

A light-emitting tube array for giant colour display

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A large screen – more than 4 m high by 5 m wide – colour display system has been developed. The display screen consists of matrix array of small, high luminant intensity light-emitting tubes, and can present sharp colour pictures even in daylight. It offers better colour and lower power consumption than conventional large displays based on incandescent lamps.

Keywords: display devices (computers); electron-beam tubes; public-address systems; Japan.

In the highly developed field of information transfer, display equipment has taken an important position among the communication media. Various technologies suit different applications and numbers of spectators. The relation between spectators and display equipment is shown in Table 1. The large screen colour display system described here, named Diamond Vision, was developed to display colour video images to the largest numbers of people.

Various display methods have been employed to display images to large numbers – over 1 000, say – of people in sports stadiums, at race tracks or from advertising boards. However, as these systems consisted mainly of incandescent lamps, there were many defects, especially in the display of colour video images. Insufficient colour quality, high power consumption and long response times are among the problems experienced with conventional large displays. To overcome the defects of the incandescent lamp, a new light-emitting tube display and control for it have been developed. Arranging these tubes in matrix array and controlling them suitably allows a display system to be designed which can show natural colour video images without high power consumption.

STRUCTURE AND CHARACTERISTICS

Conventional colour television sets reproduce images approximately in their original colours. The same method

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Table 1. Relation between spectators and display equipment

	Spectators 1 – 20	100 – 1 000	More than 1 000
Display function			
On/off control display	Indicator lamp	Signal	Score board
Character display	Panel meter	Neon sign	Score board; Neon sign
Image display	Television	Cinema	Diamond Vision; Incandescent display system

of reproduction is applied in the Diamond Vision system. The screen however consists of matrix array of small light-emitting tubes in three colours instead of using the conventional CRT design in which beams of electrons are forced onto a small area and varied in position and intensity on the surface using a magnetic coil. The new display allows the colour image to be obtained by applying a time modulation method to the individual light-emitting tubes.

Light-emitting tube design

A schematic outline and fundamental drive circuitry of the light-emitting tube are given in Figs. 1 and 2 respectively.

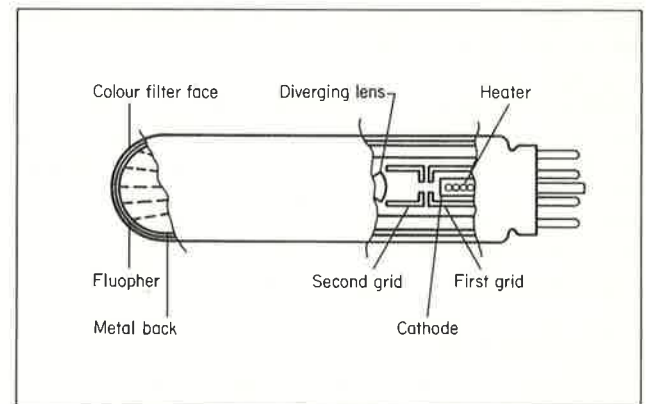


Fig. 1 Section through a light-emitting tube

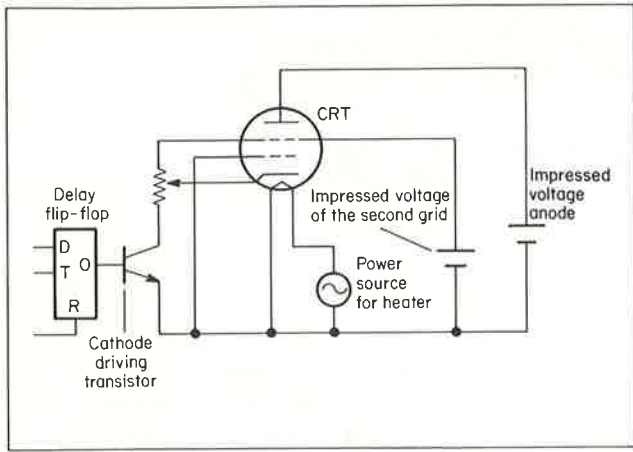


Fig. 2 Light-emitting tube driving circuitry

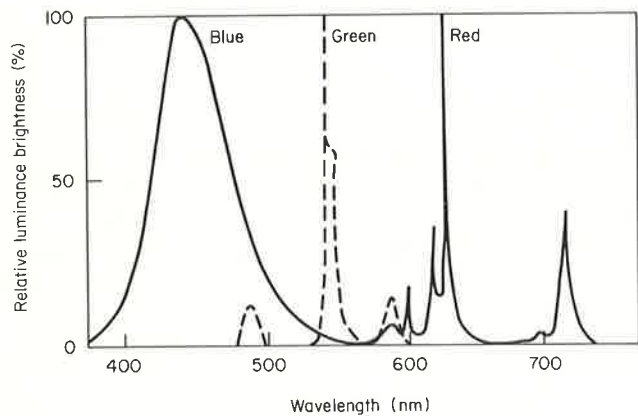


Fig. 3 Spectral characteristics of the three tube colours

The light-emitting tube is a flood-beam electron tube having a single phosphor of red, green or blue colour for each tube. Each tube works as a single picture element whose colour is one of these three.

When the cathode voltage falls below a cut-off voltage level, the light-emitting tube generates monochrome light. As the thermally generated electrons from the heater pass through the second grid of the tube, they form a flood beam and strike the phosphor uniformly. The specifications, spectral characteristics and chromaticity of each tube are shown respectively in Table 2, Fig. 3 and Fig. 4.

Tube arrangement

The complete display system has a screen board on which many individual single-colour light-emitting tubes are mounted. Clearly, the total number of tubes cannot be increased *ad infinitum* because of cost. Under this constraint of limited numbers of tubes on the screen, the picture quality varies with different arrangement patterns of the tubes. The evaluation of picture quality using simulated pictures of various arrangement patterns and small scale working models led to the following results.

1. The luminance pattern of the video image is almost solely dependent on the position of the green colour component.
2. The sharpness perception in human vision is also dependent on the green component.
3. The angle needed for the human eye to distinguish

Table 2. Light-emitting tube specification

Formula	Single beam
Type	Mitsubishi high luminance light-emitting tube Red : LSIAB 22 (R) Green : LSIAB 22 (G) Blue : LSIAB 22 (B)
Dimensions	28.6 mm diameter, 132 mm length (Effective fluopher aperture more than 22 mm)
Luminance	Red : More than 5 000 cd m ⁻² Green : More than 9 500 cd m ⁻² Blue : More than 1 700 cd m ⁻²
Power consumption	Approximately 2 W per tube
Lifetime	8 000 h
Viewing angle	120°

between each colour component is greater than its luminance resolution angle.

4. In the dot sampling and displaying system, stagger sampling increases the resolution of the screen.

On the basis of the above observations, the R-G-B-G quadrupole pattern of Fig. 5, in which the ratio of green tubes to red and blue is 2:1:1, has been adopted for the Diamond Vision screen. It has a higher picture image resolution than that of conventional R-G-B triplet pattern screens given the limited number of tubes. The maximum obtainable luminance of each tube in producing white is lowest for the green tubes, red and green having margins in their maximum luminance. By using green tubes of twice the maximum luminance of red and blue tubes the white peak of the screen can be increased up to the maximum luminance of the red or green tubes.

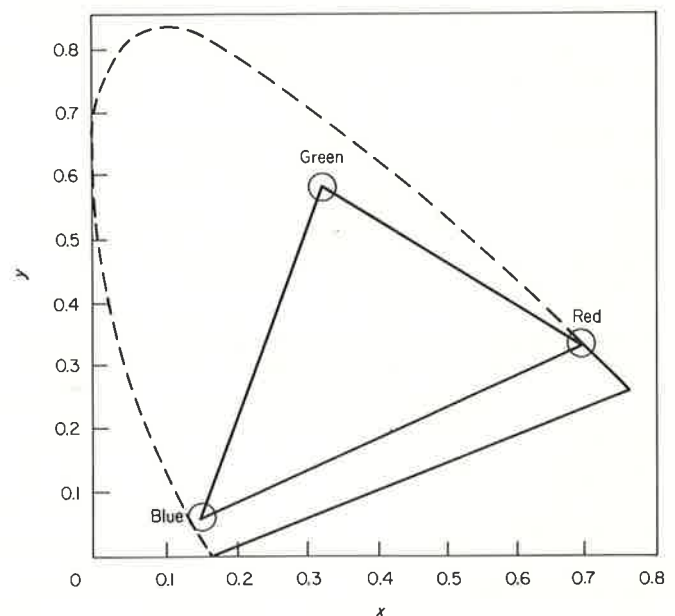


Fig. 4 Chromaticity diagram showing the colour range offered with the three colours of tube

SYSTEM CONFIGURATION

A typical system block diagram is shown in Fig. 6. The system is divided into two main parts, one of which is the display part comprising a screen, screen control apparatus and power supplies. The other is the operation part which

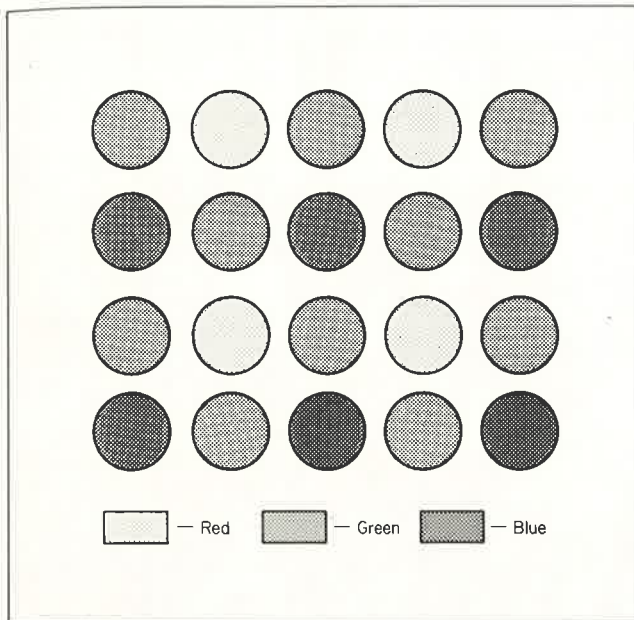


Fig. 5 Arrangement of tubes

contains the conventional video and computer equipment. Each operation for displaying images on the screen and the power control are performed remotely from the operation part. The display part is essentially controlled automatically except during maintenance periods.

The former part generates the video signal for display on the screen, while the latter generates character and graphic data as well as control signals for the screen luminance, zoom etc. The screen control apparatus receives these signals and controls each light-emitting tube digitally. Three coaxial cables are used to transmit data between two parts. One carries the video signal and the other two are for the conventional computer link.

Display control

The method for indicating the picture image on the screen in accordance with signals from the control is explained by the block diagram of Fig. 7. The control sequence is as follows:

Chrominance decoder, sync separator: The input composite video signal is colour-demodulated to generate three colour video signals and separated vertical and horizontal sync signals.

Analogue-to-digital converter: Each colour video signal is sampled and coded into six bits of binary data.

Frame memory: Binary coded data which are converted by

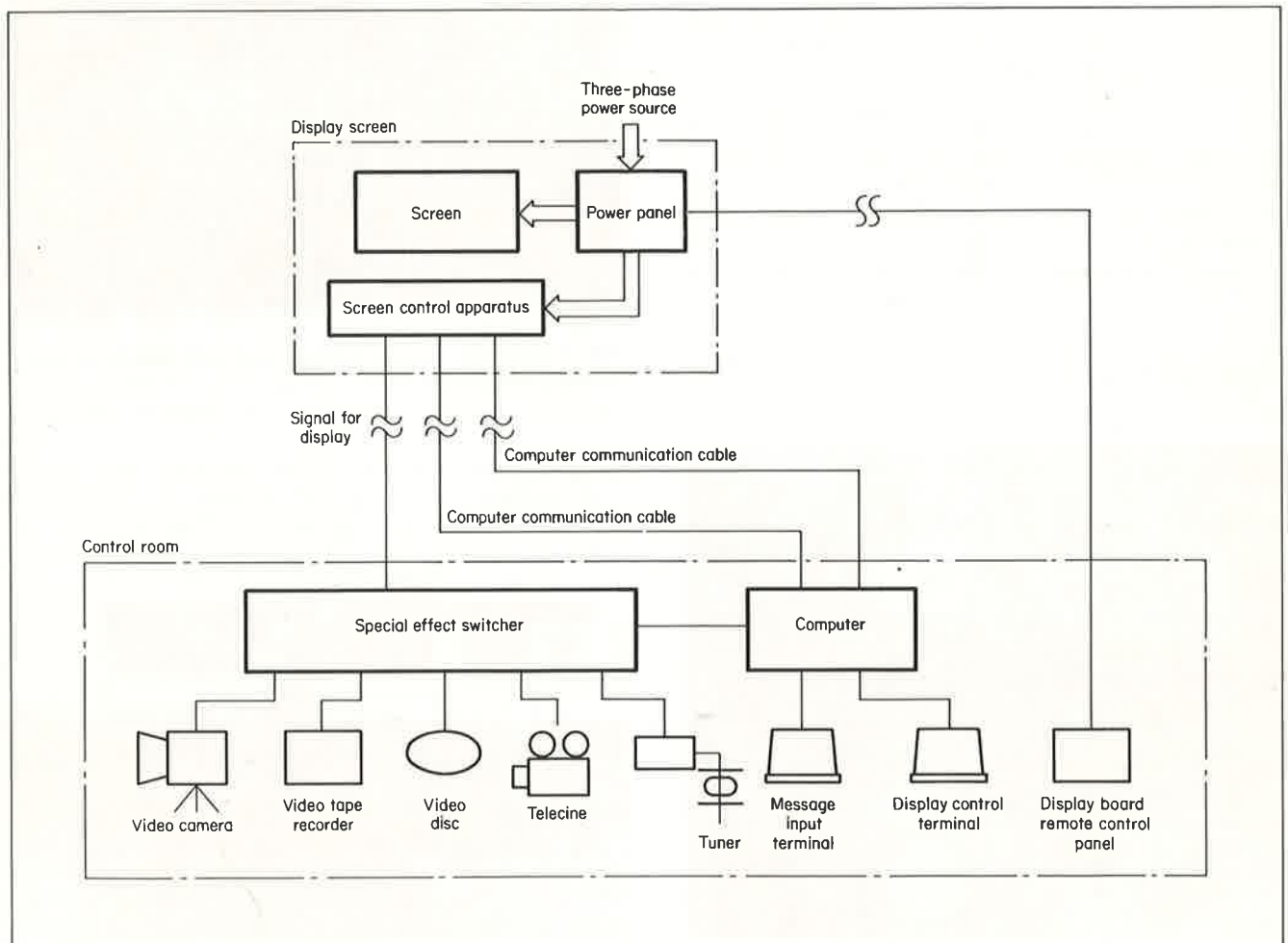


Fig. 6 System block diagram

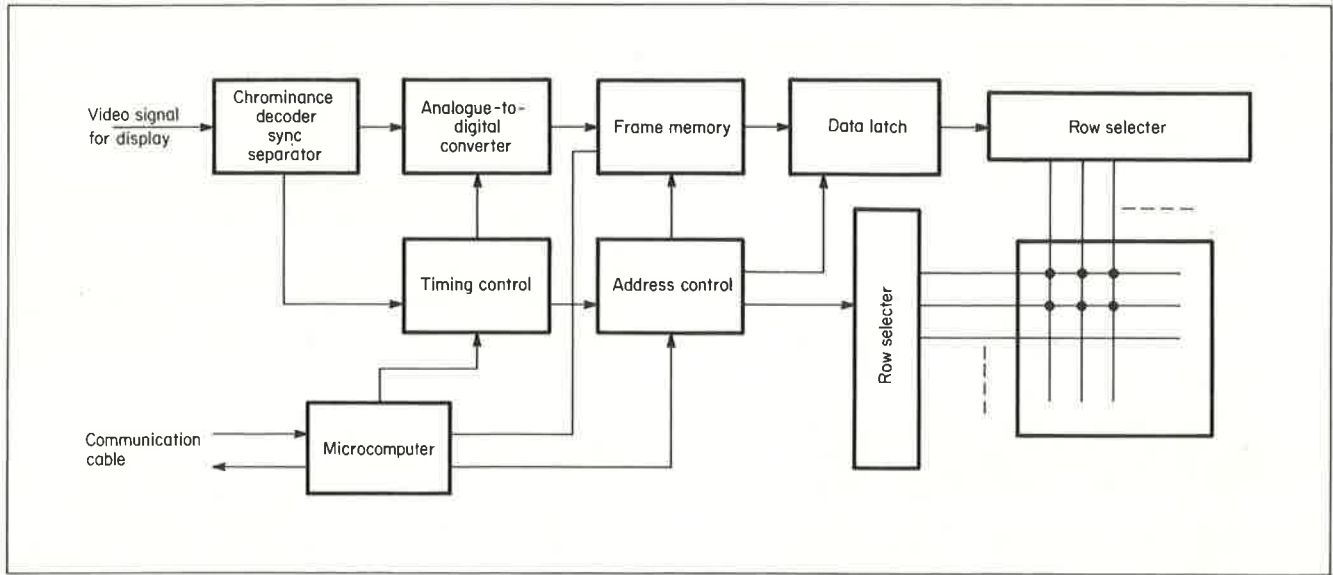


Fig. 7 Display control block diagram

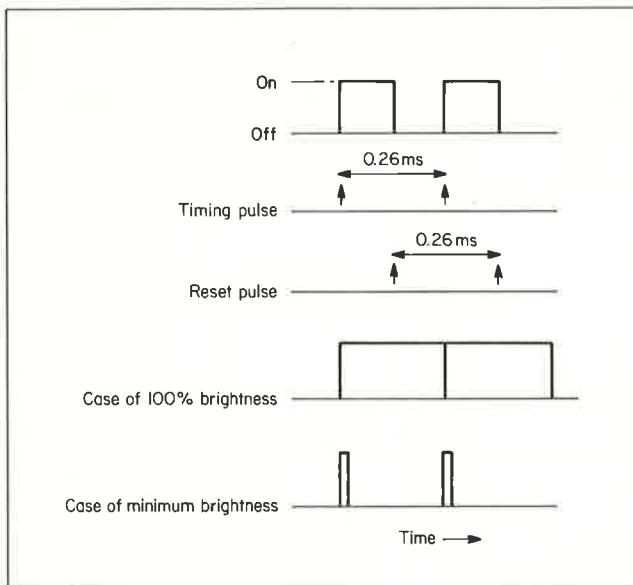


Fig. 8 CRT on/off timing



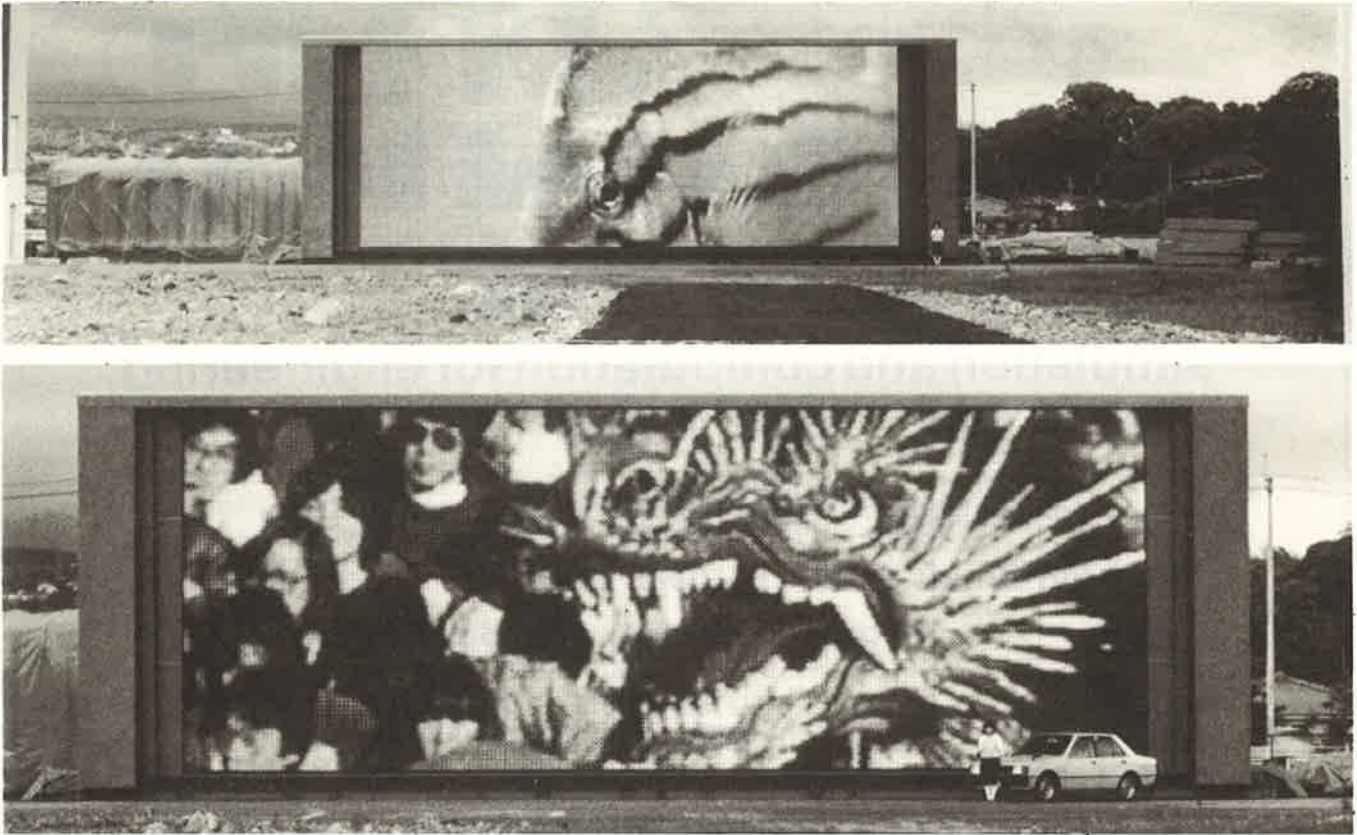
Fig. 10 7.3 x 10.9 m screen, installed April 1982, New York Mets Shea baseball stadium



Fig. 9 7.3 x 10.9 m screen, installed July 1980, Los Angeles Dodgers baseball stadium



Fig. 11 7.3 x 10.9 m screen, installed September 1982, Shaefer football stadium



Figs. 12 and 13 7.3 × 19.5 m screen, under test May 1983, Royal Hong Kong Jockey Club

the analogue-to-digital converter and sent from the control computer are stored in this memory.

Timing control: Sampling pulse and read/write control timing pulse for frame memory are generated by means of the sync pulse.

Address control: Memory read/write address signals which are synchronous with each other and on/off timing for the light-emitting tubes are generated.

Data latch: The read-out binary code data from the frame memory are sequentially compared with the given grey levels and converted to on/off signals to switch the light-emitting tubes. The row signals are temporarily stored in data latches.

Row selector: After one row line of data has been set up on the data latch, the selection timing signal is applied on the row line. (The signal from the data latch and selection timing signal are applied respectively to terminals D and T shown in Fig. 2.) The selection reset signal is applied on the row line after some delay from the selection timing pulse. (The reset signal is applied to terminal D.)

Grey level and luminance control

Grey level and luminance control are important factors in obtaining high picture quality on the screen. The former affects the colour picture images reproduced on the screen and the latter is necessary to maintain picture quality in varying ambient light levels. The Diamond Vision display uses different methods for each control.

Grey level control

The Diamond Vision display uses the time modulation to

achieve its grey levels. As the colour composite video signal (NTSC) contains 30 frames per second (60 fields per second), the numbers of on/off pulses within 1/60 of a second determines the capability of grey level indication. In this system the minimum duration of the light-emitting tube on/off control is 1/60.63 s. Thus the screen is capable of displaying 64 grey levels. In practice, the six-bit binary code data corresponding to the video signal amplitude are divided into an upper and a lower three bits. Each tube is therefore controlled a maximum of 15 times within 1/60 s.

Luminance control

Pulse width modulation controls the screen luminance. The above mentioned control pulse width is variable in 32 levels of the minimum time duration as shown in Fig. 8.

Screen size and viewing distance

The Diamond Vision is designed for use in open spaces. The preferred viewing distance is between 30 and 200 m. To satisfy this condition two different tube sizes have been developed. The smaller of the two tubes (20 mm in diameter) is used for 30 to 120 m viewing distances, and the larger tube is used for 75 to 200 m distances. To define a portrait image on the screen a minimum of 100 horizontal and 130 vertical lines are needed. The minimum size of the screen is therefore 4.5 × 5.8 m for the larger tube and 2.8 × 3.6 m for the smaller tube.

CONCLUSION

Since the first Diamond Vision screen was installed at the Dodgers' stadium in Los Angeles, USA, more than 30 systems have been delivered. It has been applied so far not only for sports, but also at rock concerts and in advertising. Examples of some screens in use are shown in Figs. 9–13.