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IN-STACK TRANSMISSOMETER EVALUATION AND APPLICATION TO PARTICULATE OPACITY MEASUREMENT

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IN-STACK TRANSMISSOMETER EVALUATION AND APPLICATION TO PARTICULATE OPACITY MEASUREMENT

by

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SUMMARY

A laboratory evaluation and field testing program has been carried out to investigate the performance of a commercially available Lear-Siegler Model RM-4 Transmissometer as an in-situ monitor of industrial exhaust stack emissions. The laboratory phase of the program involved specific tests of the transmissometer design characteristics, operational parameters, extended time performance, and calibration. The instrument was found to be within specifications proposed for transmissometers by EPA except for its spectral response which was corrected by the manufacturer by installing a filter in the instrument. The instrument was then installed in the field for a minimum period of 30 days at each of three sites which were: (1) a basic oxygen furnace for the manufacture of steel, (2) an industrial chemical plant for the manufacture of sulfuric acid, and (3) an industrial plant for the manufacture of Portland cement. At each of these three sites opacity measurements were made of the stack exit plume for comparison with transmissometer generated data. A Pritchard telephotometer was employed for this purpose and a contrasting target method was the technique used except at the steel plant where telephotometry of a lamp behind the plume was also used.

The data obtained at the steel plant basic oxygen furnace showed a good one-to-one correlation between in- and out-of-stack opacity over a wide range of emission levels. A one-to-one correlation was also observed for the cement plant emissions but the plume opacity measurements at the sulfuric acid plant were generally six to ten percent higher than the in-stack opacity. Correlation at the cement and sulfuric acid plants was limited by a small range of emission levels that were studied. In addition the contrasting target method

requires four separate measurements in quick succession to establish a single data point. This time dependency, together with variation in background conditions and difficulties in synchronizing data, adversely affected the repeatability of the plume opacity measurement method. The use or development of more refined and less time dependent techniques for exit plume measurements is recommended before undertaking any further correlation studies. The performance of the in-stack transmissometer at each of the three sites was good. Drift of the instrument zero and span was never greater than 1% over any of the 30-day test periods.

SECTION I
INTRODUCTION

This program was to achieve two goals. The first goal was to select a commercial transmissometer, evaluate its design and performance characteristics in the laboratory, and make any modifications deemed necessary to improve the instrument performance to permit long term continuous monitoring of smoke stack emissions. The second goal was to install the instrument on selected sources and evaluate the performance of the instrument for monitoring the in-stack opacity and the plume opacity.

The instrument selected for use in this program was a Lear-Siegler Model RM-4 Transmissometer, Serial No. 784. The unit was purchased complete with blower systems, covers, and a Leeds and Northrup Speedomax M strip chart recorder as the readout device. The equipment was set up in the laboratory and all pertinent characteristics and performance parameters checked. Following this phase, the system was installed at three different industrial sites to observe performance for periods of at least thirty (30) days at each site.

The first installation was at a basic oxygen furnace of a steel manufacturer for a period of approximately seventy (70) days. Following this effort, the unit was installed at a sulfuric acid plant and then at the manufacturing facility of a Portland cement company, for periods of approximately thirty (30) days each. Plume opacity measurements were made at all three installation sites with a Pritchard telephotometer using a contrasting target method for comparison with the in-stack opacity measurements. At the conclusion of the field effort phase, the transmissometer was again checked for performance in the laboratory.

Section II describes the laboratory testing of the transmissometer. Emphasis was placed on the determination of basic system characteristics and performance parameters, and the development of an output calibration chart for subsequent data reduction.

Section III describes all field work including the contrasting target method used in making the plume opacity measurements with the telephotometer. Installation methods, problems encountered, and general activities on site are discussed in detail.

Section IV contains the field measurement results. The data variations and anomalies are presented and the possible causes and effects of the discrepancies are considered.

Section V presents the conclusions reached and the recommendations offered which have resulted from the efforts conducted under this program.

The Appendices contain representative examples of computer reduced data series which were accumulated on a given day at each of the three measurement sites.

SECTION II

LABORATORY TESTING

A. INTRODUCTION

The system used for this program consisted of a Lear-Siegler RM-4 Transmissometer transmitter/receiver unit and retroreflector unit, two blower systems with weather shields, and a Leeds and Northrup Speedomax M strip chart recorder. A pair of mounting flanges was also secured for the initial field installation. No cabling or connectors were supplied other than bare wire terminated cables coming out of the transmitter/receiver unit for the data and control functions and input power.

B. BASIC SYSTEM SET UP AND ADJUSTMENTS

The transmissometer transmitter/receiver unit and the retroreflector unit were mounted in specially constructed stands and set to a flange to flange distance of 5.13 meters (16 feet 10 inches). This is the mounting distance at the steel manufacturer's basic oxygen furnace stack, the first site for field work. The accessory equipment available from Lear-Siegler for focusing the system was not procured with the instrument. However, it was discovered that by a simple trial and error correction process (removal of the electro-optical chassis, moving the lens, then reinserting the chassis) the objective lens could be focused for the correct stack diameter to within allowable limits. The strip chart recorder was not received with the rest of the equipment and, because the milliammeter on the instrument would not show a valid reading unless the output leads to the recorder were loaded, a 100-ohm, 1% resistor was connected across the leads and a vacuum tube voltmeter (VTVM) was used as a temporary monitoring device. This arrangement

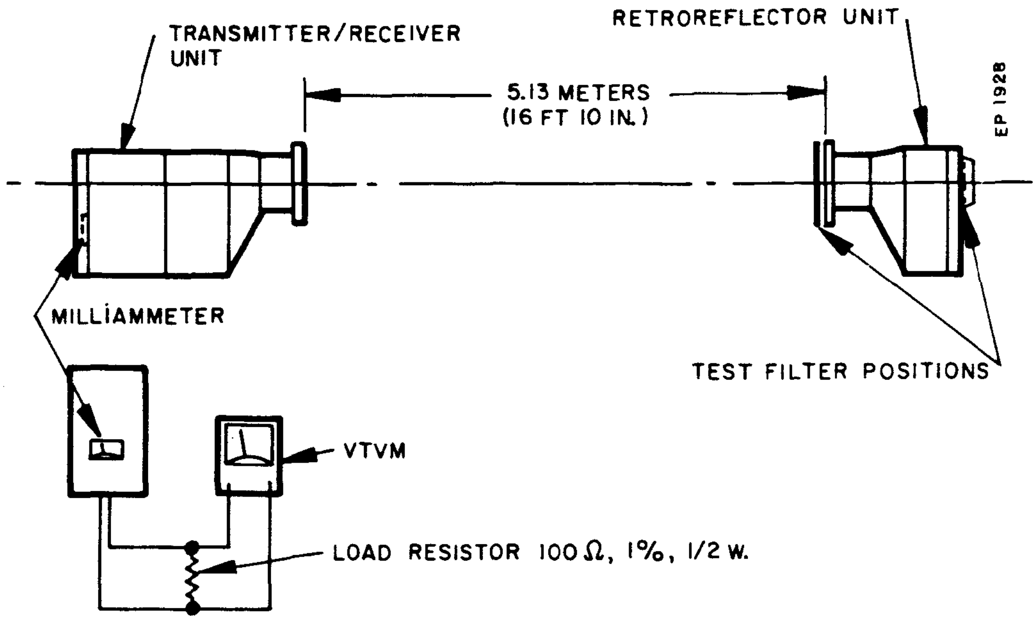


Figure 1. Transmissometer-Filter Transmission Measurement

with the load resistor and VTVM illustrated in Figure 1, was used during the laboratory tests until the strip chart recorder arrived.

After the transmissometer was focused for the selected flange to flange distance and optically aligned, the clear stack zero reading was set by adjusting the coarse and fine gain controls. The calibration retroreflector iris was then adjusted to also produce a zero opacity reading. The instrument was then ready for testing. Caution was exercised to assure that the system was properly focused and the zero opacity points reset if the flange to flange distance was changed for different test configurations.

C. PROJECTION ANGLE AND UNIFORMITY OF BEAM

Only one test configuration, shown in Figure 2, was used for both of these tests because the required data

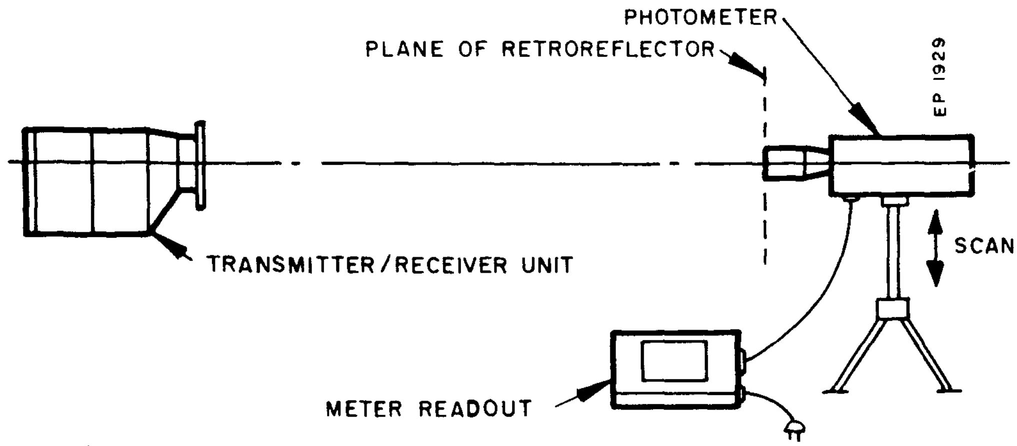


Figure 2. Uniformity of Beam Measurement

could be generated simultaneously. The retroreflector unit was moved to one side in this arrangement and a Pritchard telephotometer was placed in line with the transmitter/ receiver unit. The telephotometer entrance aperture was covered with a diffuser disc which was masked down to a rectangular opening 5 mm wide by 32 mm long, and then located in the plane of focus of the transmitter/receiver unit. The telephotometer was placed on a vertical traversing mechanism and moved in a direction perpendicular to the beam while meter readings were taken of the telephotometer output. The separation of the transmitter/receiver unit and the telephotometer was approximately 5.13 meters (16 feet 10 inches). A plot of the meter readings versus traversing distance is shown in Figure 3. The resulting curve indicates that the beam is fairly uniform across the central 8.23-cm (3.25-in.) portion but then rolls off sharply to the limits of approximately 12.7 cm (5.0 in.). At the separation distance of 5.13 meters the half angle beam width θ is defined as Arctan (6.35/513) = 0.0124 or 0.71°. The full projection angle then is approximately 1.41°.

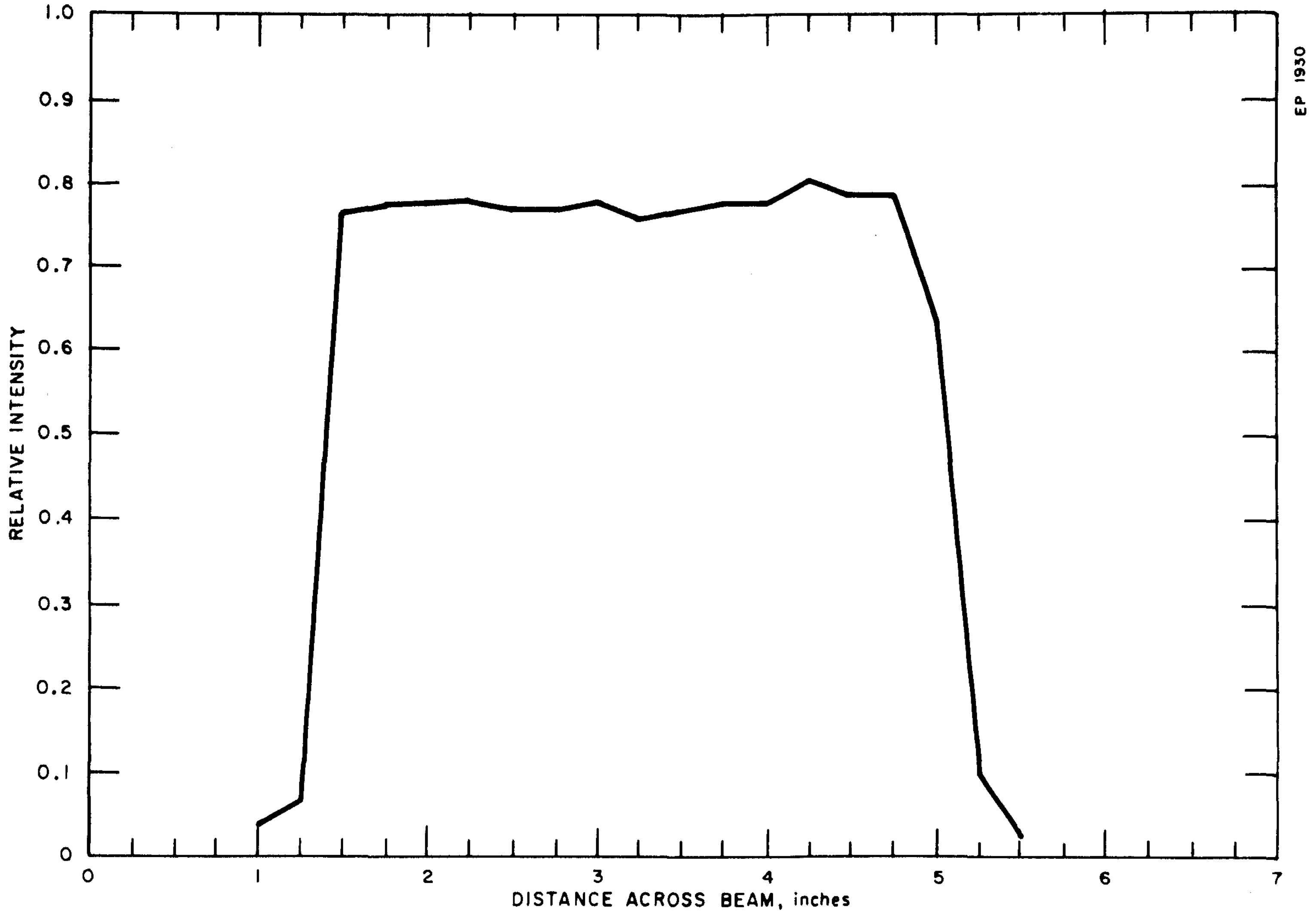


Figure 3. Uniformity of Exit Beam

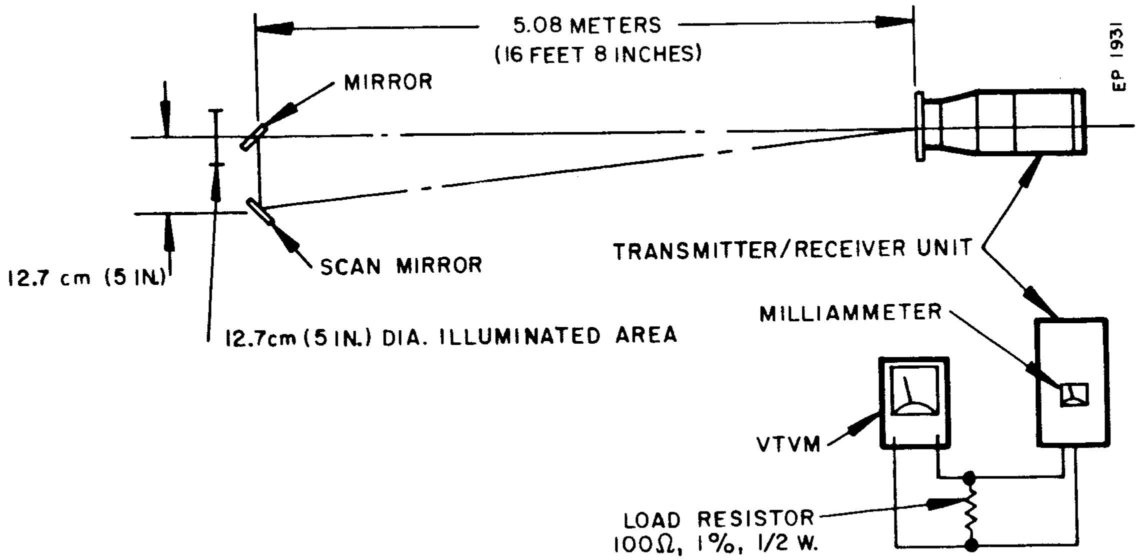


Figure 4. Field of View Measurement

D. DETECTOR FIELD OF VIEW

The experimental setup for determining the field of view of the detector is shown in Figure 4.

The scan mirror was moved laterally to one side while being adjusted in rotation to direct the beam back into the unit. The fixed mirror, directly in the line of sight, was large enough to block the path to the retroreflector unit, thus assuring that only light energy off the scan mirror would get back to the detector system. A fairly sharp signal cut-off point was found at about 12.7 cm (5.0 inches) off axis at about a distance of 5.08 meters (16 feet 8 inches) from the transmitter/receiver unit mounting flange. The half angle field of view ϕ is then defined as Arctan (12.7/508) = 0.025 or 1.43°. The full field of view angle is approximately 2.86°.

E. SENSITIVITY TO INPUT VOLTAGE VARIATION

A variac was placed in the main power line to the transmissometer for the performance of this test. The line

Table 1. VARIAC DIAL CALIBRATION (Vac, rms)

Variac Dial Setting	HP VTVM Reading
90	95
95	101
100	106
105	111
110	116
115	121
120	126
125	131

voltage at the wall outlet was measured at 121 Vac (rms) and monitored throughout this test. Prior to connecting the transmissometer to the outlet, the variac dial readings were calibrated with a Hewlett-Packard Model 400 VTVM. These readings are shown in Table 1. The readings of the milliammeter and of a second VTVM across the 100-ohm load resistor are given in Table 2.

At the variac setting of 90 volts, the solenoids for the calibration retroreflector and filter would not operate, so readings were not taken except for the clear stack condition. At 95 volts, the solenoid operation was intermittent; sometimes they would operate and sometimes they would not. At the 100-volt setting and higher, the solenoids seemed to work as they should. As the tabulated data indicate, the transmissometer signals with the calibration retroreflector and with the calibration filter in place were lower than the clear stack signals at low input

Table 2. MEASUREMENTS ACROSS THE LOAD RESISTOR

Input Voltage (rms) Variac Dial Setting	Input Voltage (rms) HP VTVM	Transmissometer Output Signals	
90	95	Clear Stack	1.9 ma
			0.17 volts
		Cal. Retro	Solenoids would
		Cal. Filter	not operate
95	101	Clear Stack	1.95 ma
			0.17 volt
		Cal. Retro	1.75 ma
			0.15 volt
		Cal. Filter	6.6 ma
			0.63 volt
100	106	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	1.8 ma
			0.15 volt
		Cal. Filter	6.7 ma
			0.64 volt
105	111	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	1.90 ma
			0.16 volt
		Cal. Filter	6.8 ma
			0.66 volt
110	116	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	1.95 ma
			0.17 volt
		Cal. Filter	6.9 ma
			0.67 volt
115	121	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	2.0 ma
			0.18 volt
		Cal. Filter	7.0 ma
			0.68 volt
120	126	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	2.0 ma
			0.18 volt
		Cal. Filter	7.0 ma
			0.68 volt
125	131	Clear Stack	2.0 ma
			0.18 volt
		Cal. Retro	2.1 ma
			0.185 volt
		Cal. Filter	7.0+ ma
			0.68+ volt

voltages, although all the signals were down slightly. For 100 volts and up, the clear stack signals remained constant, but the calibration retroreflector and filter signals continued to creep upward. The differences became clearly noticeable at the 125-volt setting on the variac.

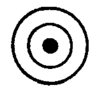
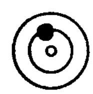
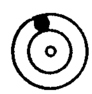
F. ALIGNMENT SENSITIVITY

In this test the system was set up as it would be in a stack at a flange to flange distance of 5.13 meters (16 feet 10 inches). The system was aligned such that the image of the retroreflector was centered in the alignment reticle and the milliammeter and VTVM readings recorded. The alignment was altered in the vertical direction to four successive positions and the milliammeter and VTVM readings recorded. These data are presented in Table 3. The retroreflector aperture was approximately 35 mm (1.38 inches) in diameter, located at a distance of 5.83 meters (19 feet 2 inches) from the vertex of the objective lens in the transmitter/receiver unit. Judging from the position of the retroreflector image in the reticle, at position no. 2 the system was misaligned by 0.26° producing a reading of about 0.5% opacity. At position no. 3., a misalignment of 0.34° produced a reading of only 2% opacity while at position no. 4 a misalignment of 0.52° caused a reading of over 30% in opacity. At position no. 5, the misalignment of 0.69° produced a reading completely off scale indicating that very little energy was being returned to the detector.

G. LONG TERM ZERO DRIFT

The transmissometer was set up in the clear stack mode and permitted to run unattended for several days, except for periodic checking to be sure the system was still operating. Initially, the calibration retroreflector iris was adjusted such that both the clear stack and calibration signals were

Table 3. EFFECT OF VERTICAL MISALIGNMENT

Position No.	Eyepiece Reticle	Error	Transmissometer Readings
1		0° 0% op.	2.0 ma 0.18 volt
2		0.26° 0.5% op.	2.1 ma 0.19 volt
3		0.34° 2.0% op.	2.4 ma 0.20 volt
4		0.52° 30.5% op.	8.4 ma 0.80 volt
5		0.69° >65% op. (off scale)	>3.2 ma (off scale) >3.48 volts (off scale)

exactly 2.0 ma on the transmissometer milliammeter which is zero opacity. The strip chart recorder was then set for the zero point to read 10 on the chart and the span point at about 33.0. After this, no further adjustments were made. After a few hours of operation, the zero point began to shift slightly. After about 18 hours of operation, the slight drift reached about one division on the chart (reading 11.0 instead of 10.0). It was noticed that the amplitude of the span signal also drifted the same amount and in the same direction. This amounts to an opacity reading error of only 1% which is usually insignificant. In subsequent field tests, this tendency to drift slightly reoccurred, but never exceeded 1.0 division on the chart. The strip chart recordings illustrating the slight zero drift are shown in Figure 5.

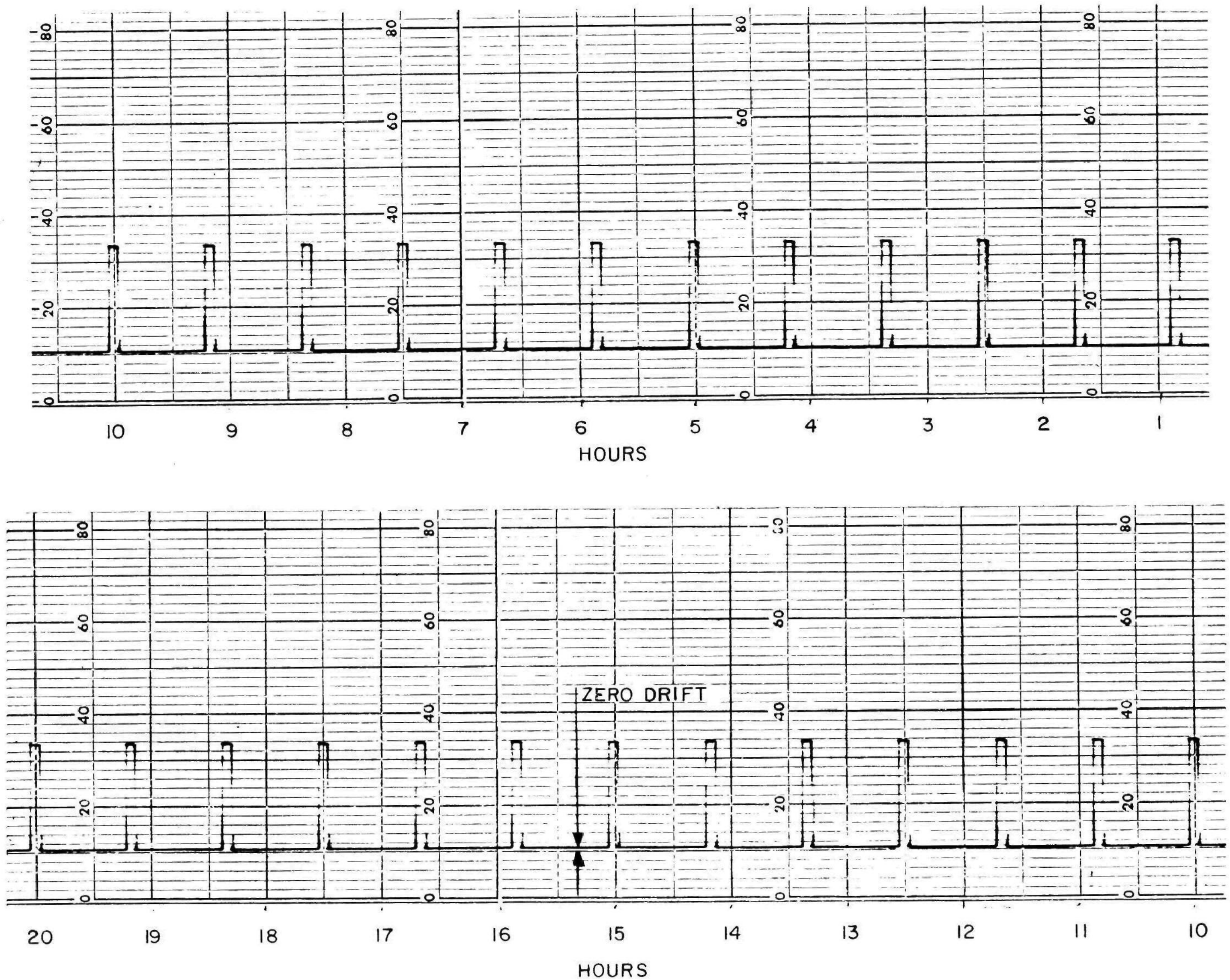


Figure 5. Strip Chart Showing Zero Drift

H. SPECTRAL RESPONSE OF THE TRANSMISSOMETER

Initial examination of the instrument spectral response indicated that the instrument's sensitivity was mostly in the near infrared part of the spectrum and did not have the desired visible light sensitivity. After discussing this with the manufacturer, a replacement spectral filter was received for installation in front of the instrument's photodetector to obtain the desired response. Prior to installing the filter, a spectral response curve was run on a spectrophotometer at the Owens-Illinois North Technical Center, Toledo, Ohio. The results of this are shown in Figure 6. The peak transmission of the filter occurs at about 5125Å, with upper and lower cutoffs at about 3150Å and 7000Å, respectively. The basic response of the RM-4 detector is that of a normal silicon photo diode. To obtain the spectral response of the transmissometer, we have combined the filter attenuation, detector response, and lamp emission characteristics into a single representative curve which is shown in Figure 7.

I. RESPONSE TIME

The transmissometer output has both a fast and a slow response setting that can be changed externally by appropriate switching. By placing neutral density filters in front of the retroreflector and then switching the calibration retroreflector in and out of the line of sight, very sharp step function inputs could be simulated. The system was set for fast response, and the output connected to a Hewlett-Packard Moseley Model 7100B strip chart recorder. Both the rise time to the 95% point and decay time to the 5% point for a signal input with a 0.3 neutral density filter in front of the target retroreflector was about 1.3 seconds. The same rise and decay times were found when using the internal calibrate filter as the step function input. The response curves are shown in Figure 8. When the system was set for slow response, the same rise time

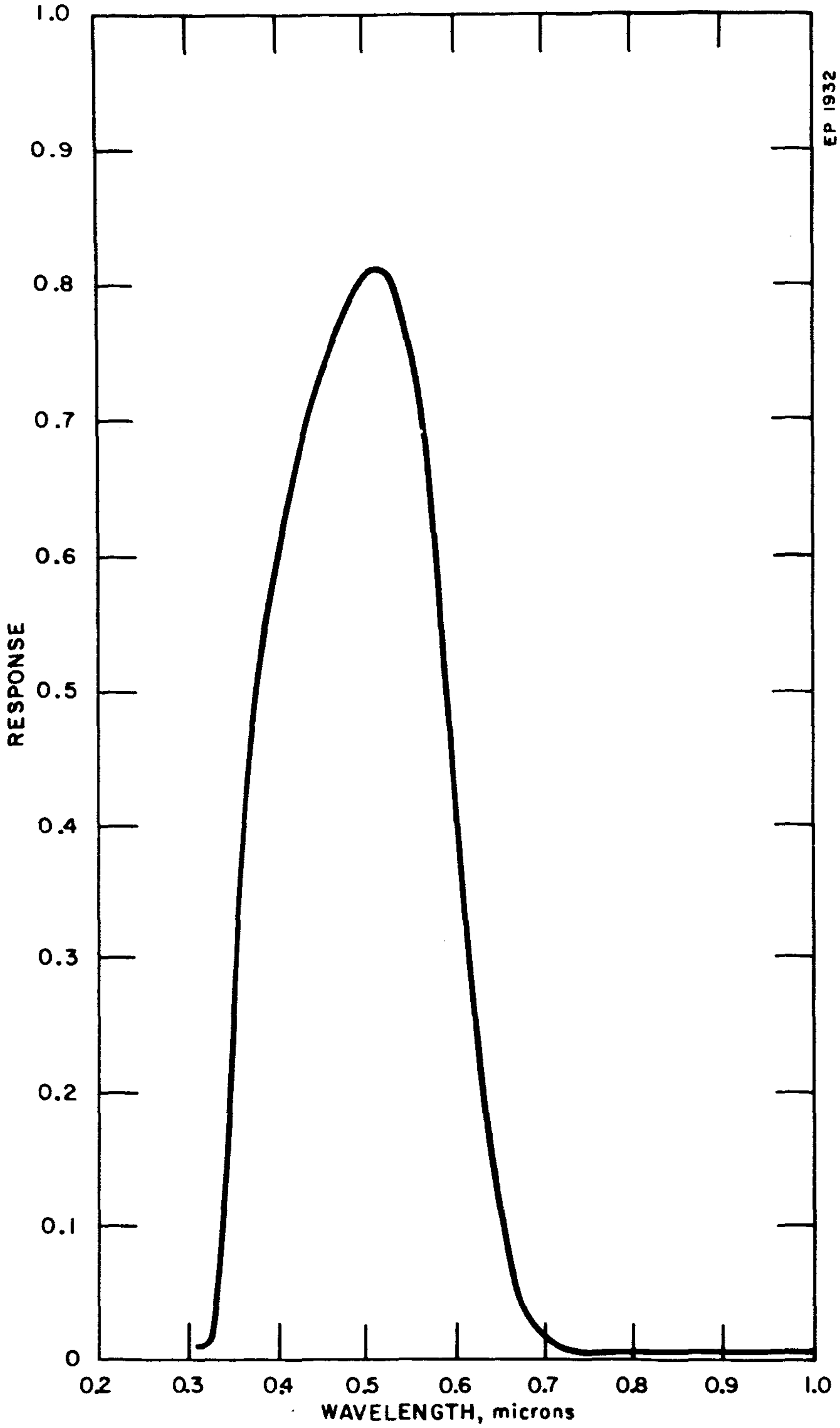


Figure 6. Filter Spectral Response

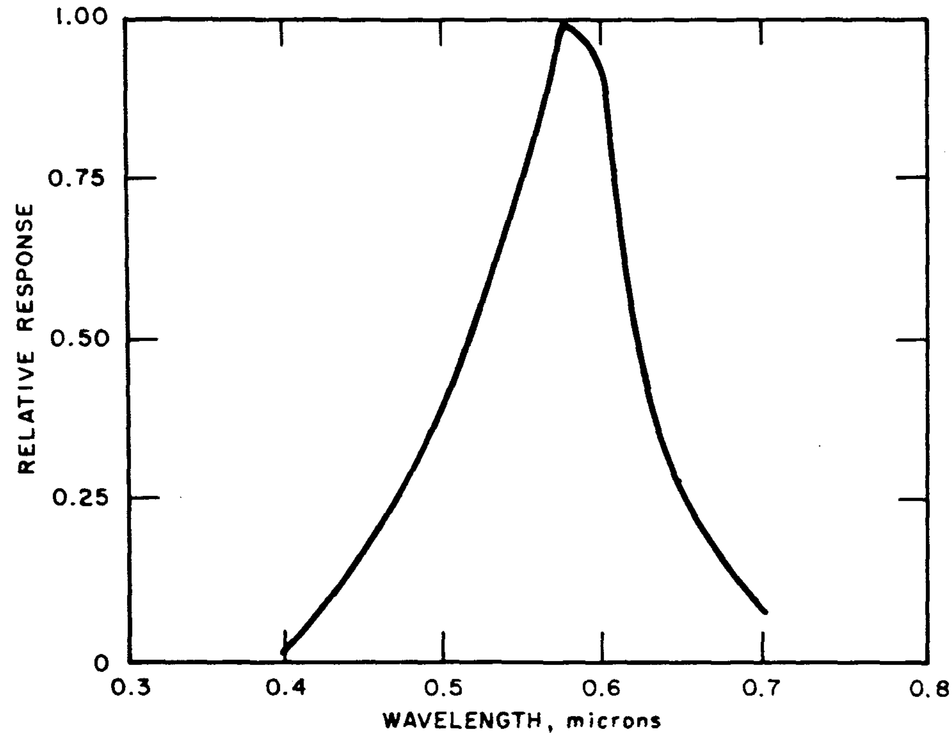


Figure 7. Transmissometer Response Curve with Tungsten Filament Lamp at 2450°K Color Temperature.

of 1.3 seconds was found for the 0.3 neutral density filter input although the decay time was 0.6 second to the 9% level and 3.0 seconds to the 5% level. However, with the calibration retroreflector switched in front of the exit beam, and using the internal calibration filter as the step function input by switching it in and out, the amount of time for the system to respond increased to almost 13.1 seconds, with the curve showing a sharp rise to about 50% of the final signal in about 0.2 second then suddenly flattening out and reaching the 95% point about 12.9 seconds later. This same characteristic appeared in reverse for the decay time. Thus placing the response switch in either the fast or slow position really had little effect on the response of the system to an external signal caused by an obscuring medium in the stack. The response curves for the slow response setting are shown in Figure 9.

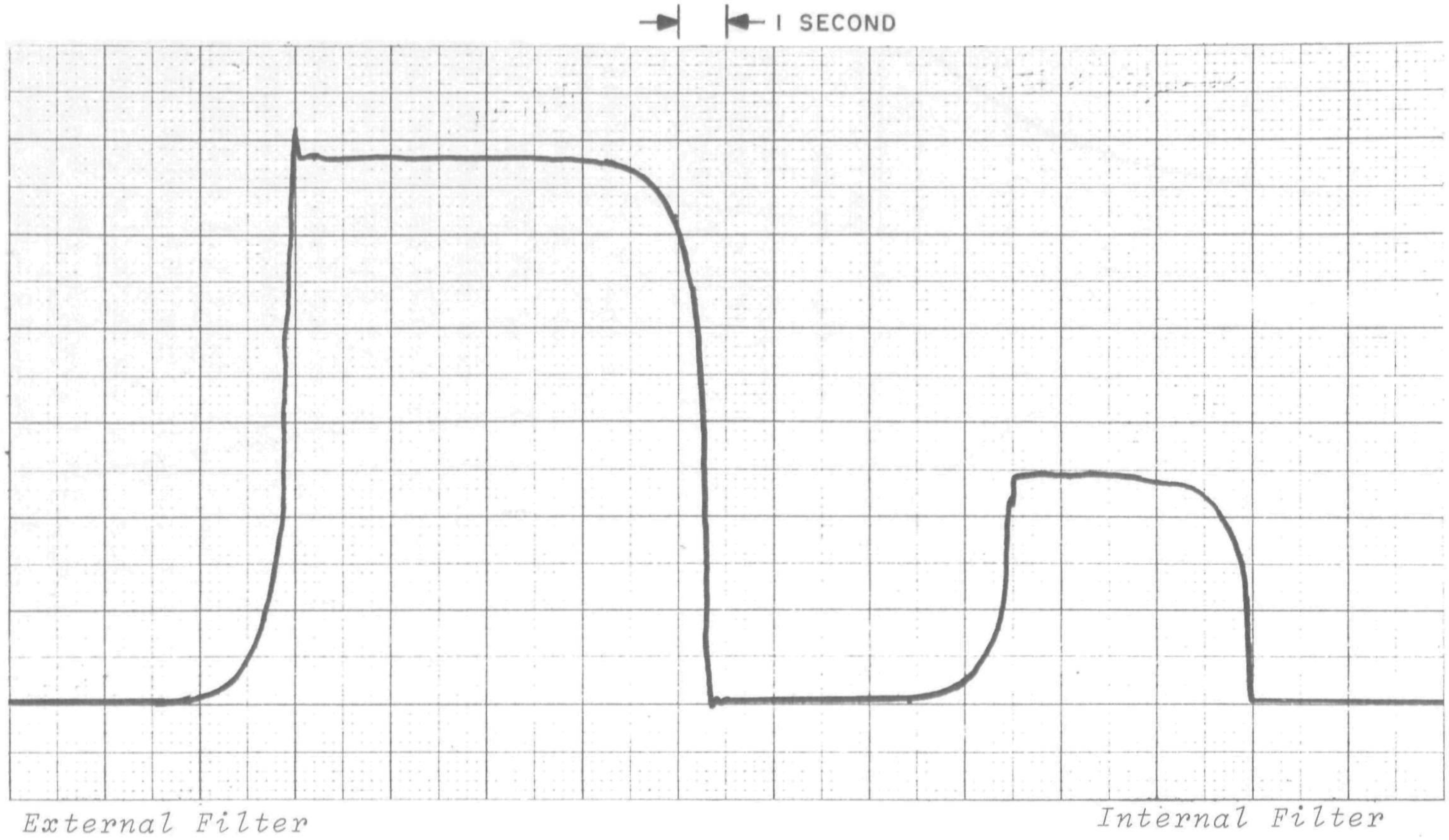
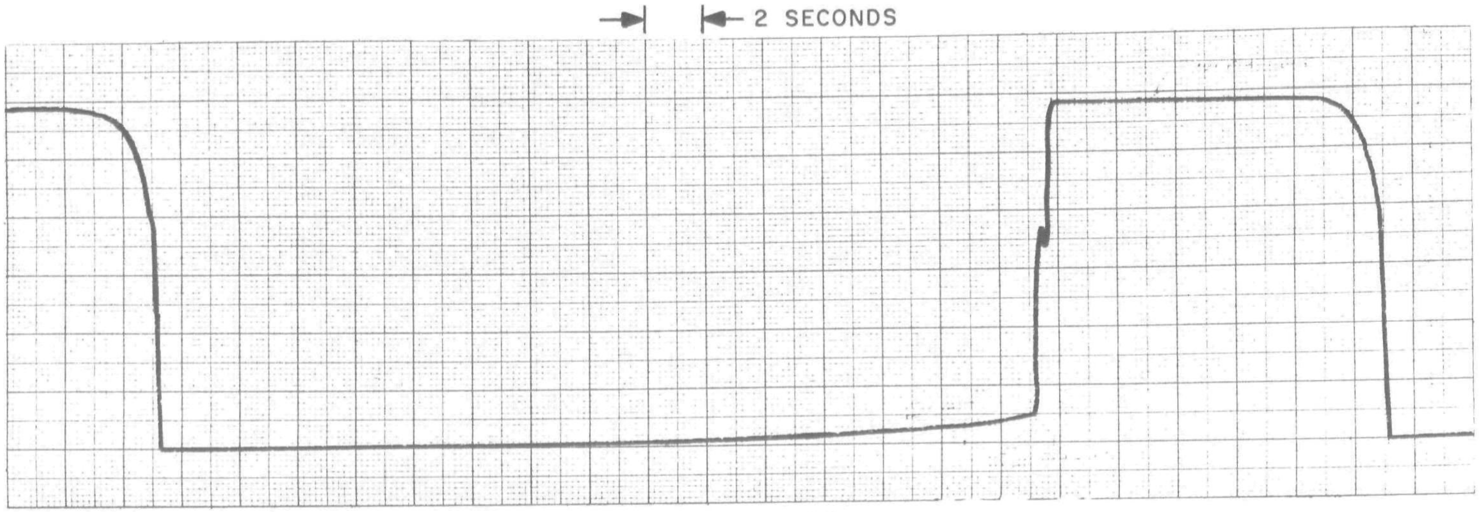
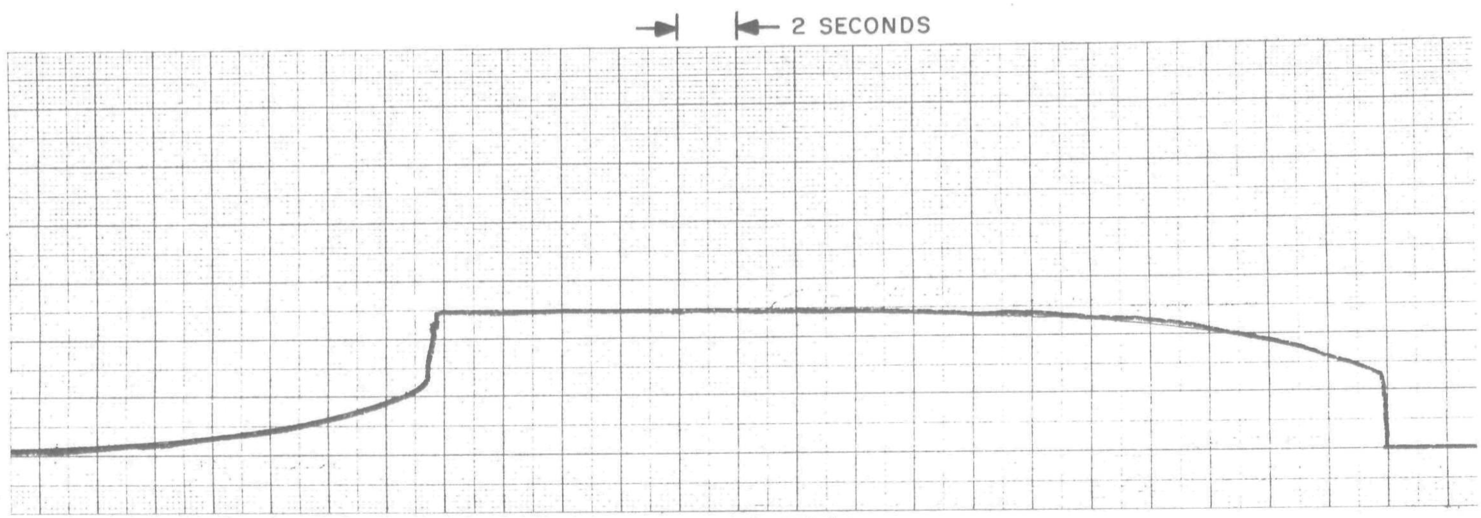


Figure 8. Fast Response Curves



External Filter



Internal Filter

Figure 9. Slow Response Curves

This was not the reported normal slow response behavior of the system and it was concluded that the slow response circuit was not operating properly. Since only the fast response was to be used for data collection, repairing the circuit was not considered and time delay in the program was avoided.

J. CALIBRATION ERROR

The calibration error curve of the transmissometer can be determined by placing a series of neutral density filters, calibrated for photopic response, one at a time, in the optical path completely covering the retroreflector and then recording the output signal from the transmissometer. Four Tiffen neutral density filters of nominal values 0.1, 0.2, 0.3, and 0.4 were calibrated with the Pritchard telephotometer with its photopic response filter in place. The filter values thus determined are shown in Table 4.

Because the RM-4 transmissometer is a double pass instrument, any intervening medium or neutral density filter will appear twice as dense as it really is. This is of no real consequence provided this fact is known and the output curve of the system properly constructed. Thus in developing the final curves for single pass, the stated value of the calibration filter in the transmissometer had to be divided by two. The transmissometer output current vs. filter effective neutral density is shown in Figure 10. Because one of the goals of this program was to compare the output of the transmissometer with measurements made of the exit plume, the transmissometer output must be calibrated in terms of single pass. The theoretical curve for single pass opacity versus the chart reading is the solid line shown in Figure 11. The broken line is the calibration curve for a uniform diameter stack (no taper), and the dashed line is the cali-

Table 4. NEUTRAL DENSITY PHOTOPIC RESPONSE VALUE

Nominal	Photopic Value
0.1	0.111
0.2	0.185
0.3	0.290
0.4	0.400

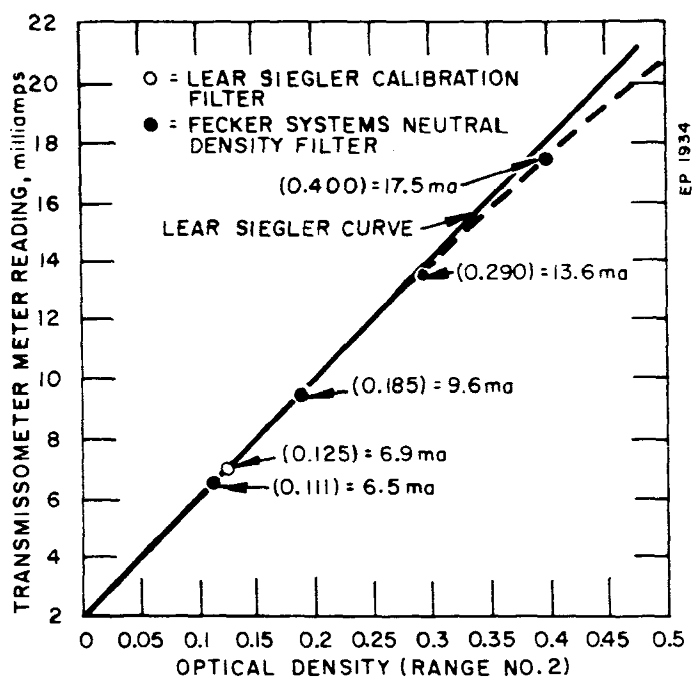


Figure 10. Transmissometer Current vs. Filter Effective Neutral Density

bration curve corrected for the stack diameter taper ratio encountered at the cement company. The exit stacks at the basic oxygen furnace and at the sulfuric acid plant were not tapered. Below an optical density of 0.25 (44% opacity) the theoretical and calibration curves are virtually coincident; above that they show a gradual departure to about 2% low at 0.45 optical density (65% opacity). The data from which the curves were generated are shown in Table 5.

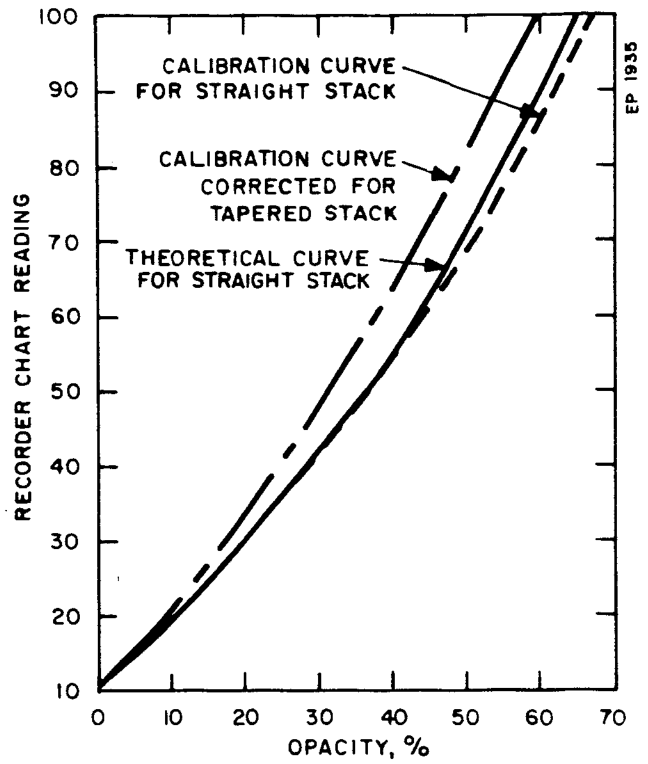


Figure 11. Transmissometer-Recorder Calibration Chart

In developing the theoretical curve, 10.0 on the chart was set to be zero opacity and 100.0 was 65% opacity. The neutral density filters, previously calibrated photopically, were placed over the retroreflector in the optical path of the system and the resulting signal read on the transmissometer. The values in the last column headed "Tapered Stack Opacity Value" are determined from the equation:

$$\log (1-O_1) = \frac{l_1}{l_2} \log (1-O_2)$$

where: O_1 = the opacity at the stack exit

O_2 = the opacity as seen by the transmissometer at the diameter where it is mounted

l_1 = stack exit diameter

l_2 = stack diameter at the transmissometer location.

Table 5. TRANSMISSOMETER CALIBRATION DATA

Neutral Density Filter Values: Nominal	Neutral Density Filter Values: Calibrated	Opacity Value (%)	Transmissometer Ammeter (ma): Theoretical	Transmissometer Ammeter (ma): Actual	Chart Divisions	Tapered Stack Opacity Value (%)
0.4	0.4001	60.2	18.0	17.5	86.5	52.4
0.3	0.2903	40.7	13.7	13.6	66.5	41.6
0.2	0.1851	34.7	9.6	9.6	46.8	29.1
Cal Filter	0.1245	24.9	6.9	6.9	34.0	20.6
0.1	0.1107	22.5	6.5	6.5	32.0	18.6

the ratio $l_1/l_2 = 0.8054$ for the Portland cement company stack. The calibration curves thus developed were used in the evaluation of all transmissometer generated data gathered during the field program. The instrument manufacturer offers an opacity converter accessory to provide a linear opacity output, however, it was not used for this study.

K. OUTDOOR ENVIRONMENTAL TESTS

At the completion of the laboratory tests, the system was set up on the roof of the Fecker Systems facility for testing in the local weather environment. The fiber glass weather shields were not installed, but the equipment was protected with heavy layers of plastic sheet. This test period lasted for approximately two weeks, with one equipment failure within the first 24 hours. A transistor on the system output card in the transmitter/receiver unit had failed, but was replaced and the system operated properly throughout the balance of the program. During this test, the slight zero drift noted earlier, repeated itself, but was not considered significant. At the conclusion of this test period, the instrument was checked for correct focus and calibration, and prepared for installation on the stack of the basic oxygen furnace.

SECTION III

FIELD PROGRAM

A. STEEL PLANT, BASIC OXYGEN FURNACE

The transmissometer was installed on the basic oxygen furnace stack on May 10, 1973 and remained there throughout an initial test period of approximately 40 days. The mounting flanges had to be placed such that the line of sight to the retroreflector unit passed beneath and cleared a 15.24-centimeter (6-inch) diameter tube which spanned the interior diameter of the stack. It was considered inadvisable to place the line of sight above the tube because of a possible adverse effect on the flow of the effluent that could cause an error in the transmissometer readings. The low position of the line of sight precluded installing the blower systems and weather covers in the normal manner. Therefore the blower systems were mounted on stands next to the units they served and connected by extended feed hoses to the instrument purge air inlets. The blower systems and the transmitter/receiver and retroreflector units were protected with plastic sheeting as was done during the roof top environmental test, and there was no operational difficulty. The only serious problem encountered was due to a fairly high level of vibration that caused the alignment of the instrument to wander such that the image of the retroreflector, as viewed through the eyepiece, moved entirely out of the field of view. The alignment adjustments of the instrument do not have positive locking features, and the most practical way to solve this problem was to apply a "loc-tite" type of sealant to the adjustment screw threads. Once this was done, and the system realigned, the problem did not occur again.

This plant has three basic oxygen furnaces, with two in continuous operation and one on standby being refurbished. Approximately 20 heats of steel are produced in a 24-hour period averaging over 200 tons per heat. The charge for each furnace consists of approximately 70 to 75% hot metal with the remainder being a mixture of scrap steel plus additives of alloying elements, depending upon the type of steel being produced. Each furnace is vented by a large ducting system into either side of a double precipitator bank with a 1 1/2 million cubic feet total capacity. Each precipitator bank has its own exit stack, one 6.1 meters (20 feet) in diameter and the other 4.88 meters (16 feet) in diameter. The transmissometer was located at the point approximately 18.29 meters (60 feet) above the exhaust fan duct connection at the bottom of the 4.88-meter (16-foot) diameter stack, almost three stack diameters from both the nearest ducting size change and the top of the stack. The installation of the transmissometer/receiver unit is shown in Figure 12. This method of mounting of the unit was essentially the same at the sulfuric acid plant, and the production facility of the Portland cement company.

Measurements of the exit plume opacity were to be made with the Pritchard telephotometer using the contrasting target method. Four sequential measurements of target and plume relative luminosities in the photopic portion of the spectrum were made which were used to derive the opacity of the plume. These measurements were to be time-matched to the transmissometer strip chart recorder and the degree of correlation between the two instruments determined. The basic sequence and location of measurements is shown in Figure 13. Transmission of the plume is given by the equation:

$$T = \frac{C-D}{A-B}$$

where A = sky without the plume

B = target without the plume

C = sky through the plume

D = target through the plume

The opacity of the plume in percent is then:

$$\% \text{ Opacity} = (1 - T)100$$

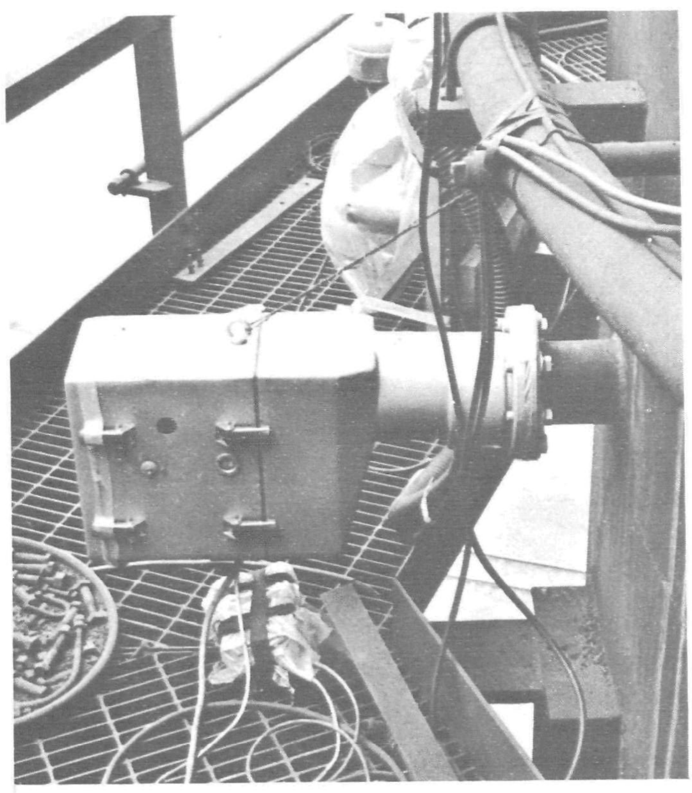


Figure 12. Transmissometer Installation, Basic Oxygen Furnace

Measurements of the plume were made from three different vantage points using two different techniques. The first was from an elevated position on the structure of the basic oxygen furnace permitting a line of sight across the top of the exit stack with a wooded hillside across a nearby river as the target area. The second position was from a highway across the river using a line of sight that used the side of the basic oxygen furnace as the target area. Several series of measurements were made at both the first and second positions.

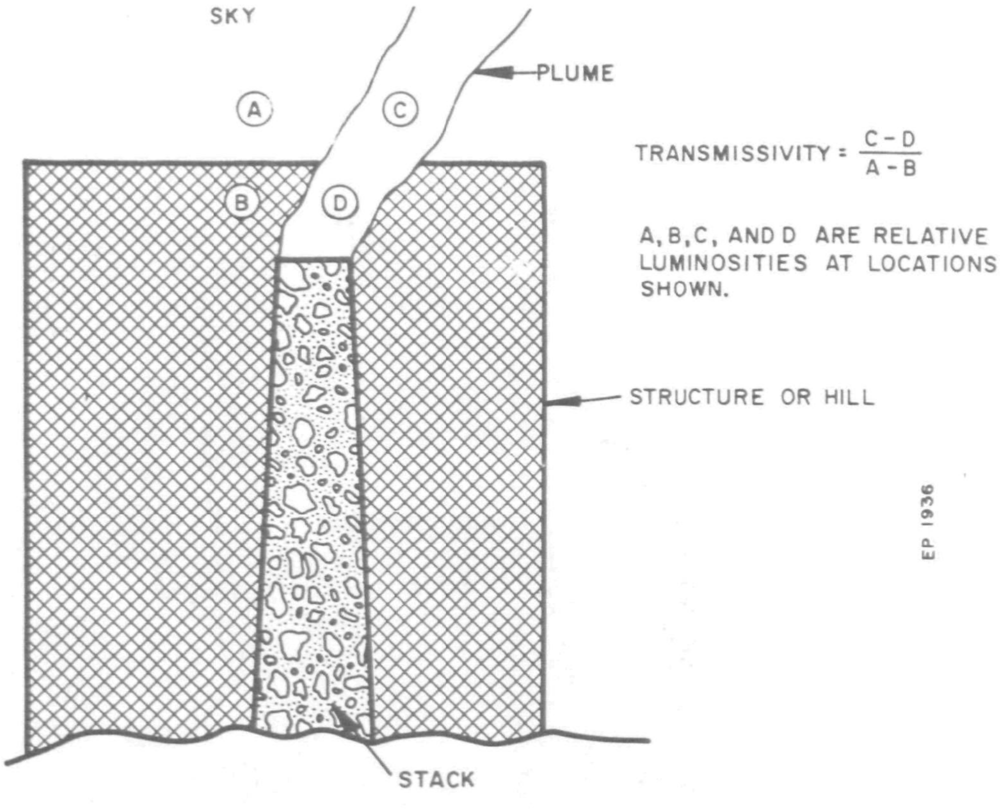


Figure 13. Contrasting Target Method

Measurement data taken at the first site were not acceptable. The measurement site was too close to the stack forcing the use of very widely separated targets with varying radiances. Better data were accumulated at the second site with good correlation achieved at the lower opacity levels when stack emission was in a fairly steady state condition. The steel making technique at the basic oxygen furnace, however, is a batch process causing the effluent output to vary rapidly, occasionally producing some heavy puffs which were not possible to measure with the time dependent sequence of the contrasting target method. It was decided to try a third vantage point and different technique by taking measurements at night looking at a light source behind the exit plume and recording directly on a strip chart the output from the telephotometer. In this manner, the time dependence problem could be eliminated, and the short term higher levels of opacity could be measured as they occurred. The setup for this method is shown in Figure 14. A timer was attached to the power cord for the light which could turn off the light for a period of a few seconds at five-minute intervals thus providing a 100% opacity calibration point. The low opacity correlation data determined previously using the contrasting target method were used as a second calibration point. Data were taken through the early evening after dark until after midnight when condensation on the telephotometer objective lens precluded further work. This last effort concluded the field work at the basic oxygen furnace, in which measurements of the exit stack were made on six different occasions.

Throughout the testing period, the transmissometer operated properly. Prior to each measurement effort, at all field sites, as well as the steel plant, the transmissometer was checked for alignment, cleanliness of the optics, and general operation. The strip chart recorder was adjusted for

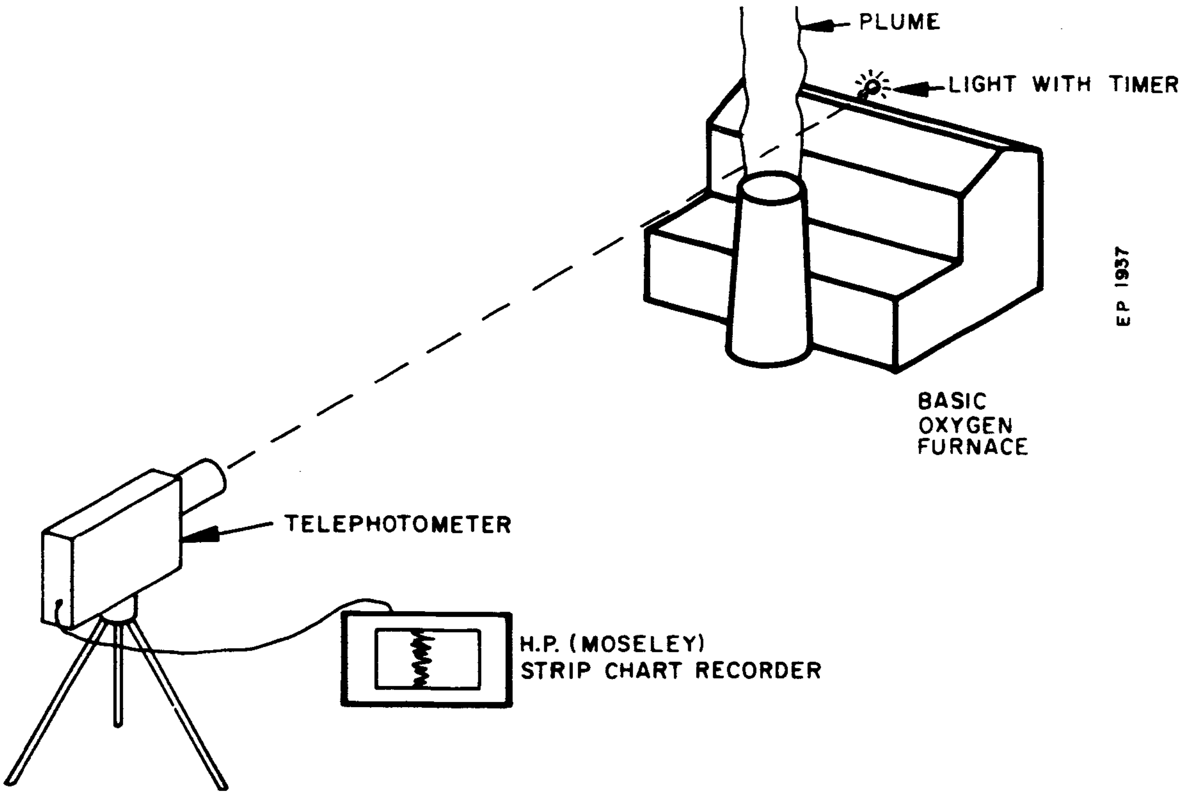


Figure 14. Direct Measurement Telephotometer Setup

zero and span prior to the beginning of data taking and switched to the fast chart drive [38.1 cm (15 in.) per hour] to provide better time resolution of the output signal. No serious problems were encountered during the time that the instrument was installed at the basic oxygen furnace. When the field work was concluded, the transmissometer system was removed from the stack, and returned to the Fecker Systems laboratory facilities for cleanup, refocusing, and recalibration for the next test site.

B. SULFURIC ACID PLANT

After a program delay, the transmissometer was finally installed on the exit stack of the sulfuric acid plant on March 5, 1974. This particular plant uses the contact process with sulfur as the basic feed stock. Approximately 400 tons of sulfuric acid, of which 25% is oleum, is the normal daily production rate. The emission control system is a Brink mist eliminator located in the process train before the effluent reaches the 1.83-meter (six-foot) diameter exit stack. The approximate location of the transmissometer is shown in Figure 15. The proximity of the supporting structure around the stack would not permit the use of weather shields, and sheet plastic was used to protect the units in a manner similiar to that at the basic oxygen facility test site. Some initial difficulty was encountered in correcting a very large signal drift that occurred almost immediately after the unit was installed. This was caused by the rapid buildup of sulfate residue in the mounting ports resulting from not completely cleaning them prior to installation. Once this condition was corrected, no further operational difficulty was encountered.

Remote measurements were made of the exit plume at a distance of approximately 915 meters (1000 yards) from the stack. The line of sight afforded a view of the wooded hillside across a nearby river as the target area. Plume opacity measurements were made on four separate occasions. Observing conditions were not ideal and the field teams were hampered by rain, high winds, a variable sky background, and changing illumination conditions. As a result, the measurement data were quite random and did not agree with the in-stack transmissometer measurements. The stack effluent was for the most part quite transparent to the in-stack transmissometer. The average transmissometer signal, when the sulfuric acid production process was in normal operation, indicated but a few percent opacity. The concurrent plume opacity measurements made with the telephotometer with the contrasting target method were generally higher.

Figure 15. Transmissometer Location, Sulphuric Acid Plant

When the production process went out of balance, SO_3 was produced which is extremely hygroscopic and forms a white mist. This condition was readily detected by the transmissometer and was visually observable in the plume. Such an event was unpredictable, however, and usually occurred over a period of but a few hours, too short a time for field measurement teams to reach the site and take advantage of the phenomenon. The sulfuric acid plant technical personnel could deliberately induce this condition, but could only produce a very small SO_3 reaction without seriously upsetting their production process. As a result, the remote opacity measurement program at the sulfuric acid plant was limited to low opacity conditions and establishment of a functional relation between in-stack opacity and plume opacity was not achieved. It was evident, however, that an optical device such as a transmissometer would be very effective as a production control or warning device in the sulfuric acid industry.

Field work at the sulfuric acid plant was concluded and the transmissometer removed from the stack on May 24, 1974 and returned to the Fecker Systems laboratory facilities for cleanup, refocusing, and recalibration in preparation for installation on the stack at the next field measurement site.

C. PORTLAND CEMENT PLANT

The transmissometer was installed on a cement plant stack on three separate occasions during this program. This plant uses a rotary kiln, wet process producing approximately 425,000 tons of finished Portland cement per year. Feed stock consists of lime and sand, with coal and coke oven gas burned as fuel. The effluent passes through a bank of electrostatic precipitators and is then vented to the atmosphere through 45.72-meter (150-foot) high steel reinforced concrete, lumnite-lined stack. The first installation was in December of 1973 through early January of 1974. The transmissometer location area is shown in Figure 16 at about 21.34 meters (70 feet) above ground level. During this period, ambient temperatures were in the near or subfreezing range. Because cement manufacturing at that facility is a wet process, a considerable amount of water vapor exists in their exhaust stack effluent. Stack temperatures are high enough to keep the water vaporized and thus transparent to the transmissometer. However, once the effluent encountered the ambient air it condensed immediately into a white plume with almost no detachment from the top of the stack. Unable to make effective measurements of the exit plume opacity, the program was suspended at that location and the transmissometer sent to the sulfuric acid plant test site.

The second installation at the cement plant occurred on June 10, 1974, after conclusion of work at the sulfuric acid plant. This test period continued until July 10, 1974 when the manufacturing process was shutdown for a two-week equipment refurbishment program. During this 30-day period on site, measurements were made of the plume opacity on three separate occasions. The observation point was located at a position approximately 450 meters (500 yards) from the stack. The target was a large industrial structure located another few hundred meters past the stack. The measurement data taken were random in nature and did not show much correlation with the transmissometer readings. The target structure was the main problem in that it did not present a uniform enough background for use in the contrasting target method. Sky background conditions, general illumination, and smoke blowing through the area from other industrial plants also contributed to the difficulties which

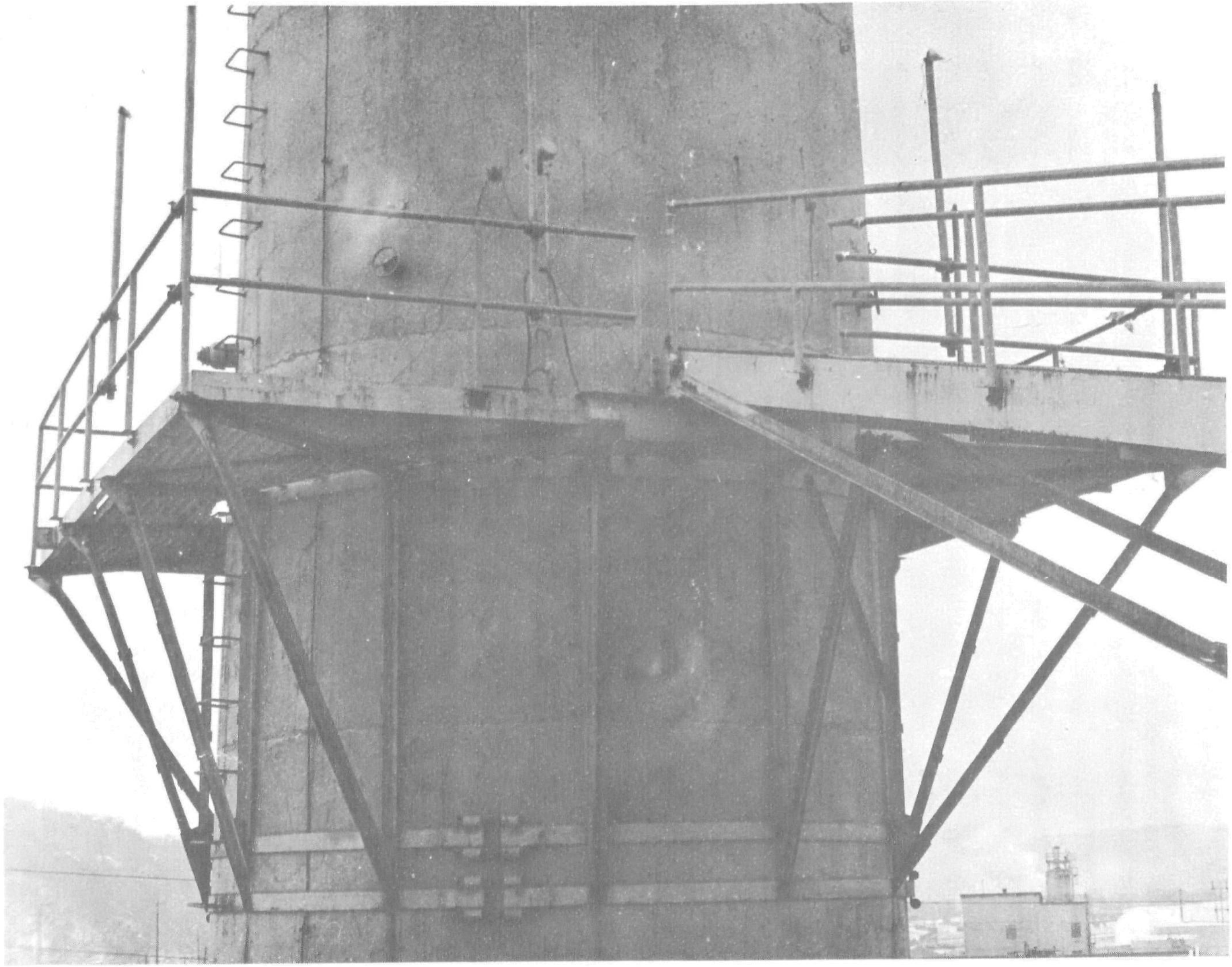


Figure 16. Transmissometer Location, Portland Cement Plant

occasionally forced the observing team to curtail measurement activity until the area cleared.

Difficulties with the transmissometer were relatively minor. One of the blower units failed (retroreflector side), but the stack has about a 5-centimeter (2.0-inch) water column negative pressure and external air continued to be drawn through the filter system, into the retroreflector unit, and then into the stack. No accumulation of dust was noticed on the optical surfaces and field work did not have to await the arrival of a new blower, which subsequently was replaced. Low voltage conditions on the input power lines to the transmitter/receiver unit (this condition occurs frequently in industry) caused the calibration retroreflector and internal filter solenoids to fail to operate, but this was remedied by placing a variac in the line and raising the voltage to the necessary level.

On July 10, 1974, operations at the cement plant were suspended for a two-week period for plant maintenance purposes. During that time the transmissometer was reinstalled at the steel plant basic oxygen furnace in support of a particulate measurement program being conducted by another corporation for EPA under separate contract. No further exit plume measurements were made at the plant. The results of that program will be described in a separate report. At the conclusion of the measurement program the transmissometer was returned to the cement plant and reinstalled on the stack.

Stack effluent opacity levels, as indicated by the transmissometer, had been averaging about 18% or less. The operation at the cement plant is fairly well controlled, and management was reluctant to cutback on their precipitators to produce higher levels of opacity without specific permission to do so from the local air pollution control authority. Details of the granting of permission were not agreed upon and plant management, understandably, elected not to reduce their control system capabilities. Consequently, it was not possible to acquire data over a sufficient range of opacities to develop a comparison curve of the transmissometer vs. plume opacity measurements.

The transmissometer was reinstalled on the stack at the cement plant on August 15, 1974 and remained there for approximately a week to gather additional data at hopefully higher opacity levels. Two new observing sites were used, with measurements made on two occasions at each site. The first position was located on an access balcony on top of their clinker silos. This afforded a line of sight across the top of the stack with a wooded hillside as the target area. The second observation site was on top of a high storage silo. The line of sight was almost level with the top of the stack, with another wooded hillside approximately two miles away used as a target area. Measurements were made both in the morning and afternoon at these sites, when the sun direction was at different angles to the line of sight. In the mornings, background haze reduced the target and sky contrast, but luminosity differences across the target or the sky areas scanned were nearly zero, thus reducing one of the sources of error inherent with the contrasting target method. By afternoon the haze generally had burned off, but concentrations of smoke from nearby industries continued to present a problem. Measurement activity had to be curtailed until the prevailing winds cleared the smoke from the area. On August 26, 1974 the transmissometer was removed from the stack at the cement plant, and the field program under this contract was concluded.

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SECTION IV

MEASUREMENT DATA REDUCTION AND ANALYSIS

A. INTRODUCTION

Telephotometer measurements of the plume opacity made in the field with the contrasting target method were initially recorded on a special form as shown in Figure 17. Prior to initiation of measurements, the transmissometer strip chart recorder was switched to the fast chart speed and time marked. Each series of measurement data subsequently taken of the exit plume was time marked on the data sheet at the beginning and the end of the series. Normally ten (10) series of ten (10) measurements each were taken during each visit to the observing site although as high as twenty-one (21) series were recorded. At the conclusion of the measurement period, the strip chart was again time marked, and that section of the chart between the two time marks removed for subsequent analysis. The beginning and end of each data series were time located on the chart and divided into ten (10) equally spaced data points. The chart reading was then matched with each measurement point on the data sheet, thus providing a transmissometer reading for each exit stack opacity value determined from the contrasting target method measurements. These raw data were card punched for reduction by computer program with the subsequent output expressed in terms of in-stack transmissometer measured plume opacity (corrected for stack diameter taper ratios) and telephotometer measured out-of-stack plume opacity. Data over a sufficient range of opacities were sought to develop functional relations between measurements; however, this was accomplished only for the work done at the basic oxygen furnace.

DATA SHEET

PLUME OPACITY MEASUREMENT

CONTRASTING TARGET METHOD

Location____

Date________________ Stack________________________

Wind Velocity________________ Direction________________

Weather____

View Direction________________ Elevation Angle________________

Sun Direction________________ Elevation________________

Distance to Stack__________ Height of Stack__________ Diameter __________

Settings: Filter Wheel________________ Attenuator________________

Field Stop ________________

Contrasting Target________________

Readings	Time of Start of Readings				
Sky thru Plume					
Target - Plume					
Target - w/o					
Sky - w/o					
Sky thru Plume					
Target - Plume					
Target - w/o					
Sky - w/o					

Time at completion.________________

Figure 17. Form Used to Record Telephotometer Measurements

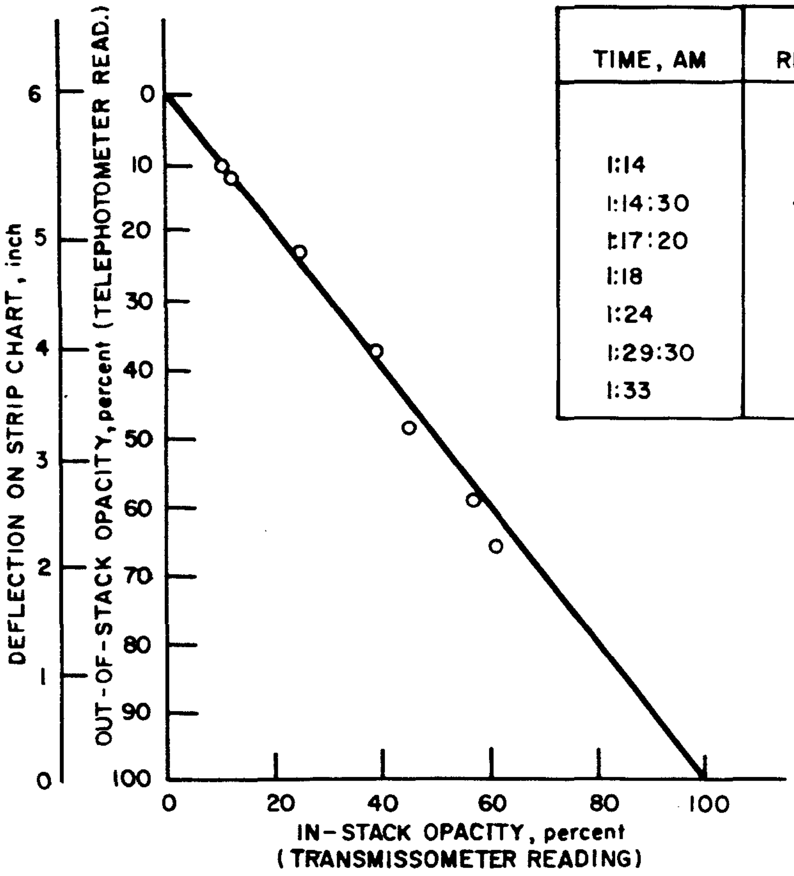
Insufficient measurements at the higher levels of opacity at the Portland cement plant and virtually no variation of the measurements at the sulfuric acid plant prevented the development of functional in and out-of-stack opacity curves for those two test sites.

To reduce some of the randomness of the measurements and to present the data that were accumulated in a meaningful manner, each measurement series of ten (10) data points for a given day was reduced to an average value for that series. This was also done for the corresponding measurements recorded by the transmissometer, and then each series of measurements plotted in terms of opacity versus the particular series number. These tables and associated graphs of the data are discussed below for each test site.

B. BASIC OXYGEN FURNACE

Figure 18 was generated from low opacity correlation data accumulated with the Pritchard telephotometer with the contrasting target method, and from data gathered on the night of July 5-6, 1973 with the telephotometer observing a bright light behind the exit plume. At the lower end of the opacity curve, the transmissometer and the telephotometer were considered to read approximately the same value. The high opacity point of 100% was established by turning off the light behind the plume and setting the 100% signal equal to zero on the Hewlett-Packard (Moseley) strip chart recorder. The data (Figure 18) show good correlation between the measurements.

The tabulated values and graph for the low opacity measurements made by the contrasting target method during the day time visit to the site on June 22 are shown in Figure 19. This series taken when observing conditions were very stable, shows good correlation and was the basis for the establishment



TIME, AM	RM-4 READING	STRIP CHART DEFLECTION	
		CM	INCHES
1:14	38.5%	9.93	3.91
1:14:30	44.7%	8.18	3.22
1:17:20	60.5%	5.38	2.12
1:18	56.7%	6.53	2.57
1:24	25.4%	12.24	4.82
1:29:30	12.3%	14.10	5.55
1:33	10.5%	14.27	5.62

Figure 18. In-Stack Transmissometer Opacity vs. Out-of-Stack Telephotometer Opacity

of the low opacity calibration point for strip chart recordings made on the overnight test of July 5 and 6, 1973.

The transmissometer performed normally throughout the measurement period. Zero drift amounted to essentially 1% as observed during laboratory testing. The severe vibration environment on the stack caused optical alignment problems, however, these were quickly corrected. No other serious problems were encountered during the measurement program at the basic oxygen furnace. The blower units operated

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	4.07	2.94	+1.13
2	3.23	2.30	+0.93
3	4.30	3.16	+1.14
4	6.84	5.18	+1.66
5	6.40	3.75	+2.65
6	7.06	7.47	-0.41
7	5.17	5.07	+0.10
	SYSTEM CALIBRATION		
8	8.03	5.84	+2.19

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
9	6.27	4.84	+1.43
10	9.82	4.98	+4.84
11	9.49	7.94	+1.55
12	8.08	4.98	+3.10
13	11.21	8.84	+2.37
14	9.39	6.24	+3.15
15	12.44	5.04	+7.40
Avg.	6.99	4.91	2.08

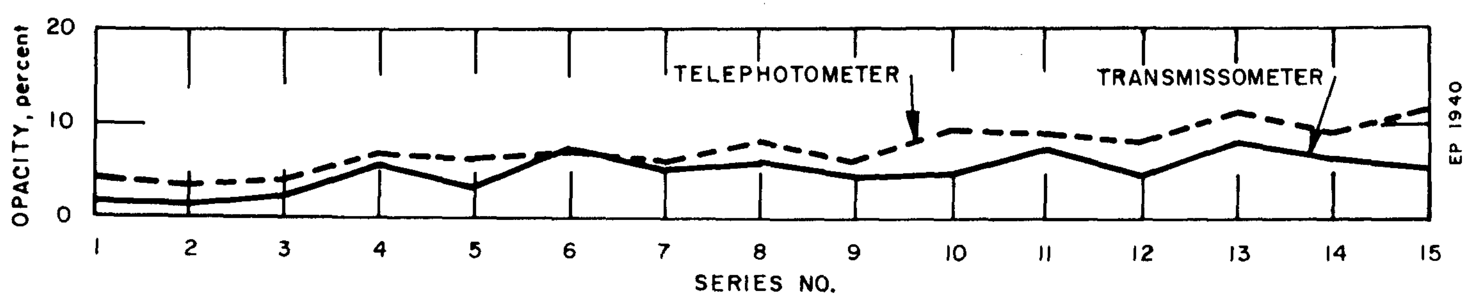


Figure 19. Series Averages, June 22, 1973 (10:19 AM to 1:35 PM) (Basic Oxygen Furnace)

continuously and effectively kept the optics clean. No noticeable change in the zero or calibration span points occurred, however, as a precautionary measure the objective lens and retroreflector were cleaned routinely prior to data taking activities at each site.

C. SULFURIC ACID PLANT

The results of the plume opacity data taken at the sulfuric acid plant did not indicate a one-to-one correlation between in-stack and plume opacity. The plume opacity measurements ran consistently 6 to 10% higher than the opacity sensed by the transmissometer. There was also randomness to the plume measurements that was probably the result of changing background conditions that occurred during the observation periods. The reason for the generally higher plume opacities is not readily apparent although effluent temperature and constituency may be contributing factors. The stack temperatures are not very high, and acid mist, and sometimes sulfur trioxide in the acid production process, can absorb water from the atmosphere as they leave the stack and produce a plume with greater opacity then can be seen in the stack by the transmissometer.

The series averages of the data gathered at the sulfuric acid plant site are shown in Figures 20, 21, 22, and 23. As with the basic oxygen furnace measurement program, zero and span drifts did not exceed the 1% level measured in the laboratory. The instrument performed well, and initial apparent drift difficulties were traced to a residue buildup in the mounting ports which resulted from improper cleaning. Once this was corrected there were no further problems.

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	12.22	2.30	+ 9.92
2	12.06	2.30	+ 9.76
3	14.12	2.30	+11.82
4	11.63	2.30	+ 9.33
5	15.43	1.10	+14.32
6	8.78	1.10	+ 7.68
7	11.15	1.10	+10.05
8	7.47	1.10	+ 6.37
9	13.08	1.10	+11.98
10	9.11	1.10	+ 8.01
Avg.	11.51	1.58	+ 9.93

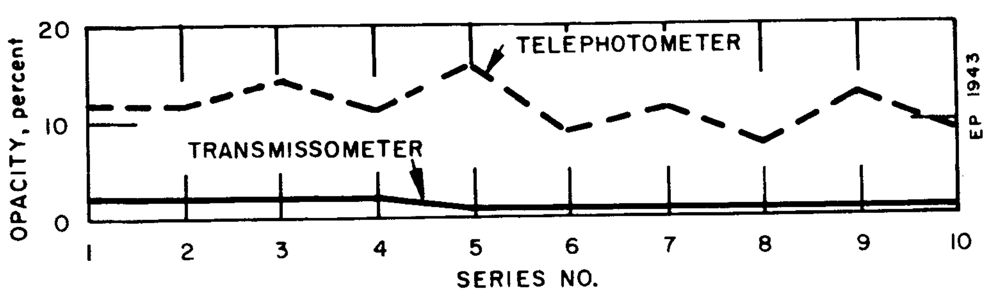


Figure 20. Series Averages, April 4, 1974
(3:07 PM to 4:16 PM)
(Sulfuric Acid Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	14.02	14.20	- 0.18
2	13.92	12.90	+ 1.02
3	15.26	11.90	+ 3.36
4	18.51	9.80	+ 8.71
5	21.63	9.80	+11.83
6	22.48	9.80	+12.68
7	25.25	9.30	+15.95
8	24.58	9.30	+15.28
9	19.22	9.30	+ 9.92
10	24.74	9.30	+15.44
Avg.	19.96	10.56	+ 9.40

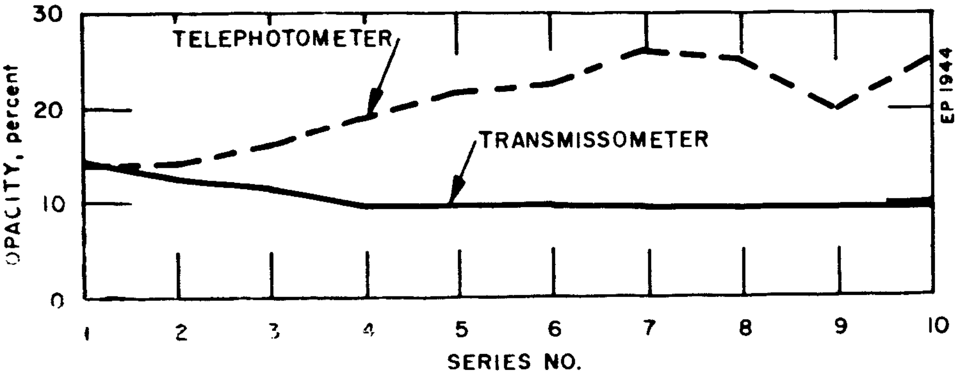


Figure 21. Series Averages, April 17, 1974 (10:28 AM to 1:15 PM) (Sulfuric Acid Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	- 7.37	2.30	- 9.67
2	13.33	2.80	+10.53
3	8.32	2.80	+ 5.52
4	12.69	2.80	+ 9.89
5	14.07	2.30	+11.77
6	0.94	2.80	- 1.86
7	4.67	2.30	+ 2.37
	SYSTEM CALIBRATION		
8	14.30	2.80	+11.50
9	11.41	2.80	+ 8.61
	SYSTEM CALIBRATION		
10	11.82	2.80	+ 9.02
11	14.28	2.80	+11.48
12	12.10	2.80	+ 9.30
13	4.96	2.80	+ 2.16
Avg.	8.89	2.68	+ 6.21

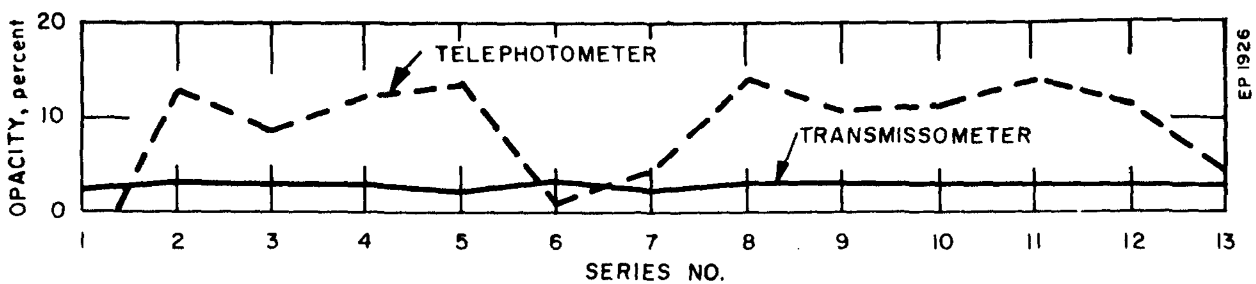


Figure 22. Series Averages, May 7, 1974
(11:17 AM to 1:27 PM)
(Sulfuric Acid Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	14.67	10.90	+ 3.77
2	14.47	11.40	+ 3.07
3	20.14	7.42	+12.72
4	16.89	7.21	+ 9.68
5	13.62	8.80	+ 4.82
6	19.57	8.80	+10.77
7	18.22	8.80	+ 9.42
8	8.21	8.27	- 0.06
Avg.	15.72	8.95	+ 6.77

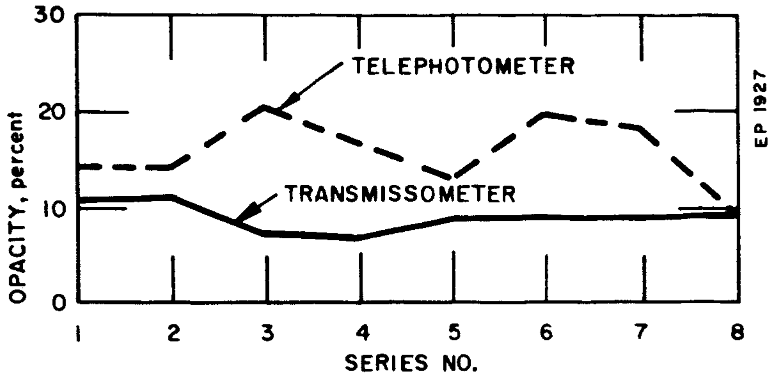


Figure 23. Series Averages, May 23, 1974 (3:48 PM to 4:25 PM) (Sulfuric Acid Plant)

D. PORTLAND CEMENT PLANT

Data taken on June 10, 18, 22, and August 16, 1974 used a large industrial structure behind the stack at the Portland cement plant as the target area. The curves derived from these data show a random variation between telephotometer and transmissometer measurements on June 10, and both positive and negative variation the other three days. On June 18 (Figure 25) and 22, (Figure 26) the transmissometer read higher than the telephotometer with just the reverse occurring on August 16, (Figure 27). The observing positions were changed for the remaining four observing dates to be able to use a more uniform target area. Data for August 20 (Figure 29) and 21, (Figure 30) made during the morning hours, were not much different than before. On August 22 (Figure 31) however, measurements were made starting early in the afternoon when the sun position had changed. The data taken at this time, though somewhat random, showed closer correlation than any of the others. The tabulations of data and associated graphs for the data taken at the cement plant are shown in Figures 24 through 31.

The transmissometer zero and span drift characteristics remained essentially the same as in the laboratory. Line voltage variations to the transmissometer optical head caused the calibration retroreflector and filter solenoids to ocassionally fail to operate. When this was corrected, no further difficulties occurred. One of the blower motors failed (retroreflector side), but the cement plant had a negative pressure stack, and the optics did not appear to be affected by the loss of the blower. The blower was quickly replaced and all equipment operated normally throughout the balance of the program.

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	29.39	21.36	+ 8.03
2	38.68	22.33	+16.35
3	18.55	22.85	- 4.30
4	15.24	20.16	- 4.92
5	16.36	23.17	- 6.81
6	14.10	20.83	- 6.73
7	22.94	19.76	+ 3.16
8	12.53	18.70	- 6.17

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
9	21.49	21.00	+ 0.49
10	18.13	19.00	- 0.87
11	33.10	18.83	+14.27
12	34.38	19.27	+15.11
13	27.30	19.64	+ 7.66
14	16.59	21.37	- 4.78
15	19.73	21.19	- 1.46
Avg.	22.57	20.63	+ 1.94

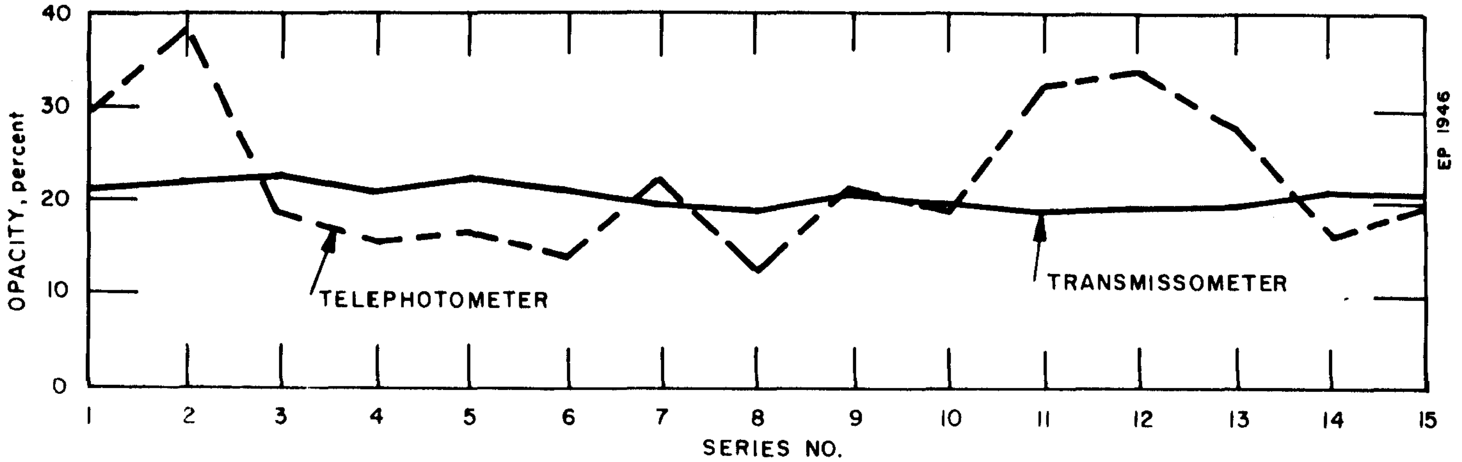


Figure 24. Series Averages, June 10, 1974
(12:20 PM to 2:00 PM)
(Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	22.03	23.44	- 1.41
2	16.94	23.00	- 6.06
3	11.03	23.94	-12.91
4	12.29	23.06	-10.77
5	12.54	22.29	- 9.75
6	14.75	22.64	- 7.89
7	12.91	17.68	- 4.77
	SYSTEM CALIBRATION		
8	18.04	25.50	- 7.46
9	20.40	24.23	- 3.83
10	20.12	24.36	- 4.24
Avg.	16.10	23.01	- 6.91

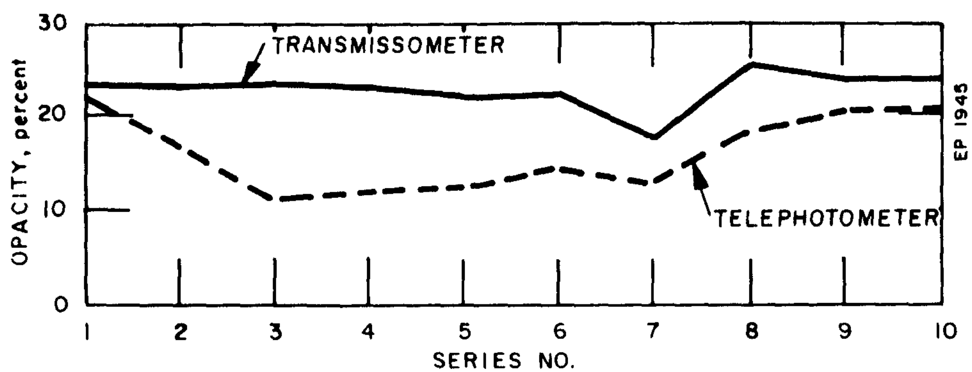


Figure 25. Series Averages, June 18, 1974
(11:29 AM to 12:11 PM)
(Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	2.31	7.55	-5.24
2	2.56	7.91	-5.36
3	4.25	8.64	-4.39
4	2.49	7.79	-5.30
5	2.31	7.10	-4.79
	SYSTEM CALIBRATION		
6	5.81	7.10	-1.29

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
7	2.54	7.86	-5.32
8	3.92	7.10	-3.18
9	3.10	9.21	-6.11
10	4.50	7.13	-2.63
Avg.	3.38	7.74	-4.36

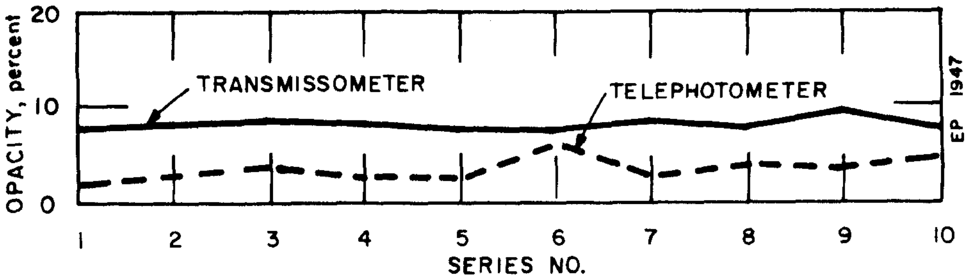


Figure 26. Series Averages, June 22, 1974 (11:19 PM. to 12:07 PM.) (Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	10.47	6.62	+3.85
2	9.04	6.53	+2.51
3	8.07	5.57	+2.50
4	10.87	5.48	+5.39
5	10.31	7.60	+2.71
6	12.77	7.12	+5.65
7	11.57	7.39	+4.18
8	10.57	7.14	+3.43

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
9	12.04	7.14	+4.90
10	11.99	6.56	+5.43
11	8.46	7.13	+1.33
12	12.27	7.72	+4.55
13	8.77	8.09	+0.68
14	11.07	8.67	+2.40
Avg.	10.59	7.05	+3.54

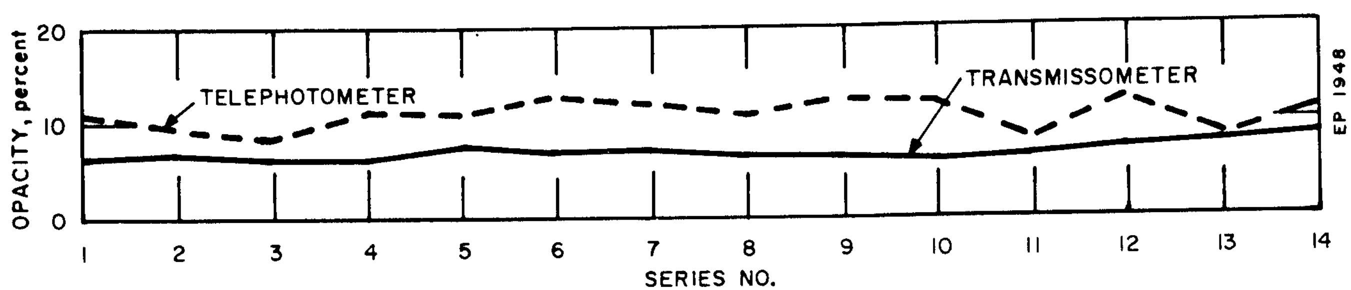


Figure 27. Series Averages, August 16, 1974
(10:13 AM to 11:05 AM)
(Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	12.88	14.12	-1.24
2	12.33	13.56	-1.23
3	12.24	14.52	-2.28
4	7.48	15.78	-8.30
5	10.69	16.43	-5.74
6	11.61	17.01	-5.40
7	12.25	16.86	-4.61
8	12.48	17.47	-4.99
9	10.30	16.68	-6.38
10	9.94	16.31	-6.37
11	9.23	14.98	-5.75
12	9.13	14.36	-5.23
13	7.26	14.82	-7.56
14	6.06	13.55	-7.49
15	6.18	9.18	-3.00
Avg.	10.00	15.04	-5.04

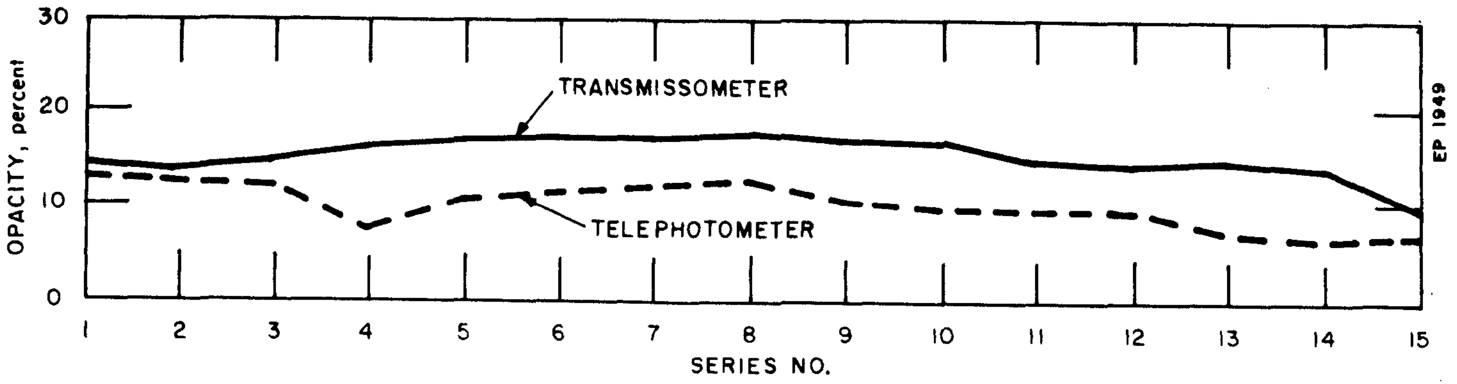


Figure 28. Series Averages, August 19, 1974 (10:38 AM to 11:23 AM) (Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	4.09	8.59	-4.50
2	15.10	9.37	+5.73
3	15.85	9.97	+5.88
4	20.89	11.20	+9.69
5	18.94	9.72	+9.22
6	19.65	11.92	+7.73
7	16.49	10.61	+5.88
8	15.56	11.10	+4.46
9	17.66	9.38	+8.28
10	17.62	9.30	+8.32
11	16.37	9.95	+6.42
12	16.93	10.05	+6.91
13	16.10	11.27	+4.83
14	9.90	10.37	+0.47
Avg.	15.80	10.20	+5.60

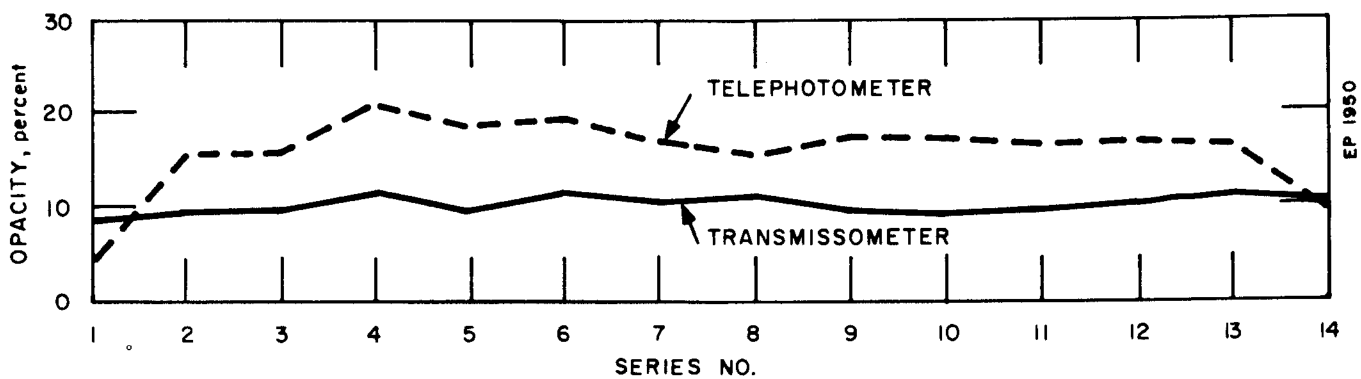


Figure 29. Series Averages, August 20, 1974
(10:03 AM to 11:13 AM)
(Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	18.33	14.99	+ 3.34
2	19.90	14.59	+ 5.31
3	21.42	13.88	+ 7.54
4	21.09	12.58	+ 8.51
5	25.04	14.42	+10.62
6	25.82	15.93	+ 9.89
7	27.60	16.89	+10.71

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
8	21.74	14.59	+ 7.15
9	20.93	14.49	+ 6.44
10	17.50	13.53	+ 3.97
11	17.25	13.32	+ 3.93
12	20.43	14.38	+ 6.05
13	20.46	13.24	+ 7.22
Avg.	19.82	13.34	+ 6.48

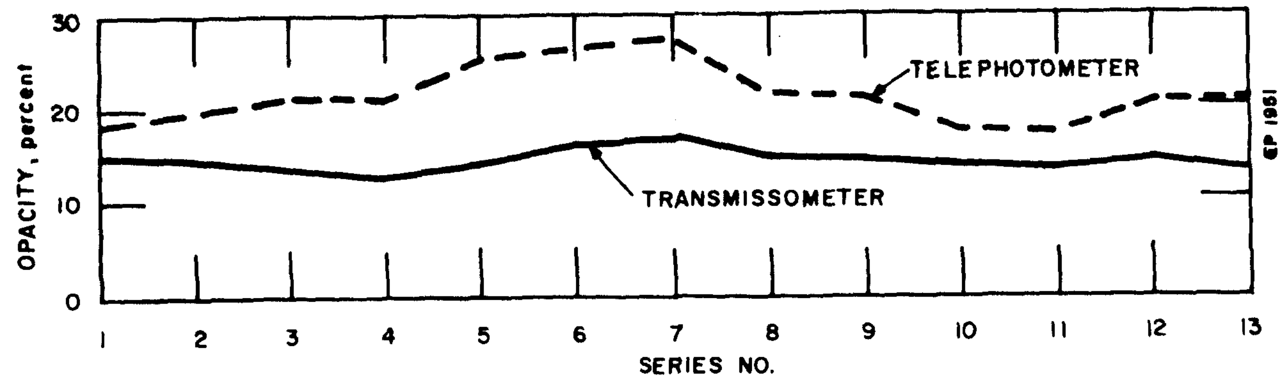


Figure 30. Series Averages, August 21, 1974 (2:48 PM to 3:30 PM) (Portland Cement Plant)

Series No.	P Photometer (Avg. %)	T Transmissometer (Avg. %)	P-T Δ Average % Points
1	20.64	12.35	+8.29
2	19.39	11.52	+7.87
3	17.53	12.19	+5.34
4	18.20	10.73	+7.47
5	10.85	11.35	-0.50
6	16.27	11.60	+4.67
7	16.08	11.10	+4.98
8	12.24	10.91	+1.33
9	15.56	10.86	+4.70
10	12.60	12.83	-0.23
11	3.52	10.93	-7.41
12	9.54	10.62	-1.08
13	13.30	7.53	+5.77
14	11.71	11.52	+0.19
15	13.43	12.60	+0.83
16	11.95	12.76	-0.81
17	13.98	13.40	+0.58
18	16.48	13.60	+2.88
Avg.	13.33	10.97	+2.36

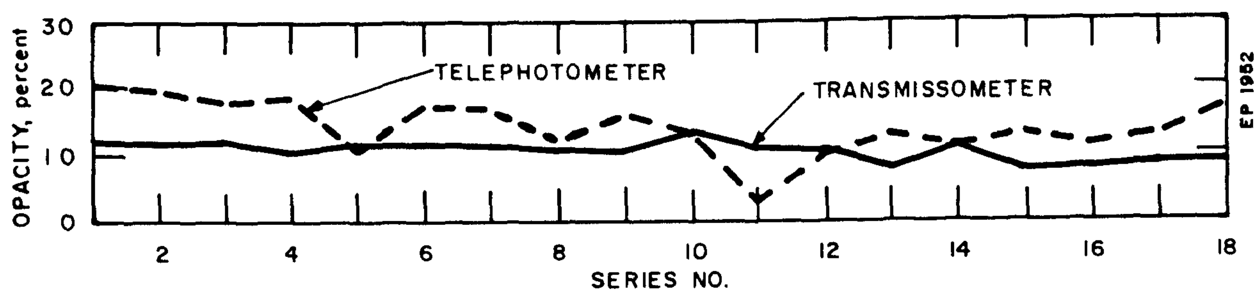


Figure 31. Series Averages, August 22, 1974
(11:34 AM to 2:42 PM)
(Portland Cement Plant)

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SECTION V

CONCLUSIONS AND RECOMMENDATIONS

One of the basic purposes of the field measurements program was to determine if in-stack transmissometer measurements of opacity would agree with plume opacity measurements at three different pollution sources. The three sources were a steel plant basic oxygen furnace, a cement plant, and a sulfuric acid plant. The program was generally successful in that good agreement between the measurements was achieved at the steel plant basic oxygen furnace over a wide range of emission levels. General agreement was obtained at the cement plant but the measurements were obtained for only a small range of emission levels and an undesirable high random error was associated with the plume opacity measurements. The sulfuric acid plant measurements indicated the plume opacity was 6 to 10% higher than in the in-stack opacity measurements. However, these measurements were obtained over little range in emission levels and an undesirable high random error was associated with the plume opacity measurements. These data indicate that the in-stack transmissometer can be used to monitor the opacity of plumes emitted from steel plant basic oxygen furnaces and from cement plants. Additional data, however, would be desirable for cement plants to cover a greater range of opacities. The data obtained for the sulfuric acid plant indicate that use of the in-stack transmissometer to monitor plume opacity is questionable.

The random error in the plume opacity measurement was primarily associated with the time dependent contrasting target method. For the method to produce precise results ambient lighting, background, and opacity of the plume must remain constant during the measurement sequence. These conditions were difficult to obtain throughout most of the study. A different, more reliable method for the plume opacity measurements is recommended before undertaking any further correlation studies. The use of a sun photometer, for example, eliminates the time dependency problem and may yield better results on clear days when the sun can be viewed through the plume. Also the direct measurement method using the lamp behind the plume was very successful but not always practical to implement.

Laboratory tests showed that the Lear-Siegler RM-4 transmissometer has the desired light collimation and spectral response characteristics for an opacity monitor. The full light projection and detector viewing angles were measured to be approximately 1.4 and 2.9 degrees respectively. The proposed EPA specification for these angles was 5 degrees or less. The spectral response of the instrument was determined to be essentially photopic after inserting the proper spectral shaping filter in front of the detector. Examination of the stability of the instrument in the laboratory over a two-week period of operation showed a slight positive drift of about 1% opacity after 18 hours of operation but thereafter no additional drift was noted. The stability of the instrument in the field at the three test sites was observed to be very good with the zero drift about the same as determined in the laboratory. The major difficulty encountered was not traceable to the instrument itself but to occasional low voltage conditions in the power lines causing the solenoids not to operate. In general, the instrument operated reliably in accordance with the manufacturer's specifications and within the limits of the specifications proposed by EPA.

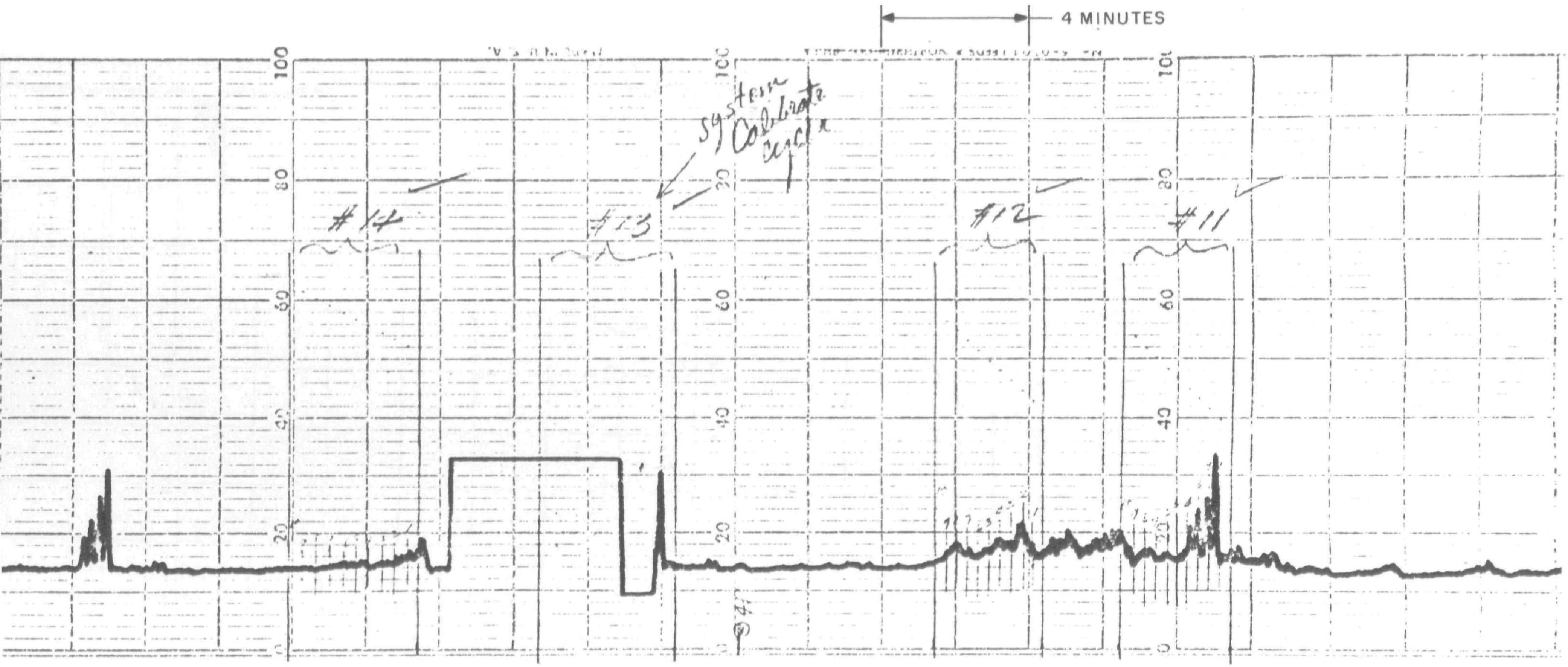
APPENDIX A

STEEL PLANT, BASIC OXYGEN FURNACE

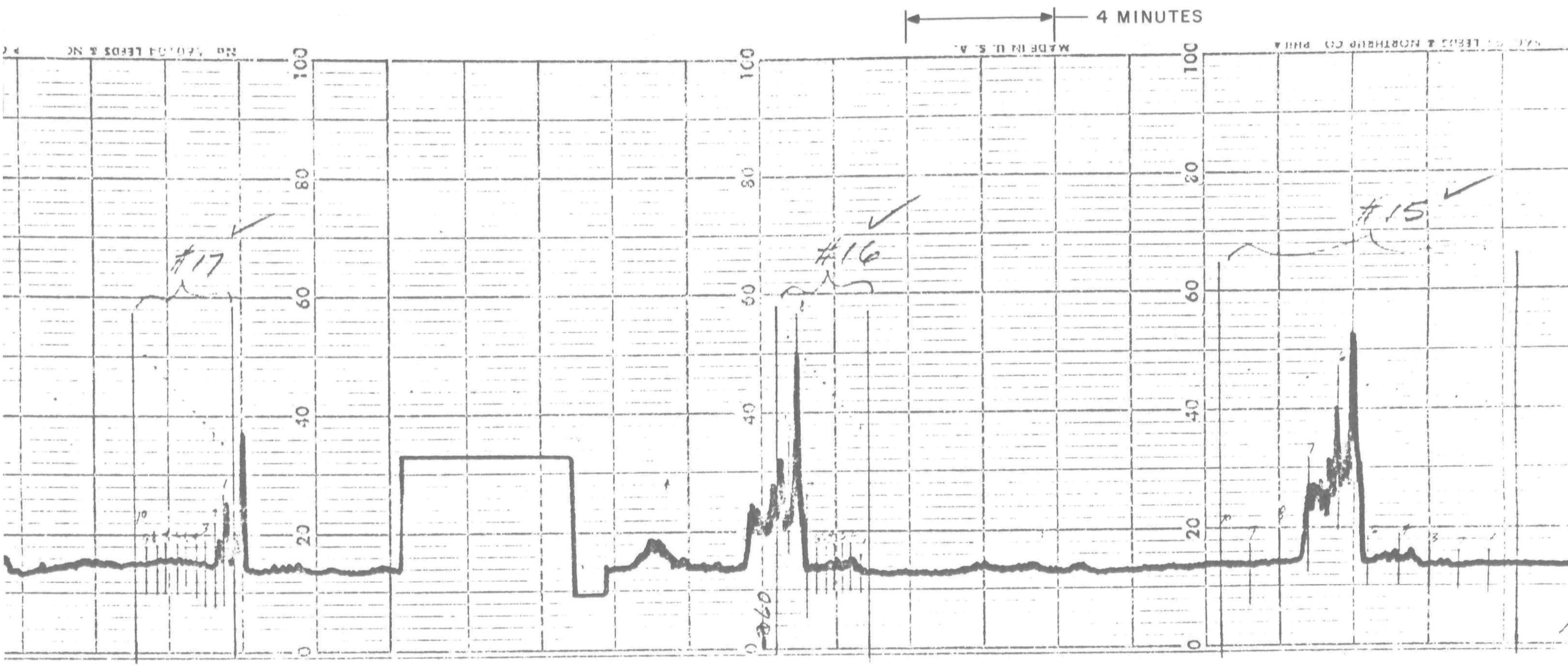
SERIES
OF
JUNE 22, 1973

BASIC OXYGEN FURNACE

6/22/73

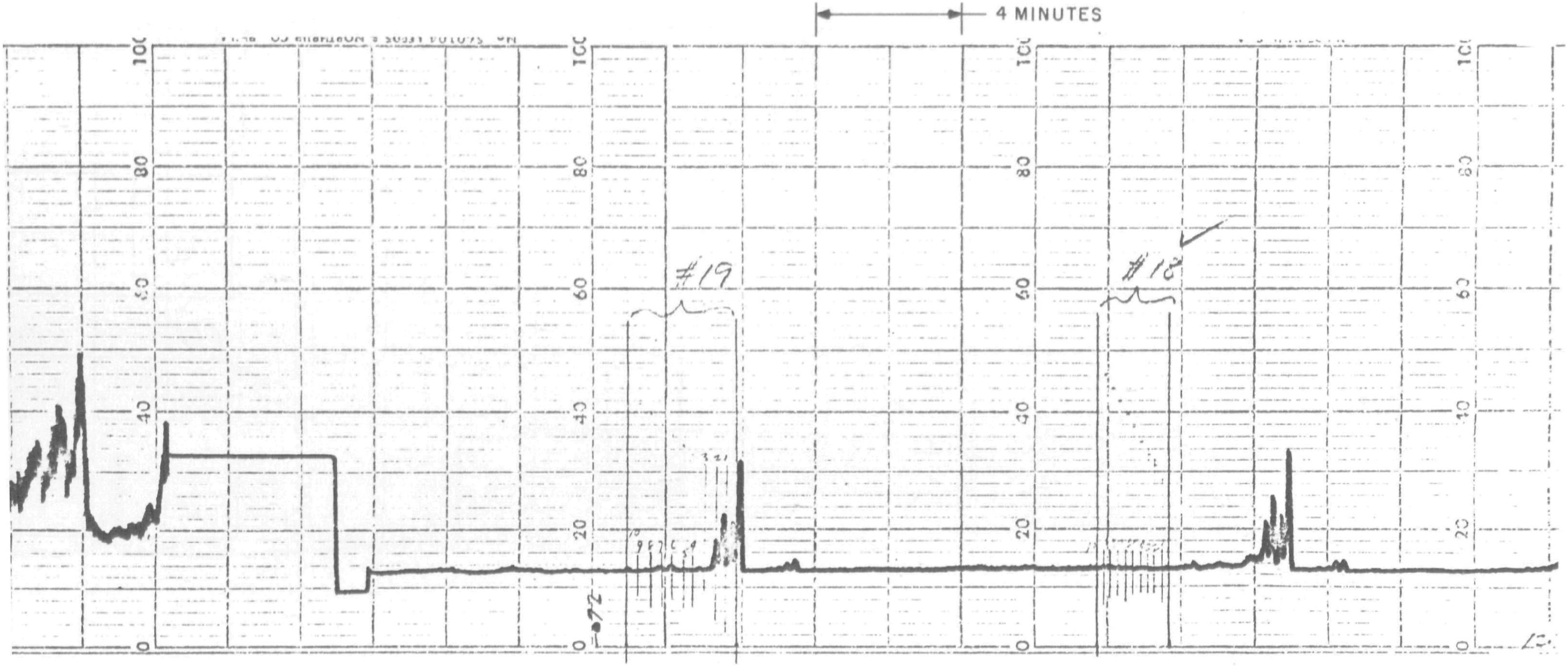


BASIC OXYGEN FURNACE
6/22/73



BASIC OXYGEN FURNACE

6/22/73

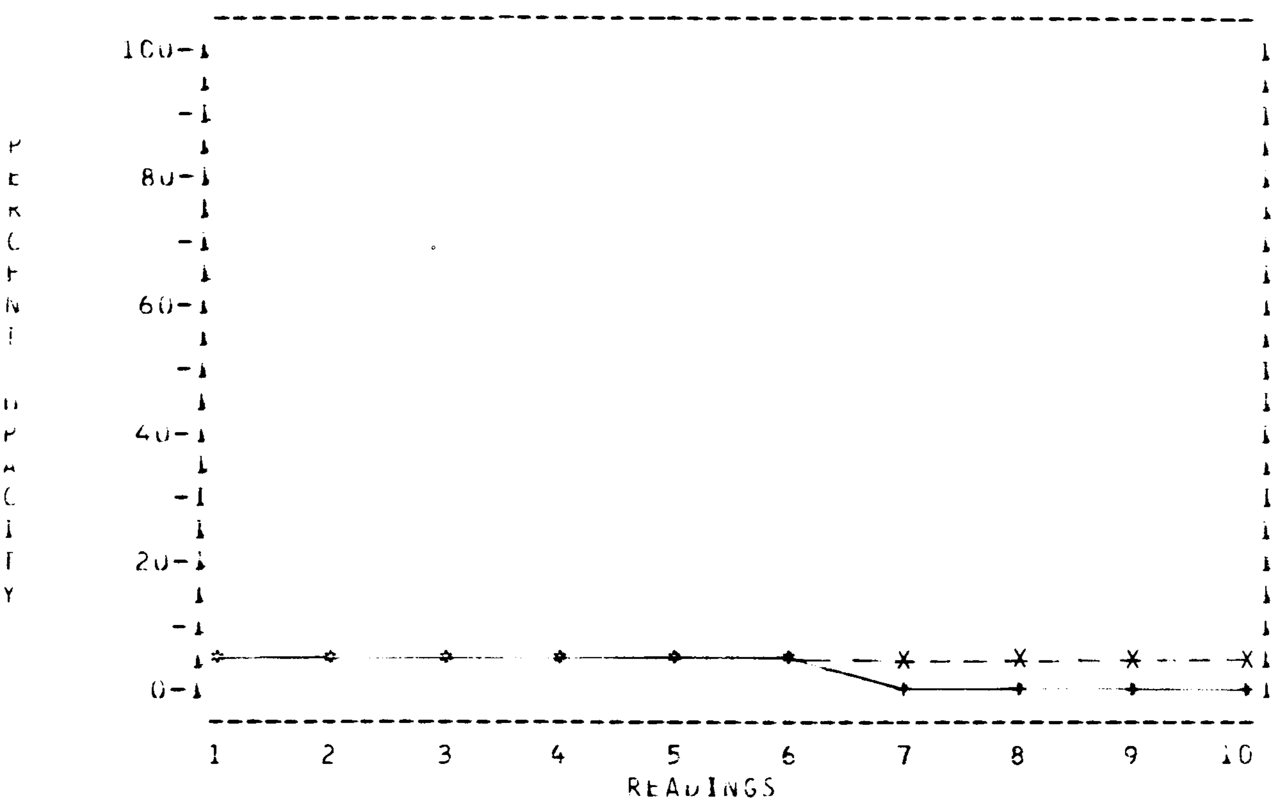


BASIC OXYGEN FURNACE

6/22/73

NO.1 DATE 6/22/73 TIME 10:18.50 - 10:22.50 AM BASIC OXYGEN FURNACE

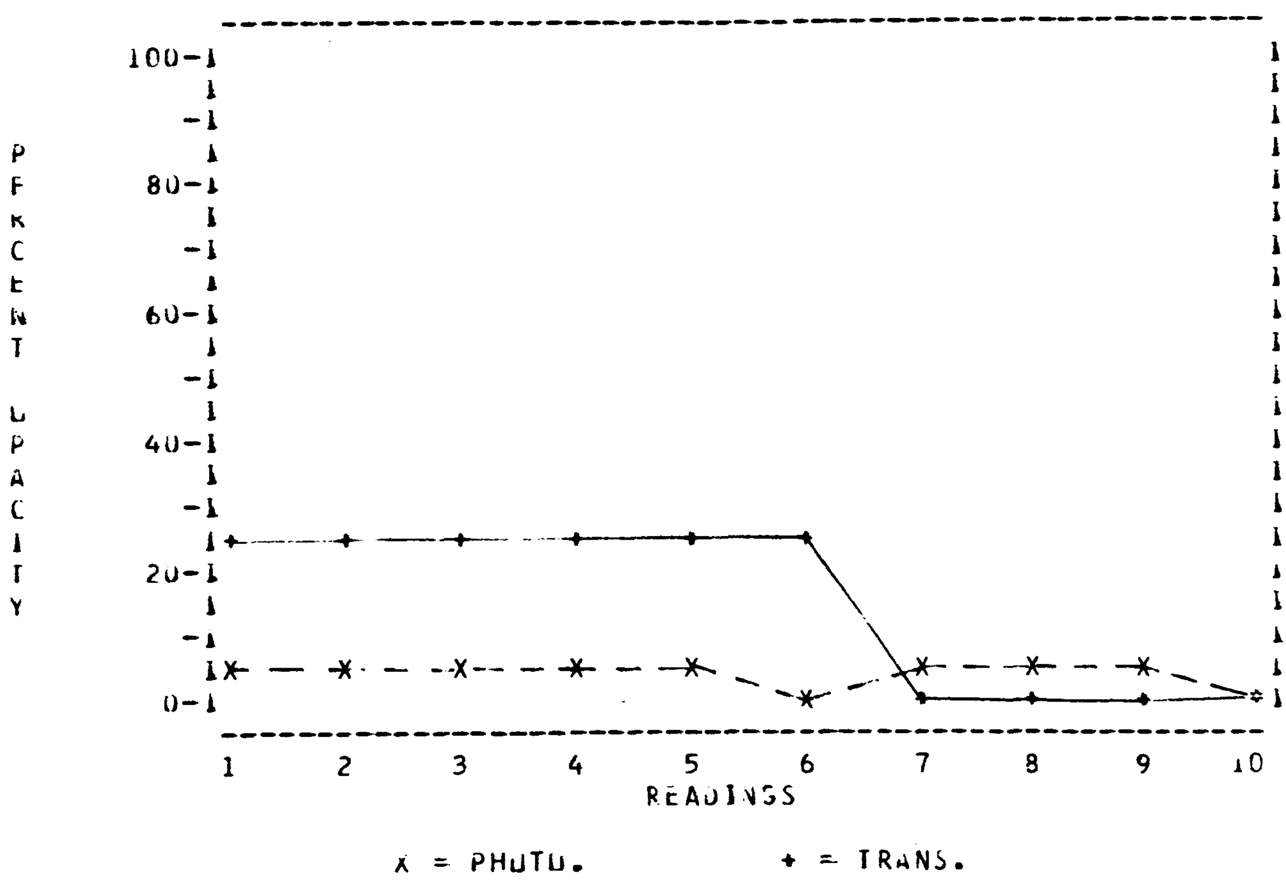
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
79.0	28.0	26.0	79.0	13.0	3.8	3.4
78.0	27.5	26.0	80.0	14.0	6.5	4.5
79.0	28.0	27.0	80.0	13.5	3.8	3.9
79.0	28.0	27.0	80.0	12.5	3.8	2.8
78.5	28.0	27.0	80.0	12.5	4.7	2.8
78.5	28.5	28.0	80.0	12.5	3.8	2.8
79.0	28.0	27.0	80.0	12.0	3.8	2.3
79.0	28.0	27.0	80.0	12.0	3.8	2.3
79.0	28.5	28.0	80.0	12.0	2.9	2.3
79.0	28.0	27.0	80.0	12.0	3.8	2.3



X = PHOTO. + = TRANS.

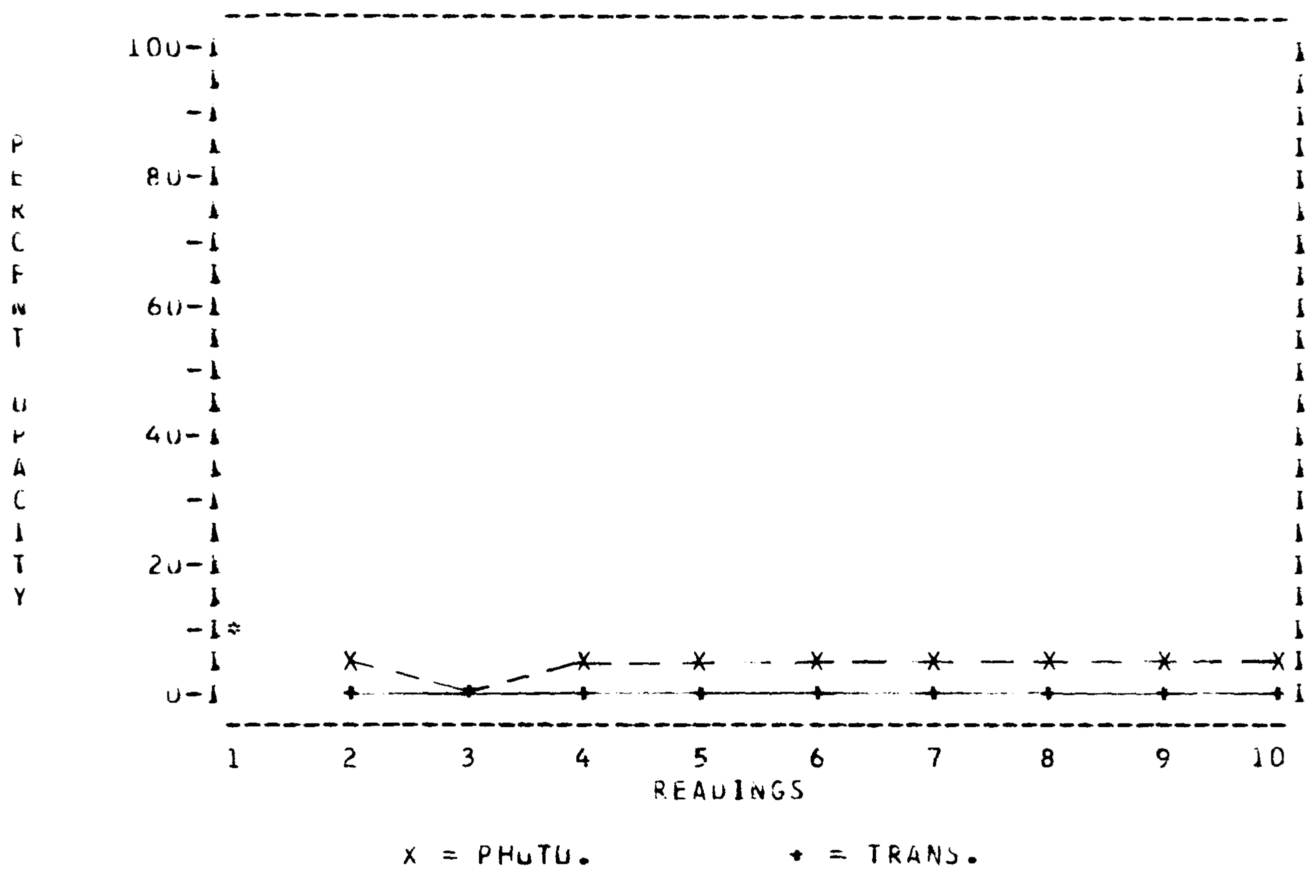
NO.2 DATE 6/22/73 TIME 10:26.00 - 10:29.50 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
78.5	25.5	24.5	79.5	33.0	3.6	23.3
78.5	26.0	24.5	79.5	33.0	4.5	23.3
78.5	25.5	25.0	79.5	33.0	2.8	23.3
78.0	26.0	24.5	79.0	33.0	4.6	23.3
78.0	26.0	25.0	78.5	33.0	2.8	23.3
77.5	27.0	27.0	78.5	33.0	1.9	23.3
77.0	26.3	26.0	78.0	12.0	2.5	2.3
76.5	26.5	25.0	77.5	12.0	4.8	2.3
76.5	26.0	25.5	77.5	12.0	2.9	2.3
76.5	25.5	25.0	77.0	12.0	1.9	2.3



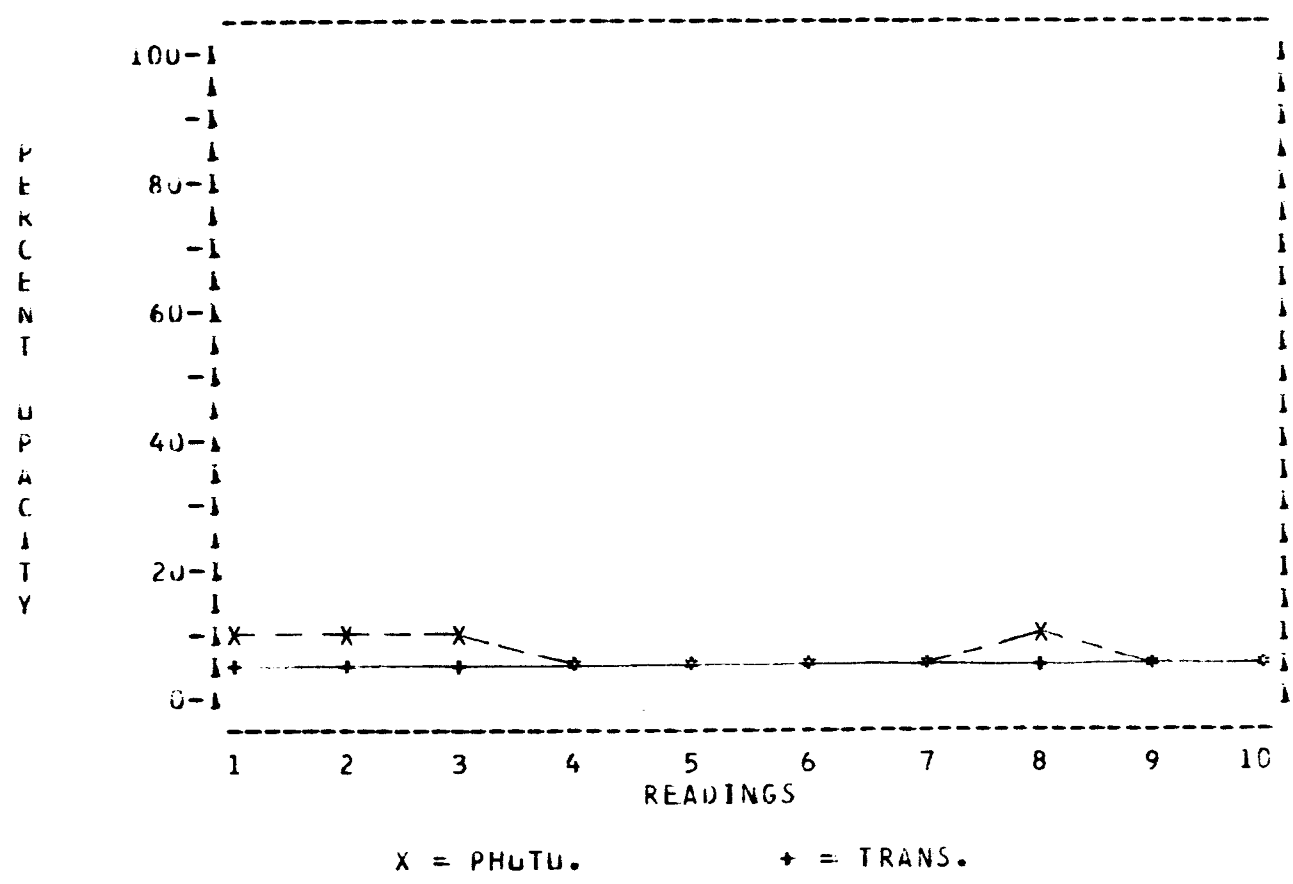
NO.3 DATE 6/22/73 TIME 10:32.50 - 10:37.25 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
71.0	27.5	26.5	74.0	20.0	8.4	10.9
72.5	26.0	25.0	74.0	12.0	5.1	2.3
73.0	25.5	25.0	73.5	12.0	2.1	2.3
72.5	25.0	24.0	73.0	12.0	3.1	2.3
72.0	25.0	24.0	73.0	12.0	4.1	2.3
72.0	24.0	23.0	73.0	12.0	4.0	2.3
71.5	25.0	23.5	72.5	12.0	5.1	2.3
71.5	24.5	23.0	72.5	12.0	5.1	2.3
72.0	24.0	23.0	72.5	12.0	3.0	2.3
71.5	23.5	22.5	72.0	12.0	3.0	2.3



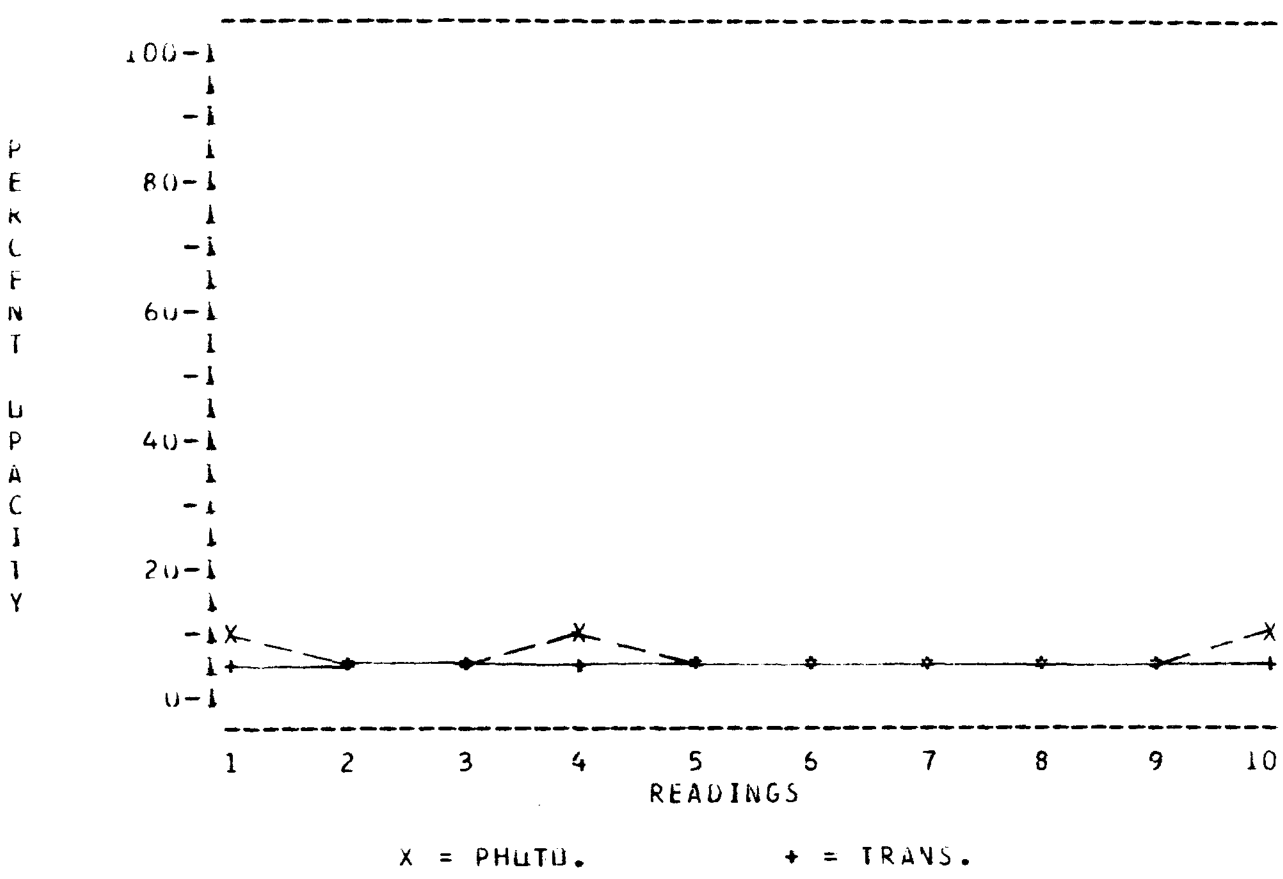
NO.4 DATE 6/22/73 TIME 10:49.75 - 10:51.75 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
78.0	29.0	26.5	80.5	14.5	9.3	5.0
77.0	31.5	28.0	79.0	15.0	10.8	5.6
77.0	32.0	30.5	79.5	15.0	8.2	5.6
76.5	28.0	26.5	77.5	14.5	4.9	5.0
77.0	26.5	25.0	78.5	14.5	5.6	5.0
75.5	26.5	25.5	77.5	14.5	5.8	5.0
76.0	26.0	25.5	78.5	14.5	5.7	5.0
77.0	26.0	24.5	80.0	15.0	8.1	5.6
78.0	26.0	24.5	79.5	14.5	5.5	5.0
78.5	25.0	24.0	80.0	14.5	4.5	5.0



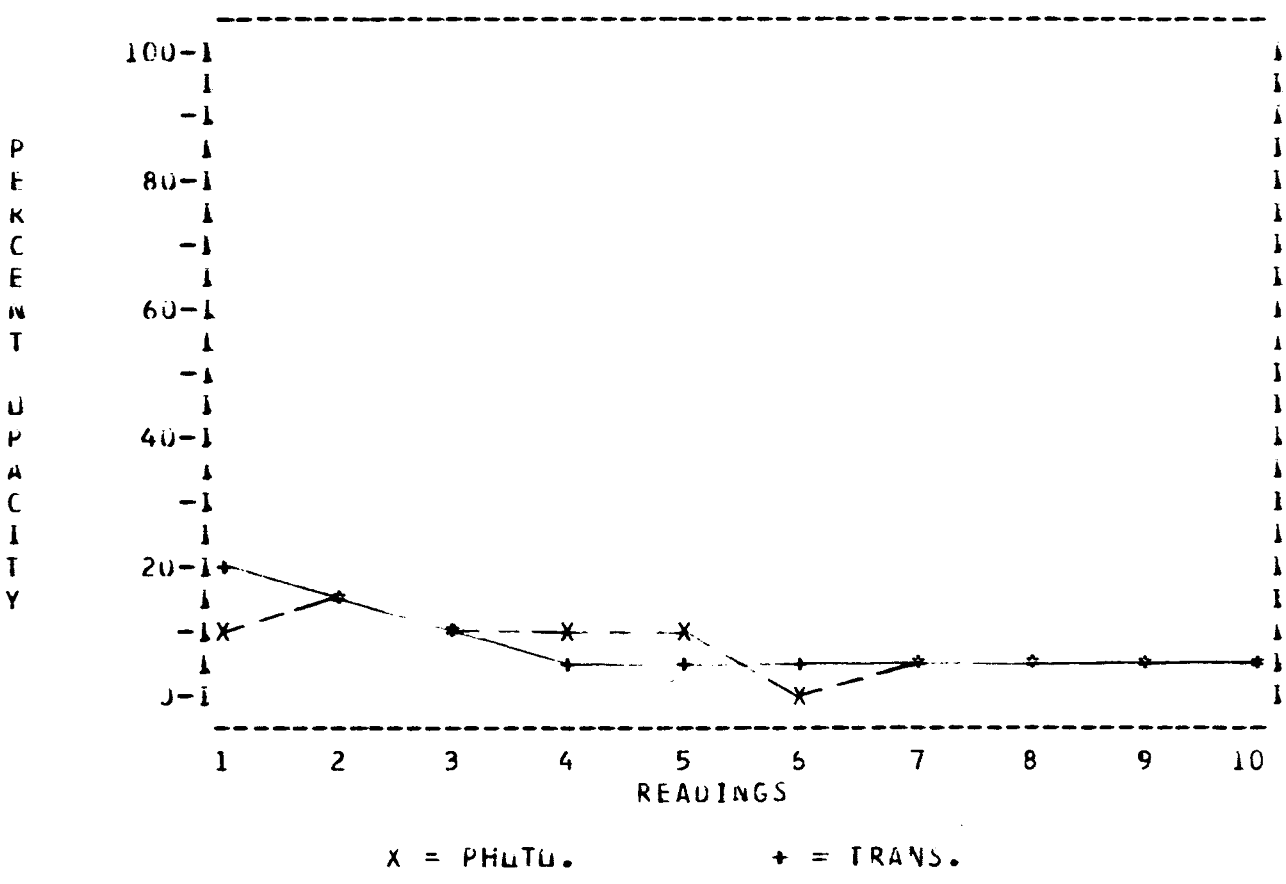
NO.5 DATE 6/22/73 TIME 10:55.00 - 10:59.50 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
78.0	30.0	28.0	80.0	13.5	7.7	3.9
80.0	29.0	28.0	83.0	13.5	7.3	3.9
82.0	28.0	27.0	84.0	13.5	5.3	3.9
82.0	30.0	27.0	84.0	13.0	8.8	3.4
82.5	31.0	29.0	84.0	13.5	6.4	3.9
83.0	30.0	28.0	84.0	13.0	5.4	3.4
81.0	33.0	31.0	82.0	13.5	5.9	3.9
81.0	32.0	30.0	82.5	13.5	6.7	3.9
82.5	29.0	29.0	84.0	13.5	2.7	3.9
83.0	30.0	27.0	84.5	13.0	7.8	3.4



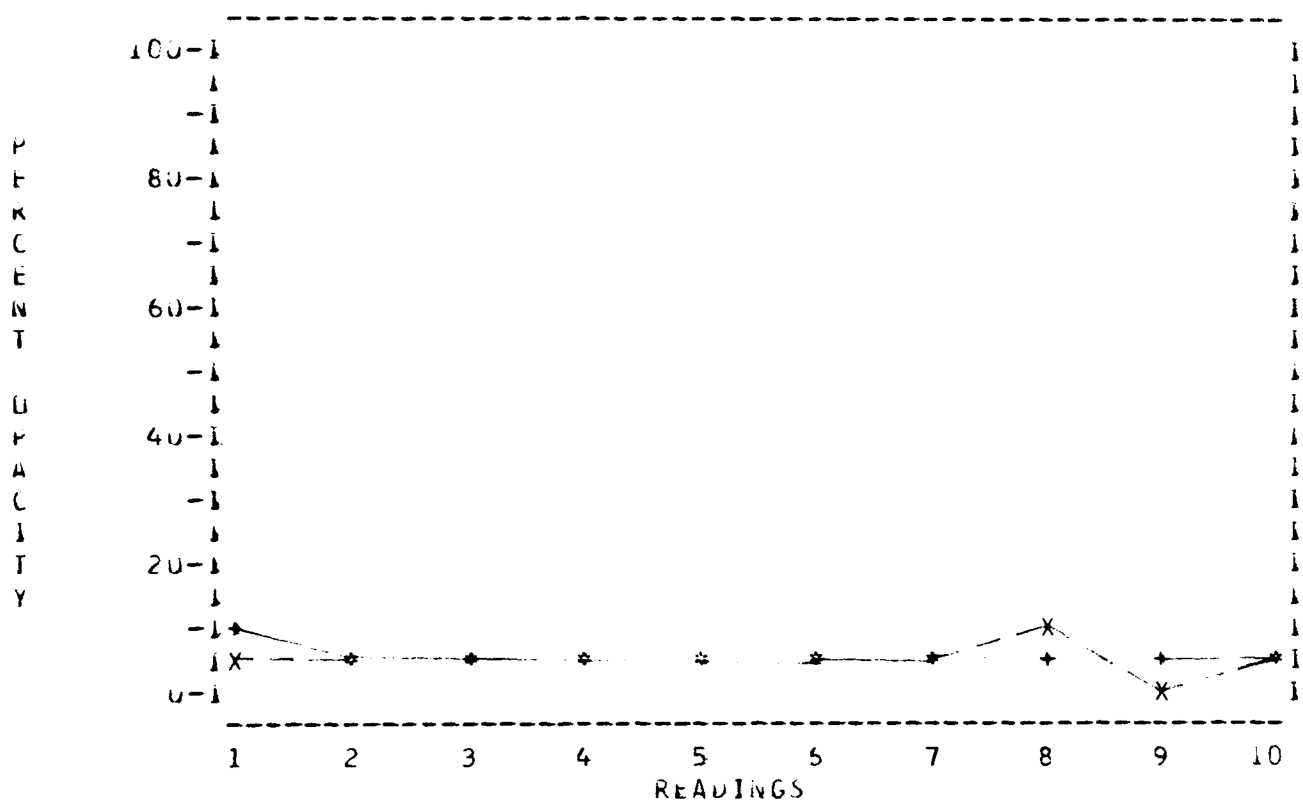
NO.6 DATE 6/22/73 TIME 11:02.00 - 11:05.25 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
87.0	40.0	38.0	89.0	30.0	7.8	20.6
80.0	34.0	31.0	85.0	24.0	14.8	14.9
79.5	29.0	28.0	84.0	21.0	9.8	11.9
83.0	32.0	27.0	85.0	13.5	12.1	3.9
84.0	36.0	34.0	86.0	13.5	7.7	3.9
83.5	32.0	33.5	84.5	13.5	-1.0	3.9
83.0	34.0	32.0	84.0	13.5	5.8	3.9
83.0	36.0	34.0	83.5	13.5	5.1	3.9
82.0	35.0	34.0	83.0	13.5	4.1	3.9
81.0	38.0	37.0	82.0	13.5	4.4	3.9



NO.7 DATE 6/22/73 TIME 11:08.00 - 11:11.25 AM BASIC OXYGEN FURNACE

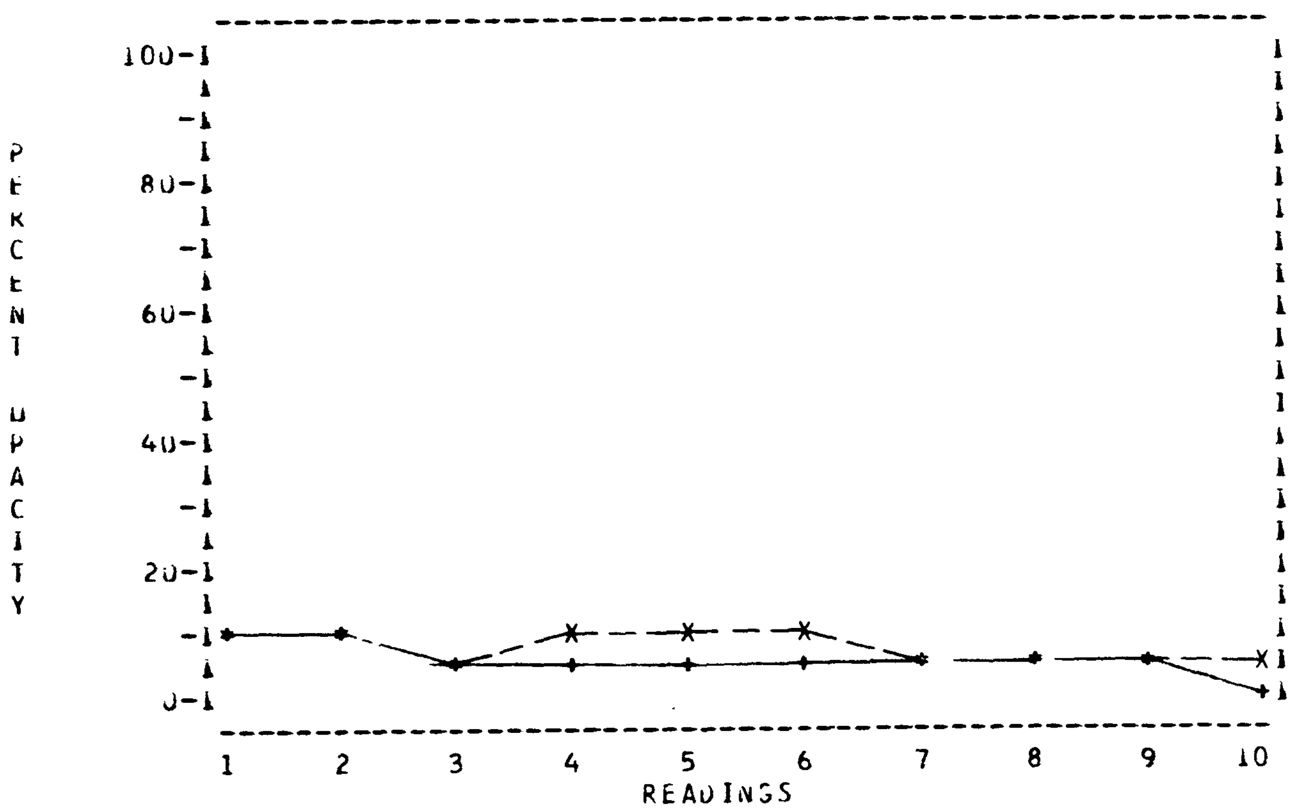
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
70.0	31.0	30.0	71.0	19.0	4.9	9.8
69.5	31.5	30.5	70.0	14.0	3.8	4.5
67.5	29.0	28.0	68.5	13.5	4.9	3.9
65.5	27.5	27.0	67.0	13.5	5.0	3.9
64.5	26.5	25.0	66.0	15.0	7.3	5.6
64.0	25.0	24.0	65.0	15.0	4.9	5.6
63.0	25.5	24.5	64.5	14.0	6.3	4.5
63.0	26.0	25.0	65.0	14.0	7.5	4.5
66.0	25.0	24.0	66.0	14.0	2.4	4.5
65.5	24.5	24.0	67.0	13.5	4.7	3.9



X = PHOTO. + = TRANS.

NO.9 DATE 6/22/73 TIME 11:17.25 - 11:20.50 AM BASIC OXYGEN FURNACE

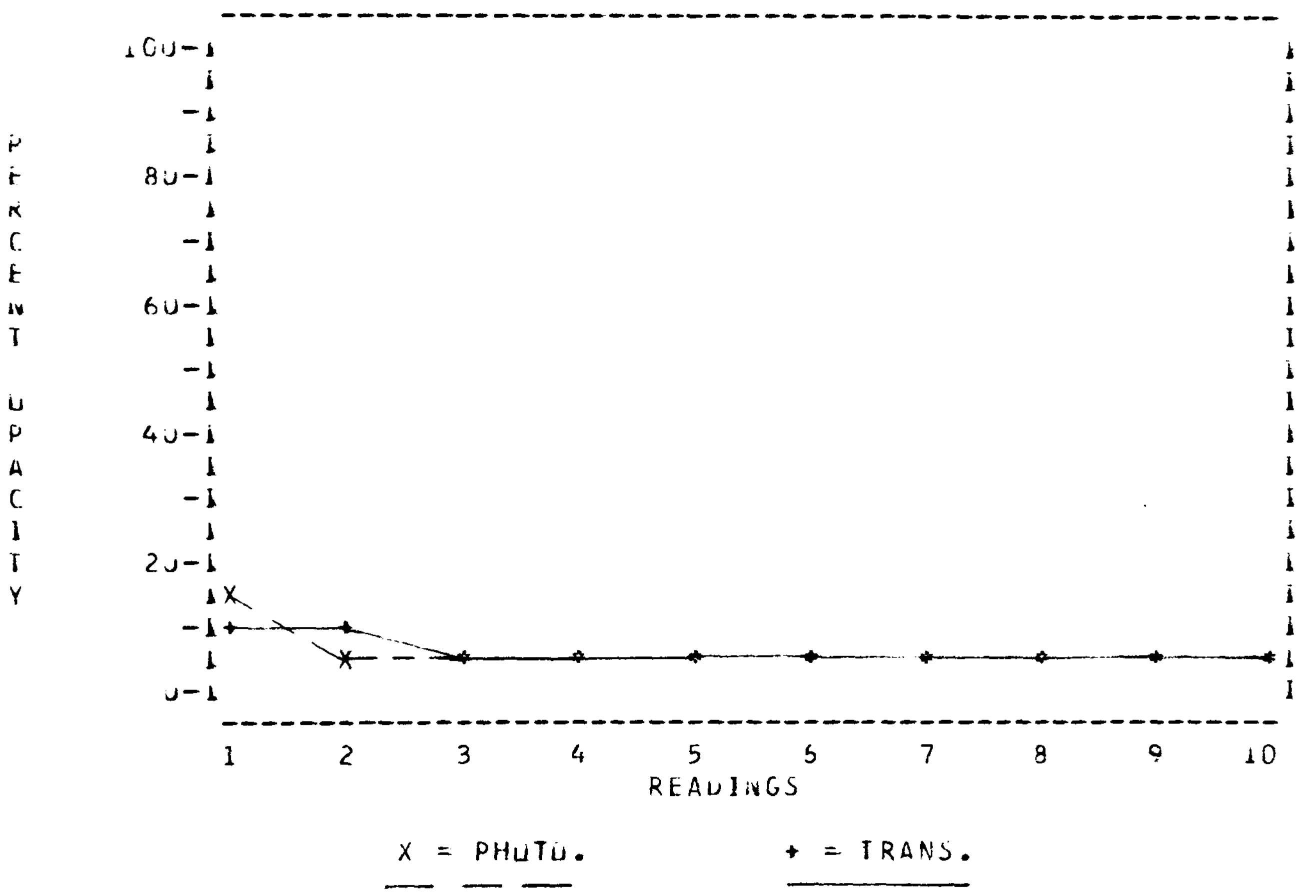
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
89.0	44.0	41.0	92.0	17.0	11.8	7.7
89.0	42.0	40.0	91.0	17.0	7.8	7.7
85.0	38.0	37.0	87.0	16.5	6.0	7.2
79.0	28.0	24.5	82.0	16.0	11.3	6.7
80.5	28.0	26.0	84.0	16.0	9.5	6.7
80.0	28.0	27.0	84.0	15.5	8.8	6.1
80.0	27.0	26.0	83.0	16.0	7.0	6.7
81.5	24.0	22.0	84.0	14.0	7.3	4.5
83.0	26.0	24.5	85.0	12.5	5.8	2.8
83.0	26.0	25.0	85.0	12.0	5.0	2.3



X = PHOTO. — — — + = TRANS. ———

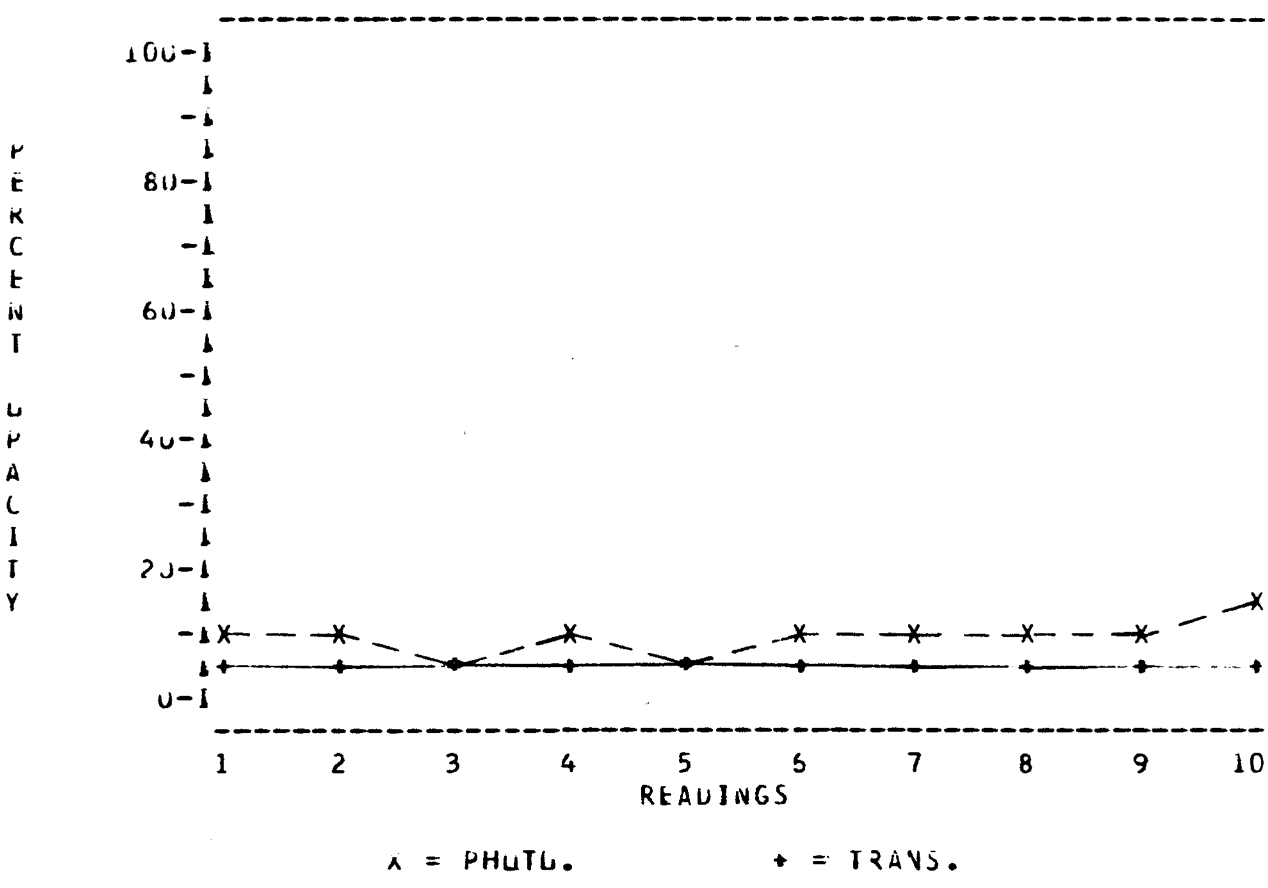
NO.10 DATE 6/22/73 TIME 11:32.50 - 11:35.00 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
86.0	27.0	22.0	90.0	20.0	13.2	10.9
90.0	25.0	23.0	90.0	19.0	3.0	9.8
88.0	24.5	22.0	90.0	13.0	6.6	3.4
86.5	24.0	22.0	88.0	13.0	5.3	3.4
86.5	24.0	22.0	88.0	13.0	5.3	3.4
89.0	32.5	30.0	90.0	13.0	5.8	3.4
88.5	32.0	30.0	89.5	13.0	5.0	3.4
90.5	33.0	30.5	92.0	13.5	6.5	3.9
91.0	32.0	31.0	93.0	13.0	4.8	3.4
91.0	27.0	25.0	94.0	13.0	7.2	3.4



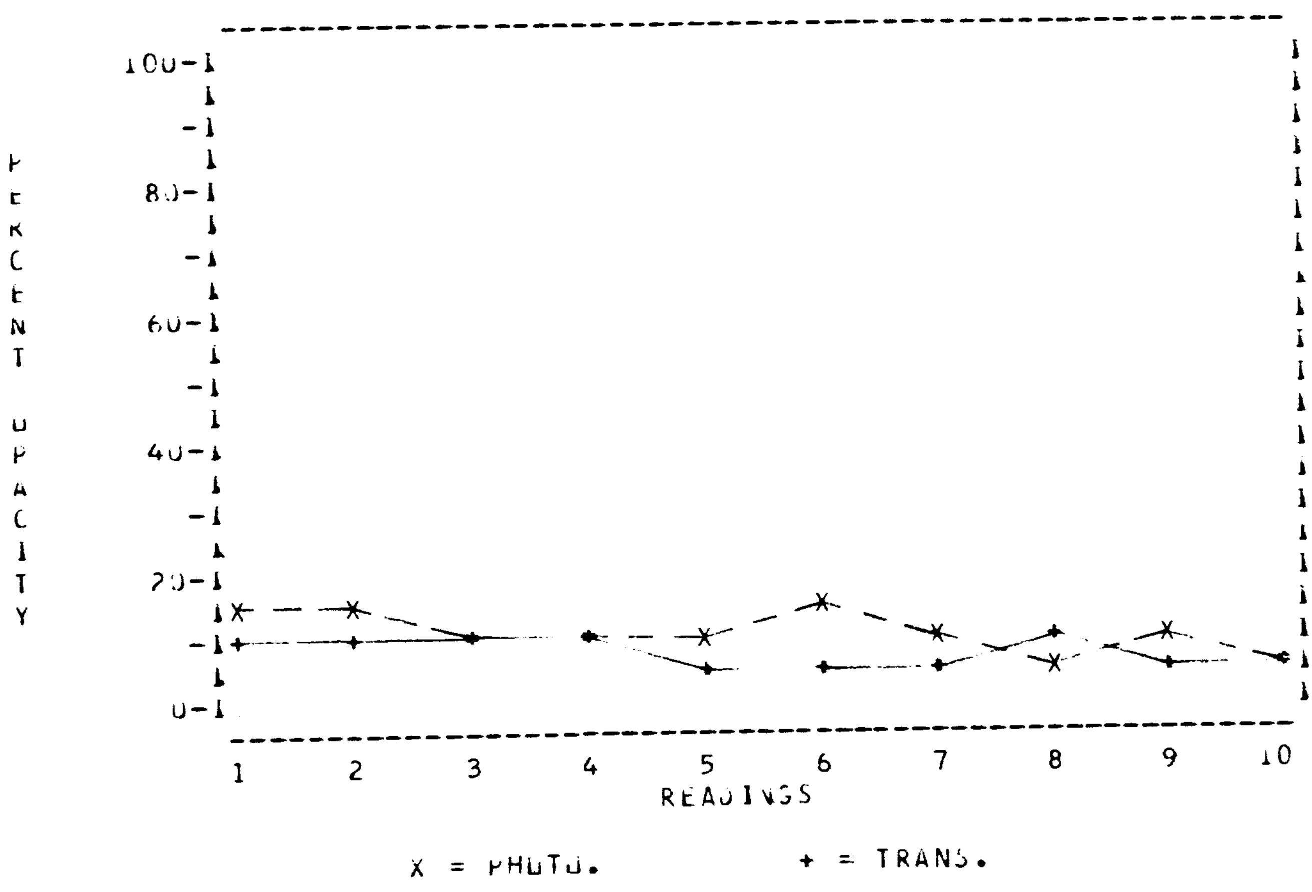
NO.11 DATE 6/22/73 TIME 11:47.00 - 11:50.00 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
76.0	30.0	30.0	82.0	16.0	11.5	6.7
78.0	28.0	26.0	82.0	15.0	10.7	5.6
78.0	24.0	25.0	82.0	14.5	5.3	5.0
78.5	22.5	20.0	82.5	14.0	10.4	4.5
78.0	21.5	21.0	81.5	14.5	6.6	5.0
79.0	24.0	21.5	82.0	14.5	9.1	5.0
80.0	25.5	22.5	83.0	14.0	9.9	4.5
79.0	27.0	25.0	83.5	14.0	11.1	4.5
80.5	26.5	25.0	85.5	14.0	10.7	4.5
80.0	26.0	23.0	85.0	14.0	12.9	4.5



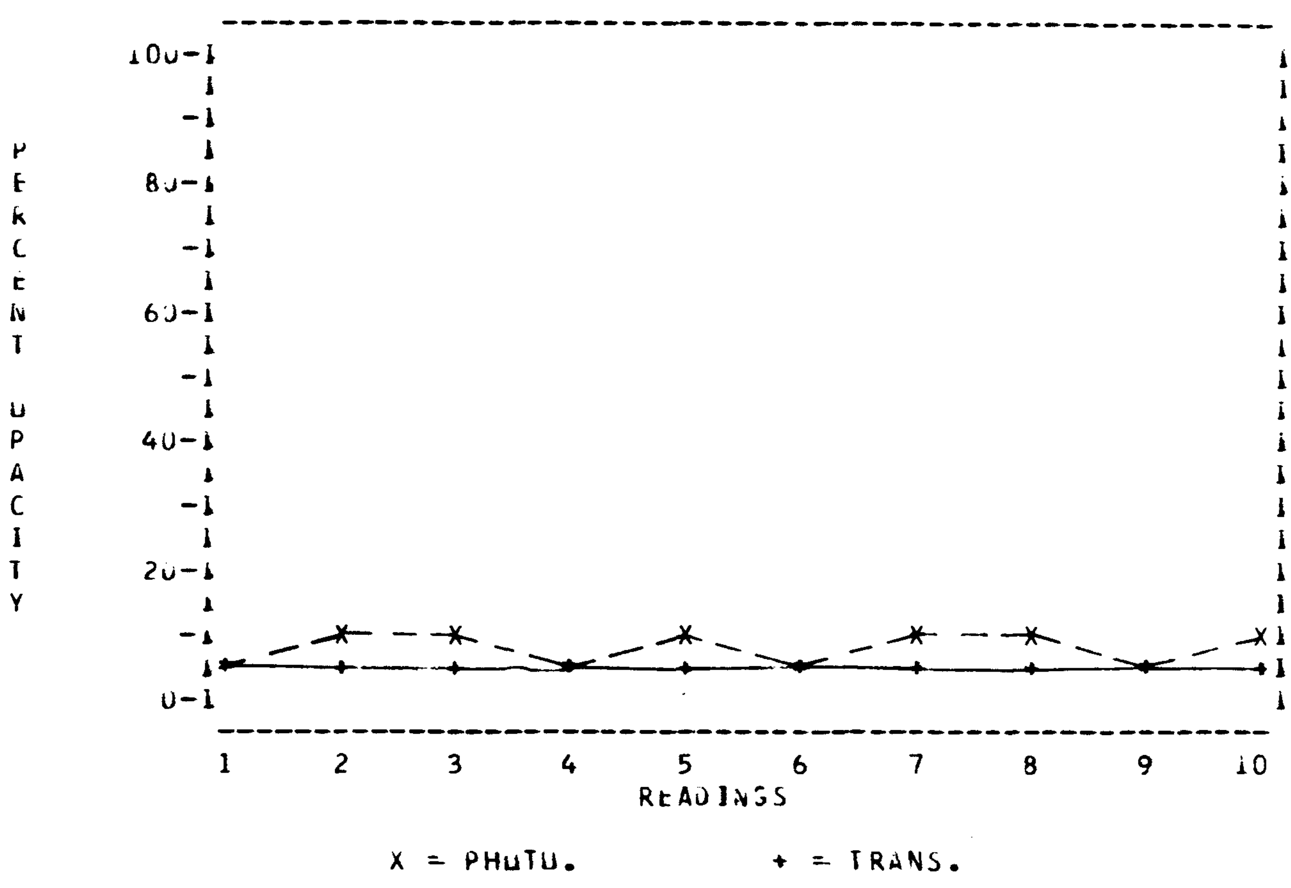
NO.12 DATE 6/22/73 TIME 11:52.00 - 11:55.00 AM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
77.0	31.0	28.0	81.0	17.0	13.2	7.7
77.0	32.0	29.5	81.0	21.0	12.6	11.9
76.0	31.5	28.5	78.0	18.0	10.1	8.8
74.5	31.5	29.0	76.0	18.0	8.5	8.8
73.0	27.0	24.0	75.0	16.5	9.8	7.2
70.5	29.0	25.0	73.0	16.0	13.5	6.7
70.0	27.0	25.0	72.0	16.5	8.5	7.2
70.0	23.0	22.0	72.0	18.0	6.0	8.8
72.0	22.0	20.0	74.5	16.0	8.3	6.7
76.0	22.0	20.5	77.0	15.0	4.4	5.6



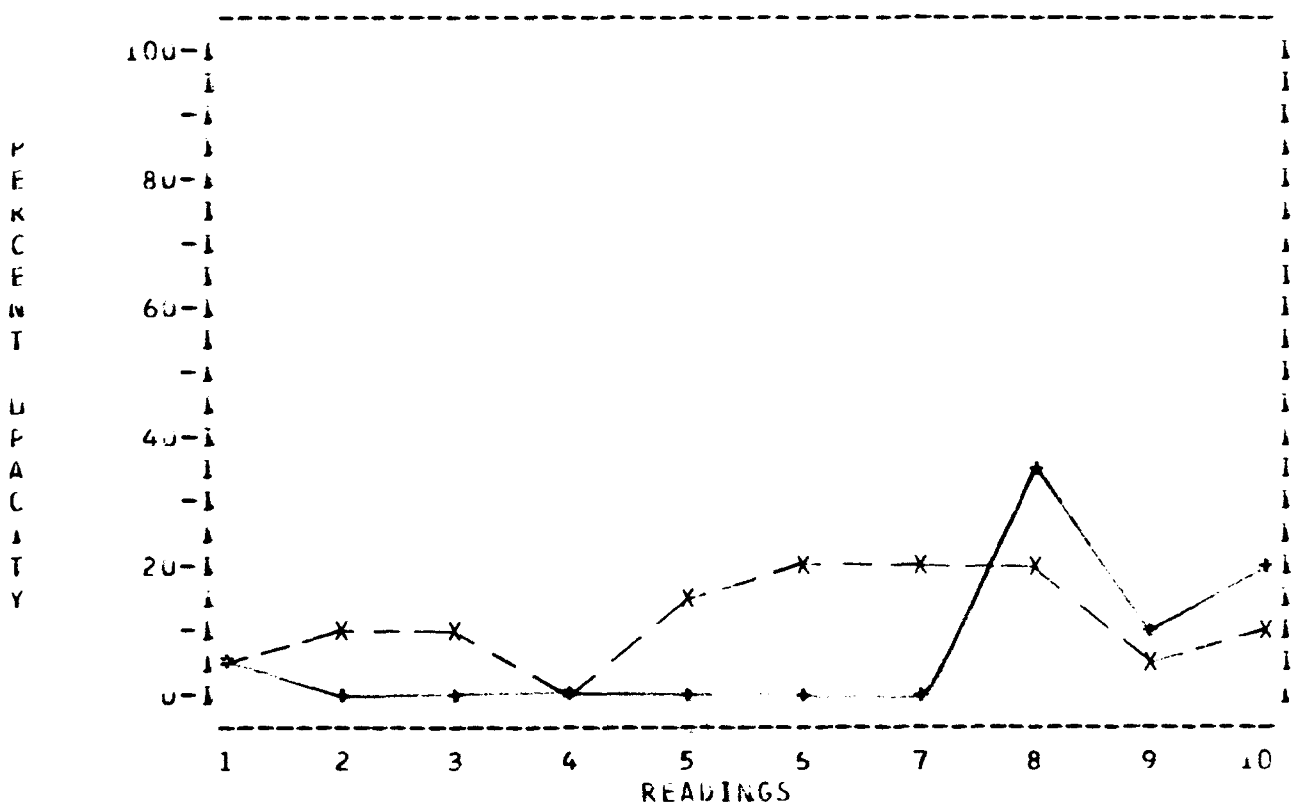
NO.14 DATE 6/22/73 TIME 12:09.00 - 12:12.33 PM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
69.5	20.5	18.0	70.0	16.0	5.8	6.7
70.5	20.0	18.0	74.0	15.0	9.8	5.6
72.0	19.5	17.0	75.0	14.5	9.5	5.0
75.0	21.0	19.5	77.5	14.0	6.9	4.5
76.0	23.0	20.0	79.0	14.5	10.2	5.0
77.5	22.0	20.5	80.0	14.5	6.7	5.0
79.0	24.0	21.5	81.0	14.0	7.6	4.5
79.0	24.0	21.0	81.0	14.0	8.3	4.5
79.0	22.0	20.0	80.5	14.0	5.8	4.5
77.5	20.0	18.0	82.0	14.0	10.2	4.5



NO.16 DATE 6/22/73 TIME 12:45.50 - 1:48.00 PM BASIC OXYGEN FURNACE

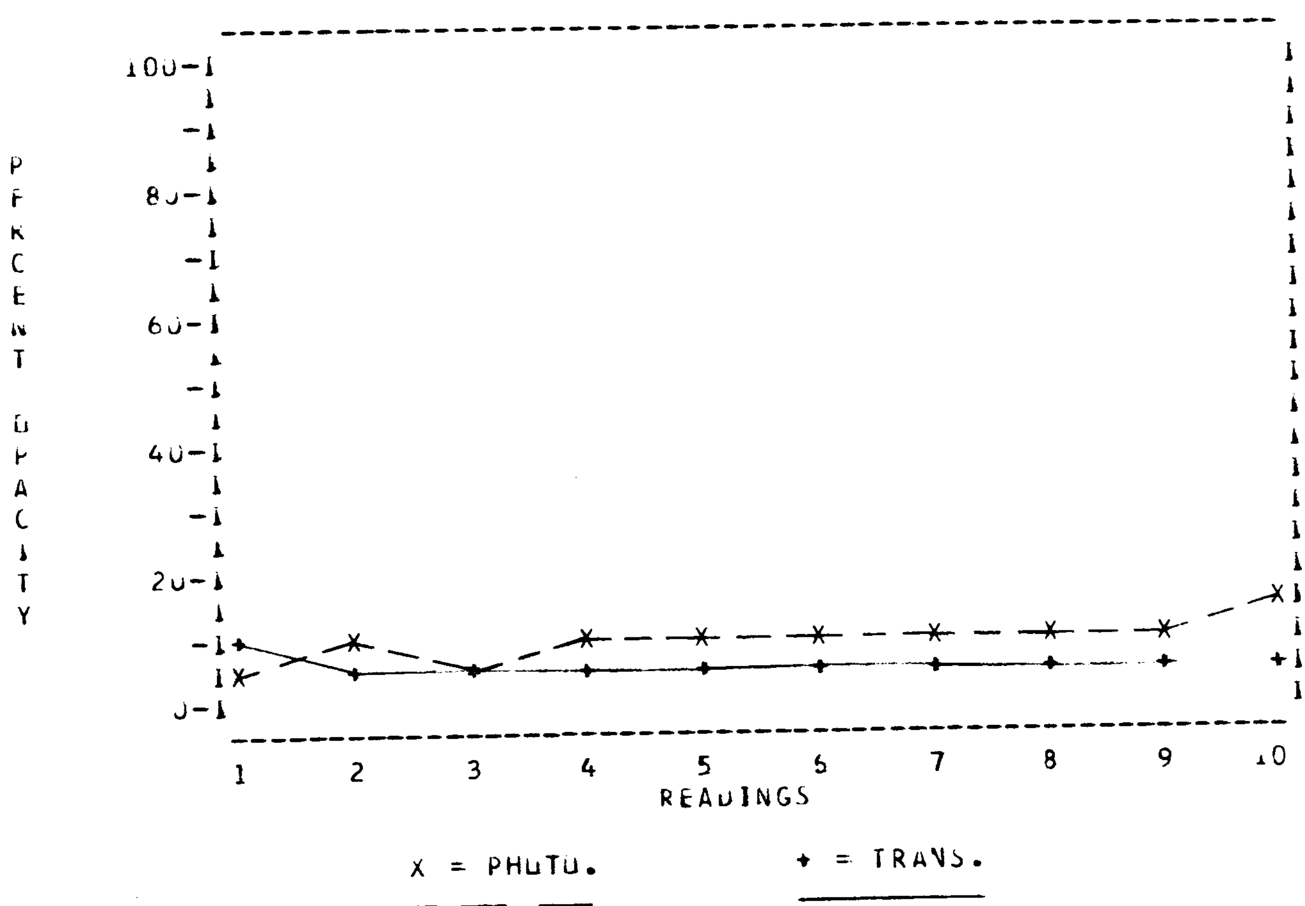
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
85.5	29.0	26.0	86.5	13.0	6.6	3.4
89.0	30.0	27.0	91.0	12.0	7.8	2.3
64.0	30.5	28.0	89.0	12.0	12.3	2.3
60.0	26.0	27.0	80.0	12.0	-1.9	2.3
61.0	32.0	28.0	66.0	12.0	15.5	2.3
78.0	32.0	28.0	84.0	12.0	17.9	2.3
79.5	30.5	24.0	85.5	12.0	20.3	2.3
78.0	30.0	24.0	65.0	50.0	21.3	36.9
84.0	24.0	22.5	65.0	21.0	4.0	11.9
84.5	24.0	21.0	67.0	32.0	8.3	22.4



X = PHOTO. + = TRANS.

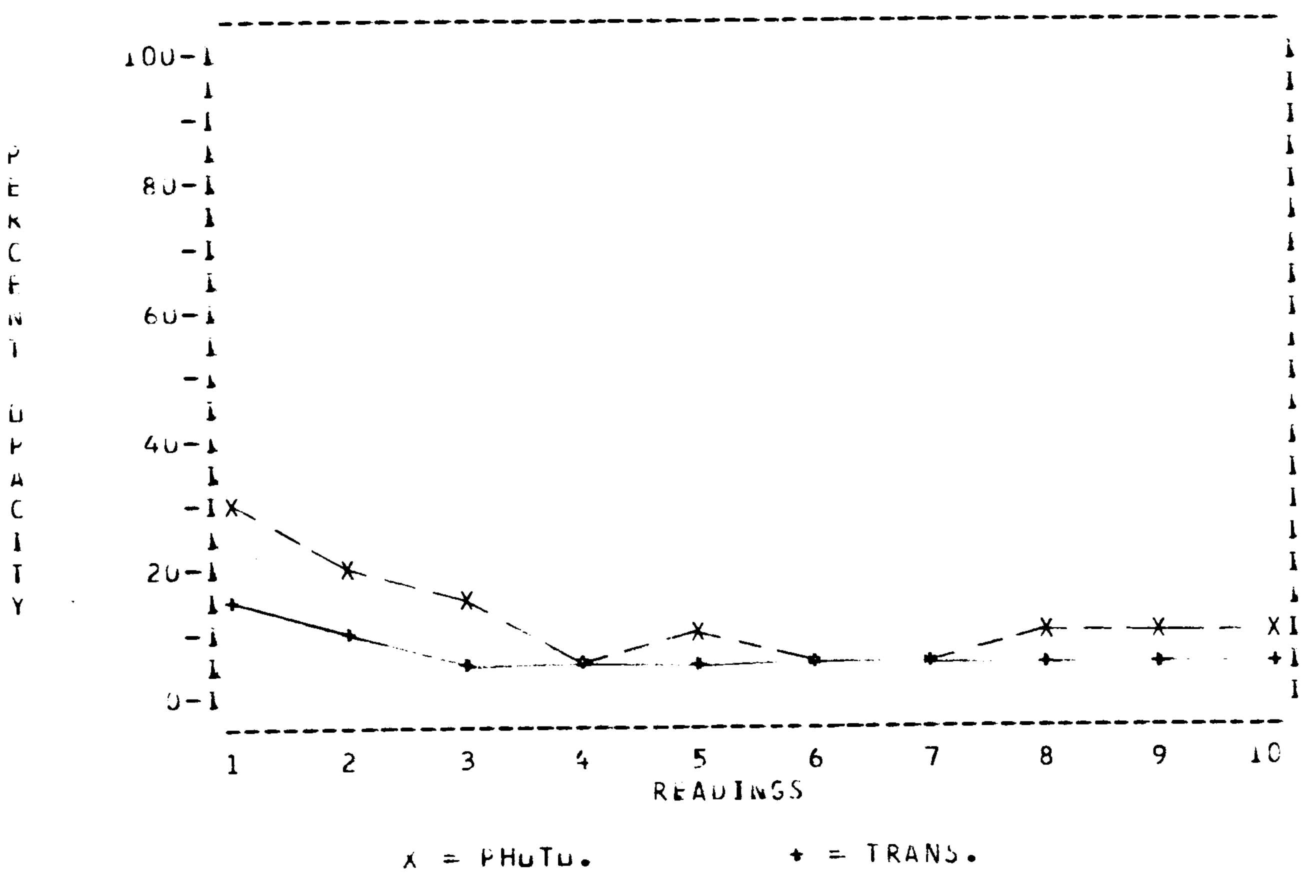
NO.17 DATE 6/22/73 TIME 1:02.75 - 1:05.75 PM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
83.0	18.0	22.0	89.0	17.0	3.0	7.7
82.0	19.0	17.0	88.0	15.0	11.3	5.6
82.0	18.0	20.0	88.0	15.0	5.9	5.6
86.0	17.0	15.0	90.0	15.5	8.0	6.1
85.5	16.5	14.0	92.0	15.5	11.5	6.1
86.5	16.0	14.0	92.5	16.0	10.2	6.7
88.0	18.0	15.5	93.5	16.0	10.3	6.7
88.5	19.0	16.0	94.0	16.0	10.9	6.7
90.5	19.0	16.0	95.0	15.0	9.5	5.6
83.0	21.0	18.5	90.0	15.0	13.3	5.6



NO.19 DATE 6/22/73 TIME 1:32.33 - 1:35.25 PM BASIC OXYGEN FURNACE

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
80.0	14.5	12.0	79.0	22.5	32.1	13.4
71.0	17.5	12.5	81.0	18.0	21.9	8.8
75.0	19.5	17.0	83.5	13.0	16.5	3.4
80.5	14.5	14.0	84.0	13.0	5.7	3.4
80.0	13.5	12.0	84.0	13.0	7.6	3.4
79.5	16.0	14.0	82.5	13.5	7.3	3.9
81.0	18.0	17.0	84.5	13.5	6.7	3.9
79.5	23.0	21.0	84.0	13.0	10.3	3.4
80.5	25.0	24.0	84.0	13.0	7.5	3.4
81.0	24.0	22.0	84.5	13.0	8.8	3.4



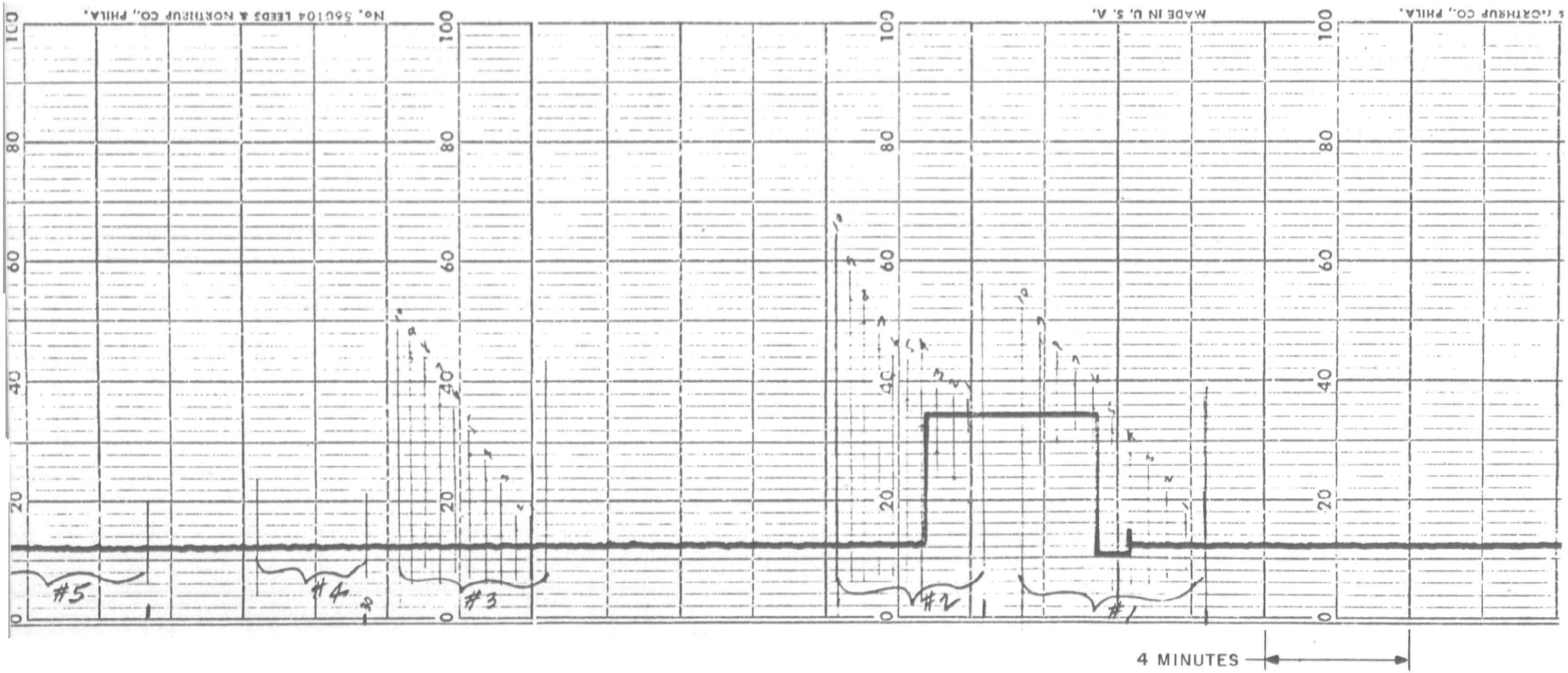
APPENDIX B

SULFURIC ACID PLANT

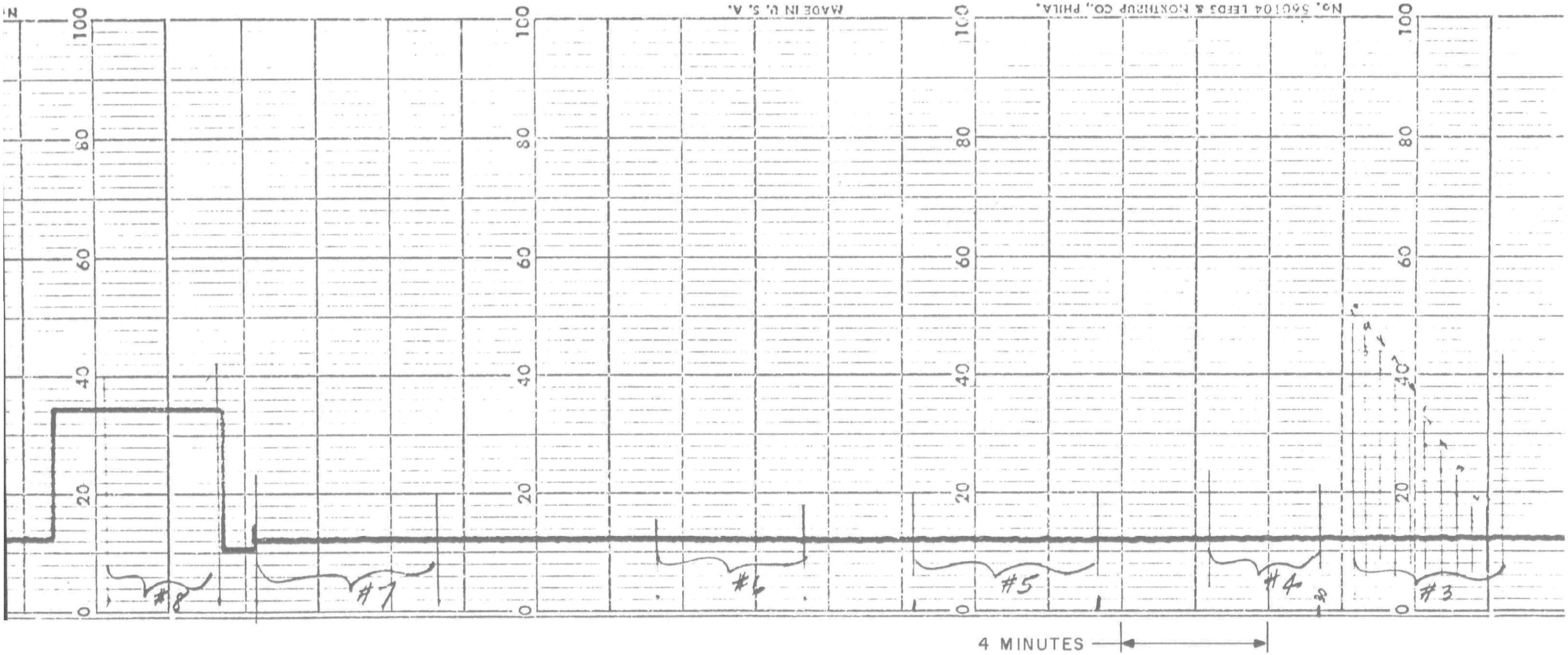
SERIES

OF

MAY 7, 1974

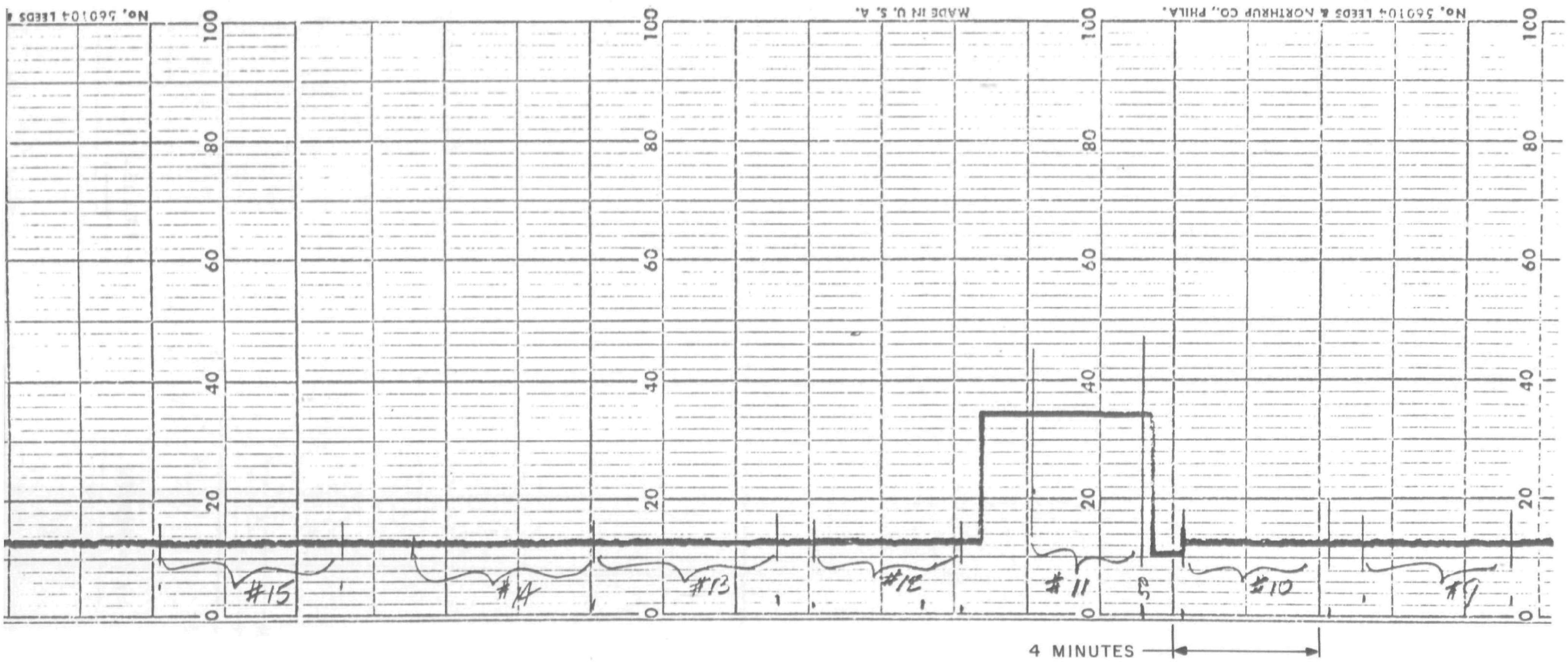


SULFURIC ACID PLANT
5/7/74



SULFURIC ACID PLANT

5/7/74

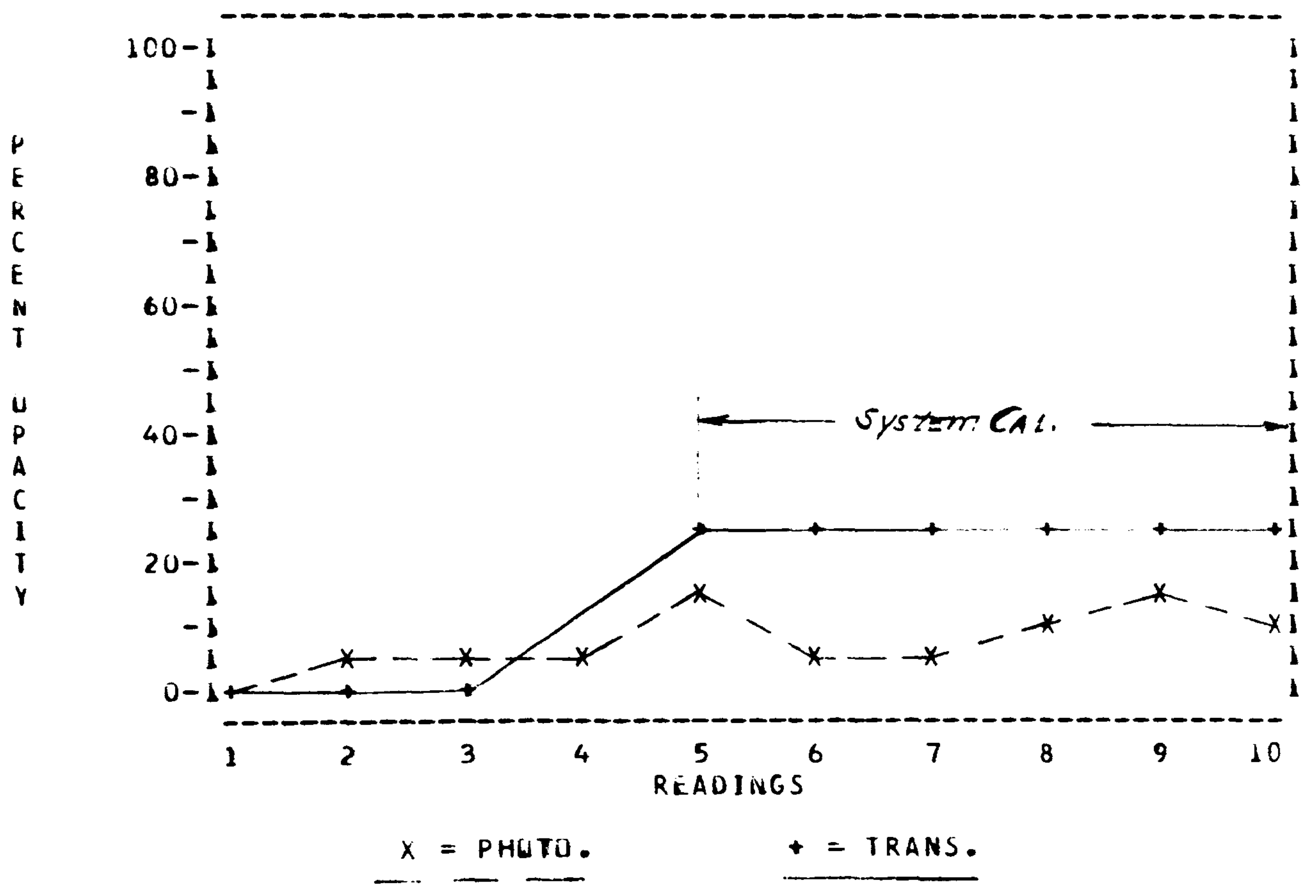


SULFURIC ACID PLANT

5/7/74

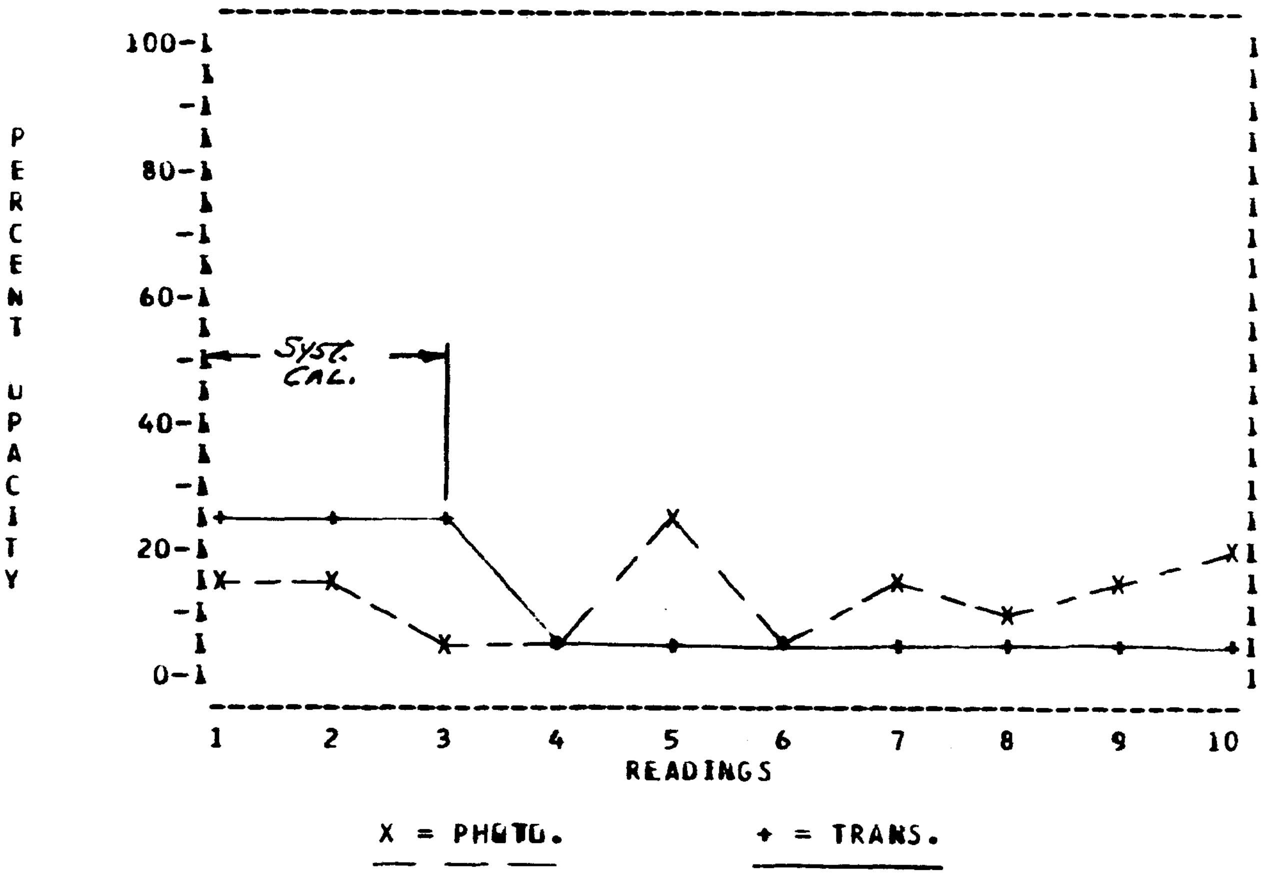
NO.1 DATE 5/7/74 TIME 11:17 - 11:22 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
100.0	32.0	46.0	97.0	12.0	-33.3	2.3
97.0	29.0	25.0	98.0	12.0	6.8	2.3
96.0	31.0	26.0	94.0	12.0	4.4	2.3
97.0	27.0	24.0	96.0	0.0	2.8	-12.2
93.0	28.0	24.0	99.0	34.0	13.3	24.1
97.0	30.0	25.0	97.0	34.0	6.9	24.1
97.0	29.0	25.0	98.0	34.0	6.8	24.1
96.0	28.0	24.0	98.0	34.0	8.1	24.1
88.0	27.0	25.0	98.0	34.0	16.4	24.1
89.0	28.0	24.0	92.0	34.0	10.3	24.1



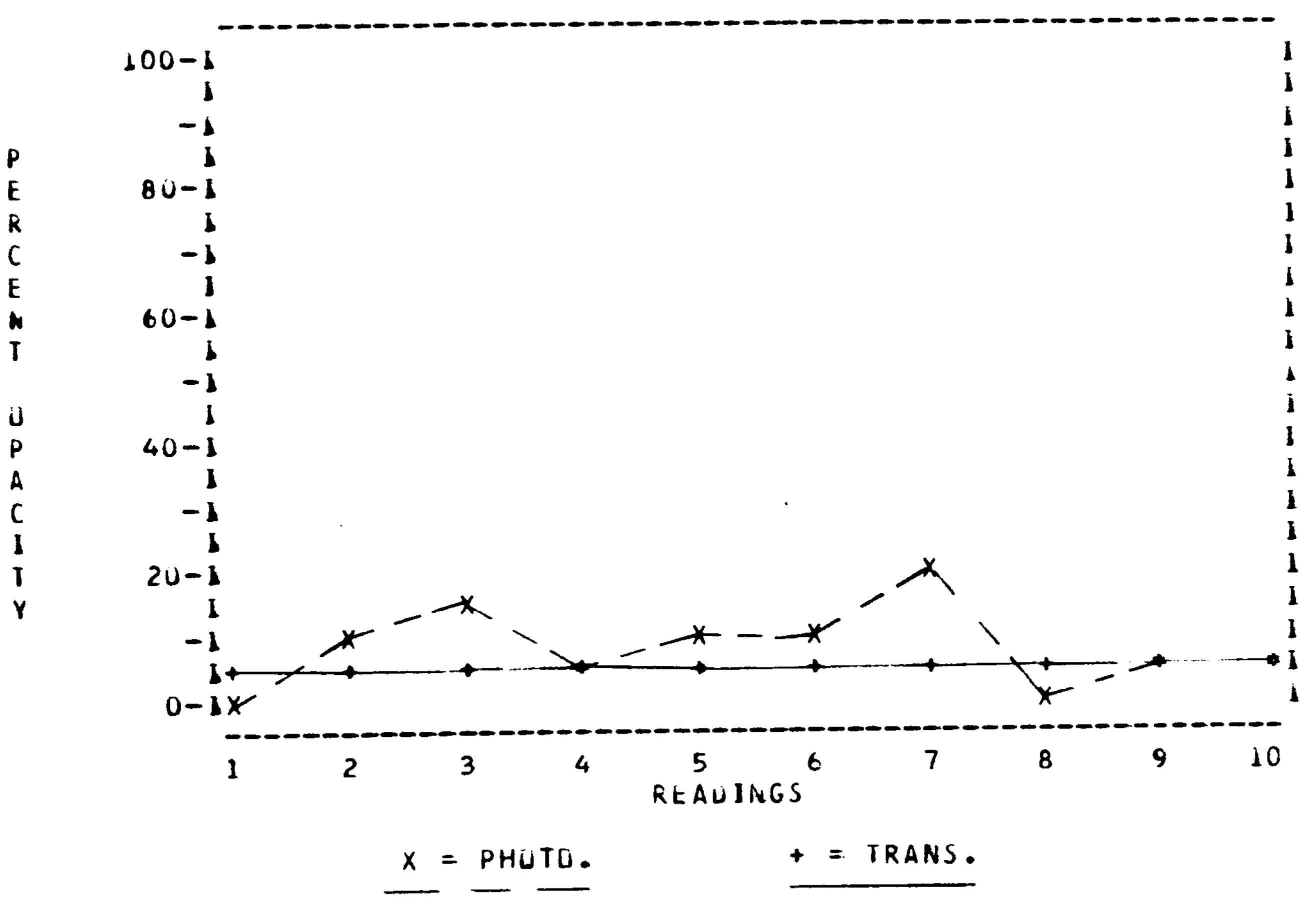
NO.2 DATE 5/7/74 TIME 11:23 - 11:27 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
93.0	42.0	32.0	93.0	34.0	16.4	24.1
93.0	40.0	32.0	93.0	34.0	13.1	24.1
93.0	39.0	35.0	93.0	34.0	6.9	24.1
90.0	40.0	38.0	90.0	12.5	3.8	2.8
85.0	42.0	34.0	90.0	12.5	23.2	2.8
97.0	33.0	28.0	96.0	12.5	5.9	2.8
94.0	41.0	30.0	94.0	12.5	17.2	2.8
92.0	38.0	32.0	91.0	12.5	8.5	2.8
88.0	40.0	33.0	91.0	12.5	17.2	2.8
85.0	38.0	32.0	89.0	12.5	17.5	2.8



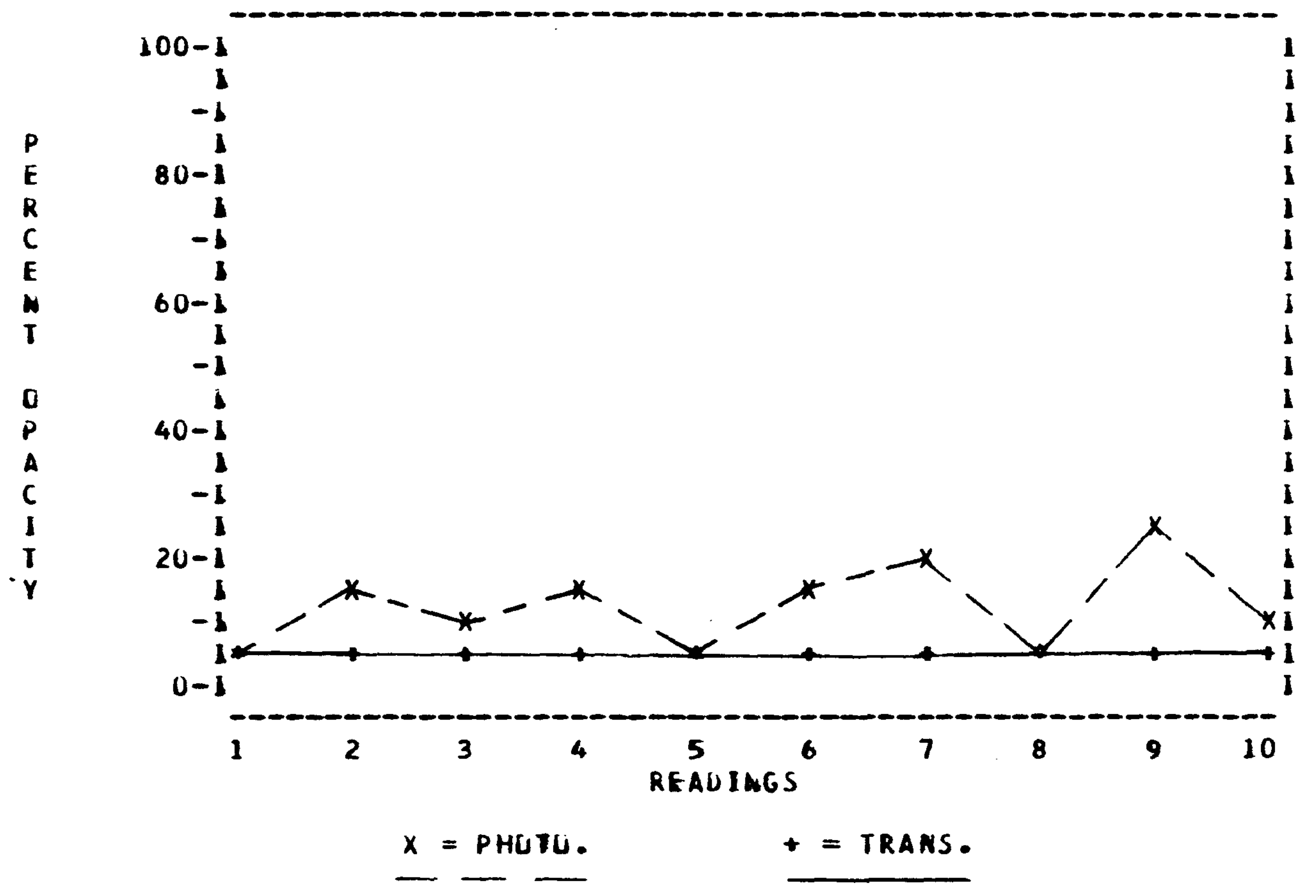
NO.3 DATE 5/7/74 TIME 11:35 - 11:39 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
97.0	41.0	38.0	95.0	12.5	1.8	2.8
94.0	38.0	32.0	93.0	12.5	8.2	2.8
88.0	34.0	29.0	94.0	12.5	16.9	2.8
100.0	34.0	28.0	96.0	12.5	2.9	2.8
97.0	33.0	28.0	100.0	12.5	11.1	2.8
95.0	36.0	32.0	98.0	12.5	10.6	2.8
90.0	34.0	28.0	99.0	12.5	21.1	2.8
92.0	34.0	30.0	89.0	12.5	1.7	2.8
97.0	33.0	29.0	95.0	12.5	3.0	2.8
98.0	34.0	30.0	98.0	12.5	5.9	2.8



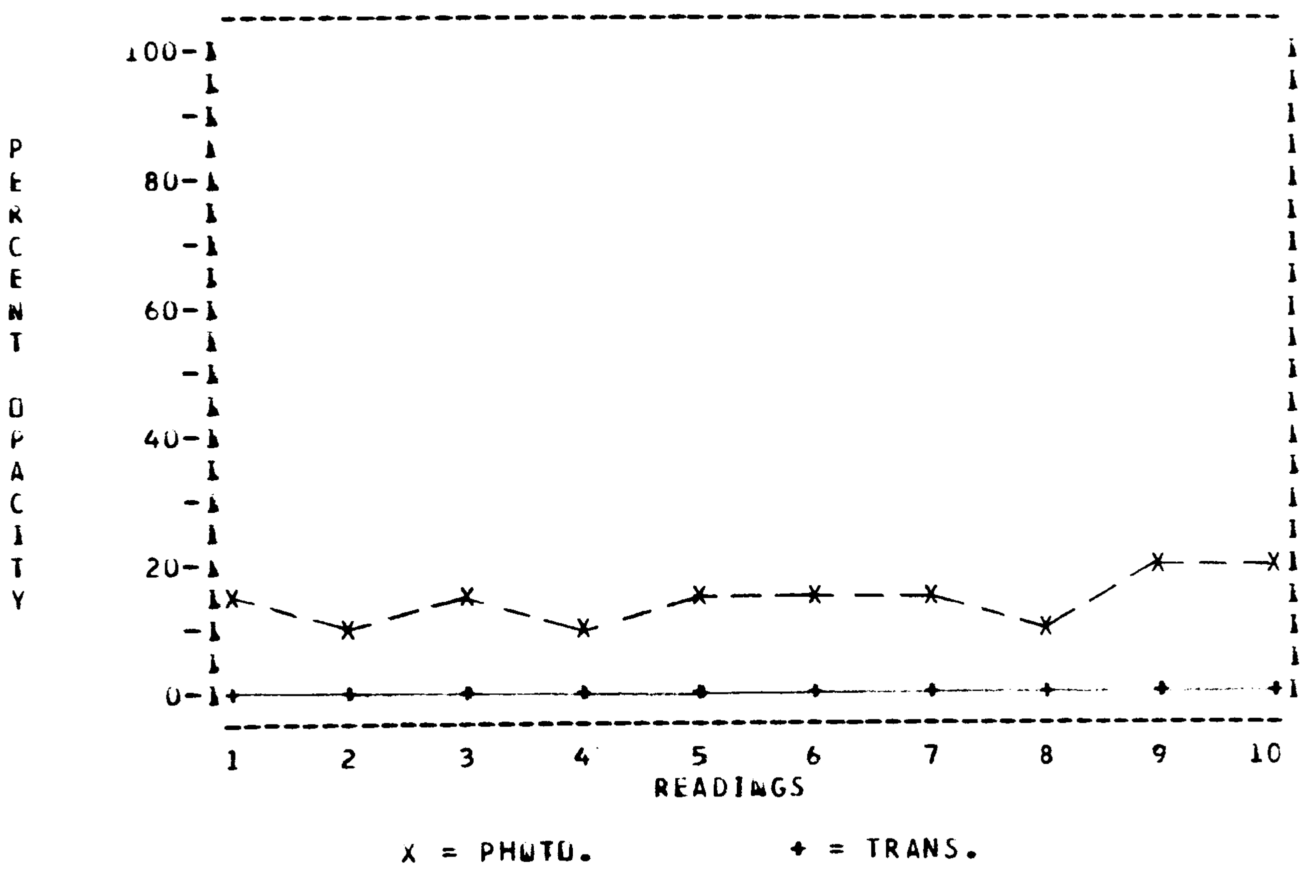
NO.4 DATE 5/7/74 TIME 11:40 - 11:43 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
100.0	30.0	21.0	95.0	12.5	5.4	2.8
93.0	30.0	21.0	96.0	12.5	16.0	2.8
90.0	29.0	23.0	92.0	12.5	11.6	2.8
94.0	36.0	24.0	92.0	12.5	14.7	2.8
92.0	32.0	25.0	87.0	12.5	3.2	2.8
95.0	30.0	23.0	99.0	12.5	14.5	2.8
94.0	33.0	21.0	95.0	12.5	17.6	2.8
96.0	28.0	24.0	96.0	12.5	5.6	2.8
87.0	34.0	25.0	97.0	12.5	26.4	2.8
92.0	33.0	25.0	92.0	12.5	11.9	2.8



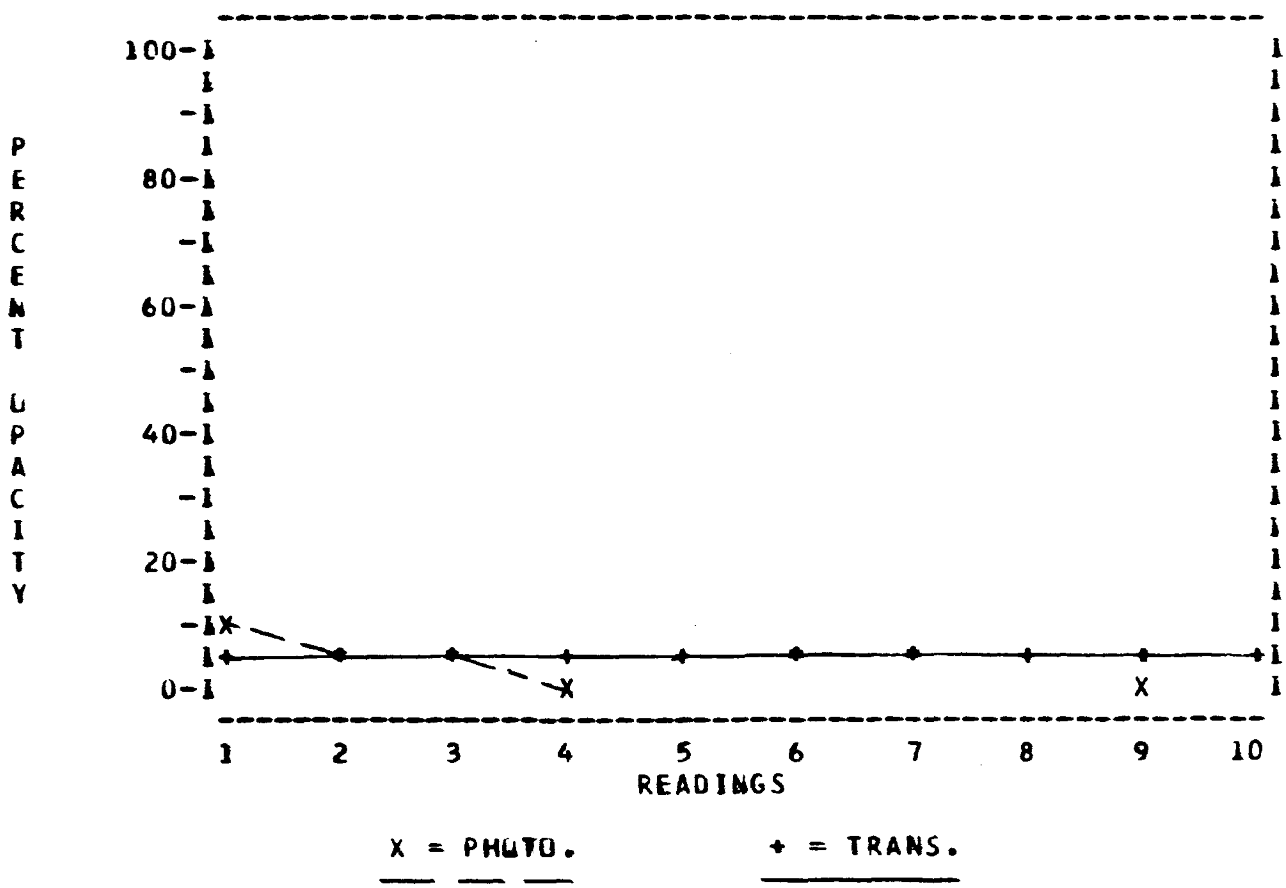
NO.5 DATE 5/7/74 TIME 11:46 - 11:51 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	34.0	27.0	92.0	12.0	13.8	2.3
96.0	32.0	24.0	96.0	12.0	11.1	2.3
89.0	32.0	24.0	90.0	12.0	13.6	2.3
89.0	33.0	26.0	88.0	12.0	9.7	2.3
86.0	33.0	24.0	88.0	12.0	17.2	2.3
93.0	34.0	24.0	92.0	12.0	13.2	2.3
96.0	34.0	24.0	96.0	12.0	13.9	2.3
92.0	34.0	25.0	90.0	12.0	10.8	2.3
83.0	33.0	25.0	87.0	12.0	19.4	2.3
83.0	33.0	25.0	86.0	12.0	18.0	2.3



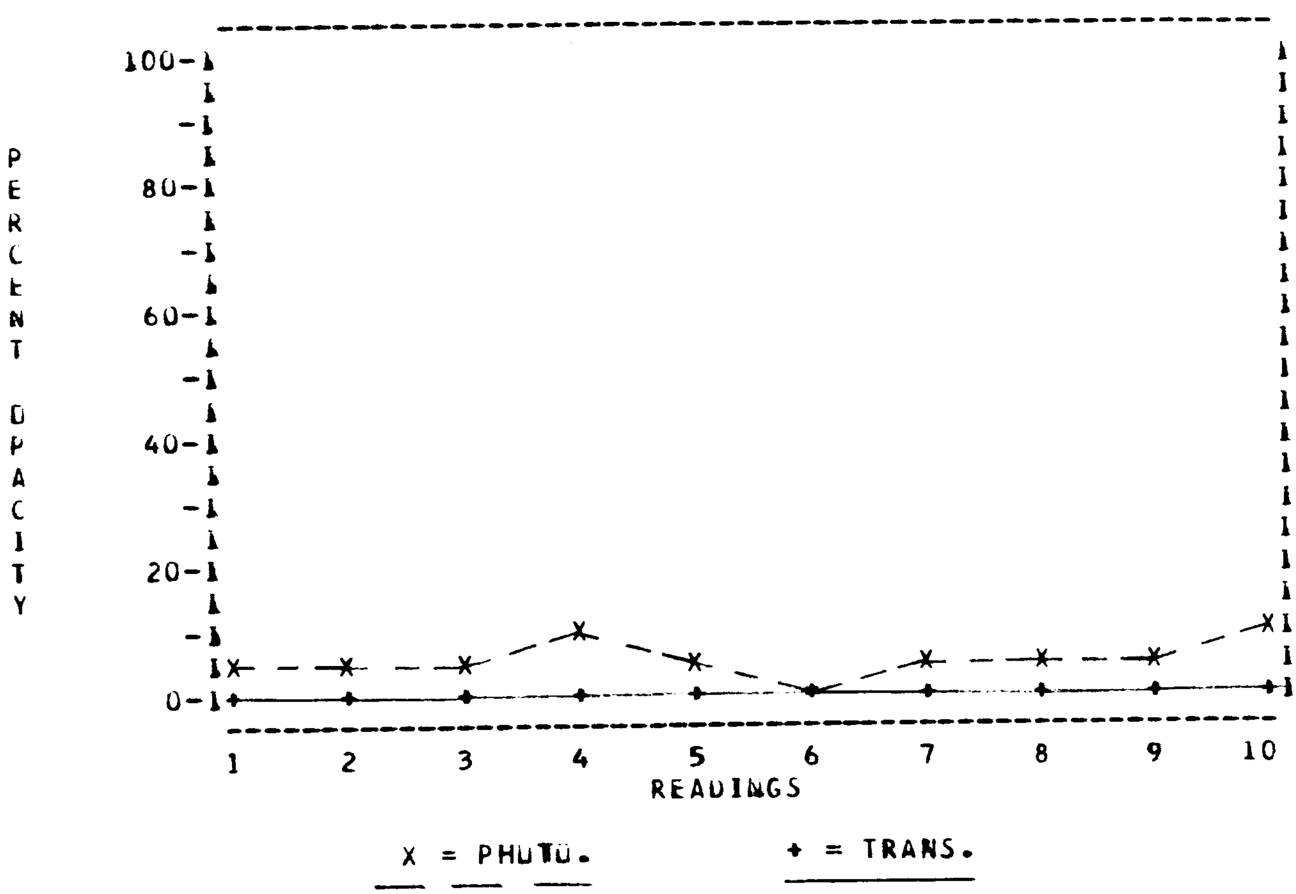
NO.6 DATE 5/7/74 TIME 11:54 - 11:58 AM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
91.0	25.0	22.0	94.0	12.5	8.3	2.8
94.0	28.0	20.0	90.0	12.5	5.7	2.8
94.0	26.0	21.0	91.0	12.5	2.9	2.8
93.0	23.0	19.0	90.0	12.5	1.4	2.8
100.0	24.0	19.0	89.0	12.5	-8.6	2.8
96.0	27.0	20.0	94.0	12.5	6.8	2.8
89.0	25.0	20.0	87.0	12.5	4.5	2.8
96.0	25.0	21.0	90.0	12.5	-2.9	2.8
100.0	25.0	19.0	94.0	12.5	0.0	2.8
100.0	25.0	21.0	90.0	12.5	-8.7	2.8



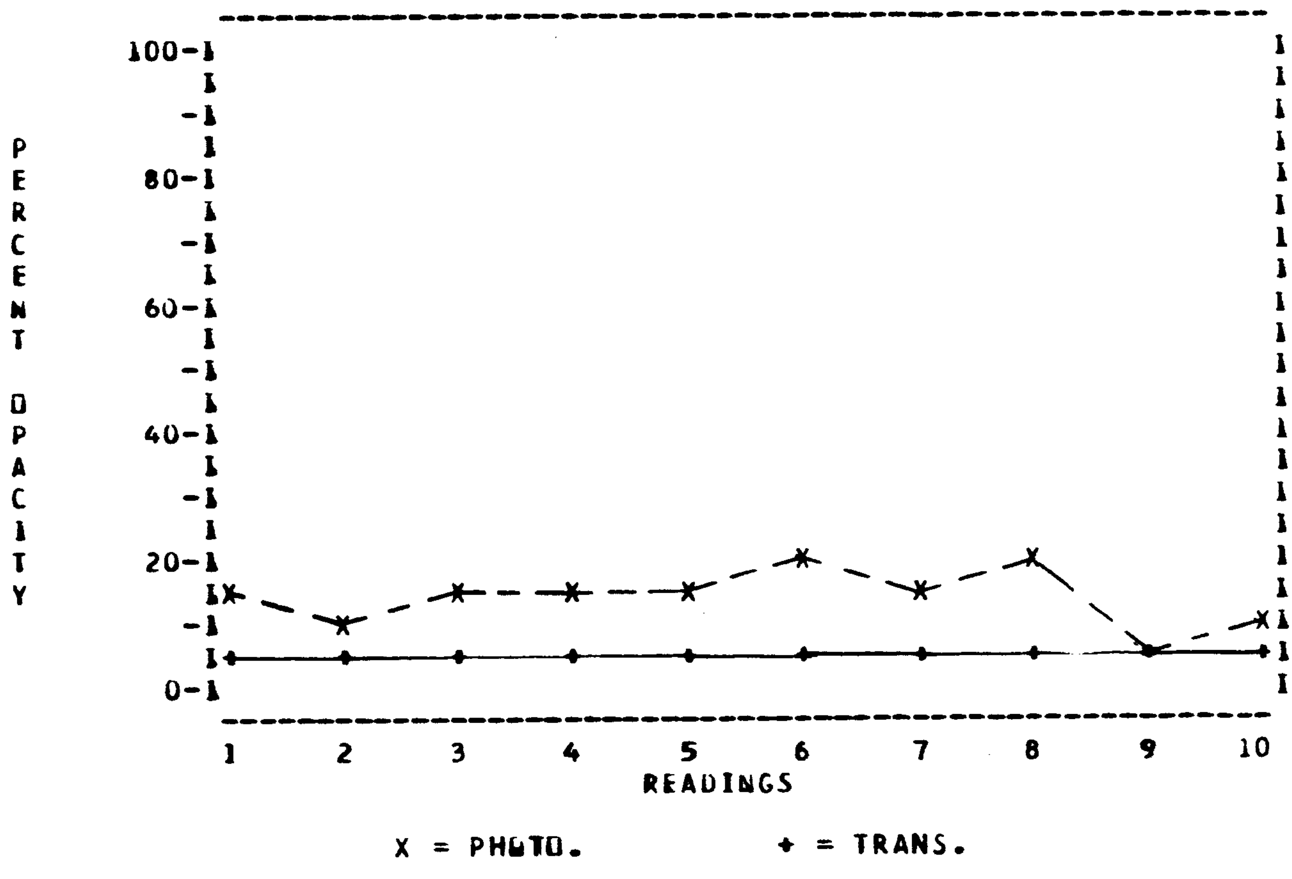
NO.7 DATE 5/7/74 TIME 12:04 - 12:09 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
95.0	36.0	29.0	91.0	12.0	4.8	2.3
91.0	22.0	16.0	90.0	12.0	6.8	2.3
90.0	23.0	21.0	90.0	12.0	2.9	2.3
89.0	21.0	16.0	90.0	12.0	8.1	2.3
92.0	22.0	17.0	91.0	12.0	5.4	2.3
92.0	21.0	21.0	92.0	12.0	0.0	2.3
91.0	21.0	18.0	90.0	12.0	2.8	2.3
90.0	19.0	17.0	90.0	12.0	2.7	2.3
93.0	21.0	17.0	91.0	12.0	2.7	2.3
91.0	23.0	18.0	94.0	12.0	10.5	2.3



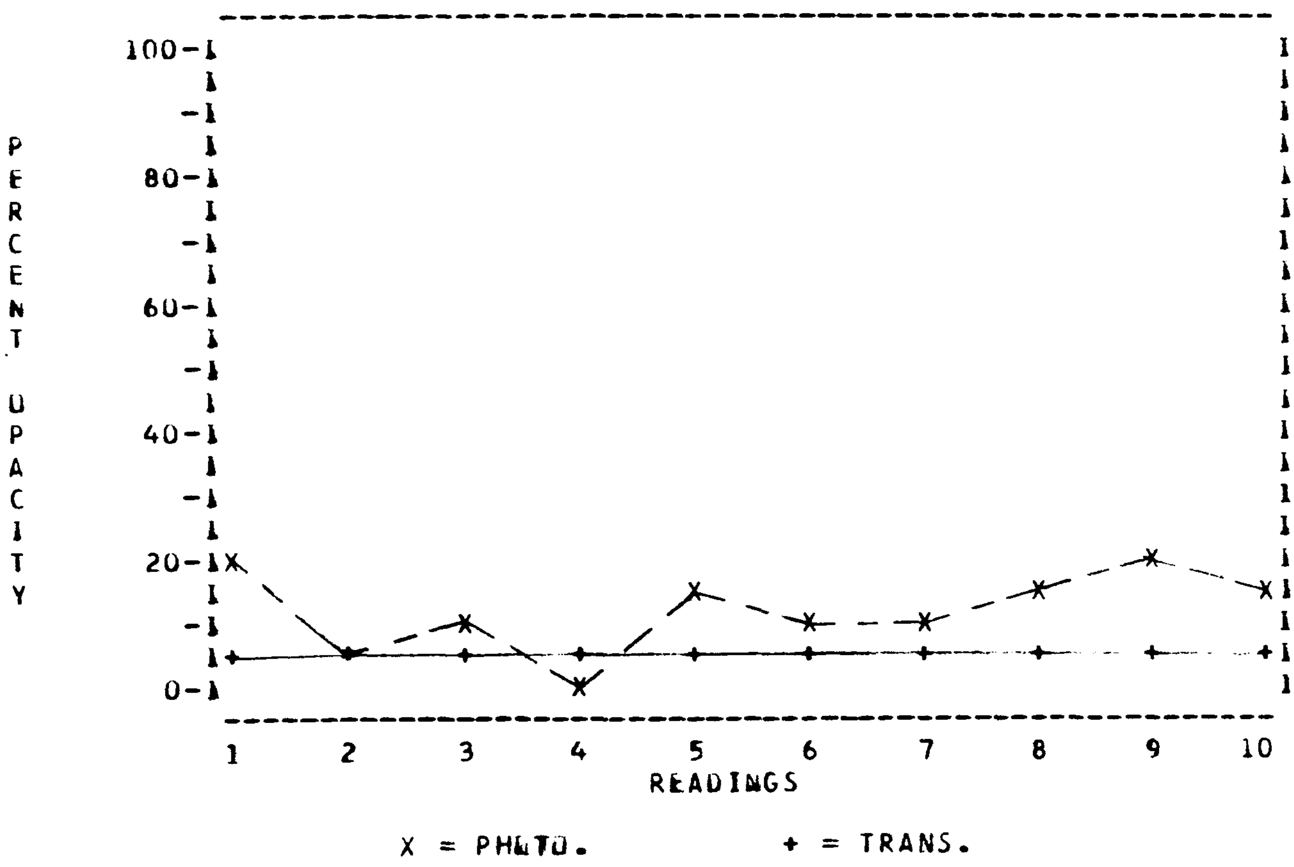
NO.9 DATE 5/7/74 TIME 12:50 - 12:54 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
97.0	43.0	32.0	96.0	12.5	15.6	2.8
97.0	37.0	30.0	97.0	12.5	10.4	2.8
98.0	41.0	30.0	97.0	12.5	14.9	2.8
98.0	43.0	31.0	96.0	12.5	15.4	2.8
97.0	41.0	32.0	96.0	12.5	12.5	2.8
96.0	43.0	31.0	97.0	12.5	19.7	2.8
99.0	42.0	28.0	97.0	12.5	17.4	2.8
98.0	43.0	29.0	98.0	12.5	20.3	2.8
98.0	40.0	35.0	96.0	12.5	4.9	2.8
97.0	38.0	30.0	97.0	12.5	11.9	2.8



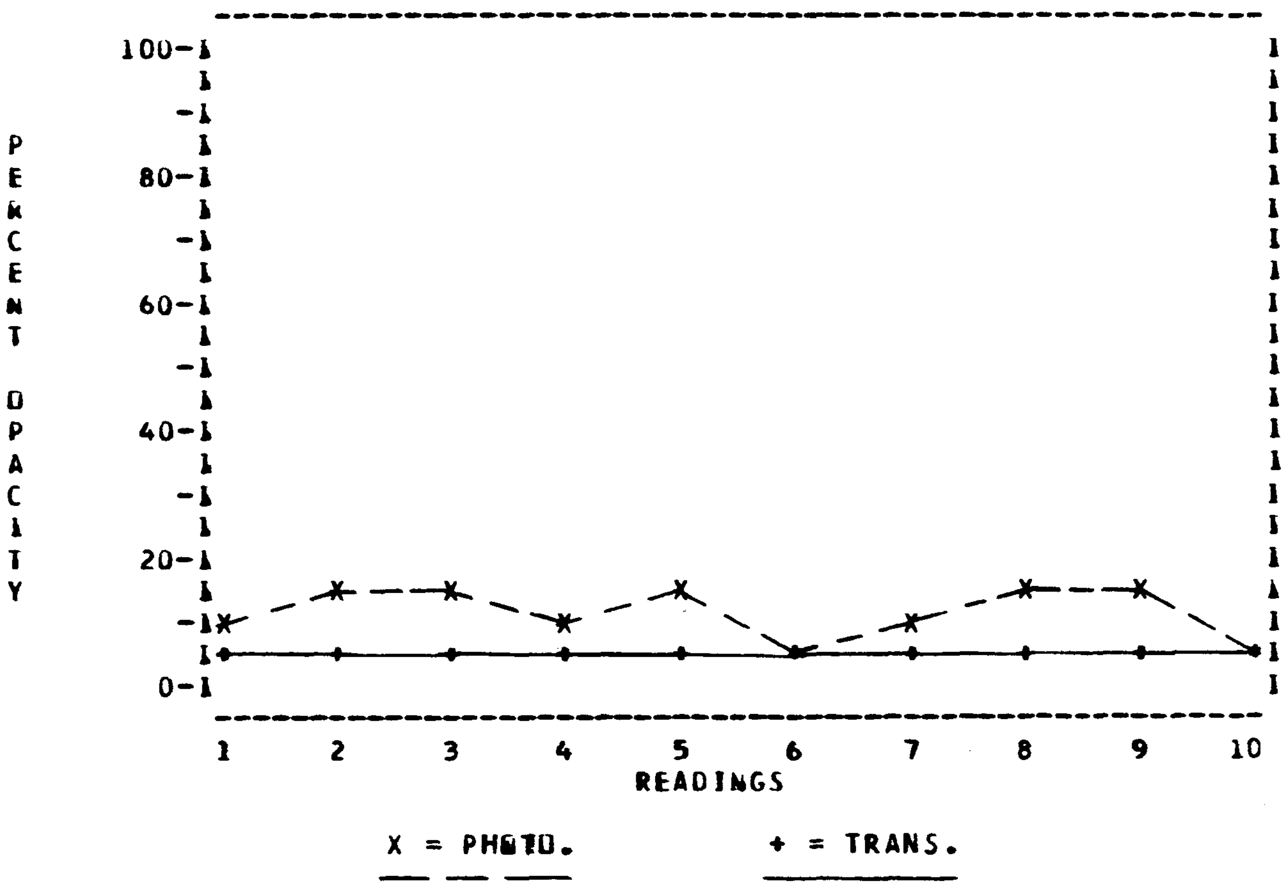
NO.10 DATE 5/7/74 TIME 12:55 - 12:59 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
97.0	43.0	31.0	97.0	12.5	18.2	2.8
98.0	42.0	38.0	97.0	12.5	5.1	2.8
100.0	38.0	29.0	98.0	12.5	10.1	2.8
94.0	33.0	25.0	86.0	12.5	0.0	2.8
88.0	36.0	27.0	87.0	12.5	13.3	2.8
98.0	40.0	32.0	97.0	12.5	10.8	2.8
100.0	38.0	29.0	97.0	12.5	8.8	2.8
92.0	32.0	25.0	94.0	12.5	13.0	2.8
84.0	36.0	26.0	86.0	12.5	20.0	2.8
88.0	36.0	27.0	88.0	12.5	14.8	2.8



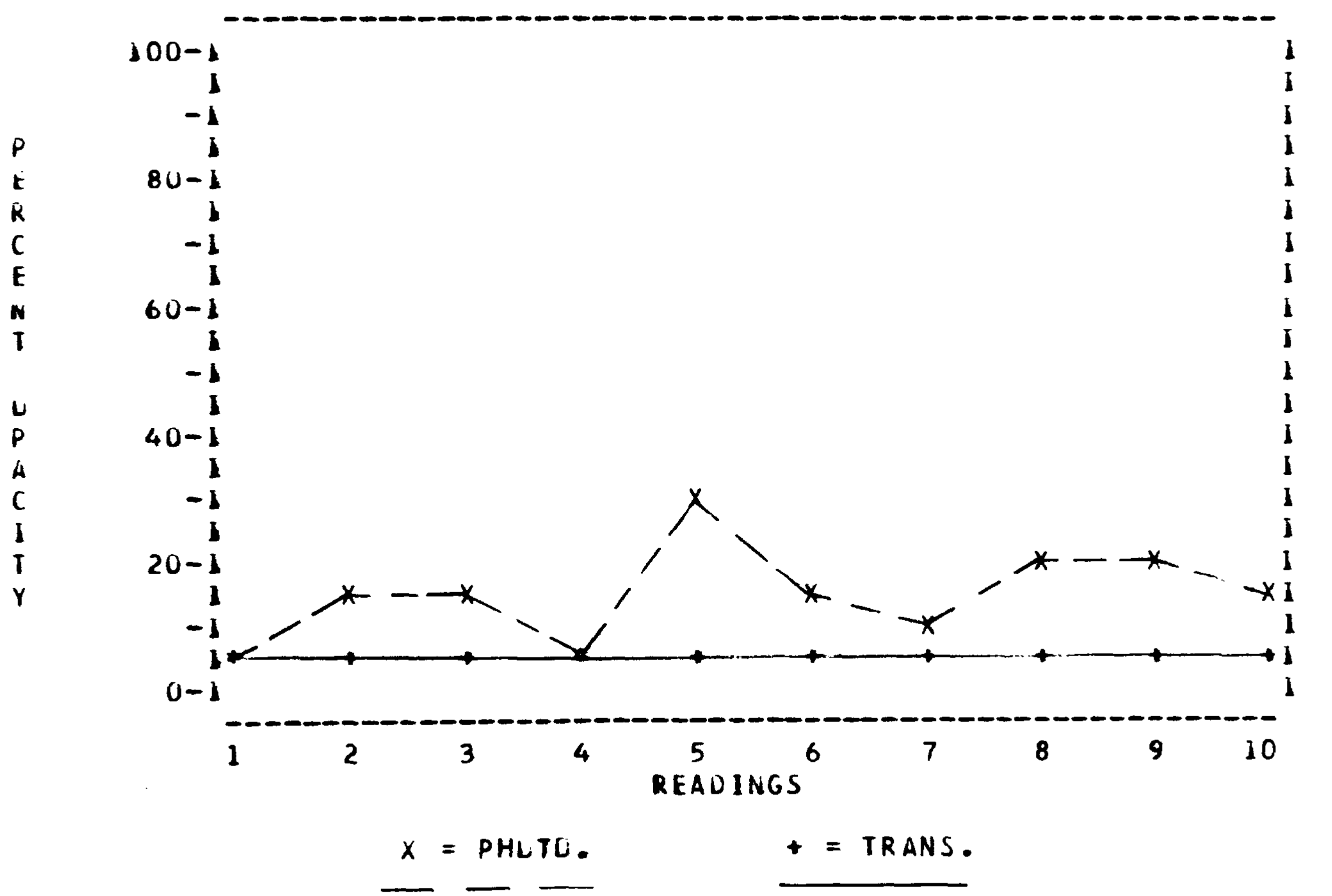
NO.12 DATE 5/7/74 TIME 1:05 - 1:09 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
98.0	34.0	23.0	96.0	12.5	12.3	2.8
91.0	34.0	24.0	90.0	12.5	13.6	2.8
89.0	32.0	24.0	91.0	12.5	14.9	2.8
88.0	32.0	25.0	88.0	12.5	11.1	2.8
91.0	31.0	24.0	94.0	12.5	14.3	2.8
97.0	34.0	23.0	90.0	12.5	6.0	2.8
94.0	34.0	26.0	92.0	12.5	9.1	2.8
89.0	34.0	24.0	88.0	12.5	14.1	2.8
88.0	33.0	24.0	89.0	12.5	15.4	2.8
94.0	31.0	25.0	93.0	12.5	7.4	2.8



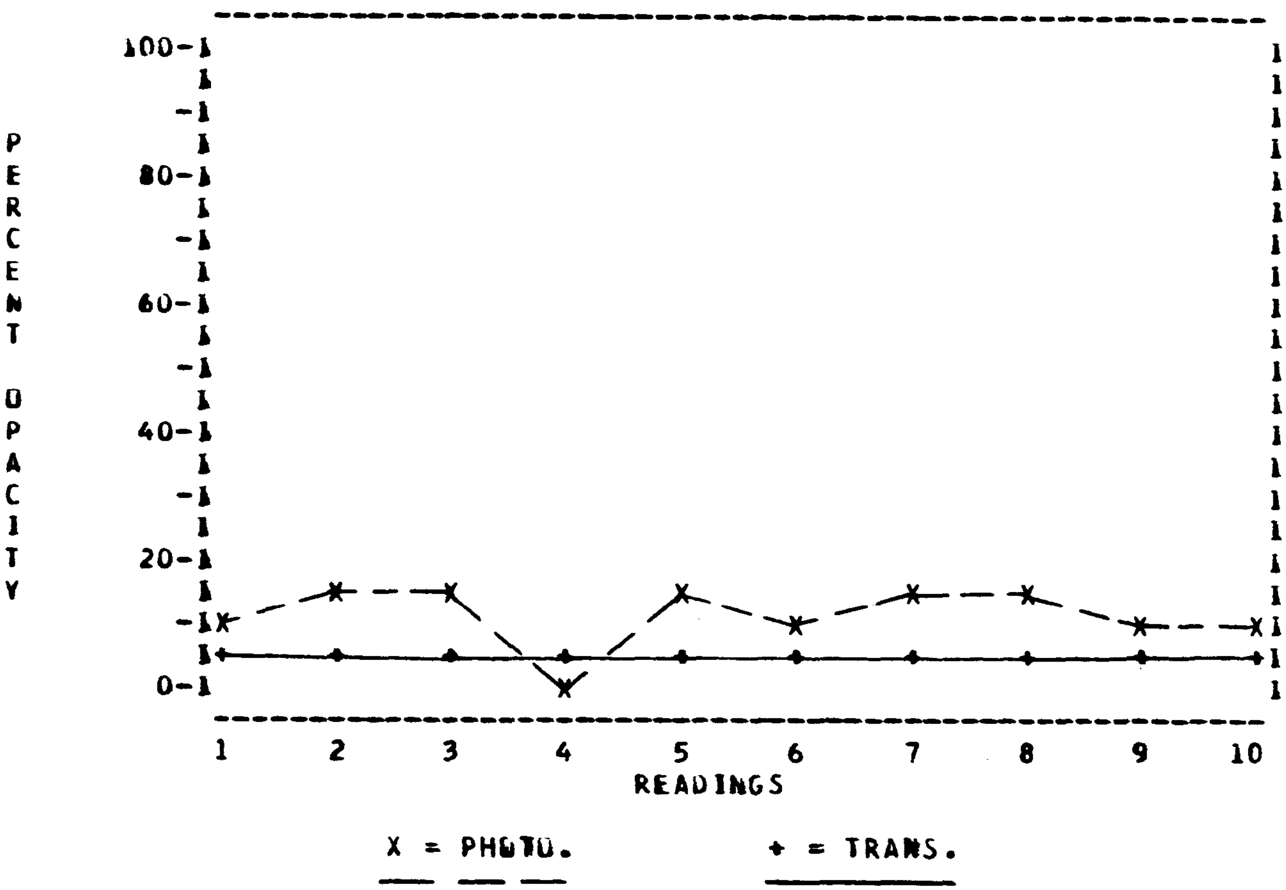
NO.13 DATE 5/7/74 TIME 1:10 - 1:15 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
91.0	36.0	31.0	89.0	12.5	5.2	2.8
88.0	32.0	25.0	89.0	12.5	12.5	2.8
88.0	32.0	26.0	90.0	12.5	12.5	2.8
86.0	34.0	30.0	86.0	12.5	7.1	2.8
84.0	38.0	25.0	90.0	12.5	29.2	2.8
90.0	34.0	25.0	89.0	12.5	12.5	2.8
89.0	34.0	29.0	90.0	12.5	9.8	2.8
86.0	36.0	24.0	87.0	12.5	20.6	2.8
86.0	31.0	24.0	92.0	12.5	19.1	2.8
84.0	36.0	30.0	86.0	12.5	14.3	2.8



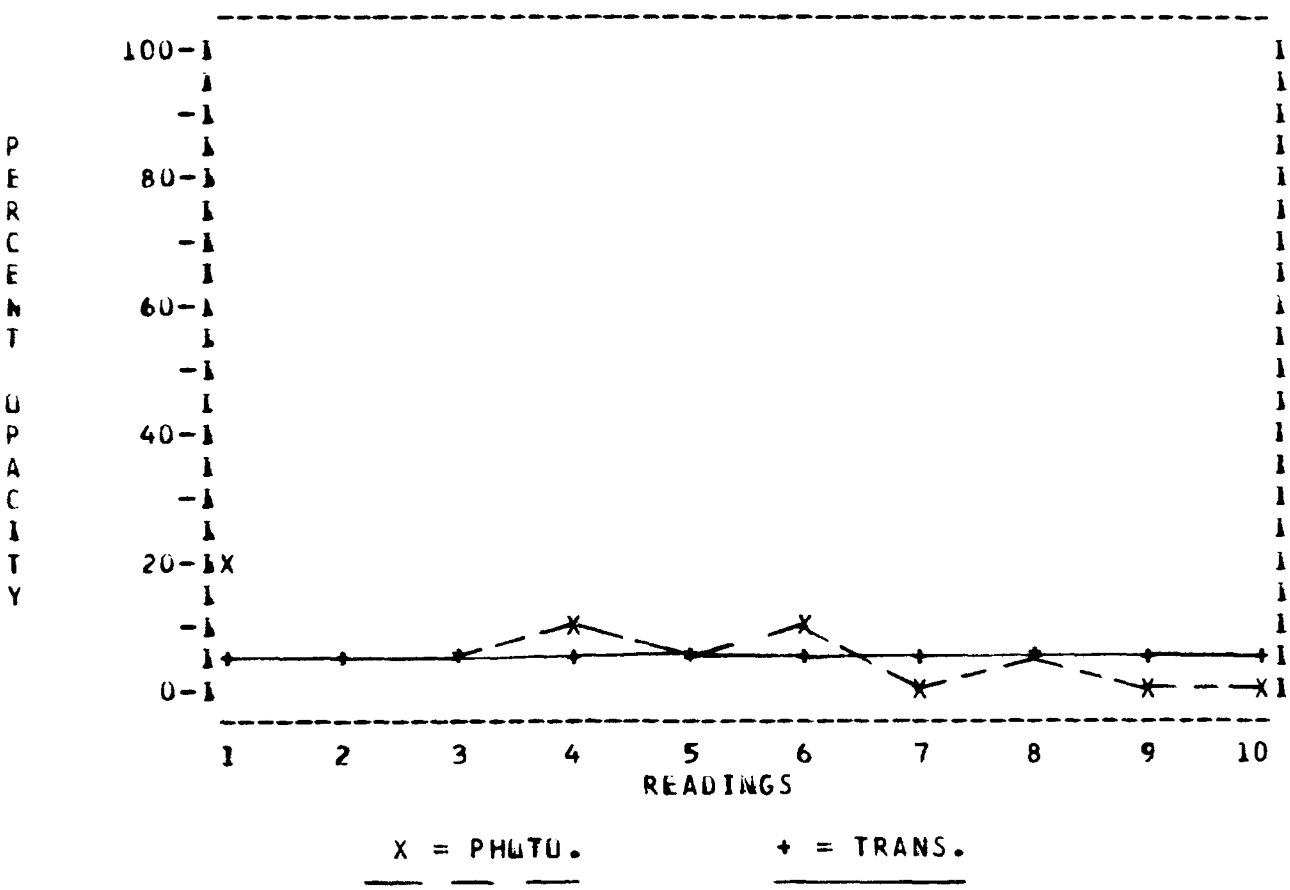
NO.14 DATE 5/7/74 TIME 1:15 - 1:20 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
89.0	35.0	29.0	90.0	12.5	11.5	2.8
92.0	37.0	27.0	90.0	12.5	12.7	2.8
90.0	38.0	28.0	90.0	12.5	16.1	2.8
96.0	37.0	31.0	91.0	12.5	1.7	2.8
92.0	40.0	30.0	92.0	12.5	16.1	2.8
94.0	36.0	27.0	90.0	12.5	7.9	2.8
90.0	38.0	28.0	91.0	12.5	17.5	2.8
90.0	38.0	29.0	90.0	12.5	14.8	2.8
99.0	39.0	26.0	93.0	12.5	10.4	2.8
96.0	39.0	28.0	93.0	12.5	12.3	2.8



NO.15 DATE 5/7/74 TIME 1:22 - 1:27 PM SULFURIC ACID PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	39.0	33.0	95.0	12.5	17.7	2.8
96.0	36.0	34.0	91.0	12.5	-5.3	2.8
97.0	38.0	33.0	94.0	12.5	3.3	2.8
94.0	35.0	33.0	100.0	12.5	11.9	2.8
95.0	34.0	33.0	97.0	12.5	4.7	2.8
96.0	38.0	32.0	96.0	12.5	9.4	2.8
96.0	38.0	32.0	91.0	12.5	1.7	2.8
95.0	33.0	33.0	98.0	12.5	4.6	2.8
95.0	35.0	35.0	96.0	12.5	1.6	2.8
96.0	34.0	34.0	96.0	12.5	0.0	2.8



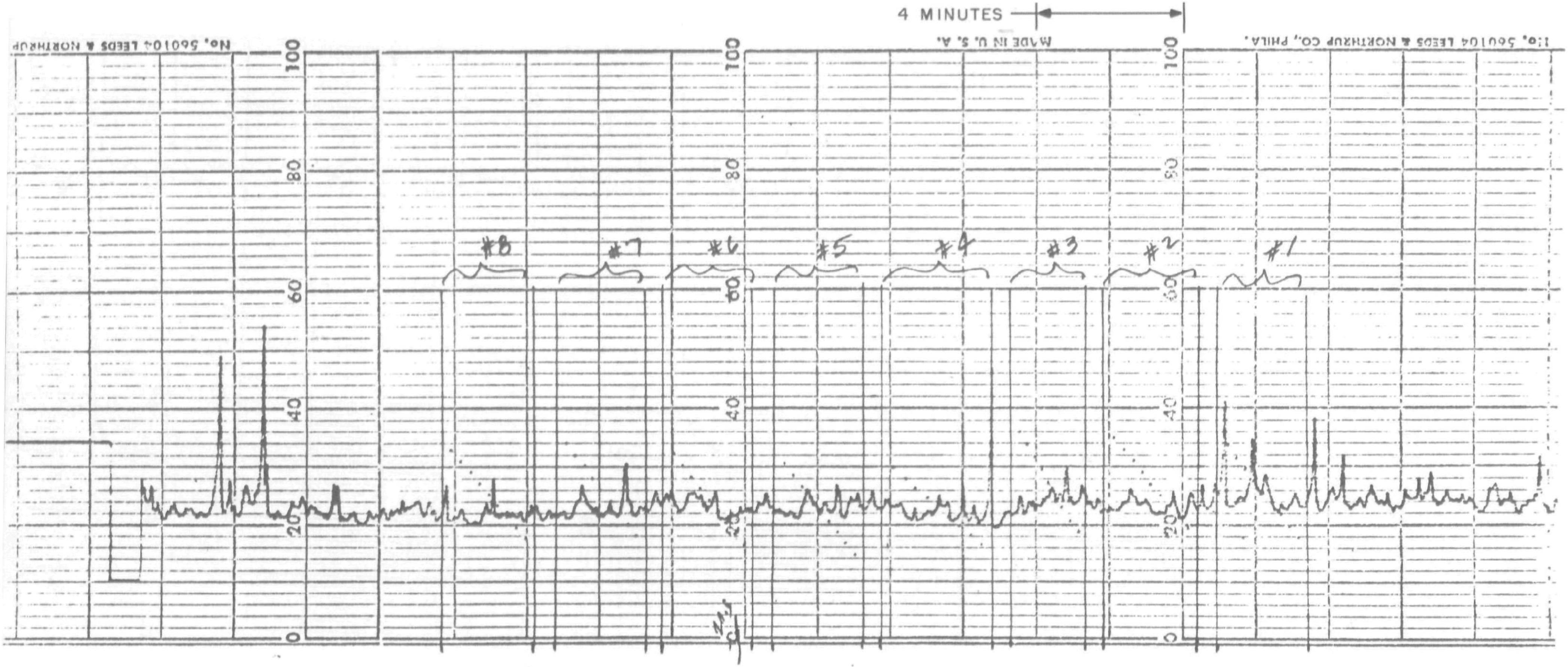
APPENDIX C

PORTLAND CEMENT PLANT

SERIES

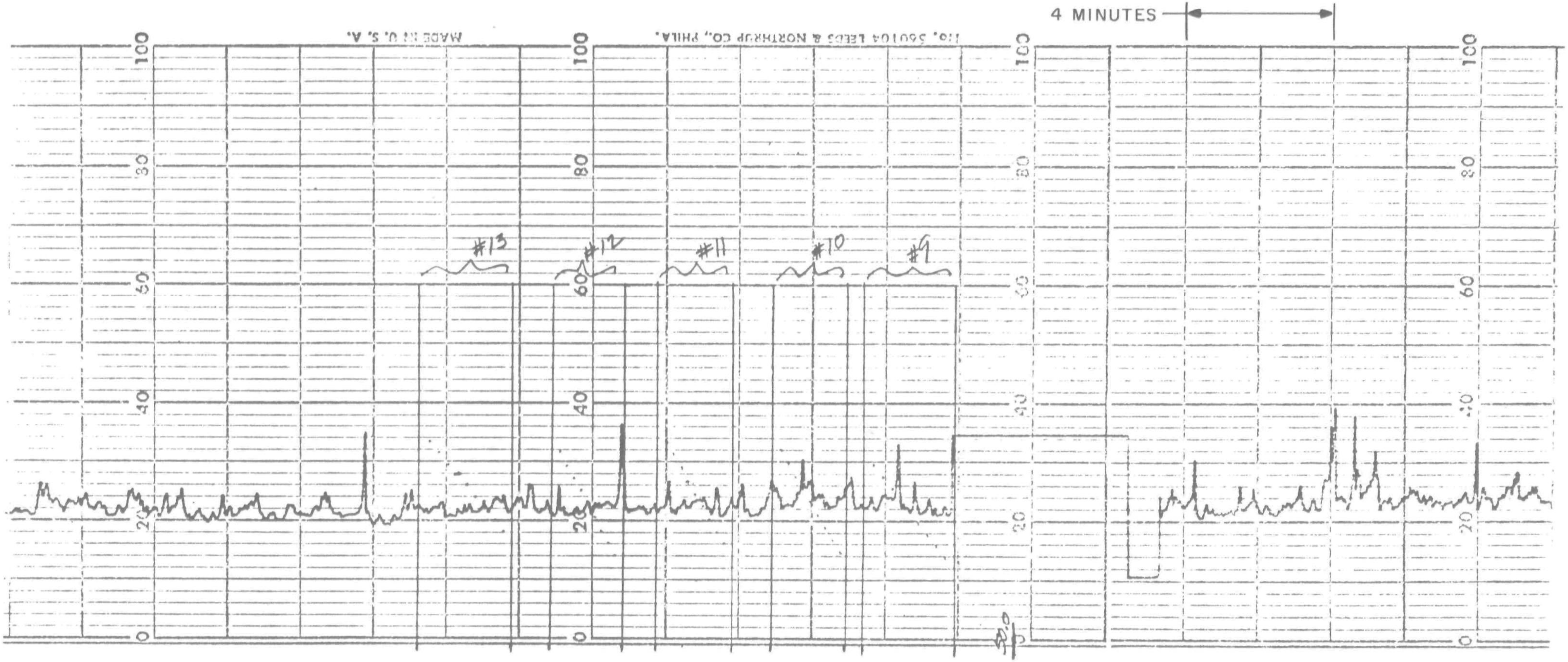
OF

AUGUST 22, 1974

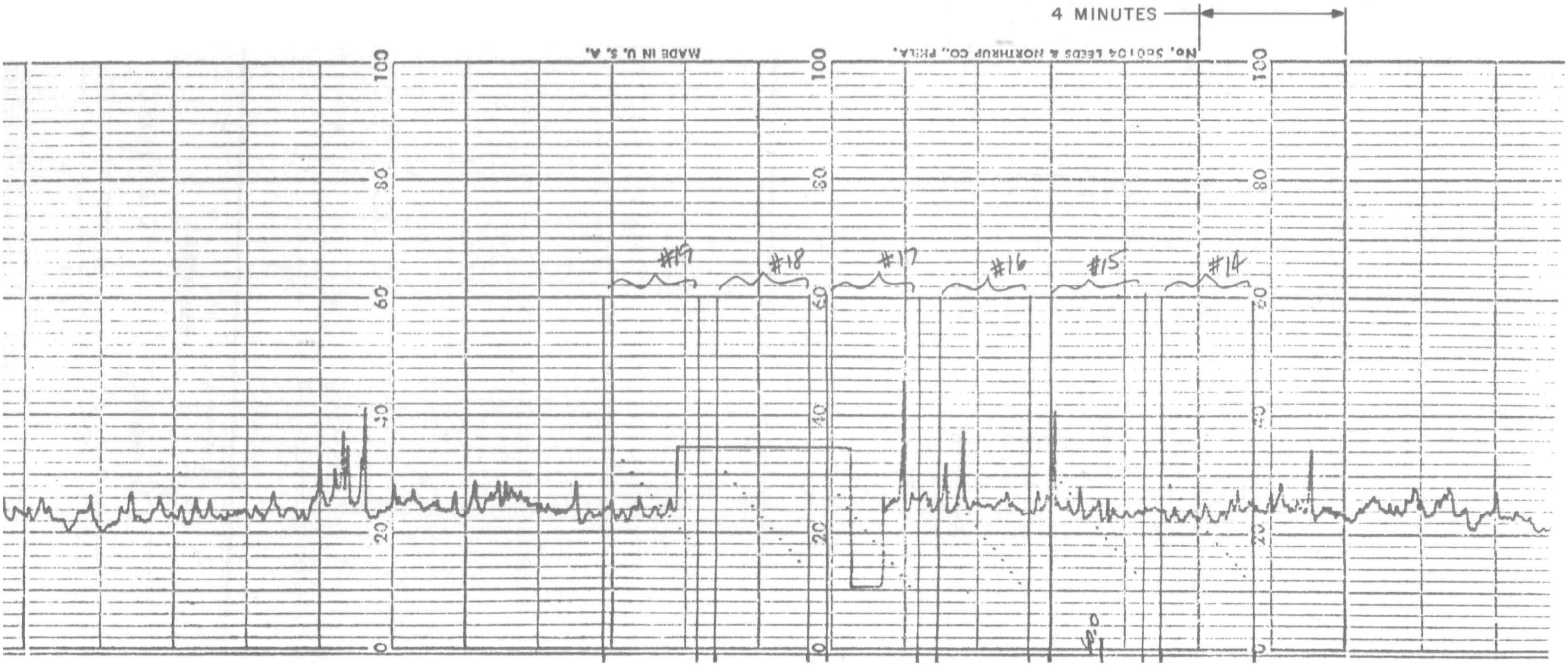


PORTLAND CEMENT PLANT

8/22/74



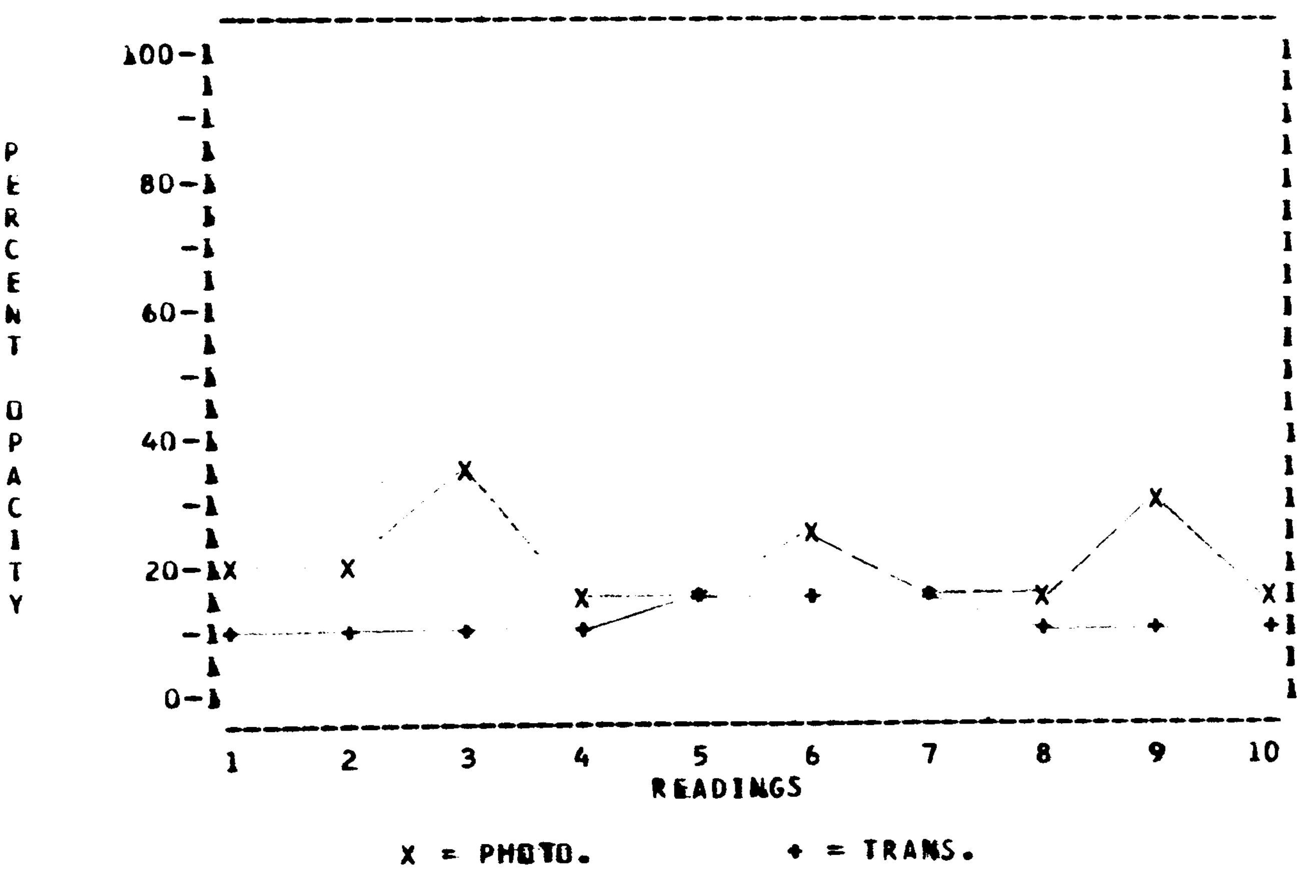
PORTLAND CEMENT PLANT
8/22/74



PORTLAND CEMENT PLANT
8/22/74

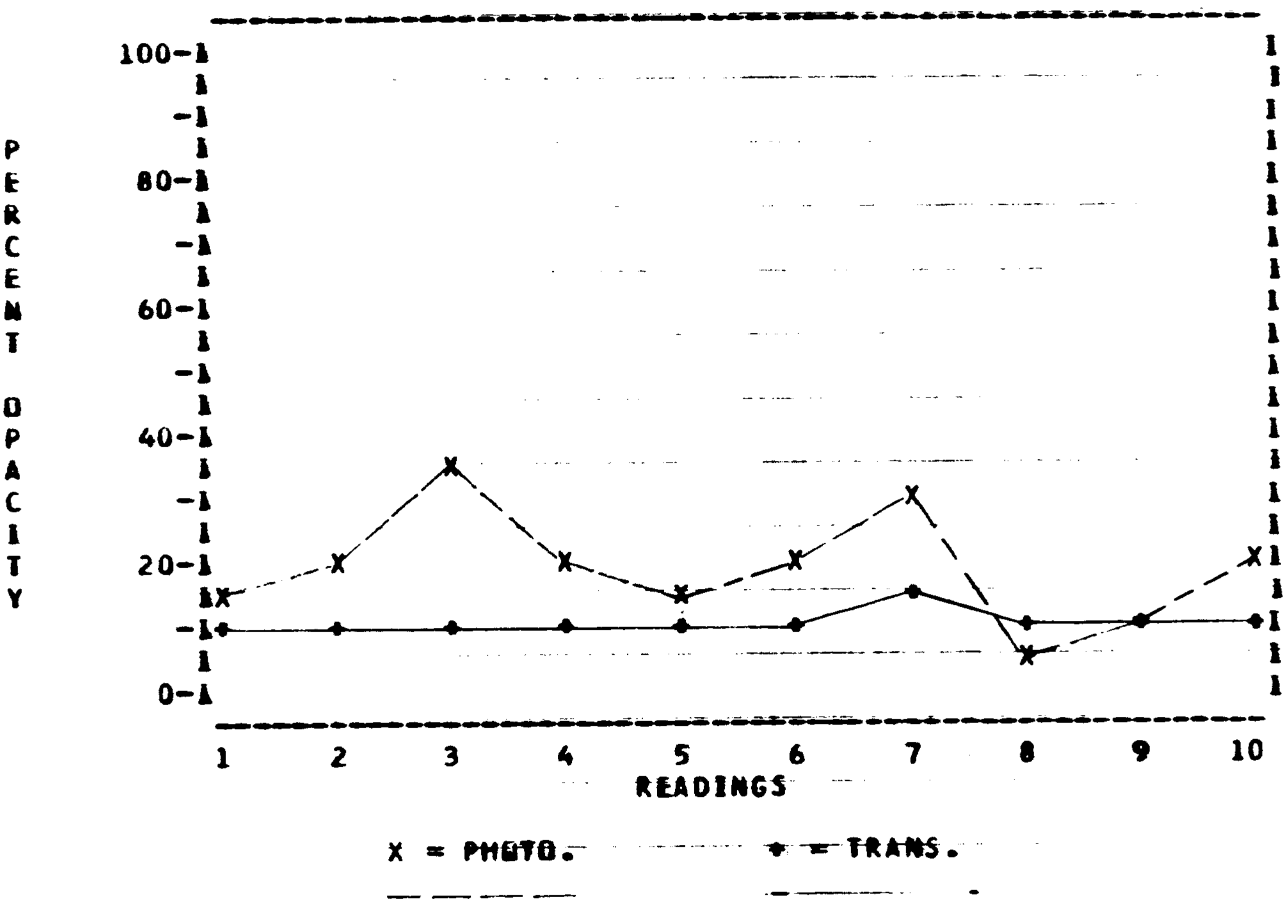
NO.1 DATE 8/22/74 TIME 11:34 - 11:36.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
83.0	63.0	59.0	84.0	23.0	20.0	11.4
77.0	66.0	62.0	76.0	23.0	21.4	11.4
80.0	69.0	64.0	81.0	22.0	35.3	10.5
86.0	68.0	64.0	85.0	24.0	14.3	12.2
87.0	73.0	68.0	84.0	26.0	12.5	13.8
81.0	67.0	63.0	82.0	28.0	26.3	15.4
82.0	68.0	64.0	80.0	25.0	12.5	13.0
87.0	72.0	70.0	88.0	24.0	16.7	12.2
90.0	76.0	71.0	91.0	23.0	30.0	11.4
93.0	74.0	68.0	91.0	24.0	17.4	12.2



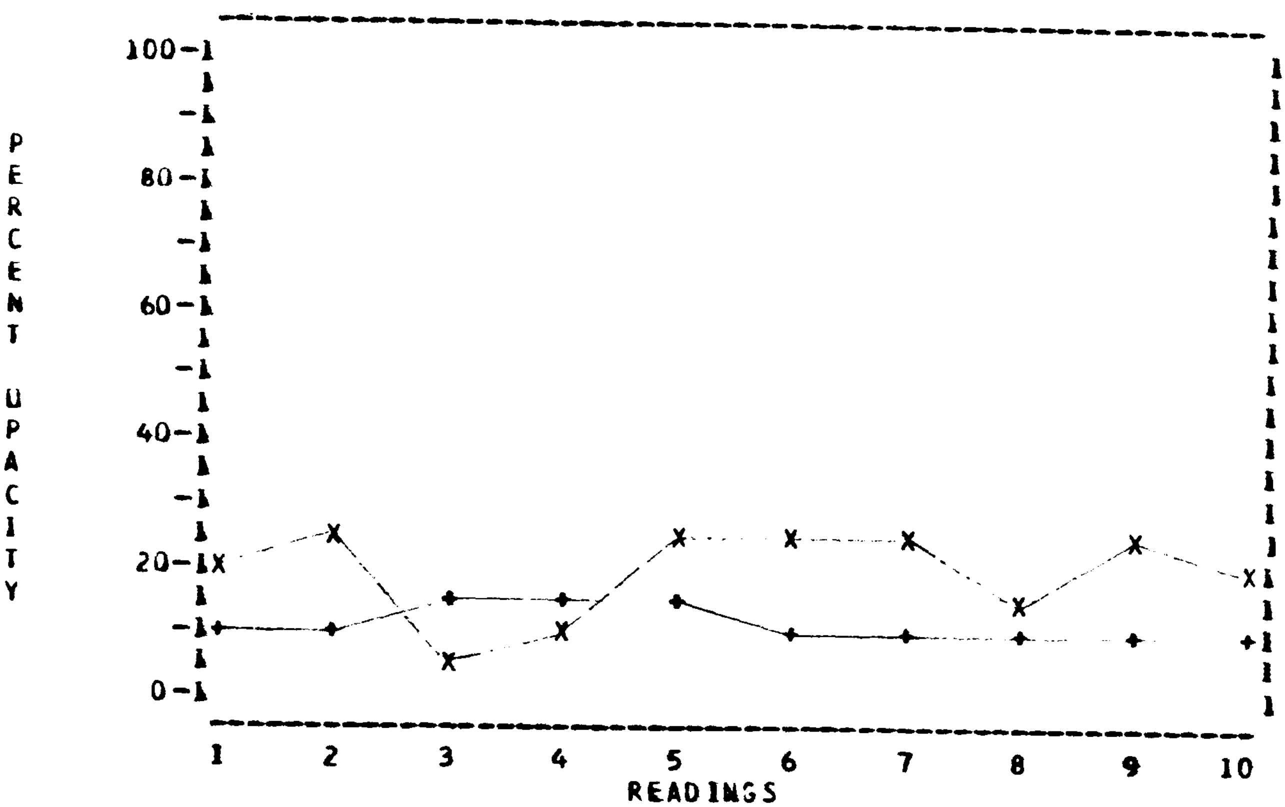
NO.2 DATE 8/22/74 TIME 11:37 - 11:39.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
88.0	68.0	64.0	87.0	24.0	13.0	12.2
82.0	67.0	65.0	84.0	21.0	21.1	9.7
84.0	72.0	67.0	86.0	23.0	36.8	11.4
88.0	73.0	69.0	88.0	22.0	21.1	10.5
87.0	71.0	68.0	87.0	24.0	15.8	12.2
87.0	71.0	66.0	86.0	24.0	20.0	12.2
85.0	76.0	70.0	83.0	26.0	30.8	13.8
91.0	73.0	71.0	90.0	24.0	5.3	12.2
88.0	70.0	68.0	88.0	22.0	10.0	10.5
86.0	70.0	66.0	86.0	22.0	20.0	10.5



NO.3 DATE 8/22/74 TIME 11:40 - 11:42 AM PORTLAND CEMENT PLANT

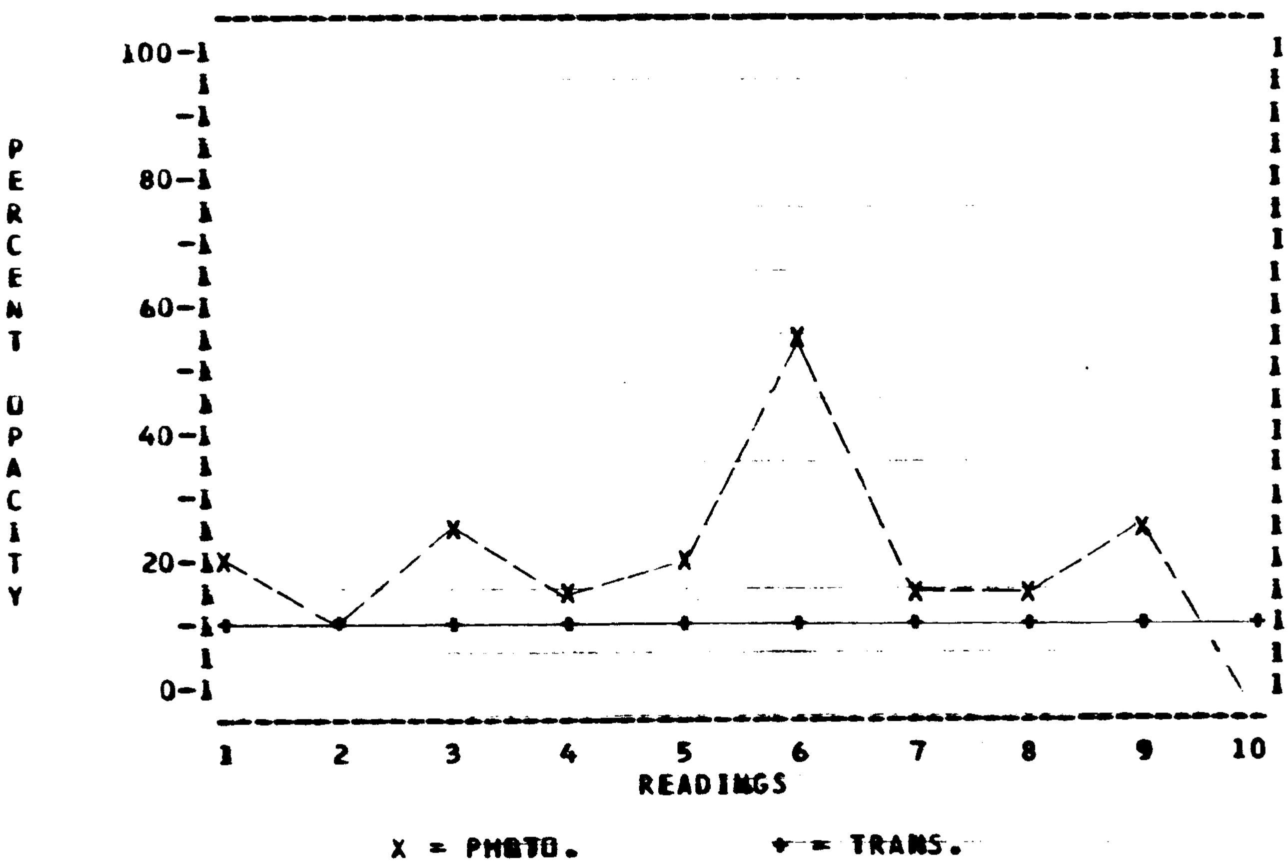
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
91.0	74.0	70.0	91.0	24.0	19.0	12.2
90.0	75.0	69.0	89.0	24.0	25.0	12.2
94.0	77.0	70.0	88.0	25.0	5.6	13.0
93.0	74.0	69.0	90.0	25.0	9.5	13.0
92.0	75.0	69.0	91.0	25.0	22.7	13.0
95.0	80.0	72.0	92.0	24.0	25.0	12.2
98.0	82.0	75.0	96.0	24.0	23.8	12.2
98.0	79.0	72.0	95.0	23.0	17.4	11.4
94.0	78.0	71.0	93.0	24.0	27.3	12.2
94.0	76.0	70.0	92.0	22.0	18.2	10.5



X = PHOTO.   + = TRANS.

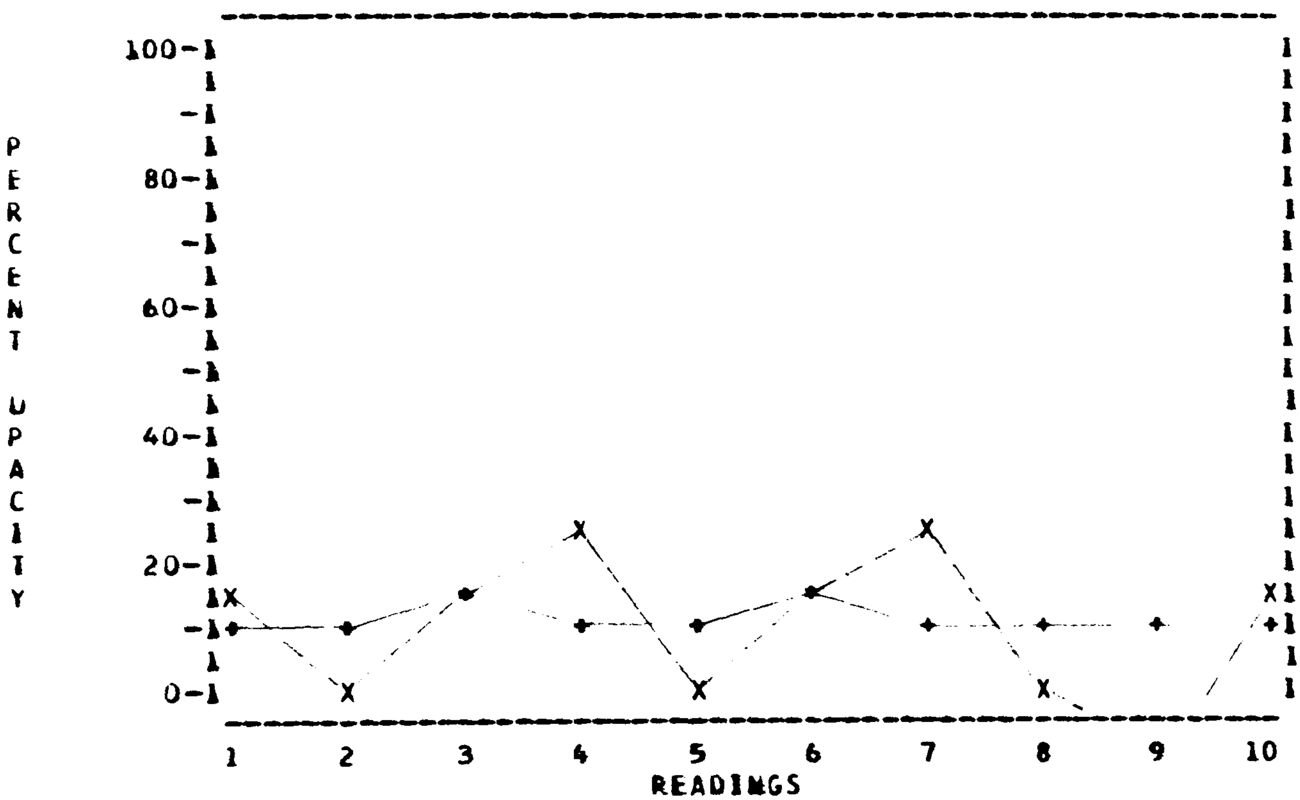
NO.4 DATE 8/22/74 TIME 11:42.5 - 11:45.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	74.0	70.0	90.0	21.0	20.0	9.7
90.0	70.0	67.0	89.0	22.0	9.1	10.5
86.0	71.0	68.0	88.0	22.0	25.0	10.5
88.0	72.0	69.0	88.0	22.0	15.8	10.5
89.0	75.0	70.0	88.0	24.0	22.2	12.2
91.0	82.0	71.0	90.0	22.0	52.6	10.5
88.0	74.0	70.0	86.0	22.0	12.5	10.5
92.0	74.0	70.0	91.0	22.0	14.3	10.5
90.0	76.0	70.0	89.0	23.0	26.3	11.4
92.0	70.0	70.0	89.0	23.0	-15.8	11.4



NO.5 DATE 8/22/74 TIME 11:46 - 11:48.5 AM PORTLAND CEMENT PLANT

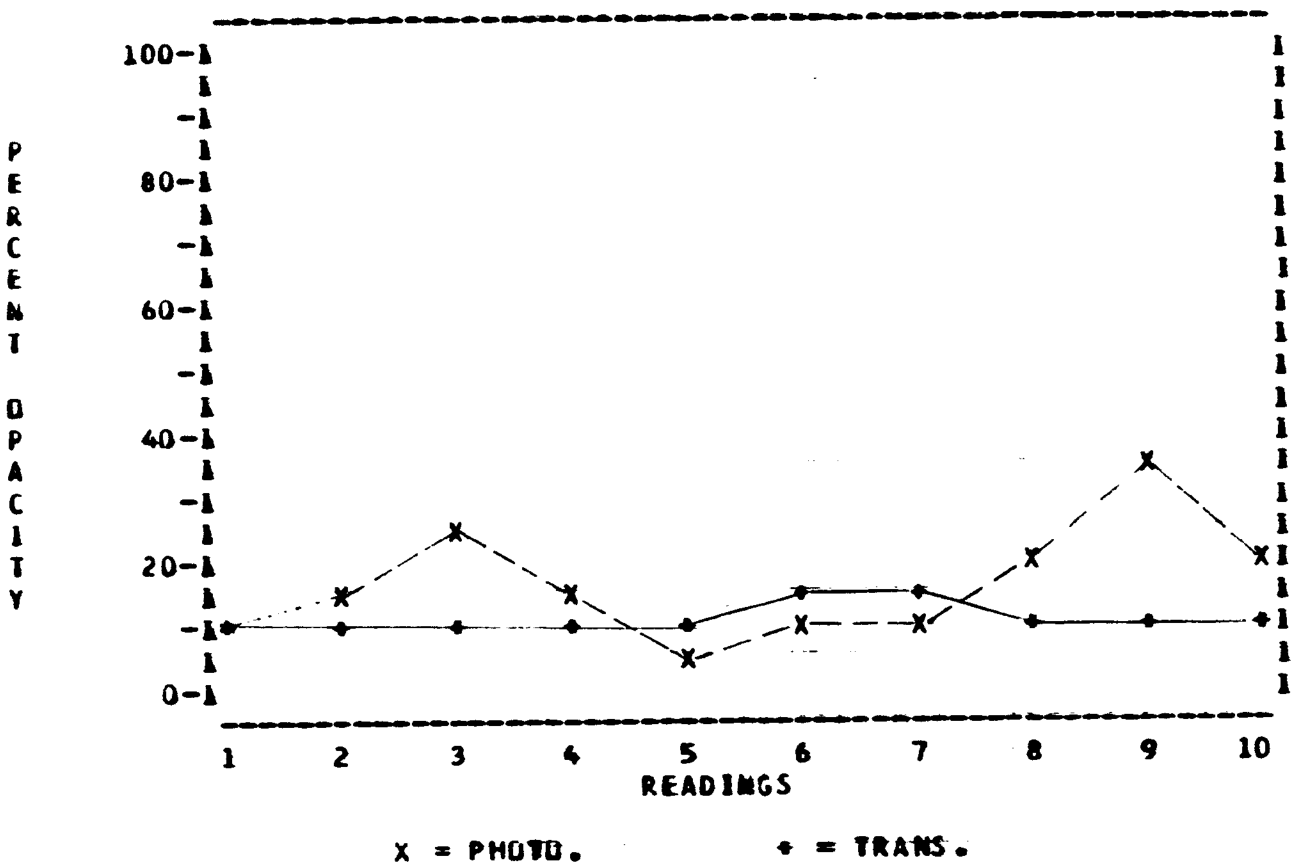
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
94.0	77.0	72.0	92.0	24.0	15.0	12.2
86.0	76.0	72.0	82.0	21.0	0.0	9.7
94.0	77.0	72.0	92.0	26.0	15.0	13.8
93.0	75.0	70.0	94.0	23.0	25.0	11.4
90.0	73.0	70.0	87.0	22.0	0.0	10.5
86.0	76.0	70.0	82.0	25.0	16.7	13.0
91.0	76.0	70.0	90.0	23.0	25.0	11.4
92.0	72.0	70.0	90.0	22.0	0.0	10.5
90.0	71.0	69.0	87.0	22.0	-5.6	10.5
92.0	73.0	70.0	93.0	22.0	17.4	10.5



X = PHOTO. + = TRANS.

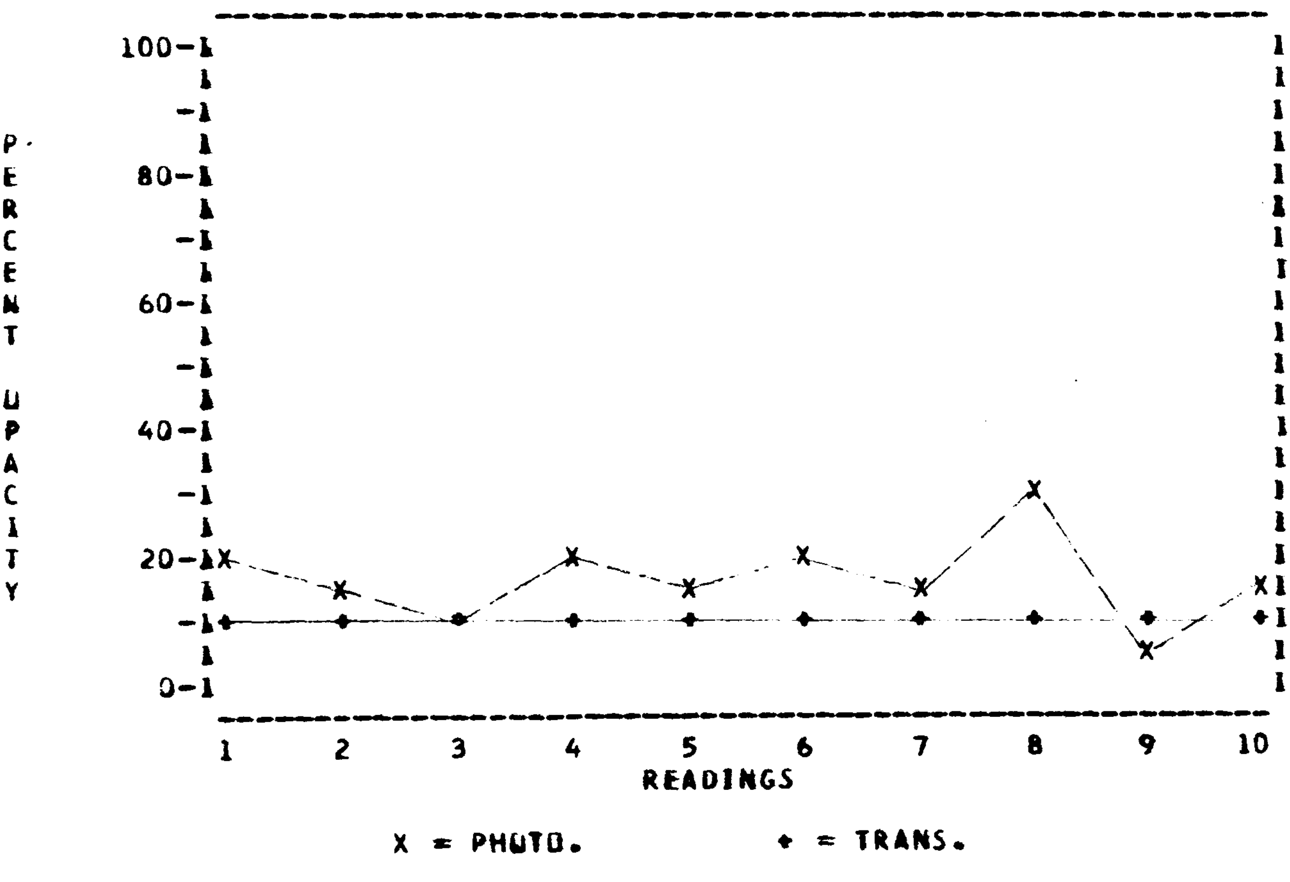
NO.6 DATE 8/22/74 TIME 11:49 - 11:51.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
89.0	70.0	68.0	89.0	22.0	9.5	10.5
84.0	70.0	67.0	83.0	22.0	12.5	10.5
84.0	65.0	61.0	86.0	21.0	24.0	9.7
85.0	70.0	66.0	84.0	22.0	16.7	10.5
85.0	66.0	64.0	84.0	24.0	5.0	12.2
82.0	67.0	65.0	82.0	25.0	11.8	13.0
83.0	65.0	64.0	84.0	26.0	10.0	13.8
81.0	63.0	62.0	84.0	23.0	18.2	11.4
78.0	65.0	62.0	82.0	24.0	35.0	12.2
80.0	64.0	62.0	82.0	24.0	20.0	12.2



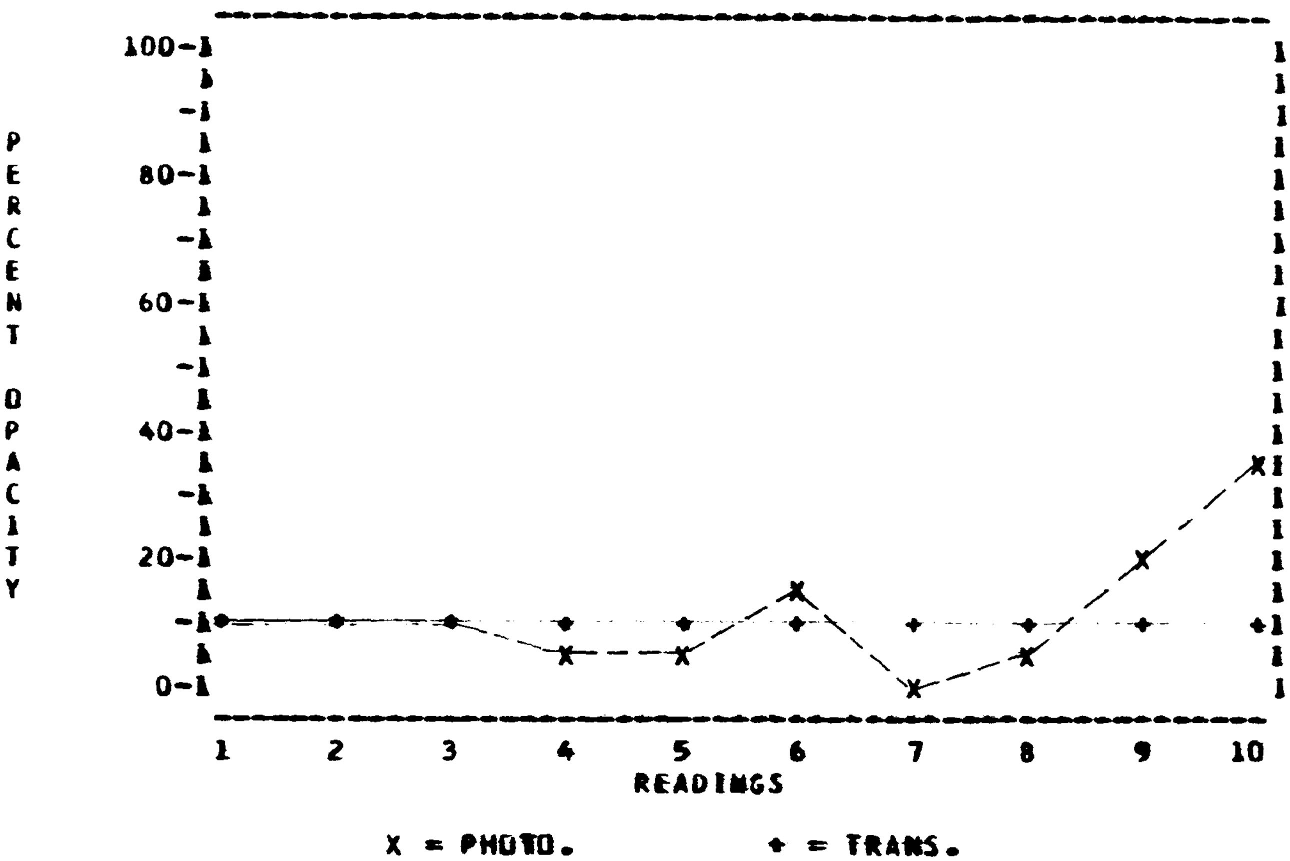
NO.7 DATE 8/22/74 TIME 11:52 - 11:54.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
80.0	66.0	65.0	82.0	22.0	17.6	10.5
84.0	66.0	64.0	85.0	24.0	14.3	12.2
84.0	66.0	64.0	84.0	22.0	10.0	10.5
83.0	66.0	62.0	83.0	24.0	19.0	12.2
84.0	69.0	64.0	82.0	22.0	16.7	10.5
86.0	70.0	64.0	84.0	23.0	20.0	11.4
84.0	68.0	64.0	83.0	24.0	15.8	12.2
81.0	68.0	61.0	79.0	22.0	27.8	10.5
80.0	65.0	60.0	76.0	22.0	6.3	10.5
78.0	65.0	61.0	76.0	22.0	13.3	10.5



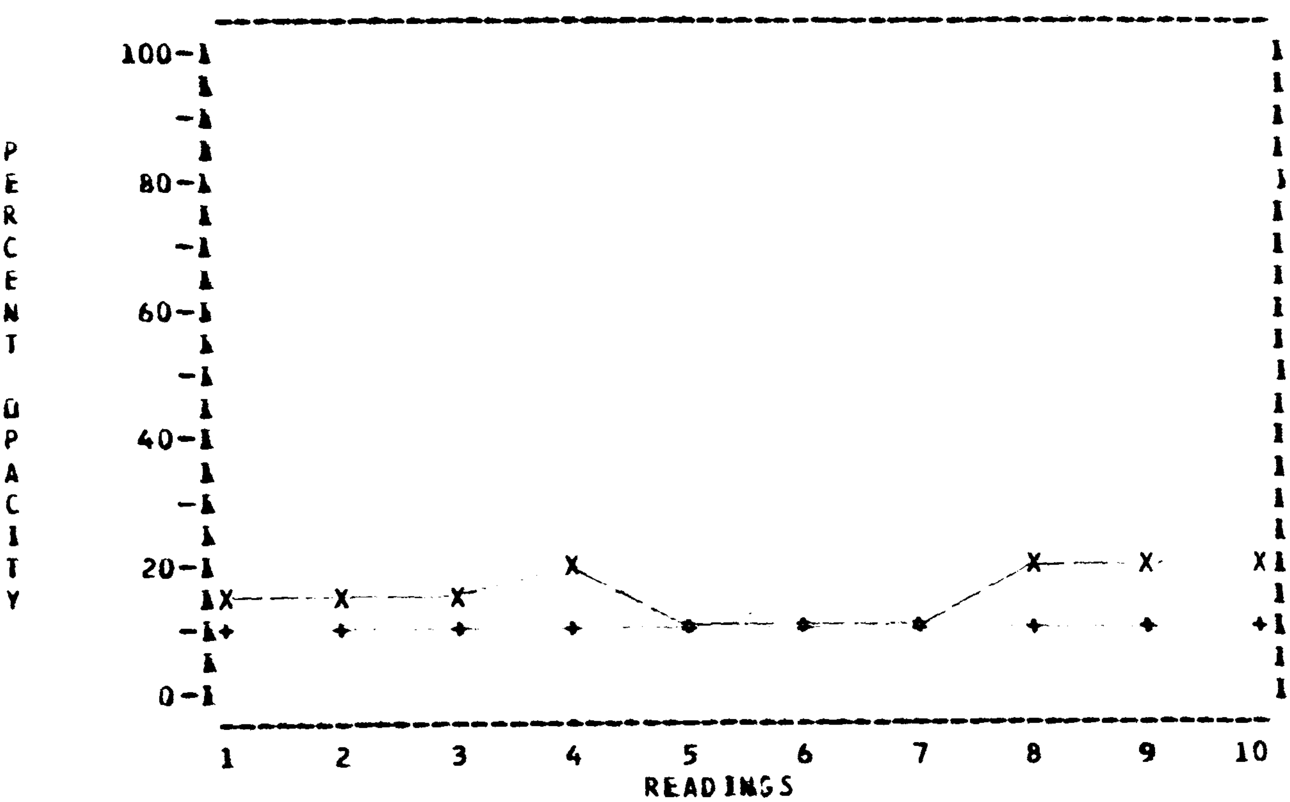
NO.8 DATE 8/22/74 TIME 11:55 - 11:57.5 AM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
81.0	65.0	61.0	79.0	21.0	11.1	9.7
80.0	64.0	62.0	80.0	22.0	11.1	10.5
81.0	64.0	61.0	80.0	22.0	10.5	10.5
79.0	63.0	60.0	77.0	22.0	5.9	10.5
80.0	65.0	62.0	78.0	22.0	6.3	10.5
81.0	66.0	62.0	80.0	20.0	16.7	8.9
81.0	66.0	62.0	77.0	20.0	0.0	8.9
82.0	64.0	62.0	81.0	21.0	5.3	9.7
78.0	64.0	61.0	79.0	21.0	22.2	9.7
79.0	65.0	61.0	82.0	22.0	33.3	10.5



NO.9 DATE 8/22/74 TIME 1:50 - 1:52.5 PM PORTLAND CEMENT PLANT

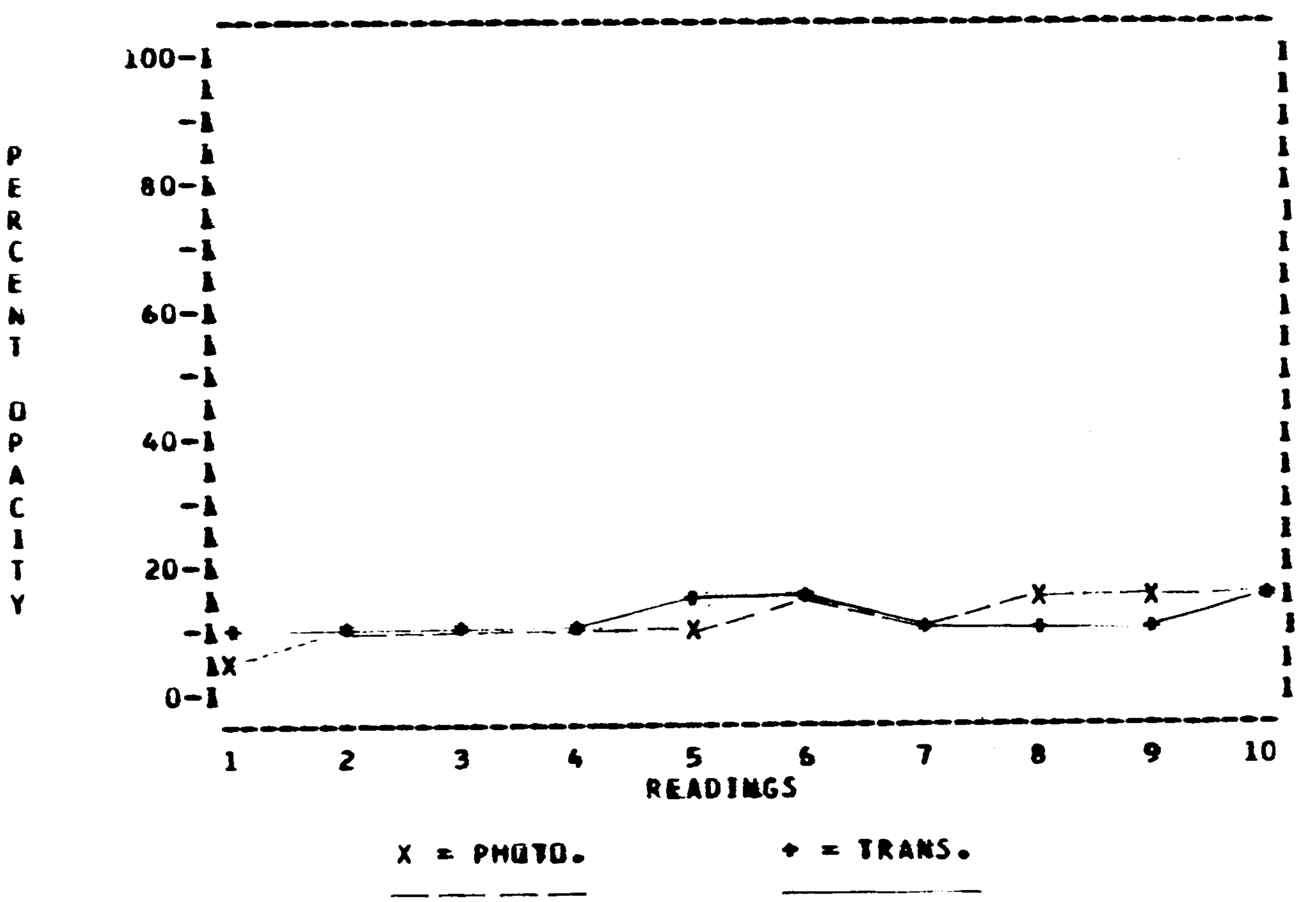
SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
88.0	63.0	58.0	88.0	22.0	16.7	10.5
88.0	62.0	58.0	88.0	21.0	13.3	9.7
88.0	64.0	59.0	88.0	21.0	17.2	9.7
89.0	66.0	59.0	88.0	22.0	20.7	10.5
89.0	64.0	60.0	88.0	22.0	10.7	10.5
90.0	64.0	60.0	89.0	23.0	10.3	11.4
88.0	60.0	59.0	90.0	24.0	9.7	12.2
88.0	63.0	59.0	90.0	24.0	19.4	12.2
88.0	63.0	59.0	90.0	23.0	19.4	11.4
89.0	62.0	58.0	91.0	22.0	18.2	10.5



X = PHOTO. + = TRANS.

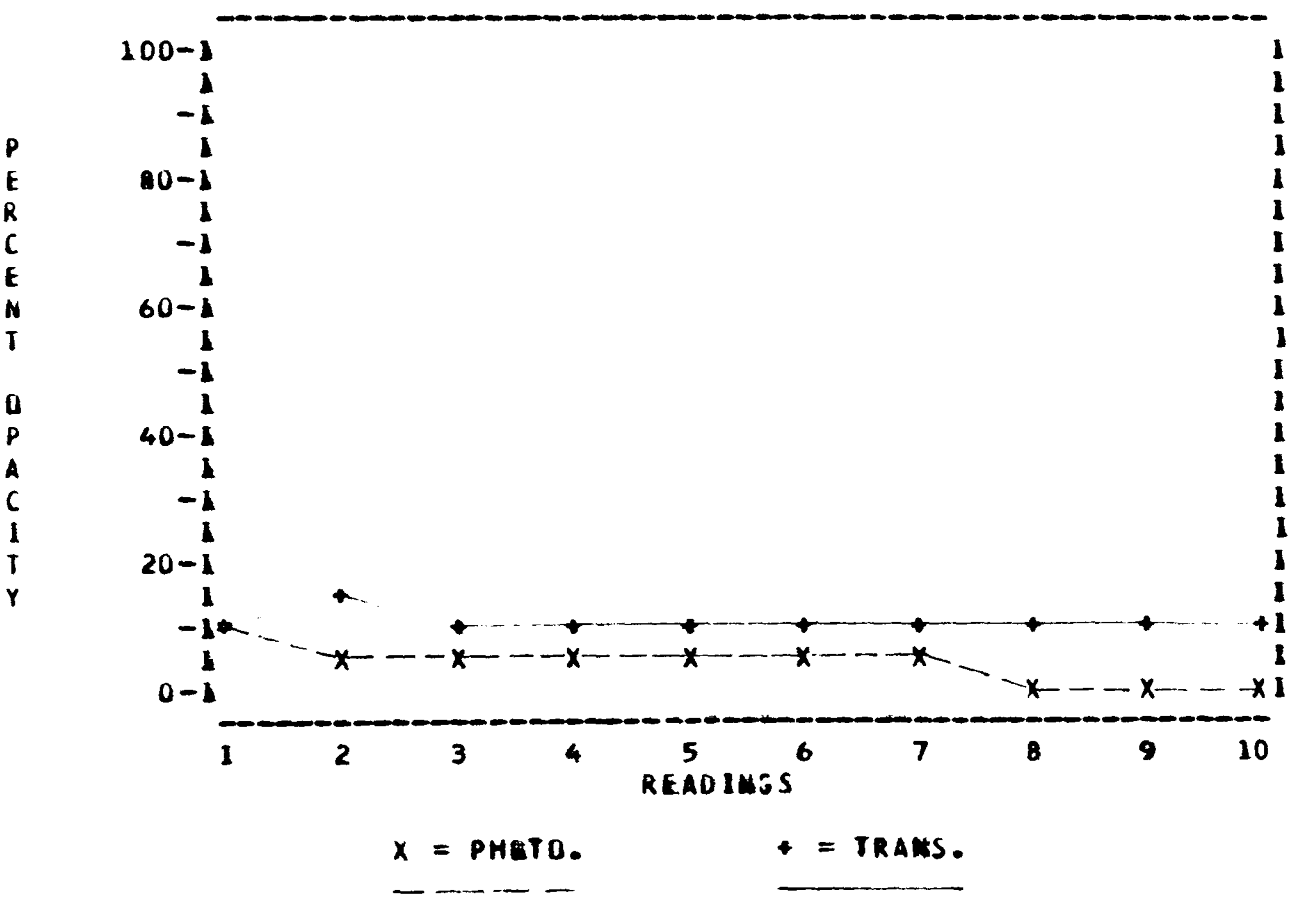
NO.10 DATE 8/22/74 TIME 1:53 - 1:55 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
91.0	60.0	57.0	90.0	24.0	6.1	12.2
88.0	58.0	56.0	90.0	23.0	11.8	11.4
87.0	57.0	56.0	90.0	23.0	11.8	11.4
87.0	58.0	56.0	89.0	24.0	12.1	12.2
87.0	57.0	56.0	89.0	26.0	9.1	13.8
87.0	58.0	56.0	91.0	30.0	17.1	16.9
87.0	58.0	58.0	91.0	24.0	12.1	12.2
87.0	58.0	57.0	91.0	23.0	14.7	11.4
87.0	60.0	58.0	90.0	24.0	15.6	12.2
89.0	62.0	59.0	91.0	27.0	15.6	14.6



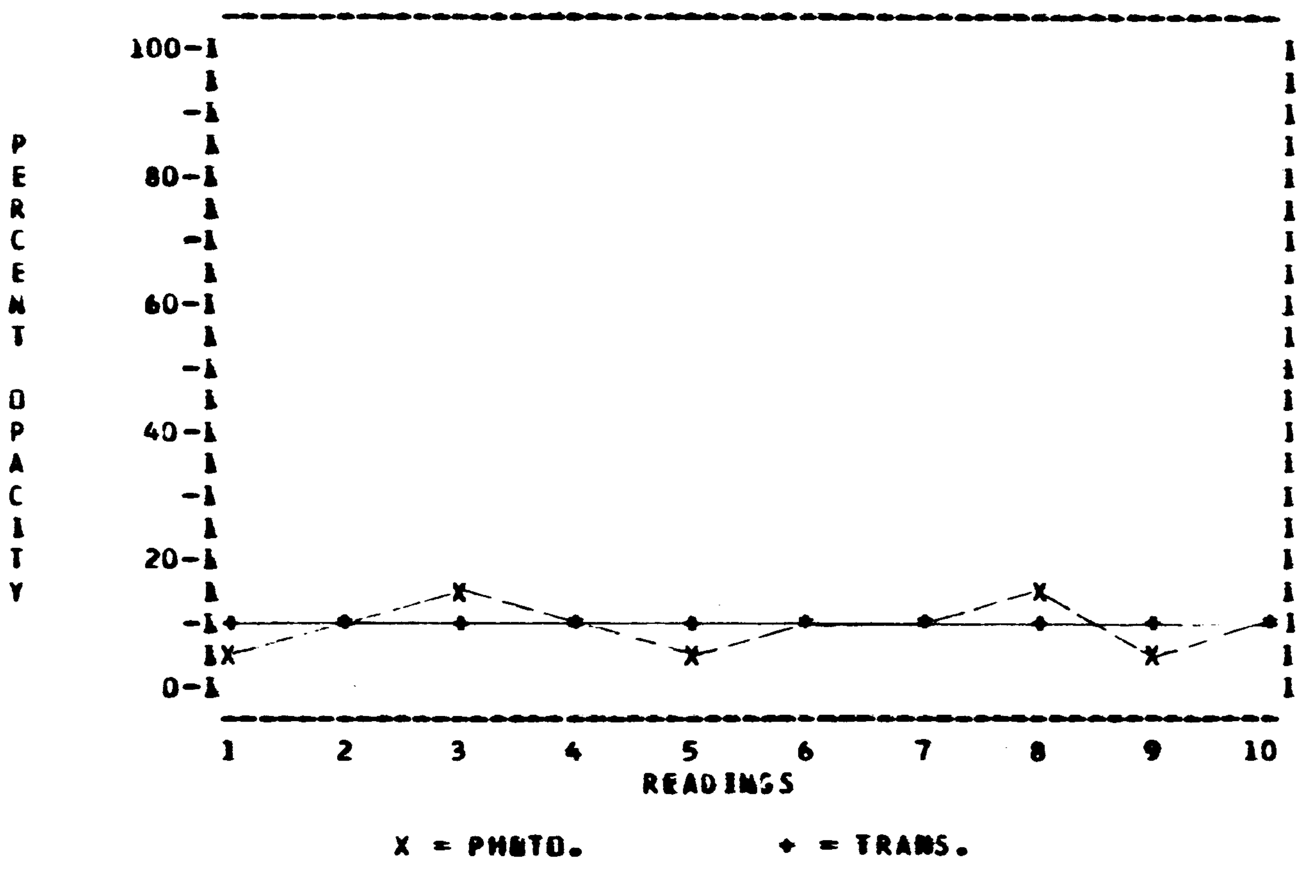
NO.11 DATE 8/22/74 TIME 1:56 - 1:58 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	60.0	58.0	91.0	21.0	9.1	9.7
88.0	58.0	58.0	90.0	26.0	6.3	13.8
88.0	59.0	59.0	90.0	21.0	6.5	9.7
89.0	60.0	60.0	90.0	24.0	3.3	12.2
88.0	59.0	59.0	89.0	23.0	3.3	11.4
88.0	59.0	59.0	89.0	22.0	3.3	10.5
89.0	61.0	61.0	90.0	22.0	3.4	10.5
91.0	64.0	64.0	91.0	22.0	0.0	10.5
91.0	64.0	64.0	91.0	22.0	0.0	10.5
92.0	66.0	66.0	92.0	22.0	0.0	10.5



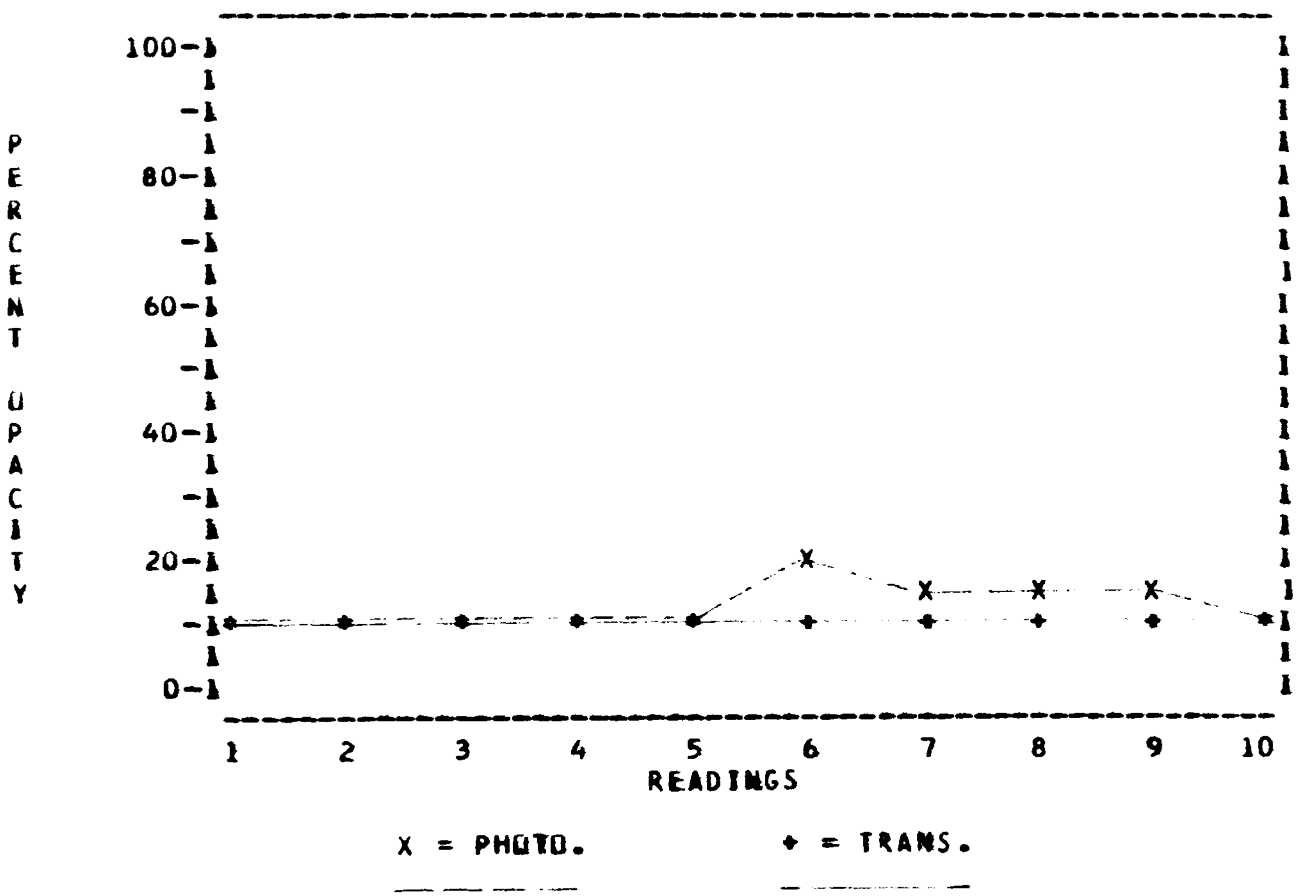
NO.12 DATE 8/22/74 TIME 1:59 - 2:01 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
91.0	61.0	58.0	90.0	22.0	6.3	10.5
88.0	60.0	58.0	89.0	23.0	9.7	11.4
89.0	61.0	57.0	89.0	23.0	12.5	11.4
90.0	61.0	56.0	89.0	22.0	12.1	10.5
90.0	59.0	56.0	89.0	23.0	6.1	11.4
88.0	59.0	56.0	88.0	21.0	9.4	9.7
88.0	59.0	55.0	87.0	21.0	9.4	9.7
86.0	59.0	53.0	85.0	21.0	15.6	9.7
84.0	57.0	52.0	80.0	24.0	3.6	12.2
81.0	56.0	51.0	79.0	21.0	10.7	9.7



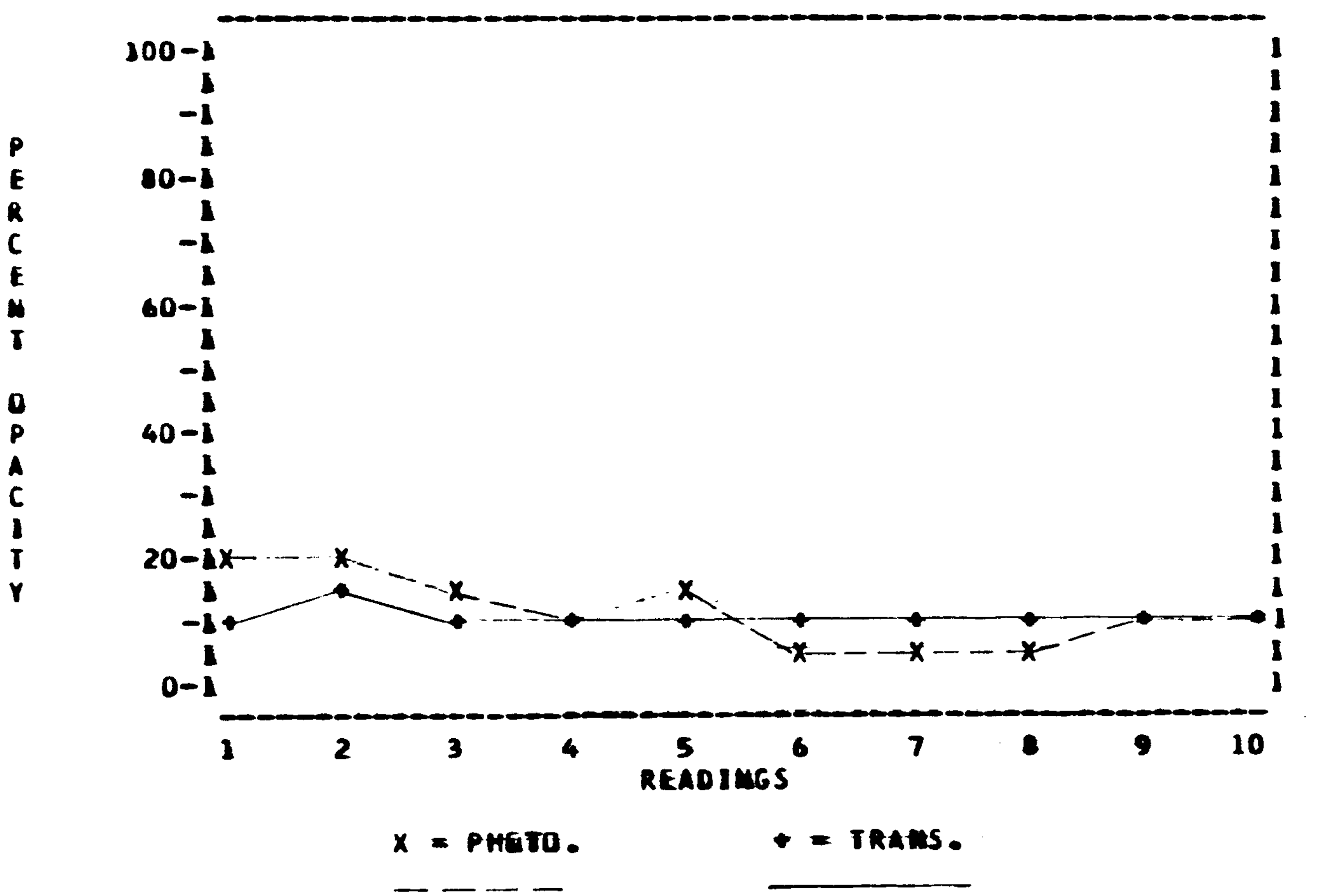
NO.13 DATE 8/22/74 TIME 2:02 - 2:04.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
87.0	62.0	57.0	85.0	24.0	10.7	12.2
87.0	62.0	57.0	85.0	24.0	10.7	12.2
87.0	62.0	57.0	85.0	22.0	10.7	10.5
84.0	59.0	53.0	81.0	21.0	10.7	9.7
81.0	59.0	54.0	79.0	22.0	12.0	10.5
80.0	61.0	53.0	77.0	22.0	20.8	10.5
78.0	59.0	55.0	78.0	21.0	17.4	9.7
78.0	58.0	54.0	78.0	22.0	16.7	10.5
81.0	61.0	57.0	80.0	22.0	13.0	10.5
84.0	58.0	56.0	85.0	22.0	10.3	10.5



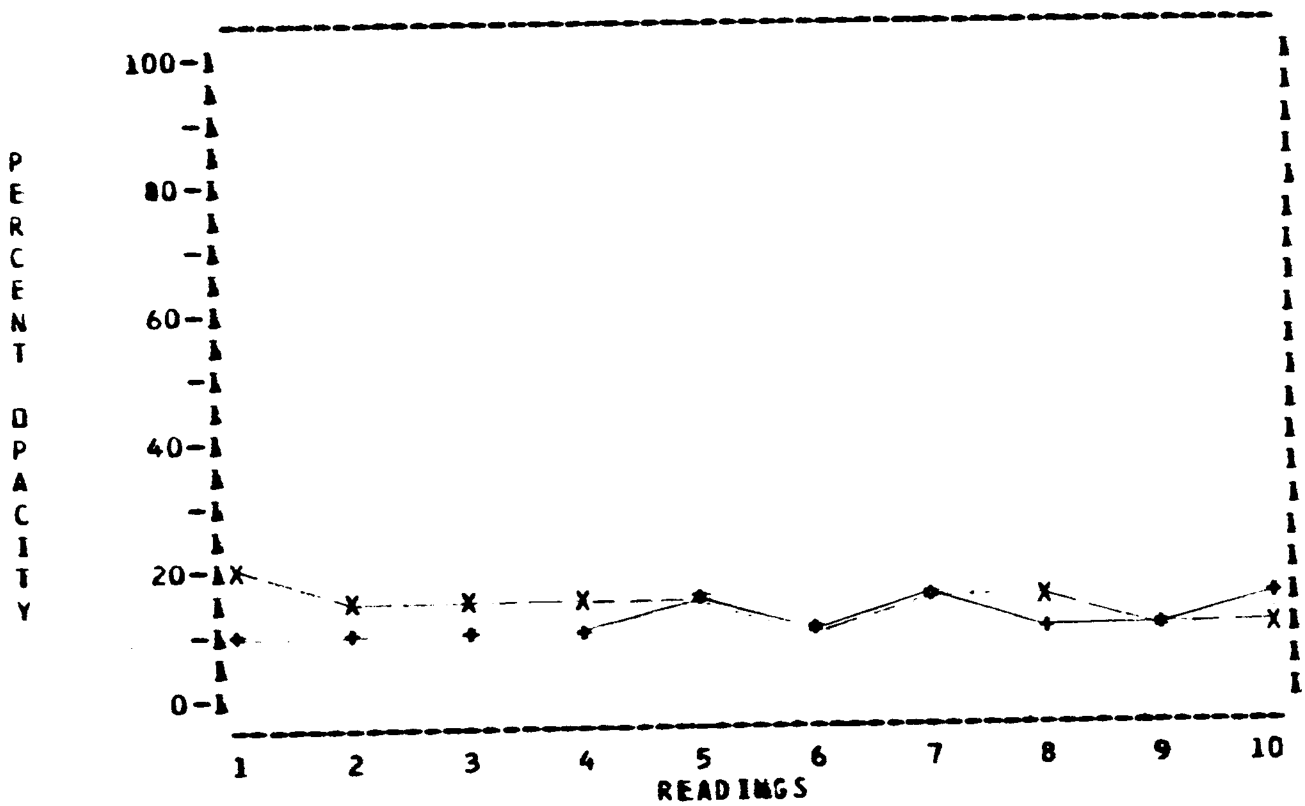
NO.14 DATE 8/22/74 TIME 2:24 - 2:26.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	67.0	63.0	91.0	24.0	17.9	12.2
90.0	67.0	62.0	90.0	25.0	17.9	13.0
90.0	67.0	63.0	90.0	23.0	14.8	11.4
90.0	67.0	63.0	89.0	22.0	11.5	10.5
89.0	65.0	61.0	89.0	24.0	14.3	12.2
87.0	61.0	61.0	89.0	22.0	7.1	10.5
85.0	60.0	60.0	87.0	24.0	7.4	12.2
84.0	59.0	59.0	86.0	22.0	7.4	10.5
83.0	59.0	59.0	86.0	22.0	11.1	10.5
83.0	59.0	60.0	86.0	24.0	7.7	12.2



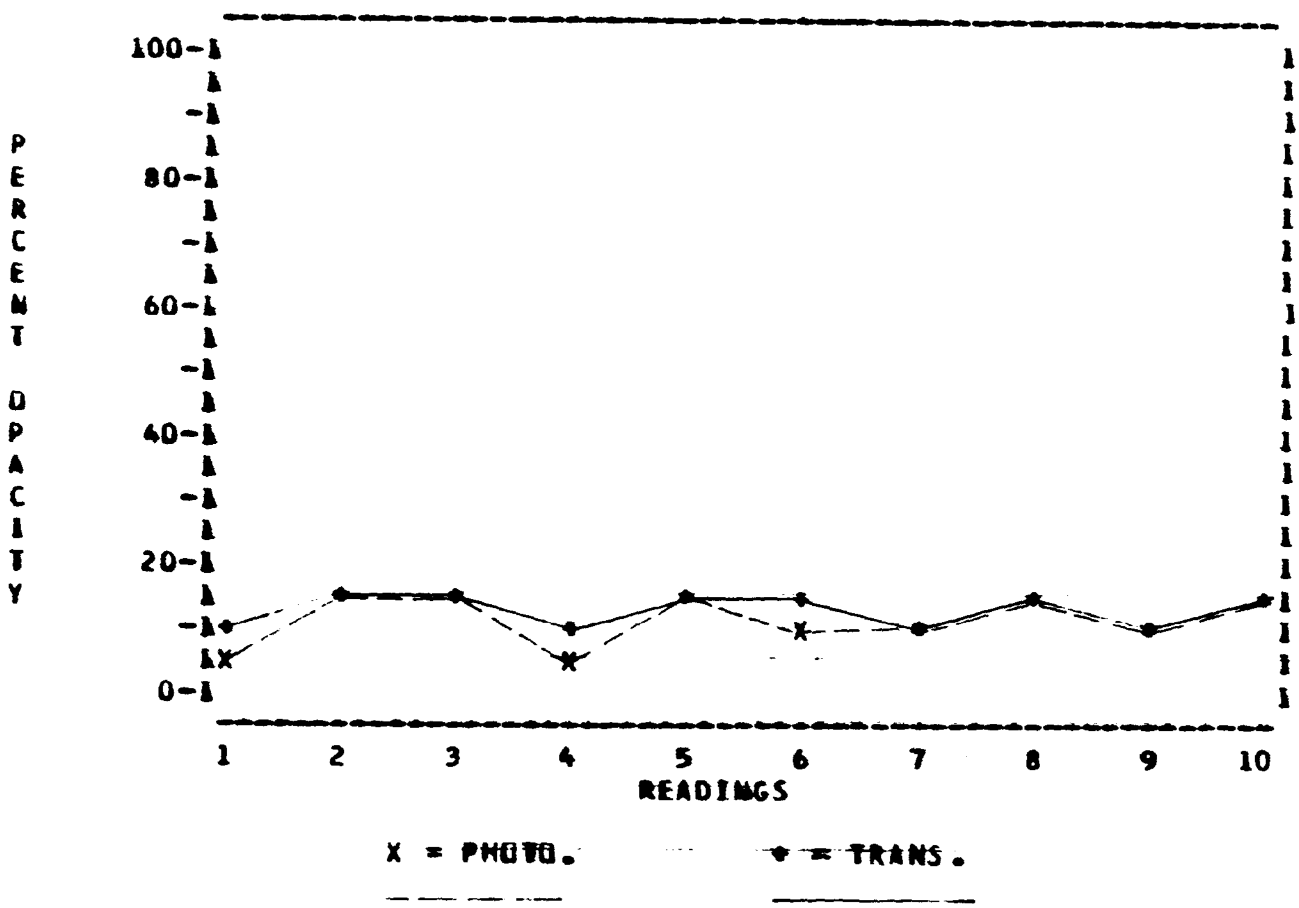
NO.15 DATE 8/22/74 TIME 2:27 - 2:29.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
83.0	60.0	59.0	87.0	24.0	17.9	12.2
84.0	59.0	59.0	88.0	24.0	13.8	12.2
84.0	59.0	59.0	88.0	23.0	13.8	11.4
83.0	59.0	59.0	88.0	24.0	17.2	12.2
82.0	56.0	56.0	86.0	25.0	13.3	13.0
80.0	57.0	57.0	82.0	23.0	8.0	11.4
82.0	56.0	56.0	86.0	26.0	13.3	13.8
78.0	55.0	55.0	82.0	24.0	14.8	12.2
79.0	56.0	56.0	82.0	24.0	11.5	12.2
82.0	57.0	56.0	84.0	28.0	10.7	15.4



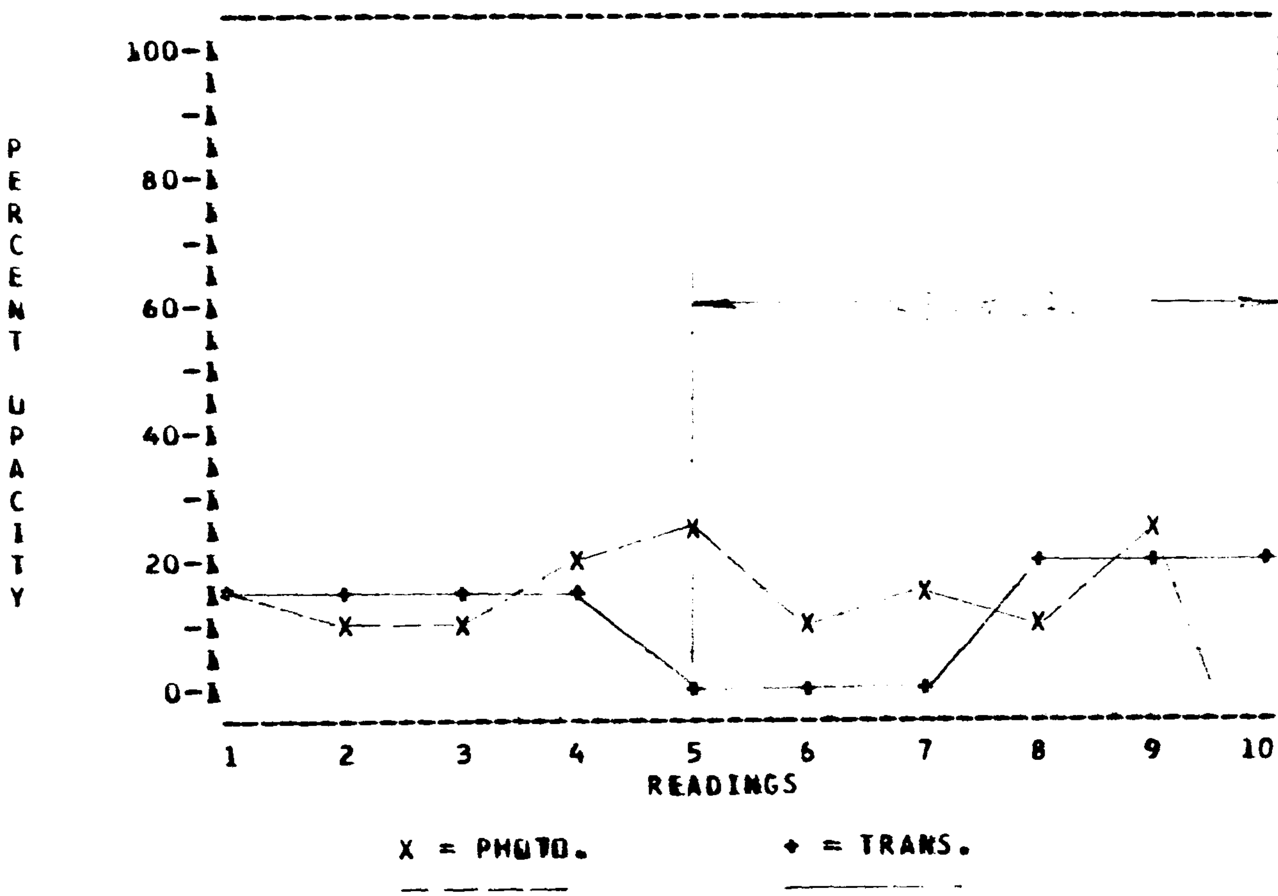
NO.16 DATE 8/22/74 TIME 2:30 - 2:32.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
86.0	59.0	59.0	88.0	24.0	6.9	12.2
86.0	60.0	58.0	88.0	25.0	13.3	13.0
87.0	63.0	60.0	88.0	26.0	14.3	13.8
87.0	61.0	60.0	88.0	24.0	7.1	12.2
87.0	63.0	60.0	88.0	25.0	14.3	13.0
88.0	63.0	61.0	89.0	25.0	10.7	13.0
88.0	63.0	61.0	89.0	24.0	10.7	12.2
88.0	64.0	61.0	89.0	25.0	14.3	13.0
89.0	64.0	62.0	90.0	24.0	10.7	12.2
89.0	65.0	61.0	90.0	25.0	17.2	13.0



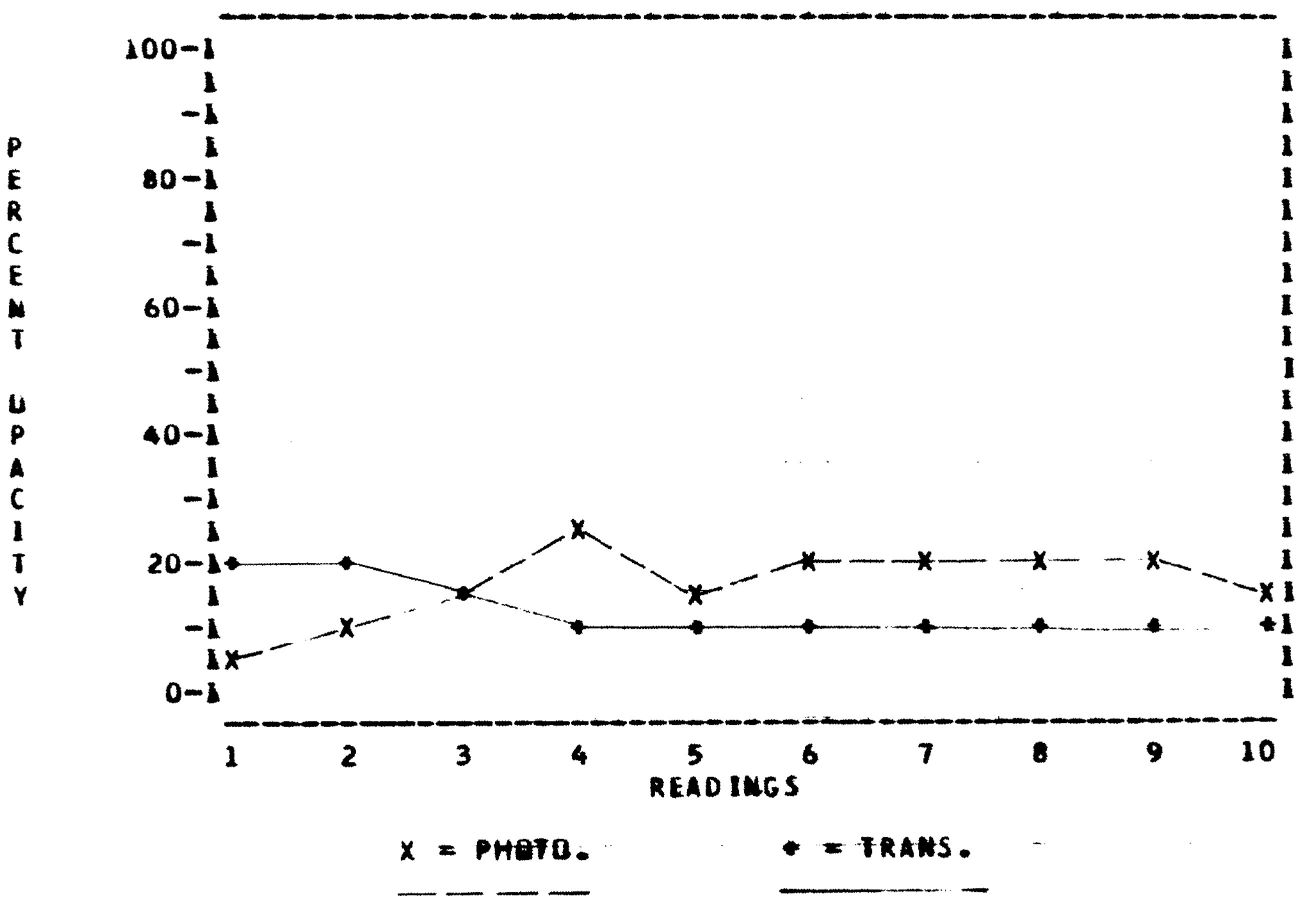
NO.17 DATE 8/22/74 TIME 2:33 - 2:35.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
90.0	65.0	62.0	91.0	25.0	13.8	13.0
90.0	65.0	62.0	90.0	26.0	10.7	13.8
90.0	65.0	62.0	90.0	26.0	10.7	13.8
89.0	66.0	62.0	91.0	25.0	20.7	13.0
90.0	68.0	61.0	90.0	10.0	24.1	0.0
89.0	64.0	62.0	90.0	10.0	10.7	0.0
89.0	65.0	62.0	91.0	10.0	17.2	0.0
89.0	64.0	62.0	90.0	34.0	10.7	20.0
89.0	68.0	62.0	90.0	34.0	25.0	20.0
89.0	64.0	62.0	86.0	34.0	-4.2	20.0



NO.19 DATE 8/22/74 TIME 2:39 - 2:41.5 PM PORTLAND CEMENT PLANT

SKY THRU PLUME	TARGET PLUME	TARGET W/O	SKY W/O	CHART	OPACITY PHOTO.	OPACITY TRANS.
83.0	57.0	58.0	86.0	34.0	7.1	20.0
83.0	58.0	58.0	86.0	34.0	10.7	20.0
84.0	60.0	57.0	86.0	26.0	17.2	13.8
84.0	64.0	59.0	86.0	23.0	25.9	11.4
85.0	62.0	59.0	86.0	23.0	14.8	11.4
85.0	62.0	59.0	87.0	24.0	17.9	12.2
86.0	63.0	59.0	88.0	24.0	20.7	12.2
87.0	64.0	60.0	88.0	23.0	17.9	11.4
87.0	64.0	59.0	87.0	24.0	17.9	12.2
88.0	65.0	61.0	88.0	23.0	14.8	11.4



TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-650/2-75-008	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE IN-STACK TRANSMISSOMETER EVALUATION AND APPLICATION TO PARTICULATE OPACITY MEASUREMENT		5. REPORT DATE January 1975
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Edward D. Avetta		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Fecker Systems Owens-Illinois, Inc. 4709 Baum Blvd. Pittsburgh, Pa. 15213		10. PROGRAM ELEMENT NO. 1AA010
		11. CONTRACT/GRANT NO. 68-02-0660
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15. SUPPLEMENTARY NOTES

16. ABSTRACT

A laboratory and field testing program has been carried out to investigate the performance of a commercially available transmissometer as an in-situ monitor of industrial exhaust stack emissions. During the laboratory phase the characteristics and operating perameters of the instrument were measured and the system calibrated for field use. The transmissometer was mounted for a period of at least 30 days at each of three different sites. At each site concurrent plume opacity measurements were made by the telephotometry of contrasting targets through the plumes for comparison to the in-stack readings with the transmissometer. Additional plume measurements were made at one of the sites by direct telephotometry of a lamp behind the plume.

A one-to-one correlation between in-stack and plume opacity was observed at one site but data obtained at the other two sites were limited to much narrower ranges of emission levels although there was also a one-to-one correlation within the narrower range at one of the other sites. The transmissometer performed well at all three sites.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Opacity Transmissometer Visible Emissions Telephotometer Particular Emissions		

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