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BACKGROUND INFORMATION FOR AN OPACITY STANDARD OF PERFORMANCE FOR BASIC OXYGEN PROCESS FURNACES IN IRON AND STEEL PLANTS

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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Emission Standards and Engineering Division

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This document does not constitute a general endorsement of supplementary control systems as a control alternative. It is intended only to assist the responsible control agencies in those limited situations where legislation, EPA or the courts permit its use.

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SUMMARY

Proposed Amendment

On March 8, 1974 (39 FR 9308), under the authority of section 111 of the Clean Air Act, as amended, EPA promulgated a standard of performance limiting particulate matter emissions from Basic Oxygen Process Furnaces (BOPFs) to less than 50 mg/dscm (0.022 gr/dscf). An opacity standard was not promulgated due to unexplained variations in opacities from well controlled facilities. This report presents the background information and the rationale for the proposed opacity standard for BOPF facilities.

EPA establishes opacity standards in conjunction with mass or concentration standards as a means of ensuring that control equipment is adequately maintained and properly operated at all times between performance tests. Opacity standards for each class of sources are established at levels which are not more restrictive than the corresponding concentration/mass standards and which consider the effect of the normal range of operating variables on opacity. The proposed standard is based on 73 hours of opacity observations taken in accordance with Reference Method 9 and consideration of known process variations. The proposed opacity standard limits emissions to less than 10 percent opacity except emissions up to 20 percent opacity are allowed once per steel production cycle. A limitation on peak emissions during the cycle in addition to the baseline emissions is

necessary because of variations in gas density over the operation cycle and the lag in response of control systems.

Economic and Environmental Impacts

The proposed opacity standard and the monitoring of operations requirements do not impose any additional significant requirements or costs over those required to comply with the concentration standard. Therefore, the proposed opacity standard does not have a major inflationary impact and no inflation impact statement has been prepared. Any environmental impacts or benefits of the standard of performance for BOPF also are incurred in complying with the concentration standard. During the development of the concentration standard, the intermedia effects of the standard were assessed and determined to be negligible. No additional intermedia effects would be incurred in complying with the opacity standard. Therefore, a formal environmental impact statement has not been prepared. The environmental impact of the proposed opacity standard is beneficial, since the standard would ensure compliance of new BOPFs with the concentration standard throughout their operational life.

BACKGROUND

On June 11, 1973 (38 FR 15406), under the authority of section 111 of the Clean Air Act, as amended, the Environmental Protection Agency (EPA) proposed standards of performance for new basic oxygen process furnaces (BOPFs) in iron and steel plants. The proposed standards limited emissions of particulate matter to less than 50 mg/dscm (0.022 gr/dscf) and to less than 10 percent opacity except for two minutes in any one hour. On March 8, 1974 (39 FR 9308), EPA promulgated the standard of performance limiting emissions from new BOPFs to less than 50 mg/dscm (0.022 gr/dscf), but the opacity standard and the attendant continuous monitoring requirement were not promulgated at that time. The opacity standard was reserved pending study of (1) the reasons for observed variations in the opacity of emissions from well-controlled facilities and (2) the effect that exemption of periods of startup, shutdown, and malfunction from opacity standards would have on the level of the opacity standard and the need for a time exemption.

On November 12, 1974 (39 FR 39872), EPA revised Reference Method 9 and the general provisions applicable to standards of performance. These revisions resulted from a study of the errors associated with single observations made by qualified observers while reading smoke plumes according to the prescribed procedures. It was shown in this study that qualified observers can determine plume opacities with maximum positive errors of less than 7.5 percent based on the average of 24 consecutive readings. Accordingly, Reference Method 9 was revised to require that opacity observations be recorded to the nearest five percent at 15-second intervals with a minimum of 24 observations. The minimum time over which opacity observations are made was extended to six minutes to obtain sufficient observations to ensure acceptable accuracy. The use of sets of opacity observations (or six-minute average opacity values) precludes a single high reading from being cited as a violation. In addition, §60.11(e) was added to the general provisions to provide a means for an owner or operator to petition EPA to obtain a higher opacity standard for any facility that demonstrates compliance with the mass standard concurrent with failure to attain the opacity standard. The provisions of §60.11(e) allow opacity standards to be established at levels which reflect the maximum expected effects of the normal range of operating variables and stack diameters at well-controlled new facilities.

The study to determine the appropriate level of an opacity standard (consistent with the revisions to Method 9) for new BOPFs considered the following factors:

1. Determination of opacity levels indicative of proper operation and maintenance of a well-controlled facility.

2. The effects on opacity of process variations and any resultant variations in the performance of the control devices.

3. Definition of startup for BOPFs.

PROCESS AND EMISSION CONTROL SYSTEMS

The basic oxygen process for production of steel uses high pressure oxygen to oxidize and remove carbon, silicon, and other undesirable elements from molten iron and scrap steel. The furnace operation is cyclic and the time required for a complete steel production cycle is typically 45 minutes, but can range from about 30 to 75 minutes due to variations in shop operating conditions. The steel production cycle for a BOPF includes five basic operations: (1) charging of scrap and hot metal, (2) oxygen blowing, (3) testing, (4) tapping, and (5) slagging.

Generally the material charged to the BOPF consists of 10-30 percent scrap and 90 to 70 percent molten pig iron. These relative proportions are used so that the heat generated by oxidation of carbon, silicon, and manganese plus the sensible heat from the molten pig iron provides sufficient energy to melt all the scrap and to raise the metal to the correct temperature for tapping. Charging of scrap and molten pig iron requires only a few minutes. Just after initiation of oxygen blowing and at intervals as necessary, slag forming flux materials (lime, limestone, fluorospar etc.) are added to the vessel to remove undesirable elements such as sulfur, phosphorus, manganese etc.

After the vessel is charged, high purity oxygen is blown into the charge materials either from above the molten charge using a lance or from below through tuyeres. Oxygen is blown generally for about 18-20 minutes[1,2], but due to variations in conditions (including scrap quality) and process used the blowing period can vary from approximately 13 to 26 minutes in duration. The gases emitted from the furnace primarily consist of CO and CO_2 from oxidation of carbon in the metal and oxygen derived from iron oxides. The evolution rate of these gases and attendent iron oxide fume varies greatly over the entire blowing period.

After blowing of oxygen for a specified period, a sample of the metal is taken for analysis. If the metal is not of correct composition, additional oxygen is blown for a short time period. If the steel is of correct composition, the vessel is tapped. Tapping of the BOPF is simply the pouring of molten metal from the vessel into a ladle.

The final operation, slagging, is the removal of slag from the vessel after completion of a tap and before the vessel is charged again. Slag is the fused product formed by the reaction of the flux materials with impurities in the metal. Because slag is of lower density than the metal, the slag floats on top of the molten metal bath and the metal can be tapped from below the slag.

The fume generation rate in the basic oxygen process is dependent on a number of factors such as: the oxygen blow rate, carbon content of iron, percentage of scrap charged, quality of scrap charged, rate of additions, and condition of the refractory lining of the vessel. Over the production cycle the gas evolution rate and gas temperature vary considerably. Due to the resultant variations in the concentration of particulate matter, gas temperature and gas volume in the inlet gas stream, emissions will be greater in the beginning of the blowing period than during the remainder of the oxygen blow and the rest of the cycle.

Particulate matter emissions from BOPFs are produced primarily by refractory erosion and by condensation of vaporized metal oxides and coagulation of these particles to form agglomerates. Thus, BOPF particulate matter emissions consist mainly of spherical or agglomerates of spherical particles of similar properties. The mass mean diameter of emissions from top blown BOPFs has been reported to vary from 0.5 to 1.0 micrometer.[4,5,6] Emissions from bottom blown BOPFs are smaller and are generally estimated to be around 0.1 micrometer diameter. From light scattering theory it is expected that emissions from bottom blown BOPFs will scatter more light than an equivalent quantity of particulate matter emitted by a tap blown BOPF. However, opacities of plumes from bottom blown BOPF facilities should not be significantly higher than those from top blown facilities due to the smaller gas volumes evolved from tightly hooded bottom blown vessels.

The analysis of the opacity data for electrostatic precipitator-controlled BOPFs operating within the expected range of variables indicated that emissions will be less than 35 percent opacity during the start of oxygen blowing and less than 20 percent during the rest of the cycle. These emission limitations were determined on the basis of an engineering judgment of the performance of the control systems since none of the opacity observations were made concurrently with the concentration measurements. The judgment of the systems' performance is based on an evaluation of the maintenance and operating conditions of the control system by EPA engineers at the time of the Method 9 observations and a comparison with opacity observations at poorly maintained or malfunctioning facilities. Even a precipitator with one sixth of the necessary plate area out of service could control emissions to no greater than 40 percent opacity during oxygen blowing and no greater than 21 percent during the rest of the cycle.

EPA's opacity study of BOPF facilities finds that those facilities which preheat scrap before the addition of hot metal to the vessel exhibit the highest opacity emissions during the preheat period with lower peak emissions occurring during the oxygen blow. The maximum opacity and the opacity levels associated with the remainder of the cycle are related to the degree of emission reduction achieved over the cycle and the stability of the gas temperature in the system. At facilities which operate the BOPF vessels with overlapping production cycles, the gas temperatures and volumes are maintained more uniformly near the peak values and hence peak opacity levels are expected to be lower; but typical baseline opacity levels also are expected to be higher than those for facilities operating each vessel with a separate production cycle.

The standard of performance, 50 mg/dscm, can be achieved by use of any of three basic types of emission control systems[2]: (1) open hood with a high-energy venturi scrubber, (2) open hood with an electrostatic precipitator, and (3) closed hood with a high-energy venturi scrubber. Most new basic oxygen process furnaces are expected to be designed with tight fitting combustion hoods and to use scrubbers for control of emissions to the atmosphere. The trend is toward this type process emission control system to reduce energy costs of the gas cleaning system.

Open hoods on BOPFs are generally located at a distance of 0.46 to 0.91 meter (1.5 to 3 feet) above the vessel rim. As a result of this separation between the vessel and the base of the collection hood, excess air is drawn into the control system. Depending on the amount of the separation the gas volume from open hooded BOPFs will be 4.7 to 6.7 times greater than gas volumes from similar closed hooded BOPFs.[1] Consequently, BOPFs with open hood control systems can be expected to have larger diameter stacks for discharge of emissions to the atmosphere than BOPFs with closed or tightly hooded control systems. Therefore, BOPFs with closed hood control systems were expected to exhibit lower opacities because the smaller the stack diameter, the smaller the length of the path through which light is attenuated before it reaches the observer.

DATA BASE FOR OPACITY STANDARD

Opacity observations for support of an opacity standard were obtained at six well-controlled facilities. A total of 73 hours of valid observations were obtained. The six observed facilities are representative of typical new BOPF shops: that is, the vessel sizes were within the typical range of 91-318 Mg* (100-350 tons) capacity of steel per heat, both two vessel and three vessel shops were observed, and some shops used dirty scrap. Three of the observed facilities had control systems consisting of an open hood with electrostatic precipitator and three facilities had control systems consisting of an open hood with venturi scrubber. Emissions from facilities C and E had been previously tested by EPA and these data were part of the bases of the concentration standard. These facility's

*Mg (Megagram) is the recommended unit for large masses in the International System of Units (SI).

codes correspond to their codes in Technical Report No. 12 of Volume I of "Background Information for New Source Performance Standards: Asphalt Concrete Plants . . ." (APTD-1352a) which gives the bases of the concentration standard for BOPFs. In order to resolve the questions on the opacity standard raised by comments on the previously proposed opacity standard, facilities F, G, H, and I were observed after proposal of the standard (June 11, 1973).

The opacity observations at the six facilities were taken in accordance with the requirements of Method 9 as revised on November 12, 1974 (39 FR 39872). As required by Method 9 the opacity levels of the data were determined as the average of 24 consecutive observations taken at 15-second intervals. Since the sets of 24 observations may not overlap, there are 10 sets of 24 observations or 10 average opacity values in any sixty-minute period of observation. For this report, the opacity data from the five topblown vessels were grouped in sets of 24 consecutive observations starting with the first six-minutes of each clock hour defining the first set. This procedure provided a consistent method for data reduction without requiring synchronization of observer times with BOPF shop operating times or arbitrary assignment of observation periods with specific production cycles.* The opacity observations from the facility using bottom blown vessels were grouped in sets of 24 consecutive observations starting at the beginning of the production cycle.

Due to the frequent occurrence of condensed water vapor plumes at both scrubber and electrostatic precipitator-controlled facilities, not

*Calculation of maximum opacity levels for start of oxygen blow periods showed that there was no significant difference between results obtained by this approach and by the method of dividing each hour into 10 sets of 24 consecutive observations.

all of the observation periods resulted in data useful for establishment of an opacity standard. That is, opacities read at the point of dissipation of attached water vapor plumes are biased low due to dilution of the concentration of particulate matter in the plume below that at the stack exit. The opacity data discussed in this report and used as the basis of the opacity standard are only the six-minute average values for periods in which either no condensed water vapor plumes were present or when a detached plume was present. Thus, the opacity standard is based on the opacities of undiluted emissions and is not biased low due to interference from steam plumes. All the opacity values, including those observations made at the end of condensed water vapor plumes, are presented in the Appendix to this report.

In general, the observed emission patterns at the six well-controlled facilities showed the expected emission cycle of three to four minutes of high opacity emissions with decreasing opacity emissions throughout the remainder of the operation cycle. Each facility observed and a summary of the six-minute average opacity values of the non-steam plume emissions are discussed below.

Facility C consists of two open hooded BOPFs each with a capacity of 130 Mg (140 tons) of steel per heat. Emissions from these BOPFs are controlled by a single dry electrostatic precipitator which has a design collection efficiency of 99.85 percent. Previous emission tests conducted by EPA on this facility showed an average effluent concentration over the BOPF cycle of 16 mg/dscm (0.007 gr/dscf). Due to the greater actual gas volumes handled by open hood electrostatic precipitator control systems, emissions from these BOPFs are exhausted to the atmosphere through a single relatively large stack of 5.03 meters (16.5 feet) diameter. Method 9 observations on visible emissions from this facility were conducted in September 1973 and again in September 1974 after maintenance and repair of the electrostatic precipitator. Emissions from the control device were observed for a total of six hours over a two day period in 1973 and 30 hours over a five day period in 1974. In the 1973 observations, a maximum opacity level (six-minute average basis) of less than 30 percent was associated with the start of oxygen blows, and typically the remainder of the cycle had emissions of less than 15 percent opacity. After repair and maintenance of the electrostatic precipitator, the opacity of emissions from this facility was substantially reduced. In 1974 opacity observations showed that the maximum opacity associated with start of oxygen blows was 11 percent, and during the rest of the operating cycle the opacity levels were typically less than five percent. (Figures 1-2 of the Appendix show the opacity levels observed in 1973 and Figures 3-14 show the opacity levels observed in 1974.)

Facility E consists of two open hooded BOPFs of 230 Mg (250 tons) of steel per heat capacity which are usually operated with overlapping production cycles. The emissions from these furnaces are controlled by a single dry electrostatic precipitator with a design collection efficiency of 99.7 percent. Previous emission tests conducted by EPA on this facility showed an average effluent concentration of 62 mg/dscm (0.027 gr/dscf). Facility E was observed to provide an indication of opacity levels associated with an effluent concentration near or slightly in excess of 50 mg/dscm (0.022 gr/dscf). Emissions from this facility are discharged through a single stack of 5.5 meters (18 feet) diameter which is near the maximum size of the typical range of stacks for open hooded BOPFs. Due to interference by weather conditions and malfunction of the electrostatic precipitator on one day, opacity data useful for establishment of a standard were obtained only during six hours of observation. These opacity observations show that during periods of proper operation of the control device, the maximum opacity level associated with the start of oxygen blowing is 22 percent and typically opacity levels during the remainder of the cycle are less than 15 percent. During the malfunction of the control device, opacity levels in excess of 41 percent were observed during the first six minutes of one oxygen blowing period. (See Figures 15 to 17 of the Appendix).

Facility F was observed to obtain further data on opacity levels associated with a well-designed and operated electrostatic precipitator. Facility F consists of three BOPF vessels each with a production capacity of 100 Mg (110 tons) of steel per heat. Emissions from the BOPF vessels are controlled by a single electrostatic precipitator. Emission tests conducted by the local air pollution control agency using an out-of-stack filter test procedure (not EPA Method 5) indicated the average concentration of particulate matter emissions was 14 mg/dscm (0.006 gr/dscf). The control system discharges emissions through three stacks of 2.67 meters (8.75 feet) diameter which is an atypically small stack diameter for an electrostatic precipitator-controlled BOPF.

On the first day of observation (December 18, 1973), one-sixth of the electrostatic precipitator was out of service and the remaining units had a higher than normal load. Consequently, emissions were higher than normal for the facility. Emissions from stack #2 were observed for 4.5 hours by observer 1 and emissions from stack #3 were observed for 5.5 hours by observer

2. The observed opacity levels of effluent from the two stacks were comparable within the errors of Method 9. The maximum observed opacity level associated with the start of oxygen blowing was 25 percent and during the rest of the production cycle emissions were typically less than 10 percent opacity. Normalization of these opacity levels to equivalent opacities at 6.1 meters pathlength to allow comparison with the other precipitator-controlled facilities shows that during malfunctions the respective opacity levels are 48 percent and 21 percent. On the second day of observation (December 19, 1973) all units of the precipitator were operating normally, and both peak and baseline opacity levels of emissions were lower. Emissions from stack #3 were observed for five hours by observer 1 and 6.5 hours by observer 2. The maximum observed opacity associated with the start of oxygen blowing was less than 15 percent and typically over the remainder of the operation cycle emissions were less than five percent opacity. (See Figures 18 to 21 of the Appendix).

Facilities G and H were observed to obtain opacity data on well-designed and operated venturi scrubber-controlled BOPF vessels using an open hood for fume capture. The BOPF shop at Facility G has three vessels of 200 Mg (220 tons) of steel per heat production capacity which usually operate with overlapping production cycles. Emissions from the three vessels are controlled by two parallel venturi scrubbers which are operated at about 11 kPa* (45 in. w.g.) pressure drop across the throat of each venturi. Emissions are discharged to the atmosphere through two stacks of 2.67 meters (8.75 feet) diameter. This facility has never been emission tested, but the design of the control system appears to be comparable to that of a system capable of

*kPa (kilopascal) is the pressure of one thousand newtons per square meter. One pascal is equivalent to 4.03 x 10^{-3} inches of water at 60°F.

achieving an emission reduction to about 50 mg/dscm (0.022 gr/dscf) over the production cycle. Emissions from the stack were observed continuously for 7.5 hours by each of the two observers. During the first hour of observation two vessels were operated simultaneously, and halfway through the cycle a malfunction occurred with the hood of one vessel and excessive emissions were observed from the control device stacks and the building roof monitor. After completion of the cycle the vessel was shutdown for repairs and was out of service for most of the remaining period of observation. During the first half of this operation cycle, the scrubber was operated at reduced pressure drop and the opacity of emissions was 35 percent. The malfunction of the hood increased the emission level further so that the associated opacity increased to 55 percent. During periods of normal operation, the maximum observed opacity associated with the start of oxygen blowing was less than 17 percent and for the rest of the cycle emissions typically were less than 10 percent opacity (See Figures 22 to 23 of the Appendix).

The BOPF shop at facility H contains two vessels with a production capacity of 254 Mg (280 tons) of steel per heat. Emissions from each vessel are captured by an open hood and are manifolded to three venturi scrubbers. Emissions from each scrubber are discharged through a stack of 2.67 meters (8.75 feet) in diameter. The scrubbers are normally operated at 14 kPa (55 in. w.g.) pressure drop across the throat of the venturi. This emission control system has been previously emission tested using an in-stack filter test procedure and the average effluent concentration (for the oxygen blowing period only) was 46 mg/dscm (0.020 gr/dscf). Due to unequal distribution of the gases to the scrubbers, the scrubber nearest the operating vessel handled the bulk of the exhaust gas load and had visible emissions. Consequently, depending on which vessel was operating and hence which stack had visible emissions, emissions from either the east or west stack were observed. Visible emissions from the two stacks were observed for a total of about 5.5 hours. The maximum observed opacity associated with the start of oxygen blowing was less than 18 percent and emissions from the rest of the cycle typically were five percent opacity or less. (See Figures 24 to 25 of the Appendix).

Facility I consists of two bottom blown basic oxygen process vessels with a steelmaking capacity of 184 Mg (200 tons) per heat. Emissions from each vessel are collected by a water cooled hood and are controlled by a venturi scrubber. Emissions from each scrubber are discharged through a stack of approximately 2.13 meters (seven feet) in diameter. The scrubbers are automatically operated and the pressure drop across the throat is maintained at about 19 kPa (76 in. w.g.). Emission tests of this control system conducted using an out-stack filter test procedure showed an average concentration of emissions of 32 mg/dscm (0.014 gr/dscf). During the period of the opacity observations only one vessel was operating.

The waste gas stream from the bottom blown basic oxygen process contains high concentration of carbon monoxide and other combustible compounds; and hence is flared. During the production cycle the flare is extinguished for four to six minutes during the beginning of the oxygen blowing period. Therefore, observations at Facility I were made at the point of maximum opacity when the flare was out or when the gases were being flared the emissions were read at a point after the flare. Visible emissions were observed for six hours by two observers. The maximum opacity level observed during the start of the oxygen blow was less than eight percent and emissions during the remainder of the cycle were zero percent opacity. (See Figures 26 and 27 of the Appendix).

The opacity data discussed above and the facility descriptions are summarized in Table 1 to facilitate comparison of the data. The opacity observations at the six facilities showed that when the facilities were properly operated the maximum six-minute average opacity was less than 30 percent at electrostatic precipitator-controlled BOPFs and less than 20 percent for scrubber-controlled BOPFs. Emissions during the remainder of the cycle were less than 16 percent opacity for properly operating precipitator-control systems and were less than 10 percent for properly operating-scrubber control systems. During malfunctions of the electrostatic precipitator-controlled units, the opacity of emissions (on a 6.1 meter basis) increased to 40-48 percent during the remainder of the cycle. Opacity observations at two electrostatic precipitator-controlled BOPFs which were not considered well-controlled because of poor maintenance or design of the system, showed maximum six-minute average opacity values of 50 to 70 percent during oxygen blow periods and typical baseline six-minute average opacity values of 25 to 30 percent.* At one scrubber-controlled BOPF (Facility G) emissions were observed to increase to 30 percent during periods of operation at reduced pressure drops across the scrubber throat. An increase in emissions to 55 percent opacity followed the occurrence of the malfunction on the hood.

Comparison of the opacity data from the six facilities shows that in general a large difference exists in the opacity levels associated with

*These data are not presented and the facilities are not discussed in this report because the control systems employed were not representative of best systems of emission reduction.

Table 1. MASS AND OPACITY EMISSIONS FOR BASIC OXYGEN PROCESS FURNACES

Facility Code (Vessel Production Capacity)	Control System	Stack Diameter	Effluent Concentration at Time of Stack Test (date of test)	Maximum Six-Minute Opacity Value (date of observation)	Baseline Six-Minute Opacity Value (date of observation)
C (127 Mg/ht)	Open hood with electrostatic precipitator	5.03 m (16.5 ft)	16 mg/dscm (0.007 gr/dscf) (10/10-11/71)	28% (9/20/73) 11% (9/8-13/74)	15% (9/20/73) 0% (9/13/74)
E (227 Mg/ht)	Open hood with electrostatic precipitator	5.49 m (18 ft)	62 mg/dscm, (0.027 gr/dscf) (1/12-14/72)	41%[a] (10/17/73) 22% (10/18/73)	13% (10/18/73)
F (100 Mg/ht)	Open hood with electrostatic precipitator	2.67 m (8.75 ft)	14 mg/dscm,[b] (0.006 gr/dscf) (7/28/73)	25%[a] (12/18/73) 15% (12/19/73)	10% (12/18/73) 5% (12/19/73)
G (200 Mg/Ht)	Open hood with scrubbers	2.67 m (8.75 ft)	Unknown	17% (5/14/74)	10% (5/14/74)
H (254 Mg/ht)	Open hood with scrubbers	2.67 m (8.75 ft)	46 mg/dscm,[c] (0.020 gr/dscf) (7/22-27/70)	16% (5/15/74)	5% (5/15/74)
I (184 Mg/ht)	Closed hood with scrubbers	2.13 m (7 ft)	32 mg/dscm[b] (0.014 gr/dscf)	7% (6/29/76)	0% (6/29/76)

[a] One sixth of electrostatic precipitator plate area was out of service

[b] Out-of-stack filter test procedure, not EPA Method 5

[c] In-stack filter test procedure

properly operating scrubber-controlled BOPFs and electrostatic precipitator-controlled BOPFs. One possible reason for the higher opacity emissions from precipitator-controlled BOPFs is that changes in gas temperatures and particle conditioning initially allow large numbers of small particles to escape collection. With an effective wet gas conditioning system and maintenance of the unit within the design operating parameters, poor collection of the finer sized particles should not be sufficient to result in a difference of 15 percent opacity. It was also considered possible that the difference in performance of the control systems could be due to variations in the stack diameter rather than due to significant differences in the emission concentrations. Stack diameter affects opacity because the diameter determines the length of the path through which light is attenuated as it passes through the plume. Consequently, the larger the stack diameter, the more light will be attenuated as it passes through the plume and hence the greater the opacity of the plume.

Since particulate matter concentration measurements and the opacity observations were not conducted concurrently, the cause of the difference in opacity levels cannot be determined exactly. However, adjusting the opacity data to a common stack diameter, does provide an indication of the effect of stack diameter on opacity levels. The opacity data were standardized to a common basis using the following relationship:

$$\ln (1-O_s) = \frac{D\ \text{standard}}{D\ \text{actual}} \ln (1-O\ \text{actual})$$

where:

O_s = The opacity at standard diameter

D standard = Standard stack diameter

D actual = Observed stack diameter

O actual = The observed opacity

Information available to EPA indicates that stacks used to discharge emissions from open hooded BOPFs are typically less than three meters (10 feet) for scrubber-controlled facilities and less than 6.1 meters (20 feet) for electrostatic precipitator-controlled facilities. Electrostatic precipitator-controlled units use a larger volume of exhaust gas to prevent explosions; consequently, larger diameter stacks are used in discharging emissions to the atmosphere. Adjusting all the opacity data to a common basis of 6.1 meters (20 feet) shows that scrubbers would have emissions of comparable opacity to those of electrostatic precipitators if comparable gas volumes were used and the gases were discharged from single stacks having the same diameter. As shown in Table 2, on an adjusted basis both scrubber and electrostatic precipitator-controlled facilities had emissions less than 35 percent opacity during start of oxygen blowing and less than 19 percent opacity during the remainder of the cycle when the control systems were operating properly. This agreement in the opacity data after normalization to a common diameter indicates that the differences in plume apparent opacities may be primarily due to differences in the gas volumes handled by the two control systems rather than any major differences in the particulate matter concentration of the emissions. In addition these projections of the data show that a well-designed and operated electrostatic precipitator-controlled facility operating within the expected range of variables, emissions will be less than 35 percent opacity during the start of oxygen blowing and less than 20 percent during the remainder of the cycle. Similarly a well-designed and operated venturi scrubber-controlled facility will have emissions less than 20 percent opacity during the start of oxygen blowing and less than 10 percent during the remainder of the cycle.

Table 2. OPACITY STANDARDIZED TO MAXIMUM STACK DIAMETER OF 6.1 METERS

Facility Code	Actual Stack Diameter	Observed Maximum Six-Minute Average Opacity	Observed Baseline Six-Minute Average Opacity	Adjusted Peak Six-Minute Average Opacity	Adjusted Baseline Six-Minute Average Opacity
C	5.03 m (16.5 ft)	28% 11	15% 0	33% 13	18% 0
E	5.49 m (18 ft)	41[a] 22	-- 13	44[a] 24	-- 14
F	2.67 m (8.75 ft)	25[a] 15	10 5	48[a] 31	21[a] 11
G	2.67 m (8.75 ft)	17	10	35	21
H	2.67 m (8.75 ft)	16	5	34	11
I	2.13 m (7 ft)	7	0	19	0

[a] One sixth of electrostatic precipitator plate area was out of service

RATIONALE FOR THE PROPOSED STANDARD

Periods of BOPF Operations Subject to Opacity Standard

Section 60.11(c) of the general provisions applicable to all new stationary sources of air pollution provides that emissions occurring during periods of startups and shutdowns of the affected facility are not subject to the limitations of opacity standards of performance. Due to the nature of BOPF operations, this general exclusion of startups and shutdowns required consideration of the appropriateness of the exclusion to BOPF operations as well as its effect on the level of the opacity standard and the need for a time exemption.

Startups and shutdowns are defined in the general provisions in a manner such that if applicable to BOPF operations, the start of every oxygen blow and every tap could potentially be exempted from the opacity standard. Consequently, this application of the definitions of startups and shutdowns in the general provisions to BOPF operations is considered inappropriate. First, the majority of emissions from BOPFs occur during the start of oxygen blowing and exemption of this period would make the opacity standard meaningless. Second, in order for the opacity standard to effectively insure proper operation and maintenance of the control device, the standard should be applicable to the same process emissions as the concentration standard. Compliance with the concentration standard is demonstrated by emission testing over an integral number of cycles which commence immediately after charging of the vessel and cease just prior to tapping of the vessel. Therefore, an opacity standard which applies to the same emissions sampled during compliance tests must limit emissions during the start of the oxygen blow as well as during the remaining periods of the cycle. Due to the lower uncontrolled emission rate and the emission period tested in determining compliance with the concentration standard, exclusion of the tapping period emissions from applicability of the opacity standard is not inappropriate. During a normal removal of a BOPF from production, excess emissions do not occur; however, a shutdown under malfunction conditions can unavoidably produce emissions in excess of best demonstrated control levels. The provisions of section 60.11(c) also exclude malfunctions from applicability of the opacity standard where a malfunction is a sudden or unavoidable failure of the control system or process to operate in the normal manner. Therefore, for BOPF operations only a specific definition of startups is required to ensure continued proper operation and maintenance of the control device.

For the purpose of standards of performance for basic oxygen process furnaces, a startup is considered to be only the setting into operation of a vessel after the vessel has been out of operation for a minimum continuous time period of eight hours. Excess emissions possibly could occur during the startup of the vessel after routine maintenance and may persist until the control system reaches stable operating conditions or the excess pitch is baked off. Thus for BOPF operations, unlike other batch operations, routine initiations of the production cycle are not considered startups; and these periods are subject to regulation by the opacity standard. During periods of startup of a vessel, the owner or operator is required to control emissions to the maximum practicable extent.

Selection of the Format of the Proposed Standard

As a result of the operation period covered by the concentration standard, the opacity standard must be structured such that it is indicative of proper operation and maintenance of the control device over all phases of the steel production cycle. Analysis of the opacity data showed that higher opacity emissions occurred during the start of oxygen blowing than during the remainder of the production cycle for both types of control systems. Separate opacity standards are necessary for these periods due to the large variations in gas volume and temperature which result in less than optimum performance of the control device during brief periods of the production cycle in addition to the fluctuations in fume generation rate over the cycle. Several alternative formats for writing the opacity were considered. The alternative formats considered were writing the standard (1) to allow higher emissions on a frequency per sixty-minute basis, (2) on a frequency (once) per primary oxygen blow basis, or (3) on a frequency (once) per production cycle basis. The advantage of frequency per hour approach to writing the opacity standard is that compliance with the standard can be determined without knowledge of, or synchronization with, shop activities. The major disadvantage of this approach is that the standard cannot be established at any one level which requires the same degree of control from both high and low productivity shops. That is, the need for allowing higher emissions is related to the number of oxygen blows started in the time period, and high and low productivity shops differ considerably in this regard (one vs. three oxygen blows in an hour).

The advantage of writing the opacity standard to allow higher emissions only during oxygen blowing periods is that higher emissions are limited to the necessary specific process operation, and a blanket exemption is not provided. However, determination of compliance with this type standard would be difficult due to the problems at some multiple furnace shops of determining if emissions in a specific period result from a specific process operation. This lack of discrete identifiable emission periods for specific process operations results from the common practice of overlapping the operation of two BOPFs (i.e. charging one BOPF vessel while another is blowing or in a delay period) and ducting the effluent gases from all vessels to a common control device. Thus, for these cases it would be difficult to determine if the separate standard were applicable for any given period in question and compliance with the standard cannot be determined.

The third alternative of allowing higher emissions on a production cycle basis requires the same degree of control from both high and low productivity shops and allows higher emissions only as necessary. This production cycle approach does have the disadvantage of requiring the observer to determine the number of production cycles in the observation period before compliance with the standard can be determined. This requirement does not represent a major disadvantage to enforcing the opacity standard because BOPF shops routinely maintain records of the furnace operations. Implementation of this approach can be facilitated by requiring that owners or operators of affected BOPF facilities keep records of the time of each steel production cycle available for inspection. As the disadvantages of the production cycle approach can be minimized by record keeping requirements in the regulation, the proposed opacity standards were written to allow one set of higher opacity emissions in each steel production cycle.

Selection of Emission Limits

Where opacity and concentration (or mass) standards are applicable to the same source, EPA establishes the opacity standards at a level which is not more restrictive than the corresponding concentration (or mass) standard. Such opacity standards are established at levels which will require continuous proper operation and maintenance of the control systems at all times. The basis for the opacity limitations considered in the alternative standards is summarized below:

For scrubber-controlled facilities, analysis of the opacity data showed that a well-controlled BOPF operating within the expected range of variables will have emissions of less than 20 percent opacity during oxygen blows and less than 10 percent opacity during the rest of the cycle. Again these limitations are based on engineering judgments and evaluations of the performance of the systems and systems required for minimal compliance with the concentration standard. In the background study on the concentration standard, it was determined that emissions from a properly operated top blown BOPF can be reduced to less than 50 mg/dscm using a well-designed scrubber operating with a minimum pressure drop of 11 kPa (45 in. w.g.) across the venturi throat. Control of emissions from bottom blown vessels requires operation of the scrubber at a minimum pressure drop of 16 kPa (65 in. w.g.) to reduce emissions to less than 50 mg/dscm. Observations at Facility G during a period of operation of the scrubber at a pressure drop of (38 in. w.g.) showed emissions of 30 percent opacity during an oxygen blow period. Opacity levels of less than 20 percent during oxygen blow periods and less than 10 percent were observed when the venturi scrubbers on top blown BOPFs were operated with pressure drops of 11-14 kPa (45-55 in. w.g.) and when venturi scrubbers on bottom blown are operated at 16 kPa (65 in. w.g.).

In the selection of the proposed opacity standard, three alternative standards based on the emission limitations for the two different control systems were considered. One alternative was to propose separate opacity standards for scrubber-controlled facilities and for electrostatic precipitator-controlled facilities.

The standards considered for proposal under alternative A were:

1. Emissions from electrostatic precipitator-controlled facilities shall be less than 20 percent opacity except emissions of up to 35 percent opacity are allowed once per steel production cycle; and

2. Emissions from BOPFs equipped with control systems other than electrostatic precipitators shall be less than 10 percent opacity except emissions of up to 20 percent opacity may occur once per steel production cycle.

This alternative established opacity limitations at levels which would require proper operation and maintenance of either control system. Since few electrostatic precipitator-controlled facilities will be constructed, inclusion of a specific standard for these facilities was not considered necessary. Hence, alternative A was not selected for the proposed standard.

Alternative B recommended that for all control systems emissions shall be less than 20 percent opacity except that emissions of greater than 20 but less than 35 percent opacity may occur once per steel production cycle. This alternative opacity standard is achievable by facilities controlled by either control device whose emissions are in compliance with the concentration standard, 50 mg/dscm (0.022 gr/dscf). However, the emission limitations of alternative B are based on the performance of well-designed and operated electrostatic precipitator-controlled BOPFs. The majority of new BOPFs are expected to use processes and control systems that reduce effluent gas volumes in order to conserve energy. Facilities designed in this manner must use scrubbers to control particulate matter emissions because of the explosion hazard in electrostatic precipitators. These scrubber-controlled facilities will discharge emissions to the atmosphere through small stack diameters relative to those used on precipitator-controlled facilities; and hence will exhibit lower opacities at equivalent concentrations. Consequently, opacity limitations established according to the second alternative would not require proper operation and maintenance of the majority of new facilities.

The final alternative opacity standard considered required that for all control systems emissions shall be less than 10 percent opacity except that emissions of greater than 10 but less than 20 percent opacity may occur once per steel production cycle. This standard is based on typical stack diameters and other operating variables expected for scrubber-controlled facilities operating with emission rates near the level of the concentration standard. The third alternative considered was to propose an opacity standard based on typical stack diameters and other variables for scrubber-controlled facilities operating with emission rates near the concentration standard. This alternative was selected since most new facilities will be scrubber-controlled and these opacity limitations would require proper operation and maintenance of these systems. Therefore, the proposed opacity standard limits emissions to less than 10 percent opacity, except emissions up to 20 percent opacity are allowed once per steel production cycle.

EPA recognizes that electrostatic precipitator-controlled facilities may not be able to achieve the proposed opacity limitations while concurrently achieving the concentration standard. As very few new electrostatic precipitator-controlled BOPFs will be constructed, it was concluded that the opacity standard should not reflect the opacity levels associated with these control systems. Should there be any electrostatic precipitator-controlled BOPFs subject to the standard, the provisions of §60.11(e) allow the owner of the facility to request establishment of a special opacity standard if the facility does not meet the opacity standard while concurrently complying with the concentration standard. This approach to considering electrostatic precipitator-controlled BOPFs will not be administratively cumbersome because it is expected that it will be necessary to establish few if any special opacity standards.

MONITORING REQUIREMENTS

Section 111(e) of the Clean Air Act, as amended, requires that new sources continue to be operated in compliance with the applicable standards throughout their operational life. Under section 301(a) of the Act, EPA is authorized to prescribe regulations as necessary to carry out its functions under the Act. Under this authority EPA establishes process and control device monitoring requirements for some source categories.

In EPA's judgment for basic oxygen process furnaces monitoring of scrubber operating parameters will allow evaluation of the performance of the control system. For basic oxygen process furnaces constructed after June 11, 1973, it is proposed to require continuous monitoring of the pressure loss through the venturi constriction and of the water supply pressure to the control device. These factors are important in determining the performance of a venturi scrubber and monitoring these parameters will provide a means of evaluating the operation and maintenance of the control system.

These scrubber operating parameters are routinely monitored in any well-designed and operated facility. Hence, the proposed monitoring requirements are expected to add negligible additional costs to the total costs of complying with the concentration standard of performance. It is estimated that the costs of complete monitoring of scrubber operations will be less than $100,000 for a typical new facility. The proposed opacity standard is no more restrictive than the concentration standard, and hence there are no additional control equipment costs associated with the opacity standard. Therefore, this proposal is not considered a major action under the Inflationary Impact Statement (IIS) program and no IIS is required.

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APPENDIX

CROSS SECTION • 10X10 TO ½ INCH

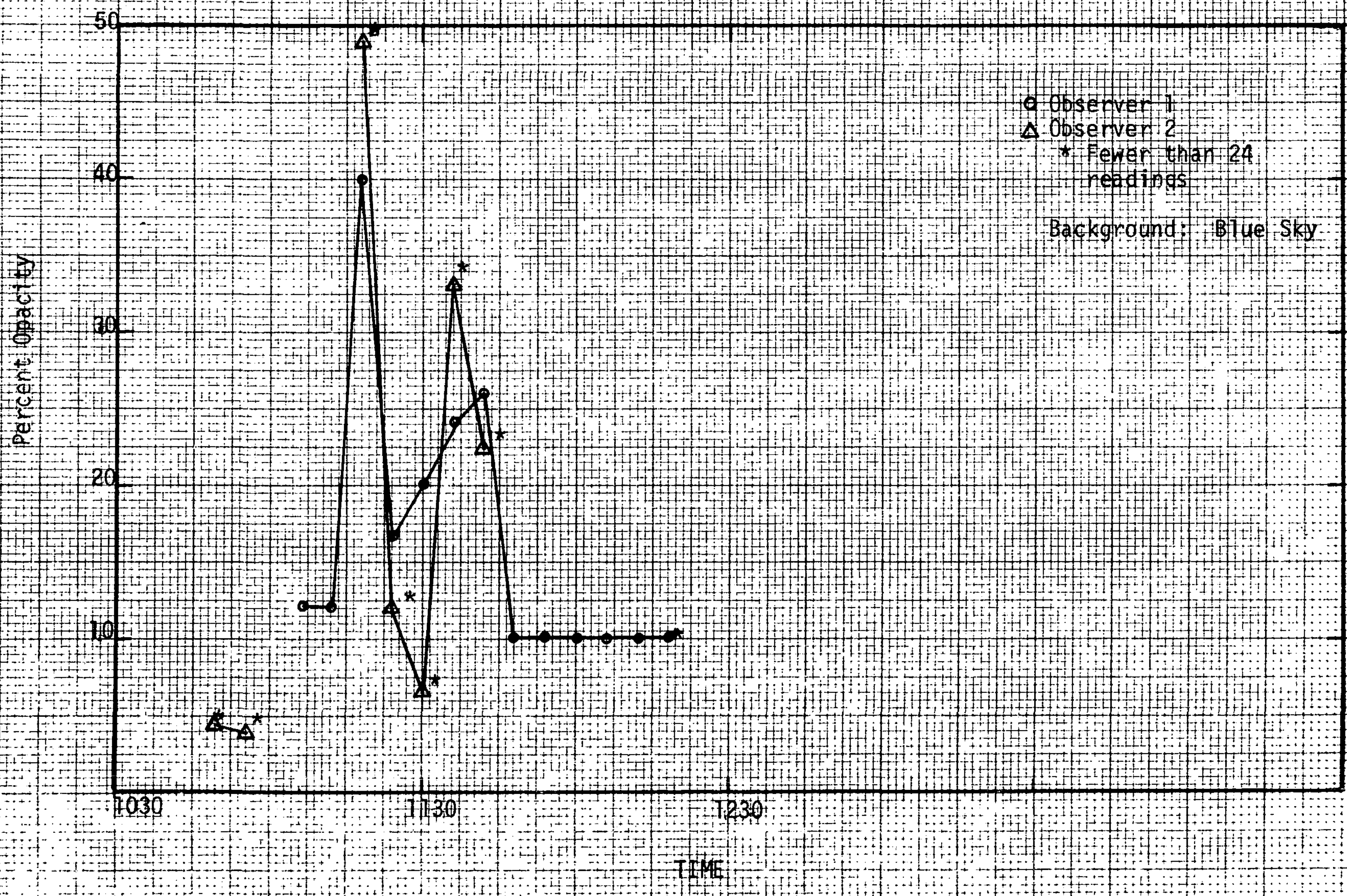
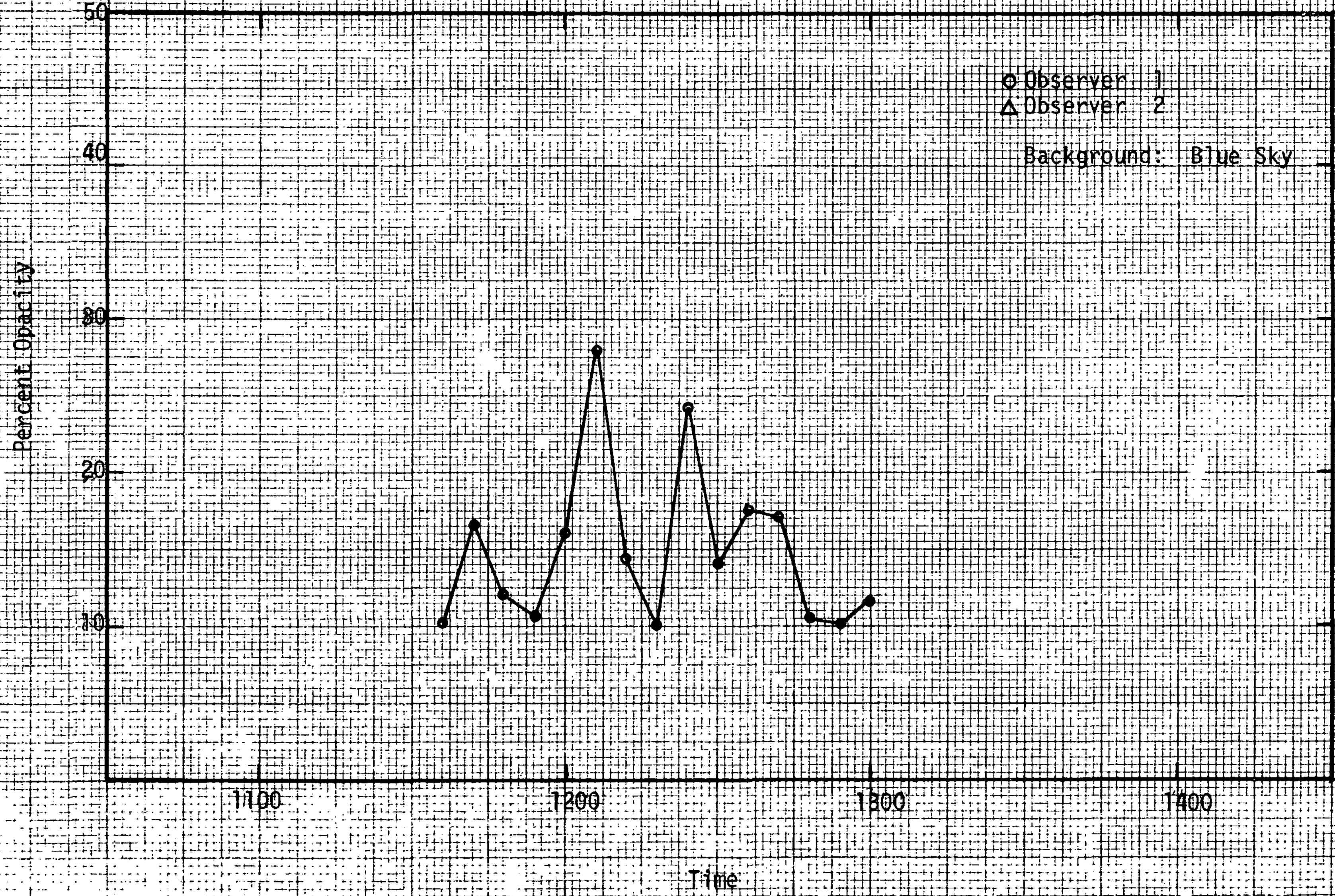


Figure 1. Opacity of Emissions from Facility C 9/19/73



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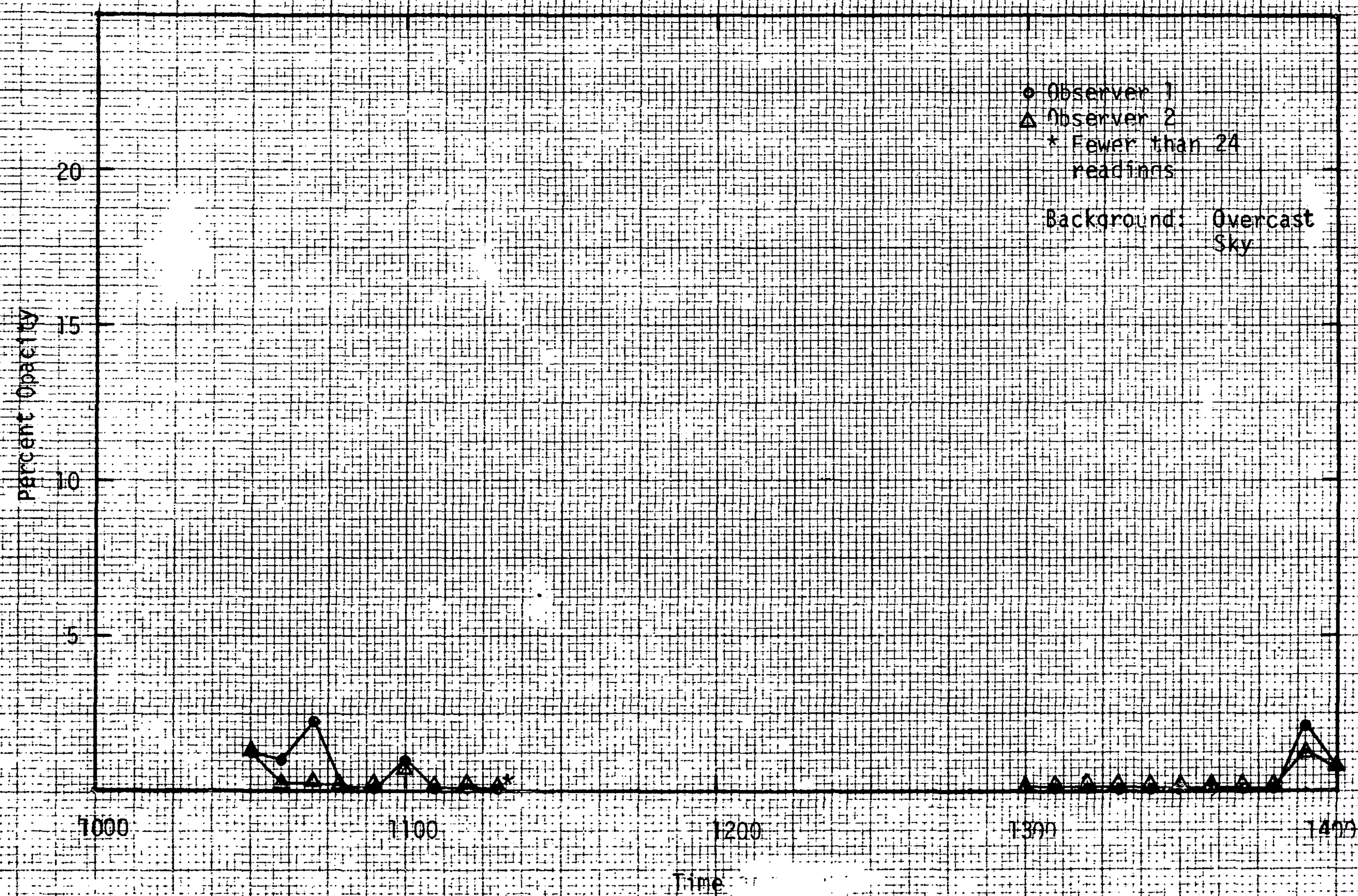

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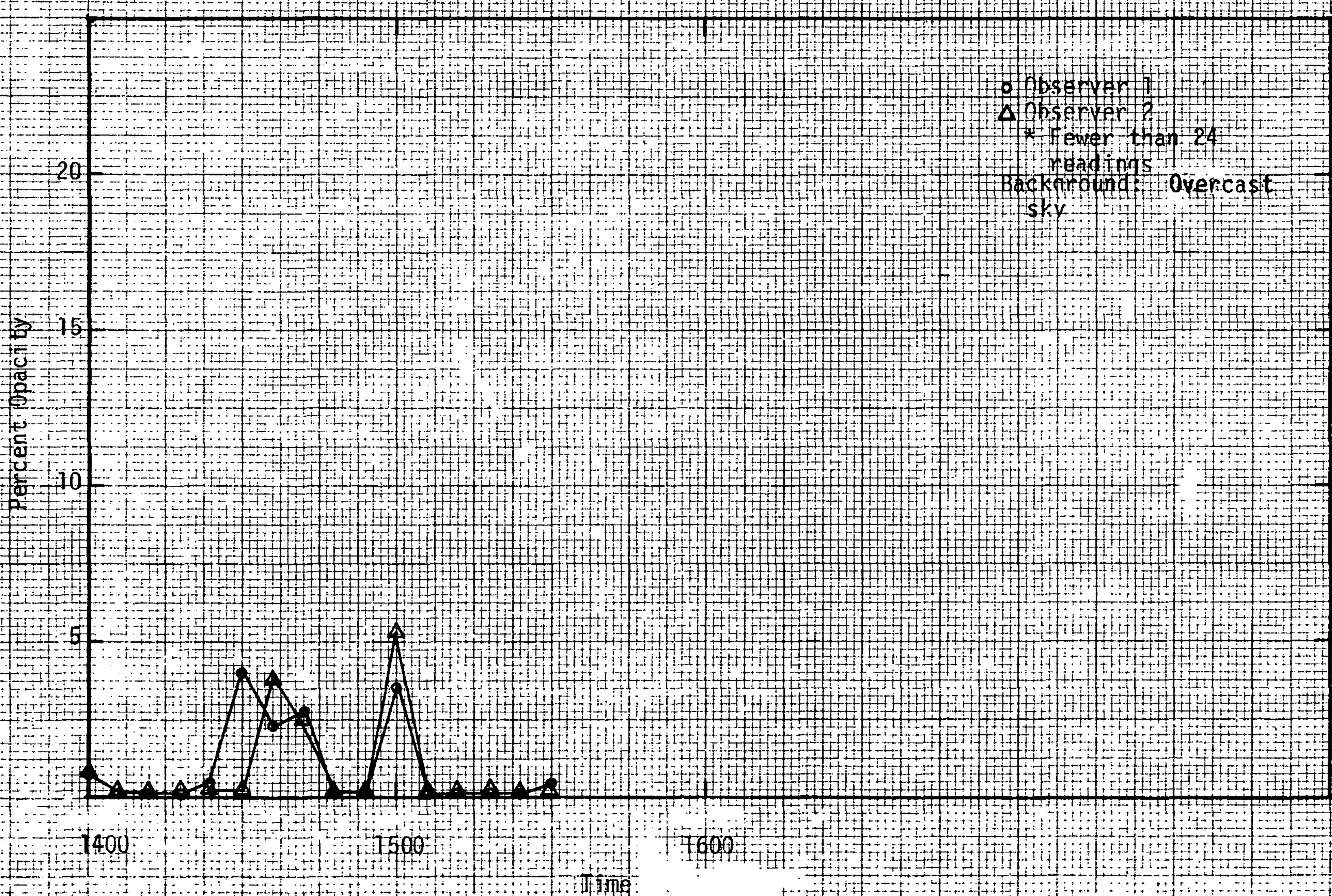

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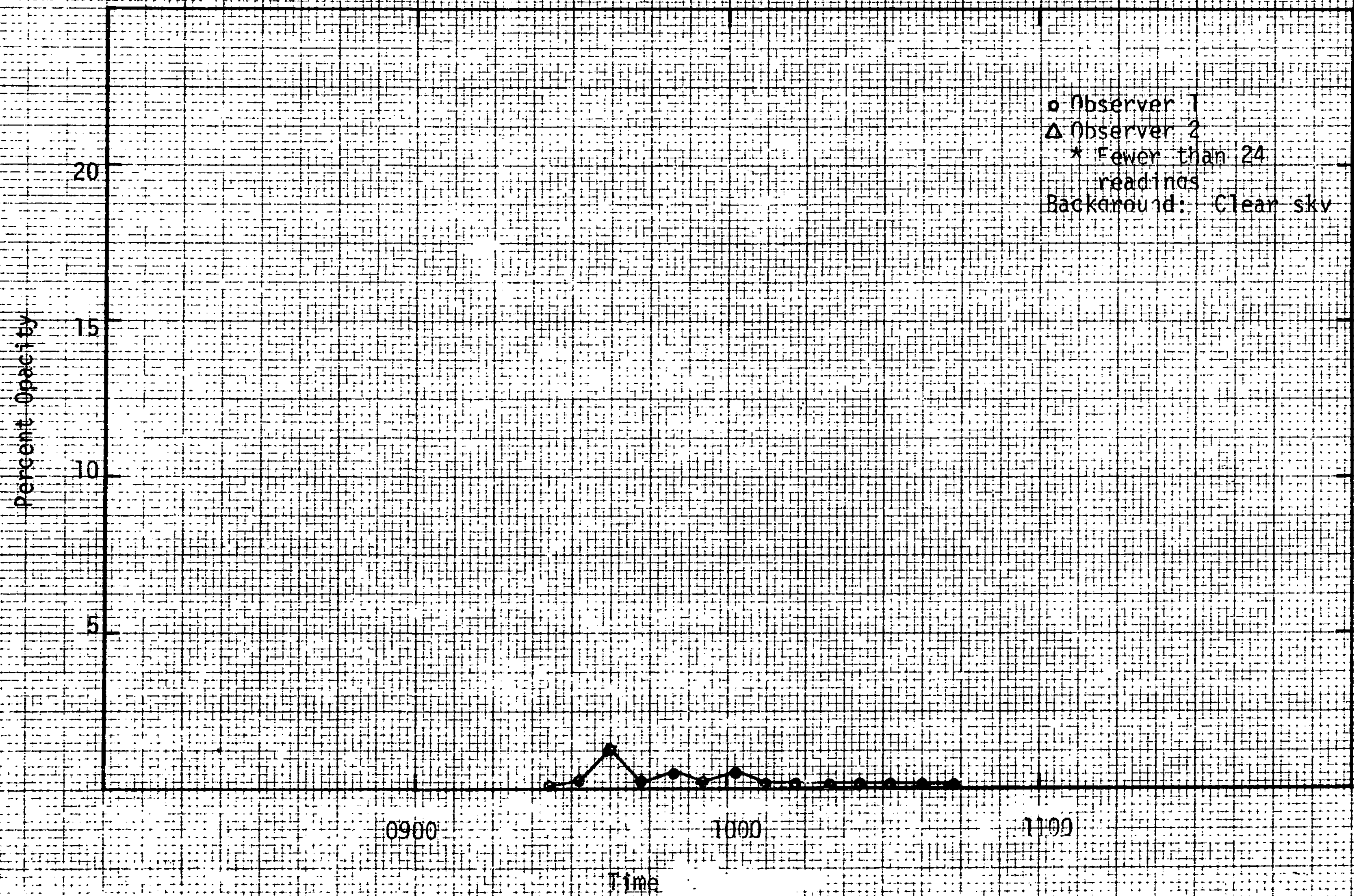

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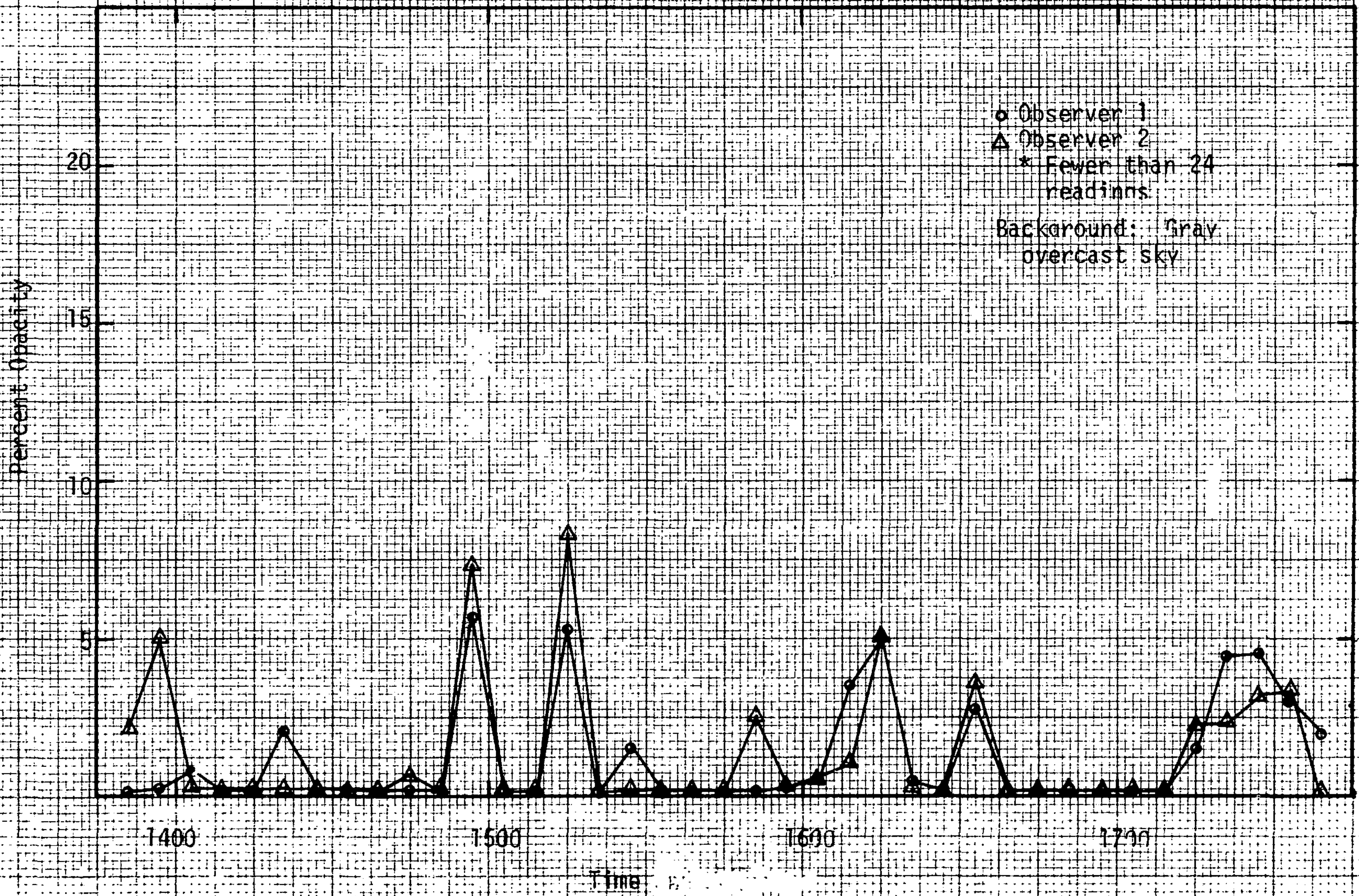

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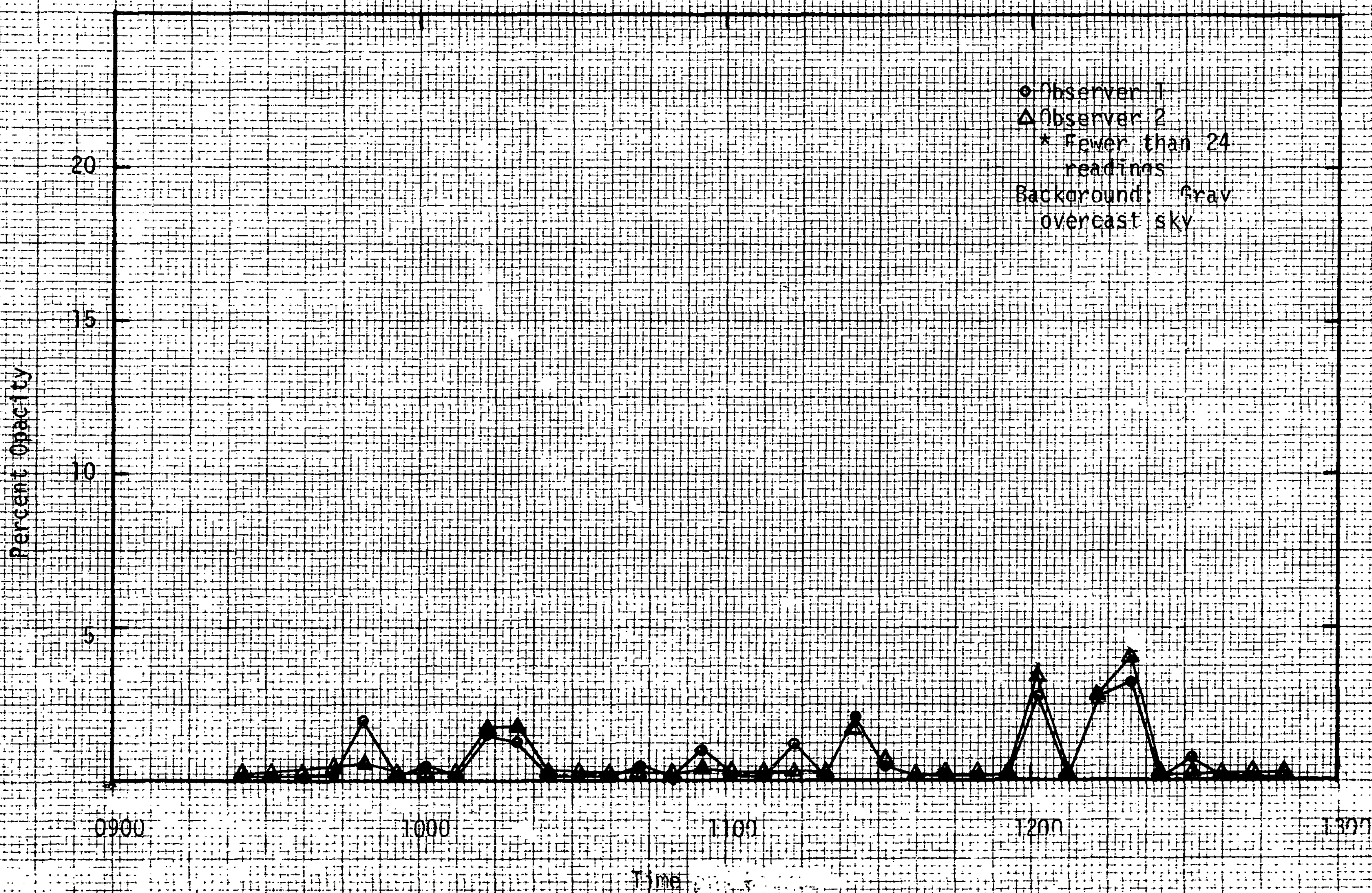

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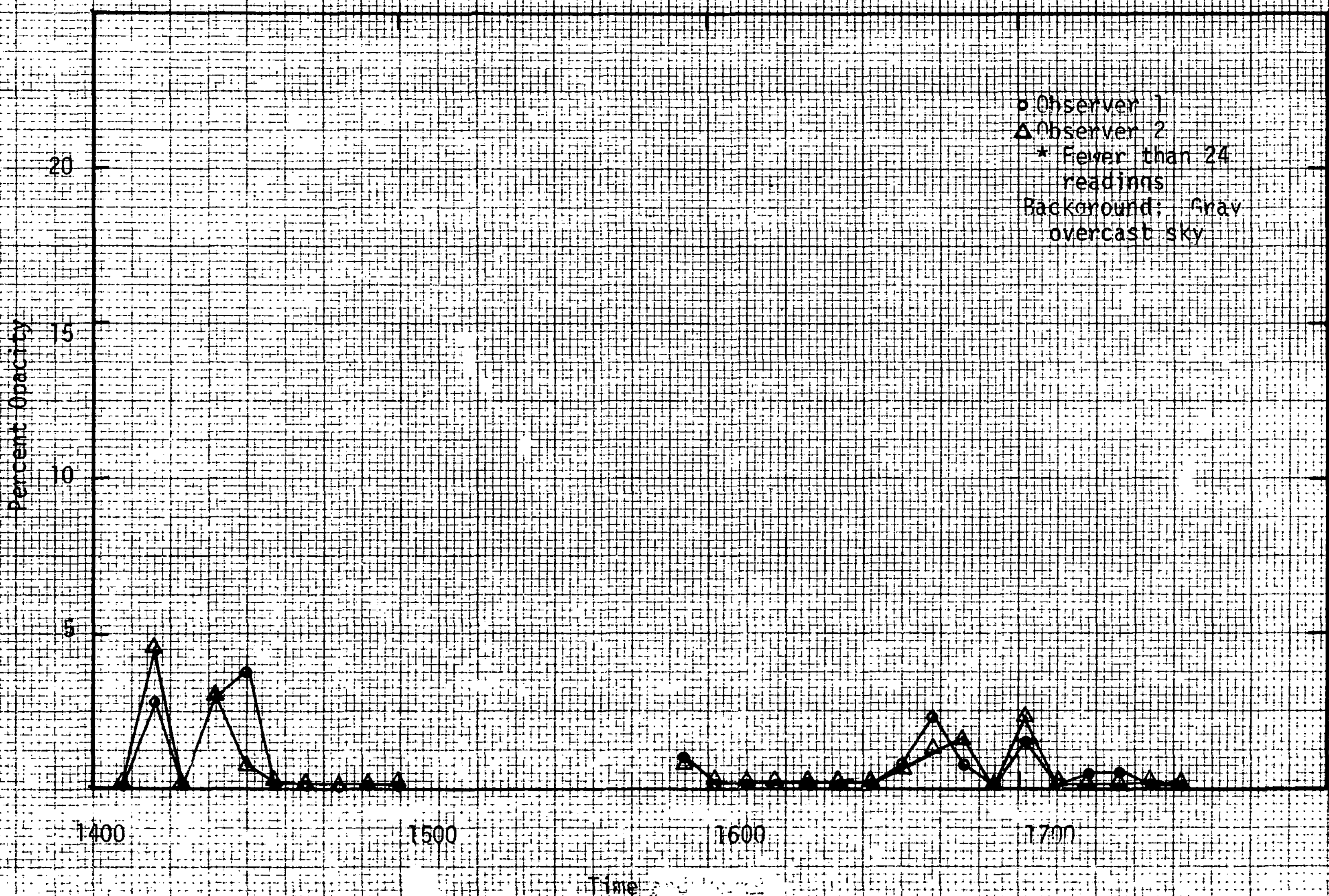

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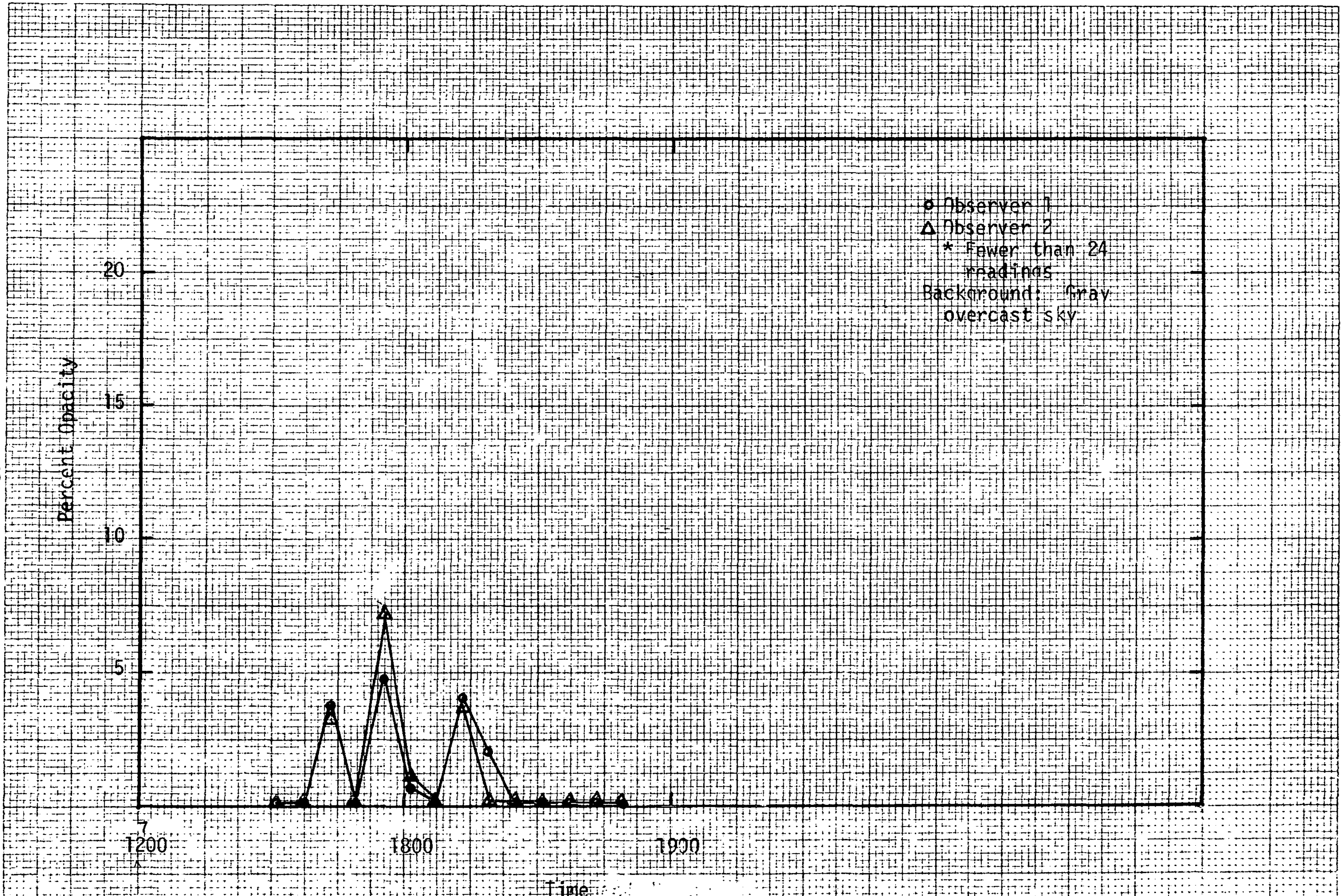

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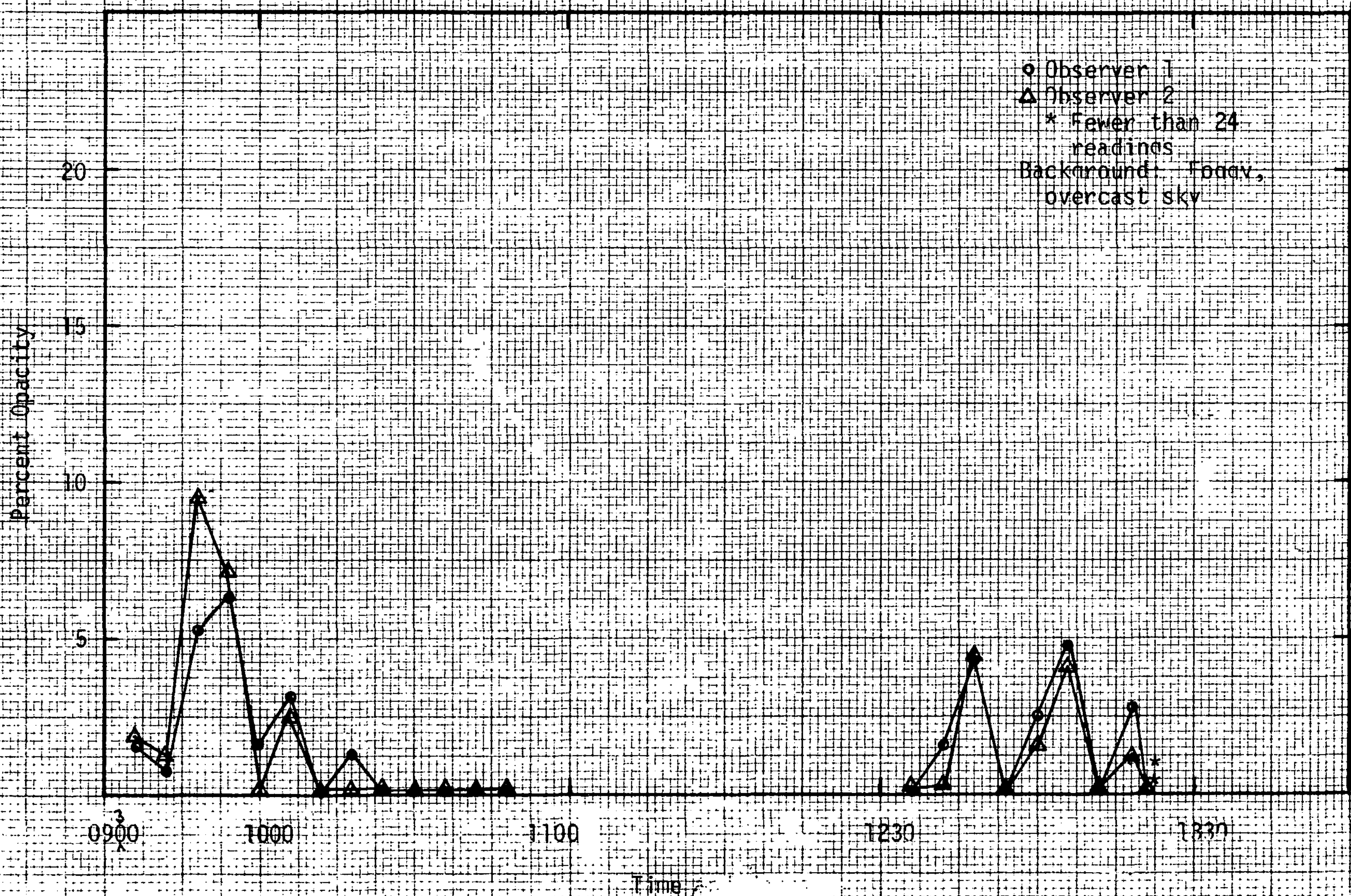

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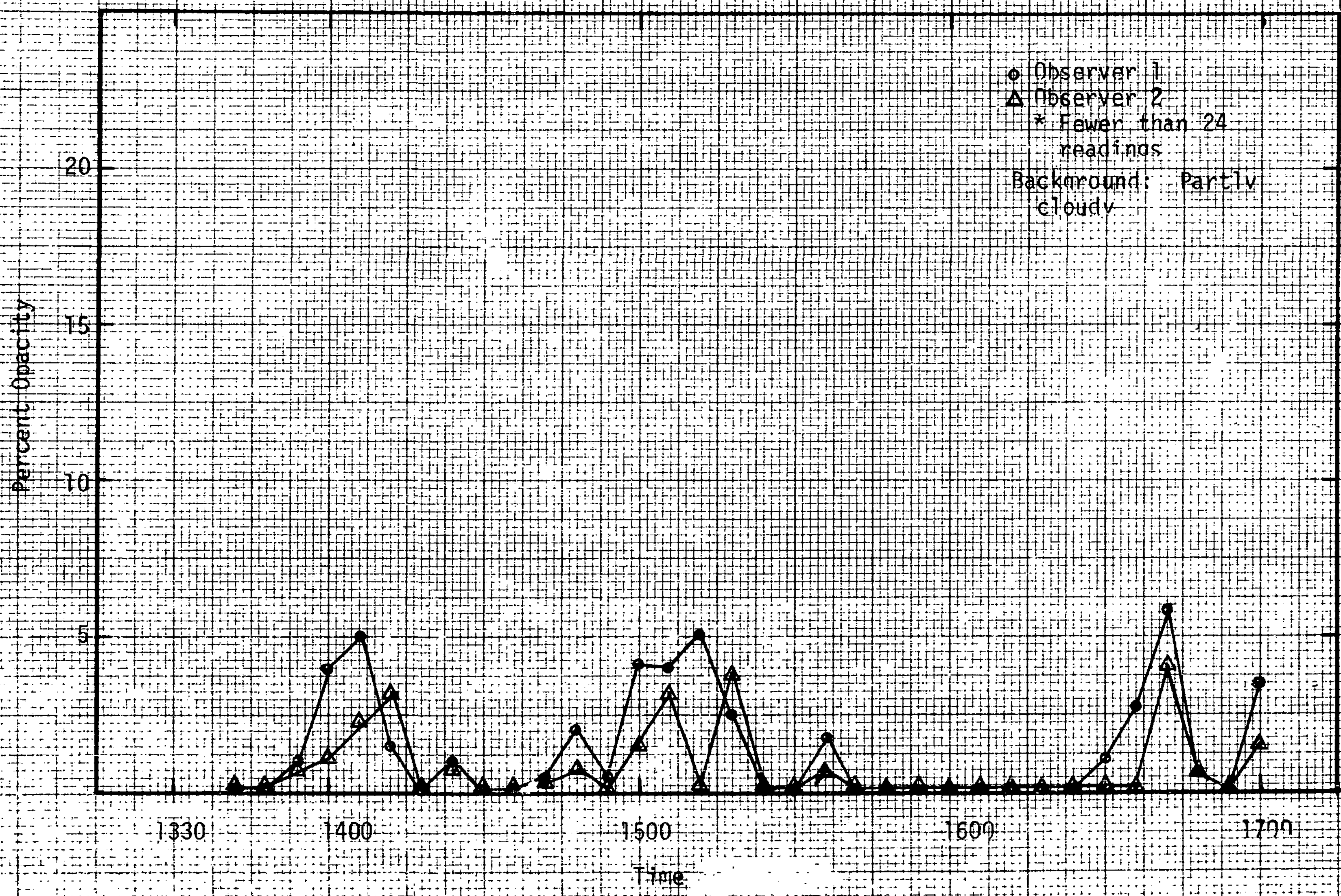

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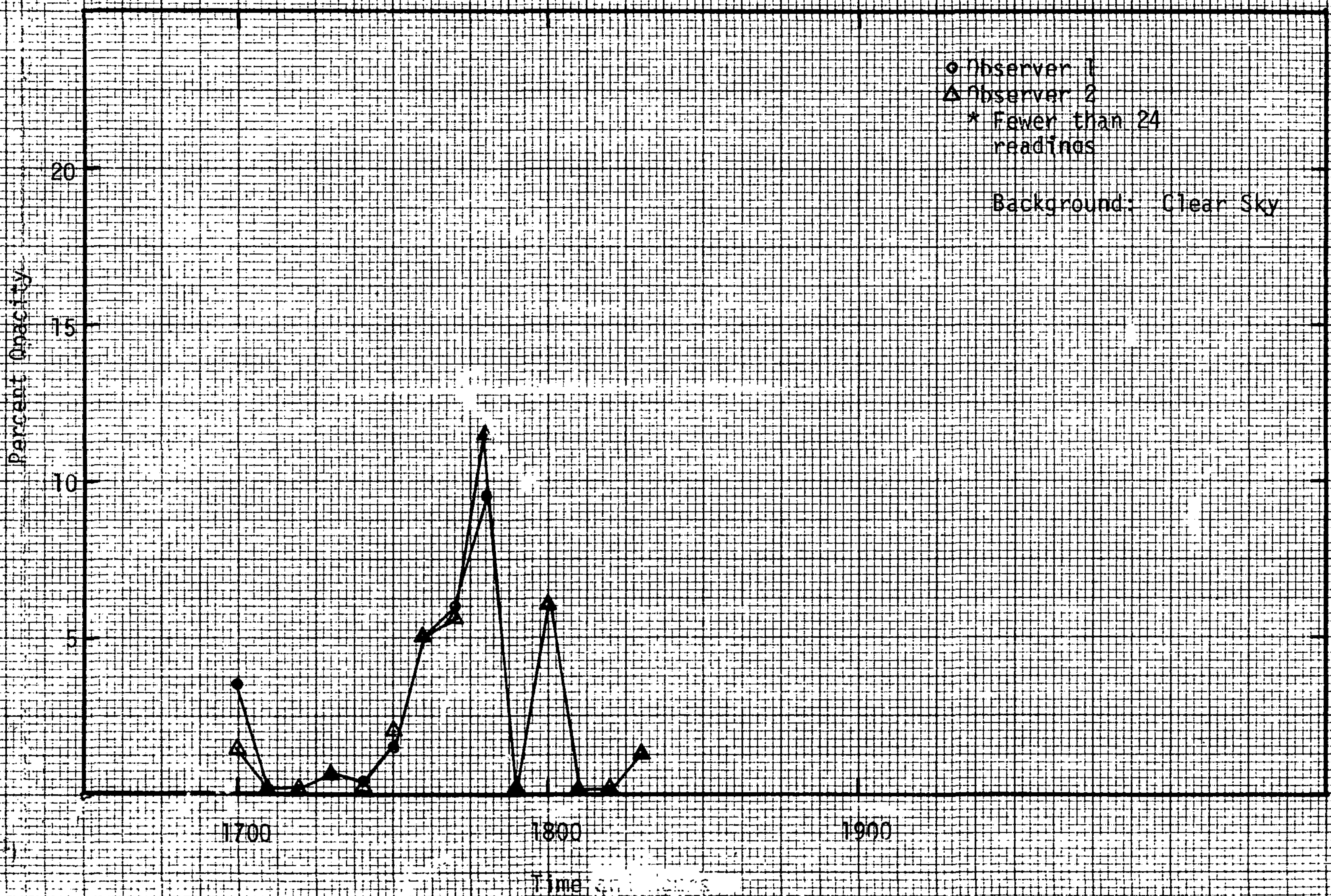

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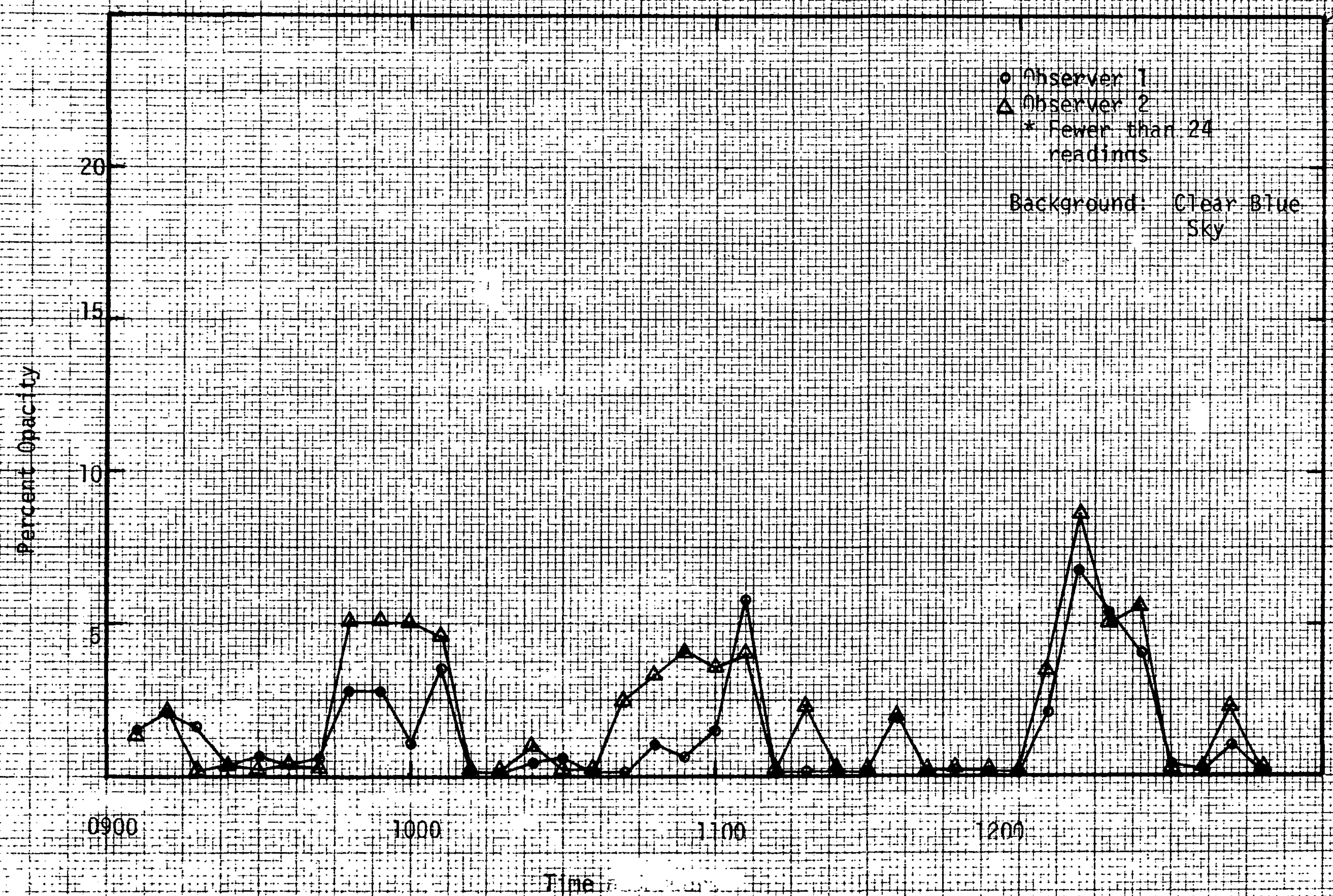

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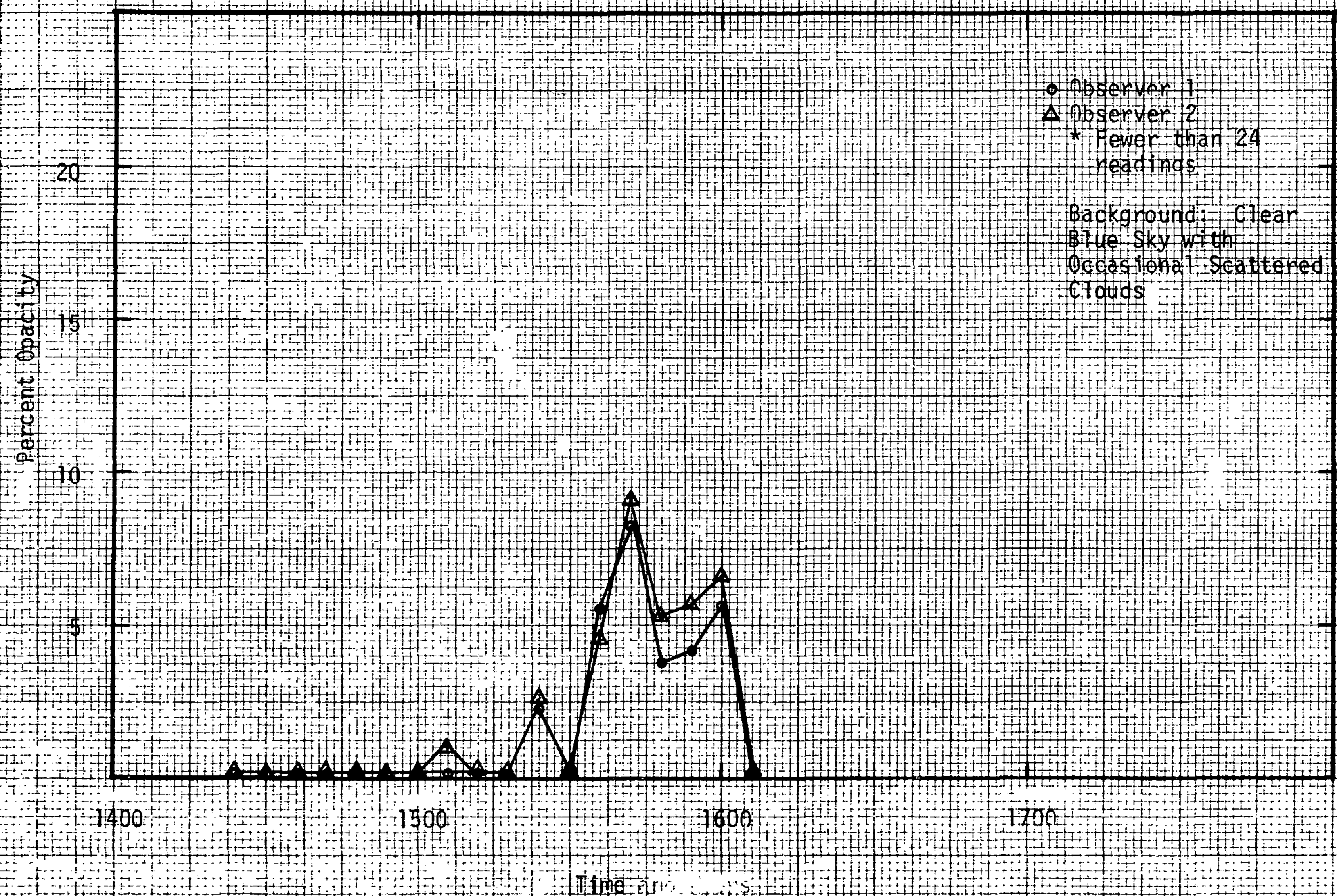

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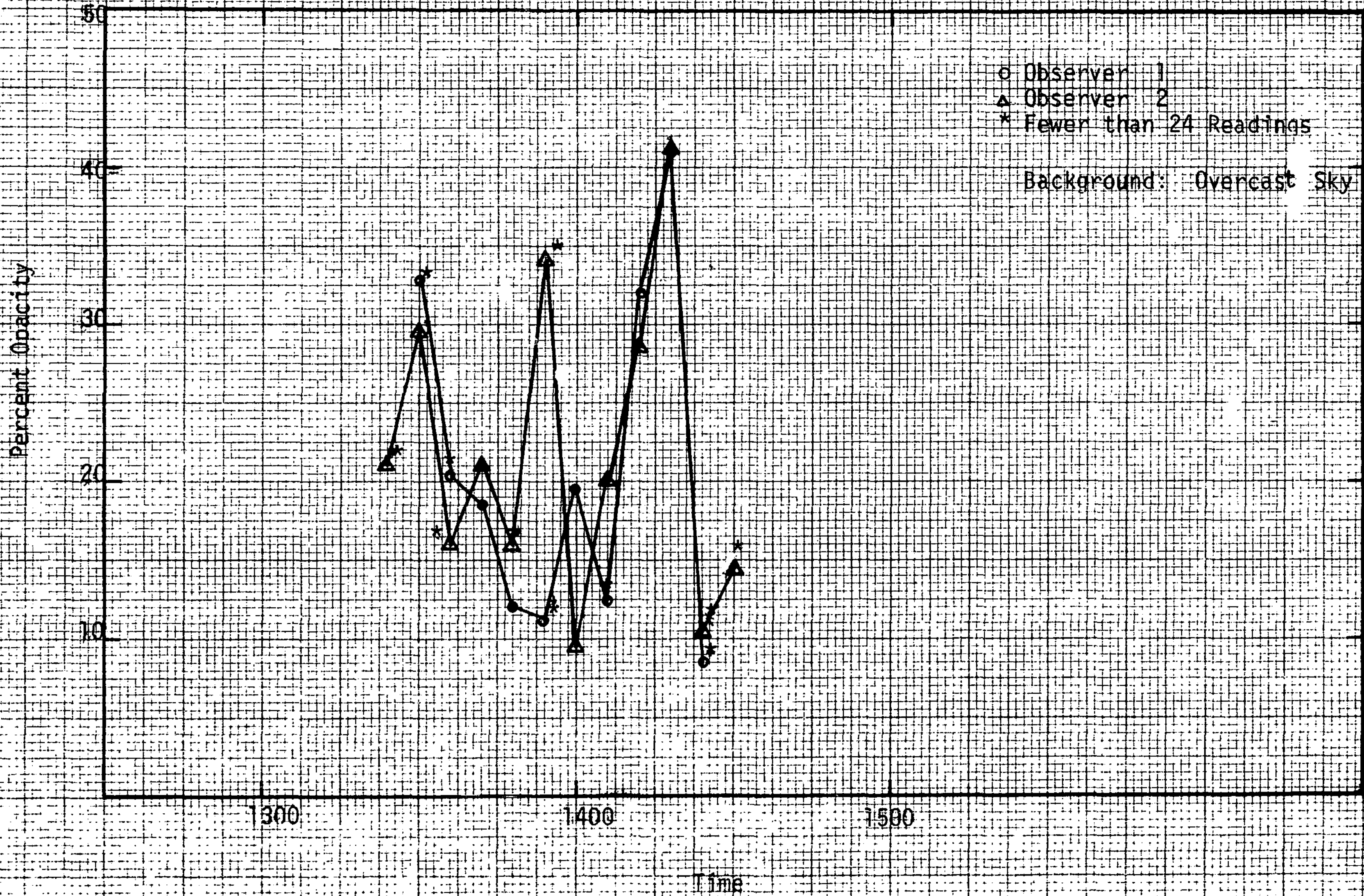

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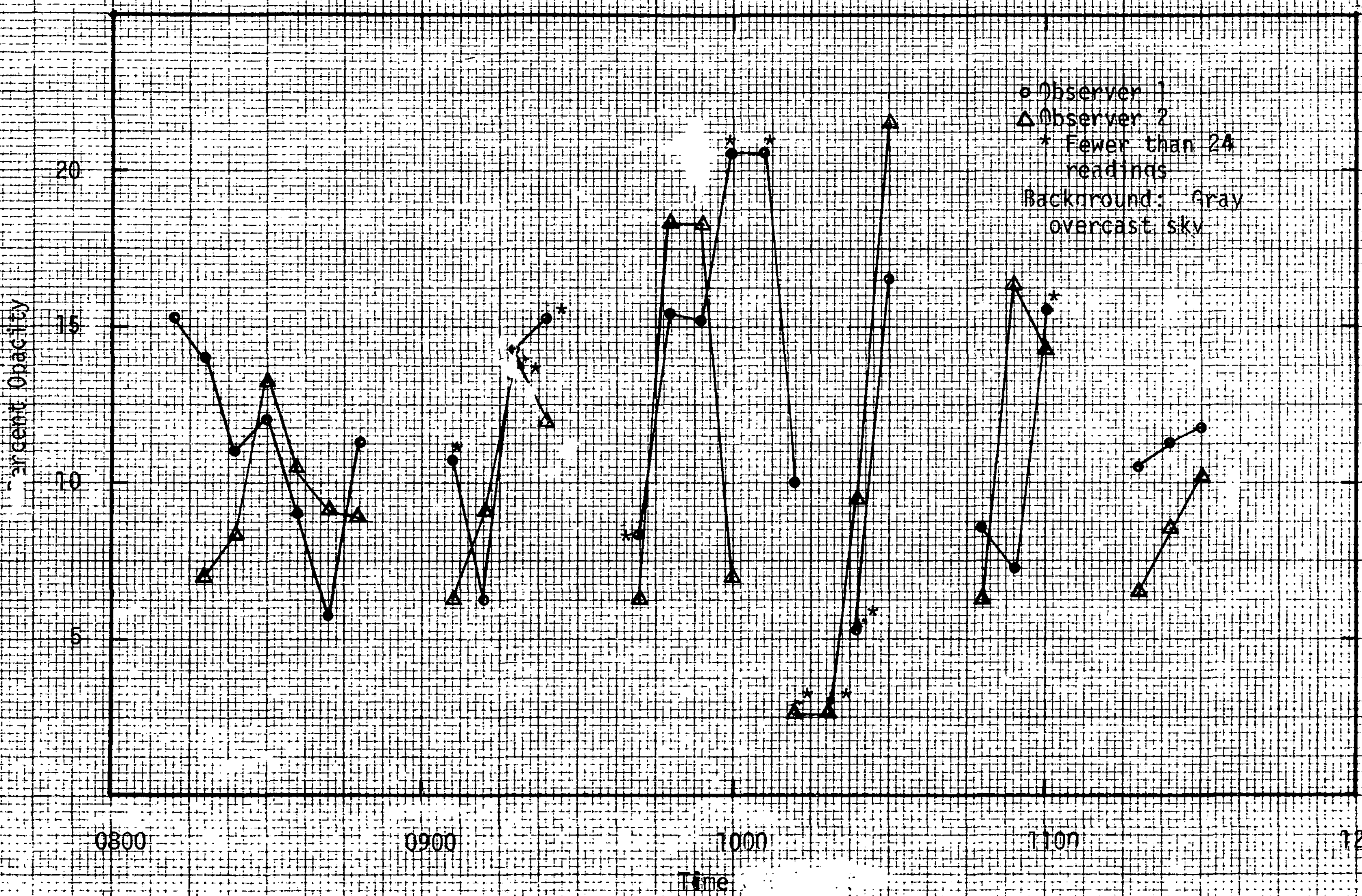

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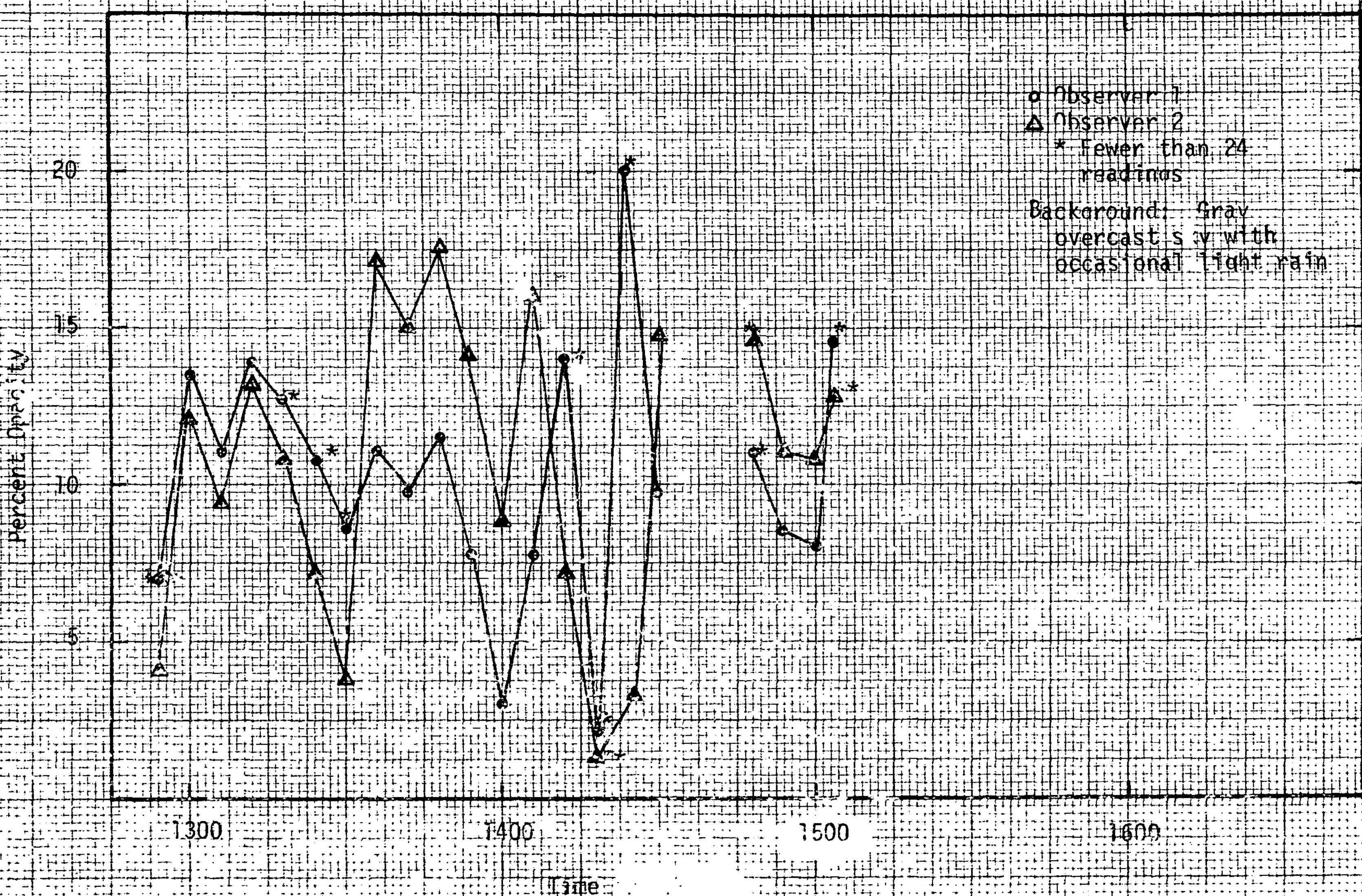

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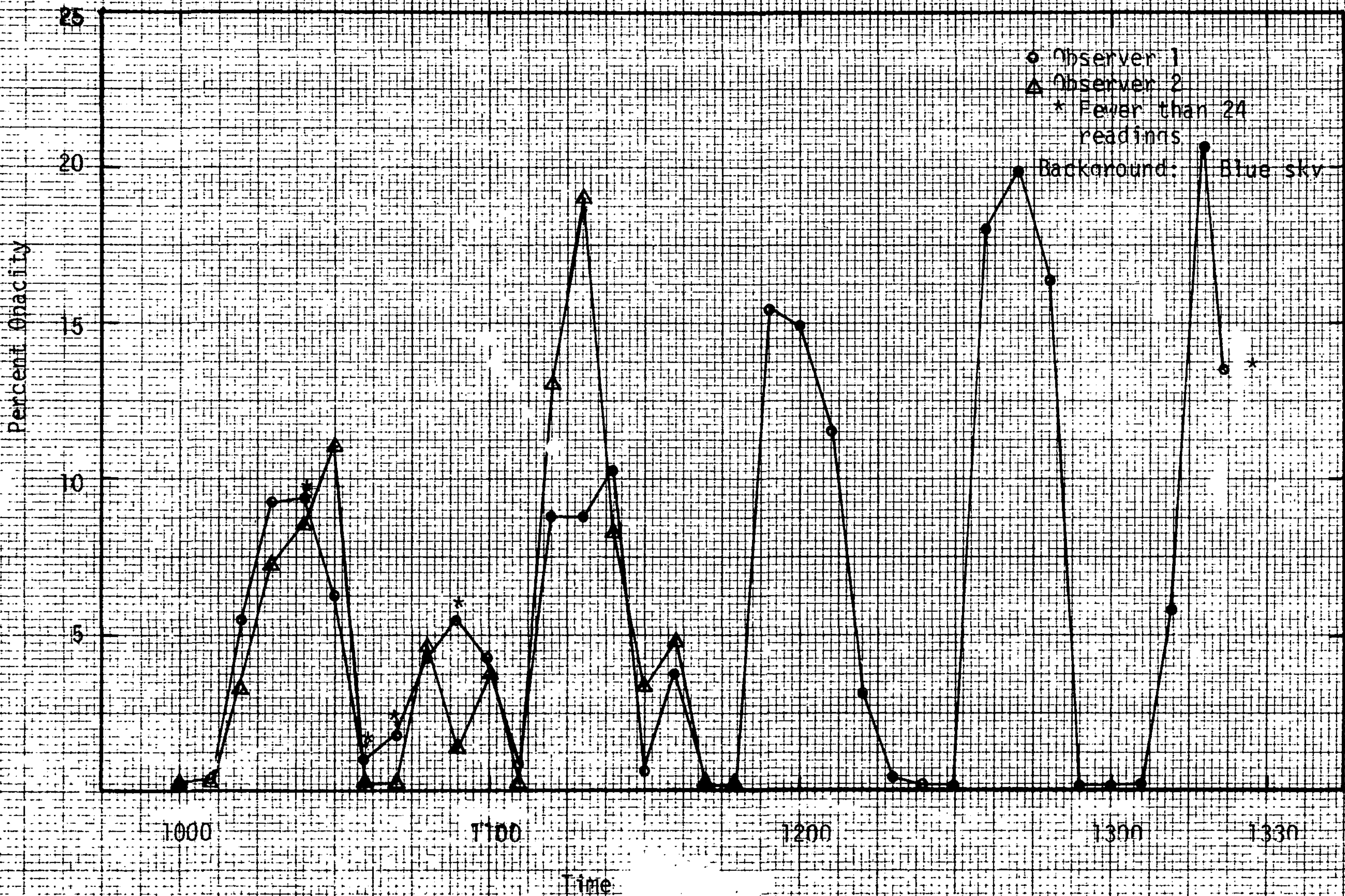

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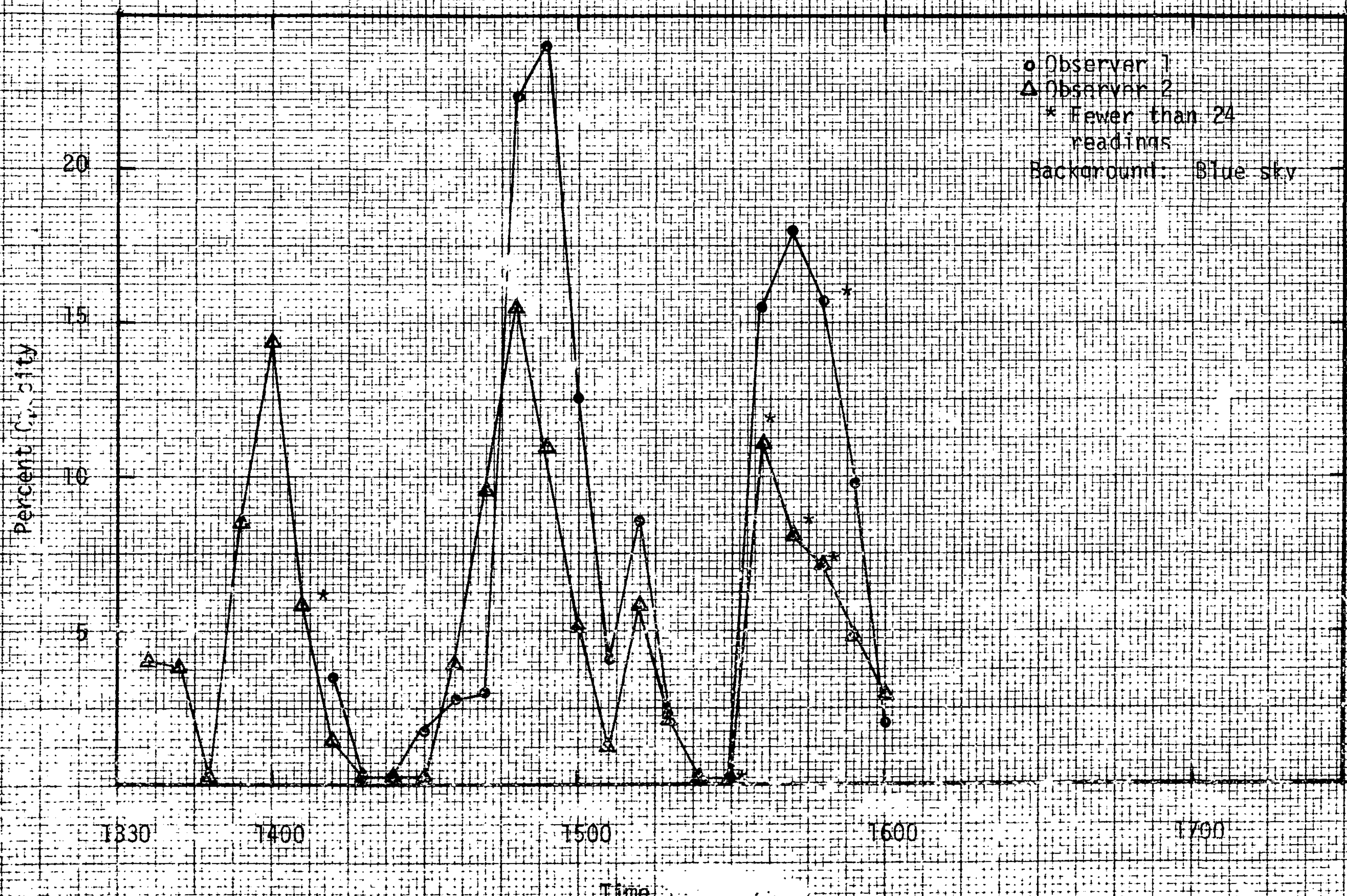

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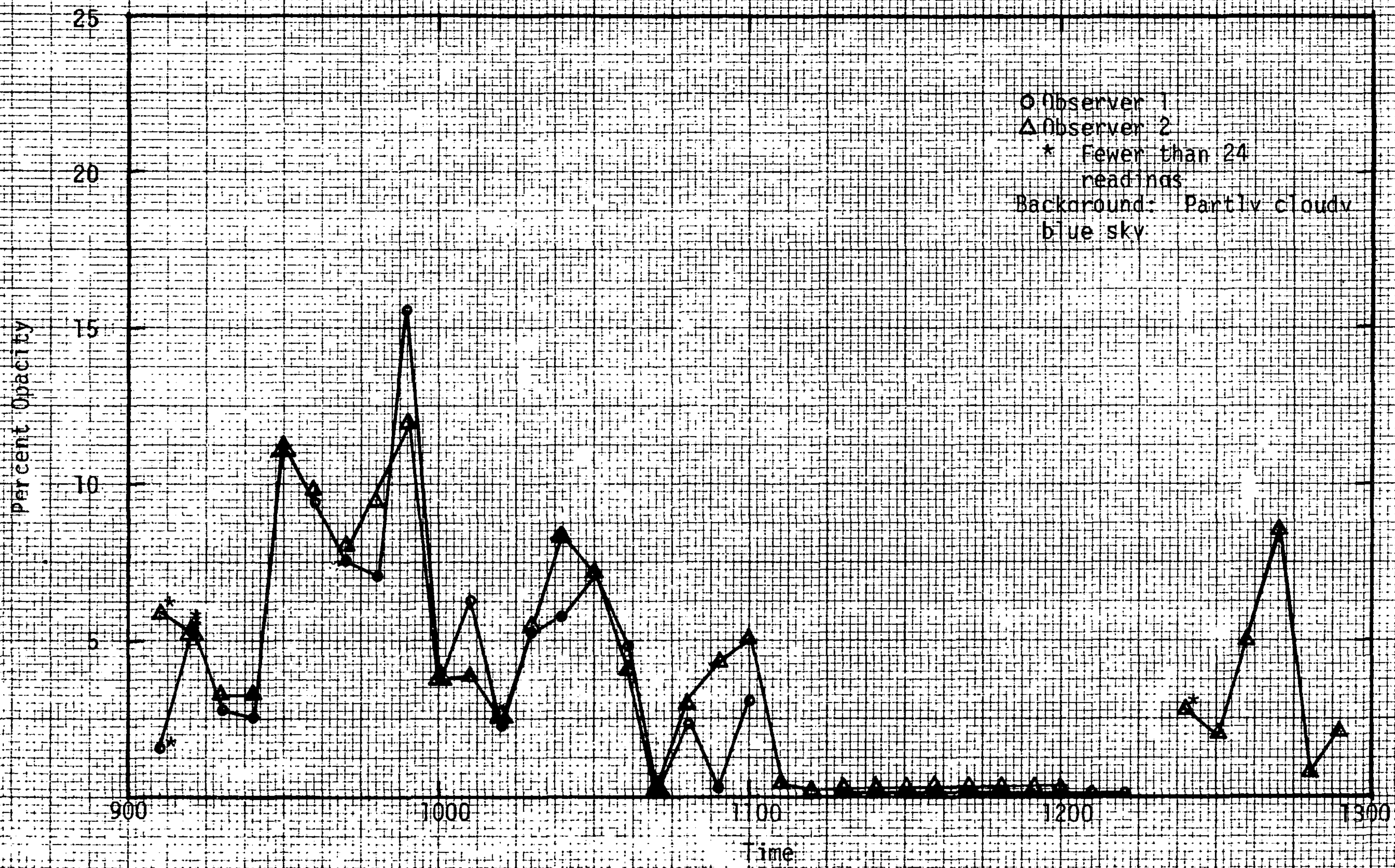

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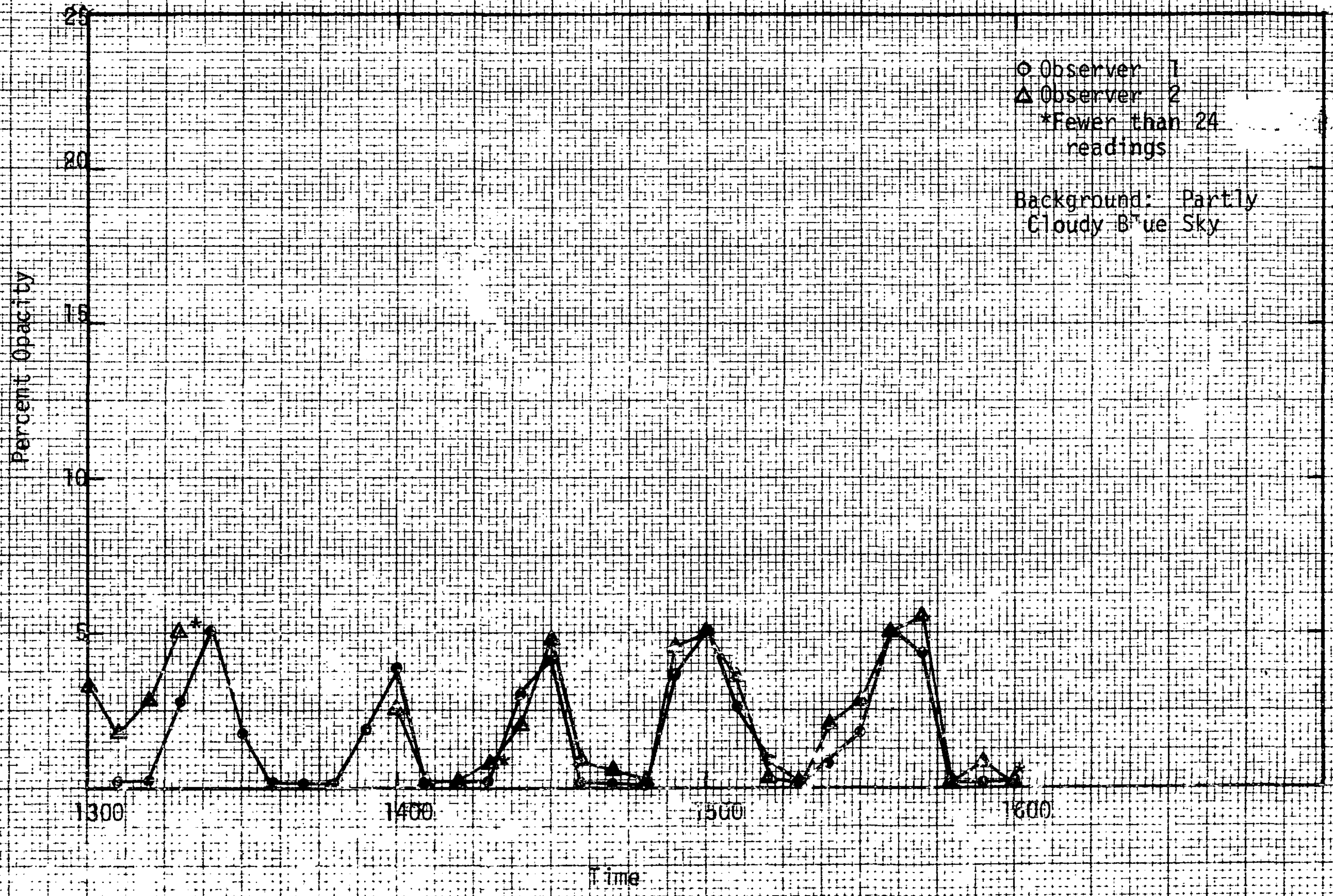

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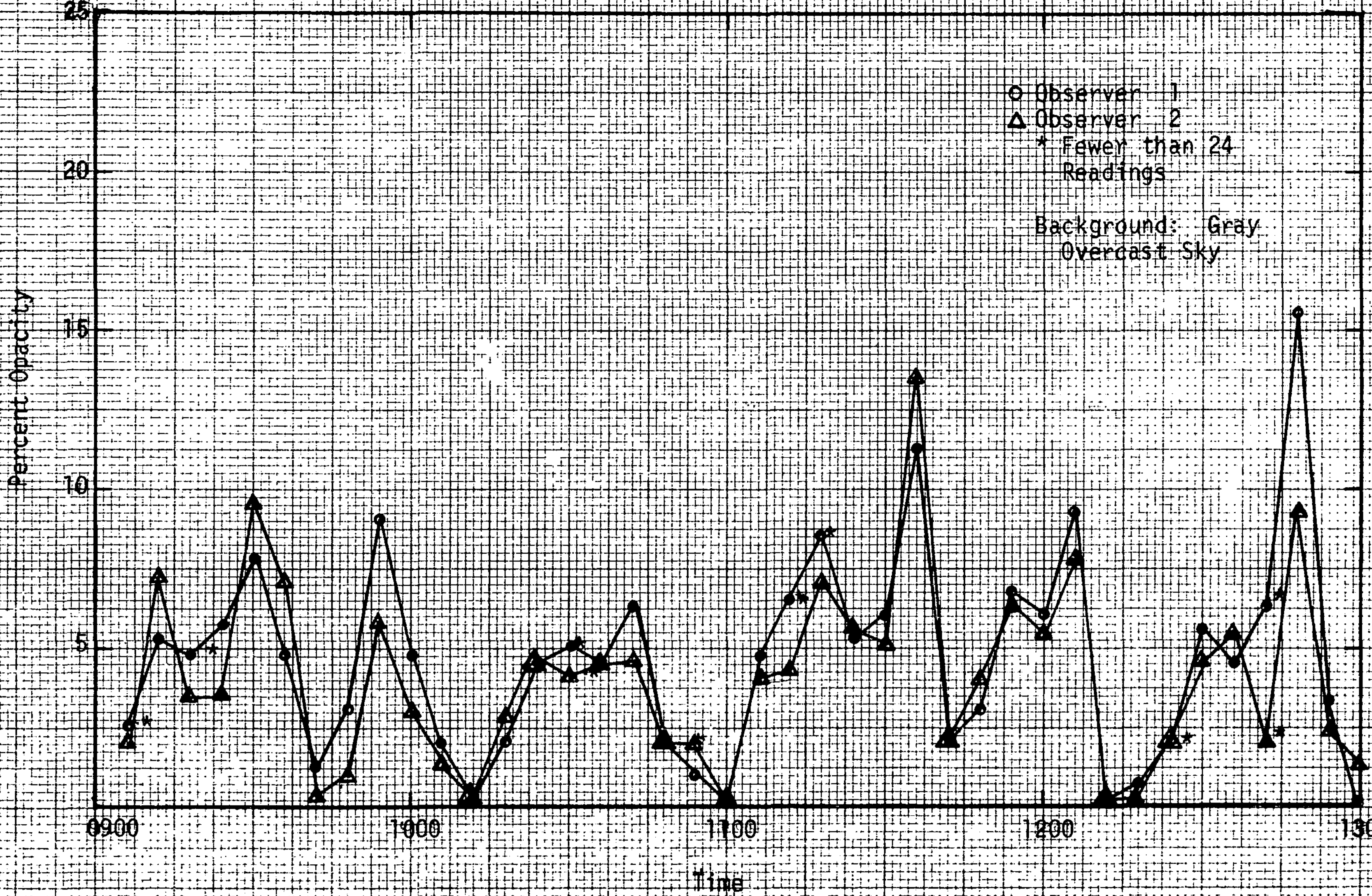

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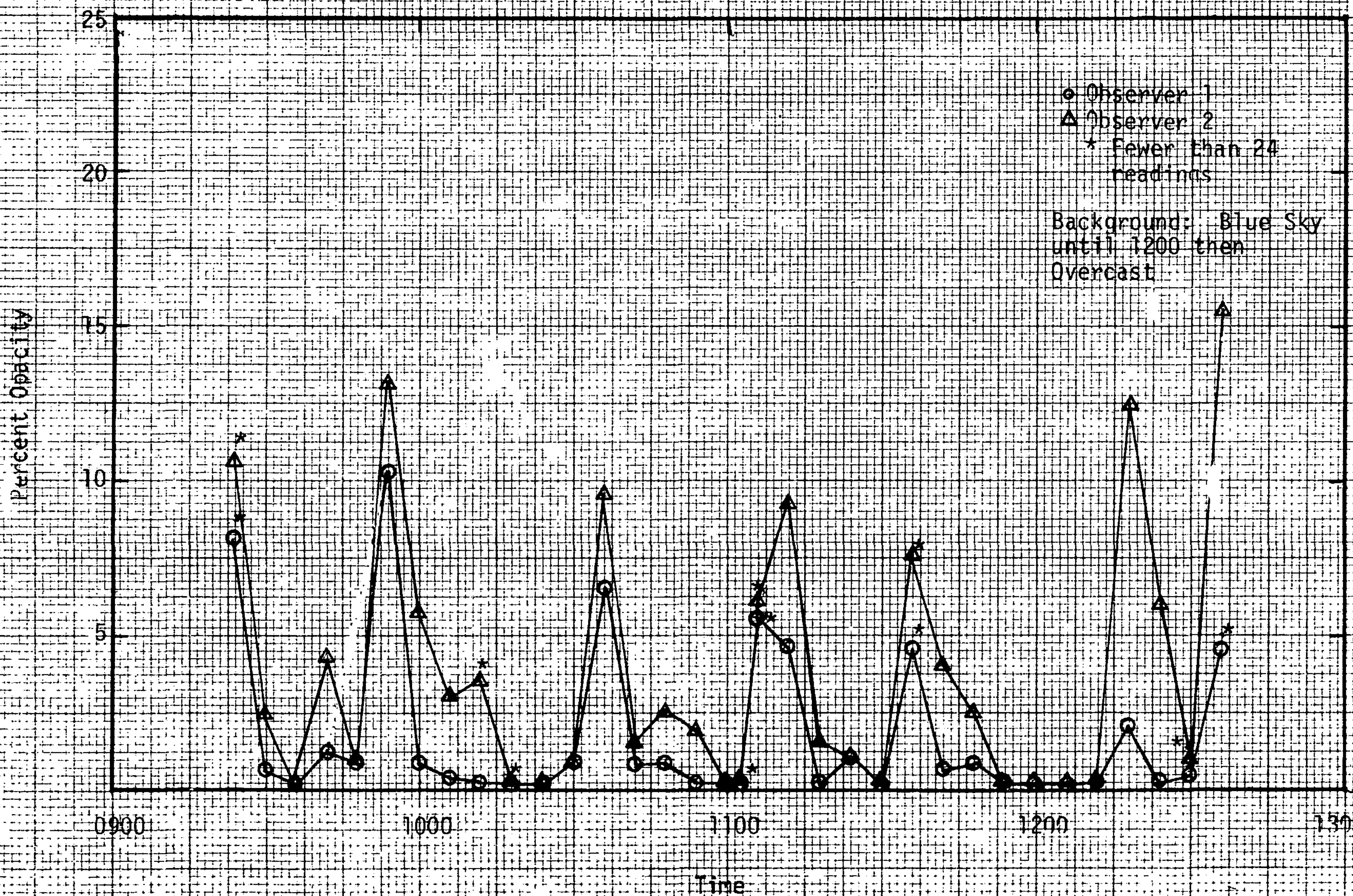

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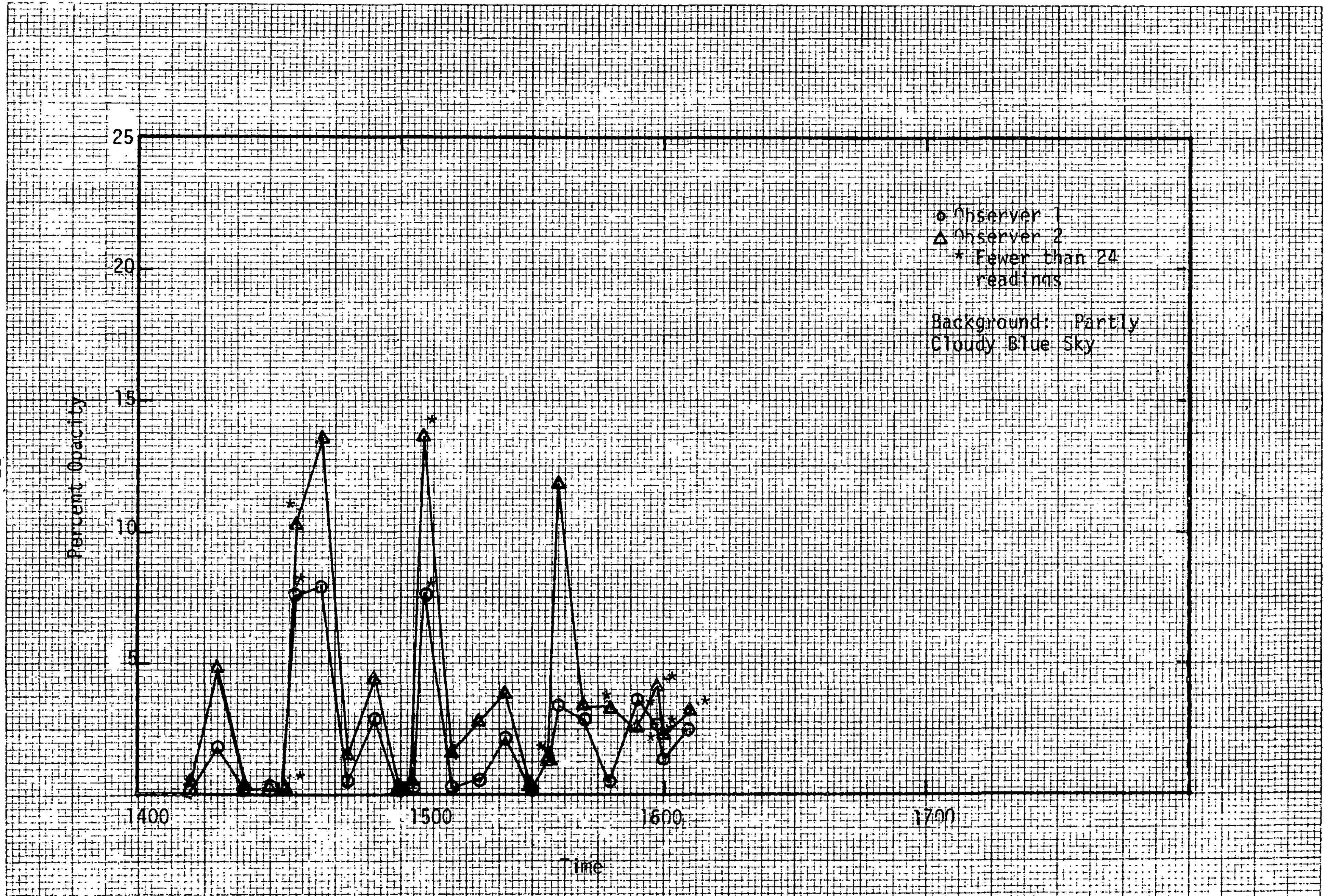

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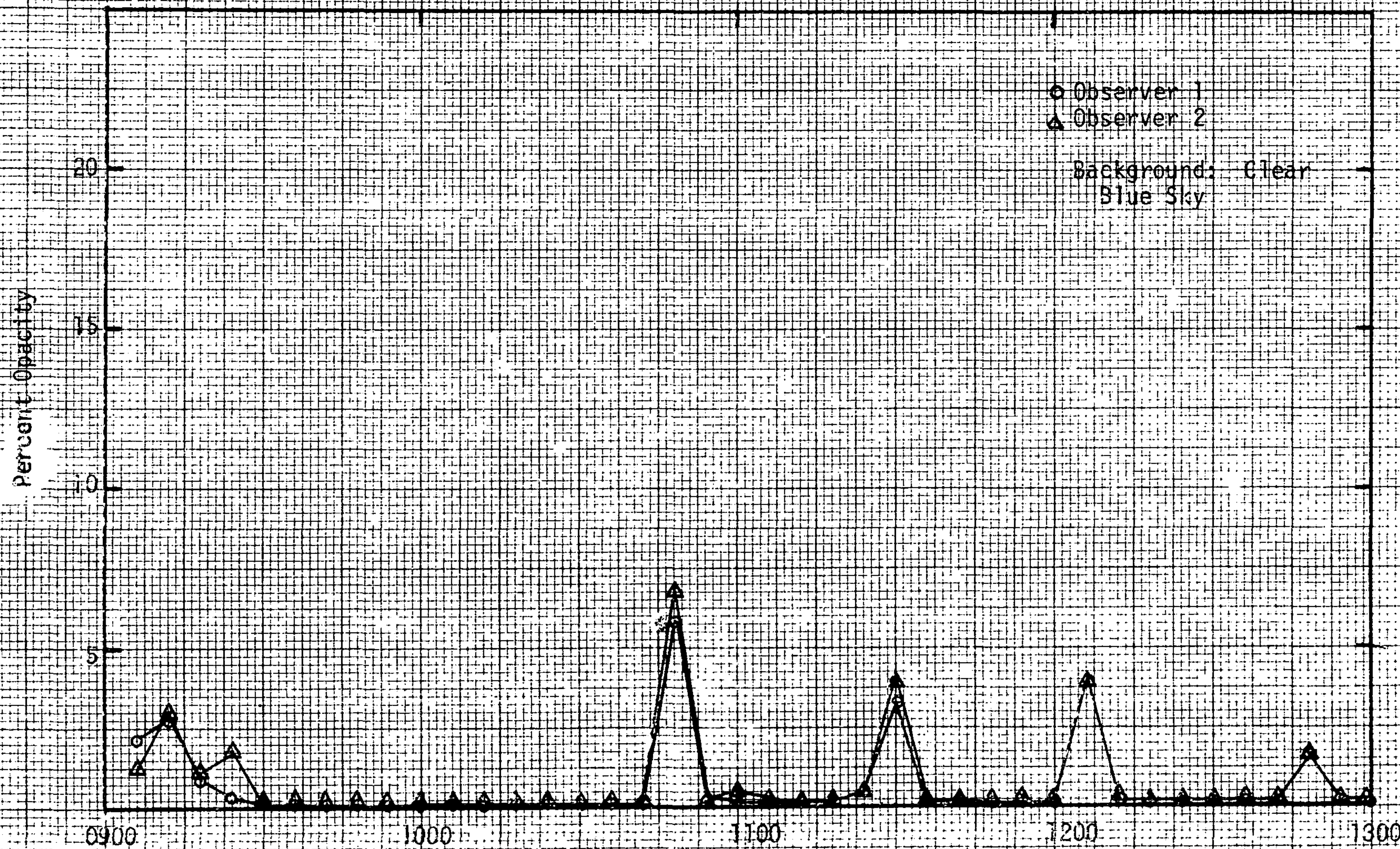

Figure 26. Opacity of Emissions from Facility I 6/29/76

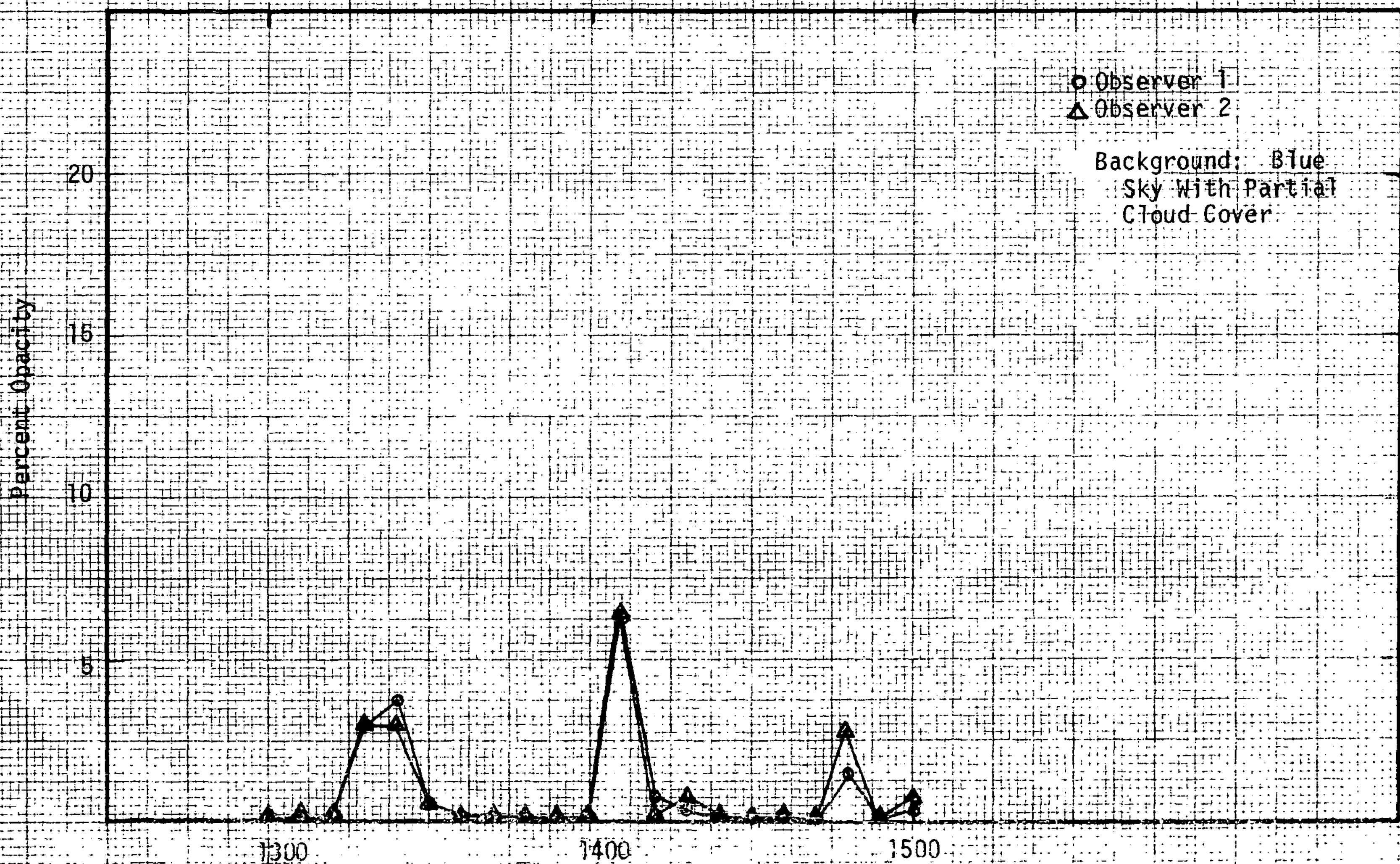

Figure 27. Opacity of Emissions from Facility I 6/29/76

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

The document presents the basis for the proposed opacity standard for basic oxygen process furnaces. Included is process and emission control information along with the rationale for the proposed standard. Monitoring requirements and visual test results are also included.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Iron and Steel Plants Basic Oxygen Process Furnaces Standards of Performance	Air Pollution Control	

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