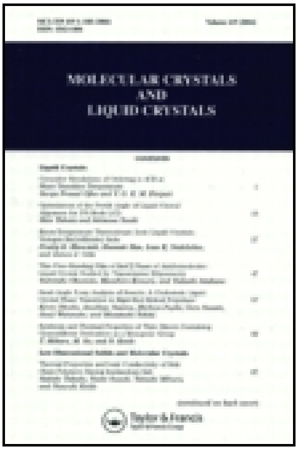

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Reliability and Standards in the U.S.A.

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Reliability and Standards in the U.S.A.†

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The first organized discussion of reliability and standards developed in the U.S.A. took place at Kent State University in August 1972. In October of that same year, a committee comprising representatives from some 14 organizations was formed and held its first meeting in New York City. Although never sanctioned by any national trade association, this early committee established guidelines for the test conditions to be used for both liquid crystal materials and finished devices.

In 1977, a new committee was formed under the auspices of the Joint Electron Devices Council (JEDEC) of the Electronic Industries Association of the U.S.A. This committee (JC 23.1), under the chairmanship of John Dunn and later, Charles Ristango, established six major areas of study: terms and definitions, environmental and reliability test methods, electro-optical test methods, sizes and configurations, polarizers, components and multiplexed displays. The results obtained by this committee in these areas of activity are described.

HISTORICAL DEVELOPMENT

The early work on development of liquid crystal display technology in the United States was carried out in the nineteen sixties. During this period a great deal of research and development was performed; theories were formulated and tested, materials with broad operating temperatures were prepared, a number of electro-optic effects were described and rudimentary fabrication techniques were developed. Between 1970 and 1972, the developments of the sixties were exploited by nearly a score of companies in the United States, Europe and Japan. The coincident development of large scale integrated circuits for driving the displays and providing time-keeping functions resulted in the development of the LCD watch and calculator. This

† Invited lecture, presented at Eighth International Liquid Crystal Conference, Kyoto (Japan), June 30–July 4, 1980.

marked the birth of the LCD industry and with it, as with all new industries, came the problems of product quality, reliability and standardization.

The first organized discussion of reliability and standards development in the U.S.A. took place in August of 1972 at the Fourth International Liquid Crystal Conference in Kent, Ohio. This session generated a great deal of debate on the problem of defining a format for standard life tests. The chemists present felt that standard life tests should be used for the evaluation of new materials. Device physicists and engineers, however, desired a standard test which evaluated only the finished device. As a result, no clear-cut resolutions were drawn up. Instead it was decided that a committee be established to further study and report on this important problem. Therefore, in October of 1972, a committee comprising representatives from some fourteen organizations was formed and held its first meeting in New York City. At this meeting, the committee resolved to establish a set of standard conditions for the life testing of both materials and devices. At this and subsequent meetings, the committee established the following five factors which must be considered for determining the deterioration of device life: cosmetic appearance, mesomorphic temperature range, electrical current consumption, contrast ratio, and response time (rise and decay).

For each factor, the testing group or organization would be required to produce data on changes in each of these parameters as a function of time. This early committee also established guidelines for the test conditions to be used for both liquid crystal materials and finished devices.

Although this was a good beginning and the committee's findings were submitted to the IEEE in 1973, the recommended guidelines were never officially sanctioned by any national trade association. This was largely due to the following factors:

1) Lack of confidence that LCD technology was viable. Light emitting displays were very strong competitors at that time.

2) The materials and production processes were largely proprietary and the leading manufacturers were reluctant to discuss their problems in an open forum.

3) Reliability problems were poorly understood. Most manufacturers did not have enough experience with products in the field to determine the nature and extent of potential reliability problems.

Between 1974 and 1976, further development of LCD's led to a better understanding of these reliability problems and to their ultimate solution. Ristango, for example, reported favorable results from extensive testing of plastic sealed LCD's at the SID's 1976 Biennial Conference in New York. It was at this same conference that we also learned of the advances made by the

Electronic Industries Association of Japan in developing standards for reliability testing. This group, headed by Prof. S. Kobayashi, also reported favorable reliability results on LCD's. In addition, studies of the degradation processes and mechanisms of these devices, which were performed by A. Sussman,[2] led to a better understanding of the relationship between electrical current consumption and display lifetime.

As a result of these developments, a second committee, known as JC 23.1, was formed in early 1977 under the auspices of the Electronic Industry Association's Joint Electron Devices Council, also known as JEDEC. The industrial organizations which have been represented on this committee include:

American Microsystems, Inc., A.N.D., Baum Chemical, Beckman Instruments, Crystalloid Electronics, Delco Electronics, EM Laboratories (BDH Chemical), Fairchild Camera & Instrument, Ford Motor Co., General Electric, Hamlin, Hewlett-Packard, Hoffman-LaRoche, IBM, John Fluke Manufacturing, Kylex, Micro Displays/Commodore Optoelectronics, Morgan Adhesive, Motorola, National Semiconductor, Nitto Denko America, Optel/Refac, Polaroid, Stanford Resources, Technit, 3M Company, Texas Instruments, Timex/Microma, Xerox.

THE JEDEC JC 23.1 COMMITTEE

JEDEC publishes recommended standards for testing and configuration of various solid state devices. The recommended standards which result from this activity are widely circulated for comment within the industry. Comments received are considered and incorporated into the original proposal which is re-submitted for further consideration and final approval. This process is shown schematically in Figure 1.

Because of the many steps involved, this is a time-consuming process. However, because test methods and product configurations change often, it seems reasonable that only those that can survive this "test of time" should be considered as standards.

The JC 23.1 committee, under the chairmanship of John Dunn and later, Charles Ristango, devoted its activities to the following six major subjects:

1. Terms and Definitions
2. Environmental and Reliability Test Methods
3. Electro-Optical Test Methods
4. Sizes and Configurations
5. Polarizers, Adhesives, Reflectors, Composites
6. Multiplexed Displays

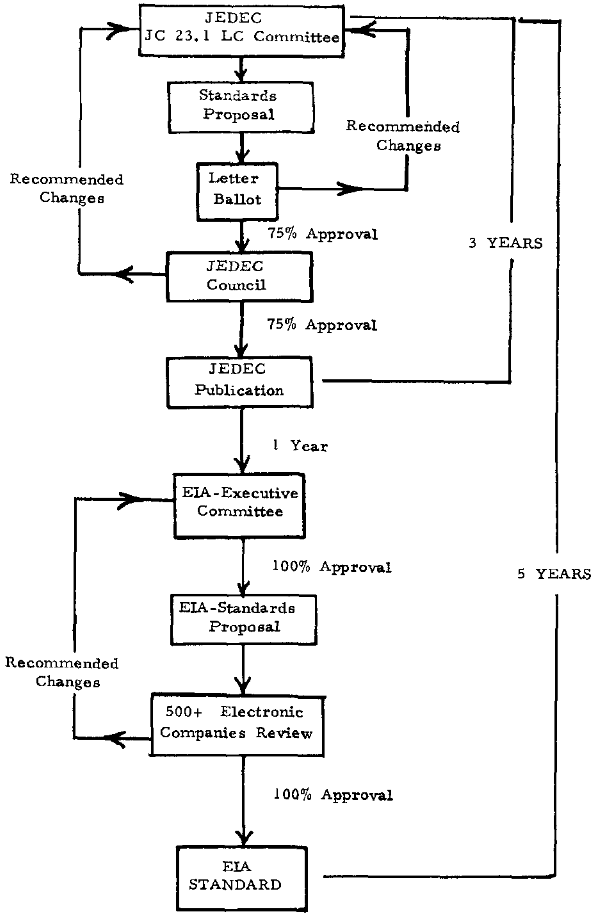

FIGURE 1 The JEDEC-EIA standards' approval process.

Thusfar, the only subject which has reached the stage of JEDEC publication, is that of Terms and Definitions. This is designated as JEDEC Publication 77-B1.[3] Environmental and reliability test methods are expected to be published soon.

The officially adopted standards as well as the committee's other activities are described below.

TERMS AND DEFINITIONS

Although some thirty-eight terms and definitions have been adopted, only those with which the committee had the most difficulty, or those that are worthy of comment are presented below:

1 Segment and common plate

In order to replace ambiguous terms such as top plate, bottom plate, front plate or back plate, the committee has adopted the terminology Segment Plate and Common Plate to denote the structures used in LCD digital displays. As shown in Figure 2, the segment plate has the segmented conductor pattern and fingers for edge connector contact while the common plate has an electrode pattern which is common on two or more segments.

2 LCD, twisted nematic field effect (TNFE)

A liquid crystal display in which the liquid crystal material is aligned in a uniform homogeneous manner on each cell wall, but the director on the surface is oriented at 90° to that on the other surface.

Note: The director angle turns smoothly through 90° as one moves through the liquid crystal film, from one surface to the other. Linearly polarized light

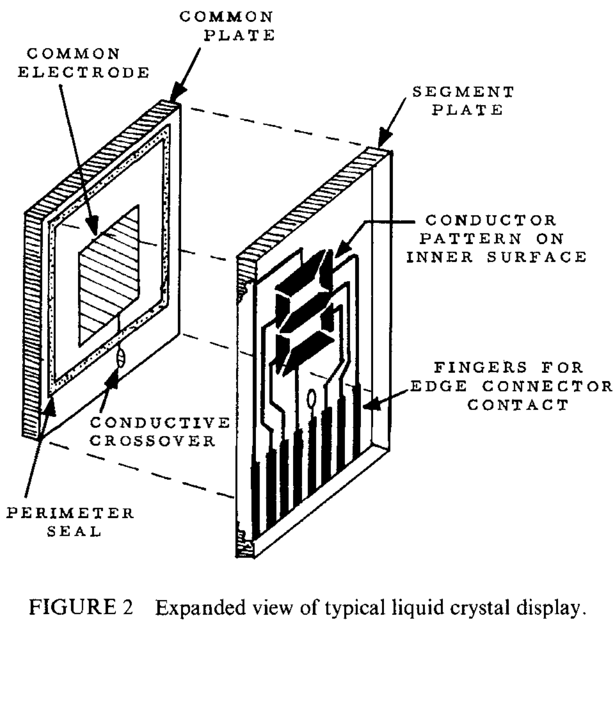

FIGURE 2 Expanded view of typical liquid crystal display.

that enters the cell with its polarization vector parallel to or perpendicular to the director at the cell wall is rotated through 90° as it passes through the liquid crystal film.

Application of a specific voltage above the threshold voltage aligns the directors of the liquid crystal material such that an alignment approximately perpendicular to the surface is obtained. The 90° rotation of polarized light is lost and the voltage-activated areas appear dark against a clear background or clear against a dark background when the polarizers are crossed and parallel respectively.

3 LCD reflective

A liquid crystal display that uses a reflective surface as part of the display structure to reflect light back through the liquid crystal material (see Figure 3).

4 LCD transmissive

A liquid crystal display that is designed to be viewed by light transmitted through the display in only one direction (see Figure 4).

5 Threshold voltage

The voltage *below* which further change in a defined optical characteristic is relatively small. The voltage at which the luminance has changed by 10% of the maximum change in luminance.

6 Saturation voltage

The voltage *above* which further change in a defined optical characteristic is relatively small. The voltage at which the luminance has changed by 90% of the maximum change in luminance.

7 Contrast ratio

The ratio of the luminance of a liquid crystal device in the light state to that in the dark state under conditions of constant illumination.

8 Delay Time (t_d)

The time interval between the initiation of an input pulse train and the luminance reaching its 10% on value (see Figure 5).

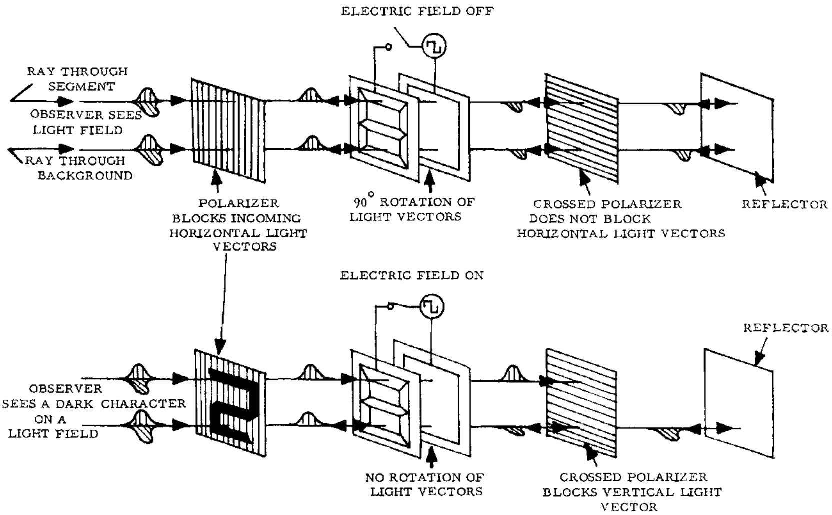

FIGURE 3 Reflective TNFE LCD.

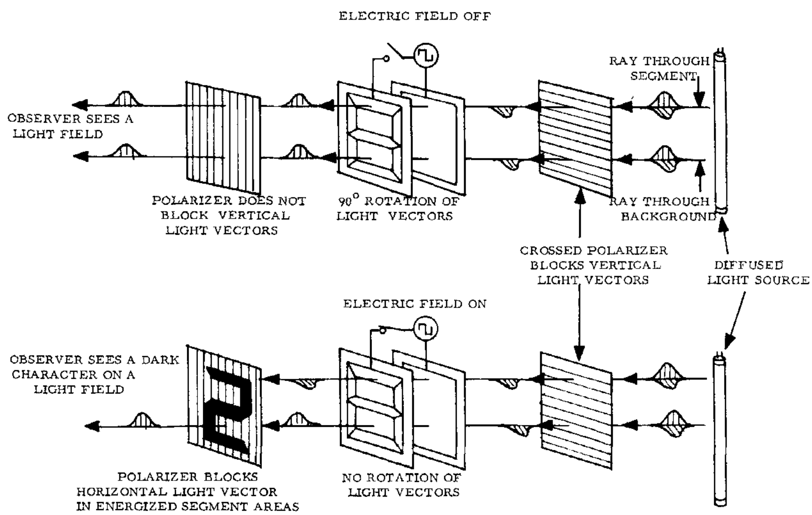

FIGURE 4 Transmissive TNFE LCD.

9 Rise time (t_r)

The time interval during which the luminance is changing from its 10% -On Value to its 90% -On Value (see Figure 5).

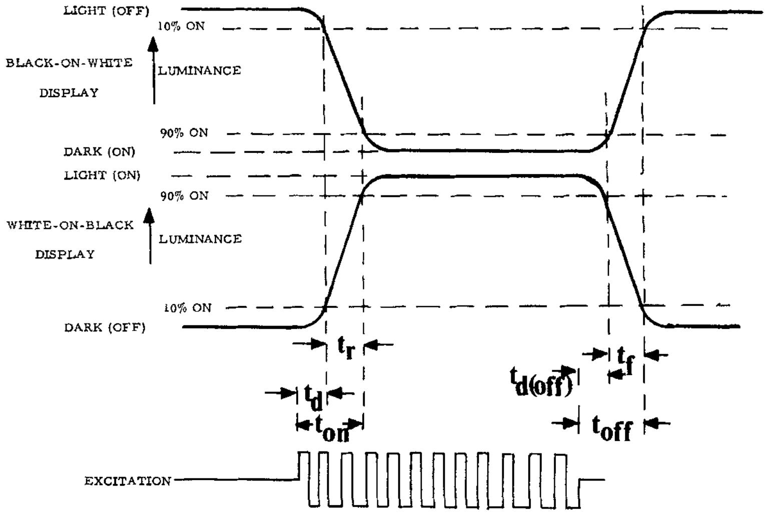

FIGURE 5 Response times.

10 Turn-on-time (t_{on})

The sum of t_d and t_r (see Figure 5).

11 Turn-off delay time ($t_{d(off)}$)

The time interval between the end of the input pulse train and the luminance reaching its 90% -On Value. Usually negligible compared with Fall Time (see Figure 5).

12 Fall time (t_f)

The time interval during which the luminance is changing from its 90% -On Value to its 10% -On Value (see Figure 5).

13 Turn-off time (t_{off})

The sum of $t_{d(off)}$ and t_f (see Figure 5).

ENVIRONMENTAL AND RELIABILITY TEST METHODS

A sub-committee headed by Frank Feyder devoted a great deal of time to the development of standards for environmental and reliability testing. The proposed test methods shown in Table I are very close to letter ballot

TABLE I
Proposed Environmental and Reliability test methods

	Temp. (°C)	Rel. humidity	Duration
Non-operating			
Temp./humidity with Polarizers	50	85±5%	48 Hrs
Temp./humidity without Polarizers	50	85±5%	200 Hrs
High-temp. storage with Polarizers	70	Ambient	96 Hrs
High-temp. storage without Polarizers	70	Ambient	1000 Hrs
Low-temp. storage with Polarizers	−20	Ambient	1000 Hrs
Temp. cycling with Polarizers	−20 to +70	Ambient	10 Cycles 10 Min @ each extreme. (5 Min. transfer time)
Operating[a]			
High-temp. storage with Polarizers	50 ± 2	Less than 40%	1000 Hrs

[a] Test to be performed at twice the operating voltage.

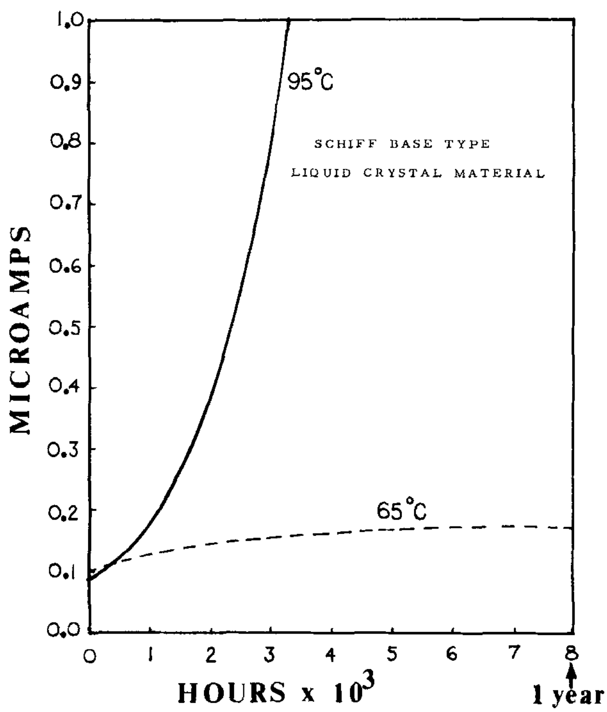

FIGURE 6 Storage life test of glass frit sealed direct driven LCD watch displays.

acceptance by the committee. For each test, three parameters must be measured:

1) *Nematic-Isotropic Transition Temperature*
The initial value and % change.

2) *Total Display Current*
The initial value and % change with all segments energized.

3) *Detectable Visual Changes*
Changes to be reported when the display is examined with the naked eye at 30 cm with 1000 Lux illumination under both operating and non-operating conditions.

Most manufacturers currently use tests which meet or exceed these proposed standards. Some typical results of testing glass frit sealed displays are shown in Figures 6, 7, and 8. In Figure 6, the total current is seen to increase steadily with time at 95°C. This is believed to be due to the diffusion of mobile ions (e.g., Sodium, Calcium, Hydroxyl, etc.) from the glass (or frit) into the

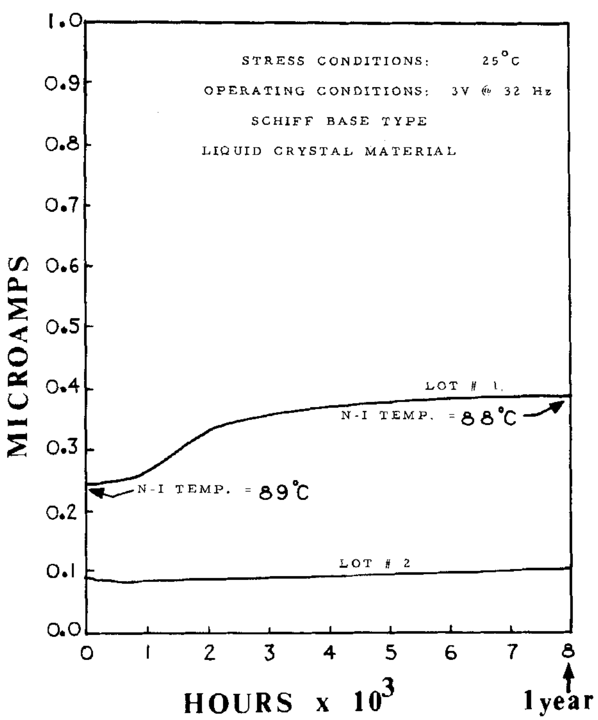

FIGURE 7 Operating life test of glass frit sealed direct driven LCD watch displays.

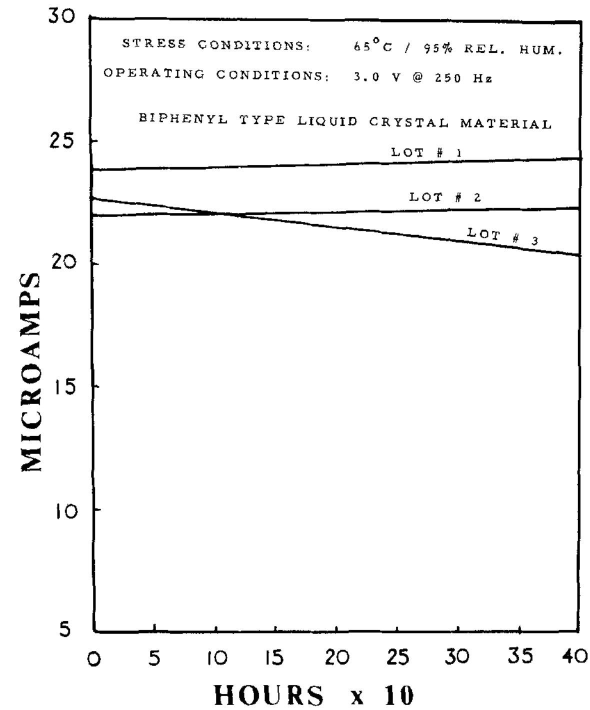

FIGURE 8 Operating life test of glass frit sealed multiplexed liquid crystal displays.

liquid crystal. At 65°C, however, the changes are quite small over a one year period.

Only very small changes in total current were observed after extended tests under typical operating conditions (Figures 7 and 8). In all of the tests shown, visual changes were negligible.

SIZES AND CONFIGURATIONS

Since there are simply too many display sizes to hope for standardization at this time, the committee has decided to devote its efforts toward the development of standards for digit and segment identification. The format proposed by a sub-committee headed by Sid McWhirter is shown in Figure 9. Most manufacturers use this proposed format at the present time and it is therefore expected that adoption of this proposal will occur quickly.

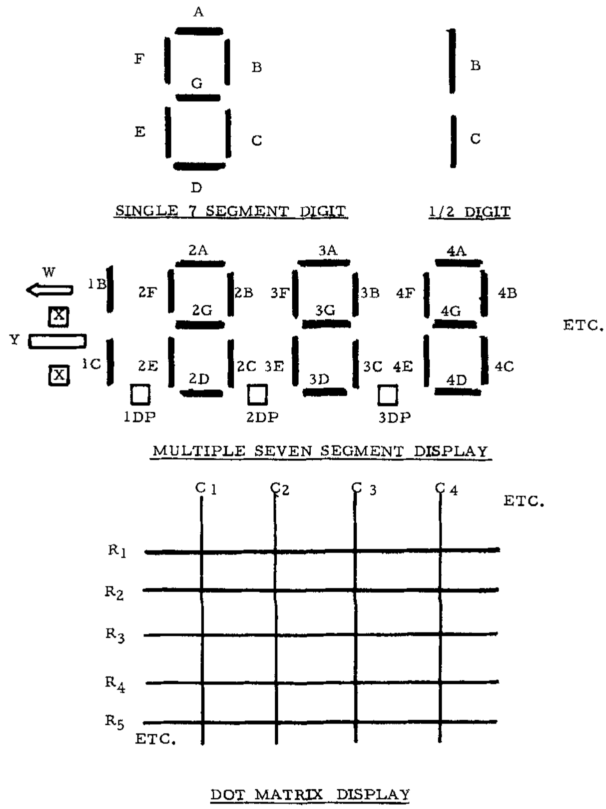

FIGURE 9 Sizes and configurations Digit and segment identification.

ELECTRO-OPTICAL TEST METHODS

A sub-committee headed by Steve Kolesar devoted a great deal of time to the development of electro-optical test methods. Although this sub-committee's work is still underway, some of the proposed methods are shown in Table II.

POLARIZERS, ADHESIVES, OTHER MATERIALS

This subject was dealt with by a sub-committee headed by John McGonagle. The proposed tests are shown in Tables III and IV. Many of the values for the "end-of-life" criteria remain to be established.

TABLE II
Proposed electro-optic test methods

ILLUMINATION CONDITIONS	
● Fluorescent Ring Illuminator at 45° from Normal	
● Liminance of 1170 Candellas/square metre	
● Photometer Normal to Centre of Display	
● Filter to Match Human Eye Response	
MEASUREMENTS	
● Voltages specified:	1.5, 3, 5, 12, 15, 24—one or more
● Frequencies:	32, 200, 1000 Hz—one or more
● Temperatures:	0°, 25°, 50°C—one or more
● Wave form:	Square Wave—±1% Variation in Period
● DC Offset:	Not to Exceed 100 Millivolts
● Operating current:	All segments energized; area dependent
● Saturation voltage:	90% of maximum contrast ratio
● Threshold voltage:	10% of maximum contrast ratio
● N-I Transition temp.:	Mid-point between onset and complete change
● Cosmetic defects:	Bubbles in liquid
	Dark or black spots
	Bubbles in polarizer
	Reverse Tilt or Twist
	Misalignment of molecules at surface
	Expanded Characters
	Decreased polarizer efficiency

MULTIPLEXED DISPLAYS

Since the committee has begun to investigate this area only recently, little progress has been made to date. However, it has been proposed that the method used to describe the electro-optical characteristics of multiplexed devices be a viewing cone contour plot.[4]

These plots (e.g., Figure 10), which were first described by F. Kahn[5] and S. Lu,[6] provide an excellent means for evaluation of the relationship between contrast ratio and viewing angle.

CONCLUSIONS

In the next few years, substantial progress in standardization of test methods, in configurations of segments and digits, and in polarizers and polarizer composites is expected. It is the author's opinion that the successful achievement of these goals is dependent upon the active and dedicated participation of individuals from the various industrial organizations in the U.S.A. who are responsible not only for engineering but most importantly, for quality control and reliability. Unlike the CWQC or company-wide quality control

TABLE III
Proposed tests to be performed on polarizer materials

Test	Conditions	Criteria
UV Light Transmission	At 2500–4000 Å	Max. % Trans.[a]
Temp./Humidity Stability	50°C/85% RH	Min. % Eff.[a]
Polarizer Efficiency	%T (parallel) & %T (crossed)	Min. % Eff.[a]
Cosmetics	View at 25 CM with with naked eye	No defects
Color	Match to NBS stand	Not Established
Thickness Tolerance	Micrometer	±7% of Nominal
Spectral Transmission	To Be Established	

[a] Values to be established.

TABLE IV
Polarizer–adhesive composites

Proposed temperature–humidity tests

Class	Temperature	% Rel. humidity	Time
I	30°C	85	100 hours
II	40°C	60	500 hours
III	50°C	85	48 hours

Criteria
A minimum % efficiency after test (value not yet established)

[a] Classes of polarizers

Class I	Iodine Based	46 to 55% Trans.
Class II	Iodine and dichroic dye polarizers	38 to 46% Trans.
Class III	Polyvinylene types	38 to 46% Trans.

system in use in Japan, the U.S. system, for better or worse, is predicated on the use of quality control specialists and quality control organizations. We must learn to make full use of their valuable talents and abilities if we are to develop meaningful standards for testing and reliability which, in turn, leads to higher quality products and lower cost. In the United States we hear a lot these days about the declining quality of American made products, and, presumably, of America's inability to maintain high quality control standards, especially in the consumer products field. As scientists, engineers, technologists and businessmen we, in the U.S.A., must do everything in our power to dispell this notion, for in the words of Kaoru Ishikawa of the Union of Japanese Scientists and Engineers, "Human beings are human beings whereever they live, and quality control activities can be disseminated and implemented anywhere in the world for human benefit."

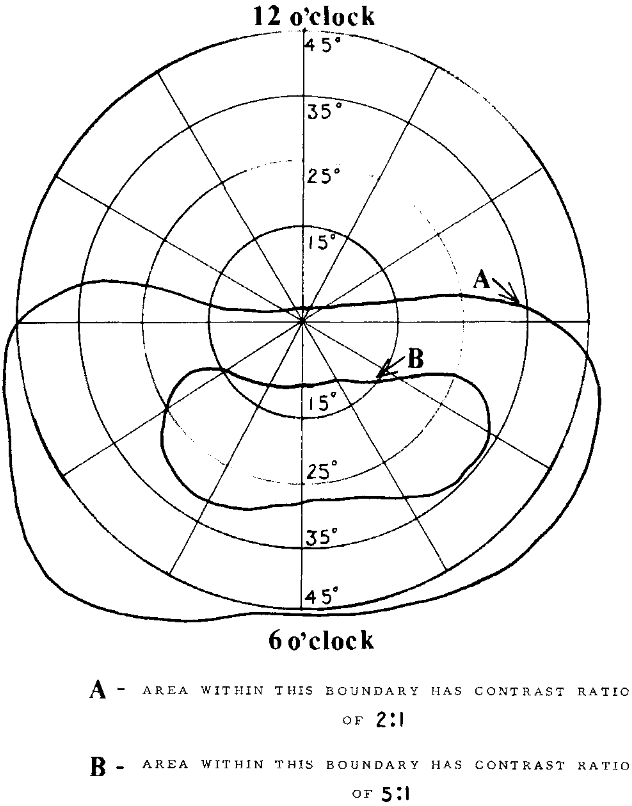

FIGURE 10 Viewing cone contour plot of multiplexed LCD.

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