

Antarctic Climate Research Data, Part 3
Radar and Microwave Radiometer Data at Syowa Station,
Antarctica in 1989

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1. Introduction

A five-year program of Antarctic Climate Research (ACR) is carried out at Syowa, Asuka and Mizuho Stations, surrounding the ice sheet and sea ice area from 1987 to 1991 by the Japanese Antarctic Research Expedition (JARE) as part of the international cooperating World Climate Research Program (WCRP) (Yamanouchi, 1989). The main research subjects are; 1) interannual variation of Antarctic atmosphere, 2) sea ice - atmosphere interaction, 3) variation of the ice sheet and the ice shelf, 4) ice core analysis. In JARE-29 and -30 (the 2nd and 3rd year of this program) we have mainly observed the items related to the interannual variation of Antarctic atmosphere. The observational data of clouds and precipitation in 1989 are shown in this report and short- and long-term variations of clouds and precipitation will be analyzed using these data in the future. The data in 1988 were already published (Wada, 1990).

2. Instruments and Observations

A 37 GHz microwave radiometer was used in 1989 for measuring the brightness temperature (T_B K) of atmosphere, which is related to vertically integrated liquid water contents, and a vertical pointing radar was used for measuring vertically integrated ice water contents (IWC mg/cm²). Specifications of them

are shown in Tables 1 and 2. System diagrams including data collecting hardware are shown in Figs. 1 and 2. The data in 1989 are listed in this report.

The vertical pointing radar had been set near the Earth Science Laboratory and the data-collecting hardware also had been set in the Laboratory in 1988. They were used in 1989. Radar data were collected every 10 s and the all data were written into an 8" floppy disk every 5 min. Radar echo intensity at 128 points along altitudes (50 m intervals) was collected every time. The echo intensity was expressed in 255 grades.

The microwave radiometer was moved from the Upper and Lower Atmosphere Laboratory, and was set on the roof of the Earth Science Laboratory and the data collecting hardware were placed in the Laboratory on January 13, 1989. In 1987 and 1988 it had been set at a different place at Syowa Station which was not far from the Laboratory. Data of the microwave radiometer were collected every 30 s and written into 3.5" floppy disks.

3. Data Reduction

Precipitation was estimated by radar reflectivity factor Z (mm^6/m^3) at 400 m height, using the following Z - R equation,

$$Z = 16 \times R^{1.3}, \quad (1)$$

where R (mm/hr) is rainfall rate. This Z - R relation was determined by the data of several cases of snowfall. Instruments for deciding this relation were an electrical balance shielded by the wooden wall against a strong wind to measure precipitation and an X-band vertical pointing radar to measure echo intensity.

Ice water contents M (mg/m^3) at individual altitudes are calculated from eqs. (2) and (3),

$$Z = 16 \times r^{1.3}, \quad (2)$$

$$M = (r/y) \cdot (1000/3.6), \quad (3)$$

where \underline{r} (mm/hr) in eq. (2) at 400 m height is equal to \underline{R} in eq. (1). The values of \underline{r} at an individual altitude are calculated from the data of \underline{Z} at the altitude using eq. (2). After that, the values of \underline{M} at an individual altitude are calculated from the value of \underline{r} at the altitude and a falling velocity of snow particles \underline{v} (m/s) using eq. (3). We surmise that the falling velocities of snow particles are the same and the value is 1 m/s. Vertically integrated ice water contents (\underline{IWC} mg/cm²) are calculated from a summation of ice water contents (\underline{M} mg/cm³) from 0.4 km height, where the ground echoes sometimes affected the reflectivity factors, to 6.4 km height.

$$\underline{IWC} = \sum_{i=8}^{128} \underline{M}_i \times (\underline{z}_i - \underline{z}_{i-1}),$$

where \underline{M}_i means ice water content at i -th altitude and \underline{z}_i means i -th altitude, e.g. $\underline{z}_7=0.35$, $\underline{z}_8=0.4$, $\underline{z}_9=0.45$, ..., $\underline{z}_{128}=6.4$. Daily mean \underline{R} and \underline{M} , and 5-min mean \underline{IWC} are described in this report.

Five-min mean brightness temperatures (\underline{TB} K) of atmosphere are obtained from the following procedure. Temperature (\underline{T}_i K) expressed by the output \underline{V} of the microwave radiometer is shown as

$$\underline{T}_i = \underline{a} \cdot \underline{V} + \underline{b},$$

where \underline{V} is 5-min mean output voltage. The values of \underline{a} and \underline{b} must be determined. The value of \underline{b} is surmised to be constant throughout the year because it expresses the temperature of reference load and is related to 0 level of amplifier. Then we take 333.2 K (60°C) for the value of \underline{b} . The relationship between value of \underline{a} and temperature for the 37 GHz radiometer was determined from a measurement in the temperature-controlled room in Japan before carrying the radiometers to Syowa Station. Values of \underline{a} towards ambient temperatures at the time are listed in Table 3 and the other values of \underline{a} with temperatures are interpolated. The value of \underline{a} is changed according to a gain adjustment of amplifier of the radiometer. On the other hand, \underline{T}_i is related to atmospheric brightness temperature (\underline{TB} K) and antenna physical temperature

(TA K) as

$$\underline{T_i} = \underline{L_a} \times \underline{T_B} + (1-\underline{L_a}) \times \underline{T_A},$$

where La is antenna loss. The antenna loss of the 37.0 GHz radiometer was estimated as 0.7447 (Wada, 1991). The antenna physical temperature (TA K) regarded as antenna surface temperature was measured and stored in the floppy disk. Five-min averaged values of TB (K) are shown in this report.

4. Description of Figures

Figure 3 shows daily precipitation in 1989. Daily precipitation was calculated from radar echo intensity at the altitude of 400 m. In the figure the horizontal axis is daily precipitation and the vertical one is month and day.

Figure 4 shows a time-height cross section of daily mean echo intensity. Daily mean echo intensities are derived from r at individual altitudes. They are expressed by eight symbols which indicate the grades of echo intensity. Order of the grades is symbol 5, 4, 3, 2, 1, asterisk, period, and space, symbol 5 being the strongest and space the weakest. The ranges of intensity of respective symbols are listed in Table 4. The ranges signify the values of one-day total of r, namely the unit of r is mm/day. Figure 5 shows the variation of 5-min mean brightness temperature by the 37.0 GHz radiometer and 5-min mean vertically integrated ice water content by the vertical pointing radar for two days. In the figure the horizontal axis indicates time and the vertical one brightness temperatures (TB K) and vertically integrated ice water contents (IWC mg/cm²). Small pluses show brightness temperatures and open circles show vertically integrated ice water contents in the figure.

5. Data List of Microwave Radiometer and Vertical Pointing Radar

1) Microwave radiometer

* One-min mean output voltages on 5" floppy disks.

2) Vertical pointing radar

- * Echo intensity data from surface to 6.4 km altitude (50 m intervals) every 10 s on 8" and 5" floppy disks.
- * Five-min mean radar reflectivity factors on 5" floppy disks.
- * Ice water contents and rainfall rates calculated from 5-min mean radar reflectivity factors on 5" floppy disks.

6. Difference Between Present and Former Data Reports

We use different equations of Z - R relation and M - Z relation between the former data report (Wada, 1990) and the present data report. Table 5 shows the equations we use in the former and the present data reports. Since R and M are calculated from Z using the non-linear equations in Table 5, we cannot easily tell the difference between R_{ee} and R_{ee} and so on. However, considering from the data throughout the two years, we can say R_{ee} was about four times larger than R_{ee} and IWC_{ee} is nearly equal to IWC_{ee} . The symbols in Fig. 4 represent the radar echo intensities. The ranges of intensity of the respective symbols are listed in Table 4. Since we use different equations of Z - R relation in the present report from the former report, different definitions of symbols are used. In the former report mean echo intensities are calculated using the following equation,

$$Z = 500 \times r^{2.0}.$$

The echo intensity expressed by symbol 5 in the former report is nearly the same as that expressed by symbol 2 in the present report. Namely, relatively strong echoes are put into plural classes and relatively weak echoes are put into one class in the present report.

References

Japan Meteorological Agency (1990): Meteorological data at the Syowa Station in 1988. *Antarct. Meteorol. Data*, 29, 326p.

Wada, M. (1990): Antarctic climate research data, Part 2. Radar and microwave radiometer data at Syowa Station, Antarctica from March to December 1988. JARE Data Rep., 153 (Meteorology 24), 97p.

Wada, M. (1991): Estimation of vertically integrated liquid water contents in the atmosphere. Nankyoku Shiryo (Antarct. Rec.), 35(in press).

Yamanouchi, T. (1989): Antarctic climate research data, Part 1. Radiation data at Syowa Station, Antarctica from February 1987 to January 1988. JARE Data Rep., 144(Meteorology 22), 193p.

Table 1. Specifications of vertical pointing radar.

```

=====
Antenna
-----
Parabolic antenna with radome of 2.4 m diameter
Antenna gain      : 44 db
Beam width       : 1.0
-----
Transmitter and receiver
-----
Carrier frequency : 9410 MHz
Peak power        : 40 kW
Pulse width       : 0.5 μs
Repetition frequency : 750 Hz
Receiver sensitivity : -106 dbm
Log amp linearity  : 70 db
-----

```

Table 2. Specifications of microwave radiometer.

```

=====
Receiver
-----
Frequency      : 37.0 GHz
Type           : Dicke
Polarization   : Lineary polarization
Bandwidth      : 100 MHz
Sensitivity    : 0.2 K
(integrated time) : (1 s)
Temperature range : 50-500 K
AGC            : Yes
-----
Antenna
-----
Diameter      : 0.2 m
Gain          : 25 db
-----

```

Table 3. Relationship between α and ambient temperature.

```

=====
Temperature (°C)      40      25      10      -10
α (arbitrary unit)  6.010  5.717  5.581  5.451
-----

```

Table 4. Ranges of symbols in Fig. 4 of the present report and in Fig. 4 of the former report (Wada, 1990).

Symbol	Range Present report (mm/day)	Range Former report (mm/day)
.	0.0 - 2.5	0.25 - 0.50
*	2.5 - 5.0	0.50 - 0.75
1	5.0 - 7.5	0.75 - 1.00
2	7.5 - 10.0	1.00 - 1.25
3	10.0 - 12.5	1.25 - 1.50
4	12.5 - 15.0	1.50 - 1.75
5	15.0 -	1.75

Table 5. Comparison of equations in the present report with those in the former report (Wada, 1990). \underline{M}_{ss} in this table derives from eqs. (2) and (3).

Former report	Present report
$\underline{Z}_{ss} = 500 \times \underline{R}^{2.0}$	$\underline{Z}_{ss} = 16 \times \underline{R}^{1.3}$
$\underline{M}_{ss} = 49 \times \underline{Z}^{0.90}$	$\underline{M}_{ss} = 33 \times \underline{Z}^{0.77}$

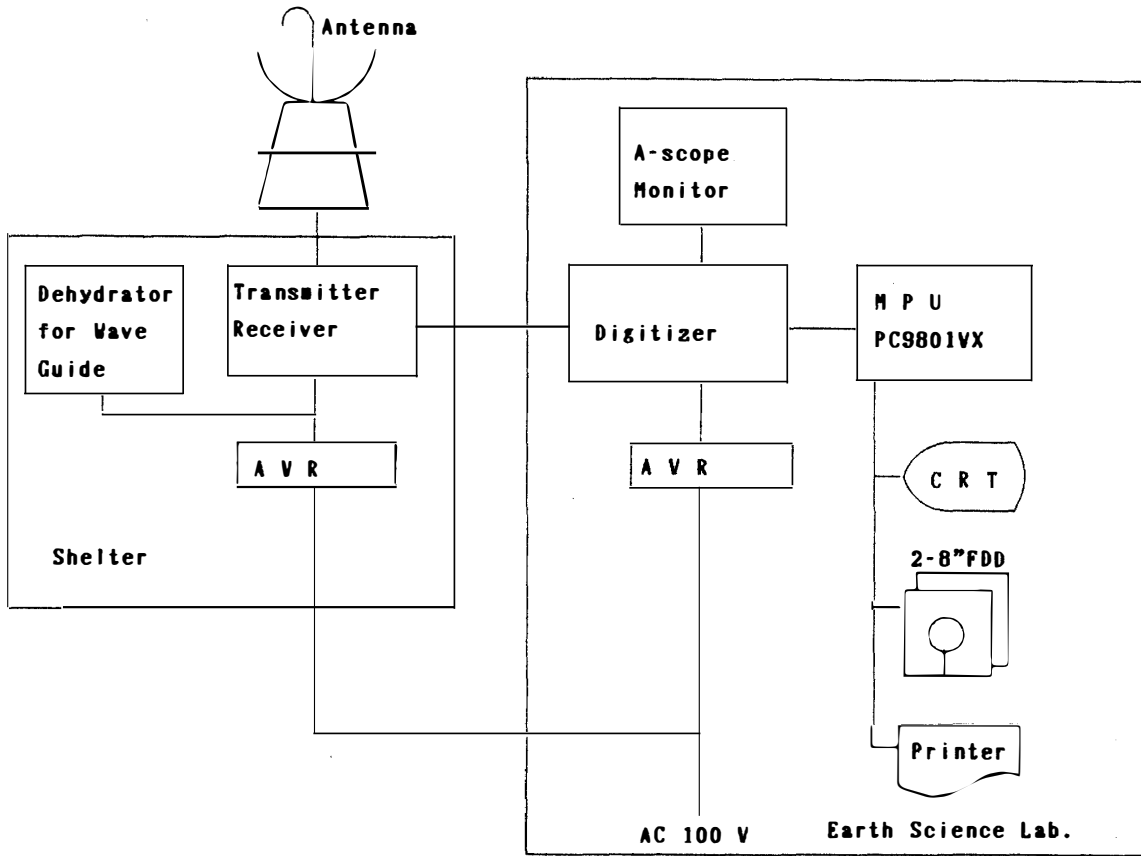


Fig. 1. System diagram of the vertical pointing radar.

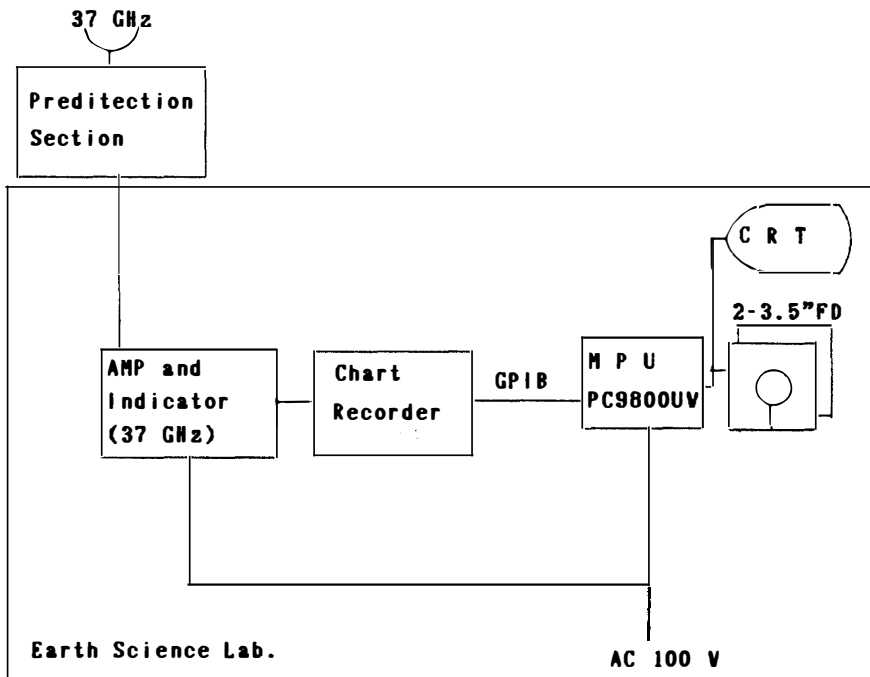


Fig. 2. System diagram of the 37 GHz microwave radiometer.

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
1	1		:				:				:				:	
1	2		:				:				:				:	
1	3	0.0					:				:				:	
1	4		:				:				:				:	
1	5		:				:				:				:	
1	6		:				:				:				:	
1	7		:				:				:				:	
1	8	0.0					:				:				:	
1	9	0.0					:				:				:	
1	10	0.0					:				:				:	
1	11	5.4*****					:				:				:	
1	12	0.1					:				:				:	
1	13	0.0					:				:				:	
1	14		:				:				:				:	
1	15	0.0					:				:				:	
1	16	0.0					:				:				:	
1	17	0.0					:				:				:	
1	18	0.0					:				:				:	
1	19	0.0					:				:				:	
1	20	0.0					:				:				:	
1	21	0.1					:				:				:	
1	22		:				:				:				:	
1	23		:				:				:				:	
1	24		:				:				:				:	
1	25		:				:				:				:	
1	26		:				:				:				:	
1	27		:				:				:				:	
1	28		:				:				:				:	
1	29		:				:				:				:	
1	30		:				:				:				:	
1	31		:				:				:				:	

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
2	1	0.0					:				:				:	
2	2	7.7*****					:				:				:	
2	3	7.7*****					:				:				:	
2	4	0.4*					:				:				:	
2	5	0.0					:				:				:	
2	6	0.0					:				:				:	
2	7	0.0					:				:				:	
2	8	0.0					:				:				:	
2	9	0.0					:				:				:	
2	10	0.0					:				:				:	
2	11	0.0					:				:				:	
2	12	0.0					:				:				:	
2	13	3.7*****					:				:				:	
2	14	0.0					:				:				:	
2	15		:				:				:				:	
2	16	0.0					:				:				:	
2	17	2.2*****					:				:				:	
2	18	0.9**					:				:				:	
2	19	0.4*					:				:				:	
2	20	0.4*					:				:				:	
2	21	2.3*****					:				:				:	
2	22		:				:				:				:	
2	23	0.0					:				:				:	
2	24	2.9*****					:				:				:	
2	25	19.0*****					:				:				:	
2	26	9.8*****					:				:				:	
2	27	0.7*					:				:				:	
2	28	4.3*****					:				:				:	

Fig. 3. One-day total rainfall at the altitude of 400 m.

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26	mm
3	1	1.2**					:				:						:
3	2	5.6*****					:				:						:
3	3	0.0					:				:						:
3	4	6.9*****					:				:						:
3	5	3.6*****					:				:						:
3	6	0.0					:				:						:
3	7	0.7*					:				:						:
3	8	0.0					:				:						:
3	9	0.0					:				:						:
3	10	0.2					:				:						:
3	11	0.2					:				:						:
3	12	0.0					:				:						:
3	13	1.0**					:				:						:
3	14	:					:				:						:
3	15	0.0					:				:						:
3	16	0.4*					:				:						:
3	17	5.0*****					:				:						:
3	18	2.8*****					:				:						:
3	19	0.0					:				:						:
3	20	0.2					:				:						:
3	21	0.4*					:				:						:
3	22	1.1**					:				:						:
3	23	0.2					:				:						:
3	24	0.0					:				:						:
3	25	0.0					:				:						:
3	26	0.0					:				:						:
3	27	0.5*					:				:						:
3	28	8.8*****					:				:						:
3	29	9.0*****					:				:						:
3	30	5.6*****					:				:						:
3	31	0.0					:				:						:

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26	mm
4	1	2.7*****					:				:						:
4	2	:					:				:						:
4	3	:					:				:						:
4	4	0.0					:				:						:
4	5	0.0					:				:						:
4	6	0.1					:				:						:
4	7	0.0					:				:						:
4	8	0.0					:				:						:
4	9	0.0					:				:						:
4	10	9.1*****					:				:						:
4	11	0.7*					:				:						:
4	12	0.0					:				:						:
4	13	:					:				:						:
4	14	3.5*****					:				:						:
4	15	7.9*****					:				:						:
4	16	7.6*****					:				:						:
4	17	7.6*****					:				:						:
4	18	1.8*****					:				:						:
4	19	:					:				:						:
4	20	:					:				:						:
4	21	:					:				:						:
4	22	0.0					:				:						:
4	23	3.4*****					:				:						:
4	24	6.6*****					:				:						:
4	25	0.0					:				:						:
4	26	0.0					:				:						:
4	27	:					:				:						:
4	28	:					:				:						:
4	29	0.0					:				:						:
4	30	:					:				:						:

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
5	1	0.0					:				:					
5	2	:					:				:					
5	3	1.4***					:				:					
5	4	2.6*****					:				:					
5	5	0.2					:				:					
5	6	:					:				:					
5	7	2.6*****					:				:					
5	8	:					:				:					
5	9	0.0					:				:					
5	10	:					:				:					
5	11	:					:				:					
5	12	:					:				:					
5	13	0.0					:				:					
5	14	:					:				:					
5	15	:					:				:					
5	16	:					:				:					
5	17	:					:				:					
5	18	:					:				:					
5	19	:					:				:					
5	20	0.6*					:				:					
5	21	0.4					:				:					
5	22	1.0**					:				:					
5	23	0.0					:				:					
5	24	0.5*					:				:					
5	25	0.0					:				:					
5	26	0.0					:				:					
5	27	:					:				:					
5	28	:					:				:					
5	29	:					:				:					
5	30	:					:				:					
5	31	:					:				:					

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
6	1	1.1**					:				:					
6	2	0.0					:				:					
6	3	:					:				:					
6	4	:					:				:					
6	5	0.5*					:				:					
6	6	0.0					:				:					
6	7	:					:				:					
6	8	:					:				:					
6	9	0.2					:				:					
6	10	6.6*****					:				:					
6	11	:					:				:					
6	12	:					:				:					
6	13	0.2					:				:					
6	14	0.0					:				:					
6	15	:					:				:					
6	16	0.0					:				:					
6	17	:					:				:					
6	18	:					:				:					
6	19	0.5*					:				:					
6	20	0.2					:				:					
6	21	1.3***					:				:					
6	22	0.6*					:				:					
6	23	:					:				:					
6	24	:					:				:					
6	25	:					:				:					
6	26	6.0*****					:				:					
6	27	10.4*****					:				:					
6	28	11.2*****					:				:					
6	29	1.3***					:				:					
6	30	9.8*****					:				:					

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
7	1	14.1	*****													
7	2	:														
7	3	:														
7	4	0.4*														
7	5	1.8****														
7	6	0.2														
7	7	:														
7	8	1.6***														
7	9	0.7*														
7	10	7.0*****														
7	11	0.9**														
7	12	:														
7	13	:														
7	14	:														
7	15	:														
7	16	:														
7	17	:														
7	18	:														
7	19	:														
7	20	:														
7	21	0.8*														
7	22	0.0														
7	23	:														
7	24	2.5*****														
7	25	4.3*****														
7	26	0.0														
7	27	0.6*														
7	28	0.0														
7	29	0.0														
7	30	0.6*														
7	31	0.0														

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
8	1	0.0														
8	2	:														
8	3	:														
8	4	:														
8	5	0.0														
8	6	0.1														
8	7	:														
8	8	:														
8	9	:														
8	10	:														
8	11	0.0														
8	12	:														
8	13	:														
8	14	:														
8	15	0.0														
8	16	2.1*****														
8	17	:														
8	18	:														
8	19	:														
8	20	:														
8	21	4.3*****														
8	22	0.6*														
8	23	0.0														
8	24	0.0														
8	25	:														
8	26	0.0														
8	27	0.2														
8	28	0.0														
8	29	:														
8	30	:														
8	31	:														

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
9	1	:					:				:				:	
9	2	:					:				:				:	
9	3	:					:				:				:	
9	4	:					:				:				:	
9	5	:					:				:				:	
9	6	:					:				:				:	
9	7	0.7*					:				:				:	
9	8	0.3					:				:				:	
9	9	1.0**					:				:				:	
9	10	:					:				:				:	
9	11	:					:				:				:	
9	12	:					:				:				:	
9	13	:					:				:				:	
9	14	:					:				:				:	
9	15	:					:				:				:	
9	16	:					:				:				:	
9	17	:					:				:				:	
9	18	:					:				:				:	
9	19	:					:				:				:	
9	20	:					:				:				:	
9	21	:					:				:				:	
9	22	:					:				:				:	
9	23	:					:				:				:	
9	24	0.0					:				:				:	
9	25	0.4					:				:				:	
9	26	0.0					:				:				:	
9	27	:					:				:				:	
9	28	:					:				:				:	
9	29	:					:				:				:	
9	30	0.0					:				:				:	

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
10	1	0.6*					:				:				:	
10	2	0.2					:				:				:	
10	3	0.1					:				:				:	
10	4	:					:				:				:	
10	5	:					:				:				:	
10	6	:					:				:				:	
10	7	:					:				:				:	
10	8	:					:				:				:	
10	9	:					:				:				:	
10	10	:					:				:				:	
10	11	:					:				:				:	
10	12	:					:				:				:	
10	13	0.2					:				:				:	
10	14	0.0					:				:				:	
10	15	0.0					:				:				:	
10	16	0.2					:				:				:	
10	17	0.1					:				:				:	
10	18	0.1					:				:				:	
10	19	:					:				:				:	
10	20	0.3					:				:				:	
10	21	3.4*****					:				:				:	
10	22	20.1*****					:				:				:	
10	23	25.7*****					:				:				:	
10	24	8.3*****					:				:				:	
10	25	4.9*****					:				:				:	
10	26	4.1*****					:				:				:	
10	27	0.9**					:				:				:	
10	28	0.0					:				:				:	
10	29	0.2					:				:				:	
10	30	2.9*****					:				:				:	
10	31	2.7*****					:				:				:	

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
11	1	:					:				:					:
11	2	:					:				:					:
11	3	0.0					:				:					:
11	4	0.8**					:				:					:
11	5	0.2					:				:					:
11	6	:					:				:					:
11	7	:					:				:					:
11	8	0.0					:				:					:
11	9	0.0					:				:					:
11	10	:					:				:					:
11	11	:					:				:					:
11	12	:					:				:					:
11	13	0.9**					:				:					:
11	14	14.0*****					:				:					:
11	15	13.8*****					:				:					:
11	16	0.0					:				:					:
11	17	0.0					:				:					:
11	18	0.0					:				:					:
11	19	0.0					:				:					:
11	20	:					:				:					:
11	21	:					:				:					:
11	22	:					:				:					:
11	23	0.8*					:				:					:
11	24	0.1					:				:					:
11	25	12.7*****					:				:					:
11	26	0.0					:				:					:
11	27	0.0					:				:					:
11	28	0.0					:				:					:
11	29	0.0					:				:					:
11	30	0.0					:				:					:

MM	DD	mm	0	2	4	6	8	10	12	14	16	18	20	22	24	26 mm
12	1	:					:				:					:
12	2	:					:				:					:
12	3	:					:				:					:
12	4	:					:				:					:
12	5	0.0					:				:					:
12	6	0.0					:				:					:
12	7	0.0					:				:					:
12	8	0.0					:				:					:
12	9	:					:				:					:
12	10	0.0					:				:					:
12	11	0.0					:				:					:
12	12	:					:				:					:
12	13	:					:				:					:
12	14	0.0					:				:					:
12	15	0.0					:				:					:

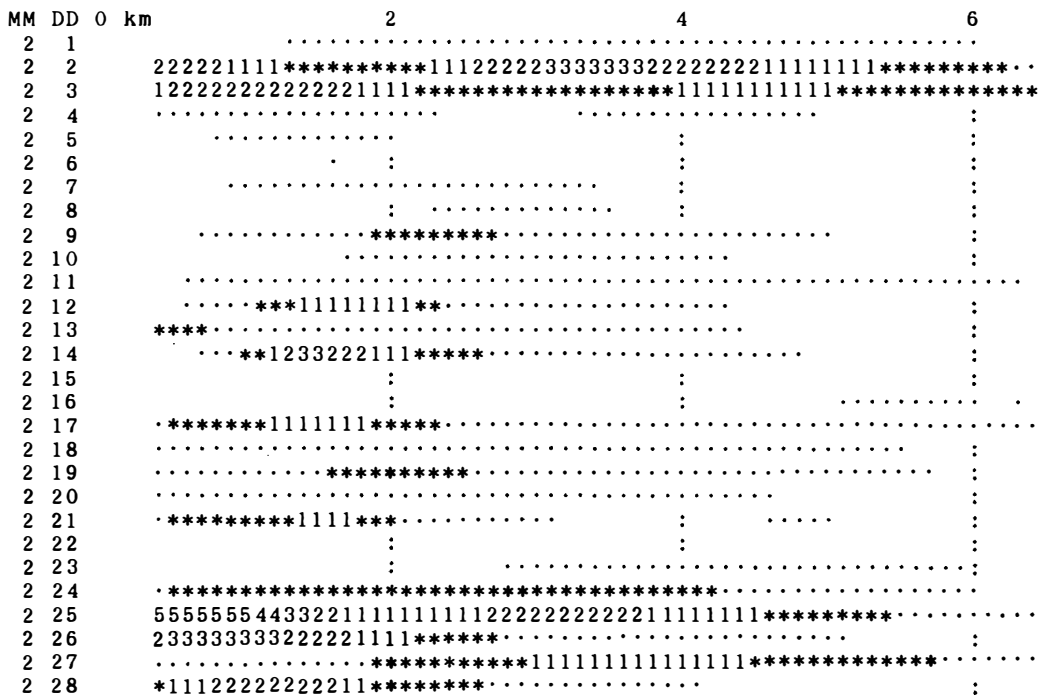
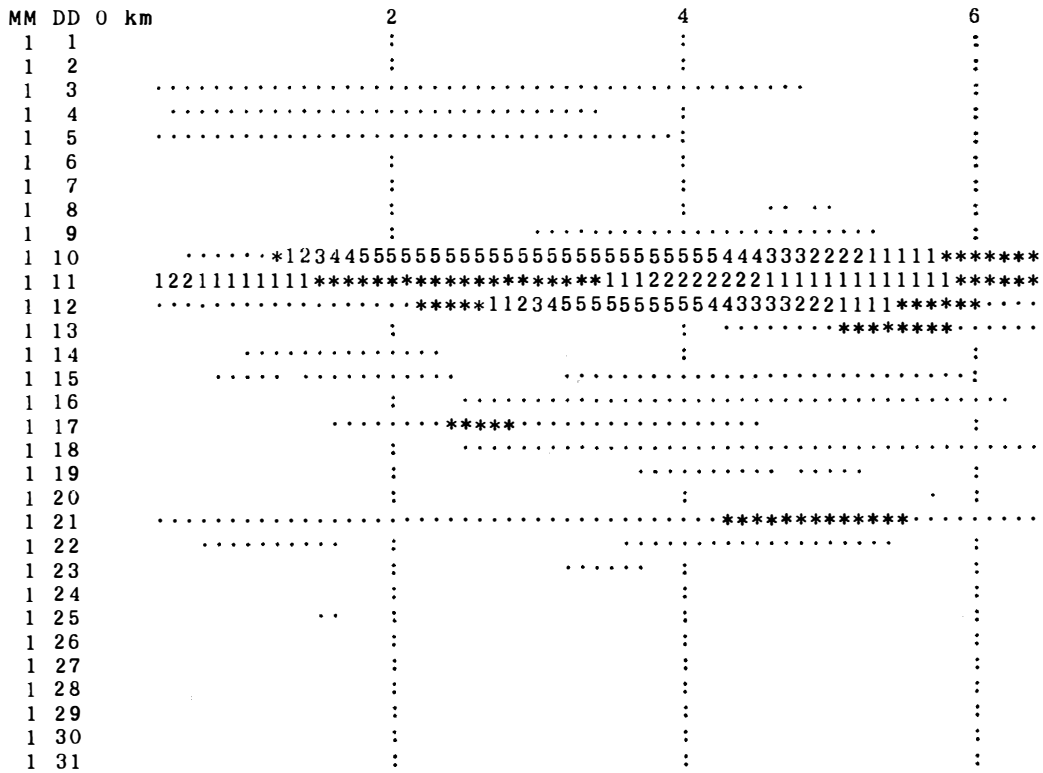


Fig. 4. Time-height cross section of daily mean echo intensity.

MM	DD	0 km	2	4	6
3	1		*****		:
3	2	11111*****		:	:
3	3		:		:
3	4	11222223333333333333333332222211111111*****		:	:
3	5	*1111111111111111111*****		:	:
3	6		*****11111111*****		:
3	7		**112334555555555555544333222111*****		:
3	8		*****		:
3	9			:	:
3	10		*****		:
3	11			:	:
3	12		:		:
3	13			:	:
3	14		:		:
3	15		:		:
3	16		*****		:
3	17	*1222222222111111*****		:	:
3	18	**1111111222221111111111111111111*****		:	:
3	19		**1111111111*****		:
3	20			:	:
3	21		*****		:
3	22			:	:
3	23			:	:
3	24		:		:
3	25			:	:
3	26		:		:
3	27			:	:
3	28	1222111****		:	:
3	29	2322111*****		:	:
3	30	1111****		:	:
3	31	..134554211****		:	:

MM	DD	0 km	2	4	6
4	1		***		:
4	2		:		:
4	3		:		:
4	4			:	:
4	5			:	:
4	6			:	:
4	7			:	:
4	8		:		:
4	9		:		:
4	10	2222211***	*****		:
4	11		***1111111111*****		:
4	12			:	:
4	13		:		:
4	14	*****		:	:
4	15	1211****		:	:
4	16	2222111***		:	:
4	17	3333222111****		:	:
4	18			:	:
4	19		:		:
4	20		:		:
4	21		:		:
4	22			:	:
4	23	*****1111222111111111111111111111111*****		:	:
4	24	122111****	*****		:
4	25			:	:
4	26		:		:
4	27		:		:
4	28		:		:
4	29			:	:
4	30		:		:

MM	DD	0 km	2	4	6
5	1		:	:	:
5	2		:	:	:
5	3	.....	:	:	:
5	4	***.....	:	:	:
5	5	.....	:	:	:
5	6		:	:	:
5	7	*****.....	:	:	:
5	8		:	:	:
5	9	...	:	:	:
5	10		:	:	:
5	11		:	:	:
5	12		:	:	:
5	13		:	:	:
5	14		:	:	:
5	15		:	:	:
5	16		:	:	:
5	17		:	:	:
5	18		:	:	:
5	19		:	:	:
5	20	.....	:	:	:
5	21	.....	:	:	:
5	22	.....	:	:	:
5	23		:	:	:
5	24	.....	:	:	:
5	25	.....	:	:	:
5	26		:	:	:
5	27		:	:	:
5	28		:	:	:
5	29		:	:	:
5	30		:	:	:
5	31		:	:	:

MM	DD	0 km	2	4	6
6	1	*****.....	:	:	:
6	2	.....	:	:	:
6	3		:	:	:
6	4		:	:	:
6	5	.....	:	:	:
6	6		:	:	:
6	7		:	:	:
6	8		:	:	:
6	9	.....	:	:	:
6	10	11****.....	:	:	:
6	11		:	:	:
6	12		:	:	:
6	13	.....	:	:	:
6	14		:	:	:
6	15	.....	:	:	:
6	16		:	:	:
6	17		:	:	:
6	18		:	:	:
6	19	.....	:	:	:
6	20	.....	:	:	:
6	21	.....	:	:	:
6	22	.....	:	:	:
6	23		:	:	:
6	24		:	:	:
6	25		:	:	:
6	26	1111*****.....	:	:	:
6	27	2221***...*11111222222211111*****.....	:	:	:
6	28	432111111*****.....	:	:	:
6	29*****.....	:	:	:
6	30	22211****.....	:	:	:

MM	DD	0 km	2	4	6
7	1	5544322111*****			
7	2		:	:	:
7	3		:	:	:
7	4	.....	:	:	:
7	5	.....	:	:	:
7	6	.....	:	:	:
7	7		:	:	:
7	8	.....	:	:	:
7	9	.....	:	:	:
7	10	1111****	:	:	:
7	11	.....	:	:	:
7	12		:	:	:
7	13		:	:	:
7	14		:	:	:
7	15		:	:	:
7	16		:	:	:
7	17		:	:	:
7	18		:	:	:
7	19		:	:	:
7	20		:	:	:
7	21	.....	:	:	:
7	22	.....	:	:	:
7	23		:	:	:
7	24	.....	:	:	:
7	25	*****	:	:	:
7	26	.....	:	:	:
7	27	.....	:	:	:
7	28	.....	:	:	:
7	29	.....	:	:	:
7	30	.....	:	:	:
7	31	.....	:	:	:

MM	DD	0 km	2	4	6
8	1	.....	:	:	:
8	2		:	:	:
8	3		:	:	:
8	4		:	:	:
8	5	.....	:	:	:
8	6	.....	:	:	:
8	7		:	:	:
8	8		:	:	:
8	9		:	:	:
8	10		:	:	:
8	11	.....	:	:	:
8	12		:	:	:
8	13		:	:	:
8	14		:	:	:
8	15	.....	:	:	:
8	16	.....	:	:	:
8	17		:	:	:
8	18		:	:	:
8	19		:	:	:
8	20		:	:	:
8	21	*****	:	:	:
8	22	.....	:	:	:
8	23	.....	:	:	:
8	24		:	:	:
8	25		:	:	:
8	26	.....	:	:	:
8	27	.....	:	:	:
8	28	.....	:	:	:
8	29		:	:	:
8	30		:	:	:
8	31		:	:	:

MM	DD	0 km	2	4	6
9	1		:	:	:
9	2		:	:	:
9	3		:	:	:
9	4		:	:	:
9	5		:	:	:
9	6		:	:	:
9	7	.....	:	:	:
9	8	.....	:	:	:
9	9	.....	:	:	:
9	10		:	:	:
9	11		:	:	:
9	12		:	:	:
9	13		:	:	:
9	14		:	:	:
9	15		:	:	:
9	16		:	:	:
9	17		:	:	:
9	18		:	:	:
9	19		:	:	:
9	20		:	:	:
9	21		:	:	:
9	22		:	:	:
9	23		:	:	:
9	24	.....	:	:	:
9	25*****.....	:	:	:
9	26	.....	:	:	:
9	27		:	:	:
9	28		:	:	:
9	29		:	:	:
9	30	.....	:	:	:

MM	DD	0 km	2	4	6
10	1	.....	:	:	:
10	2	.....	:	:	:
10	3	.....	:	:	:
10	4		:	:	:
10	5		:	:	:
10	6		:	:	:
10	7		:	:	:
10	8		:	:	:
10	9		:	:	:
10	10		:	:	:
10	11		:	:	:
10	12		:	:	:
10	13	.....	:	:	:
10	14	.....	:	:	:
10	15		:	:	:
10	16	.....**1112222222211111*****.....	:	:	:
10	17*****.....	:	:	:
10	18	.....	:	:	:
10	19		:	:	:
10	20	.....	:	:	:
10	21	*****.....*.....	:	:	:
10	22	5555432211*****.....	:	:	:
10	23	555555555444433333322222111111111*****.....	:	:	:
10	24	2221111*****.....	:	:	:
10	25	*****.....	:	:	:
10	26	*****.....	:	:	:
10	27	.....	:	:	:
10	28	.....	:	:	:
10	29	.....	:	:	:
10	30	.....	:	:	:
10	31	*****.....	:	:	:

MM	DD	0 km	2	4	6
11	1		:	:	:
11	2		:	:	:
11	3		:	:	:
11	4	***
11	5	***
11	6		:	:	:
11	7		:	:	:
11	8		:	:	:
11	9		.....	:	:
11	10		:	:	:
11	11		:	:	:
11	12		:	:	:
11	13	***
11	14		34443333333322111111***
11	15		5554433211**.....	:	:
11	16		:	.....	:
11	17		:	.....	:
11	18		.....*	11223344433333322111**
11	19		.....*	112222111**
11	20		:	:	:
11	21		:	:	:
11	22		:	:	:
11	23		.....	.....	:
11	24	***
11	25		4433322111***
11	26		:**
11	27	***
11	28	***
11	29		.....	:	:
11	30		:	:	:

MM	DD	0 km	2	4	6
12	1		:	:	:
12	2		:	:	:
12	3		:	:	:
12	4		:	:	:
12	5		:	:	:
12	6		:	.....	.....
12	7		:	:	:
12	8		:	.....	:
12	9		:	:	:
12	10		:	.....	:
12	11		:	.....	:
12	12		:	:	:
12	13		:	:	:
12	14		:	:	:
12	15		.....	.....	.....
12	16		:	:	:
12	17		:	:	:
12	18		:	:	:
12	19		:	.....	.....
12	20		:	:	:

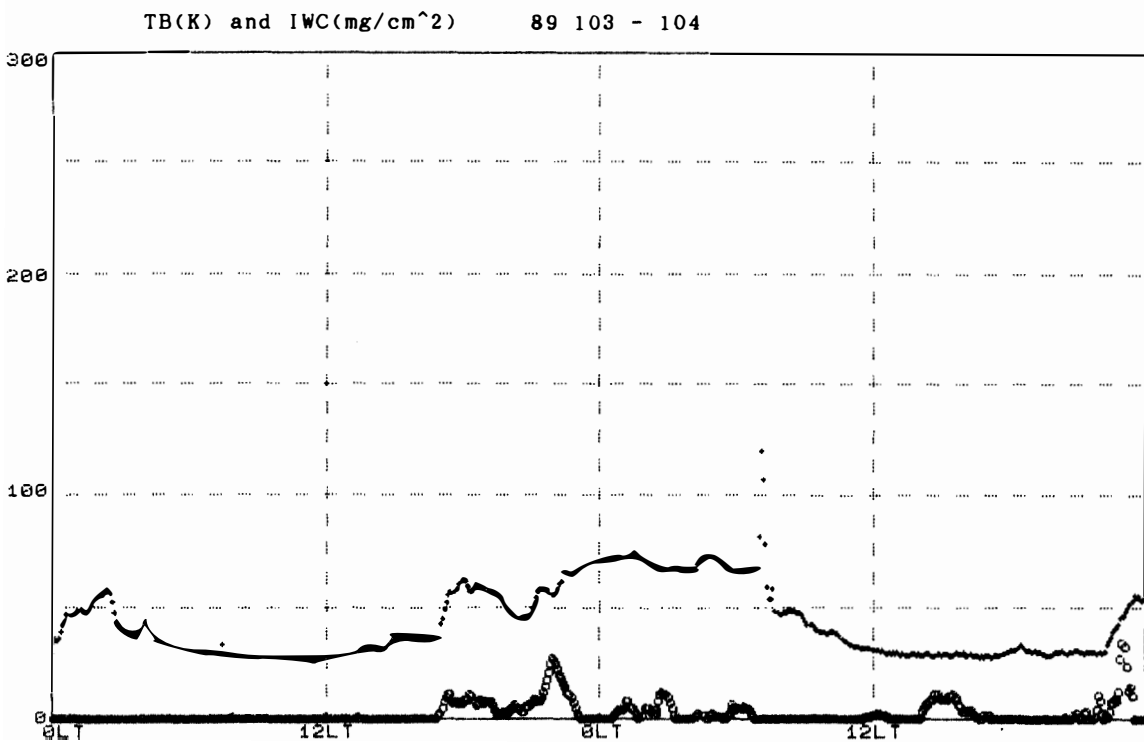
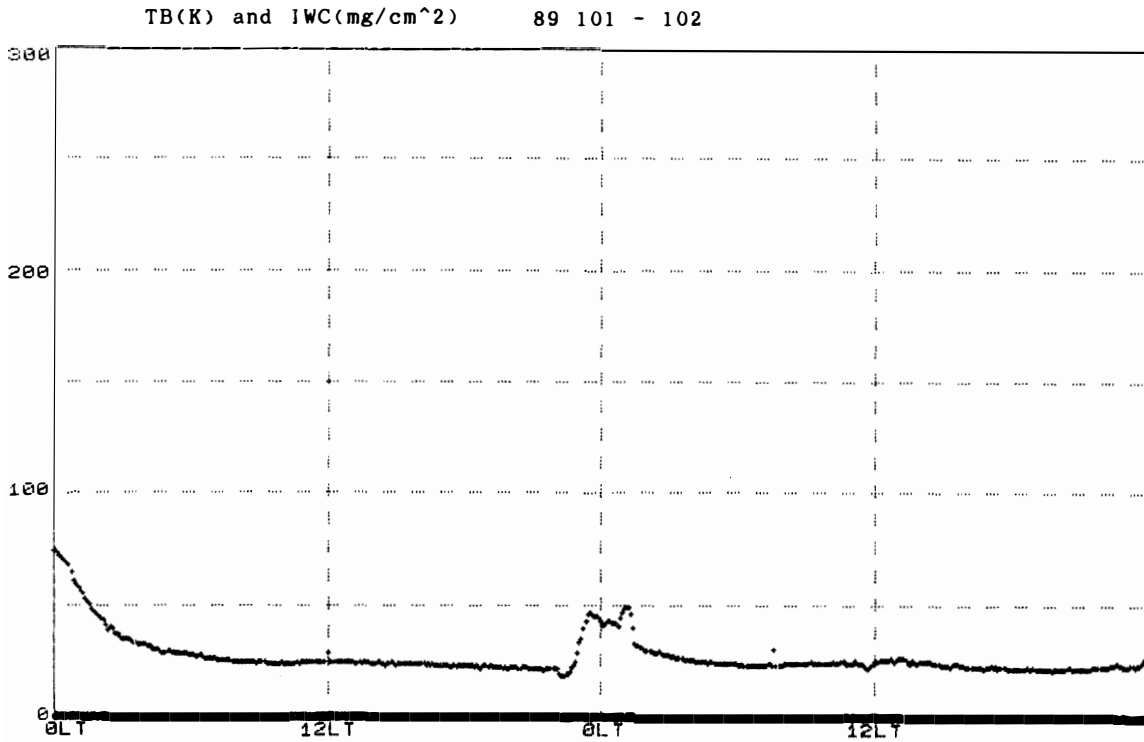
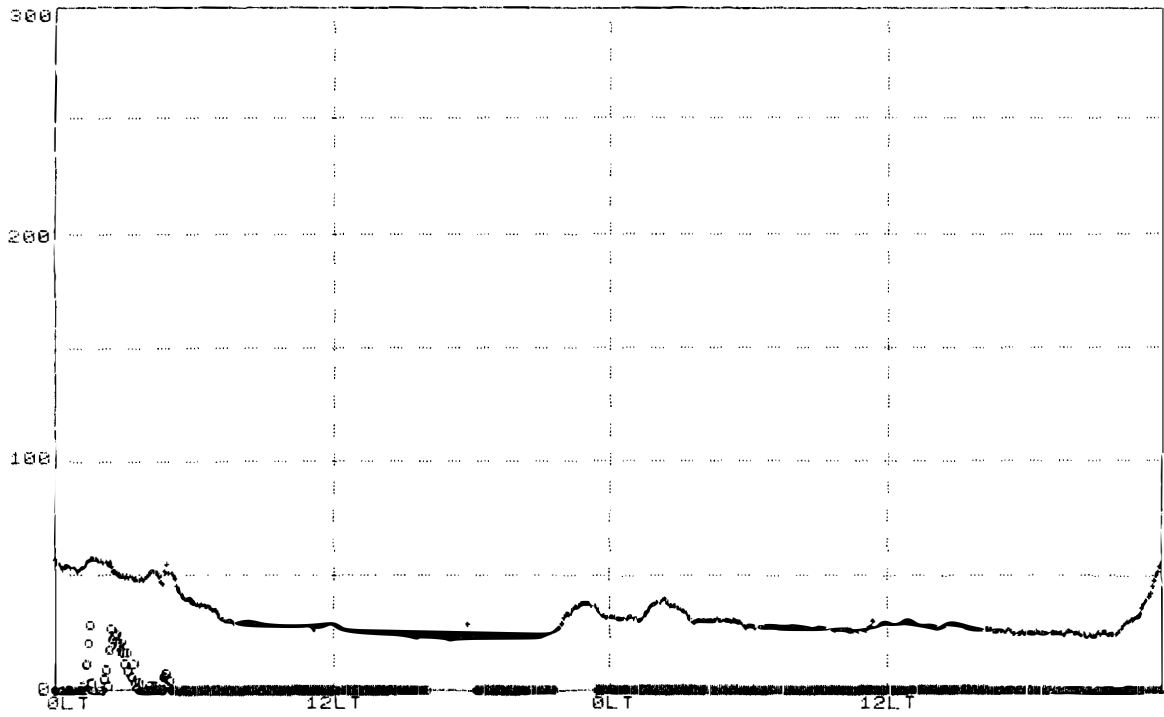
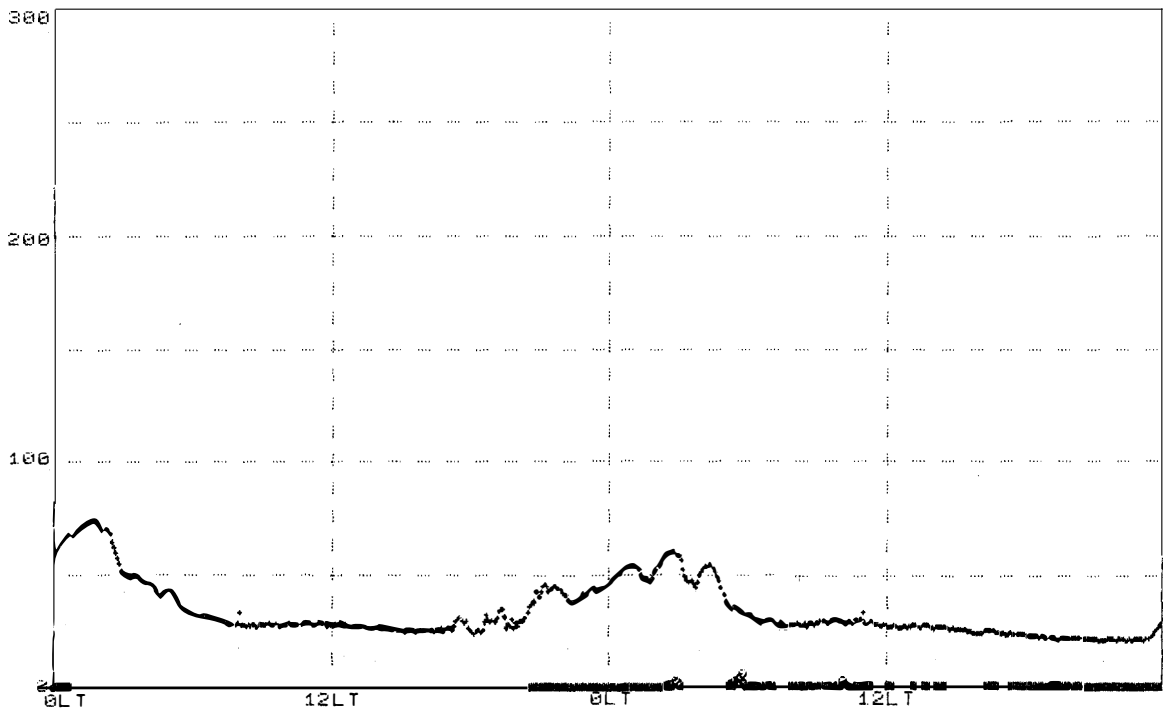


Fig. 5. Five-min mean brightness temperature (K) of the 37 GHz microwave radiometer and vertically integrated ice water content (mg/cm²).

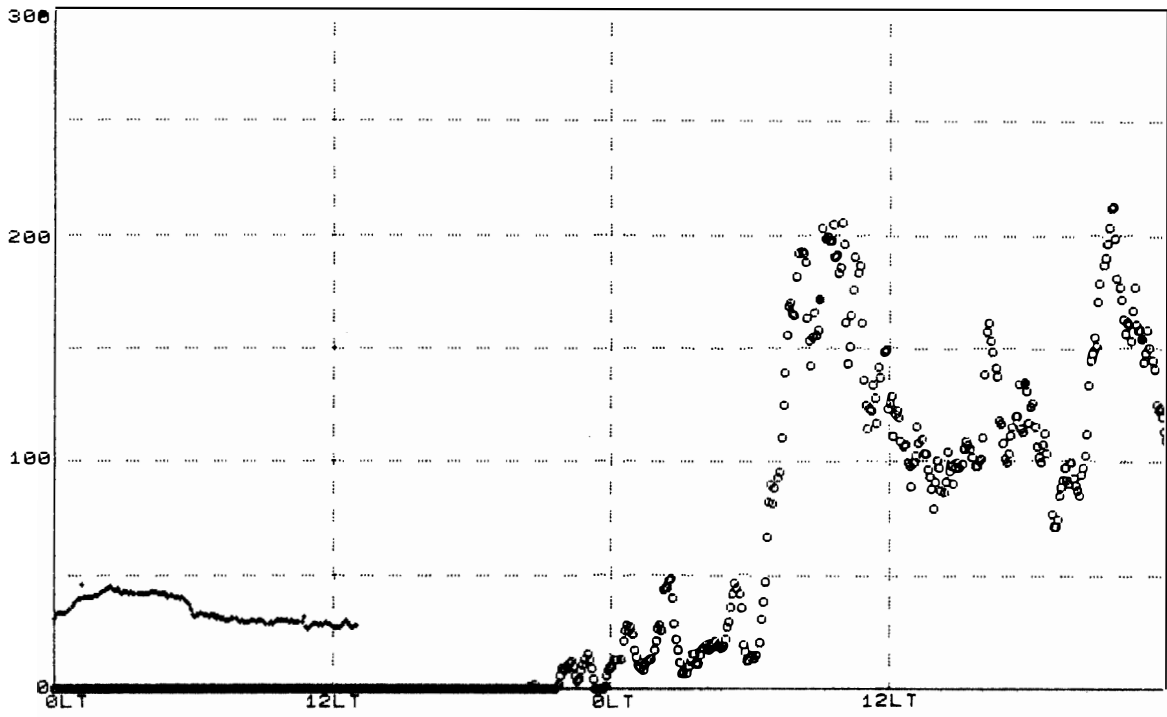
TB(K) and IWC(mg/cm²) 89 105 - 106



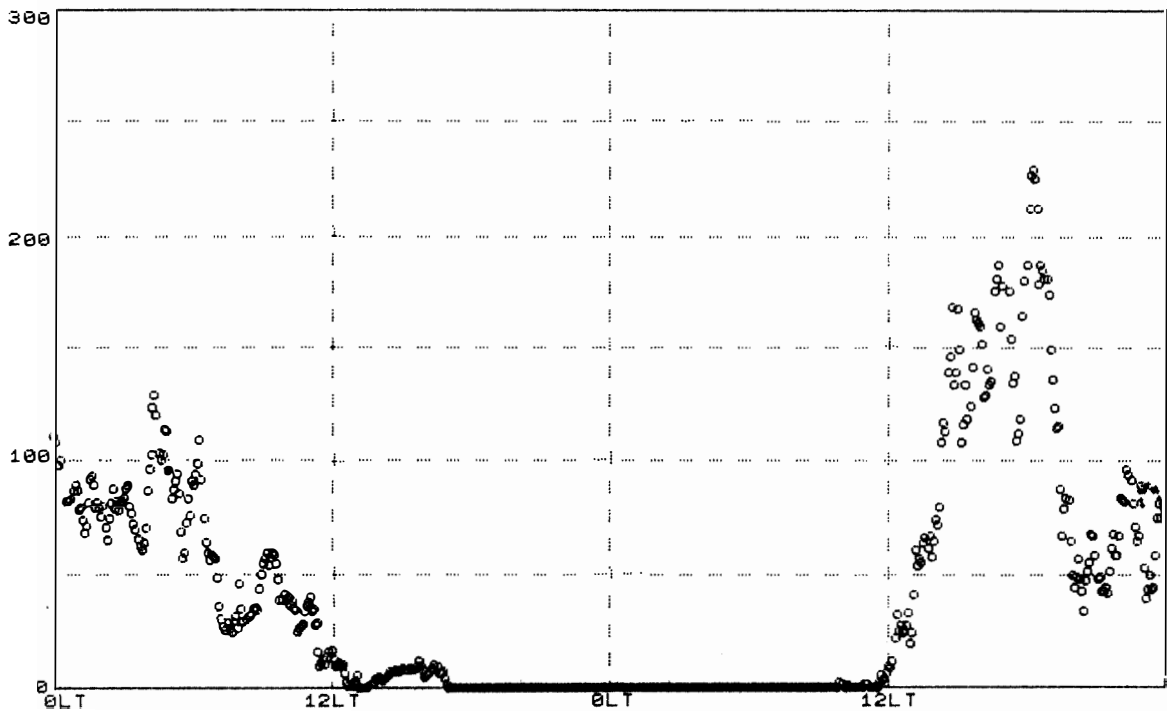
TB(K) and IWC(mg/cm²) 89 107 - 108



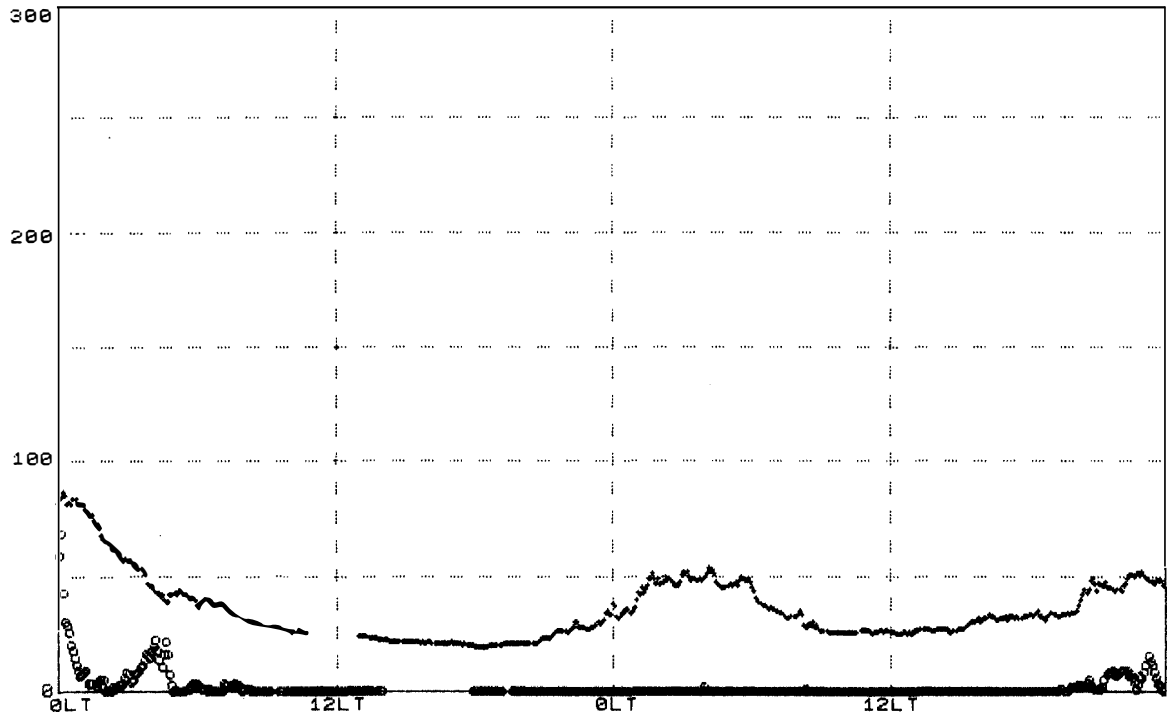
TB(K) and IWC(mg/cm²) 89 109 - 110



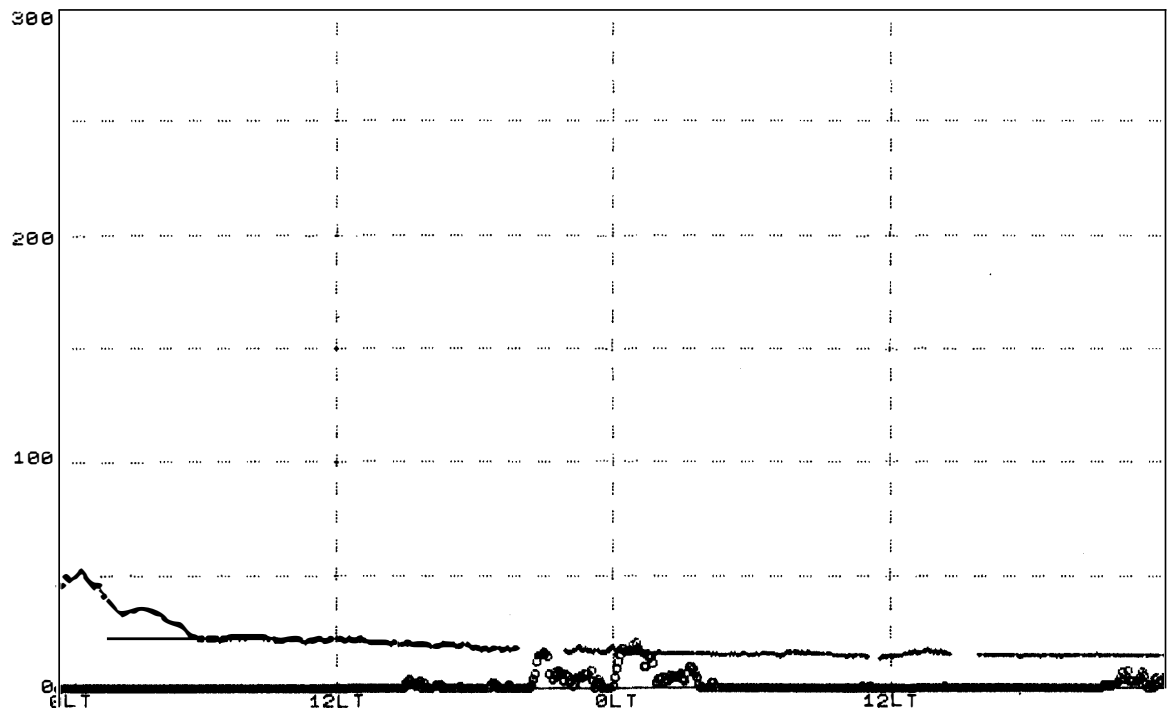
TB(K) and IWC(mg/cm²) 89 111 - 112



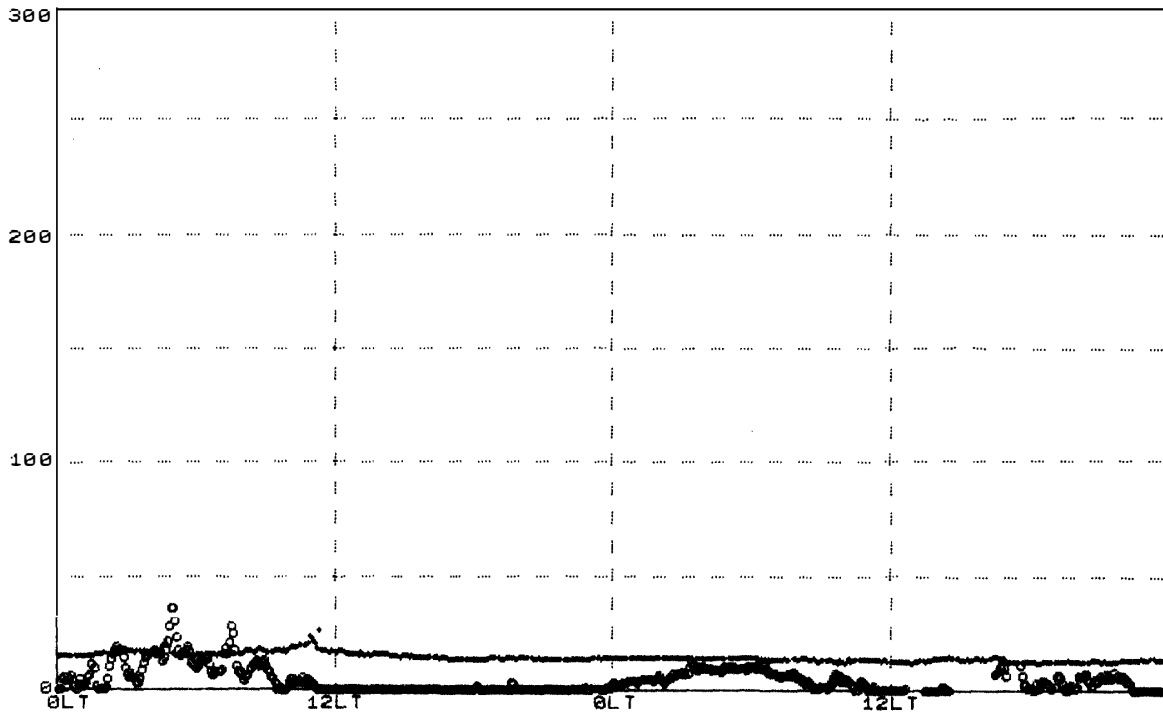
TB(K) and IWC(mg/cm²) 89 113 - 114



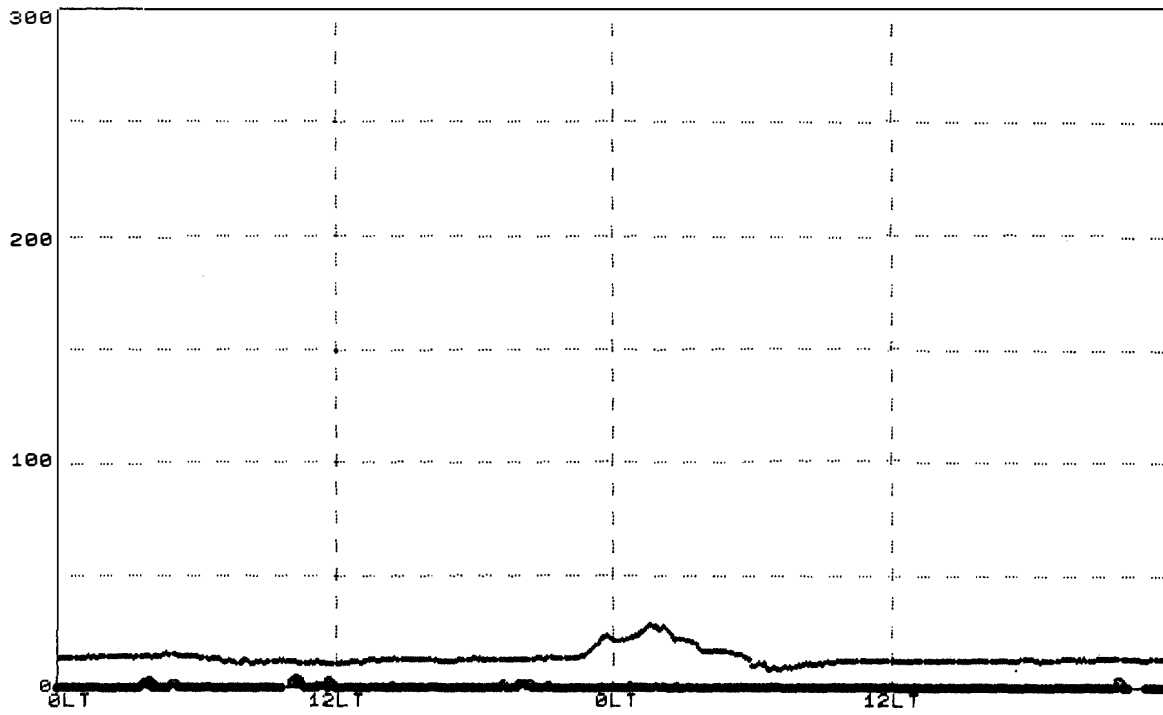
TB(K) and IWC(mg/cm²) 89 115 - 116



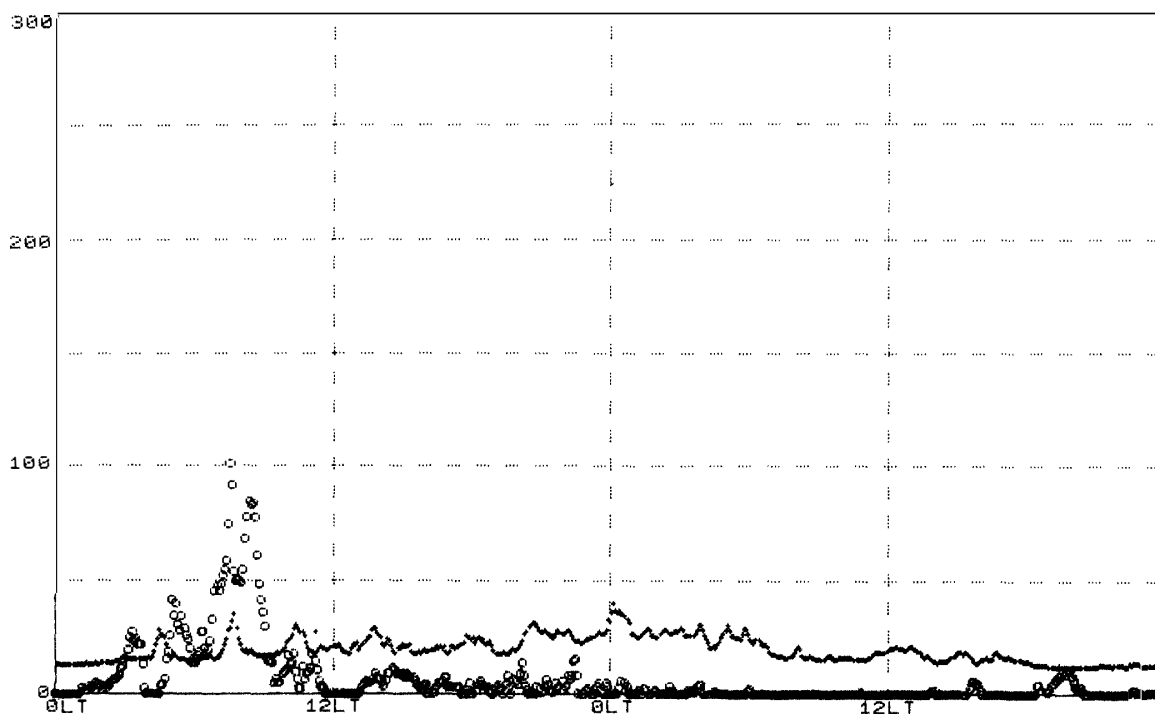
TB(K) and IWC(mg/cm²) 89 117 - 118



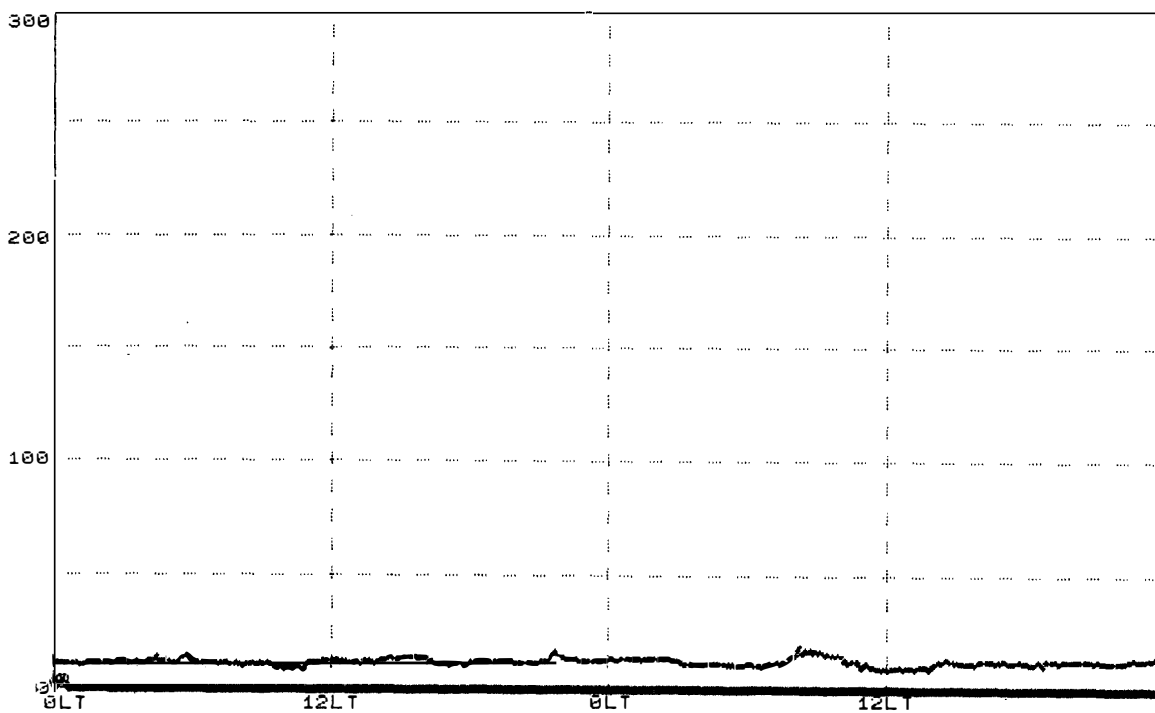
TB(K) and IWC(mg/cm²) 89 119 - 120



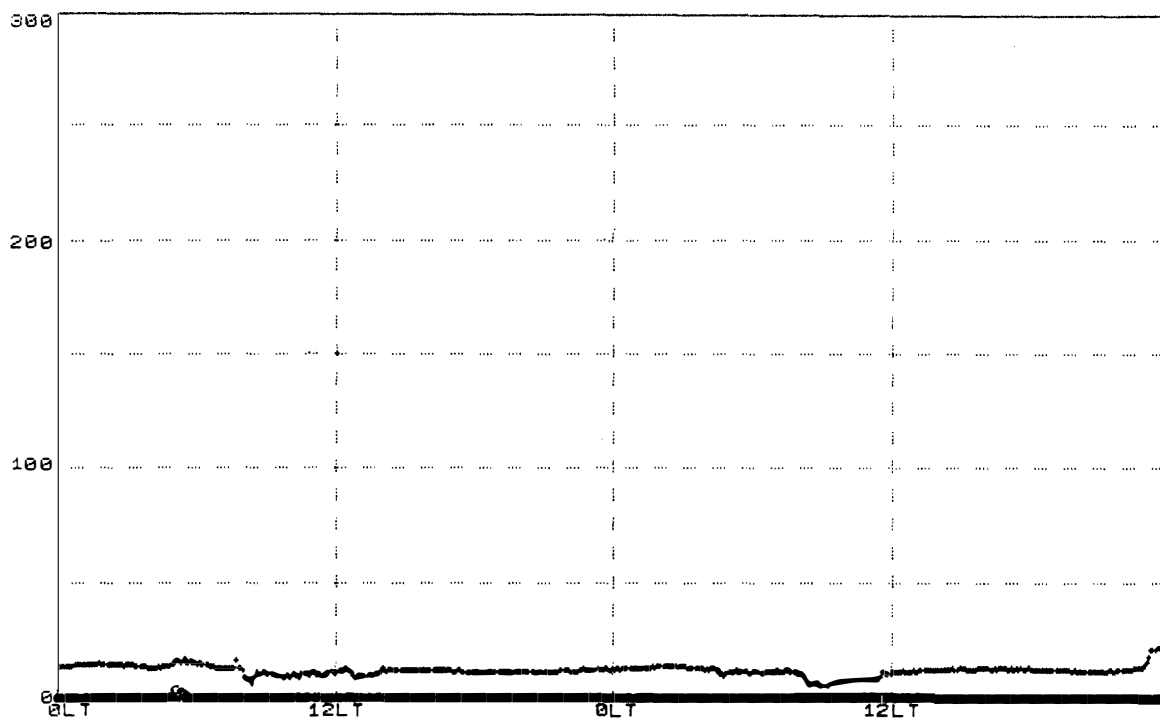
TB(K) and IWC(mg/cm²) 89 121 - 122



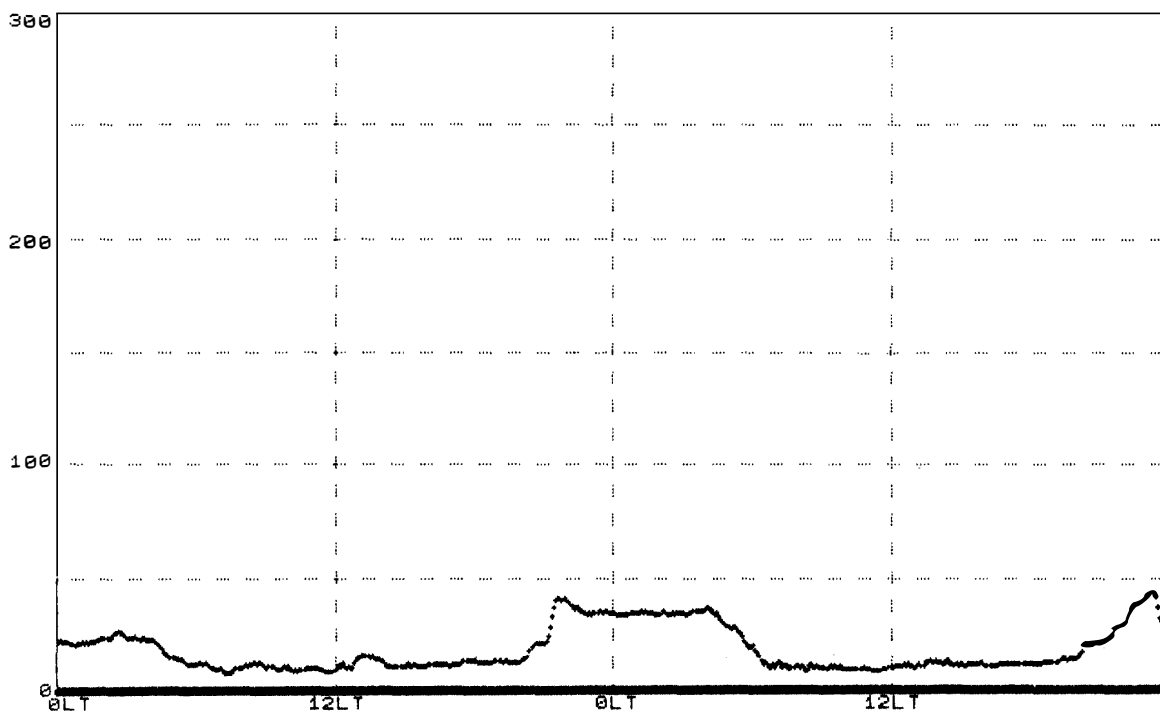
TB(K) and IWC(mg/cm²) 89 123 - 124



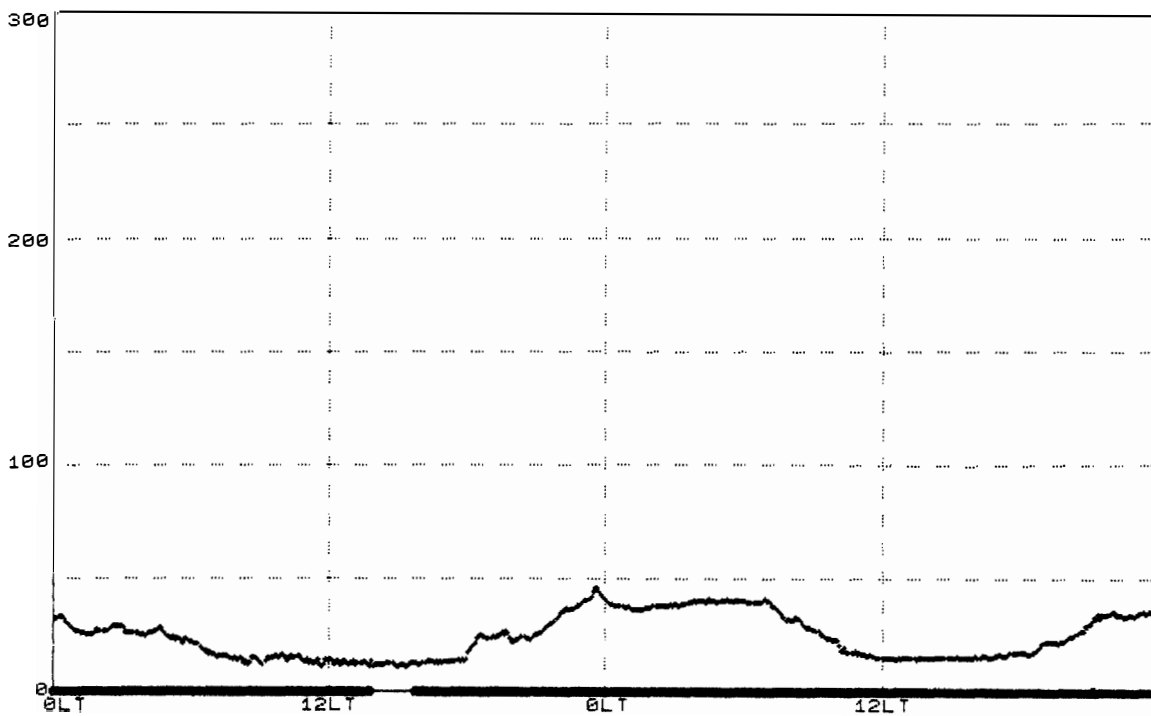
TB(K) and IWC(mg/cm²) 89 125 - 126



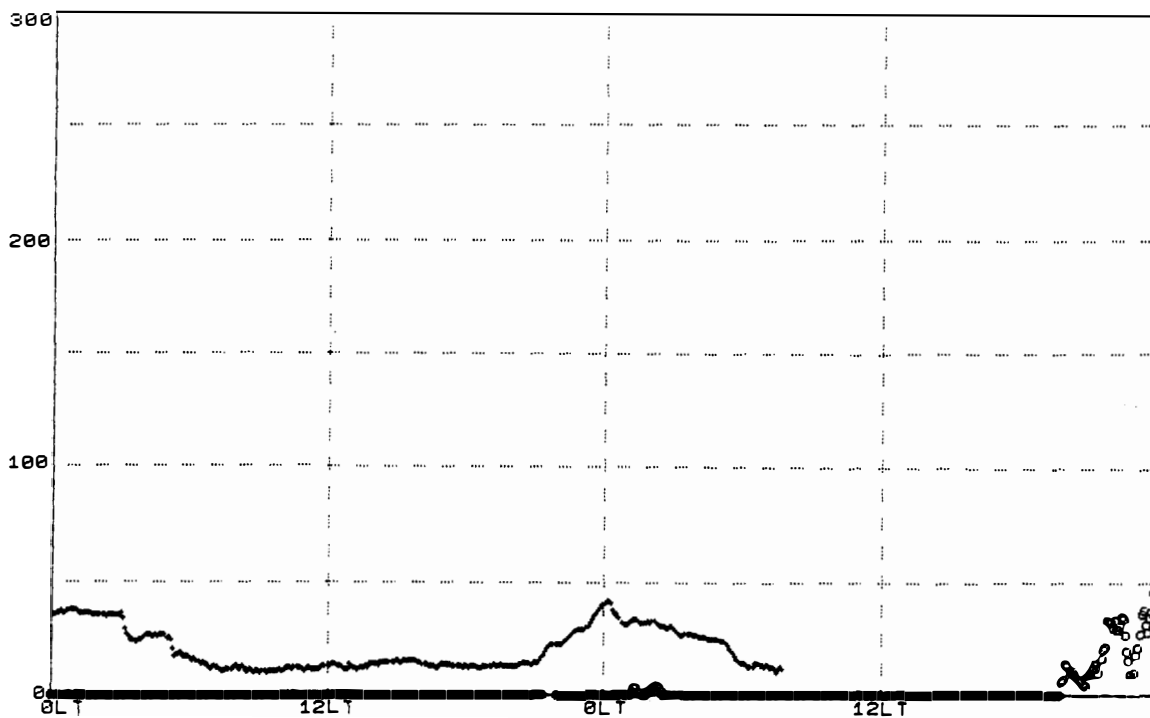
TB(K) and IWC(mg/cm²) 89 127 - 128



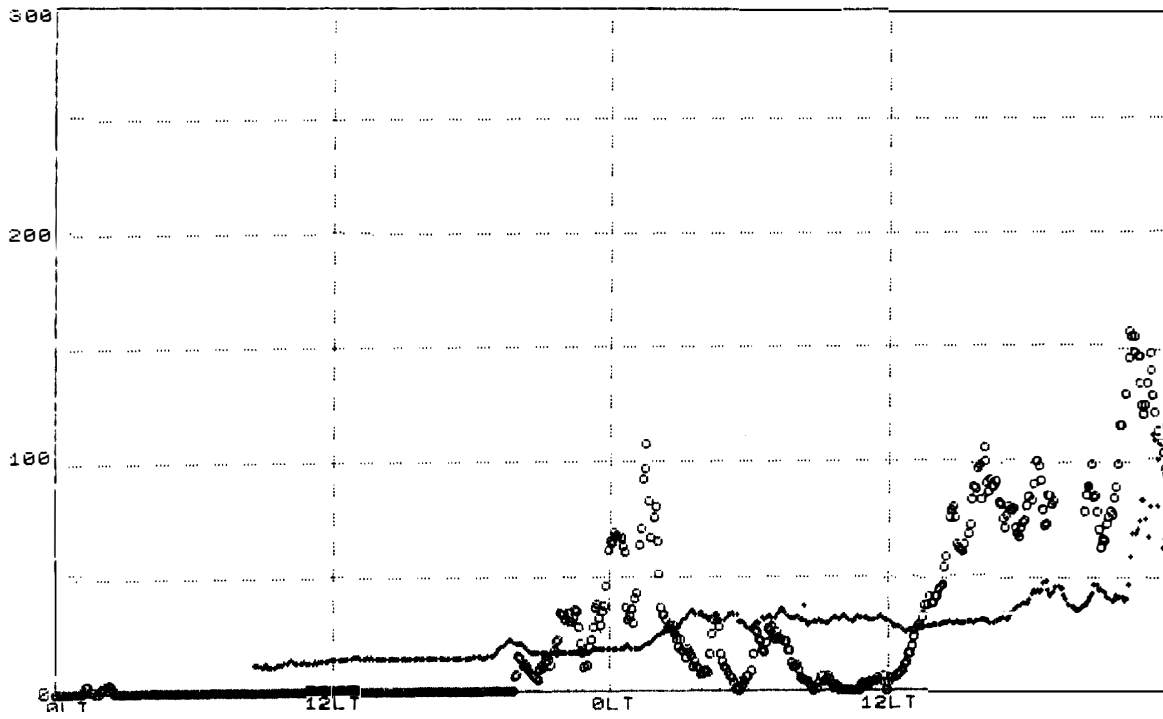
TB(K) and IWC(mg/cm²) 89 129 - 130



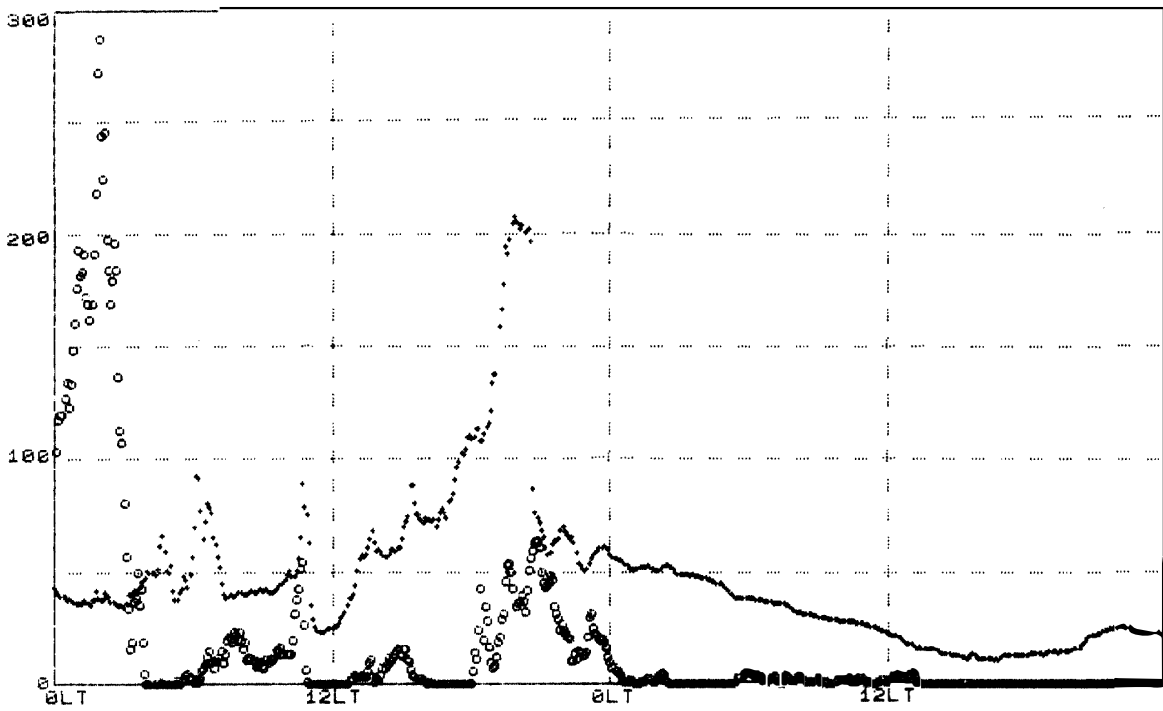
TB(K) and IWC(mg/cm²) 89 131 - 201



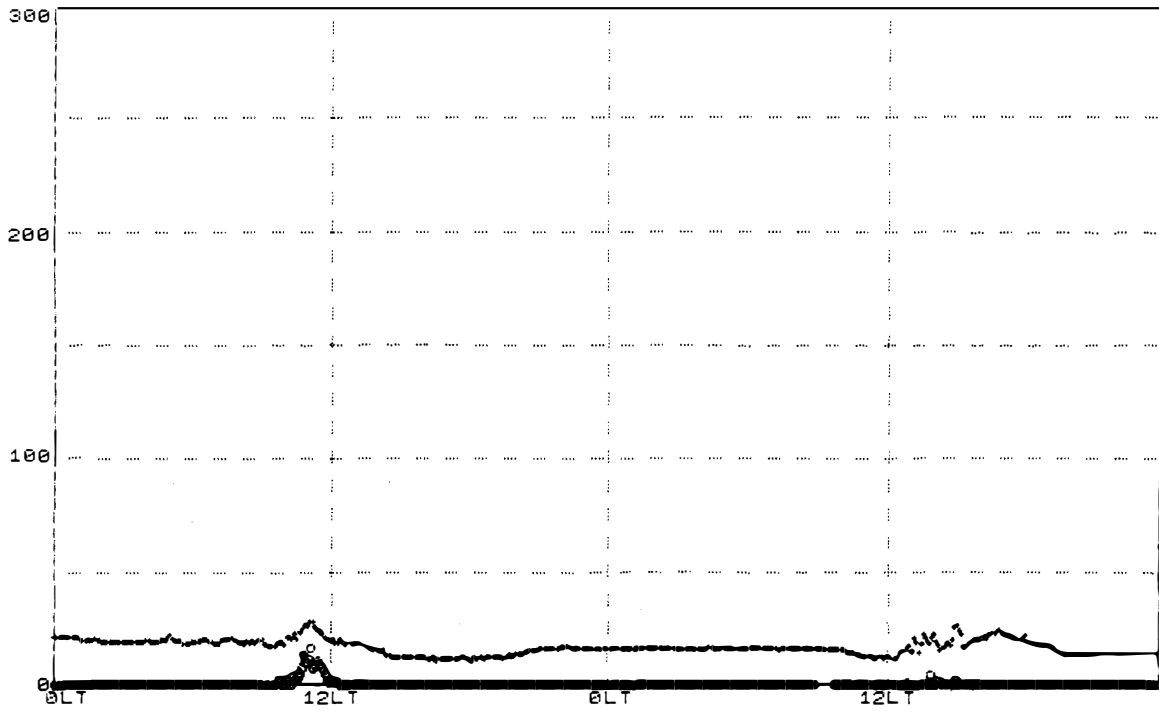
TB(K) and IWC(mg/cm²) 89 201 --> 202



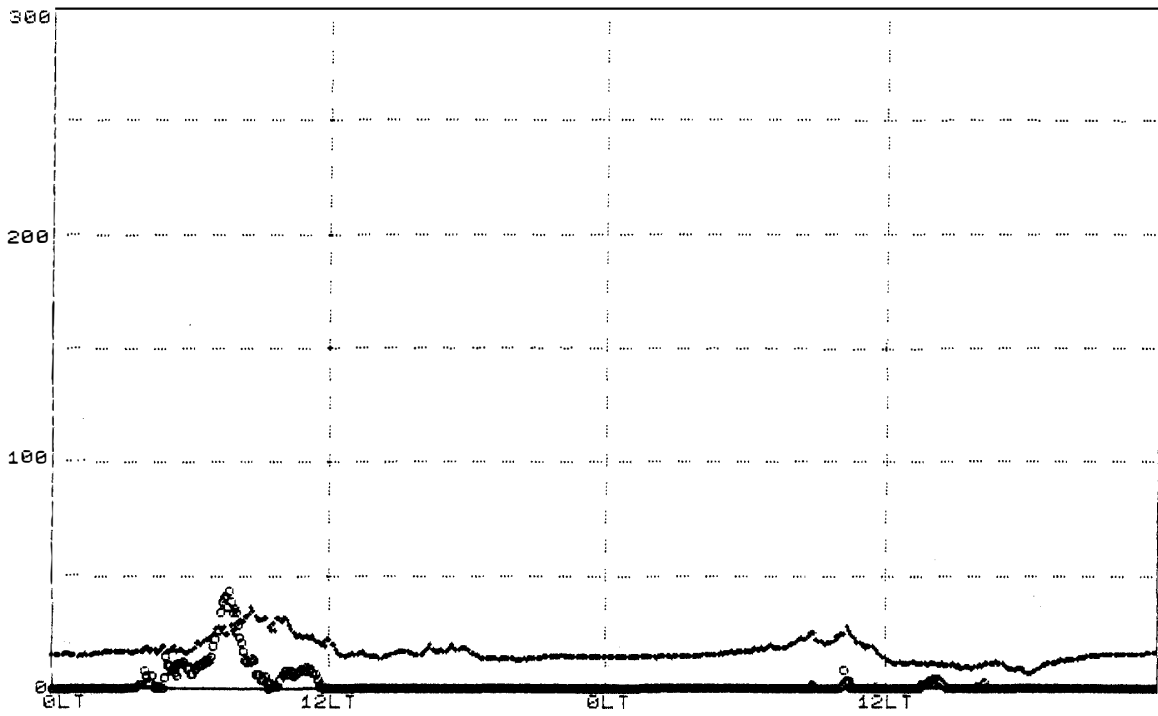
TB(K) and IWC(mg/cm²) 89 203 --> 204



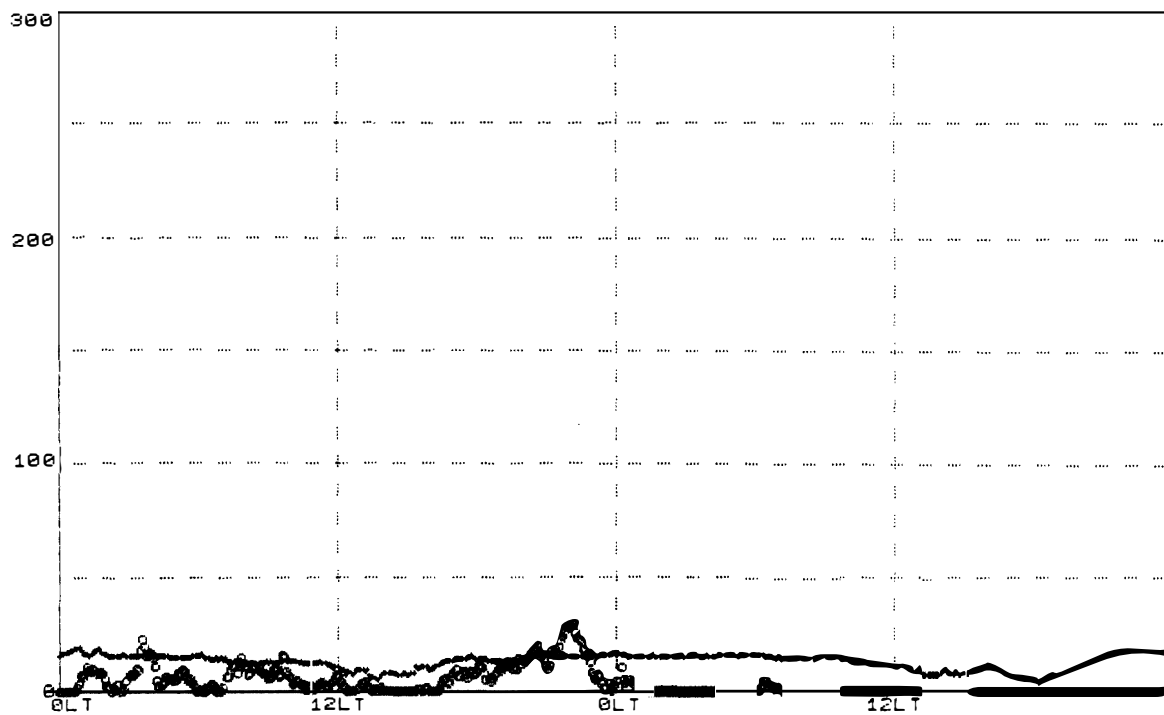
TB(K) and IWC(mg/cm²) 89 205 --> 206



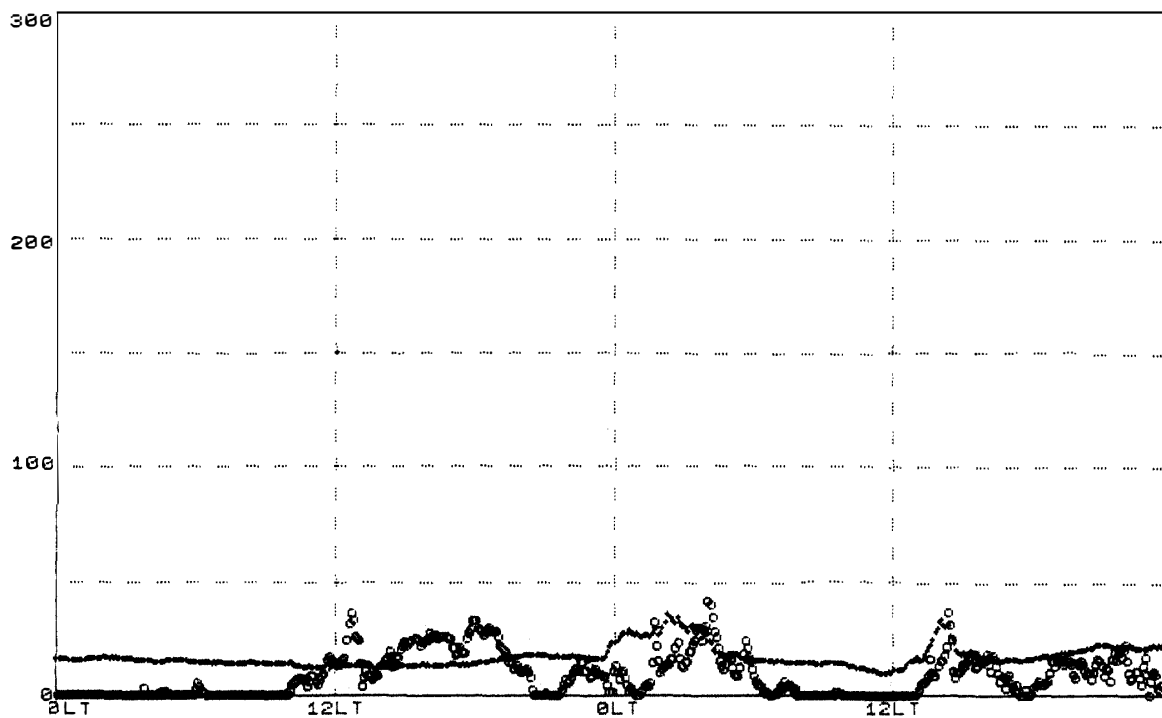
TB(K) and IWC(mg/cm²) 89 207 --> 208



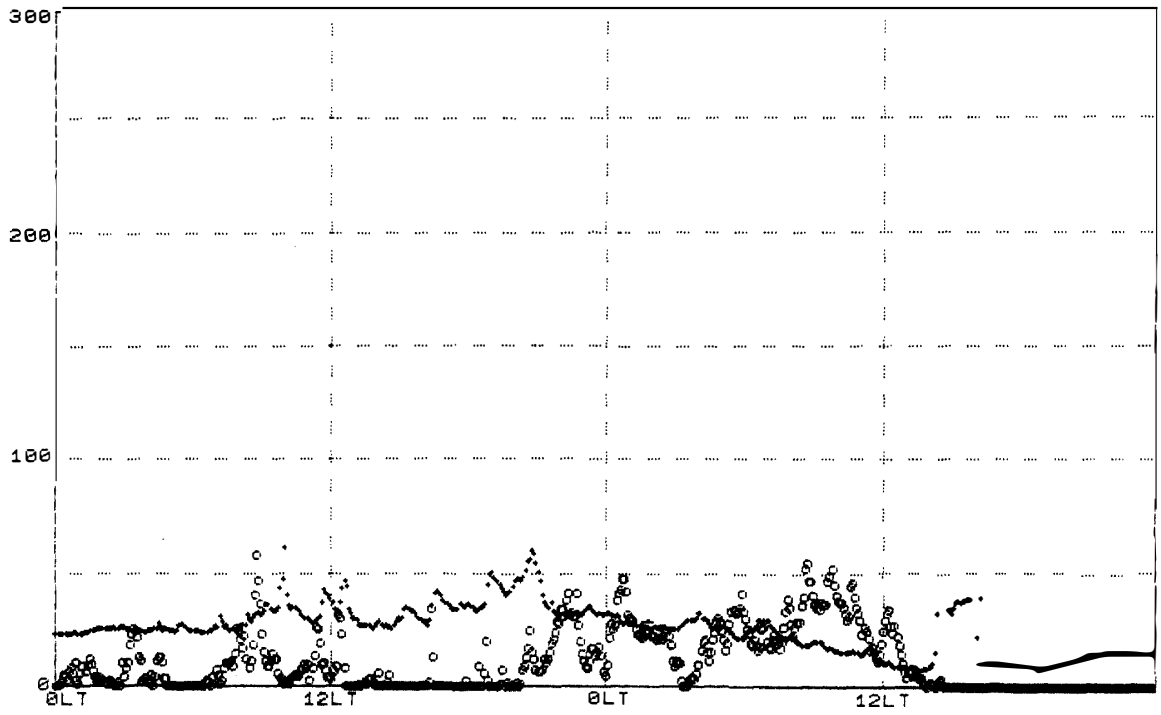
TB(K) and IWC(mg/cm²) 89 209 --> 210



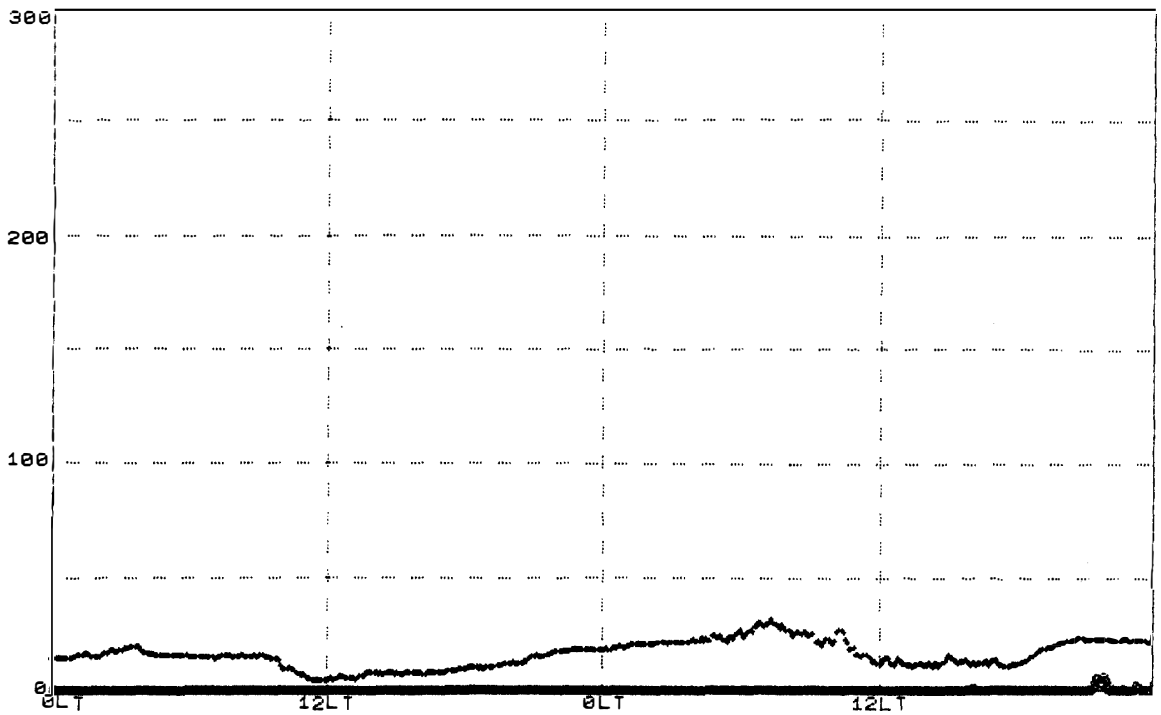
TB(K) and IWC(mg/cm²) 89 211 --> 212



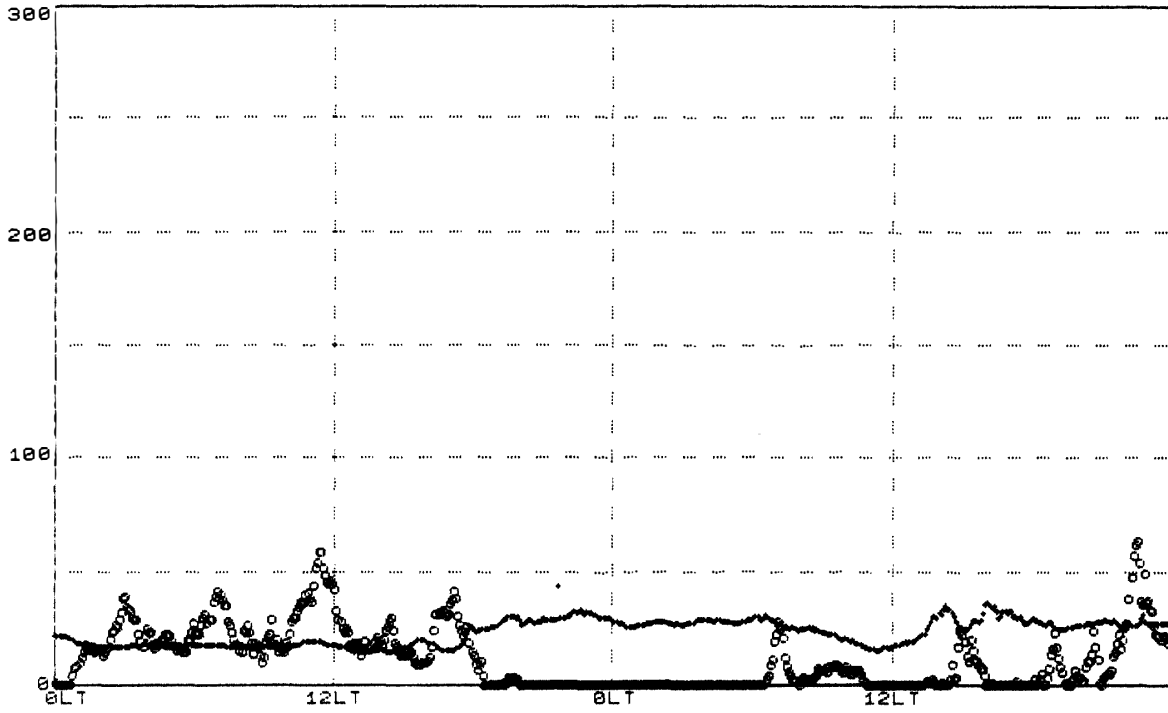
TB(K) and IWC(mg/cm²) 89 213 --> 214



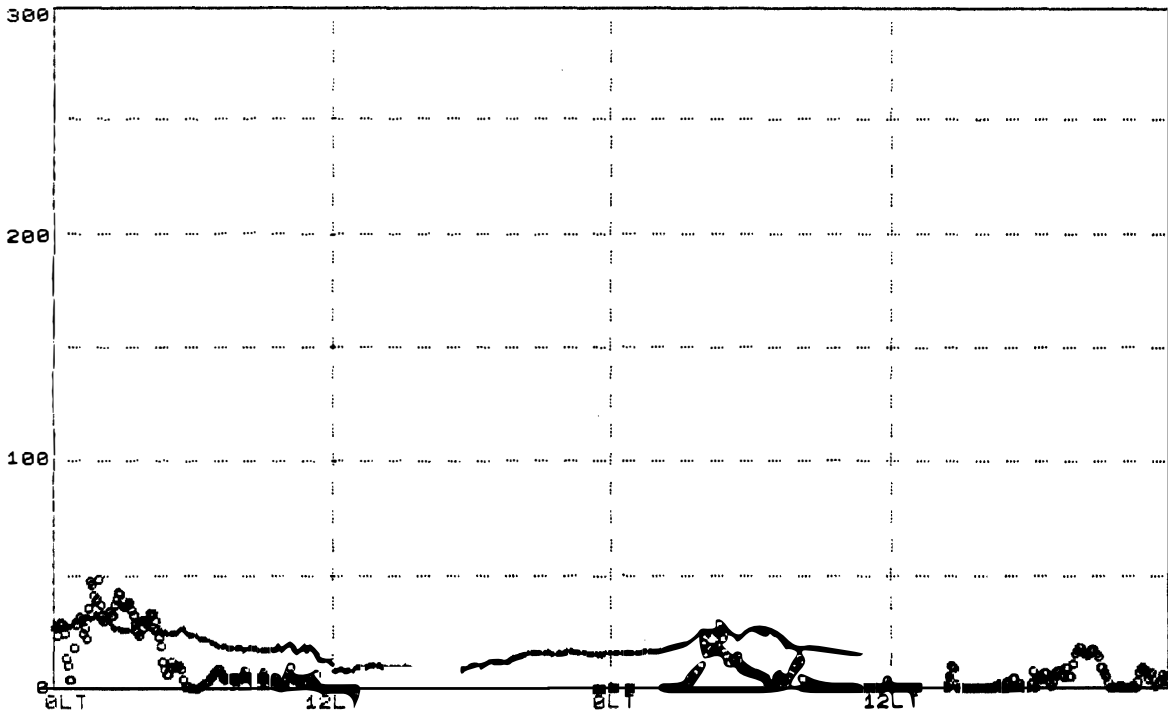
TB(K) and IWC(mg/cm²) 89 215 --> 216



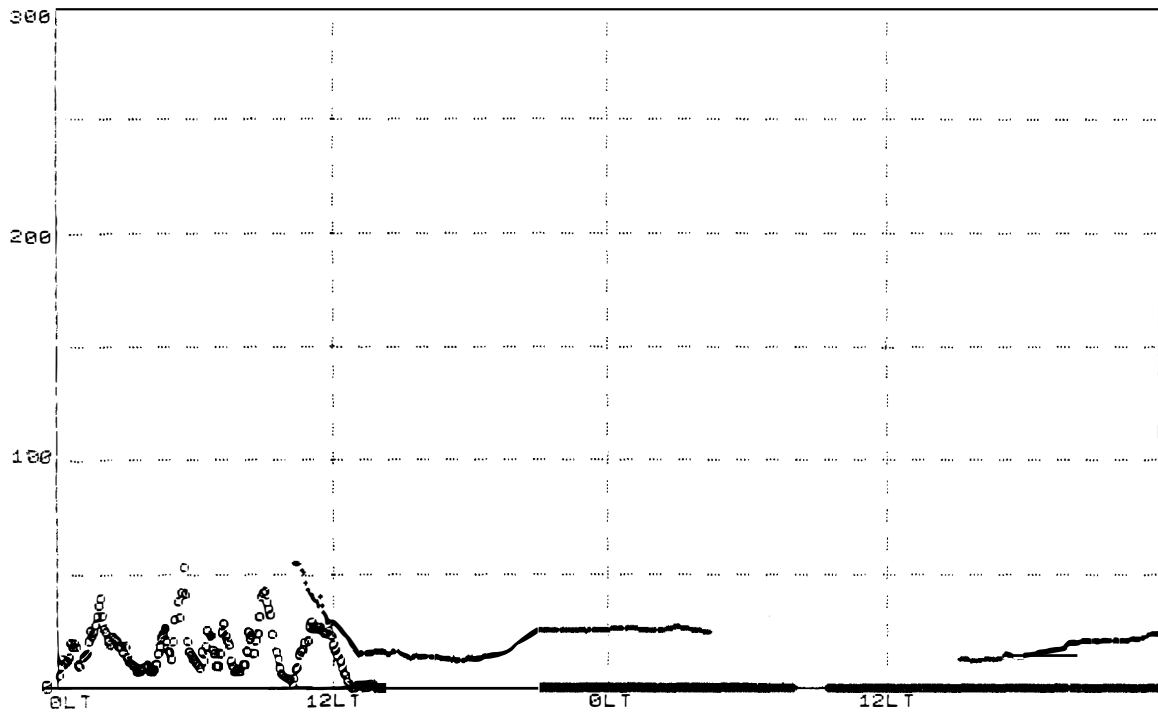
TB(K) and IWC(mg/cm²) 89 217 --> 218



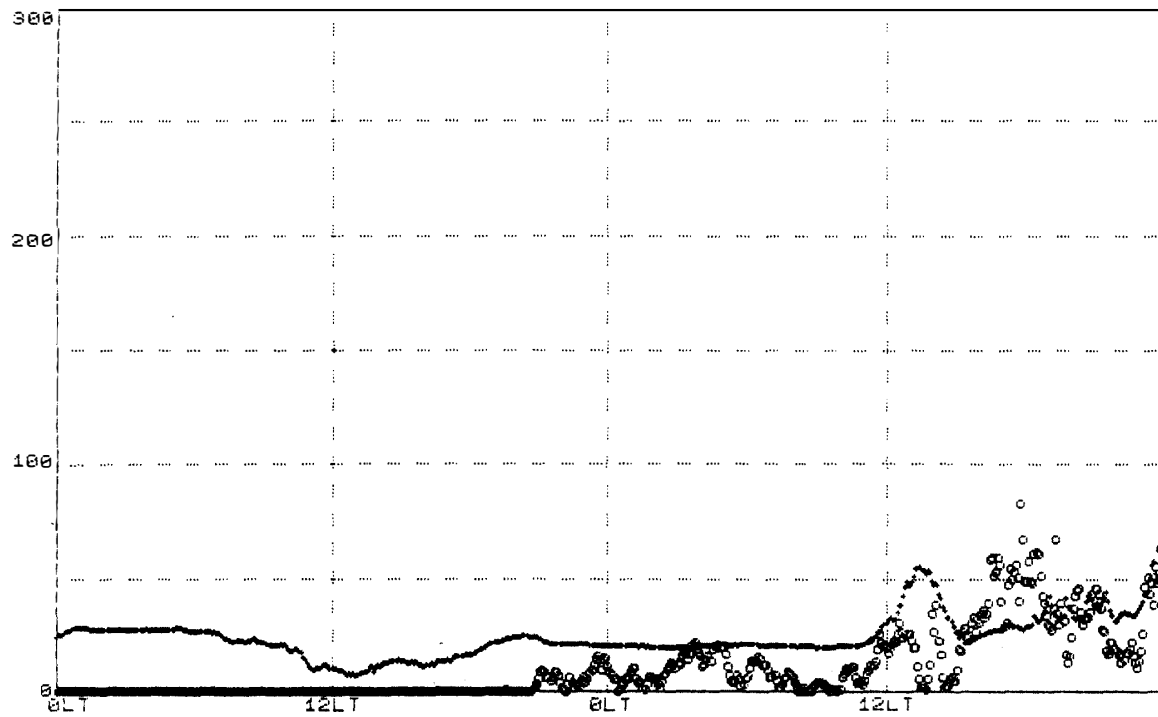
TB(K) and IWC(mg/cm²) 89 219 --> 220



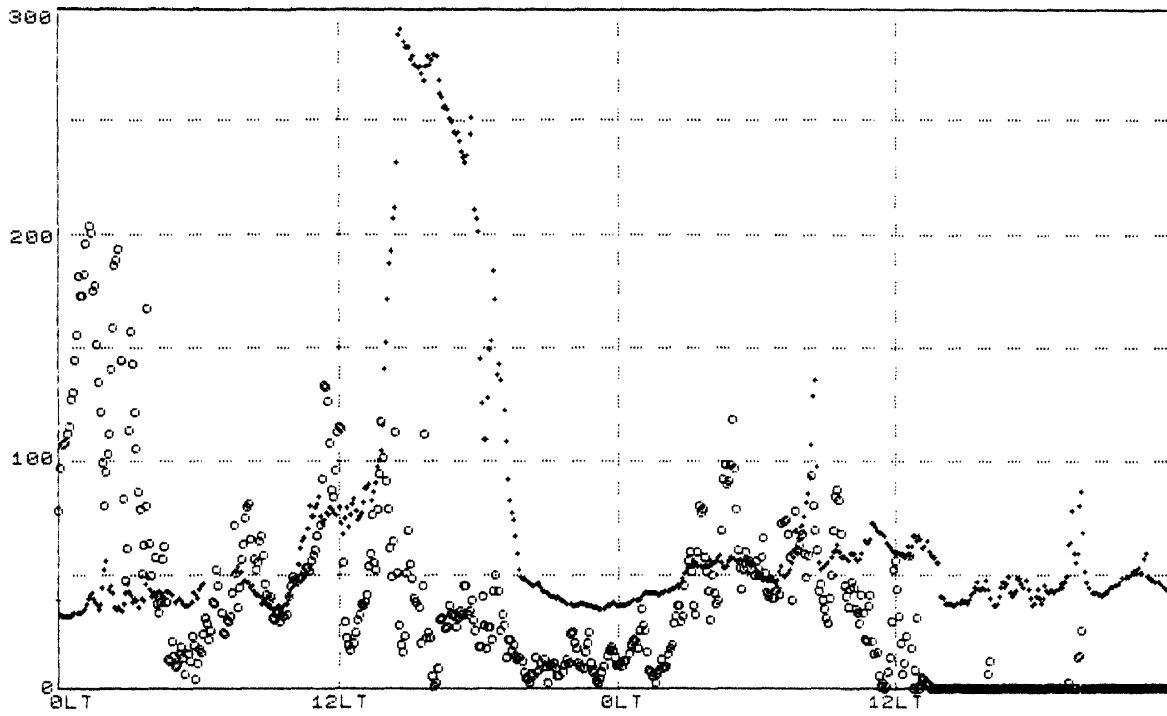
TB(K) and IWC(mg/cm²) 89 221 --> 222



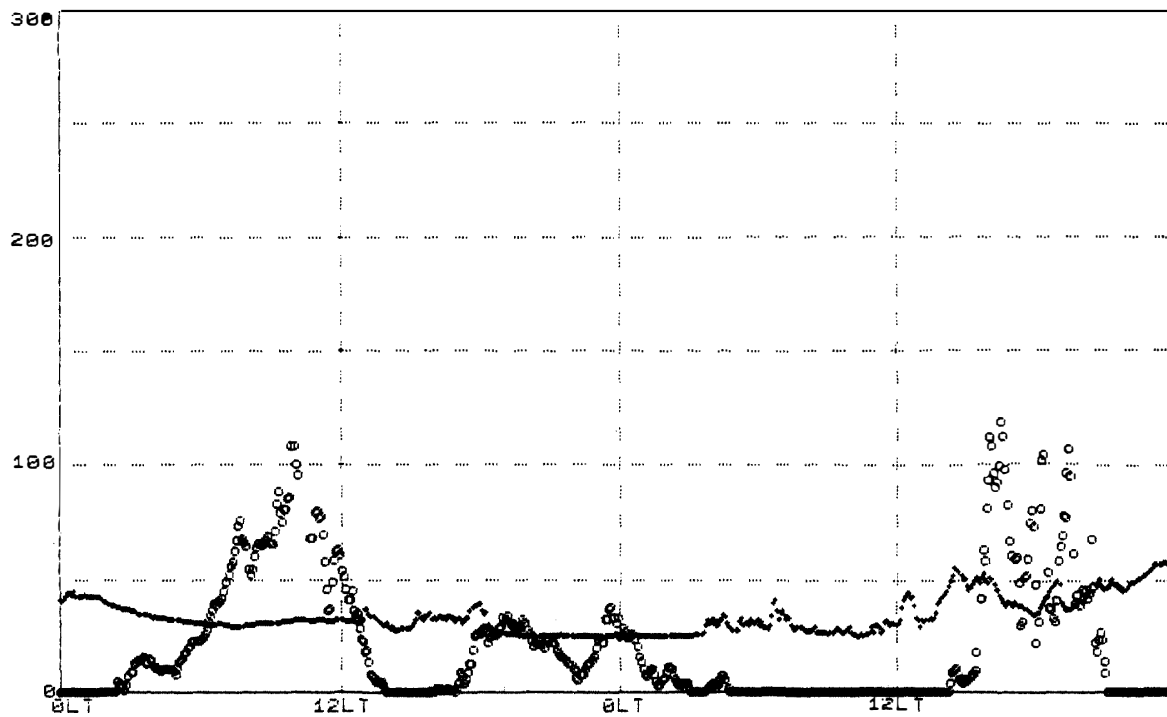
TB(K) and IWC(mg/cm²) 89 223 --> 224



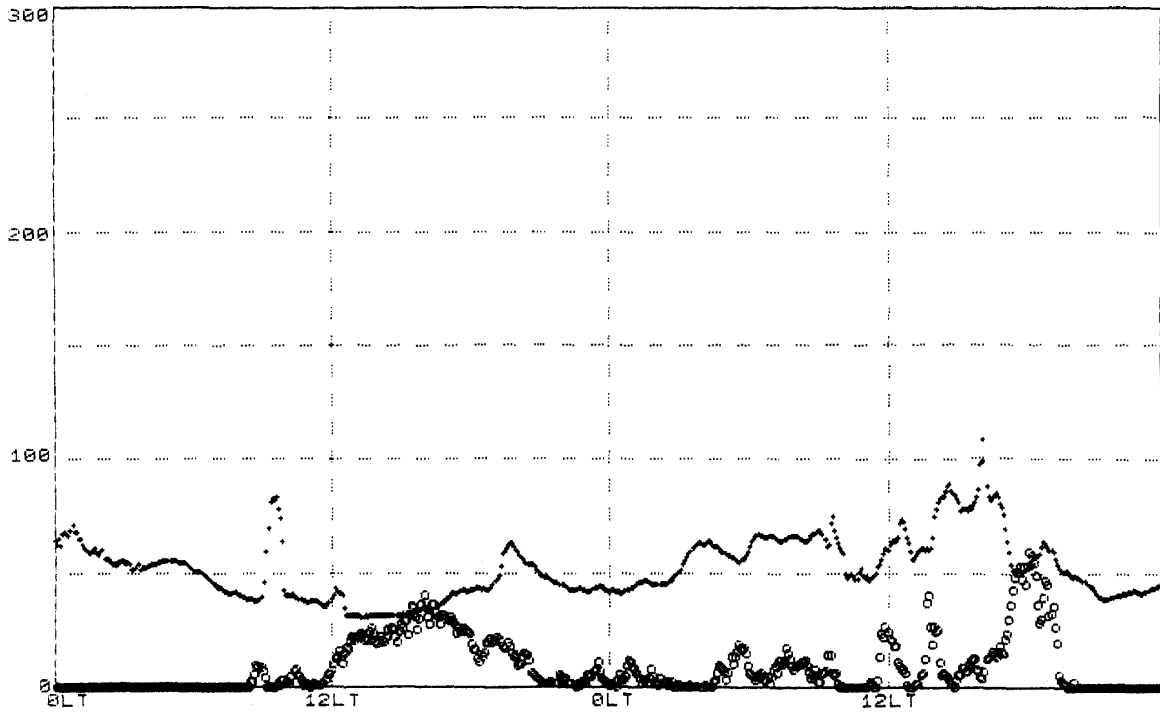
TB(K) and IWC(mg/cm²) 89 225 --> 226



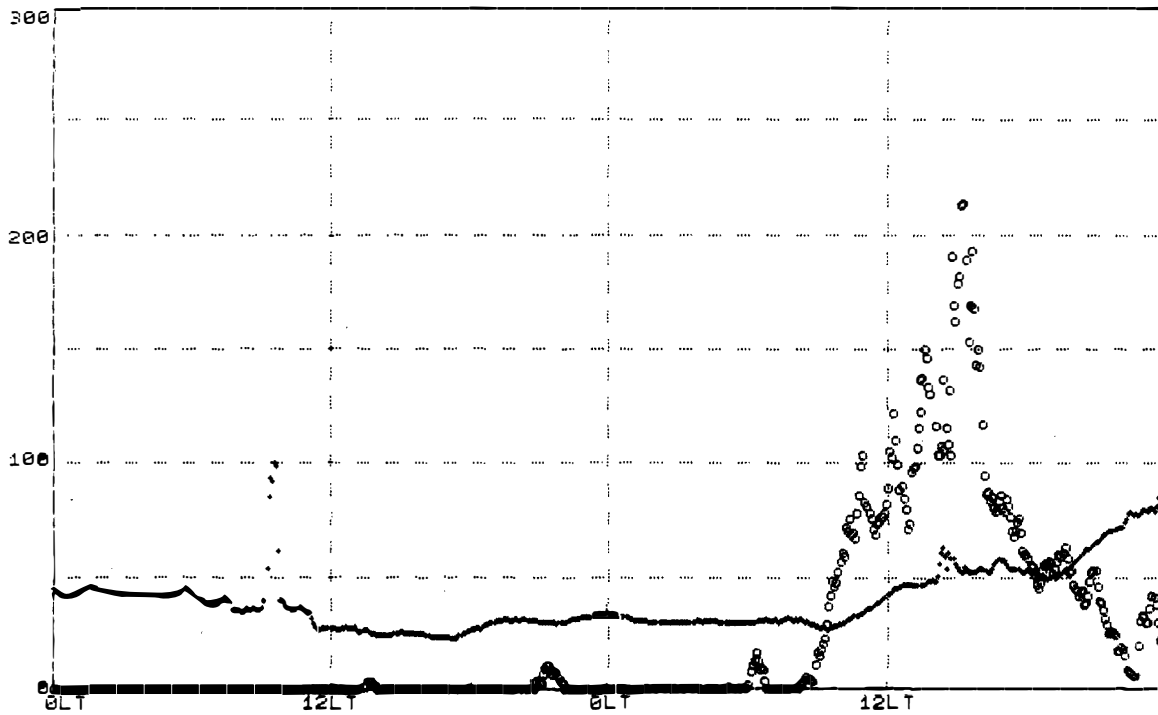
TB(K) and IWC(mg/cm²) 89 227 --> 228



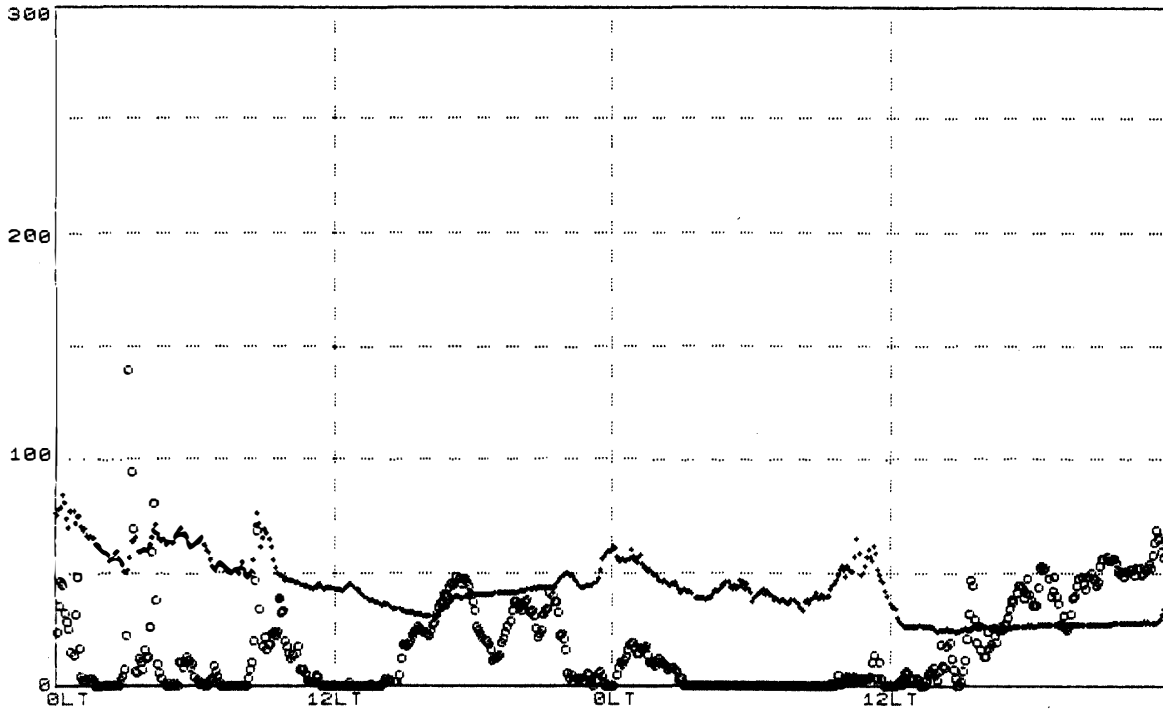
TB(K) and IWC(mg/cm²) 89 301 --> 302



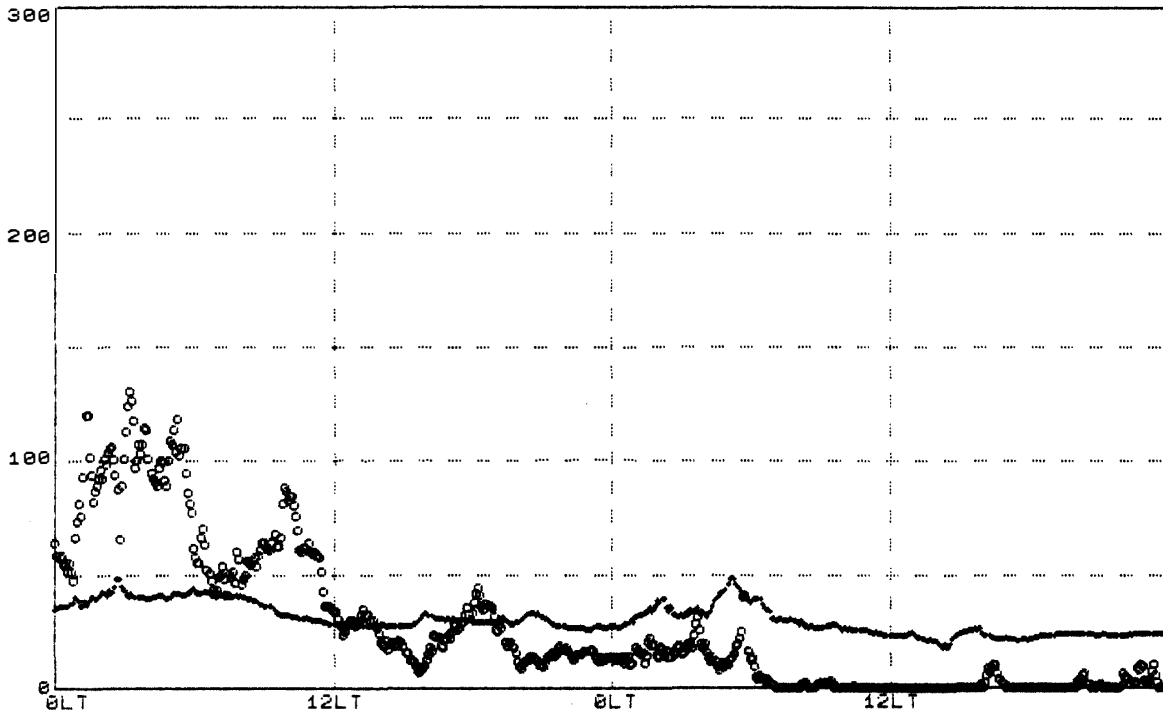
TB(K) and IWC(mg/cm²) 89 303 --> 304



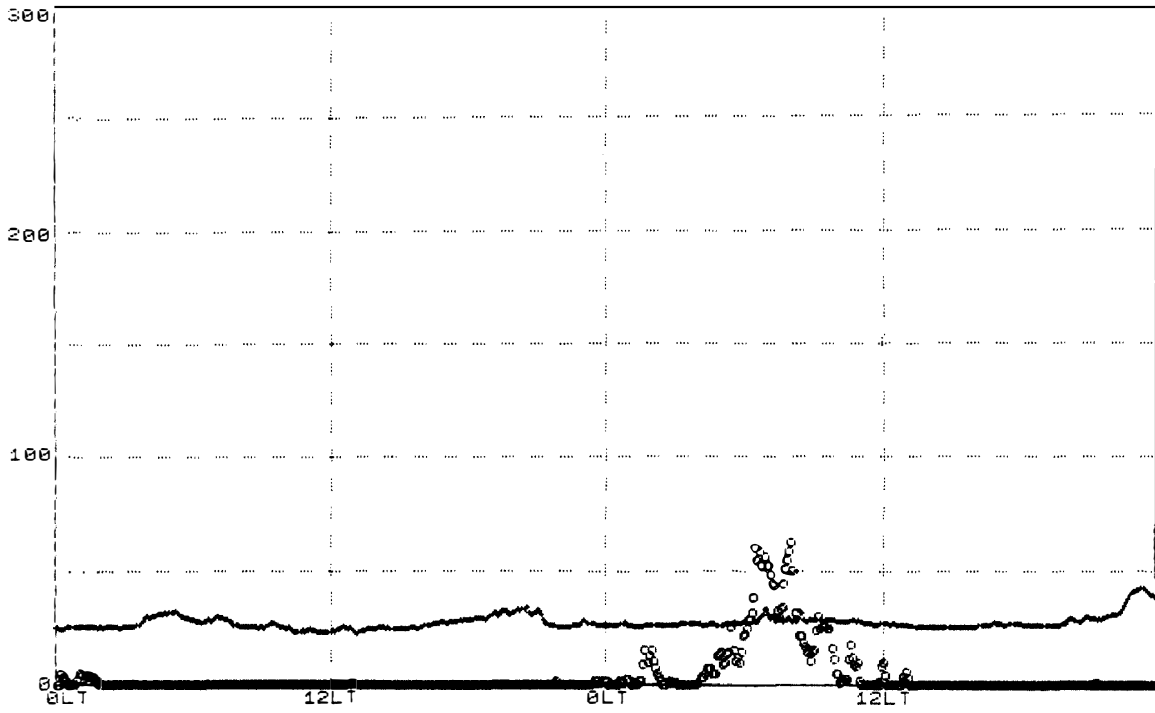
TB(K) and IWC(mg/cm²) 89 305 --> 306



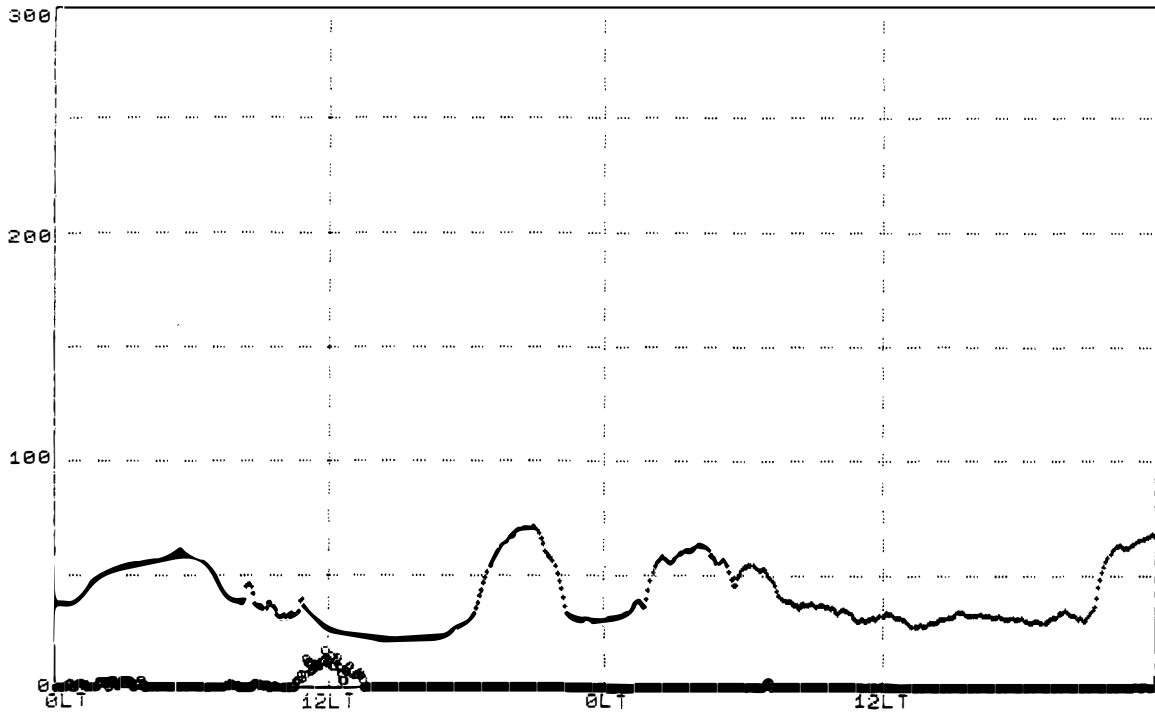
TB(K) and IWC(mg/cm²) 89 307 --> 308



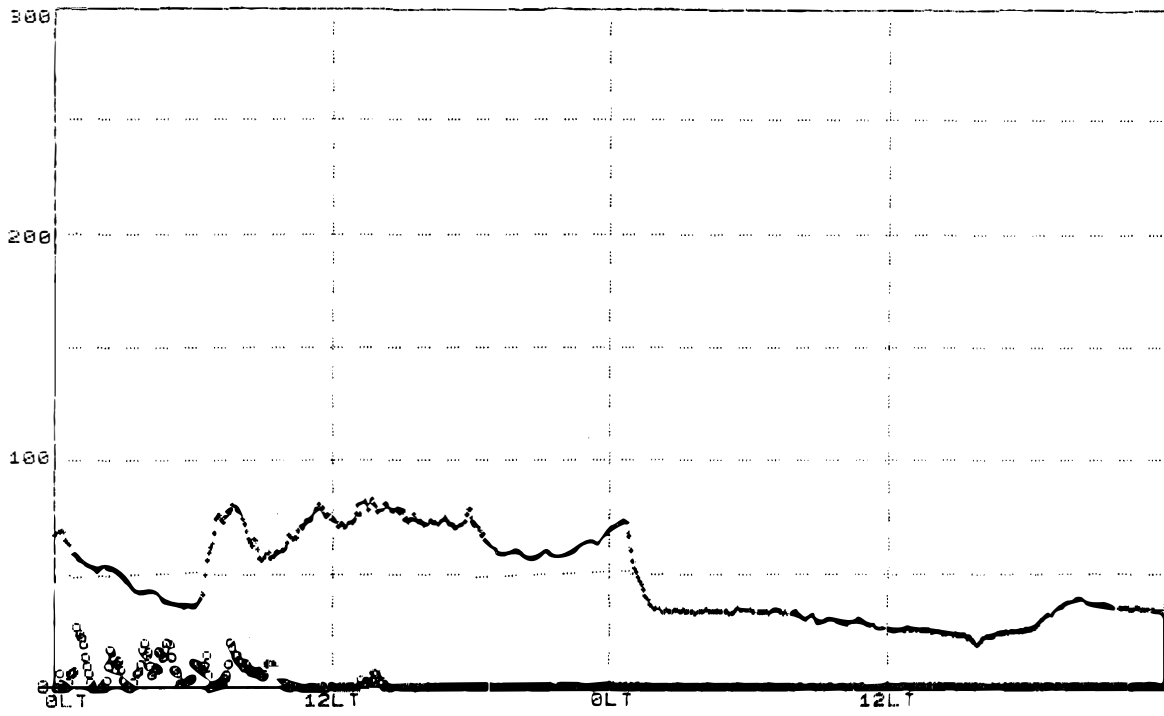
TB(K) and IWC(mg/cm²) 89 309 --> 310



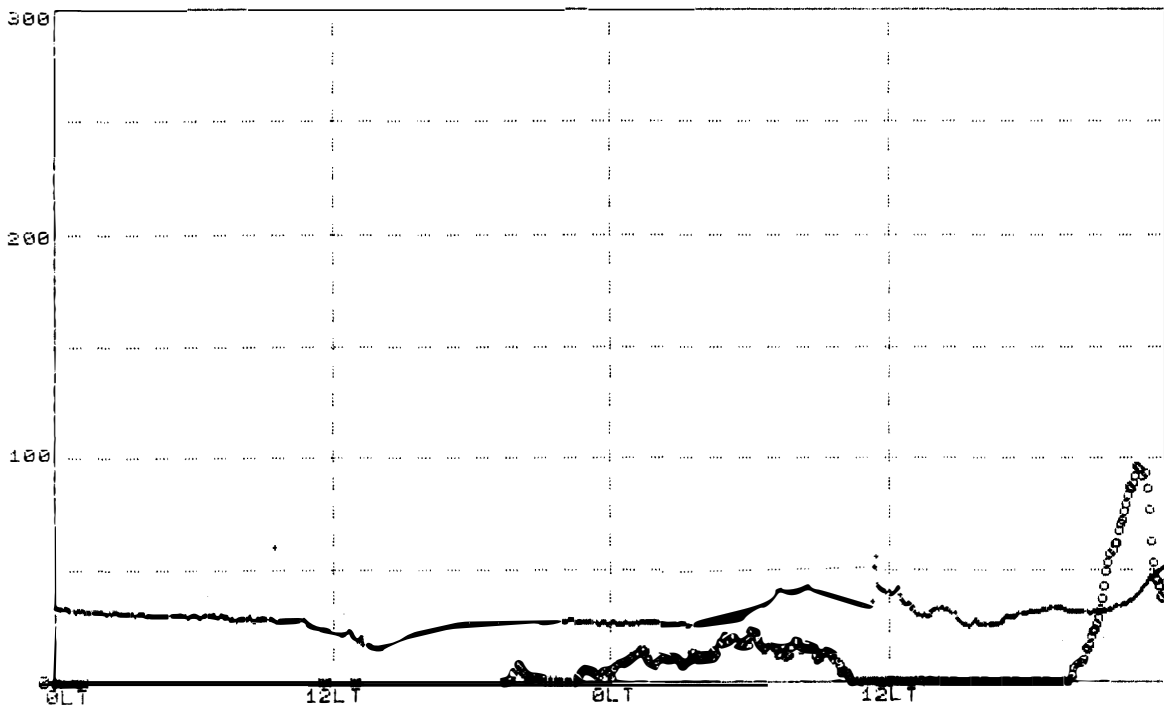
TB(K) and IWC(mg/cm²) 89 311 --> 312



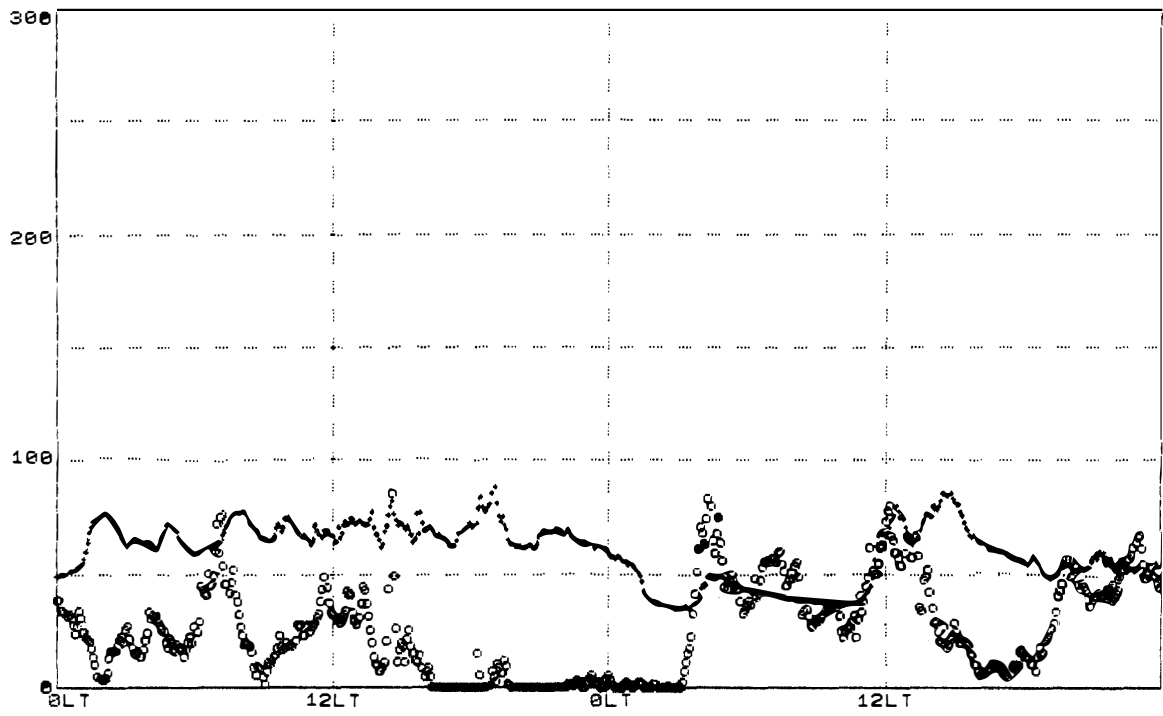
TB(K) and IWC(mg/cm²) 89 313 --> 314



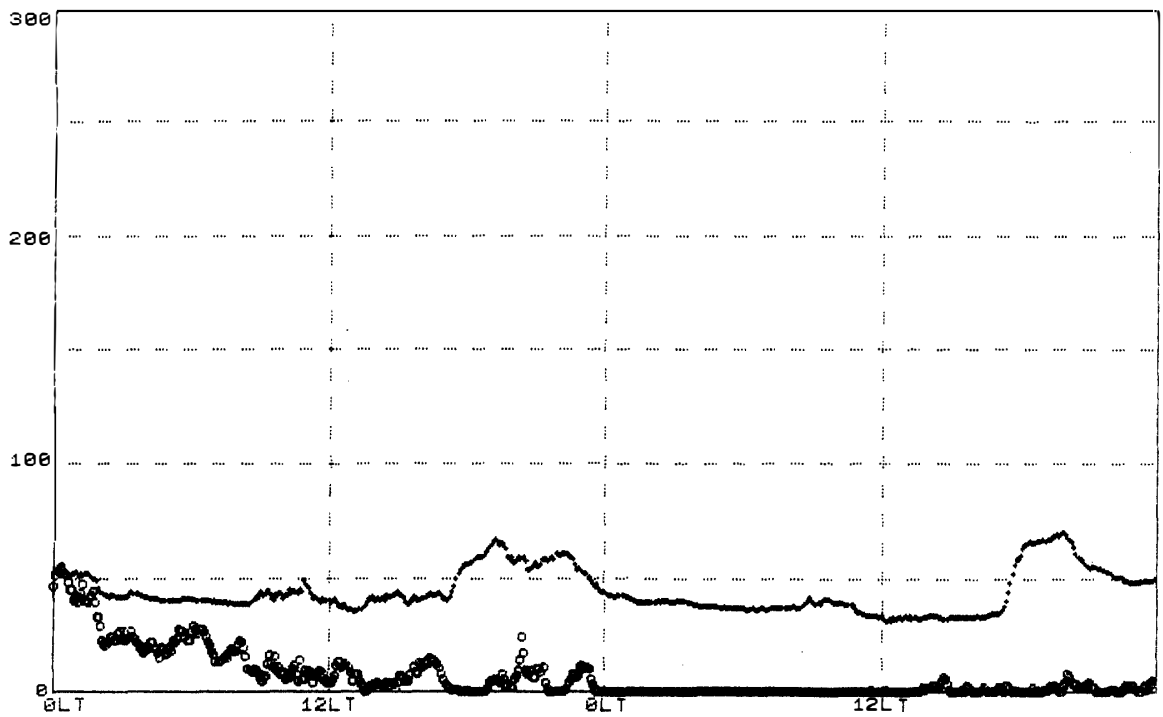
TB(K) and IWC(mg/cm²) 89 315 --> 316



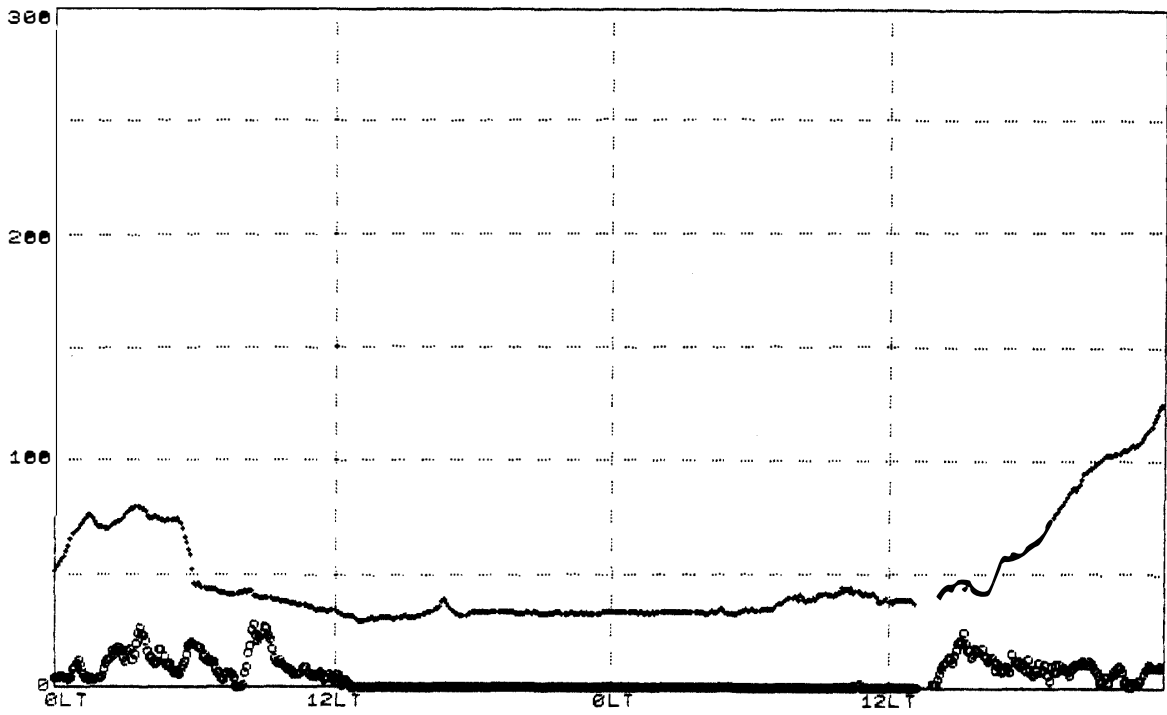
TB(K) and IWC(mg/cm²) 89 317 --> 318



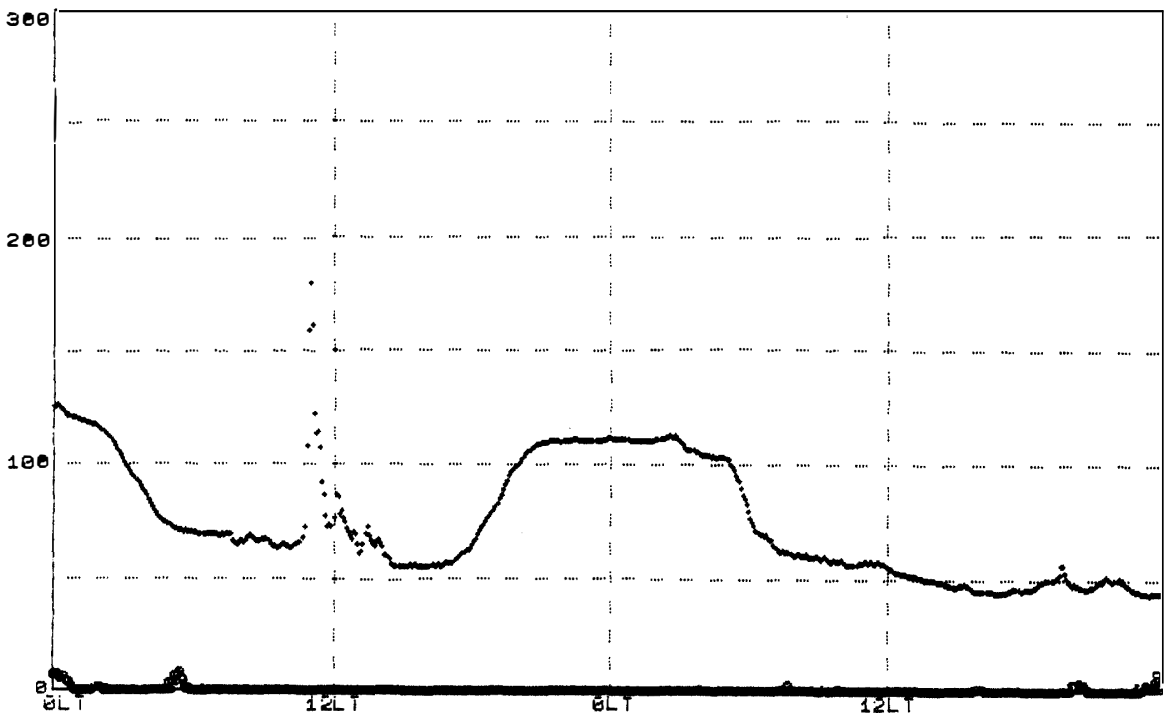
TB(K) and IWC(mg/cm²) 89 319 --> 320



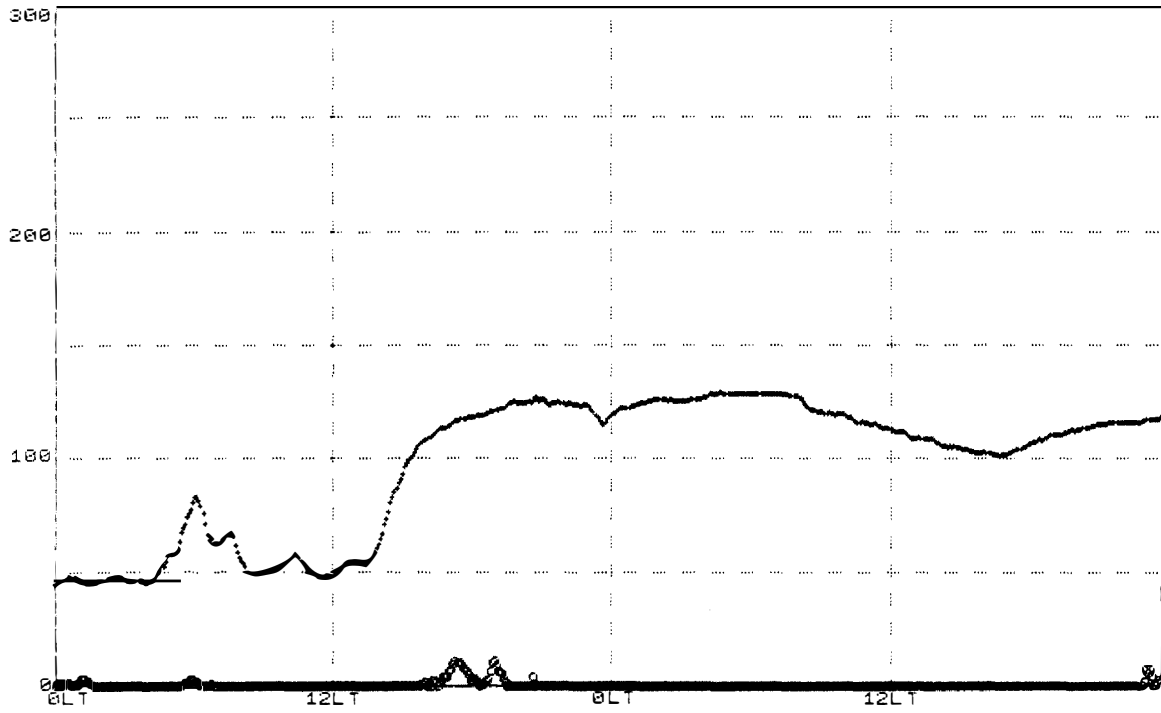
TB(K) and IWC(mg/cm²) 89 321 --> 322



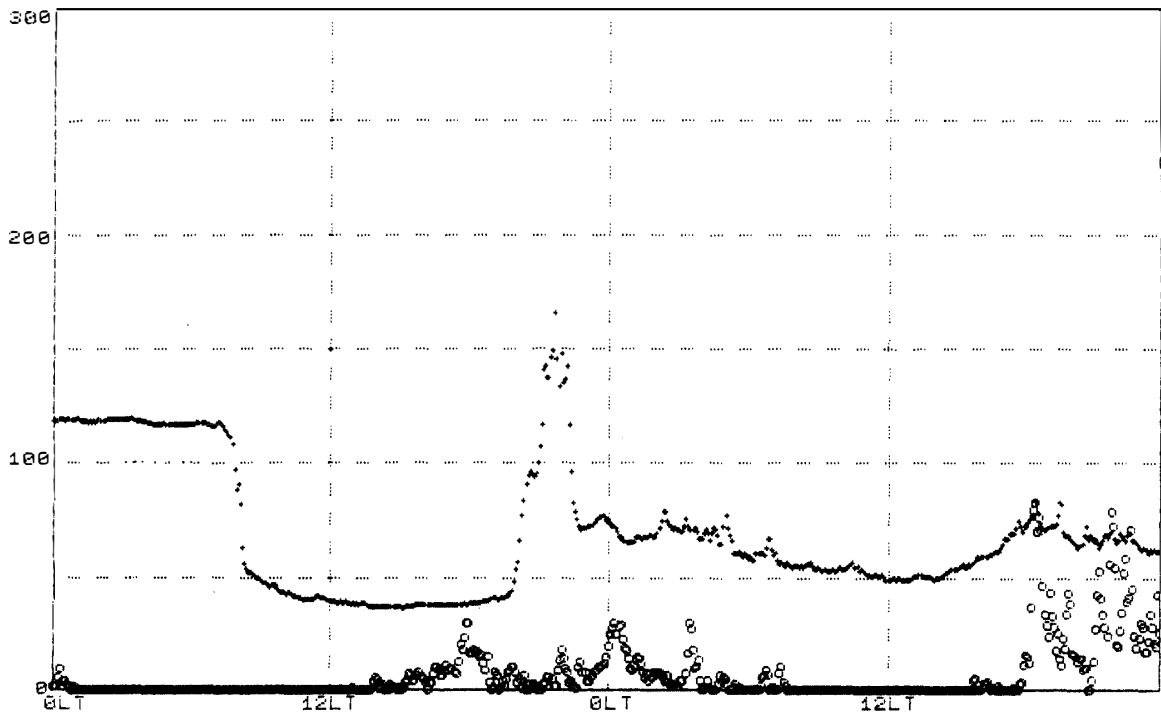
TB(K) and IWC(mg/cm²) 89 323 --> 324



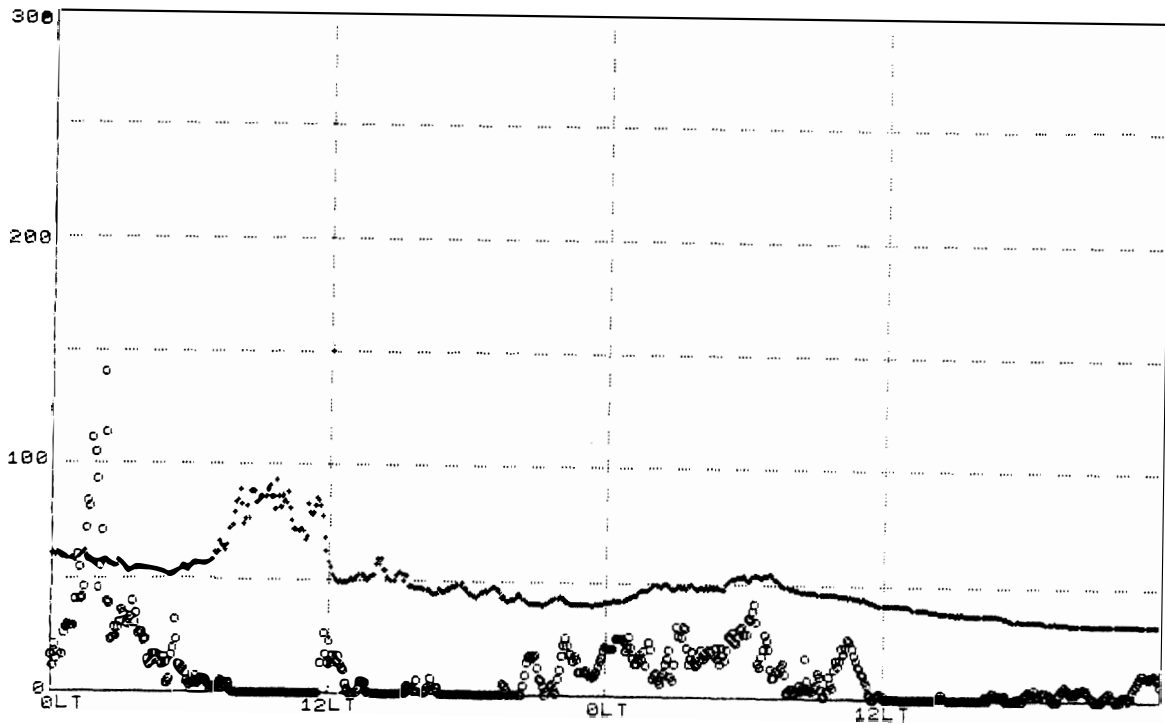
TB(K) and IWC(mg/cm²) 89 325 --> 326



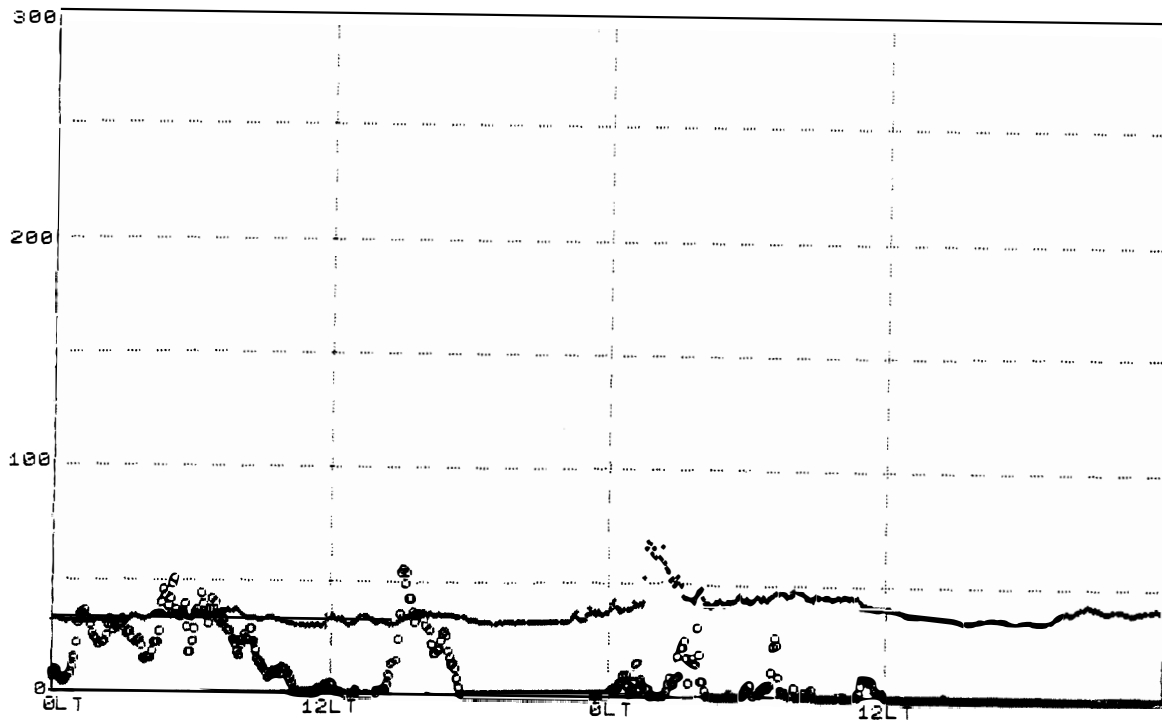
TB(K) and IWC(mg/cm²) 89 327 --> 328



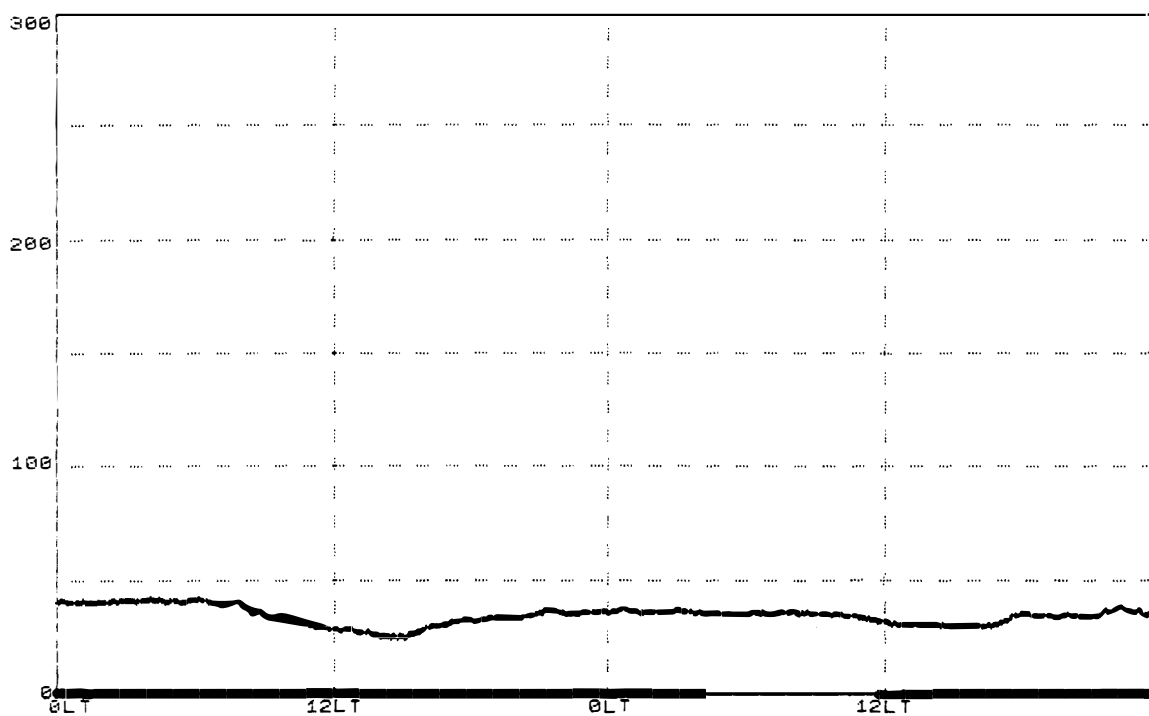
TB(K) and IWC(mg/cm²) 89 329 --> 330



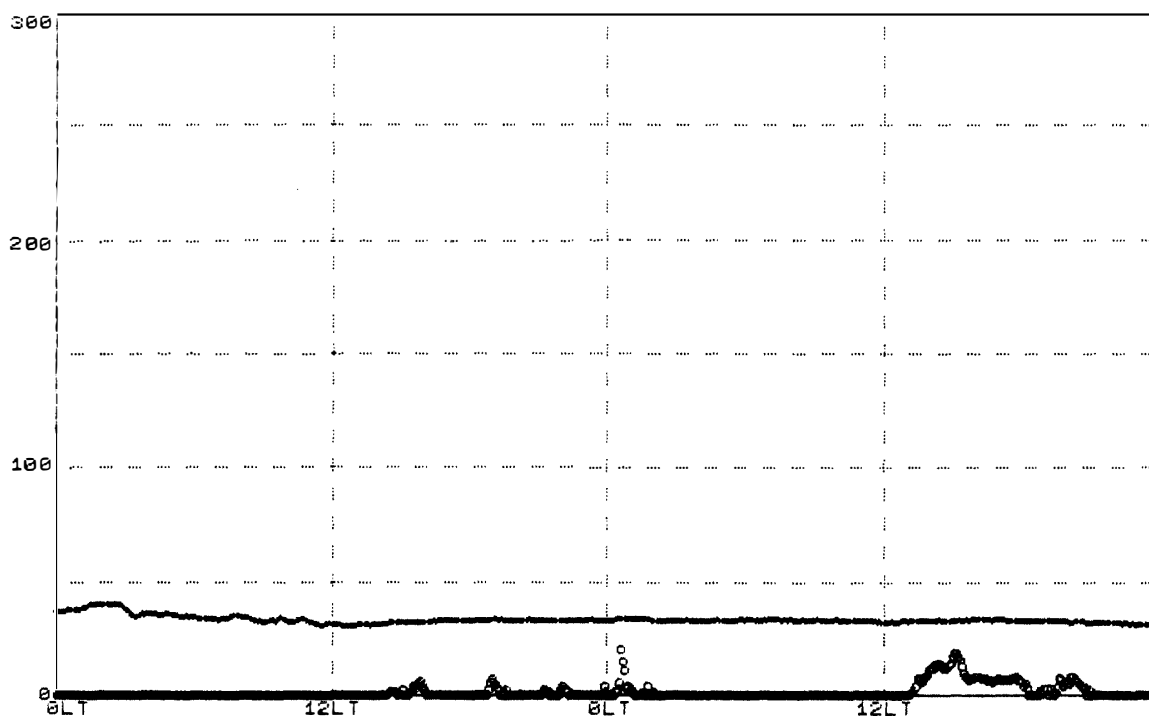
TB(K) and IWC(mg/cm²) 89 331 --> 401



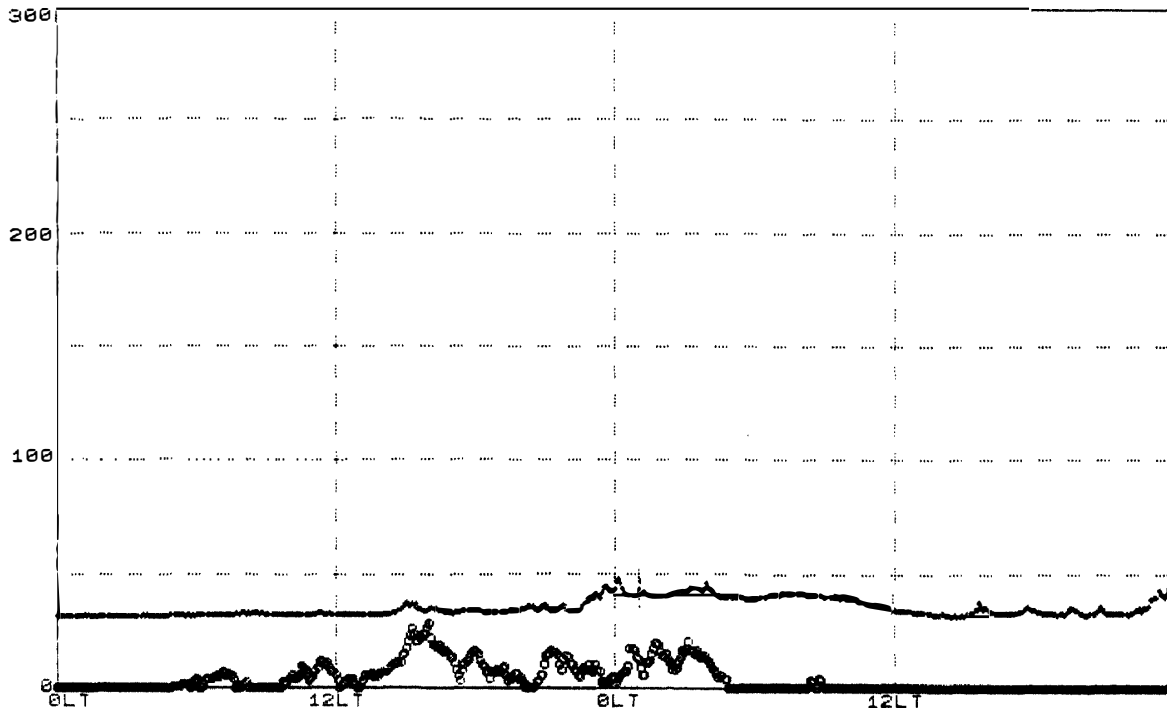
TB(K) and IWC(mg/cm²) 89 402 --> 403



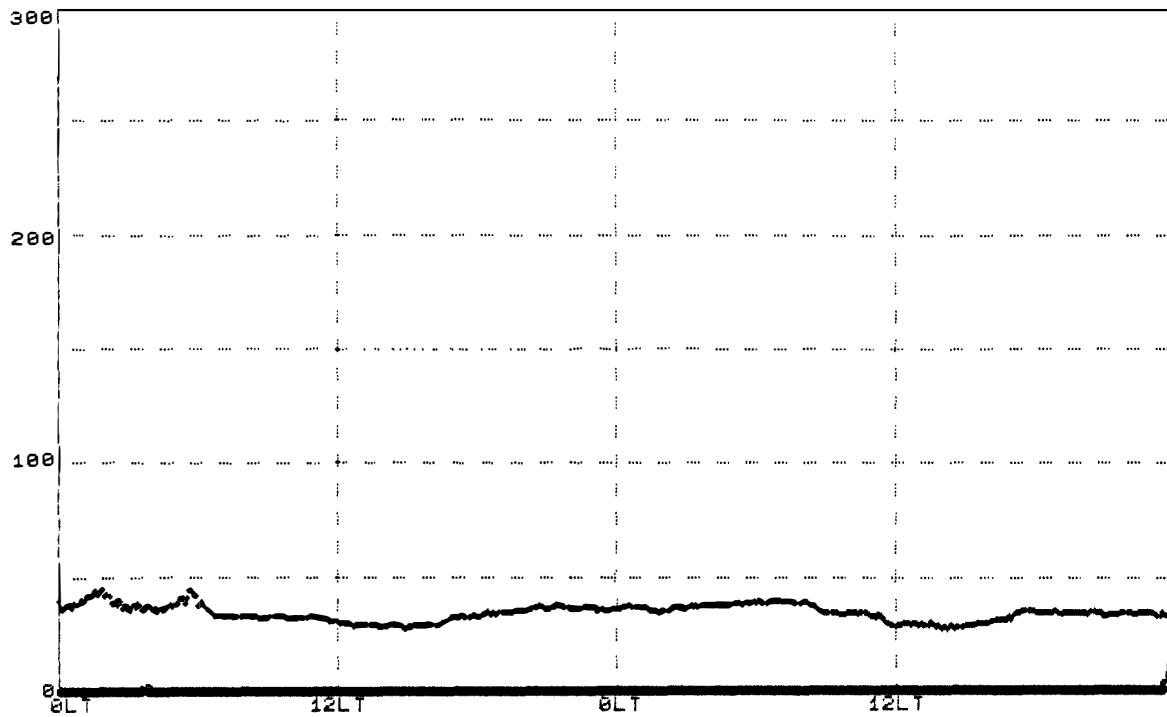
TB(K) and IWC(mg/cm²) 89 404 --> 405



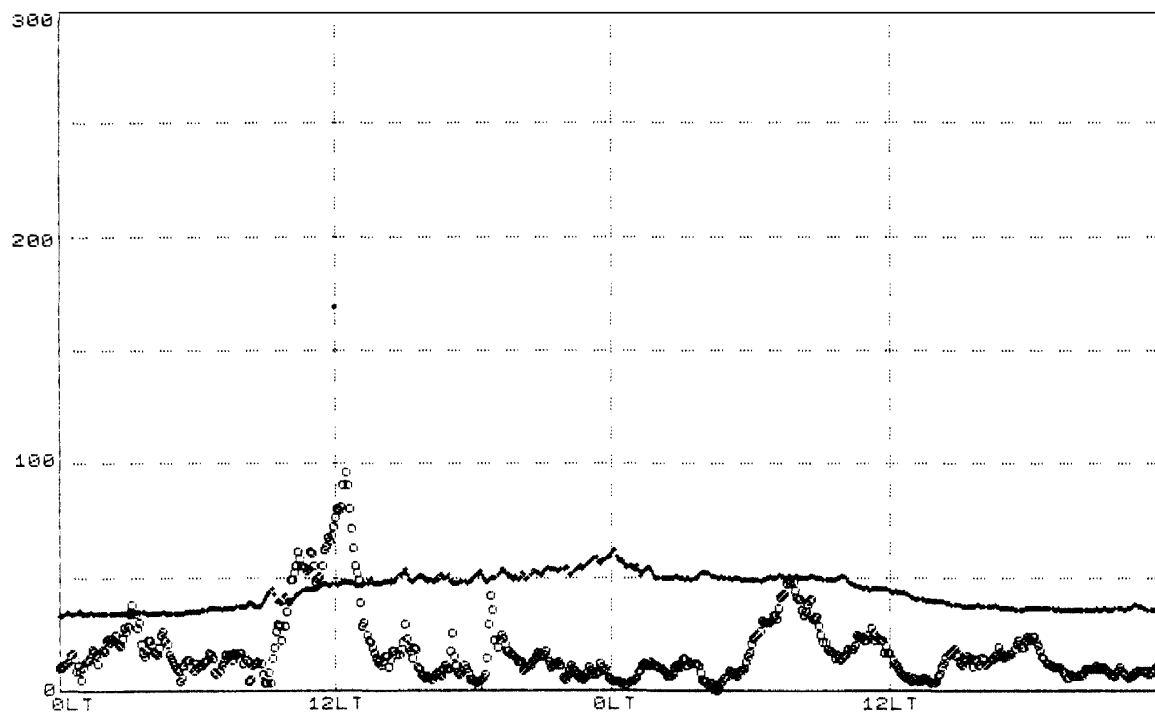
TB(K) and IWC(mg/cm²) 89 406 --> 407



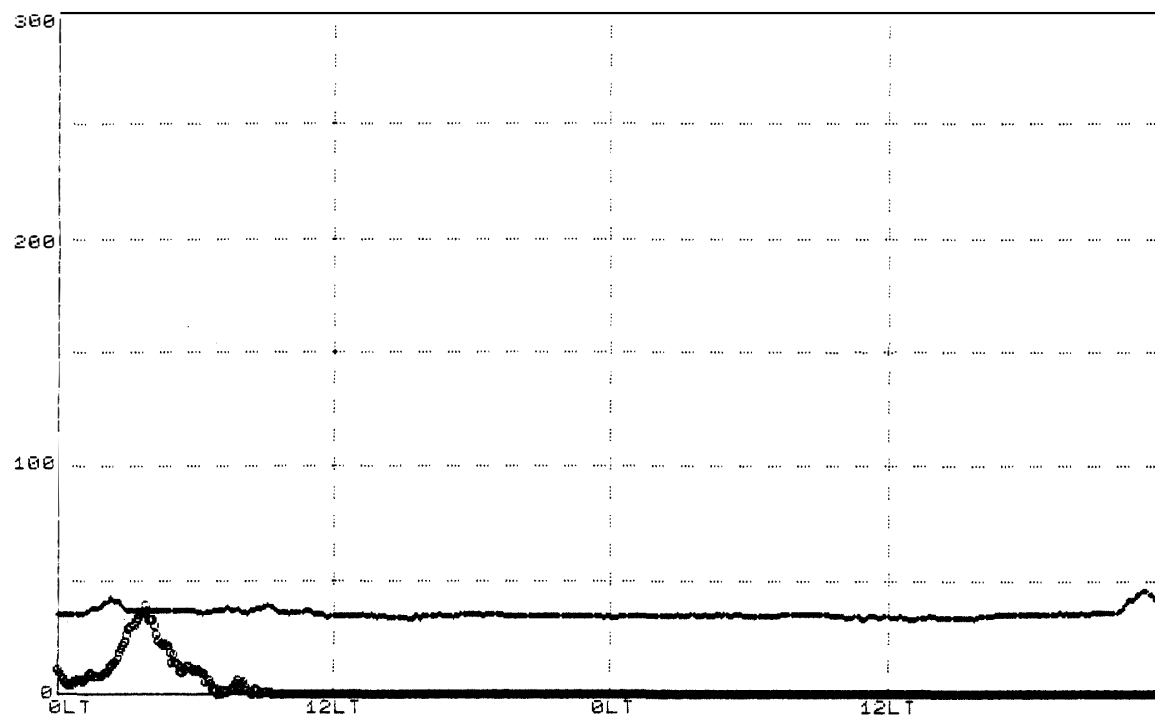
TB(K) and IWC(mg/cm²) 89 408 --> 409



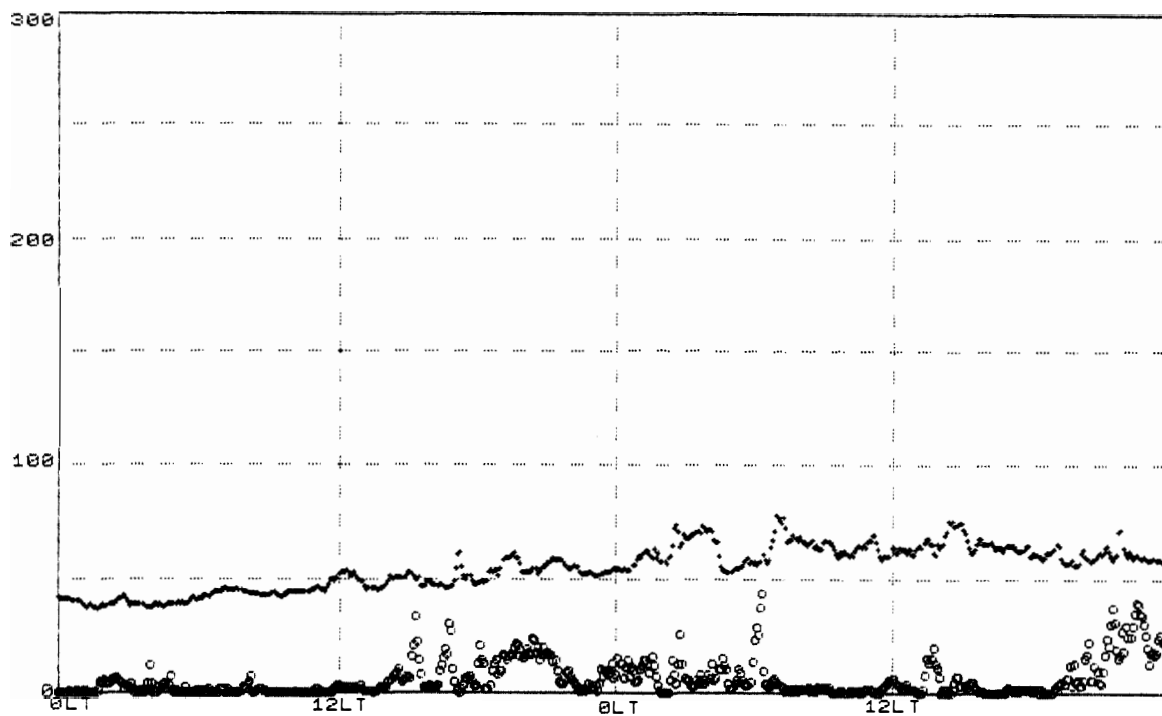
TB(K) and IWC(mg/cm²) 89 410 --> 411



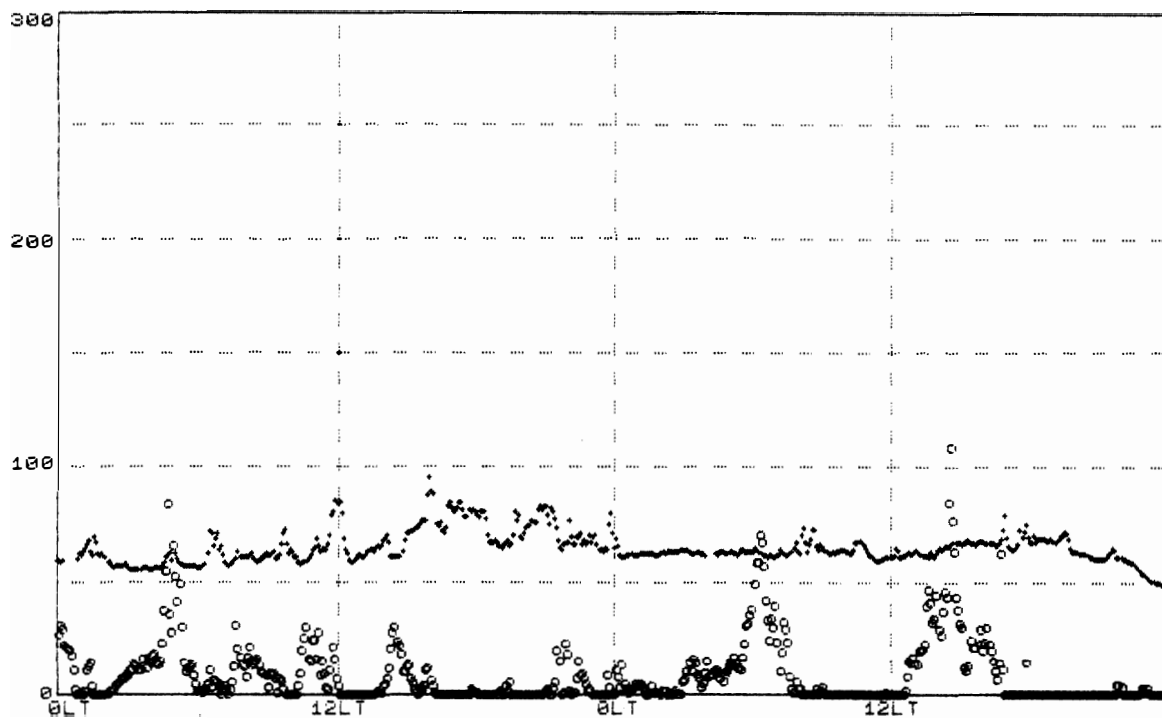
TB(K) and IWC(mg/cm²) 89 412 --> 413



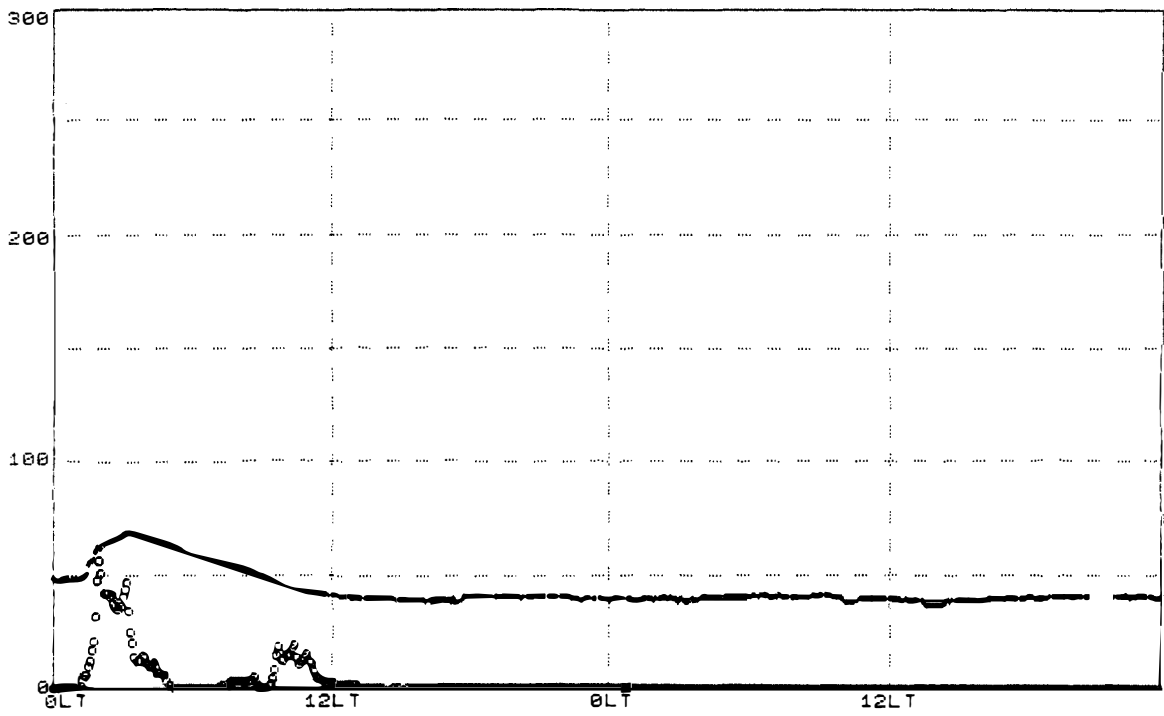
TB(K) and IWC(mg/cm²) 89 414 --> 415



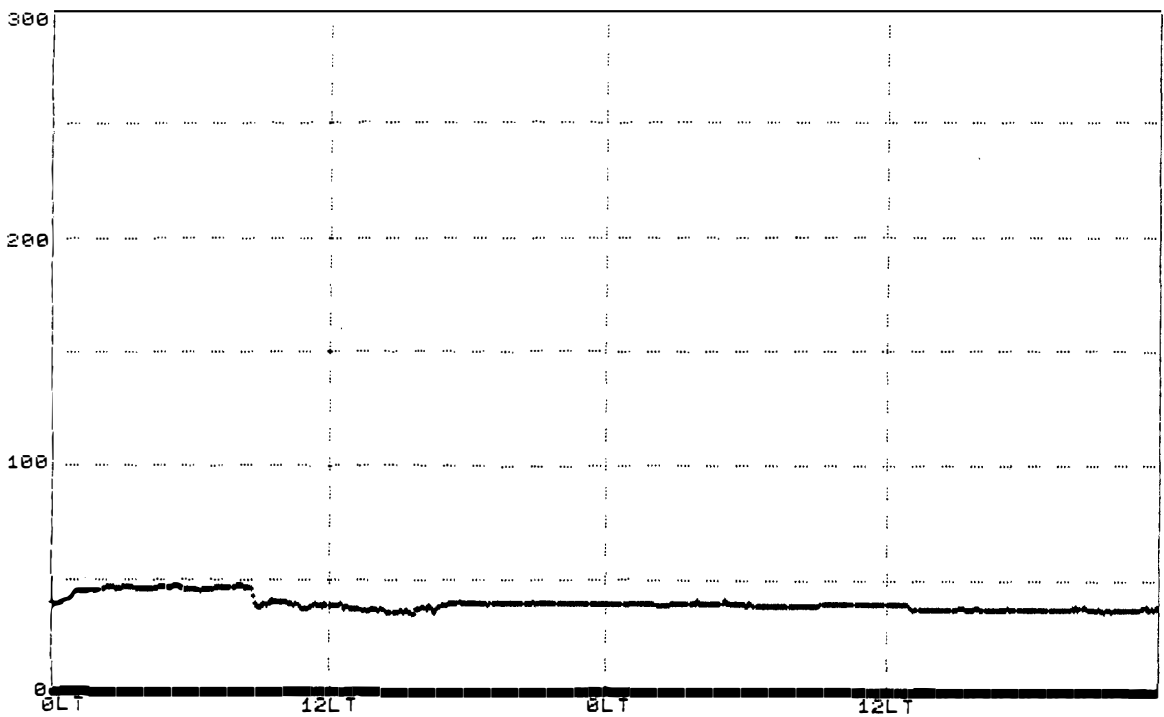
TB(K) and IWC(mg/cm²) 89 416 --> 417



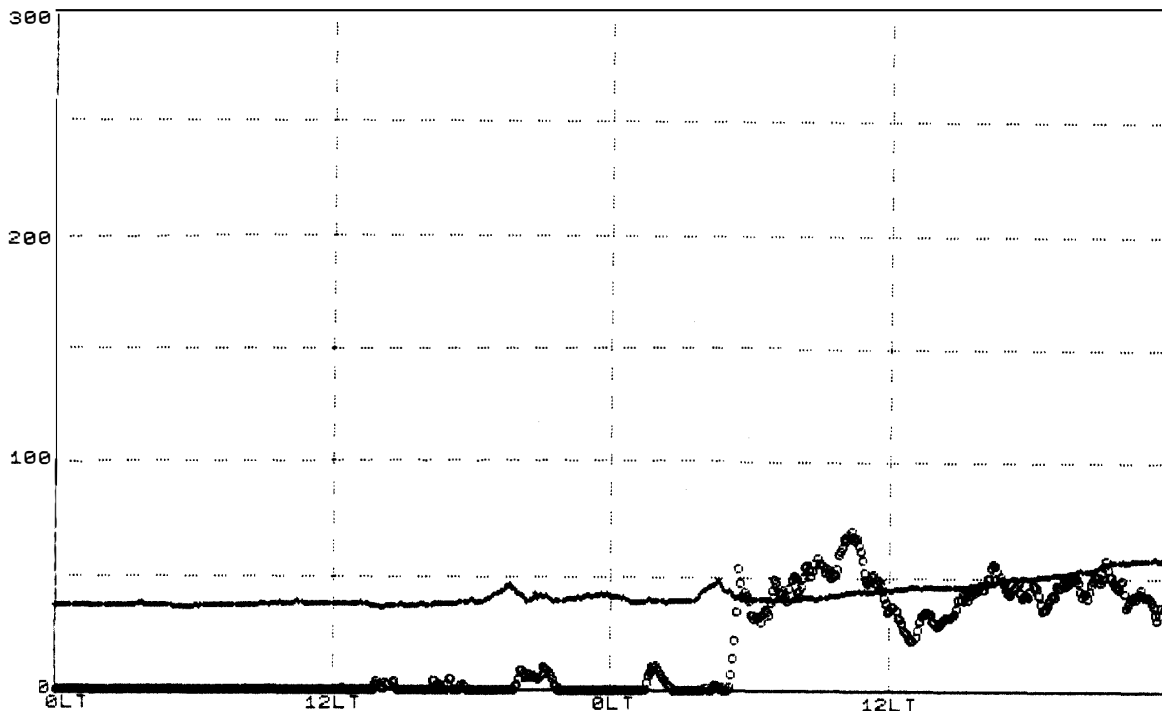
TB(K) and IWC(mg/cm²) 89 418 --> 419



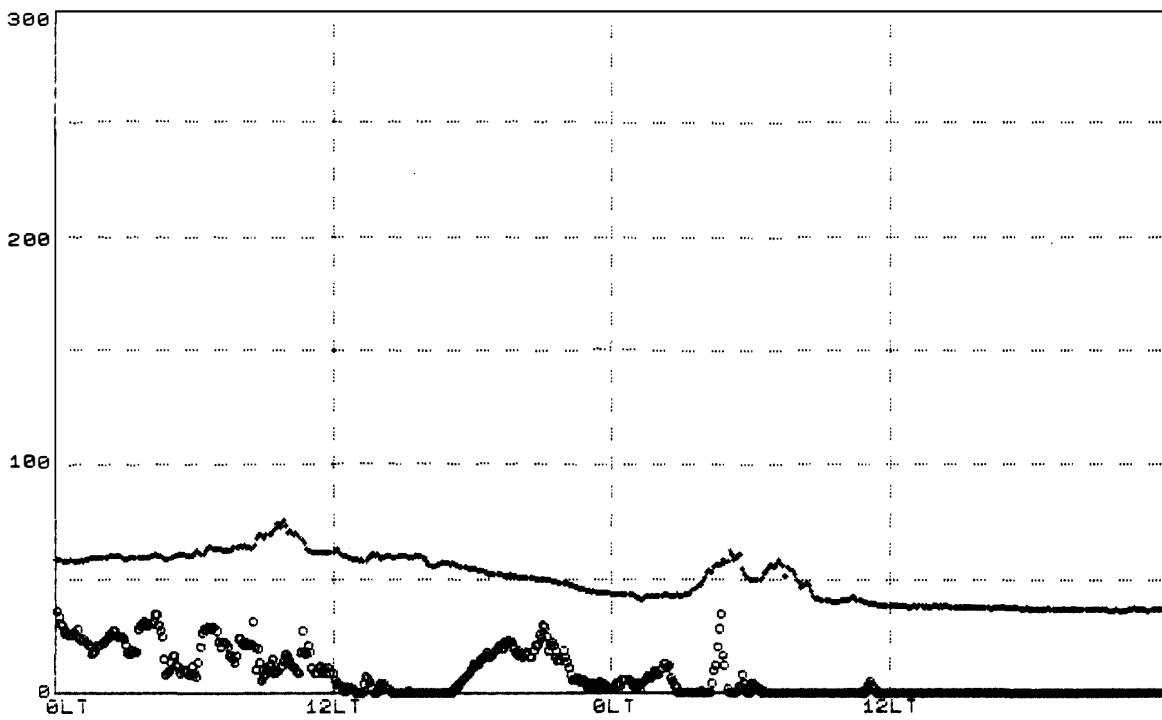
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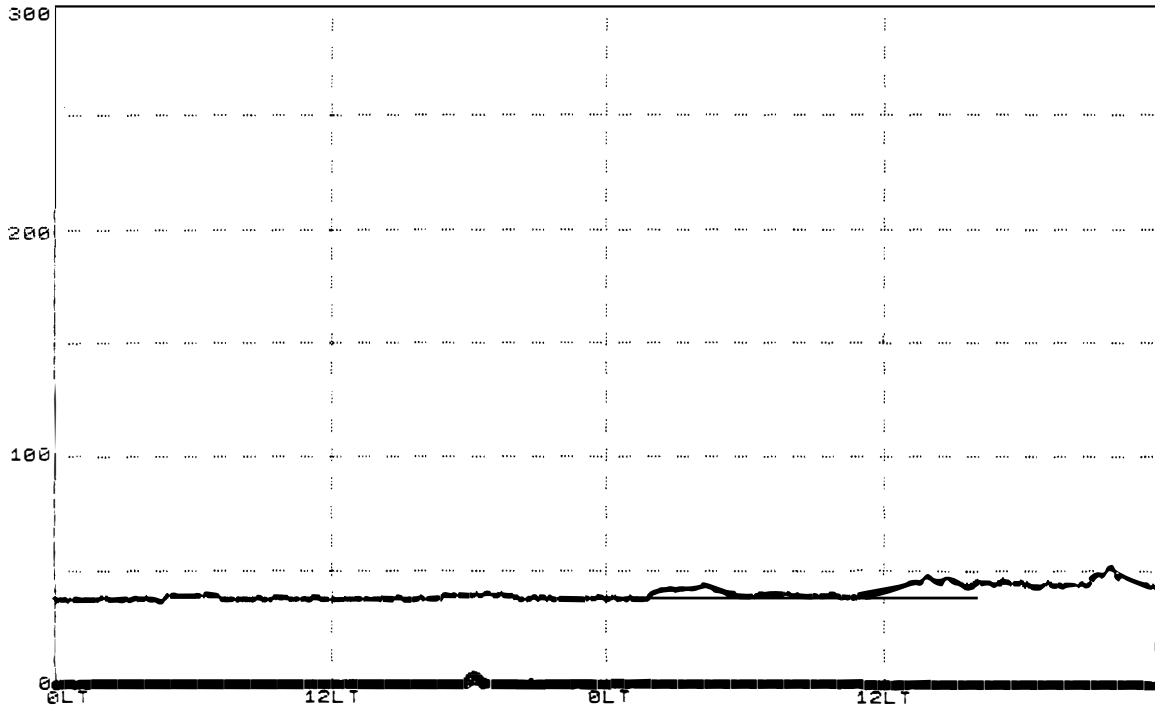
TB(K) and IWC(mg/cm²) 89 422 --> 423



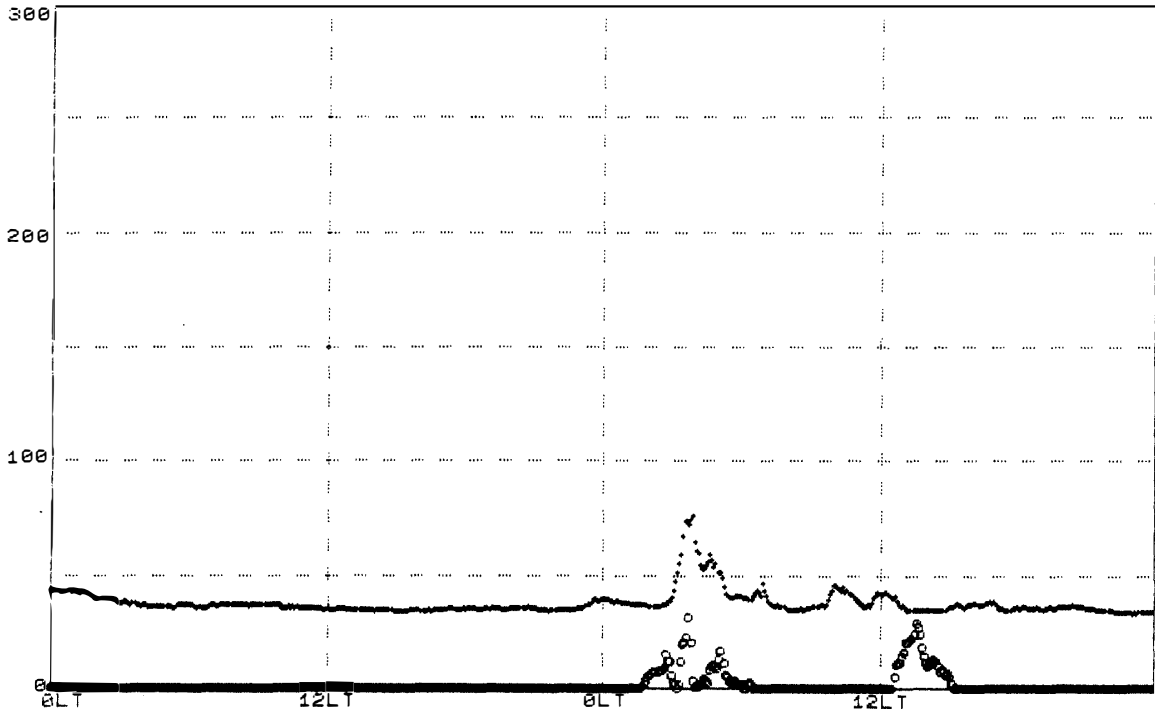
TB(K) and IWC(mg/cm²) 89 424 --> 425



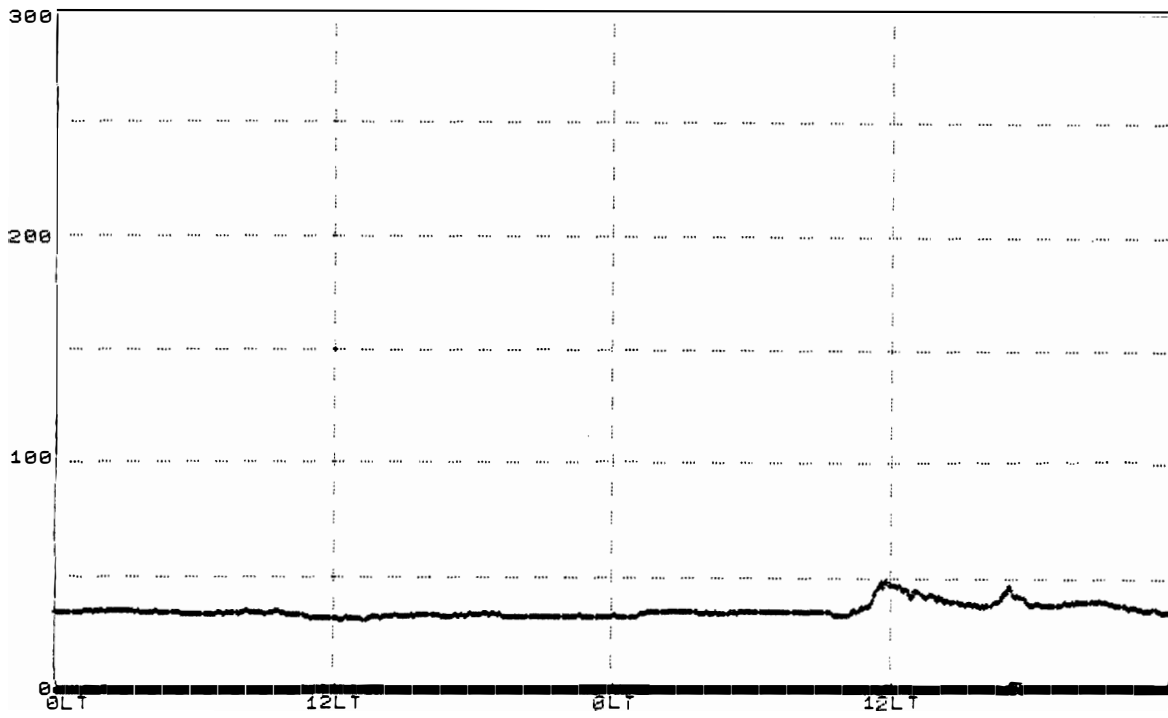
TB(K) and IWC(mg/cm²) 89 426 --> 427



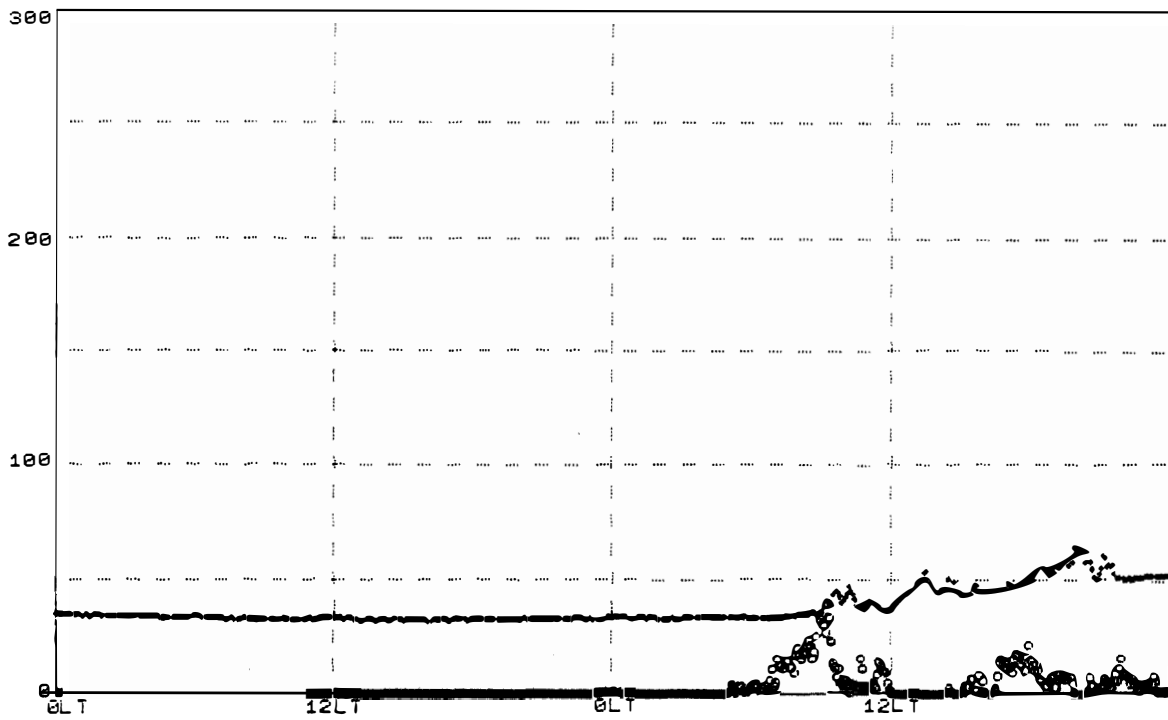
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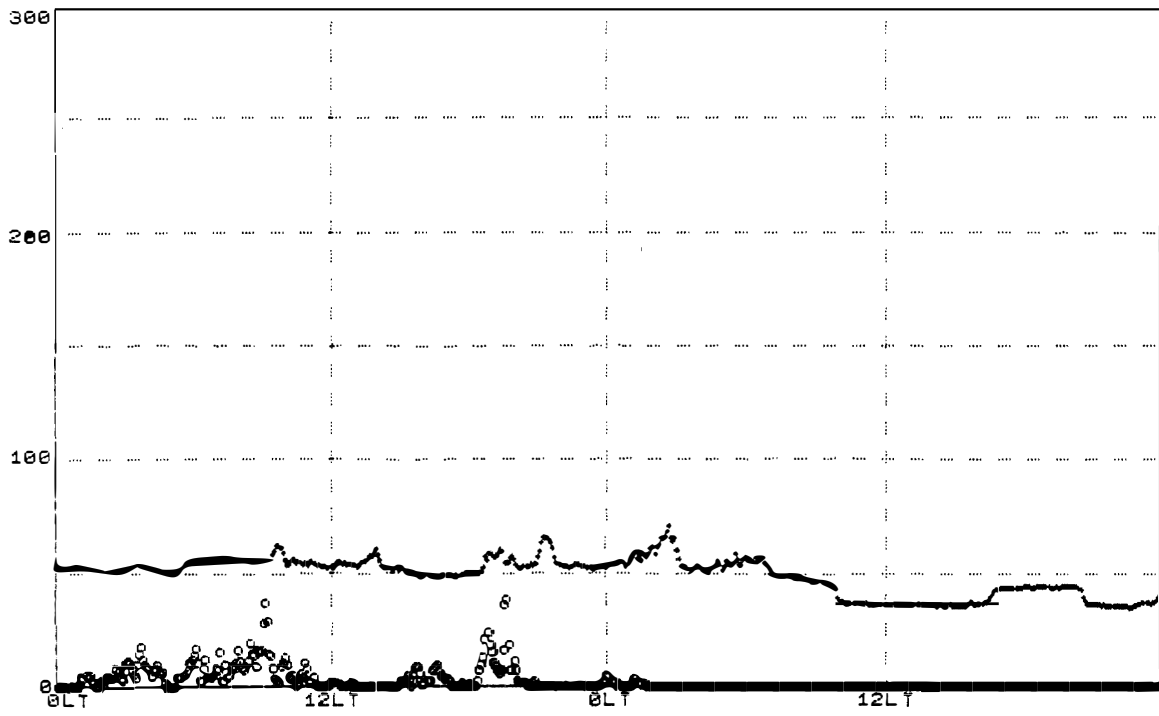
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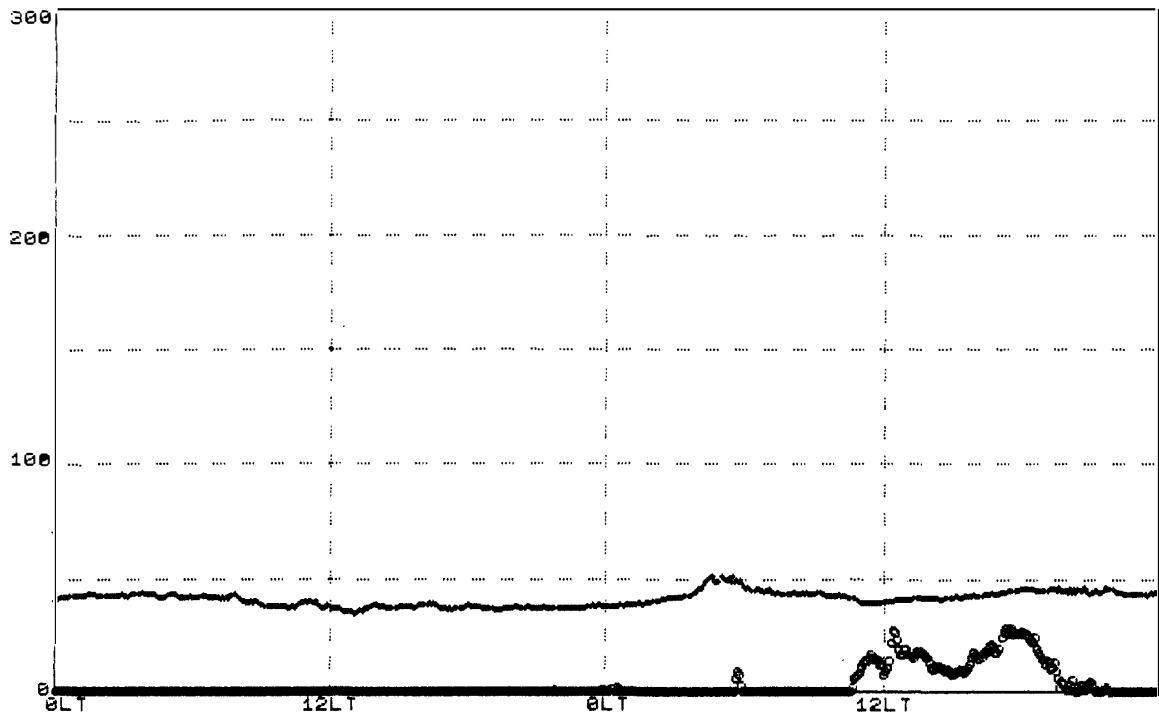
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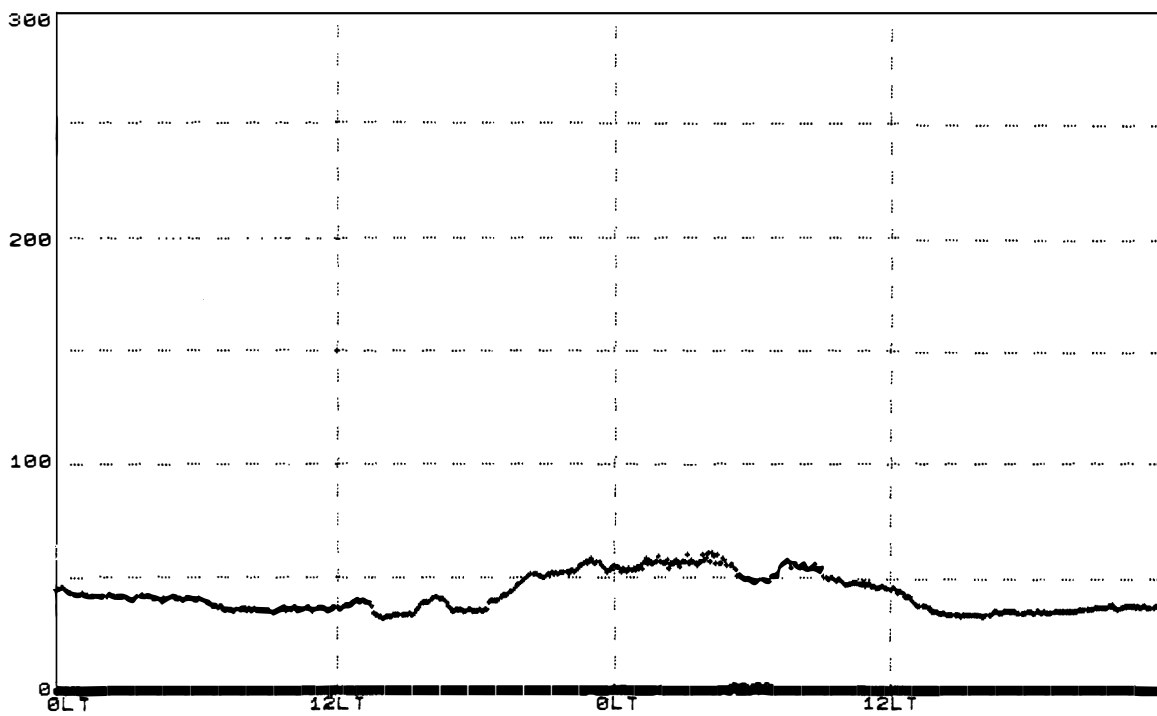
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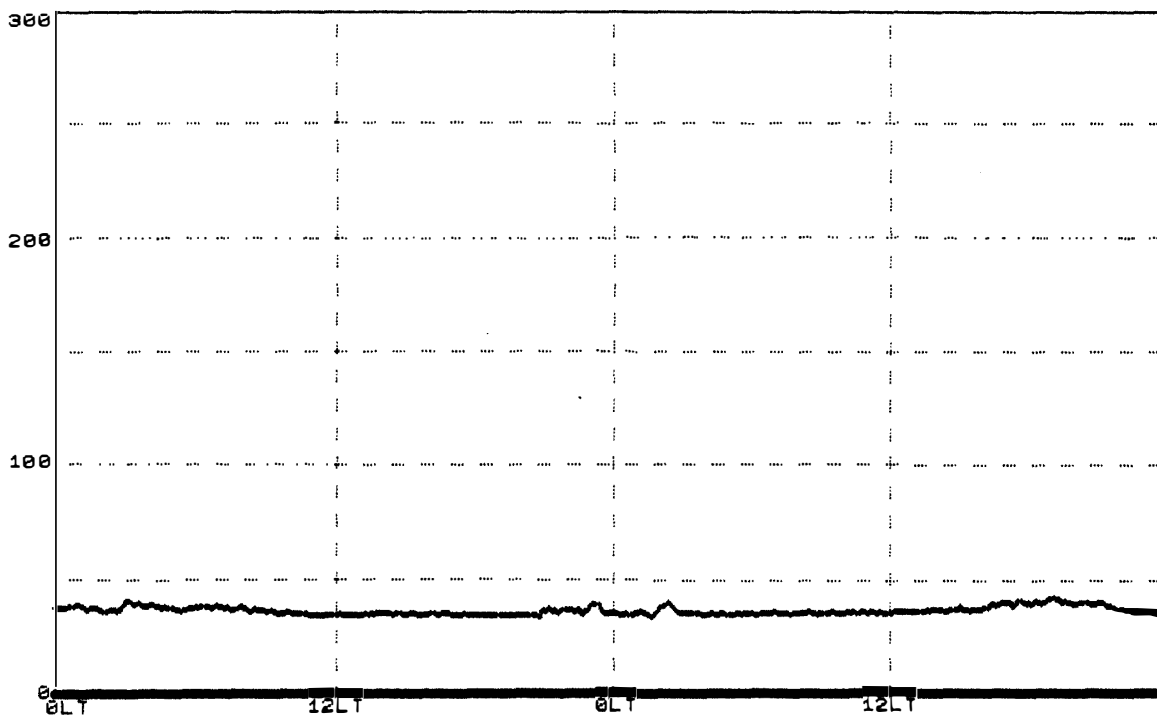
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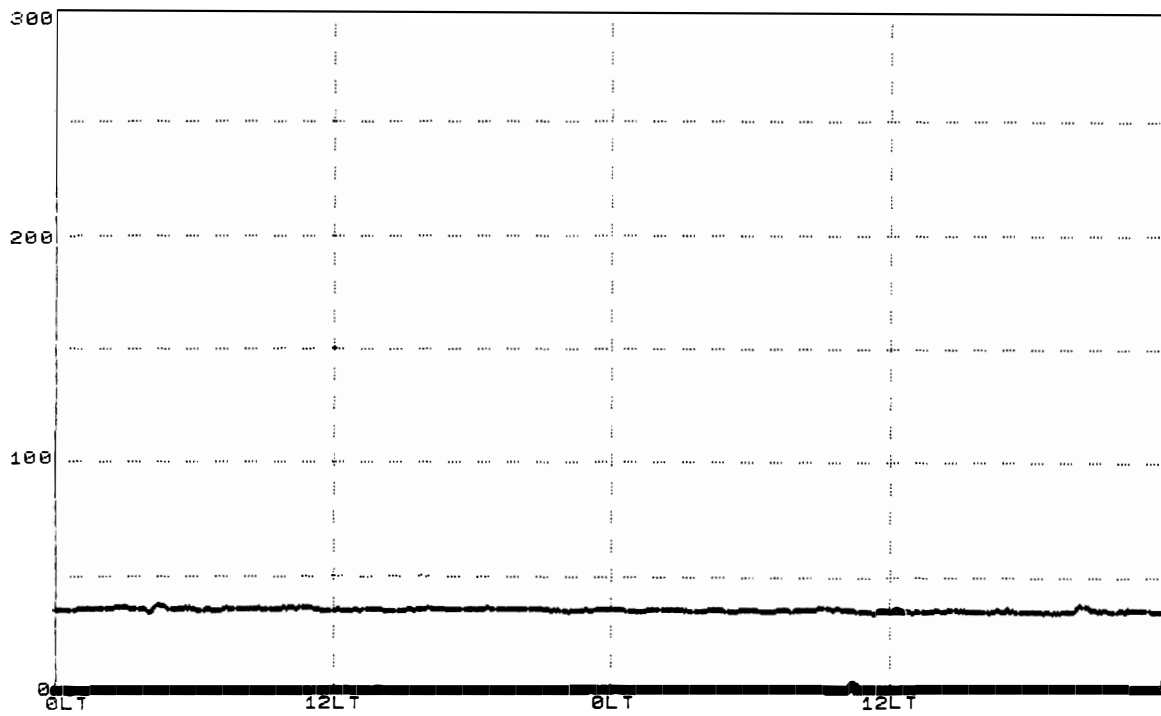
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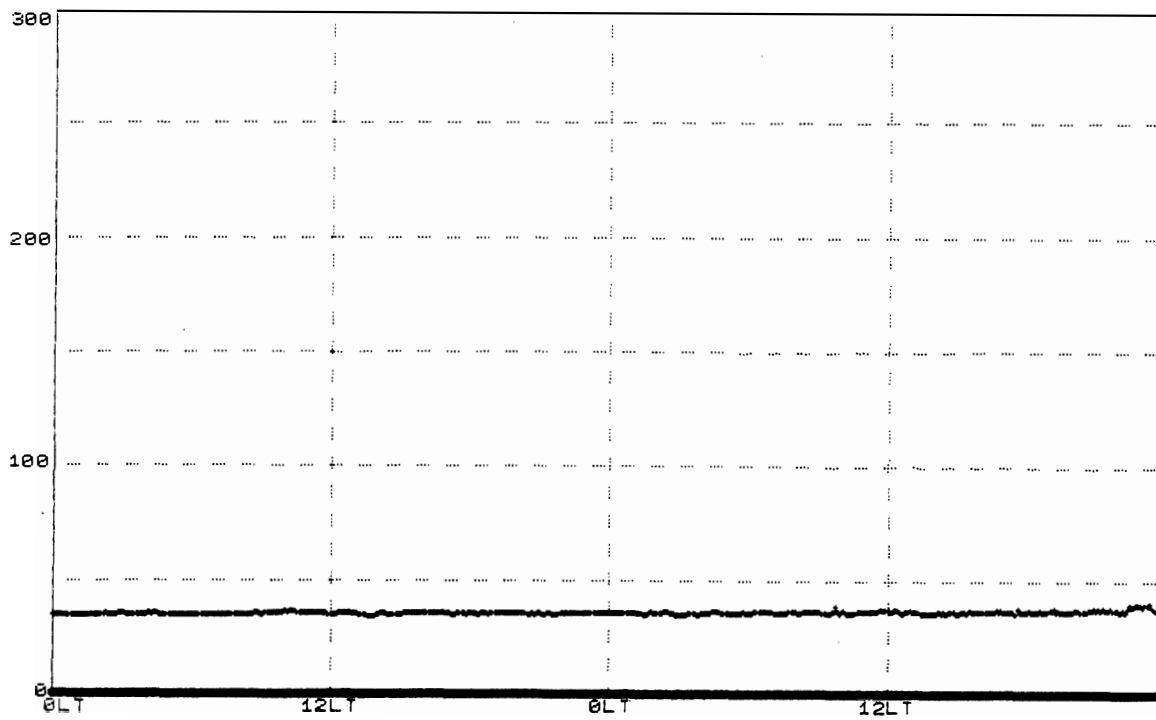
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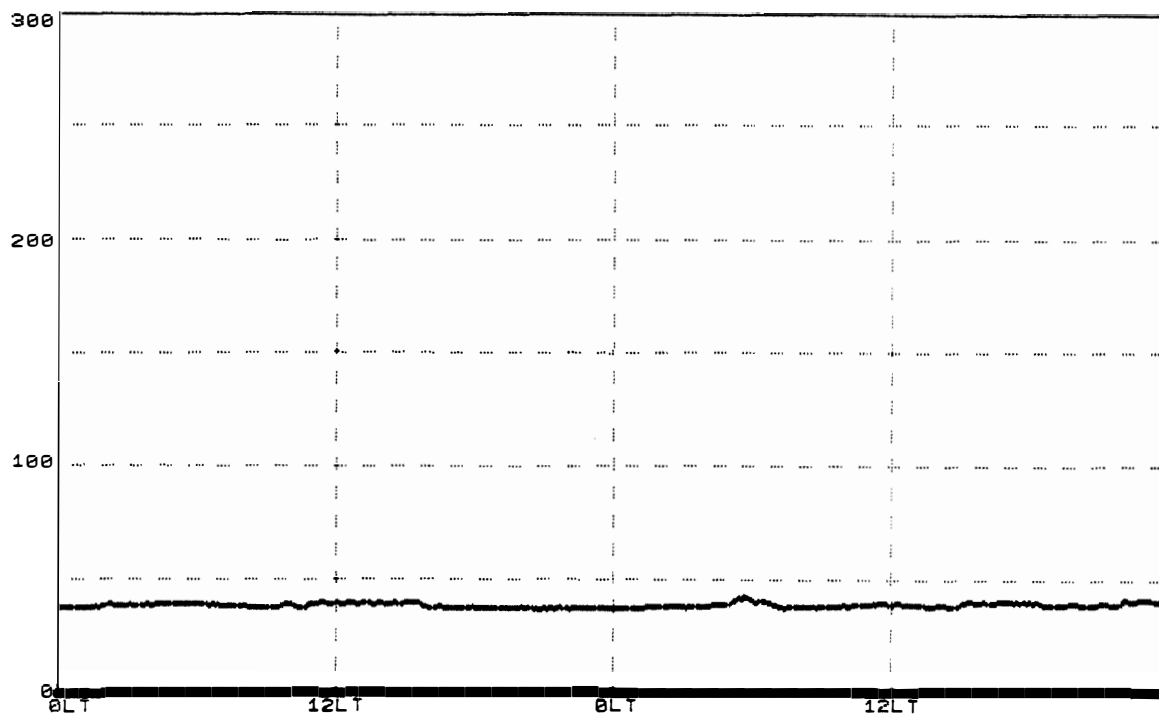
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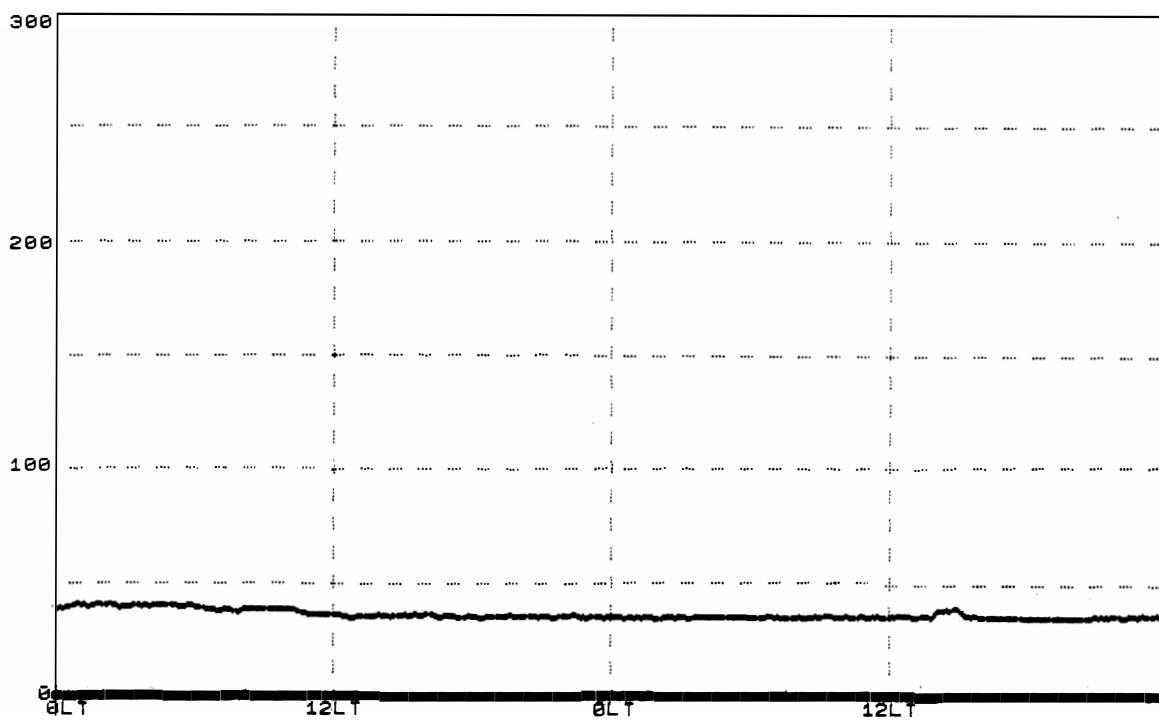
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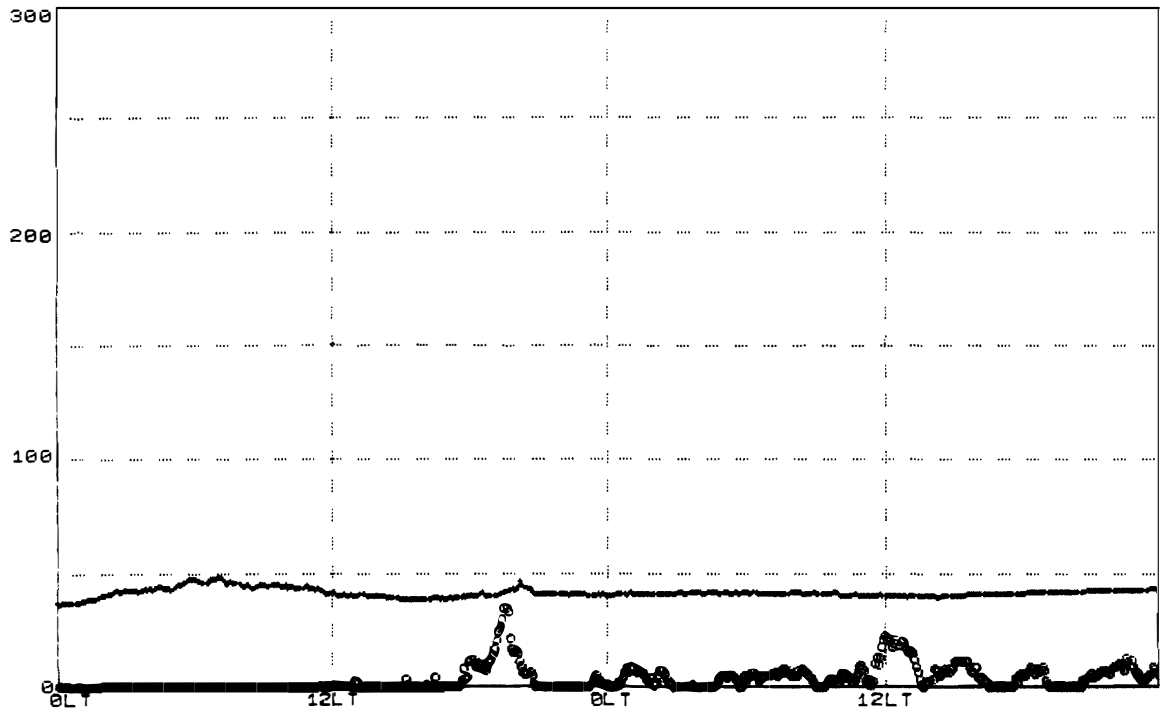
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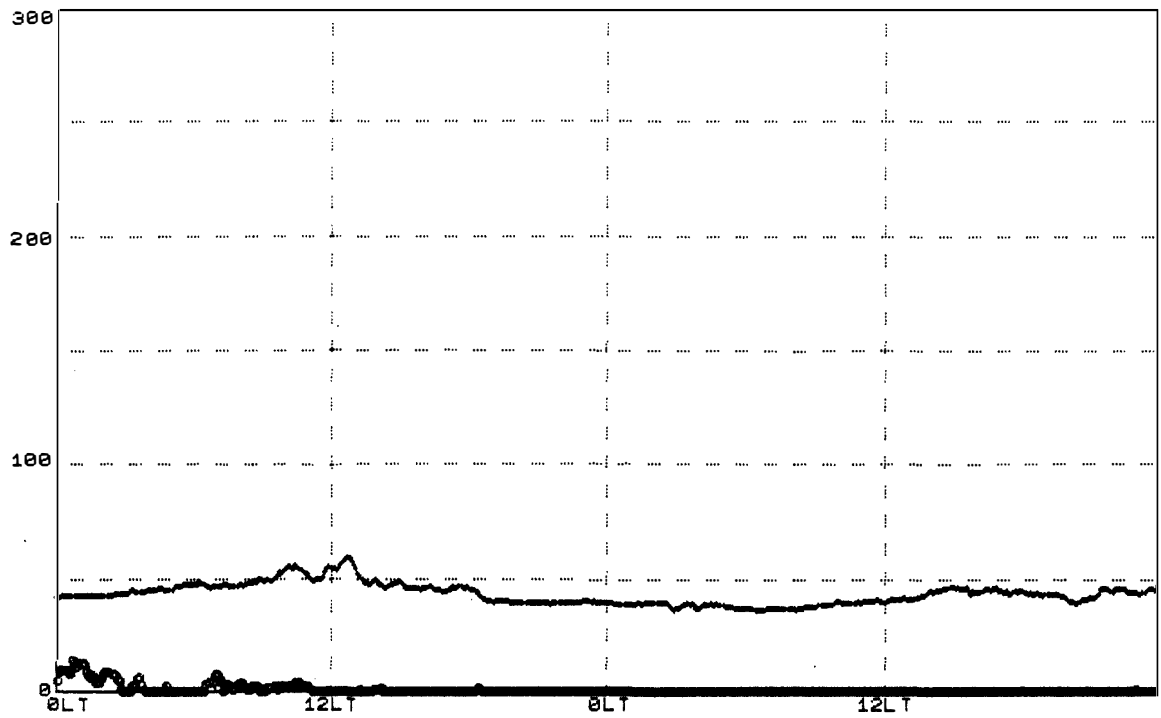
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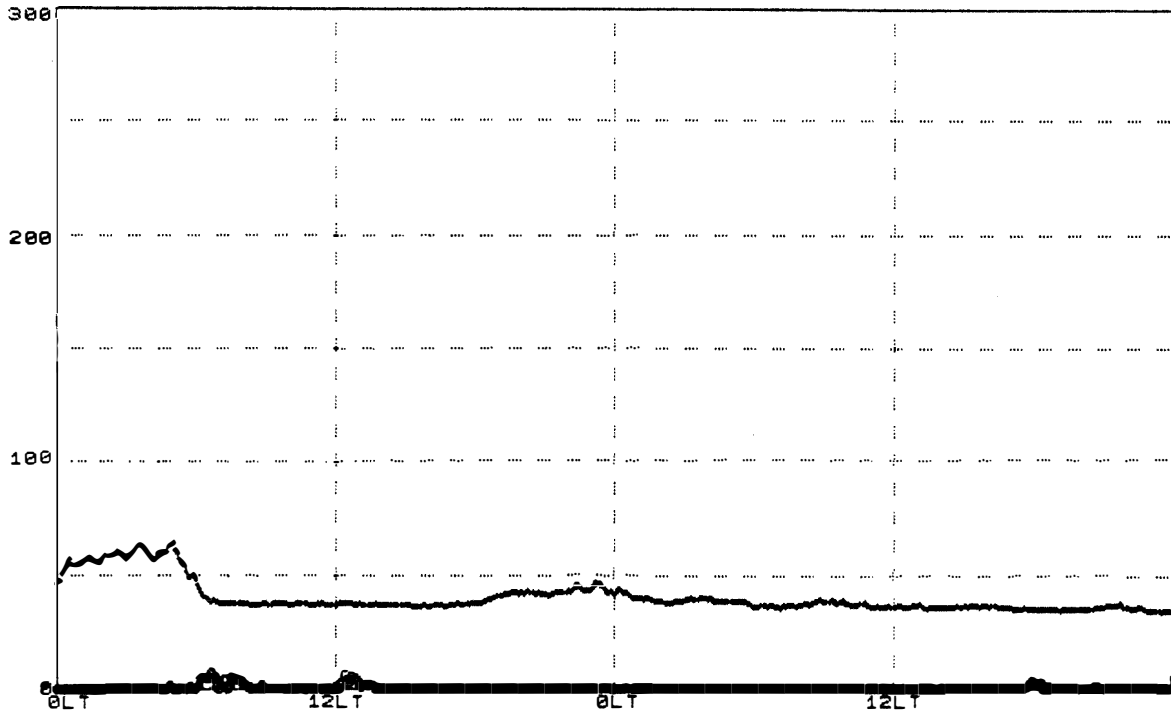
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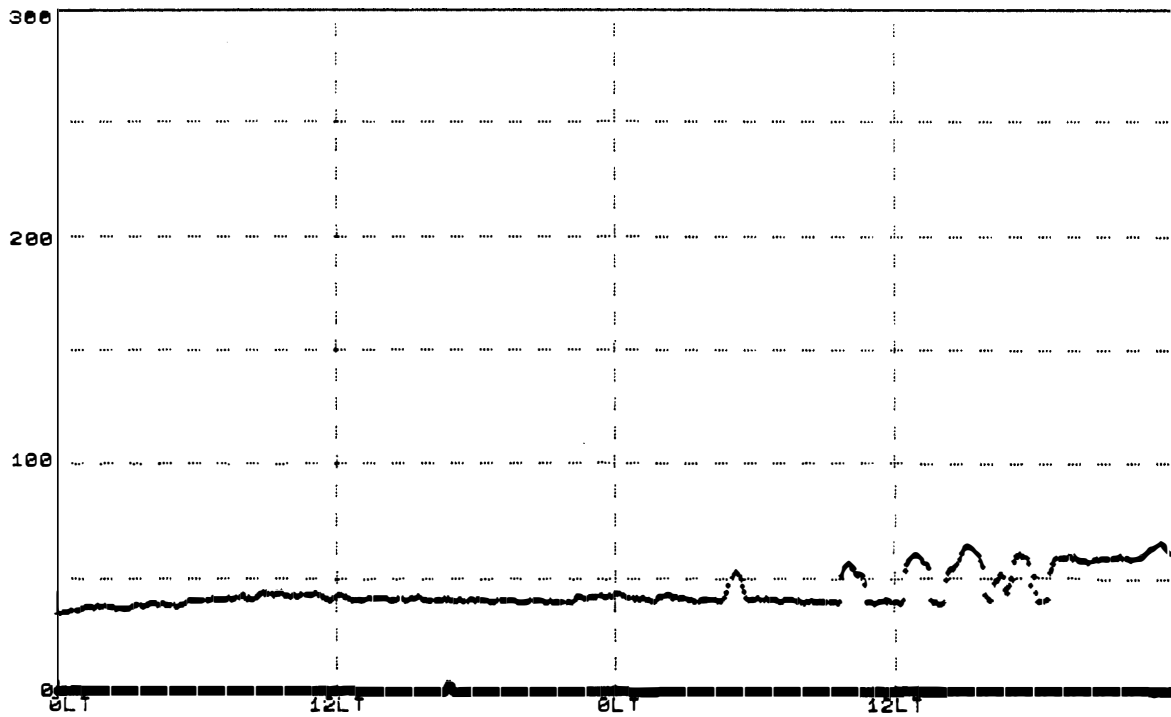
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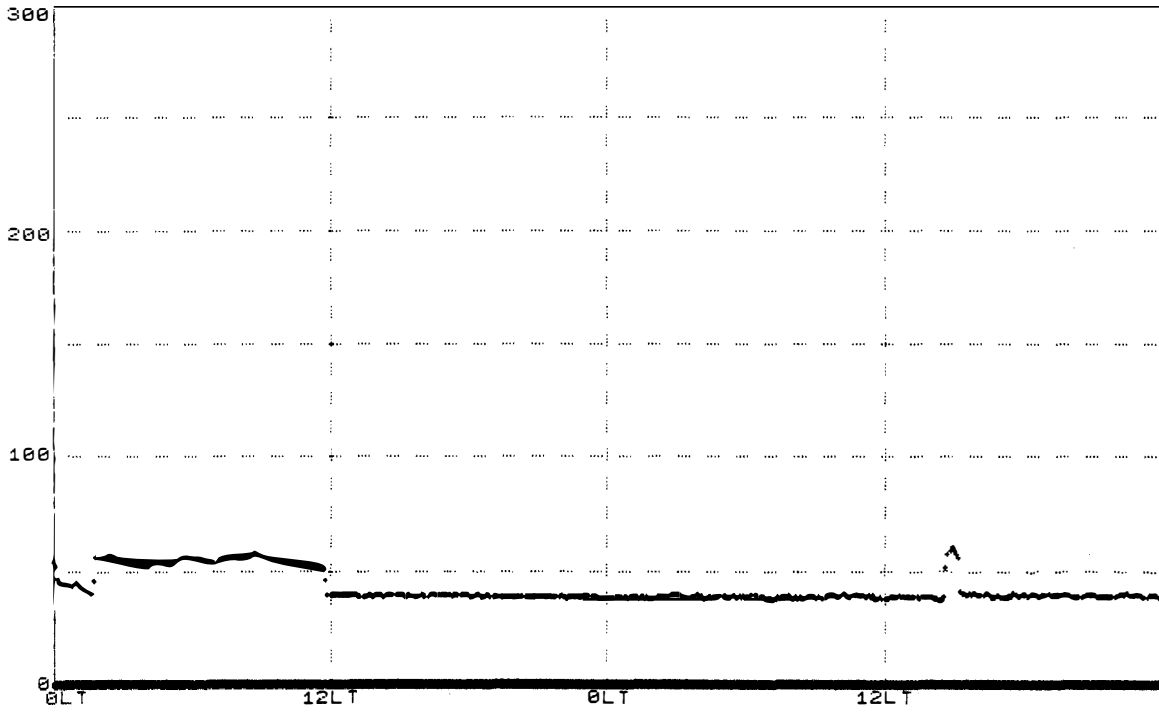
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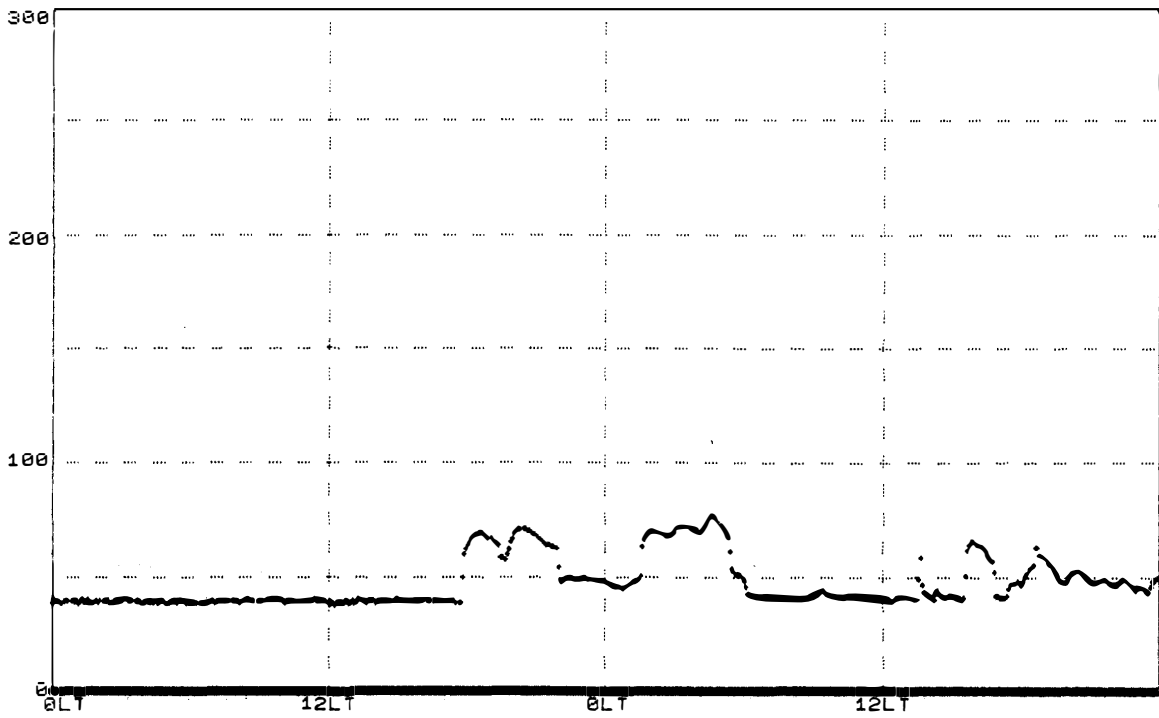
TB(K) and IWC(mg/cm²) 89 526 --> 527



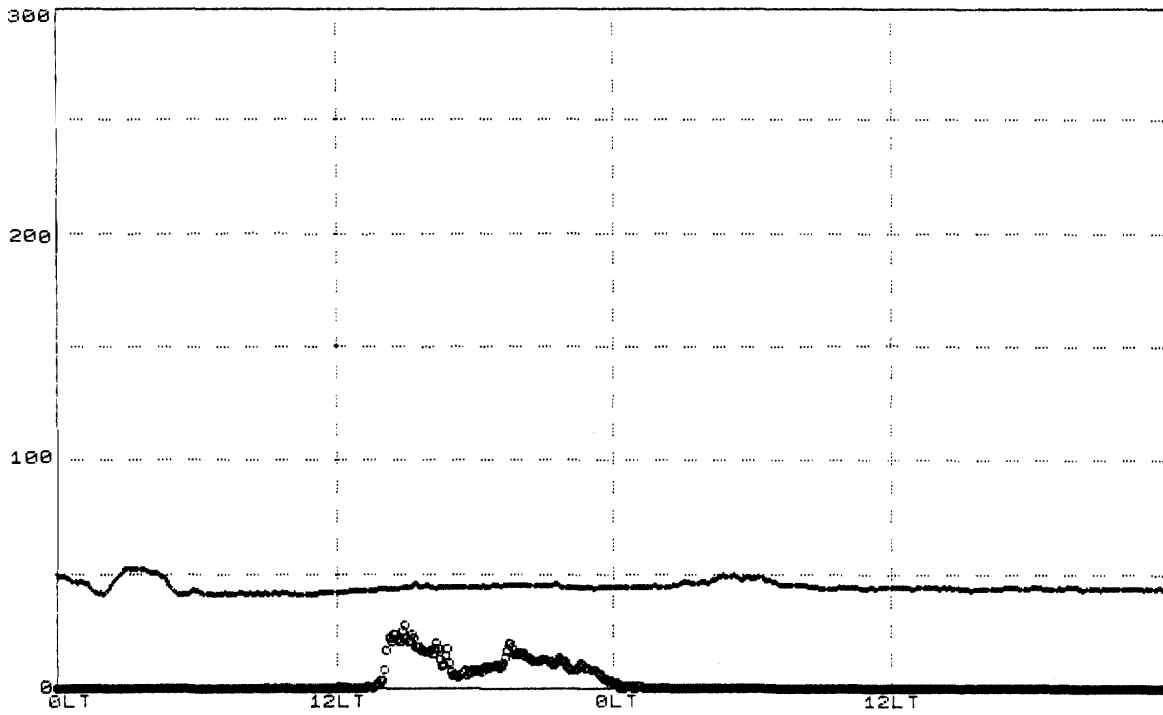
TB(K) and IWC(mg/cm²) 89 528 --> 529



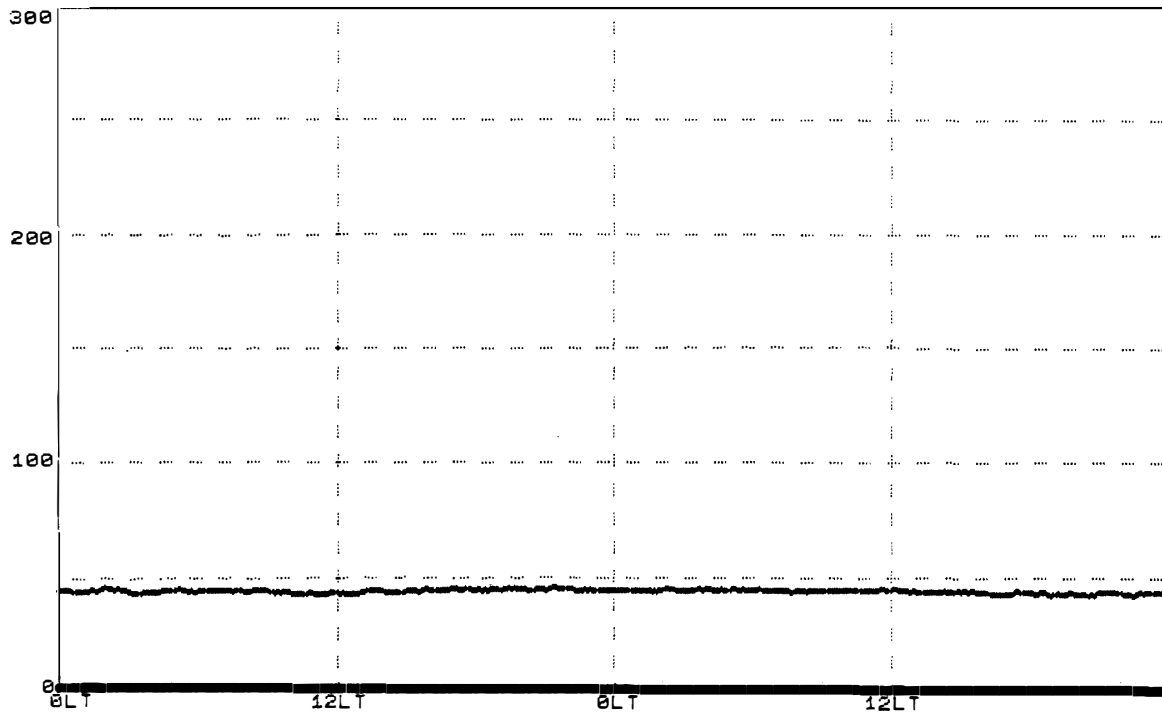
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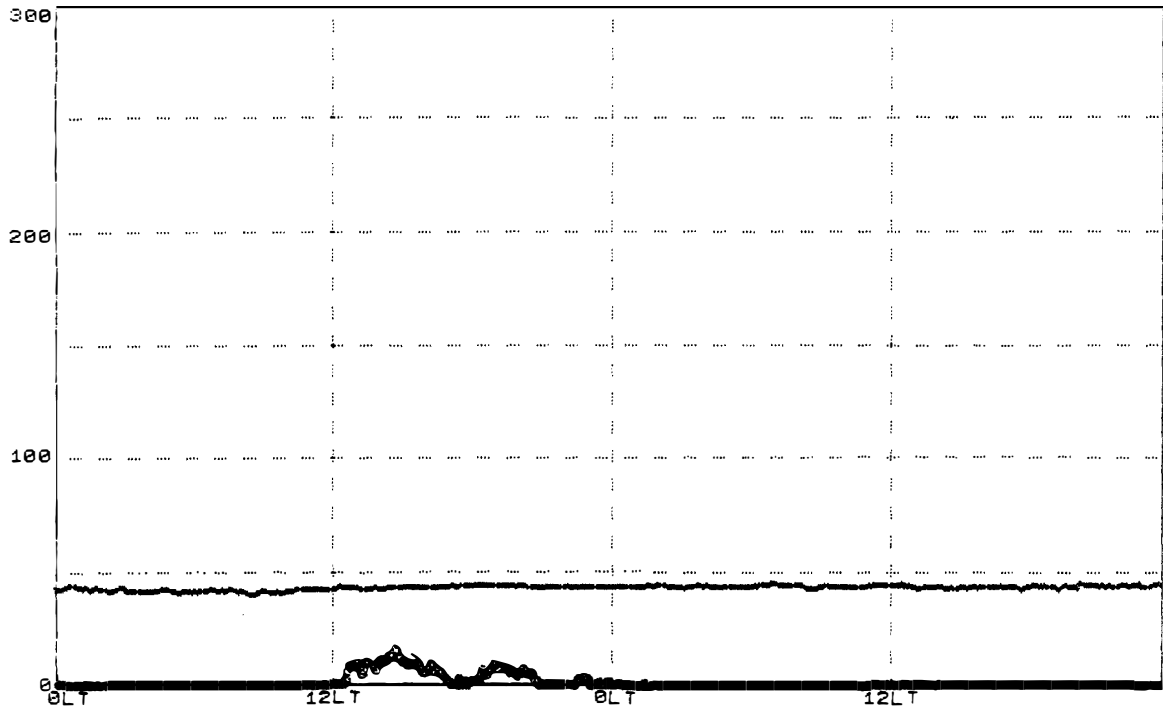
TB(K) and IWC(mg/cm²) 89 601 --> 602



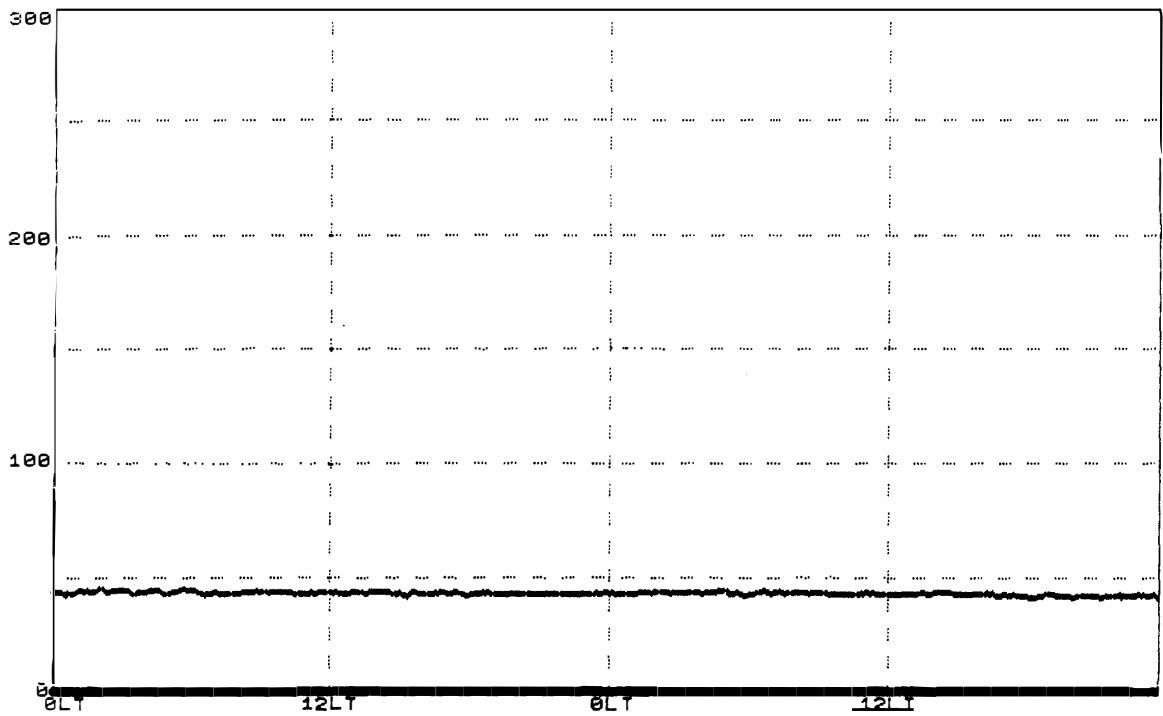
TB(K) and IWC(mg/cm²) 89 603 --> 604



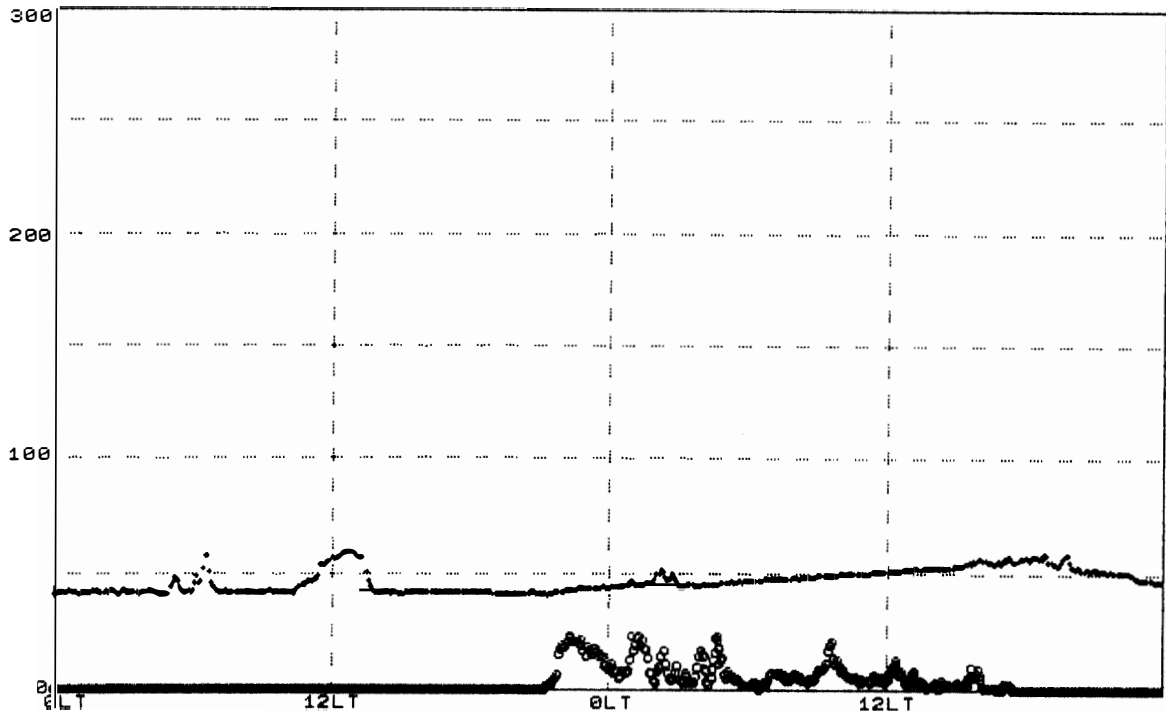
TB(K) and IWC(mg/cm²) 89 605 --> 606



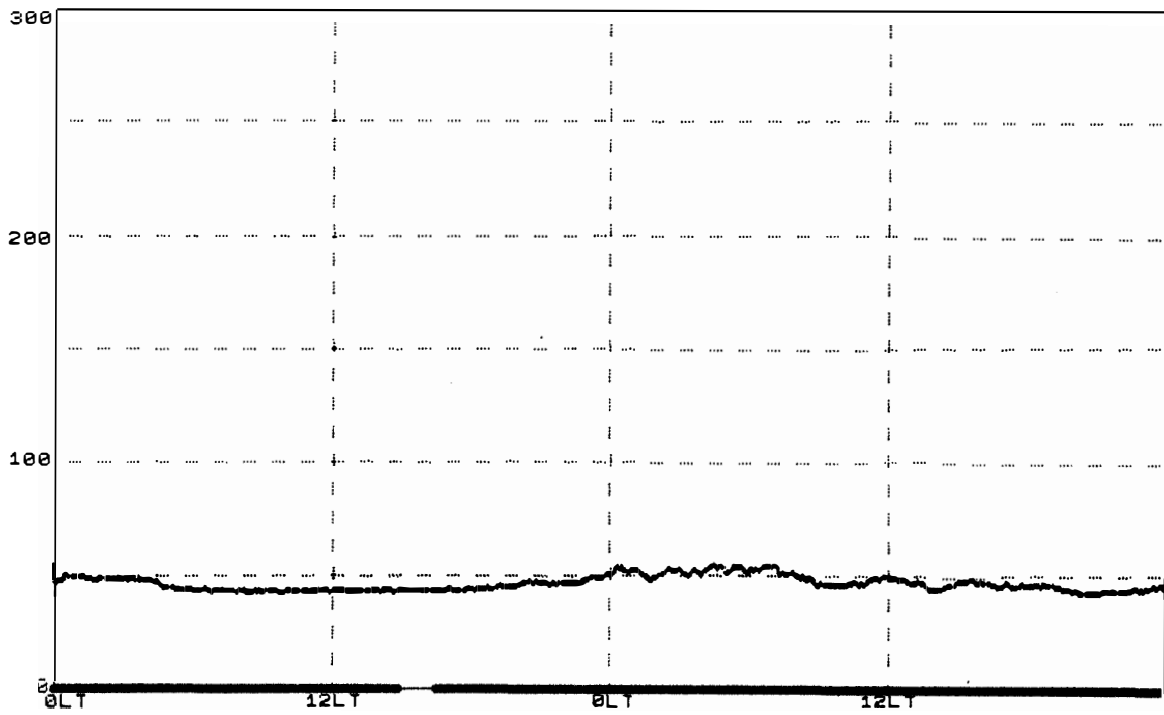
TB(K) and IWC(mg/cm²) 89 607 --> 608



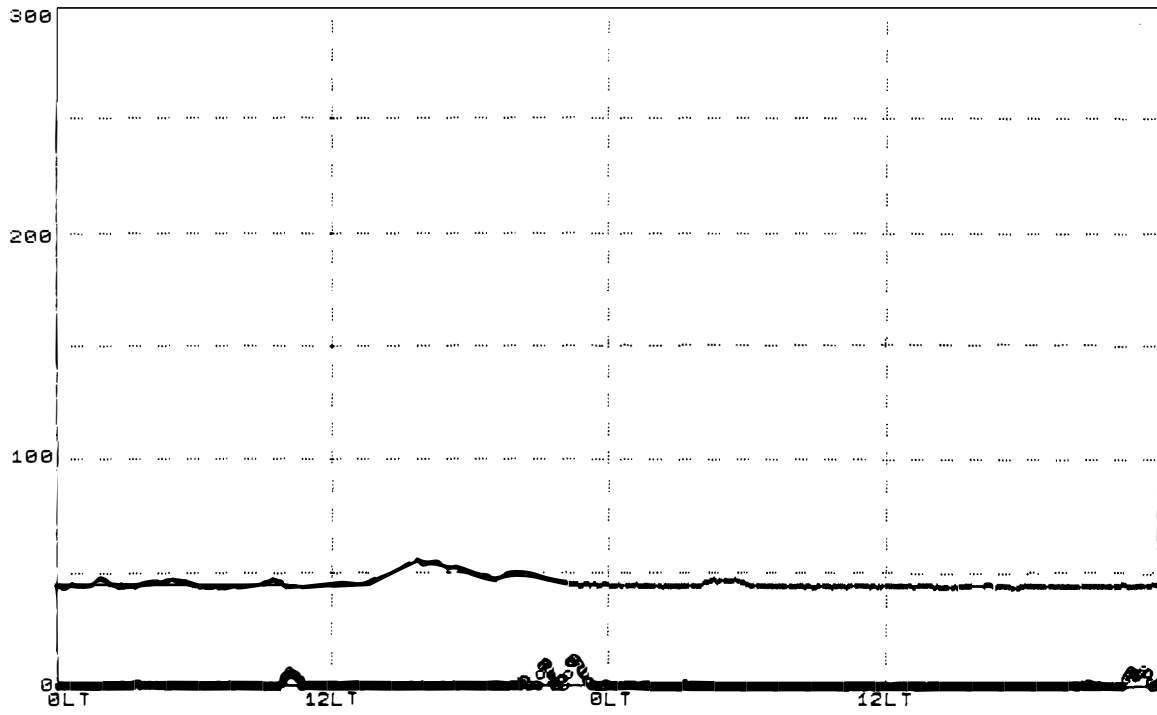
TB(K) and IWC(mg/cm²) 89 609 --> 610



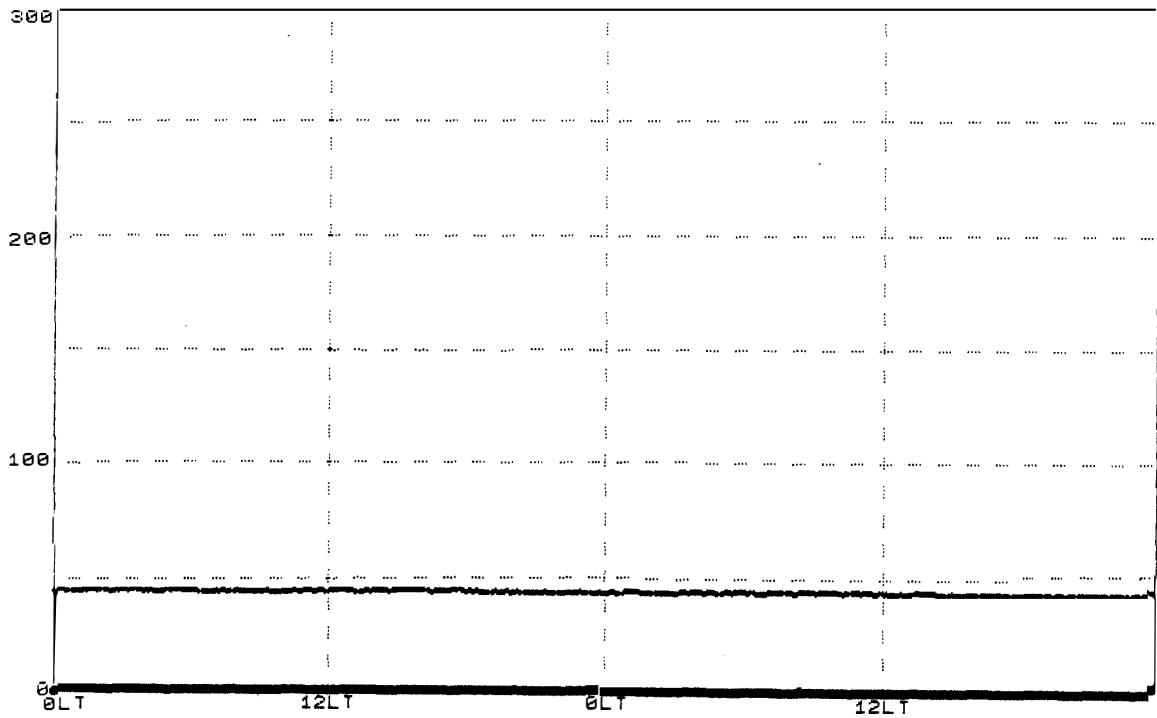
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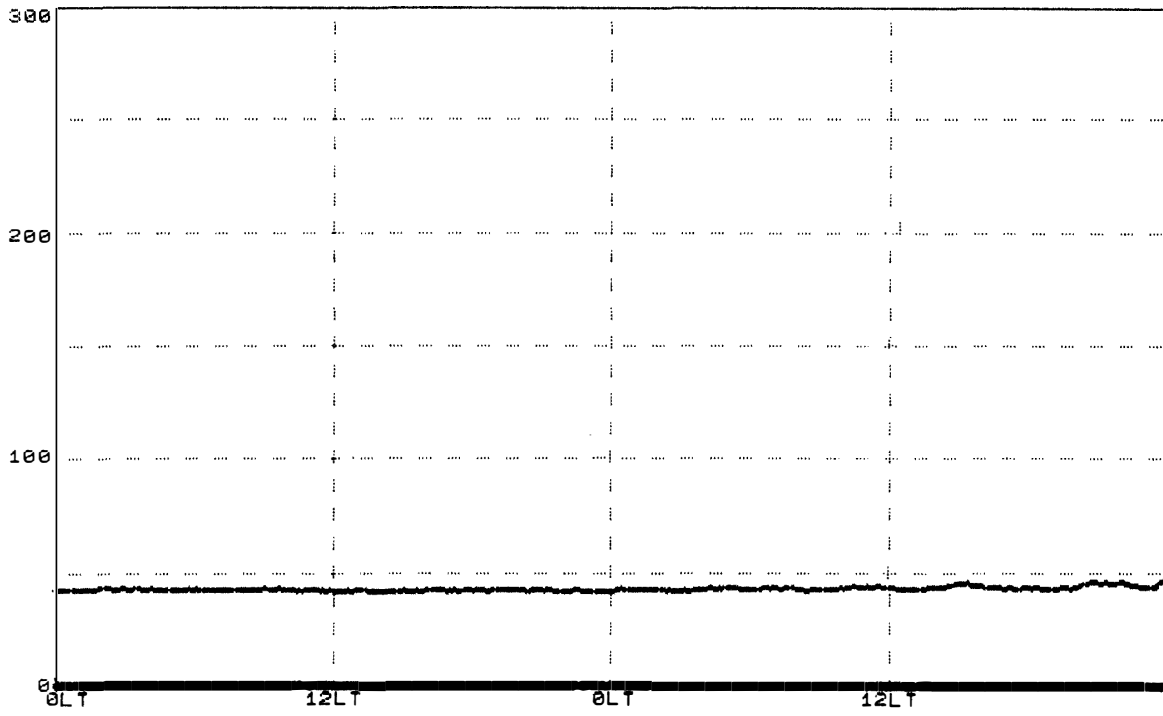
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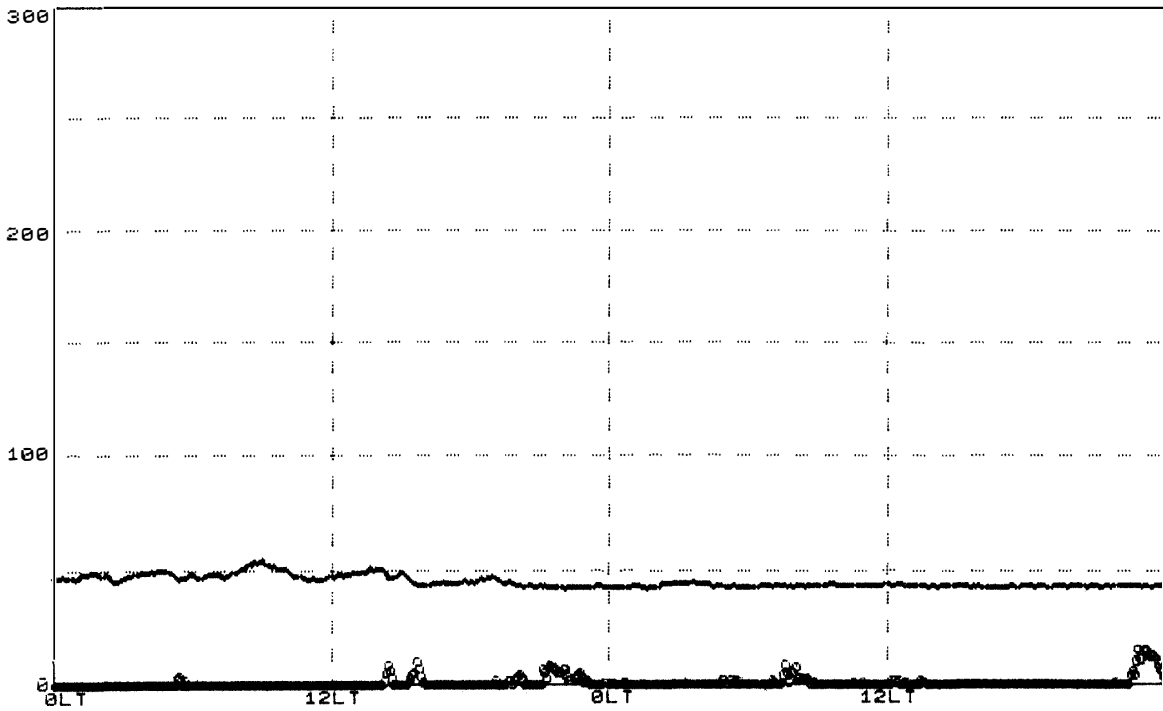
TB(K) and IWC(mg/cm²) 89 615 --> 616



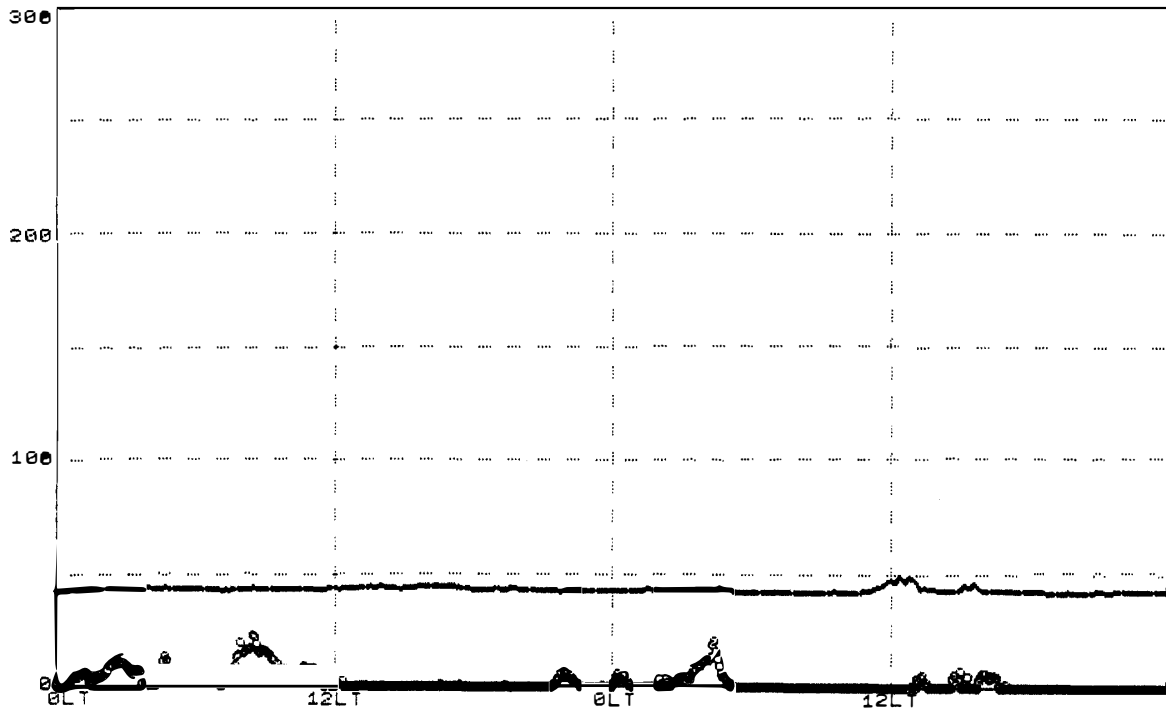
TB(K) and IWC(mg/cm²) 89 617 --> 618



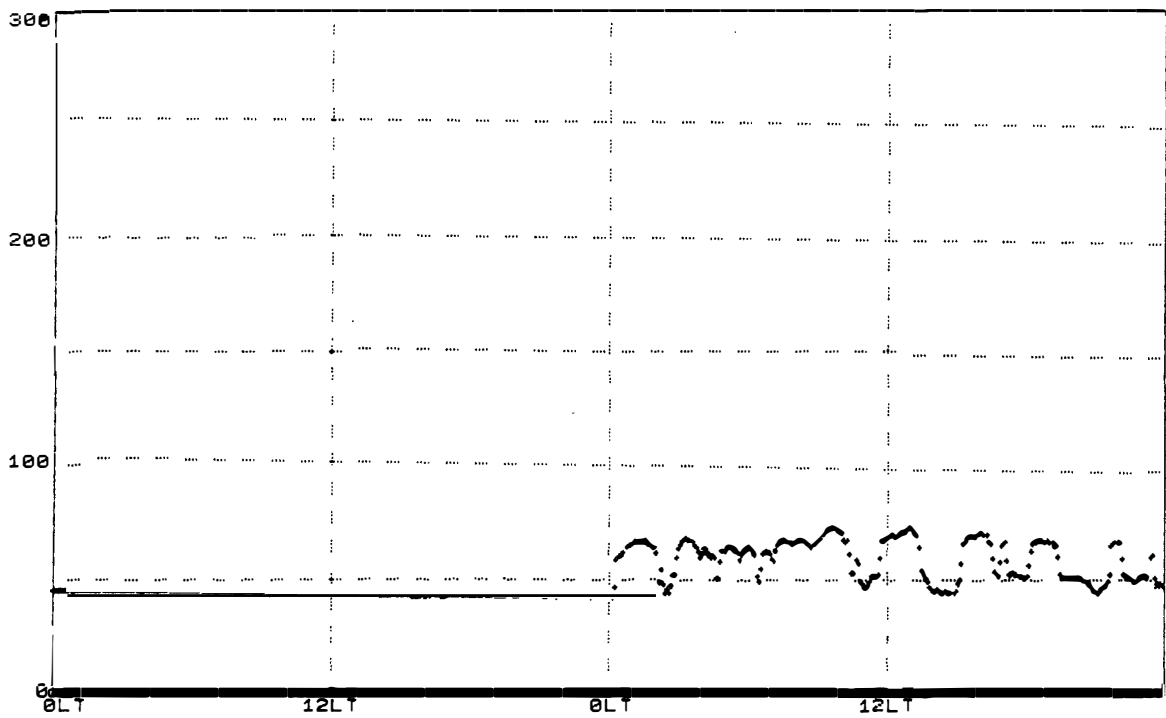
TB(K) and IWC(mg/cm²) 89 619 --> 620



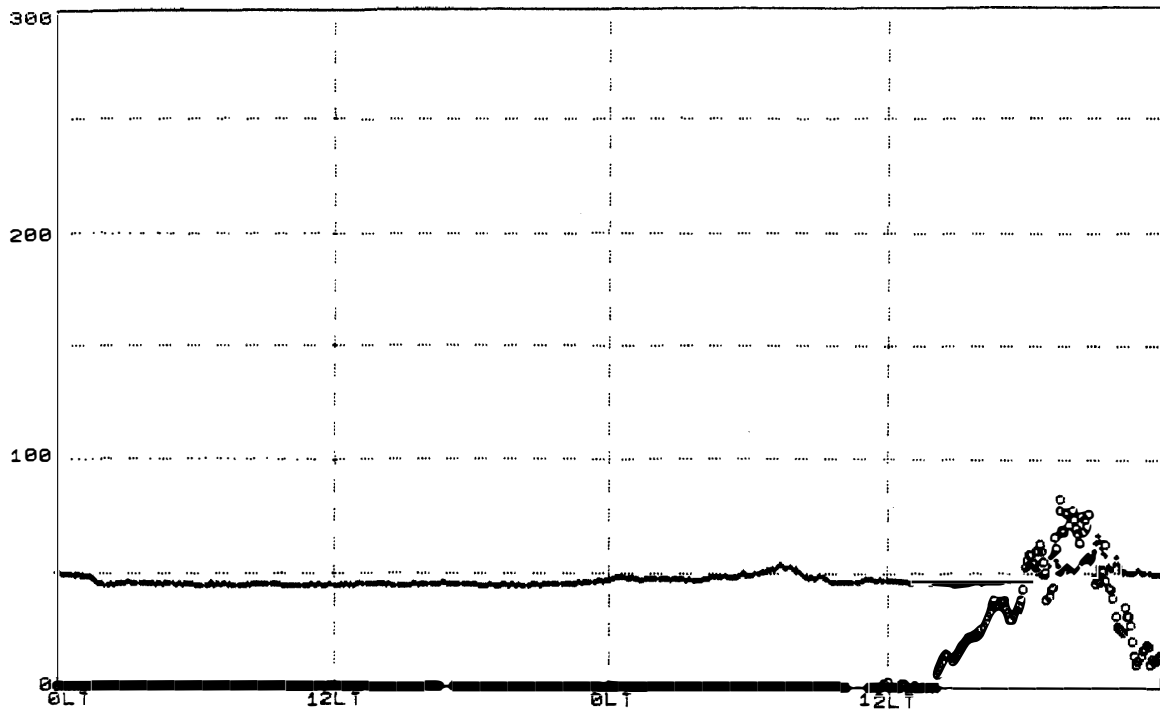
TB(K) and IWC(mg/cm²) 89 621 --> 622



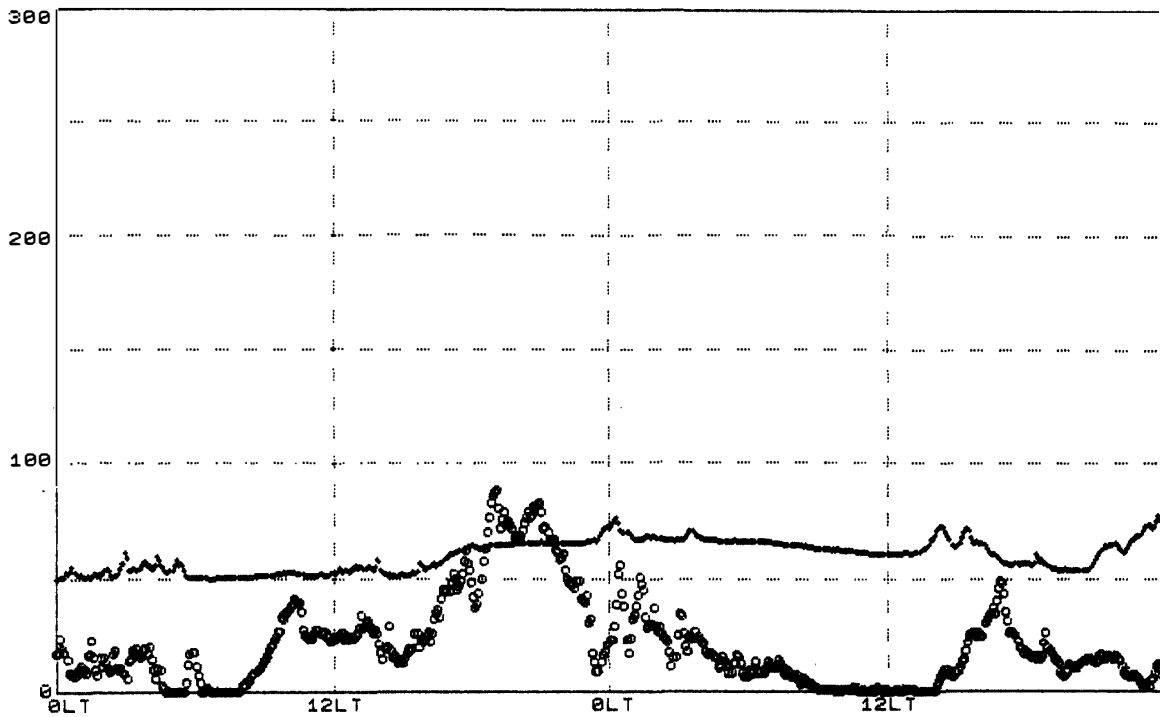
TB(K) and IWC(mg/cm²) 89 623 --> 624



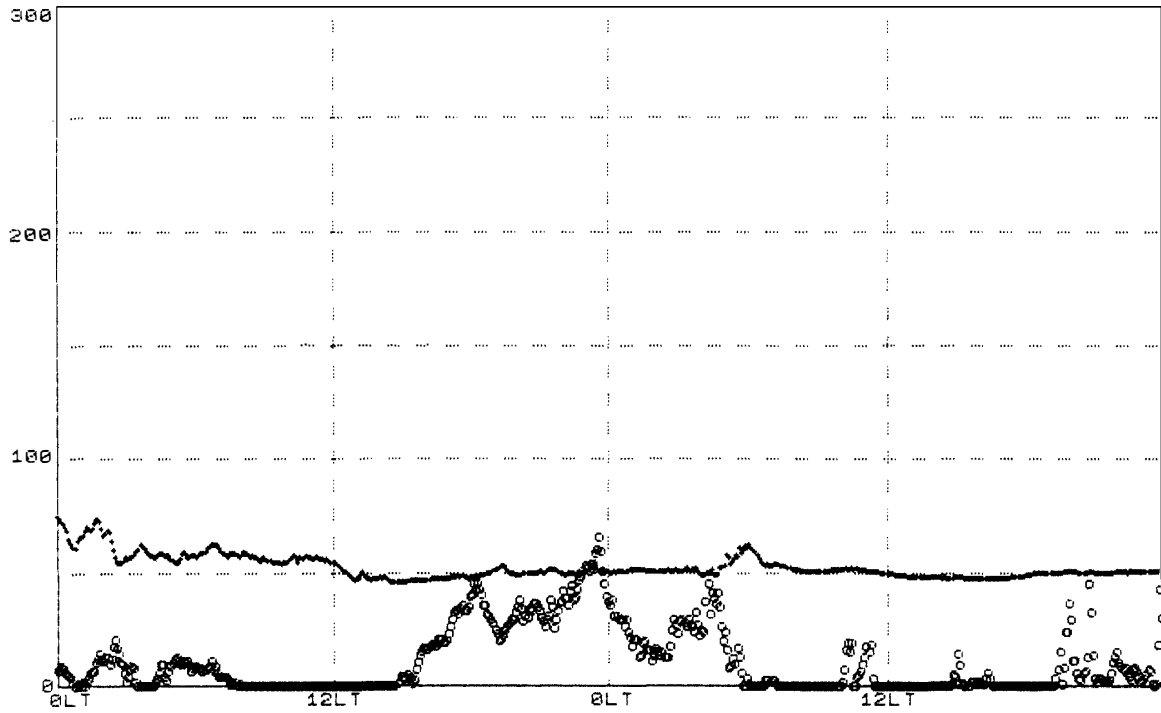
TB(K) and IWC(mg/cm²) 89 625 --> 626



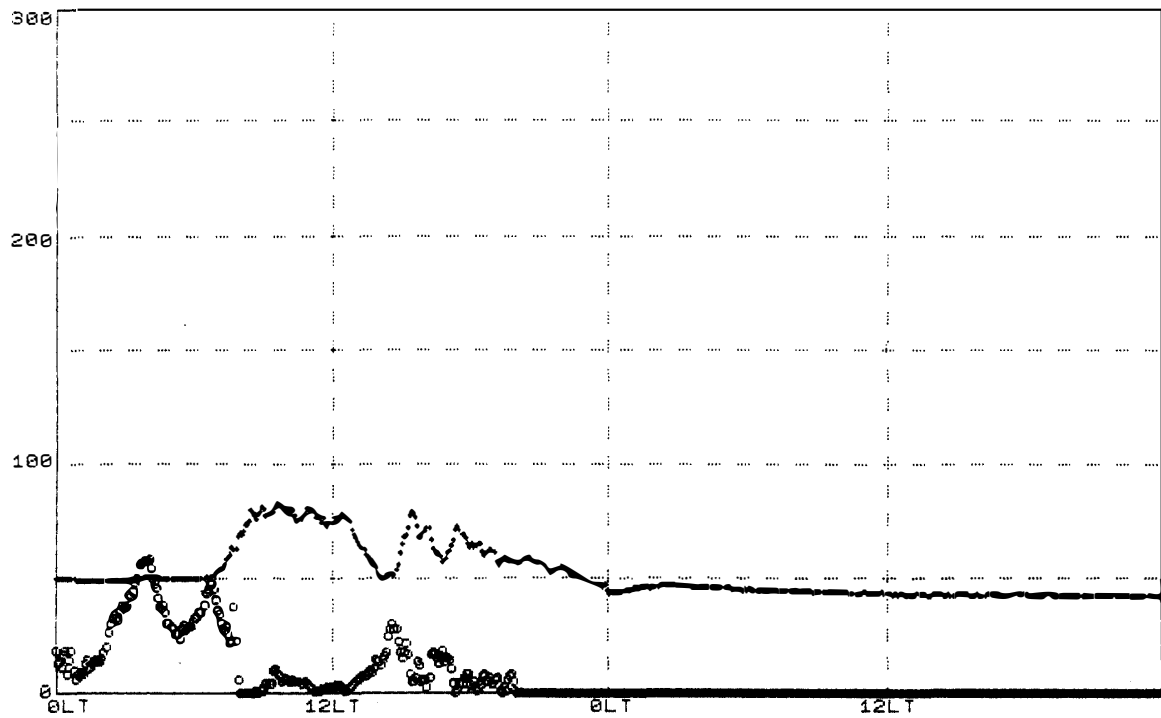
TB(K) and IWC(mg/cm²) 89 627 --> 628



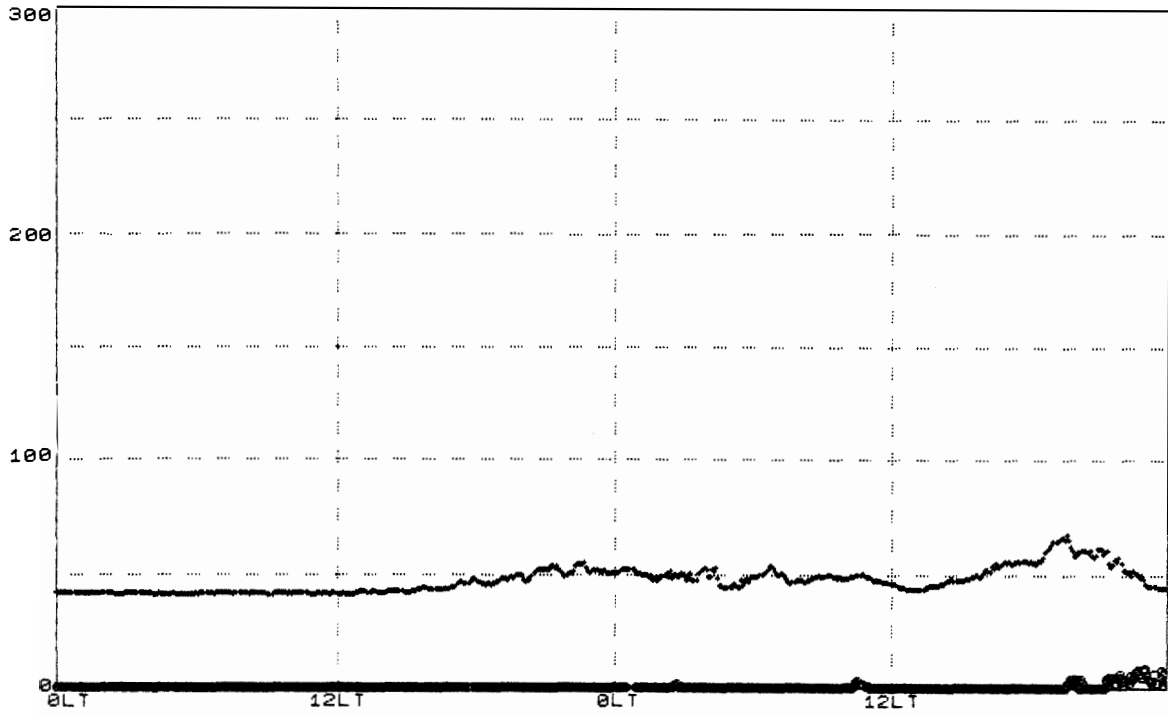
TB(K) and IWC(mg/cm²) 89 629 --> 630



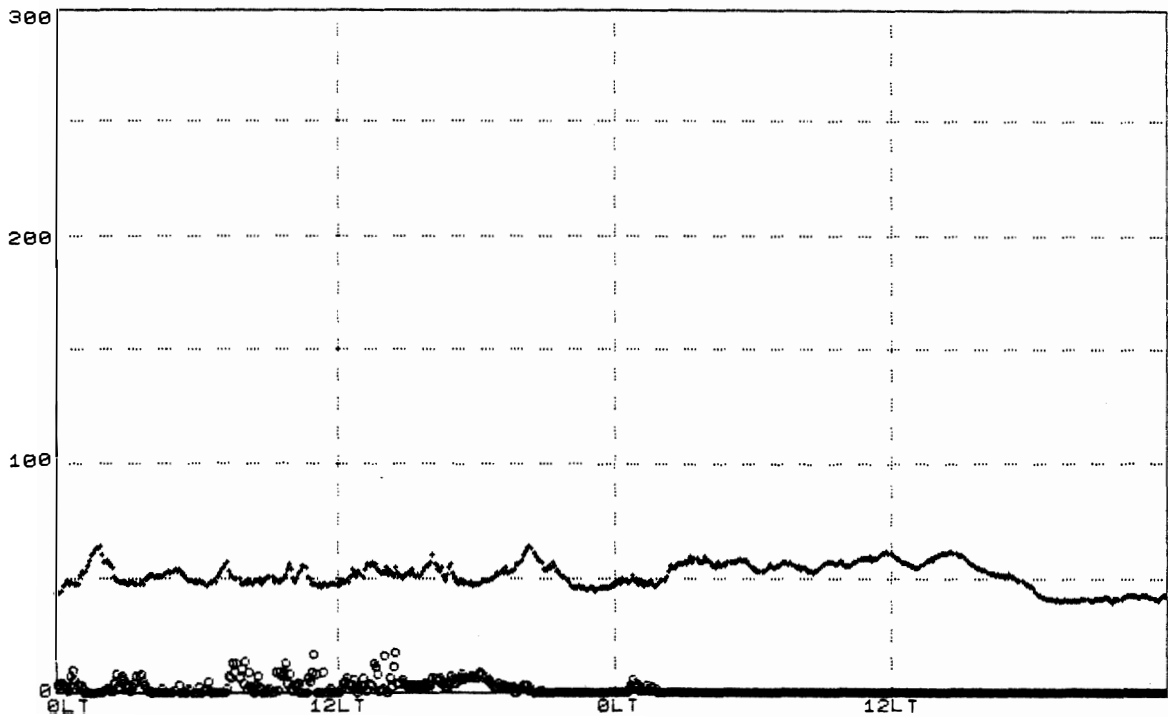
TB(K) and IWC(mg/cm²) 89 701 --> 702



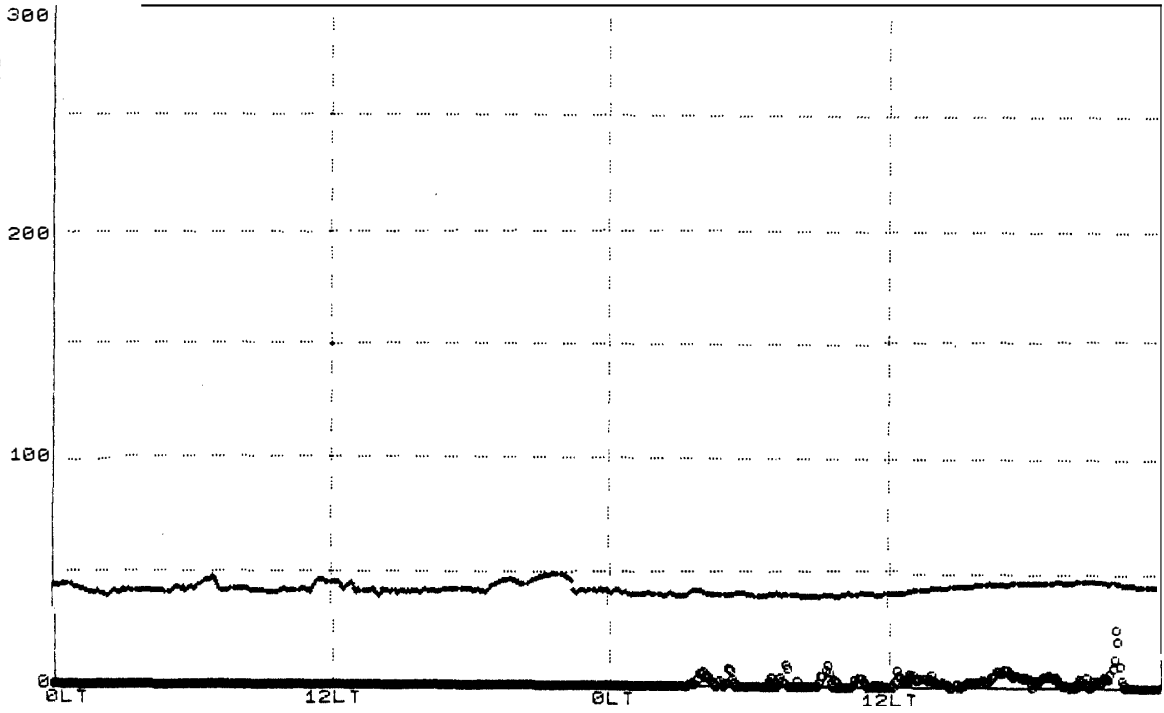
TB(K) and IWC(mg/cm²) 89 703 --> 704



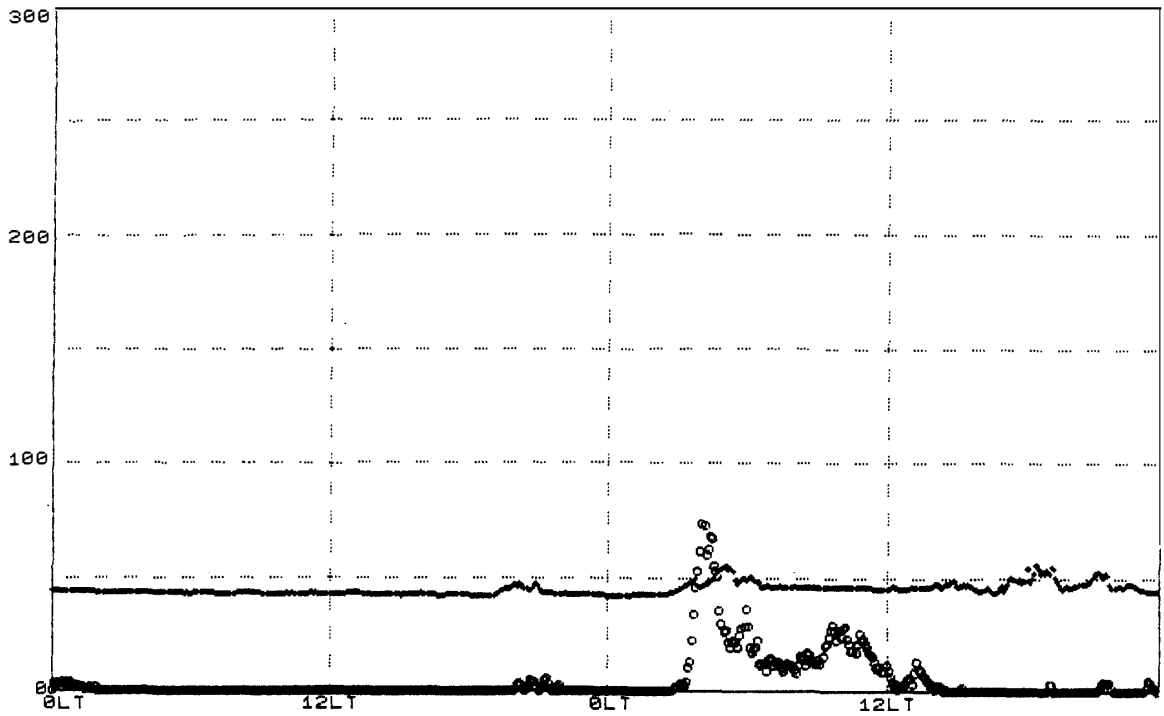
TB(K) and IWC(mg/cm²) 89 705 --> 706



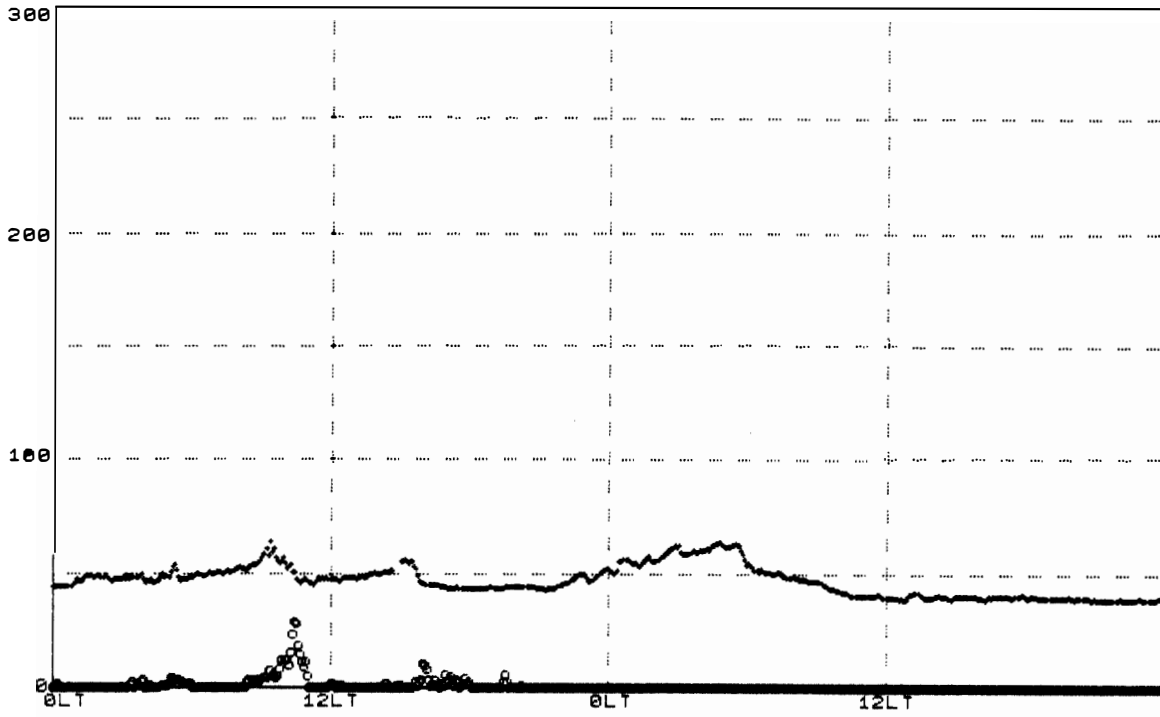
TB(K) and IWC(mg/cm²) 89 707 --> 708



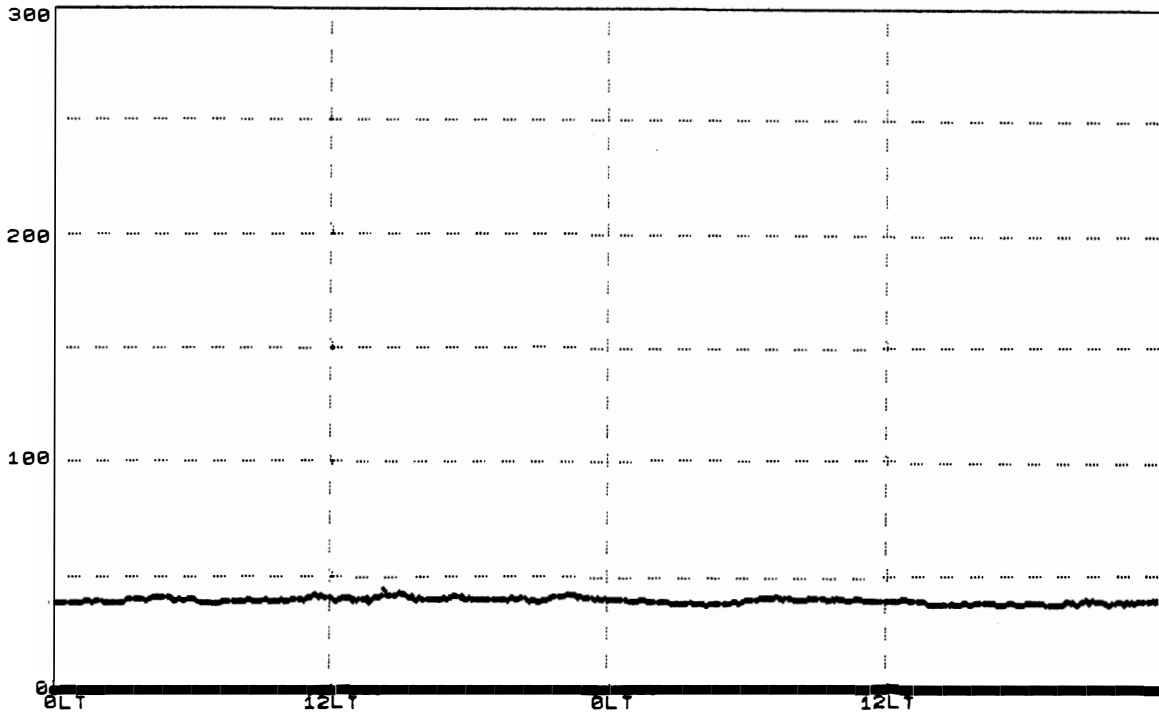
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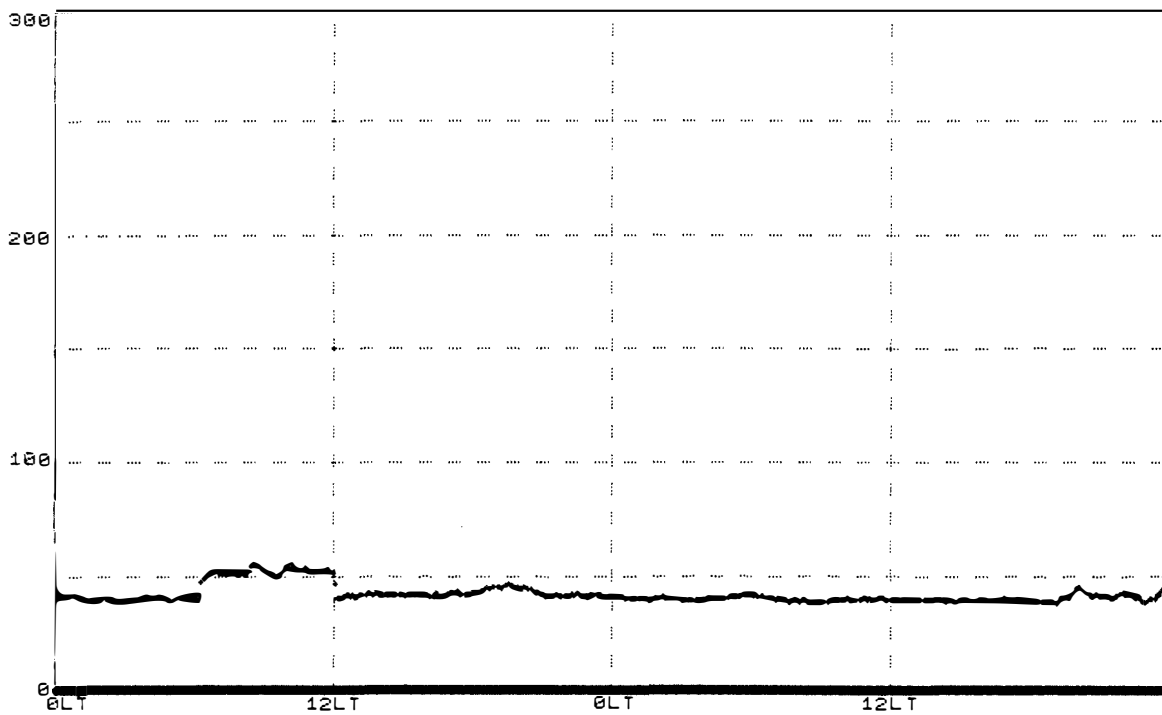
TB(K) and IWC(mg/cm²) 89 711 --> 712



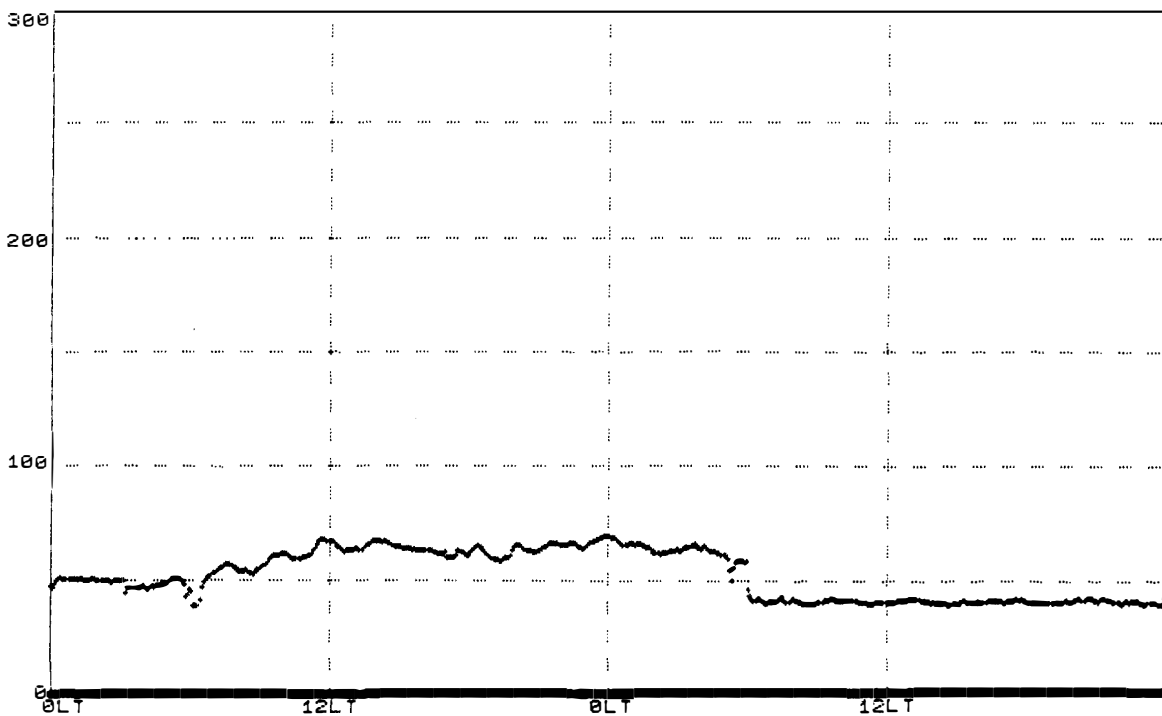
TB(K) and IWC(mg/cm²) 89 713 --> 714



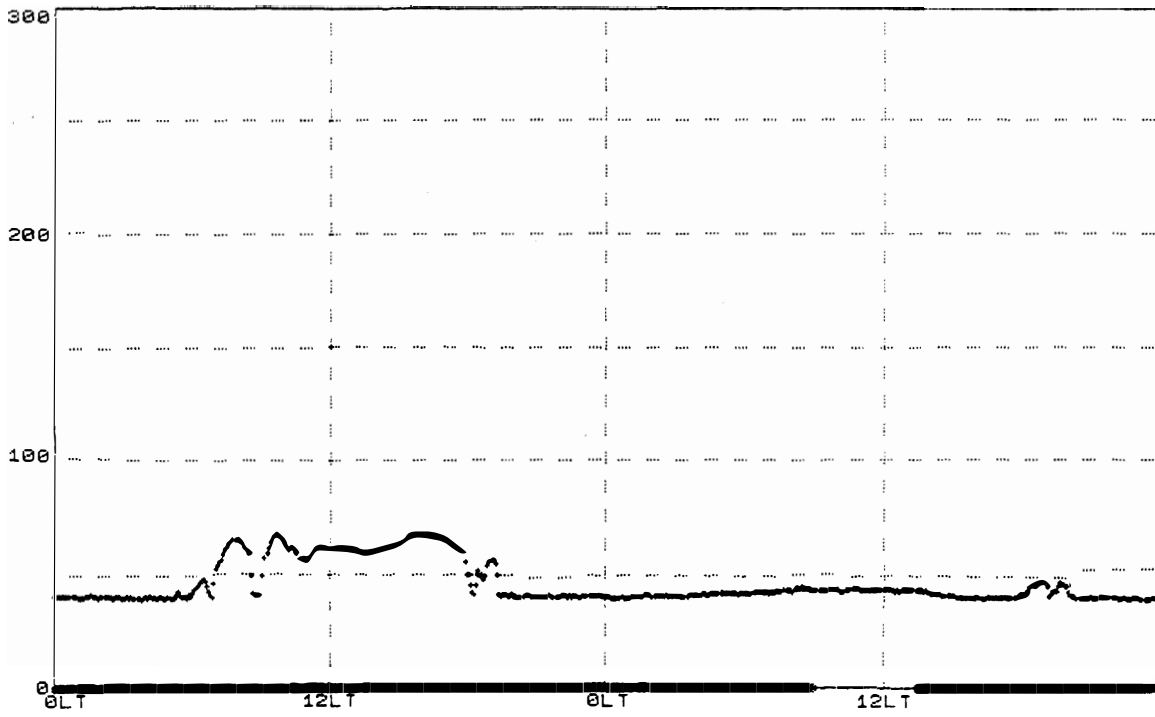
TB(K) and IWC(mg/cm²) 89 715 --> 716



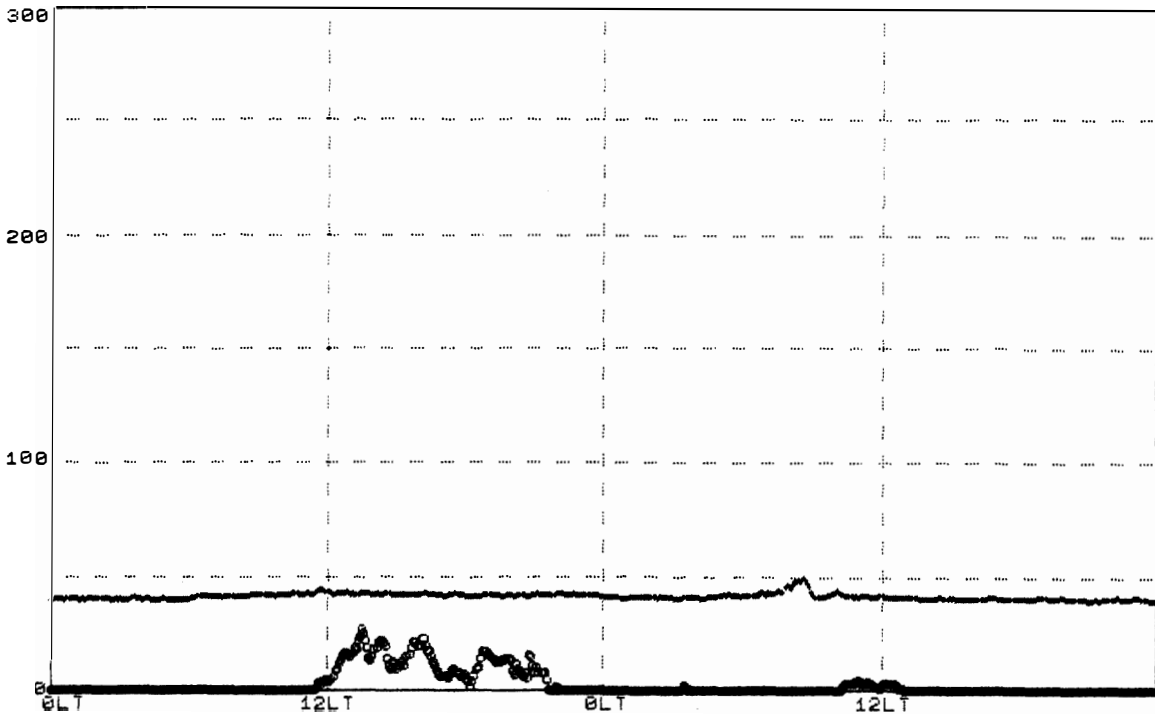
TB(K) and IWC(mg/cm²) 89 717 --> 718



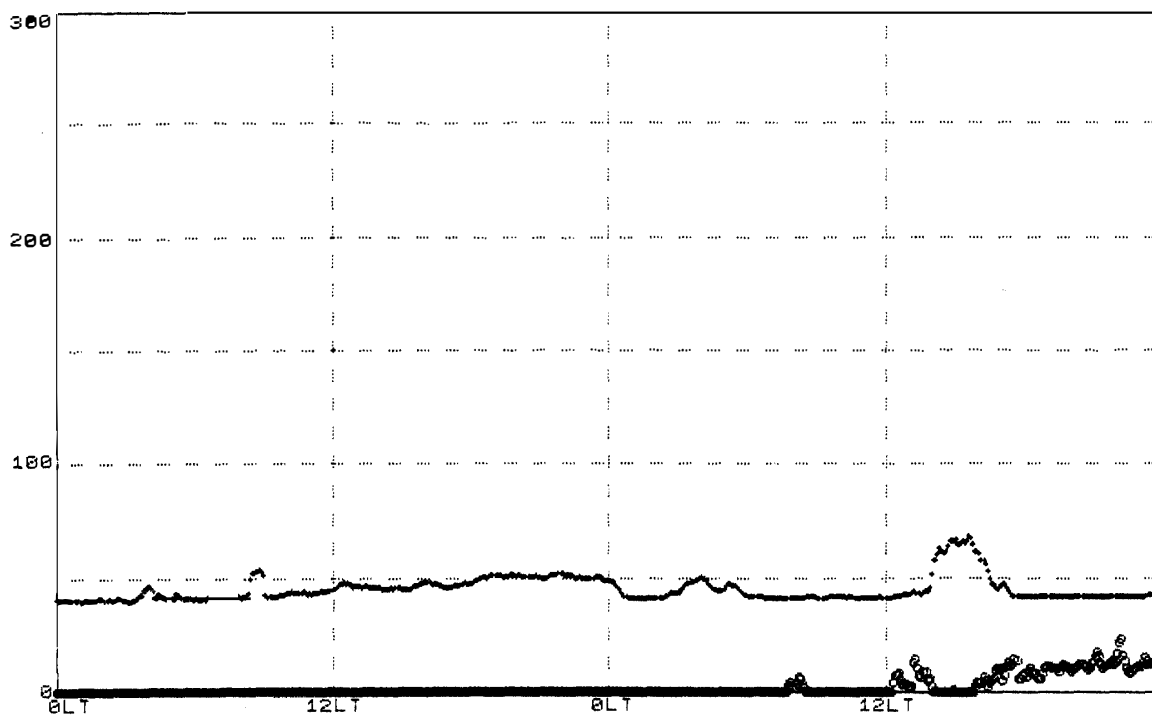
TB(K) and IWC(mg/cm²) 89 719 --> 720



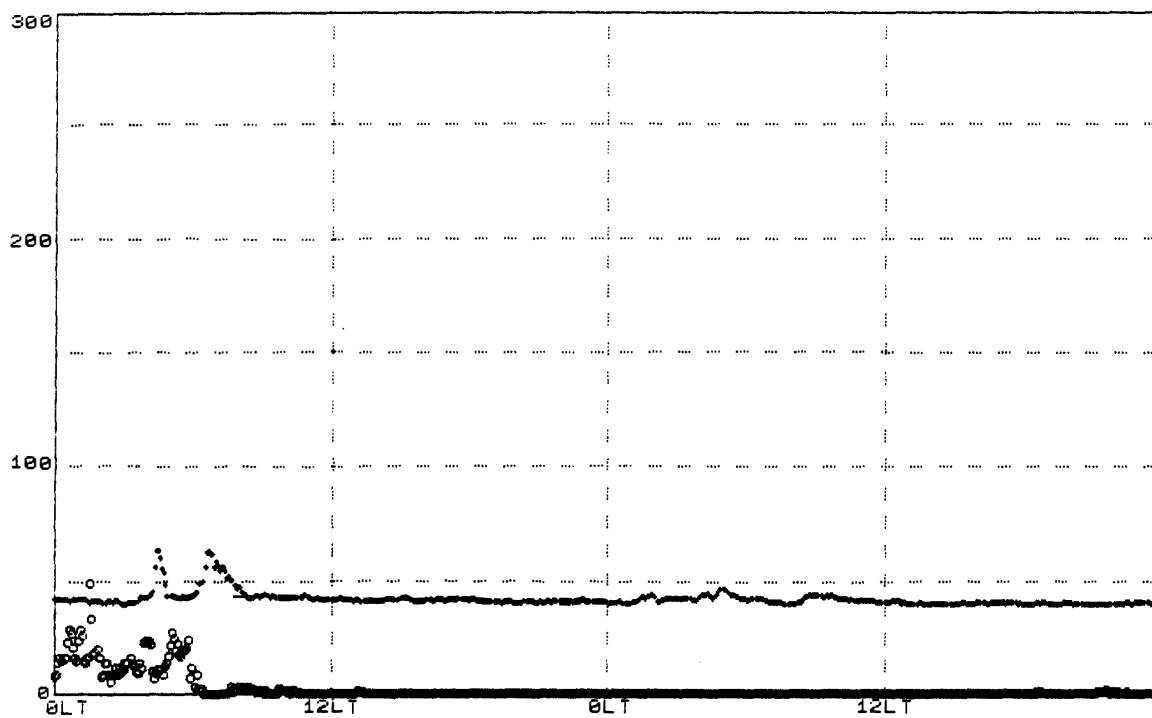
TB(K) and IWC(mg/cm²) 89 721 --> 722



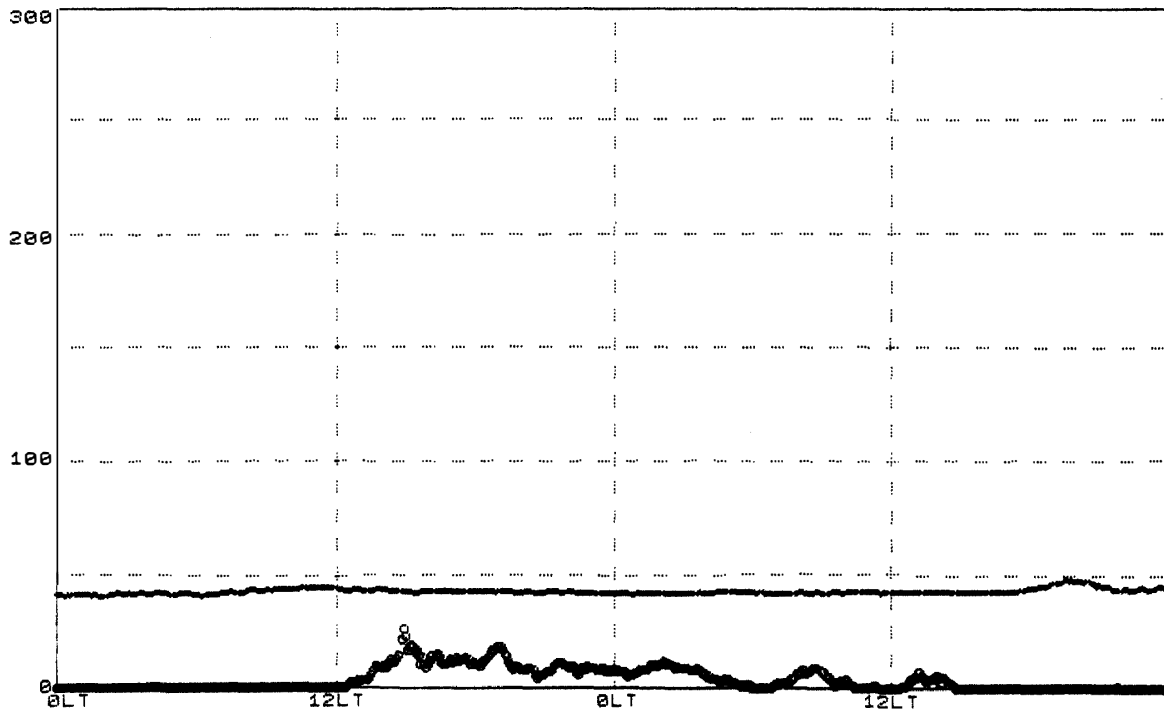
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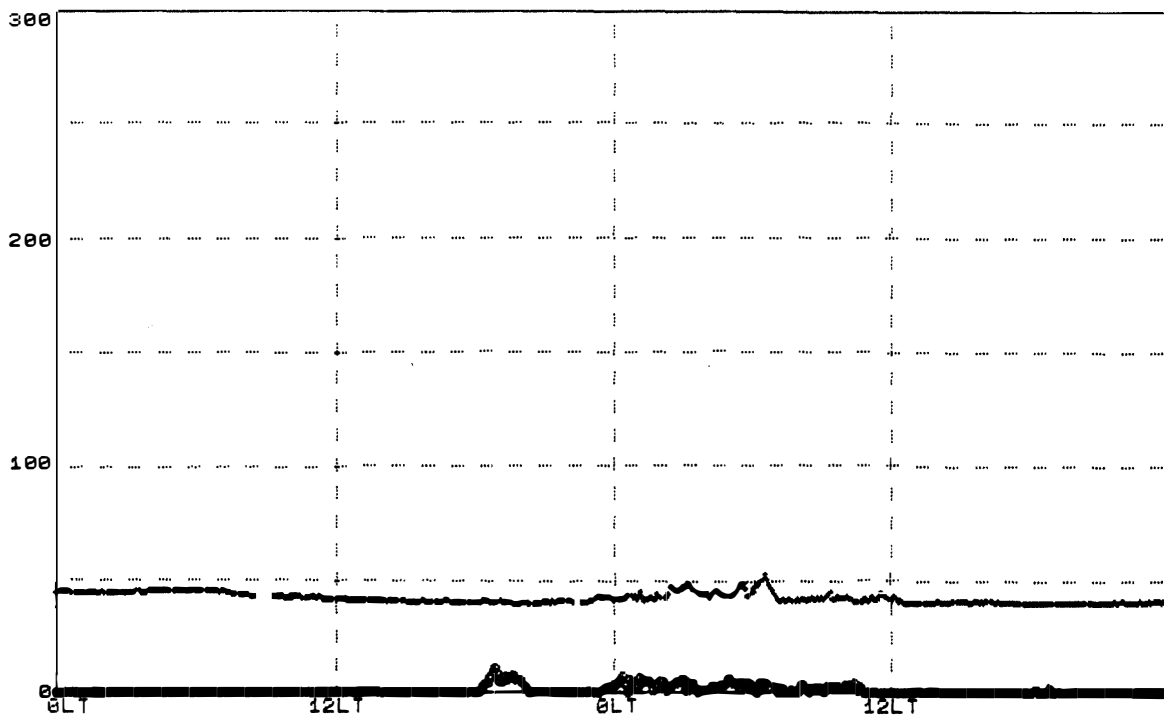
TB(K) and IWC(mg/cm²) 89 725 --> 726



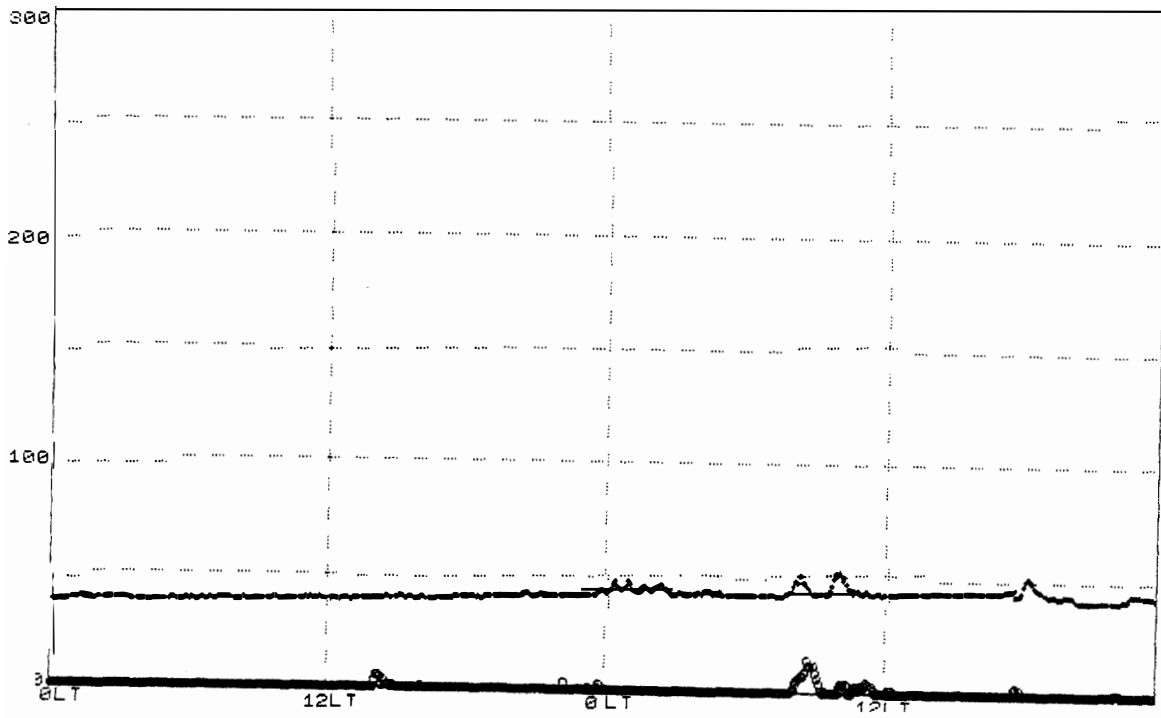
TB(K) and IWC(mg/cm²) 89 727 --> 728



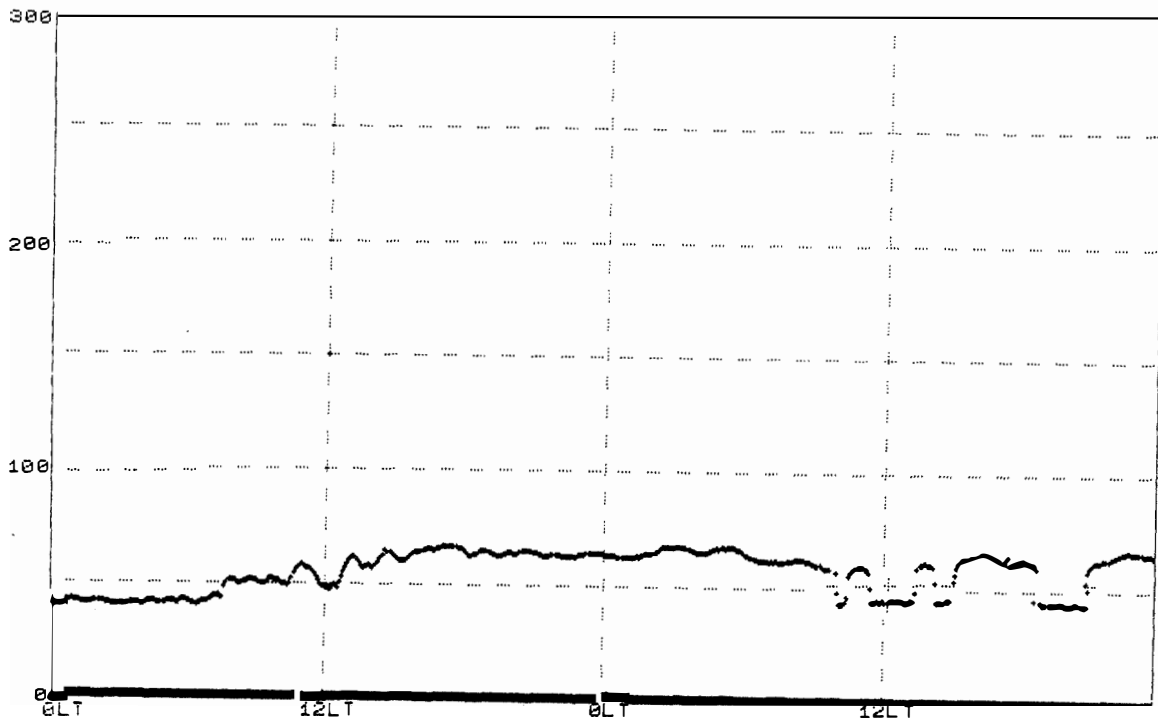
TB(K) and IWC(mg/cm²) 89 729 --> 730



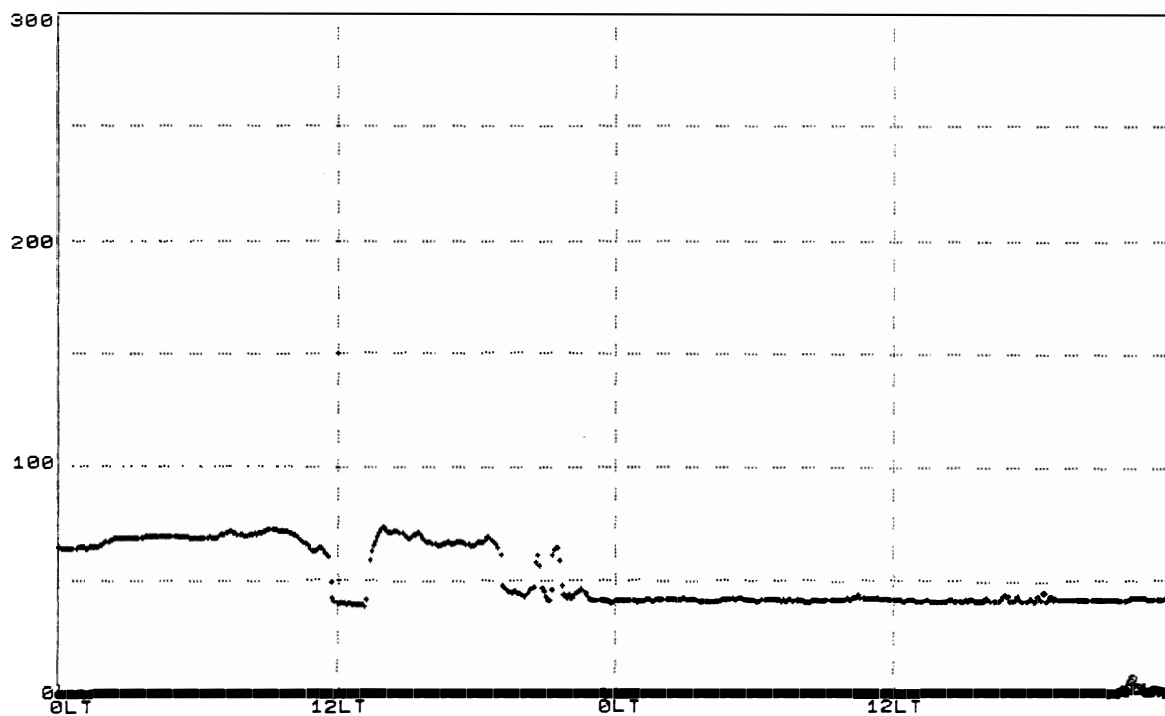
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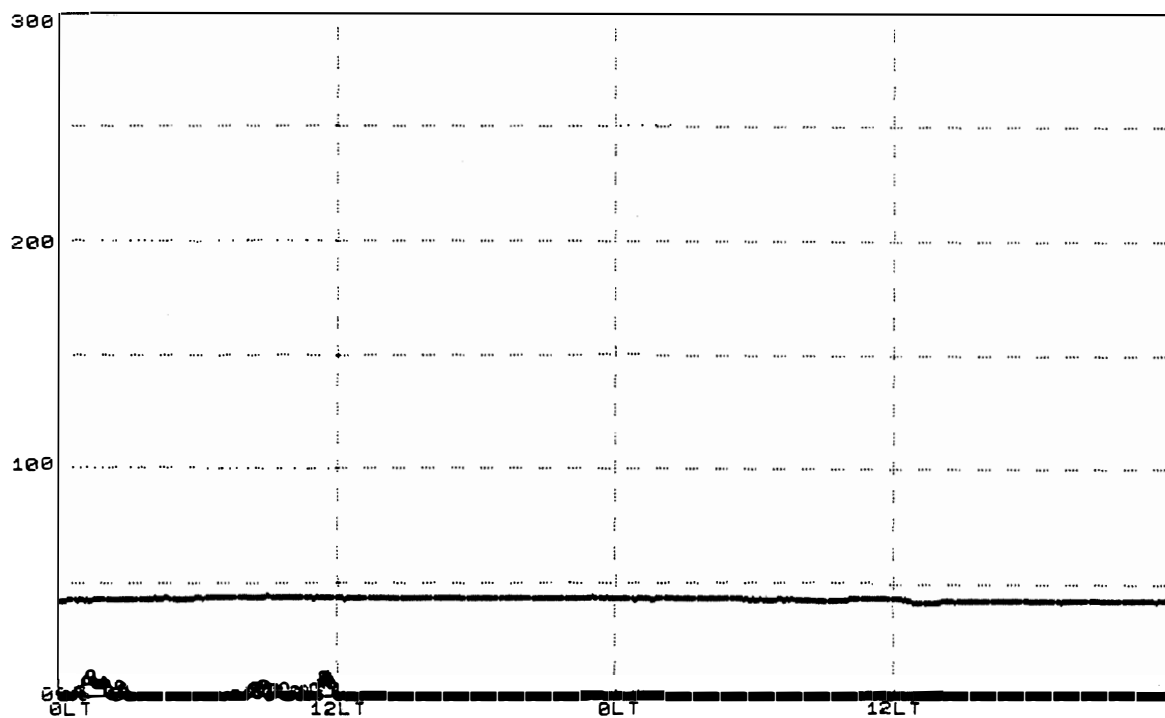
TB(K) and IWC(mg/cm²) 89 802 --> 803



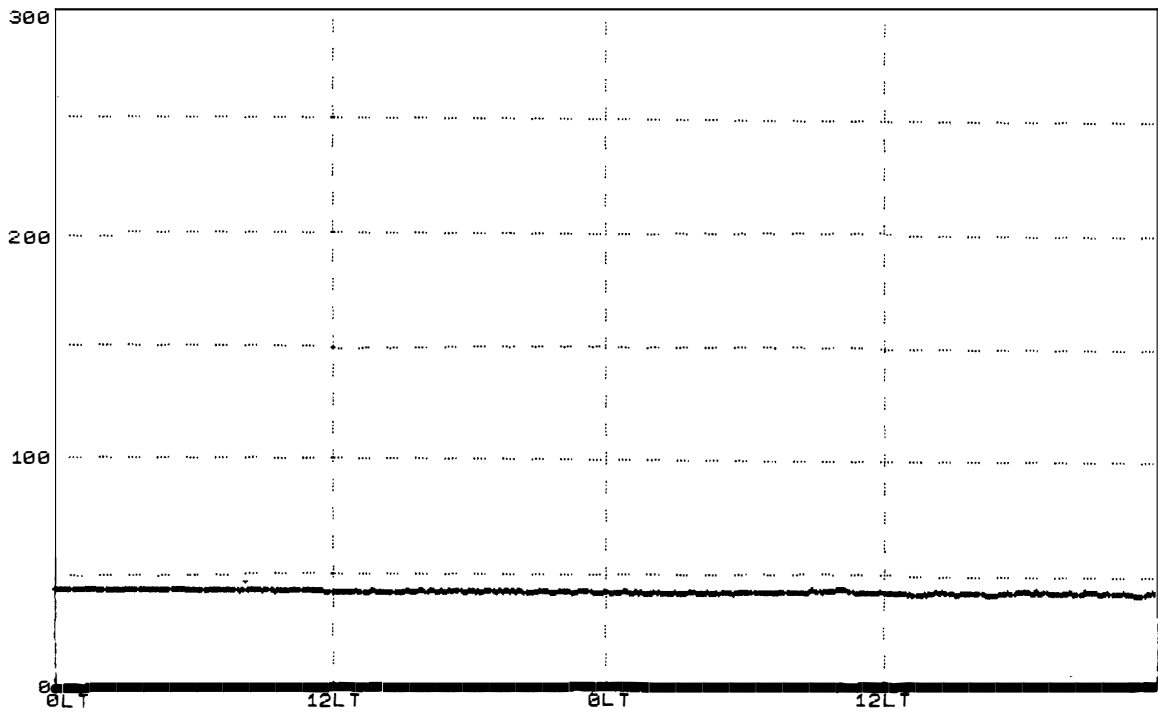
TB(K) and IWC(mg/cm²) 89 804 --> 805



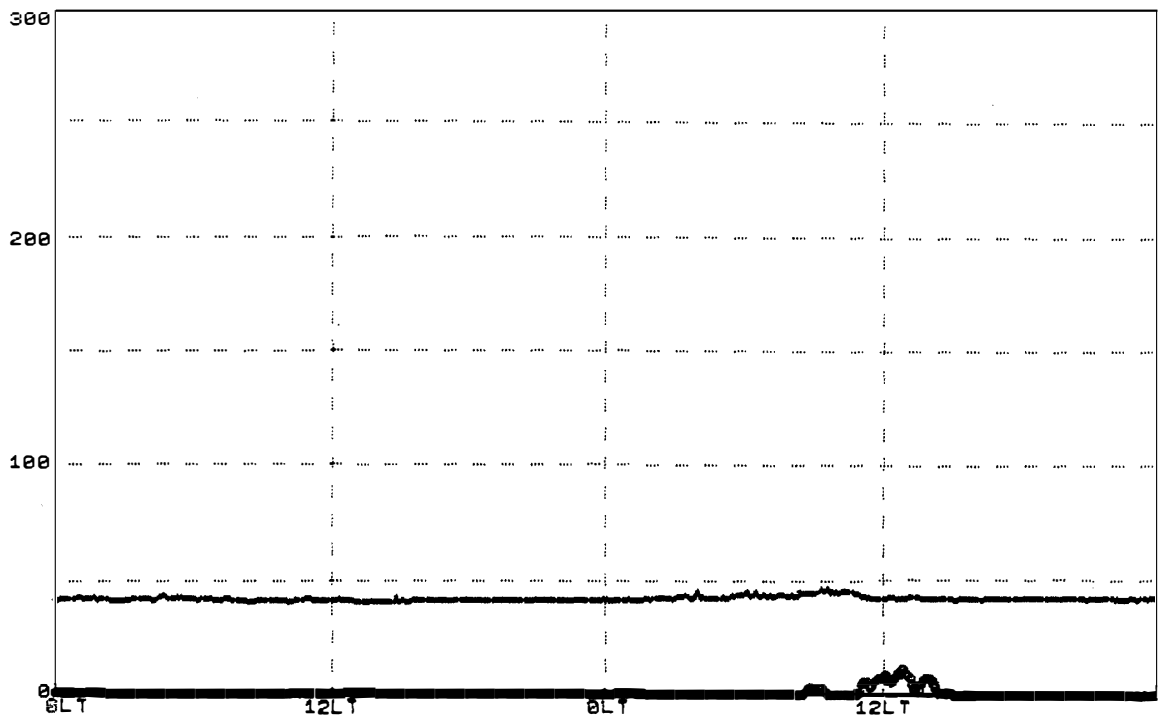
TB(K) and IWC(mg/cm²) 89 806 --> 807



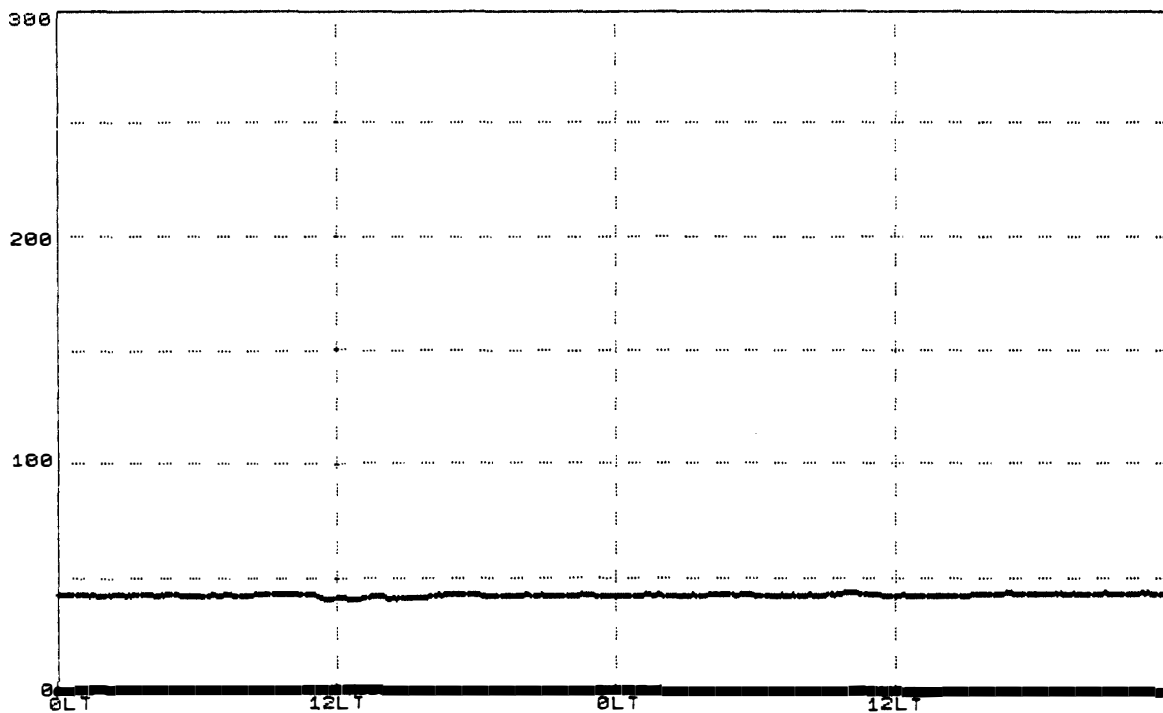
TB(K) and IWC(mg/cm²) 89 808 --> 809



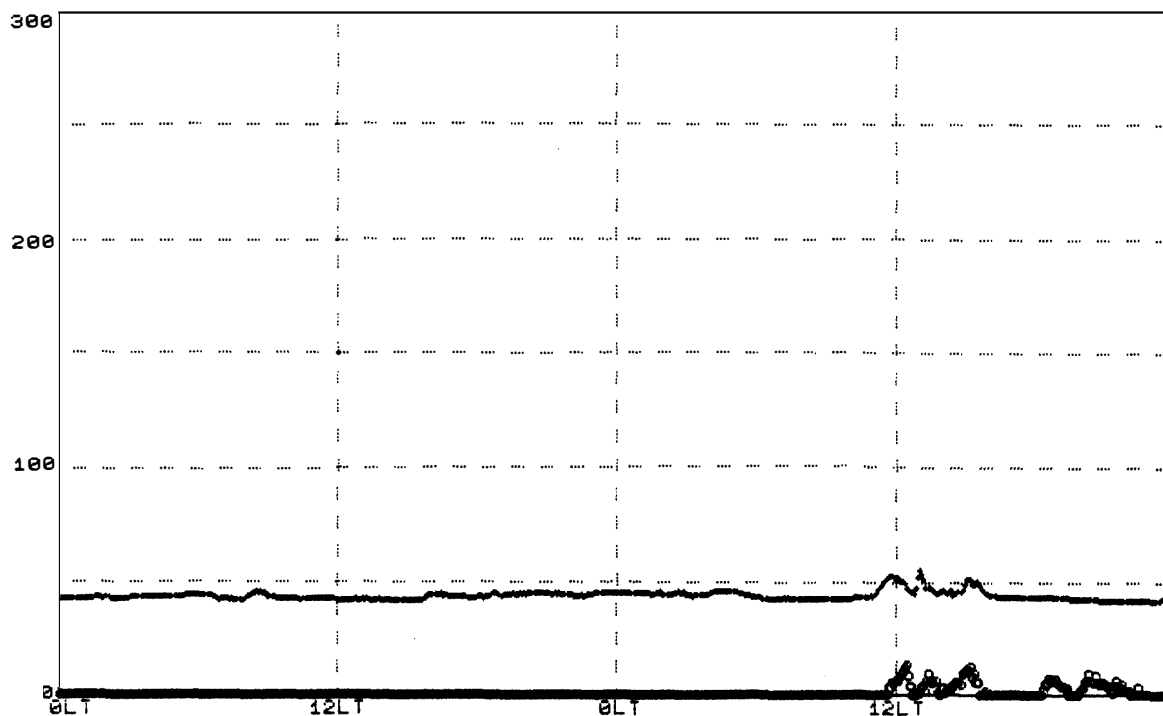
TB(K) and IWC(mg/cm²) 89 810 --> 811



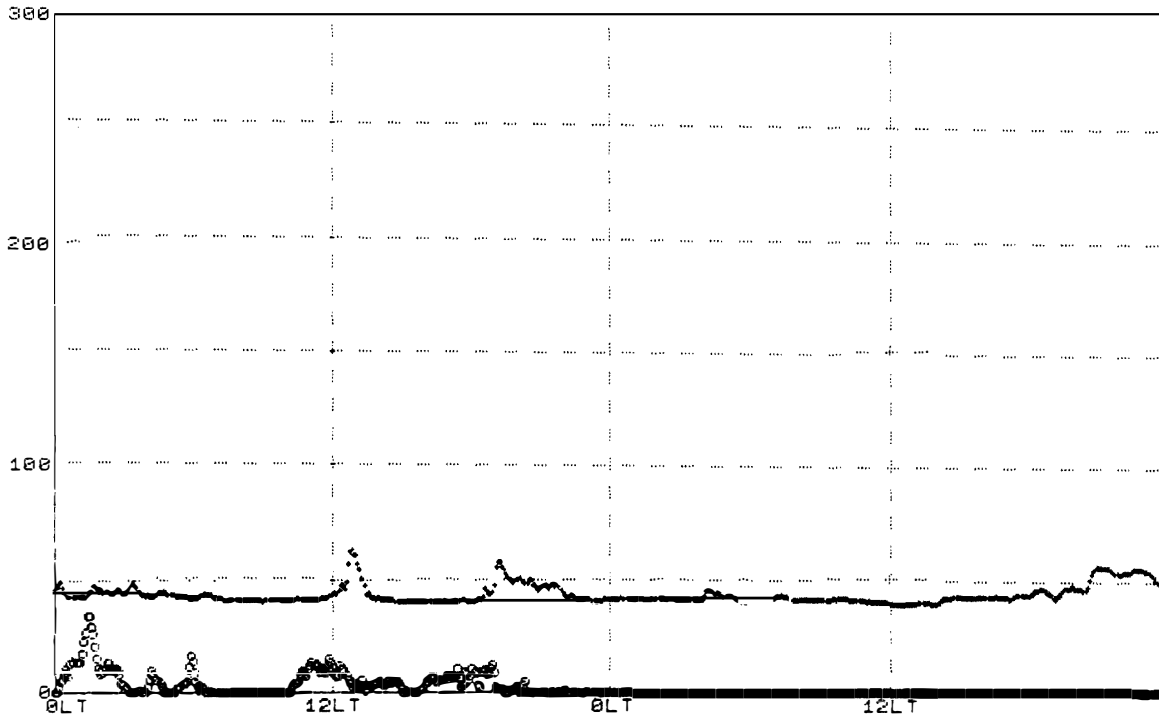
TB(K) and IWC(mg/cm²) 89 812 --> 813



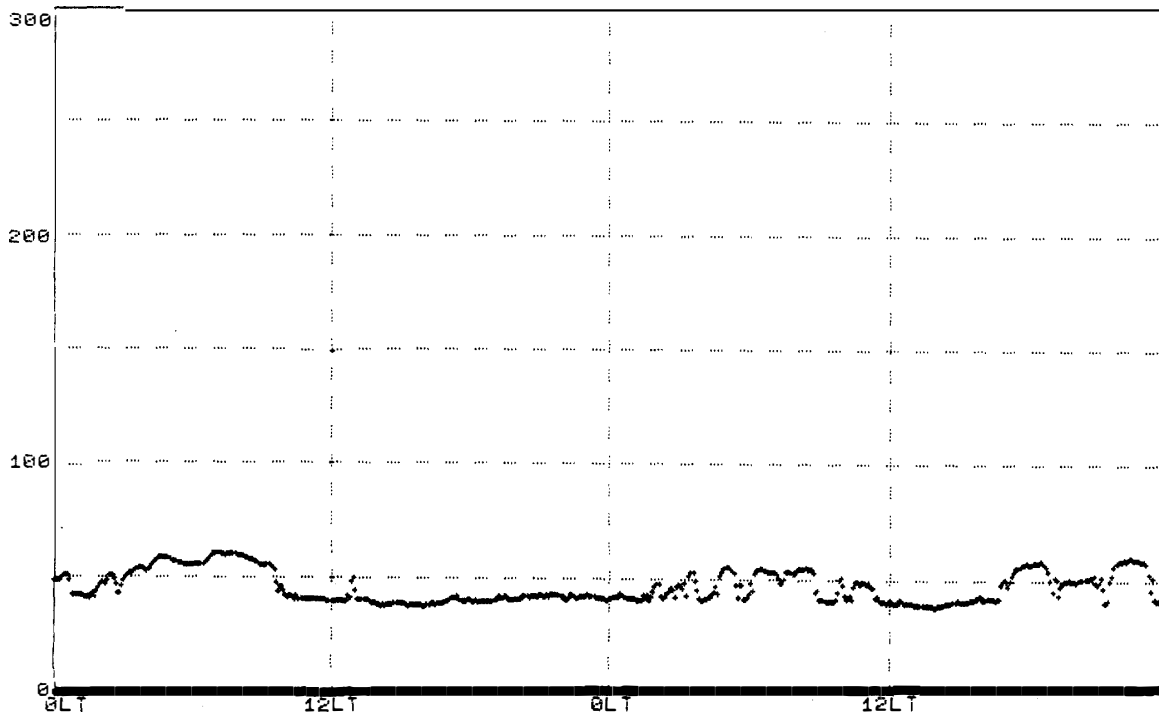
TB(K) and IWC(mg/cm²) 89 814 --> 815



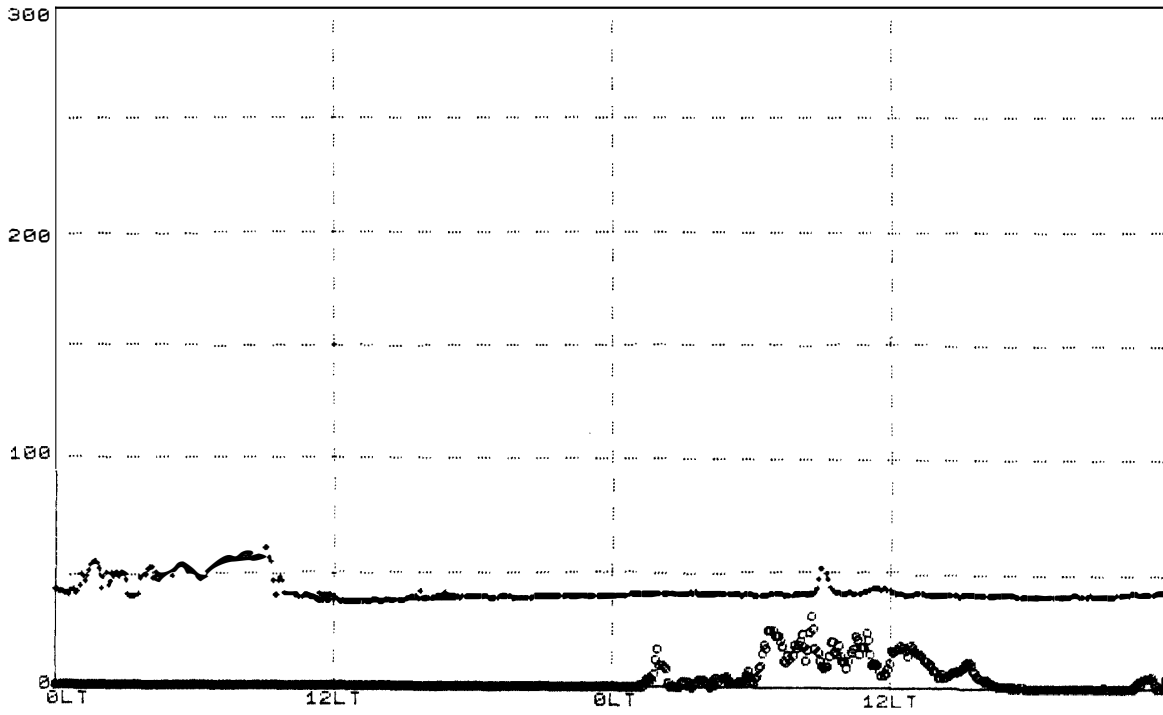
TB(K) and IWC(mg/cm²) 89 816 --> 817



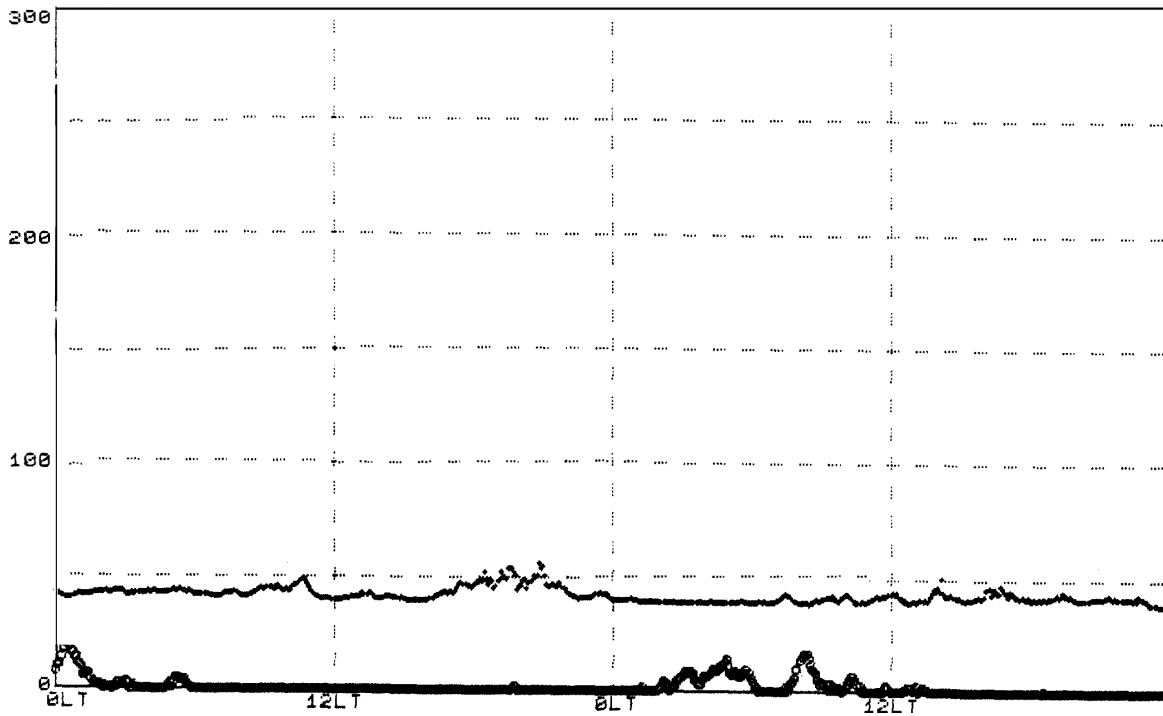
TB(K) and IWC(mg/cm²) 89 818 --> 819



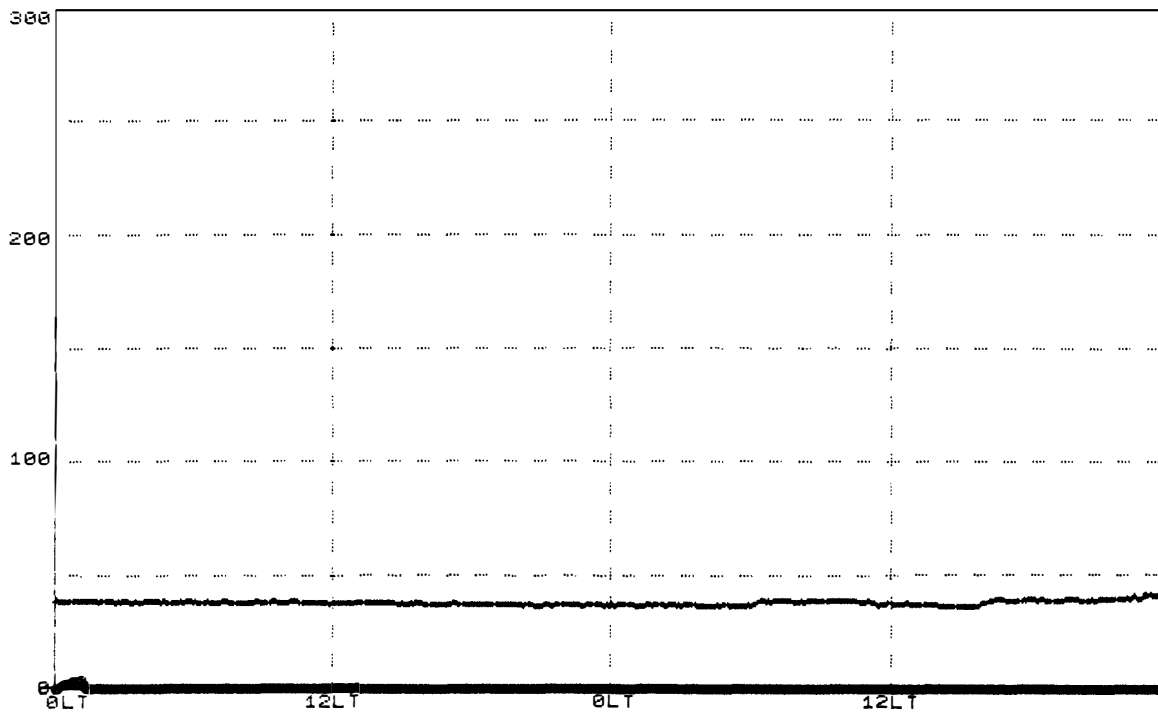
TB(K) and IWC(mg/cm²) 89 820 --> 821



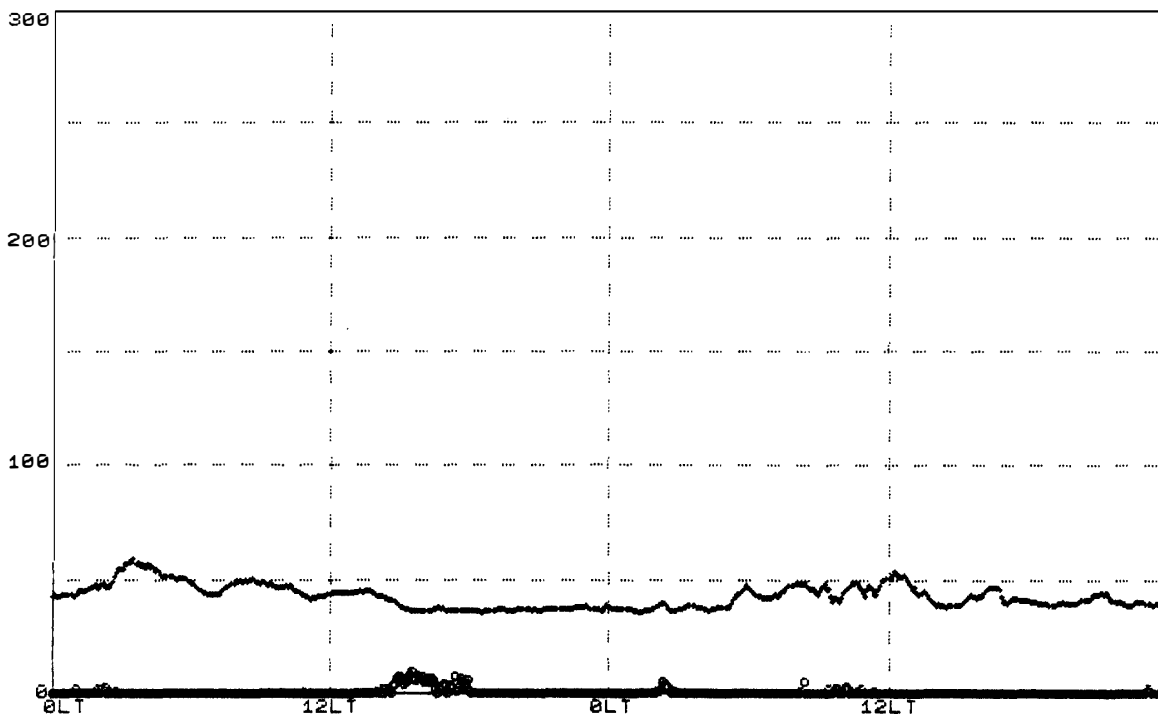
TB(K) and IWC(mg/cm²) 89 822 --> 823



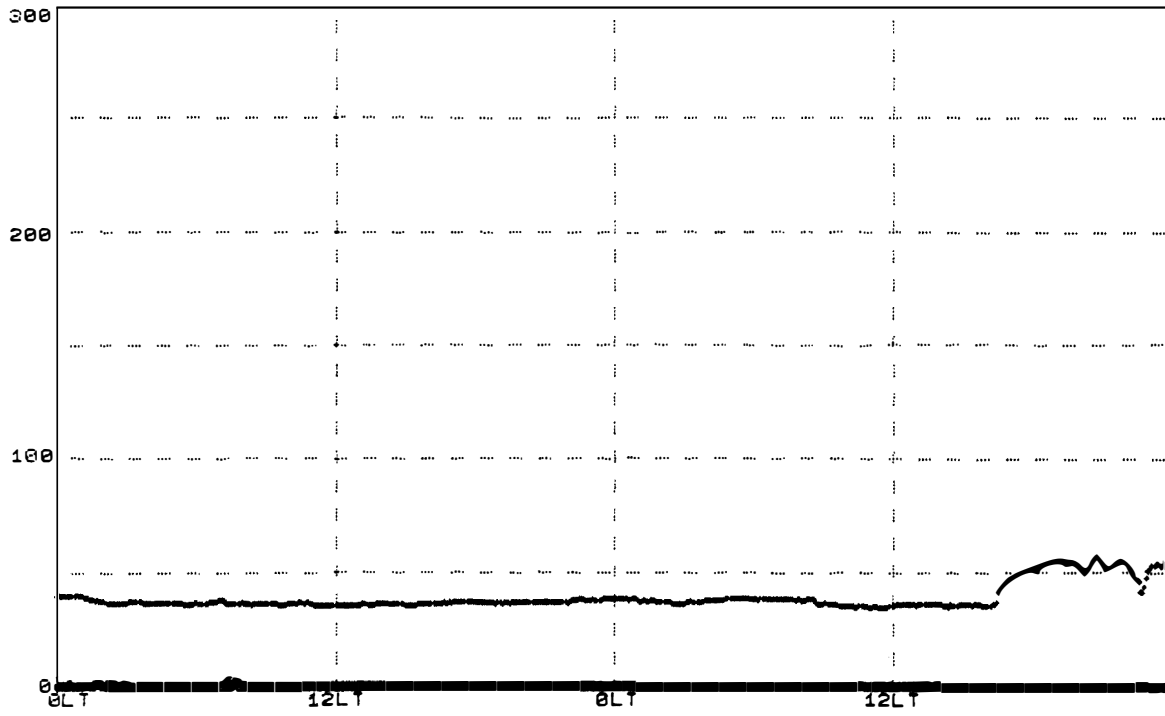
TB(K) and IWC(mg/cm²) 89 824 --> 825



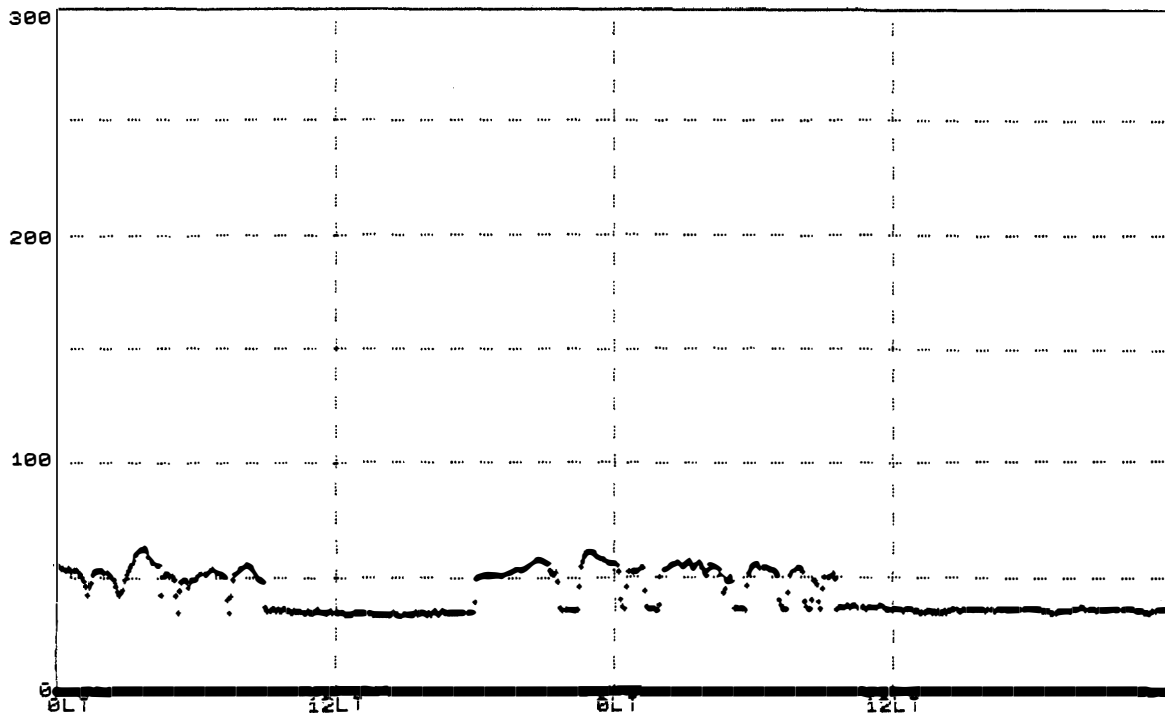
TB(K) and IWC(mg/cm²) 89 826 --> 827

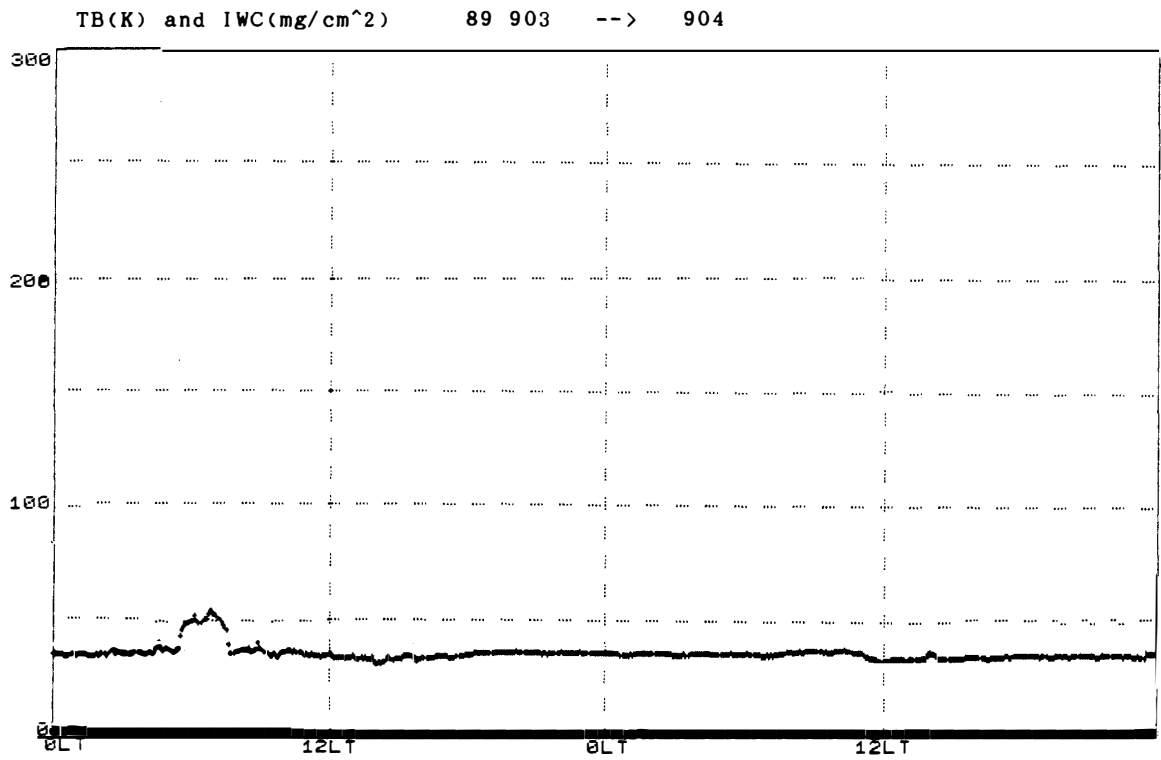
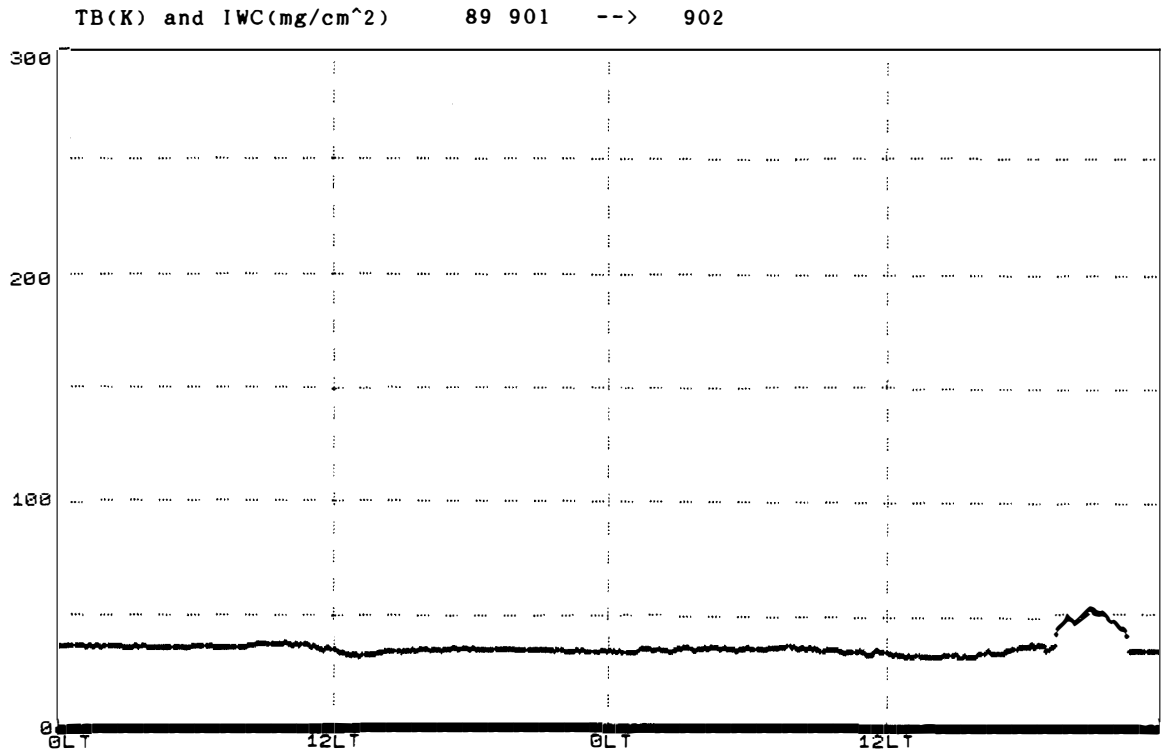


TB(K) and IWC(mg/cm²) 89 828 --> 829

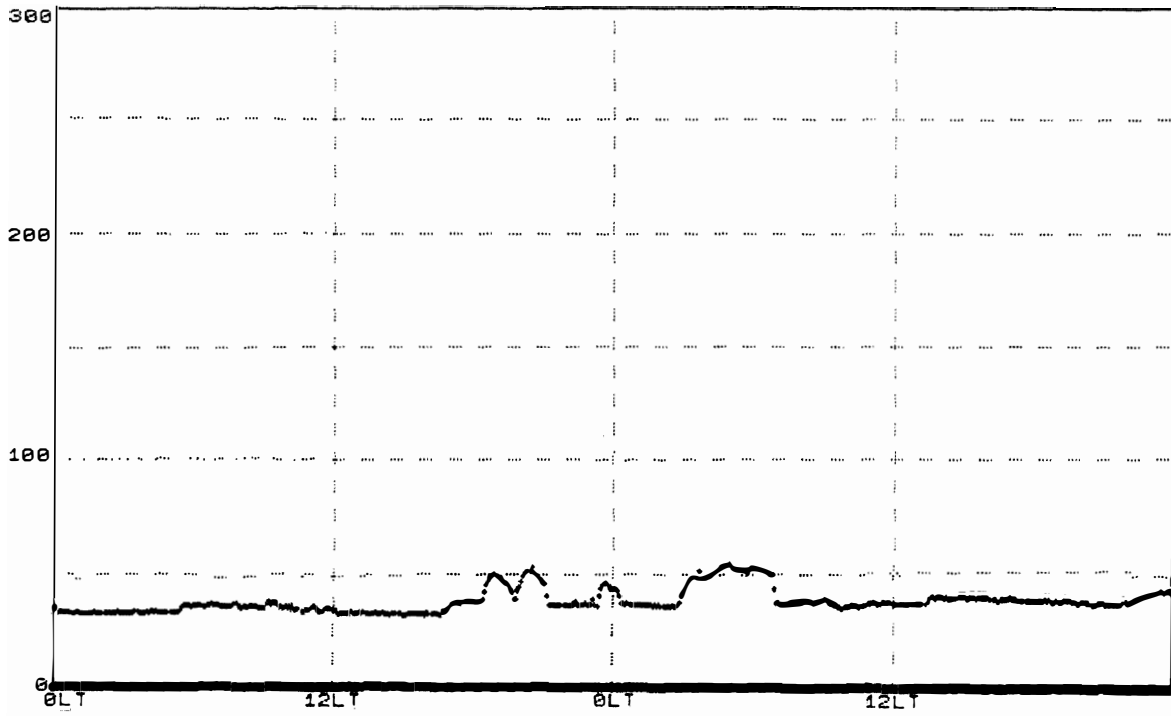


TB(K) and IWC(mg/cm²) 89 830 - --> 831

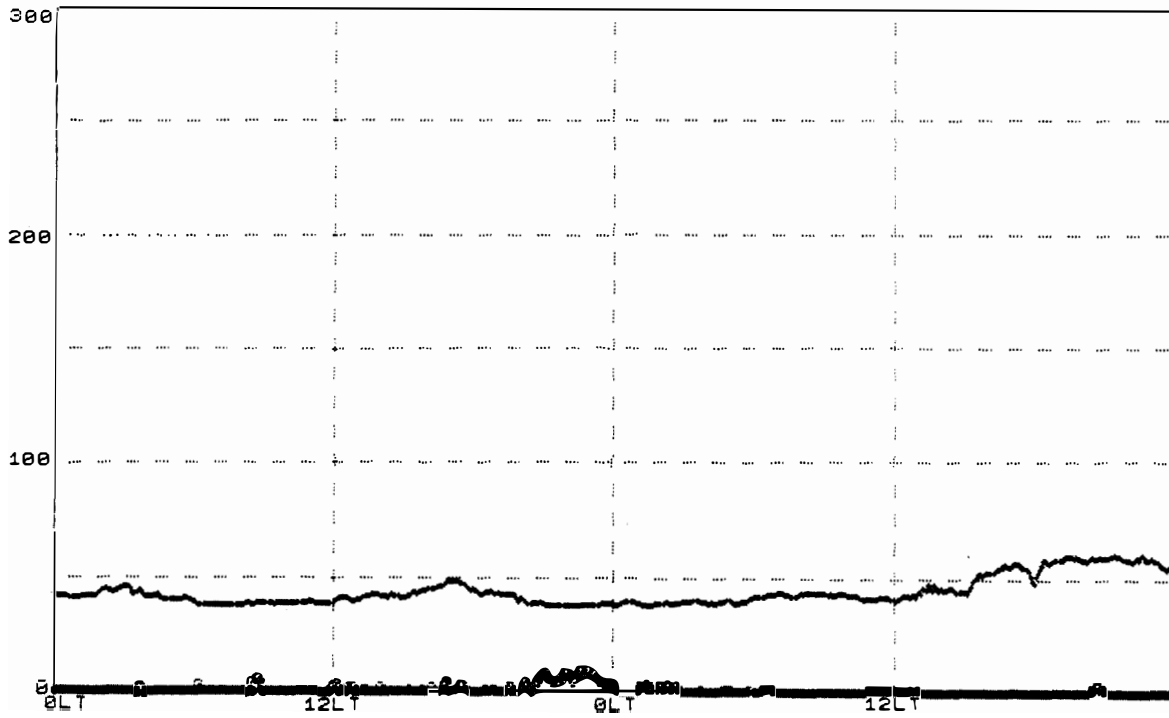




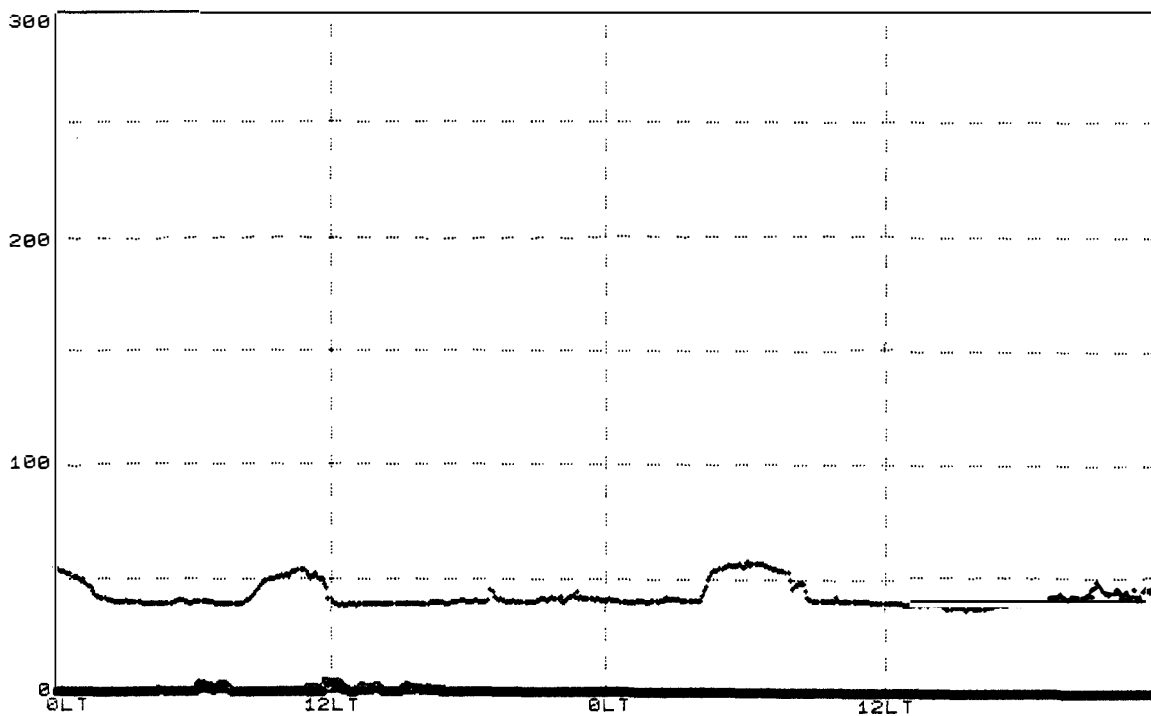
TB(K) and IWC(mg/cm²) 89 905 --> 906



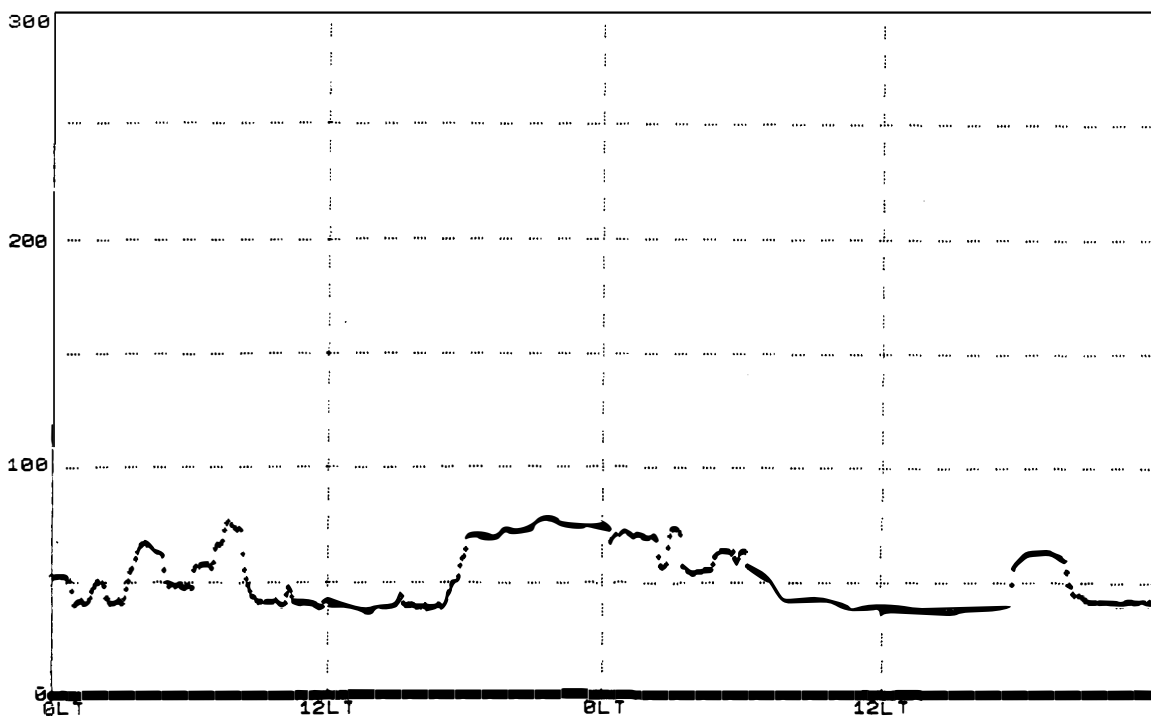
TB(K) and IWC(mg/cm²) 89 907 --> 908



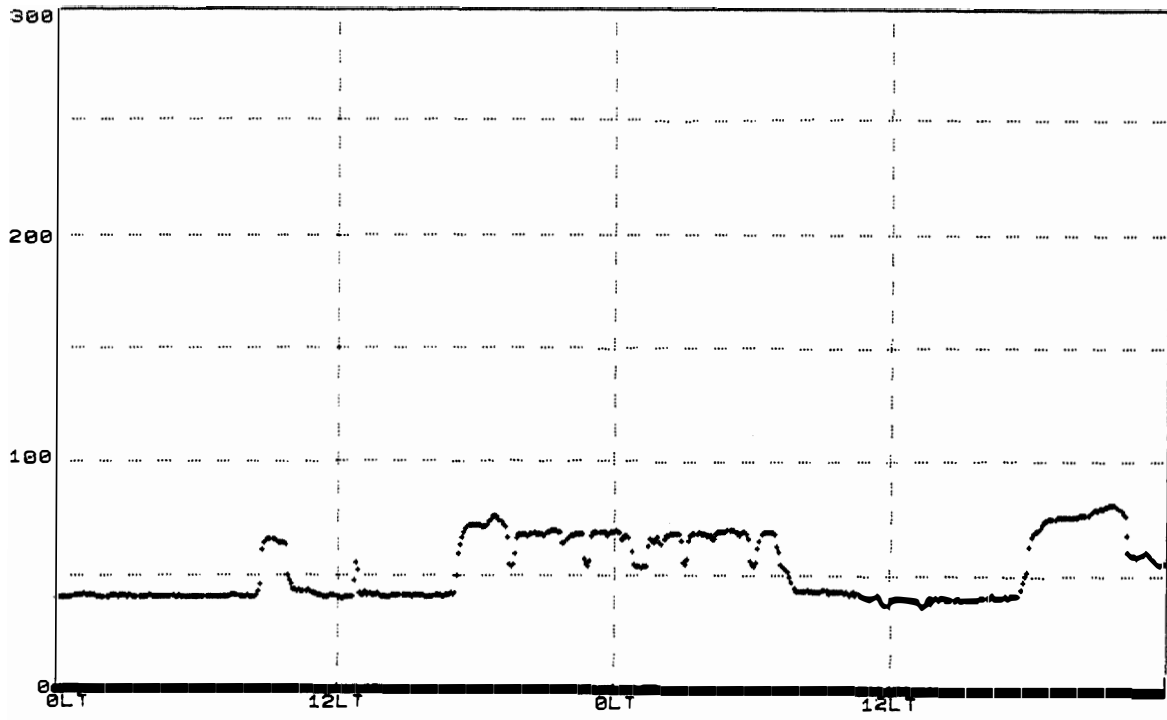
TB(K) and IWC(mg/cm²) 89 909 --> 910



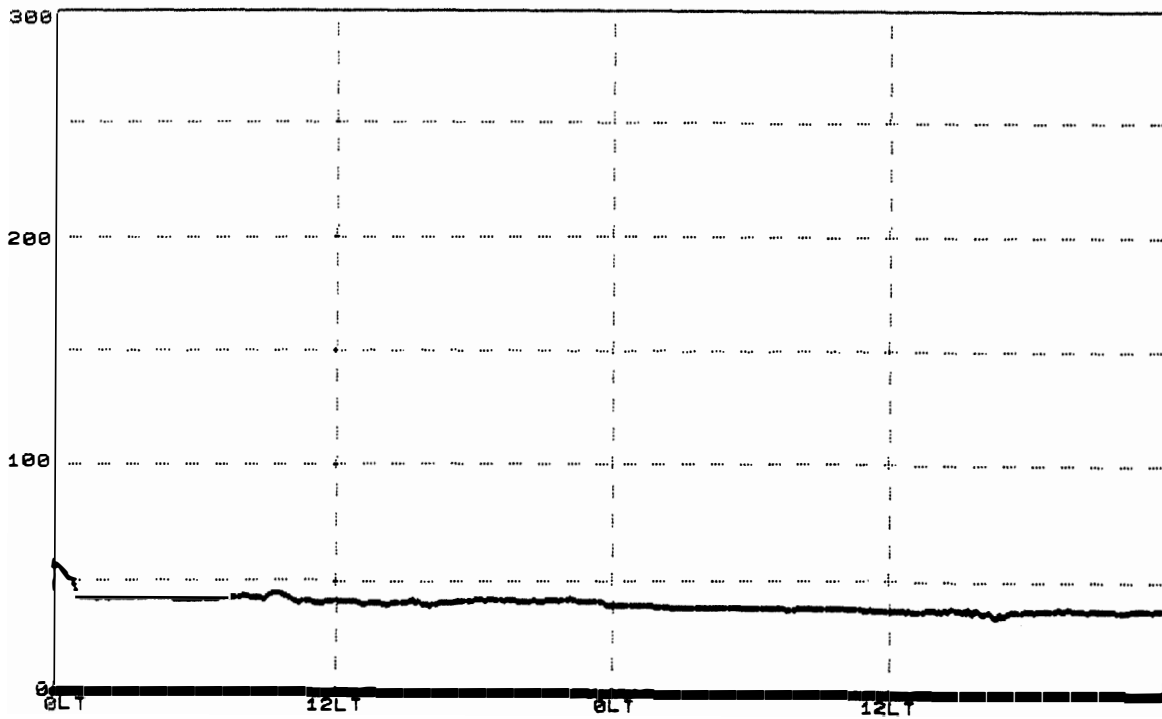
TB(K) and IWC(mg/cm²) 89 911 --> 912



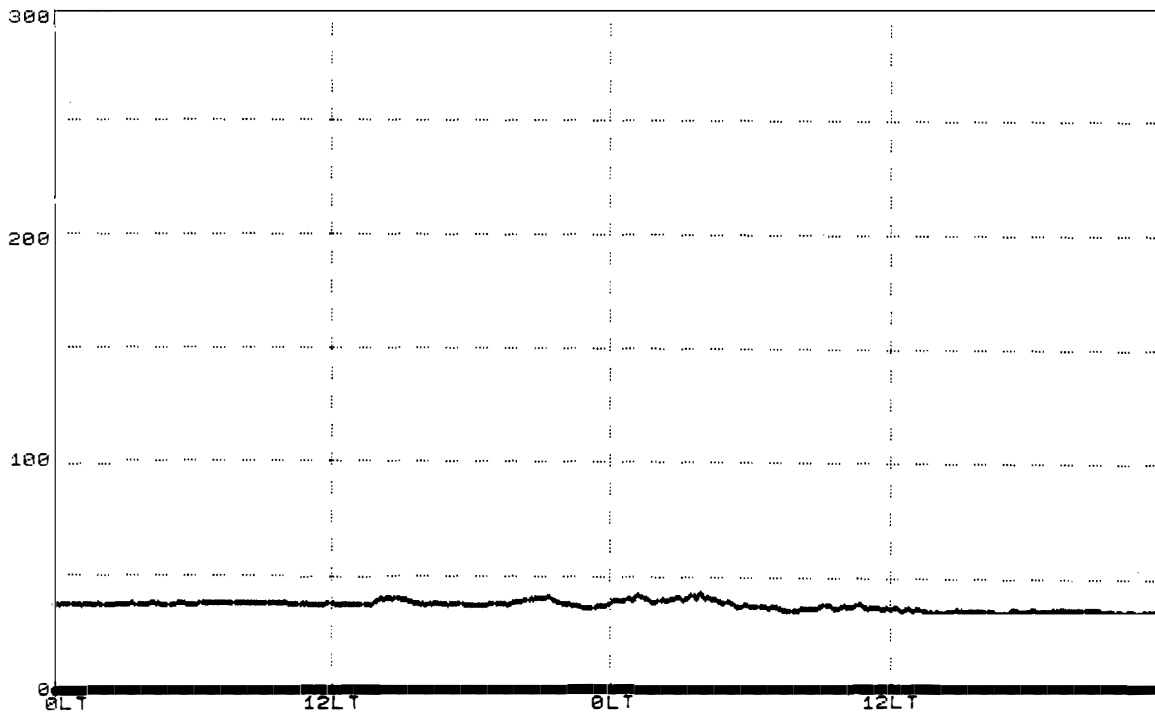
TB(K) and IWC(mg/cm²) 89 913 --> 914



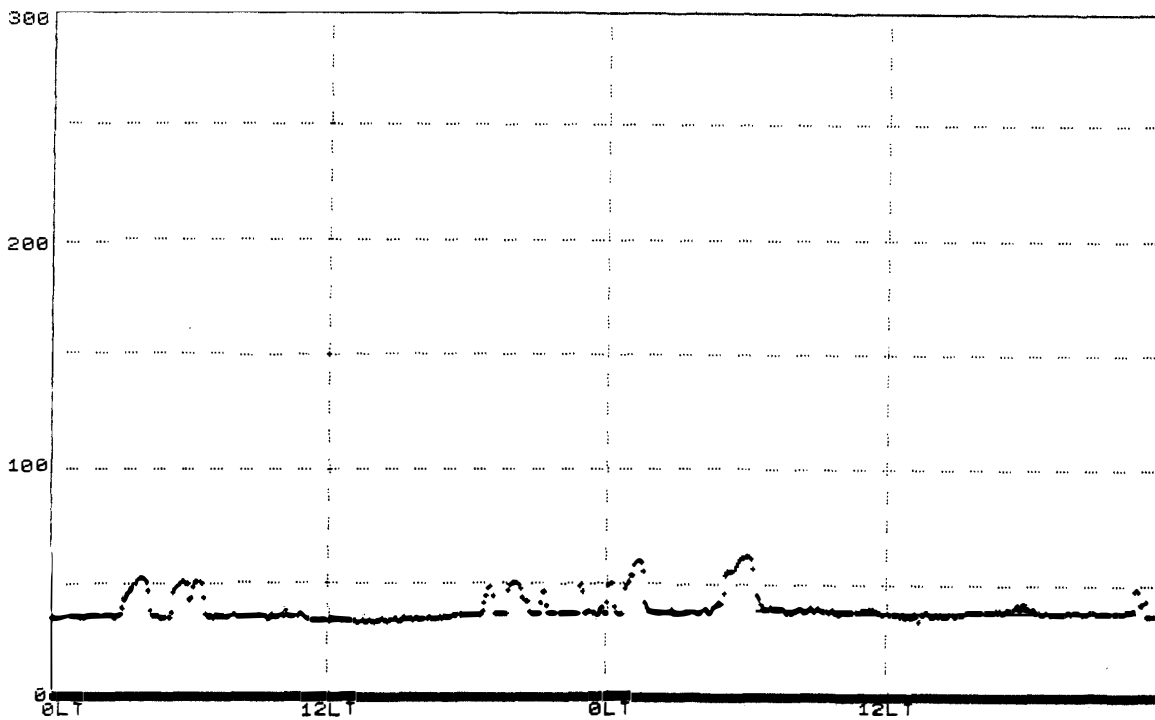
TB(K) and IWC(mg/cm²) 89 915 --> 916



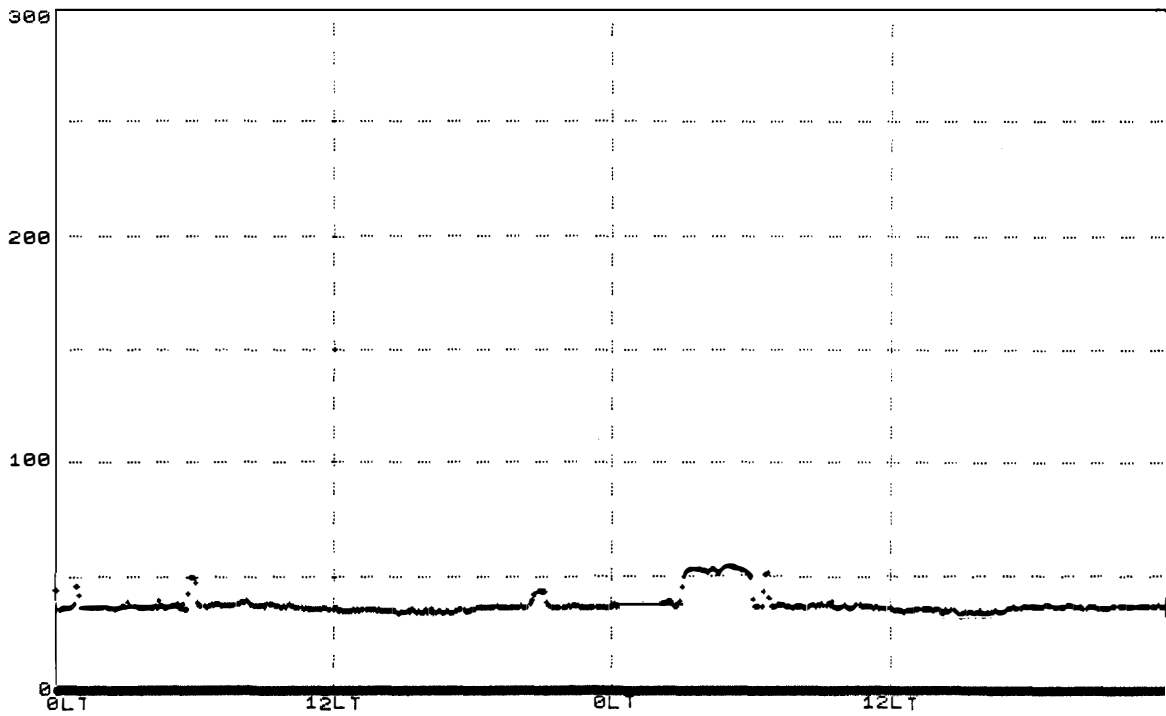
TB(K) and IWC(mg/cm²) 89 917 --> 918



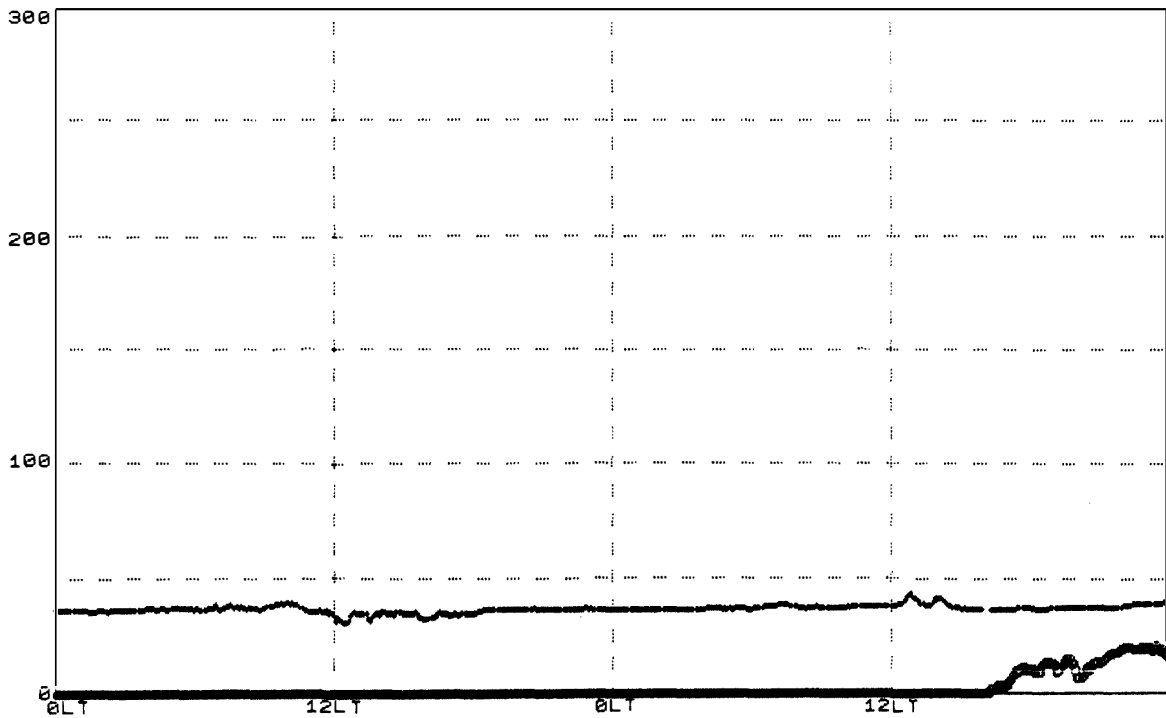
TB(K) and IWC(mg/cm²) 89 919 --> 920



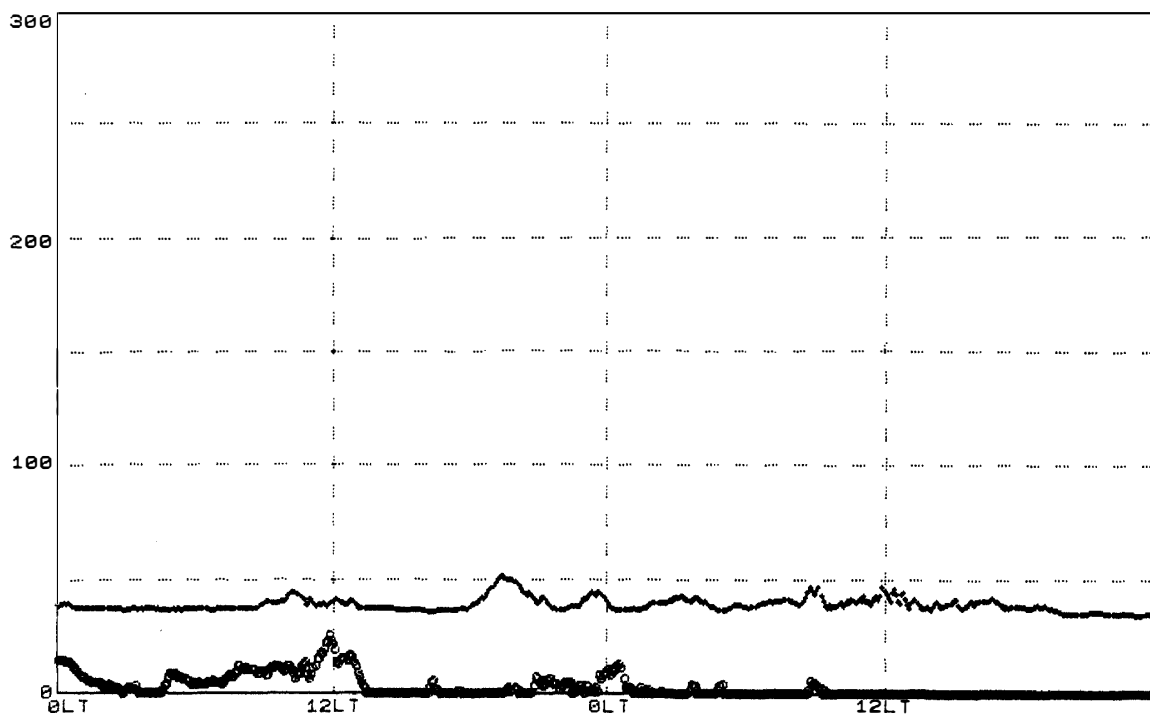
TB(K) and IWC(mg/cm²) 89 921 --> 922



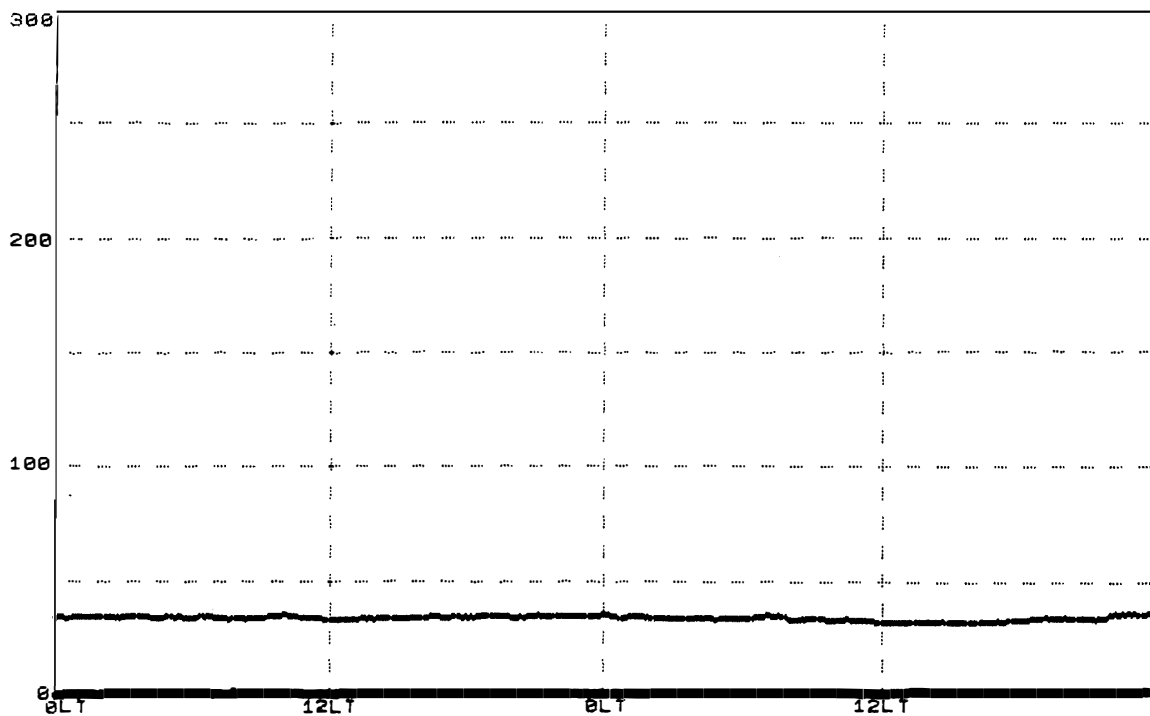
TB(K) and IWC(mg/cm²) 89 923 --> 924



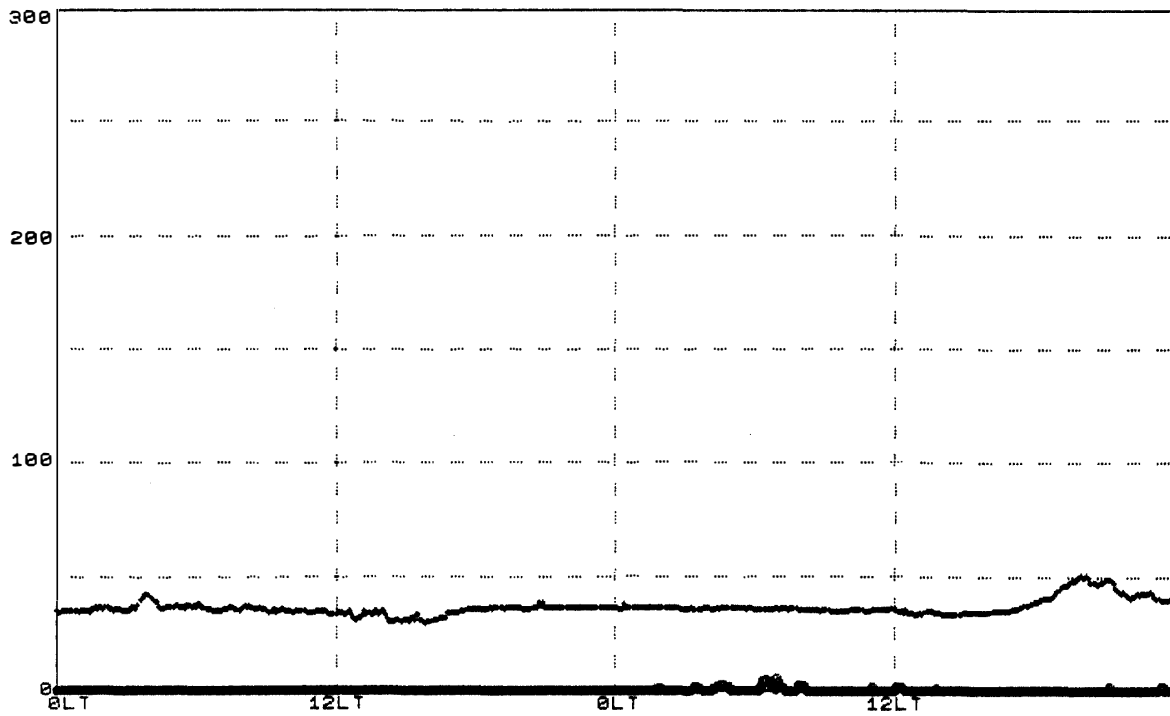
TB(K) and IWC(mg/cm²) 89 925 --> 926



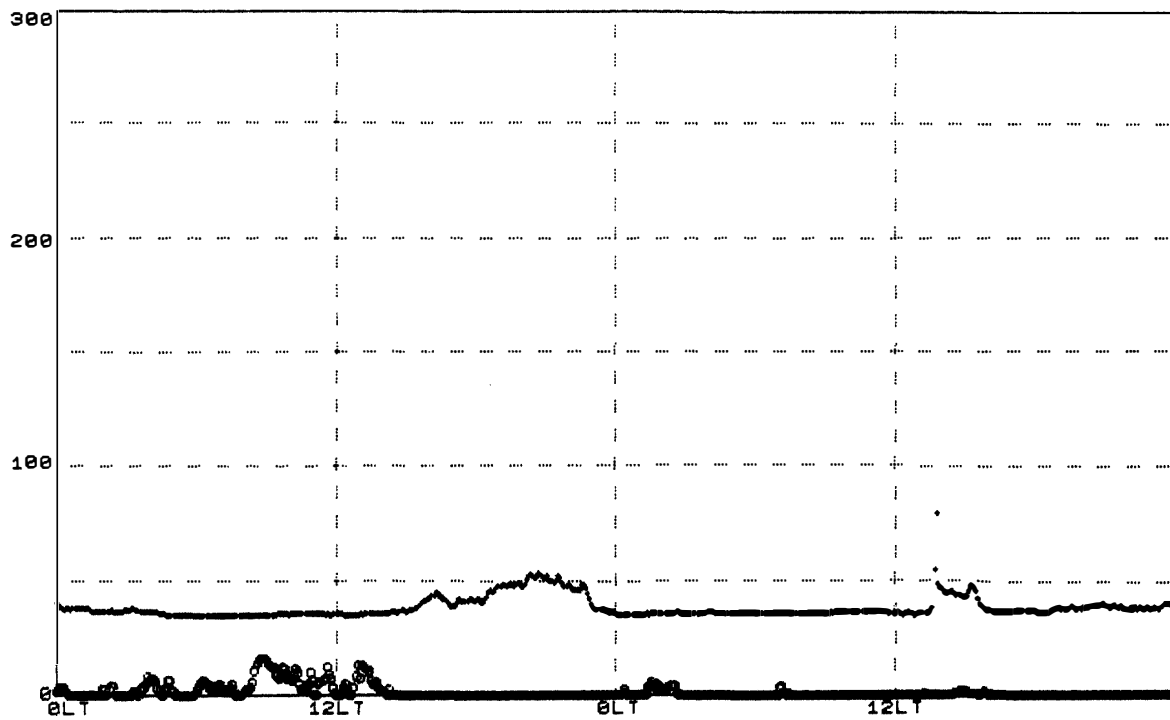
TB(K) and IWC(mg/cm²) 89 927 --> 928



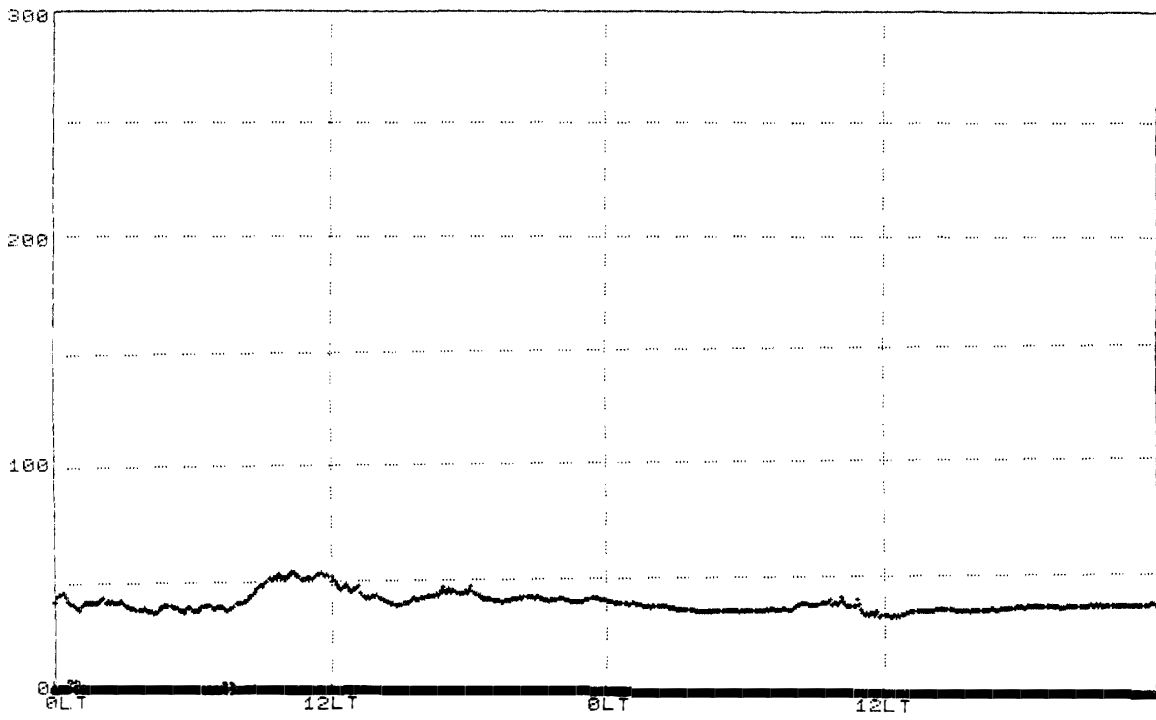
TB(K) and IWC(mg/cm²) 89 929 --> 930



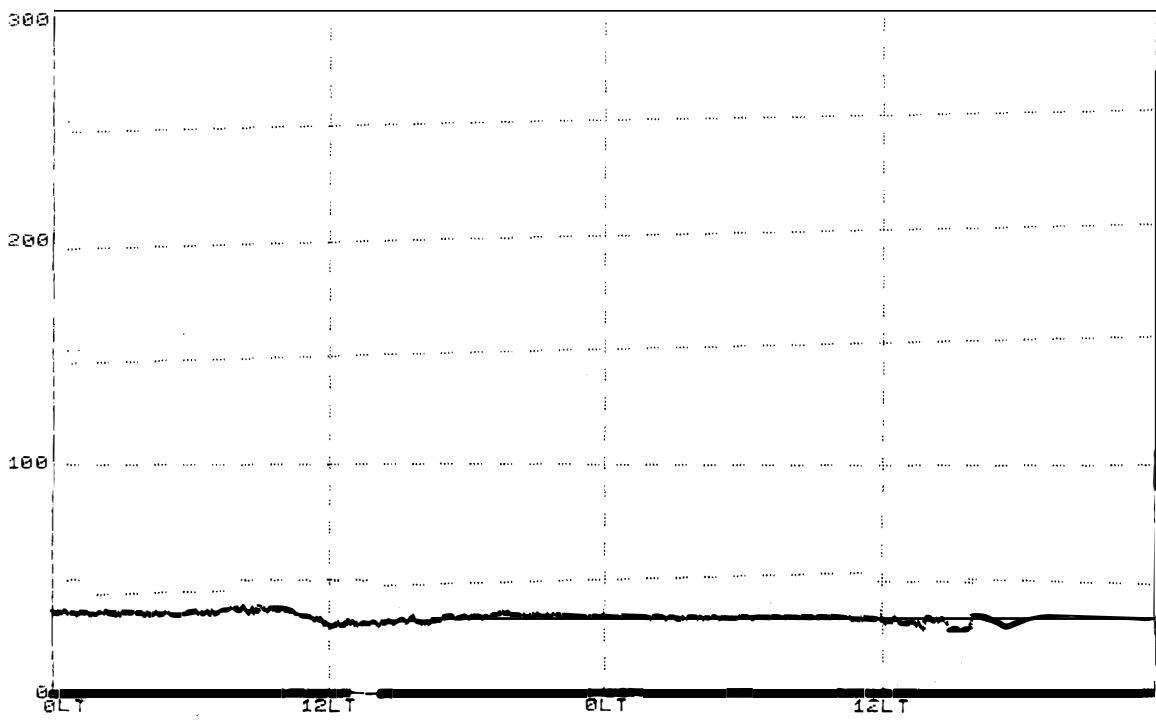
TB(K) and IWC(mg/cm²) 89 1001 --> 1002



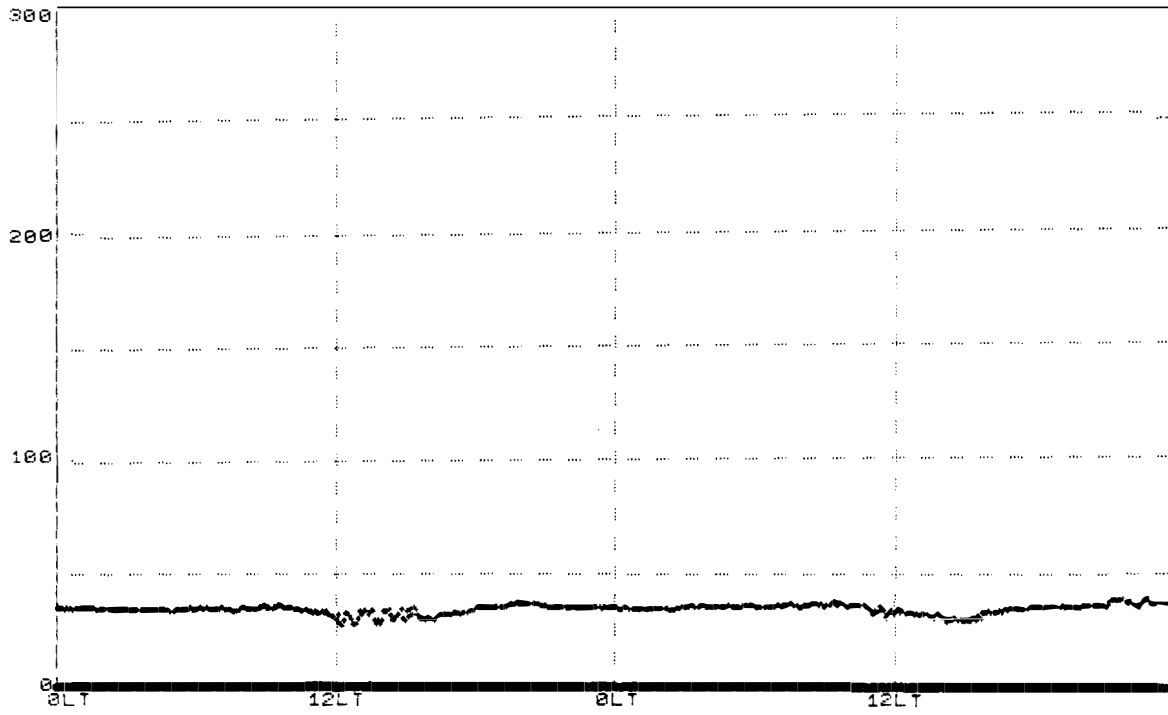
TB(K) and IWC(mg/cm²) 89 1003 --> 1004



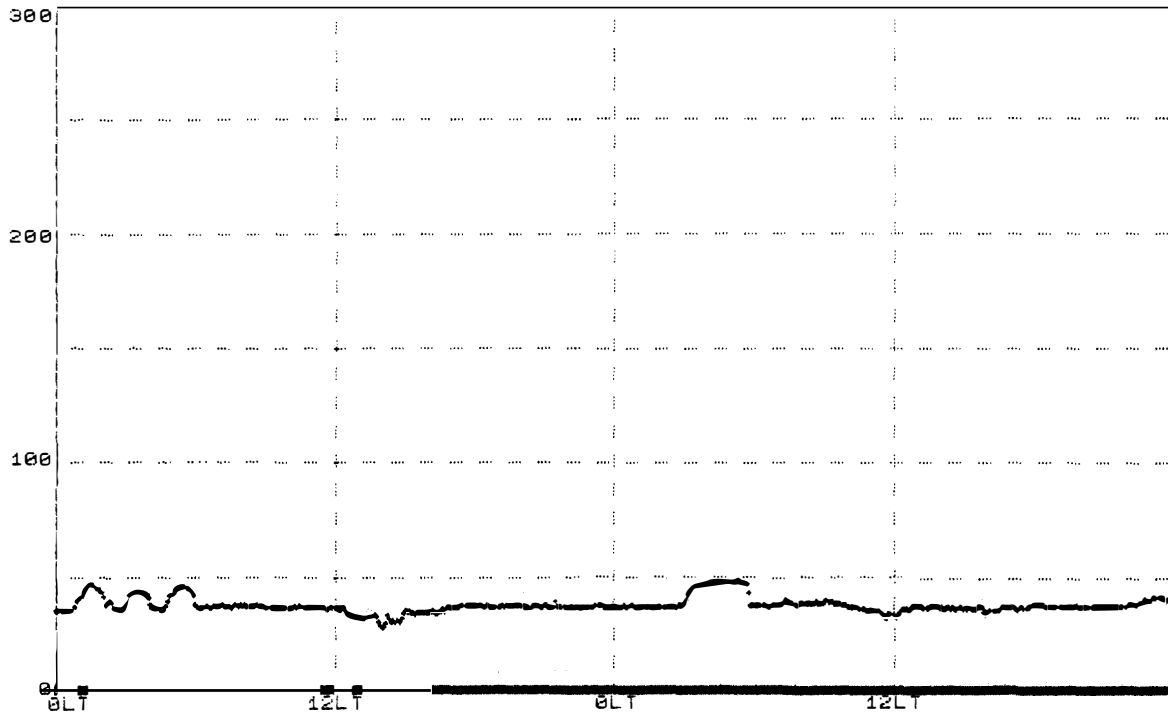
TB(K) and IWC(mg/cm²) 89 1005 --> 1006

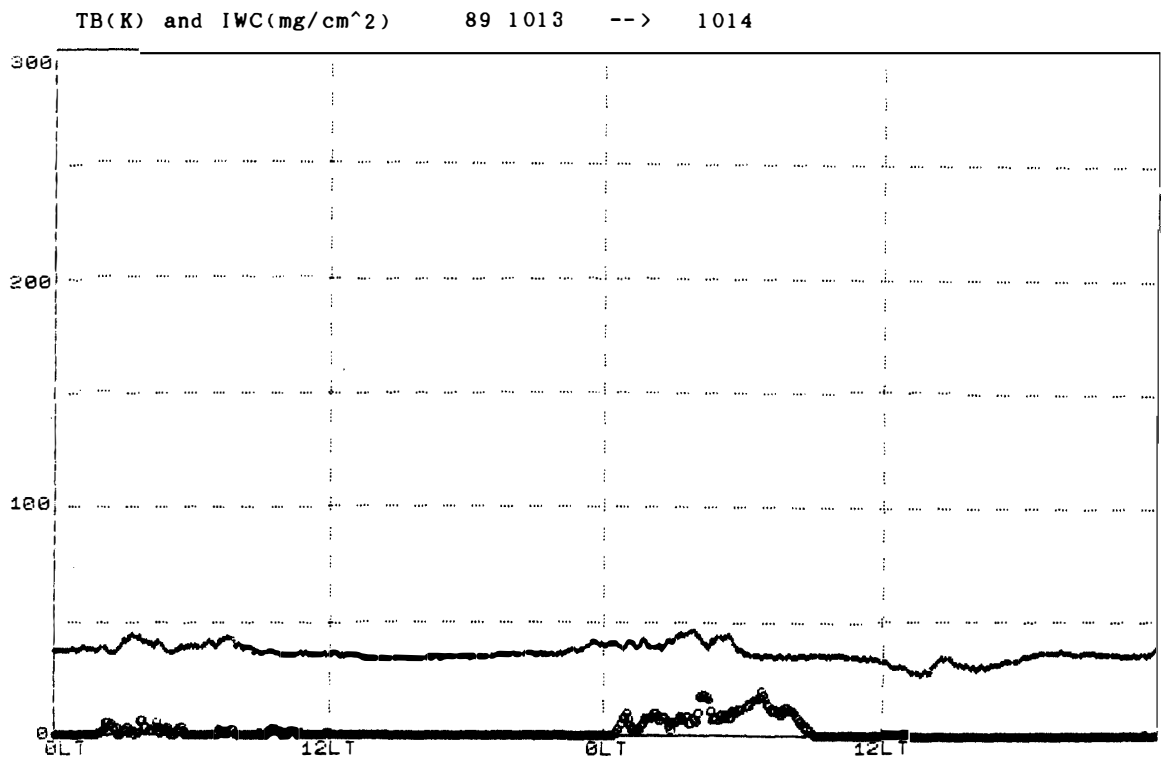
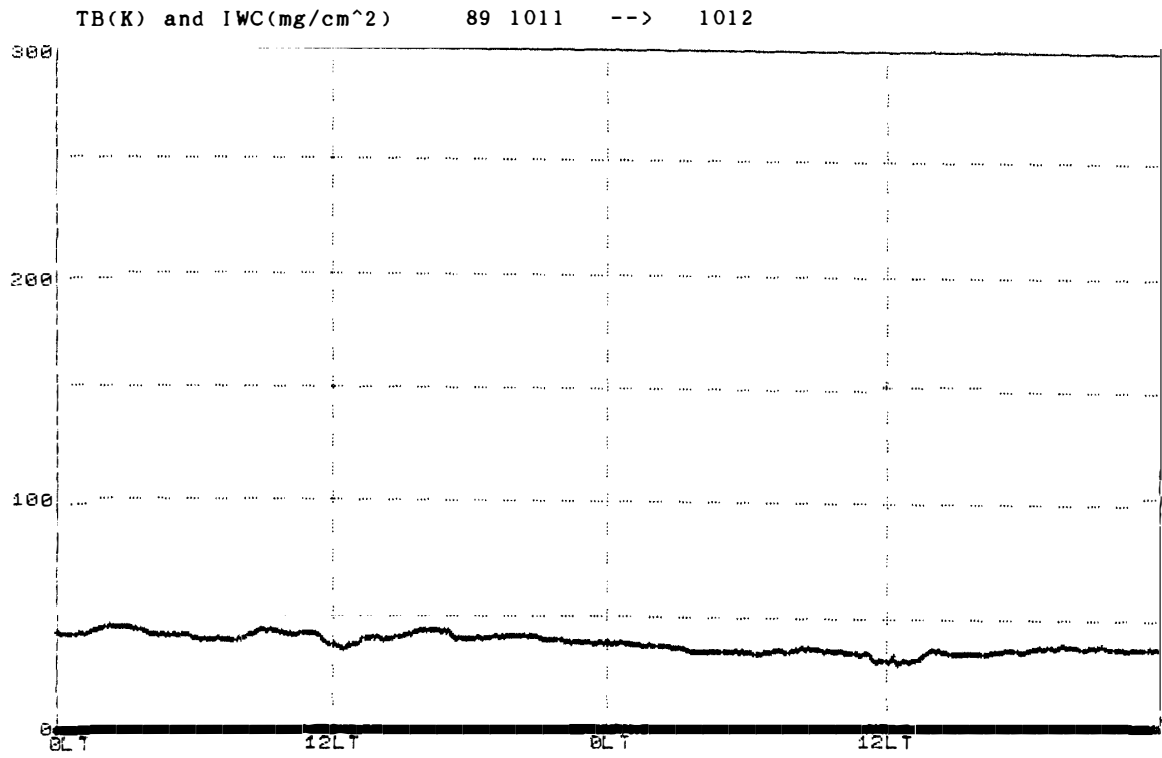


TB(K) and IWC(mg/cm²) 89 1007 --> 1008

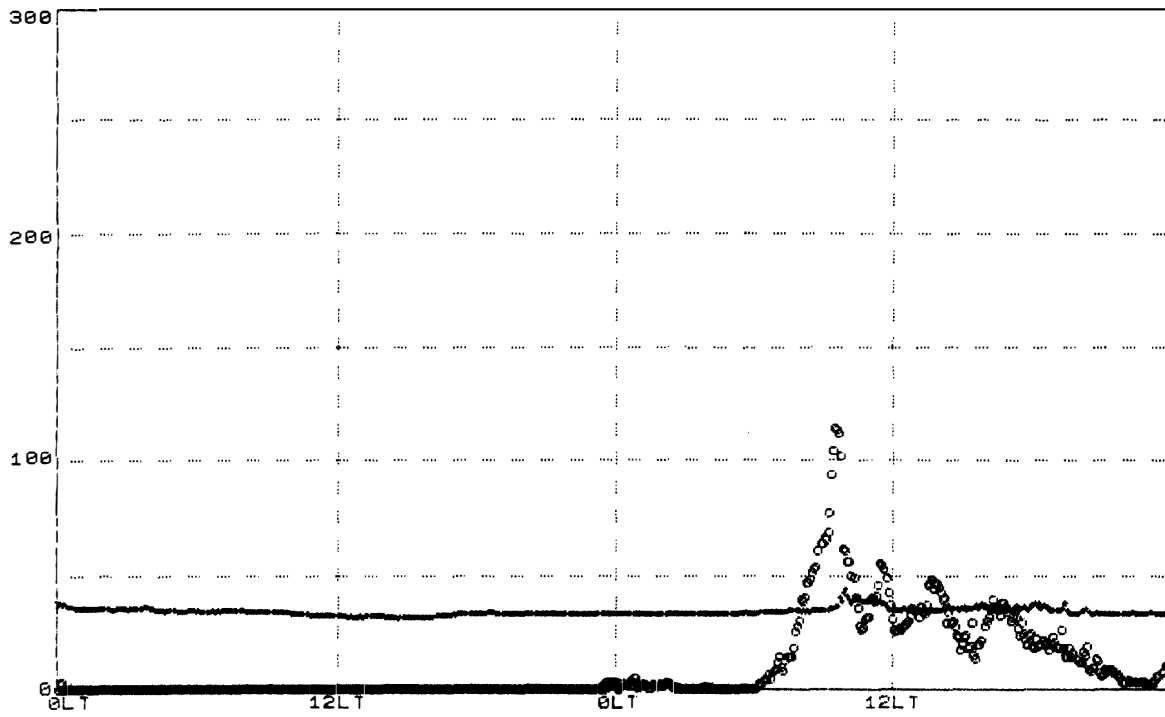


TB(K) and IWC(mg/cm²) 89 1009 --> 1010

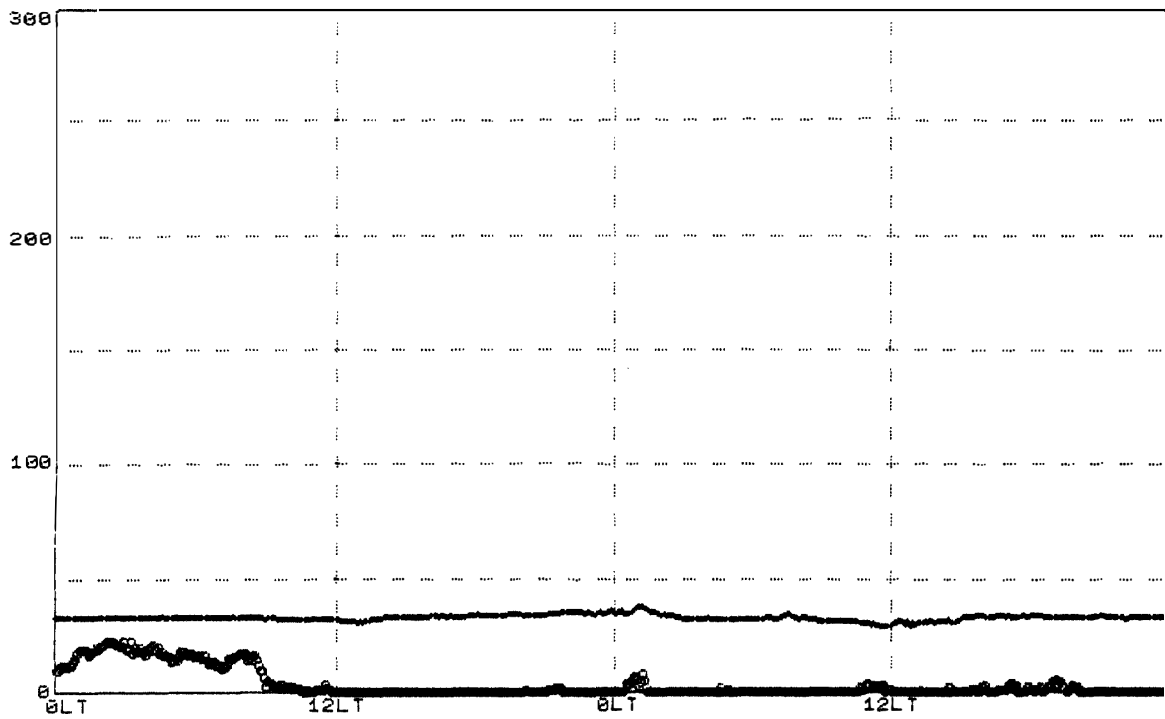




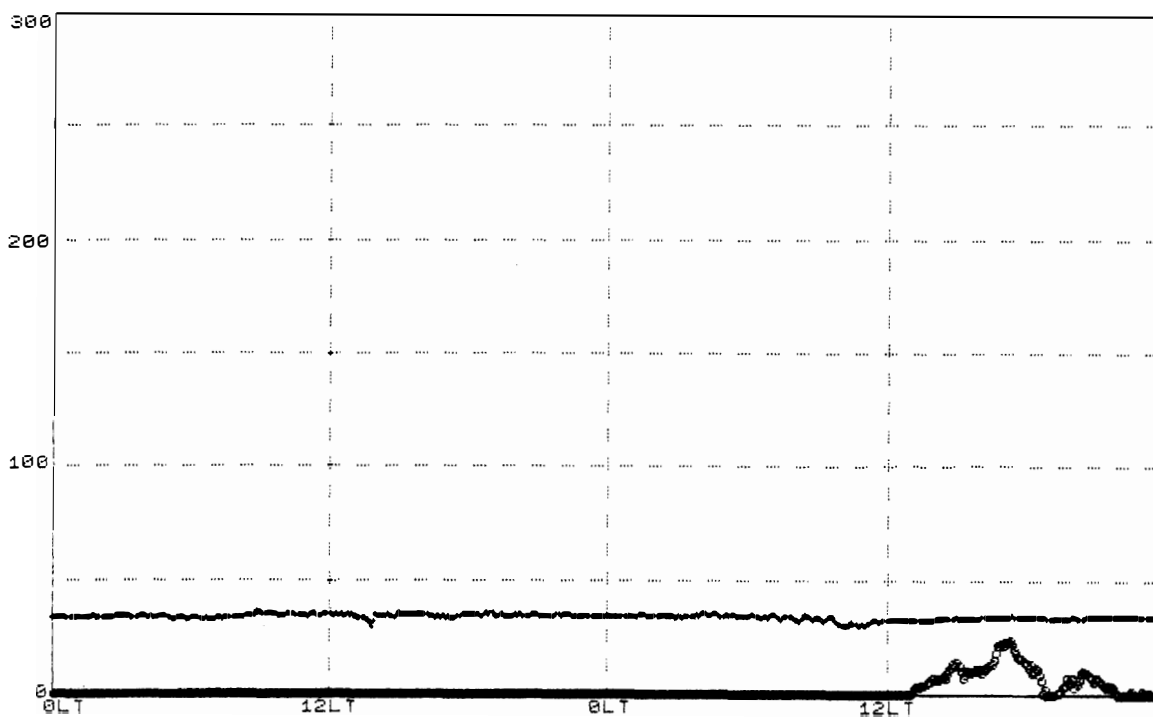
TB(K) and IWC(mg/cm²) 89 1015 --> 1016



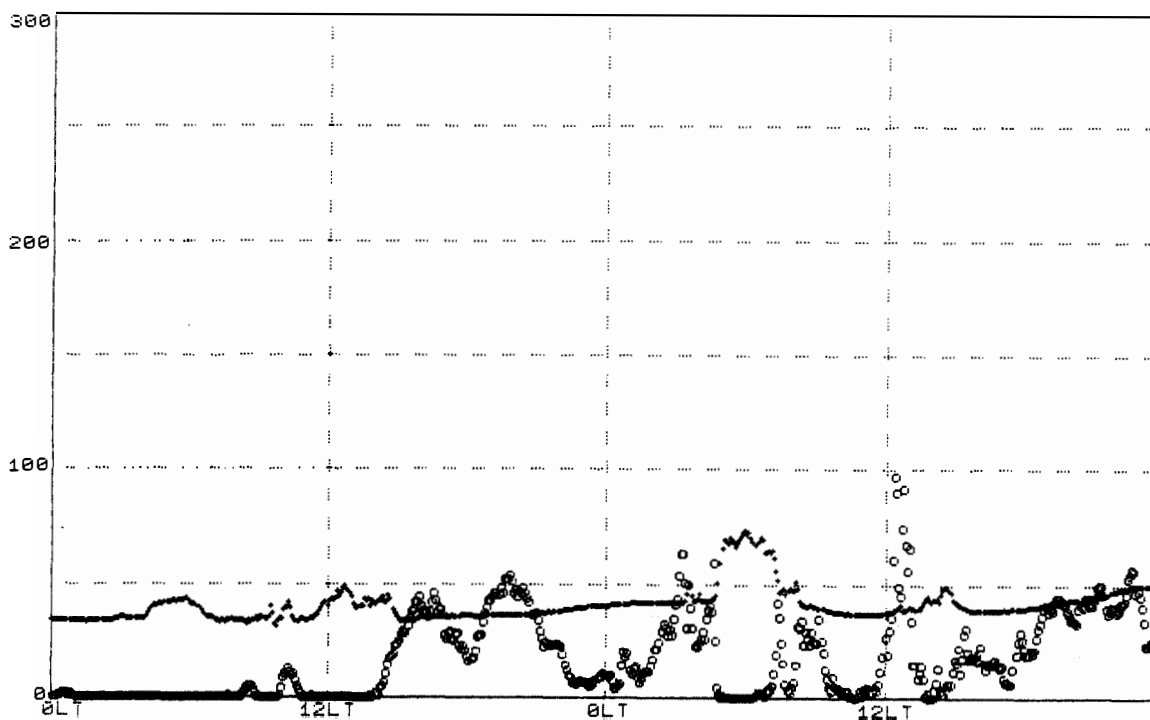
TB(K) and IWC(mg/cm²) 89 1017 --> 1018



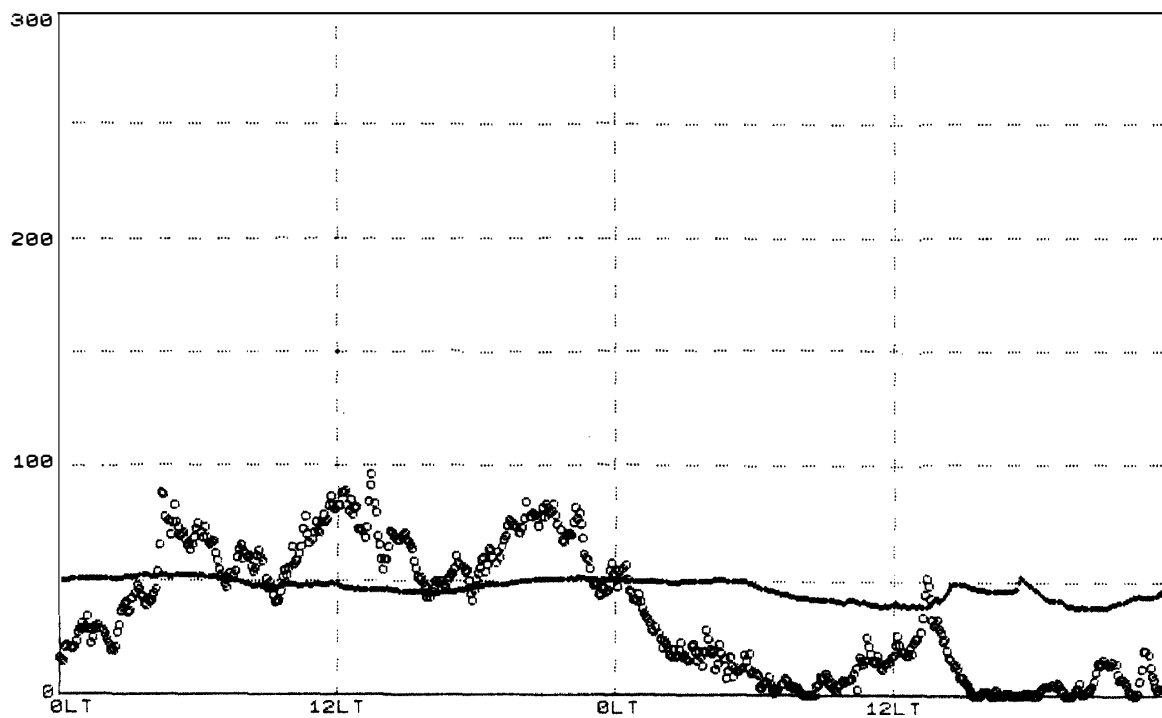
TB(K) and IWC(mg/cm²) 89 1019 --> 1020



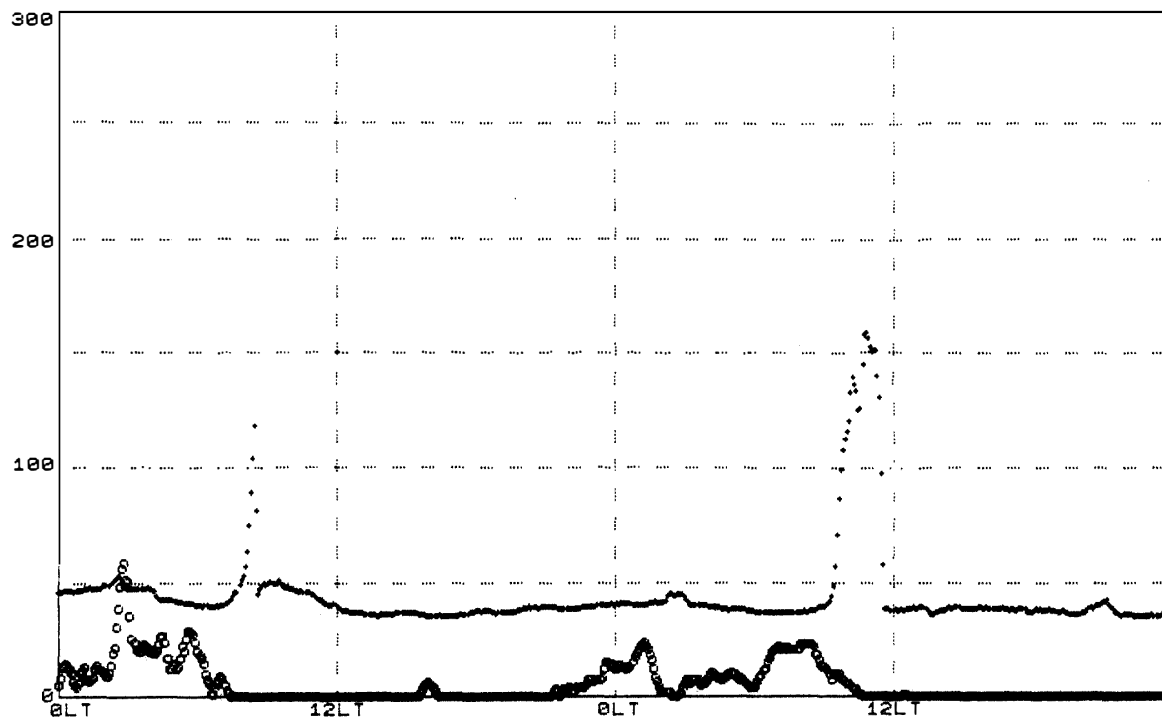
TB(K) and IWC(mg/cm²) 89 1021 --> 1022



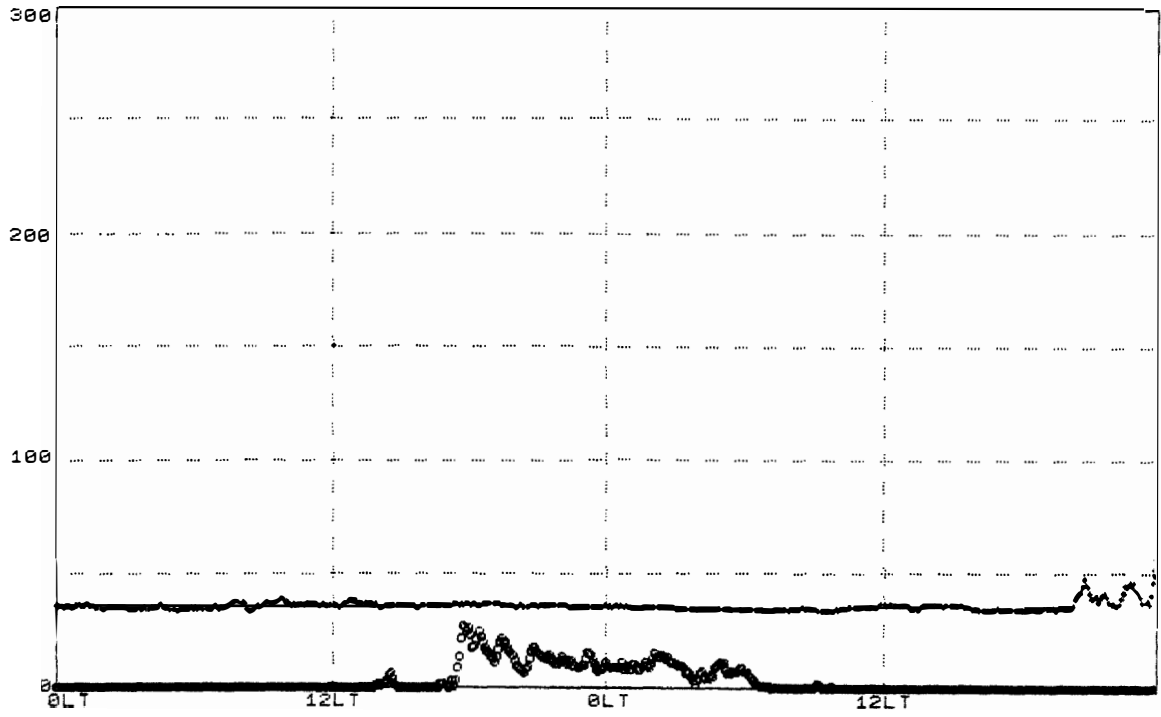
TB(K) and IWC(mg/cm²) 89 1023 --> 1024



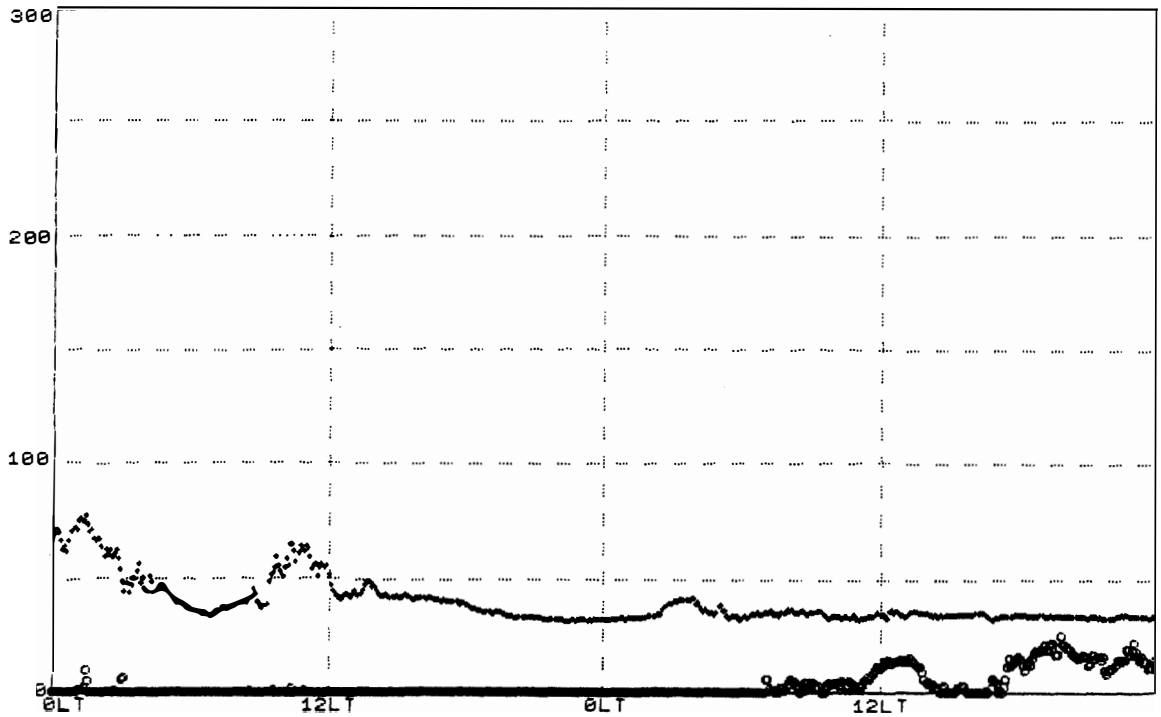
TB(K) and IWC(mg/cm²) 89 1025 --> 1026



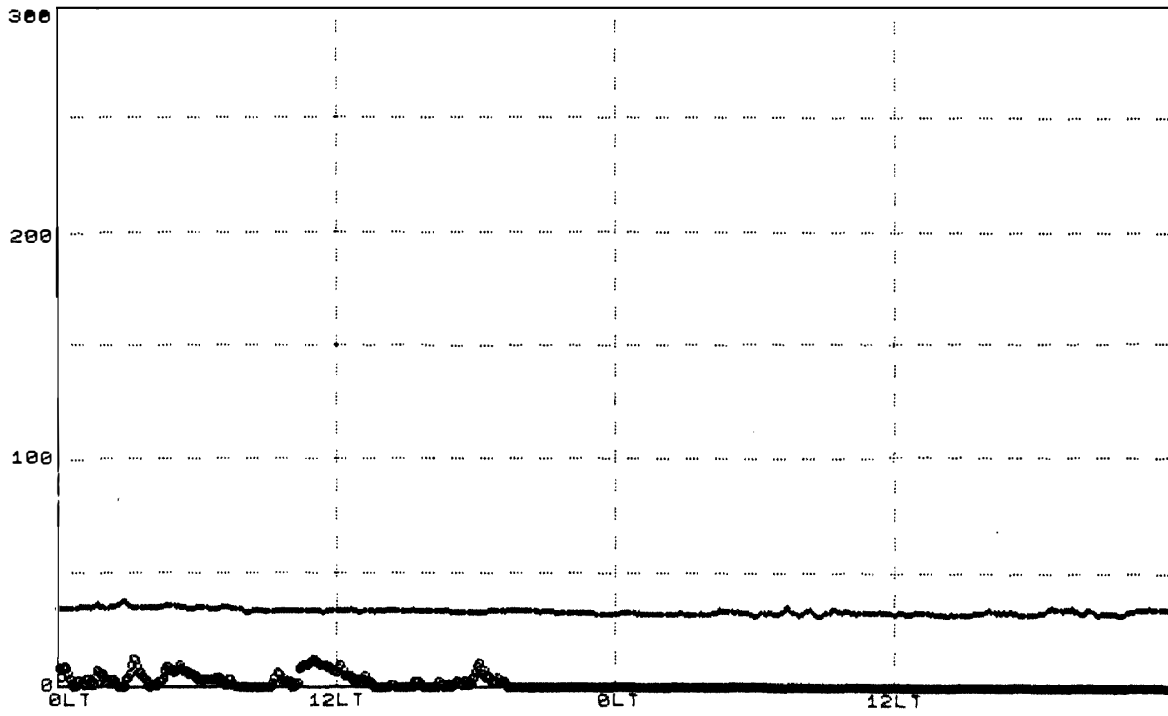
TB(K) and IWC(mg/cm²) 89 1027 --> 1028



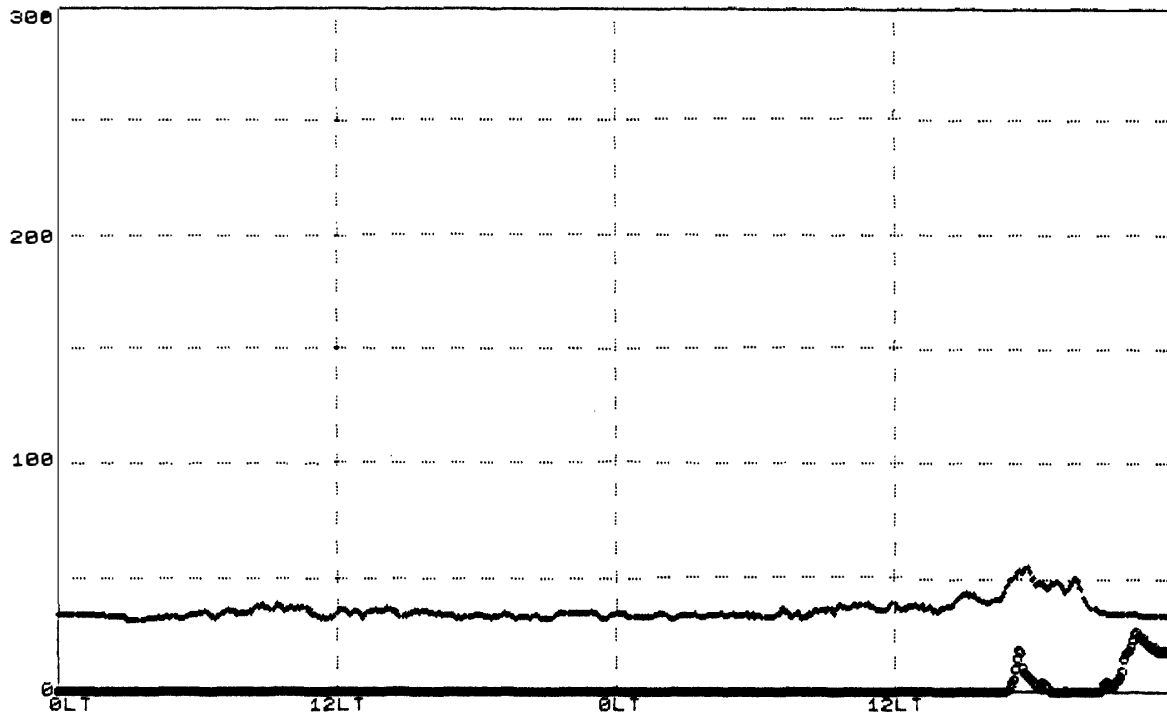
TB(K) and IWC(mg/cm²) 89 1029 --> 1030



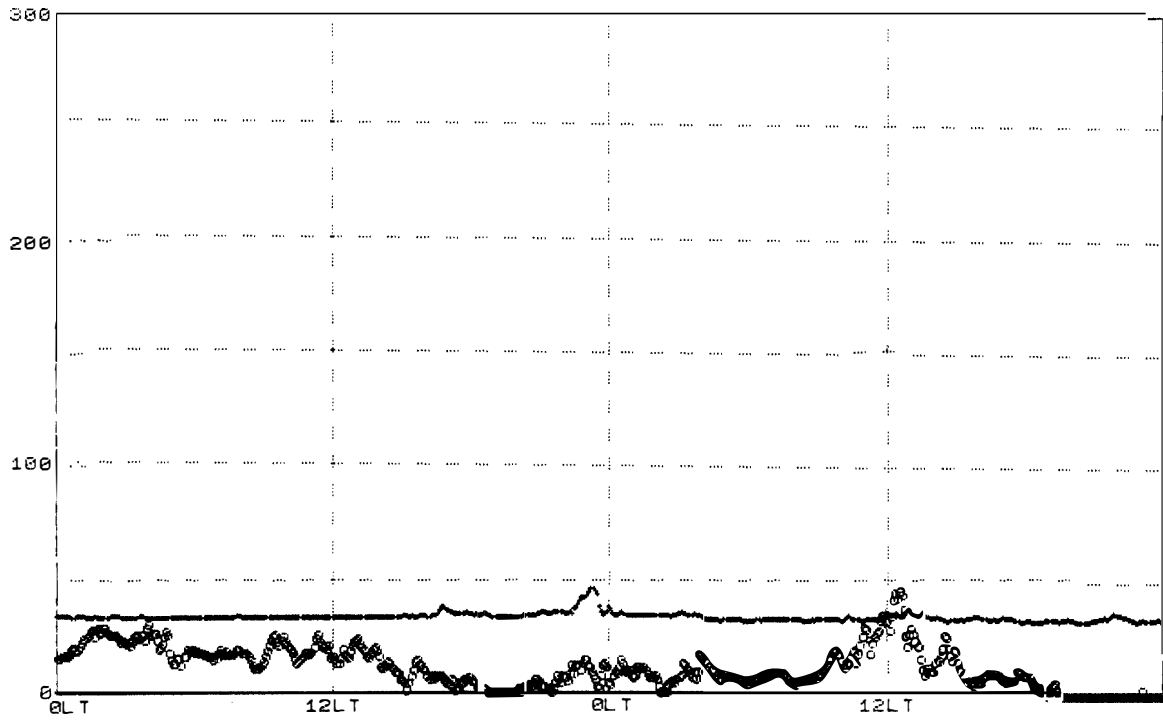
TB(K) and IWC(mg/cm²) 89 1031 --> 1101



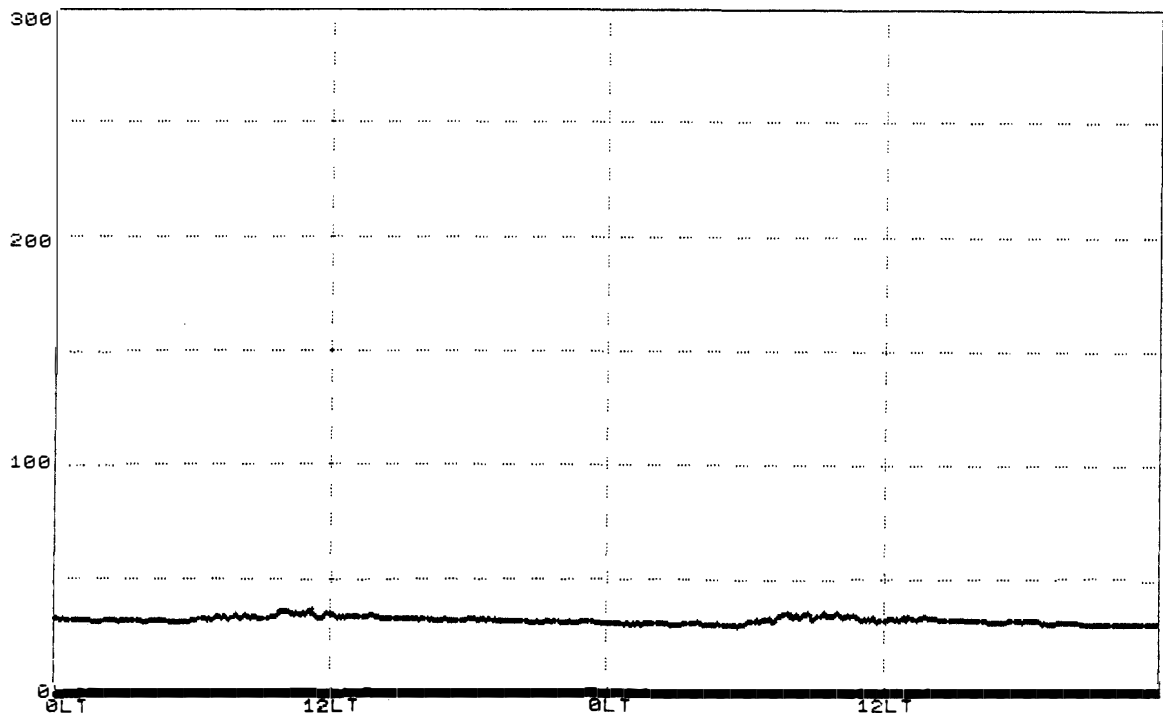
TB(K) and IWC(mg/cm²) 89 1102 --> 1103



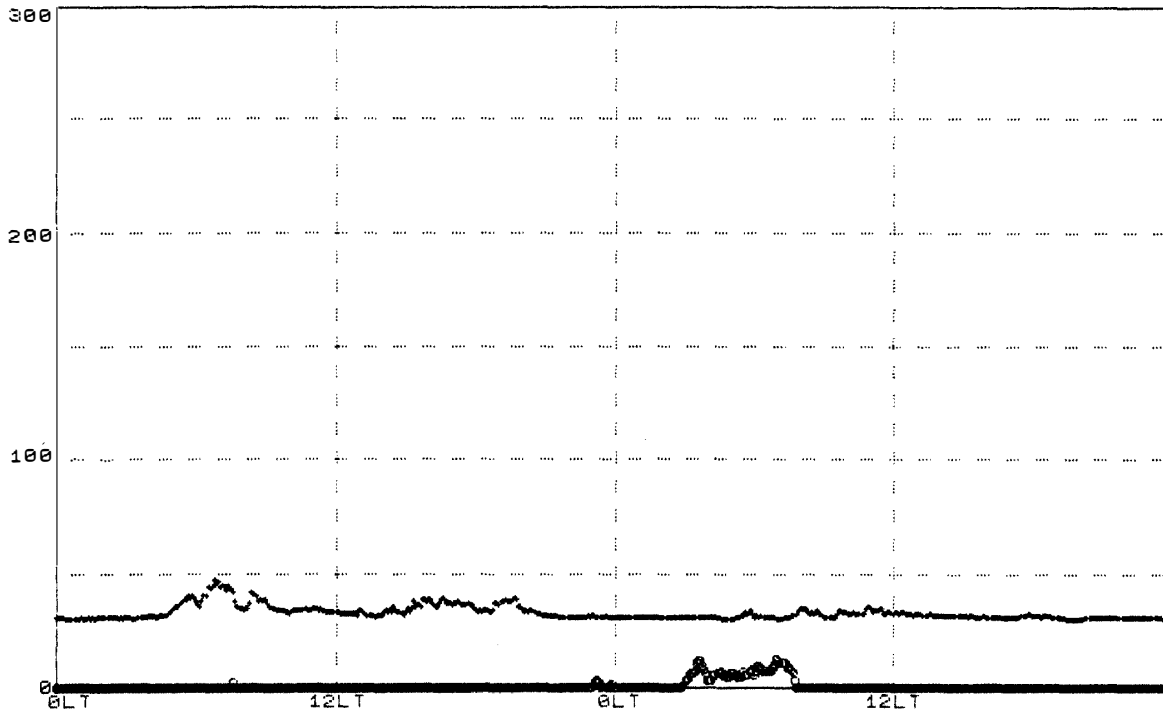
TB(K) and IWC(mg/cm²) 89 1104 --> 1105



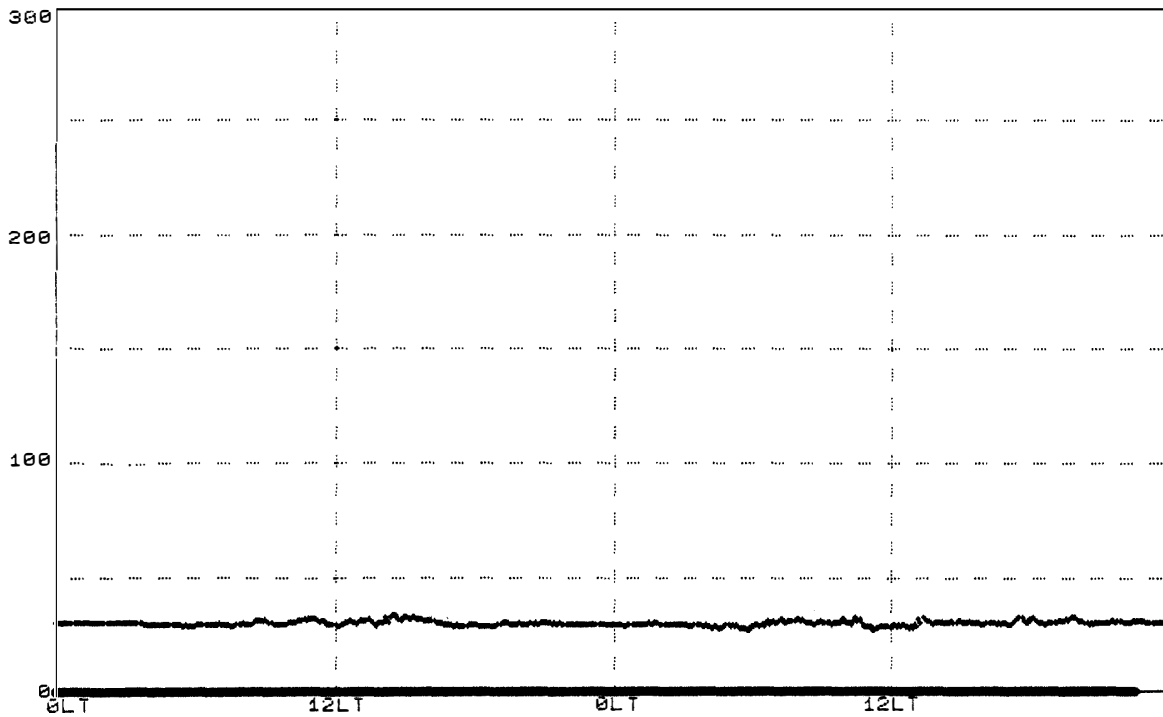
TB(K) and IWC(mg/cm²) 89 1106 --> 1107



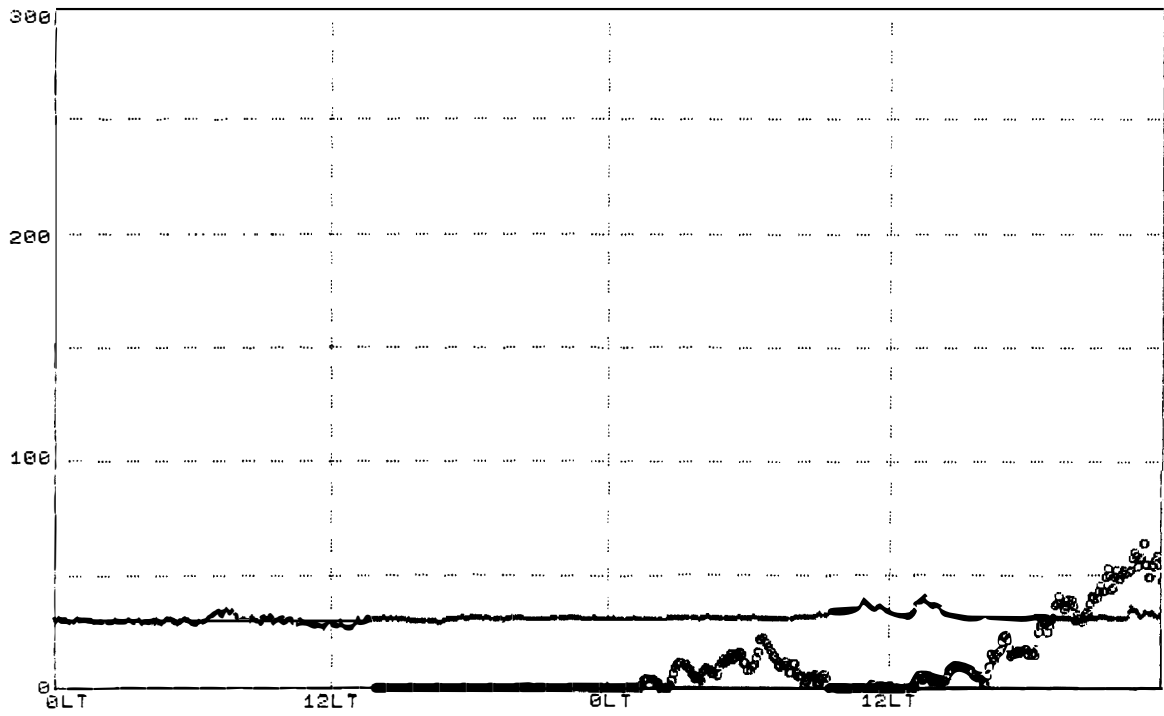
TB(K) and IWC(mg/cm²) 89 1108 --> 1109



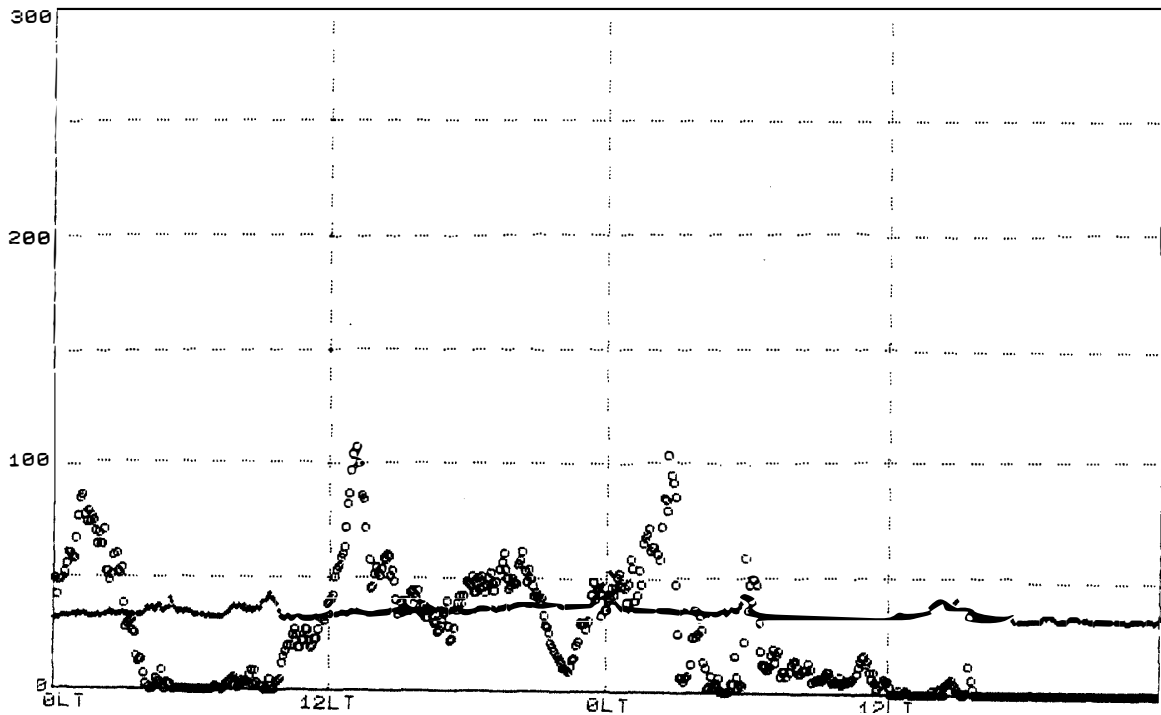
TB(K) and IWC(mg/cm²) 89 1110 --> 1111



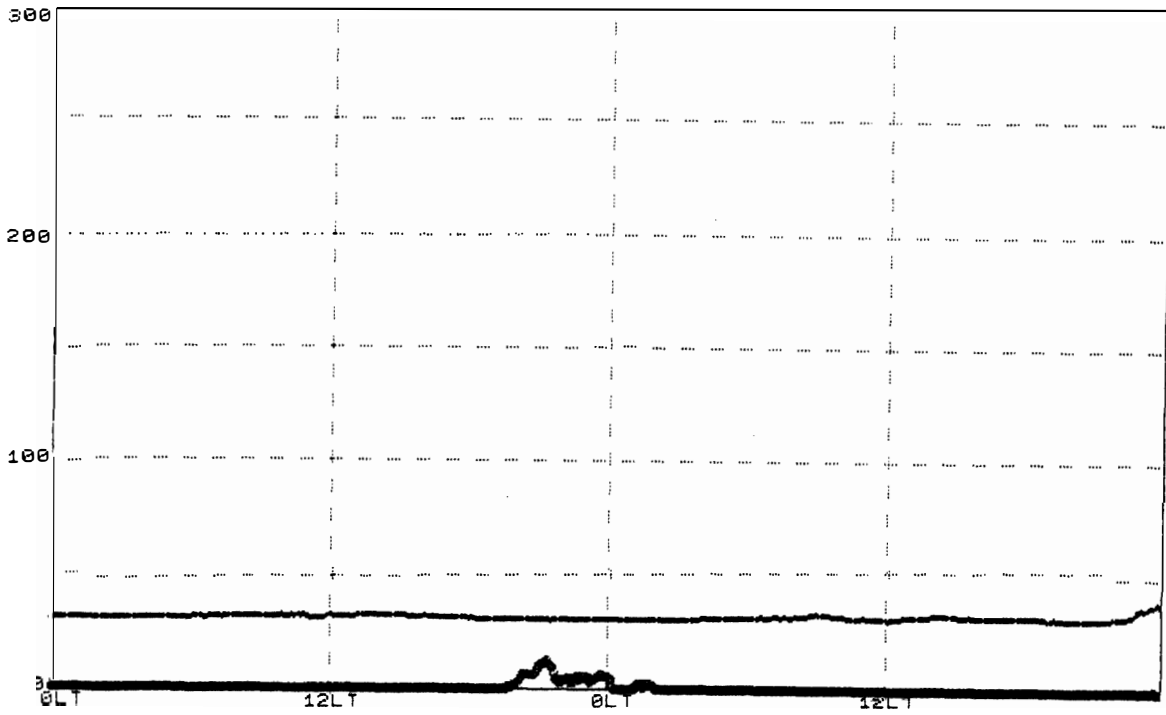
TB(K) and IWC(mg/cm²) 89 1112 --> 1113



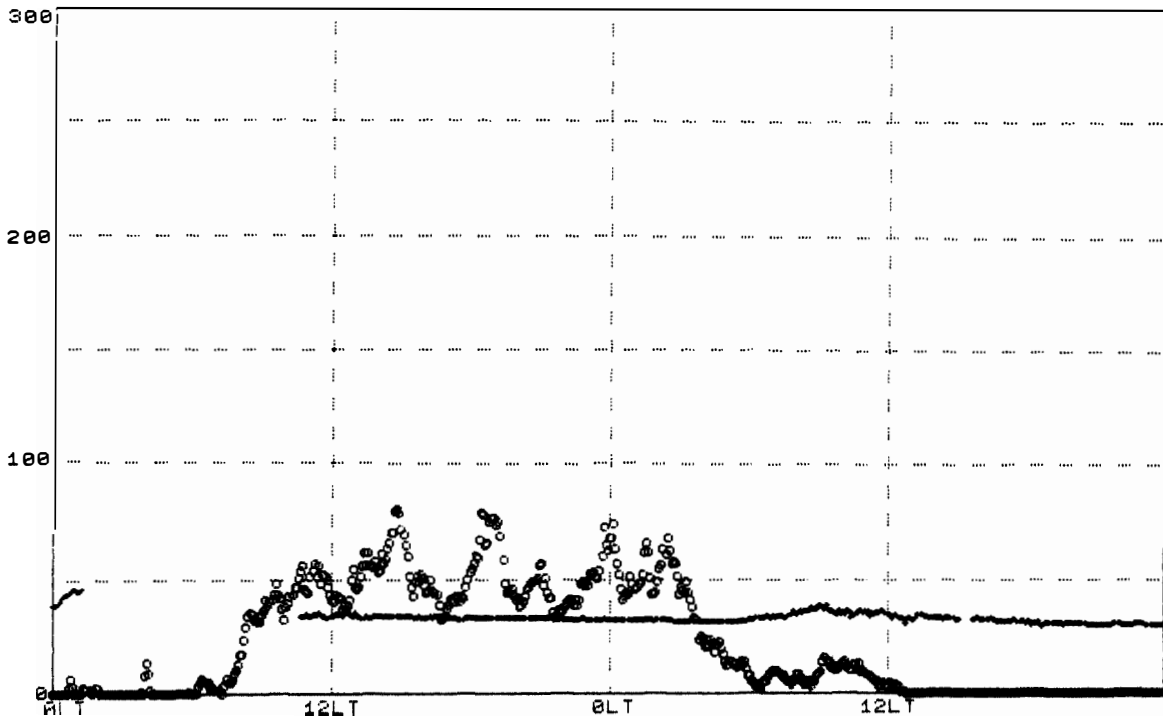
TB(K) and IWC(mg/cm²) 89 1114 --> 1115



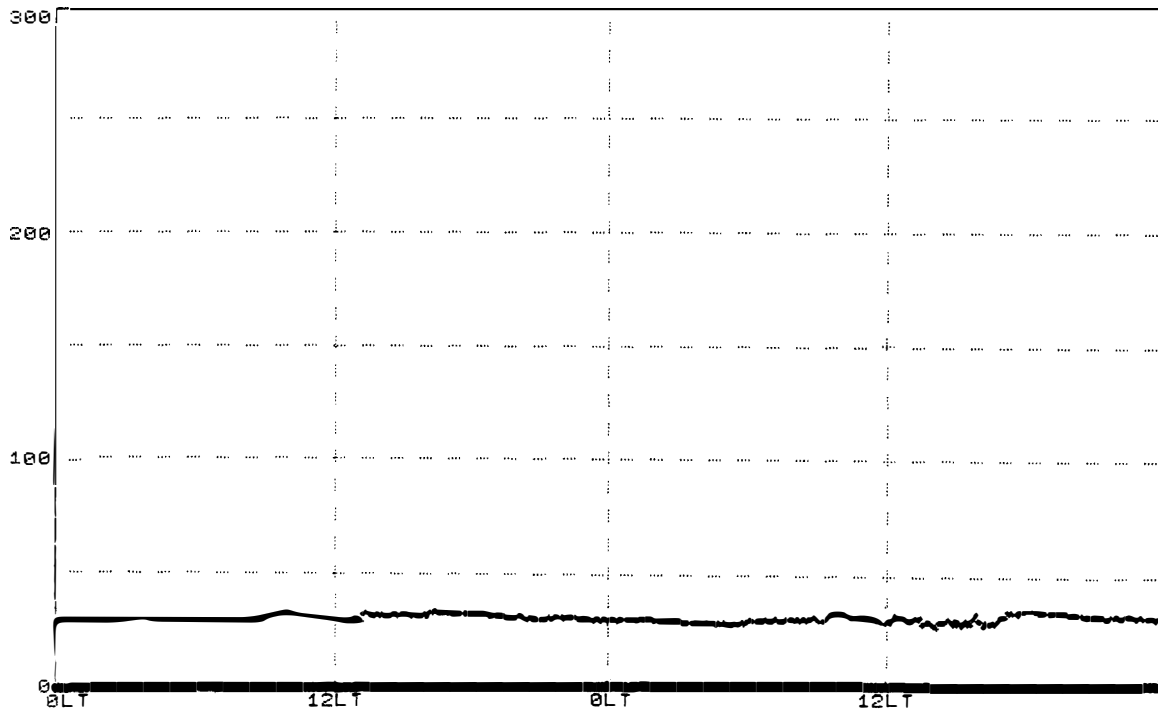
TB(K) and IWC(mg/cm²) 89 1116 --> 1117



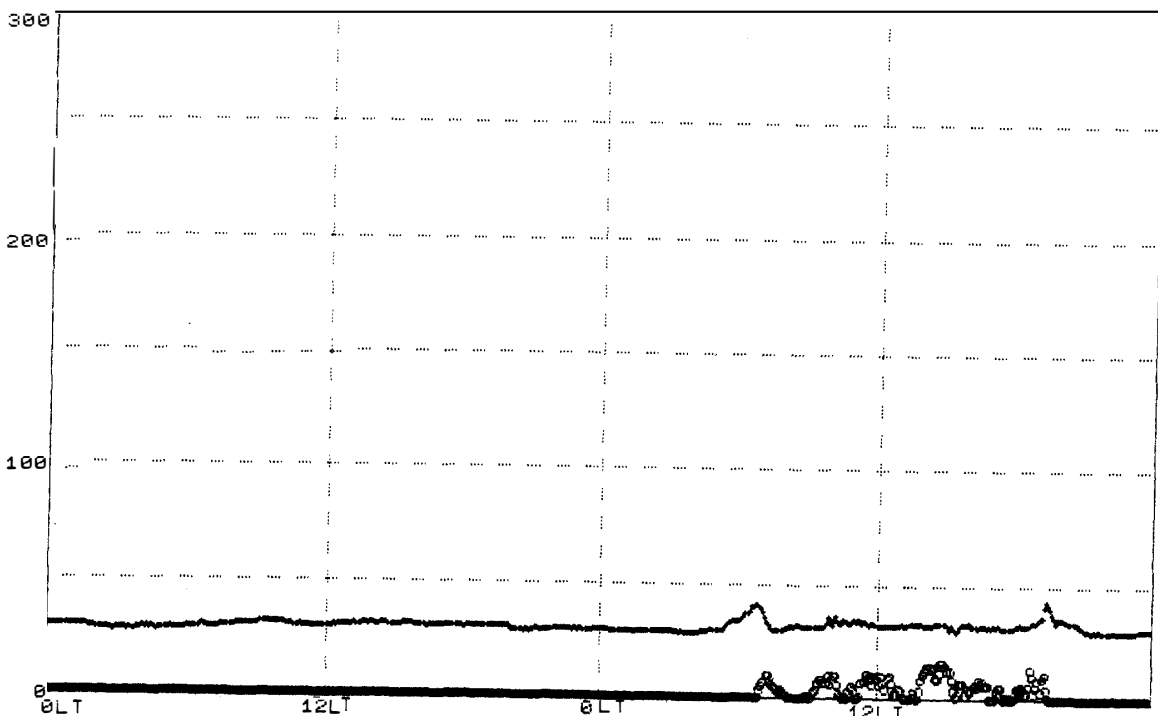
TB(K) and IWC(mg/cm²) 89 1118 --> 1119



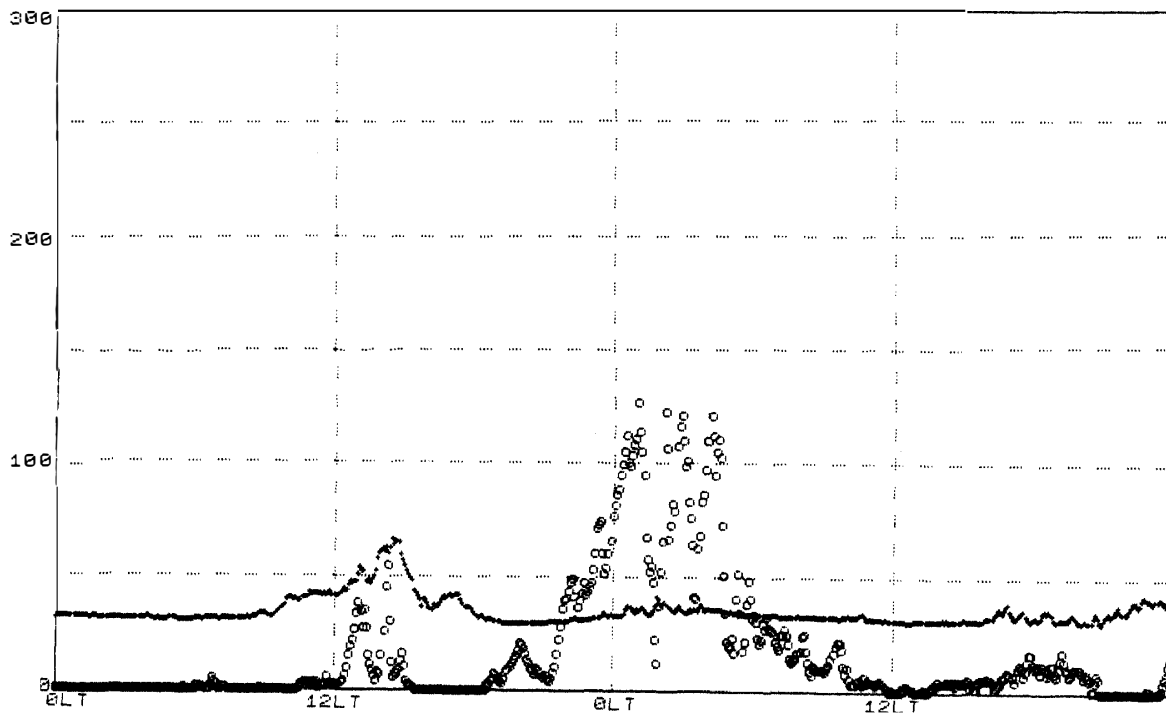
TB(K) and IWC(mg/cm²) 89 1120 --> 1121



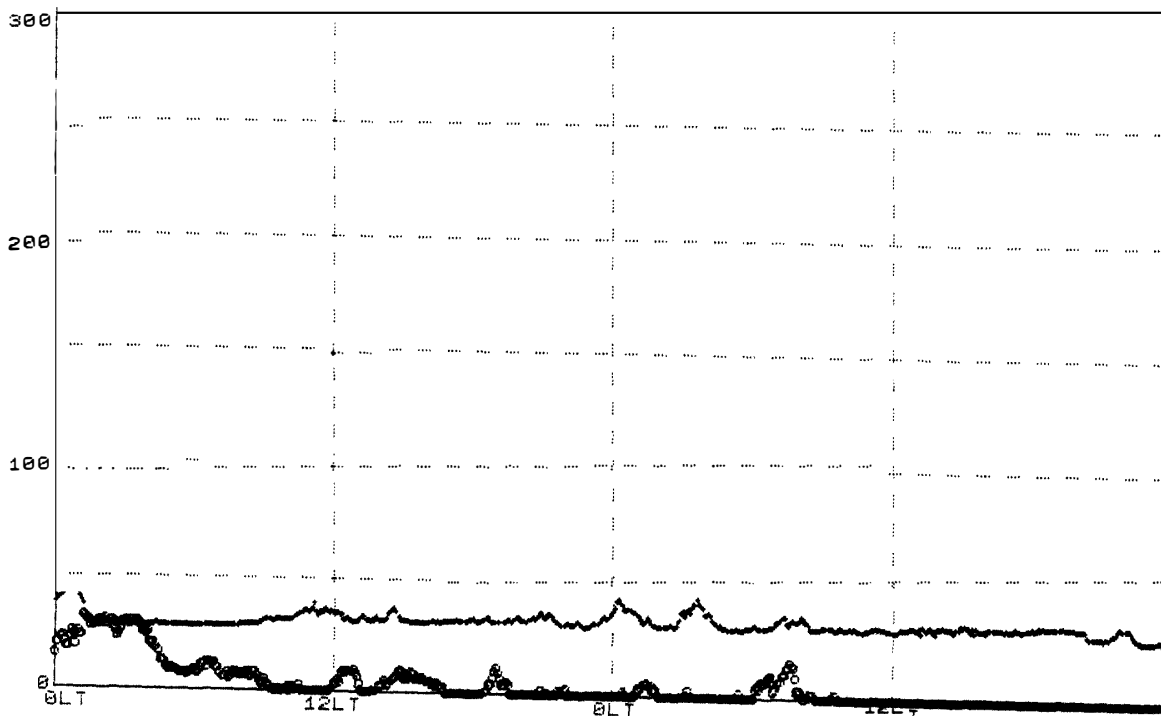
TB(K) and IWC(mg/cm²) 89 1122 --> 1123



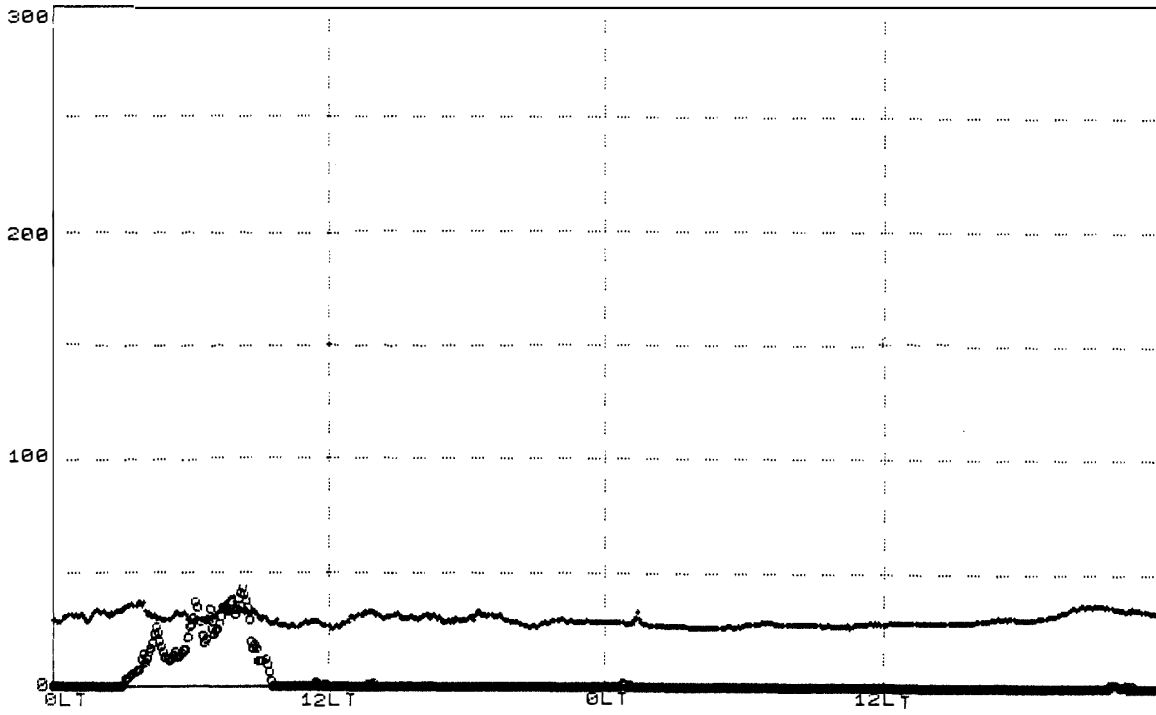
TB(K) and IWC(mg/cm²) 89 1124 --> 1125



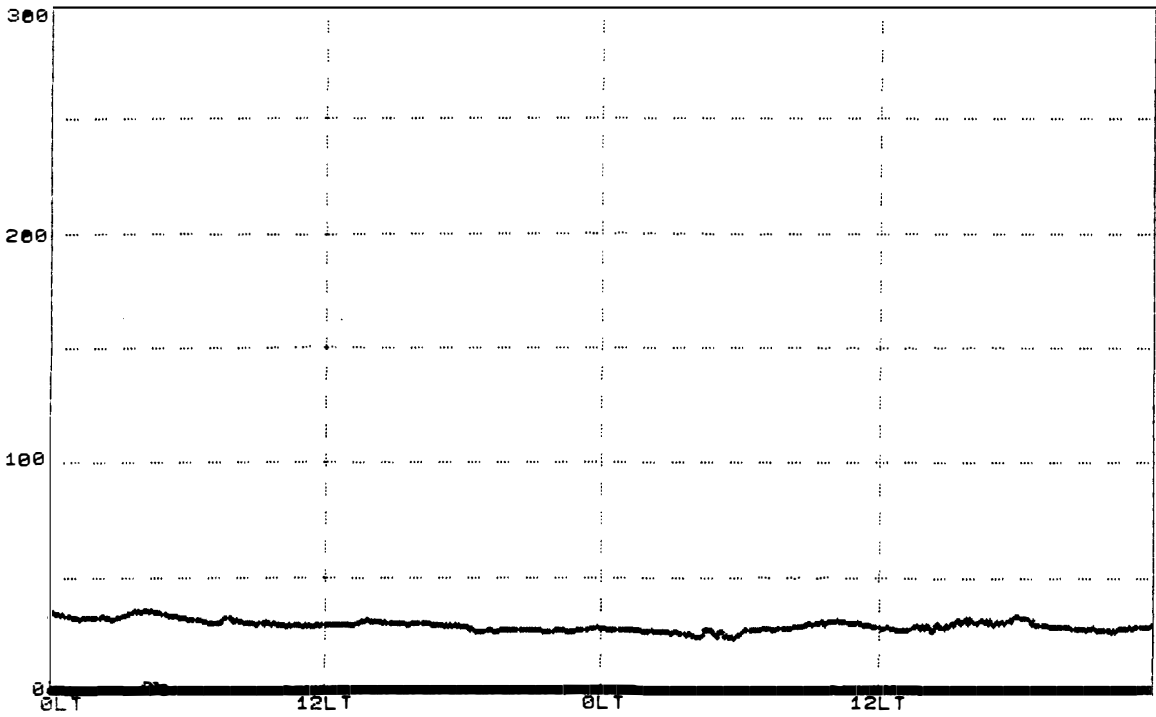
TB(K) and IWC(mg/cm²) 89 1126 --> 1127



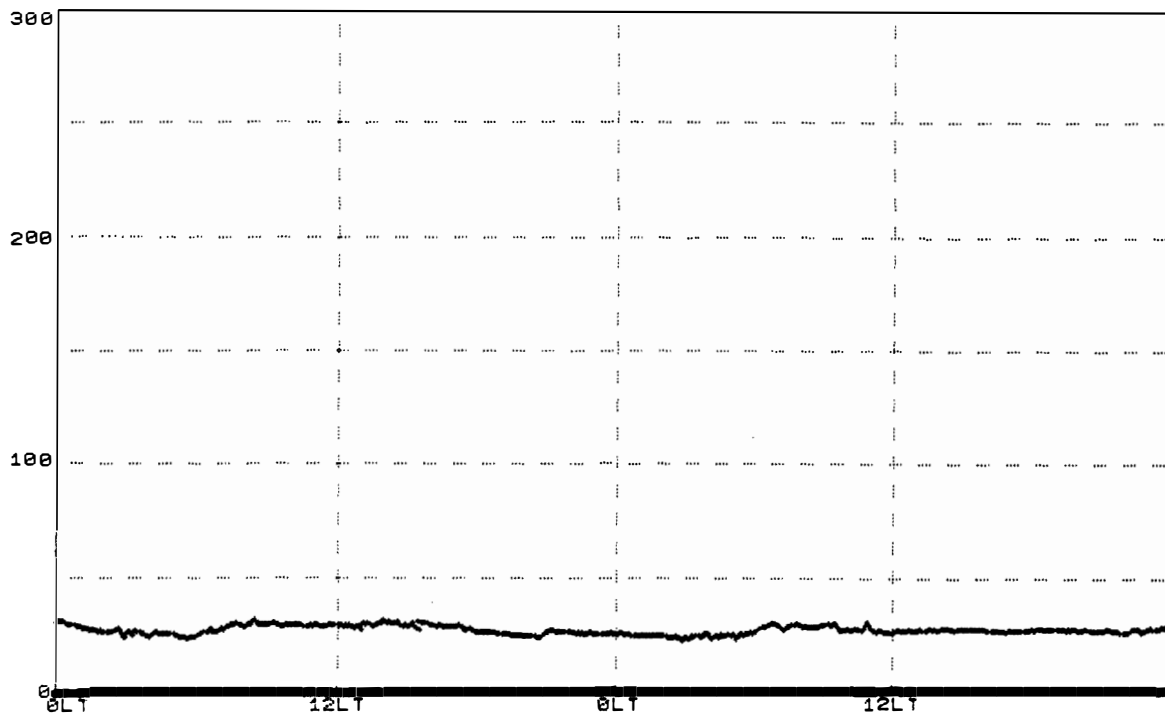
TB(K) and IWC(mg/cm²) 89 1128 --> 1129



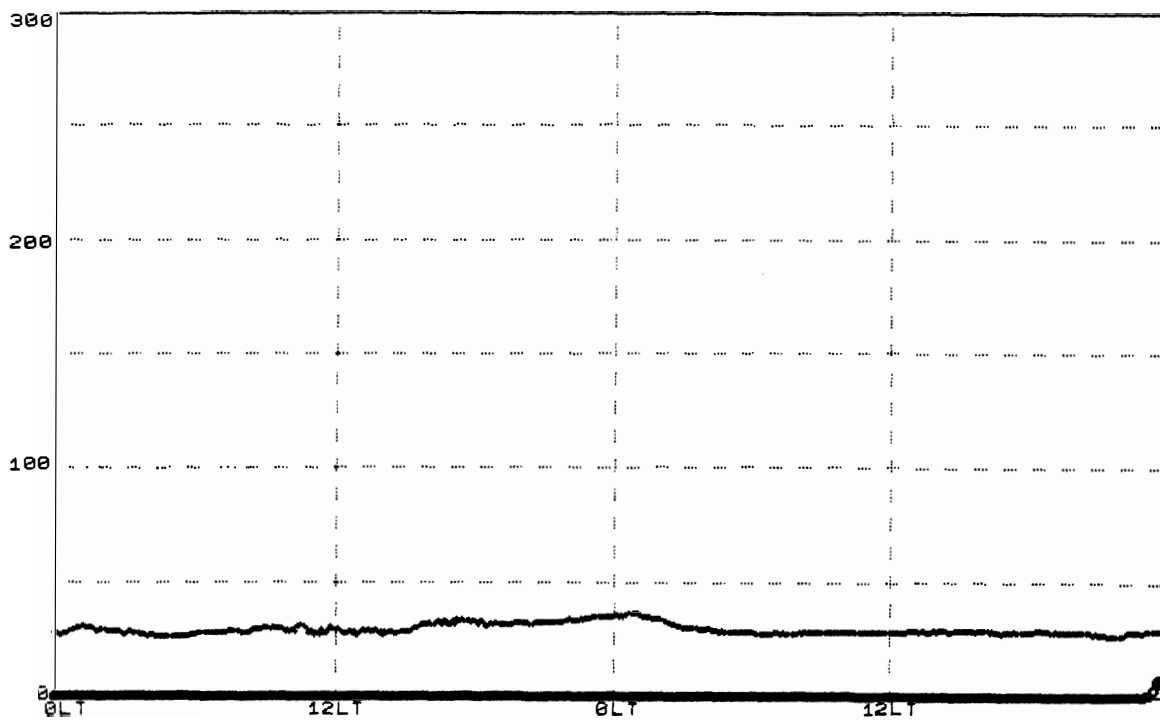
TB(K) and IWC(mg/cm²) 89 1130 --> 1201



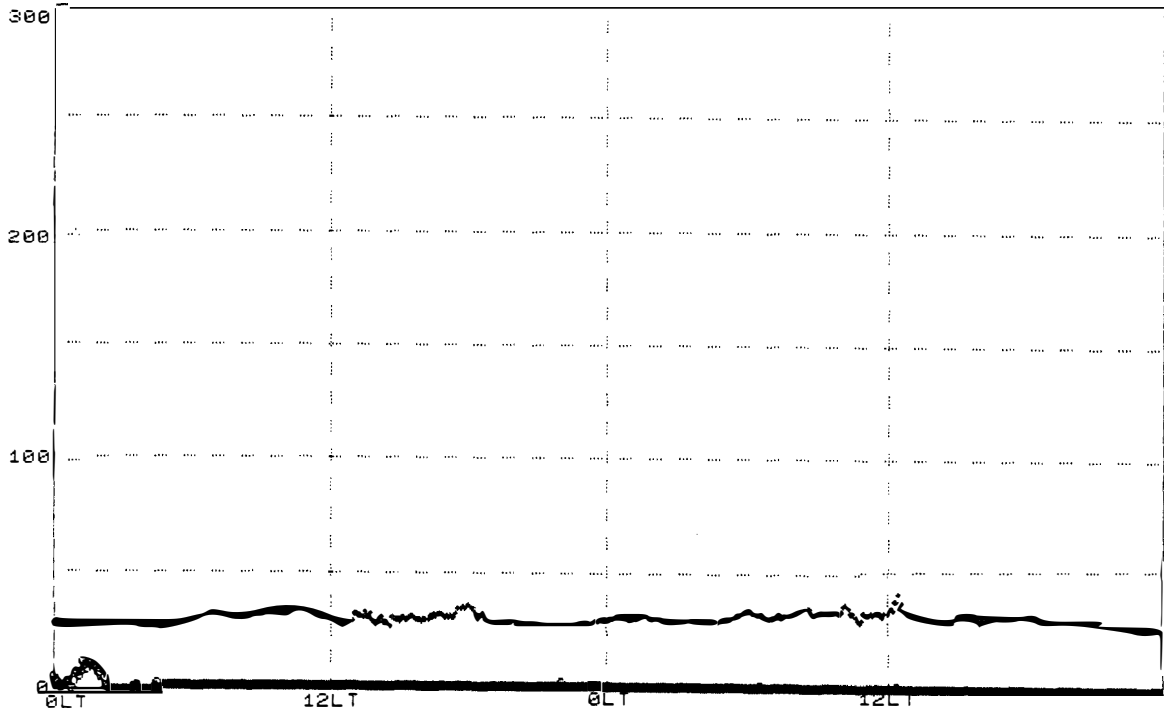
TB(K) and IWC(mg/cm²) 89 1202 --> 1203



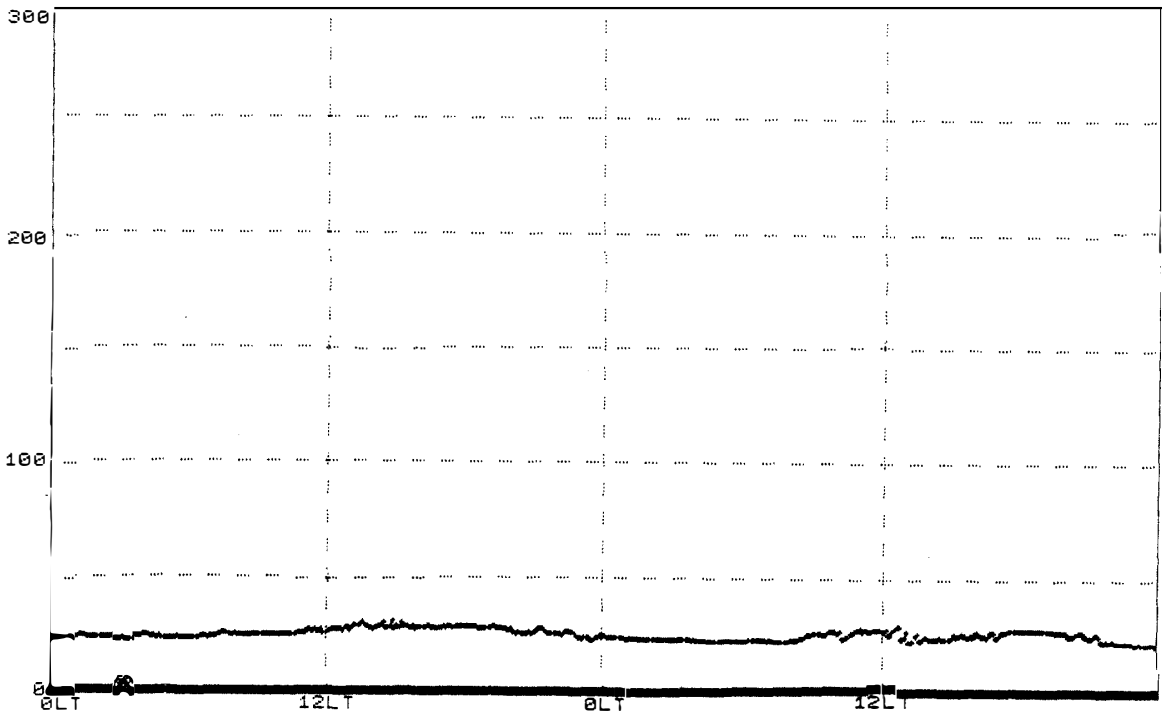
TB(K) and IWC(mg/cm²) 89 1204 --> 1205



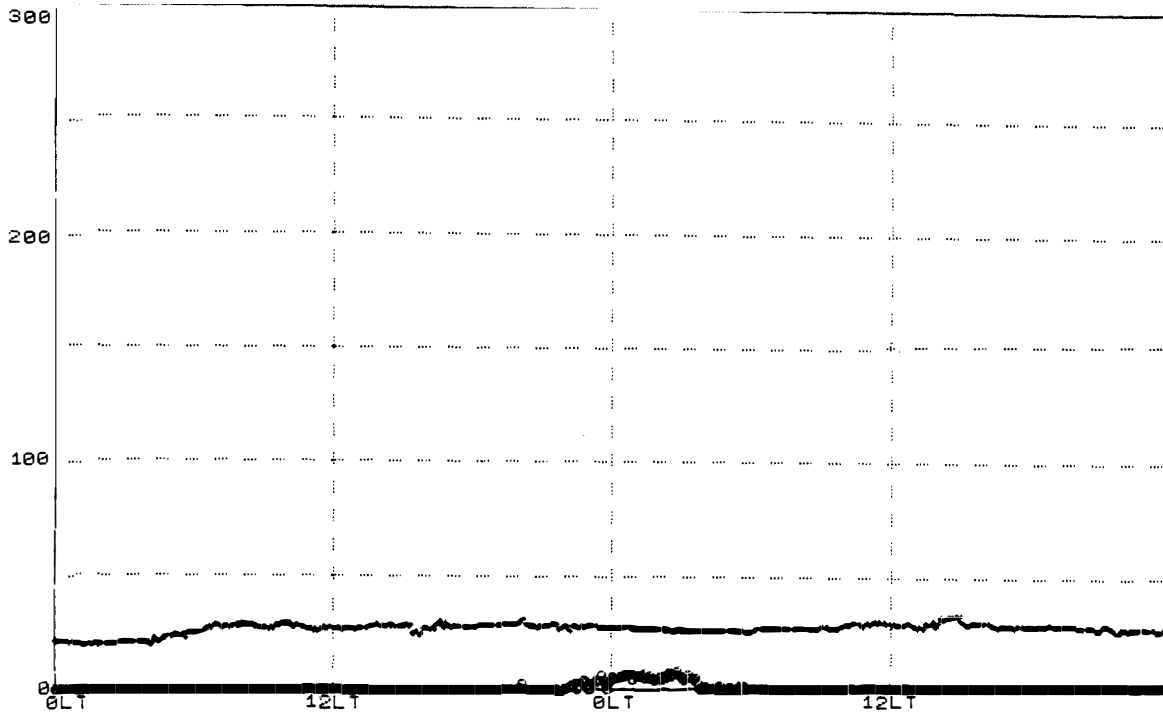
TB(K) and IWC(mg/cm²) 89 1206 --> 1207



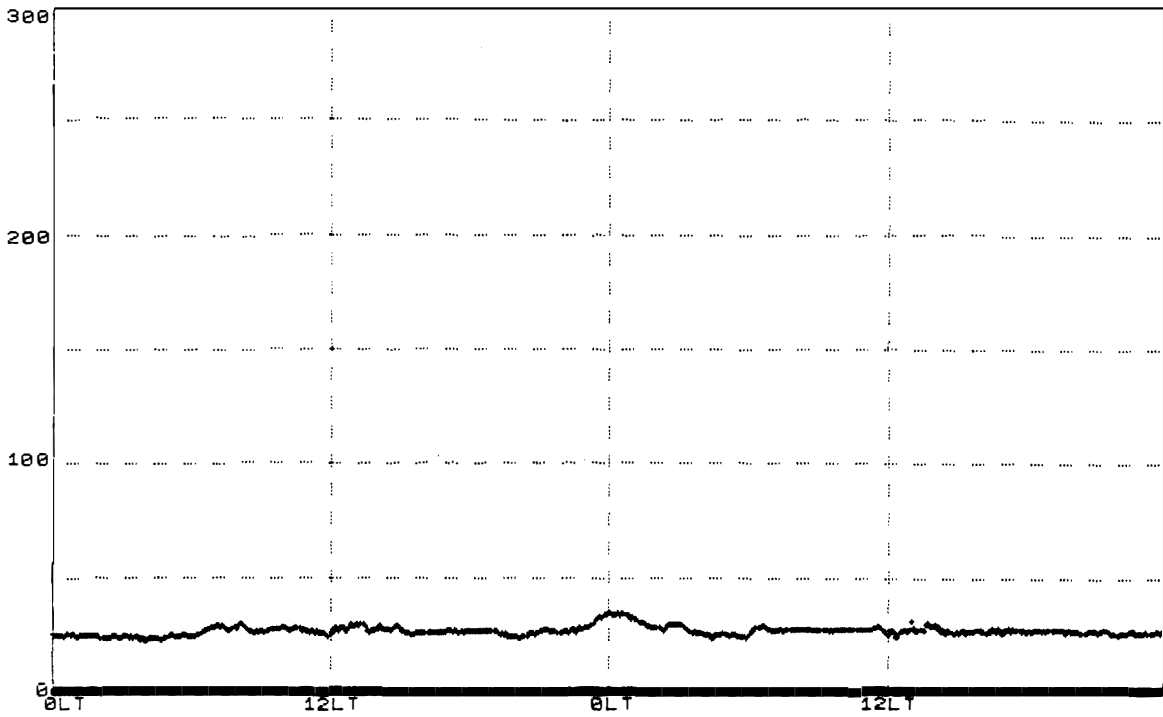
TB(K) and IWC(mg/cm²) 89 1208 --> 1209



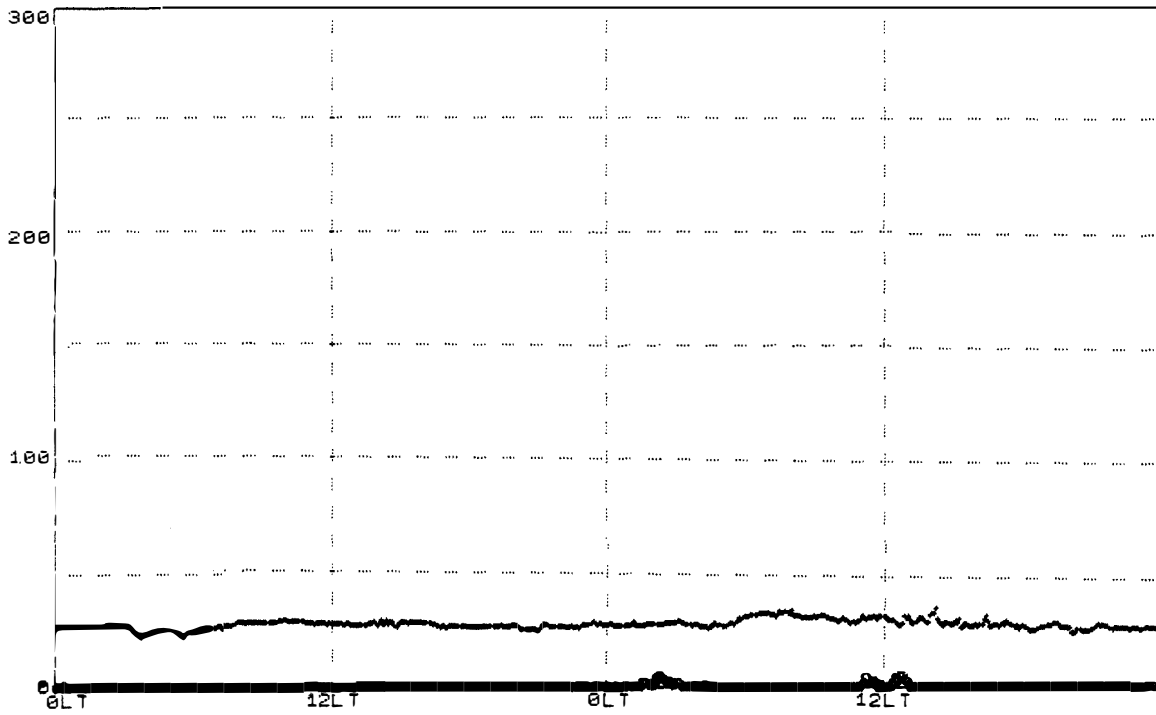
TB(K) and IWC(mg/cm²) 89 1210 --> 1211



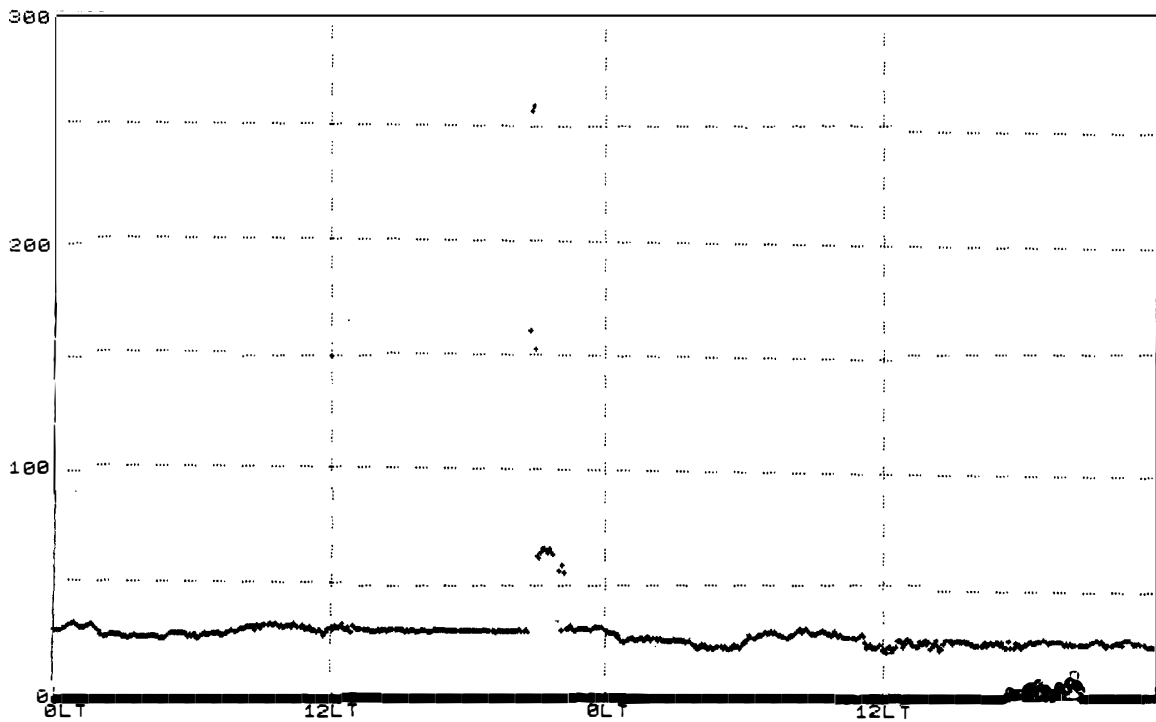
TB(K) and IWC(mg/cm²) 89 1212 --> 1213



TB(K) and IWC(mg/cm²) 89 1214 --> 1215



TB(K) and IWC(mg/cm²) 89 1216 --> 1217



TB(K) and IWC(mg/cm²) 89 1218 --> 1219

