ERGONOMIC DESIGN OF THE TRISTAN CONTROL ROOM

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MOTIVES - MINIMIZING DISCOMFORT

Until recently almost all the accelerator control systems were based on efficient extension from each decentralized control board of the equipment itself. Those systems lay stress on each hardware function and tend to ignore the physiological interaction between man and machine. One of the major differences between TRISTAN control system and those for most other accelerators is that many ergonomic studies conduct the system design to improve operator productivity by minimizing error, fatigue and discomfort. The ergonomic features involve not only each terminal component but surroundings of the operator work station.

The basis of TRISTAN control system is an N-to-N computer network and KEK NODAL which offers high software productivity.[1] But the computer, being nonhuman, prefers alphanumeric communications. This preference conflicts with most requirements for visual images in general human communication. The proper use of color graphics can aid in simplifying the interpretation of large amounts of complex accelerator data and delivering visible information to operators in an effective way. A Touch-Panel (TP) simplifies communications with computer and makes operation of Video Display Unit (VDU) systems easier by eliminating the use of keyboards.[2] A pair of TPs is a basic component in TRISTAN operator's console. One of the pair is used for a menu-selection mode and the other for a parameter-set mode. The latter mode eliminates the rotary encoder or the trackball from the console using the TP as a continuous data input terminal. Aplication of many VDUs like this, however, brings about some critical problems concerning the helth of those who work with the equipment over prolonged periods. In the following sections, we discuss about the problems in detail and give the guiding principles of the design.

CONTROL CENTER AND VDU SYSTEMS

The TRISTAN control system was designed with a view to enabling a single operator to instruct a large and complex collection of accelerator devices. At the control center, operators interact with TRISTAN as a system of central control computers. These computers aid each other in a number of distinct functions;

(1) program library,
(2) program development,
(3) KEKNET subsystem,
(4) control console support.

Many VDUs are used in man-machine interfaces to communicate with those computers. A schematic description in Fig. 1 shows a standard unit of operator console. Three units are used for the accumulation ring (AR) of TRISTAN. The unit is composed of two color graphic displays, two touch panels with color displays and 10 general purpose color TV monitors. Table 1 gives the detailed specifications of each VDU. The operator console adopts color VDUs for all parts because of the following;

(1) increase of visible information variables,
(2) easy recognition of complex data,
(3) efficient interpretation of large amounts of complex data,
(4) easy response for a series of operation.

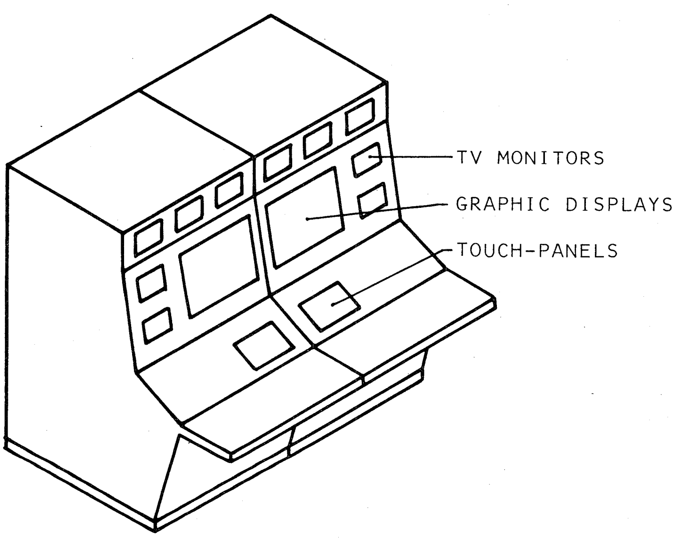

Fig. 1. A unit of the operator console.

Table 1. Specifications of VDUs

	Graphics	TP	General purpose TV monitor
Screen size	20"	14"	10"
Viewing area of CRT	300mm^W x275mm^H	250mm^W x189mm^H	173mm^W x136mm^H
Horiz. freq.	31kHz	19.2kHz	15.75kHz
Refresh rate	30Hz	45.7Hz	60Hz
Resolution	0.31mm	0.31mm	0.45mm

We use the multicolor display which is basically similar to that of color television. The phosphors, the resolution and the refresh rates, however, may be different from the general television to reduce the eye trouble for our special usage. The persistence of a phosphor has an effect on how many times per second the display must be refreshed to avoid the flicker since the image is composed of a series of light pulses. The visible flicker has adverse effects on the human eyes because it overloads on the eyes to adapt the image by the repetitive overexposure of the retina to light. This effect of flicker is very similar to that of glare.

The flicker also depends on the background luminance of CRT, glare of the CRT surface and the lighting of surroundings. Glare of the screen is critical if visual problems are to be averted. Offsetting glare is important as well as to improve character quality since the glare disturbs the operator by diminished image contrast. Although it is impractical to eliminate the glare completely, it is possible to reduce to an acceptable level. Plastic panel, silk filter, anti-reflective coating or etching directly on screen glass reduce the glare from the polished glass of standard CRT surface.

A study of the contrasts between characters and background luminances is important physiological subject for legibility. In the printings, the contrasts of 1:5 to 1:10 are generally used for black characters on white paper in order to obtain sharp edge between character and background. Until recently most terminals with CRT followed these contrasts to obtain sharpness by reverse ratio for green characters on a black or gray screen. We can get easily long persistence phosphor for green color. This means easy to reduce the flicker, but other eye troubles have occurred. Those are burning and lachrymation eyes which cause eye strain and discomfort. No clear explanation was given about the eye troubles by some appeared reprots. The experiences in KEK show that there are significant visual advantages in displays of dark characters on a light background over those of light characters on a dark back-ground. The size of the pupil is a function of average luminances within the field of view. We observed that the pupil size becomes larger for light characters on a dark background than for dark characters on a light background. The large pupil size and high contrast of light characters cause burning eyes. We can say that high average light density and uniform luminance for the most part of the display reduce the eye troubles significantly.

TPs are greatly concerned about the ergonomic design, because the gaze of the operator is mostly concentrated to TPs and the graphic displays are next to them in our case. Special attention should be paid to the following;

(1) background color of the VDU,
(2) uniform light density within the field of view,
(3) size of the screen,
(4) setting position of TPs.

As a result of our study, bluish white is the most friendly color to the eyes in the background of VDU. In order to obtain good uniformity of the light density between the VDU and its neighborhood, we pay attention to the frame of TPs being a light neutral color and having a matte finish to minimize glare. The size of the VDU being 14" is determined by the field of view at the sitting position of the operator and by the most efficient numbers of touch buttons described on the screen.

OPERATOR CONSOLE

In order to properly design the operator console, we must analyze;

(1) the task to be performed,
(2) the physical characteristics of the operators,
(3) the instruments to be used.
(4) proper location of the instruments.

Studies of the representation of operator posture have been done including anthropometric characteristics and biomechanical laws that determine the limits of each mobility of physical segments. The subject of seated positions is an important factor to reduce the fatigue. Adjustable chair, which is possible to adjust up and down and back and forth, should be considered for maximum comfort of operators. Fig. 2 shows schematically the possible and basic dimensions of work space and the optimal distance between the eyes and the work surface.

We limit the basic work surface of the console to only two kinds of parts those of which are the image surface of color graphic displays and TPs with VDUs. Each access to the accelerator components is done through the menu-selection mode of the TP. The results are described on the graphic display. The read-back data and the real setting value are given on the VDU itself under the TP in response to the time interval of the touch of a finger. We call this mode a parameter-set mode. A pair of TPs for the two modes is a basic instruments in the operator console. The parameter-set mode eliminates such as the rotary encoder from the console which may cause the operator to be puzzled and confused. In this way, operators who are unfamiliar with data-processing system can conduct an interactive dialog with TPs and VDUs to communicate with on-line equipment.

The location and orientation of the VDU and the TP strongly depend on the viewing angle and distance, the glare control and the lighting characteristics of the control room. Character size determines the distance between the screen and the eyes of operators. In our experience, many persons prefer a viewing distance of about 50 cm or longer. Visual discomfort is reduced for the longer distance because of less visual convergence and accommodation. The eye position relates to the display height. A natural and comfortable line of sight is 10 degrees or more below the horizontal. The operator needs the arm support surface which is also the writing or document surface, in order to touch the TP without constrained posture. The TP locates about 30 cm from the end of the arm support surface. The TP should be sloped at a 10- to 15-degree

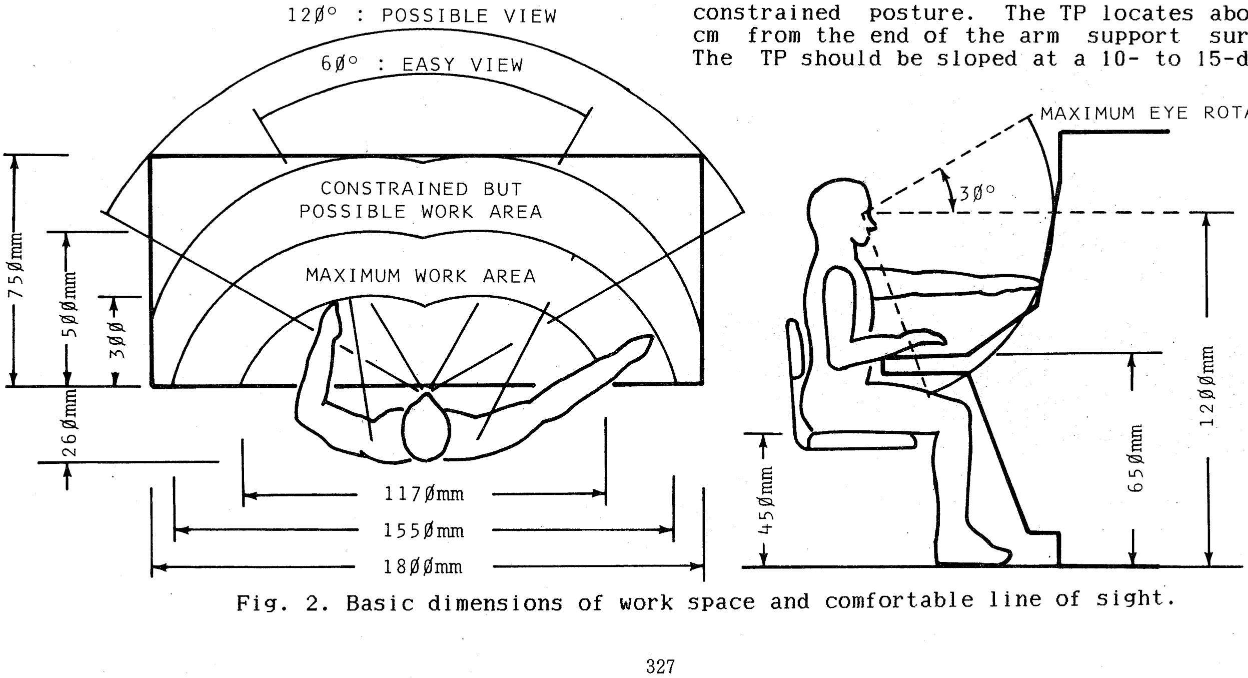

Fig. 2. Basic dimensions of work space and comfortable line of sight.

angle like that of a typewriter. Hence the graphic display and the TP should be located so that the normal line of view falls in the region shown in Fig. 2.

CONTROL ROOM

The central control room of the TRISTAN was designed considering the lighting fixture and the acoustic noise. The effective lighting on the operator console is the sum of all the light rays striking its surface, including rays directly from lamps and reflected from walls or other objects in the control room. In a usual office for the computer work station, the source document is the critical factor in determining how much and what type of light should fall on the work surface. White paper has a reflectance factor of about 70 to 80%. This means that ambient light levels are not important because only reflective surfaces are considered. On the other hand, a VDU generates its own light to create the information image on its surface. Although there is a range of adjustability for the image brightness of the VDU, the range is limited and does not automatically alter with changes in the ambient illumination. If these differences are not considered in the design of the control room including the operator console, some critical and visual discomfort may be encountered. The eye does not react so quickly to changes in light levels. It is commonly recommended for luminance balance that there should be no more than 3:1 difference in luminance between the task area and its immediate surroundings. In our case, the control room was designed to give a uniform visual field in terms of luminous intensities.

Light fixtures and reflections from shiny surfaces are common sources of discomfort glare that may be objectionable even if they do not interfere with the work itself. The angular separation between the line of sight and a glare source is an important factor of the design. The ceiling of our control room is 5 meters high to avoid directly striking the operator eyes by the ceiling lights. Variable louvers in front of the ceiling light contribute to moderate the glare and to give uniform luminous balance on the work surface.

Fig. 4. One day, a view of the control room.

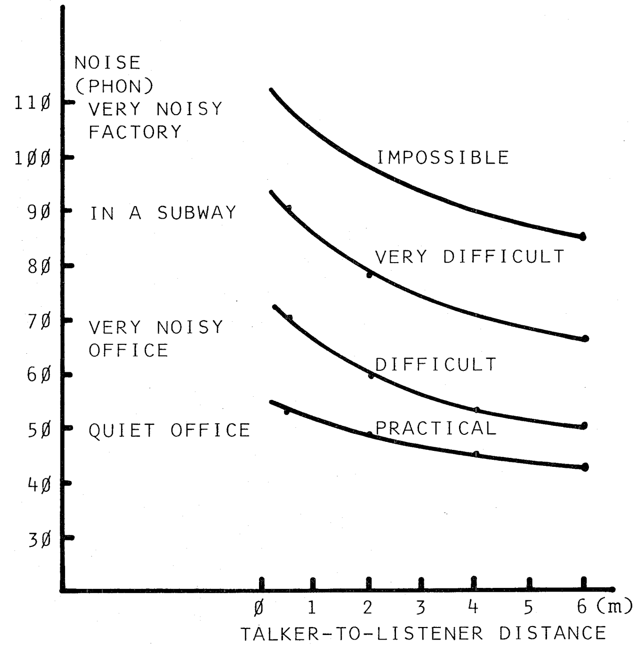

Fig. 3. Noise levels around us.

The wall of the control room is made from nongloss materials and its surface has a matte finish.

The acoustic noise, which is mainly generated from cooling fans attached to the mounted equipment on the console and from the resonance of the air duct of an air conditioner, is uncomfortable and causes the fatigue of a long operation in the control room. The usual noise levels around us are shown in Fig. 3. We suppressed the noise level in the control room as low as that of the quiet office by means of;

(1) using low noise fans,
(2) acoustic absorber under the wall surface,
(3) acoustic treatment for the air duct,
(4) carpeting the free access floor.

Now we are proceeding in an extension for the console of the main ring. Fig. 4 shows the present status of the control room. In future, we may replace the three 27" TV monitors on the wall with a large screen using liquid crystal or with a projector to obtain good performance for increasing of necessary information.

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REFERENCES

1. H. Ikeda, et al., "Design of the Control System of TRISTAN", IEEE Trans. Nucl. Sci. **NS-28** No.3, 1981.

2. T. Katoh, et al., "Touch-button System in the TRISTAN Control System", contributed paper of this meeting.