THE G.P.O. SENSING UNITS

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The G.P.O. sensing units for use with Cobras consist of two racks, one embodying single and double input on-chain sensing for a two bank machine and also the pulsing gear, the other embodying Mammoth sensing (and “Z” selection test) for a two bank machine. Several of the ordinary sensing racks have been made, but so far only two of the Mammoth racks - of which one is undergoing tests on Trinidad.

The following are some notes on the methods of working of these sensing units.

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ON - CHAIN SENSING. (Double Input).

Valves (1) = one attached to each point of each input row - i.e. 52 per bank.

(hard valves).

Valves (2) = one attached to each point of each input row - i.e. 52 per bank.
(Thyratron valves).
Searching switches: one down in each input - in the ususal way - so one point of each input (C & D in the diagram) connected to potential - 80 direct.

26 + 0 boxing: all points of input row at -80 and so valves (1) & (2) not affected.

25 + 0 boxing: (the straight being not on the current entry line): one point of input row goes to +80 volts, so reducing the resistance of the corresponding hard valve (1) from to r (where r = 10K to 20K approx.)

The control Set, by a further valve, measures the potential of the point A, which will be as follows :-

1 valve of group (1) (main chain) fired - i.e. a straight on the main chain only),

potential of A = $\frac{5K}{100K + r + 5K}$ .V = v say

2 valves of group (1)(one on each chain) fired - i.e. a straight on each chain,

potential of A = $\frac{5K}{\frac{100K + r}{2} + 5K}$ .V = 2v

3 valves of group (1) (one on main chain and two on subsidiary) fired - i.e. one straight on main chain and two on subsidiary),

potential of A = $\frac{5K}{\frac{1}{\frac{1}{100K+r} + \frac{1}{100K + r/2}} + 5K}$ .V = 2v say

etc.

(r will be small compared with 100K and so fluctuations in the value of r between different valves will hardly affect the values of v, 2v etc.)

For D.I. running, when the potential of A is 2v or greater, the Control Set controls the recording of the stop. The input relays involved are recorded by the Thyratrons (2) (which now fire and which activate further relays). The position of the stop is taken from the recording wheels (direct to relays on the M & S wheels; via further Thyratron valves on the F & VF wheels).

The stop is shown on the recording panel, & is “cleared” by a press-button when it has been noted. If a second stop comes up before the first has been cleared the carry of the machine is switched off and the machine idles until the stop is dealt with. Then the carry is switched on again.

N.B. (I) Two or three straights on the subsidiary chain will not make the potential at A appreciably different from 2v for a stop. But a large number of straights on the subsidiary chain - even when not accompanied by a straight on the main chain - may cause a stop. Suppose there are S straights on the subsidiary and none on the main chain,

potential of A = $\dfrac{5K}{100K + \frac{r}{S} + 5K} \, . \, V$ which is > v

If the sensing is being done at a potential well below 2v this phenomenon may cause stops for large values of S.

<u>Current entry line.</u> For a straight on the current entry line the potential at AA would go up to a high value, and the sensing is actually done differently - via the megohm resistances (3). These resistances are only attached to the main chain input leads, because a c.e.l. straight is on the c.e.l. for both main and subsidiary chains.

Straight - not on the c.e.l.

Straight - on the c.e.l.

They are wired up as shown above. For a straight not on the c.e.l. the left hand ends of 25 of them will be at -80, and the left hand end of 1 of them will be at +80. For a c.e.l. straight the reverse condition will hold, as shown. There is a valve which measures the potential of the point B, which will be as follows :-

no straight, potential of B = negative

1 straight, not on the c.e.l. potl. of B = $\dfrac{R^1}{M + R^1} \, . \, 80 = v^1$ say

1 straight, not on the c.e.l. potl. of B = $\dfrac{R1}{\frac{M}{25} + R^1} \, . \, 80 = 25\, v^1$ app.

since again R^1 is small compared with M.

So the valve whose grid is attached to B has to note the difference between v1 and 25v1. When we get a c.e.l. straight, i.e. when its potential rises to 25v1, the recording of the stop is done via the searching switches - not via the Thyratrons (2).

The posn. is recorded in the normal way.

<u>N.B.</u> (ii) It has been assumed so far that all points of the input row in a given “box” are at the same potential. Actually, owing to the different metals used for brushes and commutators, and to the heat of friction etc. there is a contact E.M.F. which increases arithmetically with the number of enigmas in the path, and may be as much as 6 volts per enigma. Thus, even when there is no straight, a point of the input row may be 60 - 70 volts higher than -80. For this reason the limits -80 and +80 (and not 0 and 160) were chosen, since then the potential in a false position will never rise above zero, and so will not affect the valves.

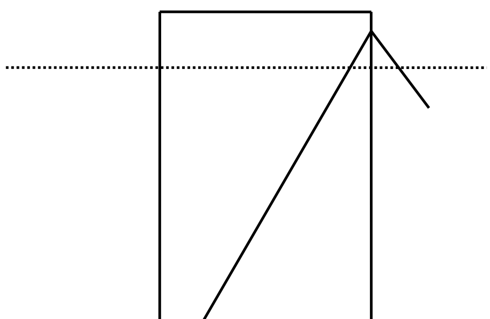
<u>ON- CHAIN SENSING</u> (single input)

Two methods are here possible. We could either cut out the subsidiary chain valves altogether, and make the Control Set record when the potential of A rises from 0 to v. Or we could connect the two sets of sensing valves in parallel, and record, as before, when the potential rise to 2v. The latter method is actually used.

In the plugging there are two input sockets. For double input one is plugged to each of the two input commons in the ordinary way. For single input both are plugged into the same (main) input common.

<u>(N.B. (iii) Build - up Times)</u>

There is actually a small time delay while the potential is building up. It is proportional to C.R, where C is the capacity of the straight with respect to the main circuit (the straight may consist of 200 - 300 yards of wire), and R is the resistance of the pulse leads - shown in the first diagram. C cannot be reduced without modifying the Bombe; R cannot be reduced without running the risk of a too heavy current burning out some of the commutators; increase of the potential of the pulse is also impossible without serious modification. So this time delay, which is of the order of 0.3 to 0.45 millisecs, is the real limitation on the speed of the very fast wheels of the machine (the Cobra commutators). For these wheels, 3,000 r.p.m. is a bit risky, 2,000 r.p.m. is fairly safe.



The build -up of potential due to this time delay is exponential, and the potentialmight not reach +80 before the pulse is cut off. It might reach say +60 volts. Then if WZ is the critical level of potential which causes the valves to fire, the effective sensing time is represented by XY. Actually only about 10 microsecs. are needed to sense, and XY is considerably longer than this.

MAMMOTH SENSING. (Single Chain).

Suppose the letters A - P are on the menu, and the letters Q - Z off it. Then for Mammoth sensing we must examine one of the two (identical) shaded areas in the above diagram. The menu is plugged up into the main diagonal board F as usual. then the off-chain (i.e. unplugged) rows of F are plugged into the sockets of another board G. The board G has 17 sockets, each having the usual 26 terminals. The rows of G are wired to the columns of another plugboard H, and the sockets of H are made to take the standard G.P.O. double-ended plugs.

Immediately below H on the G.P.O. rack is another plugboard I which contains 169 sockets. Each of the sockets of I is attached to a valve.
By the plugging from F to G, and the permanent wiring from G to H, the off-chain rows of F are plugged each to a column of H. G.P.O. double ended plugs are now put into the on-chain letters in these columns of H, their other ends being put into the valve sockets of I indiscriminately. This attaches a valve to each point of the shaded area of F. Valves not used are completely disconnected and can have no affect on sensing. Further wiring on the sockets of H ensures that the valves are connected up in groups corresponding to the columns of H. Thus the valves corresponding to the points in the row coloured would be connected in a group.

The final wiring of one such group is shown in the following diagram. The G.P.O. plugging makes the joins at the point , so putting the valves into the circuit.

To each group of valves - i.e. to each off-chain row of F - there is a control valve which measures the potential of the point C. This potential will be as follows :-

1 point of the straight in the valve group, potl. of C = $\dfrac{5K}{r + 105K}.V = v$

2 points “ “ “ “ “ “ “ “ “ “ = $\dfrac{2.5K}{r + 110K}.V = 2v$

3 points “ “ “ “ “ “ “ “ “ “ = $\dfrac{3.5K}{r + 115K}.V = 3v$

etc.

Thus if the grid potential of any one of these control valves rises to 2v or above a further valve in the control set is fired which rejects the stop.

MAMMOTH SENSING (Two chains, single input).

Suppose that the letters A - M are on the main chain, N - P on the subsidiary chain, & Q - Z off both chains. Only the shaded areas can be examined - not the dotted areas also. There are two reasons for this :-

(i) (theoretical) two straights in the right position, (whether or not one or both of them tacked on to the main straight), would cause the right stop to be missed - since two points in each of the Mammoth-sensed rows would be on the straights;
(ii) (practical) the subsidiary chain rows N - P are already plugged up on the main diagonal board F & so cannot be plugged into G.

MAMMOTH SENSING (Two chains, double input).

When both chains are sufficiently strong to make it extremely unlikely that there will be a second straight on either in the right position, the menu can be run double input and sensed on rows off both menus without risk - i.e. total Mammoth sensing can be done as for a single chain.

MAMMOTH SENSING (use)

Since it is only possible to do partial Mammoth sensing on a single input menu with a subsidiary chain it is debatable whether very short subsidiary chains are worth including at all.

Eg. For this menu,

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A — B—— C—— D—— E—— F
             |    |    |
             I —— H—— G

     P—— Q
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the different types of wrong stop are,

(1) D / P = P / D - Q / B
(2) A / Z, D / P = P / D Q / Z
(3) C / P, E / P = P / C, P / E Q / L, Q / X
(4) C / P, E / P = P / C, P / E Q / L, Q / G

of these,
(1) is rejected with the PQ chain present, and not rejected without it.
(2) is not rejected in either case,
(3) is not rejected with the PQ chain present, but is rejected without it.
(4) is rejected in either case.

So the subsidiary chain should be kept out when the stops (3) are common. From the experience obtained so far in running the machine, it appears that a subsidiary 2 chain should be left off, but that a 3 chain or longer should be included (because here (i)'s would be more common than (iii)'s.)

"z" SELECTION

The Mammoth rack is fitted up with facilities for doing "z" selection. "z" is the number of off-chain steckers, and of course the greater the number of self-steckers and confirmations the smaller "z" will be. We can then reject perhaps 90% of the stories at a risk of , say, 10%, by postulating that "z" must be z_0. (In practice z_0 is usually 6 or 7, but it depends slightly on the length of chain.)

The "z" selection device only becomes operative when Mammoth has failed to reject the story - i.e. when there are no contradictions. When there are no contradictions (for a single chain at any rate) the number of off-chain steckers (= z) will be equal to the number of groups of valves with one point on the straight(i.e. the number of points C at potential v). No point C will be at potential greater than v, otherwise Mammoth would have rejected the stop.

So there is a set of 17 pentode valves (4), one being attached to each point C, (see the diagram for Mammoth sensing). These are connected in parallel, and have the property that when activated (by a grid potential $\underline{v}$) they pass a constant current. There is also a set of resistances R" in parallel, of which the first is permanently wired and the others pluggable. Any number of them, from 1 - 10, can thus be plugged in in parallel.

If we are assuming $z \leq z_0$ we plug up $\check{s}_0$ of the resistances R" in parallel. The current passing through the resistances R" will be z i, where i is the constant current passed by one pentode valve. There is a control valve to measure the potential of the point D. This will be as follows.

$$\frac{250 \text{ -potl. of D}}{z\, i} = \frac{R''}{z_0} \quad \text{by Ohm's Law.}$$

$$\text{potl. of D} = 250 - R'' \frac{z\, i}{z_0}$$

Thus the difference in the potential of D for a unit change in z will be proportional to $1/z_0$ So the apparatus will be more sensitive for smaller values of z_0 than for larger ones. (If we are assuming $z \leq z_0$ we want stops for which the potential of D is <u>less than</u> 250 - R"i to be rejected).

Until further experiments are made Mr Chandler is only willing to guarantee accuracy within one unit - i.e. for $z_0 = 7$, a story with z = 8 might be admitted and a story with z = 7 might be rejected. It may be possible to make the device particularly sensitive round the useful range of z = 6 or 7.

<u>"z" SELECTION.</u> (Subsidiary chains).

For subsidiary chains the two-straight possibility is again troublesome, and tends to increase the value of z. And further, if we assumed a fixed value of z we should reject many of the tacking-on stories (since these would tend to have large values of z), and retain most of the non-tacking-on stories (since these would tend to have small values of z). We should thus reject most of the good stories and retain most of the poor ones - a highly undesirable state of affairs.

So we cannot use z selection for subsidiary chain menus at all. For double input menus, however, where it is safe to assume only one straight on each chain, z selection can be used. The figures for risk etc. will be the same as for a single chain of the same total length.

N.B.(iv) The Cobra Bombes have got C.S.K.O.

N.B.(v) It has been suggested that, for three wheel jobs, it might be possible to use some of the auxiliary chain sensing equipment to run jobs three times (at present the Bombes have only two banks). It will probably not be worth it, since we have plenty of two-at-a-time menus, but the possibility is there.

O.H.L.

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N.B.(vi) The total time for sensing - i.e. the duration of the pulse - is about 300 microsecs. at 3,000 r.p.m. and about 450 microsecs. at 2,000 r.p.m. The build-up time for the pulse in the enigma circuit is about 150 - 200 microsecs. About 10 microsecs. are needed to sense - i.e. to fire the Detector Valves (1).
The firing of the Thyratrons is controlled by the valves in the Control Set. They fire normally about 30 microsecs. after a stop has been noted by the valve attached to the point A. So the total time of 300 microsecs. is sufficient. For Mammoth however, the build up time for the potential to reach all relevant points and to activate, if necessary, the Mammoth valves may be larger than 30 microsecs. and so the delay on the Thyratrons is increased to 100 microsecs. This makes 3,000 r.p.m. (i.e. 300 microsecs.) barely enough, but 450 microsecs. is adequate.

The blind time is about 50 - 60 microsecs. (i.e. 2 or 3 positions of the F wheel), and for this time both the Detector Valves and the Thyratrons are insensitive. They are both put back again by the action of the recording relays.