PART III

PERFORMANCE SPECIFICATIONS FOR 16-MM PROJECTION EQUIPMENT FOR EDUCATIONAL SERVICE

The following specifications attempt to give clear definitions of good performance with respect to each of the functions of a projector or screen. Specification in terms of mechanical or electrical design or principles of operation has been avoided, since it is believed immaterial to the user how a result is obtained as long as the result is satisfactory.

In many instances it has been necessary to specify the method of measurement as well as the result required, in order that the specifications might have precision. In connection with the specifications of sound-reproducing performance it has been necessary to define a number of test-films. Arrangements have been made by the Committee for the production of these test-films, which are to be made generally available. Further announcement on this subject will appear in an early issue of the JOURNAL.

Since there are many ways in which given aspects of performance may be defined, notes have been added to certain of the specifications in order to make clear the thought processes that led the Committee to adopt the particular form of specification given.

The specifications are not complete in all details. Further investigations are being conducted with respect to several of the topics in order that definite measurement technics may be supplied where they are now lacking, and limits in some cases may be more precisely determined. The Committee recognizes these shortcomings in this report, but nevertheless believes that the specifications in their present form will be useful enough to justify publication at the present time rather than waiting until all uncertain points have been clarified.

No attempt has been made to put these specifications in a form such that they could be applied by the average user of equipment, however intelligent or well informed he may be. The Committee believes that the specifications must be definite if they are to be useful. It has been possible to achieve definiteness only by the specifica-

tion of measurement procedures that in most cases can be carried out only by a well equipped measurement laboratory.

The Committee hopes soon to be able to supplement its present report by the presentation of papers by some of its members discussing specific measurement problems in greater detail than is possible in a report of the present character.

(*A*) *Picture Projection*

(*1*) *Steadiness of Picture.*—The *Picture-Steadiness Test-Film* shall be a film carrying a readily measurable test-pattern placed upon it by a mechanism which positively locates each frame vertically by a pilot-pin entering a perforation, and horizontally by pressing the edge that is to be guided in the projector against a solid guide. The test-pattern shall have been placed on the test-film directly, and not by any intermediate printing process from another film. The pattern may consist of two or more circular holes $^1/_{16}$ inch in diameter punched through each frame of the film. If the test-pattern is produced by punching, the film used shall have been exposed and developed previously to a density between 0.8 and 1.2. The test-film shall not be shrunk more than 0.5 per cent.

Picture unsteadiness shall be measured by projecting the test-film at standard speed (16 frames per second in the case of a silent projector; 24 frames per second in the case of a sound projector). Scales shall be placed vertically and horizontally on that part of the screen on which the projected image of the test-pattern appears, and the amount of unsteadiness shall be noted by observing the movement of the test-pattern on these scales.

Vertical unsteadiness having a period shorter than one second shall not exceed 0.3 per cent of the picture width.

Horizontal unsteadiness of any period shall not exceed 0.3 per cent of the picture width.

(*2*) *Freedom from Travel-Ghost.*—The *Travel-Ghost Test-Film* shall carry a pattern of small transparent areas on a dark background. At least three of these transparent areas shall be located $^1/_{10}$ of the frame height from the top of the frame, and an equal number $^1/_{10}$ of the frame height from the bottom of the frame.

This test-film shall be projected at 16 frames per second on a screen of such size that a brightness of 40 foot-lamberts is obtained with the shutter running but with no film in the projector gate. This screen shall be viewed from a distance equal to twice its width.

Under the above test conditions, no travel-ghost shall be visible.

(3) *Freedom from Tendency to Damage Film.*—The film used for this test shall be freshly processed, having been uniformly fogged and developed to a density between 0.5 and 0.8. It shall be used in the form of a loop containing one splice. This loop shall be threaded through all parts of the projector mechanism that touch the film in normal operation. The lamp shall be turned on continuously during the test. The room in which the test is conducted shall be closed and otherwise well protected against avoidable dust.

Under these conditions, after 200 passages through the mechanism, the film shall exhibit no perforation damage and no scratches on either surface in either picture area or sound-track area.

(4) *Take-Up Efficiency.*—With reels having dimensions suitable for the projector and with the correct take-up adjustments for these reels, the take-up shall provide a tension on the film of not more than 10 ounces at the beginning of a reel and not less than $1^1/_2$ ounces when the reel is full.

(5) *Mechanical Durability.*—The projector shall be guaranteed by the manufacturer against failure due to defective material or workmanship for a period of one year.

This guarantee shall not, however, be required to extend to parts that are normally subject to wear and replacement, such as lamps and motor brushes.

(6) *Quietness in Operation.**

(7) *Provision for Framing.*—The projector shall have conveniently accessible means for framing the picture through a range extending 0.015 inch above and 0.015 inch below the normal position, measured at the film.

(8) *Light Output.*—The manufacturer shall state, in lumens, the limits of light output of each model of projector with each lamp and lens combination furnished.

For this purpose the light output shall be measured with the shutter running, but with no film in the gate.

Measurements shall be made in the plane of a screen located a distance from the projector such that the projected image of the picture aperture is 40 inches wide by (approximately) 30 inches high.

* The Committee recognizes that quiet operation is an important feature of good performance, but considers that the information at present available is not sufficient to permit the writing of a satisfactory specification of allowable noise level.

The illuminated area of the screen shall be divided into 12 equal squares. At the center of each of these squares the illumination shall be measured, either by a visual method or by means of a photoelectric light-meter corrected by suitable color-filters to conform within a good approximatiom to the visibility curve of the eye.

Suitable precautions shall be taken to insure that the optical train of the projector is in normal operating condition, and that the lamps used are representative ones, and are operated at their design voltages.

The arithmetical average of the 12 illumination measurements, in foot-candles, shall be multiplied by 8.33 (the area of the screen in square-feet) to obtain the stated result in lumens.

The statement of light output shall include a complete specification of each type of lamp used, by wattage and voltage ratings, type, and design life.

(*9*) *Color of Light on the Screen.*—The color-temperature of the light delivered to the screen when the source is operated at its rated voltage shall be in the range from 3000° to 4700°K.

(*10*) *Uniformity of Screen Illumination.*—The illumination shall be measured on a screen not less than 40 inches wide. Measurements shall be made at the center and at four points in the corners, located $^1/_{20}$ of the screen width from the top or bottom edge, and the same distance from the side edges of the screen.

The average illumination at the four corner points shall be not less than 55 per cent of the illumination at the center. At no corner shall the illumination be less than 40 per cent of the illumination at the center of the screen.

The illumination on the screen shall be free from noticeable bands or patches differing in color or brightness from the adjacent parts of the screen.

(*11*) *Accuracy of Light-Source Location.*—Unless the manufacturer has provided means of adjusting the position of the light-source, the maximum deviation of the light-source from its design position, due to the combined tolerances of the factors that affect light-source position, shall not be sufficient to cause the uniformity of screen illumination to fail to satisfy requirement No. 10, above.

(*12*) *Freedom from Flicker.*—The test for flicker shall be made by allowing the light from the projector, with no film in the gate, to fall upon a screen of size and surface such as to give a screen brightness of 3 foot-lamberts. Under this condition the projector shall

produce no visible flicker when running at its normal speed. If the projector is designed to operate at more than one speed, the test shall be made at a speed of 16 frames per second.

(*13*) *Accessibility of Optical Parts for Cleaning.*—All external surfaces of the condensing lenses, and the front surface of the mirror used behind the lamp, shall be accessible for cleaning without the use of tools. If removable for cleaning, these parts shall be so mounted as to be positively returnable to their proper positions.

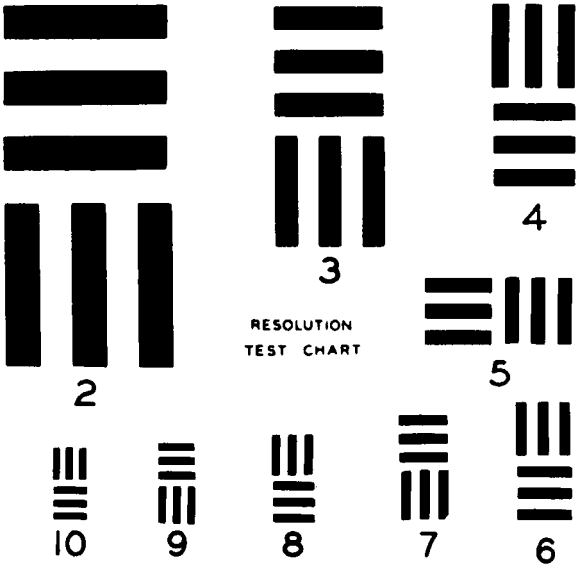

FIG. 10. Resolution test-chart.

(*14*) *Location of Film in Image Plane of Lens.*—As the film passes the picture gate of the projector, it shall be so held that its plane is perpendicular to the lens axis within limits such that there are no differences in sharpness of focus among the four corners of the picture, visible to an observer twice the screen width distant from the screen.

(*15*) *Image Quality of Projection Lens.*—The projection lens shall be tested by mounting it on a special test projector arranged to hold, in proper relation to the lens axis, a glass-plate test-object made as follows:

Copies of the test-chart shown in Fig. 10 are arranged as shown in Fig. 11, and photographed with a reduction such that the black outline shown in Fig. 11 has a height of 7.21 mm (0.284 inch) and a width of 9.65 mm (0.380 inch), with a radius of 0.5 mm in the corners. The ratio of reduction of the test-charts is such that the nine sets of lines in the reduced images are spaced at 20, 30, 40, 50, 60, 70, 80, 90, and 100 lines per millimeter. The sensitive coating of the glass-plate, and the lens used in making the reduction, have resolving

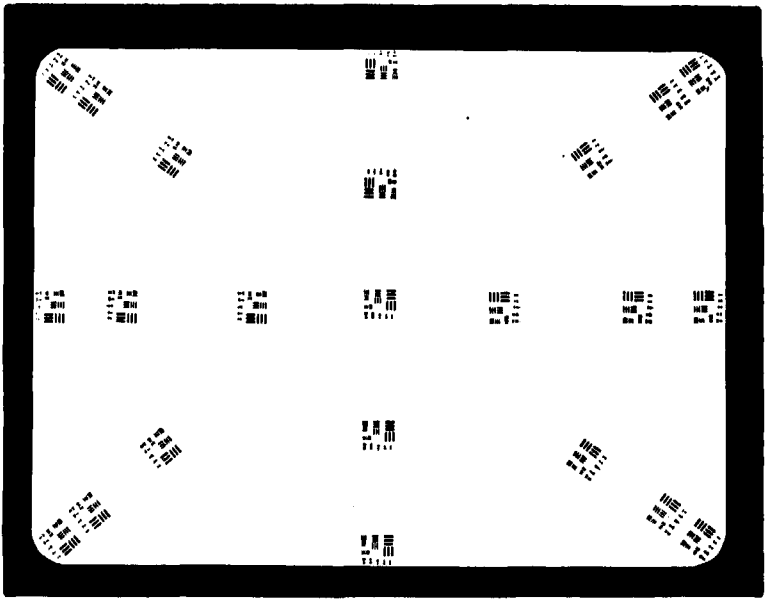

FIG. 11. Arrangement of test-chart images in picture frame area.

power high enough that all the lines of the test-pattern are clearly resolved.

The test projector shall be placed at a distance from the screen such that the projected image of the black border of the test-object measures 30 × 40 inches. Care shall be taken to insure that the screen is perpendicular to the projection axis. The lens under test shall then be focused so that the central image is as sharp as possible.

The observer, standing close to the screen, shall note the finest lines that are definitely resolved in both the tangential and radial directions, and record the resolution figures for

(*a*) Center of the screen
(*b*) Average of mid-sides (top and bottom)
(*c*) Average of mid-ends (left and right)
(*d*) Average of the four corners

The following minimum resolving powers shall be obtained:

	Lines per Millimeter
(*a*) Center	80
(*b*) Mid-sides (top and bottom)	60
(*c*) Mid-ends (right and left)	40
(*d*) Corners	30

In addition to meeting the above requirement of resolving power, the projection lens shall be free from the following defects to a degree such that they are not easily noticeable when the image is viewed from a distance equal to twice the width of the screen:

(*a*) *Haze.*—Some lenses possess a large amount of spherical aberration, which has the effect of covering the image with a misty haze of light, without seriously upsetting the resolution. This causes unpleasant projected images. A good projection lens gives a clean, crisp image.

(*b*) *Chromatic Aberration.*—This is not a common defect. It may be detected by the presence of a colored haze visible in the finer details over the whole of the field.

(*c*) *Lateral Color.*—This defect is manifested by the presence of one-sided color fringes appearing only in the outer parts of the field and vanishing completely in the center.

(*d*) *Distortion.*—In the presence of this aberration straight lines in the outer part of the field appear as curved lines. The straight boundaries of the picture gate itself make good test objects for the detection of distortion. A lens should not be rejected on the ground of distortion unless the defect is bad enough to be distracting to an average observer.

(*16*) *Provision for Focusing.*—The projection lens shall be so mounted as to be readily brought to an exact focus. The mounting either shall provide means by which the lens may be locked in its position of focus or shall hold the lens solidly enough to prevent disturbance of the focus by the vibration of the projector.

(*17*) *Mounting of Interchangeable Lenses.*—When a projector is designed to accommodate lenses of several focal lengths, the construction shall be such as to insure that each lens is centered on the optical axis and maintained with its axis perpendicular to the film plane within close enough limits to avoid any inequalities of focus among the four corners of the picture, visible to an observer twice the screen width distant from the screen.

(*18*) *Temperature Rise of Film.*—The film, during its passage through the projector, shall not be raised to a temperature high enough to cause permanent distortion of the base.

The test for possible excessive temperature rise of the film shall consist of projecting a 30-inch loop of film having a density of 2.00 or higher, for 100 continuous passages through the gate. The test-film shall then be wound into a roll of processed film in normal condition and allowed to remain so wound for a period of 24 hours before being examined for distortion of the base.

(*19*) *Temperature Rise of Projector Housing.*—During continuous operation of the projector at the lowest speed for which it is designed, at a room temperature of 80°F, the temperature of no external part of the projector except the top cover of the lamp-house shall rise above 155°F.

(*20*) *Adequacy of Ventilation for Incandescent Lamps.*—The ventilation of the lamp house shall be sufficient to prevent bulging of the lamp envelope or other damage to the lamp during continuous operation at any available speed at any time during the life of the lamp, provided that the lamp is operated at its rated voltage and the ambient temperature is not higher than 80°F.

When provision is made for reverse operation of the projector mechanism, the lamp-house ventilation during continuous reverse operation shall be sufficient to prevent damage to the lamp.

The electrical circuits of the lamp and of the motor or motors which drive the ventilating fan and projector mechanism shall be so interlocked that the lamp can not be turned on at a time when the ventilating fan is not running at a speed sufficient for proper cooling of the lamp, provided that in cases where projectors are designed for operation on either alternating or direct current, the user has properly adjusted such switches or rheostat controls as may have been provided by the manufacturer in order to obtain normal film speed on both types of current.

(*21*) *Rewind.*—Power rewind, if provided, shall be capable of rewinding 400 feet of film under a tension of not less than 3 ounces in not more than 2 minutes.

(*22*) *Lubrication.*—The projector mechanism shall either be equipped with "oilless" bearings of an efficient type or provided with easily accessible and plainly marked oiling means so constructed that the application of oil as specified by the manufacturer will insure adequate lubrication of all bearings in the machine.

(*23*) *Range of Line Voltage for Satisfactory Operation.*—The manufacturer shall specify on the name-plate of the projector the range of line voltages on which it is designed to operate.

(*24*) *Directional Reflection Characteristic of Screen.*—The distribution of the reflected light from a screen used for 16-mm projection shall be so related to the arrangement of the spectators that the brightness of the screen as seen from the maximum existing viewing angle is not less than 25 per cent of the brightness of the screen as seen from a position near the axis of projection.

(*25*) *Efficiency of Screen Reflection.*—The reflection coefficient of the screen within the angle over which requirement No. 18 is satisfied shall not be less than 70 per cent.

(*B*) *Sound Reproduction*

(*1*) *Steadiness of Film Motion.*—The *Uniform-Motion Test-Film* shall carry a 3000-cycle tone, recorded at a level not lower than 6 decibels below full modulation, with a frequency deviation of not more than 0.2 per cent. This film shall be either an original negative or a direct positive, not a print.

As measured by the RCA flutter indicator, speed variations introduced by the projector when reproducing this test-film shall not exceed 0.6 per cent.

(*2*) *Accuracy of Length and Location of Scanning Beam.*—The *Scanning-Beam Length and Location Test-Film* shall be an original negative sound-track. It shall be in two sections. The first section shall consist of a uniformly exposed band regularly interrupted to produce a 300-cycle tone and having its inner edge 0.017 inch from the edge of the film, together with a second band regularly interrupted to produce a 700-cycle tone and having its inner edge 0.099 inch from the edge of the film. The second section shall consist of a band interrupted to produce a 500-cycle tone and having its inner edge 0.026 inch from the edge of the film, together with a band interrupted to produce a 1200-cycle tone and having its inner edge 0.090 inch from the edge of the film.

The term "inner edge" in the above specification means the edge nearest the position of the centerline of the standard sound-track.

The inner edges of the exposed bands shall be free from any blurring in excess of 0.0005 inch, and shall be located within 0.001 inch of the positions specified.

The scanning light-beam in the projector shall be of such length and so located that it reproduces neither the 300-cycle tone nor the 700-cycle tone, but does reproduce both the 500-cycle tone and the 1200-cycle tone.

(*3*) *Accuracy of Azimuth Adjustment of Scanning Beam.**—The *Azimuth Test-Film* shall consist of three sections of 5000-cycle variable-density track, modulated 100 per cent.

The first section shall have an azimuth error of 1.0 degree, ±0.1 degree.

The second section shall have correct azimuth adjustment within 0.1 degree.

The third section shall have an azimuth error of 1.0 degree, ±0.1 degree, in the direction opposite to that of the error in the first section.

The test shall be made by reproducing this test-film and reading the output levels of the three sections by means of a volume indicator or output meter connected across the voice-coil of the loud speaker or a resistance load used to simulate the loud speaker. The output from the middle section shall be greater than the output from either the first or the third section.

(*4*) *Frequency Response.*—The *Frequency Test-Film* shall consist of at least 15 feet of 400-cycle track for level adjustment, followed by at least 10 feet of each of the following frequencies:

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* The Committee has attempted so far as possible to write these specifications in terms of overall performance rather than performance of individual parts. It is for this reason that scanning-beam width, for example, has not been specified, since it is covered by the specification of overall frequency response (Requirement No. 4). It may appear strange, therefore, that scanning-beam azimuth adjustment is treated separately, since the aspects of performance that it affects, that is, overall frequency response and distortion, are covered by overall specifications.

It is necessary to measure scanning-beam azimuth error separately, however, because the distortion it introduces lies mainly in the frequency range from 1000 to 3000 cycles. Direct distortion measurements in this frequency range are much more difficult than the azimuth adjustment test.

The test laid down in the specification insures that the azimuth adjustment of the projector will be correct within 0.5 degree. This limits the harmonic distortion produced to a maximum of 5 per cent total at 2000 cycles when a 1.0 mil scanning-beam is used, as in most 16-mm projectors.

Cycles	Cycles
50	2000
100	3000
200	4000
300	5000
500	6000
1000	7000

The modulation in all sections of the film shall be such that the level of modulation imparted to a scanning light-beam of negligible width (0.0002 inch or narrower) does not differ by more than 2 decibels from the level of modulation imparted by the 400-cycle section.

When reproducing this frequency test-film, it shall be possible, by at least one adjustment of the tone-control provided on the projector, to obtain a response curve having a variation of not more than 10 decibels between 100 cycles and 4000 cycles, and of not more than 14 decibels between 100 cycles and 5000 cycles. In making this test the output voltages shall be measured across a non-inductive resistance load equal to the impedance of the loud speaker at 400 cycles.

This test shall be made with a power-line voltage of 117 volts at the amplifier terminals.

(*5*) *Power Output Rating.*—The power output of the projector and amplifier system shall be measured by the use of a *Wave-Form Test-Film* consisting of a 400-cycle symmetrically modulated variable-area sound-track having a total amplitude of modulation of 0.048 inch ± 0.002 inch, and having a total harmonic content of not more than 1 per cent, of which not more than 0.5 per cent is made up of odd-order harmonics.

Using this film as the source of signal, the output shall be measured across a non-inductive resistance load equal to the impedance of the loud speaker at 400 cycles. The harmonic content shall be measured either by means of a selective wave-analyzer such as the General Radio Type *736-A* or by means of band-pass filters isolating the outputs at 800 cycles and at 1200 cycles for individual measurement.

The measurement shall be made with a power-line voltage of 117 at the amplifier terminals.

At this power-line voltage, no vacuum-tube or other component part of the amplifier shall be subjected to a higher voltage or operated at a higher rate of power dissipation than the manufacturer's

maximum ratings for the part in question. Special vacuum-tube circuits requiring special manufacturer's ratings shall be so indicated.

Using unselected vacuum-tubes which, however, perform within the manufacturer's ratings for their types, the projector and amplifier shall deliver the rated power output with a total harmonic content of not more than 5 per cent, of which not more than 4 per cent shall be made up of odd-order harmonics.

(6) *System Noise.*—A *Standard Output Test-Film* shall be provided, consisting of two sections of 400-cycle variable-area track. The first section shall have a total amplitude of modulation of 0.48 inch ± 0.002 inch. The second section shall be recorded with an input level 18 decibels lower than is required to produce the first section. The print of these two tracks shall have an image density of 1.6 or higher, and a fog density between 0.03 and 0.05.

An auxiliary short length of film uniformly exposed and developed to a density of 0.6 (transmission of 25 per cent) is required.

The test shall be made by first reproducing the higher output section of the Standard Output Film and adjusting the volume control of the projector until the rated maximum output of the amplifier is being delivered across the load resistor specified for the test under requirement No. 5. The volume control shall be left at this setting and the film removed from the machine. A short length of the 0.6-density film shall be placed in the path of the light-beam from the reproducing optical system. Then, with the projector mechanism running at standard speed, the output noise level shall be measured with a standard volume indicator meter across the load resistor.

This test shall be made with the tone-control adjusted for the most nearly uniform frequency response that is available in the range from 100 to 5000 cycles.

The test shall be made at a power-line voltage of 117 volts.

Under the above conditions of test, the noise level shall be at least 30 decibels below the rated maximum power output level of the system.

(7) *Adequacy of Available Amplification.*—Sufficient amplification shall be available to develop the rated maximum output power of the system when reproducing the lower level section of the Standard Output Test-Film specified above.

The test shall be made at a power-line voltage of 117 volts.

(8) *Loud Speaker Power-Handling Capacity.*—The loud speaker

supplied with a sound projector shall be capable of handling the full rated power output of the associated amplifier without rattling and without generating objectionable distortion.*

(*9*) *Loud Speaker Frequency Response.*—The frequency response of the loud speaker shall effectively cover the range from 100 to 5000 cycles per second.**

(*10*) *Accuracy of Exciter-Lamp Filament Location.*—The maximum departure of the filament of the exciter lamp from its design location, permitted by the combined effect of the lamp manufacturer's tolerances and the projector manufacturer's tolerances, shall not be sufficient to cause a reduction of more than two decibels in the level of reproduced sound, or to cause the production of harmonics in excess of the limit specified under requirement No. 5, above.

(*11*) *Safety of Electrical System.*—The projector shall have been approved for safety by the Underwriters' Laboratory.

(*12*) *Mechanical Noise.*†

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* This specification expresses the general intent of the Committee, but is obviously incomplete without specification of the method of test. Investigation has shown that at the present time there is not sufficiently widespread agreement among specialists in acoustical measurements to permit the writing of a generally acceptable complete specification covering the power-handling capacity of the loud speaker.

** The above note also applies to the measurement of loud speaker frequency response.

† The Committee recognizes that mechanical noise from the projector mechanism must be kept below certain limits if sound reproduction is to be satisfactory but considers that the information at present available is not sufficient for the writing of a specification.

(*Continued on next page*)