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SUBJECT: SYMPOSIUM ON WILLIAMS'-TUBE STORAGE

To: R. R. Everett

From: T. S. Greenwood

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Abstract: On December 13 and 14, 1951, The National Bureau of Standards sponsored a symposium on Williams'-type storage tubes for the purpose of interchange of information and ideas between interested groups. The following report covers the more significant information presented at this symposium. Reports which were presented by various observers established that in storage tube operation the surface potential of the CRT's is stabilized at a negative voltage with respect to the aquadag coating. Verification was given of the existence of a positively charged spot surrounded by a ring of negative charge as a result of the bombardment of a spot by the primary beam.

Operational reports on several computers using Williams'-type storage were presented. The largest single problem in the utilization of CRT's is the existence of blemishes on the surface. The "read-around" ratio problem also exists, but its severity varies greatly between computers. The solution to both problems lies in the development of a special CRT for storage applications.

One proposal for storage improvement using redundant storage of information was heard.

Contributions to the theory of Storage

One previous point of controversy between observers had been whether the potential of a spot under bombardment rose or fell. Holt of the Bureau of Standards, and Williams and Kilburn of the University of Manchester, independently determined by means of a tube with a conductive connection to the screen surface that the entire screen is charged negative by the beam. The charging and discharging time constants are of the order of several seconds so that at the ordinary repetition rates used in storage systems the surface potential is stabilized after the first minute of operation. This stable voltage is about 16 volts below the potential of the aquadag coating (depending upon the integrated beam current).

The original Williams -Kilburn paper[1] explained the storage phenomena by assuming a spot would be charged positive by the beam due to a secondary-emission ratio greater than unity.

In view of the negative charging of the surface, some clarification of this point was sought by them. This was obtained through a special tube which differed from the usual CRT in having a second electron gun. This second gun was mounted in such a way that its beam was parallel to the regular surface which then acted as a deflection plate. As this beam was swept past the surface its trace on a second screen was a one-dimensional representation of the surface potential.

It was found that, consistent with the original assumptions, the beam charges a spot positive with respect to the actual surface potential; and, a negative ring of charge is built up around the positive, so-called "well". The overall "depth" of the "well" is approximately 3 volts. With the usual beam turn-off rates the change in "well" potential is less than 0.1 volts despite the pessimistic estimates of Brillouin of the high beam turn-off rates that would be required so as not to disturb the potential.

A. W. Holt discussed the "triode" theory of storage.[2] In this theory the written potential "well" is considered as a cathode "emitting" secondary electrons to an anode (the dag coating) in a radial sheet. The negative ring of charge around the "well" acts as a grid and builds up in (negative) potential until it brings the escape of secondary emission into equilibrium with the primary beam current. The resulting negative ring serves to protect the potential "well" from discharge by secondary electrons when adjacent spots are being written. Kates agreed with the essential features of the triode theory.

Practical Storage System Problems

Probably the largest single problem in obtaining working systems is the occurrences of blemishes on the storage surface. Although these blemishes are small, if they appear close enough to a written spot, they may effectively prevent storage. If the blemishes are few enough, the raster may be moved to avoid the blemishes. Since blemish-free tubes are practically non-existent this must usually be done.

This adjustment is unusually troublesome because the storage systems described have common deflection circuits. Some juggling is usually required to avoid blemishes on all tubes.

The severity of the blemish problem can be recognized from the fact that, of the tubes initially rejected for storage use (30% or more), at least half are rejected for blemishes.

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[1] F. C. Williams and T. Kilburn, "A Storage System for Use with Binary Digital Computing Machinery" J. I. E. E., 96, Pt. II, No. 30, 1949.

[2] A. W. Holt and J. H. Wright, "Progress Report on Electrostatic Storage" N. B. S. Report #1082, July 25, 1951.

Another third of the remaining group are eventually rejected for the same cause. The problem would not be quite as bad if blemishes were stable flaws, but during operation their severity often increases and blemishes even appear where they previously did not exist. It is quite clear that blemish growth and formation is not compatible with high reliability in storage systems.

Another problem is that of "read-around-ratio". While not having the urgency of the blemish problem, it is of high priority because of its fundamental relationship to the storage method. "Read-around-ratio" is variably defined and variably named, but in any case the property under discussion is the ability of a potential "well" to exist during repeated bombardment of adjacent areas. Since there are a large number of factors which affect this property (e.g., tube size, spot size, number of spots in raster, raster size and configuration, beam currents, writing time, etc.), tests must be made in the actual computer or under computer-simulated conditions. A conclusion from several papers which discussed read-around tests on several different tube types was that the highest read-around was obtained with tubes having the greatest degree of beam "stiffness". This was defined as deflection factor (volts/in.) times the length of a side of a 1024 square raster.

In making such a test some assumption must be made to simulate the worst conditions, and on this point there is a difference of opinion among groups. SEAC, for instance, writes cyclically in four spots surrounding the spot in question and determines the total number of such writes necessary to obliterate a potential "well" in the central position. (The writes around the test spot are not the same on all four spots in all tubes, however.) ORDVAC, on the other hand, writes the worst polarity continually on a single spot and determines the minimum number of such writes which will not obliterate any adjacent potential "well". An additional variation is introduced between the groups by the fact that ORDVAC checks every point while SEAC checks only nine selected areas (center, corners, and sides). As might well be expected the variations in test and conditions lead to variations in results. SEAC obtains counts of around 1000 while ORDVAC finds counts of as low as 20 at some points.[3,4] Since SEAC uses a 3:1 regeneration ratio every spot is rewritten after, at most, 170 adjacent spot operations, and "read-around" is not a large problem. In ORDVAC the problem is not as severe as might be expected since the low "read-arounds" are obtained at only a few spots, and programs which avoid repetitive operation on adjacent spots can be run satisfactorily.

Coexistent with the previous two problems are a number of lesser problems. These problems are not so intimately concerned with tube structure and thus are more amenable to attack. Among these is the stabilization of beam current against slow drift. This does not seem immediately pressing. Another is the matter of effective video circuitry. Some groups are using wide band amplifiers while others are using low-

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3 N. B. S. Tech News Bulletin, Volume 34, No. 9, September 1950.

4 R. E. Meagher and J. P. Nash, "The Ordvac" Paper presented at Joint AIEE-IRE Computer Conference, December 10 - 12, 1951. (D. C. L. #1623)

frequency cutoff in the range of 50 KC. The choice seems to depend a great deal upon whether the group feels current or change waveforms can be more reliably detected.

A solution to the blemish problem is actively being sought. The most direct approach lies in the refinement of the phosphor surface and the elimination of the causitive agents such as the binder. This approach is receiving the most support. RCA, under a Navy Contract, has for some months pursued this course and expects to have some tubes ready for distribution in February. Some tube construction work was mentioned by IBM, but the details will not be announced until the AIEE-mid-Winter convention. In England, General Electric has developed a special tube for use in the Ferranti-University of Manchester computer and some degree of success has been achieved. In part, this was gained by using lower accelerating voltages, but very careful control of the phosphor processing was undoubtedly a large contributing factor.

Another approach to the blemish problem is to operate the tubes at lower accelerating voltages where the problem is much less severe. Since lower voltages result in increased spot size and lower "read-around-ratios", this solution can only be achieved by a redesign of electron guns for smaller spot size. Since this would be a doubly desirable objective, it is somewhat surprising that no work is being done on it in this country (with the possible exception of IBM).

On the solution of "read-around-ratio" NBS is active in seeking different surface materials which will support "deeper" potential "wells". Unfortunately, they have few tube construction facilities and are limiting their work to other available tubes such as the MIT tube.

Because it has become clear that some tube development work is necessary, NBS made an appeal for a standardization of physical characteristics of storage tubes so that tube manufacturers might find it economically feasible to do development work. There was little immediate response to the appeal.

In view of the foregoing problems the report of the Los Alamos project was interesting. Although the project is classified and not many details of the computer are known, it was reported that the computer operates in a parallel system using 40 digits. The storage system uses 2 BP1 CRT's operating at 2.2KV accelerating voltage, storing a 1024 spot raster in an area of approximately one square inch. The deflection system, which is common to all tubes, has superimposed upon its output a small, low-frequency voltage which causes the raster to drift slowly across the face of the tube to insure uniform usage of the surface.

Despite the fact that no attempt is made to avoid blemishes, the group reports no trouble from this cause after initial selection of tubes. However, their initial rejection rate, due largely to blemishes, is around 70%.

They offered as a tentative explanation of the absence of a blemish growth problem, the fact that every precaution is made to insure the beam currents at no time exceed 1 or 2 microamperes. On "read-around ratio", no difficulty was experienced, although no specific tests were made to determine actual ratios.

In view of their apparent success, it is unfortunate that so little is known of the computer and the techniques used in its achievement.

One new proposal was made at the symposium by P. Sherertz of the Naval Research Laboratories. His feeling was that the improvements which might be made in storage systems through reasonable reductions in blemish and "read-around" problems is small compared to that made by using redundant storage of information. He would use three or four CRT's per digit each storing identical information. The register numbers assigned to each spot in the raster would, however, be different in each tube and numbers would be stored in the opposite polarity. The outputs of each tube would be averaged, giving a low probable error. In addition, an error occurring in only one tube would be self-correcting. Although the proposal has some merit, it seemed to evoke little enthusiasm.

Conclusion

One of the early proposed advantages of the Williams'-type storage, that of the relative economy of using ordinary cathode-ray tubes, seems to be hard-pressed for confirmation. Despite five years of work, it appears that very few production-run CRT's are suitable for this use, and special care and construction techniques must be employed to produce a satisfactory tube. No such tube is yet available and when it may be available is, at present, unknown. However, present experience indicates that reliable high-density storage can eventually be obtained with such a tube. Until such time, Williams' storage cannot be classed as highly reliable.

Signed T. S. Greenwood
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