Memo of Present Plans for an Electro-Mechanical Analytical Machine

September 15, 1942

Joseph R. Desch, N.C.R. Co.

Editors' Preface

This document was written by the late Joseph R. Desch while he worked as the director of research of the NCR Electrical Research Laboratory during the Second World War. The document has been obtained from the US National Archives and is published on the personal Web Page of Frode Weierud. The document has been faithfully retyped by the three editors, Ralph Erskine, Philip Marks and Frode Weierud. The original document was typed and had the style and layout of a typewritten document of that period. To make the re-edited presentation more pleasing the document has been both left and right justified and a more modern type font has been used. The page numbers of the original are given as numbers in square brackets. Apart from these modifications to the layout the document has the appearance of the original.

Where there are obvious typing errors these have been corrected. The original text has been retained but with a stroke through while the corrections appear within square brackets. Where we are not sure about the corrections this has been indicated with a question mark. The Editors' comments are in square brackets and in italic. Longer and more detailed comments are in numbered footnotes. All the document's footnotes are by the Editors.

The Editors,

Ralph Erskine,
Philip Marks,
Frode Weierud,

Source:

National Archives and Records Administration (NARA), Record Group 38, Crane Library, File: CNSG 5750/441.

Acknowledgement:

Our thanks to Stephen Budiansky for finding this report and making it available to us.

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September 15, 1942

Memo of present plans for an electro-mechanical analytical machine.

This memorandum is intended to show and discuss the problems involved in the design and construction of an analytical machine based on “cribs”. Criticism of the information set forth herein is invited.

All subsequent statements of “times” involved, “hits” ~~of~~ [or] “stops” obtained and stories[1] printed are based on two photostatic copies of data prepared by the British, showing the stops and stories to be expected for various magnitudes and qualities of major and minor molecules[2] used in the bomb[3] wiring. It is our understanding that the data shown are for a bomb consisting of a group of three wheel analytical machines, and for only one wheel order of the 336 wheel orders that must be analyzed. Since we are primarily concerned with a four wheel machine, the data given must be multiplied with a factor of 26. The total hits or stories obtained for a complete analysis must be further multiplied by the wheel order combination, that is 336. Thus far a menu consisting of a major molecule of 7 letters with one closure, and a ~~monor~~ [minor] molecule of 5 letters with no closures, with double input. Some 11,076 stops per wheel order, or some 3,721,536 stops for the 336 wheel orders can be expected. In terms of stories, the number per wheel order is 2380 or about 799,680 for all ~~whell~~ [wheel] orders. Lt. Ely has agreed, per our telephone conversation on Sept. 12, 1942, to select menus for analysis on the proposed four wheel analytical machine which will yield stories per wheel order not exceeding 1000. The foregoing case exceeds this number and would therefore not ordinarily be used. Even with a limit of 1000 stories per wheel order, or roughly 3000 stops per wheel order (a ratio of 3 to 1 seems about right for this magnitude of stories, upon examination of the chart), the operating time for testing and printing, using 336 bombs simultaneously to test each wheel order, will be about 12½ hours exclusive of the actual machine cycle time (rotation of the wheels). This is based on a cold point examination, stecker[4] test and printing time of 15 seconds. The average speed of the high speed wheel, and consequently all of the other slower wheels will decrease because of the numerous stops, and consequently the estimated cycle time of 9 to 9½ minutes previously made (based on 3400 rpm) will no longer hold. Cycle time as we understand it, is divided into active and inactive times. The active time is the time during the rotation of the high

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[1] A story in this context is a Bombe stop which does not have any *Stecker* contradictions. This stop will have its results printed for further testing. Generally a story is a possible solution to a cryptographic problem.

[2] A molecule in this context is the graph made by the connected menu letters. Alan Turing called it a web.

[3] Joseph Desch uses the word “bomb” throughout his memo. We have decided to leave it like this even if the accepted spelling is Bombe.

[4] The German word *Stecker* (plug connection) is normally written with capitalization, but we have decided to retain the original spelling.

[2]

speed wheel in which a hit or cold point can be detected. Inactive cycle time is the time lost in the overlap rotations of the first wheel in relation to the second plus the time lost in the 676 mechanical transfers which occur in transferring motion to the third and fourth wheels. The time is inactive because the cold point detector is inoperative during the overlap and transfer periods. If there was no overlap nor wasted revolutions during transfer, the high speed wheel will have to make 17,576 revolutions for a complete cycle of the bomb. The overlap will probably be 4/10 revolution so that the high speed wheel will make 17576 × 1.4 or about 25000 revolutions, exclusive of idle rotations during transfer, for a complete cycle. Transfers may require 2/10 second each or 0.2 × 676 seconds or roughly 2 minutes. At 3400 rpm the first wheel will therefore make roughly 7000 extra revolutions during the transfers. If the average speed of the bomb is 3400 rpm, the first wheel would therefore revolve 25000 plus 7000 or 3200[0] times in one cycle of the bomb. As the average speed of the first wheel drops due to excessive numbers of hits, the extra revolutions during transfer of the third and fourth wheels, will drop. Based on 32000 revolutions at a rate of 3400 rpm the minimum cycle time becomes 9.4 minutes, that is, the figure mentioned earlier. However, in practice the average speed of the first wheel will not be 3400 rpm, ~~expecially~~ [especially] if many hits occur. If the average speed, in the case being considered drops to 500 rpm, as it may well do, the cycle time increases to about 52 minutes. This is determined by adding the 2 minutes required for the slow wheel transfers to the 50 minutes (25000 ÷ 500 rpm) required for active time and overlap inactive time. When this is added to the 12½ hours estimated testing time, the overall time becomes 13½ hours for the 1000 story per wheel order test. It is to be hoped that menus yielding upon analysis an average of about 130 stories or about 650 stops per wheel order (5 to 1 ratio) can be obtained. The overall operating time in this case would be about 3 hours (average speed perhaps 1700 rpm) including cycle and testing time on the basis of operating 336 bombs simultaneously.

Much of the value of high speed operation of the first wheel is lost if frequent stops are made. Consider the case of a menu wherein each wheel order yields 3000 stops (about the value of the worst case). The first wheel must make about 25000 revolutions for a complete cycle of the bomb (neglecting transfer time). If 3000 stops are made, then a stop is made on the average, every 8 revolutions of the

[3]

high speed wheel. The bomb will therefore be starting and stopping continually and the average speed of each bomb will therefore be low compared to the maximum of 3400 rpm. If [a] better case is considered, say the case of 130 stories or 624 stops per wheel order (ratio nearly 5 to 1), an actual case where the major molecule is of 8 letters with 2 closures, and the ~~monor~~ [minor] molecule is of 3 letters with no closures (on the chart as 24 stops and 5 stories), using double input on a four wheel machine, the high speed wheel will make on the average, about 40 revolutions between stops. At a speed of 3400 rpm for the high speed wheel, a stop would therefore occur every 0.8 second. Since the average speed will drop, we could possibly expect a stop about every 1½ second. Even in this more desirable case, full advantage of the 3400 rpm capabilities of the high speed wheel will not be realized. On good cribs however, where the number of stops (not stories) is below about 130 per wheel order, the full advantage of high speed operation will begin to be felt. From the chart, these cases generally occur when either the major or the minor molecule have two closures each, or one has two closures and the other one closure, and the ~~mojor~~ [major] molecule has about 7 letters or more, and the minor about 3 letters or more. Of course, in large molecules, either major or minor, the importance of closures diminishes.

The foregoing ~~dixcussion~~ [discussion] was presented to indicate the operating times encountered even when 336 bombs are used simultaneously. If half the required number are used, as maybe the case before all the bombs have been constructed, the operating times must be more than doubles, since wheels must be changed on each machine (3360 machines[5]). Many operators can work at this change simultaneously however, and the complete change should not require more than 15 to 30 minutes. Another reason for the foregoing discussion, is that it shows the mass of printed data that must be studied for each analysis. In the least desirable case, where 1000 stories are ~~prijted~~ [printed] per wheel order, the total volume of possible steckers obtained is 336000. In the more desirable case, say the case where only 130 stories per wheel [order, give] 13,680 printed steckers.

It should noted that in all cases discussed, the double input chart was used to obtain data. This for the reason, that in the bombs now being designed, the feature of utilizing double input is being incorporated. We are also arranging to use any and all tag ends as part of the menu so that they may contribute to the “wind up” of the bomb. They will not however be tested for possible stories during a stop caused by the major molecule, as will be done to the ~~monor~~ [minor] molecule, excepting when they are involved by common stecker with the major or minor molecule. It may

[4]

well happen therefore, that by using these tag ends, the number of stops and stories, as shown on the chart for a double input system, will be reduced from the value shown, but no plans are being based on this advantage, since its value cannot easily be ascertained.

Before discussing the actual plans for the machines and bombs, an example of a hypothetical case of plain and cipher text, used to prepare a menu, will be considered. The following is our conception of the manner in which the menu is set up. Assume the cipher and plain text assumption to be shown on the attached sheet, Fig. 1.[6] A menu consisting of four molecules is constructed therefrom. The major molecule has 6 letters and 2 closures, the minor has 7 letters and no closures, and the tag ends have 3 letters and 2 letters each. A total of 18 different letters are involved in the menu and 16 machines are necessary to form the bomb for each wheel order. With input to both the major and minor molecule (whenever the major molecule yields a story) we can expect to have 156 stops and 26 Warspite[7] stories per wheel order, as determined from

[5] The use of the term machines is sometimes confusing. as it is used in several contexts in this memo. Here and in many other places Joseph Desch uses machine to refer to a single Enigma analogue.

[6] This figure is missing in the editors’ copy.

[7] A double input or DI story has a story on the main chain and a stop on the subsidiary. The case which has a story on both chains GC&CS (Bletchley Park) called a Warspite story.

the double input chart. The ~~tog~~ [tag] ends will probably reduce these figures somewhat whenever the letters L, I, P, F and J appear as possible steckers for the letters in the major and at times in the minor molecule. In the system of operation to be described, the major molecule only, will be deliberately energized from an electrical source. Energy will be applied to the chosen core letter, probably to the cluster A or C, and only to one letter of that cluster. The minor molecule will receive energy from the major molecule through the diagonal board, whenever the alphabetic terminals which are energized on the clusters of the major molecule correspond to all or part of the cluster letters of the minor molecule. The three letter and two letter molecules are likewise energized excepting that they may also be involved through the ~~monor~~ [minor] molecule whenever it is energized. Whenever one or more cold points appear in the major molecule, as detected on the diagonal board, the bomb stops, and the cold points of the major molecule are energized in succession (hot point test), to determine their validity. A true cold point with this test insures correct reciprocity for every letter of the major molecule and for the letters in the minor molecule or tag ends, if these molecules are energized by common stecker with the ~~mojor~~ [major] molecule. For every true cold point (really a single hot point in this test) found in the major molecule, a test of the minor molecule will be made to determine whether or not it has received energy. If energy is found in the minor molecule, the possible steckers on the major and minor molecules are immediately

[5]

printed. steckers may also be printed from the tag ends if these molecules are energized. If the minor molecule is not found to be energized, during a hot point test of the ~~mafor~~ [major] molecule, energy will be applied to it to determine if any true cold points are present. All true cold points (really hot points) found in the minor molecule will be printed in combination with the true cold point found on the major. If the minor molecule possesses no true cold ~~poijts~~ [points], then the cold point on the major molecule is false and the bomb will resume operation. During the hot point test, any two or more letters on the menu (major or minor) steckered to a common “off the menu” letter will cause the indication of a wrong stecker.

The bombs as presently conceived, will be designed and constructed along the following lines:

Twenty machines[8], of four wheels each, will be mounted on one sturdy, probably cast framework, to form the bomb. Probably three such bombs will be mounted in one rack. Each bomb in the rack will have an individual motor drive so that a stop on one bomb will not affect other bombs as would be the case if all three were driven from the same motor. This main drive motor will probably be located in or near the center of the bomb so that short shafts can be used to lessen the effects of twist in the shafts. The high speed wheels of each machine of the bomb will be geared directly to the high speed shaft through 1 to 1 bevel gears, the wheel shafts being perpendicular to the main shaft. The next order wheels of all machines in the bomb will also be geared

[8] The final version of the US Bombe (N530 and N1530) had only 16 Enigma machines. They also built a few double unit Bombes (N800) which had 32 Enigmas. In comparison the Bletchley Park (BP) Bombe had a total of 36 Enigmas; a few earlier units had 30 Enigmas. The large number of Enigma analogues allowed the BP Bombe to run two or three menus simultaneously (or the same menu on two or three different wheel orders). All menus would stop when a stop occurred on any one of them.

to the high speed shaft through worm gears, but the gear ratio will possibly be about 37 to 1. Thus the high speed wheels will make approximately 1.4 revolutions for every 1/26 revolution of the second order wheels. In other words, the fast wheel will probably rotate 37 times as fast as the second wheel. This extra fraction of a revolution of the fast wheel is necessary to enable the contact brushes on the second wheel to move over the clearance between segments of the second wheel. A mechanical transfer mechanism to operate between the first and second wheel at a rate of 56 transfers per second (the first wheel revolves 56 times per second) is difficult to design and construct. The overlap, that is the extra fraction of a revolution that the high speed wheel makes for every displacement of the second wheel, introduces a problem involving cold point duplications. A hit occur[r]ing when the brushes of the second wheel have just entered upon the approaching contact, will reappear when the brushes are leaving that contact. This because the first wheel has made one revolution while the brushes of the second wheel are still on the same contact. With our present conception of the mechanical tolerances necessary in the wheel design

[6]

about three or four contacts on the high speed wheel may be involved in a duplication of hits. To prevent this undesirable feature, it is planned to paralyze the Rossi detector ~~duting~~ [during] the overlap period of the first wheel during the time the brushes of the second wheel are riding over the gap area between segments of the second wheel. This device is likely to take the form of a rotary switch or wheel geared 26 to 1 to the second wheel so as to accurately time the paralyzing period of the detector. Another problem presented by the overlap concerns the rewind or return to the position of the hit. Due to the manufacturing tolerances necessary, some assurance that the second wheel contacts are not bridging during the hot point test is necessary. A similar device is contemplated to prevent this trouble. It too will be geared to the second wheel. The third wheel of each machine in the bomb will be transfer connected to the second wheel. All the third wheels will be geared to a common shaft which will be advance[d] one position (1/26 rev) by means of a powerful single transfer device, once for each 1.3 revolution of the second wheel. The fourth wheels will likewise be transfer connected to the third wheels, in the same manner. A [G]eneva[9] type transfer is being considered in addition to a snap type spring transfer and a single revolution clutch type. During each transfer operation, several revolutions of the high speed wheel will occur. It is planned that during the transfer period, when a transfer to the third or fourth wheel occurs, the cold point detector will be paralyzed, so that cold point hits occur[r]ing during this time will not be indicated. Some form of rotary switch will possibly be used to effect this operation. A transfer action might occur almost simultaneously with a cold point hit, (on a contact of the high speed wheel just ahead of the contact on ~~thich~~ [which] the signal to transfer would be given) and transfer would occur during the coast over the contact following the hit and provision to prevent such action will be incorporated in the bomb. If a transfer did occur during a ~~git~~ [hit], it would not be possible to return the transferred wheel to its correct position during rewind, unless the transfer mechanism was of the [G]eneva gear type. It is planned to control the thyratron which will be used to energize the transfer device

[9] A Geneva drive mechanism or Geneva gear is also goes under the name Maltese cross and is frequently used as a mechanical control mechanism, e.g. the shutter control in cinematography projectors.

from the cold point detector as well as from the transfer signal initiator. If a hit occurs just prior to transfer, the thyratron will be paralyzed so that it will not operate as the wheels coast by the transfer point. Transfer will occur when the third wheel passes from Z to A and no provision to effect a transfer at any other point is being made. The transfer point between the second wheel and the third wheel will be maintained, so as to insure testing of all combinations, by means of an auxiliary rotary switch. Transfer cannot be said to occur at only one letter of the second wheel or the identity of the letter at which transfer occurs is not static, but the point is constantly advancing. Of

[7]

course the transfer point between the first and the second wheels constantly shifts because to the overlap. The transfer between these wheels might be called a "creeping" transfer. We do not associate transfers within the machines of the bomb as having any significance or relation to the transfers that occur[r]ed during the encipherment of the message. It is our understanding that the cribs used will be predicated on the assumption that a transfer did not occur in the portion of the encipherment being used. We are of the opinion that the displacement of the high speed wheels in the bomb simulates the successive positions of the fast wheel in the original code machine and the only function of the individual machines in the bomb is to provide the combination of wheel positions. The displacement relation between all the high speed wheels of a bomb will remain fixed, including their shifting transfer points as the bomb cycles. If a transfer point is suspected in the crib between the first and second wheels, and it therefore becomes desirable to displace the second wheel of certain machines in the bomb as the developed menu of molecules would indicate, this can be accomplished by rotating the second wheels involved on their shafts. It will be necessary for us to know the direction of displacement of the wheels and the direction of rotation of the original enciphering machine before the bomb is completed.

All wheels will be designed to be interchangeable, including the fourth wheel. All wheel shafts will be splined so that all wheels can be indexed. The bomb can then be zeroized without motor operation to return it to zero, or it may be set to a specified position without operation. Wheels might also be interchanged between bombs, some of the slow speed wheels thereby being used on the high speed wheel positions so as to distribute wear. All wheels will have two wirings. Each wiring will terminate in two rings of 26 contact segments. The back face of the wheels, when the bomb is viewed from the wheel side, will have four concentric rings of 26 contact segments each. There will therefore be 104 contacts per wheel. Each segment of the wheels must have a brush contact so that 104 brushes must be used with each wheel. The brushes, as they are presently being designed, will be easily removable cartridges in the molded brush holder. It will be possible to remove them from the wheel side of the bomb. The wheels will be molded of bakelite with the metal segment inserts of hard copper or of a wear resistant alloy. The brushes probably will be of graphitized copper, the exact composition to be determined by life tests. We hope to secure a life of 1000 hours or more with these brushes before replacement. This applies only to the high speed wheel since the life on the slower wheels will be much greater. Since our overall plans for this cold point system of operations require shorting

[8]

the segments by the brushes during the transition of the brush from one contact to another, the wheels have so been designed. This is advantageous since it enables a design of commutator with no solid plastic insulation between contacts to be used. The brushes need not therefore ride on insulation between segments. In this shorting type brush, the leading edge of the brush is well supported on the approaching segment before the rear edge has left the departing segment. Sparking will also be greatly reduced or eliminated by this design. The elimination of solid insulation between contacts is very desirable. There will be no possibility of insulation being carried over onto the contact face and leakage between contacts caused by metal bridging the insulation will not exist. Some graphite dust may collect on the bakelite insulation of the molded wheel after considerable operation, but this can be washed out easily with a good non-conductive solvent.

Each bomb will be equipped with a visual wheel position indicator, so that the exact part of a cycle, during a stop, can be easily checked. On the high speed and next lower speed shafts of the bomb there will be a 26 position commutator, from which an electronic memory device will receive a signal at the instant a hit occurs. Probably each commutator will have two sets of contacts, the second set being used for "hunting" when the bomb is returned to the exact position of the hit. The memory device will consist of two banks of 26 miniature thyratrons each, one tube in each bank being ignited when a hit occurs. Provision will also be made on each bomb so that three wheel operation can be effected. The wheel makes one complete revolution. The fourth wheel will remain stationary and the wiring of this wheel will have to be determined for this special case. Also the reflecting board wiring need be known and if it differs from the wiring of the four wheel machine reflecting board, some provision must be made to change it during three wheel operation. We also plan to provide several speeds of operation for the bomb. In cases of slim menus, the high speed wheel will make only [few ?][10] revolutions, perhaps eight, between hits. The average cycle speed of the machine will therefore drop sharply. It may actually be advantageous to drop to a lower bomb speed in these cases. If the rate of the high speed wheel is lowered to 500 rpm the cycle time increases from about 9 minutes to about 52 minutes, which is small compared to the testing time of perhaps 12 to 15 hours, needed for checking and printing the same menu. It is thought that perhaps a gear shift could be provided between the motor and the bomb to secure two or more lower speeds of say 500 and 1000 rpm for the high speed shaft. Of course the high speed of 3400 rpm would also be provided for cases where very good cribs were

[9]

available. We are also seriously considering the use of an automatic "rewind" device, instead of a hand rewind, to return the bomb to the position of the hit. A small motor, in addition to the main drive motor could perform this function. A rewind speed of about 100 rpm could possibly be realized. The bomb then would be completely automatic.

[10] Our copy is too faint to clearly identify this word.

It is planned to effect a hook-up of machines to the diagonal board, to form the bomb, by the use of two hand operated gang switches. One switch will connect the 26 input leads of the machine to the proper diagonal board column, and the other will connect the output leads to the proper column. These switches will be located just below each of the 20 machines of the bomb (40 switches per bomb). Each switch will be a 26 plate pole, 27 position device (one position is dead so [the] machine can be disconnected) probably of the Centralab wafer type switch, or perhaps a special drum switch. The use of this type of hook-up device will speed up the wiring of the bomb. Another advantage lies in the fact that the first wheel of the machines of the bomb can be permanently displaced, the number 1 machine having zero displacement, #2 having a displacement of 1/26 revolution, #3 having a displacement of 2/26 revolution, #10 having 9/26 revolution displacement etc. Any machine can therefore be connected between any 2 clusters or menu letters with these switches.

The diagonal board will consist of simply 26 columns of 26 contacts each reciprocally wired, that is to say, point ak connects to ka, bg to gb etc. The cold point detector will be plugged in to one of the clusters or columns of the diagonal board on a letter appearing in the menu of the major molecule. There will be 26 sockets permanently mounted on the diagonal board, one connecting to each column and to all the points on each column. Provision will also be made on the diagonal board to permit the 20 printer scanners to be connected to the menu letters, including the tag ends. The cold point detector will possibly consist of 26 diode sections arranged in a suitable Rossi circuit. A simple stecker test, which operates only after the cold point energy has been removed, will probably consist of one triode per diagonal board column. This triode will conduct if 2 or more points in the column are energized during the hot point test. Conduction of any one of the 26 stecker triodes will signal a false stecker. A hot point test will be made on both the major and the minor molecule after a cold point stop has been made. The hot point check on the major molecule is initiated ahead of the ~~monor~~ [minor] molecule check. The potential normally applied to the core letter cluster of the major

[10]

molecule will be removed the instant a hit occurs. The hot point checking potential will be applied in sequence to the alphabetic terminals of the core letter cluster of the major molecule through a stepping switch. As this potential is applied the tubes of the stecker tester will test for a single hot point, that is, for a possible stecker. When a true hot point is found (no stecker test triodes conduct) the ~~monor~~ [minor] molecule is instantly checked for possible energy on some terminal of a cluster therein. It requires only one tube for this operation. If a terminal is energized, the printer will scan the diagonal board and print the possible steckers (20 letters may be scanned). If no energy was found in the minor molecule, another stepping switch will sequentially energize the alphabetic terminals of one cluster in the minor molecule, and the stecker tester will detect any true hot point. The stepping switch continues to operate as long as no true hot point is found on the minor molecule. Whenever a true hot point is ~~jound~~ [found], the printer will print both the possible steckers of the major and minor molecules, and the tag ends if they have received any energy by common stecker to the major or minor molecules. Several true hot points may be found in the minor molecule. If so, each possible stecker will be printed together with a repetition of the possible stecker of the major molecule which is still energized through its stepping switch. When the ~~monor~~ [minor] molecule stepping switch reaches Z, the stepping switch of the major molecule will continue on to search for other possible true hot points in the major molecule. If any are found, the entire procedure above described, as ~~resating~~ [relating] to the ~~monor~~ [minor] molecule, will be repeated. If when the minor molecule is hot point tested, no true hot point is found, the major molecule stepping switch will continue on, and no print of the stecker of the major molecule will be made, since there is no possible stecker. It will frequently happen that in the stepping switch hot point check of the major molecule, no true hot point is found and consequently nothing will be printed (this occurs nearly as the ratio of stops to single input stories). In other words, the stop did not yield a story even in the major molecule. It is our understanding that stories or possible steckers printed from both the major and minor molecules are called "Warspite" stories. The proposed equipment will print this type of story.

The following may be typical as to how a problem will be set up and analyzed on each of the 336 bombs:

1. A bomb is arranged with one of the 336 possible wheel combinations.

[11]

2. Operator receives menu data and switches machines to satisfy the data. Machines are picked according to desired displacement.

3. Operator connects 20 of the 24 scanners on the printer to menu letters on the diagonal board, arranging scanners of the printer in groups, so that all major molecule steckers are together, and so that all minor molecule printed steckers are together. Lesser molecule letters also grouped. Operator identifies columns on paper tape of printer according to menu letters chosen. Four scanners of printer permanently connect to wheel position commutators.

4. Operator checks position of wheels and transfers to see that they are correct.

5. Operator connects cold point detector (Rossi Detector) to one menu letter of major molecule.

6. Operator switches ~~monor~~ [minor] molecule hot point detector to a menu letter of the minor molecule. (detector is single tube.)

7. Operator depresses "start" control, which energizes cold point detector, energizes wheel position memory device, applies energy to one point of a major molecule cluster and starts main driving motor. Hereinafter, after each stop, whether a story is printed or not, the start control will operate automatically.

8. Stop occurs when one or more cold points are detected on major molecule, by the Rossi detector. If a letter of the cluster of the major molecule to which energy is being applied happens to be a true cold point, then actually 25 cold points appear in the molecule and a stop will occur.

9. When a hit occurs, electronic memory device retains positions of two highest speed wheels and energized one segment on each of the two "hunting" commutators for the rewind to the hit position. Transfer devices automatically disconnect and brake is applied.

10. Rewind motor cuts in and returns bomb to hit position automatically. Bomb is stopped on rewind by hot contacts on "hunting commutator" which actuate a pawl or brake stop. Special devices on number one wheel commutator to select correct position of first wheel since overlap feature of first wheel confuses problem.

11. Hot point test as previously described, begins automatically when rewind is complete. All possible steckers printed automatically on tape. Warspite stories printed.

[12]

12. Either the printer, or the hot point testing devices whichever is last to complete its operation will operate the start control to again initiate the bomb cycle.

13. When [the] fourth wheel completes one revolution, the bomb automatically shuts down. In three wheel operation, the third wheel will control.

Statements made herein as regards to design are of course subject to change. We feel however that the general functions to be performed have been fairly well fixed. Times of operation may vary due to the requirements of design but the figures given should fairly represent the finally achieved figures. If some major item, overlooked as of this date, should present itself, we will notify the Navy Department at once.

We are anxious to receive approval of the basic plans as set forth herein, at an early date, since designs are presently being made on our understandings as stated.

Joseph R. Desch
N. C. R. Co.
Sept. 17, 1942.