Report

MEASUREMENT OF THE LIGHT FLUX DENSITY PATTERNS FROM LUMINAIRES PROPOSED AS PHOTON SOURCES FOR PHOTOSYNTHESIS DURING SPACE TRAVEL

by

Paul N. Walker

The Pennsylvania State University
College of Agriculture
Department of Agricultural Engineering
University Park, PA 16802
(814) 865-4582

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ABSTRACT

Two luminaires were evaluated to determine the light flux density pattern on a horizontal plane surface. NASA supplied both luminaires; one was made by NASA and the other is commercially available. Tests were made for three combinations of luminaire height and luminaire lens material using the NASA luminaire; only one configuration of the commercial luminaire was tested. Measurements were made using four sensors with different wavelength range capabilities. The data are presented in graphical, tabular, and magnetic disk formats.

RESEARCH FACILITIES

The Luminaire Evaluation Chamber (LECH) in the Agricultural Engineering Building at Penn State University was used to collect data. The chamber contains a stand to mount the luminaire at the desired height and to rotate the luminaire about a vertical axis. A linear track on the floor of the chamber is used to position the light sensor at desired radial distances from the axis of rotation of the luminaire. The rotation of the luminaire and the movement of the sensor are effected by stepping motors controlled by a microcomputer. The microcomputer simultaneously collects data from the light sensor and records the data on a magnetic disk. The luminaire stand and sensor track are enclosed in a structure 7.7 x 2.5 x 5.0 m high, constructed with waferboard interior surfaces, including the floor, which have been coated with flat black latex paint.

The sensor track runs the long direction of the structure and the luminaire stand is located at one end. The chamber also contains an analog-to-digital device for conditioning signals to and from the computer, two stepping motor controllers, a sensor signal amplifier, a voltage regulator to control voltage to the luminaire, two box fans to circulate the air, and a thermocouple air temperature recorder. A black cotton curtain was used to shield the sensor from any light produced by the computer or instrumentation. The layout of the structure is shown in Figure 1. The chamber is illuminated with four 40-W fluorescent tubes mounted to the ceiling. These lamps were off during data collection.

SCOPE OF TESTS

A NASA designed luminaire and a commercially available lumimaire, both provided by NASA, were evaluated in the Luminaire Evaluation Chamber. The NASA lumimaire was evaluated with a glass lens and also with a plastic (polymethylmethacrylate; Plexiglass) lens. The commercial luminaire had no lens. (The term lens is used here to mean a transparent bottom cover.) All tests were done at a luminaire mounting height of 0.5 m above the sensors, except for the NASA luminaire with the glass lens which was also tested at a height of 1.0 m. Considering each combination of luminaire, lens material, and height as a "luminaire configuration", a total of four luminaire configurations were tested.

For each luminaire configuration, light measurements were made with four sensors. 1) a Li-Cor LI-190SB (Model: QUANTUM, S/N: Q6724, Calibration date: 89 Aug 11) which measures photosynthetic photon flux density integrated over the 400-700 nm wavelength range. 2) an Eppley Precision Spectral Pyranometer (Model: PSP, S/N: 26456F3, Calibration date: 89 Sept 18) with a Schott RG805 glass hemisphere which measures energy flux density integrated over the 800-3000 nm range. A 3 mm long scratch was noted near the top of the glass hemisphere of this sensor. 3) an Eppley Precision Infrared Radiometer (Model: PIR, S/N: 26407F3, Calibration date: 89 Sept 12) which measures energy flux density integrated over the 3,000-50,000 nm range. And 4) a Li-Cor Portable Spectroradiometer (Model: LI-1800, S/N: PRS-159, Calibration date: 89 Jan) which measures energy flux density over 2 nm wavelength increments in the 300-850 nm range. These four sensors will be referred to as the Quantum, PSP, PIR, and PRS sensors, respectively.

SENSOR MEASUREMENT GRID

Measurements for all sensors were made within what represents a 2.5 m radius circle on a horizontal plane beneath the luminaire. Measurement locations were reached by moving the sensor incrementally along the sensor track and sequentially rotating the luminaire. The Quantum, PSP, and PIR sensors were mounted to a computer-controlled cart and measurement locations made a polar grid with radial increments of 0.05 m and angular increments of 3.6 degrees. The PRS sensor was too heavy to be moved by the cart and was, therefore, moved by hand. PRS measurements were made at radial increments of 0.5 m and angular increments of 45 degrees.

The center of the polar grid was directly beneath the center of rotation of the luminaire. The center of rotation for the NASA luminaire was along the axis of symmetry, 597 mm from the surface behind the air filter. This location was experimentally chosen so the axis of rotation would pass through the approximate center of gravity of the luminaire. Thus, the forces on the luminaire stand, and therefore stand deflection, remained constant at all angles of rotation.

The NASA luminaire was mounted onto the stand which was then adjusted so its axis of rotation was vertical; next, the luminaire mounting was adjusted so the luminaire opening was horizontal. A 0.5 m long level laid on top of the glass lens was used to observe that the opening remained horizontal at all angles of rotation. The lamp ballasts and related equipment were mounted remote from the luminaire.

The same mounting procedure was used for the commercial luminaire except the axis of rotation was chosen to pass through the center of the luminaire opening and the luminaire was adjusted to horizontal by holding the level across the bottom of the fixture. Also, the ballast was left attached to the luminaire.

The zero angle for the polar grid is along a line parallel to the nominal lamp axis, with a ray extending from the base to the tip of the lamp being in a positive direction. The positive angular direction is counterclockwise when viewed from the top. This means, for example, that the luminaire was rotated clockwise 3.6 degrees in order to take the readings along the +3.6 degree ray. The order in which measurements were taken using the computer controlled cart was determined by the program COLLECT.BAS. (Appendix B contains all user-generated programs.) The order is illustrated in Figure 2. This measuring scheme gave redundant measurements at the origin and points along the first ray which was both the zero and 360 degree ray. Multiple readings at a single point may be compared to determine the stability of the measurements.

The order of measurements with the PRS sensor did not follow a rigid pattern except one radius was chosen, then measurements were made at all angles for that radius before another radius was selected. At the first selected radius the order of data collection was from zero to 360 degrees; at the second selected radius the order was 360 to zero; etc. The luminaire was rotated using the computer programs CCW45.BAS and CW45.BAS, respectively, for each radius. The data files for the PRS sensor contain the time of day so the exact order of data collection can be reconstructed.

DATA COLLECTION PROCEDURE

For all tests the luminaire was allowed to stabilize for a minimum of two hours after turning it on. Likewise, the amplifier was allowed to warm-up for a minimum of two hours before using it. The computer-controlled cart was moved to a radial position of about 1.25 meters. Before each test the appropriate Quantum, PSP, or PIR sensor was attached to the cart and leveled. (The Quantum sensor had no leveling bubble and, therefore, was not precisely leveled.)

The analog to digital conversion software was initiated and then the program COLLECT.BAS was run with the stepping motors switched off. The sensor signal cable was disconnected at the sensor, a 100 ohm resistor was installed across the two signal conductors, and the amplifier was adjusted so the readings taken by the COLLECT.BAS program (and displayed on the computer screen) were approximately zero. The computer program was then stopped.

The cable was reconnected to the sensor, the cart was manually moved to its zero position, the luminaire was manually moved to its zero angle position, the stepping motors were switched on, the temperature recorder was started to collect air temperature every 15 minutes. COLLECT.BAS was restarted to begin data collection; the program allowed a 20 second delay before the first reading and in that time the operator left the chamber.

DATA ON MAGNETIC DISKS

The data is contained on 14 floppy disks (5-1/4, ASCII, MS-DOS). A fifteenth disk contains computer programs used in this study. Two of the fourteen disks contain data from the PRS sensor and are labeled PRS1 and PRS2. The files on these two disks are described in the DATA IN TABULAR FORMAT section. The other twelve disks contain data from the Quantum, PSP, and PIR sensors. They are labeled with an seven character string beginning with the letters Q, S, or I to indicate which sensor. The second and third characters in the string indicate the height of the luminaire above the sensor: 05 is 0.5 m and 10 is 1.0 m. The fourth character represents the luminaire configuration: NASA luminaire with Glass lens, NASA luminaire with Plastic lens, or Commercial luminaire. The fifth, sixth, and seventh characters represent the month and day the data were collected: N28 is November 28.

Each of the twelve disks contain three data files labeled with an eight character file name with a three character extension. The first seven characters in the file name are as described immediately above. The eighth character is 0 if the file contains sensor readings from the COLLECT.BAS program. The eighth character is C if the sensor reading has been Changed or modified using the program LUMCHG.FOR as described below. The extension .RAW indicates the file was produced by the program COLLECT.BAS while the extension .DAT indicates it was produced by the program LUMDAT.FOR. The extension .GRD indicates the file was produced by the Golden Software Inc. Surfer software program GRID.EXE.

The file on each disk with the extension .RAW contains the data as taken from the Luminaire Evaluation Chamber. Each line of data contains two numbers. The first is the order number of the sensor reading (see Figure 2) and the second is the sensor reading, converted to the appropriate units. The program COLLECT.BAS converts the millivolt output of the sensor to $\mu mol/m^2s$ for the Quantum sensor and W/m^2 for the PSP and PIR sensors.

The file on each disk with the extension .DAT contains data from the .RAW file on the same disk, but which has been modified using programs LUMCHG.FOR and LUMDAT.FOR. LUMCHG.FOR looks at the data from each ray in the polar grid and subtracts the sensor reading at the 2.5 m radius from all the other readings along that ray. The purpose was primarily to differentiate between the effects of the luminaire and the chamber for the PIR data. The secondary reason was to minimize the effect of signal drift in the instrumentation, and for that reason the program was used on the Quantum and PSP data as well. LUMCHG.FOR outputs to an intermediate file which LUMDAT.FOR reads. LUMDAT.FOR assigns cartesian coordinates to the data based on their order in the file and outputs to a .DAT file. Each line of a .DAT file contains an X-coordinate, Y-coordinate, and the sensor reading. The coordinates have units of meters and the sensor reading has the same units as before.

Golden Software Inc. SURFER software program GRID.EXE takes the data from the polar grid (albeit with cartesian coordinates) and interplates and extrapolates the data to produce data in a uniform cartesian coordinates grid. The new grid extends from -2.5 to 2.5 meters in both directions with nodes every 0.05 m for a total grid size of 101 x 101 nodes. GRID.EXE contains many options for data conversion and the options used in this study are specified by the file GRIDNASA.CMD. GRID.EXE outputs the new grid to a .GRD file. The ten lines of information at the top of the .GRD file are plotting information for the other SURFER programs SURF.EXE and TOPO.EXE. The remaining lines are the interpolated data arranged serially for node locations in the grid read left to right, line by line, starting at the node (-50,-50) which is equivalent to location (-2.5 m -2.5 m).

DATA IN TABULAR FORMAT

The data for each of the four luminaire configurations are together in a separate volume. Each volume contains the data for all four sensors. The first three sections of each volume contain the data from the Quantum, PSP, and PIR sensors and the data in these three sections are arranged in the same format. On the title page of each section is the chamber air temperature range during data collection. The first two columns of data in each section give the position of the sensor reading in polar coordinates, and the second two columns are the cartesian equivalents of those coordinates. The last column is the sensor reading. These tables were printed using the program LUMPRI.FOR operating on files produced by the program COLLECT.BAS (i.e., they were not modified using the program LUMCHG.FOR).

The fourth section contains data from the PRS1 and/or PRS2 floppy disks, collected with the PRS sensor. This section contains 54 two-page files, one for each sensor position. The sensor position is coded into the three character file name. The first character indicates the luminaire configuration; NASA luminaire with Glass lens at 0.5 m height, NASA luminaire with Glass lens at 1.0 m Height, NASA luminaire with plastic (PolyMethylmethacrylate) lens, and Conventional luminaire. The second character in the file name is a number which represents the radius in the polar grid. This number multiplied by 0.5 gives the radius in meters. The third character is a number which represents the angle in the polar grid. This number multiplied by 45 gives the angle in degrees.

The first seven lines of each file gives summary information which is self explanatory. The remaining lines are a serial listing of the data with the wavelength followed by the sensor reading at that wavelength. Wavelength units are nm and sensor reading units are micromoles per square meter second. These files began as files created by the PRS instrument. The PRS files were transformed to quantum units using the Li-Cor software program LI1800 following the FILE OPERATIONS, VIEW, and QUANTUM TRANSFORM options and suboptions. The file thus created was printed using the LIPRI.FOR program.

DATA IN GRAPHICAL FORMAT

Data from the Quantum, PSP, and PIR sensors for each of the four luminaire configurations are presented graphically in Appendix A. Two types of graphs were drawn for each data set: orthographic and contour. Both types of graphs were created using the Golden Software Inc. SURFER programs operating on files with .GRD extensions. The origin of the .GRD files is described in the section DATA ON MAGNETIC DISKS. The orthographic graphs were produced using the program SURF.EXE in conjunction with the command file SURFNASA.CMD, while the contour graphs were produced using the program TOPO.EXE in conjunction with the command file TOPONASA.CMD. and the file NASA3.LVL.

COMPUTER PROGRAMS

Numerous "user-generated" computer programs were written or modified specifically for this study and copies are provided herein. Several commercial programs were also used as noted throughout this report, but copies of these programs are not listed here. The user-generated programs are provided both on a magnetic disk labeled "Computer Programs" and as hard copy listings in Appendix B. These programs can be categorized as one of three types: GWBASIC, WATFOR77 FORTRAN, and Golden Software.

The GWBASIC programs are those used to operate the Luminaire Evaluation Chamber. These programs are COLLECT.BAS, CCW45.BAS, and CW45.BAS. COLLECT.BAS was modified during the study. When used for the NASA luminaire, all sensor readings less than zero were set to zero. Later, when used for the commercial luminaire, negative values were allowed to remain. The effects of this change are believed to be insignificant.

GRIDNASA.CMD, SURFNASA.CMD, AND TOPONASA.CMD are not true programs; they are command files specifying some of the options selected within the Golden Software Inc. SURFER programs. These files were generated by and may be used by the appropriate SURFER programs. NASA3.LVL specifies which contour lines will be graphed when using TOPONASA.CMD and SET21.SYM is the symbol set used to label the graphs in Appendix A. It contains the micron and other special symbols. Unlike the other files, SET21.SYM is provided only on magnetic disk.

Programs written in WATFOR77 FORTRAN were used to manipulate and print data files. These programs include LUMCHG.FOR, LUMDAT.FOR, LUMPRI.FOR, and LIPRI.FOR. The OPEN commands in these programs were edited to read and write to specific data files. The program PLANCK.FOR is also included; it is used calculate the flux density from a blackbody over a specified wavelength range based on Planck's law. This program was not used directly in this study, but rather, was used to check the output of the PIR sensor. An executable copy of this program, PLANCK.EXE, is provided on magnetic disk.

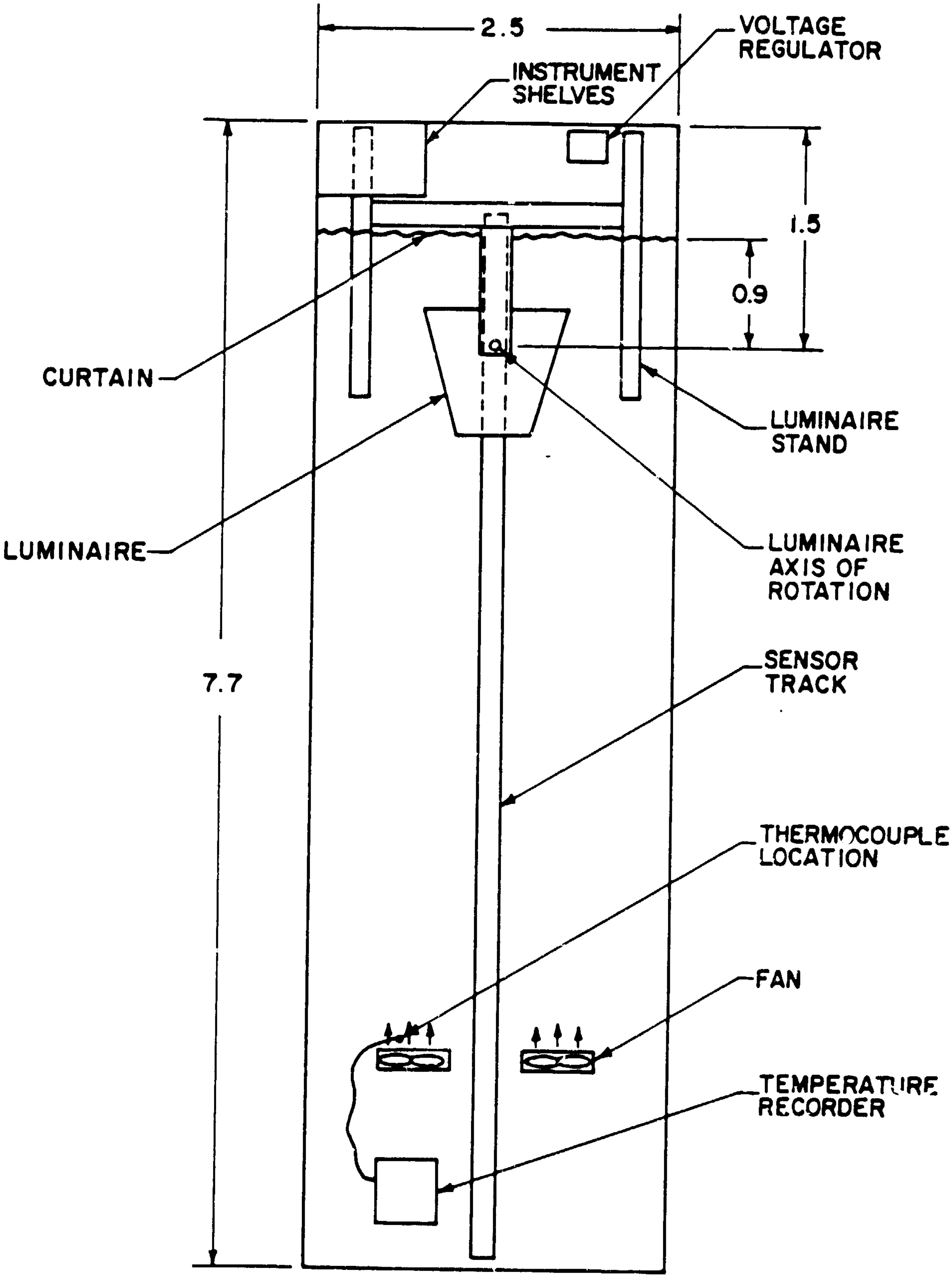

Figure 1. Top view inside Luminaire Evaluation Chamber.

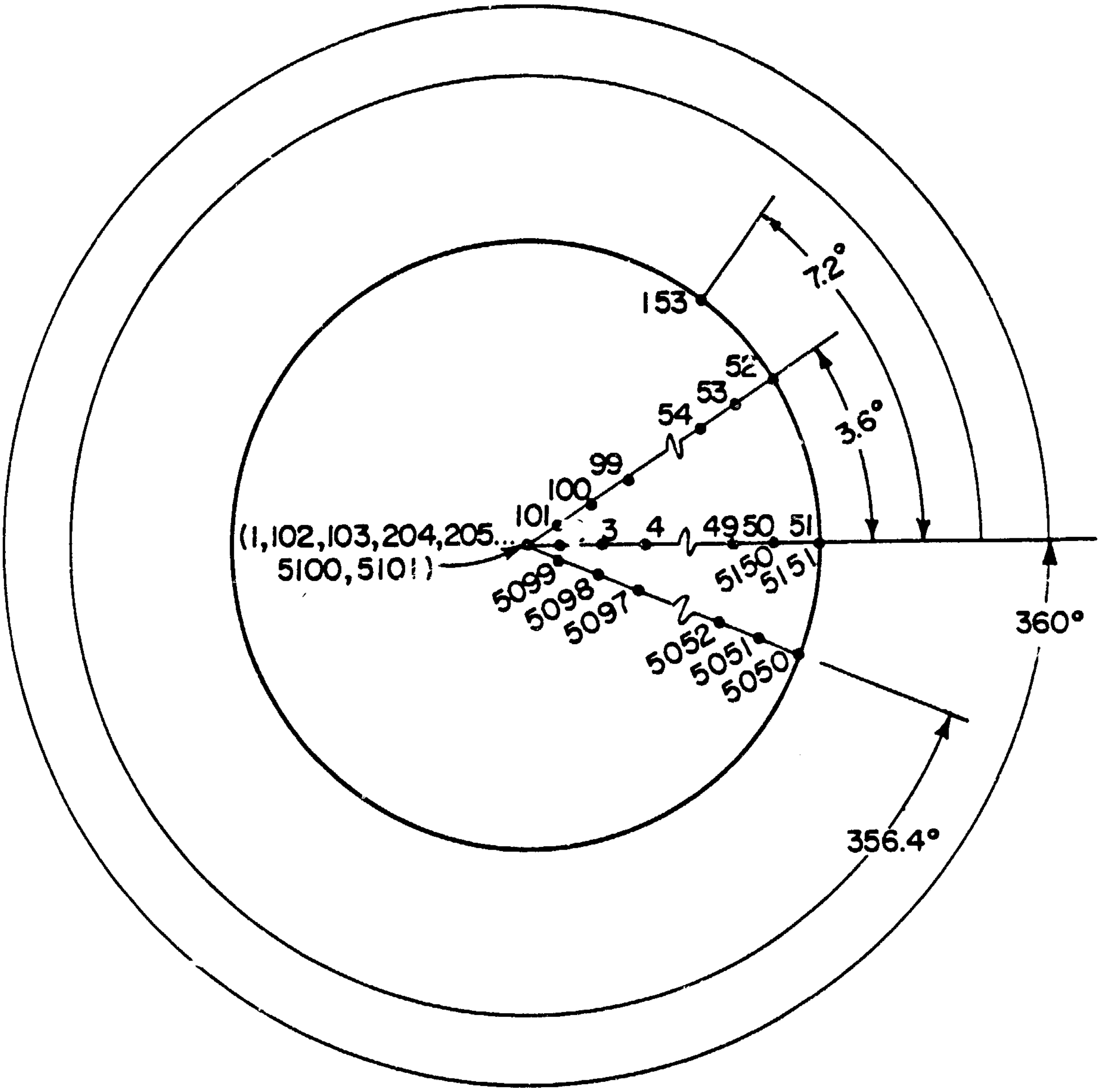

Figure 2. Order of measurements in polar grid.

Appendix A. FLUX DENSITY GRAPHS

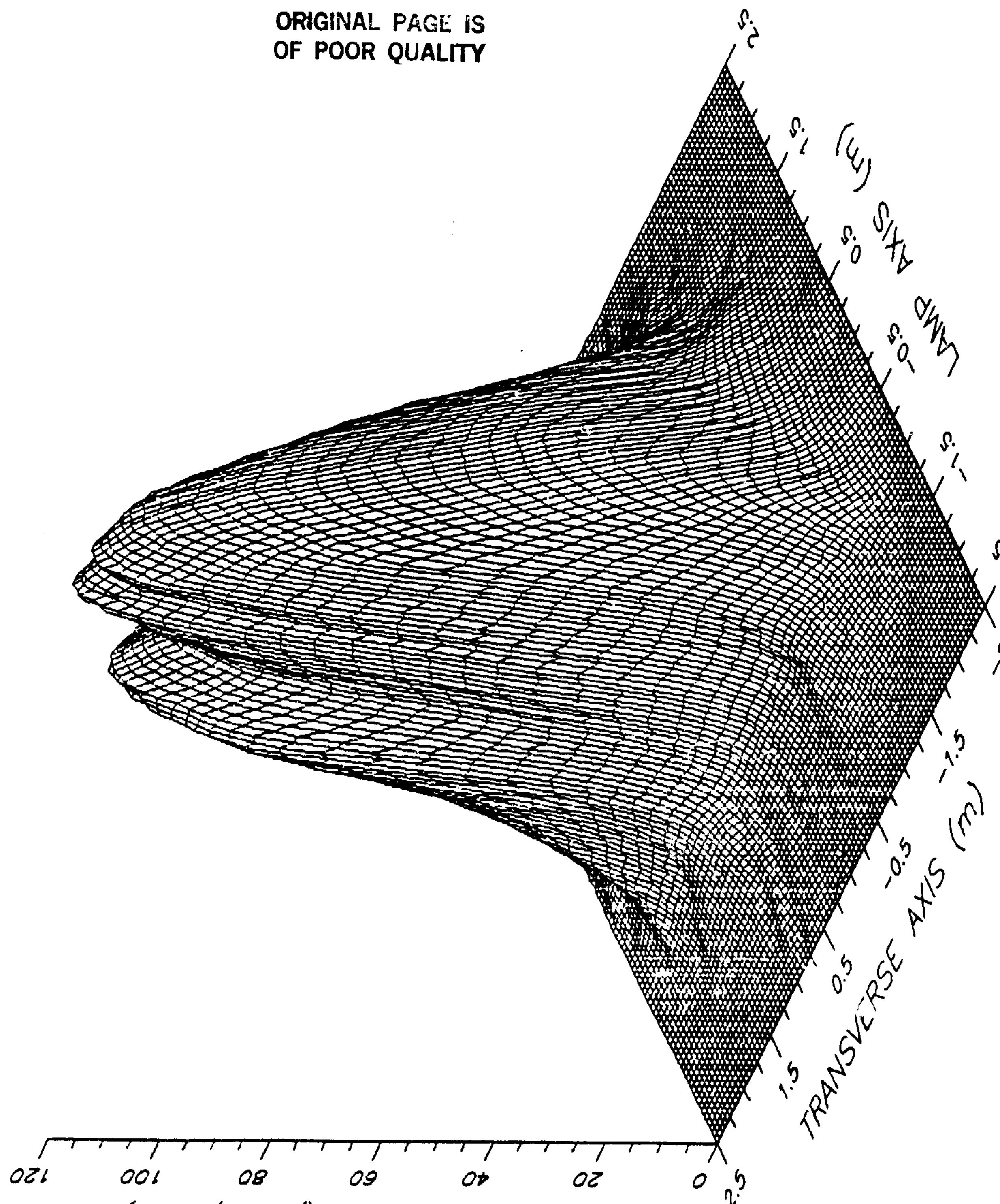

Figure A1. NASA luminaire, 1.0 m height, glass lens, Quantum sensor.

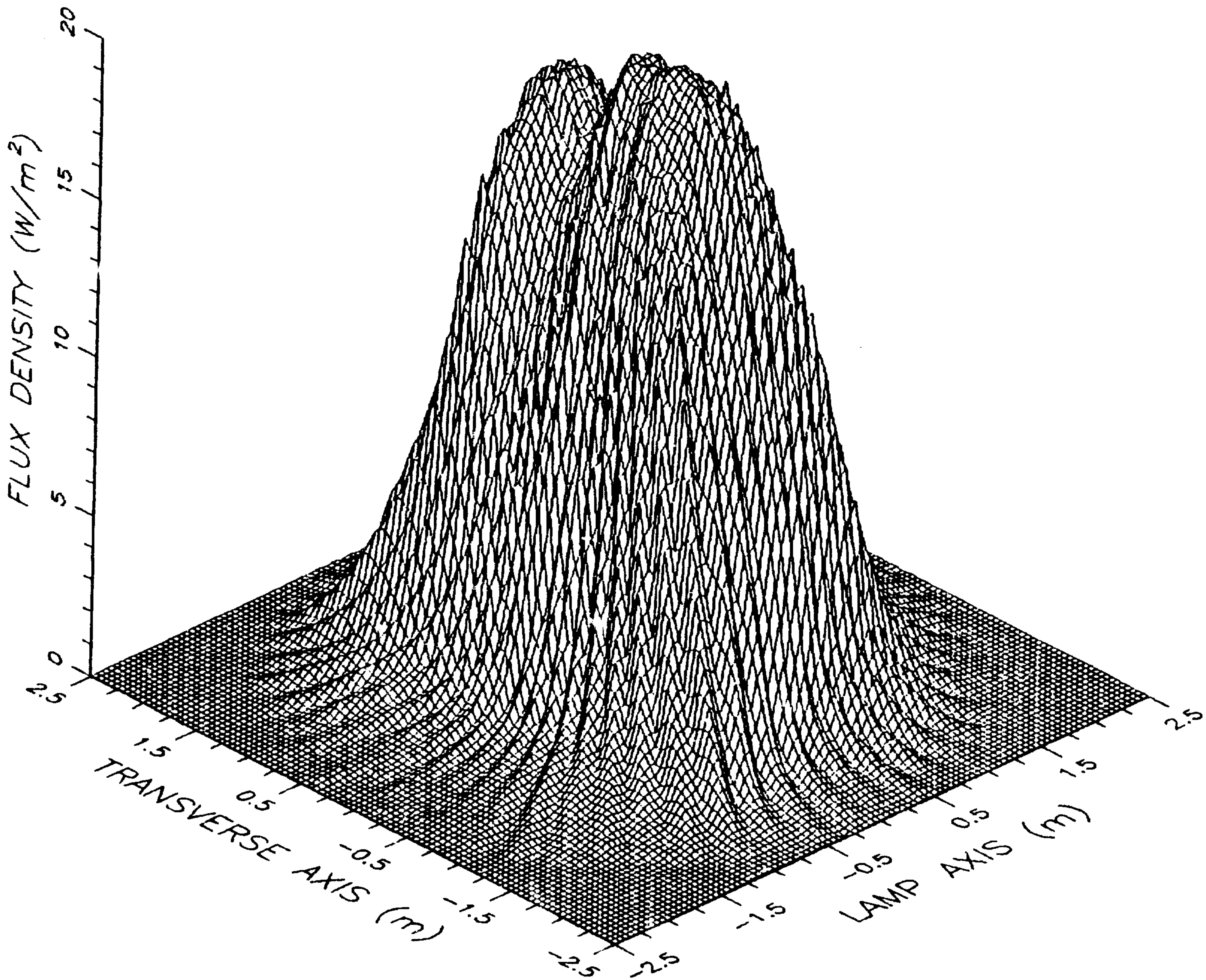

Figure A2. NASA luminaire, 1.0 m height, glass lens, PSP sensor.

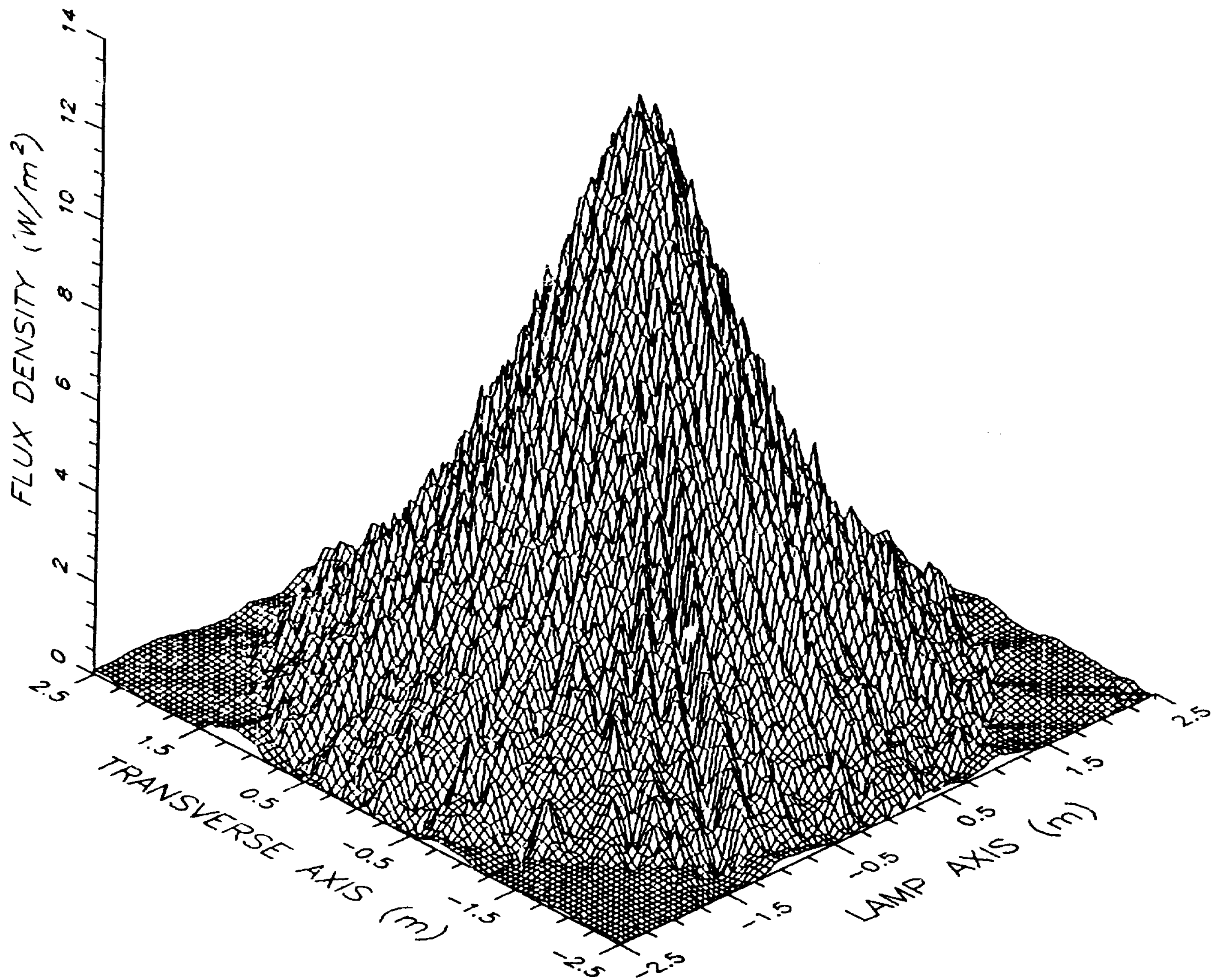

Figure A3. NASA luminaire, 1.0 m height, glass lens, PIR sensor.

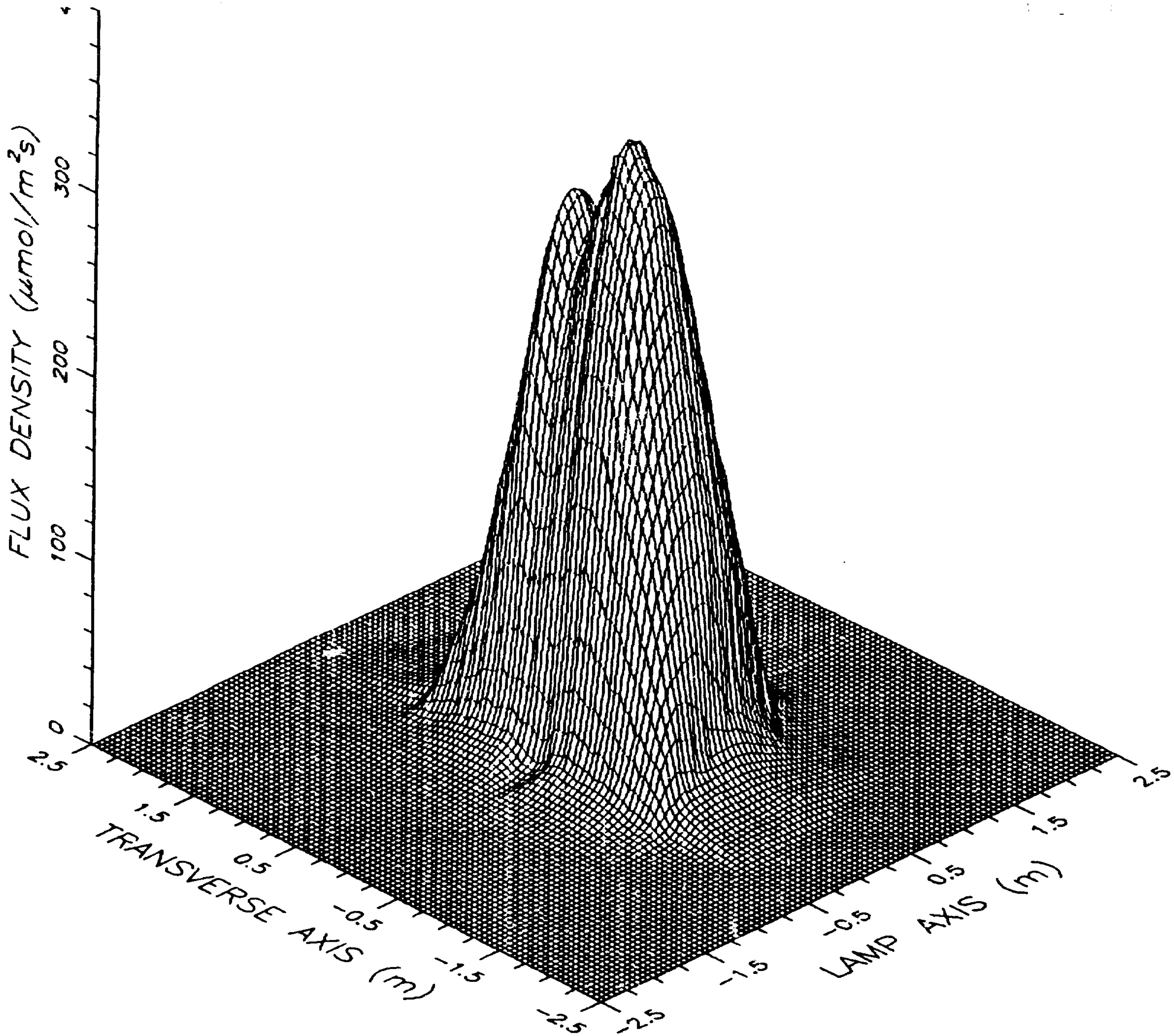

Figure A4. NASA luminaire, 0.5 m height, glass lens, Quantum sensor.

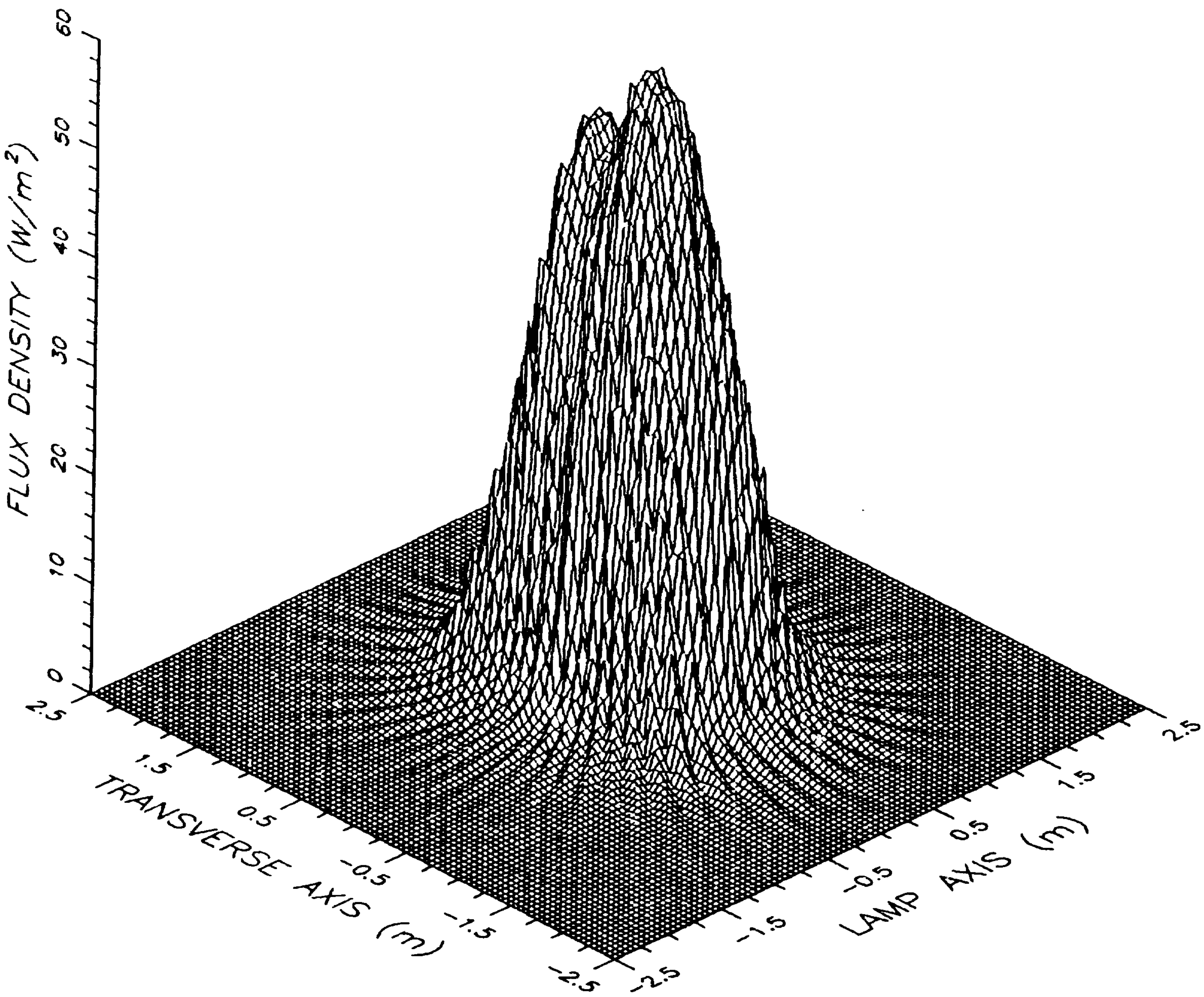

Figure A5. NASA luminaire, 0.5 m height, glass lens, PSP sensor.

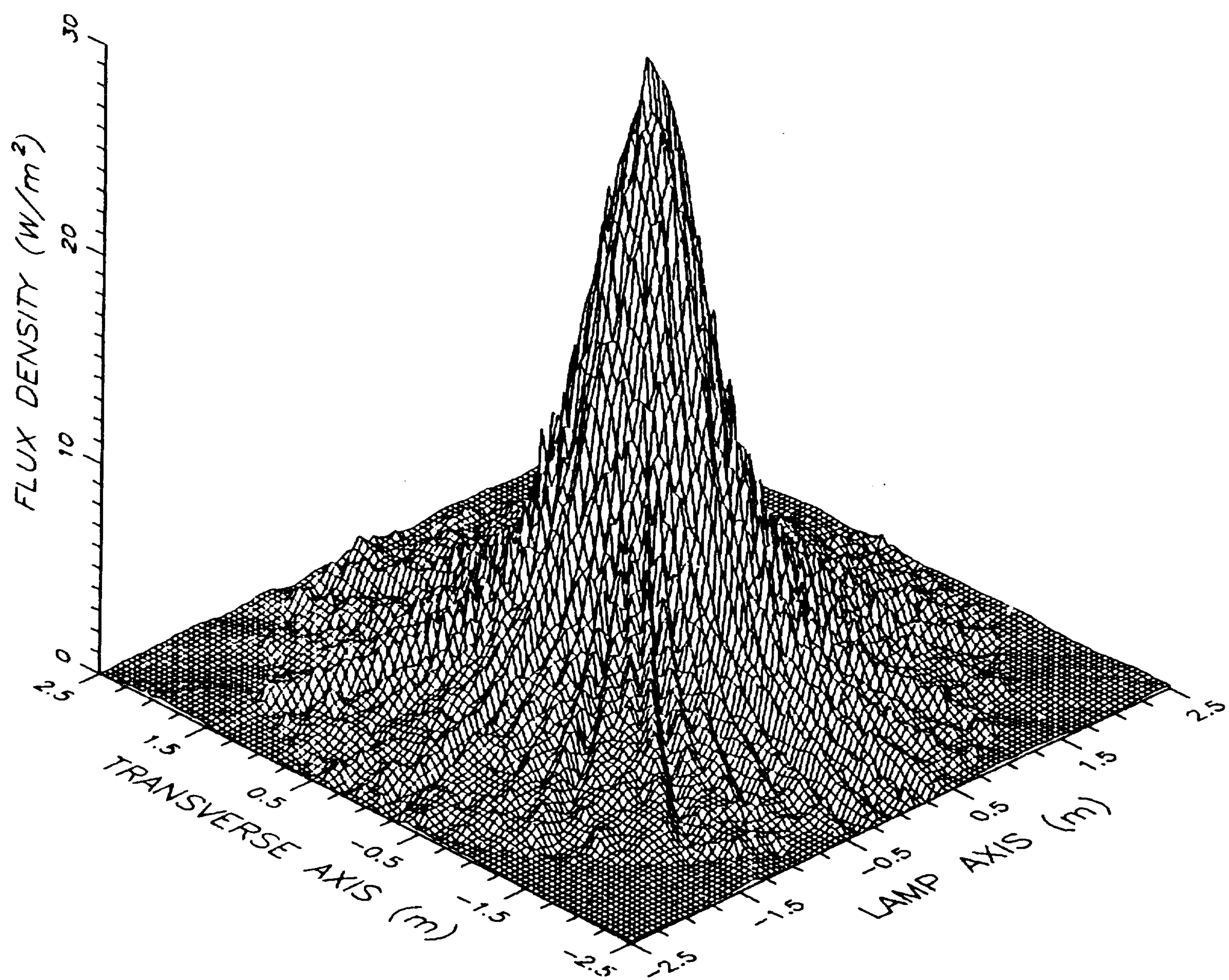

Figure A6. NASA luminaire, 0.5 m height, glass lens, PIR sensor.

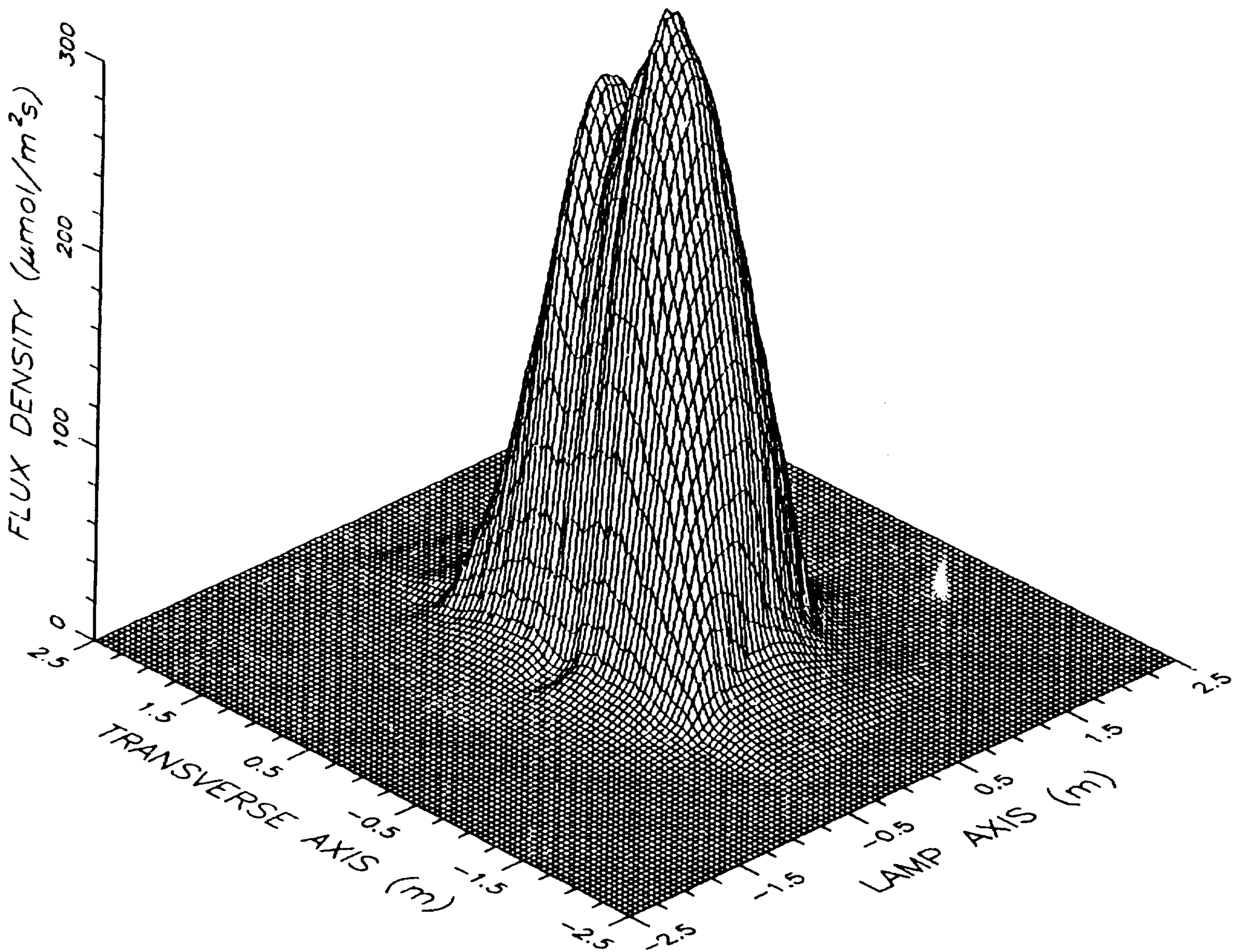

Figure A7. NASA luminaire, 0.5 m height, plastic lens, Quantum sensor.

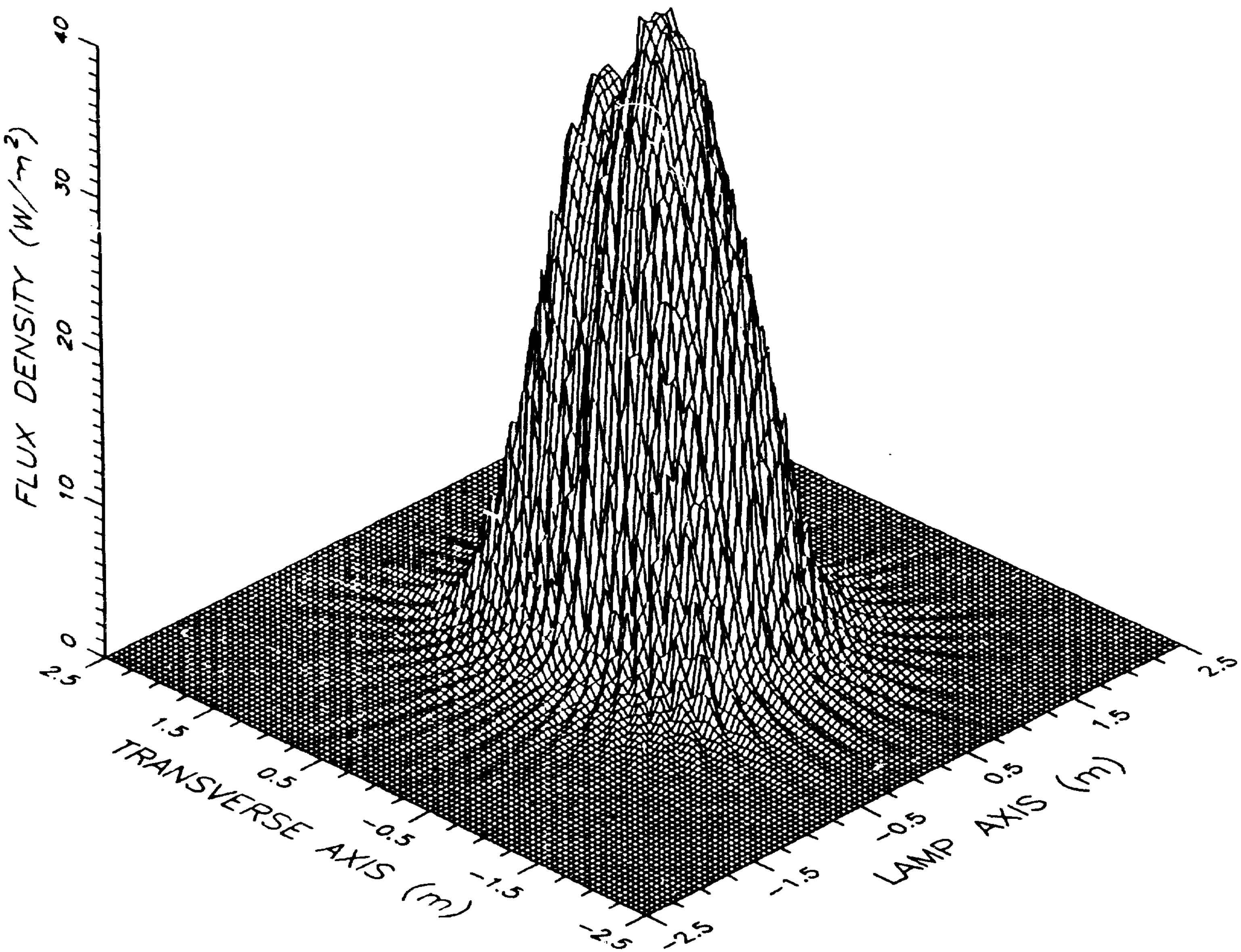

Figure A8. NASA luminaire, 0.5 m height, plastic lens, PSP sensor.

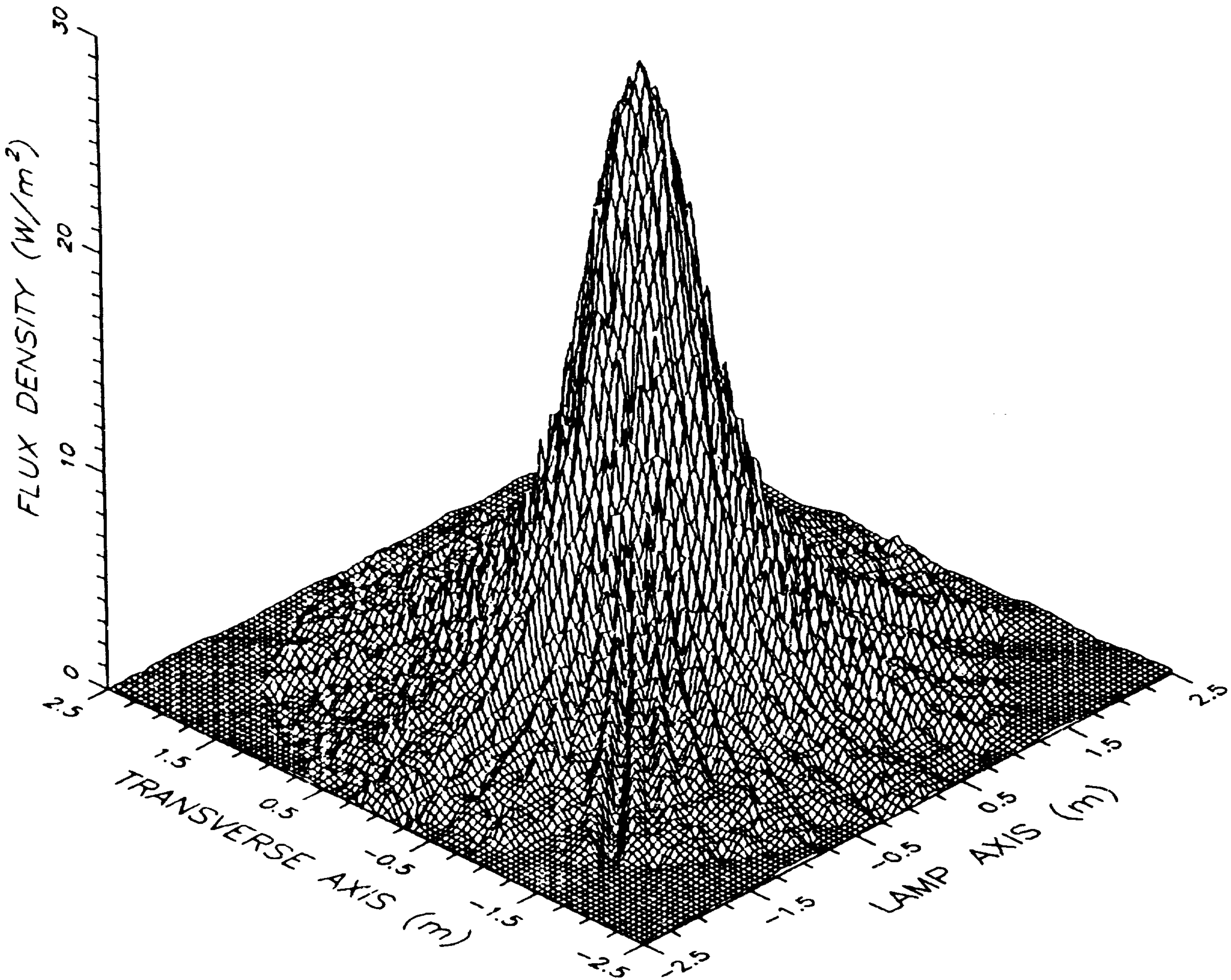

Figure A9. NASA luminaire, 0.5 m height, plastic lens, PIR sensor.

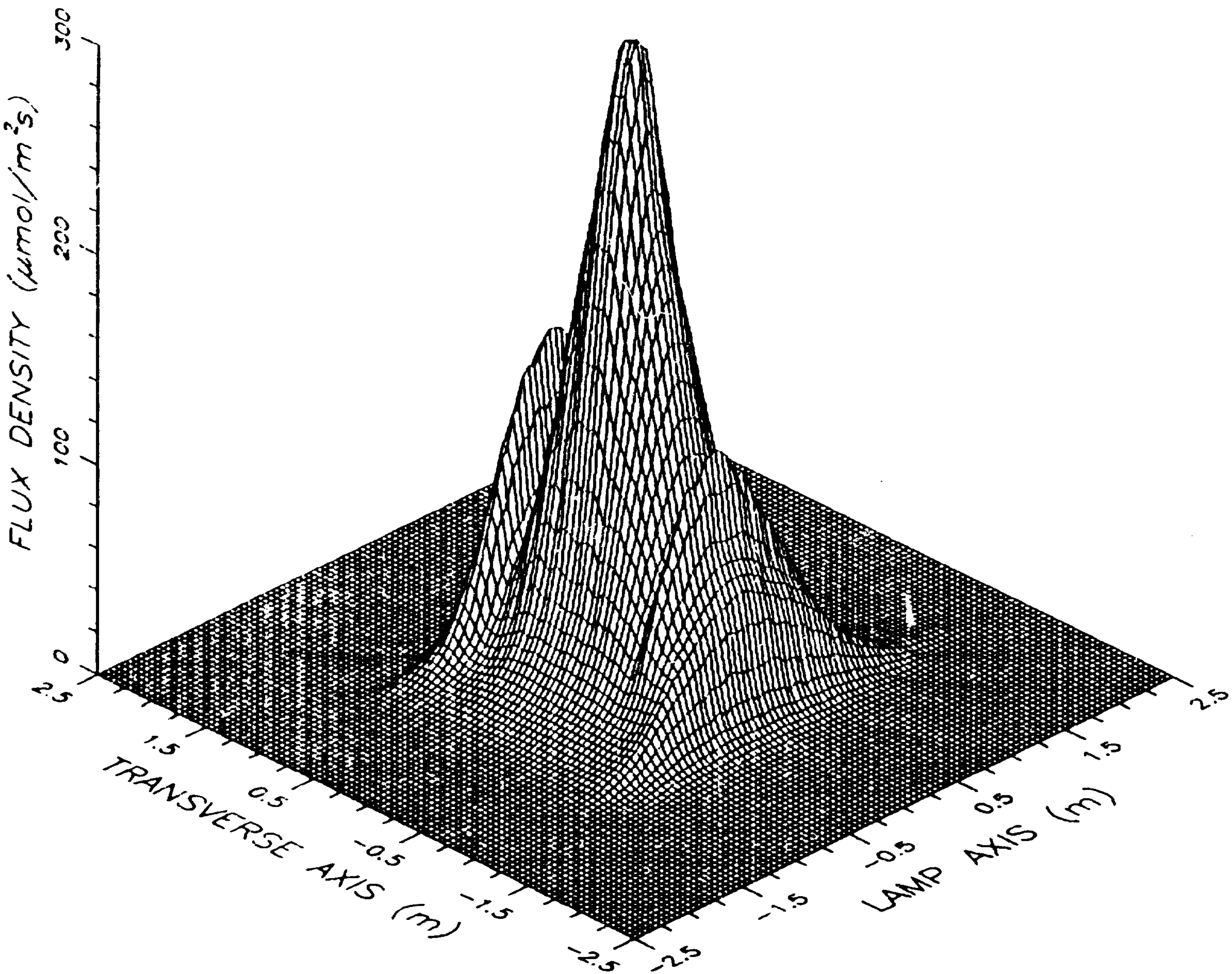

Figure A10. Commercial luminaire, 0.5 m height, Quantum sensor.

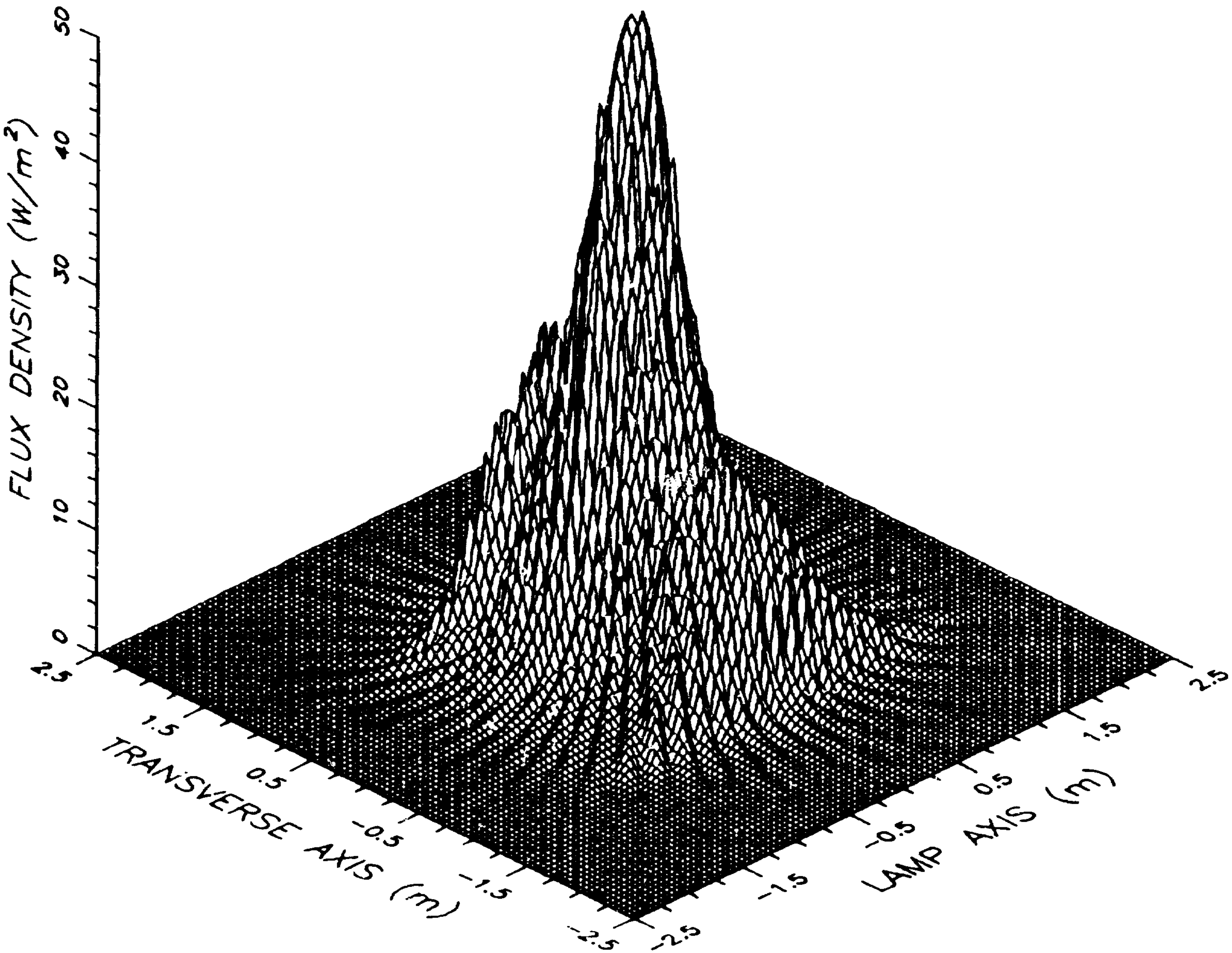

Figure A11. Commercial luminaire, 0.5 m height, PSP sensor.

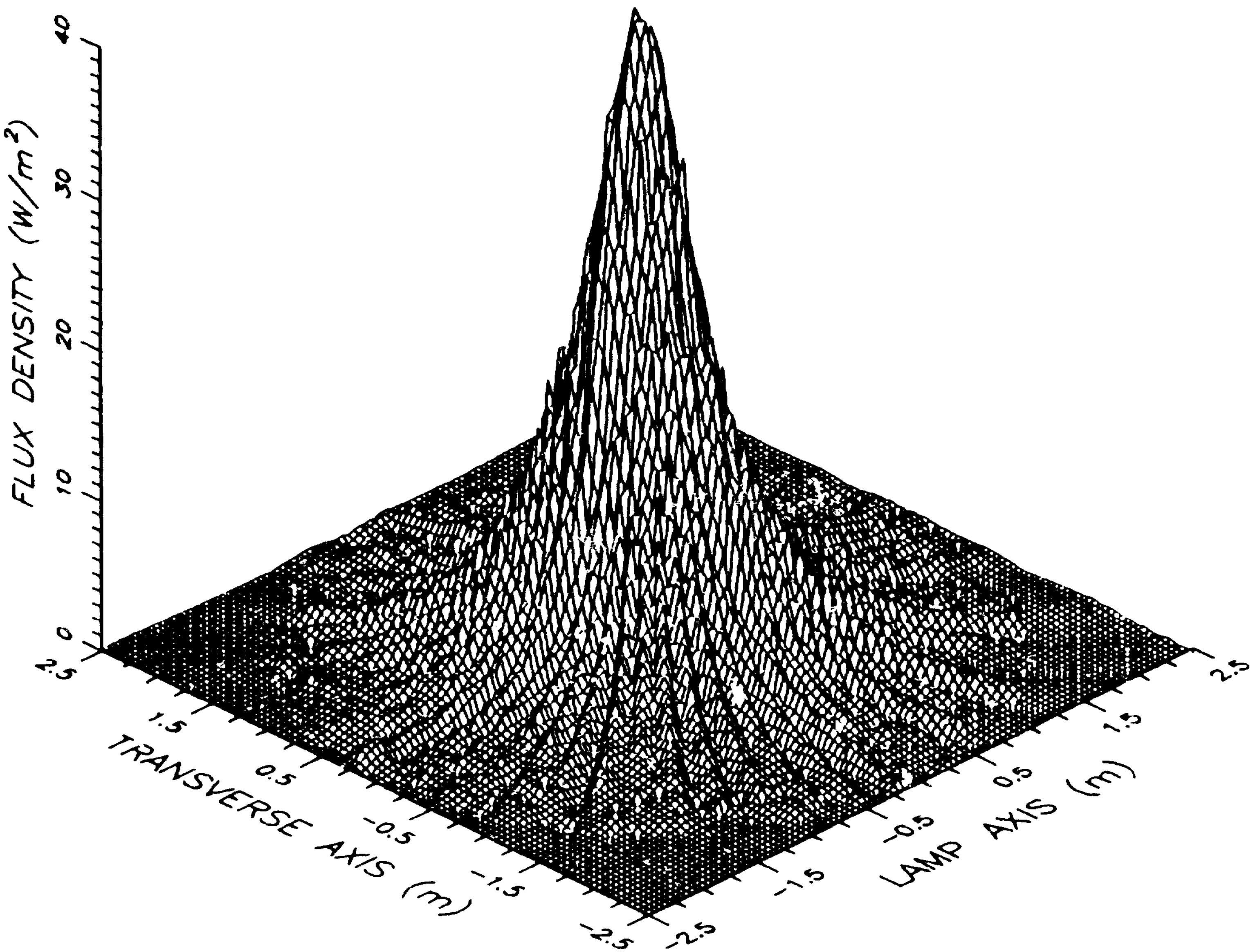

Figure A12. Commercial luminaire, 0.5 m height, PIR sensor.

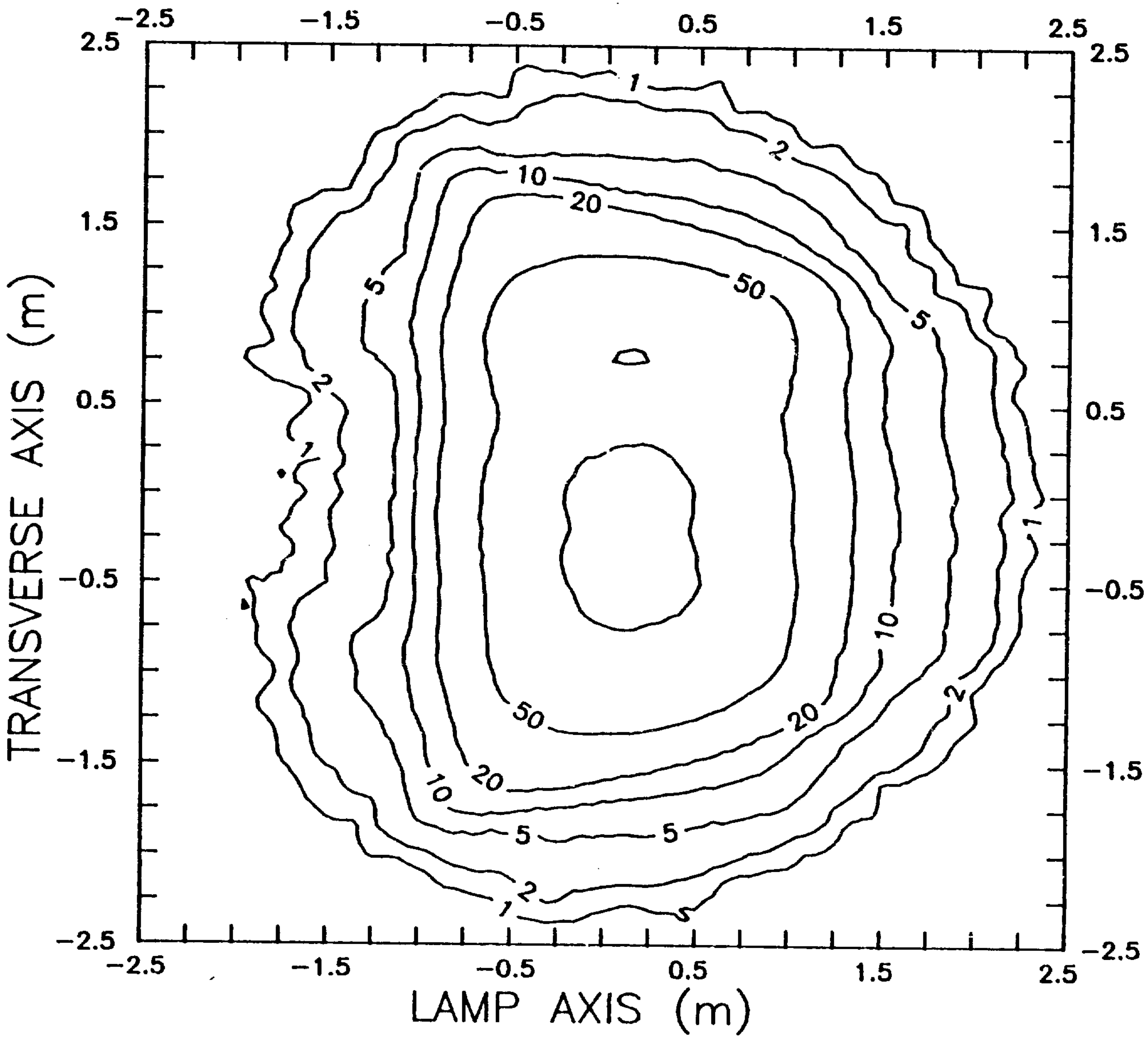

Figure A13. NASA luminaire, 1.0 m height, glass lens, Quantum sensor, contour line units are mol/m^2s.

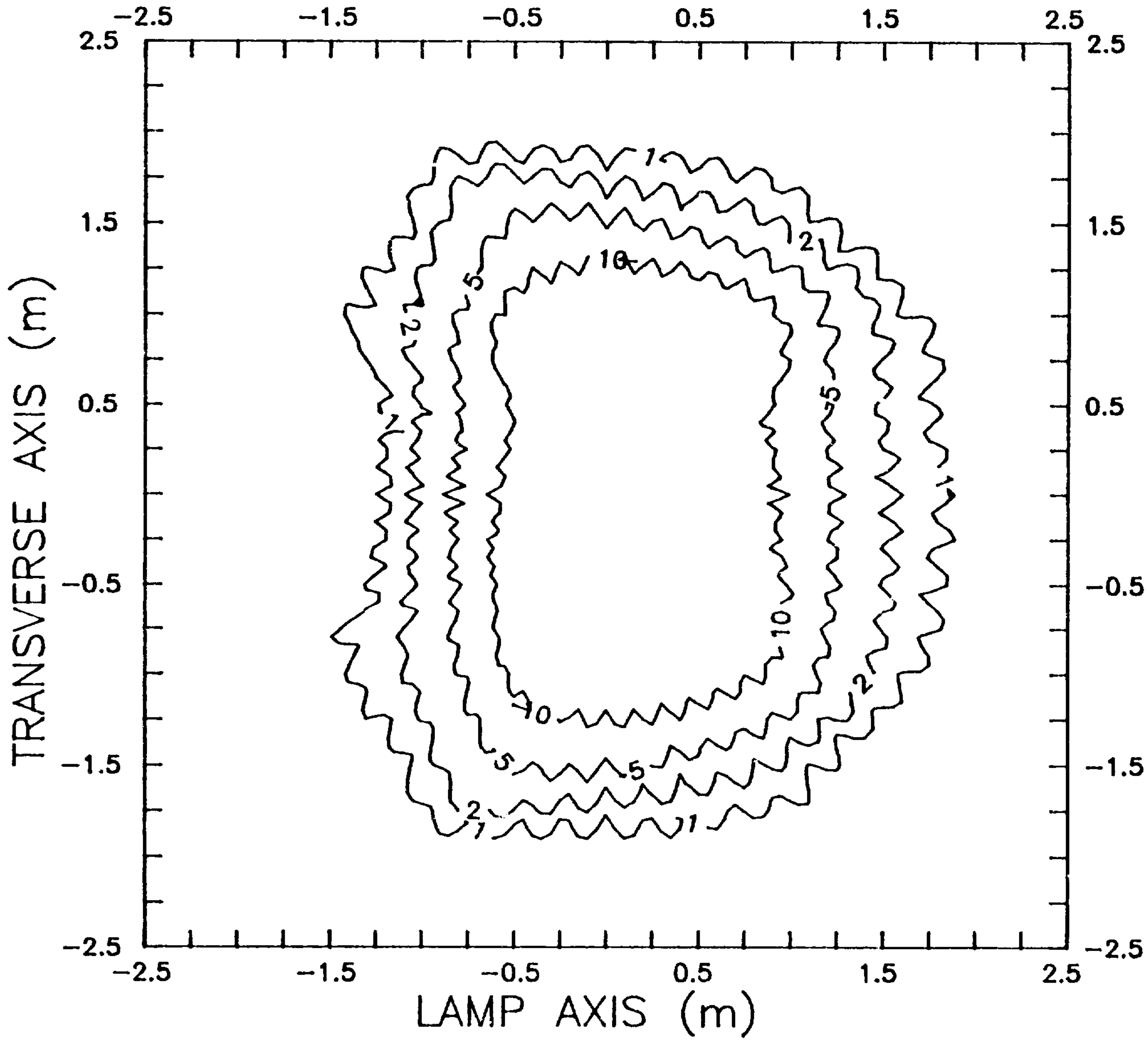

Figure A14. NASA luminaire, 1.0 m height, glass lens, PSP sensor, contour line units are W/m^2.

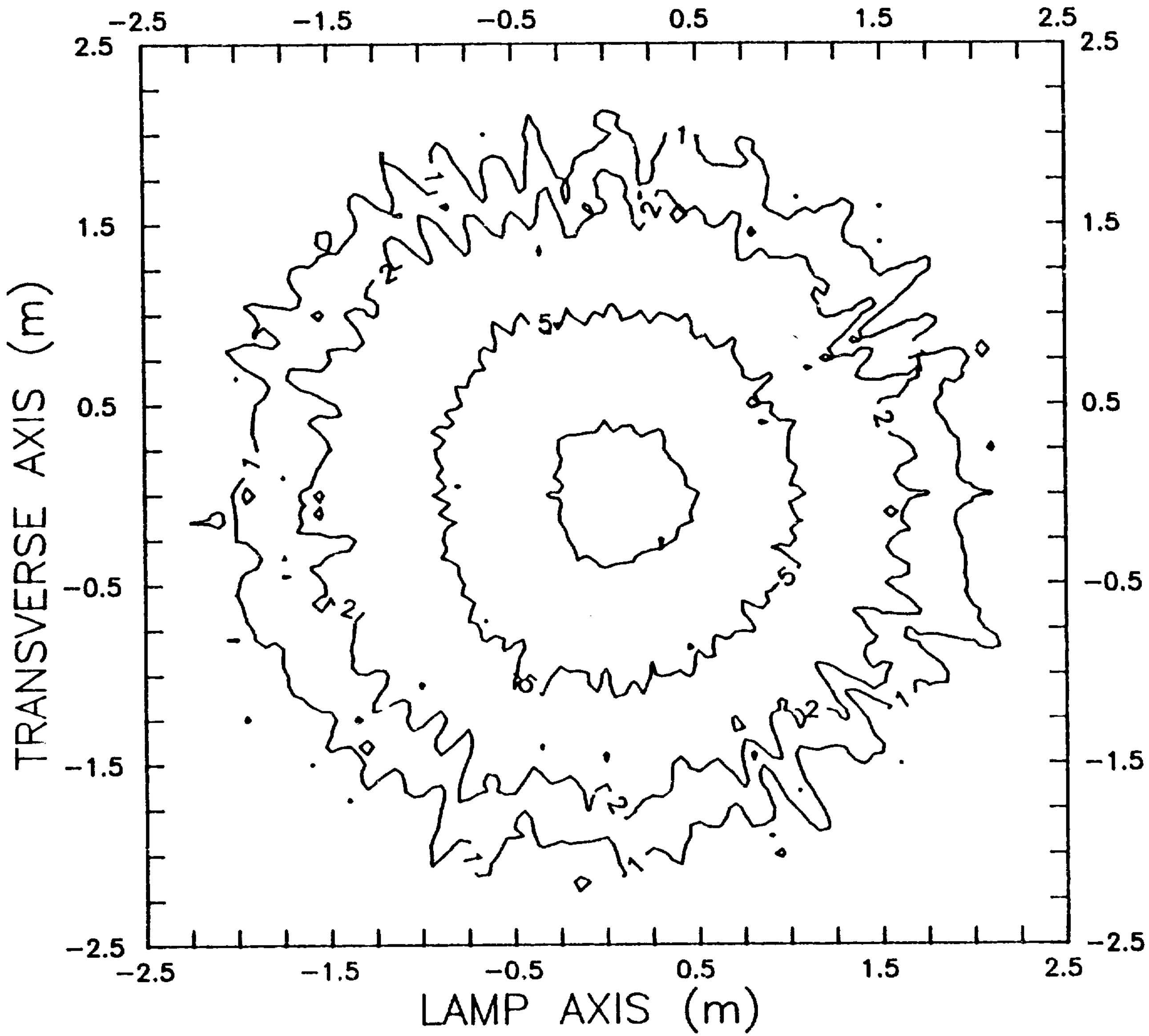

Figure A15. NASA luminaire, 1.0 m height, glass lens, PIR sensor, contour line units are W/m^2.

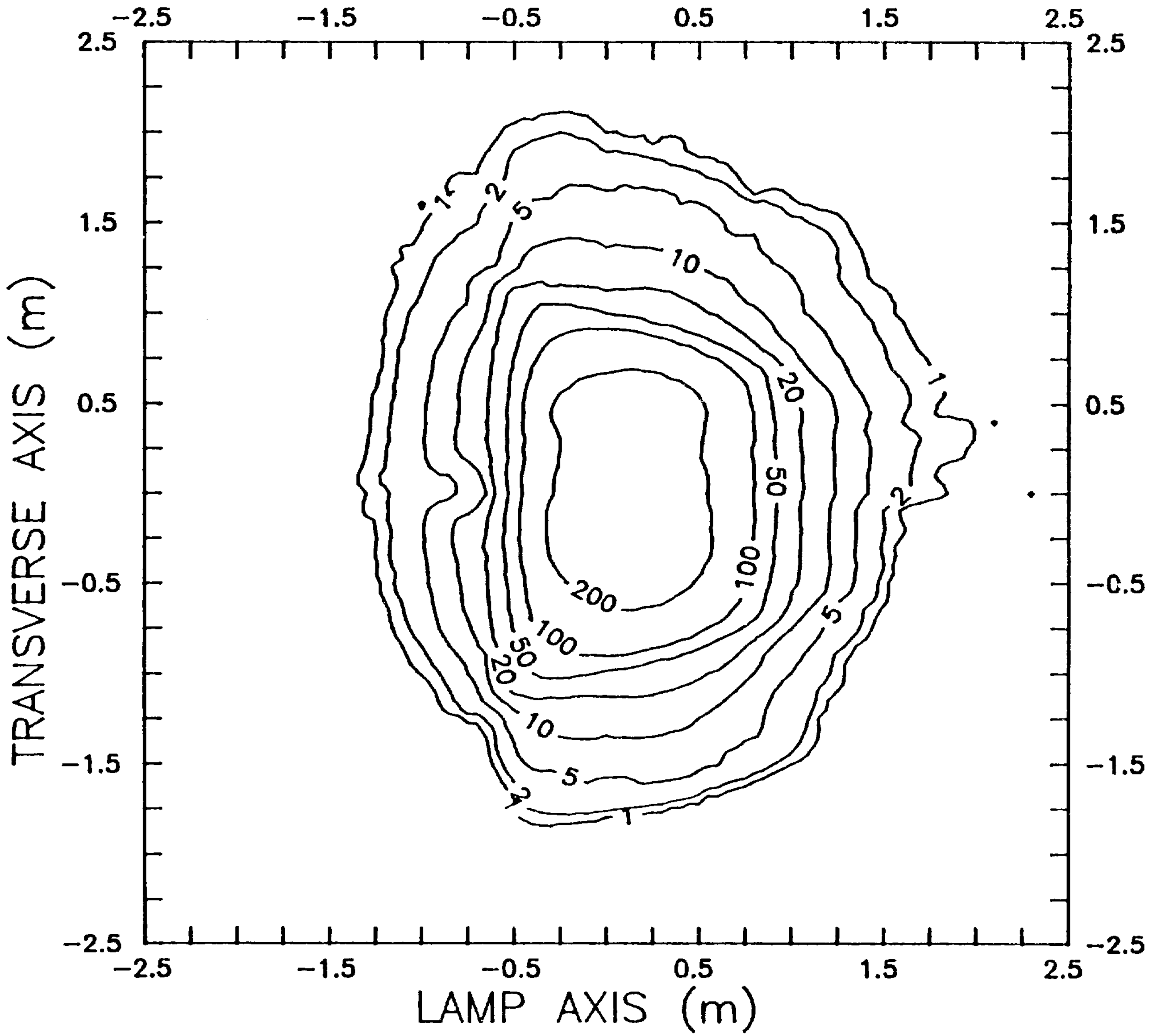

Figure A16. NASA luminaire, 0.5 m height, glass lens, Quantum sensor, contour contour line units are $\mu mol/m^2s$.

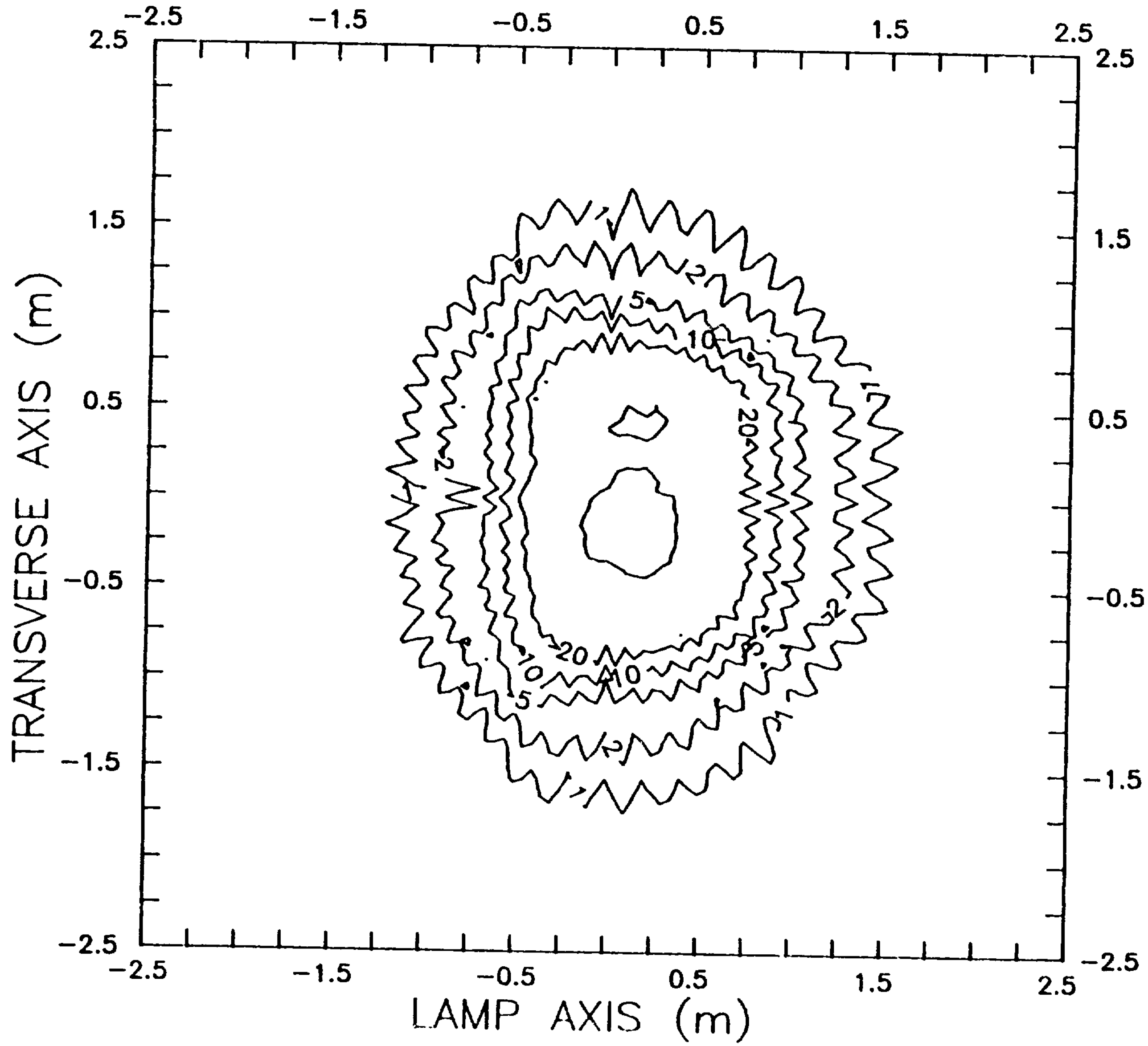

Figure A17. NASA luminaire, 0.5 m height, glass lens, PSP sensor, contour line units are W/m^2.

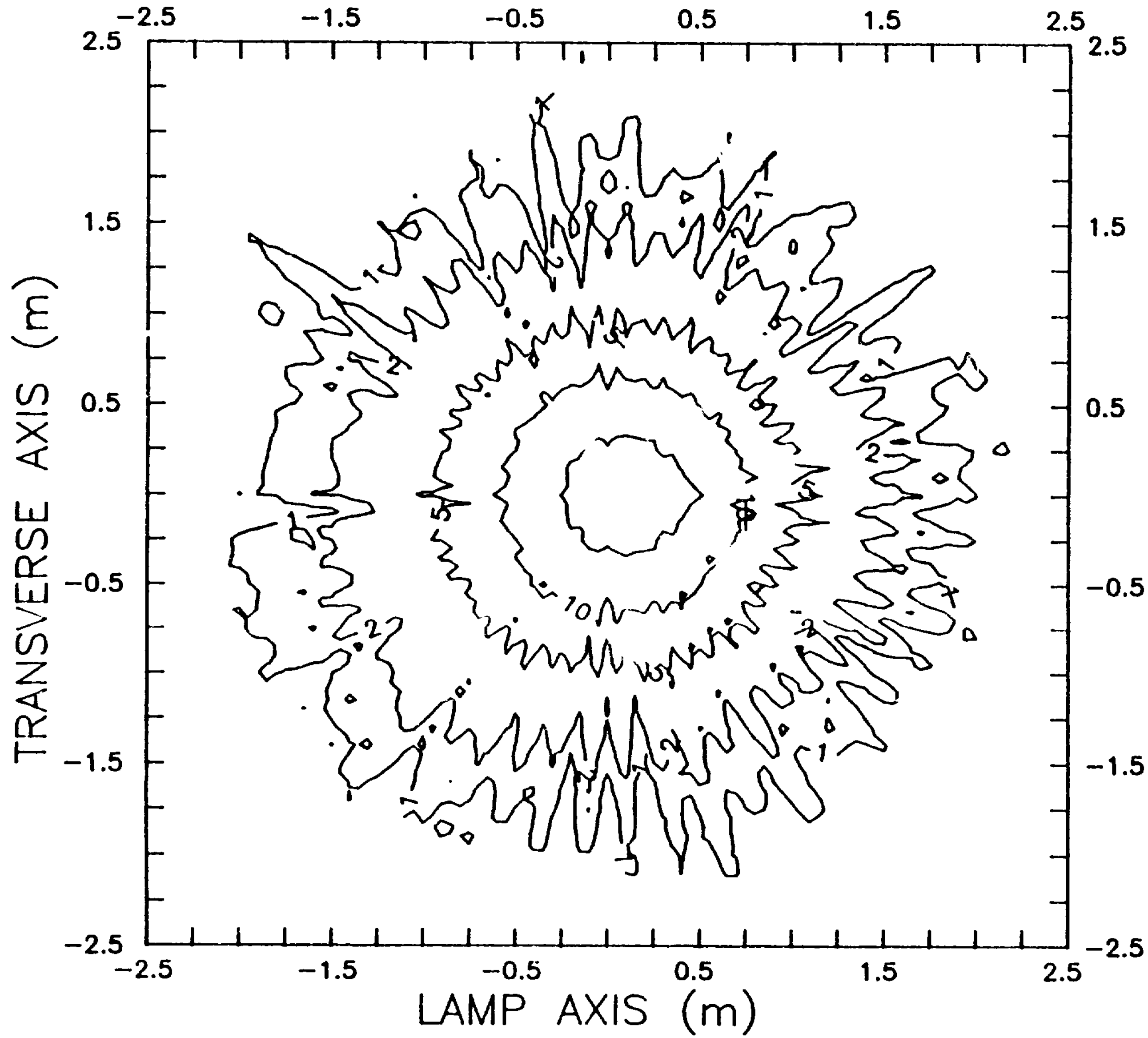

Figure A18. NASA luminaire, 0.5 m height, glass lens, PIR sensor, contour line units are W/m^2.

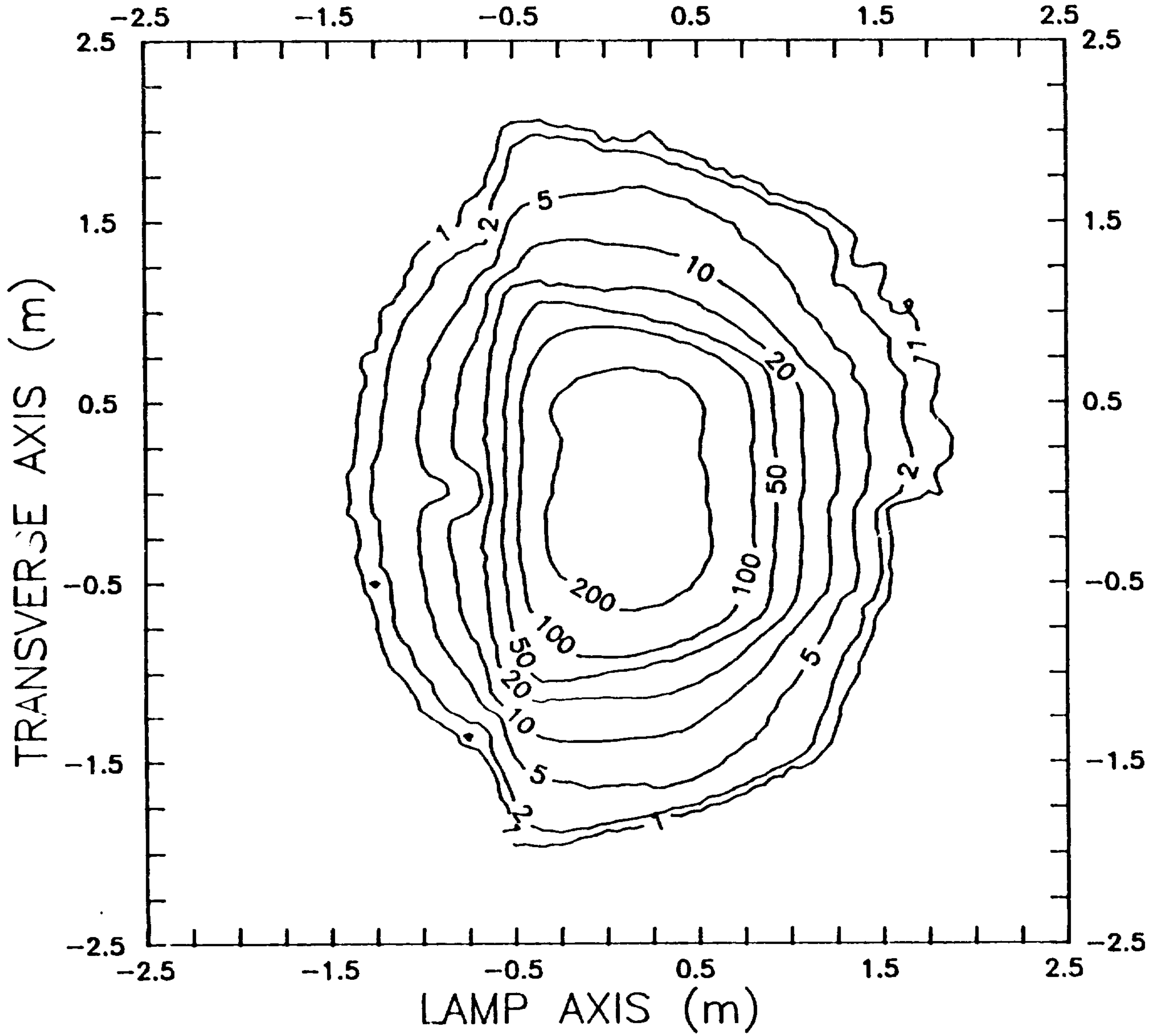

Figure A19. NASA luminaire, 0.5 m height, plastic lens, Quantum sensor, contour line units are $\mu mol/m^2s$.

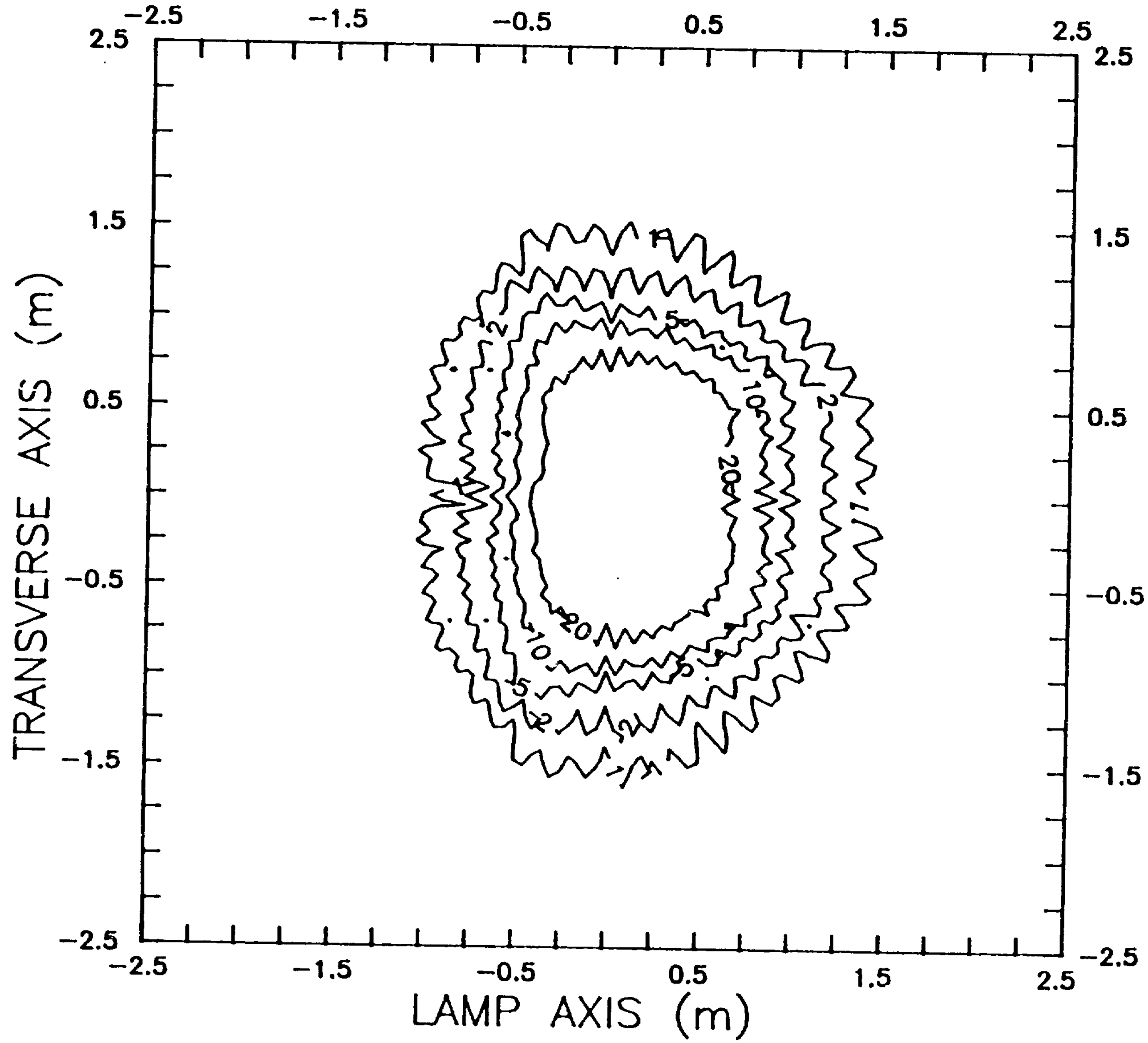

Figure A20. NASA luminaire, 0.5 m height, plastic lens, PSP sensor, contour line units are W/m^2.

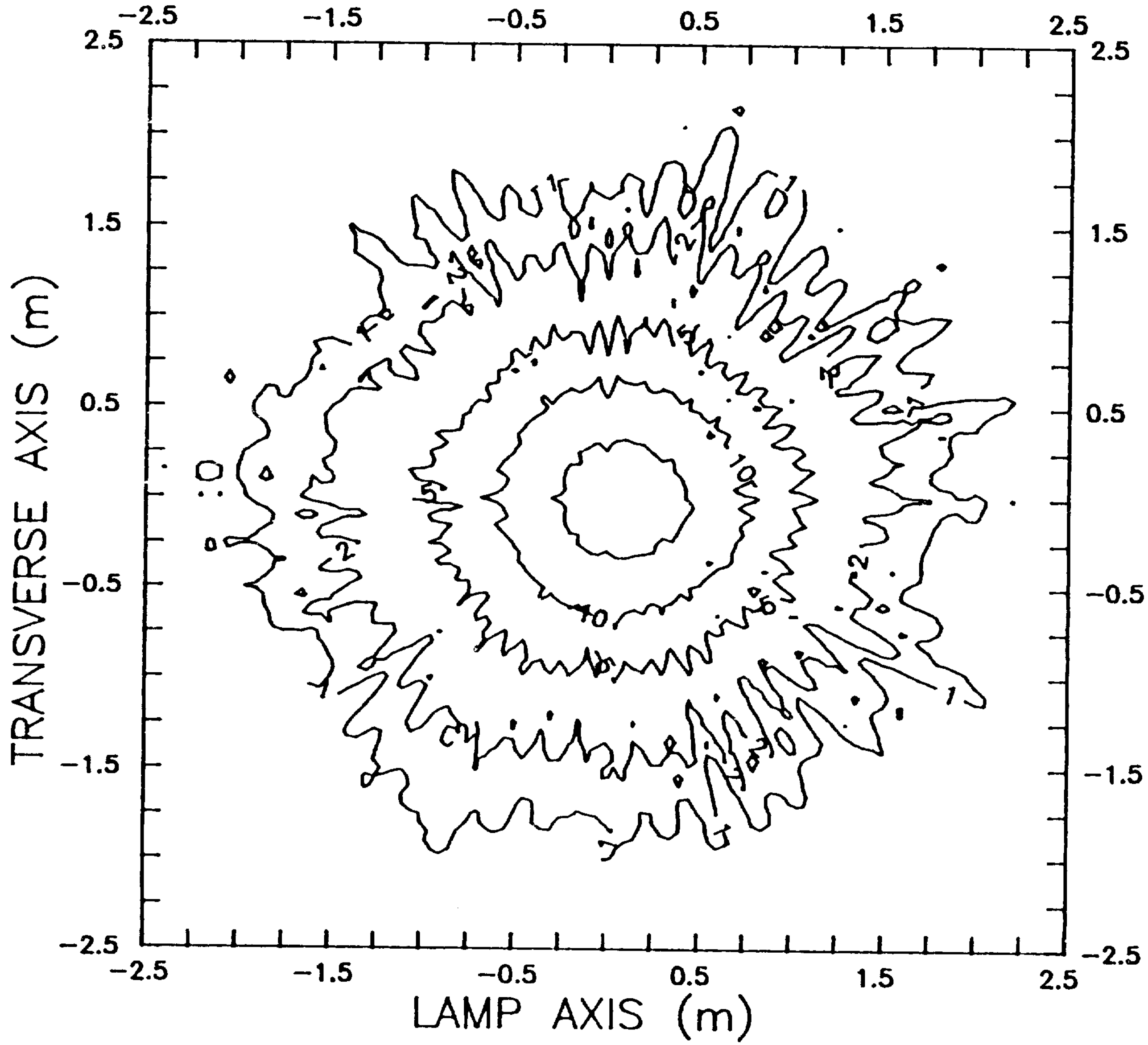

Figure A21. NASA luminaire, 0.5 m height, plastic lens, PIR sensor, contour line units are W/m^2.

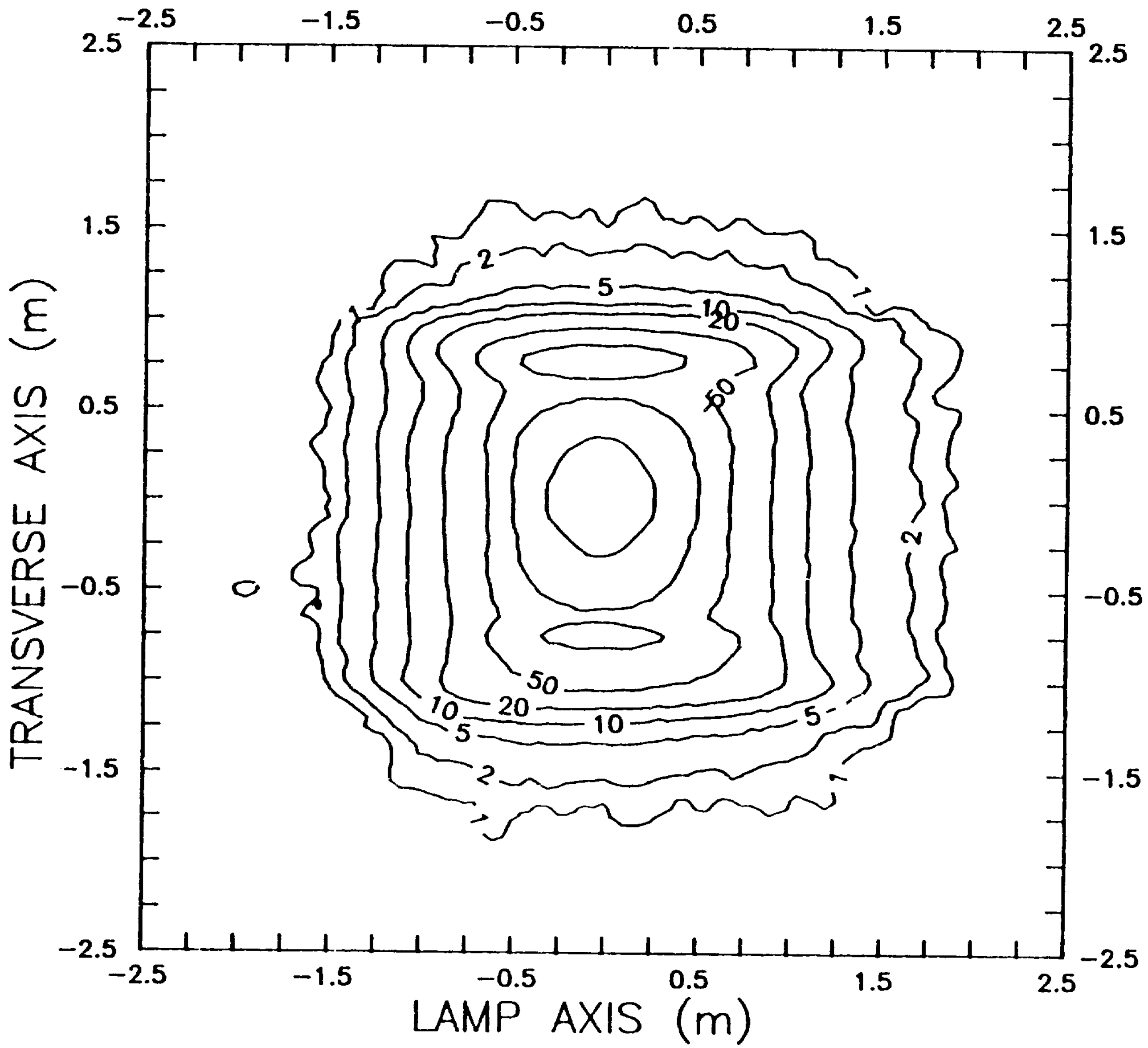

Figure A22. Commercial luminaire, 0.5 m height, Quantum sensor, contour line units are $\mu mol/m^2s$.

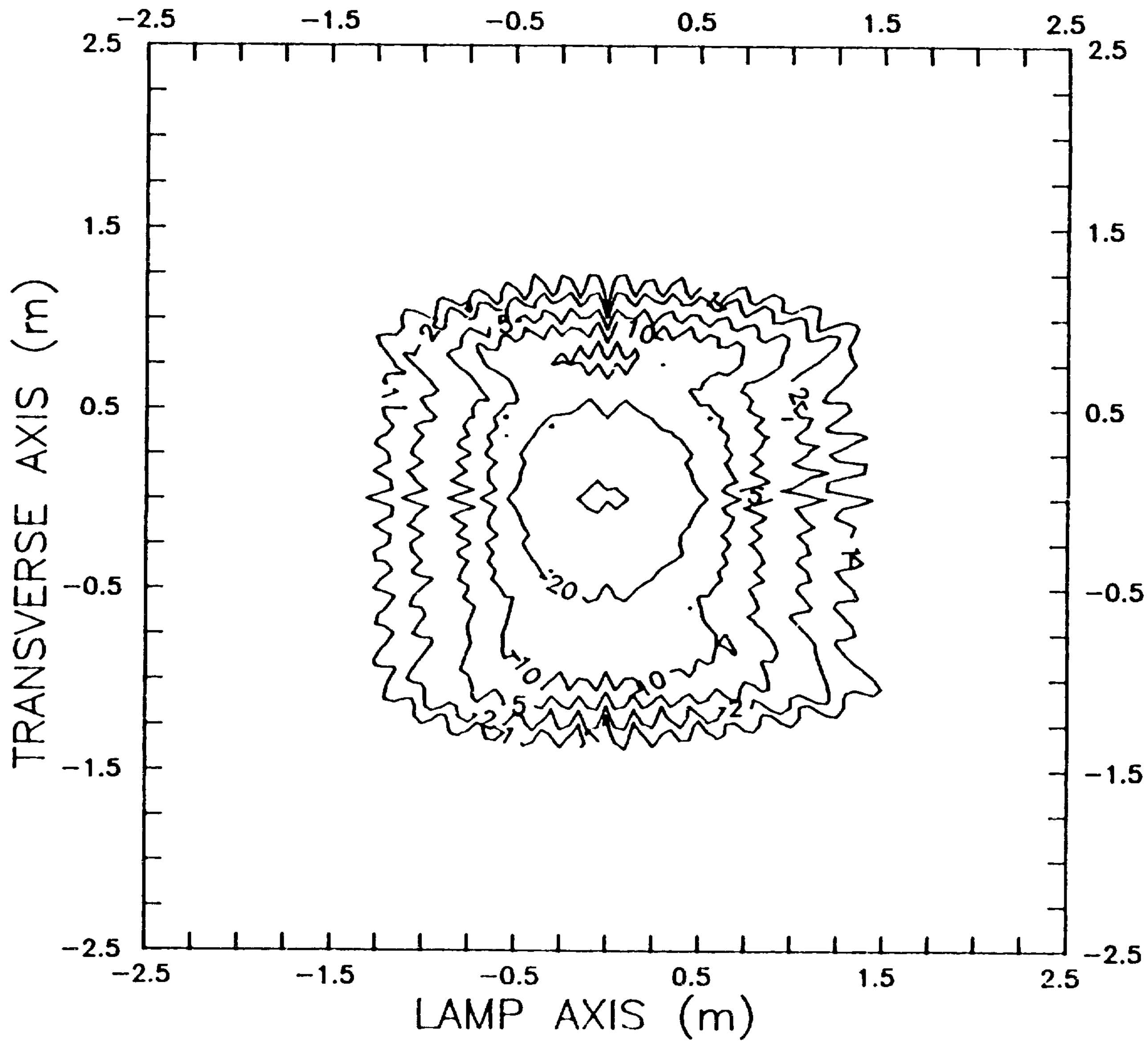

Figure A23. Commercial luminaire, 0.5 m height, PSP sensor, contour line units are W/m^2.

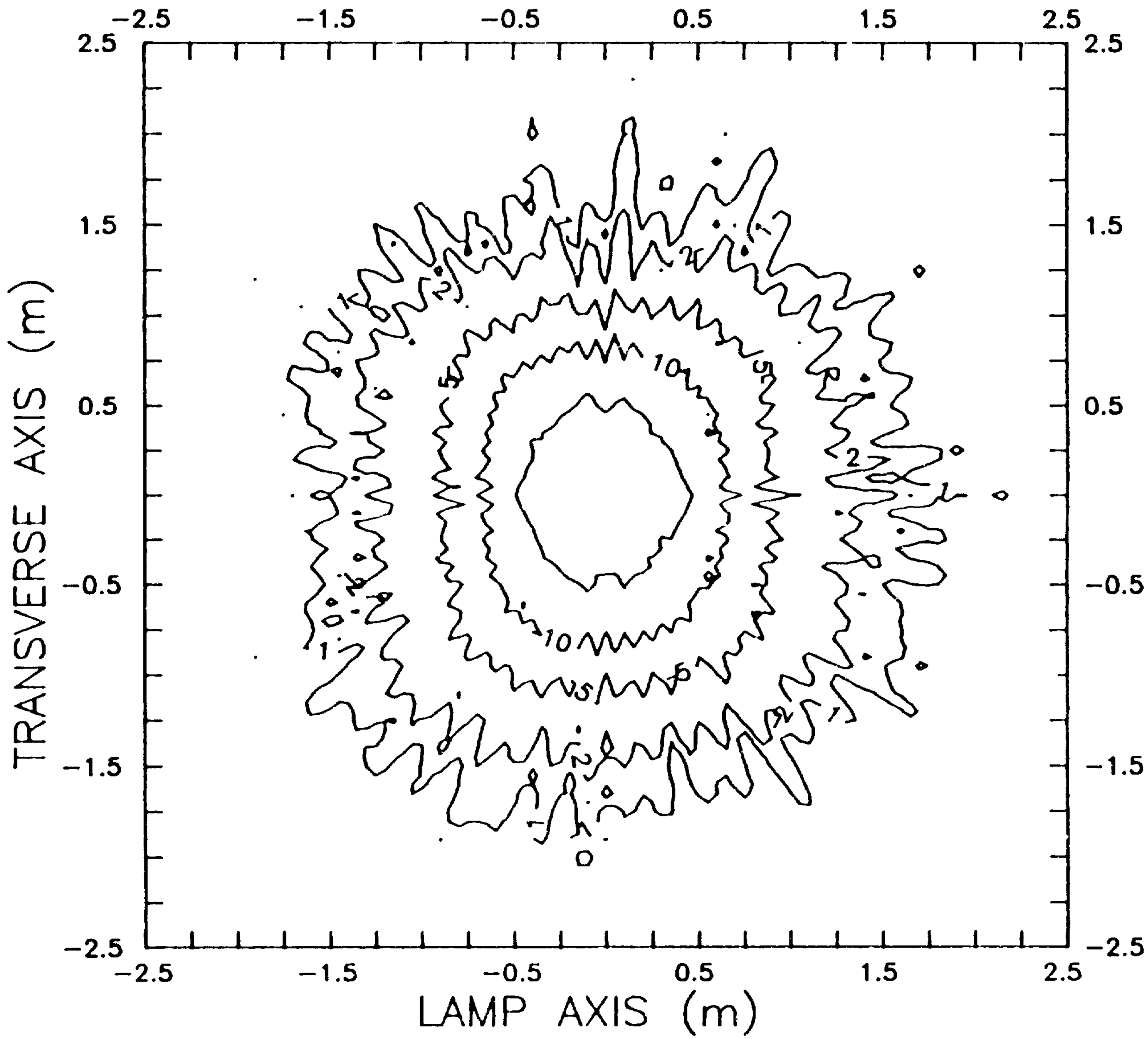

Figure A24. Commercial luminaire, 0.5 m height, PIR sensor, contour lines units are W/m^2.

Appendix B. COMPUTER PROGRAMS

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1 '**********************************************************
2 '**********************************************************
3 '     COLLECT.BAS
4 '**********************************************************
5 '**********************************************************
10 DATA &hb8,&h59,&h47,&hcd,&h60,&h90,&h90,&hca,&h06,&h0,0
20 DEF SEG
30 APROG1$=SPACE$(15)
40 APROG2$=SPACE$(15)
50 A%=VARPTR(APROG1$):AM1=PEEK(A%+1)+PEEK(A%+2)*256
60 RESTORE 10
70 FOR A=AM1 TO AM1+10
80 READ A%:POKE A,A%
90 NEXT A
100 A%=VARPTR(APROG2$):AM2=PEEK(A%+1)+PEEK(A%+2)*256
110 RESTORE 10
120 FOR A=AM2 TO AM2+10
130 READ A%: POKE A,A%
140 NEXT A
150 POKE AM2+8,16
200 COUNT=1
210 SWITCH=0
300  INPUT "Name input file, e.g., A:P05N1201.RAW; hit RETURN:  ", FILE$
305  PRINT "Identify sensor (enter number; hit RETURN)"
310  PRINT "1.  Li-Cor LI190SB (0.005 mV per micromole/(m2 s))"
315  PRINT "2.  Eppley PSP (0.00969 mV per W/m2)"
320  PRINT "3.  Eppley PIR (0.00408 mV per W/m2)"
330  PRINT "4.  Other"
390  INPUT SENSOR%
410  IF SENSOR%=1 GOTO 510
415  IF SENSOR%=2 GOTO 515
420  IF SENSOR%=3 GOTO 520
430  IF SENSOR%=4 GOTO 530
490  GOTO 305
510  CALIB=.005/3:    PRINT "SET AMPLIFIER TO 3 mV":  GOTO 700
515  CALIB=.00969:    PRINT "SET AMPLIFIER TO 1 mV":  GOTO 700
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520  CALIB=.00408/3: PRINT "SET AMPLIFIER TO 3 mV":  GOTO 700
530  INPUT "Enter sensor calibration constant in mV (per unit output):  ", CALIB
600 PRINT " "
700  INPUT "Enter desired radial travel in meters:  ", RADIUS
702  NS%=RADIUS*20+1.1
800 PRINT " "
805 PRINT "The program will allow time for you to leave the"
810 PRINT "chamber before data collection begins."
815 PRINT " "
820 INPUT "Enter desired delay in seconds:  ", II
830 FOR JJ = 1 TO II
840 FOR KK = 1 TO 1400:  NEXT KK
850 NEXT JJ
1000 ' set resolution on channel 1
1050 DIM A%(7),B(7)
1075 DIM LIGHT(6210)
1100 C$ = "A" + CHR$(0)
1200 A%(0) = 12: A%(1) = 12
1250 CALL AM1(A%(0),B(0),C$)
1260 ' calibrate analog input
1300 C$ = "c" + CHR$(0)
1350 CALL AM1(A%(0),B(0),C$)  ' CALL DRIVER
1400 C$ = "S" + CHR$(0) ' set digital i/o to output
1450 A%(0) = 1:A%(1) = 1:A%(2)=1:A%(3)=1
1475 CALL AM1(A%(0),B(0),C$)
1500  C$ = "O" + CHR$(0):A%(0)=0:A%(1)=0:A%(2)=0:A%(3)=0:CALL AM1(A%(0),B(0),C$)
2000 ' start loop
2100 FOR H = 1 TO 101
2200 IF SWITCH=1 GOTO 4000
2300  FOR V = 1 TO NS%
2400     A%(0) = 1  ' read channel 1
2500     C$ = "h" + CHR$(0)  '
2600     CALL AM1(A%(0),B(0),C$)
2700     PRINT "light = "; COUNT, B(0)/CALIB
2800     LIGHT(COUNT) = B(0)
2900  IF V=NS% GOTO 3500
```

```
3000       C$ = "O" + CHR$(0)
3100    FOR VPULSE = 1 TO 49    'step motor
3200       A%(1) = 1: CALL AM1(A%(0),B(0),C$)
3300       A%(1) = 0: CALL AM1(A%(0),B(0),C$)
3400    NEXT VPULSE
3500     COUNT=COUNT+1
3600 FOR JJ= 1 TO 700: NEXT JJ
3700  NEXT V
3800 SWITCH=1
3900 GOTO 5600
4000  FOR V = 1 TO NS%
4100    A%(0) = 1  ' read channel 1
4200    C$ = "h" + CHR$(0)  '
4300    CALL AM1(A%(0),B(0),C$)  'call driver
4400    PRINT "light = "; COUNT, B(0)/CALIB
4500    LIGHT(COUNT) = B(0)
4600  IF V=NS% GOTO 5200
4700       C$ = "O" + CHR$(0)
4800    FOR VPULSE = 1 TO 49    'step motor
4900       A%(0) = 1: CALL AM1(A%(0),B(0),C$)
5000       A%(0) = 0: CALL AM1(A%(0),B(0),C$)
5100    NEXT VPULSE
5200    COUNT=COUNT+1
5300 FOR JJ= 1 TO 700: NEXT JJ
5400 NEXT V
5500 SWITCH=0
5600    C$ = "O" + CHR$(0)
5700  IF H=101 GOTO 6300
5800  FOR HPULSE = 1 TO 100   ' rotate lamp 3.6 degrees
5900    A%(2) = 1: CALL AM1(A%(0),B(0),C$)
6000    A%(2) = 0: CALL AM1(A%(0),B(0),C$)
6100  NEXT HPULSE
6200 FOR JJ= 1 TO 5000: NEXT JJ
6300 NEXT H
6400  OPEN FILE$ FOR OUTPUT AS #1
6500  PRINT "writing data to disk..."
```

```
6600  FOR I = 1 TO 101*NS%
6800  PRINT #1, I, LIGHT(I)/CALIB: NEXT I
6900  PRINT "********* test complete ***********"
7000  C$ = "O" + CHR$(0)
7100  FOR I= 1 TO 10000 'return luminaire
7200  A%(3)=1:CALL AM1(A%(0),B(0),C$)
7300  A%(3)=0:CALL AM1(A%(0),B(0),C$)
7400  NEXT I
7500  C$ = "O" + CHR$(0)
7600  FOR VPULSE = 1 TO 49*(NS%-1) 'return sensor
7700  A%(0) = 1: CALL AM1(A%(0),B(0),C$)
7800  A%(0) = 0: CALL AM1(A%(0),B(0),C$)
7900  NEXT VPULSE
```

```
1 '************************************************************
2 '************************************************************
3 '      CCW45.BAS
4 '************************************************************
5 '************************************************************
10 DATA &hb8,&h59,&h47,&hcd,&h60,&h90,&h90,&hca,&h06,&h0,0
20 DEF SEG
30 APROG1$=SPACE$(15)
40 APROG2$=SPACE$(15)
50 A%=VARPTR(APROG1$):AM1=PEEK(A%+1)+PEEK(A%+2)*256
60 RESTORE 10
70 FOR A=AM1 TO AM1+10
80 READ A%:POKE A,A%
90 NEXT A
100 A%=VARPTR(APROG2$):AM2=PEEK(A%+1)+PEEK(A%+2)*256
110 RESTORE 10
120 FOR A=AM2 TO AM2+10
130 READ A%: POKE A,A%
140 NEXT A
150 POKE AM2+8,16
1000  C$ = "S" + CHR$(0):A%(2)=1:A%(3)=1:CALL AM1(A%(0),B(0),C$)
1500 FOR I = 1 TO 1250
2000  C$ = "O" + CHR$(0):A%(2)=1:CALL AM1(A%(0),B(0),C$)
2010  C$ = "O" + CHR$(0):A%(2)=0:CALL AM1(A%(0),B(0),C$)
2050 NEXT I
```

```
11 '*********************************************************
2 '*********************************************************
3 '     CW45.BAS
4 '*********************************************************
5 '*********************************************************
10 DATA &hb8,&h59,&h47,&hcd,&h60,&h90,&h90,&hca,&h06,&h0,0
20 DEF SEG
30 APROG1$=SPACE$(15)
40 APROG2$=SPACE$(15)
50 A%=VARPTR(APROG1$):AM1=PEEK(A%+1)+PEEK(A%+2)*256
60 RESTORE 10
70 FOR A=AM1 TO AM1+10
80 READ A%:POKE A,A%
90 NEXT A
100 A%=VARPTR(APROG2$):AM2=PEEK(A%+1)+PEEK(A%+2)*256
110 RESTORE 10
120 FOR A=AM2 TO AM2+10
130 READ A%: POKE A,A%
140 NEXT A
150 POKE AM2+8,16
1000  C$ = "S" + CHR$(0):A%(2)=1:A%(3)=1:CALL AM1(A%(0),B(0),C$)
1500 FOR I = 1 TO 1250
2000  C$ = "O" + CHR$(0):A%(3)=1:CALL AM1(A%(0),B(0),C$)
2010  C$ = "O" + CHR$(0):A%(3)=0:CALL AM1(A%(0),B(0),C$)
2050 NEXT I
```

```
*****************************************************************
*****************************************************************
      GRIDNASA.CMD
*****************************************************************
*****************************************************************

co1=10
co2=112
co3=15
snow__=y
bios__=n
path=""
gm=i
grmpower=n
gmmaxerrors=n
gmmaxiters=n
sm=n
maxret=10
maxrad=1.5
groname=""
groutfmt=a
gridupflag=i
grddistx=0.05
grddisty=0.05
grdyeqx=1
gxmin=-2.5
gxmax=2.5
gymin=-2.5
gymax=2.5
gldisc=n
grxcol=1
grycol=2
grzcol=3
gfunequ="z = x*x + y*y"
gfunxmin=0
gfunxmax=25
gfunxinc=1
gfunymin=0
gfunymax=25
gfunyinc=1
gfunog="OUT.GRD"
gfunab=b
gmsinp=""
gmsout="OUT.GRD"
gmsr1=1
gmsr2=32767
gmsc1=1
gmsc2=32767
gmsbaout=b
gmsnx=2
gmsny=2
gmsmtype=a
gmsmpow=2
gmsmcen=2
gmsmnx=2
gmsmny=2
gmbinp=""
gmbr1=1
gmbr2=32767
gmbc1=1
gmbc2=32767
gmbout="OUT.GRD"
gmboutfmt=b
gmbblk=""
gmminp1=""
gmminp2=""
gmmout="OUT.GRD"
gmmequ=""
gmm1r1=1
gmm1r2=32767
gmm1c1=1
gmm1c2=32767
gmm2r1=1
gmm2r2=32767
gmm2c1=1
gmm2c2=32767
gmmoba=b
xformequ="D = A + B"
gwkssf=""
griname=""
grinfmt=d
maxcol=3
```

```
***********************************************************************
***********************************************************************
       SURFNASA.CMD
***********************************************************************
***********************************************************************

co1=10
co2=112
co3=15
scrtype=a
scrwid=14
scrpos=-2,-0.75
snow__=y
bios__=n
egapal=""
path=""
plotunit=i
inname=""
inr1=1
inc1=1
inr2=32767
inc2=32767
proj=o
itb=u
ihe=y
angh=225
angv=30
oeyedist=a
dirstr="XY"
plotpen=1
cmin=-1
cmax=11
cint=1
levname=""
drawborder=y
czsfile=""
ipb=y
ipbl=n
basepen=1
obaseht=0
titstr=""
titsymnum=0
tpos=a
titang=0
titht=0.175
titpen=1
legstat=n
lpos=a
legpen=1
textfilemode=a
textfile="
font0="SET21.SYM"
font1="DEFAULT.SYM"
font2="DEFAULT.SYM"
font3="DEFAULT.SYM"
font4="DEFAULT.SYM"
axistitlesym=0
axistitlepen=1
axistitlesiz=0.15
axistitlesp=0.2
xplotax=y
xaxispen=1
xaxssym=0
xoplane=a
xoticdist=0.25
xotlfreq=4
xtlfmt=f
xtlndig=1
xtlsize=0.1
xtlangle=0
xtlsp=0.1
xtitle="LAMP AXIS (m)"
xtitsiz=0.15
xtitsp=0.2
yplotax=y
yaxispen=1
yaxssym=0
yoplane=a
yoticdist=0.25
yotlfreq=4
ytlfmt=f
ytlndig=1
ytlsize=0.1
ytlangle=0
ytlsp=0.1
ytitle="TRANSVERSE AXIS (m)"
ytitsiz=0.15
ytitsp=0.2
zplotax=y
zaxispen=1
zaxssym=0
zoplane=a
zoticdist=1
zotlfreq=5
ztlfmt=f
ztlndig=0
ztlsize=0.1
ztlangle=0
```

```
ztlsp=0.1
2w)"
ztitsiz=0.15
ztitsp=0.2
zstart=0
zend=10
sidelen=5
mapyeqx=1
ozscale=a
xyname=""
xypen=1
postname="A:I10GN070.DAT"
postcols="1,2,3"
postfmt=c
postndig=2
postsymnum=0
plht=0.1
plang=0
labline=1
plpen=1
plpos=a
postfilemode=a
postfile=""
outname="I10GN070.PLT"
outscale=1
pagepos=1,1
pftype=b
outmode=o
outndig=3
callplot=y
plotspec="PLOT.EXE"
```

```
****************************************************************
****************************************************************
      TOPONASA.CMD
****************************************************************
****************************************************************
```

```
col=10
co2=112
co3=15
scrtype=a
scrwid=14
scrpos=-1,-0.75
snow__=y
bios__=n
egapal=""
path=""
plotunit=i
inname=""
inr1=1
inc1=1
inr2=32767
inc2=32767
cmin=10
cmax=500
cint=
levname="NASA3.LVL"
maplen=5.5
mapyeqx=1
titstr="
titsymnum=0
titpos=a
titang=0
titht=0.175
titpen=1
legstat=n
legsymnum=0
legunits="data units"
legpos=a
leght=0.15
legpen=1
botstr="LAMP AXIS (m)"
lftstr="TRANSVERSE AXIS (m)"
rhtstr=""
topstr=""
btitsym=0
btitht=0.175
btitpen=1
textfilemode=a
textfile=""
font0="SET21.SYM"
font1="DEFAULT.SYM"
font2="DEFAULT.SYM"
font3="DEFAULT.SYM"
font4="DEFAULT.SYM"
borstat=y
borticpen=1
ticside="LRTB"
xxtic=0.25
xltfreq=4
xborang=0
yytic=0.25
yltfreq=4
yborang=0
borlabfmt=f
borndig=1
borlabpen=1
borht=0.1
borsymnum=0
xyname=""
xypen=1
grdpen=1
grddash=0
grdxx=n
grdyy=n
postname="\LECH\I10N0100.DAT"
postcols="1,2,3,0,0"
postincl=n
cencode=41
pcensymnum=0
cenhts=0.1
cenhtmin=0.1
cenhtmax=0.3
czmins=g
czmaxs=g
cenhtzcol=3
cenrotmode=d
cenang=0
cenpen=1
postfmt=c
postndig=2
postsymnum=0
plht=0.1
plang=0
plpen=1
plpos=a
postfilemode=a
postfile=""
lconfreq=1
```

```
lconpen=1
lcondash=0
lconhatch=0
lconbold=0
ulconpen=1
ulcondash=0
ulconhatch=0
ulconbold=0
clabfmt=f
clabndig=0
clabpen=1
clabht=0.1
crvtol=4
llmin=4
lemin=0.2
clabsymnum=0
smstat=n
tension=2
czsfile=""
outname="TEMP.PLT"
outscale=1
pagepos=2,1.35
pftype=b
outmode=o
outndig=3
callplot=y
plotspec="PLOT.EXE"
```

```
****************************************************************
****************************************************************
      NASA3.LVL
****************************************************************
****************************************************************
```

1
2
5
10
20
50
100
200
500

```
C************************************************************
C************************************************************
C     LUMCHG.FOR
C************************************************************
C************************************************************
      DIMENSION N(101), R(101), C(101)
      OPEN (UNIT=1, FILE=     'a:I05CN290.RAW')
      OPEN (UNIT=2, FILE='\LECH\I05CN29C.RAW')
      DO 400 I=1,50
      DO 100 J=1,51
 100  READ(1,*)N(J),R(J)
      DO 200 J=1,51
      C(J)=R(J)-R(51)
 200  WRITE(2,500)N(J),C(J)
      DO 300 J=1,51
 300  READ(1,*)N(J),R(J)
      DO 400 J=1,51
      C(J)=R(J)-R(1)
 400  WRITE(2,500)N(J),C(J)
 500  FORMAT (I4,1X,F7.3)
      END
```

```
C***********************************************************
C***********************************************************
C     LUMDAT.FOR
C***********************************************************
C***********************************************************
      open (unit=1, file='\LECH\I05CN29C.RAW')
      open (unit=2, file=    'A:I05CN29C.DAT')
      PI = 3.14159
      ANGLE=0.0
      H=0.0
      DO 400 I=1,50
      DO 200 J=1,51
      EXECUTE CONVERT
 200  H=H+0.05
      ANGLE = ANGLE + 2.*PI/100.
      DO 300 K=1,51
      H=H-0.05
      EXECUTE CONVERT
 300  CONTINUE
 400  ANGLE = ANGLE + 2.*PI/100.
      STOP
      REMOTE BLOCK CONVERT
      X=H*COS(ANGLE)
      Y=H*SIN(ANGLE)
      READ(1,*)SN,R
      WRITE(2,900) X,Y,R
  900 FORMAT(F6.3,1X,F6.3,1X,F7.3)
      ENDBLOCK
      END
```

```
C**************************************************************
C**************************************************************
C     LUMPRI.FOR
C**************************************************************
C**************************************************************
      OPEN (UNIT=1, FILE='A:P.RAW')
      OPEN (UNIT=7, FILE='(C)COM1')
      PI = 3.14159
      ANGLE=0.0
      DANGLE=0.0
      H=0.0
      WRITE(7,906)
      WRITE(7,910)
      DO 400 I=1,51
      DO 200 J=1,51
      EXECUTE CONVERT
 200  H=H+0.05
      ANGLE = ANGLE + 2.*PI/100.
      DANGLE=DANGLE + 3.6
      WRITE(7,905)
      WRITE(7,906)
      WRITE(7,910)
      DO 300 K=1,51
      H=H-0.05
      EXECUTE CONVERT
 300  CONTINUE
      ANGLE = ANGLE + 2.*PI/100.
      DANGLE=DANGLE +3.6
      WRITE(7,905)
      WRITE(7,906)
 400  WRITE(7,910)
      STOP
      REMOTE BLOCK CONVERT
      X=H*COS(ANGLE)
      Y=H*SIN(ANGLE)
      READ(1,*)SN,R
      WRITE(7,900) DANGLE,H,X,Y,R
      ENDBLOCK
 900  FORMAT(' ',17X,F12.1,F12.2,3F12.3)
 905  FORMAT('1')
 906  FORMAT('-')
 910  FORMAT(' ',21X,'ANGLE (deg)',2X,'RADIUS (m)',4X,'X (m)',7X,'Y (m)'
     1,3X,'FLUX DENSITY')
      END
```

```
C*************************************************************
C*************************************************************
C      LIPRI.FOR
C*************************************************************
C*************************************************************
       CHARACTER LINE*24, FN*20
       DIMENSION N(5), V(5)
       PRINT *, 'FILE NAME (EG., A:M00.PRN):'
       READ (6,800) FN
C      OPEN (UNIT=1, FILE='\LI1800\M00.PRN')
       OPEN (UNIT=1, FILE=FN)
       OPEN (UNIT=7, FILE='(C)COM1')
       WRITE(7,905)
       DO 100 I=1,7
       READ(1,800)LINE
 100   WRITE(7,850)LINE
       DO 300 J=1,40
       DO 200 K=1,5
 200   READ(1,*) N(K),V(K)
 300   WRITE(7,900) (N(K),V(K),K=1,5)
       WRITE(7,910)
       WRITE(7,905)
       DO 500 J=1,15
       DO 400 K=1,5
 400   READ(1,*) N(K),V(K)
 500   WRITE(7,900) (N(K),V(K),K=1,5)
       READ(1,*) N(1),V(1)
       WRITE(7,900) N(1),V(1)
       WRITE(7,910)
       STOP
 800   FORMAT(A)
 850   FORMAT(' ',11X,A24)
 900   FORMAT(' ',10X,5(I4,E10.3))
 905   FORMAT('-')
 910   FORMAT('1')
       END
```

```
C*************************************************************
C*************************************************************
C     PLANCK.FOR
C*************************************************************
C*************************************************************
      REAL K
      C=3.0E08
C     SPEED OF LIGHT IS 3.0E08 M/S
      PI=3.1416
      H=6.62E-34
      K=1.38E-23
      PRINT *, 'THIS PROGRAM FINDS RADIANT ENERGY FLUX DENSITY FROM A '
      PRINT *, 'BLACKBODY INTEGRATED OVER A WAVELENGTH RANGE'
      PRINT *, ' '
      PRINT *, 'INPUT BLACKBODY TEMPERATURE (C)'
      READ (5,*) T
      T=T+273.
      PRINT *, ' '
      PRINT *, 'INPUT LOWER RANGE OF WAVELENGTH (NM)'
      READ (5,*) W1
      W1=W1 * 1.0E-09
      F1=C/W1
      F=F1
      WF=2.0*PI*H/C**2*F**3/(EXP(H*F/K/T)-1.0)
      PRINT *, 'EQUIVALENT FREQUENCY (CYCLES/SEC) =', F1, WF
      PRINT *, ' '
      PRINT *, 'INPUT UPPER RANGE WAVELENGTHS (NM)'
      READ (5,*) W2
      W2=W2 * 1.0E-09
      F2=C/W2
      F=F2
      WF=2.0*PI*H/C**2*F**3/(EXP(H*F/K/T)-1.0)
      PRINT *, 'EQUIVALENT FREQUENCY (CYCLES/SEC) =', F2, WF
      PRINT *, ' '
      PRINT *, 'INPUT NUMBER OF INTERVALS FOR NUMERICAL INTEGRATION'
      READ (5,*) N
      W=0.0
      WF1=2.0*PI*H/C**2*F1**3/(EXP(H*F1/K/T)-1.0)
      WF2=2.0*PI*H/C**2*F2**3/(EXP(H*F2/K/T)-1.0)
      W=WF1/2.+WF2/2.
      DO 1000 NS=1,N-1
      F=F2+(F1-F2)*NS/N
      WF=2.0*PI*H/C**2*F**3/(EXP(H*F/K/T)-1.0)
1000  W=W+WF
      W=W*(F1-F2)/N
      PRINT *, 'TOTAL FLUX DENSITY =',W,' WATTS/M2'
      END
```