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16. Abstract

Currently used Iso-footcandle design curves were developed by the state in the late 1960s and early 1970s. The primary objective of this project was to develop Iso-footcandle desgin curves from modern roadway lighting fixtures, independent of manufacturers' data. Iso-footcandle curves are graphical representations of the amount of light falling on the roadway from lighting fixtures or luminaires. These curves, or lines of constant light level, were produced from production fixtures that were reported to meet the specifications of the Texas Department of Transportation. During the course of the project, 75 separate production and experimental curves were produced from high and low pressure sodium luminaires. Roadway and underpass fixtures made up 40 of the curves and high mast, 100 feet or over, made up the remainder. Fixtures from five major manufacturers were evaluated.

The production fixture curves, which are included in the appendix of this report, will serve three purposes. The first is to be as a design aid in determining fixture type, illumination levels and locations from transparency template copies of these curves used in conjunction with highway plans. The second is to evaluate the published photometrics of lighting manufacturers and cooperatively resolve any discrepancies between their laboratory data and that of production units in real world installations. Thirdly, atypical, experimental lighting systems were developed and measured during this project for which no manufacturer curves are available.

Roadway lighting design software from three luminaire manufacturers was evaluated during the project and results compared to those obtained at the Proving Ground, producing, for the most part, favorable results.

Investigations made into improving multi fixture, high mast installations in the areas of economic efficiency, greater separation, increased light levels, better uniformity and less critical aiming are described in this report.

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DEVELOPMENT OF ISO-FOOTCANDLE CURVES FOR HIGHWAY LIGHTING

by

Richard A. Zimmer
Research Specialist
&
Principal Investigator

Research Report 1144-1F

on

Research Study No. 2-8-88-1144
Development of Iso-Footcandle Curves
for Highway Lighting

Sponsored by
Texas Department of Transportation

in cooperation with
The U.S. Department of Transportation
Federal Highway Administration

August 1991

Texas Transportation Institute
The Texas A&M University System
College Station, Texas

METRIC (SI*) CONVERSION FACTORS

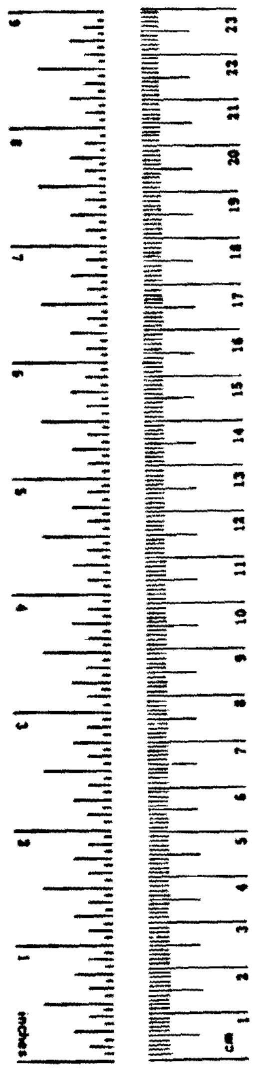
APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	2.54	centimetres	cm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km
	AREA			
in^2	square inches	645.2	centimetres squared	cm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha
	MASS (weight)			
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
	VOLUME			
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

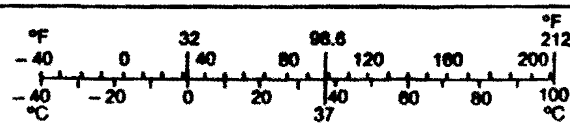


APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi
	AREA			
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectores (10 000 m^2)	2.53	acres	ac
	MASS (weight)			
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T
	VOLUME			
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

* SI is the symbol for the International System of Measurements

DISCLAIMER

The contents of this report reflect the views of the author who is responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation. The report is not intended for construction, bidding, or permit purposes.

Manufacturers' names, lighting fixture numbers and illustrations are used in this report for reference only and in no way constitute a recommendation by Texas Transportation Institute or the Texas Department of Transportation.

KEY WORDS

Iso-footcandles, Highway Lighting, Luminaires, High Mast, Illumination

ACKNOWLEDGMENTS

This research study was conducted under a cooperative program between the Texas Transportation Institute (TTI), the Texas Department of Transportation (TxDOT). and the Federal Highway Administration (FHWA). Dexter Jones and Dave Edwards (TxDOT District 12), and Karl Burkett (TxDOT D-18F) were closely involved in all phases of this study.

RESEARCH IMPLEMENTATION

To plan an effective roadway lighting system for a highway facility, many factors must be investigated, and leading the list has been the intensity and uniformity of the roadway illumination, measured in footcandles. In addition, recently *proposed* methods introduce the concept of Visibility Level (VL) and Small Target Visibility (STV). These factors must be balanced very carefully with system cost because as visibility is improved the cost increases, not always on a linear scale. The need to lower the lighting system cost is becoming more and more critical as state budgets become tighter. Also required levels of illumination for a particular type of facility must be realized after construction for nighttime safety. Should, after construction, a system be found deficient, major costs could be incurred for modification and rebuilding.

To produce a highway lighting system at the lowest cost that meets all illumination requirements, the engineer needs a vast array of information upon which to base decisions. The contents of this report are only a part of the information that may be used in the decision making process. The initial concept and preplanning of a lighting job could be assisted by fixture descriptions, footcandle curves and the successful and unsuccessful configurations described in this report. Other methodologies using computer-assisted illuminance and/or luminance computer programs should be used to the extent of the experience and facilities of the design engineers.

The Iso-footcandle curves produced on this project were from production fixtures, as would be used on a highway lighting job. It should be pointed out that differences, within manufacturers' acceptable tolerances, will be found between the sample luminaires used in this study, other similar fixtures and manufacturers' published engineering information. A lighting *system* consists of many individual units, each of which may perform slightly different from either the manufactures' curves or the curves developed during this study, solely due to allowable manufacturing tolerances of the individual component making up a roadway lighting system. The curves developed may be used as is by making transparency template copies for overlaying on highway plans. They also may be used for comparison to curves produced by lighting manufacturers. Since the manufacturers are attempting to produce economical fixtures, the final production units may not be identical to those used in their laboratory where the photometrics were developed. Small errors in fixture photometrics could result in large costs after a job is completed.

New high mast systems were developed and evaluated during the project to increase efficiency while decreasing installation and maintenance costs. This was accomplished with twelve, 400 watt modified asymmetrical fixtures aimed in one direction. Once the manufacturer implements the modification, this system may be implemented with a cost saving of less mast installations due to greater spacing.

ABSTRACT

Currently used Iso-footcandle design curves were developed by the state in the late 1960s and early 1970s. The primary objective of this project was to develop Iso-footcandle design curves from modern roadway lighting fixtures, independent of manufacturers' data. Iso-footcandle curves are graphical representations of the amount of light falling on the roadway from lighting fixtures or luminaires. These curves, or lines of constant light level, were produced from production fixtures that were reported to meet the specifications of the Texas Department of Transportation. During the project, 75 separate production and experimental curves were produced from high and low pressure sodium luminaires. Roadway and underpass fixtures made up 40 of the curves and high mast, 100 feet or over, made up the remainder. Fixtures from five major manufacturers were evaluated.

These production fixture plots, included in the appendix of this report, will serve three purposes. The first is to be as a design aid in determining fixture type, illumination levels and locations from transparency template copies of these curves used with highway plans. The second is to evaluate the published photometrics of lighting manufacturers and cooperatively resolve any discrepancies between their laboratory data and that of production units in real world installations. Third, atypical, experimental lighting systems were developed and measured during this project for which no manufacturer curves are available.

Roadway lighting design software from three luminaire manufacturers was evaluated during the project and results compared to those obtained at the Proving Ground, producing, usually, favorable results.

Investigations made into improving multi fixture, high mast installations in the areas of economic efficiency, greater separation, increased light levels, better uniformity and less critical aiming are described in this report.

PREFACE

The purpose of this report is to present the results of field measurements of illumination levels and patterns from randomly selected highway lighting fixtures. The data is presented in two sets. The first set is generic patterns of either a combination of manufacturers' fixtures of the same type or a single manufacturer that shows good photometrics and cannot be combined with similar units of other makes. These curves will not be named by make and should be considered 'typical' for design considerations and will all be on a scale of 1 in. equals 100 ft. The second set of curves is a compendium of production fixtures tested during the project and is located in the appendix. These fixtures will be described by manufacturer, mounting height, wattage, etc. and will be on various convenient scales.

Other sections of the report will describe the current illumination software available from manufacturers and how it compares to what was produced on this project. The results of high mast low pressure sodium experiments also will be included as well as an evaluation of lowmount floodlight systems.

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INTRODUCTION

The state-developed lighting Iso-footcandle curves that are in current use were developed in the late 1960s and early 1970s. Lighting equipment, technology and sources (lamps) have undergone many changes since the currently used state curves were developed. New state curves to utilize the latest industry developments were needed because industry published data is based on laboratory conditions, utilizing hand picked optimized equipment and not on production equipment used in construction projects. Experience has proven that the production equipment does not always meet the published data curves by a substantial margin.

To fill this gap, several representative lighting fixtures from various manufacturers were selected by department personnel for measurement and evaluation. Each fixture was randomly purchased and installed as would be on a highway project. Each fixture was measured at several mounting heights and configurations as specified by the department technical coordinator.

This report is divided into six chapters: a background on the methodology of illumination measurements and developing the Iso-footcandle curves; Iso-footcandle curves for design applications; industry data, curves, and design software; development of a high mast, low pressure sodium system; evaluation of low mount floodlight systems for narrow R.O.W., high mast lighting on narrow R.O.W., evaluation of a high mast, low pressure sodium, lighting systems; and the appendices that contain the remainder of the Iso-footcandle curves developed.

It was not within the scope of this project to provide guidelines for the placement, installation of highway lighting systems or setting photometric requirements for highway lighting systems.

Chapter I

DEVELOPMENT OF ISO-FOOTCANDLE CURVES

DEVELOPMENT OF ISO-FOOTCANDLE CURVES

Facilities

The Texas Transportation Institute Proving Ground at the TAMU Riverside Campus was used to replicate the luminaire mounting conditions that would be found in actual use and to provide a large, flat, paved area for illumination measurements. The area used at the Riverside Campus, formerly the Research Annex, for the work is the same that was used in the previous study of this type in the late 1960s. This is a 500 foot by 4000 foot concrete area, formerly used for parking military aircraft. The concrete pavement is constructed with expansion joints every 15 feet in the north-south direction and 12.5 feet in the east-west direction. The distance between these joints has been verified to be accurate to within a few percent. With this accuracy, these joints were used as the measurement grid as in previous lighting studies in that area. The luminaire mounts consisted of four TxDOT portable towers with a sliding carriage that would extend to 50 feet above the ground. A 150 foot high mast pole, used in previous studies, was also utilized. This high mast pole contained an electric winch and associated cables and pulleys to facilitate the raising and lowering of the steel ring upon which the luminaires were mounted. As part of this project a new high mast pole, Figure 1, was installed at the facility. This new pole was of current design with a working height of 175 feet. This pole was located 600 feet south of the old one to allow fixtures to be operated from both simultaneously to evaluate complex interaction of two similar or dissimilar configurations. To accommodate the various fixtures, special

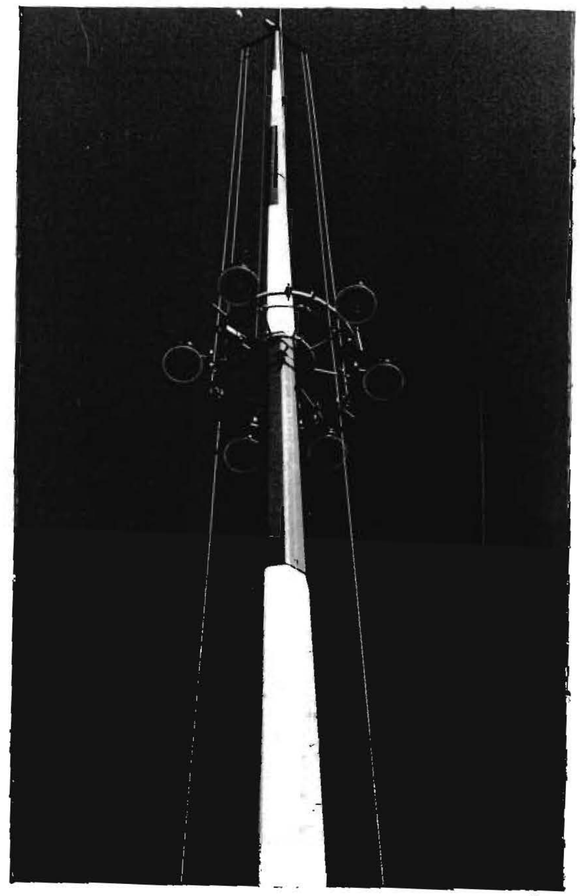

Figure 1. 175 foot, High Mast Test Facility.

mounts and arms were fabricated for the low and high supports. Each of the high mast poles and the 50 foot towers were supplied with 480 volt power that was monitored by digital instrumentation.

Instrumentation

Illumination measurements were made by a Tektronix J-16 photometer. This is the same type of unit that has been used by the department in Districts 12 and D-9 for many years. The J-16 is a self contained, portable meter that accepts various light probes. The probe used in this project was the J6511 cosine corrected illuminance unit. This probe is within 5% of NBS standards and ±1 digit in last place. The multi element glass filter ensures a close match to the CIE photopic curve (color corrected). The J-16 displays the footcandle values on the front of the unit on a four place digital readout. An electronic digital signal representing the value of the readout is also available at a connector on top of the unit.

Improved efficiency and accuracy of measuring High Mast (>100ft.) light levels, done in the past by walking the grid, carrying the light meter, was accomplished with a system similar to that developed by TTI during a previous project[1]. This system automated the process of acquiring illumination data by connecting the data output connector of the J-16 light meter to a small, dedicated central processor unit. The processor was then connected to a laptop computer that recorded the light values. These units were placed inside a standard passenger vehicle with the J6511 probe attached to the roof of the test vehicle by a magnet. Illumination data gathered above the pavement, typically 5 feet, was corrected back to pavement level, mathematically, in the data acquisition computer. This was done by decreasing the value of the illumination data using the inverse square law function, the height of the fixture and the height of the probe. A 5th wheel attached to the bumper measure distance traveled in one foot increments that were fed into the processor unit and used to initiate a light level recording. The processor was programmed to record a light value every 30 feet in the forward direction, which equated to the X axis. The test vehicle would move

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[1] Richard A. Zimmer, "Development of Automated Illumination Test Equipment," TTI Report No. 0942-F, Prepared for the Texas Department of Highways and Public Transportation, February 1989

laterally 25 feet at the beginning of each measurement lane along the Y axis. This process then set the measurement grid points at 30 by 25 feet, or every two pavement joints, as had been used in all previous lighting studies. An example of the footcandle data points located on the grid is shown in Figure 2. The beginning of each lane, or X axis, would start 600 feet south of the luminaire. Measurements would continue at a speed of about 10 mph until either 600 feet north was reached or the light level dropped below 0.05 footcandles. The process would continue, lane by lane, until a light level of more than 0.05 footcandles could not be achieved or the end of the pavement was reached in the Y axis.

The small laptop computer containing the illumination and distance values was then connected to a full size personal computer through the serial ports and transferred the data using standard communications software. The test data are then recorded to disk to provide a permanent copy. A program called 'SURFER' by Golden Software Inc. of Golden, Colorado, was used to convert the X and Y distance values and Z illumination values to Iso-footcandle curves. Surfer was designed primarily as a tool to be used in surveying but may be used to produce contour maps and surface plots of any X Y Z data. The program will produce topographical or iso plots in a two dimensional view as in this report or in a 3-D view. An example of these two forms of presentation is shown in Figures 3A and 3B. The initial output was plotted on a HP 7475 plotter. Later, a HP Laser Jet II was used with a Pacific Data Products "Plotter in a Cartridge" with superior results.

Lighting patterns other than High Mast were measured in the conventional method of walking with the light meter. The probe was located on a metal base with a long handle, like a golf club, allowing the operator to rapidly place the base on the ground, record a value and move on. The grid pattern used for fixtures mounted less than 100ft. was 12.5ft. by 15ft or less.

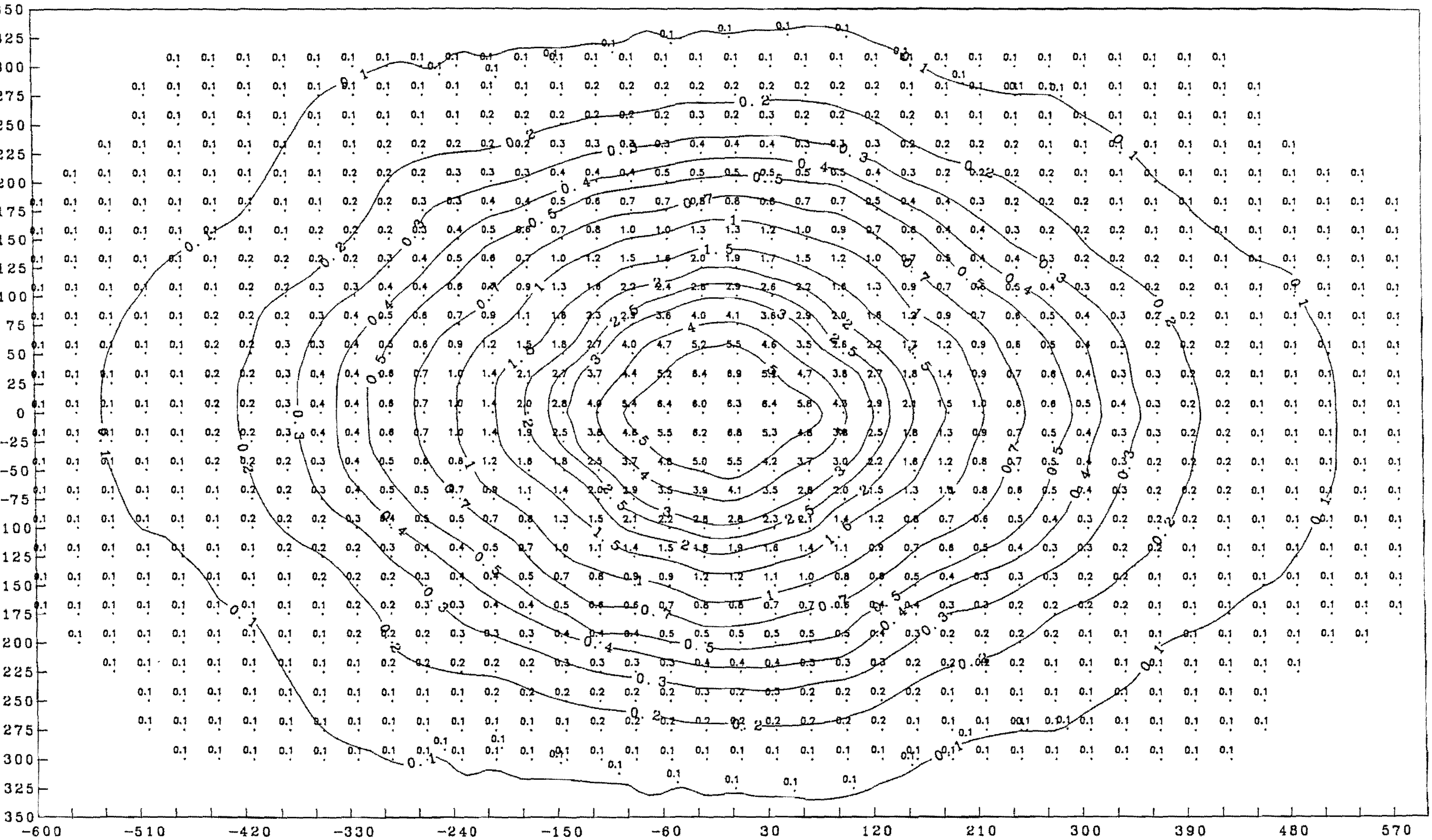


Figure 2. Example of Iso-footcandle Data Output. ALL DATA POINTS TO NEAREST TENTH F.C.

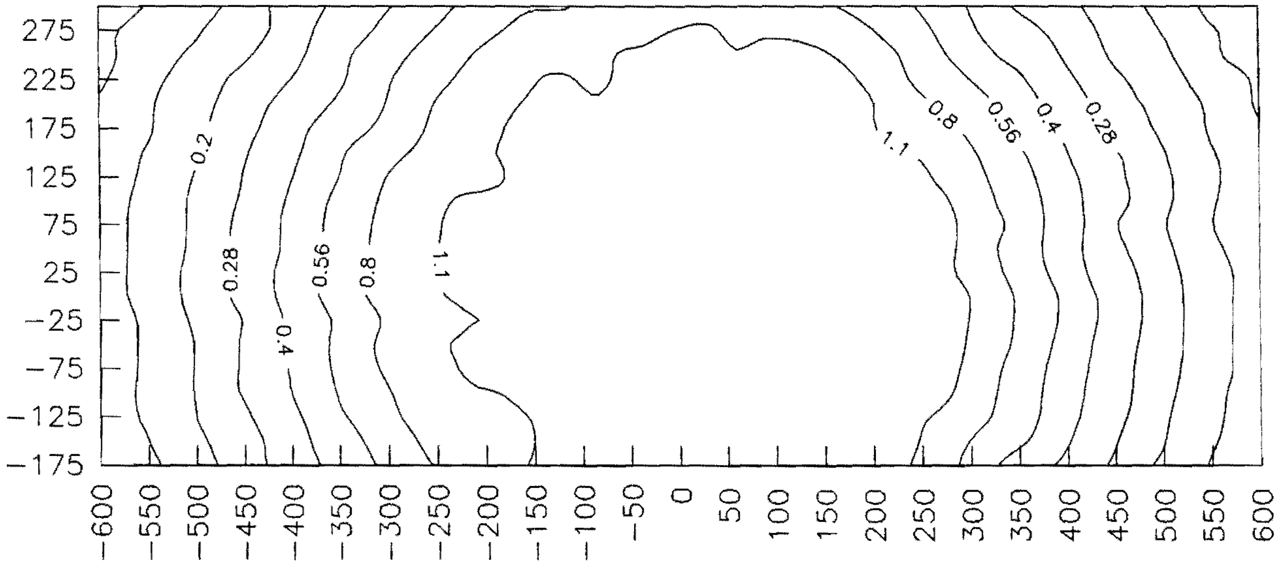


Figure 3A. Example of SURFER Plot in 2-D.

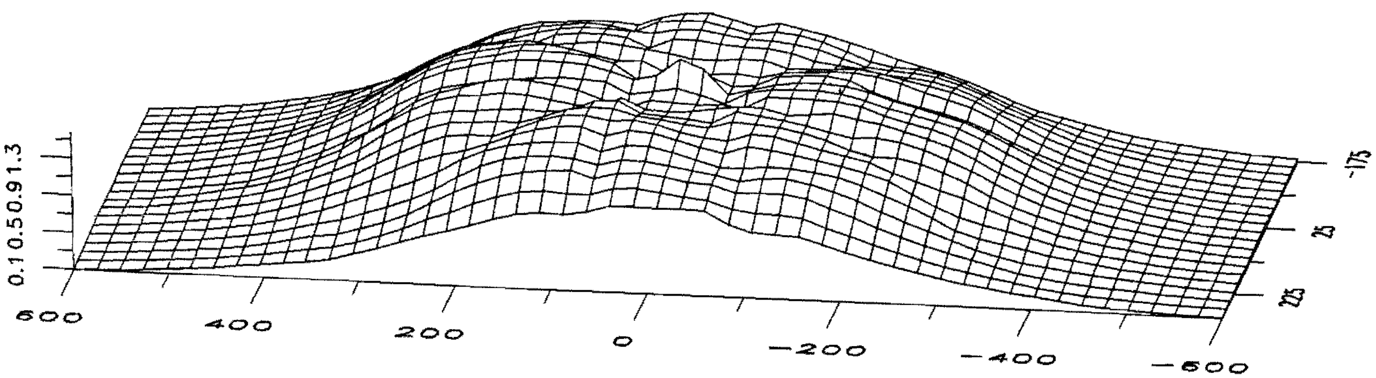


Figure 3B. Example of SURFER Plot in 3-D.

Chapter II

ISO-FOOTCANDLE CURVES FOR DESIGN APPLICATIONS

ISO-FOOTCANDLE CURVES FOR DESIGN APPLICATIONS

To provide highway engineers with another tool to assist in the development of roadway lighting systems, Iso-footcandle templates for the following fixture types and mounting heights are presented. These curves may also be useful for initial selection of fixtures by highway engineers with limited experience in roadway illumination. These templates should be considered as typical illumination patterns from these classes of fixtures and should be used only for preliminary selection of a fixture type. Actual illumination patterns measured from various manufacturers' units are shown in Appendix A.

Roadway

- Single arm 400 watt HPS mounted at 50 ft.
- Twin arm 400 watt HPS mounted at 50 ft.
- Single arm 250 watt HPS mounted at 40 ft.
- Twin arm 250 watt HPS mounted at 40 ft.
- Single 150 watt underpass "cobra head" at 20 ft.

High Mast

- Twelve 400 watt HPS symmetric mounted at 150 ft.
- Twelve 400 watt HPS asymmetric, 6 each way at 150 ft.
- Twelve 400 watt HPS asymmetric, all one way at 150 ft.

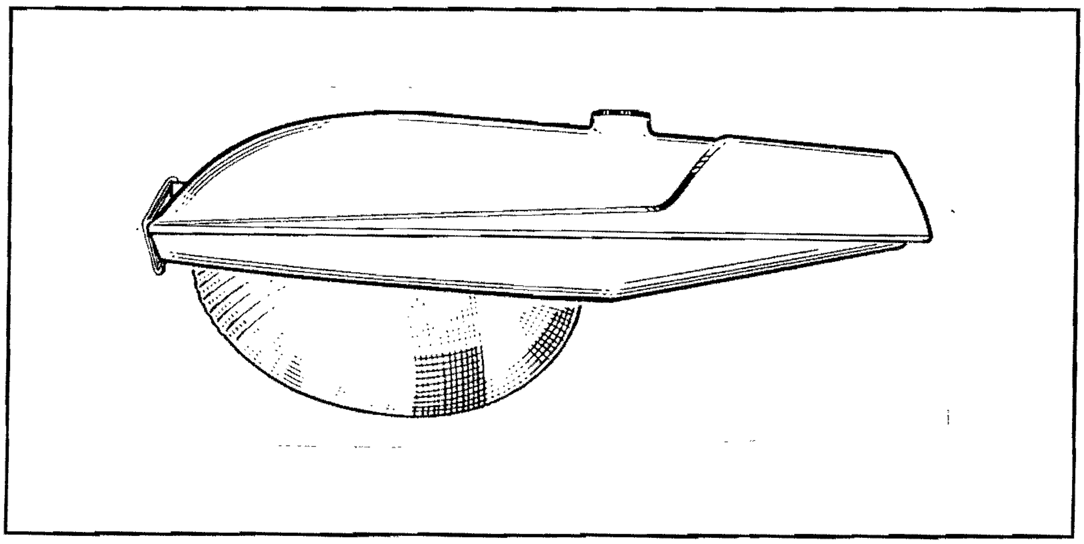
All curves will be on a scale of 1 inch equals 100 feet or 1:100 except for the very small patterns. The Iso-footcandle curve levels will be 0.1, 0.2, 0.4, 1, 2, and 4 footcandles. The curves used in these examples are for basic design planning applications and are not intended to recommend a particular fixture, mounting height or manufacturer. Any deviations in the actual luminaire installation, lighted area geometry, and the introduction of obstructions within the lighted space may produce illumination results different from the values shown. Also, normal tolerances of supply voltage, lamp output, ballast and luminaire manufacturer will affect the results. These examples may be used by making copies on transparency film and using them as overlays on highway plans with a scale of 1:100.

SINGLE ARM 400W HPS ROADWAY FIXTURE

MOUNTED AT 50 FEET

This is a standard, high pressure sodium, roadway "cobra head" fixture with both a reflector and glass prismatic refractor, for street, highway, parking lot and area lighting. The test height was 50 feet above the roadway.

The IES distribution is a Type III, Medium Semi-cutoff.



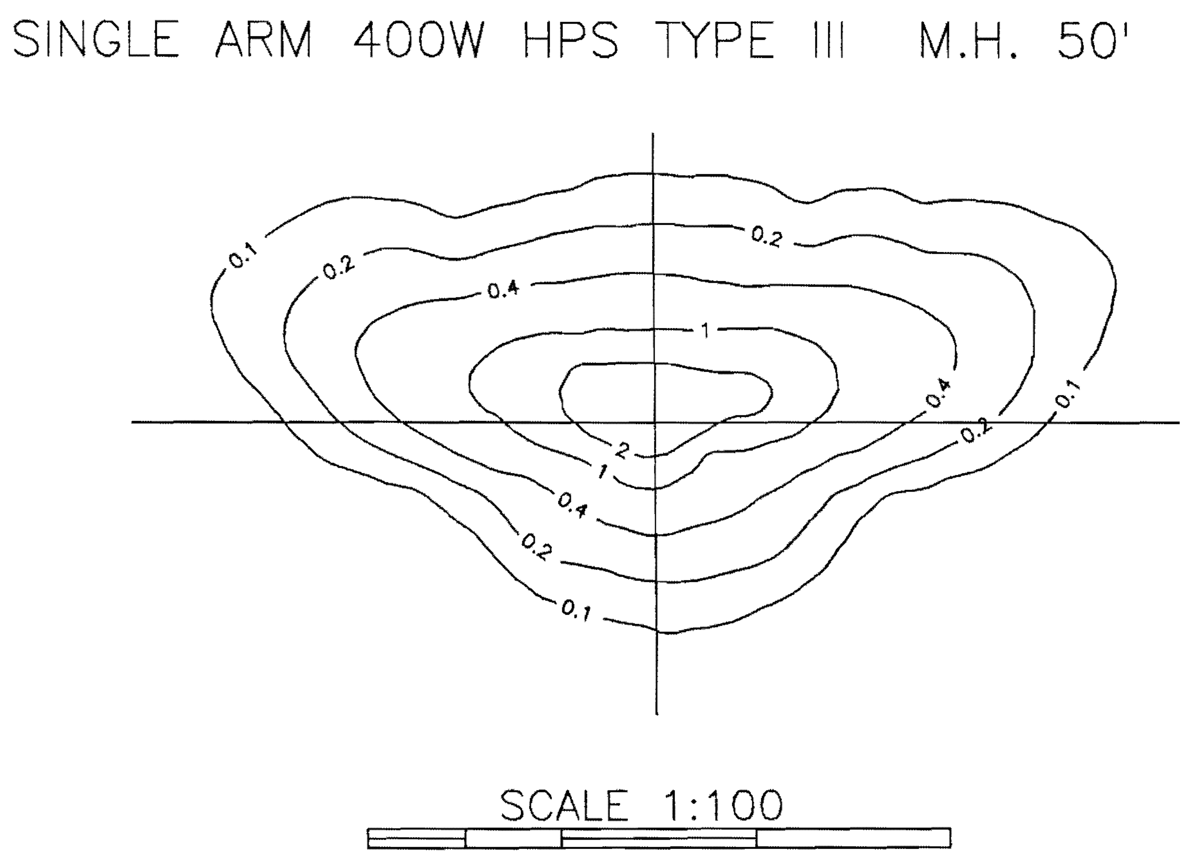


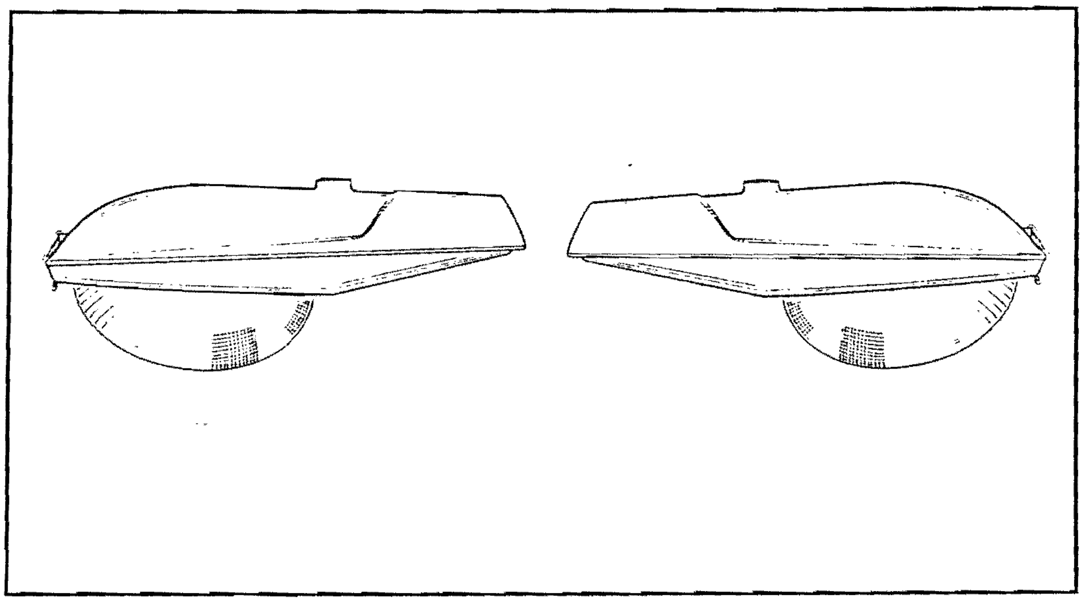
Figure 4. Iso-footcandle Curves for Single Arm 400W HPS Type III. Mounting Height at 50 Feet

TWIN ARM 400W HPS ROADWAY FIXTURES

MOUNTED AT 50 FEET

These are standard, high pressure sodium, roadway "cobra head" fixtures with both a reflector and glass prismatic refractor. They are mounted in opposing directions, 16 feet apart, in a gull wing configuration. They are recommended for street and highway medians, parking lot and area lighting. The test height was 50 feet above the roadway.

The IES distribution is a Type III, Medium Semi-cutoff.



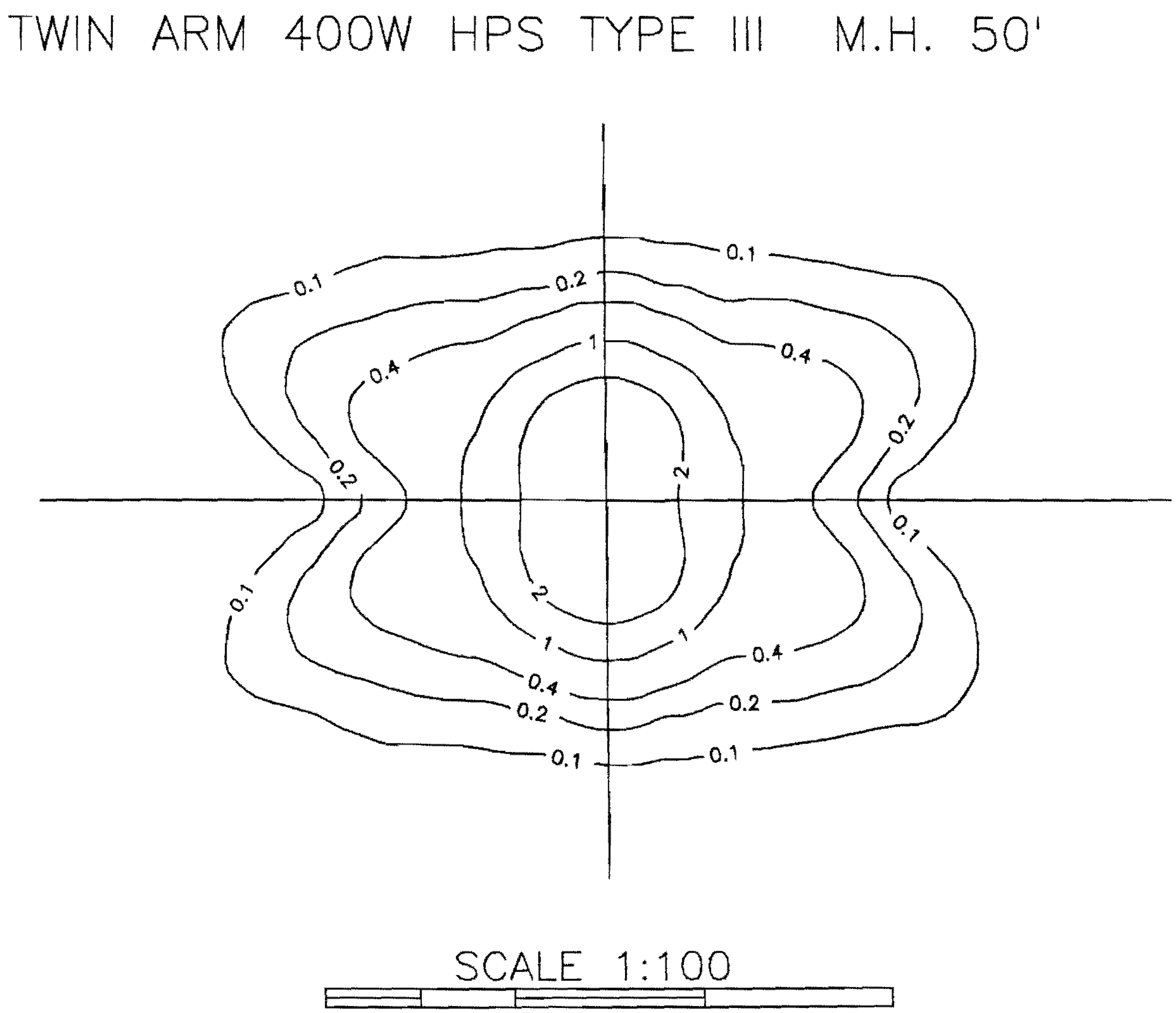
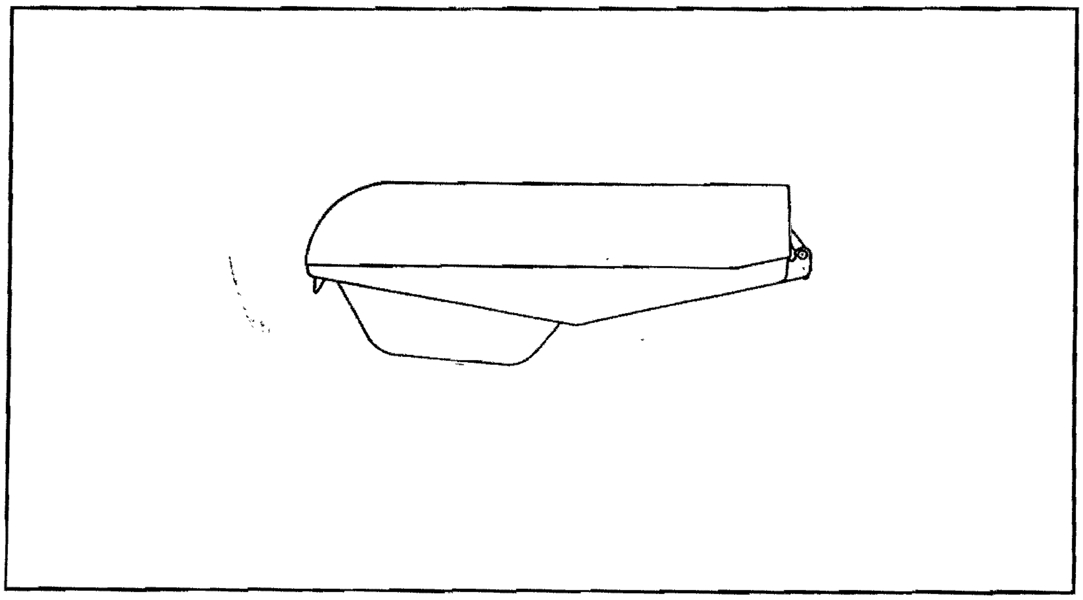


Figure 5. Iso-footcandle Curves for Twin Arm 400W HPS Type III.
Mounting Height at 50 Feet

SINGLE ARM 250W HPS ROADWAY FIXTURE
MOUNTED AT 40 FEET

This is a standard, high pressure sodium, roadway "cobra head" fixture with both a reflector and glass prismatic refractor, for street, highway, parking lot and area lighting. The test height was 40 feet above the roadway.

The IES distribution is a Type III, Medium Semi-cutoff.



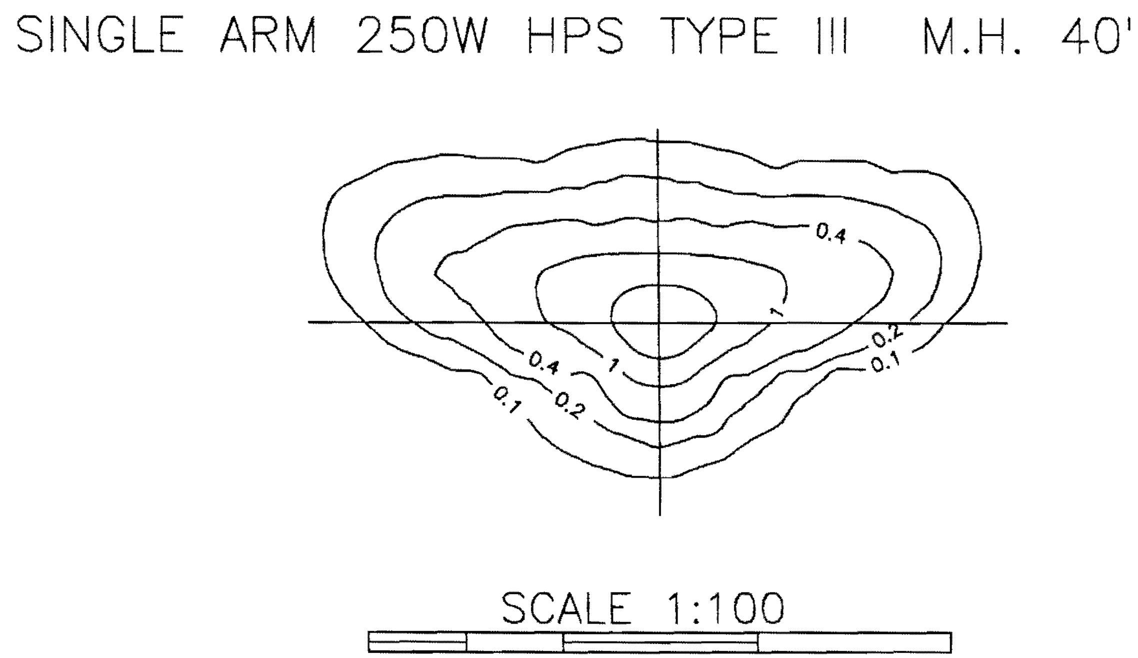
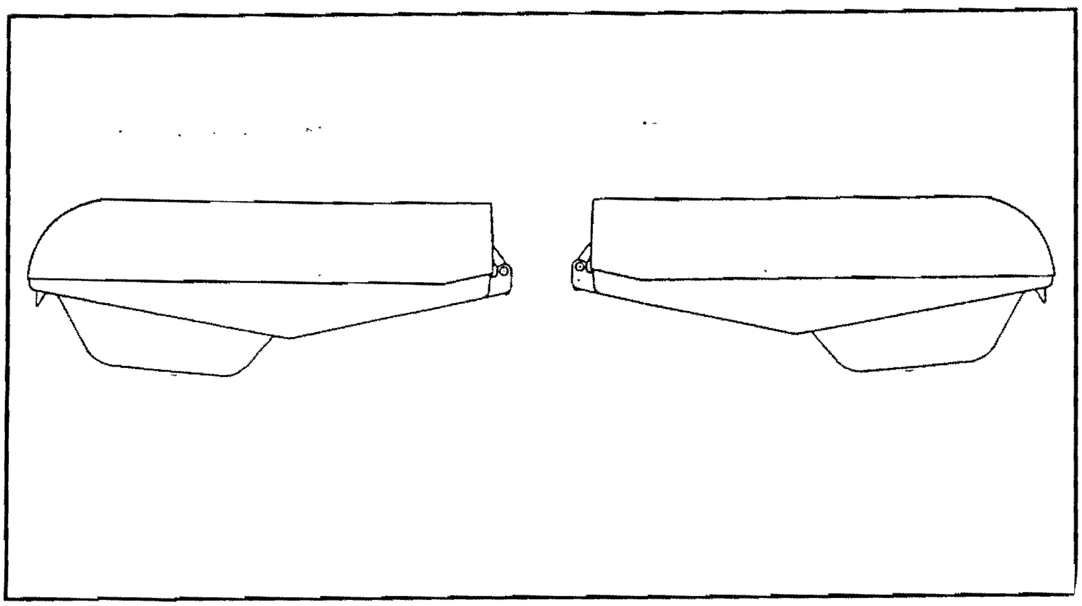


Figure 6. Iso-footcandle Curves for Single Arm 250W HPS Type III. Mounting Height at 40 Feet

TWIN ARM 250W HPS ROADWAY FIXTURES
MOUNTED AT 40 FEET

These are standard, high pressure sodium, roadway "cobra head" fixtures with both a reflector and glass prismatic refractor. They are mounted in opposing directions, 16 feet apart, in a gull wing configuration. They are recommended for street and highway medians, parking lot and area lighting. The test height was 40 feet above the roadway.

The IES distribution is a Type III, Medium Semi-cutoff.



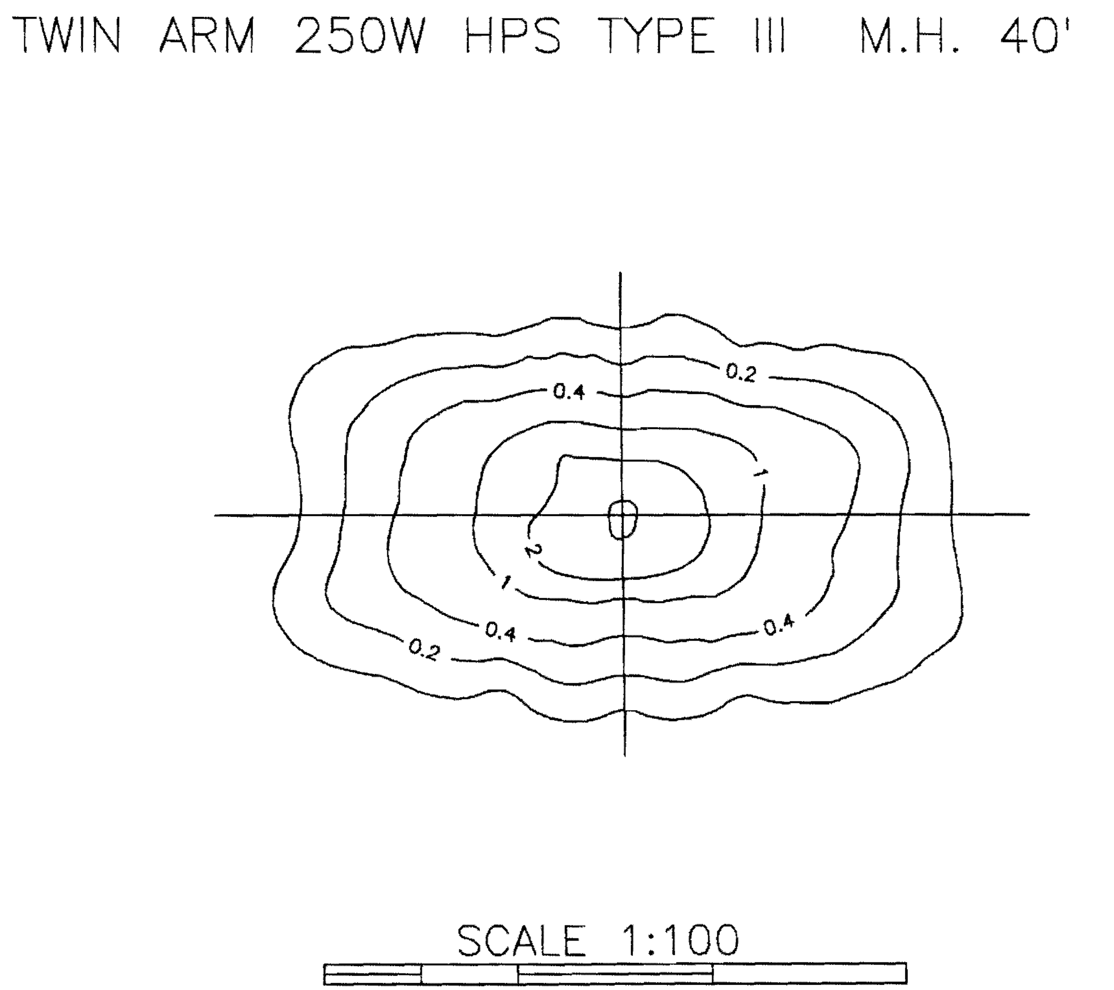
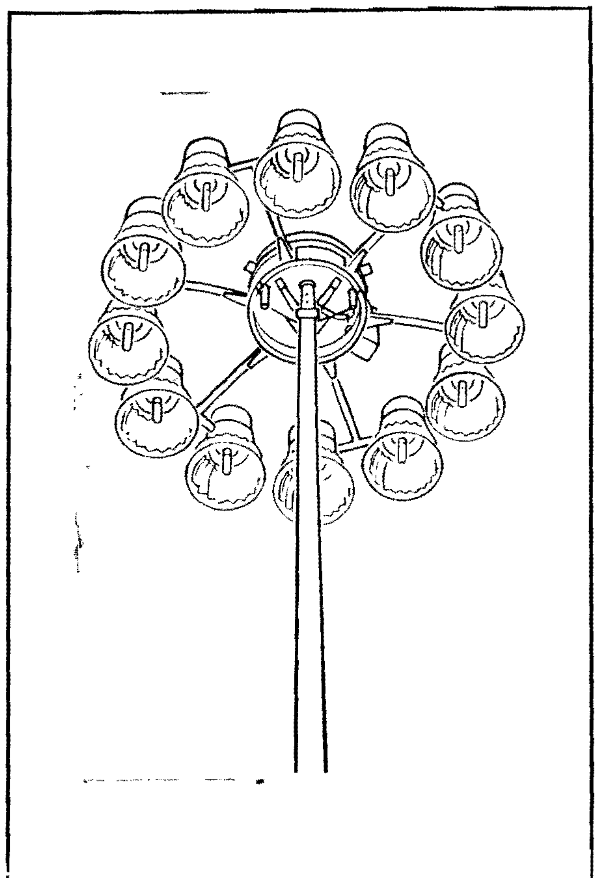


Figure 7. Iso-footcandle Curves for Twin Arm 250W HPS Type III. Mounting Height at 40 Feet

TWELVE 400 WATT, HPS, SYMMETRICAL, HIGH MAST FIXTURES MOUNTED AT 150 FEET

These symmetrical, IES medium cutoff, type V, high mast fixtures produce a near perfect circular pattern. The Iso-footcandle curves shown for these fixtures produce a circle with the 0.1 footcandle limits at a radius of 450 feet. This equates to about 636,000 square feet of illumination from one installation. This configuration was one of the easiest to aim and produce repeatable results between setups. This is probably due to the simplicity of the reflector design and the many fixtures with all the same pattern. Should one or two fixtures have a problem or go out, the others would fill in.



12 400W Medium Cutoff Type V M.H. 150'

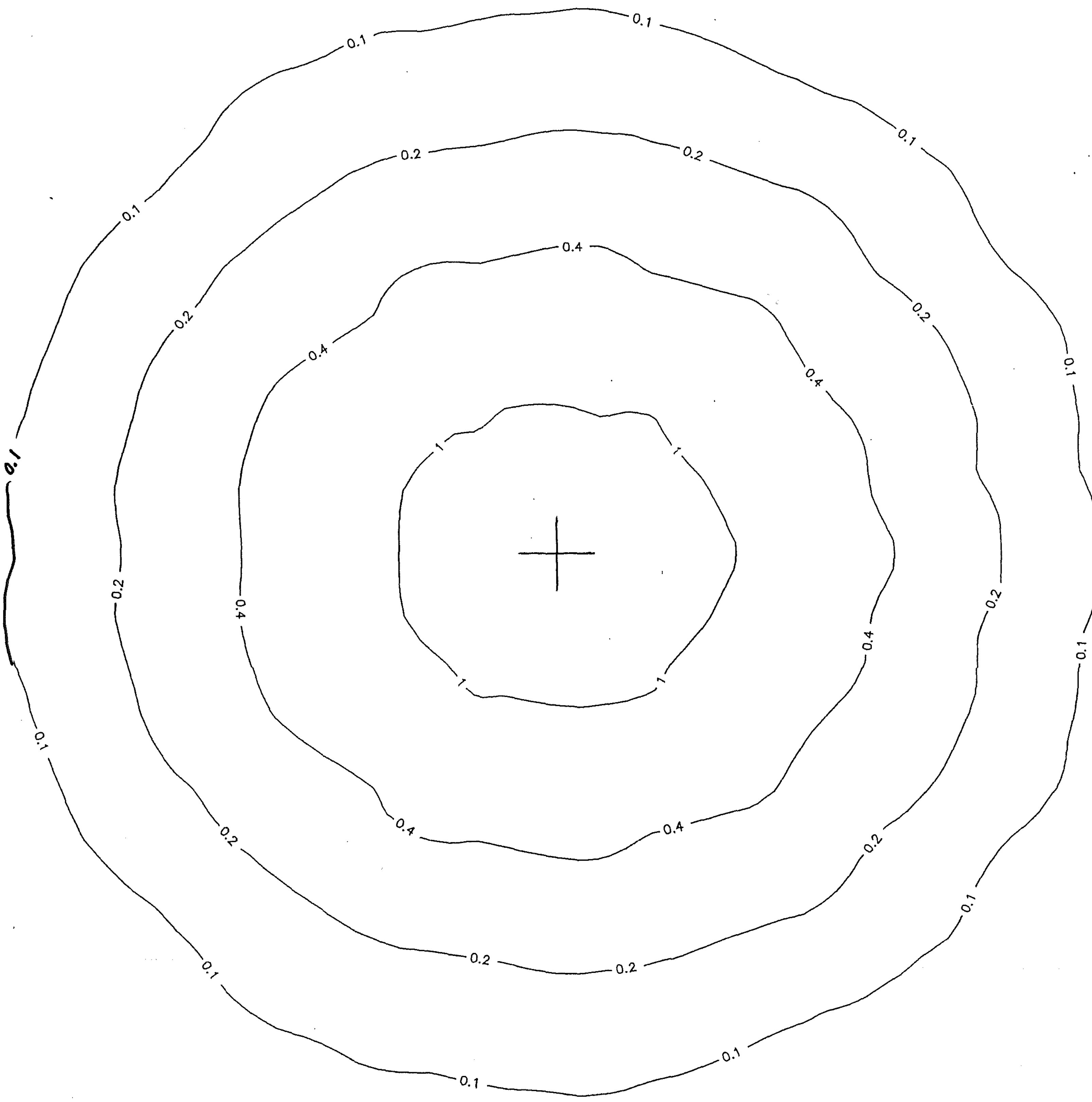


Figure 8. Iso-footcandle Curves for Twelve 400W Medium Cutoff Type II. Mounting Height at 150 Feet

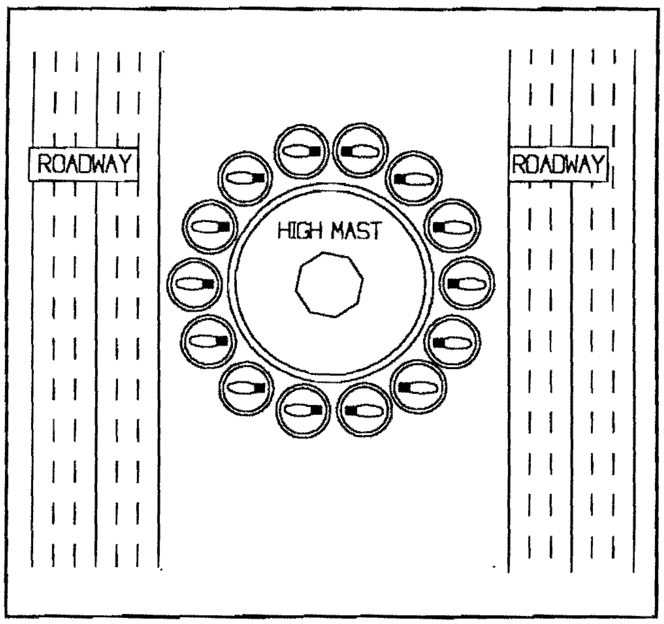
SCALE 1:100

TWELVE 400 WATT, HPS, ASYMMETRICAL, HIGH MAST FIXTURES

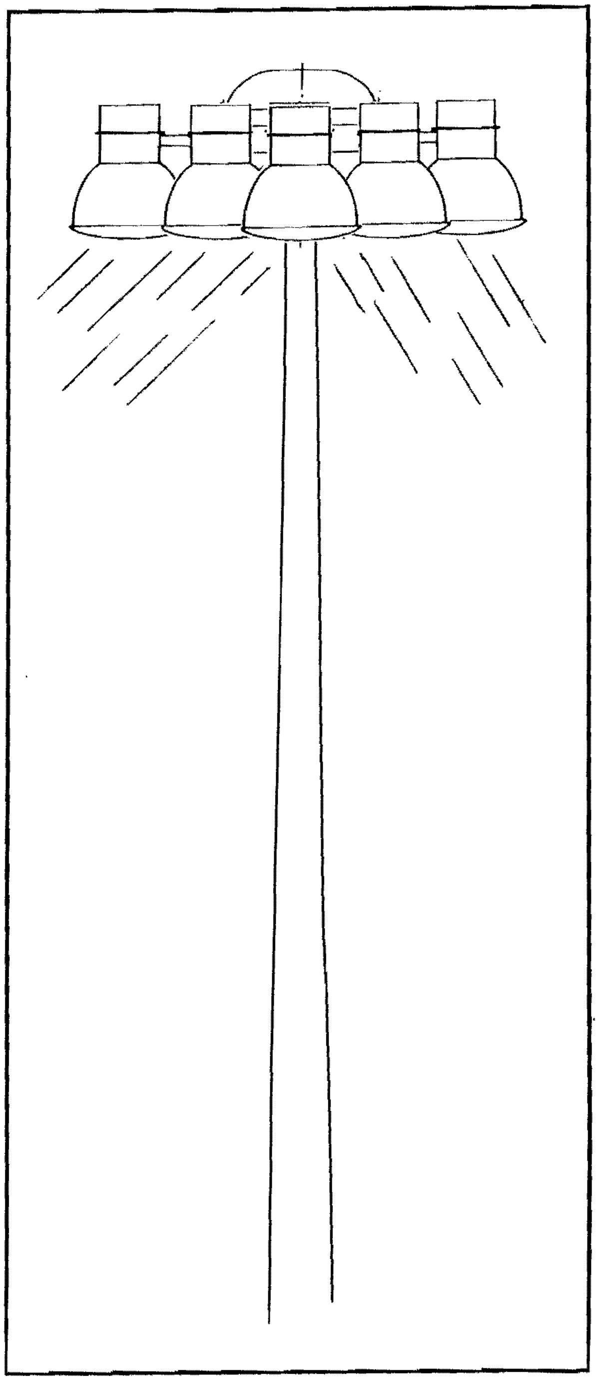
6 AIMED 0 deg. AND 6 AIMED 180 deg.

MOUNTED AT 150 FEET

These fixtures are similar in appearance to the Symmetrical type except the lamps are in a horizontal position compared to a vertical position in the Symmetrical fixture. This Asymmetrical pattern is an IES medium cutoff type II. With half the fixtures aimed opposite of the other half a rectangular pattern is developed with the pole in the center. As with the Symmetrical pattern ease of aiming and repeatability is good except be careful to orient the lamps perpendicular to the roadway.



Luminaire aiming - Plan View



12 ASYMMETRICAL (6 EACH WAY) 400W MED. CUTOFF TYPE II M.H. 150'

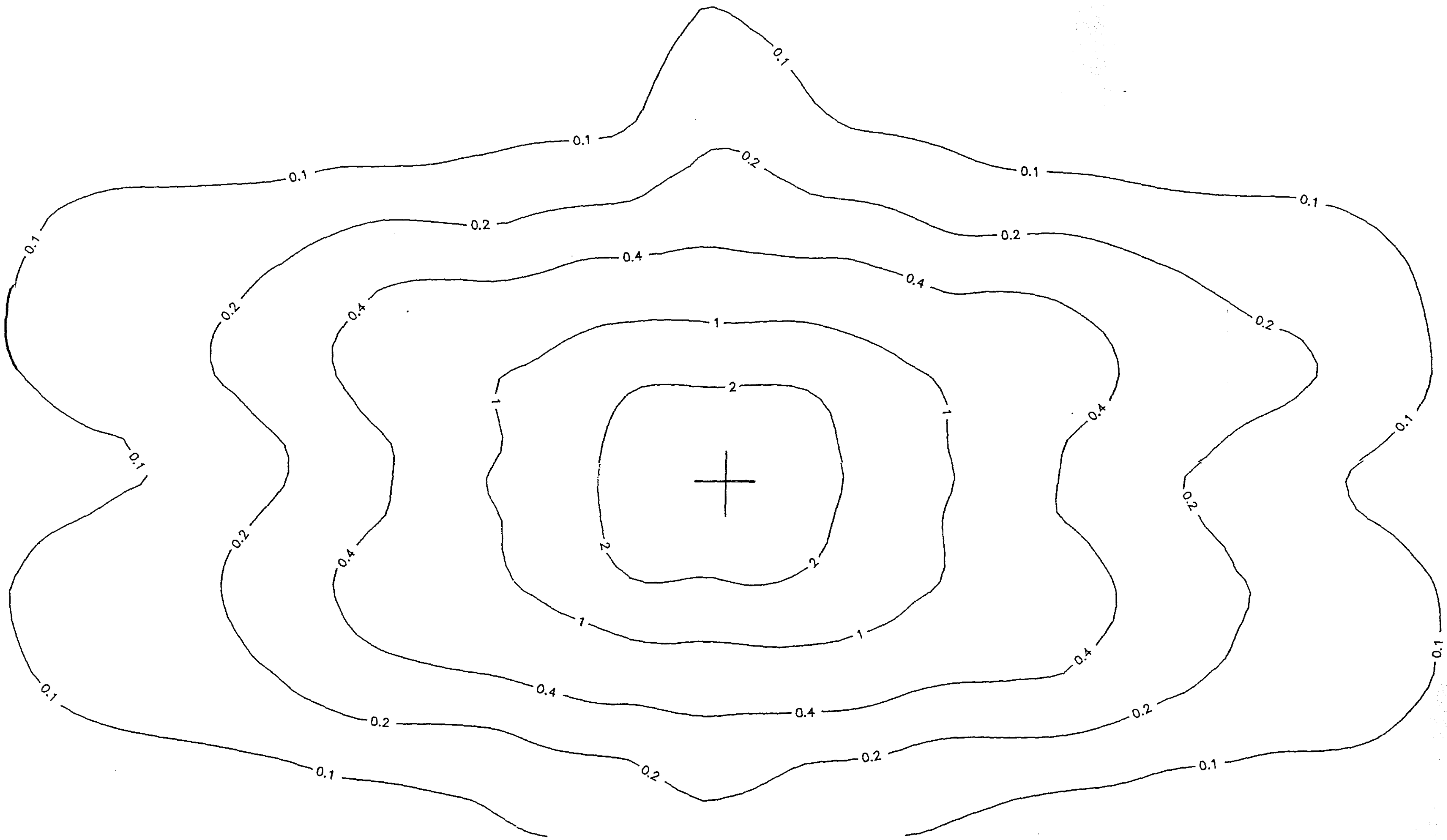
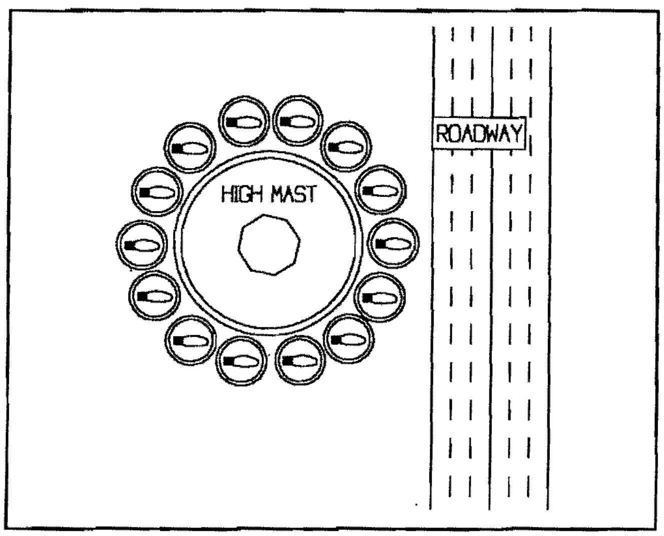


Figure 9. Iso-footcandle Curves for Twelve (6 each way) 400W Medium Cutoff Type II. Mounting Height at 150 Feet

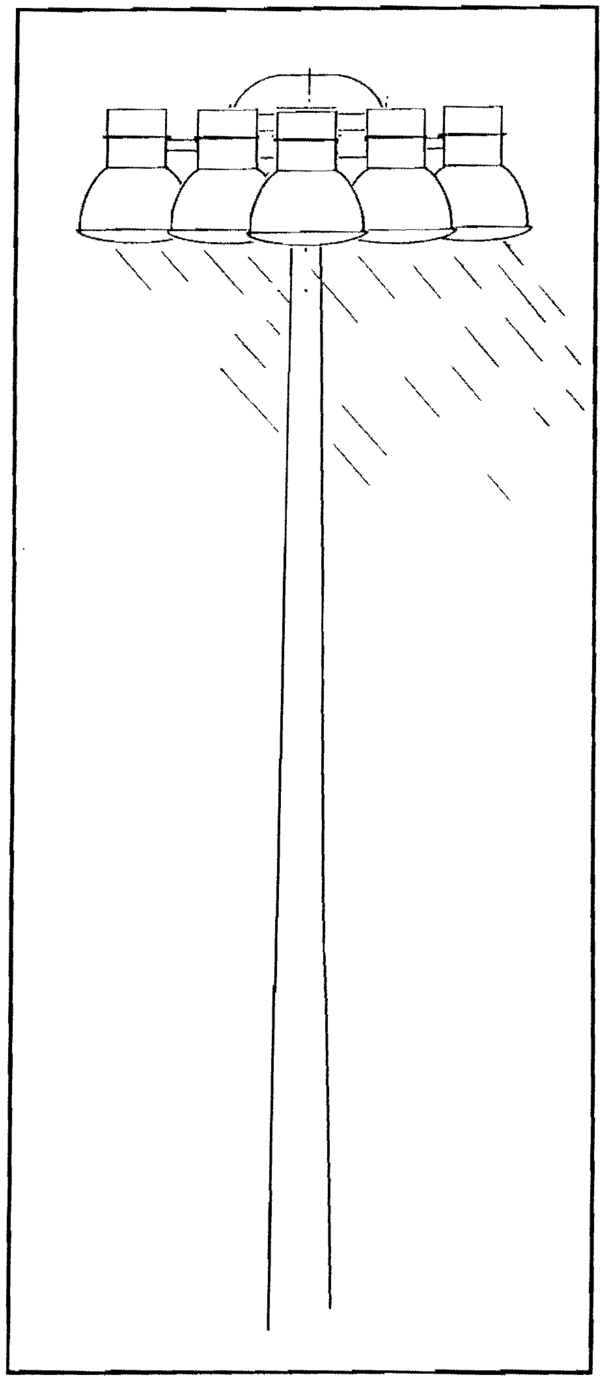
SCALE 1:100

TWELVE 400 WATT, HPS, ASYMMETRICAL, HIGH MAST FIXTURES
ALL ORIENTED ONE WAY
MOUNTED AT 150 FEET

These are the same fixtures used in the previous example except that all fixtures are turned or aimed in the same direction, toward the roadway. This configuration produces a pattern similar to a very large roadway or cobra head fixture, allowing the pole to be at the side of a highway instead of the median. The extent of the 0.1 footcandle Iso line was 650 feet on either side of the pole or 1300 feet along the roadway and 300 feet in width. A problem discovered with this setup is the high amount of light extending 175 feet behind the pole, possibly off the right of way.



Luminaire aiming - Plan View



12 ASYMMETRICAL (ALL SAME WAY) 400W MED. CUTOFF TYPE II M.H. 150'

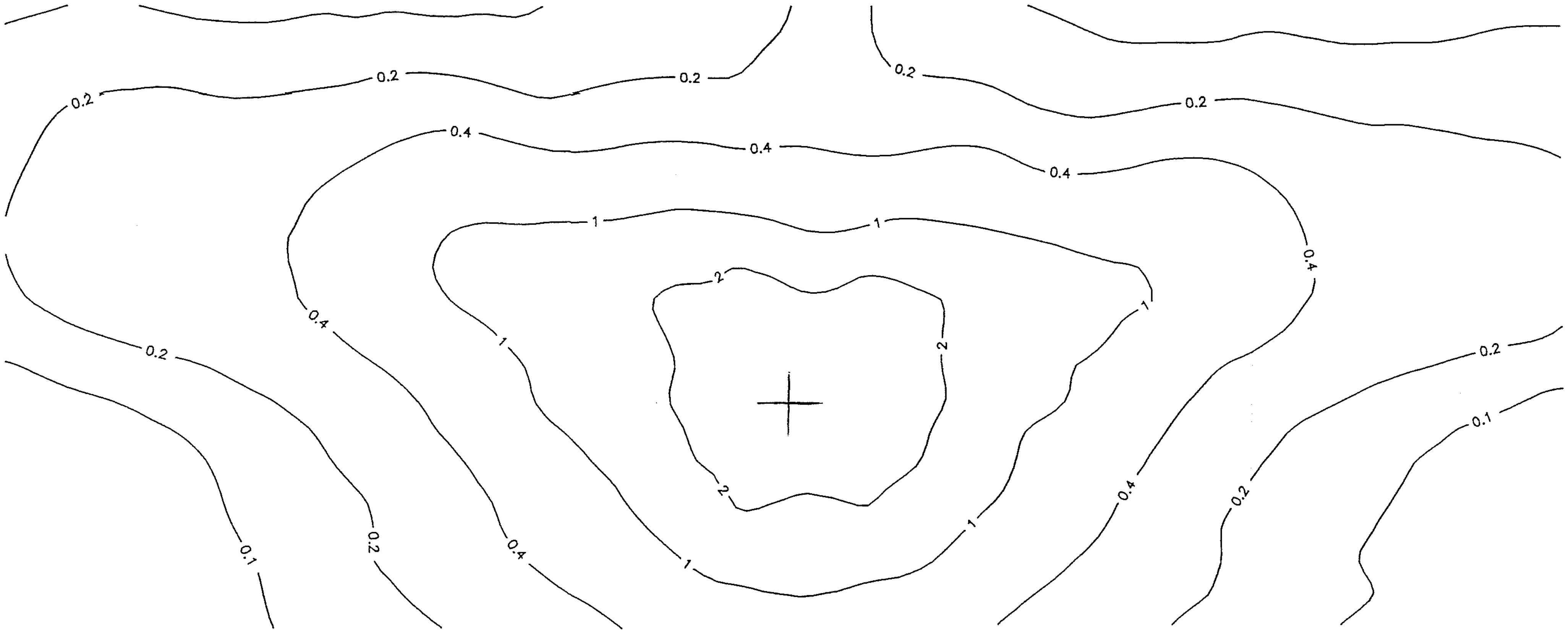


Figure 10. Iso-footcandle Curves for Twelve Asymmetrical (all same way) 400W Medium Cutoff Type II. Mounting Height at 150 Feet

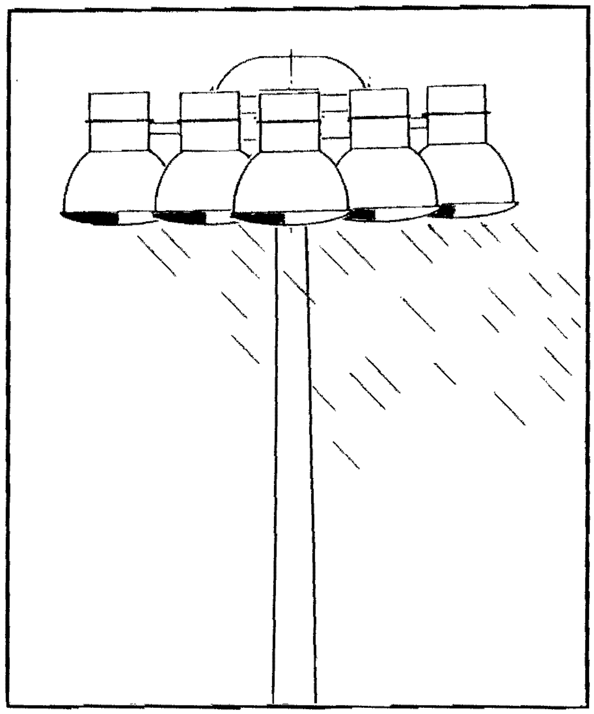
SCALE 1:100

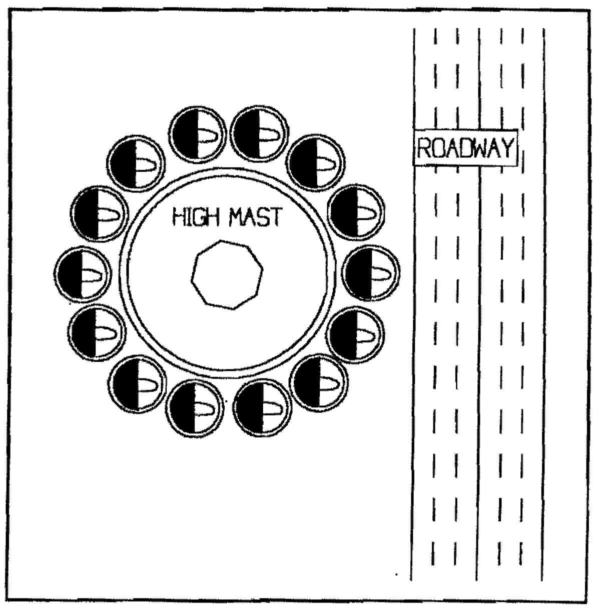
TWELVE 400 WATT, HPS, ASYMMETRICAL, HIGH MAST FIXTURES (MODIFIED)

ALL ORIENTED ONE WAY

MOUNTED AT 150 FEET

This configuration is the same as the previous Asymmetrical configuration except modifications to the twelve fixtures were made by the project researchers. The previous pattern was observed to produce too much light behind the pole and possibly off the right of way. To solve this problem the clear glass cover of each fixture was covered side to side with tape, from under center of the arc tube on the horizontal lamp, to under the socket location. This covering prevented any light from the lamp radiating behind the pole but allowed the reflected light to exit the front normally. Also a small flat portion of the reflector, which only directed the light backward was blackened. This modification was made with the assistance of a General Electric technical representative and is being considered as a production unit by that manufacturer.





Luminaire aiming - Plan View

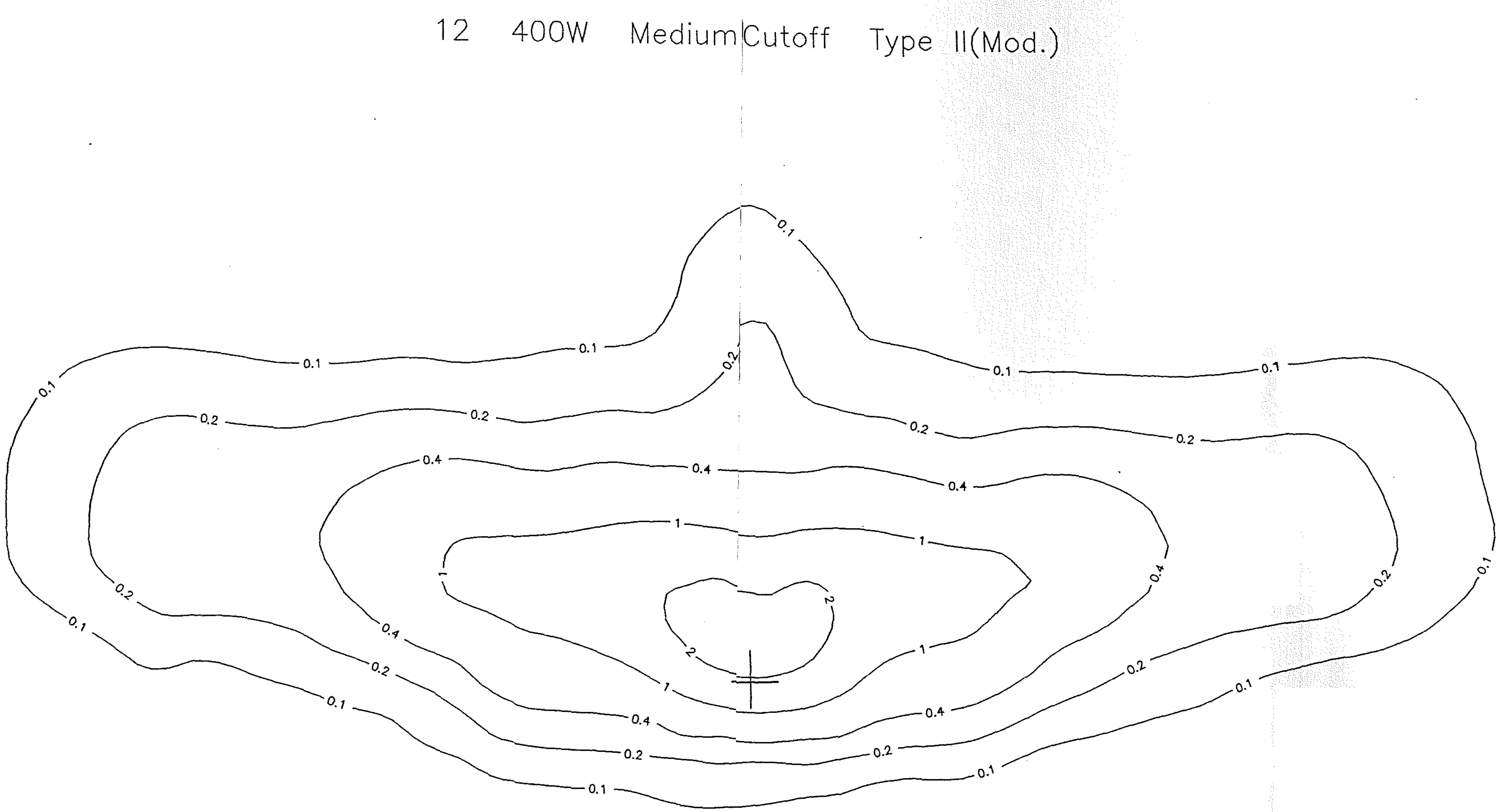
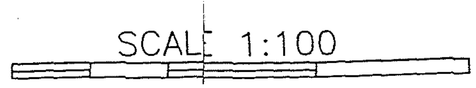


Figure 11. Iso-footcandle Cuves for Twelve 400W Medium Cutoff Type II (modified. Mounting Height at 150 Feet



Chapter III

INDUSTRY DATA, CURVES AND DESIGN SOFTWARE

INDUSTRY DATA, CURVES AND DESIGN SOFTWARE

Since the introduction of the first roadway lighting fixtures, some types of photometric data were supplied to the user. At first these data were elementary, but as technology improved more detailed information was available to the lighting engineer. This application design data, or lack of it, is what inspired this project. It was observed by some highway lighting engineers that the result of a highway lighting project did not always produce the results expected during the design phase. This could be attributed to several sources of error with inaccurate design photometrics one of them. In the mid 80s roadway lighting manufacturers started developing design application programs that would run on personal computers. These programs contained the photometric data for the manufacturers' lighting fixtures that were developed under laboratory conditions. The type and number of fixtures for an installation are selected by the user with the mounting height and lamp output. The software retrieves the photometrics for that fixture, either in IES or manufacturer format, and calculates according to the input conditions. The specific format of the output of these programs vary, but they predict the illumination on the roadway vs. location. Also some statistics are presented such as average/minimum ratio, maximum/minimum ratio and overall average.

The comparison plots produced in this chapter were made using production fixtures of the same type described in the software menu lists. Every effort was made to duplicate the fixture, lamp position and aiming. Even though these steps were taken, variations did exist between software simulations and the real world production fixtures. These production variations should be considered in critical applications or very large jobs, which may require photometric testing of sample units.

Three software packages were evaluated during this project during the review of new industry equipment, data and curves. The three were:

- *ALADEN* Jan. 91 by General Electric Lighting Systems
- *ICONTOUR* Ver. 1.0 by Cooper Lighting (Crouse Hinds)
- *AELIGHT* Ver. 1.0 by American Electric

ALADEN

This roadway lighting application program is made available by General Electric Lighting Systems and will operate successfully on IBM PC, PS/2, and most IBM compatible computers. User instructions as well as data curve numbers for specific fixtures may be printed from files in the program.

The key functions of the program are:

- *LITCOST*	Lighting Economic Analysis
- *AREA*	Area Lighting Design
- *INDOOR*	Indoor Lighting Design
- *ROAD*	Spacing Charts & FC Arrays
- *EZILLUM*	General Illumination Arrays
- *TEMPLATE*	Illumination Scale Overlays (single location)

The TEMPLATE program was used to obtain Iso-footcandle curves from selected GE fixtures to compare to the curves obtained during this project using production fixtures. For the majority of the curves compared, a reasonable fit was obtained in shape and size. Two examples are included to illustrate the technique and to show what differences might exist.

Figure 12 shows the comparison of a 400 watt roadway fixture mounted at 50 feet. The Iso-footcandle lines in the GE software are fixed at a 1, 2, 5 progression or footcandle levels of 0.1, 0.2, 0.5, 1, 2, 5 etc. Also fixed in this version of the software, and cannot be turned off, is the horizontal and vertical grid every half inch. Using the 'SURFER' program, the experimental data obtained from these fixtures were plotted using the same Iso levels as GE uses. The dotted lines are the output from the GE program and the solid lines are from actual measurements. As can be seen, the shapes of the curves are very similar. The levels measured during this project are slightly higher or extend further which could be due to a slightly higher light output from the lamp.

Figure 13 shows a comparison between a twelve fixture, 150 foot, symmetrical configuration. Though the shape, of both the measured and calculated patterns, is good

G.E. M4RR400 M.H. 50'

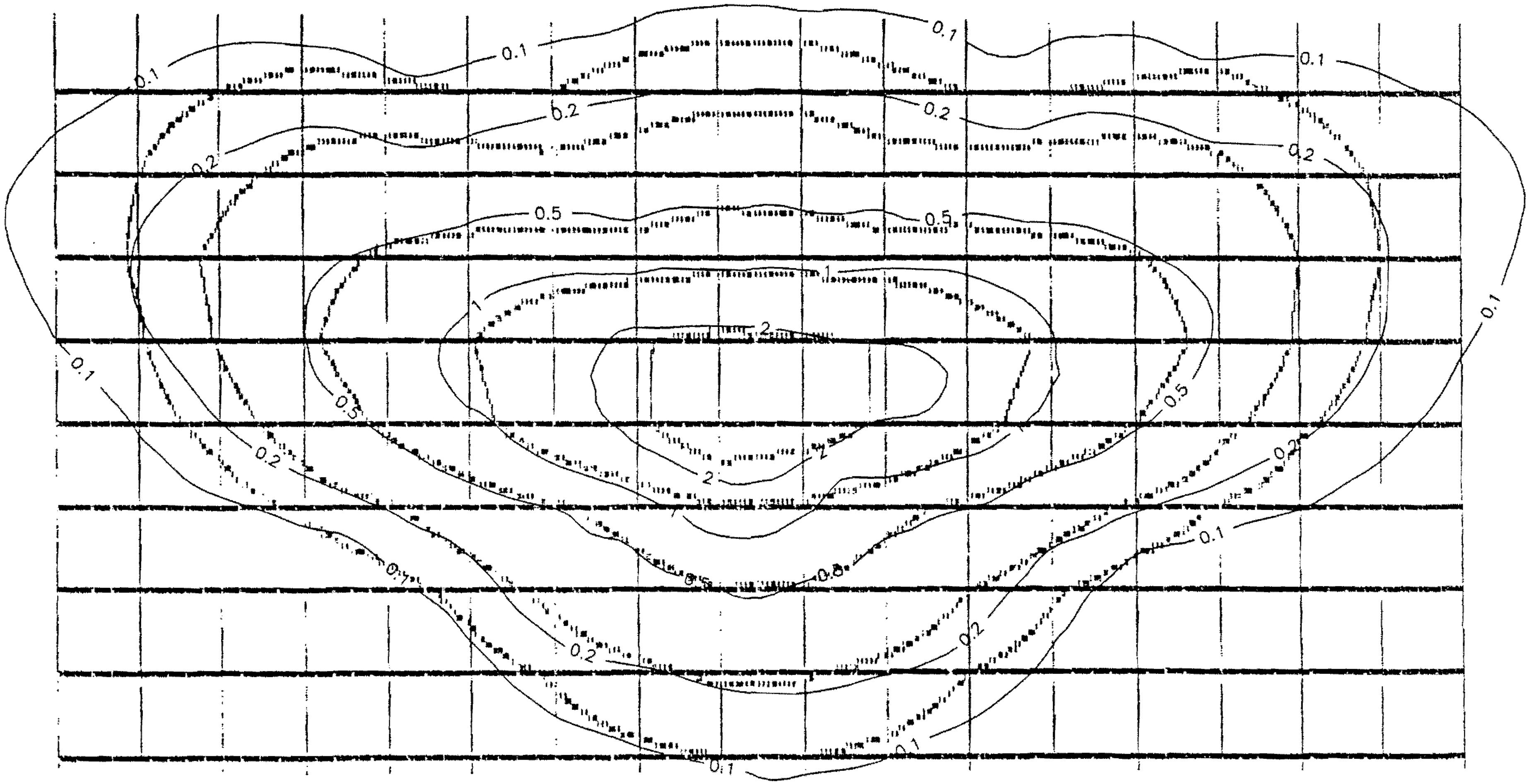


Figure 12. Comparison of SURFER and TEMPLATE Iso-footcandle Curves for G.E. M4RR400. Mounting Height at 50 Feet

SCALE 1:50

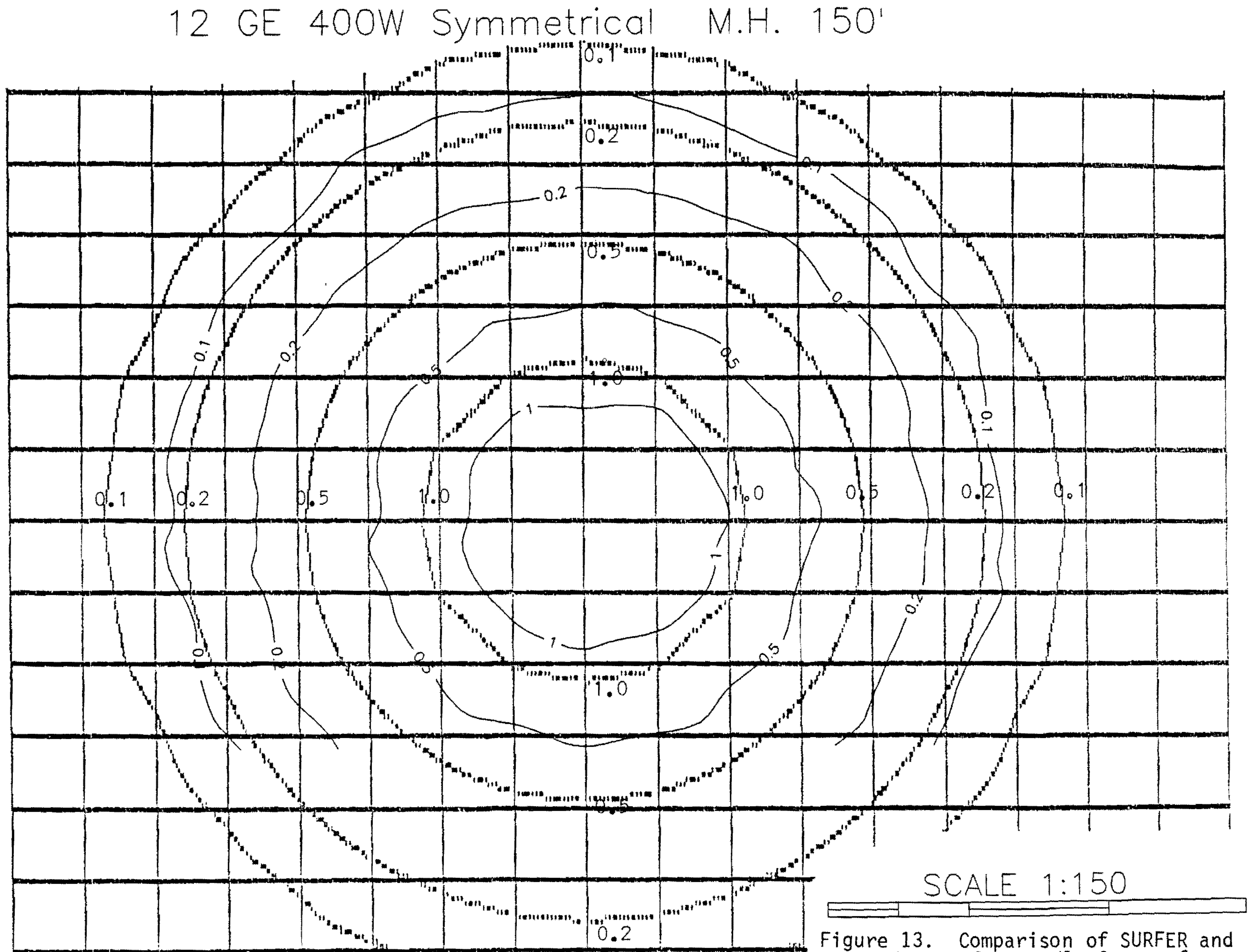


Figure 13. Comparison of SURFER and TEMPLATE Iso-footcandle Curves for 12 G.E. 400W Symmetrical. MH at 150'

(circular), the level of the measured pattern is less than the calculated one. Though the measured pattern has good coverage, 0.1 FC out to 450 feet, the calculated curves extend about 60 feet farther. This does not appear to be a lamp output level problem because a fit could not be obtained by simply reducing the lumen values in the prediction program. The anomaly is possibly due to small mechanical variances in assembly that controls the lamp position.

Overall TEMPLATE does an acceptable job of predicting the photometrics of a roadway lighting system with the understanding that variations will exist and critical applications may require measurement of representative fixtures.

TEMPLATE also produces a point-by-point array of footcandle values, maximum array value, minimum array value, average of all points, average to minimum ratio and maximum to minimum ratio.

The ROAD program allows the placement of several luminaires along a roadway, either side or median, and evaluates the uniformity ratio and average illuminance. The placement of the luminaires both along the roadway and mounting height may be changed and the results observed.

EZILLUM provides a way to test unconventional configurations such as multiple floodlights in one location. Each floodlight may be a different type with different aiming. Once all fixtures are defined the program will calculate the resultant illumination pattern.

The program has the utility to convert between IES and GE formats allowing any brand fixtures with IES data to be used with this program.

Information about the ALADAN program may be obtained from The General Electric Company, GE Lighting Systems, Hendersonville, NC 28739. The phone number is 704-693-2175.

ICONTOUR

ICON*TOUR* by Cooper Lighting, Cooper Industries, is a PC program designed to allow you to prepare Iso-footcandle templates to scale for use with site plans. It also can generate a point-by-point array of footcandle values. It requires 467K of hard disk and when used with IES formatted photometric files, will produce up to 20 Iso-footcandle lines on a grid to the scale you specify. These are the only functions this program will perform now.

Comparisons made between the program's predicted values and those measured during this project were similar to General Electric results, close but not perfect. Figure 14 is a comparison of a 400 watt Crouse Hinds roadway fixture. As before the solid lines are the measurement of the production unit and the dotted lines predicted by the software. Unlike the GE software, the Iso lines are selected by the operator as well as the option to print a background grid or not. The programs lines are lettered, and a key is included at the bottom of the graph, which has been removed in the figure. The two curves in the figure are a close match except ends of the pattern that droop toward the house side. This is again probably a slight misalignment in the mounting of the lamp. Another possibility would be small manufacturing variances in the reflector or refractor.

Figure 15 is an example of a small roadway or underpass fixture. The curves on the left were produced by ICON*TOUR* with the curves progressing inward from the outer ring at 0.1, 0.2, 0.5, 1, 2, 5 footcandle steps. The curves on the right were measured and plotted using SURFER. The 0.1 FC lines matched well, but a large deviation between plots appeared at the 0.5 and 1.0 FC lines. The failure of these lines to extend outward to the right and left as in the prediction produced a non-uniform pattern with three spots, one in the center and one above on each side. This again points out that the prediction software will make close predictions of the lighting patterns but not exact predictions due to manufacturing tolerances and quality control.

The TxDOT curves for Crouse Hinds high mast fixtures were being updated and were not available at the time of this report.

Information about the ICON*TOUR* program is available from McGraw-Edison, P.O. Box 824, Vicksburg, Mississippi, 39181. The phone number is 601-634-9662

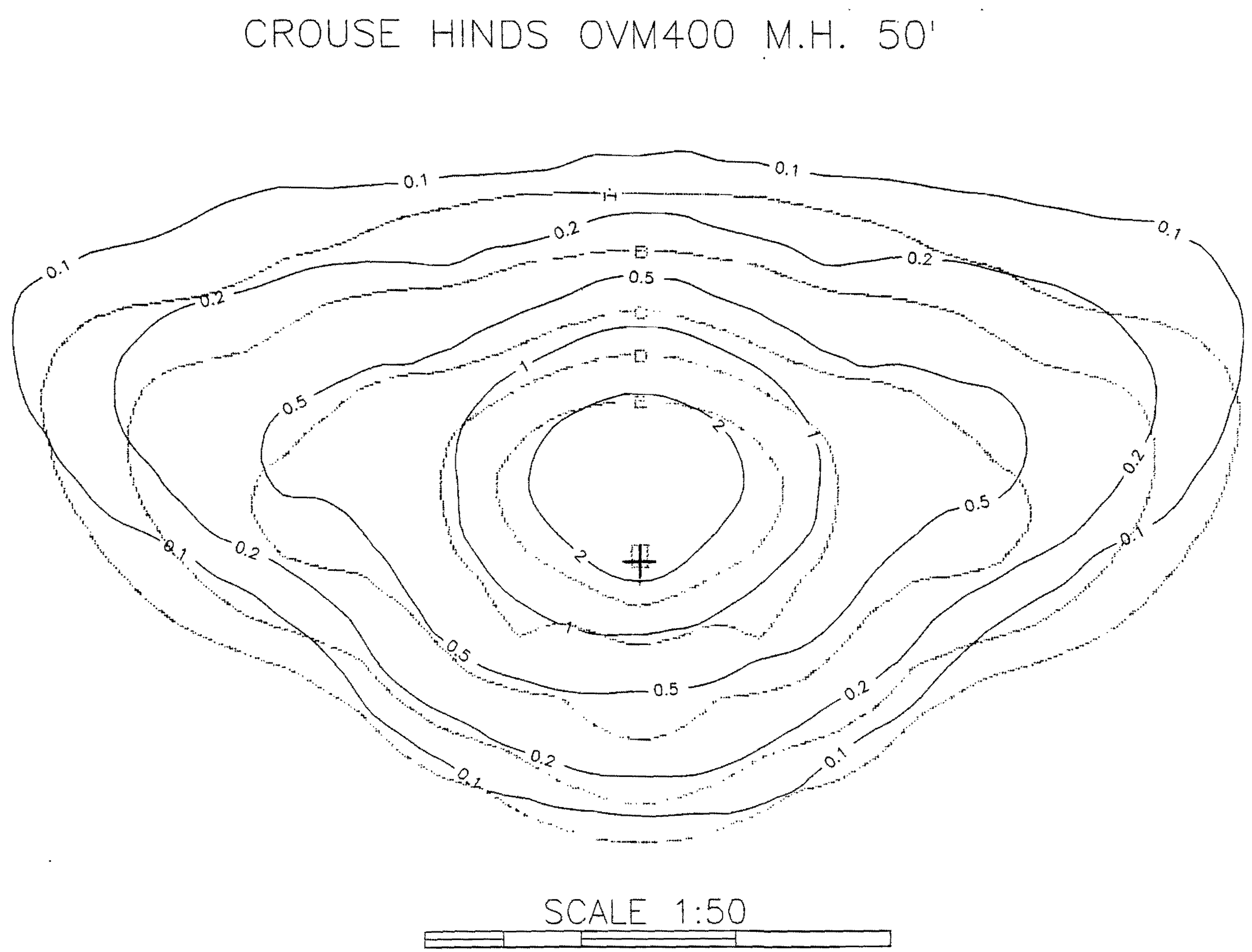


Figure 14. Comparison of SURFER and ICONTOUR Iso-footcandle Curves for Crouse Hinds OVM400. Mounting Height at 50 Feet

CROUSE HINDS OVS150 M.H. 20'

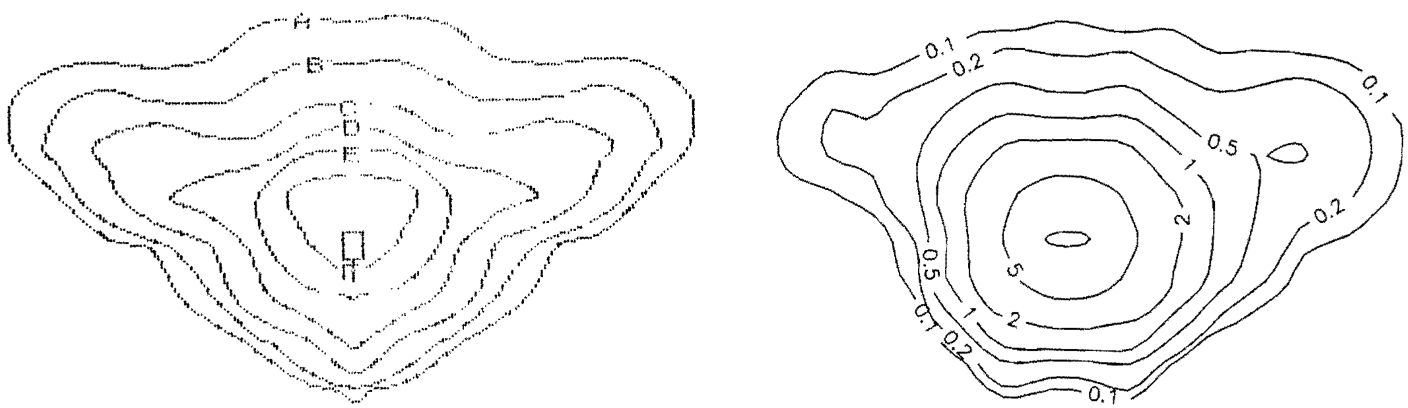


Figure 15. Comparison of SURFER and ICONTOUR Iso-footcandle Curves for Course Hinds OVS150. Mounting Height at 20 Feet

SCALE 1:50

AELIGHT

AELIGHT is the American Electric lighting application program and consumes the most disk space of the three. As with General Electric, it is a collection of several programs for the design of indoor, outdoor and roadway systems. The program requires a IBM or compatible personal computer with 10 megabyte hard disk or larger. It requires a Co-Processor and 512K RAM memory or more. The program and data files will need four megabytes of hard drive storage space. Installation is automatic but requires "1 to 2 hours depending on your computer."

The program cannot be installed without printing out the more than 50 pages of file names associated with all their fixtures. Once started the programs were found somewhat less than user friendly. If one were familiar with the input requirements of the programs, it would be a powerful system in designing roadway lighting systems. There was no instruction book supplied with this evaluation copy, and there is no way of invoking online help if a particular request is not understood. As with the G.E. program, calculations of uniformity and footcandle levels on a roadway, specified by the operator, may be made. The UTILITIES section will produce Iso-footcandle templates of American Electric fixtures at user defined mounting heights. A problem in the Iso-footcandle template program is that only up to four fixtures may be placed at one location. This prohibited the program from providing curves on the ten fixture, low pressure sodium configuration investigated during this project. AELIGHT does not have the capability to convert or use IES format data.

Figure 16 shows a typical output page from the template portion of the program. As with the other two programs, the only printer supported is a dot matrix printer excluding the popular Laser Jet series.

Information about this program may be obtained from American Electric, 1555 Lynnfield Rd., Suite 250, Memphis, Tennessee, 38119. The phone number is 901-682-7766.

AMERICAN ELECTRIC 08/08/91
1555 Lynnfield Rd, Suite 250 Memphis, TN 38119
(901) 682-7766

Photometric file: ERL1463.PHO Lumens per lamp: 20350
Mounting Height= 35.0 Tilt Angle= 15.0 degrees Height of Plot= 0.
SCALE : 1" = 50.00 feet

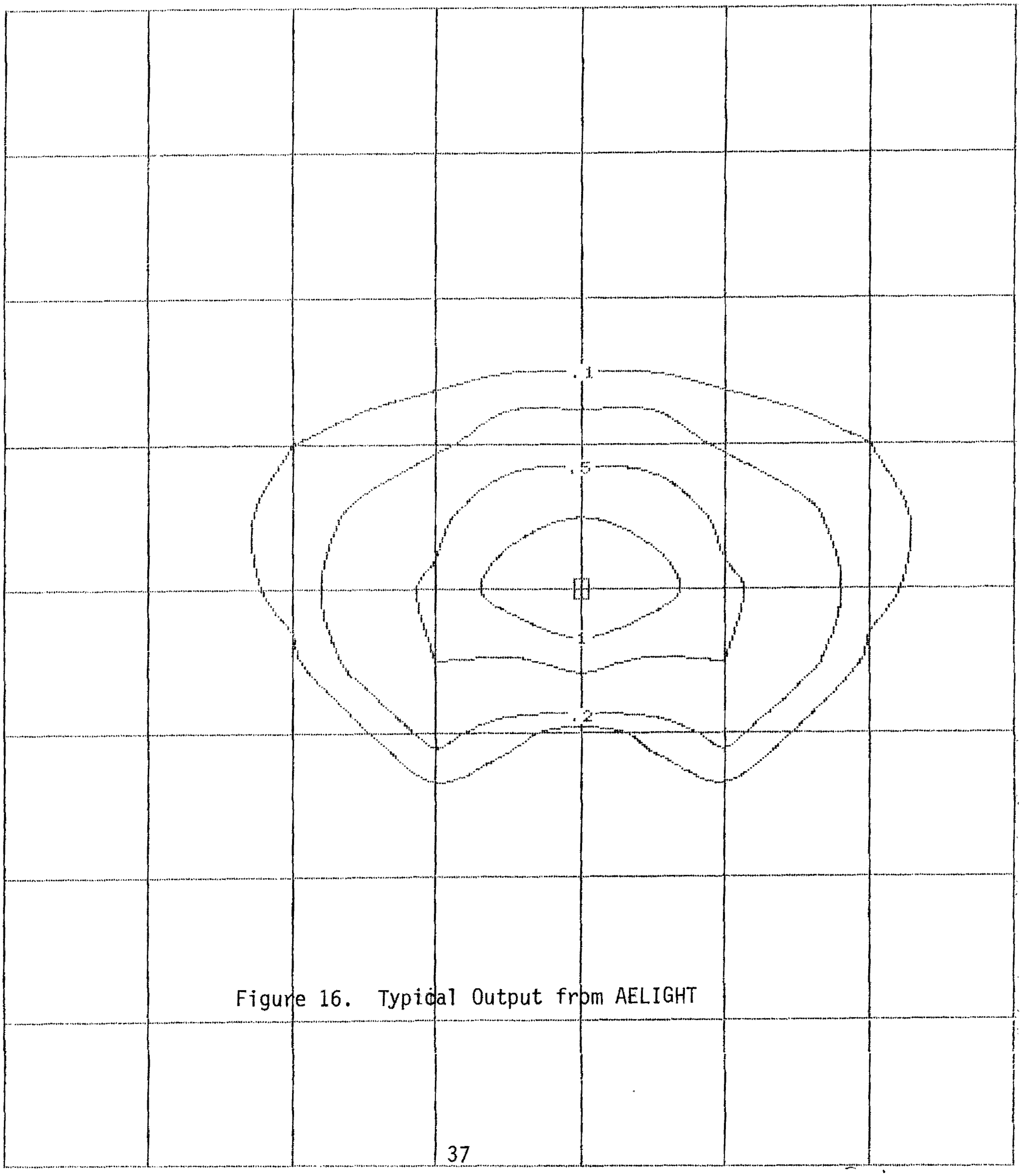


Figure 16. Typical Output from AELIGHT

Chapter IV

EVALUATION OF LOW MOUNT FLOODLIGHTS SYSTEMS FOR NARROW R.O.W.

EVALUATION OF LOW MOUNT FLOODLIGHT SYSTEMS FOR NARROW R.O.W.

Concern was expressed at the beginning of this project about narrow right-of-ways and light pollution off the right-of-way. Several fixtures were evaluated at the Proving Ground to meet the requirements. The challenge in this type of lighting job is that a floodlight that is mounted low to the ground and aimed down the roadway has a good chance of producing glare to traffic in the opposite direction. This was the problem discovered with the floodlights tested for this purpose, and all were rejected by the TxDOT representative. Consequently no Iso curves were developed for these fixtures because the mounting and aiming used on the test track was thought impractical for the application.

The following is an example of a Low Mount Floodlight system design that was successful. This example should be considered as a concept and not as a design to be duplicated.

Using different fixtures, a system of this type has been designed by the TxDOT and is in use on US 281 near San Antonio International Airport. The light pollution restrictions in that area concerned air traffic safety. It was imperative that the roadway lighting system produced no glare to pilots and the luminaire height was within FAA restrictions. The plan used two 150 watt floodlights at each location, mounted 16 feet high in two rows, one for each direction of travel, spaced 95 feet apart. A broad beam, 7X6, floodlight was aimed 90 degrees to the road and pointed at the center of the lane. The other narrow beam floodlight, 4X2, was aimed in the direction of travel at or about 30 degrees to the roadway and pointed at the center of the lane. This configuration is called an L pattern because of the shape of the two beams. With the fixtures aimed down at the roadway and equipped with top visors, landing aircraft have no view of the light source. With the low mounting height of 16 feet, the problem of glare to oncoming traffic was corrected by directing the long beam at the rear of the vehicles, lighting the roadway but not the windshield.

Chapter V

HIGH MAST LIGHTING ON NARROW R.O.W.

HIGH MAST LIGHTING ON NARROW R.O.W.

Using floodlights in a High Mast configuration, above 100 feet, produces less of a problem with glare in the drivers eyes than does the low mounted units. This allows the use of higher wattage luminaires to illuminate further thus reducing the space between poles. When the projection is increased along the roadway, it is important not to allow the light to spill off the right of way into residential areas. This becomes a complex design problem since small angle changes over a large distance could produce large errors in areas of illumination. To produce a long, narrow, rectangular pattern, a configuration similar to ones used in Houston, was investigated.

As with the Low Mount floodlights the following example is presented as a concept of one way a successful solution was found to a narrow right of way lighting problem. This information is not intended for duplication but to illustrate how unconventional designs can solve unique problems.

A configuration of five 1000 watt HPS floodlights was developed to operate at a 125 foot mounting height. After many tries with various fixtures and beam spreads, the pattern shown in Figure 17 was developed. The pattern is intended to overlap or interlock with the next installation approximately 600 feet away. This way, oncoming traffic would be receiving light at high angles from the pole in front and low angles from the one behind. This technique is designed to reduce glare from bright, low angle light in front of the driver. The final floodlight configuration was:

1. NEMA 4X4 Floodlight Horz. 180 Vert. 74
2. NEMA 6X5 Floodlight Horz. 145 Vert. 63
3. NEMA 7X7 Floodlight Horz. 90 Vert. 54
4. NEMA 6X5 Floodlight Horz. 47 Vert. 65
5. NEMA 4X4 Floodlight Horz. 32 Vert. 75

Note: Horz. 0 deg. is toward the oncoming traffic in the lane nearest the pole.
Vert. 0 deg. is down, 90 deg is toward horizon.

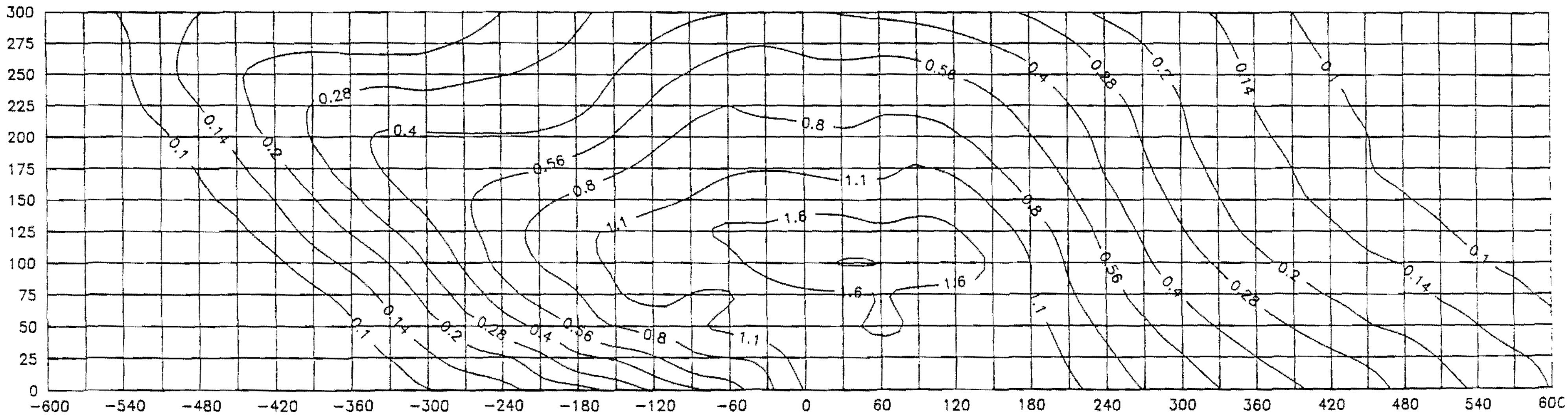


Figure 17. Iso-footcandle Curves for High Mast Lighting on Narrow R.O.W.

Chapter VI

EVALUATION OF A HIGH MAST, LOW PRESSURE SODIUM, LIGHTING SYSTEM

EVALUATION OF A
HIGH MAST, LOW PRESSURE SODIUM, LIGHTING SYSTEM

The use of low pressure sodium (LPS) fixtures in a high mast configuration was evaluated. The objective of using LPS in this application was to reduce glare, lower operation cost and increase uniformity of illumination. Since the LPS fixtures are long narrow units using tubular lamps, the light source is spread over a larger distance compared to a floodlight, reducing glare to the observer. It was decided to use ten 180 watt units

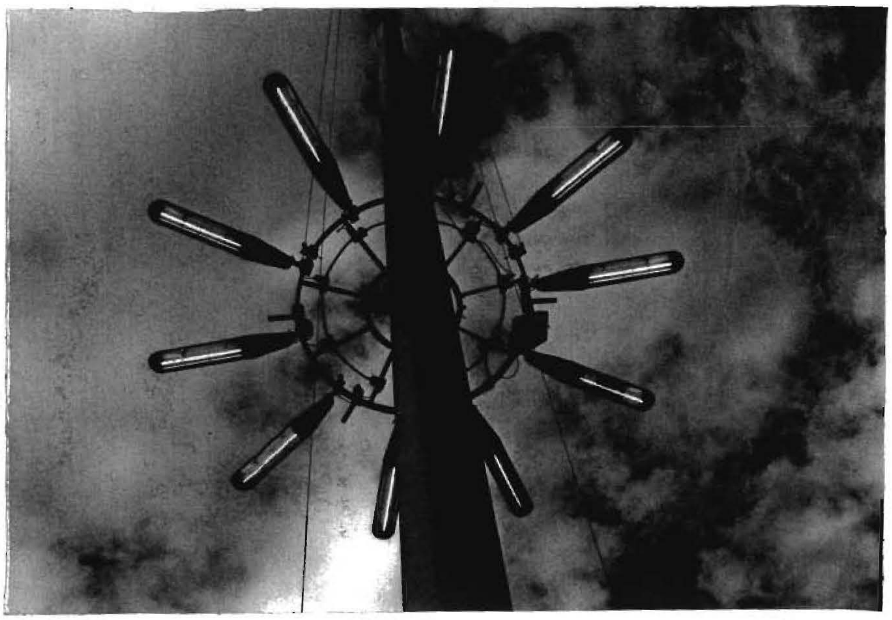


Figure 18. 180 Watt, Symmetrical, Low Pressure Sodium Test Fixtures.

mounted radially on a high mast ring as shown in Figure 18. This configuration would consume only 1800 watts of power compared to the conventional 5000 watts or more. Uniformity would be achieved by the nature of the reflector that is white instead of polished metal. To extend the range of the illumination, the fixtures were tilted up at an angle of 15 degrees.

Figure 19 shows the light levels obtained during the test at 125 feet. These results were favorable in that the glare was indeed reduced, and a uniform pattern with no abrupt changes was produced. The illumination level was less than optimum, and the level began decreasing near the pole rather than staying constant and then drop off. The low FC levels

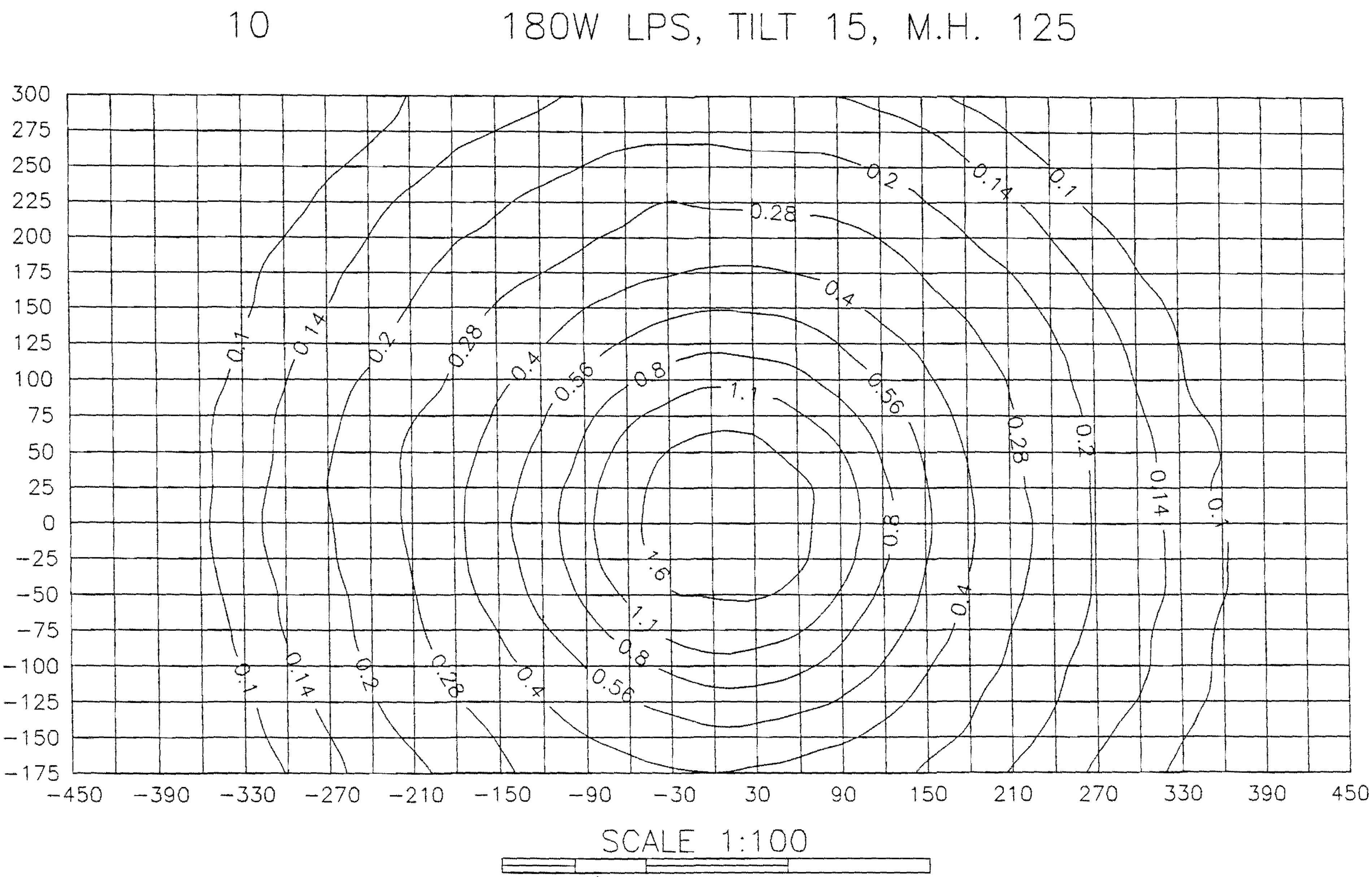


Figure 19. Iso-footcandle Curves for Ten 180W LPS, Tilt 15 deg. Mounting Height at 125 Feet

are due to the low wattage, even with the more efficient LPS lamps. The rapidly changing light level away from the pole is probably due to the design of the fixture and reflector being unable to project even tilted upward. A specular reflector may help solve this problem, but redesigning fixtures was not within the scope of this project.

Another configuration of high mast LPS fixtures evaluated was an asymmetrical pattern. Figure 20 shows the placement of ten fixtures on the high mast ring. The plan was

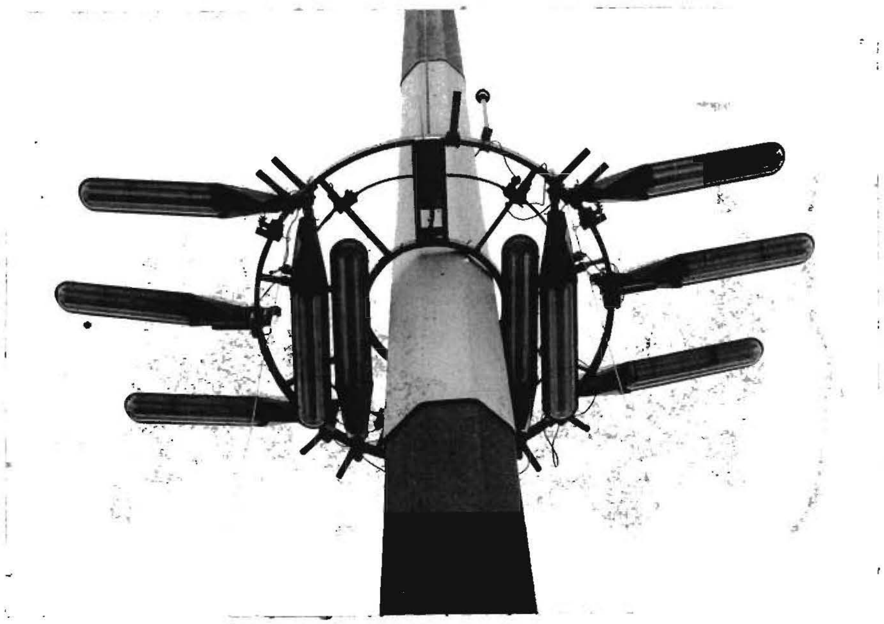


Figure 20. Low Pressure Sodium, Asymmetrical Test Setup.

that six fixtures, three east and three west, would produce the majority of the light, emitting mainly from the sides and little at the ends. This would make up the large part of the asymmetric oval with the other four fixtures filling in the shorter axis of the oval. This plan worked, as shown in Figure 21, when tested at 100 feet. The 0.1 footcandle ring extended 660 feet along the roadway and 550 feet across. As in the symmetrical pattern, the uniformity was smooth but changing rapidly outward from the pole.

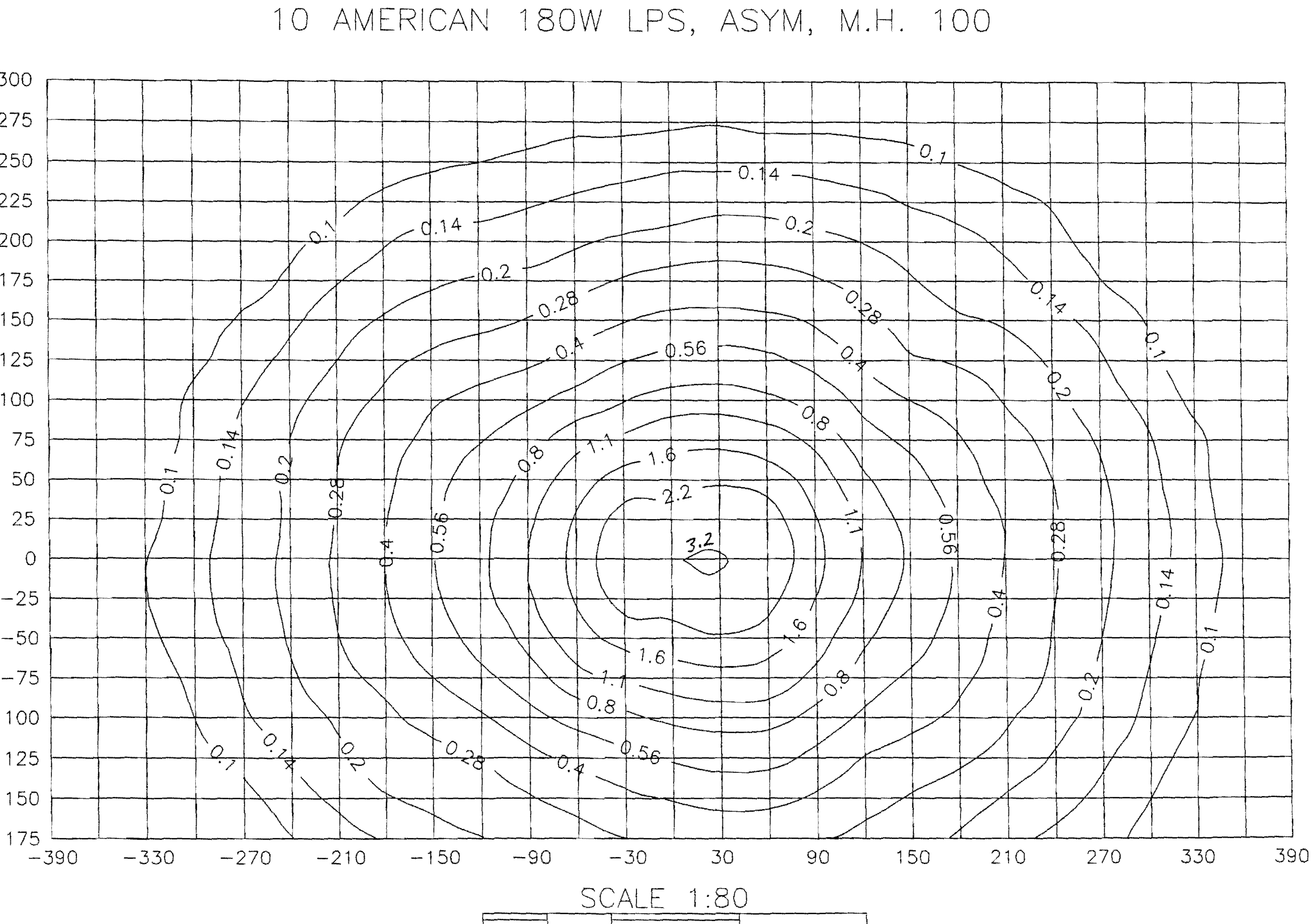


Figure 21. Iso-footcandle Curves for Ten American 180W LPS, Asym. Mounting Height at 100 Feet

CONCLUSIONS

The experimental Low Pressure Sodium/ High Mast configurations, developed by the Co-Research Supervisor, met the requirements of reduced glare and lower operation cost. It did not meet the level requirements of footcandle illumination on the roadway or uniformity. This was due to the lower lumen output of the 180 watt fixtures, the largest available, and the lack of a specular reflector. Even though the Low Pressure Sodium lamp is more efficient, more lumens per watt, the ten 180 watt fixtures produced about 330,000 lumens compared to 600,000 lumens using twelve 400 watt High Pressure Sodium fixtures. The reflectors of the LPS fixtures were painted white and produced low glare but this type of reflector will not project or aim the light toward the further edges of the pattern.

Based on the results of the experiments it appears that for the majority of roadway illumination projects the LPS fixtures produced at this time do not produce the needed lumen output for use in a high mast configuration. Possibly some special applications could use this configuration if high footcandle levels are a lower priority than glare and efficiency.

Appendix A

ISO-FOOTCANDLE CURVES

All curves are from fixtures using High Pressure Sodium (HPS) lamps unless noted.

G.E. W4OL-150 M.H. 15'

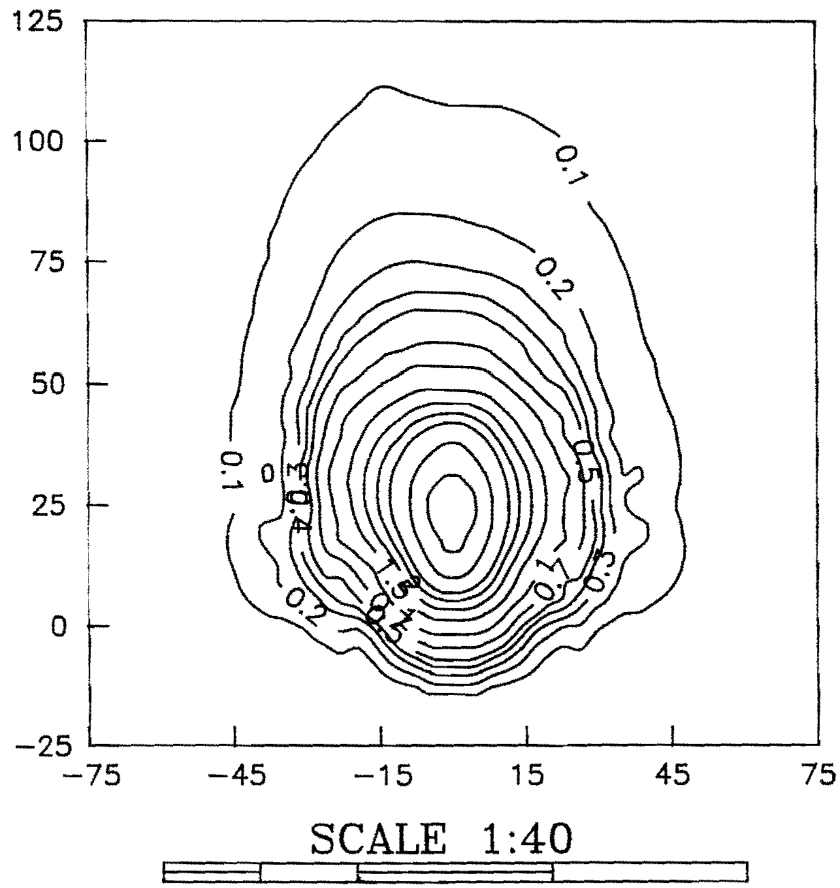
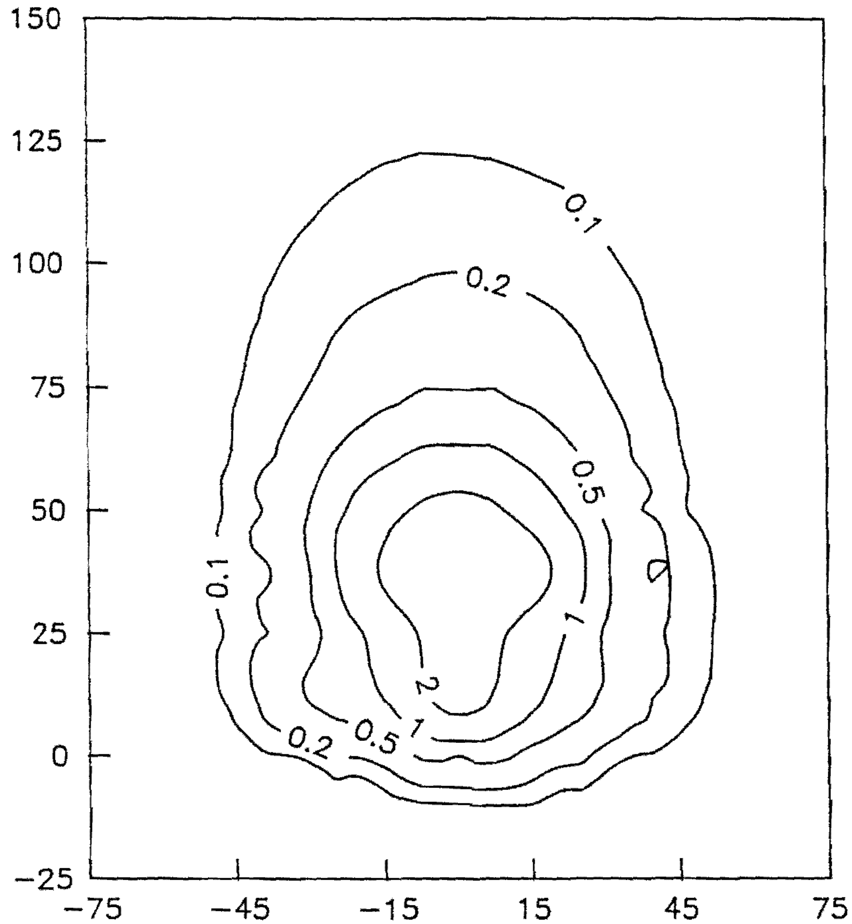
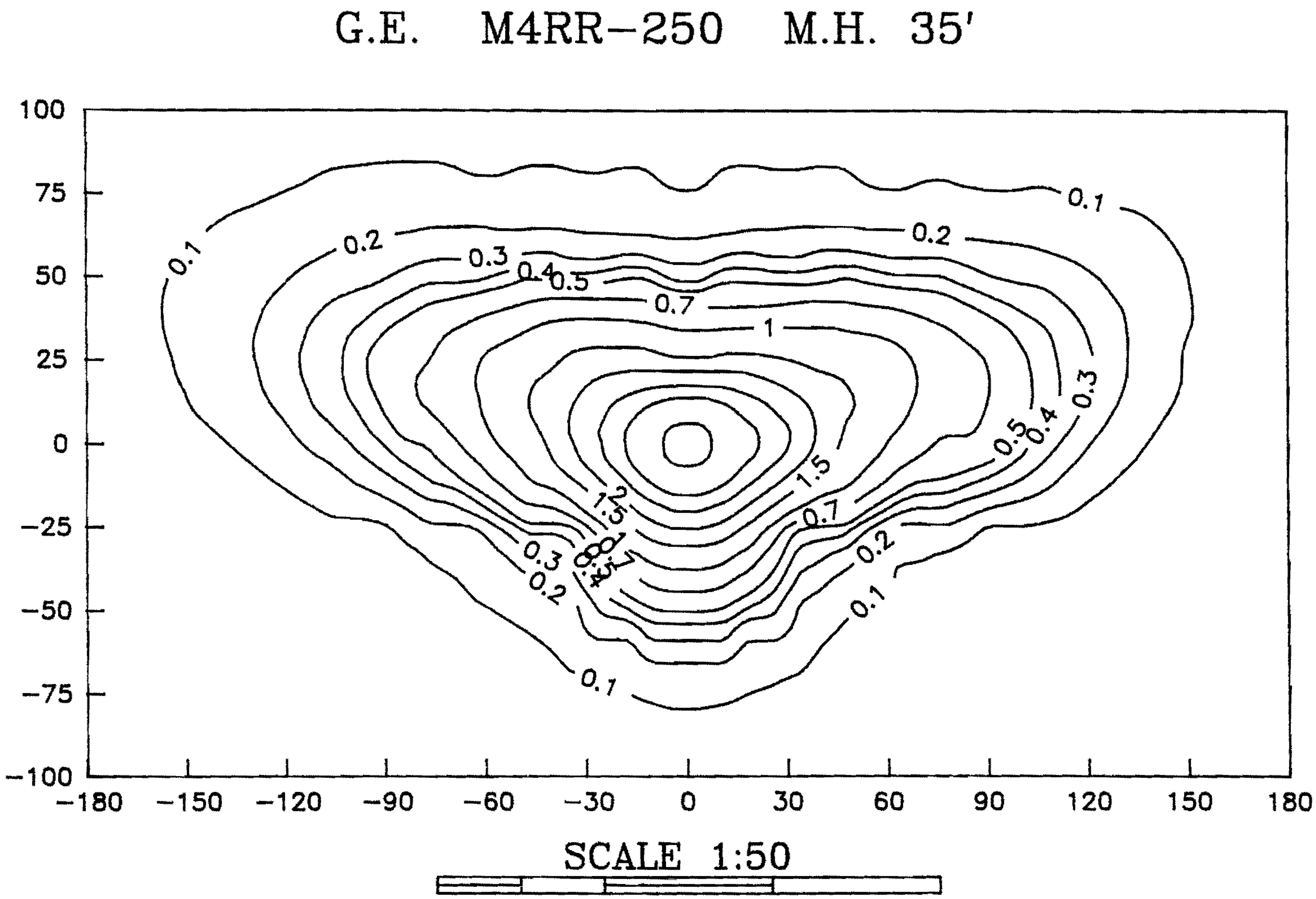


Figure A-1.

G.E. W40L–150 M.H. 20′



SCALE 1:40



G.E. M4RR-250 M.H. 35′
100
75
50
25
0
−25
−50
−75
−100
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
0.1
0.2
0.3
0.4
0.5
0.7
1
1.5
2
SCALE 1:50

Figure A-3.

G.E. M4RR-250 M.H. 50′

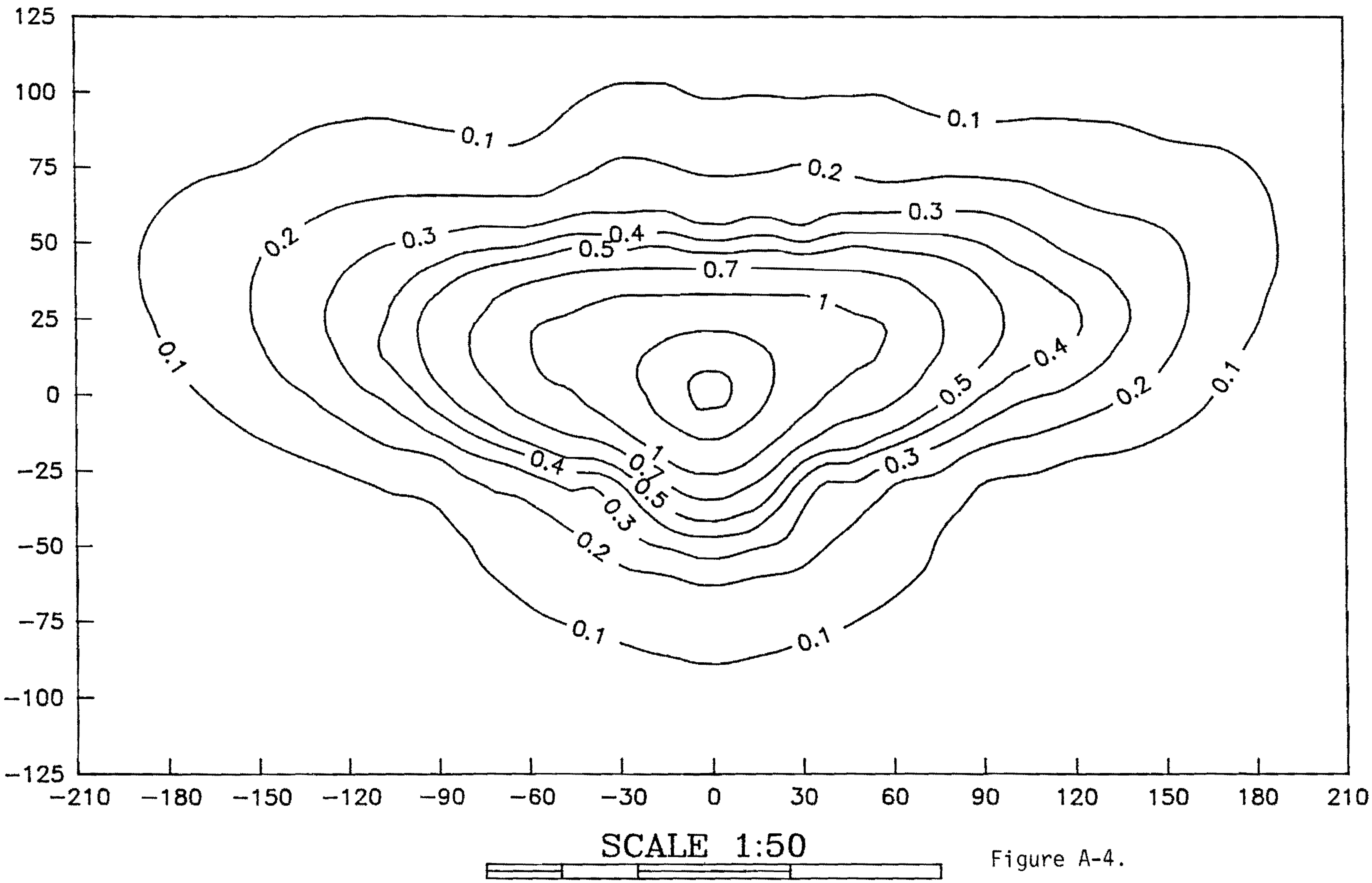


Figure A-4.

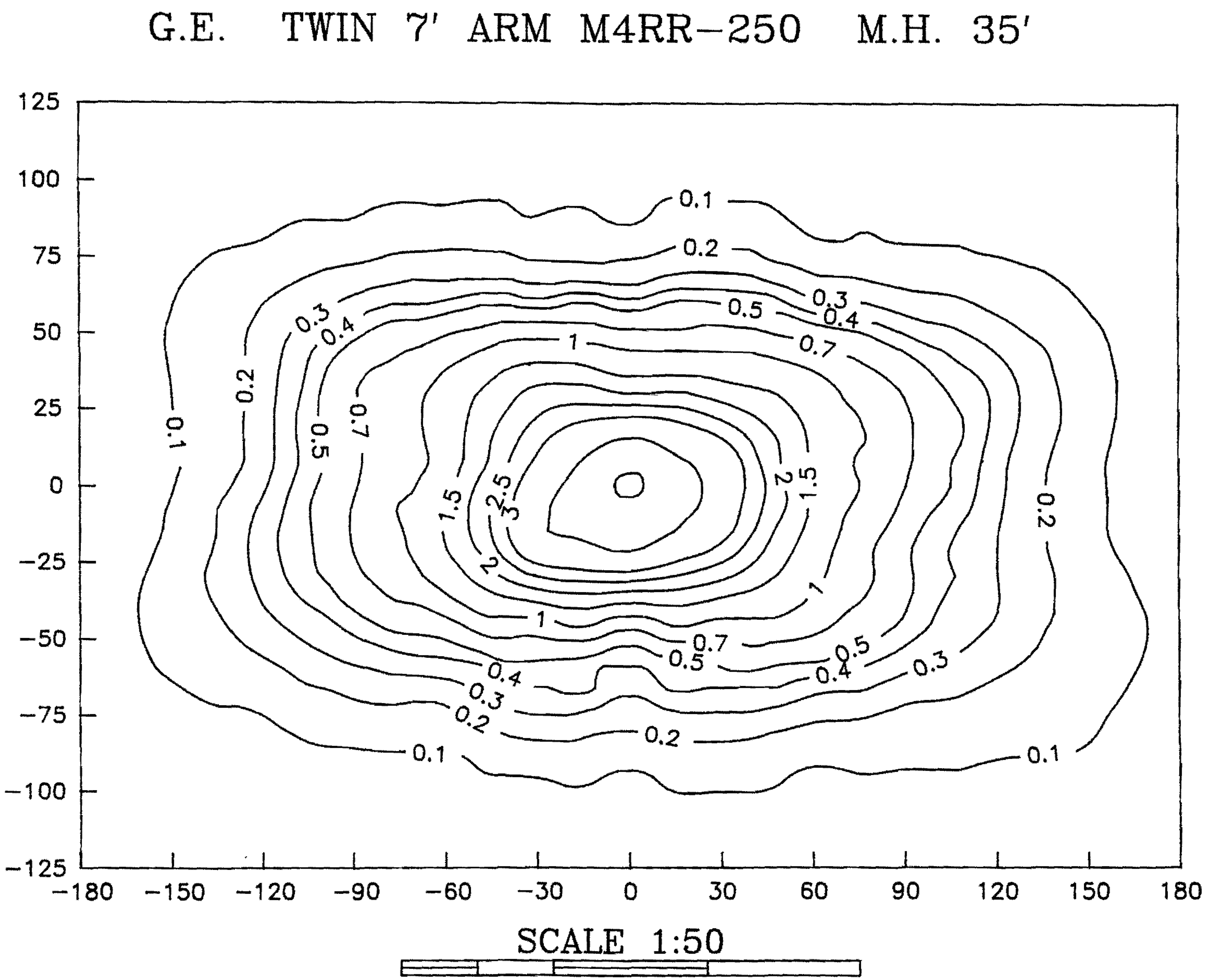

G.E. TWIN 7' ARM M4RR-250 M.H. 35'
125
100
75
50
25
0
−25
−50
−75
−100
−125
−180
−150
−120
−90
−60
−30
0
30
60
90
120
150
180
0.1
0.2
0.3
0.4
0.5
0.7
1
1.5
2
2.5
3
SCALE 1:50

Figure A-5.

G.E. M4RR 250W MS3 M.H. 40'

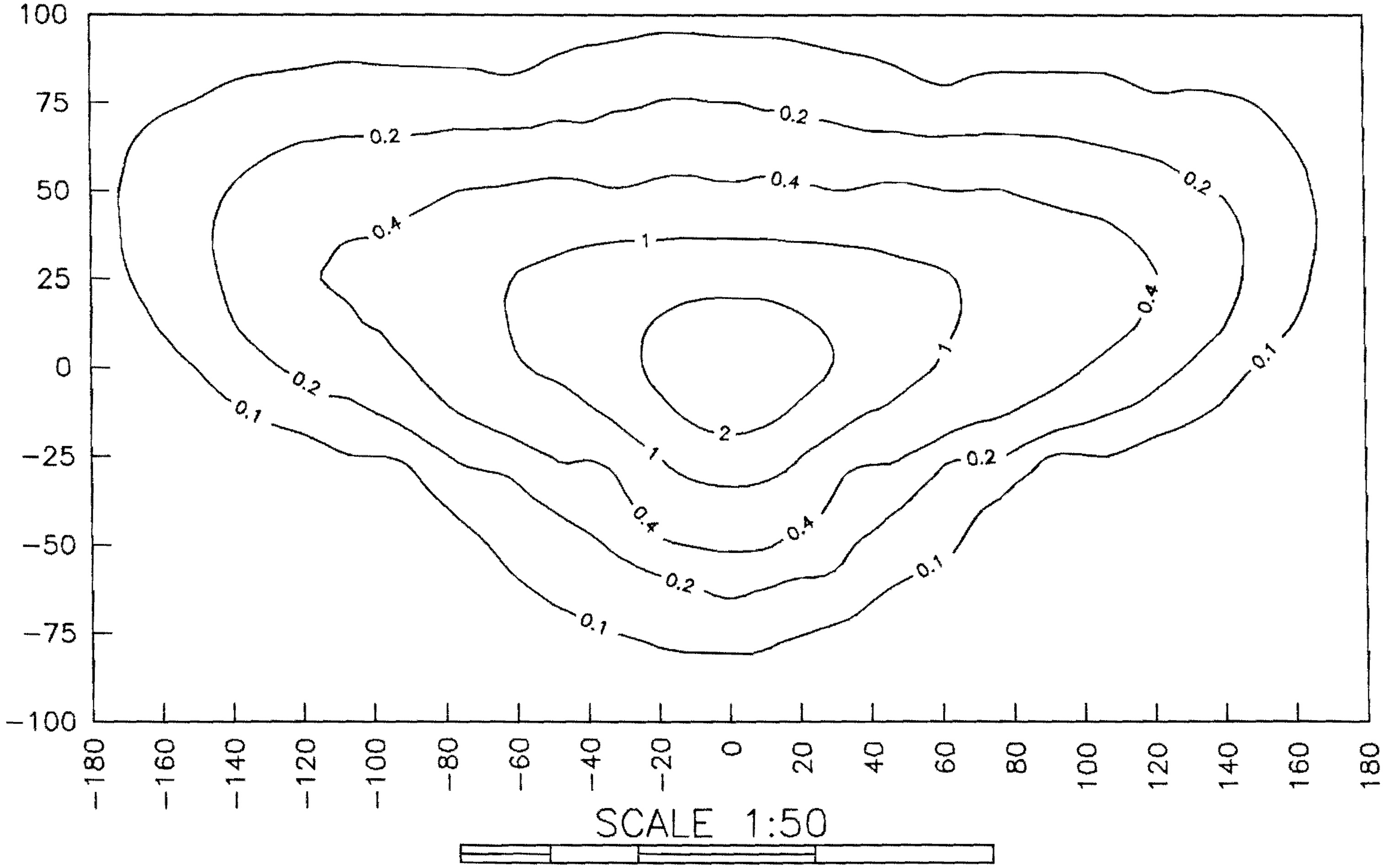
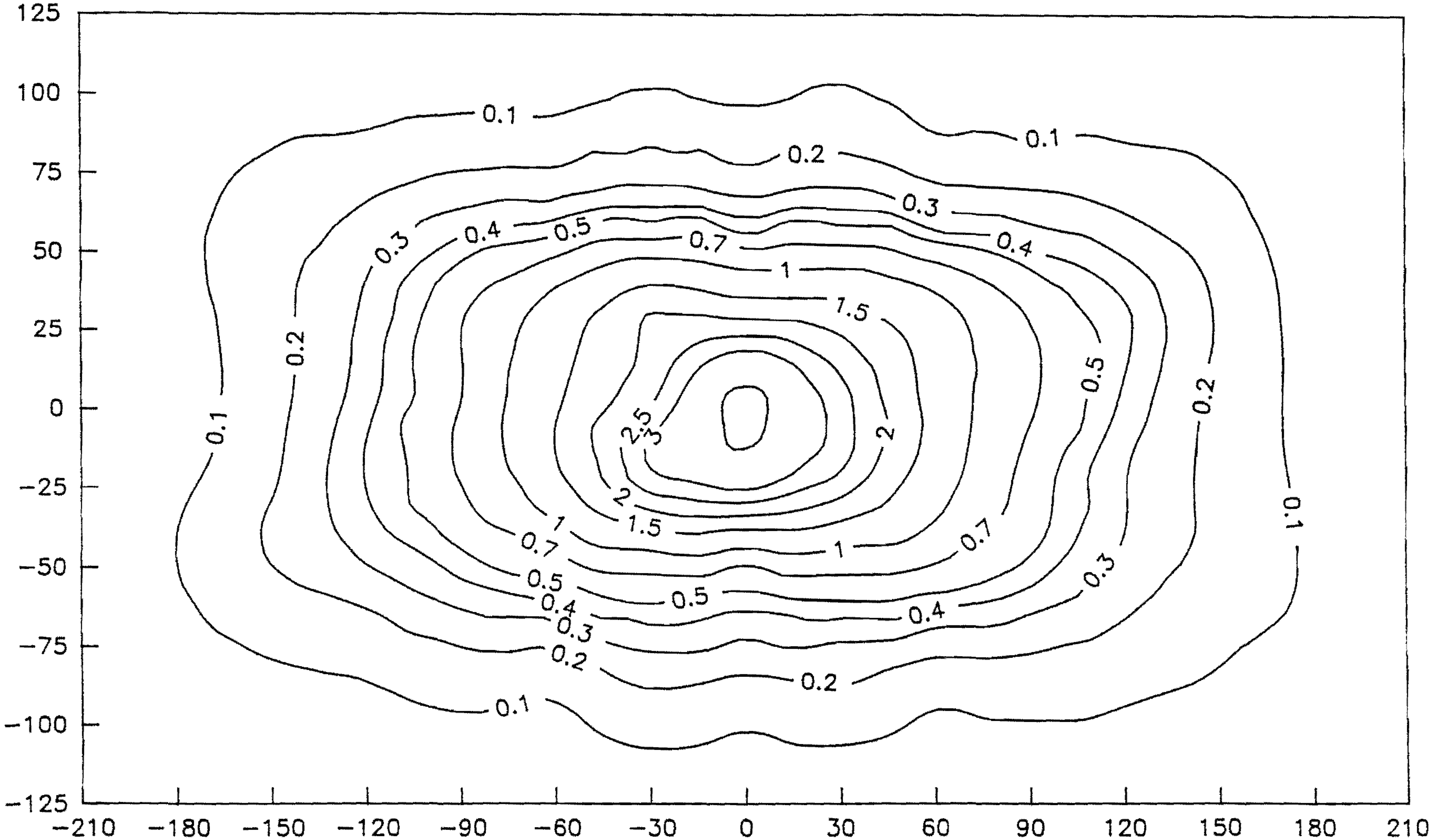


Figure A-6.

G.E. TWIN 7′ ARM M4RR–250 M.H. 40′



SCALE 1:50

Figure A-7.

G.E. TWIN 7'ARM M4RR-250 M.H. 50'

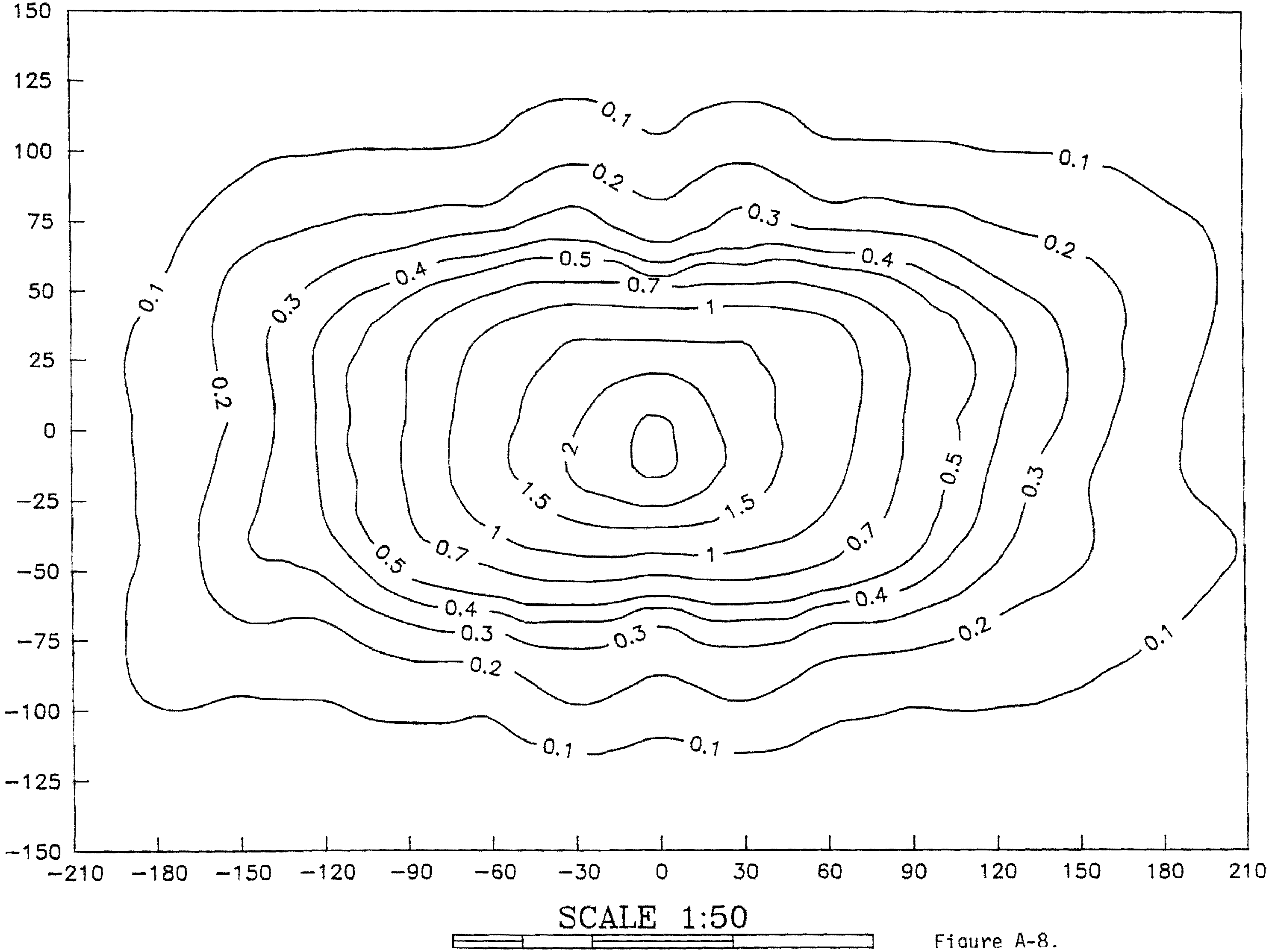
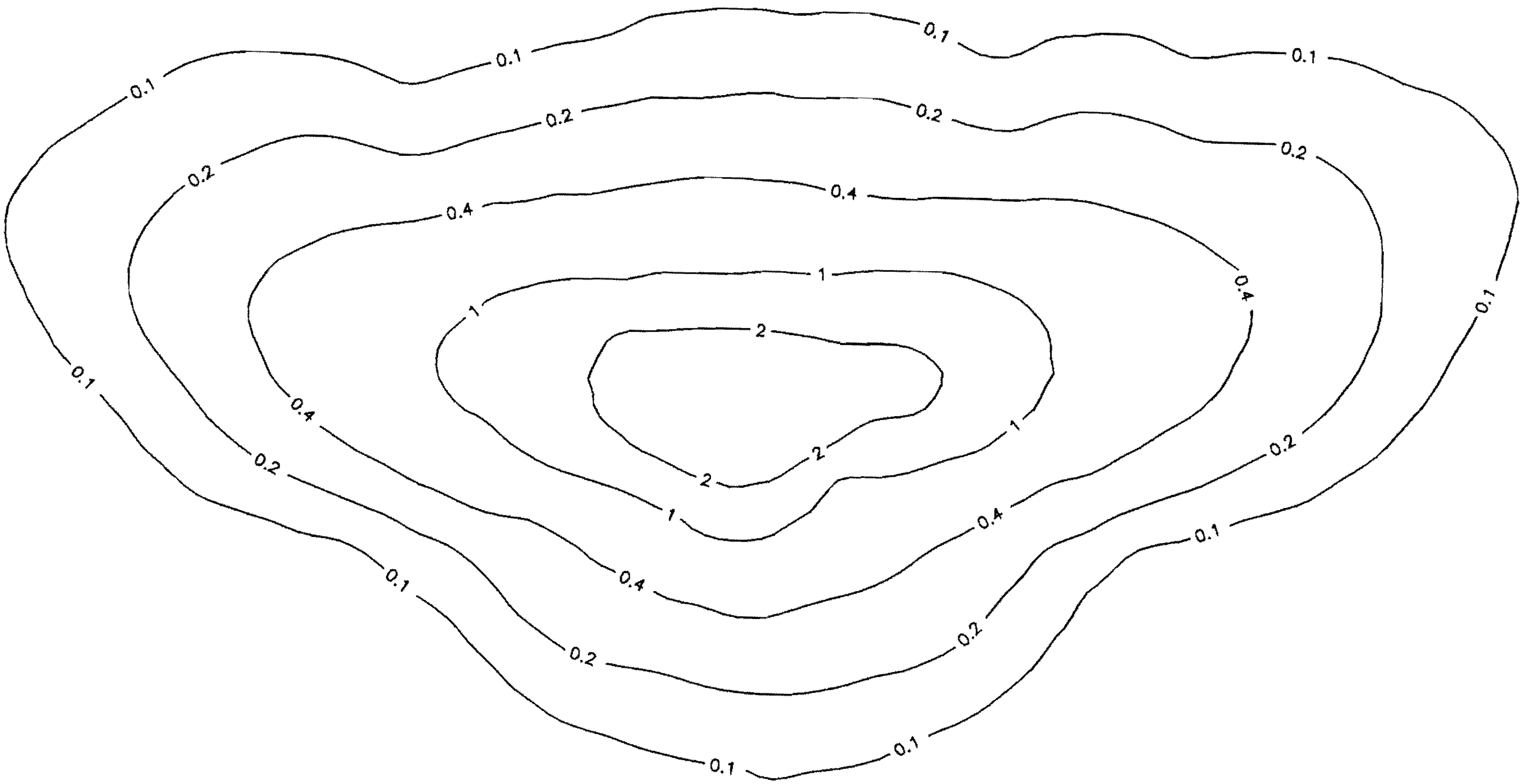


Figure A-8.

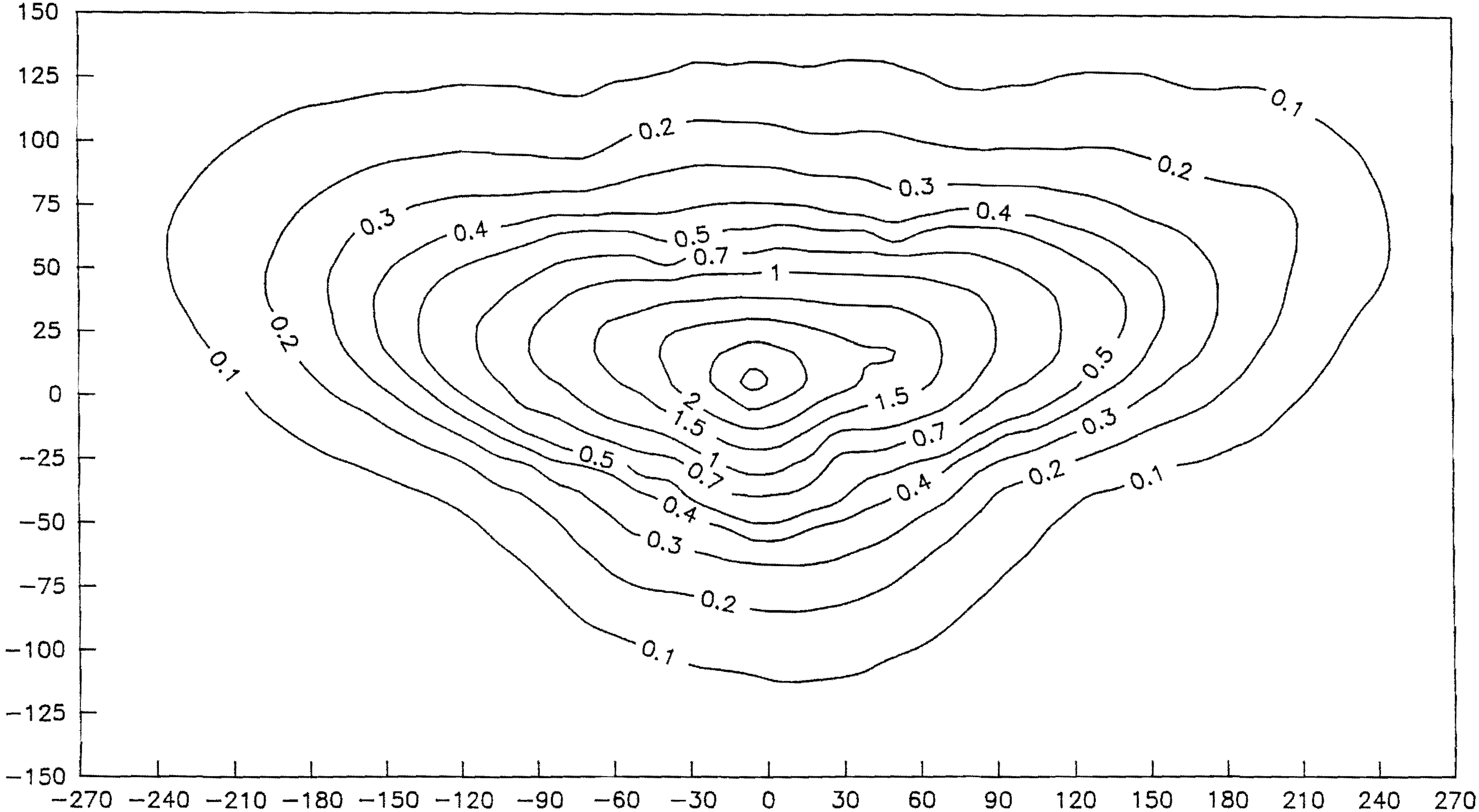
G.E. M4RR 400W MS3 M.H. 50'



SCALE 1:50

Figure A-9.

G.E. M4RR-400 M.H. 55'



SCALE 1:60

Figure A-10.

G. E. M4RR−400 M.H. 60′

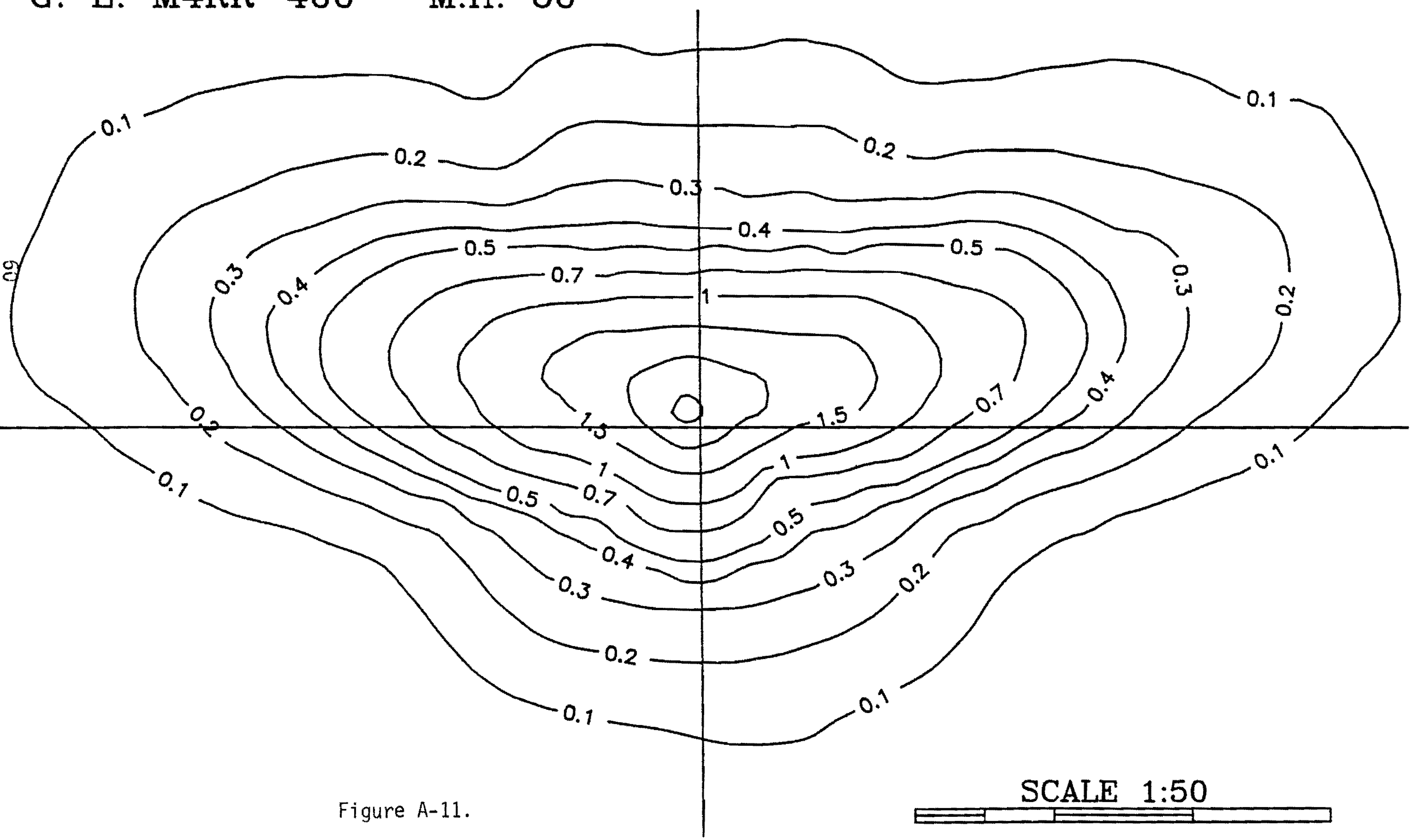


Figure A-11.

G.E. 10 HMA40S5A1GSC5 125' M.H.

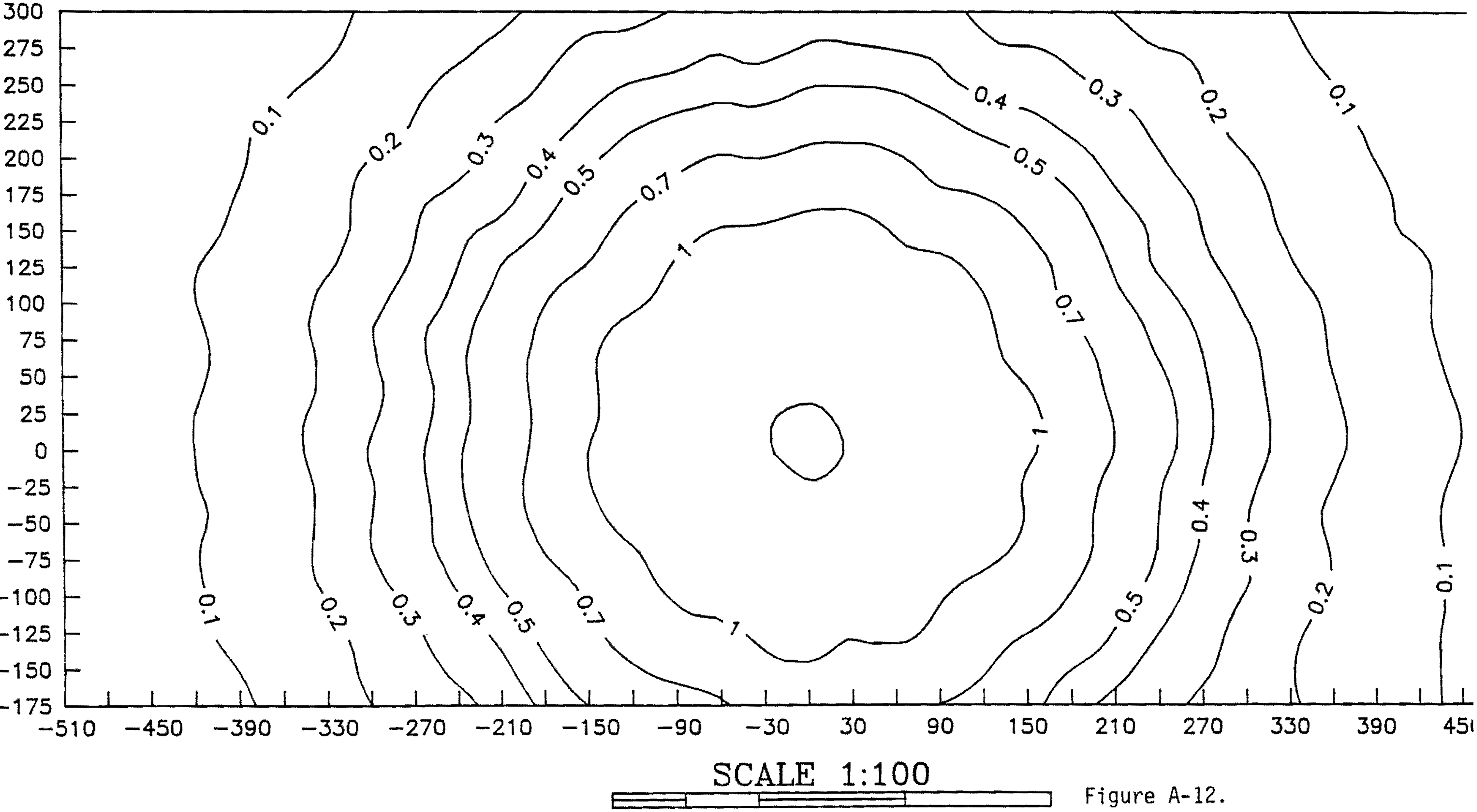
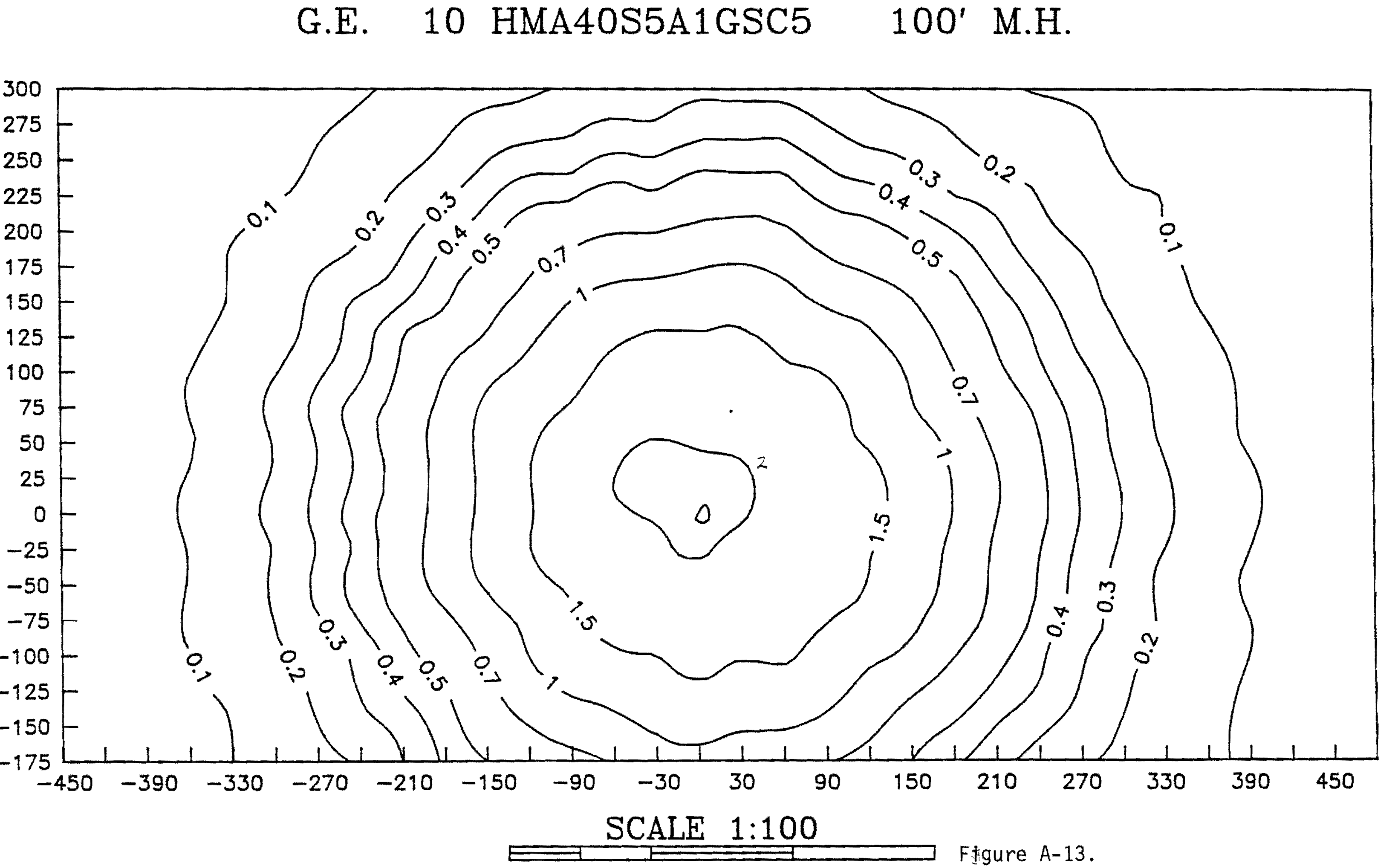
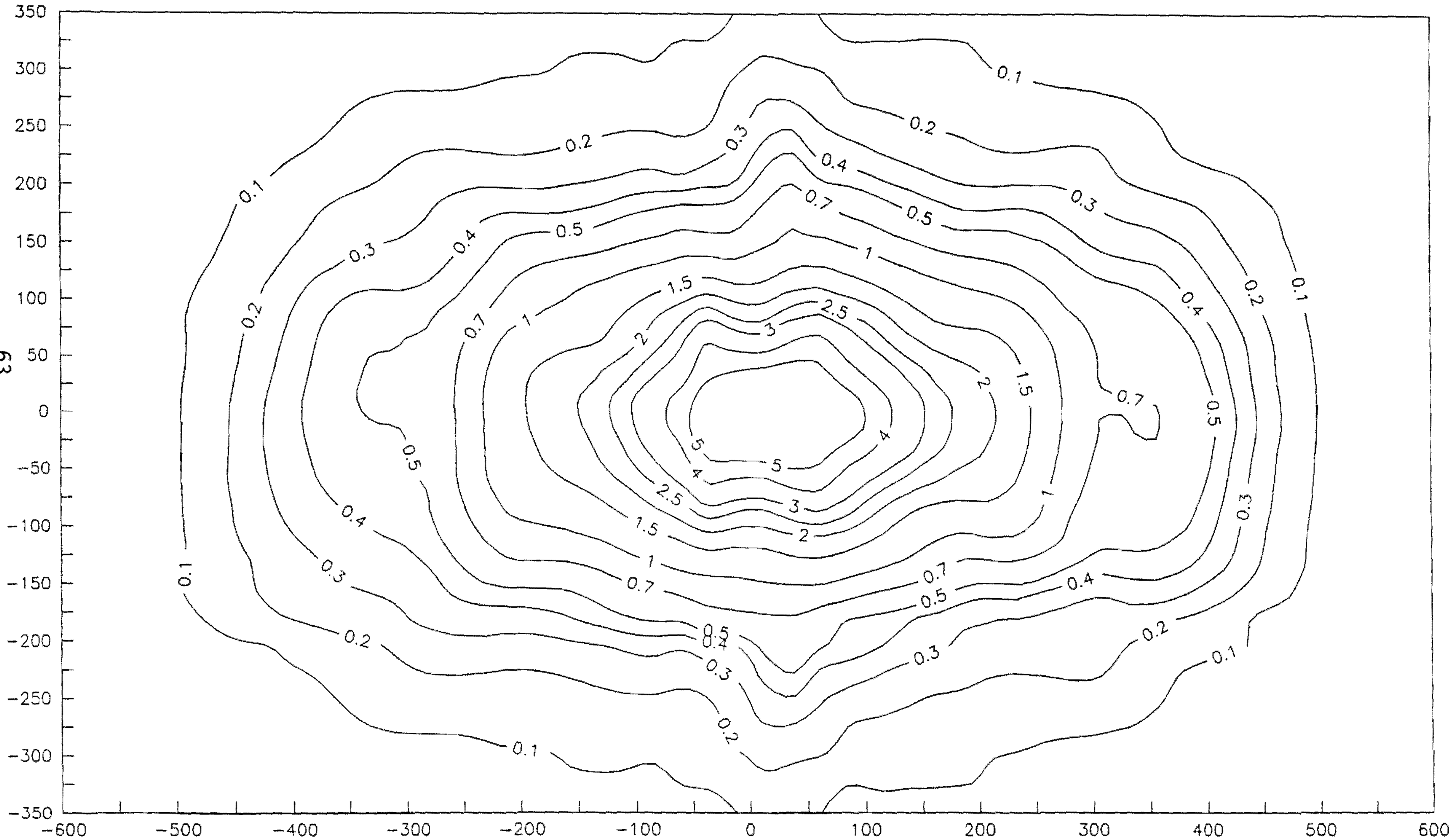


Figure A-12.


G.E. 10 HMA40S5A1GSC5 100' M.H.
300
275
250
225
200
175
150
125
100
75
50
25
0
−25
−50
−75
−100
−125
−150
−175
−450 −390 −330 −270 −210 −150 −90 −30 30 90 150 210 270 330 390 450
0.1
0.2
0.3
0.4
0.5
0.7
1
1.5
2
SCALE 1:100
Figure A-13.

6 GE HMA-01SGMC3

M.H. 125'



SCALE 1:100

Figure A-14.

12 GE HMA-40SGMC5 400W M.H. 150'

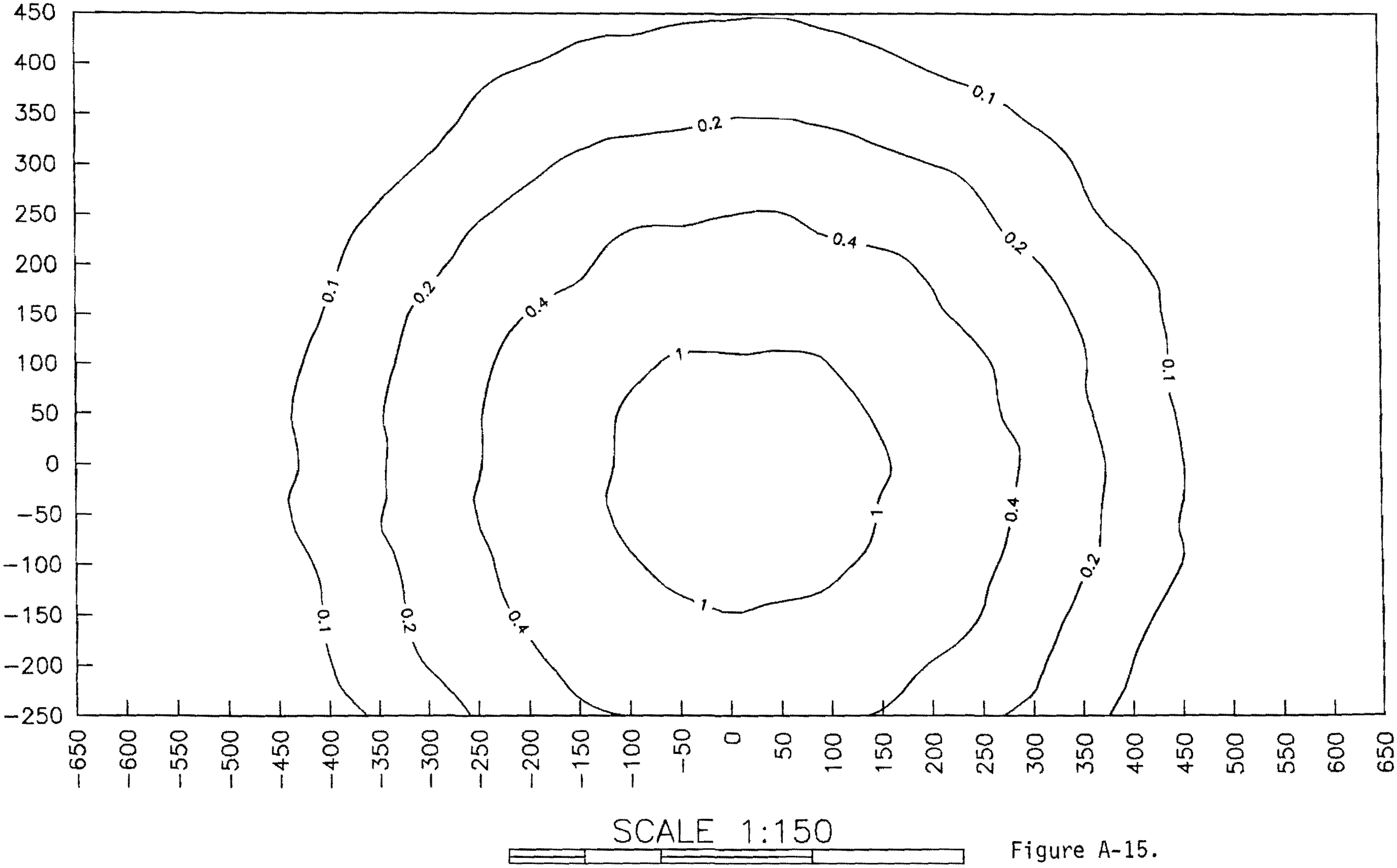
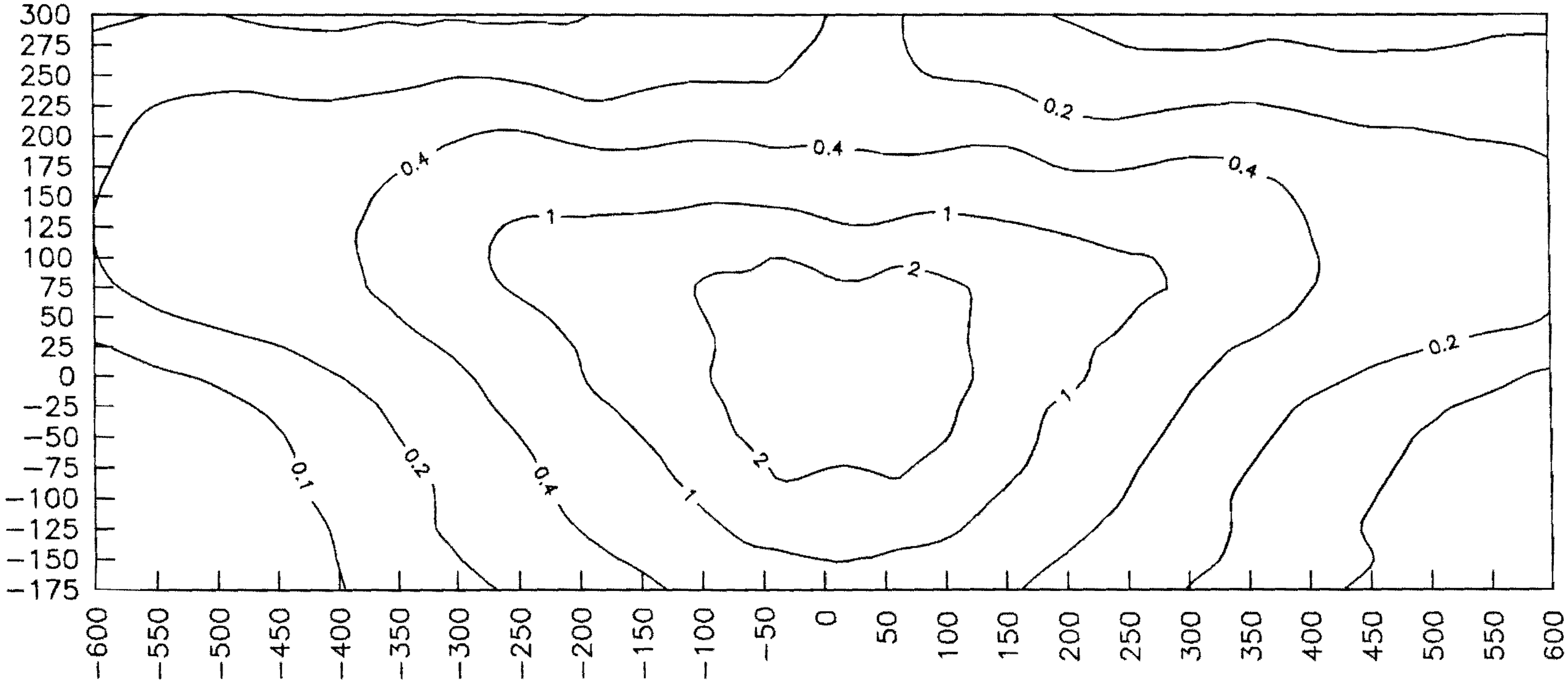


Figure A-15.

12 G.E. ASYM 400W MC2 M.H. 150'



SCALE 1:150

Figure A-16.

G.E. 400W, Asym.(mod), 12 West, M.H. 150'

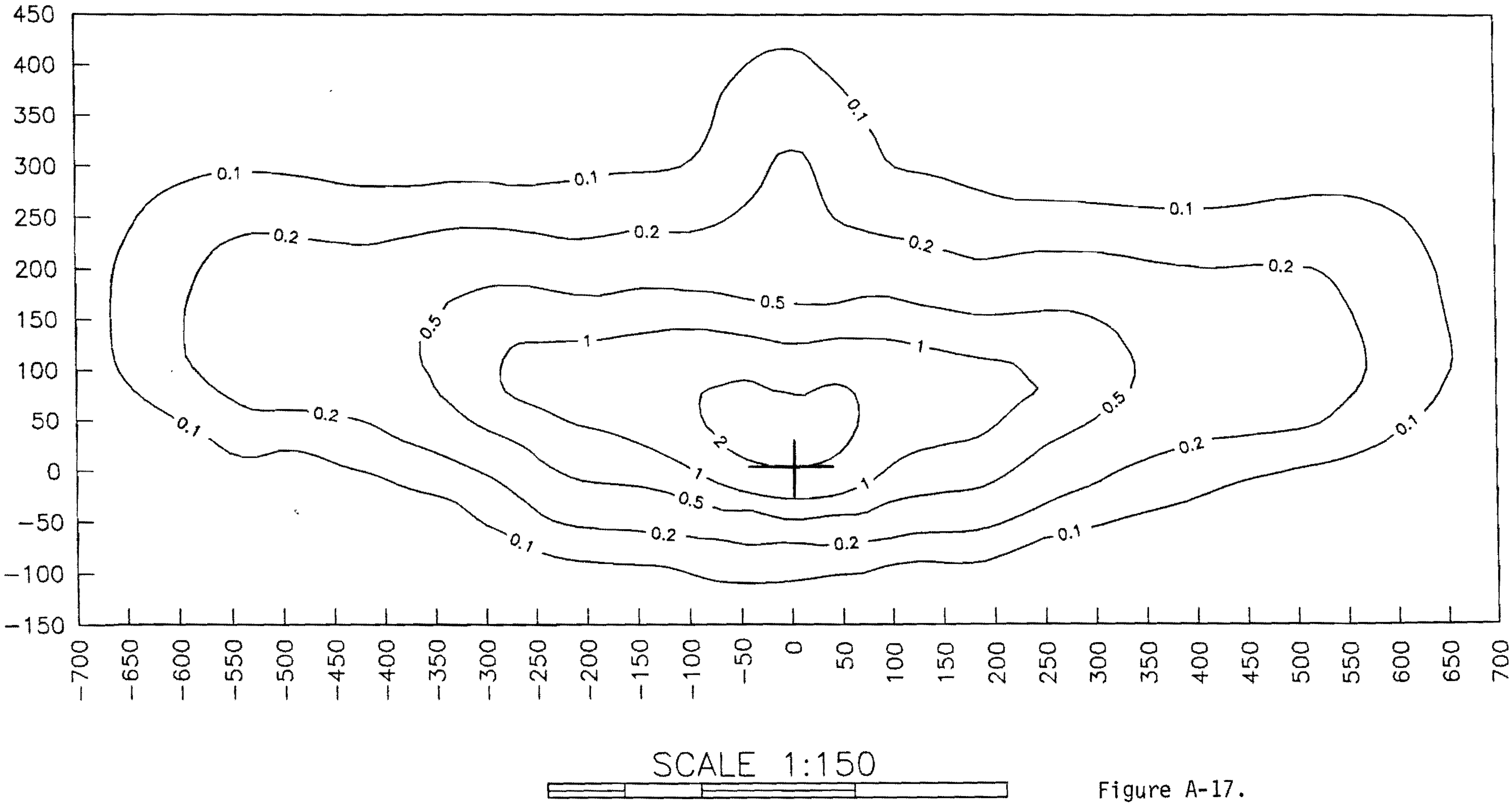


Figure A-17.

10 GE HMA01S5A1GSC5 M.H. 175′

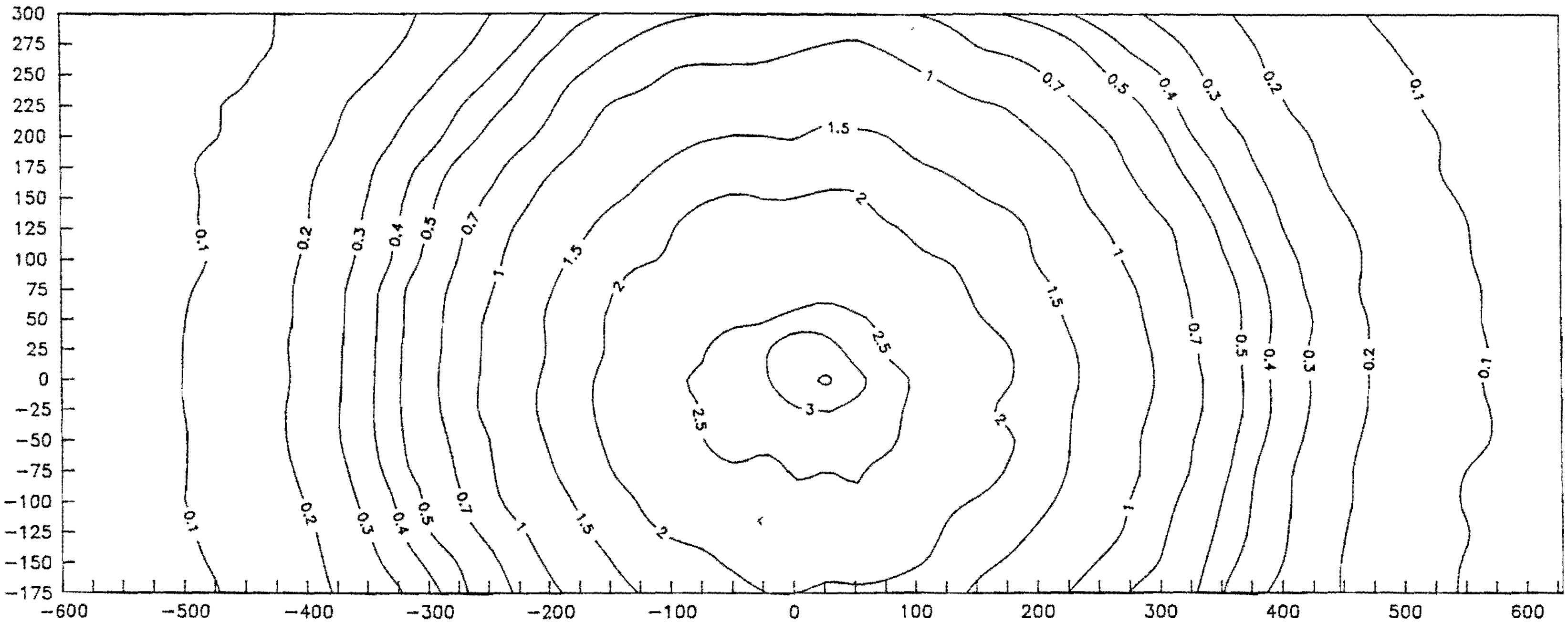
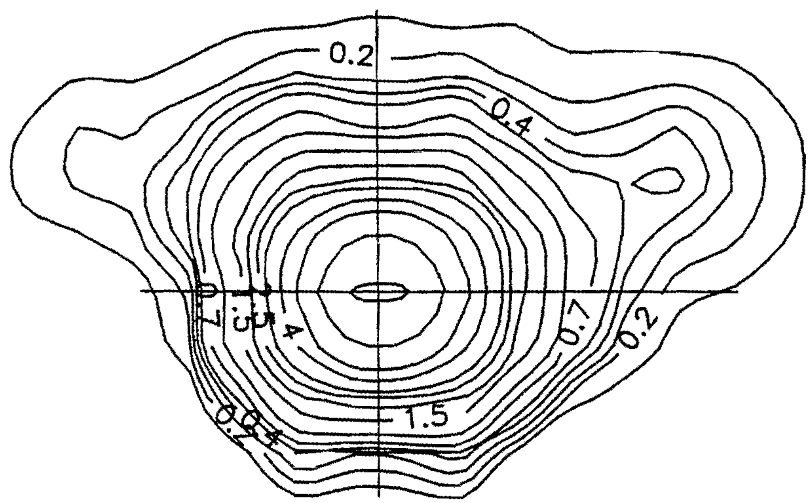


Figure A-18.

C. H. OVS150 M.H. 20'



SCALE 1:40

Figure A-19.

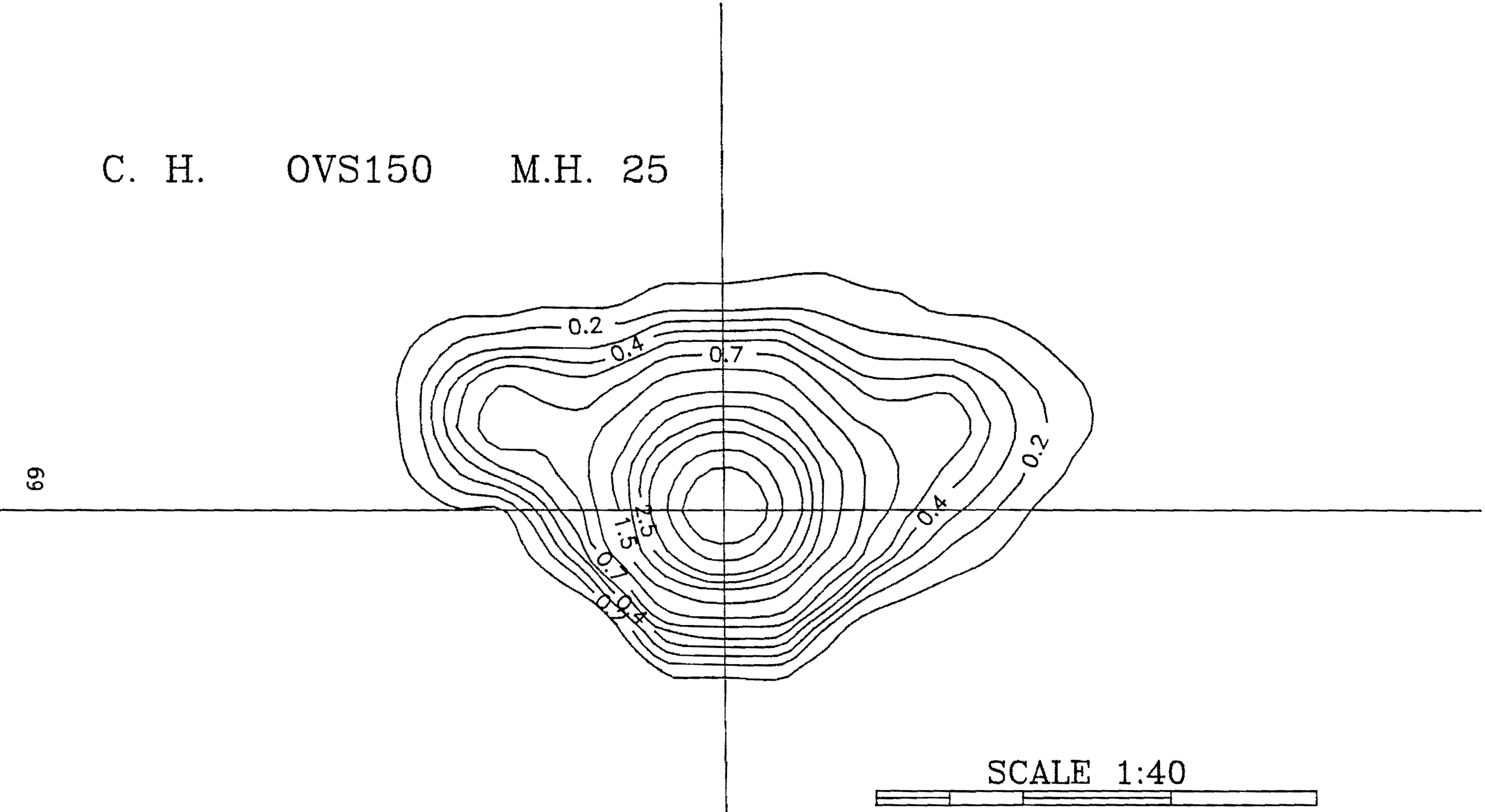


Figure A-20.

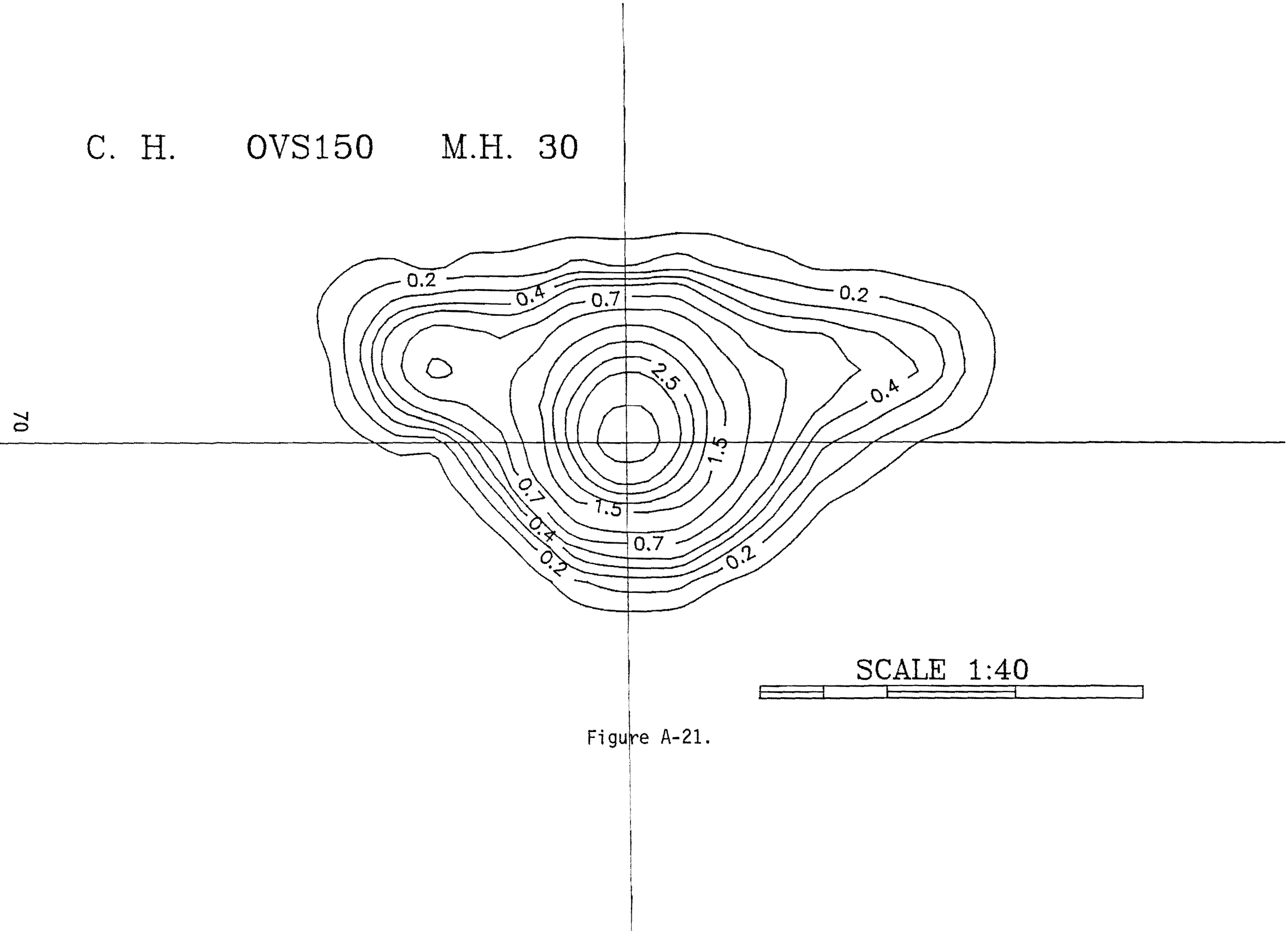


Figure A-21.

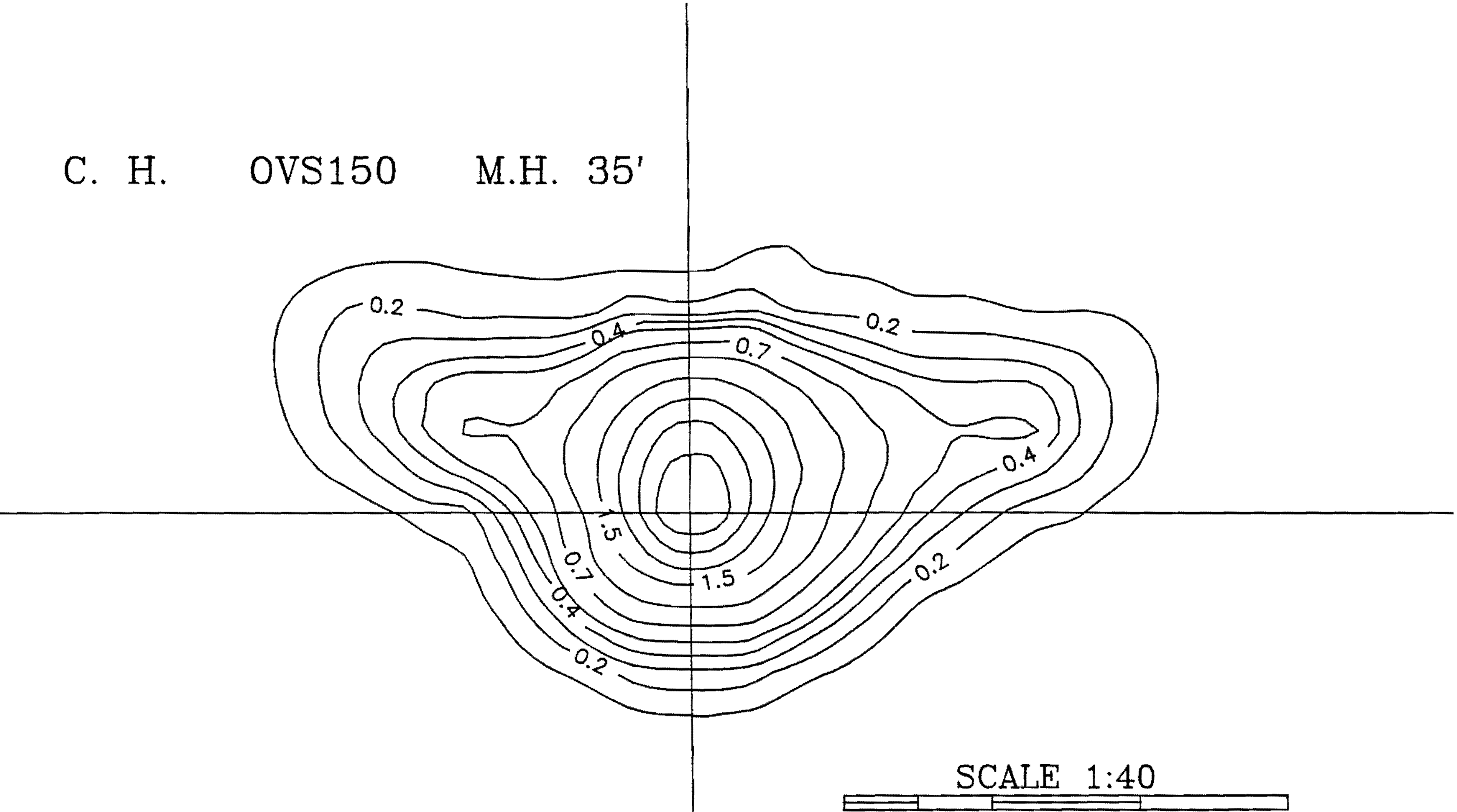


Figure A-22.

C.H. OVS 250 M.H. 35'

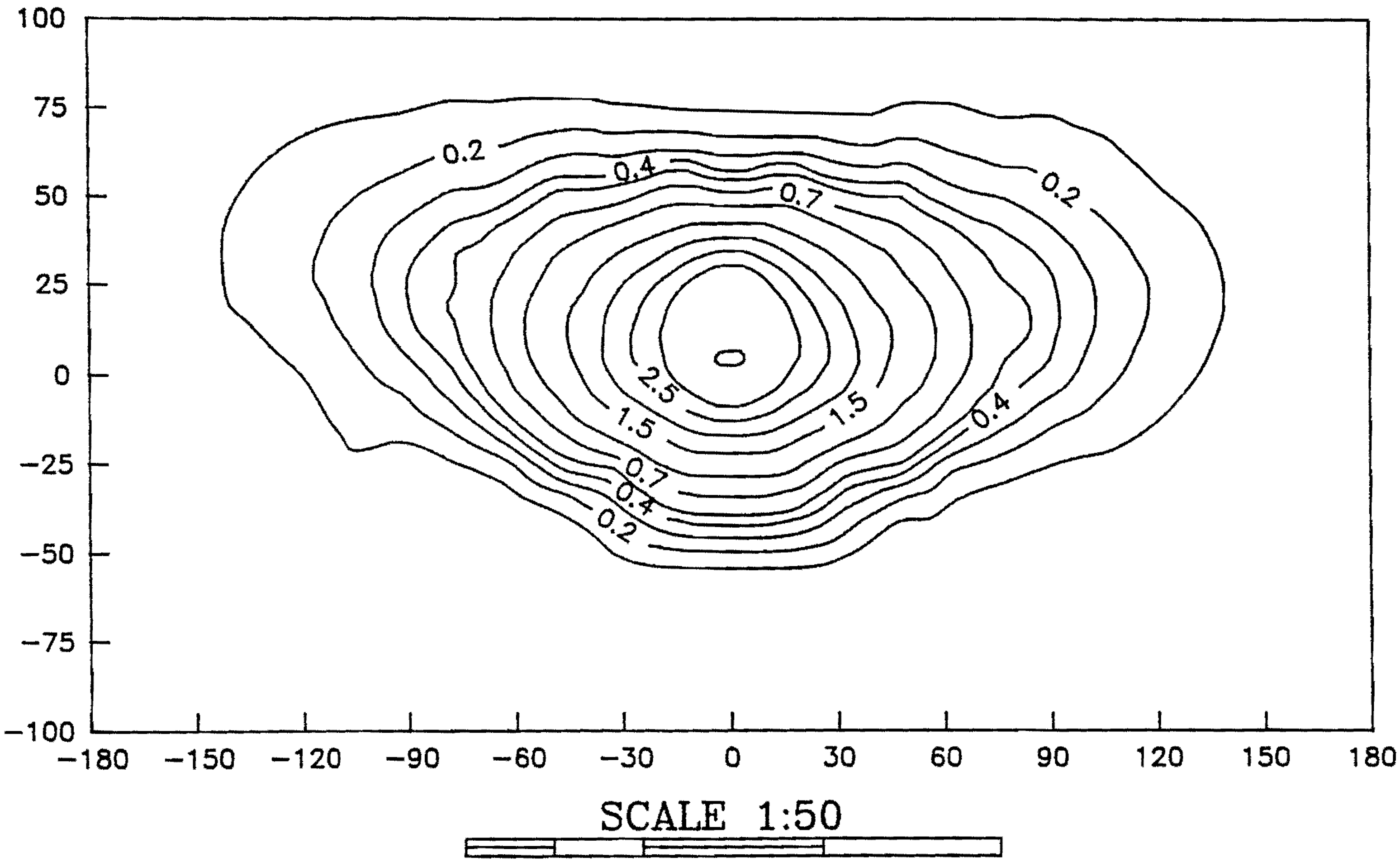
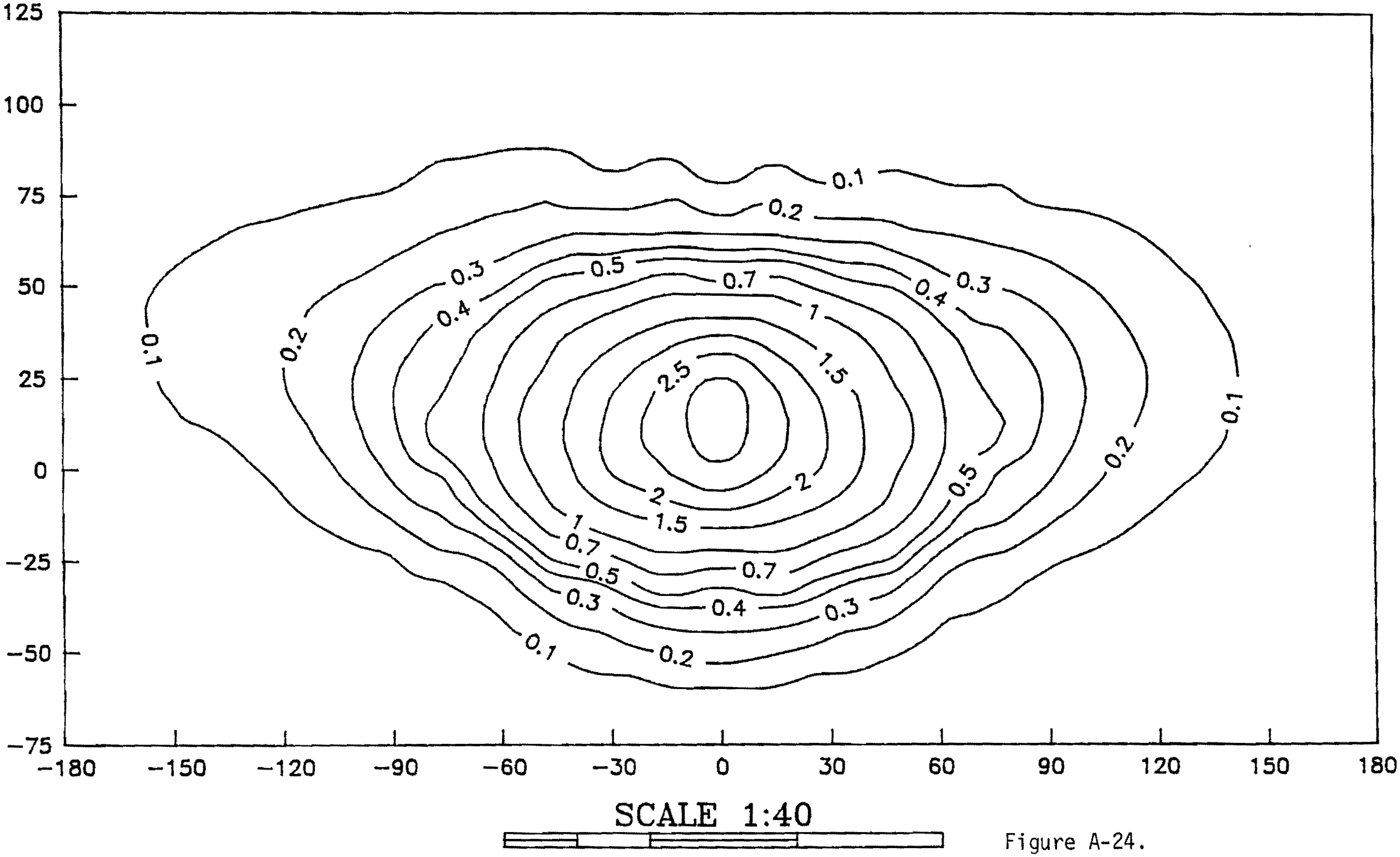


Figure A-23.

C.H. OVS-250 M.H. 40'



SCALE 1:40

Figure A-24.

C.H. OVS-250 M.H. 50′

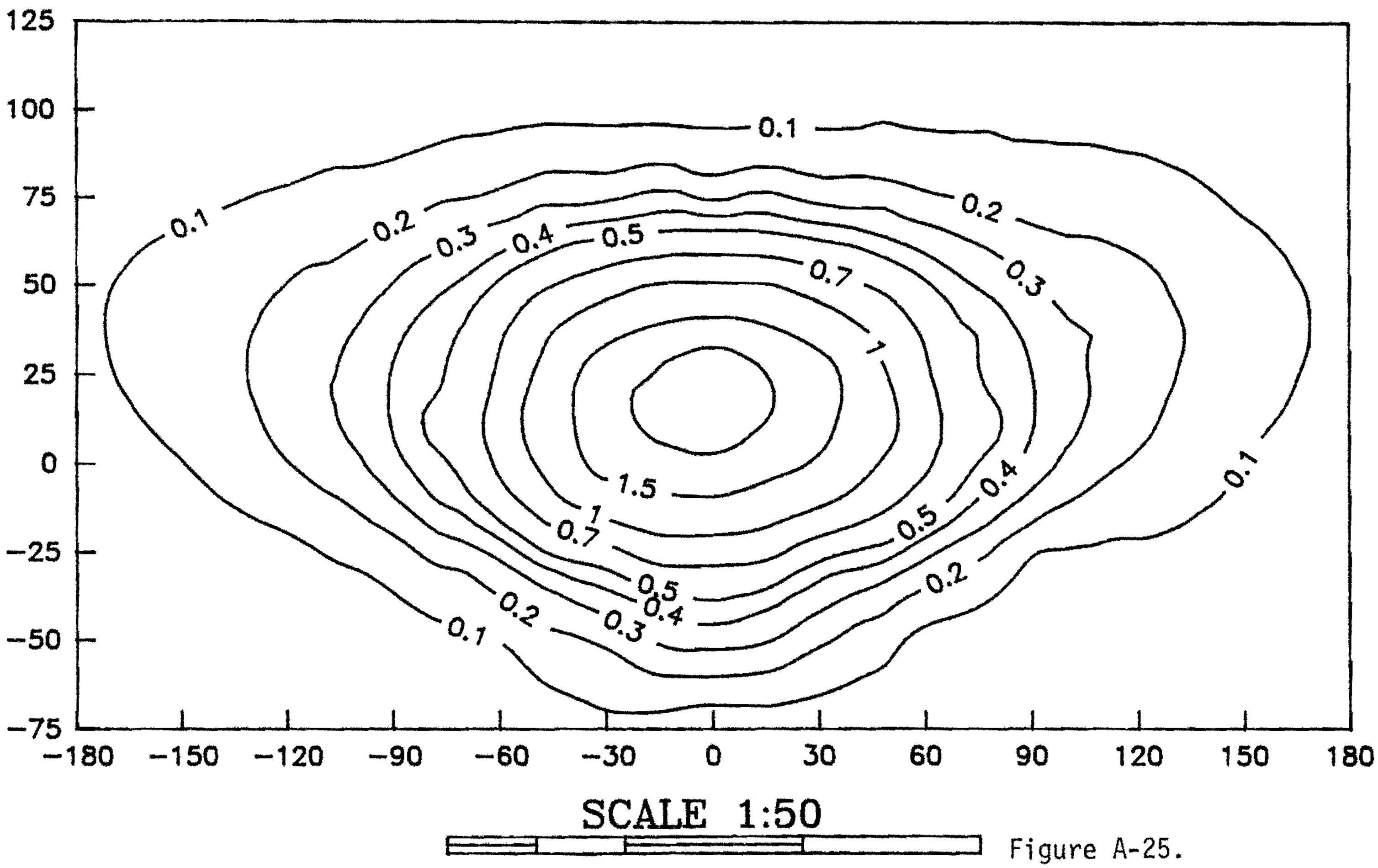


Figure A-25.

C. H. OVM400 M.H. 35′

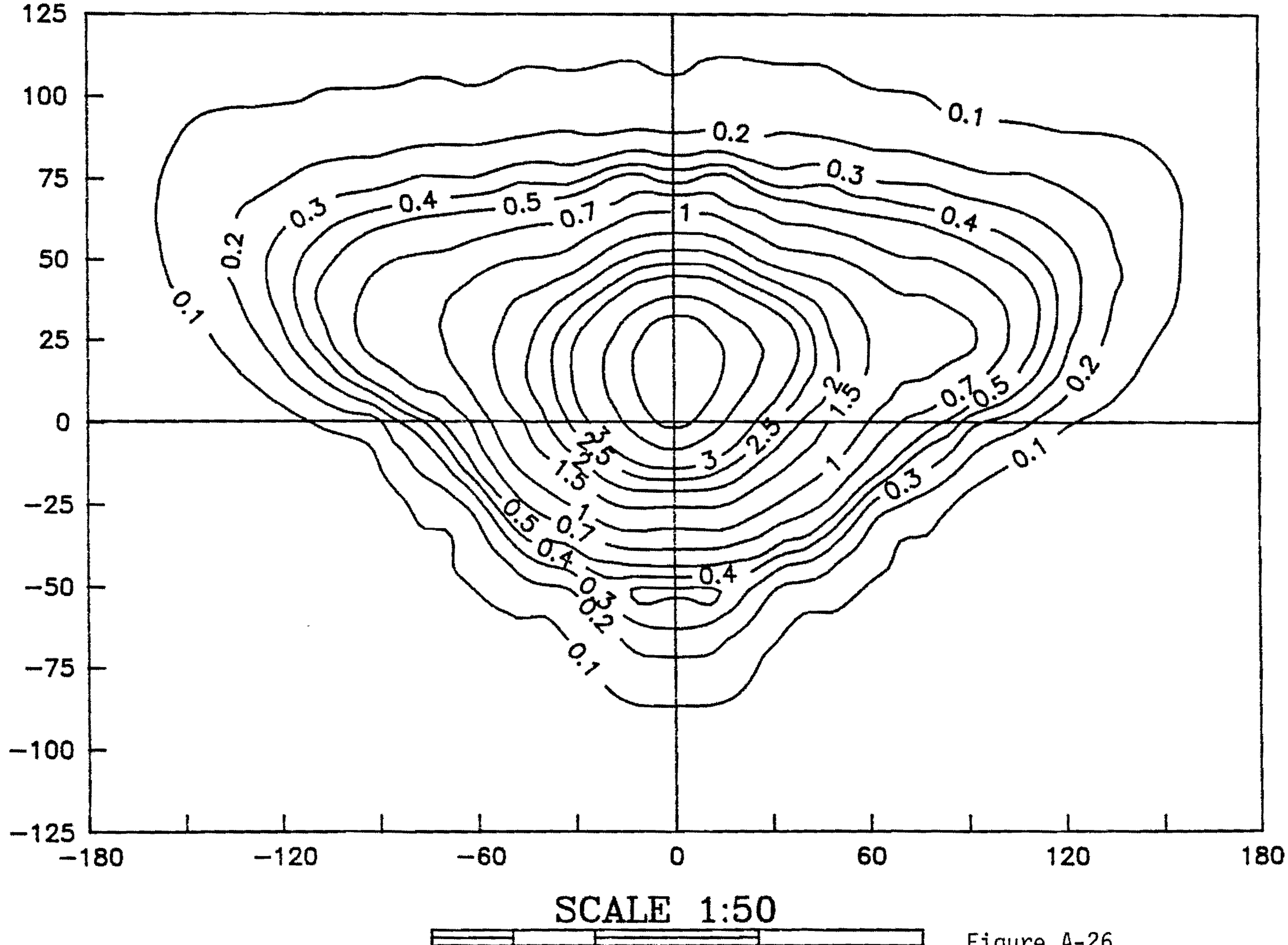


Figure A-26.

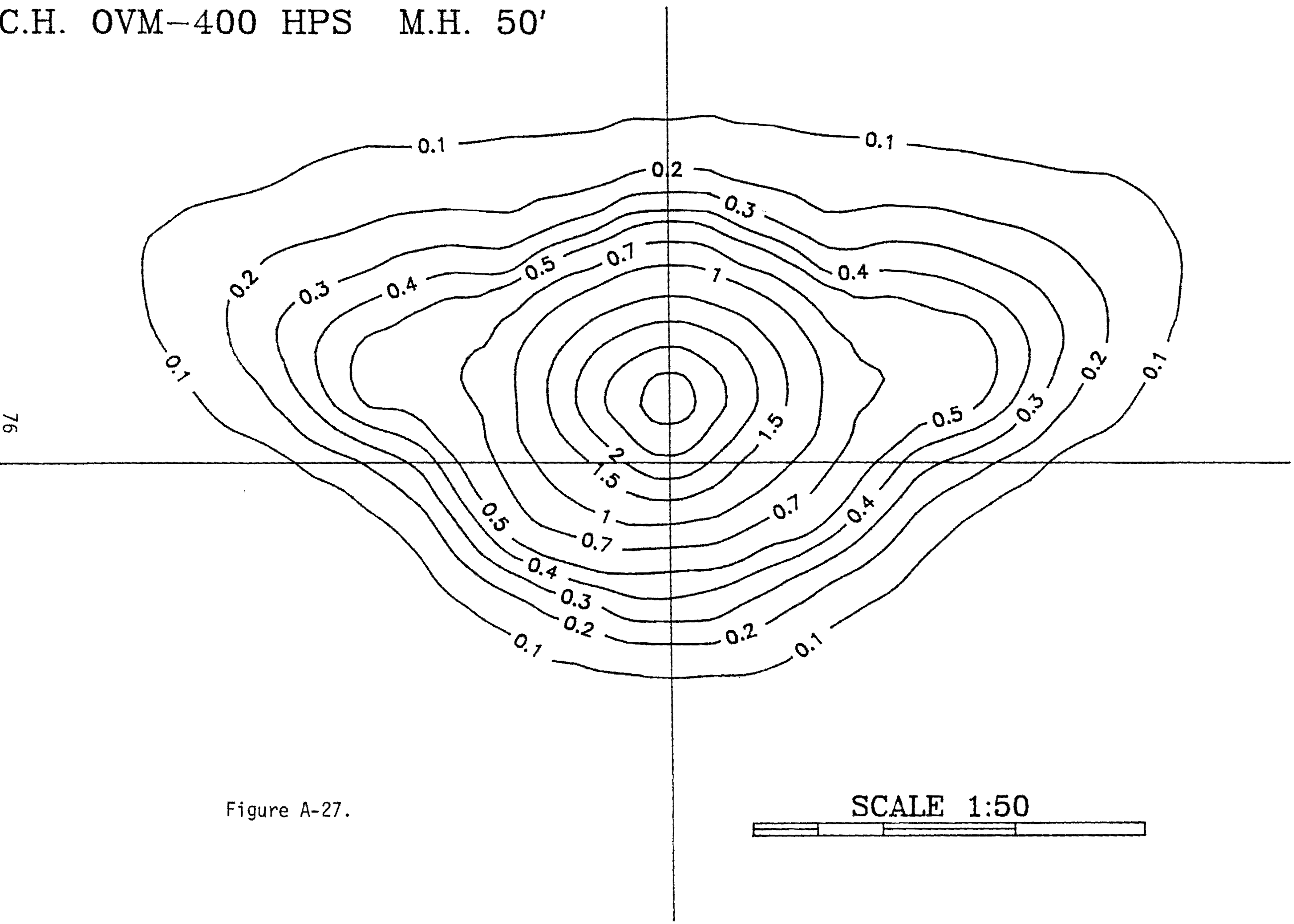


Figure A-27.

C.H. OVM–400 M.H. 55′

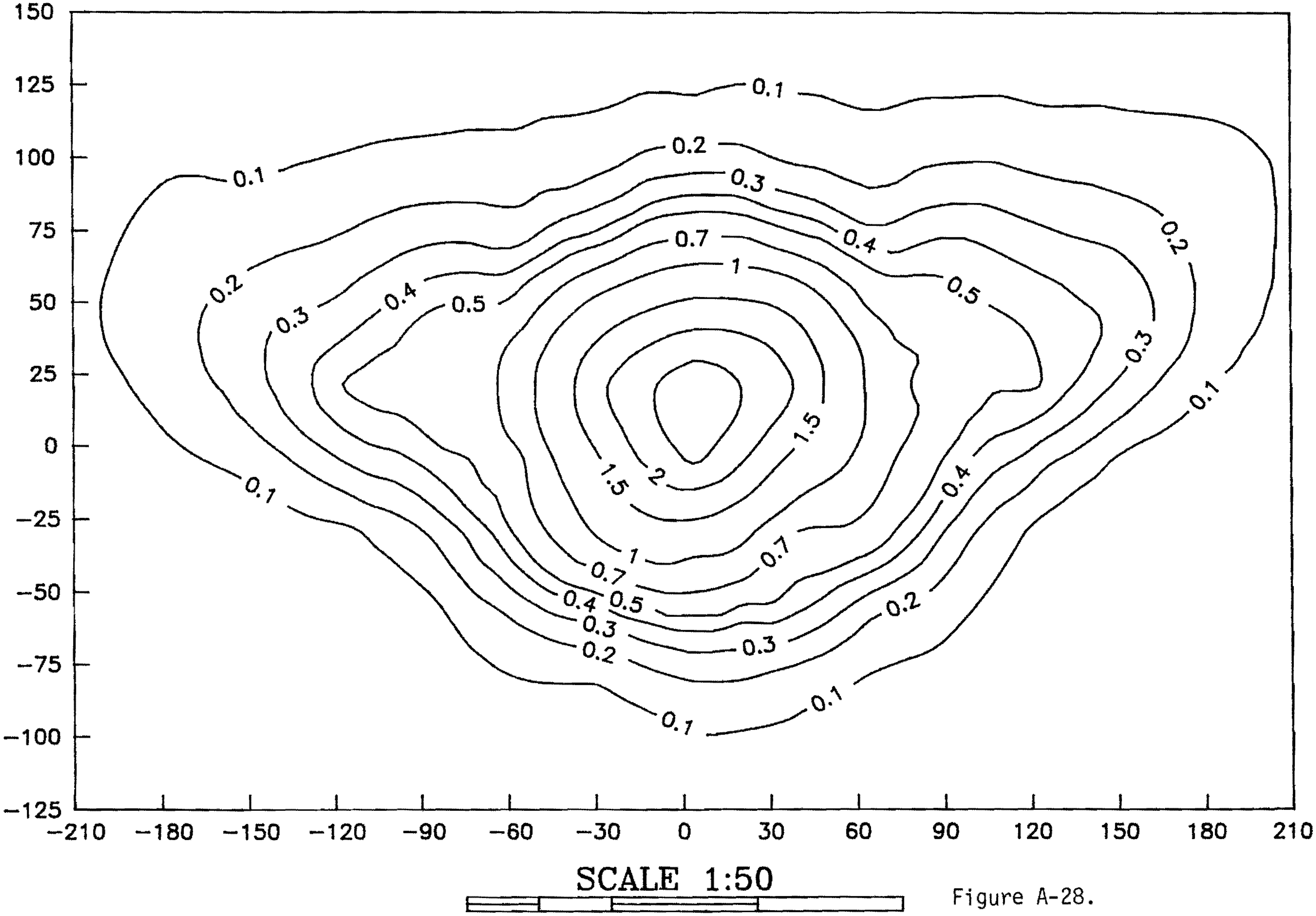


Figure A-28.

C. H. OVM400 M.H. 60′

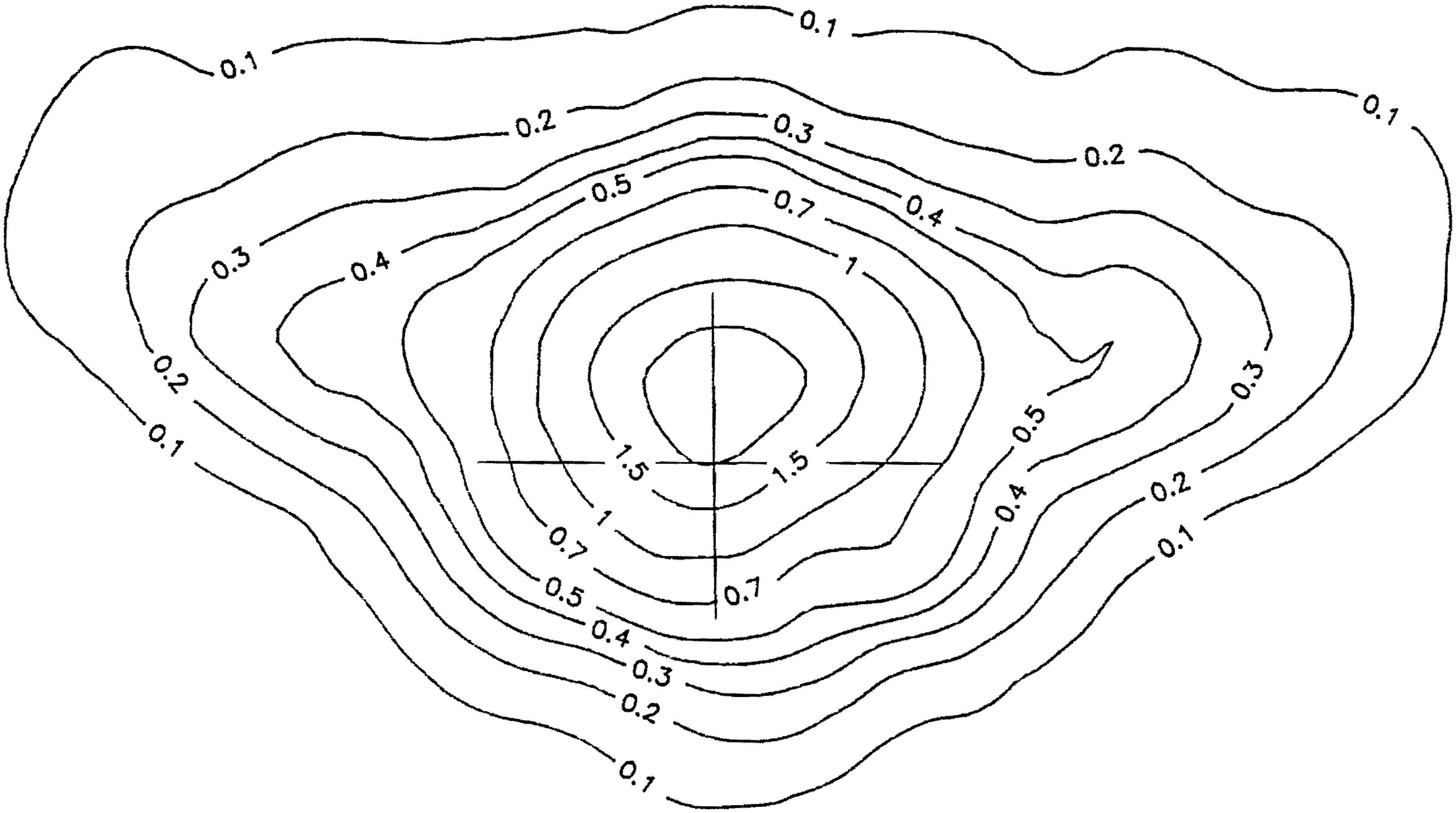


Figure A-29.

SCALE 1:50

6 CROUSE HINDS HMA91SW84ED0001 MH 125'

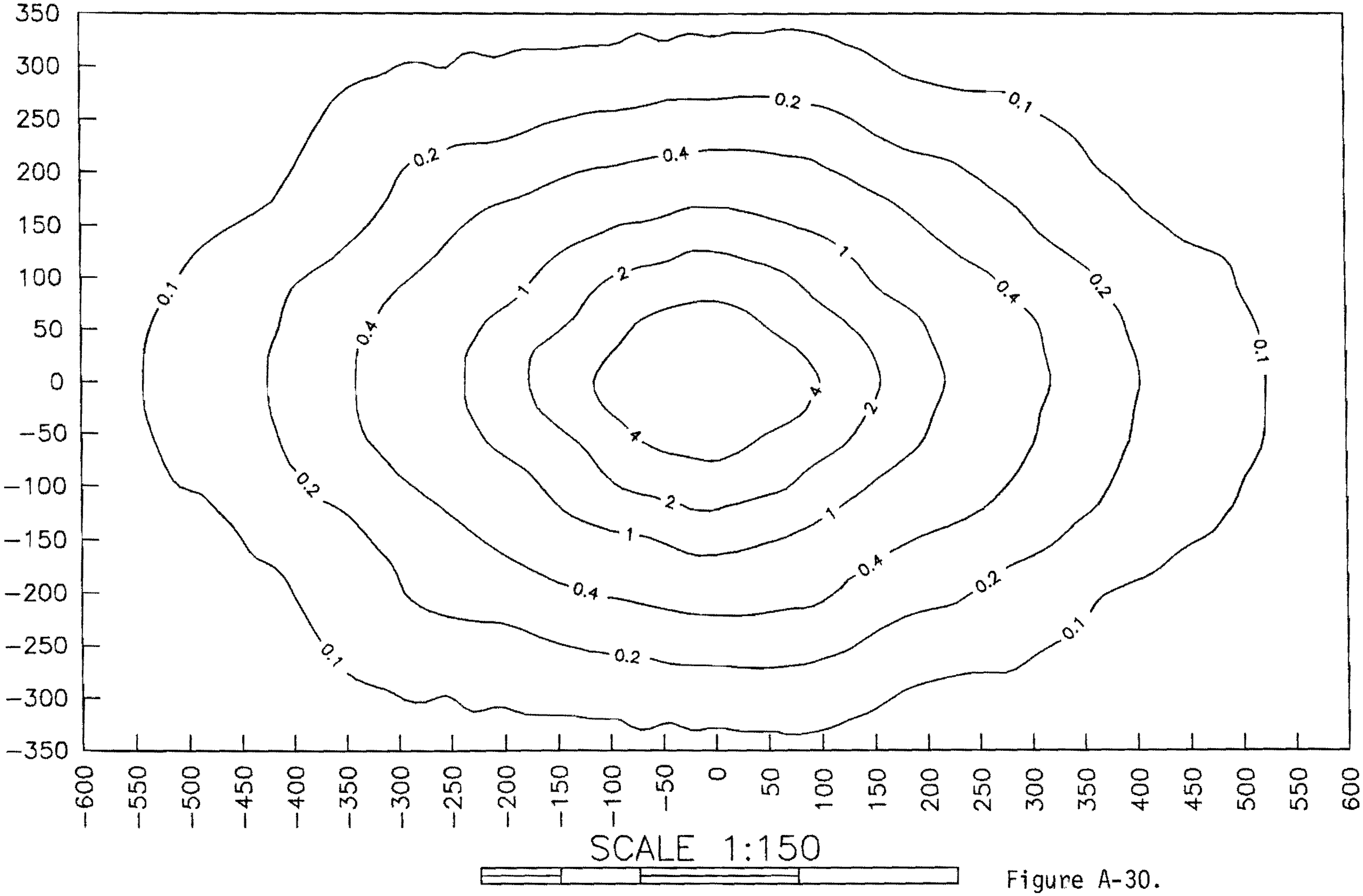


Figure A-30.

Crouse Hinds 10 HMX91S 175′

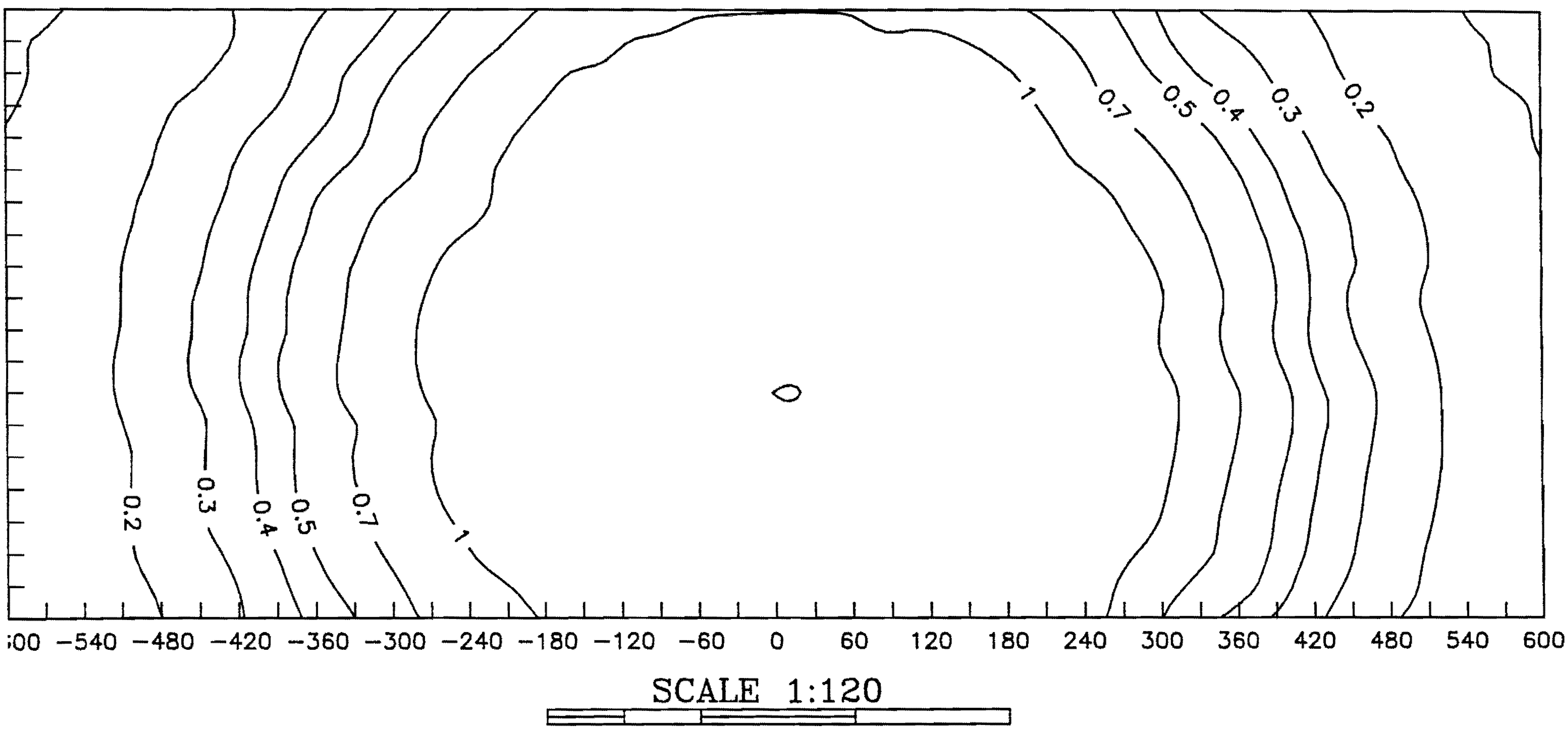


Figure A-31.

12 CROUSE HINDS ASYM. 400W M.H. 150' 6 East 6 West

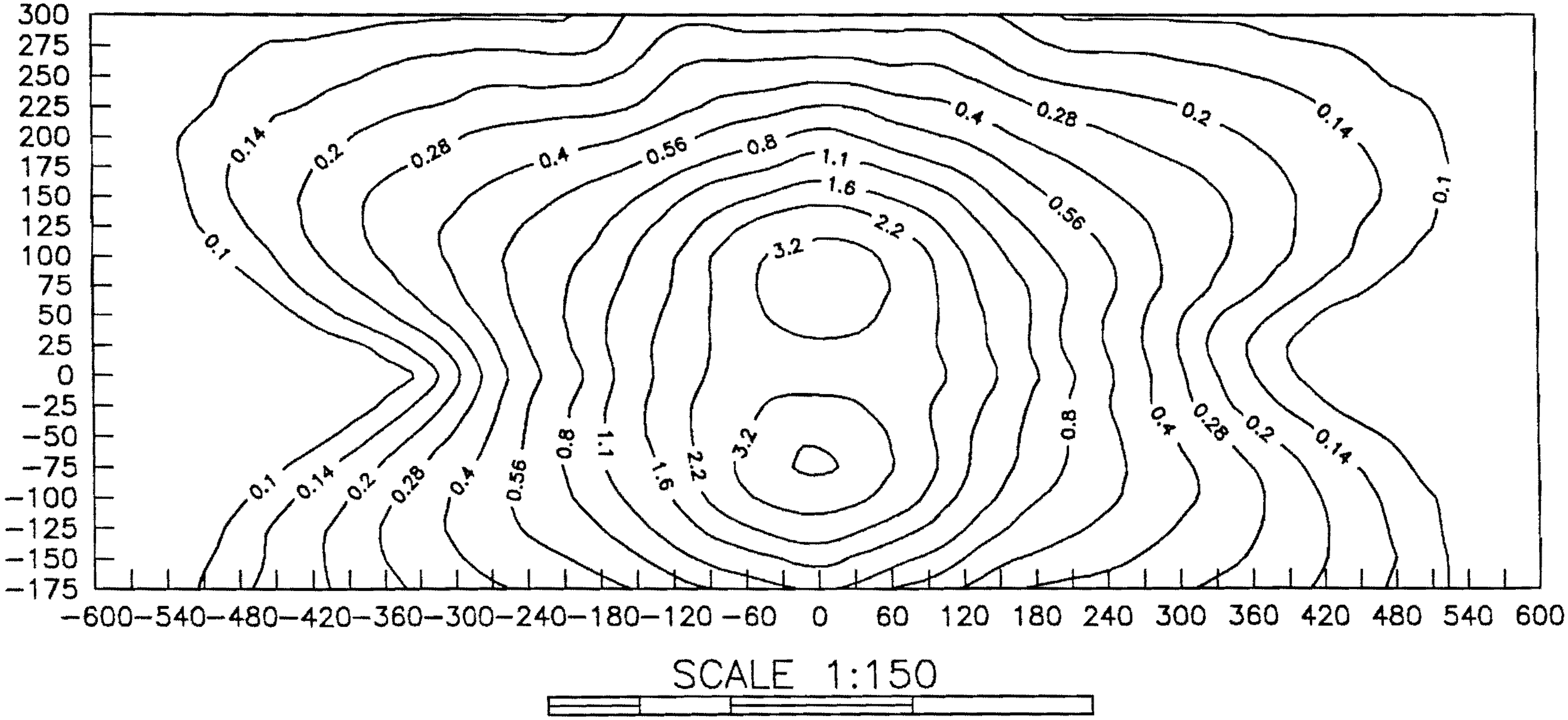
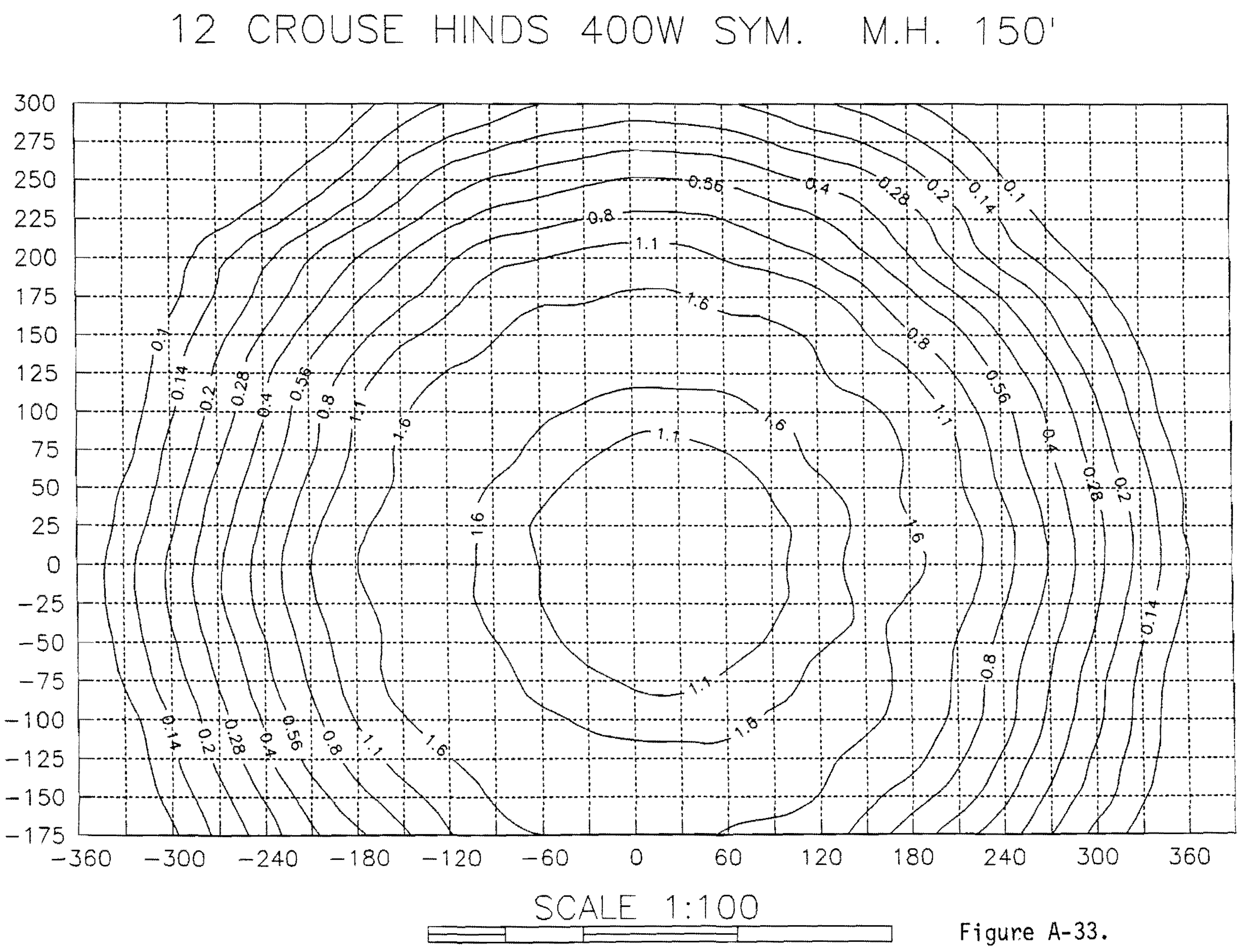


Figure A-32.



SCALE 1:100

Figure A-33.

12 CROUSE HINDS 400W SYM. M.H. 150'

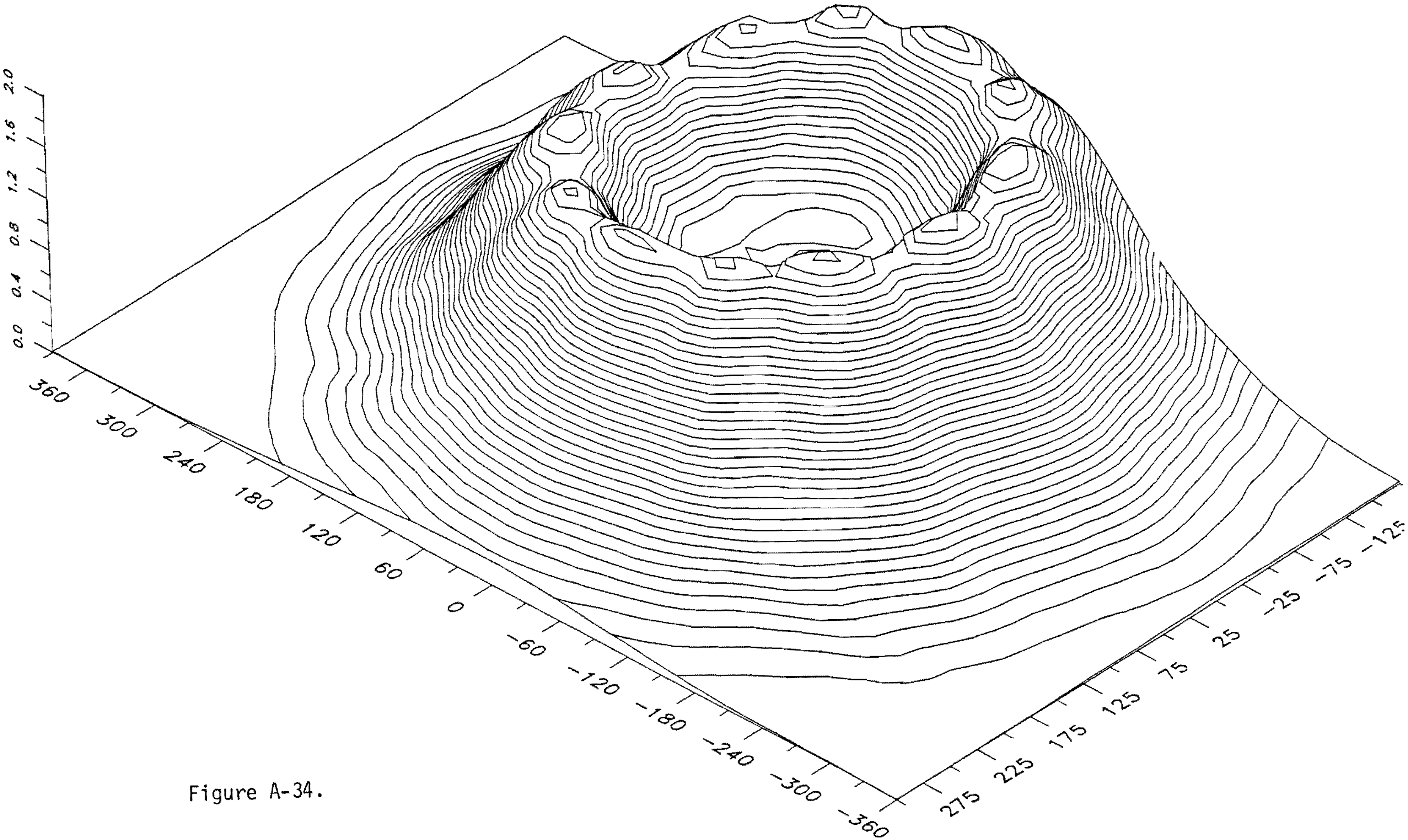
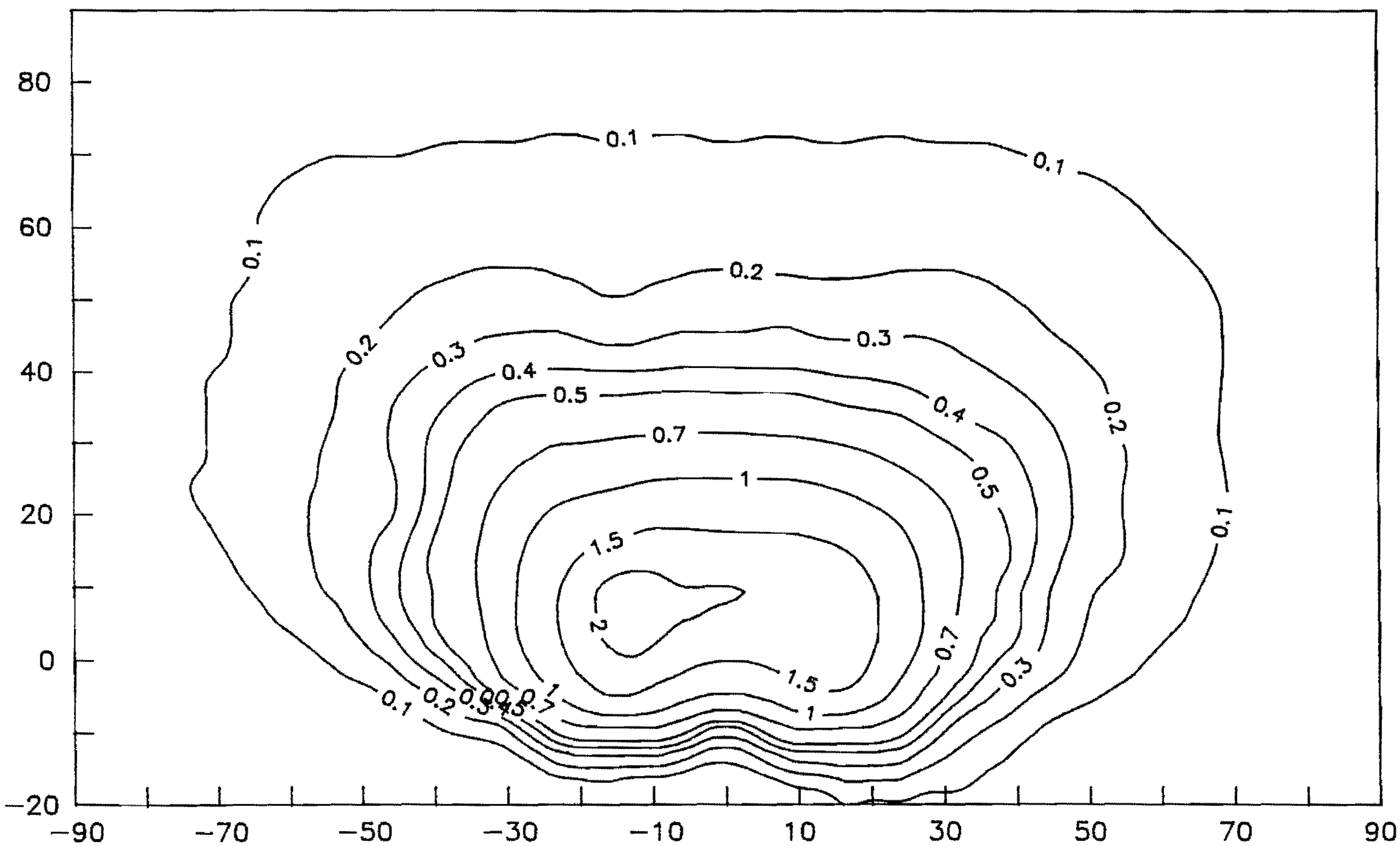


Figure A-34.

ABS 4000–90LPS–K1939 MH25' AIM 36° BH



SCALE 1:25

Figure A-35.

UNDERPASS ABS 4000-90LPS-K1939 M.H. 30'

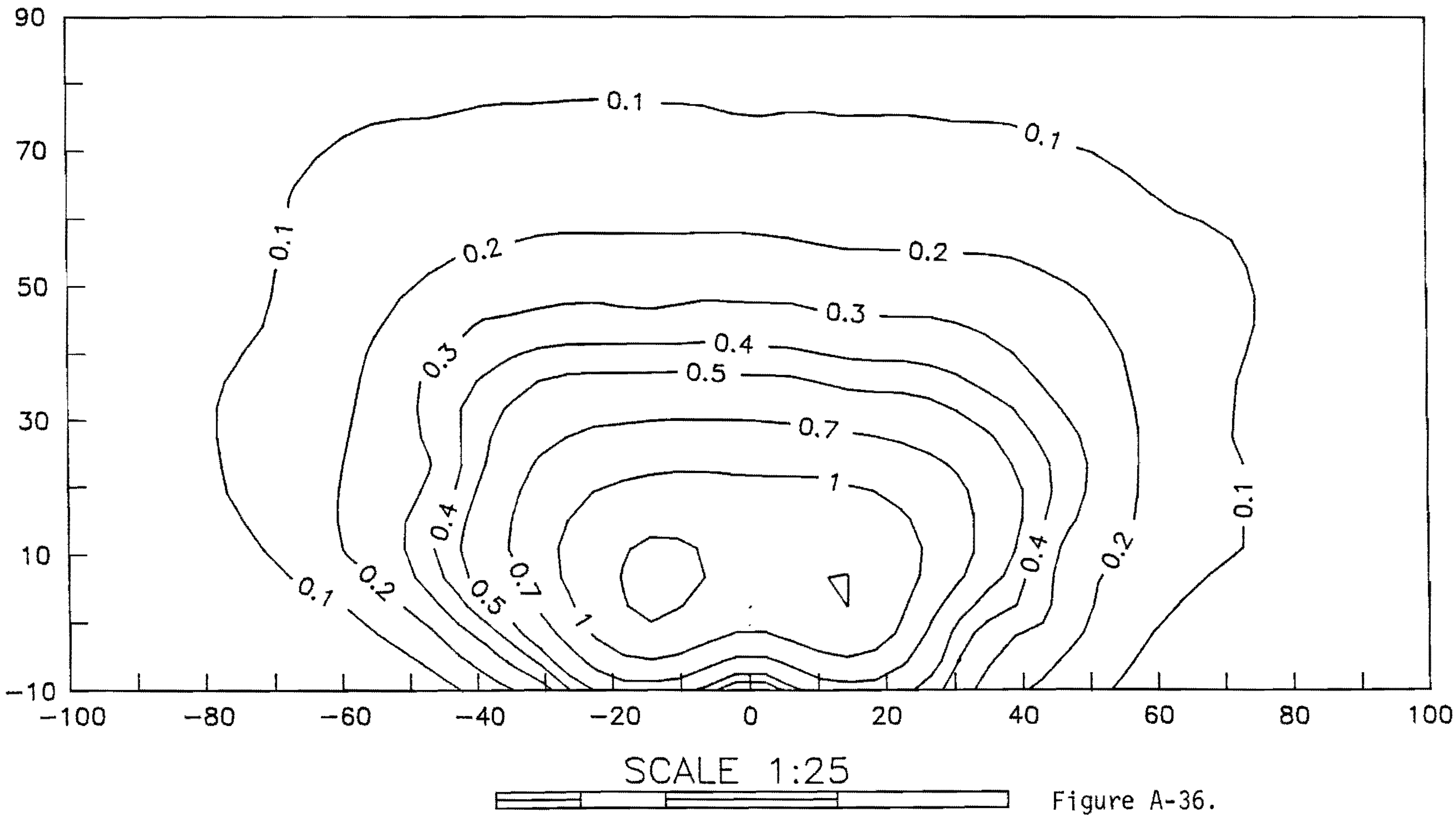


Figure A-36.

ABS 4000-55LPS-KI793B MH15' AIM 10° BH

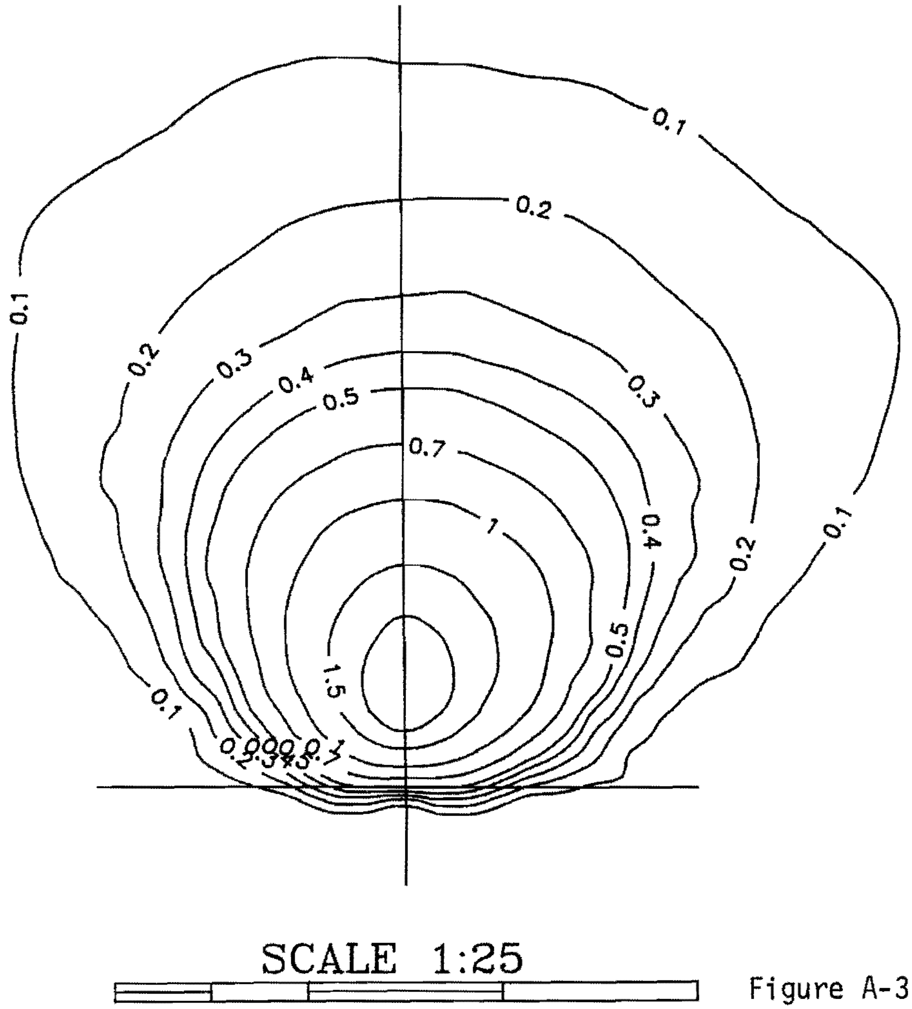


Figure A-37.

ABS 4000-90LPS-K1939 MH20' AIM 36° BH

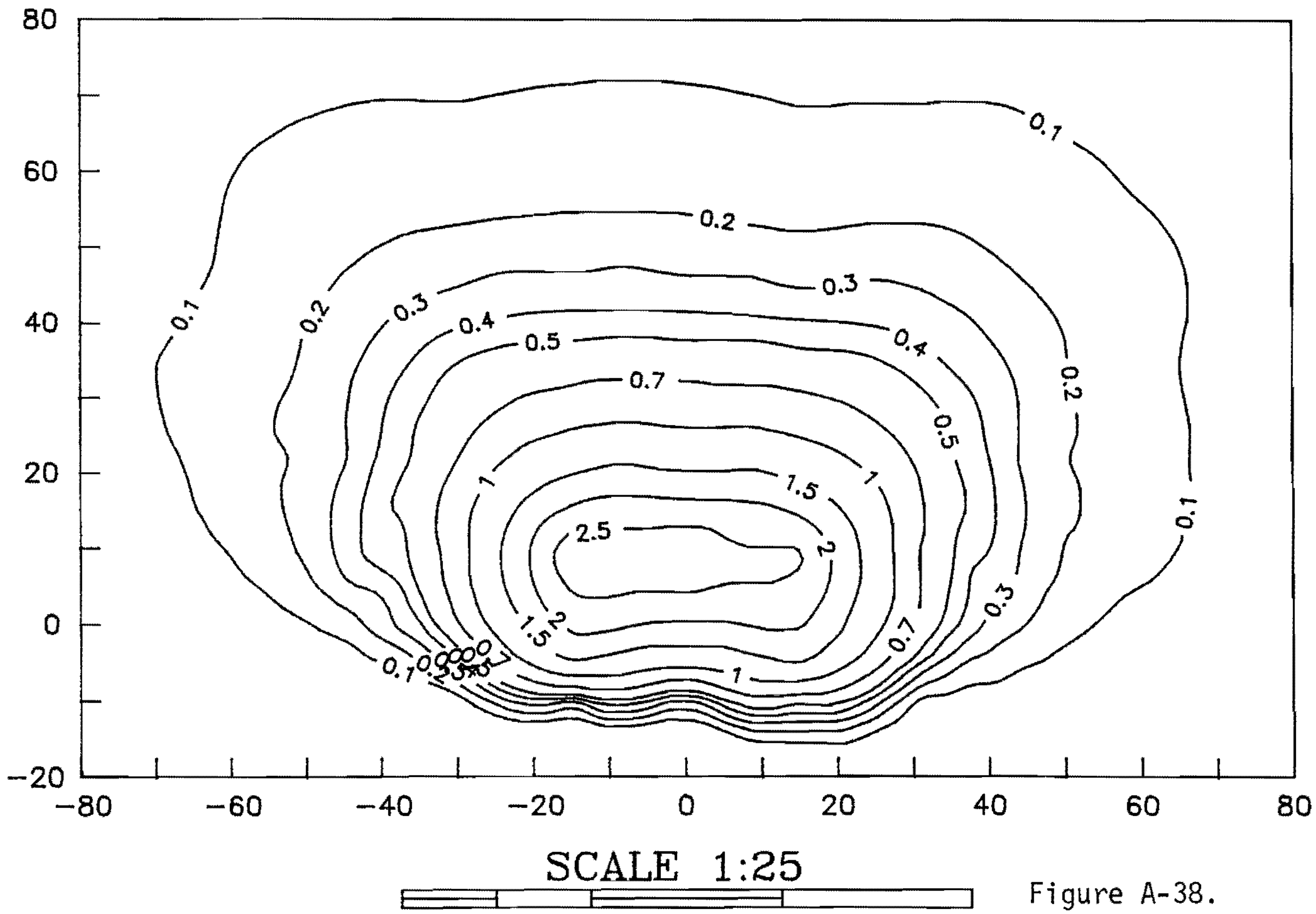


Figure A-38.

ABS 4000-55LPS-K1793B MH20' AIM 10° BH

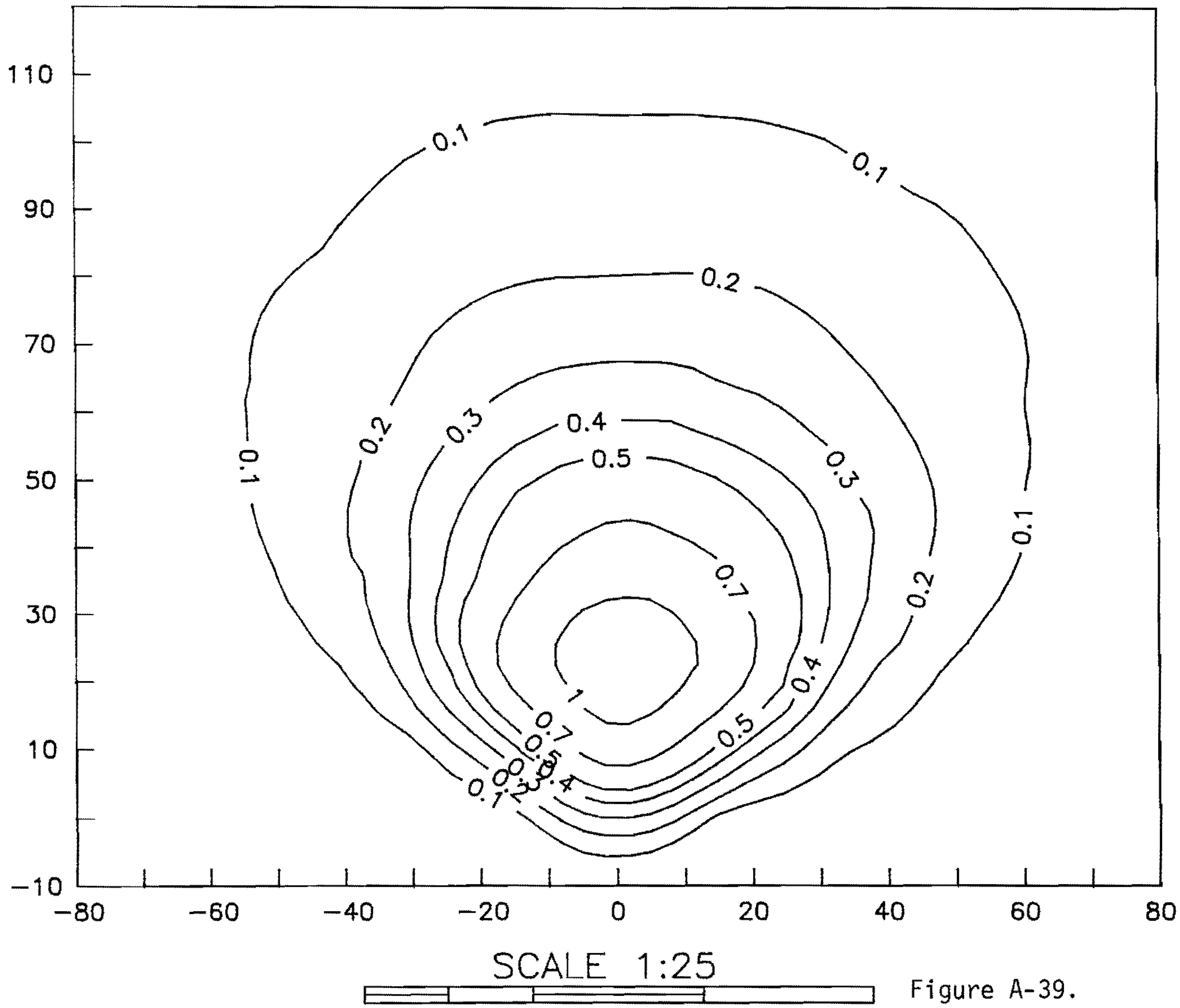


Figure A-39.

HOLOPHANE HL2A250HP48KGR M.H. 40' TILT 45

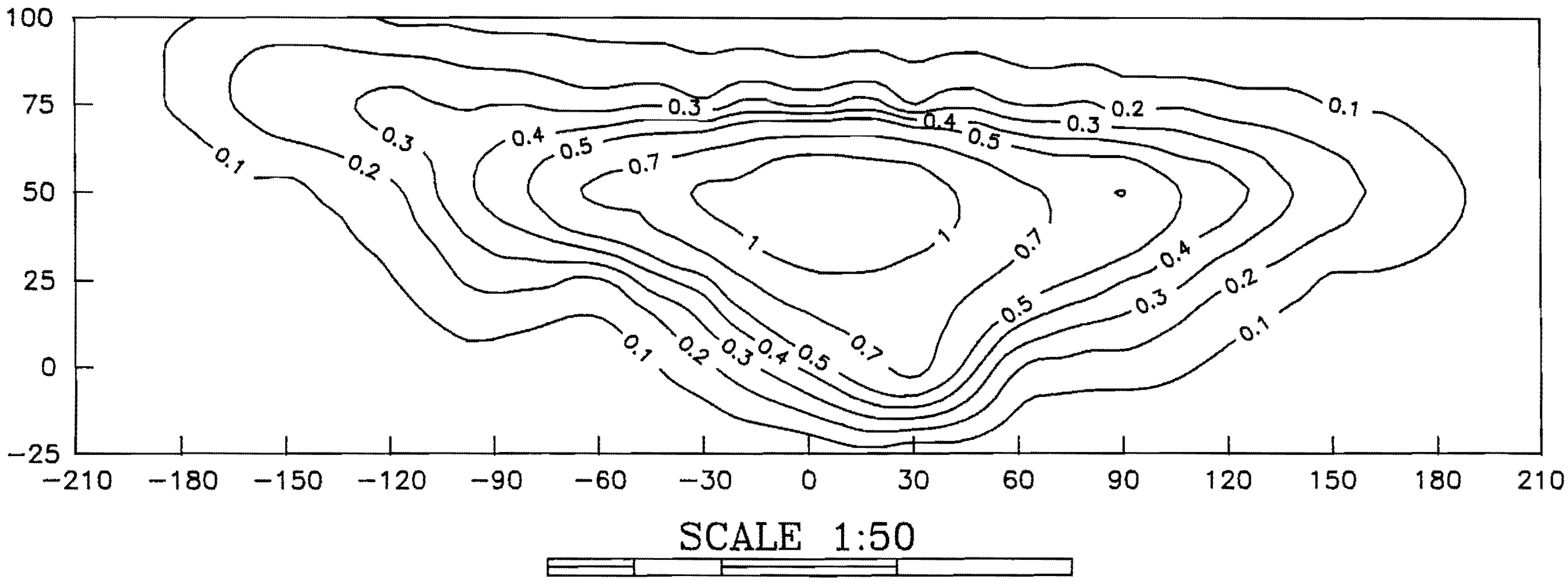


Figure A-40.

HOLOPHANE HL2A250HP48KGR M.H. 50' TILT 45

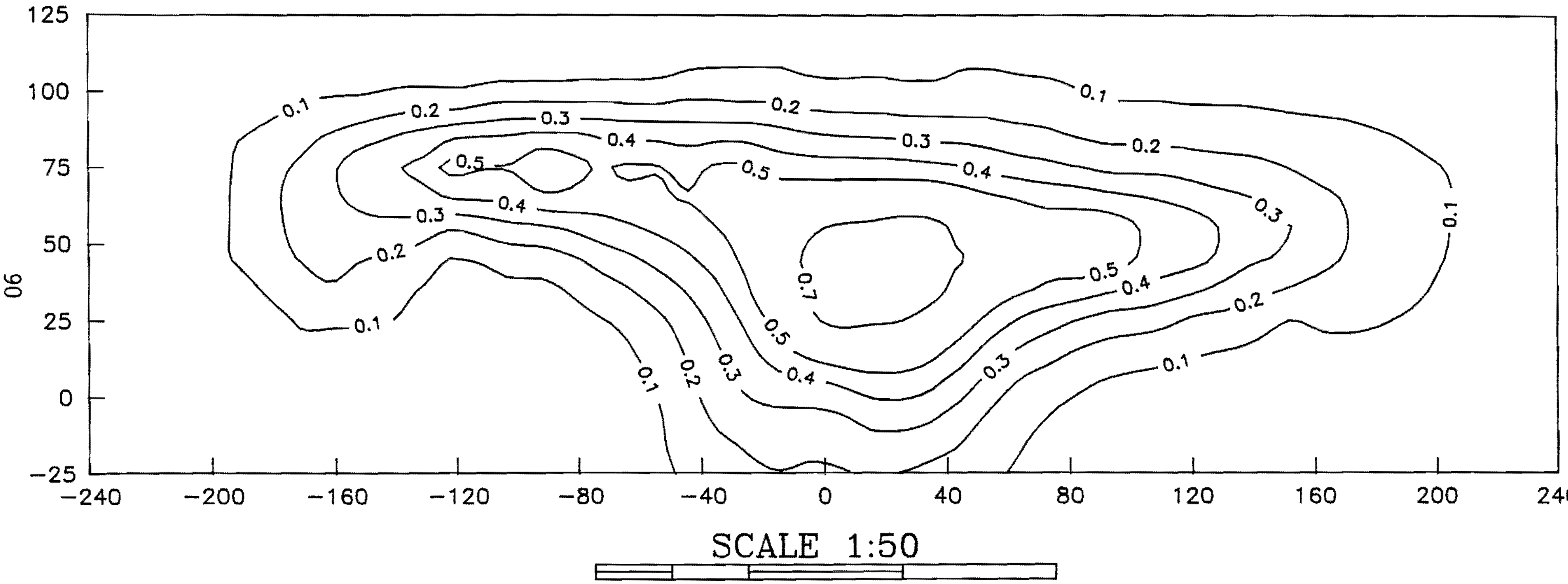
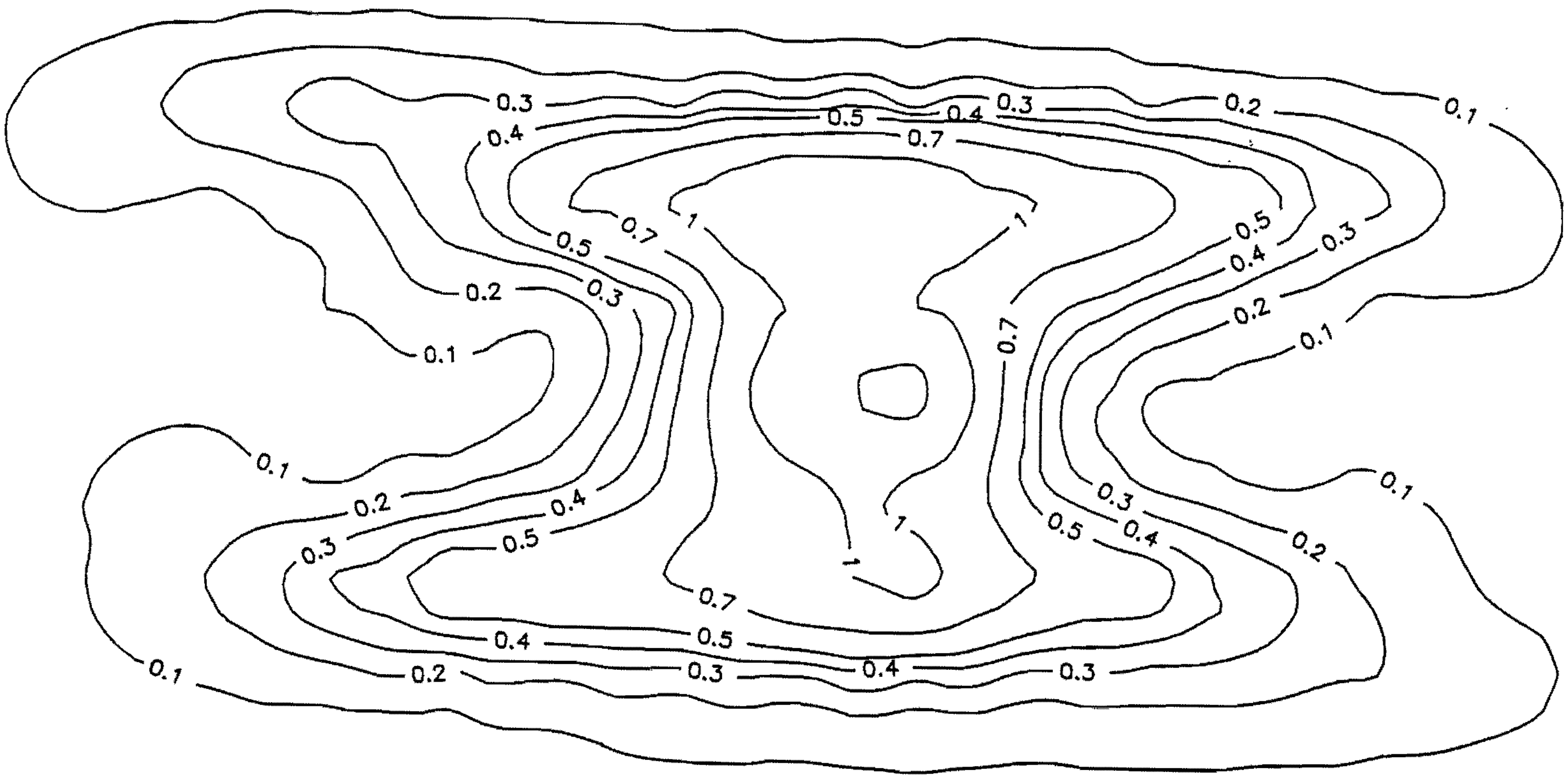


Figure A-41.

2 HOLOPHANE HL2A250HP48KGR M.H. 40′ TILT 45



SCALE 1:50

Figure A-42.

2 HOLOPHANE HL2A250HP48KGR M.H. 50′ TILT 45

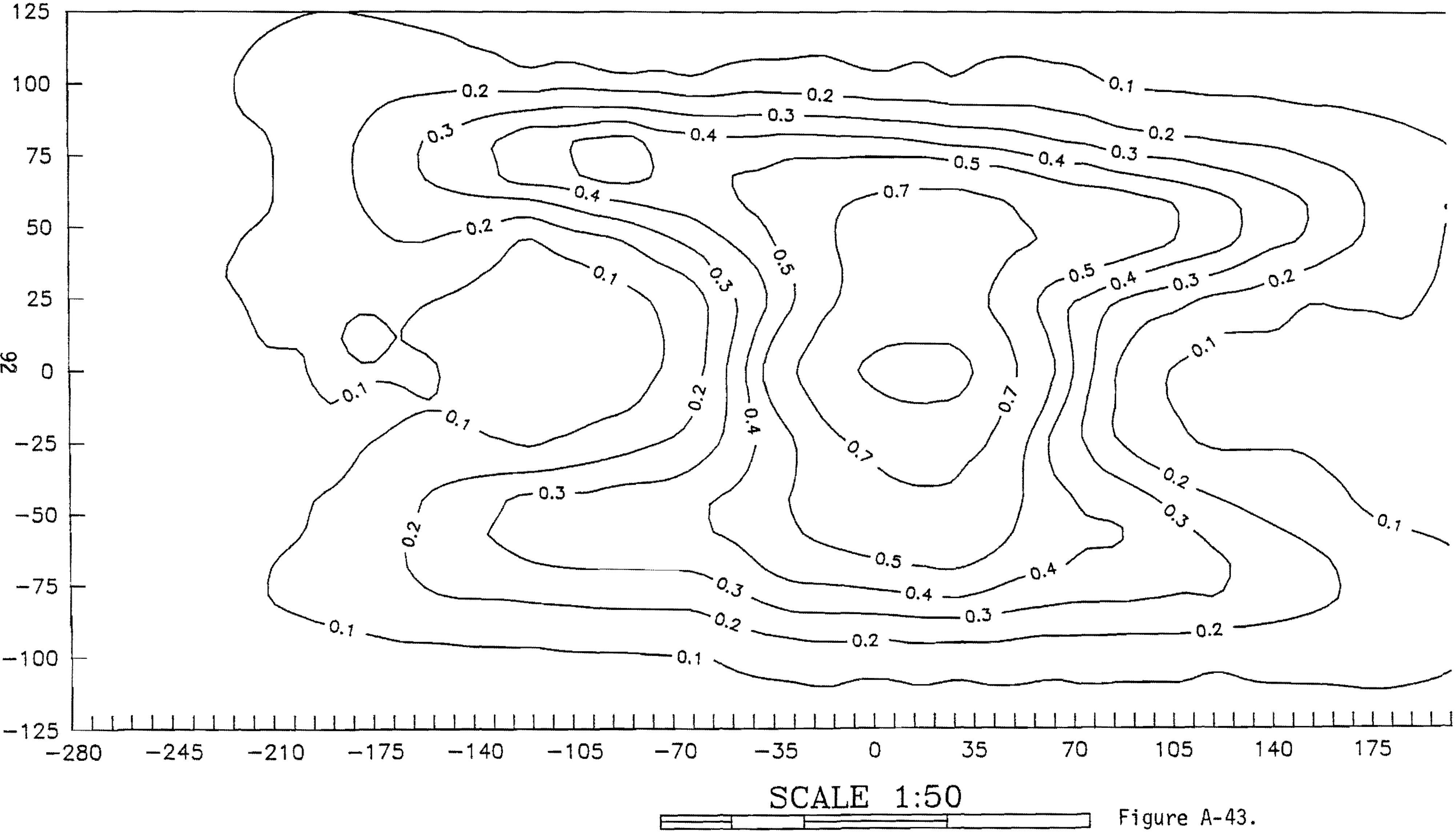
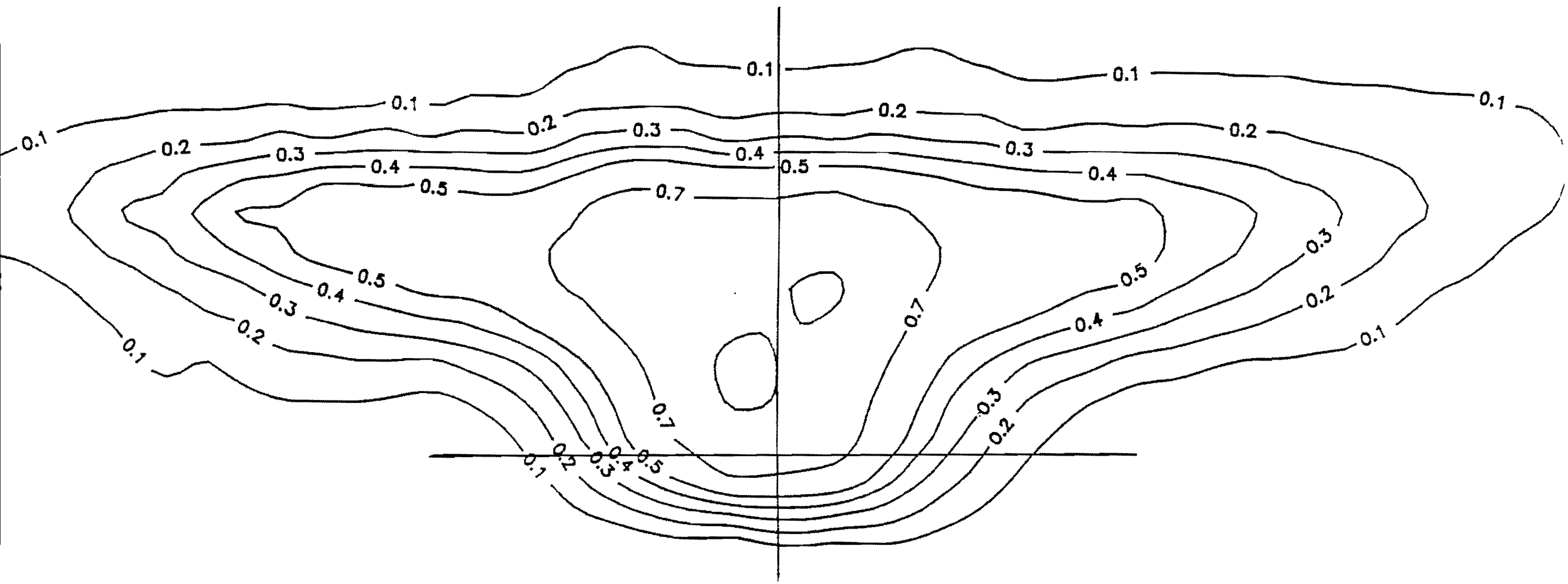


Figure A-43.

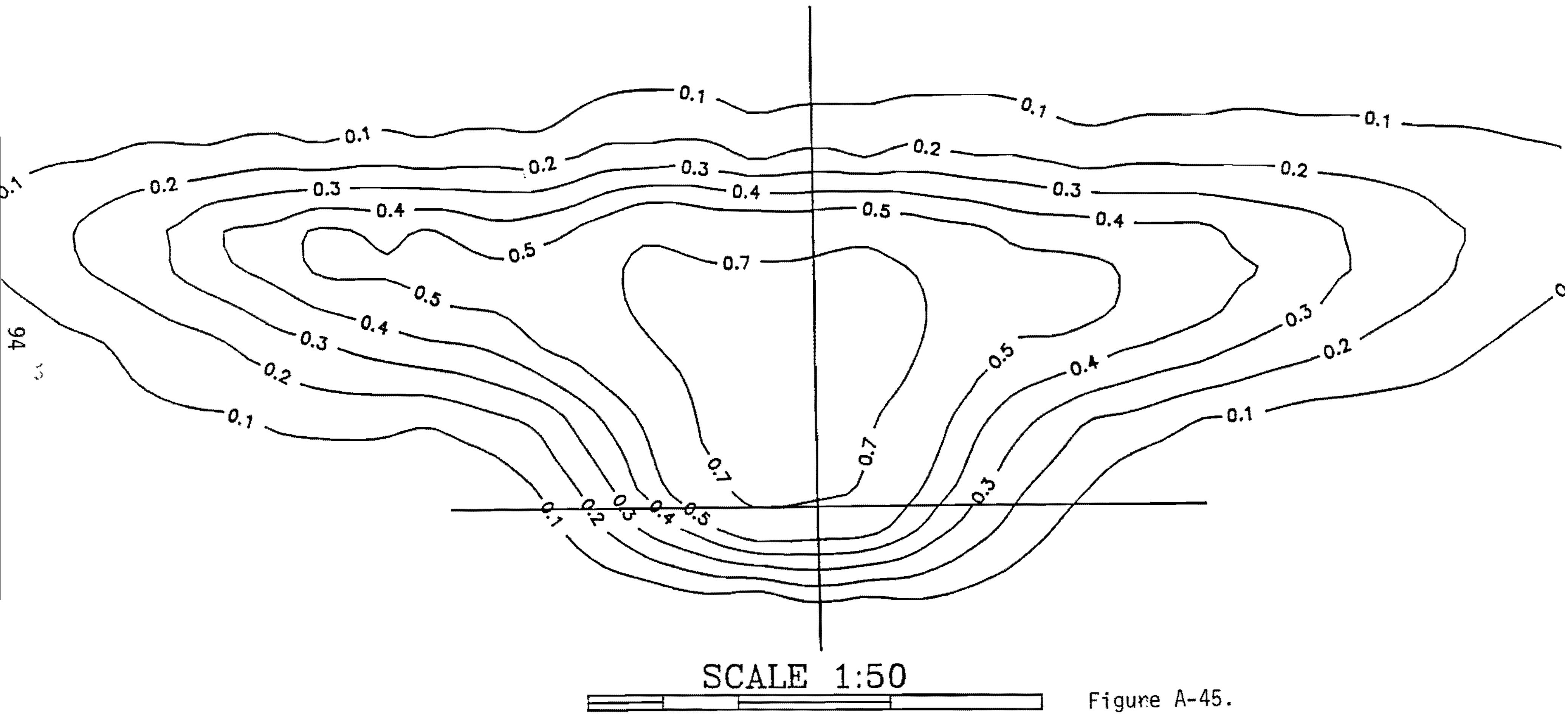
HOLOPHANE HL2A400HP48KBZ - MH 55' - TILT 45



SCALE 1:50

Figure A-44.

HOLOPHANE HL2A400HP48KBZ – MH 60' – TILT 45

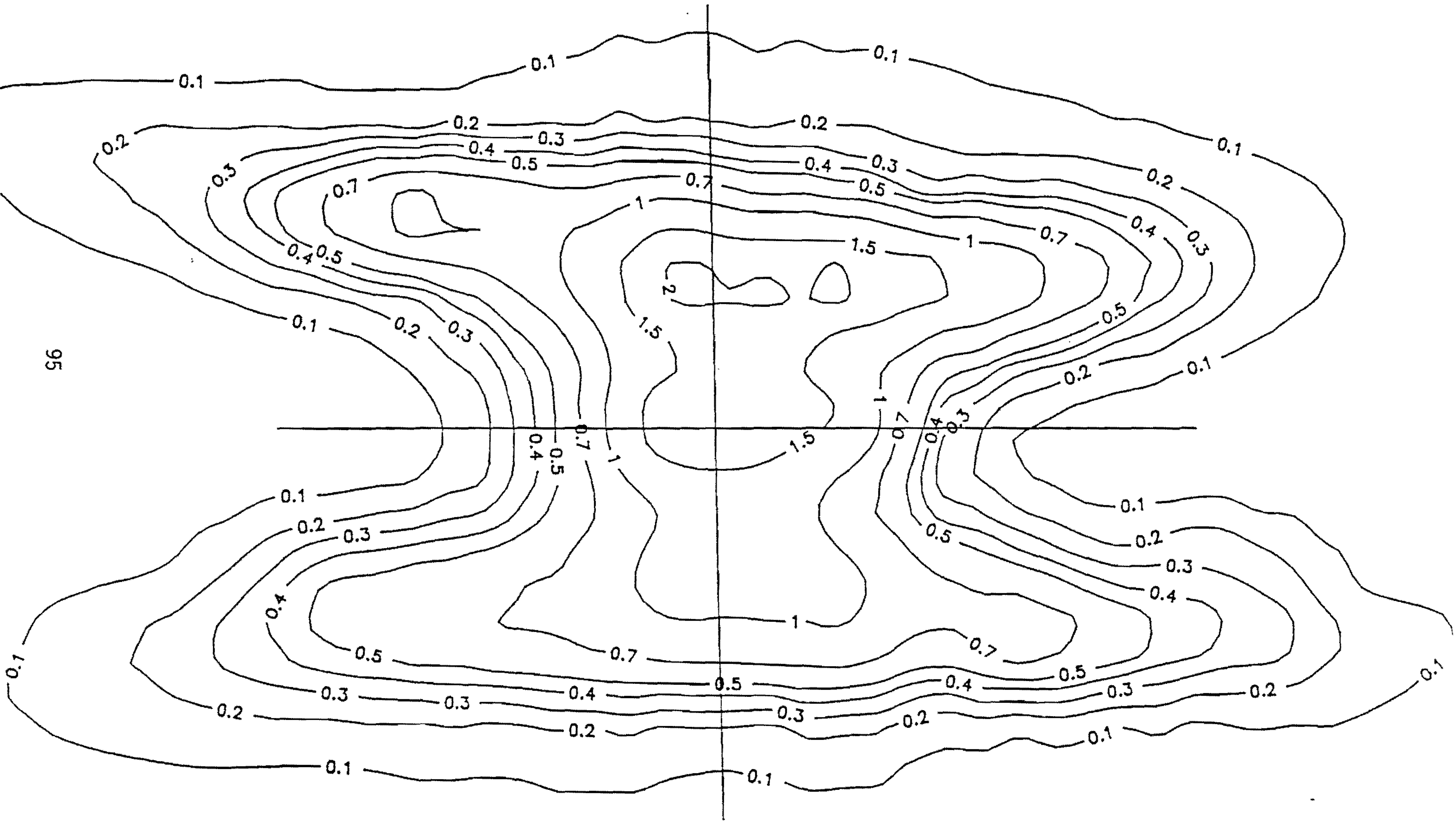


SCALE 1:50

Figure A-45.

94

2 HOLO. HL2A400HP48KBZ/MH 50'/TILT 45'/SEP. 8'



SCALE 1:50

Figure A-46.

2 HOLO. HL2A400HP48KBZ/MH 55'/TILT 45'/SEP. 8'

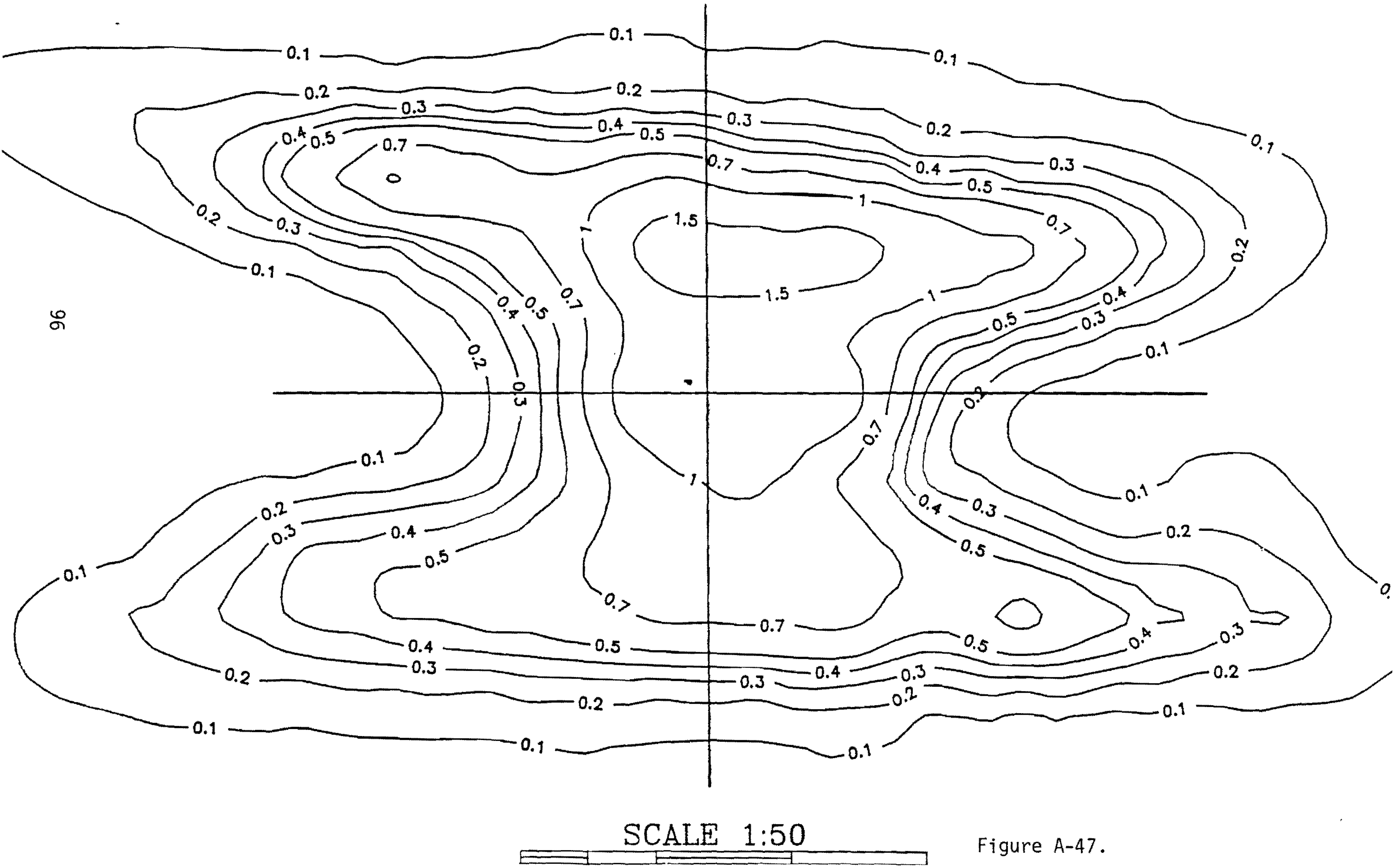
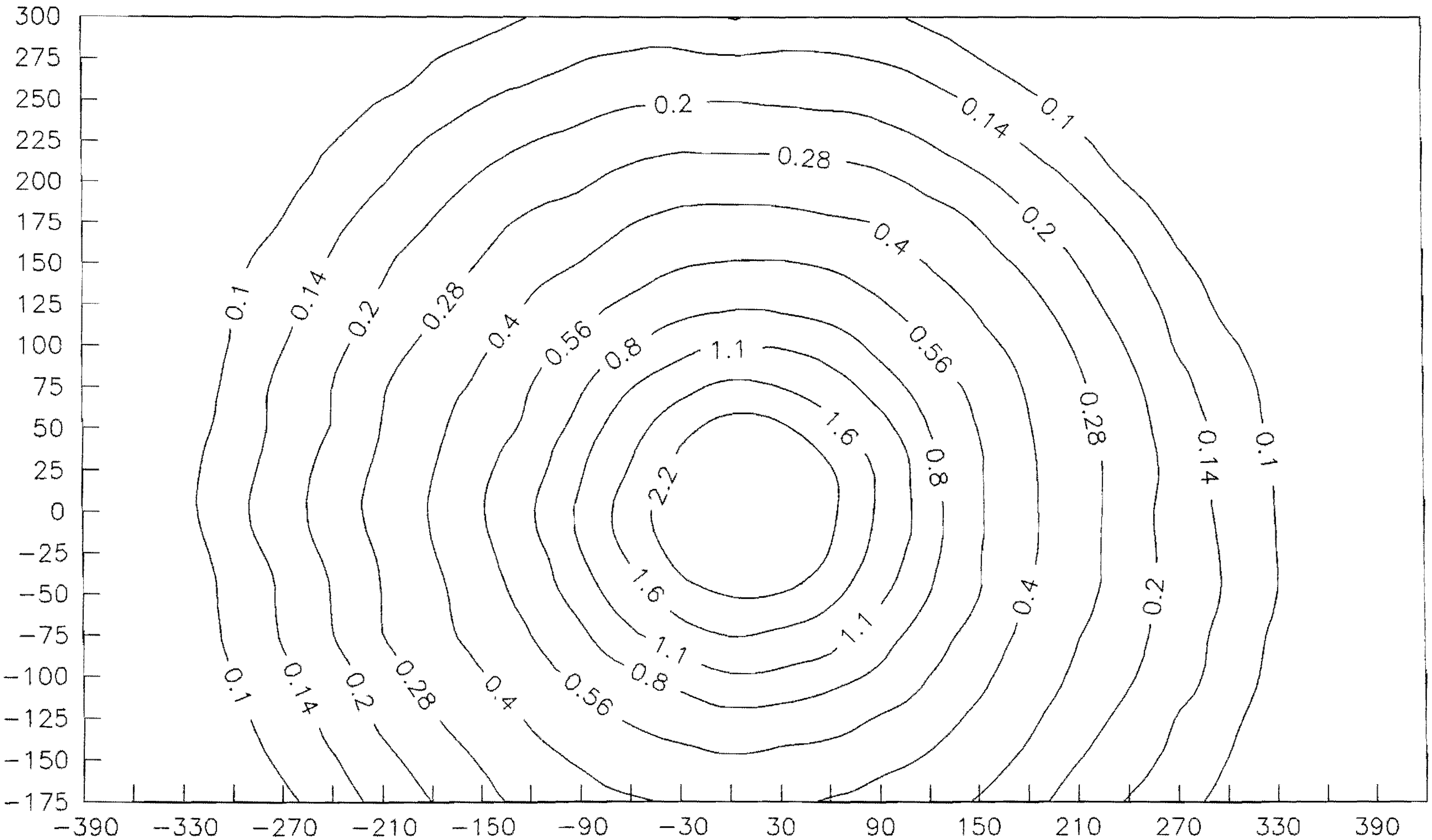


Figure A-47.

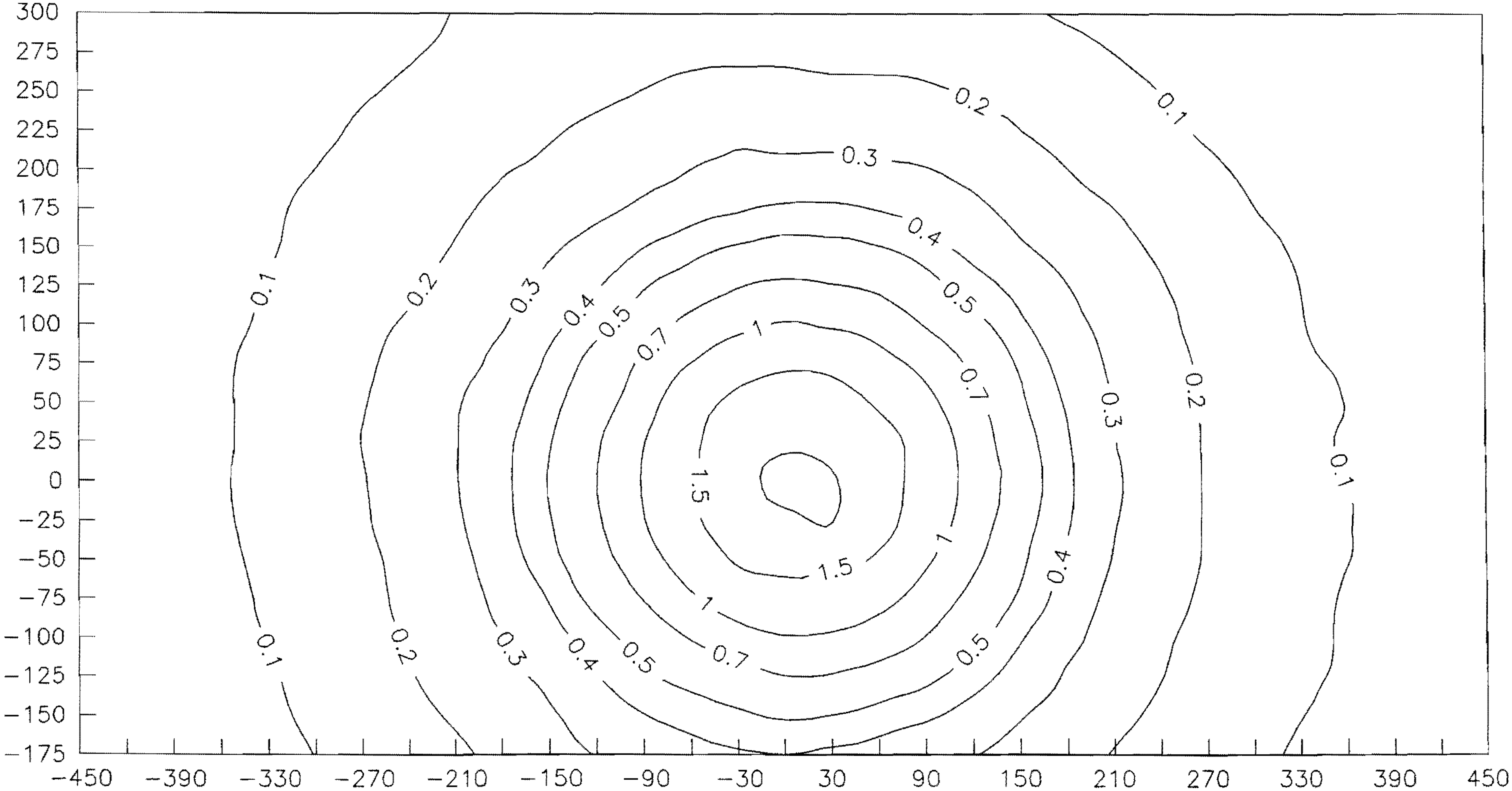
10 AMERICAN 180W LPS TILT 15 M.H. 100



SCALE 1:100

Figure A-48.

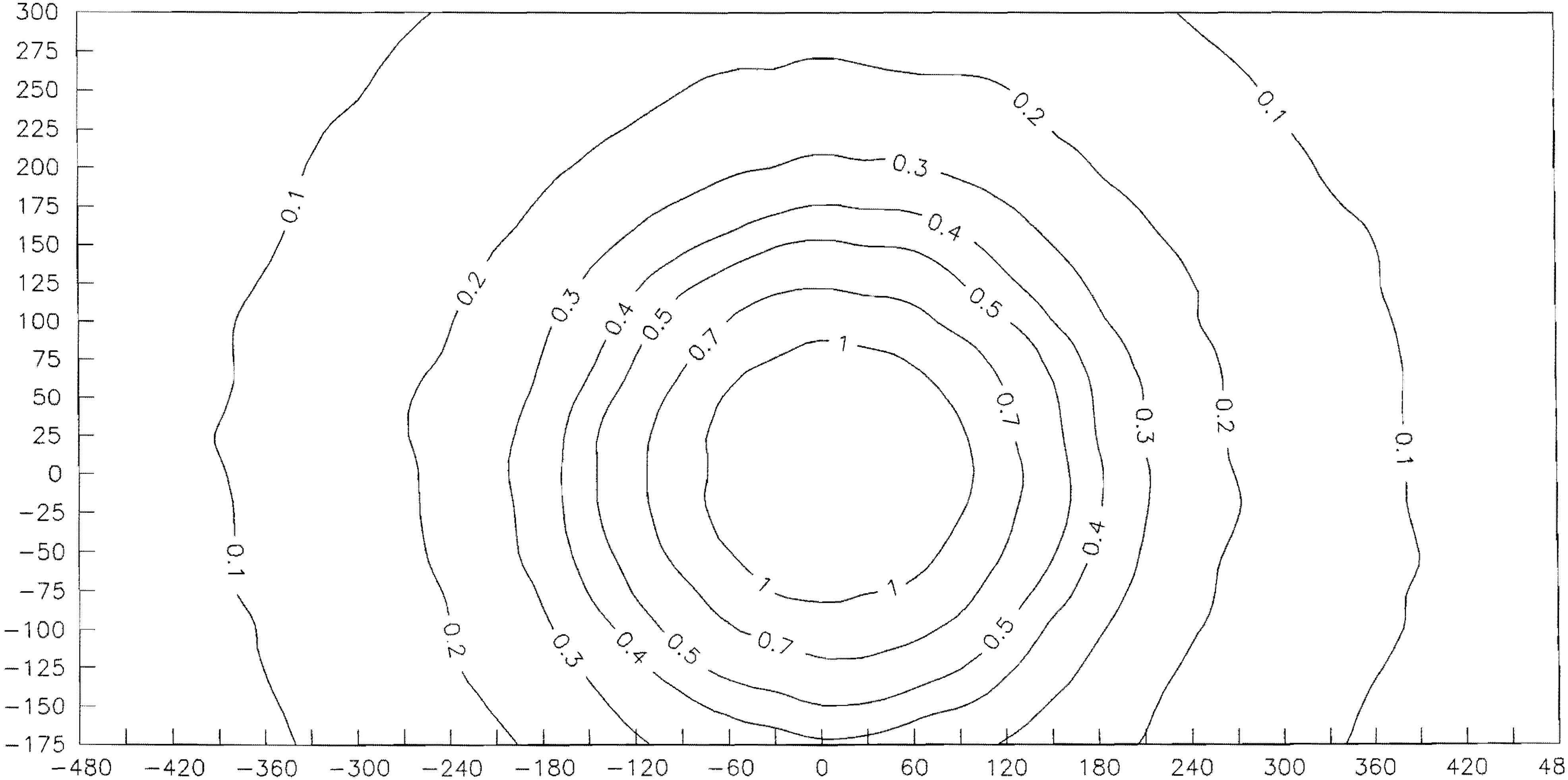
10 AMERICAN 180W LPS, TILT 15, M.H. 125



SCALE 1:100

Figure A-49.

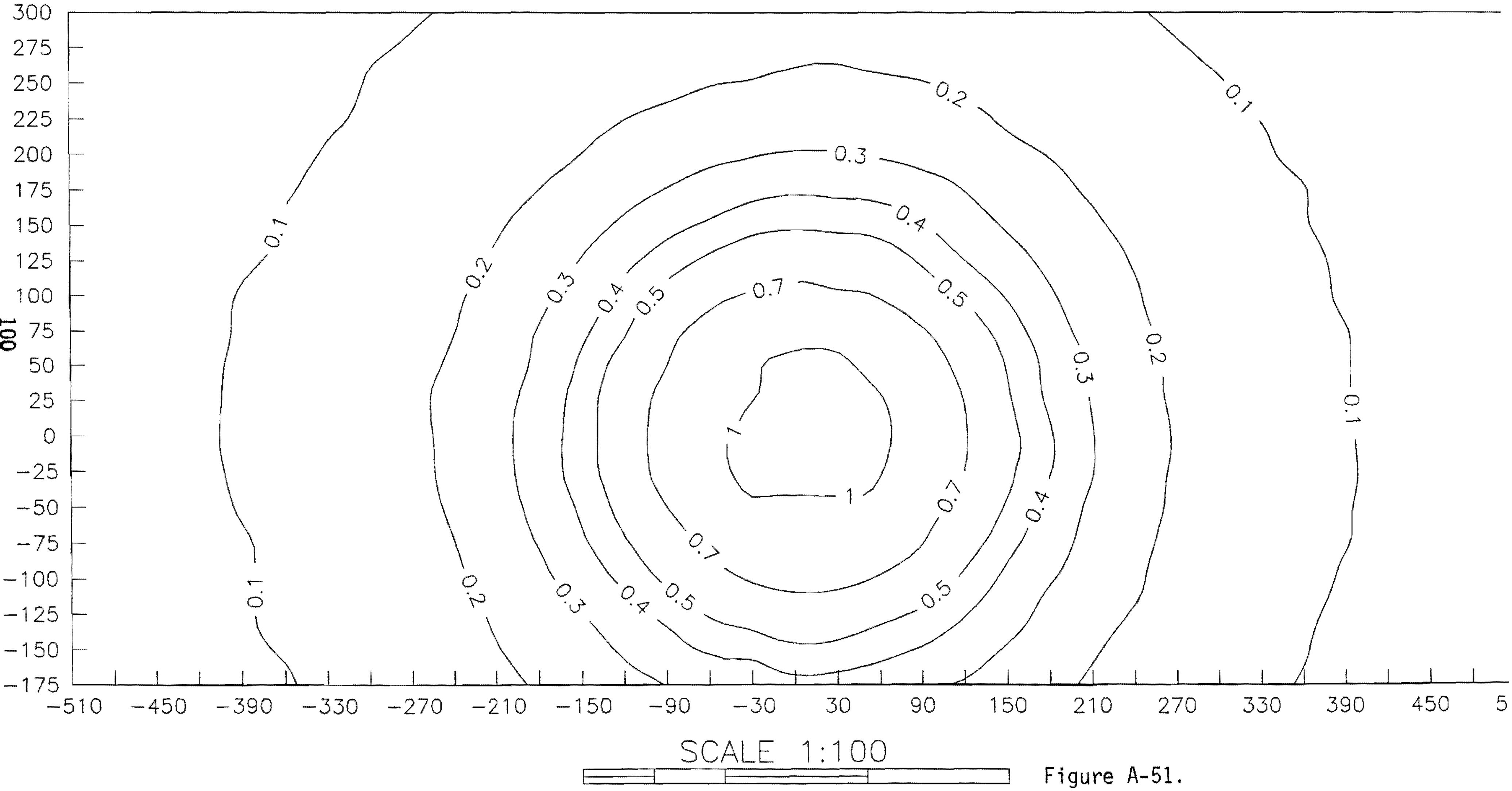
10 AMERICAN 180W LPS, TILT 15, M.H. 150



SCALE 1:100

Figure A-50.

10 AMERICAN 180W LPS, TILT 15, M.H. 175



SCALE 1:100

Figure A-51.

10 AMERICAN 180W LPS, TILT 15,

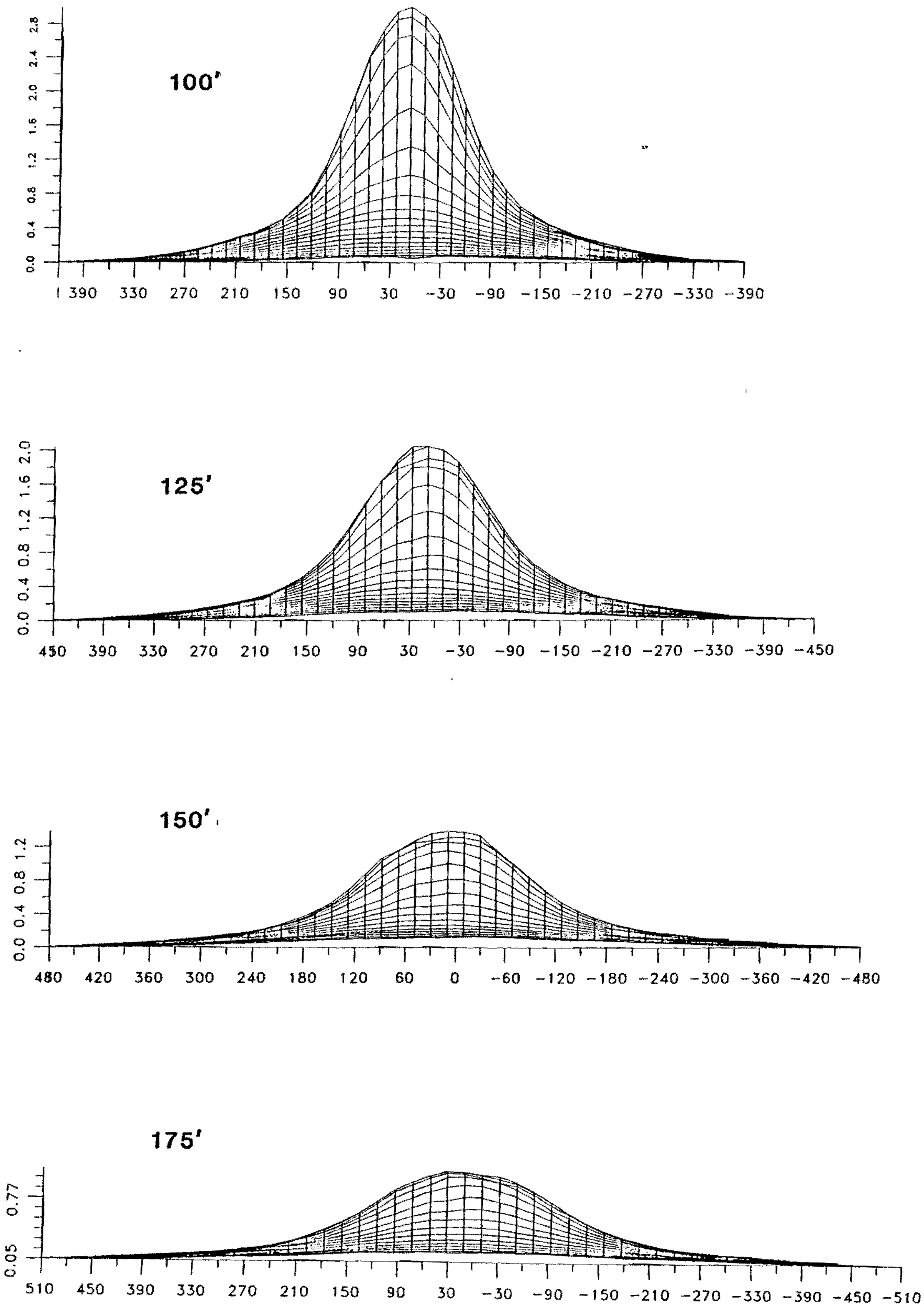
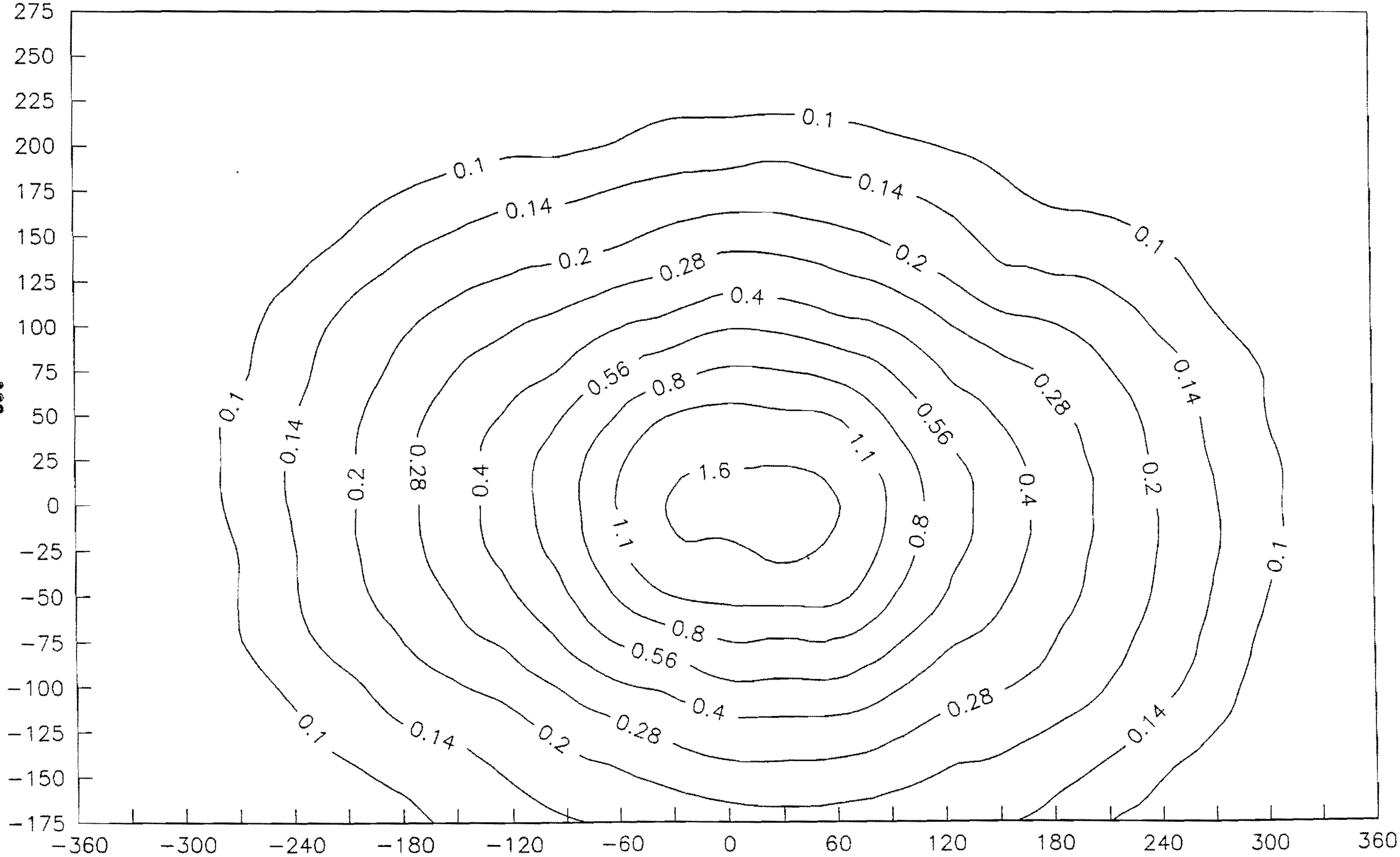


Figure A-52.

6 AMERICAN 180W LPS, ASYMMETRICAL, MH 100'



SCALE 1:80

Figure A-53.

8B AMERICAN 180W LPS, ASYM, M.H. 100

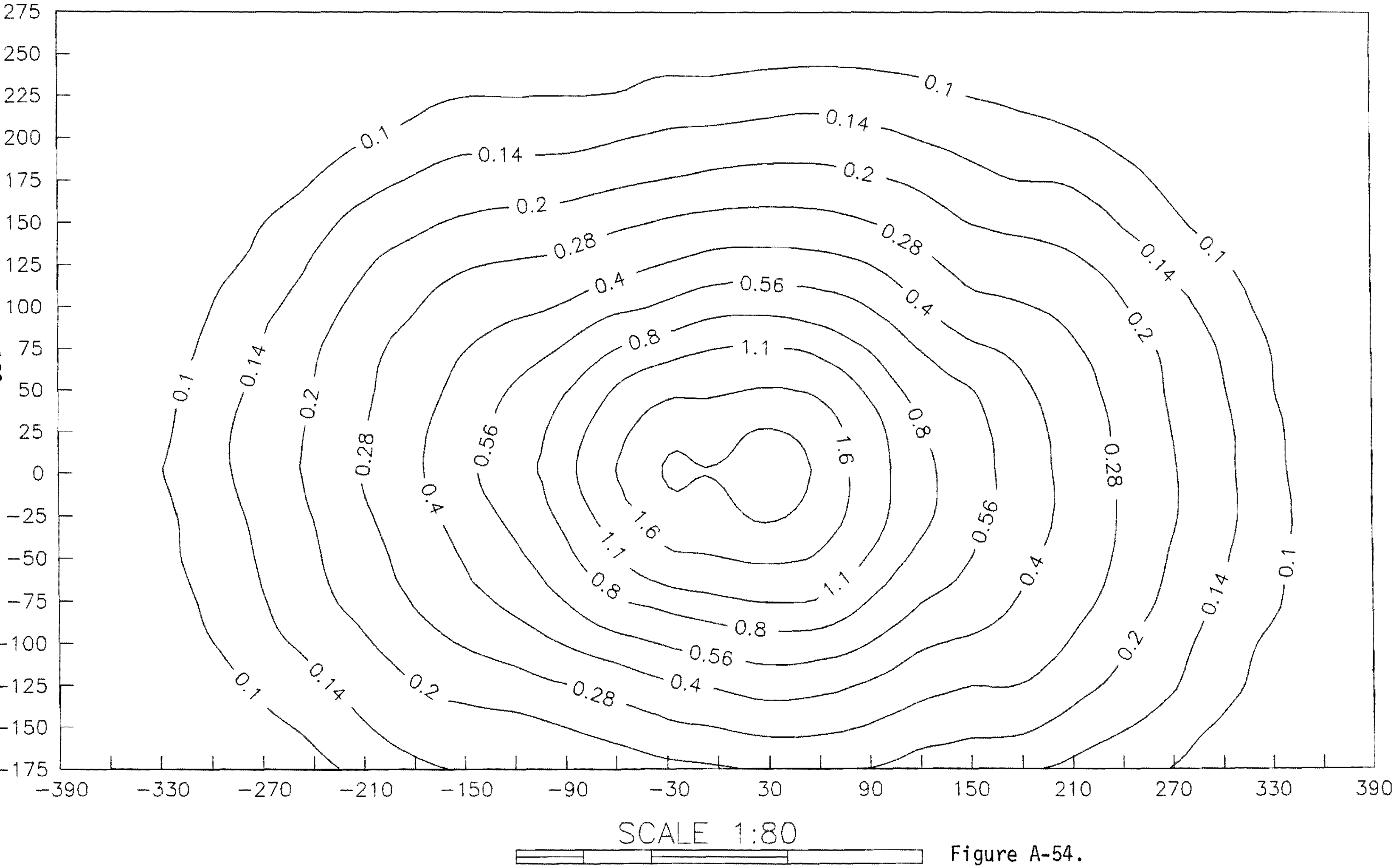


Figure A-54.

10 AMERICAN 180W LPS, ASYM, M.H. 100

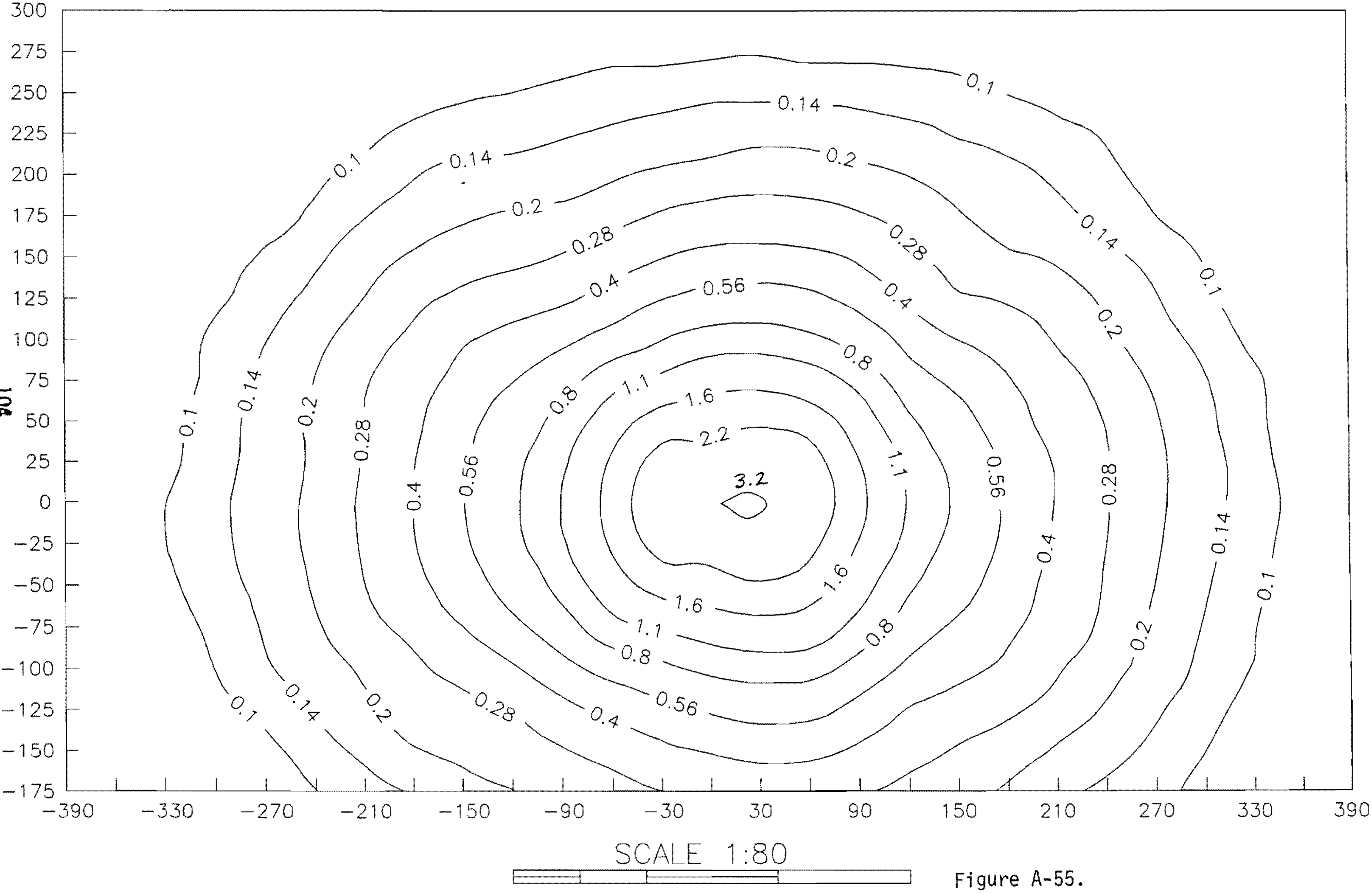


Figure A-55.

4 AMR. 180W LPS 3 TILT UP 15°, 1 ROT. 45°, MH 100'

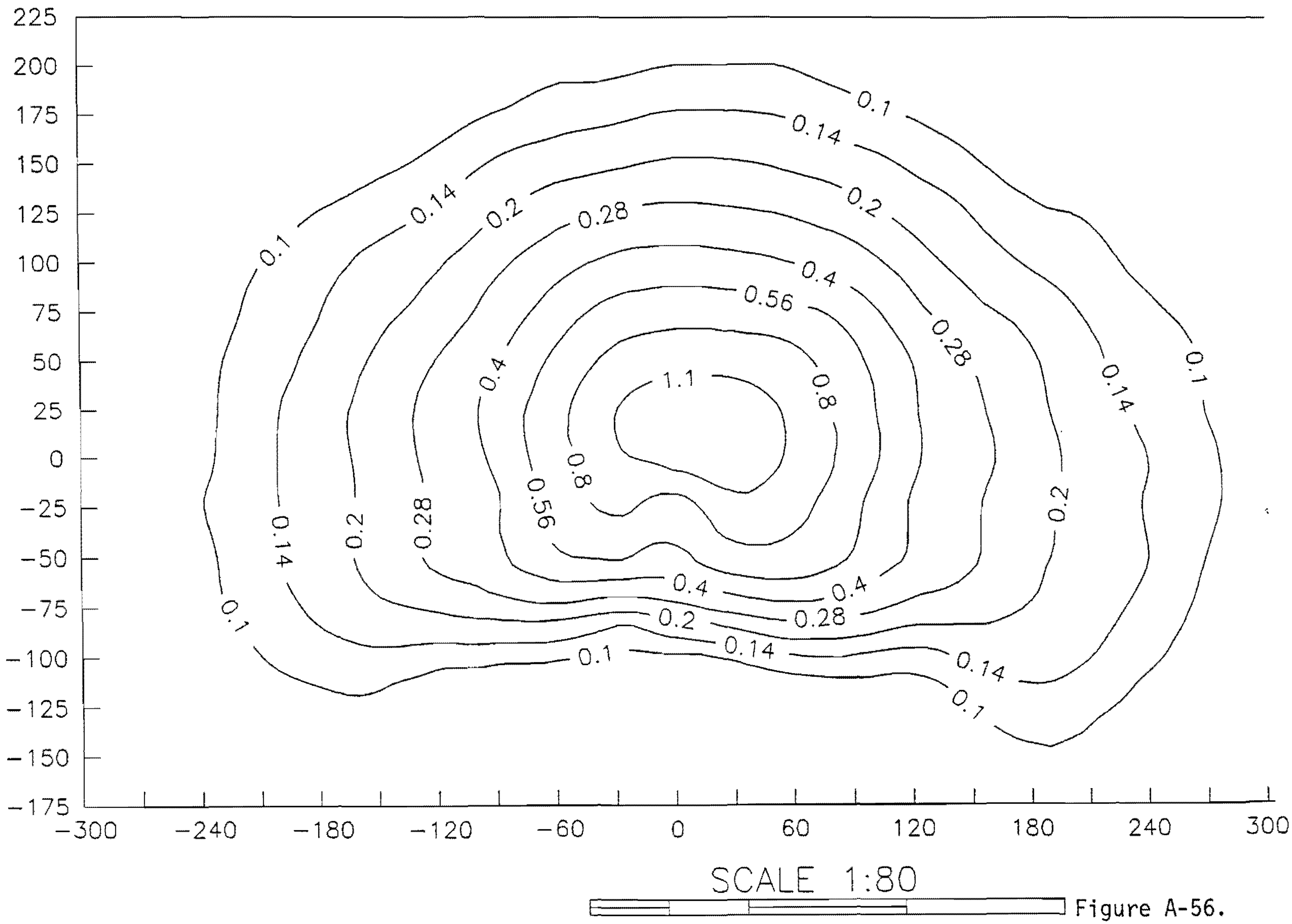


Figure A-56.