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January 21, 1942

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Mr. H. M. Williams, Vice-President,
in Charge of Engineering & Research:

Because there has been so much activity in electronic counter research and development in recent months, with perhaps a tendency toward confusion of the primary objectives, it seems to me that the time might be appropriate for an examination of this new field, to determine our relative position it it, and for the establishment of a record of the past developments. May I therefore take the liberty of presenting in this letter, a brief history of the art, the objectives and accomplishments of our electrical research laboratory, the objectives and accomplishments of the electrical engineering department of M. I. T., the work accomplished for the N. D. R. C., and our plans for future research and development.

We became interested in the possibilities of electronic counters during the summer of 1938. While much had been published concerning electronic counters for cosmic ray and radioactive emanation counting, nothing pertaining to the calculating possibilities of electronic counters had been published. These counters for cosmic ray counting, were of the type that counted by two, four, eight, sixteen, etc. They simply received the impulses from a cosmic ray ionization tube called a Geiger-Muller tube, divided the frequency of occurence of the impulses by two, four, eight, etc., and delivered an impulse to a magnet which operated a mechanical counter. The total number of cosmic ray impulses counted then, was the number registered on the mechanical counter, multiplied by the dividing number of the counter. Since the electronic counter "scaled" the arriving impulses by two, four, eight, etc., they became known as scale-of-two scale-of-four, scale-of-eight, etc. counters.

Some work had also been done in using counters as switches in oscillographic testing, switching various circuits into the oscillograph in sequence so that more than one trace could be observed simultaneously. Two kinds of counters were being used, namely high vacuum counters using "trigger tubes" and gas tube counters using "thyratrons". The idea of using counters arranged in groups of ten, for division by ten, that is decimal counting, or scale of 10 counting became evident to me in my search for ways andmeans to effect electrical arithmetical computations. Other schemes involving the addition of potentials, resistances, frequency, etc. were much more involved than the addition of impulses with electronic counters. Consequently we set about equipping ourselves to develop a practical counter, capable of being used as an element in performing arithmetical computation. We knew that the counter must be small, light in weight, inexpensive, completely reliable, be of moderate speed and be economical in power consumption, to be valuable as an element in such a machine. Since gas tube counters required fewer tubes, could probably be made smaller, and were completely reliable, we decided to begin our research work on this type of counter. A tube laboratory, for light production of gas tubes was set up, so as to expedite the development and production of the tubes and to enable us to keep our activities a secret from the tube companies. A miniature gas tube or thyratron was developed which has proven completely satisfactory, enabling us to attain much higher operating speeds than the most optimistic contempory investigators. It also enabled us to reduce the size, weight, cost and power consumption of the counters.

Now an impulse counter, or counting ring as it is also called, in an arrangement of tubes, either gas or high vacuum tubes, in aring or closed chain, with only one tube or stage, active at any one time. Electrical impulses to be counted are sent into the counter and each impulse advances the active stage one position or digit. The previously active stage passes into inactivity as the ring steps around. Every tenth impulse, if ten tubes are used in the chain, the ring passes through zero, and in passing, sends an impulse into the next higher denominational order, it transfers in other words, Thus for every ten impulses put into the counter only one is sent out, and the ring has divided the input frequency by 10, or scaled it by 10, or it is counting by tens. It is therefore a scale-of-10 counter or decimal counter. Now any number of tubes can be used in the ring, the scaling factor being the same as the number of tubes used. If only two tubes are used in a ring, the ring is a scale-of-two counter or binary counter. In a scale-of-two counter system, if the output of the first ring is fed into another similar ring, then each divides by 2, and the output of the second ring is only $\frac{1}{4}$ of the input and the scaling is by four. A third stage would cause a scaling of eight etc. This is the type mentioned earlier in this letter, used by scientists in cosmic ray work.

We developed several types of gas tube decimal counters, one was the counter using the miniature tube made in our tube laboratory. We have several varieties of this counter, each for a particular use. Another gas counter, using a special miniature tube that we developed, and having a particularly low power drain, was developed. As an outgrowth of this counter we developed a counter using a special five-in-one gas tube and later a ten-in-one gas tube. Now to use a counter to add, subtract, multiply or divide, a definite number of impulses must be sent into it, so we developed a gas tube "differential" operating from a keyboard. When the counter and the differential were arranged to function together, we had an adding machine. As far as we know, we are still the only people who have

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worked on this impulse control, a very vital part of any calculater. A patent application was filed on this first model.

Early in 1939 we began formulating plans for a machine to perform the operations of addition, subtraction, multiplication and division. Our knowledge of counters and impulse control or generation enabled us to make a complete plan for such a machine. This machine was started early in 1940 and we have had it operating on several occasions. However, we have neglected it, for about one year, due to the pressure of N.D.R.C. work and a lack of technical research workers. At present we are completing it and a patent application will be filed on it in the near future.

Now besides our plans for the above arithmetical machine, we have had plans to use counters, in computing, in our proposed sales analysis machine. On two occasions I have started work on this project, only to be forced to postpone it by the pressure of government contracts. We plan to develop a high speed tape scanner, on which register records are punched, operating into a counter or computer, converting the record into a form capable of actuating a "magnetic pin wheel" storage device. We plan a storage mechanism of from 1000 to 10,000 storage totals. We will be able to enter sales information into many totals simultaneously and will be able to read the totals and print them very rapidly. The high speed computer, with electronic counters as elements, is the very heart of this proposed machine.

We are also aware, that electronic counters may well form the basis of a fast teletype system, accomplishing the same results as the IBM tele-typewriters. Our recent suggestion to N.D.R.C. that we develop a radio signalling system based on counters, is a step in the direction of the teletype idea. We have preliminary plans for a teletype system using counters.

Probably there are three general classifications of use for electronic counters. They can be used for computation, communication and timing. In computing, we are already able to add, subtract, multiply and divide. In the category of communication are radio signalling, teletype transmission, telemetering by wire or radio and remote control. N.D.R.C. has already approached me concerning a telemetering problem. The third category of timing includes interval timing and switching, and the Aberdeen proving ground is presently using a special form of counter to determine the velocities of artillery projectiles by the interval timing method. There are probably other uses not yet conceived. However, here at NCR we are primarily concerned with the calculating possibilities of electronic counters, and we plan uses where high speed calculation is a necessity.

In the late summer of 1940 we were approached by Dr. Harrison, chairman of section D3 of the National Defense Research Committee, and requested to aid in developing electronic counters capable of ultra high speeds. A counter, operable at one million counts per second was the objective. We contracted with the N.D.R.C. to perform the research and to construct a model. In the six months of the first contract we increased the speed of gas counters from 1,500 to 150,000 per second and in addition, although it was not a contract obligation, developed and constructed an impulse controller to operate with the electronic accumulator. We received a second contract to continue the work, and during this period suggested to N.D.R.C. the possibilities of using a special resetting type binary counter to secure the high counting speeds we were seeking. Now it is the policy of N.D.R.C. not to permit one laboratory to learn the activity of another during the formative stage of development, but when they found that my proposed scheme was identical to a system that the University of Chicago had already carried far in development they requested I visit the U. of C. to see the work already done. The scheme was and still is a very practical way to achieve one million or more counts per second and the work was terminated at the U. of C. and continued here at NCR. When we started this work the best reliable speed of this counter was about 400,000 counts per second. At present its reliable top speed is 1,500,000 per second. We are using it as the units order counter (the highest speed bank) in the second model we are about to deliver to the N.D.R.C. During the time of our first two contracts with N.D.R.C. we developed several other counting rings in our search for high speed counters. Both are high vacuum tube counters known as the Dekatron and Conjugate Pair counters. Many variations of these were also developed but we did not achieve any speed over 300,000 counts per second with them. During this same time we also raised the speed of the gas tube counters to around 300,000 per second but because this speed is excessive for good life of our gas tubes, we do not use gas tubes at speeds over 150,000 per second.

The following is a tabulation of the various counters, computers and impulsers developed here at NCR since we began work in 1938:

I - Miniature gas tube ring, standard type, indirectly heated cathode, many variations for different applications.

II - Miniature gas tube ring, directly heated cathode, wire type cathode.

III - Cold cathode gas tube ring, no cathode heating power, great future possibilities in commercial calculators.

IV - Five section gas tube counter, known as Mathetron, combines five tubes in one.

V - Ten section gas tube counter, also Mathetron type, combines ten tubes in one.

VI - Conjugate Pair high speed counter, uses vacuum tubes.

VII - Dekatron Counter uses vacuum tubes.

VIII - Miniature gas tube ring, negative impulse operated.

IX - Improved U. of C. recycling binary counter, ultra high speed, uses vacuum tubes.

X - A binary to decimal converter, changes binary notation to decimal notation necessary in sales analysis machine.

XI - Controlled impulse transmitter which sends accurate numbers of impulses in one train.

XII - Controlled impulse transmitter which sends definite numbers of impulses into individual denominational orders. Used in our electronic adding machine. Several types.

XIII - Arithmetical machine which adds, subtracts, multiplies, and divides (dividing still unfinished).

XIV - Two types of read-out mechanisms or indicators for reading the count in electronic accumulators or totalizers.

Our patent department has already filed, or is in the process of preparing patent applications on numbers I, II, IV, VI, VII, VIII, X, XI, XII, and XIII listed above. Numbers I and XII are in the same application. Mr. Beust has had all these applications held secret in the patent office because of the connection of counter work with N.D.R.C. work. While many types of counters have been developed here at NCR, we have always been conscious of the fact that our primary objectives are uses for counters in calculators or other business machines, although it may have appeared at times that counter research was being prosecuted for its sake alone. Several influences caused this wide search for more counter circuits. We were motivated by a desire to cover as much of the art as rapidly as possible so as to better our patent position, by the desire to find the best basic circuit as regards cost, size, weight, speed, power consumption and reliability and by the requests of the N.D.R.C. to develop an ultra high speed counter.

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There is more activity in our laboratories at present, on electronic counters, than at any time since 1938. We have accepted two more contracts with N.D.R.C. One is for a multiple electronic counter printer and the other for research and development of a secret communication system. Both of course involve counters. Some of our counters have been developed to a high state of perfection and these will be used in these contracts. We are also increasing our activity on the arithematical calculator. In fact we should concentrate more men on this as there are signs that other laboratories are awakening to the possibilities of electronic computing. While carrying out the building of models, and developing systems for N.D.R.C. we are also alert to the necessity of conceiving and developing new counters, impulsers and systems of computing so as to maintain a good patent position. At present, it appears that we are in as good a position as anyone else.

Mention was made that others were becoming active in the electronic computing field. Of course M. I. T. has been active since 1939, operating under a money grant from NCR. Their plans and accomplishments will be discussed a little later. RCA experimented with electronic switches for oscillographic use some years ago and only recently, Dr. Weaver of N.D.R.C. stated during our visit with him in New York, that RCA had laid plans for a computer for anti-aircraft control. Dr. Zworykin of television fame, probably their most widely known research engineer was engaged in the work. As stated before, the University of Chicago, with N.D.R.C. funds, was engaged, and still is, on the "ratchet tube. At the counter conference in Washington December 4, 1941, two engineers from Eastman Kodak discussed their electronic computing problems with me, so it is evident that they are interested. It is also known that the General Electric is developing thyratron counters since the counter used at Aberdeen was constructed by them. The Shallcross Company near Philadelphia, has already offered an electronic counter for counting factory machine operations, but it is not strictly an electronic counter, since it uses relays in association with the tubes. We purchased one of their counters, a very slow speed instrument and examined it thoroughly.

Now all but a few of our counter circuits have been revealed to the N.D.R.C. in my bi-monthly reports to them, (six reports have been delivered), and our work, in addition to the work of M.I.T. and the U. of C. has been incorporated in the N.D.R.C. Section report, a hundred copies of which were made, and distributed to members of the National Defense Research Committee and to the air corps, naval, and British and Canadian Liaison personnel. Perhaps others have obtained copies. We have not revealed to them the circuits or other information in number II, III, IV, V, VIII, XII, and XIII listed in the tabulation of our research developments. We are continuing to exert every effort, so that by sheer speed in research and development, we will be able to secure and maintain a lead in electronic computer work.

You will recall that shortly after we began work on gas tube counters in 1938, we were approached by Dr. Caldwell of M.I.T. concerning electronic counters. Apparently Dr. Bush had been thinking about the possibilities of counter elements in computing and had communicated his ideas to Dr. Caldwell. They planned what they called a "Rapid Arithmetical Machine" an elaborate scheme to perform the four operations of addition, subtraction, multiplication, and division, as well as to perform operations involving fuctional relationship such as trigonometric functions, that is, sines, cosines, tangents, etc., a machine in scope, to be practically an algebraic counterpart of the "Differential Analyzer". With a money grant from NCR, W. H. Radford of M. I. T. was directed by Dr. Caldwell to survey the field and prepare a report. We received two reports from Radford, a preliminary report in May 1939, and a comprehensive report in October 1939. The general specifications of the proposed Rapid Arithmetical Machine were given and an outline of how the work should be undertaken. As Radford stated the design of such a machine must solve the problems of selection, transfer, storage, and totalization, and he recommended that the problem of totalization be attacked first.

We agreed with this recommendation and they began research work on electronic counters. They expressed a preference for high vacuum tube counters, which was also agreeable to us since we were partial to gas tube counters excepting for certain applications. Since the beginning of our association with M. I. T. we have received seven reports from them as follows:

I - Preliminary Investigation by Mr. Radford dated May 1, 1939.

II - Report of Comprehensive Investigation by Mr. Radford October 15, 1939.

III - Report of status and future plans for Rapid Arithmetical Research by Mr. Overbeck, January 3, 1940.

IV - A proposal for a multi-total analysis machine using magnetic storage by Dr. Caldwell, February 7, 1940.

V - Counter Report by Mr. Overbeck, October 15, 1940.

VI - Counter Report by Mr. Overbeck, December 9, 1941.

VII - A new high speed counter by Mr. Overbeck, January 8, 1942.

From these reports, and from inspection trips to M. I. T., we have learned of the counters they have developed. According to the original plan, they have concentrated on vacuum tube type counters, excepting in the case of their "Digitron", which is a combination counter and storage tube, and is a gas filled tube. In order, they have described in their reports the following electronic counters:

I - Radford's first stepping ring with multiple tubes in each position of the ring. Uses vacuum tubes.

II - Double triode counter. Uses two tubes sections per stage, both sections in one tube.

III - Kleiotron Ring. Uses high vacuum tubes of special design.

IV - Digitron counter and storage tube. Gas triode with ten sections. Uses magnet over tube to give direction to stepping.

V - Direct coupled trigger pair counter. Uses two high vacuum tubes per stage.

VI - Biquintary counter. High vacuum tubes. High speed.

VII - A trigger pair using secondary emission to lock trigger in on or off position.

Up until the time they accepted the N.D.R.C. contract to produce some Digitrons for the committee, they had reported on I, II, III, and IV above. At the counter conference in Washington they reported on number V, and in their reports of December 9, 1941 and January 8, 1942 they reported on the work of VI and VII. In their last report they show a block diagram of part of their proposed rapid arithmetical machine. It seems that they have chosen the Digitron as the counter tube and storage unit to be used in this machine. The digitron is a relatively slow counter, its speed being listed in the N.D.R.C. master report as 2,500 per second. They also produced a model of a two stage counter using the double triode counter for the N.D.R.C. The N.D.R.C. master report also illustrates a gas tube ring developed at M.I.T., but since it was developed on N.D.R.C. funds, it was not reported.to us in the seven reports listed earlier in this letter, and presumably we will not have license rights concerning this particular counter circuit, if a patent on this circuit does not accrue to the Research Corporation.

At the present time, the only other laboratory besides ours, doing work for the N.D.R.C., is that of the University of Chicago. They are presently developing the "ratchet", a special cathode-ray tube, with which they expect to reach enormous counting speeds. This tube was given some consideration here, but due to the urgency of other work, was set aside for future development.

Since there has been a general awakening to the possibilites of electronic counters, we may expect others to begin work in this field. I feel that our position is good at present. Others however, unknown to us, may also be working along these same or similar lines. In my opinion, the only course to follow to insure our future position, is to increase our efforts. I believe we should put greater emphasis on our calculating systems, especially multiplication and division. We now have another multiplying system in mind and may incorporate it in our next computer model. We are exerting every effort to make NCR the leader in the new field of electronic computing.

Respectfully,

Joseph R. Desch

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JRD:HMK