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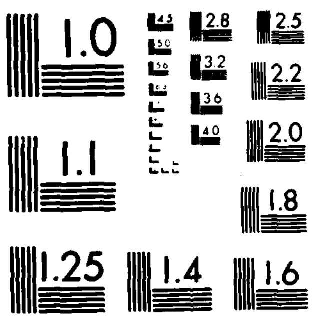

MICROCOPY RESOLUTION TEST CHART
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Technical Report 82110

November 1982

RECOMMENDED COLOURS FOR USE ON AIRBORNE DISPLAYS

by

J. Laycock

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SUMMARY

This document indicates the confusion that exists between a number of colour standards before outlining how they may have been derived. All the standards are unable to deal with modern electronic displays. A computational procedure is described which enables new colour boundaries to be specified. A summary of data derived using the procedure is presented.

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1 INTRODUCTION

Current documents which deal with the use of colour in the military cockpit attempt to incorporate data for the specification of signal lights both outside and within the cockpit and data relating to instrument dials and captions[1-9]. When attempting to use such documents it becomes apparent that considerable confusion exists. There are three major criticisms:

(i) rarely is there any indication of how the standard was derived;

(ii) it is often not clear for which of the two major applications, mentioned above, the standard is intended, or whether it may be applied to all situations;

(iii) the manner in which units are specified varies considerably across documents which makes it impossible to cross compare standards without resorting to the use of a computer to perform the necessary transformations.

In an endeavour to overcome the above criticisms this document is divided into three major sections of which only the latter is intended to be used in the derivation of an Air Standard.

Section 2 indicates the confusion that exists between a number of colour standards and presents plots and tables (in compatible units) for all the standards considered.

Section 3 outlines how the various standards may have been derived and shows how they are unable to deal with modern electronic displays. A computational procedure is described which enables new colour boundaries to be specified.

Section 4 presents a summary of data derived using the procedures in section 2. These data are intended to form the initial base from which an Air Standard may be developed.

2 CURRENT COLOUR STANDARDS

The majority of current colour standards are specified within the CIE 1931 system of colour notation, although some have also used the CIE 1960 uniform colour system[1]. As the 1931 system of notation has stood the test of time and several uniform colour systems now exist this former system has been used to compare the various data.

In Fig 1 the standards listed in Table 1 are presented[2-9]. From the figure it becomes obvious that considerable confusion exists with boundaries differing quite markedly across standards. In some instances a colour specified as a particular colour in one standard is subsumed under a different colour name for an alternative standard (*eg* brown and white). The situation becomes less confused when the standards are divided into those dealing with emissive sources (Fig 2) and surfaces (Fig 3).

The individual source and surface data are presented in Figs 4 to 10, Tables 2 to 8 and Figs 11 to 18, Tables 9 to 16, respectively. Within the figures the following conventions have been adopted. The title is plotted in the bottom right-hand corner and appears in expanded form at the head of the corresponding table. Each colour with a border on the spectrum locus has the corner points numbered in ascending numerical order starting at the shorter wavelength and proceeding round the envelope to the longer wavelength. Colours with closed areas within the spectrum locus are numbered in a clockwise direction starting at the bottom right-hand corner. Within the corresponding tables data are presented in both CIE 1931 units and CIE 1976 units. The colour names used are those present within the standard. Within each colour the column values represent the corner points indicated in the figure and the tabulated decimal numbers are the coordinate values in the appropriate notation system.

In Fig 19, Table 17, data are presented for the artificial illumination sources present within the cockpit which may modify the appearance of both source and surface colours[10].

3 DERIVATION OF COLOUR STANDARDS

Current civil flight decks now incorporate colour cathode ray tubes (CRTs) and it is probable that the next generation of military aircraft will also utilise such devices. There are a number of types of colour CRTs but the penetron and shadow mask devices are the most likely candidates for exploitation. The shadow mask tube may be described by the colour area enclosed by the lines joining the constituent phosphors incorporated in the screen. In Fig 20, Table 18, are presented a number of phosphor types from which have been produced two envelopes describing the boundaries of typical displays (1931 equations are given in Table 19). It is necessary to define an outer boundary indicating the maximum envelope presently available and an inner boundary which typifies airborne displays. The red-green vector of the inner boundary when slightly displaced towards 610 nm also typifies penetron displays. When these boundaries are superimposed on representative source (Fig 21) and surface (Fig 22) plots it is apparent that some of the colours specified by NATO STANAG 3370 cannot be produced by airborne CRTs, although such devices are able to reproduce CIE 2.2 SURFACES. This brings into question how the colour envelopes have been determined for the two classes of standards and secondly which class of standard is most suitable for use with modern electronic displays.

In Fig 23 NATO STANAG 3370 has been plotted with the addition of extrapolation of the hue boundaries and inclusion of the Plankian locus. It is observed that the hue boundaries extend through an equal energy achromatic point x 0.3333, y 0.3333. The envelope of the colour white closely matches the Plankian locus and is thus able to include artificial light sources operating at different colour temperatures. When similar hue boundary extrapolation is carried out for surface colours (Fig 24) they intersect at an achromatic point x 0.3127, y 0.3290 representing daylight illumination at 6500 K (D65). Thus this procedure is able to account for the gradients defining the hue boundaries but it is not able to account for the saturation boundary bordering on the achromatic point nor is it able to account for what determines the dominant wavelength from which each hue boundary projects.

The German DIN system is portrayed in Figs 25 and 26. In Fig 25 the concentric contours denote iso-saturation lines around an achromatic point x 0.3100, y 0.3160 representative of standard illuminant C. The radial contours denote iso-hue lines emanating from the same achromatic point. Despite the dissimilar achromatic centres it is possible to compare Figs 24 and 25 to ascertain whether there is correspondence between colour envelopes and hue/saturation categories. Such a comparison reveals reasonable but not perfect correlation between colour saturation limits and iso-saturation contour[5]. However, there is no clear correlation between hue steps in the DIN system and the position of hue boundaries in Fig 24. Although Fig 25 gives the impression of defining a uniform colour system it must be remembered that chrominance difference is also dependent upon luminance, consequently the boundaries defined in Fig 25 are subject to modification according to the relative lightness values present in Fig 26[11,12]. Even after adjustments are made the DIN system is unable to account for the hue limits present in Fig 24.

In Figs 27 and 28 iso-hue and iso-saturation contours have been derived by dividing CIE 1976 Uniform Colour Space (UCS) into equal intervals and back transforming into 1931 CIE through the standard transformation equations[1]. When Fig 25 is compared with Figs 27 and 28 it is observed that 3.5 saturation just noticeable differences (JNDs) (S3.50) match the saturation contours of the DIN system between 495 nm and 565 nm reasonably well, but 7.0 JNDs are required to achieve matching in the red/blue part of the diagram. In Fig 29 empirical colour matching data[13] are superimposed upon the derived contours to demonstrate how closely the contours indicate JND intervals throughout the chromaticity diagram. The high correlation between 1976 UCS contours and empirical JND data, and the poor correlation between UCS and DIN data suggests that the CIE 1976 system provides more accurate predictions of perceived colour intervals.

When equal chromatic areas in CIE 1976 UCS are presented in CIE 1931 notation Fig 30 results. From the figure it is possible to observe the relative spacing that would be necessary within the chromatic diagram to ensure adequate colour separation but division on a JND area basis is unable to conveniently take into account limitations imposed by the CRT envelope and the need for iso-hue boundaries.

By operating in the CIE 1976 UCS system it is easier to envisage the restrictions that are imposed. In Fig 31 CIE surface data have been plotted with the two shadow mask boundaries of Fig 20 added. If only the inner boundary is considered, as in Fig 32, daylight D65 is quite close to the green primary and is positioned some distance from the centre of gravity of the triangle indicated by X . On the periphery of the triangle are plotted the complementaries determined by projecting through X . With the iso-contour plot centred on D65 (u' 0.1978, v' 0.4683) (Fig 33) the number of saturation JNDs between D65 and saturated display colours varies, *eg* the number to yellow (585 nm) is less than to magenta. Thus if the full CRT envelope is utilised certain colours will appear much more saturated than others. By positioning the iso-contour plot on the centre of gravity of the CRT envelope (Fig 34) equivalence of saturation is more easily achieved. Unfortunately this situation can only occur when the eye is adapted to an environment where all illumination is from artificial sources (u' 0.2432, v' 0.4202). This may be possible in an operations room or crew cabin but cannot exist in the military cockpit during daylight flying.

It is thus necessary to utilise data in the form presented in Fig 33 to calculate possible new colour envelopes. In Fig 35, Table 20, each side of the triangle has been divided into three equal intervals and the resulting four colours on each vector are indicated by plus (+) marks. The complementaries from Fig 32 are also included. When the position of the calculated colour points are compared with CIE 2.2 Surfaces (ordinary) data there is considerable agreement, however, particular problems exist in the blue where two colour points are enclosed within the CIE area. When a similar division process is used to produce 13 points between vertices, Fig 36, Table 21, results. In the Figure points 2, 4, 6, 8, 10 and 12 of each side have been joined to the achromatic point (these correspond to interval values in Table 21). Thus starting at the blue corner of the CRT envelope, point 12 red (R) and point 2 blue (B) when joined to D65 enclose an envelope which could be considered to be primary blue. Moving up the blue vector points 2B, D65, 4B envelope a no-go area; points 4B, D65, 6B envelope a useable colour envelope. In this way it is possible to move along each vector defining two primaries, two intermediate colours and three no-go areas. If only a single intermediate colour is required the primaries remain unchanged and 6B, D65, 8B define the intermediate.

In Fig 37 a portion of Fig 36 is shown magnified. As before 13R, D65, 2B enclose primary blue with 6B, D65, 8B enclosing cyan. Although adequate hue separation exists around the periphery of the CRT envelope, towards the achromatic point separation is inadequate. Frequently a chrominance difference (CD) of 0.028 is used to denote adequate separation[14]. As 0.004 u' may be taken to represent a JND[15,16] a CD of 0.028 is equivalent to 7 JNDs. In Fig 37 a CD of 0.028 has been plotted in the no-go area between blue and cyan. Table 22 illustrates how this calculation is achieved. The example given in the Table is in CIE 1976 units with a D65 origin. In column 1 of the Table points 1 and 2 represent 2B and 6B of Fig 37 expressed in polar coordinates R and THETA relative to the D65 origin. With JND = 7.0 a radius R of 0.1288 is required for a line of length 0.028 (required CD: $7.0 \times 0.004 = 0.028$) to join the hue boundary lines. The four pairs of coordinates for the CORNER VALUES defining the new no-go area are given as are the equations for the hue boundaries. The six columns represent similar calculations for the six no-go areas present within the CRT envelope (Fig 38). This procedure defines the extent to which a hue may extend towards the achromatic point without becoming less than CD 0.028 closer to an adjacent colour. However, in certain instances such a separation may be achieved quite close to the achromatic point (*eg* between green and yellow). Thus it is necessary not only to take into account hue separation but also saturation separation. Fig 38 shows the no-go areas with iso-saturation contours added at 7.0 JND intervals. For any white symbology to be adequately visible against D65 illumination it must be 7 JNDs away from the achromatic point. Thus the central circle defines a white area but it is advantageous to position white symbology towards the periphery of the area. Surrounding the white area is an annulus of width 7 JNDs in which adjacent colours should not be present if adequate saturation separation is to be maintained. Within Fig 38 the useable colours are defined by joining the corners of the no-go areas extending towards the achromatic point (dotted lines). Without exception all the colours extend beyond the 14 JND contour, preventing adequate saturation from white (see also Fig 37). This problem may be overcome by allowing the saturation limit to take priority over the hue limit when the R value for hue (7 JND R, Table 22) is less than the R value for 14 JNDs of saturation at the same THETA. This has been done in the bottom portion of Table 22 where abscissa and ordinate values are given for the colour CORNER VALUES with saturation set at a value of 14 JNDs.

The above procedures are exemplified in Figs 39 to 44. To make the effects more obvious Figs 39 to 41 show hue separations of 2 JND (CD 0.008). In Fig 39 each triangle side hosts only a single intermediate colour whereas two intermediates are present in Fig 40. When saturation priority is present (denoted by SP bottom right) Fig 40 becomes modified to Fig 41, with much reduced colour areas. When the hue separation is now set to 7 JND (H 7.00) Fig 41 is modified to Fig 42 with some hue limits occurring outside the range of the CRT, but still allowing intermediate colour envelopes to be calculated. An equivalent hue/saturation situation for the single intermediate colour case is presented in Fig 43, with Fig 44 demonstrating how the 14 JND saturation priority limits the achromatic boundary of cyan, green and yellow. Figs 42 and 43 are numerically represented in Tables 23 to 25. Table 23 lists the CRT envelope equations followed by the polar coordinates of the six points (2, 4, 6, 8, 10, 12 of Fig 36) present along each of the three triangle sides (total 18), relative to a D65 origin. The u'v' values are the Cartesian equivalents of the polar coordinates. These data have been used to calculate the hue limits and the boundary equations for the cases with a single intermediate colour and two intermediate colours. The results are presented in Tables 24 and 25, respectively. The single intermediate case permits six colours plus white to be produced, whilst the two intermediate case produces nine colours plus white. If additional colours are required the colour areas can be further subdivided using the saturation contours in Fig 44 to create sub-areas separated by 7 JNDs. This cannot be achieved for all colours.

The above calculations are based on a specific CRT envelope and therefore the generality of the results is questionable. Fig 45 shows the nine colour case, with invariant white, calculated for the CRT phosphors listed in Table 18, to indicate the variance in defined boundaries that may occur. Apart from the large variance observed due to the unique outer boundary case of Table 18 the other phosphors produce remarkably equivalent colour limits with exceptions for primary green and yellow. Special requirements for these colours are discussed later. Thus it may be concluded that the procedures outlined above appear to produce an acceptable solution. However, before a total solution can be postulated it is necessary to consider the modifying effects of the ambient illumination more closely.

The effect of ambient sunlight is to desaturate the colours causing them to move towards the achromatic point[16]. The effect is demonstrated in Figs 46 and 47, representing the six colour + white and nine colour + white cases, respectively. To achieve clarity the colours are represented by a single point rather than by the entire envelopes. From the Figures it may be observed how relatively saturated colours move towards the D65 point causing the apparent colour envelope to shrink, with the result that colour separations are substantially reduced. In both instances it has been assumed that the incident illumination is D65, 20% of which is reflected back to the observer by the CRT face. (A neutral reflection is assumed for simplicity.) The three envelopes plotted represent the situations which exist when the display is set at 1 unit of luminance and illuminations of 0, 10 and 100 comparable units are present. The data are listed in Table 26. Across the columns details of the illumination are presented. Within the body of the Table are listed the Cartesian coordinates of the four colours along each of the three triangle sides for the three illumination levels. At the bottom of each column are the coordinates for the centre of gravity of the CRT envelope and the corresponding complementaries.

From these examples it may be deduced that colour boundaries created using a saturation priority of 14 JNDs (Figs 42 and 43) represent a minimum requirement that can only operate effectively when the illumination can be precisely controlled. If a manufacturer chooses to comply with the requirement by positioning the colour on or extremely close to the boundary adjacent to the achromatic region, as soon as ambient illumination is present the colour will become further desaturated and exceed the boundary condition. Obviously this movement across the boundary will not occur if the more saturated portion of the colour envelope is used. In order to produce a tighter specification to prevent such inadvertent boundary crossings occurring saturation priority has to be set to greater than 14. Support for this decision is provided when data using hue separation of 7 JND (H 7.00) and saturation priority of 14 JND (S 14.00 -- SP) are compared with existing CIE surface standards (Fig 48) (CIE data extend to spectrum locus). It is apparent that the CIE standard demands more saturated colours than those computed above. Increasing saturation priority to 21 JNDs, thus producing 14 JNDs between the colour white and other colours, results in Fig 49 and 50 for the single and two intermediate cases, respectively. The consequence of producing this tighter specification is to further reduce the colour areas and in the case of the blue neighbouring green in Fig 50 bring it almost to zero. Thus the 9 + white (W) situation reduces to 8 + W. Corner values and vector equations for the envelopes derived from data in Table 23 are presented in Tables 27 and 28.

By combining the data to produce single intermediates along blue-green and red-blue vectors whilst allowing two intermediates along the green-red vector Fig 51 is produced. The boundaries produced correlate reasonably well with the CIE surface data but subdivide the CIE blue into blue and cyan and slightly reposition the green. The envelopes also correlate reasonably well with loci used in various experiments where laboratory devices with increased envelopes have been employed (Fig 52). Greens, yellows, reds, lilac and magenta are well specified but blues and cyans show more spread which may be due to some experiments requiring only a single intermediate between blue and green, whilst others have required two intermediates. The accuracy of fit is sufficiently convincing to allow the computational procedure to be utilised to produce an advisory colour standard. This is achieved in section 4.

4 RECOMMENDED COLOURS FOR USE ON AIRBORNE DISPLAYS

4.1 Introduction

The following recommended colour envelopes have been calculated according to the procedures detailed in section 3 (above). Throughout every endeavour has been made to ensure that a chrominance difference of 0.028 exists between adjacent colours. The calculations have been based on the assumption that any new colour standard must be able to incorporate modern emissive displays within its framework. As a consequence of this assumption and the need to allow colours on emissive devices to correspond with surface colours present on reflective devices the proposed envelopes move away from those specified in NATO STANAG 3370 and CIE 2.2 Sources. The new envelopes more closely correspond with CIE 2.2 Surfaces (Ordinary) data. Further justification for this transition is that source standards are primarily concerned with lights of small angular subtense viewed from a long range such as navigation lights and airfield approach lights. In the cockpit areas of colour are of relatively large angular subtense and are viewed typically from 0.6 to 0.8 m and therefore may be likened to emissive surfaces.

4.2 Conventions

Throughout the following figures and tables the following conventions have been employed:

4.2.1 Colours are labelled in ascending numerical order starting at the shorter wavelength and proceeding to the longer wavelength (Fig 53).

4.2.2 When a single intermediate colour is required between two primaries the following names have been adopted:

blue-cyan-green; green-amber-red; red-magenta-blue.

4.2.3 When two intermediate colours are required between two primaries the following names have been adopted:

blue-cyan-(nil)-green; green-yellow-orange-red; red-mauve-purple-blue.

4.2.4 Corner values are specified according to the limits detailed in Fig 53. Points beyond the spectrum locus are terminated within a rectangle defined by the following four pairs of coordinates: 0, 0; 0, 0.6; 0.7, 0.6; 0.7, 0. However, in the red corner of the diagram points are within this rectangle to allow convenient transformation to the CIE 1931 system.

4.2.5 Throughout white remains invariant and is centred on u' 0.1978 v' 0.4683 (D65) with the outer boundary occurring at a radius of 0.028 u' from this centre.

4.2.6 To convert CIE 1976 values into CIE 1931 values the following transformation equations have been used:

$$x = \frac{9u'}{6u' - 16v' + 12}$$

$$y = \frac{4v'}{6u' - 16v' + 12} .$$

4.2.7 Titles are inset in the bottom right-hand corner of each figure with the CIE system specified at the top.

4.2.8 Each recommendation is plotted and tabulated in CIE 1931 and 1976 systems.

4.3 Data

4.3.1 In an instrument system where it is necessary to display a maximum of six colours plus white it is recommended that the corner values of the colour envelopes be those plotted in Figs 54 and 55 and listed in Table 29. For daylight applications if fewer than six colours are required the colours should be deleted in the order white, cyan, amber, unless these colours can be displayed at significantly higher luminances than the other colours.

4.3.2 When seven colours plus white are required it is recommended that the corner values of the colour envelopes be those plotted in Figs 56 and 57 and listed in Table 30.

4.3.3 When eight colours plus white are required it is recommended that the corner values of the colour envelopes be those plotted in Figs 58 and 59 and listed in Table 31.

4.3.4 For display applications when colour is used to denote a signal category it is recommended that the minimum number of colours possible be used and only under exceptional circumstances may the 8 + white case be exceeded.

4.4 Further considerations

4.4.1 Throughout the above recommendations colour boundaries have been specified in the absence of ambient illumination. In practice it is usual to perform laboratory calibrations with artificial illumination present (often illuminant A). Consideration should be given to whether it is necessary to specify measurement procedures.

4.4.2 No concessions have been made to accommodate personnel with colour perception anomalies on the assumption that the standard is for use with a selected population. Whether existing selection tests are adequate is a point for conjecture. It may be necessary to improve such tests or alternatively respecify certain colour boundaries.

4.4.3 The specified boundaries have been derived for daylight viewing conditions (6500 K) and do not take into account further limitations which may be imposed by the properties of materials which may be incorporated into reflective devices which must be compatible with emissive devices. Such limitations may require the boundaries to be slightly adjusted in the future. Other minor modifications may be necessary to take into account the artificial illumination used for night-time applications.

4.4.4 Wherever possible procedures similar to those used by CIE have been adopted. Figs 60 and 61 allow comparisons to be made with existing conventions. (CIE thick line, new proposals thin line.) Although good agreement of conventions occurs within the plots for all but white, where it may be necessary to derive a more easily numerically specifiable area, the tabular details vary. The CIE system specifies corner values and vector equations to three significant figures. In the present document the specified coordinates may be beyond the spectrum locus to facilitate the computation and plotting. This may not be desirable but it must be remembered that the intersection of colour boundaries with the spectrum locus will not occur at whole wavelength values and as the spectrum locus cannot be conveniently represented by a single equation such intersections are difficult to calculate.

Table 1

COLOUR STANDARDS

No.	Standard
1	Instrument range markings
2	IALA - sources (general)
3	IALA - sources (preferred)
4	IALA - surfaces (ordinary)
5	IALA - surfaces (fluorescent)
6	NATO STANAG 3370 (general)
7	CIE 2.2 surfaces (ordinary)
8	CIE 2.2 surfaces (ordinary) background green
9	CIE 2.2 surfaces (fluorescent)
10	CIE 2.2 surfaces (retro-reflecting)
11	CIE 2.2 surfaces (transilluminated)
12	CIE 2.2 surfaces (transilluminated) background green
13	MIL-C-25050A aviation colours
14	MIL-C-25050A identification colours
15	ICAO navigation and anti-collision

Table 2

IALA - SOURCES (GENERAL)

Colour	1		2		3		4		5		6		7	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y
White	0.500	0.382	0.440	0.382	0.285	0.264	0.285	0.332	0.453	0.440	0.500	0.440	0.500	0.382
Green	0.028	0.385	0.228	0.351	0.321	0.494	0.305	0.689	-	-	-	-	-	-
Yellow	0.560	0.440	0.555	0.435	0.596	0.396	0.600	0.400	-	-	-	-	-	-
Red	0.665	0.335	0.645	0.335	0.721	0.259	0.735	0.265	-	-	-	-	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.304	0.522	0.263	0.513	0.204	0.424	0.178	0.466	0.246	0.537	0.275	0.544	0.304	0.522
Green	0.015	0.458	0.135	0.468	0.155	0.537	0.115	0.582	-	-	-	-	-	-
Yellow	0.313	0.553	0.312	0.551	0.363	0.543	0.364	0.545	-	-	-	-	-	-
Red	0.468	0.530	0.450	0.526	0.618	0.500	0.624	0.506	-	-	-	-	-	-

Table 3

IALA - SOURCES (PREFERRED)

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.440	0.382	0.285	0.264	0.285	0.332	0.440	0.432	0.440	0.382
Green	0.013	0.494	0.207	0.397	0.282	0.518	0.022	0.778	-	-
Yellow	0.560	0.440	0.555	0.435	0.581	0.411	0.585	0.415	-	-
Red	0.680	0.320	0.670	0.320	0.700	0.290	0.710	0.290	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.263	0.513	0.204	0.424	0.178	0.466	0.241	0.532	0.263	0.513
Green	0.006	0.499	0.113	0.486	0.130	0.539	0.007	0.570	-	-
Yellow	0.313	0.553	0.312	0.551	0.343	0.546	0.344	0.549	-	-
Red	0.496	0.526	0.487	0.524	0.551	0.514	0.561	0.516	-	-

Table 4

ICAO NAVIGATION AND ANTI-COLLISION

Colour	1		2		3		4		5		6		7	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y
White	0.500	0.382	0.440	0.382	0.285	0.264	0.285	0.332	0.453	0.440	0.500	0.440	0.500	0.382
Green	0.028	0.385	0.228	0.351	0.321	0.494	0.305	0.689	-	-	-	-	-	-
Yellow	0.560	0.440	0.555	0.435	0.596	0.396	0.600	0.400	-	-	-	-	-	-
Red	0.665	0.335	0.645	0.335	0.721	0.259	0.735	0.265	-	-	-	-	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.304	0.522	0.263	0.513	0.204	0.424	0.178	0.466	0.246	0.537	0.275	0.544	0.304	0.522
Green	0.015	0.458	0.135	0.468	0.155	0.537	0.115	0.582	-	-	-	-	-	-
Yellow	0.313	0.553	0.312	0.551	0.363	0.543	0.364	0.546	-	-	-	-	-	-
Red	0.468	0.530	0.450	0.526	0.618	0.500	0.624	0.506	-	-	-	-	-	-

Table 5

MIL-C-2505A AVIATION COLOURS

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Blue	0.173	0.005	0.175	0.175	0.103	0.103	-	-
Green	0.028	0.385	0.180	0.359	0.300	0.462	0.192	0.781
Yellow	0.575	0.424	0.560	0.425	0.625	0.370	0.627	0.370
Red	0.665	0.335	0.645	0.335	0.721	0.259	0.735	0.265
	u'	v'	u'	v'	u'	v'	u'	v'
Blue	0.255	0.017	0.147	0.332	0.102	0.230	-	-
Green	0.015	0.458	0.104	0.465	0.151	0.523	0.064	0.586
Yellow	0.332	0.550	0.321	0.548	0.404	0.538	0.405	0.538
Red	0.468	0.530	0.450	0.526	0.618	0.500	0.624	0.506

Table 6

MIL-C-25050A IDENTIFICATION COLOURS

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Green	0.004	0.655	0.200	0.496	0.312	0.631	0.312	0.682
Yellow	0.575	0.430	0.570	0.423	0.625	0.370	0.631	0.370
Red	0.712	0.287	0.693	0.287	0.721	0.259	0.735	0.265
	u'	v'	u'	v'	u'	v'	u'	v'
Green	0.002	0.543	0.094	0.522	0.126	0.571	0.118	0.581
Yellow	0.328	0.552	0.329	0.549	0.404	0.538	0.409	0.539
Red	0.567	0.515	0.548	0.511	0.618	0.500	0.624	0.506

Table 7

NATO STANAG 3370 (GENERAL)

Colour	1		2		3		4		5		6		7	
	x	y	x	y	x	y	x	y	x	y	x	y	x	y
White	0.565	0.413	0.542	0.382	0.500	0.382	0.440	0.382	0.285	0.264	0.285	0.332	0.440	0.432
Blue	0.148	0.025	0.233	0.167	0.186	0.214	0.090	0.137	-	-	-	-	-	-
Green	0.028	0.385	0.228	0.351	0.321	0.493	0.305	0.689	-	-	-	-	-	-
Yellow	0.560	0.440	0.546	0.426	0.612	0.382	0.618	0.382	-	-	-	-	-	-
Red	0.665	0.335	0.645	0.335	0.721	0.259	0.735	0.265	-	-	-	-	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.331	0.545	0.334	0.529	0.304	0.522	0.263	0.513	0.204	0.424	0.178	0.466	0.241	0.532
Blue	0.197	0.075	0.205	0.331	0.143	0.371	0.081	0.276	-	-	-	-	-	-
Green	0.015	0.458	0.135	0.468	0.155	0.536	0.115	0.582	-	-	-	-	-	-
Yellow	0.313	0.553	0.311	0.546	0.385	0.541	0.389	0.542	-	-	-	-	-	-
Red	0.468	0.530	0.450	0.526	0.618	0.500	0.624	0.506	-	-	-	-	-	-

Colour	8		9		10		11	
	x	y	x	x	x	y	x	y
White	0.453	0.440	0.500	0.440	0.525	0.440	0.565	0.413
Blue	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-
Yellow	-	-	-	-	-	-	-	-
Red	-	-	-	-	-	-	-	-
	u'	v'	u'	v'	u'	v'	u'	v'
White	0.246	0.537	0.275	0.544	0.291	0.548	0.331	0.545
Blue	-	-	-	-	-	-	-	-
Green	-	-	-	-	-	-	-	-
Yellow	-	-	-	-	-	-	-	-
Red	-	-	-	-	-	-	-	-

Table 8

INSTRUMENT RANGE COLOUR MARKINGS
(IN ILLUMINATION A)

Colour	1		2	
	x	y	x	y
Green	0.406	0.493	0.422	0.505
Yellow	0.523	0.444	0.539	0.458
Red	0.638	0.327	0.642	0.335
	u'	v'	u'	v'
Green	0.200	0.548	0.206	0.553
Yellow	0.287	0.549	0.291	0.556
Red	0.452	0.521	0.448	0.526

Table 9

CIE 2.2 SURFACES (ORDINARY)

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.350	0.360	0.300	0.310	0.290	0.320	0.340	0.370	0.350	0.360
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395	0.385	0.355
Blue	0.137	0.038	0.225	0.184	0.196	0.250	0.078	0.171	-	-
Green	0.013	0.486	0.209	0.383	0.313	0.453	0.313	0.682	-	-
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477	-	-
Brown	0.510	0.370	0.427	0.353	0.407	0.373	0.475	0.405	0.510	0.370
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.212	0.489	0.196	0.456	0.185	0.460	0.201	0.493	0.212	0.489
Black	0.237	0.492	0.213	0.431	0.168	0.450	0.196	0.504	0.237	0.492
Blue	0.172	0.108	0.189	0.348	0.140	0.401	0.064	0.314	-	-
Green	0.006	0.497	0.117	0.480	0.160	0.522	0.119	0.581	-	-
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559	-	-
Brown	0.318	0.519	0.268	0.498	0.244	0.504	0.275	0.528	0.318	0.519
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 10

CIE 2.2 SURFACES (ORDINARY) BACKGROUND GREEN

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.350	0.360	0.300	0.310	0.290	0.320	0.340	0.370	0.350	0.360
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395	0.385	0.355
Blue	0.137	0.038	0.225	0.184	0.196	0.250	0.078	0.171	-	-
Green	0.026	0.399	0.177	0.362	0.313	0.453	0.313	0.682	-	-
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477	-	-
Brown	0.510	0.370	0.427	0.353	0.407	0.373	0.475	0.405	0.510	0.370
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.212	0.489	0.196	0.456	0.185	0.460	0.201	0.493	0.212	0.489
Black	0.237	0.492	0.213	0.431	0.168	0.450	0.196	0.504	0.237	0.492
Blue	0.172	0.108	0.189	0.348	0.140	0.401	0.064	0.314	-	-
Green	0.013	0.464	0.101	0.466	0.160	0.522	0.119	0.581	-	-
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559	-	-
Brown	0.318	0.519	0.268	0.498	0.244	0.504	0.275	0.528	0.318	0.519
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 11

IALA - SURFACES (ORDINARY)

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.350	0.360	0.300	0.310	0.290	0.320	0.340	0.370	0.350	0.360
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395	0.385	0.355
Blue	0.137	0.038	0.225	0.184	0.196	0.250	0.078	0.171	-	-
Green	0.004	0.632	0.238	0.402	0.313	0.453	0.313	0.682	-	-
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477	-	-
Brown	0.510	0.370	0.427	0.353	0.407	0.373	0.475	0.405	0.510	0.370
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.212	0.489	0.196	0.456	0.185	0.460	0.201	0.493	0.212	0.489
Black	0.237	0.492	0.213	0.431	0.168	0.450	0.196	0.504	0.237	0.492
Blue	0.172	0.108	0.189	0.348	0.140	0.401	0.064	0.314	-	-
Green	0.002	0.538	0.130	0.492	0.160	0.522	0.119	0.581	-	-
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559	-	-
Brown	0.318	0.519	0.268	0.498	0.244	0.504	0.275	0.528	0.318	0.519
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 12

CIE 2.2 SURFACES (FLUORESCENT)

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Green	0.013	0.486	0.209	0.383	0.313	0.453	0.313	0.682
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310
	u'	v'	u'	v'	u'	v'	u'	v'
Green	0.006	0.497	0.117	0.480	0.160	0.522	0.119	0.581
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523

Table 13

IALA - SURFACES (FLUORESCENT)

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Green	0.004	0.632	0.238	0.402	0.313	0.453	0.313	0.682
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310
	u'	v'	u'	v'	u'	v'	u'	v'
Green	0.002	0.538	0.130	0.492	0.160	0.522	0.119	0.581
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523

Table 14

CIE 2.2 SURFACES RETRO-REFLECTING

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.355	0.355	0.305	0.305	0.285	0.325	0.335	0.375	0.355	0.355
Blue	0.137	0.038	0.210	0.160	0.150	0.220	0.078	0.171	-	-
Green	0.026	0.399	0.177	0.362	0.248	0.409	0.007	0.703	-	-
Yellow	0.465	0.534	0.427	0.483	0.487	0.423	0.545	0.454	-	-
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.217	0.488	0.202	0.454	0.180	0.462	0.196	0.494	0.217	0.488
Blue	0.172	0.108	0.187	0.320	0.112	0.371	0.064	0.314	-	-
Green	0.013	0.464	0.101	0.466	0.133	0.497	0.003	0.554	-	-
Yellow	0.219	0.567	0.215	0.547	0.274	0.536	0.296	0.555	-	-
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 15

CIE 2.2 SURFACES TRANSILLUMINATED

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.440	0.382	0.285	0.264	0.285	0.332	0.440	0.432	0.440	0.382
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395	0.385	0.355
Blue	0.137	0.038	0.225	0.184	0.196	0.250	0.078	0.171	-	-
Green	0.013	0.486	0.209	0.383	0.313	0.453	0.313	0.682	-	-
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477	-	-
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.263	0.513	0.204	0.424	0.178	0.466	0.241	0.532	0.263	0.513
Black	0.237	0.492	0.213	0.431	0.168	0.450	0.196	0.504	0.237	0.492
Blue	0.172	0.108	0.189	0.348	0.140	0.401	0.064	0.314	-	-
Green	0.006	0.497	0.117	0.480	0.160	0.522	0.119	0.581	-	-
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.271	0.559	-	-
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 16

CIE 2.2 SURFACES TRANSILLUMINATED BACKGROUND GREEN

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
White	0.440	0.382	0.285	0.264	0.285	0.332	0.440	0.432	0.440	0.382
Black	0.385	0.355	0.300	0.270	0.260	0.310	0.345	0.395	0.385	0.355
Blue	0.137	0.038	0.225	0.184	0.196	0.250	0.078	0.171	-	-
Green	0.026	0.399	0.177	0.362	0.313	0.453	0.313	0.682	-	-
Yellow	0.465	0.534	0.427	0.483	0.470	0.440	0.522	0.477	-	-
Orange	0.570	0.429	0.506	0.404	0.535	0.375	0.610	0.390	-	-
Red	0.655	0.345	0.569	0.341	0.595	0.315	0.690	0.310	-	-
Purple	0.457	0.136	0.374	0.247	0.307	0.203	0.302	0.064	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
White	0.263	0.513	0.204	0.424	0.178	0.466	0.241	0.532	0.263	0.513
Black	0.237	0.492	0.213	0.431	0.168	0.450	0.196	0.504	0.237	0.492
Blue	0.172	0.108	0.189	0.348	0.140	0.401	0.064	0.314	-	-
Green	0.013	0.464	0.101	0.466	0.160	0.522	0.119	0.581	-	-
Yellow	0.219	0.567	0.215	0.547	0.256	0.540	0.272	0.559	-	-
Orange	0.325	0.551	0.296	0.532	0.333	0.525	0.378	0.543	-	-
Red	0.449	0.533	0.382	0.516	0.426	0.507	0.517	0.523	-	-
Purple	0.492	0.329	0.287	0.426	0.255	0.379	0.382	0.182	-	-

Table 17

NATO STANAG 3224

Colour	1		2		3		4		5	
	x	y	x	y	x	y	x	y	x	y
Incan white	0.530	0.380	0.480	0.380	0.480	0.410	0.530	0.410	0.530	0.380
Blue white	0.460	0.385	0.420	0.385	0.420	0.425	0.460	0.425	0.460	0.385
Red	0.664	0.336	0.655	0.335	0.703	0.287	0.714	0.286	-	-
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
Incan white	0.326	0.526	0.291	0.518	0.276	0.530	0.309	0.538	0.326	0.526
Blue white	0.275	0.517	0.248	0.511	0.231	0.527	0.256	0.533	0.275	0.517
Red	0.466	0.530	0.459	0.528	0.558	0.513	0.571	0.514	-	-

Table 18

SHADOW MASKS

Phosphor	1		2		3	
	x	y	x	y	x	y
Sulph/sil/phos	0.146	0.052	0.218	0.712	0.674	0.326
Sulph	0.155	0.060	0.285	0.600	0.663	0.337
Sulph/van	0.157	0.047	0.260	0.600	0.650	0.325
Sulph/oxysulph	0.150	0.068	0.300	0.600	0.628	0.337
Sulph/oxide	0.150	0.070	0.330	0.590	0.640	0.335
Sulph/oxysulph	0.155	0.067	0.326	0.591	0.623	0.342
	u'	v'	u'	v'	u'	v'
Sulph/sil/phos	0.175	0.140	0.079	0.577	0.485	0.527
Sulph	0.182	0.158	0.118	0.561	0.464	0.530
Sulph/van	0.193	0.130	0.107	0.558	0.464	0.522
Sulph/oxysulph	0.171	0.174	0.125	0.563	0.434	0.524
Sulph/oxide	0.170	0.178	0.140	0.564	0.446	0.525
Sulph/oxysulph	0.177	0.173	0.138	0.564	0.425	0.525
Boundaries	x	y	x	y	x	y
Outer	0.146	0.052	0.218	0.712	0.674	0.326
Inner	0.150	0.068	0.300	0.600	0.628	0.337
	u'	v'	u'	v'	u'	v'
Outer	0.175	0.141	0.079	0.577	0.485	0.527
Inner	0.171	0.174	0.125	0.563	0.434	0.524

Table 19

SHADOW MASK BOUNDARIES

		Vertex 1 x	Vertex 1 y	Vertex 2 x	Vertex 2 y	Vector equation $y = mx + c$
Outer boundary	Side 1	0.1460	0.0520	0.2180	0.7120	$y = 9.1670x - 1.2860$
	Side 2	0.2180	0.7120	0.6740	0.3260	$y = -0.8460x + 0.8970$
	Side 3	0.6740	0.3260	0.1460	0.0520	$y = 0.5190x - 0.0240$
Inner boundary	Side 1	0.1500	0.0680	0.3000	0.6000	$y = 3.5470x - 0.4640$
	Side 2	0.3000	0.6000	0.6280	0.3370	$y = -0.8020x + 0.8410$
	Side 3	0.6280	0.3370	0.1500	0.0680	$y = 0.5630x - 0.0160$

Table 20

SHADOW MASK INTERVALS (4)

Interval	Side 1 u'	Side 1 v'	Side 2 u'	Side 2 v'	Side 3 u'	Side 3 v'
1	0.1706	0.1741	0.1250	0.5625	0.4340	0.5240
2	0.1554	0.3036	0.2280	0.5497	0.3462	0.4704
3	0.1402	0.4330	0.3310	0.5368	0.2584	0.2907
4	0.1250	0.5625	0.4340	0.5240	0.1706	0.1741

	u'	v'
Centre of gravity	0.2432	0.4202
Complementary 1	0.1478	0.3683
Complementary 2	0.2795	0.5433
Complementary 3	0.3023	0.3491

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Table 21

SHADOW MASK INTERVALS (13)

	Side 1 (B)		Side 2 (G)		Side 3 (R)	
Interval	u'	v'	u'	v'	u'	v'
1	0.1706	0.1741	0.1250	0.5625	0.4340	0.5240
2	0.1668	0.2065	0.1508	0.5593	0.4121	0.4948
3	0.1630	0.2388	0.1765	0.5561	0.3901	0.4657
4	0.1592	0.2712	0.2023	0.5529	0.3682	0.4365
5	0.1554	0.3036	0.2280	0.5497	0.3462	0.4074
6	0.1516	0.3359	0.2538	0.5465	0.3243	0.3782
7	0.1478	0.3683	0.2795	0.5433	0.3023	0.3491
8	0.1440	0.4007	0.3053	0.5400	0.2804	0.3199
9	0.1402	0.4330	0.3310	0.5368	0.2584	0.2907
10	0.1364	0.4654	0.3568	0.5336	0.2365	0.2616
11	0.1326	0.4978	0.3825	0.5304	0.2145	0.2324
12	0.1288	0.5301	0.4083	0.5272	0.1926	0.2033
13	0.1250	0.5625	0.4340	0.5240	0.1706	0.1741

	u'	v'
Centre of gravity	0.2432	0.4202
Complementary 1	0.1478	0.3683
Complementary 2	0.2795	0.5433
Complementary 3	0.3023	0.3491

Table 22

NO-GO AND COLOUR AREA SPECIFICATIONS

	1		2		3		4		5		6	
	R	THETA	R	THETA	R	THETA	R	THETA	R	THETA	R	THETA
Point 1	0.2636	263.2470	0.0864	231.4852	0.1024	117.3156	0.1292	33.7024	0.2159	7.0493	0.1698	299.1005
Point 2	0.1402	250.7639	0.0926	138.1507	0.0962	54.3931	0.2186	15.6321	0.1553	324.5395	0.2651	268.8758
7 JND R	0.1288		0.0192		0.0268		0.0891		0.0386		0.0537	
No-go	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
Corner 1	0.1668	0.2065	0.1440	0.4007	0.1508	0.5593	0.3053	0.5400	0.4121	0.4948	0.2804	0.3199
Corner 2	0.1827	0.3404	0.1858	0.4532	0.1855	0.4921	0.2720	0.5178	0.2361	0.4730	0.2239	0.4214
Corner 3	0.1554	0.3467	0.1835	0.4811	0.2134	0.4901	0.2837	0.4923	0.2293	0.4459	0.1967	0.4146
Corner 4	0.1516	0.3359	0.1288	0.5301	0.2538	0.5465	0.4083	0.5272	0.3243	0.3782	0.1926	0.2033
Vec 1	v' = 8.4210u' - 1.1980		v' = 1.2560u' + 0.2200		v' = -1.9370u' + 0.8510		v' = 0.6670u' + 0.3360		v' = 0.1240u' + 0.4440		v' = -1.7960u' + 0.8240	
Vec 2	v' = 2.8420u' - 0.0950		v' = -0.8960u' + 0.6450		v' = 1.3960u' + 0.1920		v' = 0.2800u' + 0.4130		v' = -0.7130u' + 0.6090		v' = 51.5370u' - 9.7230	
Colour	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
Corner 1	0.1516	0.3359	0.1288	0.5301	0.2538	0.5465	0.4083	0.5272	0.3243	0.3782	0.1926	0.2033
Corner 2	0.1794	0.4154	0.1561	0.5057	0.2304	0.5138	0.2517	0.4834	0.2434	0.4358	0.1967	0.4123
Corner 3	0.1629	0.4245	0.1721	0.5181	0.2444	0.4994	0.2534	0.4752	0.2250	0.4194	0.1912	0.4127
Corner 4	0.1440	0.4007	0.1508	0.5593	0.3053	0.5400	0.4121	0.4948	0.2804	0.3199	0.1668	0.2065

Table 23

COLOUR SPACING INTERVALS

	Vector equation
Side 1	$v' = -8.5175u' + 1.6272$
Side 2	$v' = -0.1246u' + 0.5781$
Side 3	$v' = 1.3284u' - 0.0525$

Interval	1 (2)		2 (4)		3 (6)		4 (8)		5 (10)		6 (12)	
	R	THETA	R	THETA	R	THETA	R	THETA	R	THETA	R	THETA
Side 1 (B)	0.2637	263.2478	0.2008	258.9195	0.1402	250.7595	0.0864	231.4990	0.0615	182.7041	0.0927	138.1354
Side 2 (G)	0.1024	117.3426	0.0847	86.9881	0.0961	54.4028	0.1292	33.7300	0.1719	22.3416	0.2185	15.6378
Side 3 (R)	0.2159	7.0619	0.1733	349.4342	0.1553	324.5313	0.1698	299.0844	0.2103	280.5899	0.2651	268.8652
	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'	u'	v'
Side 1 (B)	0.1668	0.2065	0.1592	0.2712	0.1516	0.3359	0.1440	0.4007	0.1364	0.4654	0.1288	0.5301
Side 2 (G)	0.1508	0.5593	0.2023	0.5529	0.2538	0.5465	0.3053	0.5400	0.3568	0.5336	0.4083	0.5272
Side 3 (R)	0.4121	0.4948	0.3682	0.4365	0.3243	0.3782	0.2804	0.3199	0.2365	0.2616	0.1926	0.2033

Table 24

COLOUR SPACING CORNER VALUES AND VECTOR EQUATIONS (SINGLE INTERMEDIATE COLOUR)

	Corner values				Vector equation	Corner values				Vector equation
	1		2		v' = mu' + c	3		4		v' = mu' + c
Colour	u'	v'	u'	v'		u'	v'	u'	v'	
1	0.1516	0.3359	0.1554	0.3468	v' = 2.8651u' - 0.0984	0.1629	0.4245	0.1440	0.4007	v' = 1.2571u' + 0.2196
2	0.1288	0.5301	0.1561	0.5057	v' = -0.8961u' + 0.6456	0.1721	0.5180	0.1508	0.5593	v' = -1.9339u' + 0.8508
3	0.2538	0.5465	0.2304	0.5138	v' = 1.3969u' + 0.1920	0.2719	0.5177	0.3053	0.5400	v' = 0.6677u' + 0.3362
4	0.4083	0.5272	0.2835	0.4923	v' = 0.2799u' + 0.4129	0.2534	0.4752	0.4121	0.4948	v' = 0.1239u' + 0.4438
5	0.3243	0.3782	0.2434	0.4358	v' = -0.7125u' + 0.6092	0.2250	0.4194	0.2804	0.3199	v' = -1.7978u' + 0.8239
6	0.1926	0.2033	0.1967	0.4123	v' = 50.4841u' - 9.5175	0.1827	0.3405	0.1668	0.2065	v' = 8.4462u' - 1.2024

Table 25

COLOUR SPACING CORNER VALUES AND VECTOR EQUATIONS (TWO INTERMEDIATE COLOURS)

	Corner values				Vector equation	Corner values				Vector equation
	1		2		v' = mu' + c	3		4		v' = mu' + c
Colour	u'	v'	u'	v'		u'	v'	u'	v'	
1	0.1592	0.2712	0.1265	0.1045	v' = 5.1062u' - 0.5417	0.1702	0.3893	0.1516	0.3359	v' = 2.8651u' - 0.0984
2	0.1440	0.4007	0.1457	0.4028	v' = 1.2571u' + 0.2196	0.1419	0.4657	0.1364	0.4654	v' = 0.0472u' + 0.4590
3	0.1288	0.5301	0.1561	0.5057	v' = -0.8961u' + 0.6456	0.1721	0.5180	0.1508	0.5593	v' = -1.9339u' + 0.8508
4	0.2023	0.5529	0.2007	0.5242	v' = 19.0056u' - 3.2910	0.2432	0.5317	0.2538	0.5465	v' = 1.3969u' + 0.1920
5	0.3053	0.5400	0.2627	0.5116	v' = 0.6677u' + 0.3362	0.4193	0.5593	0.3568	0.5336	v' = 0.4110u' + 0.3870
6	0.4083	0.5272	0.4284	0.5328	v' = 0.2799u' + 0.4129	0.2885	0.4795	0.4121	0.4948	v' = 0.1239u' + 0.4438
7	0.3682	0.4365	0.2876	0.4515	v' = -0.1865u' + 0.5052	0.2496	0.4314	0.3243	0.3782	v' = -0.7125u' + 0.6092
8	0.2804	0.3199	0.2287	0.4127	v' = -1.7978u' + 0.8239	0.2230	0.3336	0.2365	0.2616	v' = -5.3486u' + 1.5263
9	0.1926	0.2033	0.1951	0.3313	v' = 50.4841u' - 9.5175	0.1542	0.1001	0.1668	0.2065	v' = 8.4462u' - 1.2024

Table 26

SHADOW MASK DESATURATION

	Illumination	0 units		10 units		100 units	
	Colour	u'	v'	u'	v'	u'	v'
Side 1 (B)	1	0.1706	0.1741	0.1758	0.2304	0.1897	0.3809
	2	0.1554	0.3036	0.1678	0.3517	0.1895	0.4362
	3	0.1402	0.4330	0.1615	0.4461	0.1894	0.4632
	4	0.1250	0.5625	0.1565	0.5217	0.1894	0.4792
Side 2 (G)	1	0.1250	0.5625	0.1565	0.5217	0.1894	0.4792
	2	0.2280	0.5497	0.2151	0.5149	0.2014	0.4779
	3	0.3310	0.5368	0.2748	0.5079	0.2139	0.4766
	4	0.4340	0.5240	0.3357	0.5008	0.2269	0.4752
Side 3 (R)	1	0.4340	0.5240	0.3357	0.5008	0.2269	0.4752
	2	0.3462	0.4074	0.2933	0.4291	0.2205	0.4590
	3	0.2584	0.2907	0.2412	0.3410	0.2100	0.4324
	4	0.1706	0.1741	0.1758	0.2304	0.1897	0.3809
	C of G	0.2432	0.4202	0.2227	0.4176	0.2020	0.4451
	Comp 1	0.1478	0.3683	0.1662	0.3760	0.1896	0.4301
	Comp 2	0.2795	0.5433	0.2461	0.5113	0.2081	0.4772
	Comp 3	0.3023	0.3491	0.2558	0.3656	0.2083	0.4280

Table 27

COLOUR BOUNDARIES (ONE INTERMEDIATE COLOUR)

	Corner values				Vector equation $v' = mu' + c$	Corner values				Vector equation $v' = mu' + c$
	1		2			3		4		
Colour	u'	v'	u'	v'		u'	v'	u'	v'	
1	0.1516	0.3359	0.1554	0.3468	$v' = 2.8651u' - 0.0984$	0.1455	0.4026	0.1440	0.4007	$v' = 1.2571u' + 0.2196$
2	0.1288	0.5301	0.1352	0.5244	$v' = -0.8961u' + 0.6456$	0.1592	0.5429	0.1508	0.5593	$v' = -1.9339u' + 0.8508$
3	0.2538	0.5465	0.2467	0.5366	$v' = 1.3969u' + 0.1920$	0.2719	0.5177	0.3053	0.5400	$v' = 0.6677u' + 0.3362$
4	0.4083	0.5272	0.2835	0.4923	$v' = 0.2799u' + 0.4129$	0.2812	0.4786	0.4121	0.4948	$v' = 0.1239u' + 0.4438$
5	0.3243	0.3782	0.2662	0.4196	$v' = -0.7125u' + 0.6092$	0.2386	0.3949	0.2804	0.3199	$v' = -1.7978u' + 0.8239$
6	0.1926	0.2033	0.1961	0.3843	$v' = 50.4841u' - 9.5175$	0.1827	0.3405	0.1668	0.2065	$v' = 8.4462u' - 1.2024$

Table 28

COLOUR BOUNDARIES (TWO INTERMEDIATE COLOURS)

	Corner values				Vector equation $v' = mu' + c$	Corner values				Vector equation $v' = mu' + c$
	1		2			3		4		
Colour	u'	v'	u'	v'		u'	v'	u'	v'	
1	0.1592	0.2712	0.1265	0.1045	$v' = 5.1062u' - 0.5417$	0.1701	0.3890	0.1516	0.3359	$v' = 2.8651u' - 0.0984$
2	0.1440	0.4007	0.1455	0.4026	$v' = 1.2571u' + 0.2196$	0.1139	0.4643	0.1364	0.4654	$v' = 0.0472u' + 0.4590$
3	0.1288	0.5301	0.1352	0.5244	$v' = -0.8961u' + 0.6456$	0.1592	0.5429	0.1508	0.5593	$v' = -1.9339u' + 0.8508$
4	0.2023	0.5529	0.2022	0.5522	$v' = 19.0056u' - 3.2910$	0.2467	0.5366	0.2538	0.5465	$v' = 1.3969u' + 0.1920$
5	0.3053	0.5400	0.2677	0.5149	$v' = 0.6677u' + 0.3362$	0.4193	0.5593	0.3568	0.5336	$v' = 0.4110u' + 0.3870$
6	0.4083	0.5272	0.4284	0.5328	$v' = 0.2799u' + 0.4129$	0.2885	0.4795	0.4121	0.4948	$v' = 0.1239u' + 0.4438$
7	0.3682	0.4365	0.2876	0.4515	$v' = -0.1865u' + 0.5052$	0.2662	0.4196	0.3243	0.3782	$v' = -0.7125u' + 0.6092$
8	0.2804	0.3199	0.2386	0.3949	$v' = -1.7978u' + 0.8239$	0.2230	0.3336	0.2365	0.2616	$v' = -5.3486u' + 1.5263$
9	0.1926	0.2033	0.1951	0.3313	$v' = 50.4841u' - 9.5175$	0.1542	0.1001	0.1668	0.2065	$v' = 8.4462u' - 1.2024$

Table 29

WP61/113 6+W

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Cyan	0.0253	0.0000	0.1894	0.1879	0.2036	0.2504	0.0000	0.1035
Green	0.1693	0.8871	0.2752	0.4745	0.3356	0.5087	0.3673	0.7551
Amber	0.6331	0.5780	0.4536	0.4385	0.4576	0.3872	0.7454	0.5031
Red	0.7181	0.3584	0.6378	0.3525	0.4285	0.3166	0.7788	0.2792
Magenta	0.4365	0.0306	0.3480	0.2438	0.3019	0.2221	0.2796	0.0000
Blue	0.1292	0.0000	0.2231	0.1684	0.2150	0.1781	0.0997	0.0000
	u'	v'	u'	v'	u'	v'	u'	v'
Cyan	0.0343	0.0000	0.1554	0.3468	0.1455	0.4026	0.0000	0.2196
Green	0.0509	0.6000	0.1352	0.5244	0.1592	0.5429	0.1297	0.6000
Amber	0.2921	0.6000	0.2467	0.5366	0.2719	0.5177	0.3951	0.6000
Red	0.4898	0.5500	0.4285	0.5328	0.2884	0.4795	0.6500	0.5243
Magenta	0.7000	0.1104	0.2662	0.4196	0.2386	0.3949	0.4582	0.0000
Blue	0.1885	0.0000	0.1951	0.3313	0.1827	0.3405	0.1424	0.0000

Table 30

WP61/113 7+W

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Cyan	0.0253	0.0000	0.1894	0.1879	0.2036	0.2504	0.0000	0.1035
Green	0.1693	0.8871	0.2752	0.4745	0.3356	0.5087	0.3673	0.7551
Yellow	0.5078	0.6615	0.4157	0.5045	0.4536	0.4385	0.6331	0.5780
Orange	0.7454	0.5031	0.4488	0.3837	0.6779	0.4019	0.7425	0.4148
Red	0.7181	0.3584	0.6378	0.3525	0.4285	0.3166	0.7788	0.2792
Magenta	0.4365	0.0306	0.3480	0.2438	0.3019	0.2221	0.2796	0.0000
Blue	0.1292	0.0000	0.2231	0.1684	0.2150	0.1781	0.0997	0.0000
	u'	v'	u'	v'	u'	v'	u'	v'
Cyan	0.0343	0.0000	0.1554	0.3468	0.1455	0.4026	0.0000	0.2196
Green	0.0509	0.6000	0.1352	0.5244	0.1592	0.5429	0.1297	0.6000
Yellow	0.2047	0.6000	0.2022	0.5522	0.2467	0.5366	0.2921	0.6000
Orange	0.3951	0.6000	0.2677	0.5149	0.4193	0.5593	0.4574	0.5750
Red	0.4898	0.5500	0.4285	0.5328	0.2884	0.4795	0.6500	0.5243
Magenta	0.7000	0.1104	0.2662	0.4196	0.2386	0.3949	0.4582	0.0000
Blue	0.1885	0.0000	0.1951	0.3313	0.1827	0.3405	0.1424	0.0000

Table 31

WP61/113 8+W

Colour	1		2		3		4	
	x	y	x	y	x	y	x	y
Cyan	0.0253	0.0000	0.1894	0.1879	0.2036	0.2504	0.0000	0.1035
Green	0.1693	0.8871	0.2752	0.4745	0.3356	0.5087	0.3673	0.7551
Yellow	0.5078	0.6615	0.4157	0.5045	0.4536	0.4385	0.6331	0.5780
Orange	0.7454	0.5031	0.4488	0.3837	0.6779	0.4019	0.7425	0.4148
Red	0.7181	0.3584	0.6378	0.3525	0.4285	0.3166	0.7788	0.2792
Mauve	0.6174	0.1469	0.3981	0.2778	0.3480	0.2438	0.4365	0.0306
Purple	0.2796	0.0000	0.3019	0.2221	0.2509	0.1668	0.1873	0.0000
Blue	0.1292	0.0000	0.2231	0.1684	0.2150	0.1781	0.0997	0.0000
	u'	v'	u'	v'	u'	v'	u'	v'
Cyan	0.0343	0.0000	0.1554	0.3468	0.1455	0.4026	0.0000	0.2196
Green	0.0509	0.6000	0.1352	0.5244	0.1592	0.5429	0.1297	0.6000
Yellow	0.2047	0.6000	0.2022	0.5522	0.2467	0.5366	0.2921	0.6000
Orange	0.3951	0.6000	0.2677	0.5149	0.4193	0.5593	0.4574	0.5750
Red	0.4898	0.5500	0.4285	0.5328	0.2884	0.4795	0.6500	0.5243
Mauve	0.7000	0.3747	0.2876	0.4515	0.2662	0.4196	0.7000	0.1104
Purple	0.4582	0.0000	0.2386	0.3949	0.2230	0.3336	0.2854	0.0000
Blue	0.1885	0.0000	0.1951	0.3313	0.1827	0.3405	0.1424	0.0000

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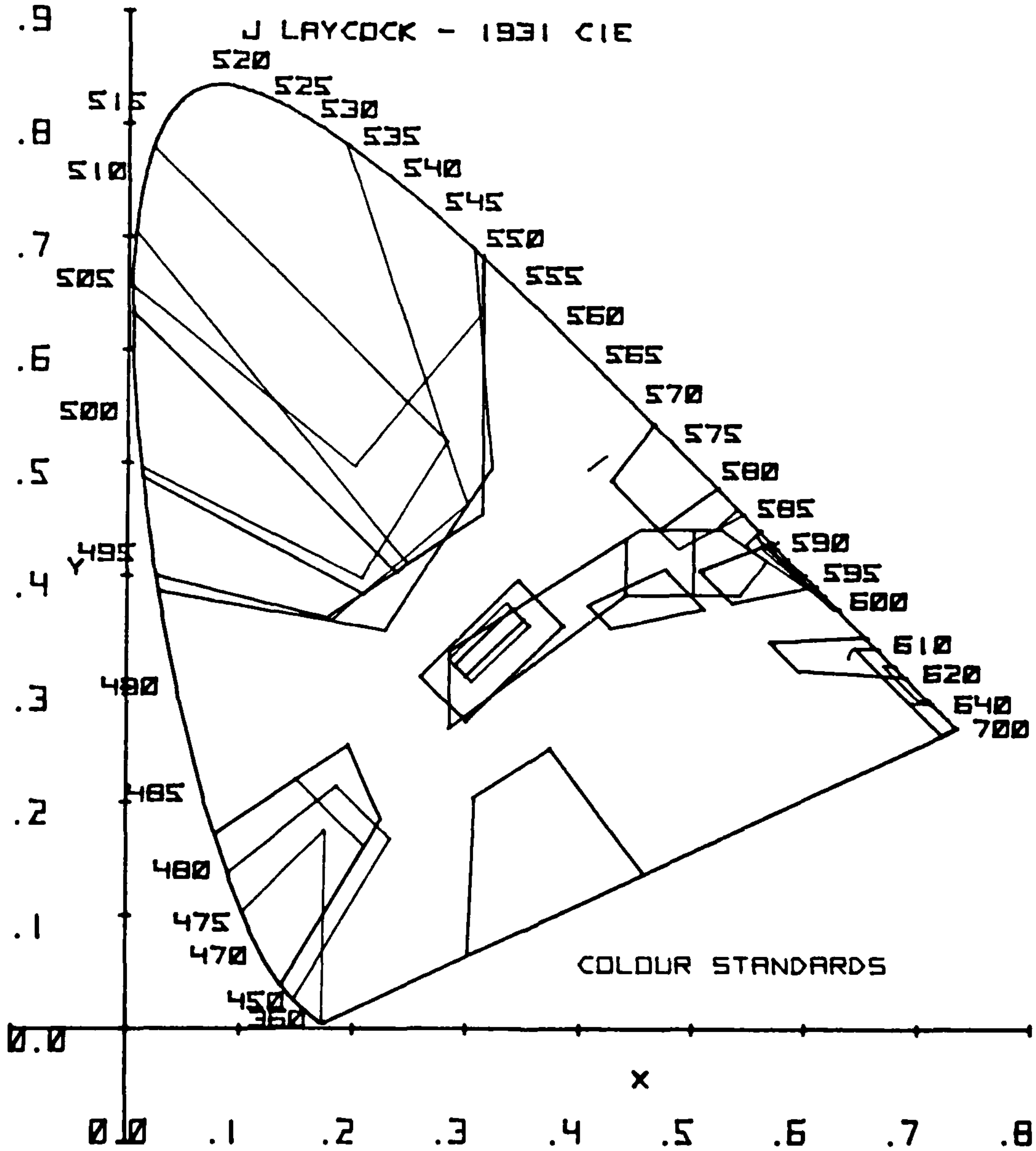

Fig 1

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Fig 2

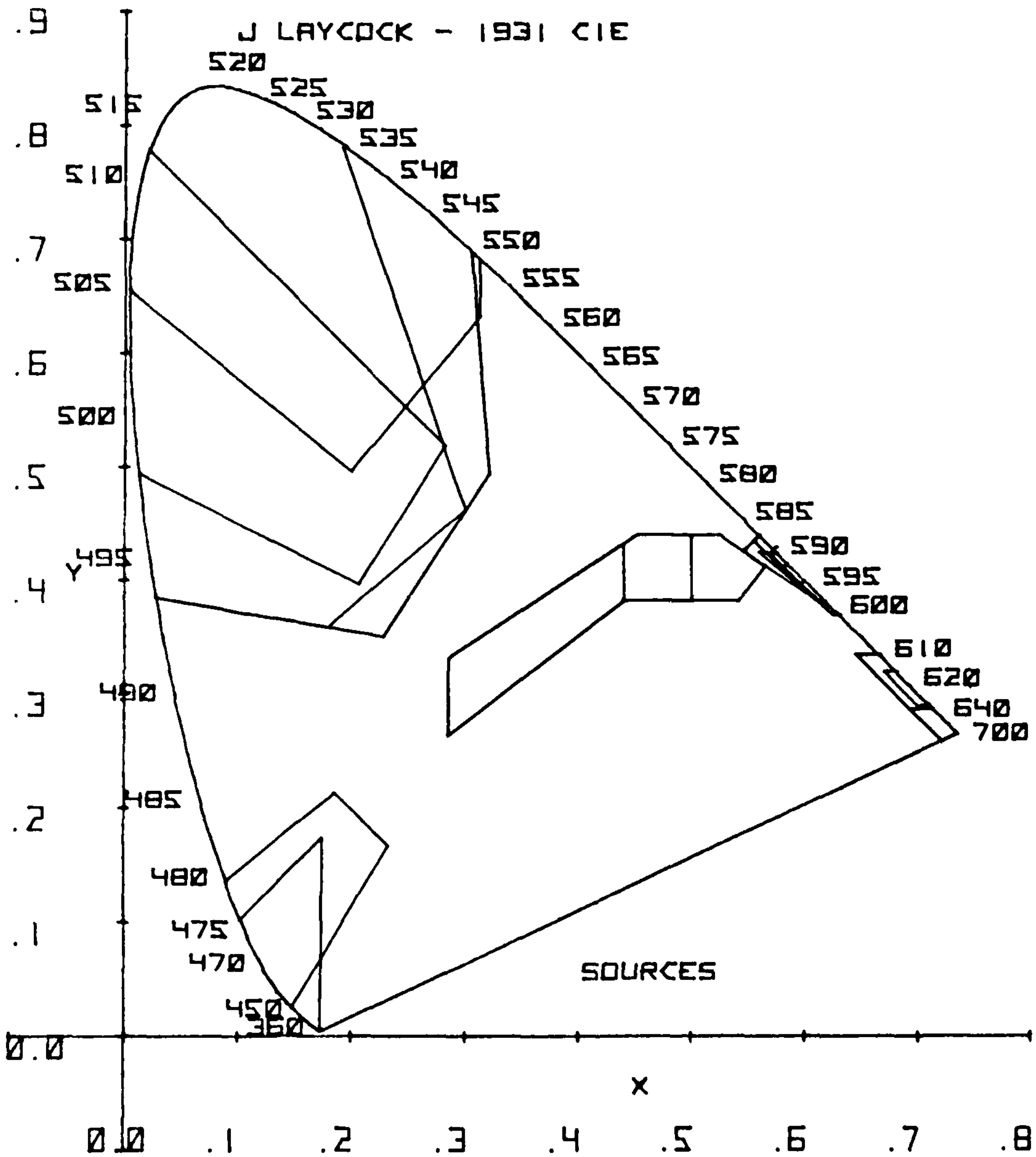

Fig 2

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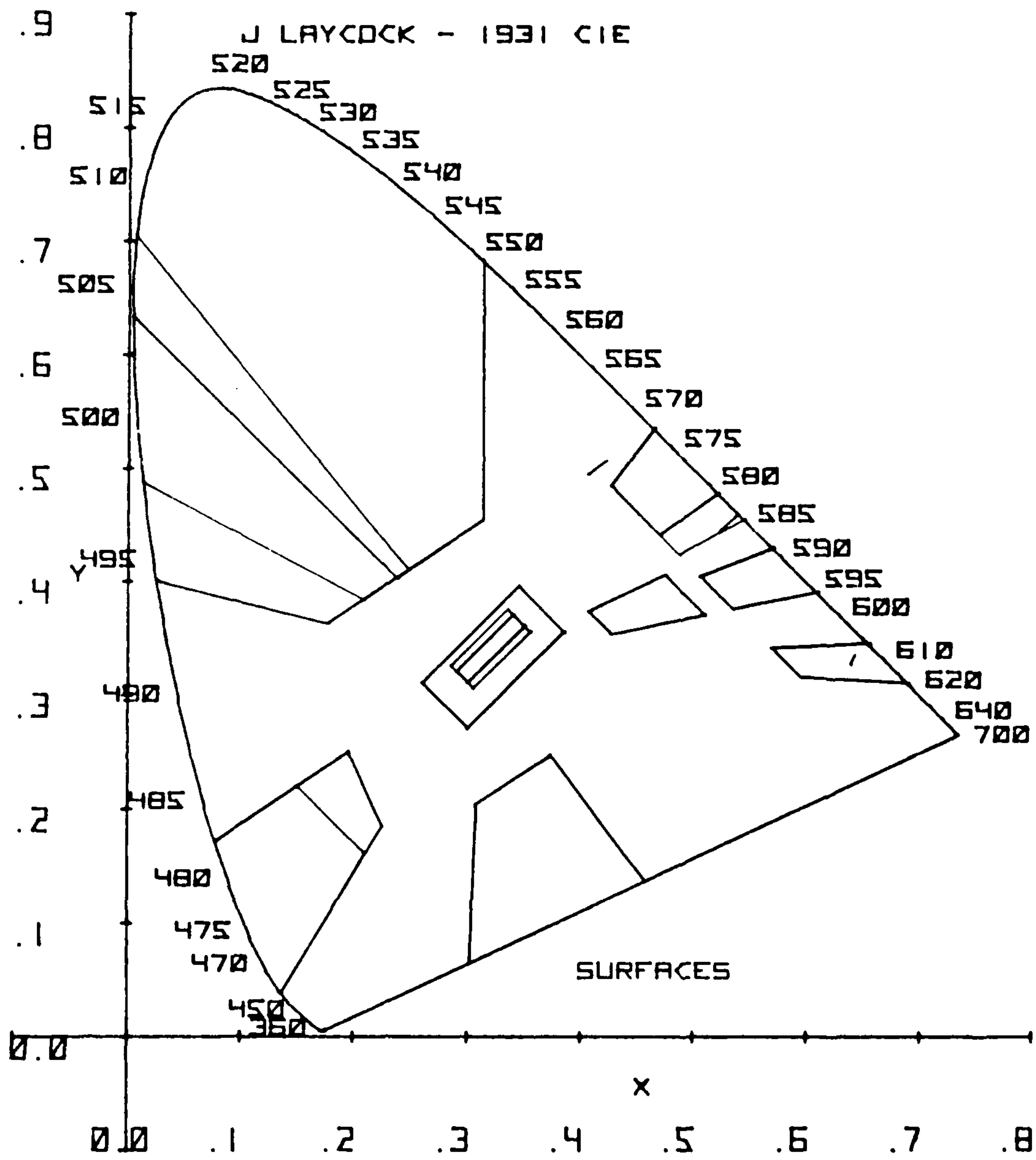
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Fig 3

Fig 4

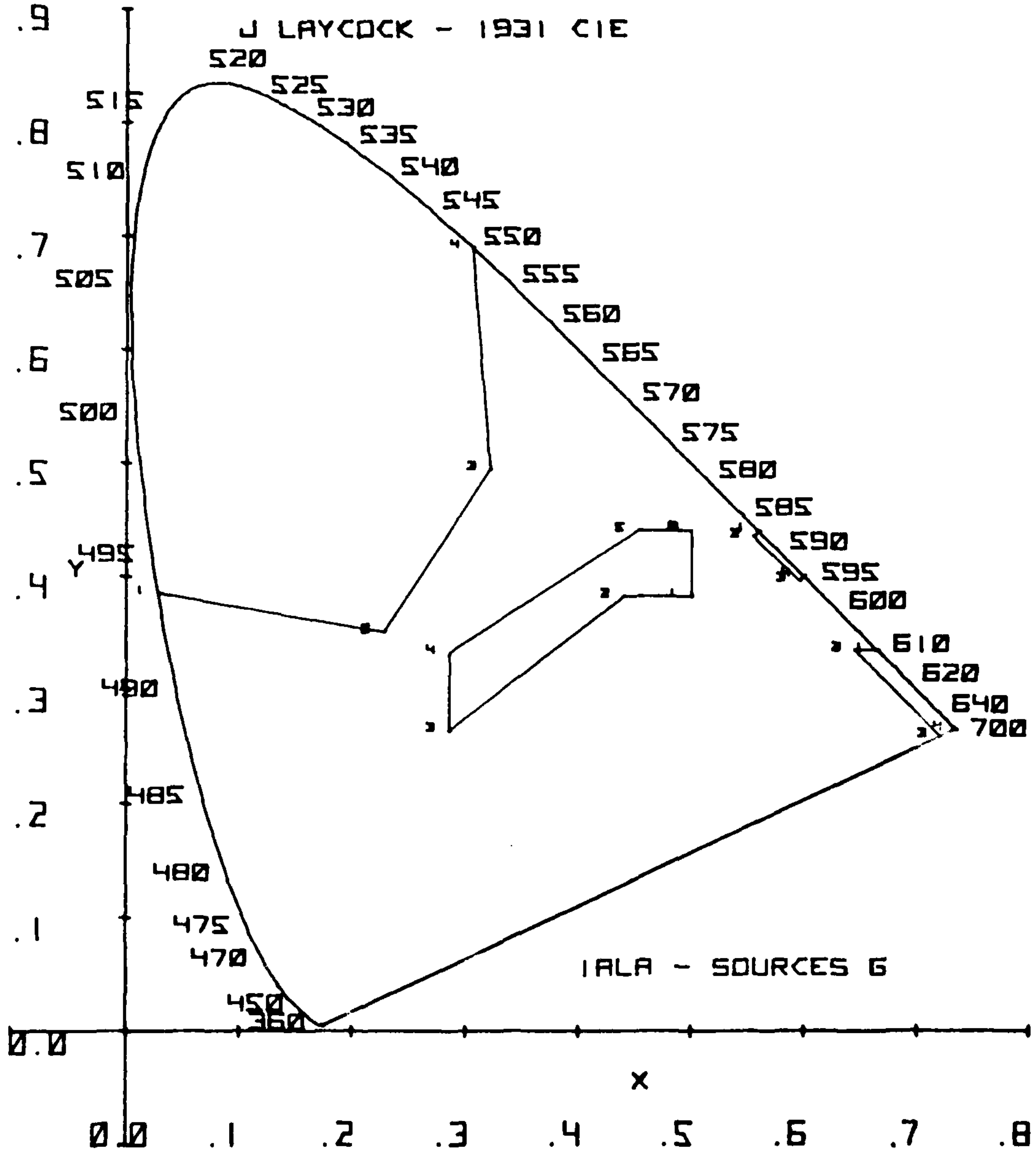

Fig 4

TR 82110

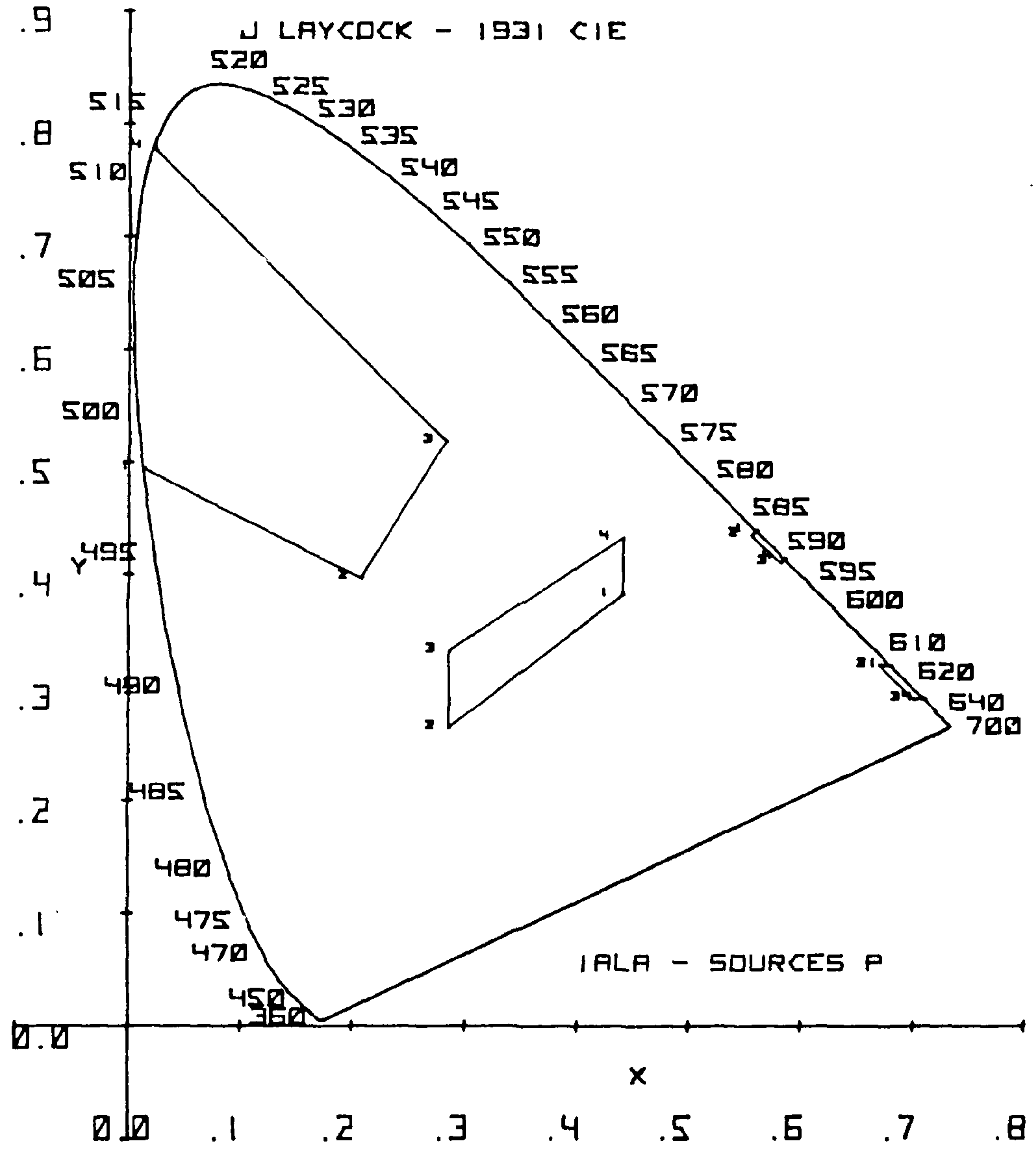
J LAYCOCK - 1931 CIE
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Fig 5

Fig 6

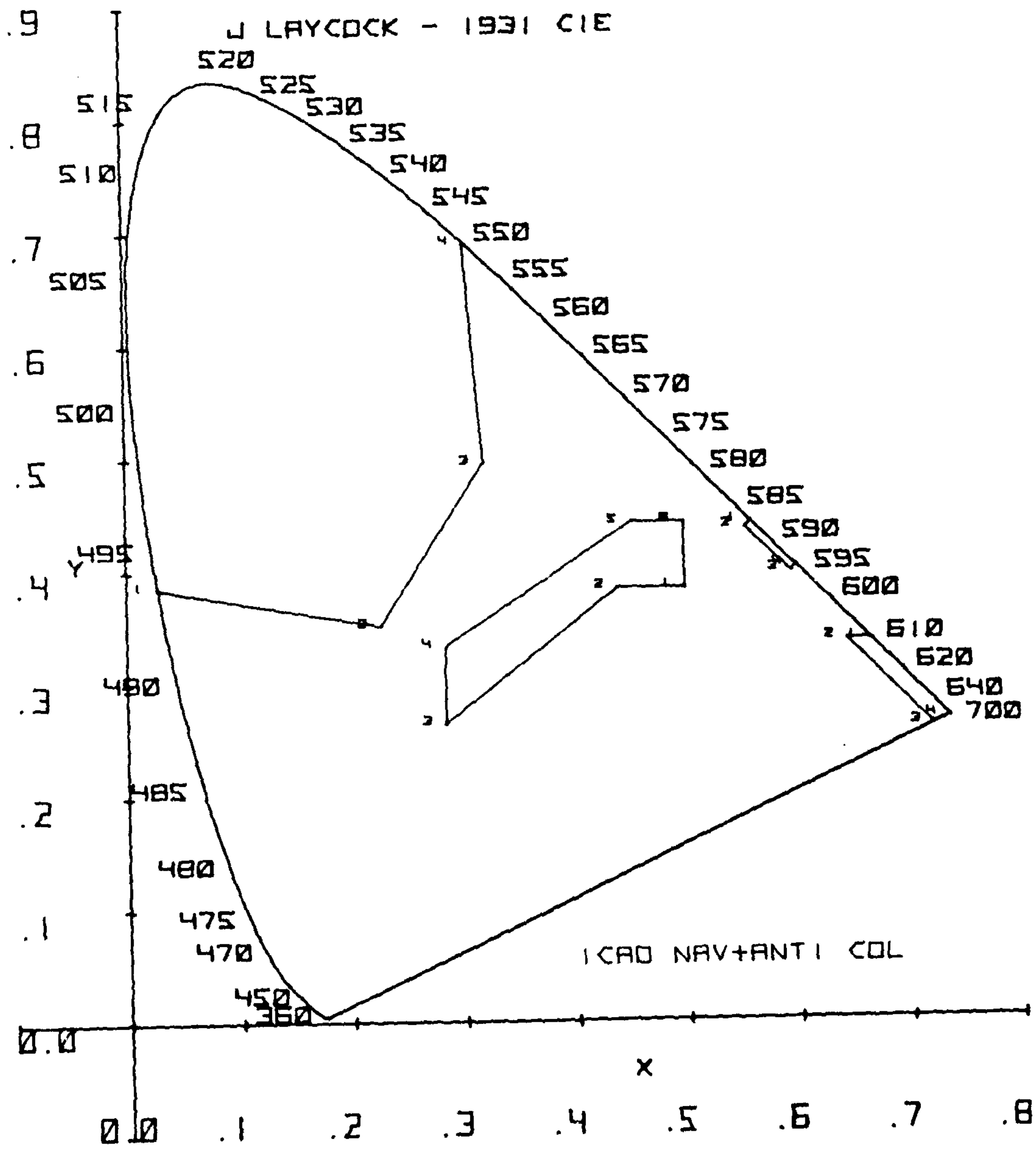
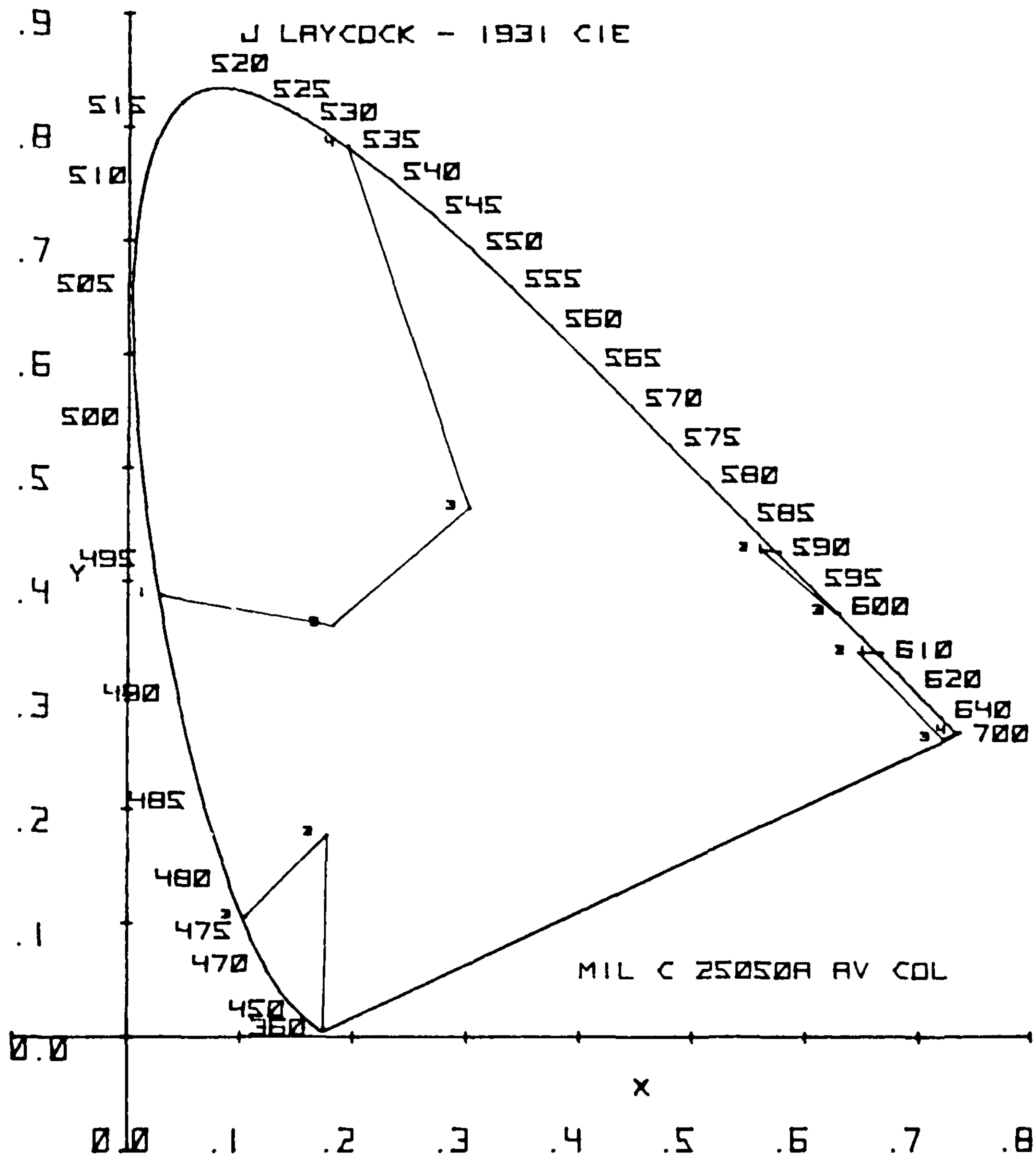


Fig 6

TR 82110



J LAYCOCK - 1931 CIE
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Fig 7

Fig 8

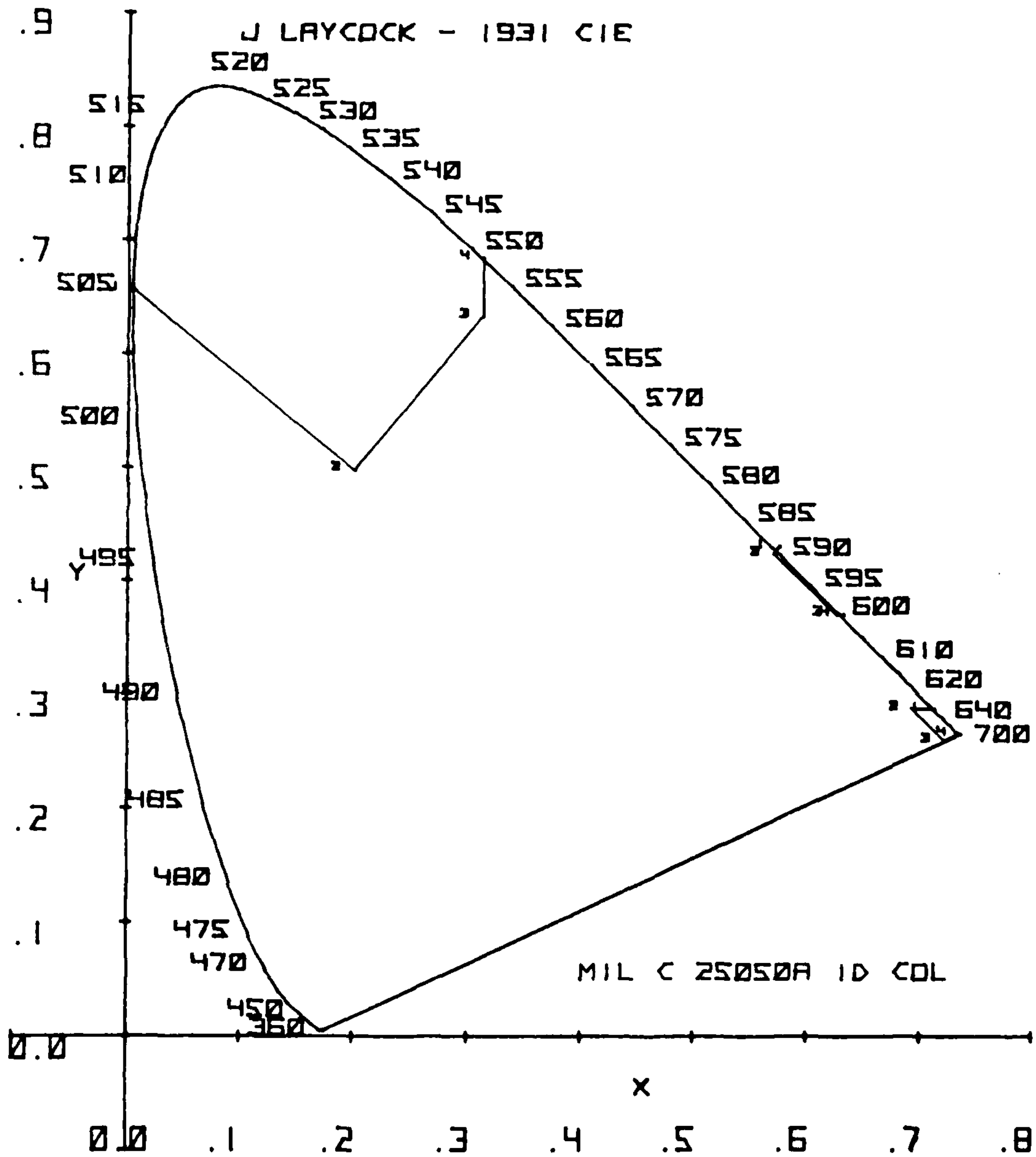
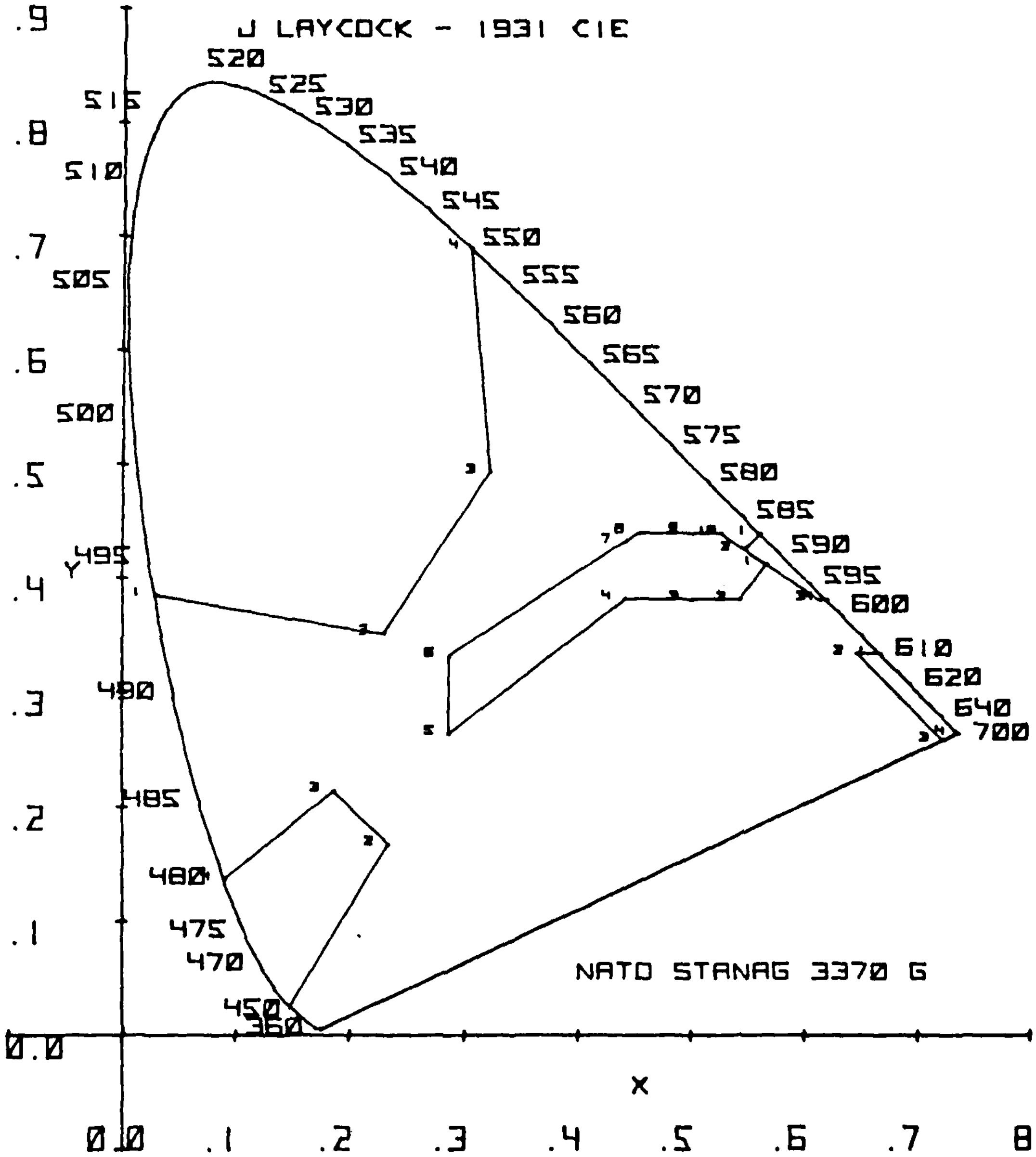


Fig 8

TR 82110



J LAYCOCK - 1931 CIE
NATO STANAG 3370 G
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Fig 9

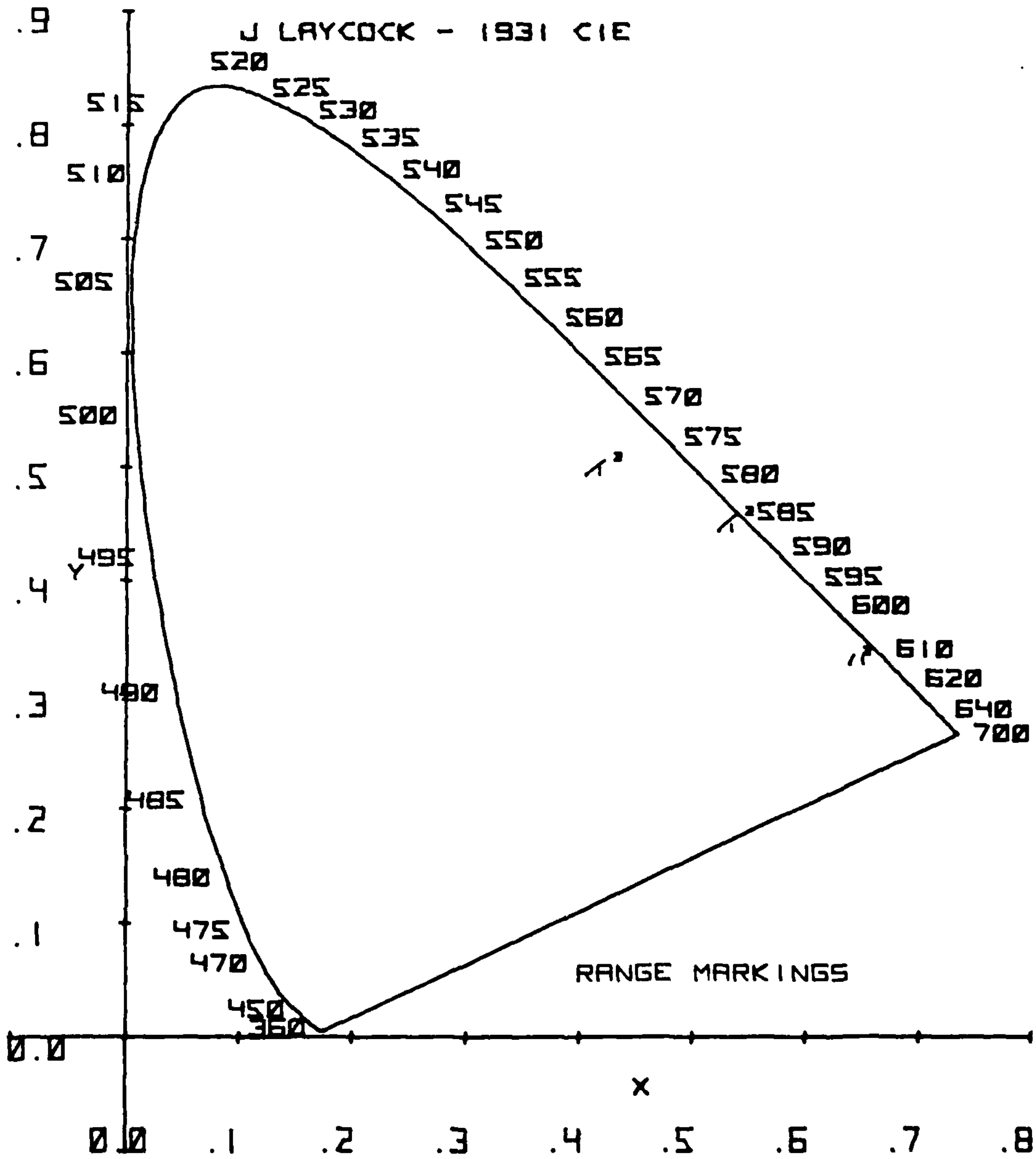
J LAYCOCK - 1931 CIE
RANGE MARKINGS
Y
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Fig 10

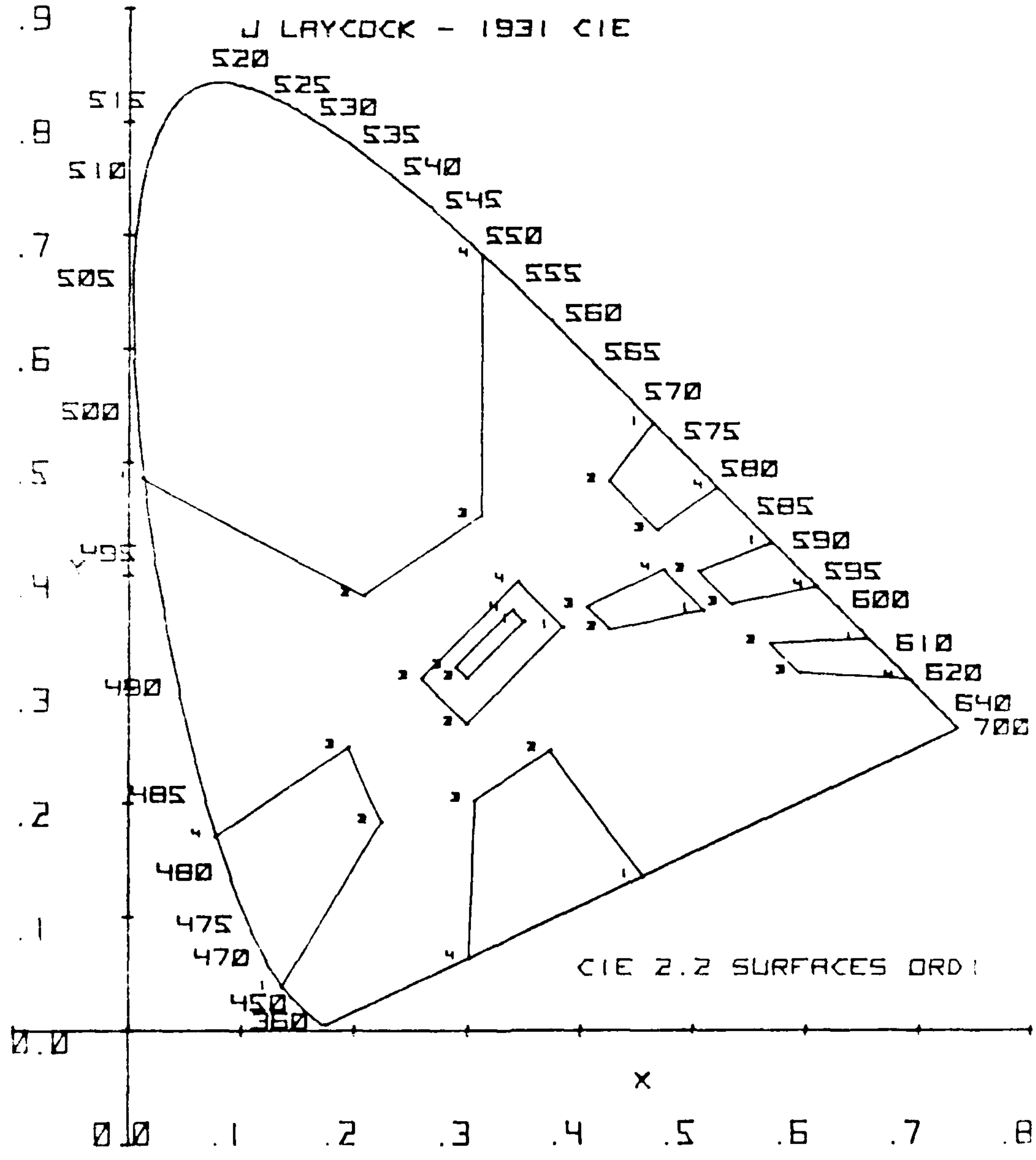
J LAYCOCK - 1931 CIE
CIE 2.2 SURFACES ORD
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Fig 11

Fig 12

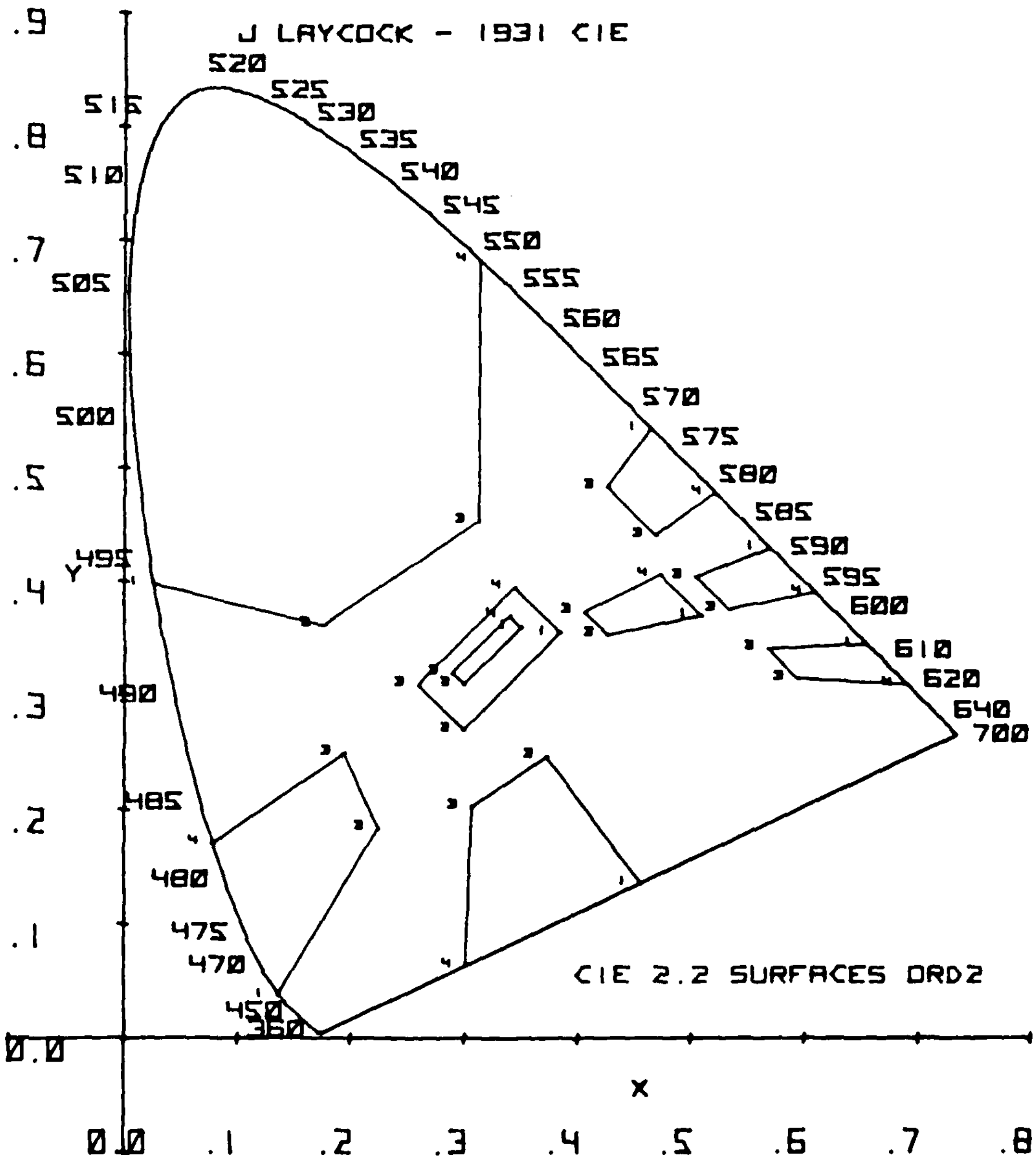

Fig 12

TR 82110

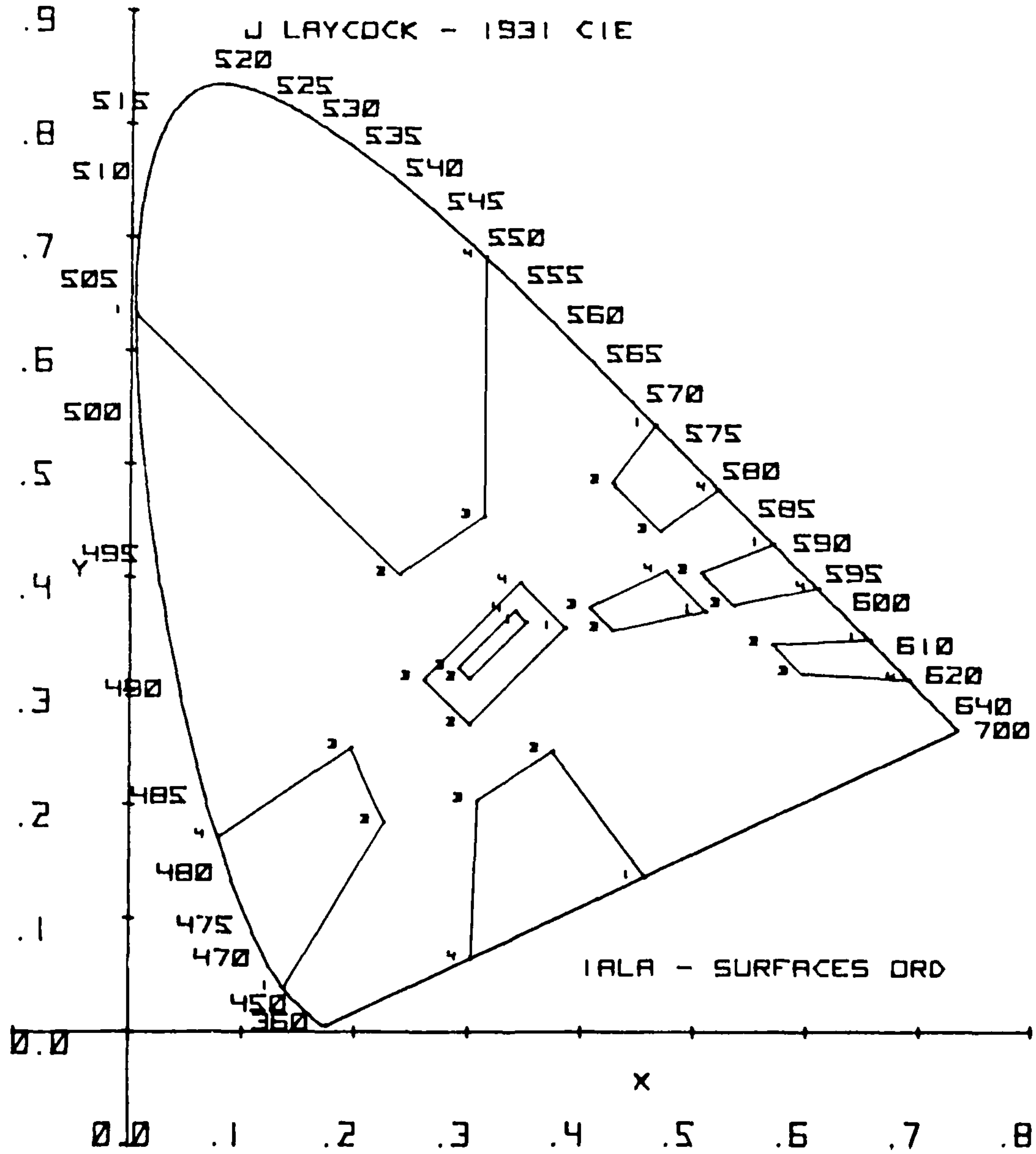
J LAYCOCK - 1931 CIE
IALA - SURFACES ORD
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Fig 13

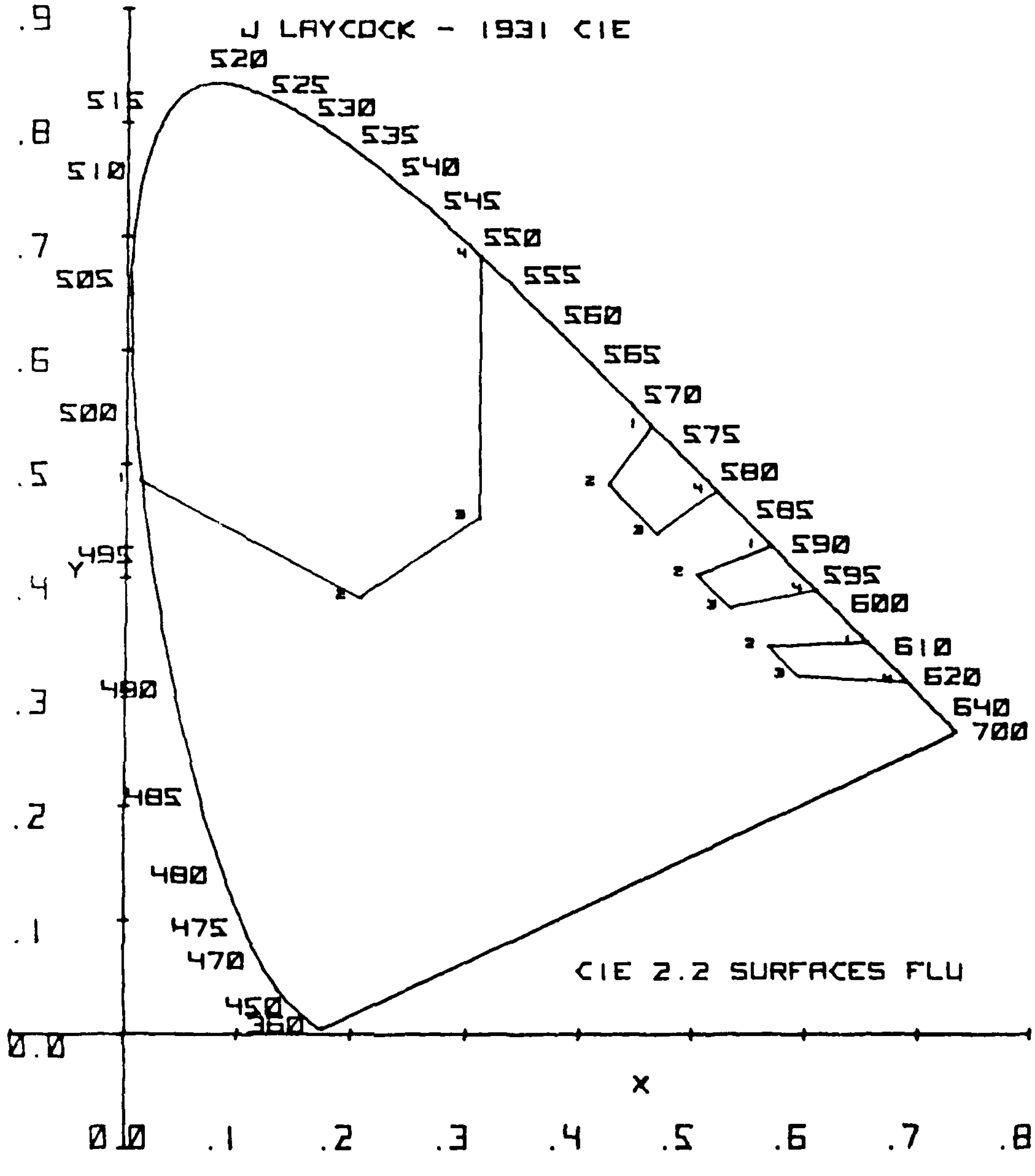

Fig 14

TR 82110

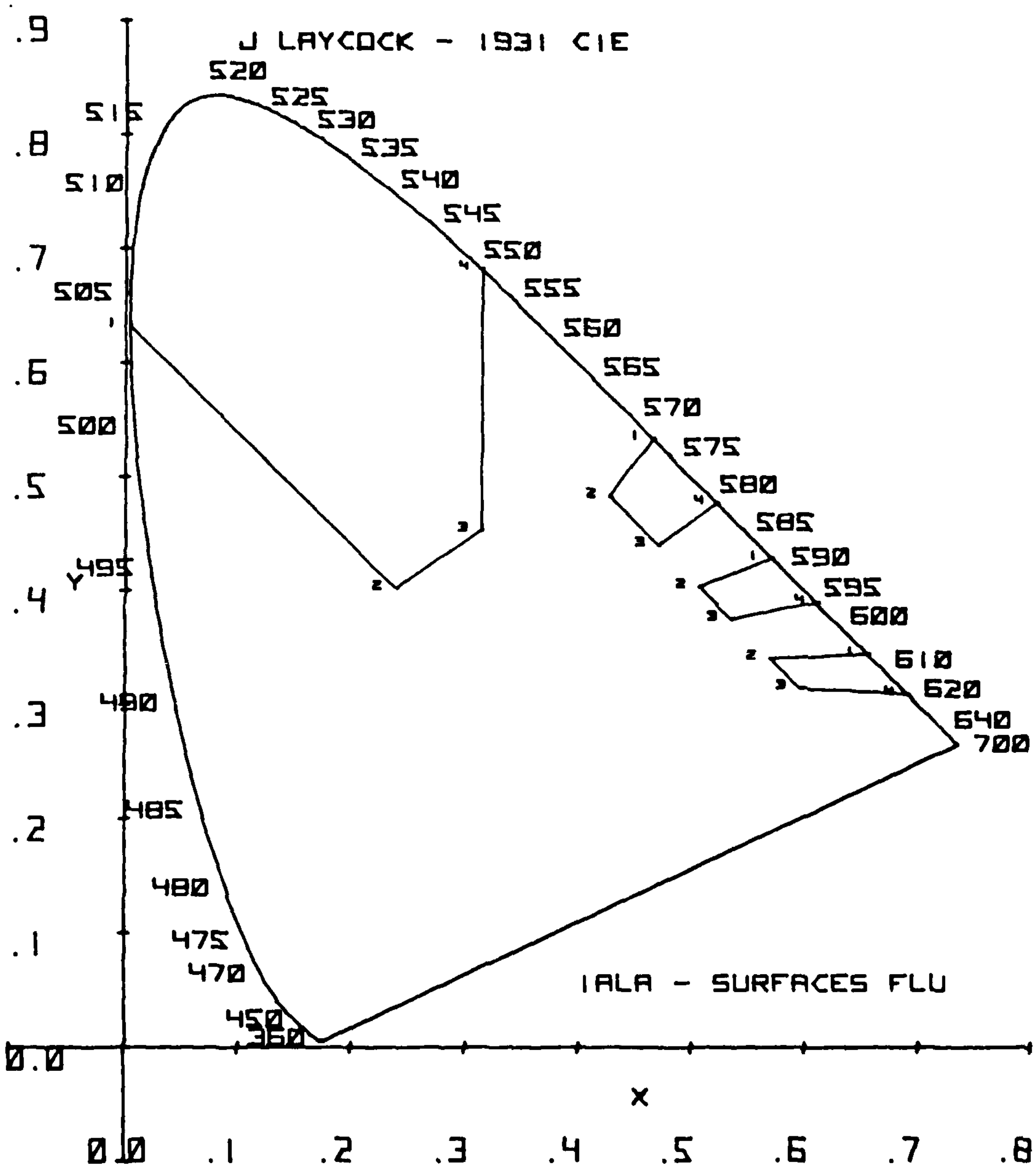
J LAYCOCK - 1931 CIE
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Fig 15

Fig 16

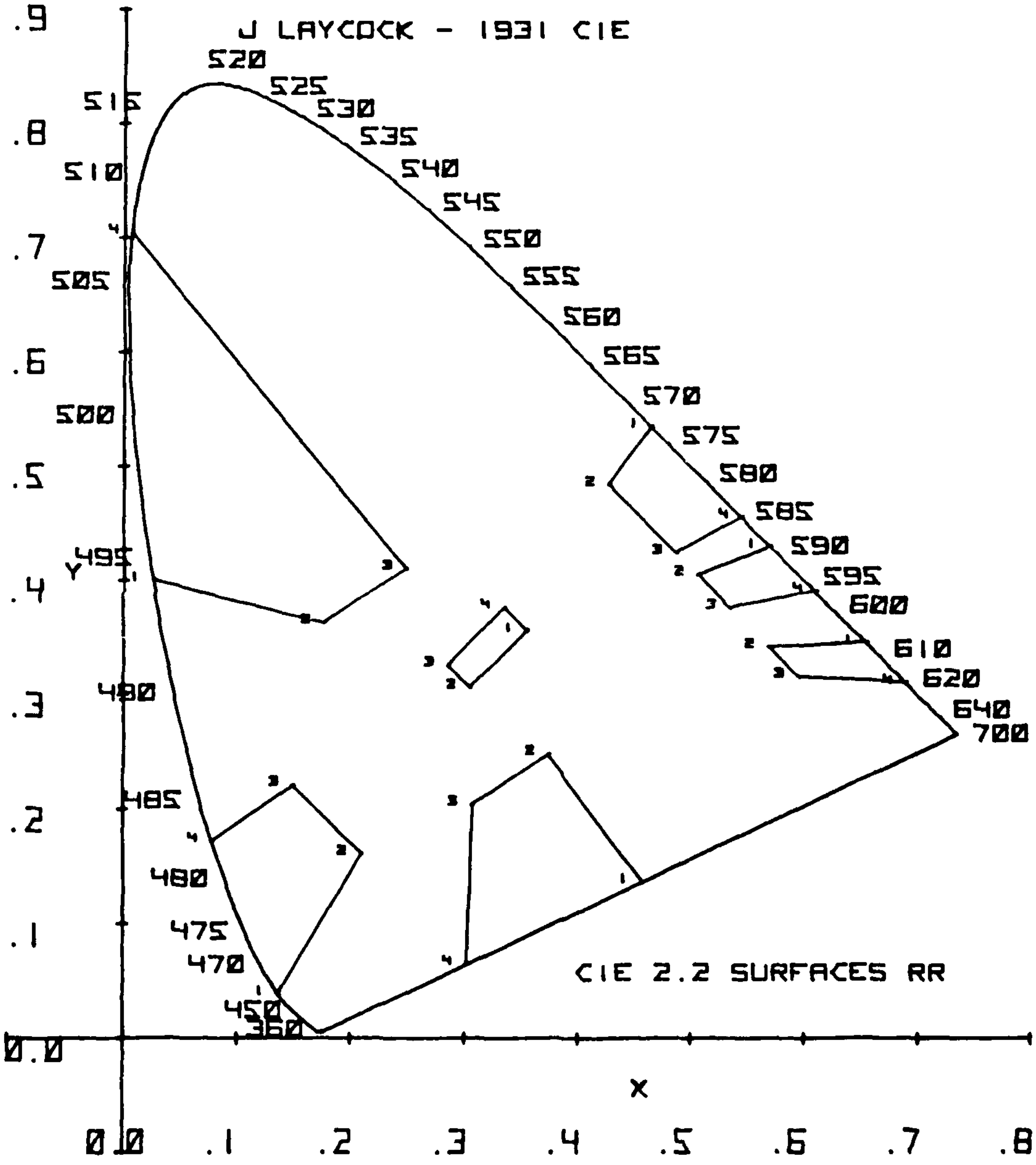

Fig 16

TR 82110

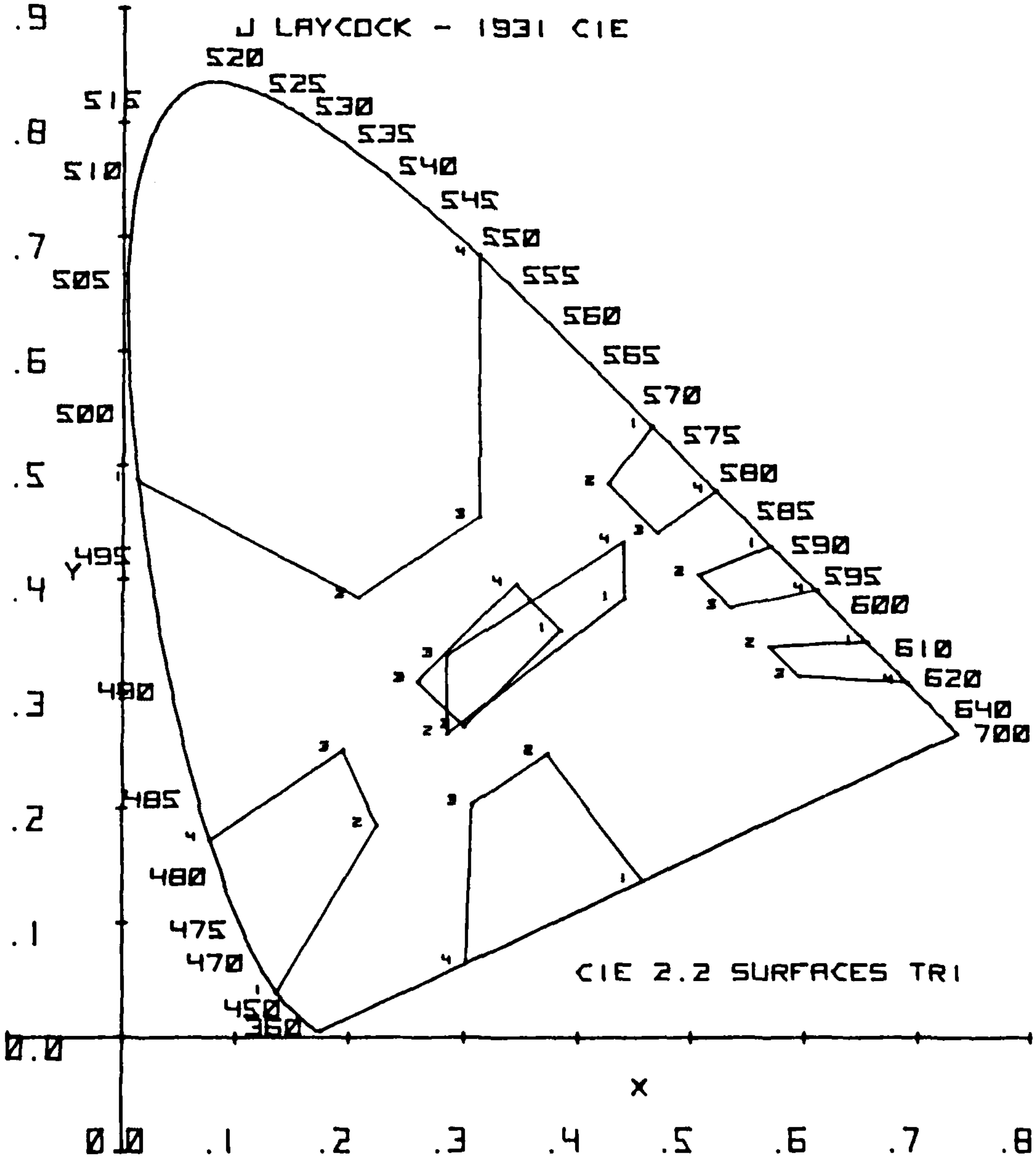
J LAYCOCK - 1931 CIE
CIE 2.2 SURFACES TRI
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Fig 17

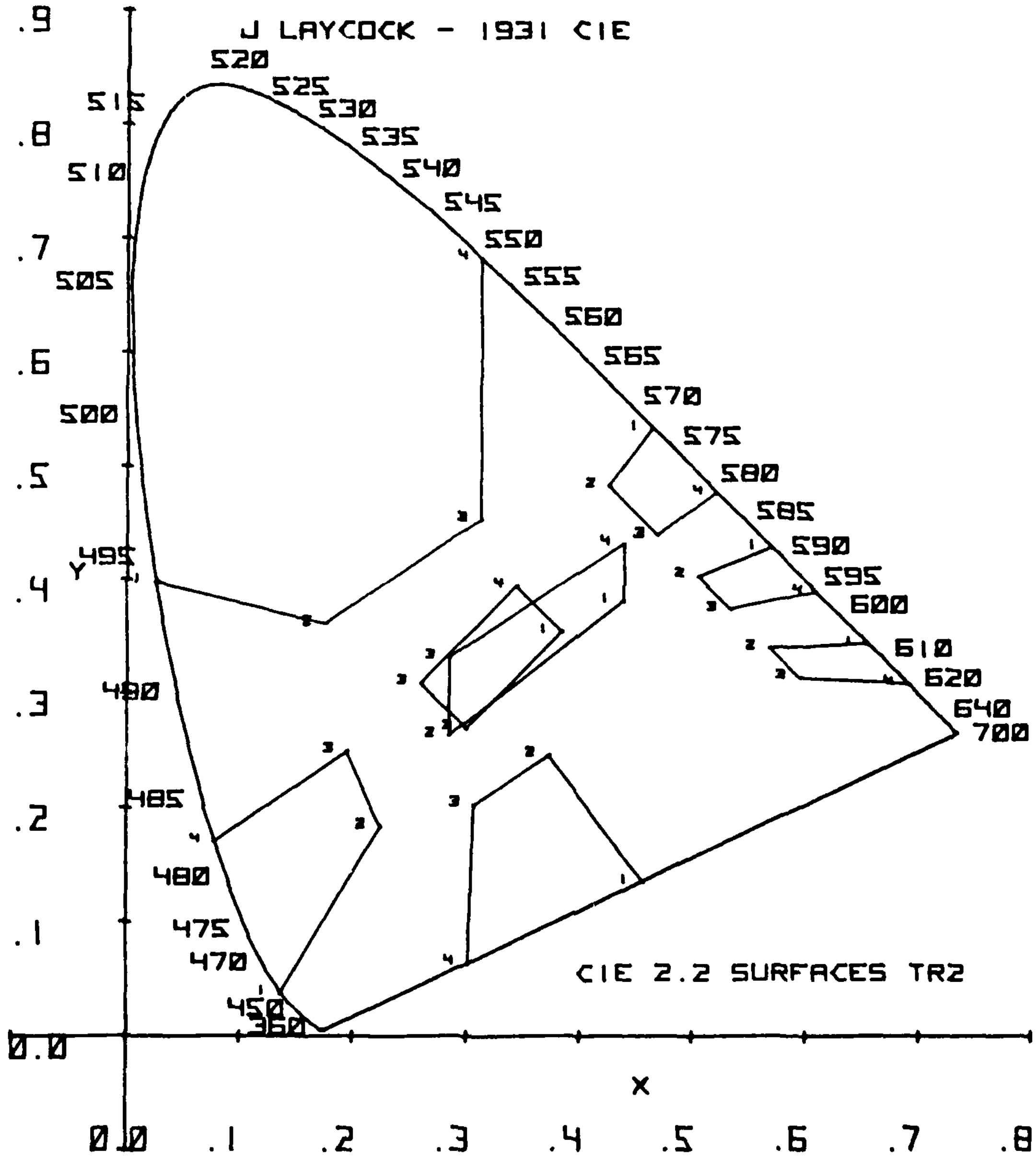

Fig 18

TR 82110

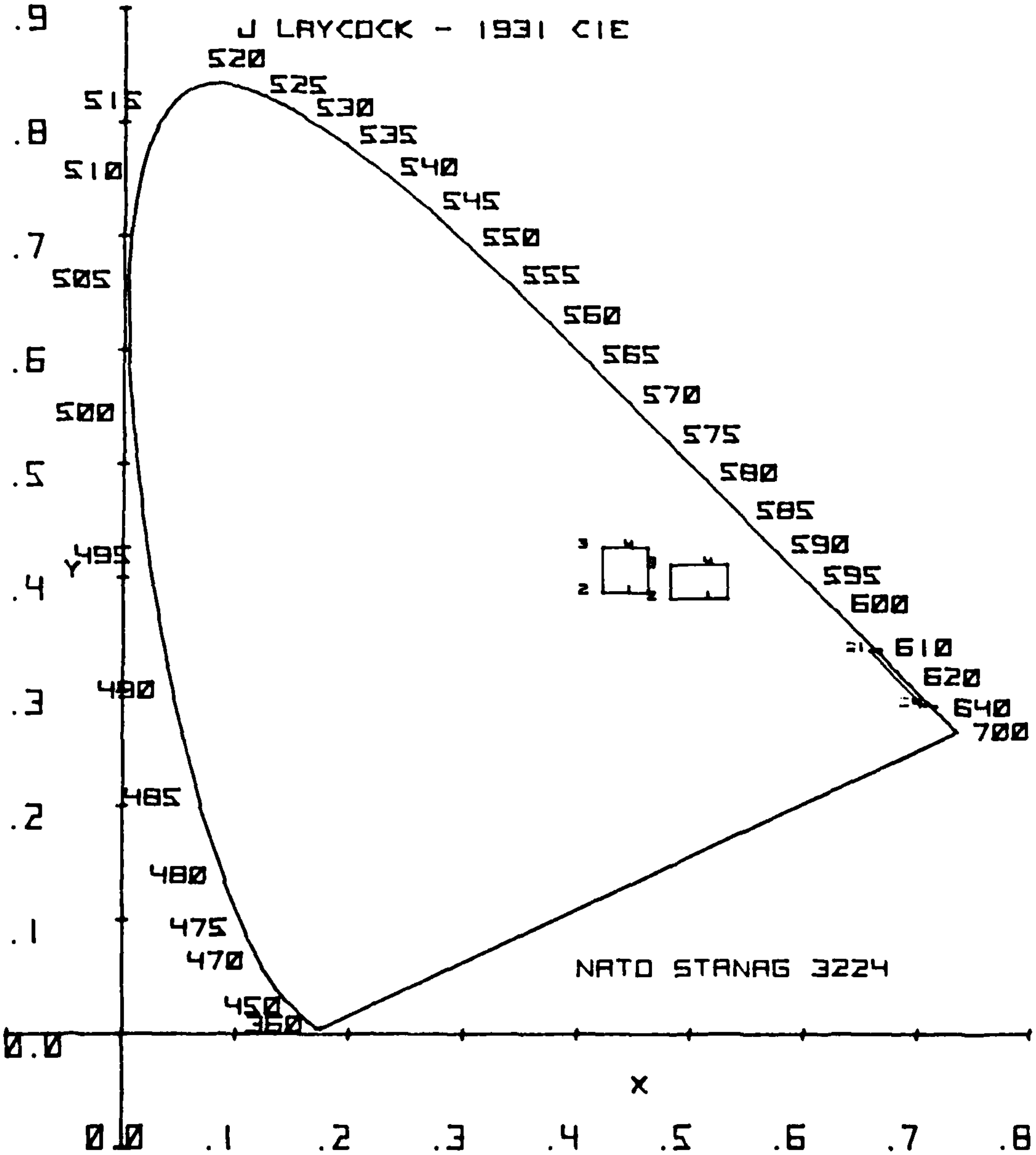
J LAYCOCK - 1931 CIE
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Fig 19

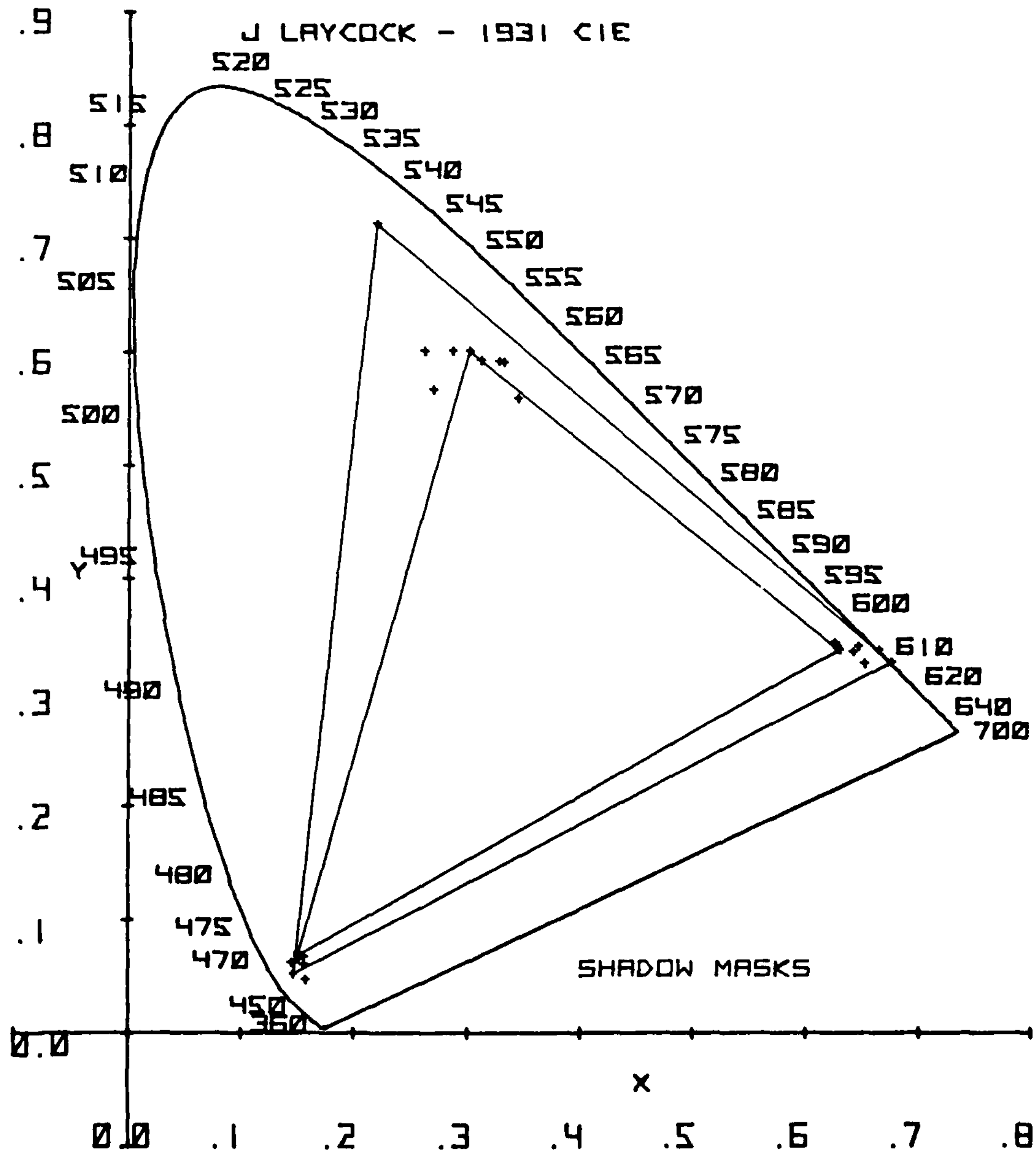
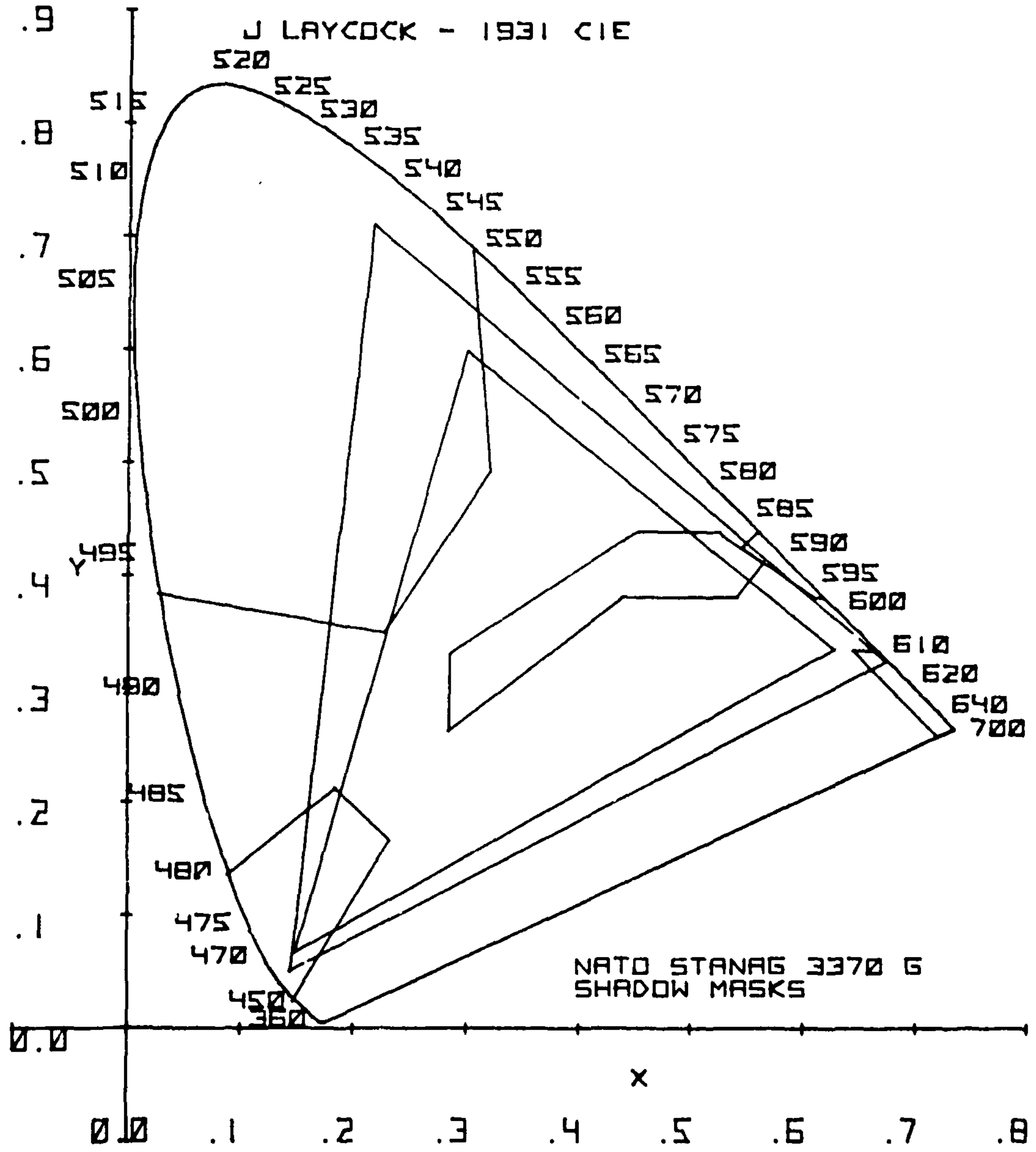


Fig 20

TR 82110


J LAYCOCK - 1931 CIE
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NATO STANAG 3370 G
SHADOW MASKS

Fig 21

Fig 22

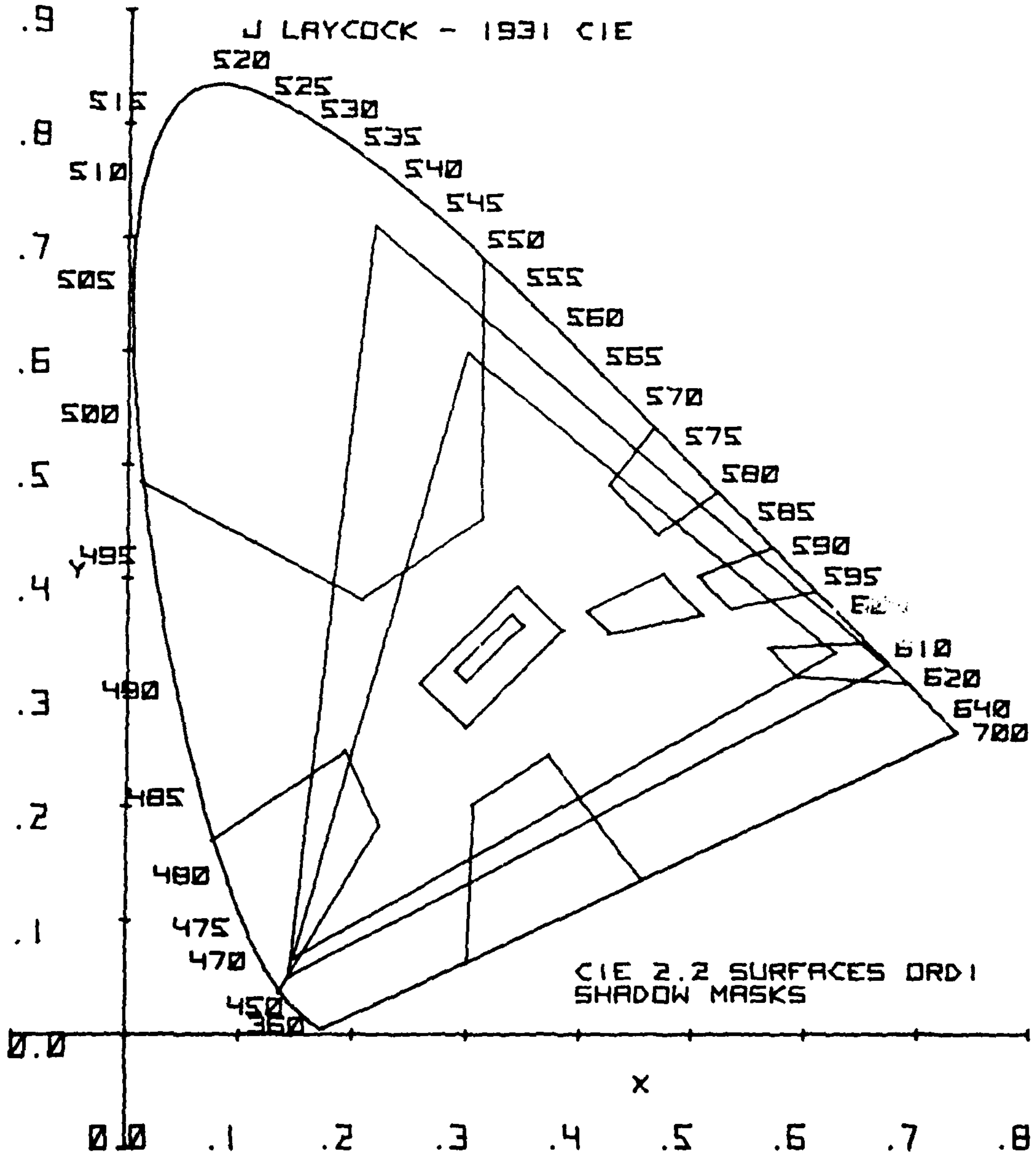

Fig 22

TR 82110

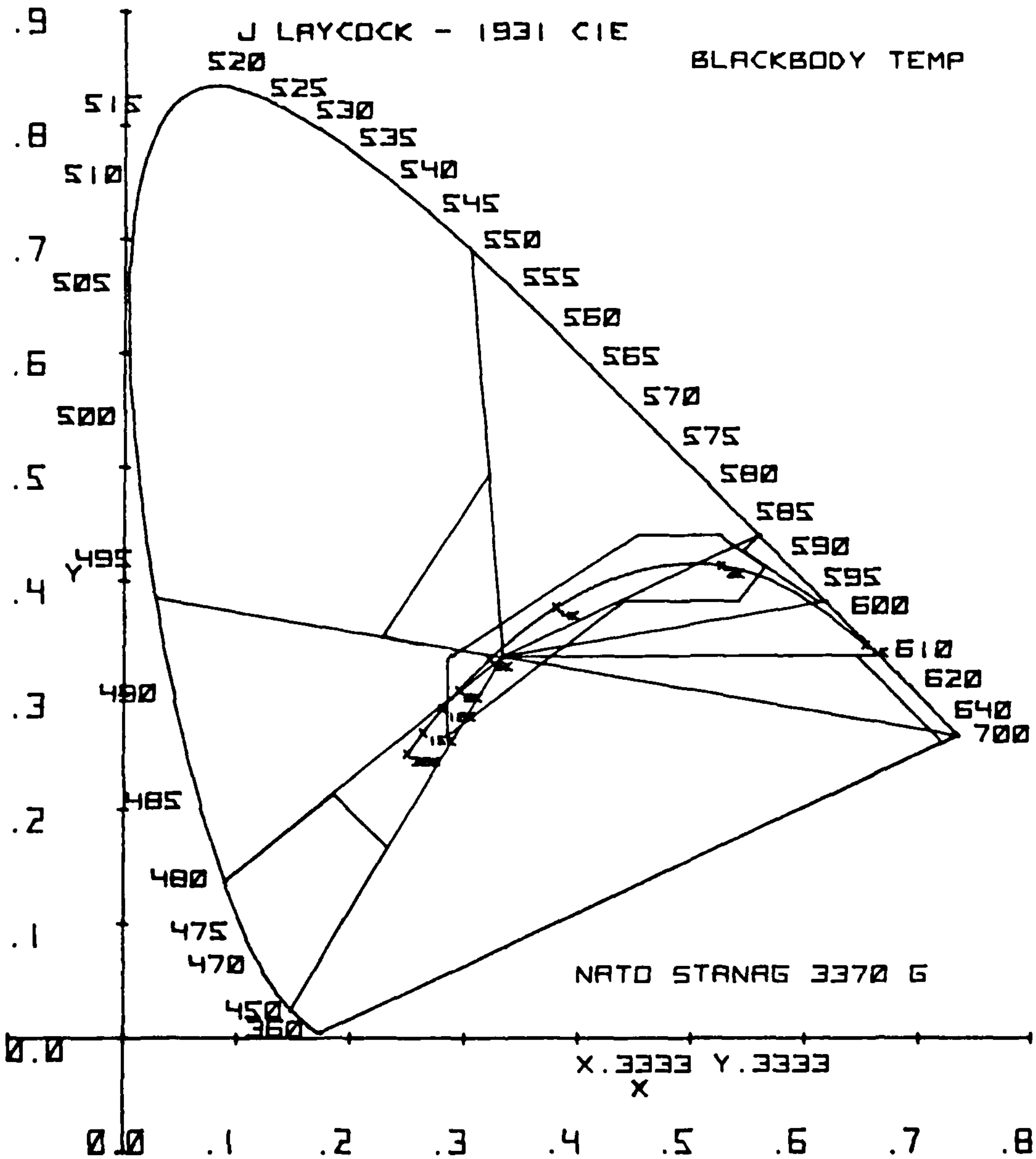
J LAYCOCK - 1931 CIE
BLACKBODY TEMP
NATO STANAG 3370 G
X.3333 Y.3333
X
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Fig 23

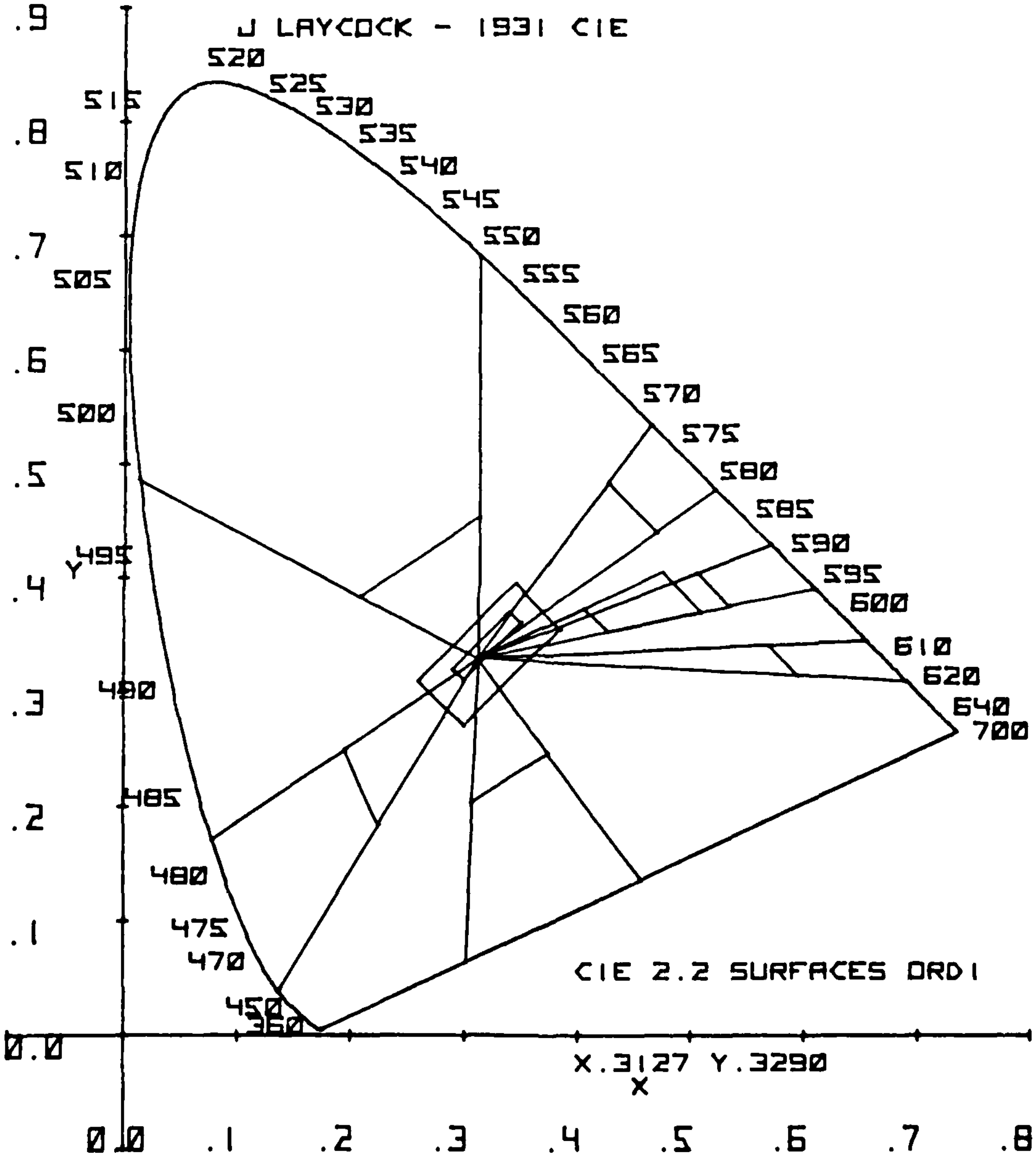
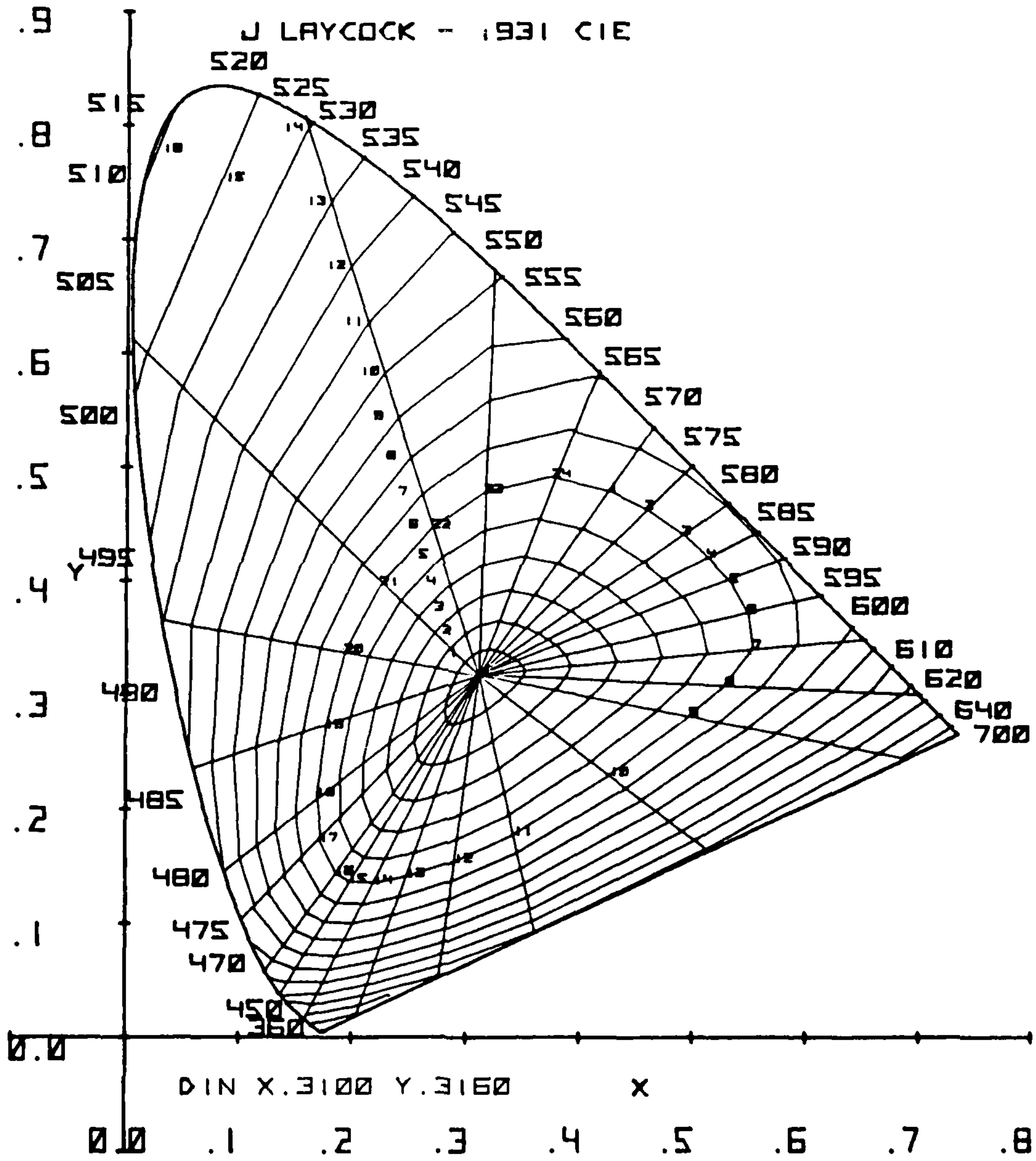


Fig 24

TR 82110


J LAYCOCK - 1931 CIE
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DIN X.3100 Y.3160
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Fig 25

Fig 26

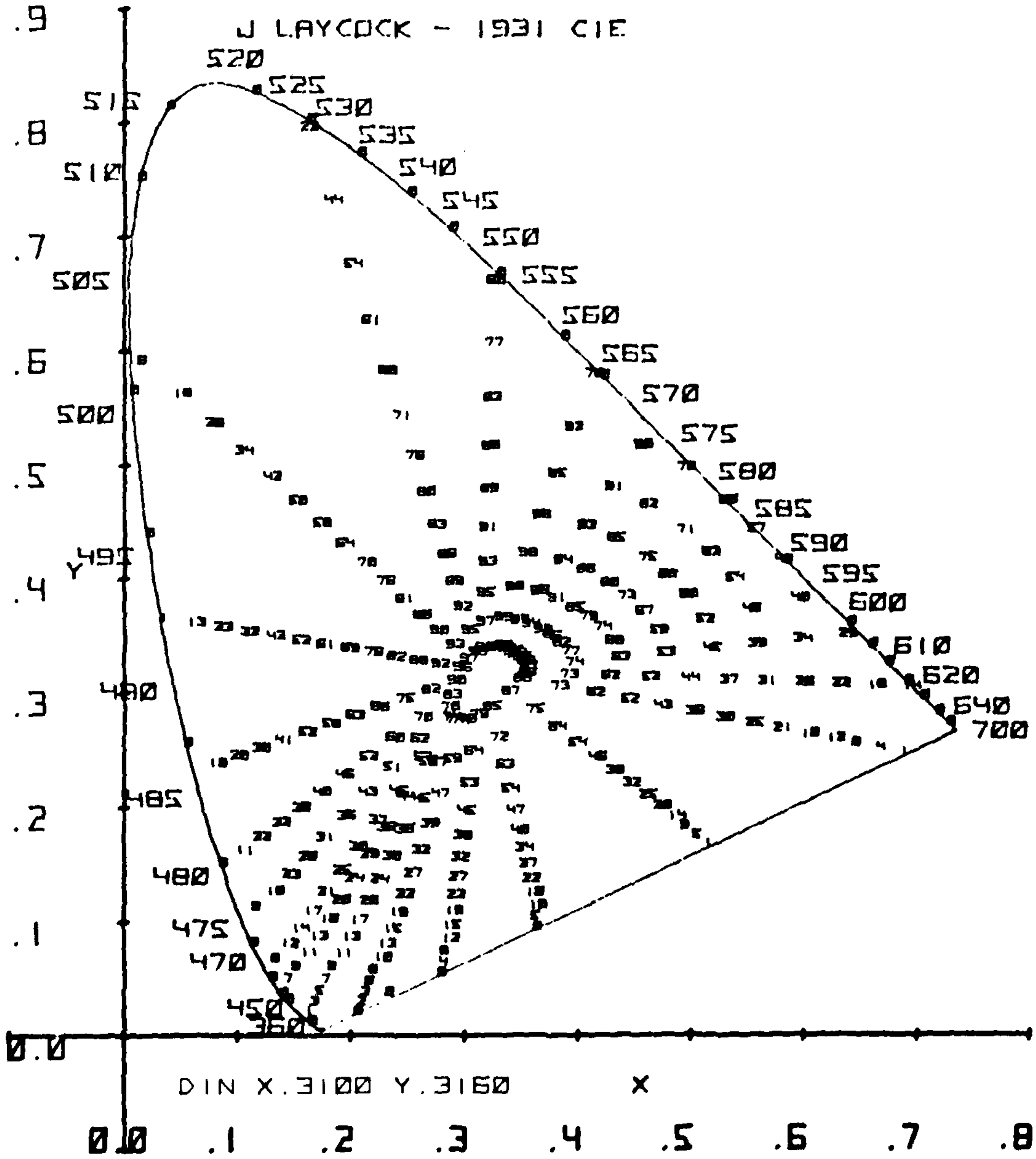
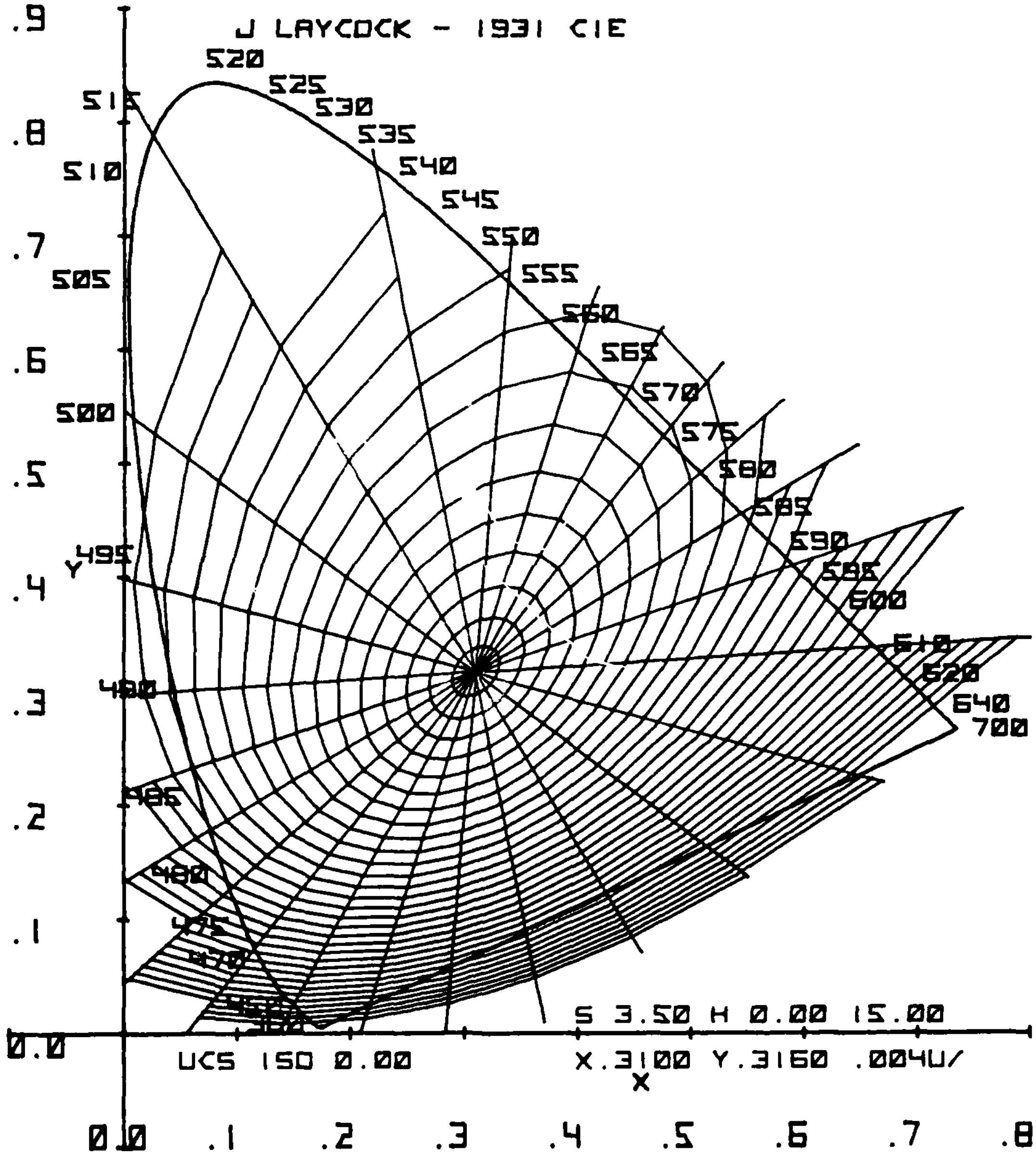


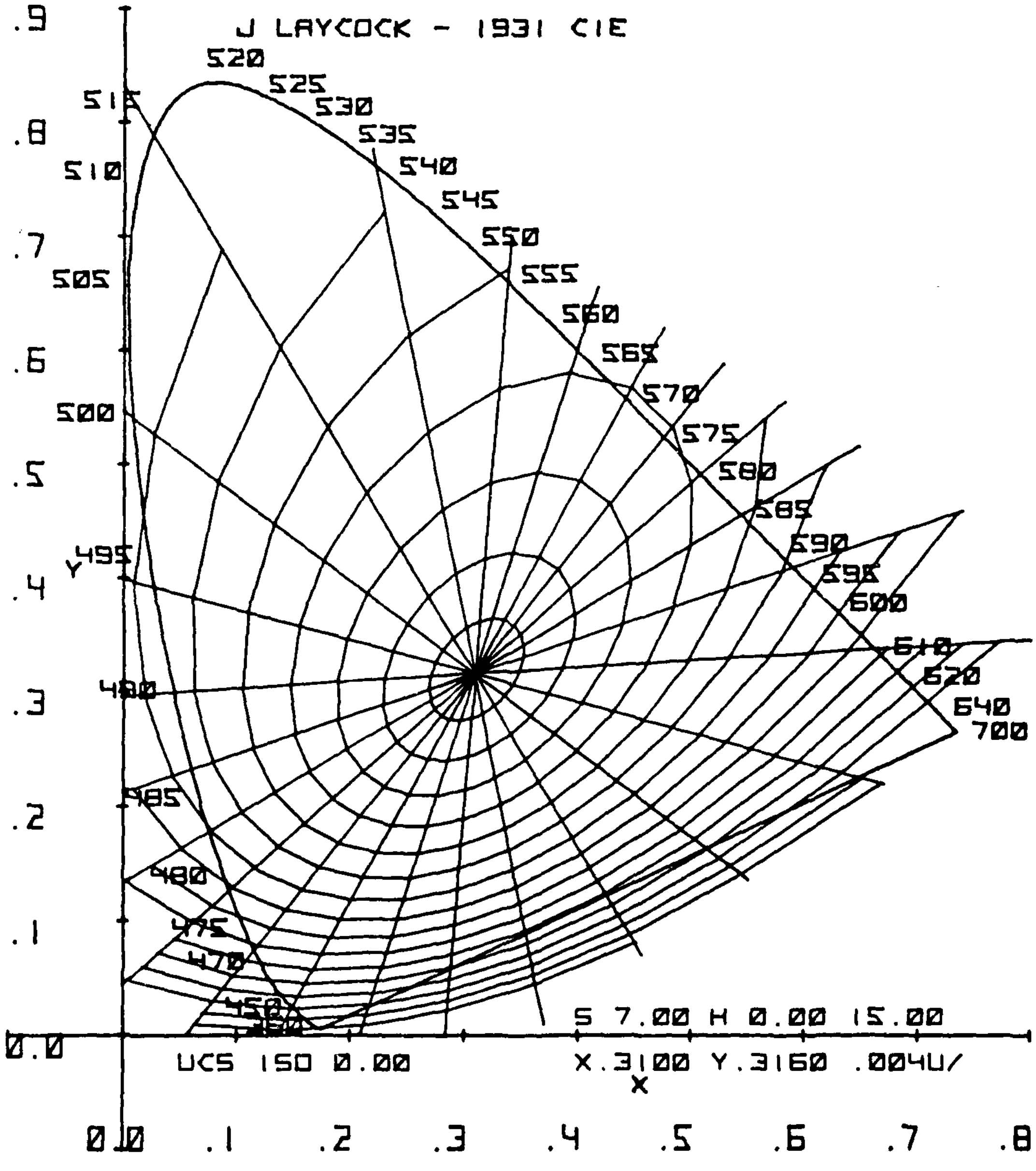
Fig 26

TR 82110



TR 82110

Fig 27


J LAYCOCK - 1931 CIE
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S 7.00 H 0.00 15.00
UCS 150 0.00
X.3100 Y.3160 .004U/
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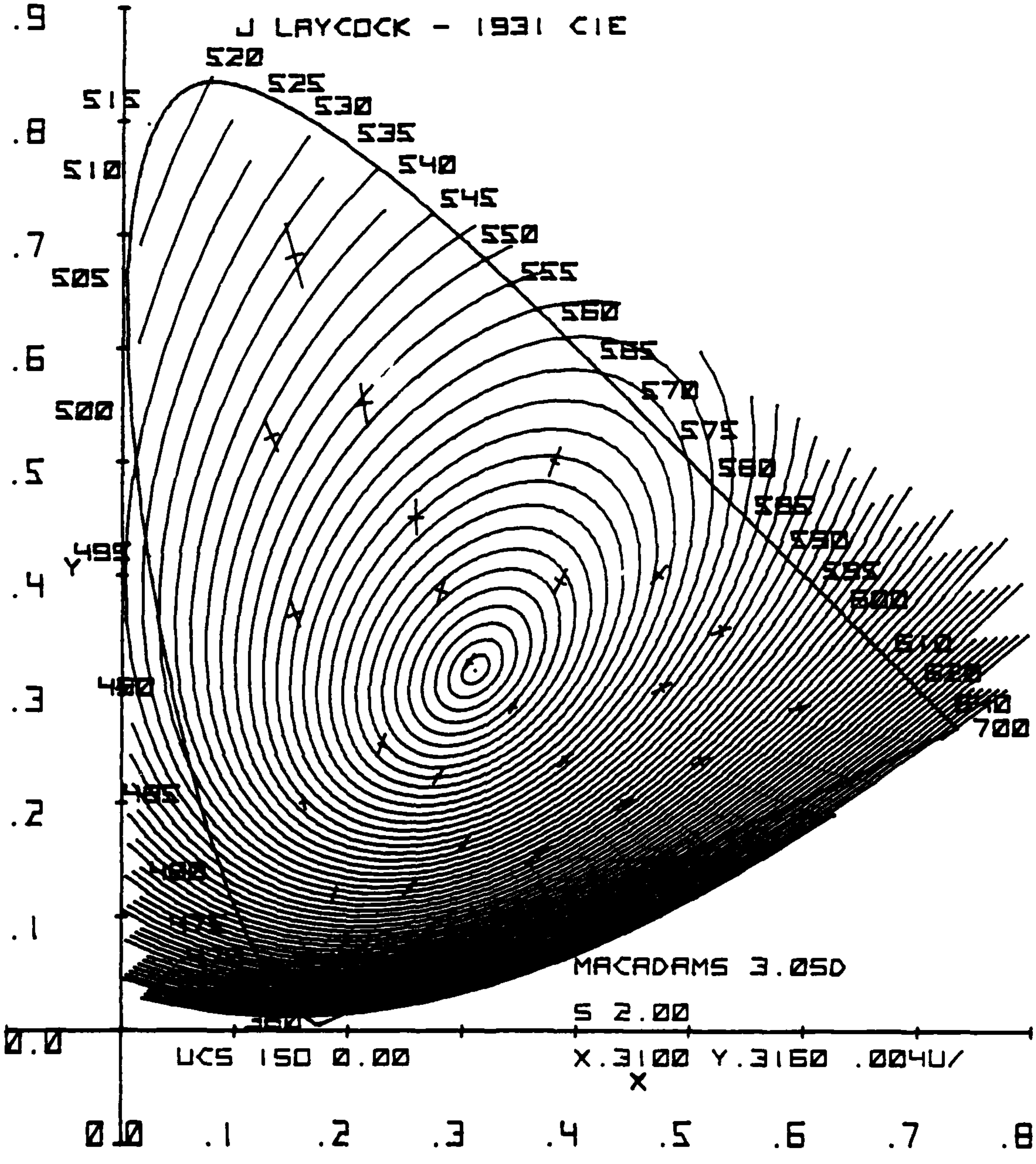
Fig 28


J LAYCOCK - 1931 CIE
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UCS 150 0.00
X.3100 Y.3160 .004U/
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Fig 29

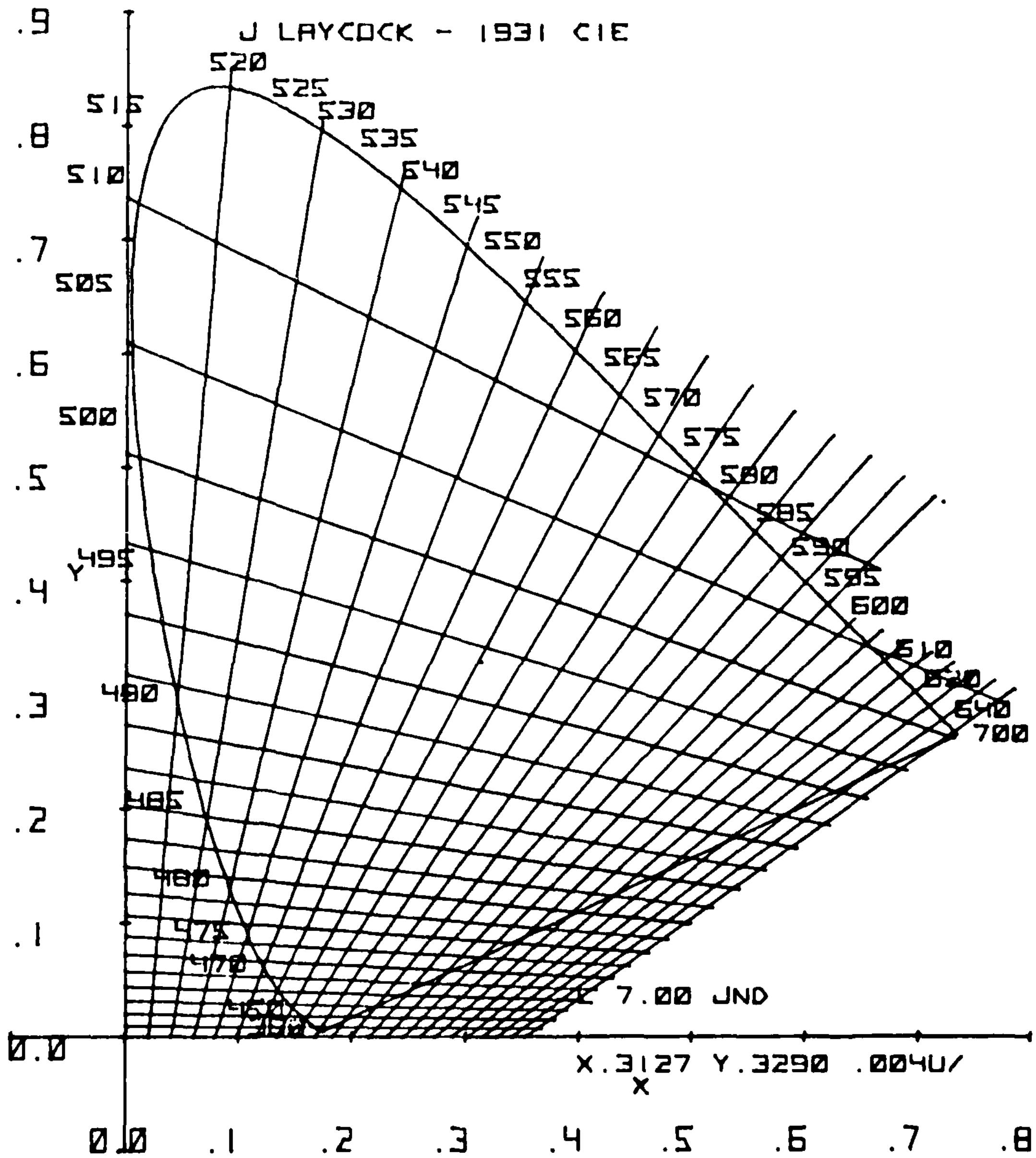


Fig 30

TR 82110

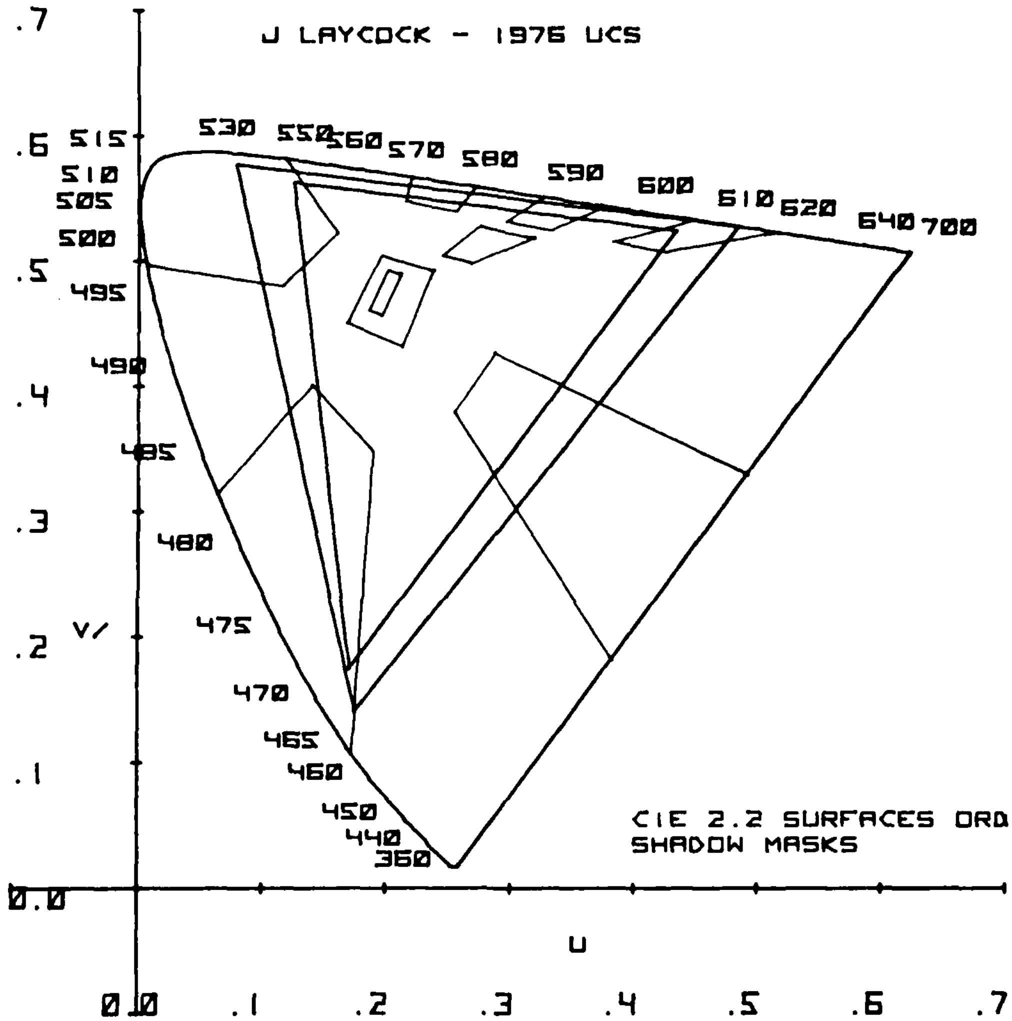

J LAYCOCK - 1976 UCS
CIE 2.2 SURFACES ORD
SHADOW MASKS
V/
U
530 550 560 570 580 590 600 610 620 640 700
515 510 505 500 495 490 485 480 475 470 465 460 450 440 360
.7 .6 .5 .4 .3 .2 .1 0.0
0.0 .1 .2 .3 .4 .5 .6 .7

Fig 31

Fig 32

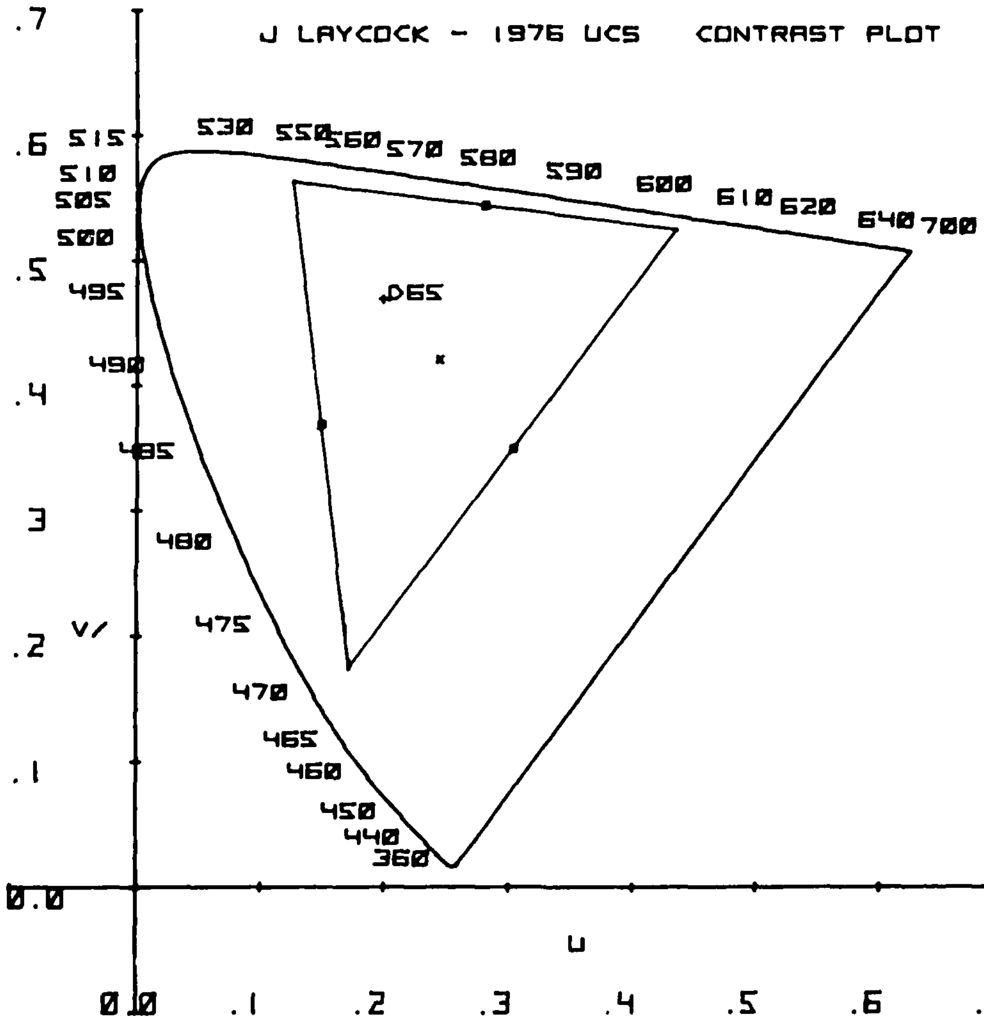
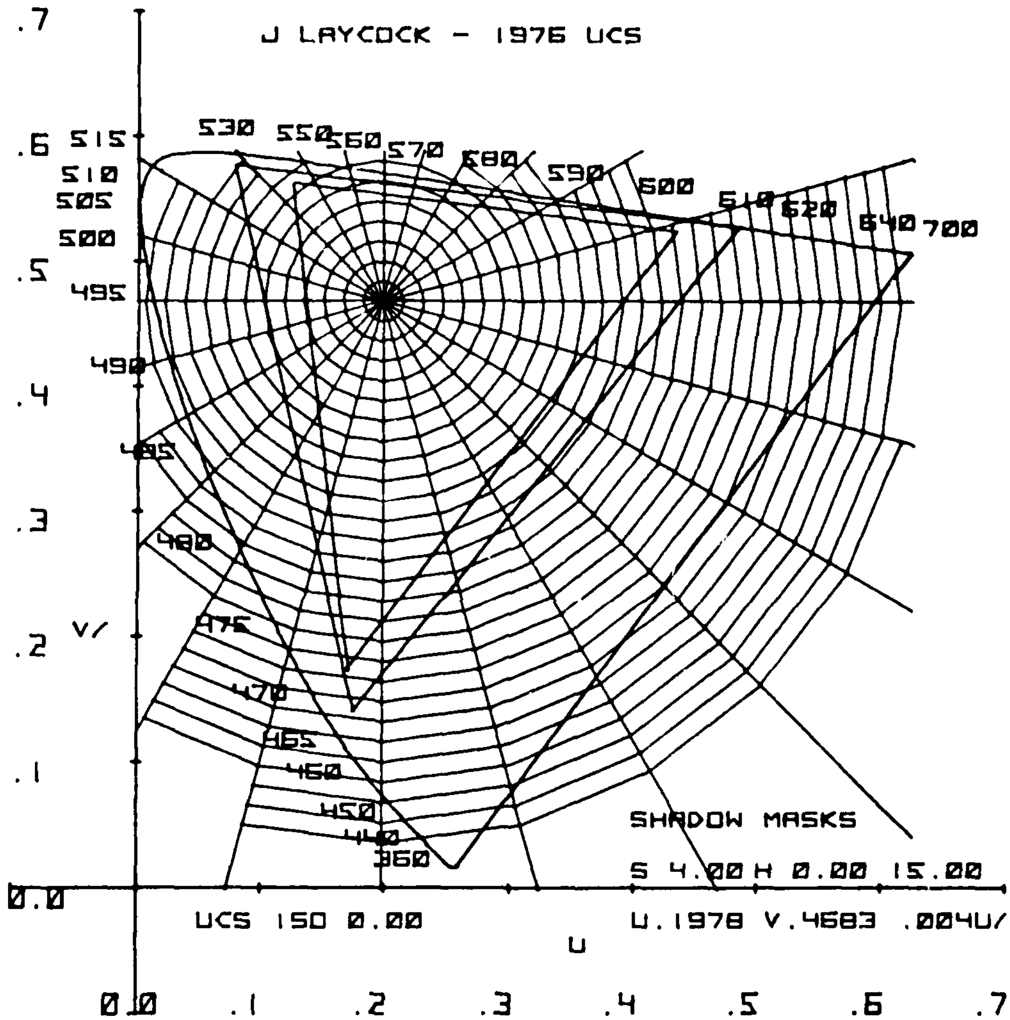


Fig 32

TR 82110


J LAYCOCK - 1976 UCS
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SHADOW MASKS
S 4.00 H 0.00 15.00
UCS 150 0.00
U.1978 V.4683 .004U'
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Fig 33

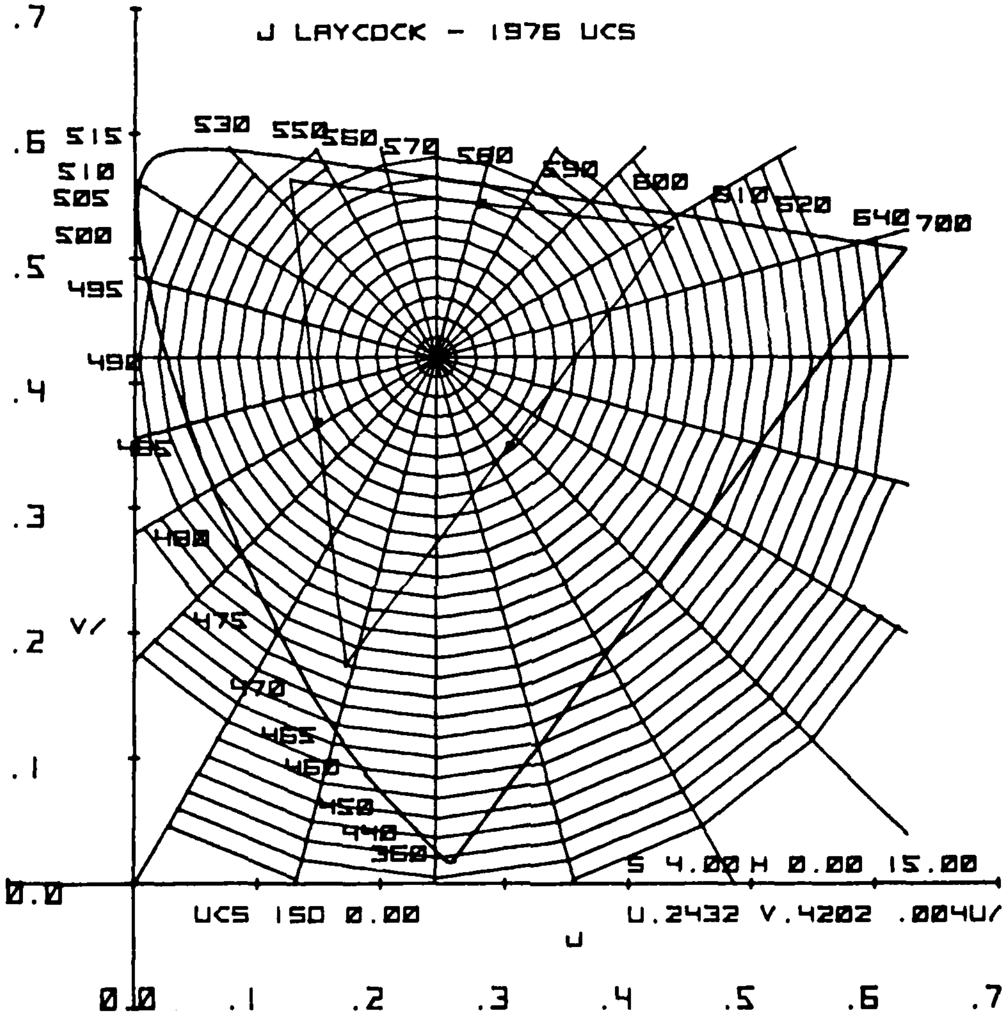
J LAYCOCK - 1976 UCS
530 550 560 570 580 590 600 610 620 640 700
515 510 505 500 495 490 485 480 475 470 465 460 450 440 360
.7 .6 .5 .4 .3 .2 .1 0.0
V/
S 4.00 H 0.00 15.00
UCS 150 0.00
U.2432 V.4202 .004U/
U
0.0 .1 .2 .3 .4 .5 .6 .7

Fig 34

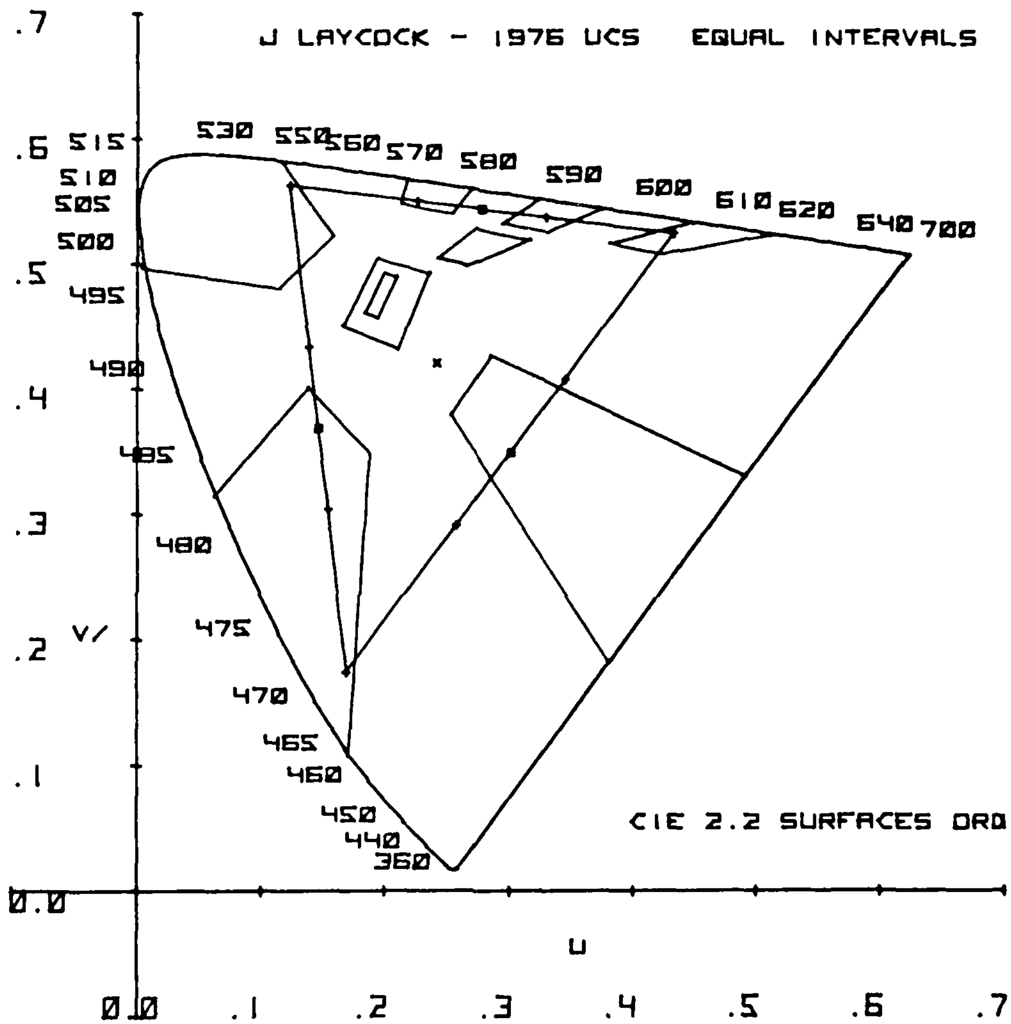
J LAYCOCK - 1976 UCS EQUAL INTERVALS
CIE 2.2 SURFACES ORD
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Fig 35

Fig 36

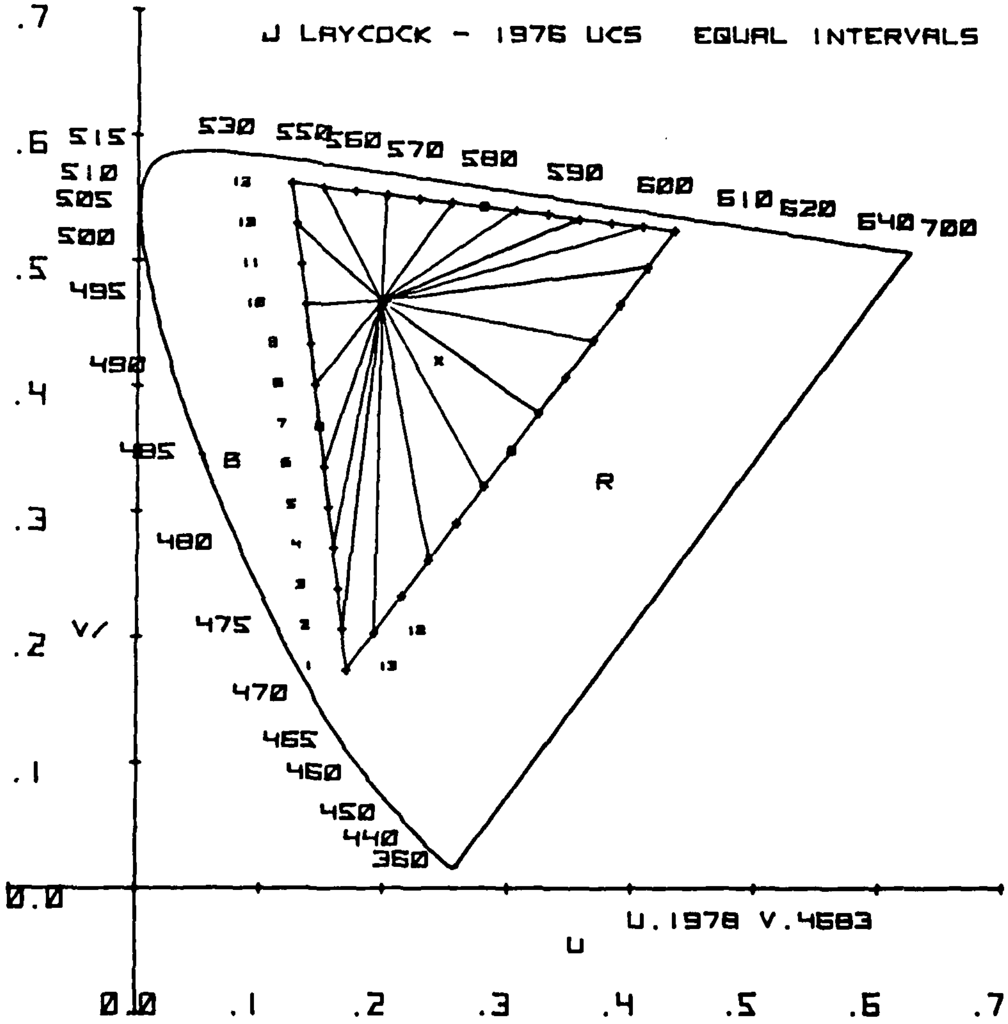
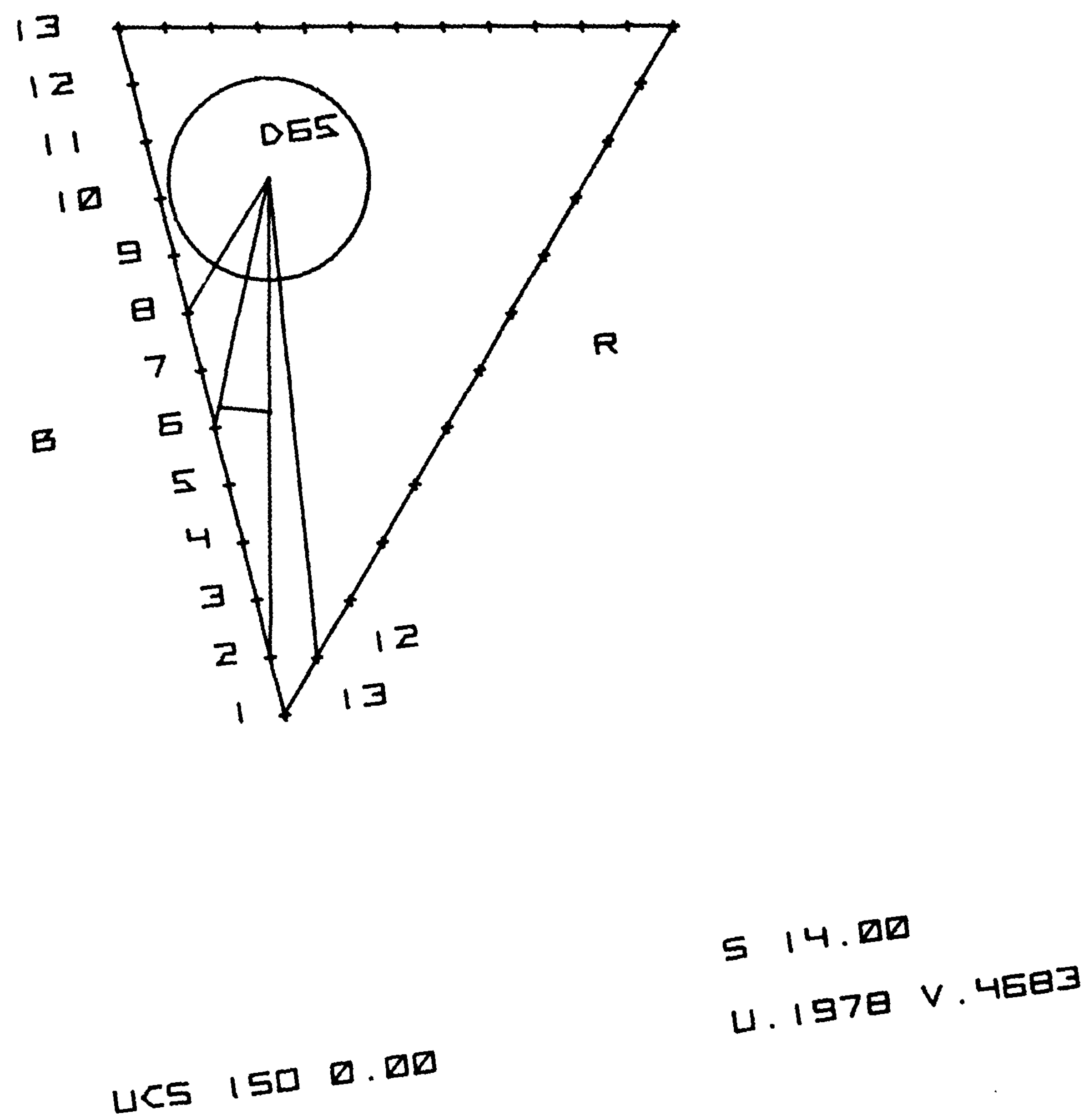


Fig 36

TR 82110


13
12
11
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D65
B
R
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S 14.00
U.1978 V.4683
UCS 150 0.00

Fig 37

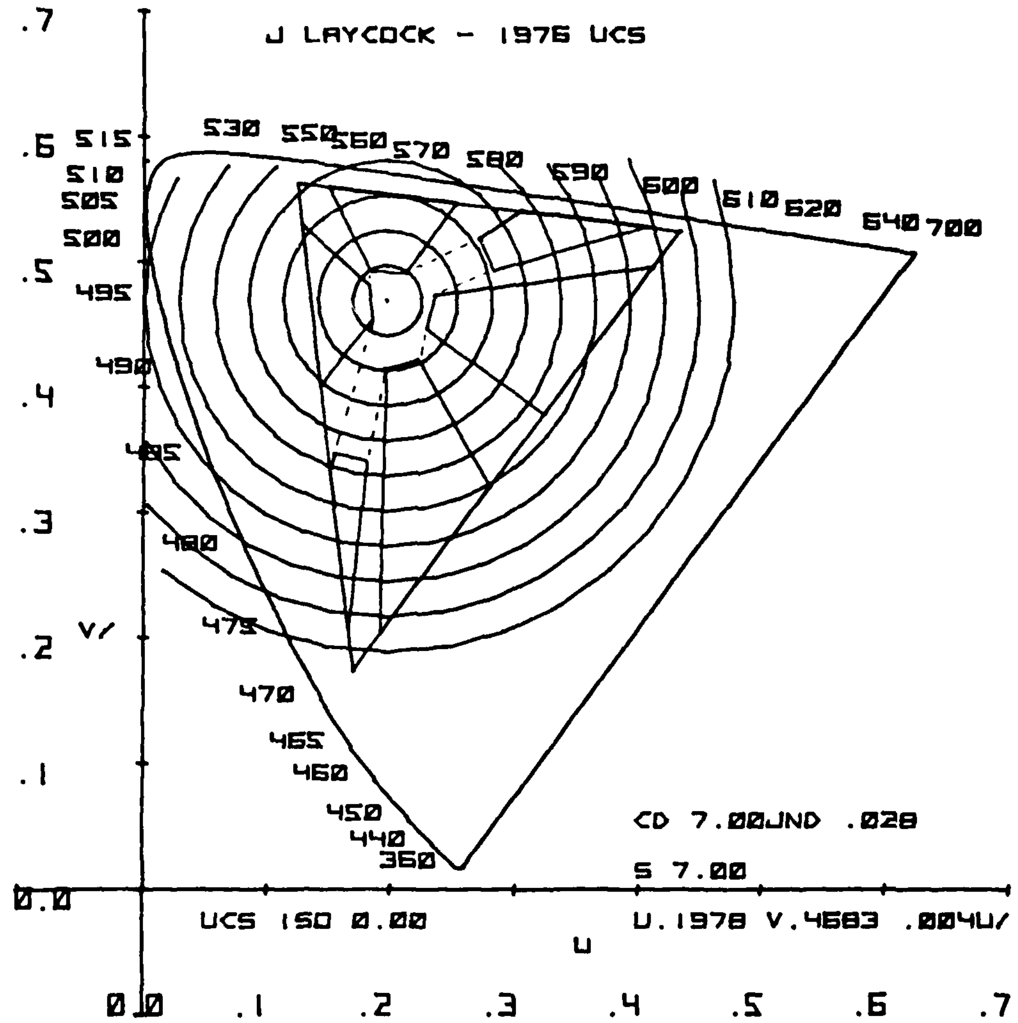
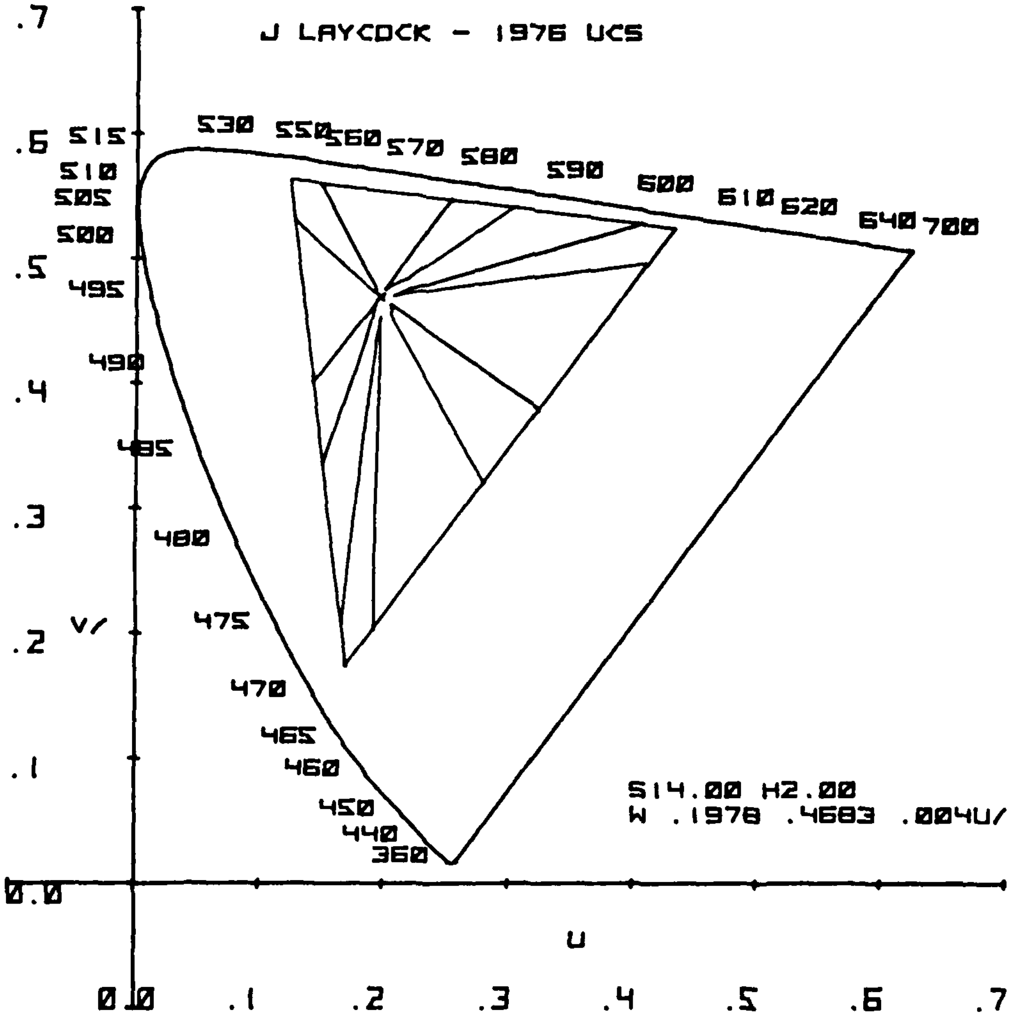


Fig 38

TR 82110


J LAYCOCK - 1976 UCS
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W .1978 .4683 .004U/
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Fig 39

Fig 40

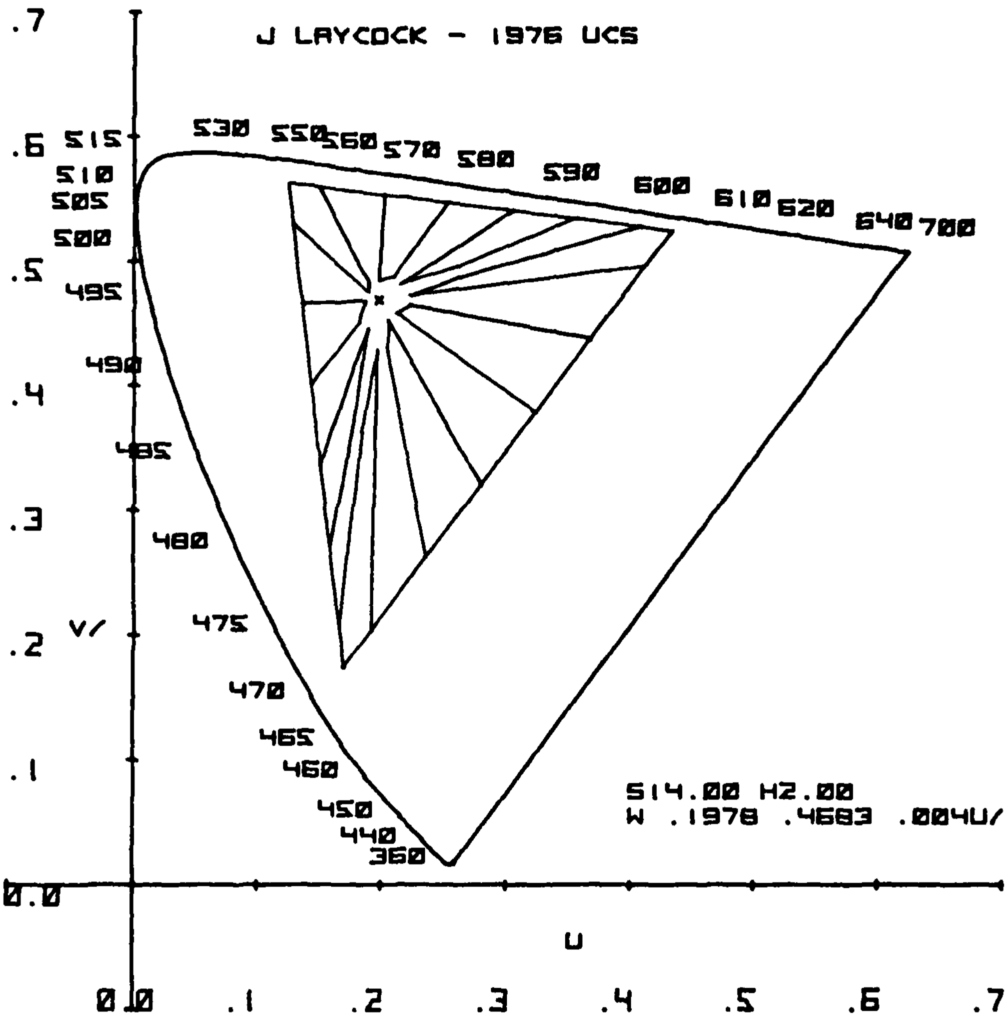

Fig 40

TR 82110

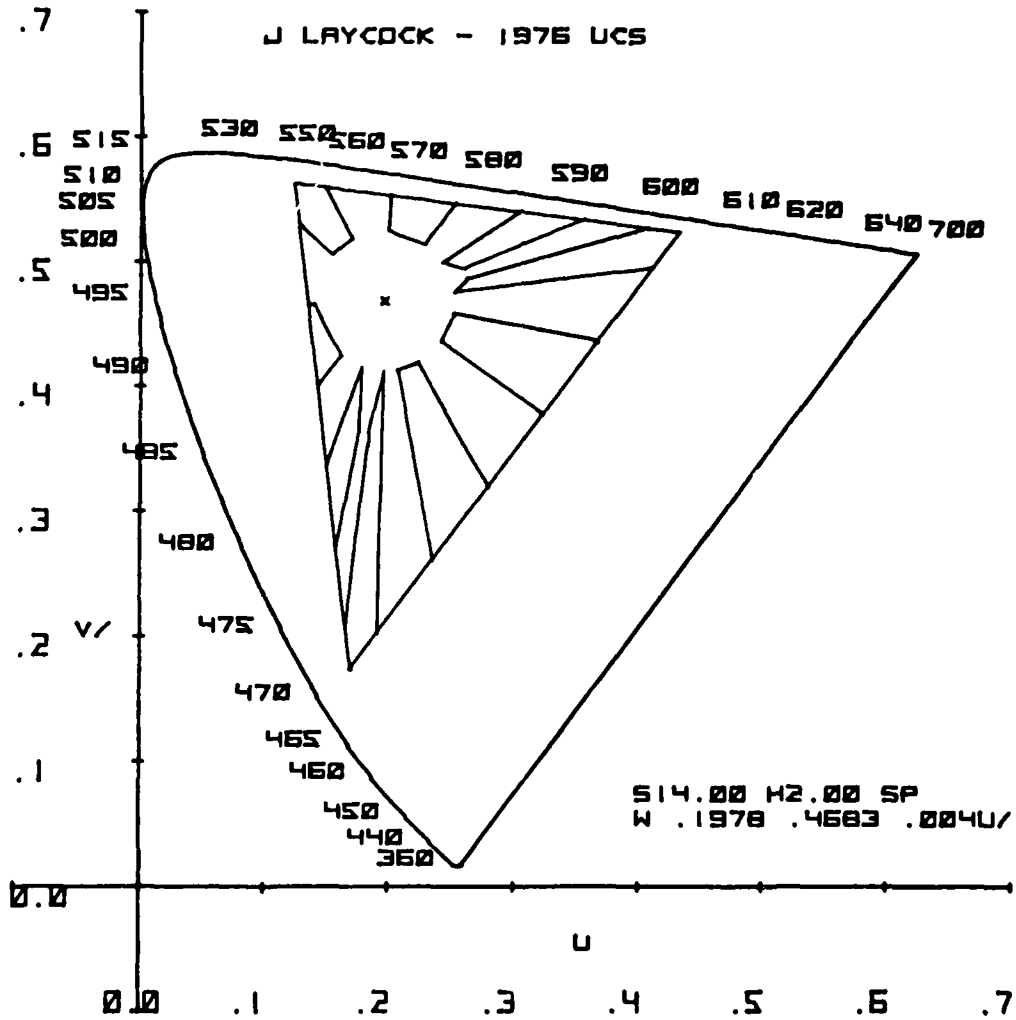
J LAYCOCK - 1976 UCS
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Fig 41

Fig 42

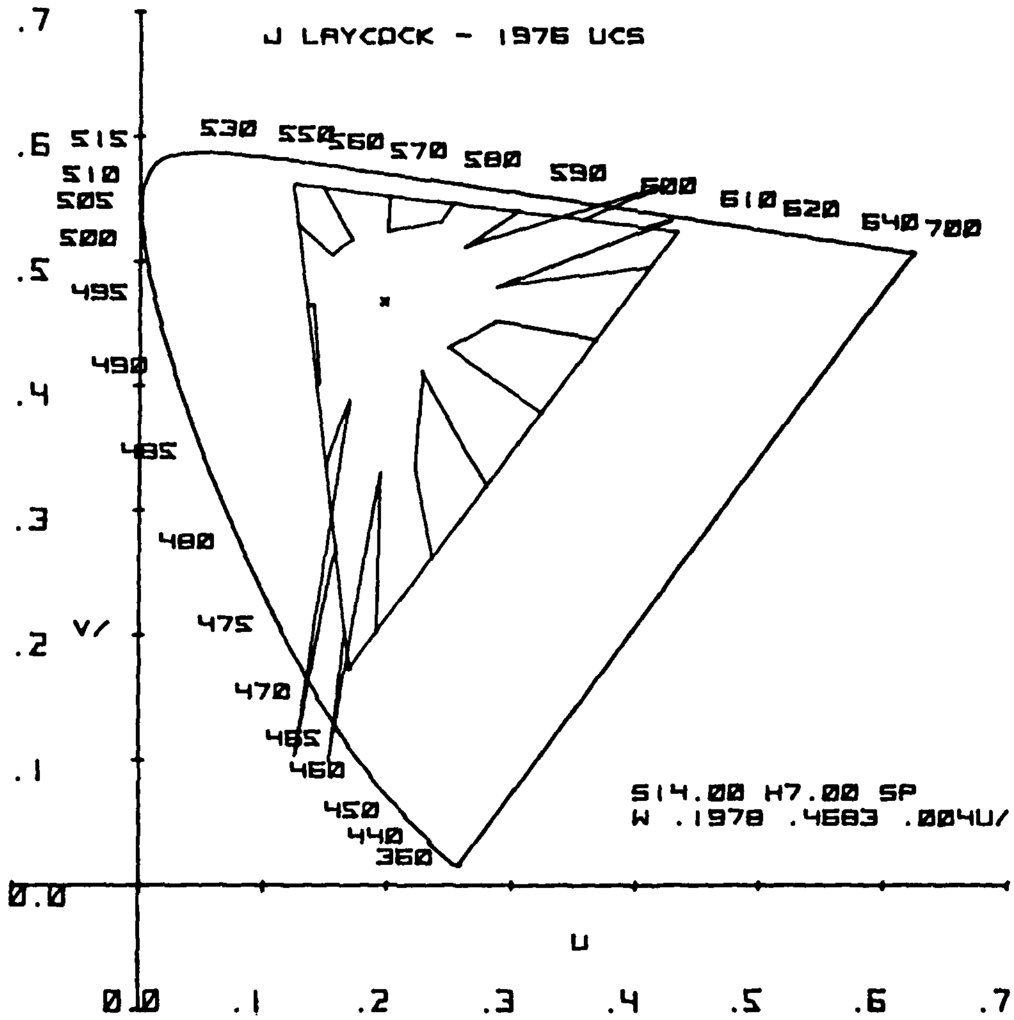

Fig 42

TR 82110

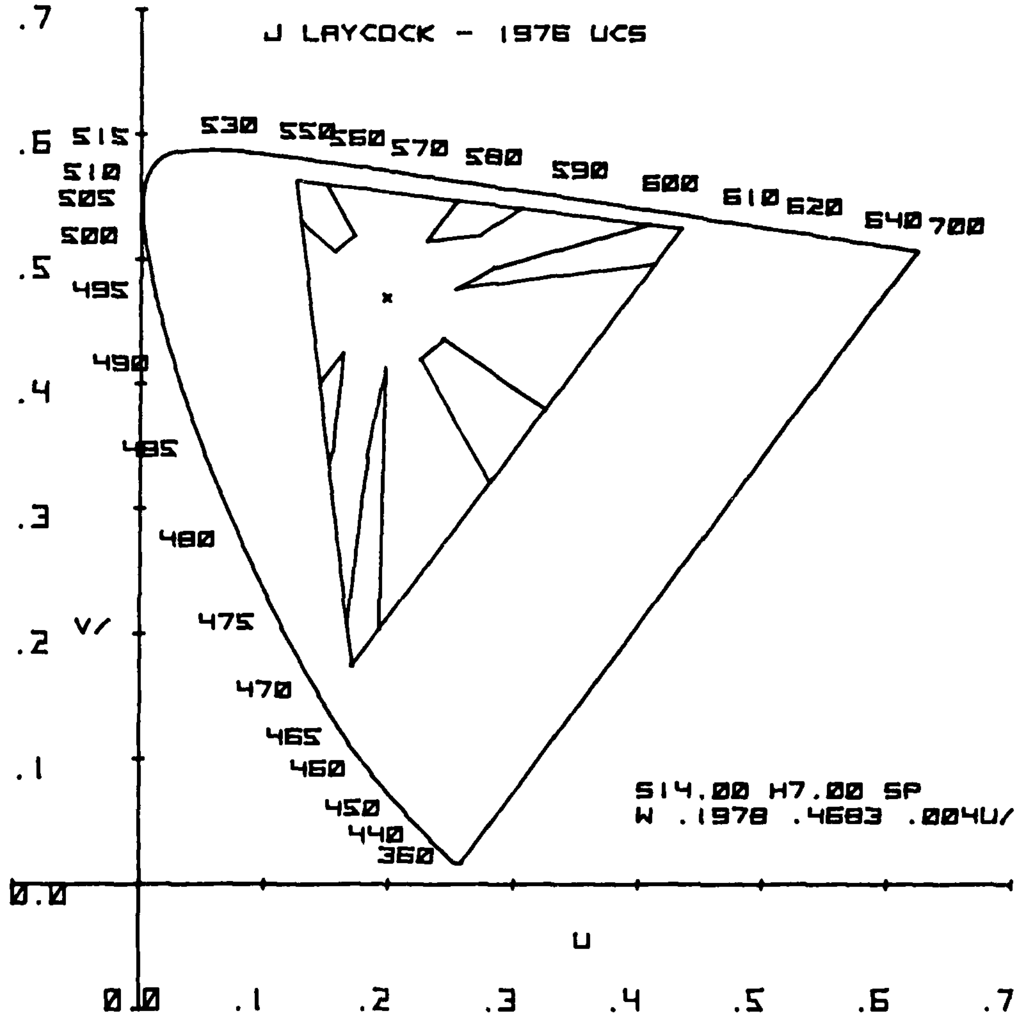
J LAYCOCK - 1976 UCS
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Fig 43

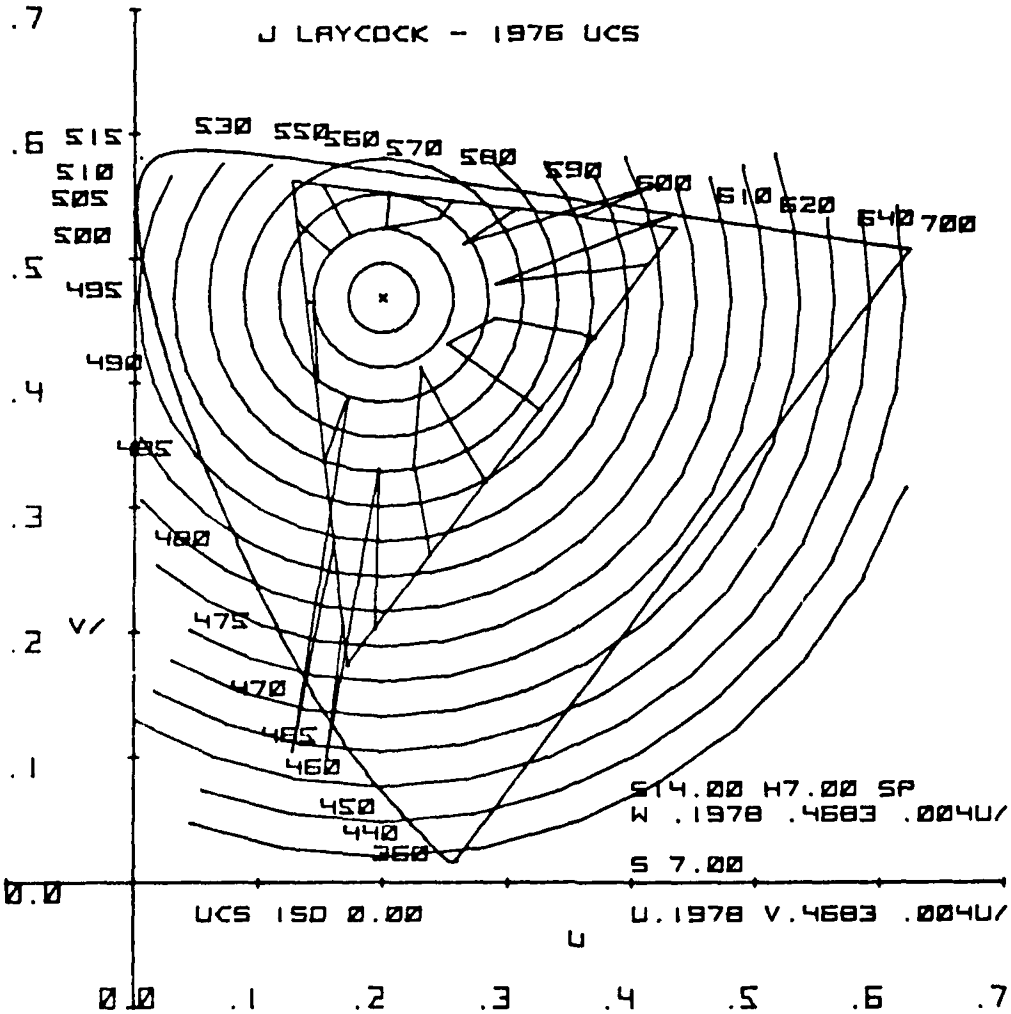
J LAYCOCK - 1976 UCS
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Fig 44

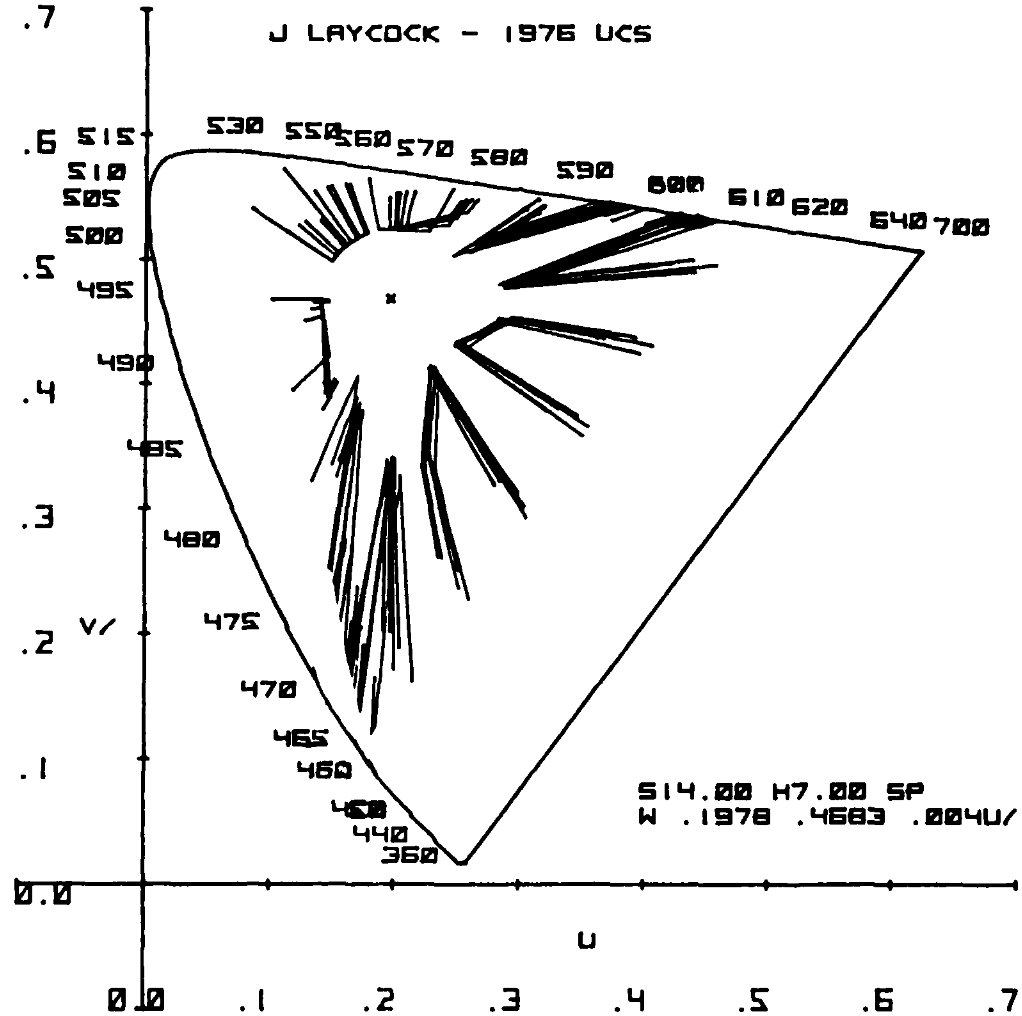
J LAYCOCK - 1976 UCS
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Fig 45

Fig 46

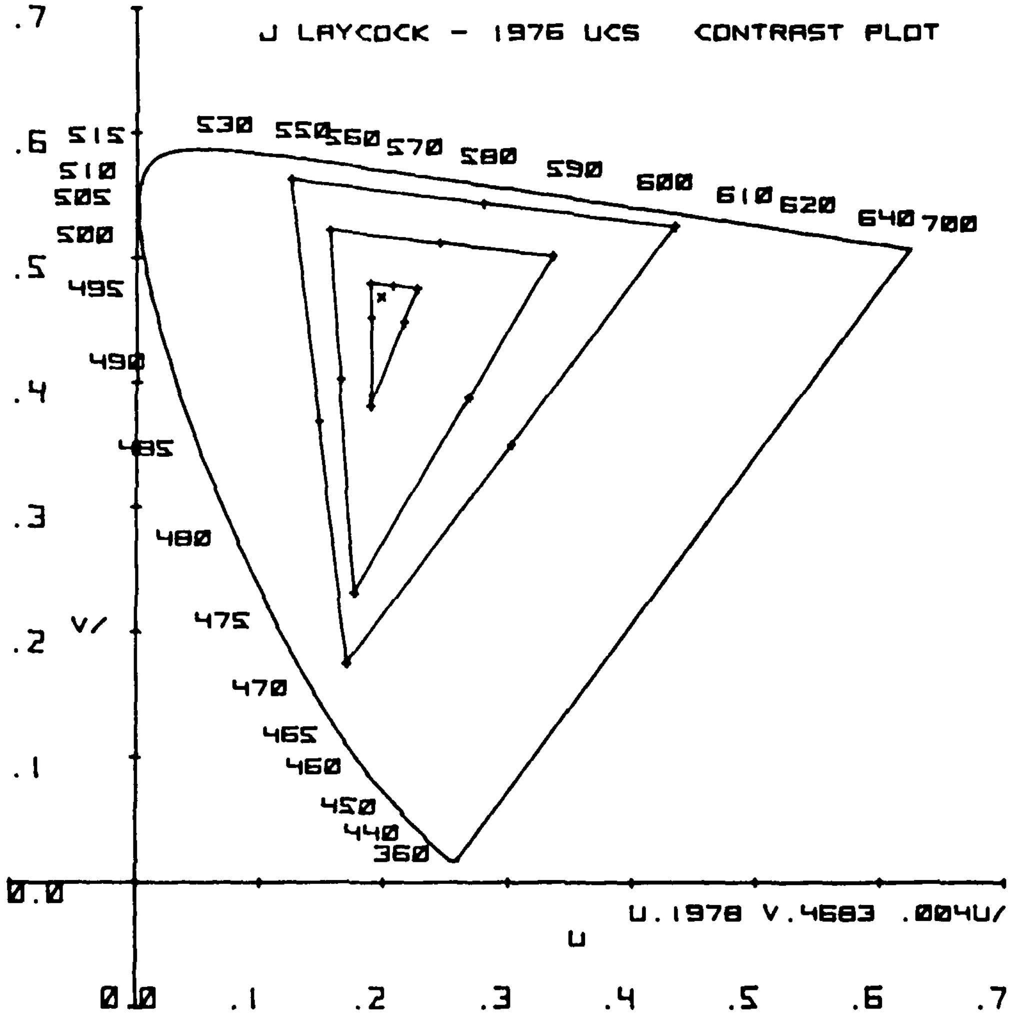
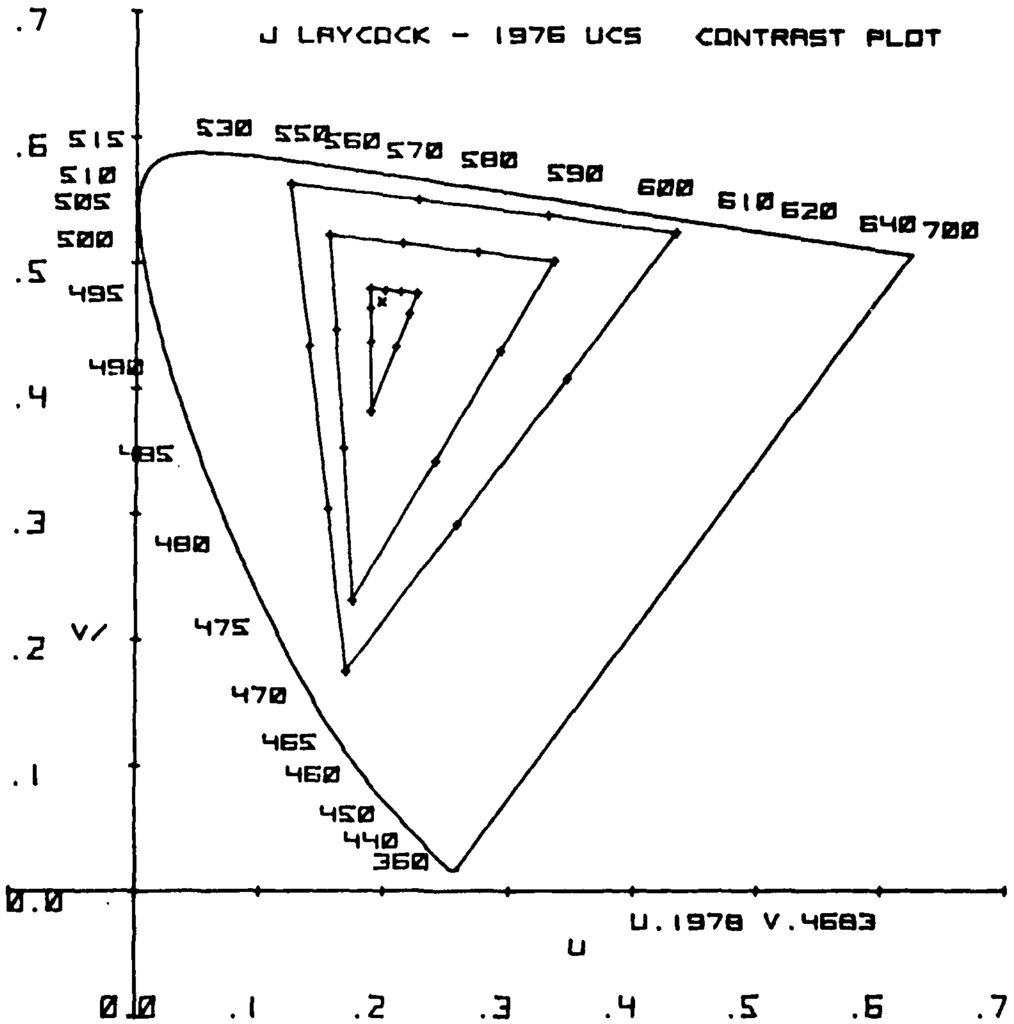


Fig 46

TR 82110



TR 82110

Fig 47

Fig 48

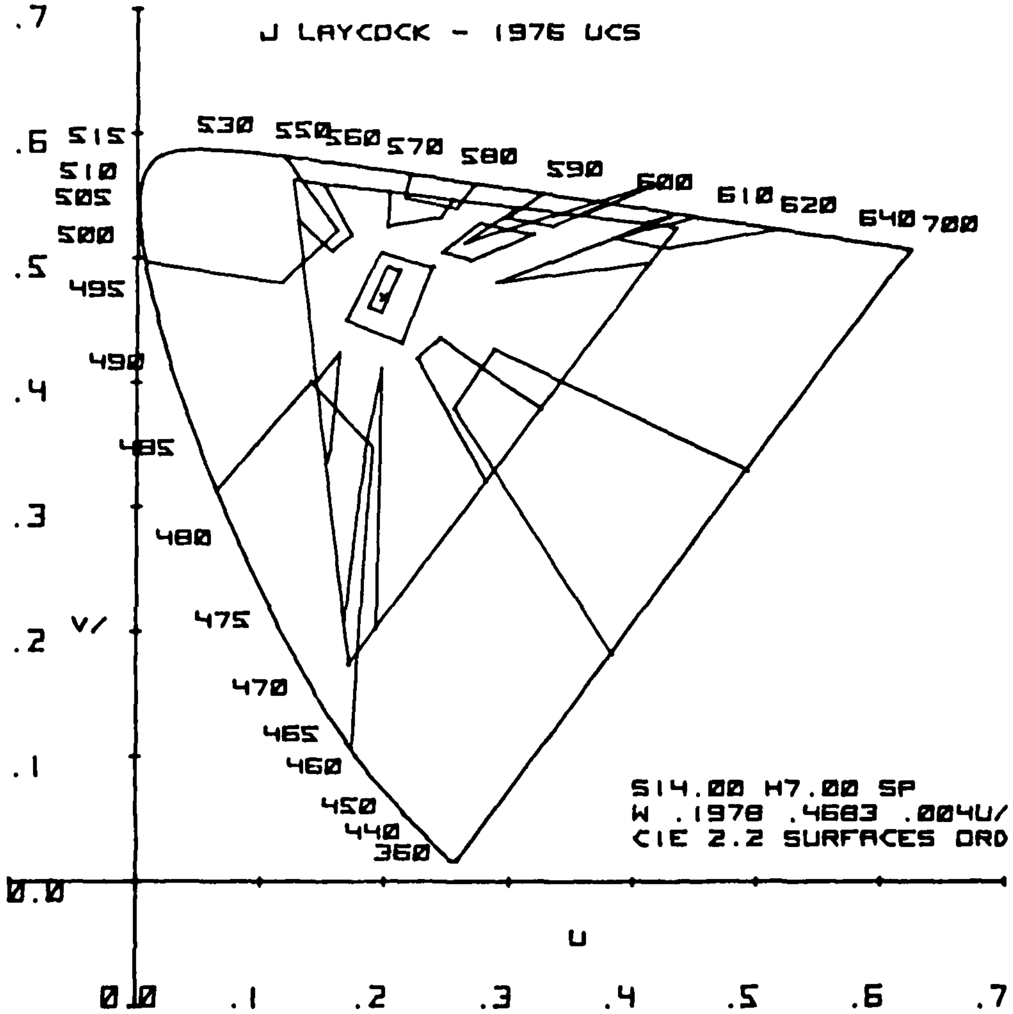


Fig 48

TR 82110

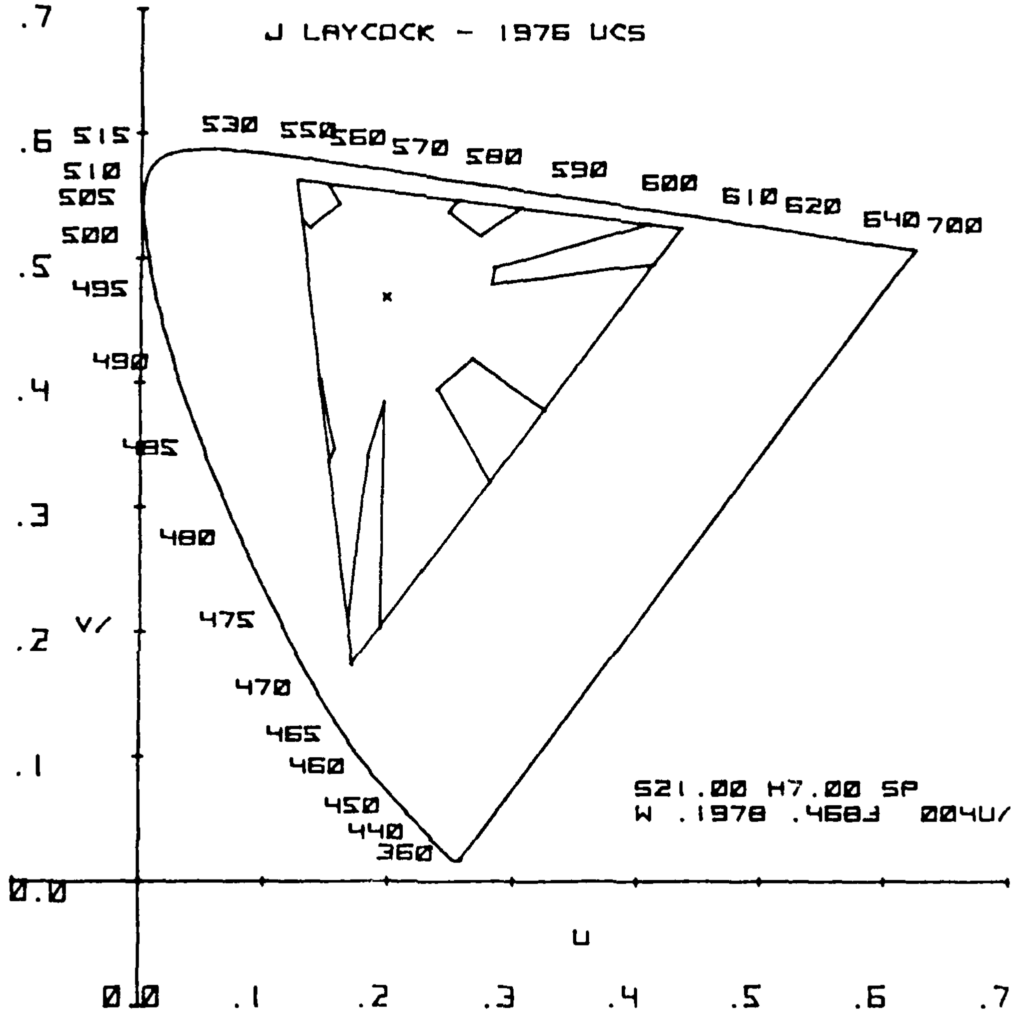

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Fig 49

Fig 50

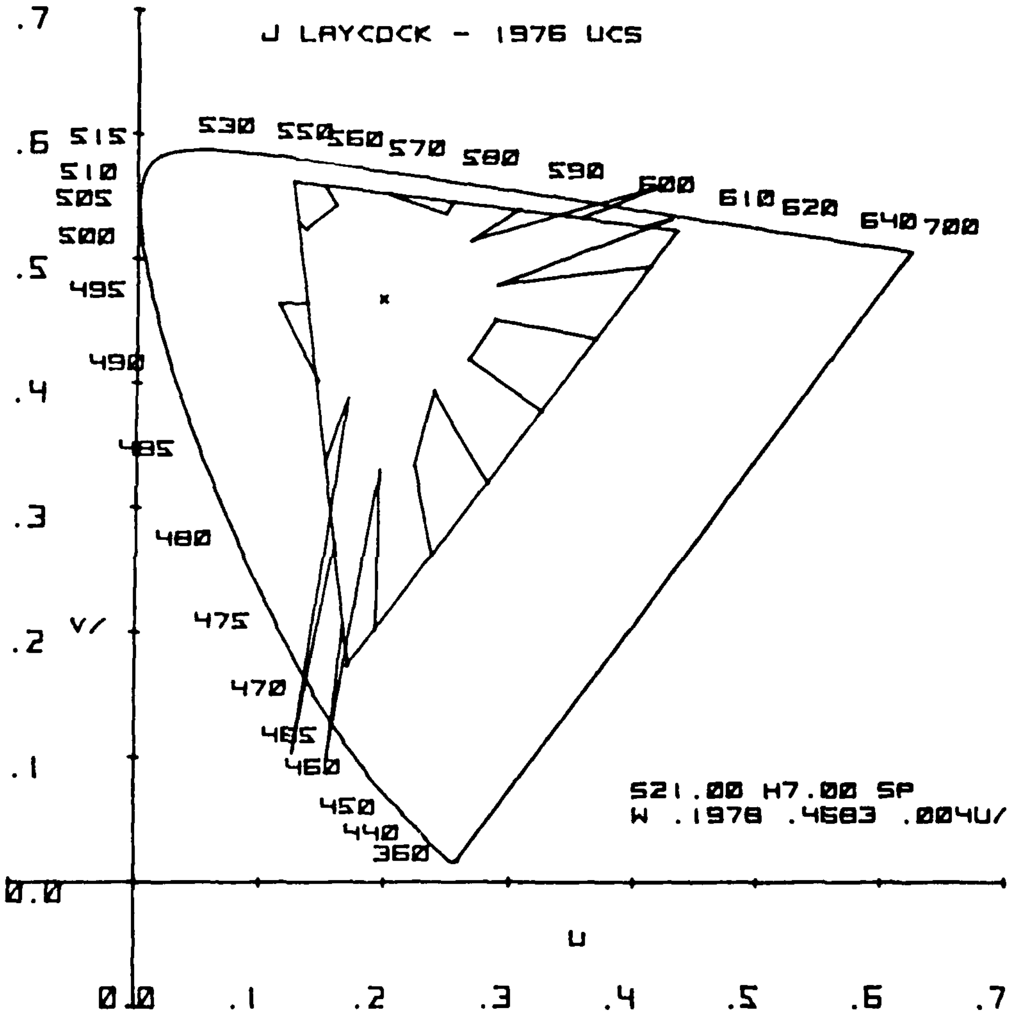

Fig 50

TR 82110

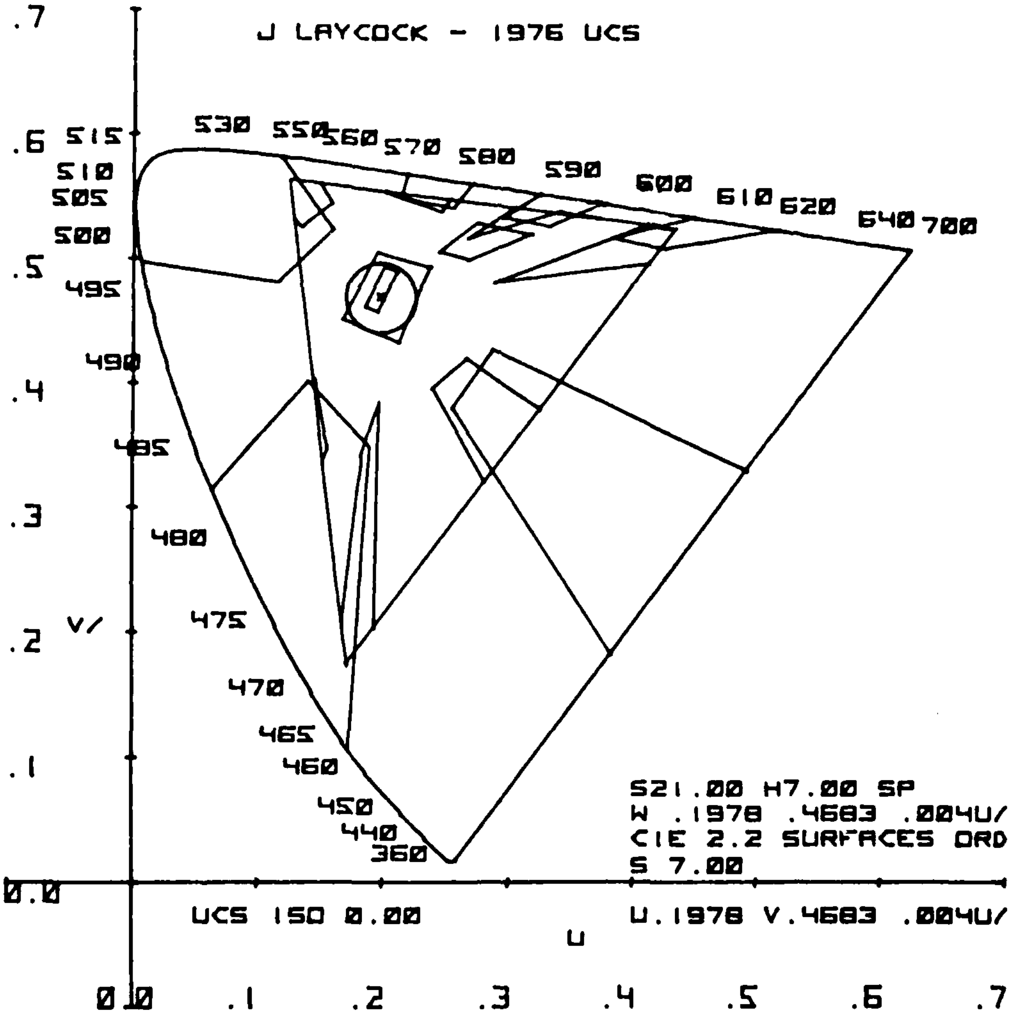
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Fig 51

Fig 52

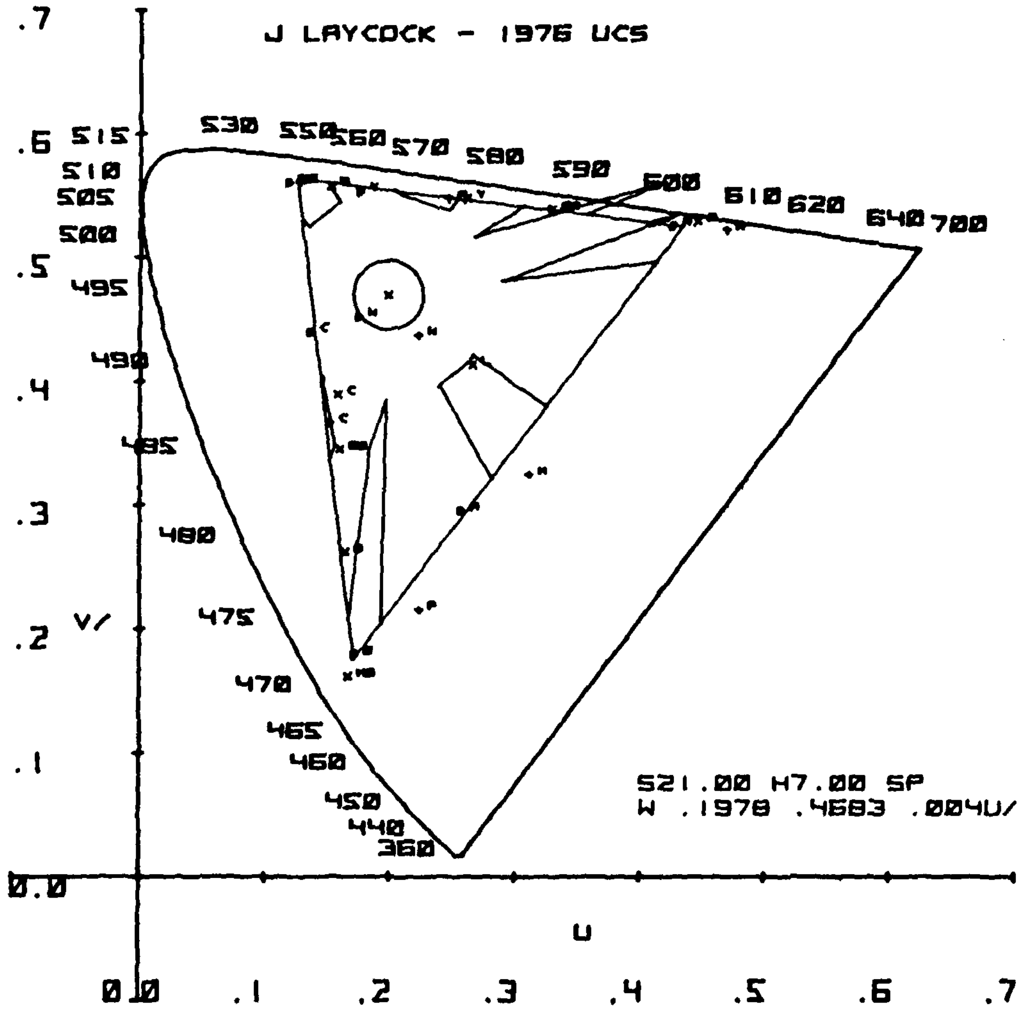

Fig 52

TR 82110

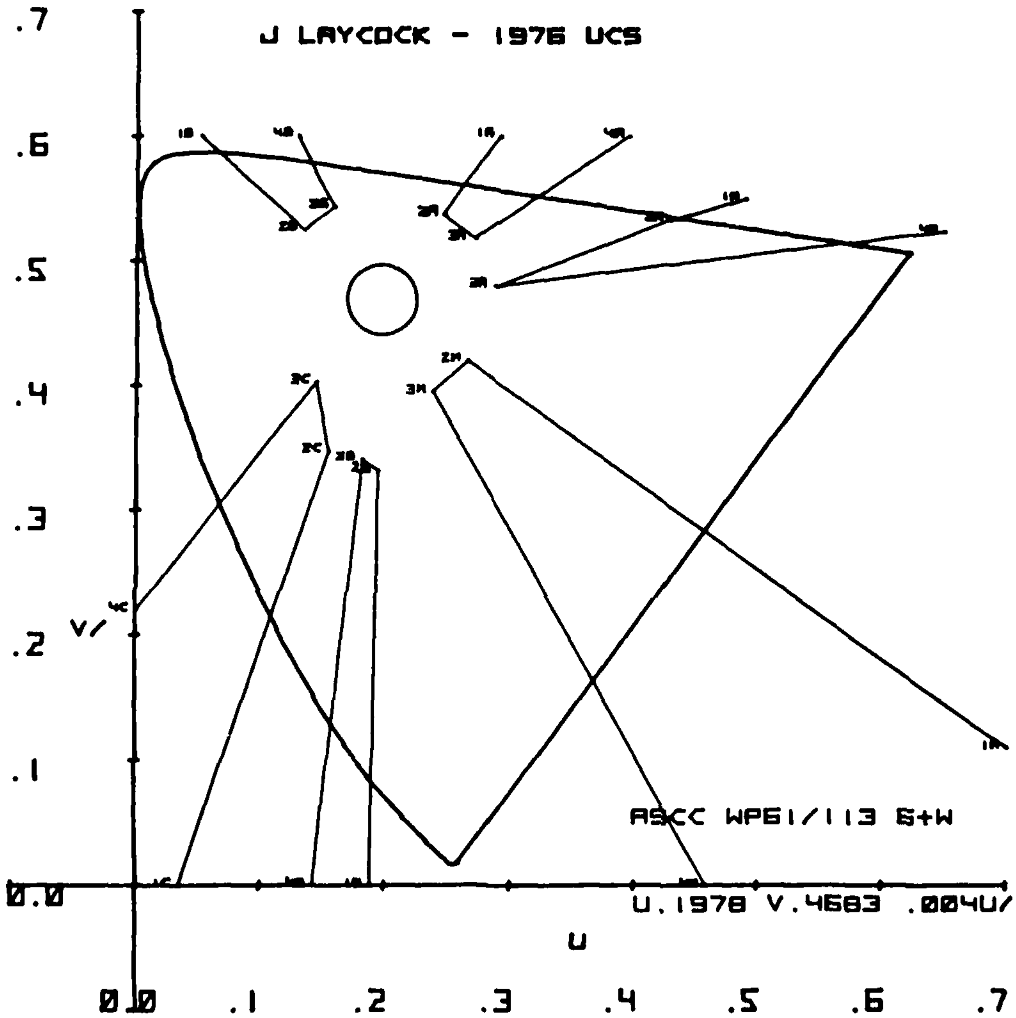
J LAYCOCK - 1976 UCS
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Fig 53

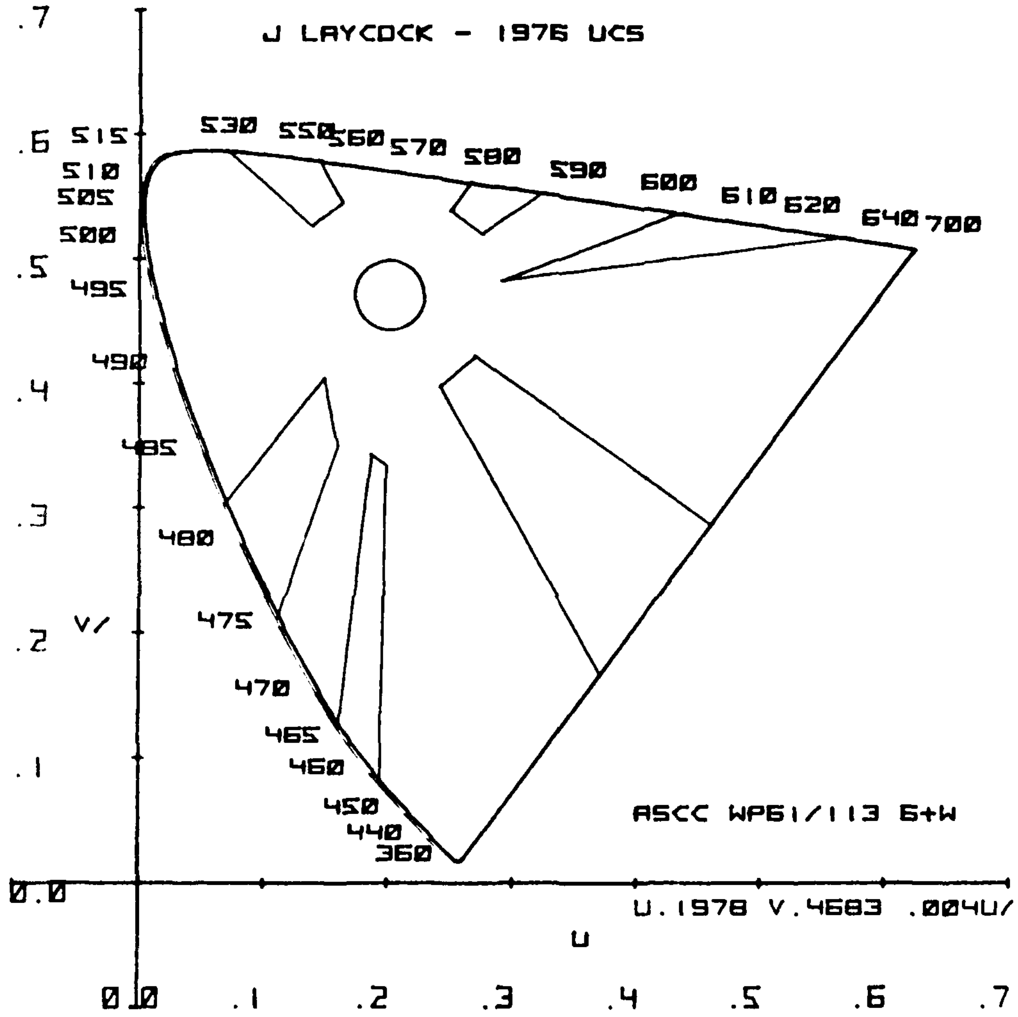
J LAYCOCK - 1976 UCS
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Fig 54

Fig 55

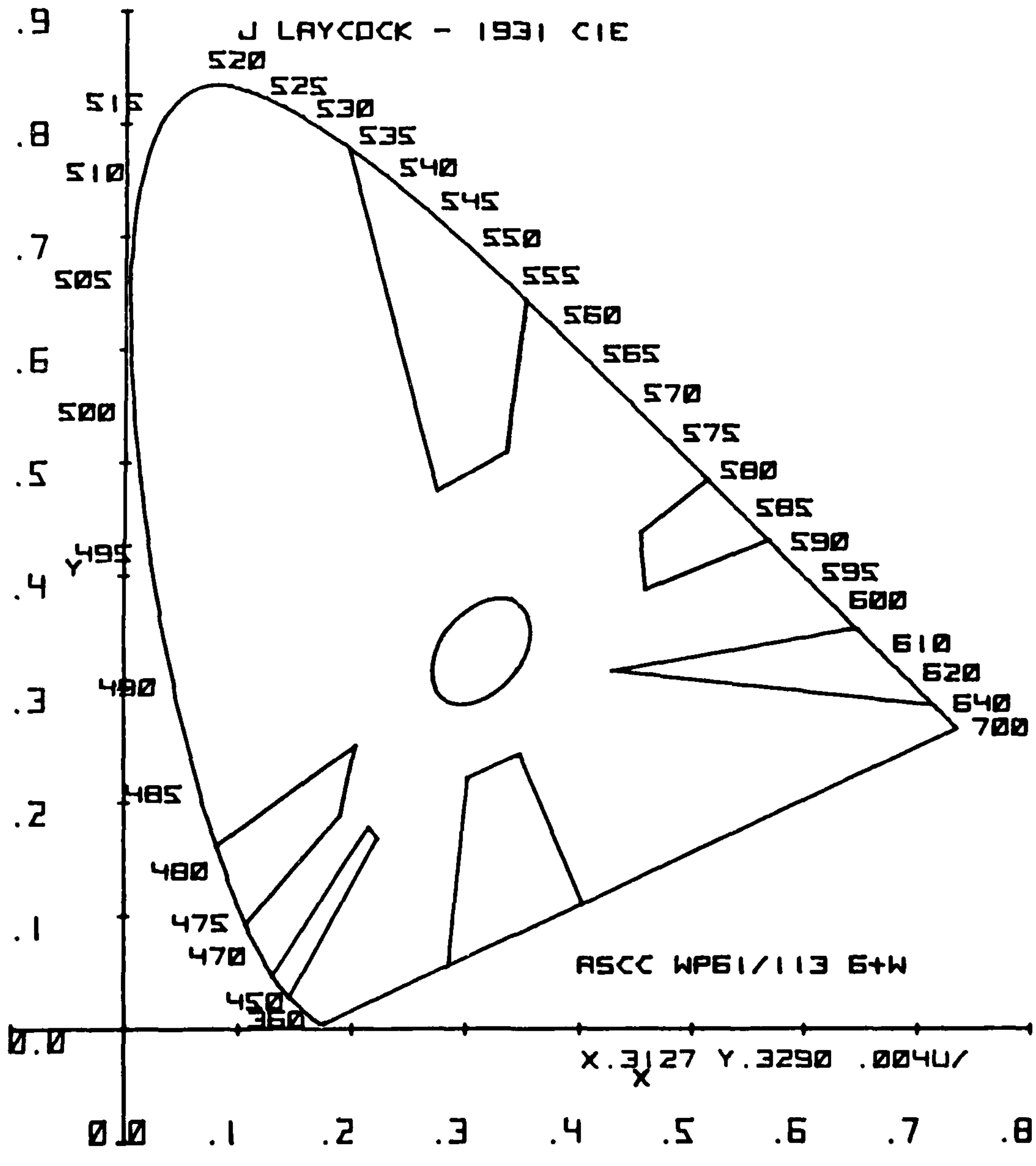

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Fig 56

Fig 56

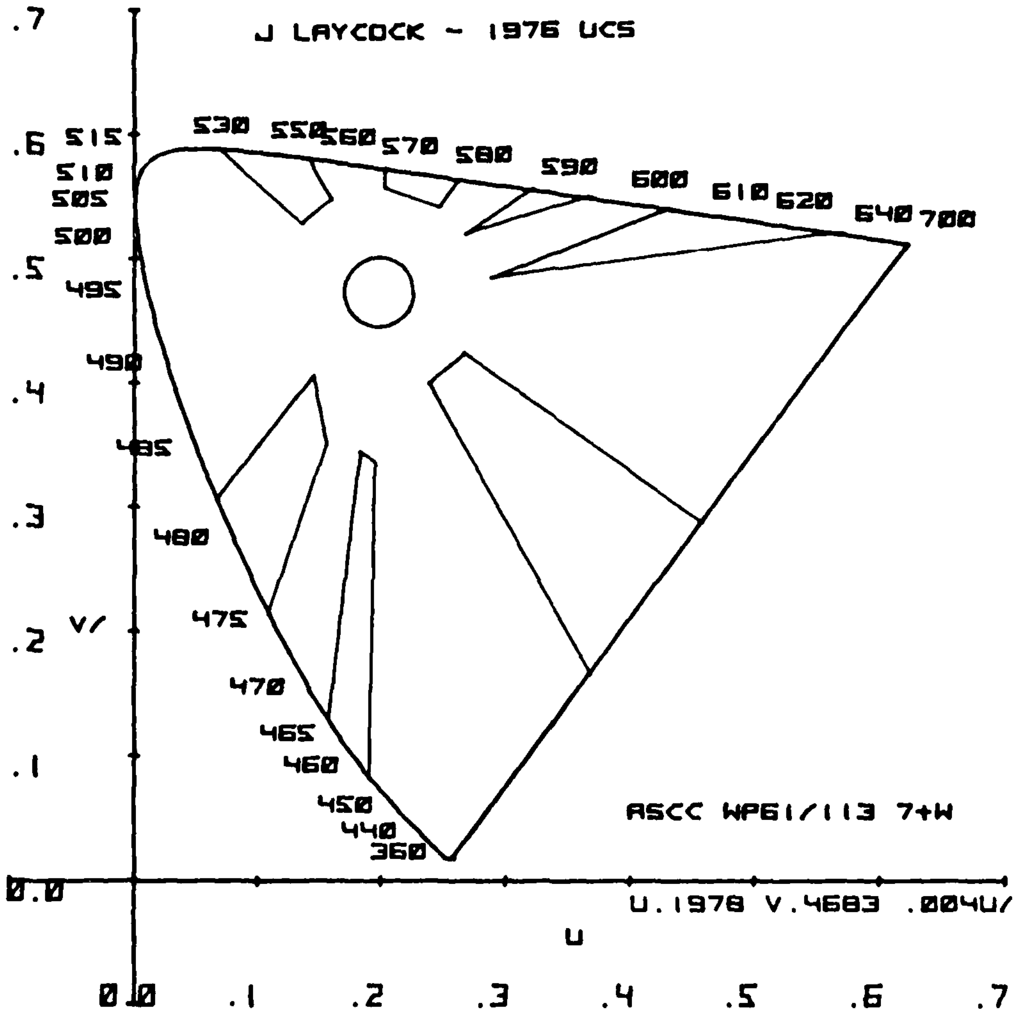

Fig 56

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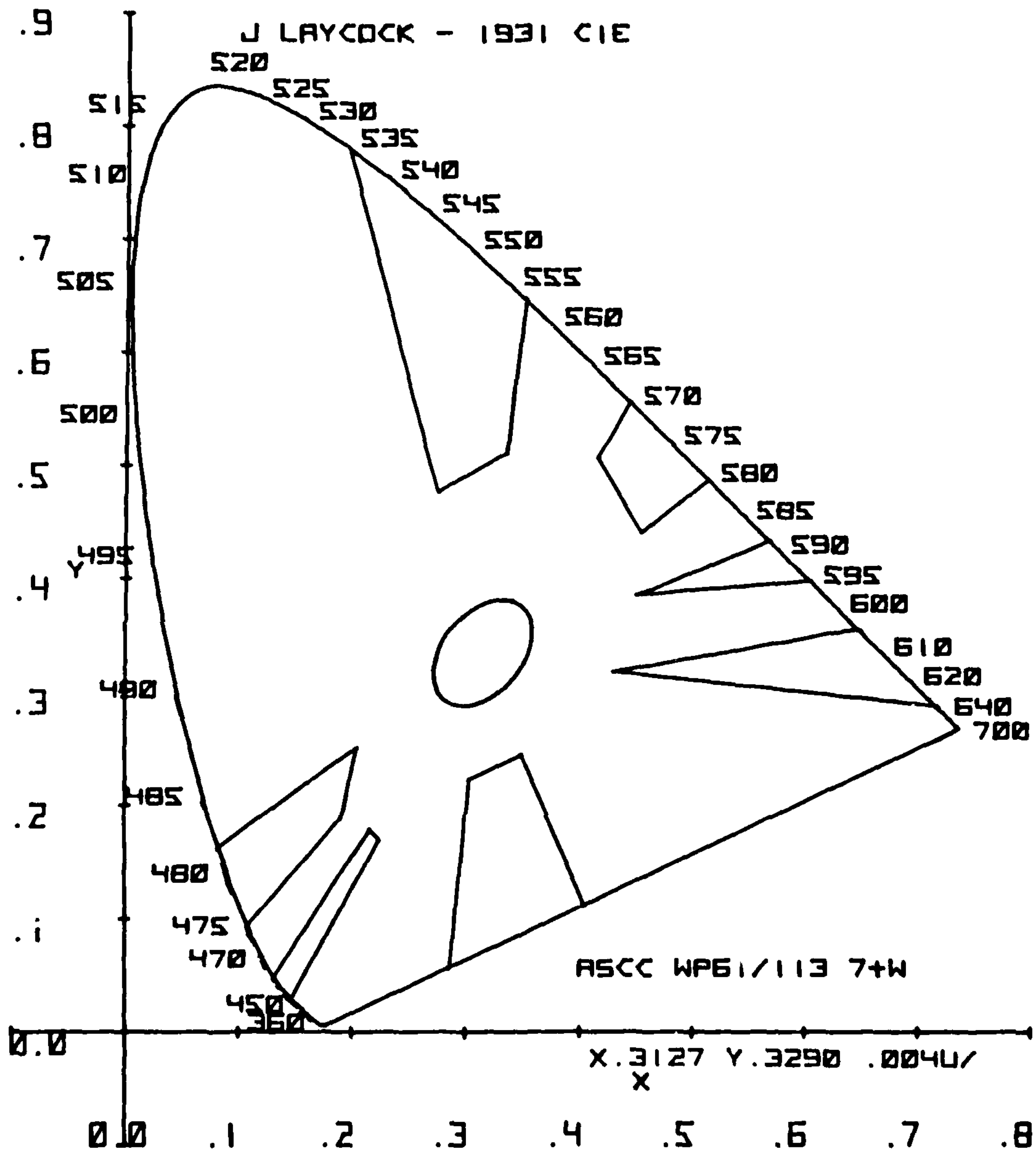
J LAYCOCK - 1931 CIE
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Fig 57

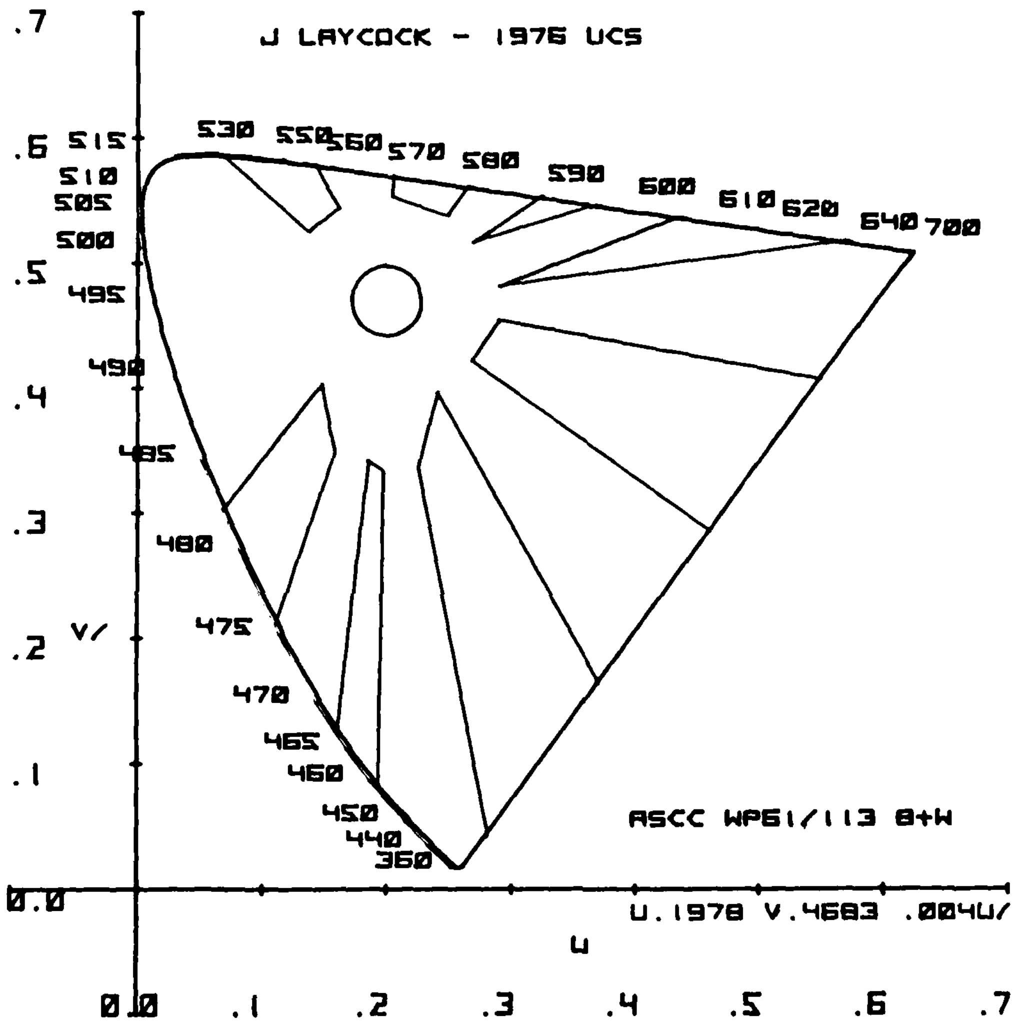
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Fig 58

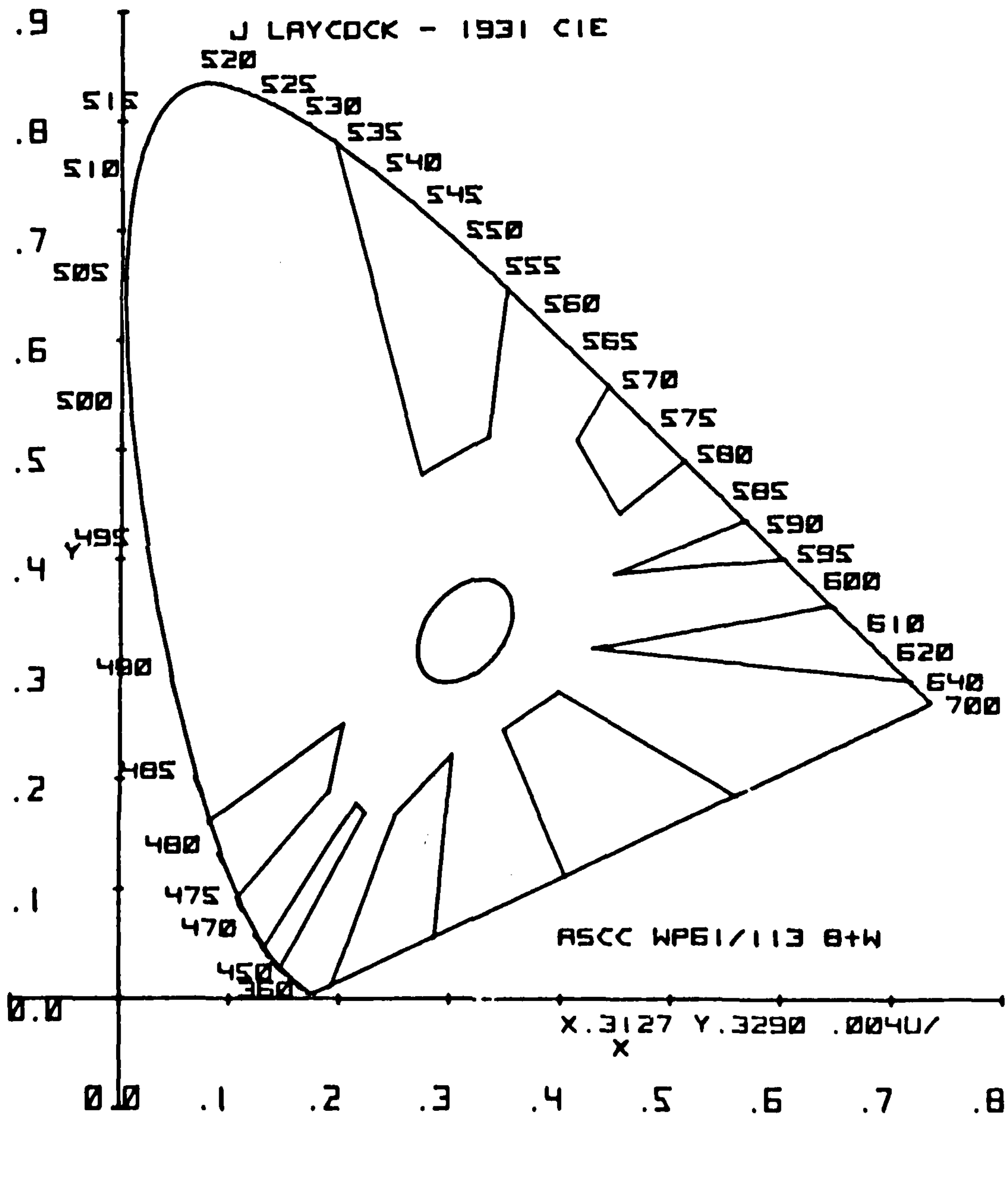
J LAYCOCK - 1931 CIE
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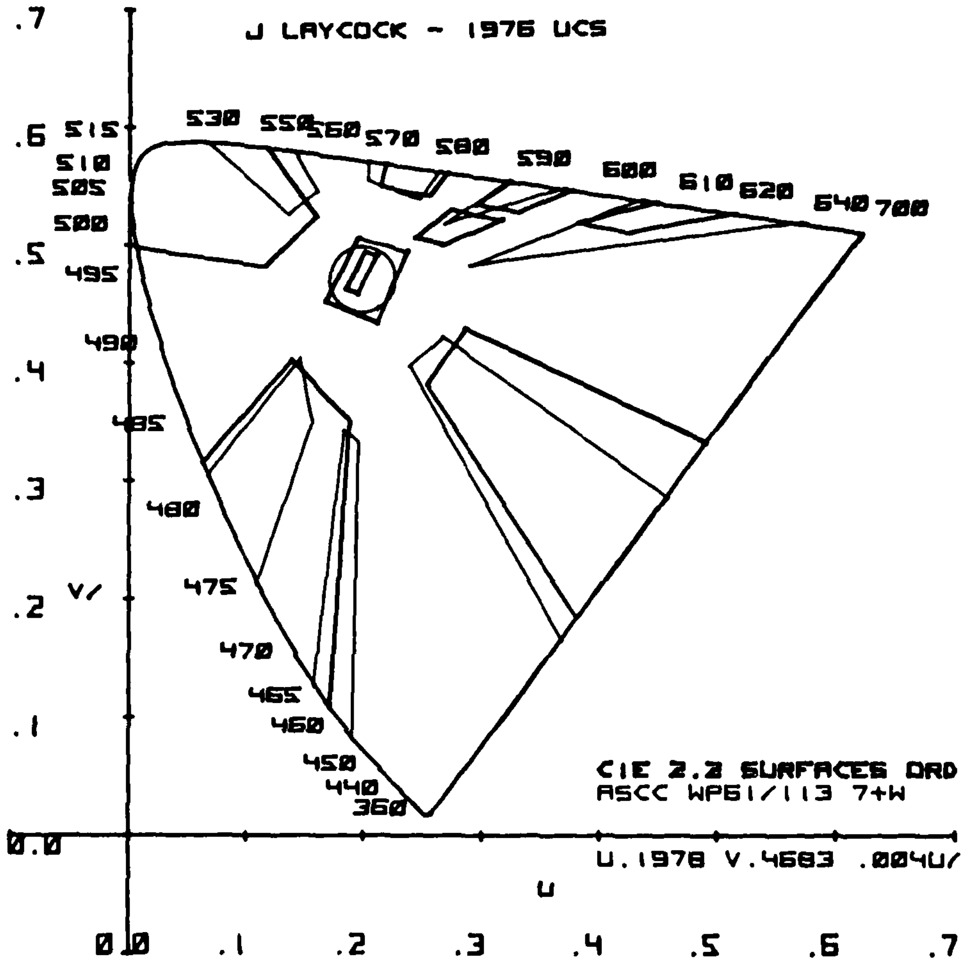
Fig 60



J LAYCOCK - 1976 UCS
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Fig 60

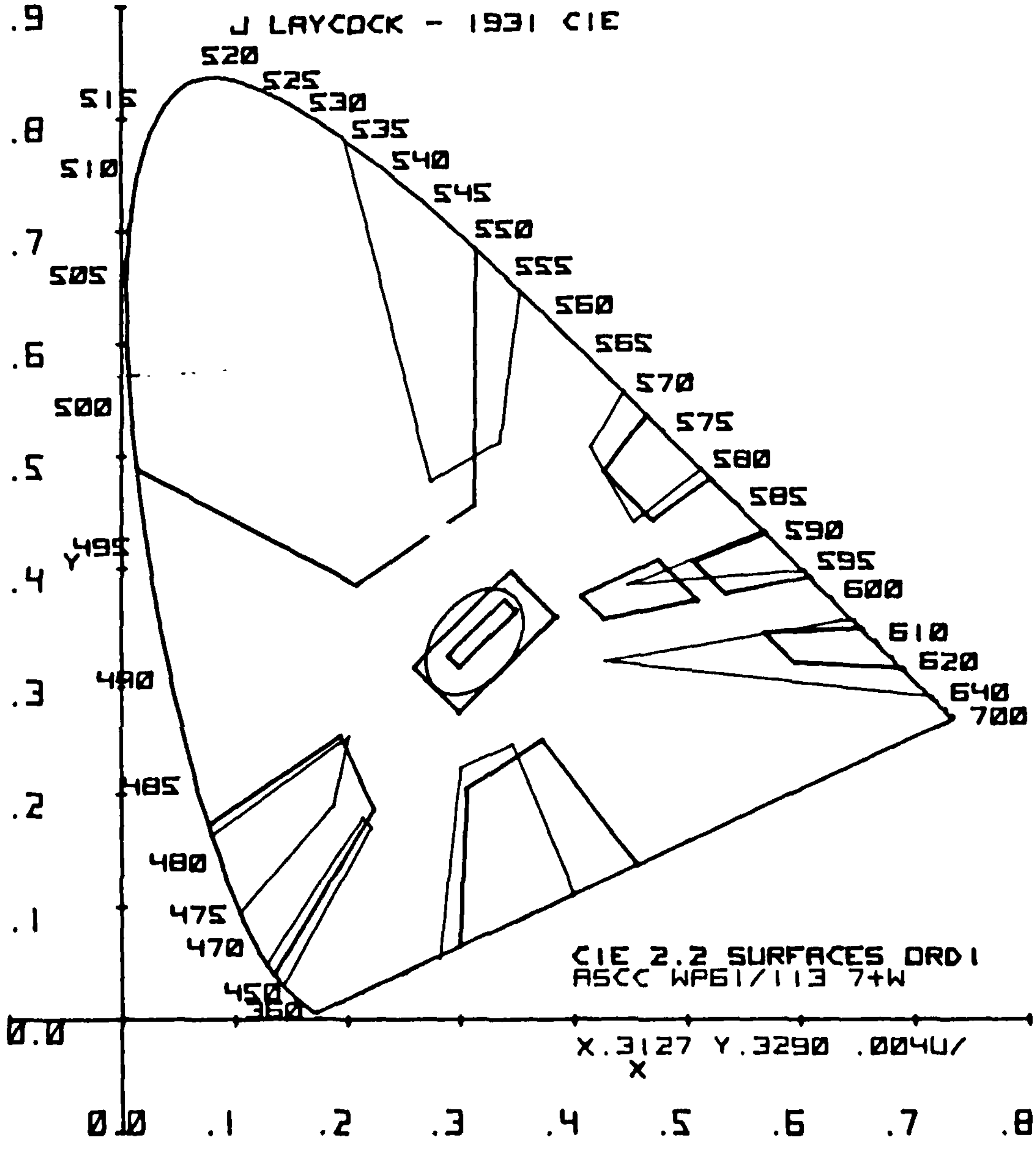

Fig 61

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REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNLIMITED

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	RAE TR 82110	N/A	UNLIMITED

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5a. Sponsoring Agency's Code	**6a. Sponsoring Agency (Contract Authority) Name and Location**
N/A	N/A

7. Title Recommended colours for use on airborne displays

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Laycock, J.			November 1982	93	16

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.
N/A	N/A		FS(F) 190

15. Distribution statement
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   (b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Colour standards. Colour displays. Visual perception.

17. Abstract

This document indicates the confusion that exists between a number of colour standards before outlining how they may have been derived. All the standards are unable to deal with modern electronic displays. A computational procedure is described which enables new colour boundaries to be specified. A summary of data derived using the procedure is presented.

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