INTERIM REPORT ON DEVELOPMENTS IN MECHANIZATION

The Present Position

The Ordinary Bombe

An ordinary bombe can scan menus down to the limit where they produce four stops; this means twelve to be tested every twenty minutes with a three-bank machine and is an outside limit. For single chains, the shortest menus runnable are 16, 14_1 and ll_2.

Using double input, it is possible to run menus consisting of two separate chains which have roughly the same total number of constatations as the borderline single-chain menu with the same number of closures. The lines making the limit of possible menus on an ordinary bombe therefore run diagonally; they are shown in chart I like this -----.

Jumbo

By using a machine-gun to eliminate straights with legal contradictions, Jumbo produces less than four stories to be tested on menus down to the limits 13, 12, and 102 The reduction in the length of chain is greater for the open chain since the ratio of stops to stories is greater for a greater length of chain. But in practice an open 13 is not runnable owing to the large number of times the machine will stop. In the diagram, two borderlines are drawn for Jumbo. The first one includes menus which produce less than 70 stops; even with this number, the machine takes an hour to do three wheel-orders. The second line ----- includes menus producing up to 200 stops which could be run on Jumbo in case of need.

Jumbo is fitted with double-input, but has the disadvantage that it doesn't find the position of the straight in the second chain, so that testing is very laborious. The position of the Jumbo borderline for double-input menus is now only of historical interest, since such menus will in future be run on Warspite, which doesn't suffer from this defect.

Warspite

Warspite produces the same results as Jumbo on single-input menus. When running double-input, its machine-gun operates on the second chain after it has found a story on the first, but it doesn't eliminate legal contradictions between the chains. It would be easy, however, to throw out stories involving such contradictions by twenty or so to be examined even in the borderline cases. The number of Warspite stories to be tested is therefore taken as the number without any contradictions between the two chains - in fact, without any contradictions at all.

The testing of these stories is different in character from the testing of an ordinary bombe stop. When the routine testing to control the running of the bombes is performed by Wrens, there will be no need to work out the complete set of stecker by going round the menu. All that will be necessary will be to take the printed stecker and test them in constatations not used in the menu. This supposes that the printed roll of stecker is available to the testers in Hut 6. If this were so, it might be possible to increase slightly the number of stories that could be dealt with.

It happens that in a number of marginal cases, the number of Warspite stories to be tested is five. These cases have been included as being runnable, though it is realised that this can't be definitely assumed until the method has been tried out. Two menus producing five stories on Jumbo have also been included, namely 92 and 82 with a subsidiary 3.

When all these assumptions about the testing of Warspite have been made, its borderline runs diagonally for the most part two squares above the ordinary bombe line. As in the case of open chains in Jumbo, the full advantage isn't secured because the number of stops is a

limiting factor. This is the factor which prevents the menus just above the borderline from being run when they are of the types 0/0, 1/0, 0/1 or 1/1.
For Warspite as for Jumbo, two alternative borderlines are shown. One, ——, includes menus producing less than 70 stops, the other ----- includes those with up to 200 stops. The menus in between should be regarded primarily as jobs for a new type of machine - Mammoth or Baby Jumbo.

Besides showing the borderlines for an ordinary bombe, Jumbo and Warspite, Chart 1 also includes lines —— and ----- showing menus runnable on Baby Jumbo or Mammoth in conjunction with a Quagga, with risks up to 5% and 20% respectively.

POSSIBLE DEVELOPMENTS

In order to reduce still further the minimum length of menus that can be run, there are 3 lines of attack. The first is to devise a machine that will eliminate stories with legal contradictions while running and that will therefore escape from the limitations imposed on Warspite by its large number of stops. The second is to use a Quagga for testing, by which means the number of stories that can be dealt with is increased from five to twenty. The third is to employ some device that will reject the more unlikely stories produced by the bombe, so that you only have to test the more promising ones.

We are considering in the first class a machine of the Mammoth type that rejects stories with legal contractions by means of 351 relays. In order to do this without stopping and scanning it must have a cast-iron input, which involves the usually slight risk that there may be some other arrangement than 25 - 1 in the position where the right story occurs. If it is to be able to machine-gun the second chain as well while running, it must also have a cast-iron input on this and the risk may be very large. It might be possible for the machine to consider the arrangement 24-1-1 on the second chain as well as 25-1 by means of a super cast-iron input, but even with this the risk is some, large, and is a restriction on the usefulness of manuals for double-input menus. The "super cast-iron input" is referred to below by the symbol χ.

In the third class of possible devices, we consider the assumptions that the right story

has a certain number of self-steckers (*s*)
has a certain number of confirmations *(c)*
or tacks on to a subsidiary chain *(t)*

When one letter is knocked off a menu, i.e. in going one square inside the borderline on the diagram - the number of stories is increased by a factor which varies from roughly 10, on the 0/0 borderline, to 3 on the 2/1 borderline. To be of general use, therefore, any device employed must reduce the number of stories by a comparable factor, though in individual cases it may be sufficient if it merely halves them. Warspite achieves its considerable advance over an ordinary bombe because the number of stories is from a tenth to a hundredth of the number of stops.

Machines

In order to be definite, we have considered two specific machines. The first is a one-bank Mammoth, either of type A or B, with

1 relays
2 cast-iron input in the main chain and optional super cast-iron input in the second chain
3 diagonal selection
4 tacking-on control (by considering a row of the diagonal board
5 a method of punching cards to go in to Quagga instead of printing stecker

the second machine is of the Jumbo type with only one bank and designed primarily for research jobs, particularly those with a restricted ringstelling range, which it's inconvenient to put on a three-bank machine. This we have supposed to have:

1	Scanning and machine-gunning as on Jumbo		
2	Diagonal Selection	}	All by means of relays
3	Confirmation control	}	specially plugged up
4	Tacking-on control	}	for each job.
5	A method of printing cards to go in to Quagga		

On Baby Jumbo, though not in Mammoth, we have suffered the devices *s*, *c* and *t* to operate while the machine is running, so that they reduce the number of stops as well as the number of stories. This means either a more complicated wiring to make the device operate both

when the story is in the input line or when it isn't, or (which is probably better) that the device should not operate when the story is in the input line, so that in those cases the bombe would stop whether the given conditions were satisfied or not.

Notes:

1. Quagga would be of very little use in conjunction with Jumbo or Warspite since the main factor limiting their range is the number of stops. The only additional menus it would enable them to run would be 8_2 and 7_2 with a 3-chain.
2. We have omitted the method of making a definite self-stecker assumption, which seemed definitely inferior.

Mammoth and Baby Jumbo Menus (with reference to chart 2)

As has been said above, Warspite enables us to run menus giving up to 70 stories per w.o. - with the possible addition of menus going up to 200 stops and 5 stories.

We now consider what further menus the new machines would make runnable. These menus fall conveniently into four categories.

α ----- Warspite menus with more than 70 stops are highly undesirable - partly from the mechanical point of view, when the machine has to stop often, and partly because of the excessive running time. They are therefore primarily Mammoth menus, and there are about 19 of them. The risk in each case is very small (<7%). (Of these menus 14 are runnable ordinarily on Mammoth; 5 require 24-1-1 on the subsidiary chain.)

The menus included are:-

	{0/0	13-0, 12-3, 11-4, 10-5, 9-6, 8-7
19	{1/0	11_1-0, 9_1-4, 8_1-5, 7_1-6, 6_1-7, 5_1-8, 4_1-9
	{0/1	1_1-2_1, 10-3_1
	{1/1	9_1-2_1, 8_1-3_1, 7_1-4_1, 6_1-5_1

β_____ Just outside the extreme Warspite borderline are several menus which, though definitely not runnable on Warspite, are easily runnable on Mammoth, either ordinarily or with diagonal selection - and in any case with negligible risk (<5%). These consist of 9 single-input menus (i.e. with short subsidiary chains) and from a very common class of menus.

These menus are:-

	{0/0	12-0, 12-2, 11-3
9	{1/0	10_1-0, 10_1-2, 9_1-3
	{2/0	8_2-0, 8_2-2, 7_2-3

γ ….. In order to get further inside the Warspite borderline we definitely have to take risks. These risks are either assumptions about the behaviour of the correct story (i.e. self-stecker, confirmation, tacking-on, etc.), or the assumption of only one (or possibly only two) straight in the correct position. This latter assumption makes simultaneous machine-gunning on two chains possible. This class of menus [γ] consists of those runnable with a risk of ,20%. The taking of this risk makes part of a further diagonal of menus runnable. The total number is 21. In the appropriate squares of Chart 2 are entered the "best" ways of running these menus (with sometimes a slightly inferior alternative method in brackets). In some cases Mammoth and Baby Jumbo are equally good: both are then entered. The suffixes denote the devices used.

These menus include:

	{0/0	11-2, 10-4, 9-5, 9-6, 7-7
	{1/0	5_1-7, 4_1-8,
	{2/0	7_2-0, 7_2-2, 6_2-3, 6_2-4
21	{0/1	10-2_1, 9-3_1
	{1/1	8_1-2_1, 7_1-3_1, 6_1-4_1, 5_1- 5_1
	{2/1	6_2 -2_1, 5_2-3_1, 4_2-4_1, 3_2-5_1

The devices chiefly used here are diagonal selection [ʢ] and 24-1-1 on the subsidiary chain [×]. 4 of the menus need both of these; 8 need × alone,; 6 need ʢ alone. Of the other 3 menus in this class, 2 need ʢ and/or c on Baby Jumbo, 1 needs t on Baby Jumbo. [Actually, this last menu could be run on Mammoth with 24-1-1 and with a risk of 25% instead of 18%.]

δ-.-.-.- The above three classes are, of course, by far the most important since a risk of more than 20% makes the menu into rather a long shot. However, since Mammoth and Baby Jumbo wil be research machines, we shall sometimes have to consider taking risks greater than this in order to make weak menus runnable.

This class [δ] consists of menus runnable with a risk of between 20% and 33% and in involves a further 15 menus:-

	{0/0	10-3, 9-4, 8-5, 7-6
	{1/1	9_1-0, 9_1-2, 8_1-3, 8_1-4, 7_1-5, 6_1-6
15	{2/0	5_2-4, 5_2-5, 4_2-6
	{2/1	5_2-2_1, 4_2-3_1

In these menus the variety of devices used is greater than in α, β, and γ. 6 need ʢ only; 4 need c on Baby Jumbo; 5 need t on Mammoth or Baby Jumbo. [One of these last is equally well runnable M_x.]

SUMMARY OF CONCLUSIONS

From the foregoing figures it is clear that the various devices fall into different categories of usefulness. Those most used are x and s - in all except the weakest menu cases.

The machine which would be of most use would be of th Mammoth type and with the following specification:

(i) 352 positive (not differential) relays.
(ii) Cast iron (25-1) input for the main chain - to be used always
(iii) Super cast iron (24-1-1) input for a second chain - to be used as an alternative to an ordinary double input.
(iv) Diagonal selection (with pluggable and differential self-stecker relays).
(v) Designed to work in conjunction with a Quagga (i.e. by punching cards).

Such a machine would run all the menus of classes [α] and [β], 18 out of 21 of the [γ] menus, and 7 out of 15 of the [δ] menus, and it would run all these in the best possible way. It would be essentially a general purposes machine, covering most of the 20% risk class, and half the 33% risk class.

In our investigations we have considered two alternative forms of Mammoth - A and B. The difference between them lies in the reduced number of pauses on Mammoth B - since it does part of its machine-gunning on negative relays while the machine is running. However, in all these menus considered the number of pauses is <1000 even on Mammoth A, and is often <500, so the difference of running time for Mammoths A and B is not more than about 10 - 15 minutes, The mechanical snags in the two machines are, A) the large number of pauses - up to about 1000, and B) the continual oscillation of the relays while the machine is running. A) seems by far the more workable arrangement. Further, it would be a great advantage if just the self-stecker relays on Mammoth were pluggable and differential (the others being fixed and positive). Then we could use them negatively while the machine was running to cut down "pauses" [the risk of losses would often be very small]. [If the relays are only positive they can then be fixed (i.e. not pluggable) and the diagonal selection will then only function on a pause.]

With this slight refinement the advantages of Mammoth B over Mammoth A are even smaller, and it seems that it is <u>not</u> necessary to have any relays - except the self-stecker relays - operating while the machine is running. All, however, come into action on a pause.

Such a Mammoth machine would produce only about 5 stories on some of its menus - which could then be tested by land - but most would require the Quagga. This Mammoth together with a Quagga would be a very powerful combination.

In order to deal with the remaining menus of classes [γ] and [δ] it is necessary to be more clumsy in our methods. The best ways of running these menus are with the use of plugging on Baby Jumbo - i.e. either confirmations or tacking-on, or possibly one <u>or</u> the other. The menus involved are (with one exception) contained in the groups 0/0 and 1/0 and are common types of menu. They could not be run nearly so well in any other way.

<u>Note</u>: In our calculations we have so far only considered a fairly "rigid" selection of stories by self-stecker and confirmations (e.g. at least one self-stecker and one confirmation.) It is not yet known how far a more intelligent selection of stires (e.g. by Forward's 2f and 3q formula) would increase our range. A fluid plugging device on Baby Jumbo would allow a large

number of different types of assumption to be made. [Forward cites the following example:- If we assume 2p+3q>=7 on an open 11-chain our risk is reduced from 36% to 7% with a comparable number of stories to be tested.]
On some of the [γ] and [δ] menus considered above (to run on Baby Jumbo) the 25-1 risk, if the menus were run on Mammoth, would be appreciable. But the Baby Jumbo type of machine really comes into its own when the 25-1 risk becomes impossibly high, - as it will, in particular, for menus weaker than any yet considered and which are to be run on a restricted RS range. Mammoth will in general be of very little use on a restricted RS range, just because the 25-1 risk will be very large.
With a small RS range the Baby Jumbo borderline could be taken some distance inside th Mammoth borderline, and could go right down to the sort of menus one runs on a dozen RS by hand. Baby Jumbo will select the best stories (which normally we should do by eye), and punch them ready for the Quagga. For this selection it is clear that plugging is essential.
NB It would be necessary, I think, To have all the pluggable Baby Jumbo relays as differential relays. We want all our plugging controls (s.s, confirmation and tacking on) to work on negative relays while the machine is running. The machine will then stop when there is some straight having the required properties. We do not want testing (or printing of stecker) for other straights in the same position, and so it will be necessary for the differential coils to be disconnected when the machine stopes, so that then the relays behave positively.

Finally it would seem that to put any plugging (except self-stecker plugging) on Mammoth would be overloading the machine. The ensuing advantage would be only very slight since the limiting factor here is the basic 25-1 risk, and this risk precludes all menus beyond a certain line.
Baby Jumbo, however, should be pluggable in a very fluid manner, and should also have devices for RS cut-out, and stecker knock-out (which latter might well be omitted on Mammoth). It should also have some sort of hand control for running over a very small range of RS.
In this way the ranges of the two machines would not greatly overlap, and both would be of use over wide ranges of menus.

[Additional note: It might be well to consider a Mammoth B with scanning on the second chain (and 25-1 on the main chain). This machine would be able to machine-gun on two chains without taking the 24-1-1 risk on the second chain; at the same time, being a Mammoth B, it would machine-gun on the main chain while running, thus reducing the stops to about 200 on the borderline. Since the 351 relays operate more quickly than a machine-gun, these stops would be shorter than Jumbo stops (7 ½ secs instead of 11 secs).
The menus runnable on this machine with a very small risk are those on the 14 diagonal in 1/0 and 0/1. These menus involve a considerably larger risk on the Mammoth's as previously considered.