DOE/EV/10374-1

Institute of Environmental Medicine

MASTER

New York University Medical Center
New York, N.Y. 10016

DISCLAIMER

DOE/EV/10374--1

DE82 005465

Direct Determination of ^{222}Rn Gas Using the Electret to Remove Daughters at Formation

USDOE Contract DE-AC02-80EV10374

Naomi H. Harley, PhD, Principal Investigator
Stuart M. Altman, Laboratory Assistant

Prog. report FY 1981? (see p. 1)

1. Introduction

This report summarizes progress made during the interval July 1, 1980 to July 30, 1981 in developing a continuous monitor which measures only ^{222}Rn without interference from its short-lived daughters.

The short-lived, alpha-emitting daughters deposit in the lung and are important in establishing the lung cancer risk to populations. However, their effective half-life is about 30 minutes and they cannot of themselves persist in any atmosphere for more than a few hours. Their gaseous parent ^{222}Rn can be transported many hundreds of kilometers from its point of origin after emanating from the earth's surface, or be confined in homes for long periods of time if its origin is in soil beneath the structure. Only by studying the behavior of ^{222}Rn both indoors and outdoors at a single location for relatively long periods of time (~ 1 year) can its behavior and thus that of its daughters be fully understood.

The counter which we are developing is based upon an original design by Chittaporn (1981). The monitor utilizes a light-tight outer housing with passive diffusion of ^{222}Rn to the interior through a baffle system. The detector is an open-ended cylinder lined with zinc sulfide alpha phosphor on a Mylar substrate. This cylinder is placed directly on a 12.7 cm diameter photomultiplier tube.

Above the cylinder is a 12.7 cm diameter electret, a thin Teflon sheet which maintains a negative surface potential of about 1500 volts for long periods of time. The electret continuously collects any positively charged ^{218}Po as it is formed inside the detector from the decay of ^{222}Rn. Thus, only the alpha particles from the decay of ^{222}Rn itself can interact with the ZnS alpha phosphor to produce a count.

The ZnS alpha phosphor has an inherently low background (~0.34 counts per day per cm^2) and high efficiency (52% for a plated alpha source directly on the phosphor). Detection of ^{222}Rn at any environmental level is therefore possible.

Five self contained units have been built (in house) to date and are undergoing extensive calibration and field testing. Some preliminary data on both calibration and field tests are presented.

2. Design of the Monitor

a. The Detector

In order to measure low environmental levels with reasonable accuracy; other continuous monitors which measure ^{222}Rn through its ^{218}Po daughter (such as the 2 filter monitor) must sample large volumes of air and are thus not particularly portable devices. Since the continuous monitor under development has inherently low background and high sensitivity, the detection chamber can be relatively small and the entire unit portable.

The monitor was developed around a 12.7 cm (5") photomultiplier tube (PMT) to detect scintillations from the ZnS alpha phosphor. The detector itself is simply a 2 pound coffee can painted black on the outside, open at both ends and lined with a 14 cm high ZnS alpha phosphor sheet.* It was decided to keep the prototype coffee can rather than fabricate a special cylinder because the can not only has the correct diameter (the same as the PMT) but has a highly polished interior which is beneficial in obtaining the highest light output from the ZnS. This polished reflective surface is the backing for the phosphor.

Each coffee can is cut to a height of 16 cm giving a 2 cm high rim above the ZnS liner for supporting the electret mount.

The power supply which delivers high voltage to the phototube is built into a 10 cm wide x 10 cm deep x 10 cm high aluminum box holding the PMT base. It consists of two miniaturized MIL** voltage packets. One is an AC to DC converter which supplies 12 volts DC output from the 120 volt AC line; and the other a DC to DC converter which supplies from 800 to 1500 volts output for a DC input of 4 to 12 volts. A voltage divider on the 12 volt DC supply is used to allow the anode voltage on the PMT to be selected from 800 to 1500 volts in 100 volt stops.

A single integrated circuit inverter/trigger to shape the PMT signal for compatibility with the scaler is also contained in the PMT base support.

---

* Obtained from William B. Johnson and Associates, Montville, NJ 07045

** Obtained from MIL Electronics, Lowell, MA 01854

b. Printer/Scaler

No compact scaler is available commercially. In addition, a printer or other form of data storage is necessary to record data continuously. It is desirable, in keeping with the portable nature of the system to have the scaler and data storage device as a single unit.

A compact printer/scaler was recently developed at the USDOE Environmental Measurements Laboratory (EML) by Watnick. This unit utilizes a Datel printer and integrated circuit electronics. Their circuit was adapted by us for the continuous ^{222}Rn monitor with only a slight modification of the mechanical design to make it more sturdy for field use. The entire printer/scaler package is 30 cm wide x 15 cm high x 25 cm deep. The scaler accumulates data from the detector continuously and the printer can be set to record at intervals from 10 minutes to 990 minutes. Data from the continuous ^{222}Rn monitor are usually collected for one hour.

If desired, the detector cylinder is easily removed from the PMT so that Lucas flasks or filtered air samples could also be counted.

c. Outer Housing

The light tight outer housing was constructed of plywood finished with a marine varnish for waterproofing. The AC electrical connectors are also weatherproof. The housing contains two compartments. The upper holds the ^{222}Rn detector and PMT and has a removable front door with a baffle system for passive diffusion of ambient air. The lower compartment houses the printer/scaler.

Photographs of the interelor of Unit 2 with and without the electret in place are shown in Figures 1 and 2.

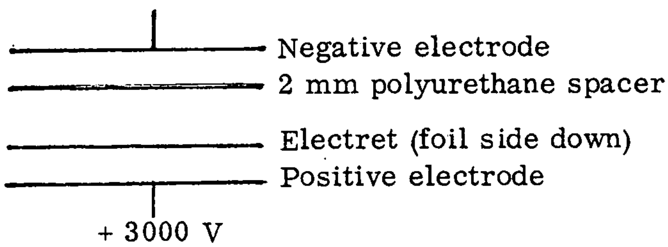
d, Electret Charging

Electrets are easily produced by placing a 13 cm diameter, 25 μm Teflon (FEP) foil, aluminized on one side, in a high voltage field of 3000 volts for one minute. In our system, the Teflon sheet is stapled to a heavy cardboard ring for mechanical support. The ring is then clipped to a fiberboard mount which sits on top of the detection cylinder and allows free passage of air into the detection chamber.

A miniature electret charger was constructed using two copper-plated printed circuit boards as electrodes and two miniature 1500 volt MIL, DC to DC converters with outputs in series to obtain 3000 volts for the electrodes. The MIL Company generously supplied us with several of these supplies at no charge and with heavier insulation in their packet so that breakdown of the insulation does not occur. These supplies are currently available at $50 a piece.

The electret with a polyurethane spacer is placed between the electrodes of the electret charger for one minute. The surface potential is then determined with a Monroe Stat-arc electrostatic voltmeter.* The electrostatic voltage initially is between - 1500 to - 1800 volts. This potential has been followed on six electrets from March through July 1981 and no discernable reduction has been observed.

The electrode, electret, polyurethane spacer (which prevents arcing of the voltage across the electrodes) sandwich is shown below.



A photograph of the charger is shown in Figure 3.

3. Detector Calibration

a. ^{222}Rn Counting Efficiency

All five continuous ^{222}Rn monitors were calibrated in the EML radon calibration room from March to June 1981. We were permitted to use this facility and the EML room monitor data, which tracks the radon level continuously with a flow-through scintillation cell.

---

* Available from Monroe Electronics Inc., 100 Housel Avenue, Lyndonville, NY 14098.

Counting plateaus were obtained on all units to establish the operating voltage. The calibration factor (in cpm per pCi ^{222}Rn per liter) was then determined for each unit.

A typical plateau is shown in Figure 4 along with the calibration factor (2.75 cpm per pCi $^{222}Rn/\ell$) at the operating voltage. The factor is also shown at the operating voltage with the electret removed and aluminum foil placed in its stead (4.85 cpm per pCi $^{222}Rn/\ell$) toshow the effect of daughter removal in the system. The reduction in count rate is consistent with less than about 8% of the radon daughters plating out on the walls. The exact percentage of daughter deposition will be determined during the course of this study.

b. Background Determination

The inherent system background is low. Measurements of background using a ZnS alpha phosphor disc directly on a bare PMT indicate the background is 0.34 counts per day per cm^2. To determine the actual operating background, a coffee can was opened at one end only, lined with ZnS alpha phosphor and the open end epoxy sealed with a clear lucite disc 13 cm in diameter. Radon in the can was allowed to decay for 30 days. Background measurements were then performed for 83 hours and the value determined as 6.2 ± 2.3 counts per hour.

Electronic background for the system was measured as 0.8 ± 1.1 cph determined by counting with no detector, merely a bare phototube. Some background is expected in a photomultiplier tube with this geometry (facing upward) since cosmic rays produce Cevenkov radiation in the PMT glass photocathode.

Based on this measured background, (6.2 ± 2.3 cph) the lower limit of detection for a one hour count is 30 pCi $^{222}Rn/m^3$ (0.03 pCi/ℓ).

3. Field Testing

Four units were deployed in pairs, so that simultaneous indoor-outdoor measurements could be performed. One pair was placed in a single family dwelling in northern New Jersey, 16 miles from Manhattan (outdoors and first floor). The other pair was placed on the 24th floor in a high rise apartment in New Jersey adjacent to the Hudson

River and directly across from New York City. Figure 5 shows the outdoor continuous monitor in the high rise apartment along with a weather hutch for collecting data on humidity, temperature and pressure. The fifth unit has been used for background measurements and has also been located in the high rise apartment on the 11th floor to determine whether there are substantial differences between floors. There were not during one month of data collection. The fifth unit is now located in the basement of the single family dwelling to determine the relationship between basement and first floor ^{222}Rn levels.

Five days (June 28 to July 2, 1981) of hourly measurements both indoors and outdoors, typical for each site are shown in Figures 6, 7, 8 and 9. The indoor/outdoor ratio for these same data are shown in Figure 10.

The patterns indicate that there is a much larger diurnal cycle in the single family dwelling than on the 24th floor of a high rise apartment. A sharp diurnal cycle is not always present, however, and this can be seen in the July 1-2 data.

All hourly ^{222}Rn measurements and weather data are added to our data base on the CDC 6600 computer at the New York University Courant Institute of Mathematical Sciences. This very large computer is available through USDOE support and has fully implemented statistical packages such as the SPSS and BMD programs.

We now have about 2500 hourly ^{222}Rn measurements at each site along with on site relative humidity, temperature and barometric pressure obtained with a clock driven, three pen meterograph. Newark Airport (~ 20 miles distant) weather data supplements our own and this is also added to our data base.

This data set when accumulated over an interval of about one year along with the capability of statistical analysis (primarily cumulative frequencies, t-testing and multiple regression) will be a valuable resource for understanding the fundamental behavior of ^{222}Rn.

4. Summary

Five compact, portable, continuous ^{222}Rn monitors have been constructed inhouse. Printed data can be obtained from intervals ranging from 10 minutes to 990 minutes. A one hour count interval provides a lower limit of detection of 0.03 pCi $^{222}Rn/\ell^{-1}$ which is sufficient for measurement of any environmental level encountered.

Calibration of the units was accomplished in the EML radon calibration room and the typical calibration factor is 165 counts per hour per pCi $^{222}Rn/\ell$.

The units are now being field tested. Two indoor/outdoor pairs are located in a single family dwelling and in a high rise apartment. One unit is being used for special studies.

Acknowledgements

We would like to thank Robert Graveson for allowing us to use the unpublished circuits in the printer/scaler, Sidney Watnick and Irwin Haskell for their expert guidance during the construction phase of the units, Dr. Earl Knutson and Andreas George for allowing free access to the radon calibration facility.

Reference

Chittaporn, P., Eisenbud, M. and Harley, N. H.
A Continuous Monitor for the Measurement of Environmental Radon
Health Physics (In Press)

Figure 1 - Continuous ^{222}Rn Monitor Showing Upper and Lower Compartments. Electret in Place Over Detection Chamber

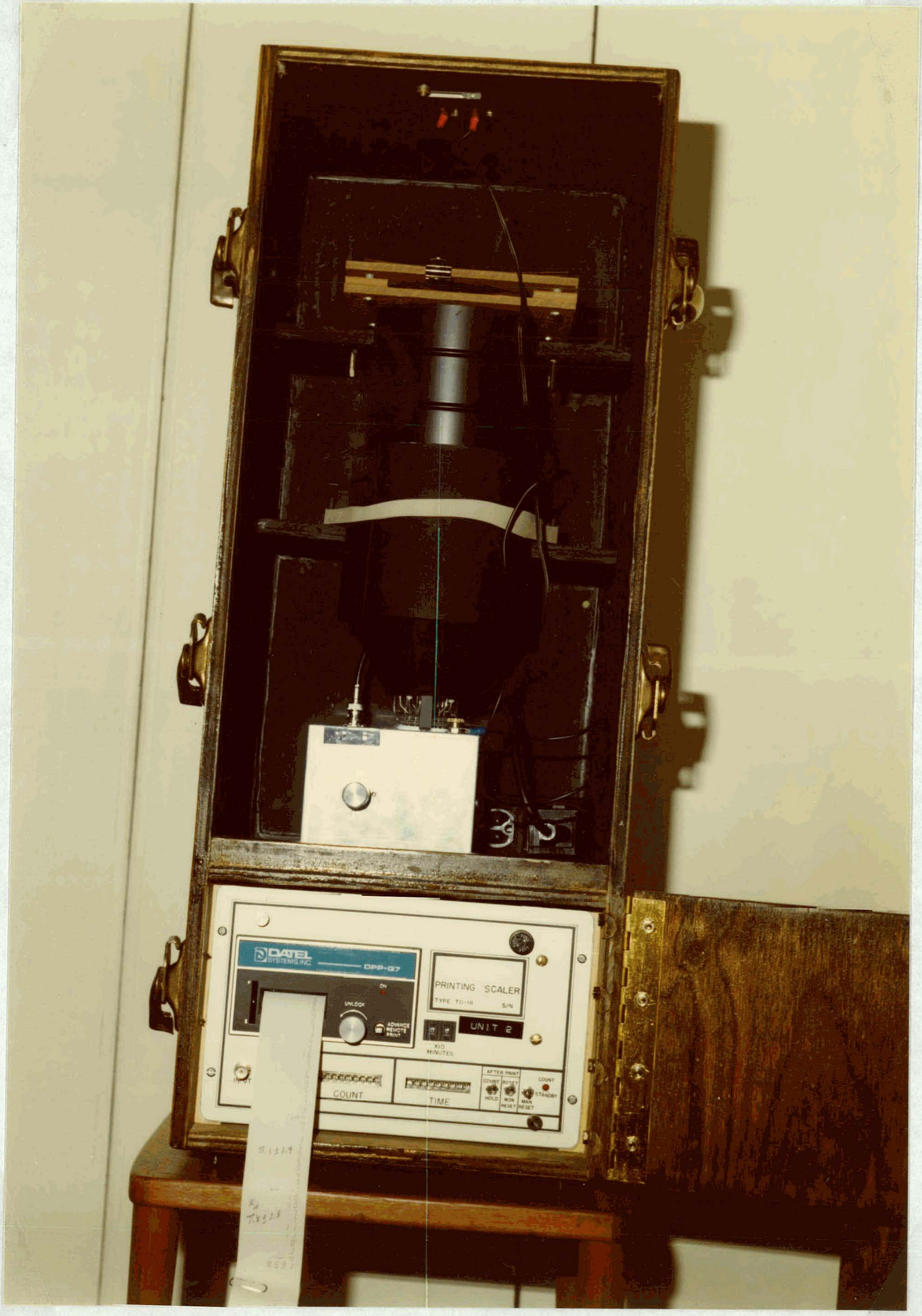

DATEL SYSTEMS INC
DPP-G7
UNLOCK
PRINTING SCALER
UNIT 2
X10 MINUTES
COUNT
TIME
STANDBY

Figure 2 - Continuous ^{222}Rn Monitor Showing Upper and Lower Compartments. Electret Removed from Detection Chamber

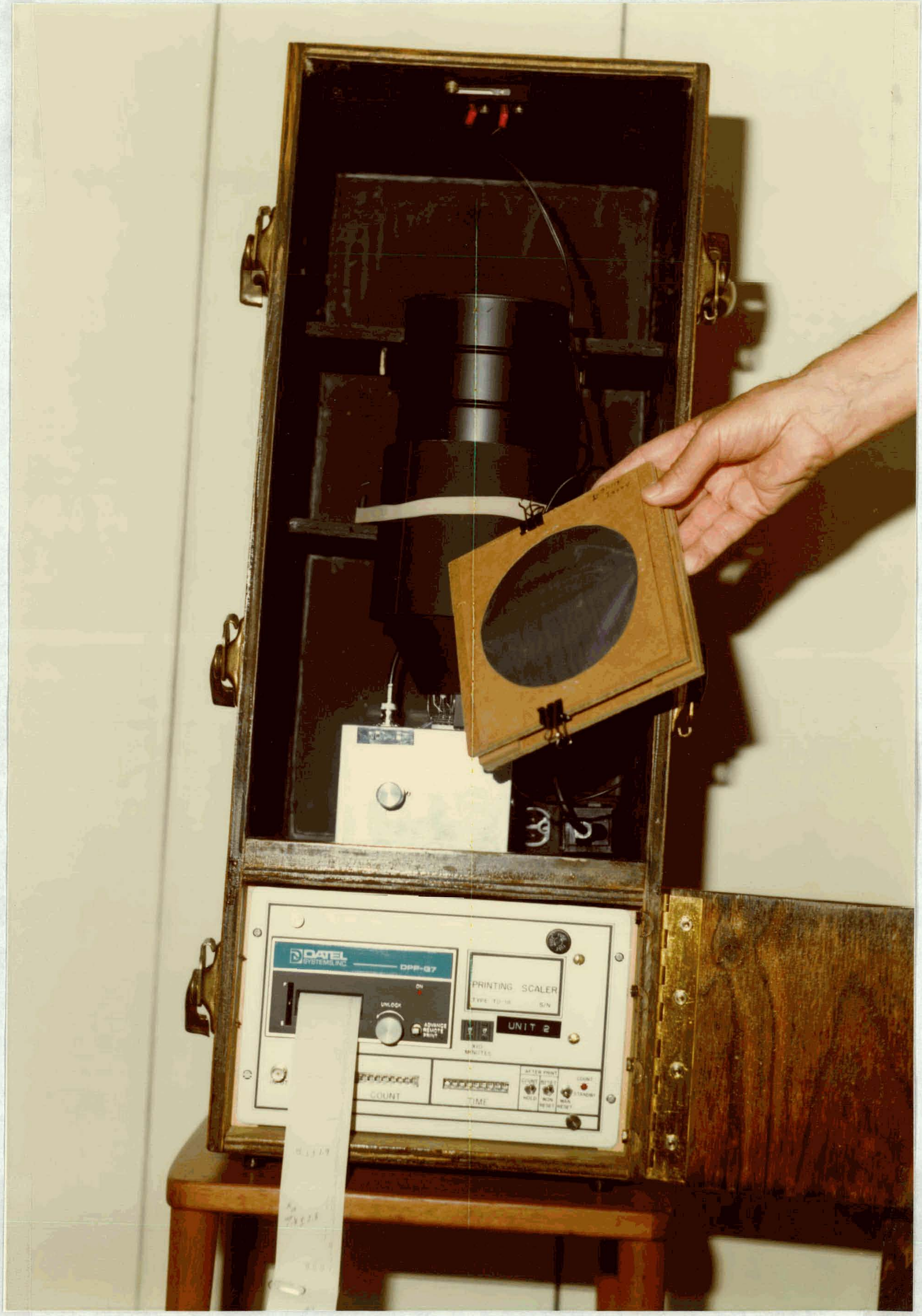

DATEL SYSTEMS, INC.
DPP-07
ON
UNLOCK
ADVANCE REMOTE PRINT
PRINTING SCALER
S/N
UNIT 2
MINUTES
COUNT
TIME
AFTER PRINT
COUNT HOLD
RESET
MAN RESET
COUNT
STANDBY

Figure 3 - Electret Charger at Left. Wooden Storage Cabinet for Six Electrets at Right


CHARGER
VOLTAGE

Figure 4 - Voltage Plateau for Continuous ^{222}Rn Monitor.
Calibration Factor shown at Operating Voltage
with and without Electret

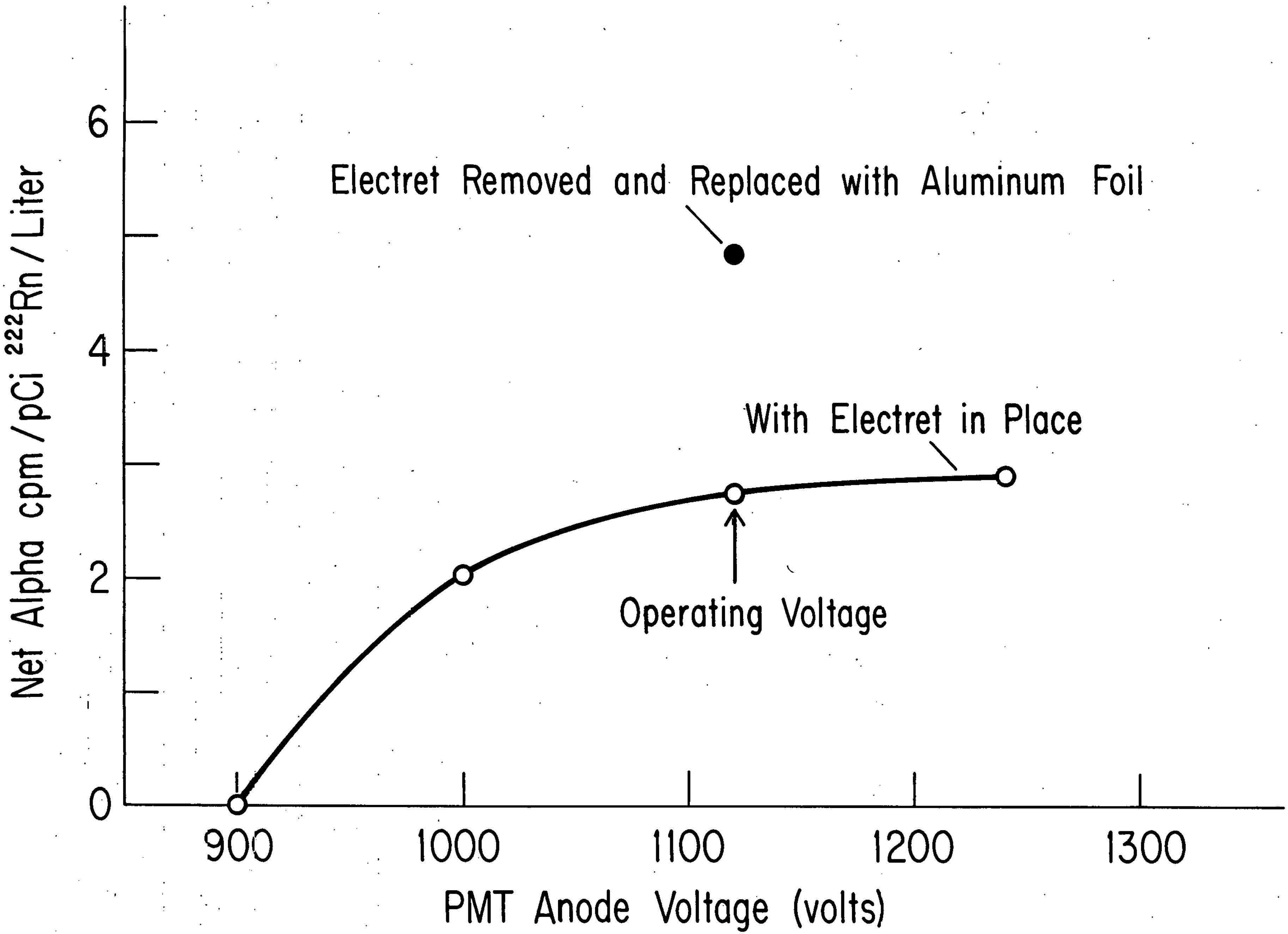
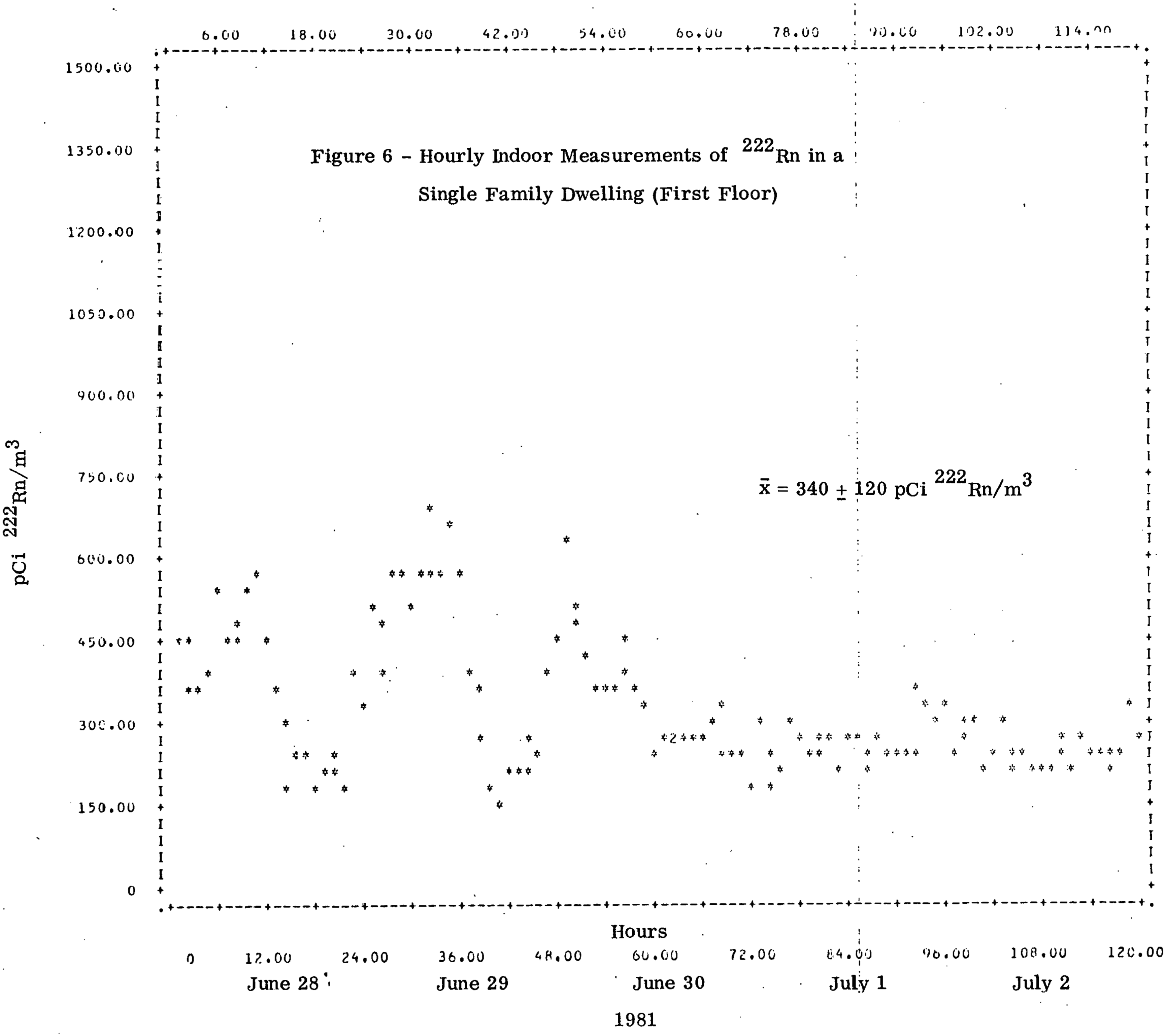

Electret Removed and Replaced with Aluminum Foil
With Electret in Place
Operating Voltage
Net Alpha cpm / pCi ^{222}Rn / Liter
PMT Anode Voltage (volts)
0
2
4
6
900
1000
1100
1200
1300

Figure 5 - Continuous ^{222}Rn Monitor Undergoing Field Testing on 24th Floor of High Rise Apartment. Hutch for Weather Instruments at Right


3
3

Figure 6 - Hourly Indoor Measurements of ^{222}Rn in a Single Family Dwelling (First Floor)



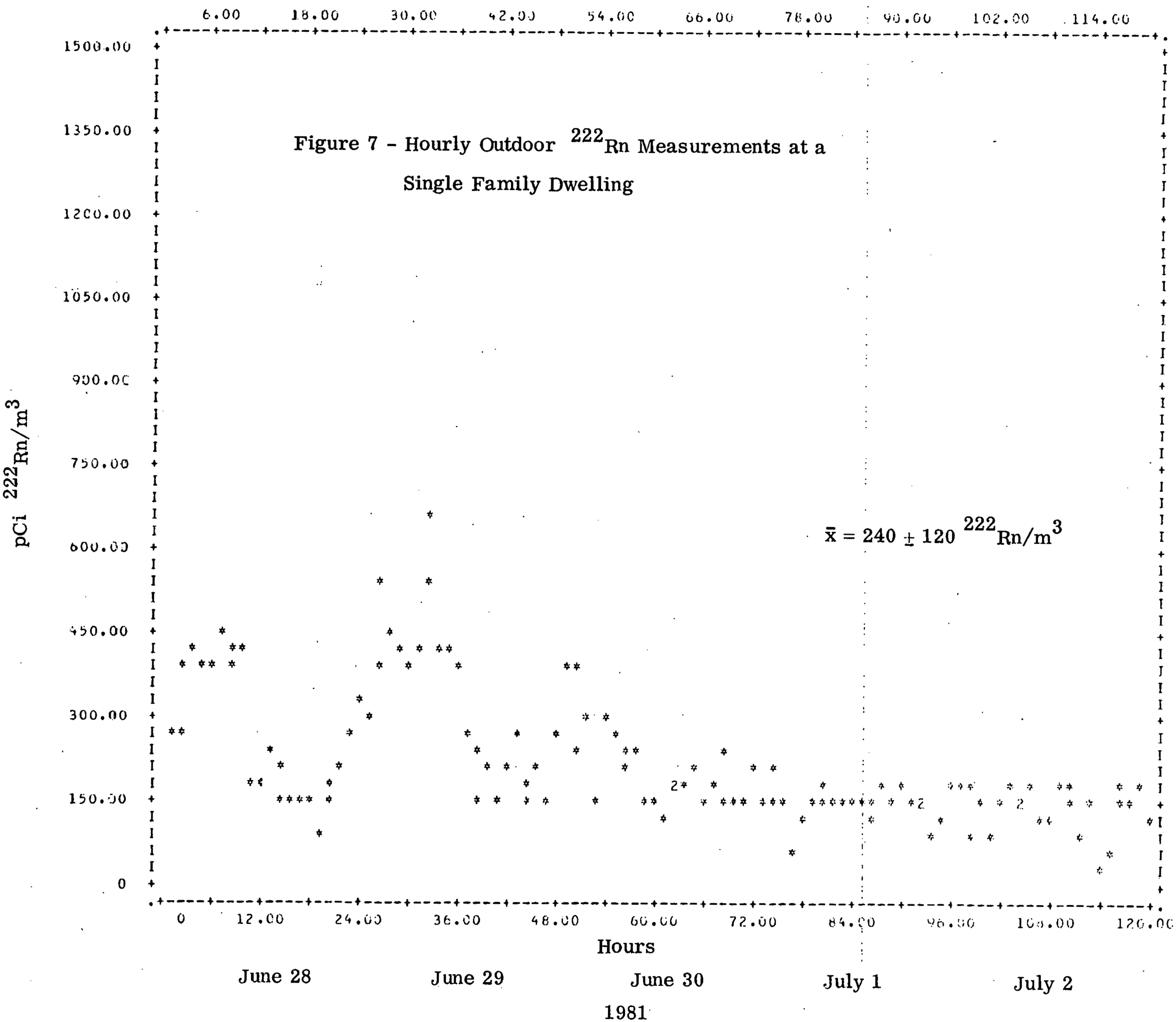


Figure 7 - Hourly Outdoor 222Rn Measurements at a Single Family Dwelling
x̄ = 240 ± 120 222Rn/m3
pCi 222Rn/m3
Hours
June 28
June 29
June 30
July 1
July 2
1981

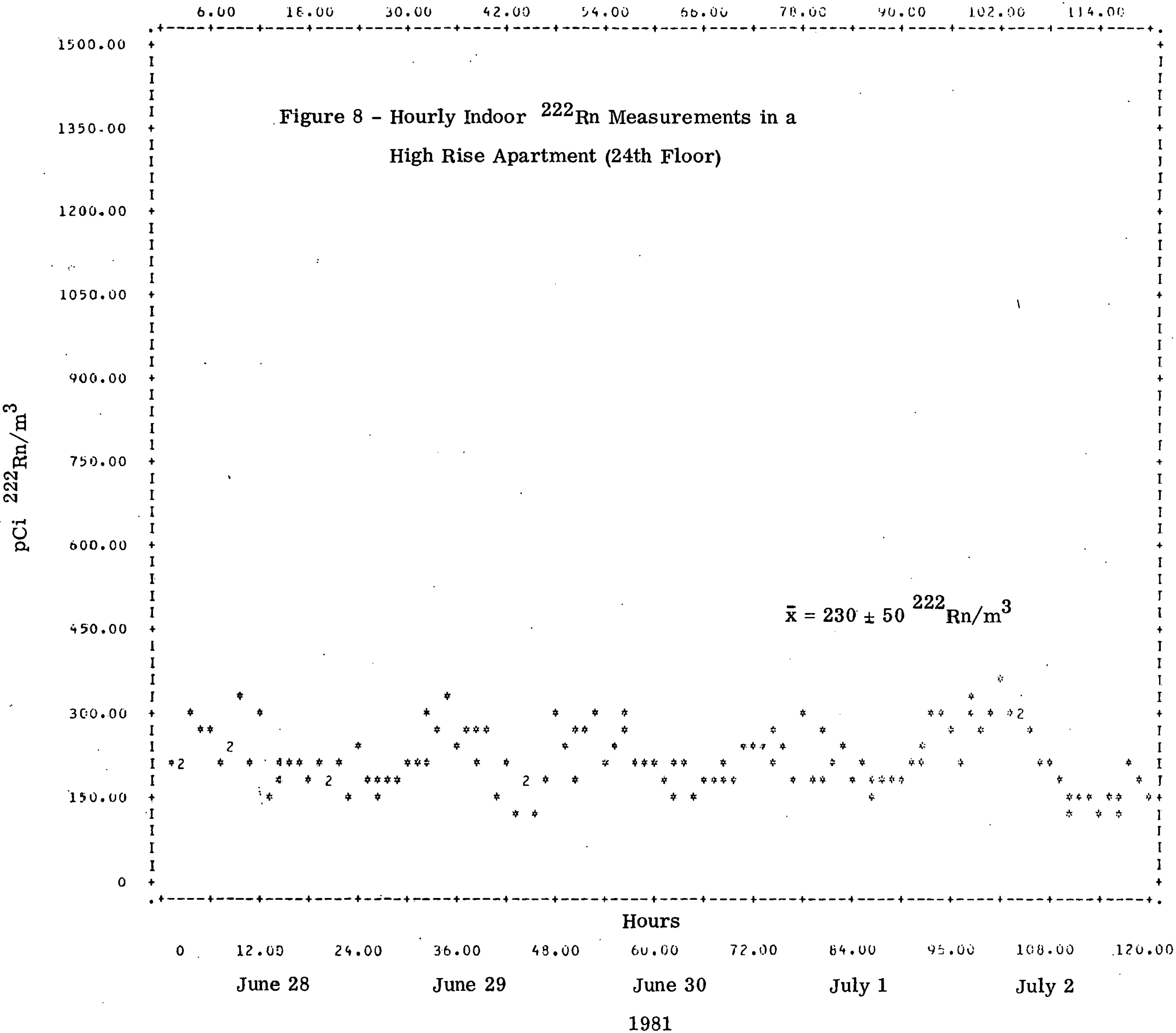


Figure 8 - Hourly Indoor ^{222}Rn Measurements in a High Rise Apartment (24th Floor)
$\bar{x} = 230 \pm 50$ ^{222}Rn/m^3
pCi ^{222}Rn/m^3
Hours
June 28
June 29
June 30
July 1
July 2
1981

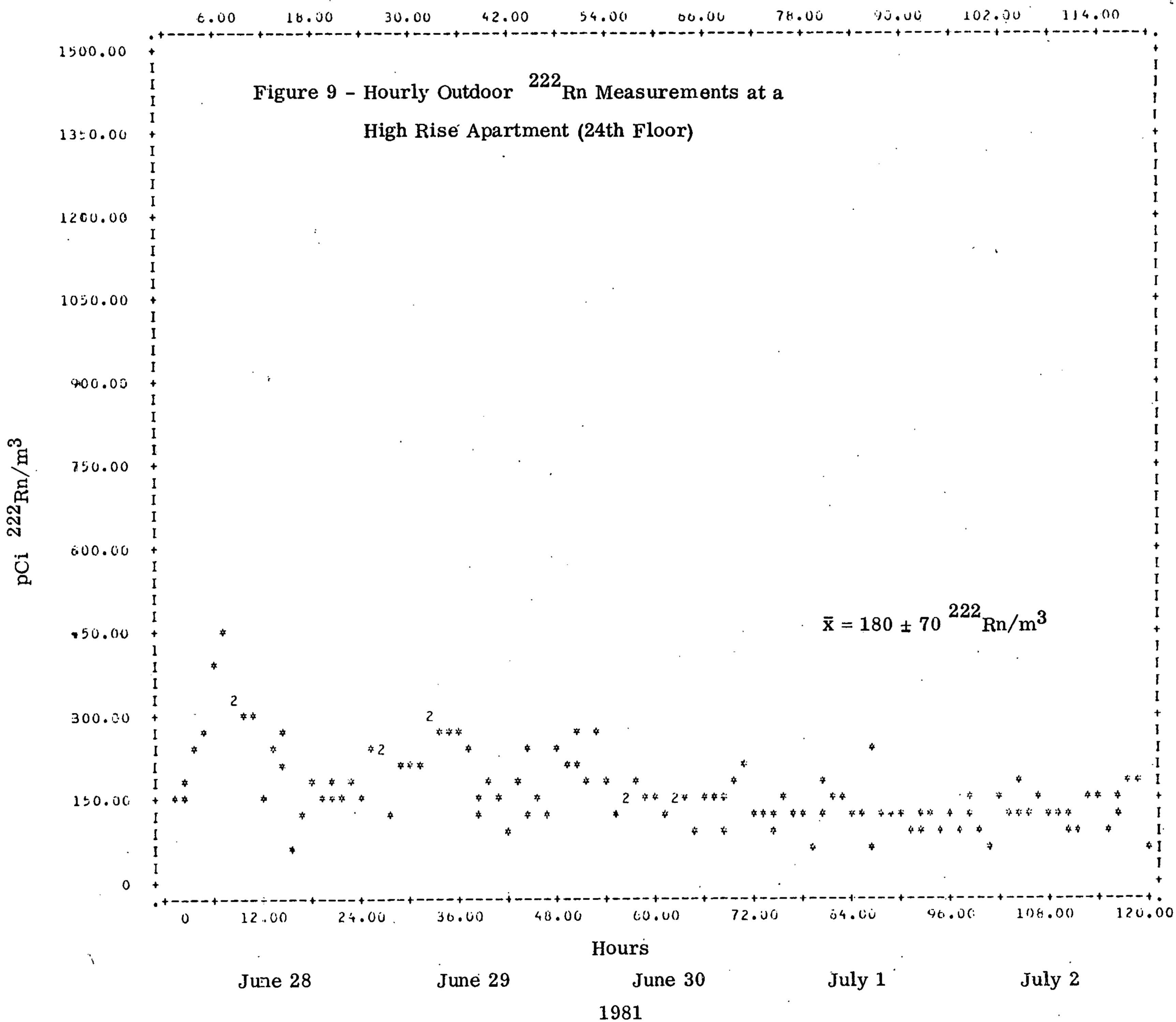


Figure 9 - Hourly Outdoor ^{222}Rn Measurements at a High Rise Apartment (24th Floor)
$\bar{x}$ = 180 ± 70 ^{222}Rn/m^3
pCi ^{222}Rn/m^3
Hours
June 28
June 29
June 30
July 1
July 2
1981

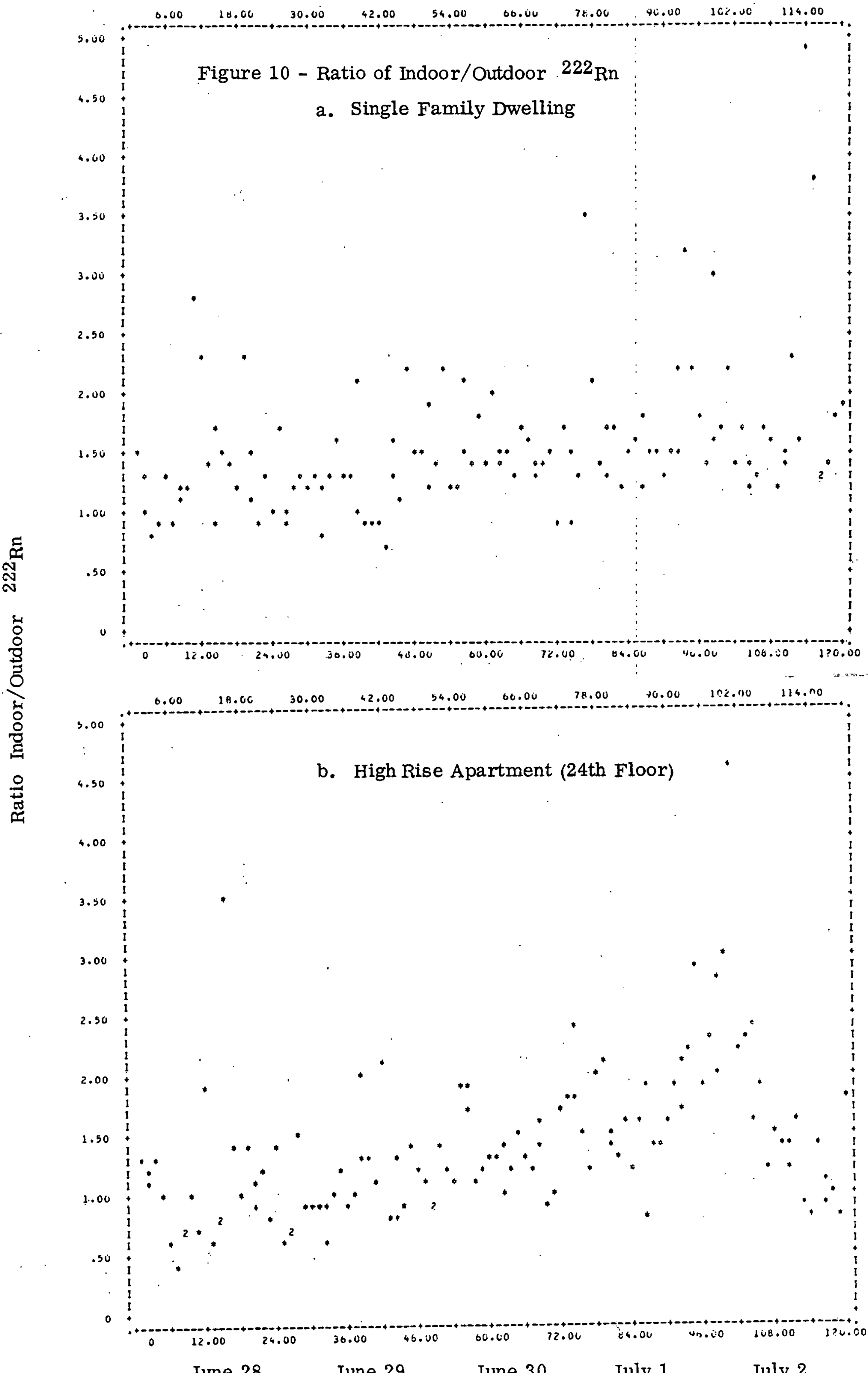


Figure 10 - Ratio of Indoor/Outdoor ^{222}Rn

New York University Medical Center
Institute of Environmental Medicine

550 FIRST AVENUE • NEW YORK, N.Y. 10016 • (212) 679-3200