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EMULSION CHAMBER TECHNOLOGY

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EMULSION CHAMBER TECHNOLOGY

REPORT (UAH)

1. INTRODUCTION - OBJECTIVES AND THE PLANNED ANALYSES

The original purpose of the ECT mission is **to assess the major uncertainties of a space exposure of large amounts of emulsions** through the early flight of a small emulsion chamber. Verification of the effectiveness of the emulsion chamber technology in space is vital for possible large-scale cosmic ray experiments on STS flights and on Space Station platform. The secondary objective is **to obtain radiation data** for studying the effects of shielding on the penetrative particles of interest, utilizing the emulsion chamber's self-shielding materials much greater than the maximum value in ordinary manned space vehicles (e.g., the STS and the Space Station).

The following components were defined in the original ECT plan as essential objectives of the ECT experiments and the analysis (Critical Design Review UAH-ECT-001, May 24, 1991):

1. Assessment on the effectiveness of the X-ray film density-mapping and densitometry.
2. Event Tracing.
3. Vertex analysis.
4. Energy analysis of the traced events.
5. Measurements of the density for background tracks, chemical fogs, and evaluate the degree of contrast for track recognition.
6. Track densities.
7. LET spectra.
8. Take pictures of track conditions in emulsions and x-ray films.
9. Highly-ionizing tracks by CR-39 etch-pit data.
10. Dosimetry assessment.

2. STATUS - ANALYSES PERFORMED

Most of the X-ray films and emulsions analyses planned in the original proposal have been performed. CR-39 plates have not yet been analyzed, due to etching schedule shift in borrowing facilities at other institutions.

1. Assessment on the effectiveness of the X-ray film density- by mapping and densitometry.

While ~1000 events were typically observed in one block of an emulsion chamber in the Antarctic 10-day flight (JC-12), the number of events recorded in the ECT experiment would be similar, if the flight attitude is kept for deep-space orientation for almost 10 days. The STS-62 had only a part of deep-space exposure and the most of the flight time was earth-facing. Cosmic rays were therefore entering the ECT from the bottom through the STS Bay floor, and the number of energetic events are expected to be notably reduced. In fact, the observed number of events above a detection thereshold of about 3 TeV was about 400 events, or 40% of expectation for full-time deep-space exposure. The scanning and analysis work on this point have been made at the UAH Cosmic. Ray Laboratory by using a in-house photometer.

A comparison of the ECT data with the balloon-borne emulsion chamber was made for the track densities in the calorimeter. The ECT data generally showed an increase of the density with the increasing thickness of the absorber materials in the calorimeter up to the middle of the chamber. Then, it decreases toward the

bottom of the ECT box. However, the track densities in the JACEE-12 Antarctic balloon-borne chamber continued to increase with the increasing shield thickness to the bottom. This result is very instructive for the future shield design in the sense that **the shower particles increase with increasing shield thickness.**

2. Event Tracing:

20 high energy events were traced in emulsions with an optical microscope. Several of them were identified as those from the "correct" direction (from space and from the top of the ECT).

About 10 events were identified as "inverse direction" (incidence from the cargo bay side and from the bottom of the ECT). The development of cascade showers in the calorimeter efficiently allowed a unique and definitive identification of the incident direction of the high energy cosmic ray tracks.

3. Vertex analysis:

A few events to evaluate any difficulties in fully analyzing the details of nuclear interactions induced by cosmic rays

4. Energy analysis of the traced events:

Measurements of electron density in the shower events have been made by optical densitometry of cascade showers on X-ray films. All 33 layers in the calorimeter were measured for a total number of about 300 high energy events. A slit size of 250 microns were used for the CCD photometry, using the Olympus-

GALAI"s CUE-2 software. The shower curve fit and energy assignments for each events can now be made by using the spot densitometry data. The photometry data for all the shower spots and nearby backgrounds at each X-ray films are stored in PC harddisc at the directory of VISDATA.

5. Measurements of the density for background tracks, chemical fogs, and evaluate the degree of contrast for track recognition.

Data on these quantities have been btained by
- Raster scanning and
  - Automatic (CUE-2) object density measurements - at every few layers

6. Track densities:

- Measured track densities in 7B and 6B
  - Counted and recorded the number of straight tracks in the field of view
- Estimated the density of δ-rays and Comptons (Knock-on electrons by X-rays).
  - Measured in several plates and compared at the center and at the edges
  - Compared the data with those of the Antarctic balloon flight data

7. LET spectra:

Measured at 3 different levels of absorptive materials.

8. Take pictures of track conditions in emulsions and x-ray films:

Beautiful tracks were photographed from emulsions, visualizing the successful exposure of the ECT and a proof of excellent detector quality in space-flight environment.

9. **CR-39:**
Plates should be cut in quarters. Etching in NRL (Jim Adams)'s lab; Etching will be completed by the end May.

10. **Dosimetry detectors:** Being undertaken by USF (separate report). Small pieces of CR-39 were snapped out and sent to SF along with TLD's.

3. PLAN OF WORK - ANALYSES CONTINUED

Since the mid-term review (October, 1994), the mapping and CCD photometry of about 400 events were made. About 20 more events are to be traced to fulfill the original goal for emulsion work, which is now planned for completion during May - August, 1995. Densitometry of all registered shower events in many X-ray films have been performed since the last fall (Mid-Term Review) and most of the data are presently available

Background density and LET's are available at three layers. Comparisons of them with JACEE-12 Antarctic data are also available.

What were still missing are

ITEMS **2., 3., 4.**, and **9**. in the original goals.

Among these, the ITEMS **2 - 4** do not require any preparations. 9 requires etching at NRL in March.

The CR39 dosimetry (which is USF task) will not be envisaged in this part of the report.

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EMULSION CHAMBER TECHNOLOGY

REPORT (UAH)

SUMMARY OF THE ANALYZED DATA

- **1. PHOTOGRAPHIC MATERIALS: X-RAY FILMS & EMULSIONS**

  INITIAL ANALYSIS COMPLETE

- **2. EVENT TRACING**

  20 HIGH ENERGY EVENTS TRACED, SHOWING INCIDENCE FROM BOTH TOP AND BOTTOM OF THE CHAMBER

- **3. COMPARISONS WITH BALLOON EXPERIMENTS AND PRE-FLIGHT ESTIMATE OF BACKGROUND**

  MEASUREMENTS DONE. DATA COMPARISONS TO BE MADE.

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1. X-RAY FILMS

- **GENERAL CONDITION:** ***EXCELLENT,*** NO DETERIORATION IN THE FLIGHT.

  BACKGROUND DENSITY (D = 0.15 - 0.50) AS GOOD AS THOSE OF ANTARCTIC BALLOON DATA.

- **ANALYSIS:**

  GENERAL DENSITY MEASUREMENTS WERE DONE WITH ***CCD PHOTOMETER***

- **ANALYZED LAYERS:** C1, C2, C3, C4, C5, C9, C12, C15, C18, C21, C24, C27, C30, C33, C35

- **LOCATION OF THE POINTS FOR ANALYSIS:** EVERY 2 INCHES IN X- AND Y-COORIDNATES (11 IN X- AND 9 IN Y-DIRECTION)
- **RESULTS:** CLOSE TO EXPECTED FOR CASCADE DEVELOPMENTS

  (C1 -> C30, INCREASE) EXCEPT AT C30 - C35 (LOWER THAN EXPECTED), PERHAPS DUE TO LONGER DURATION OF INVERSE EXPOSURE DURING THE FLIGHT

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2. EMULSIONS

- **GENERAL CONDITION:** ***EXCELLENT***

- **ANALYSIS:** ***FOG*** MEASUREMENTS, ***GRAIN*** COUNTS,
  LINEAR ENERGY TRANSFER (LET) SPECTRUM,
  HIGH ENERGY ***EVENT-TRACING***

- **ANALYZED LAYERS:** P-03, P-69, C-35 FOR GENERAL MEASUREMENTS,
  ALL LAYERS FOR EVENT-TRACING

- **RESULTS:** ***GOOD TO EXCELLENT.***

GRAIN DENSITY/FOG DENSITY:

FLIGHT DATA	***GROUND DATA***
(26.1 - 32.4/100μm)/[1.49 - 1.71/1000μm^3]	(32.4/100μm)/[1.24/1000μm^3]

Cf. Berriman Curve:

BACKGROUND TRACK DENSITY: (2.5 - 4.3) X 10^5 / CM^2.

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ECT BACKGROUND MEASUREMENTS

PLATE NO.	LOCATION FROM THE TOP (g/cm^2)	DENSITY OF FOG (FOG/1000 μm^3)	GRAIN DENSITY (/100 μm)	BACK-GROUND TRACK DENSITY ($/CM^2$)
P-03	1.4	1.61 ± 0.14	26.09 ± 4.20	(4.30 ± 0.16) x 10^5
P-69	16.7	1.49 ± 0.14	30.93 ± 2.96	(3.56 ± 0.36) x 10^5
C-35	94.5	1.71 ± 0.15	31.37 ± 2.80	(2.53 ± 0.27) x 10^5
CONTROL	GROUND	1.24 ± 0.13	32.42 ± 1.92	(4.18 ± 1.92) x 10^4

MEASURED SPOT: CENTER OF THE PLATE

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LIST OF EVENTS IN TEST TRACING

EVENT NUMBER	ANGLE TAN Θ	PRIMARY ELEMENT	VERTEX OF INTERACTION	TARGET	REMARKS
ECT #1	1.60	-	-	-	INVERSE
ECT #2	0.70	-	-	-	INVERSE
ECT #3	0.36	-	-	-	INVERSE
ECT #4	0.72	-	OUTSIDE-	LID-	
ECT #5	0.38	-	OUTSIDE	SIDEWALL	
ECT #6	1.13	PROTON	P30/P31	LEAD	
ECT #7	2.16	PROTON	P69/C00	SS PLATE	
ECT #8	1.00	HELIUM	P01	LUCITE	

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LIST OF THE DATA FIGURES

1. Bar Histogram of **track area-size** in emulsions: For layers P03, P45, C18 and C35 (ECT)

2. Bar Histogram of **track area-size** in emulsions: For layers P04, P20, C10 and C21 (JACEE)

3. **Berriman Curve and the Data:** All the emulsion data proved **EXCELLENT** for track recognition (area above the solid curve).

4. **Integral Linear Energy Transfer Spectrum :** **(a)** ECT at P03 layer, 1.4 g/cm^2
   (b) ECT at P69 layer, 16.7 g/cm^2
   (c) ECT at C35 layer, 94.5 g/cm^2
   (d) JACEE at P01 layer, 1.5 g/cm^2
   (e) JACEE at C22 layer, 70 g/cm^2

5. **Iso-Density Data on X-ray films:** **ECT** layers, C1, C4, C12, C18, C24, C30, C33, C35

6. Photographs of tracks in emulsions: CCD snapshot with a microscope (x 1,000, blue) and CUE-2 object data-taking by grey-thresholding

7. Object data in CCD-microscope measurements: Color (Area-size), Black Arrow (Orientation)

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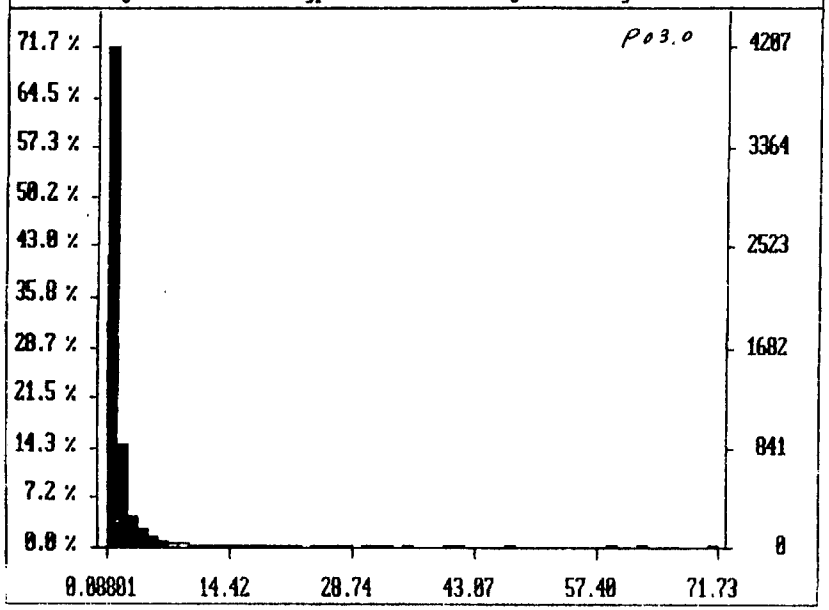
8. Photographs of high energy cascade showers in the ECT calorimeter:
Frames taken from the layers, P01, P03, P21, P69, C01, C05, C11, and C13 from top left -> right -> next left -> ...). Very clear profiles of developing shower at very high energy ($E > 5 \times 10^{14}$ eV) are obtained with the ECT flight.

9. Photographs of a high energy cascade shower that develops inversely in direction. This demonstrates high energy cosmic ray event entered into the bottom of the ECT chamber after passing through the Shuttle's Cargo Bay Floor during earth-facing peroiod. Top-left (C10), top-right (C18), bottom-left (C25), and bottom-right (C35). The layer C35 (botoom of the cahmber) shows a young shower (narrowly collimated), the C25 shows the shower maximum, the C18 indicates aged (spreaded and weakening) shower profile, and the C18 illustrates the end of the shower (widely scattered and absorbed).

ECT

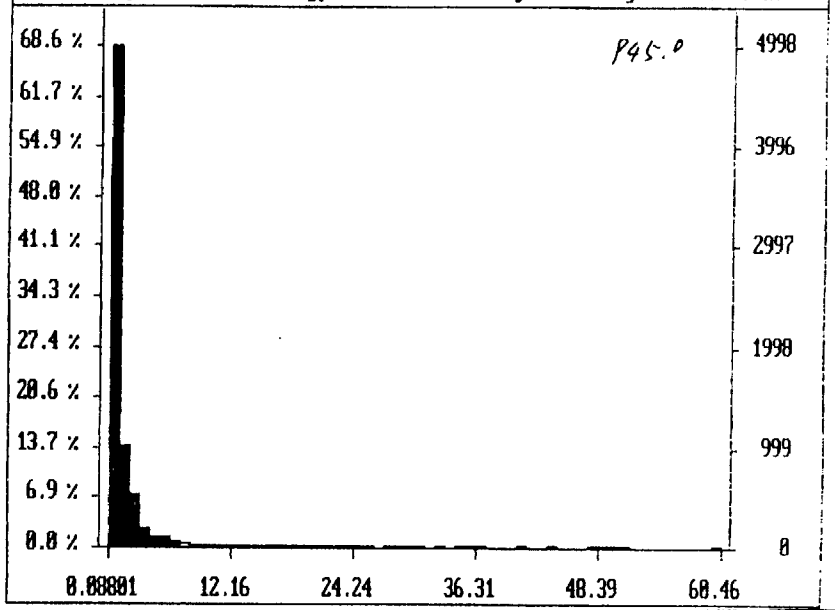
Bar Histogram of Area

Units: Microns | No.of pictures: 10 | Average : 1.70 ± 3.34
Total objects: 5869 | Type: All | Object density: 3.59E+06/Cm²



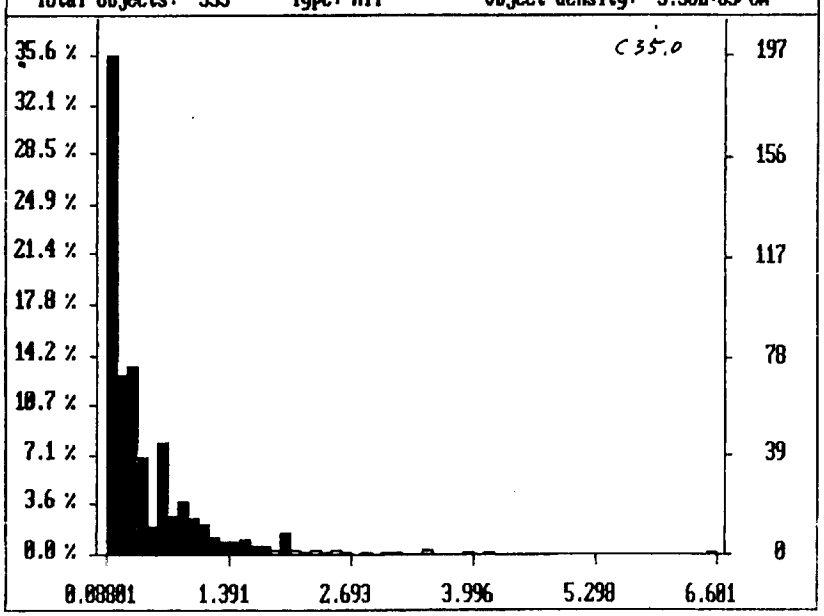
Bar Histogram of Area

Units: Microns | No.of pictures: 10 | Average : 1.63 ± 3.12
Total objects: 7200 | Type: All | Object density: 4.46E+06/Cm²



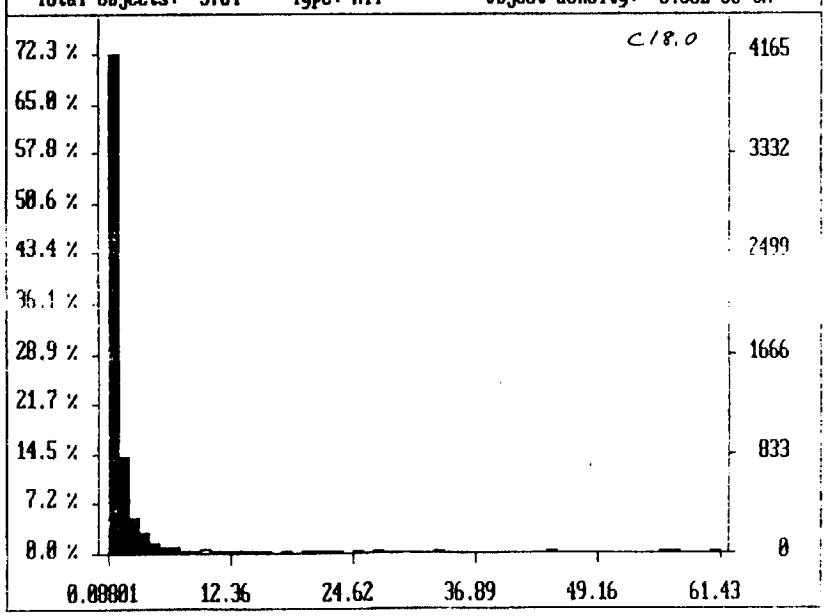
Bar Histogram of Area

Units: Microns | No.of pictures: 10 | Average : 0.5403 ± 0.6361
Total objects: 553 | Type: All | Object density: 3.38E+05/Cm²



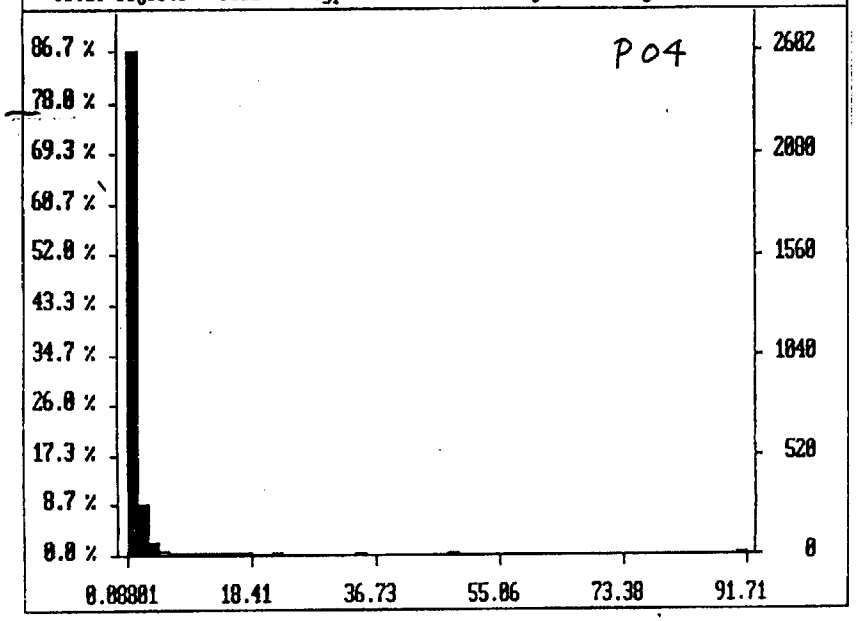
Bar Histogram of Area

Units: Microns | No.of pictures: 10 | Average : 1.34 ± 2.33
Total objects: 5764 | Type: All | Object density: 3.53E+06/Cm²



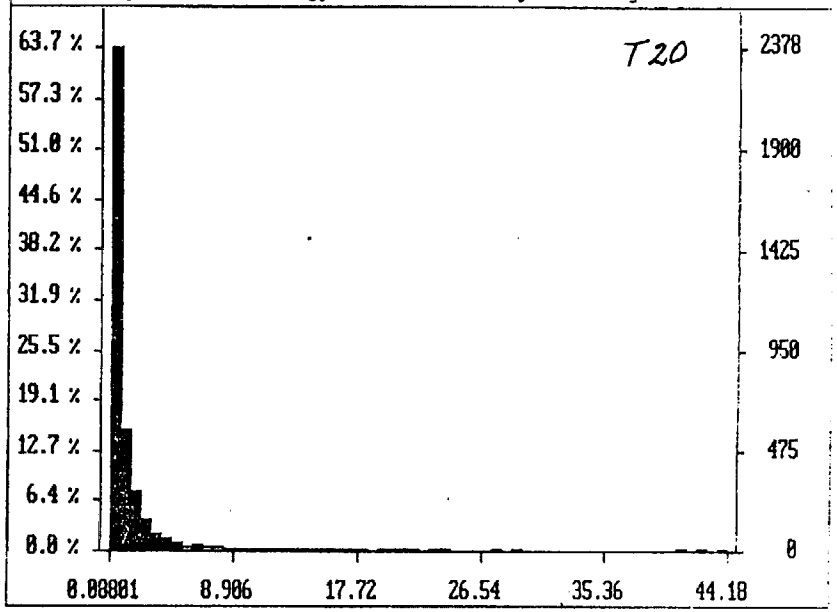
Bar Histogram of Area

Units: Microns | No.of pictures: 10 | Average : 1.28 ± 2.44
Total objects: 3002 | Type: All | Object density: 1.84E+06/Cm²



Bar Histogram of Area

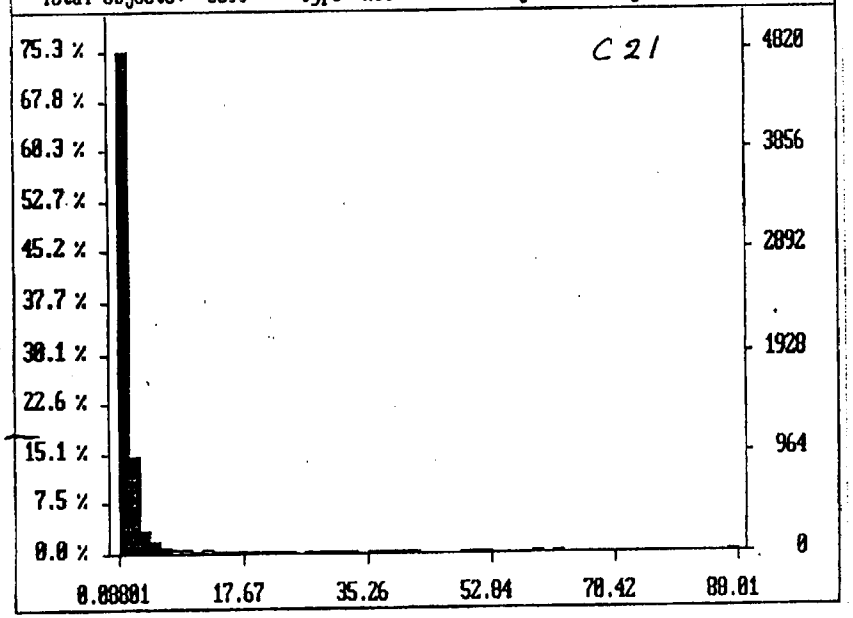
Units: Microns | No.of pictures: 5 | Average : 1.40 ± 2.68
Total objects: 3732 | Type: All | Object density: 4.57E+06/Cm²



BALLOON

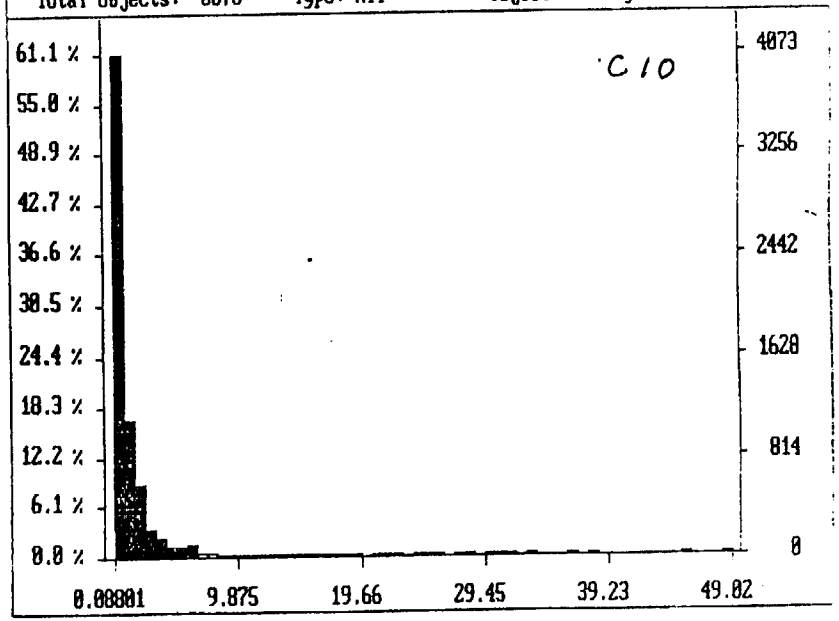
Bar Histogram of Area

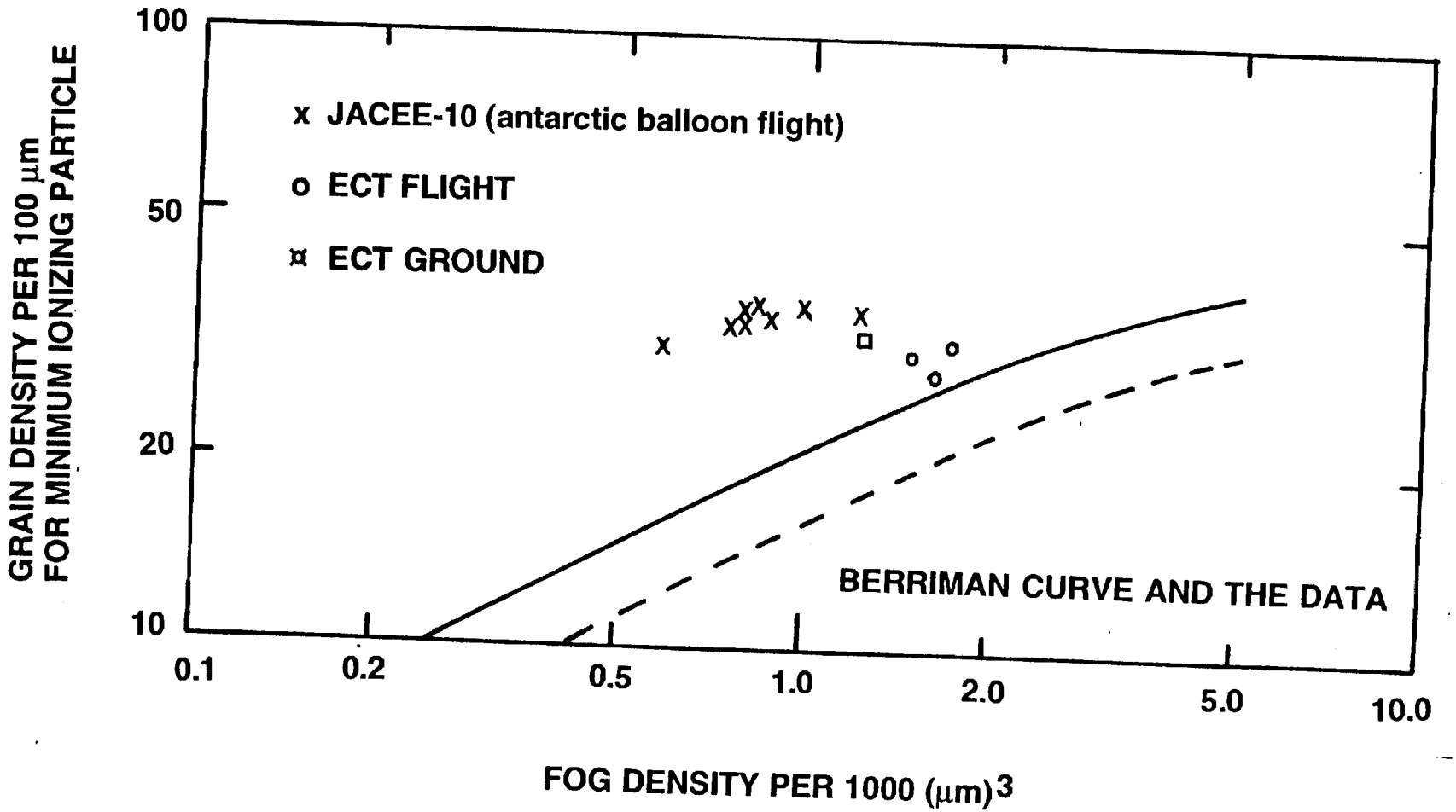
Units: Microns | No.of pictures: 10 | Average : 1.79 ± 3.40
Total objects: 6399 | Type: All | Object density: 3.91E+06/Cm²



Bar Histogram of Area

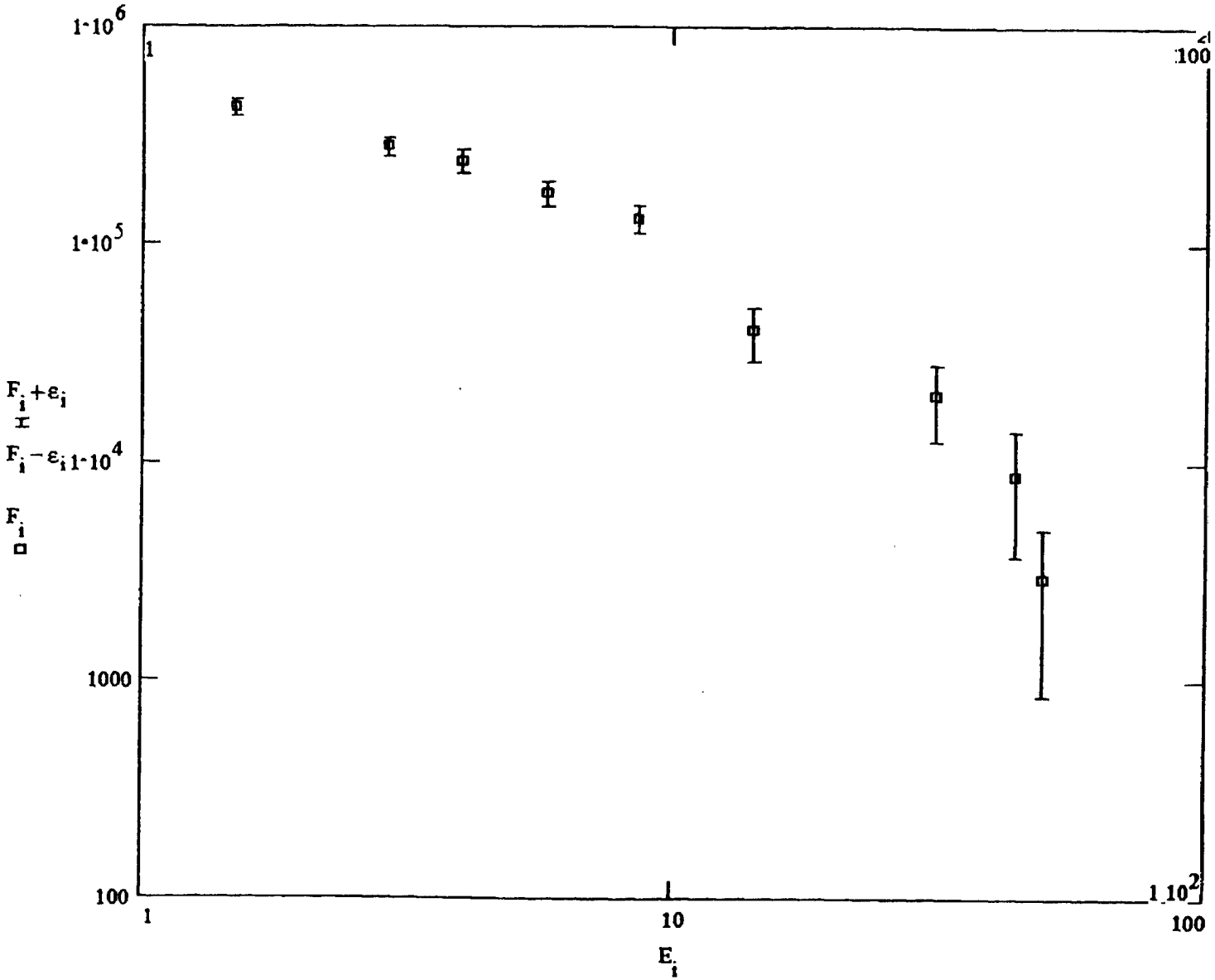
Units: Microns | No.of pictures: 9 | Average : 1.57 ± 2.80
Total objects: 6670 | Type: All | Object density: 4.53E+06/Cm²




GRAIN DENSITY PER 100 μm
FOR MINIMUM IONIZING PARTICLE
100
50
20
10
x JACEE-10 (antarctic balloon flight)
o ECT FLIGHT
¤ ECT GROUND
BERRIMAN CURVE AND THE DATA
0.1
0.2
0.5
1.0
2.0
5.0
10.0
FOG DENSITY PER 1000 (μm)3

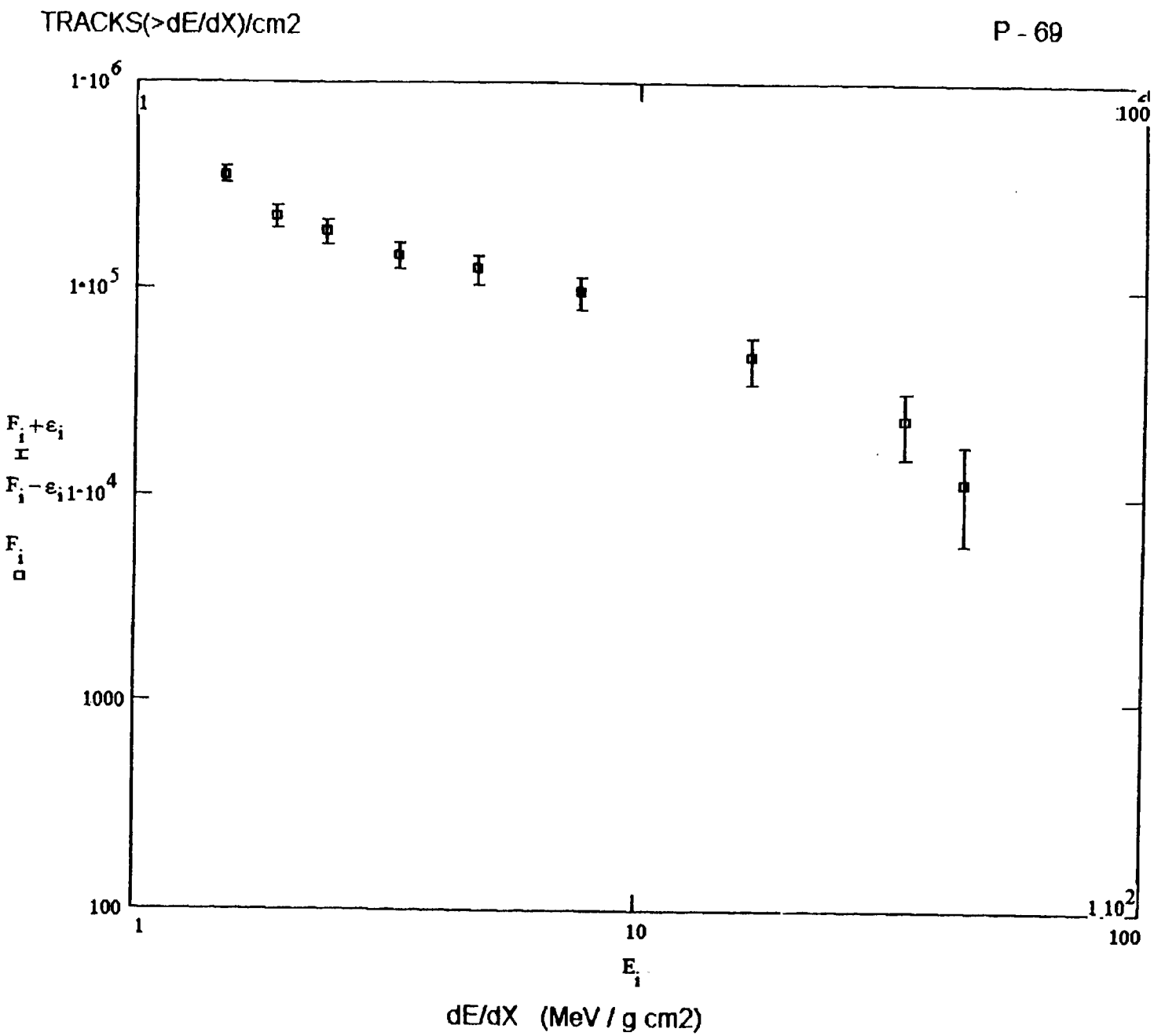
TRACKS(>dE/dX)/cm2

P - 03

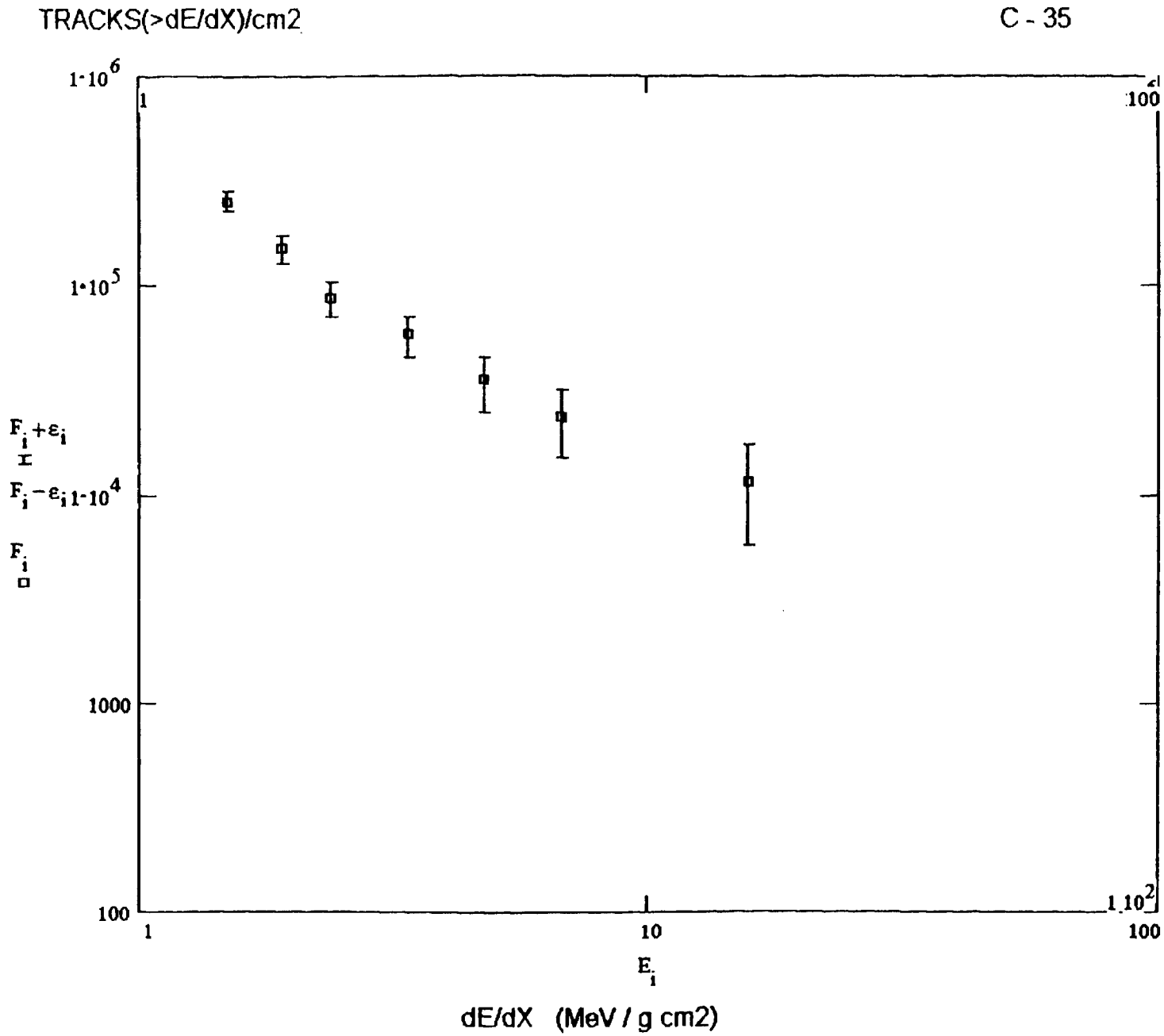


dE/dX (MeV / g cm2)

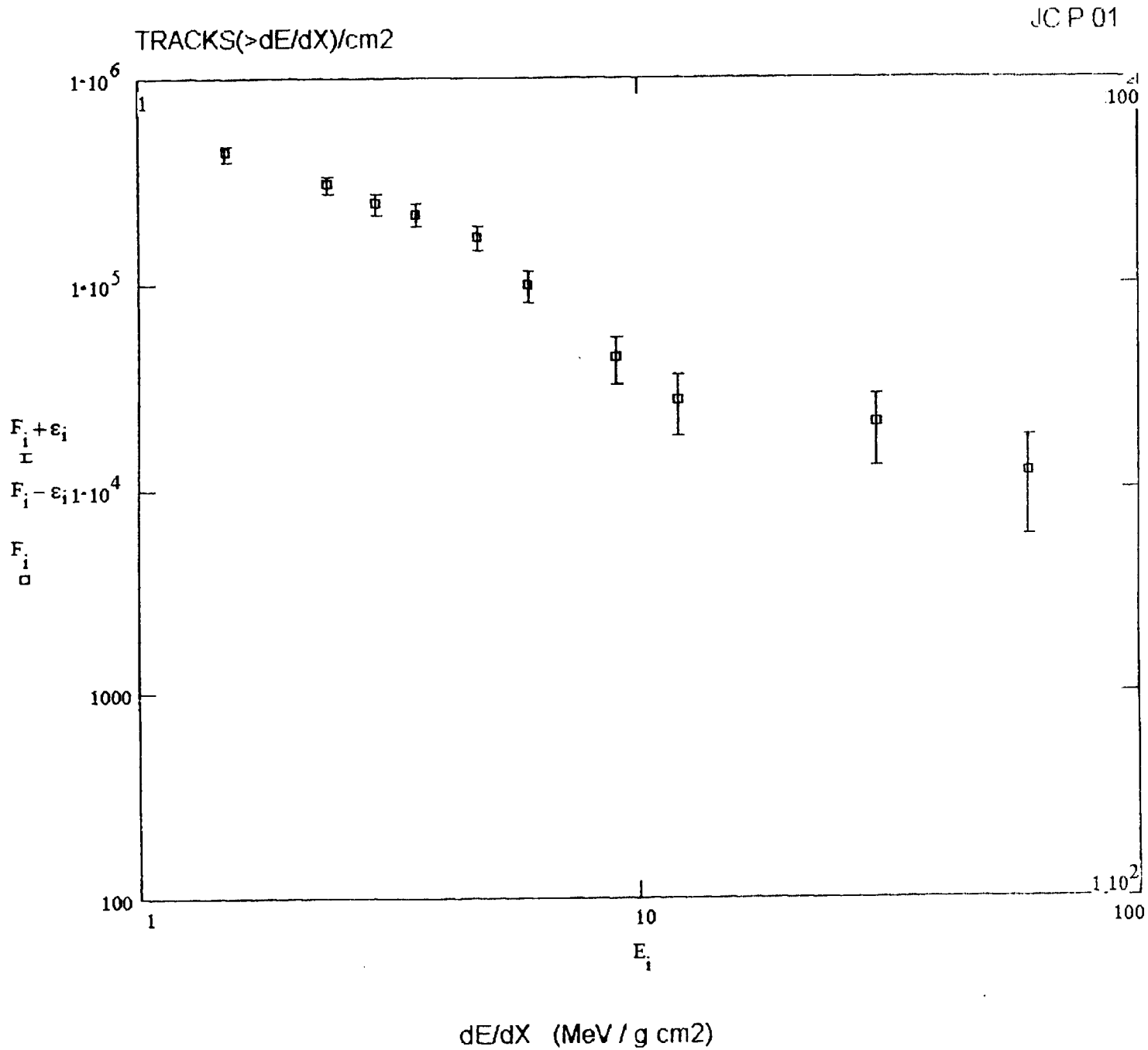
Integral Linear Energy Transfer Spectrum
in the emulsion plate located 1.4 g/cm2
from the top of ECT chamber



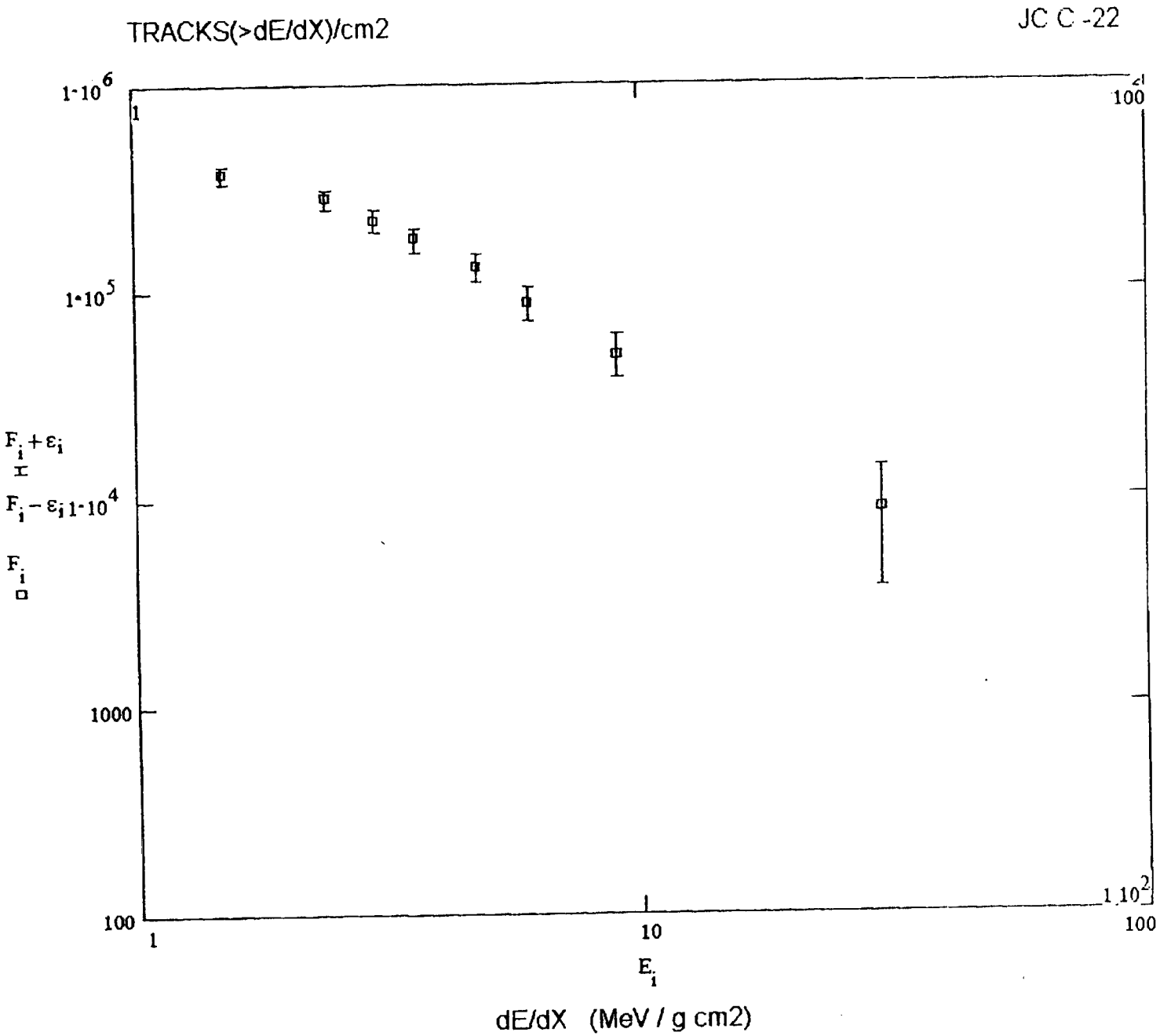
Integral Linear Energy Transfer Spectrum
in the emulsion plate located 16.7 g/cm2
from the top of ECT chamber



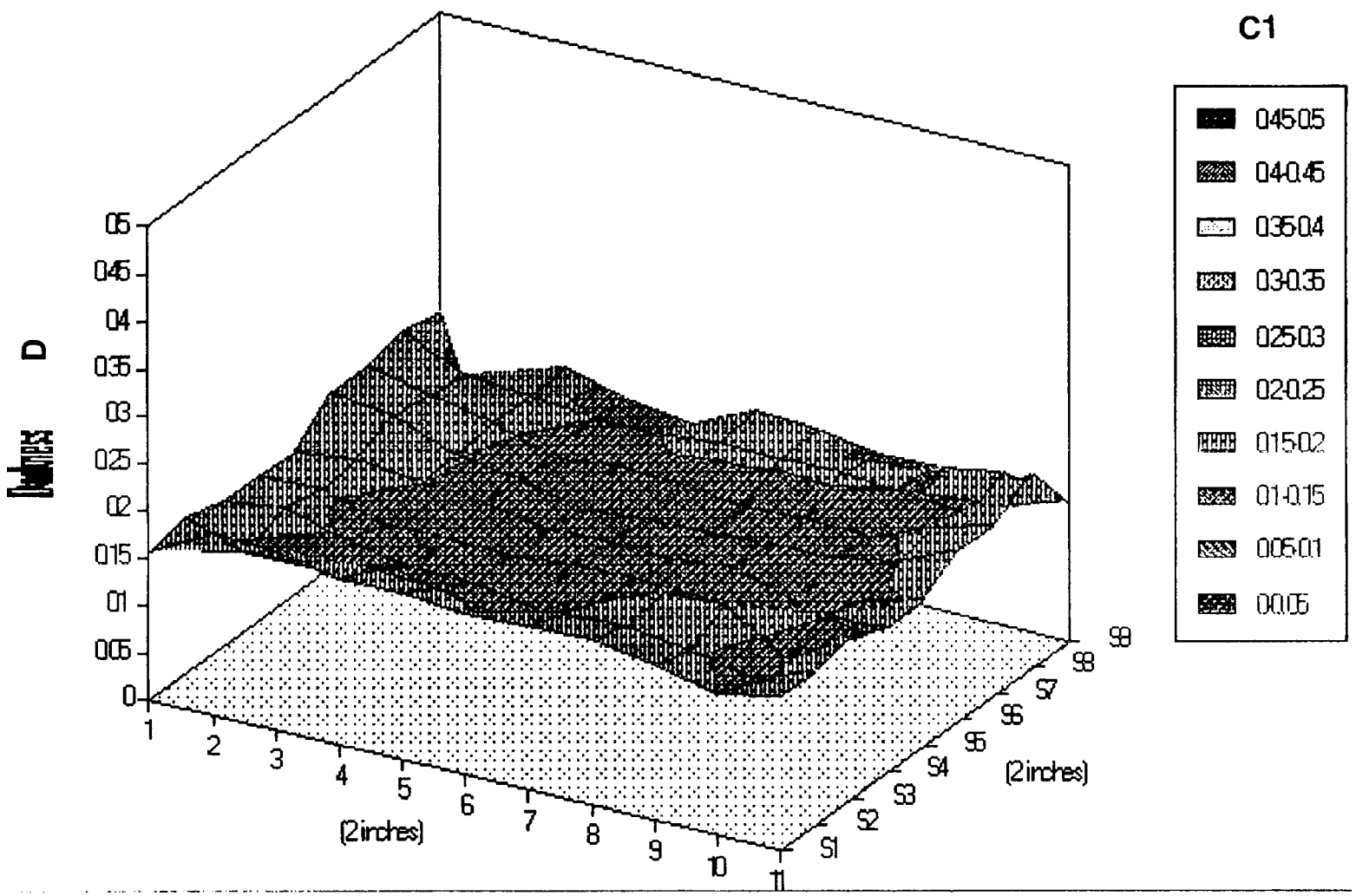
Integral Linear Energy Transfer Spectrum
in the emulsion plate located 94.5 g/cm2
from the top of ECT chamber

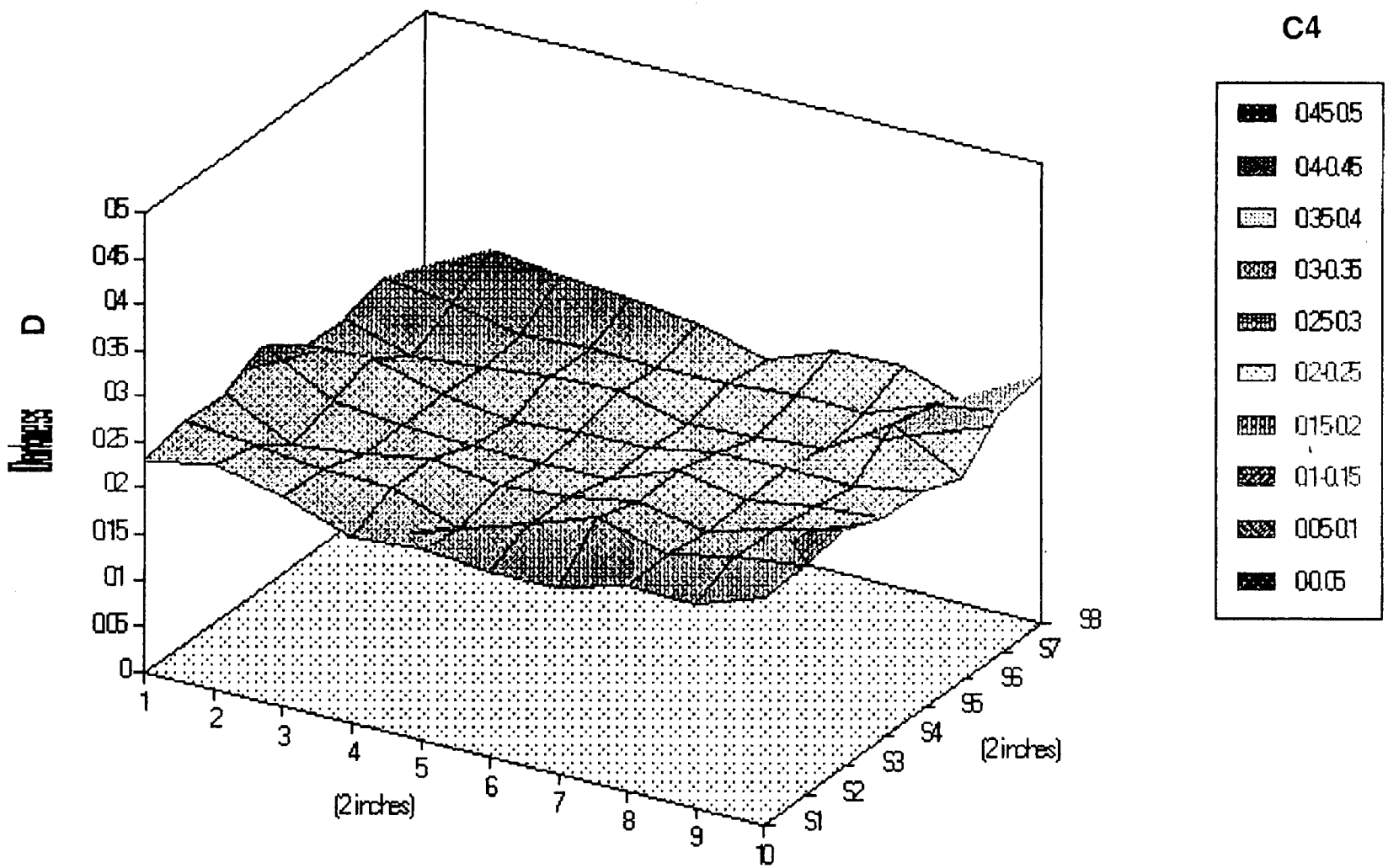


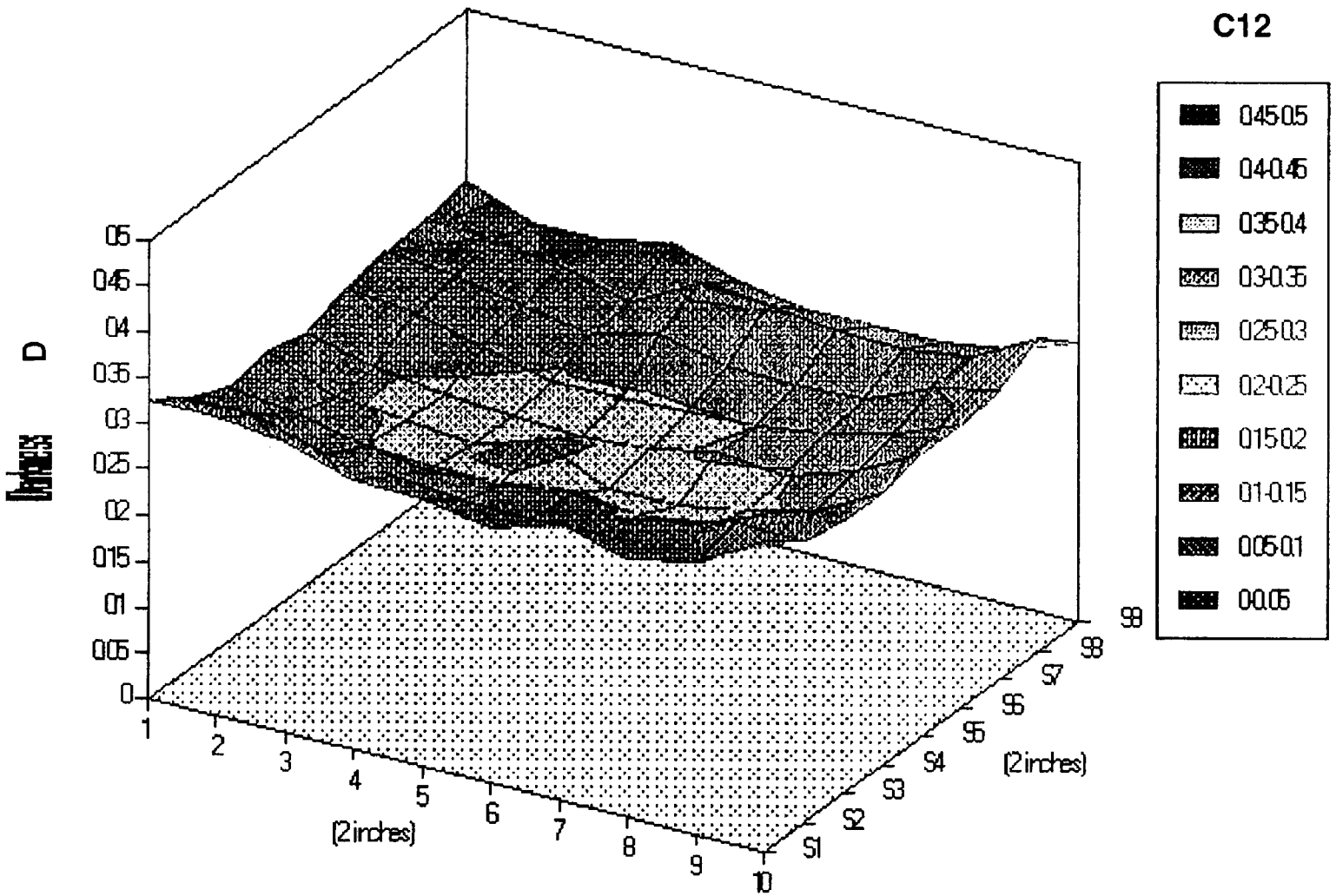
Integral Linear Energy Transfer Spectrum
in the emulsion plate located about 1.5 g/cm2
from the top of JACEE chamber

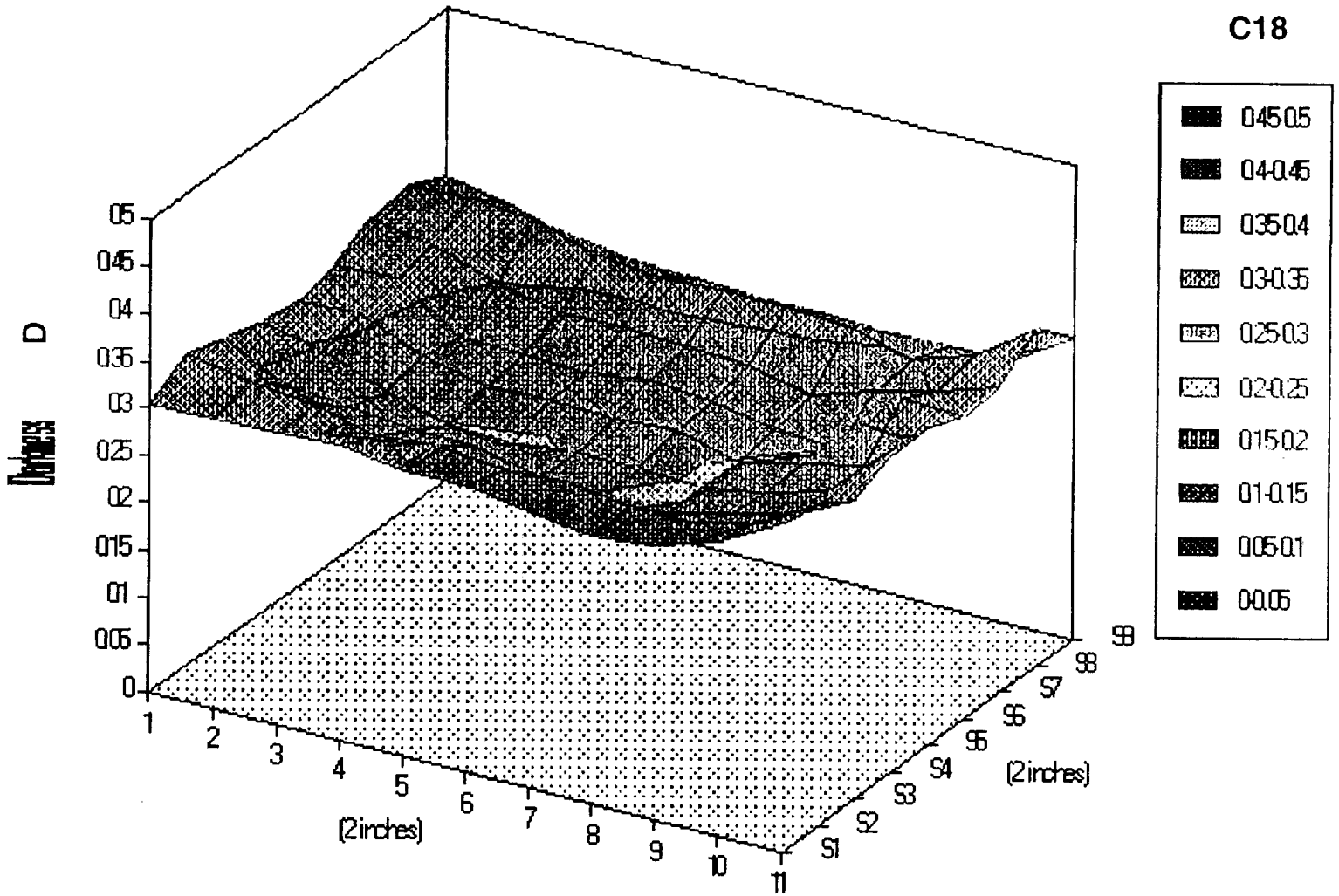


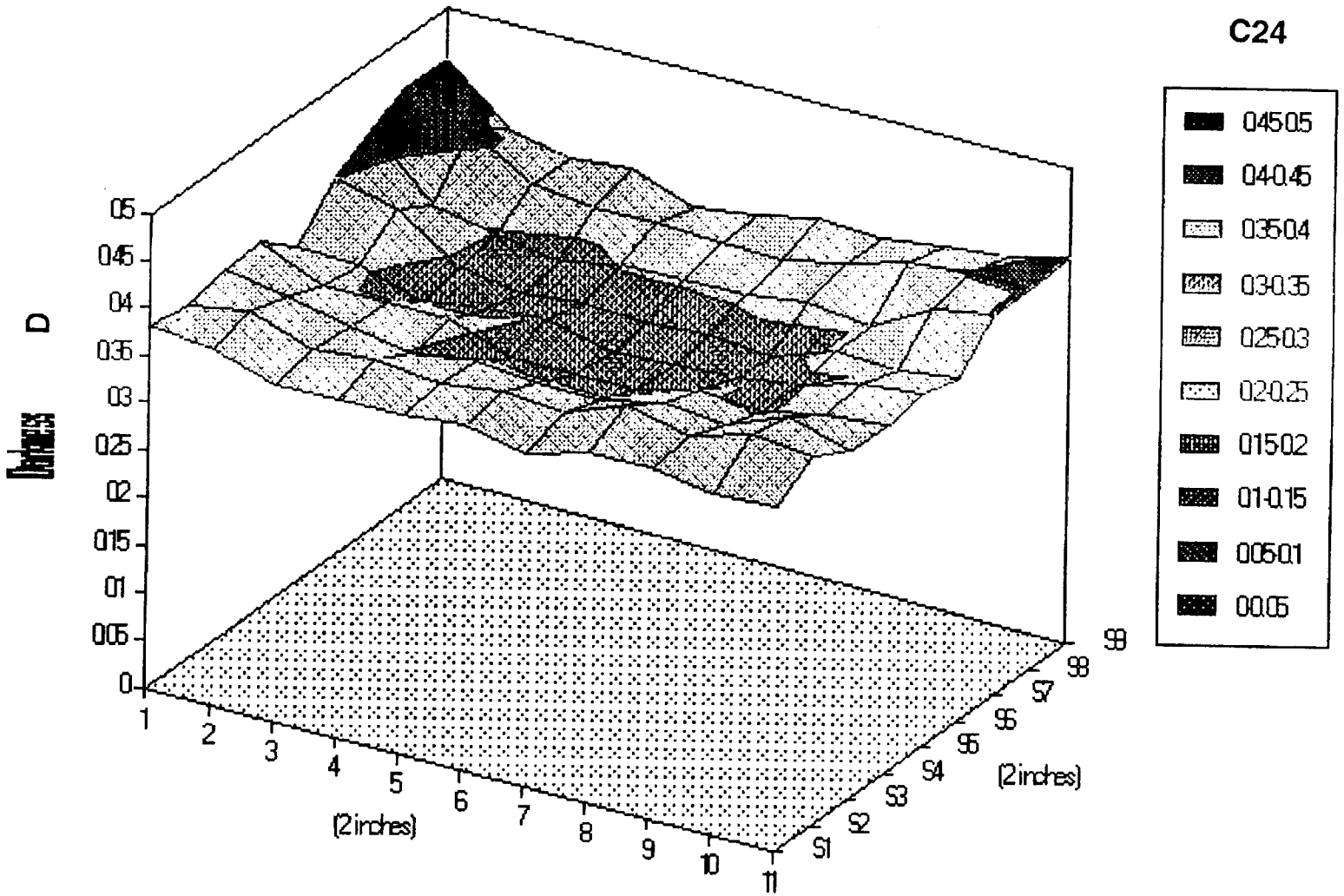
Integral Linear Energy Transfer Spectrum
in the emulsion plate located about 70 g/cm2
from the top of JACEE chamber

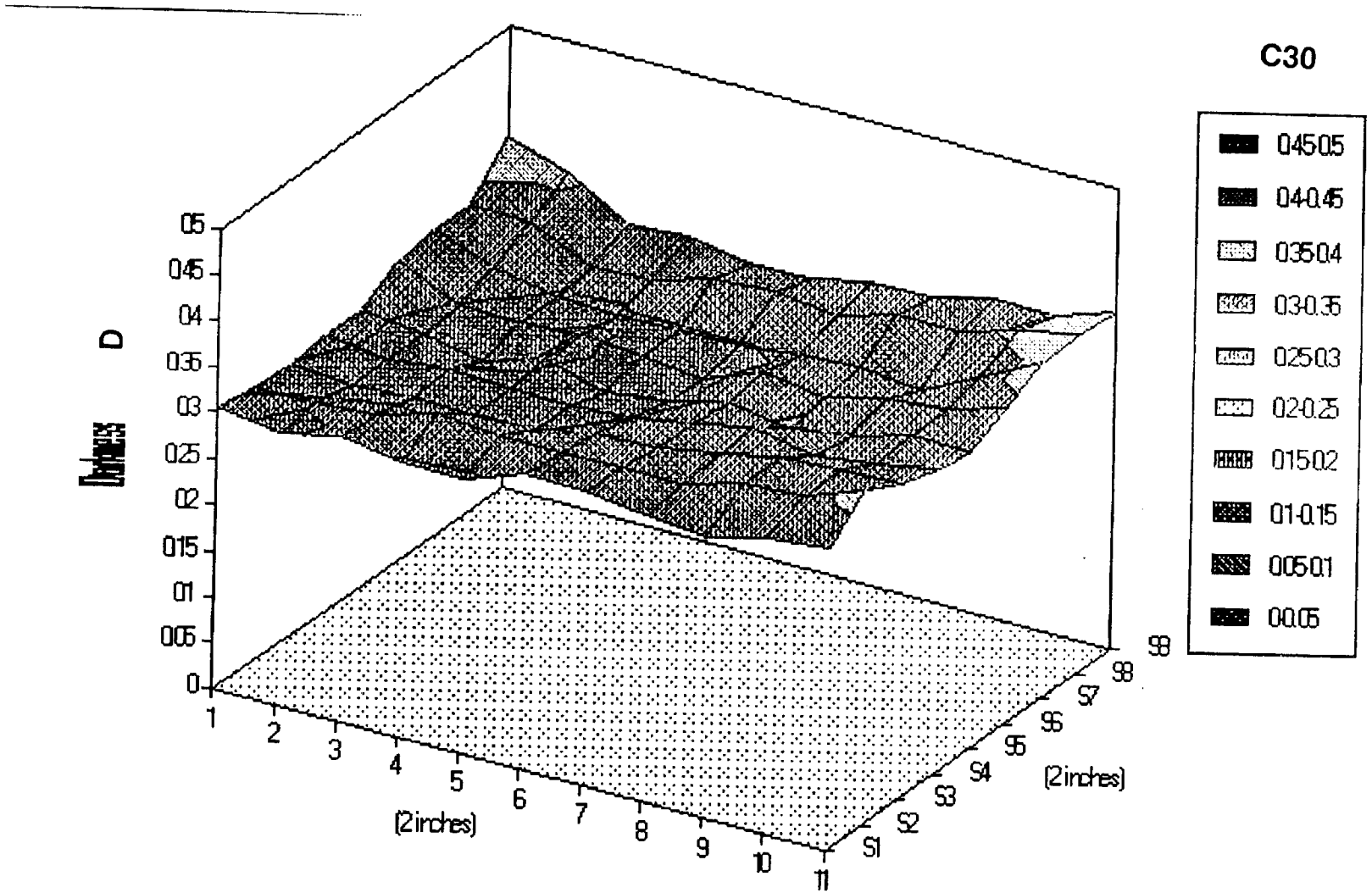

C1
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)

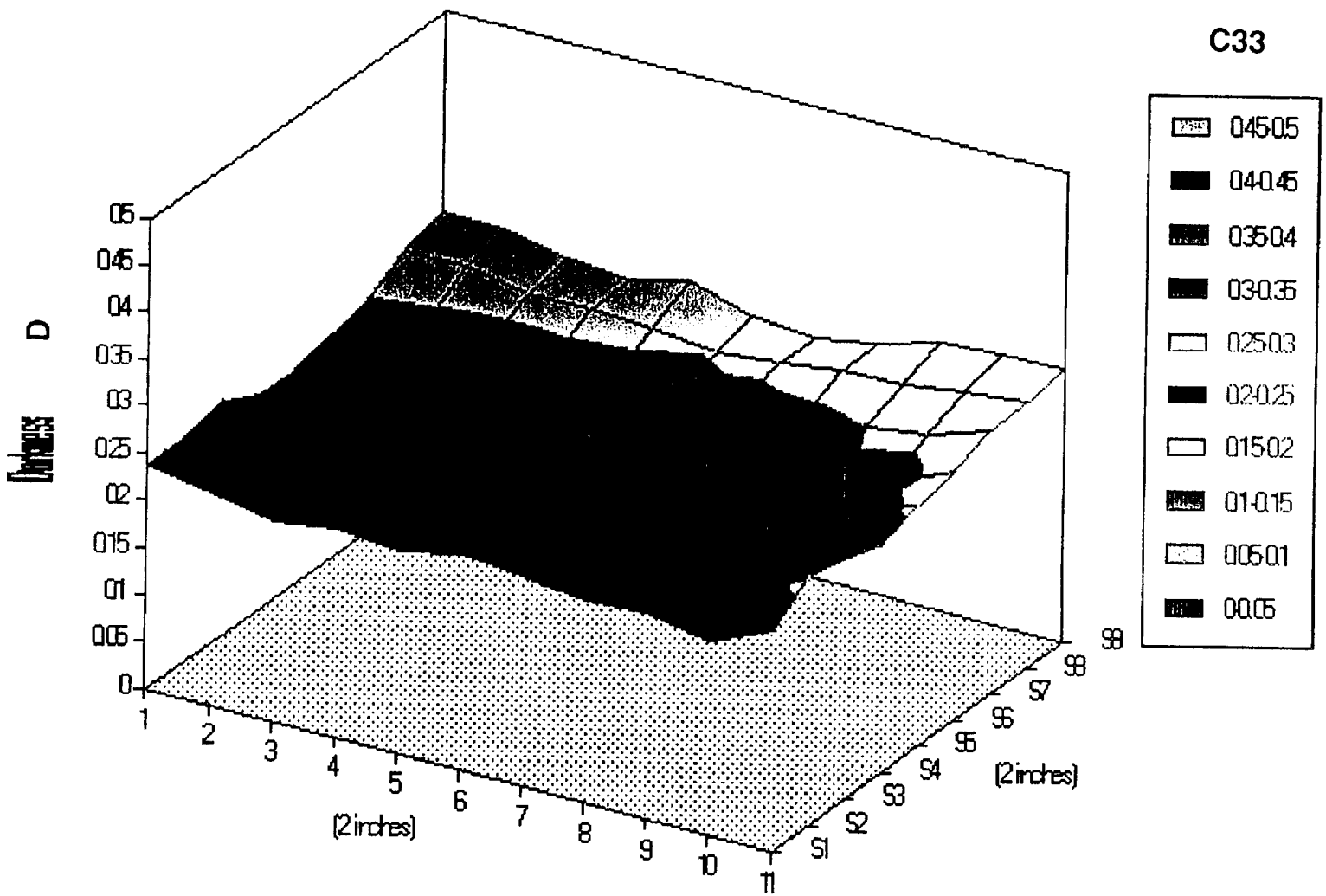

C4
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
(2 inches)

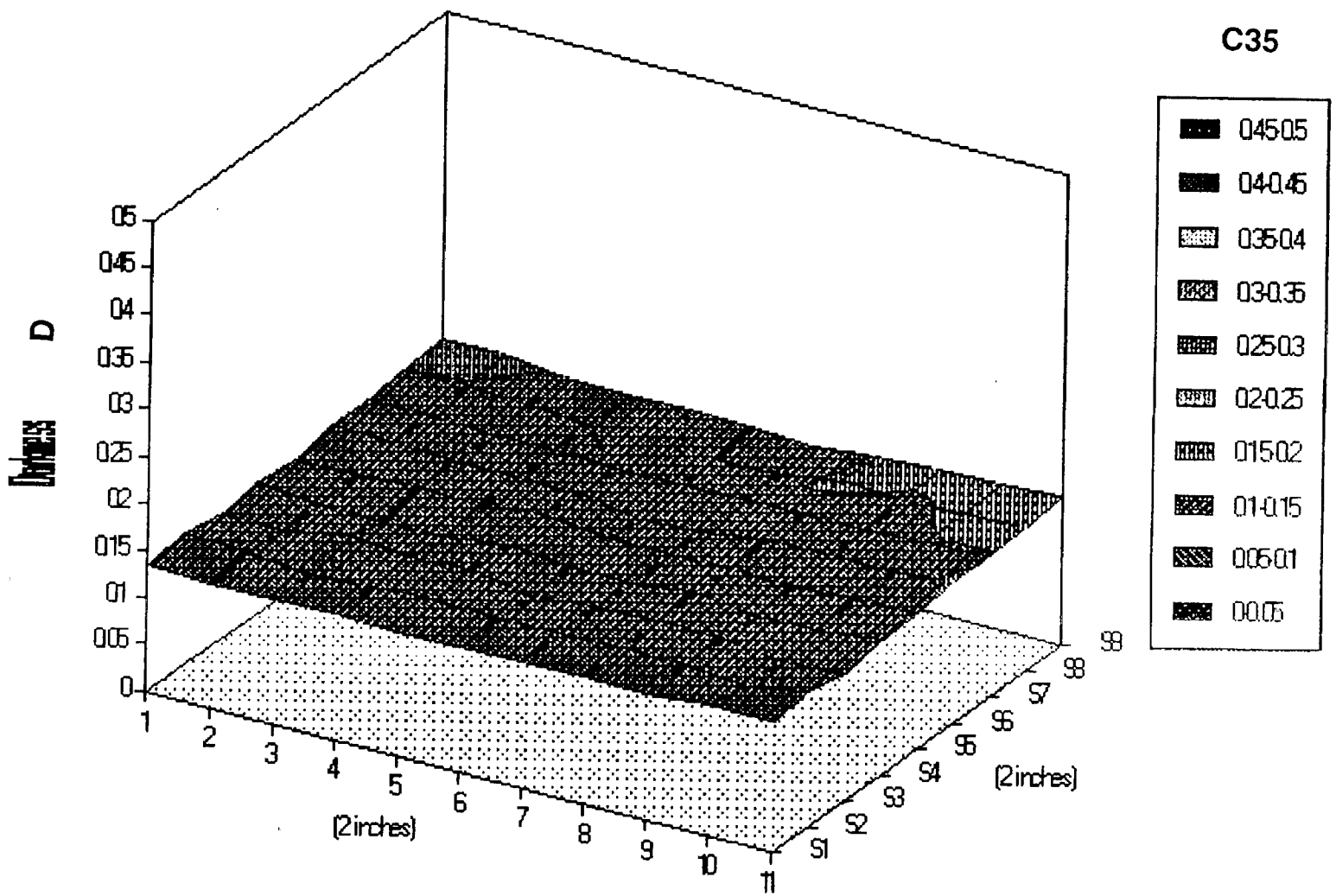

C12
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)

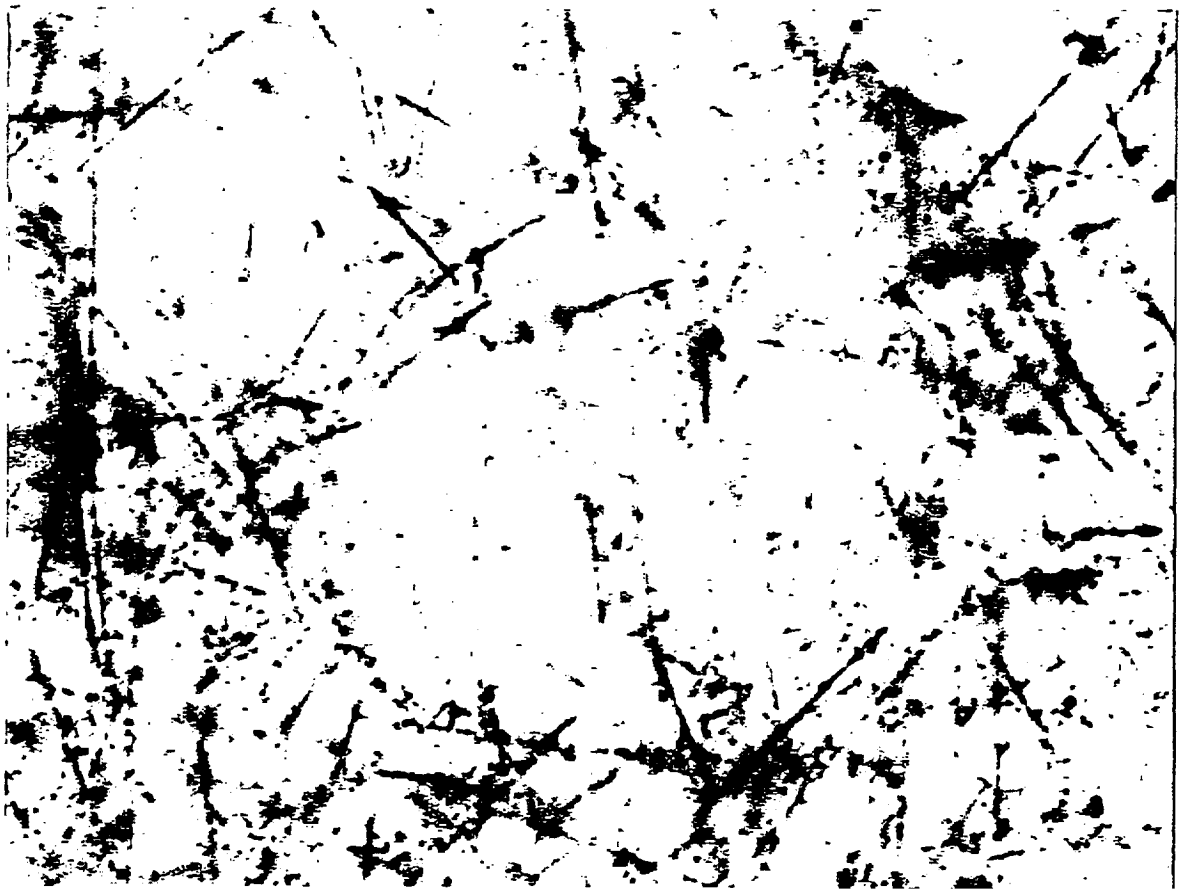

C18
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)


C24
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)


C30
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
Deflection D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)


C33
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)


C35
0.45-0.5
0.4-0.45
0.35-0.4
0.3-0.35
0.25-0.3
0.2-0.25
0.15-0.2
0.1-0.15
0.05-0.1
0-0.05
D
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
(2 inches)
S1
S2
S3
S4
S5
S6
S7
S8
S9
(2 inches)



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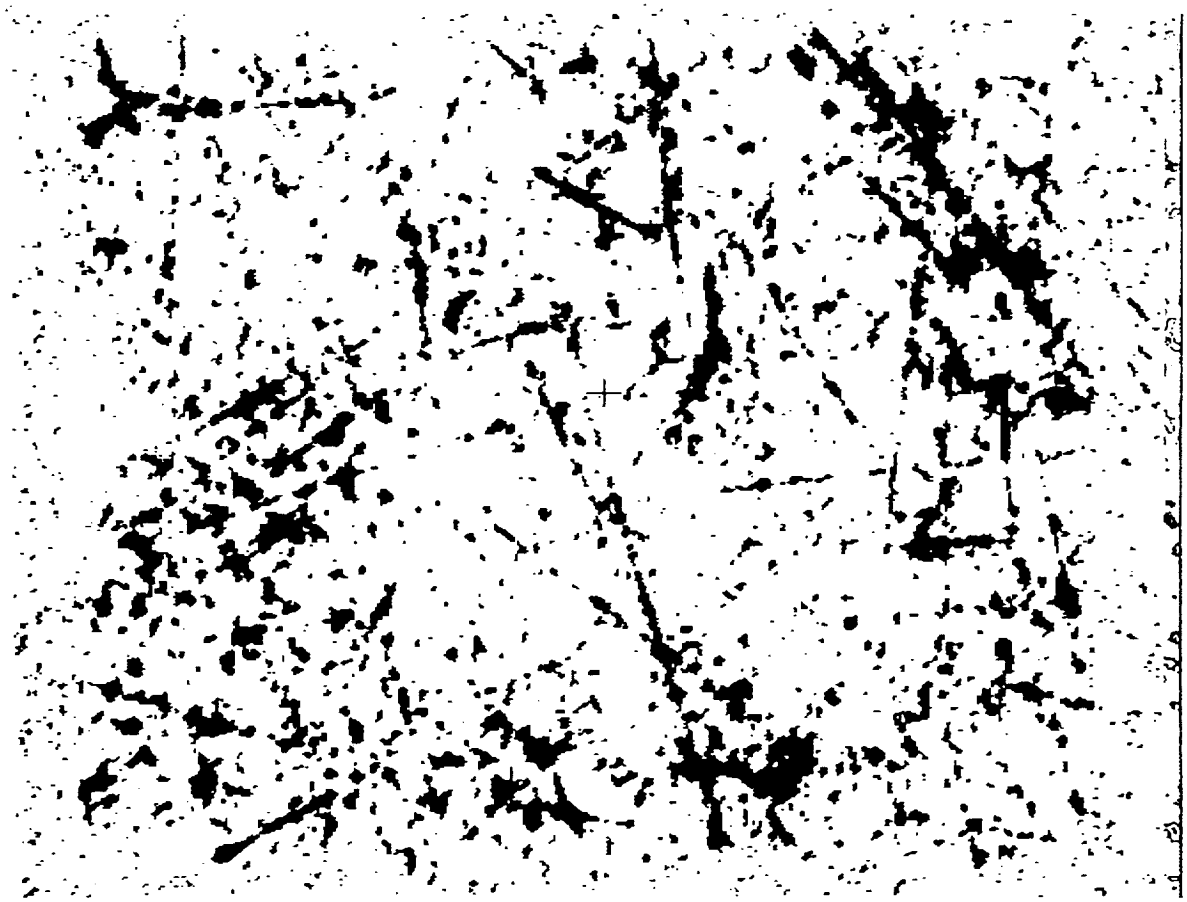

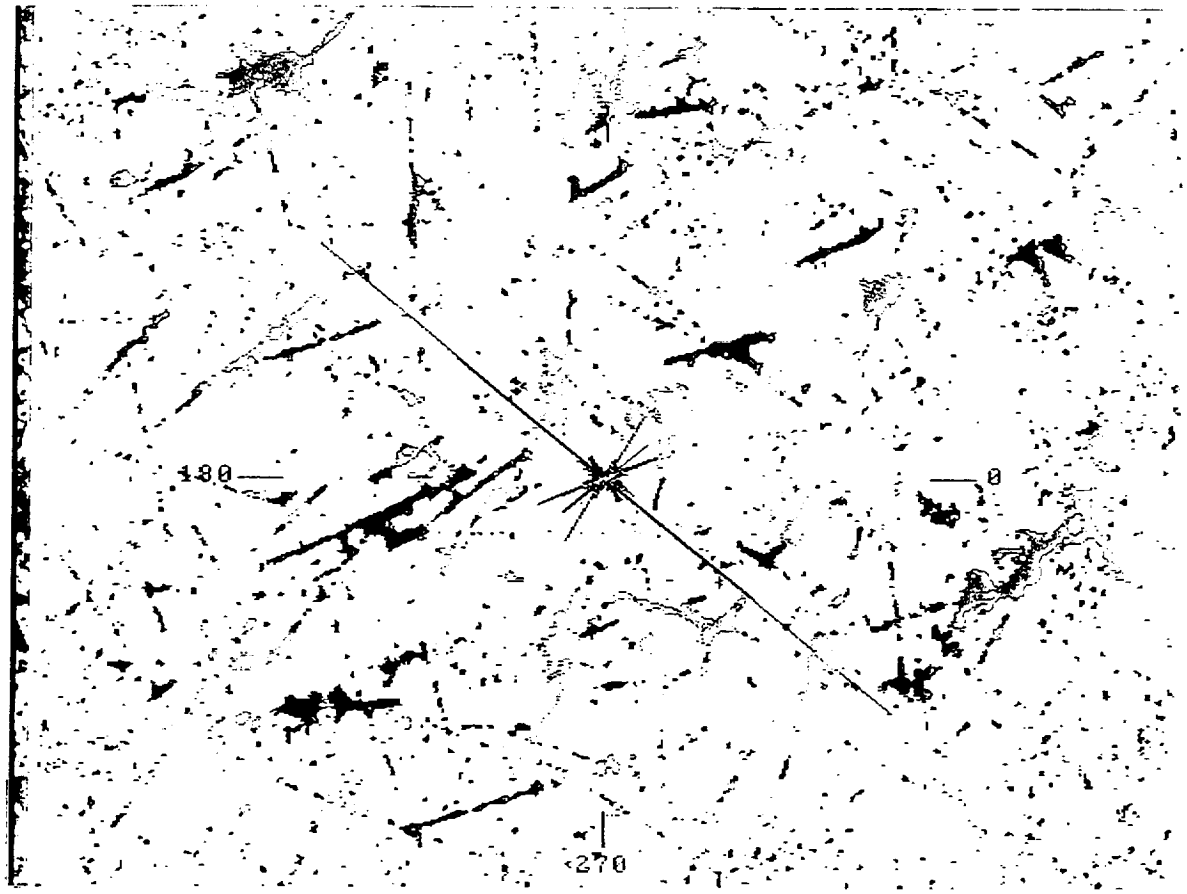

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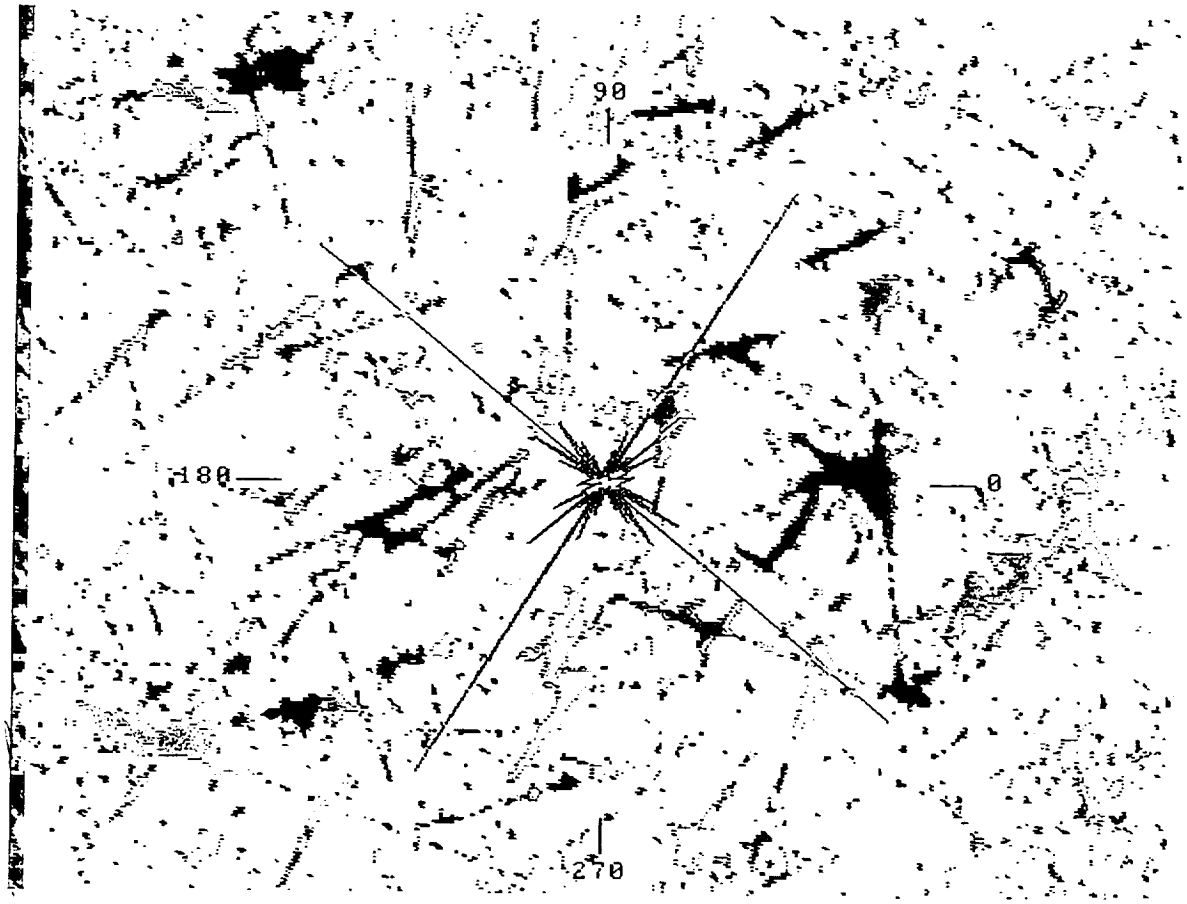
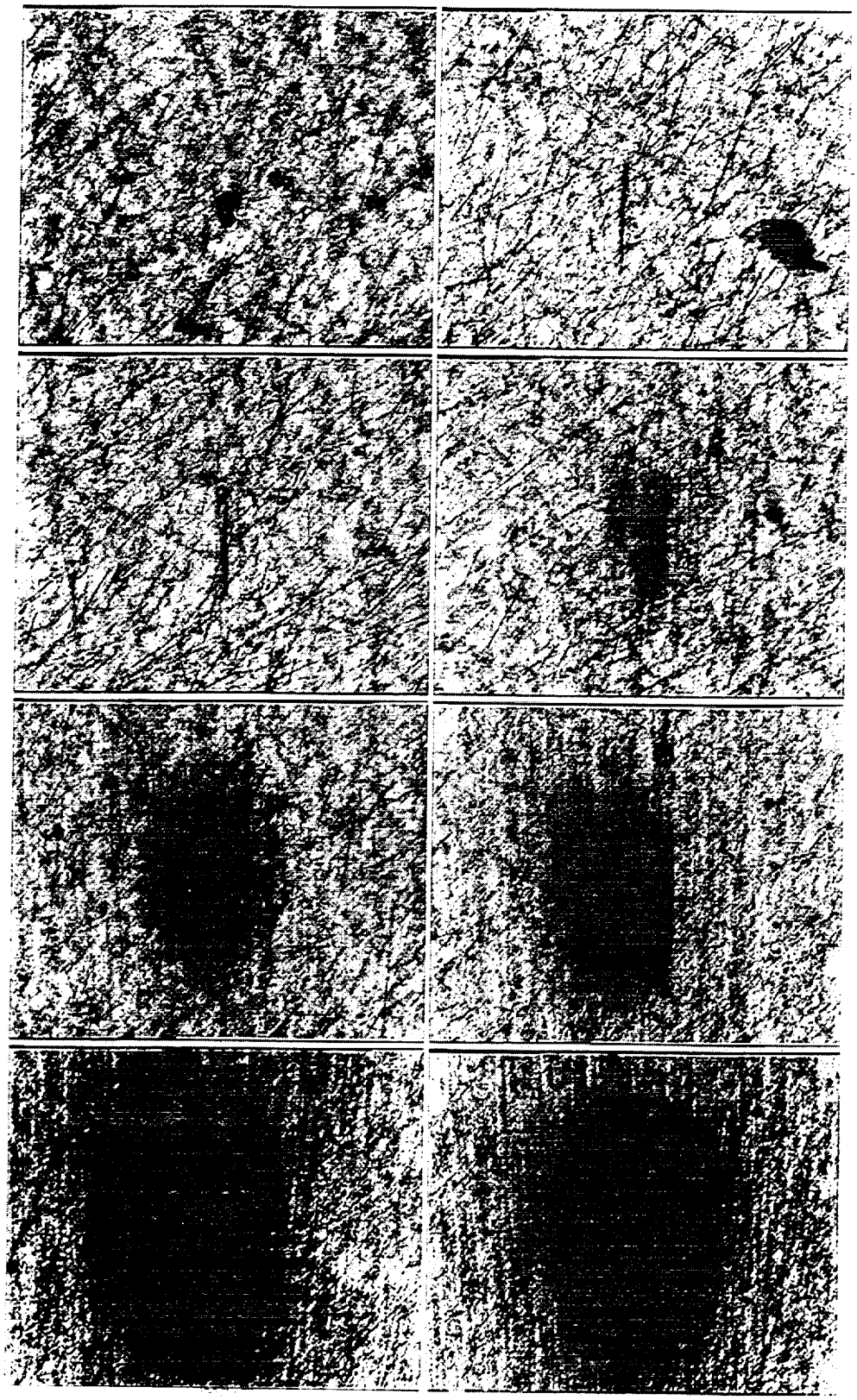
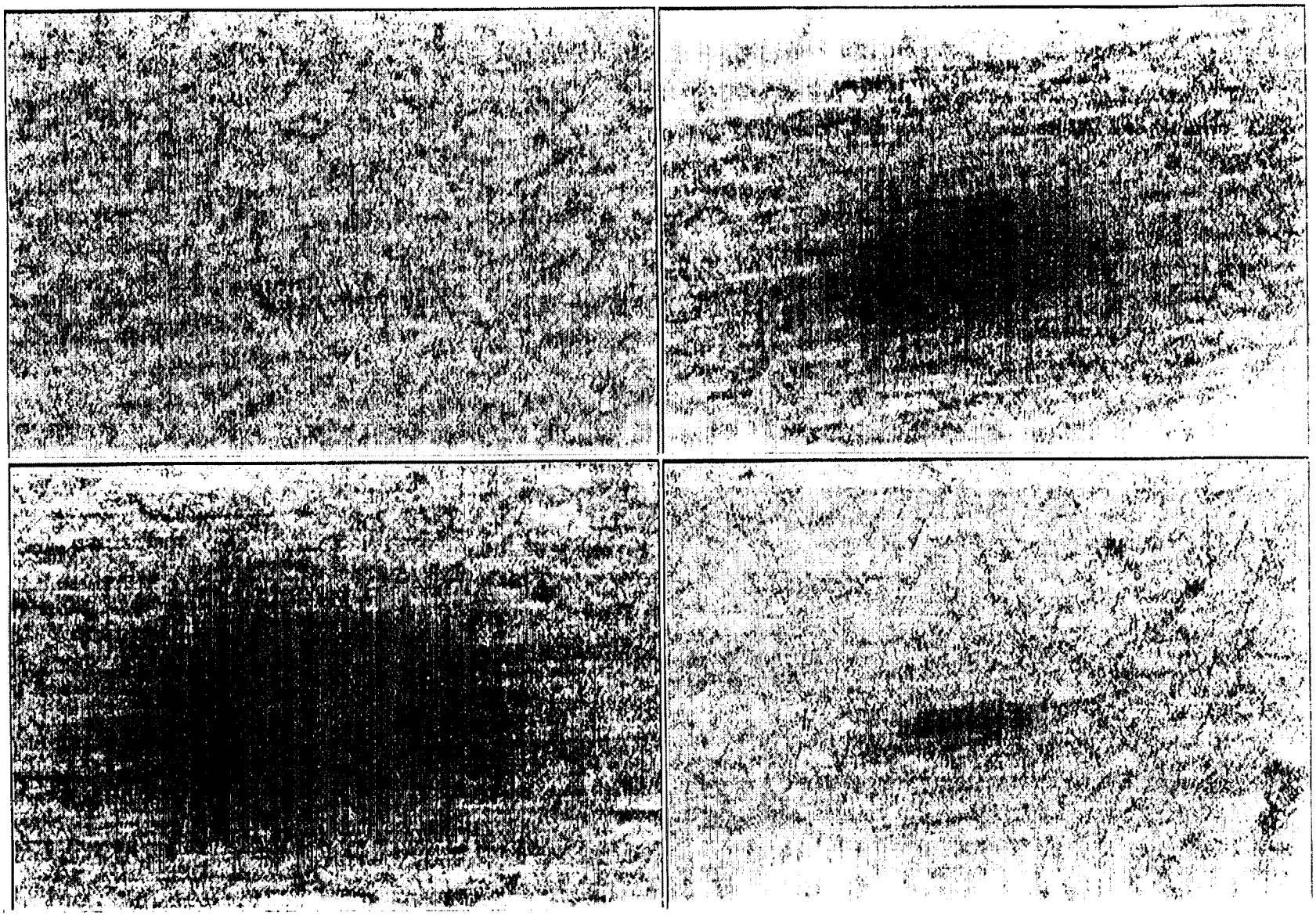




ECT FLIGHT EMULSIONS P01/03/21/69/C01/05/11/13



ECT FLIGHT EMULSIONSC10/18/25/35 RLVLRSI