL height (m)

Q_h = Surface heat flux over land (cal/m^2/sec)

x = Overland fetch (m)

$\Delta\theta/\Delta z$ = Atmospheric potential temperature gradient over the water (K/m)

ρ = Density of the atmosphere (gm/m^3)

Cp = Specific heat of the atmosphere at constant pressure (cal/gm/K)

$\overline{U}$ = Mean wind speed (m/s)

Use of the Weisman method was limited to "case days" when meteorological conditions were favorable and a "complete" data set was available. The measured values used to represent these parameters are as follows:

Q_h = Surface heat flux over land was approximated using the available measure of incoming solar radiation at the Fermi 2 site. (Total solar radiation times 0.3).

X = Overland fetch was identified as the distance from the acoustic radar site to the lakeshore.

$\Delta\theta/\Delta z$ = Atmospheric potential temperature gradient over the water was approximated using measured atmospheric stability based on sigma theta at the shoreline.

ρ = Density of the atmosphere was approximated as 1250 gm/m^3.

Cp = Specific heat of the atmosphere at constant pressure was approximated as 0.24 cal/gm/K.

$\overline{U}$ = Average wind speed taken from the Fermi 60m tower at the 10m level.

3.3.4 PARAMETERIZATION OF DATA

Each of the TIBL height equations had limitations on some of the input parameters. For this reason the data base shown in Table 3.2 was reduced to that shown in Table 3.3.

The Raynor and Venkatram methods require that land temperature is higher than water temperature to prevent the TIBL height from approaching artifically high values. Therefore, the data base had to be limited to those hours where $\Delta T/\Delta z$ and $\Delta\theta/\Delta z$ were greater than 0.002° K/m. Additional limitations were placed on the data base: TIBL

temperature variation fraction must be less than 0.5 in Venkatram, and surface sensible heat flux greater than zero in Weisman.

Sigma theta from the lakeshore site was chosen to approximate the overwater vertical temperature gradient. Stability classification schemes from Regulatory Guide 1.23 (1980)[3] were used as the basis of the parameterization. Table 3.4 lists the two methods recommended to identify stability class. Points of equality between delta temperature and sigma theta methods were used as the basis for interpolating delta temperatures from sigma theta measurements.

The vertical temperature gradient and potential temperature gradient over water were parameterized as shown in Table 3.5. A discrete method was utilized for every one degree change in sigma theta. The value of $\Delta T/\Delta z$ was held constant at 0.002° K/m for sigma theta values when it would normally be negative. This maximizes the data base that could be run in the Raynor equation. Sigma thetas above 8.4 degress, were not included in the data base.

TABLE 3.1 - SUMMARY OF POTENTIAL TIBL HOURS: MARCH - OCTOBER 1983 FERMI 2 60 METER TOWER

MONTH	POTENTIAL TIBL HOURS LAKE BREEEZE	ONSHORE GRADIENT FLOW	LAKE INFLUENCE	TOTAL	DAYLIGHT HOURS	PERCENT OF DAYLIGHT HOURS TIBL MAY OCCUR	NUMBER OF DAYS IN MONTH ASSOCIATED WITH POTENTIAL TIBL HOURS
March	23	24	0	47	334	14	13
April	16	16	11	43	391	11	19
May	23	57	0	80	454	18	13
June	68	54	37	159	435	37	21
July	49	48	0	97	406	24	17
August	77	17	1	95	403	24	18
Sept.	21	32	15	68	334	20	14
Oct.	16	41	0	57	329	17	10
Total	293	289	64	646	3086	21	115
	(45%)	(45%)	(10%)				

NOTES:

1. Potential TIBL hours defined as onshore flow during daylight hours with sunny skies and land temperature greater than lake temperature.

2. Wind directions for onshore flow at Fermi 2 Site - 57 degrees to 213 degrees.

3. Onshore Flow Classification:

   a. Onshore Gradient Flow - Onshore flow begins prior to sunrise or inland direction shift before Fermi shift.

   b. Lake Breeze - Offshore to onshore wind direction shift of at least 30 degrees and inland direction shift after Fermi shift, wind speed less than 10 miles per hour prior to shift.

   c. Lake Influence - Similar to lake breeze but less than 30 degree shift.

4. Screening analysis performed on Fermi 2 60 meter tower data.

TABLE 3.2 - TIBL HOURS SELECTED BASED ON MEASURED TIBL HEIGHT - ACOUSTIC RADAR DATA

1983 DATE	TIME(S) (EST)	NUMBER OF HOURS	ONSHORE FLOW CLASSIFICATION	TIBL OBSERVATIONS, HOURS FERMI	TIBL OBSERVATIONS, HOURS NEWPORT
6-20	1300-2000	8	LB	8	4
6-22	0900-1100	3	LB	3	3
	1700-2000	4	LB	4	4
6-25	1300-2000	8	LB	6	6
7-13	1800-2000	3	LB	3	0
7-26	1800-2000	3	LB	3	0
7-27	1000-2000	11	LB	11	0
8-2	1300-1400	2	LB	2	0
8-4	1900-2000	2	LB	2	0
8-6	1400-2000	7	LB	7	0
8-7	1200-1800	7	LB	7	0
8-10	1000-1500	6	LB	5	5
8-14	1900-2000	2	LB	2	0
8-15	1000-1900	10	LB	10	2
8-16	1000-2000	11	LB	11	2
8-18	1300-2000	8	LB	8	3
8-21	0800-1900	12	OGF	10	12
8-24	1700-1900	3	LB	0	3
8-25	1100-1900	9	LB	9	2
8-28	1400-1900	6	LB	6	5
8-29	1600-1900	4	LB	0	4
9-3	1300-1900	7	LI	7	5
		136			

NOTE: 1. TIBL hour selection criteria - clearly defined TIBL indicated by acoustic radar; meteorological parameters are available.

2. Onshore Flow Classification:

OGF - Onshore Gradient Flow
LB - Lake Breeze
LI - Lake Influence

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TABLE 3.3 - TIBL HOUR DATA BASE SELECTED FOR PREDICTED EVALUATION

DATE, 1983	FERMI Time (EST)	FERMI Hours	NEWPORT Time (EST)	NEWPORT Hours
6-20	1400-1500	2		
	1800	1	1800	1
6-22	1000-1100	2	1000-1100	2
	1700-2000	4	1700-2000	4
6-25	1600-1800	3	1600-1800	3
7-13	1800-2000	3		
7-27	1200-2000	8		
8-6	1400-1800	5		
8-7	1300-1400	2		
	1600-1800	3		
8-10	1100	1		
8-15	1500-1900	5	1500-1900	5
8-16	1000-1100	2	1000-1200	2
	1600-2000	5	2000	1
8-18	1300	1	1300	1
	2000	1	2000	1
8-21	0800	1	0800	1
8-21	1600-1800	3	1600-1800	3
8-25	1600	1		
	1900	1		
Total		54		24

NOTE: Hours were selected on the basis of a clearly defined TIBL being present and all meteorological parameters required to predict TIBL heights were available. Restrictions on data for use in equations are described in Section 3.3.4.

TABLE 3.4 - CLASSIFICATION OF ATMOSPHERIC STABILITY

(Source: NRC Regulatory Guide 1.23[3])

A. USING TEMPERATURE CHANGE WITH HEIGHT

Stability Classification	Pasquill Categories	Temperature Change with Height (°C/100 m)
Extremely unstable	A	$\Delta T/\Delta z \leq -1.9$
Moderately unstable	B	$-1.9 < \Delta T/\Delta z \leq -1.7$
Slightly unstable	C	$-1.7 < \Delta T/\Delta z \leq -1.5$
Neutral	D	$-1.5 < \Delta T/\Delta z \leq -0.5$
Slightly stable	E	$-0.5 < \Delta T/\Delta z \leq 1.5$
Moderately stable	F	$1.5 < \Delta T/\Delta z \leq 4.0$
Extremely stable	G	$4.0 < \Delta T/\Delta z$

B. USING SIGMA THETA

Stability Classification	Pasquill Categories	σ_θ* (Degrees)
Extremely unstable	A	$\sigma_\theta \geq 22.5$
Moderately unstable	B	$22.5 > \sigma_\theta \geq 17.5$
Slightly unstable	C	$17.5 > \sigma_\theta \geq 12.5$
Neutral	D	$12.5 > \sigma_\theta \geq 7.5$
Slightly stable	E	$7.5 > \sigma_\theta \geq 3.8$
Moderately stable	F	$3.8 > \sigma_\theta \geq 2.1$
Extremely stable	G	$2.1 > \sigma_\theta$

*Standard deviation of horizontal wind direction fluctuation over a period of 15 minutes to 1 hour.

TABLE 3.5 - PARAMETERIZATION OF VERTICAL OVERWATER TEMPERATURE GRADIENTS USING SIGMA THETA MEASUREMENTS

SIGMA THETA (Degrees)	$\Delta T/\Delta z$ (°K/100m)	$\Delta\theta/\Delta z$ (°K/100m)
$8 < \sigma_\theta \leq 8.4$	0.20 (-0.74)	0.24
$7 < \sigma_\theta \leq 8$	0.20 (-0.50)	0.48
$6 < \sigma_\theta \leq 7$	0.20 (-0.10)	0.88
$5 < \sigma_\theta \leq 6$	0.36	1.34
$4 < \sigma_\theta \leq 5$	0.91	1.89
$3 < \sigma_\theta \leq 4$	1.70	2.68
$2 < \sigma_\theta \leq 3$	2.94	3.92
$1 < \sigma_\theta \leq 2$	5.80	6.78
$0 < \sigma_\theta \leq 1$	10.00	10.98

NOTES:

1. $\Delta T/\Delta z$ = overwater vertical temperature gradient
   σ_θ = Lakeshore site 10-meter level sigma theta
   $\Delta\theta/\Delta z$ = Overwater vertical potential temperature gradient ($\Delta T/\Delta z$ plus 0.98)

2. The numbers in parentheses in the final parameterization indicate the value that $\Delta T/\Delta z$ would have taken had it not been held constant at 0.2° K/100m for sigma thetas above six.

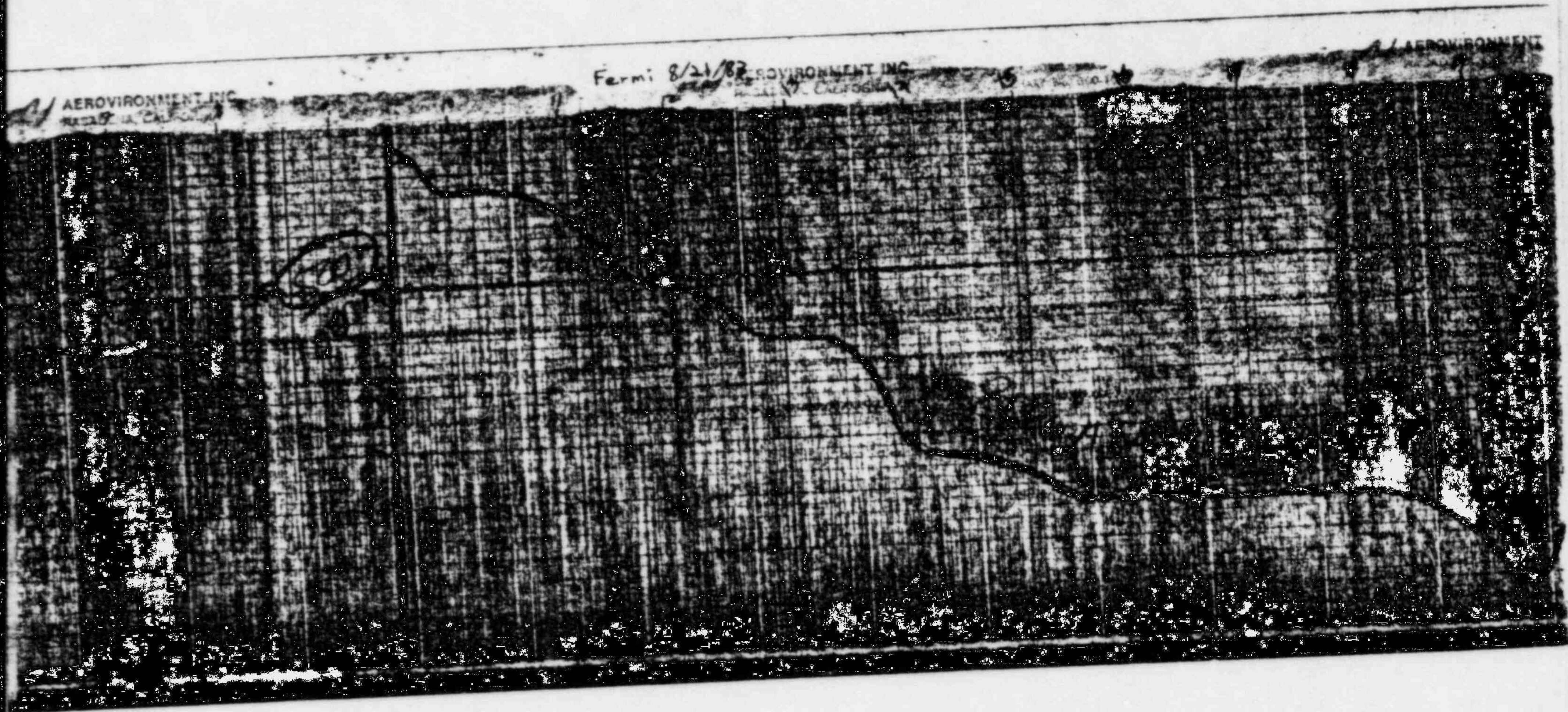

FIGURE 3.1 TYPICAL STRIP CHART TRACE FROM MONOSTATIC ACOUSTIC RADAR

4.0 DATA ANALYSIS AND RESULTS

As stated in Section 3, a three stage data selection process was used to obtain the data base for the analysis. This data base is shown in Table 3.3

Once the data base was developed, TIBL height was predicted for each of the available hours for each of the three methods. Equation performance was evaluted using statistical techniques. Scatter diagrams, correlation coefficients, and mean deviations were developed for each set of predicted and measured (observed) values.

Table 4.1 presents a summary of predicted and observed TIBL heights. The mean TIBL height observed for the 54 hours selected at the Fermi 2 site was 134 meters. Mean predicted heights ranged from 76 meters with the Raynor equation to 119 meters with Weisman. Observed TIBLs at Fermi 2 were in the 52 to 261 meter range, while predicted values varied from 6 to 307 meters, depending on which equation was used.

The performance of each equation is illustrated in Figures 4.1 through 4.3. The correlation coefficients are:

Raynor:	-0.13
Venkatram:	-0.19
Weisman:	0.02

These results indicate that the predictive capabilities of the equations are unsatisfactory for data collected specifically at the Fermi 2 Site over the study period.

Mean deviation analyses also support the conclusion that the published equations do not accurately predict the TIBL heights at the Fermi 2 Site. Results of this analysis are presented in Table 4.2 and Figures 4.4 through 4.6. Raynor and Venkatram tend to underpredict the TIBL height. Although Weisman also underpredicted, the deviations were not as great and approximated a normal distribution, (Figure 4.6).

Tables 4.1 and 4.2 and Figures 4.7 through 4.12 provide similar information on the performance of the three equations for the Newport site. The conclusions are essentially the same. That is, none of the equations adequately predict the observed TIBL heights. However, of the three equations, Weisman performs best at the Newport site.

To verify that there was a relationship between overland fetch and TIBL height, the observed values were plotted as a function of inland distance. Results are presented in Figure 4.13. Although the acoustic radar units were at fixed locations, overland fetch varied with the wind direction sector corresponding to the TIBL hour. Figure 4.13 shows that TIBL height tends to increase as inland distance increases. The least squares linear regression line has a slope of 0.021 and intercept of 115 meters. The correlation coefficient is 0.48. This offers encouragement that a relationship can be found to reasonably predict the TIBL growth near the Fermi 2 Site.

Observed TIBL heights at both Fermi and Newport were correlated with each of 13 meteorological parameters used in the equations. This comparison is summarized in Table 4.3. Solar radiation ranked number one at Newport (R = 0.78) and number two at Fermi 2 (R = 0.48). This indicates that the higher the solar radiation the higher the TIBL height. No other parameters were as significant at both sites. In fact, approximately half of the parameters had a positive correlation with measured TIBL at one location and a negative correlation at the other site. Based on this analysis and the TIBL height versus fetch comparison above, solar radiation and inland distance appear to be the two most important variables in TIBL formation with onshore flow regimes at the Fermi 2 Site.

In summary, the results of the data analysis, to date, indicated that none of the three published TIBL equations perform adequately when tested with the 1983 Fermi 2 data base. The Weisman equation performs the best; however, the scatter associated with the prediction is substantial.

Observed TIBL heights show a tendency to increase with increasing inland distance. In addition, solar radiation was identified as an important meteorological parameter in the formation of TIBLs with onshore flow.

TABLE 4.1 - SUMMARY OF PREDICTED AND OBSERVED TIBL HEIGHTS

	NUMBER OF VALUES	HEIGHT, METERS			
		MEAN	MAXIMUM	MINIMUM	STANDARD DEVIATION
FERMI PREDICTED:					
Raynor	54	76	208	6	60
Venkatram	54	84	225	6	66
Weisman	54	119	307	12	67
FERMI OBSERVED	54	134	261	52	55
NEWPORT PREDICTED:					
Raynor	24	94	310	8	88
Venkatram	24	112	357	11	99
Weisman	24	290	626	43	130
NEWPORT OBSERVED	24	324	504	100	134

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TABLE 4.2 - FERMI 2 TIBL ANALYSIS MEAN DEVIATIONS (PREDICTED - OBSERVED)

	MEAN, m	STANDARD DEVIATION, m	MINIMUM, m	MAXIMUM, m
FERMI				
Raynor	-58.3	86.6	-244	134
Venkatram	-40.9	93.9	-245	163
Weisman	-14.8	86.0	-207	219
NEWPORT				
Raynor	-230.8	162.2	-468	148
Venkatram	-212.4	160.2	-461	123
Weisman	- 34.2	182.9	-416	365

TABLE 4.3 - FERMI 2 TIBL ANALYSIS CORRELATION COEFFICIENTS

PARAMETER	WITH FERMI ACOUSTIC RADAR	WITH NEWPORT ACOUSTIC RADAR
10m Windspeed	0.494 (1)	0.336 (7)
Solar Radiation	0.476 (2)	0.783 (1)
$\Delta T/\Delta z$	-0.382 (3)	-0.347 (6)
Hour	-0.363 (4)	0.066 (10)
Land/Water Temperature Difference	0.309 (5)	-0.214 (9)
Distance Inland	0.008 (11)	0.487 (4)
10m Temperature	-0.159 (7)	-0.322 (8)
Newport Temperature	-0.069 (8)	0.035 (11)
10m Sigma Theta	-0.066 (9)	0.402 (5)
60m Wind Speed	-0.005 (10)	0.669 (2)
60m Temperature	-0.262 (6)	-0.508 (3)

NOTE: Numbers in parentheses represent the rank of the correlation for each parameter with acoustic radar (observed TIBL height) at each site.

FIGURE 4.1

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

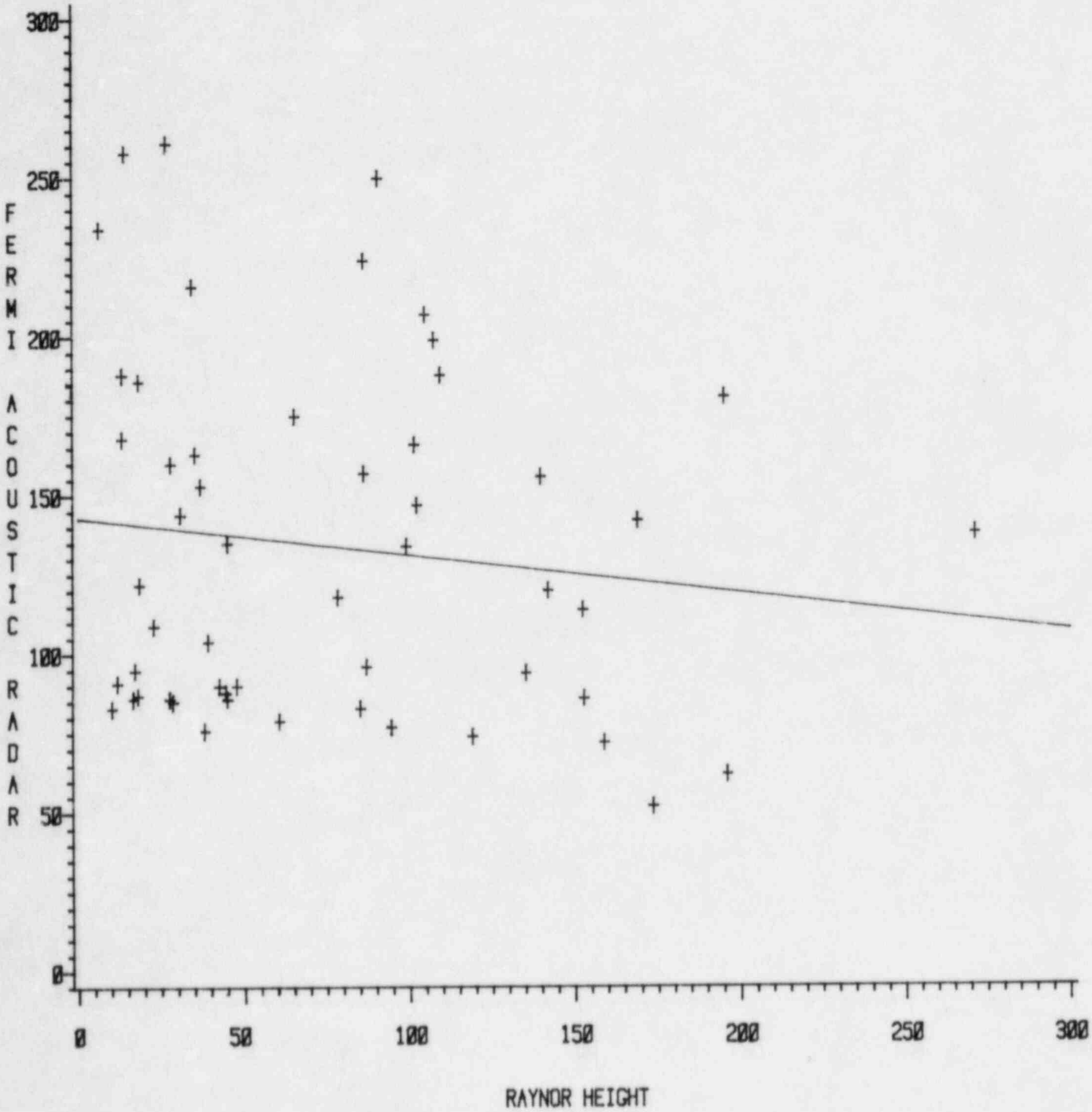


FIGURE 4.2

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

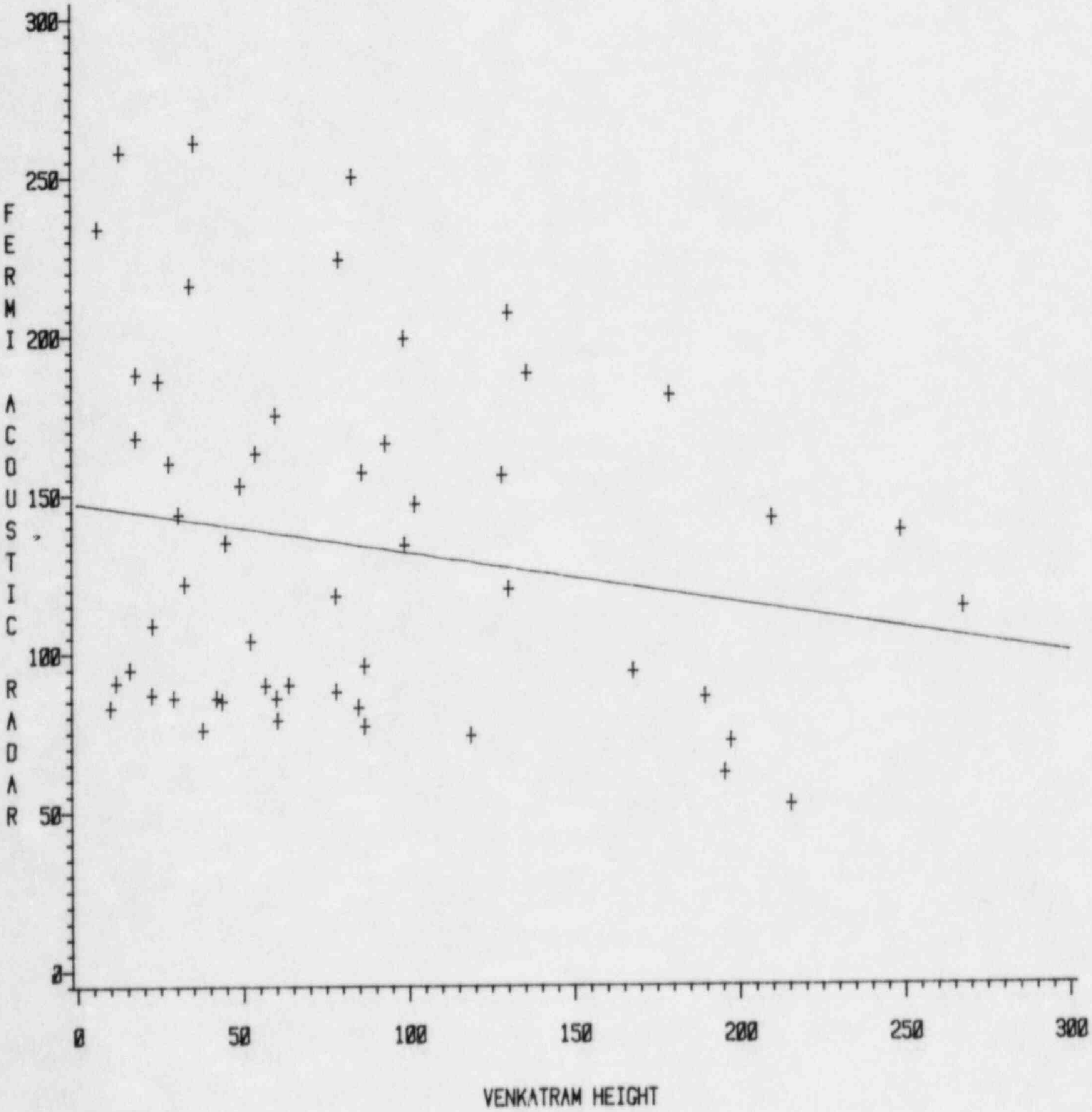


FIGURE 4.3

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

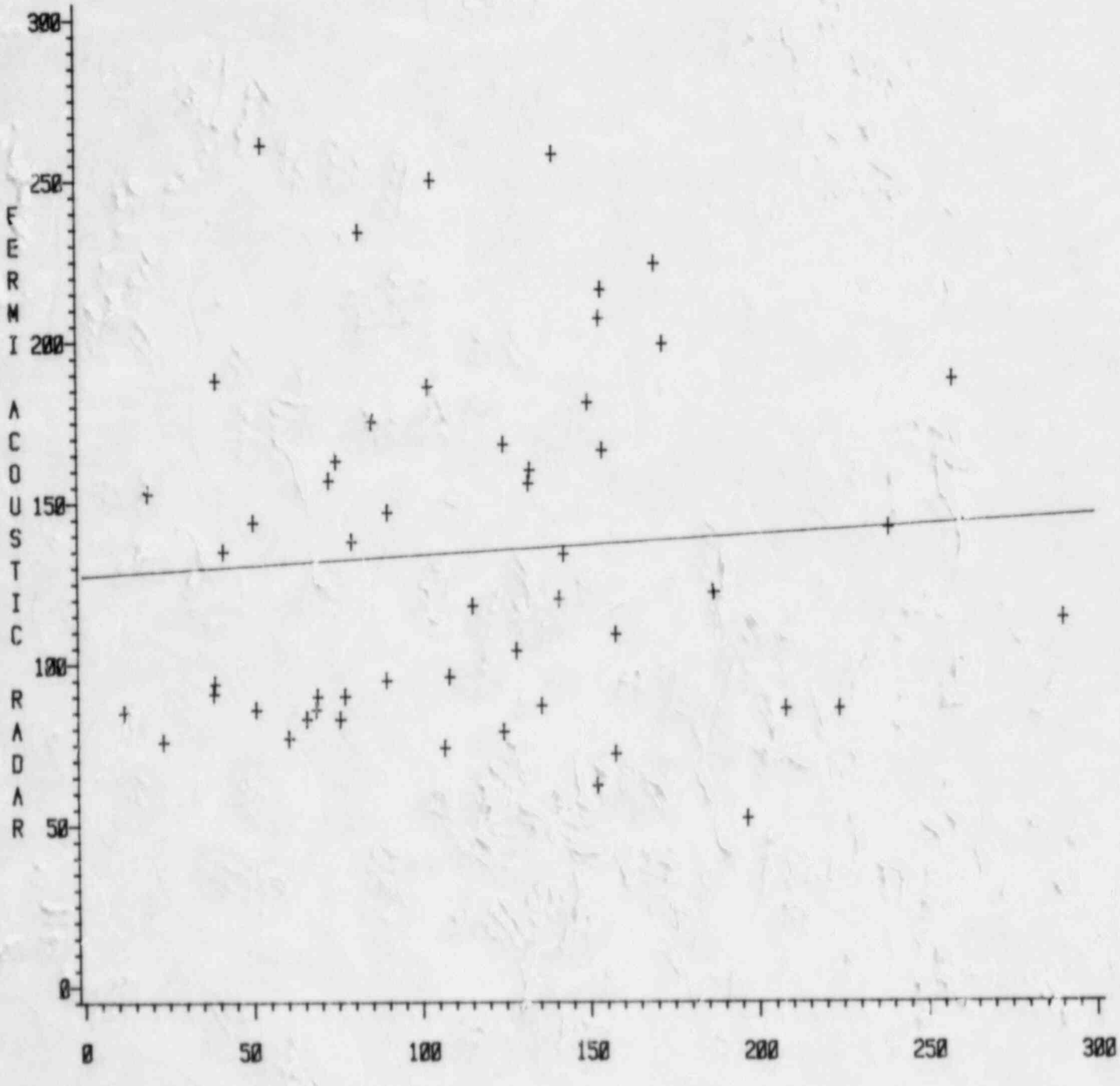


FIGURE 4.4

FERMI 2 TIBL ANALYSIS

MEAN DEVIATIONS FOR RAYNOR HEIGHT

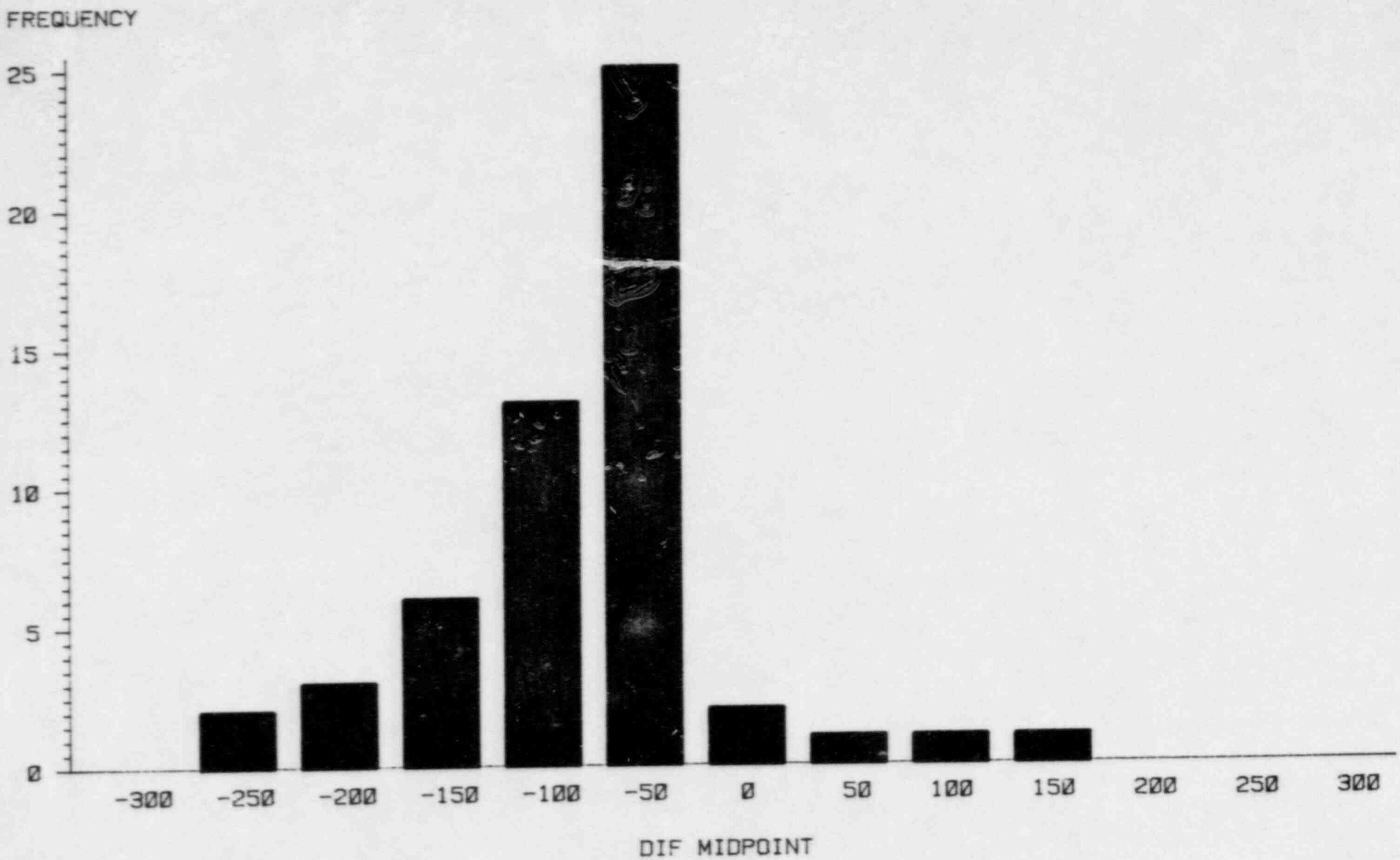


FIGURE 4.5

FERMI 2 TIBL ANALYSIS

MEAN DEVIATIONS FOR VENKATRAM HEIGHT

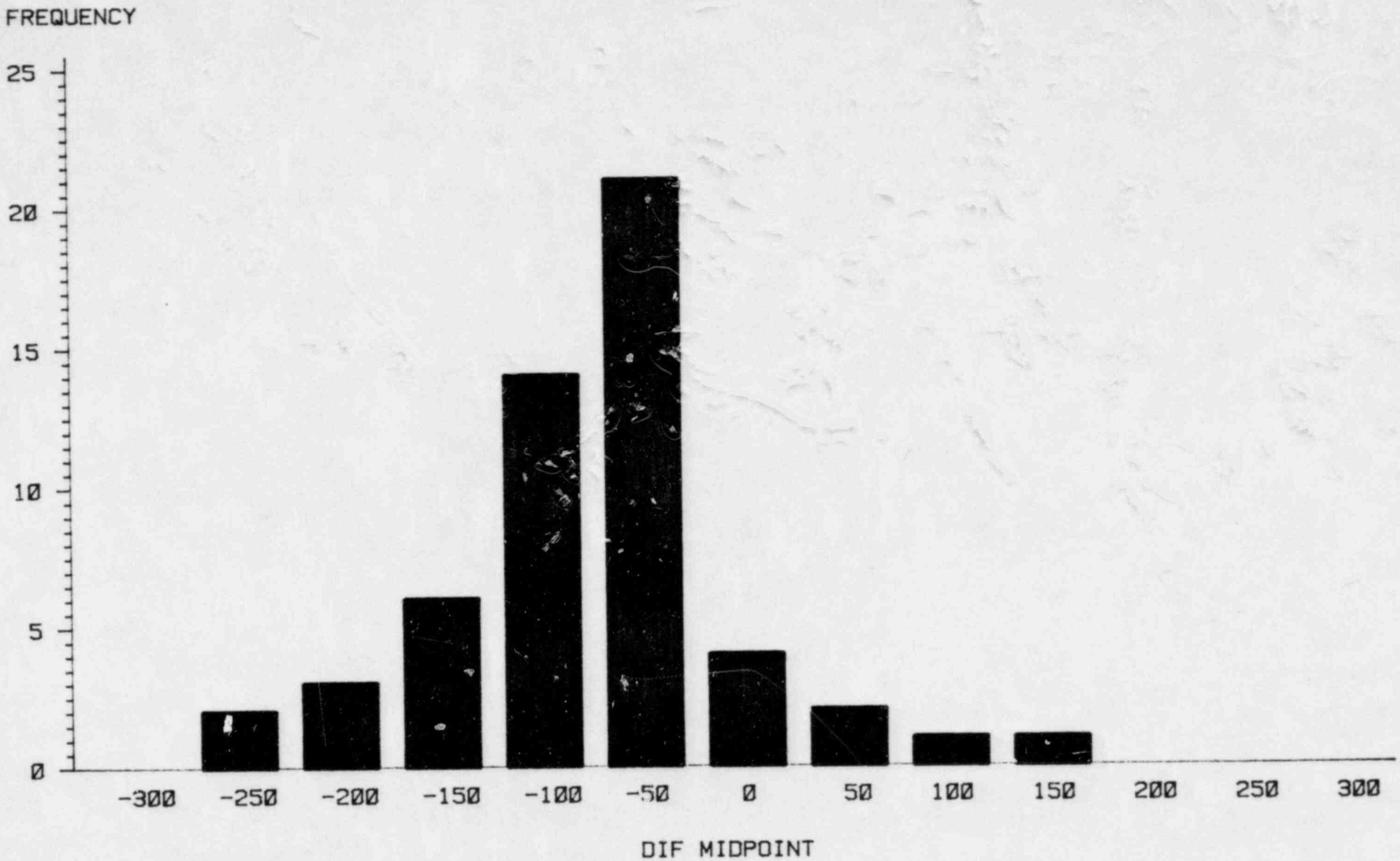


FIGURE 4.6

FERMI 2 TIBL ANALYSIS

MEAN DEVIATIONS FOR WEISMAN HEIGHT

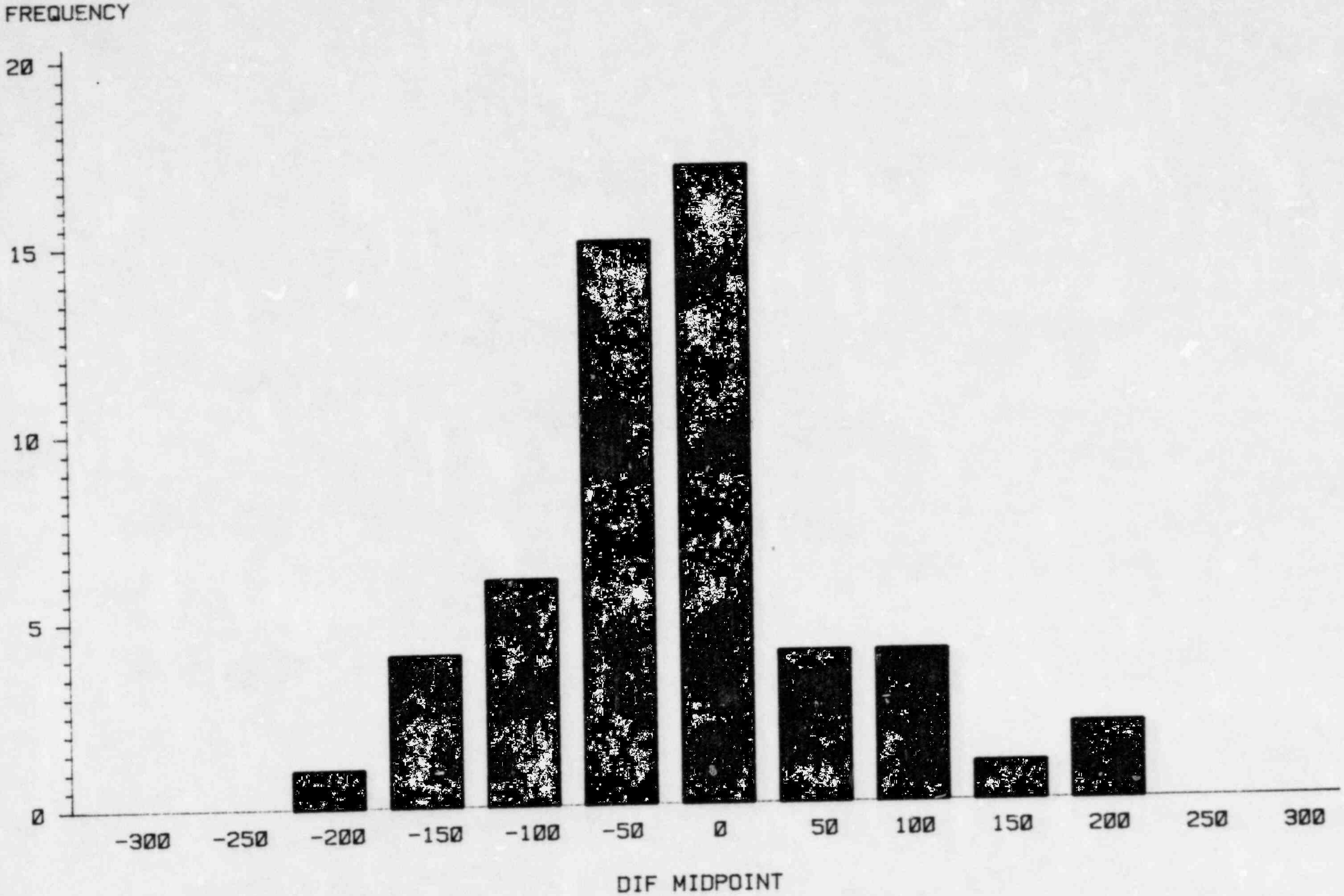


FIGURE 4.7

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

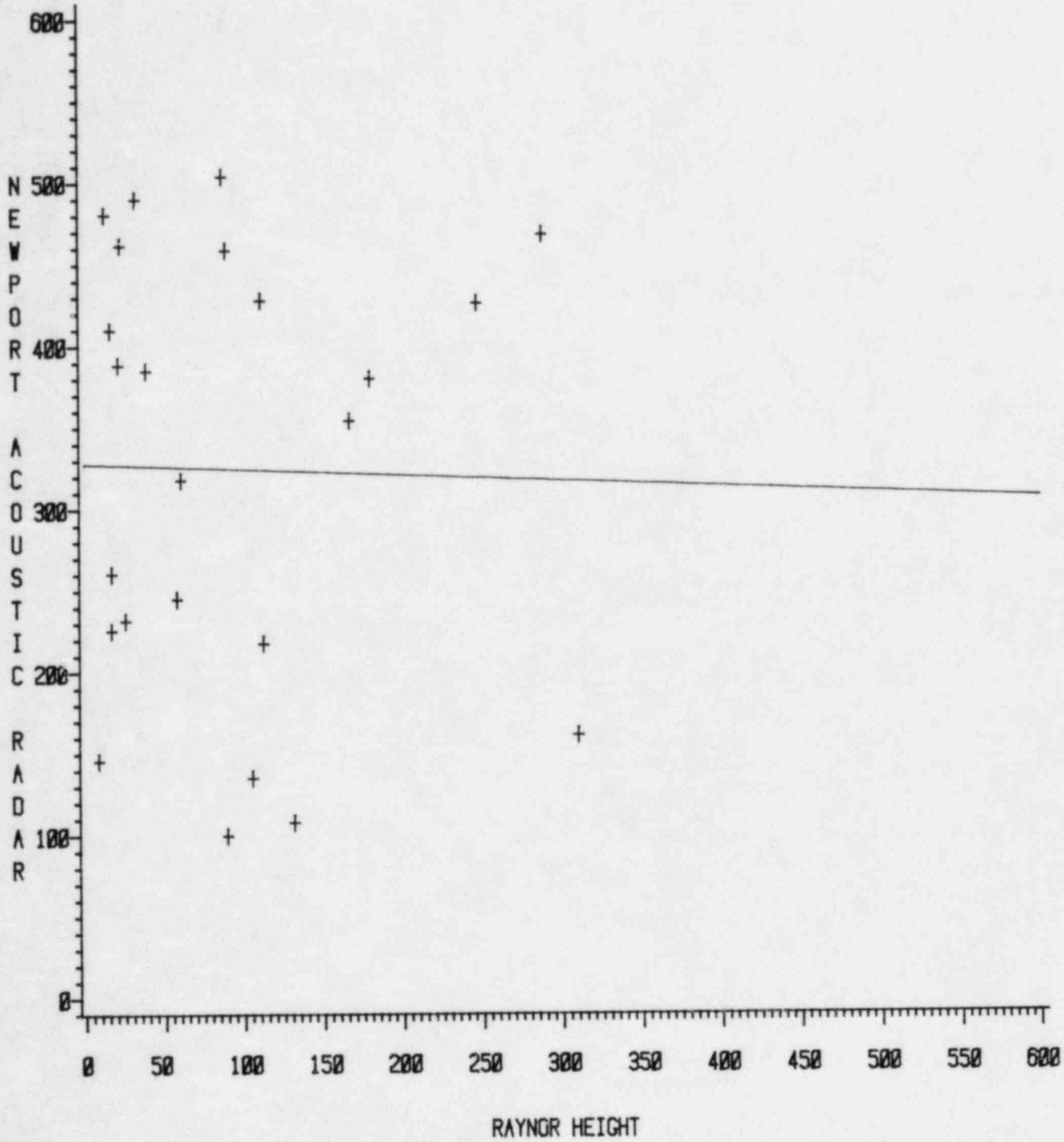


FIGURE 4.8

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

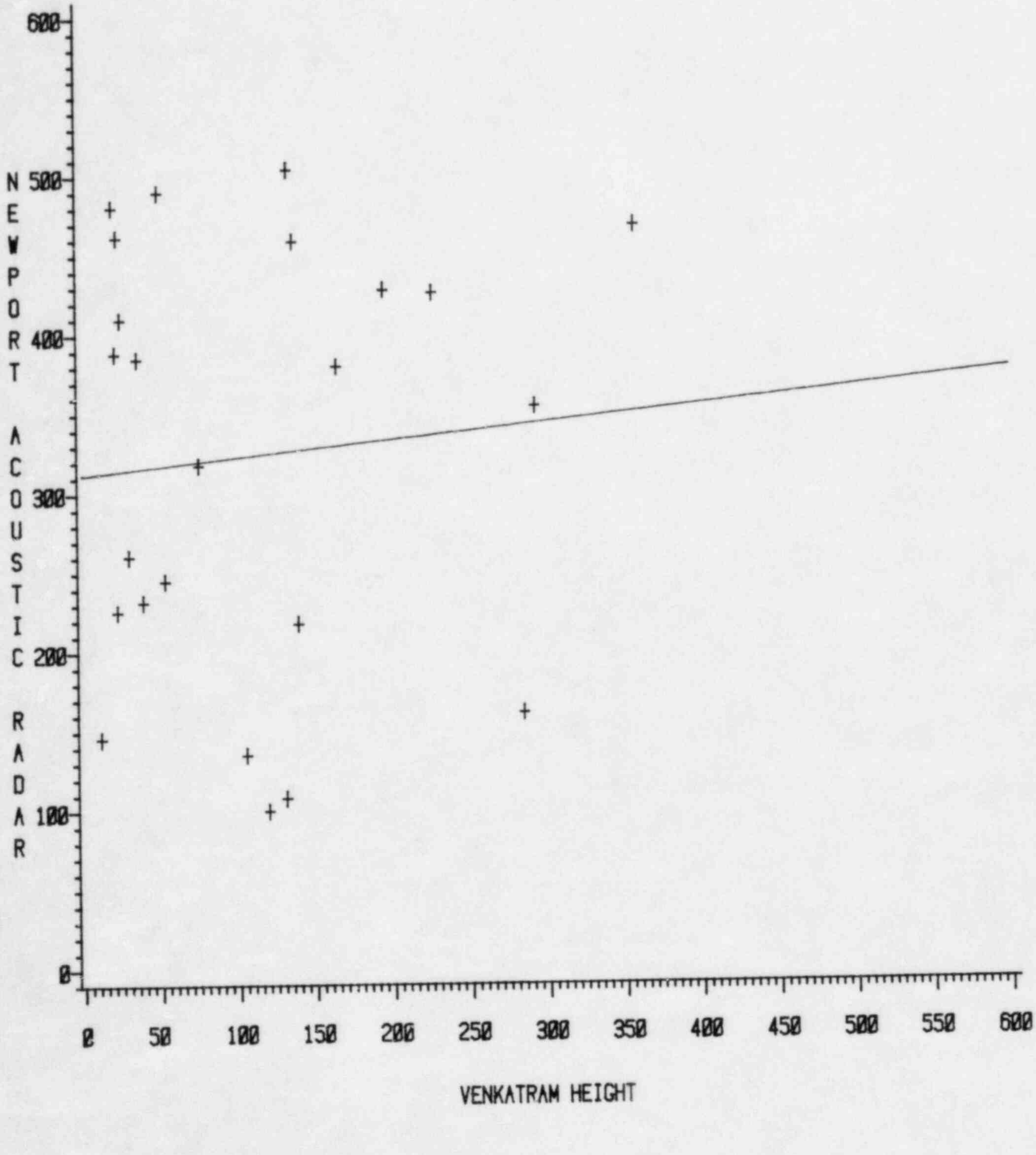


FIGURE 4.9

FERMI 2 TIBL ANALYSIS

TIBL PREDICTED VS. OBSERVED

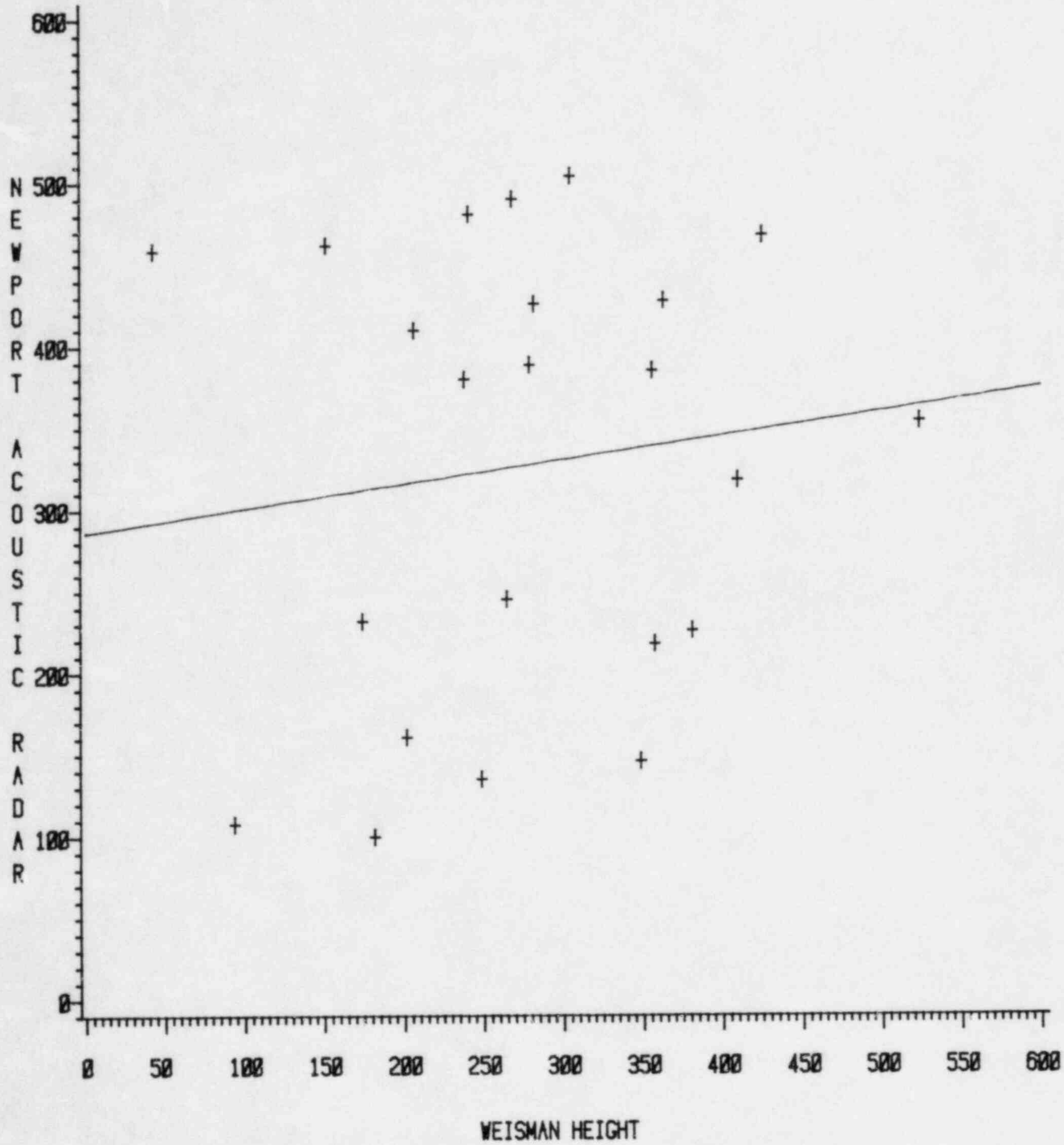


FIGURE 4.10

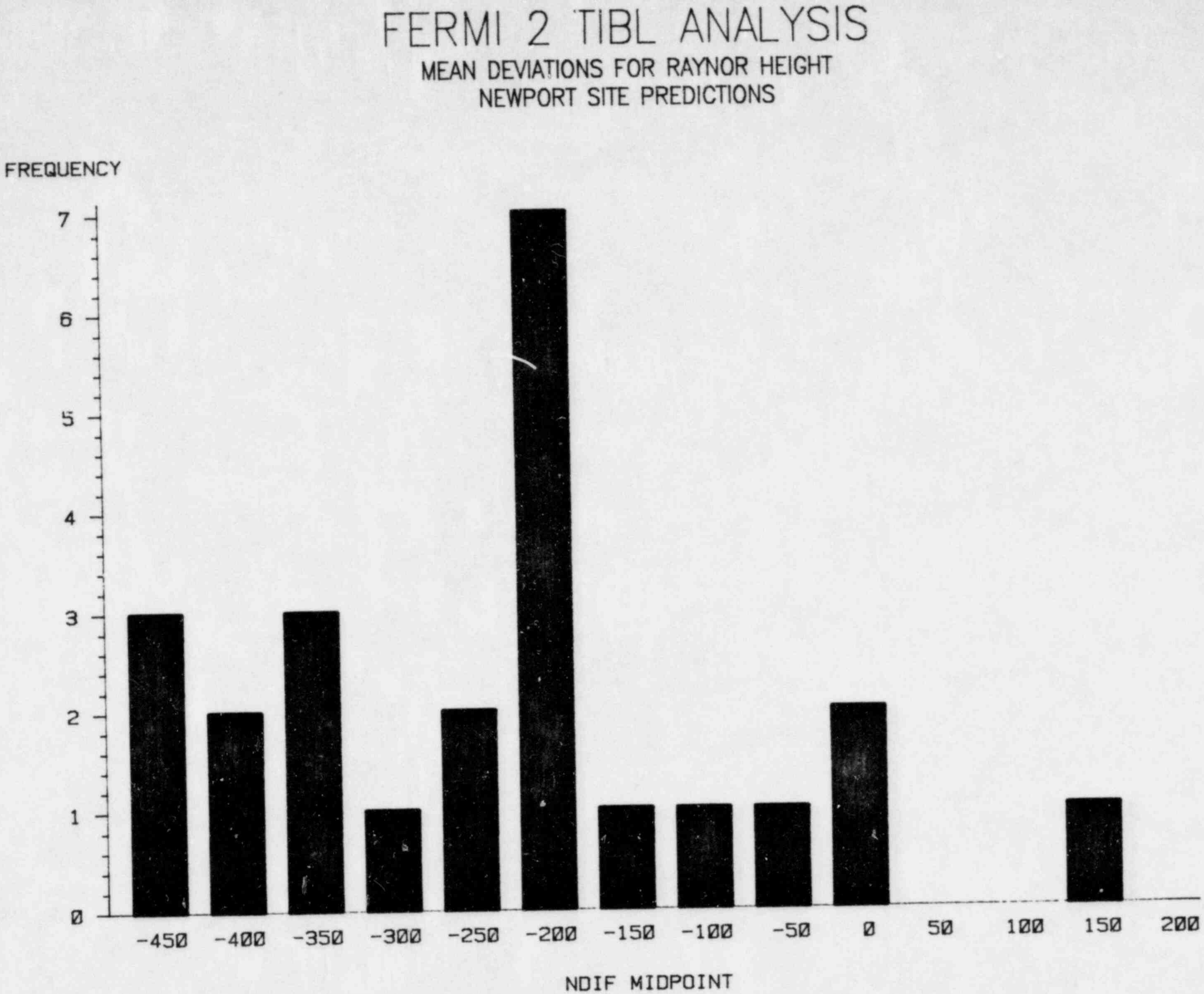

FERMI 2 TIBL ANALYSIS
MEAN DEVIATIONS FOR RAYNOR HEIGHT
NEWPORT SITE PREDICTIONS
FREQUENCY
7
6
5
4
3
2
1
0
-450
-400
-350
-300
-250
-200
-150
-100
-50
0
50
100
150
200
NDIF MIDPOINT

FIGURE 4.11

FERMI 2 TIBL ANALYSIS

MEAN DEVIATIONS FOR VENKATRAM HEIGHT
NEWPORT SITE PREDICTIONS

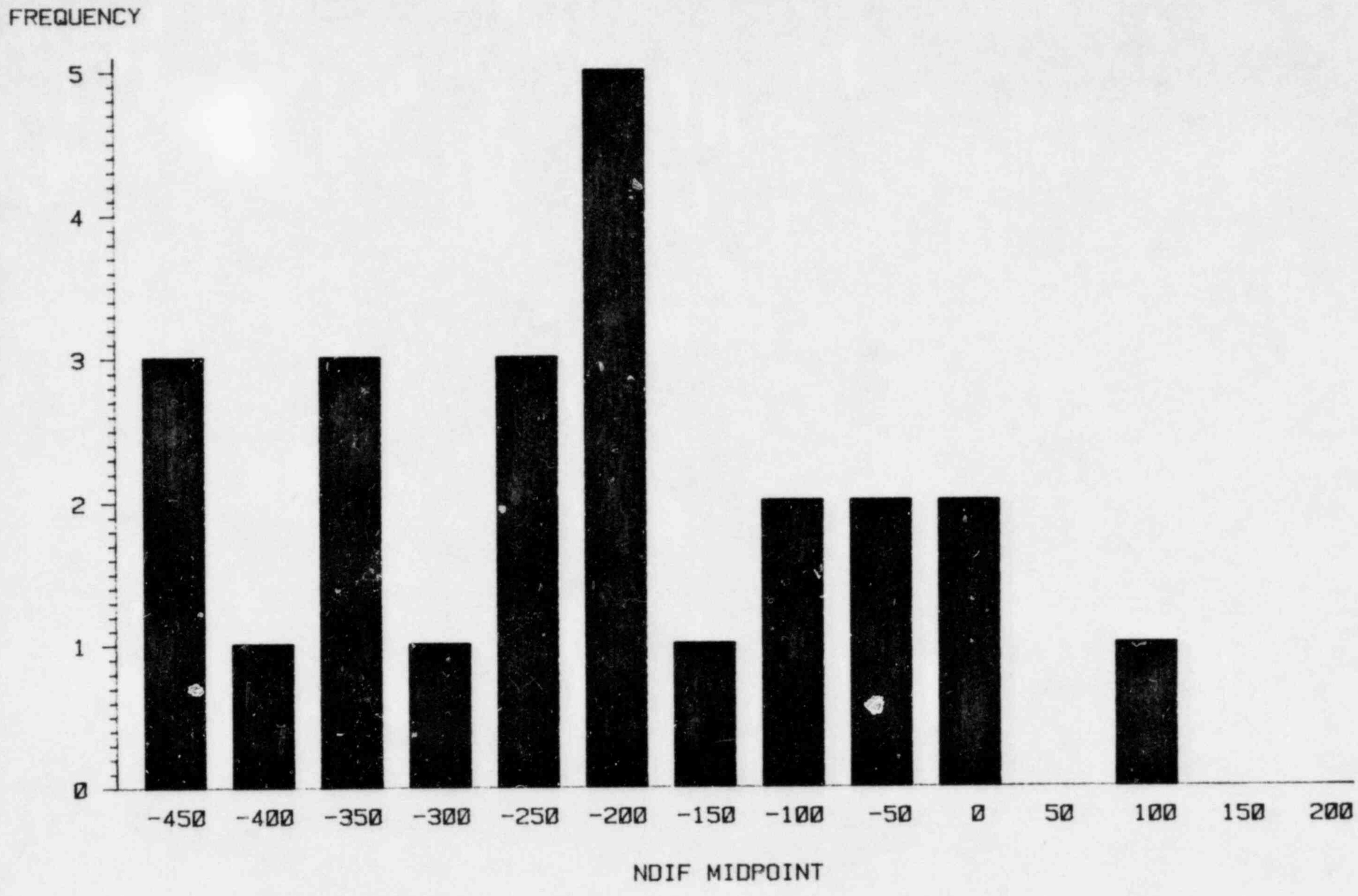


FIGURE 4.12

FERMI 2 TIBL ANALYSIS

MEAN DEVIATIONS FOR WEISMAN HEIGHT
NEWPORT SITE PREDICTIONS

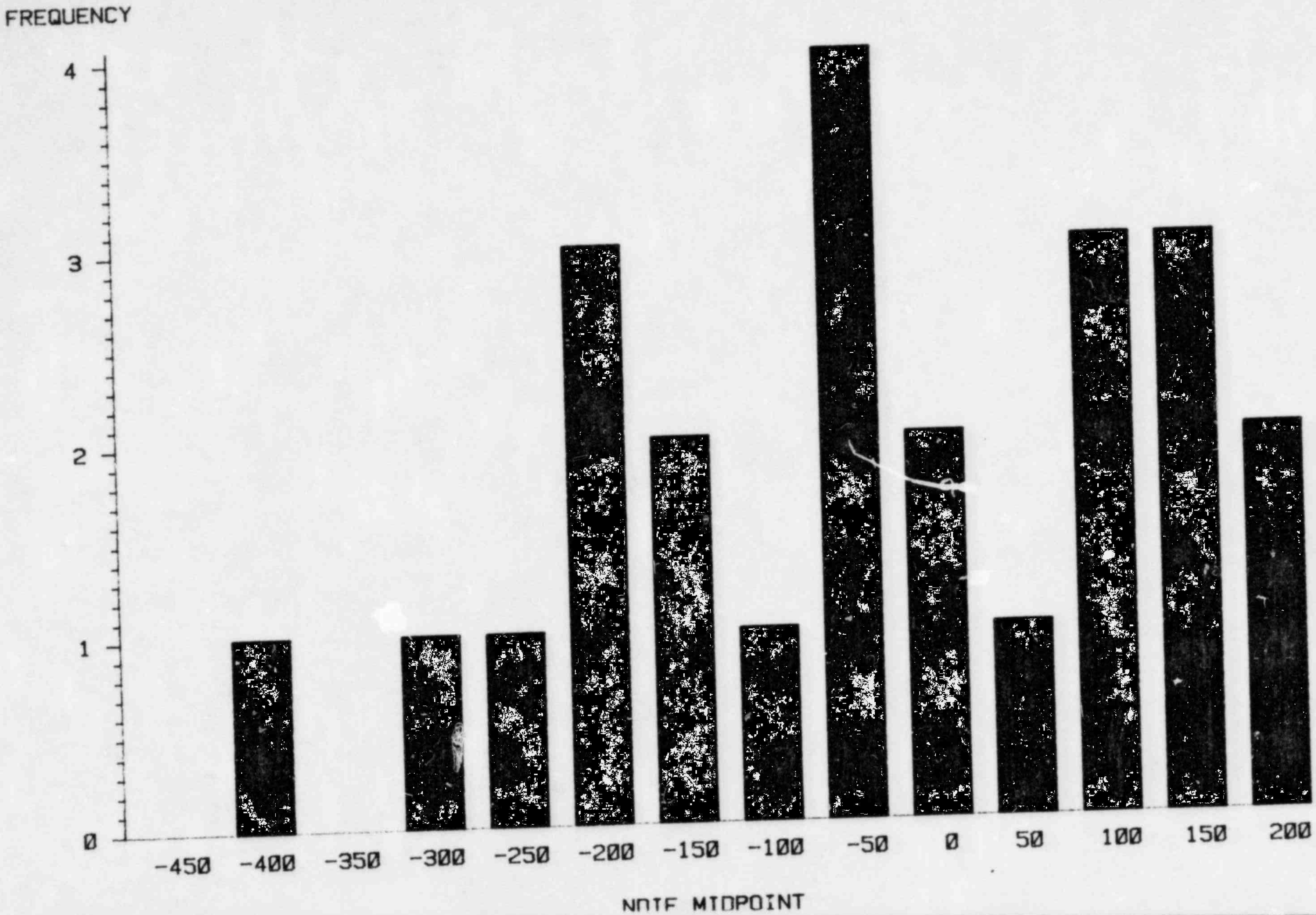
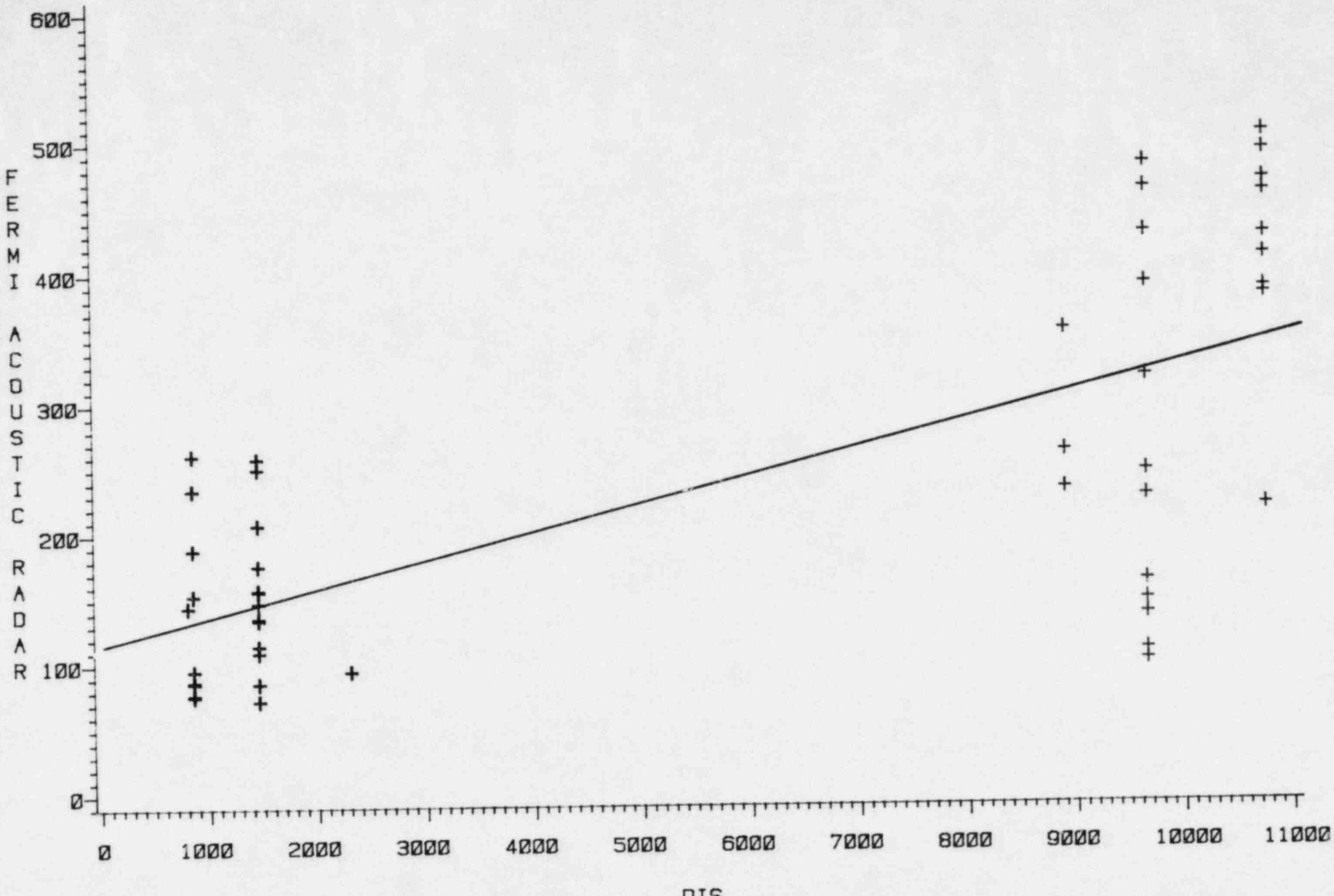


FIGURE 4.13

FERMI 2 TIBL ANALYSIS

ACOUSTIC RADAR WITH FETCH



5.0 CONCLUSIONS

The objective of the study is to determine the influence of Lake Erie on plume transport at the Fermi 2 Site and, if significant, modify the offsite dose assessment model.

When the study was initiated in 1983, it was believed that through measurement of the appropriate parameters, data could be entered in "coastal site" equations presented in the literature and an appropriate model could be selected for the Fermi 2 site. With actual TIBL heights being measured by acoustic radar, the capability to statistically compare measured and predicted values was available. A review of the results presented herein clearly indicates that well known methods of predictive modeling do not satisfactorily correlate with values measured when using the Fermi 2 specific data base.

Analytical work is continuing on the 1983 data base to identify a TIBL equation best suited for the Fermi 2 Site. Two approaches are under investigation:

- o Improvements to the predictive capability of the equations used in the study.
- o Development of a site specific relationship.

The results of this investigation will be used to determine the significance of TIBL formation on the dispersion of radioactive releases from Fermi 2. If this effect is significant, appropriate modifications to the offsite dose assessment model used during an emergency will be made.

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