Copy 1. W.G.W.

SPIDERS (Second Note)

4

MOST SECRET

1. Banbury Jobs.

1.1 In an ordinary single input job one input is used for each bank and the spider stops whenever one of the associated relays is up. When a menu contains two disconnected webs, a straight on one web does not imply a straight on the other and the number of stops may be reduced by the double input method, which prevents the spider from stopping unless there is a straight on each of the two webs. In double input jobs two inputs are used for each bank, and there are two sets of associated relays. The spider stops when at least one relay of each set is up. The method is explained more fully in the previous note.

1.2 The idea behind Banbury Jobs is quite different. They deal with menus that are made up from partial alphabets at two machine positions 1 and 2. These menus are of the form :-

```
   1   2   1   2   1   2   1   2   1
A - B - C - D - E - F - G - H - I - J

       1   2   1   2   1
   K - L - M - N - O - P

       1   2   1
   Q - R - S - T
```

the enigmas in each web being alternately in positions 1 and 2. The trouble about these menus is that a large number of bogus straights occur, giving stecker of the form :-

A / X B / Y C / X D / Y .....J / Y

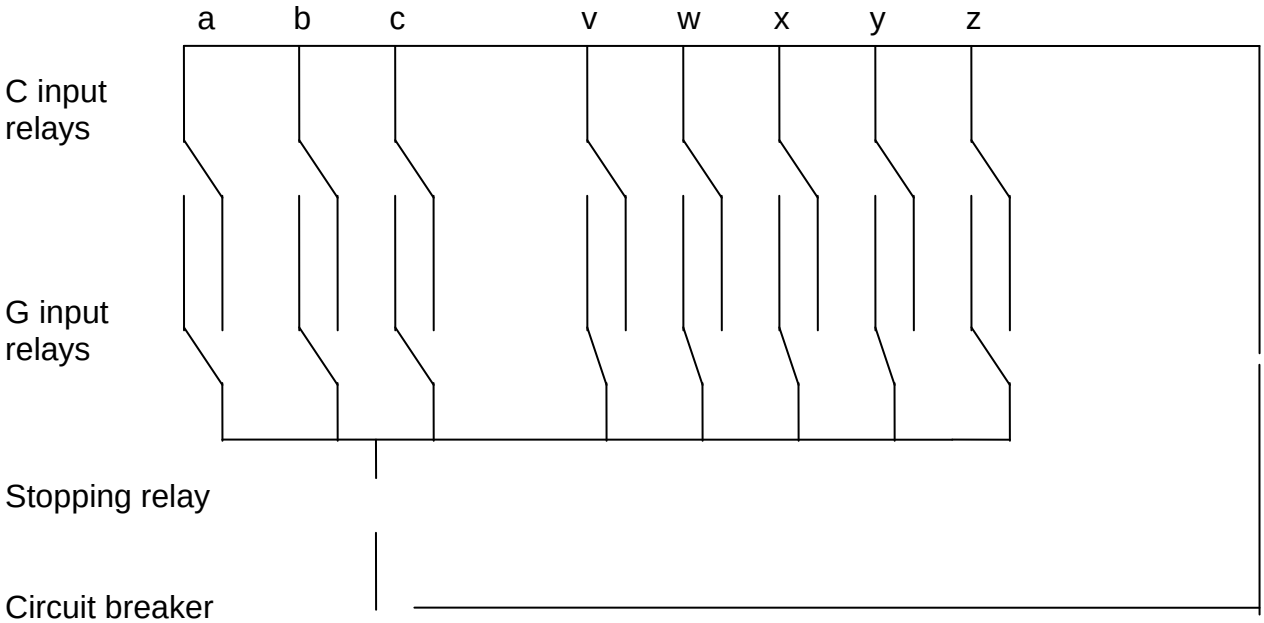
These bogus straights would of course be thrown out by Jumbo's machine gun, but they occur in such large numbers that a run on Jumbo takes too long. (Note that Jumbo is Spider Number Three, whereas Ming is Number Four, the first of the Standard Spiders.) The object of Banbury Jobs is to prevent the spider from stopping for a bogus straight. Incidentally another type of bogus straight, which occurs less frequently, is one which gives stecker of the form :-

A / W B / X C / Y D / Z E / W F / X .....J / X,

and the method used prevents the spider from taking any notice of this type also.

1.3 We first choose two letters at a distance of four on the main web, say C and G. Two inputs are connected to rows C and G of the diagonal board. Forget about the current entry line for the moment. A straight on Cv means that the v line of the C input is not connected to any other line of that input i.e. that the stecker assumption C / V does not lead to any other stecker of C. The letters C and G are on the same web, so, when there is a straight on Cv, the v line of the C input is connected to one and only one line of the G input, and there is a straight on this line of the G input. In fact a straight on Cv is also a straight on some line of the G input, and these lines may be said to be mates. If the mate of Cv is Gv, the straight is bogus and we do not want the spider to stop unless there is a genuine straight on some other line. On the other hand we do the spider to stop if the mate of Cv is any line of the G input other than the v line.

1.4 The sensing circuit is so arranged that the spider will only stop when a sensing relay of one input is up and the corresponding relay of the other input is down. This is achieved by the wiring shown in the following diagram, in which all relays are shown in the down position.



It will be seen in the diagram on page 5 of the previous note that the sensing relay associated with a current entry line is permanently down. Remember that the sensing relays are differential relays, which go up when current passes through one coil but not through the other.

1.5 Suppose first that C is not steckered to G, but that the true stecker of C and G are V and W. Then in the true position the lines Cv and Gw are mates, i.e. these lines are connected to each other, but to no other line of either input. It is possible that a bogus straight may also occur in the true position, say on Cx and Gx. We will assume that no further grouping takes place, so that all other lines of the two inputs are connected together.

Now consider the effect of different positions of the current entry line. A choice of the current entry line is equivalent to a stecker assumption and only one such assumption must be made. (If two different stecker assumptions are made the true position will be missed if one assumption is right and the other wrong). Consequently it is only possible to have a current entry line on both inputs by making

the assumption C/G, when the current entry lines would be Cg and Gc. There are four cases to consider.

1) Current entry lines Cg and Gc.

All relays down except Cv, Gw, Cx, Gx. Current flows in the sensing circuit through the points of the pairs of relays Cv, Gv and Cw, Gw, but not through the points of the pair Cx, Gx. The spider stops, and the significant letter indicator shows both letters V and W on both inputs. (Note that it is not possible to tell whether the story is C/V, G/W or C/w, G/V without feeling the relays.)

2) Current entry line Ca, (or any line on the C input other than Cg, Cv, Cx) :-

All relays down except Cv, Gw, Cx, Gx. The spider stops and records C/V, C/W, G/V, G/W.

3) Current entry line Cv :-

All relays up except Cv, Gw. The spider stops and records C/V, C/W, G/V, G/W.

4) Current entry line Cx :-

All relays up except Cx, Gx. The spider fails to stop and the true position is missed.

1.6 Suppose now that the true stecker of C is G, and that in the true position there is also a bogus straight on Cx, Gx.
Suppose also that no further grouping occurs. Three cases arise.

1) Current entry lines Cg and Gc :-
All relays up except Cg and Gc. The spider stops and records C/C, C/G, G/C, G/G.

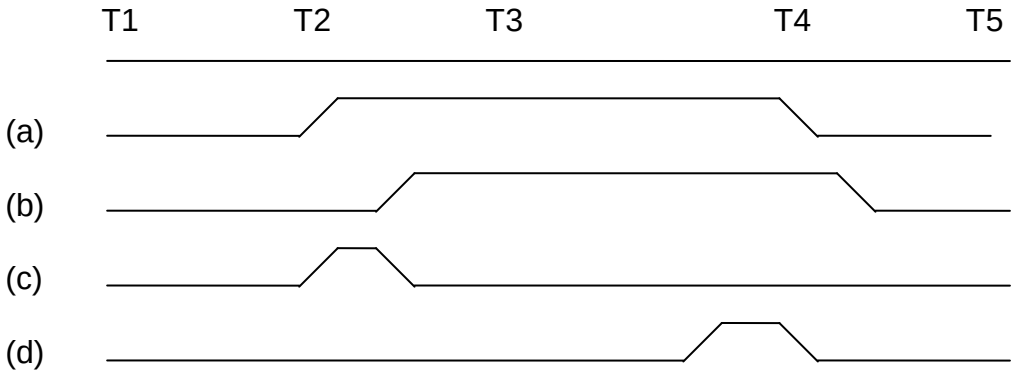
2) Current entry line Ca, (or any other line of the C input other than Cg, Cx) :-
All relays down except Cg, Gc. The spider stops and records C/C, C/G, G/C, G/G.

3) Current entry line Cx :-
All relays up except Cx and Gx. The spider fails to stop and the true position is missed.

1.7 It appears then that the correct position will not be missed provided that the current entry line is not one that can give a bogus straight, and provided that no further grouping occurs. It is also evident that a bogus straight will not cause the spider to stop. There is a technical advantage to be gained by using the two entry lines Cg and Gc rather than a single entry line, and I suggest that this should be the normal procedure with Banbury Jobs. The current which enters the machine has to operate 52 sensing relays and there is a danger of overloading brush contacts. The use of two current entry lines spreads the current.

1.8 A technical difficulty arose which necessitated the use of a circuit breaker in the sensing circuit, and it is perhaps worth while to discuss the use of circuit

breakers and the meaning of the word “creeper”. It must be remembered that the current through one coil of each relay reaches that coil direct, while the current through the other coil has to pass through a number of brushes and through thediagonal board. The relay goes up when there is current through one coil but not through the other. A relay may go up when it ought not to, either because some bad contact causes a resistance which weakens the current through the second coil of the relay or because some contact is made late, and the current only reaches the second coil after the relay has gone up. This is known as creeper trouble, and is reduced by high resistance in series with the coils of the relays, and by the timing of the circuit breaker in the main spider circuit.



In the above diagram T1 T5 represents the time interval during which all brushes should be making contact. A circuit breaker ensures that the main spider circuit is only made during the shorter time interval T2 T4, during which interval it can be expected that all brush contacts will be properly made. Graph (a) shows the proper behaviour of a relay which is due to go up. Graph (b) shows the behaviour of a slightly sluggish relay. Graph (c) shows creeper trouble caused by a contact which is not properly made during the time T1 T2. Graph (d) shows creeper trouble caused by a contact which is properly made by time T2 but which is broken or weakened before time T4. Incidentally the time interval T1 T5 is about 5 milliseconds.

The main trouble with Banbury Jobs is that, when a bogus straight occurs on Cz and Gz , so that the Cz and Gz relays should both be up, the Cz relay may behave in the manner (a) while the Gz relay behaves in the manner (b). There will then be a short time interval during which the Cz relay is up and the Gz relay is down, and the spider will stop. This trouble is largely overcome by a circuit breaker in the sensing circuit, which ensures that that circuit is made during the shorter time T3 T4.

1.9 The danger of grouping is illustrated by the following example. Consider the menu :-

```
   1     2     1     2     1     2     1     2     1
Y  -  G  -  Z  -  C  -  H  -  I  -  R  -  X  -  F  -  U  -
```

```
   1     2     1
K - P - A - V

   1
B - M

   1
J - T
```

Suppose that in the true position the alphabets at the two positions box in the following way :-

```
        1     2     1     2     1     2     1     2     1     2
1.      P - C - Z - G - R - A - H - X - E - Q - P

        C - P - Q - E - X - H - A - R - G - Z - C

2.      F - V - T - O - L - I -Y - K - B - D - S - W - F

        V - F - W - S - D - B - K - Y - I - L - O - T - V

3.      U - N - U

        N - U - N

4.      M - J - M

        J - M - J
```

(This means that P goes to C in position 1, C to Z in position 2, Z to G in position 1, and so on.)

The possible stecker deductions that can be made from the menu are shown in the table on page 5. For example, looking at line 5 it follows from the second web that the stecker K / Z, P /G, A / R, V / A are such that any one of them involves the others.

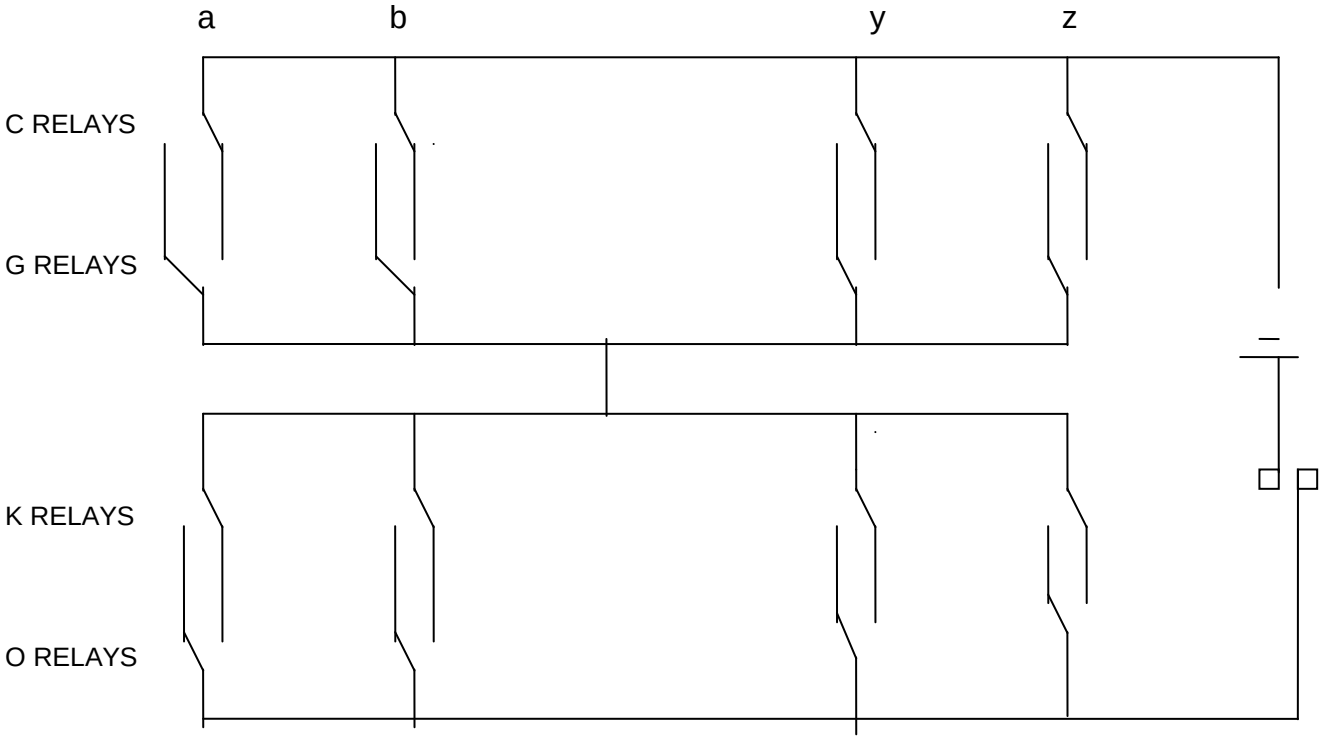
Suppose that the two input letters are H, R, that the current entry line is Hi, and that the true story is that under-lined in red. Then the true story will be recorded if and only if the relays Hr and Rh are up, which is sure to happen, and the relays Hh and Rr are down. We must therefore investigate the result of the stecker assumption H / I. This assumption occurs in line 21 on the first web, and the relevant deductions are shown in the table in green and brown. (The entry 3 / 7 against line 25 of web one means that this line follows from line 7 of web 3, which will be seen to follow from line 21 of web one.) The green entries are those which follow from the first web only. It will be seen that, with the whole menu, all relays of both inputs are down, with the exception of Hr and Rh, so the spider should stop and record H / H, H / R, R / H, R / R.

If webs 3 and 4 were left off, the relays Hj, Hm, Rj, Rm would also be up, but would not be recorded. If only web one was used, the relays r, z, p, e, h, l, t, f, s, b, y, n, m, j would be up on both inputs, so the spider would fail to stop.

	YGZCHIRXFU		KPAV		BM		JT	
1	PCZGRAHXEQ		PCZG	1/7	PC	2/21	PC	1/19
2	EQPCZGRAHX	2/10	EQPC	2/4	EQ		EQ	
3	HXEQPCZGRA	2/9	HXEQ	1/22	HX	1/15	HX	1/21
4	RAHXEQPCZG	2/8	RAHX	1/10	RA	1/16	RA	2/11
5	ZGRAHXEQPC	1/3	ZGRA	1/21	ZG	1/14	ZG	1/18
---	---		---		---		---	
6	CPQEXHARGZ	1/21	CPQE	1/15	CP	1/22	CP	2/18
7	GZCPQEXHAR	1/23	GZCP	2/11	GZ	1/21	GZ	1/25
8	ARGZCPQEXH	1/23	ARGZ	1/18	AR	2/14	AR	1/13
9	XHARGZCPQE	1/17	XHAR	1/20	XH	1/18	XH	1/25
10	QEXHARGXCP	1/8	QEXH	1/19	QE		QE	
11	FVTOLIYKBD	2/1	FVTO	1/18	FV	1/11	FV	1/26
12	SWFVTOLIYK	2/2	SWFV	1/7	SW		SW	
13	BDSWFVTOLI	1/2	BDSW	3/20	BD		BD	
14	YKBDSWFVTO	2/4	YKBD	1/20	YK	1/13	YK	1/26
15	LIYKBDSWFV	2/24	LIYK	1/8	LI	1/26	LI	1/20
16	TOLIYKBDSW	1/3	TOLI	4/14	TO		TO	
---	---		---		---		---	
17	VFWSDBKYIL	1/6	VFWS	2/15	VF	1/25	VFWS	2/25
18	OTVFWSDBKY	1/23	OTVF	1/21	OT		OT	
19	ILOTVFWSDB	1/17	ILOT	1/16	IL	1/17	IL	1/25
20	KYILOTVFWS	1/7	KYIL		KY	1/25	KY	1/16
21	DBKYILOTVF	-----X	DBKY	1/17	DB		DB	
22	WSDBKYILOT	1/10	WSDB	3/17	WS		WS	
23	UNUNUNUNUN	1/21	UNUN	1/12	UN	1/19	UN	1/25
---	---		---	----		----		
24	NUNUNUNUNU	1/2	NUNU	1/10	NU	1/23	NU	1/22
25	MJMJMJMJMJ	3/7	MJMJ	4/1	MJ		MJ	
---	---		---		---		---	
26	JMJMJMJMJM	4/3	JMJM	3/6	JM		JM	

1.10 It is clear then that grouping is likely to occur when menus are too short, but it is very difficult to say how long a menu should be for safety. It is also clear that, unless somebody has a bright idea, the only safe thing to do when there is a danger of the true story being obscured by grouping, is to use Jumbo in the ordinary way. It may be possible to modify the design of a future Jumbo so that bogus straights can be thrown out at the second rather than the third stage, (see previous note, page 4), and this would reduce the time taken by Jumbo. In the meantime it seems fairly certain that any menu, which is calculated to produce a small number of stops when run as a Banbury job, is pretty safe.

1.11 It is worth mentioning that the idea of double input jobs can be extended to Banbury Jobs by using four inputs on one bank. For the menu on page 1 the inputs could be connected to the rows C, G, K, O of the diagonal board. The sensing relays of the inputs C, G would be connected as for an ordinary Banbury Job, and the same would be done for the inputs K, O. The two pairs of sets of relays would then be connected in series thus :-



Two current entry lines could be used, Ck and Kc, both equivalent to the assumption C/K. The effect would be to prevent the spider from stopping unless genuine straights occurred on each of the first two webs of the menu. Apparently Ming does not like this idea, and it is very doubtful if it would ever be worth while. When a Banbury Job menu is weak enough to demand such drastic steps it is quite possible that the danger of grouping makes the Banbury Job method unsafe. In such a case it would probably be better to run the menu on two banks of Jumbo as an ordinary double input job.

Incidentally it is possible that the weakness of a Banbury menu may not be shown by the number of stops which occur when it is run as a Banbury Job on Ming. For it appears likely from the example of para. 1.9 that grouping would not always cause Ming to stop, owing to the fact that the stecker values of the input letters tend to hang together in groups. In fact if one could assess the danger of grouping, it would probably depend on a calculated number of stops rather than on the number which actually occur in a run.

(For the benefit of geometers it appears that the arithmetical genus of the variety is the one that matters.)

2. Dummy Letter Jobs

2.1 It occasionally happens that a menu can be made consisting of three disconnected webs such that the stecker of the end letters of each web are known. For example consider the menu :-

	1	2	3	4		5	6	7
(a)	A -	B -	C -	D -	E	F -	G -	H I - J

and suppose that the stecker of A, E, F, H, I, J are known to be P, Q, R, S, T, U. Then the actual connections through the enigmas are represented by the menu :-

```
          1     2     3     4              5     6              7
(b)    P  -  ?  -  ?  -  ?  -  Q        R  -  ?  -  S        T  -  U
```

The problem could be solved on a bombe without a diagonal board by the following wiring of seven enigmas.

With this wiring the bombe would only stop at positions which satisfy menu (b), i.e. at about one position per wheel order.

2.2 The above wiring is not possible on existing spiders, though it would not be difficult to introduce plugboards which would make it possible. But the job can be done on existing spiders by running the “dummy letter menu”.

```
                1     2     3     4              5     6           7
(c)          P  -  ?  -  ?  -  ?  -  R        Q  -  ?  -  T     S  -  U,
```

with input at R, current entry line q. and all stecker of P, R, T, U shorted except P, Q, S, u respectively. (Note that menu (c) differs from (b) in that pairs of letters Q, R and S, T have been interchanged.)

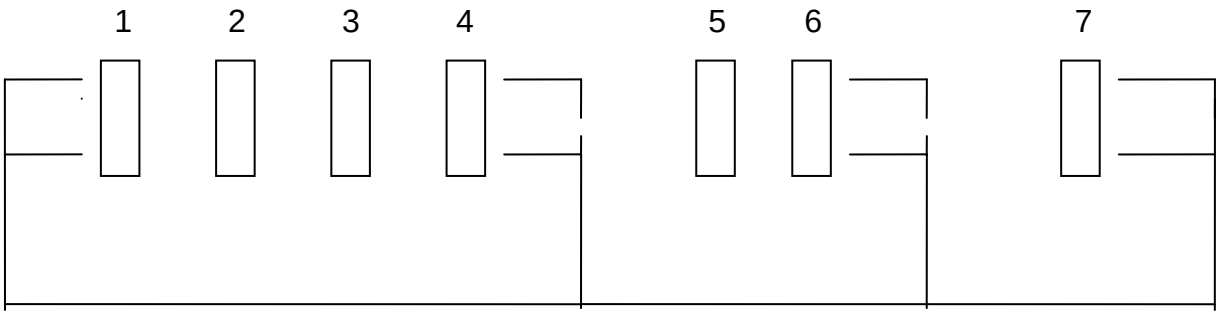
The details of the plugging are :-

Enigma 1 in ...	to row P of the diagonal board; all lines shorted except p line
Enigma 1 out ...	to 2 in.
Enigma 2 out ...	to 3 in.
Enigma 3 out ...	to 4 in.
Enigma 4 out ...	to INPUT, to row R of the diagonal board; all lines shorted except the q line.
Enigma 5 out ...	to row Q of the diagonal board
Enigma 5 out ...	to 6 in.
Enigma 6 out ...	To row T of the diagonal board; all lines shorted except the s line.
Enigma 7 in ...	to row S of the diagonal board.
Enigma 7 out ...	To row U of the diagonal board; all lines shorted except the u line.

In this “dummy letter” job the diagonal board is not being used in the ordinary way, but it doe two
things :-

1) The connections between the points Rq, Qr and between the points Ts, St of the diagonal board effect connections between the q line of 4 out and the r line of 5 in, and between the s line of 6 out and the t line of 7 in.

2) The connections between Rp, Rt, Ru and Pr, Tr, Ur effect connections between the shorted lines of 1 in, 4 out, 6 out and 7 out.
The actual wiring is as follows :-



the input being connected to 4 out with current entry line q.
In any position which satisfies menu (b0 the spider will stop, because the current cannot reach any line of the input other than the q line.

In any other position the current reaches some line of 1 in other than the p line or some line of 6 out other than the s line or some line of 7 out other than the u line, so the input will be full and the spider will not stop.

2.3 The menu of para. 2.1 contains three webs and the stecker of two letters in each web were known. An example of a slightly different type of menu which lends itself to the dummy letter method is :-

```
   1   2   3   4           5   6
A - B - C - D - E       F - G - H
```

with known stecker A/P, B/Q, E/R, F/S, H/T.
The actual enigma connections are given by :-

```
   1   2   3   4           5   6
P - Q - ? - ? - R       S - ? - T
```

and the problem can be dealt with by the dummy letter menu :-

```
   1   2   3   4           5   6
P - Q - ? - ? - S       R - ? - T
```

with input S, current entry line r, and all stecker of P, Q, S, T shorted except P, Q, R, T respectively.

2.4 The dummy letter method can also be applied to closed webs, and a closed web can be used when it contains one letter with a known stecker. For example consider the menu :-

```
   1   2   3       4           5
A - B - C - A   D - E       F - G
```

with known stecker A/P, D/Q, E/R, F/S, G/T.
The actual enigma connections are given by :-

```
   1     2     3              4              5
P  -  ?  -  ?  -  P        Q  -  R        S  -  T
```

The problem can be dealt with by the dummy letter menu :-

```
   1     2     3              4              5
Q  -  ?  -  ?  -  Q        P  -  S        R  -  T,
```

with input Q, current entry line p, and all stecker of Q, S, T shorted except P, R, T respectively.

Of course in certain cases it might be necessary to accept about 26 stops per wheel order. For example suppose the third web of menu (a) of para. 2.1. is removed. The job can still be done by the dummy letter menu :-

```
   1     2     3     4              5     6
P  -  ?  -  ?  -  ?  -  R        Q  -  ?  -  S,
```

with input R, current entry line q, and all stecker of P, R, S shorted except P, Q,. S respectively. This should give about 26 stops per wheel order.

Again, suppose that in the example of para. 2.3 the second web is removed. The job can still be done by the dummy letter menu :-

```
   1     2     3     4
P  -  Q  -  ?  -  ?  -  R,
```

with input Q, current entry line q, and all stecker of P, Q, R shorted except P, Q, R. In this case however it would be better to use the spider in the ordinary way, with the menu :-

```
   1     2     3     4
A  -  B  -  C  -  D  -  E ,
```

and all stecker of A, B, E shorted except P, Q, R respectively.

2.6 It is of course important that there should be no confusion between dummy letter menus and ordinary menus in which a knowledge of certain stecker is used. When a spider is being used in the ordinary way, say with input P and current entry line q, the current reaches those points of the diagonal board which correspond to the stecker which can be deduced from P/Q. In the true position, no true stecker can be connected to a false stecker. Consequently, if it is known that certain stecker cannot occur, the corresponding points on the diagonal board may be shorted without preventing the spider from finding the true story. This shorting of stecker makes it more likely that the input will be full in false positions, and consequently reduces the number of stops.

In ordinary jobs the shorting of stecker has been used in two ways.

(1) When it is known that the stecker A/B, C/D,...Y/Z will not occur, the corresponding points on the diagonal board can be shorted.

(2) When it is known that some letter of the menu, say P, is steckered to itself, then all other stecker of P can be shorted. The reduction in stops is the same as would be produced by an additional closure in the web in which P occurs and a reduction of one in the length of the web.

It is quite clear that the dummy letter method is based on an entirely different principle. As was explained at the outset, this method does not depend on deductions that can be made from certain stecker assumptions, but depends entirely on a knowledge of actual connections through a number of enigmas, such as those represented by menu (b) of 2.1. No letter must be allowed to stray into a dummy letter menu if it is not the known stecker of a letter of the original menu. Incidentally the known stecker will usually be self stecker, but the more general case has been considered. The letters P, Q, R,... in the above theory should be thought of as not necessarily distinct from the letters A, B, C.. of the original menus.