THOMSON-CSF
GROUPEMENT TUBES ELECTRONIQUES

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PRESENTATION OF A NEW FAMILY OF STORAGE TUBES

TME 1238 - TME 1239

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38 - St-Egrève - France

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1 - INTRODUCTION

In numerous applications where it is necessary to store information, the storage tube offers an ideal solution, because of the high speed access capability of the electron beam and because of the excellent ratio between quantity of stored information and related systems size.

There are potentially large requirements for systems utilizing storage tubes if the following conditions can be met :

- Simple systems operation
- Low price
- Small size
- Long tube life

Until now, these criteria could not be met by existing storage tubes.

The new family of TME's just developed by THOMSON-CSF meet requirements set forth above, that is they are simple to operate, rugged, inexpensively priced and long lived. They can also be used in a broad range of applications.

Storage tubes can be classified in a variety of ways depending upon thèir principle of operation, the display mode and/or the internal geometry. The TME type features the following :

- Electrical input - electrical output :

Information input is an electrical signal and information output is also an electrical signal, either identical but shifted in time, or processed according to a predetermined function.

- Single gun :

The various functions of storage (writing, reading, erasing and rewriting) are sequential because of the single gun geometry. This limitation is however seldom a problem, and it offers a considerable reduction in the price of the overall system. It should be noted that for applications where simultaneous writing and reading are necessary, it is often possible to design a lower cost systems by using two single-ended tubes instead of one of the double-ended type.

- Non-destructive reading :

The reading function of the TME's is normally non-destructive, however where required, it is possible to operate them in a destructive read-out mode.

2 - DESCRIPTION

2.1 General

Figure 1 shows the exterior of the tubes. Their size is comparable to standard vidicons (1" for the TME 1238 and 1.5" for the TME 1239). Focusing and deflection are magnectic and they use standard vidicon hardware. The pin configuration is also similar to a vidicon.
Furthermore, the capacitance of the output signal electrode is such that it allows for the use of

vidicon-type preamplifiers. Thus, the associated electronics are quite similar to those used widely and inexpensively for vidicons.

2.2 Internal construction

Figure 2 shows the inside geometry of the TME's. Essentially, they include an electron gun and a storage target.

2.2.1 Electron gun

The electron gun consists of a cathode, a control grid G1, an acceleration electrode G2, a so-called erasing electrode G3 (the operation of which is explained later), a focusing electrode G4 and a field mesh G5. This 20 to 40 wire/mm field mesh is located in very close proximity to the storage target.

2.2.2 Storage target

The target is made of a silicon structured wafer, manufactured by integrated circuit technology.

This structure offers significant advantages in terms of simplicity and ruggedness and has none of the disadvantages of the more standard storage tube, using a grid as the storage element. In addition to its insensitivity to vibrations, the TME is also unaffected by temperature variations which makes it highly suitable for airborne and shipborne environments.

3 - OPERATING PRINCIPLES

3.1 General

If a target is bombarded by electrons, two possibilities may arise. Either the electron energy is small, in which case the surface of the insulated target will become negatively charged because the secondary emission coefficient is lower than one, or the energy of the impinging electrons is higher, and then the surface of the target will become positively charged because the secondary emission is greater than one. Typically, the cross-over voltage at which the secondary emission coefficient changes from a value lower than one to a value greater than one is in the order of a few tens of volts.

3.2 Operation of the TME

For both the TME 1238 and TME 1239, the cathode is kept at ground potential and the target voltage is adjusted to change from operation with a secondary emission coefficient lower than one to a coefficient greater than one.

The input signal, corresponding to the information to be stored, is applied to the Wehnelt grid G1.

After magnetic focus and deflection, the electron beam is collimated so that the electron trajectories are perpendicular to the surface of the target.

The metal back-plate of the target is used as the output signal electrode.

Figure 4 shows the operation of the tube for the following modes :

3.2.1 Erasing (Figure 4 a)

In this mode, a constant-current electron beam scans the target uniformly, for instance according to a TV standard.

The cathode is grounded and the target is placed at a voltage lower than the cross-over value previously mentioned, for instance at 15 Volts. The secondary emission coefficient being lower than one, the target becomes negatively charged and the potential of its surface goes down to a level which is approximately the cathode potential, value below which no further electron reaches the target.

3.2.2 Writing (Figure 4 b)

The voltage of the target back-plate is raised from 15 V to 200 V. This increase of 185 Volts is capacitively transmitted to the surface of the target and causes the secondary emission coefficient to become greater than one. Positive charges are therefore deposited on the target when the electron beam scans it, and the potential of each point of the surface becomes dependent upon the intensity of the writing electrom beam which impinges on it. For instance, after a writing sequence the potential of certain "strongly written" points will be at 190 V and the "non-written" points will have stayed at the 185 V level. Thus, it can be seen that the target potential reproduces faithfully the signal to be stored.

3.2.3 Reading (Figure 4 c)

The potential of the metal target back-plate is now lowered to 5 V, which represents a decrease of 195 V with respect to the writing level. This decrease is again transmitted capacitively to the insulating surface of the target. The "strongly written" points are now at the 0 V level, the "less strongly written" points are at -5 Volts and the "non-written" points are at -10 Volts. A constant-current reading beam which can be of any scanning standard will therefore be locally modulated by the potential of the area it impinges upon. In areas where the potential is -10 Volts (non written points) the electrons will be repelled by the target and subsequently captured by the G5 grid. In the "strongly written" areas where the potential is 0 Volt, a large number of electrons will reach the metal back-plate which is, as noted earlier, at +5 V potential. In intermediate cases ("less strongly written" points) certain electrons will be repelled by the target and captured by the G5 grid, and only part of the reading electron beam will reach the back-plate.

It can be seen that the current reaching the back-plate will faithfully reproduce the stored information. In fact, the insulating surface of the target acts upon the reading beam as the grid of a conventional triode.

The output signal current develops a proportionate voltage through a load resistance, voltage which after amplification is applied to a standard display tube (TV monitor or other) where the stored image is displayed.

It is important to note that the scanning of the target by the reading beam has not modified the electrostatic image deposited on the target during the writing mode, since the potential of the insulating surface is always lower than 0 Volt and, therefore, cannot be reached by any electrons. Successive readings will then generate identical signals, which gives the TME its so-called non-destructive readout characteristics.

It can also be noted that the electrons of the constant-current reading beam which do not reach the target are captured by the G5 grid. The signal on G5 is therefore complementary of the target signal. For certain applications, it can be of interest to use this particularity of operation and pick-up the output signal current from the G5 grid which is always at a fixed potential instead of picking it up from the target, the potential of which varies during the various cycles of operation.

3.2.4. Retention time

The retention time, as noted earlier, is theoretically infinite. In practice, it is limited by two different phenomena :

- progressive discharge of the dielectric target because of inherent dielectric leakage current. Considering that the dielectric used for the target is of high quality and its thickness is large in comparison to the low voltage existing between the surface of the target and the back-plate, this phenomenon has usually a negligible effect upon the retention time.

- creation of ions by the reading beam :
Vacuum is not perfect inside the tube, and the electrons of the reading beam ionize some molecules of residual gas. The positive ions created in the G5 grid-target space are attracted by the negatively charged areas of the dielectric surface and progressively neutralize the electrostatically stored information. We will see later how this factor limits the retention time.

3.2.5 Fast erasing

Erasing time is a function, on one hand, of the capacitance of the storage dielectric target, and on the other hand, of the intensity of the erasing beam. Electrode G3 permits increasing the erasing current in large proportion, when fast erasing is required.

In the reading mode, electrode G3 is at the potential of the acceleration electrode G2 and has no effect on the beam ; the diaphragm is therefore fully efficient and only a low-current fine spot size beam emerges from the electron gun. For fast erasing, the G3 electrode potential is modified in such a way that all the current is focused on the diaphragm. The latter is therefore not effective anymore and the beam current emerging from the gun is increased by a factor ranging from 10 to 30, thereby achieving a fast erasing.

4 - PERFORMANCES

4.1. Performances of the TME 1238 and TME 1239 are as follows :

	TME 1238	TME 1239
Writing speed		
- for the overall target area	33 ms	33 ms
- for one target diameter	50 μs	50 μs
Storage time with reading beam turned-off	several weeks	several weeks
Output signal current for performance as follows:	200 nA	200 nA
Output capacitance	5 pF	5 pF
Resolution measured by the orthogonal read-write technique at a 50 % relative response.	800 TV lines per diameter	1200 TV lines per diameter
Gray scale :		
- Number of half-tone levels.	10	10
Retention time with constant reading :		
- for a gray scale image	5 mn min.	10 mn min.
- for a black and white image	10 mn min.	15 mn min.
Erasing time :		
- fast erasing, by switching of the erasing electrode, down to noise level	33 ms	33 ms
- normal erasing, with no switching of the erasing electrode, down to 10 % of the original signal level.	120 ms	250 ms

4.2 The values mentioned in the above chart call for the following comments :

4.2.1 Writing speed

It refers to the writing of a signal up to the saturation level. Significantly higher speeds can be achieved at a lower writing level in the case of a black and white image.

4.2.2 Output signal current

The 200 nA current is capable of achieving an equivalent visual signal/noise ratio of 200 with a 3 nA RMS noise - 7 MHz bandwidth amplifier. Higher values of output current are possible with a slight degradation of both the resolution and the retention time, whereas lower values of output current will have the opposite effect. Extreme values are typically 20 nA and 1 μA.

4.2.3 Resolution

It corresponds to a 50 % modulation of the output signal at the center of the target. Figure 5 shows the modulation transfer characteristic at the center of the target, as well as the 50 % modulation resolution at a 0.8 x radius distance from the center.

4.2.4 Gray scale

Figure 6 permits a more precise evaluation of gray scale reproduction. It shows the overall read-write response of the tube.

4.2.5 Retention time

Figures 7a and 7b show the output signal characteristics of the TME 1238 and TME 1239 as a function of time during a standard TV read-out mode for saturation-written and non-written areas. The rise of the "black" current corresponding to non-written areas is caused by positive ions discharging the surface of the target.

4.2.6 Uniformity

Figures 8a and 8b show a picture stored in a TME and displayed on a TV monitor. They give a qualitative idea of background and signal uniformity, as well as of the reproduction of shades of gray which is quite similar to a camera tube. Figure 9 shows a two-level picture application where a TME is used to store and display alphanumerics. Figure 10 demonstrates the possibility of local and precise erasing offered by the TME's.

5 - POSSIBLE FUNCTIONS AND APPLICATIONS

Performance that has been previously described permits the TME's to achieve several types of "memory functions". These will be discussed hereunder, along with the corresponding applications.

5.1 Non-destructive read-out storage function

In this case, information is written and it is subsequently read with no expected degradation.

5.1.1 Writing and reading with same TV standard

There is only a time shift between writing and reading of the information and it can be called video frame storage. It must be noted that it is entirely possible to read only one part of the stored image (zoom effect : figure 11).

Two possible applications :

- capture of high-speed events :
The image of a mobile object frozen by a light flash is picked-up by a TV camera, written on a TME and then displayed for the necessary time.

- comparison of images :
A real time image is compared to a stored image in order to analyze differences, if any.

5.1.2 Reading and writing in two different TV standards

It is possible to write information in a certain TV standard and read it in a different standard. This results in either bandwidth compression or expansion. It is interesting to note that the output signal amplitude of a TME does not depend on the speed of the reading beam ; this permits enhancing of the signal to noise ratio by using a slow-scan reading beam.

This function permits bandwidth reduction of a video signal (normal TV standard writing-slow scan reading) to transmit signals on a telephone line, the bandwidth expansion being achieved after transmission by using an inverse process with a second tube (slow scan writing-normal TV standard reading).

5.1.3 Non-TV scanning

It is of course possible to use scannings different from a TV type, for instance :

- Random scan : For presentation of alphanumerics or graphics on a display terminal. For this application, a precise local erasing permits the removal of one letter or a group of letters and its replacement by other information.

- PPI Scan for Radar or Sonar : It may sometimes be necessary to shorten the transmitting time as much as possible to avoid detection. An image generated during one rotation of the antenna can be stored on the TME and looked at for a long time, using either a TV scan or any other for the reading process.

5.2 Integration function

Figure 12 shows the amplitude of the output signal versus the number of writing scans at low level. A point of interest is the excellent linearity of the useful part of the curve. Two applications of this property can be mentioned :

- through integration of several images generated by a TV camera, it is possible to display a very low light level scene.

- a number n of recurrent radar scannings will enhance the signal by a factor n whereas the noise will only increase by $\sqrt{n}$. Useful signals can then be distinguished from high-noise level environment.

5.3 Destructive read-out function

In many Radar and Sonar applications, it is necessary to gradually erase the "old" information so that it does not interfere with the "new" one. This function can be achieved quite easily with a TME by performing partial erasing during the non-reading periods (for instance, line returns in the case of a TV scan). Figure 13 shows that progressiveness of erasing can be varied in large proportions by adjusting the erasing current.

5.4 Memory function

We have already seen that the only cause for degradation of stored information is the reading beam itself because of the ionization of the residual gas it produces. When the reading beam is turned-off, it is therefore possible to store information during long periods of time.

An important application is the use of a TME as part of a computer central memory. The precision of accessing is presently 0.2 % of the target diameter, which corresponds to about 100 000 bits of information stored in a square area. The combination price, capacity and access time (approx. 1 μs) is already interesting and the future looks very promising.

This memory function can also be used where a non-recurrent event has a probability to happen when no personnel is on duty. A recording by the TME will allow examination in convenient time (Grounds & Building Surveillance - Electrical Lines Surveillance).

5.5 Other functions

5.5.1 Mixing

It is quite possible to write sequentially on the target of one tube informations generated by various sensors such as TV, radar, cockpit instruments and to display them simultaneously.

5.5.2 Permanent memory

A mask reproducing a certain pattern can be used during the manufacturing of the target, so this pattern becomes permanently "printed" upon it. For example, the terrain surrounding an airport can be printed on a TME target and the corresponding image may be super-imposed on the radar image.

6 - COST

Three different elements have to be taken into account for cost purposes :

6.1 Tube cost

Because of their simple structure and a good manufacturing yield, cost of the TME's in quantity production is equivalent to quality vidicons.

6.2 Cost of associated electronics

Power supplies, deflection yokes and preamplifiers manufactured for vidicons in large quantities can be used, resulting in basic equipment low cost.

6.3 Hourly cost

Life expectancy of vidicons is typically a few thousand hours. Two factors will concur in giving the TME"s a longer life expectancy :

- better processing than the vidicons (exhaust to a lower vacuum pressure and baking-out at higher temperature).

- the storage target is not altered by the electron beam scanning.

In fact, failure of a tube will normally occur when its cathode is exhausted and, for special applications, it is envisaged to fit the TME's with extra long life cathodes.

7 - CONCLUSION

A new family of miniaturized storage tubes has been developed, which offers a good price-performance combination.

THOMSON-CSF scientists are working actively to further improve on these new developments, especially in the areas of :

- TME's with electrostatic deflection for memory scopes and equipments withstanding severe environmental conditions.

- TME's with better resolution and more precise addressing for large-capacity memories.

- tubes with optical input, but using the storage and reading principles of the TME's.

- TME's of the double-ended configuration to allow for simultaneous writing and reading.

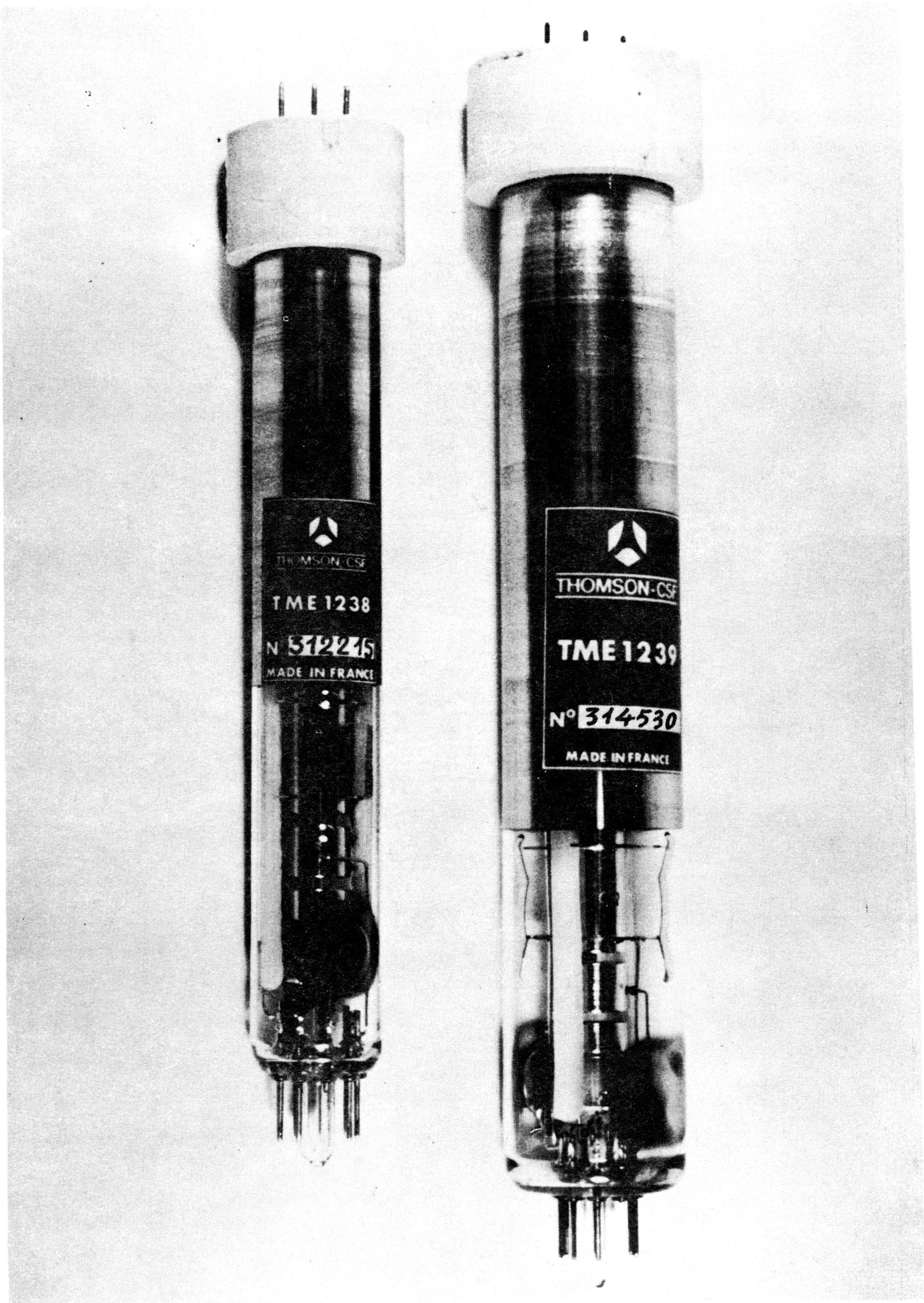

Fig. 1 : Miniaturized Storage Tubes TME 1238 and TME 1239

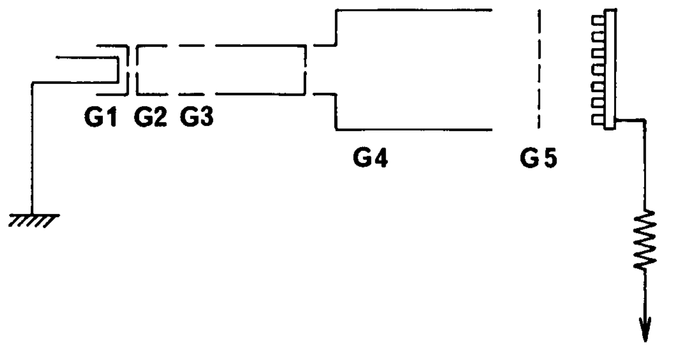

Fig. 2 : Electrode configuration

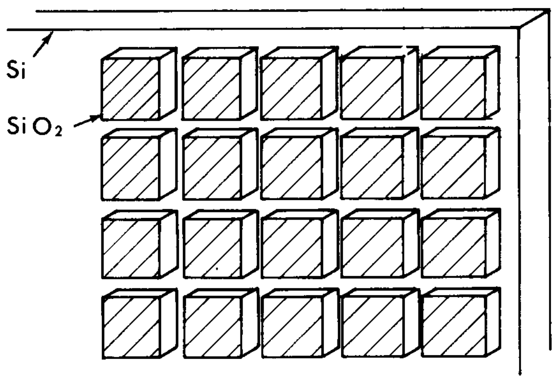

Fig. 3 : Target Layout

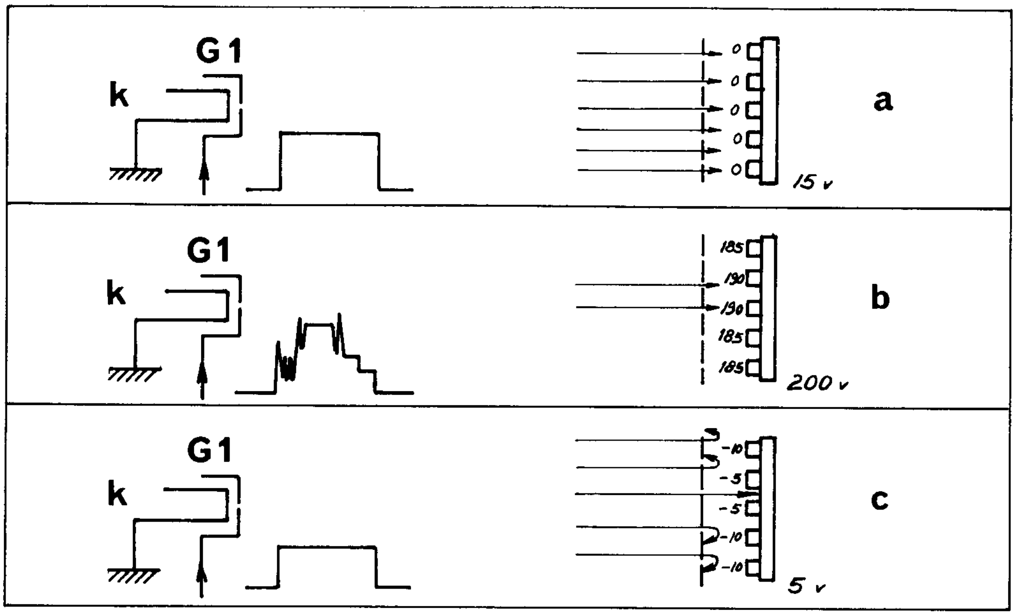

Fig. 4: Operation principle

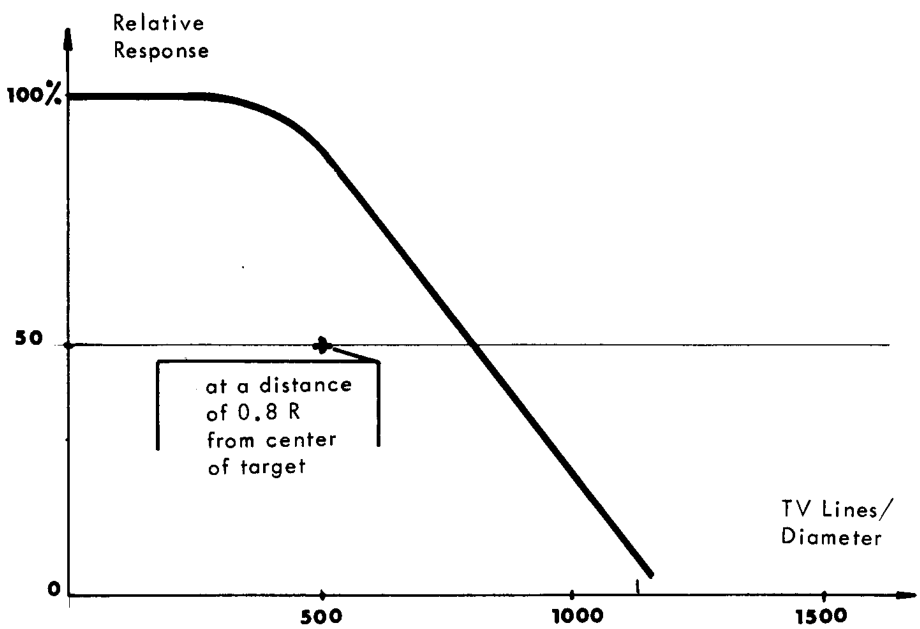

Fig. 5a : Modulation Transfer Characteristics TME 1238

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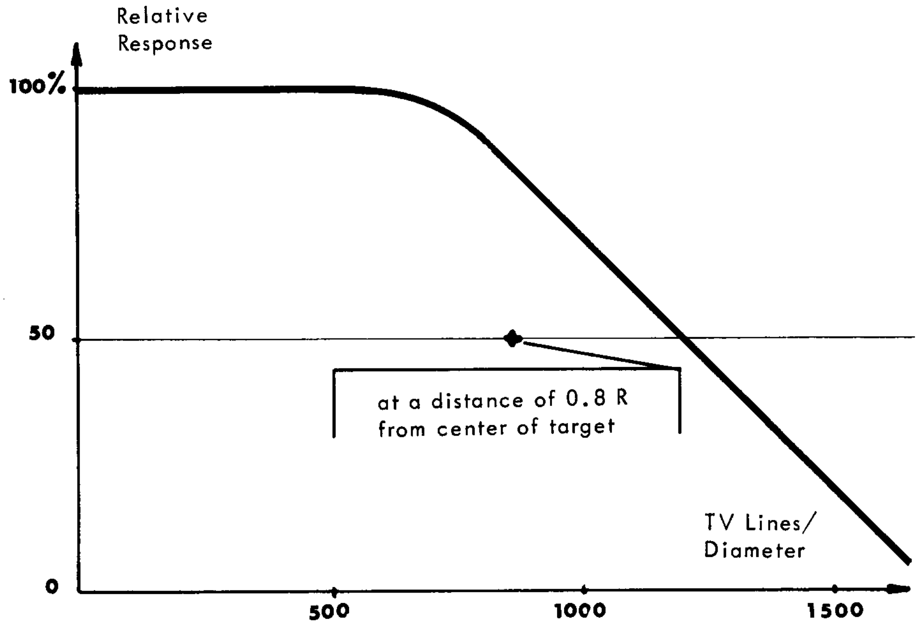


Fig. 5b : Modulation Transfer Characteristics TME 1239

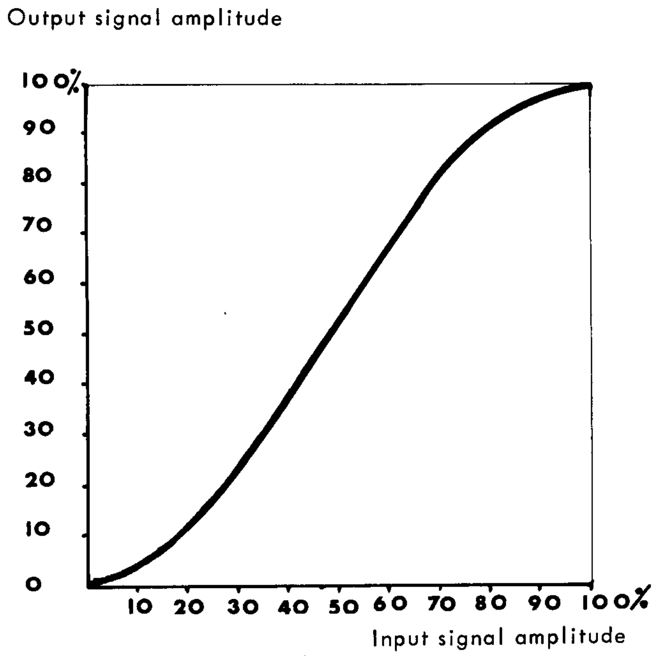


Fig. 6 : Read-Write Overall Response

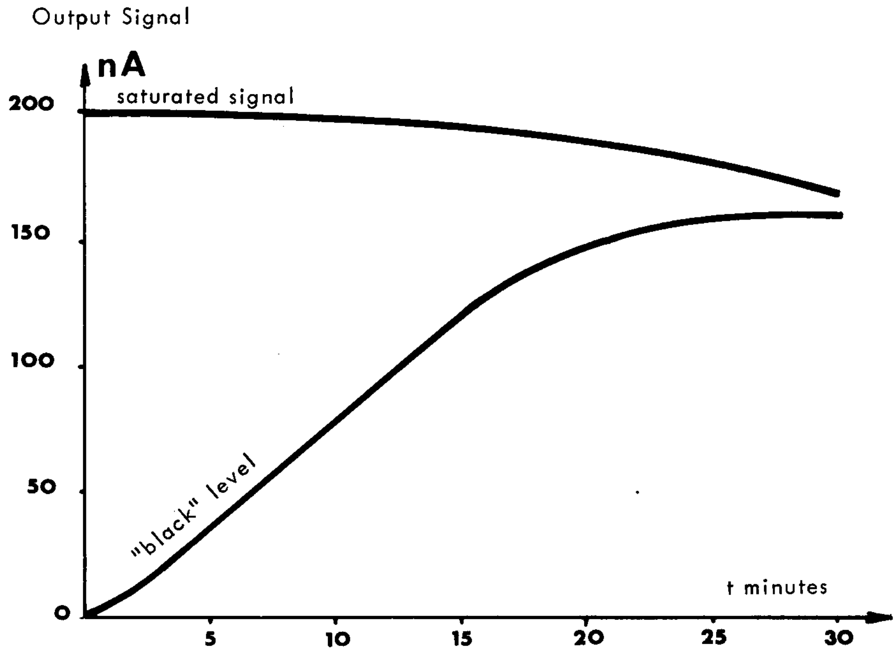


Fig. 7a : Retention Time TME 1238

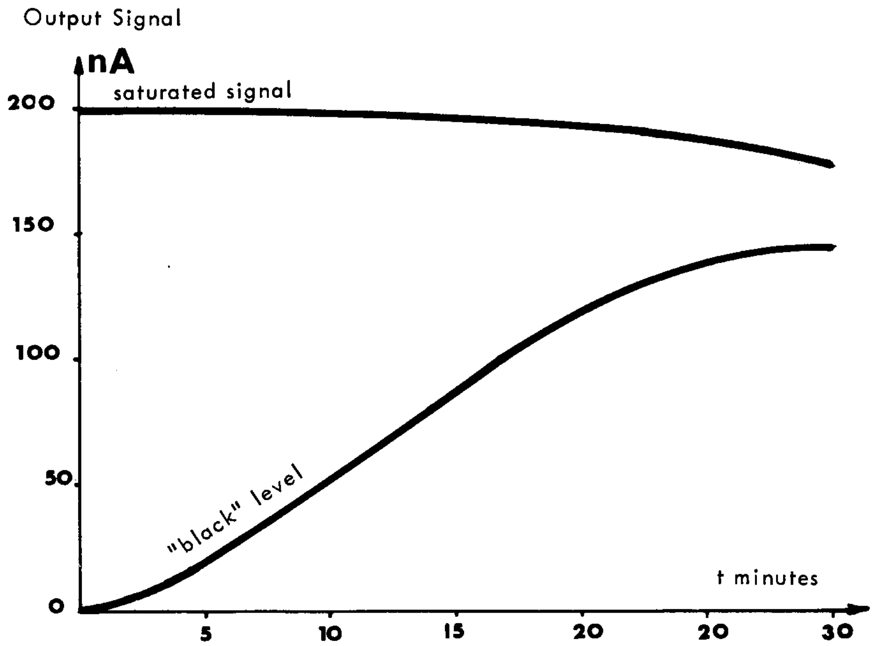
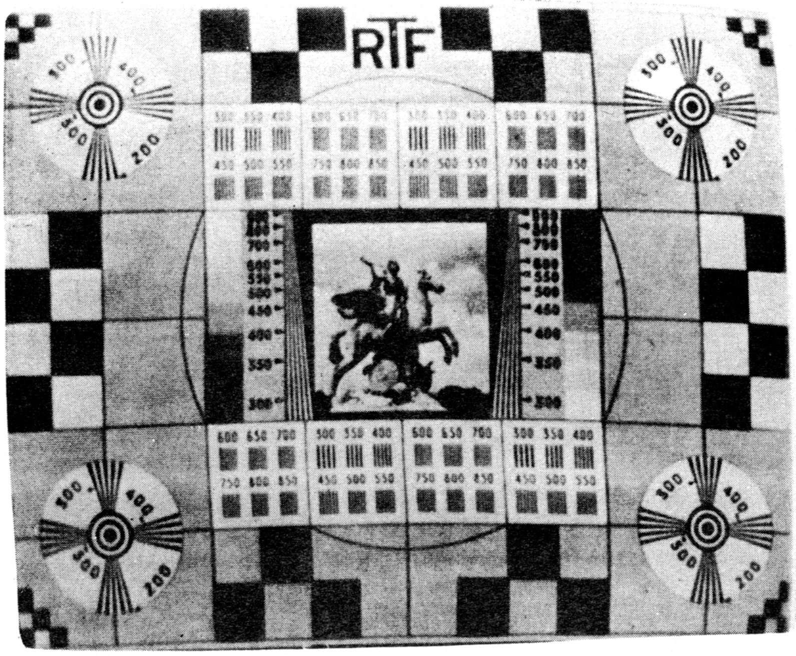


Fig. 7b : Retention Time TME 1239



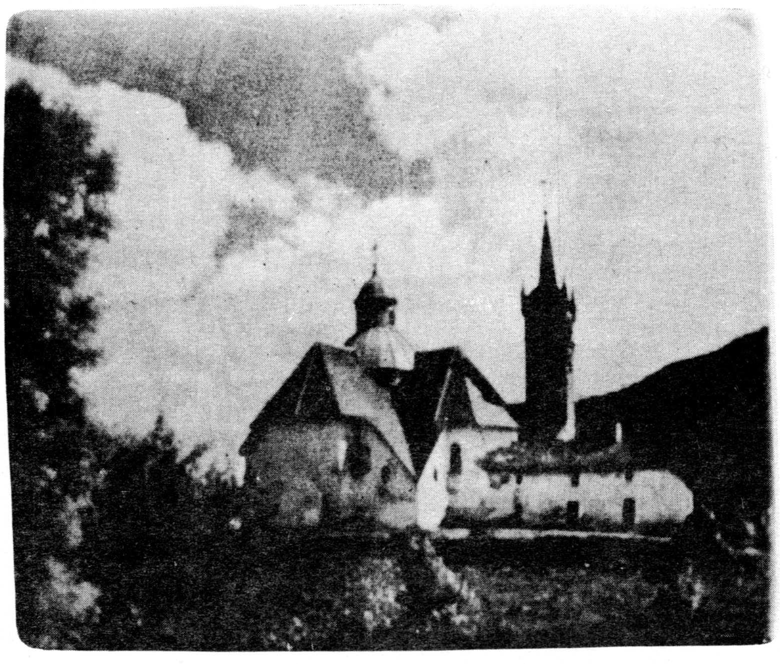


Fig. 8a & 8b : Gray-Scale Image Reproduction

Fig. 9 : Two-Level Image

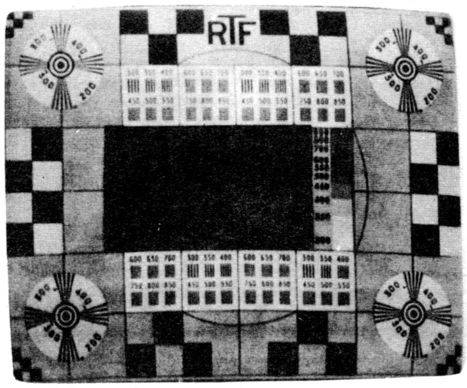


Fig. 10 : Selective Erasing

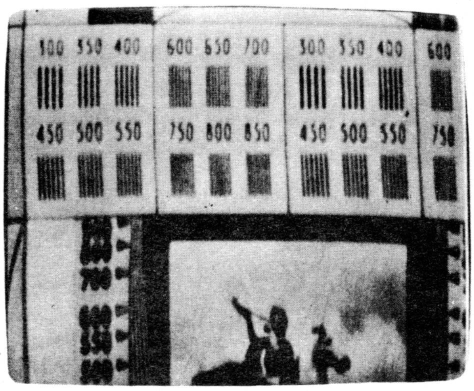


Fig. 11 : Zoom Effect

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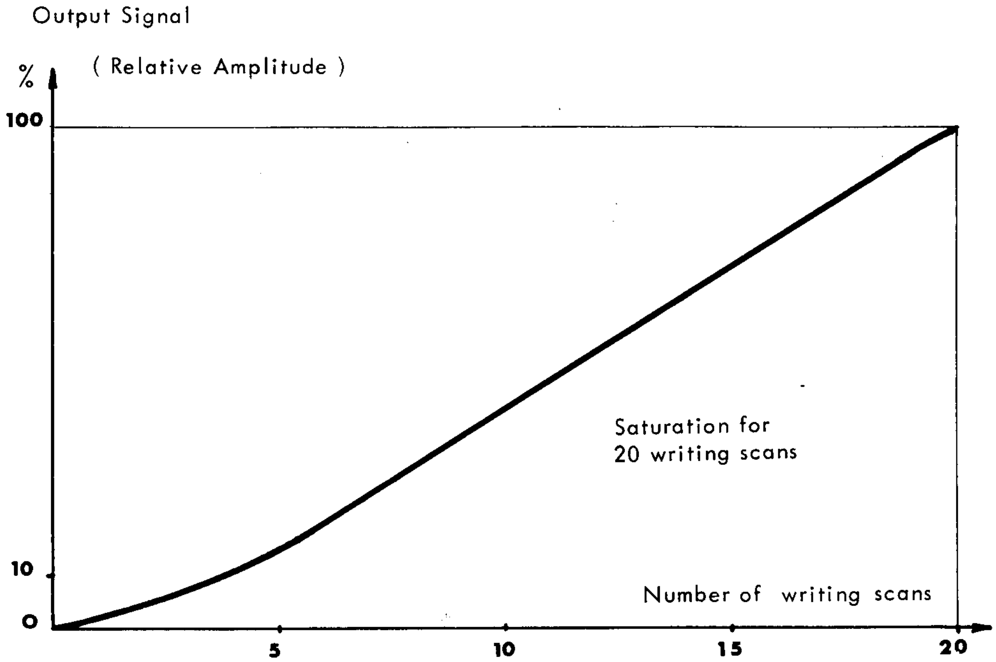

Fig. 12 : Integration of Weak Signals

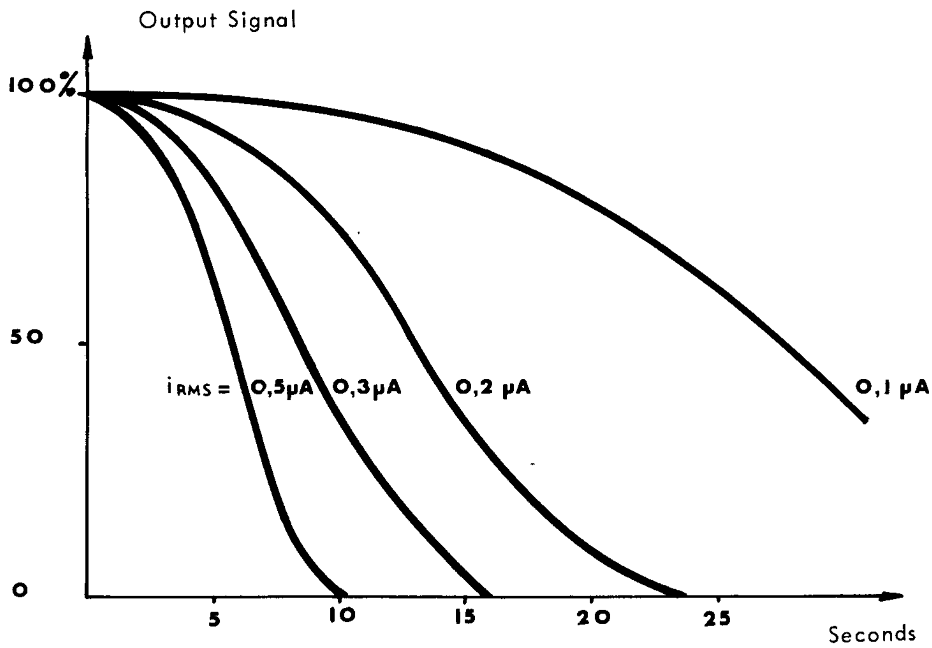

Fig. 13 : Controlled decay