Hut 6

REPORT ON FOUR WHEEL BOMBES

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31st October 1942

F O U R W H E E L B O M B E S

I. MAIN REQUIREMENTS

a) Reliability

The machine must go on running for 24 hours a day for months on end with little maintenance. A reliable machine taking as much as 30 minutes a run would be better than a machine three times as fast but continually out of action for repairs and maintenance.

b) Adaptability

The machines are not faced with a definite problem, but with a wide range of problems, and we cannot hope to foresee all the jobs which the machines will be required to do in the future. The design must be such that modifications can be made at a later date as they become necessary.

c) Standardisation

This is obviously important for rapid production, but it is also important for efficient running. Mistakes will be less likely to occur and maintenance will be easier if all apparatus is of similar design.

d) Mobility

It is likely to be necessary to return machines to the works for alterations, if not for overhaul.

e) Compactness

A machine which is built on one frame will be easier to operate than one which consists of several separate units connected by cables.

f) Simplicity

Both the reliability of a machine and the rate of production are likely to be reduced by the addition of too many complicated devices. Provided the machines are adaptable there is little point in making them capable of dealing with complications that may never arise, but simplicity without adaptability would be dangerous.

g) Speed of Running

This is of obvious importance.

h) Speed of Production

This also is of obvious important, but a long term view must be taken.

II. EXPLANATORY NOTES

a) Sensing

The 36 enigmas of a four wheel bombe have to be turned through 26^4 positions, and as each position is passed a test is applied, this process being known as "sensing". The simplest test, known as "on chain" or "input" sensing, is achieved by examining the stecker of one letter only. A more powerful test, known as "Mammoth sensing", depends on examining the on chain stecker of all letters of the alphabet. More powerful tests still may prove to be necessary, but the type of sensing required depends on the nature of the available cribs and is difficult to forecast. For cribs of 20 letters or more Mammoth sensing is not necessary, though it might sometimes be a convenience, while unfavourable cribs of 15 letters may barely offer a theoretical solution.

b) Recording

As long as cribs are reasonably satisfactory, it will be possible to adjust menus so that only one or two positions have to be recorded on each wheel order. But if we get into real difficulties it may be necessary to record a large number of positions and a good deal of information about these positions. For example, in the absence of any respectable crib we may be reduced to running weak menus on two very short cribs and comparing results.

c) Relays and Valves

Valves will operate faster than relays, but, apart from this disadvantage relays are on the whole more suitable than valves for most forms of sensing. (A relay has two contacts each of which can either make or break a circuit). On the other hand, it appears that valves alone can enable us to use a resister board for Mammoth sensing.

Mammoth sensing can be done by relays, but the proposed resister board method may both simplify production and reduce the amount of space required. It may also overcome the difficulty of breaking down high contact resistances. Finally the resister board method should simplify plugging of Mammoth menus.

d) Banks

Standard three wheel bombes have three separate diagonal boards and sensing equipment so that the 36 enigmas can be divided into three "banks" to run three wheel orders at a time. It is clear that three banks can only be used when a menu can be made up involving 12 enigmas or less. This would seldom happen for a four wheel machine doing only input sensing, so the complication of a third bank would not be justified on such a machine. But a machine with mammoth sensing could often make use of three banks, and the resister board scheme may enable us to obtain three bank Mammoths without excessive complications. The advantages of this are obvious.

e) Mechanical Motion and the New Carry

In the standard three wheel bombe the fast wheels move continuously, while the medium and the slow wheels carry. Until recently it was thought that in a four wheel bombe two sets of wheels, the fast and the very fast, would have to move continuously, and this introduces considerable difficulties, both in the sensing and in the recording of particulars about positions detected. But Keen has designed an electrically controlled carry, operating separately on each wheel, which goes so fast that it may be possible to make the fast wheels carry and still do a run in well under 20 minutes. This would mean that the slow, medium and fast wheels could all stay on a position in which a straight is detected until any necessary operations have been performed.

This development would not only get over a number of difficulties and simplify the problem of recording, but it would also prepare the way for further refinements in sensing, just as preselected stopping of three wheel bombes make Jumbos possible. It is clearly desirable to do as much sensing as is necessary on the bombe because the information which is given instantaneously by electrical connections through the bombe cannot be easily reproduced by hand, or even by an Analyser.

III. EXPERIMENTS IN PROGRESS

a) Keen's Mammoth

This machine is undergoing exhaustive trials and a good deal more will be known when these trials are complete. A set of 36 very fast wheels have been fitted on to the end of a standard bombe frame and geared to the standard bombe mechanism. Input sensing, Mammoth sensing and recording of stecker are all achieved by Siemen's high speed relays mounted on the bombe frame, the only separate unit being a gang punch. The machine has two banks.

b) Flowers' Unit for Input Sensing

This unit, which does input sensing for two banks, will be tested on the enigmas of Keen's Mammoth. Of course this unit is meant for use with a machine that runs too fast for relay sensing, but the test with Mammoth should give a good idea of how the unit can be expected to behave at higher speeds. The unit has been so designed that complications such as double input and Mammoth sensing can be added later; it is built on a separate frame and is fairly bulky.

c) Wynn Williams Attachments

Trouble with the commutator assembly, or Cobra, has prevented any exhaustive tests, but new brushes are being fitted and it is hoped to continue experiments shortly. it has been established that the valve sensing unit can pick up a straight at the estimated speed with favourable menus. Lack of enough working enigmas has prevented a test on the sort of menus that are likely to be run.

IV. FURTHER EXPERIMENTS

a) Four Wheel Bombe

It seems likely that the mechanical part of Keen's high speed bombe can be made to run considerably faster than his first Mammoth, whose speed was determined by the speed of the Siemens relay. It is hoped that it may achieve a run in about 14 minutes, though it may be necessary to replace the present 28 point carry by a 30 point carry. It is most important to find out just how fast the machine will run with a reasonable safety margin.

b) New Relays

A modified Siemens relay, designed by Keen and both smaller and slightly faster than the standard Siemens model should be in production by the end of November. It will be important to know how fast Keen's four wheel bombe will run with input sensing by this new relay. If this speed is not much less than the maximum speed possible with valves, then relay sensing will be preferable. (It seems quite likely that a run in 15 minutes will be achieved with relay sensing).

c) Resister Board

An experimental model is being built using standard Letchworth equipment, which can be fitted to the frame of a four wheel bombe. If it is successful and not too bulky, it may enable us to get a three bank bombe with Mammoth sensing.

d) New Carry

The development of the new electrically controlled carry clutch mechanism is likely to prove very important, but it cannot be expected to be in production for some time.

e) Mawdsley's Cobra

A prototype is being built, which will have to be tested in combination with a standard three wheel bombe and a valve sensing unit.

V. CONCLUSIONS

a) The Best Machine

Of all the developments which at present appear to be practicable, there is little doubt that the best would be a Keen four wheel Bombe with the new electrically controlled carry. Input sensing should be done by relays provided that this does not involve too great a sacrifice of speed. Mammoth sensing should probably be done by a resister board and valves. If possible three banks should be provided, and the whole machine should be built as one unit. A further development which would be most valuable but which does not at present seem at all easy, is some simplification of wheel changing.

b) A Standard Machine

We cannot afford to bank on the success of the somewhat ambitious machine described above, and this machine cannot be put into production for many months,. Also two or three machines are urgently needed to break into the U-Boat traffic, and discover the state of the cribs on which so much depends. It is therefore necessary to decide the specification of a standard machine on the production of which every effort can be concentrated at once, and the choice is fairly clear. The basis of the standard machine should be the Keen four wheel bombe modified to go as fast as possible. Whether input sensing is done by relays or by valves will depend on the speed of the new relays and on the performance of Flowers' valve sensing unit under test.

To be on the safe side it would be better to think of the standard machine as a two bank bombe doing input sensing only, and in this form it will be extremely useful. But, if the resister board works, some or possibly all the machines should have Mammoth sensing added. When this is done a third bank should be provided if possible. If input sensing is done by relays, it should be quite easy to add a fourth input so that double input jobs can be run on two banks.

If the resister board fails, some of the standard bombes will have to be fitted with Mammoth sensing by relays.

c) Use of Three Wheel Bombes

A machine that is built as a four wheel bombe is likely to give better service than an adaptation of a three wheel bombe, and our first aim should be concentrate on the production of the four wheel machines. It would be possible to return the standard three wheel bombes to Letchworth for conversion into four wheel machines, but this might delay production. It seems that the best way of making use of the standard three wheel machines is to build separate attachments, consisting of the very fast wheel assembly of Keen's four wheel bombe. These attachments would be simple to produce, as nearly all the parts are standard. Each attachment would be compact and on wheels, and would be bolted to the frame of the standard bombe. It would not be necessary to return the standard bombes to Letchworth.

The Mawdsley very fast wheel assembly, consisting of two sets of 18 wheels, could be used instead, but the Keen assembly could probably be produced more quickly and is also preferable on other grounds.

d) The Mawdsley Assembly

This has rather faded into the background because several advances have been made since Wynn Williams made his plans last winter, and because the development of these plans has taken longer than was expected. The machine still has the advantage of speed, but this advantage is not nearly as great as was originally supposed. Also the possibility of making Keen's four wheel machine into a three bank Mammoth may well reverse this advantage. The main disadvantages are as follows:-

(i) Large amount of floor space required.

(ii) Immobility.

(iii) It is a new type of equipment,and its serviceability cannot be judged until it has been tried under operational conditions. Maintenance problems will be different from those to which we are accustomed.

(iv) The wheels are in two separate sets of 18, which limits us to two banks.

(v) Lack of adaptability might well prove to be the most serious disadvantage. It is impossible to forecast what sort of modification may be required in the future, but it seems that any sort of modification would be difficult. For example, the wheel wiring is permanent and it would be difficult to arrange that the wheels could be set at arbitrary relative positions.

On the other hand, we cannot afford to neglect the possibility that Keen's machine may not be as successful as we expect, and the construction of Mawdsley's prototype is a safeguard.

e) <u>The Flowers' Valve Sensing Unit</u>

This is also a new type of equipment, which cannot be judged until it has been tried under operational conditions. If the preliminary tests are satisfactory, there is a good deal to be said for attaching it to Keen's second four wheel bombe, for operational use. We clearly want to know its performance as soon as possible, as a choice will have to be made between valves and relays for the input sensing of the standard four wheel machine.

VI. <u>NECESSARY ACTION</u>

a) The following instructions should be given to Letchworth:-

(i) To switch over from three wheel bombes to standard four wheel bombes at the earliest possible date.

(ii) To aim at a rate of production of three machines per week.

(iii) To accelerate all experiments affecting the design of the standard four wheel machine.

(iv) To advance the production of the six four wheel machines already ordered.

(v) To set aside one of these machines to be used in conjunction with Flowers' valve sensing prototype unit for operational tests.

(vi) To make very fast wheel attachments for the conversion of standard three wheel bombes to four wheel machines. The production of these to start at the earliest possible date, and to be at the rate of three a week in addition to the four wheel machines.

(vii) To accelerate experiments on the electrically controlled carry machine.

(viii) To be prepared to switch over to the production of this machine when possible.

b) In order that this large programme may be carried out with the greatest possible speed, the facilities at Letchworth must be considerably increased. If necessary, arrangements must be made to farm out some of the work to other firms. The entire assembly, however, should be done at Letchworth.

c) Further instructions about the production of valve sensing units cannot be given until the prototype has undergone operational tests.

31st October 1942

APPENDIX TO REPORT ON FOUR WHEEL BOMBES

1) Estimated Times for a Run

Keen four wheel bombes:- a) with relays ... 15 minutes
b) with valves ... 13 minutes

Wynn Williams attachments with modified three wheel bombe (30 point carry) ... 14 minutes

2) Reasons for Changes in Estimates Times

Keen's original running time of 22 minutes allowed a 100% safety margin in the time of operation of relays. The new relay is slightly faster, and its speed can be further increased by raising the peak voltage. A 50% margin should be considered sufficient.

For a given time of run the amount of time available for sensing in each position depends on the wastage of time due to carry and clean time ratios. On Keen's machine, thanks to synchronisation and flexibility of design, it has become possible to reduce this wastage considerably. As a result relay sensing becomes possible at a much lower running time.

Wynn Williams finds that with the standard bombe he cannot get a clean time ratio of more than about 50%. It is difficult to get over this trouble without a prohibitive amount of brush timing and even with a change to 30 point carry the least possible time for a run seems to be about 14 minutes.

3) Quantities to be Ordered from Letchworth

a) Four machines of next bath of twelve to be the remaining high speed machines already ordered, but of a modified design.

b) In addition 36 more high speed bombes to be ordered now, production to start if possible with the next batch but one.

c) Two dozen attachments to be ordered now, and to be in production during December.

d) Enough equipment to be made to build 24 more high speed machines and to convert all three wheel bombes.