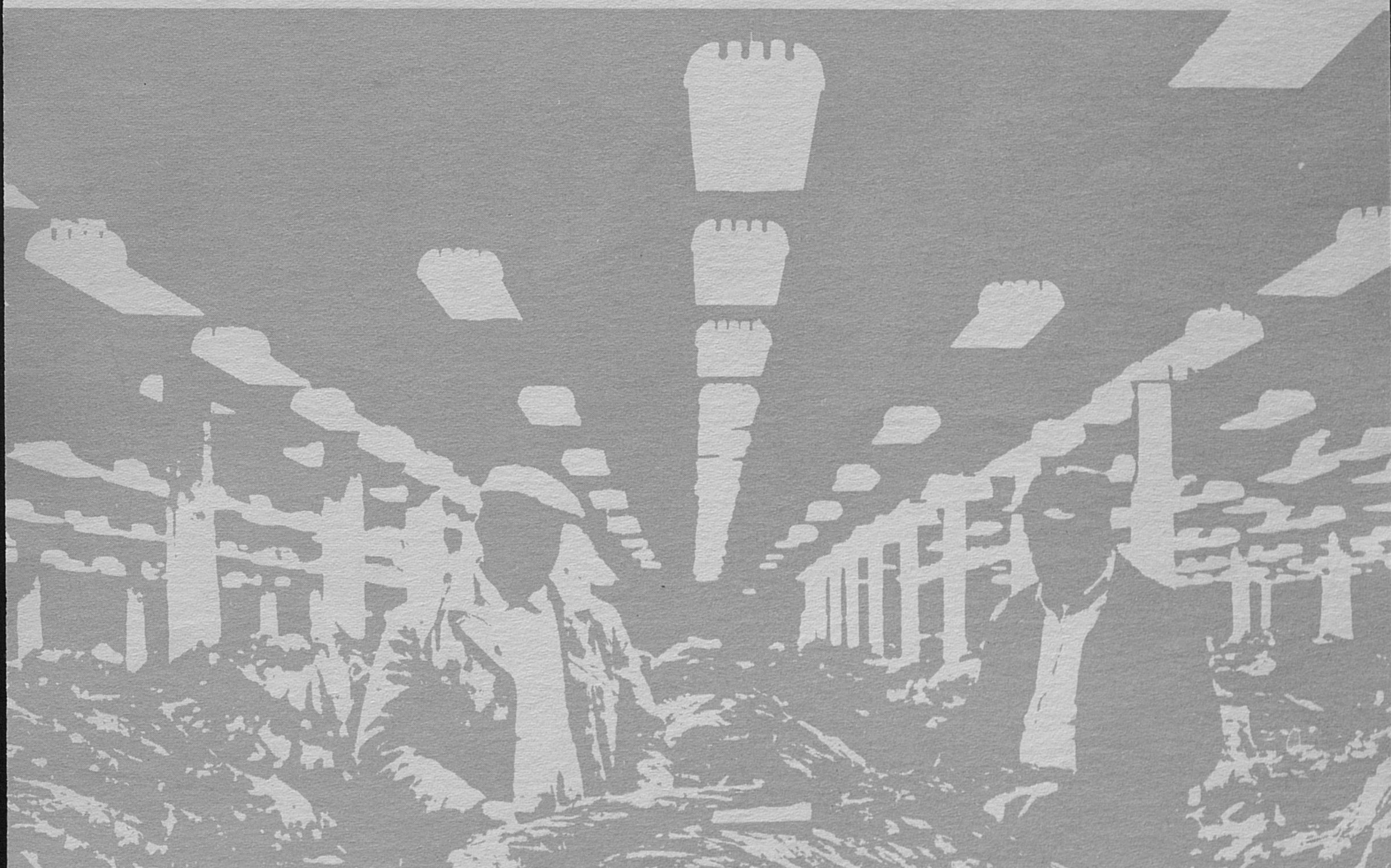
Recommendations For Grading Tobacco Under Fluorescent Light Source

By Carl M. Clark and Gerald M. White

PROGRESS REPORT 154



UNIVERSITY OF KENTUCKY AGRICULTURAL EXPERIMENT STATION
DEPARTMENTS OF AGRICULTURAL ECONOMICS AND AGRICULTURAL ENGINEERING ▪ LEXINGTON

KEY POINTS OF GRADE EVALUATION IN THE FLOW OF TOBACCO THROUGH THE MARKET CHANNEL

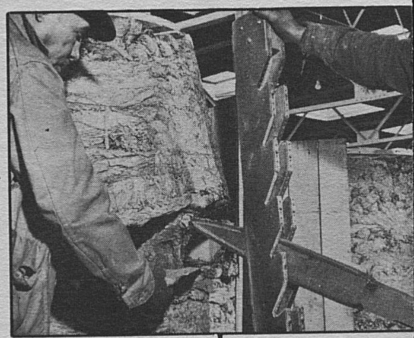
Leaf Grading on the Farm

Stick Sorting for Basket

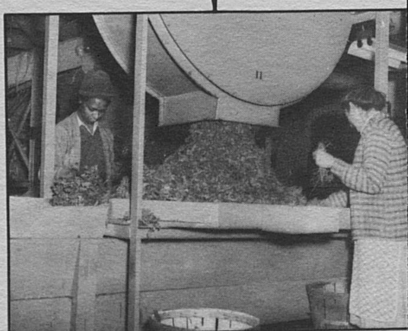
Federal Grading for Auction Sale

Auction Selling of Baskets

Sale Purchase Regrading for Redrying and Storage



Sample Grading of Hogsheads in Storage



Leaf Preparation for Processing Consumer Products

Tobacco leaf is graded at several points and at different times in the market flow. This is a part of the complexity of achieving a uniformity of light conditions throughout the market channel.

<u>Cover Picture</u>—Floor of burley ready for auction sale under the first electric lamp officially approved for selling purposes.
(Photo - Lexington, Ky., Herald-Leader)

(Photos on this page furnished by Louisville, Ky., Courier-Journal and Lexington, Ky., Herald-Leader.)

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CONTENTS

RECOMMENDATIONS FOR GRADING TOBACCO UNDER FLUORESCENT LIGHT SOURCE

By Carl M. Clark and Gerald M. White

Tobacco lighting research work of the Kentucky Agricultural Experiment Station stems from a study made of basket price variation in the auction selling of burley tobacco. The wide variation in daylight conditions occurring during the auction sale has been generally recognized throughout trade channels as one of the possible causal factors for the price risks of buying and selling (1).[1] This was the basis for initiating research on the character and influence of light in grading tobacco. The first step was to study daylight conditions existing in the looseleaf auction sale. Light quantity or intensity was found to vary from day to day through the sale season, from hour to hour through the sale day, from warehouse to warehouse, and from basket to basket on the sale floor (2).

The next phase was to survey progress made by different industries toward adapting the electric lamp as a substitute for northsky daylight in product evaluation. Much progress has been made in some areas toward dependence on the electric lamp as a source of light. Over the past 30 years, considerable research on light requirements for product evaluation has been done by the United States Department of Agriculture and others. Much of this research has concerned the light quality of the electric lamp, and, as such, has been directed largely toward bringing the color composition of the electric lamp more in line with that of normal northsky daylight. Until substantial technical progress was made in improving the electric lamp, commerce and industry depended, as a base point, on northsky daylight at high noon for product evaluation and standardization. Some industries—for example, the cotton and textile—have progressed to an extensive dependence on the electric lamp for product evaluation and color standardization.

The next step in the research of the Kentucky Station was an experimental phase, testing the various electric lamps designed for grading and color evaluation as to their suitability for use in grading tobacco. The lamp developed for the grading of cotton was the first and most important lamp used. It became the base lamp in the experimental research work for tobacco and was put through much testing for its suitability and adaptability. Other lamps were included in comparative testing as to usefulness and economy of application. During the 10 years or more that the experimental phase has been under way, considerable technical progress has been made by the lamp industry in improving the color composition of the electric lamp—mainly that of bringing the color composition of the output of the fluorescent lamp more in line with the color balance as found in northsky daylight.

At least three major factors stand out in past research as essential to achieving optimum light conditions in all-product evaluation. Much of the research in this study has been that of establishing the dimensions or specifications for each of these three factors to assure the most satisfactory light for grading tobacco. The factors are (a) quality or color balance of light source, (b) quantity of light, and (c) color of background. The first factor has been by far the most difficult one for which to establish technical specifications.

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[1] Numbers in parentheses refer to "Literature Cited," page 20.

The objective of this publication is to report on the progress made in establishing the conditions essential to a good uniform light for grading tobacco. The specifications are given in terms of the three major factors recognized above. The full, comprehensive report on the light research program, to be published later, will present the research methods, the results of the experimental tests, and the problems and advantages of establishing a uniform light throughout the tobacco market channel.

QUALITY OF ILLUMINATION

To understand and describe the quality characteristics of light energy, it is necessary for one to be familiar with certain concepts and terminology used by lighting engineers. These concepts include the use of spectral energy distribution curves, chromaticity values, and chromaticity diagrams, and color temperature designations. Each is useful in evaluating the possible application of different light sources for tobacco grading.

The spectral energy distribution of a light source indicates the relative amount of radiant energy provided by that light source at all wavelengths throughout the visible spectrum. It can be displayed graphically (as in Fig. 1) or in tabular form. Knowing the spectral energy distribution of a light source enables one

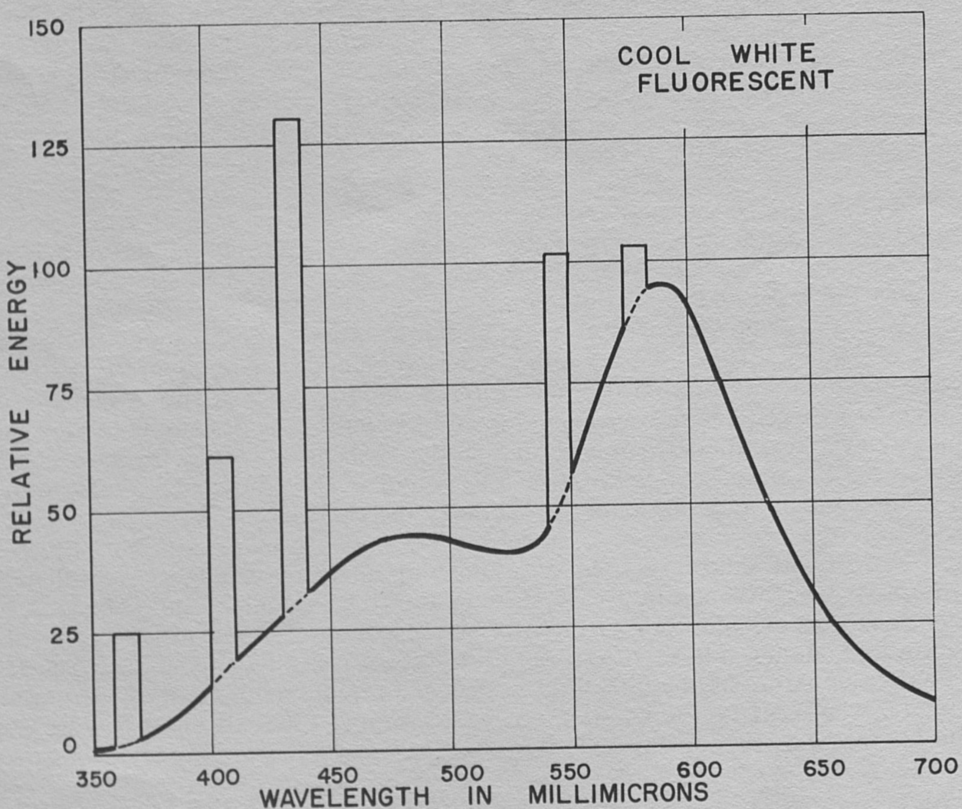

FIG. 1. - SPECTRAL ENERGY DISTRIBUTION CURVE FOR A COOL WHITE FLUORESCENT LAMP.

to determine the color of the light source by using standard colorimetric techniques (3) to establish its location on a C.I.E. chromaticity chart (Fig. 2). Each position on this diagram corresponds to a specific color. This allows one to specify the color which the light source itself will exhibit when viewed by an observer having average or normal color vision.

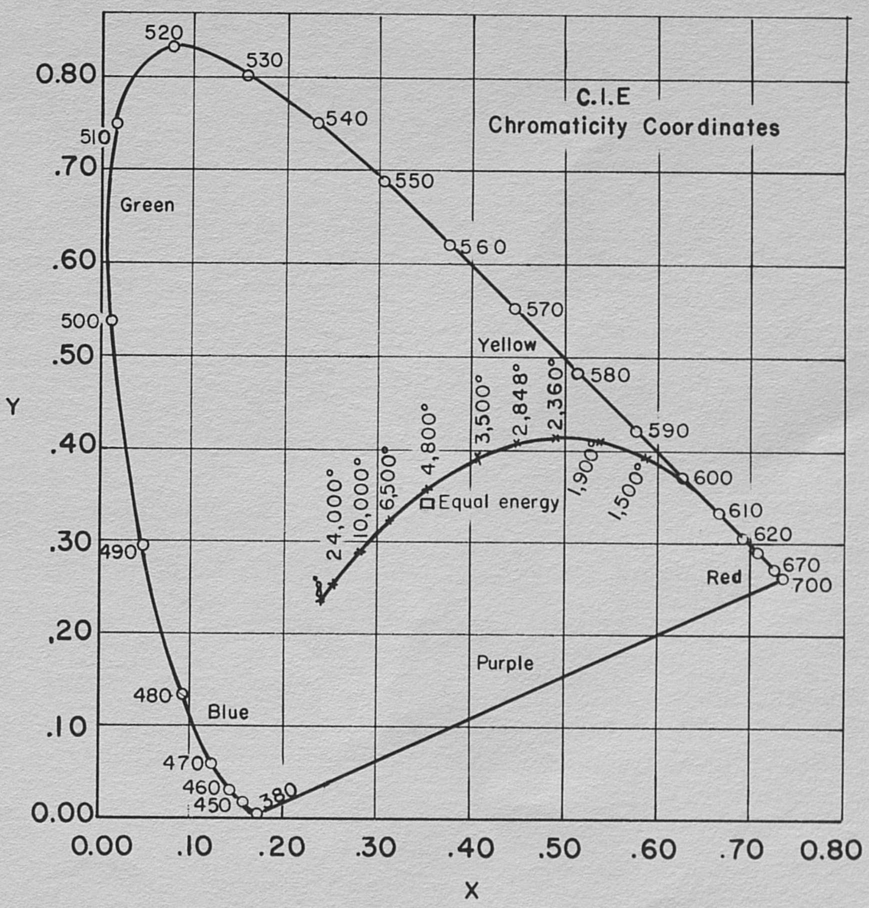

FIG. 2. - CIE CHROMATICITY DIAGRAM WITH LOCUS FOR PLANCKIAN RADIATOR.

The foregoing procedure is very useful in making it possible for the color of a light source or that of any object to be specified by only two numbers—the x and y coordinates on the chromaticity diagram. This does not imply, however, that all light sources located at the same point on the chromaticity diagram will have the same spectral energy distribution. This difference in spectral distribution can cause a wide variation in the color-rendering abilities of two or more light sources having the same chromaticity coordinates (x, y values).

Another concept employed by engineers in describing light sources is color temperature. This refers to the color exhibited by a Planckian (or so-called black body) radiator when heated to different absolute temperatures (degrees Kelvin). When such a body is heated, it emits a continuous spectrum of radiation according to Planck's Law (4). At low temperatures this radiation is invisible, but as the temperature of the body is increased the radiation emitted shifts more toward the visible region of the spectrum. The color exhibited by this visible radiation is precisely related to its absolute temperature, and this effect has resulted in the use of the term "color temperature" to describe the color of light sources. The chromaticity of the radiation emitted by a Planckian radiator at various temperatures can easily be determined; the locus of these chromaticities is presented on the chart in Fig. 2.

Although there is no such thing as a perfect black body radiator, many objects behave so much like one that the concept of color temperature can be reliably applied to describe their radiant energy output at high temperatures. The filament in an incandescent lamp is one such body; thus, color temperature (as well as chromaticity values) can be used in specifying the color of the light from an incandescent lamp. For light sources not supplying radiant energy with the same spectral distribution as that produced by a black body, the term "color temperature" cannot be strictly applied. For such lights the term "correlated color temperature" is used to indicate the color temperature of the point on the Planckian locus which affords the nearest color match for the light source being described. Thus, correlated color temperature can be used to represent the color of any light source, although it does not give any specific information about the spectral energy distribution of the light source itself.

Research (5) has indicated that, when there is sufficient light intensity, warehousemen and tobacco graders prefer to grade under natural light from "north" skylights with a high overcast sky. Similar studies (6, 7) with other products have yielded similar results. Measurements (7) have shown that north skylight conditions classed as "very good" by textile color matchers required a minimum color temperature close to 7500°K for a minimum of 100 footcandles light intensity. On the basis of such research, several industries (8, 9) have taken as a standard for preferred north skylighting the 7400°K Abbot-Gibson spectral distribution (10). This distribution represents a combination of 85 percent Abbot sunlight plus 15 percent blue skylight. It was also adopted for use in this investigation as a reference standard against which to compare the color and spectral distribution of the different light sources.

Progress in Lamp Development

From the facts just stated, it would appear that for tobacco lighting, one would need only to specify an illuminant with the same color temperature and spectral distribution as the "standard" illuminant and then to install a sufficient number of these fixtures in a certain designated manner so as to meet all other specifications for proper lighting. However, no commercially available illuminant duplicates the spectral distribution of the established standard light source. Fluorescent light tubes are available over a wide range of color temperatures, some of which are near that of the established standard; however, the spectral distribution of most of these lamps deviates considerably from that of the standard and, therefore, results in poor color rendition.

One company has developed a lighting fixture employing both fluorescent and incandescent lights. This unit approaches the spectral distribution of the Abbot-Gibson source and provides a high degree of daylight color rendering. However, it is relatively expensive in comparison with standard fluorescent fixtures and has, therefore, been limited in its use to installations much smaller than those which would normally be required for lighting tobacco auction sales areas or long production lines in processing.

In some of the work done at the Kentucky Station, a combination of several different fluorescent tubes was employed in a single fixture to produce a light source with more desirable color-rendering properties than those available with one type of tube. While a certain degree of success was obtained with this approach, the authors felt that it would be more desirable from an application standpoint if an acceptable illuminant could be produced using only one type of fluorescent tube. Lamp manufacturers have indicated that it is now possible to achieve the desired color balance by using a particular mixture of fluorescent chemicals. A research grading experiment in which a number of experimental lamps supplied by different lamp manufacturers were evaluated as to their ability to do a satisfactory job of tobacco lighting will be discussed later in this report.

Color Rendition of Light Sources

The perceived color of a tobacco sample placed under any given illuminant depends on the illuminant, the nature of the tobacco sample and its surroundings, and the response of the observer's eye-brain mechanism. The intensity, color temperature and the spectral distribution of the light source are important in that these factors have a major influence on the nature of the light energy seen by the observer in looking at the tobacco sample. The tobacco sample affects its perceived color by the manner in which it modifies light energy falling on it from the illuminant.

The response of the human eye-brain mechanism in perceiving the color of a tobacco sample or any other object is complex and sometimes relatively unstable. The perceived color depends not only on the physical nature of the radiation received by the eye from the sample being viewed, but also on the adaptation of the eye, the intensity of radiant energy and the degree of "normalcy" of the viewer's color vision. The sensitivity of the human eye to any given color in the spectrum increases or decreases, depending on whether the light received by the eye is lacking or is rich in energy in that portion of the spectrum. Thus, the sensitivity of the eye to the different colors of the spectrum is inversely related to the spectral distribution of the light energy received by the eye. This type of eye adaptation tends to make the color of objects viewed under different illuminants appear similar and is referred to as "color constancy." This effect does not result in precisely the same color being perceived under different illuminants; but it does result in approximately the same color perception as long as illuminants with extreme color temperatures and/or unusual spectral distributions are not employed. Thus, eye sensitivity and adaptation become very important factors in evaluating the color-rendering ability of a light source.

In selecting a light source for grading tobacco, one needs to be concerned with the quality of the illuminant, its luminous efficiency, its ease of installation and maintenance, its expected life, and its overall installation and operating costs. All other things being comparable, lamp selection must be made on the basis of light quality as denoted by the illuminant's spectral energy distribution. This, in turn, must be related to the ability of the light to render tobacco colors the same as they would appear under an accepted standard light source. One method of specifying the color-rendering ability of light sources is the I.E.S. color-rendering index (11, 12). This method is based on determining the relative amount of colorimetric shift on a chromaticity diagram for a number of standardized color samples when viewed under a test light source as compared with the same samples when viewed under a standard reference source of approximately the same correlated color temperature. For light sources with correlated color temperatures below 6000°K, the reference standard is a Planckian radiator at the nearest color temperature (± 50°K); above 6000°K, the Abbot-Gibson series of spectral energy distributions is used, with the selected reference standard being that distribution having the nearest correlated color temperature (± 250°K) to that of the test source. While the method described above does a satisfactory job of specifying the relative color-rendering abilities of light sources which vary in spectral quality but not in correlated color temperature, it is still limited in that it cannot take into account the influence of chromatic adaptation. For this reason, it cannot be used for comparing the color-rendering abilities of lamps which vary widely in their color temperatures as well as in their spectral energy distribution. Therefore, the method rates illuminants only in terms of how well their color-rendering abilities approach that of natural daylight of the same correlated color temperature.

Experimental Research Procedures

At Kentucky work was conducted in the spring of 1964 to show which of several experimental fluorescent tubes supplied by lamp manufacturers would be most satisfactory for use in grading leaf tobacco. There was also a need for some definite means of specifying and rating different illuminants as to their acceptability or relative merit for use in such an application. Correlated color temperature and the I. E. S. color-rendering index were used to specify the different light sources.

For the experimental work, eight grading booths were constructed. The walls of each booth were covered with neutral gray paper of about Munsell value 8, and the tops of the grading tables were covered with brown tobacco-colored paper to conform with the current operating procedures of the Federal Tobacco Grading Laboratory (13). Conventional four-tube lamp fixtures were installed in seven of the booths with a commercial fluorescent-incandescent daylighting fixture in the eighth booth. This combination fixture was the same as that employed in Federal Tobacco Grading Laboratories and widely accepted for use in other industries where accurate daylight color-rendering is considered important. It was, therefore, used as the light source for the base booth against which to compare the grading performance in the other seven booths. The seven conventional fixtures were equipped with commercially available and experimental fluorescent tubes ranging in color temperature from 4200°K to 8400°K. The I. E. S. color-rendering indexes of these lights varied from 85 to 92. Each of the light sources was randomly assigned to the different booths and adjusted so that the light intensity on the table top in each booth was 100 footcandles.

The Tobacco Division, Agricultural Marketing Service, USDA, cooperated in this study by supplying tobacco samples and graders for the experimental work and by scoring the performance of the graders under each of the illuminants. Four sets of burley tobacco samples were used, with each set containing 60 samples boxed into three lots of 20 samples each. The base grade of each sample was established by the Federal Grading Service under the light source approved for use in Federal Tobacco Grading Laboratories. Twelve Federal tobacco graders participated in the grading experiments, and the Federal tobacco grading score system was used for evaluating performance under each of the illuminants. Each grader graded a complete set of 60 tobacco samples under each light source in a random sequence. The set of samples graded in each booth consisted of three 20-sample boxes drawn at random from the four available sets with the restriction that no grader would grade any box of samples more than twice in completing the eight-booth grading sequence. This restriction was introduced to reduce the effect of memory bias in the grading results.

Results of Experimental Tests

Data obtained from the experimental grading procedures described in the above section are summarized in Table 1. The average number of points deducted per box of samples for errors made in establishing the group, quality and color designation of the tobacco samples is presented along with the average net grading index of the graders under each light source. These results indicate that there is no pronounced difference in overall grading performance under the various light sources. This result, while somewhat unexpected, probably indicates the extent to which eye adaptation can compensate for variations in the color and spectral distribution of different light sources.

Examination of the number of points deducted under different lights owing to errors made in establishing color grades indicates very little variation between booths. No apparent effect of lamp correlated color temperature on a grader's ability to designate color grades is indicated. There is some indication that overall color grading accuracy is improved with an increase in lamp color-rendering index; however, no definite conclusion can be drawn from the composite color grading scores.

TABLE 1. — Results of Experimental Tobacco Grading Tests Under Various Light Sources (Error Points Deducted and Average Net Rating of Graders)

Booth No.	Correlated Color Temp.	I. E. S. Color Rendering Index	Average Number of Grade Points Deducted: Group Factor	Quality Factor	Color Factor	Total	Net Rating Average of Grading
1	4200°K	85	2.9	10.7	4.8	18.4	81.6
2	5125°K	—	2.9	9.9	3.7	16.5	83.5
3	8400°K	88	3.6	9.3	4.2	17.1	82.9
4	6570°K	90	2.4	9.3	4.2	15.9	84.1
5	5890°K	92	3.0	10.7	4.1	17.8	82.2
6	6900°K	—	3.6	10.8	3.7	18.1	81.9
7	7300°K	92	3.1	10.4	3.5	17.0	83.0
8	7050°K	89	2.9	9.7	4.5	17.1	82.9
		Average	3.0	10.1	4.1	17.2	82.8

Further consideration of grading performance for specific grades indicated a variation in grading accuracy for different color grades. The grading of well-defined colors such as tan (F), red (R), and green (G) was more accurate and less variable between booths than was the grading of combination colors such as tannish-red (FR), green-tan (GF), and green-red (GR). An analysis of the percentage of color grades graded differently from their established base grade for several well-defined and several combination colors indicated an apparent improvement in grading performance for combination color grades with an increase in the color-rendering index of the light source. A summary of these data is shown in Table 2 for those light sources on which color-rendering indexes were available. A very definite improvement in the over-all grading accuracy for FG, GF, and GR color grades can be noted with an increase in the color-rendering index of the light sources. No such effect can be detected in relation to correlated lamp color temperatures.

TABLE 2. — Percentage of Color Grades Unchanged from Base Grades—Arranged in Order of I.E.S. Color-rendering Index

I. E. S. Color-Rendering Index	Booth Number	Percentage Unchanged: FR, GF and GR Color Grades	Percentage Unchanged: F, G, R, D and K Color Grades
85	1	71.6	87.4
88	3	72.8	84.4
89	8	73.9	82.0
90	4	73.8	85.4
92	5	82.3	84.3
92	7	79.2	87.2

Another phenomenon noted in analyzing the results of this study was that the graders tended to raise the color grade of tobacco samples above the base grade more often than they tended to lower it. This was equally true for all light sources and cannot be fully explained by the authors. One possible explanation for such a tendency might be that the graders were not accustomed to grading under the foot-candle light intensity which was established in each booth. Light intensities on warehouse floors vary considerably and probably average closer to 60 footcandles than to 100 footcandles. The light intensity used in test booths may have "washed out" or made less perceptible to the grader certain secondary colors in the tobacco samples, thereby raising their designation of those color grades in which such color factors were important.

After completing the entire sequence of grading operation, as described in the experimental procedure, each grader was asked to make a visual appraisal of the different light sources—indicating which sources he preferred for grading purposes and also those that he considered least desirable. Ten graders gave the relative ranking of enough lights to establish a complete preference order. By adding up the number corresponding to the ranking (1 for best, 2 for second choice, etc.)

TABLE 3. — Color Temperature, I.E.S. Color-rendering Index and Grader Preference Index for Light Sources Used in Grading Experiment

Booth	Correlated Lamp Color Temperature (K°)	Rendering Index	Preference Index
1	4200	85	80.0
2	5125	—	46.5
3	8400	88	48.0
4	6570	90	51.0
5	5890	92	32.0
6	6900	—	30.0
7	7300	92	30.5
8	7050	89	42.0

given each light by these 10 graders, a numerical preference index was obtained, as shown in Table 3. A high degree of preference by the graders resulted in a low index, while a low ranking resulted in a high index. The tabular values show that all graders listed the light source in the first booth as being the least desirable. Booths 5, 6, and 7 received ratings well above those of the other five booths. In general, the values in Table 3 indicate that grader preference for the different light sources is much more closely related to a light's color-rendering index than to its correlated color temperature.

Light Quality Recommendations

Based on the research of the Kentucky Station reported in this study and on lighting practices currently being employed where daylight color rendering is important, the following specifications are recommended for providing acceptable and standardized light quality when tobacco is graded under electric fluorescent lamps.

Color quality specifications.—The standard for color quality of illumination is the color and spectral distribution of a moderately overcast northern sky as represented by the 7400°K Abbot-Gibson daylight. Acceptable illuminants for general tobacco grading and sorting should have a correlated color temperature between 6500°K and 7500°K.

Color-rendering index.—Acceptable light sources should provide an I.E.S. color-rendering index of not less than 90.[2] For establishing standards and for more critical grading operations, the color-rendering index should be 92 or higher.

As noted earlier in this report, the results of experimental grading tests under various light sources ranging well below the foregoing recommended color temperature range showed no significant difference in the grader's ability to evaluate grade factors under the different lights. It was deemed advisable, however, to narrow the recommended tolerance for color quality to the specified limits as set forth. This is because the long-established objective of the lamp industry has been to create a light source which would provide a spectral energy distribution or exhibit a color quality equal to or comparable with northsky daylight at high noon. Technological progress in the electrical industry has arrived at the stage where color energy of the level of northsky daylight can be provided in a single, standard fluorescent tube at an economical cost to the user. Another reason for specifying a specific narrow range of tolerance is for the sake of achieving uniform light quality. Uniformity of light, not only over a given work area but also throughout the many points of product evaluation in the tobacco market channel, is more important than any one specific level or quality of light energy. Experimental grading tests at the Kentucky Station substantiate the point that the human eye has the capacity for considerable adjustment to various levels of color energy without losing grading accuracy. But this condition for product evaluation need not exist now since the electrical industry has the capacity to manufacture an economical lamp reproducing a color energy approximating northsky daylight. A uniform light over all points of grade evaluation of the market channel means a more efficient, coordinated flow where grading is essential to price and use determination.

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[2]Fluorescent light sources which meet these specifications have been shown in grading experiments to be acceptable illuminants for tobacco grading. The reference or standard light source used to compute the color-rendering index of different light sources should be the Abbot-Gibson spectral distribution having the nearest correlated color temperature (± 250°K) to that of the test source. Standard I. E. S. procedures (4) should be used for computing the color-rendering index.

QUANTITY OF ILLUMINATION

A considerable amount of change has occurred over the past decade or two as to the light levels recommended for performing various visual tasks. Part of this change can be credited to technological improvements which have increased the light output of lamps. But, in no small way, research has pointed the way to certain levels of light illumination as best to perform certain, specific tasks or functions involving human sight. Generally speaking, the trend has been upward as to the amount of illumination needed or required. The increased use of more light is based on either a reduction of eye fatigue or more efficient human performance of functions dependent on eyesight, or both.

Under normal daylight conditions during the marketing season, the amount of illumination on warehouse sale floors and in farm stripping sheds is well below that preferred where the electric lamp is used in grading burley or dark tobaccos. During the fall and winter months much of the total tobacco production is stripped, graded, and sold under light conditions of 30-60 footcandles (2). Under daylight conditions, the amount of light illumination varies from hour to hour through the day—depending in part on weather conditions (Figs. 3, 4 and 5). Through the use of the electric lamp the amount of illumination can be stabilized at the most desirable level.

Level of Light Illumination

In this study several hundred farmers, Federal graders and buyers participated in a series of experimental tests conducted to determine the level of illumination desirable for grading tobacco. The amount of light available is in part a function of the output of the lamp and in part the distance of the lamp from the object being observed. In the experimental tests conducted, the lamp was mounted on an elevator in order to vary the amount of light available for observing and grading of leaf tobacco. The optimum amount of light was sought through varying the height of the lamp over the leaf tobacco. The quantity of light was measured and expressed in terms of footcandles.

Optimum level.—The predominant selection of illumination levels by farmers, graders, and buyers alike was 100 footcandles (Fig. 4). This is well above—in fact, nearly double—the amount of footcandles available under normal daylight conditions. Good grading can be done under light conditions of a considerable range above and below a norm of 100 footcandles.

Minimum level.—In the experimental tests, buyers, graders and farmers quickly turned negative in their appreciation of the light when the amount of light was reduced to 50 footcandles or less. Under daylight conditions this is close to the normal or prevailing level.

Maximum level.—There did not exist quite so close unity of opinion among buyers, graders and farmers as to the maximum amount of light desirable. Appreciation for the light turned negative quickly after the quantity exceeded 150 footcandles.

Uniformity of Illumination

The quantity of light should be highly uniform over the entire work area. This is achieved largely through the height and spacing of the light fixtures. Uniformity as to area is just as important as uniformity or stability in respect to time. The

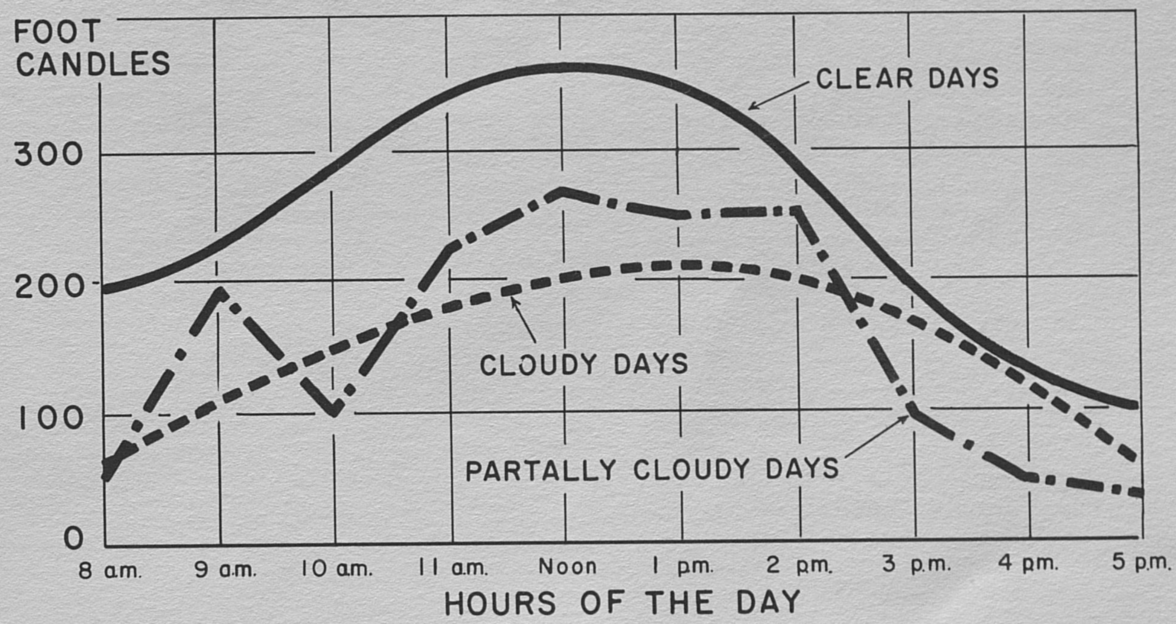

FIG. 3. - HOURLY VARIATION IN THE QUANTITY OF DAYLIGHT ON SELECTED DAYS DURING THE MARKETING SEASON FOR BURLEY TOBACCO.

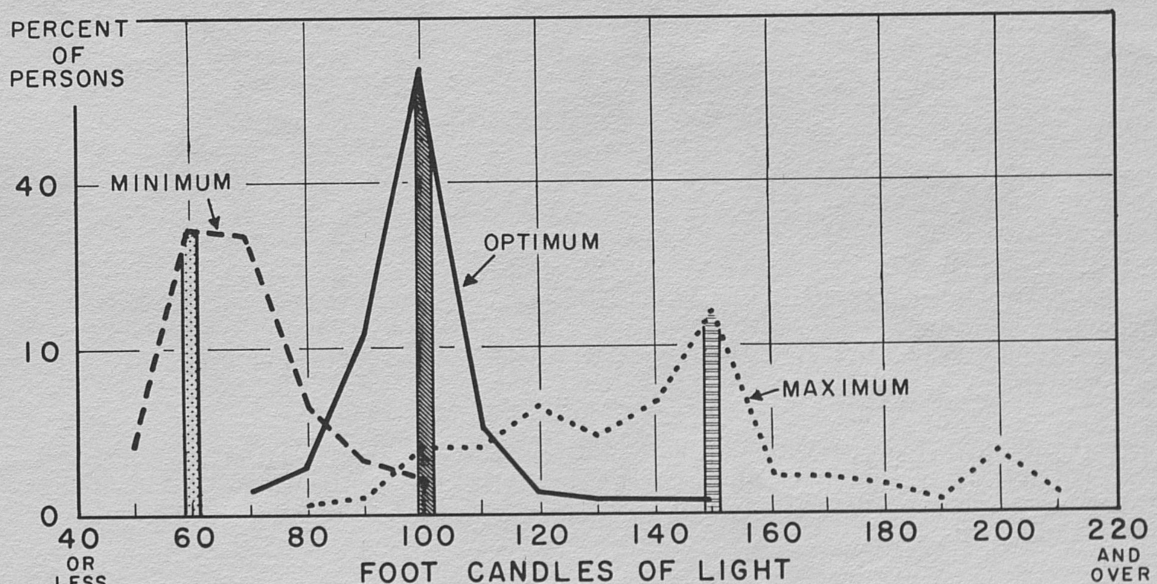

FIG. 4. - QUANTITY OF LIGHT PREFERRED BY FARMERS, FEDERAL GRADERS AND BUYERS WITH AN ELECTRIC LIGHT SOURCE.

(AUCTION SALES FLOOR UNDER DAYLIGHT)

(AUCTION SALES FLOOR UNDER ELECTRIC LAMP)

FIG. 5. - AUCTION SALES DEPENDENT ON DAYLIGHT WILL HAVE LIGHT VARIATIONS OVER THE SALE AREA CREATED BY THE STRUCTURAL FEATURES OR OTHER PHYSICAL FACILITIES. THOSE SALES DEPENDENT ON THE PROPERLY INSTALLED ELECTRIC LAMP WILL HAVE UNIFORM LIGHT OVER THE ENTIRE AREA AT ALL TIMES.

installation of fixtures can be such as to achieve almost a perfect uniformity from point to point throughout the work area. Ten percent variation is a maximum that should be permitted over the work area.

Lighting fixtures should be designed to provide uniform, diffused and glare-free lighting in the proper quantity and quality for satisfactory grading. They should be of the reflector type so that a maximum amount of light will be directed downward. Nonselective diffusers should be used to eliminate glare from the grader's field of vision. Low-temperature ballasts should be used in all fluorescent lamp circuits installed in farmers' stripping sheds and auction warehouses in order to insure reliable lamp starting in cold weather.

Maintenance of Light Equipment

Light fixtures should be as light in weight as practical and be easy to install, inspect, change tubes, and otherwise perform routine maintenance. Lamps and other equipment should be properly maintained to sustain proper and uniform levels of lighting. It is not enough to install a good lighting system; it must be maintained for satisfactory service. All lighting equipment should be inspected at frequent intervals to insure that it is in good working order and to facilitate the prompt replacement of defective or inferior tubes. In lighting systems specifically designed for tobacco lighting, all fluorescent tubes must be replaced by identically the same type of tubes or the desired light quality will not be maintained.

Light meter readings should be taken from time to time to see how illumination levels vary with ambient temperature and amount of use. Such information should help set up definite cleaning and tube replacement schedules. Tubes should be cleaned as necessary to help maintain illumination levels.

Light Quantity Recommendations

A uniform quantity of 100 footcandles should be sought at the time of installation.[3] The light output of tubes can be expected to diminish some with use. Also, dust and moisture will coat the surface of tubes, reflectors, and louvers—thus cutting down on the amount of light available. Again, background surfaces such as walls and structural supports will accumulate a dust film that will reduce the amount of reflected light. The depreciation of light output at the work level should not be permitted to fall below 75 footcandles. Good grading can be done at 75 footcandles if the quantity is still uniform over the area at the work level. Since light quantity can be expected to decline through time and use, it is recommended that the starting point should be 100 footcandles and that reasonable effort be made to maintain this level of illumination.

COLOR OF BACKGROUND

A part of the light available at the work level is of a secondary or reflected character. Light from the lamp falling on background features will be reflected down on the work area and added to the quantity of light falling on the work area directly from the lamp source. Any color in background surfaces will cause selective

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[3] This is assuming that the temperature is normal at the time of installation and that the fixtures are equipped with cold weather ballasts.

reflection of light energy onto the work area and distort the color of the object being viewed. This factor becomes increasingly important where the work area is relatively small compared with that of the background surface. Background surface above the level of the lamp installation is of little importance as a factor in reflected light.

Neutrality of Background Color

All background features, especially those below the lamp, should be of a neutral color. Black or white or any tone of gray between, of course, is neutral in the sense of adding no color to the color balance or the quality of the light provided the work area. Research done elsewhere has long established the need for a neutral background color.

Tone of Background Color

Previous research has established a preference for the lighter tones of gray. The research attention devoted to the background factor in this study has been to determine the preference, if any, of buyers, graders and farmers as to the tone of gray. The preferences were predominantly for a light gray—Munsell 8.[4] Munsell 0 is black. Munsell 10 is white. This tone of gray is close to a white—a dull white. There appeared to be more preference for a darker tone of gray—a Munsell 6 in the case of those concerned with the dark types of tobacco. This may be due to the fact that the tobacco workers in these types of tobacco are more accustomed to darker backgrounds.

The background surfaces should be painted a flat coat of gray paint—not a glossy finish. Large, bright contrasts within the grader's field of vision should be avoided as much as possible. A light tone of gray means that more light will be reflected off the background, helping to build up the amount of light around the outer edges of the work area—thus, a more uniform quantity of light over the total work area.

Color of Background Recommended

A neutral tone of gray of Munsell 8 is recommended for the background surrounding. Munsell 6 is a minimum. A flat paint should be used.

SUMMARY

This is one of a series of research studies on determining light requirements and improving light conditions in grading tobacco. The progress made through these research activities is set forth in this report.

Much research on determining light requirements for product evaluation preceded the efforts of this study. A part of this research effort has been directed toward testing and evaluating the results of previous light research as to their suitability and application in serving the needs of tobacco grading. Previous research to establish the light requirements for product evaluation have considered

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[4]See reference 13 for more details on the Munsell System of specifying color.

many factors, but much of the work may be classed under three major factors: (a) color quality of illumination, (b) quantity of illumination, and (c) color character of background. A major part of past research efforts has been directed toward improving the electric lamp as a source of light because of the variability of daylight.

Quality of Illumination

The standard for color quality of illumination is the color and spectral distribution of a moderately overcast northern sky as represented by the 7400°K Abbot-Gibson daylight. Acceptable illuminants for general tobacco grading and sorting should have a correlated color temperature between 6500°K and 7500°K and an I. E. S. color-rendering index of not less than 90. For establishing standards and for more critical grading operations, the color-rendering index should be 92 or longer.

Quantity of Illumination

The research work of this study indicated a predominant preference of farmers, graders, and buyers for a light quantity of 100 footcandles at the work level. This is the same level of illumination that has come to be accepted as the standard for some other agricultural products. In some industries quantity standard for illumination has been advanced up to higher levels—150 to 200 footcandles. Good evaluation of tobacco was done under experimental tests with light illumination ranging from as low as 60 to as high as 150 footcandles. Beyond this range there was much dissatisfaction expressed by participants in the experiment.

To achieve uniformity in light conditions over a given work area and from one grading operation to the next, it is recommended that 100 footcandles be established in the initial installation and that maintenance work be directed to hold closely to this level. Seventy-five footcandles should be considered a minimum. Variation in the quantity of illumination should be held to less than 10 percent over the entire work area. Special ballasts should be used in lamps for providing stability of light output where grading is done under freezing temperatures.

Color of Background

A neutral gray of a Munsell 8 should cover the background surrounding the work area. Munsell 6 is a minimum. A flat paint—not glossy finish—should be used.

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