Communications Research Centre

DISPLAY OF TEXT ON TELEVISION

by

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Department of Communications

Ministère des Communications

CRC TECHNICAL NOTE NO. 705-E

OTTAWA, MAY 1981

COMMUNICATIONS RESEARCH CENTRE

DEPARTMENT OF COMMUNICATIONS
CANADA

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SUMMARY

As part of the Department of Communication's efforts to facilitate the development of videotex services in Canada, the Behavioural Research Group has studied a number of issues related to the promotion of national and international standards. In particular, it was necessary to agree on the size and spacing of characters used in the composition of text so that text and graphics would always retain the intended spatial relationships on any video display adhering to the standard. The European 625 line television system has enough raster lines so that 24 rows of text can be displayed. For reasons of compatibility of page contents, it would be desirable to display the same number of rows on the North American 525 line system. However, a number of constraints compel us to adopt the position that only 20 rows of text should be displayed on videotex using the 525 line system. Televisions of most manufacturers overscan in both horizontal and vertical directions so that 80 percent of the total scan presently defines the safe title area. The resulting 193 lines per television field in the vertical direction permits 21.5 rows of characters with a 6 x 9 dot matrix or only 19 rows with a 6 x 10 dot matrix. An acceptable compromise of 20 rows of characters with a 6 x 10 matrix depends on an 83 percent safe title area. This document justifies the selection of a 6 x 10 character matrix. The following points relevant to the display of text on television need to be considered to determine the maximum number of rows of text that can be displayed.

OVERSCAN

Although there are 525 raster lines in one television frame, all of these lines cannot be used to display information. Forty-two of these lines occur during the vertical blanking interval, leaving 483 lines that could possibly be used. However, the SMPTE Recommended Practice 27.3 (1972) recommends that 80 percent of this image height be considered the "safe title image area within which the more important information must be confined to ensure visibility of the information". Eighty percent of the total frame translates to 386 raster lines that would be in the safe viewable area. Since each field must contain the same information in order to minimize flicker, the number of addressable points along the vertical axis in that area is 193.

CHARACTER MATRIX SIZE

The minimum letter height for good legibility has been addressed by several studies. For example, Smith (1979) studied legibility of letters on conventional print media and concluded that a letter subtense of 10 minutes of arc was required for 90 percent accuracy in recognition, while a subtense of 24 min. gave 100 percent accuracy. Seibert, Kasten, and Potter (1959) found that a subtense of at least 10 min. was required for 100 percent legibility of letters transmitted to a monitor via a TV camera. Hemingway and Erickson (1969), who also used a TV camera, found an inverse relationship between the subtense of the letter and the number of raster lines per symbol for angles between 6 and 16 minutes. The relationship for 95 percent accuracy was $S \times A = 90$, where S is the number of lines per symbol and A is the angular subtense of the symbol in minutes. This equation indicates that at least 9 scan lines should be used for a letter subtending 10 min. of arc.

Results obtained from systems displaying letters via a TV camera appear comparable to results from computer-driven dot-matrix displays. Snyder and Taylor (1979) found that the angle subtended by a dot-matrix character should be at least 10.8 min. for viewing distances less than 1.5 m. Shurtleff (1970) (reviewed in Scanlan and Carel, 1976) demonstrated that a 3 x 5 character matrix resulted in more identification errors and slower identifications than a 5 x 7 matrix or larger. Buckle (1977) recommends, on the basis of a literature review, that 5 x 7 should be the minimum matrix size, and that 7 x 9 is to be preferred. He further recommends that a letter should subtend a minimum of 15 min. of arc.

The available evidence indicates, therefore, that a character should subtend a minimum height of 10 min, and that the dot-matrix should be at least 5 x 7. A matrix six rows high has not been tested probably because an even number of rows forces an unusual, and thus undesirable, asymmetry in letters such as "B", "E", and "H".

VIEWING DISTANCE

Thompson (1957) studied the viewing distance that viewers preferred when watching either an unmodulated raster or a live telecast. In both instances, the average preferred distance was the point at which the line structure began to be imperceptible. This distance was about seven times the picture height. These studies were done using the technology that existed 25 years ago, and the results may not apply to modern colour television picture tubes. However, there is no evidence to suggest that people would now view television from farther distances that would reduce the visual angle of objects in the display. In fact, line structure is even less evident on modern colour television displays.

LENGTH OF DESCENDER

Very little experimental work has been published on lower case fonts. Thus, the problem of descender length has not been addressed until the experiment by Treurniet (1980) summarized in this technical note. The experiment found that detection and recognition of descender characters was faster in a search task when the descender protruded below the line by one pixel, than when the "descender" did not descend at all. Further improvements were not obtained when the descender protruded more than one pixel. Thus it may be concluded that a descender aids legibility and that a length of one pixel is sufficient. The additional pixel for descenders extends the minimum height of the character matrix to eight pixels.

POSITION OF ACCENTS

This technical note describes an experiment conducted to obtain preference rankings regarding accent placements. Photographs of French text displayed on television were shown to twenty French-speaking people. In condition A, the accent was drawn entirely inside the 5 x 7 matrix without modifying the shape of the letters so that the accent was often in contact with the letter. In condition B, the accent was drawn entirely above the matrix in what would be the interline space. In condition C, the accent was drawn partly inside the matrix and partly in the interline space. Finally in condition D, the accent was drawn completely inside the matrix, reducing the height of accented letters in order to put a space between the accent and letter. The 20 rankings very strongly indicated that condition C was preferred. In this condition, the accent extended above the 5 x 8 matrix by one pixel.

SPACING BETWEEN LINES

The minimum space required between successive rows of text on television has been studied in legibility and preference experiments described in this technical note. The legibility experiment measured the time to locate a particular character in a row of random letters on a page of text. A 5 x 7 character matrix, with additional lines added for descenders, was employed. Letter scanning rate was significantly increased when the space between rows was three pixels compared to spacings of one or two pixels. The latter two conditions did not differ. These row spacings are in addition to the space allowed for descenders. It can be argued that the effect of row spacing would not be obtained with the sequential and positional redundancies found in real text. However, it is also true that videotex pages will often contain pages of proper names and digit strings such as stock market quotations and train schedules. These may not contain much redundancy. Therefore, a space of three pixels is to be preferred.

In the preference experiment, 35 subjects were asked to read a short story of about 40 or 50 display pages. After each page, each subject was given the opportunity to change the spacing between rows on the following page. When two successive pages were read without a change in the spacing, that spacing was taken as a preferred spacing, and a new very wide or very narrow spacing was automatically presented on the next page. Subjects were asked to select the most preferred spacing. The mean of the last two preferred spacings for each subject was chosen as the dependent measure. Considerable variability of this measure across subjects was indicated by the range of 2.3 to 9.5 pixels. The overall mean was 4.8 pixels. If it is assumed that such an experiment did measure preferred spacing, it is clear that the preferred space between rows is not less than the best spacing inferred from the search task. Therefore, it may still be concluded that three pixels should separate rows of text.

The above points can be summarized as follows:

1. There are 193 addressable points in the vertical direction in the safe title area.

2. The average distance for viewing television may be considered to be less than equal to seven times the picture height.

3. The minimum character dot matrix size, excluding the space around a character, should be 5 x 7. This size subtends approximately 17 min. of arc at the distance noted in Item 2 which is considerably larger than the recommended minimum subtense of 10 min.

4. At least one line of pixels should be added to the bottom of the character matrix for descender characters.

5. At least one line of pixels should be added to the top of the character matrix for the accents found in the Latin languages.

6. The space between rows of text should be three pixels.

Consideration of these points leads to a recommendation for the maximum number of rows of text that should be displayed on North American videotex systems. The two extra matrix lines required for descenders and accents increases the height of the character matrix from seven to nine lines. The recommended interrow space of three pixels increases the space for one character to 12 lines. This would permit only 16 rows of text to be displayed with the 193 lines of pixels available. Compromising by reducing the interrow space to two pixels would permit display of 17 rows of text. A further reduction of the height of the character space to 10 lines of pixels can be obtained by replacing one line of the interrow space by the top line of the character matrix used for drawing accents. This permits display of 19 rows of text. The number of rows can be stretched to 20 by assuming that the safe title area is 83 rather than 80 percent of the total picture height.

Further reduction of the interline space by one pixel (i.e., a character height of 9 pixels) would permit display of 22 rows of text, but would also allow the undesirable possibility of an accent on a lower case letter touching a descender character in the row above. Since there is no pressing reason to adopt a 22 row capability, a maximum of 20 rows of text is recommended. The 24 row display advocated by proponents of European videotex systems is clearly not desirable for North American systems in view of the overscan present in ordinary TV receivers.

Another factor affecting spacing between adjacent rows of characters is the need for accents on capital letters. The French language in Canada requires the use of accents on capitals, and the need may also arise elsewhere when other languages using accents are to be displayed. A matrix ten lines high is the minimum height within which an accent can be placed over a capital letter. Even then, the accent touches both the letter and a descender in the row above. Accenting a capital would be impossible with a matrix only nine lines high.

Preferably, there should be a space of one pixel immediately below the accent and at least one pixel immediately above the accent. Thus, the ideal minimum character space for drawing accents on capitals is two lines higher than the ten lines recommended without considering such a need. As discussed earlier, the resulting character space 12 lines in height would permit 16 rows of text to be displayed within the safe title area. The Canadian Telidon system was designed to permit spacing between rows to increase by increments of half the matrix height. Thus, accents on capital letters occupying a space ten lines high can be easily accommodated by increasing the space between rows by an additional five lines. A character space of fifteen lines provides ample room for placing accents on capital letters, and limits the number of rows of characters on the display to 13.

Additional conclusions and recommendations regarding the presentation of text on a video display follow from the work described in this technical note.

1. No difference was found in average speed of reading upper versus lower case text from the television display. Therefore, established convention may be followed in the choice of case for the display of text.

2. The results of legibility experiments suggest that the optimal spacings between letters and lines of text on a page is dependent on the design of the character set employed. Specifically, it was suggested that these spacings depend on the extent to which the letters fill the character matrix.

3. Proportional spacing is generally considered to improve the readability of a page of text. It should be implemented whenever possible.

4. When proportional spacing is used, the space character separating words should be reduced in width. For the 5 x 8 and the 7 x 11 character sets tested, the preferred space between words was six pixels when the space between letters within words was two pixels.

5. NTSC composite video input to the television display requires that care be exercised when designing the image contents. Proper character set design results in an acceptable black and white display of text. Colour combinations should be used with extreme caution because of the inevitability of chroma-crawl along the colour contours. Vertical line elements should be at least two pixels wide to be fully illuminated. RGB video input eliminates most of the problems inherent with NTSC composite video input. Therefore, RGB video input is most desirable.

6. Designing character sets is a skill or art that requires proper training. Presented in this report are character set styles created by professional graphic artists. They are recommended for use on television picture tubes with a shadow mask like that in the Electrohome Model C40-852 television receiver.

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ABSTRACT

A videotex service is a means whereby the general public will be able to access various kinds of information from central data bases. Textual and graphical information will be displayed on television receivers much like those currently used in people's homes. Technical and graphic design problems related to the display of such information on a colour television are addressed in this report. The results of several studies concerned with the display of text are described, and the relative merits of Red—Green—Blue versus composite video input are discussed.

INTRODUCTION

A television system should display visual information so that it corresponds satisfactorily to an average observer's visual capabilities and preferences (e.g. Condon, Bailey, Everitt, Fink and Smith, 1950). For this reason, it is sometimes necessary to recommend technical changes to the television system, or to recommend that the image content be constrained in various ways when new applications for television technology are devised. Major engineering changes to the television system are difficult and expensive to implement if backward compatibility is not maintained. Thus, colour was added to the monochrome system in such a way that monochrome receivers could display a colour video signal by simply ignoring the colour information. New applications such as videotex pose new questions regarding the adequacy of the television display characteristics.

Videotex services require satisfactory presentation of alphanumeric and other graphical material on static displays. When extensive reading is to be done from the television display, it is being used for a purpose for which it was not expressly designed. The restriction of limited television channel bandwidth has several perceptual consequences. Some of these consequences can be minimized by proper design of image content. Others require significant technical changes. This report briefly describes some relevant aspects of North American television standards, and discusses experiments and demonstrations concerned with the presentation of static video imagery.

1. CURRENT TELEVISION STANDARDS

In North America, the accepted standards for television transmission are those recommended by the National Television System Committee (NTSC) (see Pritchard (1977) for a review). These standards impose restrictions on how the radio frequency spectrum can be used to transmit and receive television signals. New innovations in broadcasting must be compatible with these existing standards to minimize obsolescence of television equipment. The standards limit television displays mainly in terms of resolution and image flicker.

1.1 RESOLUTION

Television pictures are the result of horizontal scan lines that are displayed sequentially by an electron beam on the face of a cathode-ray tube. The total image frame is composed of 525 scan lines. Since a number of lines occur during the vertical blanking interval when the electron beam returns from the bottom to the top of the screen, about 483 lines may contain video information. Each frame is further divided into two fields so that each field consists of alternate lines of the image frame. The technique of placing adjacent scan lines in alternate fields is called "line interlace". Each field is presented at a rate of 30 Hz. The complete image frame therefore, is redisplayed at the rate of 30 Hz. Because one and then the other of the two fields is presented every 1/60 sec, the image appears to be redisplayed at a rate of 60 Hz when the observer is sufficiently far away that successive raster lines are indistinguishable. The 483 scan lines place an upper limit on the vertical resolution with which an image can be displayed.

Horizontal resolution is determined by how quickly the intensity of the electron beam can change as it scans the line. In colour receivers using a shadow-mask picture tube, each line is subdivided into a series of red, green and blue circular or rectangular elements. The distance between successive groups of three elements places one limit on the horizontal resolution. The members of a pair of elements of a given colour are separated by two elements of the other two colours. Elements of the same colour are staggered on successive lines. The decrement in horizontal resolution caused by the addition of colour information to the fixed bandwidth video signal is reduced by a technique known as "mixed highs". This procedure uses the fact that the eye's "acuity for detail residing in colour differences is less than half as great as the acuity for detail residing in brightness" (Bedford, 1950). This differential sensitivity to intensity and colour allowed television designers to reduce the amount of colour detail without significantly degrading the appearance of the image. Only fine details with respect to luminance differences were required. The luminance signal is derived by mixing the highest frequencies in the three colour signals before transmission. The resulting signal is represented at the receiver as shades of gray. Consequently, very fine colour details in a television image are represented by brightness variations alone. Further, intermediate colour detail is adequately represented by a two-colour process resulting in orange and cyan. Only large coloured areas require all three primary colours of red, green, and blue for adequate reproduction. By transmitting only information that the eye can discriminate, the resolution provided by a colour image was enhanced within the restriction of the available bandwidth. Horizontal resolution, then, is limited by the available bandwidth as well as the design of the colour dot layout on the face of the picture tube.

1.2 FLICKER

As indicated in the last section, the interlaced image frame appears to be presented at the rate of 60 Hz. This rate was considered fast enough to maintain the appearance of constant luminance of a picture of adequate brightness when the picture is repetitively refreshed. Too low a refresh rate results in annoying flicker of the image, while a refresh rate higher than the minimum necessary to avoid flicker is wasteful of bandwidth.

Two types of television flicker have been distinguished. "Large-area flicker" is observed when a bright part of the image subtends a relatively large visual angle. "Small-area flicker" appears when detail in a picture is of the size of a few picture elements or a few scanning lines. This type of flicker is most noticeable when the picture is inspected closely. One form of small-area flicker is interline flicker which occurs when horizontal detail is shown on only one scan line. Such detail is refreshed at a rate of 30 Hz which is at or below critical flicker fusion frequency for most people. Small-area flicker is also manifested as line crawl, which is an apparent upward or downward motion of lines due to successive illumination of adjacent lines in bright parts of the image. The effect may be caused by vertical movement of picture content.

Flicker can be reduced either by reducing the image intensity or by increasing the refresh rate of the image. When the available bandwidth is fixed, an increase in refresh rate requires a reduction in resolution, while a reduction in image intensity produces a possibly undesirable reduction in contrast or the dynamic range of intensity.

2. THE DISPLAY OF TEXT ON TELEVISION

The number of addressable picture elements (pixels) on the television display determines the maximum density of textual information that can be displayed. Since the number of pixels is fixed by the character generator hardware, the number of words that can be displayed depends on the number of pixels used to draw each letter. It is generally accepted on the basis of legibility studies that a 5 x 7 dot-matrix is the minimum size for adequate representation of characters (e.g., Scanlan and Carel, 1976). Further variation in the amount of text that can be displayed arises from the spacing between letters, words, and lines, and from the use of proportional spacing. Proportional spacing is the reduction of the letter matrix width to match the width of the letter. The most desirable spacings will probably depend to some extent on the bandwidth of the signal carrying the information. Thus, the NTSC composite video signal may require different spacings than a wider bandwidth Red, Green, and Blue (RGB) video signal. RGB video input drives the three CRT electron guns directly and is not limited to the bandwidth imposed by the NTSC standards.

The following experiments employed a Norpak RGP500 graphics processor to generate text on a display with 240 vertical, and 320 horizontal, addressable picture elements. Letter spacing requirements were studied with an RGB display, and problems specific to composite video displays are also demonstrated and discussed.

2.1 EXPERIMENTS MEASURING PERFORMANCE

Most experimental work with dot-matrix character design has been done with upper case characters. It was not clear at the beginning of the project whether experiments on reading from television should be done with all capitals or with lower case text. Therefore, the first experiments examined the readability of upper versus lower case text using a validated speed of reading test. A search task was used in subsequent experiments to study the legibility of characters when the spacings between characters and lines were varied.

2.1.1 Upper Case Versus Lower Case

We are most accustomed to reading textual information in lower case. Several reports in the literature suggest that lower case is preferred because it is read more quickly at normal reading distances than all capitals. (Breland and Breland, 1944; Paterson and Tinker, 1946; Warren, 1942), and that it is also comprehended better (Poulton and Brown, 1968). Faster and improved processing of lower case text may occur because more information about word shapes and word boundaries is available in the visual periphery. This hypothesis is supported by an earlier study (Tinker and Paterson, 1939) that found more eye fixation pauses while reading upper case text than while reading lower case text. If peripheral processing is better when text is lower case, the difference between speed of reading upper and lower case text from paper should also be found when reading from a television display.

A pilot study was performed to determine how reading performance varies as a function of reading distance when text is presented on a video display in either upper or lower case. Reading rate was determined using the Basic Reading Rate Scale (Carver, 1971), a modification of the Tinker Speed of Reading Test (Tinker, 1955). This test requires identification of a word that does not fit the context of a sentence or sentences consisting of about 30 words. Since comprehension is easy, the speed of identification is considered to measure perceptual processes. For example, a test item might be as follows: Whenever I go to the park, I take a baseball, bat, and glove, and anything else I need to sleep. In this example, the word "sleep" is obviously the word that does not fit the context of the sentence. Carver (1971) reports that the test has high reliability (.96) and it also appears to have validity since comprehension is required to perform correctly.

The text was displayed on a 17 inch black and white Setchell-Carlson monitor with base-band video input. Characters were designed on a 5 x 7 dot-matrix that spanned a height of 14 scan lines on the display. Subjects' oral responses were detected by an electronic voice switch. Voice onset resulted in erasure of the display, and the experimenter initiated the next display with a press of a push button. Reading times were measured to the nearest msec by a computer controlled clock.

Subjects were instructed to read the sentences as fast as they could, and to say the inappropriate word as soon as it was identified. Three reading distances of 18 in, 40 in, and 84 in were investigated. Each subject experienced only one reading distance, but read both upper and lower case text. Text content and order of case was counterbalanced across subjects.

Analysis of the experiment showed no effect on reading rate of reading distance or case of text. This result was not anticipated, and a second experiment was performed to test hypotheses to explain the unexpected finding.

In earlier work that had found differences in speed of reading upper and lower case text using the same task, subjects were permitted to progress at their own speed from one item to the next. In the above experiment, subjects were constrained by the experimenter in this regard. This methodological difference may have interfered somehow in the reading process. Another difference between the experiments was the relative stability of the displays. Whereas paper provides a stable display, the video medium tends to flicker somewhat because of the 30 Hz refresh rate. This instability may have interfered with the use of peripheral information, thus causing lower case to give results similar to upper case. The second experiment was performed to determine if the difference in speed of reading upper and lower case text could be obtained under conditions similar to those employed by other investigators, and to evaluate the effect of television flicker on reading performance.

Again, texts to be read were items from the Basic Reading Rate Scale (Carver, 1971). In this experiment however, subjects read from three different media. Items were read in upper or lower case from paper to approximate conditions of experiments that found an effect of case on reading rate. Times to read 10 items were measured with a stopwatch. Items were also presented on the video display in two manners. One way was to create the characters on the display by exciting the display phosphor with the electron beam. The other way was to project photographic images of these displays onto the unilluminated television screen with a slide projector. The latter method preserved the luminance and content of each display, but eliminated any flicker that might have been present. Although all subjects were exposed to the three media, the design of the experiment using the paper medium was treated separately from the design of the experiment using the televised and projected displays. This was done to permit partial counterbalancing of experimental conditions and materials. Counterbalancing would have been unmanageable if all conditions had been included in one large design. This compromise does not permit comparisons of absolute speed of reading from paper and the other two media because of a confound with text content.

Each experimental condition consisted of ten trials. Therefore, since each subject was exposed to upper and lower case in each of three media conditions, each session consisted of 60 items to be read. Thirty-two people participated in the experiment.

Analysis of mean reading times again showed no significant effect of case on reading rate using any of the three media. Also, no interaction was found between case and televised versus projected images. The results suggest either that no difference in speed of reading upper and lower case exists for the character set employed, or the Speed of Reading Test is not sensitive enough to consistently detect such a difference. Other studies that did find the effect either used a large number of subjects with the attendant increase in statistical power (e.g., Paterson and Tinker, 1946) or used experimental conditions more extreme than those imposed by a mere difference in case (Snyder and Maddox, 1978).

An indication of the similarity of reading from the paper and television media was found in the second experiment by a further post hoc analysis. A linear regression was performed between people's mean time reading from paper and their mean time reading from the television screen. The slope of the resulting regression line was .92 and the correlation between the two variables was a highly significant .86. These values indicate that a change from one person to the next in time of reading from paper was accompanied by a similar change in time reading from television. In other words, if a person is a fast (slow) reader using one medium, he tends to be fast (slow) using the other medium as well.

Since the experiments found no effect of case on speed of reading from television, it appears that the most desirable case of text may be dictated more by preference than by performance. Consequently, there appears to be no good reason why established practice should not be followed in the choice of letter case.

2.1.2 Character Size and Spacing

Character size and spacing have a direct impact on the amount of text that can be displayed on a television screen. On raster displays, characters are created by illuminating dots within a matrix of a particular size. When the matrix is quite small, characters tend to appear rectangular. However, they are usually easily recognizable when dot matrices are equal to or larger than 5 x 7 (Scanlan and Carel, 1976). Shurtleff (1967) has recommended that a minimum of 10 television raster lines be used for the display of alphanumeric symbols using a conventional television camera as the source of the displayed material. This is less than the 14 lines that would be used by a 5 x 7 matrix using two raster lines per picture element (pixel).

The spaces between characters and lines of text must be standardized for the purpose of annotating graphics. Specifically, if words were displayed with different interletter spacings than intended by the picture creator, they would not retain the proper spatial relationships with any accompanying graphics. The spacings chosen as the standard should be large enough to permit good legibility, yet not so large that the amount of text that can be displayed is significantly reduced.

An experiment that studies the effect of various spacings on the legibility of letters has been reported in detail elsewhere (Treurniet, 1980). In that experiment, letters were presented on a CONRAC Model RHN 19/C 19 inch RGB colour monitor which has circular phosphor elements. The letters were displayed in white (6500 degrees colour temperature equivalent) on a colourless background. The intensity of the fully illuminated display was adjusted to be 14 foot lamberts, and the ambient room lighting was approximately 34 foot candles. A full screen of randomly selected 5 x 7 characters was presented on each trial. The subject was to attend only to a row of characters near the center of the display. Locating this critical row was facilitated by placing a "plus" symbol adjacent to it in the left margin. The subject's task was to identify the first letter in the critical row, locate the same letter elsewhere in the row, and say the name of the letter immediately following the second occurrance of this target letter. If the target letter was not found in the row, the subject was instructed not to retrace, but to say the name of the letter at the end of the row. The target letter was always one of the letters "g", "j", "p", "q", and "y". This set of target letters permitted the length of descenders to be manipulated as well as the horizontal and vertical spacing between the letters. The descender extended below the line by either 0, 1, or 2 pixels, while the horizontal and vertical spacings were either 1, 2, or 3 pixels. All three variables were varied in a factorial design, and each observer was exposed to all experimental conditions. The dependent measures were scanning time per letter when the target was located, and the frequency with which the letter at the end of the row was reported.

Analysis of the results showed no interactions between any of the independent variables. However, all main effects were significant when scanning rate was the dependent measure. Scanning rate was significantly reduced when the descender did not extend below the line, but there was no difference between an extension of one or two pixels. Scanning rate was significantly increased when the space between lines of letters was increased to three pixels, but there was no difference between a space of one or two pixels. Finally, scanning rate decreased significantly with each increment in spacing between letters on the line. However, analysis of miss frequencies showed that the smallest space of one pixel resulted in significantly more misses that did spaces of two or three pixels. The latter two spacings did not produce a significant difference in the number of search targets missed.

These data led to the conclusion that, for best legibility, the descender should extend below the line by at least one pixel, that the space between rows of letters should be at least three pixels, and that the space between letters on a row should be two pixels. When these dimensions are added to the basic 5 x 7 character matrix, the area occupied by a character and the accompnaying space measures 7 pixels by 11 pixels.

Because of the restrictions imposed on the number of scan lines by the NTSC television standard, only about 240 pixels can be displayed vertically. This number needs to be reduced by 20 percent (SMPTE Recommended Practice 27.3, 1972) to 193 to allow for the overscan built into television receivers by manufacturers. A simple calculation shows that the 7 x 11 matrix size permits display of 17 rows of characters in this area. Assuming only 16 percent vertical overscan, and reducing the inter-row space to two pixels permits display of 20 rows of text. The number of pixels that can be displayed horizontally is limited by the bandwidth specified in the NTSC standard, as well as the number of colour elements on the picture tube shadow mask. In practice, these constraints allow a maximum of about 40 characters to be displayed on the television screen.

A larger, 7 x 9 character set is thought to improve legibility by some authors (e.g., Buckle, 1977). For this reason, it was felt that videotex terminals should provide an additional larger character set based on a 7 x 9 character matrix. The above experiment was repeated with a 7 x 9 character set instead of the 5 x 7 character set in order to determine the inter-character and inter-row spacings required. Instead of the CONRAC monitor, the experiment employed an Electrohome Model C40-852 colour television receiver modified for RGB video input. This change was made because the Electrohome receiver was to be used in forthcoming videotex field trials.

Analysis of the results of this experiment also showed no interactions between any of the independent variables. However, scanning rate was influenced significantly by two of the independent variables. Each decrement in horizontal spacing produced a significant increase in scanning rate. Although the scanning rate measure alone suggests that the minimum spacing gives the highest rate of information input, analysis of miss frequencies indicated that a space of three pixels between letters resulted in significantly fewer misses than the two smaller spacings. The latter two did not differ. These data suggest that too high a rate of character input encouraged by the smaller spacings caused less accurate target detection. The slower input rate with a spacing of three pixels was associated with a lower miss frequency.

Scanning rate was also affected by the length of descenders. Each increment in length produced a significant increase in scanning rate. Further, the frequency of misses decreased significantly with each increase in descender length. Thus, it appears that performance had not yet asymptoted with the longest descender length of two pixels.

Unlike the previous experiment, varying the spacing between rows of letters did not affect scanning rate.

This experiment suggests that for 7 x 9 characters, descenders should extend below the line by at least two pixels, that letters should have a horizontal separation of three pixels, and that the space between lines can be as little as one pixel. Adding these amounts to the basic 7 x 9 matrix makes the area occupied by a character and the accompanying space 10 pixels by 12 pixels. These dimensions permit 18 lines of 28 characters/line to be presented in the visible display area.

The results of the two studies show that the effect of descender length, and horizontal and vertical spacing on legibility is not independent of character matrix size. This dependency might be attributable to the differences in the ratio of stroke width to matrix size (SW/MS). When this ratio is small, the interior of letters appears more empty than when the ratio is larger. The impression of emptyness within the letter structure may decrease letter discriminability when letters are very close together. In other words, recognition of the space between letters is more difficult when the average empty area within letters is larger. However, the difference between character sets with respect to best vertical spacing is contrary to this hypothesis. The character set with the larger SW/MS ratio appeared to require a larger instead of smaller space between lines. As an alternative hypotheses, the vertical spacing may affect the impression of overall density of letter strokes on the page. Too high a density may interfere with perceptual processes at the fovea. Breitmeyer and Valberg (1979) have shown that peripheral stimulation can produce foveal inhibition. The high density associated with a relatively large SW/MS ratio can be decreased by increasing the space between lines. With a smaller SW/MS ratio, the extra spacing between lines would not be required to improve legibility. These hypotheses can be tested directly by repeating the second experiment using the same size character set but with a thicker stroke. The hypotheses predict that such a character set will require more space between the lines and less space between the characters on a line. Further work, to be reported elsewhere, has confirmed these predictions. The results showed that the spacing between these characters can be reduced to one pixel, and therefore, that at least 32 characters can be displayed on one row of text.

2.2 EXPERIMENTS MEASURING VIEWER PREFERENCE

Some aspects of displays are not easily evaluated with performance measures. In these cases, relative preference ratings can often provide a quick indication of how a display should be constructed. An individual's preference regarding the display of text is heavily conditioned by past experience, and obtained ratings likely reflect how well the stimulus material matches that which is familiar. The method of obtaining preference rankings was used to study placement of accents on letters, and spacing between letters, words, and lines of text.

2.2.1 Placement of Accents

The character sets employed in Figures 1 to 4 were created to show the effects of different placements of accents. The basic 5 x 7 character matrix was extended to 5 x 8 to provide one line of pixels for drawing letters with descenders. Accent placements are described as follows:

Method 1:

All accents on both upper and lower case letters are squeezed into the top two lines of the 5 x 8 character matrix. Both upper and lower case letters are reduced in height where possible to allow a space of one pixel between the accent and the letter. Figure 1 displays this placement of accents.

Method 2:

All accents are placed on the top two lines of the 5 x 8 character matrix. Accented letter shapes and sizes are identical to non-accented letters. Consequently, upper case letters in this set cannot have accents, and little or no separation can exist between accents and lower case letters. Figure 2 displays this placement of accents.

Method 3:

All accents are placed entirely above the 5 x 8 character matrix in an interrow space three pixels wide. Little or no separation can exist between accents and upper case letters, while two pixels separate accents and lower case letters. Figure 3 displays this placement of accents.

Method 4:

Accents on upper case letters are placed above the 5 x 8 character matrix in an interrowspace three pixels wide. Accents on lower case letters extend into the character matrix and use only one pixel of the interrowspace. Figure 4 displays this placement of accents.

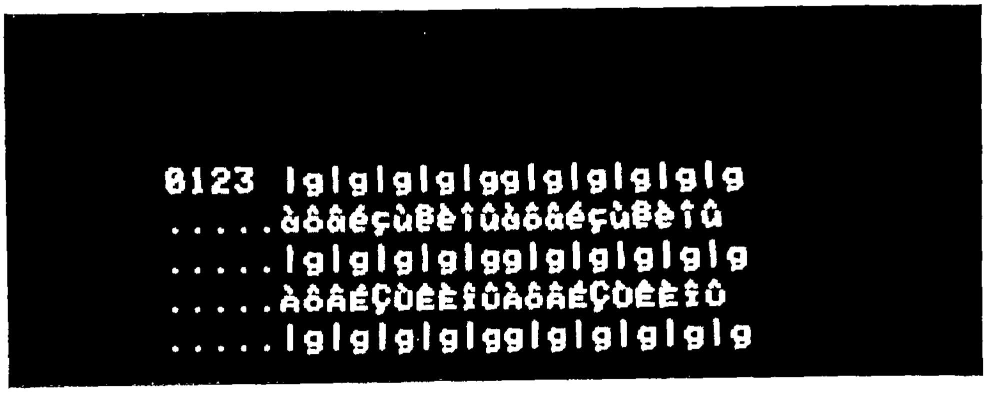


Figure 1(a). Accent Placements of Method 1 Shown in Relation to Ascending and Descending Letters

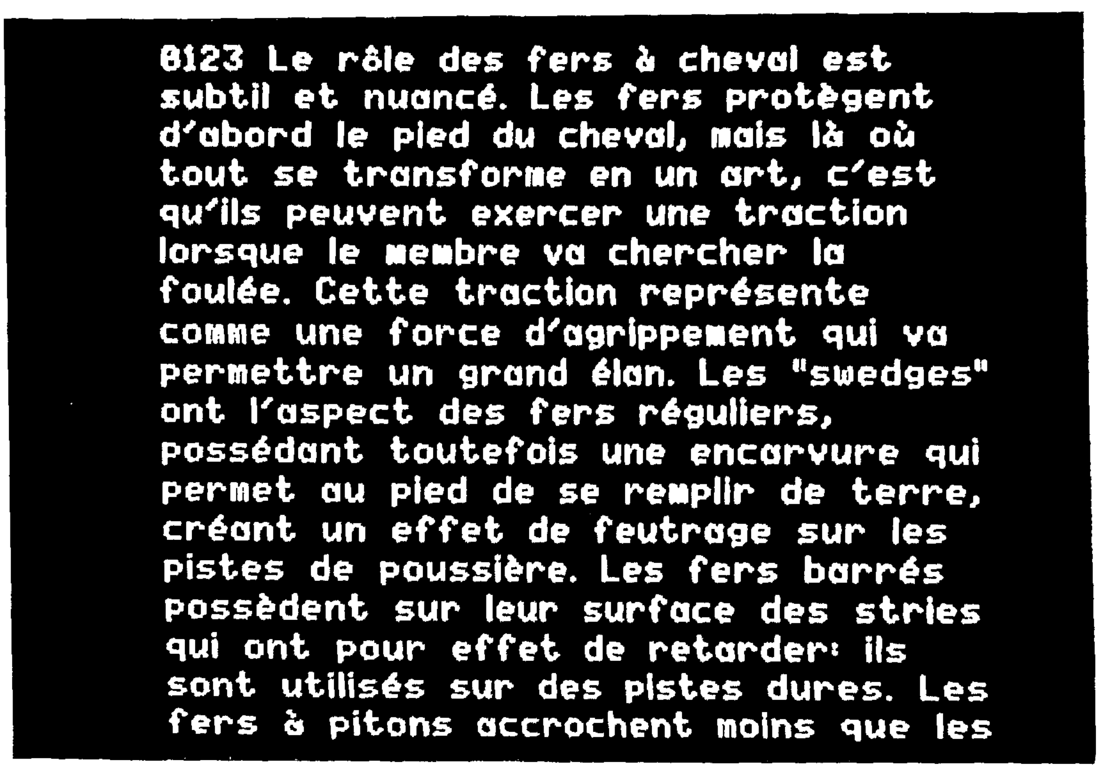


Figure 1(b). Accent Placements of Method 1 Shown in the Context of Lower Case Text

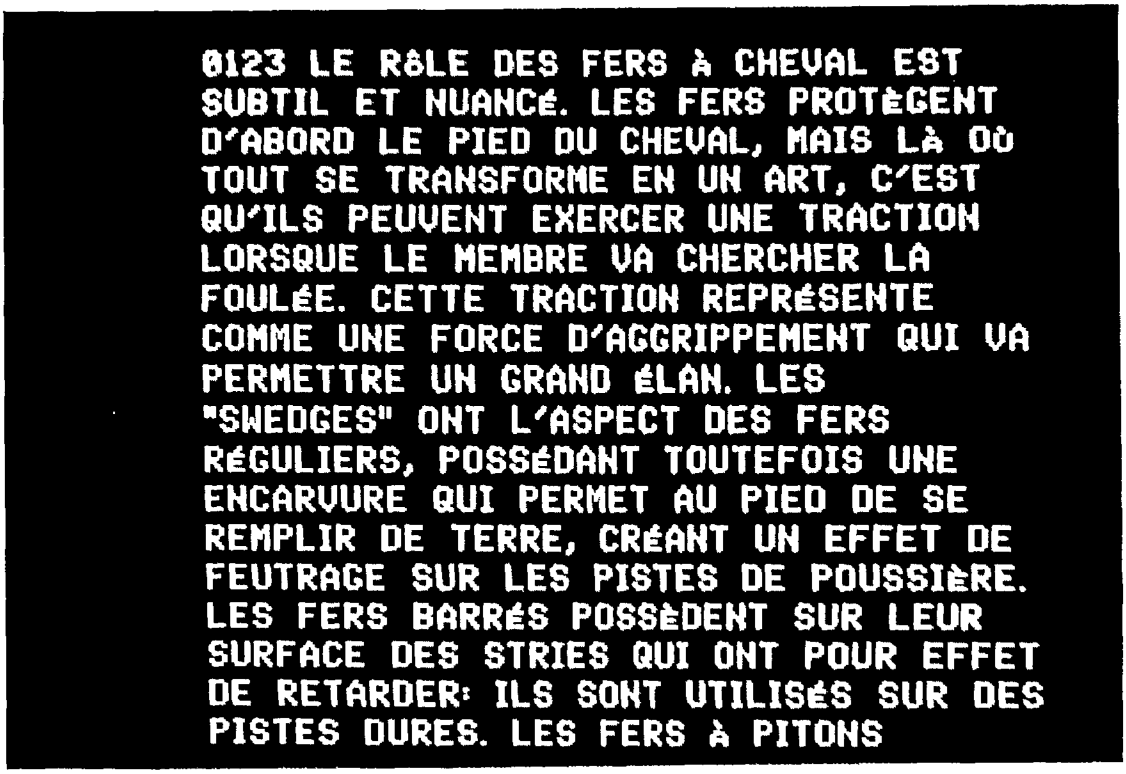


Figure 1(c). Accent Placements of Method 1 Shown in the Context of Upper Case Text

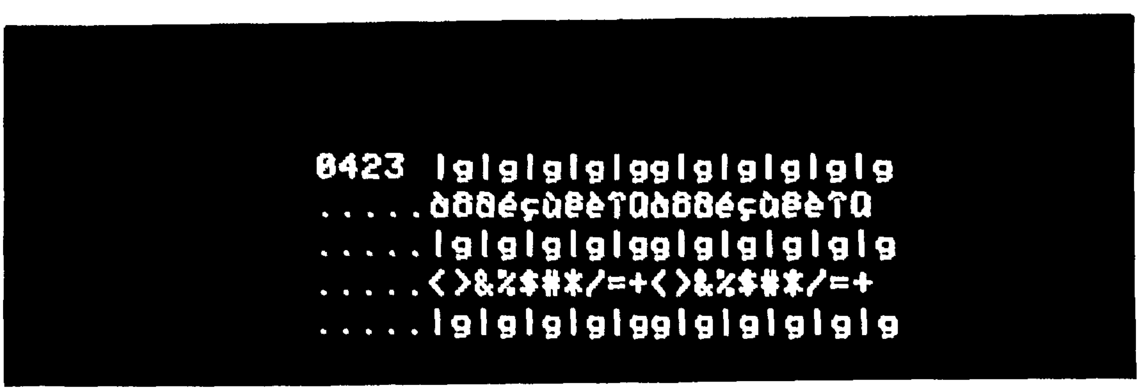


Figure 2(a). Accent Placements of Method 2 Shown in Relation to Ascending and Descending Letters

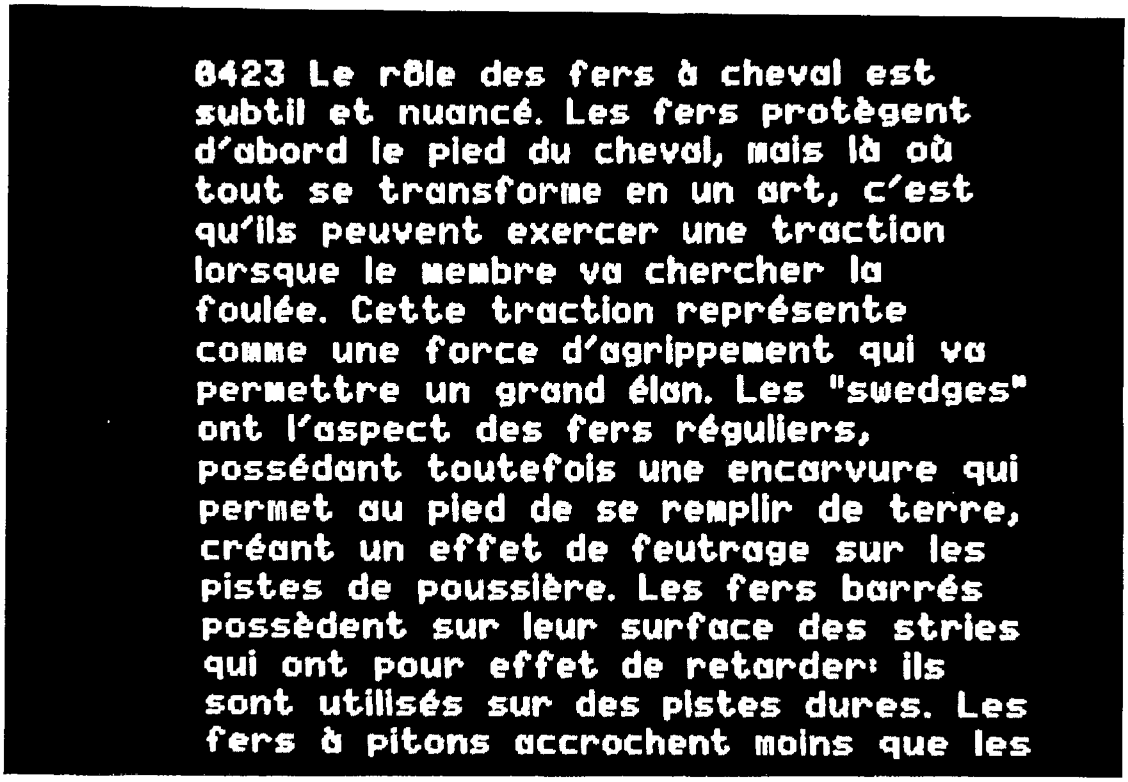


Figure 2(b). Accent Placements of Method 2 Shown in the Context of Lower Cast Text

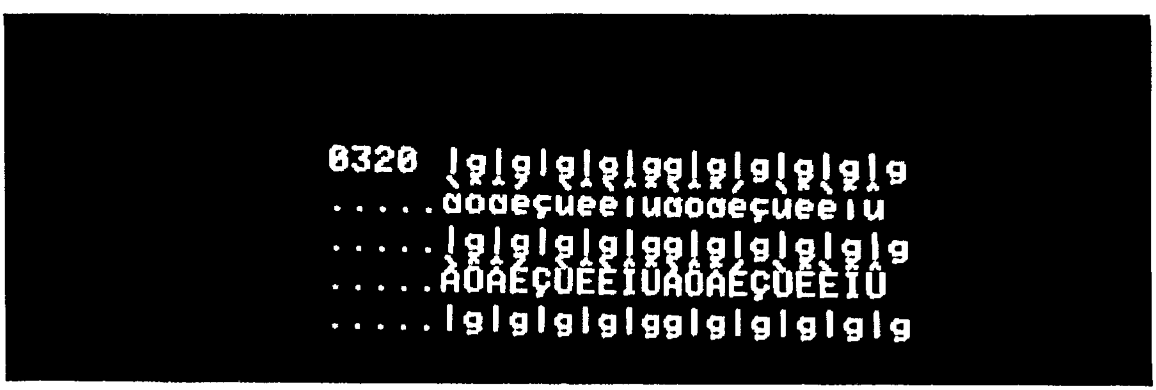
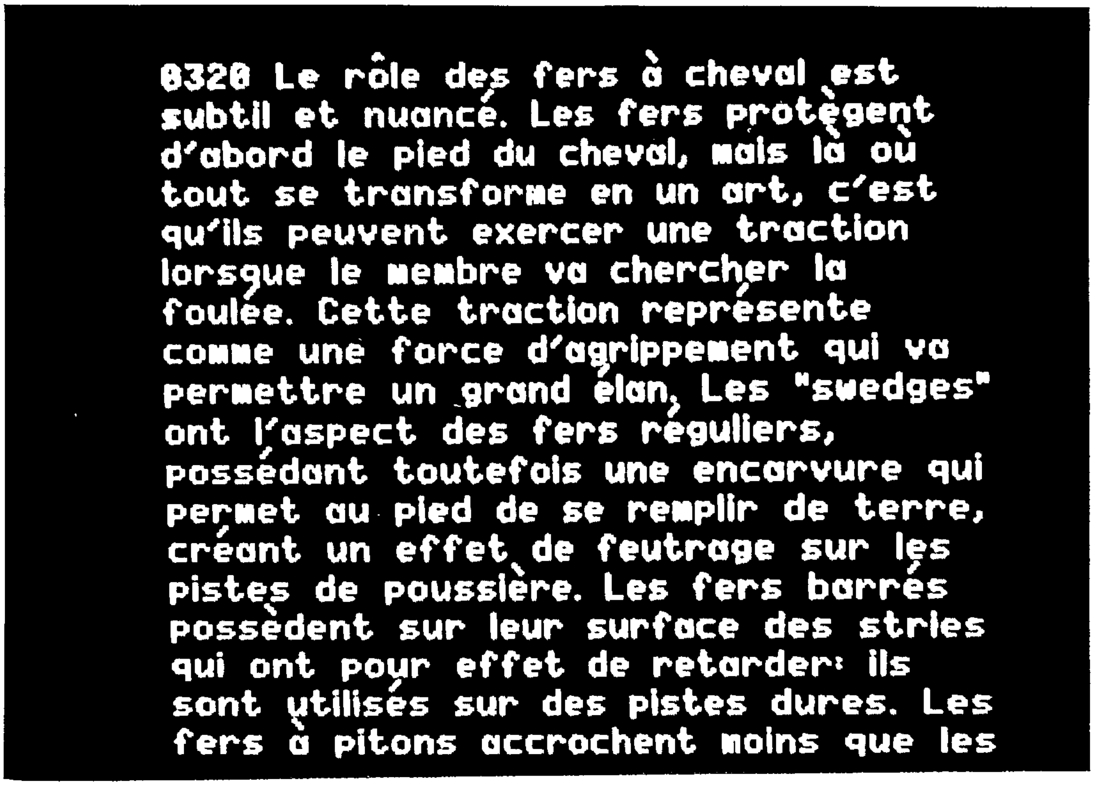
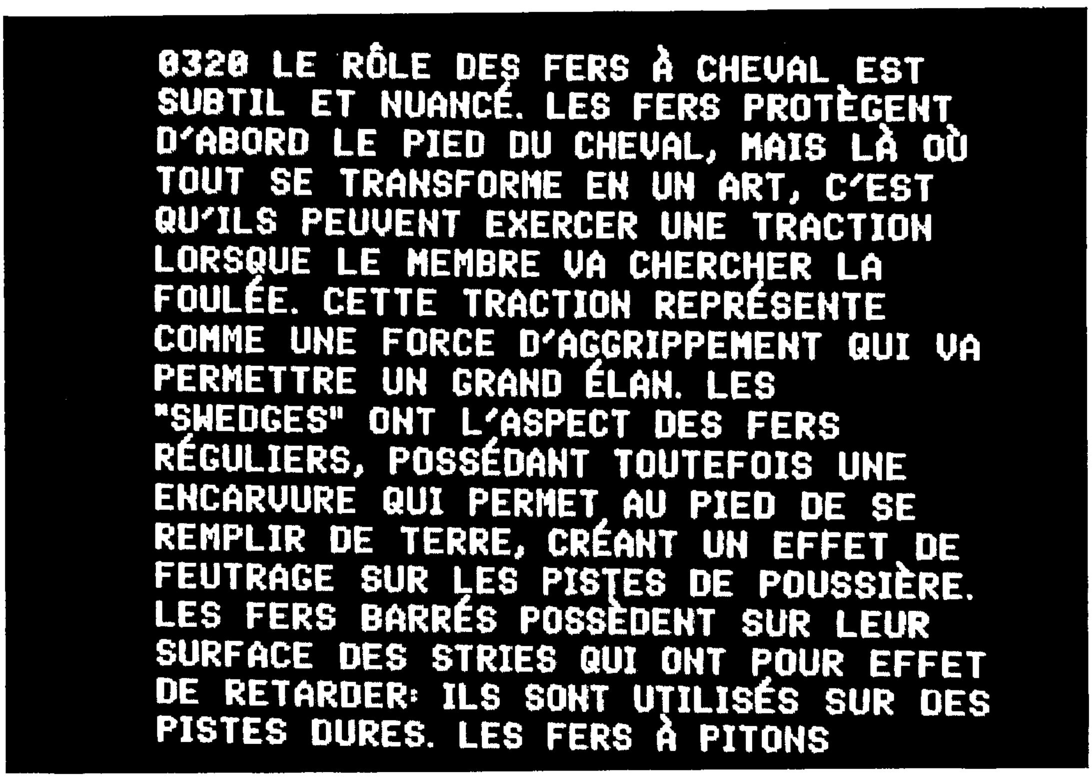


Figure 3(a). Accent Placements of Method 3 Shown in Relation to Ascending and Descending Letters



0320 Le rôle des fers à cheval est
subtil et nuancé. Les fers protègent
d'abord le pied du cheval, mais là où
tout se transforme en un art, c'est
qu'ils peuvent exercer une traction
lorsque le membre va chercher la
foulée. Cette traction représente
comme une force d'agrippement qui va
permettre un grand élan. Les "swedges"
ont l'aspect des fers réguliers,
possédant toutefois une encarvure qui
permet au pied de se remplir de terre,
créant un effet de feutrage sur les
pistes de poussière. Les fers barrés
possèdent sur leur surface des stries
qui ont pour effet de retarder: ils
sont utilisés sur des pistes dures. Les
fers à pitons accrochent moins que les

Figure 3(b). Accent Placements of Method 3 Shown in the Context of Lower Case Text



0320 LE RÔLE DES FERS À CHEVAL EST
SUBTIL ET NUANCÉ. LES FERS PROTÈGENT
D'ABORD LE PIED DU CHEVAL, MAIS LÀ OÙ
TOUT SE TRANSFORME EN UN ART, C'EST
QU'ILS PEUVENT EXERCER UNE TRACTION
LORSQUE LE MEMBRE VA CHERCHER LA
FOULÉE. CETTE TRACTION REPRÉSENTE
COMME UNE FORCE D'AGGRIPPEMENT QUI VA
PERMETTRE UN GRAND ÉLAN. LES
"SWEDGES" ONT L'ASPECT DES FERS
RÉGULIERS, POSSÉDANT TOUTEFOIS UNE
ENCARVURE QUI PERMET AU PIED DE SE
REMPLIR DE TERRE, CRÉANT UN EFFET DE
FEUTRAGE SUR LES PISTES DE POUSSIÈRE.
LES FERS BARRÉS POSSÈDENT SUR LEUR
SURFACE DES STRIES QUI ONT POUR EFFET
DE RETARDER: ILS SONT UTILISÉS SUR DES
PISTES DURES. LES FERS À PITONS

Figure 3(c). Accent Placements of Method 3 Shown in the Context of Upper Case Text

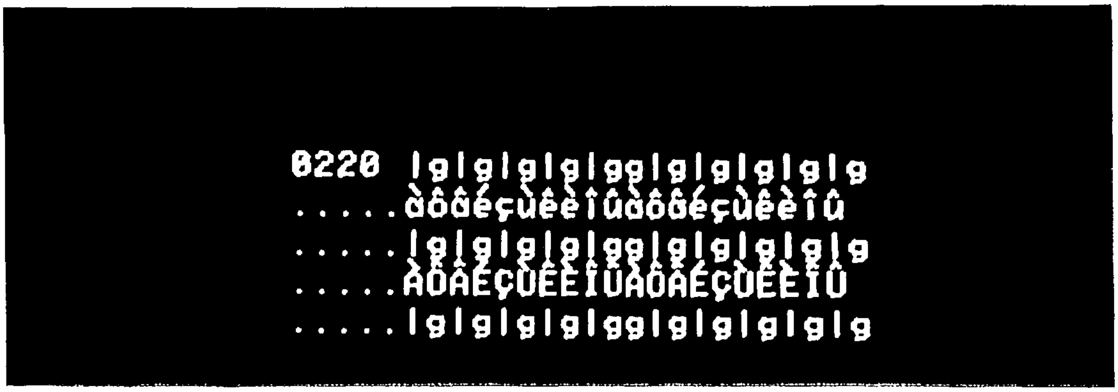


Figure 4(a). Accent Placements of Method 4 Shown in Relation to Ascending and Descending Letters

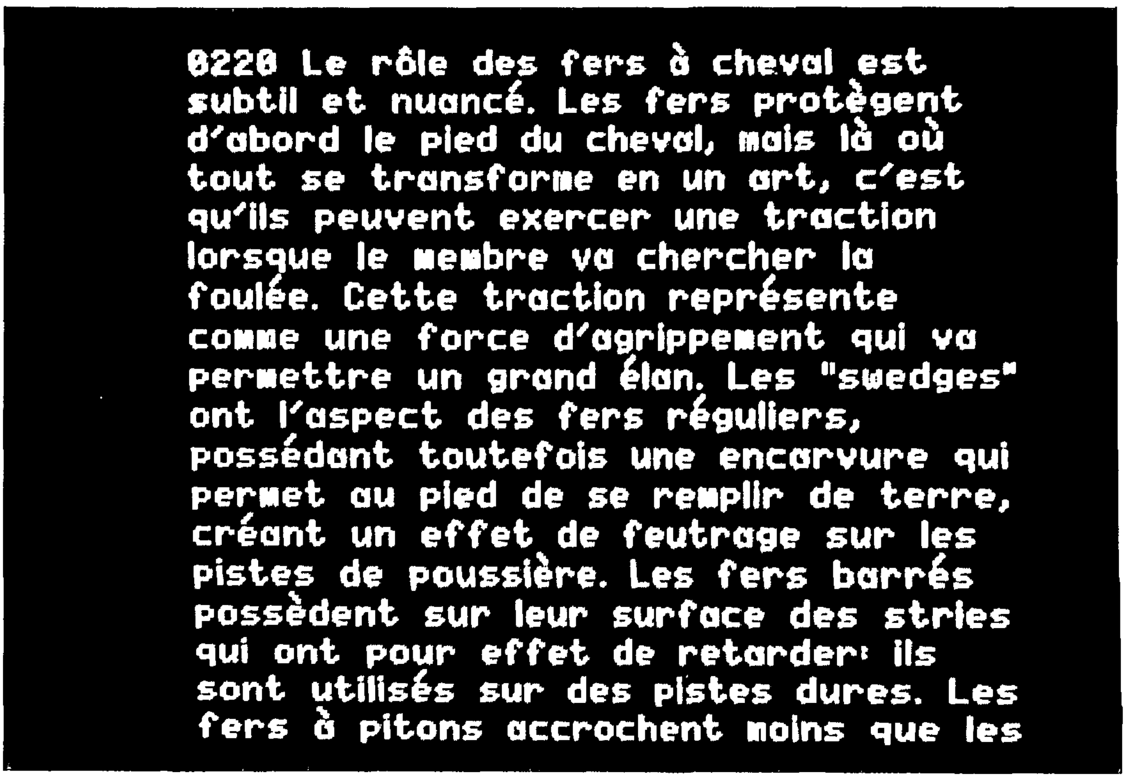
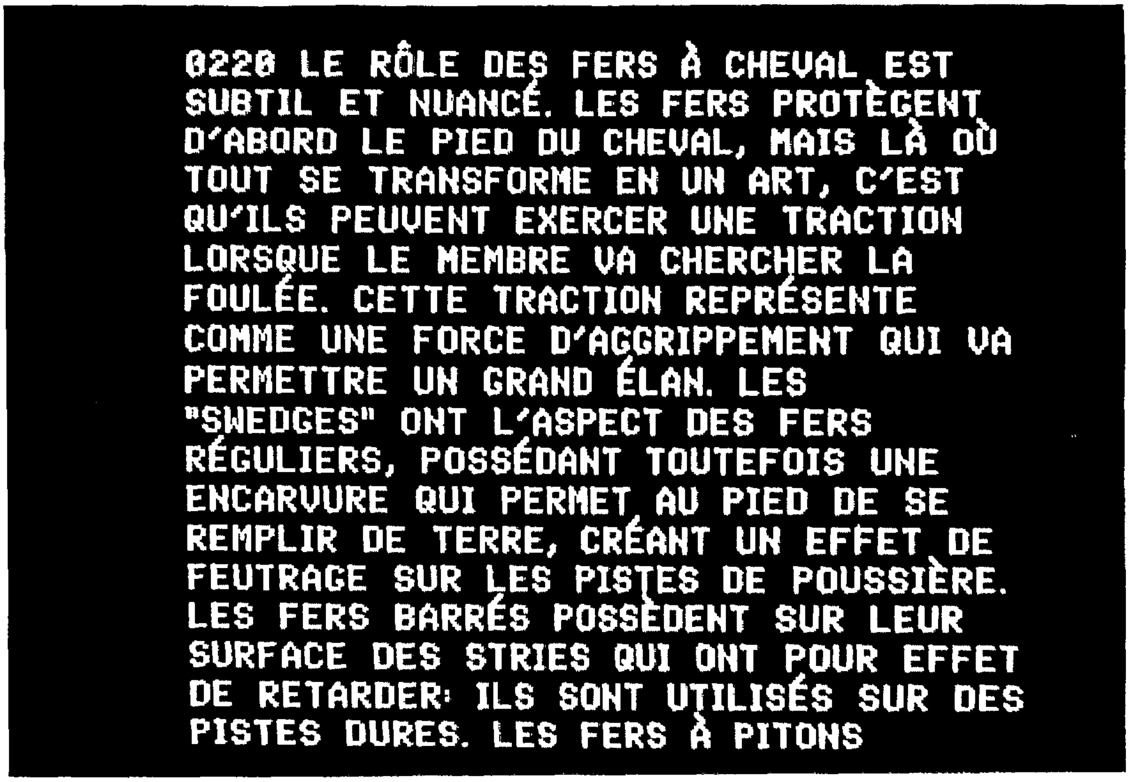
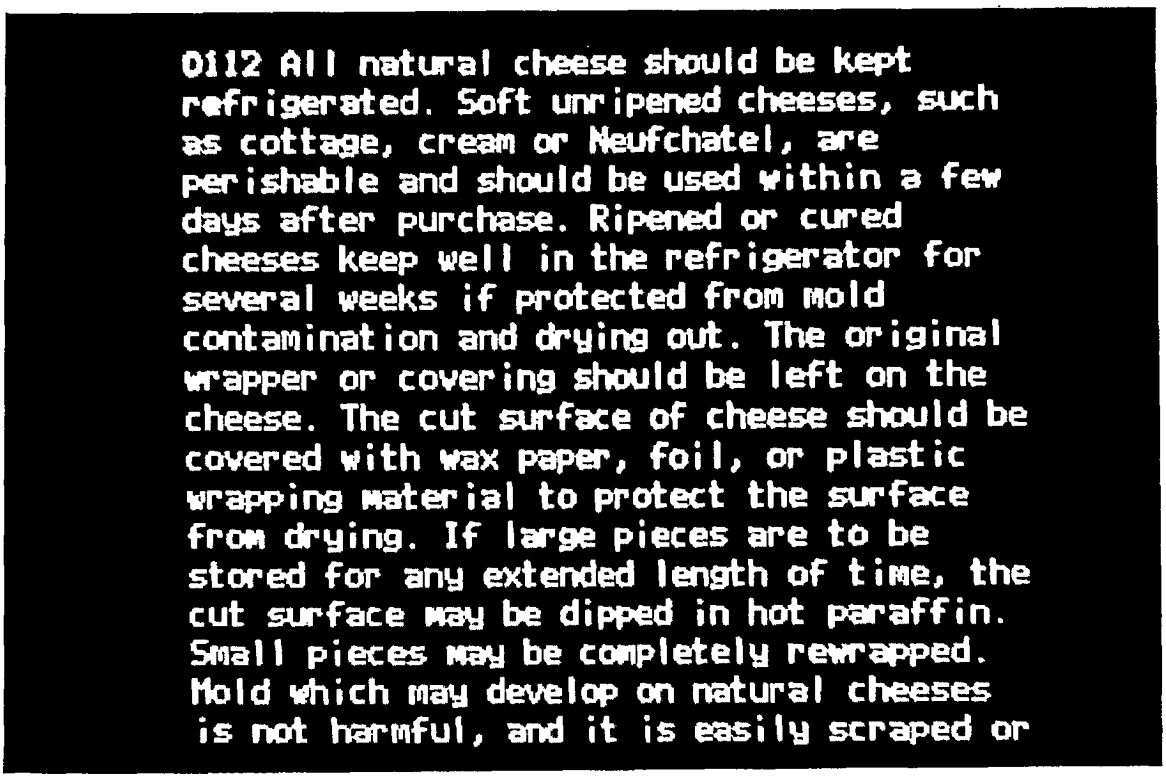


Figure 4(b). Accent Placements of Method 4 Shown in the Context of Lower Case Text



0220 LE RÔLE DES FERS À CHEVAL EST
SUBTIL ET NUANCÉ. LES FERS PROTÈGENT
D'ABORD LE PIED DU CHEVAL, MAIS LÀ OÙ
TOUT SE TRANSFORME EN UN ART, C'EST
QU'ILS PEUVENT EXERCER UNE TRACTION
LORSQUE LE MEMBRE VA CHERCHER LA
FOULÉE. CETTE TRACTION REPRÉSENTE
COMME UNE FORCE D'AGGRIPPEMENT QUI VA
PERMETTRE UN GRAND ÉLAN. LES
"SWEDGES" ONT L'ASPECT DES FERS
RÉGULIERS, POSSÉDANT TOUTEFOIS UNE
ENCARVURE QUI PERMET AU PIED DE SE
REMPLIR DE TERRE, CRÉANT UN EFFET DE
FEUTRAGE SUR LES PISTES DE POUSSIÈRE.
LES FERS BARRÉS POSSÈDENT SUR LEUR
SURFACE DES STRIES QUI ONT POUR EFFET
DE RETARDER: ILS SONT UTILISÉS SUR DES
PISTES DURES. LES FERS À PITONS

Figure 4(c). Accent Placements of Method 4 Shown in the Context of Upper Case Text



0112 All natural cheese should be kept
refrigerated. Soft unripened cheeses, such
as cottage, cream or Neufchatel, are
perishable and should be used within a few
days after purchase. Ripened or cured
cheeses keep well in the refrigerator for
several weeks if protected from mold
contamination and drying out. The original
wrapper or covering should be left on the
cheese. The cut surface of cheese should be
covered with wax paper, foil, or plastic
wrapping material to protect the surface
from drying. If large pieces are to be
stored for any extended length of time, the
cut surface may be dipped in hot paraffin.
Small pieces may be completely rewrapped.
Mold which may develop on natural cheeses
is not harmful, and it is easily scraped or

Figure 5. Examples of Text With No Proportional Spacing Between Letters (Page 1 of 2)

Part (a) of Figures 1, 2, 3, and 4 includes the most common accented letters of the French alphabet as they would appear with each placement. Parts (b) and (c) of each figure show the appearance of each placement in the context of lower and upper case text, respectively. Figure 2(c) does not exist because that placement variation does not permit accents on upper case letters.

Photographs corresponding to Part (b) of each figure were shown to 20 French-speaking individuals. Each person was asked to rank the accent placements in the four photographs in order of preference. Statistical analysis of the rankings showed that significant differences existed. Further, pairwise comparisons indicated that each of the six possible comparisons were significantly different at the ninety-five percent level of confidence. The accent placements were ranked in the following decreasing order of preference: Figure 4, Figure 3, Figure 1, and Figure 2.

The relatively poor acceptability of the accent placements shown in Figure 1 indicates that upper and lower case letters should not be reduced in size in order to make room for accents. A much better solution, as shown by the responses to Figures 3 and 4, is to place accents in the interrow space. The most acceptable solution is shown in Figure 4 where accents on lower case letters are lower than accents on upper case letters. Therefore, to draw accents using a character matrix of this size, the interrow space should be at least two pixels if only lower case letters are to be accented, and at least three pixels if upper case letters are to be accented as well.

2.2.2 Proportional Spacing of Letters

When letter matrices are placed adjacent to one another to form text, the effect is uneven spacing between letters. This occurs because some characters occupy fewer columns of the matrix than do other characters. For example, the letter "m" may occupy five columns of the matrix, while the letter "i" only occupies one column. The apparent inequality of letter spacing can be eliminated by removing matrix columns that are not used to define the character. This action results in what is known as proportional spacing between characters.

Proportional spacing is used regularly by typographers to enhance readability of a page of text. Text that is not proportionally spaced is regarded with disdain by typographers and graphic artists (Hewson, 1979; Wrolstad, 1979; Bronsard, 1980). As well as exhibiting uneven spacing between letters, such text is also typically marred by vertical rivers of background colour that tend to interfere with horizontal scanning of eye movements during reading (Figure 5). Because proportional spacing is typically used in the print medium to improve reading performance, not doing so in the new video medium would be experienced by users as a retrograde step. Figure 6 shows how the appearance of the text in Figure 5 is enhanced by proportional spacing. It is safe to say without further formal experimentation that this aspect of the typographer's experience should be generalized to the display of text on videotex.

2.2.3 Width of the Space Character

When proportional spacing is employed, the space between words appears excessive when the space is the full width of the character matrix plus the space separating characters. Again, a preference measure was considered appropriate for deciding what the width of the space character should be. Photographs were made of text with different spacings between words. The size of the space varied in one pixel steps from four to seven pixels for the smaller 5 x 8 character set, and from four to nine pixels for the larger 7 x 11 character set. The space between letters within a word was fixed at two pixels.

0511 All natural cheese should
be kept refrigerated. Soft
unripened cheeses, such as
cottage, cream or Neufchatel,
are perishable and should be
used within a few days after
purchase. Ripened or cured
cheeses keep well in the
refrigerator for several weeks
if protected from mold
contamination and drying out.
The original wrapper or covering
should be left on the cheese.
The cut surface of cheese should
be covered with wax paper, foil,
or plastic wrapping material to

Figure 5. Examples of Text With No Proportional Spacing Between Letters (Page 2 of 2)

0122 All natural cheese should be kept
refrigerated. Soft unripened cheeses, such
as cottage, cream or Neufchatel, are
perishable and should be used within a few
days after purchase. Ripened or cured
cheeses keep well in the refrigerator for
several weeks if protected from mold
contamination and drying out. The original
wrapper or covering should be left on the
cheese. The cut surface of cheese should
be covered with wax paper, foil, or plastic
wrapping material to protect the surface
from drying. If large pieces are to be
stored for any extended length of time,
the cut surface may be dipped in hot
paraffin. Small pieces may be completely
rewrapped. Mold which may develop on
natural cheeses is not harmful, and it is

Figure 6. Examples of Text With Proportional Spacing Between Letters (Page 1 of 2)

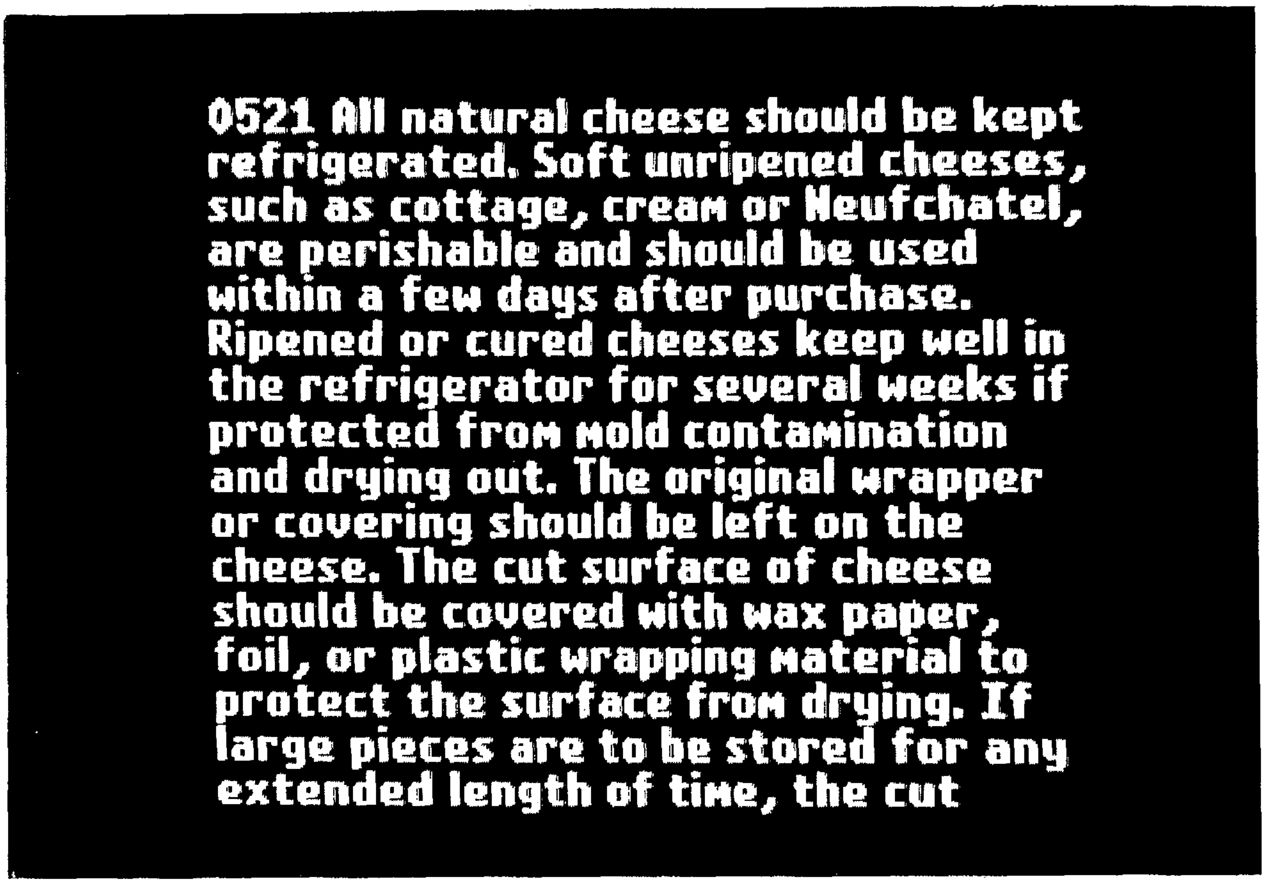


Figure 6. Examples of Text With Proportional Spacing Between Letters (Page 2 of 2)

Ten people were asked to choose the most preferred spacing from the photographs of each character set. Table 1 summarizes the results of their choices.

TABLE 1

Preferred Number of Pixels Between Words

	Character Set	
	5 x 8	**7 x 11**
Mean	6.15	6.25
Median	6	6
Mode	6,7	6
Range	5–7	6–7

These data strongly suggest that the width of the space character should be six pixels for both character sets. This width is demonstrated in Figure 6.

2.2.4 Space Between Letters and Between Lines

Performances measures in the experiments described above showed the minimum horizontal and vertical spacing for producing the best possible legibility of individual letters. It can be argued, however, that the legibility of individual letters does not predict the readability of text composed of such letters. There is considerable evidence that the speed at which letters are recognized is increased when they are placed in the context of words (e.g., Adams, 1979; Mason, 1978). This phenomenon, called the word superiority effect, leads to the prediction that good readability of text can be obtained with smaller spacings than those suggested by the legibility experiments which employed strings of random letters.

Legibility is easily measured in terms of the speed or accuracy with which symbols are identified. It is more difficult to state an operational definition of readability. Readability appears to be a quality of text that is influenced by legibility of letters as well as other less easily quantifiable characteristics such as syntax, vocabulary, page layout, and other more elusive aspects of writing style. Speed of reading has been used in the past as a measure of readability (e.g., Tinker, 1965). However, the experiments reported above using that test were too insensitive to differentiate between upper and lower case text if such a difference existed. A different and possibly more successful approach for specifying the value of some page characteristics is to determine the reader's preference. Some evidence exists that readability measured by speed of reading is correlated with subjective dimensions such as "pleasingness" and judged legibility of the page (Tinker, 1965, p. 120). Therefore, it seems plausible to accept the reader's preference as an operational definition of readability. If the reader is permitted some control over the dimension in question, his most frequent selection may be taken as an indication of his preference.

In the following experiment, pages of text were displayed to the readers using one or the other of the two character sets employed in the search experiments. Additionally, another version of the larger character set was created so that all vertical strokes were two pixels wide instead of one. The extra width compensates somewhat for the effect of limited bandwidth when text is displayed via an NTSC composite video signal (see Section 2.3). Text was presented in white on an RGB display, and the background was not illuminated. Letters were proportionally spaced, and the space between words was four pixels more than the space between letters within a word.

Ten subjects read English text and five read French text displayed using the 5 x 8 character set (CHSET 1). Ten subjects read English text displayed using the 7 x 11 character set with vertical strokes one pixel wide (CHSET 2). Finally, five subjects read English text and five read French text displayed using the 7 x 11 character set with vertical strokes two pixels wide (CHSET 3). The language of the text as well as the reading distance was chosen by each subject. The selected reading distances ranged between approximately three and five feet.

After each page was read, the reader pressed the RETURN key on a keyboard attached to the graphics processor driving the display. Immediately, an "H" and a "V" appeared in the left margin of the text. Pressing keys of the cursor cluster adjusted the horizontal and vertical spacing variables for display of the next page, and the deviations from the current settings were displayed adjacent to the H and V in the margin. Arrows of the cursor cluster pointing upward and to the right increased the vertical and horizontal spacings, respectively, while arrows pointing in the opposite directions decreased the spacings. For example, pressing the arrow pointing to the right two times resulted in the appearance of a two beside the H. Pressing the arrow pointing down once resulted in appearance of a −1 beside the V. Pressing RETURN once more cleared the screen and began display of the next page of text with the adjusted spacings.

The first page of the session was begun with a spacing of one pixel or five pixels both horizontally and vertically. When two consecutive pages were read without a requested adjustment of the spacings, it was assumed that the reader was satisfied with the current setting. The spacings for the next page were automatically set to either five pixels or one pixel. The value was chosen to alternate from the previous value chosen by the system. In this way, a number of preferred settings were obtained from each reader. The number of such settings obtained varied considerably among subjects. It appeared that some readers recognized their preferred settings quickly while others needed to experiment with more pages.

The mean of the last four preferred settings of the session was taken to represent each person's preferred horizontal and vertical spacing. Table 2 shows the average preference for each character set and language, as well as the range of preferences within each group.

TABLE 2

Preferred Spacings in Pixels for Each Character Set and Language

		HORIZONTAL		VERTICAL	
	N	MEAN	RANGE	MEAN	RANGE
CHSET 1					
FRENCH	5	3.8	1.5–4.5	4.8	2.8–6.5
ENGLISH	10	3.3	1.8–5.0	4.3	2.3–9.5
TOTAL	15	3.5	1.5–5.0	4.5	2.3–9.5
CHSET 2					
ENGLISH	10	3.5	1.8–5.0	4.5	1.8–7.0
CHSET 3					
FRENCH	5	2.7	1.8–5.0	4.4	3.3–6.3
ENGLISH	5	2.7	1.8–5.0	5.8	4.3–8.5
TOTAL	10	2.7	1.8–5.0	5.1	3.3–8.5

CHSET 1 and CHSET 2 were compared for the English groups using a multivariate analysis of variance on the preferred horizontal and vertical spacings. The results showed no significant differences between the character sets. A similar analysis compared CHSET 2 and CHSET 3 using all ten subjects within each group. Again, the analysis showed no differences between these character sets. There is, therefore, no evidence from this experiment that the preferred spacings between characters were affected by either the size of the character set matrix or the vertical stroke width. However, it is clear from the ranges indicated in Table 1 that there were large individual differences among subjects within each of the categories. This source of variability could easily have overshadowed any differences that might have been obtained by a more sensitive experiment. Further work of this type should consider the use of a within-subject design to measure the effect of important independent variables. There appeared to be consistency within each session with regard to a person's selected spacings.

It is interesting to compare the results of this experiment with those obtained in the legibility experiments described in Section 2.1.1. The mean preferred horizontal and vertical spacings for CHSET 1 of 3.5 and 4.5 pixels are somewhat more than the minimum spacings of 2 and 3 pixels, respectively, recommended on the basis of the legibility experiment. The mean preferred vertical spacing for CHSET 2 was 4.5 pixels while the legibility experiment found no change as vertical spacing was varied from one pixel to three pixels. The mean preferred horizontal spacing for CHSET 2 of 3.5 pixels is the only value that is consistent with the results of the legibility experiment which recommended a minimum horizontal spacing of three pixels. It is also true, however, that the results of the legibility experiments fall within the ranges of preferred spacings. In that sense, there is some consistency between these two kinds of experiments.

The recommendations for horizontal and vertical spacings arose from the legibility experiments by considering both rate and accuracy of character processing with various spacings. Apparently, the preferred spacings found in this experiment were not determined by these considerations alone. Instead of being smaller as predicted on the basis of the word superiority effect, the preferred spacings were generally larger. Perhaps the search experiments place lower limits on character spacings, and larger spacings should be used if possible to improve the display acceptability on other grounds.

Further work is needed to understand the reason for the large variability between subjects found in this experiment. Viewing distance should be imposed, and eye acuity could be measured. The space between words could be varied independently of the space between letters. It is not at all clear why some people would choose spacings between letters that approximate the character widths themselves. In fact, Mewhort (1966) has shown that such wide spacings interfere with the recall of word-like letter strings, presumably because of reduced ability to make use of redundancy present in such strings. A similar, detrimental effect on reading would be expected for the same reason.

2.3 RED-GREEN-BLUE (RGB) VERSUS NTSC COMPOSITE VIDEO

Television was not originally developed to display textual material. There are several theoretical reasons to expect the display of text in black-and-white and in colour to be less than adequate. One shortcoming is the limited bandwidth of 4.2 MHz. This bandwidth limits the rate of change of the luminance signal so that a vertical stroke of a character must exceed a certain minimum width in order to reach full intensity. If one pixel is less than this minimum width, the luminance of a vertical line one pixel wide should be less than the luminance of a vertical line two or more pixels wide. This effect should cause letters made up of strokes one pixel wide to have unequally illuminated horizontal and vertical components. Further, spaces one pixel wide between two vertical strokes should be smeared so that the strokes are not easily discriminable. In fact, these effects are observed as can be seen in the photograph of Figure 7. Twenty lines of 40 characters/line are presented in black-and-white on an Electrohome colour television. Input is baseband video, so any additional degradation that might arise from modulation and demodulation of the video carrier is not present.

Another problem arises when text and background are displayed in colour. The colour of the displayed image is encoded in the composite video signal by varying the phase and amplitude of a 3.58 MHz colour subcarrier relative to a colour burst signal appearing at the beginning of each horizontal scan line. The colour subcarrier frequency is such that the time to scan one pixel is equivalent to about three-quarters of the period of the colour signal. This is insufficient time to detect and act upon a phase shift in the colour subcarrier

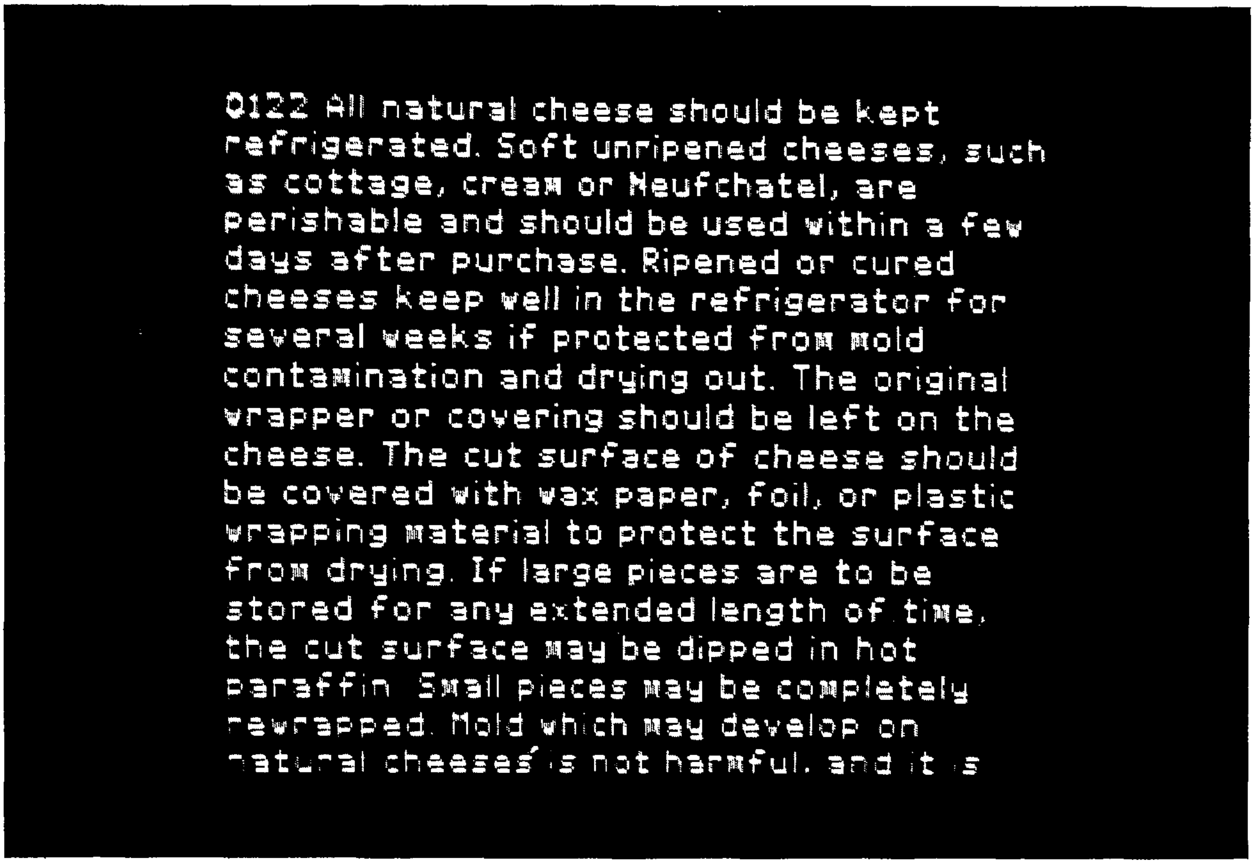


Figure 7. Smearing and Uneven Illumination of Letters When Composite Video Input is Employed

corresponding to a colour change. Thus, a vertical line one pixel wide should show very little colour as well as the reduced luminance noted above.

The frequency of the colour subcarrier is also such that the phase at any point on a horizontal scan line differs by 180 degrees from the phase at the same point on the two adjacent lines. This phase difference on adjacent lines, and the fact that a colour transition is interpreted first by the receiver as a luminance change, cause the luminance at the vertical contour separating different colours to alternate from black to white from one scan line to the next (coloured edge artifact). To make matters worse, the odd number of lines per frame causes the alternating black and white areas to appear to be moving slowly upwards. This effect is referred to as "chroma-crawl" or "dot-crawl". The severity of chroma-crawl is influenced by the magnitude of the phase shift corresponding to the colour change. Thus, some colour combinations exhibit more chroma-crawl than others.

White or black text on a coloured background or coloured text on a white or black background, is not affected as much by chroma-crawl because televisions process very high and very low luminosity signals differently from intermediate luminosity signals. That is, luminosity signals less than about 10 percent or greater than about 90 percent of the maximum possible are not processed for extraction of colour information, but rather, automatically produce saturated black or white on the television display.

As predicted, the degradation due to limited bandwidth demonstrated in Figure 7 is compounded by the addition of colour information. Figure 8 shows the additional degradation produced by the coloured edge artifact and poor colour rendition. Of course, a photograph cannot communicate the further degradation due to chroma-crawl. There is no question that displaying this character set with an NTSC composite video signal is unacceptable.

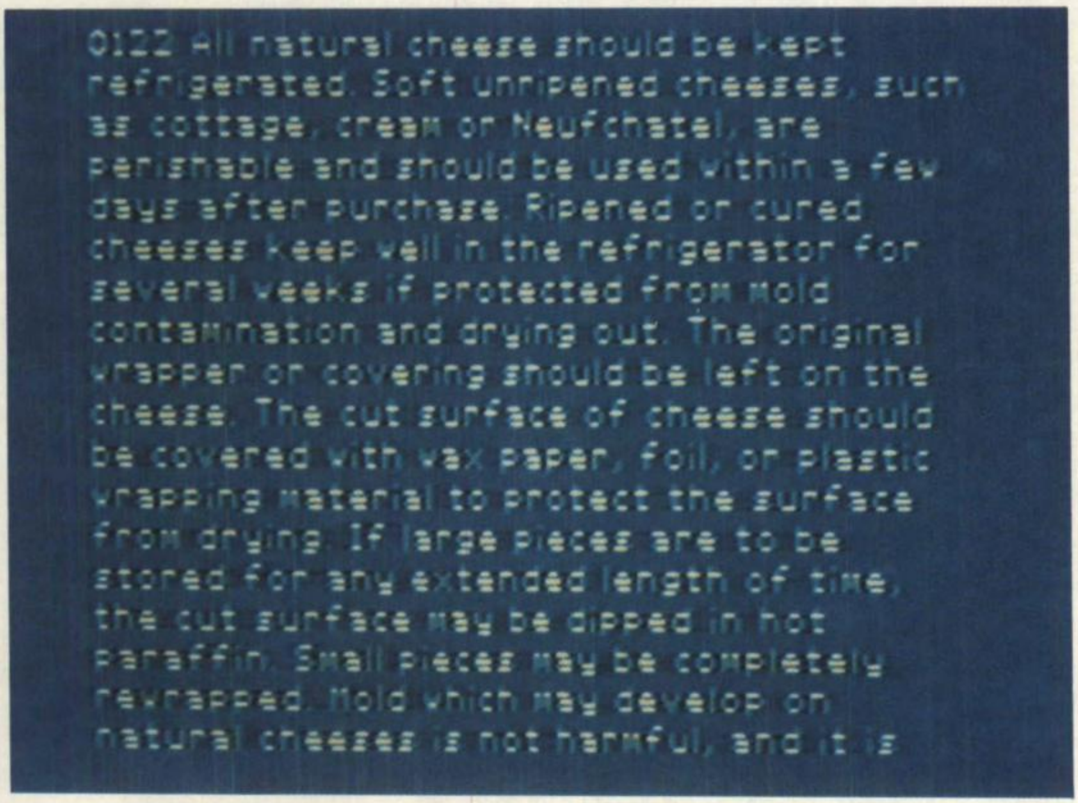


Figure 8. Smearing of Letters and Poor Colour Rendition When Composite Video is Employed

The luminance signal bandwidth limitation can be tolerated if the character set is designed to compensate for its effect. Specifically, each element of the characters, including spaces within characters, need to be made at least two pixels wide. This cannot be done on a character matrix five pixels wide, but can be done on a matrix seven pixels wide. Figure 9 shows the result when this constraint is incorporated into a character set designed on the larger matrix. The result is much less luminance variation within characters. Element doubling also improves slightly the display of coloured text, but significant display instability due to chroma-crawl still exists. Figure 10 shows characters without element doubling, and Figure 11 shows the slightly improved colour rendition due to element doubling.

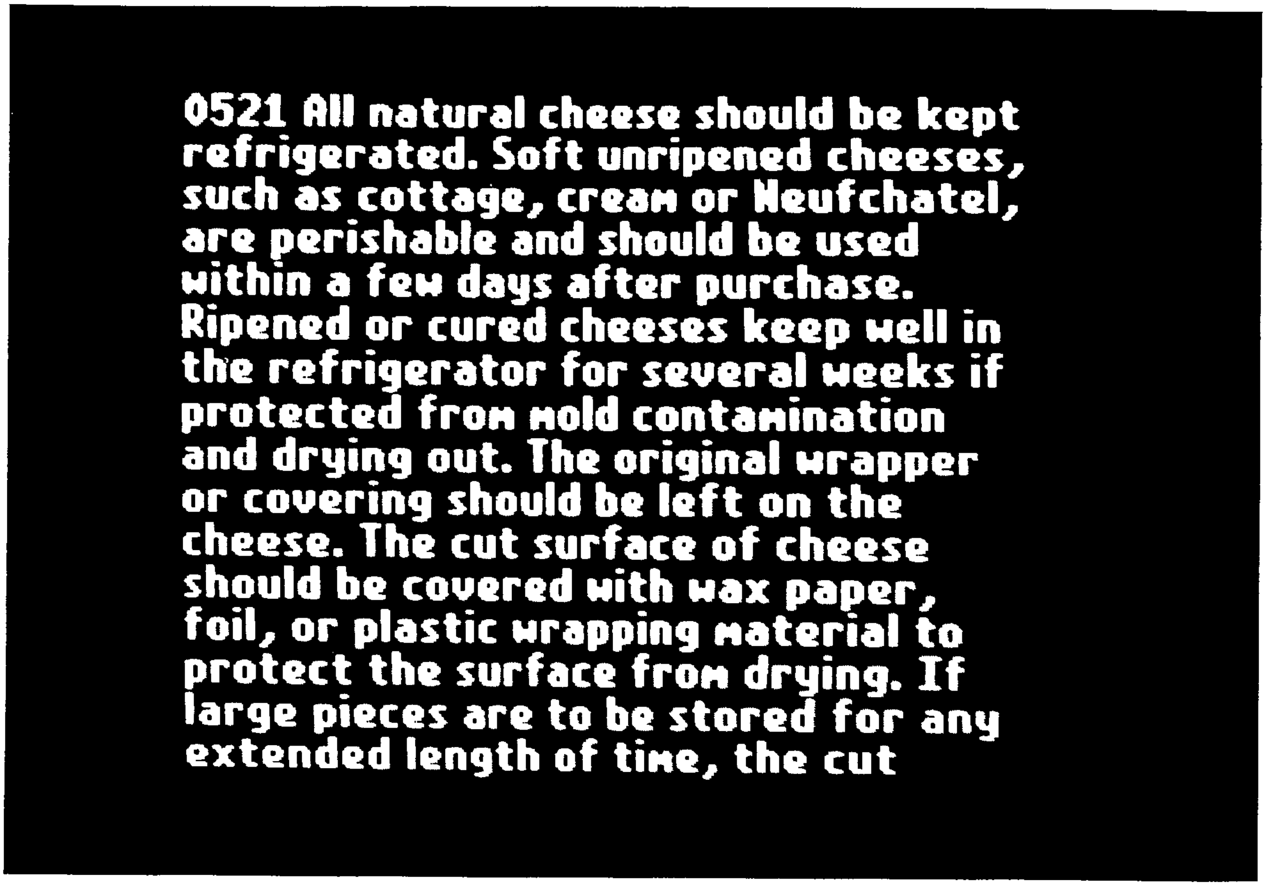


Figure 9. The Appearance of Text With Composite Video Input When Letter Strokes are at Least Two Pixels Wide

Figure 10. Uneven Luminance and Colour When Composite Video is Employed

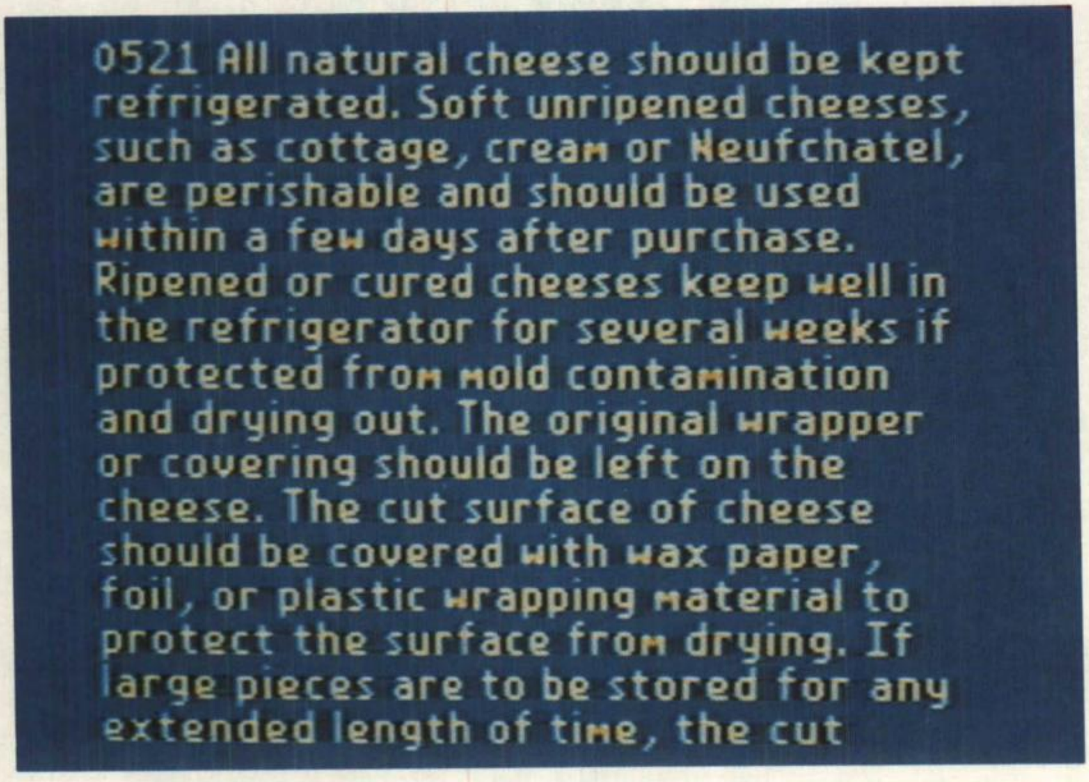


Figure 11. Improvement of Degradation Shown in Figure 10 by Doubling the Width of Vertical Letter Components

It appears that text can be displayed in black-and-white with a composite video signal if a properly designed character set is used. The use of colour combinations is not recommended. If colour combinations are used, they should be carefully selected to minimize chroma-crawl. Also, luminance and colour contrast should be maximized, especially since contrast suffers when the background colour bleeds through the colour of the text.

All of the problems arising from displaying text with a composite video signal can be avoided entirely by using an RGB video signal. An RGB signal provides independent colour information to each of the red, green and blue electron guns of the monitor. There is no need to limit the RGB signal to 4.2 MHz. The wider bandwidth permits equal stimulation of character elements one or more pixels in width. Further, the three colour signals are not combined for transmission to the receiver. There are, therefore, none of the difficulties arising from decoding the colour information. Colour rendition is always as intended, and coloured edge artifact and chroma-crawl are non-existent. Figure 12 shows the RGB presentation of the contents of Figure 7. Similarly, the RGB versions of Figures 8 and 11 are presented in Figures 13 and 14, respectively. The relative improvement of the RGB image over the composite video image is apparent.

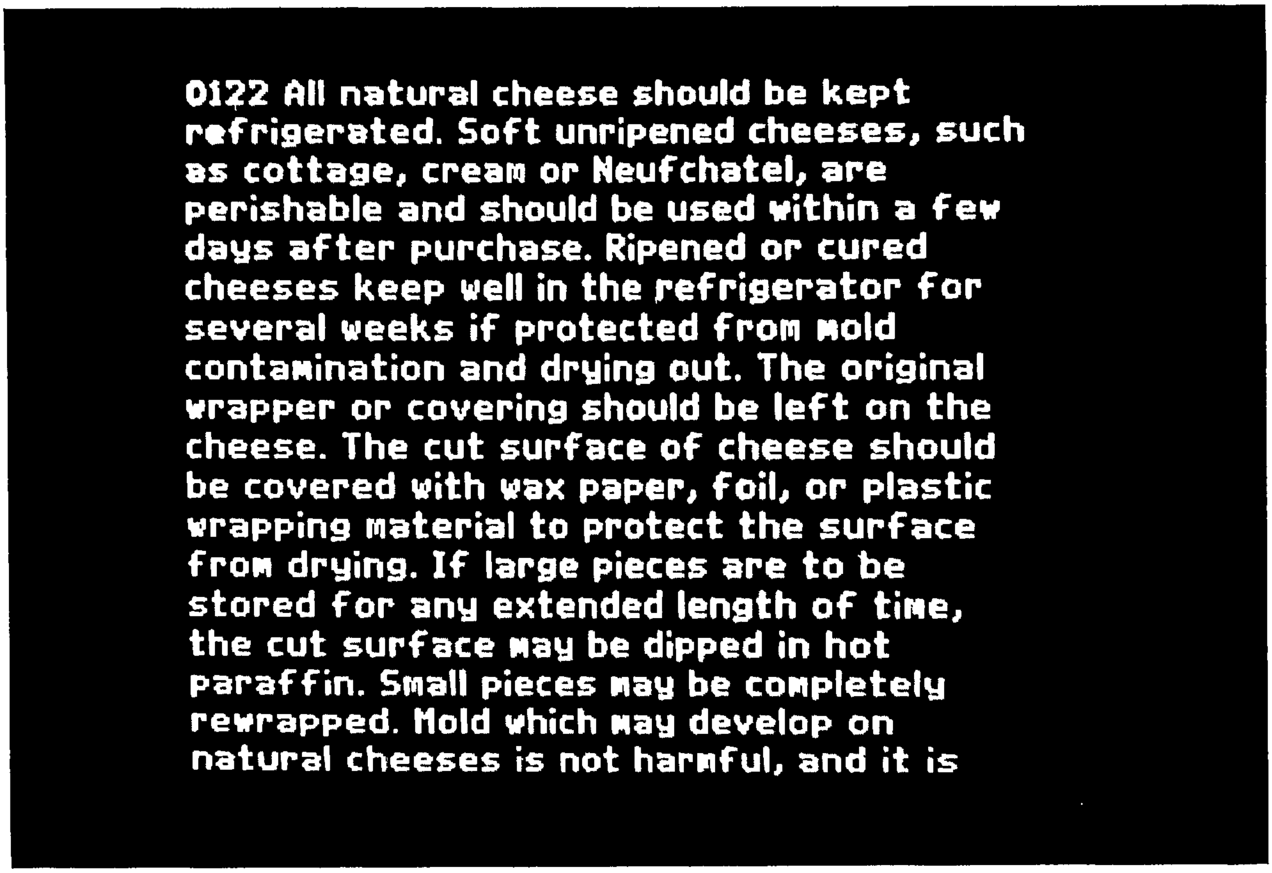

0122 All natural cheese should be kept
refrigerated. Soft unripened cheeses, such
as cottage, cream or Neufchatel, are
perishable and should be used within a few
days after purchase. Ripened or cured
cheeses keep well in the refrigerator for
several weeks if protected from mold
contamination and drying out. The original
wrapper or covering should be left on the
cheese. The cut surface of cheese should
be covered with wax paper, foil, or plastic
wrapping material to protect the surface
from drying. If large pieces are to be
stored for any extended length of time,
the cut surface may be dipped in hot
paraffin. Small pieces may be completely
rewrapped. Mold which may develop on
natural cheeses is not harmful, and it is

Figure 12. The Text of Figure 7 When RGB Video Input is Employed

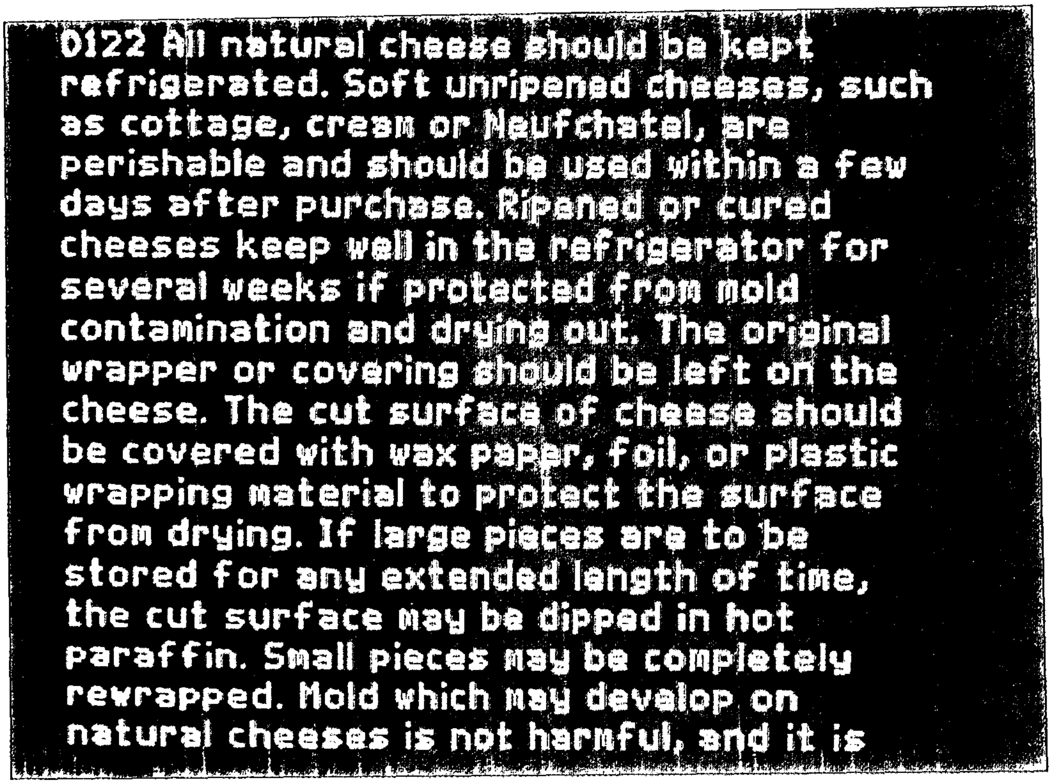


Figure 13. Improvement of Degradation Shown in Figure 8 by Using RGB Video

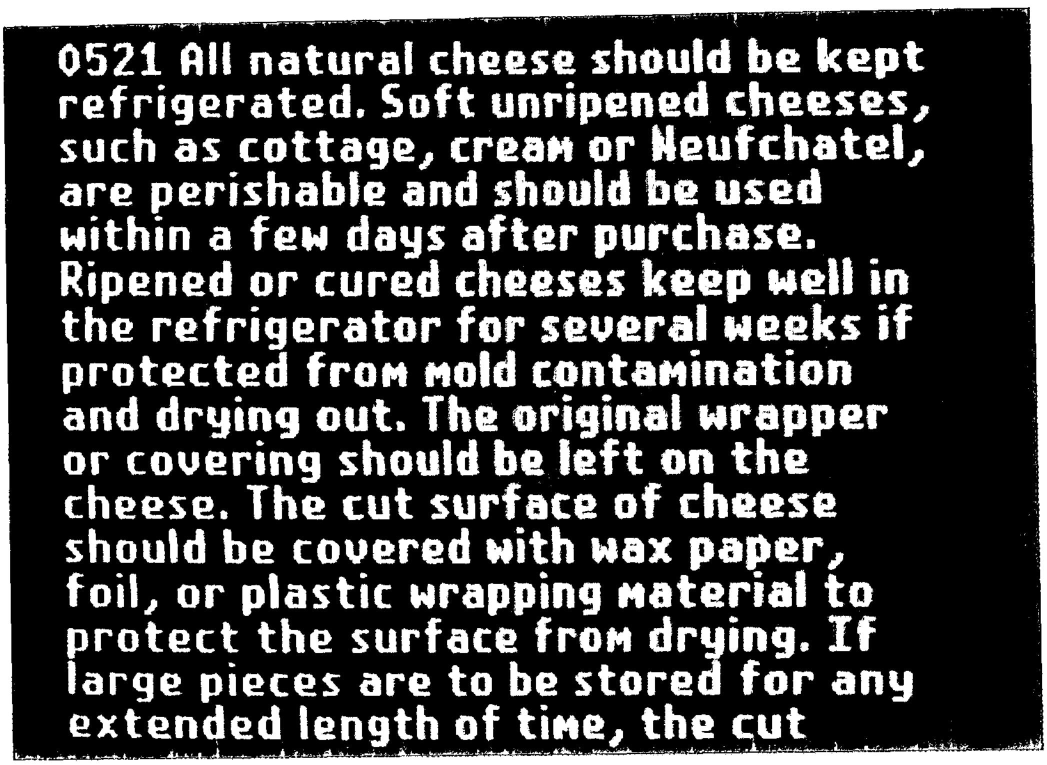


Figure 14. Improvement of Degradation Apparent in Figure 11 by Using RGB Video

Although the above discussion has dealt only with the presentation of alphanumeric information, the same observations and conclusions apply to the presentation of other graphical entities. Figures 15 and 16 demonstrate the difference in the appearance of simple graphics when the signals are RGB or composite video, respectively. Again, it is apparent that the coloured RGB image is much superior to the corresponding composite video image.

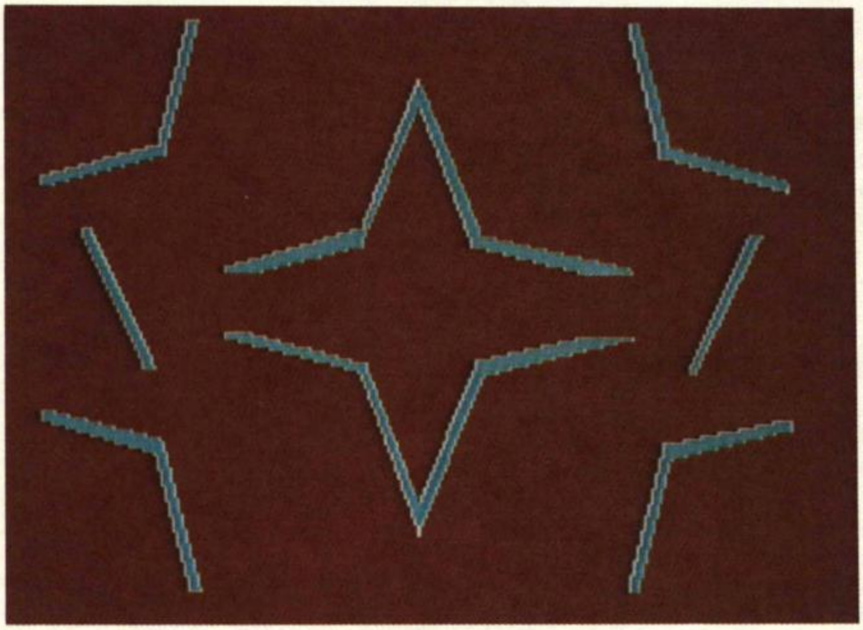


Figure 15. Appearance of Simple Graphics When RGB Video is Used

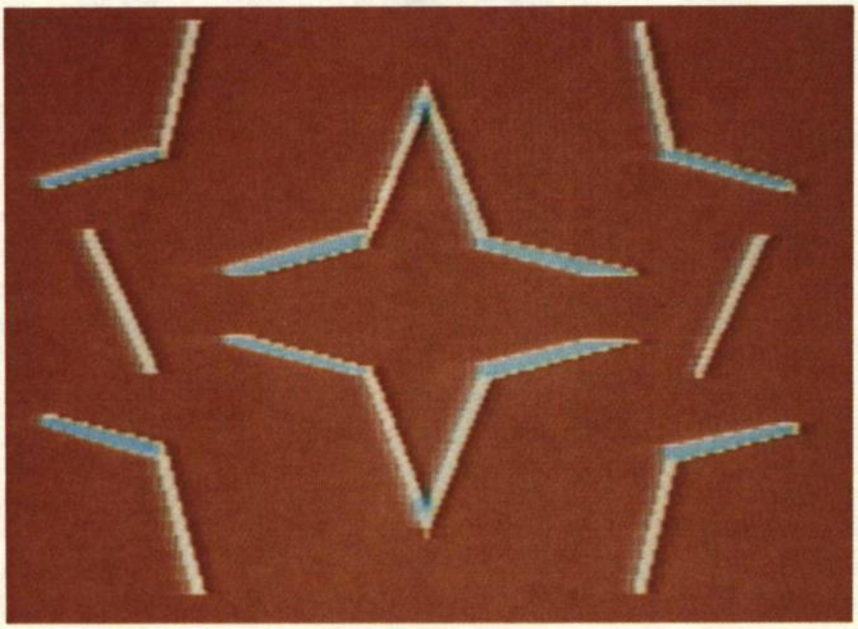


Figure 16. Degradation of Graphics Shown in Figure 15 When Composite Video is Used

3. CHARACTER SET DESIGN

Comments from typographers and graphic artists who were shown slides of Telidon images, were quite critical of the readability of text composed of the then current character sets shown in Figures 17 and 18 (Baudin, 1979; Wrolstad, 1979). Dissatisfaction with the character sets was also expressed by at least one information provider representative (Lane, 1980).

In response to these comments, a professional typographer (H.P. Bronsard) was contracted to design one character set on a 5 x 8 matrix and another set on a 7 x 11 matrix. The characters were optimized on an Electrohome Model C40-852 television receiver. The improved character sets are presented in Figures 19 and 20. Samples of text using these character sets were presented in earlier figures such as Figures 12 and 13. The reader may judge the improved readability by comparison with the original character sets in Figures 17 and 18, respectively. Comments regarding readability of the new character sets from people associated with the publishing industry have been favourable. The new character sets of Figures 19 and 20 have been made available to manufacturers for inclusion in their terminal designs.

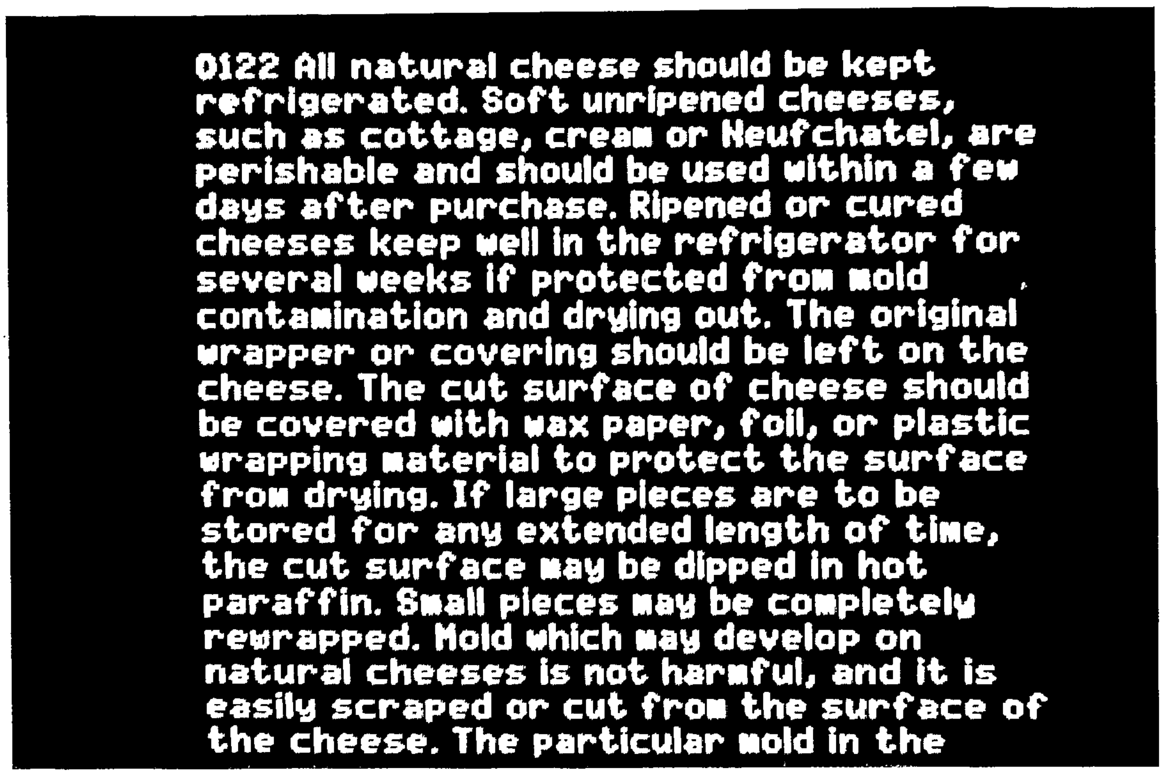


Figure 17. Text Considered by Experts to have Impaired Readability Because of Poor Character Set Design

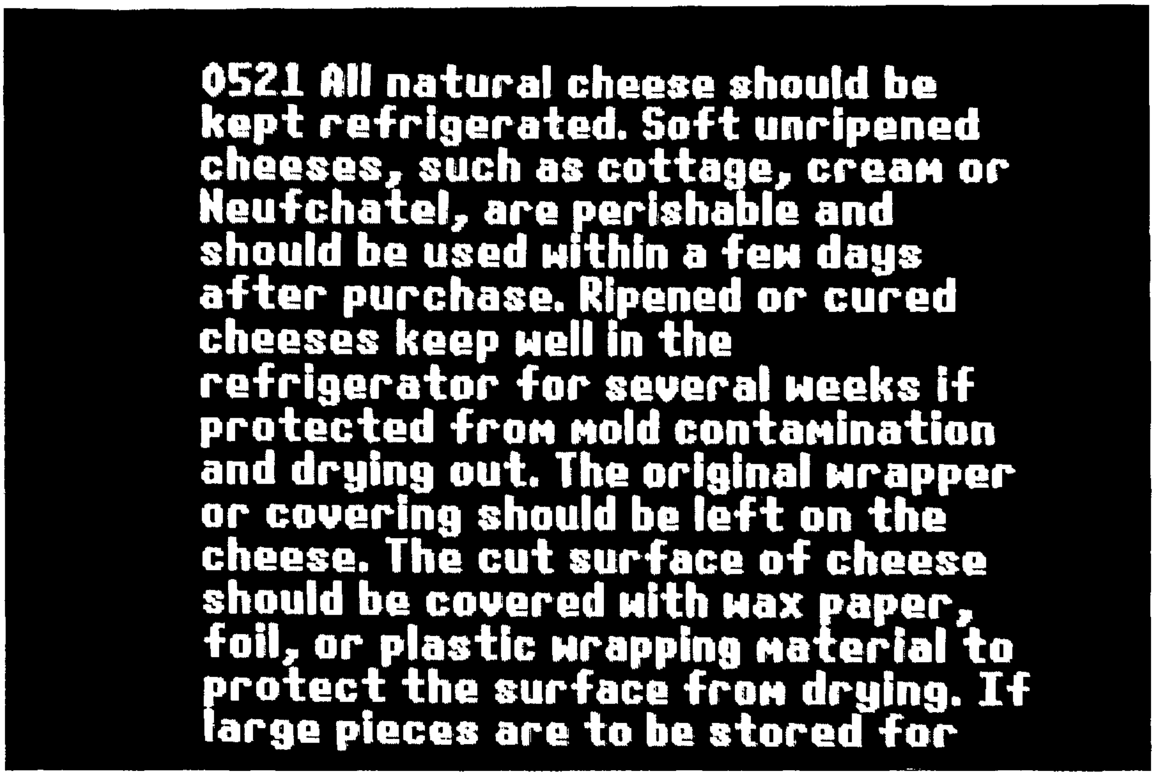


Figure 18. Text Considered by Experts to have Impaired Readability Because of Poor Character Set Design

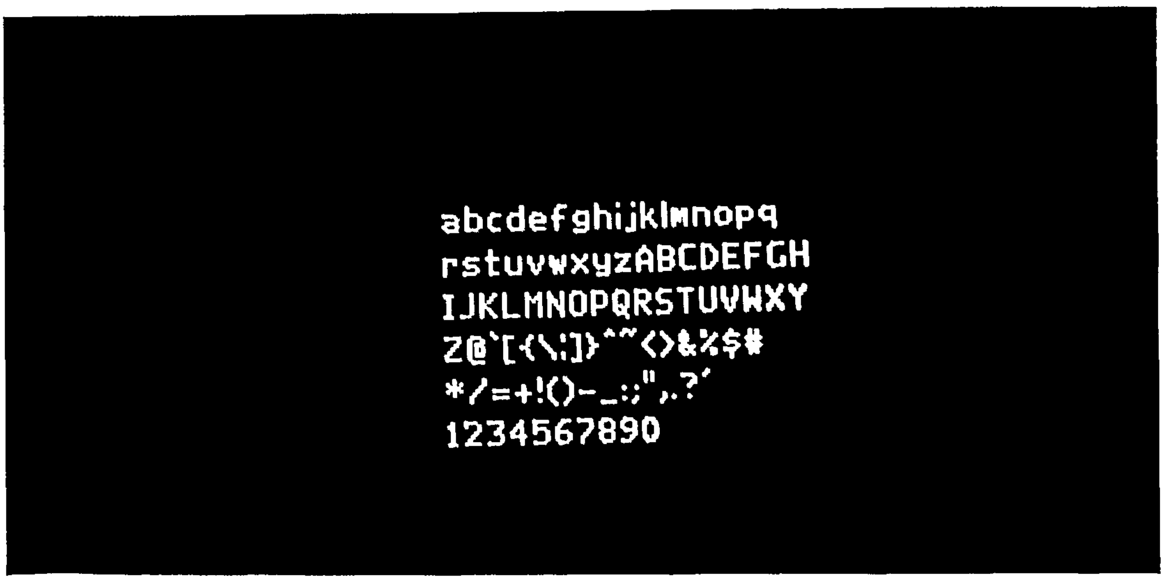


Figure 19. Character Set 3 of the Telidon Specifications (Bronsard 3 Character Style)

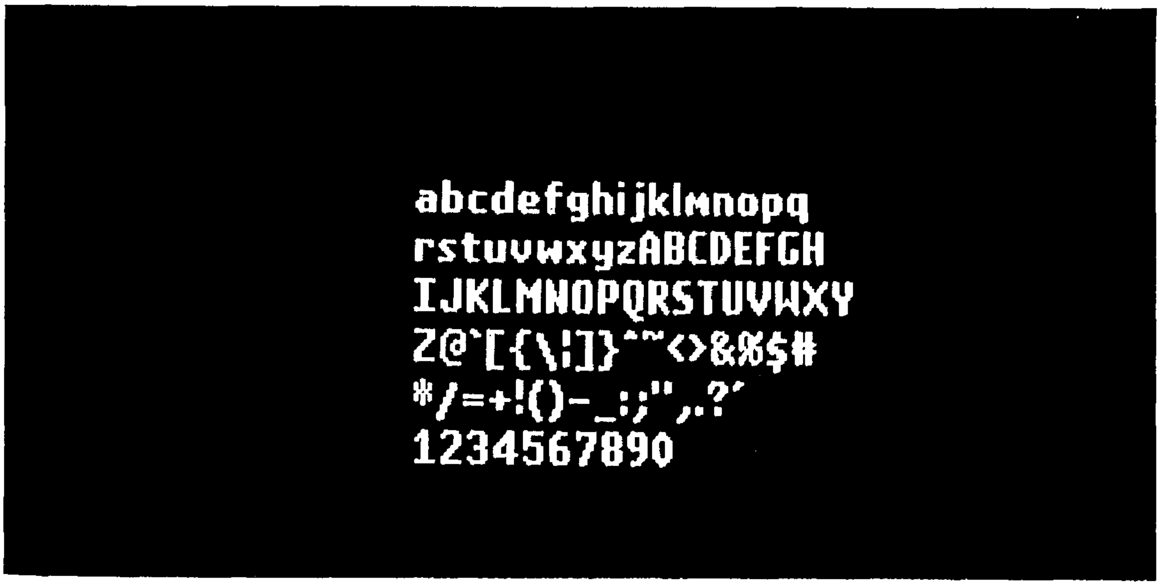


Figure 20. Character Set 2 of the Telidon Specifications (Bronsard 2 Character Style)

In order to provide a range of character sizes, the Telidon specifications (Bown et al., 1979) define character sets double the size of those shown thus far, as well as smaller character sets for high resolution terminals. It is possible to generate the larger sets (Sets 0 and 1) merely by doubling the size of character elements of the smaller sets (Sets 2 and 3). However, the resulting characters are not as pleasing as they could be since irregularities in the character designs are amplified. Preferably, Sets 0 and 1 should be designed on the larger matrix to take advantage of the increased design flexibility provided by the larger number of pixels. This task was contracted to a graphic artist (M. Cartier) who consulted with H.P. Bronsard. Since Mr. Bronsard had designed Sets 2 and 3, this collaboration helped to ensure that the characters from the different sets would not appear incongruous when presented on the same page. Figure 21 shows text printed with Character Sets 0 and 1 obtained by doubling the size of Character Sets 2 and 3. Figure 22 shows text printed with Character Sets 0 and 1 designed on the larger matrix by the graphic artists. Although the improvement is self-evident, the larger character sets can not be implemented immediately because of the considerable memory required to store them in the terminal. Their use may become practical when they can be transmitted to the terminal when required, or when the cost of memory reduces sufficiently.

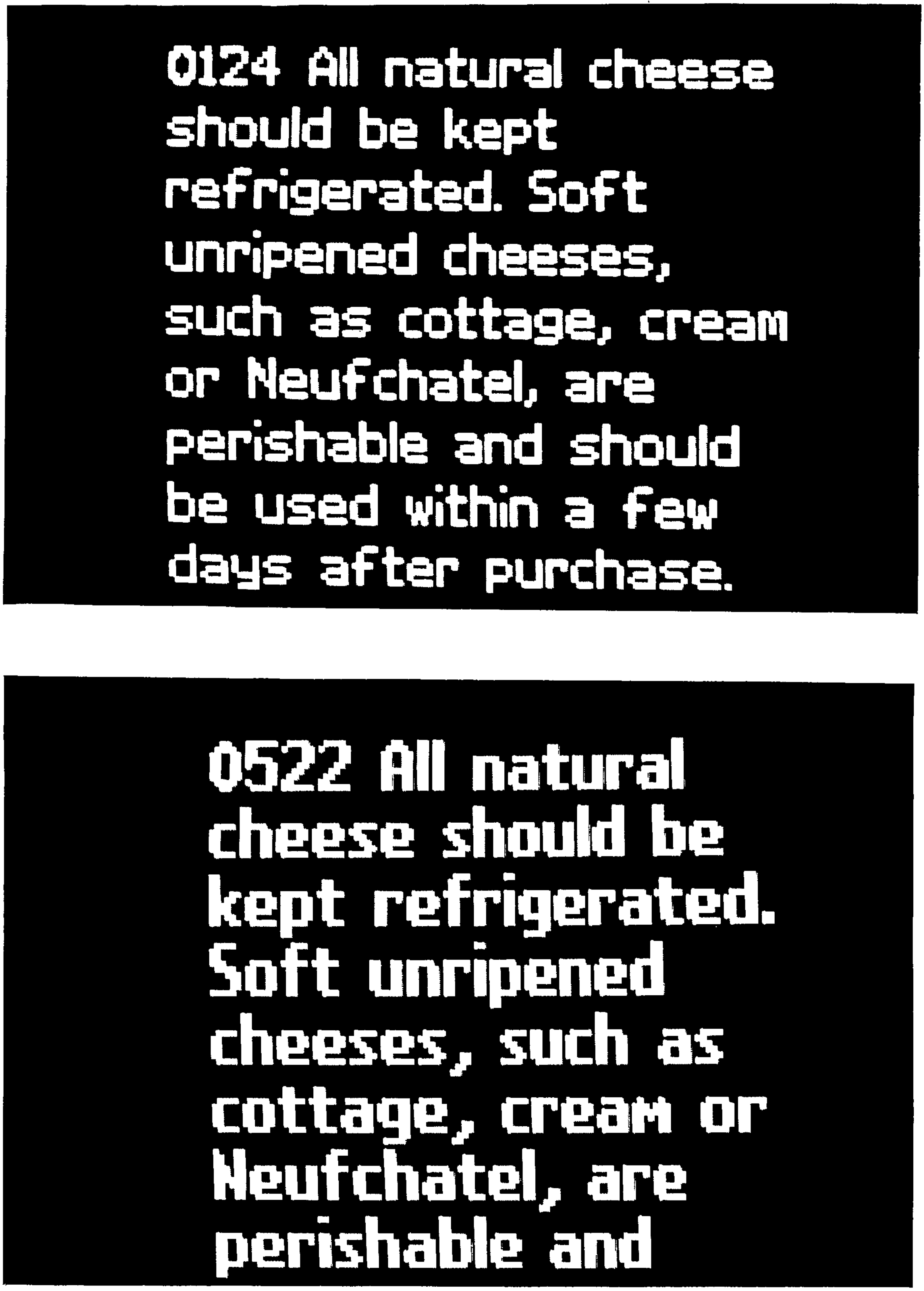


Figure 21. Larger Text Obtained by Simply Doubling the Size of Small Letters

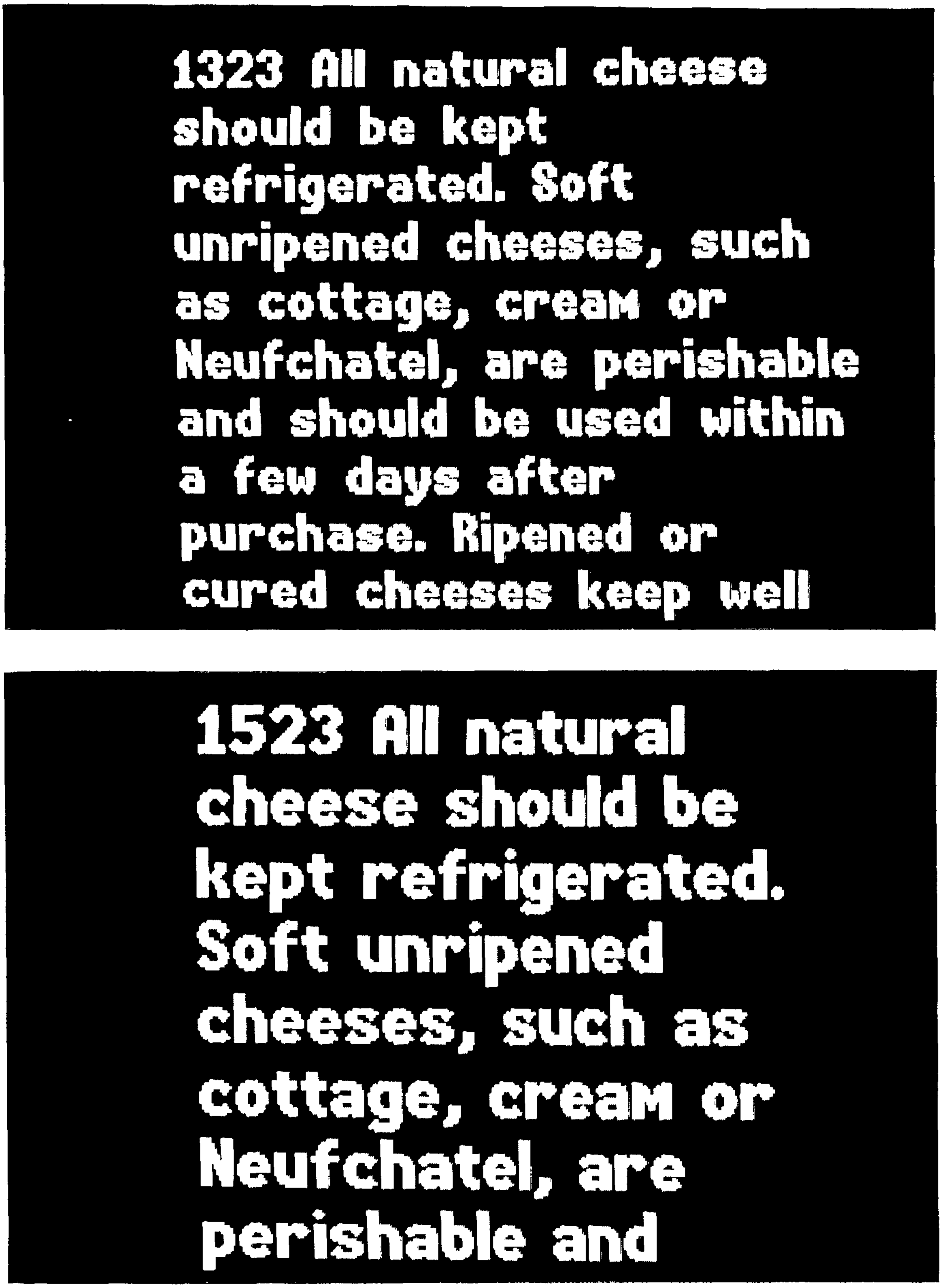


Figure 22. The Larger Text of Figure 21 Obtained Using Character Sets Designed on Larger Matrices by H.P. Bronsard and M. Cartier

By convention, the character set designs are given the names of the designers who created them. Thus, the two larger character fonts are called Bronsard-Cartier 0 and 1, and the two smaller character fonts are called Bronsard 2 and 3. The detailed design of each font is shown in Figures 23 to 26.

Figure 23. Detailed Design of Bronsard 3 Character Style

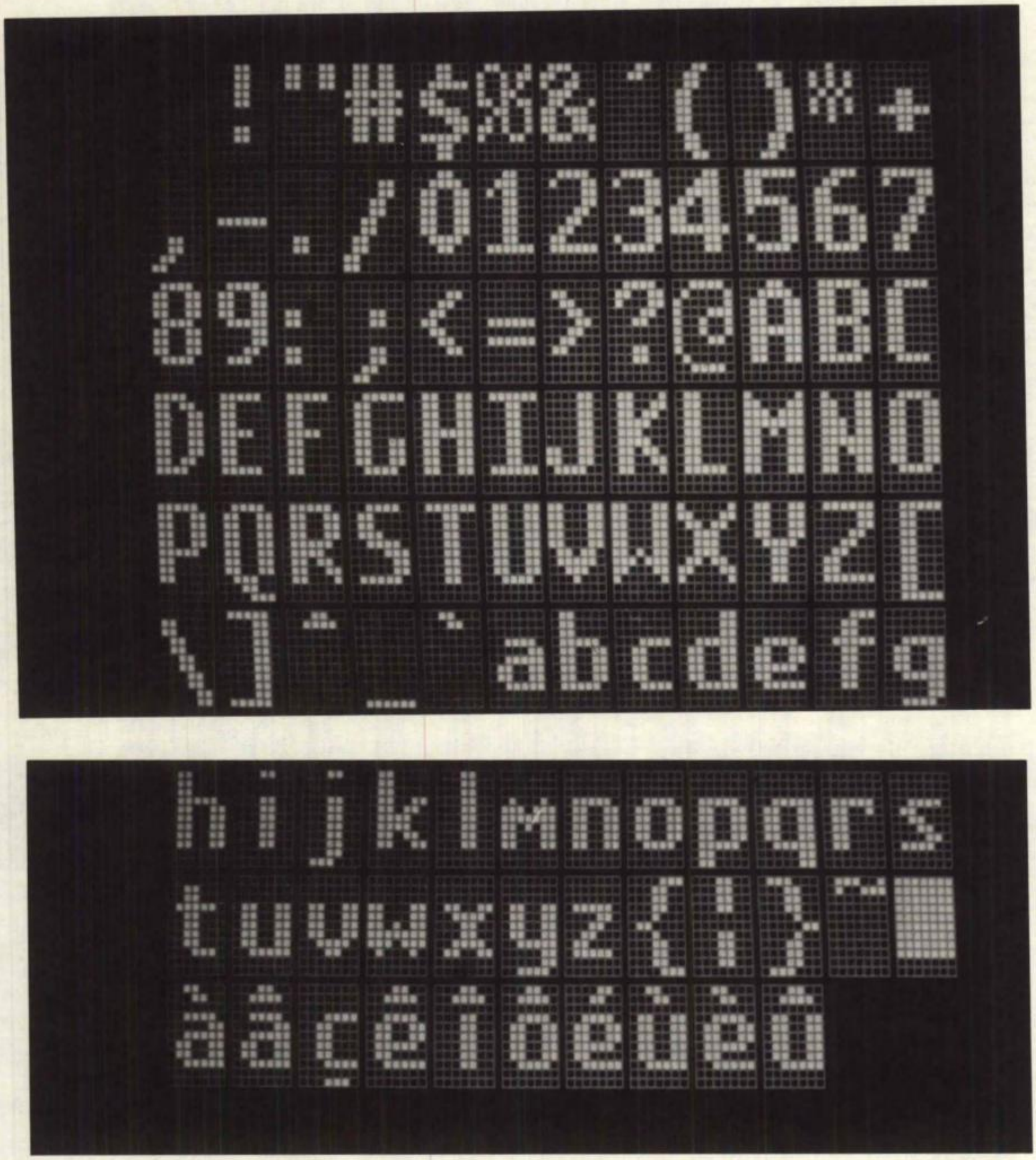


Figure 24. Detailed Design of Bronsard 2 Character Style

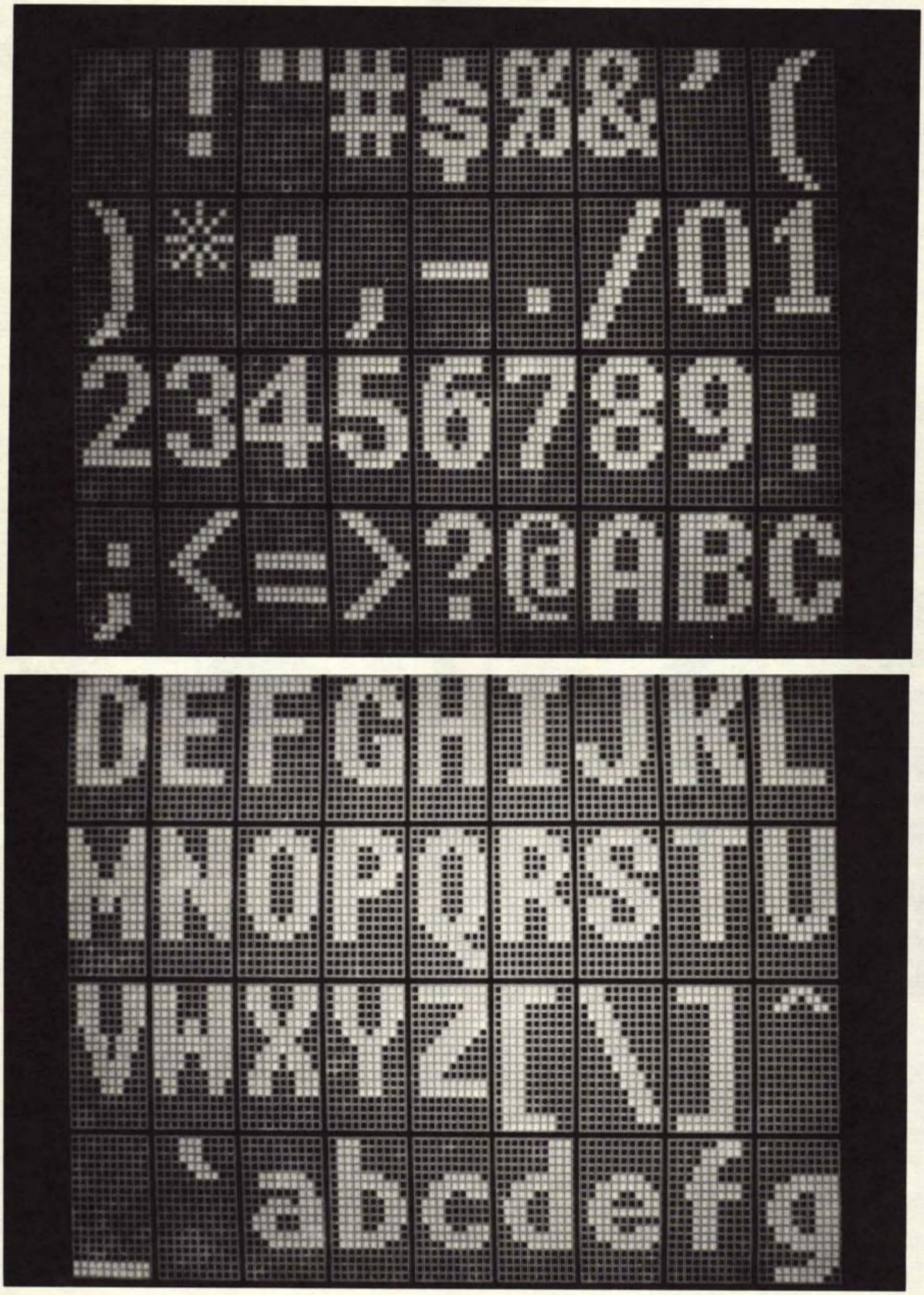


Figure 25. Detailed Design of Bronsard-Cartier 1 Character Style (Page 1 of 2)

Figure 25. Detailed Design of Bronsard-Cartier 1 Character Style (Page 2 of 2)

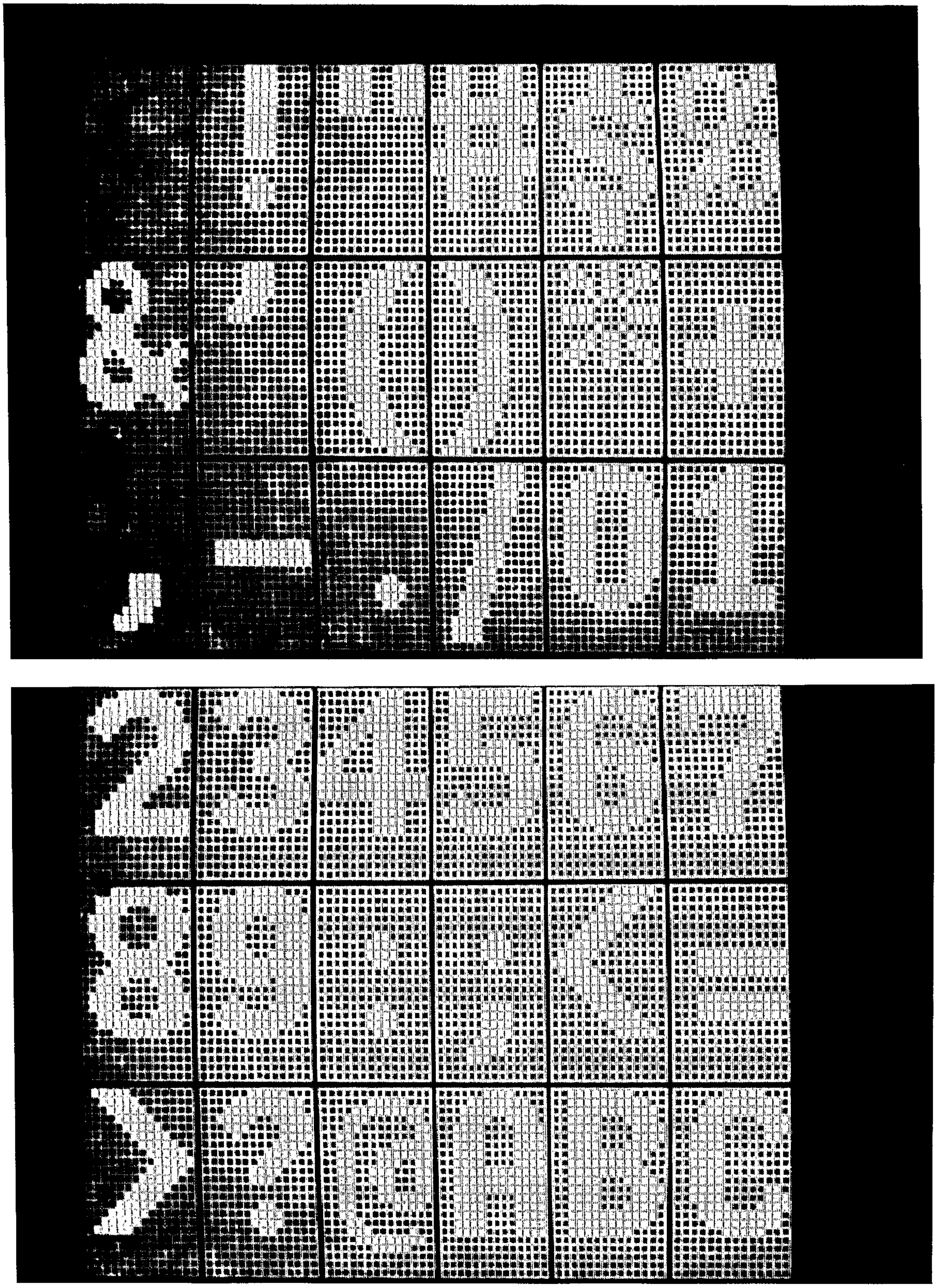


Figure 26. Detailed Design of Bronsard-Cartier 0 Character Style (Page 1 of 3)

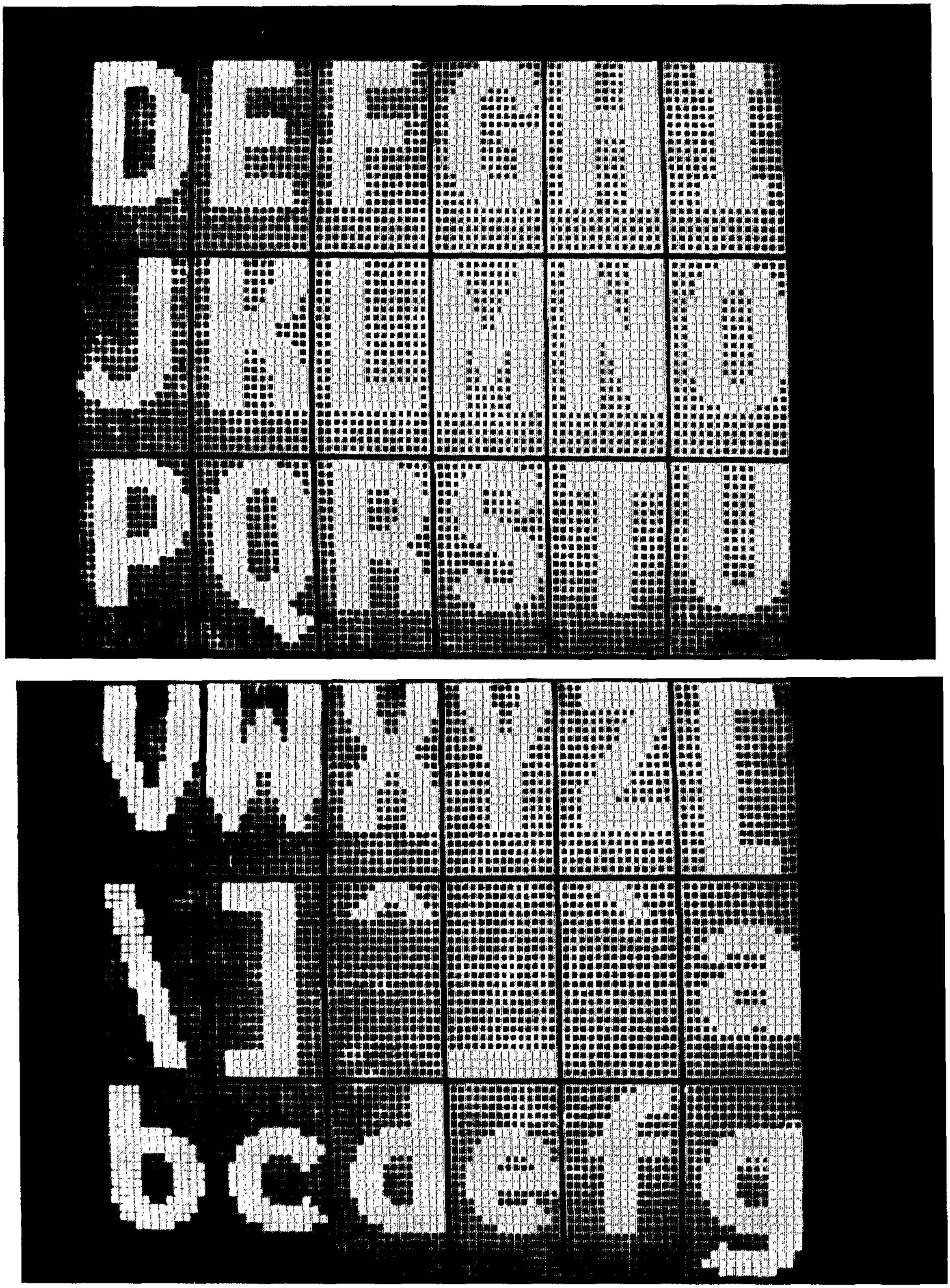


Figure 26. Detailed Design of Bronsard-Cartier 0 Character Style (Page 2 of 3)

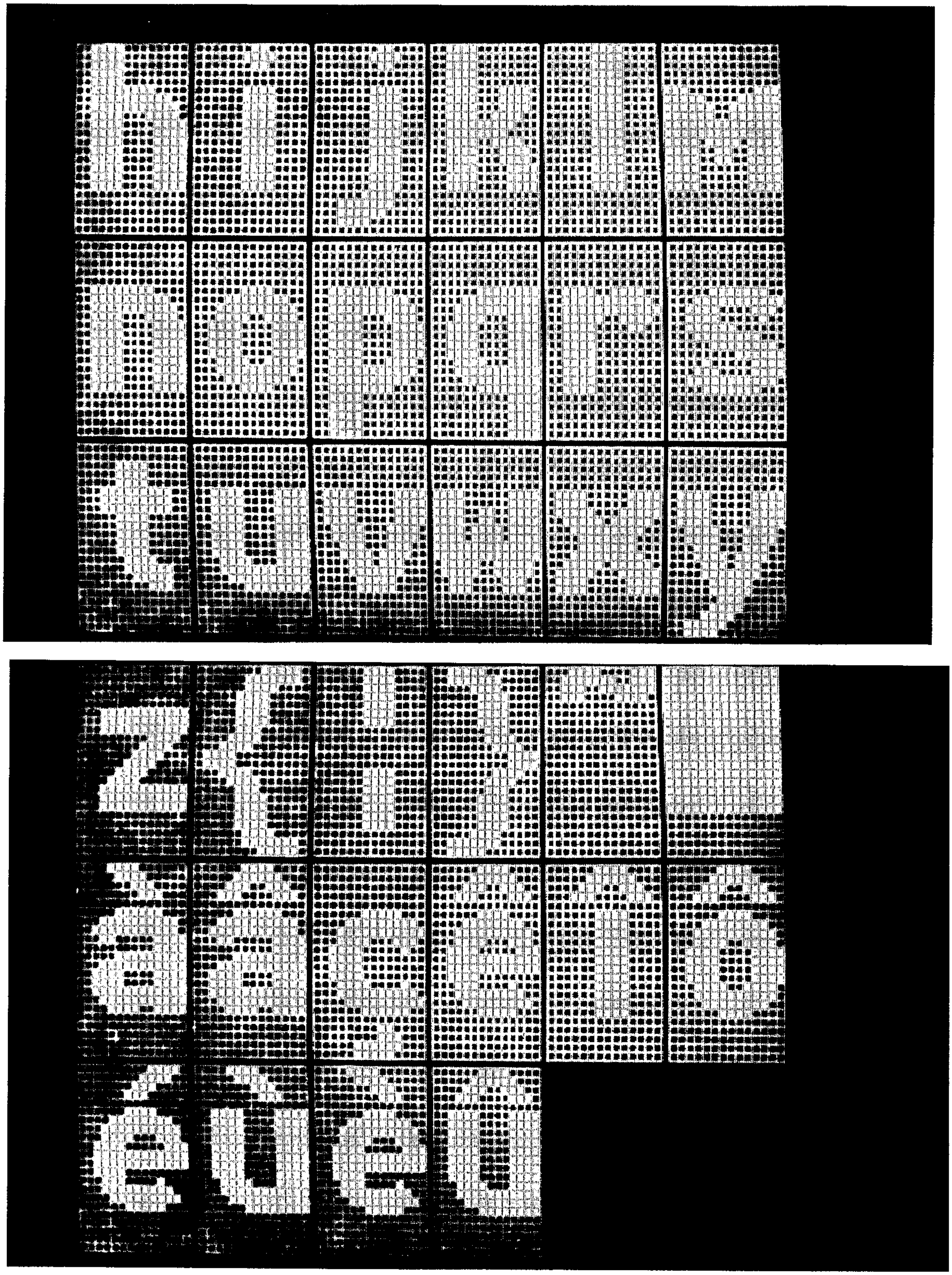


Figure 26. Detailed Design of Bronsard-Cartier 0 Character Style (Page 3 of 3)

More recently, the task of designing the international G2 character set for Telidon terminals was also contracted to Mr. Bronsard. Two sizes were created to correspond to the sizes of Bronsard 2 and 3. These sets are named Bronsard 2-G2 and Bronsard 3-G2. The detailed designs of the latter character sets are shown in Figures 27 and 28. Figures 29 and 30 show the characters of the two sets as they would appear in actual usage.

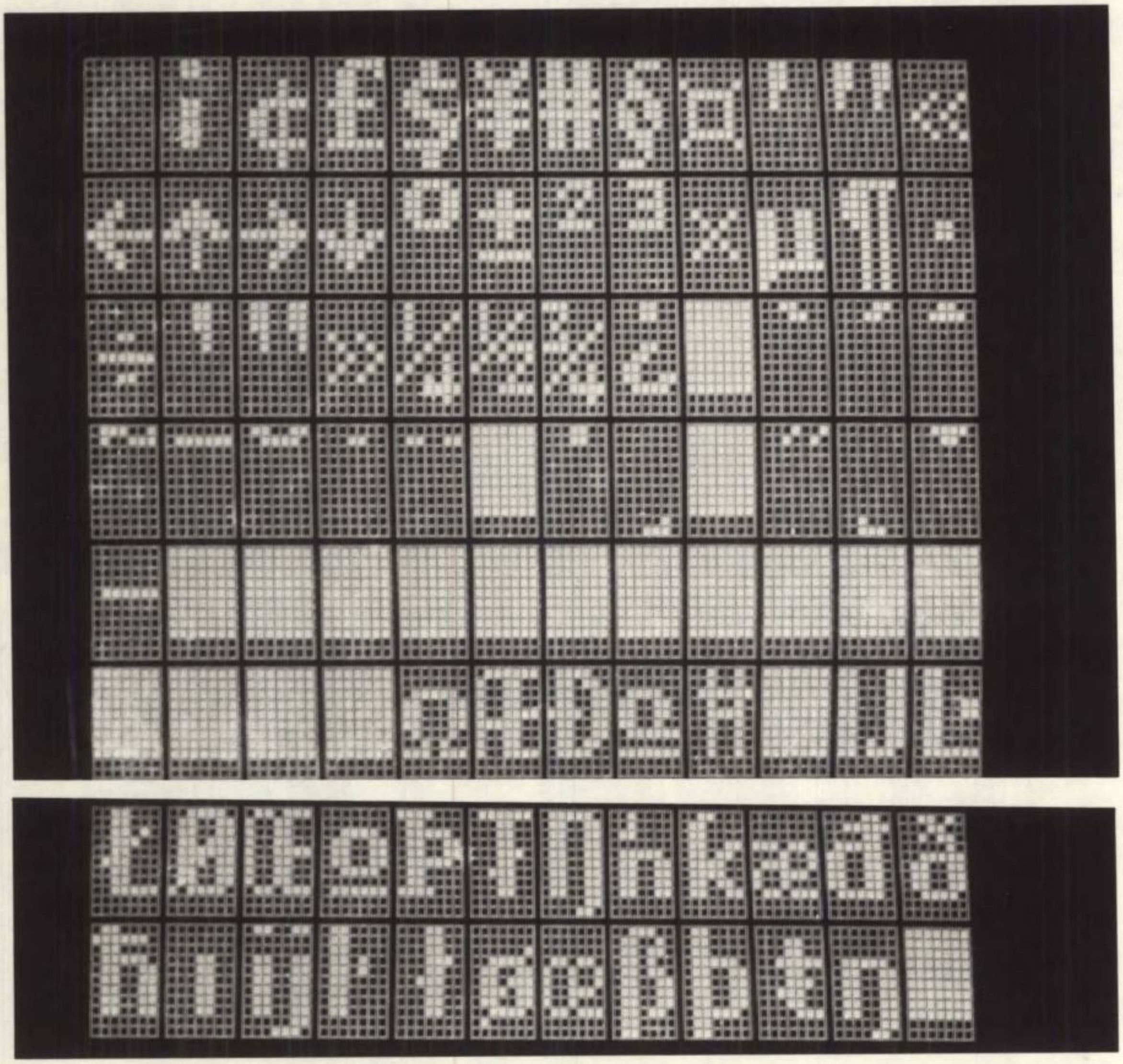


Figure 27. Detailed Design of Bronsard 2-G2 Character Style

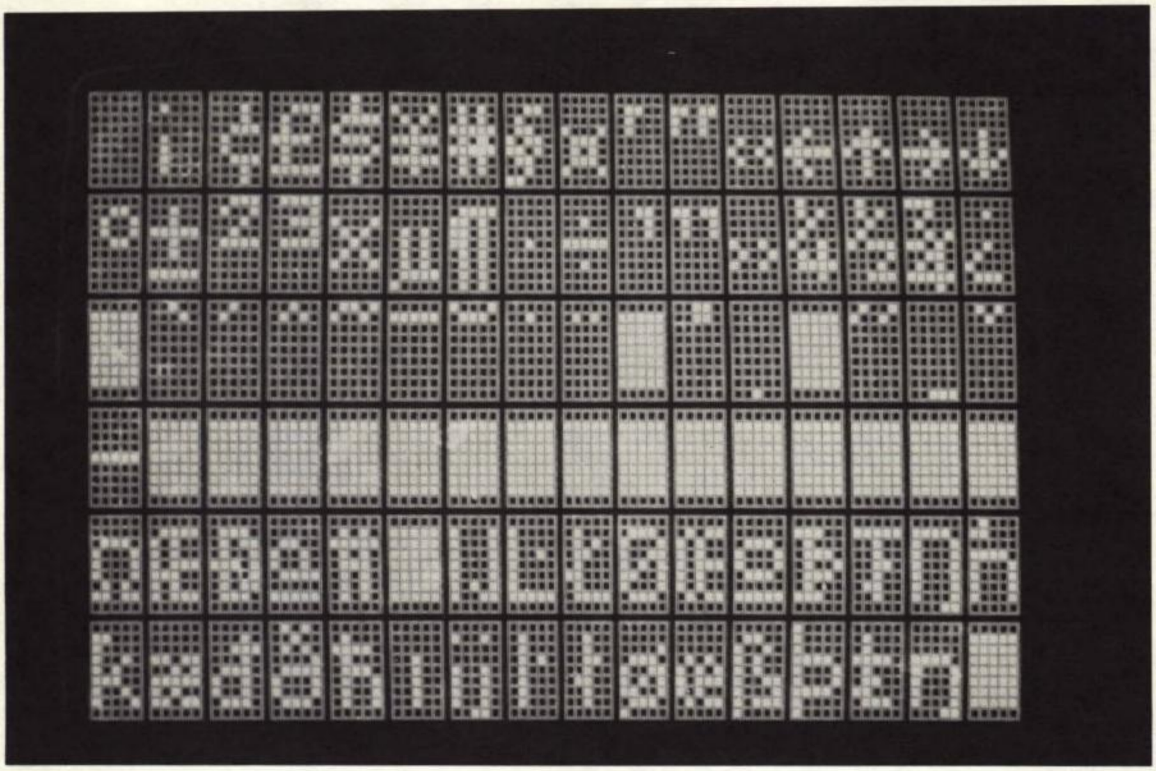


Figure 28. Detailed Design of Bronsard 3-G2 Character Style

Figure 29. Appearance of Bronsard 2-G2 Character Set

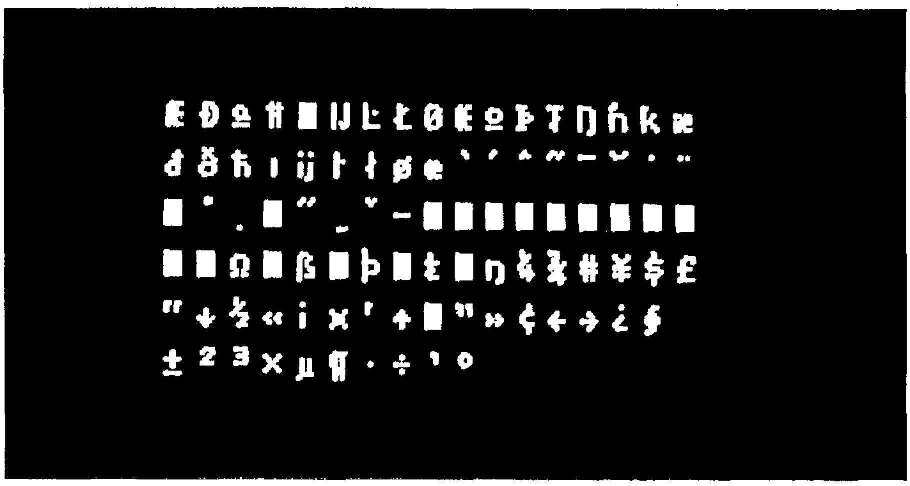


Figure 30. Appearance of Bronsard 3-G2 Character Set

4. CONCLUSIONS

Although work is continuing, some problems have been identified and some recommendations may be made regarding the display of text on a video display with 240 x 320 pixel resolution.

1) No difference was found in average speed of reading upper versus lower case text from the television display. Therefore, established convention may be followed in the choice of case for the display of text.

2) The results of legibility experiments suggest that the optimal spacings between letters and lines of text on a page is dependent on the design of the character set employed. Specifically, it was suggested that these spacings depend on the extent to which the letters fill the character matrix.

3) Proportional spacing is generally considered to improve the readability of a page of text. It should be implemented whenever possible.

4) When proportional spacing is used, the space character separating words should be reduced in width. For the 5 x 8 and the 7 x 11 character sets tested, the preferred space between words was six pixels when the space between letters within words was two pixels.

5) Inter-letter spacings preferred by viewers were somewhat larger than the optimal spacing inferred from the legibility experiments. However, the indicated preferences were quite variable when the data for different viewers were compared. The source of the variability is unknown.

6) Accents should be placed over letters so that one pixel separates the accent from the letter. The shape of the letter itself should not be noticeably changed from its usual form in order to accommodate the accent.

7) NTSC composite video input to the television display requires that care be exercised when designing the image contents. Proper character set design results in an acceptable black and white display. Colour combinations should be used with extreme caution because of the inevitability of chroma-crawl along the colour contours. Vertical line elements should be at least two pixels wide to be fully illuminated. RGB video input eliminates most of the problems inherent with NTSC composite video input. Therefore, RGB video input is most desirable.

8) Designing character sets is a skill or art that requires proper training. Presented in this report are character set styles created by professional graphic artists. They are recommended for use on television picture tubes with a shadow mask like that in the Electrohome Model C40-852 television receiver.

5. ACKNOWLEDGEMENTS

I gratefully acknowledge the contribution of Susane Latrémouille who assisted in performing some of the experiments. I also acknowledge the helpful technical assistance provided by the Image Communication Group in establishing and maintaining the laboratory facilities.

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CRC DOCUMENT CONTROL DATA

1. **ORIGINATOR:** Department of Communications/Communications Research Centre

2. **DOCUMENT NO:** CRC Technical Note No. 705-E

3. **DOCUMENT DATE:** May 1981

4. **DOCUMENT TITLE:** Display of Text on Television

5. **AUTHOR(s):** W.C. Treurniet

6. **KEYWORDS:**
   (1) Text
   (2) Television
   (3) Display

7. **SUBJECT CATEGORY (FIELD & GROUP: COSATI)**

   5 Behavioral and Social Sciences

   5 05 Human Factors Engineering

8. **ABSTRACT:**

A videotex service is a means whereby the general public will be able to access various kinds of information from central data bases. Textual and graphical information will be displayed on television receivers much like those currently used in people's homes. Technical and graphic design problems related to the display of such information on a colour television are addressed in this report. The results of several studies concerned with the display of text are described, and the relative merits of Red–Green–Blue versus composite video input are discussed.

9. **CITATION:** ______________________

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