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AIR QUALITY SAMPLER III

Operations Manual

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AIR QUALITY SAMPLER-III

(AQS-III)

Sequential Sampler

OPERATIONS MANUAL

Manufactured by

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SECTION 1

INTRODUCTION

AIR SAMPLING IN BAGS

Bag sampling techniques have been developed by EMI to collect gases in plastic bags. The results are automatically time-averaged concentrations collected over the sampling period. In comparison, a continuous analyzer provides a strip chart record with many instantaneous variations which must be averaged to determine the desired result, the average.

EMI Air Quality Samplers collect air in real time. An array of samplers, controlled by their built-in electronic time clocks, sample simultaneously to monitor many sites. The results are synoptic. This method of gas collection is cost-effective because only one set of analyzers are required to analyze the bag contents from many Air Quality Samplers.

AIR QUALITY SAMPLER-III

The Air Quality Sampler (AQS-III) is designed to collect ambient air from a point source into plastic bags for later analysis. This multiple-bag, air collection system operates sequentially and offers variable sampling periods from 10 to 60 minutes. Longer sampling periods (up to 16 hours) may be arranged by consulting with the factory.

Point source sampling refers to a single air-sample inlet. A sampling cane may be connected to this inlet. A **manifold** purges the gas inlet line just prior to any **sample** pump operation. This assures that only a current ambient air sample is collected; the air does not become stale in the input manifold.

The 1980-designed AQS-III controller, based in part on previous designs, is simple to operate and reliable. The system can be easily programmed for sampling up to four days in advance. In operation, the user sets the time of day and start time on the clock display, selects the sample starting day and the sampling period. The AQS-III will then start sampling at the selected time and day; thereafter, each bags fills sequentially. Operation ceases after the last bag has been filled.

Four basic modules make up the AQS-III:

1. Controller - the electronic time/controller package.
2. Pumper - sample pumps with their associated sample cane, inlet manifold and calibration and pump driver electronics.
3. Bag Box™ - collection and sample bag identification of 12 2-liter bags is accomplished with this shippable box.
4. Power Supply - power options are rechargeable gel-cell batteries (with charger) or an AC power supply.

All four modules easily fit into a four-cubic-foot enclosure. This rectangular-shaped, heavy-duty ABS container provides good environmental protection, is easily transportable and very rugged. Other sampler containers are also available to fit particular sampling requirements

These modules can be mixed and matched to fulfill a particular sampling requirement. For example, many pump modules may be connected in a series for a long sampling run. 12 to 144 pumps will operate sequentially. Gangs of pumps can also be connected in parallel for multiple sampling locations, such as various heights on a tower.

Figure 1-1 presents the AQS-III specifications.

AQS DESIGN PHILOSOPHY

All Air Quality Samplers (AQS) are multiple pump/bag samplers which operate by battery or AC power, completely unattended. To conserve battery power, the DC pump motor assemblies use the **pulse pump** principle patented by EMI. In this type of operation the pump is switched on for a short duration. Varying the length of time that the pump is on either increases or decreases the flow. Typically, a 500-msec pulse will pump 10 ml of air. The number of pulses per sampling period is usually fixed.

EMI uses the one-pump-per-bag philosophy. This redundancy provides very simple sample line plumbing and a high degree of reliability. If one pump should fail, only one sample is lost. Another approach would rely upon solenoid valves, more complex plumbing and a single pump to achieve multiple samples. This approach is very sensitive to pump malfunction.

APPLICATIONS

The AQS bag sampling system can be used for many types of air pollution and tracer gas studies. Most state departments of transportation and the Federal Highways Administration use these systems successfully to determine hourly carbon monoxide concentrations. The systems have been used to verify model predictions and make the preliminary measurements for atmospheric studies. Their use in tracer studies with sulfur hexafluoride and fluorocarbons is very common.

The AQS-III can be programmed to take 12 eight-hour samples. For example, a system can be placed in a working area where high CO concentrations are suspect. Four days of continuous measurements will provide samples for the eight-hour averaged CO exposure.

SPECIFICATIONS

MODEL NUMBERS:	AQS III #12-2422, 12-pump, 112-liter enclosure, (holds 12 2-liter sample bags in EMI Bag Box™) rechargeable gel-cell battery pack. AQS III #12-2452, 13-pump (12 sample, 1 manifold) 112-liter enclosure, (holds 12 2-liter sample bags in EMI Bag Box™), rechargeable gel-cell battery pack.
SAMPLING PERIOD:	Time-averaged air flow into gas sampling bags for delayed analysis.
NUMBER OF BAGS:	Typically 12. Additional sets of sample bags can be accomodated by one control unit.
SAMPLE BAG HANDLING:	Sampling bags organized in portable, protective container, the EMI Bag Box™, Bags without protective container can be used.
SAMPLE INLET:	Single point sample inlet, 0.5-to-2 meters high.
PUMP UNITS:	Single-action, dc motor driven, user-replaceable, positive and negative pressure ports.
SAMPLING PERIOD:	Selectable 10, 15, 20, 30, 40, or 60 minutes per bag. Other periods to 16 hours available.
START/STOP:	Automatic, by time-of-day setting. Sampling terminates after last bag is filled. Remote control start/stop optionally available.
PROGRAMMING PERIOD:	Up to 96 hours, set by operator.
FLOW RATE:	To 2-liters per sample period, normally calibrated at 2 liters. Automatic flow adjustment for sampling period setting changes.
CONTROLS:	Power, set minute, hour and start time, sampling period, start cycle.
DISPLAY:	0.5 inch LCD clock display. Dot LED's show battery low voltage condition and cycle status.
POWER:	12 volt dc rechargeable gel-cell or ac power pack.
BATTERY LIFE:	30 hours at 10-minute to 250 hours at 60-minute sampler rate, before recharging required.
ENCLOSURE:	61 x 41 x 47 cm (24 x 16 x 18.5 inches) heavy-duty ABS enclosure, white.
ENVIRONMENTAL:	Operating temperature limits: -10°C to 40°C (14°F to 104°F).
WEIGHT:	Approximately 25 pounds.

Figure 1-1
Specifications for the AQS-III

SECTION 2

GENERAL DESCRIPTION

COMPONENTS

The AQS-III consists of the following modules: Controller, Pumper, Bag Box and Power Supply. The photo in Figure 2-1 shows the packaging configuration in an ABS plastic enclosure. The modules are shown in the system diagram, Figure 2-2.

Figure 2-1
AQS-III in Case

The AQS-III controller/pumper assembly contains the first two modules. All sampling functions, as well as the sample bag attachments, are provided with this assembly. Included are 12 sampling pumps and a manifold pump, electronic timer/controller, remote interface and pump driver/calibration electronics. Optionally, a composite sample pump can be installed. This unit may be installed in the user's sampling system or enclosure, or can be purchased in various EMI enclosures.

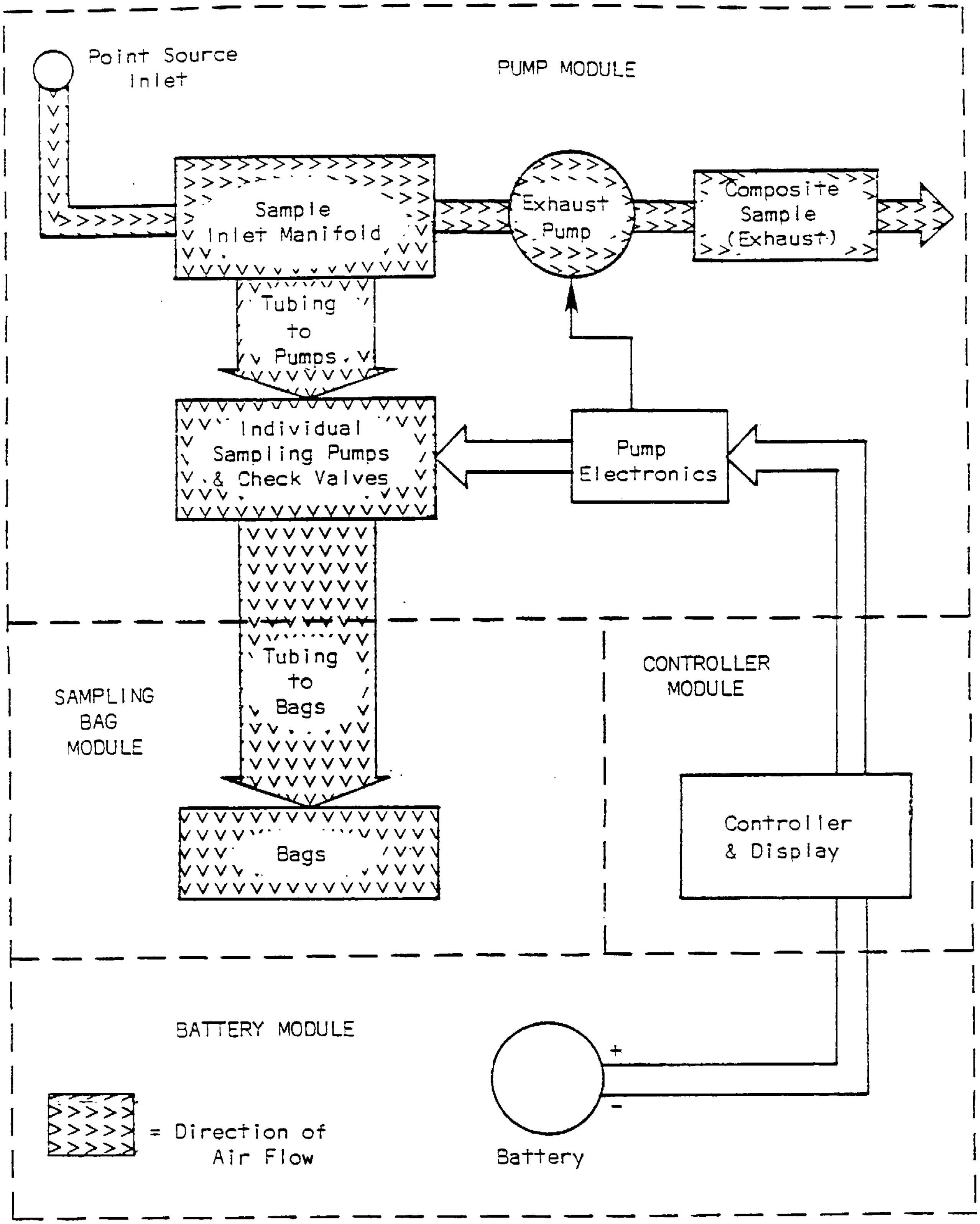


Figure 2-2
AQS-III System Diagram

CONTROLLER

The AQS-III Controller, based in part on previous AQS designs, uses state-of-the-art MOS and CMOS electronic circuitry. This controller offers sampling flexibility with ease of operation and high reliability.

The user presets time-of-day and start time using the mode switch, time setting switches and clock display, and then selects the sample starting day (1, 2, 3, 4 days hence) and the sample period (10, 15, 20, 30, 40, 60 minutes) using convenient slide switches. The sampler will start sampling when the previously set start time and start day occur. Thereafter, each bag fills for the sample period selected. The bags are filled in sequence. Operation ceases after the last bag is filled.

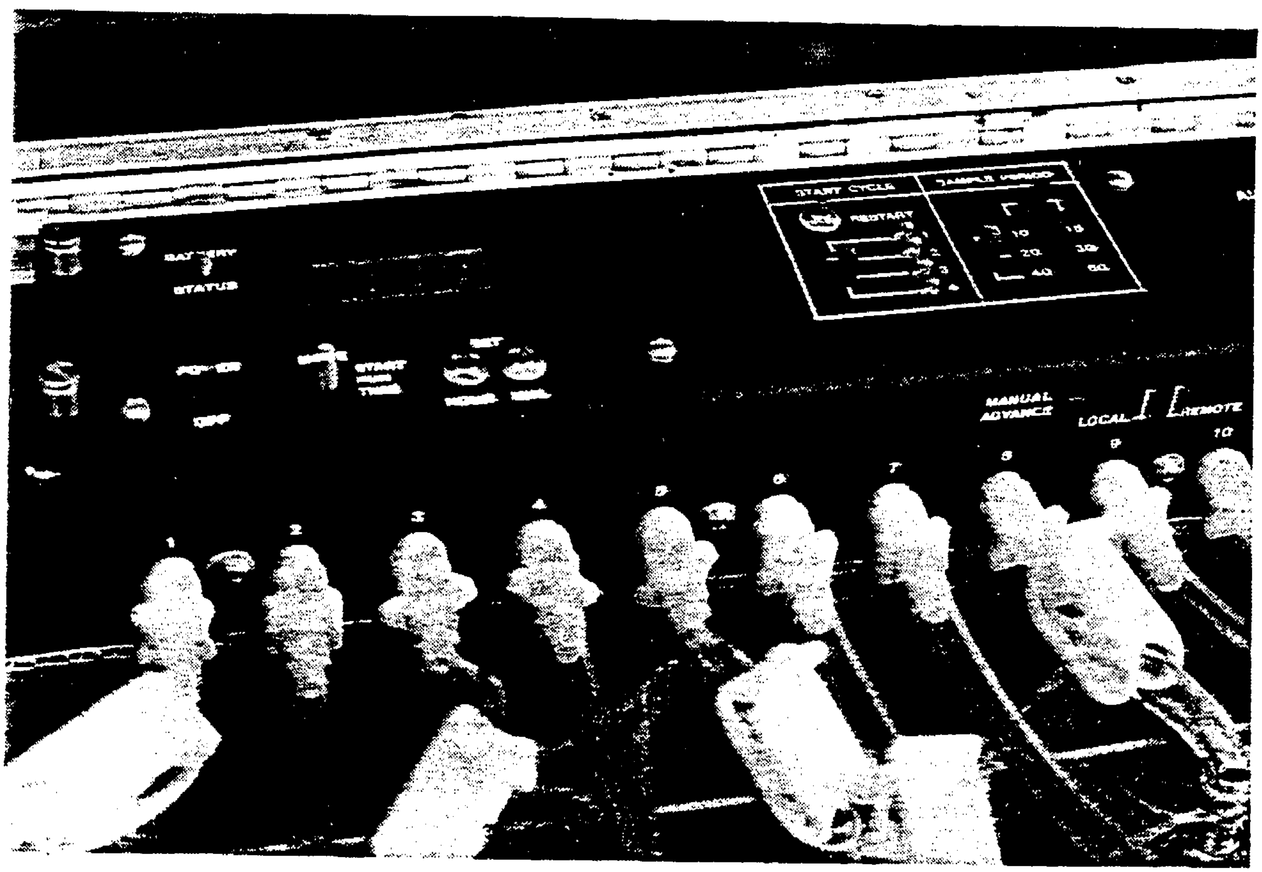


Figure 2-3
View of Chassis

The AQS-III operating switches and indicators as shown in Figure 2-3 include:

Power A switch which connects battery or AC power to the controller.

Battery Status This LED indicator flashes on and off to warn of a low battery (9.6 volts or less). It can be reset by either turning the sampler power off-then-on or by depressing the restart button.

Clock Display A 4-digit liquid crystal display (LCD) indicates either time of day (00:00 to 23:59) hours or sampler starting time (using the same 24-hour time). The mode switch selects the data that will be displayed.

Mode Switch This 3-position switch selects the clock display function. In the **start** position sample start time is displayed. In the **time** and **run** positions the display shows time of day. The time position is selected when the time of day is set.

Set Hour/Minute Buttons When the mode switch is held in the START position, depressing either the hour or minute button advances the clock display to set the sampler starting time. When the mode switch is held in the TIME position, depressing either hour or minute button advances the clock display to set the time of day. When the mode switch is in the RUN position, set time buttons are inactive.

> NOTE: Do not press both hour and minute buttons simultaneously. To do so will reset the clock to 00 hours 00 minutes.

Start Cycle LEDs #1, #2, #3 or #4 indicate the current status of the controller in the four-day sequence. The sampler assumes day-one status the first time the start time occurs. The slide switch selects the day of sampling. For example, if time-of-day is 07:00, start time is 08:00, and switch is in #2 position, the sampler will start operating tomorrow at 08:00, the second time the clock passes 08:00. Initially none of the LEDs will be lit. At 08:00 the #1 LED will come on. At 08:00 the next day #2 LED will come on, #1 will go off, etc.

Restart Depress button to reset sampler to repeat the sampling procedure. This clears the LED status. At the start time #1 will come on. Restart is generally pressed after bags are exchanged and a new start is desired.

Sample Period Depending on the position of the upper (horizontally operating) slide switch, the three-position vertical slide switch will select any single sample period from 10 to 60 minutes. When the sampling period is changed, the pumping rate is automatically affected to maintain the same sample size for the selected sample period.

Manual Advance This push-button switch is recessed to avoid accidental advancing. It is located on the side of the controller and can be used as a pre-sampling check. When pump #1 is activated, depressing this button will advance sampler to activate pump #2. Repeating advances to pump #3, etc. By this means the operator can check to confirm that each pump operates.

Local/Remote This slide switch is recessed for its own protection. It is located on the side of the controller, normally set to the **local** position. If a remote control interface is added (radio control, telephone link, etc.) placing the switch in local position means that the sampler will be activated by its internal time clock, but could be de-activated remotely to abort a sample session. If the switch is in **remote** position, the sampler will start only by the remote control unit.

Power Connector This connector is on the short cable at the bottom of the controller. Connect this to either a 12-volt dc battery pack or other 12-volt dc power supply. The narrow blade on the connector is positive (+), the wider blade is negative (-).

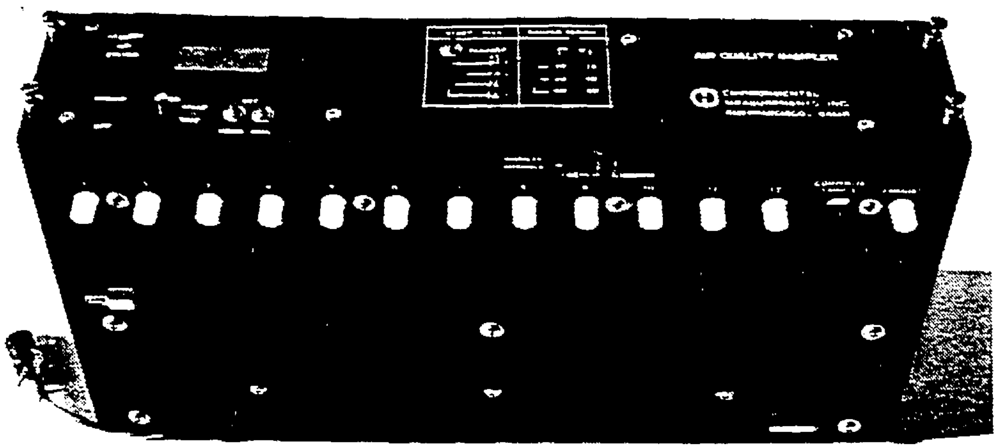


Figure 2-4
Sample Ports and Bag Connections

SAMPLING PORTS

The air flow for the AQS-III consists of the following input/output connections:

Intake Port Gas is collected through this port from the inlet point. The intake port is located at the entrance to the manifold from which all samples are extracted.

Pump Outputs 1-12 Connect the sampling bags to these output ports using the female quick disconnect, part no. 10-3000. See Figure 2-4.

Composite Sample Port The gas collected from this port is a composite sample. It can be used as a qualifier of all gas samples taken during a sampling session. This is an optional item not necessarily installed on all samplers.

Exhaust Port The gas exiting from this port is the exhaust from the sampling manifold. The manifold pump is optional and not necessarily installed on all samplers.

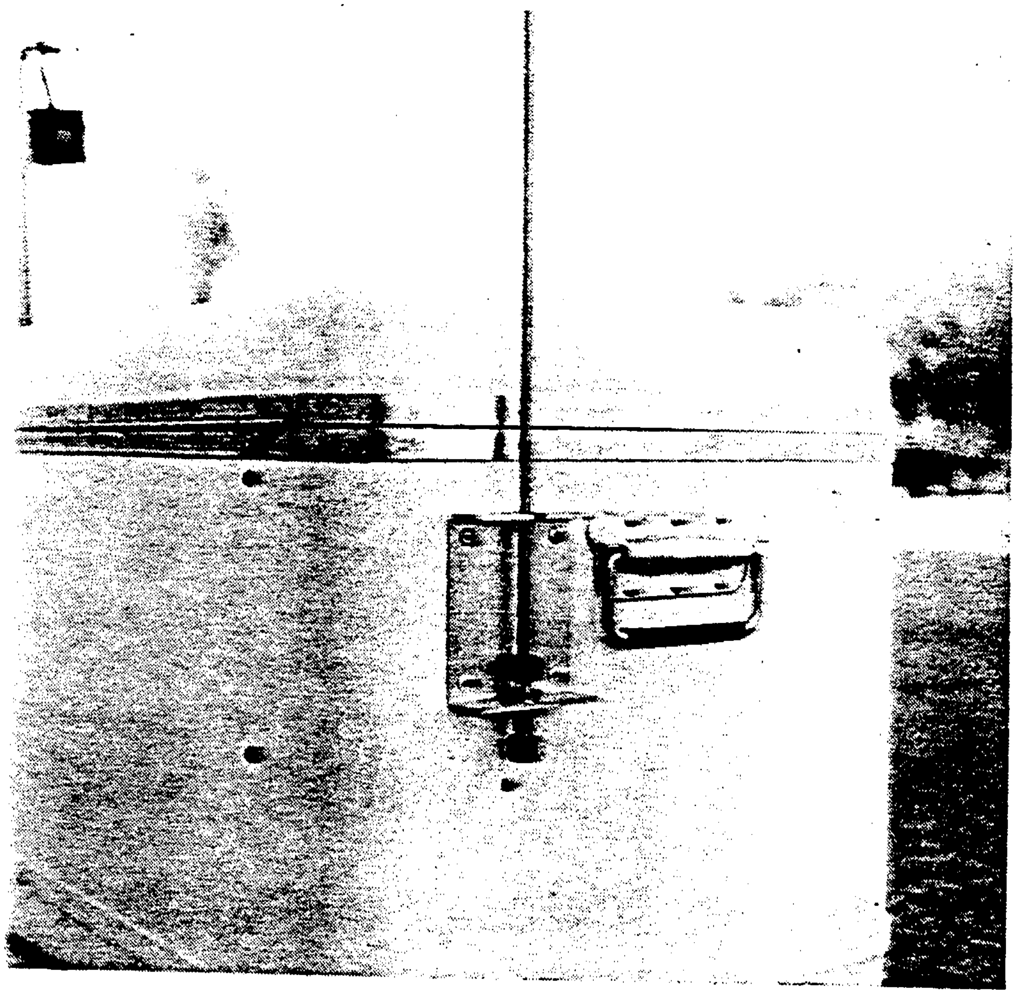


Figure 2-5
Sampling Cane and Cane Mounting Bracket

SAMPLING CANE

Located on the left side of the sampler enclosure (as viewed from the front) is a metal U-shaped bracket with a 1/4-inch swage-type connector. A sampling cane made of stainless steel tubing of 0.18 inch ID is attached to the connector thereby providing an extension of the point at which the air sample is taken. A sampling cane of two meters or less can be used. Different sampling cane lengths may require adjustment of the manifold pump operating time.

SECTION 3

SAMPLER OPERATION

OPENING THE ENCLOSURE

<u>ABS Case</u> Three latches are located on the front of this case. The two outside draw latches are twisted counter-clockwise one-half turn to release and twisted clockwise one-half turn to secure. The center, catch latch is primarily used for padlocking. Raising the lid assembly will expose the sampler control/pump module, power pack and sample Bag Box (or individual sampling bags).

Located on the underside of the lid is the sampling cane assembly. It consists of two one-half meter sections and one cane section.

FITTING THE SAMPLING CANE

The stainless steel 1/4-inch OD sampling cane or other 1/4-inch OD tubing is easily inserted in the mounting flange located on the left of the enclosure. Remove the sampling cane assembly from its storage location in the lid of the enclosure. Assemble to the length desired, placing the cane-shaped section at the top of the assembled unit. Remove the securing clip and insert the sampling cane or tubing with flange nut and ferrule; these two items are attached to the sample cane. Use two suitable wrenches, (one to hold the bulkhead fitting, the other for the flange nut) to tighten the flange nut, being careful not to twist the entire fitting. Place securing clip back into position.

ADJUSTING THE CONTROLLER

<u>Select Sampling Period</u> Note the position of the upper slide switch. If it is in the right-hand position, the location of the vertical three-position switch is indicated by the right-hand column. To set a 30-minute sample period: upper slide switch to right, lower switch in middle position. To select a 10-minute sampling period, locate the upper switch to the left, the lower switch in 10-minute (highest) position.

<u>Start Cycle</u> Select day (24-hour cycle) in which sampling is to occur, position #1 is first 24-hour period following the start time setting, position #2 is second 24-hour period, etc.

Power Supply Cable Connect female and male plug and socket which are on the cables from the controller module and from the power module.

Powering Up Sampler Set the power switch to the power (up) position.

Battery Status If LED indicator is flashing, depress restart button to stop the flashing. If LED continues to flash, this indicates the batteries of the power module are too low for reliable operation and should be recharged.

SETTING THE CLOCK

Sample Start Time Hold mode switch in start position and depress hour or minute button to advance the display. As soon as the desired time is reached, release the button.

Time of Day Hold mode switch in time position and depress hour and minute button as described above to set time of day.

Mode Switch in Run Position Clock is operating normally if colon between hours and minutes (:) flashes every second.

Checking Start Time Hold mode switch in start position to display sample start time.

Restart Button After clock is set, depress the restart button. All electronic counter functions will be reset. This initializes the unit to run the sampling sequence chosen without a false start due to some unpredictable initial condition which may occur when power is first applied. The restart button is used to repeat a sampling sequence conveniently avoiding a complete repeat of the setup.

CONNECTING SAMPLING BAGS

Individual Bags Normally the AQS-III is calibrated to pump 2 liters of air over the selected sampling period. (Other rates can be adjusted at time of ordering or by internal re-calibration.) Attach suitable sized sample bags with female quick disconnect fittings (10mm ID) to their male counterparts mounted on the sampler and numbered 1-12. The position identifies the order in which they will be filled.

OPEN THE PINCH CLAMP OR VALVE LOCATED ON THE BAG.

EMI Bag Box Fitted into a reusable and transportable container, this box contains 12 2-liter sample bags with locator yoke to facilitate bag numbering and mounting to the controller. Open box lid, then set box into sampler taking care to align bag #1 with pump port #1.

Connect tubing as above, release the tubing clamps, rest the box lid on the tubing. Close the sampler lid and the sampler will be environmentally secured for operation.

CLOSING THE ENCLOSURE

Secure the draw latches and lock hasp, if desired. The unit is now ready for operation. As soon as the clock advances to the time-of-day start time, and the proper cycle is activated, the sampler will start. Bag #1 will fill for the set sample period, then bag #2, etc. The system will stop after the last bag is filled. The time-of-day display will continue to indicate correct time.

RETRIEVING THE SAMPLES

When the sampling sequence is complete return to the sampler. First, close the pinch clamp for each bag to prevent any loss of the sample. Then, disconnect the bag input line from the sample by pulling the quick disconnect mating halves apart and remove the filled sample bags.

Place the free tubing length in the EMI Bag Box. Close the lid and secure in place with the velcro latch. Remove the box from the sampler enclosure and transport to the analysis site.

If the EMI Bag Box is not used, be extremely careful to protect the bags for transport to the analysis site.

SECTION 4

CALIBRATION PROCEDURE

REMOVE CONTROLLER

- Disconnect power cable from power supply.
- Remove intake tubing, located on the front of the sampler controller/pump module, by sliding the tubing off the barbed fitting. Hold the fitting securely while pulling on the tubing being removed to avoid damaging the fitting-to-manifold connection.
- Remove the four controller hold-down bolts which pass through the rear of the enclosure; use a suitable flatblade screwdriver. Take care to support the controller while the four screws are removed.
- Pump calibration potentiometers are identified by a silk-screened notation on the rear panel of the controller/pump module.

Place the controller/pump module in an upright position to make the following calibration adjustments.

NOTE: No calibration of the controller digital electronics is necessary. Any questions should be referred to the factory.

PUMP MODULE

Each pump in this module can be adjusted individually to achieve the desired flow rate for the sample volume being gathered. The flow rate is adjusted at the factory and should not require further adjustment under normal conditions. If, however, an adjustment becomes necessary, the following procedure should be followed. Please refer to Figure 4-1.

Sample Pumps (Individual Calibration) Each pump can be adjusted individually by the potentiometers located on the back of the pump module labeled CAL. 1 through CAL. 12. To increase the flow rate, turn the pots clockwise, a few degrees at a time, while measuring the pump output at the sample port with a bubble meter. Since there are 128 pump operations for each pump per sample period, the flow rate per pump operation multiplied by 128 will give the

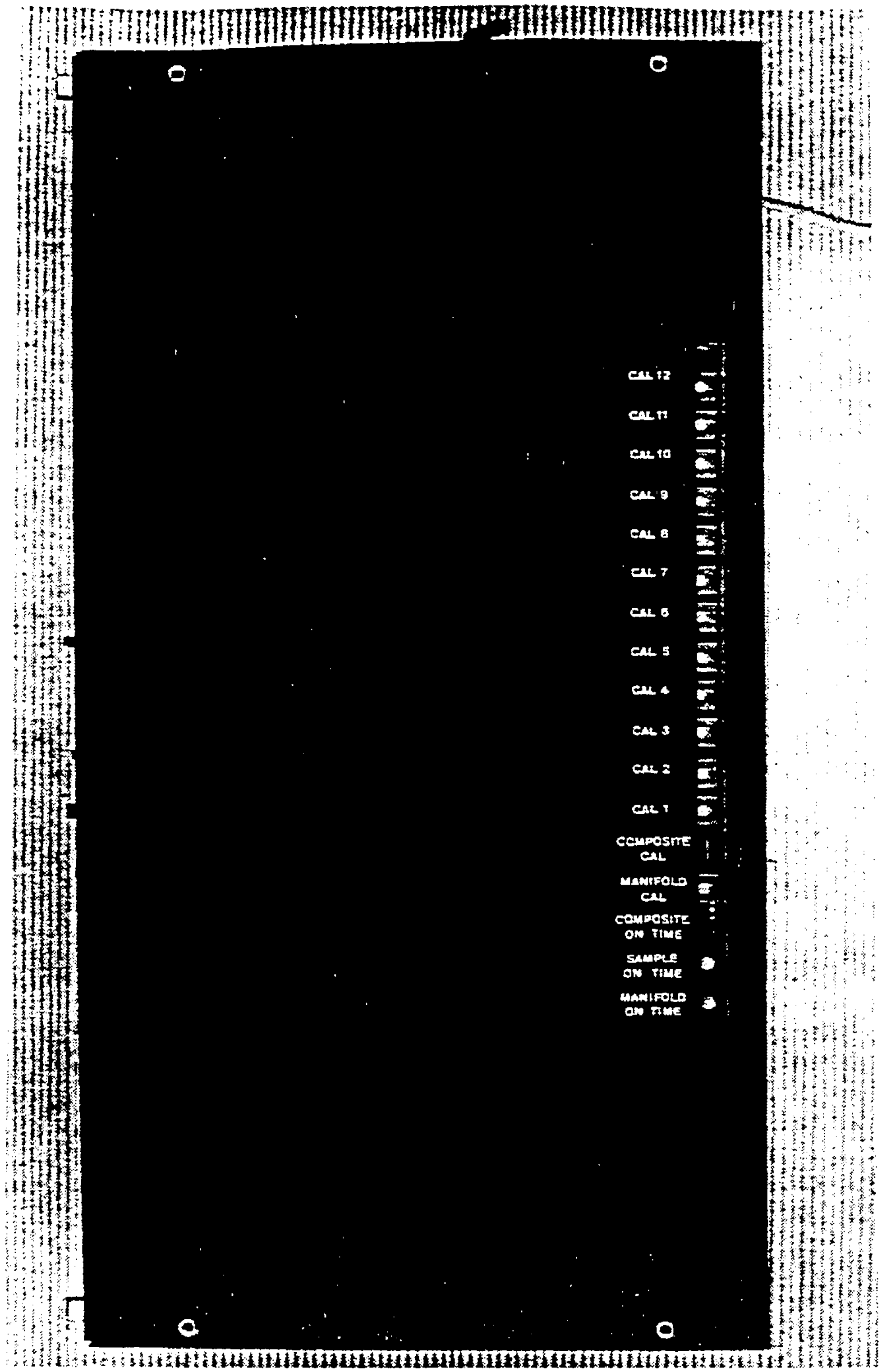


Figure 4-1
Back of Pump Module

total volume of air delivered to that bag during the sampling sequence. A 1-liter bag requires 7.8 ml per pump operation (7.8 ml * 128 = 1 liter).

Manifold/Composite Sample Pump Calibration The manifold and composite sample pumps also have separate flow-rate adjustments. The manifold pump is adjusted at the factory to clear the sampling cane and manifold during one pump operation. Using the following formula, the flow rate can be adjusted if a different cane height (manifold length) is used:

Volume (ml) = 2.4 (2 + cane length in feet).

Measure the output of the sample port with a bubble meter and adjust the CAL. manifold pot to obtain the desired flow. Turning the potentiometer clockwise will increase the flow rate.

Different Flow Rates The sample and manifold "on time" pots will set the length of time that the pumps are on. If the CAL. adjust pots do not have the range to provide the desired flow rate, on times can be adjusted to increase or decrease the flow rate adjust range. The manifold on-time pot, turned counterclockwise, will increase the time the manifold pump is on. A small amount of pot rotation will significantly change the on-time. The sample on-time pot will affect all of the sample pumps together. Adjusting the pot counterclockwise will increase the on-time of each sample pump and, thus, increase the flow rate for all pumps simultaneously.

SECTION 5

TECHNICAL DESCRIPTION

CONTROLLER

The schematic for the controller is provided in Figure 5-1.

In the AQS-III, all timing originates from a 32,768-hz crystal, X1. The real-time clock, A1, provides a buffered 32,768-hz output for timing, a pre-settable start signal to begin the sampling sequence, as well as the direct drive signals necessary to drive a 0.5-inch LCD display. The timing signal is divided by A8 and A9, to provide the necessary pump-drive and pump-advance signals to the pump module. The **start** signal is used to activate the counters and start the sampling sequence. Provision has been made to accommodate remote start and stop input. Other sampling periods and bag volumes can be accommodated with slight modification. The AQS-III controller also features an up-to-96 hour delayed starting time and low battery indicator. The standard controller is designed to drive up-to-24 pumps sequentially, but can be modified to control up-to-144 pumps or other devices.

The 32,768-hz crystal signal is fed directly to the crystal input of A1. Real time and start time are preset with switches Sw-2, Sw-5 and Sw-6. Sw-2 selects one of three modes which are either set time of day, set start time or run. Sw-2 is constructed such that it normally will be in the run mode. The operator presses the switch toggle to either of the time setting modes where the toggle is held in position while Sw-5 or Sw-6 are pressed to advance hours or minutes respectively. Once the correct times have been set the switch Sw-2 automatically returns to the run position. The start time setting is visible on the LCD. It can be checked at any time by putting Sw-2 momentarily to the correct position for viewing the start setting. When the real time and the start time coincide, a start signal will be output to the cycle counter A-5. A-5 will count up to four start signals, 24 hours apart, and will actuate the counting sequence via A-4 and A-7, when the preset cycle has occurred as determined by the setting of Sw-10. A-1 provides all the necessary drive signals for an 0.5-inch LCD display.

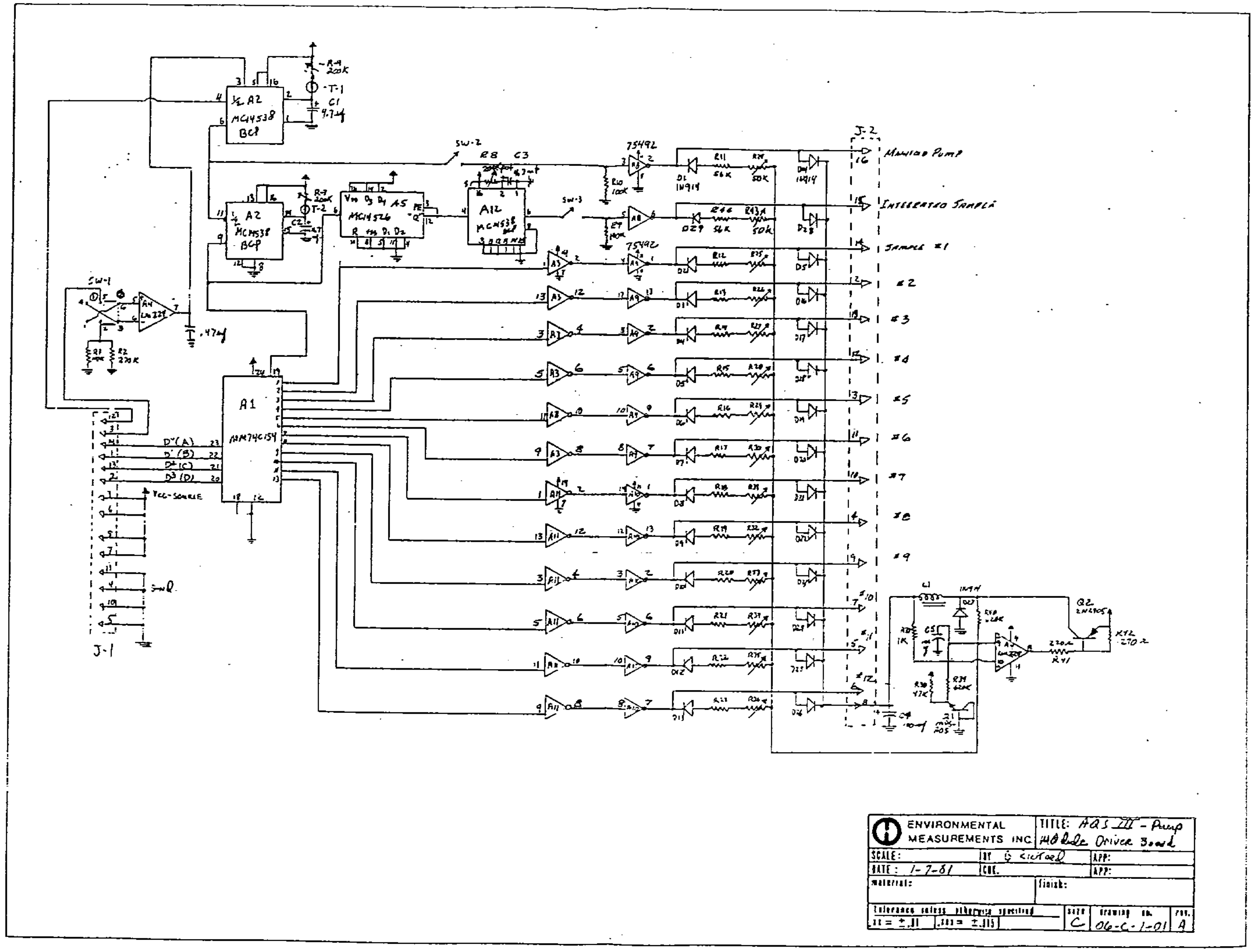
The timing signal originates at the buffered crystal output of A-1 at a 32,768-hz rate. These counting pulses are divided by A-8 and A-9, to provide the necessary timing signals to the pump driver module for pump actuation and for incrementing the pump sequence. Switch 3 selects one of two "divide by" modes for A-8. Dividing by 4800 provides the necessary frequency for 10, 20 and 40 minute sampling. Dividing by 7200, provides for 15, 30 and 60 minute sampling. One half of Sw-4 selects one of three timing signals for pump actuation from the binary counter A-9. The other half of Sw-4 selects one of three pump increment signals to increment the BCD counter A-11 and provide a BCD output corresponding to pumps 1 through 12. The relationship of the timing signals and pump increment signals is maintained by Sw-4, to provide the proper pump drive frequency for each sample period selected. The BCD output of A11-A is used to advance the module select counter (A11-B) and reset A11-A to zero after the first 12 bags have been filled. The module select signal is used to select one of two pump modules: module #1 first and module #2 immediately after, if it is to be used.

The battery voltage level is detected by comparator A-2. When the battery voltage falls below 9.6 volts, A-2 output goes to a logic 0 level and presets A-4 to a logic one level. This condition enables the oscillator section of A-2 to cause LED 5 to flash, indicating a low battery condition.

PUMPS AND PLUMBING

The sampler uses positive displacement DC operated pumps with a stainless steel cylinder, nylon piston and a built-in check valve. Each pump is constructed of hi-density polyethelene, sealed with an inert coating and fitted with a 1/8-inch Tygon™ tubing inlet line. The pumps are arranged in line on a mounting bracket which attaches to the controller faceplate. The inlet line for each pump is attached to a barbed Teflon™ fitting which is attached to a common-line inlet manifold. The air sample is drawn into the manifold by the exhaust pump, and the operating sample pump draws its sample from the manifold. The air sample is delivered from the pump through a check valve (external to pump) to the quick disconnect fitting on the front panel. Bags with corresponding quick disconnect fittings are connected directly to the fittings on the front panel.

The pump module contains all the electronics necessary to drive twelve 1.5vdc pumps, as well as an exhaust pump (refer to Figure 5-2). The controller input connector J-1, supplies the four BCD pump select lines, a module select line, timing pulses, +12 volts and ground. Switch 1 is set to identify the pump module as module #1 or #2. It enables the BCD-to-decimal decoder, A1, as


ENVIRONMENTAL MEASUREMENTS INC
TITLE: AQS III - Pump
Mobile Driver Board
SCALE:
BY G. Kickard
DATE: 1-7-81
CHK.
APP:
APP:
material:
finish:
Tolerance unless otherwise specified
.xx = ±.01
.xxx = ±.005
SIZE C
drawing no. 06-C-1-01
rev. A
J-1
J-2
Manual Pump
Integrated Sample
Sample #1
#2
#3
#4
#5
#6
#7
#8
#9
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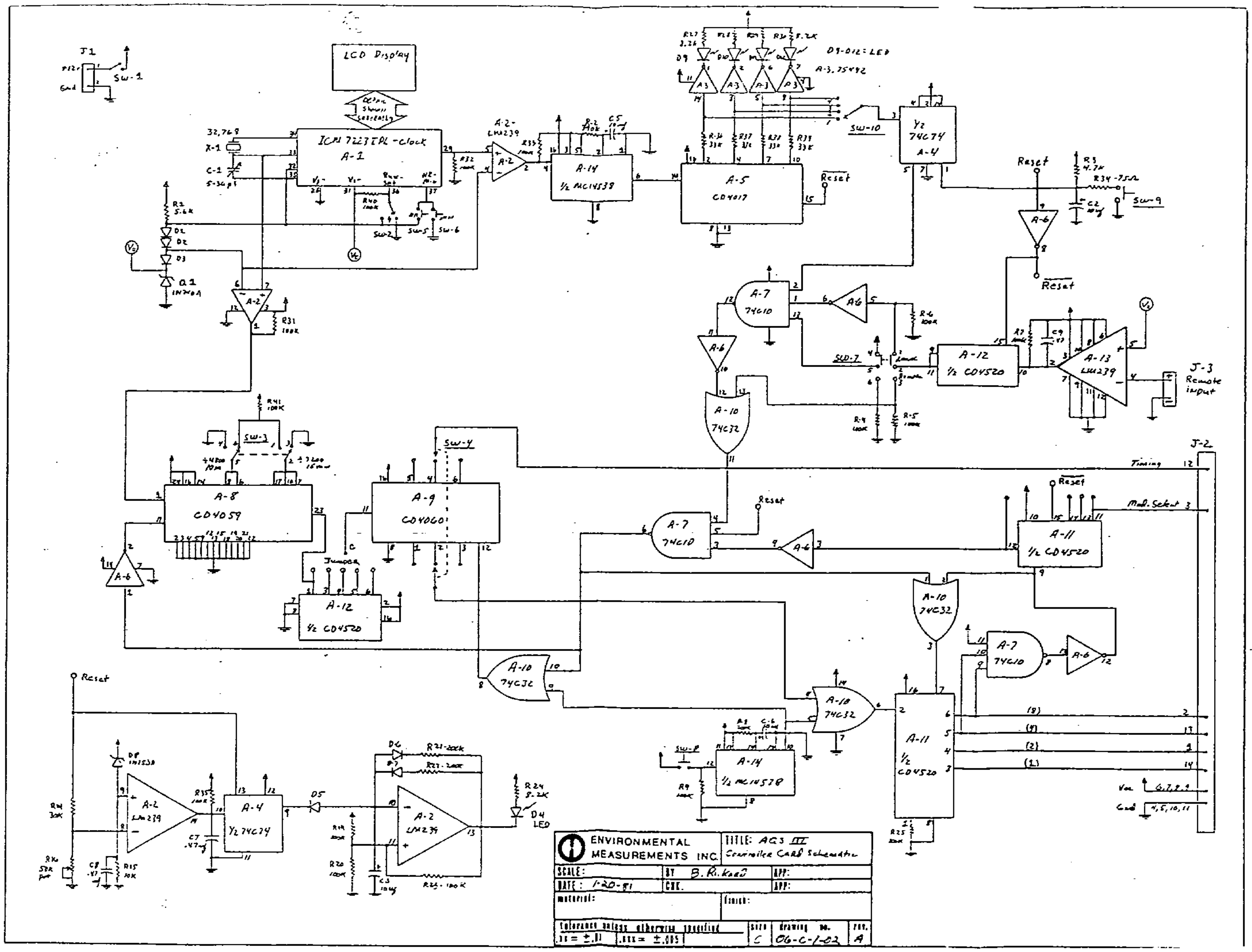
A2
MC14538
BCP
MC14526
A12
75492
SW-1
SW-2
SW-3
VCC-Source
Q2


LCD Display
ICM 7227EPL-clock
A-1
A-2-LM239
A-14
1/2 MC14538
A-5
CD4017
D9-D12: LED
A-3, 75492
SW-10
1/2 74C74
A-4
Reset
SW-9
A-6
A-7
74C10
A-G
SW-7
A-12
1/2 CD4520
A-13
LM239
J-3
Remote input
J-2
Timing
Mod. Select
A-8
CD4059
A-9
CD4060
SW-4
SW-1
Jumper
A-10
74C32
A-11
1/2 CD4520
SW-8
Vcc
Gnd
D4 LED
ENVIRONMENTAL MEASUREMENTS INC.
TITLE: AG3 III Controller Card Schematic
BY B. R. Kued
DATE: 1-20-81
drawing no. 06-C-1-02
rev. A

APPENDIX F

Beckman Model 866 Ambient CO Monitoring System Operations Manual

BECKMAN®

MODEL 866
AMBIENT CO MONITORING SYSTEM

EPA DESIGNATED IDENTIFICATION NUMBER RFCA-0876-012

Beckman Instruments, Inc., Fullerton, CA 92634
October 1976   750953   015-555312   Printed in U.S.A.

CONTENTS

ILLUSTRATIONS

SPECIFICATIONS

RANGE
0 to 50 parts per million CO.

NOISE
0.2 parts per million (one standard deviation as defined by EPA).

TOTAL INTERFERENCE EQUIVALENT
Less than 1.5 parts per million.

ZERO DRIFT
±0.5 parts per million per 12 and 24 hours.

SPAN DRIFT
±1% of fullscale per 24 hours.

ELECTRONIC RESPONSE TIME
0.5 to 26 seconds, field selectable, EPA designated at 13 seconds.

PRECISION
0.2 parts per million (one standard deviation as defined by EPA).

AMBIENT TEMPERATURE LIMITS
32°F to 120°F (0°C to 50°C). EPA designated at 68°F to 86°F (20°C to 30°C).

ELECTRICAL POWER REQUIREMENTS
115 ±10 volts rms, 50/60 Hz ±0.3 Hz (EPA designated at 60 Hz ±0.3 Hz), 500 watts maximum.

OUTPUTS
10 millivolts, 100 millivolts, 1 volt, 5 volts; 4 to 20 milliamperes optional.

SECTION ONE INTRODUCTION

1.1 DESIGNATION BY THE ENVIRONMENTAL PROTECTION AGENCY

Section 110 (a) (2) (c) of the Clean Air Act of 1970 provides in part that any state implementation plan must include ". . . provision for establishment and operation of appropriate devices, methods, systems and procedures necessary to monitor, compile and analyze data on ambient air quality . . . " This provision has been amplified to require that plans must provide for the establishment of air quality surveillance systems. Each such system used by a state must be either the appropriate reference method or a method that is "equivalent" to the reference method. To assist the State and local governments, the Environmental Protection Agency has designated the Beckman Ambient CO Monitoring System as a reference method when maintained and operated in accordance with this instruction manual. Any reference to "designation" throughout the manual refers to the above-mentioned designation of the system by the Environmental Protection Agency.

The designation is applicable under the following conditions:

Range: 0 to 50 parts per million CO

Electronic Response Time: 13 seconds to 90% of final reading. (See Figure 3-4 for settings.)

Automatic Standardization: One complete zero/span standardization sequence every 24 hours, plus separate zero standardization sequences at intervals of 4 hours. Internal clock frequency set at 16 Hz, resulting in a duration of 5 minutes 30 seconds for the auto zero/span sequence.

Ambient Temperature: 68°F to 86°F (20°C to 30°C)

Electrical Power Source: 115 ±10 volts rms, 60 ±0.3 Hz

Outputs: 10 millivolts, 100 millivolts, 1 volt, 5 volts standard; 4 to 20 milliamperes optional; linearized output optional.

1.2 THE BECKMAN AMBIENT CO MONITORING SYSTEM

The Beckman Ambient CO Monitoring System automatically and continuously analyzes ambient air for carbon monoxide, and provides automatic, periodic, zero/span standardization, to permit long-term unattended service. The analysis is based on a differential measurement of the absorption of non-dispersed infrared energy.

As shown in Figure 1-1, the system consists of four interconnected units:

1. Pump/Sample-Handling Module, Paragraph 1.2.1.
2. Gas Control Panel, Paragraph 1.2.2.
3. Analyzer Unit, Paragraph 1.2.3.
4. Automatic Zero/Span Standardizer, Paragraph 1.2.4.

1.2.1 PUMP/SAMPLE-HANDLING MODULE

The Pump/Sample-Handling Module consists of a

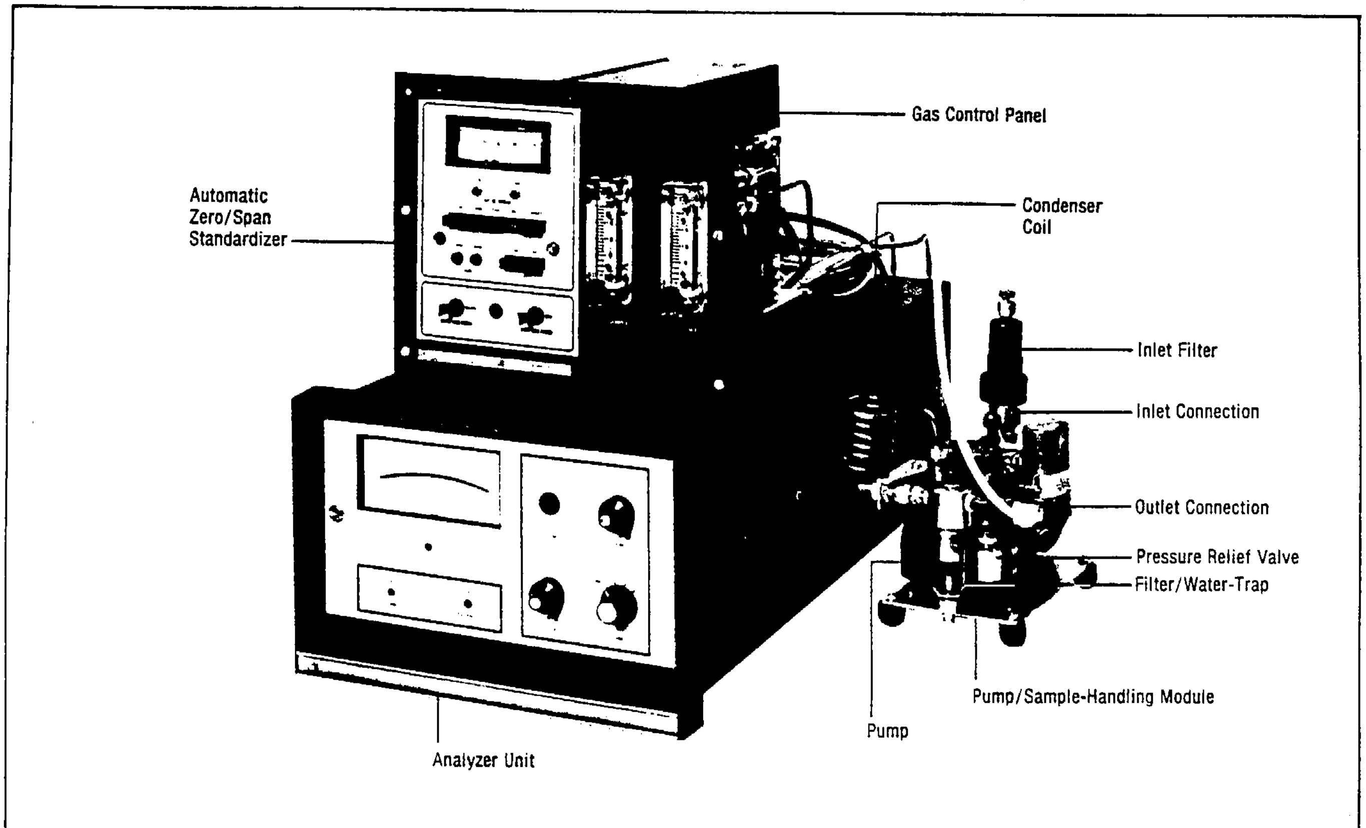


Figure 1-1. Model 866 Ambient CO Monitoring System

diaphragm-type pump with associated inlet and outlet filters, and pressure relief valve. The module intakes ambient air and supplies a constant stream to the Gas Control Panel, Paragraph 1.2.2.

1.2.2 GAS CONTROL PANEL

The Gas Control Panel receives ambient air from the Pump/Sample-Handling Module (Paragraph 1.2.1) and upscale standard gas from an external cylinder, not supplied. The panel routes gases appropriate to the operating mode to the sample and reference cells of the analyzer unit (Paragraph 1.2.3). Flow mode is determined by the status of two solenoid valves, actuated by the Automatic Zero/Span Standardizer (Paragraph 1.2.4). There are three flow modes:

1. SAMPLE Mode — The sample cell of the analyzer receives ambient air sample containing carbon monoxide; the reference cell receives CO-free air, obtained by passing ambient air through a catalytic converter where the CO is converted into CO_2.
2. ZERO Mode — *Both* cells of the analyzer receive the CO-free air.
3. SPAN Mode — The sample cell receives upscale standard gas from a cylinder; the reference cell receives CO-free air.

The panel incorporates flowmeters, flow adjustment valves, and filters for sample and reference sides of the analyzer.

1.2.3 ANALYZER UNIT

Within the analyzer, two infrared beams are directed through sample and reference flowthrough cells. During sample analysis, the sample cell receives ambient air containing carbon monoxide, while the reference cell receives CO-free air. Composition of the gas in the two cells is very similar except for carbon monoxide content. Solid-state electronic circuitry continuously measures the *difference* between the amounts of infrared energy absorbed in the two cells. This difference is a measure of the concentration of carbon monoxide in the sample. The analyzer provides a 0 to 5 volts d.c. output, which is routed through the Automatic Zero/Span Standardizer (Paragraph 1.2.4) to the recorder.

Upon initial startup, and at periodic intervals thereafter, the system requires dynamic multipoint calibration per Paragraph 3.2. The resultant calibration curve may be used to convert recorder readings into CO concentration values. Alternatively, the analyzer unit may utilize an optional plug-in linearizer circuit board to equip a given operating range for linear readout of concentration values on the recorder chart. The linearizer board, if used, may be calibrated for either the *designated* range of 0 to 50 parts per million CO, or for a *non-designated* range involving higher CO concentrations; e.g., 0 to 100 parts per million CO.

1.2.4 AUTOMATIC ZERO/SPAN STANDARDIZER

The Automatic Zero/Span Standardizer provides automatic, periodic standardization of the system. At preselected times, the standardizer automatically gates CO-free zero air to the sample cell of the analyzer and corrects the recorder readout to zero (or preselected offset value, typically between +3% and +5% of fullscale), then gates an upscale standard gas to the sample cell and corrects the recorder readout to the appropriate value. Duration of the automatic standardization sequence is factory-set for five minutes 30 seconds. No other setting is designated for ambient CO monitoring.

During normal automatic operation, a built-in cam-operated timer initiates one complete zero/span standardization sequence every 24 hours, plus separate zero standardization sequences at intervals of four hours. No other settings are designated for ambient CO monitoring.

Two toggle switches on the standardizer front panel are used for *manual* selection of zero and span gas flow modes, when desired. Afterwards, both switches should be returned to AUTO position.

Recorder Output Provisions of the Standardizer

A field-selectable output for a potentiometric (voltage) recorder is provided as standard. An isolated 4 to 20 milliamperes current-output is obtainable through use of an optional plug-in circuit board.

Standardizer Output Modes

Rear-panel switches permit selection of either of two standardizer output modes:

1. STD (standard) output mode permits recorder response at all times, including during automatic standardization sequences. If an appropriate chart speed is used, the recorder trace will indicate the amount of zero and span correction applied during each automatic standardization sequence.
2. S/H (sample-and-hold) output mode prevents recorder response during auto standardization sequences. During these sequences, the recorder output remains at the last-recorded *sample* value. This mode is required with certain data-acquisition systems.

SECTION TWO INSTALLATION

2.1 FACILITY PREPARATION

2.1.1 OUTLINE AND MOUNTING DIMENSIONS
For mounting dimensions, refer to Figure 2-1.

2.1.2 ELECTRICAL INTERCONNECTION DIAGRAM
Electrical connections are shown in Figure 2-2.

2.1.3 FLOW DIAGRAM
Gas connections are shown in Figure 2-3.

2.1.4 LOCATION

Analyzer Unit
Preferably, the analyzer unit should be mounted near the sampling point, to minimize transport time. The site must be free of any appreciable vibration. (Within the analyzer unit, the entire optical system is on a shock-mounted plate, to minimize response to vibration. The shock-mounted plate has suspension adjustments to permit minimizing vibration effects. If, during subsequent operation, the analyzer exhibits *excessive* sensitivity to vibration, suspension should be adjusted per Figure 7-3.)

A thermistor-controlled heating circuit holds internal temperature of the analyzer to the correct operating level for ambient temperatures within the specified range.

Recorder
Preferably, the recorder should be near enough to the analyzer and standardizer, and so oriented, that the operator can easily observe response to adjustment of the controls. A ten-foot (3m) recorder output cable is provided as standard.

2.1.5 UTILITY SPECIFICATIONS
Electrical power requirements are:

Voltage
115 ±10 volts rms.

Frequency
The system is designated for operation on 60 ±0.3 Hz. It may be operated on 50 ±0.3 Hz, but is not designated for use on this frequency.

Maximum Power Consumption
500 watts.

2.2 GAS CONNECTIONS
Gas connections are shown in Figure 2-3.

2.2.1 SAMPLE LINES
As shown in Figure 2-3, the system requires two sample lines:
1. Line from the ambient sampling point, or the sampling manifold, to the inlet fitting of filter F1 on the Pump/Sample-Handling Module.
2. Line from the outlet of the Pump/Sample-Handling Module to the sample inlet of the Gas Control Panel.

Recommendations for both sample lines are: ¼-inch tubing; plastic or solvent-cleaned stainless steel, copper, or aluminum. The lines should be as short as practicable, total length not over 20 feet (6.1 m).

2.2.2 SPAN GAS REQUIREMENTS AND CONNECTION

Span Gas Composition
The working standard gas used for automatic span standardization should have a CO content that corresponds to a recorder reading of approximately 85% to 95%. The CO concentration should be known to within ±1%, and should be traceable to the National Bureau of Standards (NBS). The CO should be in *air* background gas, which should also contain approximately 350 parts per million of CO_2.

Note that the required concentration of CO in the working standard depends on the characteristics of the *recorder zero:*
1. Preferably, the recorder should have *below-zero* capability, to permit observation of *downscale* zero drift. The 0 parts per million CO level is set at the 0% ordinate on the chart, and the 50 parts per million CO level is set at the 100% ordinate. Thus the working standard should contain *42 to 48 parts per million CO.*
2. If the recorder does *not* have below-zero capability, the capability of observing downscale zero drift is obtainable by setting the 0 parts per million CO level at between +3% and +5% of fullscale. Thus if the 0 parts per million CO level is set at the +5% ordinate, the 100% ordinate would correspond to 47.5 parts per million CO, and the working standard should contain *40 to 45 parts per million CO.*

The required zero offset should be obtained with the *recorder* zero adjustment, if provided. If the recorder does *not* have adjustable zero, the offset is obtained by insertion of an appropriate resistance into the zero-correction circuitry of the Automatic Zero/Span Standardizer. Refer to Paragraph 2.3.4.

Span Gas Cylinders
Span gas should be supplied from a suitable cylinder. Untreated steel cylinders are unsuitable, as CO reacts with the cylinder walls.

Specially treated aluminum cylinders, available from various suppliers, are recommended.

Span Gas Connection
Connect the span gas to the appropriate inlet on the Gas Control Panel, Figure 2-3. Set cylinder regulator for output pressure of 10 psi (69 kPa).

2.2.3 SAMPLE OUTLET CONNECTIONS
Sample and reference cells discharge from the sample outlet fittings on the analyzer unit, Figure 2-1.

WARNING

During span standardization, the sample cell discharges approximately 50 parts per million of CO, a toxic gas. Therefore, sample outlet should be vented to a well ventilated area.

2.3 STANDARDIZER SETUP AND CONNECTIONS

2.3.1 STANDARDIZER OUTPUT MODE SELECTION
On MET/REC Switch SW8, Figure 3-6, close the contact appropriate to the desired standardizer output mode:
1. STD (standard) output mode permits recorder response

A. BRACKET & HARDWARE FOR PANEL MOUNTING SUPPLIED BY BECKMAN.
B. RECORDER CABLE, 10 FT. (3m) LONG SUPPLIED BY BECKMAN.
C. SAMPLE INLET (SWAGELOK BULKHEAD FITTING FOR 1/4 (6 mm) O.D. TUBING).
D. SAMPLE OUTLET (SWAGELOK BULKHEAD FITTING FOR 1/4 (6 mm) O.D. TUBING).
E. 120 VAC INPUT (SUPPLIED BY BECKMAN).
F. SOURCE VOLTAGE ADJUSTMENT.
G. BUMPERS SUPPLIED FOR BENCH MOUNT APPLICATION, OPTIONAL.
H. OPTIONAL PURGE KIT (1/4-18 FPT).
J. SCRUBBER INLET & OUTLET (SWAGELOK BULKHEAD FITTING FOR 1/4 (6mm) O.D. TUBING).

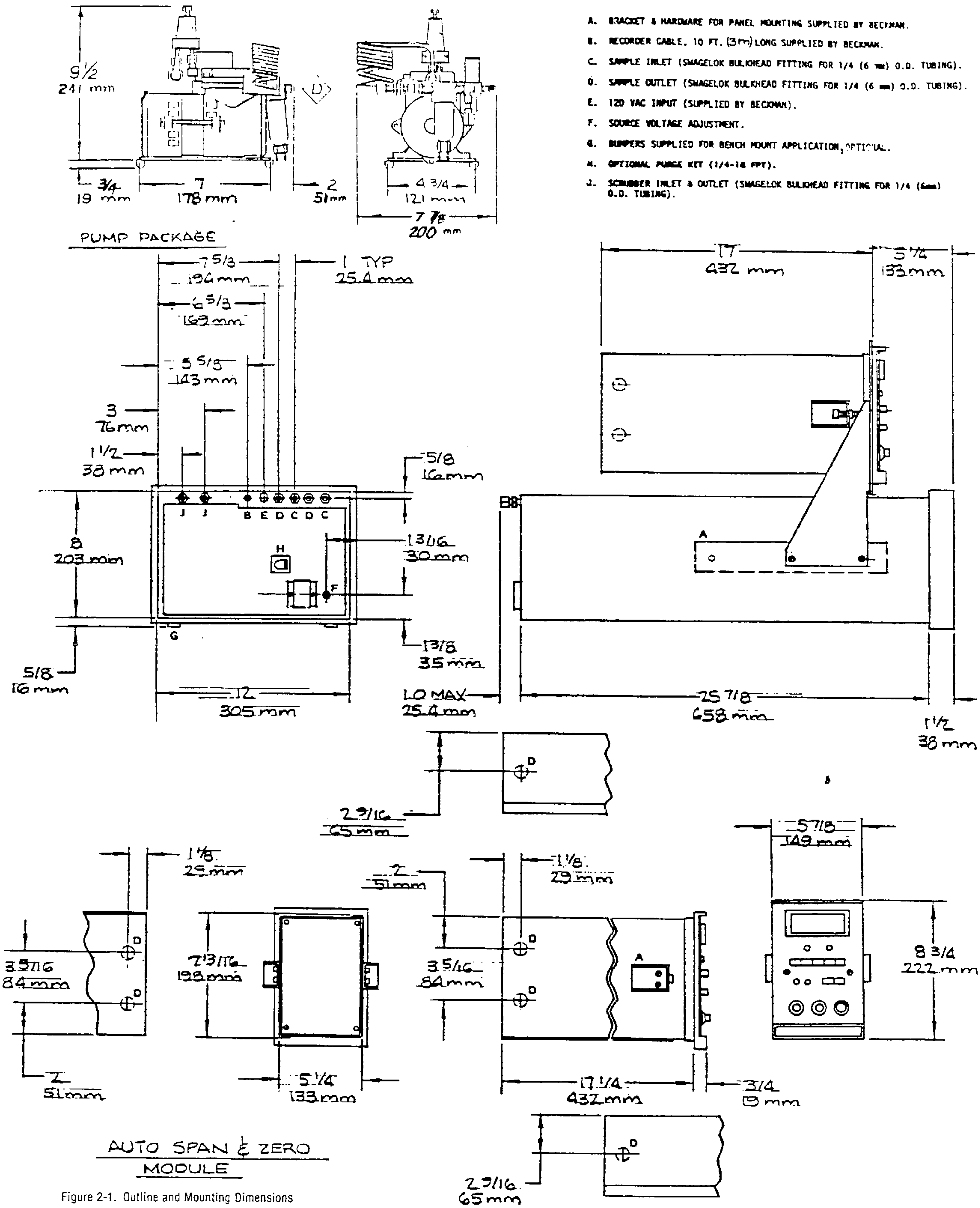
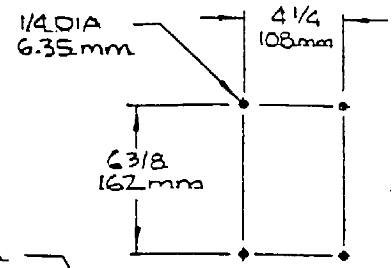
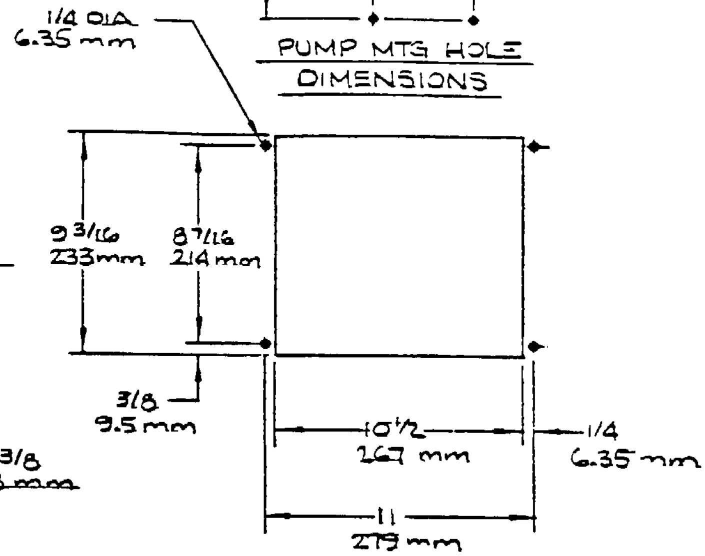


Figure 2-1. Outline and Mounting Dimensions

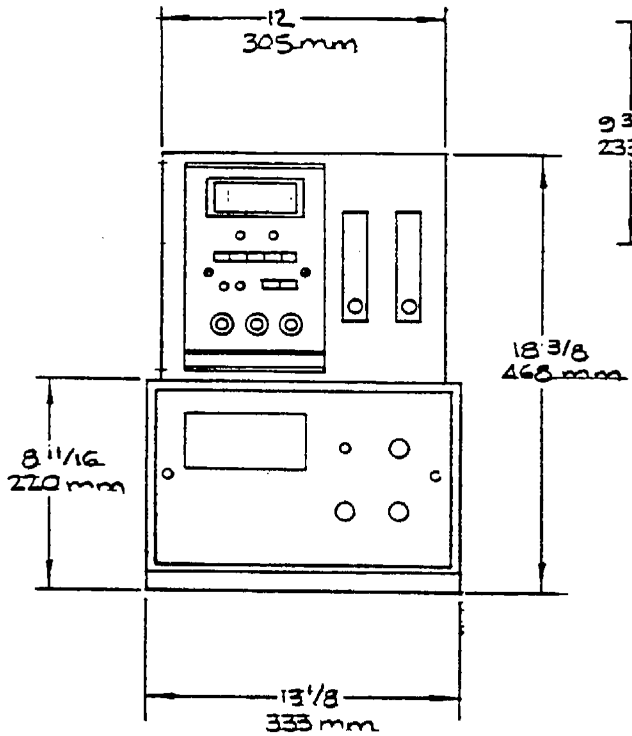
1. ALL DIMENSIONS IN INCHES ± 1/16, MILLIMETERS ± 1.5 MM.
2. ALLOW CLEARANCE IN REAR FOR INFREQUENT MAINTENANCE.
3. UNIT NOT WEATHERPROOF.
4. WEIGHT APPROX: 57 LBS. (26 KG).
5. 120 VAC 50/60 HZ.
6. ALLOW EXTRA CLEARANCE FOR TUBING HOOKUP.
7. ALLOW 19 3/8 (493 mm) FOR CHASSIS EXTENSION.



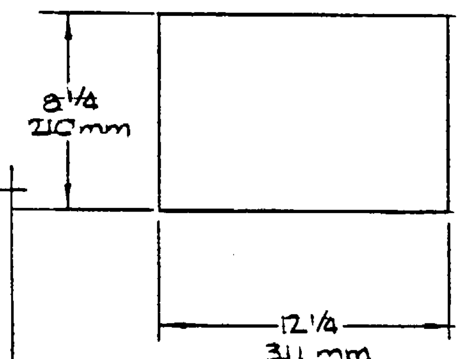
PUMP MTG HOLE DIMENSIONS



PANEL CUTOUT FOR AUTO SPAN & ZERO CONTROL PANEL



NDIR ANALYZER WITH AUTO SPAN & ZERO MODULE



PANEL CUTOUT FOR NDIR ANALYZER MODEL

NOTES FOR AUTO SPAN & ZERO

A. BRACKET AND HARDWARE FOR PANEL MOUNTING SUPPLIED BY BECKMAN.
B. RECORDER CABLE, 10 FT. (3m) LONG SUPPLIED BY BECKMAN.
C. 120 VAC CABLE SUPPLIED BY BECKMAN.
D. SIX KNOCKOUTS FOR 3/4 INCH CONDUIT FITTINGS.

1. ALL DIMENSIONS IN INCHES ± 1/16, MILLIMETERS ± 1.5 MM.
2. ALLOW CLEARANCE IN REAR FOR INFREQUENT MAINTENANCE.
3. UNIT NOT WEATHERPROOF.
4. WEIGHT APPROX: 15 LBS. (6.8 Kg).
5. 120/240 VAC 50/60 HZ.
6. ALLOW 15 (381 mm) FOR CHASSIS REMOVAL.

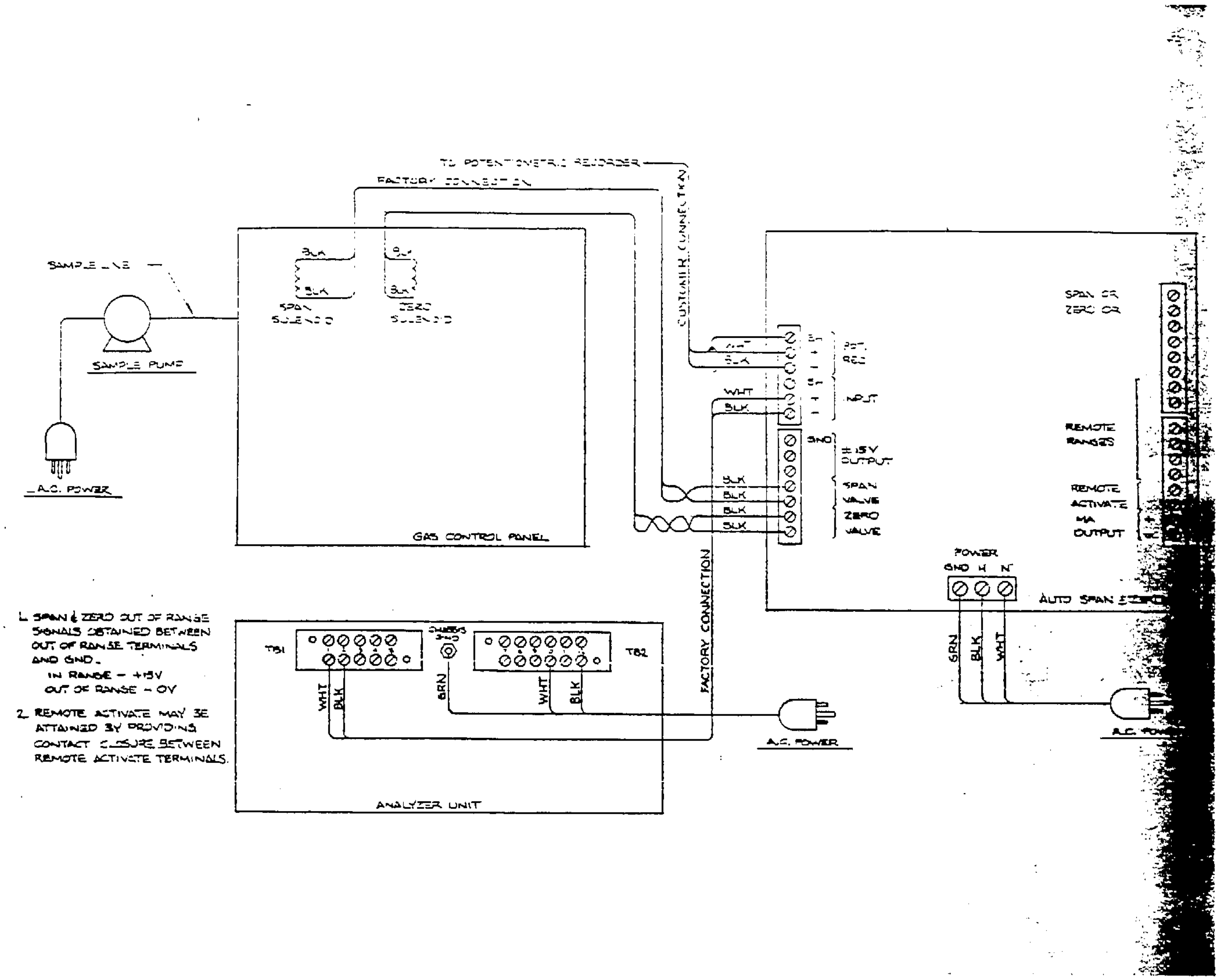


Figure 2-2. Electrical Interconnection Diagram

at all times, including during automatic standardization sequences. If an appropriate chart speed is used, the recorder trace will indicate the amount of zero and span correction applied during each automatic standardization sequence.

2. S/H (sample-and-hold) output mode prevents recorder response during auto standardization sequences. During these sequences, the recorder output remains at the last-recorded *sample* value.

2.3.2 STANDARDIZER OUTPUT SELECTION AND RECORDER CABLE CONNECTIONS

If *voltage* output is desired, perform the following steps:

1. On MET/REC Switch SW8, Figure 3-6, close the switch contact appropriate to the desired output: 0.01, 0.1, 1, or 5 volts. The other three contacts must be in OFF position. In factory checkout, the 0.1 volt output is selected.
2. Verify that recorder cable has been factory-connected to rear-panel REC terminals: (+), (−), and SHIELD. Note color coding of cable leads, as shown in Figure 2-2.

If standardizer is equipped with 636270 Current Output Board, a 4 to 20 milliamperes current output is obtainable by connecting the recorder cable to the rear-panel CURRENT OUTPUT (+) and (−) terminals.

2.3.3 ZERO AND SPAN OUT-OF-RANGE SIGNALS

Out-of-range signals, for use by a computer, are available on the standardizer rear panel, Figure 2-2.

The zero out-of-range signal is obtained between the ZERO O.R. terminal and ground.

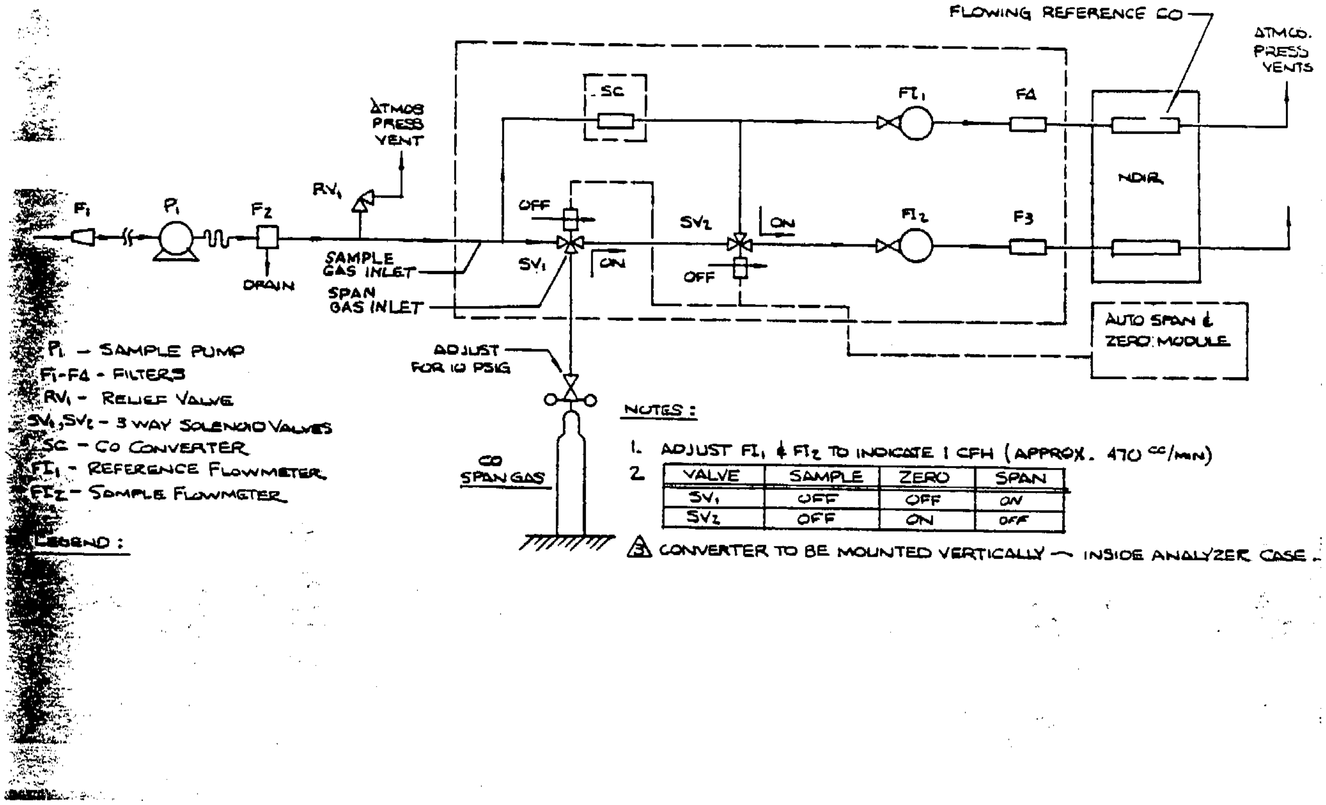


Figure 2-3. Flow Diagram

The span out-of-range signal is obtained between the SPAN O.R. terminal and ground.

Signal voltages are: in-range signal, +13 volts; out-of-range signal, 0 volts.

2.3.4 ZERO OFFSET CAPABILITY OF STANDARDIZER

If the recorder does not have *either* below-zero capability *or* adjustable zero, the standardizer should be set to provide a zero offset of between +3% and +5% of fullscale. Refer to Paragraph 2.2.2.

To obtain the desired offset, an appropriate resistance (designated R48) must be inserted between circuit ground and input 10 of AR1C, Figure 9-11.

R48 = 200 ohms × desired offset, % of fullscale.

EXAMPLE

For 5% offset, R48 = 1000 ohms.

2.4 A.C. POWER CONNECTIONS

As shown in Figure 2-2, the system has three power cords, one each for the analyzer unit, standardizer, and pump/sample-handling module. The power cords are equipped with three-pronged grounded-type plugs, and should be connected to matching three-wire, grounded-type receptacles.

Line voltage should be 115 ±10 volts. The system is designated for operation on 60 ±0.3 Hz. It may be operated on 50 ±0.3 Hz, but is not designated for use on this frequency.

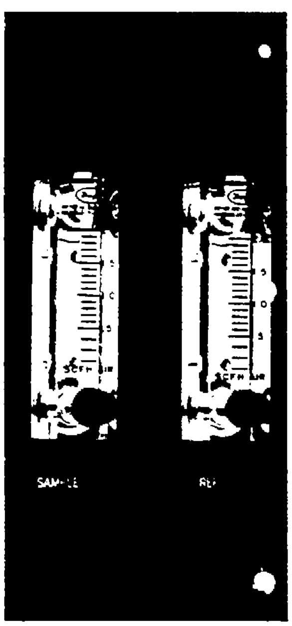
SECTION THREE STARTUP

Figures 3-1 through 3-7 give locations and brief descriptions of controls and adjustments. Preparatory to startup and operation, a thorough familiarization with these figures is recommended. For more detailed information on control functions, refer to Section Five.

3.1 SYSTEM STARTUP

1. With *analyzer* power cord disconnected, verify that front-panel meter of analyzer unit reads zero. If not, adjust Meter Mechanical Zero Screw for zero reading.
2. Connect analyzer power cord. On analyzer front panel, turn RANGE Switch to position 3. Allow analyzer to warm up for at least two hours, and preferably for eight hours. Analyzer is operable immediately after connection to a.c. power, but drifts at first and requires several hours to equilibrate completely.
3. Check analyzer tuning:
   a. Turn RANGE Switch to TUNE.
   b. If instrument has been in routine operation, compare present reading on analyzer meter with previous readings obtained in TUNE mode. Present and past readings should agree to within two of the smallest scale divisions; if so, oscillator is properly tuned; proceed directly to Step 4.

      If analyzer *has not* yet been in operation, or if reading in TUNE mode is not within the acceptable limits, tune oscillator per Steps 3c through 3e following.



NOTE
Normal setting for both flowmeters is 1 CFH (approximately 470 ml/min).

Figure 3-1. Operating Controls on Gas Control Panel

   c. Slide analyzer chassis forward, partially out of the case. Reach behind analyzer front panel, slightly above hole marked OSC TUNE. With the fingers, grasp the small knob on the oscillator tuning adjustment shaft. Turn knob to the *counterclockwise* limit. Then, turn *clockwise* until peak reading is obtained on meter. For accurate determination of maximum reading, approach this peak from both directions.
   d. Turn OSC TUNE Adjustment *counterclockwise* until meter reading decreases to between 70% and 75% of the maximum obtainable value noted in Step 3c. Oscillator is now properly tuned.
   e. Return RANGE Switch to position 3.
4. Check for Proper Tracking of *Standardizer* Meter:
   a. On standardizer, depress POWER ON and METER SELECT INPUT Pushbuttons. The front-panel meter of the *standardizer* will now indicate the output from the *analyzer*.
   b. Adjust front-panel ZERO Control on analyzer so that *analyzer* meter reads 100%. Front-panel meter on *standardizer* should also read 100%; if not, obtain 100% reading via Meter Adjustment Potentiometer, Figure 3-7.

NOTE

During the remainder of the procedure, readings may be taken on the front-panel meter of either the analyzer or the standardizer.

5. Check Analyzer Bias Adjustment:

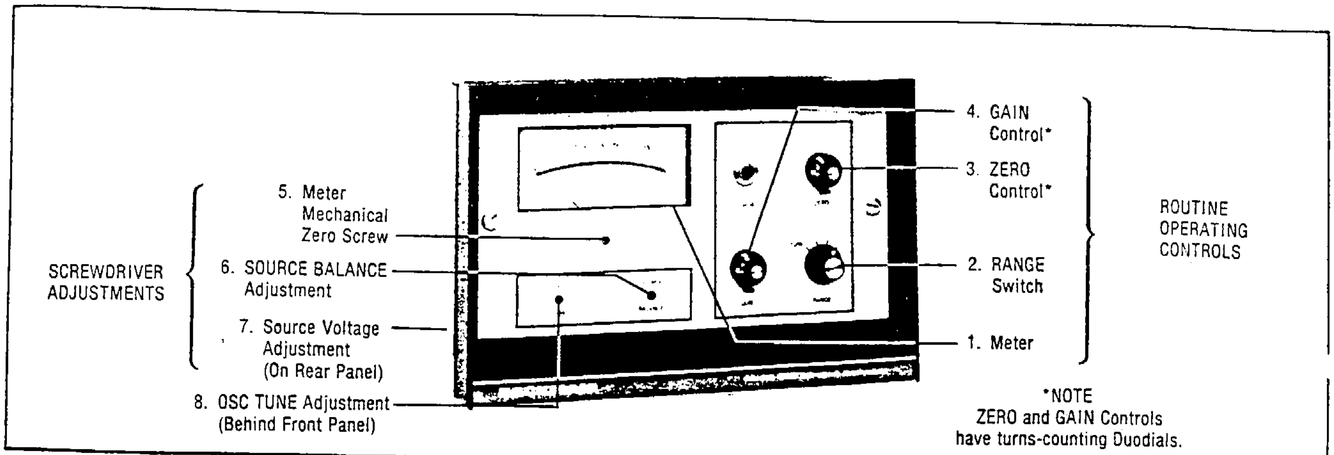
NOTE

Component electronic offsets will shift slightly as the interior temperature of the analyzer changes. For this reason it is recommended that, immediately prior to adjustment of the Bias Controls, the analyzer be allowed to run with case closed for at least several hours. If subsequently bias level drifts slightly, correct instrument operation and readings will still be obtained. The only effect will be the introduction of a small interaction between the ZERO and GAIN Controls.

   a. Set analyzer front-panel controls: GAIN Control at counterclockwise limit to remove all signal from input of amplifier; ZERO Control at clockwise limit to remove all compensation for normal optical offset signal; RANGE Switch at position 3.
   b. Within the analyzer, locate the D.C. Amplifier Board, Figure 3-4. Set Switch SW3 to RUN. Adjust Coarse Bias Control R33 until meter reads 50% of fullscale, or, if this is unobtainable, until maximum reading is obtained.

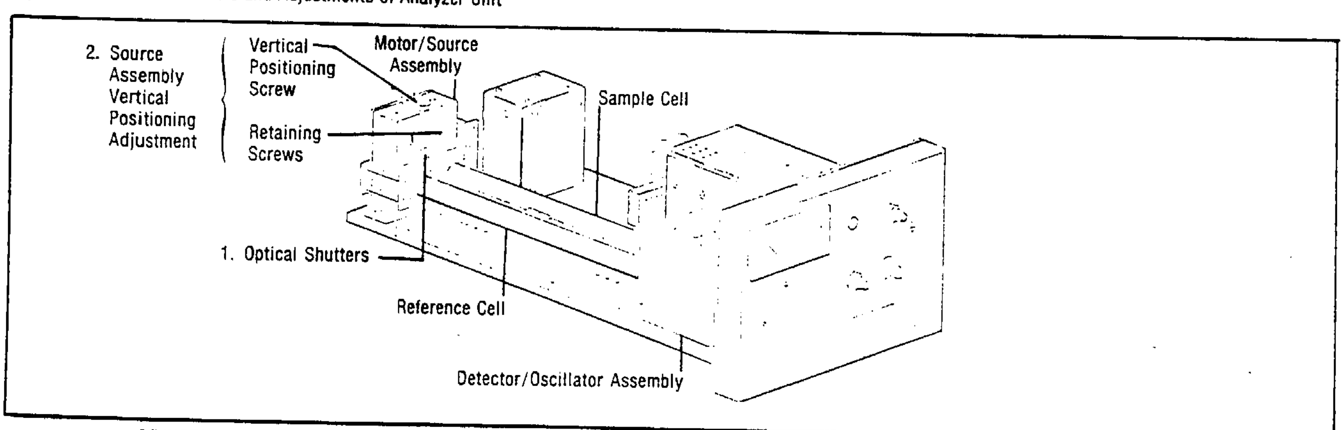
      Next, adjust Fine Bias Control R34 back and forth to determine the extreme meter readings obtainable. (If meter goes offscale, consider end of scale to be the extreme.) Then, set R34 so meter reads approximately midway between these extremes.

      Readjust Coarse Bias Control R33 until meter reads approximately zero. Then, readjust Fine Bias Control R34 so meter reads exactly zero.



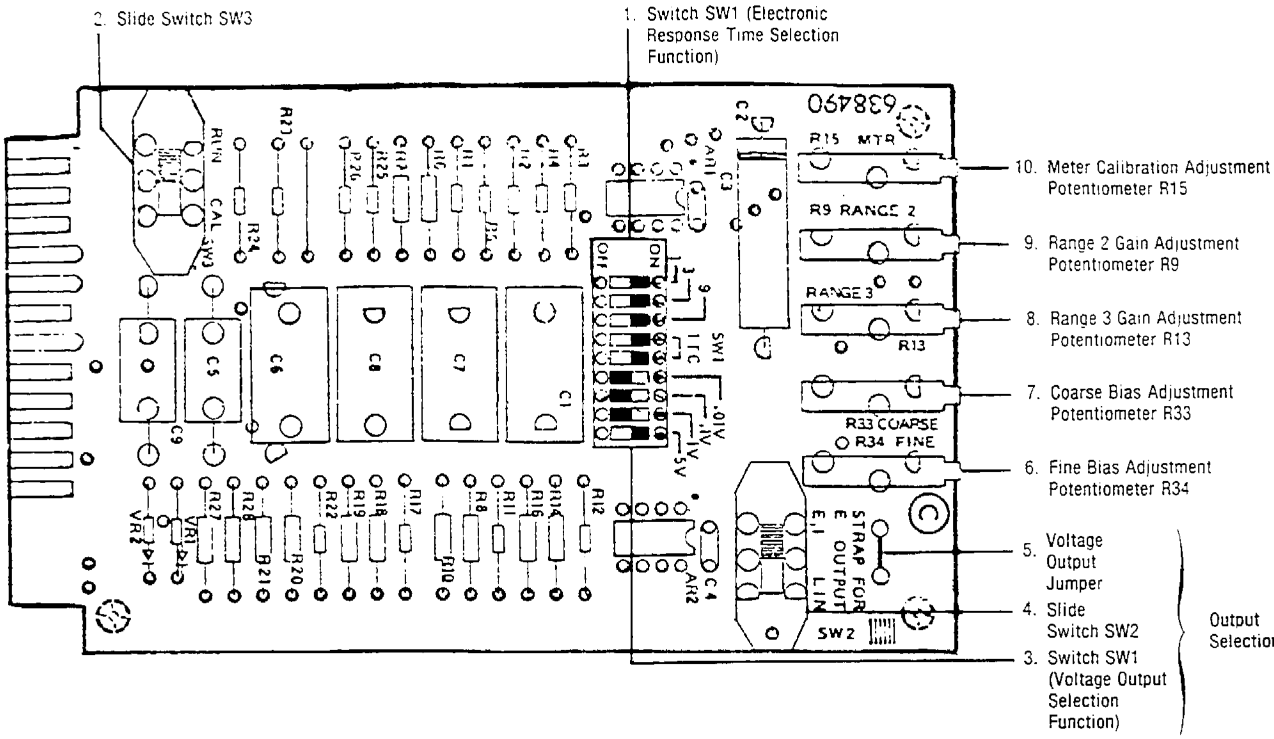
CONTROL	FUNCTION(S)
1. Meter	Readout of sample data or oscillator tuning check, depending on position of RANGE Switch (item 2).
2. RANGE Switch	TUNE: Test position, used periodically to verify proper oscillator tuning. In TUNE mode, meter should indicate the previously determined "Normal Tuning Value." If not, reset OSC TUNE Adjustment, item 8. Range 3 is normal operating setting. Range 1 is used only for certain electronic checks. Range 2 is operative, but is not normally used.
3. ZERO Control	Used to set zero point on recorder chart. With RANGE Switch at 3, GAIN Control at appropriate setting, and zero air flowing through sample and reference cells, the ZERO Control is adjusted for zero reading.
4. GAIN Control	Used to set an upscale standardization point on front-panel meter. With RANGE Switch at 3, and upscale standard gas flowing through the sample cell, the GAIN Control is adjusted for the correct reading. (With GAIN Control at counterclockwise limit, gain is zero. Clockwise rotation of 10.0 turns increases gain to maximum).
5. Meter Mechanical Zero Screw	With analyzer power cord disconnected, meter should read zero. If not, this screw is adjusted to zero the meter.
6. SOURCE BALANCE Adjustment	Used to obtain proper balance between intensities of sample and reference sources, and to bias the optical system into linearity. Procedures for initial adjustment and subsequent checkout of the SOURCE BALANCE are included in Startup Procedure of Paragraph 3.1.
7. Source Voltage Adjustment (On Analyzer Rear Panel)	Used to set the voltage applied to the two sources. Nominal setting is 30 volts a.c.
8. OSC TUNE Adjustment (Behind Front Panel)	Used to tune oscillator circuit. The oscillator tuning adjustment shaft has a small knob, accessible to the fingers by reaching behind the front panel, slightly above the hole marked OSC TUNE. During initial startup, RANGE Switch is placed at TUNE. The OSC TUNE Adjustment is set at counterclockwise limit, and then turned clockwise until a peak reading is obtained on the meter. Then, OSC TUNE Adjustment is rotated counterclockwise until meter reading decreases to between 70% and 75% of the peak reading previously obtained. The resultant meter reading, designated "Normal Meter Reading in TUNE Mode," is noted for future reference. During subsequent operation, oscillator tuning is checked periodically by turning RANGE Switch to TUNE. Meter should read within 2 scale divisions of "Normal Meter Reading in TUNE Mode." If meter reading is outside the acceptable limit, repeat tuning procedure described above.

Figure 3-2. External Controls and Adjustments of Analyzer Unit



ADJUSTMENT	FUNCTION
1. Optical Shutters	Provide coarse optical balance adjustment, used if acceptable balance is unobtainable with front-panel SOURCE BALANCE Adjustment, or is obtained near the clockwise limit of this control. Shutters are sliding metal plates attached to entrance ends of sample and reference cells, permitting partial blocking of either beam, as required to obtain balance.
2. Source Assembly Vertical Positioning Adjustment (Out-of-Phase Adjustment)	Used for optical alignment of source assembly, to minimize out-of-phase signal. With zero air flowing through sample and reference cells, Vertical Positioning Screw is rotated to move source assembly up or down, as required to minimize the meter reading. If Vertical Positioning Screw is difficult to rotate, very slightly loosen the two retaining screws. After adjusting Vertical Positioning Screw, retighten retaining screws to secure sources to Motor/Source Assembly.

Figure 3-3. Optical System Adjustments Within Analyzer Unit

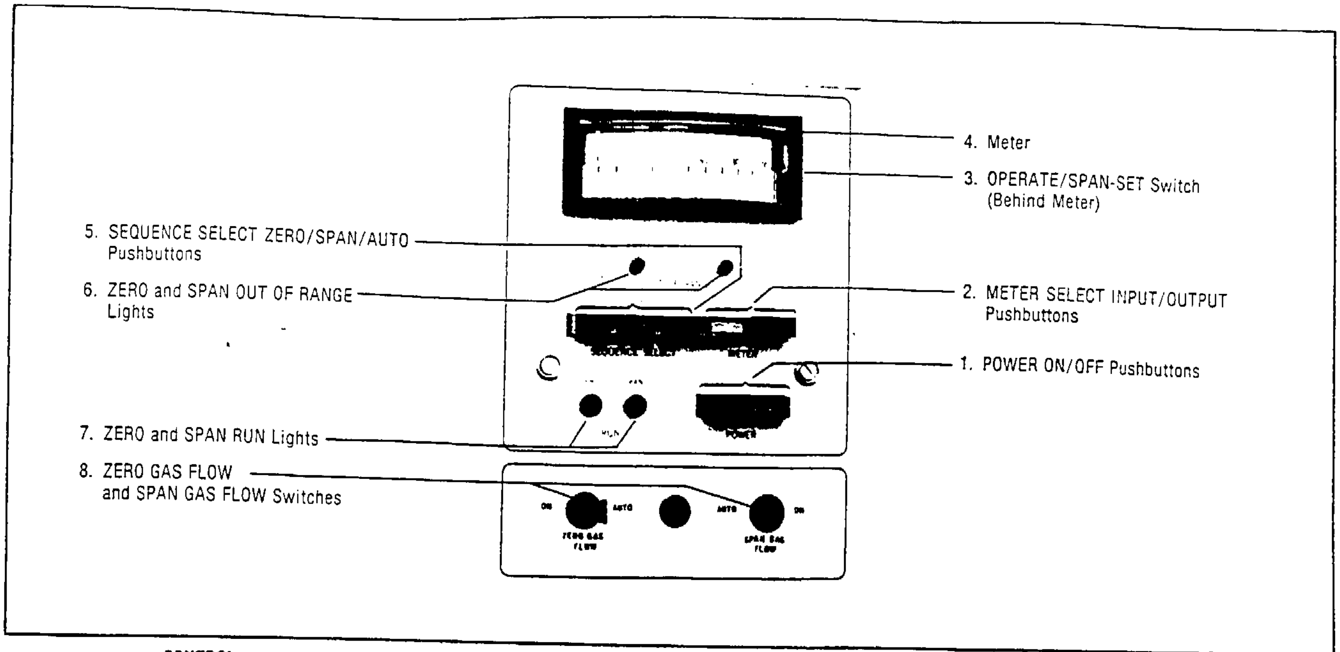


CONTROL	FUNCTION
1. Switch SW1 (Electronic Response Time Selection Function)	The desired electronic response time is obtained by selection of the appropriate combination of settings on the specified switch contacts, as given in the following table. Time values (1, 3, and 9) are number of seconds to 90% of final reading. Standard setting is 13 seconds, obtained with switch contacts 1 through 5 in ON position. No other setting is designated for ambient CO monitoring.

CONTACT NUMBER ON SW1	BOARD MARKING	RESPONSE TIME IN SECONDS														
		0.5	1	2	3	4	6	8	9	10	12	13	18	20	24	26
1	1	Off	On	On	Off	On	Off	On	Off	On	Off	On	Off	On	Off	On
2	3	Off	Off	Off	On	On	On	On	Off	Off	On	On	Off	Off	On	On
3	9	Off	Off	Off	Off	Off	Off	Off	On	On	On	On	On	On	On	On
4 & 5	1 TC (Two Contacts)	On	On	Off	On	On	Off	Off	On	On	On	On	Off	Off	Off	Off

CONTROL	FUNCTION
2. Slide Switch SW3	RUN is normal operating position. CAL position is used only during calibration of the optional 633756 Linearizer Board. Selection of CAL position grounds the input to the D.C. Amplifier Board, and reverses the polarity of the front-panel ZERO Control.
3. Switch SW1 (Voltage Output Selection Function)	The contact marked 5V must be placed in ON position, to provide the 0 to 5 volt output required for the Automatic Zero/Span Standardizer. The contacts marked .01V, .1V, and 1V must be placed in OFF position.
4. Slide Switch SW2	These two items used in combination to provide the internal signal routing appropriate to the desired type of output. For standard, nonlinearized, potentiometric output, place SW2 at position E.I and verify that jumper is connected.
5. Voltage Output Jumper	For optional linearized potentiometric output, if analyzer is so equipped, place SW2 at LIN and verify that jumper has been removed.
6. Fine Bias Adjustment Potentiometer R34	Used in combination to null out component electronic offsets. With GAIN Control at counterclockwise limit, and ZERO Control at clockwise limit, R33 is adjusted to center the span of R34 near the required near-ground d.c. level; then, R34 is adjusted for zero reading on meter or recorder.
7. Coarse Bias Adjustment Potentiometer R33	
8. Range 3 Gain Adjustment Potentiometer R13	Used in conjunction with front-panel GAIN Control to establish upscale calibration.
9. Range 2 Gain Adjustment Potentiometer R9	Not normally used in Ambient CO Monitoring System.
10. Meter Calibration Adjustment Potentiometer R15	Factory-set so that 100% reading on analyzer meter corresponds to 5-volt fullscale output from analyzer unit.

Figure 3-4. D.C. Amplifier Board of Analyzer Unit



CONTROL	FUNCTION
1. POWER ON/OFF Pushbuttons	Provide on/off control of a.c. power to standardizer.
2. METER SELECT INPUT/OUTPUT Pushbuttons	With INPUT Pushbutton depressed, meter indicates input to the standardizer; i.e., the output from the analyzer. With OUTPUT Pushbutton depressed, meter indicates output from the standardizer, or the auto span setpoint, depending on the position of the OPERATE/SPAN-SET Switch, item 3.
3. OPERATE/SPAN-SET Switch (Behind Meter)	Determines meter readout when METER SELECT OUTPUT Pushbutton is depressed. OPERATE: Meter indicates output from the standardizer. SPAN SET: Meter indicates auto span setpoint.
4. Meter	Indicates the variable selected with the METER SELECT INPUT/OUTPUT Pushbuttons and the OPERATE/SPAN-SET Switch.
5. SEQUENCE SELECT ZERO/SPAN/AUTO Pushbuttons	Depression of ZERO or SPAN Pushbutton initiates the corresponding standardization sequence. Depression of AUTO Pushbutton initiates a complete zero/span standardization sequence.
6. ZERO and SPAN OUT OF RANGE Lights	Illumination of ZERO or SPAN OUT OF RANGE Light indicates that the corresponding correction circuit within the standardizer has reached the limit of its compensating capability, and that the analyzer must therefore be recalibrated.
7. ZERO and SPAN RUN Lights	Illumination of ZERO or SPAN RUN Light indicates that the corresponding standardization sequence is occurring.
8. ZERO GAS FLOW and SPAN GAS FLOW Switches	These switches permit manual selection of zero and span flow modes of the Gas Control Panel. Selection of the ON position of the ZERO GAS FLOW or SPAN GAS FLOW Switch places the solenoid valves of the Gas Control Panel in the corresponding flow mode. With both switches in AUTO position, the solenoid valves are under automatic control of internal circuitry within the Standardizer.

Figure 3-5. Front-Panel Controls of Automatic Zero/Span Standardizer

MET/REC Switch (Output Mode Selection Function)

Desired output mode is selected by placing the corresponding one of two switch contacts in ON position. STD (standard) output mode permits recorder response at all times, including during automatic standardization sequences. S/H (sample-and-hold) mode prevents recorder response during standardization sequences. During these sequences, the recorder reading remains at the last-recorded sample value.

MET/REC Switch (Voltage Output Selection Function)

Desired voltage output is obtained by placing the corresponding one of four switch contacts in ON position. The other three contacts must be in OFF position. Contacts are marked .01V, .1V, 1V, and 5V.

Regulated ±13 volts d.c., up to 100 milliamperes, obtainable at these terminals.

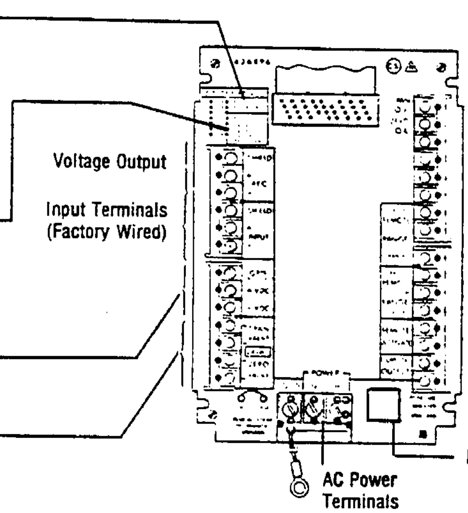
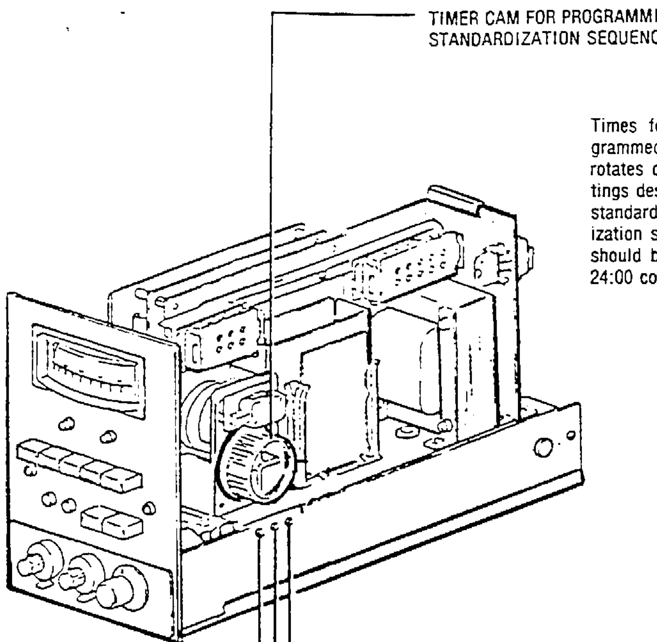


Figure 3-6 Rear-Panel Controls of Automatic Zero-Span Standardizer



Times for initiation of automatic standardization sequences are programmed by inserting tripping pins into appropriate grooves in cam. Cam rotates one revolution per 24 hours, and has 60 grooves. The only settings designated for ambient CO monitoring are: one complete zero/span standardization sequence every 24 hours, plus separate zero standardization sequences at intervals of four hours. Refer to table below. Cam should be set for real time; i.e., 12:00 on timer corresponds to noon; 24:00 corresponds to midnight.

Groove Number	Time	Standardization	Groove Number	Time	Standardization	Groove Number	Time	Standardization	Groove Number	Time	Standardization
1	00:24		16	06:24		31	12:24		46	18:24	
2	00:48		17	06:48		32	12:48		47	18:48	
3	01:12		18	07:12		33	13:12		48	19:12	
4	01:36		19	07:36		34	13:36		49	19:36	
5	02:00		20	08:00	zero only	35	14:00		50	20:00	zero only
6	02:24		21	08:24		36	14:24		51	20:24	
7	02:48		22	08:48		37	14:48		52	20:48	
8	03:12		23	09:12		38	15:12		53	21:12	
9	03:36		24	09:36		39	15:36		54	21:36	
10	04:00	zero only	25	10:00		40	16:00	zero only	55	22:00	
11	04:24		26	10:24		41	16:24		56	22:24	
12	04:48		27	10:48		42	16:48		57	22:48	
13	05:12		28	11:12		43	17:12		58	23:12	
14	05:36		29	11:36		44	17:36		59	23:36	
15	06:00		30	12:00	zero only	45	18:00		60	24:00	zero and span

Figure 3-7. Internal Adjustments of Automatic Zero/Span Standardizer

c. Turn front-panel RANGE Switch back and forth between positions 1 and 3. When instrument is properly biased, meter reading will not change when RANGE is changed.

NOTE
In the Ambient CO Monitoring System, Range 3 is normal operating setting. Range 1 is used only for certain electronic checks. Range 2 is operative, but is not normally used.

6. Analyzer SOURCE BALANCE Adjustment:
   a. Turn on sample pump. On *standardizer*, place ZERO GAS FLOW Switch at ON, thus routing CO-free zero air through sample and reference cells of *analyzer*.

NOTE
Continue flow of zero air until conclusion of Step 7.

   b. On Gas Control Panel, set sample and reference flows at 1 CFH (approximately 470 ml/min).
   c. On analyzer, turn ZERO Control to clockwise limit, set RANGE Switch to position 1. Turn up GAIN Control until meter reads about 5% of fullscale. If this reading is unobtainable by adjustment of front-panel GAIN Control, leave it at maximum setting.

      Move RANGE Switch to position 3. Meter should now read at least three times the reading on Range 1; if not, adjust R13 on D.C. Amplifier Board, Figure 3-4, so that meter reading is equal to three times the Range 1 reading.
   d. Adjust analyzer SOURCE BALANCE Control for minimum obtainable meter reading. This will be zero, or slightly above, provided that bias adjustment has been properly made. To verify that a minimum has been obtained, make sure that the signal decreases as the SOURCE BALANCE Control is rotated toward the position of the minimum from both directions. An acceptable minimum is 15% or less (the smaller, the better). If an acceptable minimum is obtained, proceed directly to Step f.

      If an acceptable minimum is unobtainable, adjust shutters (Figure 3-3) to obtain a minimum. If an acceptable minimum is still not obtained, proceed to Step e.
   e. Within the analyzer, Figure 3-3, adjust Vertical Positioning Screw on Motor/Source Assembly to minimize meter reading.

NOTE
If Vertical Positioning Screw is difficult to rotate, very slightly loosen source retaining screws, Figure 3-3. After completing adjustment of Vertical Position Screw, retighten retaining screws so sources are secure to Motor/Source Assembly. A loose source assembly will cause electronic noise.

Repeat Step d, and Step e if necessary, as many times as required to obtain an acceptable minimum.

   f. Turn SOURCE BALANCE Control *clockwise* until meter reading is between 50% and 80% of fullscale. If reading of 50% is unobtainable by adjustment of the SOURCE BALANCE Control, leave it at the clockwise limit for the present; subsequently, during Step 8e, it will be readjusted counterclockwise.
7. Set Zero for all analyzer ranges:
   a. On standardizer, verify that ZERO GAS FLOW Switch is at ON, so that CO-free zero air is flowing through sample and reference cells of analyzer.
   b. On analyzer, increase GAIN Control setting until meter reads fullscale. If fullscale reading is unobtainable by adjustment of GAIN Control, leave it at maximum setting.
   c. Allow analyzer to come to steady equilibrium.
   d. Turn analyzer ZERO Control counterclockwise until meter reads exactly zero. To check zero, move RANGE Switch to position 1; zero should not change. Tighten lock-ring on ZERO Control knob.
   e. On standardizer, move ZERO GAS FLOW switch to AUTO position.

NOTE
If, in subsequent operation, significant interaction between ZERO and GAIN Controls is observed, the setting of the Bias Controls should be checked. If significant interaction between analyzer ZERO and GAIN Controls still remains, see Paragraph 7.1, Step 13.

8. Analyzer Gain Adjustment

NOTE
Preparatory to the following procedure, pressurized upscale standard gas of appropriate composition must be supplied to the span gas inlet on the Gas Control Panel. Refer to Paragraph 2.2.2.

   a. On standardizer, place SPAN GAS FLOW Switch at ON, so that analyzer sample cell receives span gas from external cylinder, and reference cell receives CO-free zero air.
   b. On Gas Control Panel, verify that both flowmeters read 1 CFH (approximately 470 ml/min). If reading on SAMPLE flowmeter differs, adjust span gas pressure to obtain 1 CFH (approximately 470 ml/min).
   c. Set analyzer front-panel GAIN Control at 500.
   d. If the system is to be used on the standard range of 0 to 50 parts per million CO, place analyzer front-panel RANGE Switch at position 3. Then, adjust R13 on D.C. Amplifier Board (Figure 3-4) so that analyzer front-panel meter indicates the reading appropriate to the CO content of the span gas.

      If the system is to be operated on a less-sensitive, *non-designated* range, such as 0 to 100 parts per million CO, place front-panel RANGE Switch at position 2. Then, adjust R9 on D.C. Amplifier Board to obtain the reading appropriate to the CO content of the span gas.

c. Place analyzer RANGE Switch at 3. On standardizer, place SPAN GAS FLOW Switch at AUTO and ZERO GAS FLOW Switch at ON. On analyzer, turn front-panel ZERO Control to clockwise limit and repeat Steps 6d through 6f to ensure proper offset of optical balance: then, readjust ZERO Control to obtain zero reading.
f. Return ZERO GAS FLOW Switch to AUTO.

9. Standardizer Setup:
   a. If the standardizer is required to provide zero offset, as explained in Paragraph 2.2.2, verify that an appropriate resistance has been inserted into the zero-correction circuit. Refer to Paragraph 2.3.4.
   b. On standardizer front panel, depress METER SELECT OUTPUT Pushbutton.
   c. Select SPAN-SET position on OPERATE/SPAN-SET Switch, located behind standardizer meter.
   d. Adjust Range 1 Span Set Potentiometer, Figure 3-7, so that reading on standardizer meter is equal to the concentration of carbon monoxide in the span gas. (Note that Range 1 on the *standardizer* corresponds to Range 3 on the *analyzer.)*
   e. Return OPERATE/SPAN-SET Switch to OPERATE Position.
10. Checkout of System Operation. Depress SEQUENCE SELECT AUTO Button on standardizer, and observe the auto zero/span sequence thus initiated:
   a. CO-free air will flow for sufficient time to purge the analyzer sample cell. The analyzer meter, standardizer meter, and recorder will then drive downscale to zero (or preselected offset value, typically between +3% and +5% of fullscale).
   b. Span gas will flow for sufficient time to purge the analyzer sample cell. The analyzer meter, standardizer meter, and recorder will then drive upscale to the reading appropriate to the CO content of the span gas.
   Repeat the sequence twice more to verify correct operation.

System startup is now complete. However, before the system is placed in operation, it must be calibrated per Paragraph 3.2.

NOTE

When the system is placed in operation, analyzer zero and/or span may gradually drift. This will cause readout error on the **analyzer** *meter, but not on the standardizer meter or the recorder unless the drift exceeds the compensating capability of the standardizer. The OUT OF RANGE Lights on the standardizer permit monitoring for this condition. When an out-of-range condition occurs, it may be correctable by the routine adjustments of Paragraph 4.3. If not, further corrective action may be required, per troubleshooting chart of Figure 7-1.*

3.2 DYNAMIC MULTIPOINT CALIBRATION

When this analysis system is used for purposes of 40CFR 51.17 (a) of the Code of Federal Regulations (i.e. Regional Air Quality Surveillance), it requires initial and periodic calibration by the dynamic multipoint method. The procedure is specified in 40 CFR Part 50, Appendix C, and described here in detail. For recommendations on frequency of calibration, refer to Paragraph 4.5.

During calibration, the analyzer must sample the standard atmosphere in the same way as it would normally sample the ambient atmosphere. The calibration gas must pass through the same path and the same components as the ambient air samples. This is accomplished by using a vented manifold and passing the calibration gas through it at a higher flowrate than that demanded by the analyzer. The analyzer is then allowed to draw a sample from the manifold in its normal mode of operation. Since several various CO concentrations are necessary for the calibration it is expedient and economical to use a single standard gas cylinder containing a high CO concentration, diluting this standard with zero air to obtain the required calibration concentrations.

A simple calibration system is shown in Figure 3-8. Flowmeters FI_1 and FI_2 should be precalibrated by an appropriate method; e.g. ASTM D3195, preferably traceable to NBS.

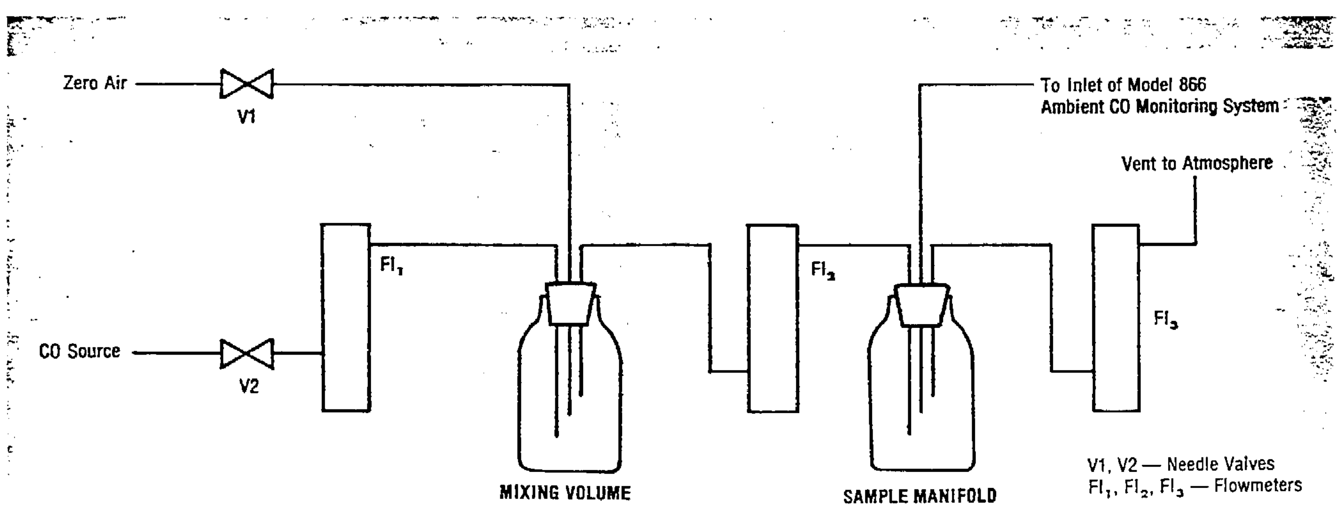


Figure 3-8. Flow Diagram of Typical Gas Dilution System for Dynamic Multipoint Calibration

The calibration of FI_3 is not critical, as it is used only to indicate the excess flow. The CO source should be a cylinder of zero air or nitrogen containing a concentration of CO as high as, or higher than, the highest point on the calibration curve. It should be a National Bureau of Standards (NBS) Standard Reference Material or one with a certified analysis traceable to an NBS cylinder. The zero air should be dry and free of CO, and should contain approximately 350 parts per million of CO_2. It may be ambient air, treated to remove CO and water vapor or cylinder zero air (real air, not synthetic) certified by the supplier or an independent laboratory to be free of CO.

If the chart recorder does not have below-zero capability, adjust it (*not* the analyzer zero) to obtain a +3 to +5 percent offset zero reading on the chart, to facilitate later observation of downscale zero drift, before starting the calibration procedure.

NOTE

If the recorder does not have an adjustable zero, the offset can be obtained by using an offset zero point on the automatic zero/span standardizer. See Paragraph 2.3.4.

Calibration Procedure

1. After the startup procedure of Paragraph 3.1 is completed, assemble a calibration system similar to Figure 3-8. Connect zero air source, CO source, and CO monitoring system, making sure all connections are tight.
2. With V2 shut off, adjust V1 to obtain flow of zero air, indicated by FI_2, 10 to 20 percent higher than that required by the monitoring system. (The monitoring system requires approximately 5 liters per minute.)
   With the monitoring system in normal sampling mode, ascertain that FI_3 indicates appropriate bypass flow.
3. Adjust analyzer ZERO Control to make analyzer meter read zero.
   On standardizer panel, depress SEQUENCE SELECT ZERO Pushbutton. If the startup procedure was performed correctly, the recorder will now come to the desired reading for zero CO concentration. Note this recorder reading.
4. Adjust V1 and V2 to obtain the parts per million CO concentration that should cause the recorder to read 90 +5 percent of fullscale and at the same time to obtain a reading on FI_2 close to that of Step 2.
   Parts per million CO is calculated from the formula:

$$p/10^6\ CO = \frac{\text{Flow Rate } FI_1}{\text{Flow Rate } FI_2} \times p/10^6\ CO \text{ source}$$

NOTE

If both flowmeters were not calibrated at the same temperature and pressure, both indicated flowrates should first be corrected by multiplying by the factor:

$$\sqrt{\frac{T_c}{T_m} \times \frac{P_m}{P_c}}$$

Where T = absolute temperature
P = absolute pressure
sub c = calibrate conditions
sub m = measuring conditions

   With monitoring system in normal sampling mode, ascertain that FI_3 indicates appropriate bypass flow.
4. Adjust the analyzer GAIN Control to make the recorder read the desired value for the generated parts per million CO concentration. Note this recorder reading.
5. Repeat Step 2 to be sure the recorder zero CO reading has not changed. If it changed by more than 0.6 percent of fullscale, repeat Steps 3 and 4.
6. In similar fashion to Step 4, readjust V1 and V2 to obtain five more parts per million CO concentrations of approximately equal spacing and note the recorder readings.
7. Prepare a calibration curve for the monitoring system by plotting the seven values of CO (including zero) against the recorder readings.
   Use this curve to convert subsequent recorder readings into CO concentrations. If the analyzer is equipped with the optional linearizer board, the curve should be a straight line within the accuracy of the analyzer and the accuracy of the flowmeters. (See Paragraph 7.2 for calibration of the linearizer board.)
8. On the standardizer panel, place the SPAN GAS FLOW Switch in ON position. When the recorder has reached a stable position, note the reading. This is the reading that should be obtained each time the auto span cycle occurs. Also note, from the calibration curve, the parts per million CO value it represents. This is the "true" value of the span gas cylinder.
9. Return the SPAN GAS FLOW Switch to the AUTO position and depress the SEQUENCE SELECT SPAN Pushbutton.
   Note the recorder reading obtained at the end of the span adjust cycle. If it is different from that obtained in Step 8, slide open the standardizer and make a small adjustment on the RANGE 1 SPAN SET Potentiometer.
10. Repeat Step 9 until the recorder reading obtained at the end of the span adjust cycle is the same as that obtained in Step 8, to within ±0.6 percent of fullscale.

The monitoring system is now ready to monitor ambient CO. It is recommended that the converter efficiency be checked at this time. See Paragraph 6.4.1.

3.3 INITIATING THE OPERATING AND MAINTENANCE LOG

As an aid to possible future troubleshooting and corrective maintenance, it is recommended that the operator keep an operating and maintenance log, as explained in Paragraph 6.1. A typical example is shown in Figure 6-1. The log should be initiated, upon completion of initial startup and calibration, by noting the following parameters.

1. Analyzer Unit:
   a. Duodial setting on ZERO Control.
   b. Duodial setting on GAIN Control.
   c. Meter reading with RANGE Switch at TUNE.
2. Gas Control Panel: Flowmeter settings.
3. Pump/Sample-Handling Module: Check inlet filter F1 (Paragraph 6.3.1) and filter/water-trap F2 (Paragraph 6.3.3).

Subsequently, these checks and adjustments, and the others given in Figure 6-1, should be performed at the specified intervals.

SECTION FOUR OPERATION

4.1 ROUTINE OPERATION

First complete startup procedure of Paragraph 3.1 and calibration procedure of Paragraph 3.2. The system will now continuously analyze the ambient air sample for carbon monoxide, and will automatically perform zero and span standardization at the programmed times. There will be one complete zero/span standardization sequence every 24 hours, plus separate zero standardization sequences at intervals of four hours. See Figure 3-7. No other settings are designated for ambient CO monitoring.

4.2 READOUT OF CARBON MONOXIDE CONCENTRATION VALUES

The curve obtained during the calibration procedure of Paragraph 3.2 may be used to convert recorder readings into CO concentration values. Alternatively, the analyzer unit may utilize an optional plug-in linearizer circuit board to equip a given operating range for linear readout of concentration values on the recorder chart. The linearizer board, if used, may be calibrated for either the *designated* range of 0 to 50 parts per million CO, or for a *non-designated* range involving higher CO concentrations; e.g., 0 to 100 parts per million CO.

4.3 ROUTINE CORRECTION FOR OUT-OF-RANGE CONDITION

During operation, analyzer zero and/or span may gradually drift. This will cause an error on the analyzer meter, but not on the recorder unless the drift exceeds the compensating capability of the standardizer. The standardizer can correct for a drift of 15% of fullscale above or below the zero setpoint, and a drift of 10% of fullscale above or below the span setpoint. If zero or span drift exceeds the specified limit, the out-of-range light will illuminate. To correct this condition:

1. Switch to appropriate standard gas (zero or span), and adjust the appropriate front-panel control on the analyzer to bring the *analyzer meter* reading to the correct setpoint.
2. Manually initiate a zero/span standardization cycle, to reset the standardizer controls and extinguish the out-of-range lights.

It is recommended that after illumination of either or both lamps, and adjustment of the appropriate control(s), the operator note their settings. These control settings should also be noted each time the startup procedure of Paragraph 3.1 is performed. The ZERO and GAIN Controls have turns-counting Duodials®* for convenience in noting settings, which should then be logged in a chart such as Figure 6-1.

If the adjustment range of the analyzer front-panel ZERO or GAIN Control is insufficient to bring the meter reading to the correct setpoint, *or* if zero out-of-range condition occurs more often than once a week, *or* if span out-of-range condition occurs more often than once a month, further corrective action may be required, per troubleshooting chart of Figure 7-1.

*Duodial® is a trademark of Beckman Instruments, Inc.

4.4 EFFECT OF BAROMETRIC PRESSURE ON ANALYZER RESPONSE

Analyzer response is proportional to the number of CO molecules in the sample cell, and is therefore affected by barometric pressure. However, the automatic span standardization corrects for this effect, on a daily basis.

4.5 RECOMMENDED CALIBRATION FREQUENCY

Upon initial startup, and at periodic intervals thereafter, the system requires dynamic multipoint calibration per Paragraph 3.2.

Recommended Practice

At intervals of thirty days following the initial multipoint calibration, use the NBS-certified calibration gas or a suitable transfer standard to check a *single point* at or near midscale. The recorder reading should be correct to within 1%; if so, calibration is within acceptable limits, and the dynamic multipoint calibration need not be repeated at this time.

Dynamic multipoint calibration *should* be repeated upon failure of the thirty-day one-point check, or at intervals of six months, whichever occurs first.

Quality Control

The user should have a quality control plan whereby calibration frequency and the number of points used for calibration can be modified on the basis of data, collected over a period of time, covering both dynamic calibration and automatic zero/span standardization. Such a quality control program is essential to ascertain the accuracy and reliability of the air quality data collected, and to alert the user if the accuracy and reliability of the data should become unacceptable.

4.6 REPETITION OF INITIAL STARTUP PROCEDURE

The initial startup procedure of Paragraph 3.1 should be repeated under any of the following circumstances: (1) ZERO OUT OF RANGE Lamp illuminates more often than once a week, *or* (2) SPAN OUT OF RANGE Lamp illuminates more often than once a month, *or* (3) out-of-range condition is not correctable by adjustment of analyzer front-panel controls, per Paragraph 4.3. Any of these circumstances requires corrective action; see troubleshooting chart of Figure 7-1.

With time, system sensitivity may gradually decrease. The system will no longer operate satisfactorily when the sensitivity loss becomes so great that the amount of adjustment provided by the analyzer gain controls is insufficient to set the span point. In this case, refer to troubleshooting procedure of Paragraph 7.1.

If the loss of sensitivity is accompanied by a significant change in the setting of the analyzer ZERO Control, first examine walls and windows of the flowthrough cells for dirt. If present, clean cells per Paragraph 6.5.1. If cleaning cells does not improve instrument sensitivity, use troubleshooting procedure of Paragraph 7.1.

4.7 SHUTDOWN

Normally, instrument power is left on at all times except during a prolonged shutdown. Before resuming operation, repeat procedure of Paragraph 3.1 to restore instrument to service.

SECTION FIVE PRINCIPLES OF OPERATION

5.1 GAS CONTROL PANEL

The Gas Control Panel controls the flow of gases to the sample and reference cells of the analyzer unit (Paragraph 5.2). As shown in the schematic diagram of Figure 5-1, routing of gases is determined by two 24 volts a.c. solenoid valves. These are actuated by the Automatic Zero/Span Standardizer, Paragraph 5.4.

There are three flow modes:

1. SAMPLE Mode — Valve 1 is in SAMPLE/ZERO position (de-energized); and Valve 2 in SAMPLE/SPAN position (de-energized). The sample cell of the analyzer receives ambient air; the reference cell receives CO-free air, obtained by passing ambient air through a catalytic converter where CO is converted into CO_2.
2. ZERO Mode — Valve 1 is in SAMPLE/ZERO position (de-energized) and Valve 2 in ZERO position (energized). *Both* cells of the analyzer now receive CO-free air.
3. SPAN Mode — Valve 1 is in SPAN position (energized) and Valve 2 in SAMPLE/SPAN position (de-energized). The sample cell now receives upscale standard gas from a cylinder; the reference cell receives CO-free air.

Before leaving the control panel, the gas streams destined for the analyzer sample and reference cells pass through flowmeters with manually adjustable needle valves, and then through in-line filters. Normal setting for both flowmeters is 1 CFH (approximately 470 ml/min).

5.2 ANALYZER DETECTION SYSTEM

As shown in Figure 5-2, the analyzer produces infrared radiation from two separate energy sources. Once produced, this radiation is beamed separately through a chopper which interrupts it at 10 Hz. The radiation then passes through narrow-bandpass optical filters to reduce background interference from infrared-absorbing components other than carbon monoxide.

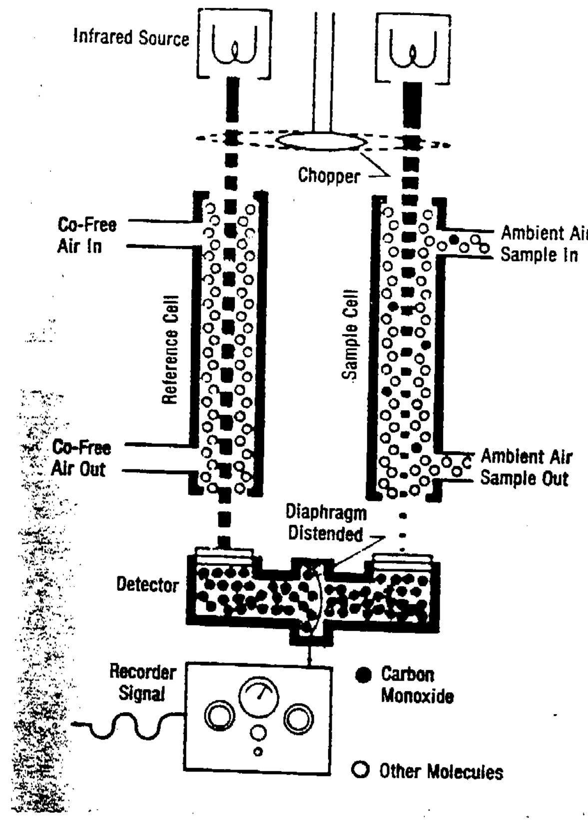


Figure 5-2. Functional Diagram of Analyzer Detection System

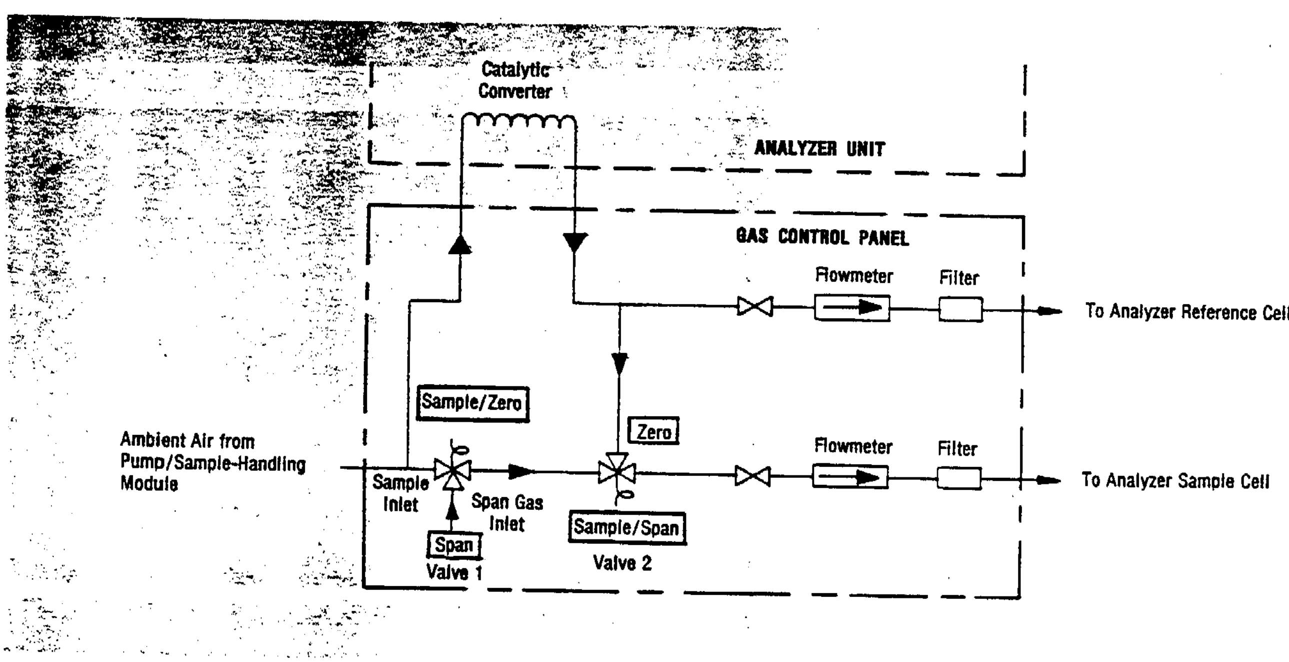


Figure 5-1. Schematic Flow Diagram of Gas Control Panel

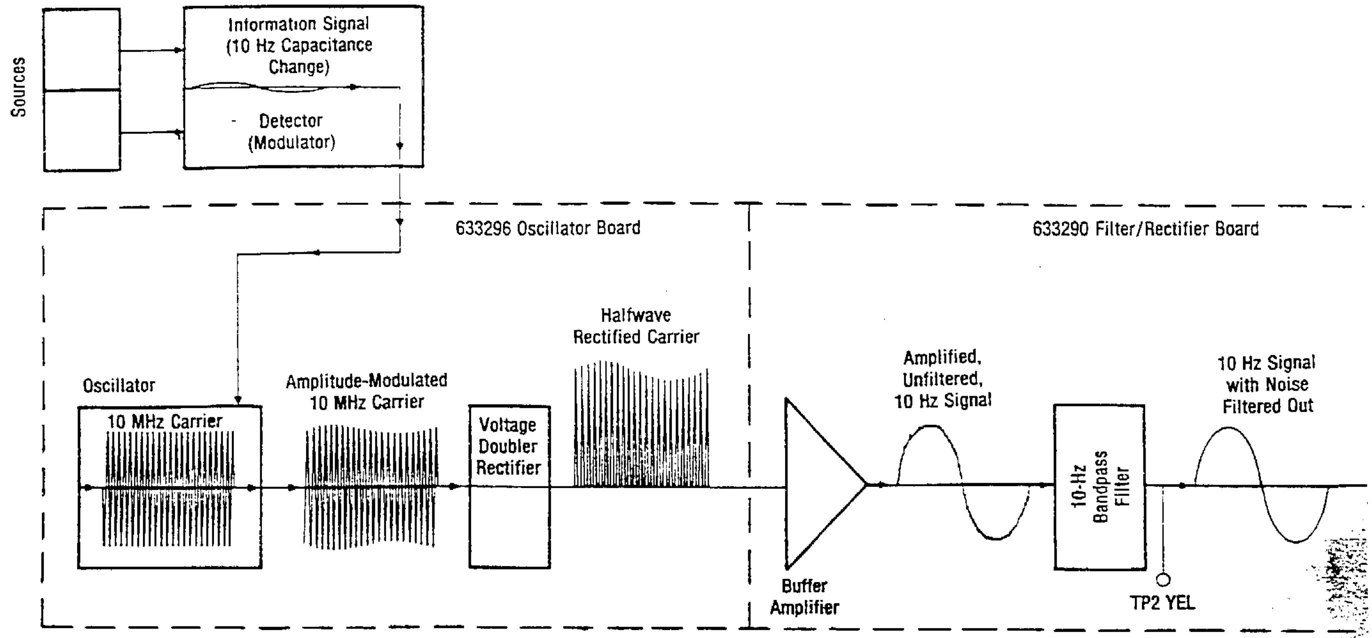
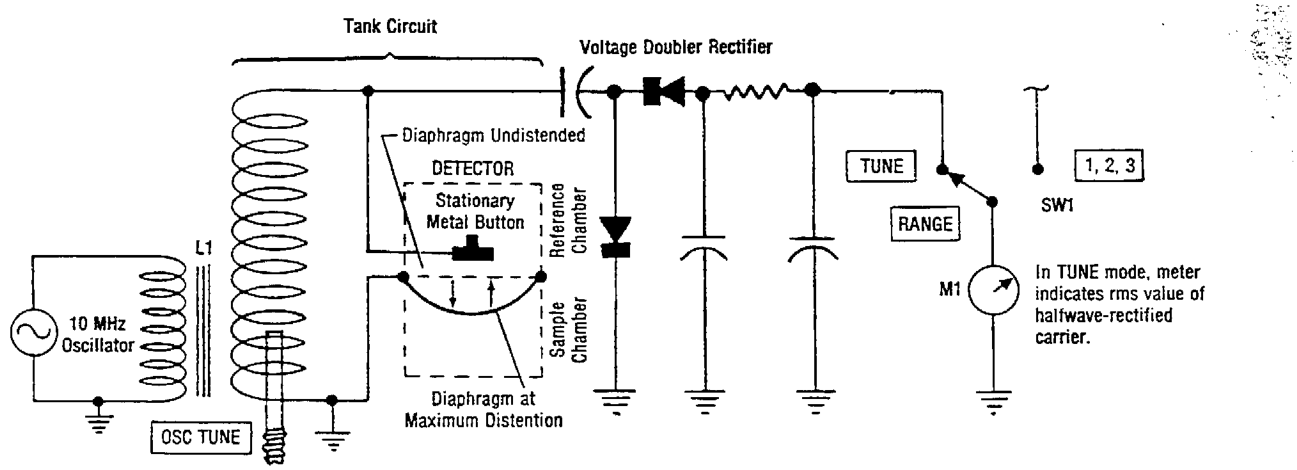
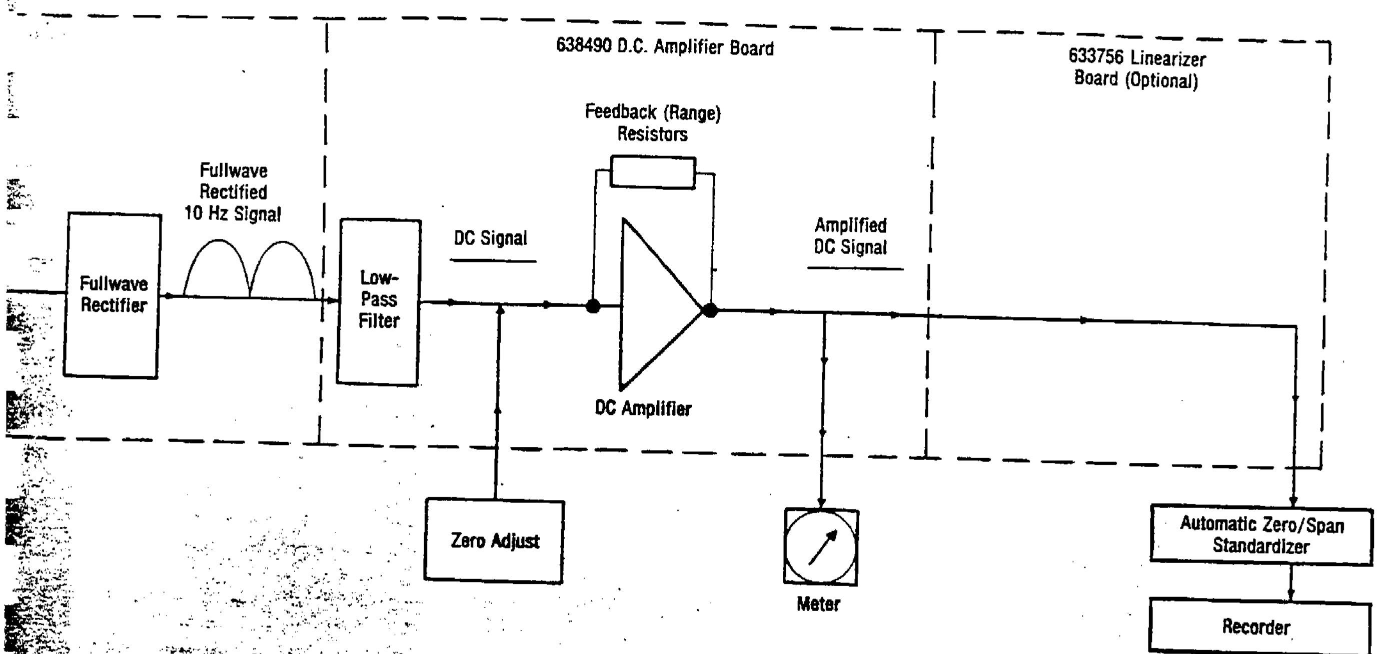


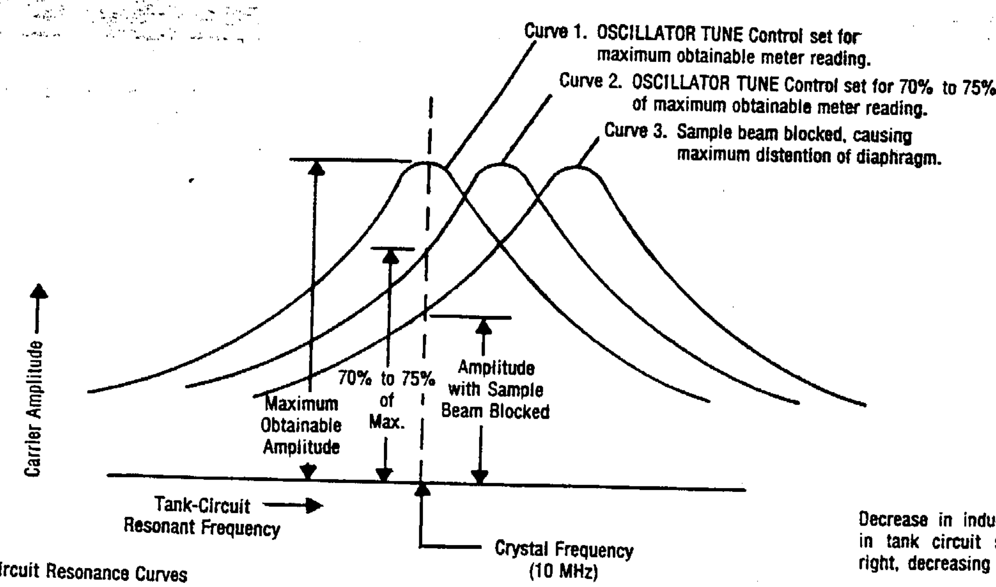
Figure 5-3. Functional Block Diagram of Analyzer Signal Circuitry



A. Functional Diagram — Circuitry in TUNE Mode

Figure 5-4. Analyzer Modulation System





B. Tank-Circuit Resonance Curves

NOTE
Decrease in inductance and/or capacitance in tank circuit shifts resonance curve to right, decreasing carrier amplitude.

The infrared beams pass through two flowthrough cells. The sample cell receives an ambient air sample containing carbon monoxide, while the reference cell receives a continuous flow of CO-free air, obtained by passing ambient air through a catalytic converter where CO is converted into CO_2. Composition of the gas in the two cells is very similar except for CO content.

During operation, a portion of the infrared radiation is absorbed by the carbon monoxide in the sample, with the percentage of infrared radiation absorbed being proportional to the CO concentration. The detector is a "gas microphone" on the Luft principle. It converts the difference in energy between sample and reference cells into a capacitance change. This capacitance change, equivalent to CO concentration, is amplified and indicated on a meter, and is routed through the Automatic Zero/Span Standardizer to a recorder.

5.3 ANALYZER ELECTRONIC CIRCUITRY

The block diagram of Figure 5-3 traces the signal through the analyzer electronic circuitry and depicts the various waveforms involved. For a more detailed picture of the circuitry, refer to analyzer schematic and pictorial wiring diagrams, Figures 9-1 and 9-2, and to schematic diagrams of individual circuit boards, Figures 9-3 through 9-10.

5.3.1 THE 633296 OSCILLATOR CIRCUIT BOARD AND ASSOCIATED ELEMENTS OF AMPLITUDE-MODULATION CIRCUIT

In the 633296 Oscillator Circuit Board, Figure 9-3, the 10 MHz carrier wave is generated by a crystal-controlled radio-frequency oscillator using crystal Y1 and transistors Q1 and Q2.

The modulation circuit is driven by the detector, the sensing element of the analyzer. *Mechanical* functioning of the detector is explained in Paragraph 5.2. Considered *electronically,* the detector is a two-plate variable capacitor. The modulator is coupled inductively, through one winding of inductance L1, to the oscillator. Amplitude of the 10 MHz carrier thus varies with the 10-Hz modulating signal.

The following paragraphs consider functioning of the modulation circuit in greater detail. As shown in Figure 5-4, A, the detector and one winding of inductance L1 constitute a tank circuit. Both circuit elements are variable:

1. During *tuning,* inductance is changed by manual rotation of the OSC TUNE Adjustment, which moves a metallic slug in the core of L1.
2. During *operation,* capacitance of the detector changes *continuously* as the diaphragm is displaced. The resultant variations in capacitative and inductive reactance change the impedance of the tank circuit with respect to the fixed-frequence carrier wave.

$$\text{Resonant frequency for the tank circuit} = \frac{1}{2\pi\sqrt{LC}}$$

Where L = inductance of the winding on L1
C = capacitance of the detector

Functioning of Modulation System in Tune Mode

Preparatory to oscillator tuning, the RANGE Switch is placed in TUNE position, to place the electronic circuitry in the mode shown in Figure 5-4, A. In this mode, the meter indicates the rms value of the halfwave-rectified carrier. The tank circuit is now adjusted in the following two-step sequence.

1. **Tuning** — Initially, the OSC TUNE Adjustment is at its counterclockwise limit. Then, it is rotated clockwise to move the slug into the core, thus *increasing* inductance and *decreasing* resonant frequency. The adjustment is set for maximum obtainable meter reading. At this setting, tank-circuit resonant frequency is the same as oscillator frequency; i.e., nominal 10 MHz. See Resonance Curve Number 1, Figure 5-4, B.
2. **Detuning** — By counterclockwise rotation of the OSC TUNE Adjustment, the slug is partially withdrawn from the core, thus *decreasing* inductance and *increasing* resonant frequency. The adjustment is set so meter reading decreases to between 70% and 75% of the maximum obtainable value noted in Step 1, above. See Resonance Curve Number 2, Figure 5-4, B. This curve has the same shape as that obtained in Step 1, immediately preceding, but is displaced to the right.

Functioning of Modulation System in Operating Mode

After tuning is completed, the RANGE Switch should be moved to position 3 to place the zero and span adjustment circuitry in operation. In this mode, the meter indicates the amplitude of the 10-Hz detector-output signal. Overall sensitivity of the analyzer system may now be checked by blocking the sample-beam to simulate total absorption of sample-beam energy and thus provide the maximum obtainable 10-Hz detector-output signal. During that portion of the chopping cycle while the chopper is unblocking the sample and reference beams, the diaphragm distends away from the metal button, thus decreasing detector capacitance and shifting the tank-circuit resonance curve to the right. At the moment the diaphragm reaches maximum distention, the curve reaches the position of Curve 3, Figure 5-4, B.

Assume that the analyzer is now placed in normal operation by removing the blockage from the sample beam and passing sample gas through the sample cell. The diaphragm now pulses cyclically, causing the resonance curve to move continuously back and forth within the limits defined by curves 2 and 3 of Figure 5-4, B. Carrier amplitude decreases as the curve moves to the right, and increases as it moves to the left. Thus the response characteristics of the system depend on the location of curve 2. Position of this curve depends on the degree of tank-circuit detuning used. Advantages of operating on the portion of the curve obtained by detuning to 70% to 75% of the maximum obtainable carrier amplitude are: maximum slope yields highest sensitivity; minimum curvature provides best linearity.

Radio Frequency Demodulator

The amplitude-modulated 10 MHz carrier from the detector/oscillator circuit is applied to the radio-frequency demodulator. This circuit is a voltage-doubler type rectifier utilizing diodes CR1, CR2, CR3, and CR4; capacitors C6, C7, and C8; and resistor R6. The circuit gives approximately double the output voltage of a conventional halfwave rectifier. This result is obtained by charging a capacitor during the normally wasted half-cycle, and then discharging it in series with the output voltage during the next half-cycle.

5.3.2 THE 633290 FILTER/RECTIFIER BOARD AND ASSOCIATED ELEMENTS

Within the Filter/Rectifier Board, Figure 9-4, the signal passes in turn through the following stages:

1. **Buffer Amplifier.** The signal from the detector/oscillator combination is applied to a buffer amplifier utilizing transistors Q3 and Q4. The output signal from the buffer amplifier is applied to front-panel GAIN Control R4. This potentiometer changes the gain of the overall system by adjustable attenuation of the signal applied to the 10-Hz bandpass filter, item 2.
2. **10-Hz Bandpass Filter.** This active filter, utilizing operational amplifier AR1, discriminates against all frequencies other than the 10 Hz chopping frequency. The resultant clean 10 Hz signal, with undesired frequencies filtered out, is observable by connecting an oscilloscope to TP2 YEL. Filter Pass Adjustment Potentiometer R16 is adjusted for maximum amplitude of the 10 Hz signal.
3. **Fullwave Rectifier Circuit.** This circuit provides fullwave rectification of the 10 Hz signal. Filter Balance Potentiometer R21 is used to equalize peak heights of adjacent halfwave pulses. Filter Rectifier Potentiometer R30 is used to adjust the rectification level of the rectifier to the d.c. offset voltage level of the filter amplifier.

5.3.3 THE 638490 D. C. AMPLIFIER BOARD AND ASSOCIATED CIRCUITRY

In the 638490 D. C. Amplifier Board, Figure 9-5, the fullwave rectified signal from the 633290 Filter/Rectifier Board is conditioned by the following circuitry.

1. **Response Time Selection Function of Switch SW1.** The first five contacts of Switch SW1 determine the electronic response time. The standard setting is 13 seconds, obtained by closing switch contacts 1 through 5. No other setting is *designated* for ambient CO monitoring. However, other settings are available for *non-designated* applications. The fastest available response, 0.5-second to 90% of final reading, is obtained by opening the contacts designated 1, 3, and 9 on the board; and closing the two contacts designated 1T. Longer response times are obtainable by appropriate combination of switching settings:
   a. Basic response time is selected by closing one or more of the three contacts designated 1, 3, and 9. The designations indicate time, in seconds, for 90% of fullscale response. Values thus selected are *additive*.
   b. The two contacts designated 1T provide an optional multiplication factor of 2X. With these contacts in *closed* position (marked 1T), effective response time is the sum of the values selected with the contacts marked 1, 3, and 9.

   With contacts in *open* position (designated "2T" in Figure 9-5, but not marked on the board), effective response is *twice* the sum of the values selected with the contacts marked 1, 3, and 9.

NOTE

Changing the response time will necessitate readjustment of Bias Adjust Potentiometers R33 and R34, item 4.

2. **Low-Pass Filter.** This active filter utilizes operational amplifier AR1 to smooth the fullwave-rectified signal.
3. **D.C. Amplifier and Associated Feedback Divider (Range Resistor Network).** The output signal from the low-pass filter circuit is applied to an operational amplifier circuit. It consists of high-gain d.c. amplifier AR2, connected in an operational amplifier configuration. The feedback divider associated with AR2 provides the capability of varying the d.c. gain, to permit use of different operating ranges. The feedback signal is applied to input 2 of AR2 via one deck of the front-panel RANGE Switch.

   With RANGE Switch at position 1, overall gain of the system is adjustable with the front-panel GAIN Control (Paragraph 5.3.2).

   With RANGE Switch at position 2, the gain of AR2 may be adjusted with trimming potentiometer R9. Range 2 gain is adjustable from 1X to 3.5X the Range 1 gain.

   With RANGE Switch at position 3, the gain of AR2 may be adjusted with trimming potentiometer R13. Range 3 gain is adjustable from 2X to 10X the Range 1 gain.

NOTE

In the Ambient CO Monitoring System, Range 3 is the normal operating setting. Range 1 is used only for certain electronic checks. Range 2 is operative, but is not normally used.

4. **Bias Adjustment Potentiometers R33 and R34.** These controls apply an adjustable zero-biasing signal to the input of the D.C. Amplifier, to null out instrument component electronic offsets. Electronic zero may be established as follows:
   a. With RANGE Switch set for Range 3, GAIN Control is set at counterclockwise limit to remove all signal from input of amplifier circuitry, and ZERO Control is set at clockwise limit to remove all compensation for normal optical offset signals.
   b. Coarse Bias Adjustment R33 is adjusted to center the span of Fine Bias Adjustment R34 at or near the required near-zero d.c. level. Potentiometer R34 is then adjusted for zero reading on meter or recorder.
5. **Front-Panel ZERO Control.** This control applies an additional zero-biasing signal to the input of the D.C. Amplifier, to null out the normal optical offset signal.

   With CO-free air routed through sample and reference cells, the input signal to the amplification circuitry, and therefore the meter reading, should ideally be zero. Ordinarily, however, a small input signal is present. This is due to slight inequality between intensities of the two sources, differences between transmission characteristics of the sample and reference cells, out-of-phase signal, etc. This residual imbalance signal is minimized with the SOURCE BALANCE Adjustment, Source Alignment Adjustment (Vertical Positioning Screw), and if necessary, with the appropriate optical shutter (Paragraph 5.3.6).

After the best possible minimum has been achieved, the SOURCE BALANCE Control is offset, by an amount determined by the size of the residual imbalance, to bias the optical system into linearity. It is the electronic signal induced by this normal optical offset which is nulled out; i.e., compensated with the ZERO Control. With CO-free zero air still flowing through the analyzer, the *final* zero adjustment is made by setting the front-panel ZERO Control for zero reading on meter or recorder. After the ZERO Control has been set as directed in Step 7 of Paragraph 3.1, the amount of compensating signal fed into the zero-biasing input of the D.C. Amplifier is automatically adjusted in proportion to changes in setting of the GAIN Control, thus ensuring proper compensation independent of gain setting

6. **Slide Switch SW2 and Voltage Output Jumper.** These two items control routing of the output signal from D.C. Amplifier AR2.

   Slide Switch SW2 is set at the position marked "E.I" to obtain the standard (nonlinearized) voltage output, and at "LIN" to obtain the linearized voltage output provided by the optional 633756 Linearizer Circuit Board.

   If a jumper is connected between the points marked STRAP FOR E OUTPUT, the output signal is routed to ground via a voltage divider associated with SW1 (item 7) to provide a selectable voltage output. The jumper is not used if the signal is to be routed through the optional 633756 Linearizer Board.
7. **Potentiometric Output Selection Function of Switch SW1.** The desired potentiometric output is obtained by closing the corresponding contact on Switch SW1, thus selecting the appropriate tap on the voltage divider mentioned in item 6. Contacts are marked: 0.01V, .1V, 1V, and 5V. In the Ambient CO Monitoring System, the 5-volt output is used, to provide the 0 to 5 volts d.c. output required for the Automatic Zero/Span Standardizer.
8. **Meter Sensitivity Adjustment Potentiometer R15.** Potentiometer R15 permits adjusting the fullscale span of the meter so that a 100% reading on the analyzer meter corresponds to a 5-volt fullscale output from the analyzer unit.

5.3.4 THE 633756 LINEARIZER BOARD (OPTIONAL)

The output signal from the 638490 D. C. Amplifier Board (Paragraph 5.3.3) is proportional to absorption of optical energy in the sample cell, and therefore is not strictly linear with respect to CO concentration. The curve obtained during the calibration procedure of Paragraph 3.2 may be used to convert recorder readings into CO concentration values. Alternatively, the optional 633756 Linearizer Board, Figure 9-6, may be used to equip a given operating range for linear readout of CO concentration on the recorder. The linearizer board, if used, may be calibrated for either the *designated* range of 0 to 50 parts per million CO, or for a *non-designated* range involving higher CO concentrations; e.g., 0 to 100 parts per million CO.

Straightening of the absorbance-versus-concentration curve is accomplished by sequential adjustment of eight odd-numbered trimming potentiometers designated R19 through R33. Each controls the gain of an associated operational amplifier.

During factory checkout of a linearizer circuit board, potentiometers R19 through R33 are initially set at midrange. With zero input signal applied to the linearizer circuit, ZERO Potentiometer R35 is adjusted for zero output. Then an appropriate low-level signal is applied to the input, and R19 is adjusted for the corresponding output. Input voltage is increased in steps, and each successive potentiometer is adjusted in turn. Finally, with maximum input signal applied, potentiometer R33 is adjusted for fullscale output. The procedure is repeated as many times as required to obtain properly linearized output.

Field procedure for setup of the linearizer is essentially the same as that described above, except that it is advisable to start with the potentiometers at their original factory settings rather than at midrange. Refer to Paragraph 7.2.2.

A simpler procedure is possible if the curve has less than 5% nonlinearity at 50% of fullscale. Here the required correction can be obtained by adjustment of only three potentiometers, thus setting the 0%, 50%, and 100% points. Refer to Paragraph 7.2.1.

5.3.5 THE 633842 +15 VOLT/−15 VOLT POWER SUPPLY

The 633842 +15 Volt/−15 Volt Power Supply, Figure 9-7, consists of:

1. Two identical, regulated 15-volt power supplies. Each supply utilizes one 19.6-volt secondary of power transformer T1 to drive a fullwave rectifier circuit consisting of diode bridge and filter capacitor. A series-type integrated-circuit voltage regulator holds the output constant. Output voltage is adjustable via a trimming potentiometer: R2 for the +15 volt supply; R4 for the −15 volt supply. Negative output of the +15 volt supply and positive output of the −15 volt supply are connected to circuit ground at test point TP2.

   NOTE
   The so-called +15 volt supply is actually adjusted to +15.5 volts. The −15 volt supply is a true −15.0 volts.

   The +15 volt and −15 volt outputs are used for individual amplifiers on the various circuit boards, and for the zero-biasing circuit associated with the front-panel ZERO Control (Paragraph 5.3.3).
2. A 90-volt center-tapped secondary of transformer T1. This secondary is not used in the Ambient CO Monitoring System.

5.3.6 THE 637862 REGULATED A.C. SOURCE POWER SUPPLY, FRONT-PANEL SOURCE BALANCE ADJUSTMENT, OUT-OF-PHASE ADJUSTMENT, AND OPTICAL SHUTTERS

The 637862 Source Power Supply, Figure 9-8, provides a regulated, adjustable, a.c. output to drive the dual infrared sources. Output voltage is adjustable via dual potentiometer R7. Recommended setting is 30 volts.

Note that a.c. voltage regulation is accomplished by clipping the waveform; thus the regulated output is *not* a true sine wave, and will *not* give a true a.c. reading on most com-

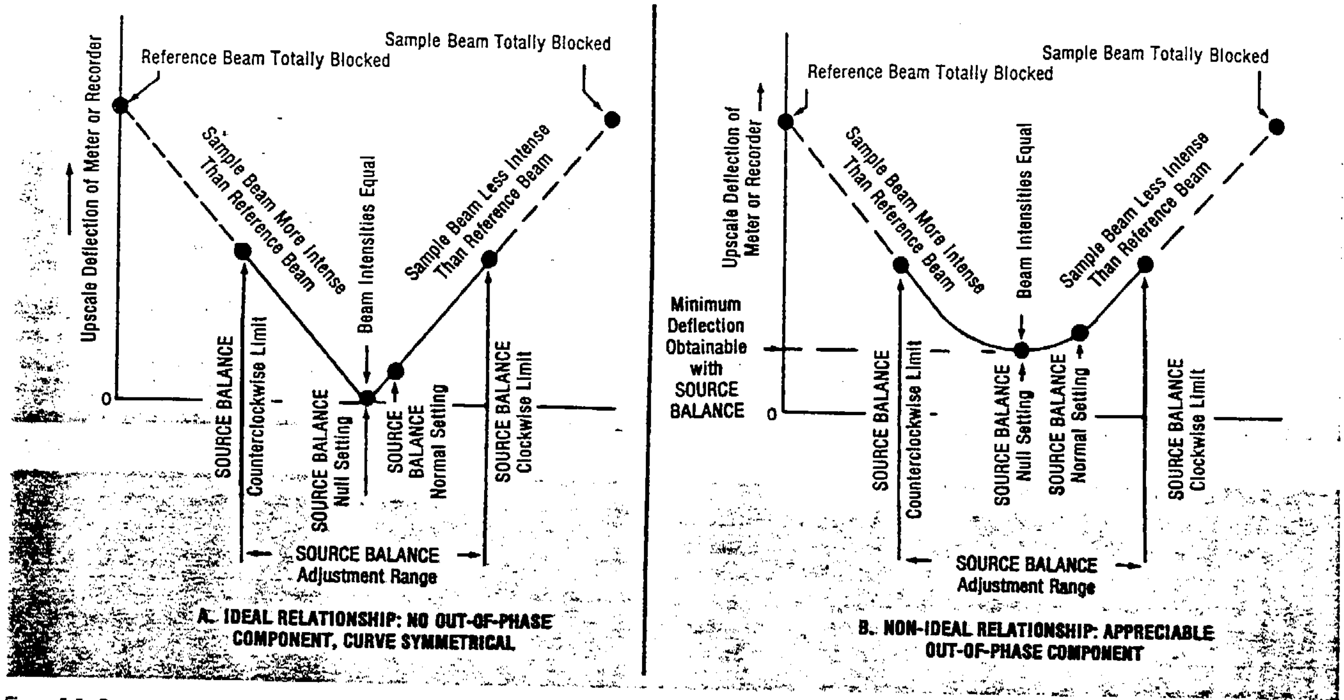


Figure 5-5. Response of Meter or Recorder to Analyzer SOURCE BALANCE Adjustment

monly used multimeters; e.g., Simpson, Triplett. At normal operating levels of the output voltage, a multimeter will read one to two volts higher than the true a.c. value.

Front-Panel SOURCE BALANCE Adjustment

As shown in Figure 9-1, the power supply output is applied to the sources via a resistor bridge that includes the front-panel SOURCE BALANCE Adjustment. This potentiometer adjusts the relative intensities of sample and reference sources, to compensate for slight inequality in characteristics of the two sources, differences between transmission characteristics of sample and reference cells, etc.

As explained in Paragraph 5.2, the detector responds to the *difference* between the radiant energies of the incident sample and reference beams. When the detector receives beams of *equal* energy, the detector-output signal and therefore also the meter reading are zero. When beam intensities differ in *either direction*, the detector responds to the beam-imbalance signal, causing an *upscale* deflection on meter and recorder. (The reason that analyzer response to beam imbalance is the same, regardless of which beam is attenuated, is that the 10 Hz rectifier is *not* phase-sensitive.)

Ideal response of the meter or recorder to manipulation of the SOURCE BALANCE Adjustment is exemplified by the curve of Figure 5-5, A. Assume that, initially, the SOURCE BALANCE Adjustment is at its *counterclockwise* limit. Intensity of the sample beam is now considerably greater than that of the reference beam, resulting in an appreciable upscale reading on the meter or recorder. Clockwise rotation of the SOURCE BALANCE Adjustment will decrease the relative intensity of the sample beam, and will therefore *decrease* the meter or recorder reading. At some point on or near the midrange setting of the SOURCE BALANCE Adjustment, sample and reference beams will be of equal intensity; therefore, the meter or recorder will read zero (or near-zero value). Further *clockwise* rotation of the SOURCE BALANCE Adjustment beyond the null setting will decrease the intensity of the sample beam to a value less than that of the reference beam. Consequently, the reading will rise above zero, or above the near-zero minimum previously obtained, and will continue to rise until the SOURCE BALANCE Adjustment reaches its clockwise limit.

Effect of Out-of-Phase Signal Component

Ideally, the meter or recorder reading should be reducible to zero via the SOURCE BALANCE Adjustment, as described above and as shown in Figure 5-5, A. In practice, however, a zero reading may be unobtainable. If so, the probable cause of the residual signal imbalance is excessive out-of-phase signal component due to misalignment of the optical system. The result is that the characteristic curve for the SOURCE BALANCE Adjustment has the shape shown in Figure 5-5, B. This curve is similar to the ideal curve of Figure 5-5, A, except that, at the null setting of the SOURCE BALANCE Adjustment, where beam intensities are equal, the meter or recorder reading is an upscale value instead of zero. To correct this condition, the Vertical Positioning Screw on the Motor/Source Assembly, Figure 3-3, is used to move the sources up or down, as required to minimize the reading.

Normal Operating Setting of SOURCE BALANCE Adjustment

Normal operating setting for the SOURCE BALANCE Adjustment is clockwise from null point, causing intensity of the sample beam to be *slightly less* than that of the reference beam. Otherwise, if the SOURCE BALANCE Adjustment were set *exactly* at the null point, subsequent slight drift of the sources might cause the intensity of the sample beam to become slightly *greater* than that of the reference beam. Sample monitoring under these conditions would result in anomalous meter response at the low-concentration end of the readout range; i.e., in this region the meter would drive downscale when it should give a small *upscale* reading.

If the out-of-phase component is appreciable, as in Figure 5-5, B, adjustment of the SOURCE BALANCE away from the null point is also necessary in order to bias the optical system into the linear region of the curve.

Optical Shutters

The shutters, Figure 3-3, constitute a coarse optical balance adjustment which is used if an acceptable balance is unobtainable with the front-panel SOURCE BALANCE Adjustment, or is obtained near the clockwise limit of this control. The shutters are sliding metal plates attached to the entrance ends of the sample and reference cells, permitting partial blocking of either beam, as required to obtain balance.

NOTE

Avoid excessive attenuation with a shutter, as it will decrease system energy undesirably, resulting in unfavorable signal-to-noise ratio. If extreme attenuation of a beam is required to obtain balance, the probable cause is dirty flowthrough cells, necessitating cleaning per Paragraph 6.2.1.

5.3.7 THE 631688 DETECTOR TEMPERATURE CONTROL BOARD AND ASSOCIATED ELEMENTS

The 631688 Detector Temperature Control Board, Figure 9-9, utilizes thermistor RT1 as its temperature sensor, mounted adjacent to the detector. See Figure 9-2. The circuit board controls application of electrical power to 125-watt resistive heating element R10, thus maintaining temperature *at the sensor point* at approximately 140°F (60°C). When the circuit is in control, the light on the board will blink at intervals of approximately one second.

5.3.8 THE 635883 CASE TEMPERATURE CONTROL BOARD AND ASSOCIATED ELEMENTS

The 635883 Case Temperature Control Board, Figure 9-10, utilizes thermistor RT2 as its temperature sensor, Figure 9-2. The circuit board controls application of electrical power to 150-watt resistive heating element HR11, thus maintaining

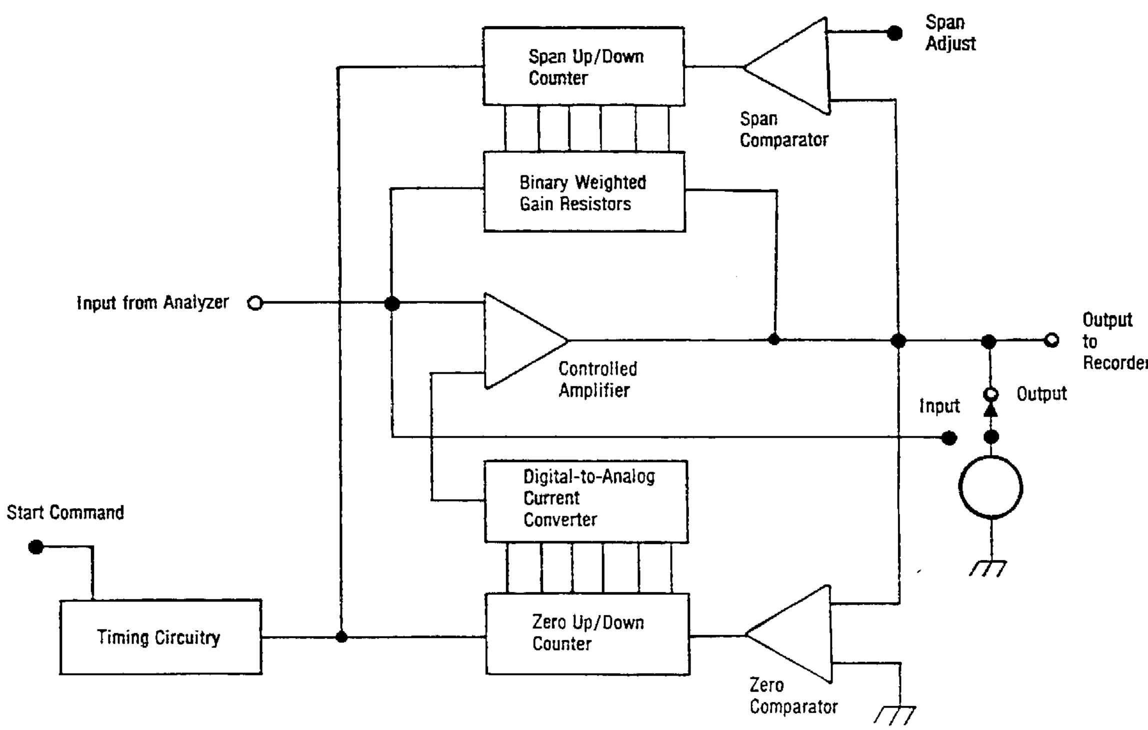


Figure 5-6. Functional Block Diagram of Automatic Zero/Span Standardizer

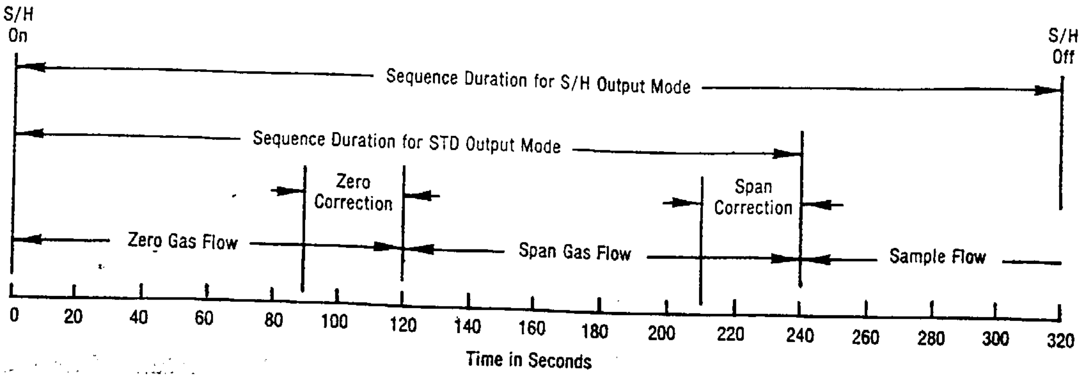


Figure 5-7. Standard Timing Sequence for Automatic Zero/Span Standardization

temperature *at the sensor point* at approximately 120°F (49°C). Blower fan B2 provides air circulation throughout the analyzer case.

5.4 AUTOMATIC ZERO/SPAN STANDARDIZER

Electronic circuitry of the Automatic Zero/Span Sandardizer is shown in simplified form in the functional block diagram of Figure 5-6, and in greater detail in the schematic diagram of Figure 9-11. Functionally, the standardizer consists of:

1. Valve-actuation circuitry. Upon automatic or manual command, it provides 24 volts a.c. signals to actuate two solenoid valves on the Gas Control Panel. Paragraph 5.1.
2. Signal-conditioning circuitry. It receives the output from the analyzer, performs the zero and span-correction functions, and provides a corrected output to drive a front-panel meter and an external recorder.

The following paragraphs provide brief descriptions of individual circuits.

5.4.1 TIMING CIRCUIT

Timing of the zero-and-span standardization sequence is controlled by twelve-stage counter U13. The sequence is initiated by starting the counter. Duration of the sequence is determined by clock frequency. This is a factory-set at 16 Hz, resulting in a duration of 5 minutes and 30 seconds for the standard zero/span standardization sequence, Figure 5-7. This is the only setting designated for ambient CO monitoring.

Clock frequency, and therefore sequence duration, may be changed by appropriate connection of resistors in the basic timing circuit, Figure 9-11. The alternate clock frequencies and the corresponding sequence durations are: 32 Hz, 2 minutes 45 seconds; and, 2.2 Hz, 40 minutes. Note, however, that these settings are *not designated* for ambient CO monitoring.

5.4.2 ZERO-CORRECTION CIRCUIT

The zero-correction circuit consists of 8-bit up/down counters U17, U18, digital-to-analog converter U25, and comparator AR1C. When the timing circuitry activates the zero-correction sequence, the comparator compares the present output voltage, obtained with zero gas flowing, to ground (or to the offset zero value). The comparator then generates an up/down command to the zero counters. The count stored in the counters is decoded by the D-A converter to generate a bias current that affects the output voltage level of the standardizer amplifier. Thus the digital servo-loop forces the amplifier output to ground potential, or to the offset zero voltage. When the zeroing sequence is over, the bias current level supplied by the D-A converter is latched at the last value, providing a constant zero-correction current.

5.4.3 SPAN-CORRECTION CIRCUIT

The span-correction circuit consists of 8-bit up/down counters U15 and U16, resistor ladder network R11, and comparator AR1D. When the timing circuitry activates the span-correction sequence, comparator AR1D compares the present output voltage (obtained with span gas flowing) against a preset reference voltage. The comparator then generates an up/down count command to the counters. The resultant count from the counters pulls binary weighted resistors into and out of the feedback divider of the signal amplifier. This digital servo-loop alters the gain of the amplifier to equalize the span signal with the preset voltage. At the end of the span sequence, the circuit latches, holding the gain at the last value obtained.

5.4.4 SAMPLE-AND-HOLD AMPLIFIER CIRCUIT

The standardizer has the capability of preventing recorder response during the automatic standardization sequence. This function is provided by sample-and-hold amplifier circuit AR4/AR5. During sample analysis, the amplifier circuit continuously tracks the output to the recorder. Upon initiation of the automatic standardization sequence, the amplifier circuit holds the output at the value then in effect, and continues to hold this value throughout the sequence.

Note that when the S/H standardizer output mode is to be used in certain *non-designated* applications, where automatic standardizations are to be programmed to occur at frequent intervals, it is necessary to allow certain minimum delays between successive standardizations. These delays ensure that sample has purged the analyzer before the sample-and-hold circuit unlatches. With 2.5-minute or 5-minute sequence, minimum interval between sequences is approximately one minute. With 40-minute sequence, minimum interval is approximately ten minutes. This limitation is not a concern with the *designated* application, where automatic standardizations occur four hours apart.

5.4.5 OUT-OF-RANGE CIRCUIT

The out-of-range-circuit, consisting of two majority logic gates, activates front-panel indicators when the zero and span counters approach the limits of their count capability. Such indication notifies the operator that the *analyzer* requires recalibration.

SECTION SIX MAINTENANCE

6.1 PERIODIC MAINTENANCE

Procedures and recommended frequency for performance of periodic maintenance are tabulated in the typical operating and maintenance log of Figure 6-1.

6.2 CORRECTIVE MAINTENANCE

Corrective maintenance procedures are normally performed only after the cause of a malfunction has been determined during the troubleshooting procedure of Paragraph 7.1.

6.3 MAINTENANCE OF PUMP/SAMPLE-HANDLING MODULE

Maintenance procedures for the Pump/Sample-Handling Module, Figure 6-2, are covered in Paragraphs 6.3.1 through 6.3.4, following.

6.3.1 INLET FILTER (THREE-WEEK PERIODIC MAINTENANCE)

Ambient air is drawn into the Pump/Sample-Handling Module through inlet filter F1, Figure 6-2. This filter should be checked at intervals of about three weeks, depending on the dust load in the ambient atmosphere. If filter element shows particulate loading, replace it.

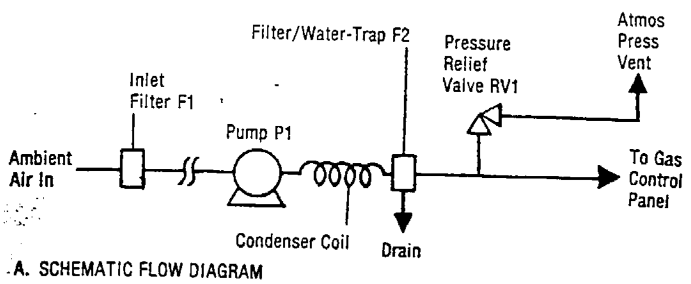
6.3.2 SAMPLE PUMP

The Pump/Sample-Handling Module should supply flows of 1 CFH (approximately 470 ml/min) each for the sample and reference channels of the Gas Control Panel. If flows are subnormal, examine diaphragm and flapper valves within Sample Pump P1 (Figure 6-2). Replace any defective components.

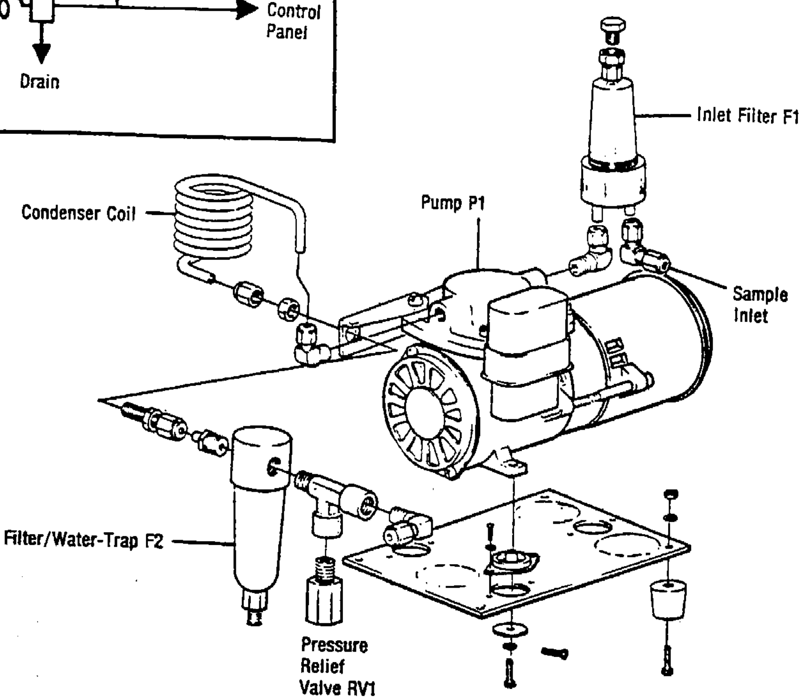
MODULE	CHECK OR ADJUSTMENT	REFERENCE	WEEK ENDING 1/3 76	1/10 76	1/17 76	1/24 76	1/31 76	2/7 76	2/14 76	2/21 76	2/28 76	3/6 76	3/13 76	3/20 76
Analyzer Unit	1. Log setting of ZERO Control	Figure 3-2	*	*	*	*	*	*	*	*	*	*	*	[illegible]
	2. Log setting of GAIN Control	Figure 3-2	*	*	*	*	*	*	*	*	*	*	*	[illegible]
	3. Check meter reading in TUNE mode	Paragraph 3.1, Steps 1 through 3	*	*	*	*	*	*	*	*	*	*	*	[illegible]
	4. Check electronic bias adjustment	Paragraph 3.1, Step 5	*											[illegible]
	5. Check SOURCE BALANCE Adjustment	Paragraph 3.1, Step 6	*											[illegible]
	6. Check cell windows and walls for dirt; clean if necessary. (6-month intervals)	Paragraph 6.5.1												[illegible]
Pump/Sample-Handling Module	1. Check Inlet Filter F1	Paragraph 6.3.1	*			*			*			*		[illegible]
	2. Check Filter/Water-Trap F2	Paragraph 6.3.3	*			*			*			*		[illegible]
Gas Control Panel	1. Log SAMPLE and REF flowmeter settings	Figure 3-1	*	*	*	*	*	*	*	*	*	*	*	*
	2. Check efficiency of catalytic converter	Paragraph 6.4.1												*
	3. Check Span Gas Solenoid Valve SV1	Paragraph 6.4.2	*			*			*			*		
	4. Check sample and reference filters	Paragraph 6.4.3												*
Standardizer	1. Illumination of ZERO OUT OF RANGE Lamp (log date of occurrence)	Figure 3-5												
	2. Illumination of SPAN OUT OF RANGE Lamp (log date of occurrence)	Figure 3-5												

NOTE
Asterisks indicate when the various checks should be made if scheduled according to the minimum recommended frequency of maintenance.

Figure 6-1. Typical Operating and Maintenance Log



A. SCHEMATIC FLOW DIAGRAM



B. EXPLODED VIEW

ITEM	MAT'L	DESCRIPTION	QTY
1	TEFLON COATED	HEAD	1
2	MFG STD	HEAD SCREW	4
3	" "	PLUG BUTTON	2
4	" "	FAN	1
5	" "	FAN	1
6	" "	BALL BEARING END CAP	1
7	" "	LOADING SPRING	1
8	" "	MOTOR END CAP	1
9	" "	STATOR	1
10	" "	SHAFT & ROTOR ASSY	1
11	" "	ECCENTRIC & BEARING ASSY	1
12	" "	VALVE PLATE GASKET	1
13	TEFLON COATED	VALVE KEEPER STRIP	2
14	" "	SCREW VALVE FLAPPER	2
15	" "	VALVE FLAPPER	2
16	" "	VALVE PLATE	1
17	" "	VALVE PLATE & HOLD DOWN SCR	6
18	" "	DIAPHRAGM HOLD DOWN PLATE	1
19	MFG STD	BALL BEARING HOUSING	1
20	" "	HOUSING	1
21	.06 THK HYPALON	DIAPHRAGM	1
22	MFG STD	CONNECTING ROD	1
23	" "	SET SCREW FOR ECCENTRIC	1
24	" "	CONN. ROD SCREW	1
25	" "	RUBBER GROMMET (NOT SHOWN)	1
26	" "	STATOR SCREW	2
27	" "	CAPACITOR	1
28	" "	END COVER VENTED	2

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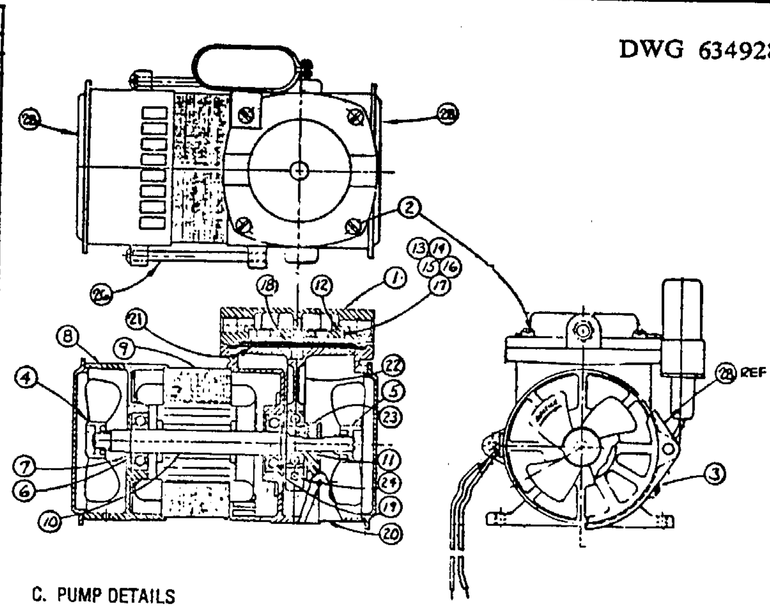
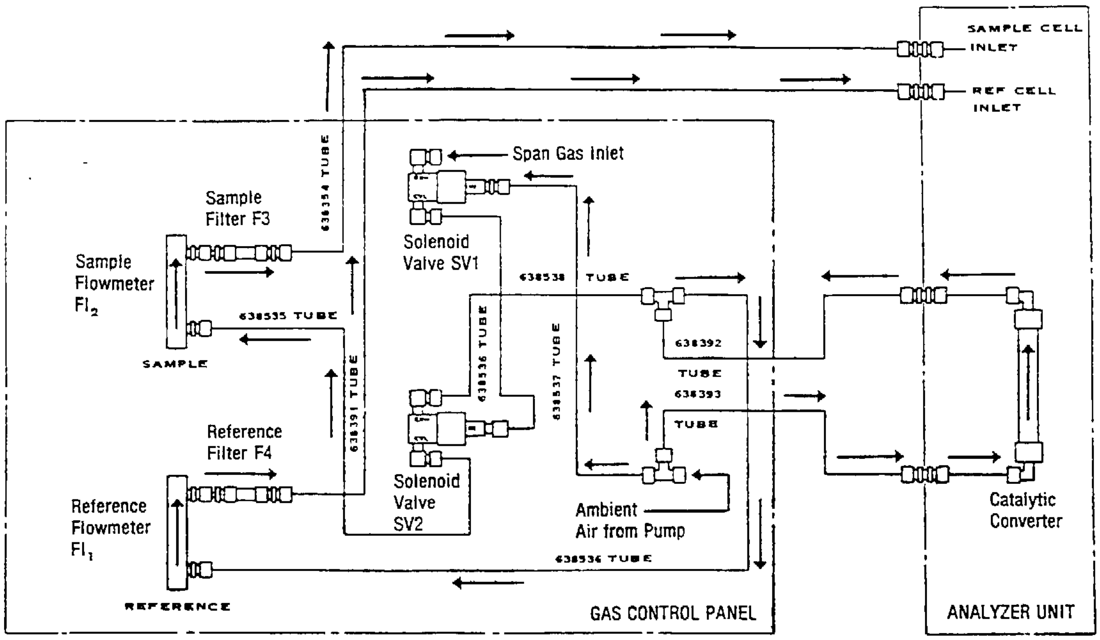
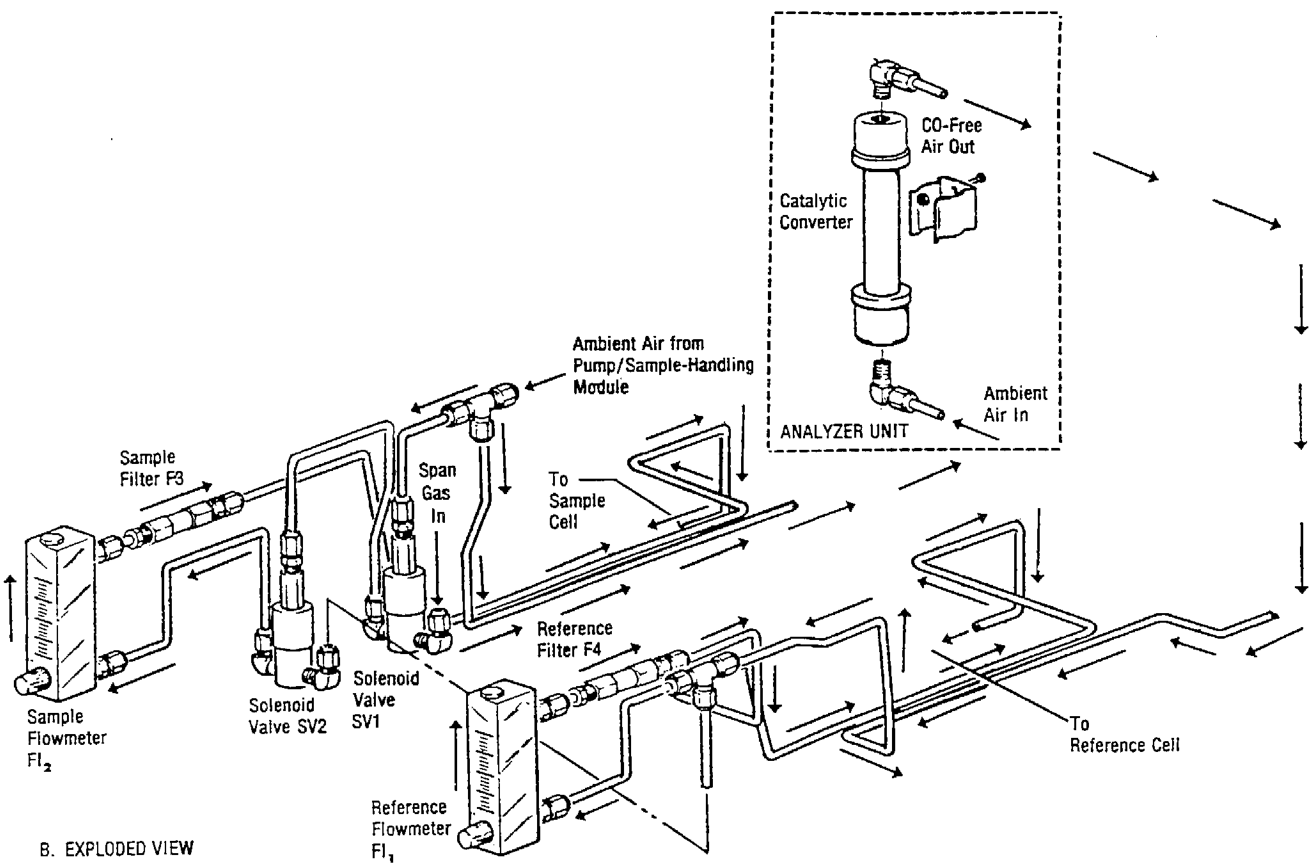


C. PUMP DETAILS

Figure 6-2. Pump/Sample-Handling Module



A. SCHEMATIC FLOW DIAGRAM



B. EXPLODED VIEW

Figure 6-3. Gas Control Panel and Catalytic Converter

6.3.3 FILTER/WATER-TRAP (THREE-WEEK PERIODIC MAINTENANCE)

The output from the sample pump passes through Filter/Water-Trap F2, where condensate drains off. The filter should be checked at intervals of about three weeks, depending on the dust load. If the sintered metallic filter element shows particulate loading, replace it.

6.3.4 PRESSURE RELIEF VALVE

Immediately downstream from Filter F2 is pressure relief valve RV1, nominal setting 5 psig (34.5 kPa).

6.4 MAINTENANCE OF GAS CONTROL PANEL AND CATALYTIC CONVERTER

Maintenance procedures for the gas control panel and catalytic converter, Figure 6-3, are covered in Paragraphs 6.4.1 through 6.4.3, following.

6.4.1 CHECKOUT OF CATALYTIC CONVERTER (THREE-MONTH PERIODIC MAINTENANCE)

Life of the catalytic material depends on local air contaminants. Exposure to strong acids, chlorine, H_2S and vapors of some organic solvents might reduce catalyst activity. At least once every three months, the converter material should be tested for efficiency, by means of the following procedure.

Test Procedure

Step 1. Supply a span gas, consisting of approximately 50 parts per million CO in air, to the span gas inlet, Figure 2-3. (Span gas must contain air to provide oxygen required for conversion of CO to CO_2.) On standardizer, place SPAN GAS FLOW Switch in ON position; wait until CO reading registers on recorder; then, return switch to AUTO.

Step 2. Disconnect span gas cylinder from span gas inlet and connect to sample inlet, Figure 2-3. Place standardizer in sample mode (ZERO GAS FLOW and SPAN GAS FLOW Switches at AUTO). Note CO reading on recorder.

The carbon monoxide readings obtained in Steps 1 and 2 must agree to within 1% of fullscale. If the reading in Step 2 is less than the reading in Step 1, the catalytic material is no longer efficient and should be regenerated or replaced.

Catalyst Regeneration

The converter, Figure 6-3, is mounted inside the case of the analyzer unit, with inlet and outlet fittings at the rear of the analyzer.

To regenerate the catalyst, proceed as follows:

1. Turn on analyzer power and allow analyzer to reach normal operating temperature.
2. On analyzer rear panel, disconnect tubing from converter inlet and outlet connections, designated "J" in Figure 2-1.

WARNING

The following step involves purging with hydrogen, a highly flammable gas. During this procedure, the exhaust from the converter should be conducted to a well-ventilated area.

3. Supply hydrogen to converter inlet. Set flow at 50 ml/min and purge for two hours. Catalyst should now be completely regenerated.
4. On analyzer rear panel, restore tubing connections to normal.

Catalyst Replacement

The catalytic material, if needed, should be ordered from Beckman Instruments, Inc., because of the selective nature of the catalyst.

6.4.2 SPAN GAS SOLENOID VALVE (THREE-WEEK PERIODIC MAINTENANCE)

Flow of span gas to the analyzer sample cell is controlled by the span gas solenoid valve, SV1 in Figure 6-3. Span gas should flow only during the span portion of the programmed automatic zero/span standardization sequence. See Figures 3-7 and 5-7. Leakage in the valve can cause span gas to leak into the sample channel during sample monitoring, resulting in erroneously high readings for the ambient air sample. The valve should be checked for leakage at intervals of about three weeks. With system in sample mode, proceed as follows:

1. Reduce span gas supply pressure to zero.
2. Supply zero air to inlet fitting on Pump/Sample-Handling Module. Note recorder reading.
3. Set span gas supply pressure at normal value. Note recorder reading.

   If reading in Step 3 is higher than in Step 2, the span solenoid valve is leaky, and should be replaced.

6.4.3 SAMPLE AND REFERENCE FILTERS

Downstream from the flowmeters, the sample and reference flows pass through in-line filters F3 and F4, Figure 6-3. These filters should be cleaned at periodic intervals, dependent on the dust load.

6.5 MAINTENANCE OF ANALYZER UNIT

The analyzer proper requires no *periodic* maintenance. (The catalytic converter, Paragraph 6.4.1, although *physically* mounted within the analyzer, is *functionally* associated with the Gas Control Panel, and is thus considered to be a part of the latter.)

Corrective maintenance procedures, covered in Paragraphs 6.5.1 through 6.5.3, are normally performed only after the cause of a malfunction has been determined during the troubleshooting procedure of Paragraph 7.1.

6.5.1 REMOVAL, CLEANING, AND REPLACEMENT OF SAMPLE AND REFERENCE CELLS

Typical symptoms of dirty cells are subnormal sensitivity and excessive drift. To clean cells:

1. Slide analyzer chassis out of case. Loosen cable clamps on bottom of main baseplate to allow further freedom of analyzer from case.
2. Disconnect tubing from sample and reference cells. Note tube connections to ensure proper reconnection during reassembly.
3. Loosen hold-down screw on cell-cap/shutter mounting bracket, Figure 6-4.
4. Loosen cells by inserting a small screwdriver, pin, or Allen wrench into holes in tie-rod adjusting nut, Figure 6-4, and turning counterclockwise. Then, while supporting the cells with one hand, continue unscrewing the

tie-rod adjusting nut, thus sliding back the cell-cap/shutter mounting bracket. The cells may now be released and lifted free.

5. Remove contaminants from cell walls and windows by rinsing in suitable solvent, such as alcohol.
6. To remove adhering contaminants, swab out cell interiors with a piece of soft flannel wrapped around a ½-inch (13 mm) diameter plastic rod.

CAUTION

Be particularly careful to avoid scratching the gold plating on the interior walls of the cells.

7. Make sure that all ports are clean.
8. Examine O-rings associated with both ends of sample and reference cells. If condition of O-rings is question-

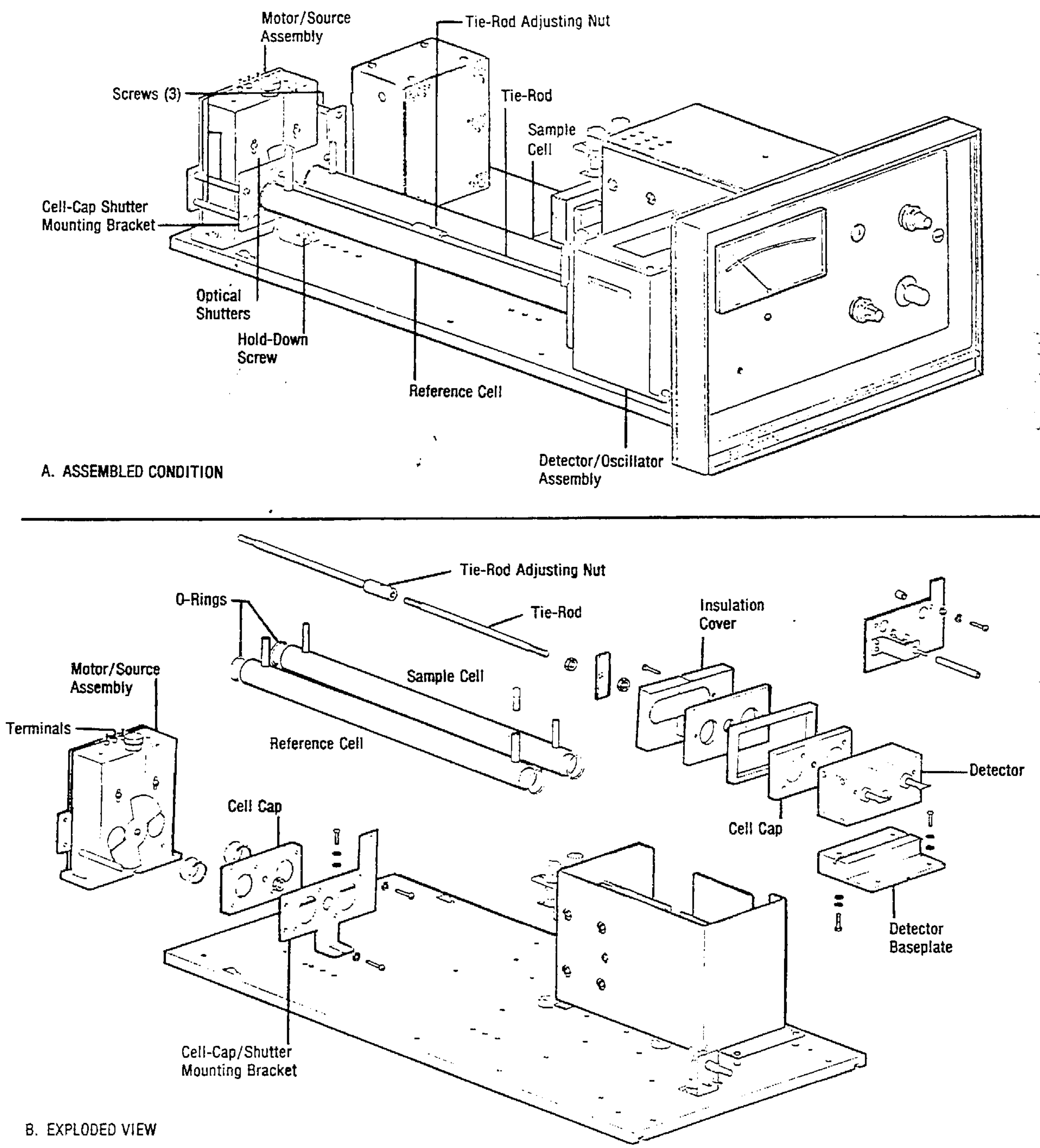


Figure 6-4. Interior of Analyzer Unit

able, replace with new (Beckman Part 817287). Insert original or replacement O-rings into windows of cell-cap assemblies, to facilitate cell installation.

9. Slide cell-support bracket forward on tie-rod, to a position approximately 1 inch (25 mm) from the detector assembly. This will facilitate cell installation.
10. Insert ends of both cells into detector assembly. With cells supported by sliding bracket on tie-rod, carefully turn tie-rod adjusting nut clockwise. As nut tightens, and cell-cap shutter mounting bracket is drawn forward, guide the ends of the cells into the cell-cap/shutter assembly, making sure that cells center into their respective holes and that O-rings are properly seated at both ends of cells.

CAUTION

Tighten tie-rod adjusting nut until the cells are seated firmly against the O-rings in both the cell-cap/shutter assembly and the detector assembly, but do not over-tighten.

6.5.2 REMOVAL AND REPLACEMENT OF MOTOR/SOURCE ASSEMBLY

First remove cells per Paragraph 6.5.1, then proceed as follows:

1. Remove three screws that fasten cell-cap/shutter mounting bracket to motor/source assembly. See Figure 6-4. Lift out motor/source assembly to permit access to wiring.
2. Unsolder terminal wires from top of source assembly case. Make sure to note which wire is attached to each of the three terminals, Figure 9-2.
3. Remove the four screws that hold the motor mounting plate to the housing of the motor/source assembly. This exposes the motor wiring terminals.
4. Unsolder the four cable leads from the motor terminals, noting which lead goes to each terminal.
5. Remove motor/source assembly from analyzer.

To install replacement motor/source assembly, use reverse sequence. Make sure that wires are connected to proper terminals (Figure 9-2) and that soldering is sufficient to hold wires to terminals.

6.5.3 REMOVAL AND REPLACEMENT OF DETECTOR

First remove cells per Paragraph 6.5.1, then proceed as follows:

1. Remove four top screws and cover plate from outer housing of detector/oscillator assembly, Figure 6-5, A. The filter/rectifier board, Figure 6-5, B, is now exposed.
2. Remove three mounting screws that retain the filter/rectifier board, and the three standoffs underneath the board. Be careful not to drop the standoffs into the interior, as they can cause shorting. Save screws and standoffs for reassembly.
3. Remove two screws that secure outer housing of detector/oscillator assembly to chassis. Lift off outer housing and insulator cloth.

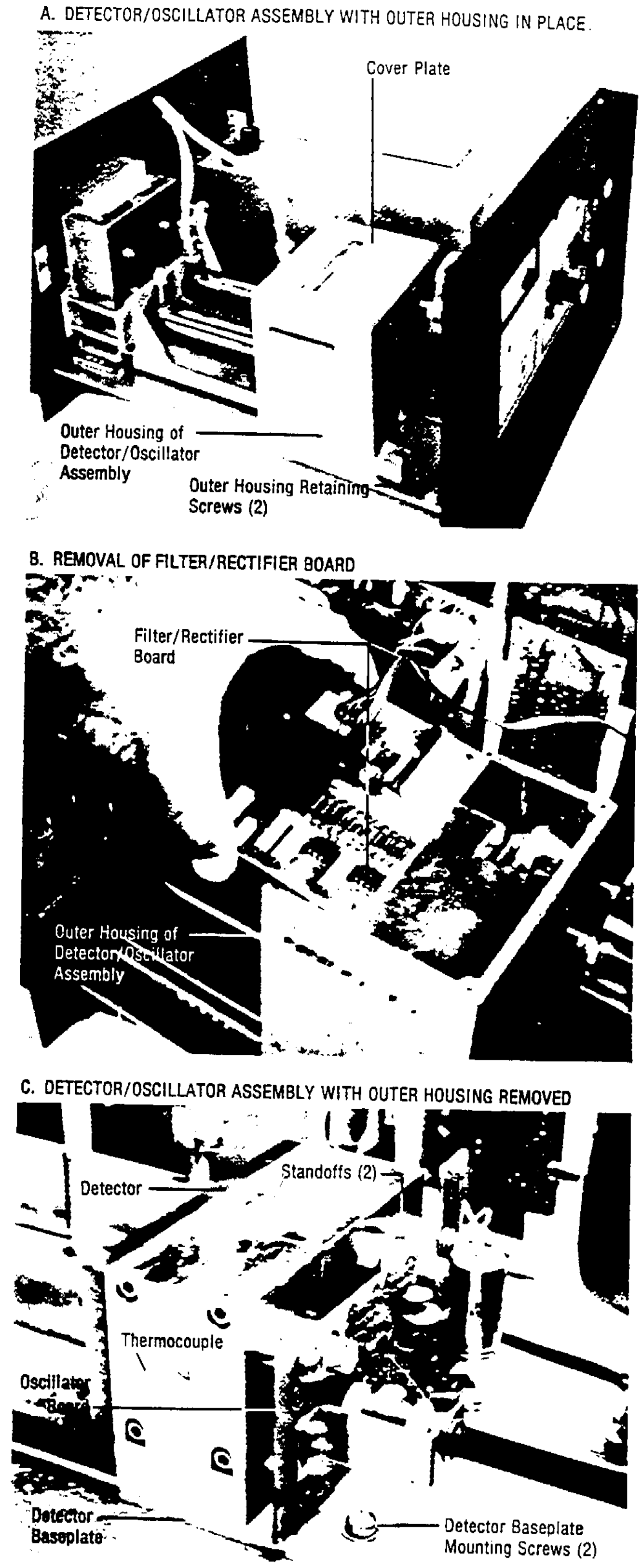


Figure 6-5. Disassembly of Detector/Oscillator Assembly

4. Remove two mounting screws from oscillator board, Figure 6-5, C. Pull oscillator board forward until disconnected from detector pin. Save the two standoffs for reassembly.
5. Remove two small screws that hold insulation cover to detector cell-cap assembly, Figure 6-4, B. Loosen tie-rod end-nut, thus permitting removal of insulation cover. Remove insulation cover, exposing four screws that hold detector cell-cap assembly to detector. Remove the four screws carefully, to avoid damaging detector windows.
6. Remove two mounting screws from detector baseplate, Figure 6-5, C. Remove thermocouple wire from side of baseplate and detector. A gentle pull will detach thermocouple from detector; there are no screws to remove.

CAUTION

Do not unglue detector heater which is attached to chassis beneath detector baseplate. There are no screws under the heater.

7. Slide detector baseplate back and forth to free from heat-sink compound that holds it to the chassis. Lift out detector and detector baseplate. Remove two screws that secure the detector to detector baseplate.
Perform following steps to install replacement detector.
8. Place a moderate amount of heat-sink compound on base of replacement detector, to ensure efficient heat transfer between baseplate and detector. Install two screws that secure detector to detector baseplate. Place moderate amount of heat-sink compound on bottom detector baseplate, and position it on the chassis.
9. Install four screws to hold detector cell-cap assembly to detector. Tighten against detector O-rings until snug. Replace and tighten two mounting screws that hold detector baseplate to chassis.
10. Reinstall thermocouple into side of detector, using sufficient heat-sink compound.
11. Reinstall oscillator board on detector pin, and secure with two mounting screws and associated standoffs.
12. Replace insulator cloth. Replace outer housing of detector/oscillator assembly. Install base screws, but do not tighten.
13. Replace the three standoffs associated with the filter/rectifier board, making sure that the three connector pins at the bottom of this board are properly aligned into the oscillator board. Replace three mounting screws that retain filter/rectifier board, making sure they are aligned with the standoffs.
14. Replace cover plate on outer housing of detector/oscillator assembly, and fasten in place with four screws. Replace insulation on detector cell-cap assembly. Replace the two insulation covers and secure with the two small screws. Secure tie-rod end-nut.

SECTION SEVEN SERVICE

Troubleshooting for the Ambient CO Monitoring System is summarized in Figure 7-1.

7.1 CHECKOUT OF ANALYZER UNIT

If analyzer performance is unsatisfactory, make the following tests *in the sequence given.*

1. **Meter Mechanical Zero**
   With *analyzer* power cord disconnected, verify that front-panel meter of analyzer unit reads zero. If not, adjust Meter Mechanical Zero Screw for zero reading.
2. **Warmup**
   Connect analyzer power cord. On analyzer front panel, turn RANGE Switch to position 3. Allow analyzer to warm up for at least two hours, then proceed with following steps.
3. **Oscillator Tuning**
   a. Turn RANGE Switch to TUNE.
   b. Slide analyzer chassis forward, partially out of the case. Reach behind analyzer front panel, slightly above hole marked OSC TUNE. With the fingers, grasp the small knob on the oscillator tuning adjustment shaft. Turn knob to the *counterclockwise limit.* Then, turn *clockwise* until peak reading is obtained on meter. For accurate determination of maximum reading, approach this peak from both directions.
   c. Turn OSC TUNE Adjustment *counterclockwise* until meter reading decreases to between 70% and 75% of the maximum obtainable value noted in Step 3b. When this reading is obtained, oscillator is functioning properly; return RANGE Switch to position 3 and proceed to Step 4.
   If specified reading is unobtainable, the trouble is in the oscillator circuit board, the detector, or the +15 Volt/−15 Volt Power Supply. On the +15 Volt/−15 Volt Power Supply, check for +15.5 volts with respect to ground at test point TP1 RED. If the voltage is correct, substitute a replacement oscillator board and determine if circuit can be tuned.
   If circuit still cannot be tuned, disconnect detector, and connect a 15 to 20 picofarad capacitor in its place. If oscillator now can be tuned, detector is defective. If detector is all right, but circuit cannot be tuned, substitute a replacement crystal for Y1.

When correct tuning is obtained, Return RANGE Switch to position 3 and proceed to Step 4.

4. Disconnect recorder from standardizer, and connect directly to appropriate terminals on analyzer unit. See Figure 2-2. Throughout the analyzer checkout procedure, the signal will bypass the standardizer. The standardizer will be used only to provide manual control of zero and span solenoid valves on Gas Control Panel.

The following troubleshooting table will enable the operator or qualified service personnel to identify the source of a malfunction. OSHA regulations require internal analyzer adjustments to be performed by qualified service personnel only.

SYMPTOM	PROBABLE CAUSE	REMEDY
Illumination of ZERO OUT OF RANGE Lamp Only, or Illumination of **both** ZERO **and** SPAN OUT OF RANGE Lamps. (If ZERO OUT OF RANGE Lamp illuminates more often than once a week, **or** if out-of-range condition is not correctable by adjustment of analyzer front-panel ZERO Control, per Paragraph 4.3, check the following.)	a. Detector or oscillator defective.	Refer to Paragraph 7.1, Step 3.
	b. Sources defective.	Refer to Paragraph 7.1, Step 10.
	c. Temperature control defective.	Refer to Paragraphs 5.3.7 and 5.3.8.
	d. Chopper motor B1 defective.	Refer to Paragraph 6.5.2.
	e. +15/−15 Volt Power Supply defective.	Replace board, Figure 9-2.
	f. Source power supply defective.	Refer to Paragraph 5.3.6.
	g. D.C. Amplifier Board defective.	Refer to Paragraph 7.1, Step 12.
	h. Filter/Rectifier Board defective.	Refer to Paragraph 7.1, Step 12.
	i. Loss of sample flow.	Refer to Symptom "No Sample Flow."
	j. Automatic Zero/Span Standardizer defective.	Refer to Symptom "Automatic Zero/Span Standardizer Fails to Standardize."
Illumination of SPAN OUT OF RANGE Lamp Only. (If SPAN OUT OF RANGE Lamp illuminates more often than once a month, or if out-of-range condition is not correctable by adjustment of analyzer front-panel GAIN Control, per Paragraph 4.3, check the following.)	a. Loss of span gas flow.	Refer to Symptom "No Span Gas Flow."
	b. Automatic Zero/Span Standardizer defective.	Refer to Symptom "Automatic Zero/Span Standardizer Fails to Standardize."
	c. D.C. Amplifier Board defective.	Refer to Paragraph 7.1, Step 12.
No Sample Flow	a. Leakage in interconnecting tubing.	Check tubing connections, Figure 2-3.
	b. Plugged filter(s) on Pump/Sample-Handling Module.	Refer to Paragraphs 6.3.1 and 6.3.3.
	c. Sample pump failure.	Refer to Paragraph 6.3.2.
No Reference Gas Flow	a. Leakage in interconnecting tubing.	Check tubing connections, Figure 2-3.
	b. Plugged filter(s) on Pump/Sample-Handling Module.	Refer to Paragraphs 6.3.1. and 6.3.3.
	c. Sample pump failure.	Refer to Paragraph 6.3.2.
	d. Automatic Zero/Span Standardizer defective.	Refer to Symptom "Automatic Zero/Span Standardizer Fails to Standardize."
No Span Gas Flow	a. Leakage in interconnecting tubing.	Check tubing connections, Figure 2-3.
	b. Span gas cylinder depleted.	Check cylinder pressure; if low, replace cylinder.
	c. Span gas solenoid valve defective.	Replace solenoid valve, Figure 6-3.
	d. Automatic Zero/Span Standardizer defective.	Refer to Symptom "Automatic Zero/Span Standardizer Fails to Standardize."
Recorder Trace Excessively Noisy (Noise Greater than 1% of Fullscale)	a. Detector or oscillator defective.	Refer to Paragraph 7.1, Step 3.
	b. Sources defective.	Refer to Paragraph 7.1, Step 10.
	c. Excessive vibration.	Refer to Paragraph 7.1, Step 13.
	d. Dirty cells.	
	e. Contaminated sample-handling system.	
	f. Line voltage fluctuations.	
Recorder Trace Shows Cycling	a. Detector Temperature Control Board defective.	Replace board, Figure 9-2.
	b. Fan Motor B2 defective.	Replace motor.
	c. Defective thermistor RT2 in fan motor on/off control circuit.	Replace thermistor.
Automatic Zero-Span Standardizer Fails to Standardize	a. Faulty timer switch.	Replace switch.
	b. 637002 Analog/Digital Board defective.	Replace board.
	c. 636871 ±15 Volt Power Supply defective.	Replace board.
Automatic Zero-Span Standardizer Standardizes Continuously	a. 637002 Analog/Digital Board defective.	Replace board.

Figure 7-1. Troubleshooting Chart

5. **Check Analyzer Bias Adjustment**

NOTE

Component electronic offsets will shift slightly as the interior temperature of the analyzer changes. For this reason it is recommended that, immediately prior to adjustment of the Bias Controls, the analyzer be allowed to run with cabinet closed for at least several hours. If subsequently bias level drifts slightly, correct instrument operation and readings will still be obtained. The only effect will be the introduction of a small interaction between the ZERO and GAIN Controls.

a. Set analyzer front-panel controls: GAIN Control at counterclockwise limit to remove all signal from input of amplifier; ZERO Control at clockwise limit to remove all compensation for normal optical offset signal; RANGE Switch at position 3.

b. Within the analyzer, locate the D.C. Amplifier Board, Figure 3-4. Set Switch SW3 to RUN. Adjust Coarse Bias Control R33 until recorder reads 50% of fullscale, or, if this is unobtainable, until maximum reading is obtained.

   Next, adjust Fine Bias Control R34 back and forth to determine the extreme recorder readings obtainable. (If recorder goes offscale, consider end of scale to be the extreme.) Then, set R34 so recorder reads approximately midway between these extremes.

   Readjust Coarse Bias Control R33 until recorder reads approximately zero. Then, readjust Fine Bias Control R34 so recorder reads exactly zero.

c. Turn front-panel RANGE Switch back and forth between positions 1 and 3. When instrument is properly biased, recorder reading will not change when RANGE Switch is moved.

NOTE

In the Ambient CO Monitoring System, Range 3 is the normal operating setting. Range 1 is used only for certain electronic checks. Range 2 is operative, but is not normally used.

6. **Analyzer SOURCE BALANCE Adjustment**

a. Turn on sample pump. On Standardizer, place ZERO GAS FLOW Switch at ON, thus routing CO-free zero air through sample and reference cells of *analyzer.*

NOTE

Continue flow of zero air until conclusion of Step 7.

b. On Gas Control Panel, set sample and reference flows at 1 CFH (approximately 470 ml/min).

c. On analyzer, turn ZERO Control to clockwise limit; set RANGE Switch to position 1. Turn up GAIN Control until recorder reads about 5% of fullscale. If this reading is unobtainable by adjustment of front-panel GAIN Control, leave it at maximum setting.

   Move RANGE Switch to position 3. Recorder should now read at least three times the reading on Range 1; if not, obtain reading of three times the Range 1 reading by adjustment of R13 on the D.C. Amplifier Board, Figure 3-4.

d. Adjust analyzer SOURCE BALANCE Control for minimum obtainable recorder reading. This will be zero, or slightly above, provided that bias adjustment has been properly made. To verify that a minimum has been obtained, make sure that the signal decreases as the SOURCE BALANCE Control is rotated toward the position of the minimum from both directions. An acceptable minimum is 15% or less (the smaller, the better). If an acceptable minimum is obtained, proceed directly to step f.

   If an acceptable minimum is unobtainable, adjust shutters (Figure 3-3) to obtain a minimum. If an acceptable minimum is still not obtained, proceed to Step e.

e. Within the analyzer, Figure 3-3, adjust Vertical Positioning Screw on Motor/Source Assembly to minimize recorder reading.

NOTE

If Vertical Positioning Screw is difficult to rotate, very slightly loosen source retaining screws, Figure 3-3. After completing adjustment of Vertical Positioning Screw, retighten retaining screws so sources are secure to Motor/Source Assembly. A loose source assembly will cause electronic noise.

Repeat Step d, and Step e if necessary, as many times as required to obtain an acceptable minimum. If an acceptable minimum is unobtainable, the most probable cause is dirt on windows or walls of flowthrough cells. Examine flowthrough cells; if cleaning is necessary, use procedure of Paragraph 6.2.1. When satisfactory minimum reading is obtained, proceed to Step 6f, following.

f. Turn SOURCE BALANCE Control *clockwise* until recorder reading is between 50% and 80% of fullscale. If reading of 50% is unobtainable by adjustment of the SOURCE BALANCE Control, leave it at the clockwise limit for the present; subsequently, during Step 8e, it will be readjusted counterclockwise.

7. **Set zero for all analyzer ranges**

a. On Standardizer, verify that ZERO GAS FLOW Switch is at ON, so that CO-free zero air is flowing through sample and reference cells of analyzer.

b. On analyzer, increase GAIN Control setting until recorder reads fullscale. If fullscale reading is unobtainable by adjustment of GAIN Control, leave it at maximum setting.

c. Allow analyzer to come to steady equilibrium.

d. Turn analyzer ZERO Control counterclockwise until recorder reads exactly zero. To check zero, move RANGE Switch to position 1; zero should not change. Tighten lock-ring on ZERO Control knob.

e. On standardizer, move ZERO GAS FLOW Switch to AUTO position.

8. **Analyzer Gain Adjustment**

NOTE

Preparatory to the following procedure, pressurized upscale standard gas of appropriate composition must be supplied to the span gas inlet on the Gas Control Panel. Refer to Paragraph 2.2.2.

a. On standardizer, place SPAN GAS FLOW Switch at ON, so that analyzer sample cell receives span gas from external cylinder, and reference cell receives CO-free zero air.
b. On Gas Control Panel, verify that both flowmeters read 1 CFH (approximately 470 ml/min). If reading on SAMPLE Flowmeter differs, adjust span gas pressure to obtain 1 CFH (approximately 470 ml/min).
c. Set analyzer front-panel GAIN Control at 500.
d. If the system is to be used on the standard range of 0 to 50 parts per million CO, place analyzer front-panel RANGE Switch at position 3. Then, adjust R13 on D.C. Amplifier Board (Figure 3-4) so that analyzer front-panel meter indicates the reading appropriate to the CO content of the span gas.

   If the system is to be operated on a less-sensitive, *non-designated* range, such as 0 to 100 parts per million CO, place front-panel RANGE Switch at position 2. Then, adjust R9 on D.C. Amplifier Board to obtain the reading appropriate to the CO content of the span gas.
e. Place analyzer RANGE Switch at 3. On standardizer, place SPAN GAS FLOW Switch at AUTO and ZERO GAS FLOW Switch at ON. On analyzer, turn front-panel ZERO Control to clockwise limit and repeat Steps 6d through 6f to ensure proper offset of optical balance; then, readjust ZERO Control to obtain zero reading.
f. Return ZERO GAS FLOW Switch to AUTO.

9. **Overall Sensitivity Check**

a. Block sample beam by placing a card over window of sample cell. Blocked sample beam simulates total absorption of sample-beam energy, causing maximum obtainable output signal from detector/oscillator circuit.
b. Adjust GAIN Control for reading of 100 on recorder. Note GAIN Control setting; it should be less than 120. If so, the sources, detector/oscillator, and amplification circuitry are all in good working order. Unsatisfactory instrument performance is probably due to the sampling system, contaminated standard gases, etc.

   If GAIN Control setting of greater than 120 is required, overall sensitivity is subnormal. The next step is to isolate the malfunction to (a) sources and detector/oscillator combination, or (b) the filtering and amplification circuitry. With sample beam still blocked and without changing setting on GAIN Control, proceed to Step 10, following.

10. **Measuring Output Signal from Detector/Oscillator Combination**

Connect a calibrated oscilloscope between CW terminal (signal output) and CCW terminal (ground) on GAIN Control Potentiometer R4A, Figure 9-2. Read peak-to-peak voltage of the 10-Hz signal; it should be at least 1.6 volts.

If reading is less than 1.6 volts peak-to-peak, the trouble is in the sources or the detector/oscillator combination. Proceed to Step 11.

If detector/oscillator peak-to-peak voltage is 1.6 volts or greater, and yet the blocked-beam GAIN setting measured in Step 8b was abnormally high; i.e., greater than 120, the trouble is in the filtering and/or amplification circuitry. Proceed directly to Step 12.

11. **Checking Sources**

Since sources emit only infrared energy, sample and reference beams are invisible. To determine if sources are functioning:

a. Measure total voltage across the two sources by connecting a voltmeter to the two outer terminals on the source assembly, Figure 9-2. The terminal connected to the sample source has GRN and WHT-BLK harness leads attached. The terminal connected to the reference source has BLU and WHT-BRN harness leads attached. The rear-panel Source Voltage Adjustment is nominally set for 30 volts a.c.

NOTE

The regulated a.c. voltage applied to the sources is **not** *a true sine wave, and will* **not** *give a true a.c. reading on most commonly used multimeters. At normal operating levels of the output voltage, a multimeter will read one to two volts higher than the true a.c. value.*

b. Measure the voltage across each of the individual sources. On the source assembly, Figure 9-2, connect a voltmeter from the common; i.e., center, terminal to each of the outer terminals, in turn. The common terminal has a WHT-ORN harness lead attached. The terminal connected to the sample source has GRN and WHT-BLK harness leads attached. The terminal connected to the reference source has BLU and WHT-BRN harness leads attached. Voltage across each source should be very nearly equal to one-half the total voltage, depending on the setting of the SOURCE BALANCE Adjustment. If voltage is incorrect, replace the sources. Note that replacement of the sources may necessitate optical realignment to minimize the out-of-phase signal. Refer to Step 6.

12. **Checking Output Signal from 10-Hz Bandpass Filter**

With sample beam still blocked, connect oscilloscope from chassis ground to test point TP2 YEL of the 633290 Filter/Rectifier Board. Set RANGE Switch at position 1. Adjust GAIN Control for reading of 100 (fullscale) on front-panel meter. Oscilloscope should show a clean 10-Hz signal with peak-to-peak amplitude of about 2.5 volts. If amplitude is subnormal, adjust Filter Pass Adjustment Potentiometer R16 on Filter/Rectifier Board for maximum signal amplitude.

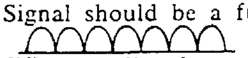
13. **Checking Output Signal from Fullwave Rectifier**

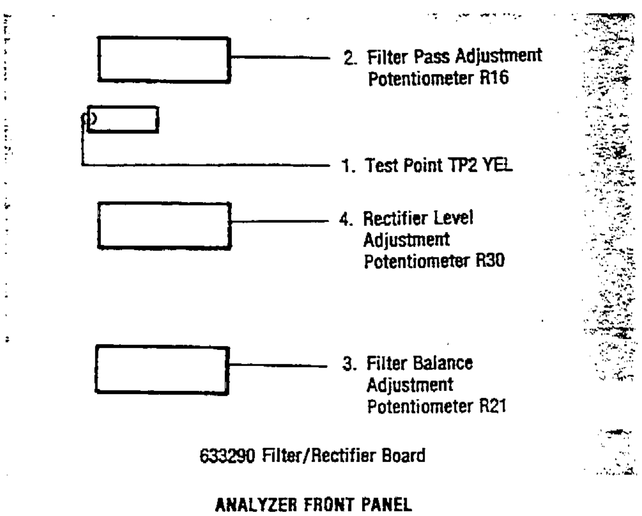
a. Turn GAIN Control to counterclockwise limit.
b. With sample beam still blocked, connect calibrated oscilloscope between terminal S (signal input) and

CCW terminal (ground) on GAIN Control Potentiometer R4A. Figure 9-2. Oscilloscope now indicates the input signal to the 10-Hz bandpass filter section of the Filter/Rectifier Board.

c. Adjust GAIN Control so oscilloscope shows peak-to-peak reading of 100 millivolts. Now disconnect oscilloscope but do not disturb GAIN Control setting.

d. Note meter reading. It should be at least 50% of fullscale: if so. the 633290 Filter/Rectifier Board and the 638490 D.C. Amplifier Board are functioning properly. If reading is subnormal. repeat Step d after completing Step c. If correct meter reading is now obtained. sensitivity of the filtering and amplification circuitry is satisfactory. If meter reading is still subnormal. the 638490 D.C. Amplifier Board is probably at fault: to check. substitute a replacement board.

e. With GAIN Control still at setting established in Step 12c. connect oscilloscope between chassis ground and pin J of the D.C. Amplifier Board. Signal should be a fullwave-rectified waveform  . If heights of adjacent peaks differ. equalize the peak heights via Filter Balance Adjustment potentiometer R21 on the Filter/Rectifier Circuit Board, Figure 7-2. Peak voltage of the halfwave pulses should be at least 1.7 volts. If so, proceed directly to Step 13f.



ADJUSTMENT	FUNCTION
1. Test Point TP2	Permit adjustment of 10 Hz bandpass filter. With an oscilloscope connected to TP2, R16 is adjusted for maximum amplitude of 10 Hz signal.
2. Filter Pass Adjustment Potentiometer R16	
3. Filter Balance Adjustment Potentiometer R21	Adjustments for circuit that provides fullwave rectification of 10 Hz signal. Potentiometer R21 is used to equalize heights of adjacent halfwave pulses. Potentiometer R30 is used to adjust the rectification level of the rectifier to the d.c. offset voltage level of the filter amplifier.
4. Rectifier Level Adjustment Potentiometer R30	

Figure 7-2. Adjustments on Filter/Rectifier Board (Analyzer Unit)

If output is incorrect. Filter/Rectifier Board is a fault; replace it — then repeat Steps 13a through 13e

f. Continue to monitor signal at pin J of 638490 Ampli fier Board as in Step 13e. Set GAIN Control at coun terclockwise limit. Set oscilloscope at sensitivity o at least 10 mV/cm. and preferably 1 mV/cm, i available. Turn up GAIN Control slightly unti fullwave-rectified signal is clear.

g. If heights of adjacent peaks differ, equalize the pea heights by adjusting Rectifier Level Adjustment Pc tentiometer R30 on 633290 Filter/Rectifier Circui Board, Figure 7-2. Turn GAIN Control slowly dow to counterclockwise limit. and then back up. Adja cent peaks should disappear and reappear simulta neously, and should remain respectively equal i height as GAIN Control is turned down and up. I not, and/or if fullwave-rectified signal changes to a unrectified signal, just before GAIN Control reache counterclockwise limit, continue to adjust R30 unti the prescribed behavior is achieved.

NOTE

Failure to adjust R30 until prescribed behavior is achieved will result in a slight interaction between GAIN and ZERO Controls, and possibly also output nonlinearity for very low level signals.

h. If adjustment of R30 on 633290 Filter/Rectifie Board as required in Step g above, repeat Steps f an g until the prescribed behavior is obtained withou requiring readjustment.

14. **Electronic Noise Check**

If analyzer shows normal sensitivity and response, bu excessively *noisy* readout, first check for possible loos source. Tighten source retaining screws, Figure 3-3. An other possible cause of noise is vibration at the installa tion site. Sporadically noisy readout in an instrumen that is moved frequently from one location to another i particularly suggestive of vibration. The site *must* be fre of appreciable vibrations. If analyzer is *excessively* sensi tive to vibration, readjust shock mounts, Figure 7-3 After checking for vibration, examine the recorder trac to determine the characteristics of the noise. Genera types are:

a. Pen fluctuates rapidly so that, in effect, the trace i a broad band instead of a narrow line. First verif that recorder gain is not too high. Turn recorder gai low, then gradually increase it until nonresponsiv deadband disappears. To determine if deadband ha been minimized, mechanically force recorder pen drive mechanism away from balance point, first i one direction, then in the other. If balance point i the same (to within 0.2% fullscale) in both cases deadband has been reduced to desired level.

Another possible cause of a broad recorder trac is dirt on cell walls and windows. Any foreig material on these surfaces decreases the amount o infrared energy transmitted, lowering the signal to-noise ratio. In addition, loose dirt in the flow through cells may move, thus generating noise. Clea

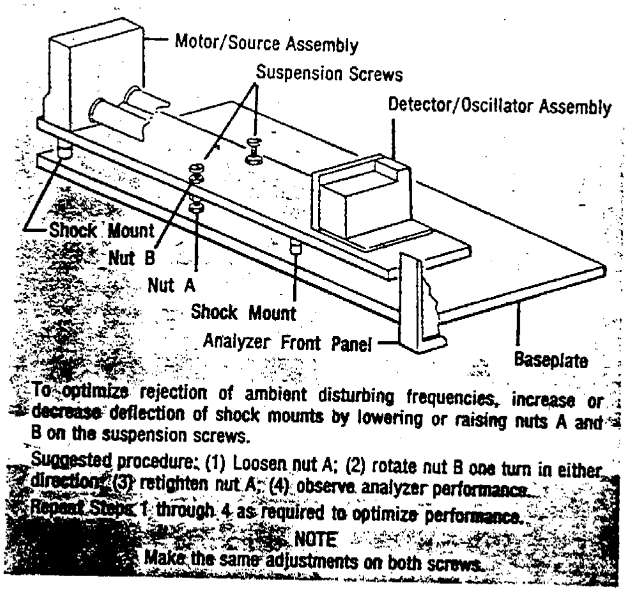


Figure 7-3. Adjustments for Minimizing Vibration Effects in Analyzer Unit

sample and reference cells as explained in Paragraph 6.5.1. If noise persists, a contaminated sample-handling system may be responsible.

If recorder still shows erratic response, consult your Beckman Field Service Representative.

b. Trace is narrow but erratic. Possible cause is sudden line-voltage fluctuations (spikes).

15. If all tests yield correct results, analyzer is operational; source of the trouble is elsewhere in the system. Check for contaminated sample-handling system or standard gases, etc.
16. Restore recorder connections to normal. Refer to Figure 2-2.
17. **Check Standardizer Meter Sensitivity**
    a. On *standardizer*, depress POWER ON and METER SELECT INPUT Pushbuttons. The front-panel meter of the *standardizer* will now indicate the output from the *analyzer*.
    b. Adjust front-panel ZERO Control on analyzer so that *analyzer* meter reads 100%. Front-panel meter on *standardizer* should also read 100%; if not, obtain 100% reading via Meter Adjustment Potentiometer, Figure 3-7.
18. If the standardizer is required to provide zero offset, as explained in Paragraph 2.2.2, verify that an appropriate resistance has been inserted into the zero-correction circuitry. Refer to Paragraph 2.3.4.
19. **Standardizer Span Set Adjustment**
    a. On standardizer, depress METER SELECT OUTPUT button.
    b. Select SPAN-SET position on OPERATE/SPAN-SET Switch, located behind standardizer meter.
    c. Adjust Range 1 Span Set potentiometer, Figure 3-7, to obtain meter reading equal to the concentration of carbon monoxide in the span gas. (Note that Range 1 on the *standardizer* corresponds to Range 3 on the *analyzer*).

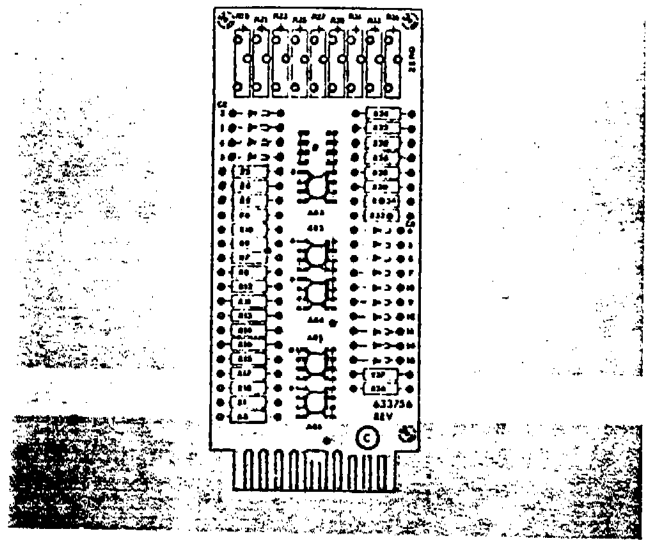


Figure 7-4. Optional Linearizer Board (Analyzer Unit)

    d. Return OPERATE/SPAN-SET Switch to OPERATE position.
20. **Checkout of System Operation**
    Depress SEQUENCE SELECT AUTO Pushbutton on standardizer, and observe the auto zero/span sequence thus initiated.
    a. CO-free air will flow for sufficient time to purge the analyzer sample cell. The analyzer meter, standardizer meter, and recorder will then drive downscale to zero (or preselected offset value, typically between +3% and +5% of fullscale).
    b. Span gas will flow for sufficient time to purge the analyzer sample cell. The Analyzer meter, standardizer meter, and recorder will then drive upscale to the reading appropriate to the CO content of the span gas.

    Repeat the sequence twice more to verify correct operation.

7.2 SETUP AND CALIBRATION OF 633756 LINEARIZER BOARD (OPTIONAL)

The output signal from the analyzer amplifier is proportional to the absorption of optical energy in the sample cell, and therefore is not strictly linear with respect to CO concentration. If improved linearity is desired, the optional 633756 Linearizer Board (Figure 7-4) may be used to equip a given operating range for linear readout of CO concentration on the recorder. The linearizer board, if used, may be calibrated for either the *designated* range of 0 to 50 parts per million CO, or for a *non-designated* range involving higher CO concentrations: e.g., 0 to 100 parts per million CO.

If the linearizer board is factory-installed, it is factory-adjusted for correct readout on the particular operating range desired. However, if the board is custom-installed subsequent to purchase of the system, or if a factory-installed

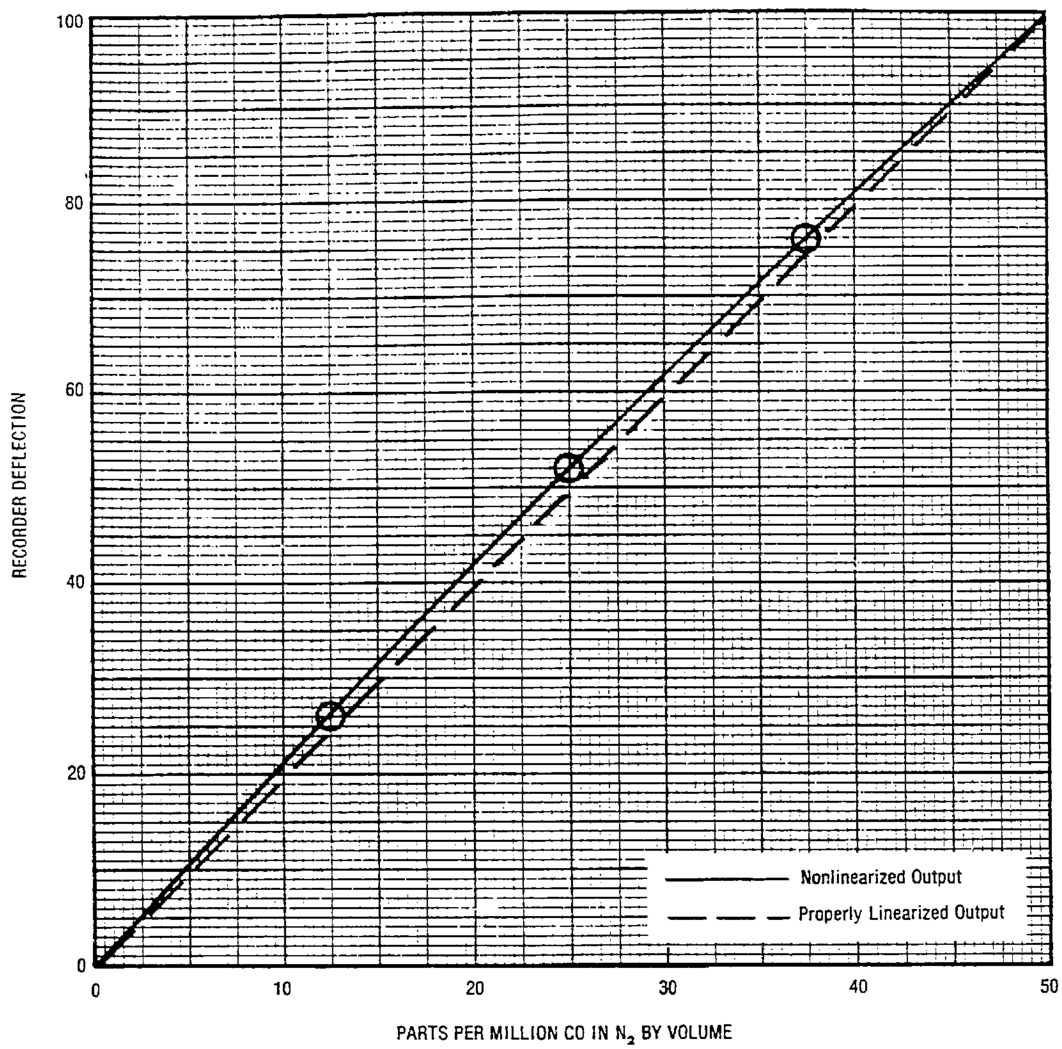


Figure 7-5. Typical Calibration Curve with Nonlinearity of Less Than 5%

board is to be changed from the original operating range to another, the circuit must be adjusted by the user, as explained subsequently.

Use of Calibration Curve

For the particular application, a quantative comparison between the standard, nonlinearized output, and the optional linearized output can be obtained by reference to the curve obtained during the dynamic multipoint calibration procedure of Paragraph 3.2. This calibration curve will be similar to the typical example of Figure 7-5, which is for the standard range of 0 to 50 parts per million CO. For example, in Figure 7-5 consider instrument response to 25 parts per million CO. With *nonlinearized* output, the recorder would read 52% of fullscale. With *properly linearized output*, the reading would be 50%. To obtain the desired relationship, the instrument is placed in *nonlinearized* mode and the front-panel ZERO Control is adjusted to *simulate* a signal level of 52%. Then, with instrument in *linearized* mode, the appropriate trimming potentiometers on the 633756 Linearizer Board are adjusted to obtain a reading of 50% on meter or recorder.

RUN/CAL Switch SW3 on D.C. Amplifier Board

Preparatory to calibration of the 633756 Linearizer Board, Switch SW3 on the 638490 D.C. Amplifier Board, Figure 3-4, *must* be set to CAL, to remove all real signal from the input of the D.C. amplification circuitry, and to provide the front-panel ZERO Control with proper polarity for linearizer calibration.

NOTE

Switch SW3 on the 638490 D.C. Amplifier Board must remain at CAL throughout the entire linearizer calibration procedure. Only after completion of this procedure should SW3 be returned to RUN. At all times except during linearizer calibration, SW3 must remain at RUN.

Requirements to Ensure Adequate Simulation Signal
To provide the front-panel ZERO Control with the maximum possible "simulation signal," the front-panel GAIN Control must be set at its clockwise limit.

Analyzer Zeroing During Linearizer Calibration
During linearizer calibration, with SW3 on D.C. Amplifier Board set at CAL, analyzer zero must be set by adjustment of R33 and R34 on the amplifier board, not by adjustment of the front-panel ZERO Control as in normal operation. Under present conditions, zero is thus obtainable even though the front-panel GAIN Control is not at zero, because selection of CAL position of SW3 automatically removes the input signal from the amplification circuitry. When the linearizer calibration procedure is finished, and SW3 is returned to RUN, R33 and R34 will have to be readjusted according to Step 5, of Paragraph 3.1.

Summary of Linearizer Calibration Procedure
Basically, linearizer calibration consists of repetitive, sequential, performance of the following two-step adjustment:

a. With output circuitry set up for nonlinearized readout, the front-panel ZERO Control is adjusted to obtain a specified reading on the recorder. This reading *simulates* the presence of a particular concentration of CO in the sample.
b. With ZERO Control still at the setting established in Step a, the output circuit is switched over to *linearized* readout. The appropriate potentiometer on the linearizer board is now adjusted for the correct *linearized* reading on the recorder.

Selection of Appropriate Calibration Procedure
If nonlinearity of the calibration curve is less than 5% at 50% of fullscale, use procedure of Paragraph 7.2.1. If nonlinearity exceeds 5%, use procedure of Paragraph 7.2.2.

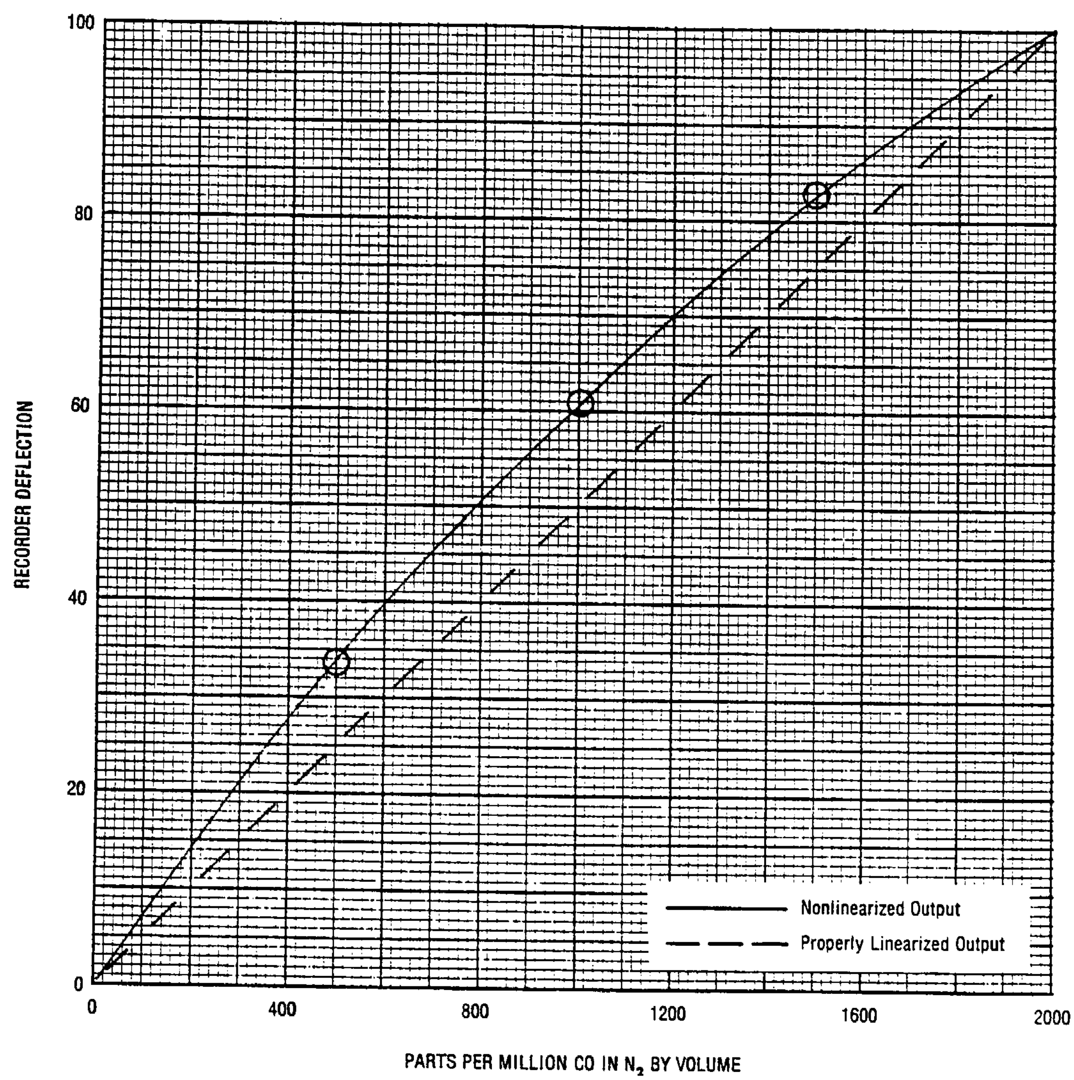


Figure 7-6. Typical Calibration Curve with Nonlinearity of Greater than 5%

Minimum Recommended Spare Parts Inventory for Analyzer Unit

BECKMAN PART NO.	DESCRIPTION	QUANTITY
633296	Board Assembly, Oscillator	1
633842	Power Supply, ±15 Volts	1
635376	Detector	1
635886	Heater Assembly	1
637056	Board, Temperature Control	1
637485	Board, Filter/Rectifier	1
637862	Source Power Supply, a.c.	1
638450	Motor Assembly, Sapphire Windows	1
638490	Board, Amplifier	1

Additional Spare Parts Recommended to Minimize Downtime For Analyzer Unit

Where it is desired to keep downtime to a minimum, stocking of the following additional spare parts for the analyzer unit is recommended.

BECKMAN PART NO.	DESCRIPTION	QUANTITY
633875	Meter	1
633896	Heater, Detector, R10	1
633899	Switch, Range	1
860478	Resistor, R4, Span, Dual: 125K, 1K	1
869552	Resistor R5, Zero, 10K	1

8.4 AUTOMATIC ZERO/SPAN STANDARDIZER

Expendable Supplies For Automatic Zero/Span Standardizer

BECKMAN PART NO.	DESCRIPTION	QUANTITY
860522	Run Lamp	1
876688	Out-of-Range Indicator	1

Minimum Recommended Spare Parts Inventory For Automatic Zero Span Standardizer

The following items constitute the minimum recommended spare parts inventory for the Automatic Zero/Span Standardizer.

BECKMAN PART NO.	DESCRIPTION	QUANTITY
636871	±15 Volt Power Supply	1
637002	Analog/Digital Board Assembly	1
860514	Actuator Pins for Timer	

Additional Spare Parts Recommended to Minimize Downtime For Automatic Zero/Span Standardizer

Where it is desired to keep downtime to a minimum, stocking of the following additional spare parts for the standardizer is recommended.

BECKMAN PART NO.	DESCRIPTION	QUANTITY
637011	Power Switch	1
637012	Meter	1
637014	Cable Assembly (Includes Sequence Switches)	1
860513	Timer, 60 Hz	1

SECTION NINE SCHEMATIC WIRING DIAGRAMS

The following schematic wiring diagrams are provided as an aid in troubleshooting and servicing the electronic circuitry.

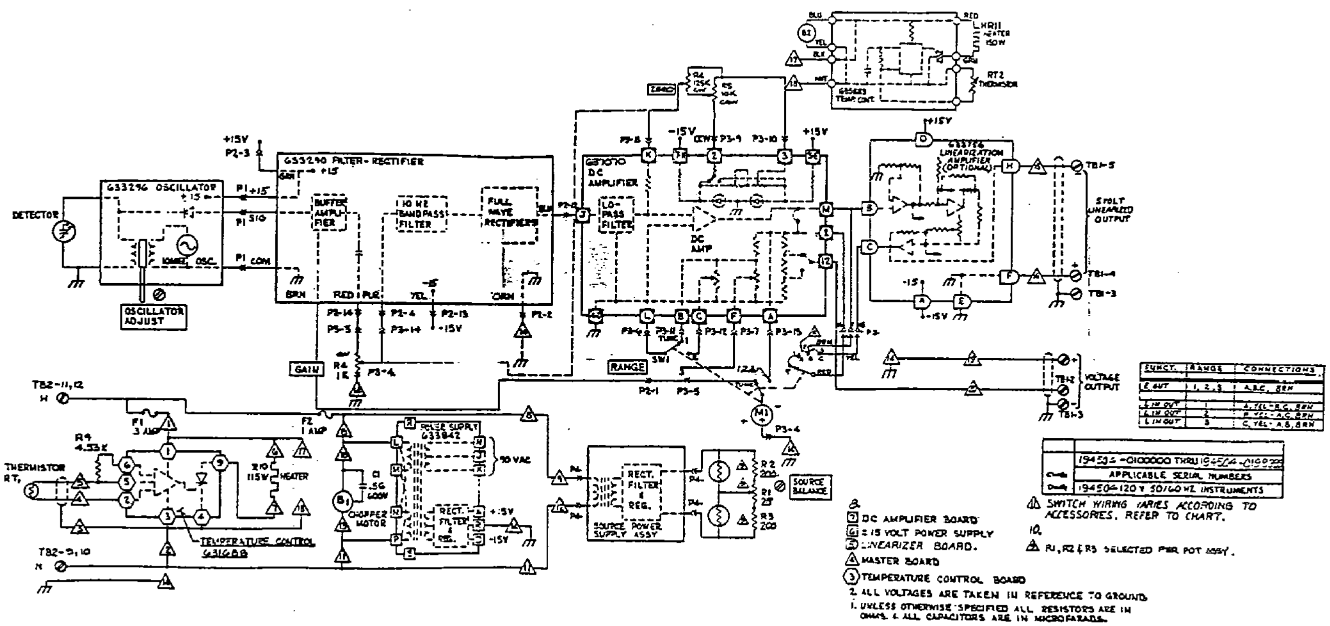


Figure 9-1. Schematic Wiring Diagram of Analyzer Unit

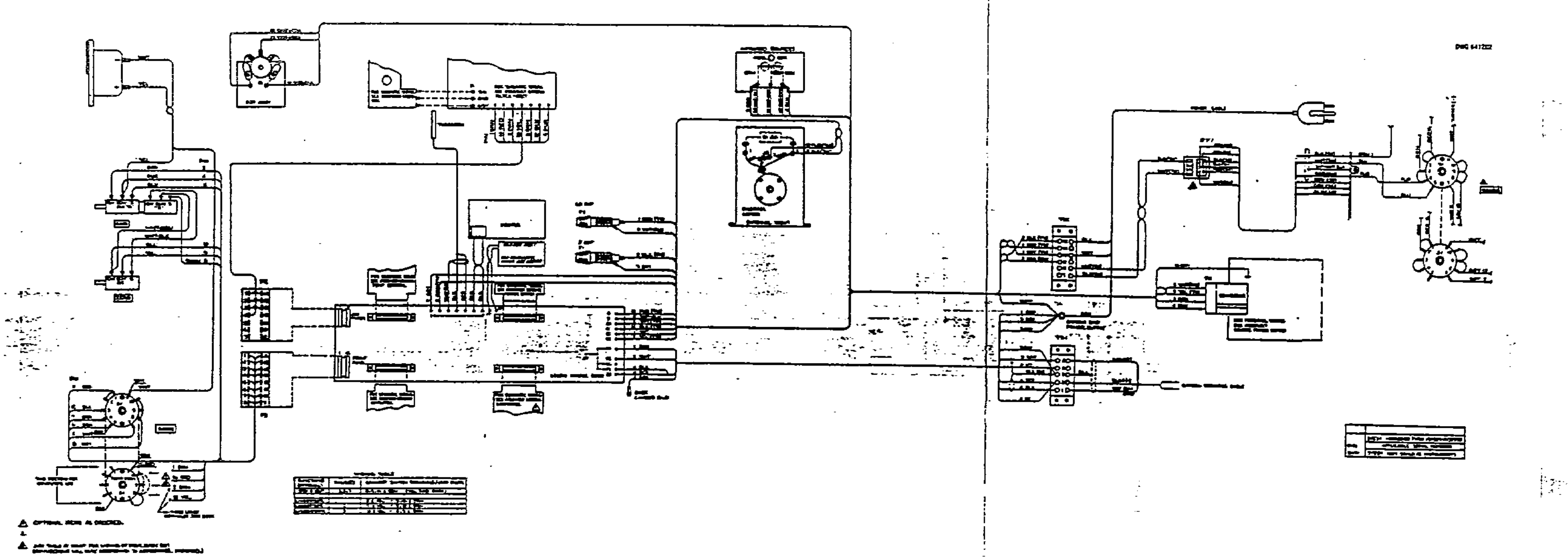
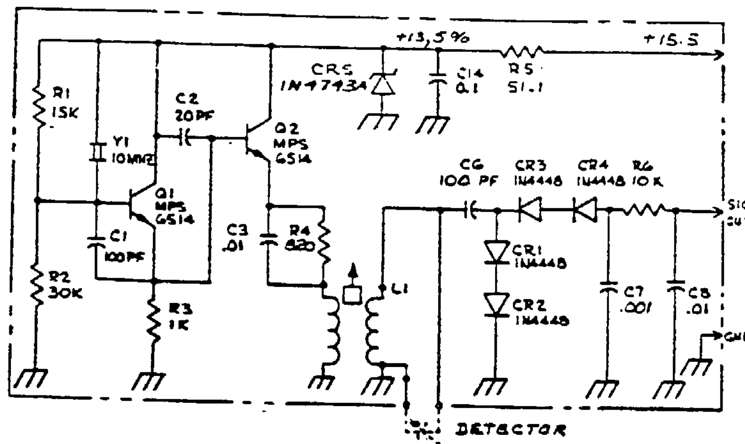


Figure 4-2. Pictorial Wiring Diagram of Analyzer Unit.

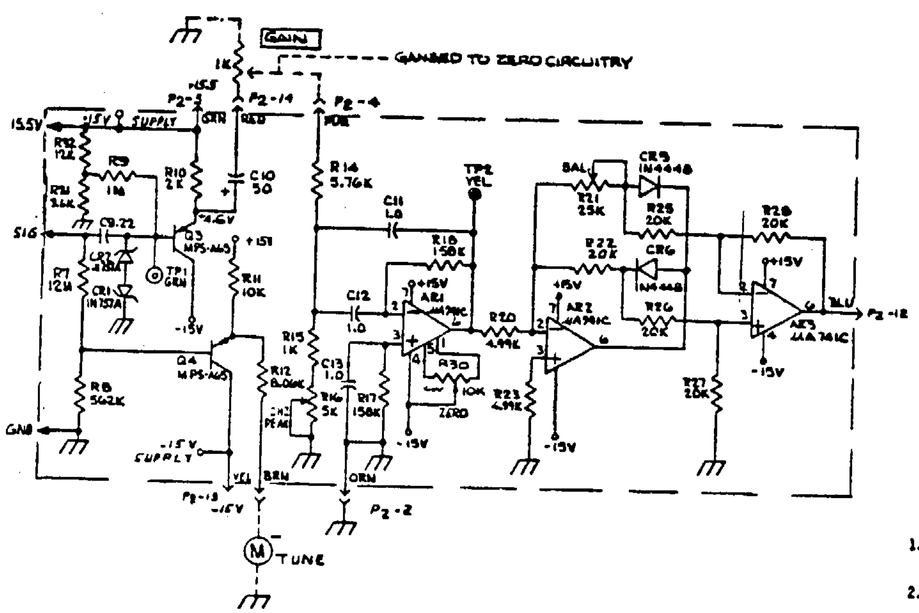
DWG 633296
Sheet 2



1. All Resistor Values are in Ohms unless otherwise specified.
2. All Capacitor Values are in Microfarads unless otherwise specified.
3. All Voltage Readings taken in Reference to Ground.

Figure 9-3. Schematic Wiring Diagram of 633296 Oscillator Board (Analyzer Unit)

DWG 633290



1. All Resistor Values are in Ohms unless otherwise specified.
2. All Capacitor Values are in Microfarads unless otherwise specified.
3. All Voltage Readings taken in Reference to Ground.

Figure 9-4. Schematic Wiring Diagram of 633290 Filter/Rectifier Board (Analyzer Unit)

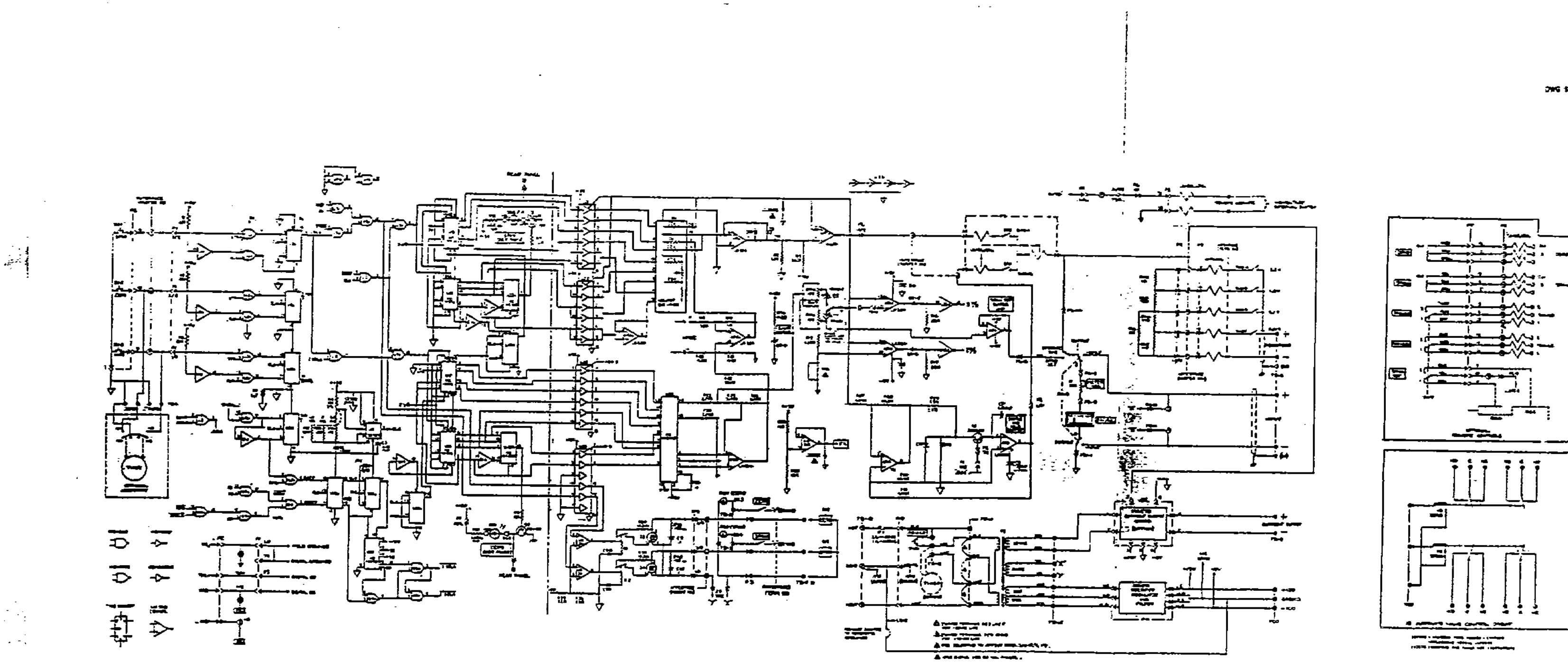
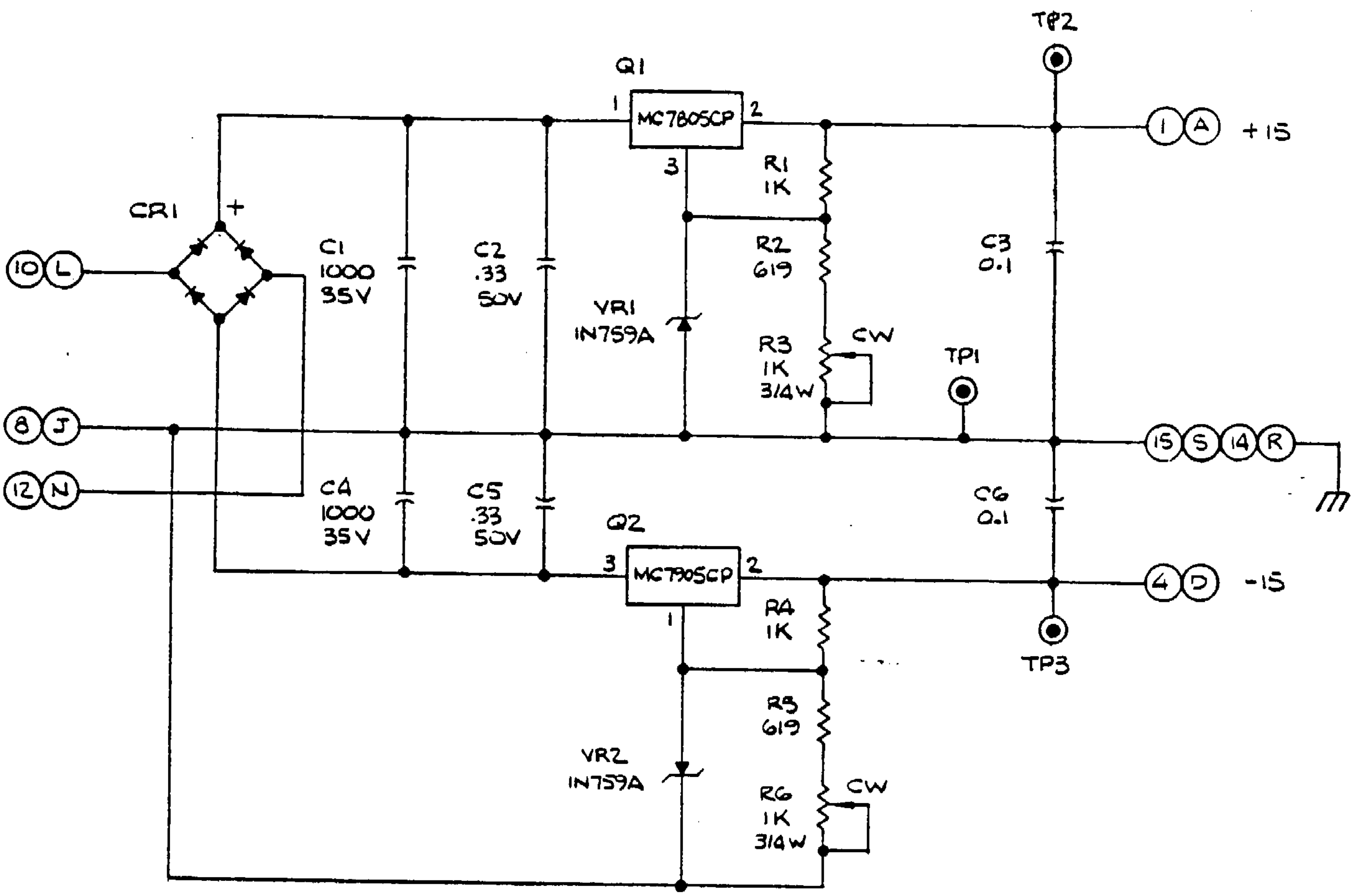


Figure 9-11. Schematic Wiring Diagram of Automatic Zero/Span Standardizer

DWG 637052



3. NEXT ASSY : 636871
SCHEMATIC : 637051

2. ALL CAPACITORS ARE IN MICROFAREDS.

1. ALL RESISTORS ARE 1/4 W UNLESS OTHERWISE SPECIFIED.

NOTES:

Figure 9-12. Schematic Wiring Diagram of 636871 Rectifier, Regulator, and Filter Board (Standardizer Unit)

DWG 636270

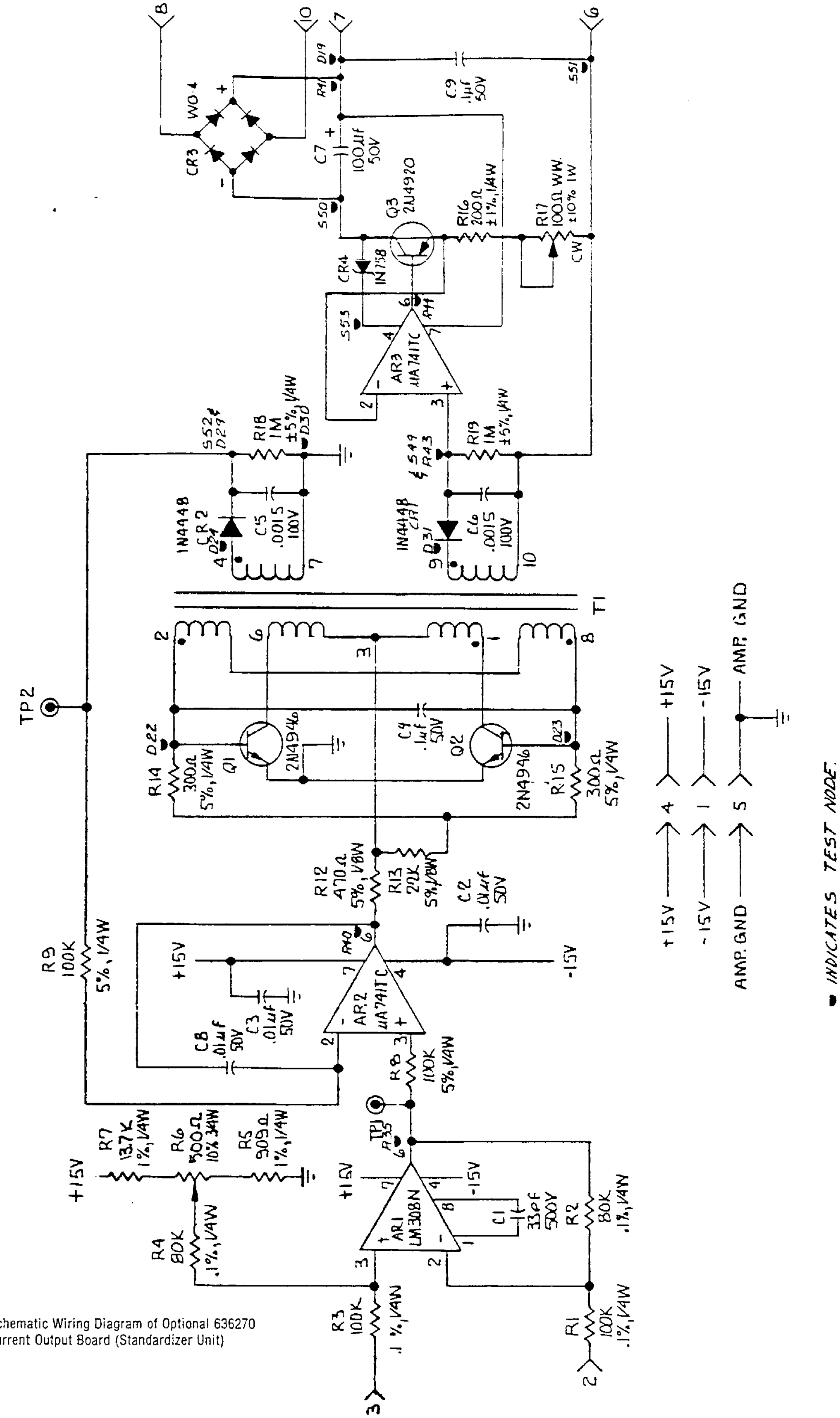


Figure 9-13. Schematic Wiring Diagram of Optional 636270 Current Output Board (Standardizer Unit)

APPENDIX I: INTERFERENCE TEST

A representative test analyzer has been tested for interference from water vapor (20 000 parts per million) and CO_2 (750 parts per million absolute) according to the procedure specified by EPA. Each interferent, alone, gave less than one parts per million equivalent CO response and, combined, less than 1.5 parts per million equivalent. No further testing should be required; however, if it is desired to do so, the following method should be used. The analyzer should be operated in its normal sampling mode and the gases should be introduced through a vented manifold. If results differ from those given above, your Beckman Service Representative should be consulted.

The following paragraphs are taken from the Federal Register, Tuesday, February 18, 1975, Volume 40, Number 33, Pages 7054 and 7055.

The subject test procedures in the Federal Register are general in nature, for various types of analyzers. Those paragraphs not applicable to the non-dispersive infrared method were omitted so that the following procedure is specific to the Beckman Ambient CO Monitoring System.

(d) *Interference Equivalent* — (1) *Technical Definition. Positive or negative response caused by a substance other than the one being measured.*

(2) Test Procedure. The test analyzer shall be tested for all substances likely to cause a detectable response. The test analyzer shall be challenged for responses to 750 parts per million CO_2 and 20 000 parts per million water vapor.

The interference may be either positive or negative, depending on whether the test analyzer's response is increased or decreased by the presence of the interferent. Interference equivalents shall be determined by mixing each interferent, one at a time, with the pollutant at the concentrations specified above and comparing the test analyzer's response to the response caused by the pollutant alone.

(i) Allow sufficient time for warm-up and stabilization of the test analyzer.

(ii) Not applicable.

(iii) Generate three test atmosphere streams as follows:

(A) *Test atmosphere P:* Pollutant concentration.

(B) *Test atmosphere I:* Interference concentration.

(C) *Test atmosphere Z:* Zero air.

(iv) Adjust the individual flow rates and the pollutant or interferent generators for the three test atmospheres as follows:

(A) The flow rates of test atmospheres I and Z shall be identical.

(B) The concentration of pollutant in test atmosphere P shall be adjusted such that when P is mixed (diluted) with either test atmosphere I or Z, the resulting concentration of pollutant shall be 10 parts per million ±10% CO by volume.

(C) The concentration of interferent in test atmosphere I shall be adjusted such that when I is mixed (diluted) with test atmosphere P, the resulting concentration of interferent shall be equal to the value specified; i.e., 750 parts per million CO_2 or 20 000 parts per million water vapor.

(D) To minimize concentration errors due to flow rate differences between I and Z, it is recommended that, when possible, the flow rate of P be from 10 to 20 times larger than the flow rates of I and Z.

(v) Mix test atmospheres P and Z by passing the total flow of both atmospheres through a mixing flask.

(vi) Sample and measure the mixture of test atmospheres P and Z with the test analyzer. Allow for a stable reading, and record the reading in concentration units, as R.

(vii) Mix test atmospheres P and I by passing the total flow of both atmospheres through a mixing flask.

(viii) Sample and measure this mixture. Record the stable reading, in concentration units, as R_1.

(ix) Calculate the interference equivalent (IE) as:

$$IE = R_1 - R$$

IE must be equal to or less than ±1 parts per million CO for each interferent to pass the test.

(x) Follow steps (iii) through (ix), in turn, to determine the interference equivalent for each interferent.

(xi) Not applicable.

(xii) Sum the absolute values of the individual interference equivalents. This sum must be equal to or less than 1.5 parts per million CO.

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PROCESS INSTRUMENTS DIVISION
FULLERTON, CALIFORNIA • 92634

INFRARED ANALYZER CALIBRATION & DATA SHEET

Customer:	Aerovironment
Address:	Pasadena, Calif.
Application:	Carbon Monoxide
Ranges:	1. 0-500PPM 2. 3. 0-50PPM

1. Uncalibrated Linearizer Range 1 [ ]
2. Calibrated Linearizer Range 1. [ ] 2. [ ] 3. [ ]
   Refer to switch chart on schematic
3. Gas Free Calibration Assy. [ ]
4. Calibration Curve [ ] Typical Curve [X]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [X] Teflon Tubing [X]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [X]
12. Motor Source Assembly Replacement:
    633773 [ ] 638449 [ ]
    638450 [X] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [X] Other [ ]

REMARKS:

S.O. No.:	RAPID 7230.2
P.O. No.:	48020
Model No.:	866
Serial No.:	7230.2

Detector Ser. No.:	2452 F
Detector Part No.:	635376
Tag No.:	
Configuration No.:	788917

CO Monitoring System

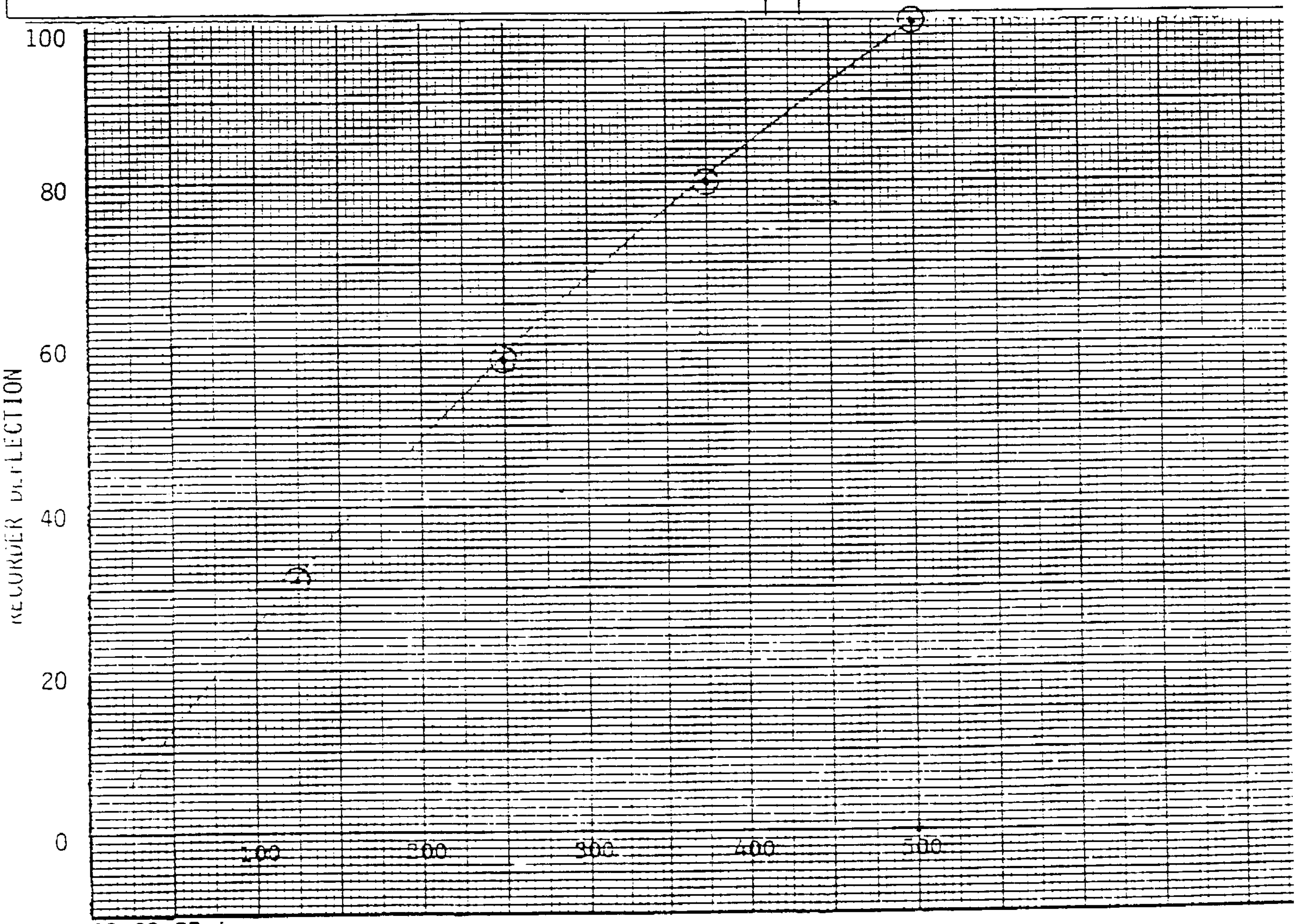
Repeatability: (In % of F.S.)

Range 1: ±1 %	Range 3: ±1 %
Range 2: %	Range 4: %

Interference Gas	Mol %	Resp. Equiv.
1. CO_2	.1	≤ 0.5 PPM CO
2. H_2O	3	≤ 1.0 PPM CO
3.		

Engineer:
James Wilson

Date:
October 18, 1977



22-22.77.4

P.P.M. CO in Air by Volume

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PROCESS INSTRUMENTS DIVISION
FULLERTON, CALIFORNIA • 92634

INFRARED ANALYZER CALIBRATION & DATA SHEET

Customer:
Address:
Application: "Carbon Monoxide
Ranges: 1. 0-500PPM 2. 3. 0-50PPM

1. Uncalibrated Linearizer Range 1 [ ]
2. Calibrated Linearizer Range 1. [ ] 2. [ ] 3. [ ]
   Refer to switch chart on schematic
3. Gas Free Calibration Assy. [ ]
4. Calibration Curve [ ] Typical Curve [x]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [X] Teflon Tubing [X]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [X]
12. Motor Source Assembly Replacement:
    633773 [X] 638449 [ ]
    638450 [ ] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [X] Other [ ]

REMARKS:

S.O. No.:
P.O. No.:
Model No.: 866
Serial No.:

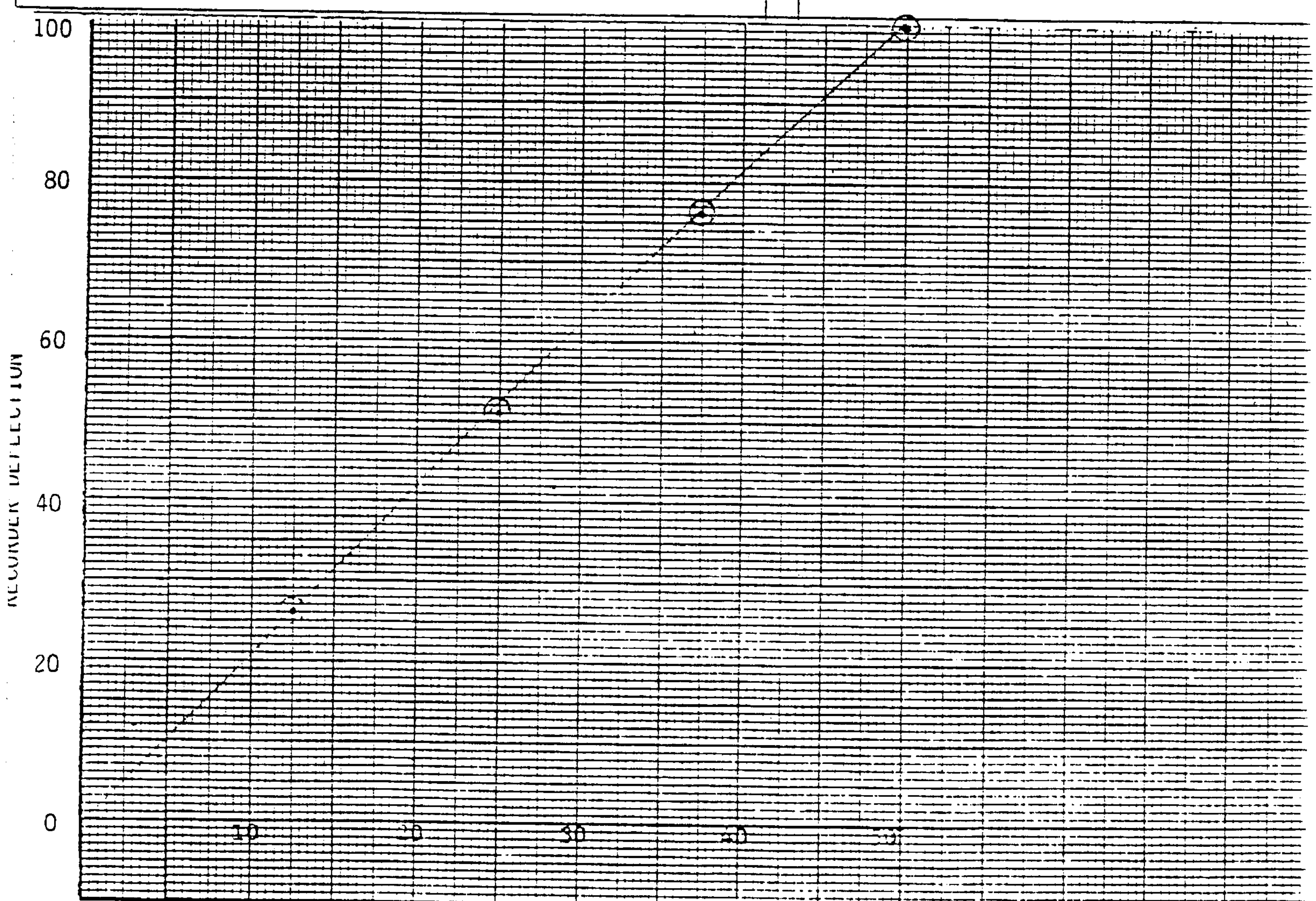
Detector Ser. No.:
Detector Part No.: 635376
Tag No.:
Configuration No.: 788917

Repeatability: (In % of F.S.)
Range 1: ±1 % Range 3: ±1 %
Range 2: % Range 4: %

Interference Gas	Mol %	Resp. Equiv.
1. CO_2	.1	≤ 0.5 PPM CO
2. H_2O	3	≤ 1.0PPM CO
3.		

Engineer:

Date:



22-22.77.4

P.P.M. CO in Air by Volume

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FULLERTON, CALIFORNIA • 92634

INFRARED ANALYZER CALIBRATION & DATA SHEET

Customer:
Address:
Application: "Carbon Monoxide
Ranges: 1. 0-500PPM 2. 3. 0-50PPM

1. Uncalibrated Linearizer Range 1[ ]
2. Calibrated Linearizer Range 1.[ ] 2.[ ] 3.[ ]
   Refer to switch chart on schematic
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4. Calibration Curve [ ] Typical Curve [x]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [X] Teflon Tubing [X]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [X]
12. Motor Source Assembly Replacement:
    633773 [x] 638449 [ ]
    638450 [ ] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [x] Other [ ]

REMARKS:

S.O. No.:
P.O. No.:
Model No.: 866
Serial No.:

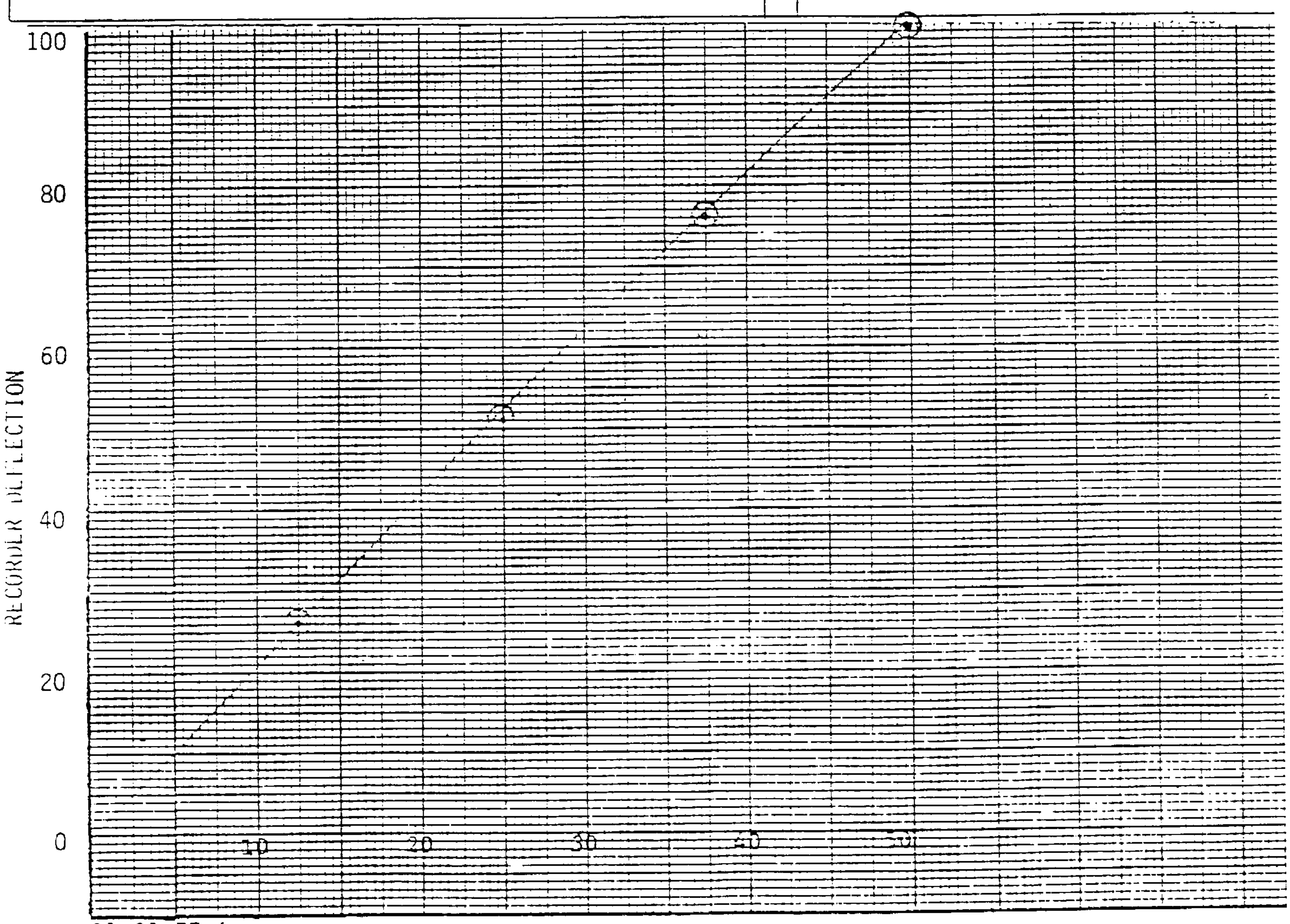
Detector Ser. No.:
Detector Part No.: 635376
Tag No.:
Configuration No.: 788917

Repeatability: (In % of F.S.)
Range 1: ±1 % Range 3: ±1 %
Range 2: % Range 4: %

Interference Gas	Mol %	Resp. Equiv
1. CO_2	.1	≤ 0.5 PPM (
2. H_2O	3	≤ 1.0PPM C(
3.		

Engineer:

Date:



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P.P.M. CO in Air by Volume

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INFRARED ANALYZER CALIBRATION & DATA SHEET

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Address: Pasadena, Calif.
Application: "Carbon Monoxide
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   Refer to switch chart on schematic
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4. Calibration Curve [ ] Typical Curve [X]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [X] Teflon Tubing [X]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [X]
12. Motor Source Assembly Replacement:
    633773 [X] 638449 [ ]
    638450 [ ] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [X] Other [ ]

REMARKS:

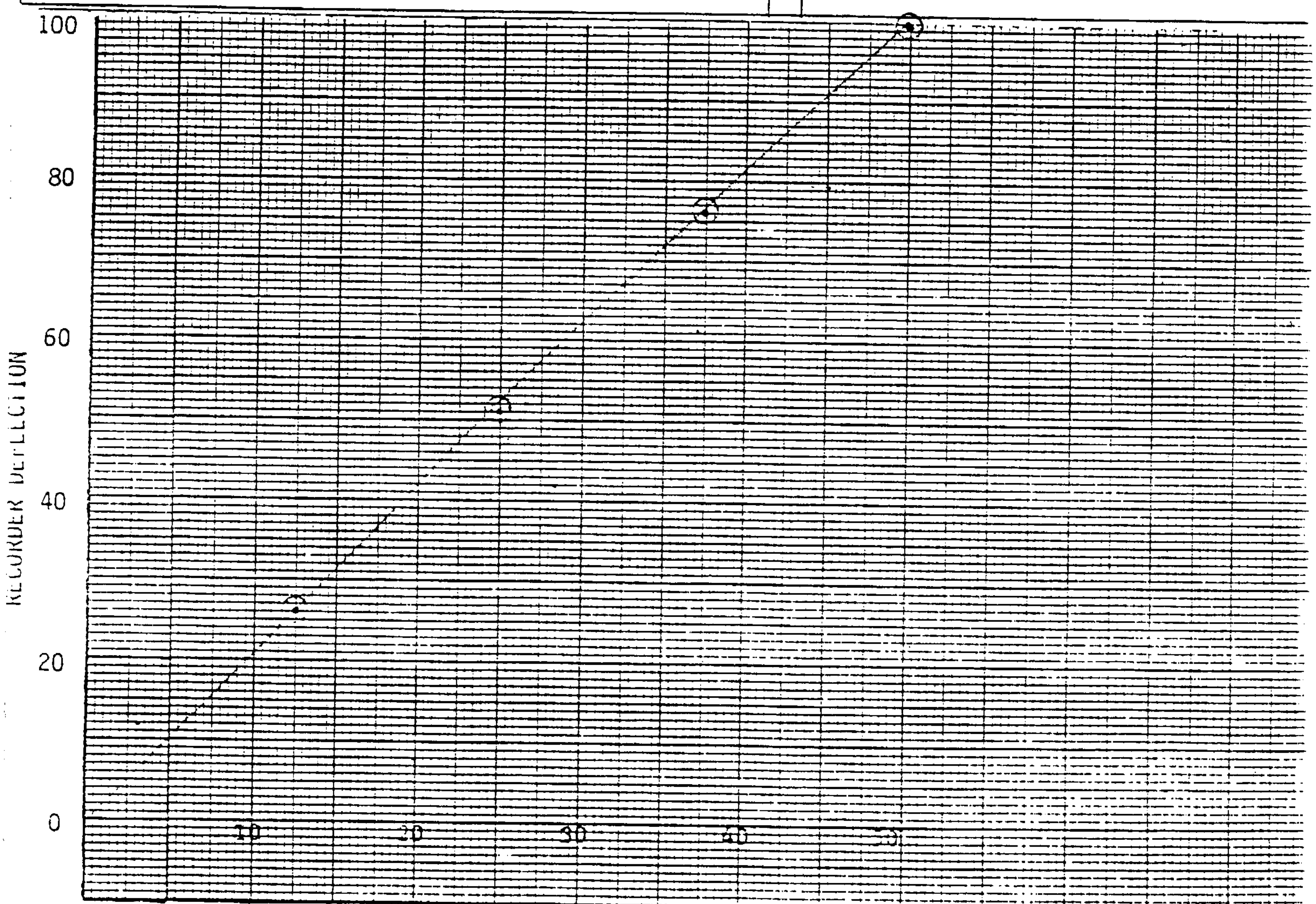
S.O. No.: RAPID 7230.2
P.O. No.: 48020
Model No.: 866
Serial No.: 7230.2

Detector Ser. No.: 2452 F
Detector Part No.: 635376
Tag No.:
Configuration No.: 788917

Repeatability: (In % of F.S.)
Range 1: ±1 % Range 3: ±1 %
Range 2: % Range 4: %

Interference Gas	Mol %	Resp. Equiv.
1. CO_2	.1	≤ 0.5 PPM CO
2. H_2O	3	≤ 1.0PPM CO
3.		

Engineer:
James Wilson
Date:
October 18, 1977



22-22.77.4

P.P.M. CO in Air by Volume

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PROCESS INSTRUMENTS DIVISION
FULLERTON, CALIFORNIA - 92634

INFRARED ANALYZER CALIBRATION & DATA SHEET

Customer:
Address:
Application: Carbon Monoxide
Ranges: 1. 0-500PPM 2. 3. 0-50PPM

1. Uncalibrated Linearizer Range 1 [ ]
2. Calibrated Linearizer Range 1. [ ] 2. [ ] 3. [ ]
   Refer to switch chart on schematic
3. Gas Free Calibration Assy. [ ]
4. Calibration Curve [ ] Typical Curve [x]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [x] Teflon Tubing [x]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [x]
12. Motor Source Assembly Replacement:
    633773 [ ] 638449 [ ]
    638450 [x] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [x] Other [ ]

REMARKS:

S.O. No.:
P.O. No.:
Model No.: 866
Serial No.:

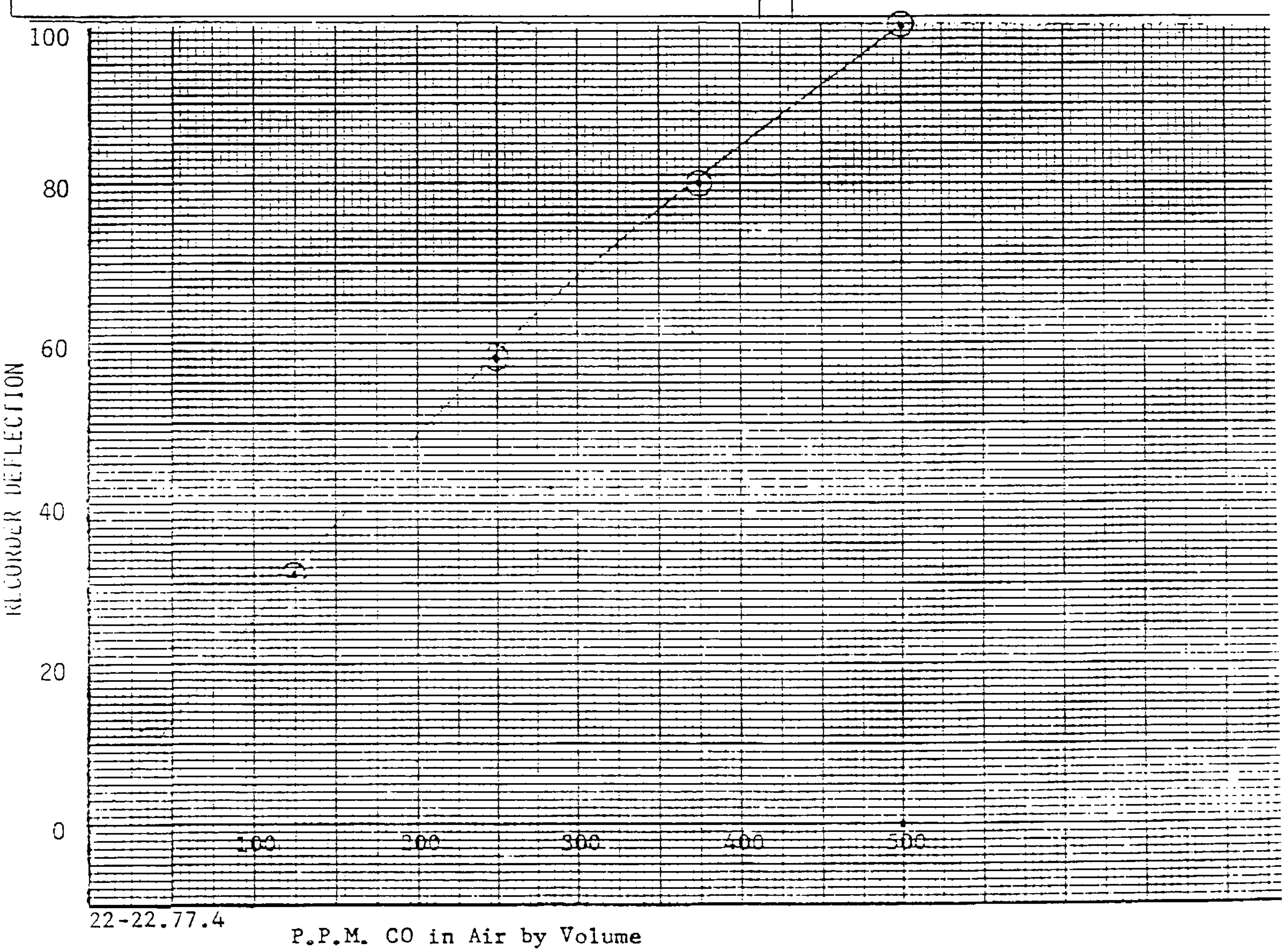
Detector Ser. No.:
Detector Part No.: 635376
Tag No.:
Configuration No.: 788917

CO Monitoring System
Repeatability: (In % of F.S.)
Range 1: ±1 % Range 3: ±1 %
Range 2: % Range 4: %

Interference Gas	Mol %	Resp. Equiv.
1. CO_2	.1	≤ 0.5 PPM CO
2. H_2O	3	≤ 1.0 PPM CO
3.		

Engineer:

Date:



22-22.77.4

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PROCESS INSTRUMENTS DIVISION
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INFRARED ANALYZER CALIBRATION & DATA SHEET

Customer:
Address:
Application: Carbon Monoxide
Ranges: 1. 0-500PPM 2. 3. 0-50PPM

1. Uncalibrated Linearizer Range 1 [ ]
2. Calibrated Linearizer Range 1. [ ] 2. [ ] 3. [ ]
   Refer to switch chart on schematic
3. Gas Free Calibration Assy. [ ]
4. Calibration Curve [ ] Typical Curve [X]
5. Current Output Board [ ]
6. Bench Mounting Kit [ ]
7. Stainless Steel Tubing [X] Teflon Tubing [X]
8. Air Purge Kit [ ]
9. Explosion Proof Case [ ]
10. Remote Range Switching [ ]
11. AC Power 50 HZ [ ] 60 HZ [X]
12. Motor Source Assembly Replacement:
    633773 [ ] 638449 [ ]
    638450 [X] 638451 [ ]
13. Calibration Pressure:
    Atmospheric [X] Other [ ]

REMARKS:

S.O. No.:
P.O. No.:
Model No.: 866
Serial No.:

Detector Ser. No.:
Detector Part No.: 635376
Tag No.:
Configuration No.: 788917

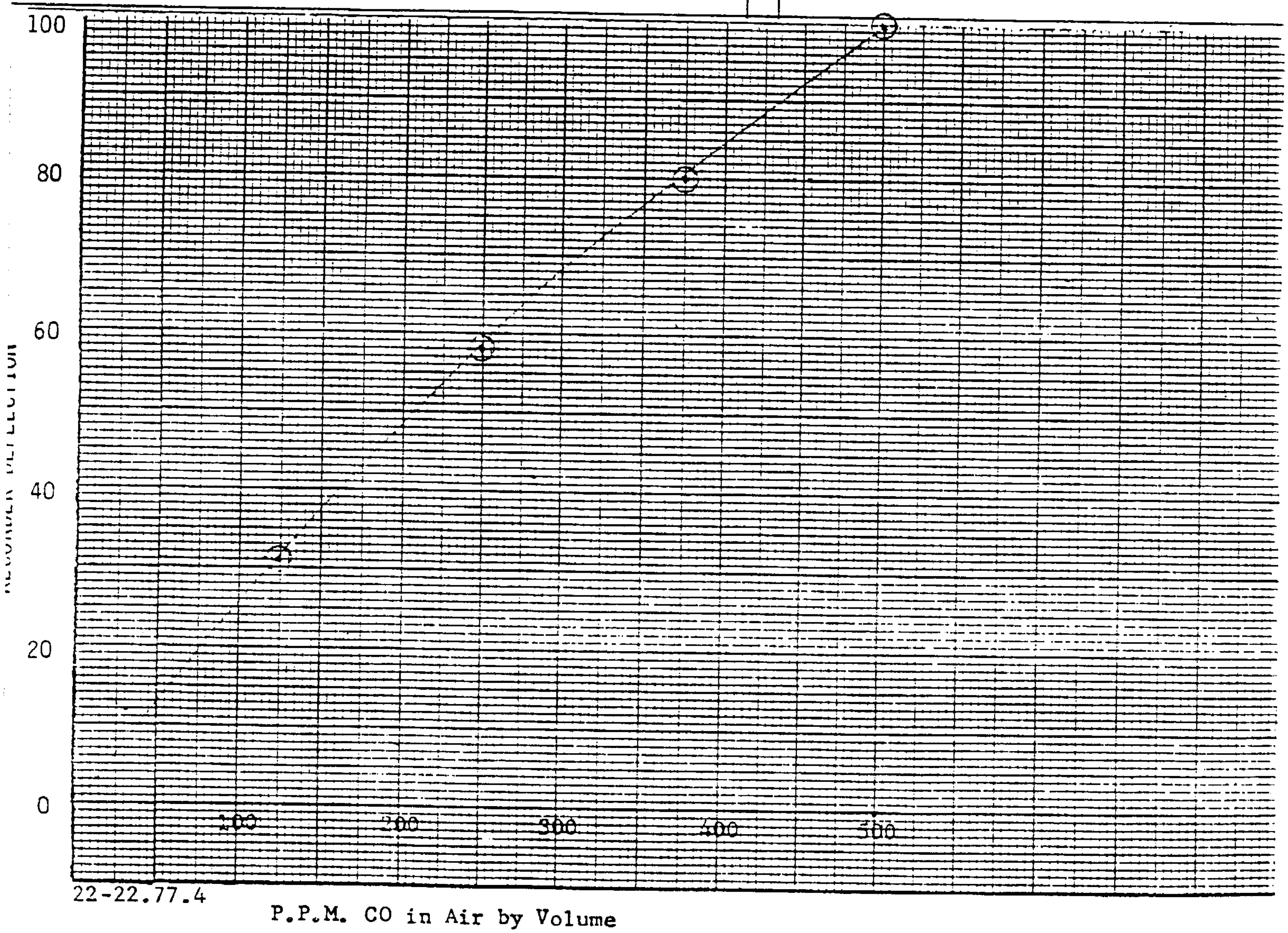
CO Monitoring System

Repeatability: (In % of F.S.)
Range 1: ±1 % Range 3: ±1 %
Range 2: % Range 4: %

Interference Gas	Mol %	Resp. Equiv.
1. CO_2	.1	≤ 0.5 PPM CO
2. H_2O	3	≤ 1.0 PPM CO
3.		

Engineer:

Date:



22-22.77.4

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Beckman Instruments, Inc.,
Fullerton, CA 92634

APPENDIX G

Fixed Height Meteorological Station Operation Procedures

1. METEOROLOGICAL INSTRUMENT INSTALLATION PROCEDURES

1.1 INSTRUMENT SYSTEM SET UP

1.1.1 Wind Speed and Wind Direction

1. Attach the anemometer cups and wind vane to the sensors. Check that the cups are installed on the wind speed sensor and the vane is installed on the wind direction sensor.

2. Mount the sensors to the crossarm. Check that the sensors are mounted in their designated locations. The wind direction sensor orientation is pre-aligned before being sent to the field so that the sensor output is 0^{o} or 360^{o} (toward true north) when the vane tail is directly over the crossarm.

3. Connect the sensor cables to the transmuter.

4. Connect the transmuter to the data logger and chart recorder.

5. Plug the system into a 115 VAC receptacle.

6. Turn the system on.

7. Rotate the wind vane, first clockwise then counter-clockwise, through it's entire 540^{o} range. Verify that the wind direction signal to the data logger and chart recorder is correct and that the crossovers occur at the north and south points.

8. Verify that the data logger and chart recorder indicates north when the wind vane tail is directly over the crossarm.

9. Spin the wind speed cups to verify that the system indicates an up scale value when the cups are spinning and zero when the cups are stationary.

1.1.2 Ambient Temperature

1. Turn the power off.

2. Connect the signal cable between the temperature sensor/aspirator assembly and the transmuter.

3. Connect the transmuter to the data logger and chart recorder.

4. Turn the power on and verify that the aspirator fan in the temperature assembly is operating.

5. Verify that the data logger and chart recorder are indicating the correct ambient temperature by comparing the readings with a mercury-in-glass thermometer standard.

6. Turn the power off.

1.2 TOWER INSTALLATIONS

Once the tower has been installed:

1. Establish a true north marker using a compass corrected for the local declination angle.

2. Place the crossarm on the tower mast.

3. Rotate the crossarm until it is directly in line with the true north marker and tighten the mounting allen head screws securely.

   Note: The wind direction sensor will be toward the true north marker.

4. Mount the temperature asperator assembly below the crossarm using hose clamps. The asperator arm should point toward the north with the inlet downward. A minor adjustment in the asperator orientation may have to be made to minimize the effects of obstructions or other radiating surfaces.

5. Secure the sensor cables to the tower using electrical tie wraps.

6. Turn the transmuter on and perform the calibration procedures in Section 1.3.

1.3 METEOROLOGICAL INSTRUMENT CALIBRATION PROCEDURES

1.3.1 Wind Speed

1.3.1.1 Calibration Equipment

1. Hurst Model A constant RPM motor (300 RPM)
2. Hurst Model AB constant RPM motor (600 RPM)
3. Hand held compass
4. Inclinometer

1.3.1.2 Calibration Procedures

1. Record the station name and address on the calibration form.

2. Record the instrument's manufacturer, model and serial numbers.

3. Remove all meteorological parameters from recording routine data on the DAS and record this action in the station log book.

4. Mark the strip charts for all meteorological parameters with the time, date, and a notation indicating the start of the calibration.

5. Check the orientation of the meteorological instrument crossarm with a compass, and record the results.

6. Lower the meteorological tower.

7. With an inclinometer, check that the sensor is vertical.

8. Check that the sensor is securely mounted to the instrument crossarm.

9. Check that the sensor shaft turns freely by rotating the shaft slowly by hand and feeling for possible dragging or binding.

10. Remove the the anemometer cups from the sensor shaft and place them aside in a safe place.

11. Attach the 300 rpm motor to the sensor shaft.

12. Turn the motor on and check that the motor rotates in the same direction that the anemometer cups would rotate.

13. Take the reading of wind speed as displayed on the DAS and the strip chart recorder and record these readings.

14. Remove the 300 rpm motor from the anemometer sensor and replace it with the 600 rpm motor.

15. Repeat Steps 12 and 13.

16. Turn the motor off and record the DAS and strip chart readings.

17. Remove the 600 rpm motor from the sensor and replace the anemometer cups.

1.3.2 Wind Direction

1.3.2.1 Calibration Equipment

1. Wind vane jig

1.3.2.2 Calibration Procedures

With the meteorological tower already lowered, the DAS out of the routine data collection mode and the strip charts marked to reflect that the tower is down for the calibration:

1. Record the station name and address in the calibration form.

2. Record the instrument's manufacturer, model and serial numbers.

3. Using an inclinometer, check that the sensor is vertical.

4. Check that the sensor is securely mounted to the instrument crossarm.

5. Check that the sensor shaft turns freely by rotating the shaft slowly by hand and feeling for possible dragging or binding.

6. Attach the wind jig to the wind vane and set the wind vane to point toward zero degrees true.

7. Read the wind direction output on the DAS and the strip chart and record these readings in the AV audit log book.

8. Turn the wind vane clockwise 90 degrees and secure in place with the wind vane jig.

9. Read the wind direction output on the DAS and the strip chart and record these readings.

10. Repeat Steps 9 and 10 until readings of the wind direction have been taken for the remaining compass directions of 180, 270, 360, 450 and 540 degrees.

11. Remove the wind direction jig.

1.3.3 Temperature

1.3.3.1 Calibration Equipment

1. Mercury in glass thermometer, calibrated to NBS-traceable thermometer
2. Thermos bottle
3. Distilled water
4. Ice made from distilled water
5. Heating coil

1.3.3.2 Calibration Procedures

With the meteorological tower already lowered, the DAS in the mode not to collect routine data, and the strip charts marked to reflect that the tower is down for the calibration:

1. Remove the thermister from the radiation shield.

2. Fill the thermos bottle with distilled water and crushed ice and place and cover with the styrofoam top.

3. Shake the thermos bottle vigorously to cool the water.

4. Push the thermometer and station thermister through the holes of the thermos top and shake the thermos vigorously, being careful to keep the thermister and thermometer from touching the bottom of the thermos bottle.

5. At approximately 30-second intervals, read the thermometer, DAS and chart recorder outputs and record these readings in the calibration form.

6. Continue taking readings until three consecutive readings show no change.

7. Discard the water in the thermos bottle and refill with water that is at approximately 20^{o}C. Warm the water with the heating coil if necessary.

8. Repeat Steps 4 through 6.

9. With the heating coil heat the water in the thermos bottle to approximately 40^{o}C.

10. Repeat Steps 4 through 6.

11. Remove the thermometer and thermister from the water bath.

12. Reinstall the thermister into the radiation shield.

13. Raise the meteorological instrument tower and replace the safety stops if there are no further meteorological parameters to be calibrated.

1.4 METEOROLOGICAL INSTRUMENT STATION CHECK

1. Check that there is no damage to meteorological sensors (e.g., bullet holes, missing wind speed cups, and damaged wind direction vane, etc.).

2. Qualitatively that the wind direction response on the data logger corresponds to the vane position.

3. Qualitatively compare the wind speed response to ambient; if the cups are spinning fast, the wind speed displayed by the SUM-X should be greater than zero.

4. Confirm that the temperature aspirator blower is working; listen for the low humming sound at the mast.

5. Qualitatively compare the temperature response to ambient.

WIND SPEED CALIBRATION RECORD

Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Station Operator ______________________ Client ______________________

Meteorological Monitoring System

Make ______________________ Model ______________________

Serial Number ______________________ Nominal full scale ______________________

Wind cups serial number ____________

Translator card:

Model ______________________ Serial number ______________________

Is system single-scale or dual-scale? ______________________

If dual-scale, verify range crossover position: ______________________

System Orientation and Condition

Physical condition ______________________

Cups horizontal ______________________

Sensor operation unimpeded ______________________

Other ______________________

Comparison to hand-held anemometer:

Anemometer model and number ______________________

Reading(s) ______________________

DAS Reading: Volts ____________ Chart reading: % ____________

WS ____________ WS ____________

Torque watch: model and number ______________________

Reading(s) ______________________

Manufacturer's specification/tolerance ______________________

Electronic Calibration

Record results on next page.

Frequency generator make, model, number ______________________

Frequency counter make, model, number ______________________

Conversions: DAS Volts x ________ + ________ = WS mph/mps

Chart % x ________ + ________ = WS mph/mps

Calibrated by ______________________

Checked by ______________________ Date ______________

Comments ______________________

____

____

WIND SPEED CALIBRATION RECORD

Performance Calibration

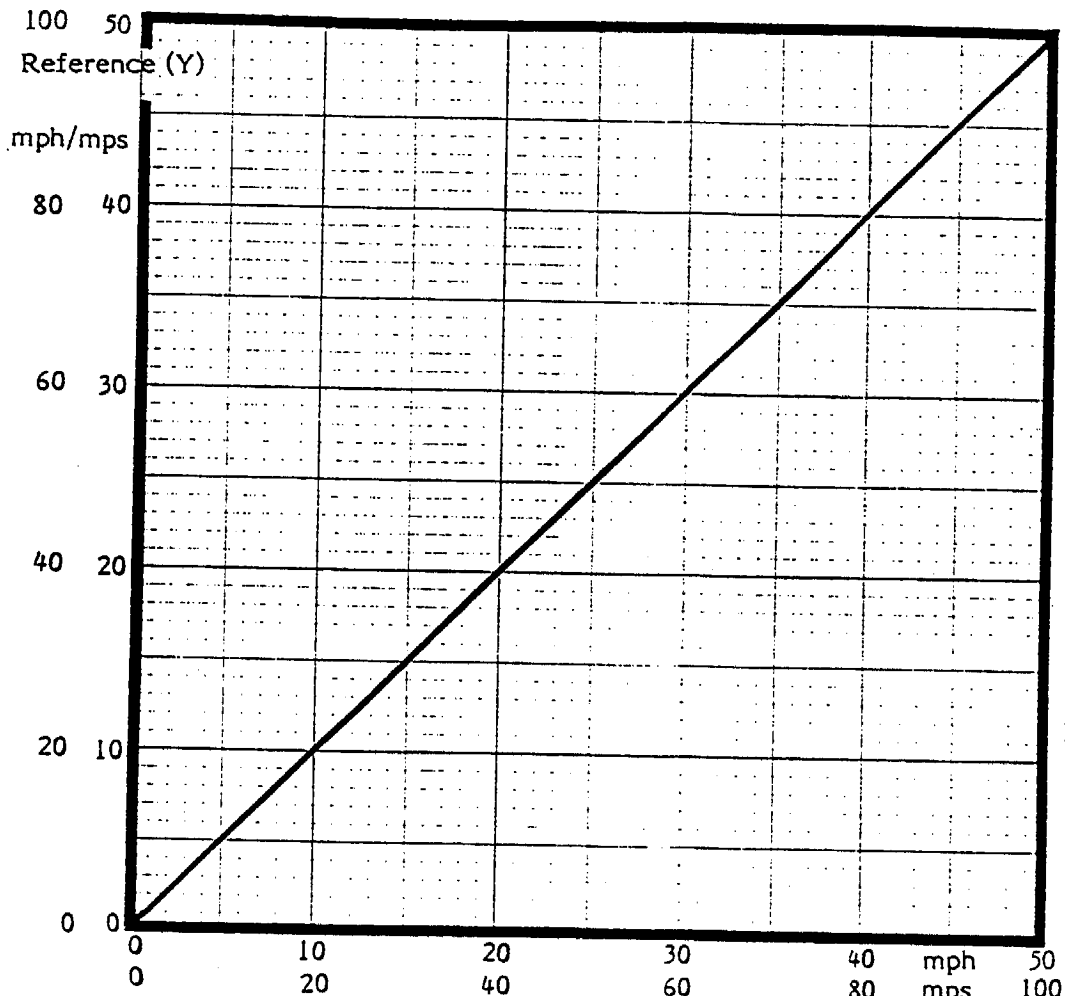
Date ____________________ Site Name/Number ____________________

Project Number ____________________ Time: Start __________ Finish __________

Meteorological Monitoring System

Make ____________________ Model ____________________

Serial Number ____________________ Nominal full scale ____________________



Y = A X + B

DAS:
A = __________
B = __________
R = __________

Chart:
A = __________
B = __________
R = __________

Sensor Output (X)

Frequency Hz	Ref. Input mps/mph (Y)	DAS Output		Chart Output	
		Volts	(X) WS mps/mph	%	(X) WS mps/mph

WIND DIRECTION CALIBRATION RECORD

Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Station Operator ______________________ Client ______________________

Declination of site ______________________

Meteorological Monitoring System

Make __________ Model __________ Serial Number ______________________

Wind vane model ______________________ Serial Number ______________________

Translator card:

Model ______________________ Serial Number ______________________

CIRCLE ONE:

Nominal full scale: 360° 540°

Zero on scale is set at: N E S W

Full scale is set at: N E S W

System Orientation and Condition

Physical condition ______________________

Vane vertical ______________________

Crossarm direction ______________________

Other ______________________

____

Low To High Crossover __________ High To Low Crossover __________

Reference (degrees)		10/ 370	40/ 400	90/ 450	130/ 490	180	230	270	310
DAS VOLTS	Low								
	High								
DAS DEGREES	Low								
	High								
CHART %	Low								
	High								
CHART DEGREES	Low								
	High								

Calibrated by ______________________

Checked by ______________________ Date __________

Comments ______________________

____

TEMPERATURE CALIBRATION RECORD

Date ____________________ Site Name/Number ____________________

Project Number ____________________ Time: Start __________ Finish __________

Station Operator ____________________ Client ____________________

Temperature System

Make ____________________ Model ____________________

Serial Number ____________________ Nominal scale __________ °C to __________ °C

System Orientation and Condition

Probe facing north ____________________

Local interferences ____________________

Other ____________________

Comparison to Mercury thermometer:

Reference thermometer model and number ____________________

Bath	DAS		Chart	
Temp. °C	Volts	°C	%	°C

Calibrated by ____________________

Checked by ____________________ Date ____________________

Comments ____________________

AEROVIRONMENT, INC. 825 Myrtle Ave., Monrovia, CA 91016 (818) 357-9983 AV-F-FOIB5a

APPENDIX H

Multiple Height Meteorological Station Operation Procedures

A.I.R. TS-3A-SP (small) TETHERSONDE
DATA COLLECTION AND PROCESSING PROCEDURES

I) DATA COLLECTION

A) Equipment Checklist

1) A.I.R. model AIR-3B Tethersonde Ground-station (ADAS)
2) A.I.R. TS-3A-SP Tethersonde
3) A.I.R. TS-2AW Tethersonde Winch
4) A.I.R. TS-1BR-0 tethersonde balloon (2.25 cu meter)
5) Ground-station antenna
6) Ground-station antenna cable
7) NEC (laptop) computer
8) Computer printer
9) 6 DOS formated blank floppy disks.
10) Computer printer paper
11) Ground-station/laptop interface cable
12) Program disk (gwbasic, TSONDLOG.bas and SNDTEMP.wk1)
13) Helium
14) Reference precision barometer
15) Reference psychrometer
16) Distilled water
17) Syringe
18) Rubber bands

B) Equipment Setup

Tethersonde Ground-Station

1) Plug ADAS into AC power source.

2) Connect antenna to ADAS.

3) Connect laptop to ADAS. Plug the ADAS/laptop interface (RS-232) cable and null adaptor into the RS-232 port of the ADAS and the serial port of the laptop.

4) Set-up the printer and interface it with the laptop.

5) Insert the program disk into disk drive A, data recording disk into drive B and turn the laptop power switch on.

6) Set ADAS controls as follows:

    a) Press the AC power switch.

    b) Enter LF2 and press the <ENTER> key to select the tethersonde mode.

    c) Enter HC and press the <ENTER> key to reset the ADAS default parameters.

    d) Place the end of the paper tape, that accompanies the sonde, into the paper tape reader according to the diagram above the paper tape reader slot. Enter LE, press the <ENTER> key and pull the paper tape through the paper tape reader at a steady rate. This enters the sonde calibration coefficients into the ADAS.

7) On laptop keyboard enter the following commands:

    a) gwbasic TSONDLOG and press the <RTN> key.

    b) At the prompt, "Enter the type of sonde?", enter a 1 and press the <RTN> key.

    c) At the prompt, "Enter the ADAS surface pressure (mb) with the airsonde or tethersonde at ground level?", enter the pressure reading of the precision barometer in millibars and press the <RTN> key.

    d) Press the <ESC> key to open a data file on the B drive disk and begin logging data.

    e) Press the CTRL and Prt Sc Keys simultaneously, to put the printer on line.

8) Fill the wet bulb thermistor reservoir with distilled water.

9) Turn on the sonde by plugging in the battery.

10) On the ADAS keyboard, enter LA and press the <ENTER> key to allow the sonde and ADAS to synchronize.

11) Take readings of temperature, wet bulb temperature, barometric pressure, wind speed and wind direction using the reference psychrometer, reference barometer and the hand held anemometer. Record the readings on the computer printout.

12) Record cloud cover (clear, scattered, broken or overcast), cloud altitude and weather condition on header of data printout. Also note the date, launch time, location, flight#, declination angle, station altitude and operator's initials.

13) Compare the laptop barometric pressure, temperature, wet bulb temperature and altitude readings to the reference readings.

14) If any of the sonde outputs varies greatly from the reference readings or if the sonde outputs are unstable, restart the ADAS using the procedures in step 6. If this does not correct the problem replace the battery. If after trying all of the above the problem persists, call A.I.R. at (303) 443-7187.

C) Tethersonde Launch and Flight Procedures

1) Launch tethersonde according to the launch instructions outlined in the A.I.R. manual.

2) Attach red colored streamers to the tetherline at 50 foot intervals.

NOTE: All flight operations are to be conducted in accordance with FAA regulations part 101, subpart B.

3) Allow the balloon and sonde to ascend to the specified altitude using the laptop CRT readings.

4) Once the balloon and sonde have reached the specified altitude, monitor the laptop CRT altitude readings continuously and adjust the balloon altitude accordingly.

NOTE: If wind speeds are greater than 7 m/s, balloon operations are to be terminated immediately to prevent damaging or losing the balloon and sonde package.

4) Every 30 minutes verify the altitude of the balloon. Measure the distance to the balloon using the optical range finder and the elevation angle of the balloon using the inclinometer. Calculate the altitude using the following equation:

$$A = B * \sin(\theta)$$

where: A = balloon altitude in meters

B = distance from the winch to the balloon in meters measured with an optical range finder.

θ = elevation angle of the balloon from the winch measured with an inclinometer.

5) Every hour lower the balloon to ground level and compare the sonde pressure reading with the reading of the precision barometer. Close the current file and re-initiate the TSONDLOG program using the updated pressure reading of the precision barometer.

6) Every 2 hours, in addition to the procedures in step 5, change the sensor battery.

D) After Flight Procedures

1) Once the balloon reaches ground level, allow the sonde to make at least 3 more data cycles and for the laptop to write to the B drive before proceeding to the next step.

2) Press the <ESC> key of the laptop to close the data file.

3) Remove and label the data disk.

4) Remove the program disk and turn the laptop off.

5) Turn off the sonde.

6) Turn off the ADAS.

II) DATA PROCESSING PROCESSING

A) Data Correction and File Creation

1) Go through the data printout and mark all errors with a red pen. Errors will appear as missing data or symbols in place of numerals.

2) Place the Lotus 123 system disk into the A drive of the laptop.

3) At the dos A prompt, type 123 and press the <RTN> key.

4) Place the program disk in drive b.

5) Press the /, f and r keys.

6) Move the cursor to the SNDTEMP.wk1 program title and press the <RTN> key.

7) Place the data disk into drive b.

8) Press the /,f,i,n keys.

9) Enter the file name being sure to prefix it with the B drive designation (ex: B:11091702.dat).

10) Once the data appears on the screen, correct the errors noted in the printout and resave the data file by pressing the /, f and s keys. Enter the file name used in step 9, being sure to prefix it with the B drive designation and press the <RTN> key.

B) Data Averaging

1) Average the wind speed, wind direction and altitude data for each of the averaging periods using the @avg(..) function.

2) Save the spreadsheet by pressing the /, f, s, <RTN> and y keys.

APPENDIX G

Fixed Height Meteorological Station Operation Procedures

1. METEOROLOGICAL INSTRUMENT INSTALLATION PROCEDURES

1.1 INSTRUMENT SYSTEM SET UP

1.1.1 Wind Speed and Wind Direction

1. Attach the anemometer cups and wind vane to the sensors. Check that the cups are installed on the wind speed sensor and the vane is installed on the wind direction sensor.

2. Mount the sensors to the crossarm. Check that the sensors are mounted in their designated locations. The wind direction sensor orientation is pre-aligned before being sent to the field so that the sensor output is 0^{o} or 360^{o} (toward true north) when the vane tail is directly over the crossarm.

3. Connect the sensor cables to the transmuter.

4. Connect the transmuter to the data logger and chart recorder.

5. Plug the system into a 115 VAC receptacle.

6. Turn the system on.

7. Rotate the wind vane, first clockwise then counter-clockwise, through it's entire 540^{o} range. Verify that the wind direction signal to the data logger and chart recorder is correct and that the crossovers occur at the north and south points.

8. Verify that the data logger and chart recorder indicates north when the wind vane tail is directly over the crossarm.

9. Spin the wind speed cups to verify that the system indicates an up scale value when the cups are spinning and zero when the cups are stationary.

1.1.2 Ambient Temperature

1. Turn the power off.

2. Connect the signal cable between the temperature sensor/aspirator assembly and the transmuter.

3. Connect the transmuter to the data logger and chart recorder.

4. Turn the power on and verify that the aspirator fan in the temperature assembly is operating.

5. Verify that the data logger and chart recorder are indicating the correct ambient temperature by comparing the readings with a mercury-in-glass thermometer standard.

6. Turn the power off.

1.2 TOWER INSTALLATIONS

Once the tower has been installed:

1. Establish a true north marker using a compass corrected for the local declination angle.

2. Place the crossarm on the tower mast.

3. Rotate the crossarm until it is directly in line with the true north marker and tighten the mounting allen head screws securely.

   Note: The wind direction sensor will be toward the true north marker.

4. Mount the temperature asperator assembly below the crossarm using hose clamps. The asperator arm should point toward the north with the inlet downward. A minor adjustment in the asperator orientation may have to be made to minimize the effects of obstructions or other radiating surfaces.

5. Secure the sensor cables to the tower using electrical tie wraps.

6. Turn the transmuter on and perform the calibration procedures in Section 1.3.

1.3 METEOROLOGICAL INSTRUMENT CALIBRATION PROCEDURES

1.3.1 Wind Speed

1.3.1.1 Calibration Equipment

1. Hurst Model A constant RPM motor (300 RPM)
2. Hurst Model AB constant RPM motor (600 RPM)
3. Hand held compass
4. Inclinometer

1.3.1.2 Calibration Procedures

1. Record the station name and address on the calibration form.

2. Record the instrument's manufacturer, model and serial numbers.

3. Remove all meteorological parameters from recording routine data on the DAS and record this action in the station log book.

4. Mark the strip charts for all meteorological parameters with the time, date, and a notation indicating the start of the calibration.

5. Check the orientation of the meteorological instrument crossarm with a compass, and record the results.

6. Lower the meteorological tower.

7. With an inclinometer, check that the sensor is vertical.

8. Check that the sensor is securely mounted to the instrument crossarm.

9. Check that the sensor shaft turns freely by rotating the shaft slowly by hand and feeling for possible dragging or binding.

10. Remove the the anemometer cups from the sensor shaft and place them aside in a safe place.

11. Attach the 300 rpm motor to the sensor shaft.

12. Turn the motor on and check that the motor rotates in the same direction that the anemometer cups would rotate.

13. Take the reading of wind speed as displayed on the DAS and the strip chart recorder and record these readings.

14. Remove the 300 rpm motor from the anemometer sensor and replace it with the 600 rpm motor.

15. Repeat Steps 12 and 13.

16. Turn the motor off and record the DAS and strip chart readings.

17. Remove the 600 rpm motor from the sensor and replace the anemometer cups.

1.3.2 <u>Wind Direction</u>

1.3.2.1 Calibration Equipment

1. Wind vane jig

1.3.2.2 Calibration Procedures

With the meteorological tower already lowered, the DAS out of the routine data collection mode and the strip charts marked to reflect that the tower is down for the calibration:

1. Record the station name and address in the calibration form.

2. Record the instrument's manufacturer, model and serial numbers.

3. Using an inclinometer, check that the sensor is vertical.

4. Check that the sensor is securely mounted to the instrument crossarm.

5. Check that the sensor shaft turns freely by rotating the shaft slowly by hand and feeling for possible dragging or binding.

6. Attach the wind jig to the wind vane and set the wind vane to point toward zero degrees true.

7. Read the wind direction output on the DAS and the strip chart and record these readings in the AV audit log book.

8. Turn the wind vane clockwise 90 degrees and secure in place with the wind vane jig.

9. Read the wind direction output on the DAS and the strip chart and record these readings.

10. Repeat Steps 9 and 10 until readings of the wind direction have been taken for the remaining compass directions of 180, 270, 360, 450 and 540 degrees.

11. Remove the wind direction jig.

1.3.3 Temperature

1.3.3.1 Calibration Equipment

1. Mercury in glass thermometer, calibrated to NBS-traceable thermometer
2. Thermos bottle
3. Distilled water
4. Ice made from distilled water
5. Heating coil

1.3.3.2 Calibration Procedures

With the meteorological tower already lowered, the DAS in the mode not to collect routine data, and the strip charts marked to reflect that the tower is down for the calibration:

1. Remove the thermister from the radiation shield.

2. Fill the thermos bottle with distilled water and crushed ice and place and cover with the styrofoam top.

3. Shake the thermos bottle vigorously to cool the water.

4. Push the thermometer and station thermister through the holes of the thermos top and shake the thermos vigorously, being careful to keep the thermister and thermometer from touching the bottom of the thermos bottle.

5. At approximately 30-second intervals, read the thermometer, DAS and chart recorder outputs and record these readings in the calibration form.

6. Continue taking readings until three consecutive readings show no change.

7. Discard the water in the thermos bottle and refill with water that is at approximately 20°C. Warm the water with the heating coil if necessary.

8. Repeat Steps 4 through 6.

9. With the heating coil heat the water in the thermos bottle to approximately 40°C.

10. Repeat Steps 4 through 6.

11. Remove the thermometer and thermister from the water bath.

12. Reinstall the thermister into the radiation shield.

13. Raise the meteorological instrument tower and replace the safety stops if there are no further meteorological parameters to be calibrated.

1.4 METEOROLOGICAL INSTRUMENT STATION CHECK

1. Check that there is no damage to meteorological sensors (e.g., bullet holes, missing wind speed cups, and damaged wind direction vane, etc.).

2. Qualitatively that the wind direction response on the data logger corresponds to the vane position.

3. Qualitatively compare the wind speed response to ambient; if the cups are spinning fast, the wind speed displayed by the SUM-X should be greater than zero.

4. Confirm that the temperature aspirator blower is working; listen for the low humming sound at the mast.

5. Qualitatively compare the temperature response to ambient.

WIND SPEED CALIBRATION RECORD

Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Station Operator ______________________ Client ______________________

Meteorological Monitoring System

Make ______________________ Model ______________________

Serial Number ______________________ Nominal full scale ______________________

Wind cups serial number __________

Translator card:

Model ______________________ Serial number ______________________

Is system single-scale or dual-scale? ______________________

If dual-scale, verify range crossover position: ______________________

System Orientation and Condition

Physical condition ______________________

Cups horizontal ______________________

Sensor operation unimpeded ______________________

Other ______________________

Comparison to hand-held anemometer:

Anemometer model and number ______________________

Reading(s) ______________________

DAS Reading: Volts __________ Chart reading: % __________

WS __________ WS __________

Torque watch: model and number ______________________

Reading(s) ______________________

Manufacturer's specification/tolerance ______________________

Electronic Calibration

Record results on next page.

Frequency generator make, model, number ______________________

Frequency counter make, model, number ______________________

Conversions: DAS Volts x __________ + __________ = WS mph/mps

Chart % x __________ + __________ = WS mph/mps

Calibrated by ______________________

Checked by ______________________ Date __________

Comments ______________________

____

____

WIND SPEED CALIBRATION RECORD
Performance Calibration

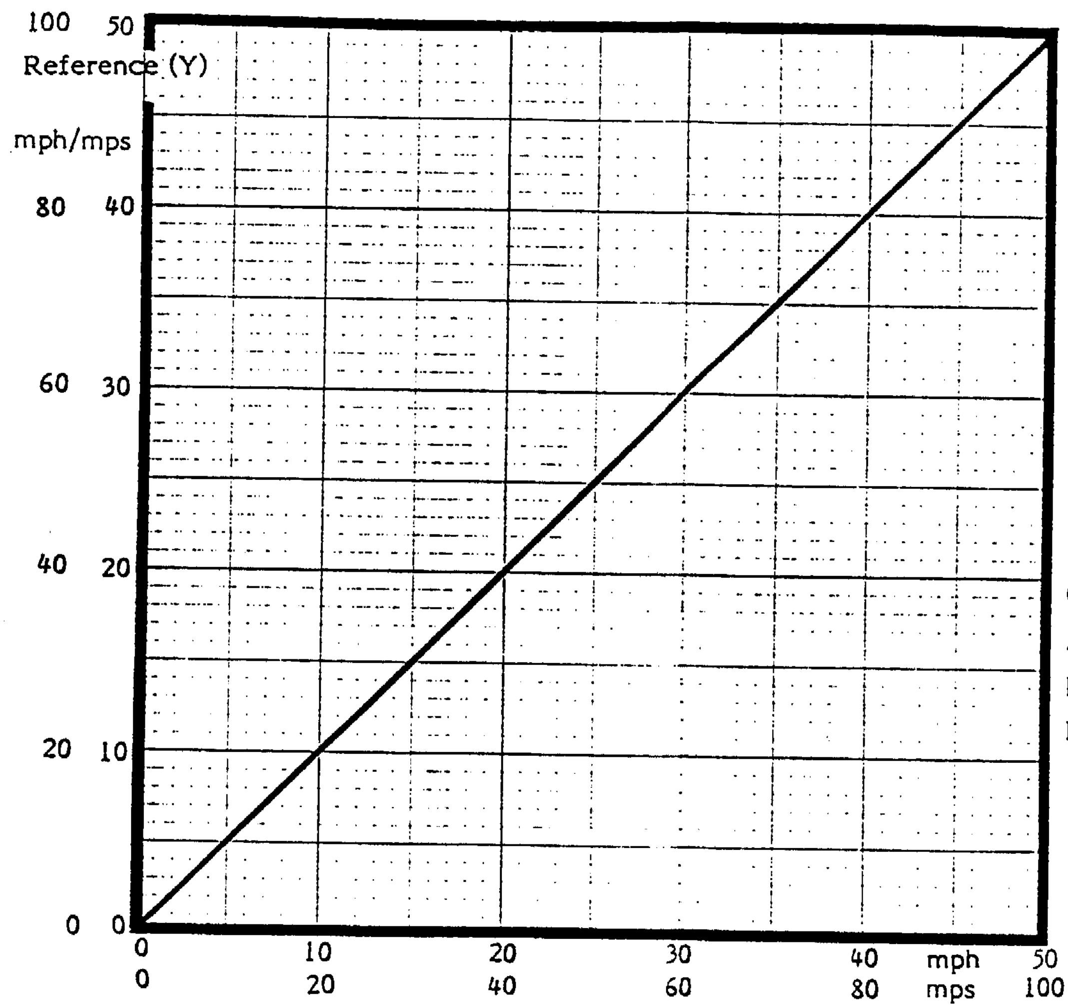
Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Meteorological Monitoring System

Make ______________________ Model ______________________

Serial Number ______________________ Nominal full scale ______________________



Y = AX + B

DAS:
A = __________
B = __________
R = __________

Chart:
A = __________
B = __________
R = __________

Sensor Output (X)

Frequency Hz	Ref. Input mps/mph (Y)	DAS Output		Chart Output	
		Volts	(X) WS mps/mph	%	(X) WS mps/mph

AEROVIRONMENT, INC. 825 Myrtle Ave., Monrovia, CA 91016 (818) 357-9983

AV-F-?OIB2b

WIND DIRECTION CALIBRATION RECORD

Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Station Operator ______________________ Client ______________________

Declination of site ______________________

Meteorological Monitoring System

Make __________ Model __________ Serial Number ______________________

Wind vane model ______________________ Serial Number ______________________

Translator card:

Model ______________________ Serial Number ______________________

CIRCLE ONE:

Nominal full scale: 360° 540°

Zero on scale is set at: N E S W

Full scale is set at: N E S W

System Orientation and Condition

Physical condition ______________________

Vane vertical ______________________

Crossarm direction ______________________

Other ______________________

____

Low To High Crossover __________ High To Low Crossover __________

Reference (degrees)		10/ 370	40/ 400	90/ 450	130/ 490	180	230	270	310
DAS VOLTS	Low								
	High								
DAS DEGREES	Low								
	High								
CHART %	Low								
	High								
CHART DEGREES	Low								
	High								

Calibrated by ______________________

Checked by ______________________ Date ______________________

Comments ______________________

____

TEMPERATURE CALIBRATION RECORD

Date ______________________ Site Name/Number ______________________

Project Number ______________________ Time: Start __________ Finish __________

Station Operator ______________________ Client ______________________

Temperature System

Make ______________________ Model ______________________

Serial Number ______________________ Nominal scale __________ °C to __________ °C

System Orientation and Condition

Probe facing north ______________________

Local interferences ______________________

Other ______________________

Comparison to Mercury thermometer:

Reference thermometer model and number ______________________

Bath	DAS		Chart	
Temp. °C	Volts	°C	%	°C

Calibrated by ______________________

Checked by ______________________ Date ______________________

Comments ______________________

A.I.R. TS-3A-SP (small) TETHERSONDE
DATA COLLECTION AND PROCESSING PROCEDURES

I) DATA COLLECTION

A) Equipment Checklist

1) A.I.R. model AIR-3B Tethersonde Ground-station (ADAS)
2) A.I.R. TS-3A-SP Tethersonde
3) A.I.R. TS-2AW Tethersonde Winch
4) A.I.R. TS-1BR-0 tethersonde balloon (2.25 cu meter)
5) Ground-station antenna
6) Ground-station antenna cable
7) NEC (laptop) computer
8) Computer printer
9) 6 DOS formated blank floppy disks.
10) Computer printer paper
11) Ground-station/laptop interface cable
12) Program disk (gwbasic, TSONDLOG.bas and SNDTEMP.wk1)
13) Helium
14) Reference precision barometer
15) Reference psychrometer
16) Distilled water
17) Syringe
18) Rubber bands

B) Equipment Setup

Tethersonde Ground-Station

1) Plug ADAS into AC power source.

2) Connect antenna to ADAS.

3) Connect laptop to ADAS. Plug the ADAS/laptop interface (RS-232) cable and null adaptor into the RS-232 port of the ADAS and the serial port of the laptop.

4) Set-up the printer and interface it with the laptop.

5) Insert the program disk into disk drive A, data recording disk into drive B and turn the laptop power switch on.

6) Set ADAS controls as follows:

   a) Press the AC power switch.

   b) Enter LF2 and press the <ENTER> key to select the tethersonde mode.

   c) Enter HC and press the <ENTER> key to reset the ADAS default parameters.

   d) Place the end of the paper tape, that accompanies the sonde, into the paper tape reader according to the diagram above the paper tape reader slot. Enter LE, press the <ENTER> key and pull the paper tape through the paper tape reader at a steady rate. This enters the sonde calibration coefficients into the ADAS.

7) On laptop keyboard enter the following commands:

   a) gwbasic TSONDLOG and press the <RTN> key.

   b) At the prompt, "Enter the type of sonde?", enter a 1 and press the <RTN> key.

   c) At the prompt, "Enter the ADAS surface pressure (mb) with the airsonde or tethersonde at ground level?", enter the pressure reading of the precision barometer in millibars and press the <RTN> key.

   d) Press the <ESC> key to open a data file on the B drive disk and begin logging data.

   e) Press the CTRL and Prt Sc Keys simultaneously, to put the printer on line.

8) Fill the wet bulb thermistor reservoir with distilled water.

9) Turn on the sonde by plugging in the battery.

10) On the ADAS keyboard, enter LA and press the <ENTER> key to allow the sonde and ADAS to synchronize.

11) Take readings of temperature, wet bulb temperature, barometric pressure, wind speed and wind direction using the reference psychrometer, reference barometer and the hand held anemometer. Record the readings on the computer printout.

12) Record cloud cover (clear, scattered, broken or overcast), cloud altitude and weather condition on header of data printout. Also note the date, launch time, location, flight#, declination angle, station altitude and operator's initials.

13) Compare the laptop barometric pressure, temperature, wet bulb temperature and altitude readings to the reference readings.

14) If any of the sonde outputs varies greatly from the reference readings or if the sonde outputs are unstable, restart the ADAS using the procedures in step 6. If this does not correct the problem replace the battery. If after trying all of the above the problem persists, call A.I.R. at (303) 443-7187.

C) Tethersonde Launch and Flight Procedures

1) Launch tethersonde according to the launch instructions outlined in the A.I.R. manual.

2) Attach red colored streamers to the tetherline at 50 foot intervals.

NOTE: All flight operations are to be conducted in accordance with FAA regulations part 101, subpart B.

3) Allow the balloon and sonde to ascend to the specified altitude using the laptop CRT readings.

4) Once the balloon and sonde have reached the specified altitude, monitor the laptop CRT altitude readings continuously and adjust the balloon altitude accordingly.

NOTE: If wind speeds are greater than 7 m/s, balloon operations are to be terminated immediately to prevent damaging or losing the balloon and sonde package.

4) Every 30 minutes verify the altitude of the balloon. Measure the distance to the balloon using the optical range finder and the elevation angle of the balloon using the inclinometer. Calculate the altitude using the following equation:

$$A = B * \sin(\theta)$$

where: A = balloon altitude in meters

B = distance from the winch to the balloon in meters measured with an optical range finder.

θ = elevation angle of the balloon from the winch measured with an inclinometer.

5) Every hour lower the balloon to ground level and compare the sonde pressure reading with the reading of the precision barometer. Close the current file and re-initiate the TSONDLOG program using the updated pressure reading of the precision barometer.

6) Every 2 hours, in addition to the procedures in step 5, change the sensor battery.

D) After Flight Procedures

1) Once the balloon reaches ground level, allow the sonde to make at least 3 more data cycles and for the laptop to write to the B drive before proceeding to the next step.

2) Press the <ESC> key of the laptop to close the data file.

3) Remove and label the data disk.

4) Remove the program disk and turn the laptop off.

5) Turn off the sonde.

6) Turn off the ADAS.

II) DATA PROCESSING PROCESSING

A) Data Correction and File Creation

1) Go through the data printout and mark all errors with a red pen. Errors will appear as missing data or symbols in place of numerals.

2) Place the Lotus 123 system disk into the A drive of the laptop.

3) At the dos A prompt, type 123 and press the <RTN> key.

4) Place the program disk in drive b.

5) Press the /, f and r keys.

6) Move the cursor to the SNDTEMP.wk1 program title and press the <RTN> key.

7) Place the data disk into drive b.

8) Press the /,f,i,n keys.

9) Enter the file name being sure to prefix it with the B drive designation (ex: B:11091702.dat).

10) Once the data appears on the screen, correct the errors noted in the printout and resave the data file by pressing the /, f and s keys. Enter the file name used in step 9, being sure to prefix it with the B drive designation and press the <RTN> key.

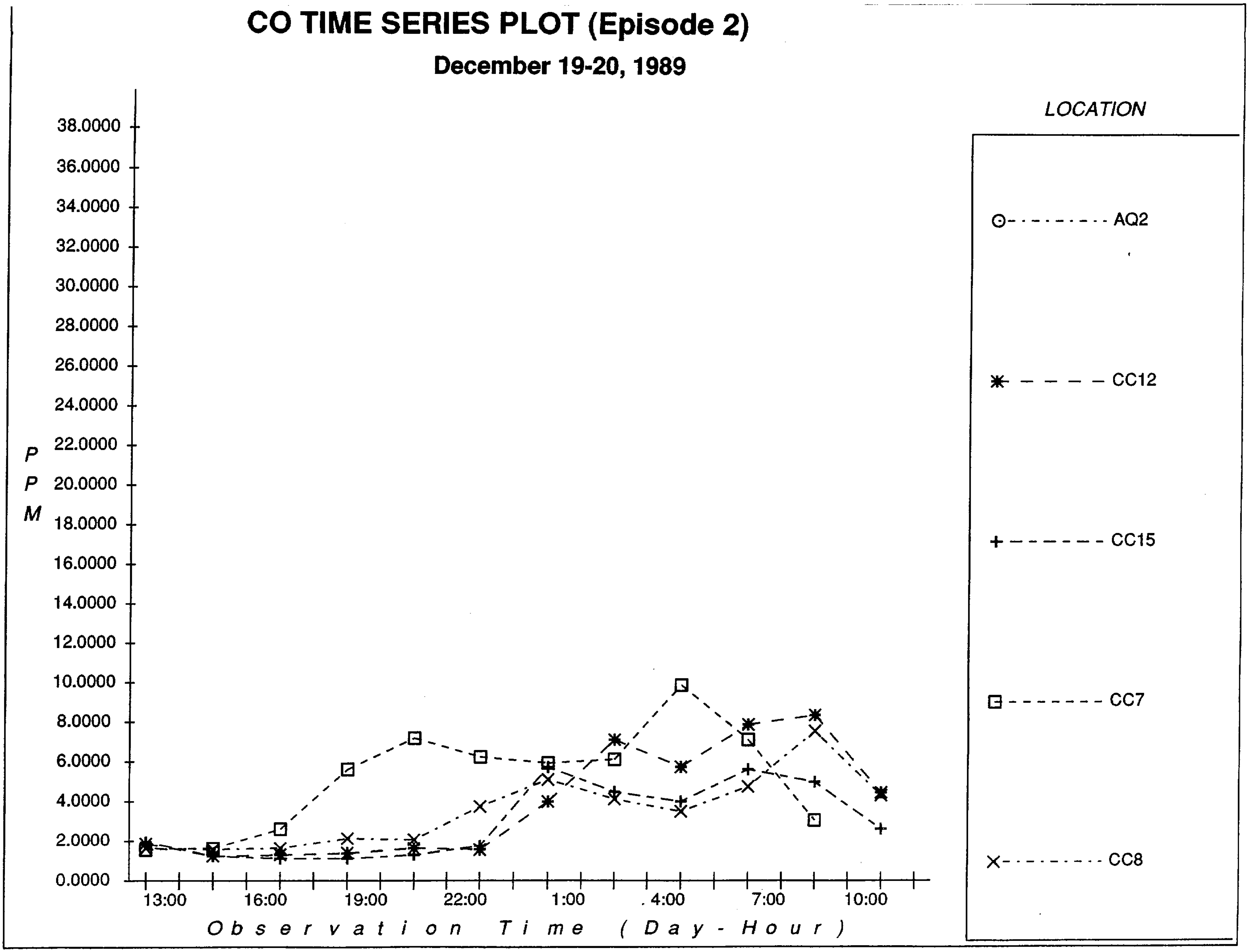
B) Data Averaging

1) Average the wind speed, wind direction and altitude data for each of the averaging periods using the @avg(..) function.

2) Save the spreadsheet by pressing the /, f, s, <RTN> and y keys.

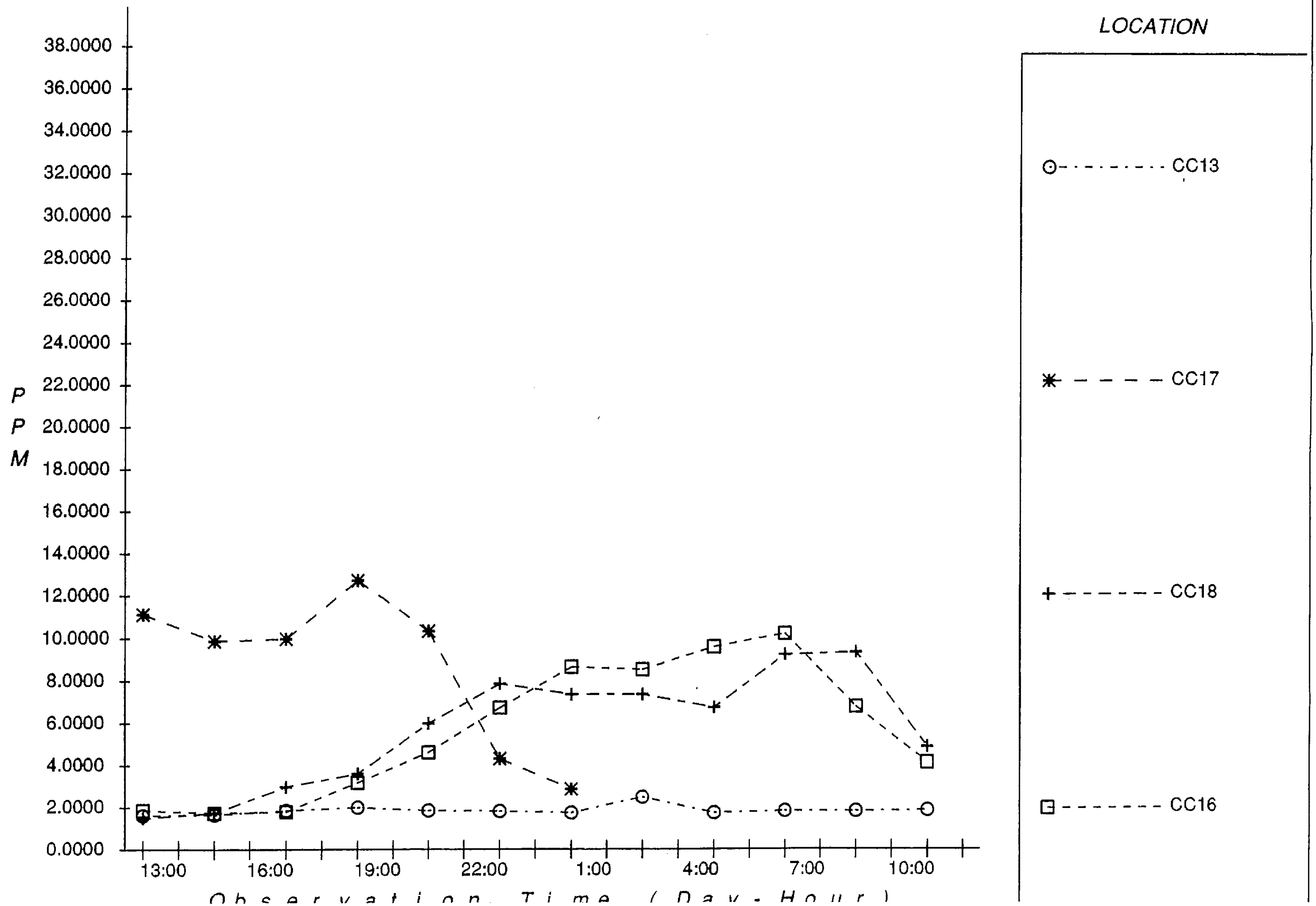
Appendix B-1

Episode 2


CO TIME SERIES PLOT (Episode 2)
December 19-20, 1989
PPM
38.0000
36.0000
34.0000
32.0000
30.0000
28.0000
26.0000
24.0000
22.0000
20.0000
18.0000
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
13:00
16:00
19:00
22:00
1:00
4:00
7:00
10:00
Observation Time (Day - Hour)
LOCATION
AQ2
CC12
CC15
CC7
CC8

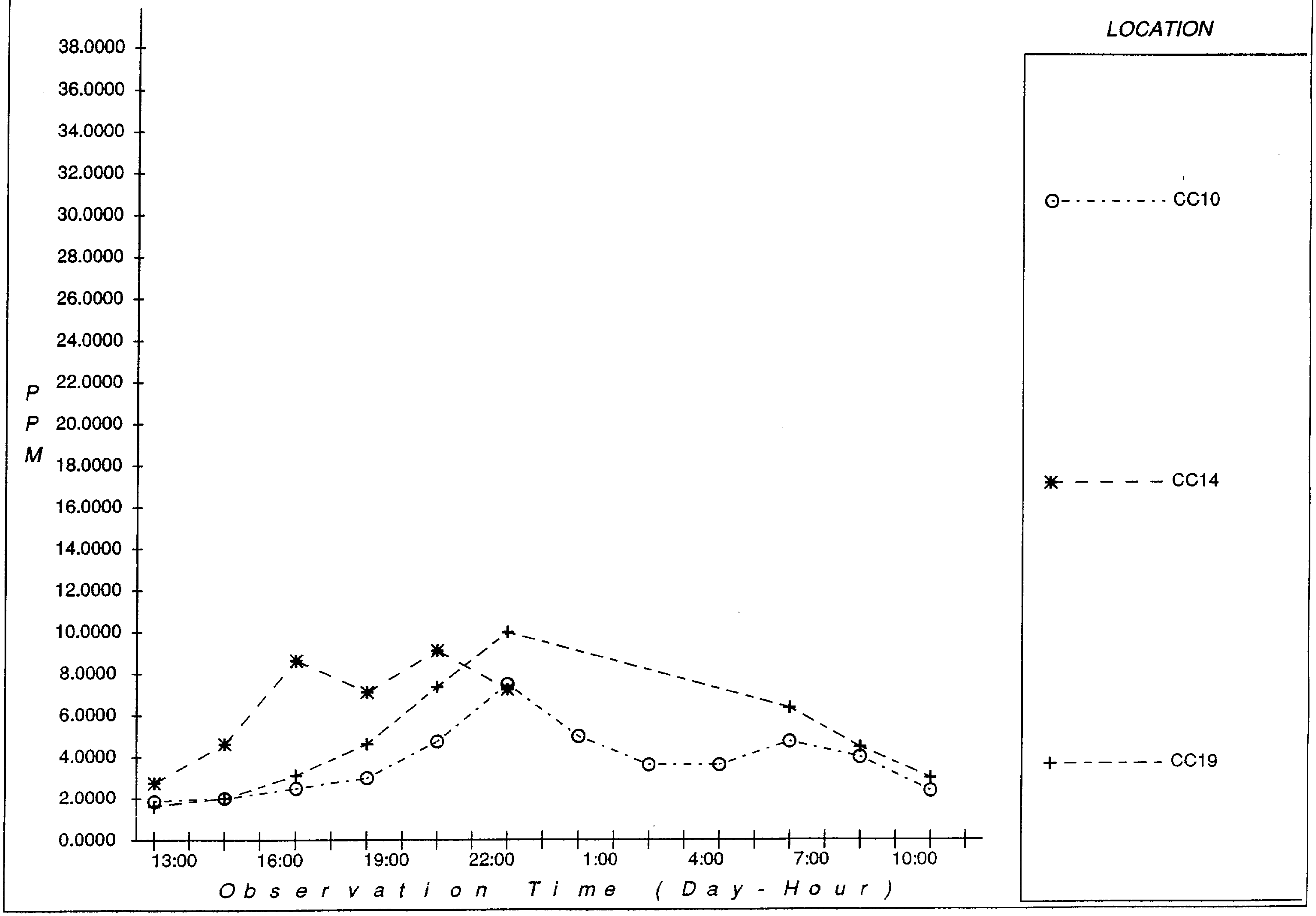
CO TIME SERIES PLOT (Episode 2)

December 19-20, 1989



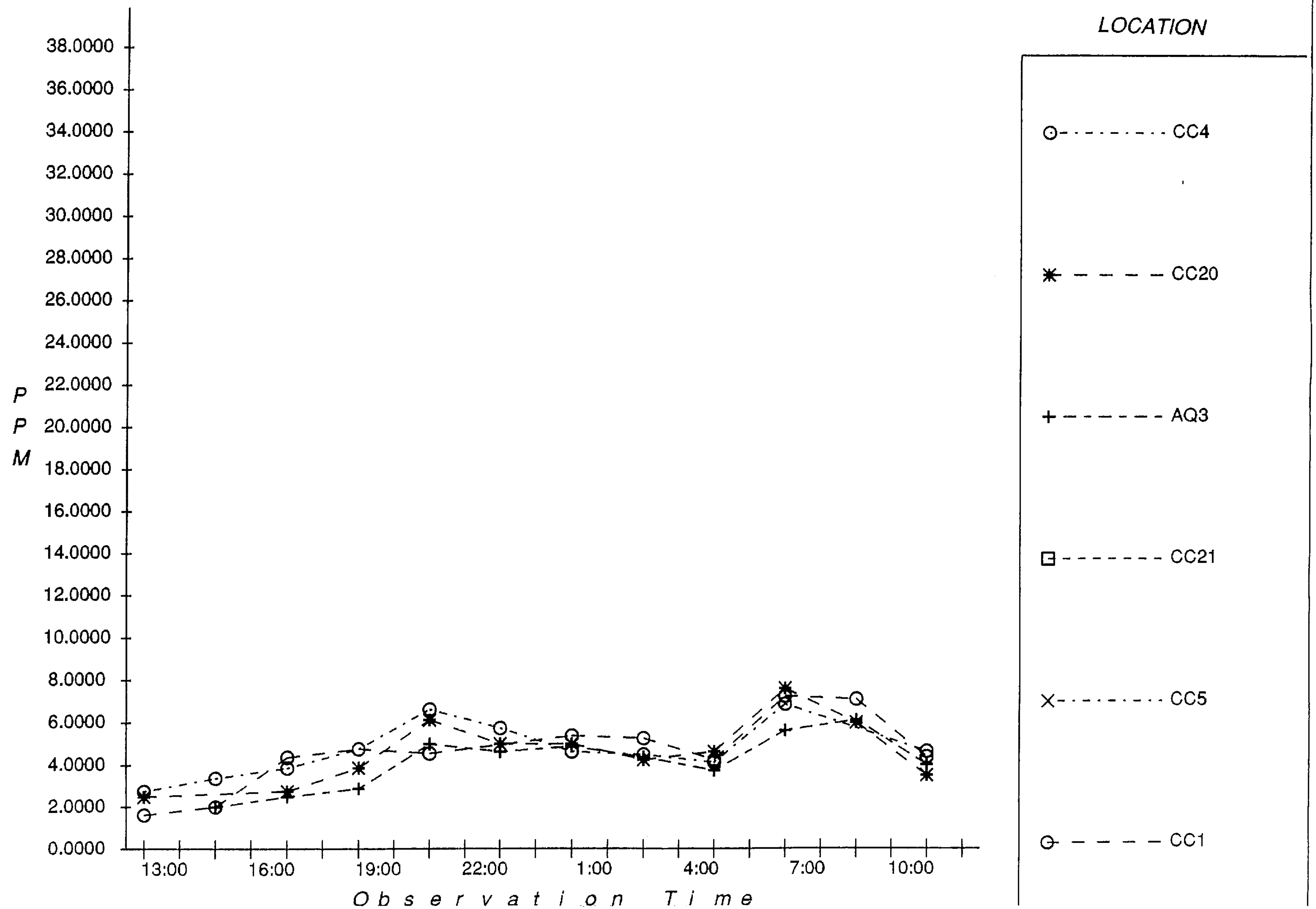
CO TIME SERIES PLOT (Episode 2)

December 19-20, 1989



CO TIME SERIES PLOT (Episode 2)

December 19-20, 1989



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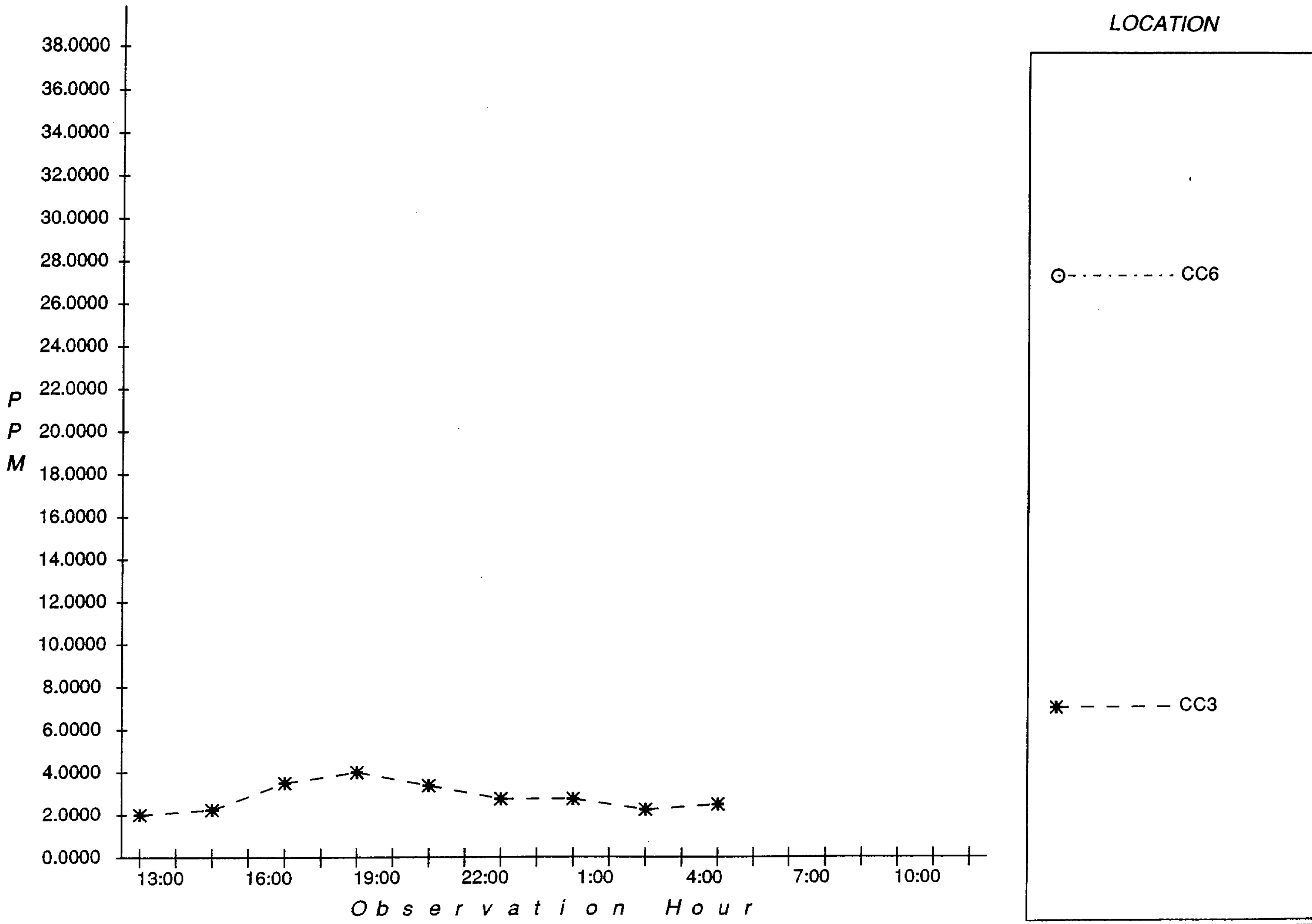
December 19-20, 1989



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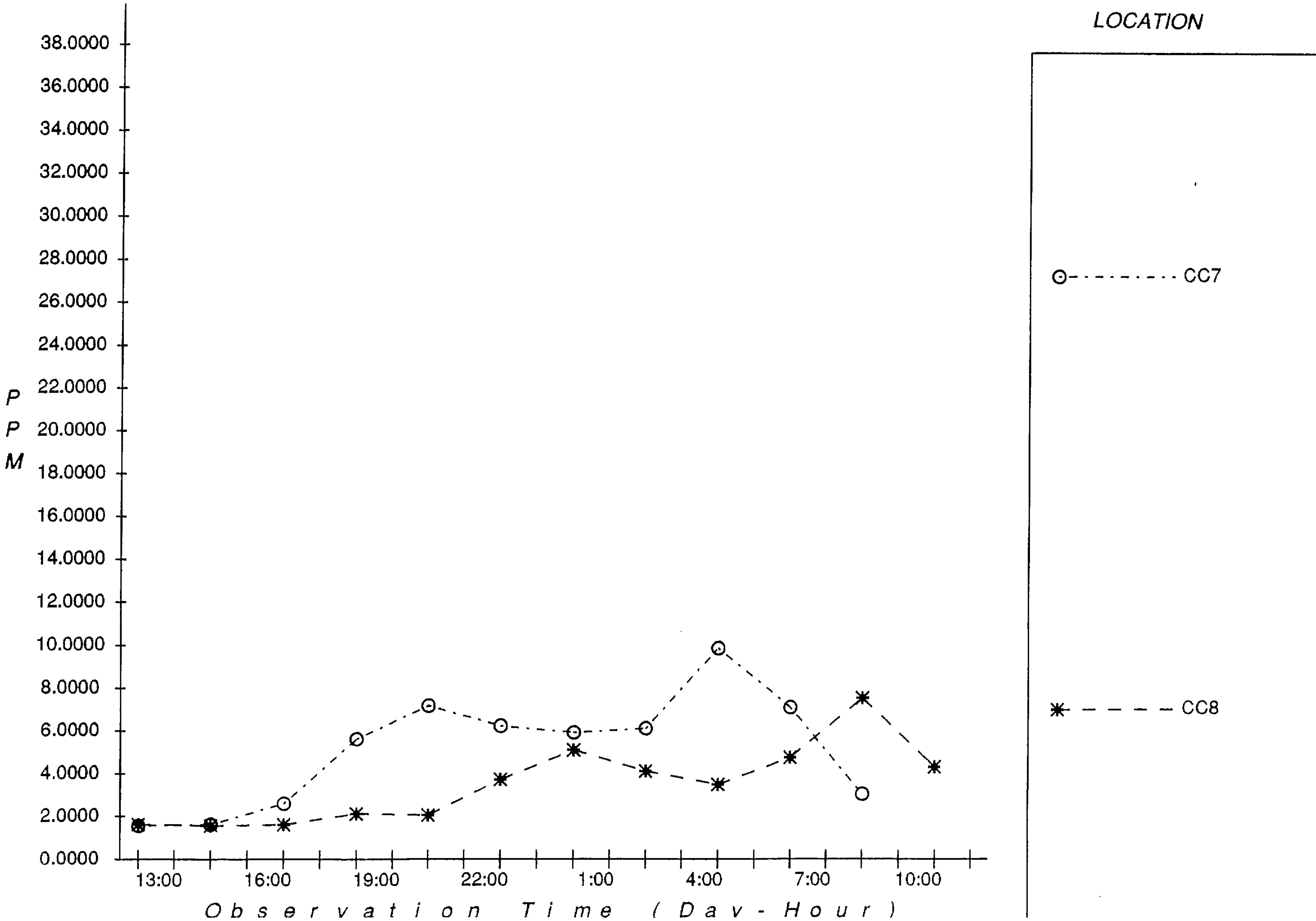
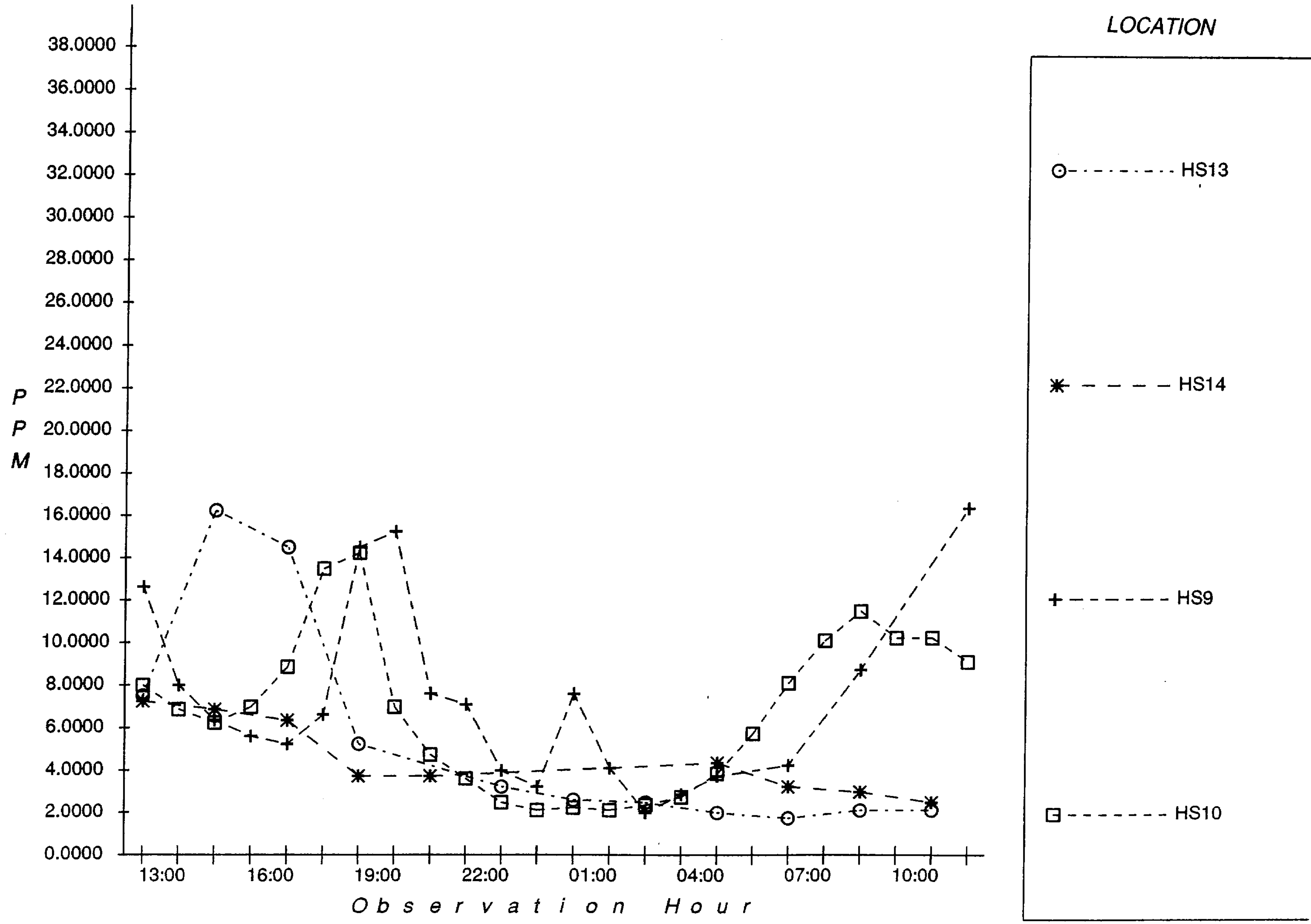
December 19-20, 1989



CO TIME SERIES PLOT (Episode 2)

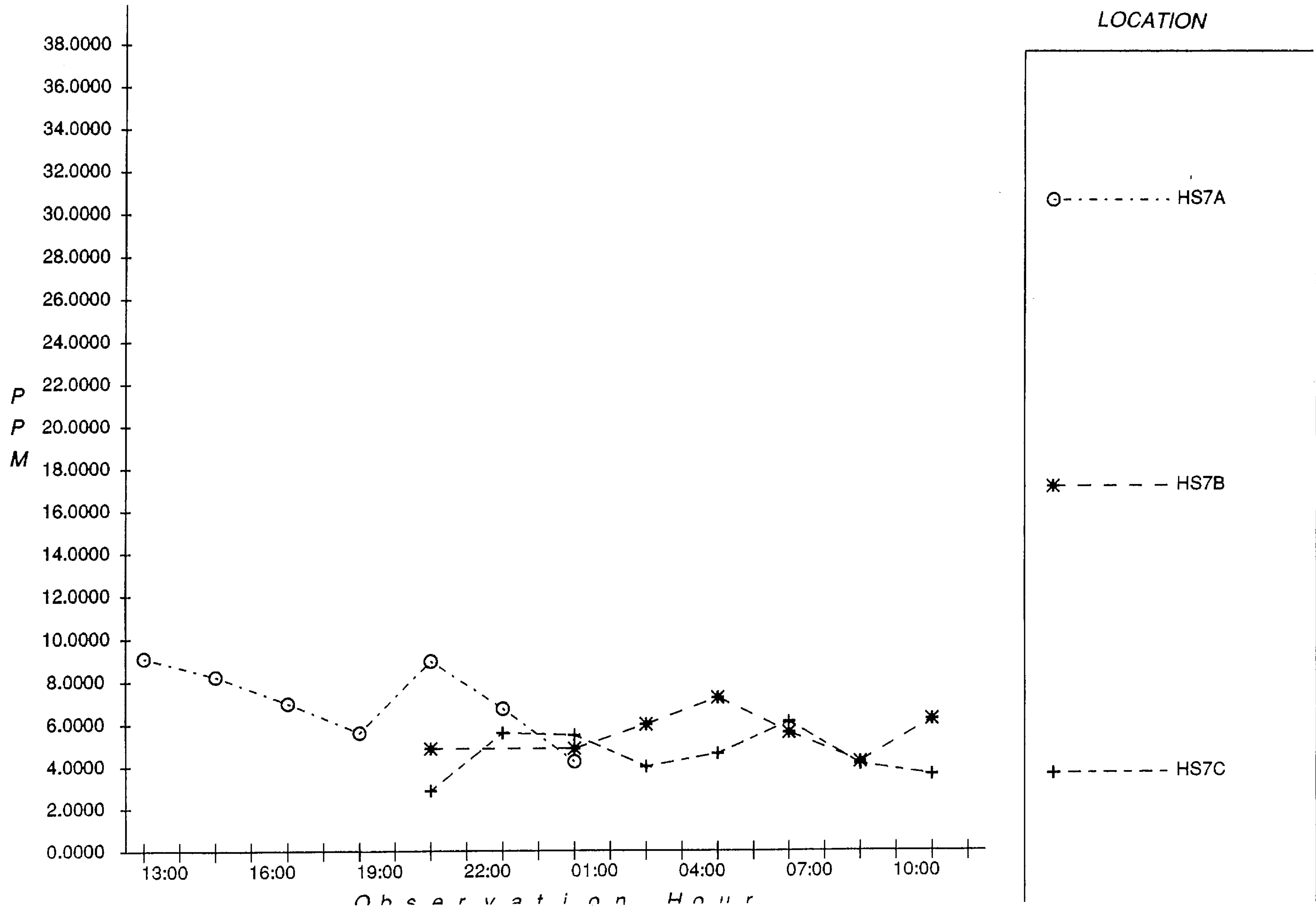
CO TIME SERIES PLOT (Episode 2)

December 19-20, 1989



LYNWOOD CO TIME SERIES PLOT (Episode 2)

December 19-20, 1989 (ELEVATED SAMPLING)

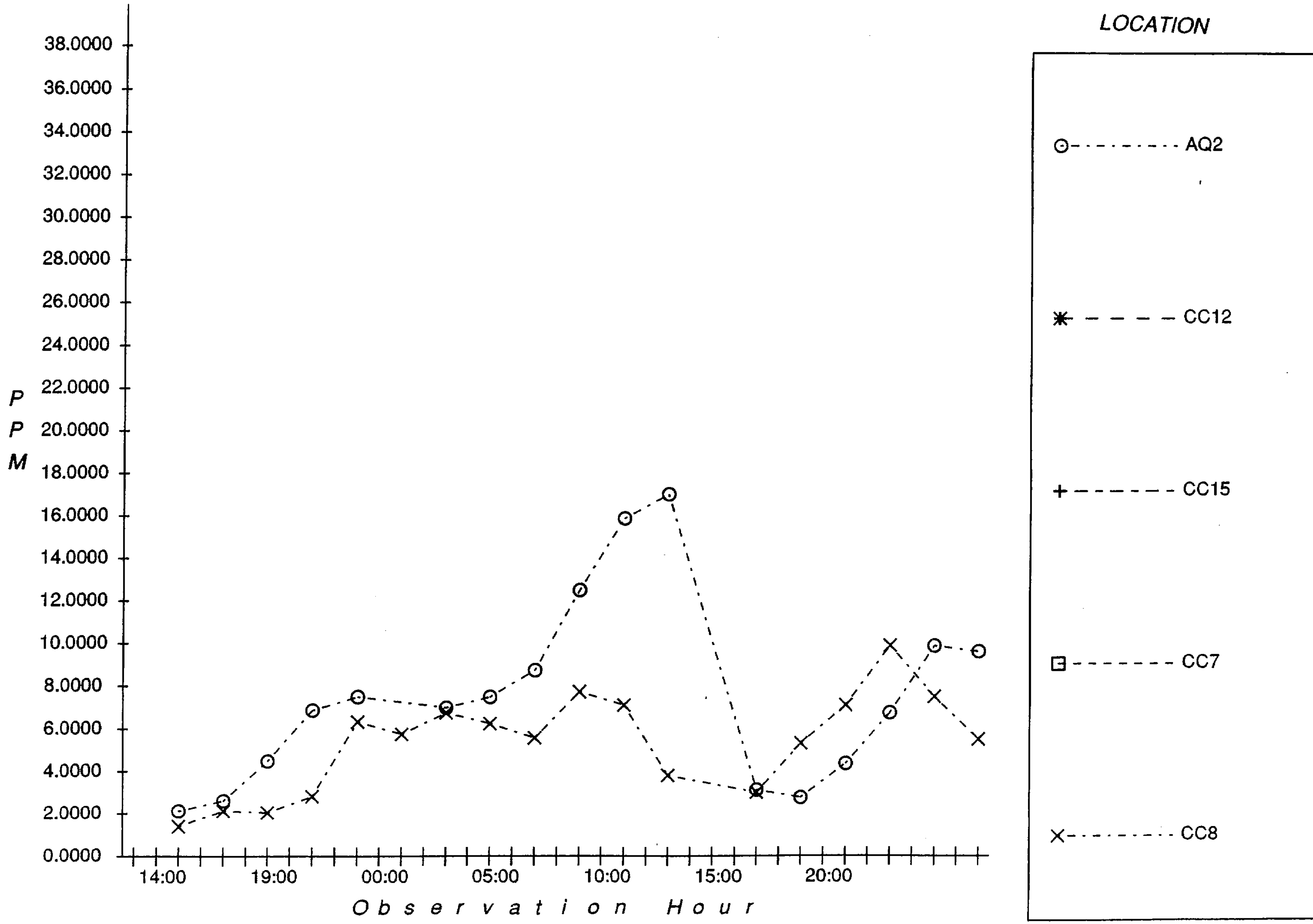


Appendix B-2

Episode 3

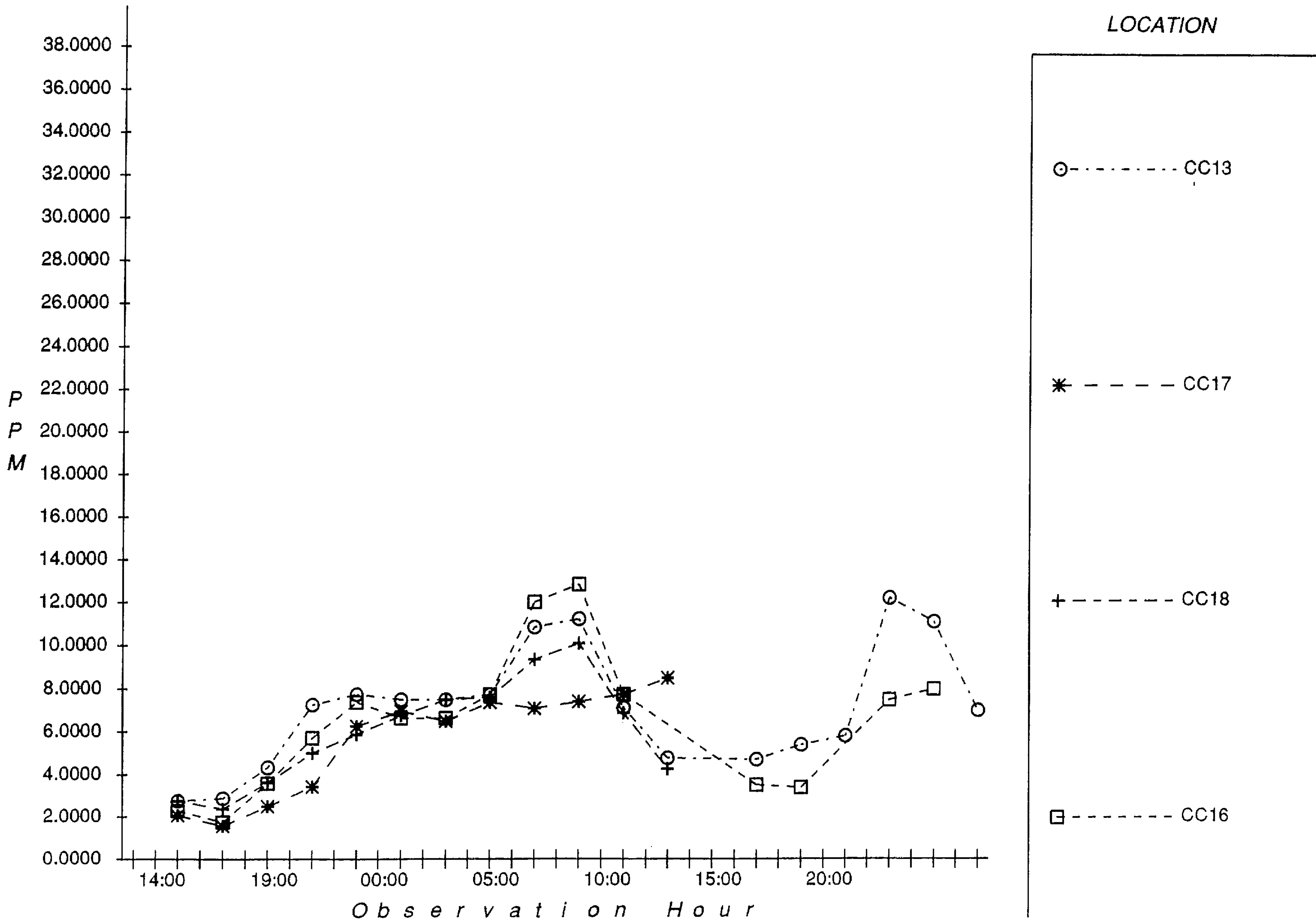
CO TIME SERIES PLOT (Episode 3)

January 08-10, 1990



CO TIME SERIES PLOT (Episode 3)

January 08-10, 1990



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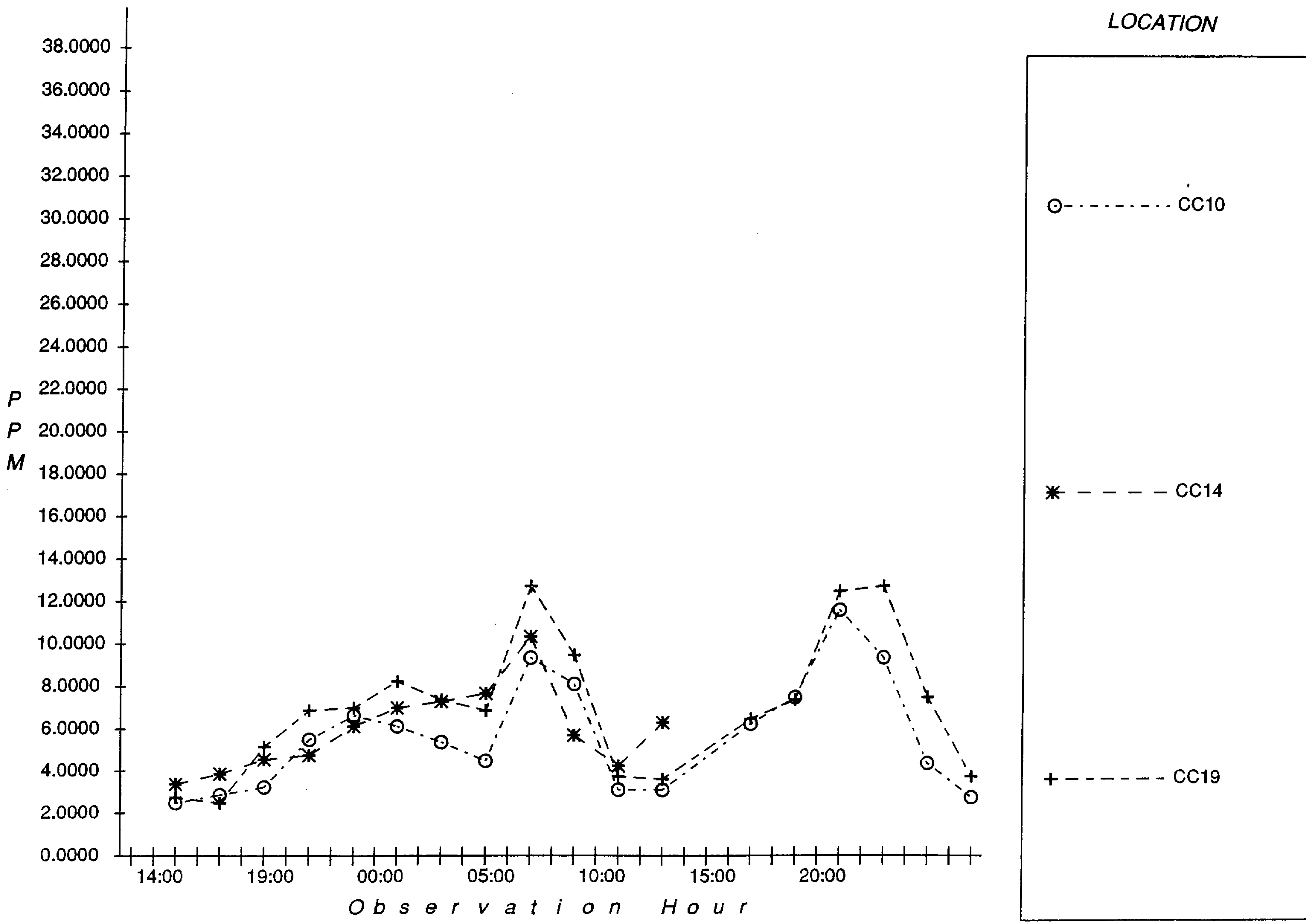
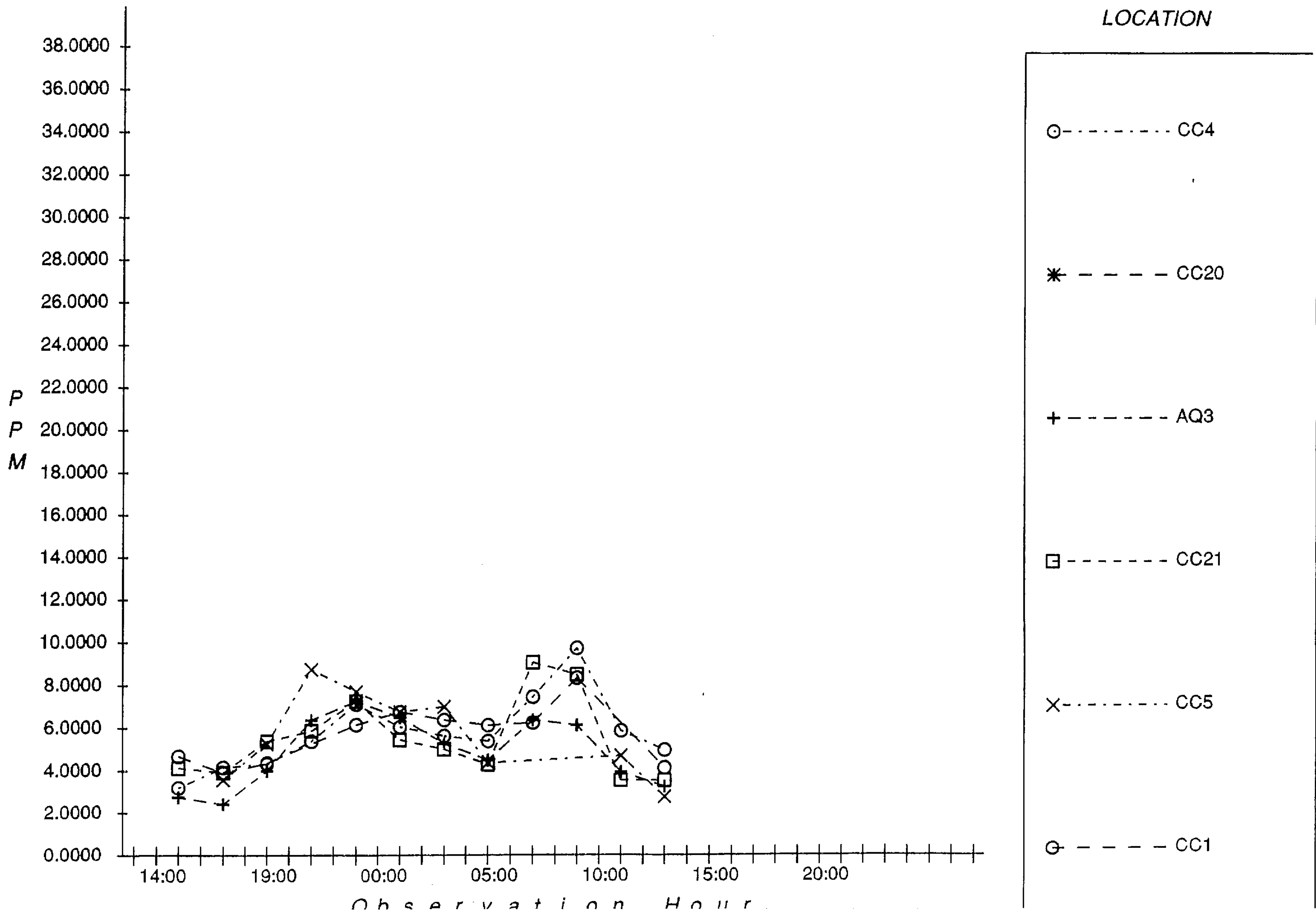
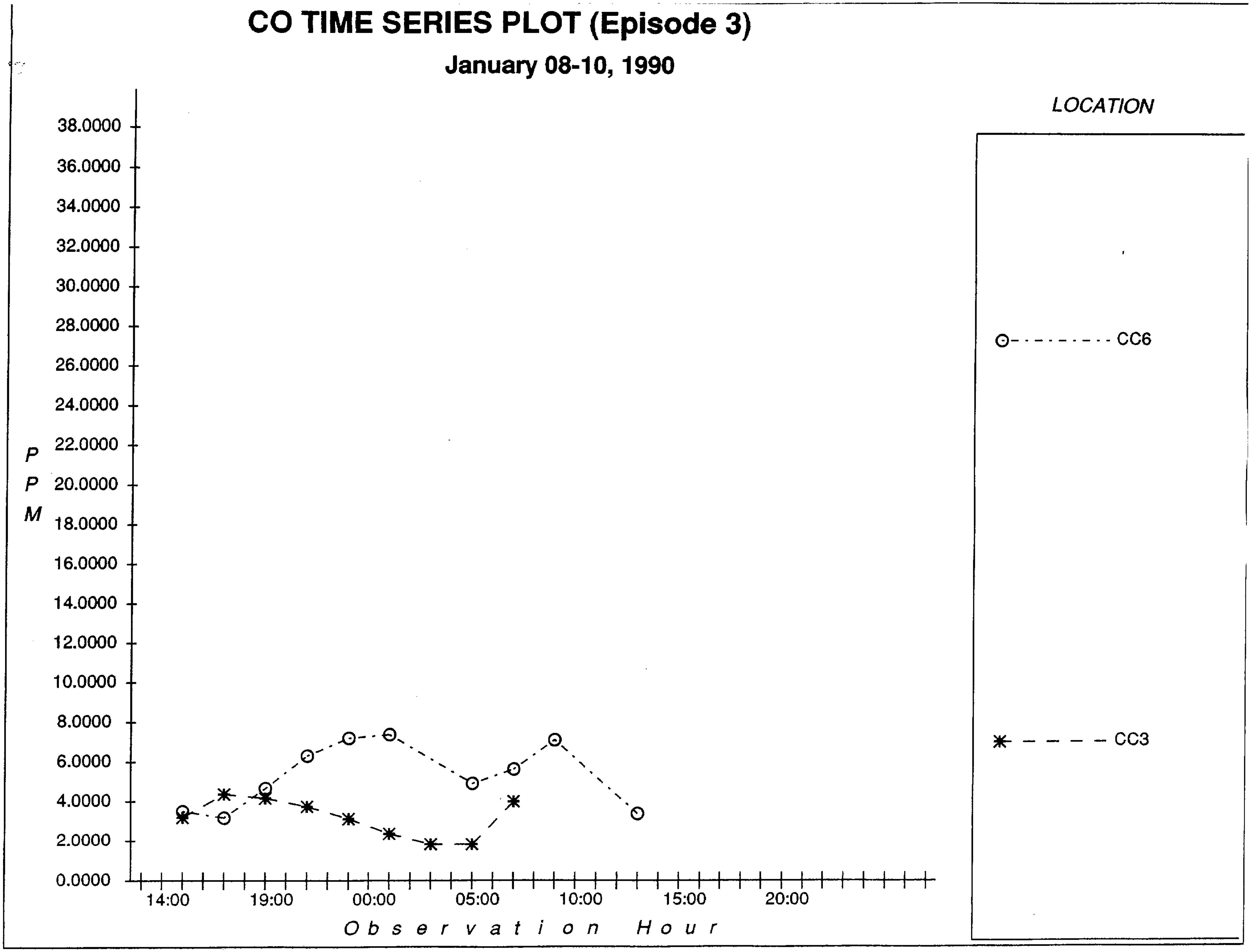
January 08-10, 1990



CO TIME SERIES PLOT (Episode 3)

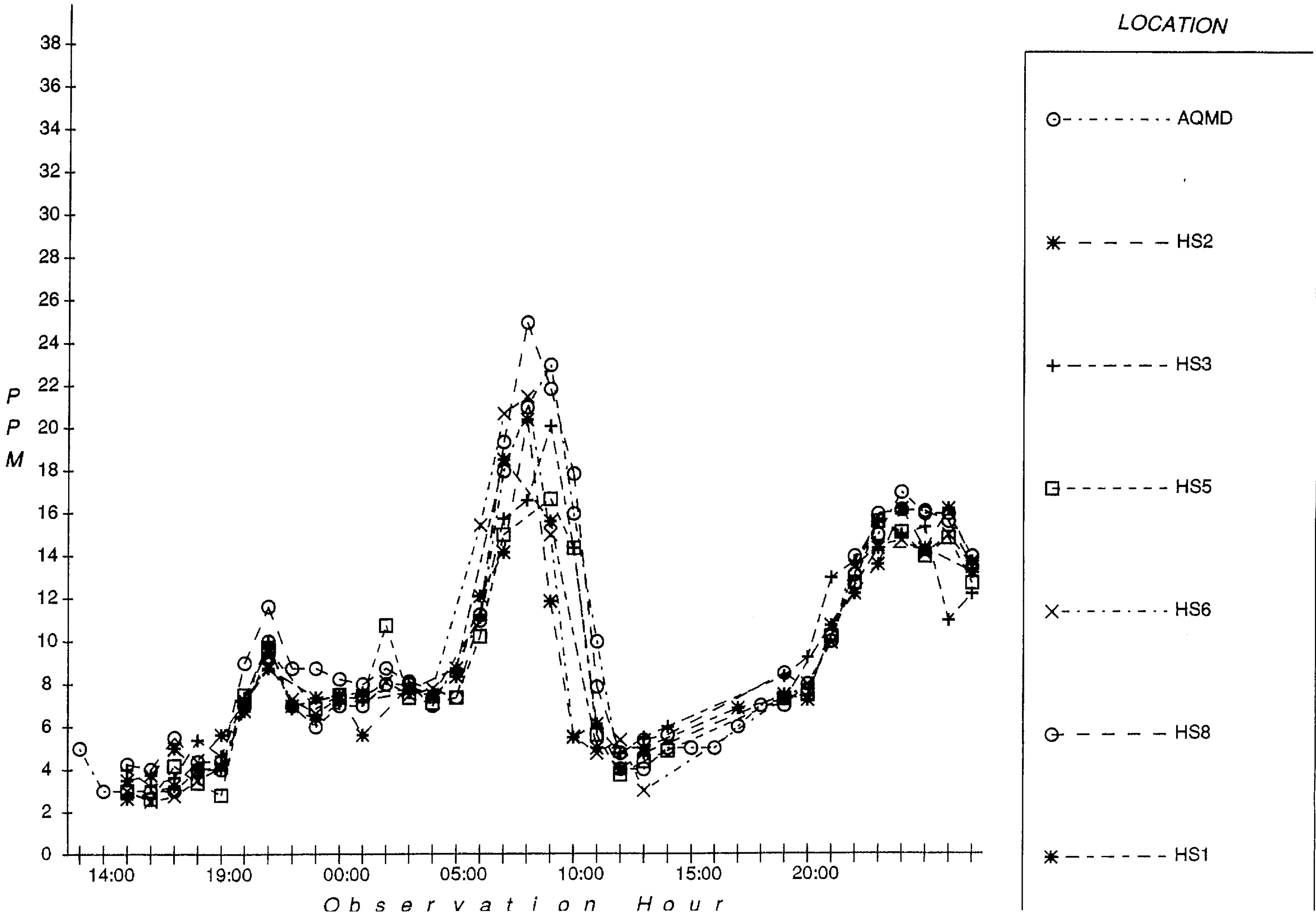
January 08-10, 1990




CO TIME SERIES PLOT (Episode 3)
January 08-10, 1990
PPM
38.0000
36.0000
34.0000
32.0000
30.0000
28.0000
26.0000
24.0000
22.0000
20.0000
18.0000
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
14:00
19:00
00:00
05:00
10:00
15:00
20:00
Observation Hour
LOCATION
CC6
CC3

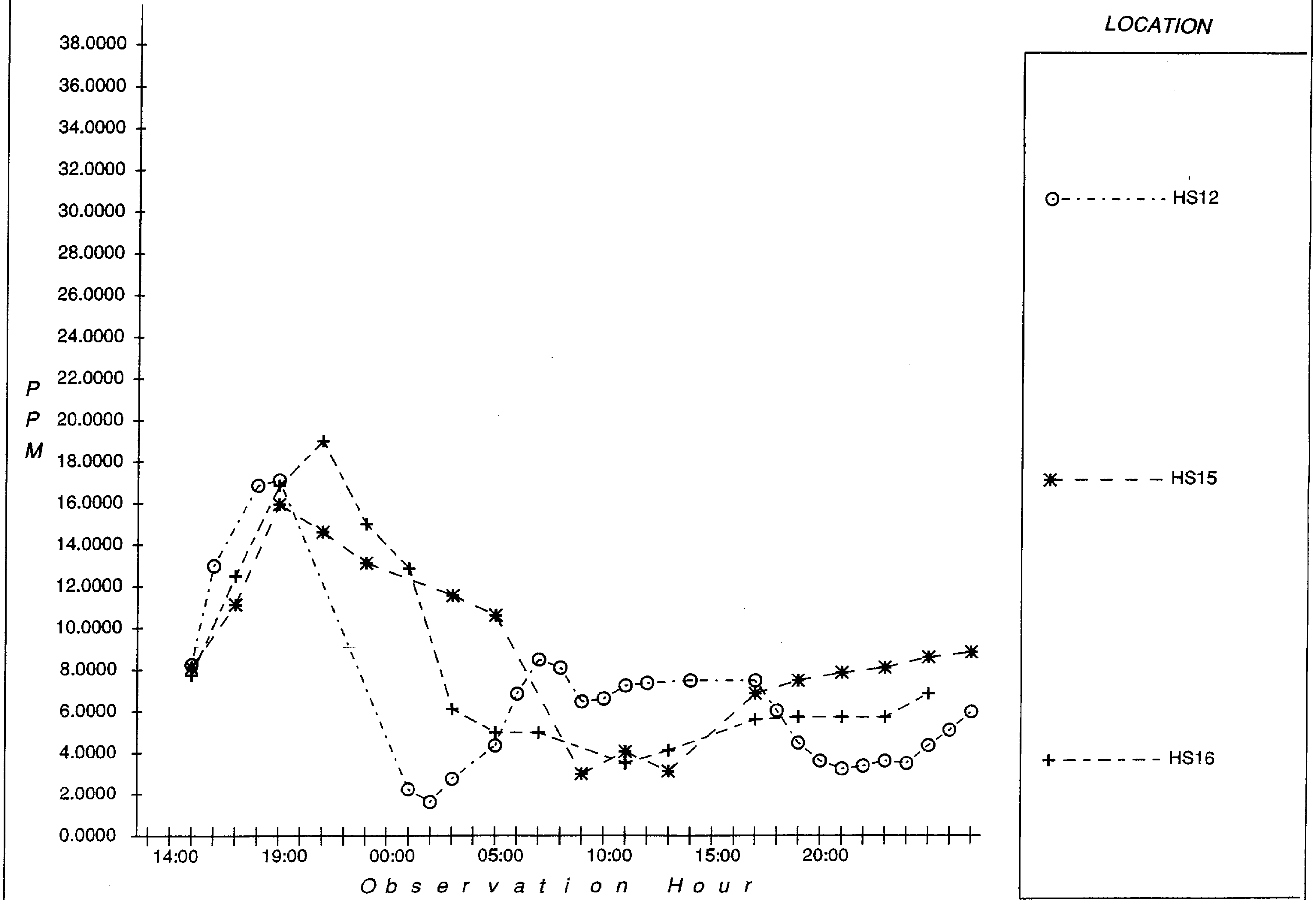
LYNWOOD CO TIME SERIES PLOT (Episode 3)

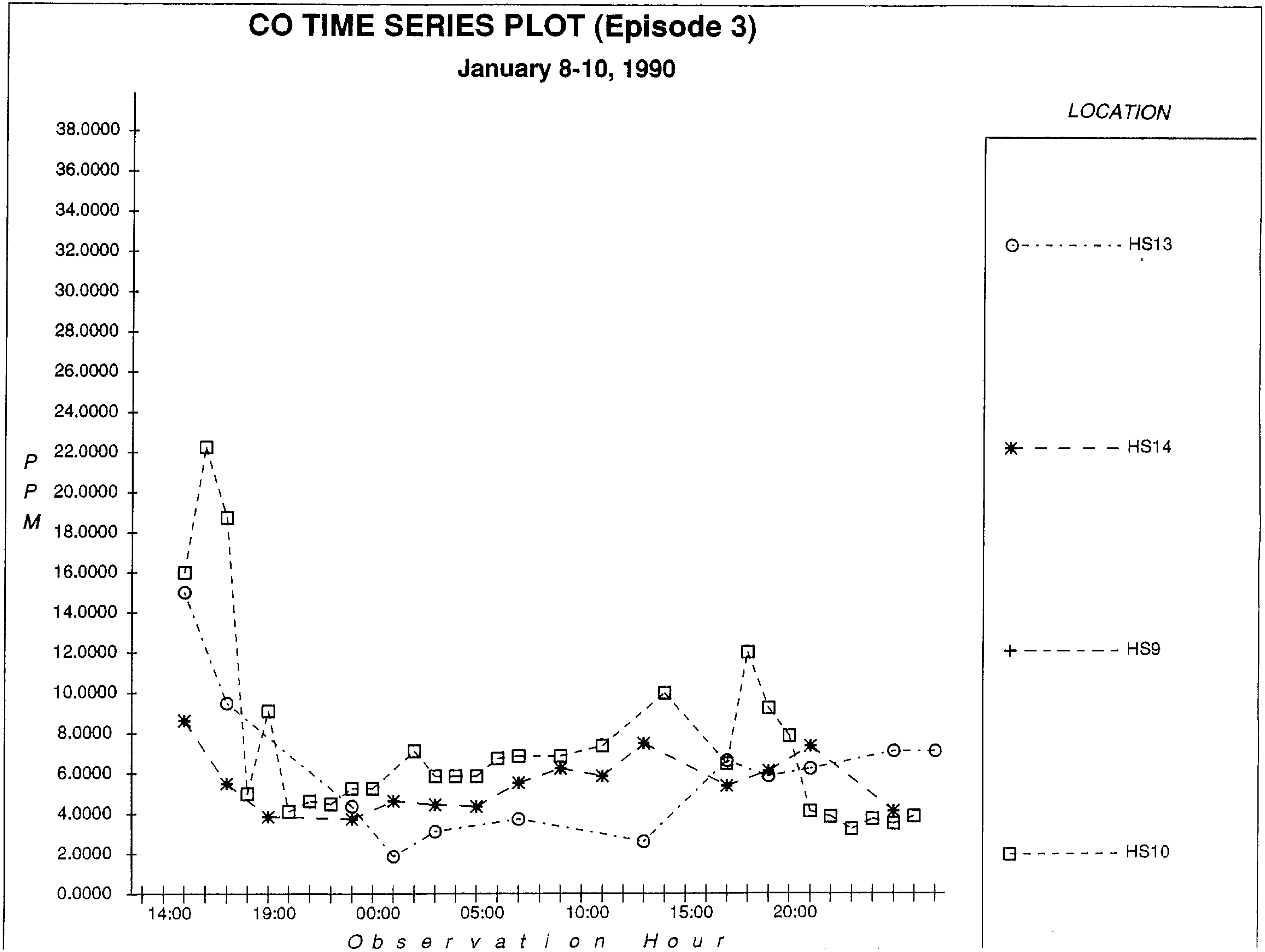
January 8-10, 1990

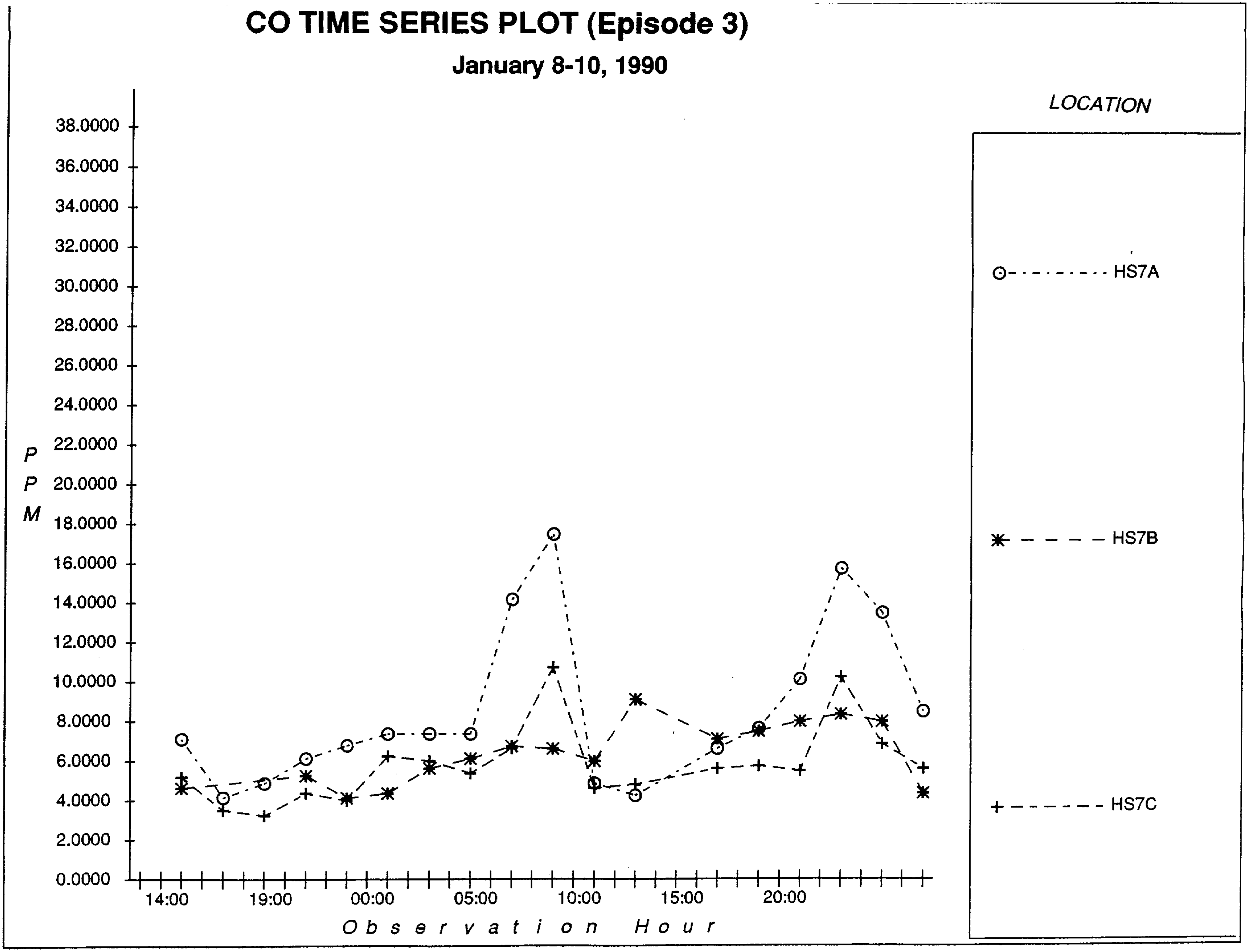


CO TIME SERIES PLOT (Episode 3)

January 8-10, 1990




CO TIME SERIES PLOT (Episode 3)
January 8-10, 1990
PPM
38.0000
36.0000
34.0000
32.0000
30.0000
28.0000
26.0000
24.0000
22.0000
20.0000
18.0000
16.0000
14.0000
12.0000
10.0000
8.0000
6.0000
4.0000
2.0000
0.0000
14:00
19:00
00:00
05:00
10:00
15:00
20:00
Observation Hour
LOCATION
HS13
HS14
HS9
HS10


CO TIME SERIES PLOT (Episode 3)
January 8-10, 1990
PPM
38.0000
36.0000
34.0000
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26.0000
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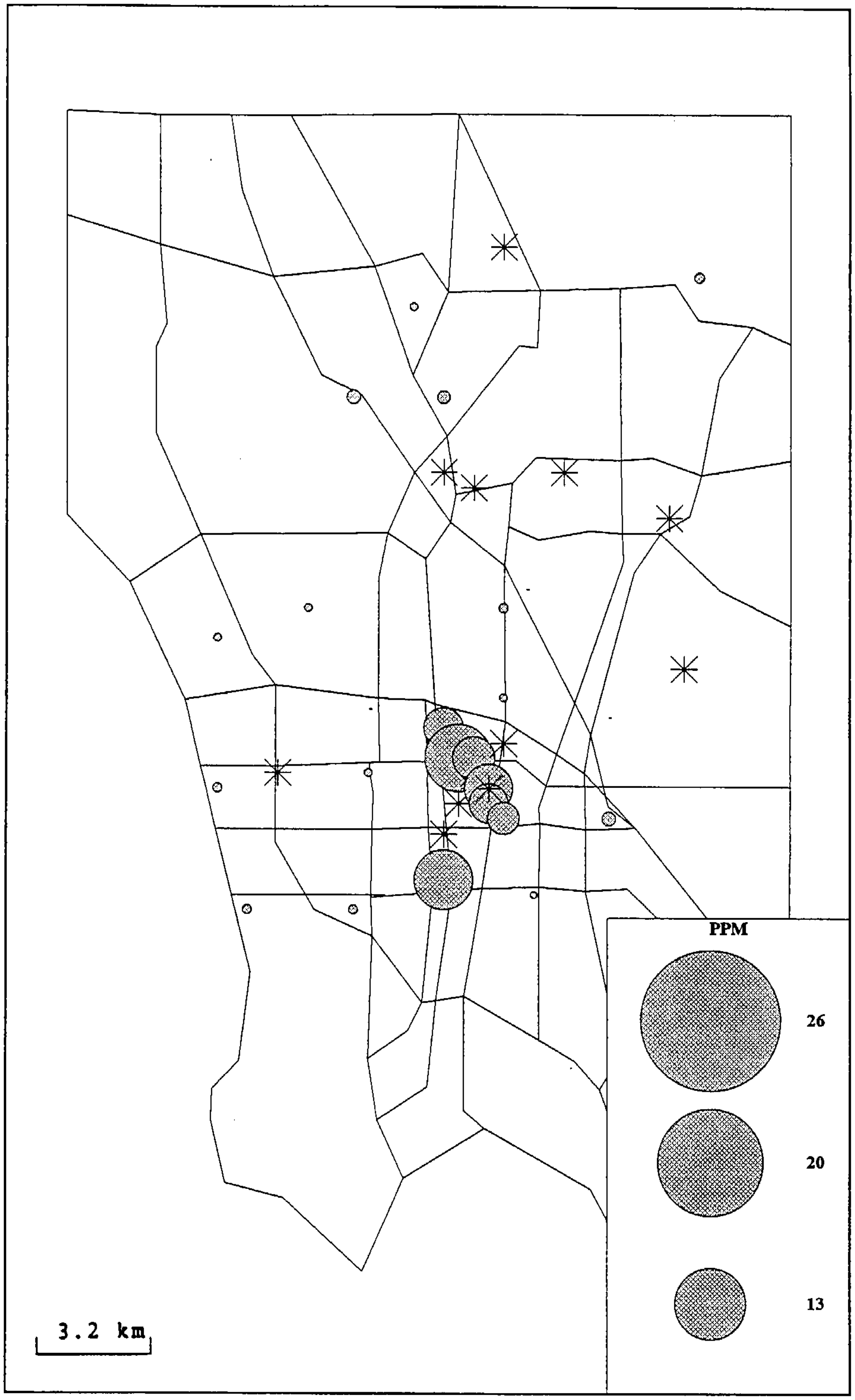
8.0000
6.0000
4.0000
2.0000
0.0000
14:00
19:00
00:00
05:00
10:00
15:00
20:00
Observation Hour
LOCATION
HS7A
HS7B
HS7C

Appendix C

SPATIAL VARIATION OF CO CONCENTRATIONS

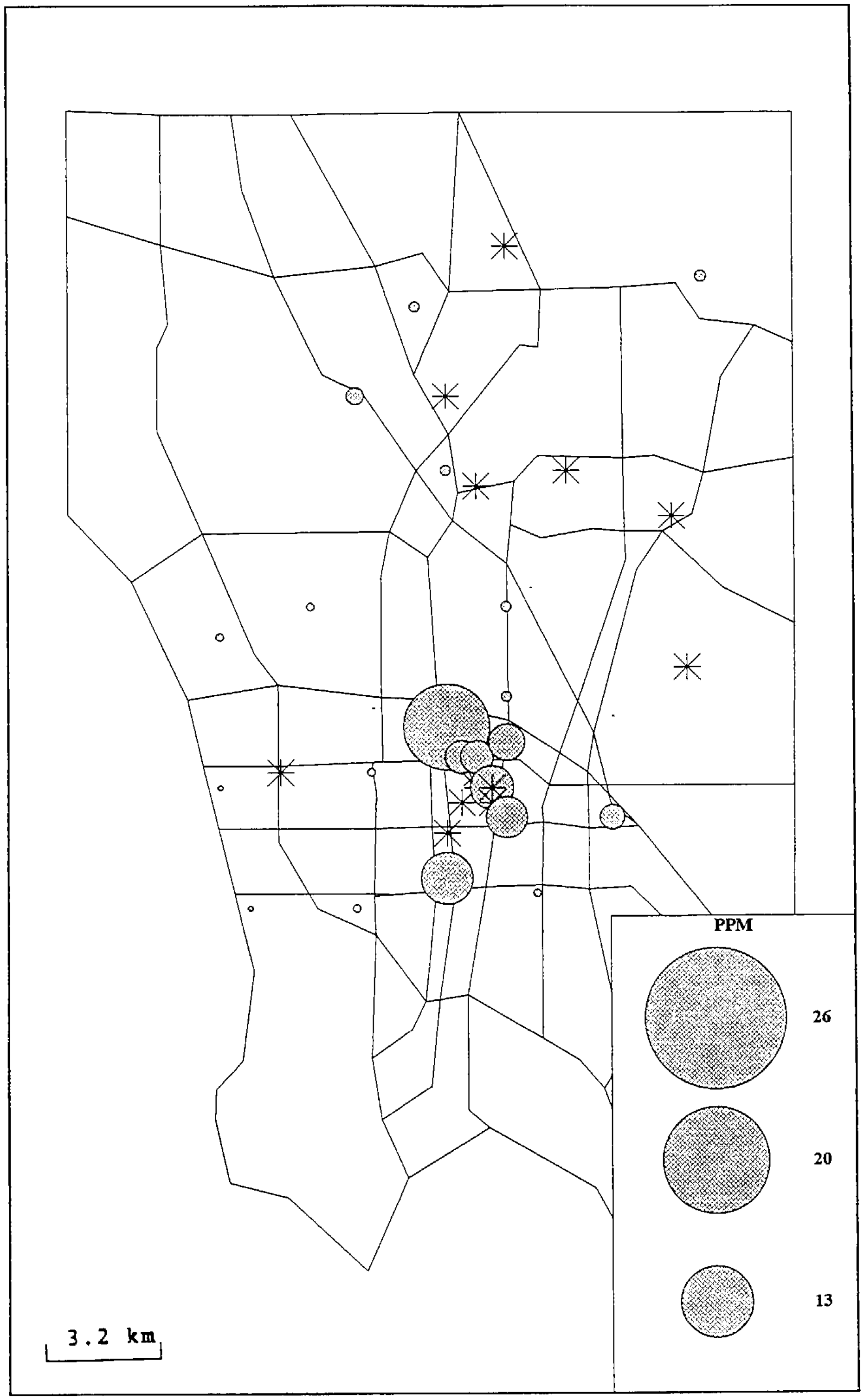
Appendix C-1

CO Concentration



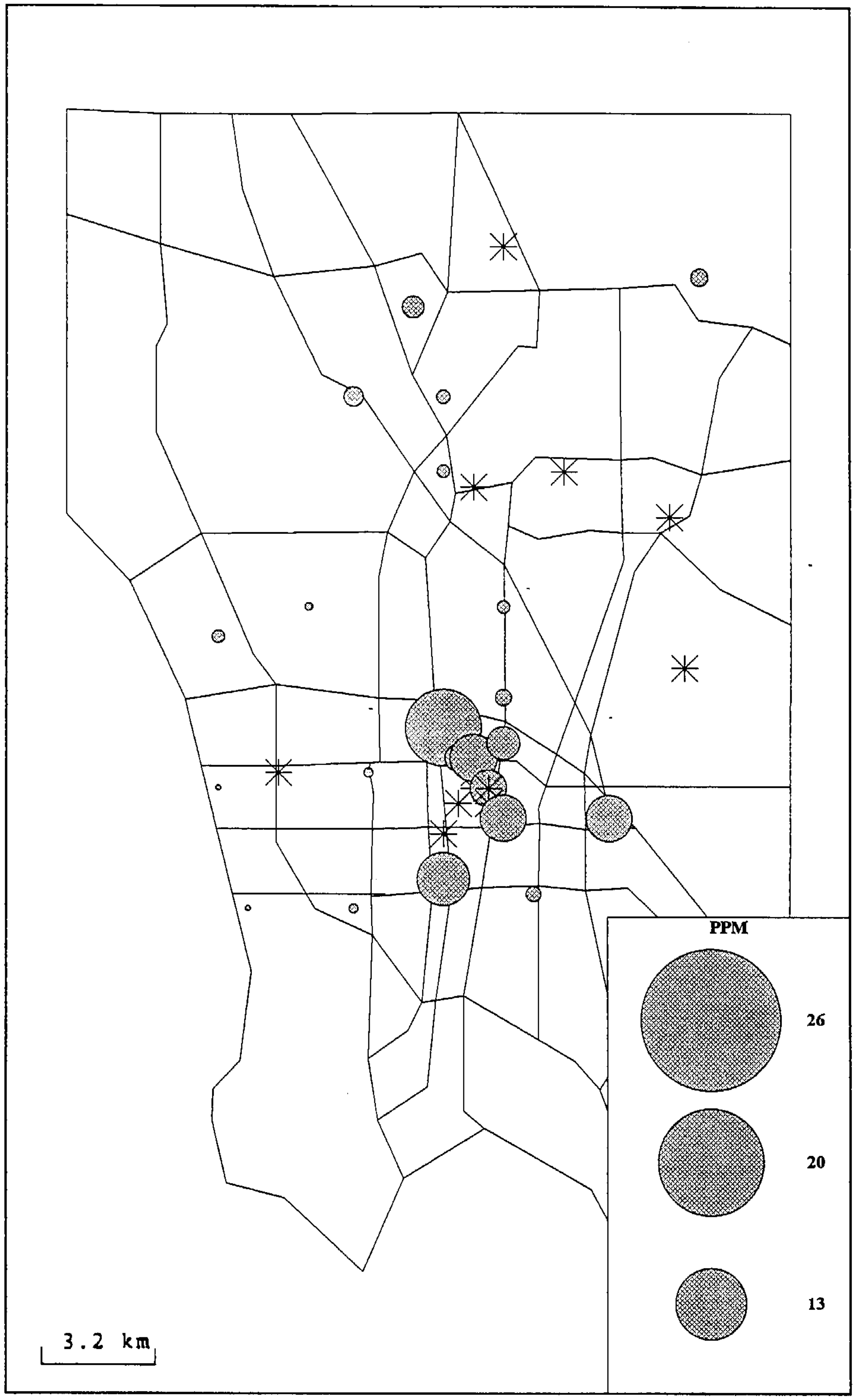
CO 12/19/1989 12:00

CO Concentration



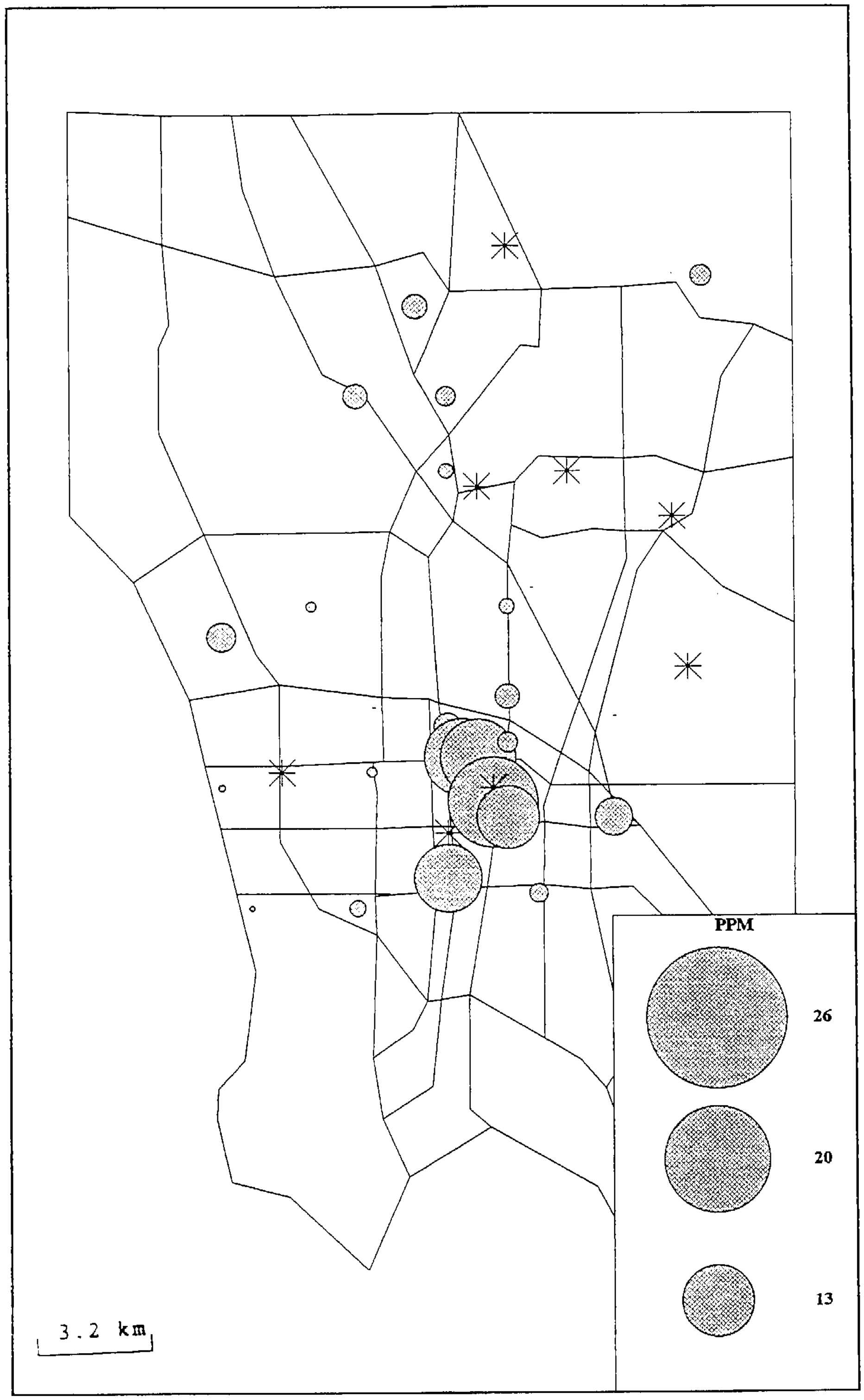
CO 12/19/1989 14:00

CO Concentration



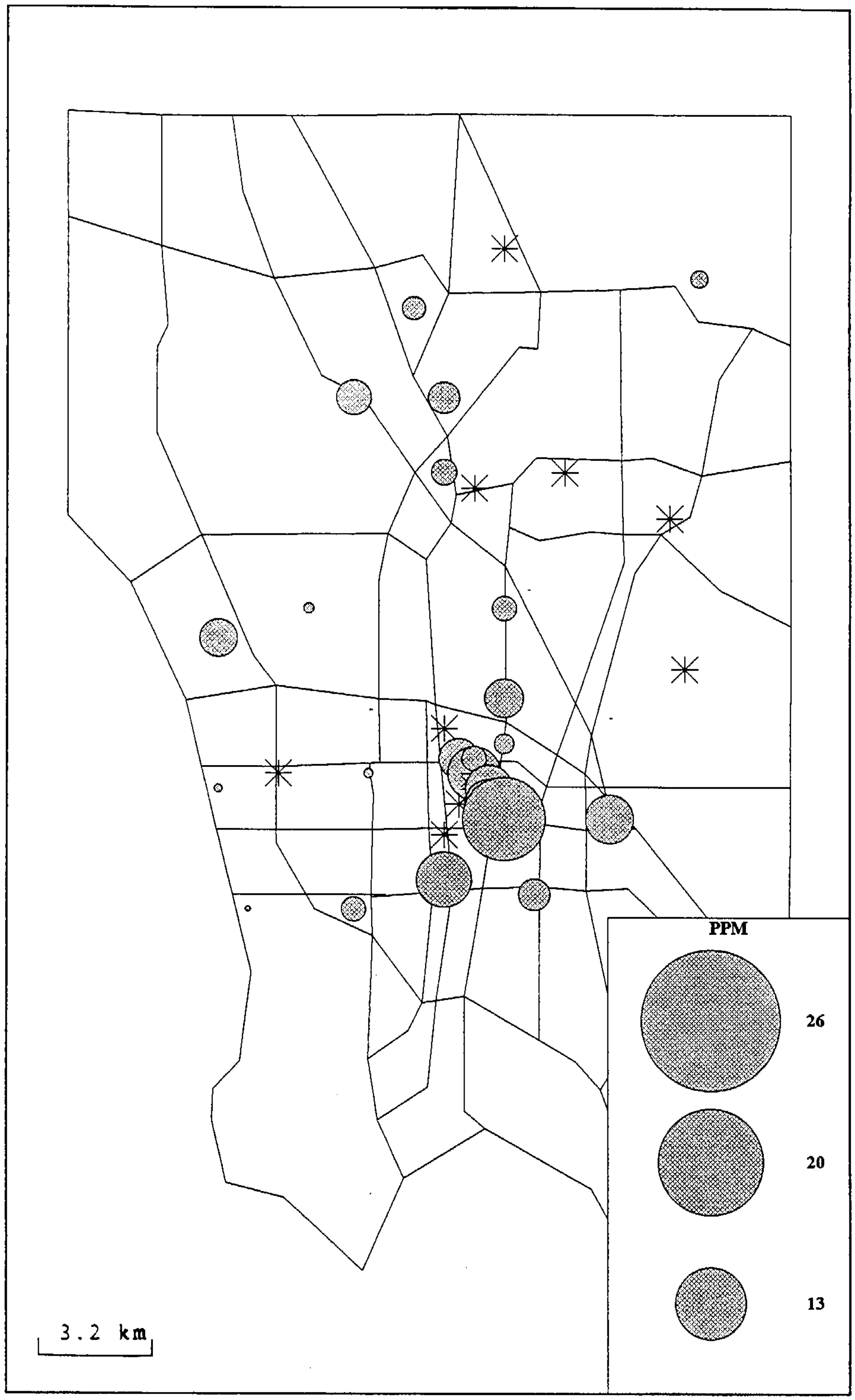
CO 12/19/1989 16:00

CO Concentration



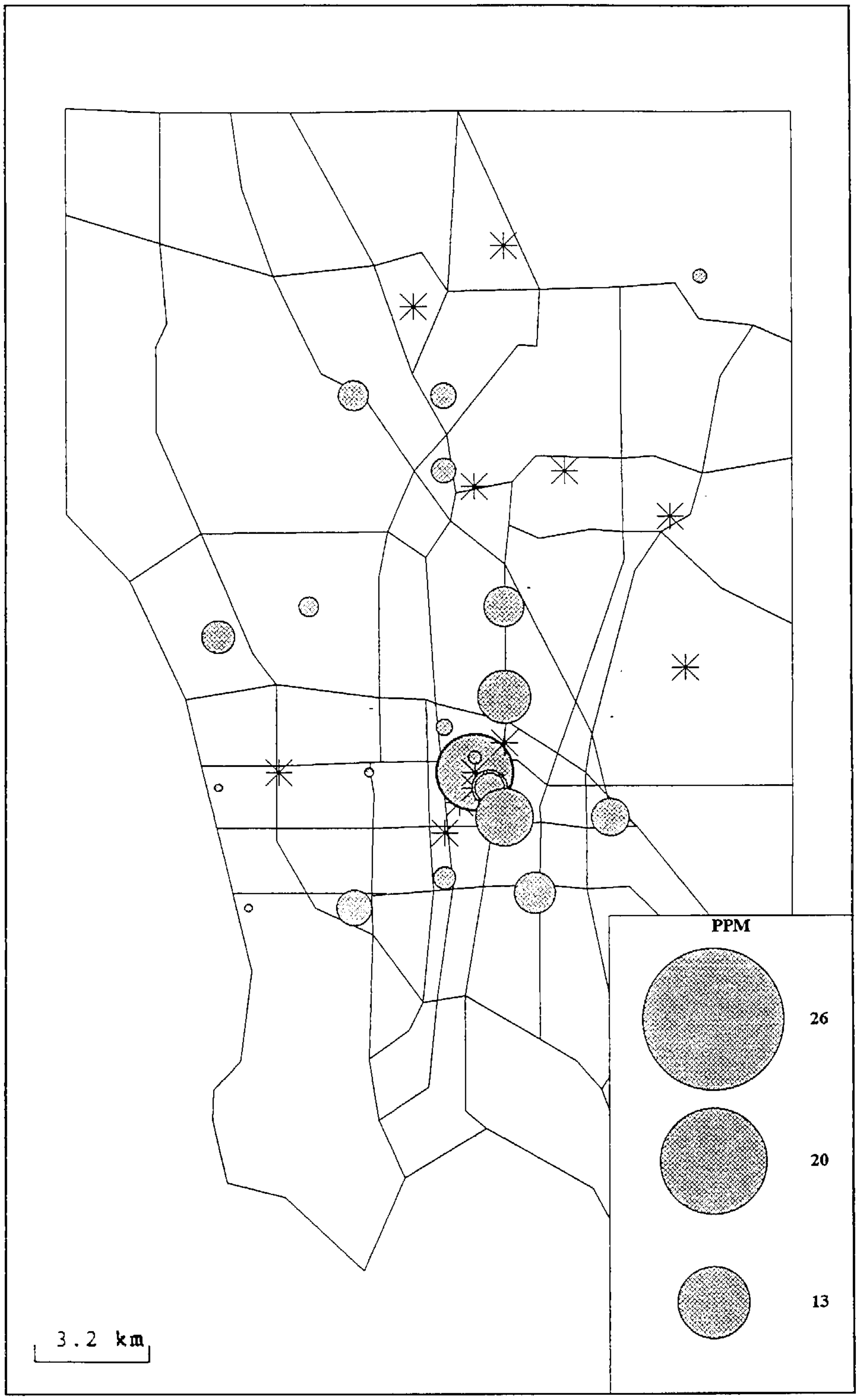
CO 12/19/1989 18:00

CO Concentration



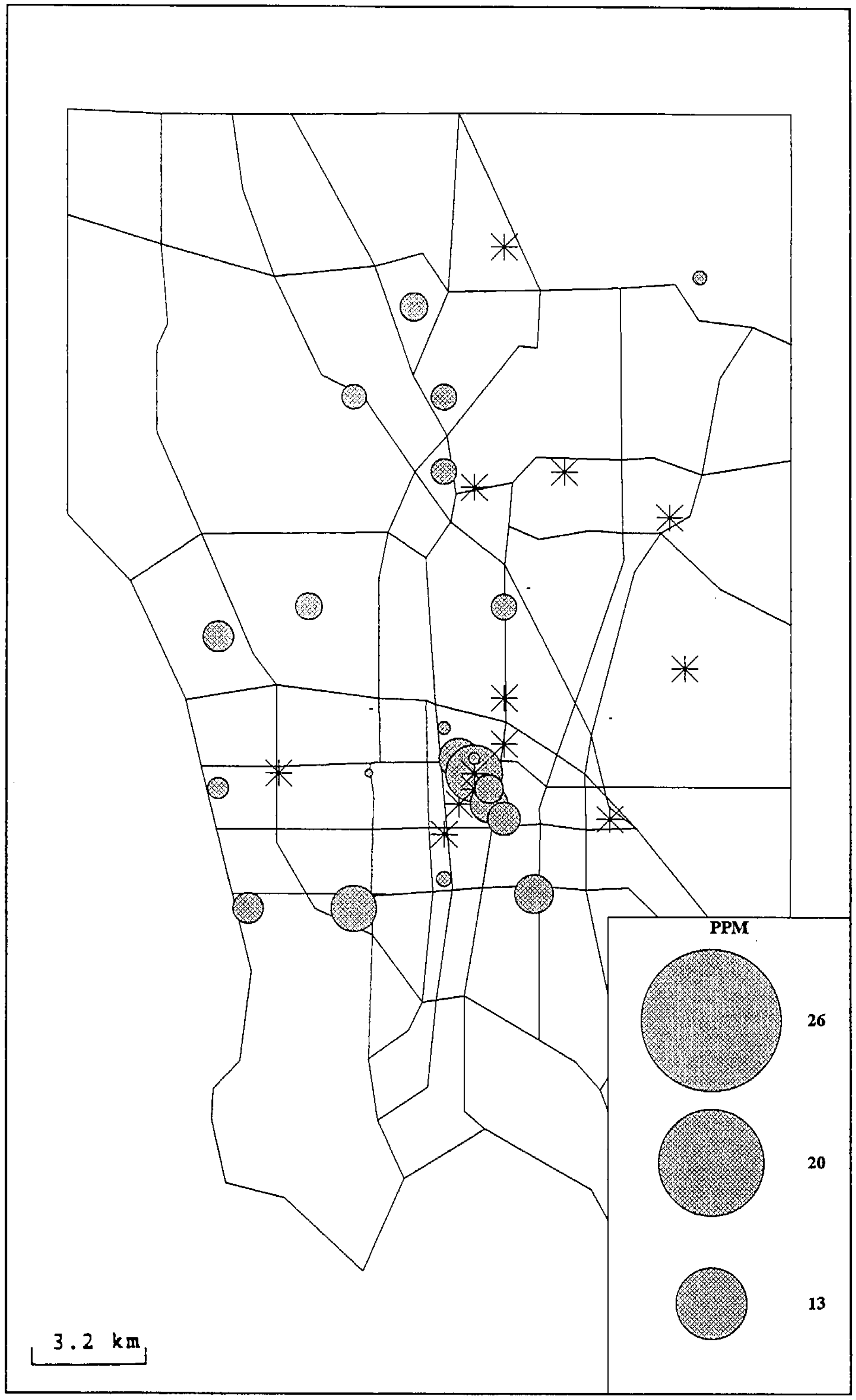
CO 12/19/1989 20:00

CO Concentration



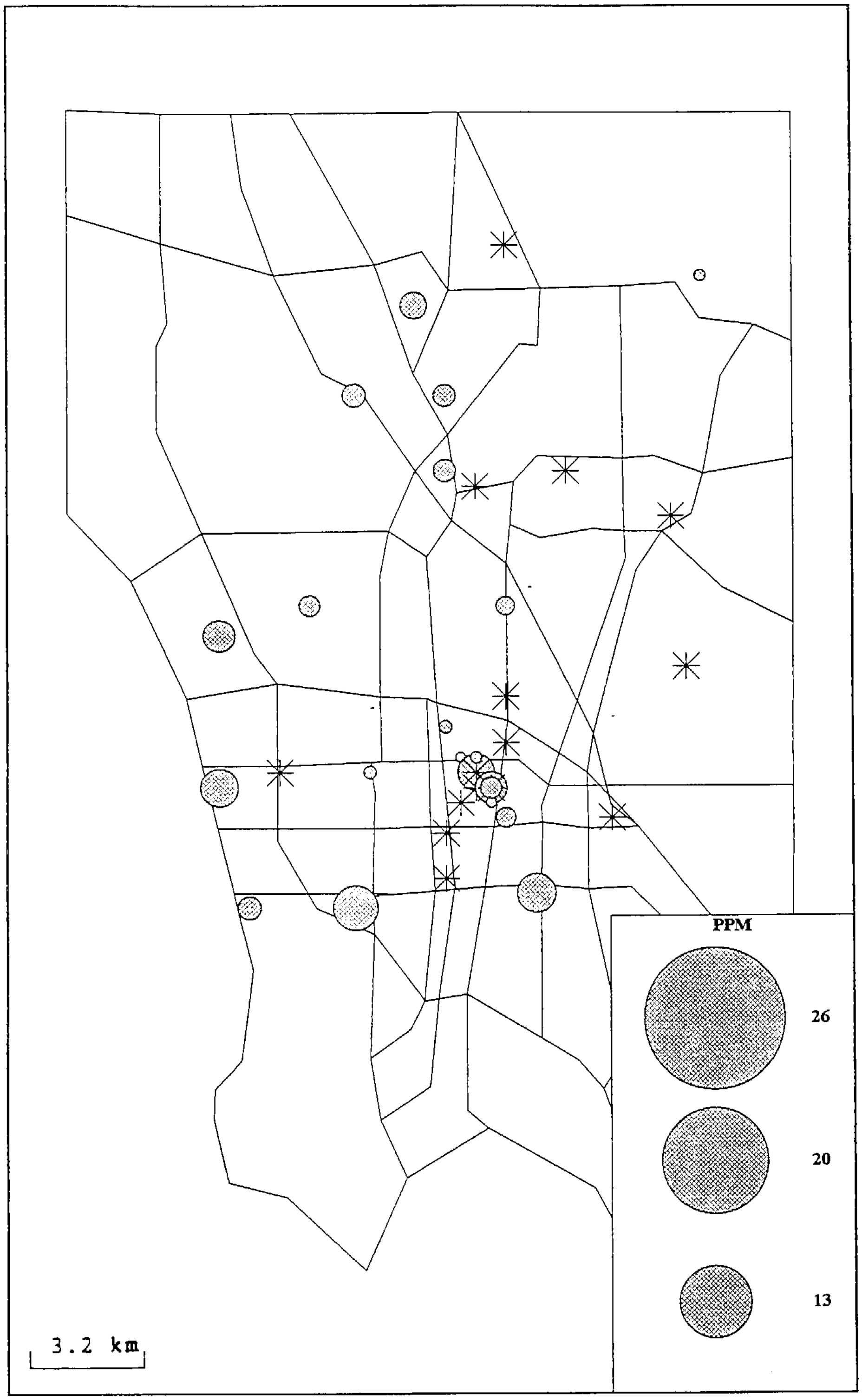
CO 12/19/1989 22:00

CO Concentration



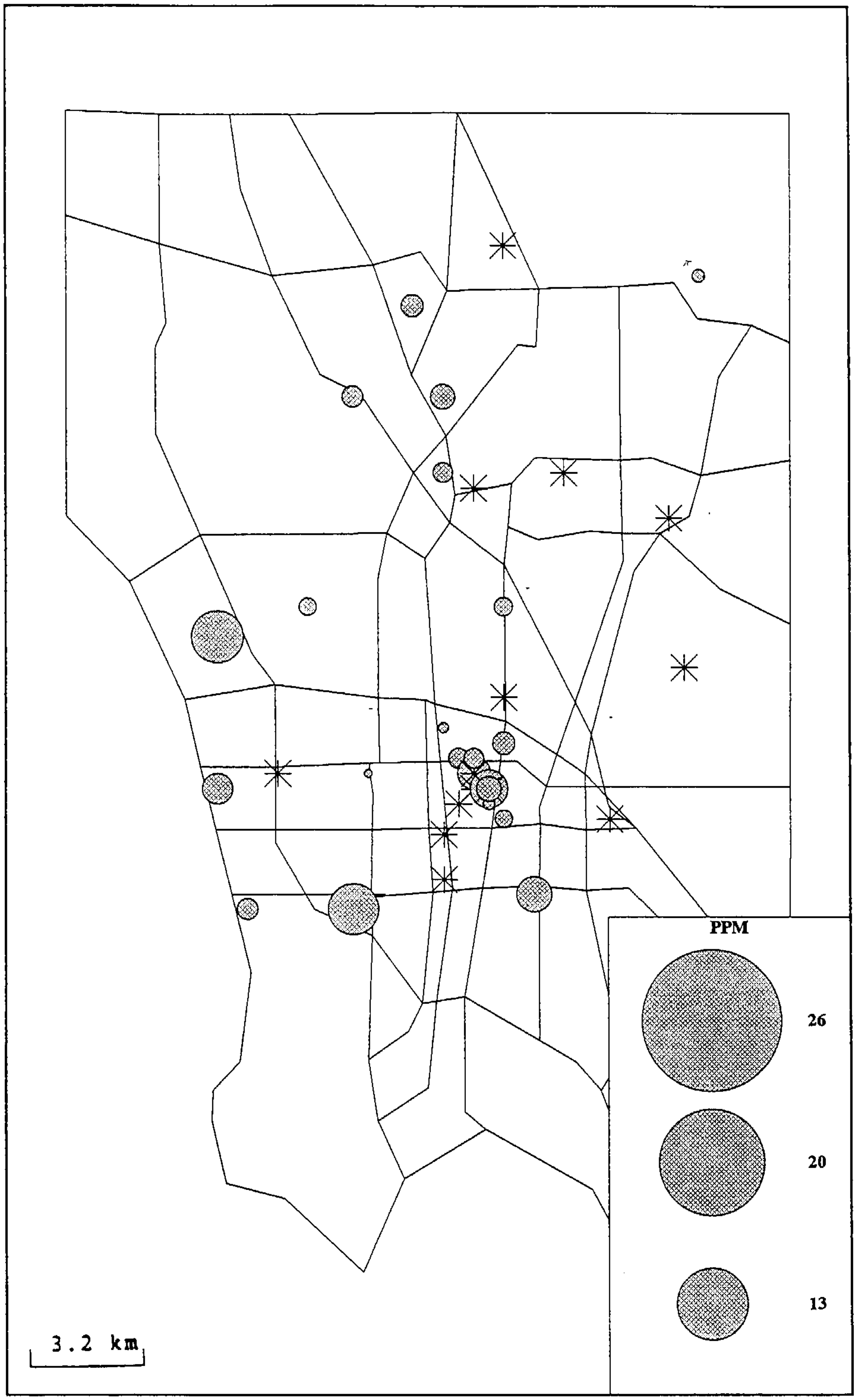
CO 12/20/1989 00:00

CO Concentration



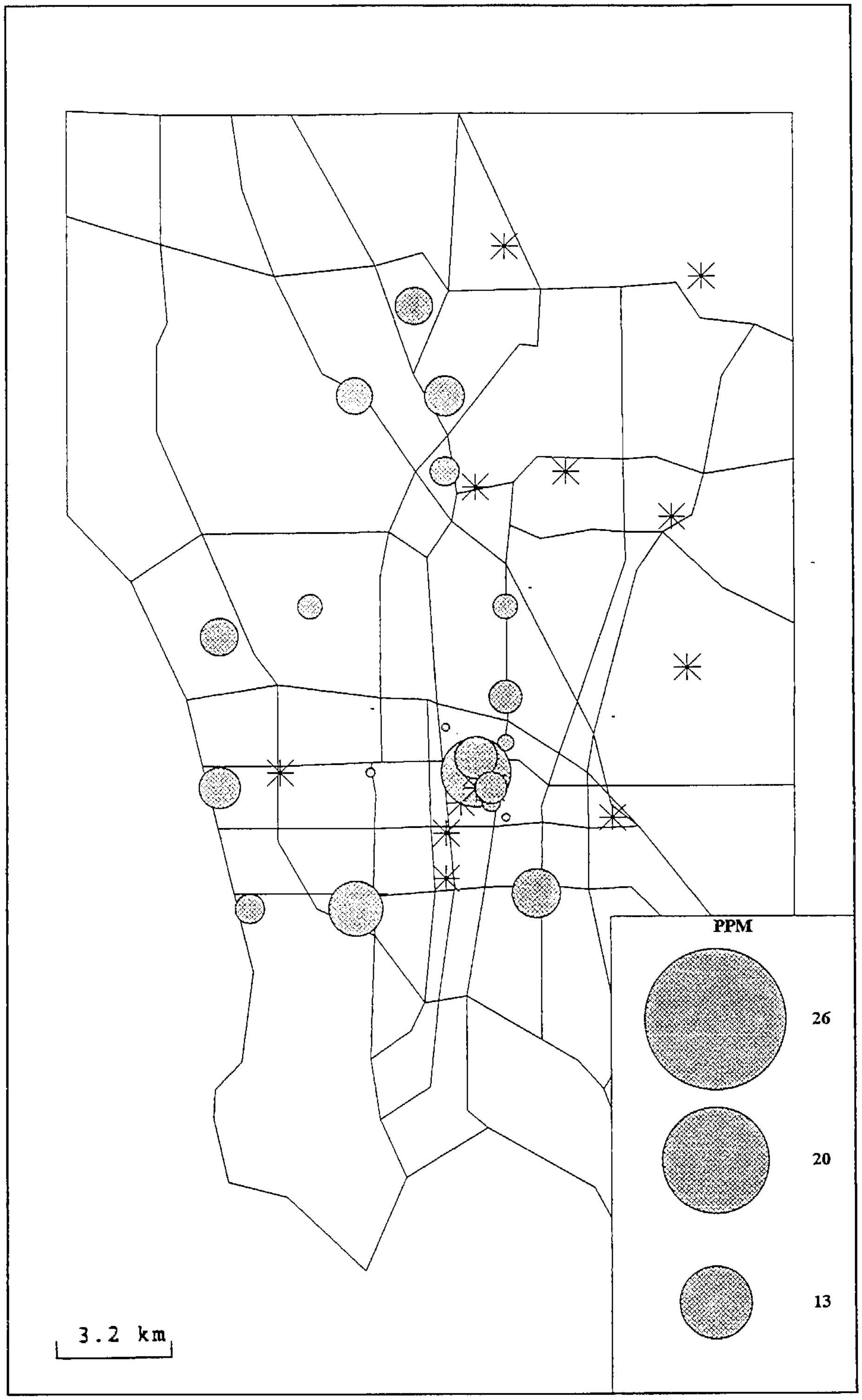
CO 12/20/1989 02:00

CO Concentration



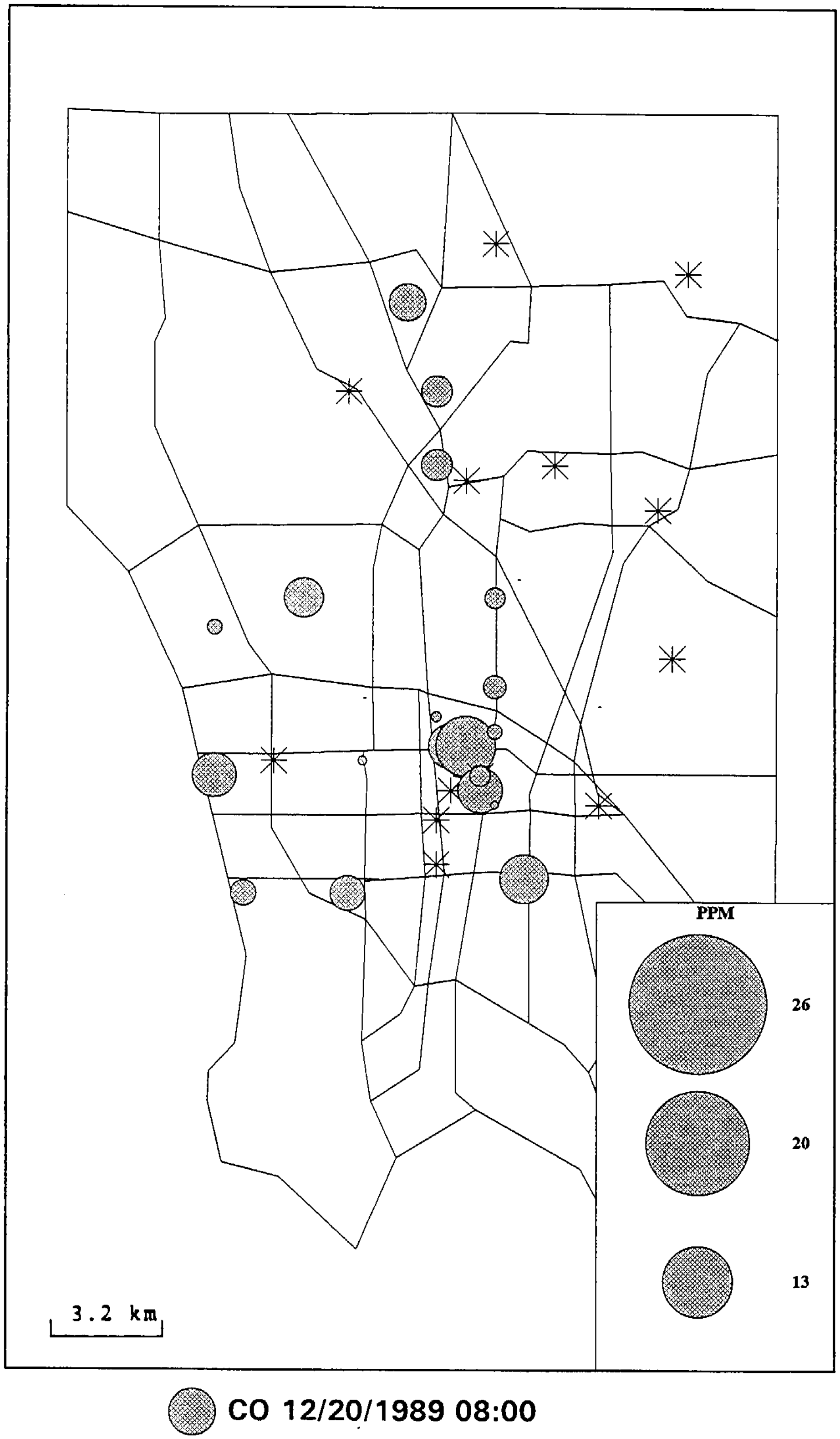
CO 12/20/1989 04:00

CO Concentration



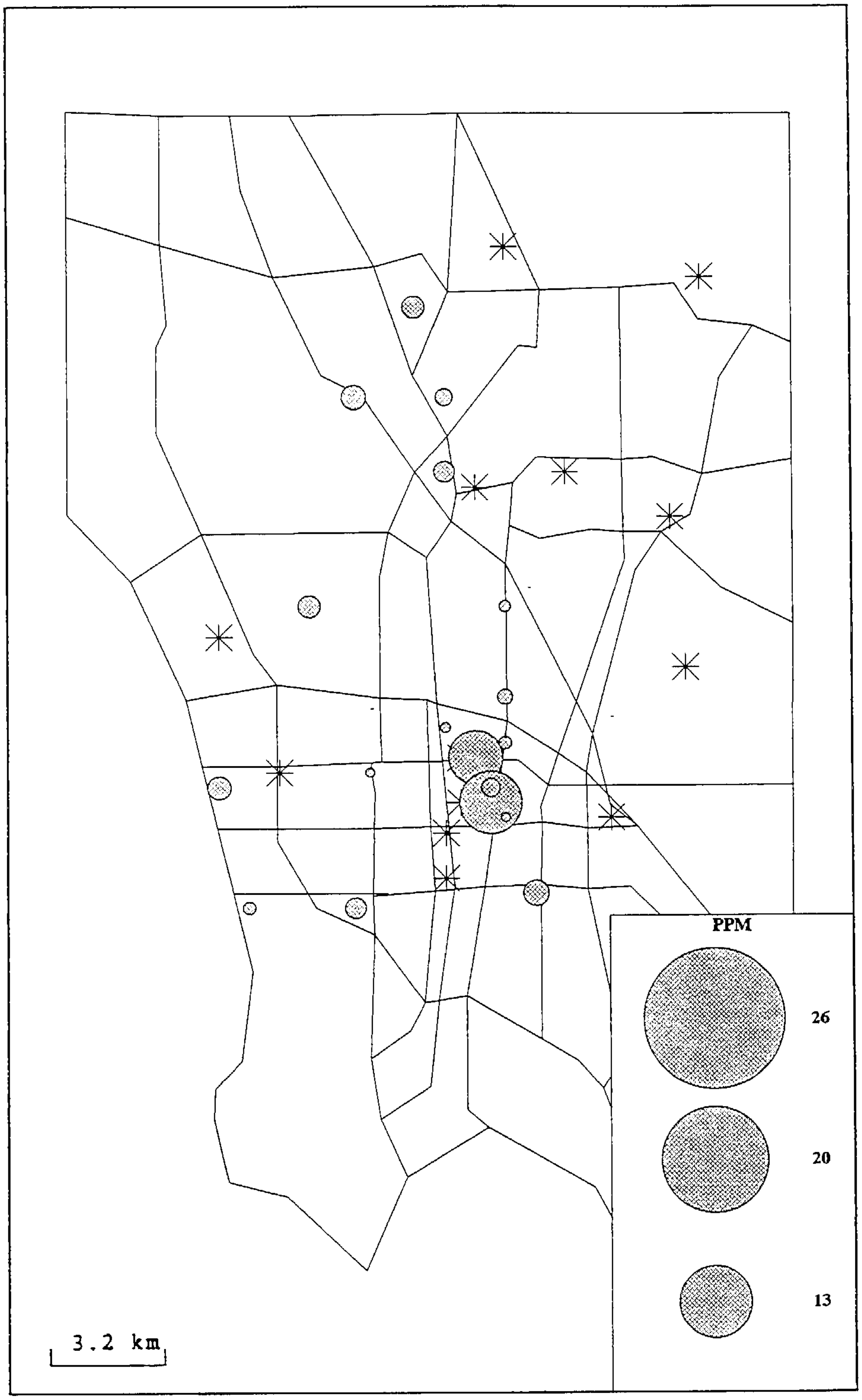
CO 12/20/1989 06:00

CO Concentration



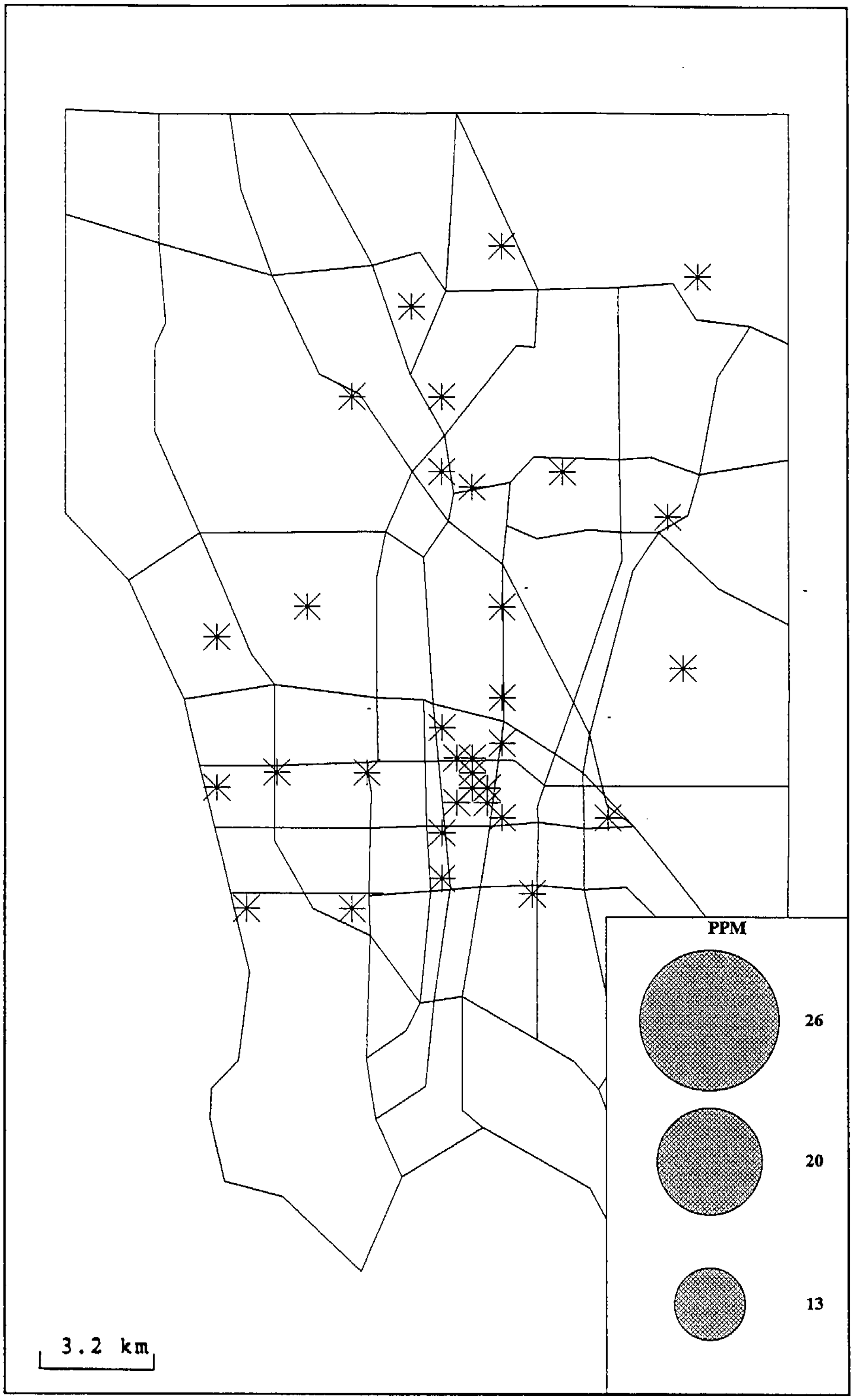
CO 12/20/1989 08:00

CO Concentration



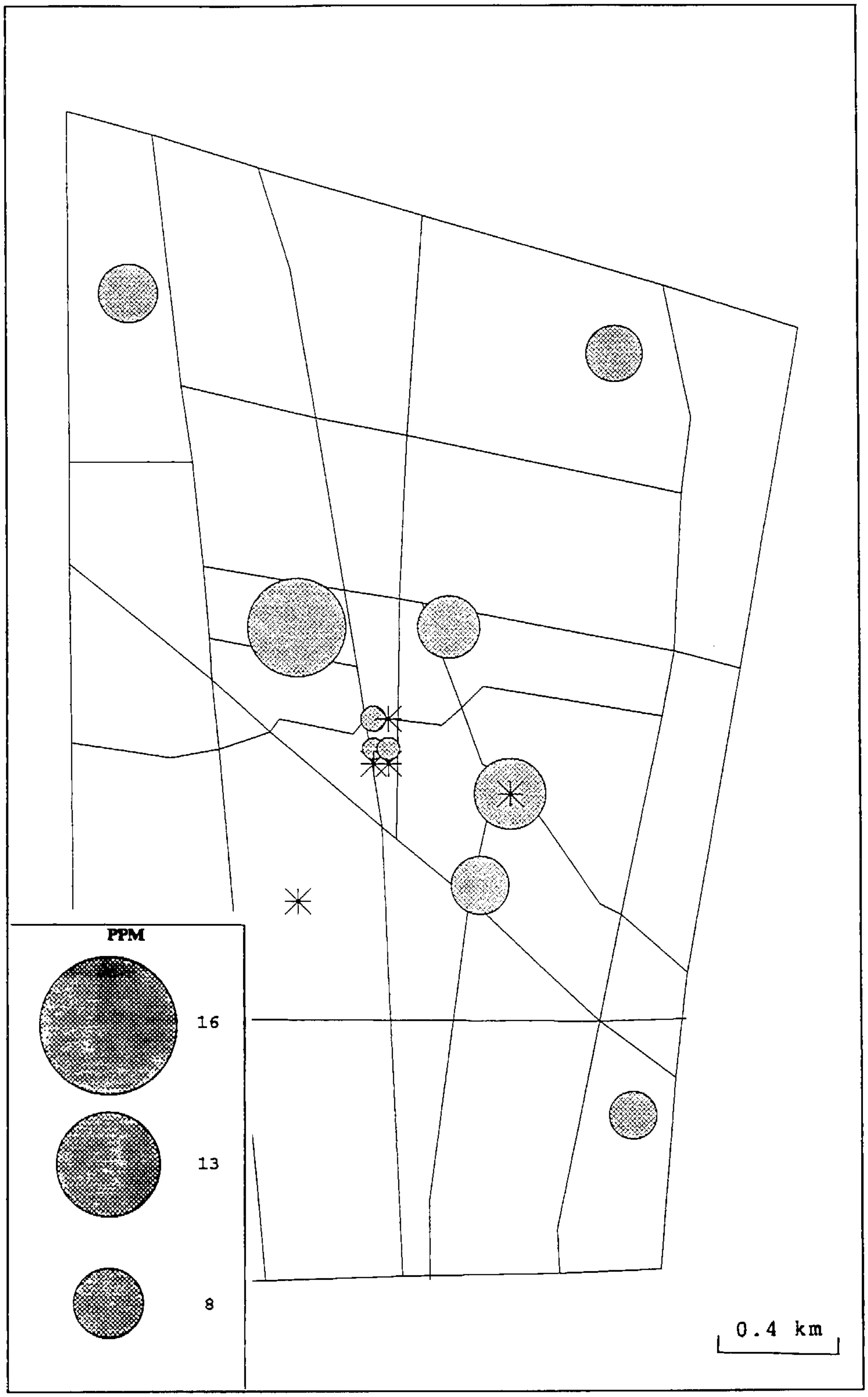
CO 12/20/1989 10:00

CO Concentration



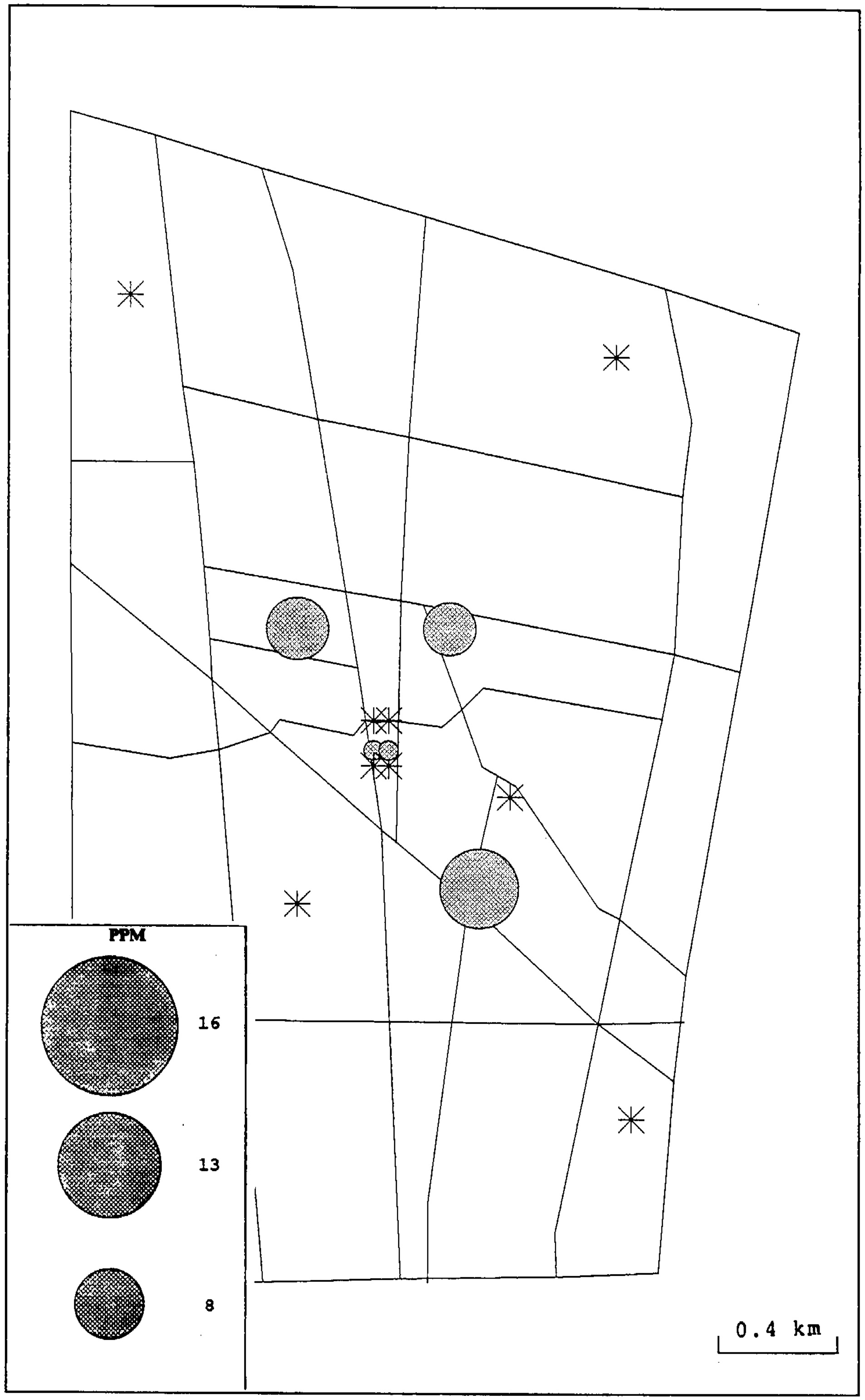
CO 12/20/1989 12:00

Lynwood CO Concentration



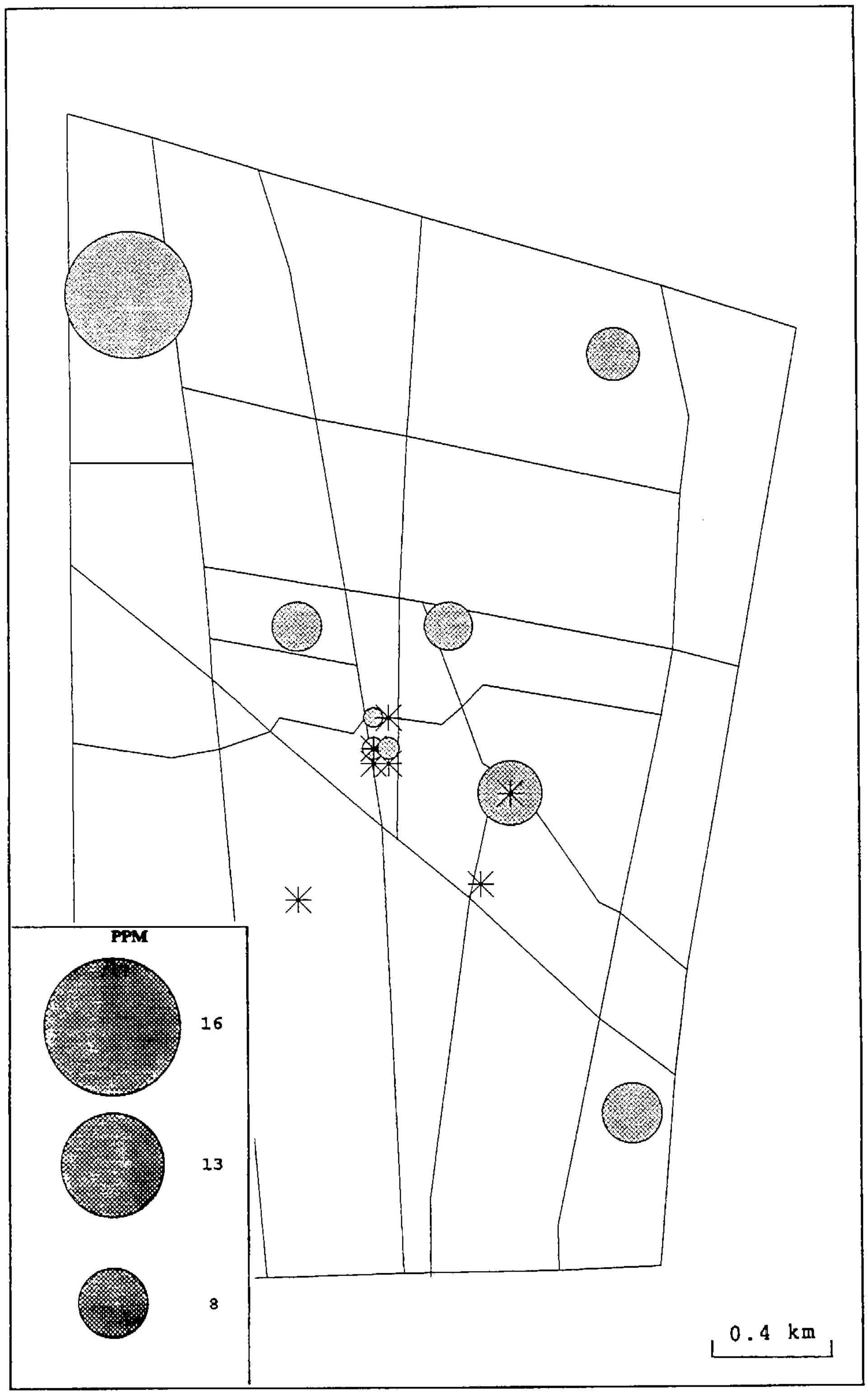
CO 12/19/1989 12:00

Lynwood CO Concentration



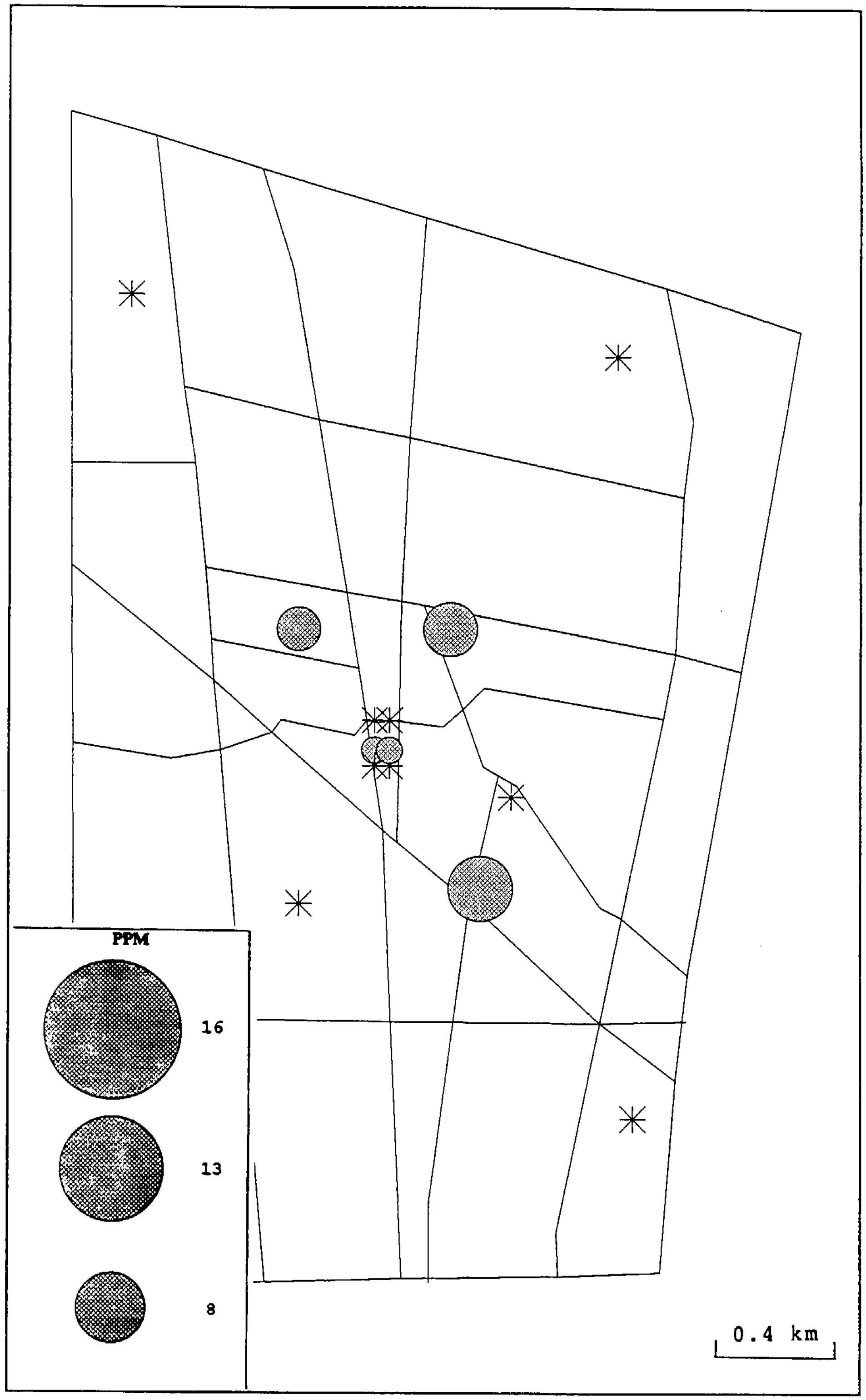
CO 12/19/1989 13:00

Lynwood CO Concentration



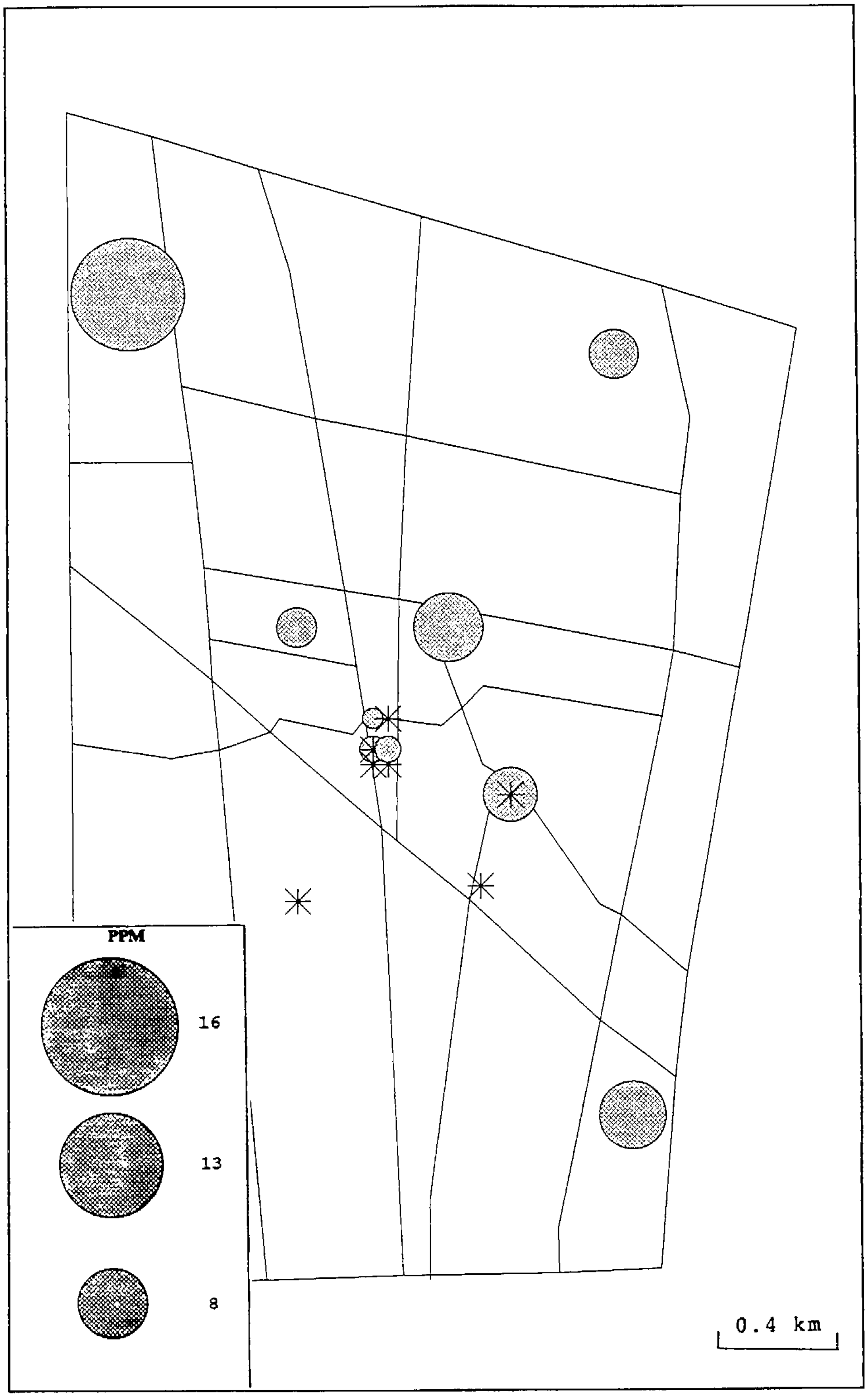
CO 12/19/1989 14:00

Lynwood CO Concentration



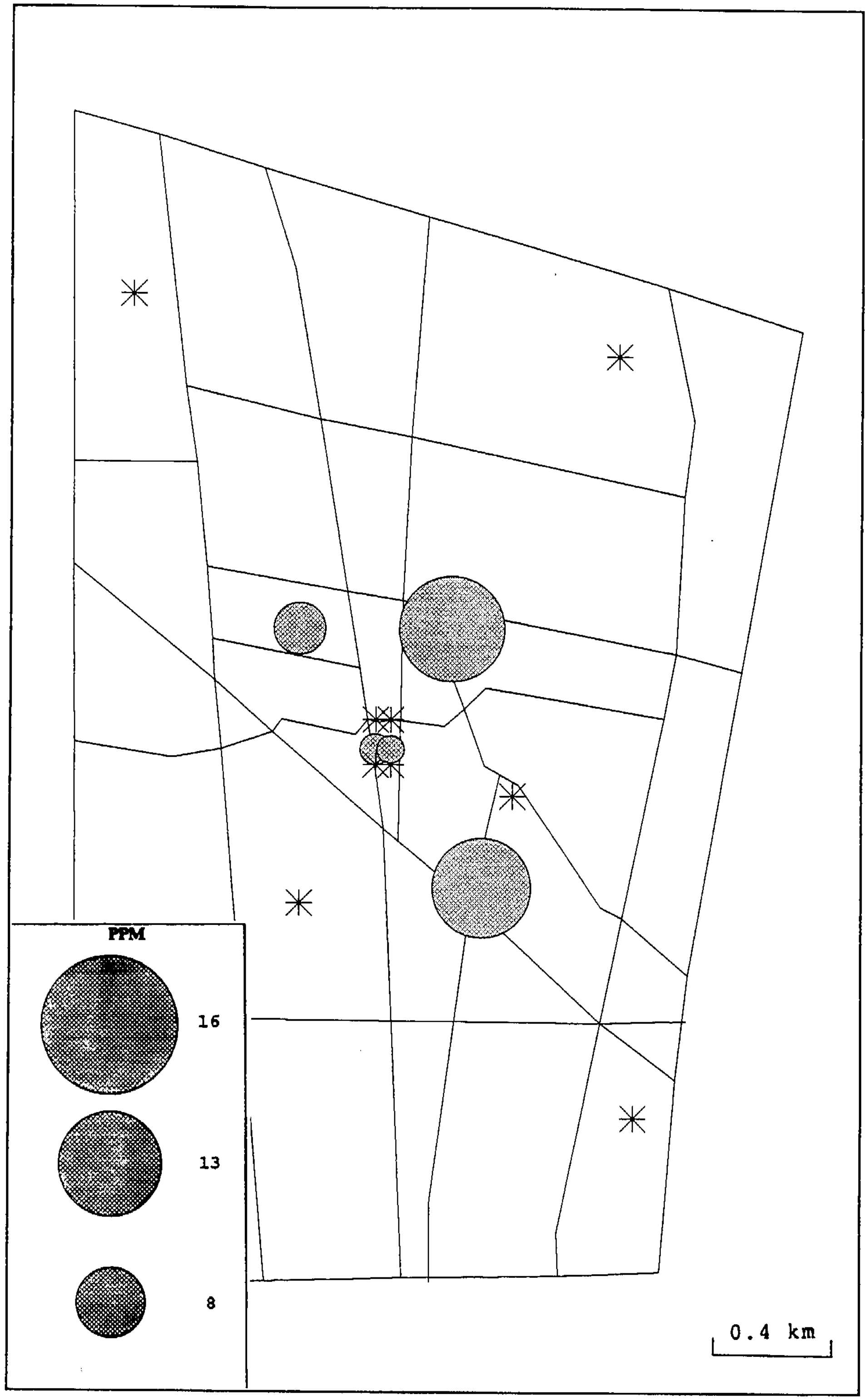
CO 12/19/1989 15:00

Lynwood Monitoring Stations



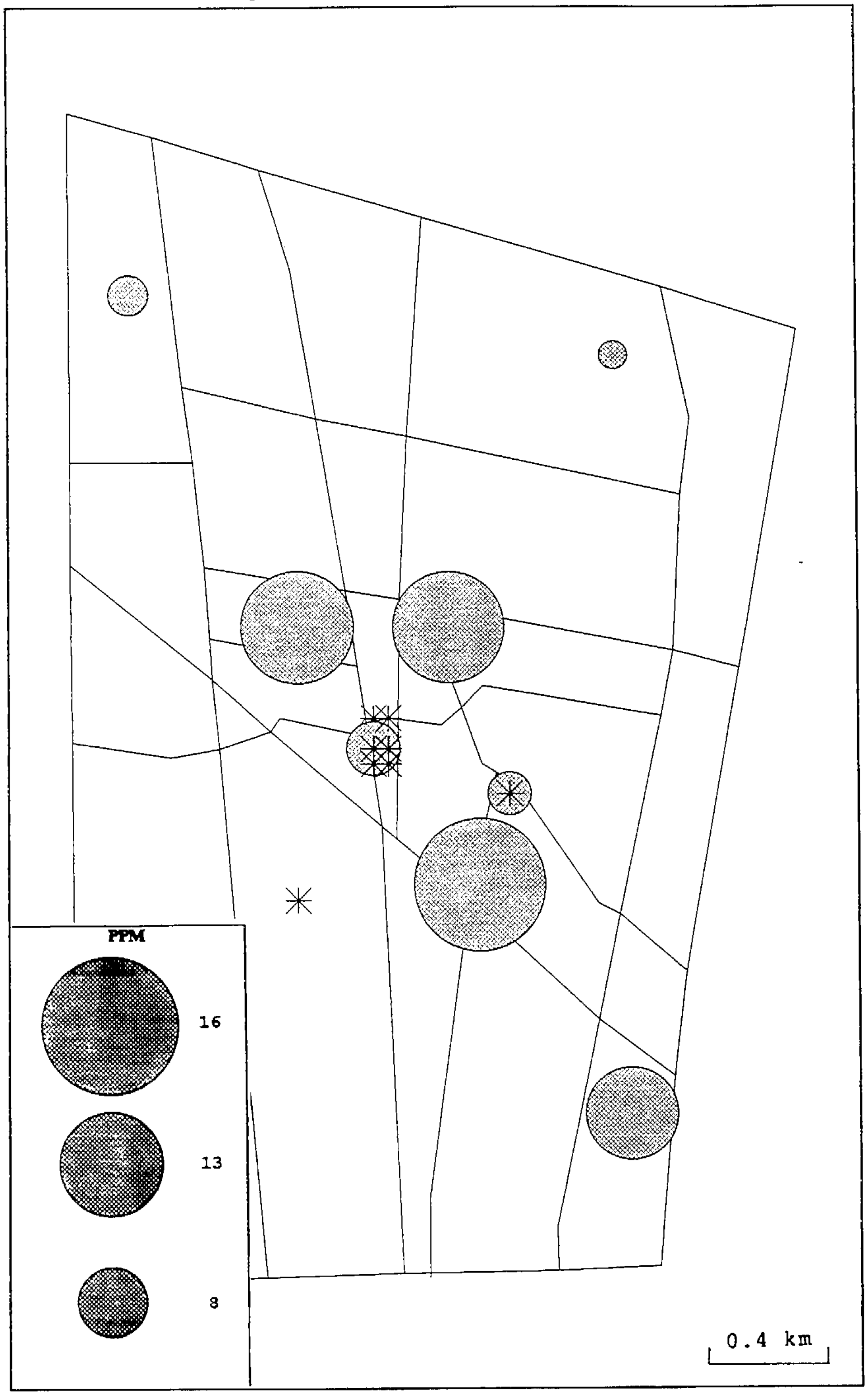
CO 12/19/1989 16:00

Lynwood CO Concentration



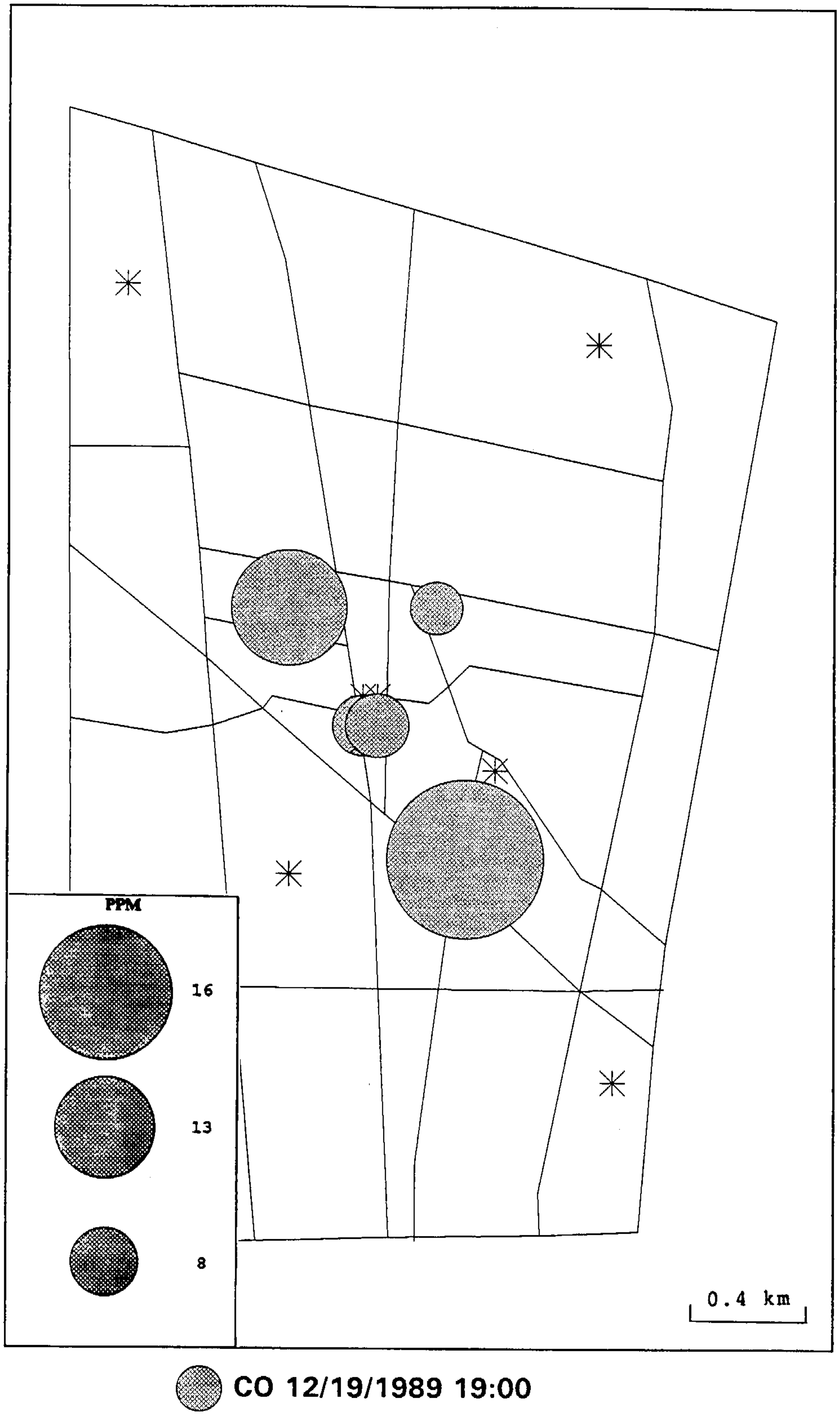
CO 12/19/1989 17:00

Lynwood Monitoring Stations

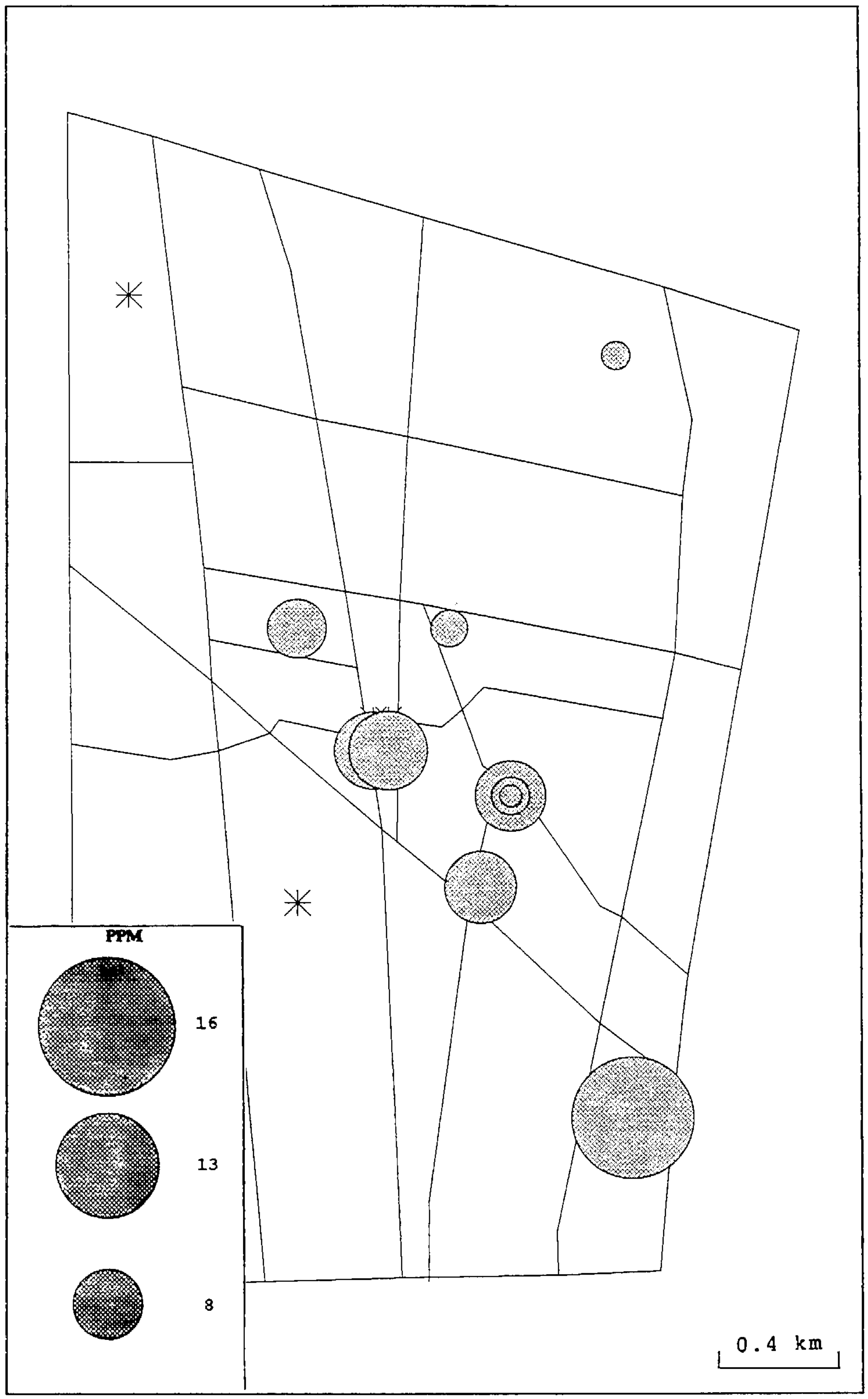


CO 12/19/1989 18:00

Lynwood CO Concentration

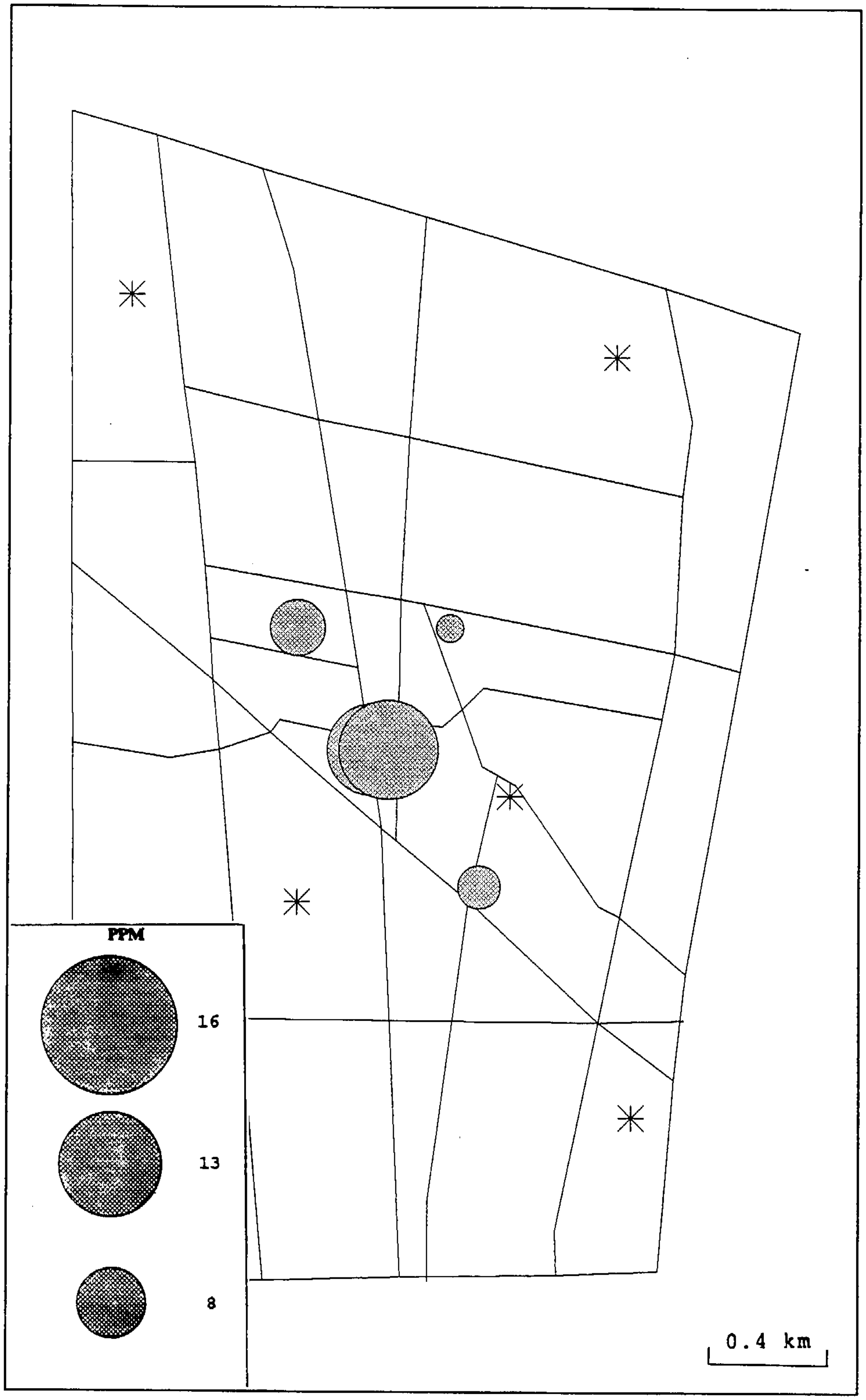


Lynwood Monitoring Stations



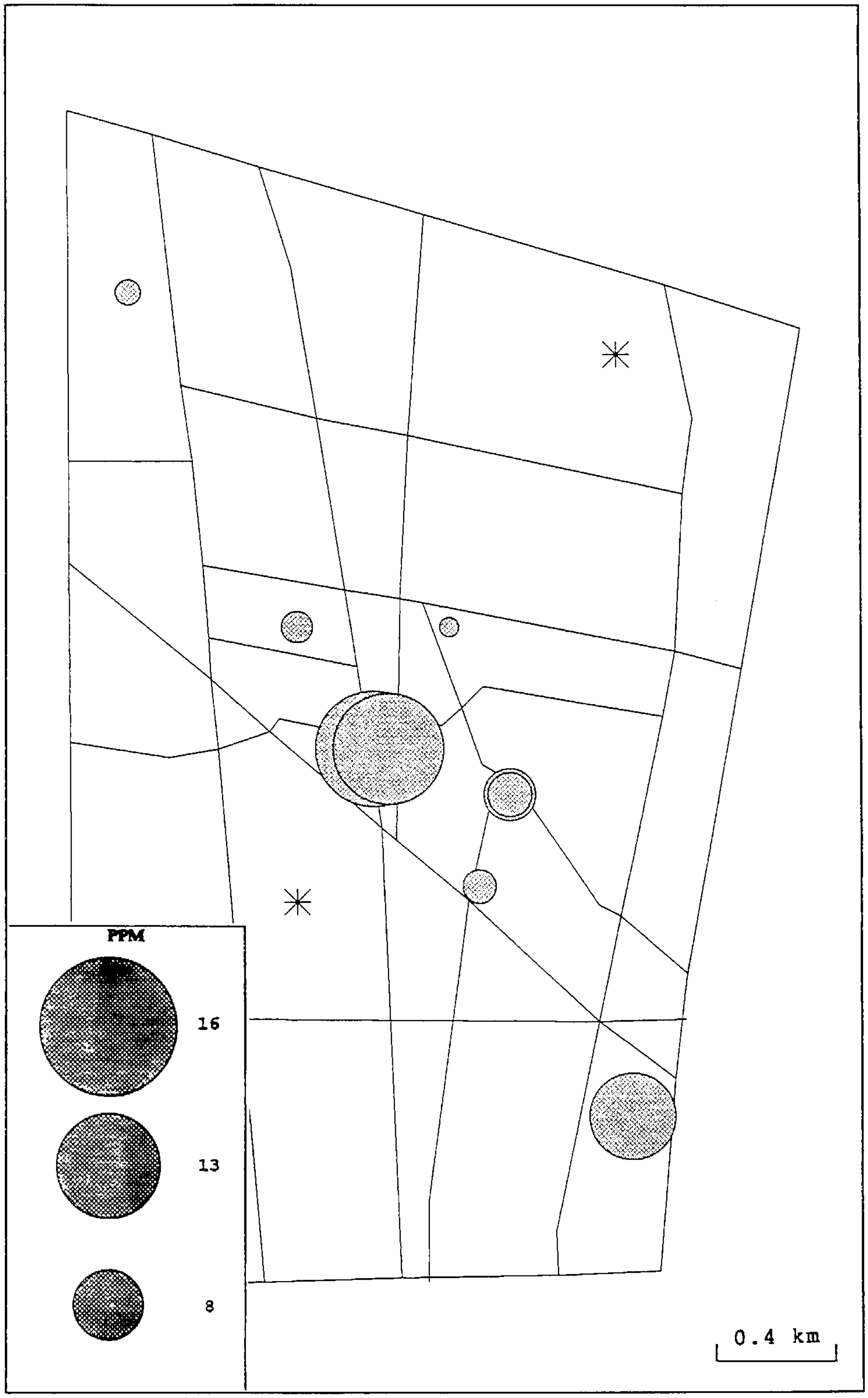
CO 12/19/1989 20:00

Lynwood CO Concentration

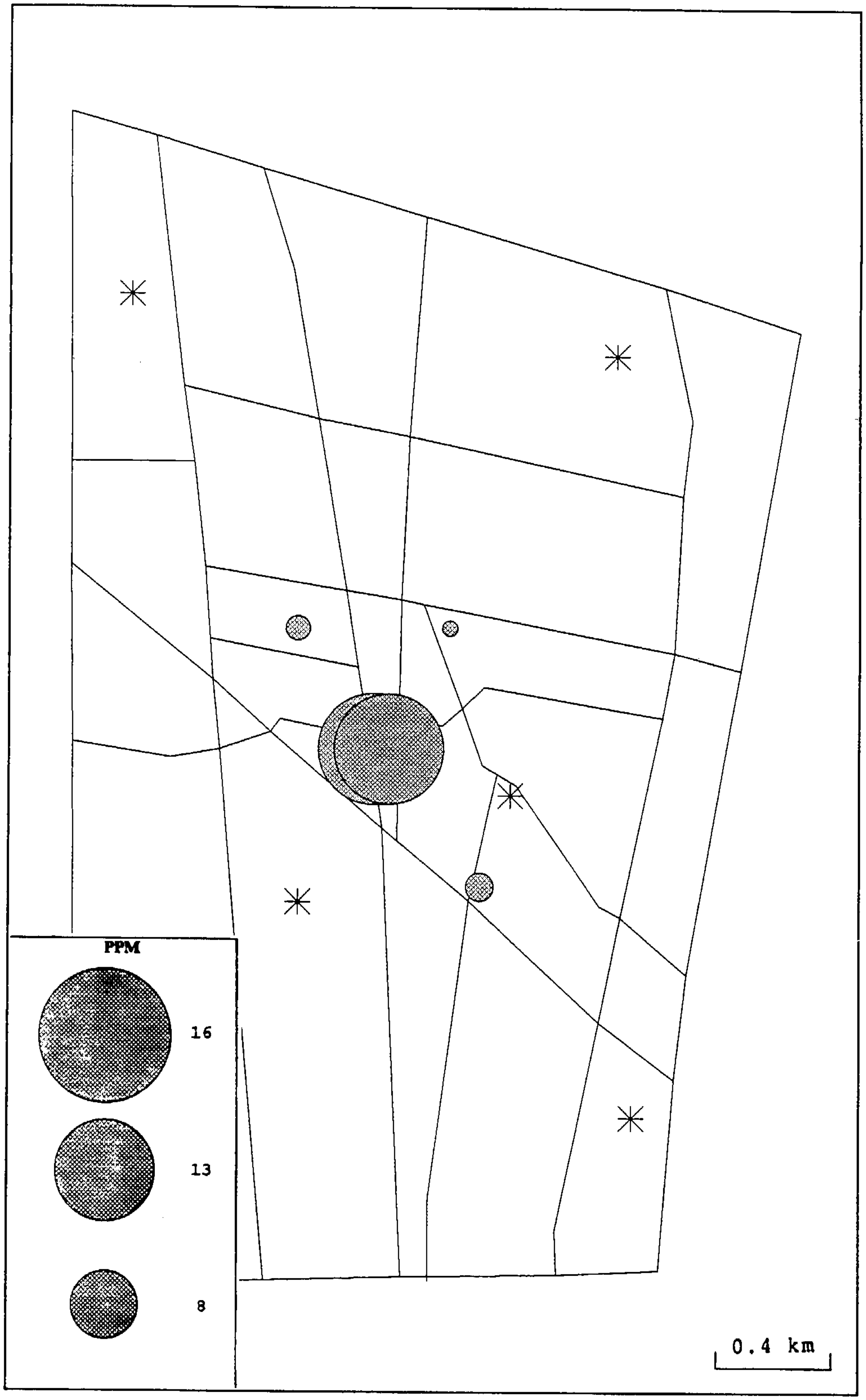


CO 12/19/1989 21:00

Lynwood CO Concentration

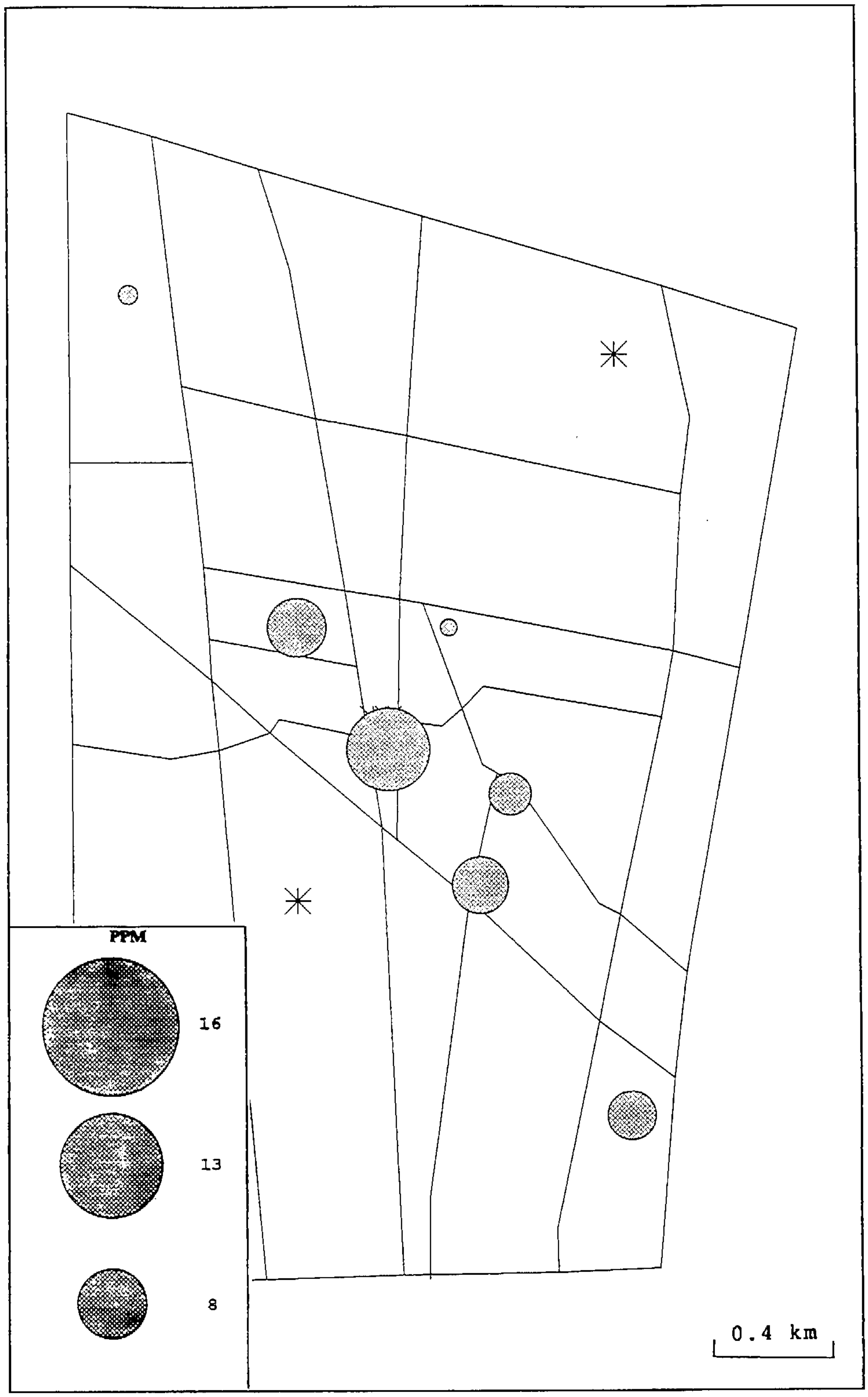


CO 12/19/1989 22:00



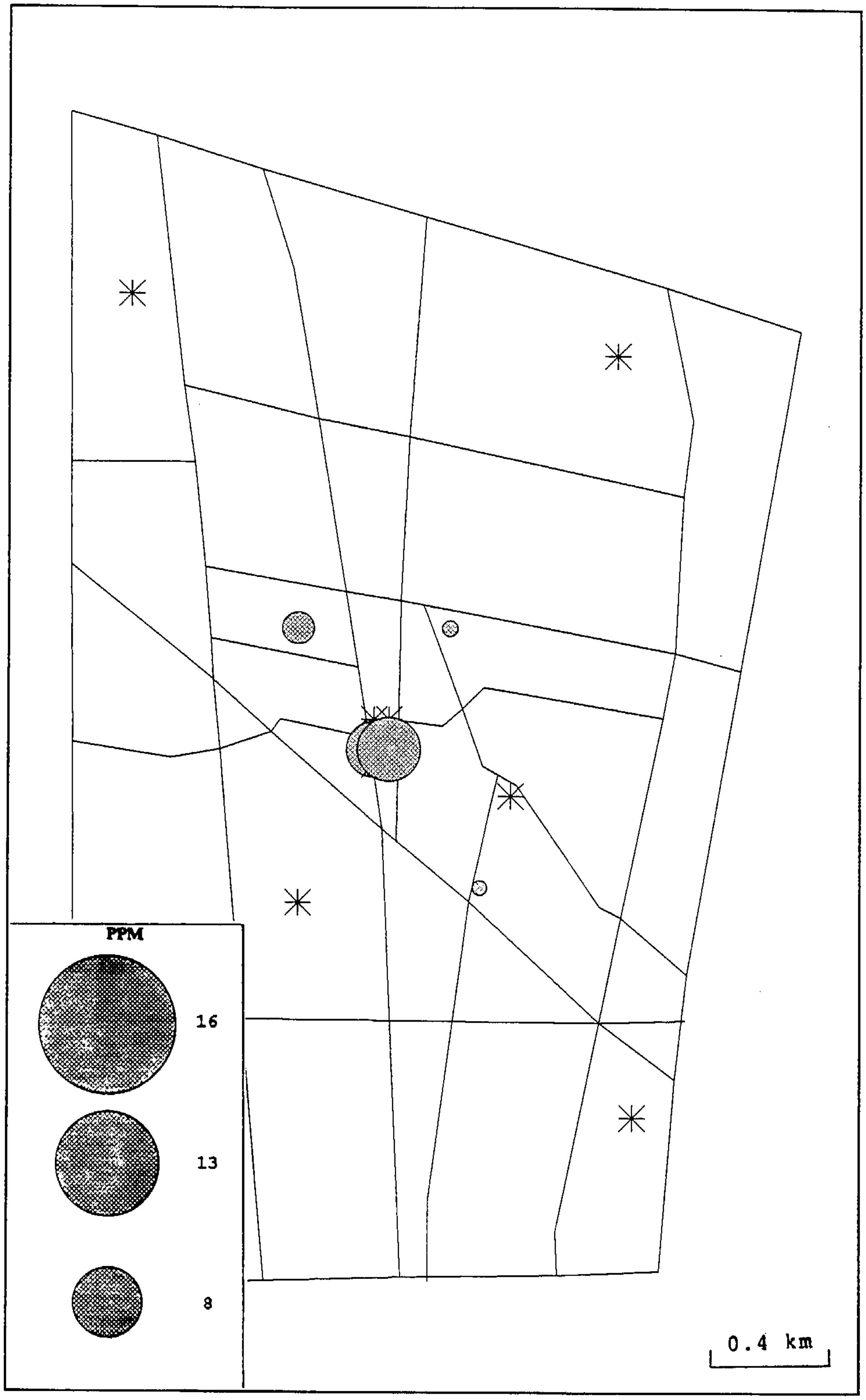
CO 12/19/1989 23:00

Lynwood Monitoring Stations



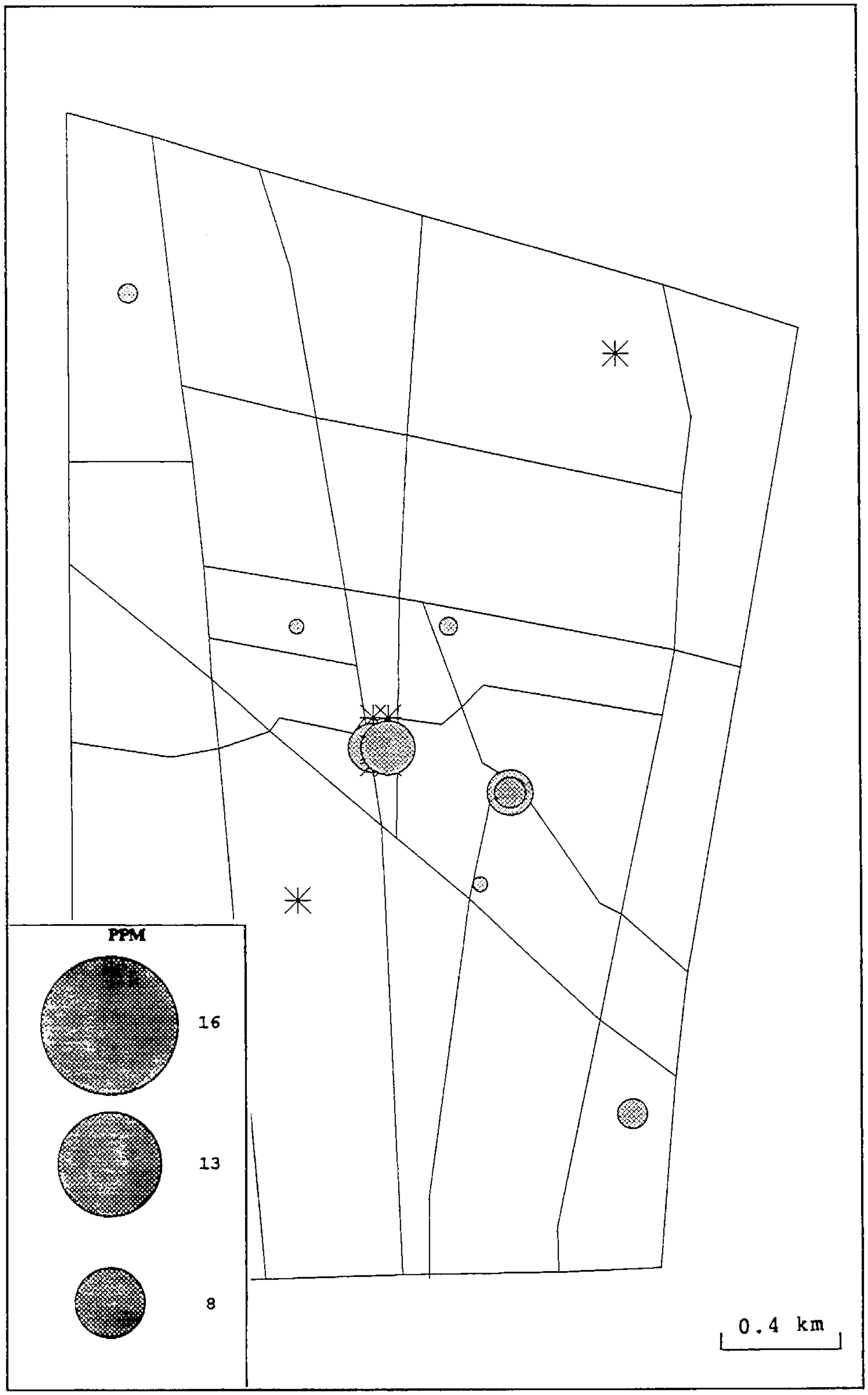
CO 12/20/1989 00:00

Lynwood CO Concentration

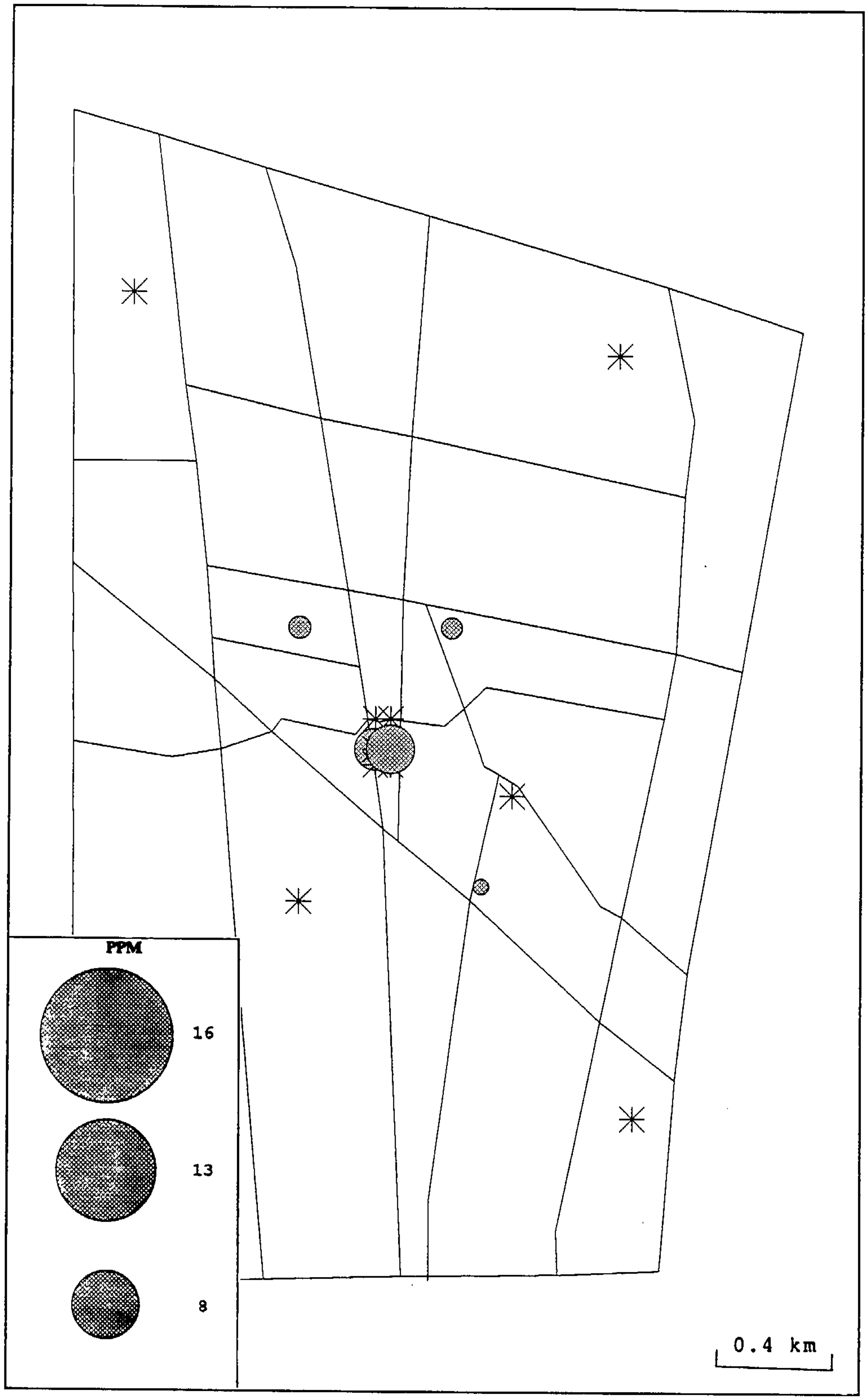


CO 12/20/1989 01:00

Lynwood Monitoring Stations

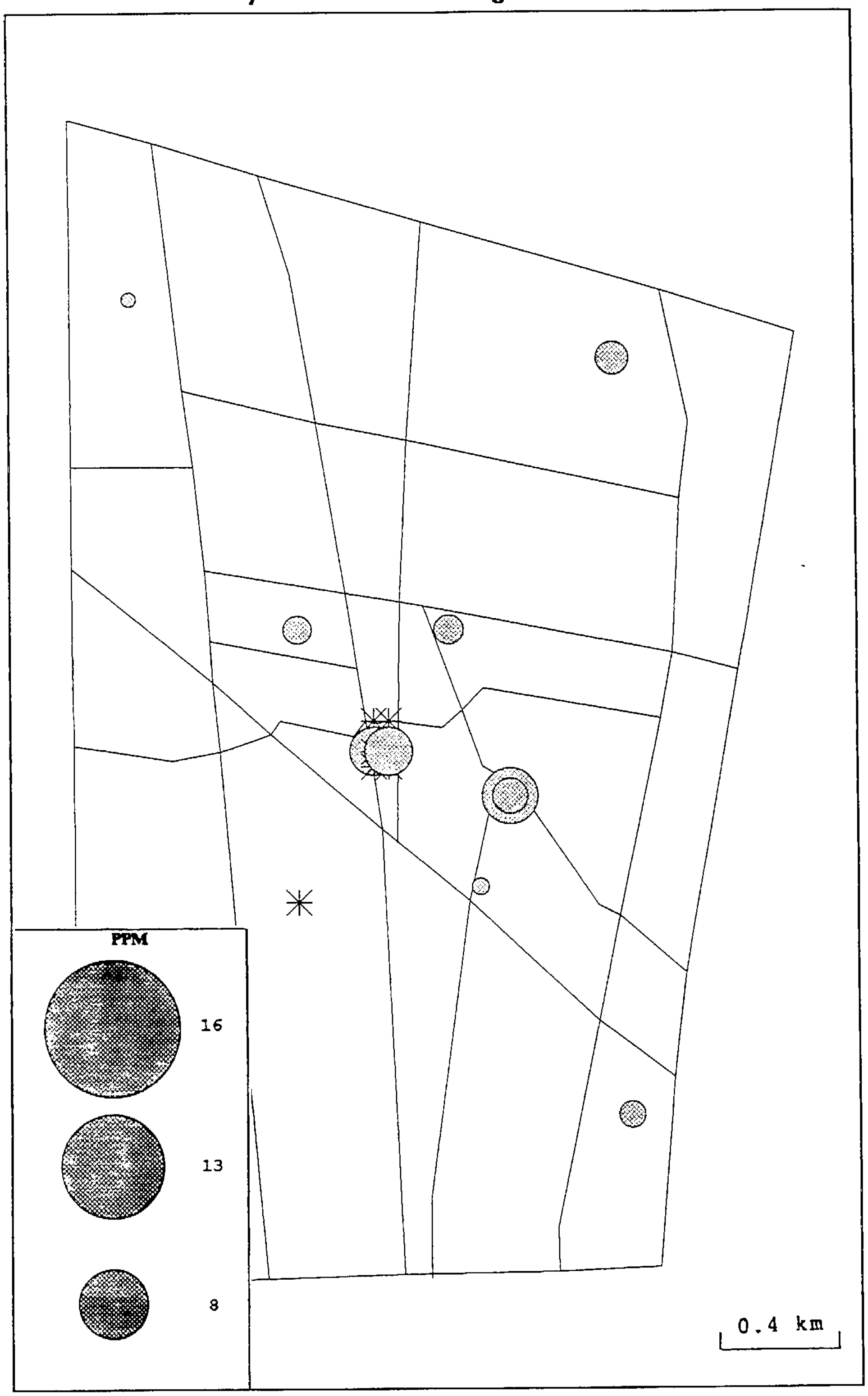


CO 12/20/1989 02:00



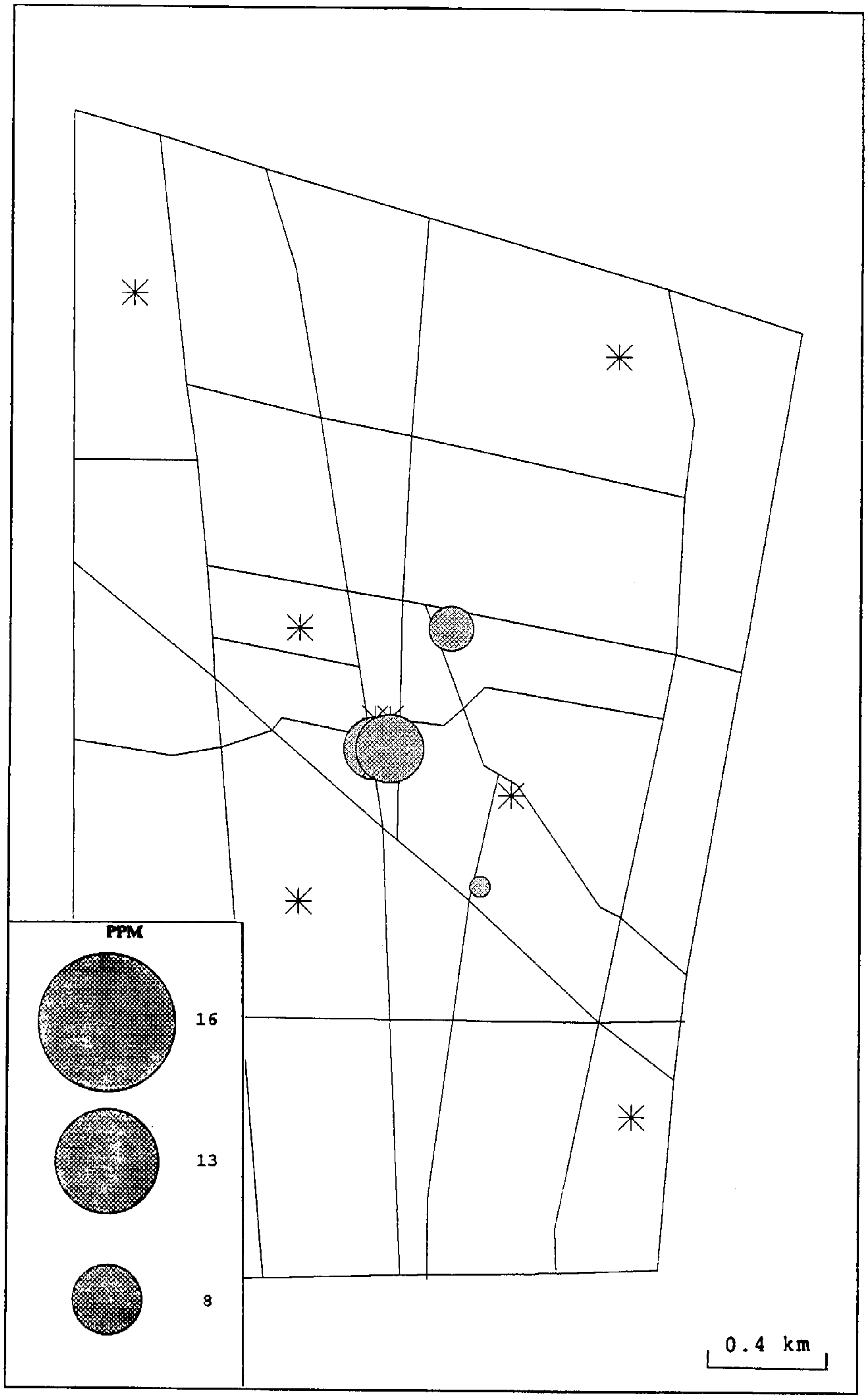
CO 12/20/1989 03:00

Lynwood Monitoring Stations



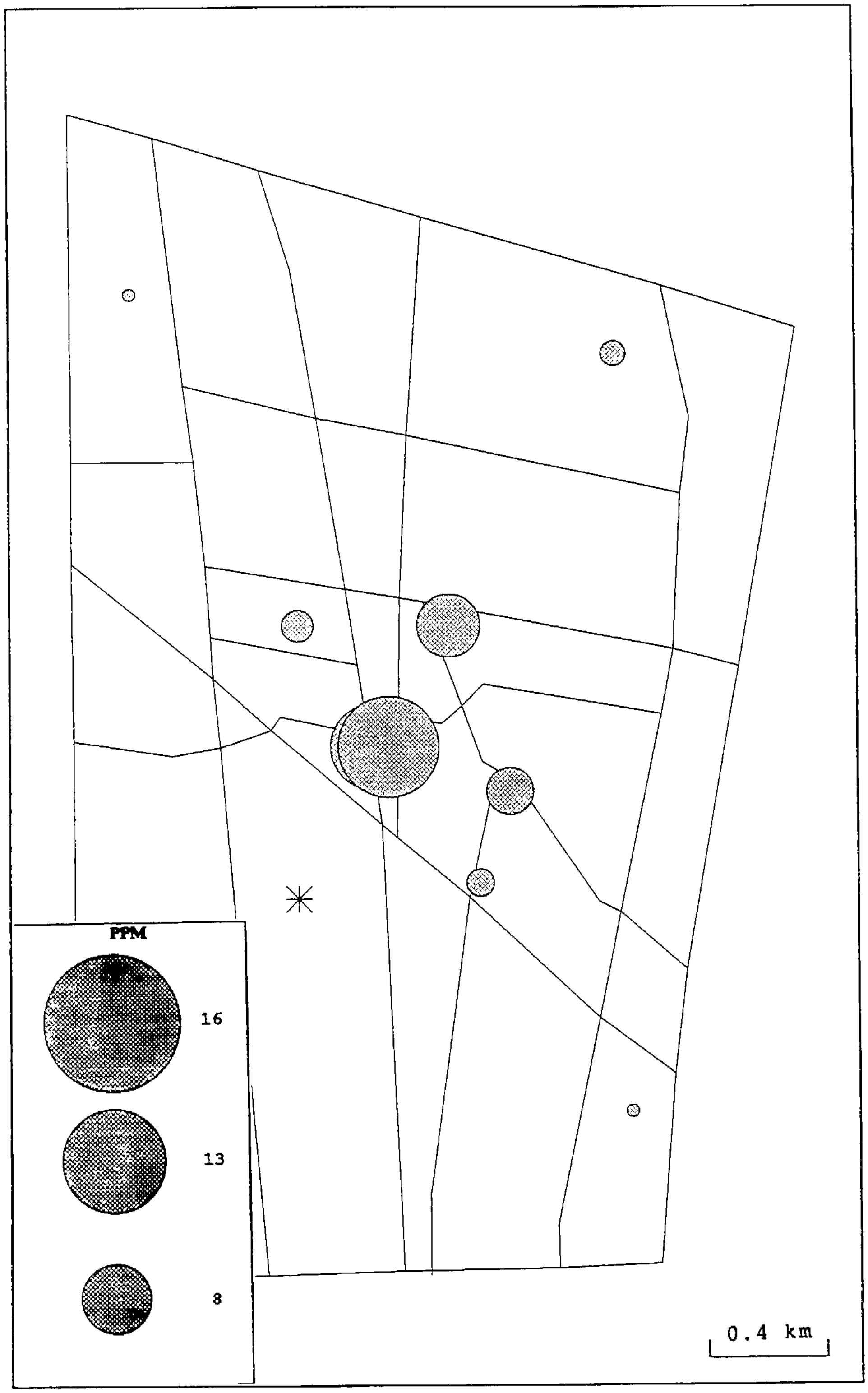
CO 12/20/1989 04:00

Lynwood CO Concentration

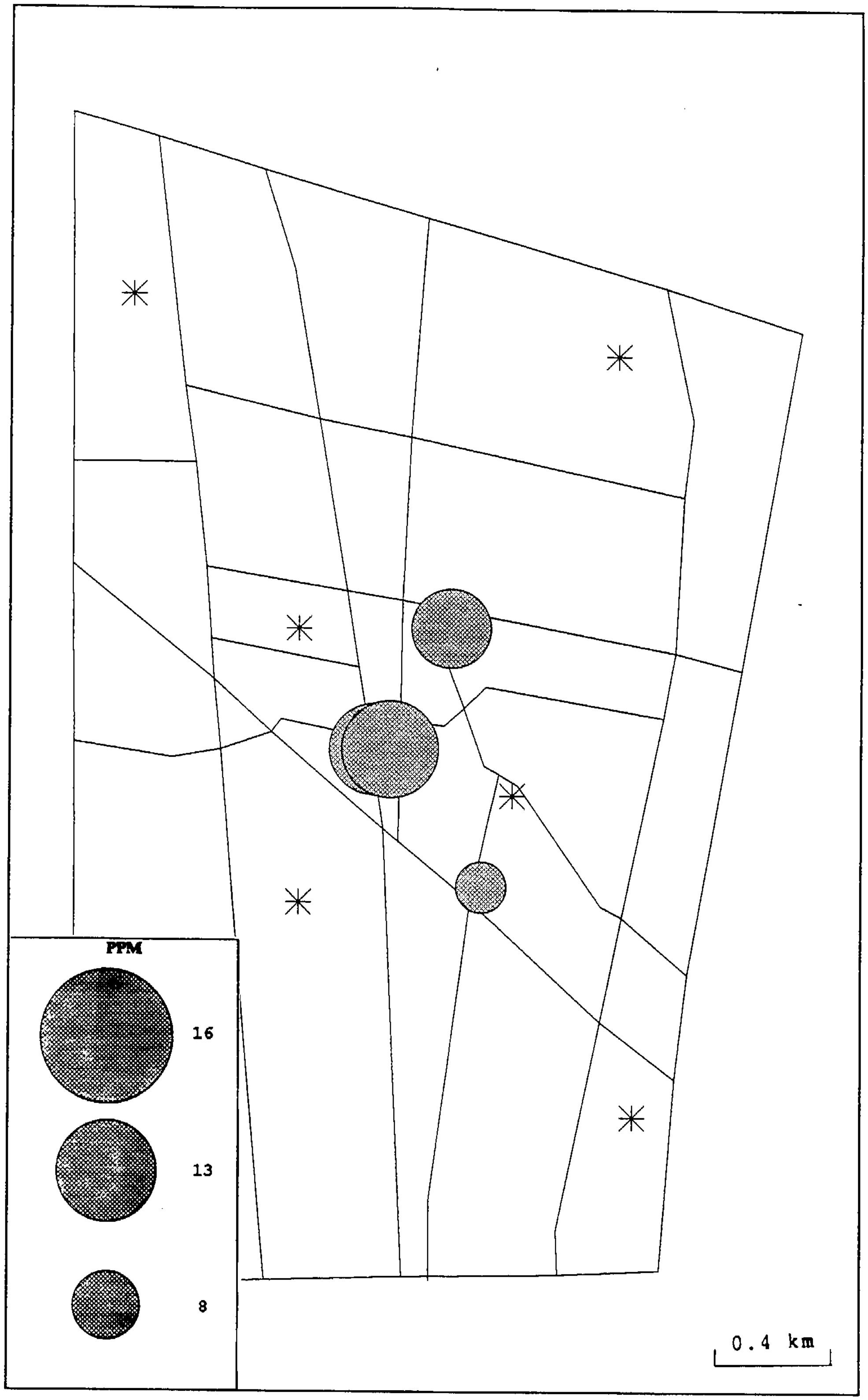


CO 12/20/1989 05:00

Lynwood Monitoring Stations

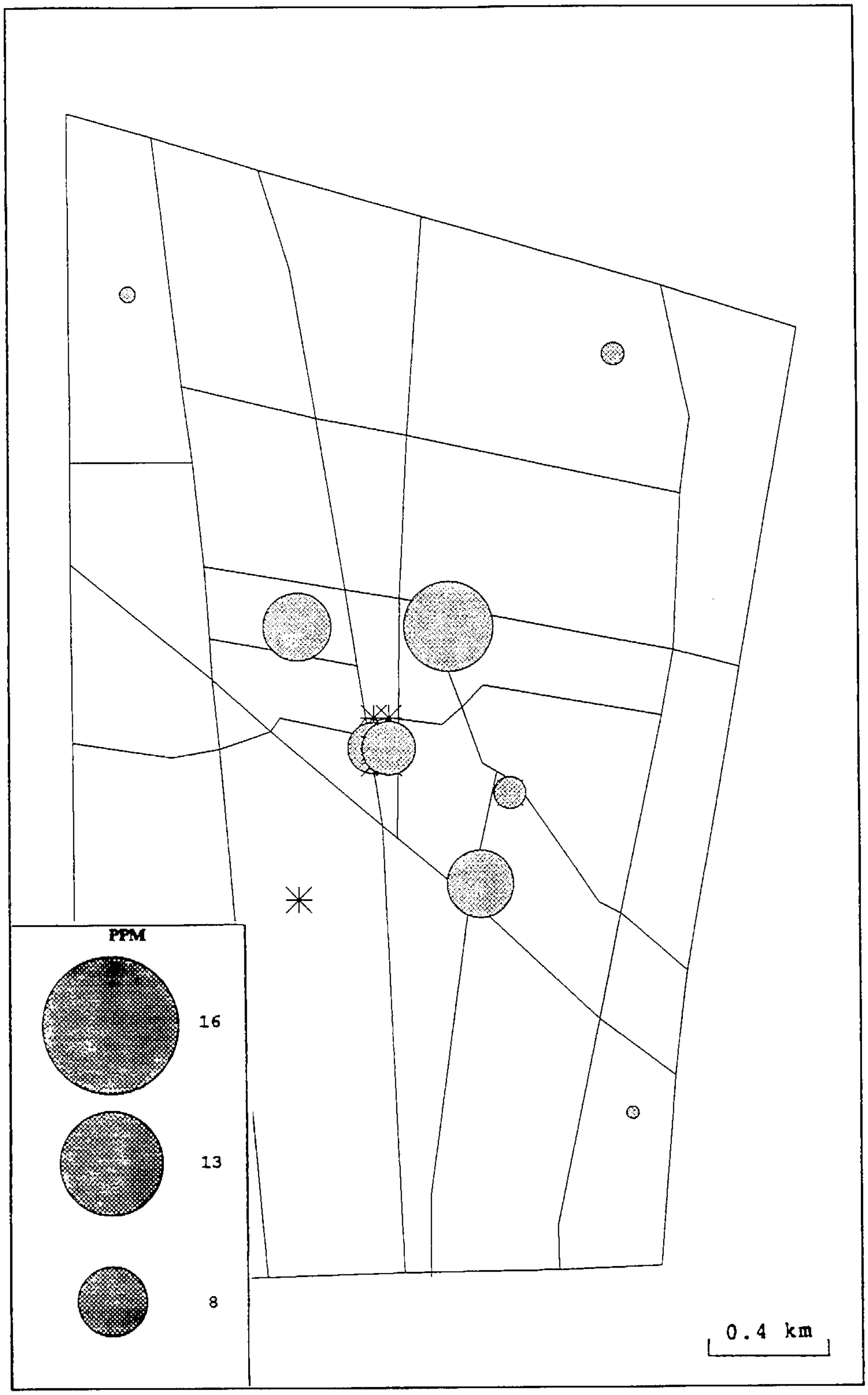


CO 12/20/1989 06:00

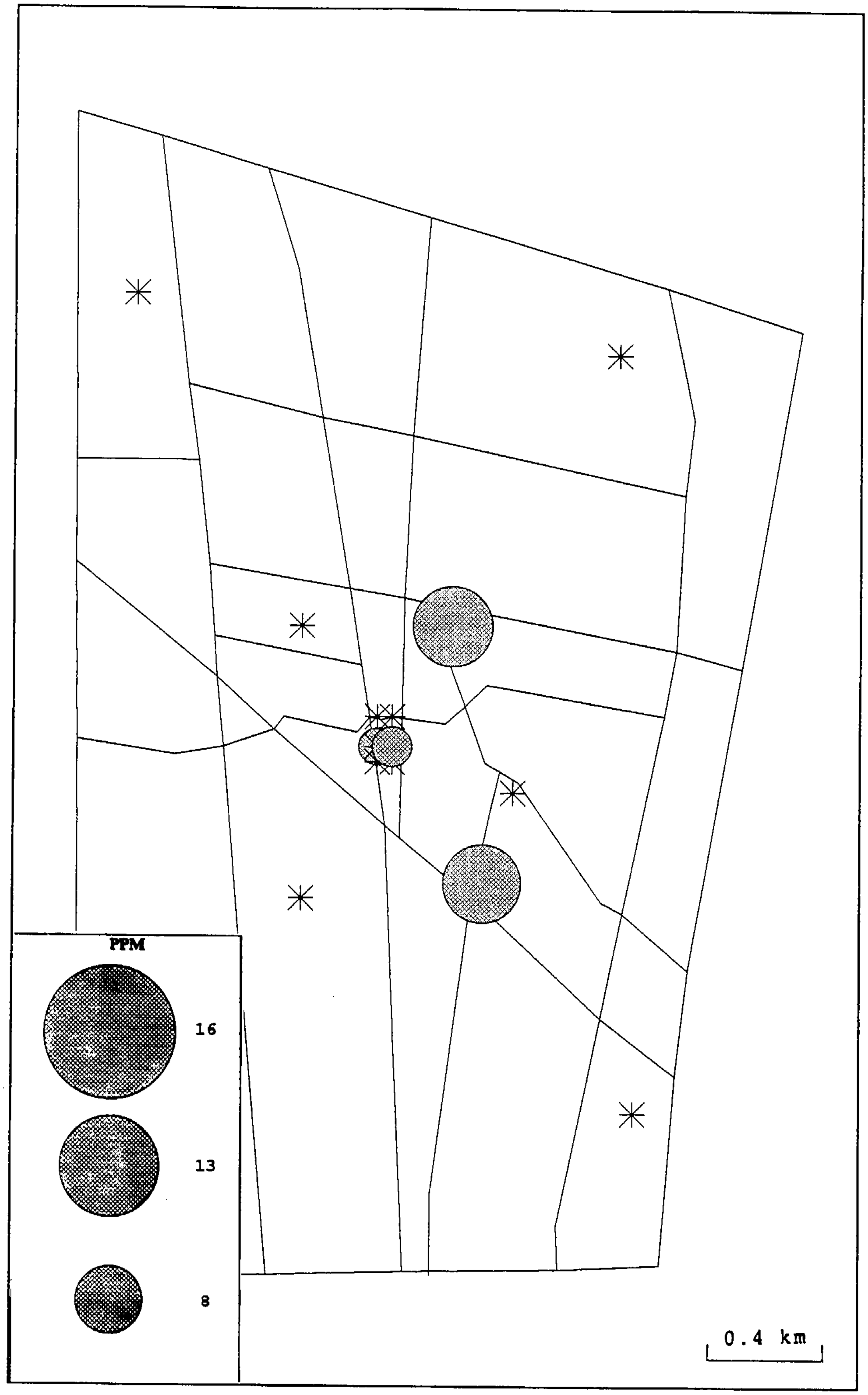


CO 12/20/1989 07:00

Lynwood Monitoring Stations

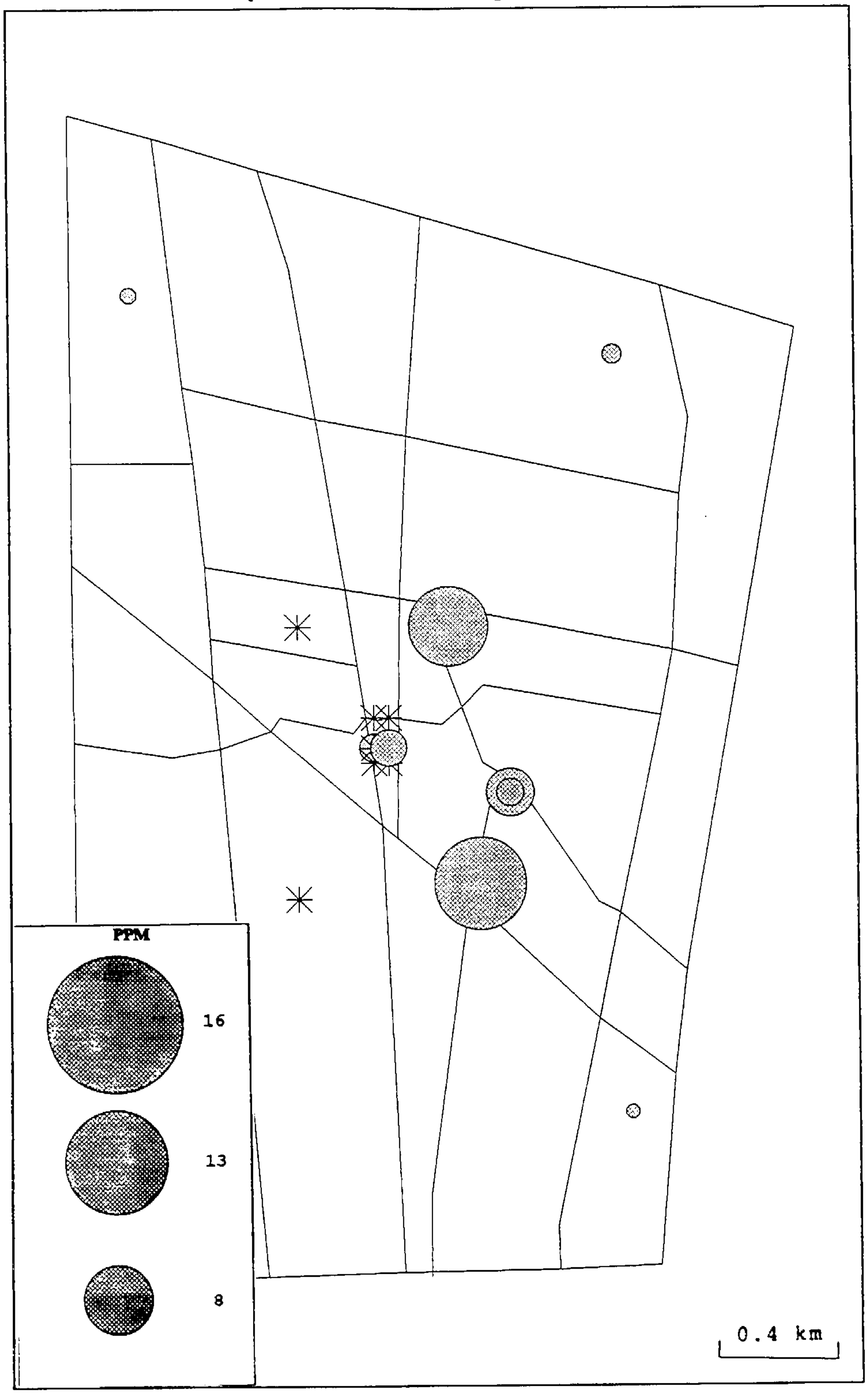


CO 12/20/1989 08:00

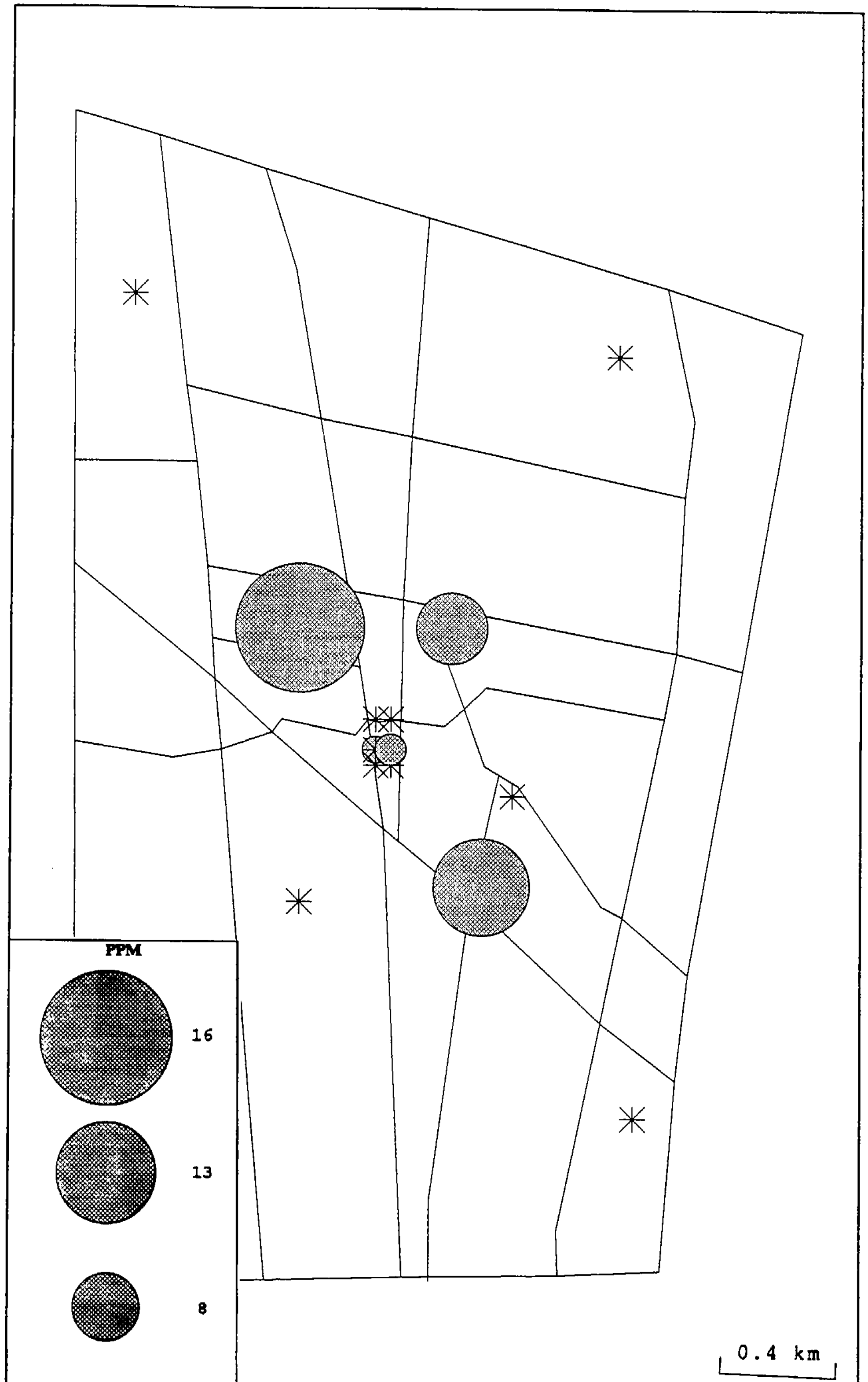


CO 12/20/1989 09:00

Lynwood Monitoring Stations



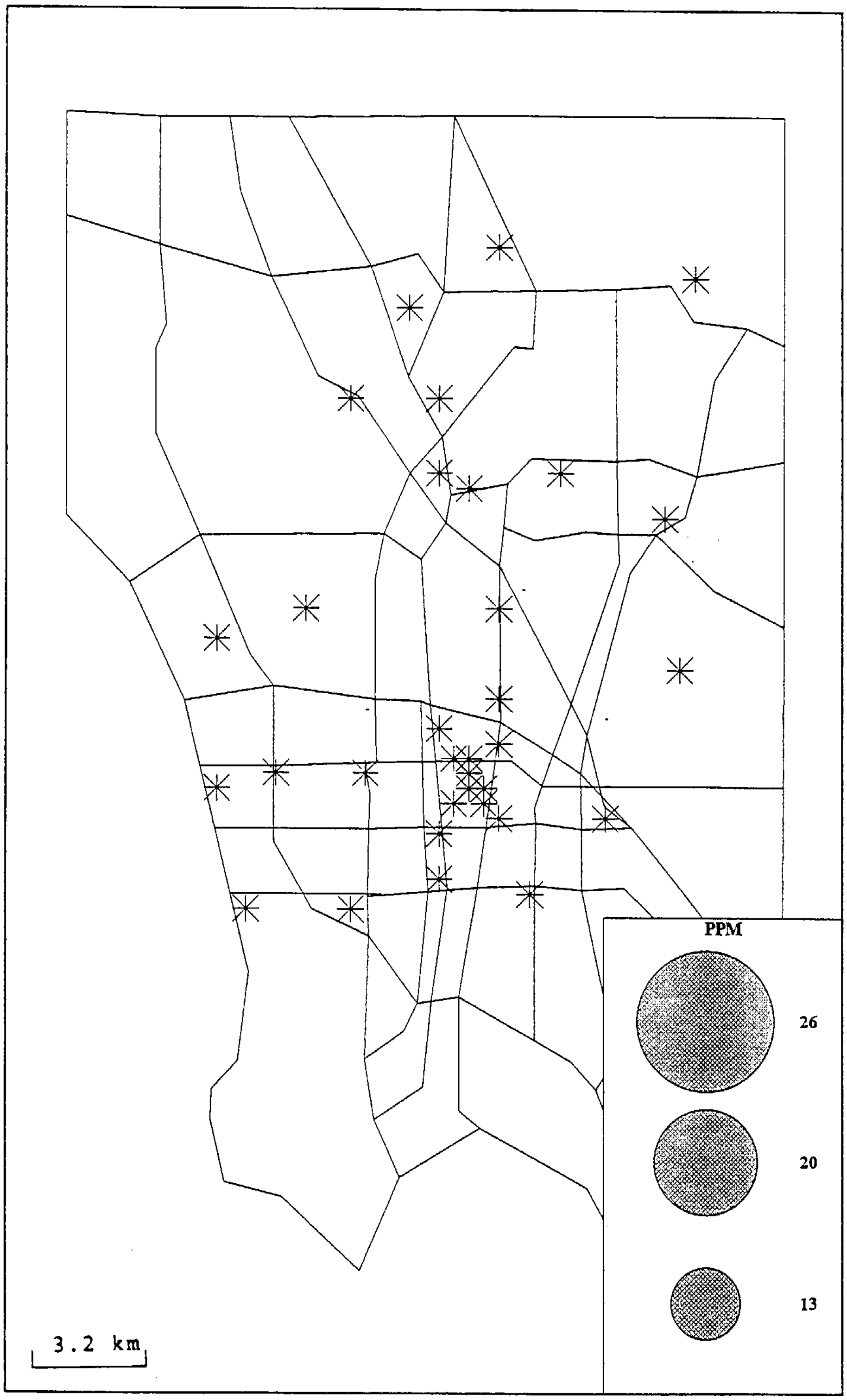
CO 12/20/1989 10:00



CO 12/20/1989 11:00

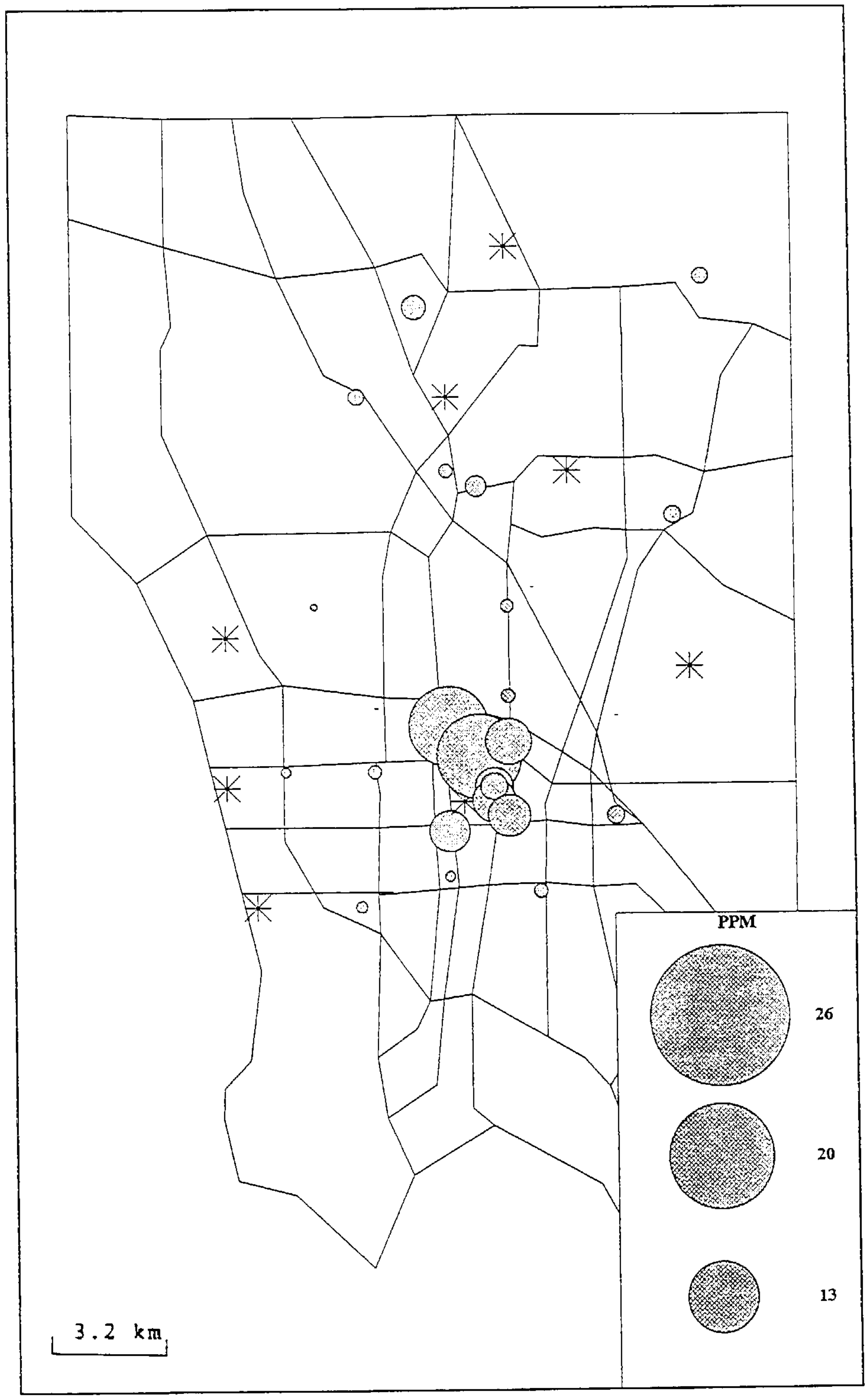
Appendix C-2

CO Concentration



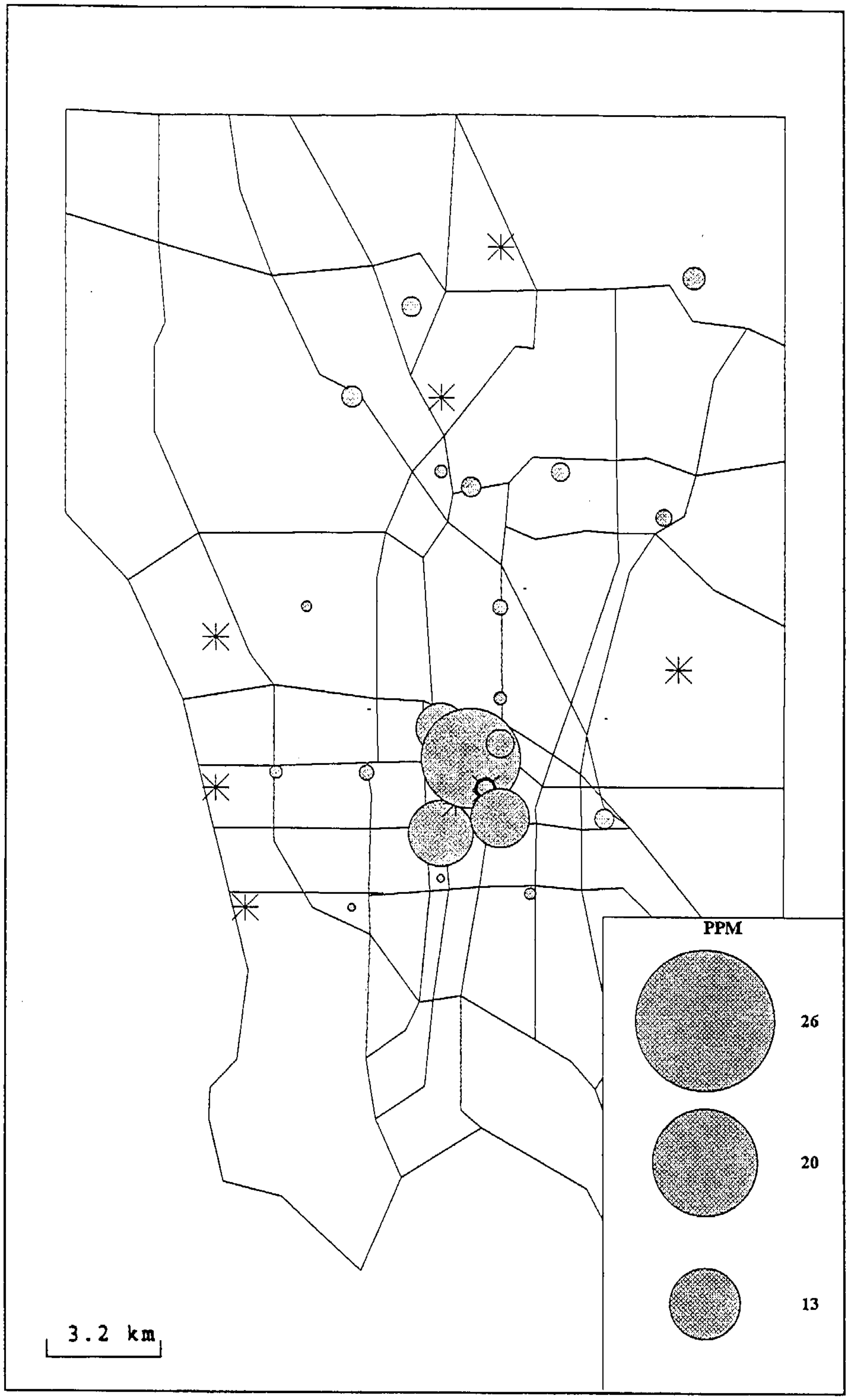
CO 01/08/1990 12:00

CO Concentration



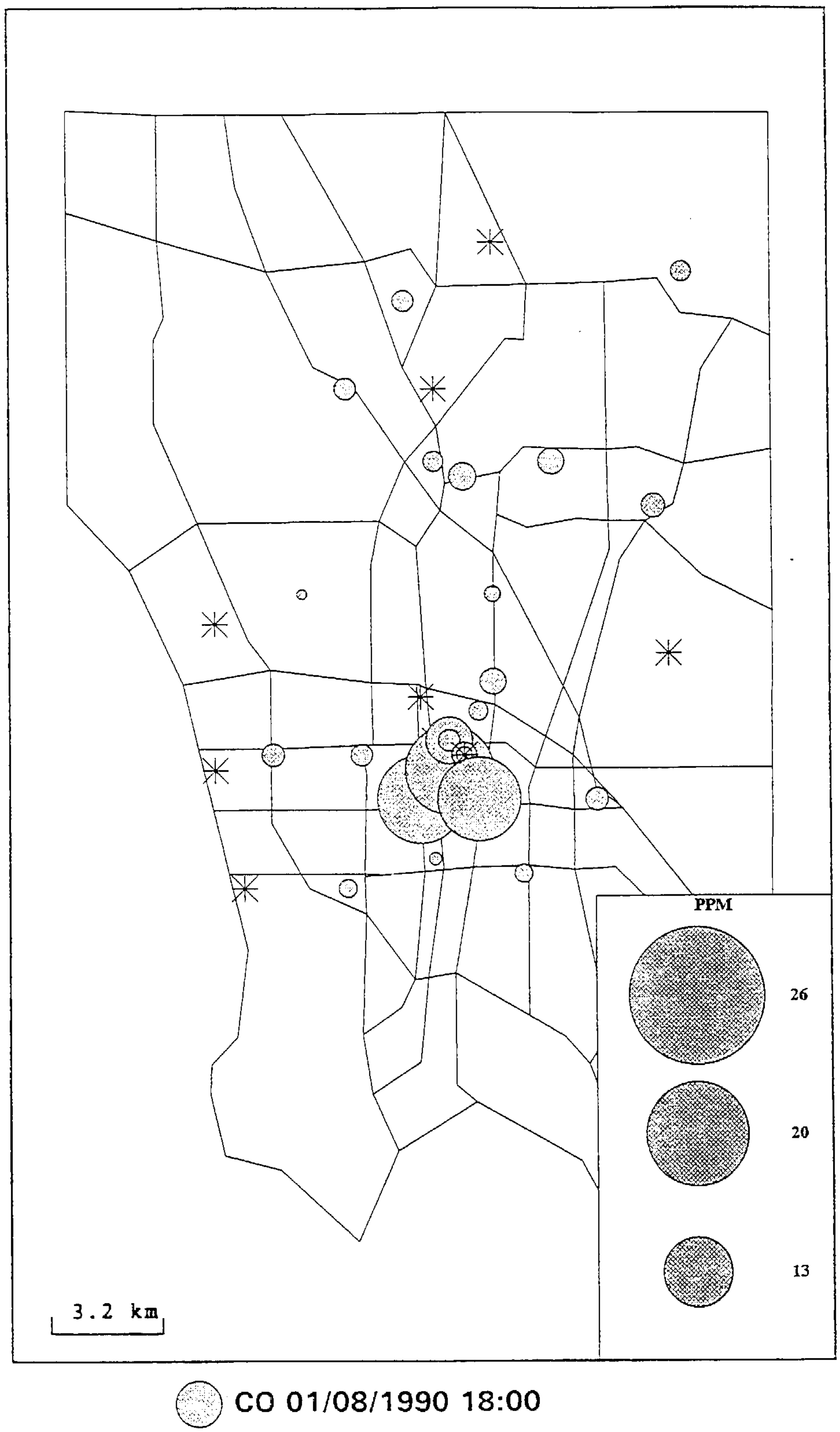
CO 01/08/1990 14:00

CO Concentration

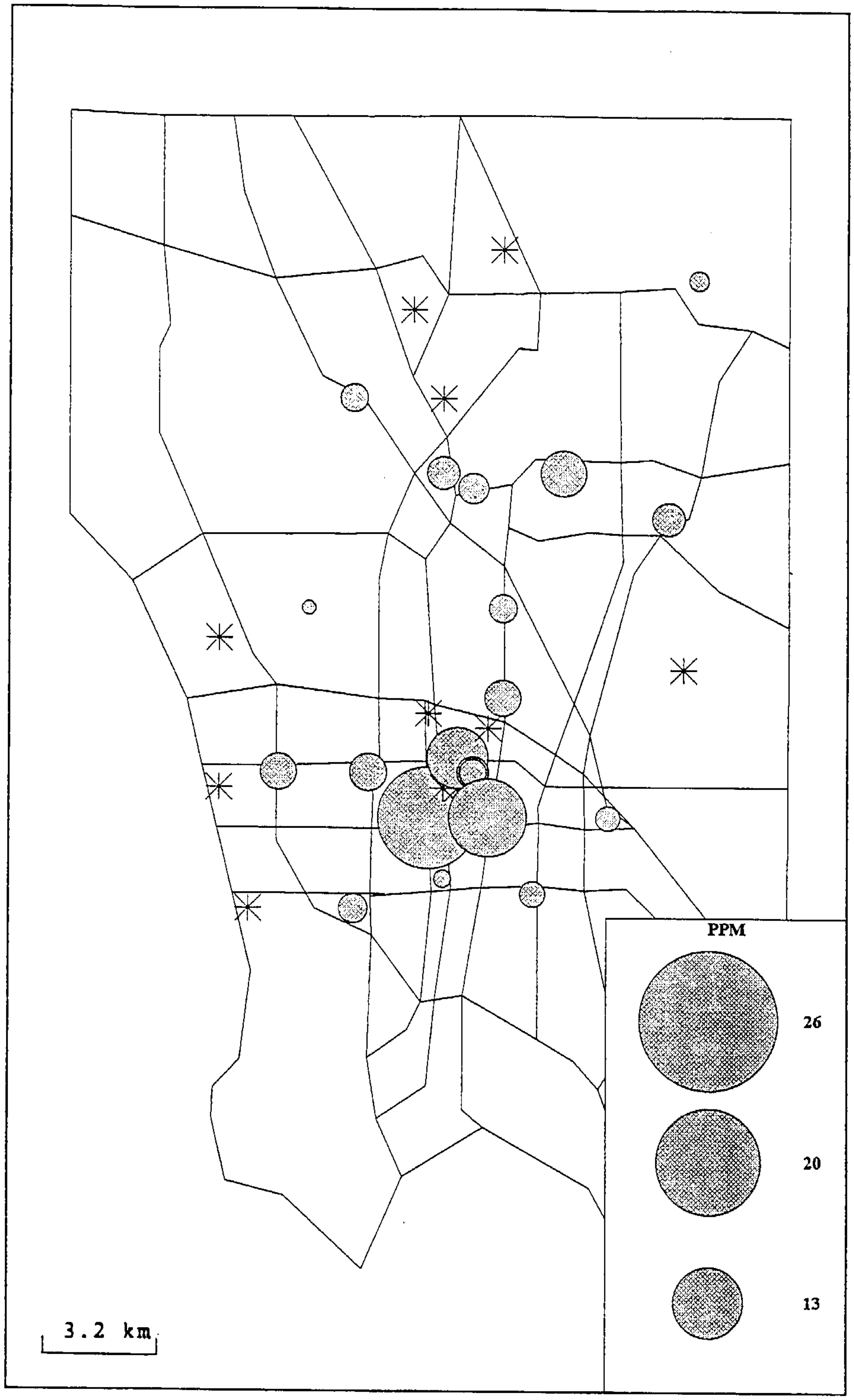


CO 01/08/1990 16:00

CO Concentration

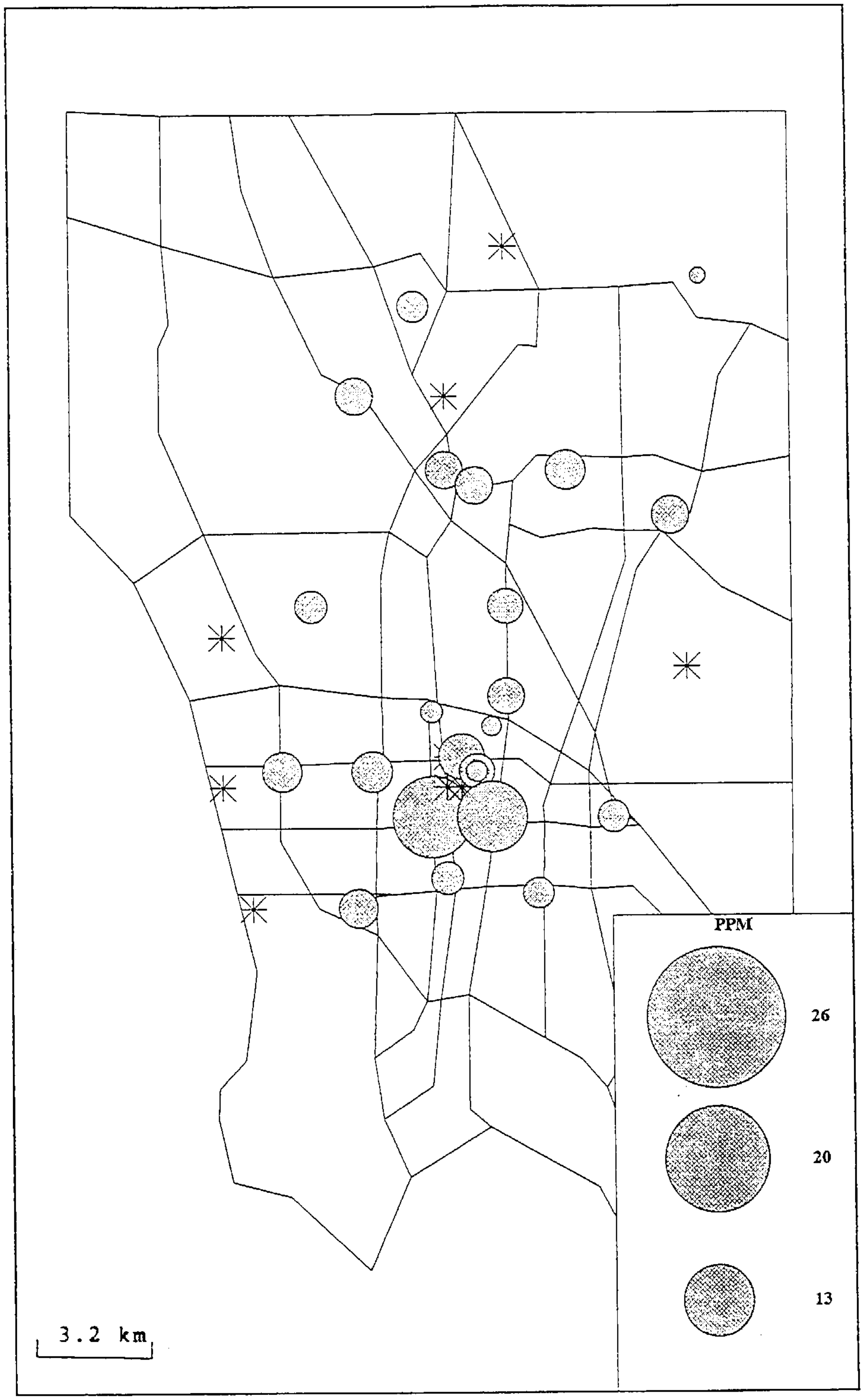


CO Concentration



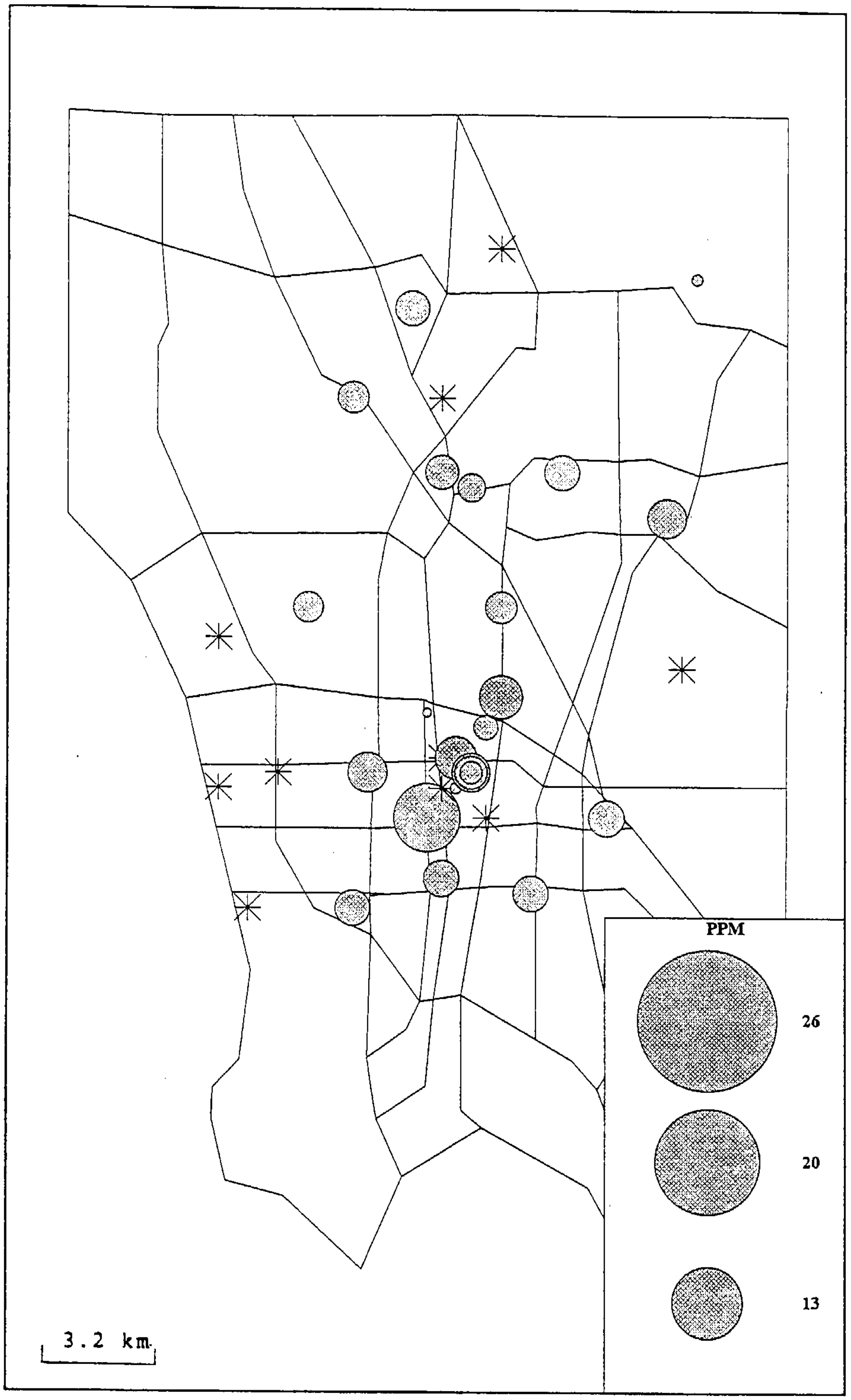
CO 01/08/1990 20:00

CO Concentration



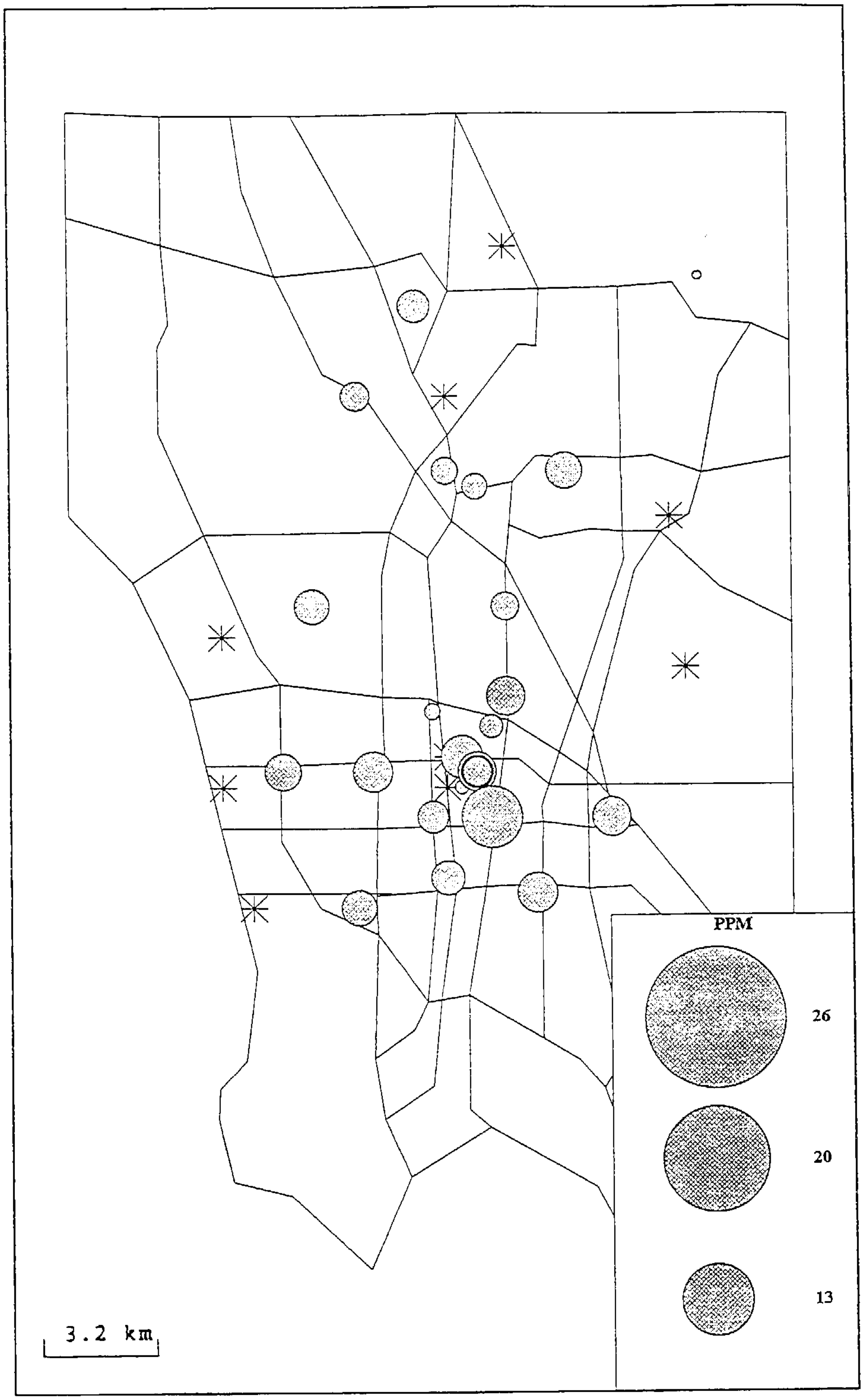
CO 01/08/1990 22:00

CO Concentration



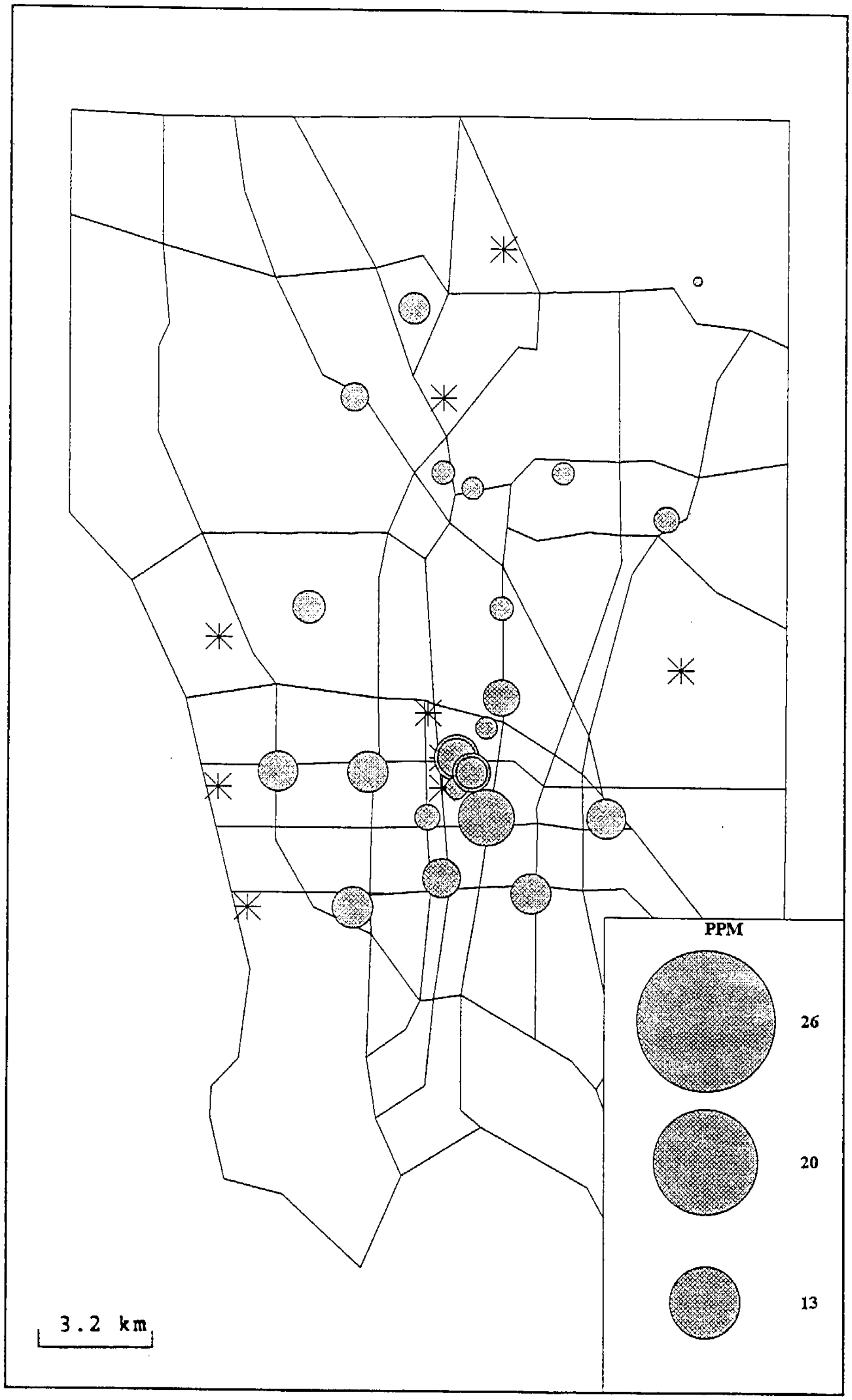
CO 01/09/1990 00:00

CO Concentration



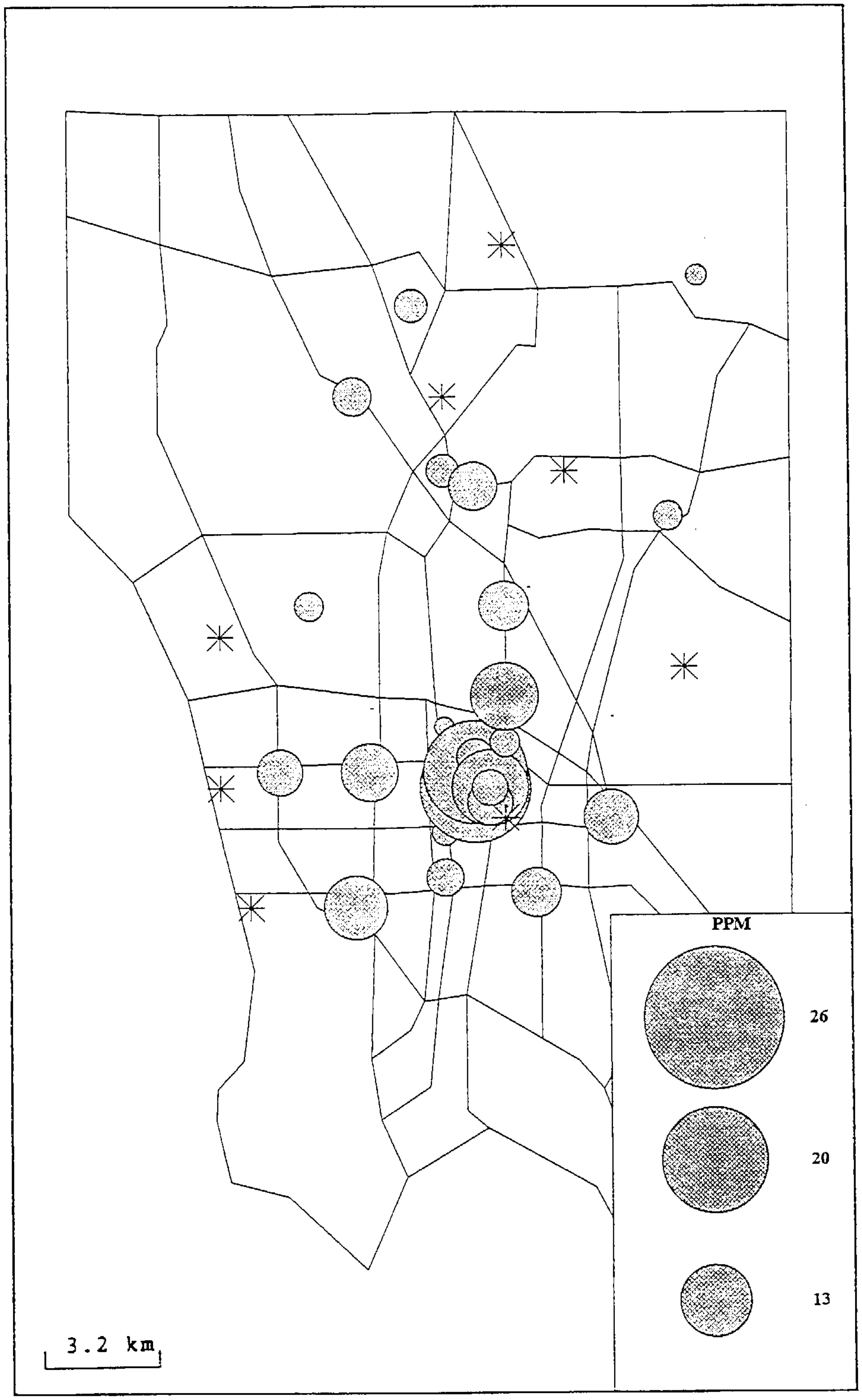
CO 01/09/1990 02:00

CO Concentration



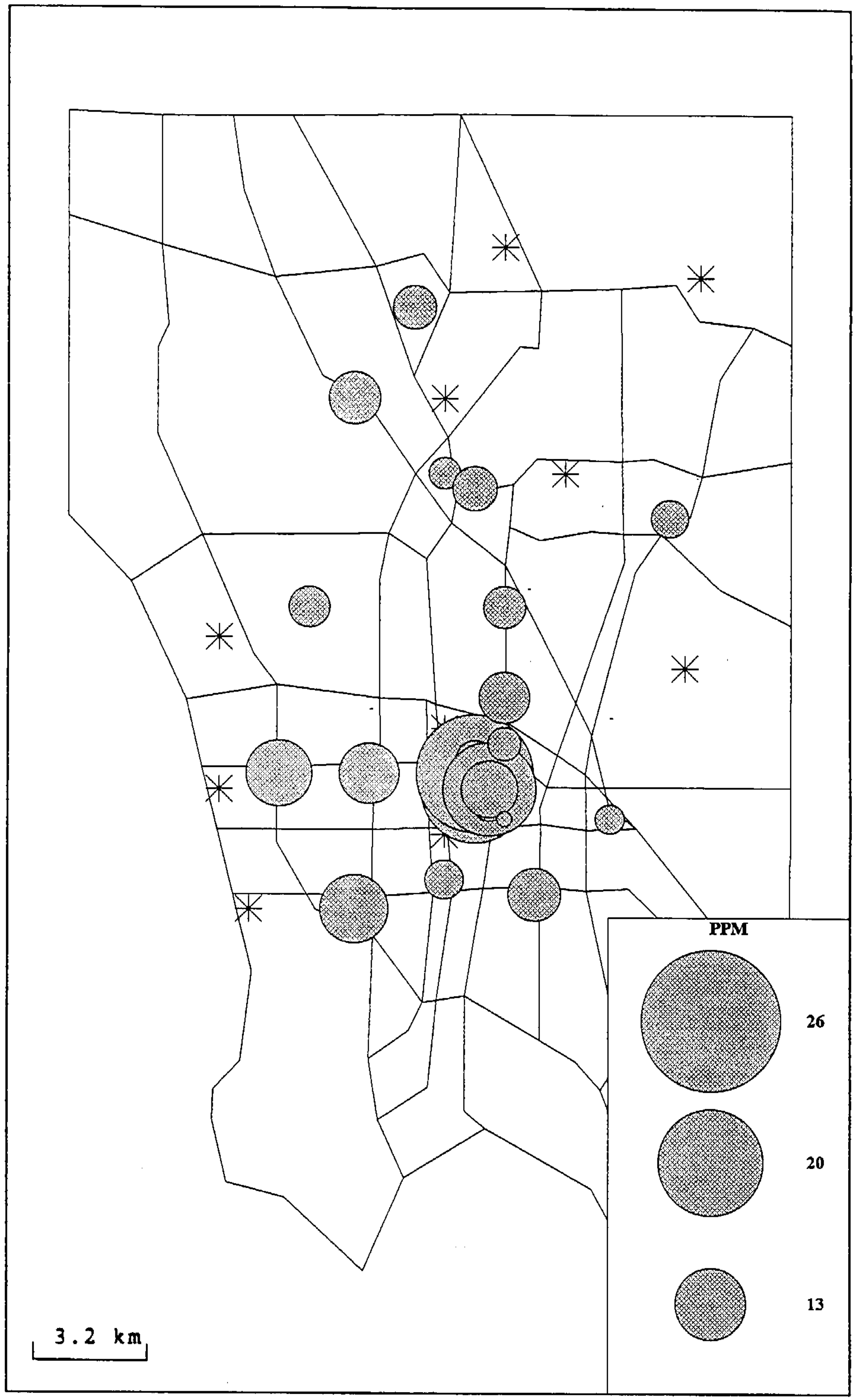
CO 01/09/1990 04:00

CO Concentration



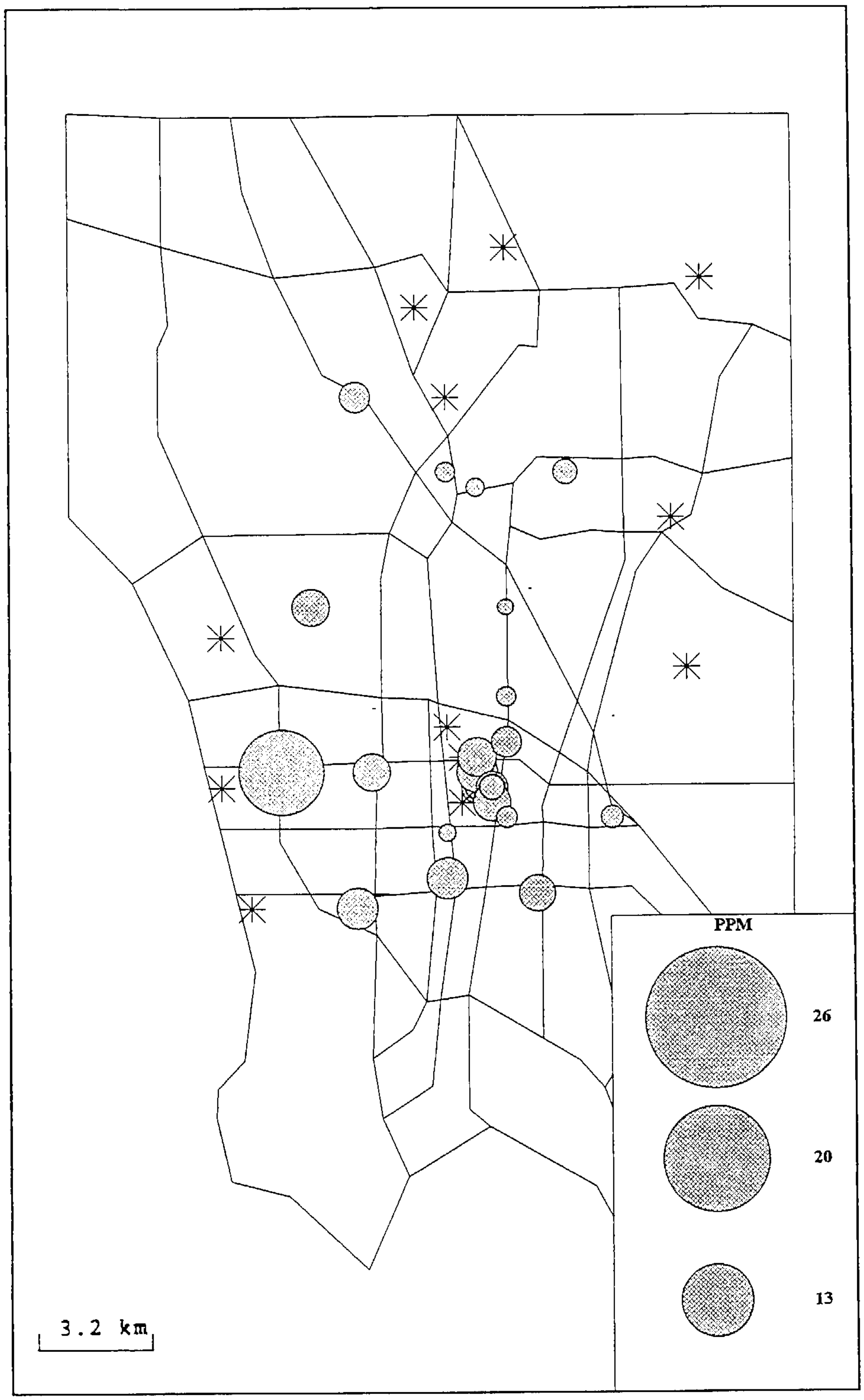
CO 01/09/1990 06:00

CO Concentration



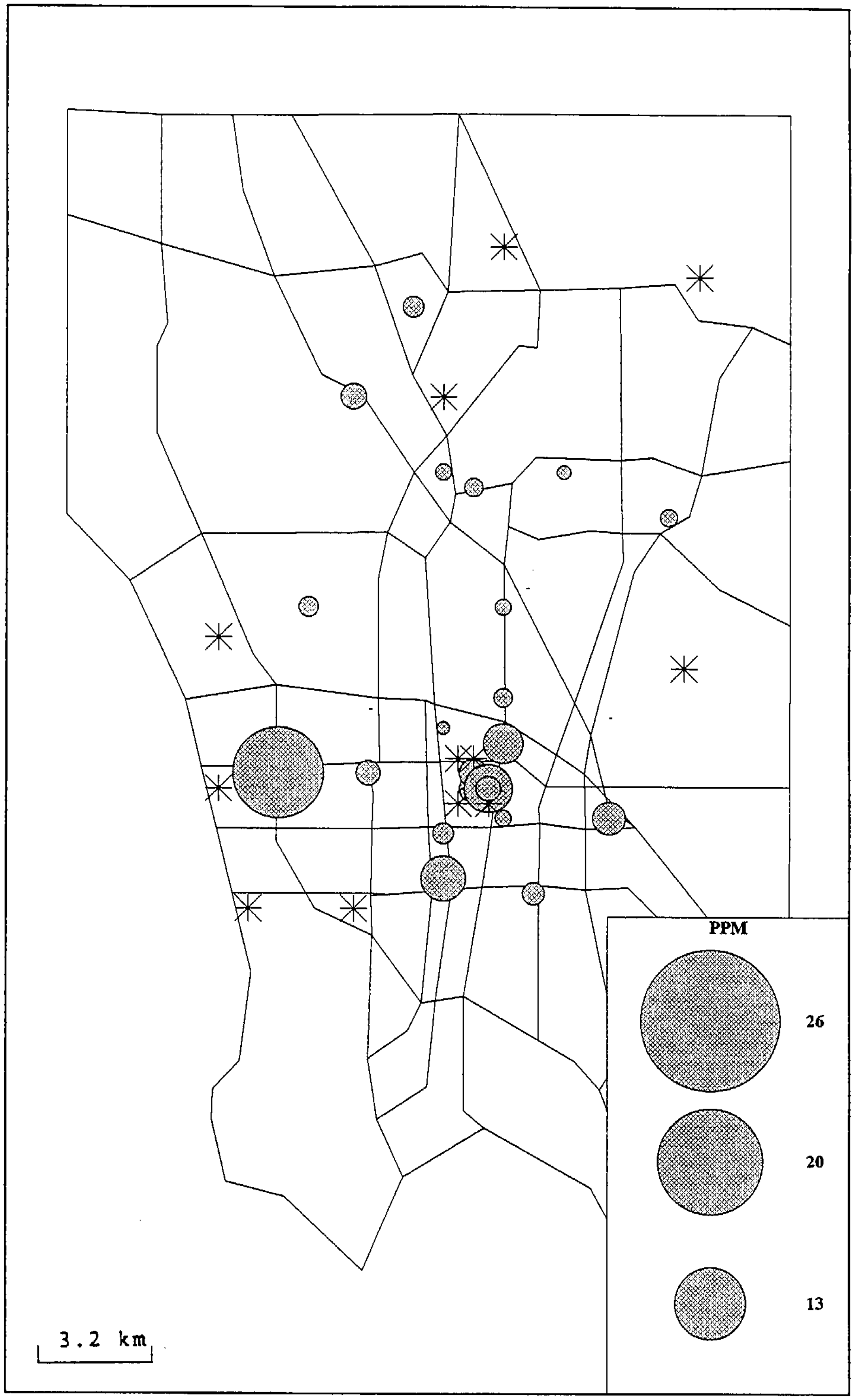
CO 01/09/1990 08:00

CO Concentration



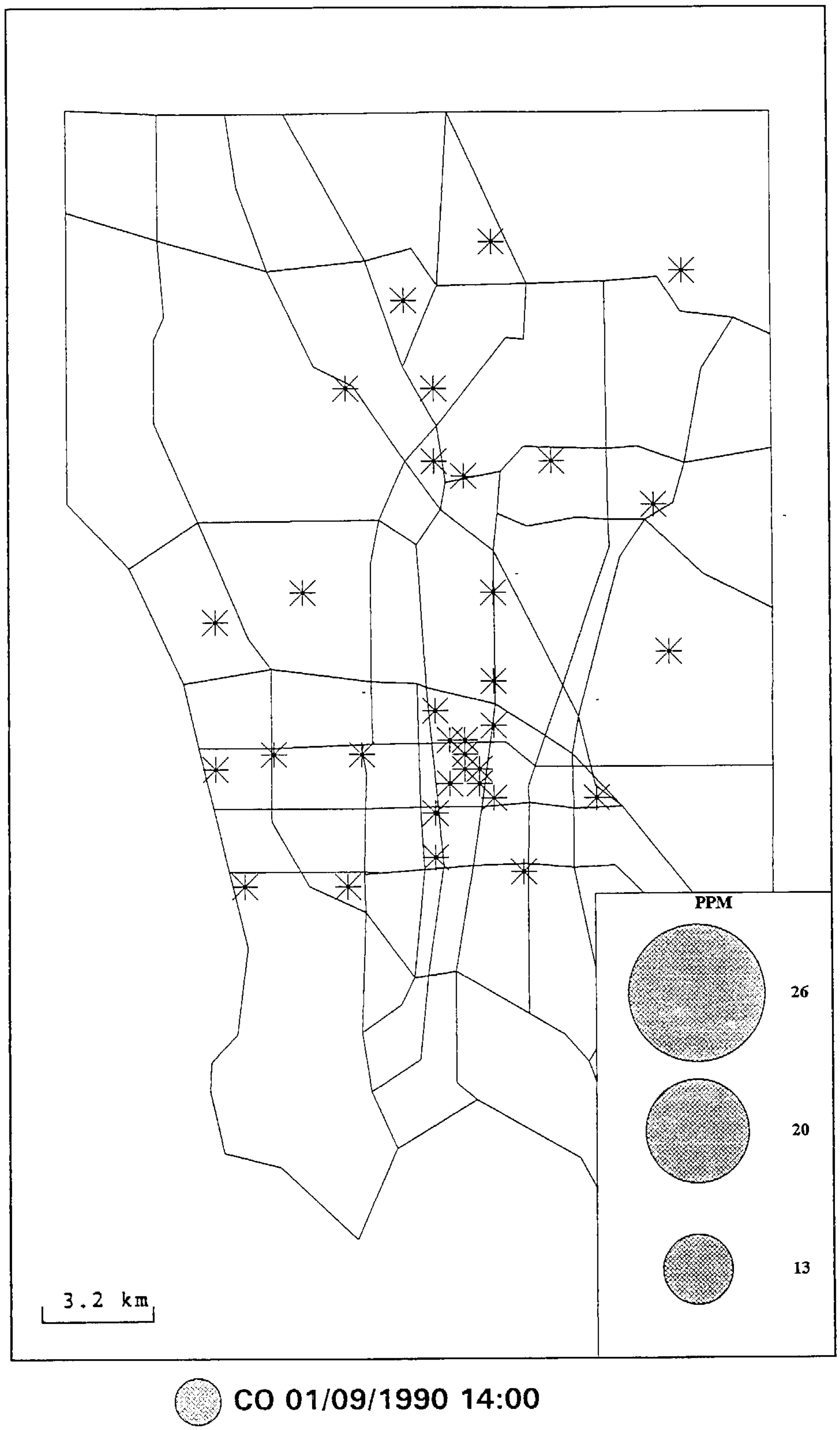
CO 01/09/1990 10:00

CO Concentration

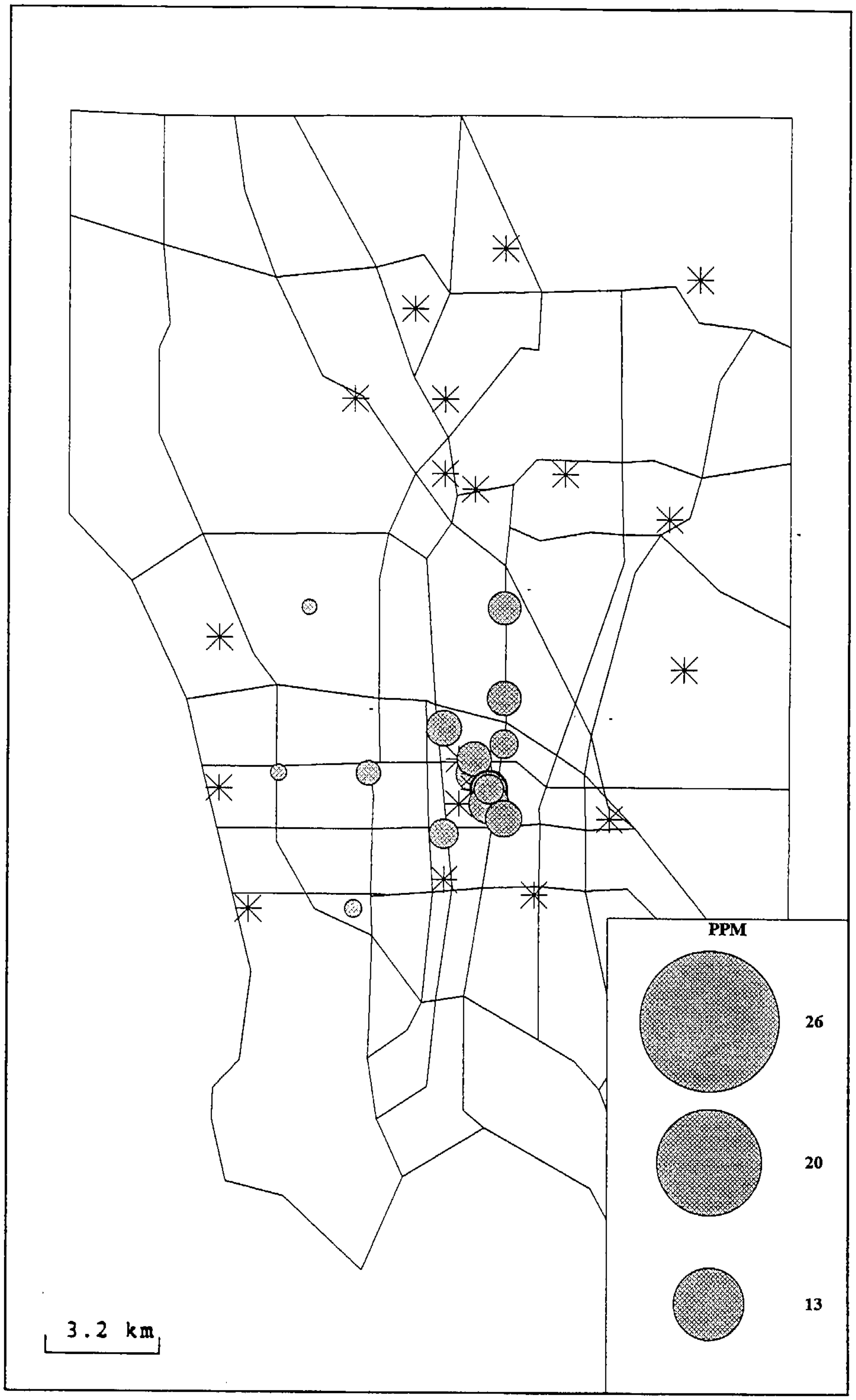


CO 01/09/1990 12:00

CO Concentration

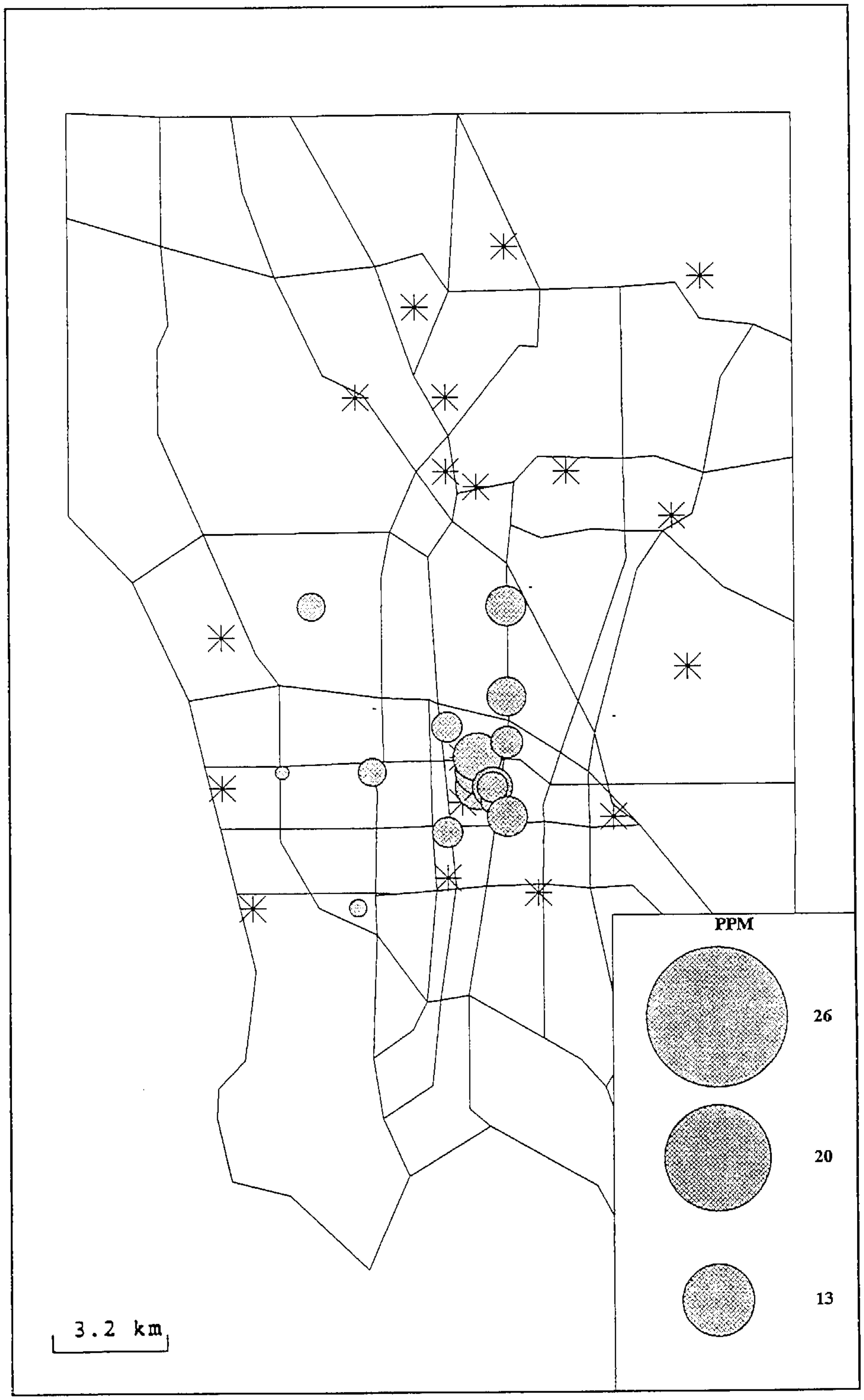


CO Concentration



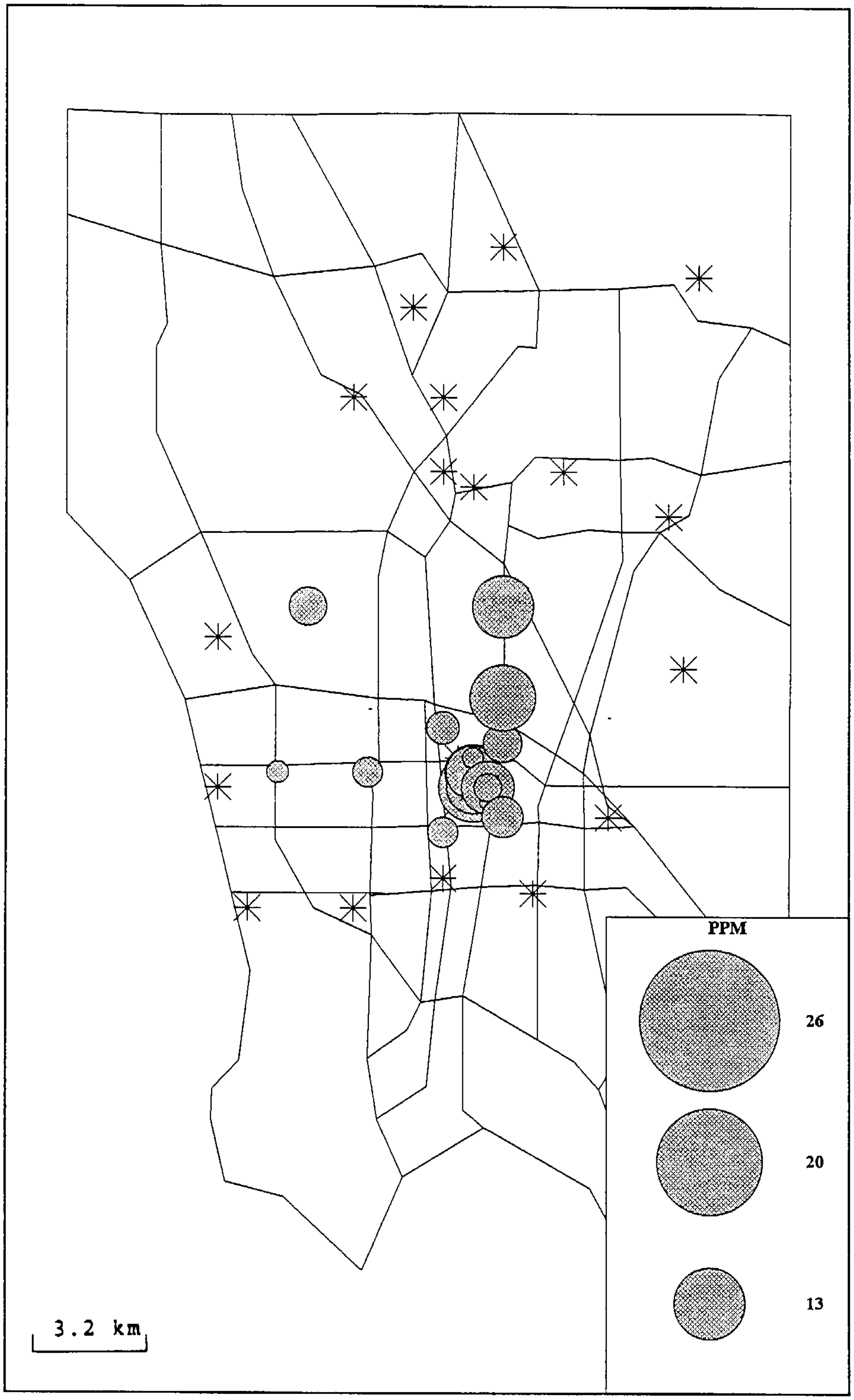
CO 01/09/1990 16:00

CO Concentration



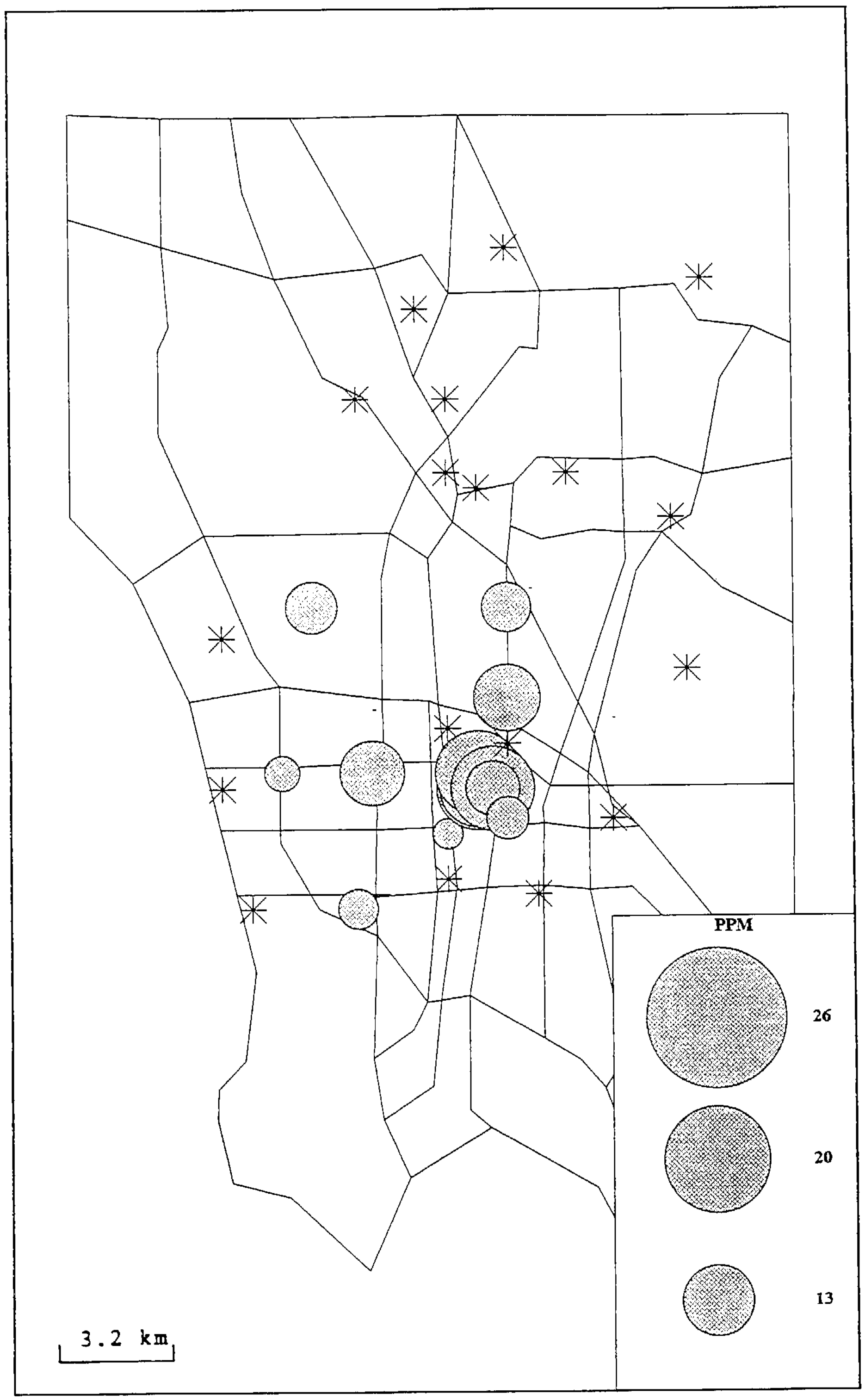
CO 01/09/1990 18:00

CO Concentration



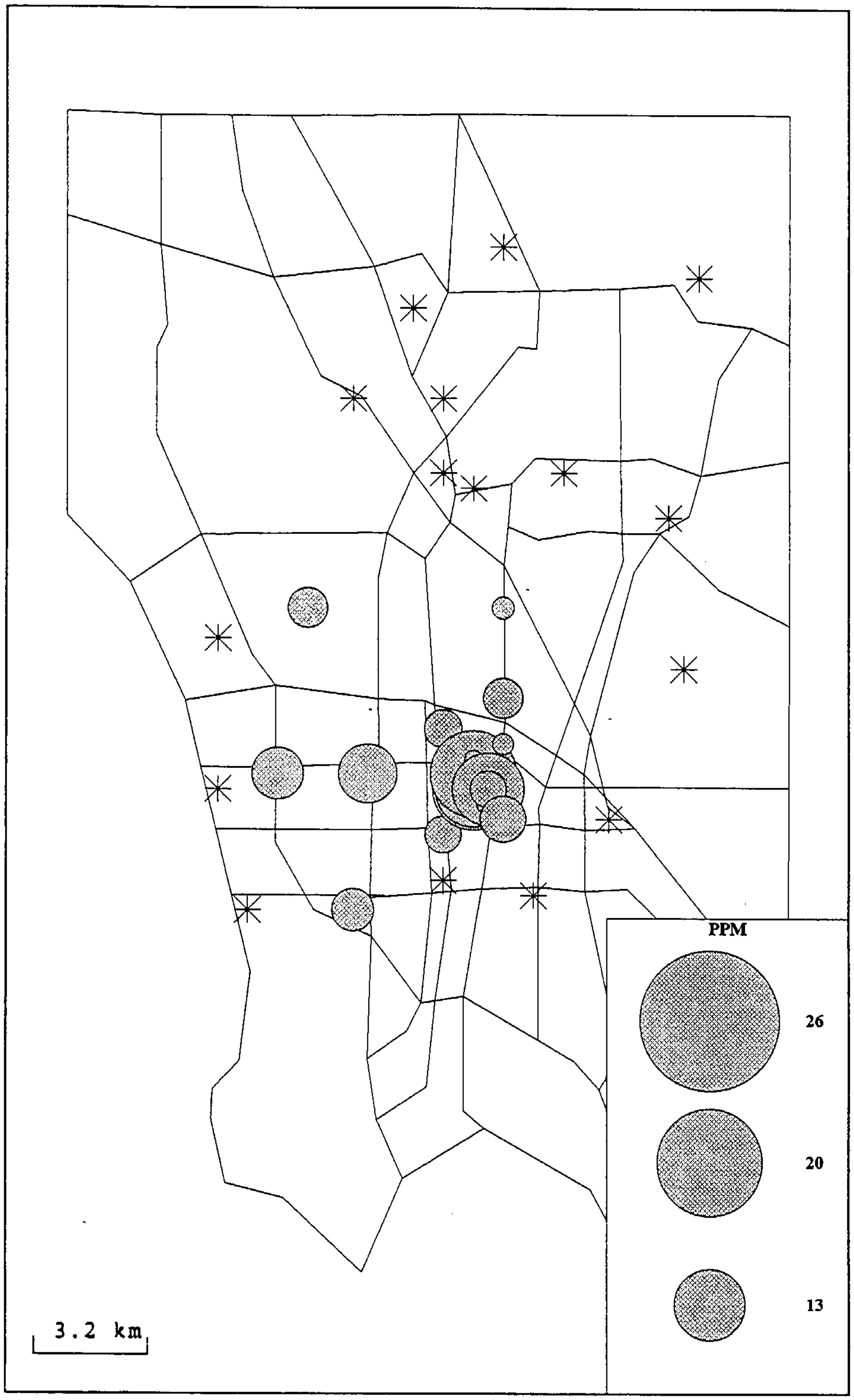
CO 01/09/1990 20:00

CO Concentration



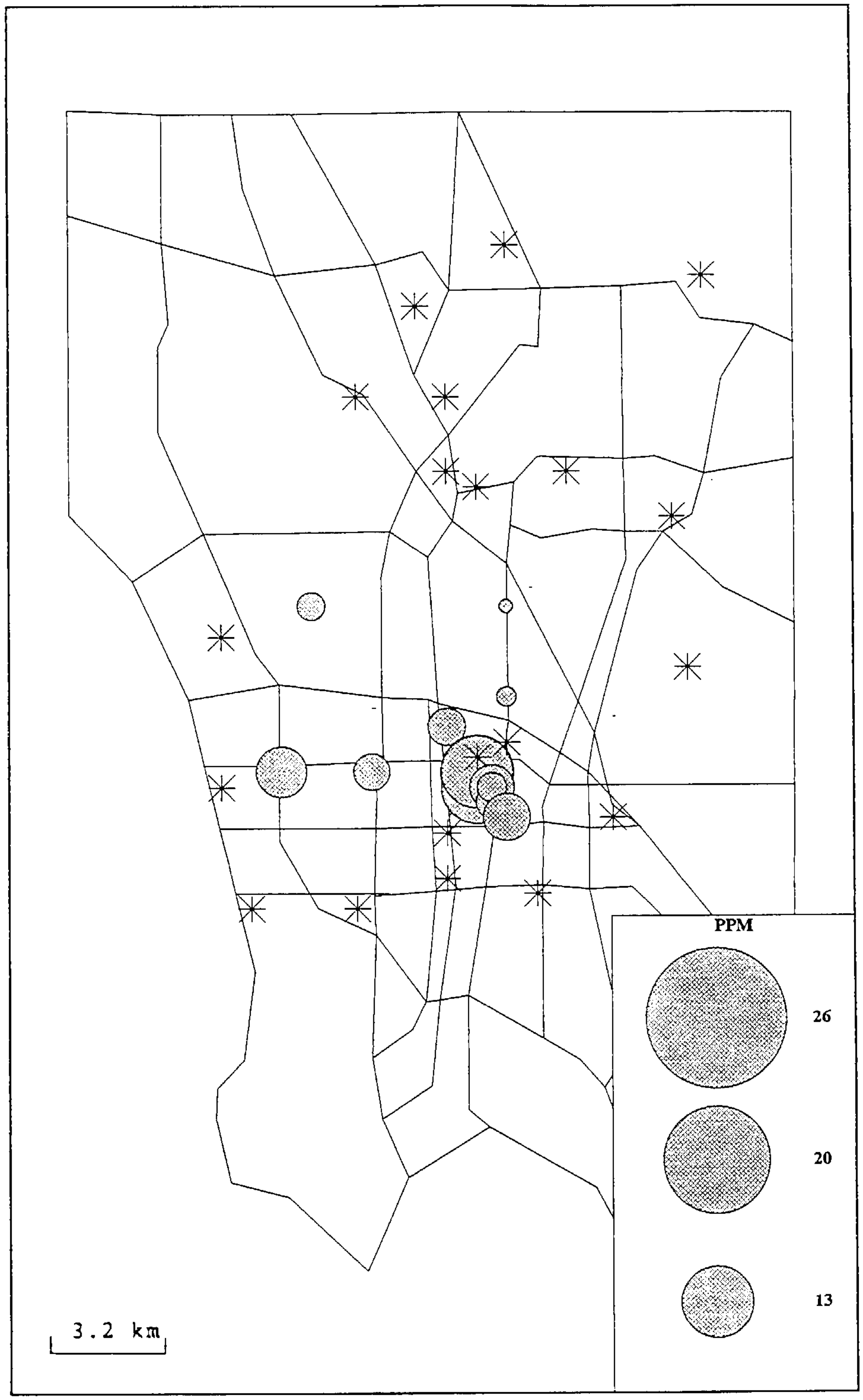
CO 01/09/1990 22:00

CO Concentration



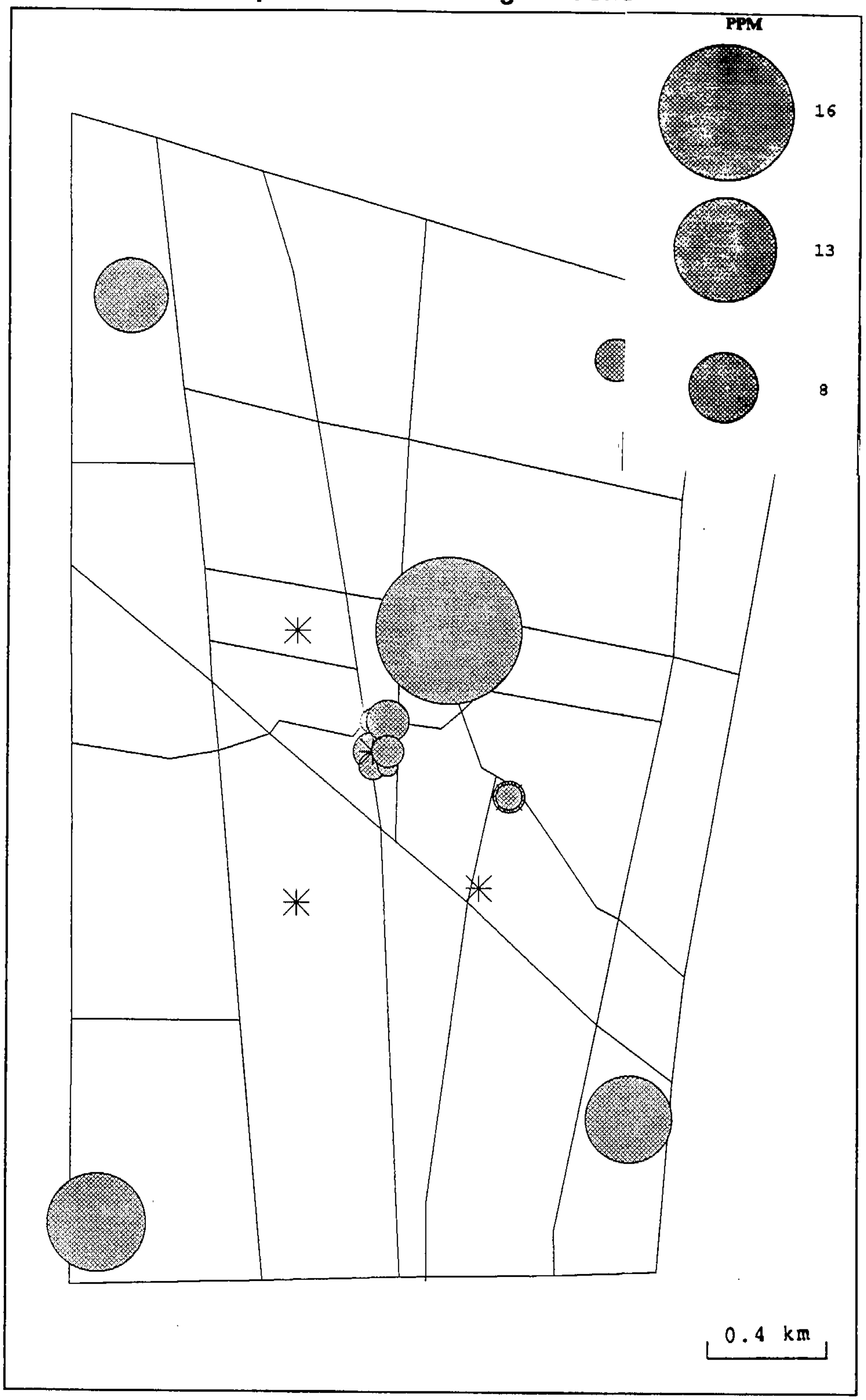
CO 01/10/1990 00:00

CO Concentration



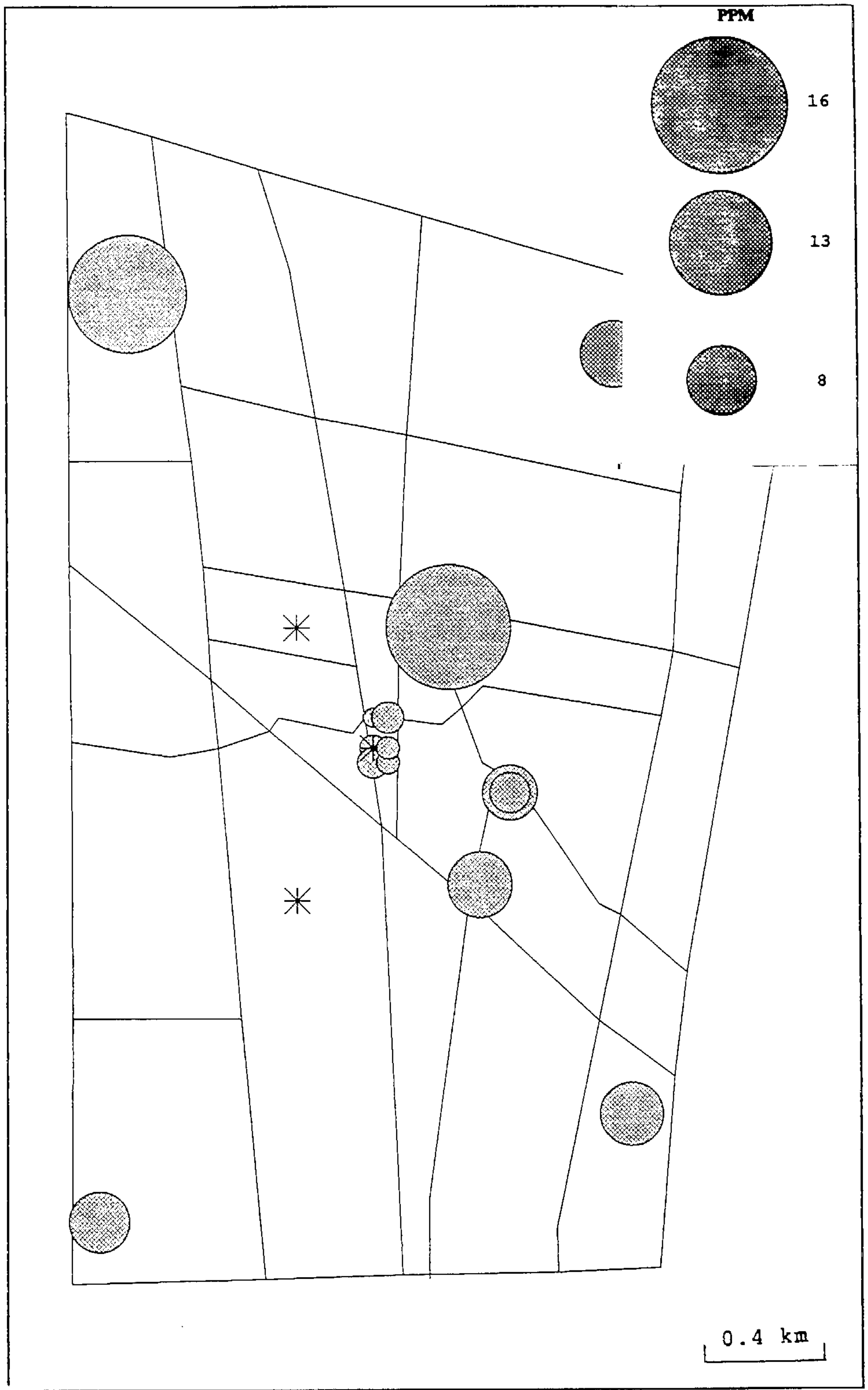
CO 01/10/1990 02:00

Lynwood Monitoring Stations



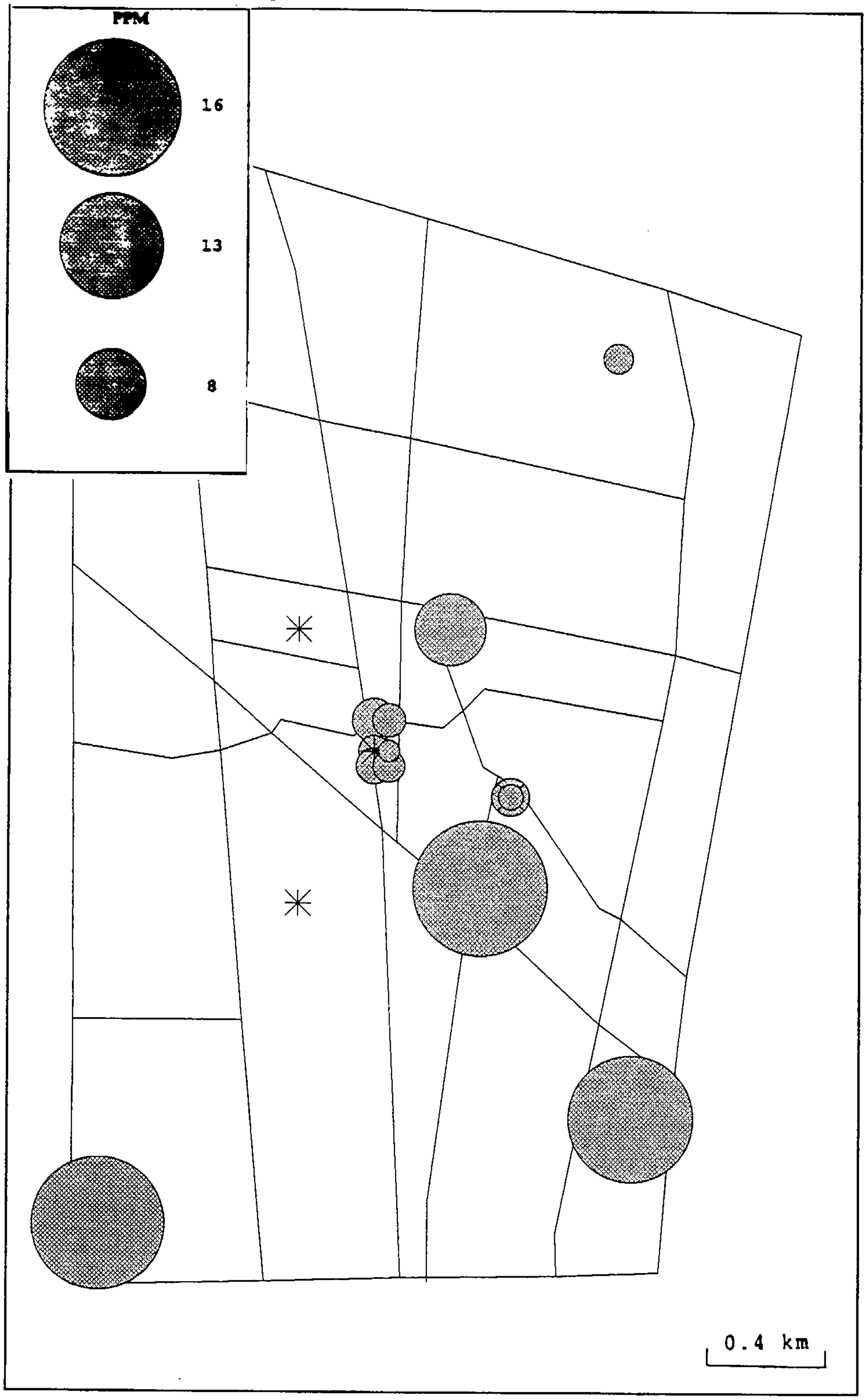
CO 01/08/1990 16:00

Lynwood Monitoring Stations



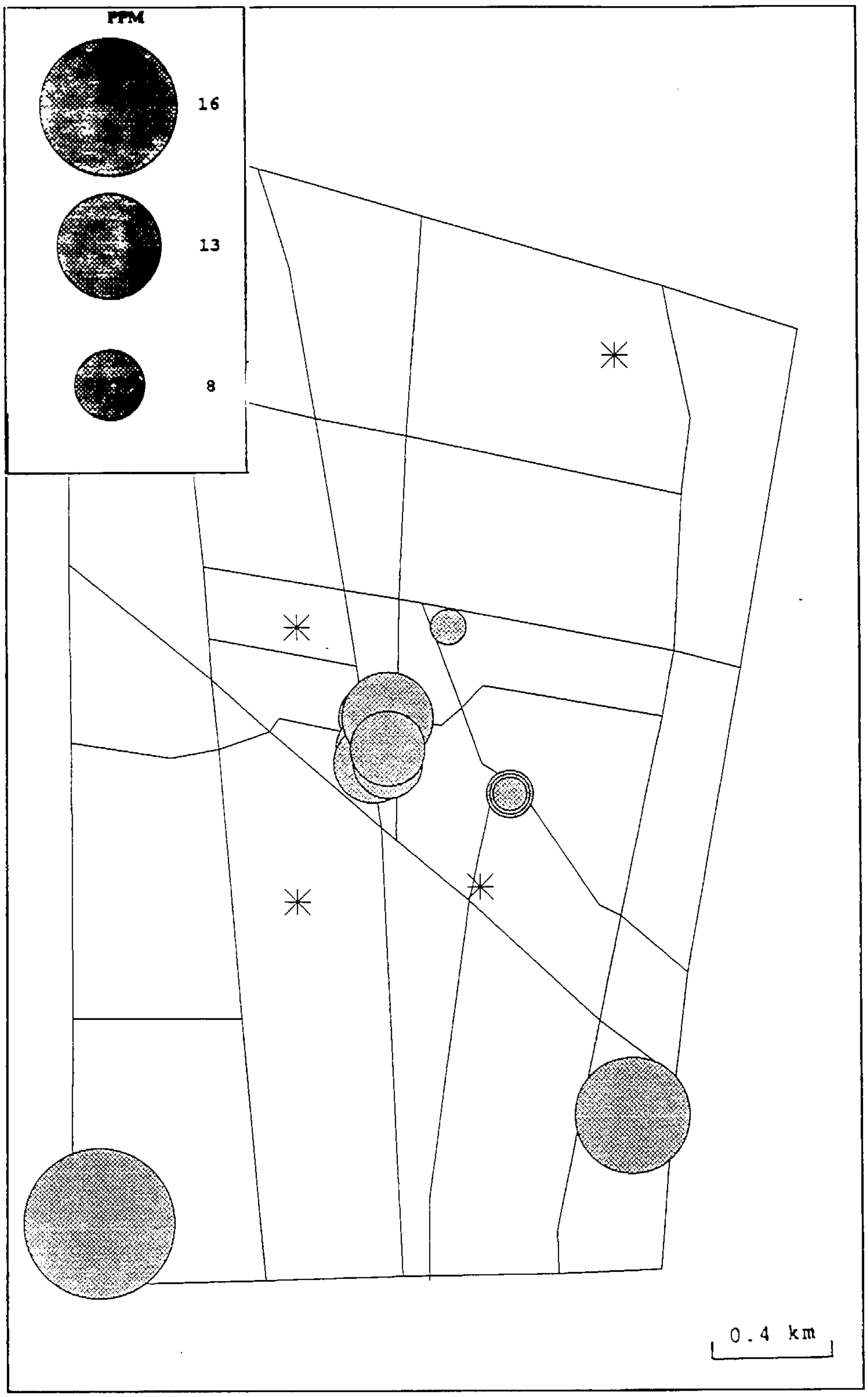
CO 01/08/1990 14:00

Lynwood CO Concentration



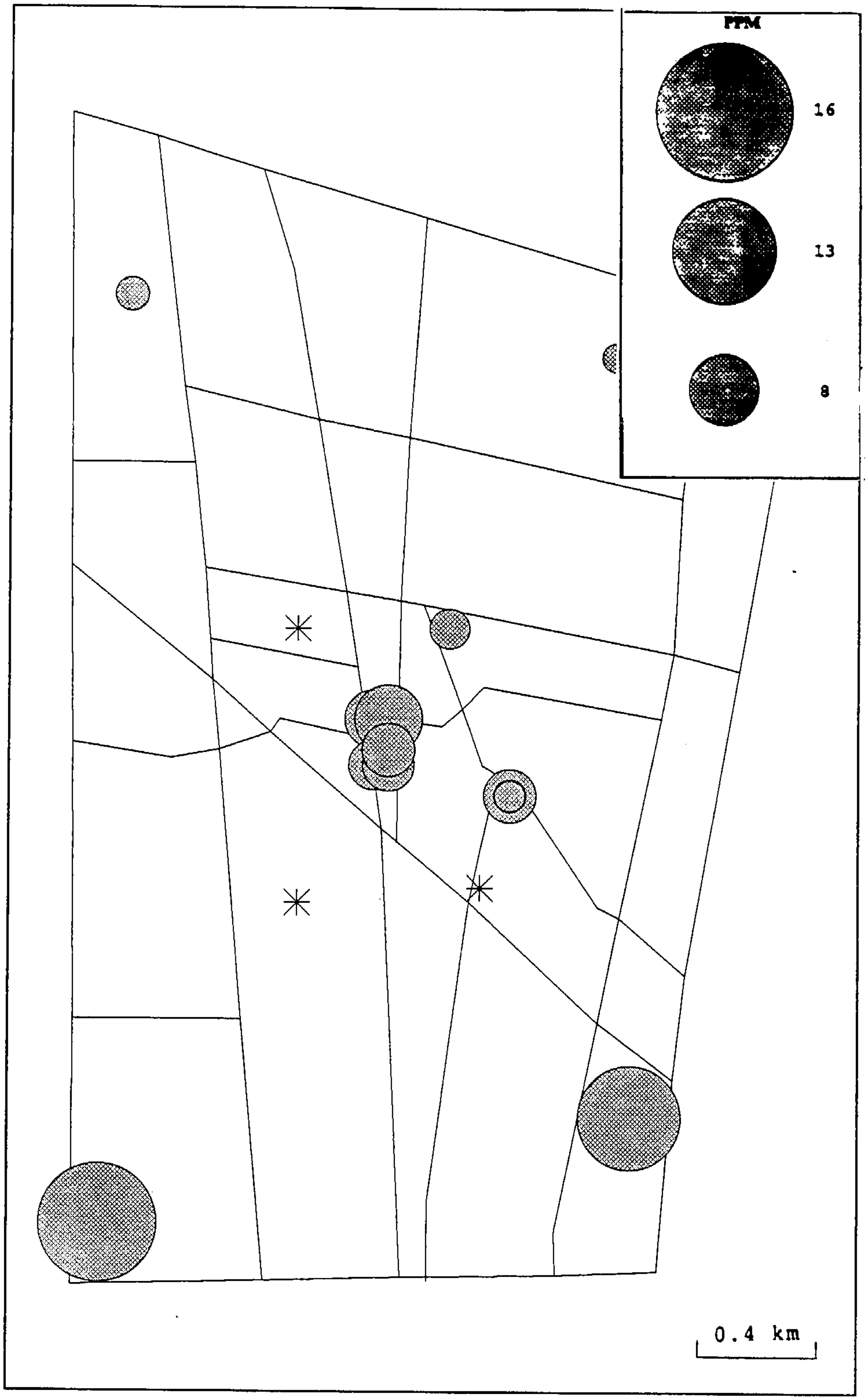
CO 01/08/1990 18:00

Lynwood CO Concentration



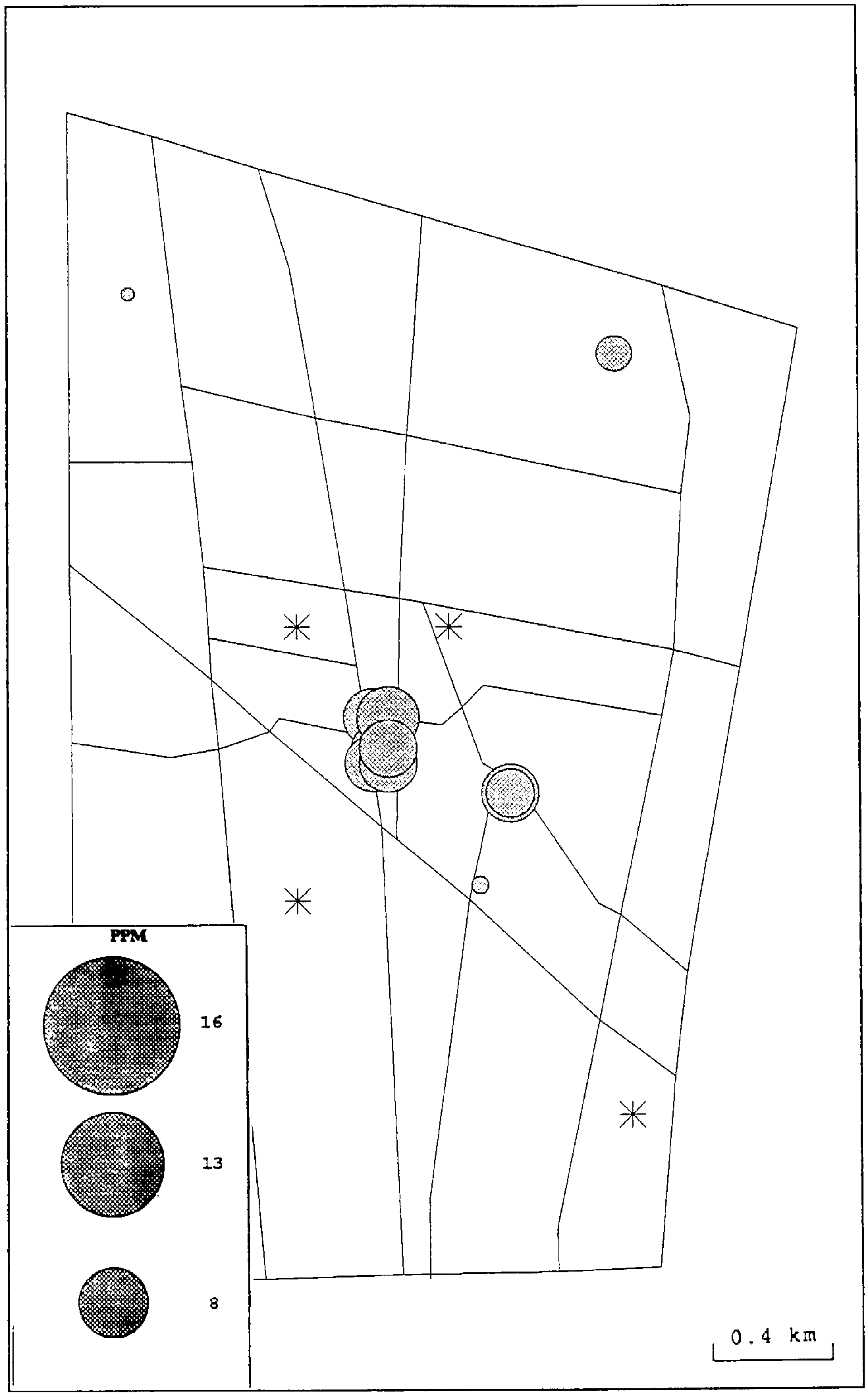
CO 01/08/1990 20:00

Lynwood CO Concentration

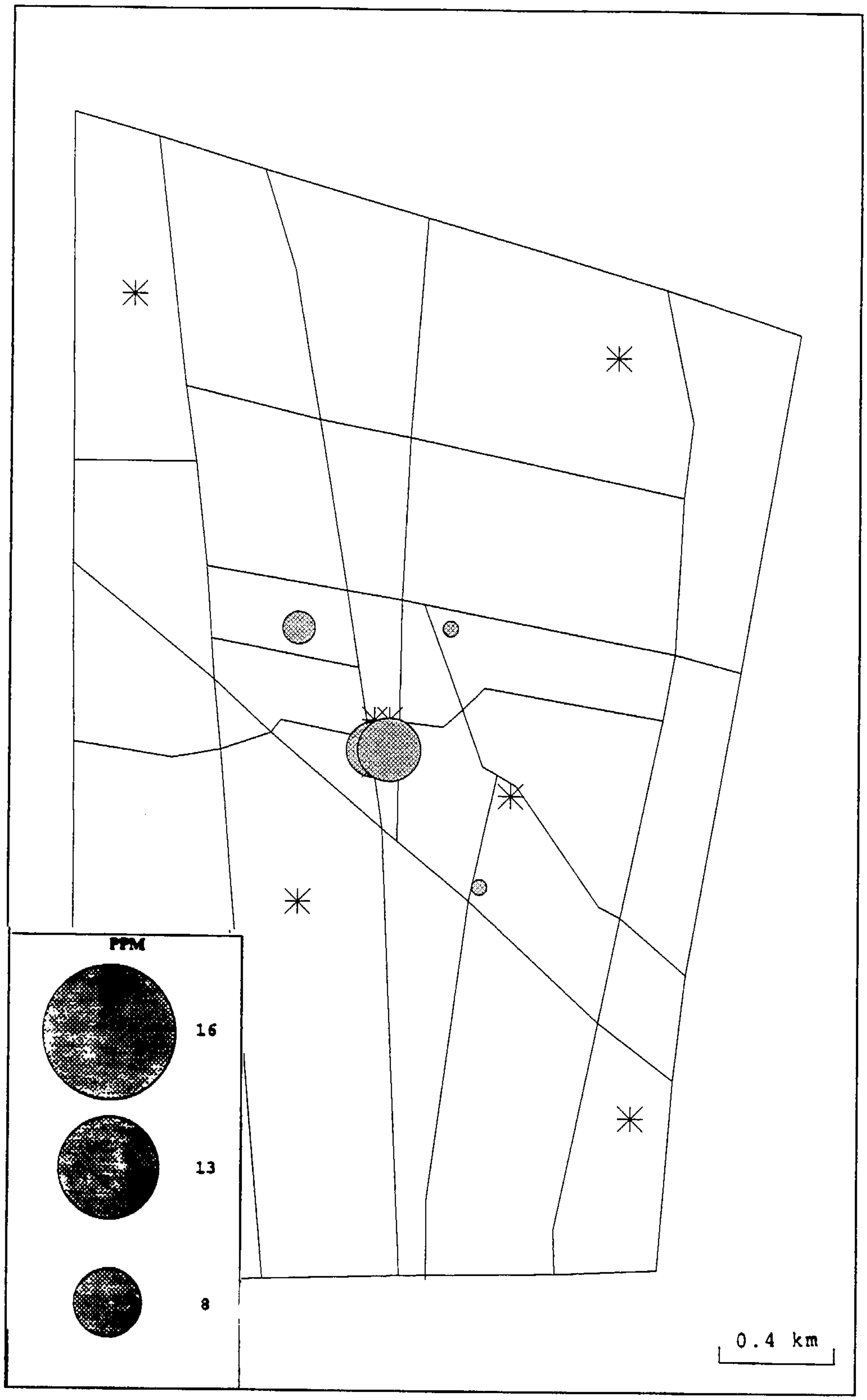


CO 01/08/1990 22:00

Lynwood CO Concentration

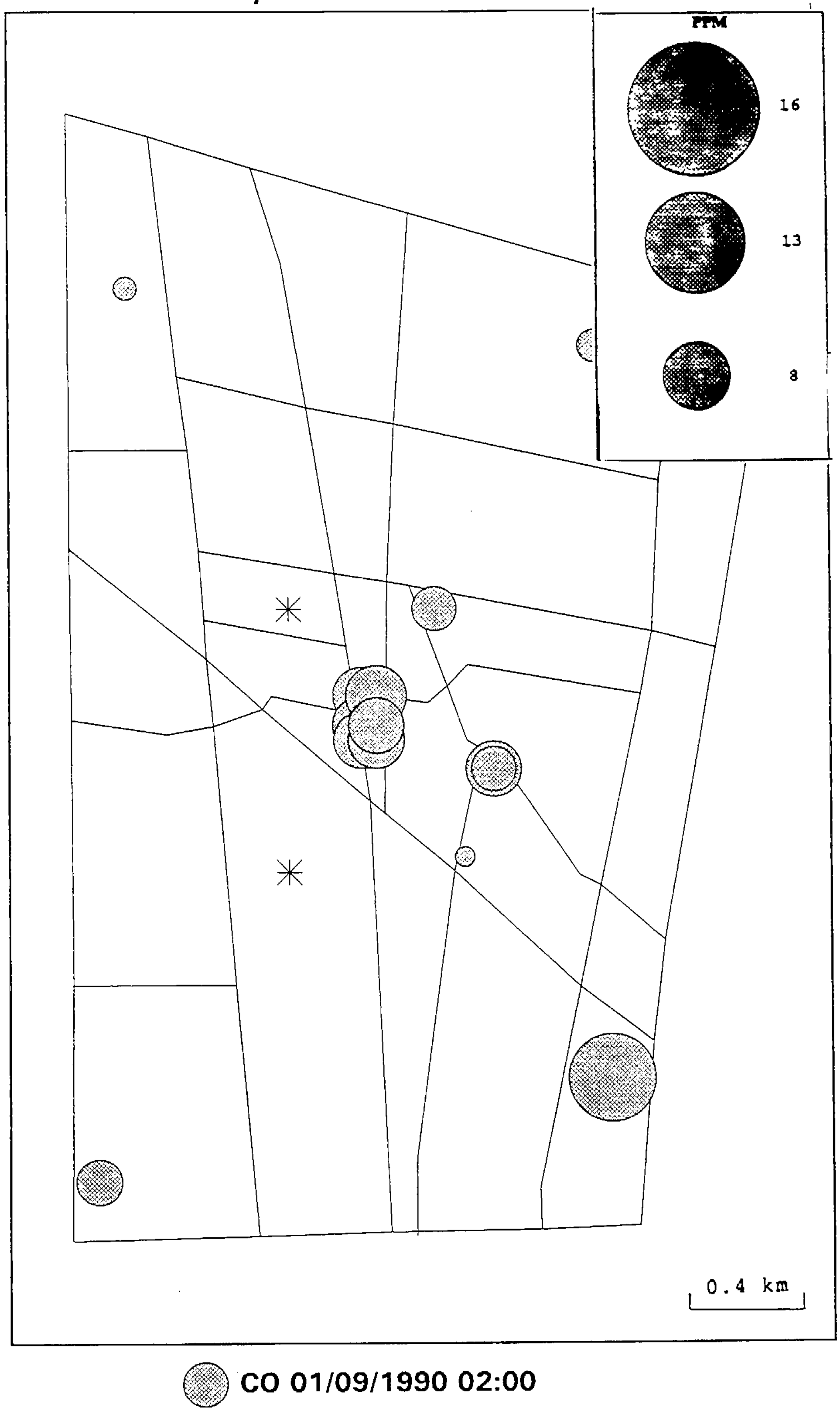


CO 01/09/1990 00:00

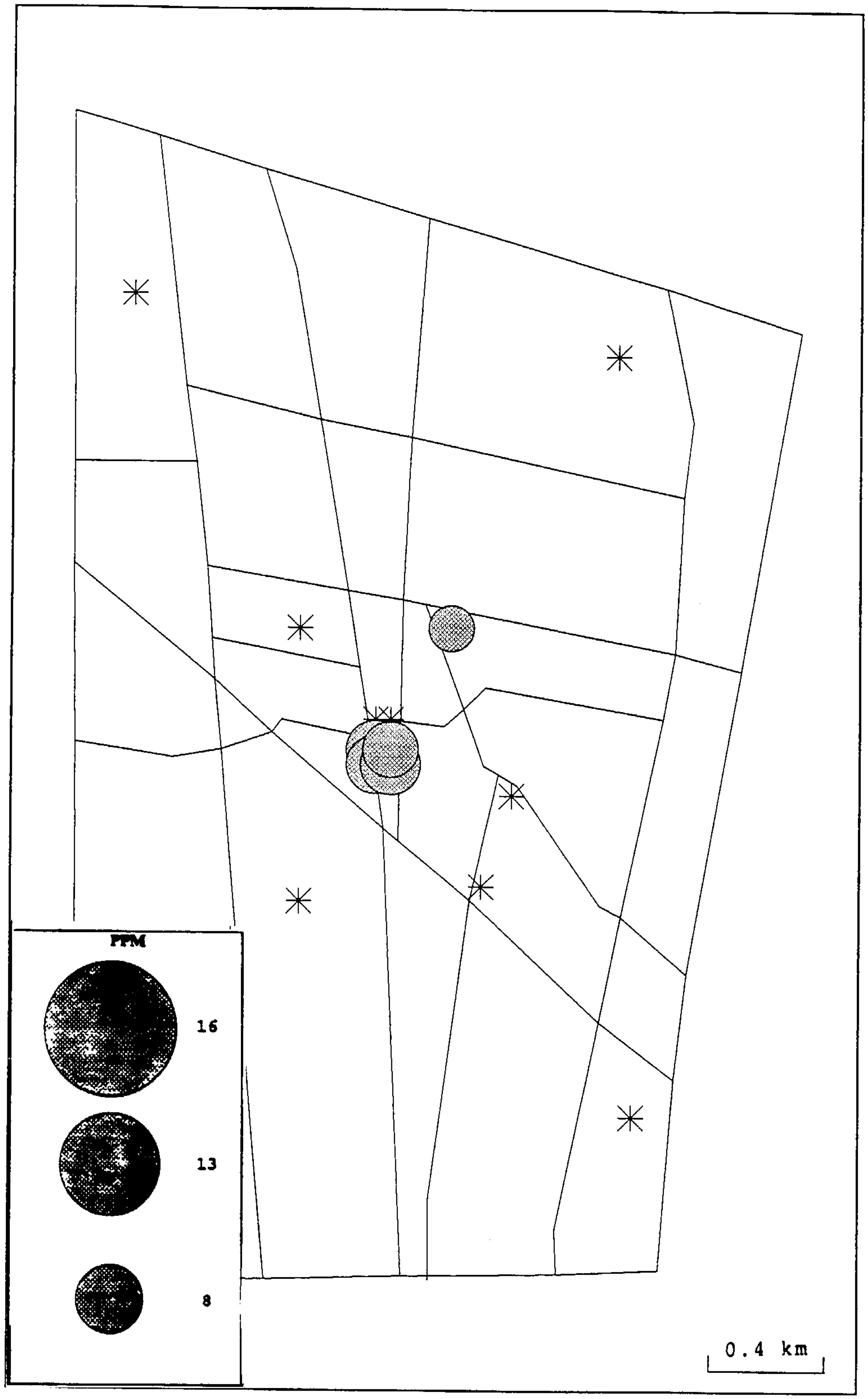


CO 12/20/1989 01:00

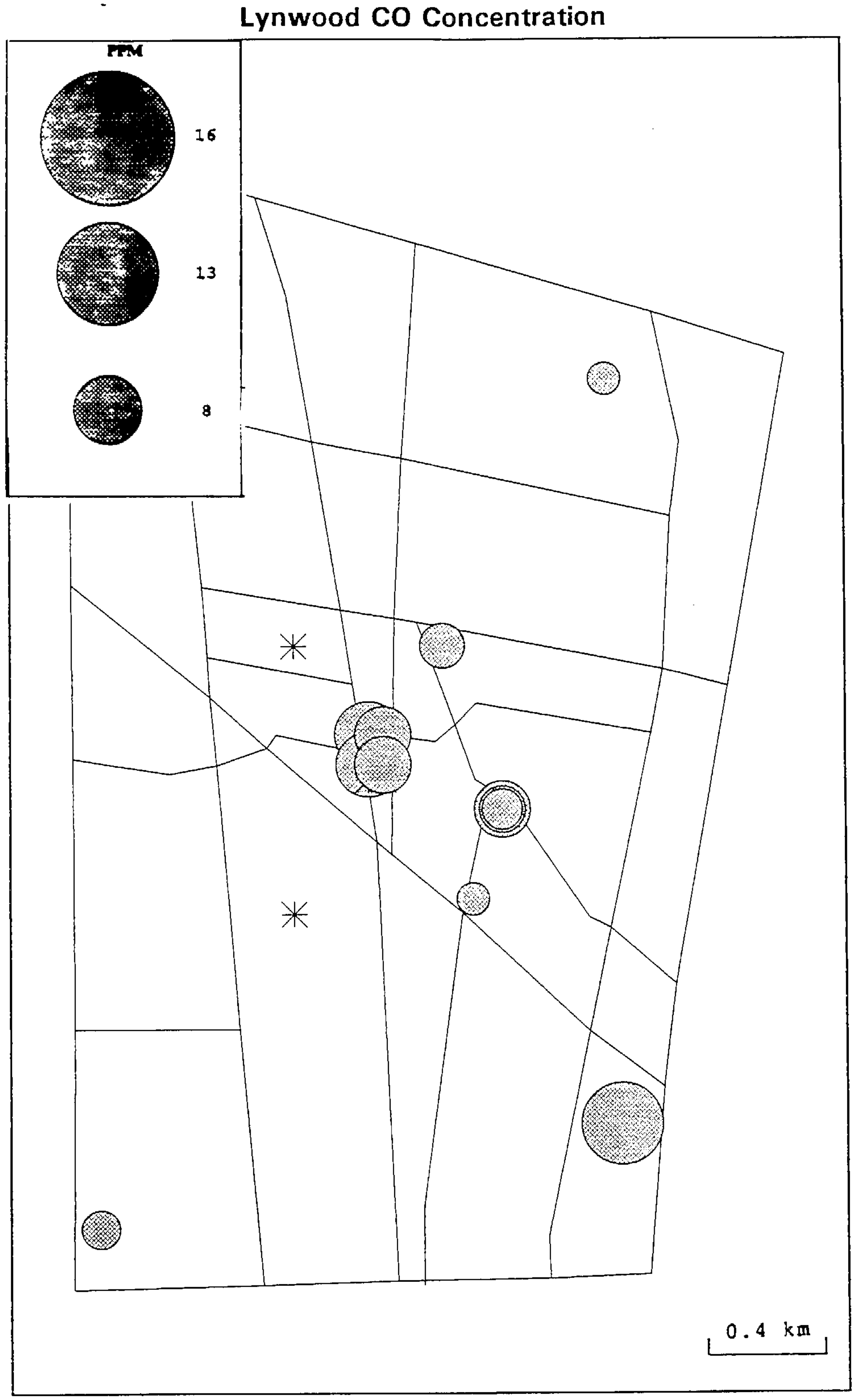
Lynwood CO Concentration



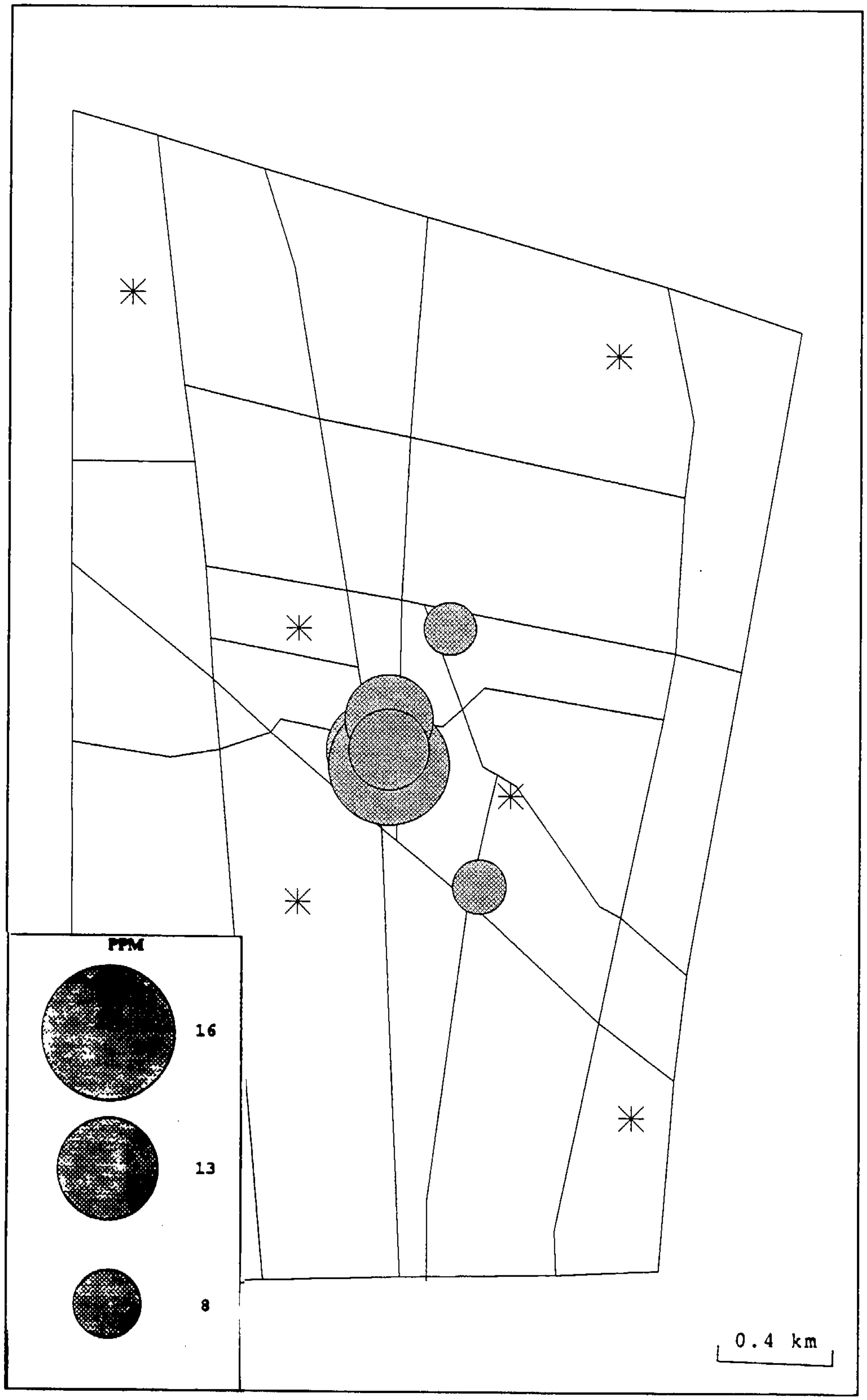
CO 01/09/1990 02:00



CO 01/09/1990 03:00

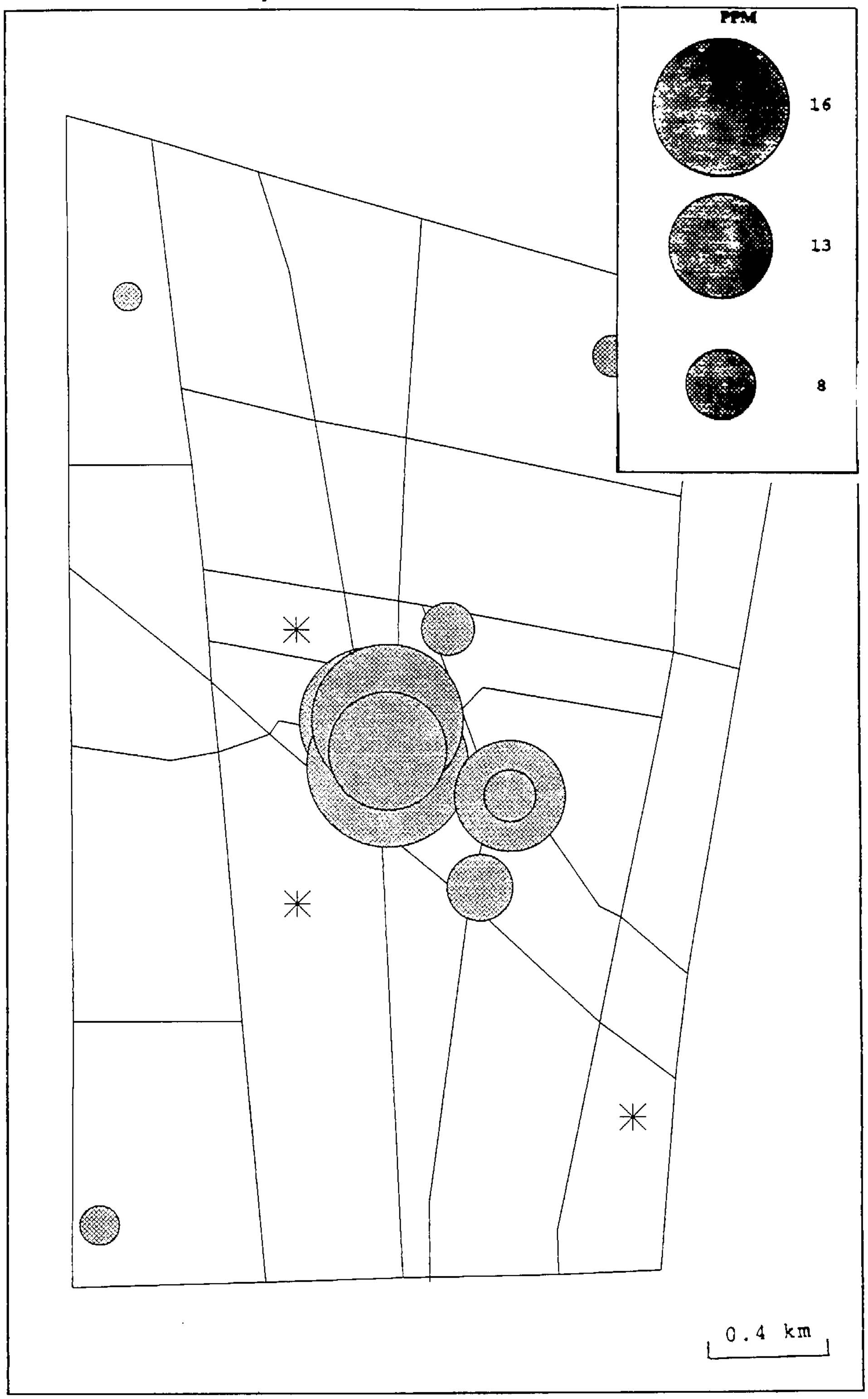


CO 01/09/1990 04:00



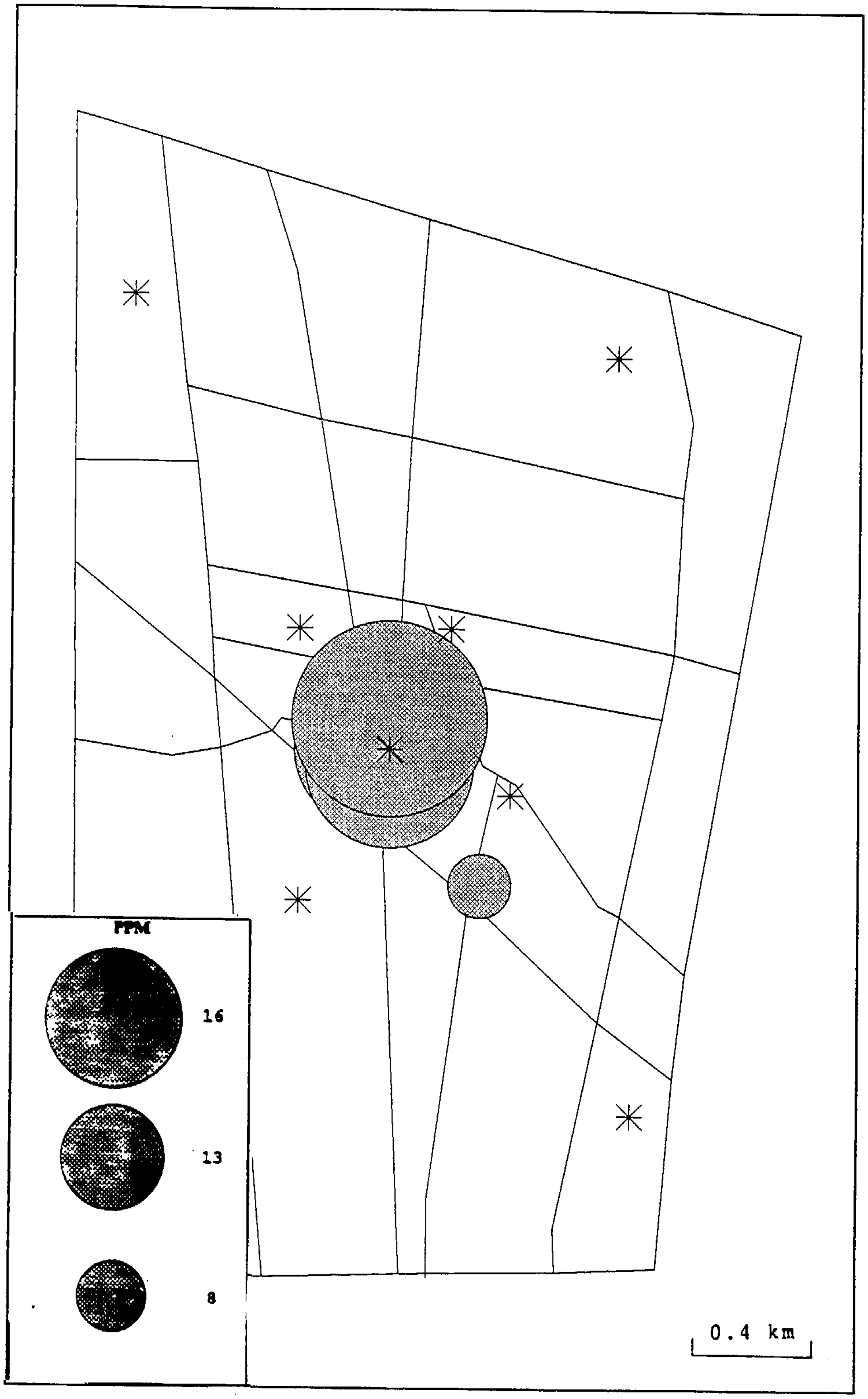
CO 01/09/1990 05:00

Lynwood CO Concentration



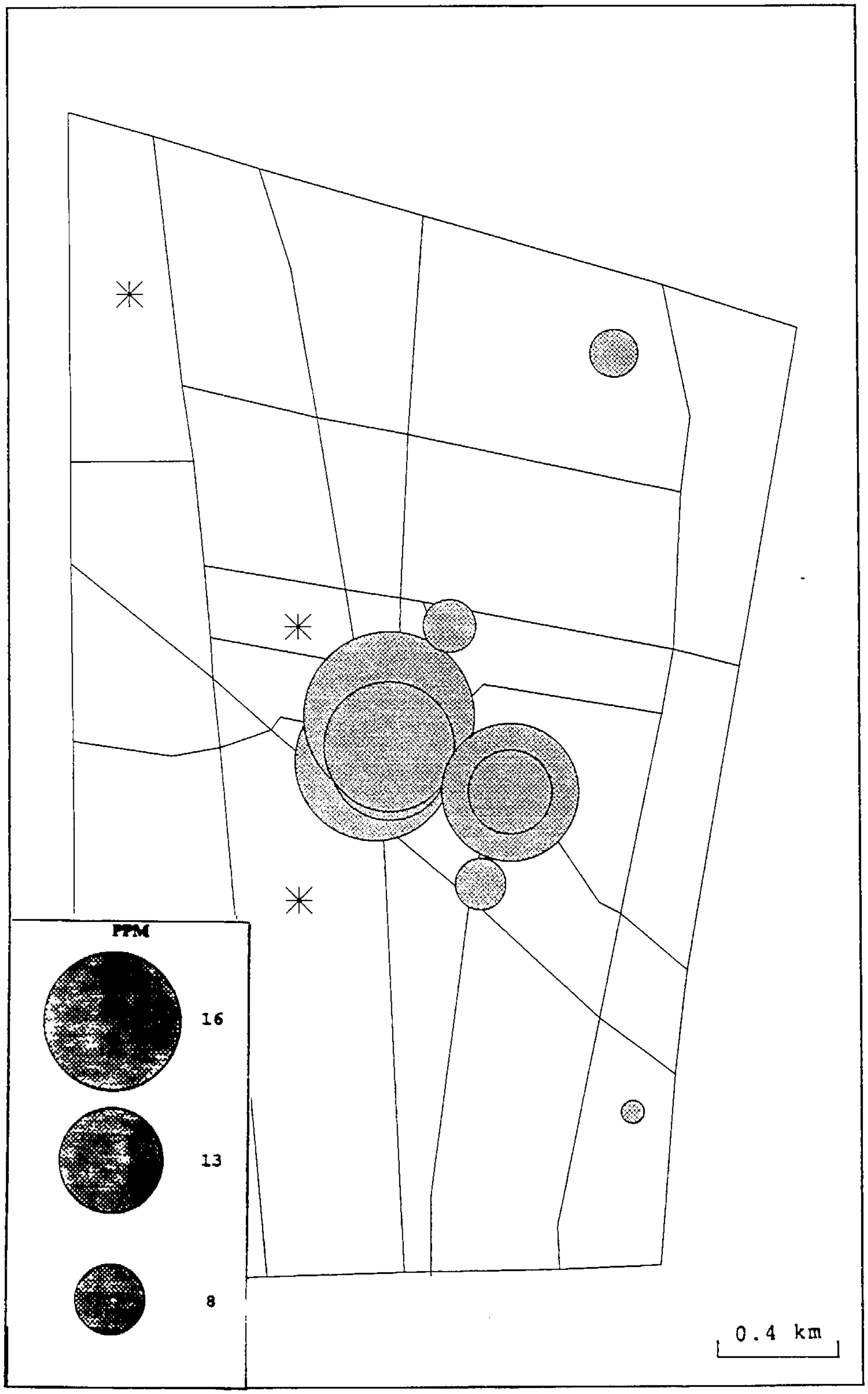
CO 01/09/1990 06:00

Lynwood CO Concentration



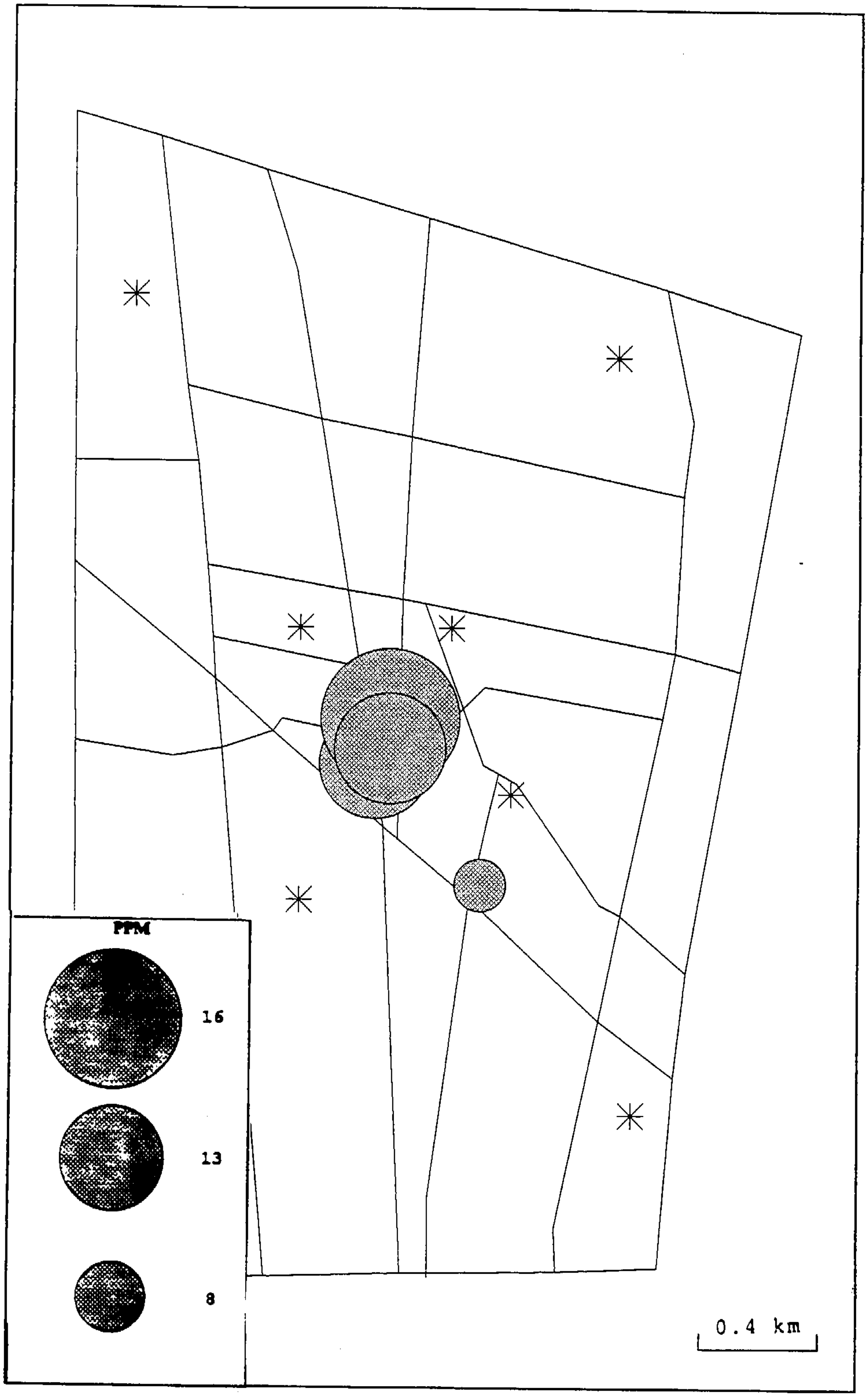
CO 01/09/1990 07:00

Lynwood CO Concentration



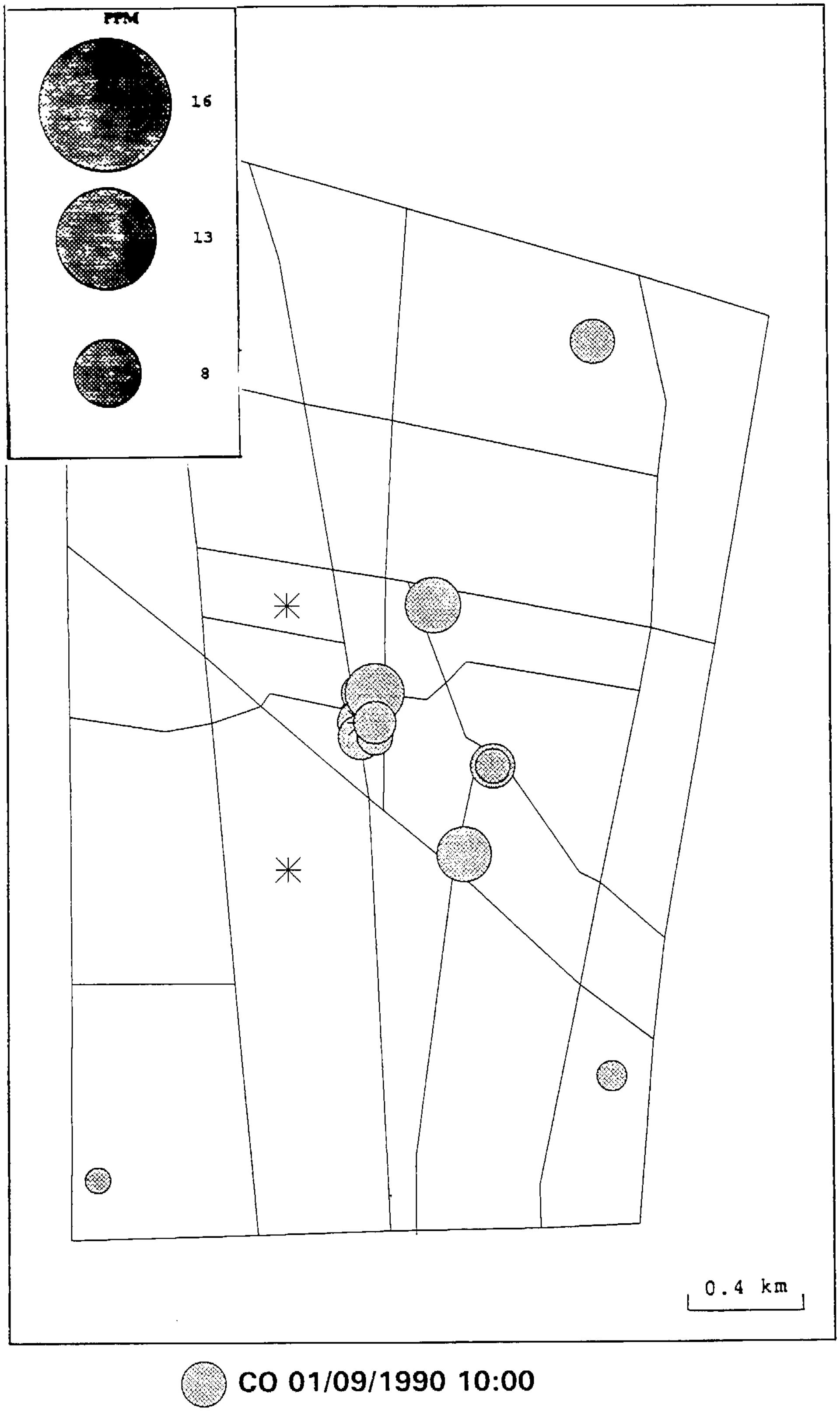
CO 01/09/1990 08:00

Lynwood CO Concentration

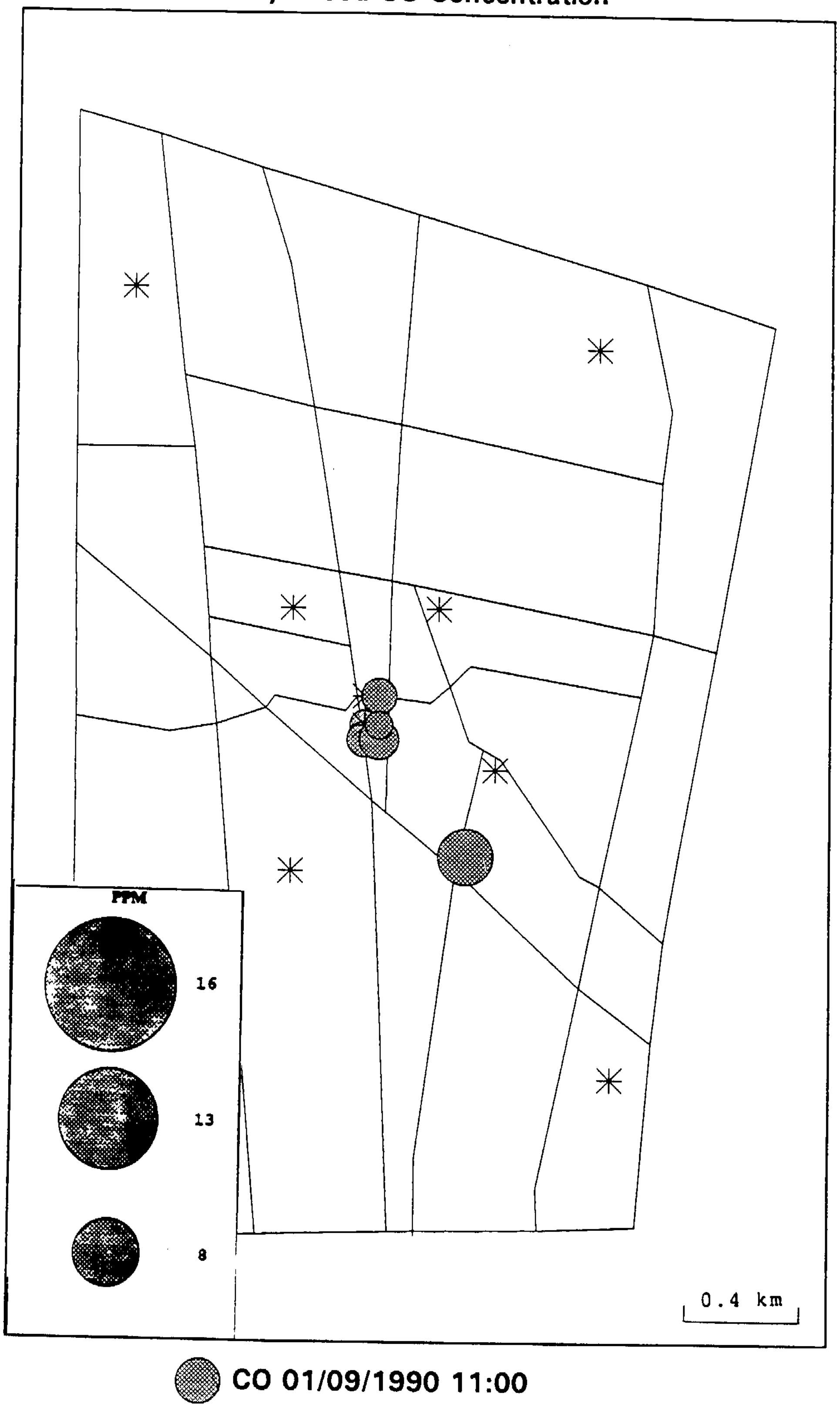


CO 01/09/1990 09:00

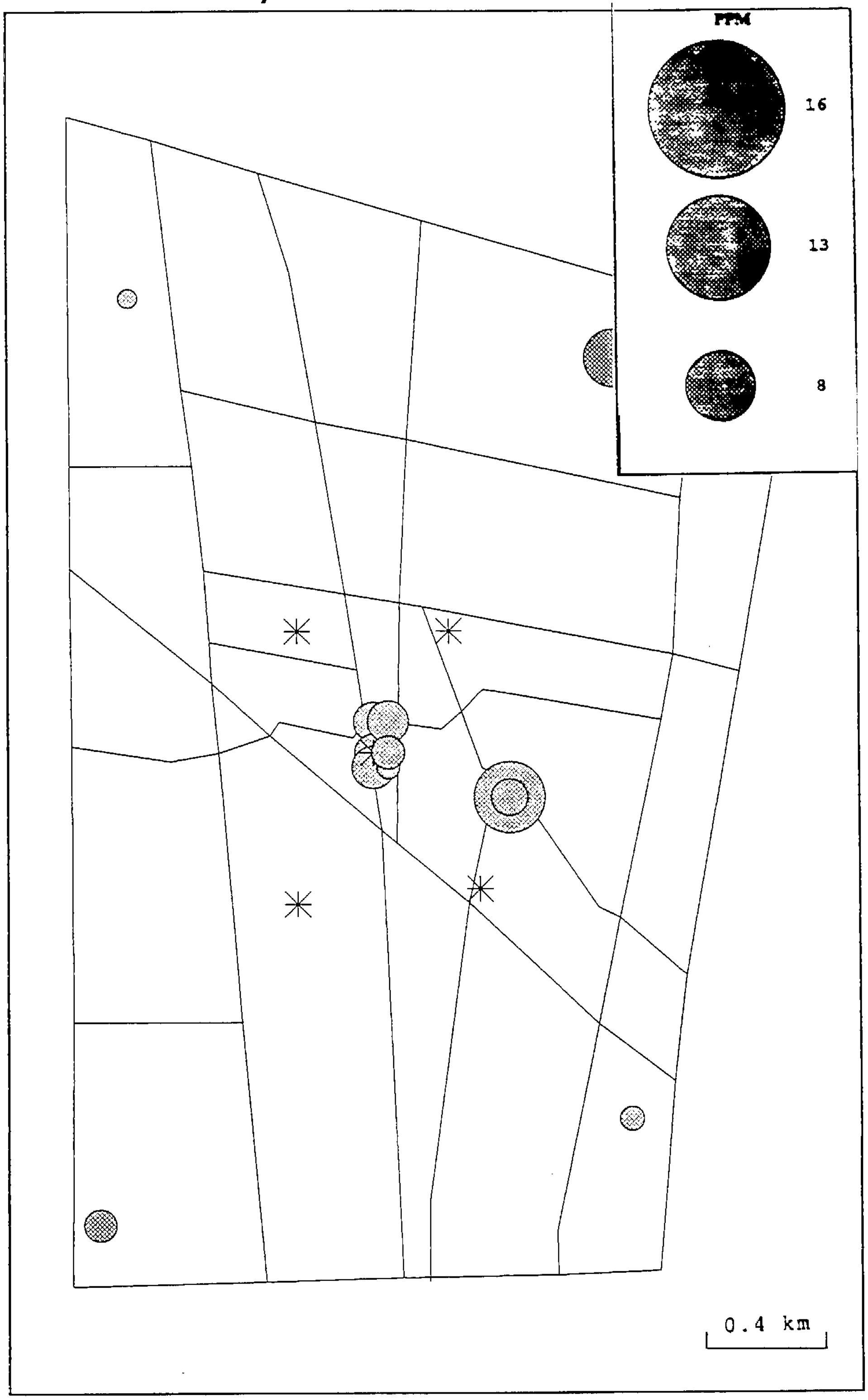
Lynwood CO Concentration



Lynwood CO Concentration

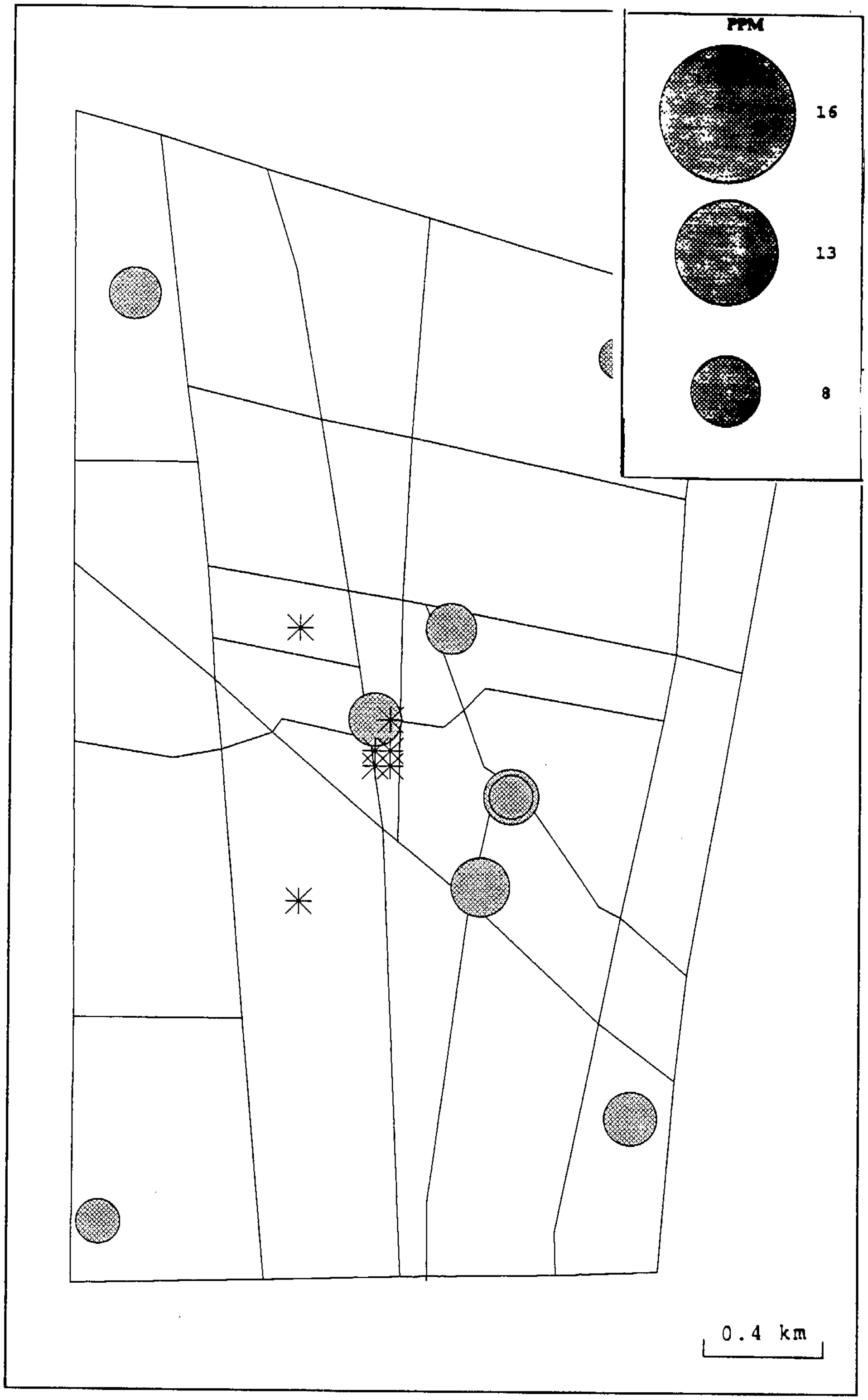


Lynwood CO Concentration



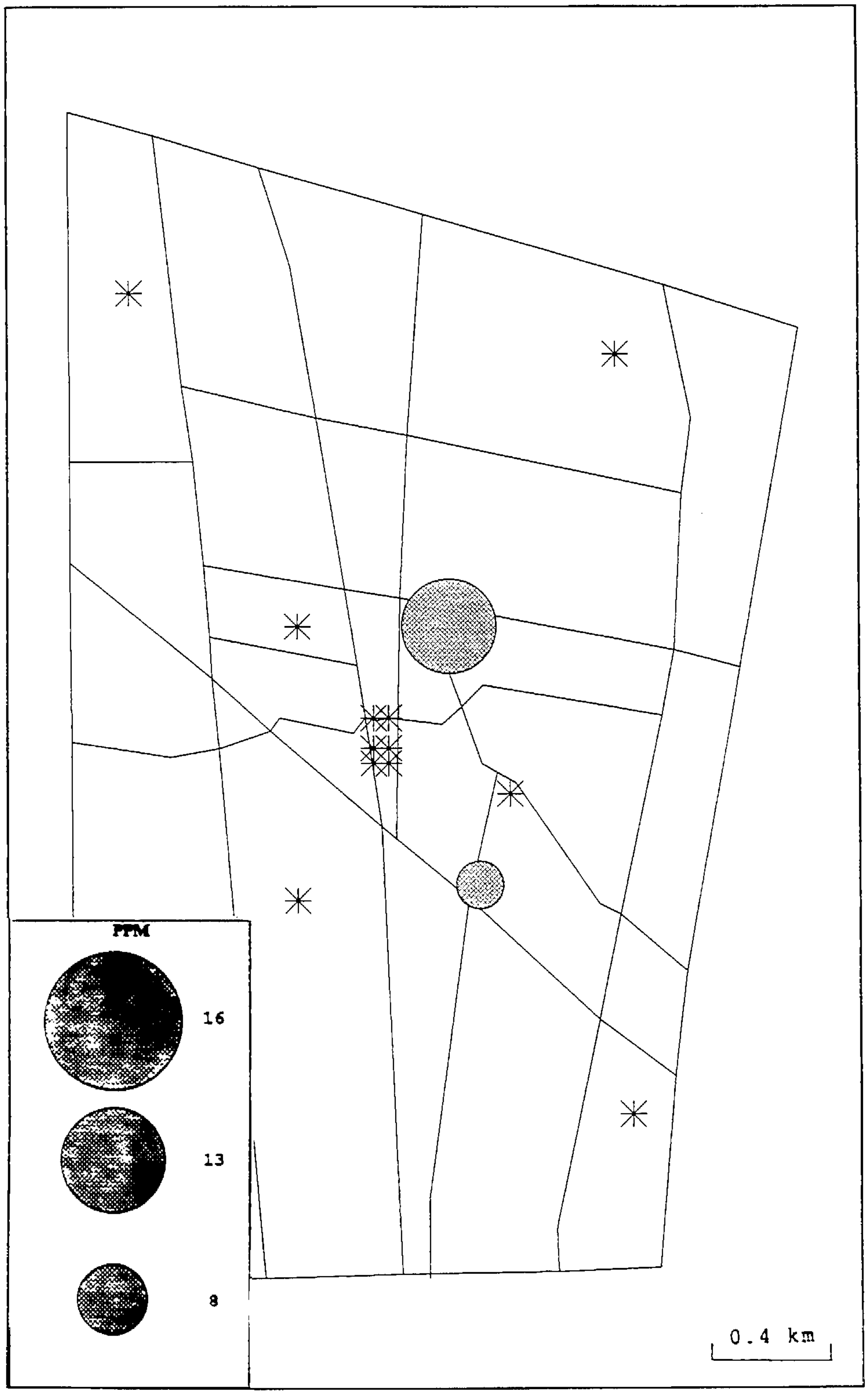
CO 01/09/1990 12:00

Lynwood CO Concentration

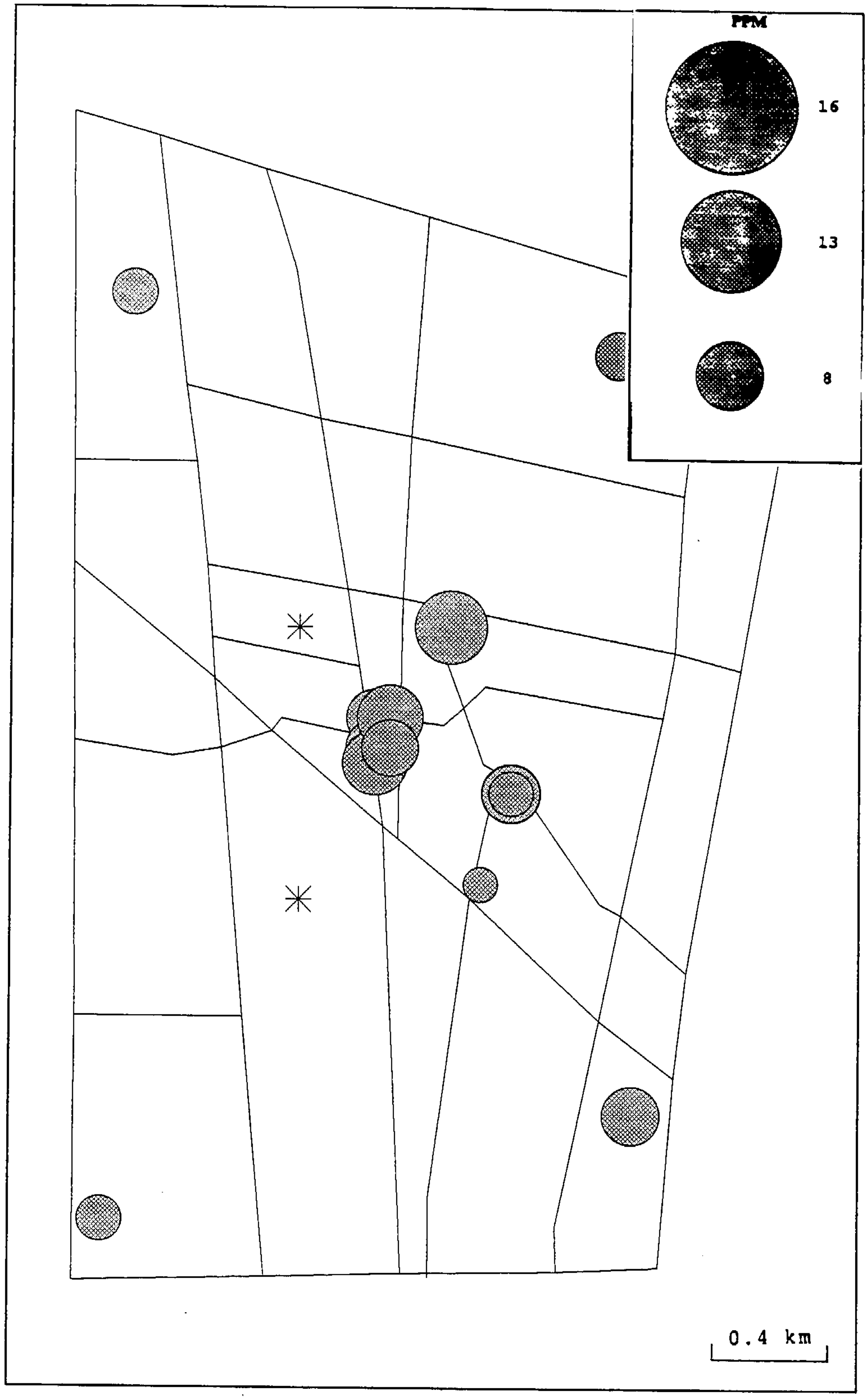


CO 01/09/1990 16:00

Lynwood CO Concentration

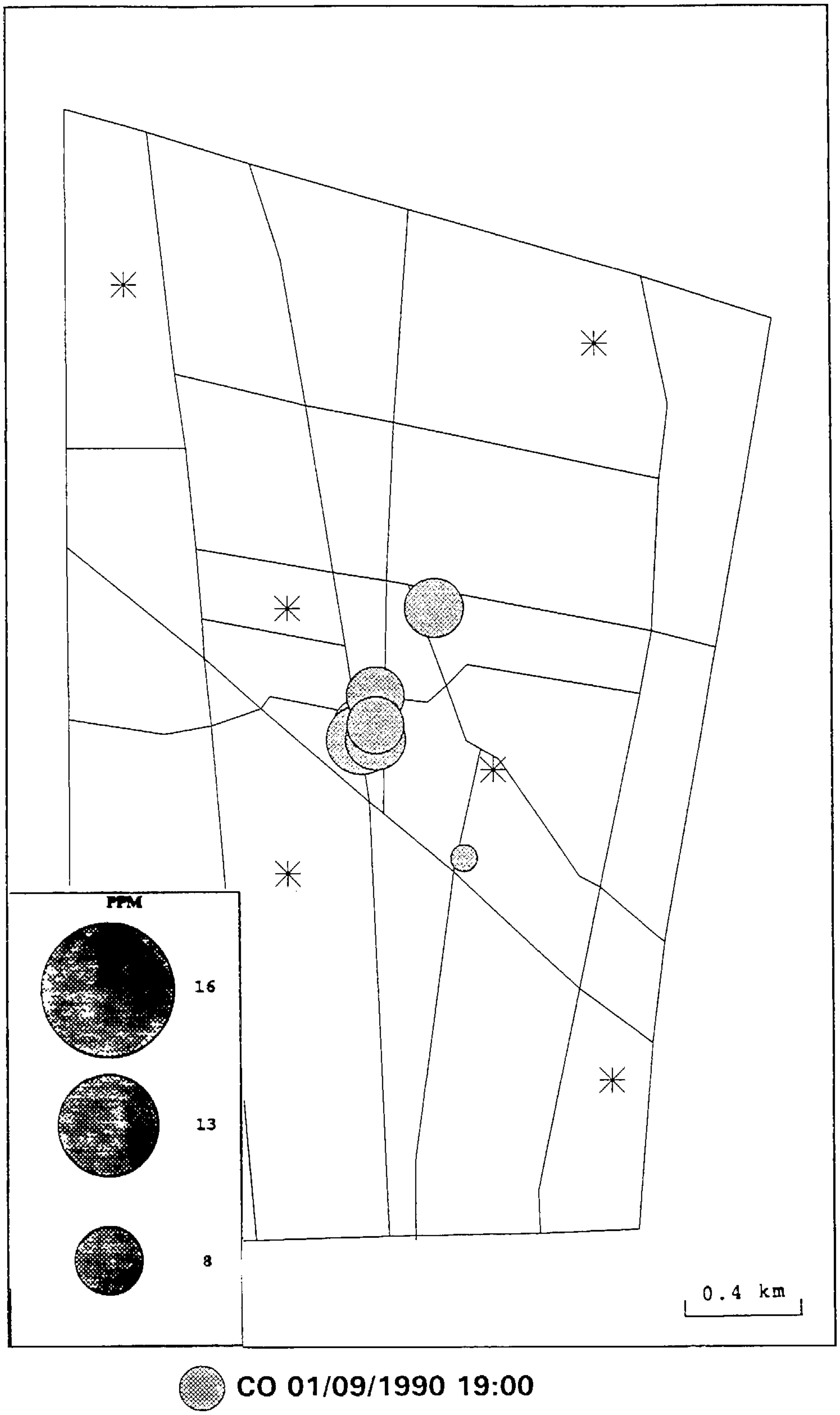


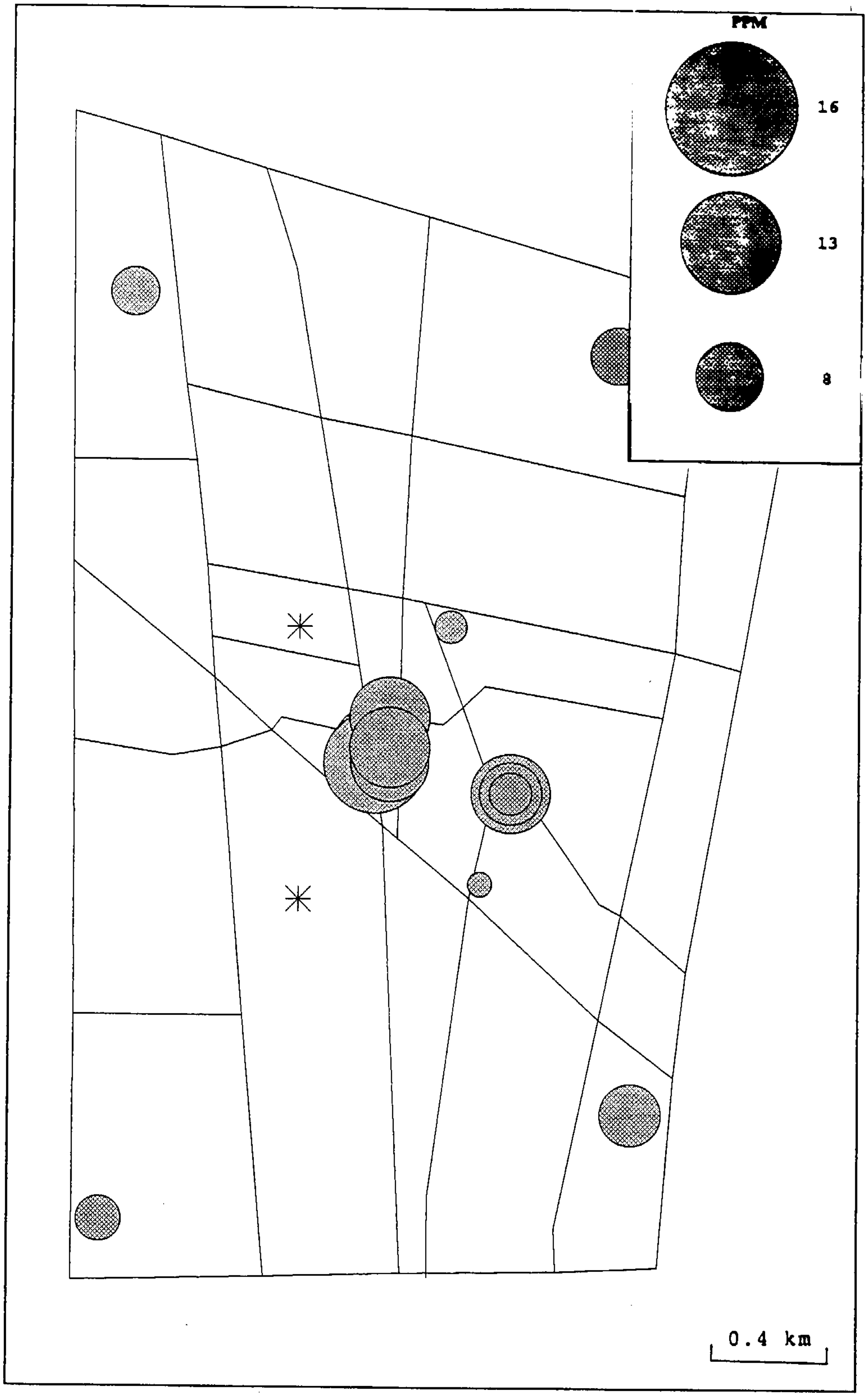
CO 01/09/1990 17:00



CO 01/09/1990 18:00

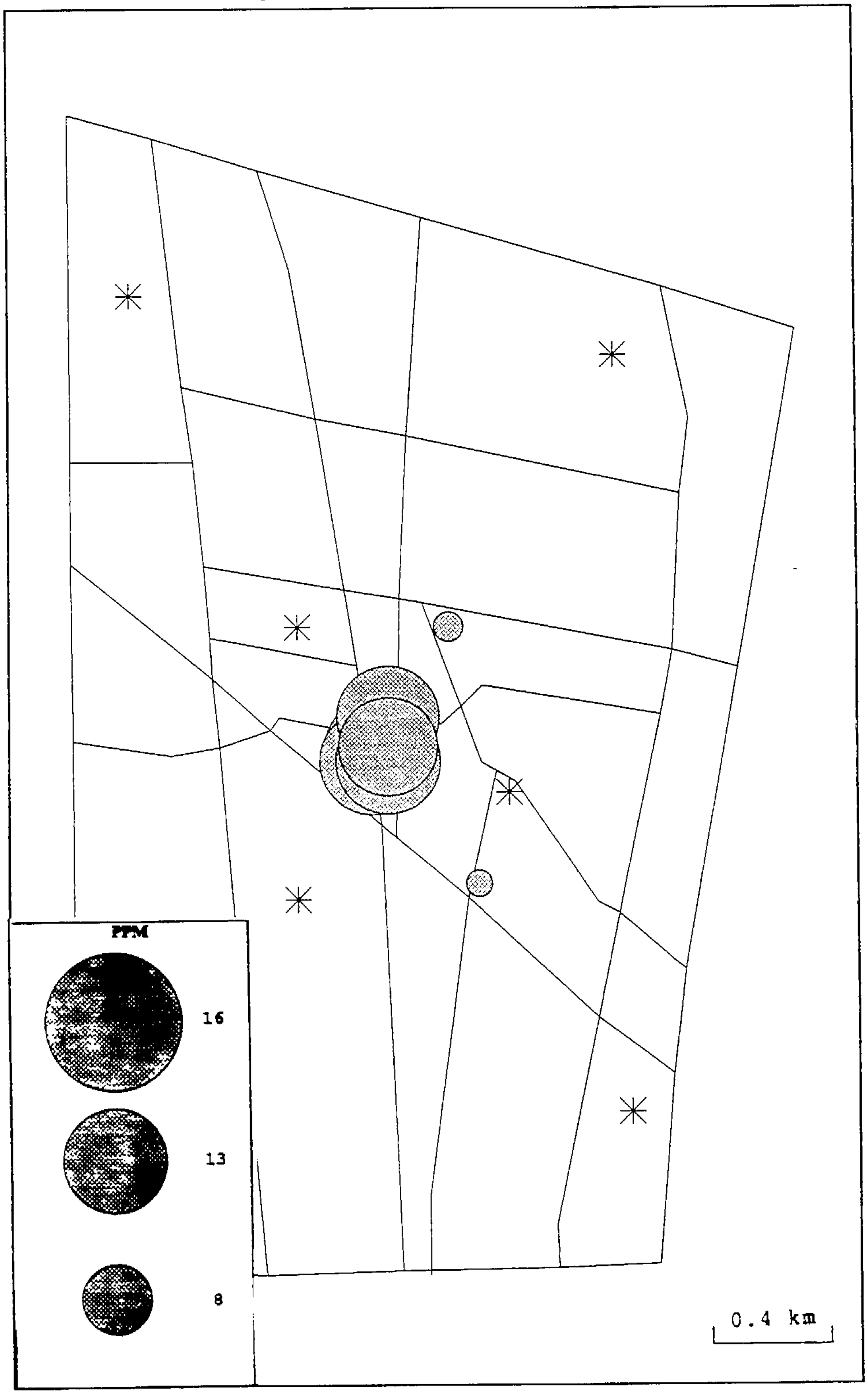
Lynwood CO Concentration



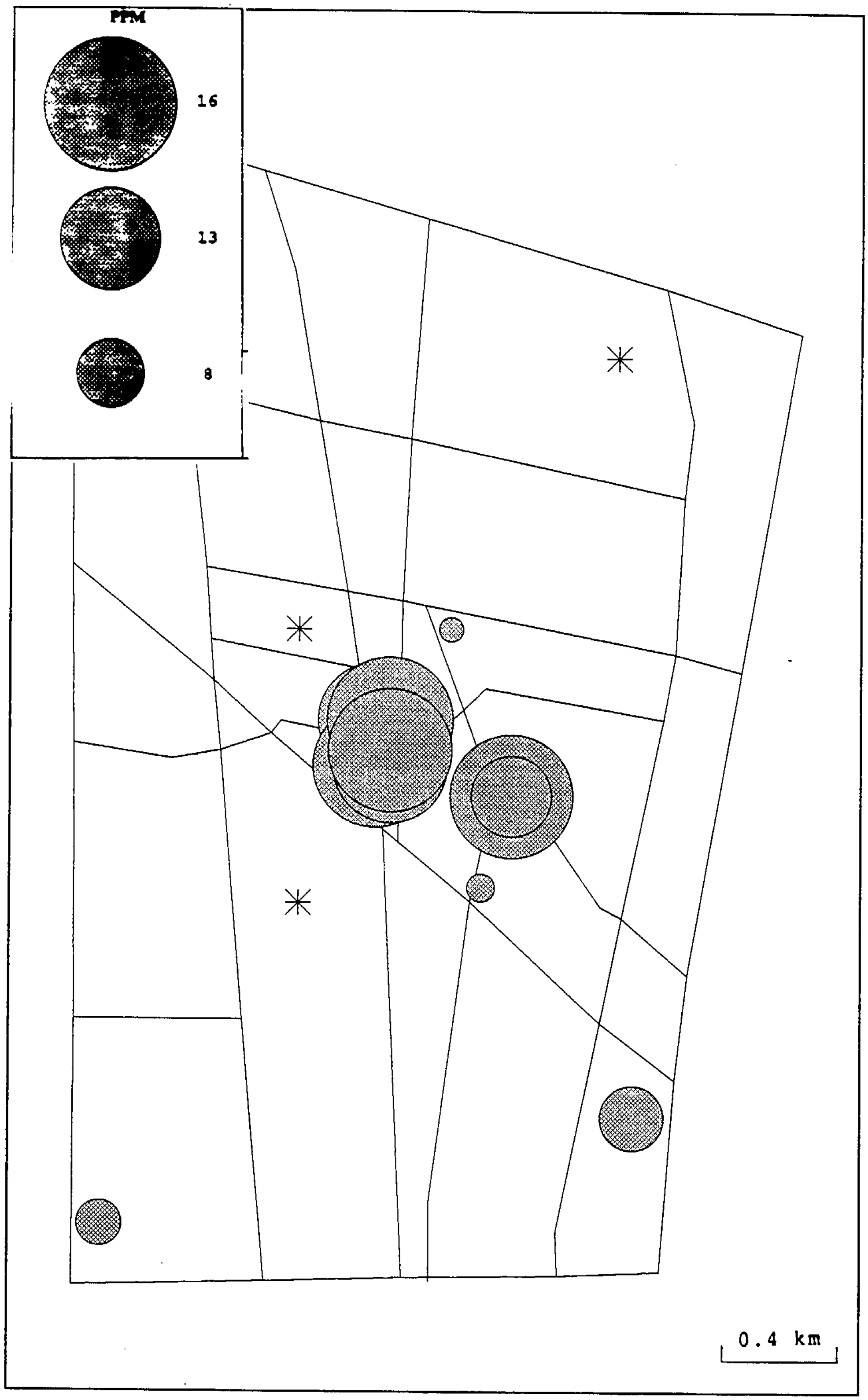


CO 01/09/1990 20:00

Lynwood CO Concentration

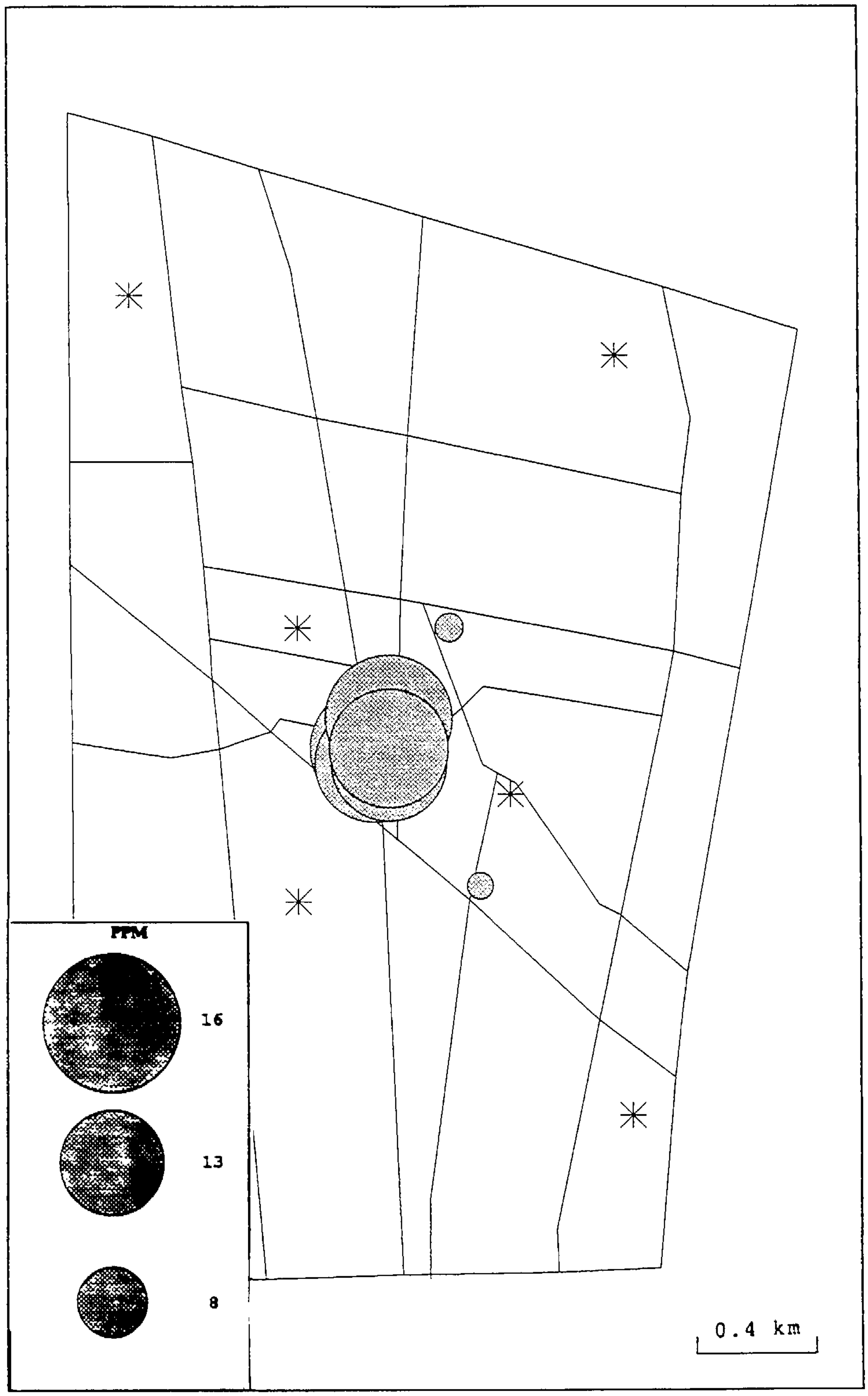


CO 01/09/1990 21:00

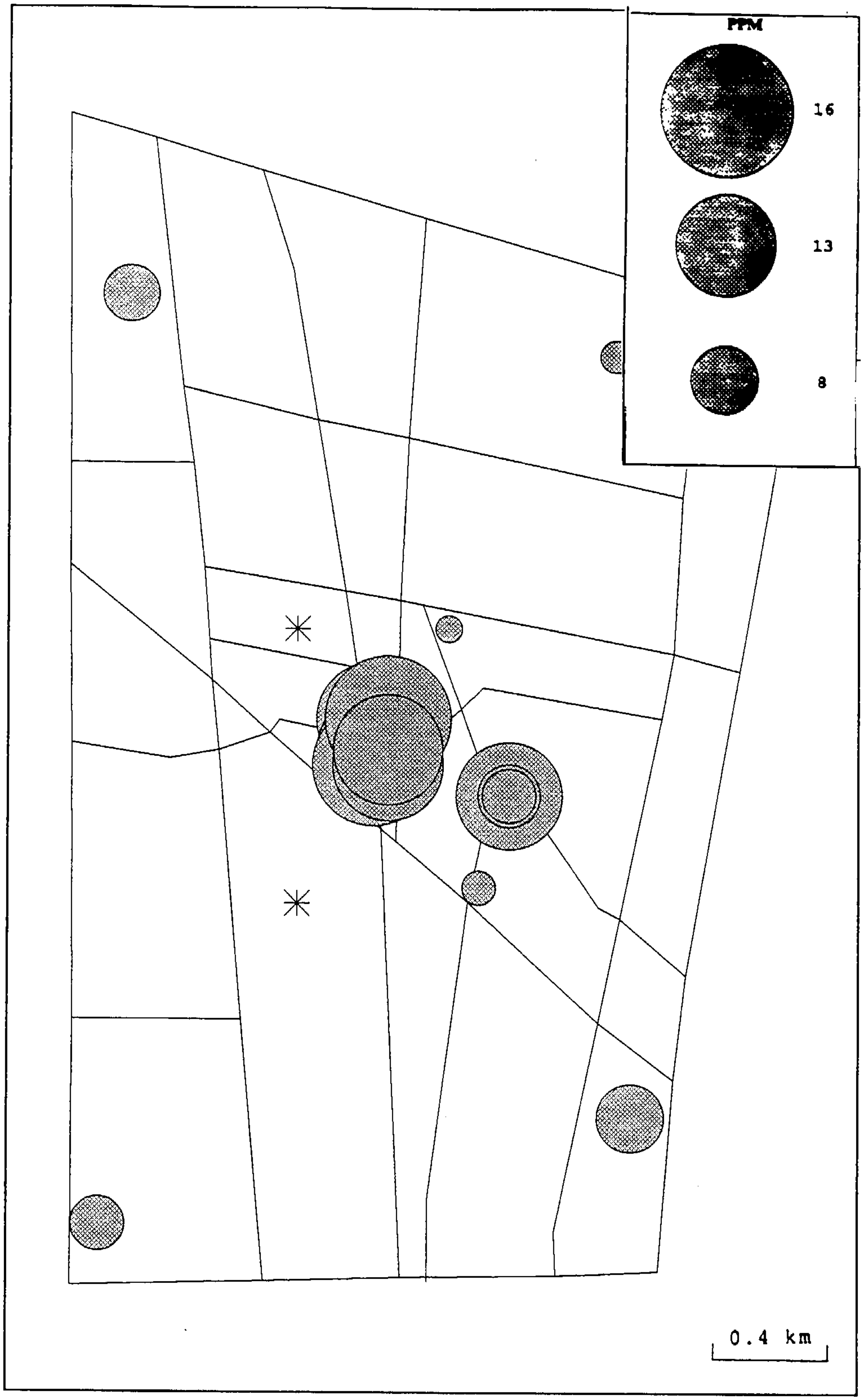


CO 01/09/1990 22:00

Lynwood CO Concentration

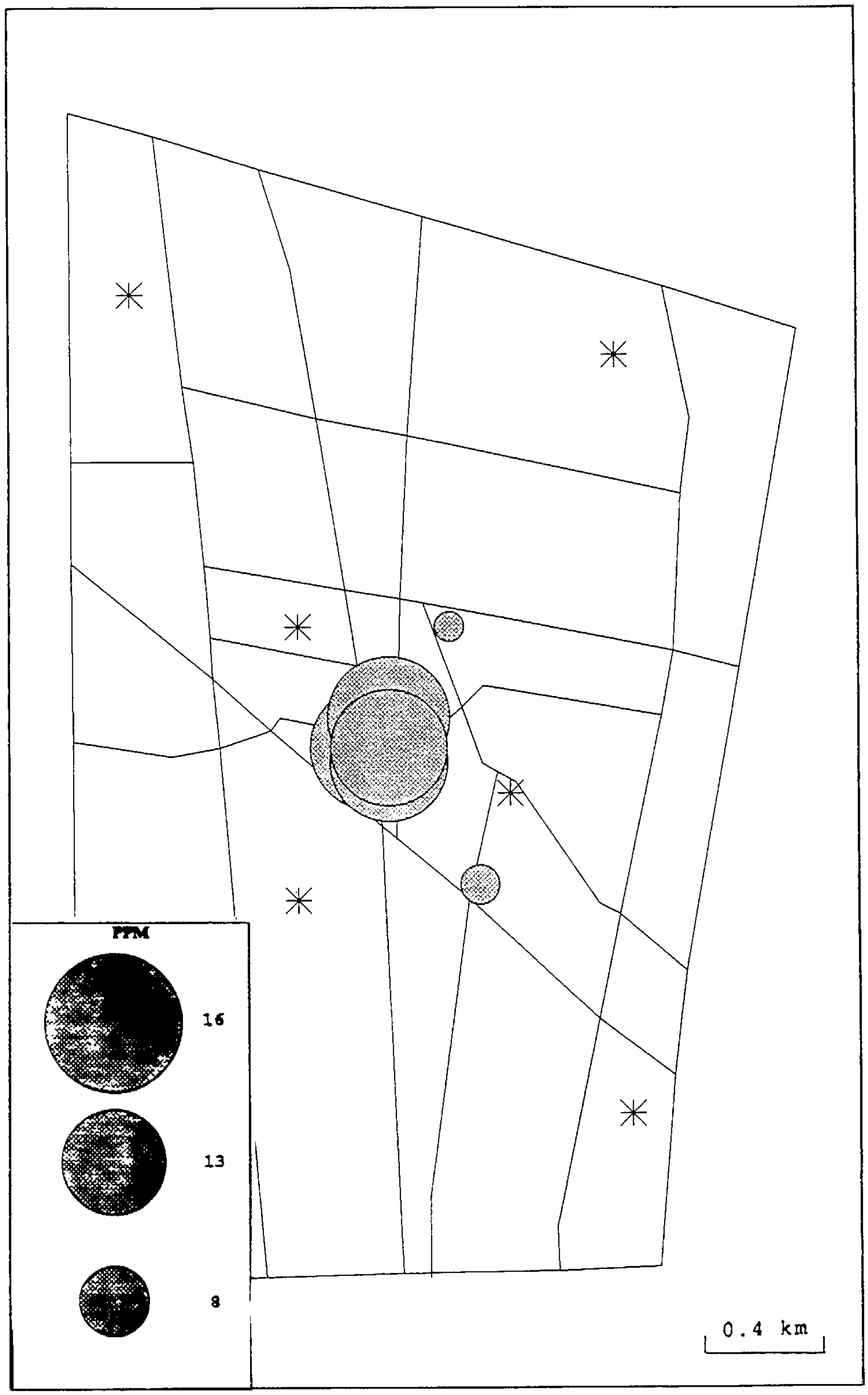


CO 01/09/1990 23:00

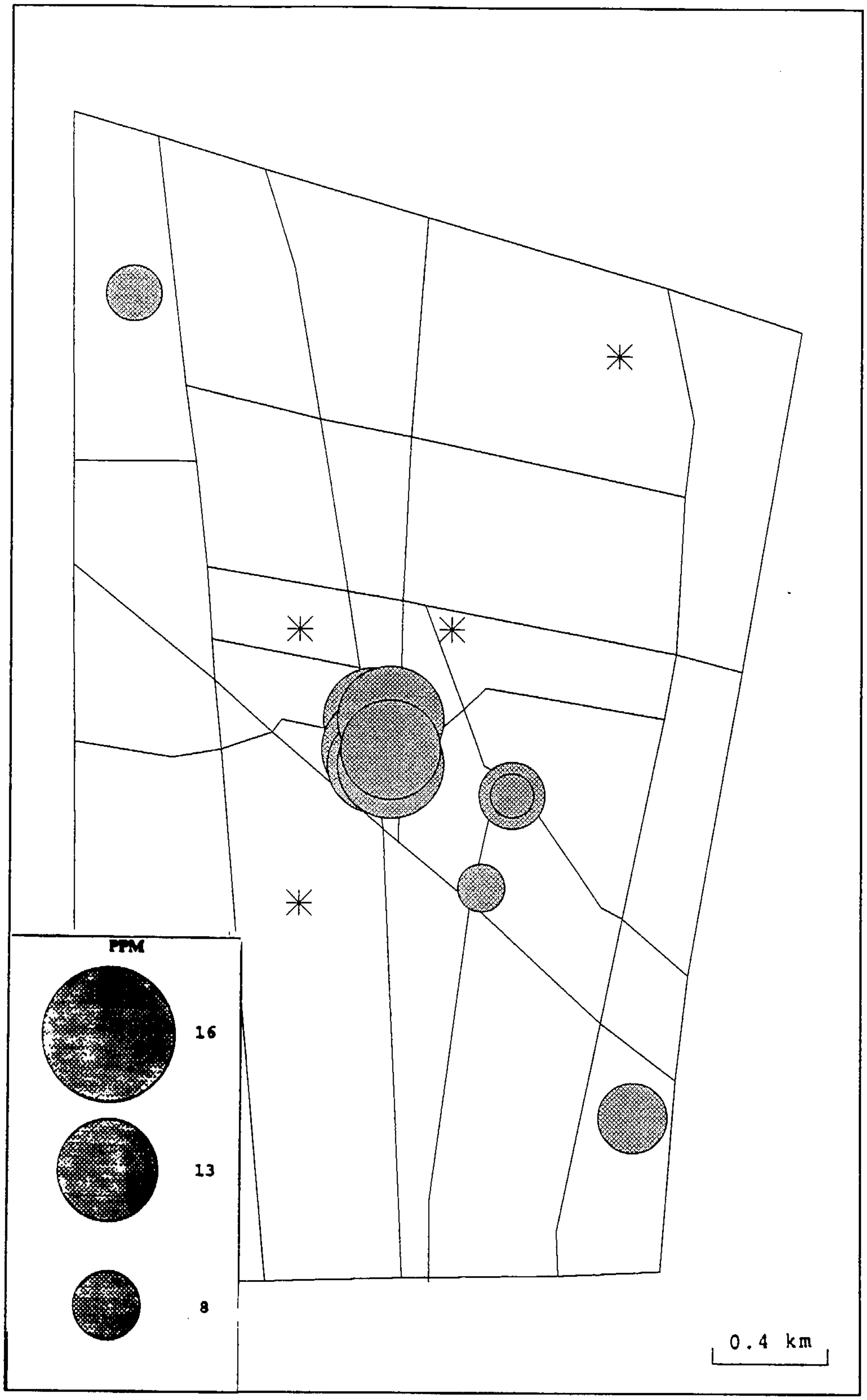


CO 01/10/1990 00:00

Lynwood CO Concentration



CO 01/10/1990 01:00

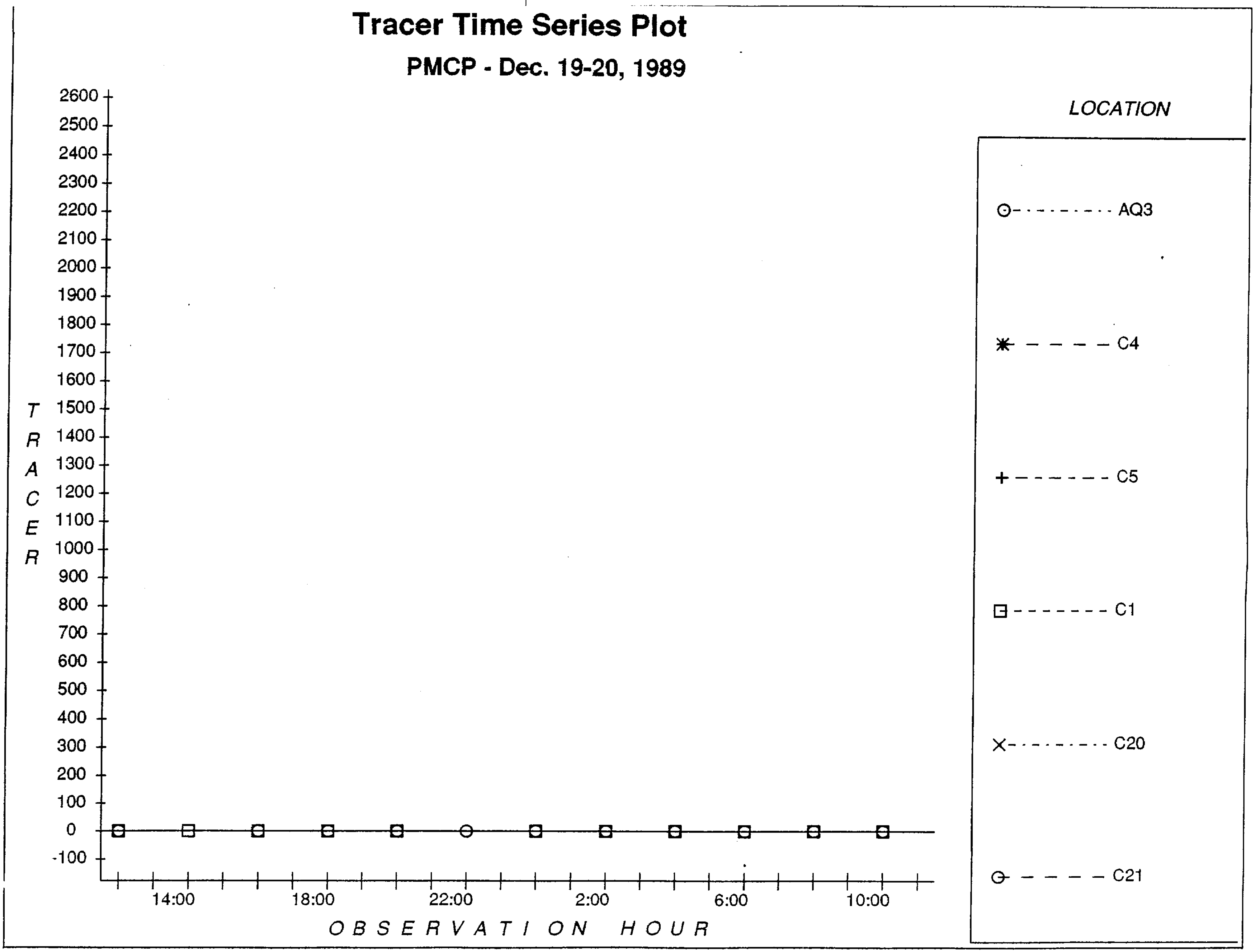


CO 01/10/1990 02:00

Appendix D

TRACER TIME SERIES PLOTS

Appendix D-1


Tracer Time Series Plot
PMCP - Dec. 19-20, 1989
TRACER
2600
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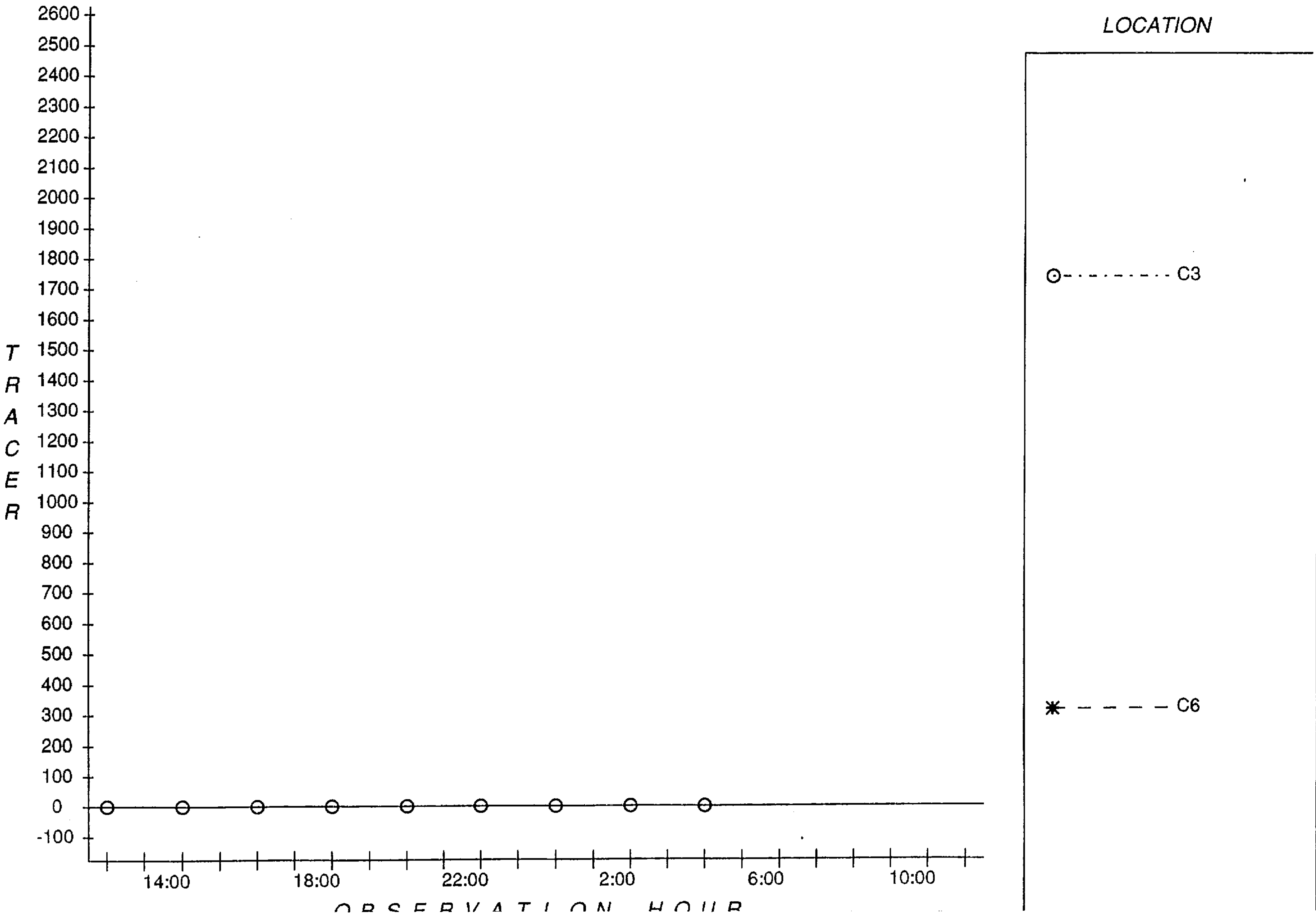
OBSERVATION HOUR
LOCATION
AQ3
C4
C5
C1
C20
C21

Tracer Time Series Plot

PMCP - Dec. 19-20, 1989



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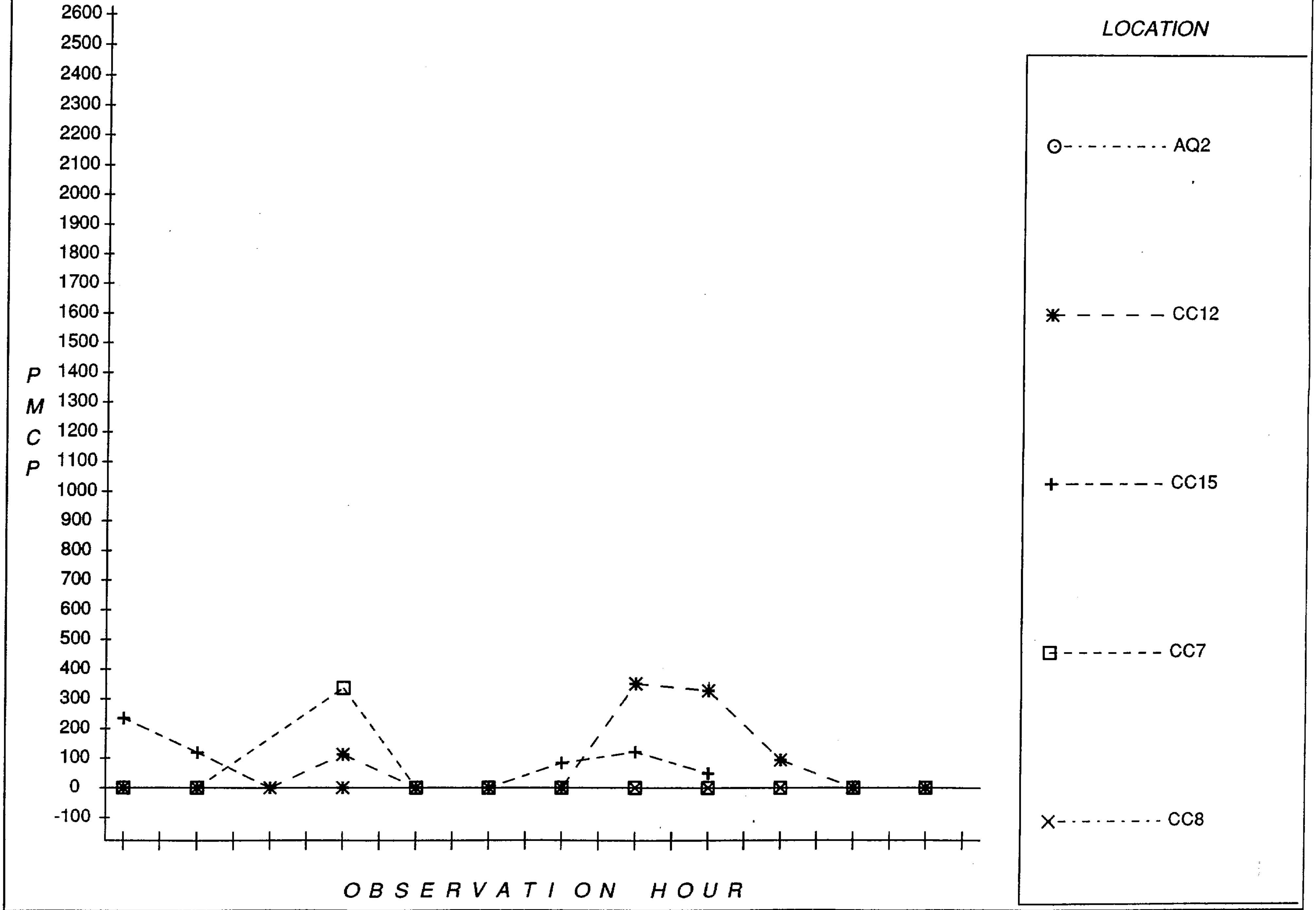
PMCP - Dec. 19-20, 1989



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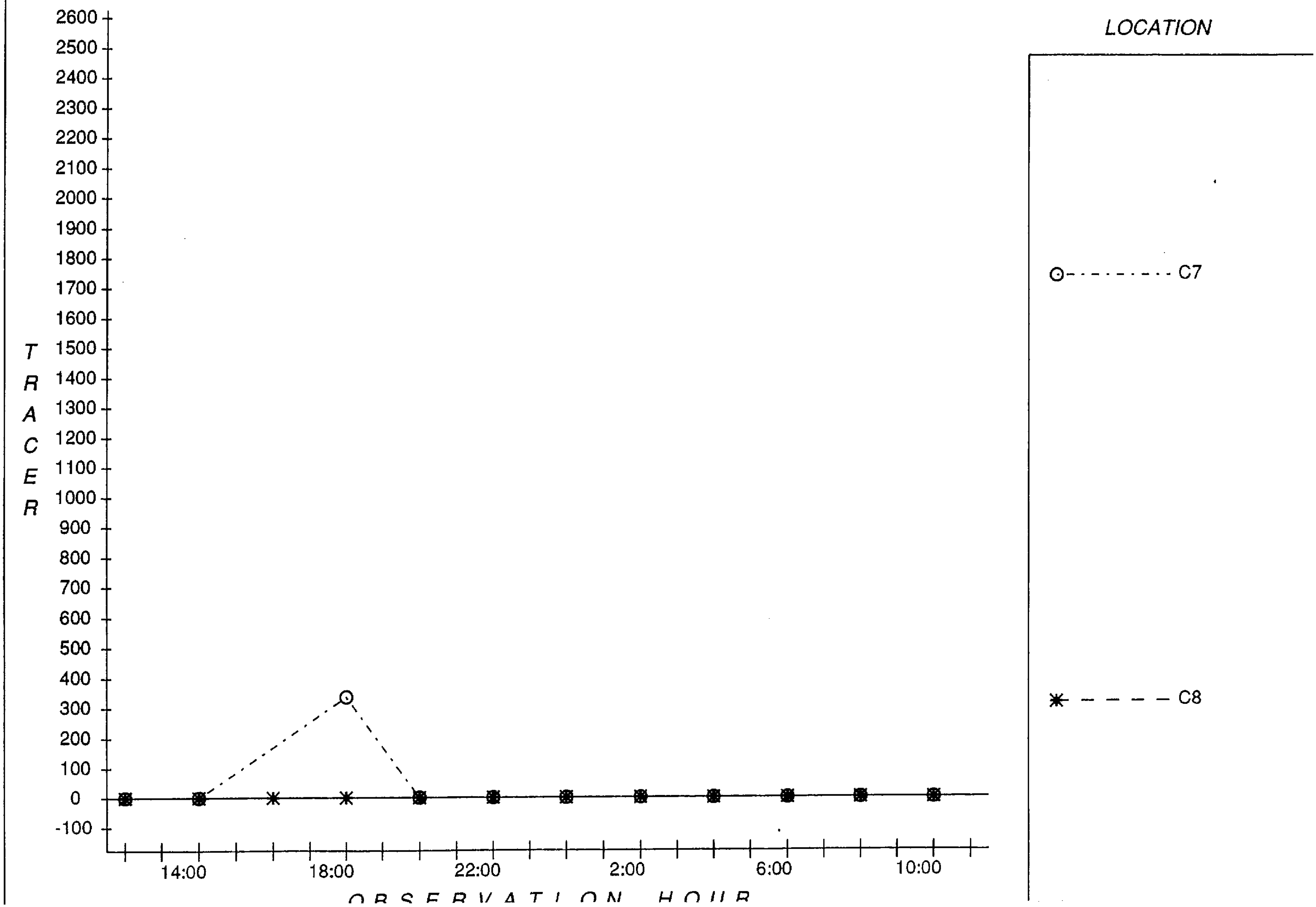
PMCP - Dec. 19-20, 1989



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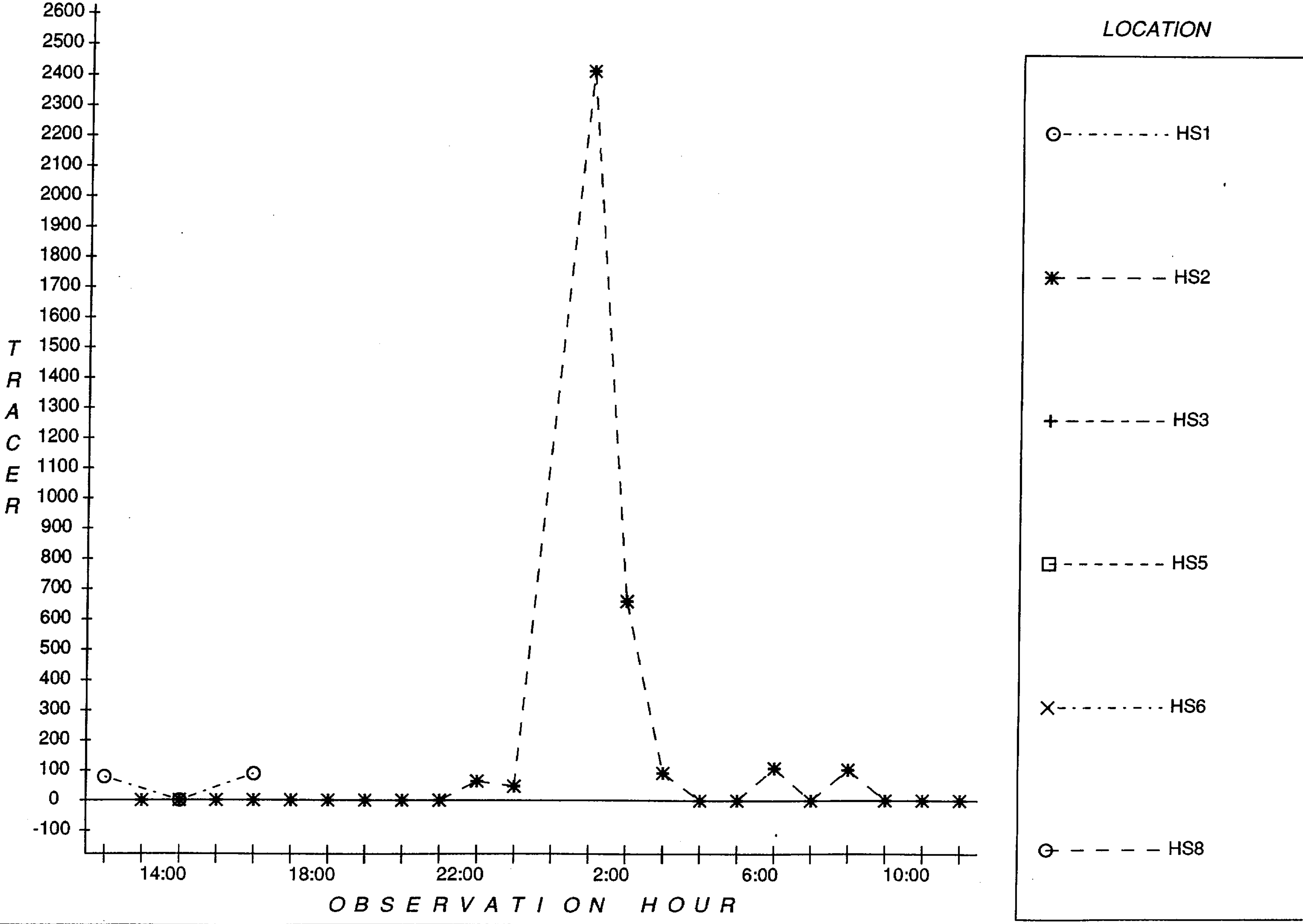
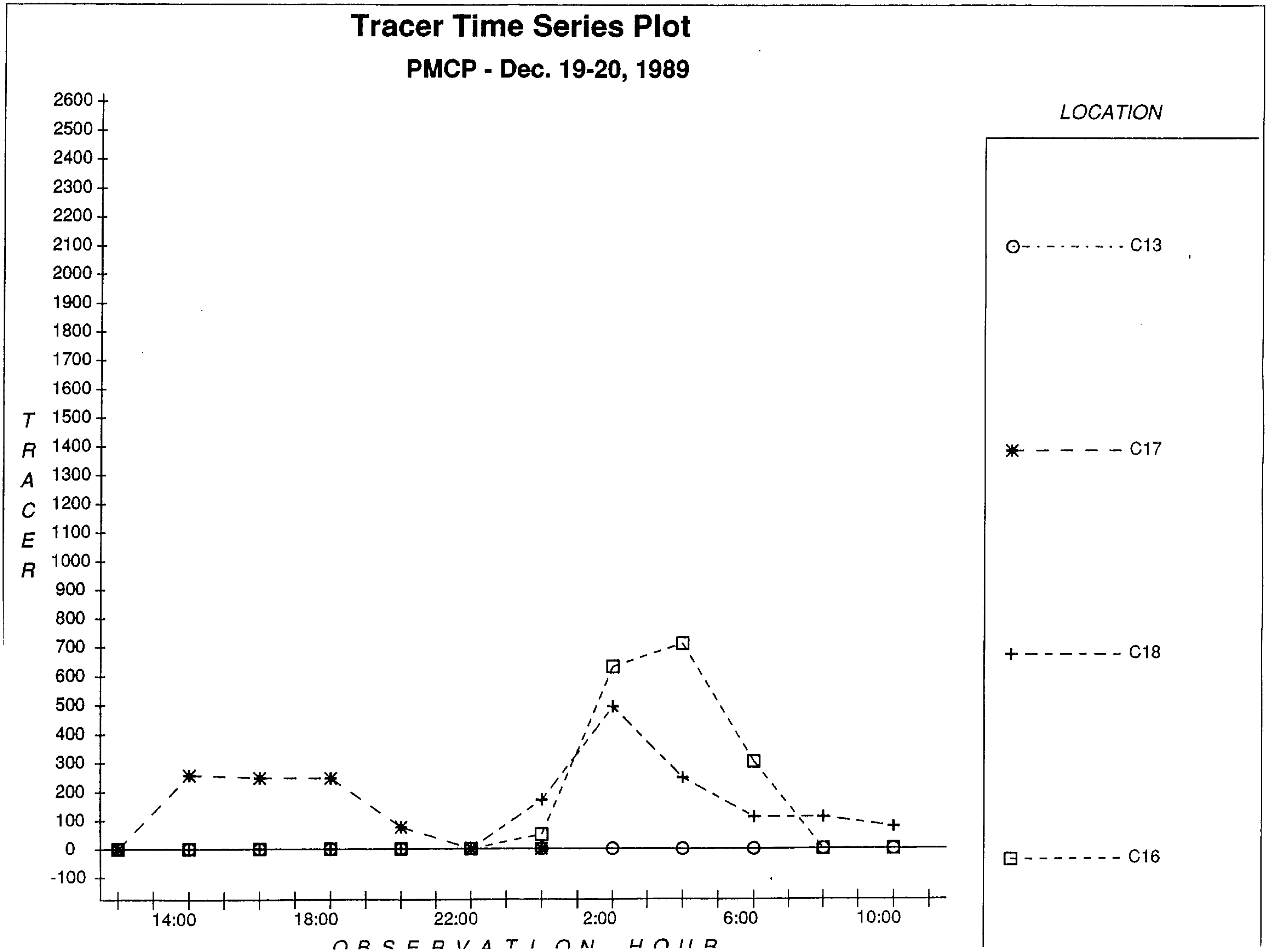
PMCP - Dec. 19-20, 1989





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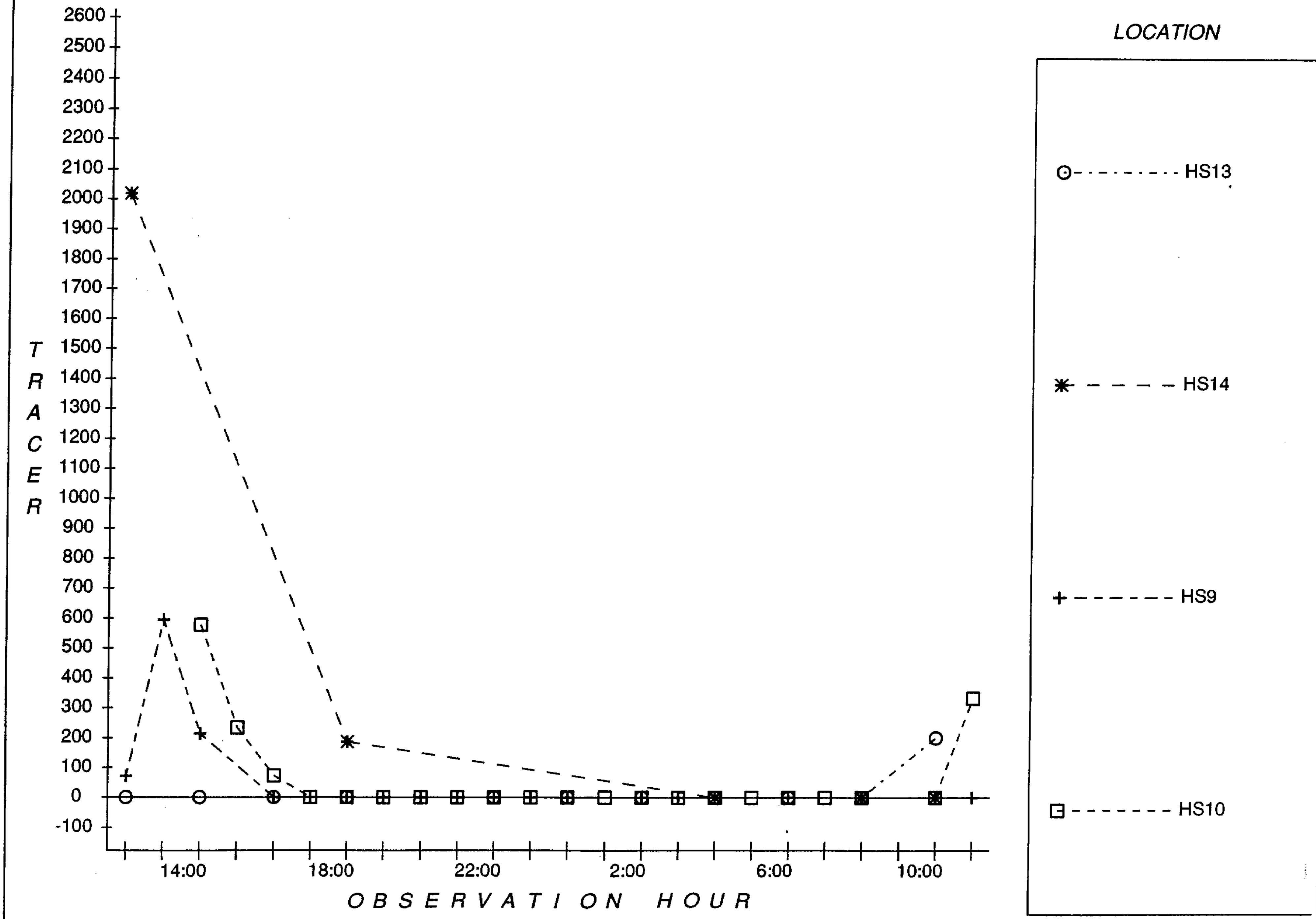
LOCATION
C13
C17
C18
C16

Tracer Time Series Plot

PMCP - Dec. 19-20, 1989



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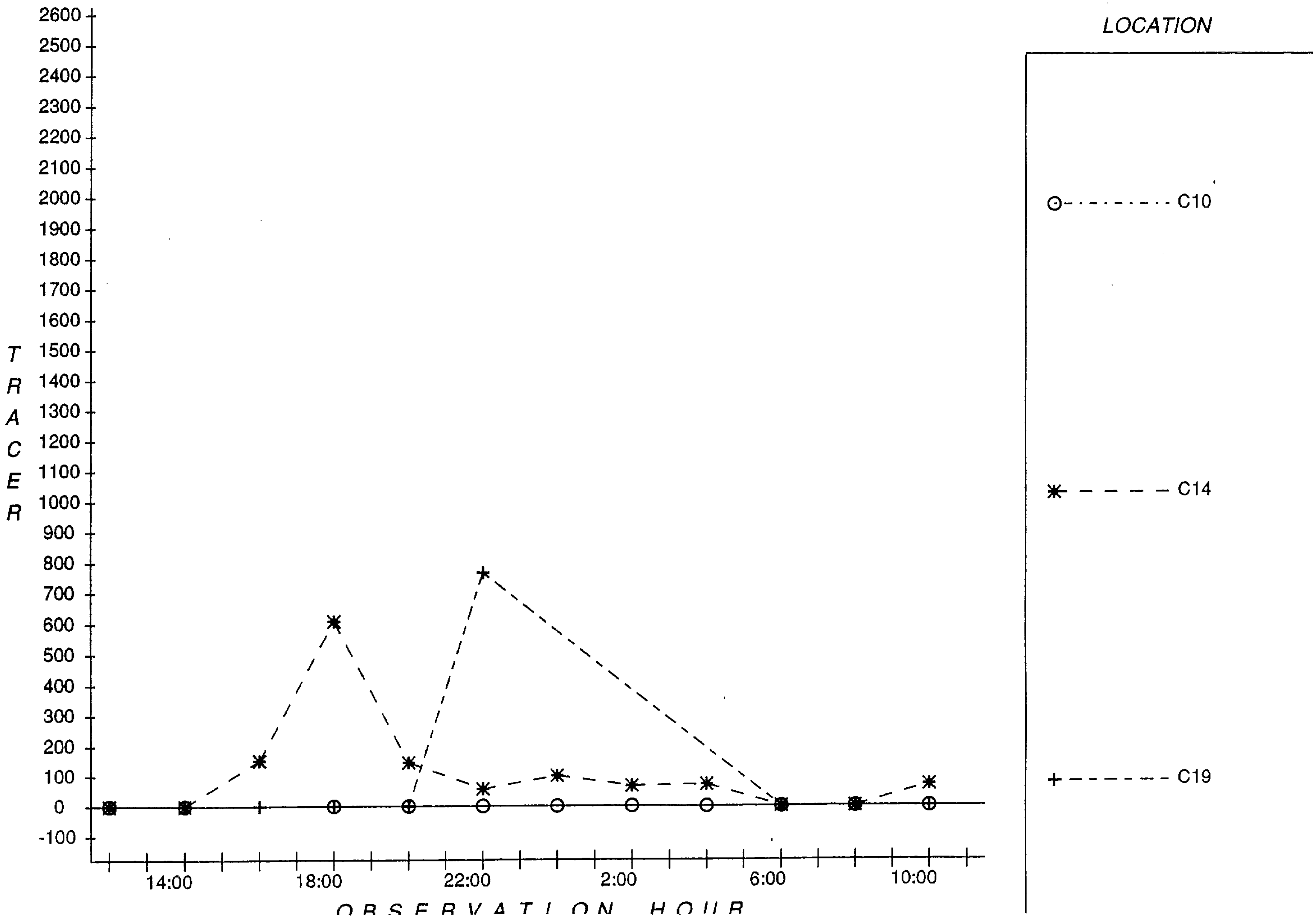
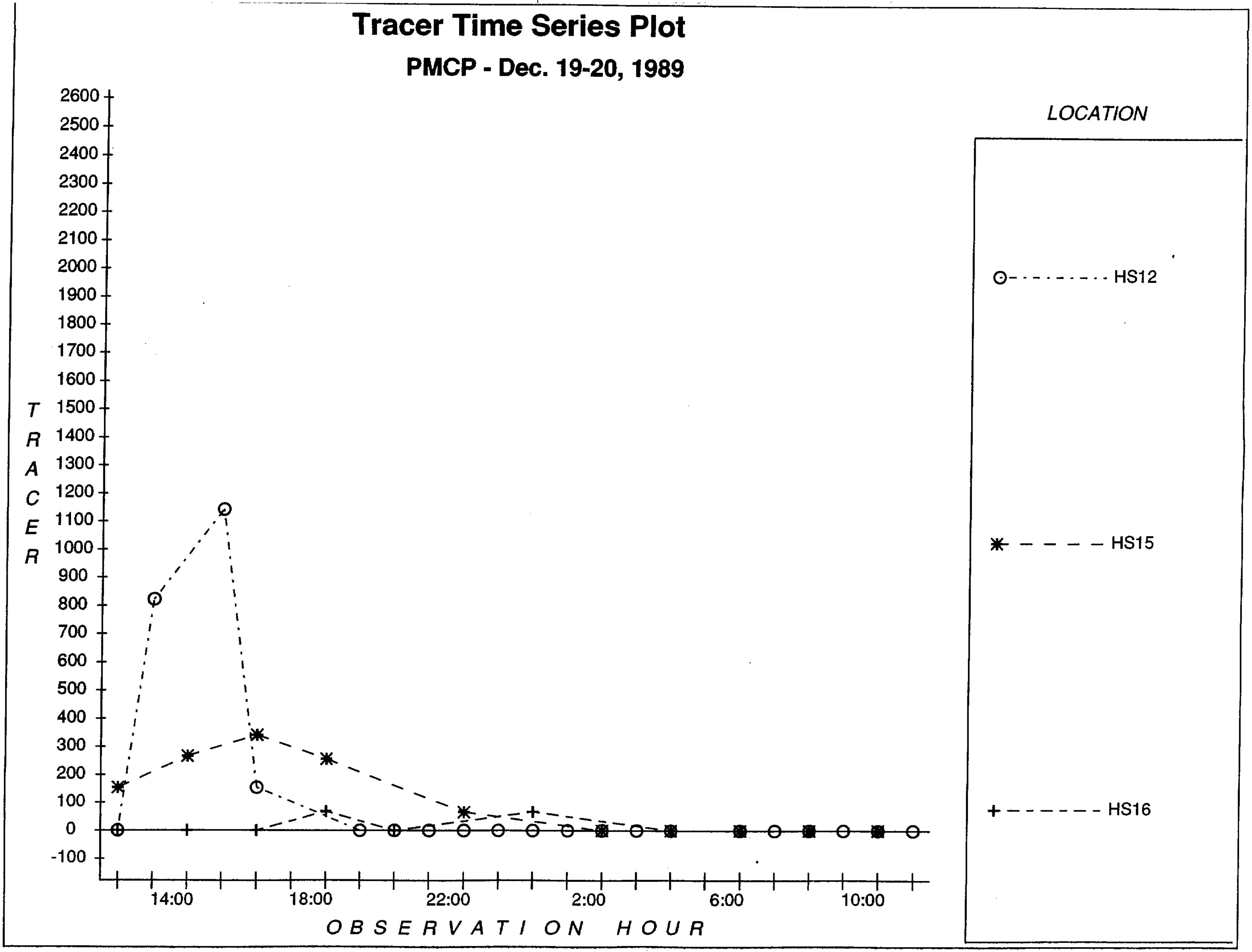
PMCP - Dec. 19-20, 1989





Tracer Time Series Plot
PMCP - Dec. 19-20, 1989
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OBSERVATION HOUR
LOCATION
HS12
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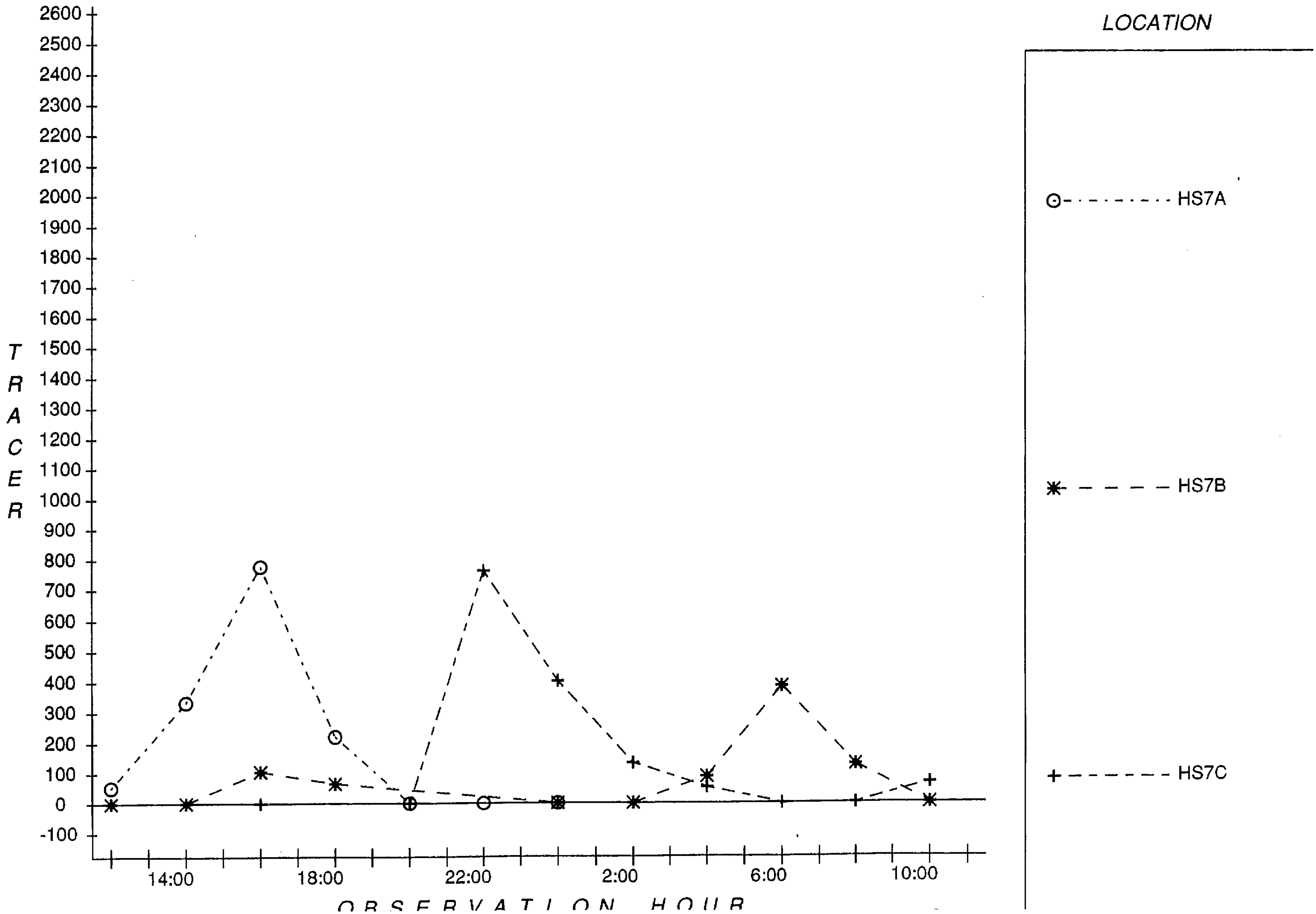
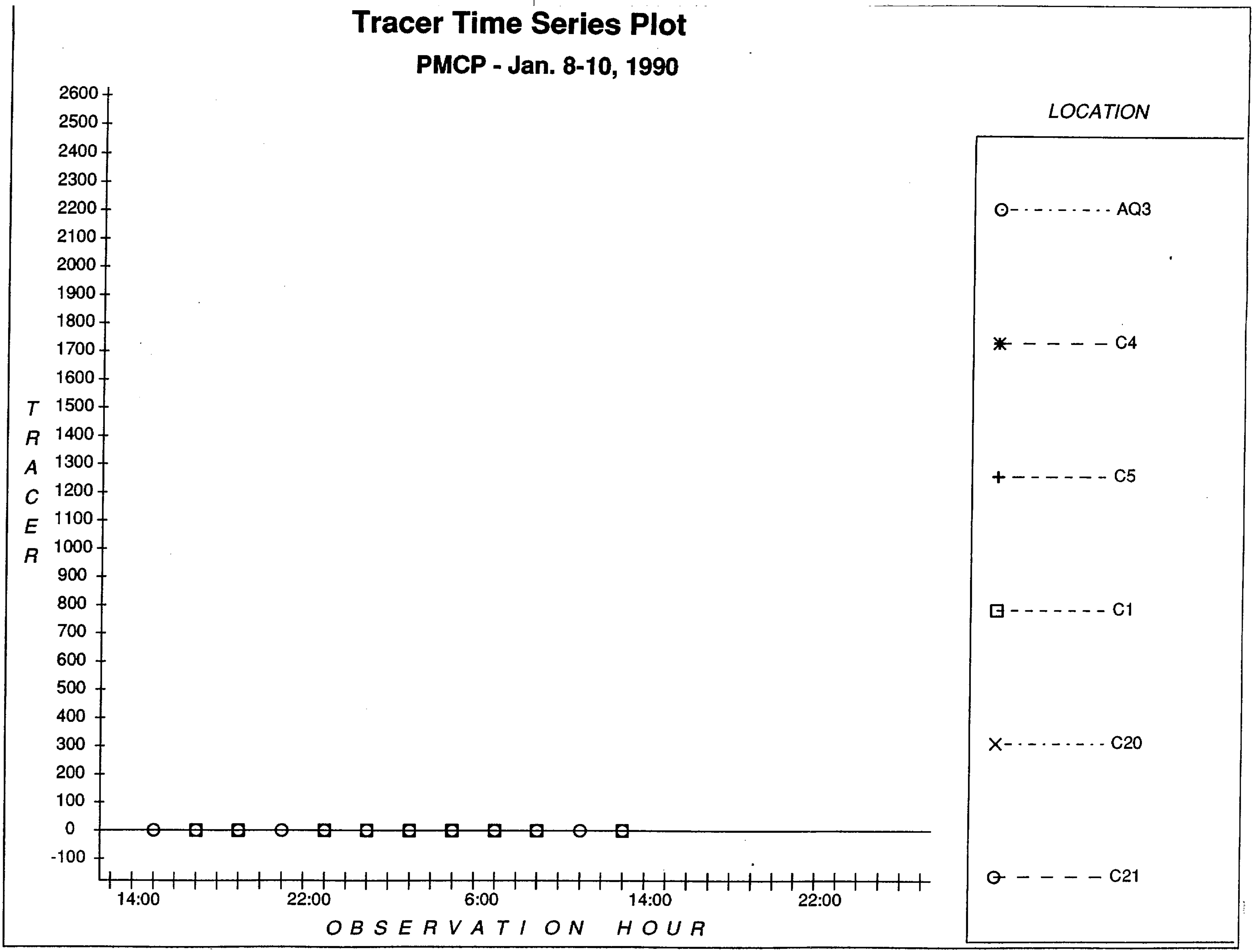
HS16

Tracer Time Series Plot

PMCP - Dec. 19-20, 1989

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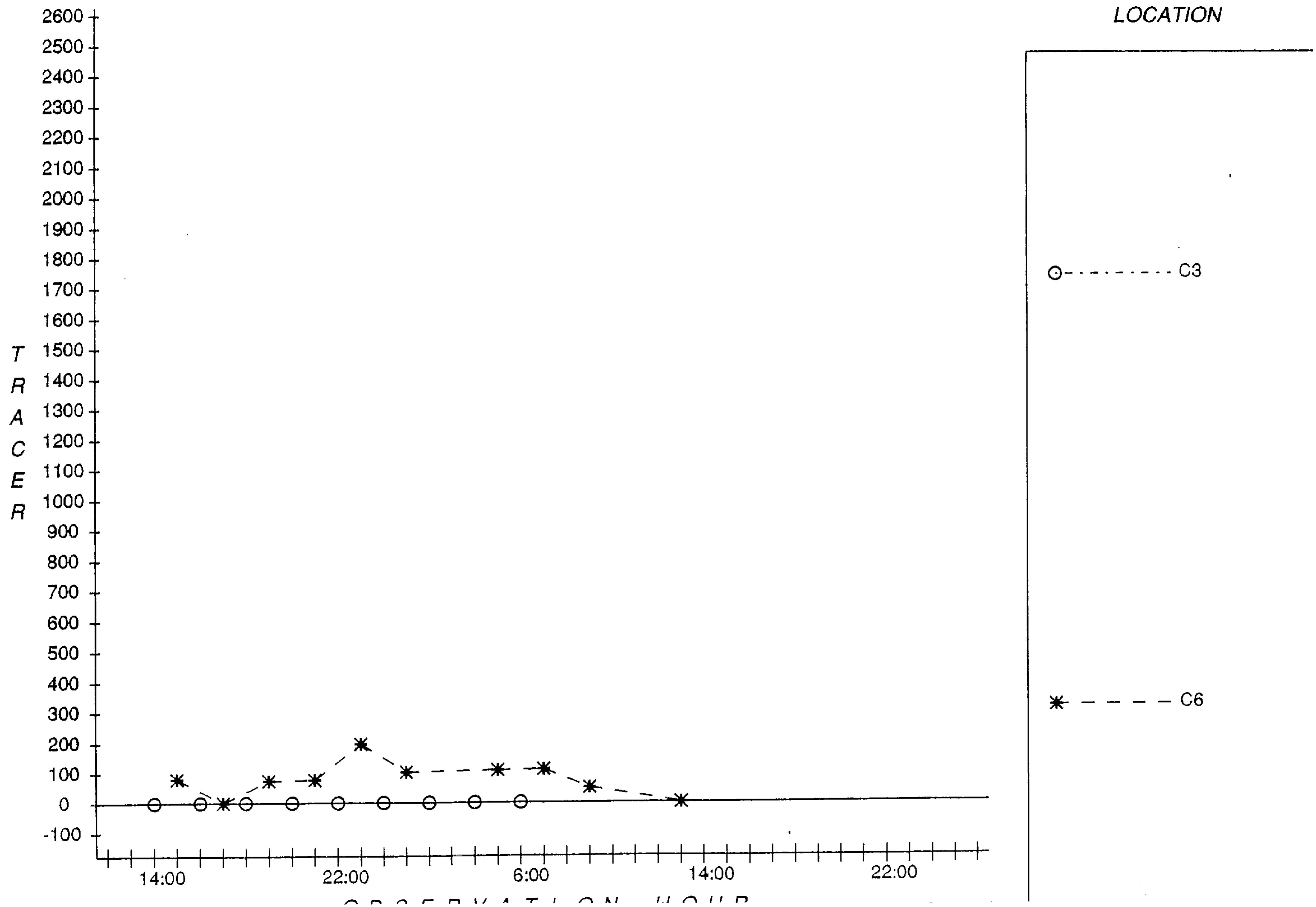
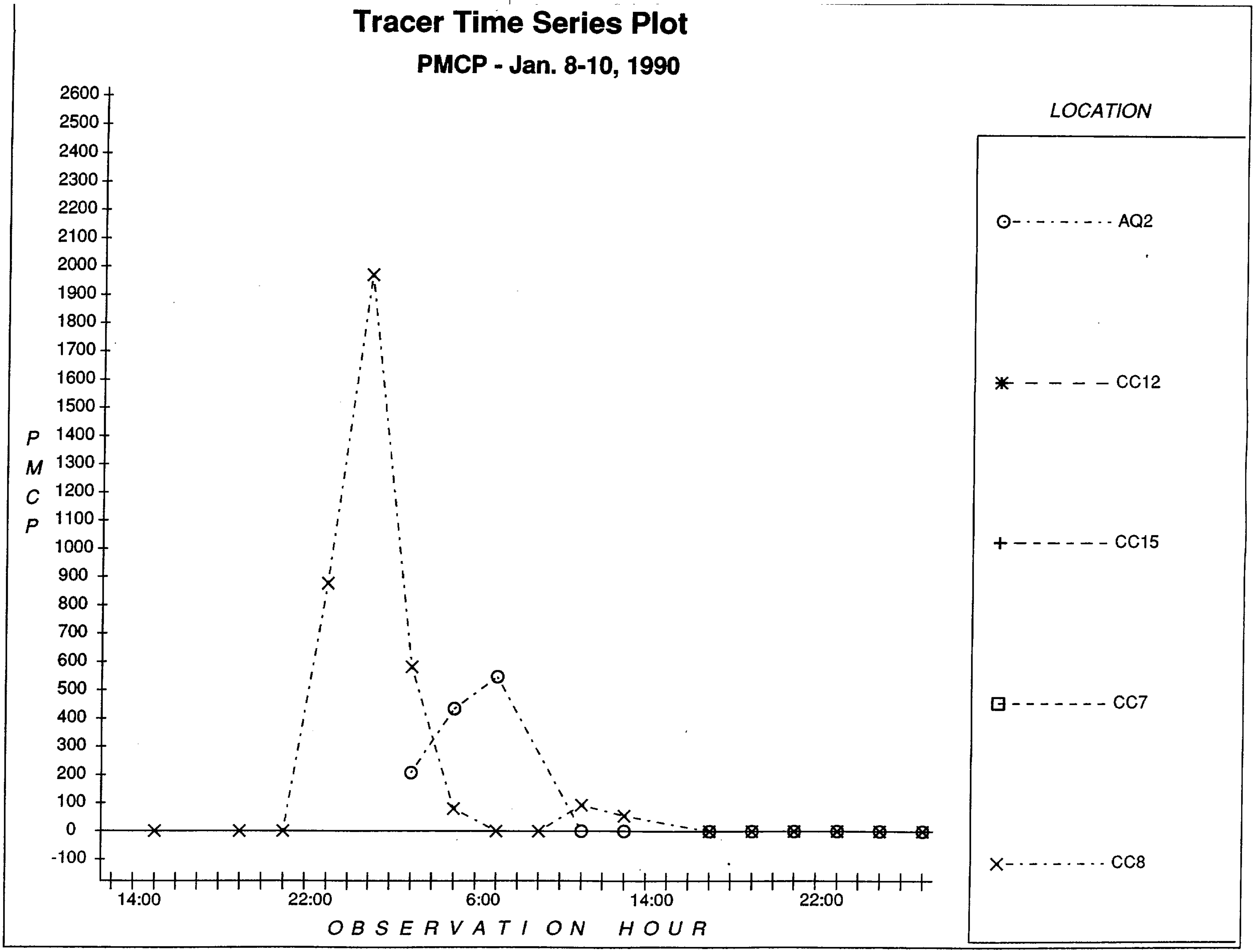
OBSERVATION HOUR
LOCATION
AQ3
C4
C5
C1
C20
C21

Tracer Time Series Plot

PMCP - Jan. 8-10, 1990





Tracer Time Series Plot
PMCP - Jan. 8-10, 1990
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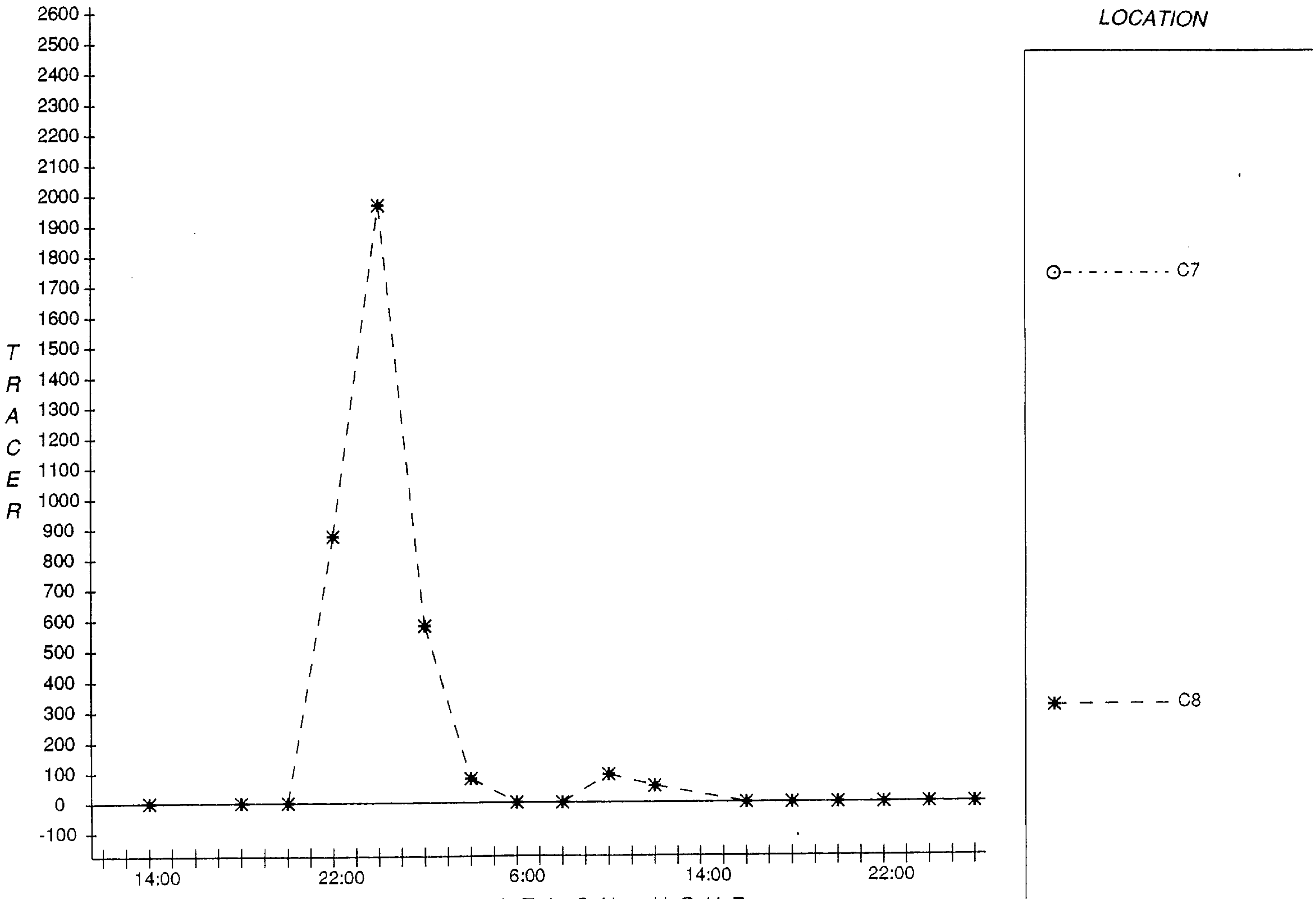
OBSERVATION HOUR
LOCATION
AQ2
CC12
CC15
CC7
CC8

Tracer Time Series Plot

PMCP - Jan. 8-10, 1990



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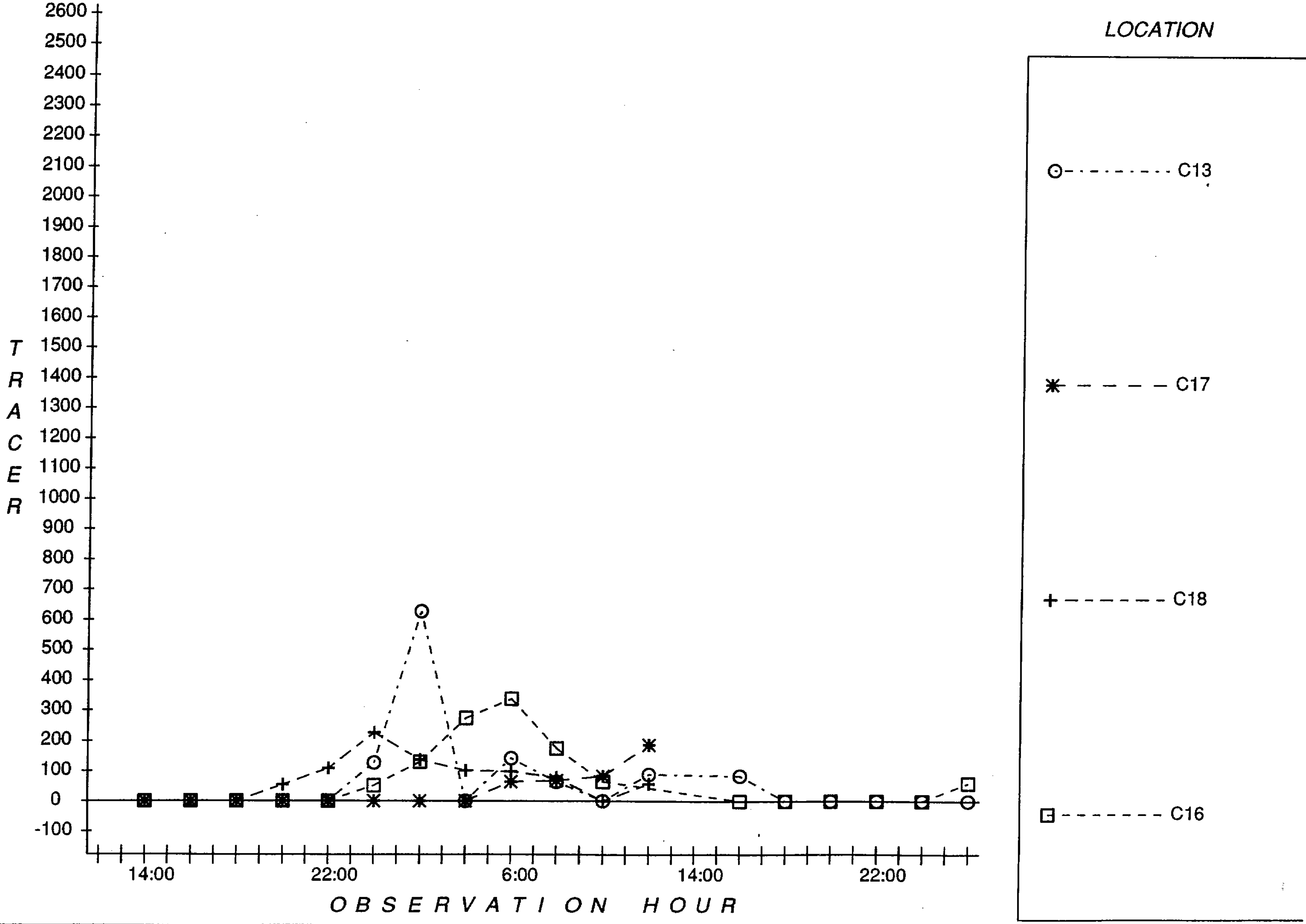
PMCP - Jan. 8-10, 1990



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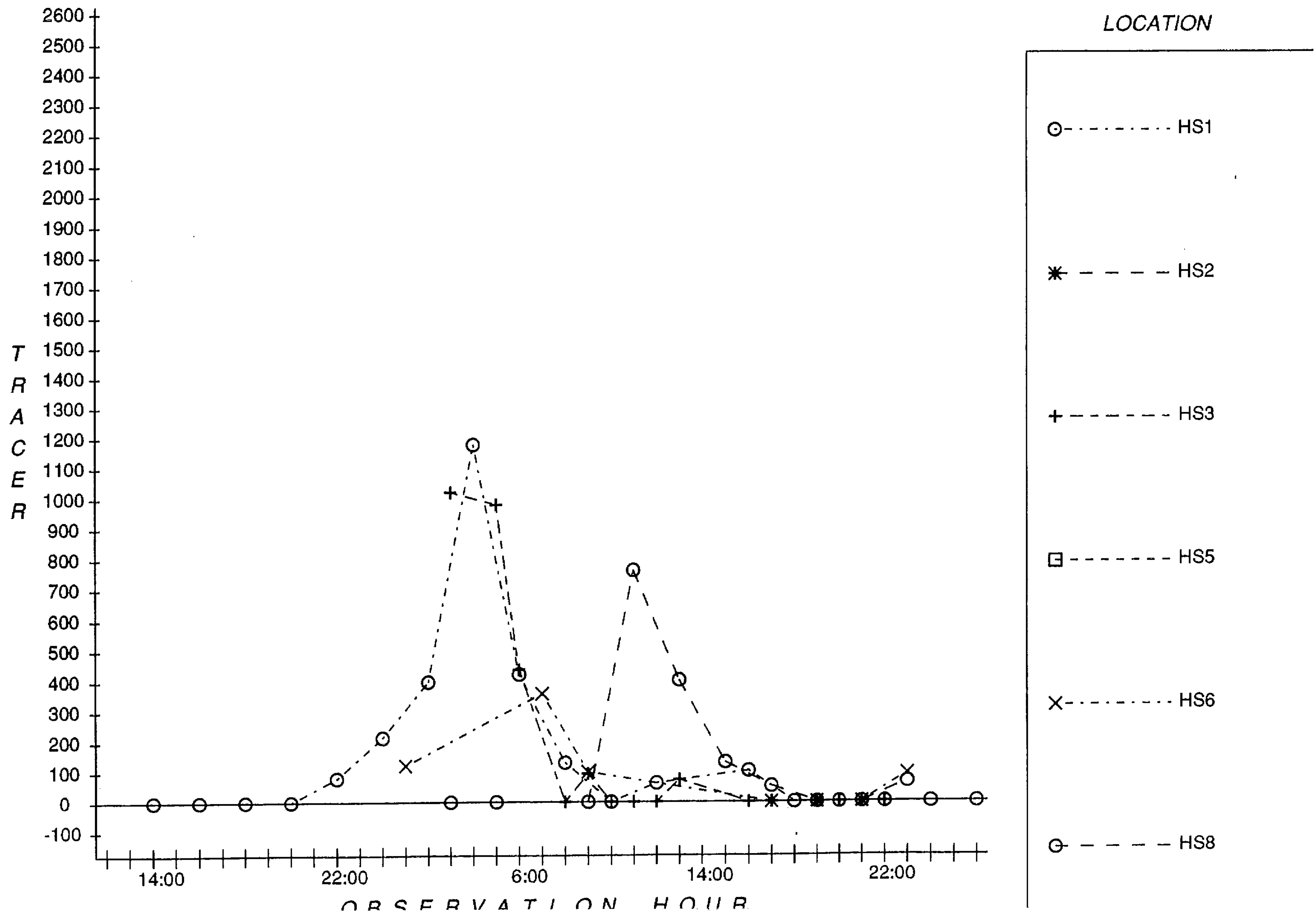

Tracer Time Series Plot

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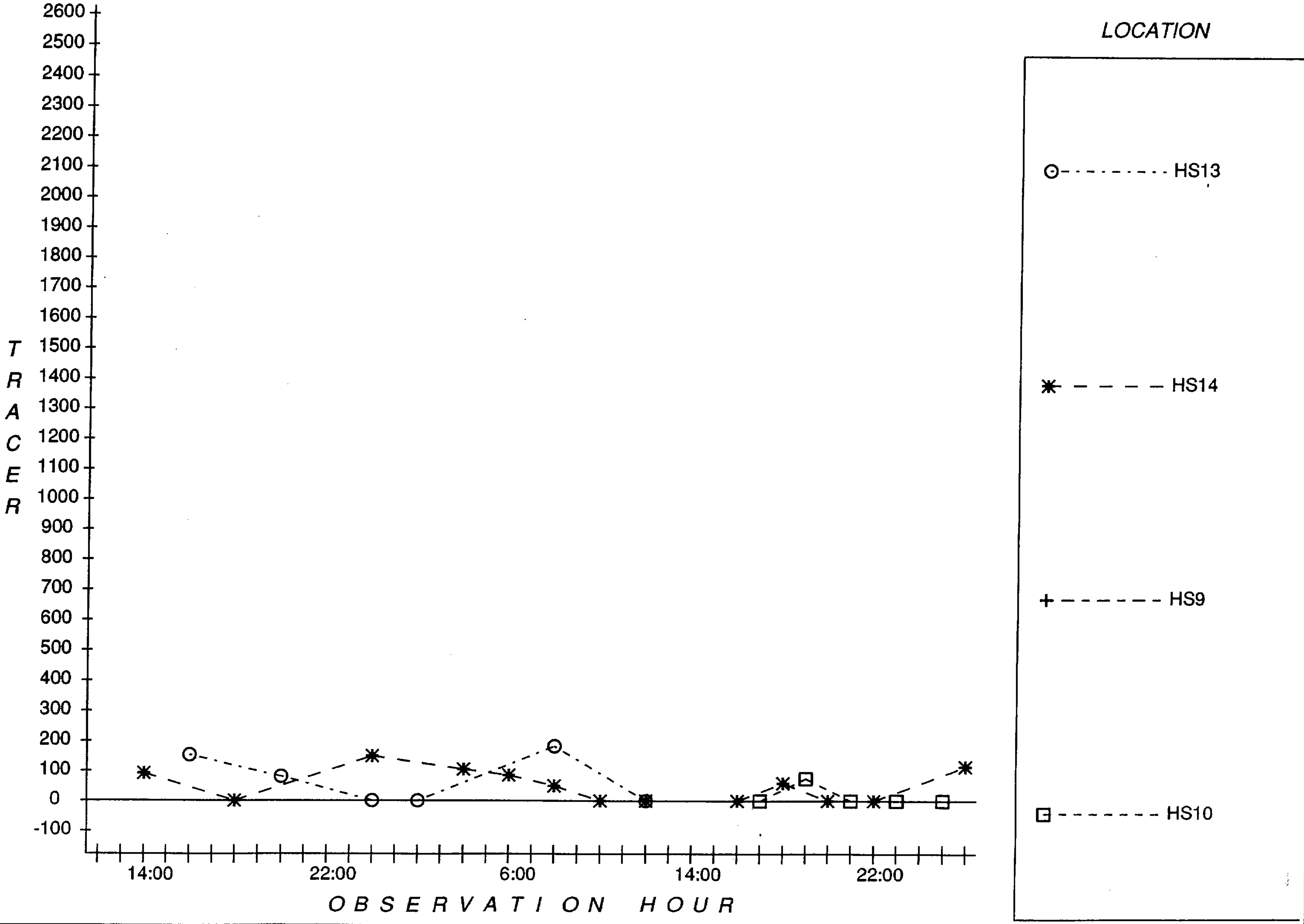

Tracer Time Series Plot

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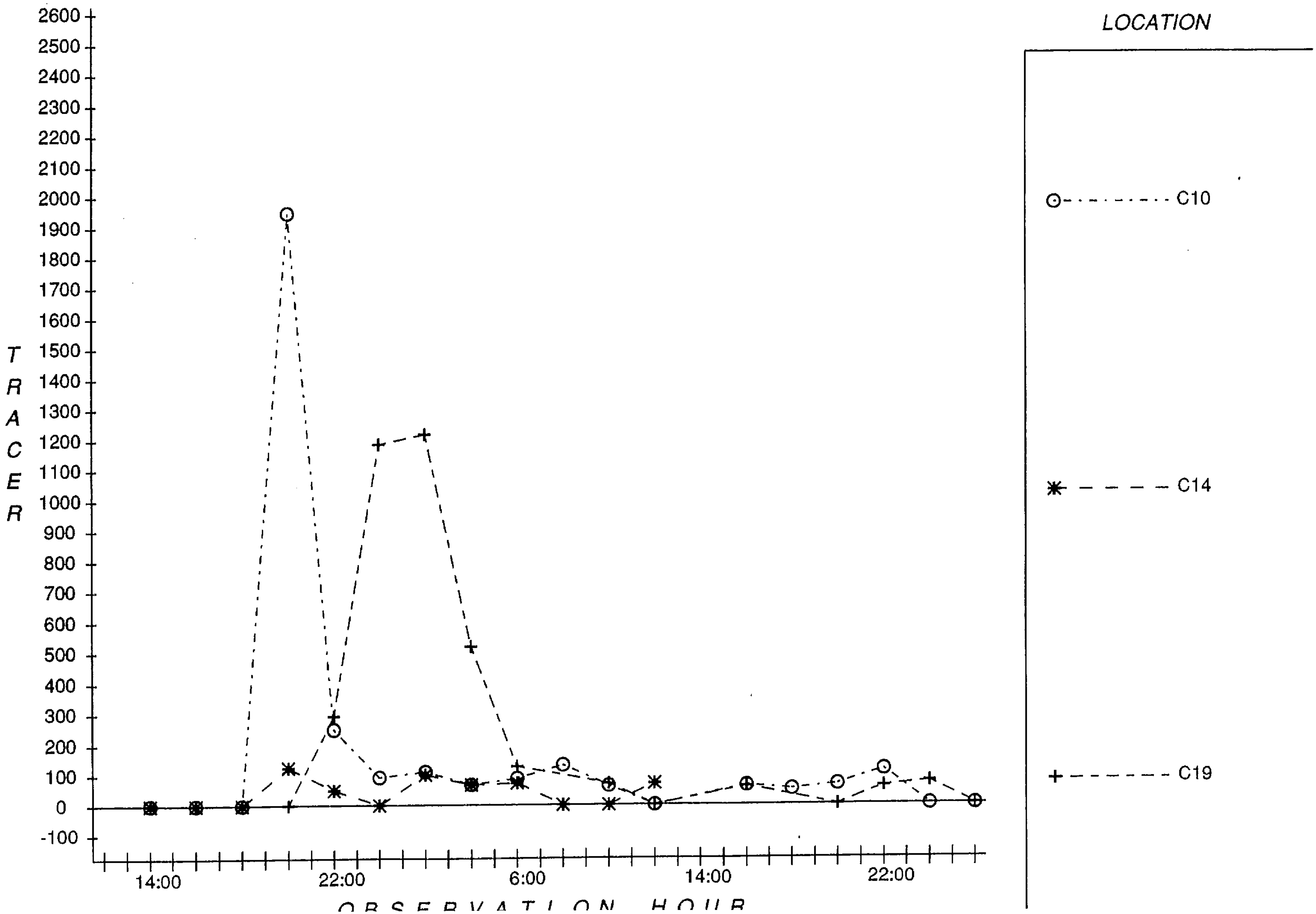

Tracer Time Series Plot

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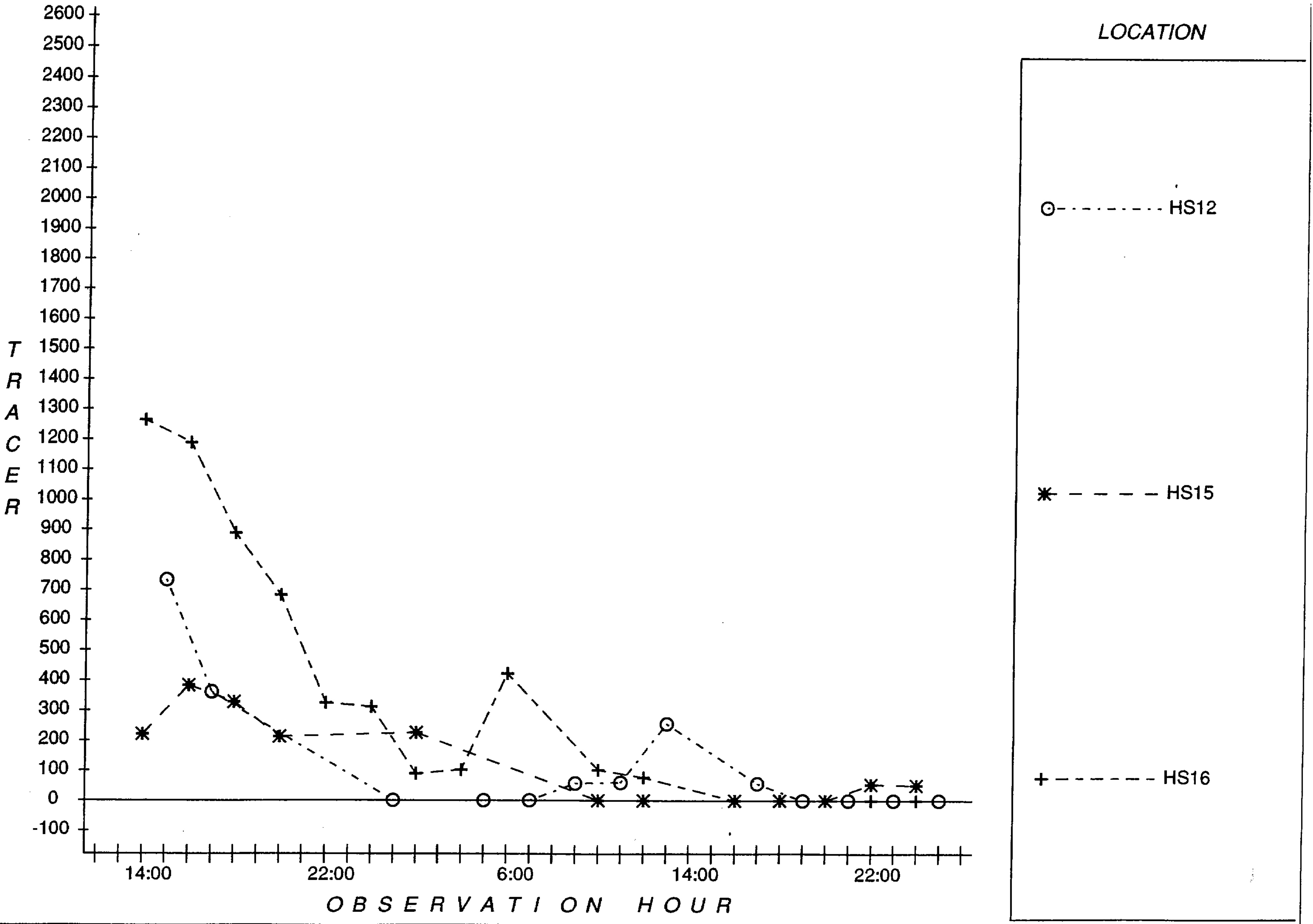

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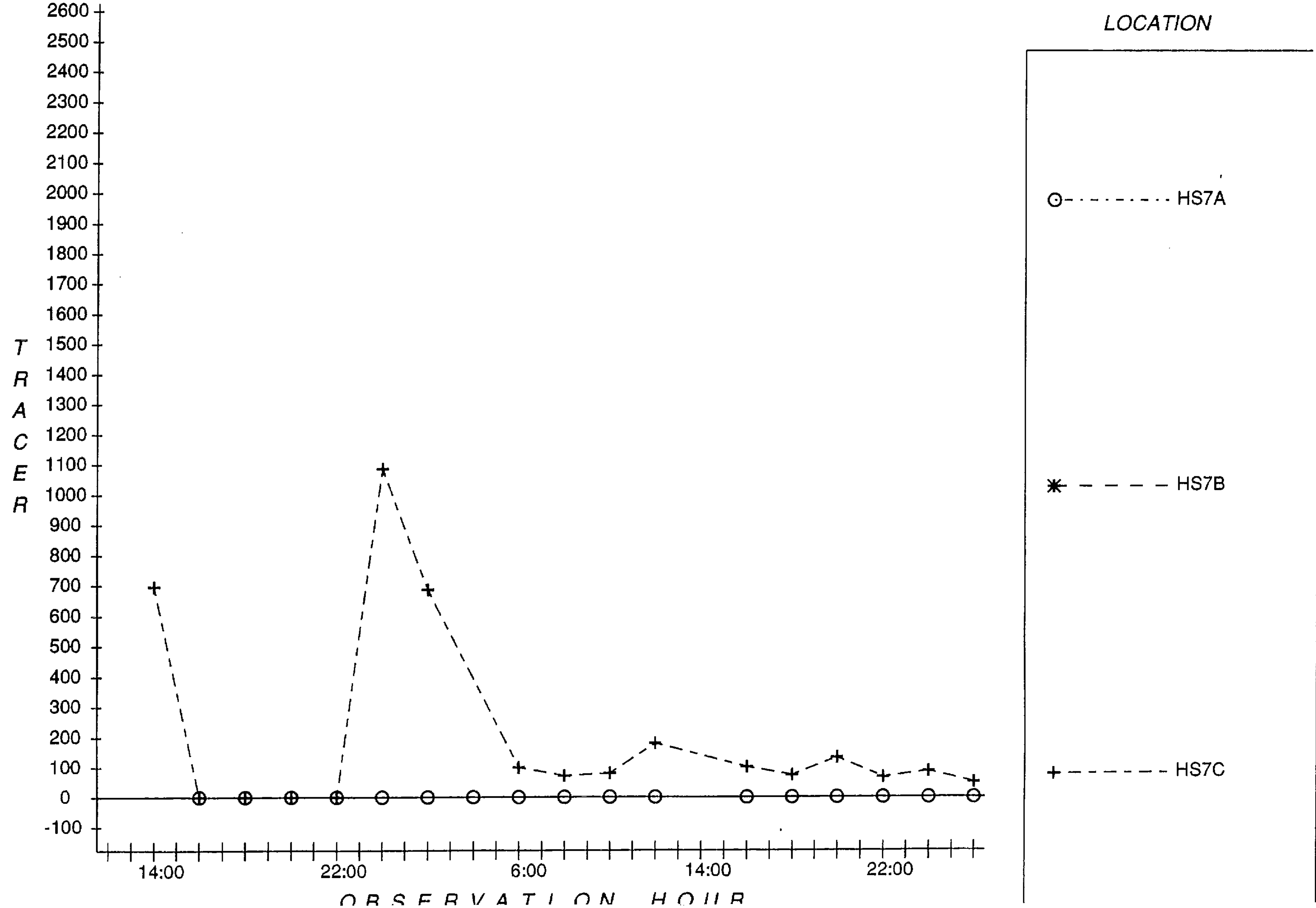
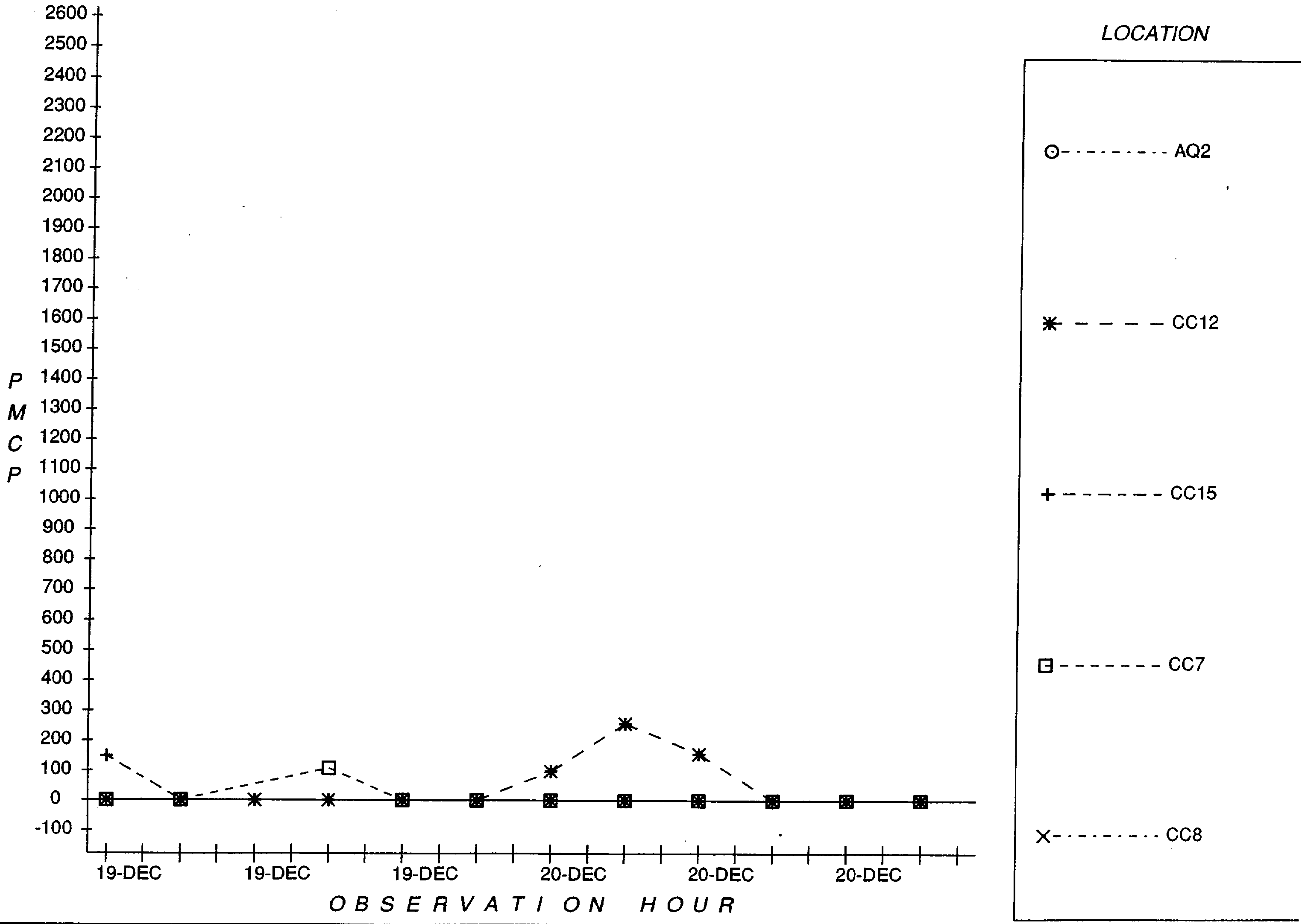


Tracer Time Series Plot

PMCH - Dec. 19-20, 1989



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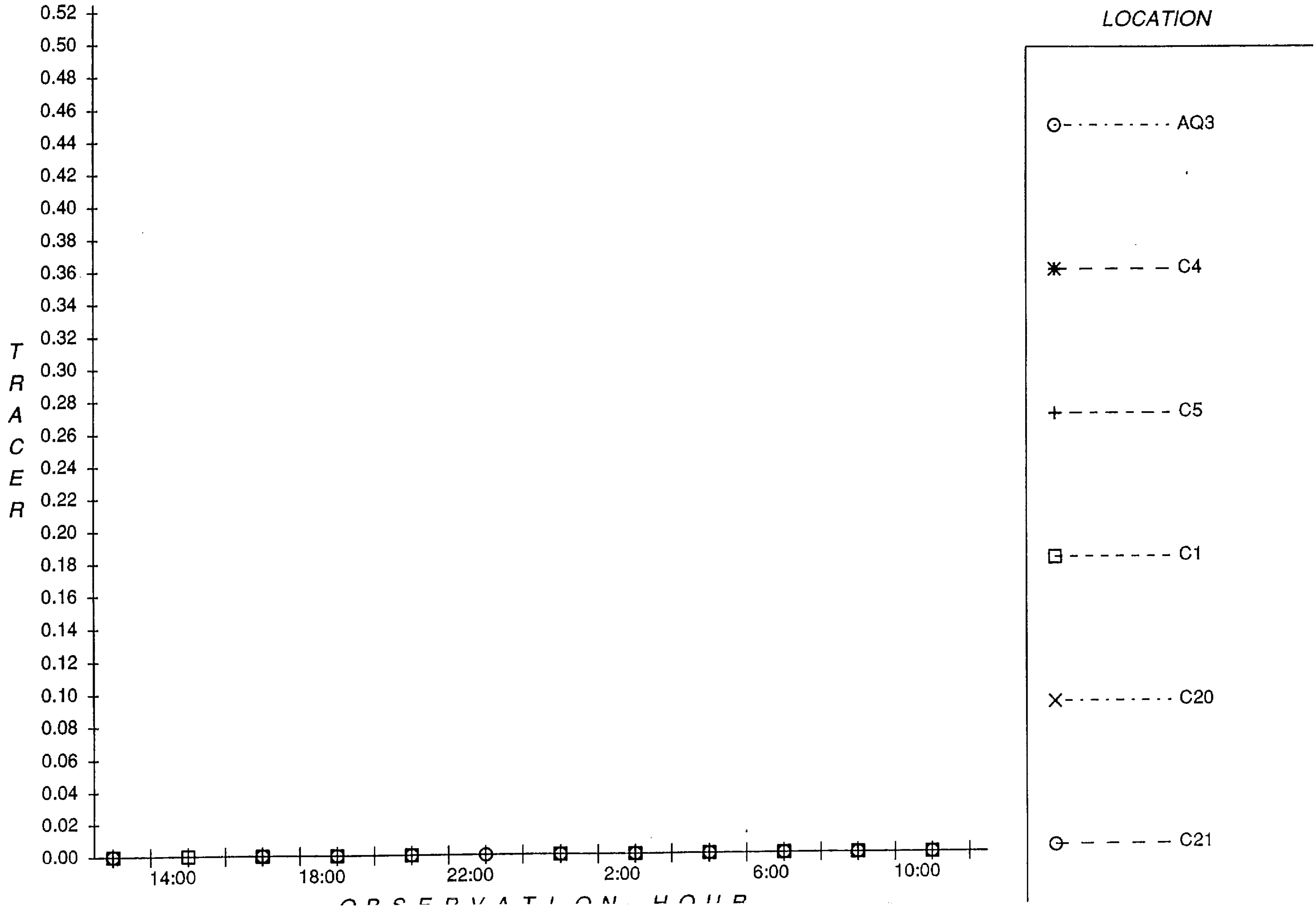

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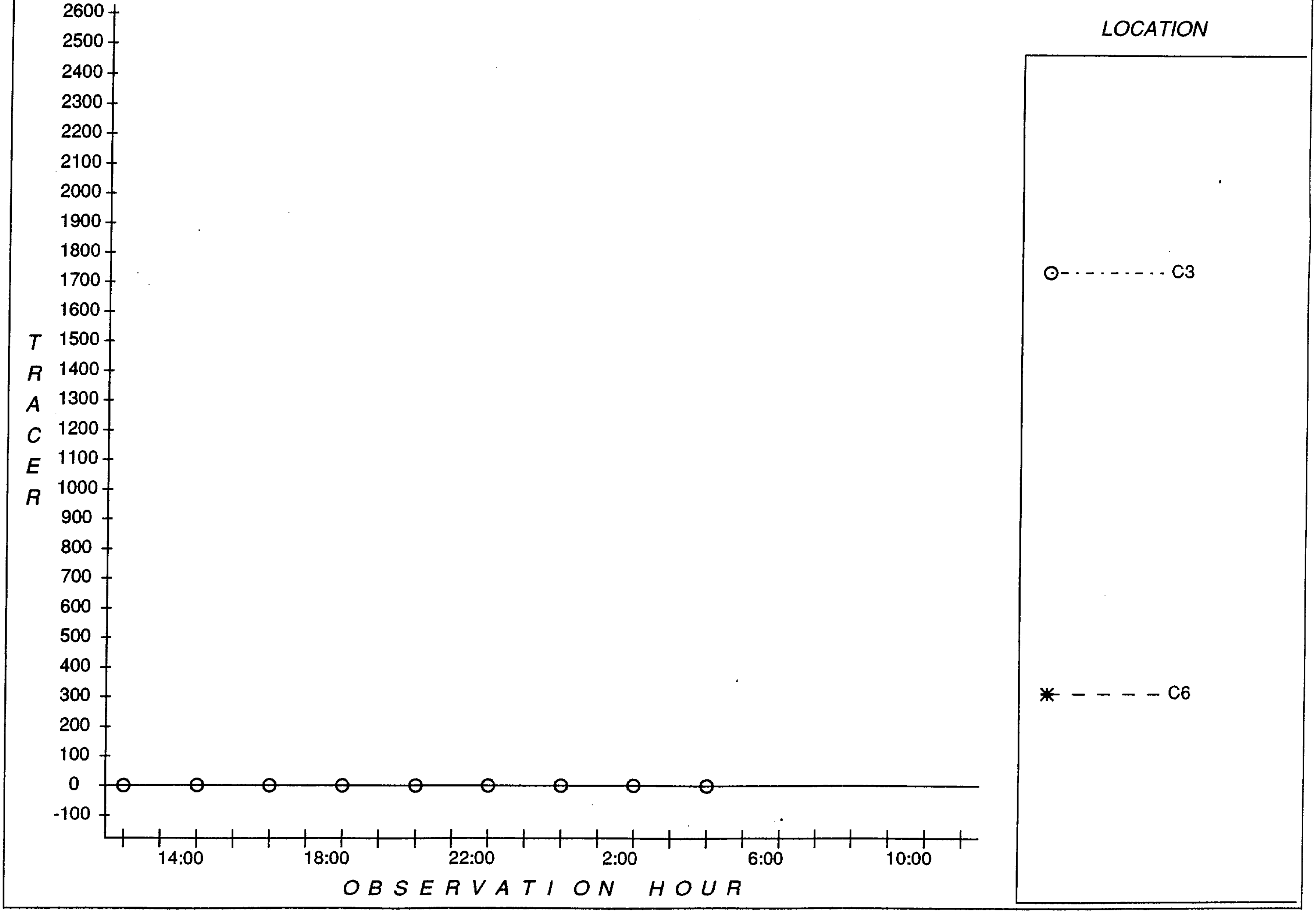

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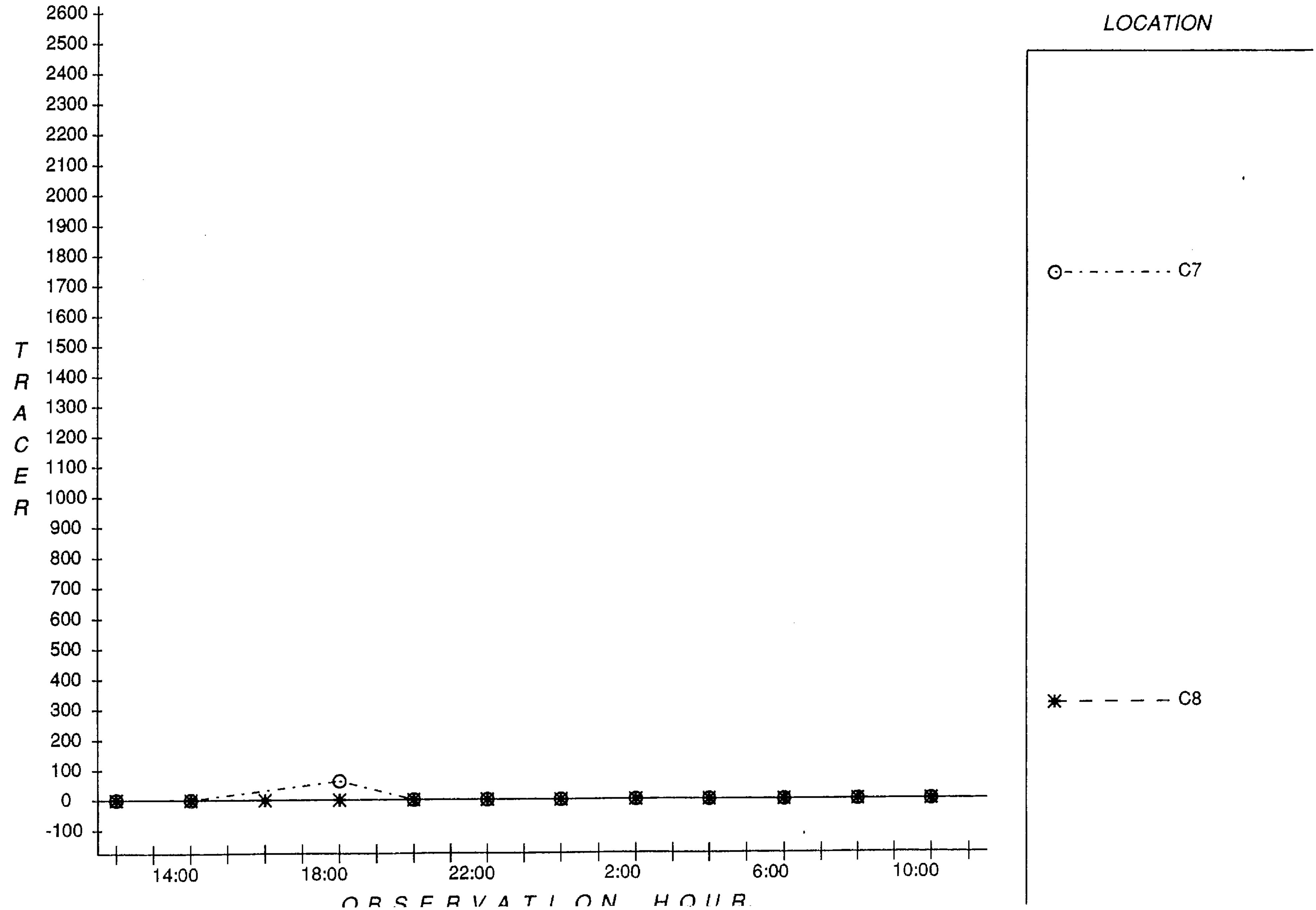

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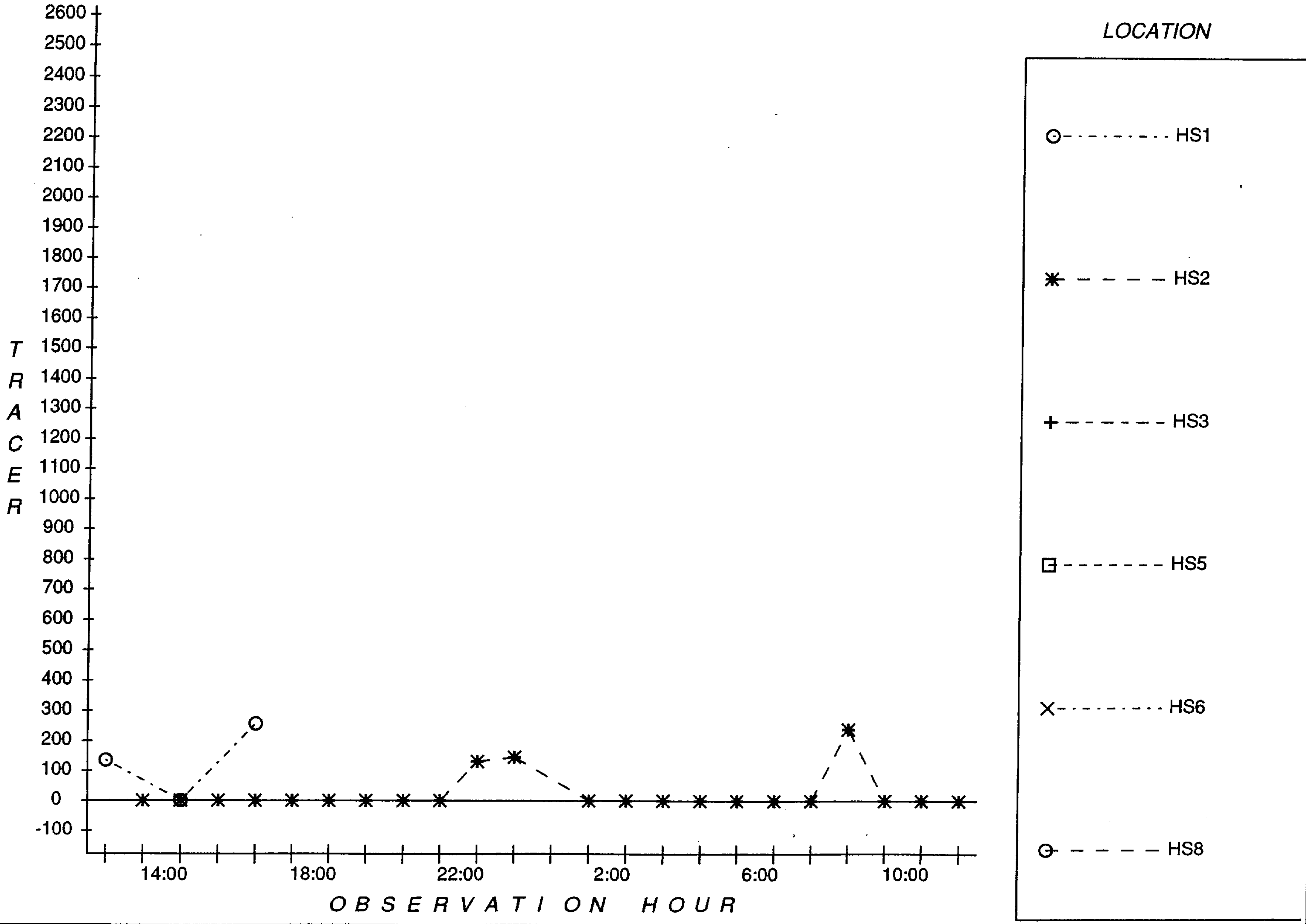

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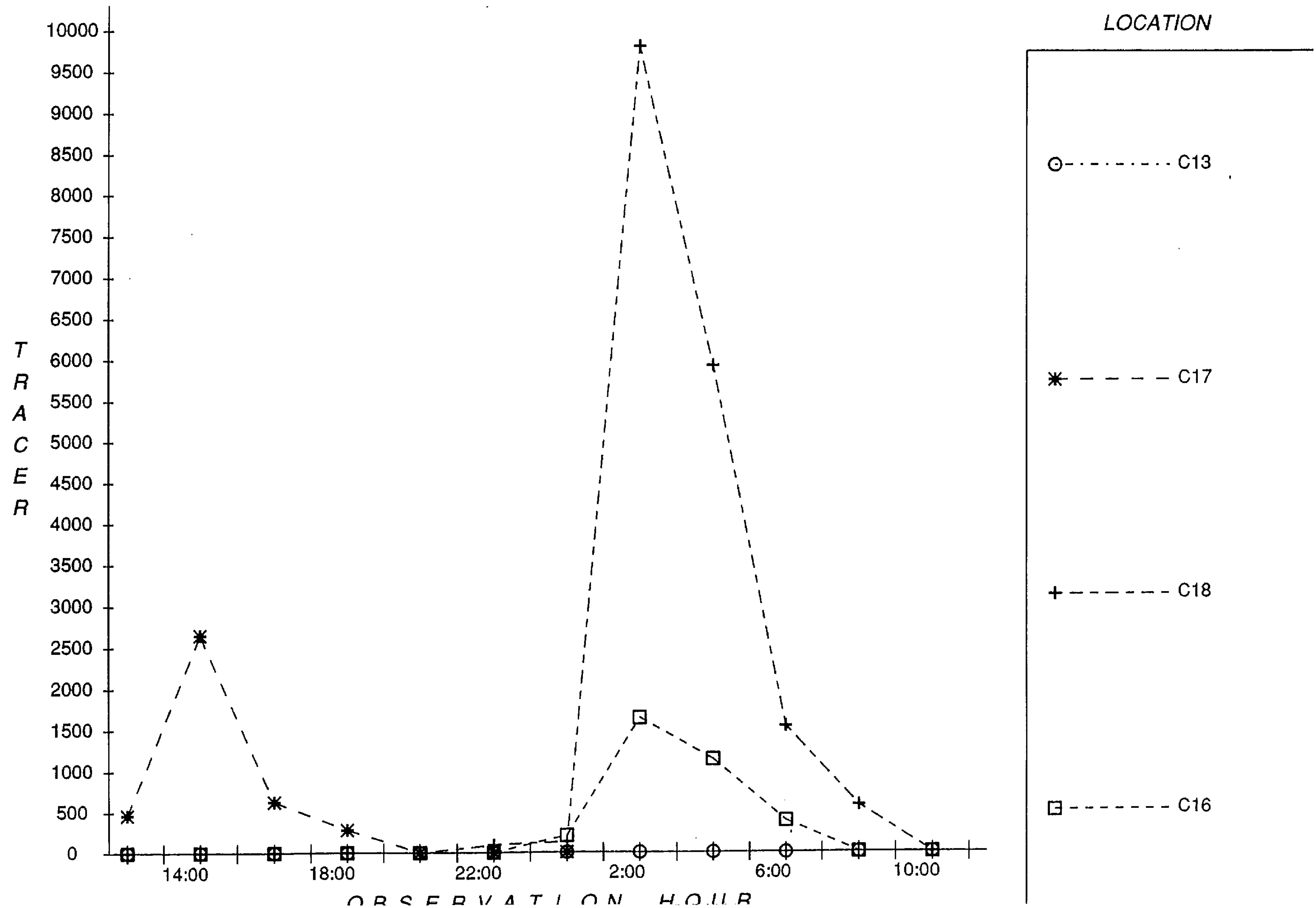

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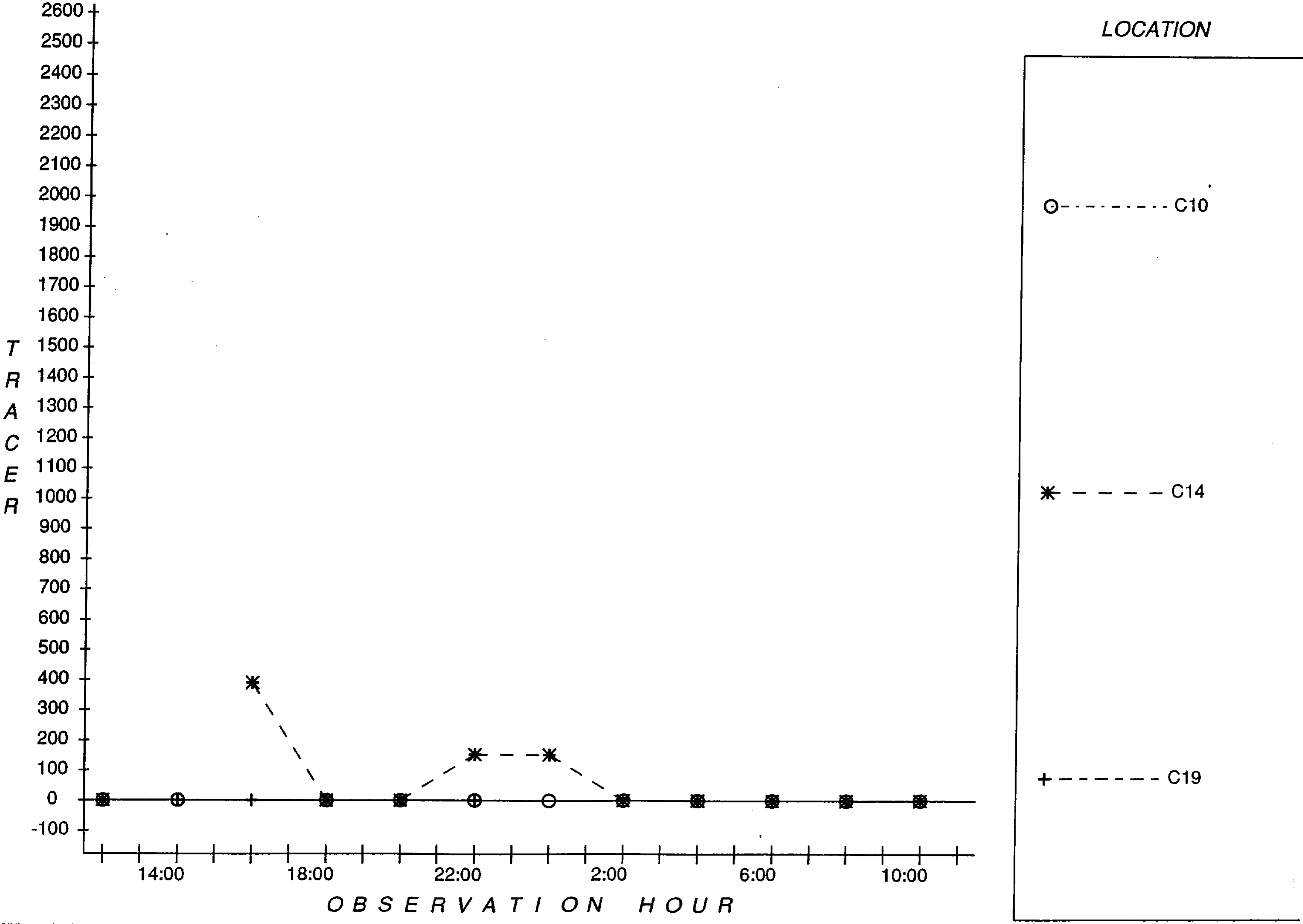

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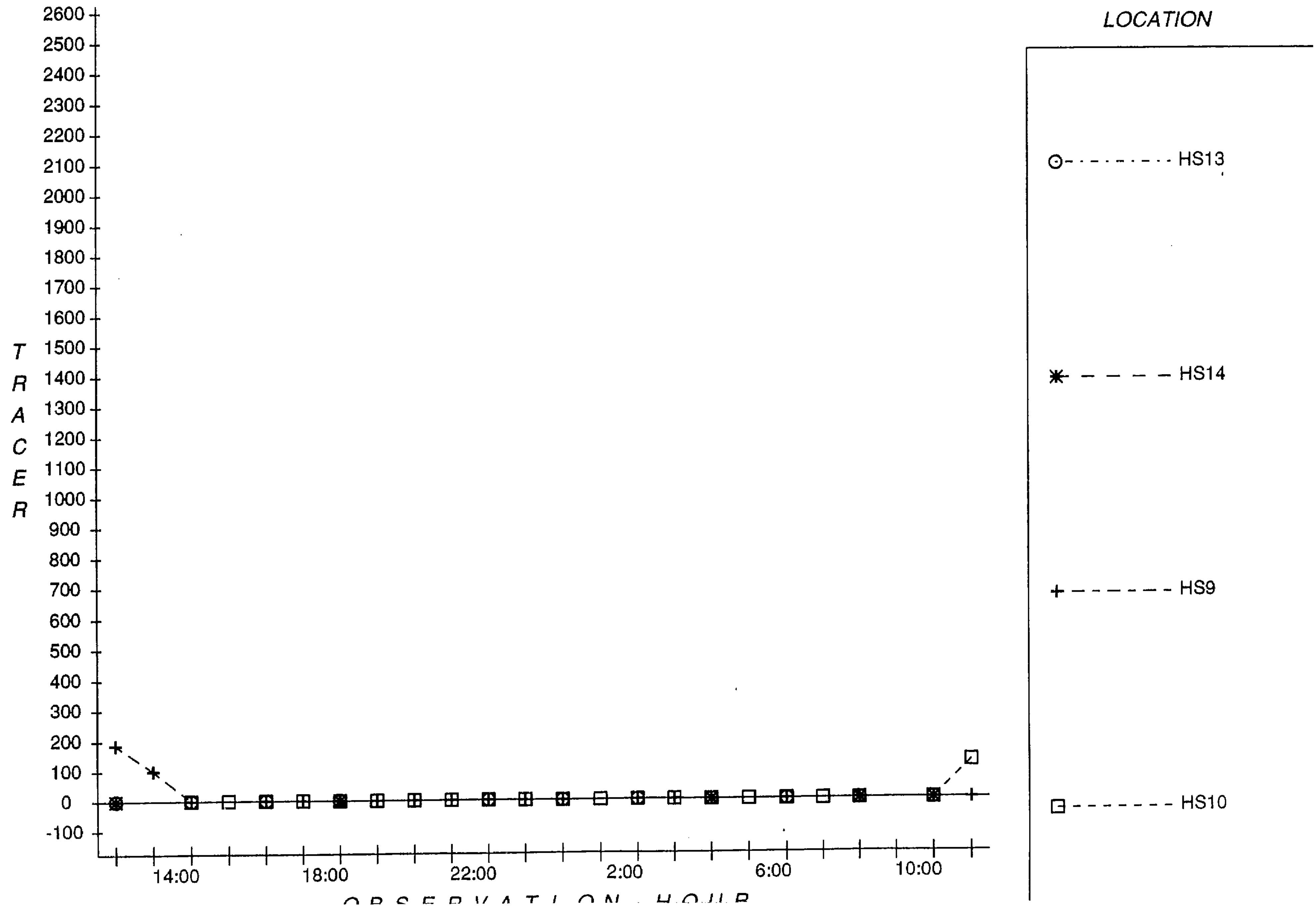

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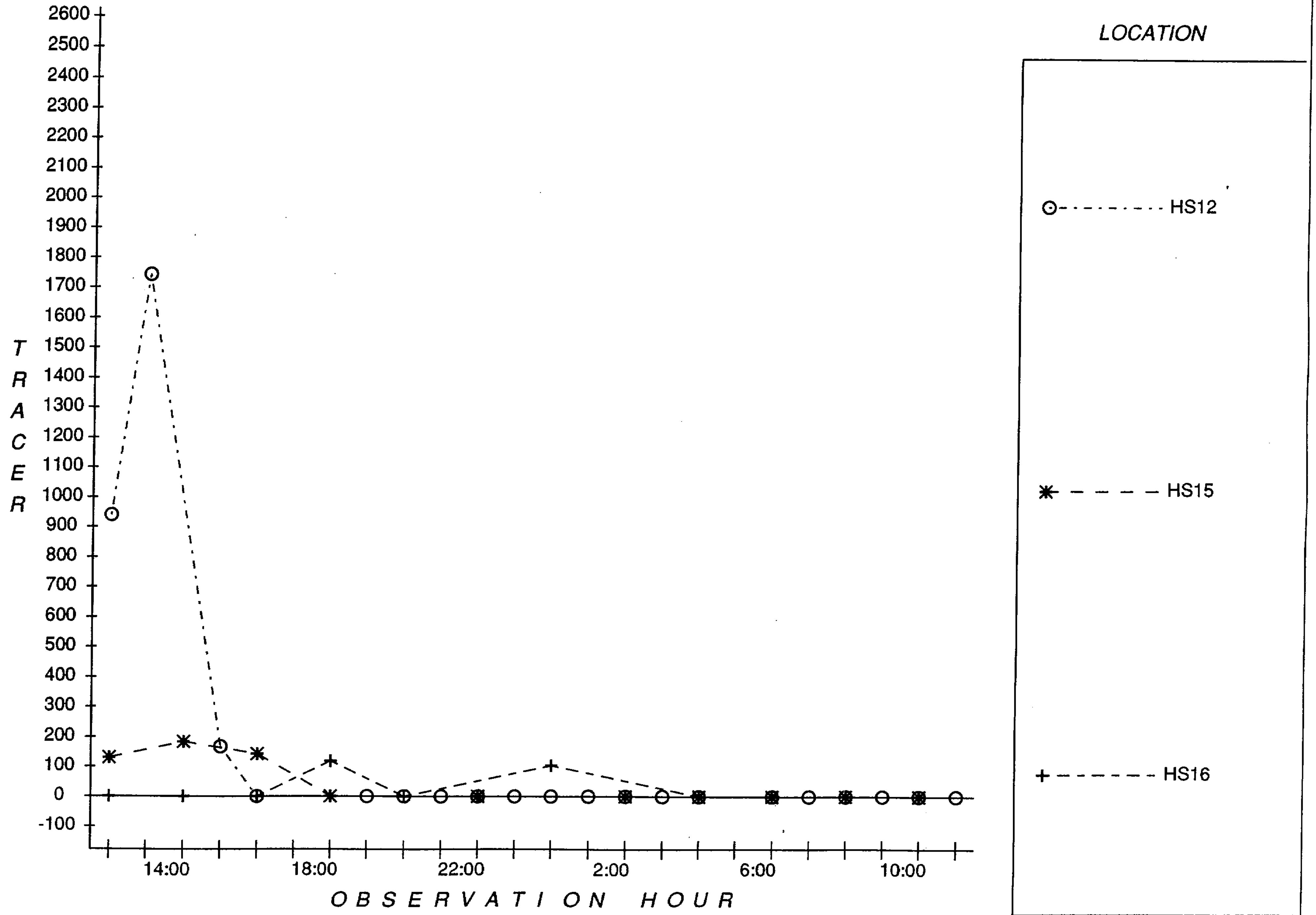

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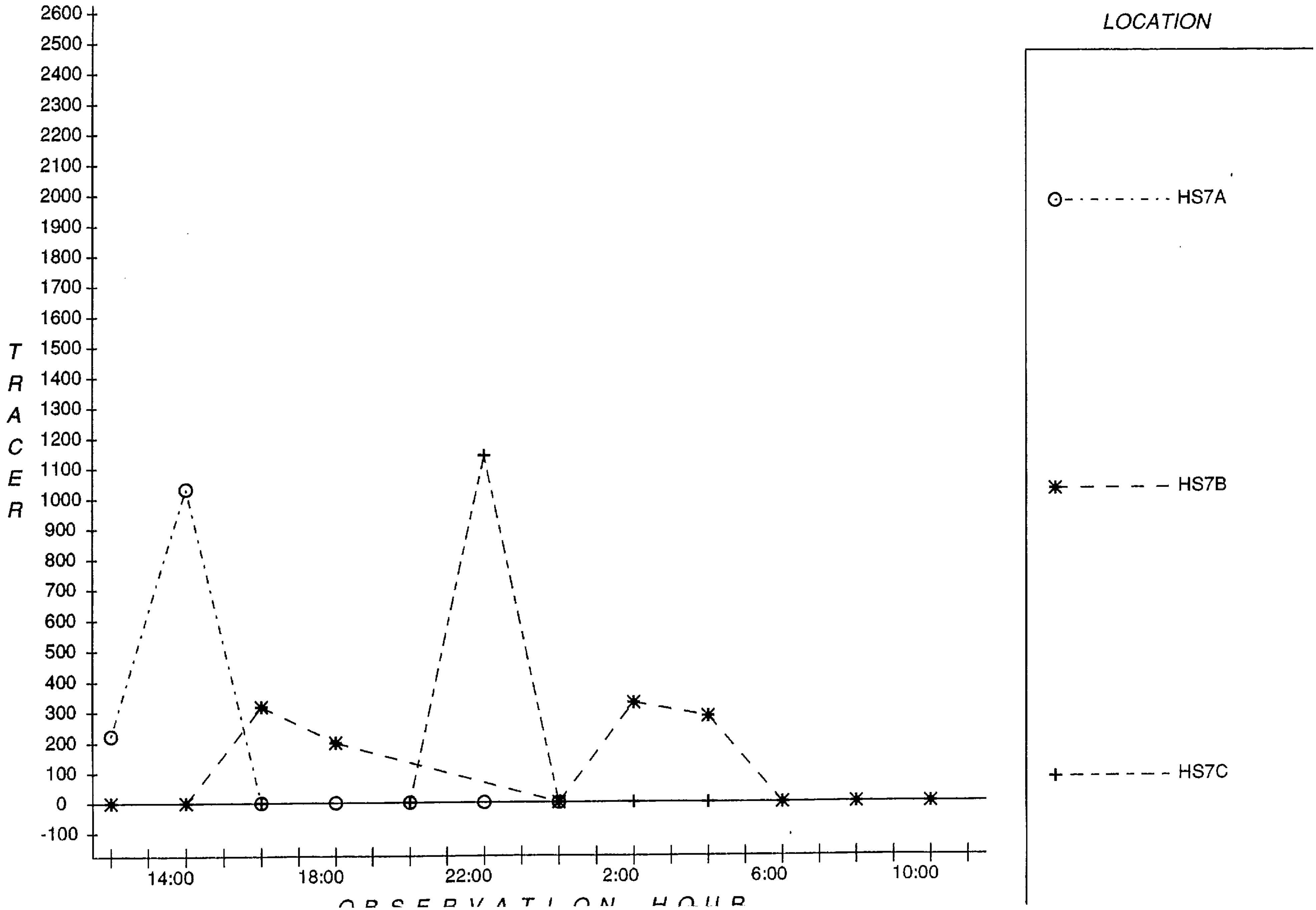

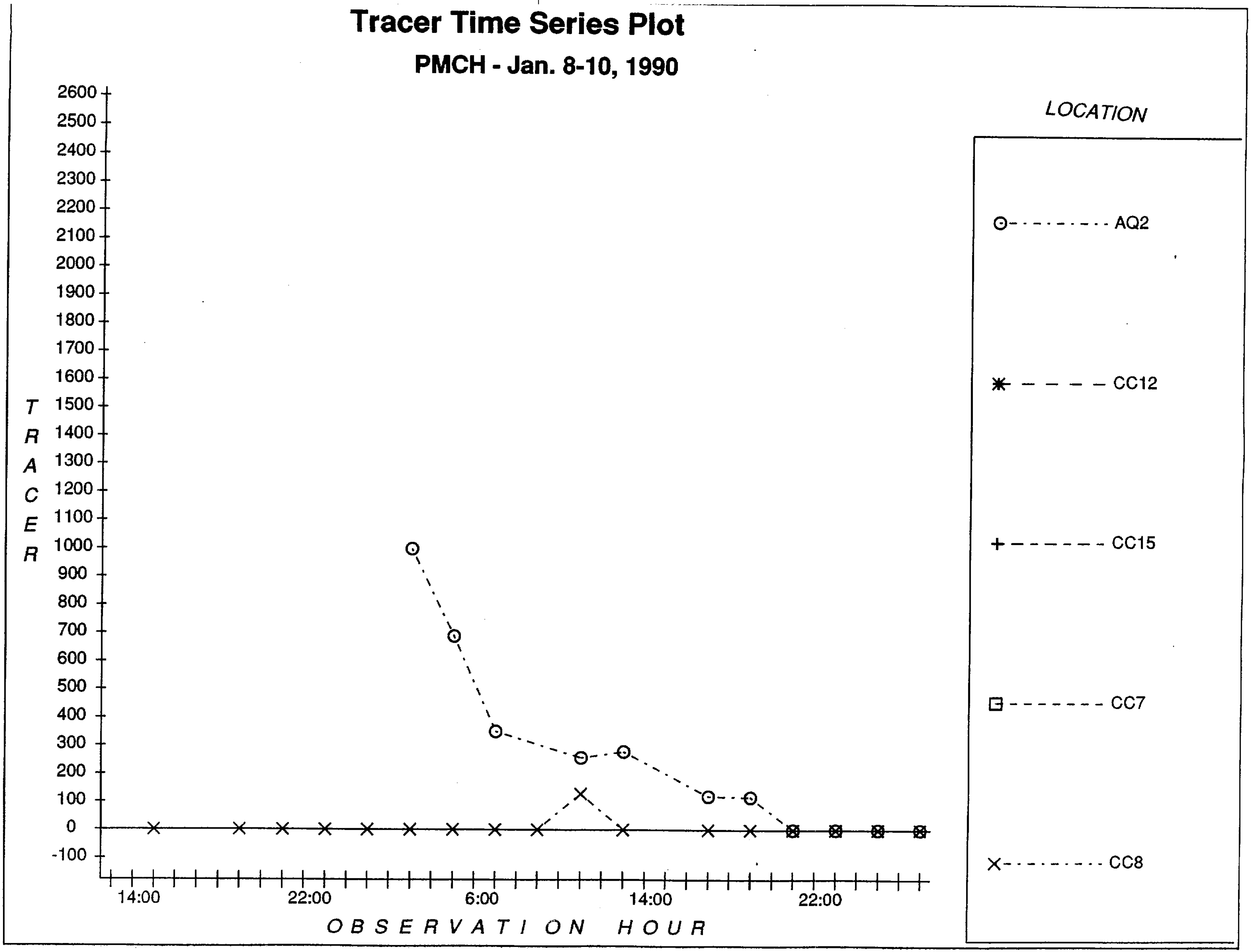
Tracer Time Series Plot
PMCH - Jan. 8-10, 1990
TRACER
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OBSERVATION HOUR
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CC12
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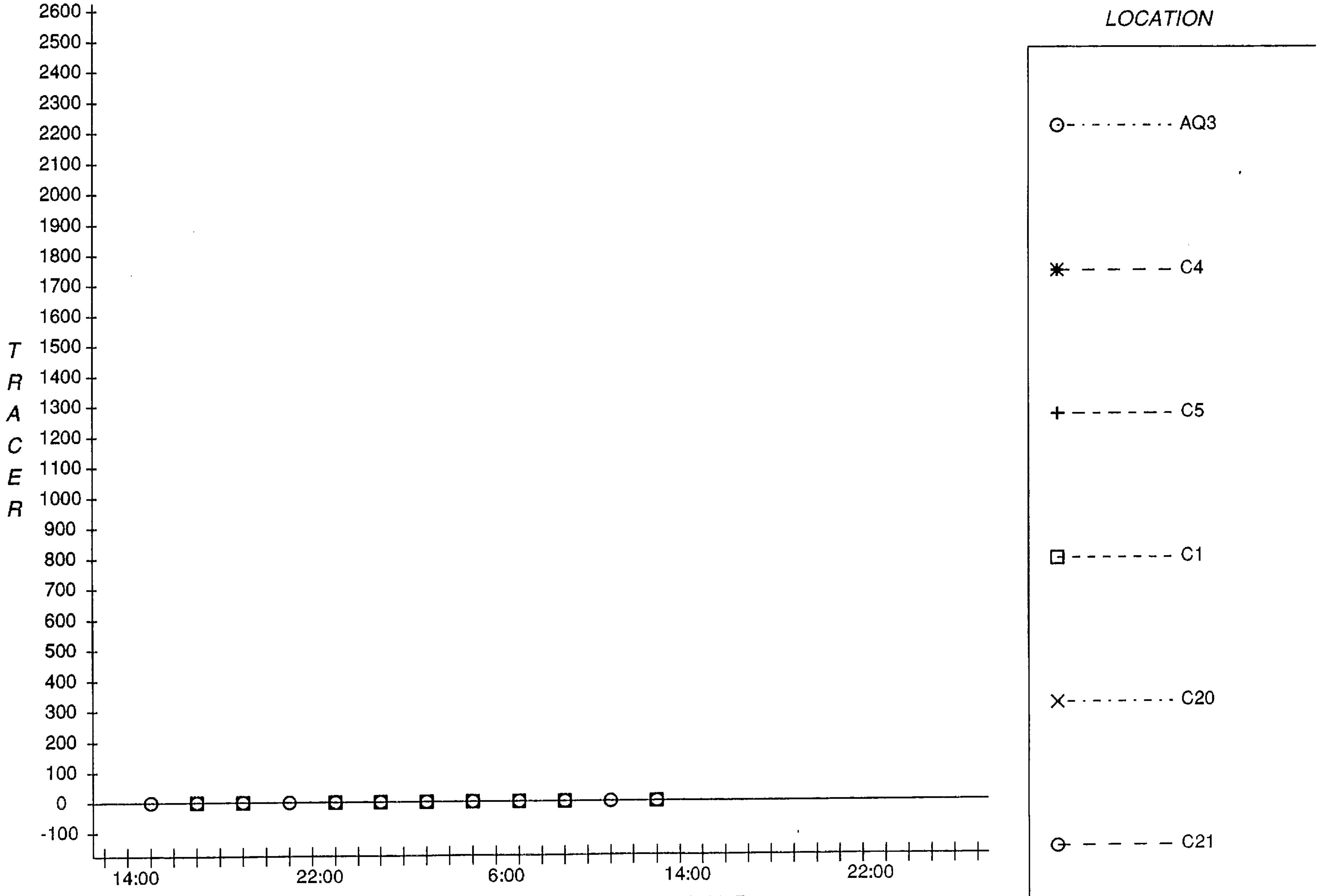
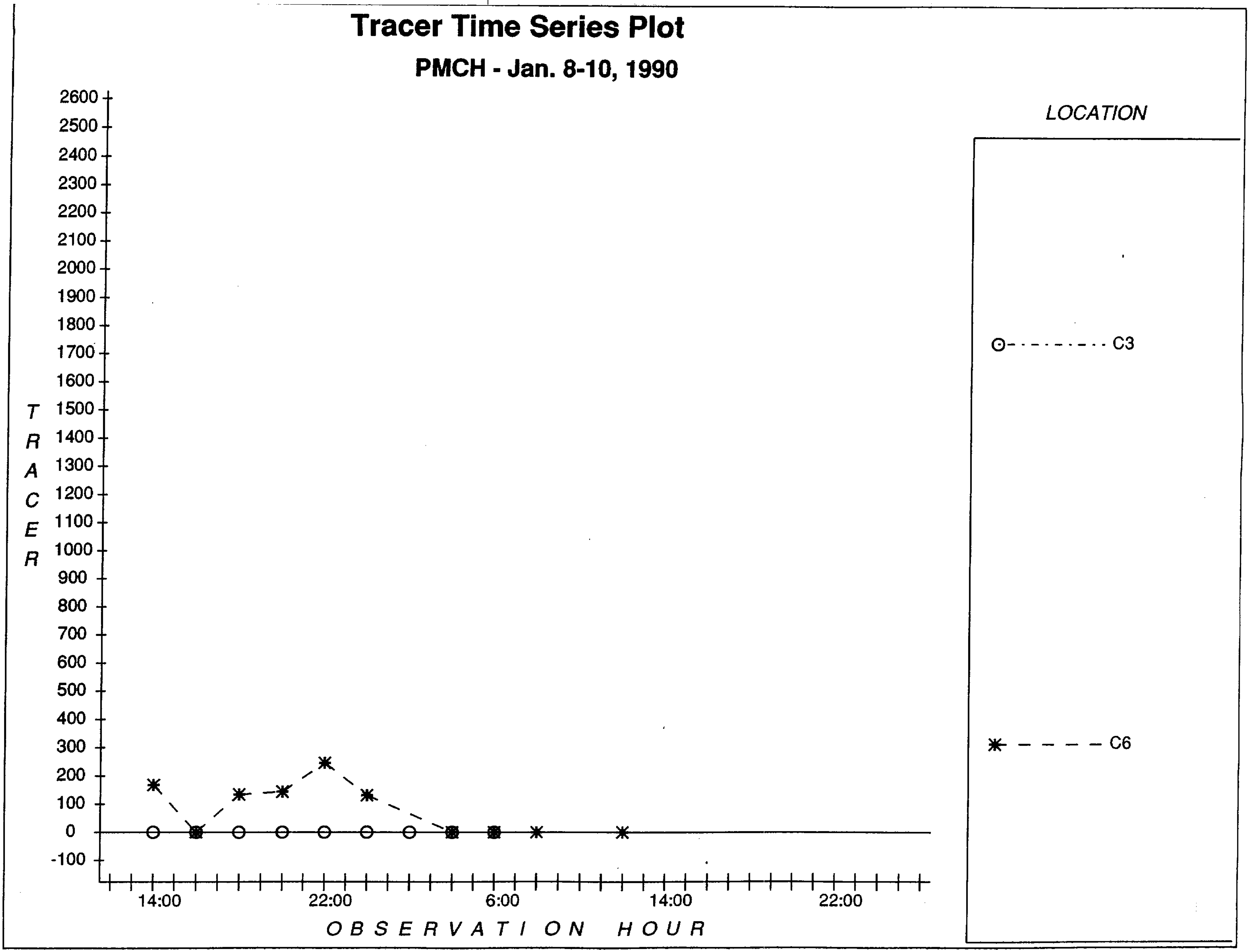
Tracer Time Series Plot

PMCH - Jan. 8-10, 1990





Tracer Time Series Plot
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OBSERVATION HOUR
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Tracer Time Series Plot

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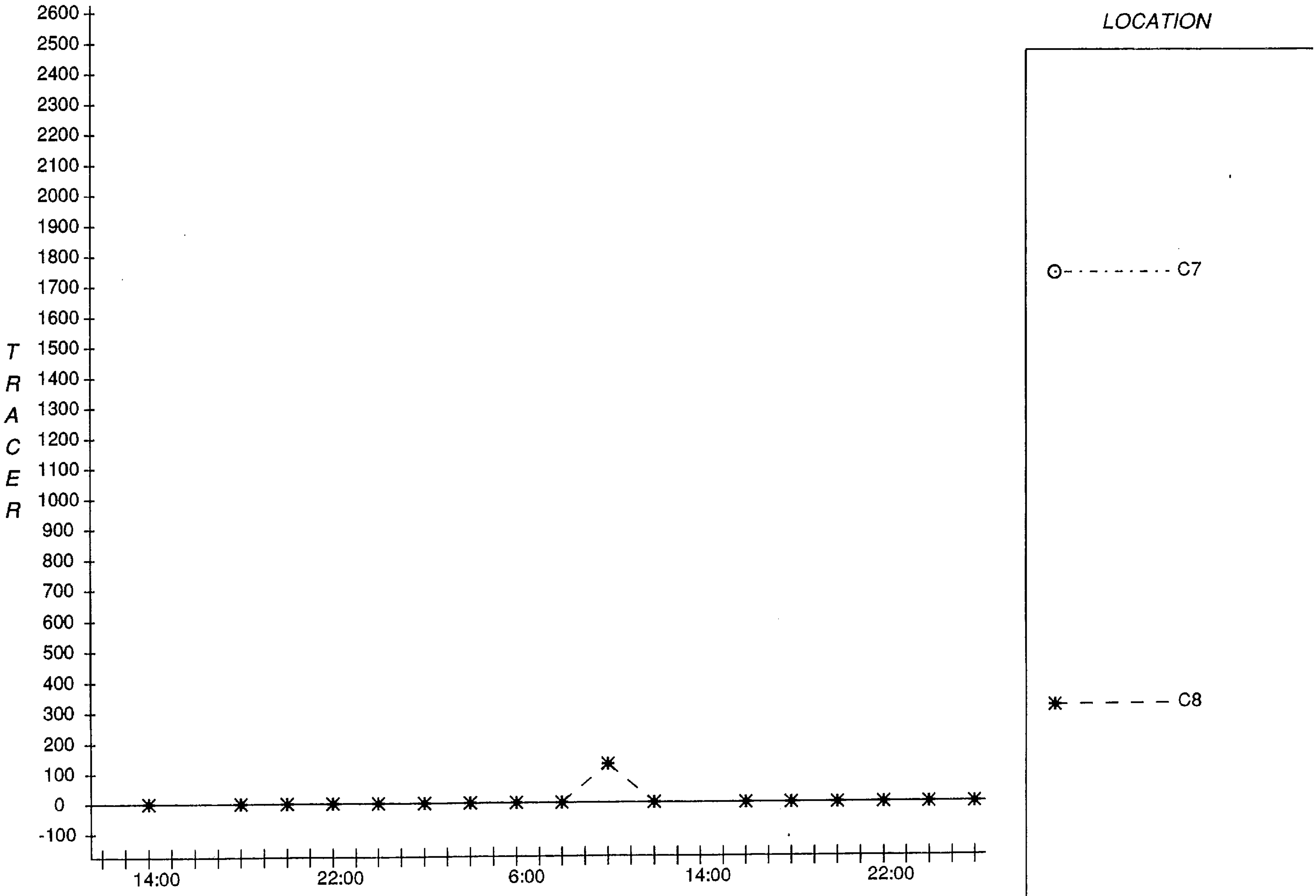

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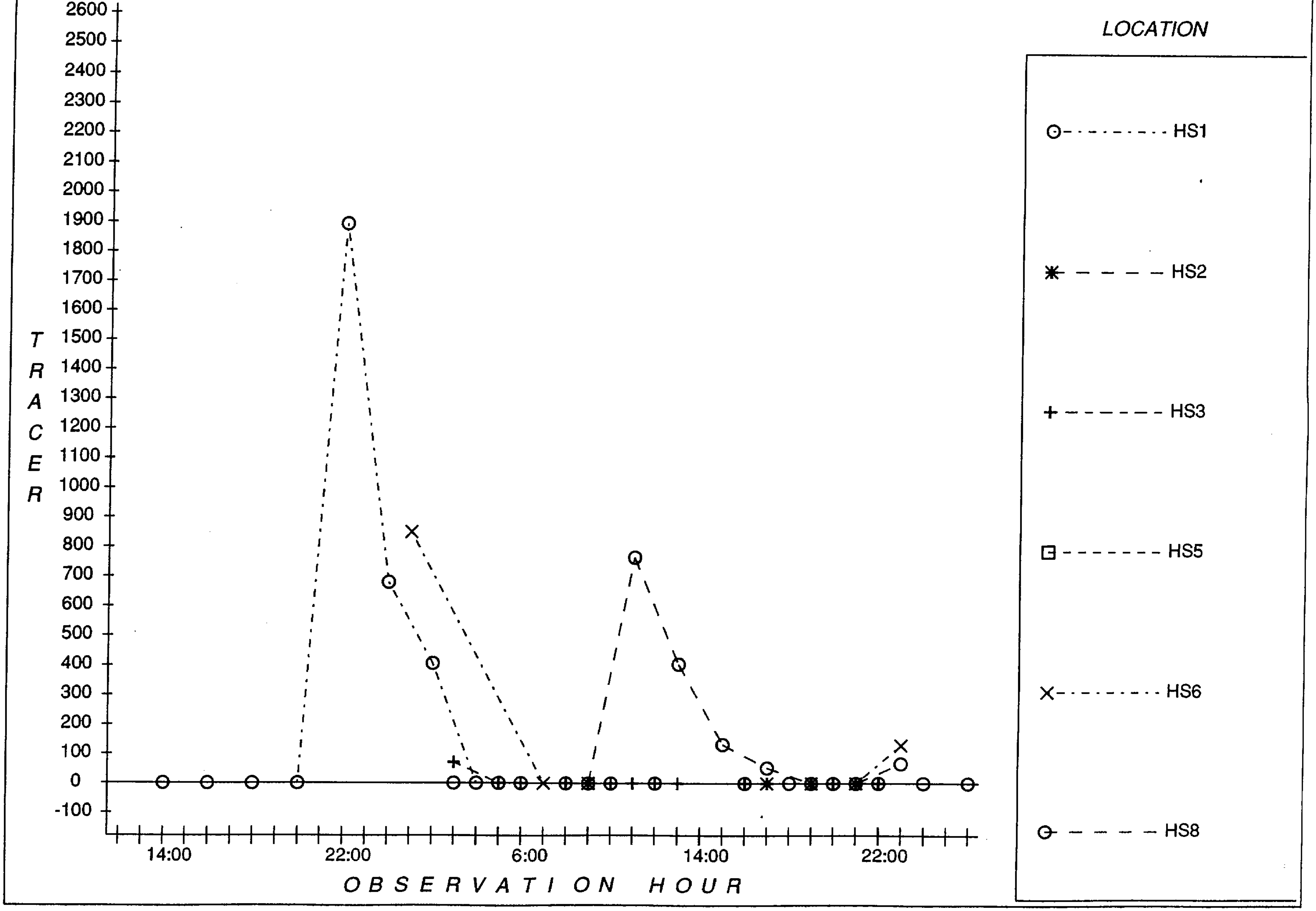

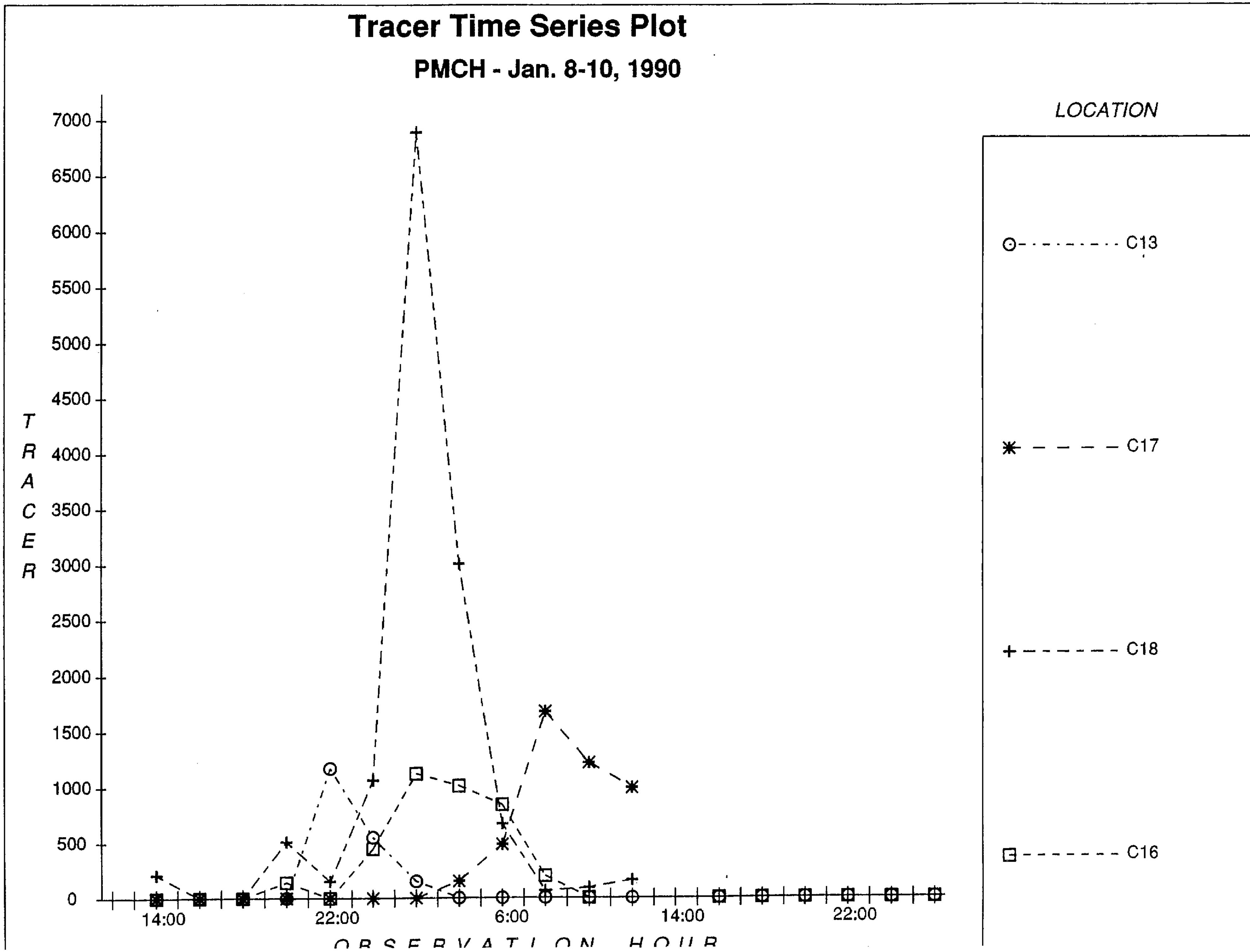
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PMCH - Jan. 8-10, 1990
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OBSERVATION HOUR
LOCATION
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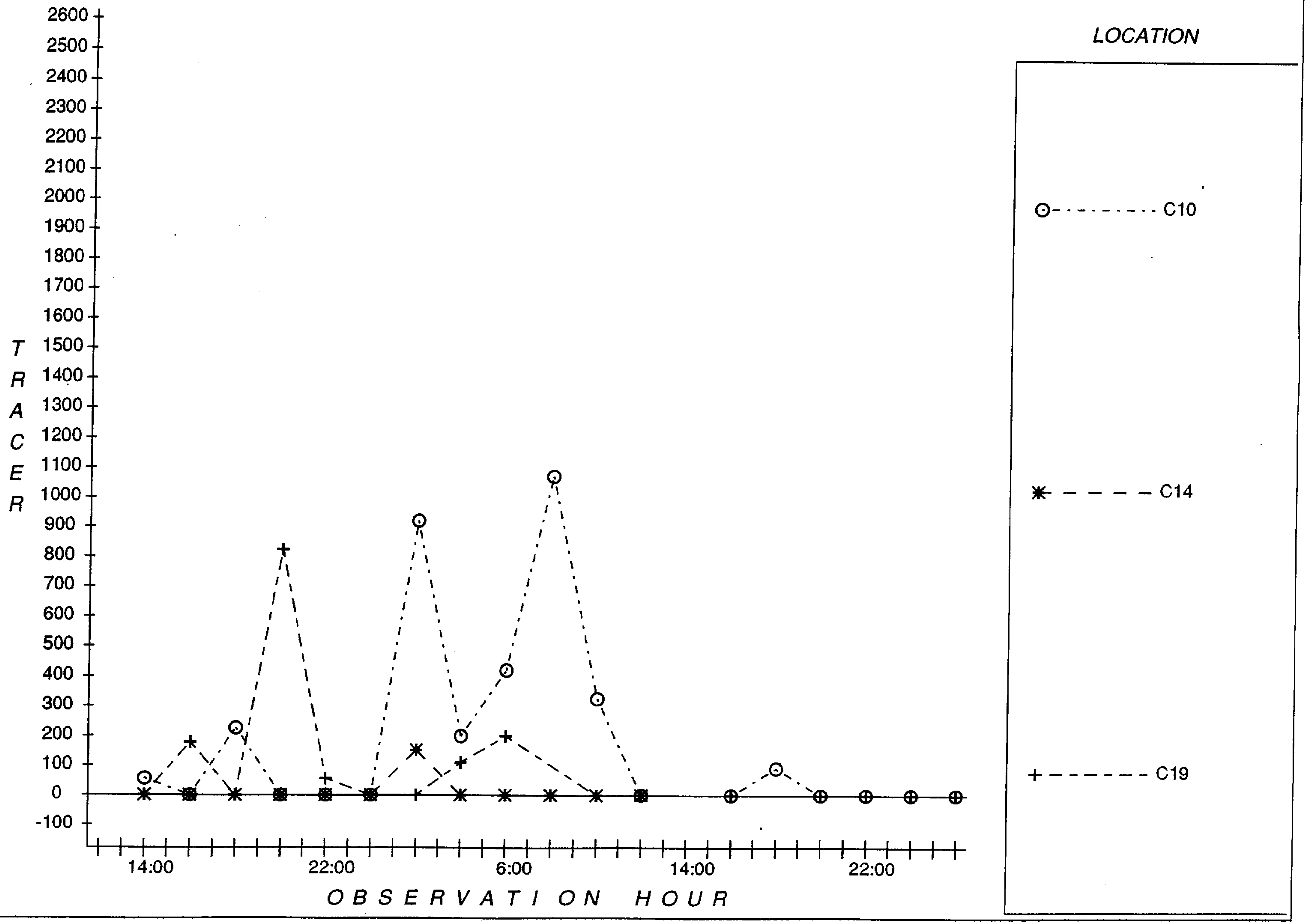
C17
C18
C16

Tracer Time Series Plot

PMCH - Jan. 8-10, 1990



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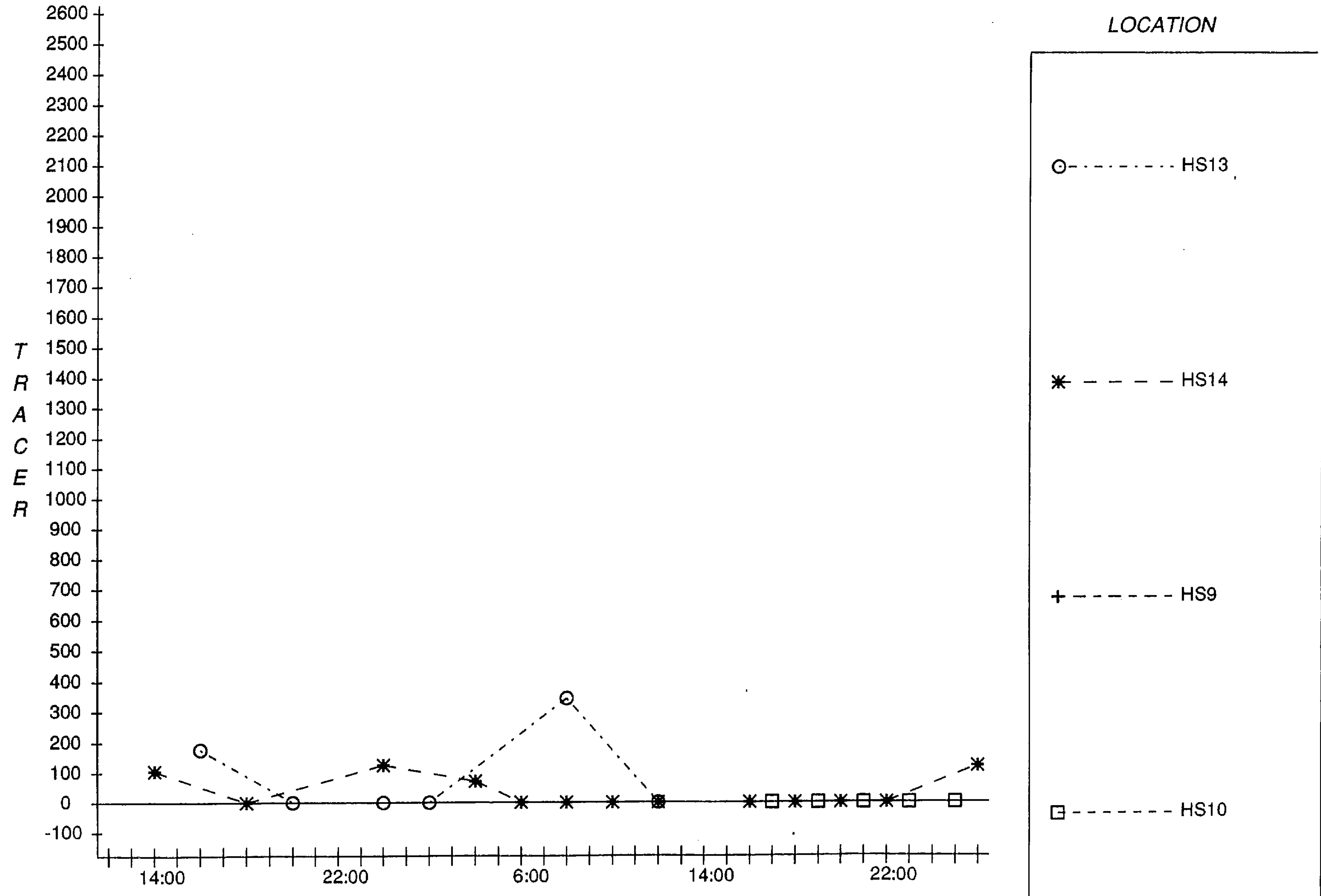

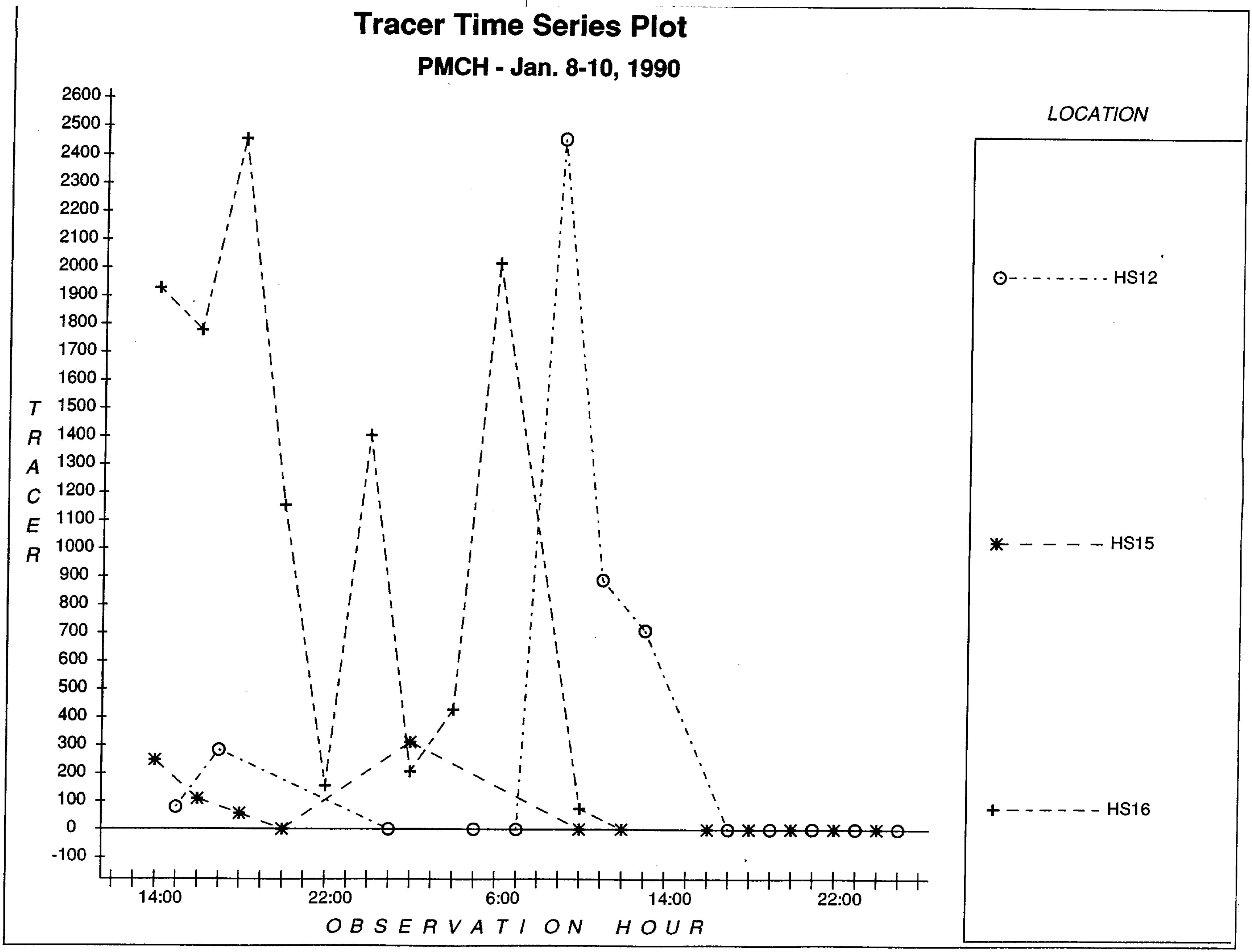
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PMCH - Jan. 8-10, 1990
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OBSERVATION HOUR
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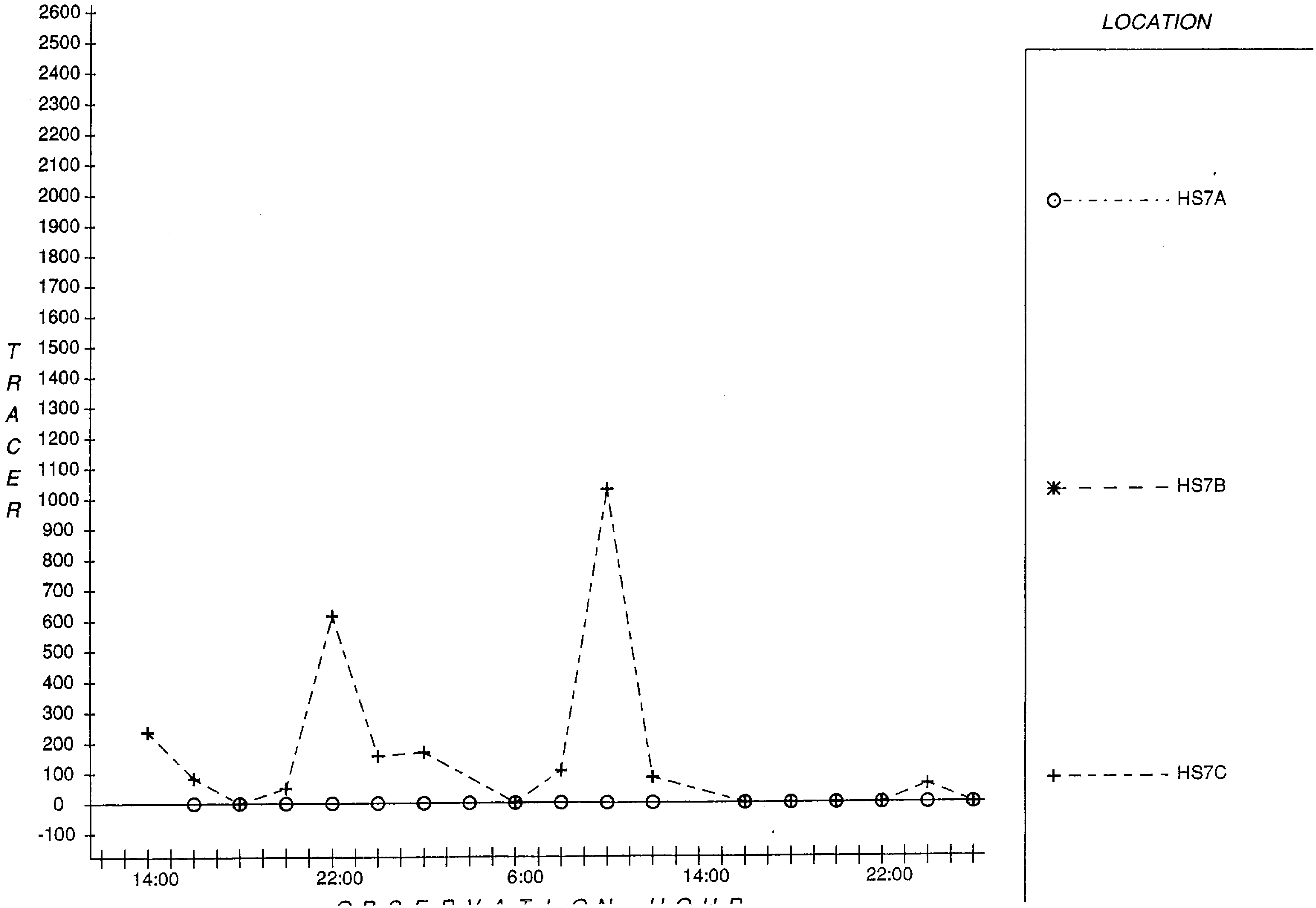
Tracer Time Series Plot

PMCH - Jan. 8-10, 1990



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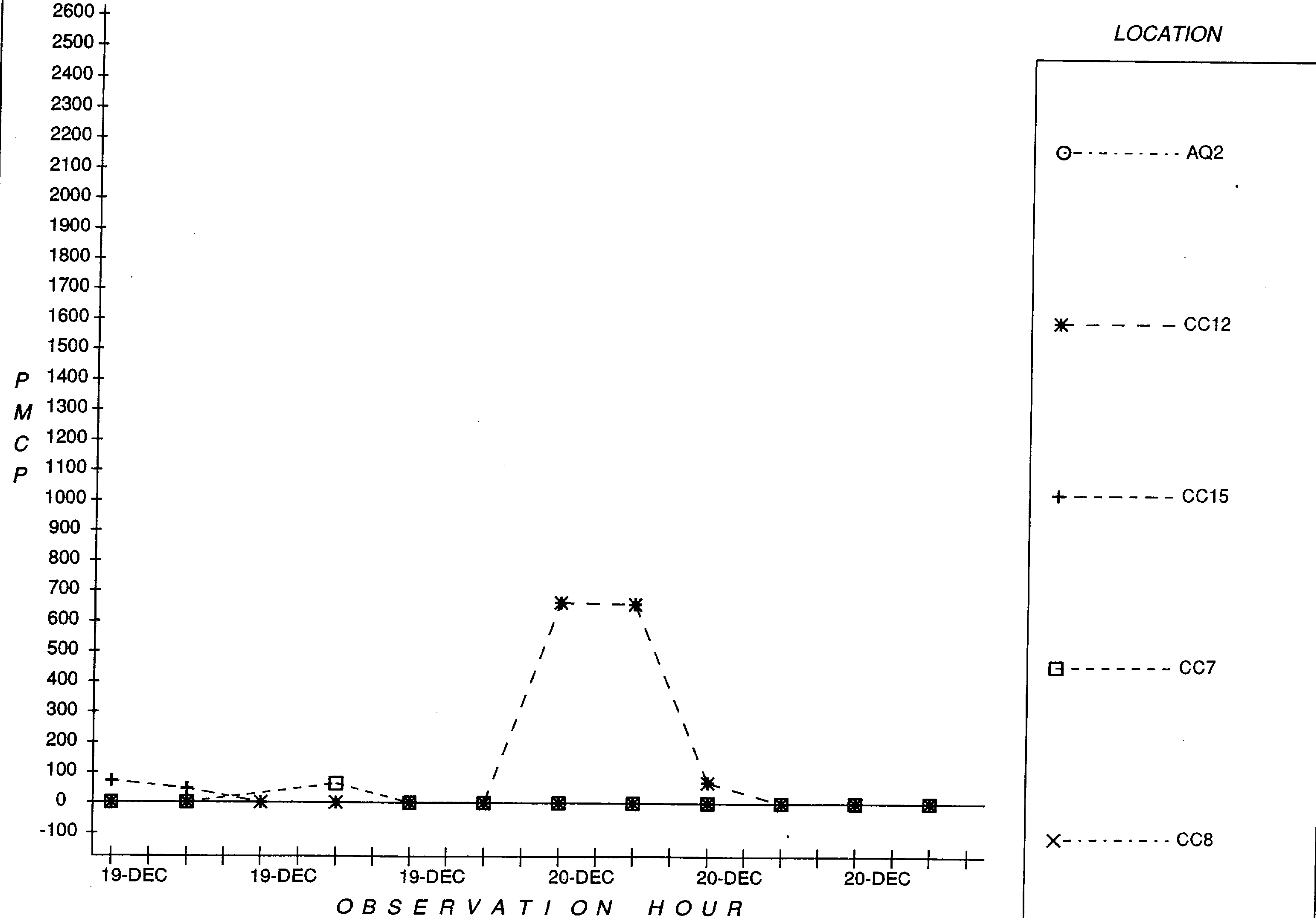

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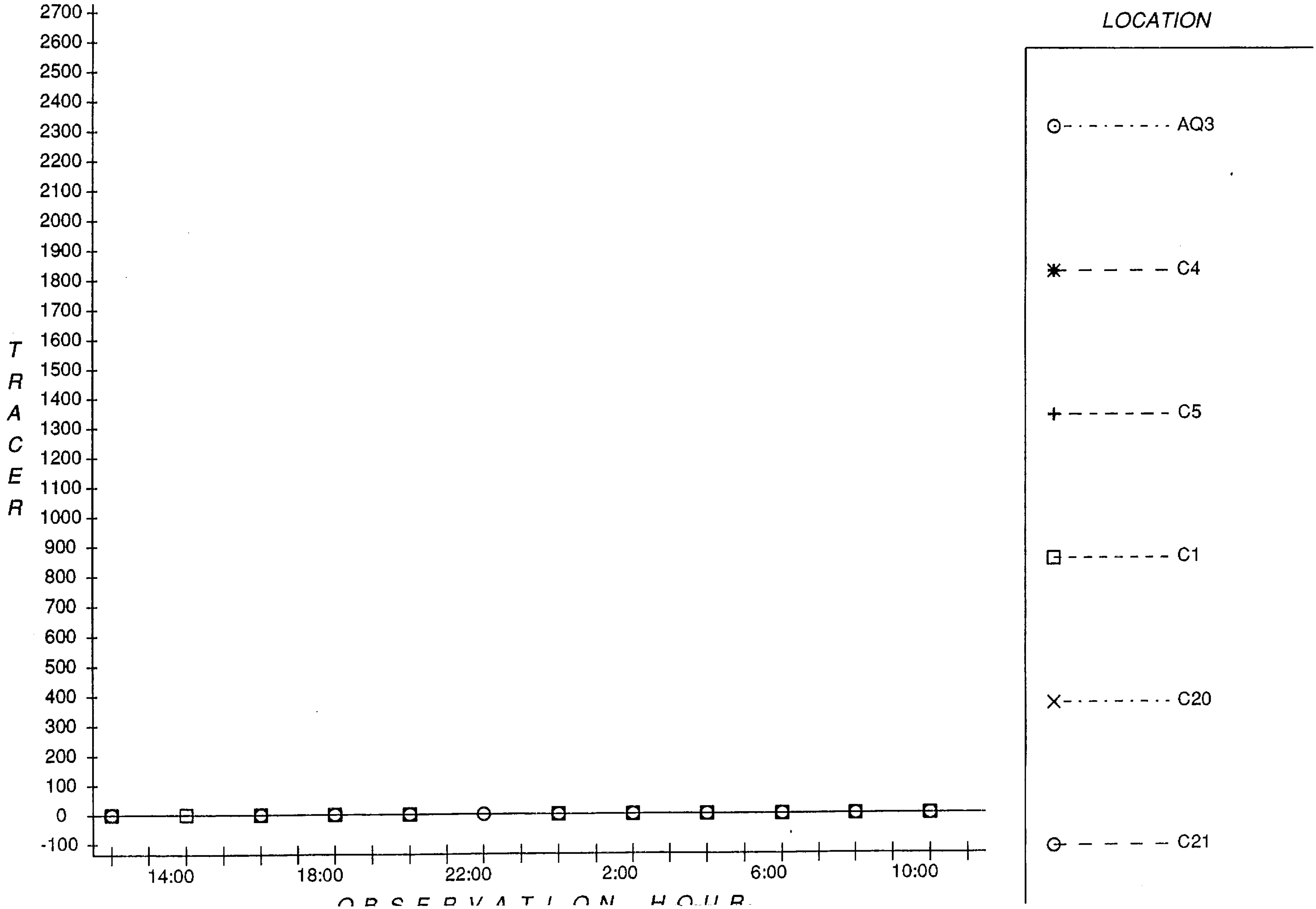
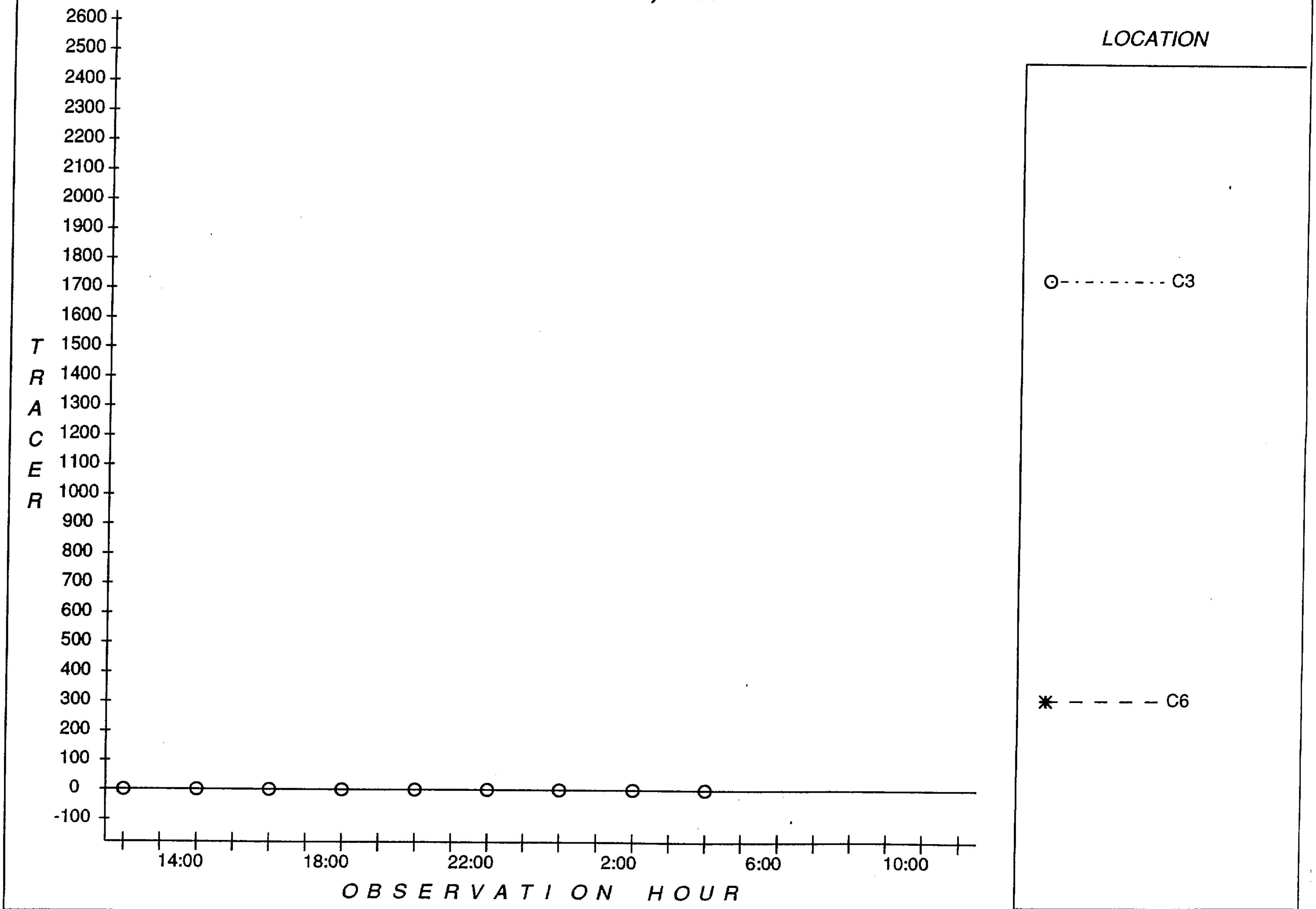
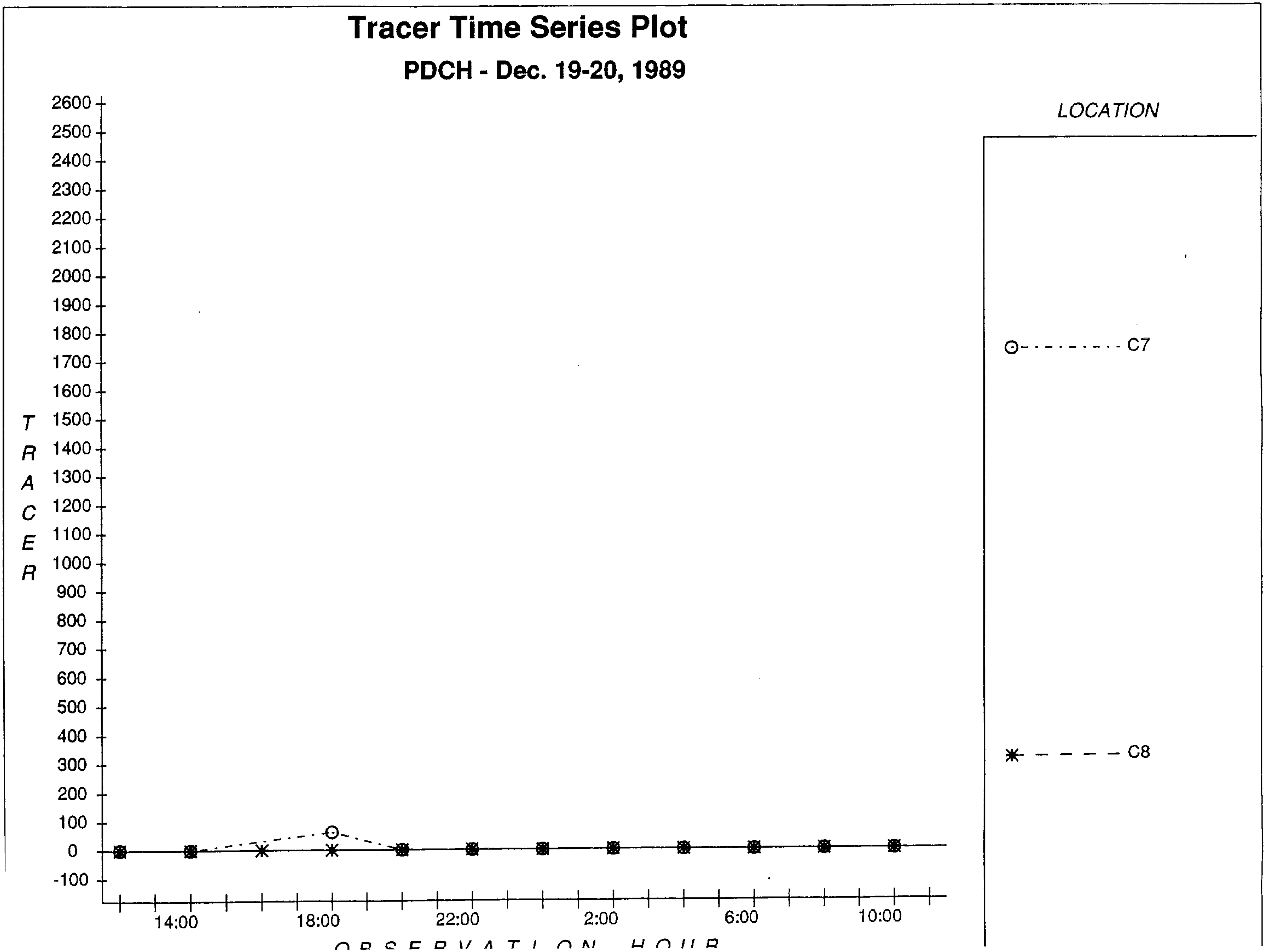
PDCH - Dec. 19-20, 1989



Tracer Time Series Plot

PDCH - Dec. 19-20, 1989

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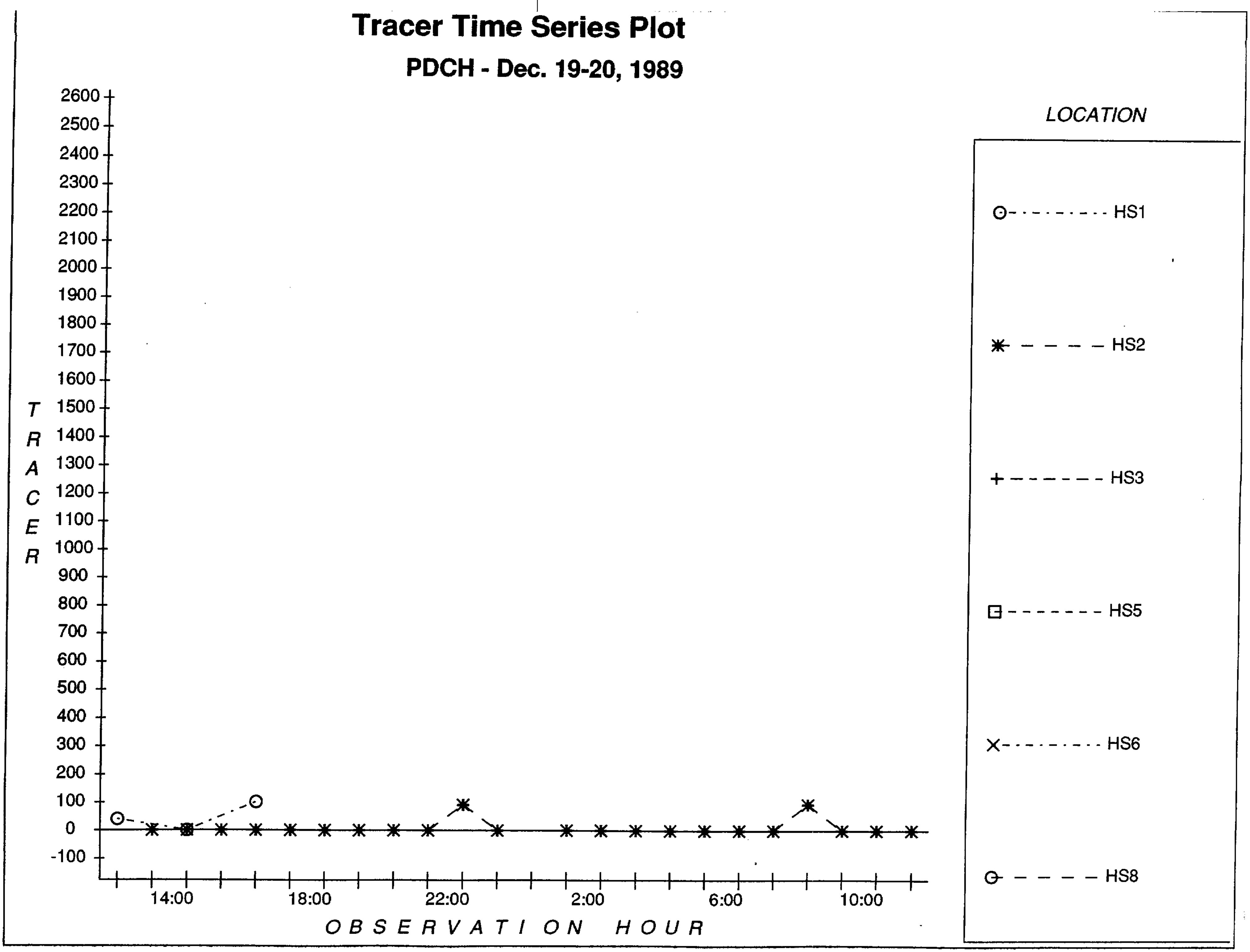
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PDCH - Dec. 19-20, 1989
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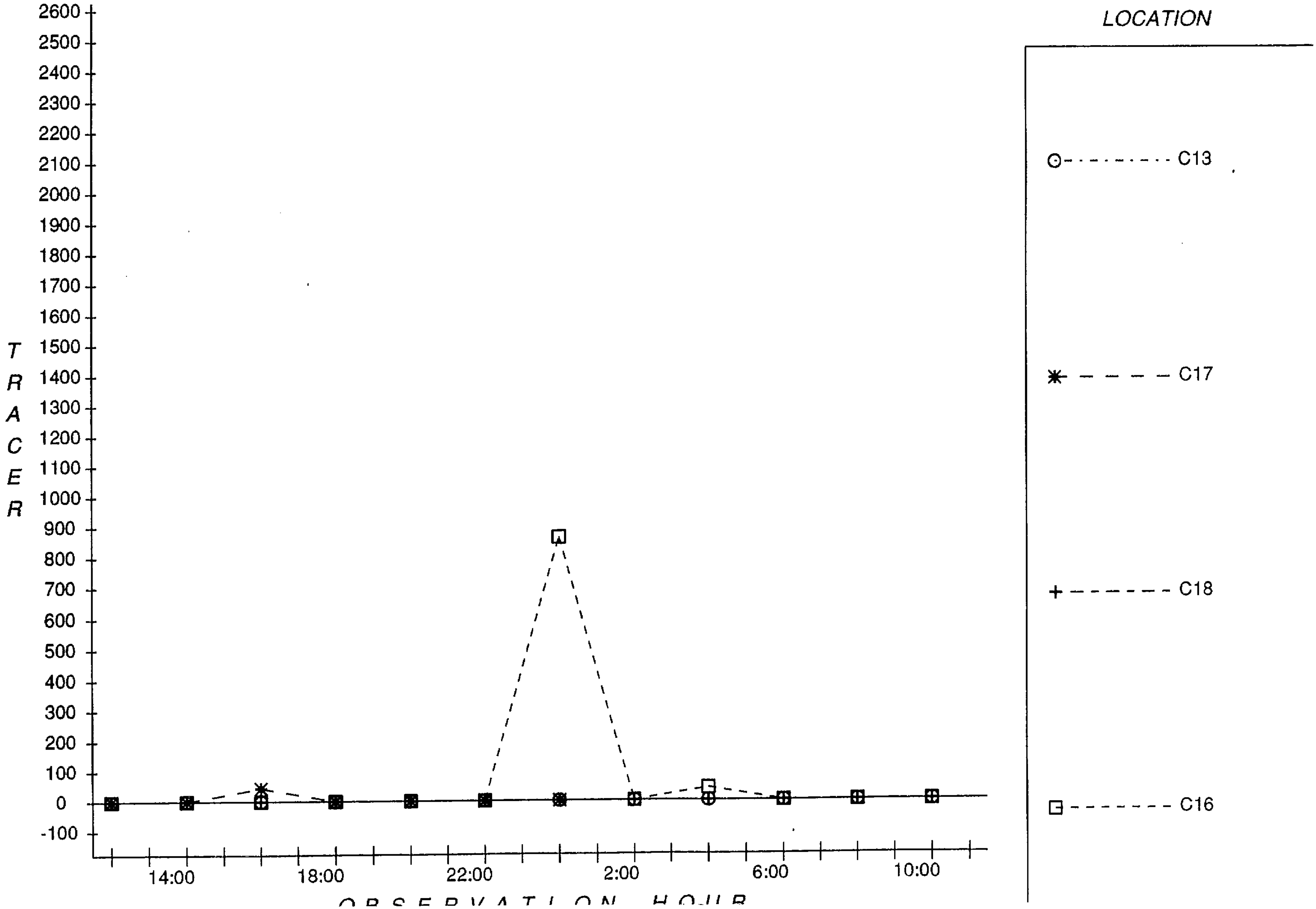
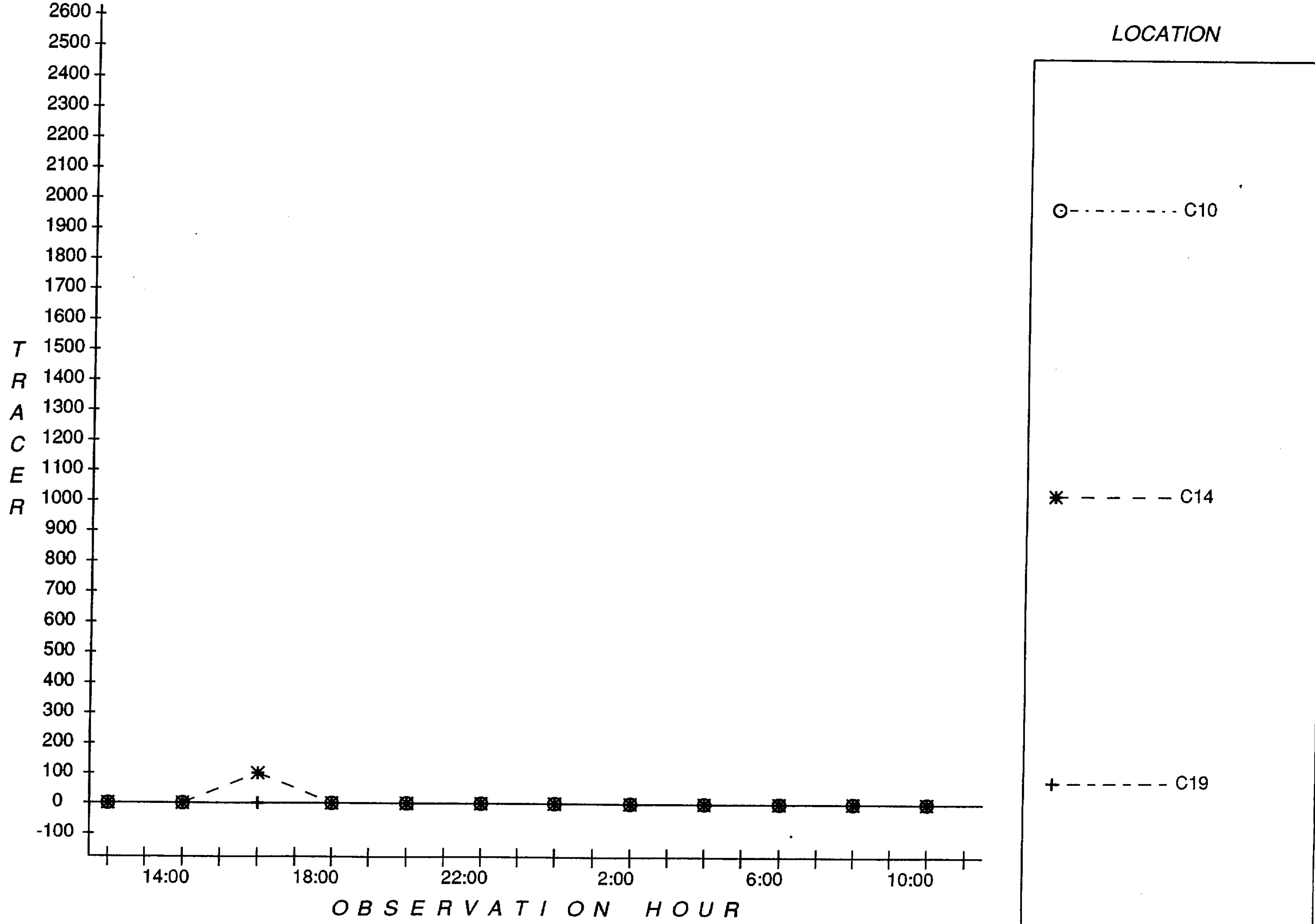
Tracer Time Series Plot

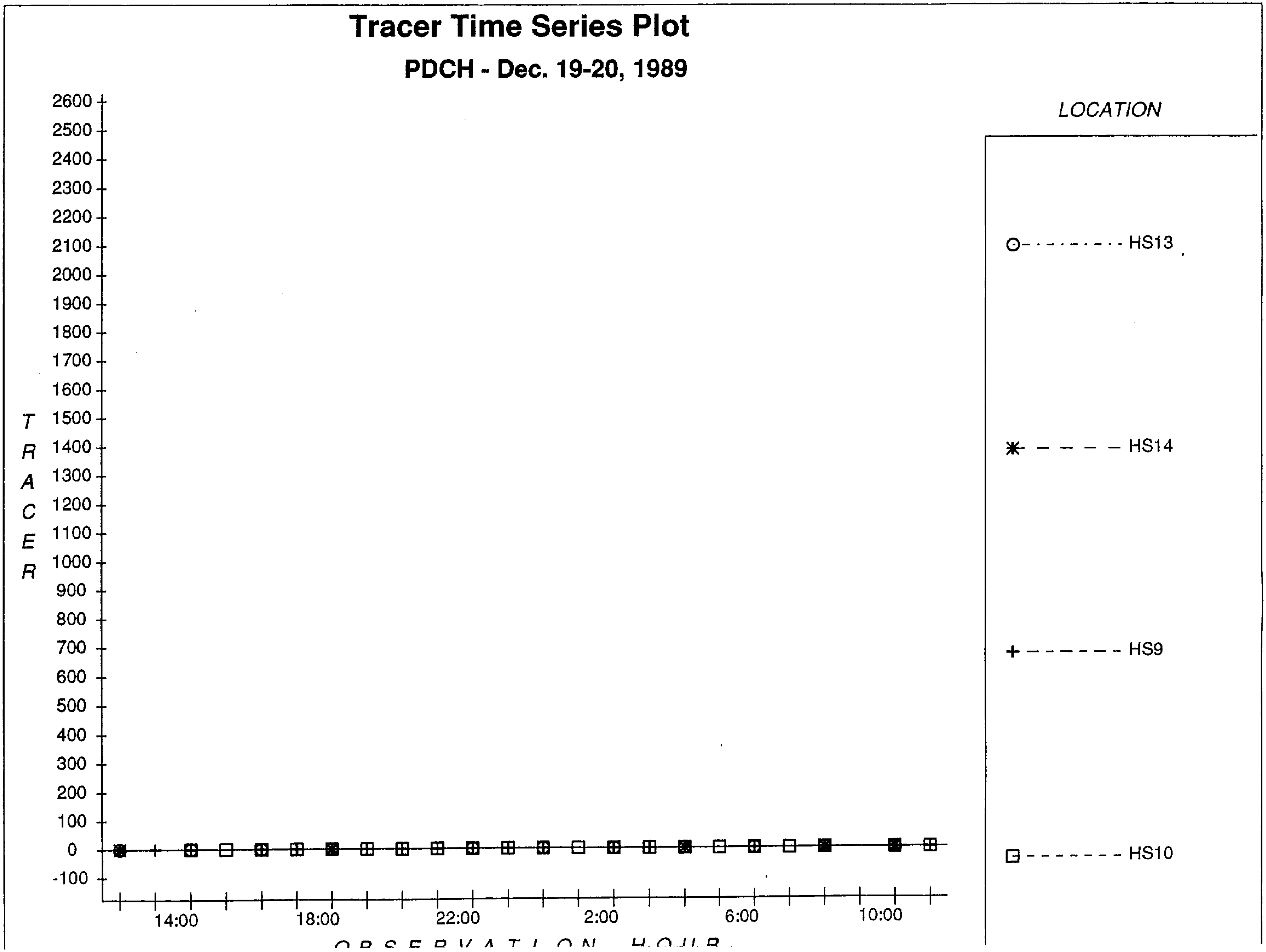
PDCH - Dec. 19-20, 1989



Tracer Time Series Plot

PDCH - Dec. 19-20, 1989

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PDCH - Dec. 19-20, 1989
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LOCATION
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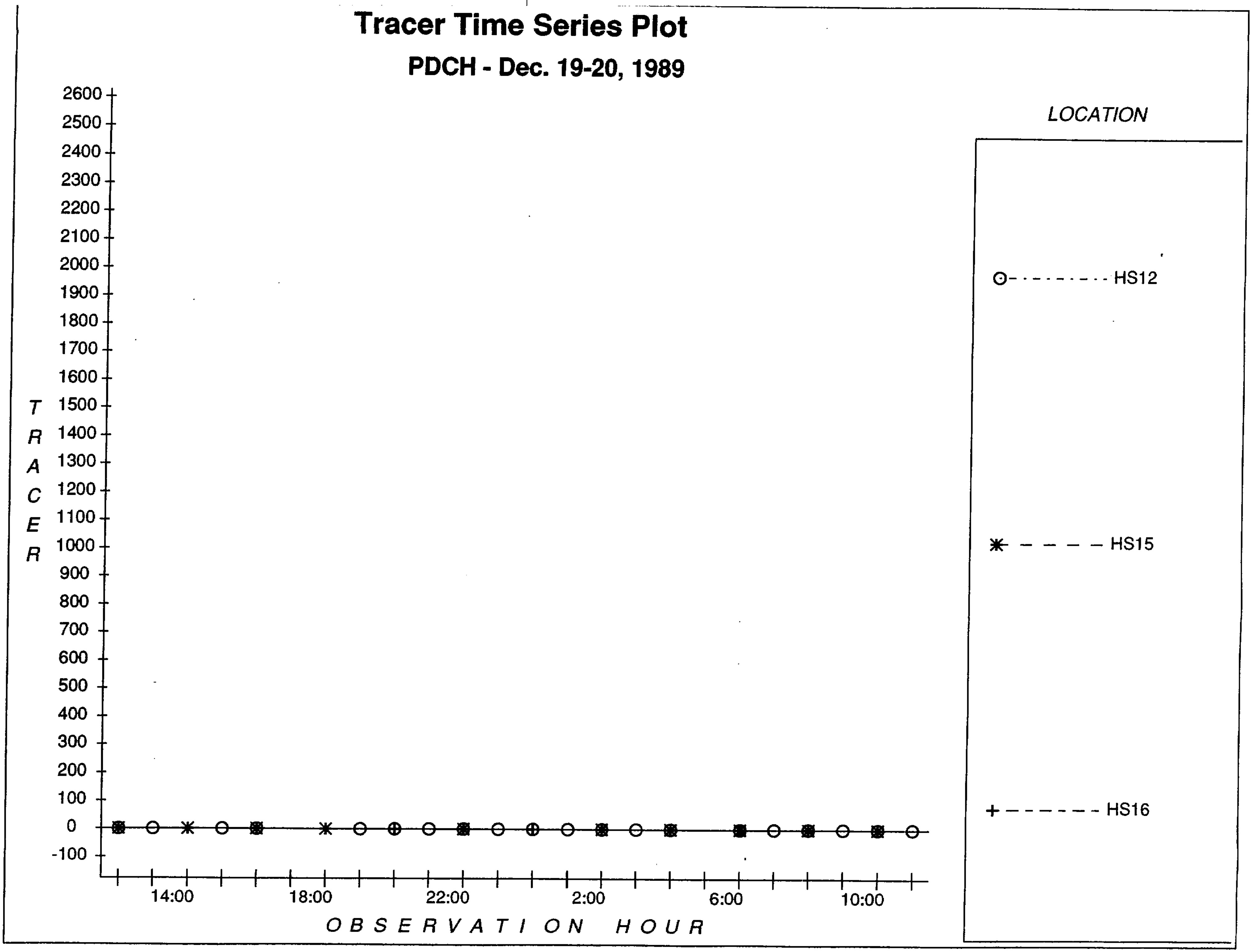
HS10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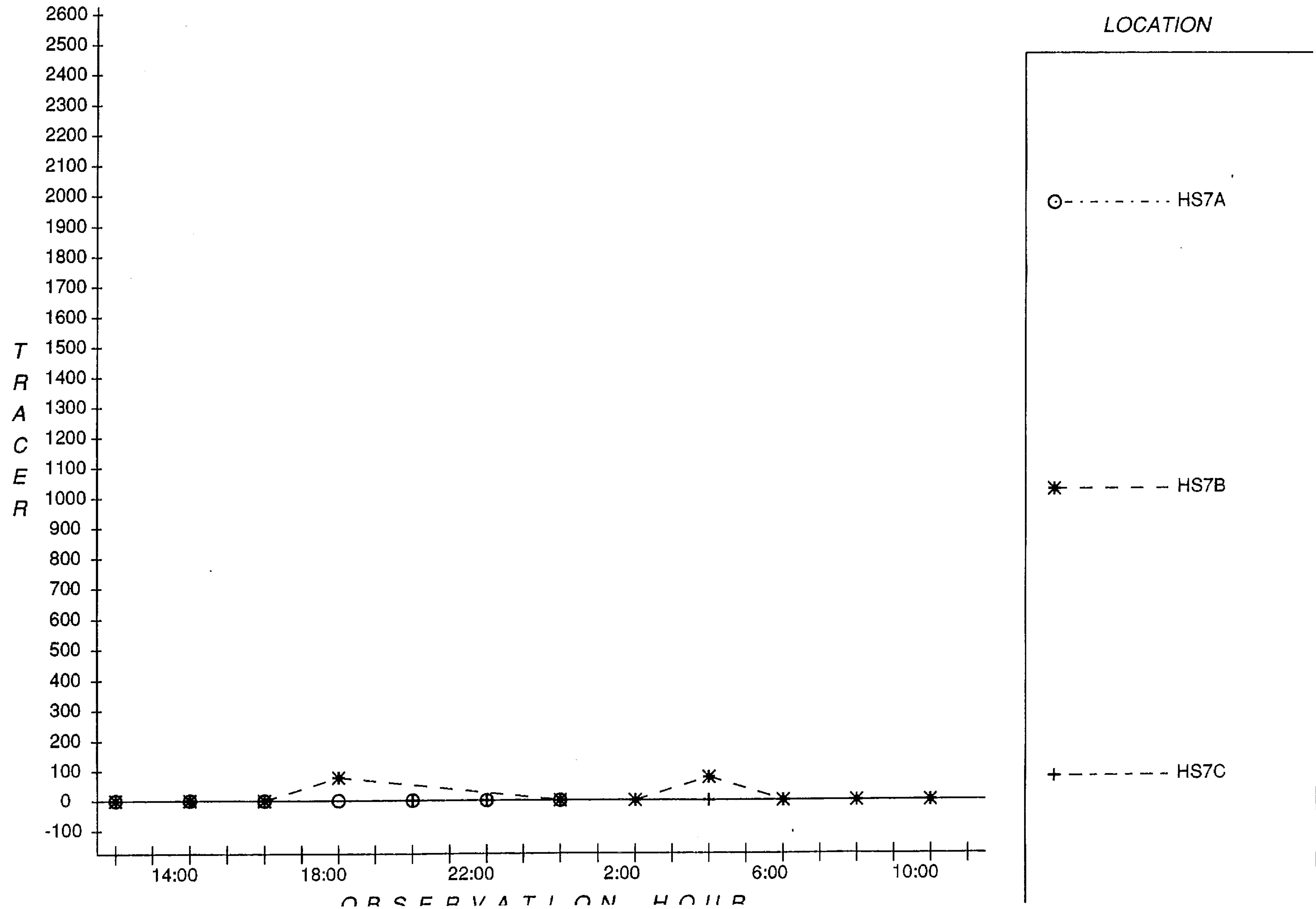
OBSERVATION HOUR
LOCATION
HS12
HS15
HS16

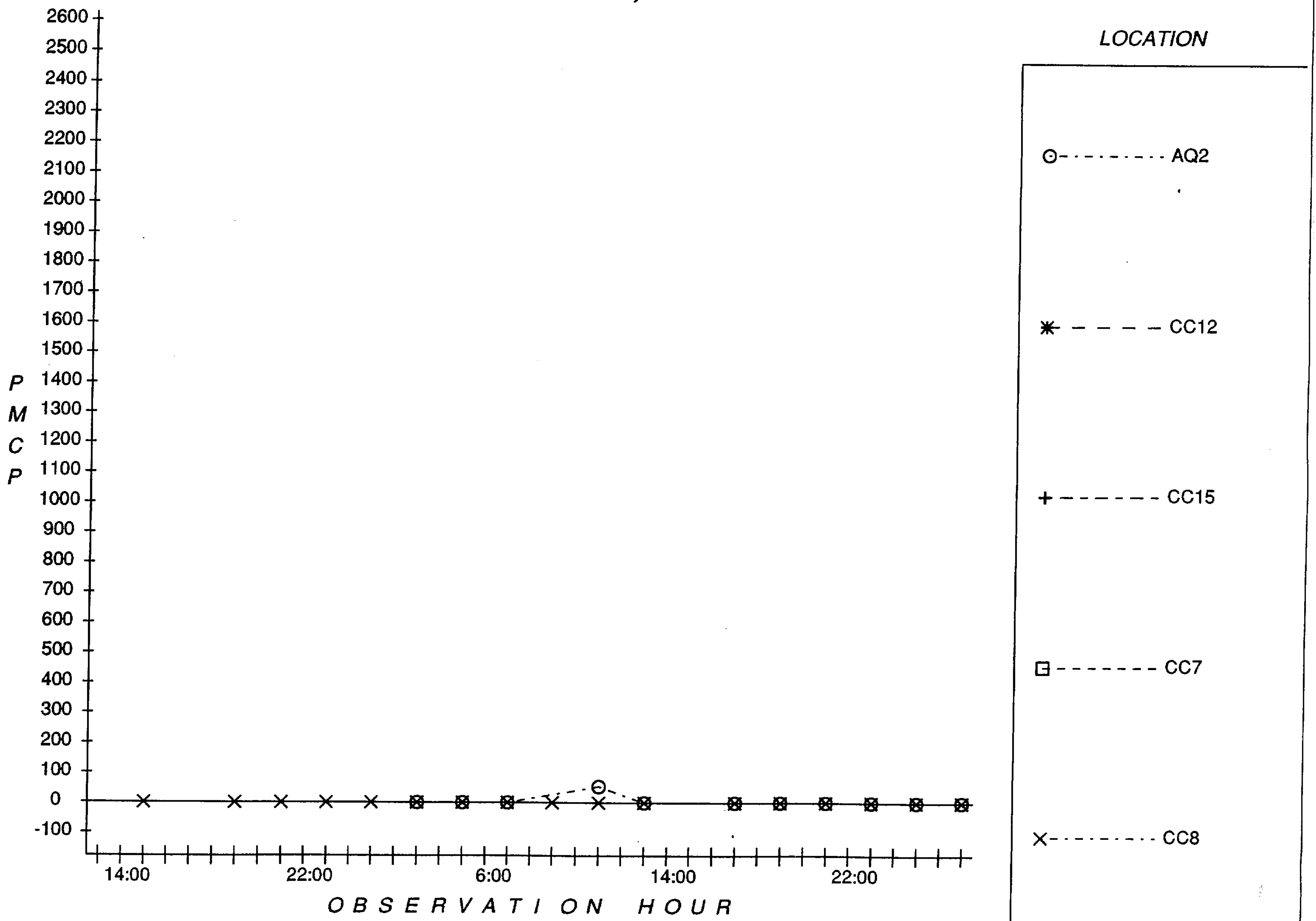
Tracer Time Series Plot

PDCH - Dec. 19-20, 1989



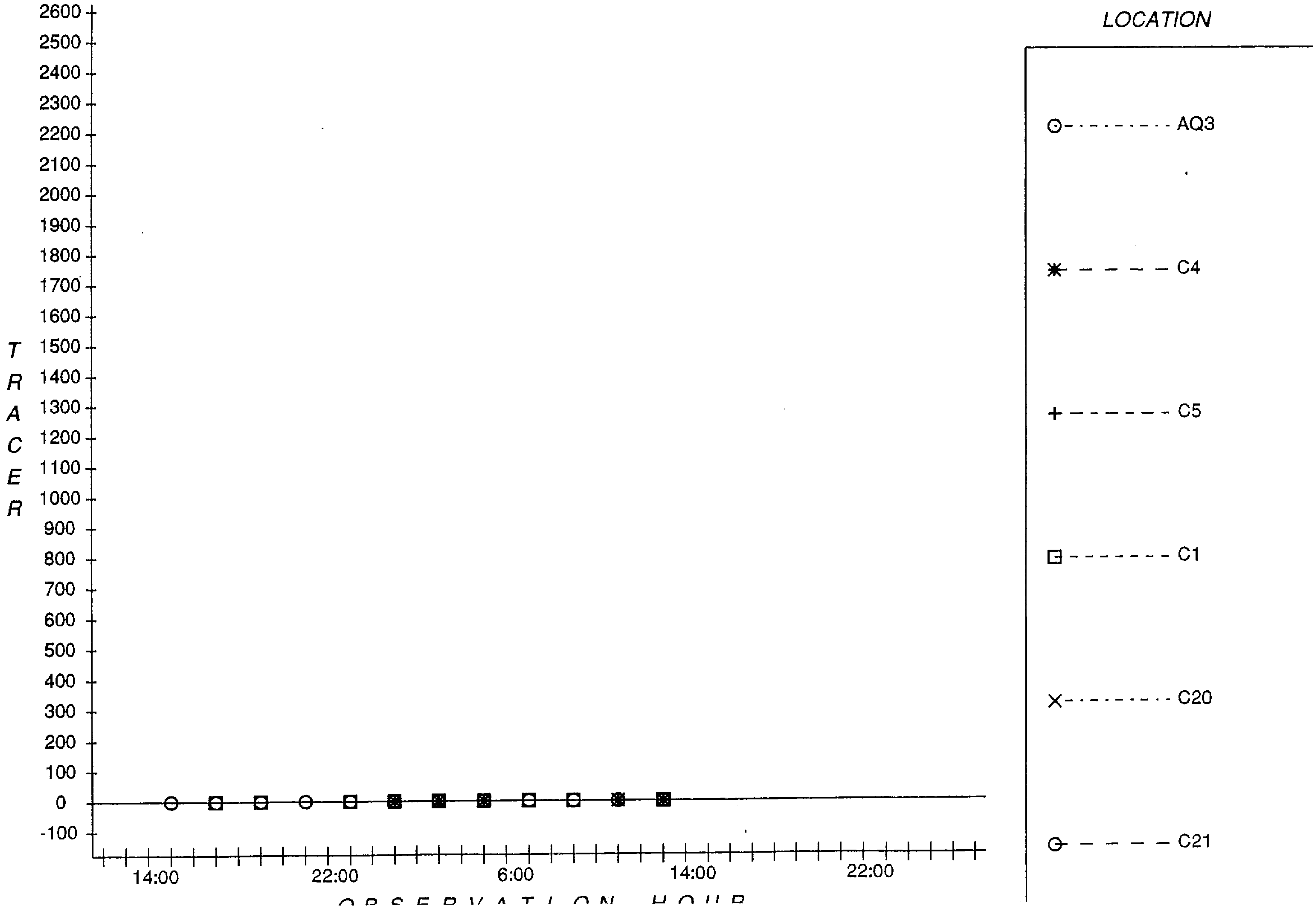
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



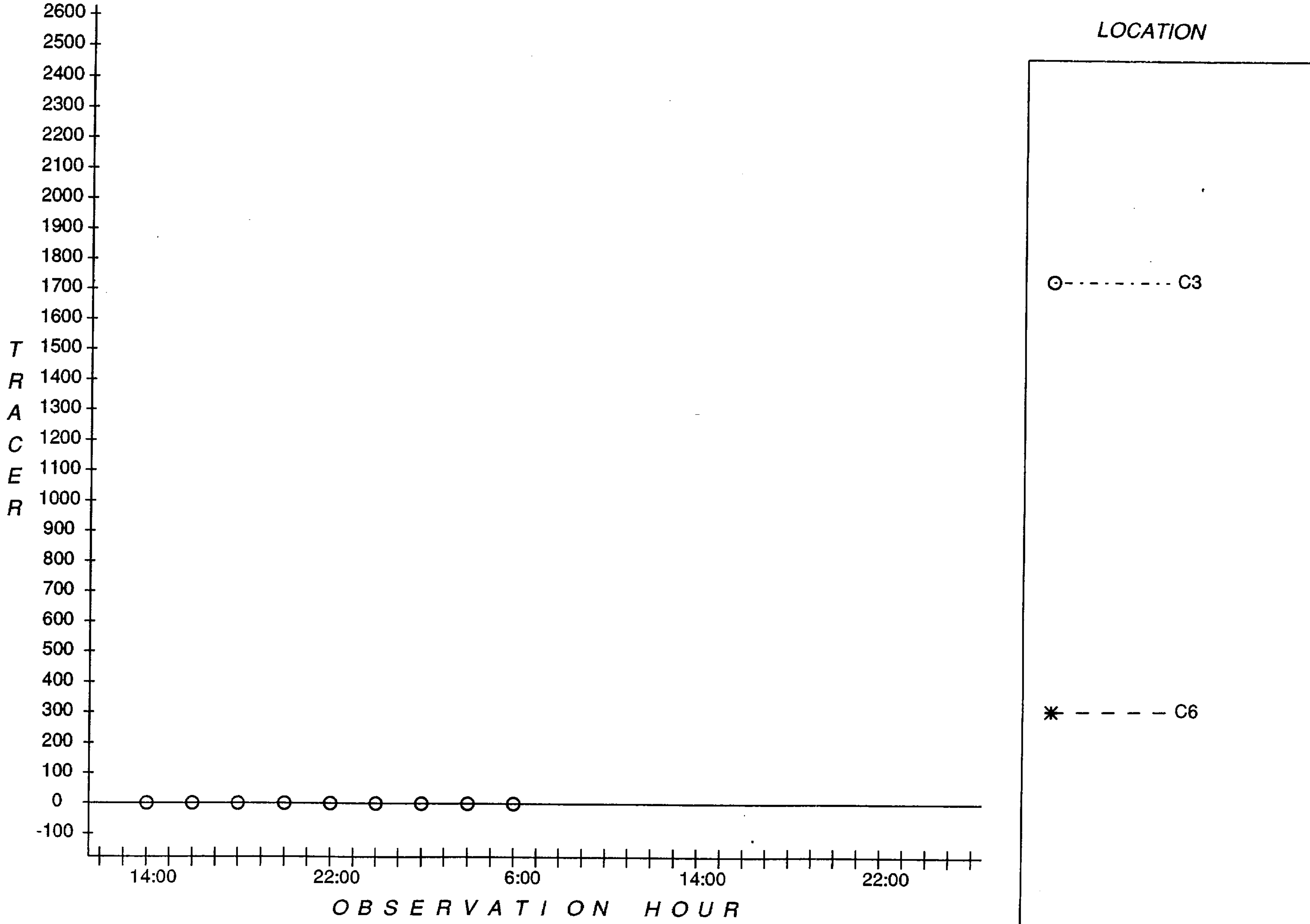
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



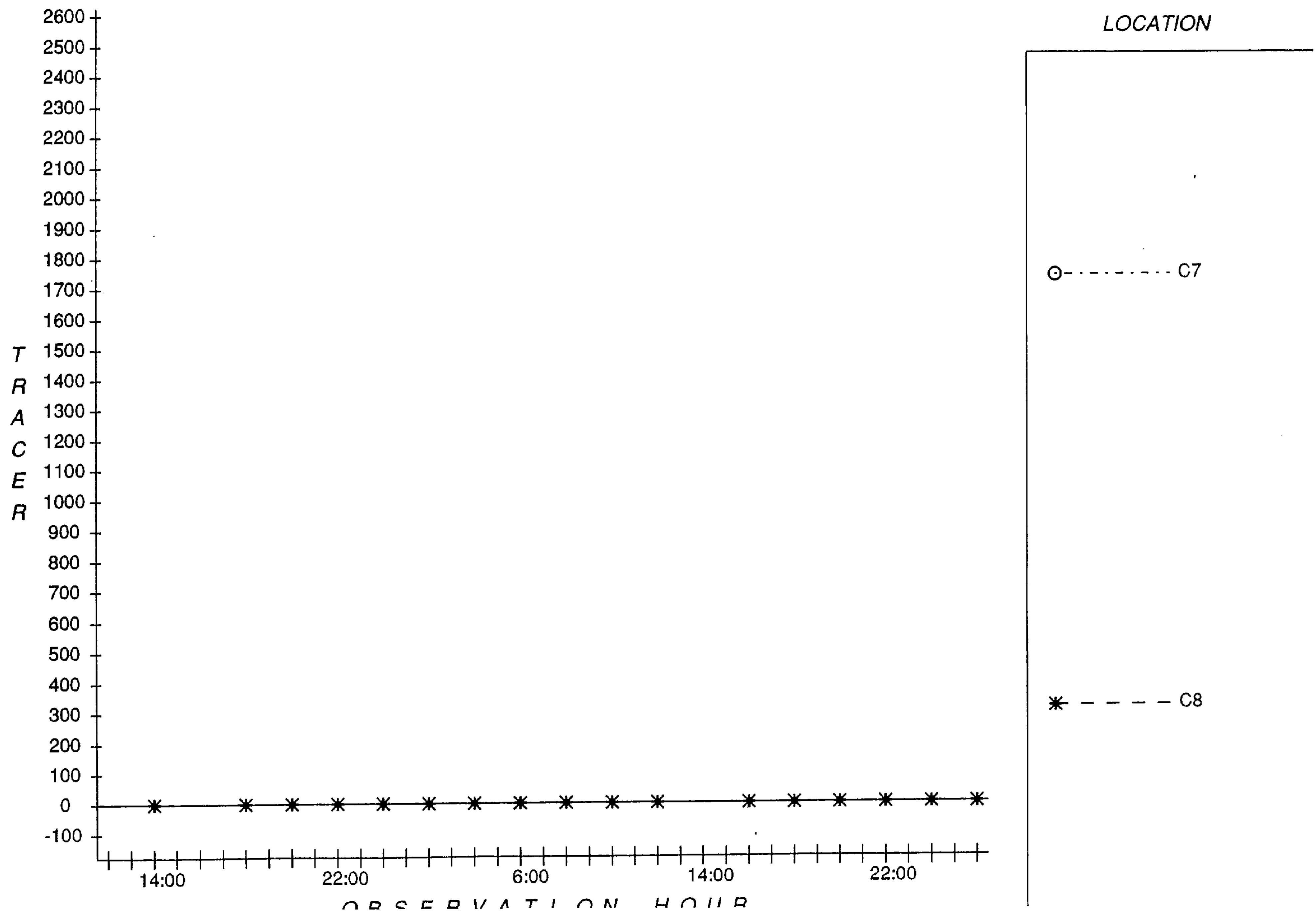
Tracer Time Series Plot

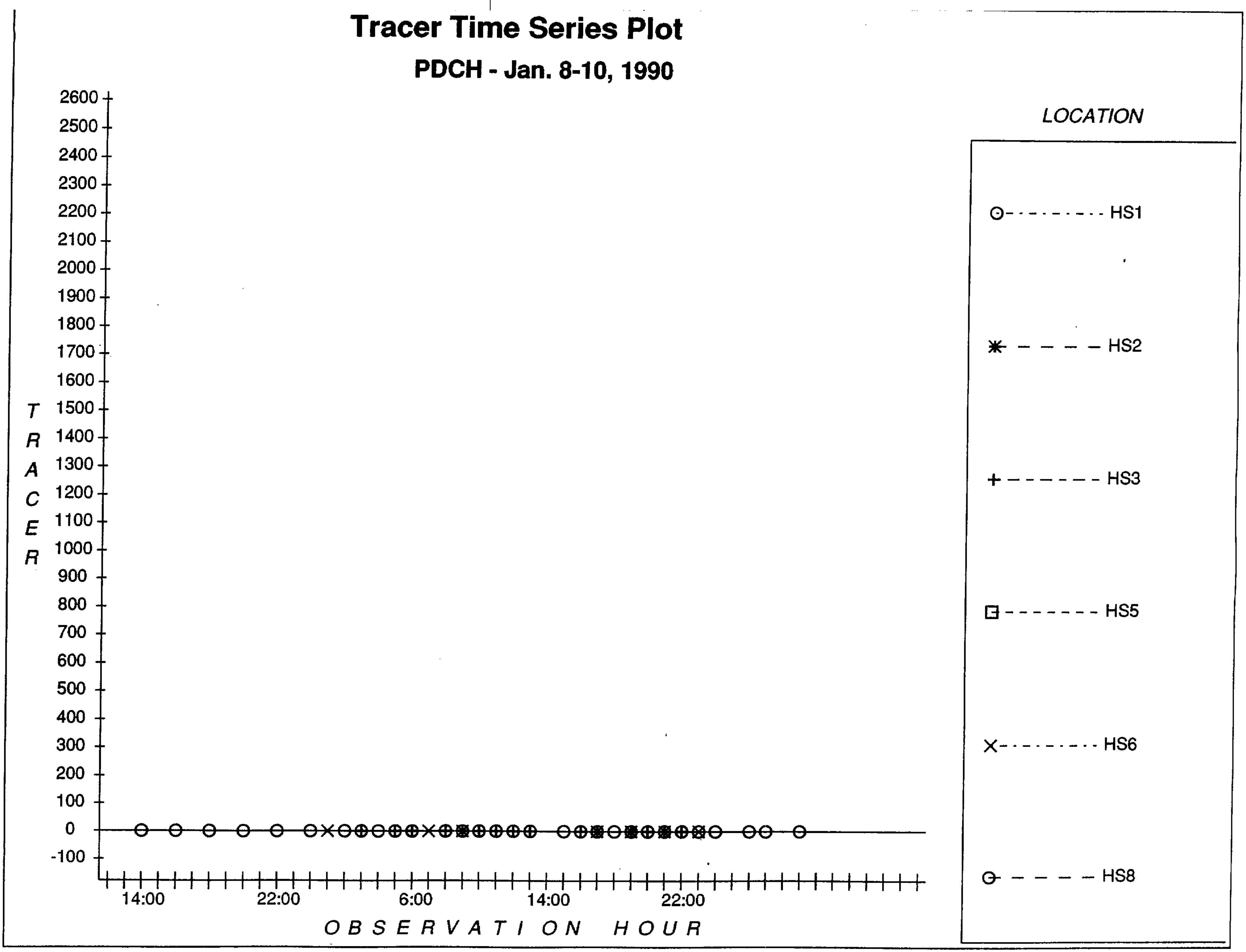
PDCH - Jan. 8-10, 1990



Tracer Time Series Plot

PDCH - Jan. 8-10, 1990




Tracer Time Series Plot
PDCH - Jan. 8-10, 1990
TRACER
2600
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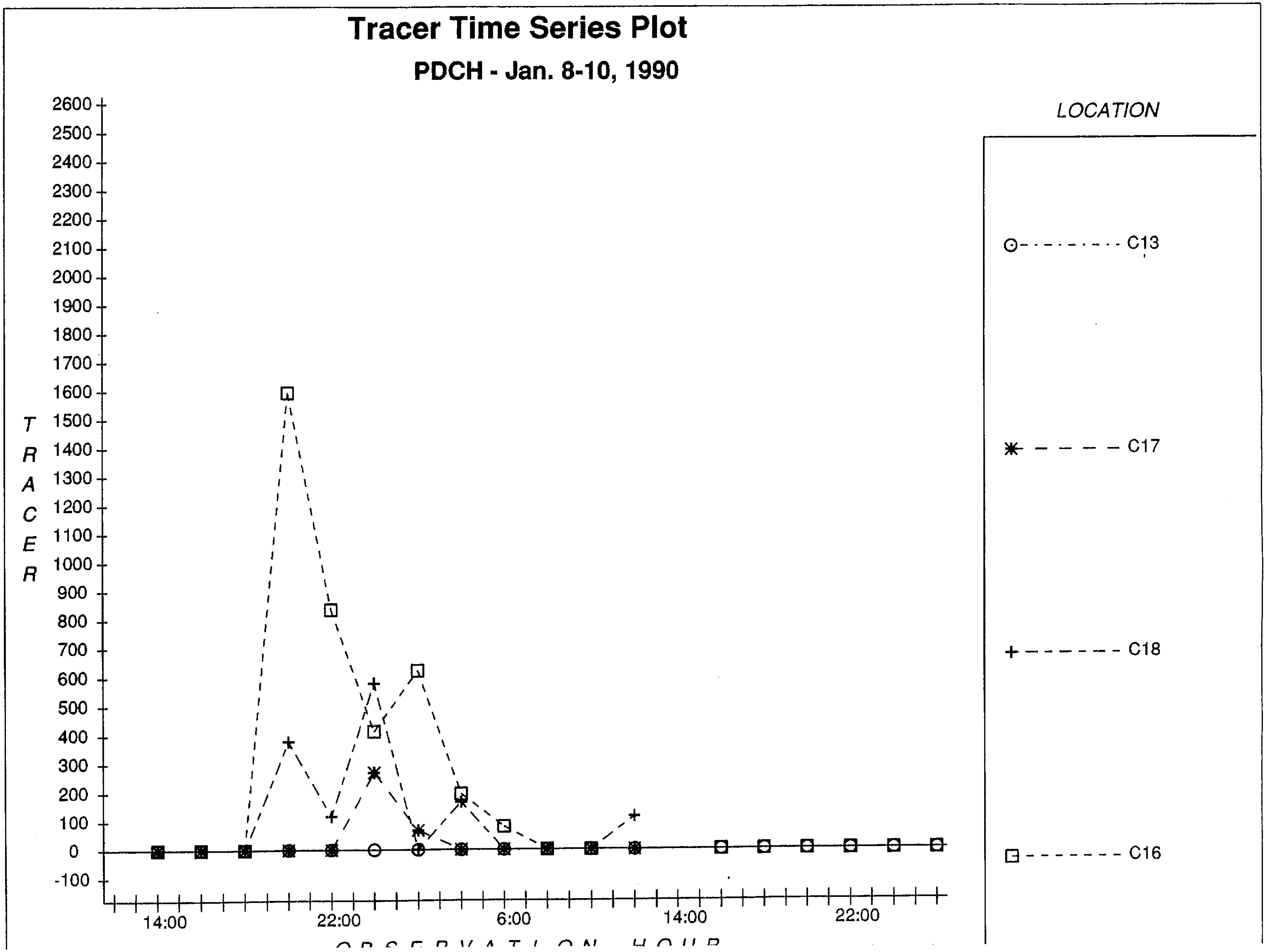
-100
14:00
22:00
6:00
14:00
22:00
OBSERVATION HOUR
LOCATION
HS1
HS2
HS3
HS5
HS6
HS8


Tracer Time Series Plot
PDCH - Jan. 8-10, 1990
TRACER
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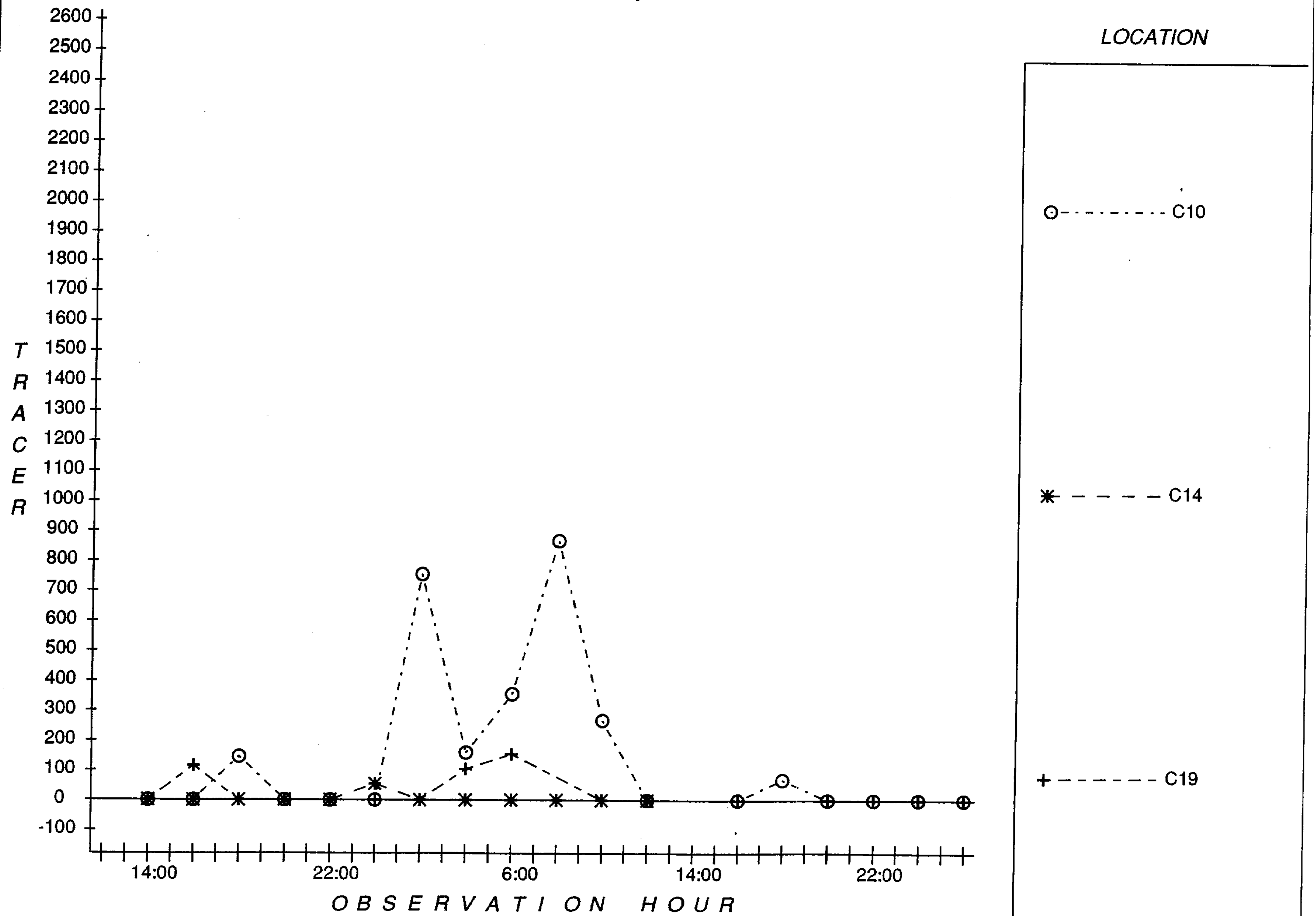
14:00
22:00
6:00
14:00
22:00
LOCATION
C13
C17
C18
C16

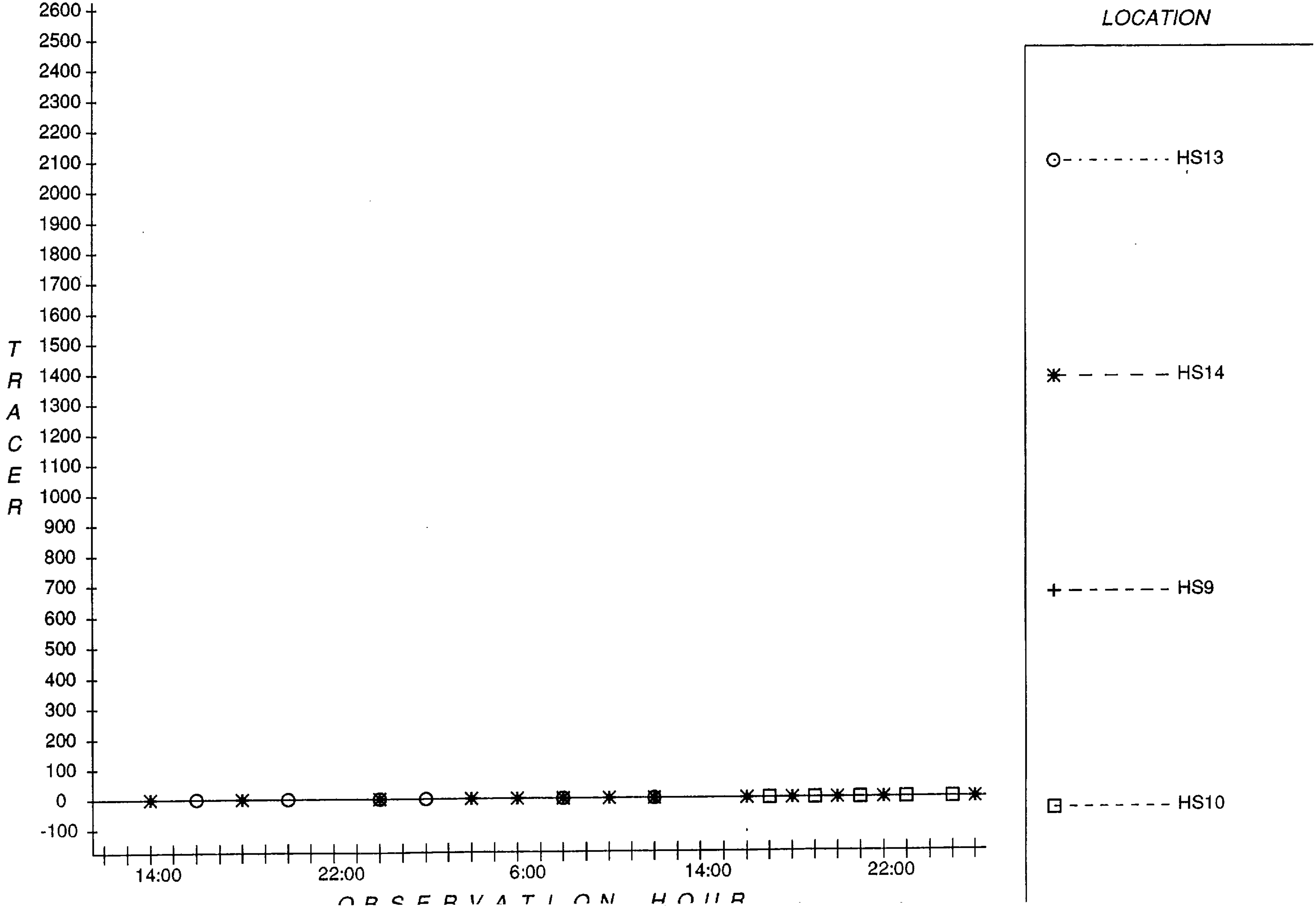
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



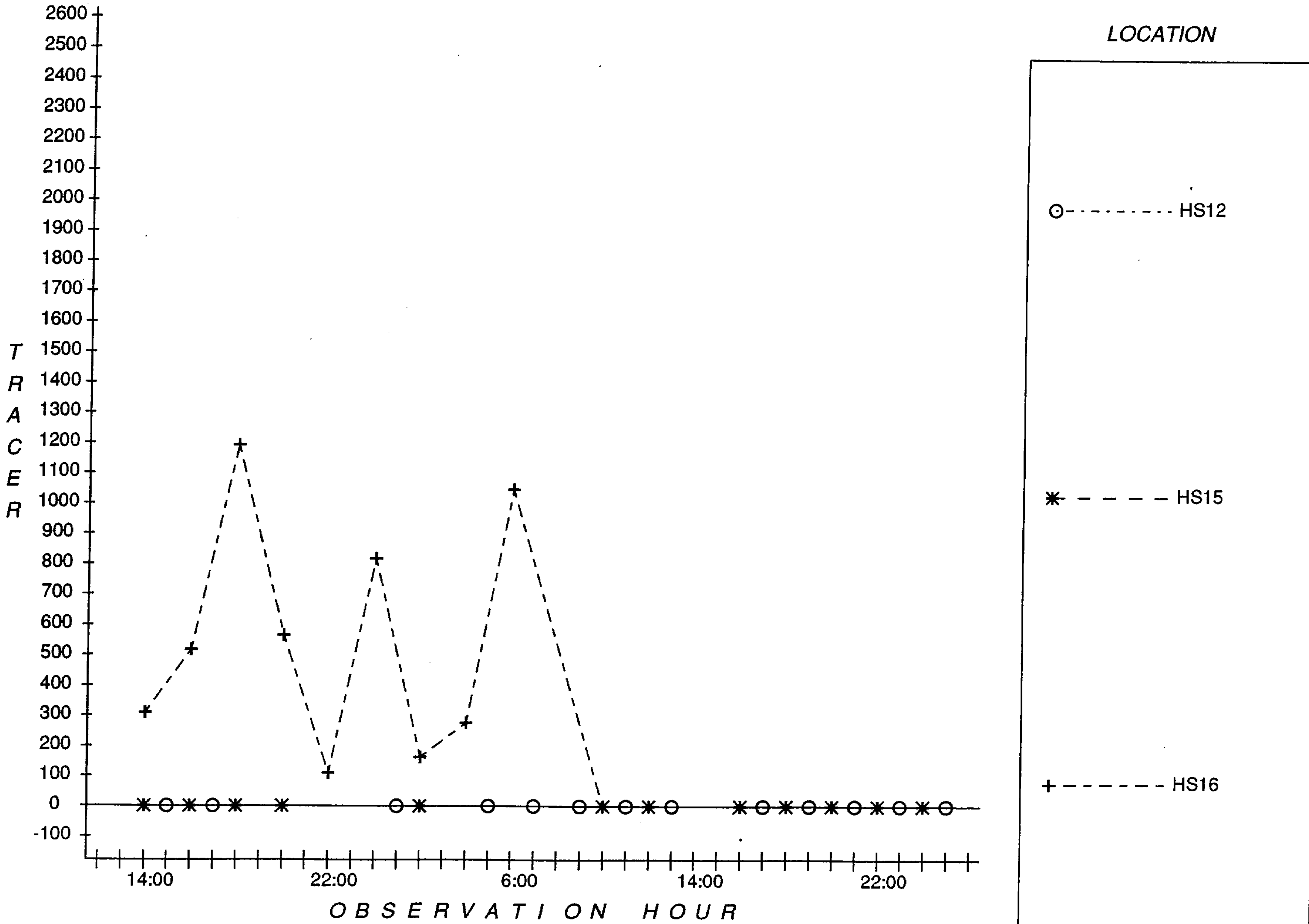
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



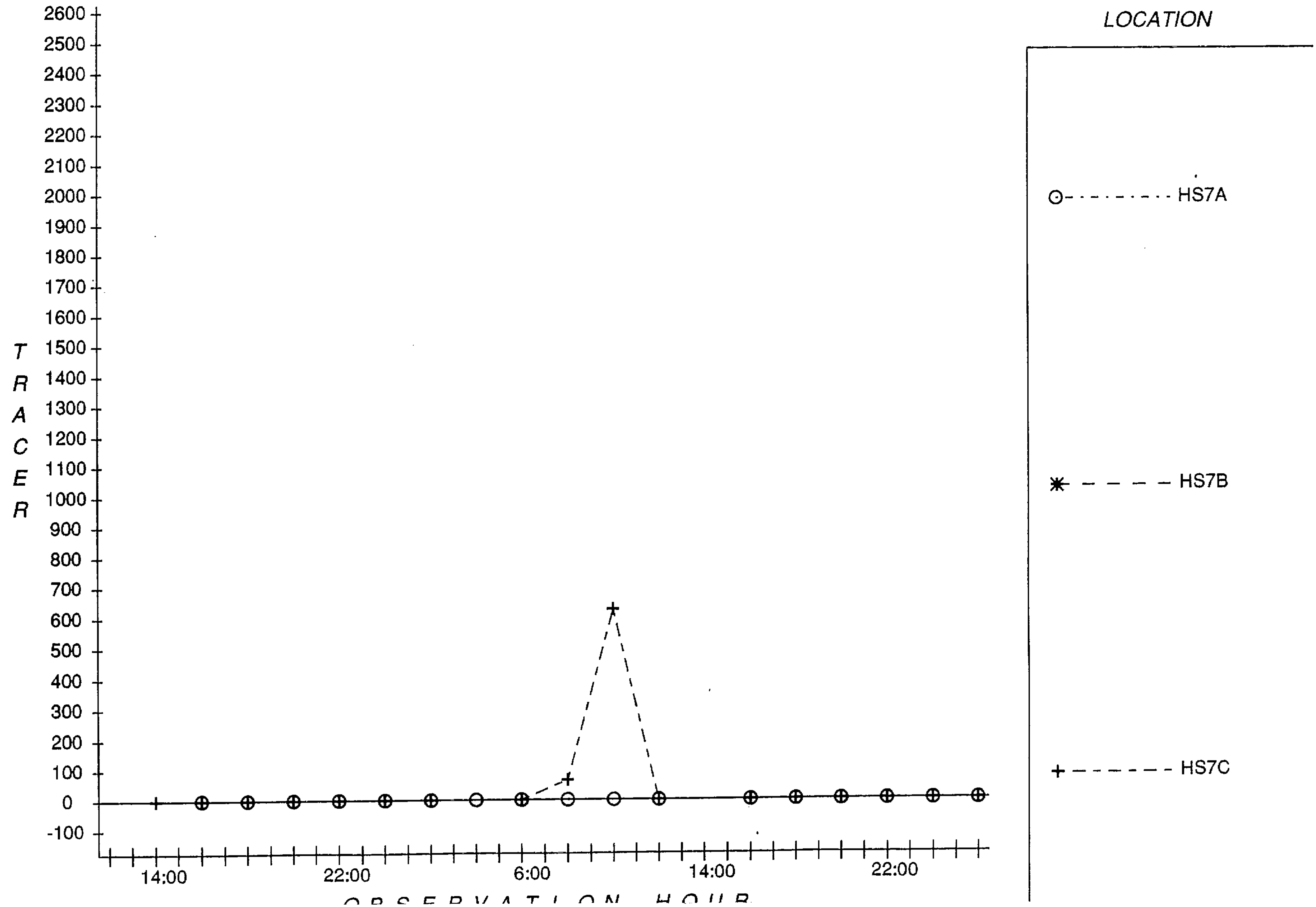
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



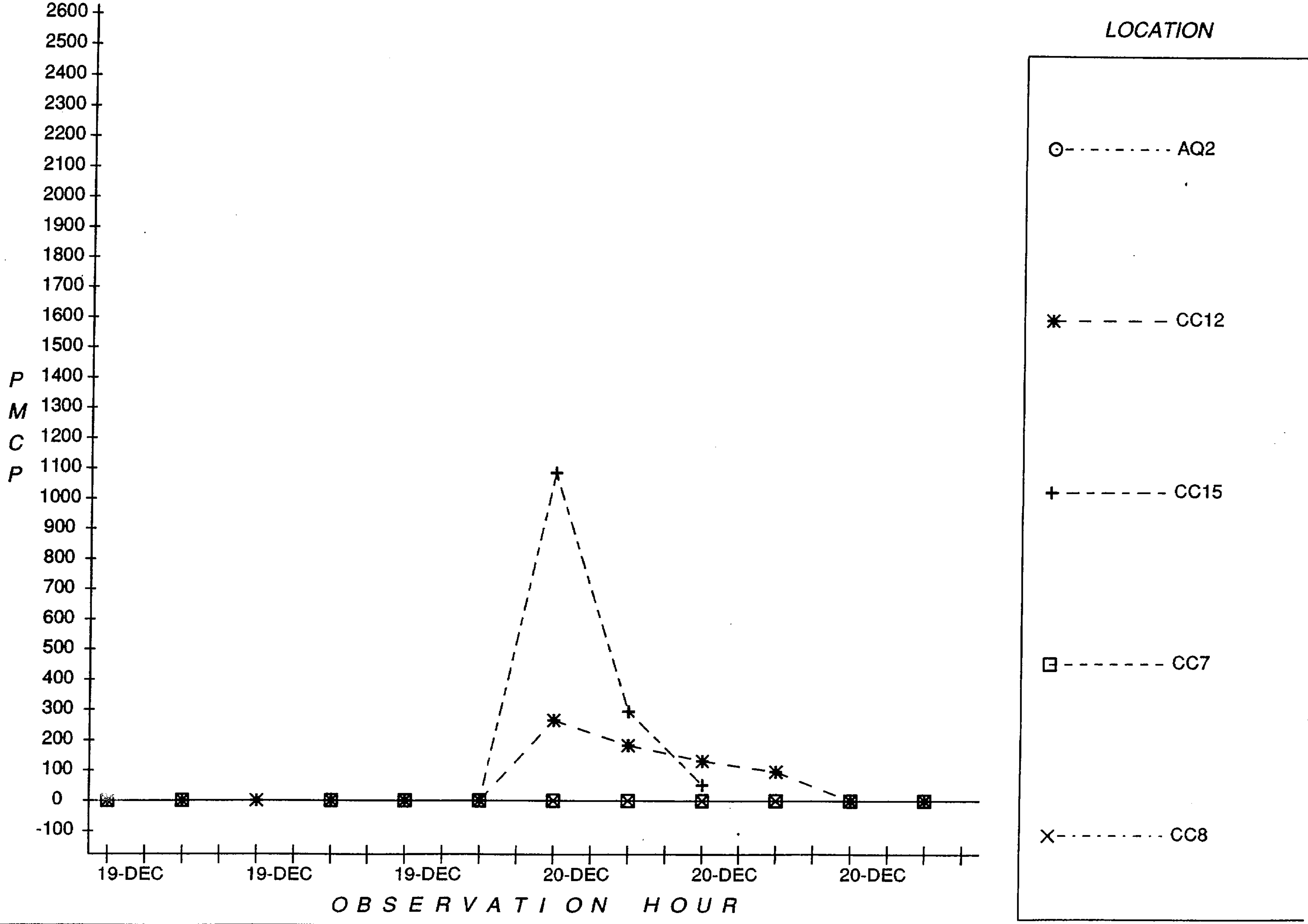
Tracer Time Series Plot

PDCH - Jan. 8-10, 1990



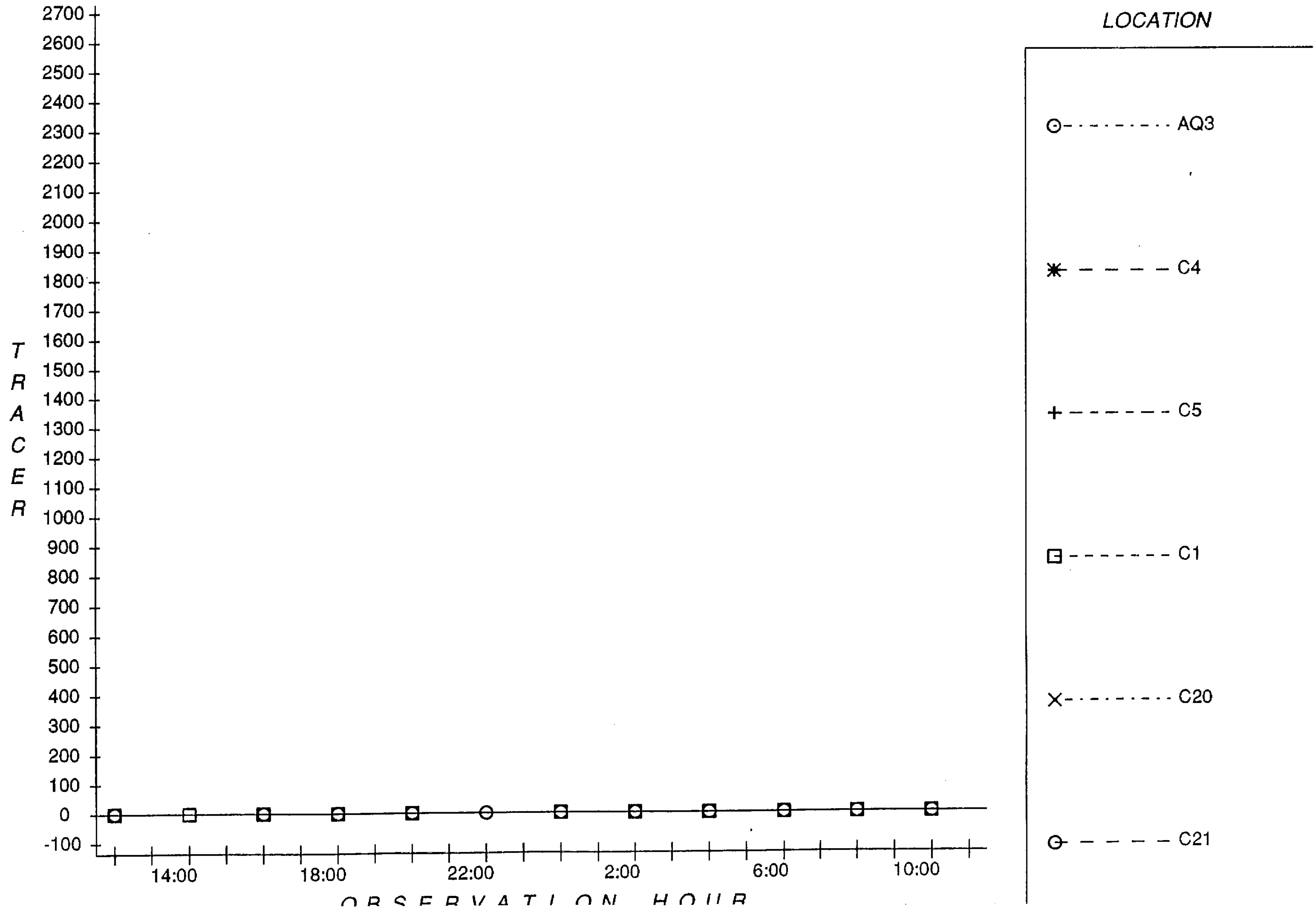
Tracer Time Series Plot

PTCH - Dec. 19-20, 1989



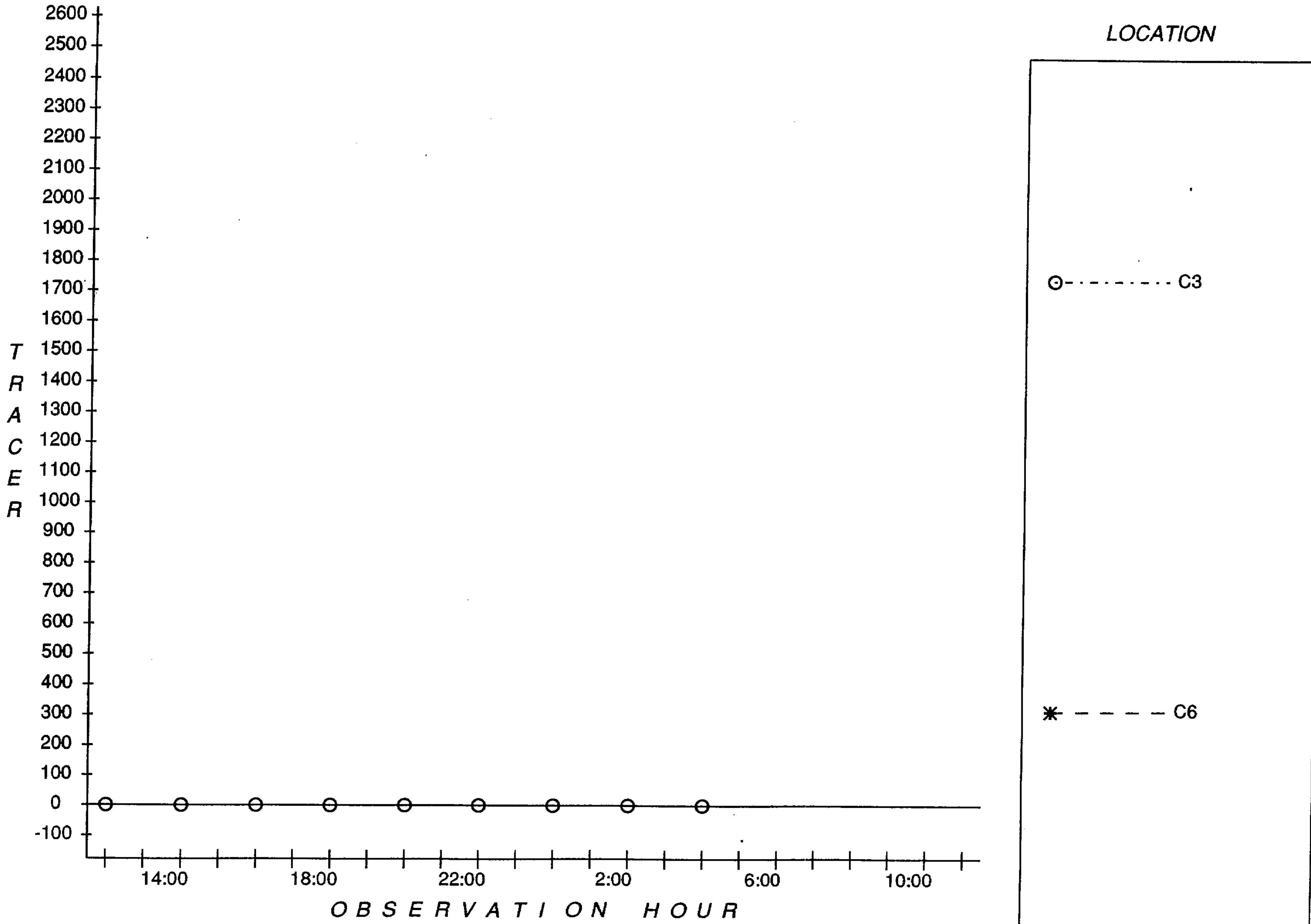
Tracer Time Series Plot

PTCH - Dec. 19-20, 1989



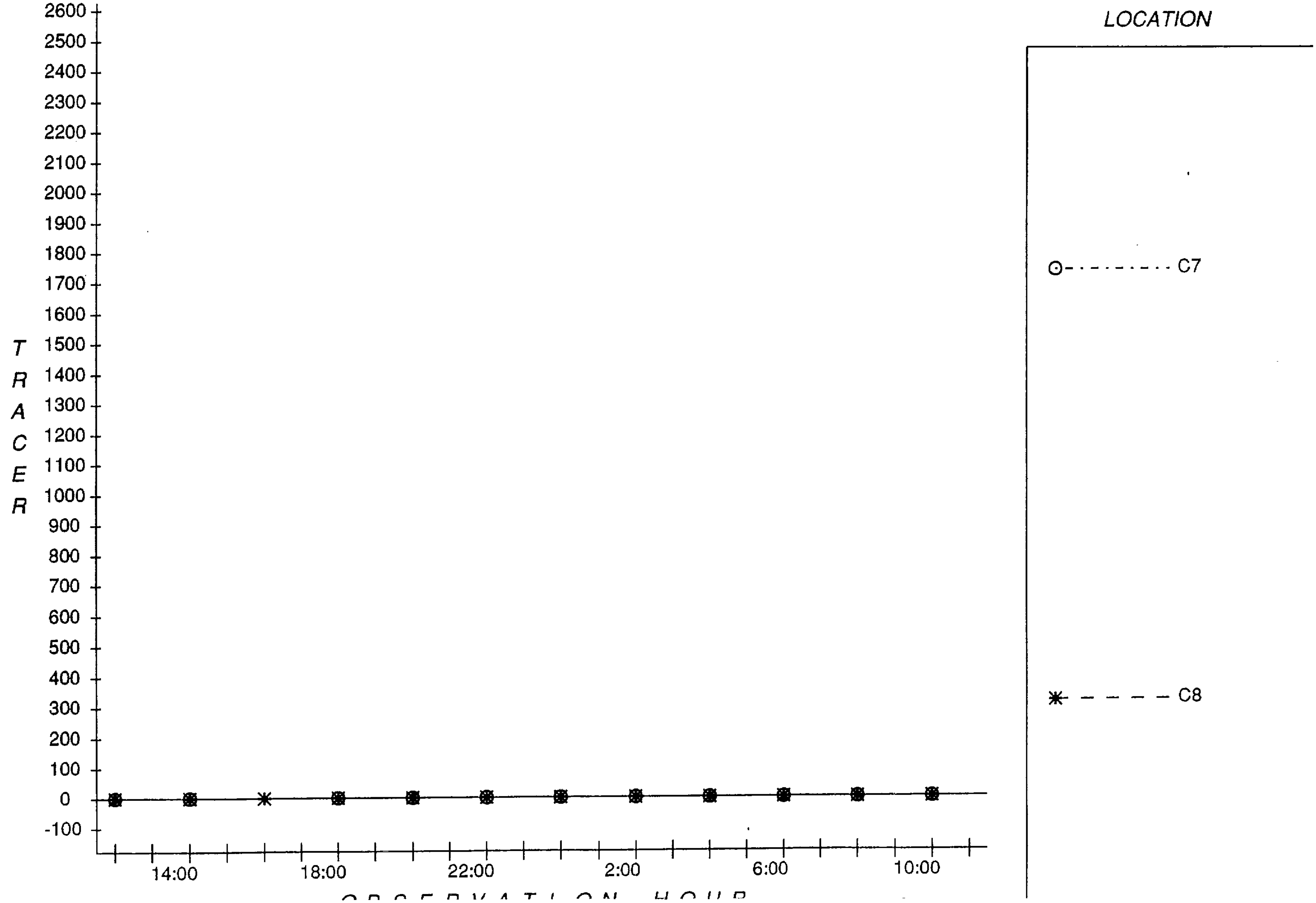
Tracer Time Series Plot

PTCH - Dec. 19-20, 1989



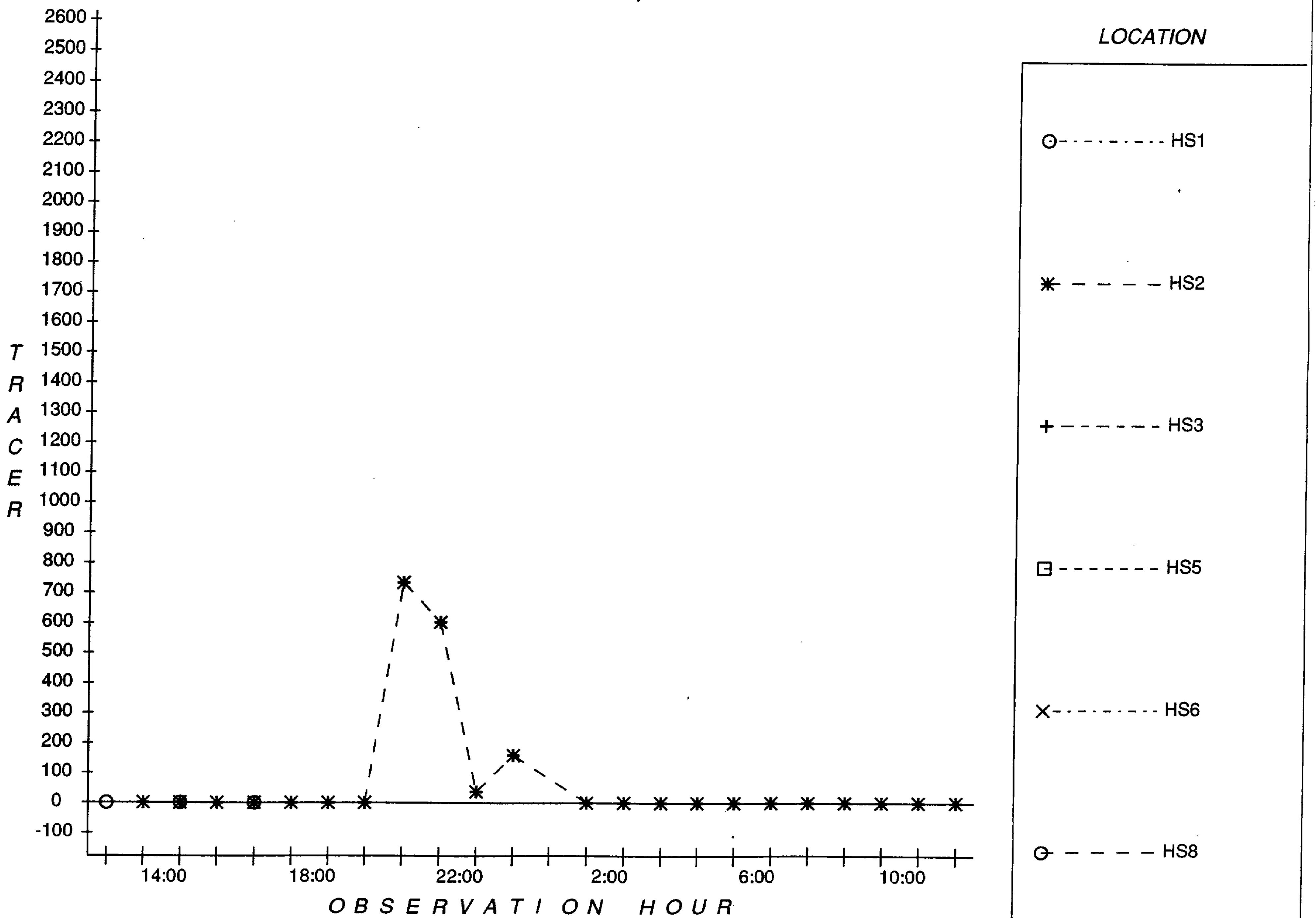
Tracer Time Series Plot

PTCH - Dec. 19-20, 1989



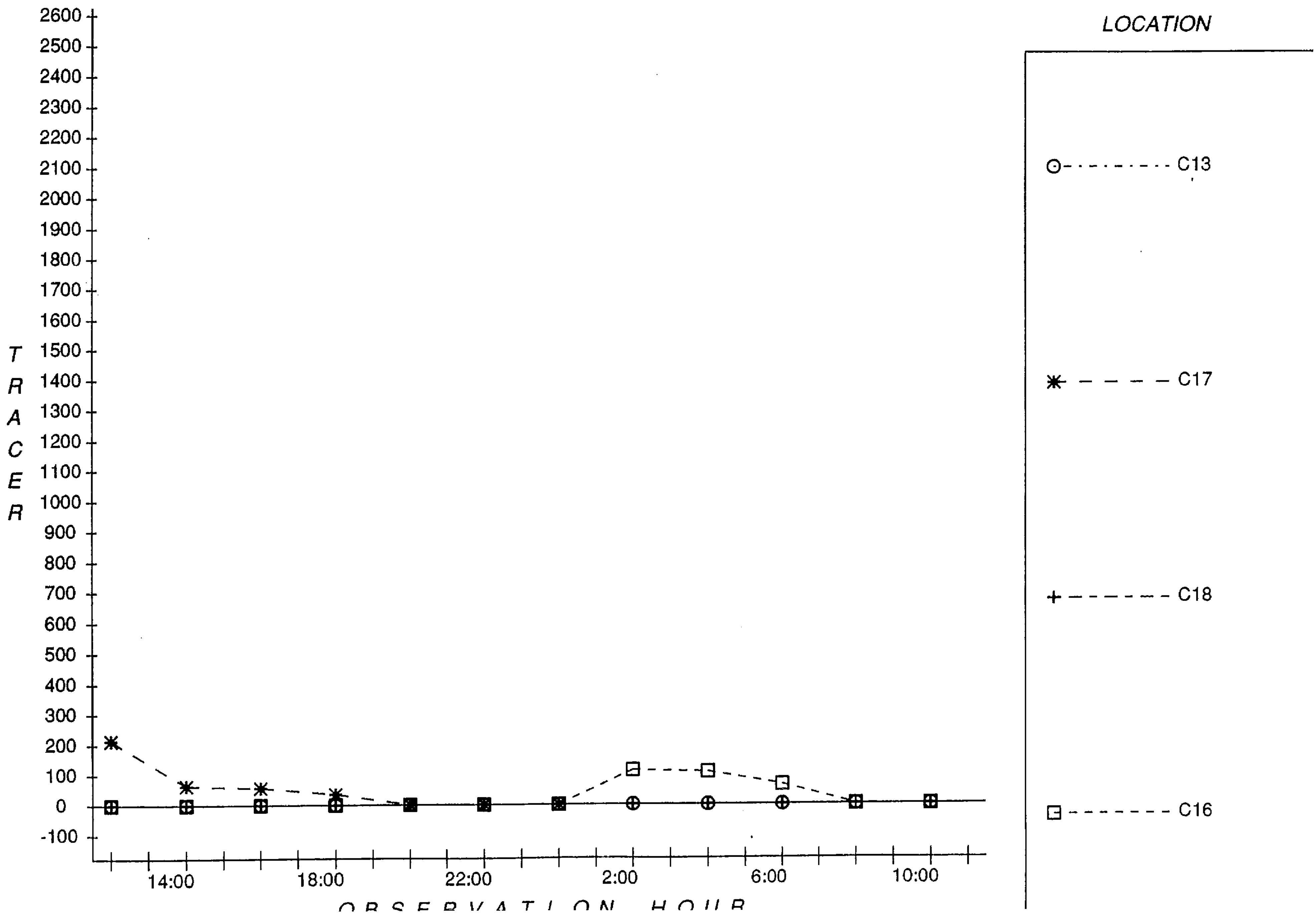
Tracer Time Series Plot

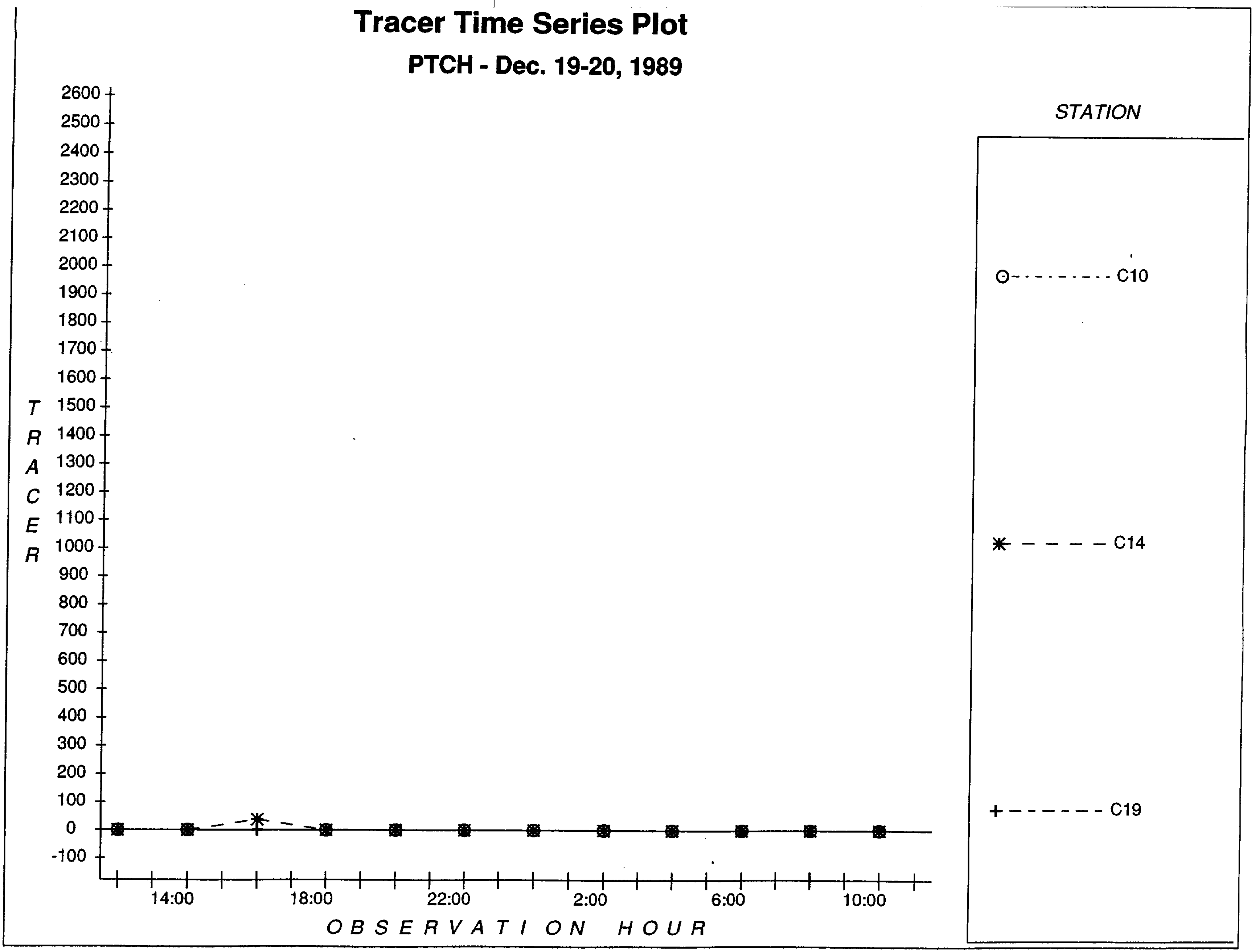
PTCH - Dec. 19-20, 1989



Tracer Time Series Plot

PTCH - Dec. 19-20, 1989




Tracer Time Series Plot
PTCH - Dec. 19-20, 1989
TRACER
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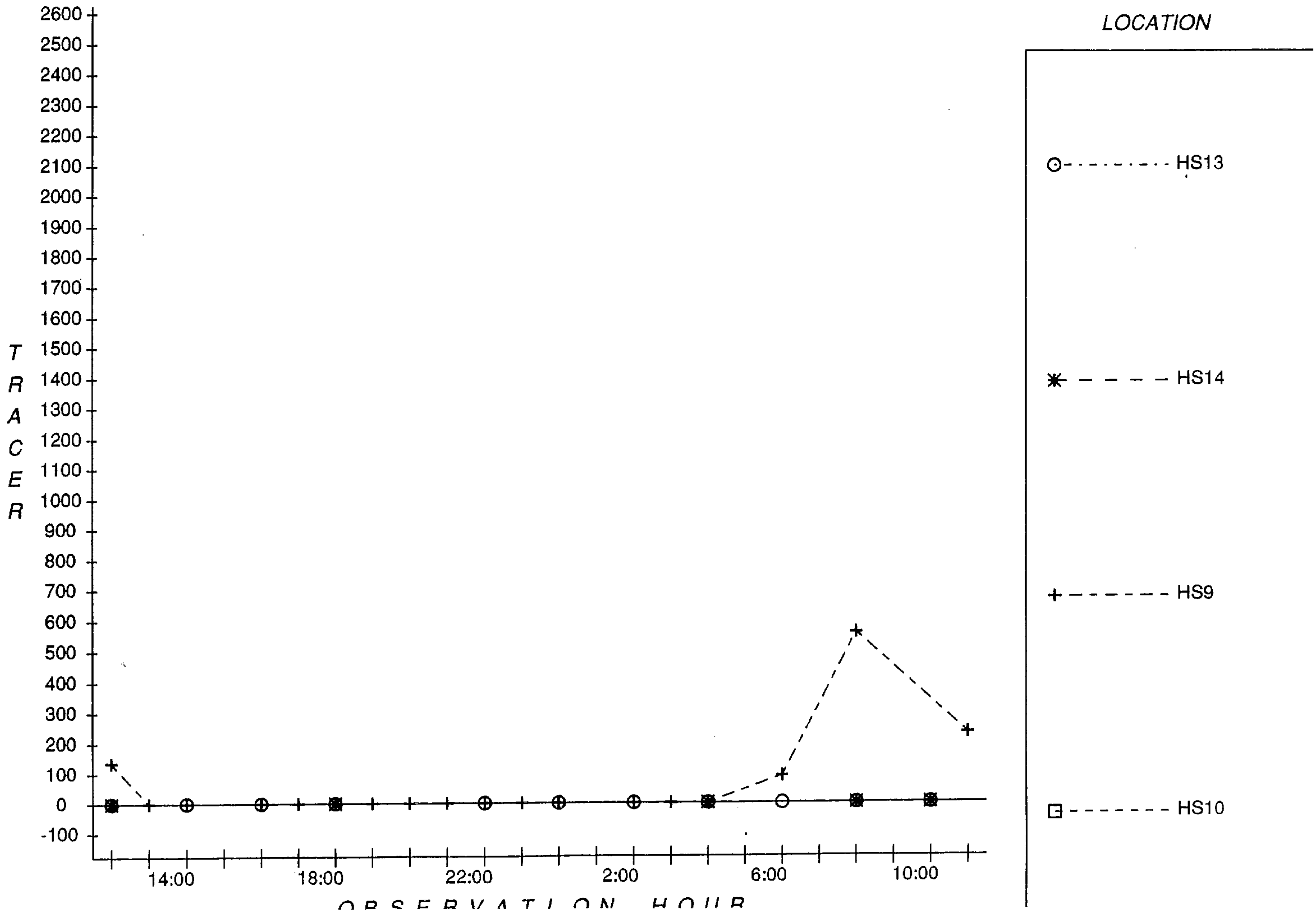
OBSERVATION HOUR
STATION
C10
C14
C19

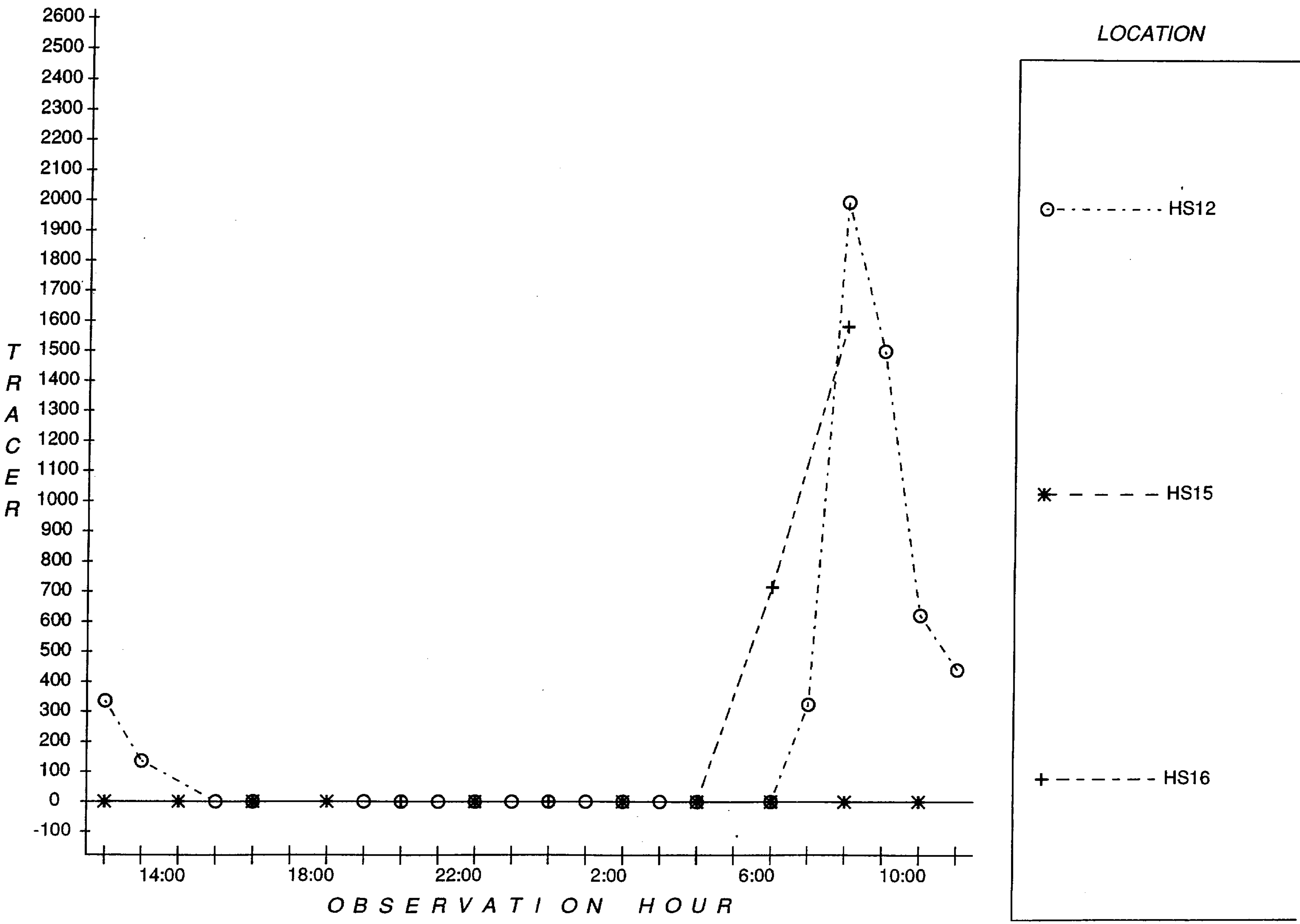
Tracer Time Series Plot

PTCH - Dec. 19-20, 1989



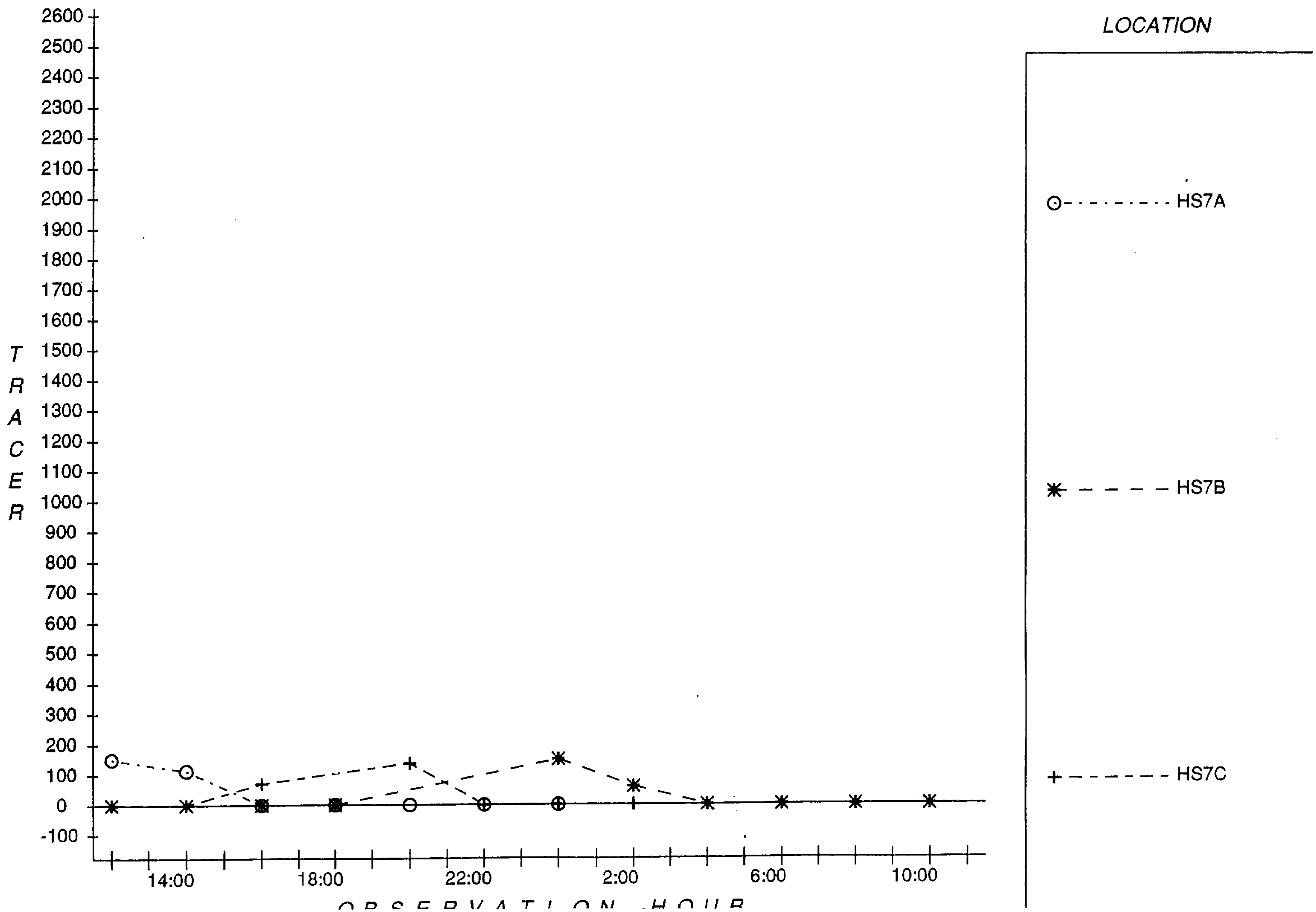
Tracer Time Series Plot

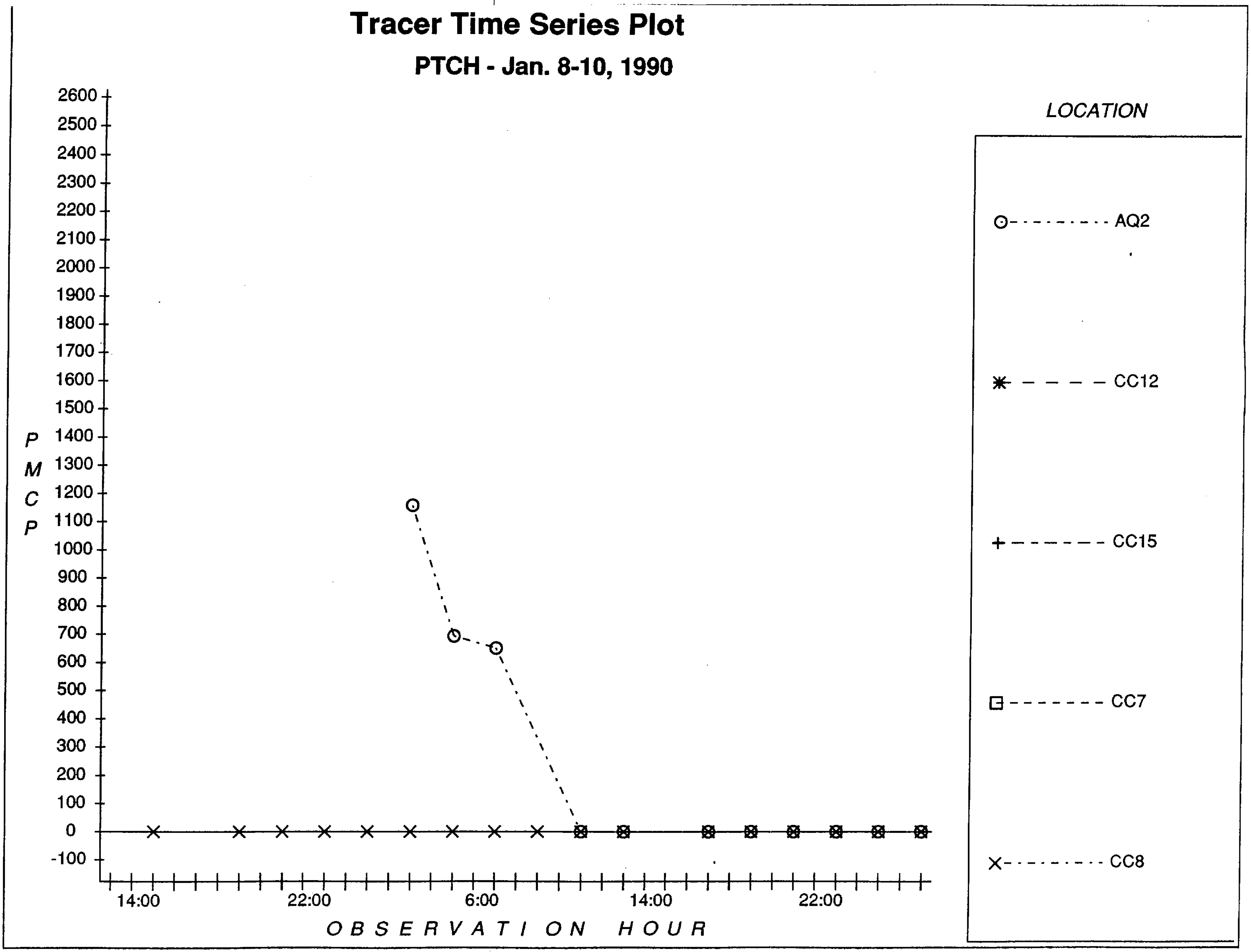
PTCH - Dec. 19-20, 1989



Tracer Time Series Plot

PTCH - Dec. 19-20, 1989




Tracer Time Series Plot
PTCH - Jan. 8-10, 1990
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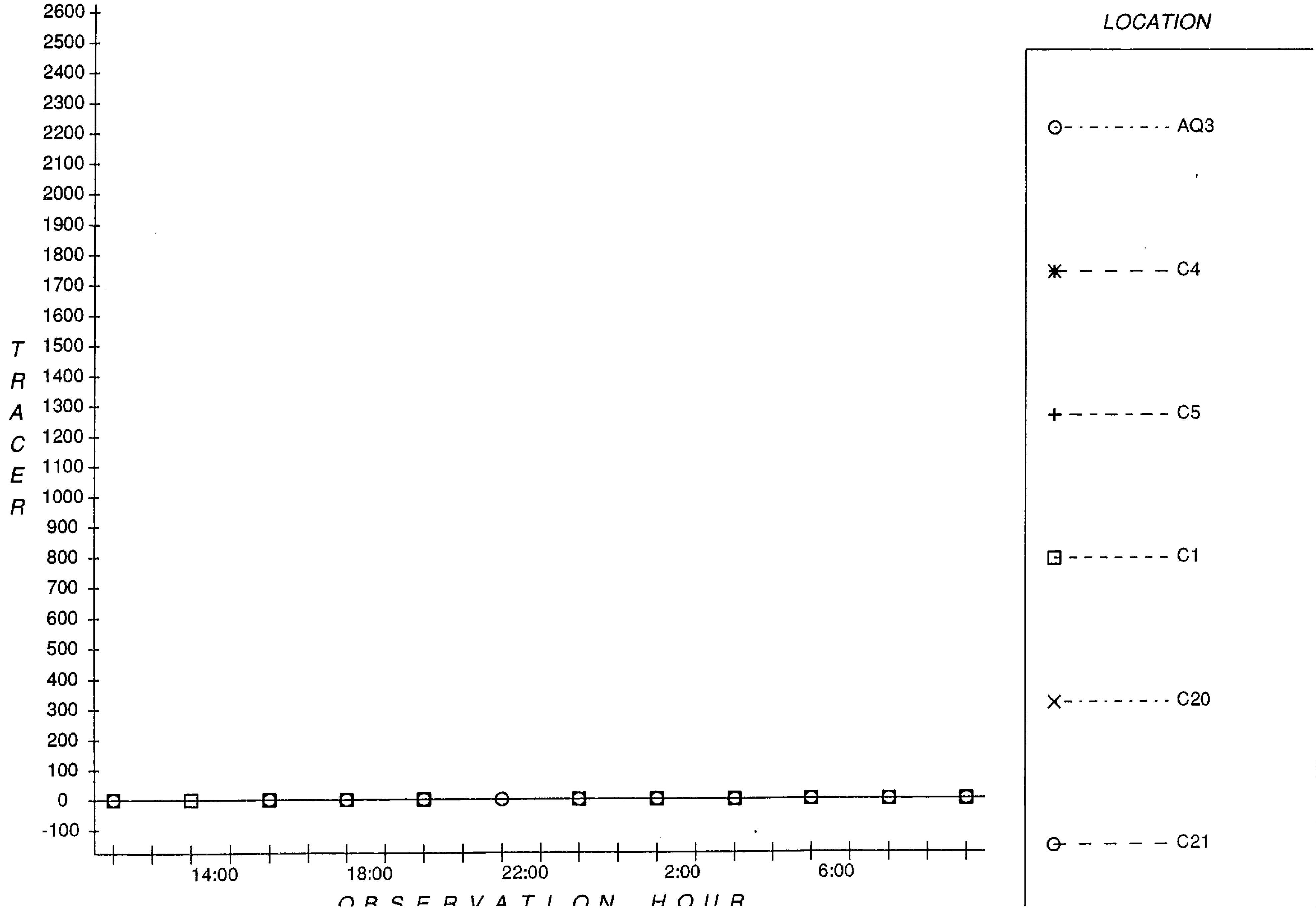
OBSERVATION HOUR
LOCATION
AQ2
CC12
CC15
CC7
CC8

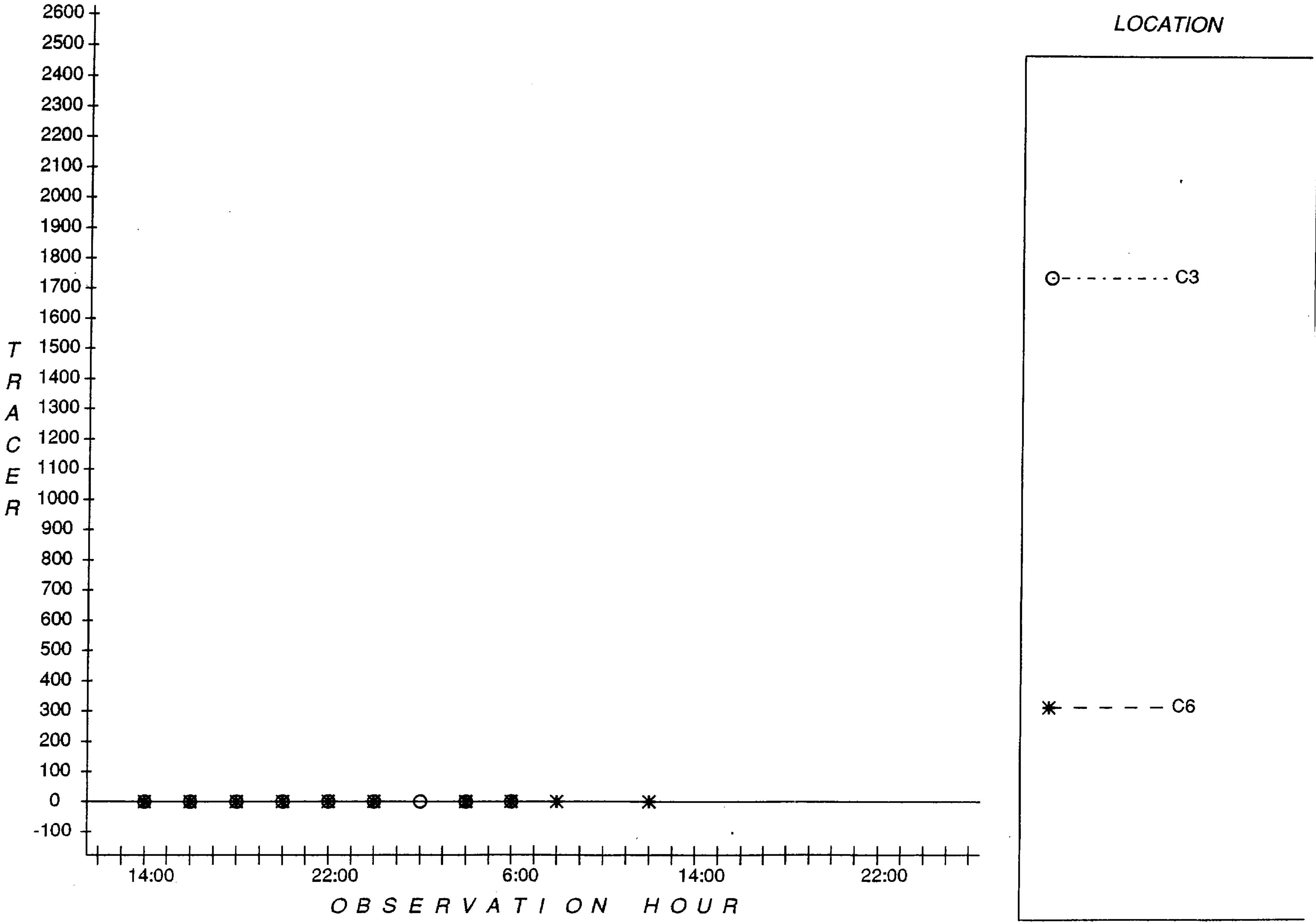
Tracer Time Series Plot

PTCH - Jan. 8-10, 1990



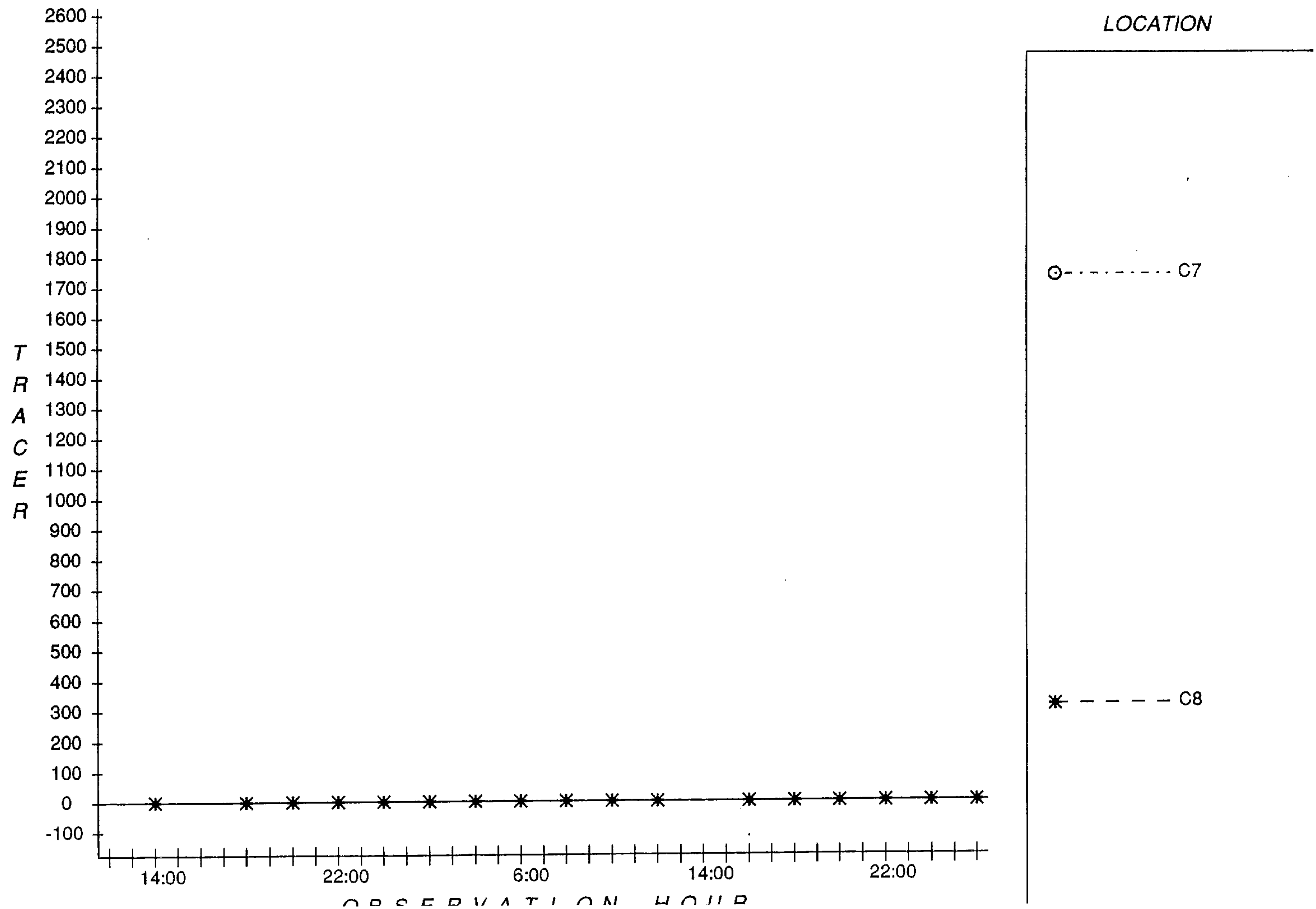
Tracer Time Series Plot

PTCH - Jan. 8-10, 1990



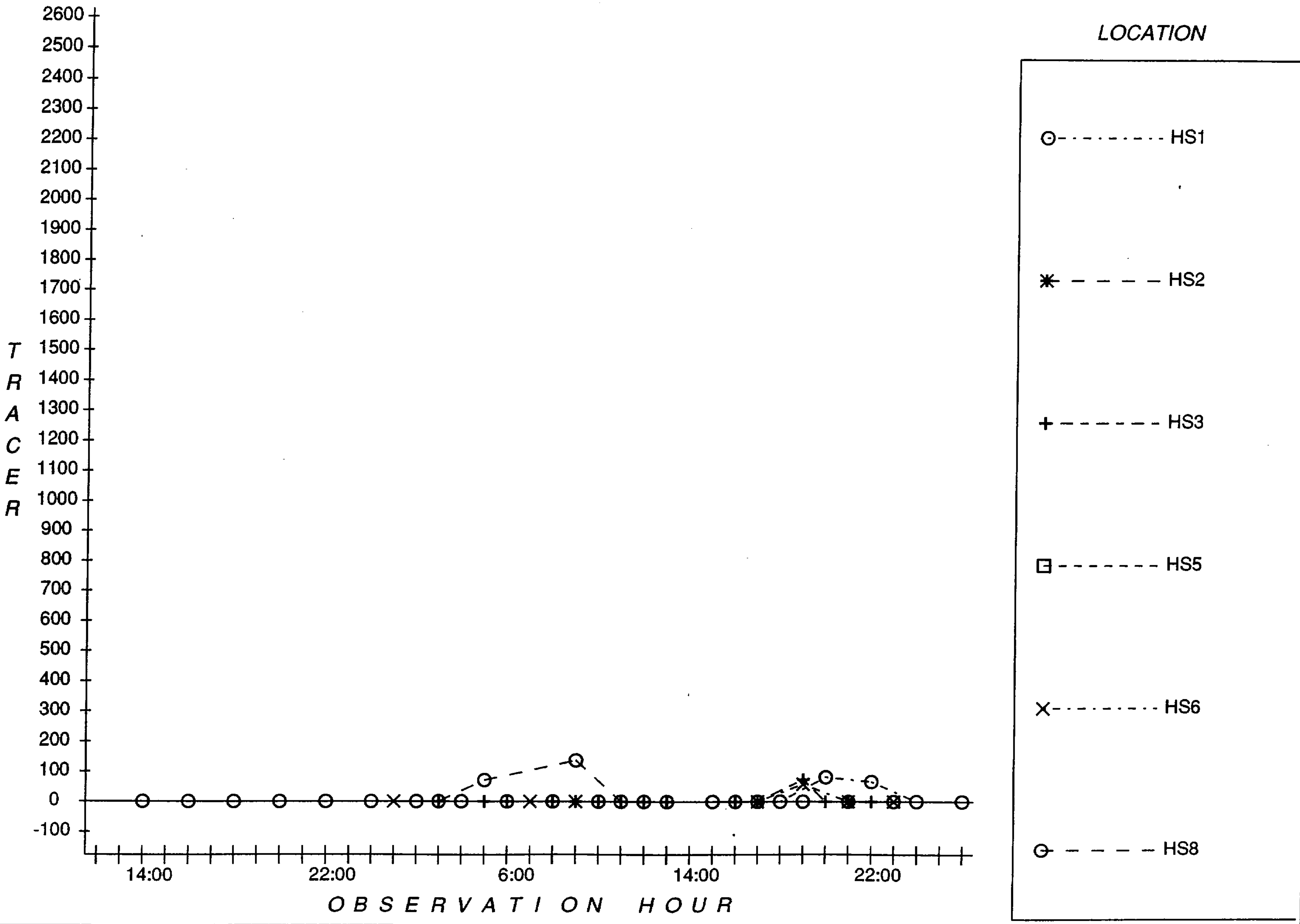
Tracer Time Series Plot

PTCH - Jan. 8-10, 1990



Tracer Time Series Plot

PTCH - Jan. 8-10, 1990



Tracer Time Series Plot

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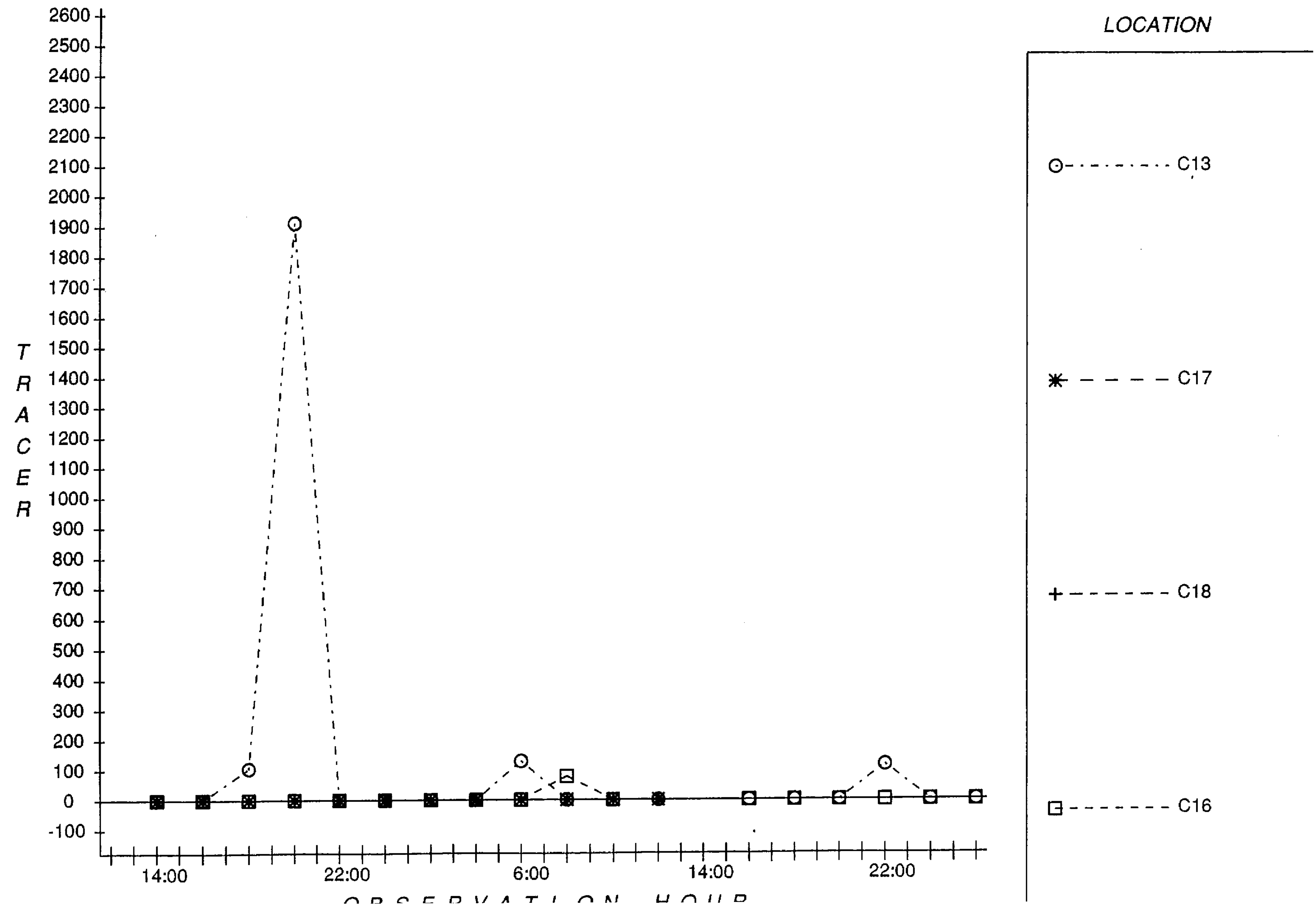

Tracer Time Series Plot

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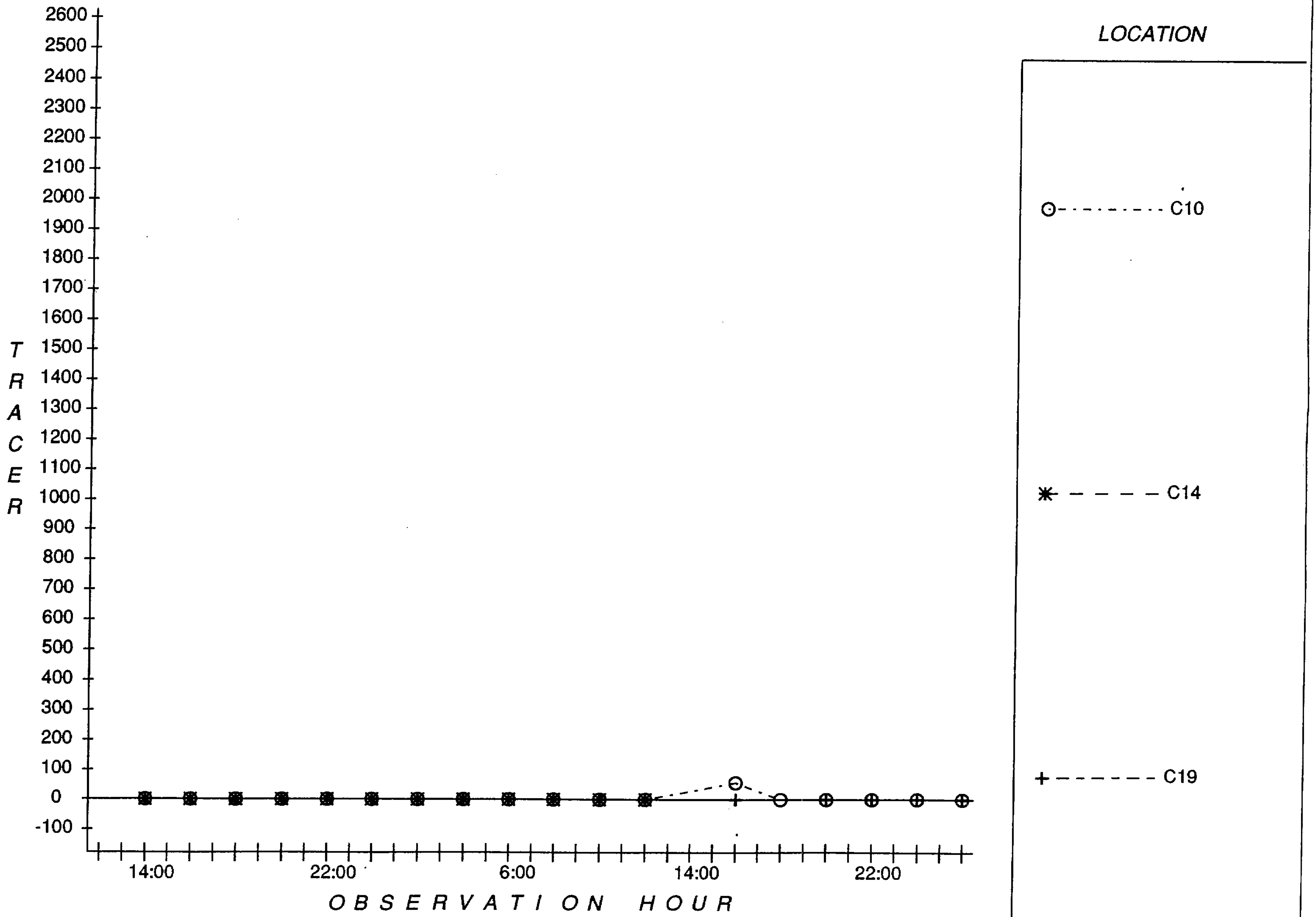

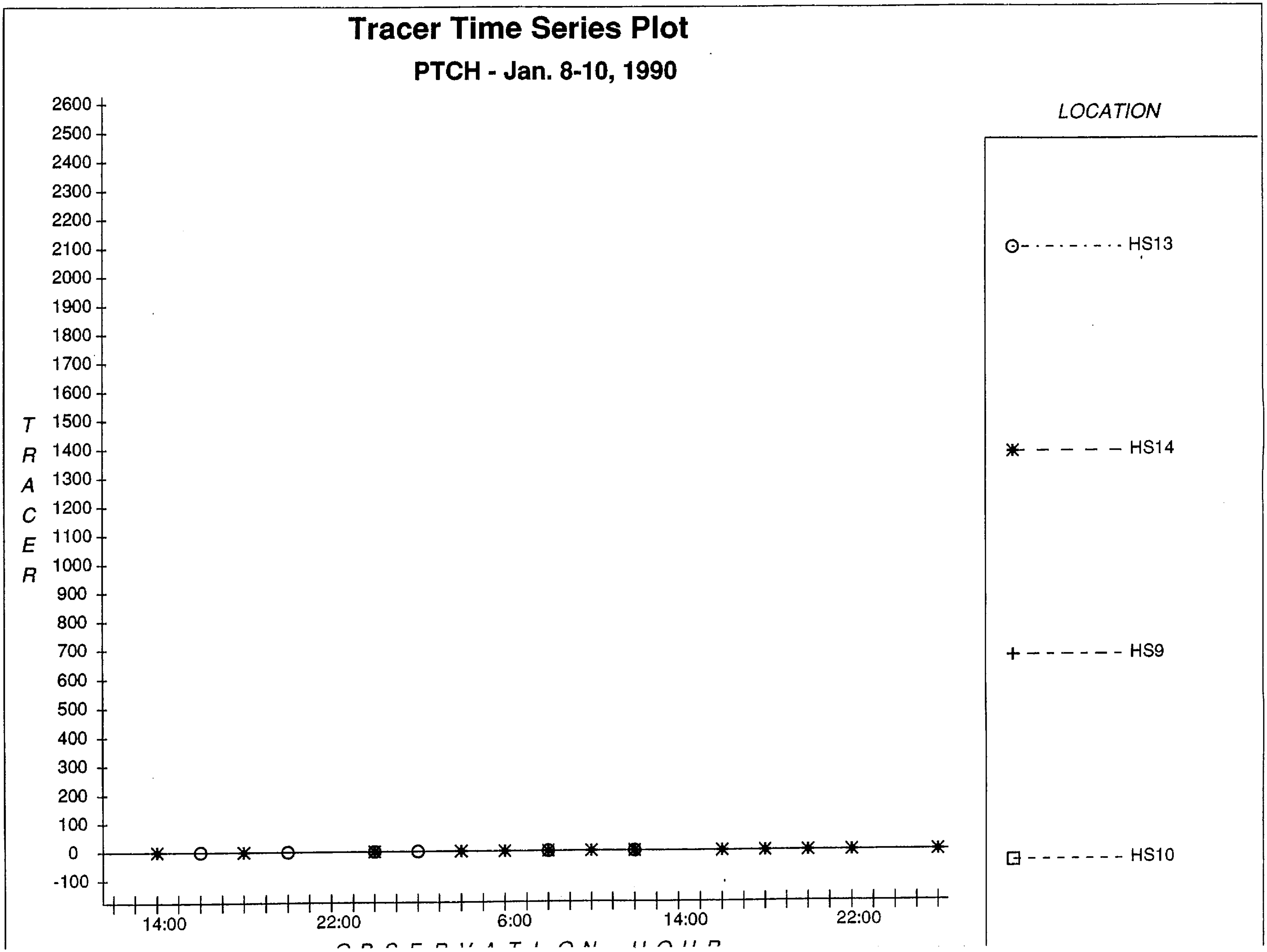
Tracer Time Series Plot
PTCH - Jan. 8-10, 1990
TRACER
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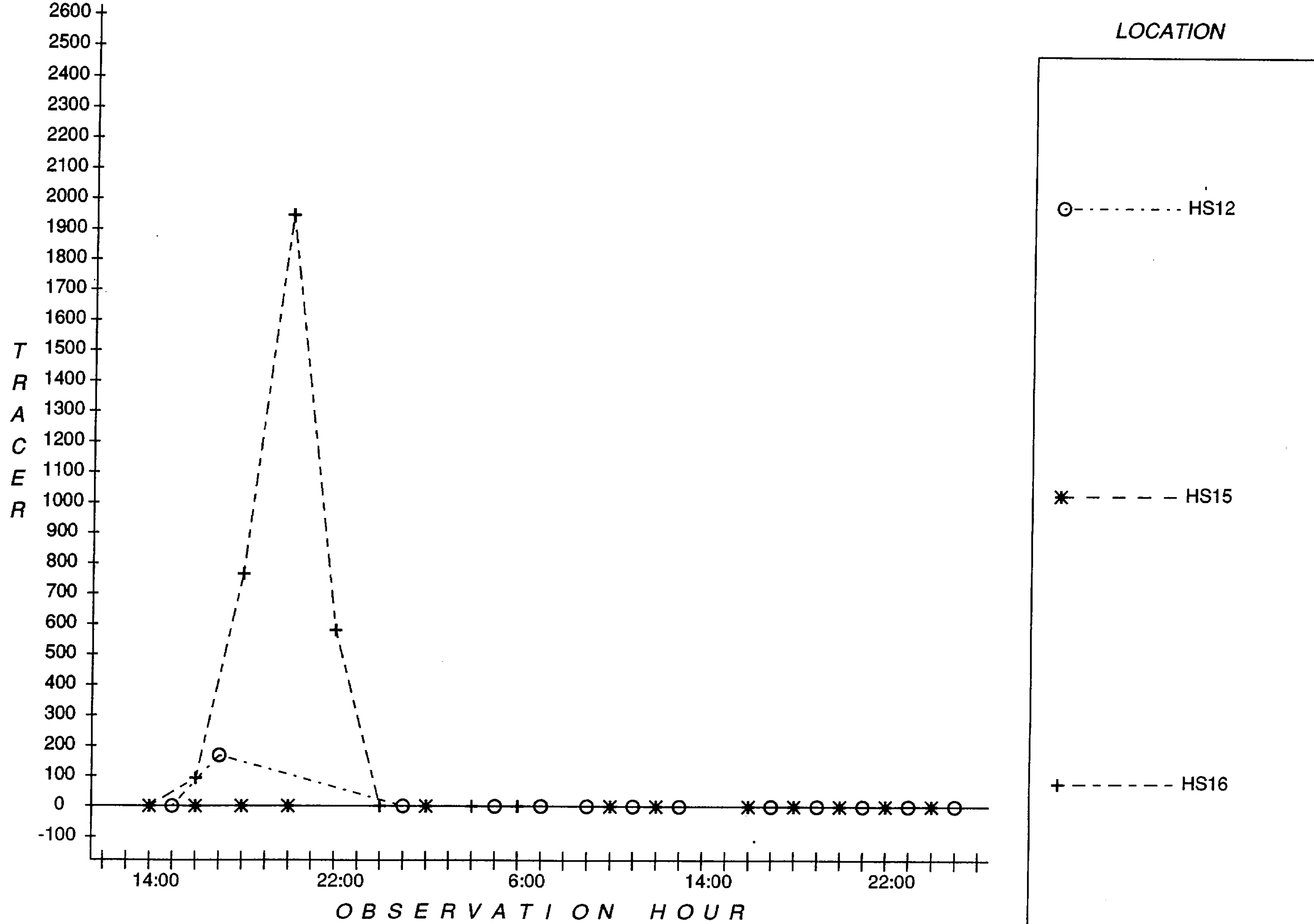
14:00
22:00
LOCATION
HS13
HS14
HS9
HS10

Tracer Time Series Plot

PTCH - Jan. 8-10, 1990



Tracer Time Series Plot

PTCH - Jan. 8-10, 1990