Materials on the effect of illumination on industrial efficiency and on the illumination study at Hawthorne. 1920's.

27

Howard

DEVELOPMENT OF THE ILLUMINATION STUDY

AND THE RELATIONSHIP TO OTHER RESEARCH PROJECTS

The earliest organized effort at research in employee effectiveness at Hawthorne began on November 24, 1924. A week or two previous to this time the following bulletin board announcement appeared in three departments - (1) Relay Assembly Department, (2) Miscellaneous Punch Press Inspection Department, and (3) Receiver Coil Winding Department:

"The National Research Council of the American Academy of Science is an established association of some years standing composed of the leading scientists and engineers of the United States and created for the advancement of science in all paths.

"The National Research Council has for some time realized that the lighting of industrial establishments generally throughout the world has been determined in a rather crude fashion, and it has reached the conclusion that a scientific study of the entire question of factory lighting would likely result in substantial benefit to the people engaged in that class of work and to industry itself. The National Research Council has decided to conduct a line of scientific research of the entire question during the next two years, and to carry out the work has appointed a committee headed by Professor D. C. Jackson to the Massachusetts Institute of Technology. That the Committee aims to make this research of a very thorough character is indicated by the fact that the National Research Council has appropriated fifty thousand dollars to cover the cost of its investigations to determine what improvement of working conditions can be secured by better lighting.

"Professor Jackson, acting for the Committee, has asked permission of the Western Electric Company to make some tests at the Hawthorne Works bearing on this general subject, and this request has been readily granted as the Western Electric Company is interested in any study of conditions that has for its object the determination of improved working conditions.

"After a survey of the various classes of manufacturing conducted at Hawthorne, the Committee has selected the Relay Assembly Department as one of the departments in which to conduct its tests of varying degrees of lighting and various forms of illumination. As soon as the National Research Council perfects its plans, further details as to the method of conducting the proposed tests will be given to you.

"As the Company is interested in the results, it intends to lend all the assistance it can in the conduct of these tests, and it asks that the employees of the Relay Assembly Department give their full and free co-operation to the engineer assigned by the Committee to conduct this work."

The purpose of this study as stated by Professor Jackson, who was in charge of the study, in a paper which he presented before the Franklin Institute at Philadelphia on Thursday, December 8, 1927, was to seek the "Relation of Quality and Quantity of Illumination to Efficiency in Industry."

These illumination studies which definitely got under way in November, 1924 continued until April 30, 1927. The experiments which took place during this period of two years and six months are too involved to be covered in detail, but the following excerpts from a report by Mr. C. E. Snow,* who was in charge of the research experiment at Hawthorne, give interesting indications as to the progress of the study:

"During the first winter, three different departments were investigated. In one department the operatives inspected shiny metallic switch-jack shells and springs for a large number of possible defects. In the second department the operatives assembled electrical relays. This work consisted of placing the coils, springs and insulators into the proper position and then bolting them together. In the third department the operatives wound small induction coils on wooden spools.

"The general test procedure for each department was the same. First there was a preliminary period, during which the operatives worked under the existing lighting installation supplemented by daylight. The average production rates obtained during this preliminary period furnished base lines for calculating any future production changes.

"The various levels of average illumination intensity for the shell and spring inspectors were 3, 6, 14, and 23 foot-candles. The corresponding production efficiencies by no means followed the magnitude or trend of the lighting intensities. The output bobbed up and down without direct relation to the amount of illumination.

"The illumination intensities furnished the relay assemblers were 5, 12, 25 and 44 foot-candles. The efficiency of this department increased more or less continuously during the test but not as a sole function of illumination.

*Research on Industrial Illumination by C. E. Snow '23, Tech Engineering News.

"The various levels of average illumination intensity furnished to the coil winders were 10, 16, 27 and 46 foot-candles. The production efficiencies corresponding to these period of different lighting intensities were always higher than the starting level and did not always fall off with a decrease in illumination.

"The results of this first winter's test, covering the three departments described, brought out very forcibly the necessity of controlling or eliminating the various additional factors which affected production output in either the same or opposing direction to that which we could ascribe to illumination.

"During the following summer, production records were kept of the three departments tested. A consideration of the favorable and unfavorable test factors existing in each department led to the choosing of the coil winding department for another test the following winter. The essential change in procedure for this test was the division of the coil winders into two groups. Each group had an equal number of operatives of equal experience and were so selected as to have equal average productive efficiencies at the start of the test, based on their summer records. One group, called the test group, was to work under variable illumination intensities and the other group, called the control group, was to work under as near a constant illumination as possible considering the fact that the artificial illumination was supplemented by the ever variable daylight. The groups were located in different buildings in order to make the separation complete and in this way reduce the influence of any spirit of competition.

"The test group worked under three different average lighting intensity periods of 24, 46, and 70 foot-candles while the control group worked under a more or less constant level of 16 to 28 foot-candles. The increase in daylight accompanying the advancing season was responsible for the large variation in illumination intensity. This plan of having a control group was decided upon as a means of evaluating the effect of illumination by subtracting the output of the control group from the output of the test group. The differential between the two should be related by any increase in productive efficiency caused by the higher levels of illumination intensity.

"This test resulted in very appreciable production increases in both groups and of almost identical magnitude.

The difference in efficiency of the groups was so small as to be less than the probable error of the values. Consequently we were again unable to determine what definite part of the improvement in performance should be ascribed to improved illumination. However, it should be borne in mind that the illumination intensity furnished the control group was relatively high and may have included the same benefits as the higher illumination furnished the test group.

"The following year another test was conducted with the coil winders, using two essentially different methods of procedure. The mixture of artificial with natural illumination during the previous test had resulted in a lack of definite control of the illumination intensities. Therefore, this new test used artificial lighting only. The levels of illumination intensity formerly used were in most cases considerably higher than are found in most plants. Furthermore, the results of the laboratory tests, being carried on at this time for the committee, indicated that the critical point of illumination for the coil winding operation probably was in the neighborhood of 5 to 10 foot-candles. For this reason it was decided to provide intensity levels from 10 to 3 foot-candles in steps, decreasing 1 foot-candle at a time. This, of course, applied to the test group, since it was decided to follow the test control and group method as outlined in the previous test. The control group was to be provided with a constant level of 10 foot-candles. Physical separation of the two groups was provided by locating each group in an enclosure, being careful, of course, to provide sufficient ventilation and to minimize any feeling of confinement.

"The illumination intensity of the test group started at 10 foot-candles and decreased to 3 foot-candles, cutting down 1 foot-candle at a step. As the level of illumination in the test group enclosure changed to a lower value, the efficiencies of both the test and control groups increased slowly but steadily. When the level of illumination for the test group finally reached 3 foot-candles the operatives protested, saying that they were hardly able to see what they were doing and the production rate decreased. The operatives could and did maintain their efficiency to this point in spite of the discomfort and handicap of insufficient illumination."

C Result III

Shortly after the completion of the regular illumination study, Mr. Hibarger, who was in charge of the Hawthorne's part of the investigation, requested and received permission to submit

two operators to still further experimentation. Two rather capable operators who were selected for their willingness to cooperate in such a study and also because they had taken part in the original illumination study, were provided with working facilities in a locker room which could be made completely dark. Mr. Hibarger then cut down the amount of light from what the girls had been working under, to .06 of a foot-candle at the bench, which is about the light given on an ordinary moonlight night.

Even with this very low intensity of light the girls kept their efficiency up and said that they suffered no eye strain and indicated that they felt less tired than when working under bright lights. One of the girls said she would not mind working under these conditions of lighting for some time if she could have a radio in the room. When asked if she thought she could assemble her work if she were blindfolded, she said, "Yes, but it wouldn't be nice to have your eyes covered up all the time. You do need to see a little because you can work faster."

Mr. Hibarger was interested in these results, but was not yet completely satisfied that it had been clearly demonstrated that the effects of illumination secured in the previous studies were more psychological than real. He, therefore, without authorization, tried still further light tests on the girls. He first made regular day by day changes in the light, increasing the amount of light and daily asking the girls how they liked the changes in light. As the light was increased they told him they liked it better for various reasons, and then for a day or two he let them see the electrician come in and ostensibly change the light globes. In reality, the electrician merely took out bulbs of a given size and reinserted bulbs of the same size without any way changing the amount of light. The girls, thinking that the lighting was still being stepped up day by day, commented favorably about the increase of light. After a few days of this he started stepping the light down day by day and at various periods again let them see the electrician change bulbs without really changing them; in other words, leaving the lighting the same. Again the girls gave him the answers that were to be expected as we see it now in that they told him that the "lesser" light was not as pleasant to work under as the brighter light. Their production did not materially change at any stage in the experiment.

The net conclusions of the Hawthorne folk's instrumental in carrying out this part of the research program is well expressed in a memorandum which Mr. Pennock wrote to Professor Jackson three years after the completion of the illumination study (8-4-30). He says in part:

"..... in my opinion the work we have done in the last three years does prove pretty conclusively that what we were trying to do in the testing for the effect of illumination on output was an impossibility. By that I mean that after three years of further tests for the effect of various factors on output we are convinced that it is impossible to test a group of people for the effect of any single variable, as all other conditions affecting the performance of human beings cannot be maintained constant, and therefore, any results obtained may be affected by any one of several variables."

"..... if I were to write a closing statement for the Illumination Report I should say that, while the tests failed in answering the specific question involved, they did ultimately teach us a great deal about the technique of making such studies, and this knowledge applied to problems involving human factors cannot fail to be of immense value to industry."

In some ways the Illumination Study can be regarded as so much lost motion in that it proved that the relations of the amount of illumination and production could not be definitely determined because there are too many other uncontrollable features in the industrial situation. This conclusion, however, led us into the very much broader field of inquiry covered in the Relay Test Room which was set up following the completion of the Illumination Study.

It is interesting to note in this connection that the objectives of this new test room which started in the early part of 1927 were stated in the form of six rather definite questions. The following six questions were the original list:

1. Do employees actually get tired out?

2. Are rest pauses desirable?

3. Is a shorter working day desirable?

4. What is the attitude of employees toward their work and toward the Company?

5. What is the effect of changing the type of working equipment?

6. Why does production fall off in the afternoon?

In addition to these questions, it was felt, from the experience in the illumination study, that there was much to learn

from the operators themselves if we could establish the proper relationship with them. It was felt, too, that our experience would indicate our objectives more and more clearly as we progressed in the study.

The actual working out of these questions is in itself a long and involved story and is covered in other papers.

RESEARCH

ON INDUSTRIAL ILLUMINATION

Main Title

A DISCUSSION OF THE RELATION OF ILLUMINATION INTENSITY TO PRODUCTIVE EFFICIENCY

Sub-title

BY C. E. SNOW, '23

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RESEARCH ON INDUSTRIAL ILLUMINATION

A Discussion of the Relation of Illumination Intensity to Productive Efficiency.

It is the purpose of this article to give a general description of a series of tests of the effect of illumination intensity on production conducted under the supervision of the committee on industrial illumination of the division of engineering and research of the National Research Council. The phases of the tests toward which attention will be directed are the methods of test procedure, the industrial operations investigated, a statement of results, and a statement and analysis of some of the problems which arise in such an investigation.

The late Dr. Ernest Fox Nichols, president of the Massachusetts Institute of Technology in 1921, and chairman of the committee on research of the Illuminating Engineering Society in 1924, was in a large measure the instigator of this illumination study. He contributed a large part of his valuable time in organizing a tentative program for such an important undertaking, and with the approval of President Stratton, persuaded Professor Jackson of the Massachusetts Institute of Technology, to accept the active chairmanship of a committee on industrial illumination. This committee represents the division of engineering and research of the National Research Council and is part of a large directive board composed of most distinguished men. These men include well-known executives, electrical engineers, illuminating engineers, educators, psychologists, ophthalmologists and an official of the American Federation of Labor. This committee in handling such an investigation, was practically ideal in that it represented a completely impartial but highly interested and informed body of men. Mr. Thomas Edison accepted the honorary chairmanship of the directive board and in the spring of 1924, the first meeting was held in the library room of his laboratory at West Orange, N. J., to discuss and pass upon the policy and program of the investigation. The phases covered in this investigation included an exhaustive review of the literature, and a series of laboratory tests and industrial illumination-production tests carried out in the factories. This paper will be confined to a consideration of the industrial tests. The classes of work chosen for investigation are representative, with respect to their eye task, of the most common types in industry. The Institute of Technology was selected as the central organization to carry on the tests and the Illuminating Engineering Society gave its endorsement and adherence to the plan.

The first industrial test was conducted in the switch assembly department of a large eastern manufacturing plant and covered a period of six months. A group of operatives to be included in the test were selected and means taken to record the average hourly production of the group. The first part of the test constituted a period during which the operatives worked under the original lighting installation and gave

a production rate which was used as the base, or arbitrary standard, for any future changes in production efficiency caused by the introduction of a higher illumination intensity. The level of artificial illumination intensity furnished by the original installation was 7 foot-candles. This intensity was raised to 9 and then to 23 foot-candles for periods lasting 5 to 6 weeks. Throughout the test the artificial illumination was supplemented by so much daylight that any average based on these intensities is of little value. It will be observed that the original level of intensity of artificial illumination (7 foot-candles) was well above factory lighting characteristic of the United States, and this was also aided by natural lighting.

In each case of increased illumination intensity there was an appreciable increase in the production rate. However, when the artificial intensity was changed to that of the two lower levels, the production rate remained at its new high level.

This test brought to mind clearly the important effect of uncontrolled influences. The factors which affected production vary greatly, and which consequently obscured any possible lighting effect which might be present, were increasing demand for the product increasing efficiency, (operatives becoming more experienced), variation in working material and changes in product and operation.

Another test was started about the same time as the first one and continued over a period of two and one half years. This test was conducted in a large plant in the middle west and was broken up into three separate divisions, corresponding to three different winters.

During the first winter, three different departments were investigated. In one department the operatives inspected shiny metallic switch-jack shells and springs for a large number of possible defects. In the second department the operatives assembled electrical relays. This work consisted of placing the coils, springs and insulators into the proper position and then bolting them together. Figure 2 shows an operative in the process of assembling a relay. In the third department the operatives wound small induction coils on wooden spools.

The general test procedure for each department was the same. First there was a preliminary period, during which the operatives worked under the existing lighting installation supplemented by daylight. The average production rates obtained during this preliminary period furnished base lines for calculating any future production changes.

The various levels of average illumination intensity for the shell and spring inspectors were 3, 6, 14 and 23 foot-chandles. The corresponding production efficiencies by no means followed the magnitude or trend of the lighting intensities. The output bobbed up and down

without direct relation to the amount of illumination.

The illumination intensities furnished the relay assemblers were 5, 12, 25 and 44 foot-candles. The efficiency of this department increased more or less continuously during the test but not as a sole function of illumination.

The various levels of average illumination intensity furnished to the coil winders were 10, 16, 27 and 46 foot-candles. The production efficiencies corresponding to these periods of different lighting intensities were always higher than the starting level and did not always fall off with a decrease in illumination.

The results of this first winter's test, covering the three departments described, brought out very forcibly the necessity of controlling or eliminating the various additional factors which affected production output in either the same or opposing direction to that which we could ascribe to illumination.

During the following summer, production records were kept of the three departments tested. A consideration of the favorable and unfavorable test factors existing in each department led to the choosing of the coil winding department for another test the following winter. The essential change in procedure for this test was the division of the coil winders into two groups. Each group had an equal number of operatives of equal experience and were so selected as to have equal average productive efficiencies at the start of the test, based on their summer records. One group, called the test group, was to work under variable illumination intensities and the other group, called the control group, was to work under as near a constant illumination as possible considering the fact that the artificial illumination was supplemented by the ever variable daylight. The groups were located in different buildings in order to make the separation complete and in this way reduce the influence of any spirit of competition.

The test group worked under three different average lighting intensity periods of 24, 46 and 70 foot-candles while the control group worked under a more or less constant level of 16 to 28 foot-candles. The increase in daylight accompanying the advancing season was responsible for the large variation in illumination by subtracting the output of the control group from the output of the test group. The differential between the two should be related to any increase in productive efficiency caused by the higher levels of illumination intensity.

This test resulted in very appreciable production increases in both groups and of almost identical magnitude. The difference in efficiency of the groups was so small as to be less than the probable error of the values. Consequently we were again unable to determine what

definite part of the improvement in performance should be ascribed to improved illumination. However, it should be borne in mind that the illumination intensity furnished the control group was relatively high and may have included the same benefits as the higher illumination furnished the test group.

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The illumination intensity of the test group started at 10 foot-candles and decreased to 3 foot-candles, cutting down 1 foot-candle at a step. As the level of illumination in the test group enclosure changed to a lower value, the efficiencies of both the test and control groups increased slowly but steadily. When the level of illumination for the test group finally reached 3 foot-candles, the operatives protested, saying that they were hardly able to see what they were doing and the production rate decreased. The operatives could and did maintain their efficiency to this point in spite of the discomfort and handicap of insufficient illumination.

An entirely different illumination-production test was conducted in the paper cutting department of an eastern plant. This test involved the use of natural illumination only and was possible because of the very large amount of window space in the room and because the test was conducted in the part of year when the intensity of daylight was strong and getting stronger daily.

The operation performed by the workers consisted of cutting paper napkins from a large roll of paper stock mounted on rollers. The

paper was pulled across the lower blade of a large knife and stopped at a spot mark which indicated the place for cutting, but the location of the spot was indicated both manually and visually. The upper blade of the knife was operated by a treadle so that the actual cutting operation was accomplished by a foot movement. As soon as one cut was made, the operative pulled the paper along and the action was repeated over and over. Figure 3 indicates very clearly the operation of cutting the napkins and the brightness of the white paper.

The brightness of the white paper and production counts were read hourly at each operative's machine. Nature was relied upon for the variation in illumination since daylight varies considerably over different hours of the day and skies, (clear, light clouds, dark clouds, etc.,) sufficient variation of illumination for our purpose was obtained. Therefore we had a means of obtaining the hourly production and hourly variation in illumination for each individual in the test.

The results of this test indicated that this particular operation can be performed nearly as effectively under low values of illumination as under high values. The general range of illumination intensities existing throughout the test was from 2 to 40 foot-candles.

The next investigation was carried out in an eastern jewelry manufacturing plant. The operation tested was the joining of minute metal links of mesh bags. This particular job seemed rather ideal for the purpose of the experiment because it possessed a considerably greater eye task than m any industrial operations. Sheet mesh (composed of very small wire rings joined together on automatic machines) was furnished to the operatives cut into the proper sizes for bags. In order to make the bag, the sides had to be joined together. The actual operation of joining, as performed by the operatives, was to place the little rings to be joined over one half of the small circular die by using tweezers. The operatives pressed a foot pedal and the upper half of the die came down upon the lower. Simultaneously wire was fed to the dies, cut off, and formed into a ring around the other rings which were to be joined. The number of rings inserted by the operative was recorded by a counter attached to the machine.

Three types of illumination were available--daylight, overhead artificial illumination and local illumination from individual reflectors. The general overhead illumination was used at the operative's discretion - usually in the early morning and late afternoon. Illumination measurements were made at each machine hourly and at the same time the production was read from the counters.

This particular operation was studied in the laboratory at Technology the following year and gave more definite results than could be obtained under the necessarily irregular conditions existing in the factory. With two increases of illumination intensity, a single operative produced appreciable increases in efficiency of production. Before further changes in illumination intensity could be attempted, or the

first figures checked, the trained test subject resigned.

A very different class of work was subjected to investigation by conducting an illumination-production test in a large eastern cotton-tape weaving mill. The actual production of the tape was, of course, from power driven looms. However, there was a sufficient number of strictly manual operations requiring close visual attention to be performed to have a direct bearing upon the actual production of the looms.

During the test, the operatives worked under artificial illumination of fine quality furnished by indirect lighting units. This luxurious type of illumination was of especial value for the work because the shadows were reduced to a minimum. Shadows would have had an extremely detrimental effect with direct lighting because of the physical characteristics of intricate mechanisms such as looms.

The results of this test were not unlike those of previous tests in that they illustrated the manner in which influences other than illumination affect efficiency to so great an extent that it is difficult to fully isolate the benefits of good illumination.

These uncontrolled outside influences are many in number and varied in effect. Some of them are beyond the control of the operatives, but many are a direct result of psychological effects bound up in the individuality of the worker. As soon as lessons were learned from the experience of one test and corrective measures applied, additional lesser variables would become apparent to continue the process of obscuring the results.

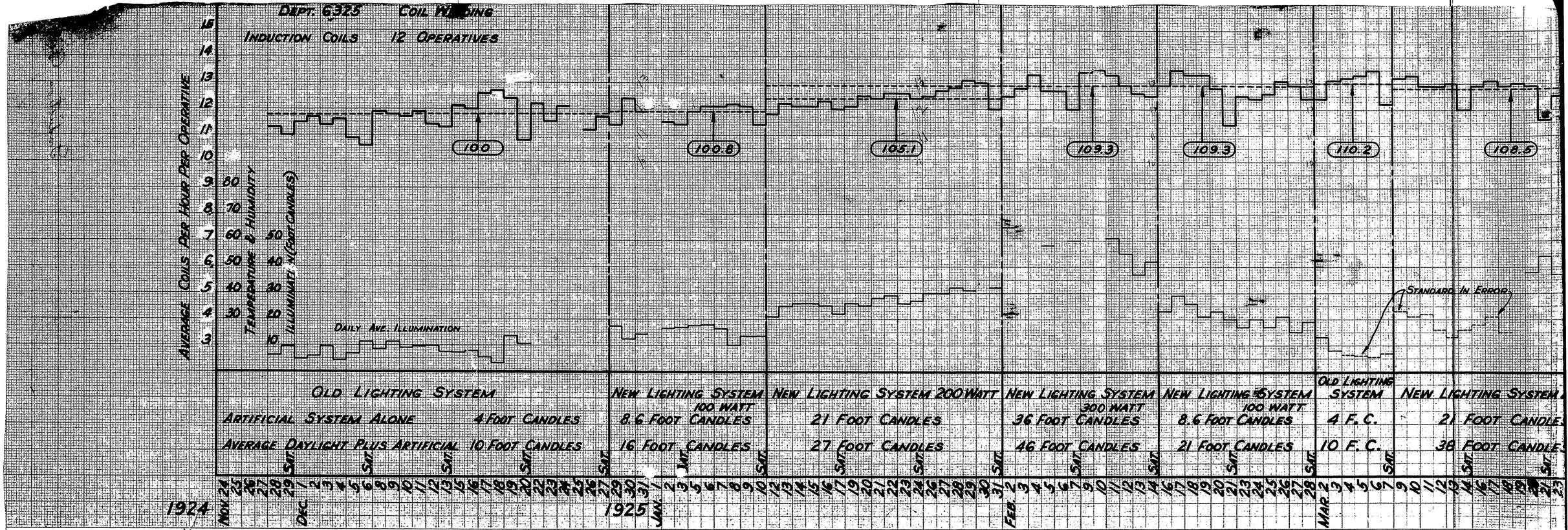
A partial enumeration of the various factors will bring out forcibly the difficulties and problems of such an investigation. The demand for the produce will cause a large variation in the rate of output. A sudden large increase in orders will result in a large total output but it may or may not cause an increase in individual output. If new workers are employed and have to go through a learning period, the average efficiency of a group will decrease in spite of the increase in total output. If the original employees take care of the increased production, then, of course, the efficiency goes up in proportion. Fear of a lay-off will cause employees to work very hard to hold their jobs. With plenty of jobs available, they will be independent and the tendency is to work more as they please.

Piece rate workers have a different incentive for production than day rate workers. Some piece rate employees perhaps intentionally limit their production in the fear of having a rate cut. A sudden desire for money may result in a tremendous spurt on the part of a piece rate worker. A very marked effect is observed in the kind and amount of supervision applied to workers. A new foreman or shop boss may cause a large change in efficiency.

Outside interests and activities contribute their share in the general effect. The drop in production around holidays is known to every factory man. Then there is the vital effect of physical condition. This subject needs no enlargement — we all have first hand information on the relation of our general condition with what we accomplish.

In conclusion it is desired to emphasize the following statements. Any investigation attempting to evaluate definitely the effect of illumination or some such influence, must take the greatest of pains to control or eliminate all factors but the one being studied. Many of them can be controlled or eliminated, but the one great stumbling block remaining is the problem of the psychology of the human individual.

This résumé of a series of tests has merely touched the high spots. Detail was impossible in such a short article. The complete and final report of the whole investigation will be published by the division of engineering and research of the National Research Council in 1928, associating numberous tests in factories, much laboratory work and study by notable psychologists carried on at the instance of the committee which has secured a volume of information that it is believed will prove serviceable to the industries in this important factor of artificial illumination.



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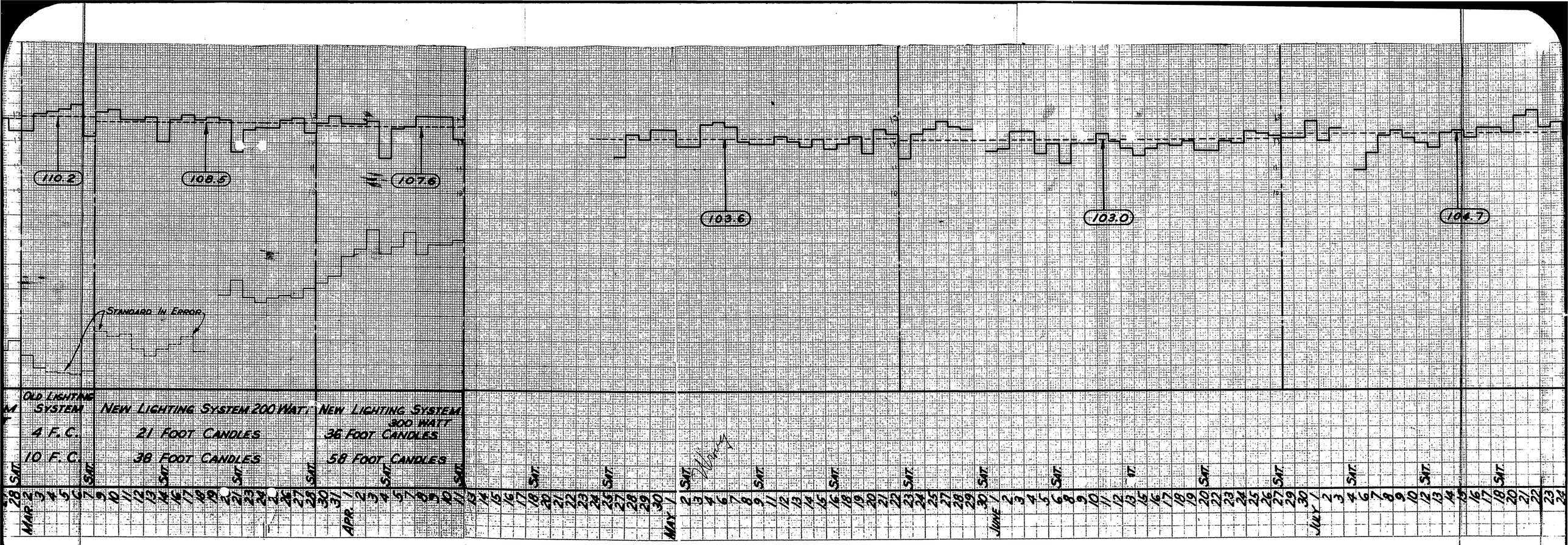

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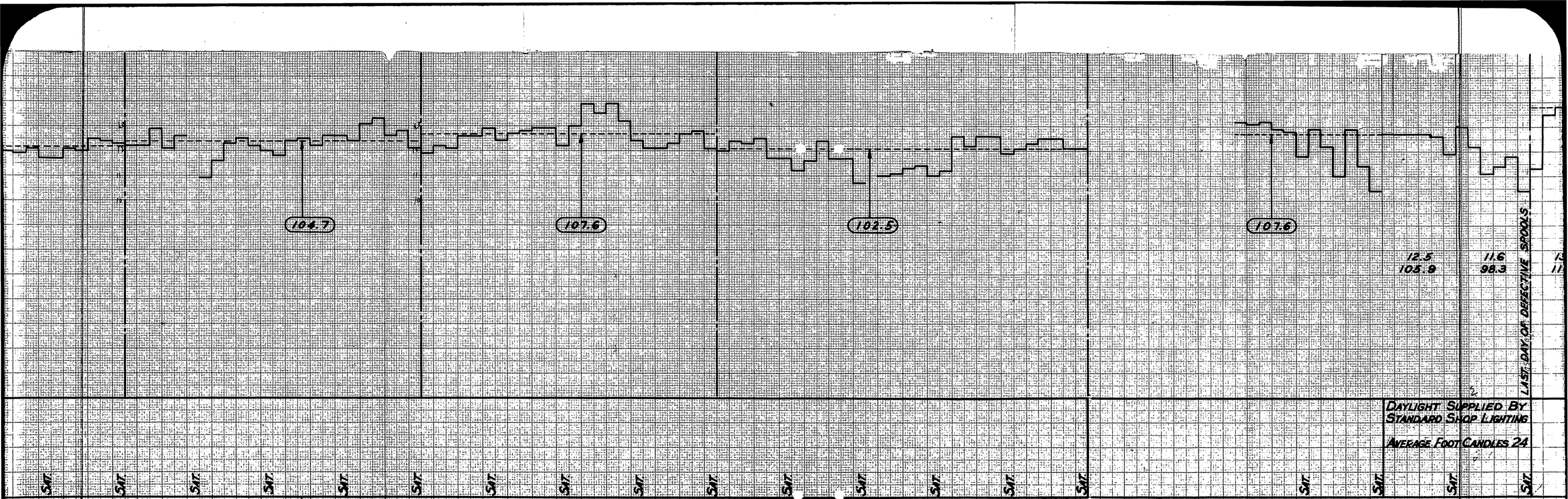
104.7
107.6
102.5
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105.9
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LAST DAY OF DEFECTIVE SCHOOLS
DAYLIGHT SUPPLIED BY STANDARD SHOP LIGHTING
AVERAGE FOOT CANDLES 24
1926
JULY
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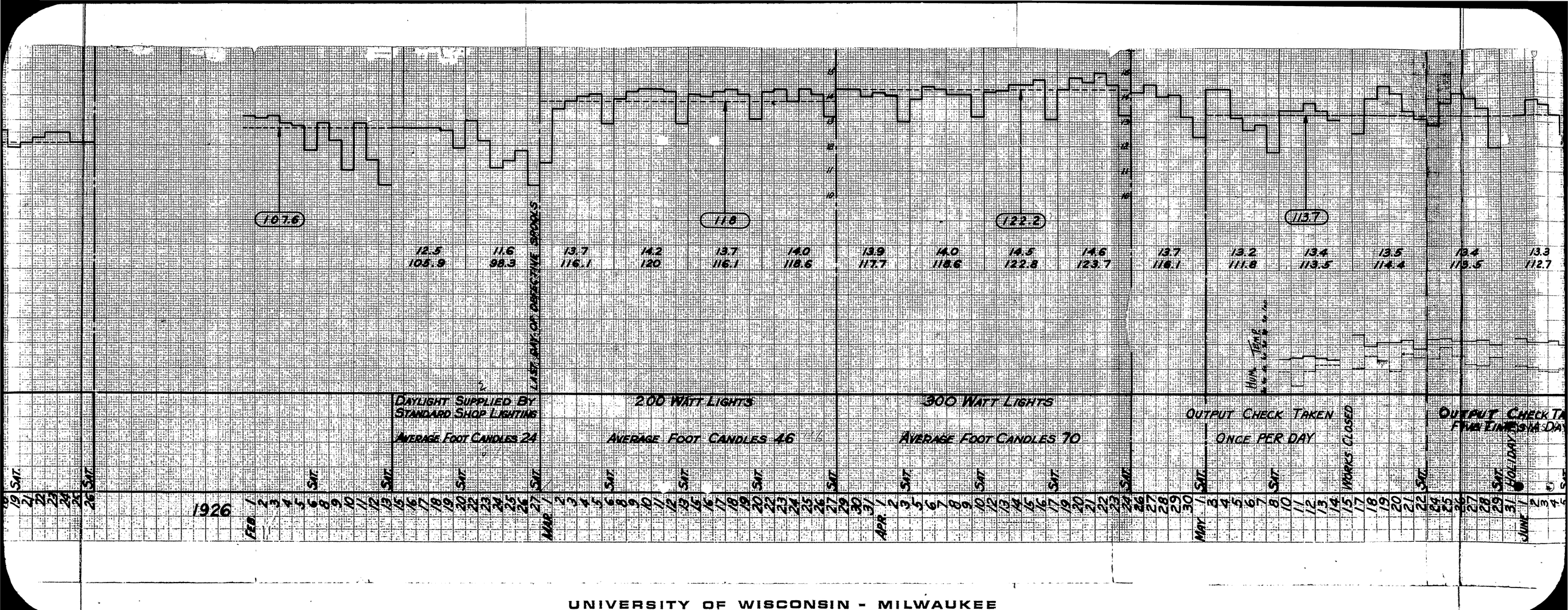
107.6
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14.0 118.6
14.5 122.8
14.6 123.7
13.7 116.1
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LAST DAY OF DAYLIGHT SAVING'S
DAYLIGHT SUPPLIED BY STANDARD SHOP LIGHTING
AVERAGE FOOT CANDLES 24
200 WATT LIGHTS
AVERAGE FOOT CANDLES 46
300 WATT LIGHTS
AVERAGE FOOT CANDLES 70
OUTPUT CHECK TAKEN ONCE PER DAY
OUTPUT CHECK TA FIVE TIMES A DA
HOURS CLOSED
HOLIDAY
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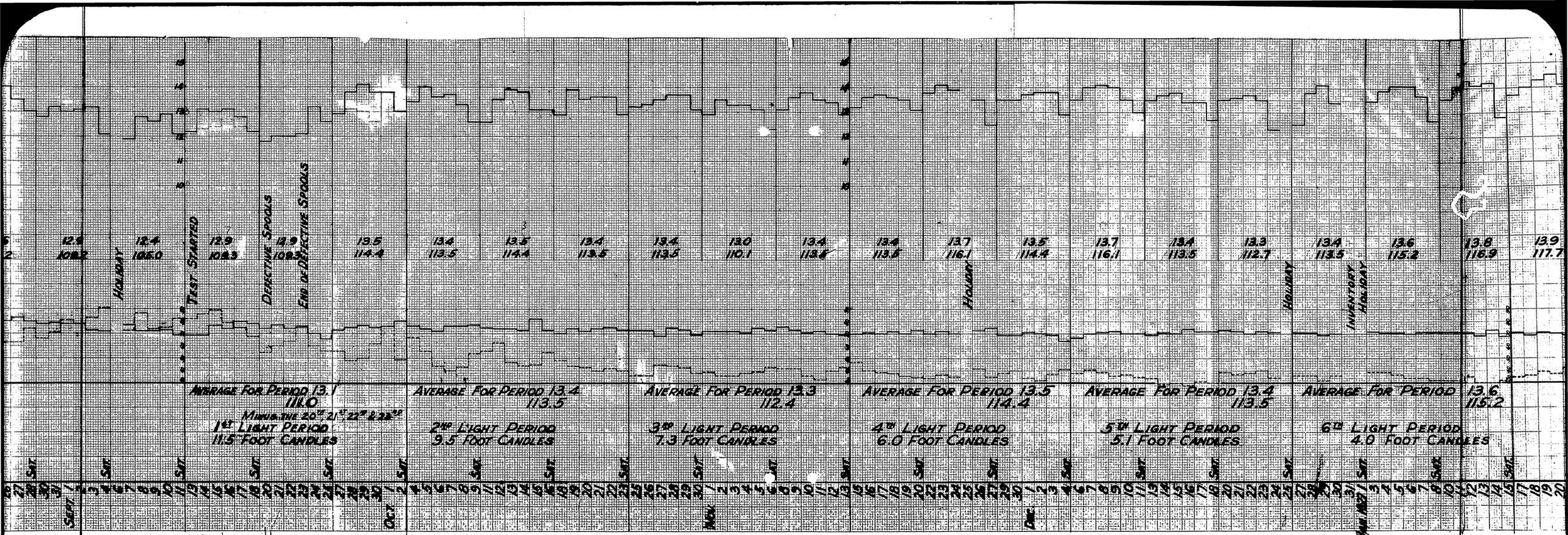

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TEST GROUP TRANSFERRED
TO WEST ROOM
GANGS STARTED ON DAY WORK
GANGS RETURNED TO PIECE WORK
AVERAGE FOR PERIOD 13.6
116.2
AVERAGE FOR PERIOD 13.9
117.7
AVERAGE FOR PERIOD 13.7
116.1
AVERAGE FOR PERIOD 13.9
117.7
6TH LIGHT PERIOD
4.9 FOOT CANDLES
7TH LIGHT PERIOD
2.7 FOOT CANDLES
9TH LIGHT PERIOD
11 FOOT CANDLES
10TH LIGHT PERIOD
11 FOOT CANDLES
11TH LIGHT PERIOD
4 FOOT CANDLES
INVENTORY HOLIDAY
END OF III. STUDY
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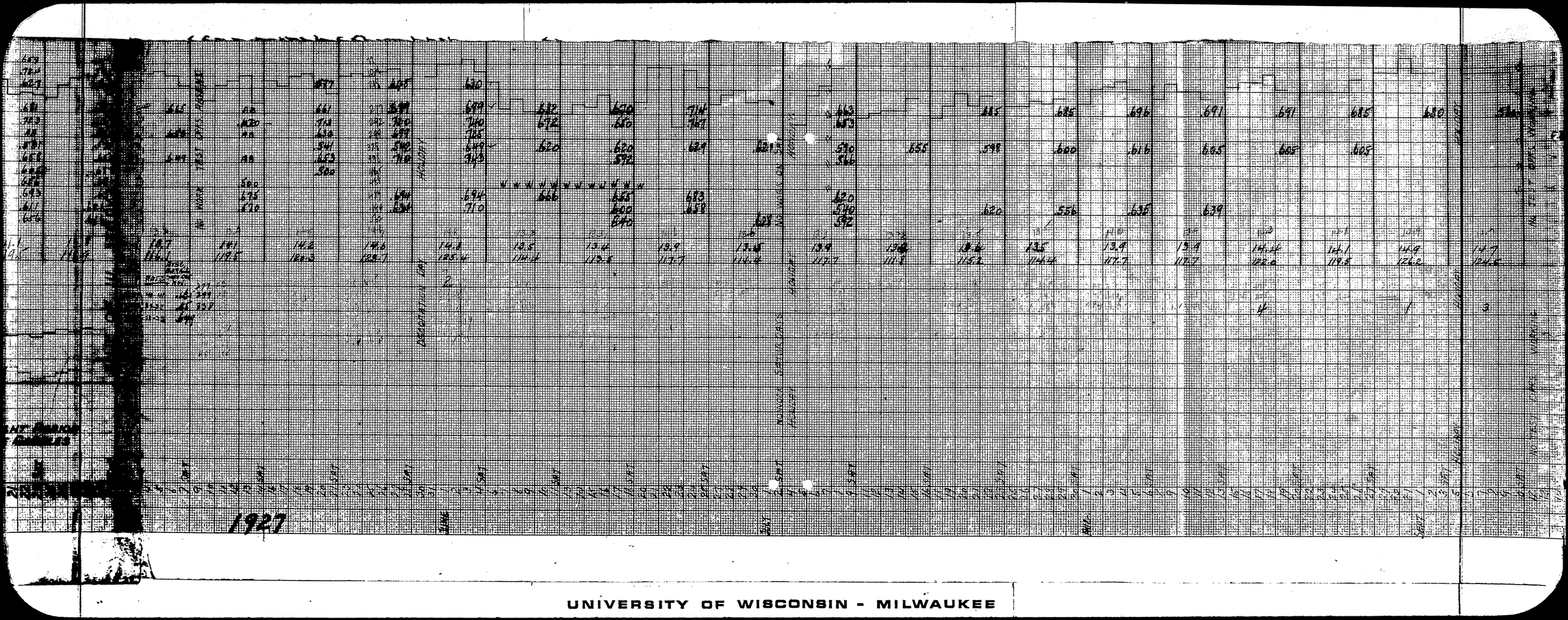


NO TEST OPRS WORKING
HOLIDAY

24-1 (5-31)

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CORRESPONDENCE FOLDER—CHARGE RECORD

[illegible]DER NO.	VOL. NO.	CHARGED TO— WRITE FULL NAME	DEPARTMENT	DATE CHARGED	DATE RETURNED
53		[illegible]	[illegible]		
		[illegible]	[illegible]		
		[illegible]	12-3-[illegible]		1/6/[illegible]
		[illegible]	1/[illegible]/[illegible]		