GENERAL REPORT ON TUNNY

With Emphasis on Statistical Methods.

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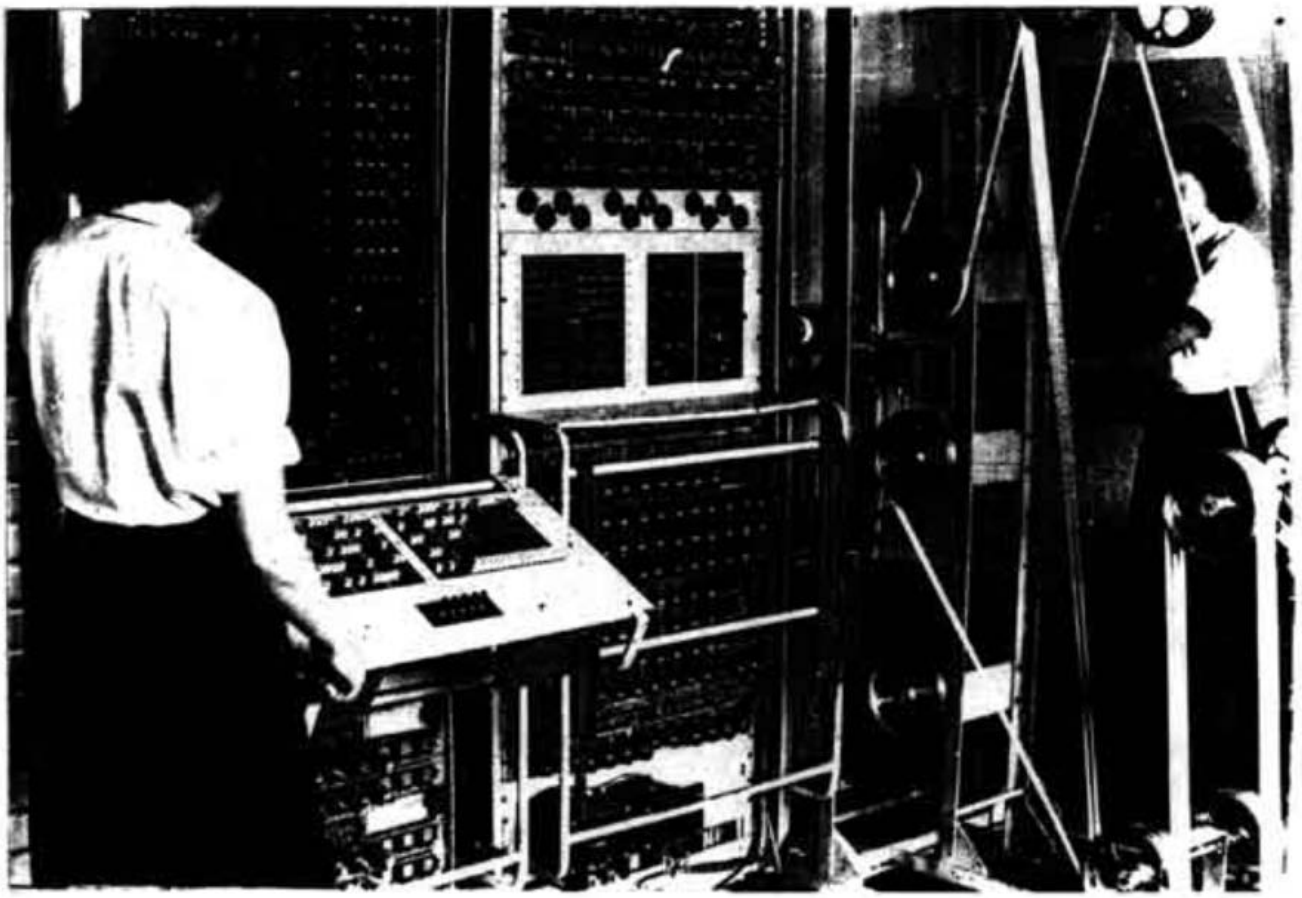
53. COLOSSUS



53 - COLOSSUS

53A INTRODUCTION

The photographs in chapter 58 show the layout both of the whole machine and of individual panels, far more clearly than verbal description, which is therefore omitte

Colossus makes counts concerning certain streams of teleprinter letters. One, denoted by Z and represented on a punched tape, is wholly arbitrary; the others, denoted by χ, μ, ψ and represented electrically, are specialized and composed from certain fixed periods. These patterns χ, μ, ψ, do in fact represent the 12 wheels of the German Tunny machine, and move in the same way. Their 12 components will here be called wheels. For given "settings" there will be, corresponding to each place on the tape Z, definite positions on all the wheels.

Colossus counts the number of places of Z where a condition involving some or all pf these streams is satisfied. An essential feature is that the counts can be made in rapid succession with the various wheels in different relative positi ("stepping").

Colossus cannot count a condition involving two different places in the stream except in a limited way by memory circuits, used mostly for delta-ing.

The sum Q of any number of the three 5-impulse streams Z, χ, ψ, each either differenced or undifferenced, can be switched into the Q panel: the switches of this panel suffice to impose the majority of the $2^{35} = 5,000,000,000$ combinations of conditions which are theoretically possible. Less specialized conditions can be imposed by the plugboard.

Note 1 Although the streams are named Z, χ, μ, ψ, these are not necessarily used as the real Z, χ, μ, ψ of Tunny. In a short wheelbreaking run (25) the pattern set up in χ is really delta χ except in the wheel for which the run is made, where it has only one cross and is used merely to select in turn the characters of that wheel.

Note 2 A tape is required in every case, because it controls counting, but Z need not occur in the conditions imposed (e.g. χ test runs).

53B THE Z STREAM

(a) The tape

The tape is a continuous loop of five-impulse tape carrying the Z stream, the usual sprocket holes, a start sign, a stop sign, and 150 blanks.

The sprocket holes are utilized

(i) to cause the machine to count if the conditions imposed are satisfied: the machine counts once, at most, for each sprocket hole.

(ii) to maintain the correct motion of χ, μ, ψ.

The start sign is a hole between the 3rd and 4th impulses, which

(i) causes the machine to start counting (the start sign has to be punched $2\frac{1}{2}$ sprocket lengths before the first place to be counted),

(ii) sets χ, ψ, Ψ, in motion.

The stop sign is a hole between the 4th and 5th impulses, $1\frac{1}{2}$ places beyond the end of the text, which

(i) causes the machine to stop counting, and generally prepares for the next start sign.

(ii) transfers to relays the score which has been counted.

150 blanks between stop and start give Colossus time to prepare for the next start sign.

(b) The Bedstead

The bedstead is a system of pulleys round which the tape is driven by friction at about 40 feet or 5000 sprocket holes per second, so as to pass through a gate where it is scanned by eight photo-electric cells, one for each impulse and one each for sprocket hole, start and stop.

Each Colossus has two bedsteads; while one is in use a tape can be put on the other. An on-off switch by each bedstead controls both its driving motor and its lamp. There is a switch on the selection panel, whereby either bedstead can be selected (near or far), not both at once.

The maximum length of tape which a bedstead can carry is either 11,000 (short bedstead) or, on Colossi 5,6,7,8,10 30,000 (long bedstead). Ona long bedstead the voltage applied to the motor can be adjusted to maintain the correct speed whatever the length of tape and number of pulleys in use.

Although shorter tapes can be put on the pulleys, Colossus does not work well with a tape less than 2,000 long.

53C THE χ, μ, ψ, STREAMS

(a) The triggers

The twelve wheels constituting χ, μ, ψ, are set up in 'triggers' of length 41,31 etc. These triggers, except the wheel-breaking panel are inconveniently situated at the back of Colossus.

For each character of a wheel there are two small sockets: a cross is represented by short-circuiting these with a U-shaped pin ("putting in a pin"); a dot by leaving them vacant. (Fig 58 (xvii)).

There are several alternative triggers for each wheel. The χ, ψ patterns have five triggers (a,b,c,d,e) each selected by a switch on the selection panel. χ a must be used with ψ a.

The μ pattern has seven triggers a,b,c,d,e,f,g, any one of which can be used with any χ, ψ trigger. This discriminatory treatment of μ was arranged when only the μ a

(b) Special Patterns

By using the switch position e' the χ, Ψ trigger e can be used in a different way, as a "special pattern" or "doubting" trigger. Similarly g' is the special pattern μ trigger.

e' is not added into Q (see Q panel: 53J (a)).

g' does not motorize the Ψ's.

Indeed these patterns appear nowhere except in the seven ppecial pattern jacks on the plug panel, and to have any effect must be plugged.

These are used in addition to an ordinary trigger.

(c) Wheel-breaking Panel

On wheel-breaking Colossi there is the inestimable boon of a panel on the front of the machine, carrying an ordinary χ trigger and a special pattern χ trigger: in place of U-shaped pins, easily inserted plugs are used: they are so much easier that they are often used for setting. Each of the 5 χ wheels has its ordinary and special patterns adjacent and each is controlled by a 3-way switch whose positions are

down: ordinary and special patterns in,

normal: all out,

up: single cross in the last position of the ordinary pattern.

(d) Motorization and Limitation determiner switches

The motion of μ_{37} and the Ψ's is not uniform, but simulates that of the corresponding wheels of the German Tunny machine.

On Colossus the extension of the μ_{37} pattern by μ_{61} is fixed. The extension of the μ pattern is naturally adjustable to suit the limitation. The appropriate switches are near the bottom of the selection panel viz

$\overline{\Psi}'$, $\overline{\chi}_2$, $\overline{\overline{P}}_5$: if one or more of these switches are either up or down the corresponding impulses are added and used as th limitation. At the beginning of the text these, since they refer to places one or two back, are indeterminate: the up and down positions of these switches and of P_5 impose an arbitrary dot or cross, in these places.

BM C/o is the basic motor cut-out . When it is used the total motor is simply lim.

53D STEPPING AND SETTING

(a) Setting

The setting of a wheel is that character of the wheel which corresponds to the first sprocket hole of Z,

All wheels can be given assigned settings, simultaneously, by putting plugs in the appropriate setting jacks and depressing the switch SU. The setting jacks are arranged below the control panel in 12 rows which correspond to the 12 wheels.

(b) Stepping

Any wheel can be stepped i.e. its setting increased at each revolution of the tape.

This will not of course be confused with the ordinary motion of the wheels at a fixed setting. It should be noticed that increasing settings imply that the patterns move backwards relative to Z. Any number of wheels may be stepped simultaneously.

(c) Stepping Switches

Each wheel has two 3-way switches in the control panel, one in the upper row, one in the lower.

Either of these two switches may be thrown up or dow

Upper switch up
or Upper switch down
or Lower switch down
} causes the wheel to step fas i.e. to step at each tape revolution.

Lower switch up - causes the wheel to step slowly i.e. to step only when a wheel whose lower switch is thrown down reached the plug in the setting jacks. If in some frenzied fantasy, several wheels have their lower switches down, each of them will step a slow stepping wheel.

(d) Repeat Light

When all wheels return to their original settings (strictly to the plug in the setting jack), the repeat light glows. A wheel whose upper switch is thrown up is ignored.

53E DIFFERENCING

Any pattern, except a "special pattern" is available deltaed either on the Q panel (by throwing the Q selection switch to delta) or on the plug panel (by using deltaed output jacks).

The conventional Tunny delta is the sum of present and future i.e. forwards. Colossus deltas by remembering and adding the letter one place back i.e. backwards.

This is immaterial provided that all patterns in use are deltaed by Colossus or all not deltaed by Colossus; but if some are and some not, then those which are, are recorded by Colossus as one place back.

For example suppose that Z is a plain Z tape which is being deltaed by Colossus and added to delta χ set up deltaed on the χ trigger, the two patterns being level so that the recorded setting is 01.

Opposite the second sprocket hole Colossus produces for delta Z: 1st character + 2nd character.

Opposite the second sprocket hole delta χ is plugged as: 2nd character + 3rd character.

It follows that the true setting of χ is 02.

This is in many cases corrected by adjusting the settings, whence the phrase "Settings of deltaed wheels should be one back".

A "Special Pattern" , however, steps level with the corresponding ordinary pattern, and accordingly when the latter is to be deltaed by Colossus, the former must be set up in the trigger one back, in the sense that the 2nd position of the trigger contains the first character of the wheel.

If the same pattern is used both differenced and undifferenced, the correction cannot be made either by setting or by setting up, but must be made internally by Colossus.

The following are all one back so as to be in the present place when used with wheels deltaed on Colossus
(1) The TM switch at the bottom of the Q panel (including $\tilde{\chi}_2$ when BM is cut out and the χ_2 determiner switch is in.)
(2) the jacks $\overline{\mu_{61}}$, $\overline{\chi_{37}}$, $\overline{P_5}$, TM on either side of the special pattern jacks.

It will be noticed that the labelling is inconsistent.

53F COUNTING

(a) The five Counters

Colossus counts up to 9999 and then returns to zero.

To increase the speed of operation, Colossus has five separate counters, which can be used simultaneously either for five (or fewer) distinct runs or for multiple testing on a single run. Spanning and stepping must be the same for all runs. The five counters are labelled 1,2,3,4,5, but printed on Colossus records a,b,c,d,e.

(b) Switching into counters

To be effective a condition must be switched (on the Q panel) or plugged (on the plug panel), into the proper counter. In particular in multiple testing the condition on each of the remembered impulses must be plugged or switched to its proper counter.

53G RECORDING OF SCORES

When a count has been completed, i.e. when the stop sign on the tape is reached, Colossus can transfer it to the "display" and the printer.

(a) Set Total

To avoid displaying and printing useless scores a "set total" can be imposed so that only scores which exceed, or, alternatively, only scores which do not exceed this set total appear, others being cancelled.

The set total controls for the five counters are independent, and for each of the five, consist of decade switches reading 0000 - 9999 , and a three-way switch <, off,>. With the off position all scores are displayed and printed. (Fig 5a(xvi))

(b) SIP

On Colossus 10 S.I.P. ("Significance Interpretation" switch on control panel) causes all counters to print if one

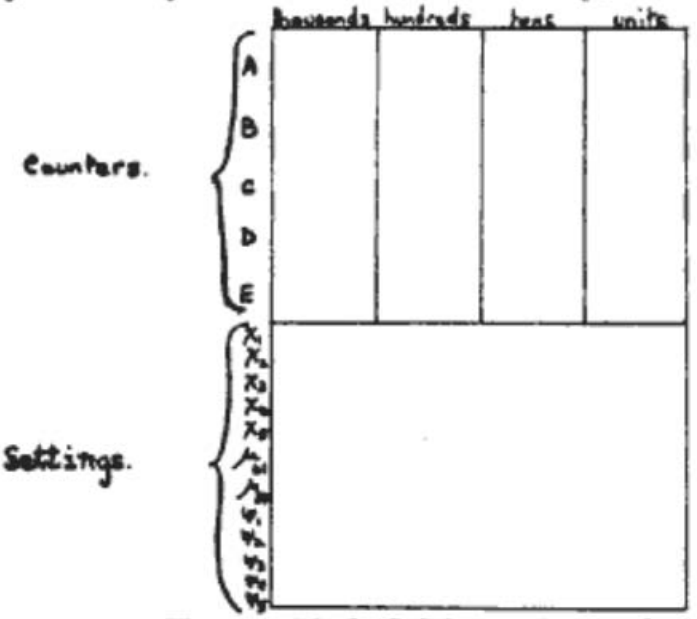
exceeds the set total.

(c) Storage of scores.

Scores which are to be printed, together with the relevant settings, are stored on relays and appear on display. While the next count is being made these relays send impulses to the printer and so clear themselves. If the printing is not completed in time to clear the relays for the next score, stepping is automatically inhibited till the relays are clear: thus no scores are lost.

(d) The display

The display is a glass screen on which the scores are projected by small electric lamps



The switch LC/o cuts out the "settings" lamps. The switch EL extinguishes the "settings" lamps when all scores in storage have been printed.

(e) Printing of settings

When the machine is started it prints in a horizontal row the symbols for all wheels which are stepping. In the printed record the settings of these stepping wheels appear before every score, each below its appropriate heading. When runs are done simultaneously, some of these settings may be relevant to certain runs only. To avoid the printing of confusingly meaningless settings there is a 5 x 12 array of jacks to the right of the X setting jacks, whose 5 rows correspond to the 5 counters, and 12 columns to the 12 wheels: in order that a score on a particular counter shall cause the setting of a particular wheel to be printed, a shorting plug must be inserted in the corresponding jack.

In all cases the name (a,b,c,d,e) of the appropriate counter is printed before each score.

(f) Printing of Scores

After a score is printed there is an automatic carriage return so that each score is on a separate line.

(g) "Print Main Heading". (PMH switch on control panel).

Prints the settings of all 12 wheels, each below its appropriate symbol. Colossus has to be restarted after printing the symbols.

(h)"Letter Count" (LEC switch on control panel)

is for making counts at fixed settings. It stops the machine after printing a batch of scores: without it the same count would be repeated. Whilst one batch of scores is being printed, the next batch can be switched.

(i) Printer Cut Out (PCO switch on control panel)

prevents Colossus from sending impulses to the printer, so that stepping ceases [cf. Storage of scores in para. (c) above].

(j) Reset (switch on control panel)

clears all scores in storage: in particular if PCO is in use it allows stepping to be resumed.

(k) The Printer

The printer is an electromatic typewriter.

It can be operated manually for the insertion of data (e.g. ~ , S.T., span) not printed by Colossus.

Single, double and triple line feed are available.

The inexplicably assorted founts are not intended for cryptography, but this seems to be no handicap: ~ has appeared as £, @, ¢, $.

53H SPANNING

(a) Spanning

is a device whereby Colossus counts only over a selected stretch of the tape.

There are three groups of decade switches (Fig 88 (xvi)) above the plug panel each reading 0000 - 9999 labelled

START COUNTERS , START PSIS , END OF SPAN.

If "start counter" is set to m when m is not 0000 "end of span" to n, Colossus counts only from the $\overline{m+1}^{th}$ to the n^{th} places on the tape, inclusive.

If "start counter" is set to 0000, spanning is ineffective, the first place on the tape cannot be included in a span.

(b) The Settings

The settings on Colossus refer to the start of the tape, not the start of the span.

Motorizing of the Ψ's begins at the place to which "start psis" is set: normally this is 0000, the start of the tape.

(c) On Colossi with long bedsteads

there is a rudimentary 5th decade in the bottom row of the selection panel. Switches are thrown down for

+10,000, up for + 20,000.

(d) On Colossi with short bedsteads

spanning is unable to distinguish places 10,000 apart so that e.g. 500 - 1,000 cannot be disentangled from 10,500 - 11,000.

(e) End of Span cut-out

The ES c/o switch in the bottom row of the selection panel overrides the end of span switches and spans to the end of the tape.

53J Q PANEL (Fig 58(xiii))

(a) Q Selection Switches

At the top right of the selection panel there are three large three-way switches. Each switch has a neutral position and the active positions are Z, delta Z; χ, delta χ; ψ, delta ψ. The streams to which these switches are thrown are added together, and their sum appears in the Q panel: the five impulses of this sum are called Q_1, Q_2, Q_3, Q_4, Q_5.

Note: each large switch is really five switches linked together viz. one switch for each impulse : if necessary these can be separated.

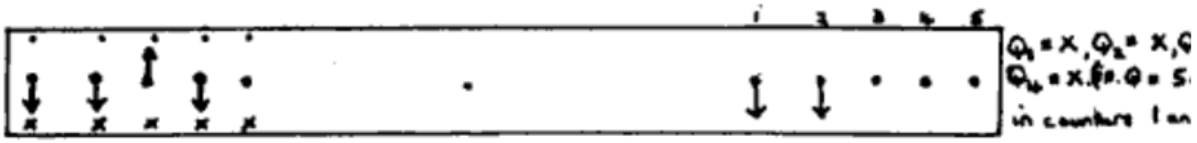
(b) The Layout of the Q panel

The upper part (10 rows) is used for imposing conditions on individual impulses.

The lower part (5 rows) is used for imposing condition on the sums of impulses.

(c) Conditions on Individual impulses

Every row in the upper part of the panel is arranged as follows. At the left there are five 3-way switches, one for each impulse, each of which can be thrown to dot or cross to make the corresponding impulse of Q dot or cross. At the right there are five switches labelled 1,2,3,4,5, one for each counter, to determine the counters in which the condition is to be imposed.



Any number of rows may be used: if conditions from two of them are switched into the same counter, both will be imposed.

(d) "Not" switches

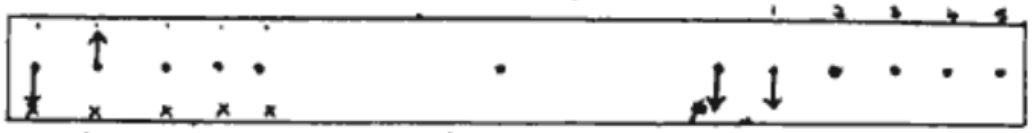
To impose alternative conditions

"either A or B"

is replaced by the equivalent

"not (not A and not B)".

Just to the left of the counter switches is a "not" switch labelled ≠ , which negates the conditions.

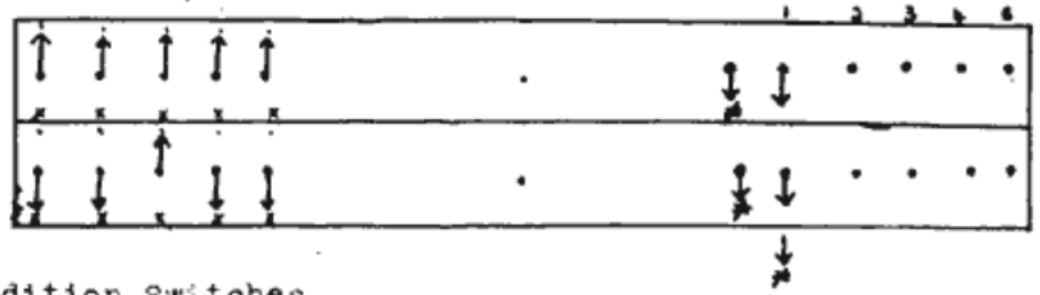


means not (Q_1 = x and Q_2 = .) : this allows Q_1 = ., Q_2 = x, or Q_1 = x, Q_2 = x, or Q_1 = ., Q_2 = .

At the foot of each column of ten counter switches is another "not" switch, which negates the whole column.

For example: to impose Q = either / or 5

This is equivalent to not (Q ≠ / and Q ≠ 5)



(e) Addition Switches

In a row in the lower part of the Q panel the 5 switches at the left which are separated by + signs. can be thrown down only, to make the sum of any number of impulses a dot. There are five counter switches exactly as in the upper part of the panel. the "not" switch is labelled ẋ , but it has the same effect.

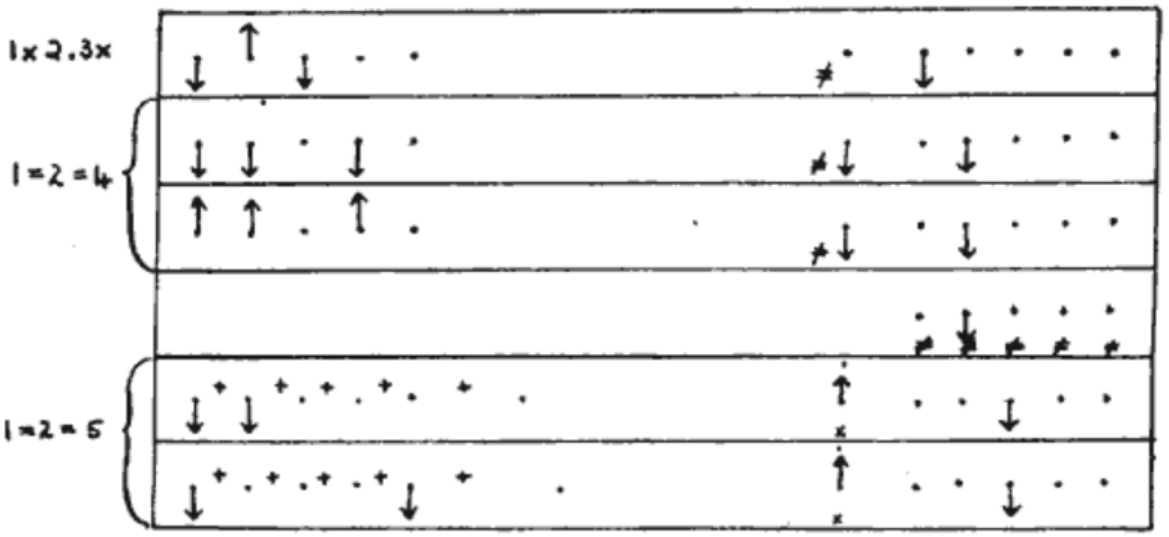
Footnote: Clearly not(i + j = .) is the same as (i + j = x). These "not" switches actually have a neutral position, but it is not needed and is not alike on all Colossi: on some it causes no condition to be imposed, on others an impossible condition.

The five "not" switches at the bottom of the Q panel labelled ≠ negate whole columns, not merely the lower part of the panel; in particular they negate the upper row of "not" switches.

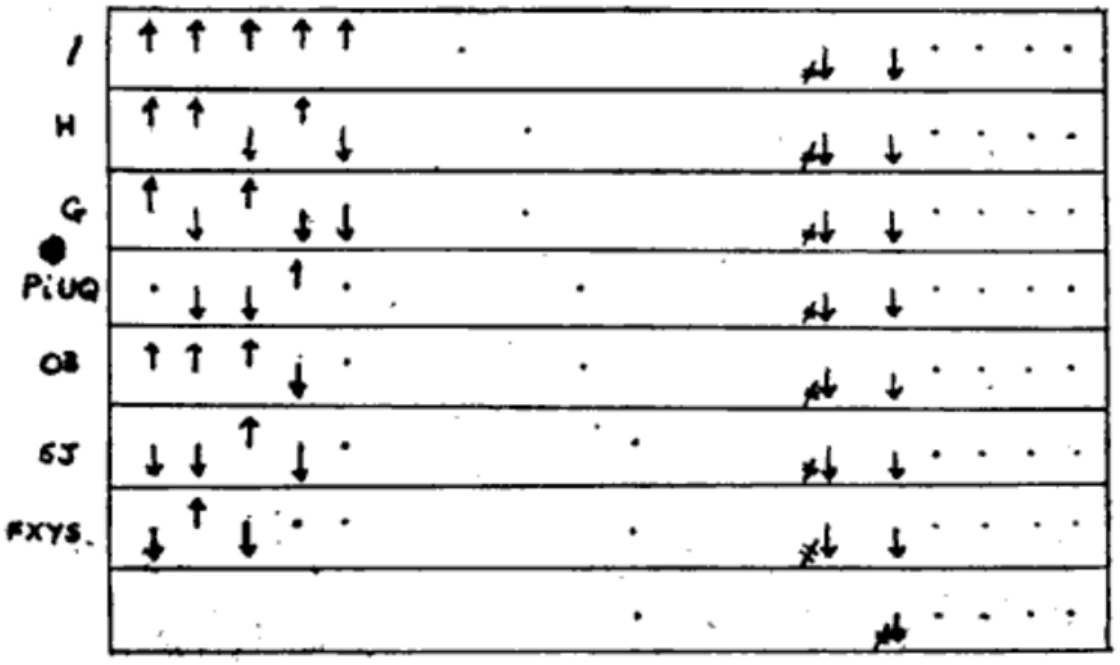
(f) Examples of Switching

It is worthy of emphasis that what is switched is Q, and that Q is whatever is selected by big black switches. In runs to set χ's, Q is $\Delta Z + \Delta\chi$ (though if $\Delta d\chi$ patterns are set up it is $\Delta Z + \chi$ so far as Colossus is concerned); in runs to set Ψ's it is usually $Z + \chi + \Psi$. Use has been made of Q as χ, Z, $Z+\chi$, $\Delta Z + \Delta\chi + \Delta\Psi$. The methods of switching on the Q panel are the same in all cases.

(i) 3x/1x2., 4 = /1=2, 5=/1=2 simultaneously on counters 1,2,3 The two runs 4=/1=2, 5=/1=2 would ordinarily be done on the same principle: here, for purposes of demonstration, they are done quite differently.



(ii) / H O 3 G P I U Q 5 J F X Y S as a single run



If this were done in a hurry it would be very easy to overlook that PIUQ can be switched in a single row; if PI, UQ were in separate runs it would not matter, but it is necessary to put some of the fifteen letters together, for there are only 10 rows.

(g) Possible Runs

This suggests the problem of whether all possible sets of conditions can be imposed on Q, i.e. whether it is possible to run for an entirely arbitrary selection of letters from the 32 letter alphabet.

It is obviously possible to run for any ten letters but, for example, R A S H D O N 8 L I Z , 11 letters, is impossible.

Despite the aid of the addition switches, 15 rows in the upper part of panel are needed to include all runs.

(h) The R Switches

These are the multiple test switches carrying the impulses R_1, R_2, R_3, R_4, R_5 [see Multiple Test 53L(c)] : each occurs in two rows in the upper part of the panel and in one row in the lower part.

Evidently the choice of runs will be much more restricted on multiple test than without it.

For examples of multiple test switching see 53 L(k)

(i) Total Motor Switch

In the bottom row of the Q panel is a three-way switch whose active positions are labelled TM . and TM x .

This switch is not used for motorizing, but only for counting against TM = . or TM = x . It is rather more general than this, for by use of the limitation determiner switches TM can be made to mean

BM = : all switches normal

TM : Switches for the appropriate limitation

: BM c/o , in.

Note: TM is in the present position when used with wheels which are deltaed by Colossus (as it usually will be) Compared to patterns not deltaed by Colossus it is TM, i.e. TM one back [cf. Differencing 53E].

53K PLUG PANEL (Fig 58(xv))

(a) The Jacks

The jacks in this panel are essentially of four kinds:

1. Jacks carrying streams, (including some combined streams.

2. Addition Field;

3. Common Jacks;

4. Jacks carrying input to counters.

Streams may be plugged into counters, either directly or via the addition field and common jacks. To plug anything into a counter is to equate it to a dot.

(b) Jacks carrying streams are described in paragraphs (c) to (h)

(c) Q Jacks

The whole top row of jacks is really a dependency of the Q panel. Q_1, Q_2, Q_3, Q_4, Q_5 are the five impulses switched into Q by the selection switches. R_1, R_2, R_3, R_4, R_5 are the present and remembered items of Q_m when Q_m is on multiple test. All these have two jacks each.

(d) Z, χ, Ψ,

Each impulse of Z, χ, Ψ, has two jacks, one deltaed and one undeltaed.

(e) Special Patterns

χ_1, χ_2, χ_3, χ_4, χ_5, μ_{36}, μ_{37}, have each one jack for the pattern set up, independently of the ordinary pattern in use, in the special trigger.

(f) $\overline{F_4}$, $\overline{F_{23}}$, $\overline{P_5}$, $\overline{TM}$

These are derived from ordinary patterns. If used with streams deltaed by Colossus they are in the present position If used with streams not deltaed by Colossus they are one back, as labelled [cf. 53E]

(g) Not 99

This is used to inhibit counting at doubtful letters of cipher replaced by Z = 9. Such 9's rarely occur singly. Genuine 9's usually do occur singly. It is therefore only imposed at a 9 adjacent to another 9: at such places this jack carries a cross, elsewhere a dot.

Note: Not 99 is intended for use with a Z pattern which is deltaed by Colossus and therefore, since delta Z is rubbish if

Z one forward is rubbish, it is in use, for each stretch of 9's, from one place before the first 9 to the last 9. Colossus however, because it deltas backwards, treats this as being from the first 9 to one place after the last 9; and accordingly if not 99 is used with Z not deltaed by Colossus one place will be lost unnecessarily at the end of each stretch of 9's.

(h) Start Units

These carry a permanent dot or cross as labelled.

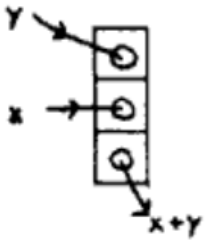
(i) Addition Field

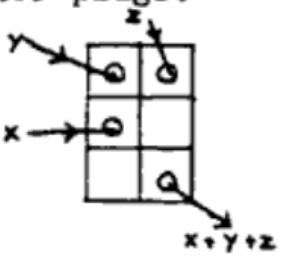
These are of course used to add impulses: there are three rows, 28 columns.

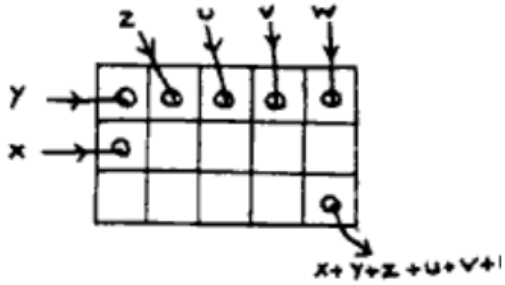
All but one of the impulses to be added are plugged into consecutive jacks in the top row.

The odd one is plugged in the middle row below the first of the other plugs.

The output (sum) is taken from the bottom row below the last of the other plugs.







The columns used thus are isolated so that several additions can be carried out simultaneously.

To plug any impulse to equal a cross, add a cross and plug normally.

(j) Common Jacks

There are on each Colossus six or more commons of five jacks each. An impulse put in can be taken out four times: if this is insufficient common jacks can be linked together.

(k) Counter Jacks

There are 8 jacks for carrying conditions to each counter.

There are also 6 jacks carrying conditions to all counters. One of these is marked TM because it will not work if the TM switch on the Q panel is thrown.

There is a special counter jack (Multiple Test Doubting) used only for multiple testing on special patterns.

(l) Examples of the use of the Plug Panel

(i) Before not 99 was available it was usual, on corrupt texts, to switch Q = Z, ● ≠ 9, and plug all wheel-breaking runs.

(ii) The wheelbreaking run $\Delta\chi_1 + \Delta Z_1 + \Delta\chi_4 = .$ is normally done by plugging (delta χ_4 is usually set up in the χ_2 trigger).

If the Q panel were used delta Z_2 would be switched in along with delta Z_1. This could be avoided, alternatively, by splitting the delta Z selecting switch.

(iii) the run 1=2=lim (i.e. $\Delta D_1 = \Delta D_2 = \bar{\chi}_1$) can be switched and plugged thus

1=2 on the Q panel, multiple testing on χ_1

$Q_2 + \chi + TM = .$ on the plug panel

$TM = \tilde{\bar{\chi}}_1$ on the limitation determiner switches, using BMc/o, $\bar{\chi}_1$.

53L MULTIPLE TEST

(a) To save time it is arranged that the same wheel can be examined at five different settings simultaneously, the five scores appearing in the five counters.

(b) Memory Circuits

When the multiple test switch for any wheel is thrown, a memory device is switched in, which stores the characters of that wheel 1,2,3, and 4 places back.

Footnote More explicitly Colossus remembers characters of the wheel opposite places on the tape 1,2,3,4, back; in particular characters of Ψ' not of Ψ . In the first four places of the text some of the remembered characters are really those at the end of the text in the preceeding tape revolution; and will give random scores, unless the text length is a multiple of the wheel length: it is customary to span from o4 onwards.

Thus when Colossus is examining a particular place on Z, it has available for comparison:-

(i) on the multiply tested wheel, the present character and the characters 1,2,3,4, back. These are associated with the numbers 1,2,3,4,5 (i back with i+1).

(ii) on Z, and on all other wheels, only the present character.

(c) R_1, R_2, R_3, R_4, R_5.

Most operators are surprised to find that the remembered characters appear nowhere except as a component of Q, the corresponding five characters of Q are called R_1, R_2, R_3, R_4, R_5.

e.g. if χ is multiply tested and $Q = \Delta\chi + \Delta Z$ then

$$
\begin{aligned}
R_1 &= \Delta Z_1 \text{ (present)} + \Delta \chi_1 \text{ (present)} \\
R_2 &= \Delta Z_1 \text{ "} + \Delta \chi_1 \text{ (1 back)} \\
R_3 &= \Delta Z_1 \text{ "} + \Delta \chi_1 \text{ (2 "} \\
R_4 &= \Delta Z_1 \text{ "} + \Delta \chi_1 \text{ (3 "} \\
R_5 &= \Delta Z_1 \text{ "} + \Delta \chi_1 \text{ (4 "}
\end{aligned}
$$

Five counts made simultaneously, with R_1, R_2, R_3, R_4, R_5, used instead of the corresponding impulse of Q, are evidently equivalent to a count, for the same conditions, at each of the following settings for a multiply tested wheel: present, 1 back, 2 back, 3 back, 4 back.

(d) $R_1 R_2 R_3 R_4 R_5$: Switching and Plugging.

R_1 R_2 R_3 R_4 R_5, must be plugged or switched in the usual way. The provision for them is less generous than for ordinary impulses. On the Q panel they have two switches each in the upper part, one switch each in the lower part. On the plug panel they have one jack each: these jacks are part of Q and are controlled by the main Q selecting switches.

(e) R_1 R_2 R_3 R_4 R_5 : Relation to the Five Counters. (regrettably obscure.)

R_1 R_2 R_3 R_4 R_5 may of course be switched or plugged into the counters in any order; but Colossus cannot recognise this and therefore always prints the settings for a batch of five scores in the same order, viz backwards (e.g. 11, 10, 09, 08, 07).

The counters print in the order 1, 2, 3, 4, 5, and therefore if each setting is to be printed opposite the appropriate score, th settings in the five counters must likewise run backwards. (e.g. 11 in 1, 10 in 2, 9 in 3 , 8 in 4, 7 in 5).

The settings corresponding to R_1 R_2 R_3 R_4 R_5 also run backwards (R_1 is present, R_2 one back etc.) and, therefore, finally R_1 is switched to counter 1 etc.

It may sometimes be profitable to put R_1 R_2 R_3 R_4 R_5 into the counters in reverse order (e.g. in redtangling).

(f) Manner of stepping

The wheel on multiple test can step either fast or slow [53D (c)] but in either case it steps five positions at a time, for obvious reasons. The batches of five settings are not arbitrar but must belong to the sequence 02-06, 07-11, 12-16 ..... ending with the batch whose present position is 01 (e.g. ends with 38-01).

(g) Multiple Testable Wheels.

Multiple testing is provided for all wheels except μ_{61}. χ_5 , ψ_5 , were added later and have not been fitted to all Colossi. μ_{37} has its own switch: the others are in pairs, each pair sharing a three-way switch, viz χ_1 , χ_2 , χ_3 , χ_4 ; ψ_1 , ψ_2 , ψ_3 , ψ_4 ; χ_5 , ψ_5.

(h) Mu 37

Multiple testing on Mu 37 has some special features. It can be used only for motor runs in which a count is made against motor = ., or motor = x. It cannot be used for motorizing the psis.

The Mu37 multiple test switch, not only puts the wheel on multiple test, but also puts Mu 37 alone into the switches R_1 R_2 R_3 R_4 R_5 on the Q panel, where it can be switched in the normal manner. (Commonly Mu 37' =., but sometimes M37 + ΔD_{12} = .) The effect of these switches is <u>not</u> modified by the limitation determiner switches: they always represent the basic motor. For a total motor run what is required is BM = . and lim = x. BM = . is imposed by these R switches. Lim = x is imposed by the TM switch on the Q panel, the limitation determiner switches being thrown to BM c/o and the appropriate limitation.

(i) No Multiple Test for Motorizing.

It is impossible, in a run involving the psis, to use multipl test on any wheel which influences the total motor, for this would require that the psis should move in two different ways at once. In practice the wheels thus restricted are Mu 37, psi 1, and, with P_5 limitation, chi 5, psi 5. It is however, possible to use the multiple test switch merely to step one of these wheels five positions at a time, ignoring four setting out of five. This is useful for Ψ' because of coalescence [23X].

(j) Multiple Test Doubting (Special Patterns).

Multiple test normally applies only to ordinary patterns, not to special patterns. On Colossi 5,8,10, however, it can be applied to the corresponding special pattern also. The appropriat switch is in the bottom row of the selection panel. As always with special patterns, it must be plugged, viz. from the appropriate special pattern jack to one of the two jacks labelled Multiple Test Doubting . or x : these select places where the special pattern is ., or x, respectively, in all counters.

(k) Checking of Multiple Test Scores.

It is generally undesirable, because of confusion about settings, to check scores with multiple testing in. In place of R_1 R_2 R_3 R_4 R_5 the ordinary impulse is used, and, of course, the wheels must be reset.

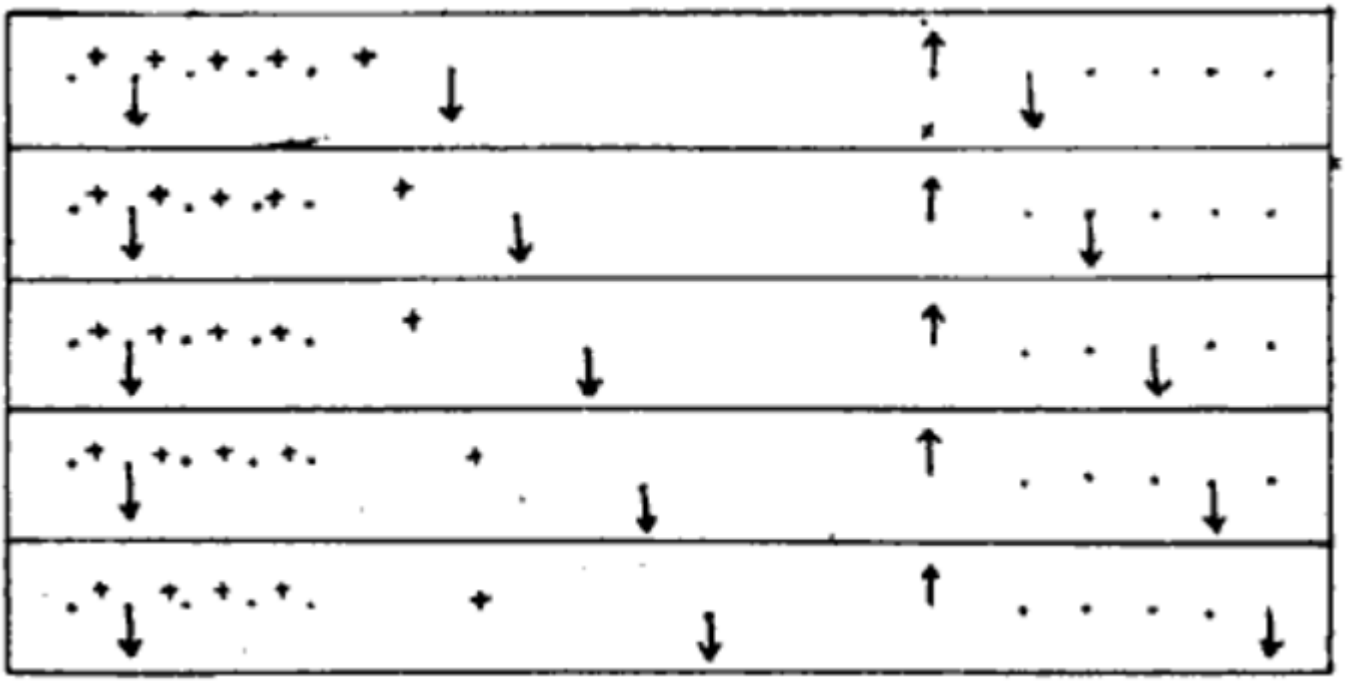
For Mu 37 this means that, in the lower part of the ⅋ panel, what is used is not R_1 R_2 R_3 R_4 R_5 but TM. In checking a total motor run the BM c/o must be restored to its normal position.

For special pattern multiple test this means that the special pattern shall be plugged into the ordinary all-counters, not into the multiple test doubting jacks.

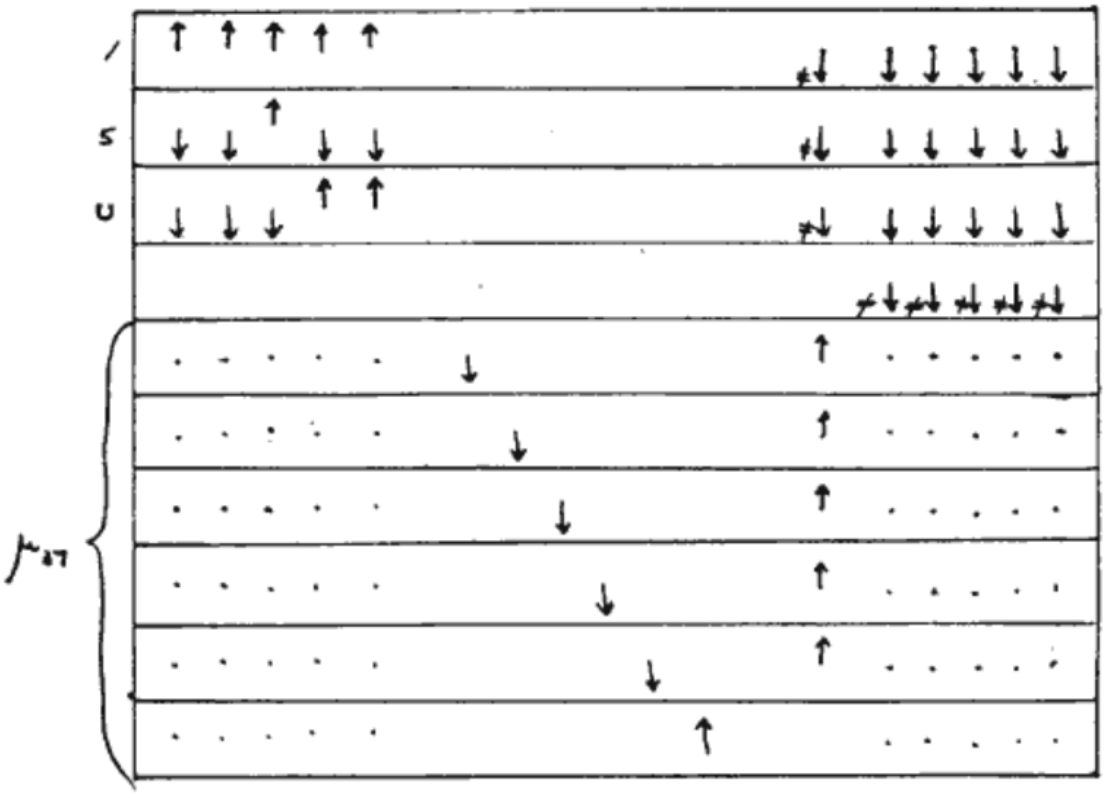
(l) Examples of Multiple Test Switching.

(i) 1+2 = .

Note : this may be either ΔD_{12} = . to set χ_1 and χ_2,
or F_{12} = . to set Ψ_1 and Ψ_2.
On the ⅋ panel the switching for their two cases is identical.

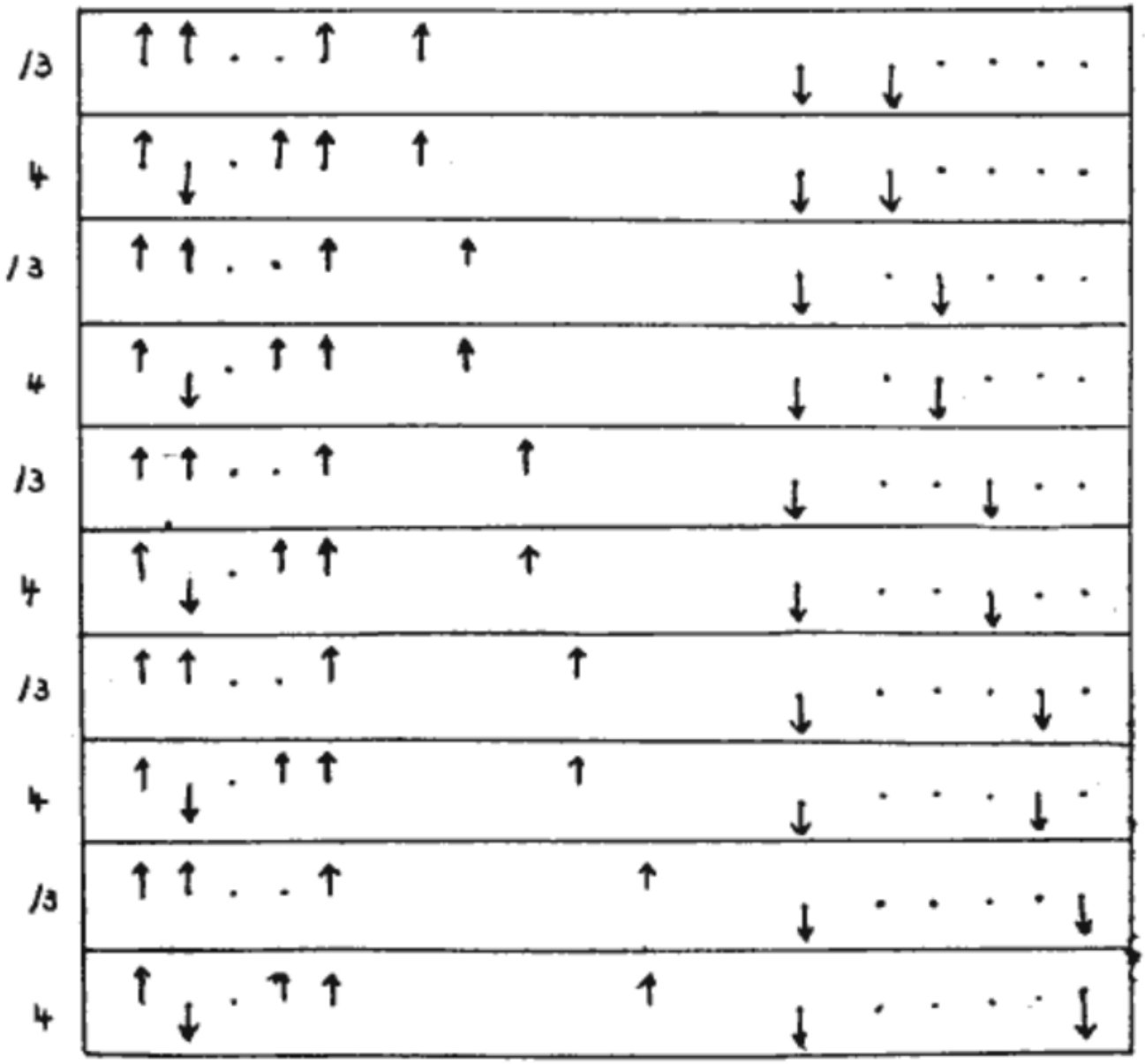


(ii) Mu 37 = •/5U, $\bar{X}_2$. A total motor run for M61 M37 when $\bar{X}_2$ limitation is in use, counting TM=., where ΔD = /,5,U.

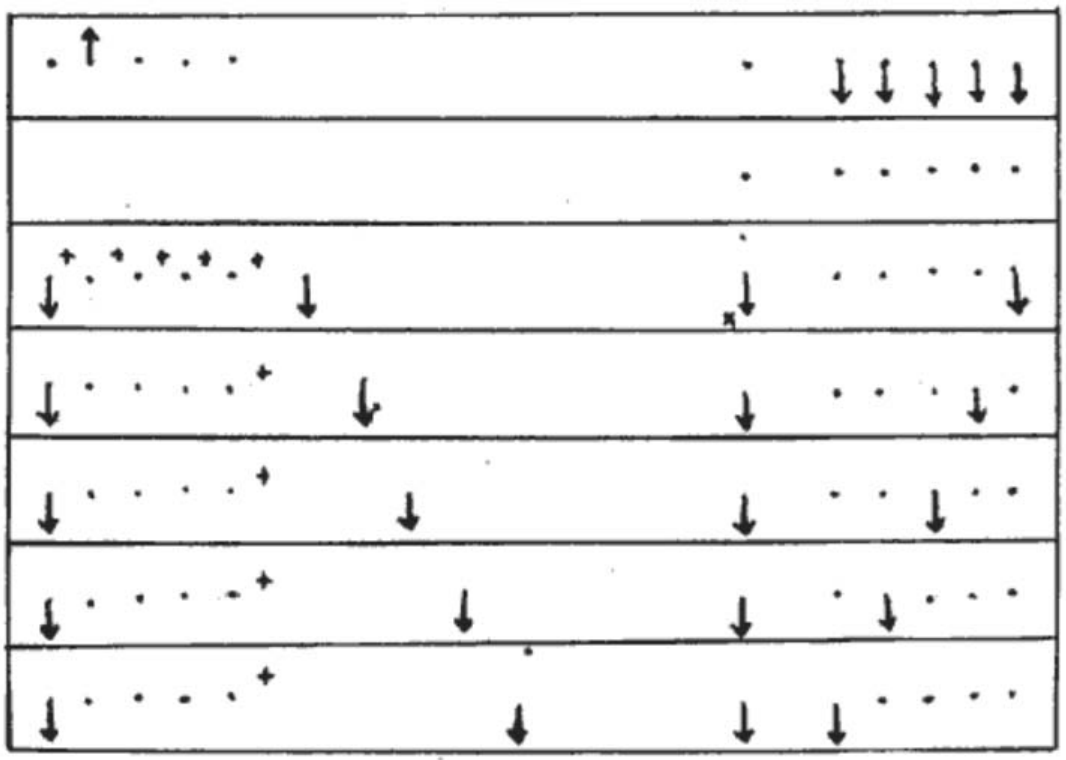


Other switching
M37 multiple test, step M37 slow, M61 fast.
Limitation determiner switches : BM c/o, $\bar{X}_2$ in.
For checking this run see 53L (k).

(iii) P /,3,4 to set Chi 3, Psi 3, with multiple testing on Chi 3, all other wheels being set


/3
4
/3
4
/3
4
/3
4
/3
4

(iv) The short wheel-breaking run 3+/1.2.
It is not worth while to use multiple test for one-wheel runs, unless the tape is very long, as it may be in chi-breaking.
For the reason why 3+1 is switched to cross see 25 .
R_1 R_2 R_3 R_4 R_5 are switched into counters 5,4,3,2,1 so that scores shall be printed in the correct order [53L (d)].



53M. COLOSSUS RECTANGLING GADGETS.

(a) The principle of Colossus Rectangling.

To render the gadget more intelligible the how and why of Colossus rectangling is explained [see also 24B(f)].

Suppose that the Chi 1, Chi 2 triggers each contain one cross, that $Q = X$; and that Q is switched : $Q_1 = x$, $Q_2 = x$
This will select a set of places all of which are opposite a particular character of chi 1, and also opposite a particular character of chi 2, i.e. they will belong to the same cell of the rectangle.

Plug $\Delta z_1 + \Delta z_2 = \cdot$

Throw the lower stepping switches, so that chi 1 (down) steps fast and controls chi 2 (up).

Chi 1 will step, producing a row of the rectangle : when Chi 1 reaches the setting plug, chi 2 will step one.

Chi 1 then steps again, producing the next row, and so on.

(b) The Rectangling Gadget.

If the rectangle were made exactly as above the entries would be printed on separate lines each preceded by the setting of chi 1, chi 2. It is much better to have the row printed as row. Accordingly a gadget is fitted such that :

(i) Carriage return is operated only after the completion of a row.

(ii) Settings are not printed.

(iii) A score is printed as a single figure.

On Colossus 6 scores exceeding 9 are represented by letters viz. A = 10, B = 11 and so on.

(c) Multiple Test in Rectangling.

To increase the speed of rectangling, multiple testing on χ_1 is used. Multiple testing always examines batches of settings whose "present" member belongs to the sequence 1,6,11.....41. The first batch of settings in each row of the rectangle is chosen to be 02 - 06, 06 being "present", 02,03,04, 05 "remembered". In order that χ_2 shall step at the correct position of χ_1, the χ_1 setting plug must be at 01. If however χ_1 were actually set at 01, the first row would begin with settings 38, 39, 40, 41, 01. To make the first row begin 02,03, 04, 05, 06 the wheels are set with the χ_1 plug at 06: the plug is then returned to 01 without resetting.

Because the rectangle is made backwards the first five readings whould be for the last five cells of the rectangle, which contain places of the cipher whose remainders on division by 41 are 37, 38, 39, 40, 41 so that the required differences (ΔZ_1) are 37 + 38, 38 + 39, 39 + 40, 40 + 41, 41 + 01. Since Colossus differences backwards, the cross in χ_1 must be against cipher places 38,39,40,41,01. The first batch of settings is 02,03,04,05,06; and therefore the cross must be in position 02:

Position in cipher (remainder on division by 41)		37	38	39	40	41	1	2
Character of χ_1 opposite each letter of cipher when the setting is 06 (i.e. 06 of χ_1 opposite 01 of Z)	R1	1	2x	3	4	5	6	7
Remembered character of χ_1	R2	41	1	2x	3	4	5	6
	R3	40	41	1	2x	3	4	5
	R4	39	40	41	1	2x	3	4
	R5	38	39	40	41	1	2x	3

R_1 sees the cross in 02 of χ_1 opposite 38 of Z

R_2 remembers the cross of 02 of χ_1 opposite 39o

χ_2 has a cross in 02, for symmetry, and it follows that its setting is 02.

The last batch of settings is 38,39,40,41 and 01 of which 38, 40,41 are also in the last batch but one: the rectangle gadget prevents these from being printed twice.

(d) Print Scores

Done thus, the rectangle would have to be done twice, for $\Delta Z_1 + \Delta Z_2 = .$, and for $\Delta Z_1 + \Delta Z_2 = x$. Conditional rectangles are done this way; the rectangling switch is thrown to "print score

(e) The Subtraction Gadget.

If the depth is constant, which will be the case if the text length is a multiple of 1271 and 99's are not cancelled, the score for $\Delta Z_1 + \Delta Z_2 = .$ will suffice, for the bulge equals ($\Delta Z_1 + \Delta Z_2 = .$) minus depth. A further rectangling gadget performs this arithmetical operation if the rectangling switch

is thrown to "normal", and the appropriate depth switched in on the rectangling panel.

This is the usual Colossus rectangle method : it is often disadvantageous for short texts because so much is lost by reduction to a multiple of 1271.

Note: Although the subtraction gadget can be used independently of the rectangle gadget proper, it is too limited in scope to be of value.

(f) Switching.

The 3-way rectangling switch at the extreme right of the control panel has two active positions : "Print scores" and "normal".

The other switches are on the rectangling panel. Any chi-wheel can be multiply testing for making a rectangle : the corresponding switch of the bottom of the rectangling panel must be thrown. This determines when carriage return is operated and how many surplus scores are cancelled.

The subtraction gadget is controlled by a series of switches labelled 1 to 36, each number indicating the depth to be subtracte

(g) The Cyclometers.

The Θ_{ij}^2 significance test is based on the number of occurrences of each possible value for the entries in a rectangle.

At the top of the rectangling panel is a row of cyclometers to record these occurrences.

Below these is a row of jacks, one for each cyclometer. A pulse here steps the corresponding cyclometer.

Below these again are two rows of jacks labelled 1,2,3.... A score of $\pm\theta$ produces a pulse in the jack θ.

These score jacks can be plugged arbitrarily to the cyclomete jacks.

(h) The Punch.

Colossus 6 can make a rectangle in the form of punched tape. A negative score is always represented by a cross in the fifth impulse, but otherwise a score can be represented by an arbitrary letter, selected by plugging from a score jack to a punch jack.

There is a score jack labelled CR which carries the pulse of the carriage return at the end of each row of the rectangle. This is normally plugged to the punch jack labelled $\overline{9}$/ which punches / and adds a cross to the third impulse of the preceding letter (c.f. Appendix 95).

(i) Rectangle not 99.

In any cell of the rectangle containing a place where Z = 9 adjacent to another 9, this replaces the entry by zero. It is useful only for rectangles of depth one.

53[illegible]. CONTROL PANEL.

See the photograph. (Fig 55(b))

MAS is the master switch (upper row, second switch from right; labelling obscured in the photograph). Unless this switc is thrown Colossus can neither count nor step. It is however possible to set wheels and to reset counters.

The switches labelled χ, μ, ψ, are the stepping switches 53D(c). The switches labelled mult are multiple test switches 53L(g). χ_3, ψ_5 are oddly placed.

The other switches are

PMH	Print main heading [53G(g)]	PCO	Printer cut-out	[53G(i
SET ⊻	Set wheels [53D(a)]	Lc/o	Lamp cut-out	[53G(d
RESET	Reset counters [53G(j)]	LC	Letter count	[53G(h
REC	Rectangle [53M(f)]	KL	Cancel lights	[53G(d
		SIP	Significance Interpretation	[53G(b

53P. COLOSSUS TESTING.

Any account of the methods used by the engineers to test Colossi would be entirely out of place in this report, but it is appropriate to refer to the methods used by Wrens, chosen to carry out routine tests.

Owing to the complexity of its operations Colossus can produce results so erroneous as to be useless without arousing suspicion till valuable time has been wasted.

Runs have therefore been selected such that a machine faulty in any respect is unlikely to give correct scores, and these have been done on Colossi known to be in good order, using selected standard wheel patterns and a selected standard tape. One set of triggers on each Colossus is now assigned to these standard patterns, and standard tapes are kept in stock : the runs are repeated on all Colossi at frequent intervals.

A single fantastic run could doubtless be devised to check everything, but it is preferrable to use a number of runs, which in themselves will aid in locating faults. Z and χ are first tested without ψ .

Of course when there is a fault the ordinary chi and psi tests [23K(d)] will fail, thus providing a crude test of Colossus very frequently.

54 ROBINSON

54 - ROBINSON

54A INTRODUCTION

Robinson was made in three versions known as

Heath Robinson,
Old Robinson,
Super Rob(inson).

Super Robinson is described in detail: the others, which do not differ in principle, are mentioned in chapter 52.

For photographs see the end of this volume. (Fig 58 (III, IV, X, VI, VII))

Let four or fewer teleprinter streams punched on tapes, with uniformly spaced sprocket-holes, be imagined laid side by side, so that their letters correspond, sprocket-hole by sprocket-hole.

Robinson can count the number of places in the combined stream where certain conditions are satisfied.

Rather more generally, it can count the number of places such that certain conditions are satisfied, involving that place, and the place one forward (this includes differencing), together with two conditions involving the place one back, and one condition involving the place two back.

Apart from this it cannot count a condition involving two different places, except by using two tapes alike, appropriately staggered.

An essential feature is that the counts can be made in rapid succession, with the various tapes in different relative positions (stepping): stepping is necessarily uniform though the step between successive counts may be any number of sprocket-holes.

54B HOW SCORES ARE EXHIBITED.

The scores so counted are exhibited in two ways

(i) On display,

(ii) By the printer.

The display is a ground glass screen on which numbers can be projected by small electric lamps.

The four upper digits are the position counter i.e. they show the relative position of tapes.

The four lower digits are the score counter.

The printer simply prints all 8 digits in order, without spacing, so that e.g. 25341798, means position 2534 score 1798.

Footnote Display can be switched off either entirely or to show position only. There are more printer details later.

54C BEDSTEADS AND POSITION COUNTING

(a) Bedsteads

A bedstead is a system of pulleys round which the tape is driven by a sprocket wheel at about 2000 sprocket-holes per second, so as to be scanned by photo-electric cells.

There are four bedsteads A,B,C,D: to ensure simultaneous scanning of corresponding places on different tapes, their four sprocket wheels are on a common shaft.

(b) Bedstead Drive

To reduce the tearing of sprocket-holes, two of the pulleys are driven at the correct speed. For the same reason the drive is applied gradually when starting, and removed gradually when stopping (by means of relays).

The tapes are draped loosely on the pulleys centrifugal actio tends t tighten them, and they may need to be slackened. After a long run tapes may stretch.

Between the "Gate" and the sprocket wheel the tape moves past two engraved marks: to ensure that the tape is correctly placed these are aligned with an appropriate pencil mark of the tape [Fig.58(iv)]

The tapes, which are of course continuous loops, are jointed flexibly with Boatick.

One springswitch is used both for starting and stopping: it is thrown down (and released) for start, up for stop.

(c) The Gate

Each bedstead has 12 photo-electric cells which scan the tape as it passes (downwards) through the "gate". The gate is placed as near as possible to the driving sprocket to reduce the effect of stretched tapes.

One of the photo-cells scans the sprocket-holes, permitting th counters to add 1 or 0 at each sprocket hole.

In <u>each</u> position of the tape 10 of these cells scan the 10 dots and crosses in <u>two</u> consecutive places on the tape, the 10 outputs appearing in 10 jacks on the plug panel (the output from each bedstead in the 10 jacks immediately below the corresponding letter), and howhere else.

(d) Start and Stop Signs

The remaining two photo-cells look for the start and stop signs which are punched in the $4\frac{1}{2}$th and $3\frac{1}{2}$th impulses of the tape, exactly as on Colossus.

A start sign causes the machine to start counting.

A stop sign causes the machine to stop counting, transfer the count to relays, and prepare for the next start sign.

Only one start sign and one stop sign are used as such at any time; these are not necessarily taken from the same bedstead: they are selected by the switches above the plugboard. Start (on A,B,C, or D) by the first four: stop (on A,B,C, or D) by the second four.

(e) Position Counter

The start signs are used also for finding the relative positio

of tapes. If one (say B) of the right-hand switches above the display is thrown, the position counter shows how many sprocket-holes the start sign on B is behind the start sign used as a start sign.

(f) Period Dials

These are above the display reading 0000 - 9999.

If they are set e.g. to 1271, as soon as the position counter reaches 1271 it returns to 0000 i.e. the reading is always the remainder on division by 1271.

(g) Split Position Counter

If one of the left-hand switches above the display is thrown the position counter is split in two, each half working independen reading up to 99. The first two digits show the position of the tape selected by the left-hand switch. The second two digits show the position of the tape selected by the right-hand switch.

Splitting splits the period dials also, e.g. if the dials are set to 4131, the first two digits show the remainder on division by 41, the second two digits show the remainder on division by 31. These may refer to the same or different tapes.

(h) Note

By convention the setting of one pattern relative to another is the place on the latter against the 1st and not the 0th place on the former. Thus setting = Rob reading + 1.

(i) Stepping

Stepping is effected on Robinson by using tapes on different lengths. If A is m sprocket-holes longer than B, and the original setting is 01, then after a revolution, A will return m sprocket-holes later than B, i.e. the 1st place on A is opposite the $\overline{m+1}^{th}$ place on B, and the setting of A relative to B is $+m$

A is said to have moved forward relative to B.

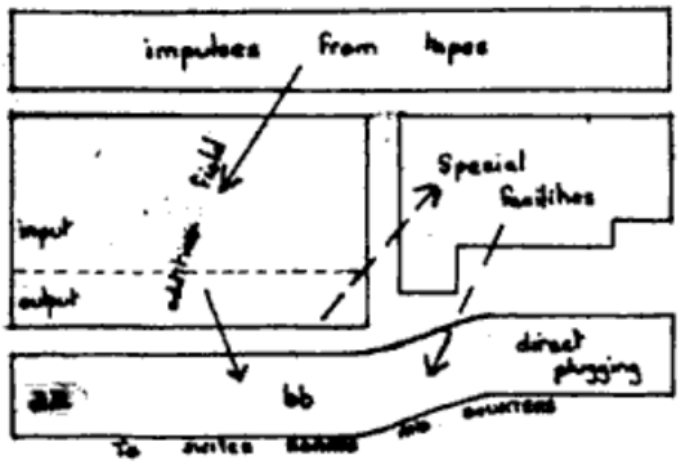
(j) Repeat light

When the position counter returns to its original reading a repeat light appears below the display.

54D THE PLUG PANEL

(a) Layout

The jacks on the plug panel may be grouped thus.



Conditions can be imposed only by plugging both:

1. From tapes to Addition Field input.

2. From Addition Field output to switch panel.

The latter however may be plugged via "Special Facilities". Note that this forbids plugging direct from tapes to switch panel.

Subject to the above rules (and some minor restrictions in the ordinary addition fields) any jack may be plugged to any other. No jacks in the plug panel are permanently linked except the columns of the addition fields (ordinary and special).

(b) Pulses from Tapes

The arrangement is obvious from the picture.

The upper row is one forward on the tape.

The lower row is present position on the tape.

(c) Ordinary addition fields

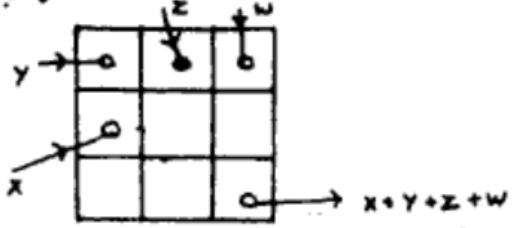
Pulses (one or more) from tapes, plugged into input jacks in any column, appear added together in both the output jacks of that column. For technical reasons there are certain restrictions on the use of these fields. Each of the left-hand five columns has two pairs of input jacks (upper and lower). Each of the right-hand five columns has a single pair of input jacks. Impulses plugged into the two jacks of a pair must come from the same tape. If there is only one impulse in a pair it should be in the upper jack of the pair. Impulses from different tapes can be added only in the five right-hand columns (or in the special addition field). Each column of the addition field has two output jacks from which the impulse may be plugged directly to the switchboard or to some special facility.

(d) Special Facilities

These are special addition, Permanent cross, one back and two back,

(e) Special addition field

This is exactly the same as a Colossus addition field e.g.



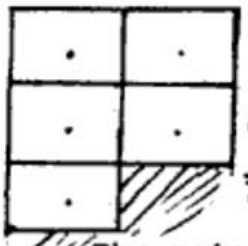
Note: Other columns in the addition field are unaffected by this and can be used separately.

(f) Permanent Cross.

There is a column of jacks to the left of the special-addition field: each of them bears a permanent cross, which can be added, in the special addition field, to any impulse. This is useful for making an impulse equal a cross when using "direct plugging".

(g) One back and two back

There are five jacks at the right of the addition field



in each column any impulse plugged into Q appears one back in $\bar{Q}$ and, in the left-hand column two back in $\bar{\bar{Q}}$

The notation Q is unfortunate: it is not analegous to Q on Colossus. I would be better.

(h) Plugging into the switch panel.

The output of an ordinary addition field, or of any special facility may be plugged into the switch panel where the conditions, a count for which is to be made, can be imposed.

An impulse plugged into one of the 10 jacks in the bottom row of the switch panel appears on two switches, one labelled $\dot{x}$, and, immediately below this, one labelled +. The first five jacks correspond to the five pairs of switches aa, the second five to those of bb. The impulses are called (not written on machine) $Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, Q_7, Q_8, Q_9, Q_{10}$.

Footnote: These are not related to Q, $\bar{Q}$, $\bar{\bar{Q}}$: they (i.e. Q_1, Q_2 etc.) are broadly analegous to Q on Colossus, but the impulses plugged into them are quite arbitrary.

The five jacks marked "direct plug" in the diagram have essentially the same function, but are permanently switched to dot.

54E THE SWITCH PANEL

(a) Layout

Without the diagram at the end of this volume this description will probably be complete obscure: Fig 55(vm).

(b) Q Switches

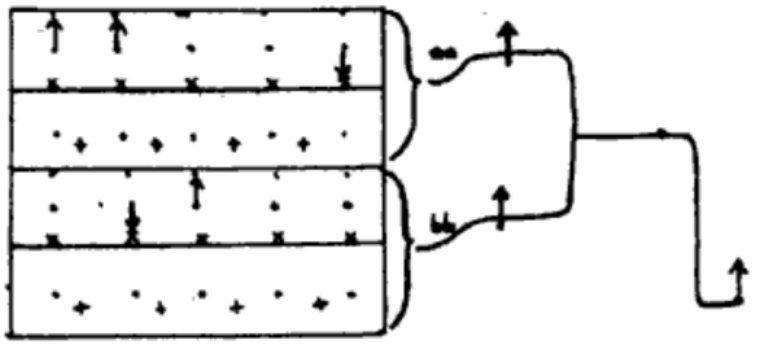
The two rows of switches in the left half of the switch panel will be described first: the conditions they impose may be modified (may even be reversed) by the switches in the right half.

The switches to the left of aa control impulses Q_1, Q_2, Q_3, Q_4, Q_5.

The switches to the left of bb control impulses $Q_6, Q_7, Q_8, Q_9, Q_{10}$.

A switch labelled $\dot{x}$ can be thrown either to make its impulse a dot or to make its impulse a cross.

If several are thrown, all their conditions are imposed.

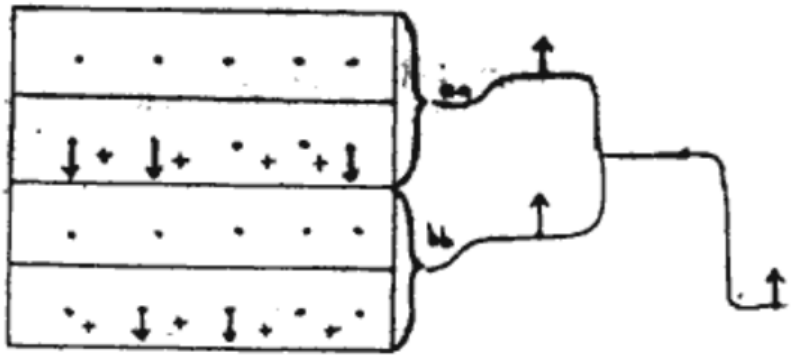


Imposes the conditio

$q_1 = . \; q_2 = . \; q_5 = x$

$q_7 = x \; q_8 = .$

Switches labelled + can be thrown (down only) to add one or more impulses and equate their sum to a dot.



imposes the conditions

$q_1+q_2+q_5 = \cdot$

$q_7+q_8 = \cdot$

(c) Yes Not Switches

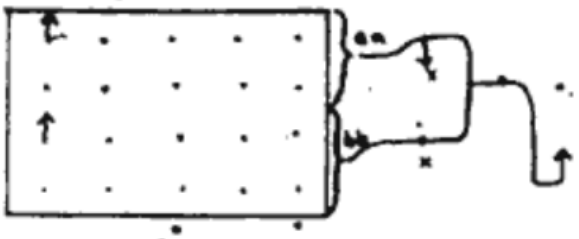
On the right half of the switch panel white lines are drawn: conditions imposed must in effect, pass along these lines.

Switches situated on these lines modify the conditions which pass through them: of these aa, bb and the bottom switch are three-way switches labelled

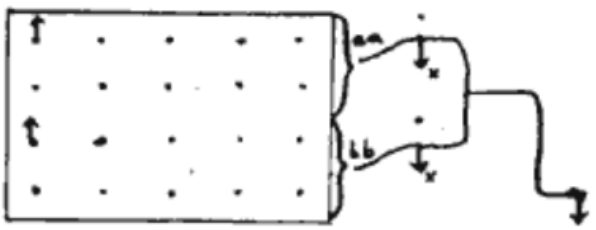
- $\cdot$ which means : condition is unchanged (yes)
- which means : condition in cancelled
- x which means : condition is reversed (not)

The & + and red switches are described later: at present they are supposed to be in their normal positions.

Examples.



$q_1 = x$



Either $q_1 = x$ or $q_6 = x$.

(d) & +

Two conditions reach this switch, from aa and bb.

& means both;

+ means both or neither.

It is intended for use with Q + switches

e.g. $Q_1 + Q_2 + Q_3 = .$, $Q_8 + Q_9 = .$, +, means

$$\begin{cases} \text{either } Q_1 + Q_2 + Q_3 = . \text{ and } Q_8 + Q_9 = . \\ \text{or } \quad Q_1 + Q_2 + Q_3 = x \text{ and } Q_8 + Q_9 = x \end{cases}$$

i.e. $Q_1 + Q_2 + Q_3 + Q_8 + Q_9 = .$

Obviously any number of Q's can be added.

54F MISCELLANEOUS COUNTER FACILITIES

(a) Split Score Counter

If the red switch to the right of & + is thrown the score

counter is split into two, each counting independently up to 99.

The 1st and 2nd digits count for conditions imposed in bb

The 3rd. and 4th digits count for condition imposed in aa and direct plugging.

(b) Span Counter

This makes it possible to count on a part only of the text between start and stop.

It controls two sets of decade switches (0000 - 9999) labelled "start", "end", on the panel above the printer.

If "start" is set at m, "end" at n, the places counted on from the $\overline{m+1}^{th}$ to n^{th} inclusive, on the tape from which the start sign is taken.

Note: The position counter continues to work in terms of start signs not in terms of the beginning of span.

(c) Set Total

A device whereby only scores which exceed, or, alternatively, scores which do not exceed, a fixed score, are displayed or printed. The switches are above the plug panel, viz. a set of decade switches (0000 - 9999) and a three way switch.

540 THE PRINTER

(a) Lost scores

On Robinson stepping is always uniform, so that when scores appear in rapid succession it is not possible to inhibit stepping till they can be printed and scores may thus be "lost". Various devices are used to prevent this.

1. The printer is made to print as fast as possible, without spacing, in fact too fast to print the same figure twice successively. When two or more digits which are alike occur together, the printer replaces all but the last by arbitrary letters (actually a,b,c,d,e,f,g for the first seven digits respectively) for example ab072f39 means 00072339.

2. Two scores can be storedat once (instead of one as on Colossus).

3. The machine is not made to count as fast as it could be.

4. If nevertheless a score is lost, this is shewn in two ways.

(i) A light appears below the display (labelled "lost co

(ii) A cyclometer records the number of lost scores.

The cyclometer can be reset (but only one at a time) by throwing a switch near the cyclometer up to "meter".

(b) PCQ

This switch cuts out the printer: unfortunately if it is thrown to normal during a run it is apt to demoralize the printer and produce rows of dots.

(c) RESET

This switch clears the display and all scores which are in storage.

54H CONTROL TAPES

(a) Definition

A control tape is one used to select a set of places on another tape whereon a count is to be made.

These places may be all consecutive, or in isolated groups, either regular or irregular.

(b) Spanning by means of control tapes

In particular if all the places are consecutive, and if still more particularly the tape steps in unison with the tape from which the start is taken, a control tape is equivalent to spanning. Spanning by dials has of course the advantage that it can be adjusted rapidly, and if the spanning required is not known beforehand this advantage is overwhelming.

Spanning by a control tape was used for some early versions of mechanical flags and rectangles, in which several different spans are needed: the spans were represented on the control tape by different letters, and selected by means of a letter count which is easier that respanning. This was discontinued when the split score counter was introduced only because it absorbed too many of the conditions which can be imposed on the bb half-counter

A compromise, spanning large pieces of text by dial and subdividing these by a control tape is quite feasible.

Old Robinson had no span counter so that spanning had to be effected by control tape, or more commonly by a control impulse replacing an impulse of the tape to be counted. This was often necessary because the minimum text length was 2,000.

(c) Irregularly spaced selection

When the places to be selected are not consecutive a control tape must be used: the method is obvious: it can be employed to eliminate corrupt letters.

(d) Regularly spaced selection

Some simplification is usually possible: the length of the control tape can be any multiple of the cycle which can be put on the bedstead. A proper choice for the length of the other tape will usually suffice for any stepping required. A good example is the 1+2 rectangle [24 B (e)]

(e) Number of different selections made by one tape

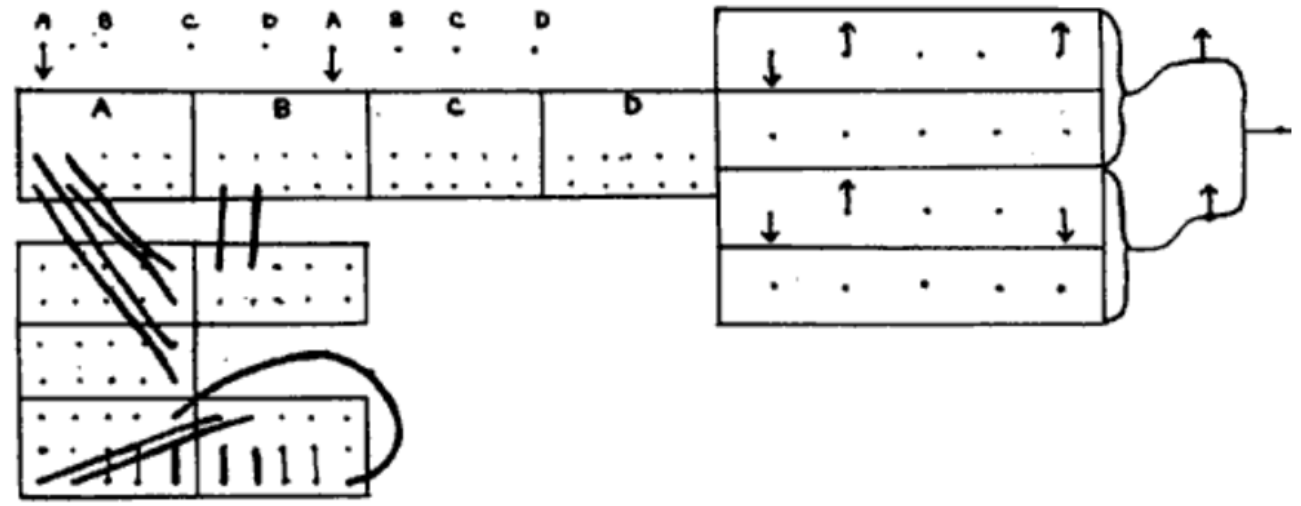
A single control tape /9/H/T and so on, can, by imposing the conditions $\underline{C} = 9$. $C = 9$, $\underline{C} = H, C = H$ and so on, be made to select a cycle of 62 or fewer places.

A single impulse of a tape with the pattern xxxx....xx.x..x. can, by use of $\underline{C}$, C, $\overline{C}$, $\overline{\underline{C}}$, be made to select a cycle of 16 places

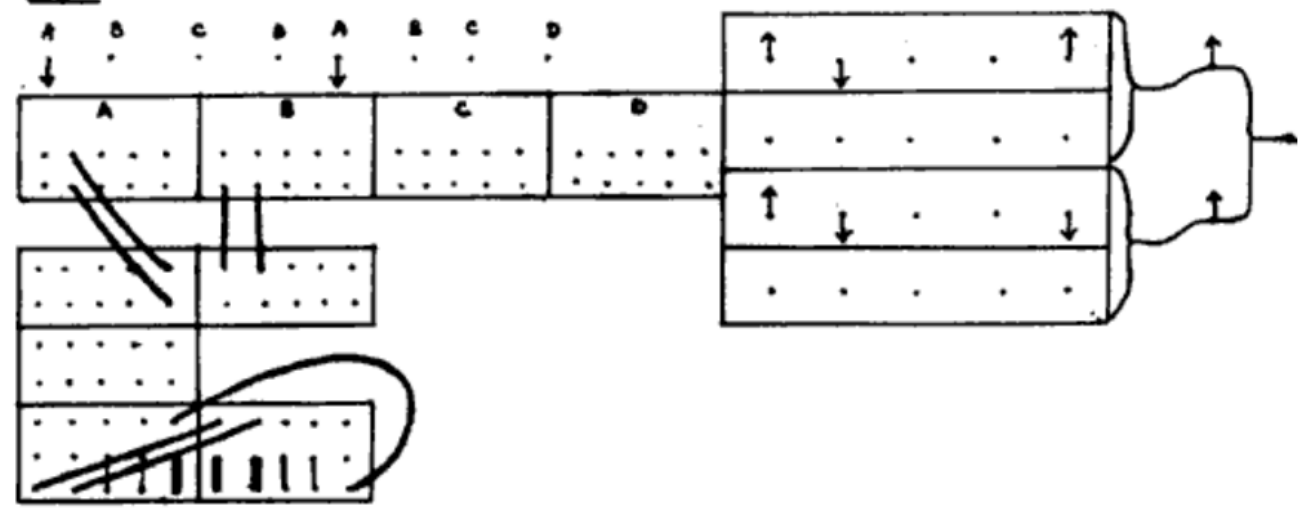
[R3 p 75]

54J SOME ROBINSON PLUGGING USED OPERATIONALLY

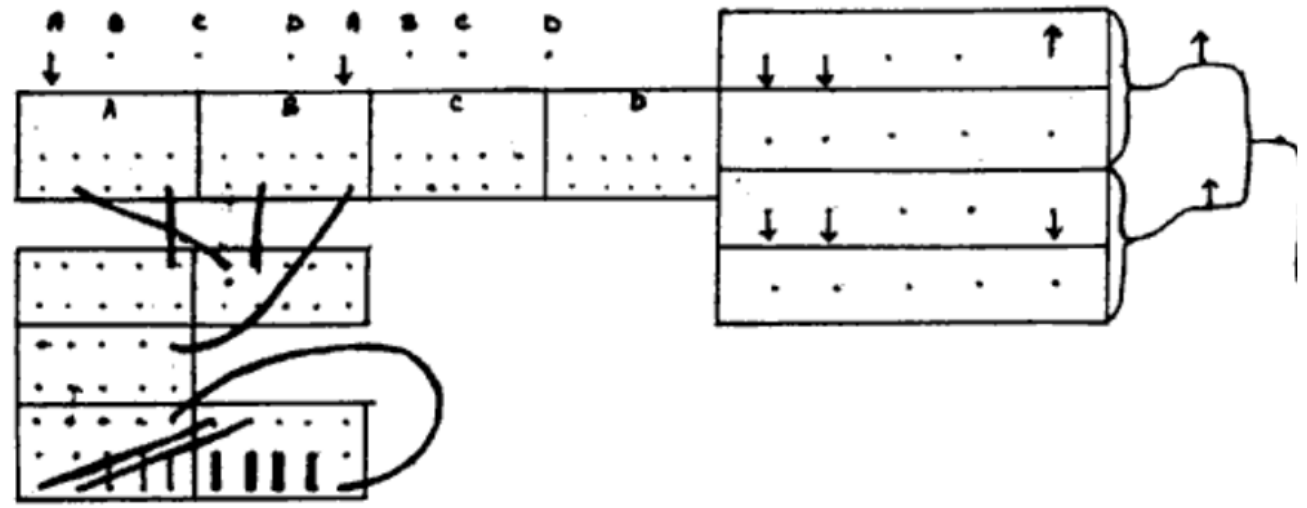
(a) 1+2 Rectangle [54 B(a)]



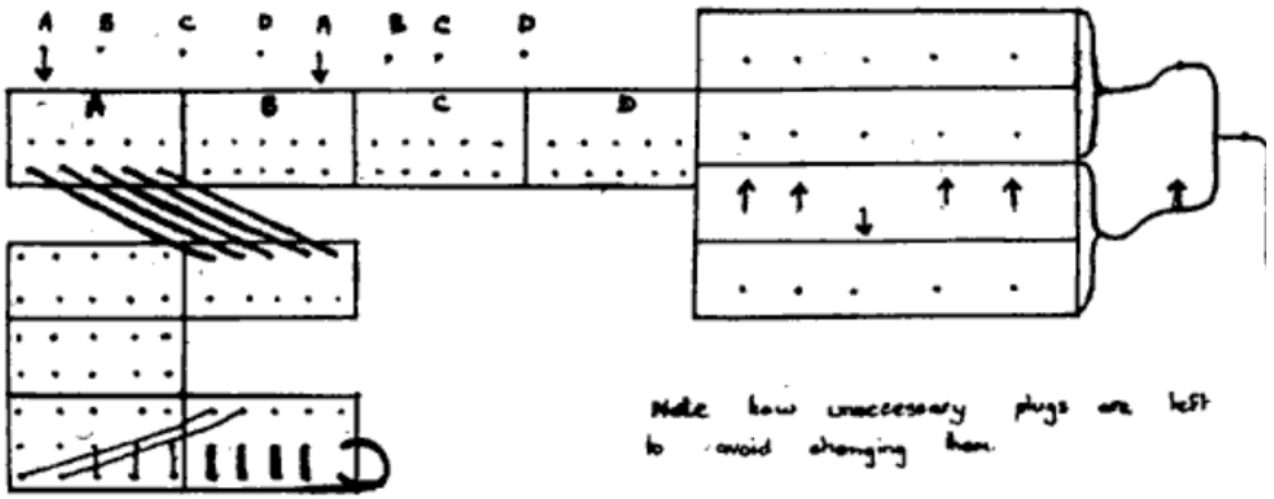
(b) [25 E(a)]



(c) Mechanical Flange [25 C(a)]



(2) Counting 999 on whole Rack.



Make how unnecessary plugs are left to avoid changing them.

55 - SPECIALISED COUNTING MACHINES

55A DRAGON Figs 58(xxvi-xxx) (Details apply to Dragon 2 only)

(a) Purpose and method

The purpose is to set a common crib P, of up to 10 letters, in a given de-chi D, i.e. to find a stretch of D (if there is one) where the underlying plain text is P, so that P + D = Ψ', which when the extensions are removed, yields Ψ.

Dragon adds P to a stretch of D in all positions in turn: in each position it contracts P + D, i.e. omits repeated letters, and then compares each impulse of the result, independently, with the corresponding Ψ wheel : if all five can be fitted the machine stops and displays the settings of D and all Ψ's at the last letter of the crib.

(b) Use of motor or limitation

Although the majority of repeated letters in Ψ' are due to extension some are not, and the method will obviously be more powerful if P + D is contracted only at total motor dots.

Dragon 1 cannot do this; Dragons 2,3 can. In practice if the motor settings are known it is unneccessary to use Dragon: the facility can however be used with great benefit to forbid contraction at limitation dots.

(c) Setting up D, Ψ, χ_2, μ .

(i) The de-chi D is on a tape fed into a tape-reader. Dragon remembers it ten letters at a time.

(ii) The crib P is plugged on a 10 x 5 array of jacks. The length of the crib can be reduced by the top row switches: starting at the left, each switch thrown up cuts out one letter. The only letter which can be cut out from the middle of the crib is the fifth, by throwing its switch down.

There are actually two 10 x 5 arrays, selected by a switch, so that one can be set up while the other is in use.

(iii) Ψ Ψ is plugged up as usual: above each jack is a lamp to show the setting at the end of a successful crib.

(iv) μ, χ_2 μ_1, μ_2, χ_2 have each two rows of jacks, the lower for the pattern, the upper for the setting at the start of the de-chi.

(d) The display

When a crib sets, this shews the settings, at the end of the crib, of μ_4, μ_{37}, χ_3 , D. D is measured in lines of 31.

The display also shows each position (1,2,....9) where P + D has been contracted.

(e) The de-chi display

Above the crib jacks is a display showing, in dots and

crosses, the ten letters currently under examination.

(f) Miscellaneous facilities.

(i) A cut-out switch for each of the five impulses.

(ii) Set total for extensions such that Dragon does not stop unless there is a minimum number of extensions. Switch 5 means 5, switches 5 and i means i.

(iii) Switch for use when setting tapes back, such that the recorded setting of D remains stationary.

(g) Miscellaneous switches

Reset tape, Reset tape and wheels, reset λ, μ, limitation, single step, de-chi display cut-out, test, start-stop.

(h) Dragon 1

Always contracts a repeated letter.

(i) Dragon 3

A much larger machine; can deal with a 16 letter crib, or with two or three shorter ones simultaneously. It can cope with a gap of up to 5 letters in the crib, trying every possible number of extensions in the gap.

(j) Salamander

This is a "compatability" gadget for attachment to Dragon [see 28B (d)].

55B PROTEUS (Figs 55 (1000))

(a) Purpose and method

Proteus anagrams depths [28A(α)(ii)]

The given depth V is known to be the sum of two plain texts $P_{(a)} + P_{(b)}$. It is expected that at some position one of these will be a very common group of plain text, say one of the six commonest: this is called the crib, $P^{(a)}$; and that at the same position the other is a fairly common group, one of several hundred, called the dictionary $P^{(b)}$.

Then of course $P^{(a)} + P^{(b)} + V = /$.

What Proteus does is to add $P^{(a)}, P^{(b)} V$ in all positions looking for a position where the sum is all /'s.

(b) Setting up $P^{(1)}$, $P^{(2)}$, V .

(i) $P^{(1)}$ The crib has a length of seven or fewer letters and is set up by plugging. Each letter has 6 jacks: a cross in the 6th means "ignore this letter". Actually six cribs are set up and examined simultaneously but independently.

(ii) $P^{(2)}$ The dictionary is on a tape running on a Colossus bedstead, with blanks between groups.

(iii) ✓ The depth is on a tape fed into a tape-reader.

(c) Operation

Proteus is started: it reads and remembers the first seven letters of the depth, adds them to the crib, and as the dictionary is scanned adds this also in all positions looking for a click consisting entirely of strokes.

If no click is found, the tape reader steps. Proteus acquires the 8th letter and forgets the 1st, so that letters 1-7 are replaced by letters 2 - 8; and so on.

When a click is found, Proteus stops, and displays

(i) the position in the depth (last letter) measured in lines 31 long.

(ii) the successful crib (1,2,3,4,5, or 6).

The place in the dictionary must be found by hand, (by addition).

The anagram can be checked throwing a switch to "rerun", so re-examining the same seven letters of the depth.

To resume stepping throw the switch to "reset".

(d) Other Applications

Proteus is equally applicable to any mod-2-addition teleprinter cipher which has true depths.

55C AQUARIUS Fig 55 (xxxvi).

(a) Purpose and method

Aquarius sets go-backs [28&(f)] using a de-chi.

In the correct position, the two P's are the same, so that

$$\Delta D_{(a)} + \Delta D_{(b)} = \Delta P_{(a)} + \Delta \Psi'_{(a)} + \Delta P_{(b)} + \Delta \Psi'_{(b)} = \Delta \Psi'_{(a)} + \Delta \Psi'_{(b)}$$

Aquarius adds a stretch of de-chi immediately after the autopause to a stretch before the autopause, differences the sum, and makes counts for resemblance to the sum of two $\Delta\Psi$'s. The proportional frequency of each letter depends only on the number of crosses in it, and the six switches are for counting letters with 0, 1, 2, 3, 4, 5 crosses: throwing more than one switch provides "either - or",

Two counters are provided (generally used for all dots, all crosses.).

(b) Stepping

At first the comparison is made on a steadily increasing text, thus: first 11 letters after the auto-pause with last 11 before; then first 12 after with last 12 before, and so on.

After the text length has reached 97 there is no further increase, but the 97 letters following the autopause are stepped back relative to the part before the autopause. 97 letters are sufficient: in a long go-back the letters immediately before the autopause may be rubbish.

(c) Setting up the de-chi

The most entertaining feature of Aquarius is that the tape is used only at the outset, to set up the de-chi electrically, viz. on condensers : a charge represents a cross: these are automatically recharged at least once every two minutes, according to the rule "to him that hath shall be given".

The tape is marked at the 97th letter beyond the autopause and (switch: reading position, home, charge operating length, start reader) run backwards through a tape-reader and so transferred to the condensers. It stops automatically at the autopause, where its position is checked. Then (switch: charge comparison length, start reader) 218 letters before the autopause are similarly transferred. Switch: comparison length off, reader off, comparison position, home.

(d) Running

A set total is imposed on each counter (for /'s and 8's) and the machine is started.

In a position where the score on either counter exceeds the set total, the machine stops. The set total is taken off and the switch thrown to "rerun" (i.e. count again without stepping). This checks the score and finds the score on the other counter.

To resume stepping the switch is thrown to "go on".

Because the text length increases, the set total requires occassional adjustment.

(e) Impulse cut-out

Switches labelled 1,2,3,4,5 cut out these impulses, causing them to be treated as all dots.

(f) The Buzzer

This is provided to call attention to imminent catastrophe.

56 - COPYING MACHINES

56A Hand Perforator.
56B Angel.
56C Insert Machine.
56D Junior.
56E Garbo.
56F Miles
56G Miles B C D.
56H Miles A.
56J Tunny and Decoding Machine.
56K Tunny.
56L Decoding Machine.

For general description and classification see chapter 13.

56A. HAND PERFORATOR.

Operation of the keyboard produces punched tape.

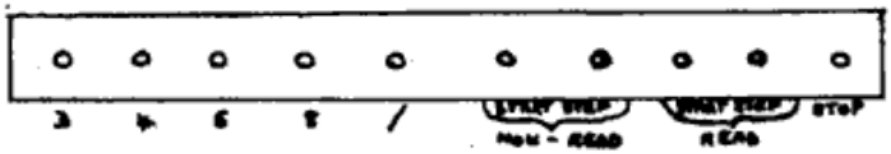
56B. ANGEL.

This simply copies tapes. It consists of a tape-reader linked to a reperforator. To make corrections by hand, it is necessary to stop the machine, and replace the input tape by one bearing the letter to be inserted.

56C. INSERT MACHINE.

(Vulgarly known as the IBM machine)

Functionally this is an Angel with a device for making corrections by hand easily. In addition to the reader and reperforator it has a punch insertion typewriter to which nine special keys have been added, thus



For normal running use "read" : "start" means start and continue to run; "step" means step one letter.

To insert letters, "stop" and
for A to Z use the ordinary keyboard;
for 9 use the space bar;
for 3458/ use the special keys.

To step the reader but not the reperforator use "non-read".

To step the reperforator but not the reader use special key "/".

To correct a letter, use "non-read", and insert.

The tapes produced are unsuitable for Colossus and need to be copied.

56D. JUNIOR.

(a) Function.

Junior prints from a tape. It consists of a tape-reader, a steckerboard, and an electric typewriter.

By steckering any character can be made to print any other character. Any number of characters can be steckered to print the same character.

(b) Details of steckering.

The three upper rows of jacks carry the output from the reader.

The three lower rows carry the input to the typewriter.

Steckering is effected by plug cords.

Letters not steckered are printed normally (as Tunny letters, e.g. 5 as 5 not by actual figure shift).

Different letters to be printed alike are plugged into a common jack and thence to the desired letter.

To common a large group of letters a Ring Common can be used.

The reader output has two jacks for each letter, a mere shorting plug in the upper jack connects the letter to Ring Common RC 1; a plug in the lower jack connects it to RC 2. RC 1, RC 2 can be plugged to any desired letters : if they are left blank the letters commoned into them are printed as ., x respectively.

In a jack carrying input to the typewriter FS means literally figure shift; 5 means 5; similarly for CR etc. Note : some Juniors have a different and much smaller steckerboard, unsuitable for rapid steckering.

(c) The Typewriter.

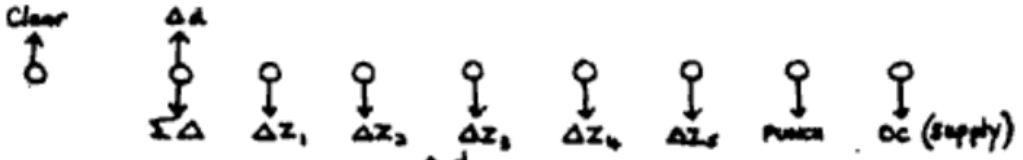
This has three switches : "start"; "stop" and "insert". "Insert" causes the whole machine to stop at the end of each line. The arrangement of these switches varies considerably.

The typewriter can be set to print in any width up to 60.

Letters can be inserted by using the keyboard.

56E. GARBO. Fig 55(xxi).

Everything said about Junior applies to Garbo : the only difference is that, in addition, Garbo has a row of switches for Δ'ing. Garbo always Δ's backwards.



1. If the switch labelled $\overset{\Delta d}{\Sigma\Delta}$ is thrown to Δd, each letter is differenced; it may thereafter be steckered.

2. If the same switch is thrown to $\Sigma\Delta$, and some Δz swithhes are thrown the corresponding impulses are differenced and added, being printed as . or x : no steckering is needed.

"Clear" merely clears any letter left from the preceding run.

"Punch" is thrown if the output is connected to a punch instead of a typewriter.

56F. MILES.

(a) Function.

A Miles is a machine which when fed with one or more tapes produces a tape combining them in some way.

(b) The early Miles.

The early Miles could combine tapes by adding them (in the Tunny sense). Impulses could not be permuted, though an impulse could be cut out. No further description is given.

(c) Miles B, C, D.

These are a development of the early Miles. With no plugging and switches all normal the tapes are merely added. By plugging impulses can be permuted. Differencing is not possible except by using two tapes at a stagger of one. (Details : 56G)

(d) The Mechanical flag Gadget (Miles D).

This introduced an extension of the notion of combining tapes, viz that one tape can be used to control the stepping of another, or of itself. (Details 56G (m)).

(e) Miles A.

This was designed to be as flexible as possible : nothing is transferred from input to output without being plugged. Plugging is therefore usually more extensive than on Miles B,C,D; but because it is based on a simple uniform principle (56H (c)), it is very easy and can be made quickly.

Differencing, up to eight times, is provided by means of memory circuits. (Details 56H).

(f) Performance of Miles

This has not been entirely satisfactory. These machines could not of course claim the attention devoted to Colossi, but even relatively they have been rather neglected. The design is believed to be sound, but there has been no adequate supply of spare parts. In particular Miles A has been rarely in proper working order, the existing model being the experimental one, not really intended for regular use: this rather than the extra plugging, explains the operators' preference for B,C,D.

(g) Possible Improvements.

The ideal Miles would probably be on the lines of Miles A. It would be desirable to include a generalization of the Flagging Gadget [56G (m)], viz. an automatic stepping control such that any reader or reperforator control could be started or stopped either by pulses from any tape or after a fixed number of letters : one suggestion is two automatic control jacks (stop and start) on each reader and reperforator control, into which any pulse could be plugged.

If Miles were required to combine letters in accordance with a general combination square, extensive changes would be needed.

The counters would probably be of real use only if they could be reset to zero.

56G MILES B,C,D.

(a) Layout

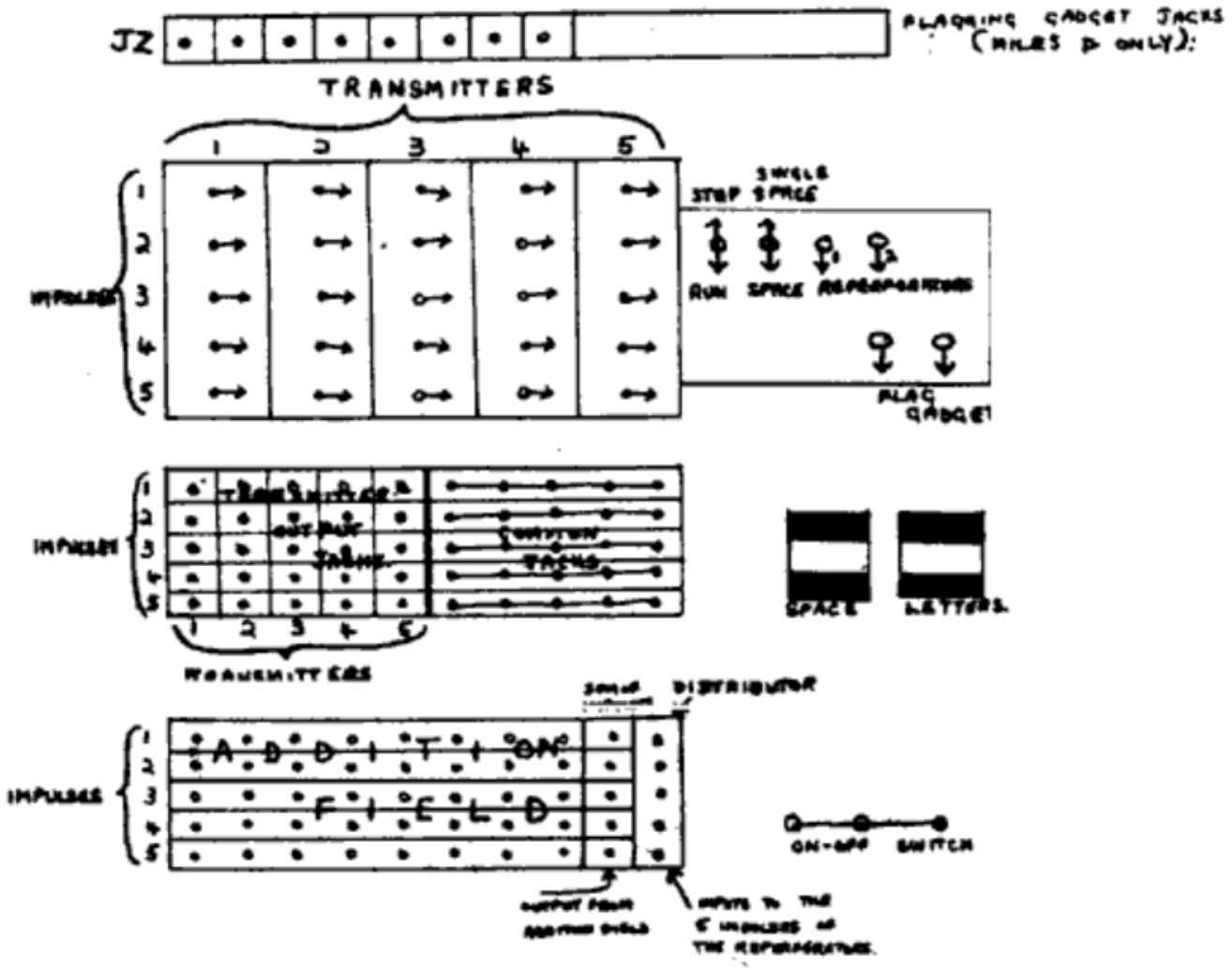
Each of these consist of 5 tape-readers, a plugboard, and 2 reperforators.

B is now incomplete.

The control panel is arranged as in the following diagram.

This may be compared with the photograph (Fig 58(xxvi)).

In the description of Miles, tape-readers will be called transmitters, as is customary: these are not auto-transmitters.



(b) The items of the plugboard

1. Transmitter impulse cut-out switches.

2. Transmitter output jacks, each carrying one of the 5X5 impulses for the 5 transmitters.

3. Addition field : this has 5 rows of jacks, one for each impulse.

4. Sum of impulses : these 5 jacks are the output jacks for the 5 sums of the addition field.

5. Distributor : these 5 jacks carry the input to the 5 impulses of the reperforators.

6. Commons : each row constitutes one common jack.

(c) Normal Connection, ie. without plugging.

The first impulses (for example) from all five transmitters are added in the first row of the addition field and taken to the first impulse of "Distributor".

(d) Plugging and Switching.

The more important items are described in paras. (e) (f) (g) (h) (i).

(e) Impulse cut-out switches.

Any impulse can be cut out completely by its impulse cut-out switch : if all the impulses of a transmitter are cut out it does not step.

(f) Transmitter output jacks.

Any one of the 25 impulses in the transmitter output jacks can, by the obvious plugging, be transferred to a different row of the addition field. This means that it is

(i) cut out from its own row

(ii) added to the impulses already in its new row.

For example, if T4 T5 are cut out, and a plug cord is taken from $T3_1$, the first impulse of T3, to the second row of the addition field the first row now carries $T1_1 + T2_1$ and the second row $T1_2+T2_2+T3_2+T3_1$.

(g) Adding a cross.

A shorting plug in a jack of addition field adds a cross thereto.

(h) Permuting sums of impulses.

The outputs from the addition field can be transferred to other impulses, cancelling what is already there e.g. if the 2nd impulse in 'Sum of Impulses' is plugged to the 5th impulse of 'Distributor', the reperforators will have nothing in the 2nd impulse, and whatever is in the 2nd row of the addition field in the 5th impulse.

(i) Common jacks.

These, unlike the other jacks, are not permanently connected to anything else.

Impulses plugged into a common jack are added, not in the ordinary way, but by the rule that the output is a cross unless all inputs are dots (Boolean addition).

Two or more outputs can be taken.

(j) Reperforators.

Either one or both can be used.

(k) Counters.

(Cyclometers) are supposed to record the number of blanks and letters punched : they were used very little and all but one are out of order.

(l) Miscellaneous switches.

Step ("run" on Miles D) causes both the transmitters and reperforators to start and continue to step.

Space causes the reperforators to step, and punch blanks, the transmitters remaining stationery.

Single step, single space can be flicked on and off for a single step or space.

The unlabelled switch to the right of the reperforator switches on Miles C controls an improvised gadget used for making motor tapes when Tunny was disabled by the Fire (See Glossary).

The pair of switches below these on Miles D are for flagging (Next para. 56G.).

The Triple switch is the on-off switch.

(m) Mechanized Flag Gadget (Miles D only).

The basic idea is to control the stepping of transmitters automatically be means of impulses from the tapes themselves.

This may be needed if tapes are to be combined not concurrently, but consecutively, in a large number of stretches.

The gadget was made specially for Mechanical Flagging (56 95) without much regard to flexibility. Nevertheless, though designed for ordinary flags it proved suitable for combined key flags, when it is used quite differently.

This explains the rather odd facilities available.

The gadget manifests itself as a series of jacks JZ1 - JZ8. A cross in :

JZ1,2,3,4 starts transmitters 1,2,3,4, respectively.
JZ5 produces a cross in JZ7 and, if JZ1,2,3,4 are all dots, produces a cross in JZ8 & steps transmitter 4.
JZ6 stops transmitters 1,2,3,4 and steps transmitter 5 one sprocket hole.

The gadget has two switches : the right hand one switches in the gadgets, the left hand one then acts as an off switch.

56H. MILES A.

(a) Layout (see photograph Fig 56(xxxi)).

There are
6 Transmitters.
3 Reperforators.
3 Controls (which control the stepping of both transmitters and reperforators).
6 Common jacks.
8 Sets of jacks for differencing an impulse (backwards) or taking an impulse one back.
2 Sets of extra jacks for addition.

(b) All 28 items are completely independent.

Three different tape-making jobs may be done simultaneously, each being started and stopped by its own control without interfering with the running of the others. The allocation of items to each job is quite arbitrary.

At the other extreme one control may control everything, producing identical tapes from all three reperforators.

The linking of items is by plug cords.

(c) Principle of plugging.

Plugging depends on a very simple principle

Each item has a series of corresponding { IN jacks / OUT jacks

Any impulse plugged into an IN jack appears suitably modified in the corresponding OUT jack.

NOTES. Reperforators have, naturally, no OUT jacks.
Even transmitters have IN jacks.
In a common jack, IN and OUT jacks are the same.
In a control, OUT jacks are common to all 5 impulses.
Corresponding IN and OUT jacks are in the same column.

(d) The effects of the various items on an impulse taken through them.

(i) Any one of the 5 impulses of a transmitter : adds that impulse.

(ii) Common jack : the impulse can be taken out on several cords.

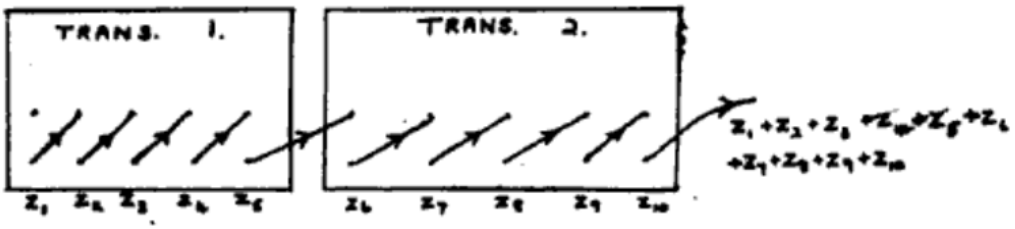
(iii) Delta*; from $\bar{I}$: the same impulse one back.
from Δ : the same impulse Δ'd backwards (Δ'd).

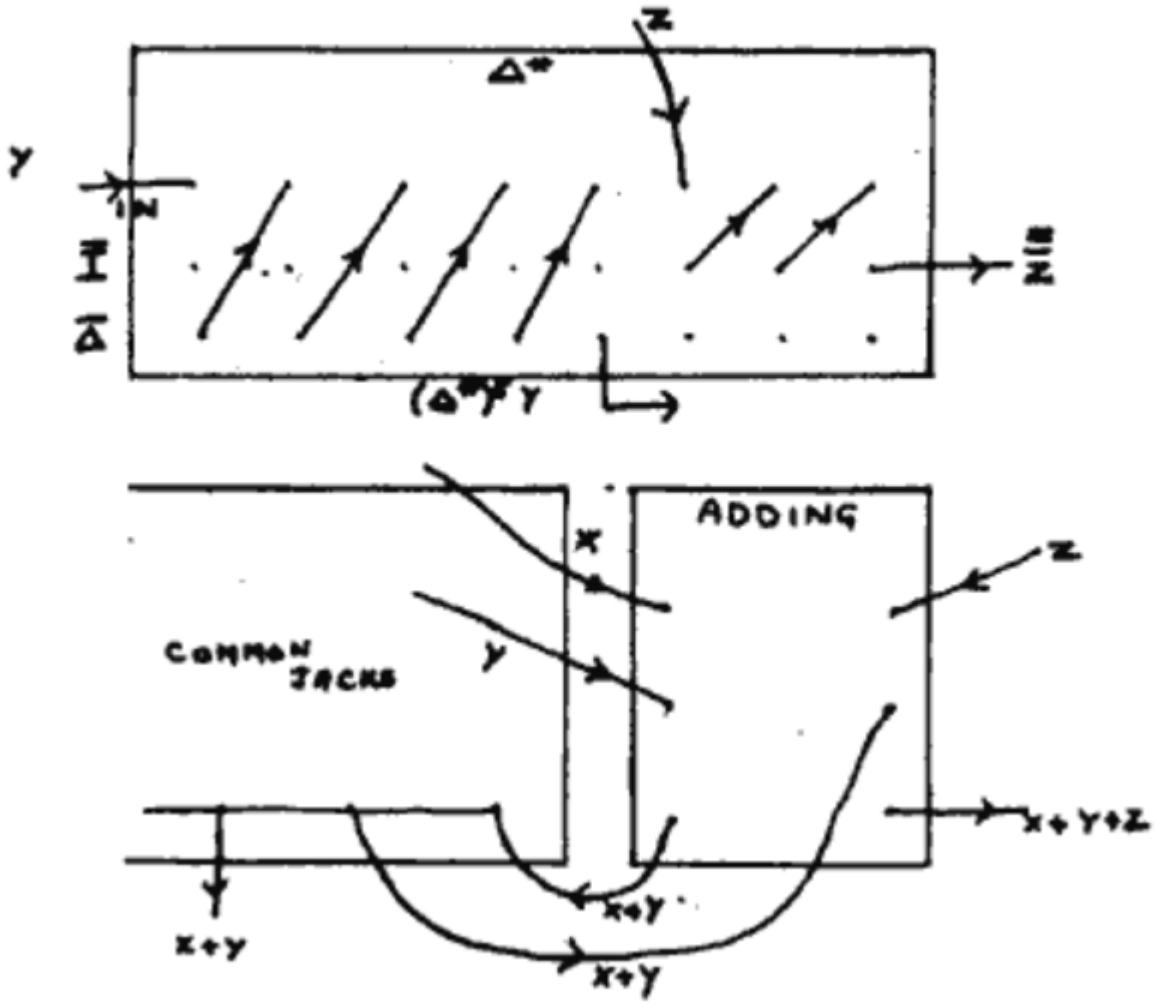
(iv) "Add" : two inputs can be added (may be useful for adding two impulses already complex).

(v) Controls : the impulses plugged into a control can be taken out into reperforators (only one cord for each reperforator); each impulse is punched in the corresponding impulse of the tape.

"IN and OUT" can be continued without restriction as long as there are jacks to spare

(e) Examples :


TRANS. 1.
TRANS. 2.
z_1 z_2 z_3 z_4 z_5
z_6 z_7 z_8 z_9 z_{10}
$z_1+z_2+z_3+z_{10}+z_5+z_6$
$+z_7+z_8+z_9+z_{10}$



A good practical example is given in 27.

An amusing example is to take an impulse to a common jack thence (i) to control (ii) one back ($\bar{I}$) to the IN jack of the same impulse.

This integrates ($\omega - \Delta$) the impulse : it can be applied to five impulses simultaneously.

56J TUNNY AND DECODING MACHINES

The original Tunny machine was simply a functional reproduction of the German Tunny machine, operated electrically instead of largely mechanically. It was intended primarily for straight forward decoding. It was developed in two directions:

(i) as a decoding machine improvements were effected and gadgets added for ease of operation, not for versatility.

(ii) as an aid to Newmanry setting and breaking, much more versatile models were produced.

There were several versions of each, some of the early ones being very awkward in operation e.g. patterns were set up by means of U-shaped pins, and wheels were reset by stepping each uniselector switch by hand, one position at a time, and forwards only. Only the later models will be described.

A weakness common to all Tunnies is that the five impulses of each letter of Z are sent through the machine successively, though by different routes, and can be added or permuted only with the aid of remembering circuits. This restriction does not apply to the wheels.

56K THE (NEWMANRY) TUNNY MACHINE (Fig 58 (xxv))

(a) General description of operation.

The tape is fed into an auto-transmitter: Chi, psi, unless cut out, are added automatically, and the sum appears on another tape, letter by letter. At each letter the current settings of all wheels are exhibited.

(b) Wheel-patterns.

Each wheel has two rows of jacks, in which shorting plugs can be inserted. The upper row represents the pattern; the lower row determines the initial setting. Each wheel has also one row of indicator lamps to show its current setting.

The "display" shows not the wheel settings but the number of positions through which the wheels have moved: the three rows of figures correspond to Chi, (with Z and μ_{61}) μ_{37}, Psi. Each row has a cut-out switch.

(c) Limitation

Switches K P S (for $\overline{\chi}_1$, $\overline{P}_5$, $\overline{\psi}_1'$,) one or more being thrown determine the limitation.

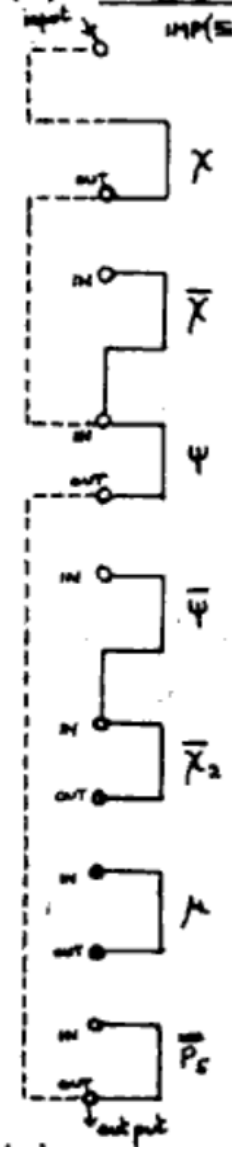
The characters of $\overline{\Psi}$, $\overline{P_5}$, $\overline{P_6}$, which are just before the start of Z can be preset by spring switches: $\overline{P_5}$ $\overline{P_6}$ are set simultaneously by switch positions: .. , .x, x., xx .

(d) Wheel switches.

Each wheel has a separate switch. Unless a wheel is switched in, it has no effect whatever, e.g. if χ_2 is not in, the limitation will be incorrect and the psis will move incorrectly [c.f. Para (e)].

The chi, psi master switches merely determine whether the wheels move or remain stationary.

(e) Plug panel.



In normal operation the motion of the psis depends on some or all of Z, Chi, Psi, Motor, but only Z, Chi, Psi are added in the resultant tape. It is sometimes desirable to modify this in various ways, e.g. in a total motor tape μ_{37} and the limitation are involved in the resultant tape; Z, Chi, Psi are not to be added to it, but Z, Chi, Psi (or χ_4 at least) cannot be switched out [compare para (d)] because they determine the limitation.

To each of the five impulses corresponds a column of jacks (see diagram : where no suffix is shown, that corresponding to the column is to be assumed). It will be seen that Psi, $\bar{\chi}_2$, μ, $\bar{P}_5$ have each an "in" jack and an "out" jack. Anything put into "in" appears at "out" with the appropriate impulse added to it. Chi has no in jack being normally connected to "IMP", which is in effect, "Z out". $\bar{\chi}$ $\bar{\psi}$ have no out jacks being permanently connected to ψ , $\bar{\chi}_2$ respectively. Chi and psi are normally connected both up and down (dotted lines), but a plug inserted in one of their jacks automatically breaks the normal connection to that jack.

Wheels may be transferred from one column to another, but Z cannot.

There are a few common jacks.

(f) Stop setting.

Decode switches reading 0-9999 can be set so that the machine stops after so many letters of Z.

(g) Contraction.

Because Robinson psi-setting required a de-chi tape contracted by the omission of letters against total motor dots [52 (d)], several Tunnies included a facility for making such tapes.

(h) Miscellaneous facilities.

(i) Reversing one or more of the five impulses.
(ii) Making blank one or more of the five impulses.
(iii) Running backwards.
(iv) Encoding with P_5 limitation.
(v) Innumerable switches for cutting out lamps.

(i) Differencing.

Tunnies "1" and "3" can produce differenced tapes.

56L. DECODING MACHINE. Fig 58(XXIV).

(a) General description of operation.

Given a cipher text all of whose settings are known, the appropriate patterns, settings and limitation are imposed, and the machine is started.

As each letter of cipher is typed out on the keyboard, Chi, Psi, are automatically added so that a letter of clear text is printed.

In place of the keyboard an auto-transmitter reading a cipher tape can be plugged in, but its speed is apt to be too great for the machine.

The settings of all wheels at each letter are shown by indicating lamps.

For swift operation some switches are on a control box adjacent to the keyboard.

(b) Wheel patterns.

See 56K(b), but there is no display of positions moved through, only of current settings.

(c) Limitation.

See 56K(c).

(d) Chaser settings.

In early models if it were necessary for any reason, such as typists' error or corruption, to start again a few places back, the position of each wheel had to be calculated and set separately. This is now avoided by "chaser settings" which are stationary during ordinary running, but

(i) the "set reading" switch causes the chaser settings to move forward to current settings (used once per line or so)

(ii) the "reset" switch causes the current settings to move back to the chaser settings.

These switches are duplicated on the control box.

The same lamps are used to indicate both current and chaser settings, but confusion is avoided by "DCL" which extinguishes the chaser settings.

(e) Snaking

On corrupt texts using P_5 limitation the psis may be incorrectly motorized. If the SN and the psi cut-out switches are in the active posision, then each time SS is thrown the psi settings are increased by one. Several versions for different psi settings can be printed: by "snaking" through these the clear text can be found. In practice it was done better by hand.

(f) Chi, mu, Psi cut-out switches.

These switches (on the control box) cut out a set of wheels completely, including their effect in the total motor.

Cutting out Psi produces de-chi, which may be checked against that provided by the Newmanry.

(g) χ_2 inside out

This switch interchanges dot and cross in χ_2 .

57 - SIMPLE MACHINES

(a) Slide-rules

The operations required are multiplication, division, squaring, extracting square roots, and taking logarithms to base 10. Many of the slide rules used lack logarithms, and have elaborate useless scales.

(b) Adding Machines

"Plus" comptometers are used, reading up to 10^9. For each digit there is a column of five keys 1,2,3,4,5. These are quite suitable, though a few specimens wasted three columns by provision for adding £.s.d.

(c) Hand Counter (For counting sprocket holes in tapes).

The tape is carried forwards by a sprocket wheel, against which it is held by a hinged wedge made of perspex. The wedge is made transparent so that characters can easily be indentified; its edge is used as a ruler for marking the tape.

A single handle drives both

(1) the sprocket-wheel,

(2) a cyclometer.

The cyclometer is geared so that each movement of one sprocket increases the reading by 1. The cyclometer can be reset to zero.

Hand counters were at first very troublesome.

(d) Sticker

This is a long tape guide with four dummy sprocket teeth to hold two tape ends in the correct relative position for jointing ("sticking") them.

For Colossus tapes Secotine was used as the adhesive. For Robinson tapes Bostick, which yields a weaker but flatter and more flexible joint, was used, the central part of the sticker being heated electrically.

(e) Stop and Start

A simple hand punch for punching the holes, in the 4½th and 3½th impulses, used as start and stop signals. To make it easy to place the tape correctly the slide which holds it has an engraved mark (for the first or last letter) and a dummy sprocket tooth.

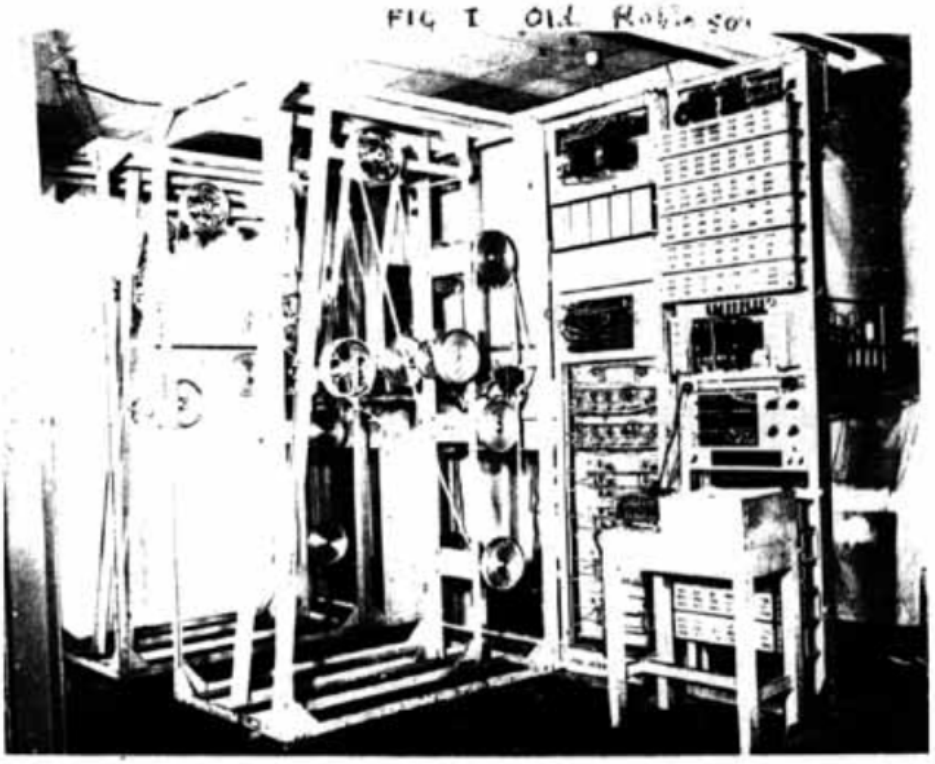


Fig. I

Old Robinson (52 (c)).

Fig. II

Specimen of Old Robinson printing (52 (c)).

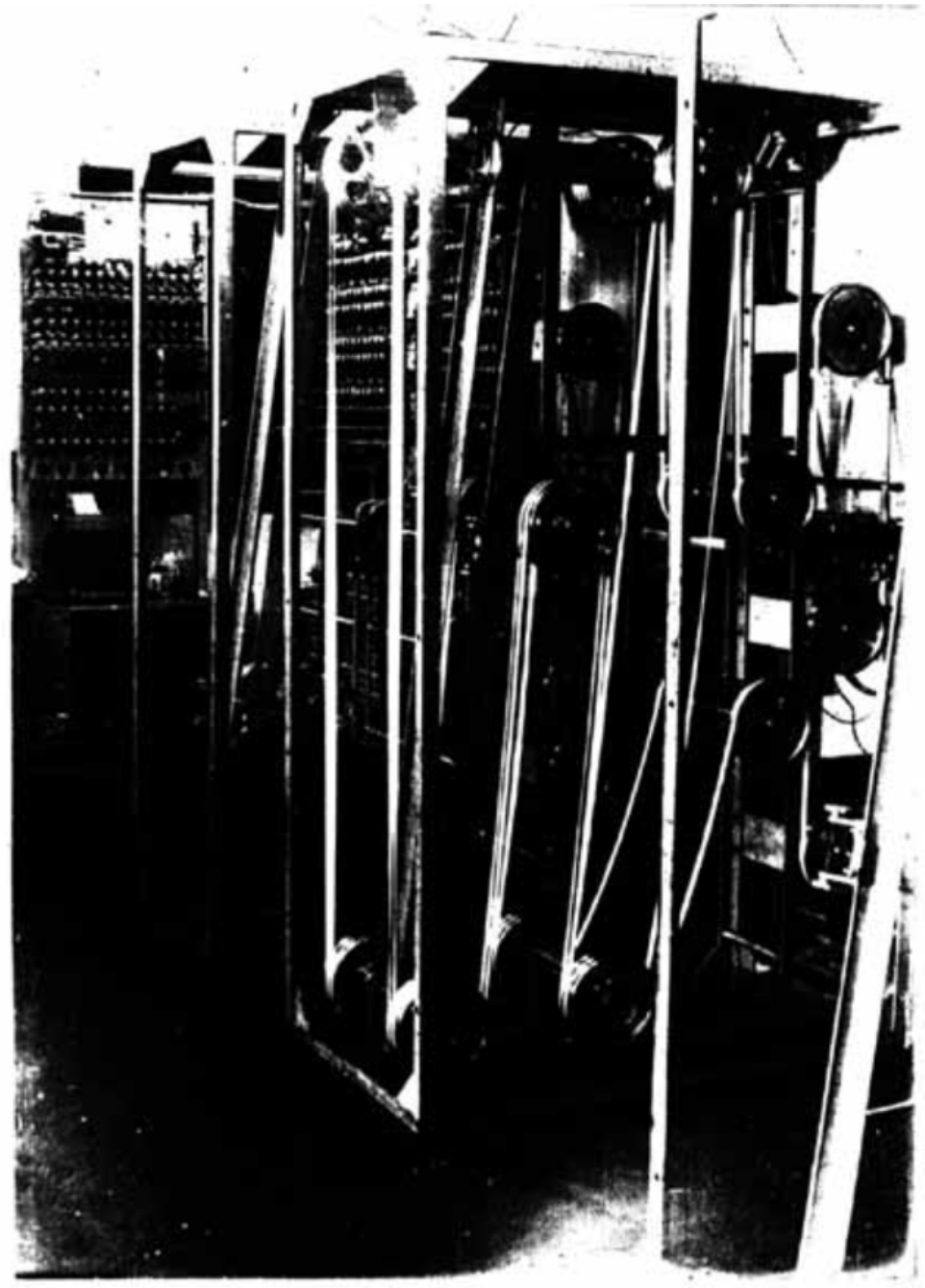


Fig. III

Super-Robinson (54)

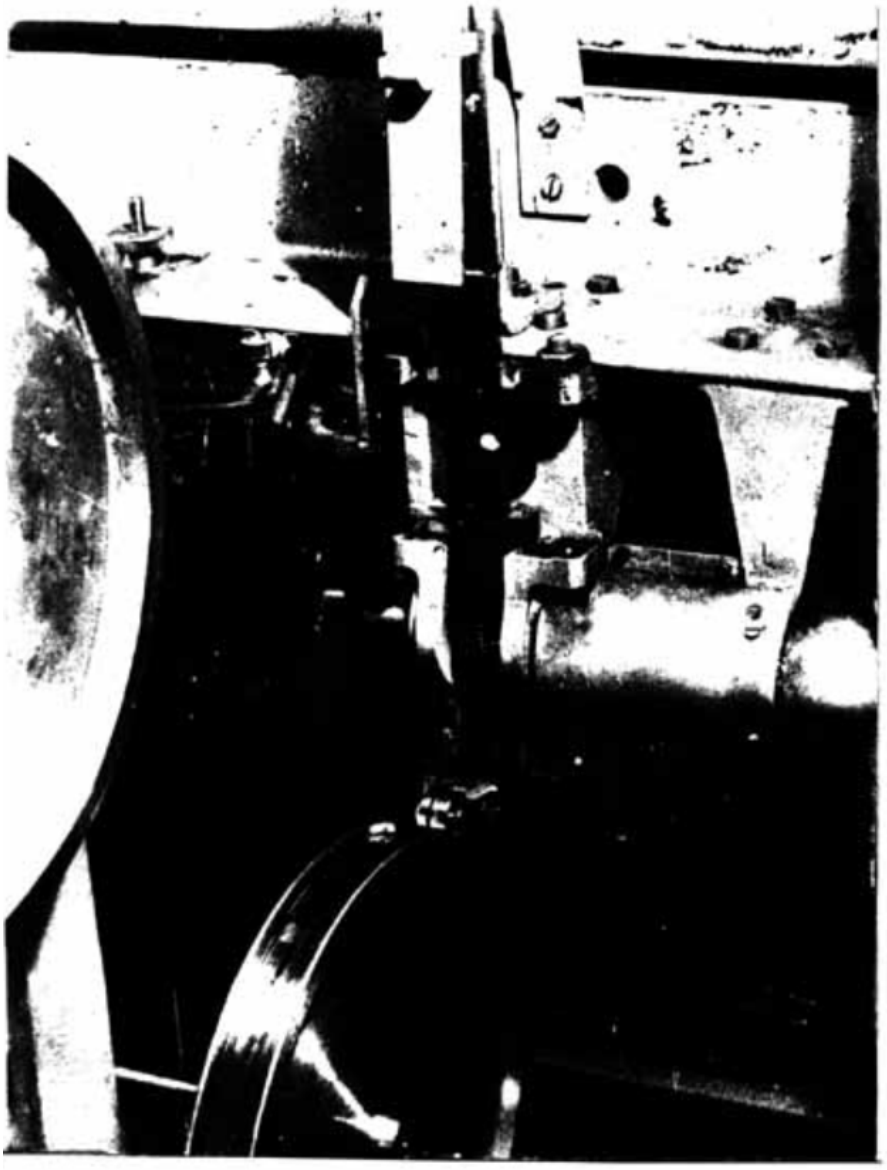


Fig. IV

Super-Robinson: details of gate. Note sprocket teeth and 13 holes through which light passes to photo-cells.

(54C(c))

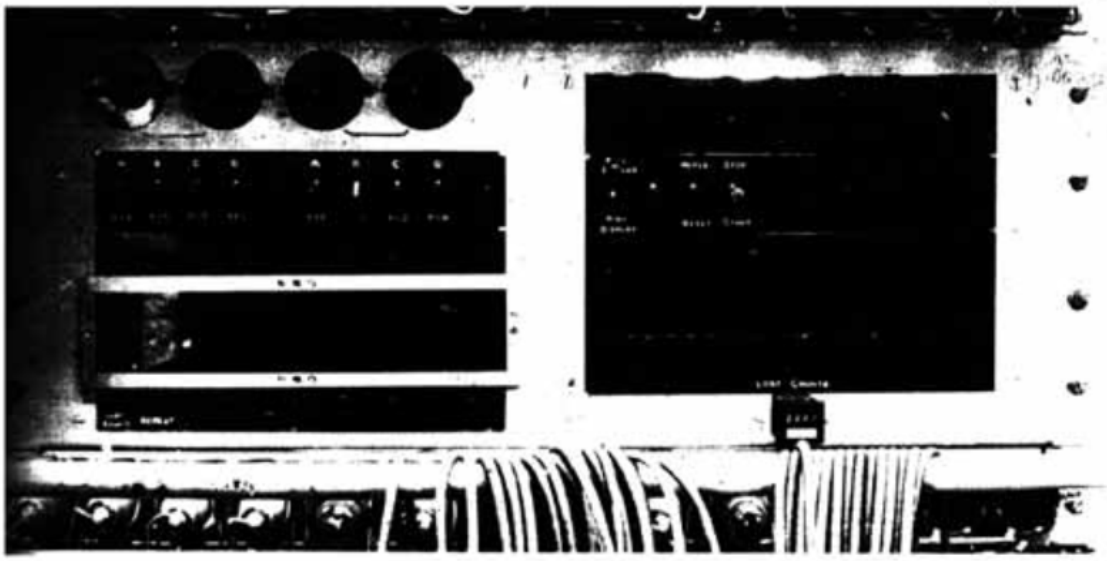


Fig. V

Super-Robinson position counter switches (54C(e,f,g)), display (54B), miscellaneous switches.

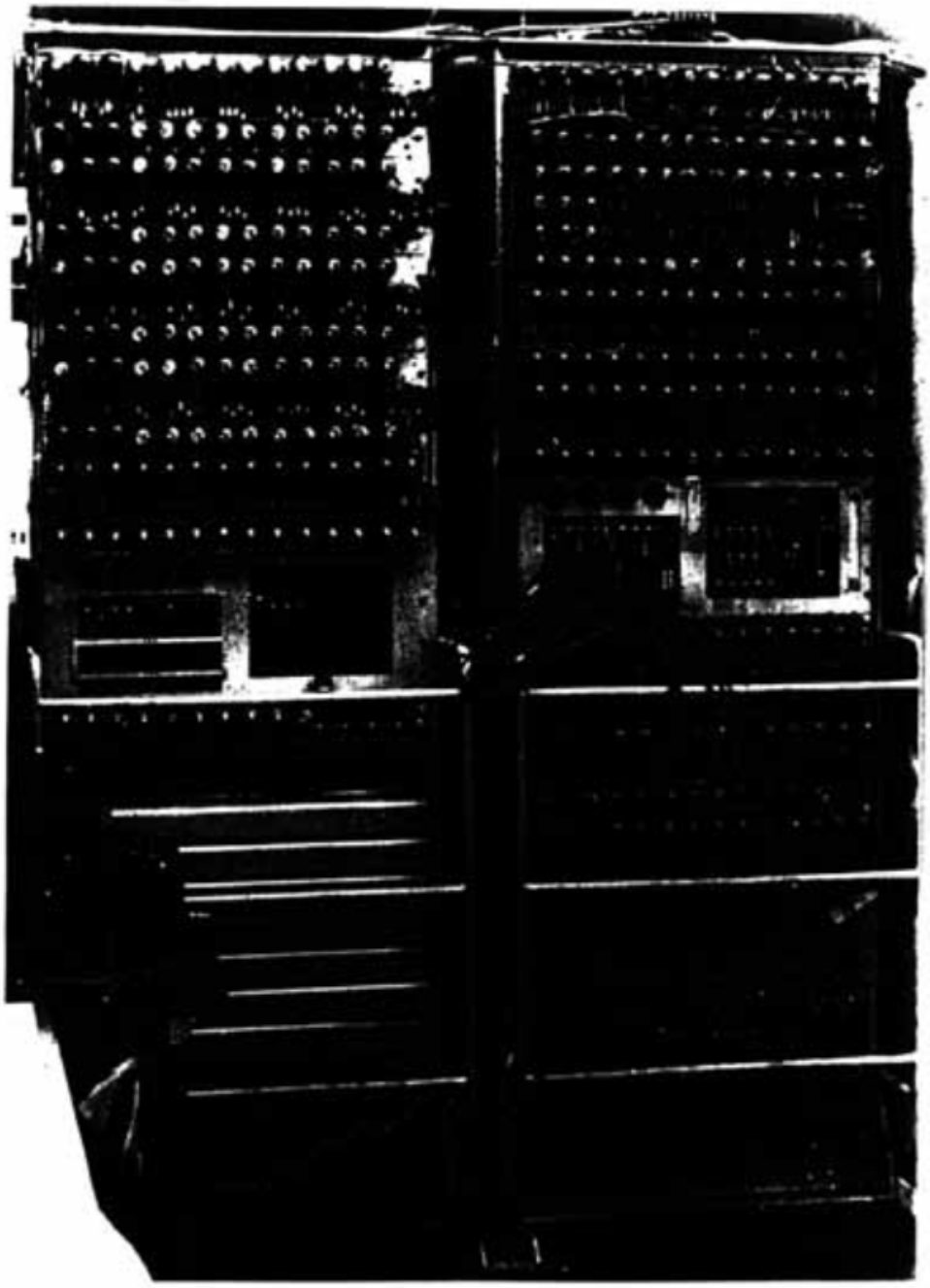


FIG VI

Super - Robinson: panels.

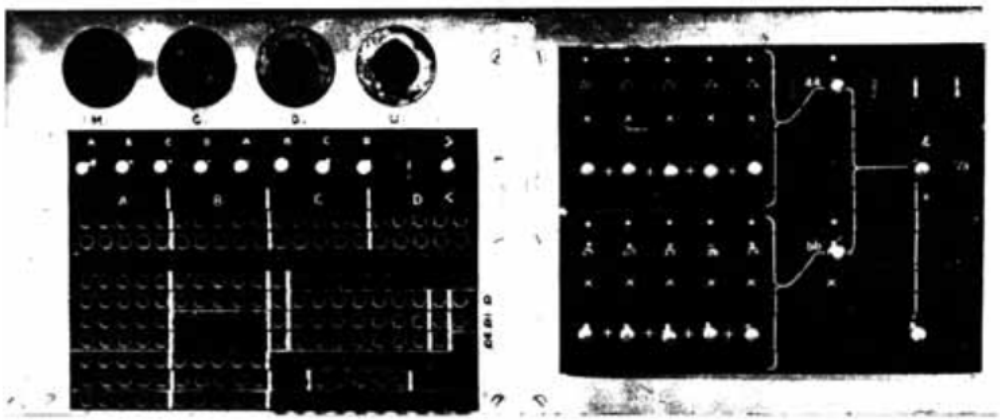


Fig. VII

Super-Robinson: plug Δ switch panels (54D, 54E), "start" & "stop" switches (54C(d))

Fig. VIII

Colossus 5: back view. (53)

Fig. IX

Colossus 10. (53)

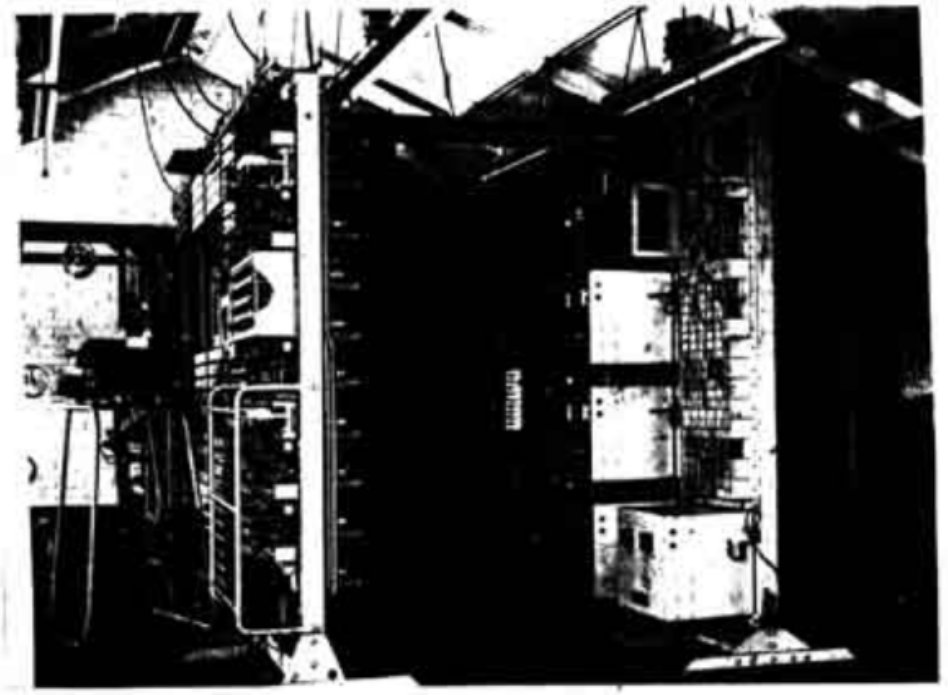


Fig. X

Colossus 7. (53)

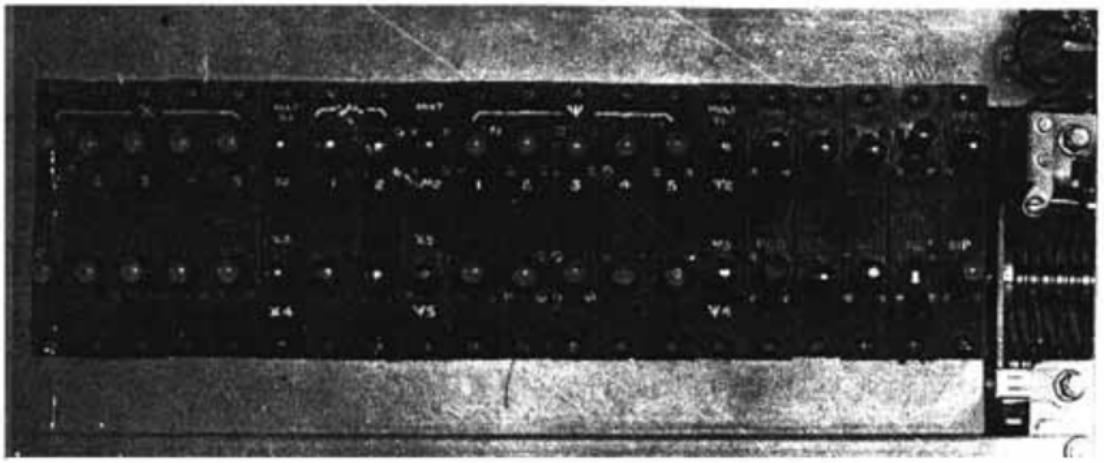


Fig. XI

Colossus 10: control panel. (53N)

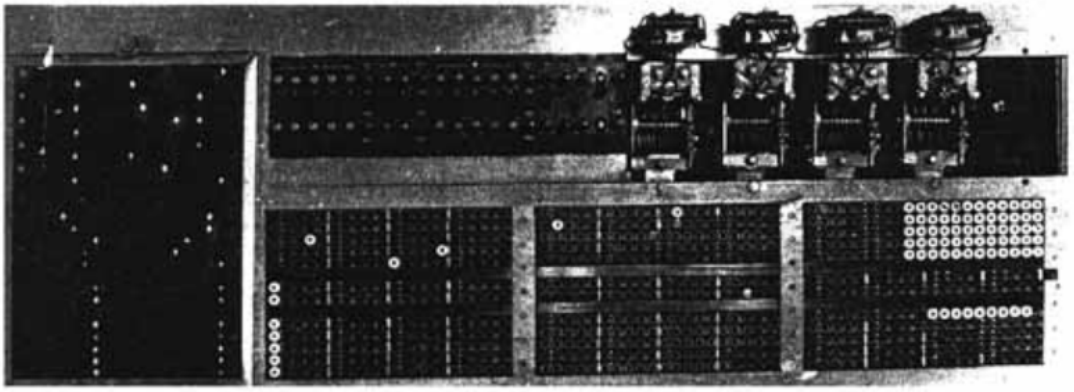
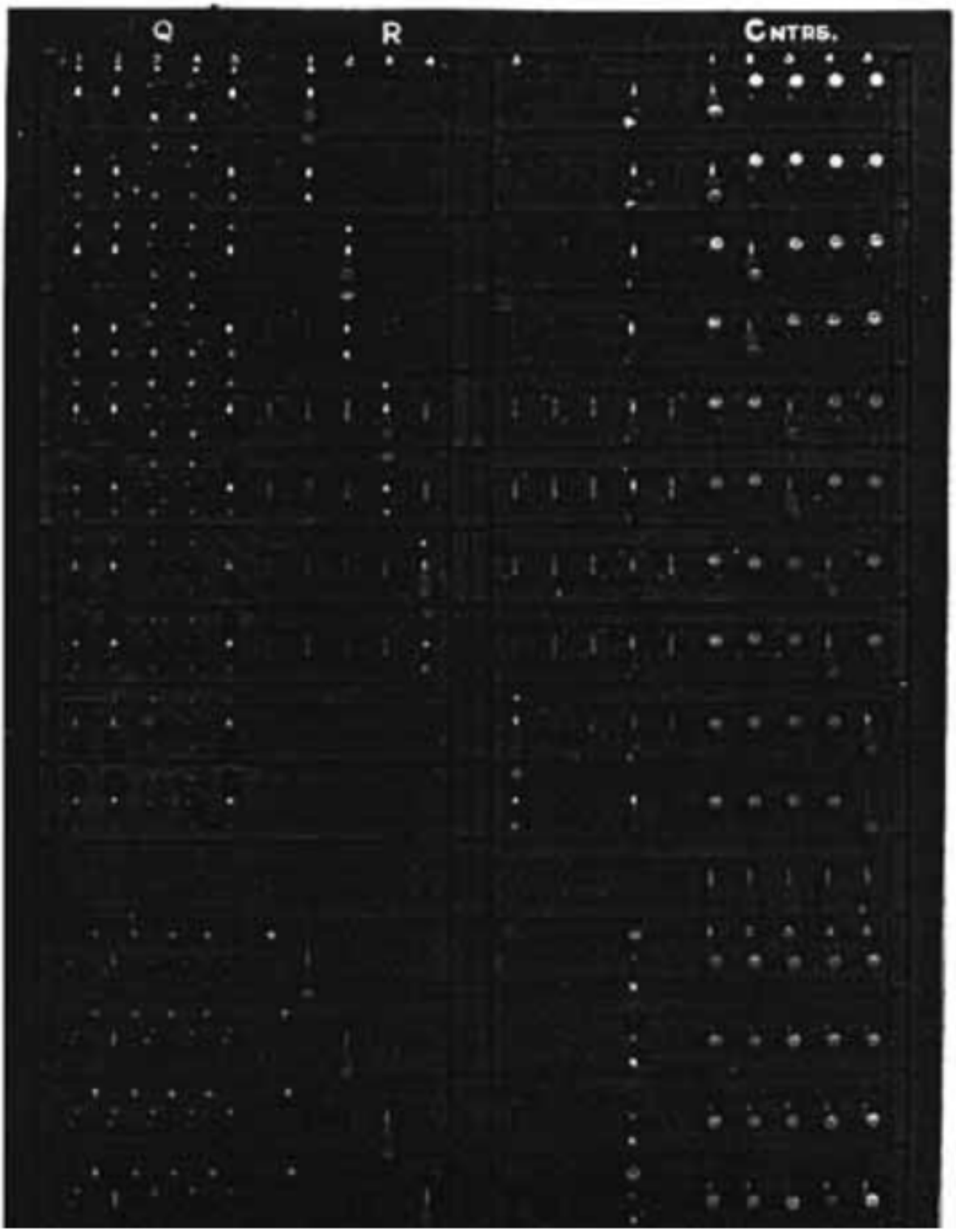


Fig. XII

Colossus 10: display (53G) control panel setting jacks (53D)


Q
R
CNTRS.

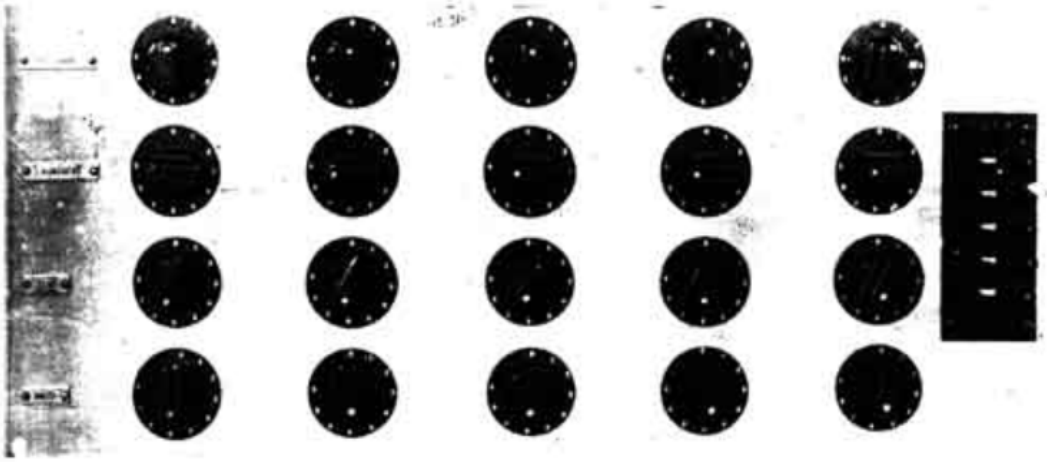


Fig. XIV

Colossus 10: set total switches (53G(a))

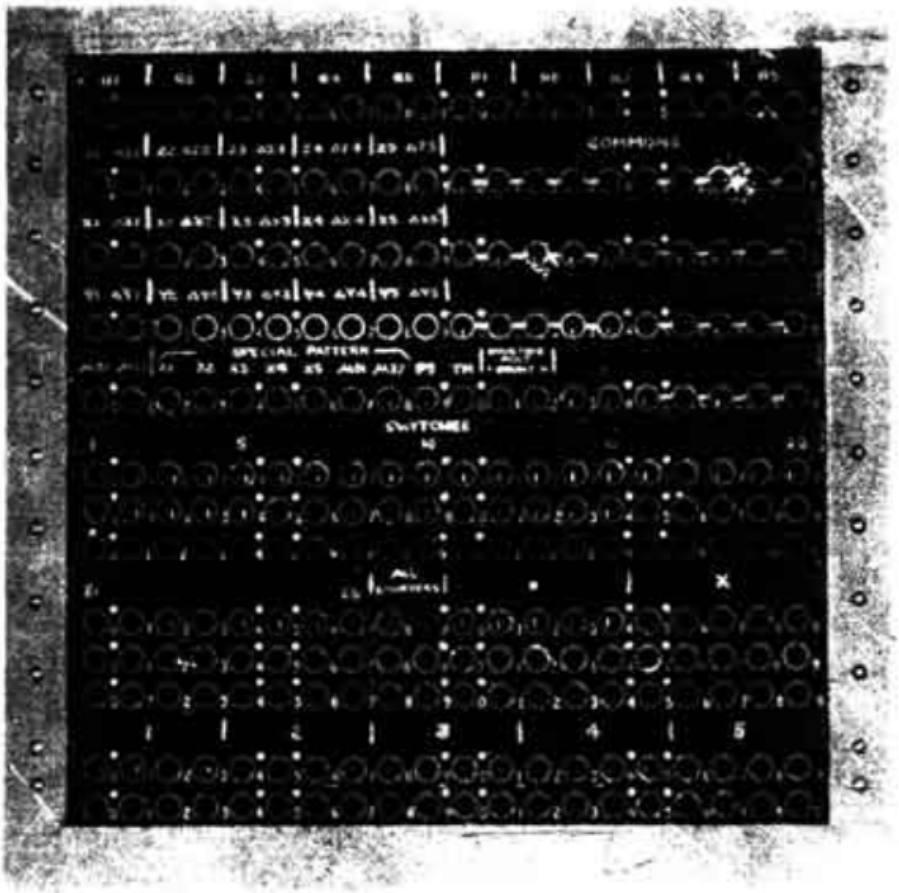


Fig. XV

Colossus 10: plug panel. (53K)

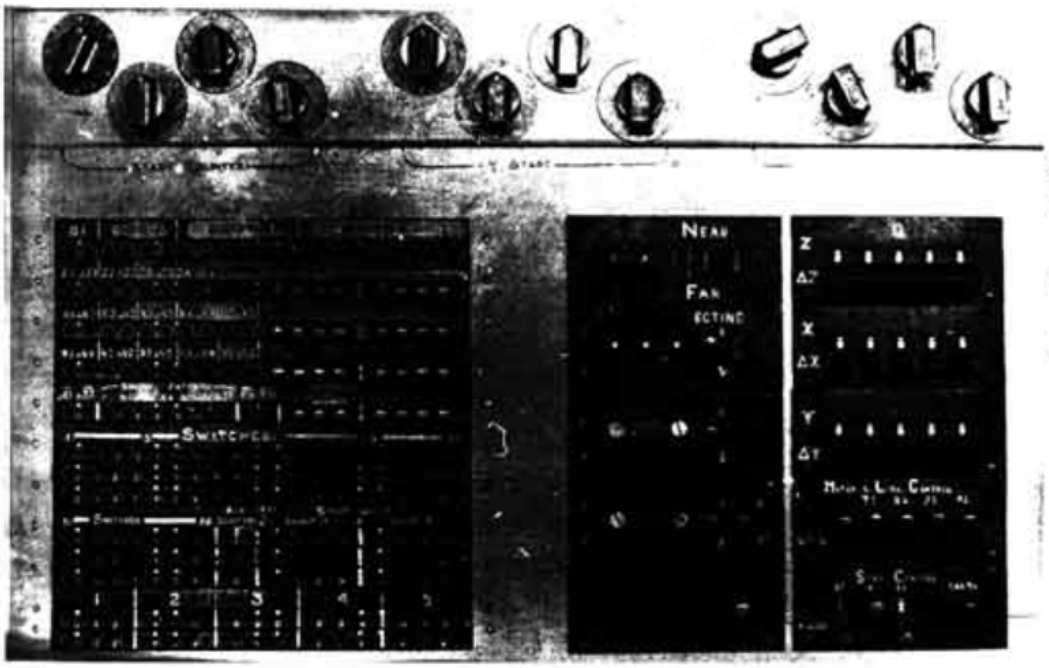


Fig. XVI

Colossus 6:
span counters (53H),
plug panel (53K),
selection panel (53C).

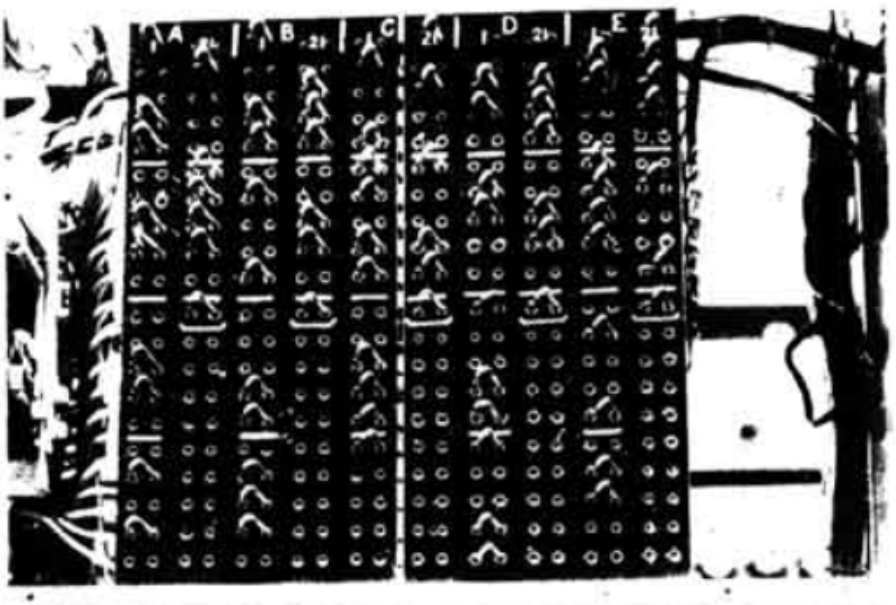
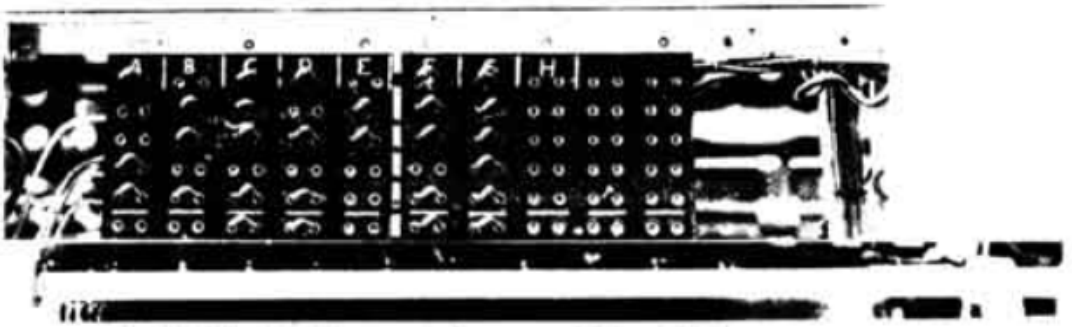


Fig. XVII

Colossus 10: X2 wheel trigger, and part of Mel. (5:C)



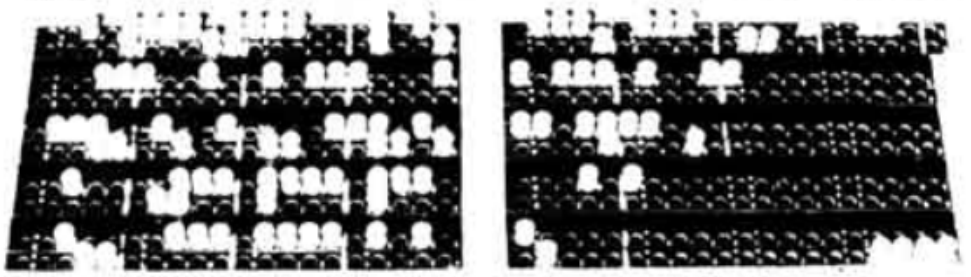


Fig. XVIII

Colossus 10: wheel checking panel. (5:C(1))

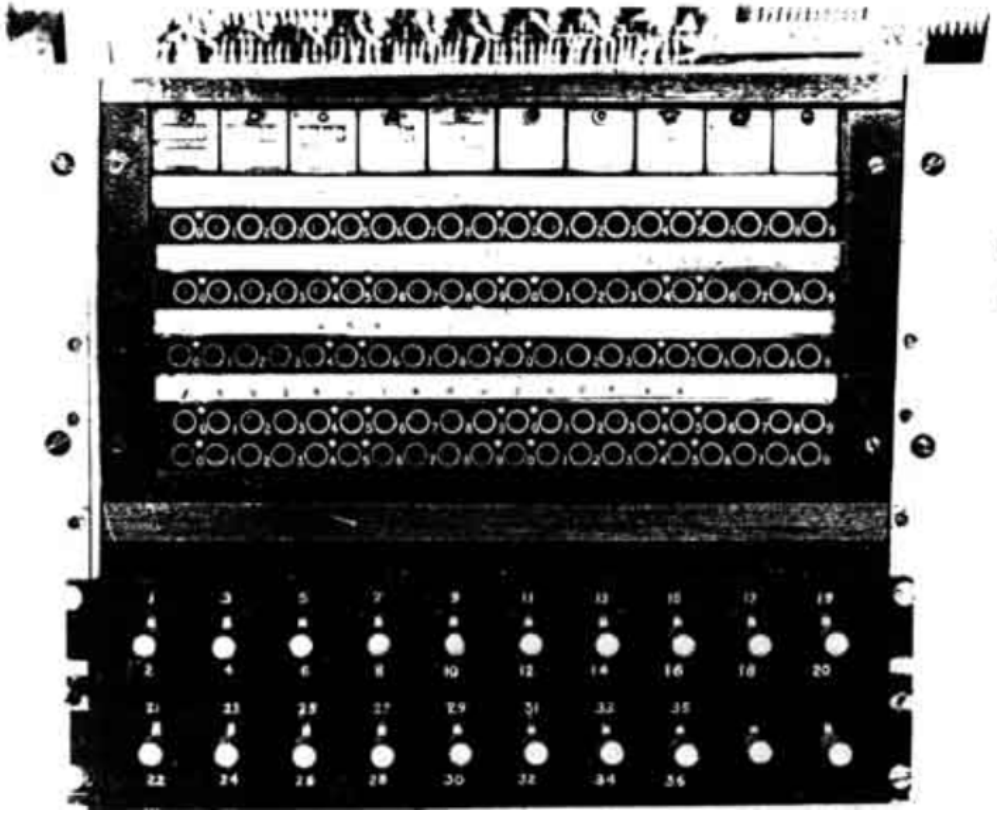


Fig. XIX

Colossus 6: switching panel (53 M)

Fig XX

In foreground Insert Machine (56C).

In background Miles C, D (56C).

Stickers and hand-counters (57)

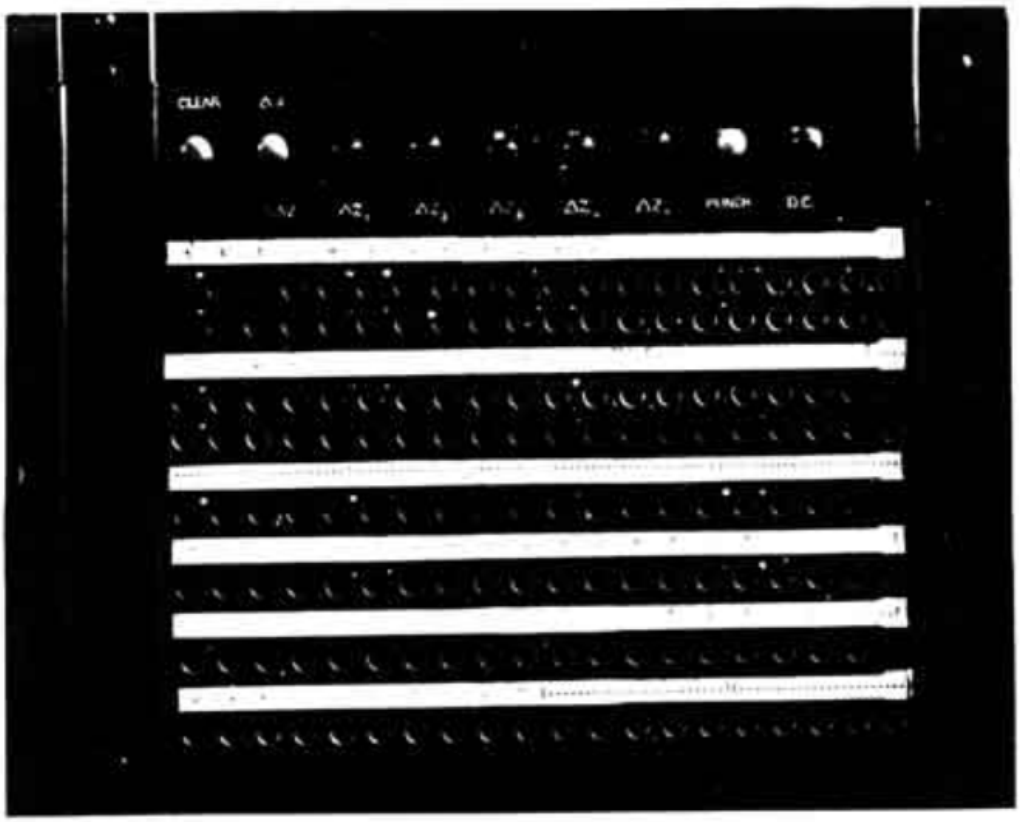


Fig XXI

Garbo Panel (56E)

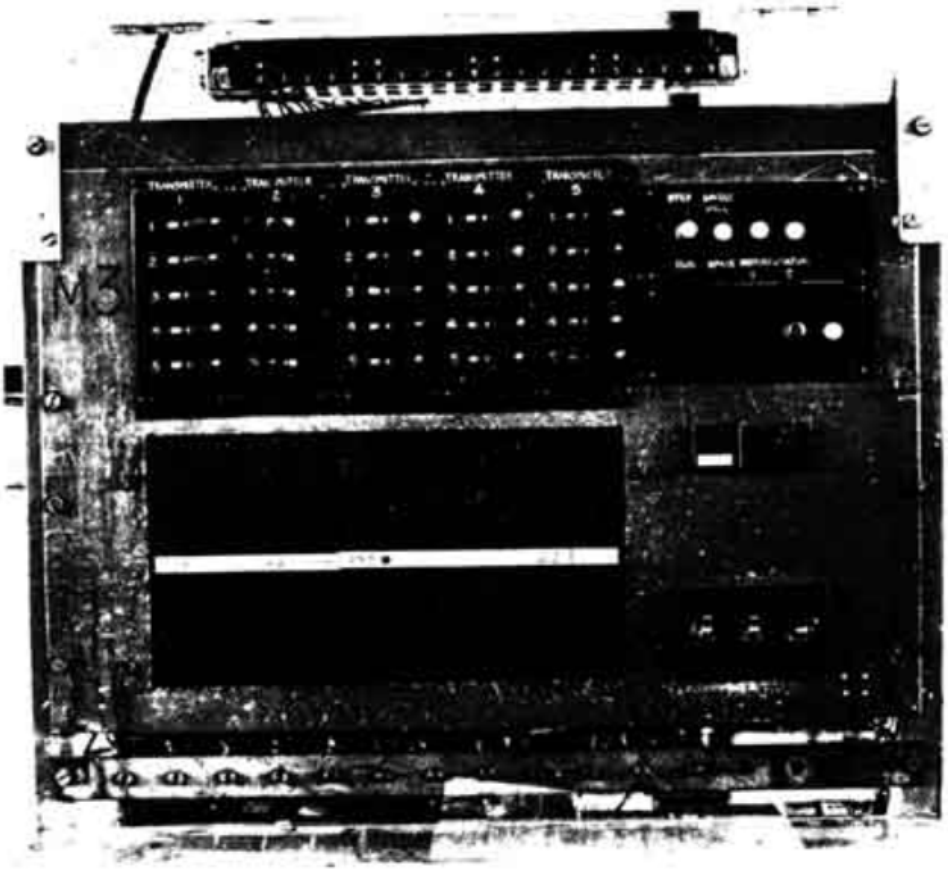


Fig. XXII

Miles D panel
(56 G)

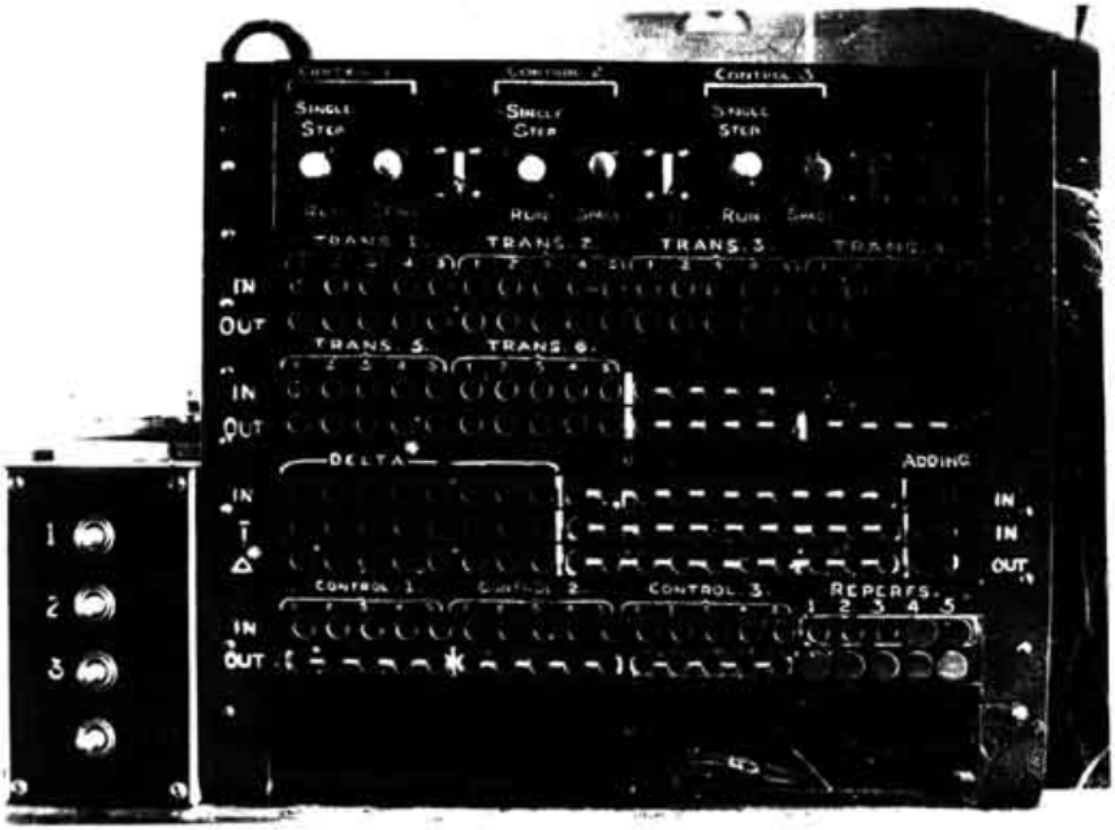


Fig XXIII

Miles A panel. (56H)

Fig XXIV

Decoding machines (56 L)

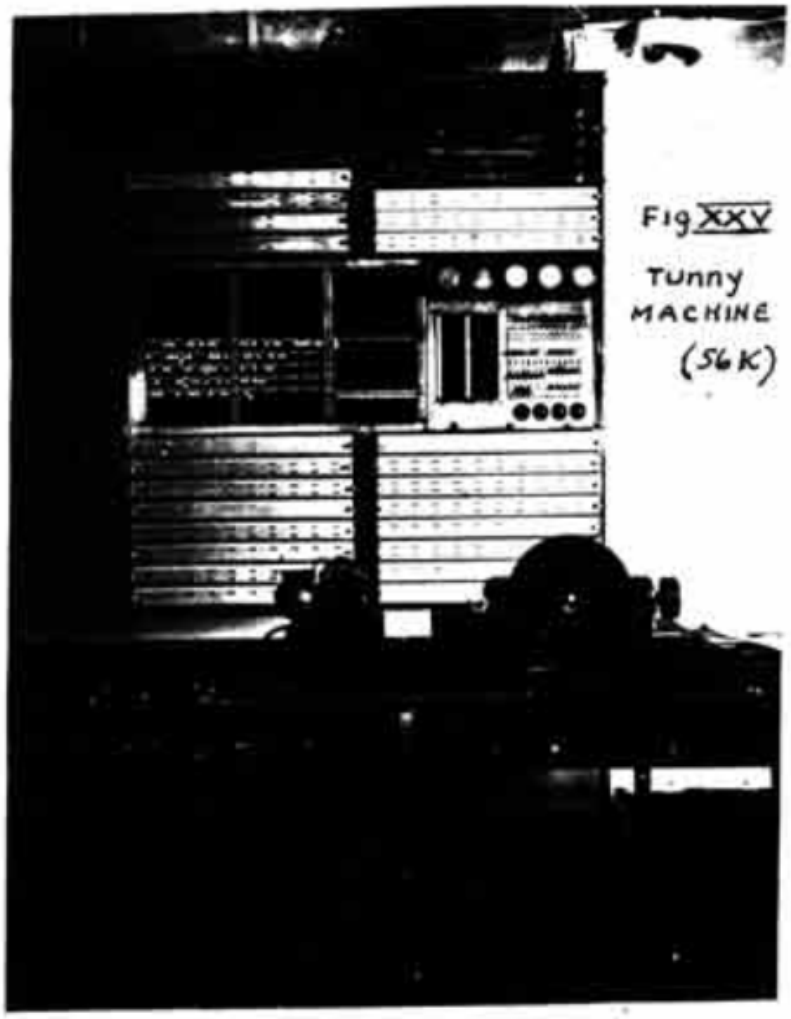


Fig XXV

TUNNY MACHINE (56 K)

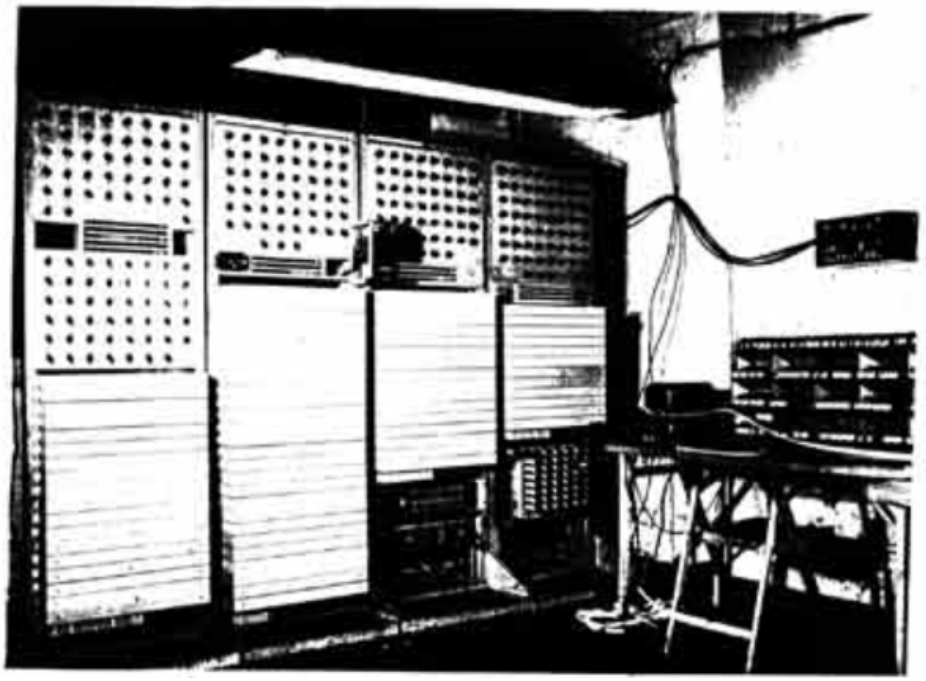


Fig. XXVI

Dragon 1 (55A)

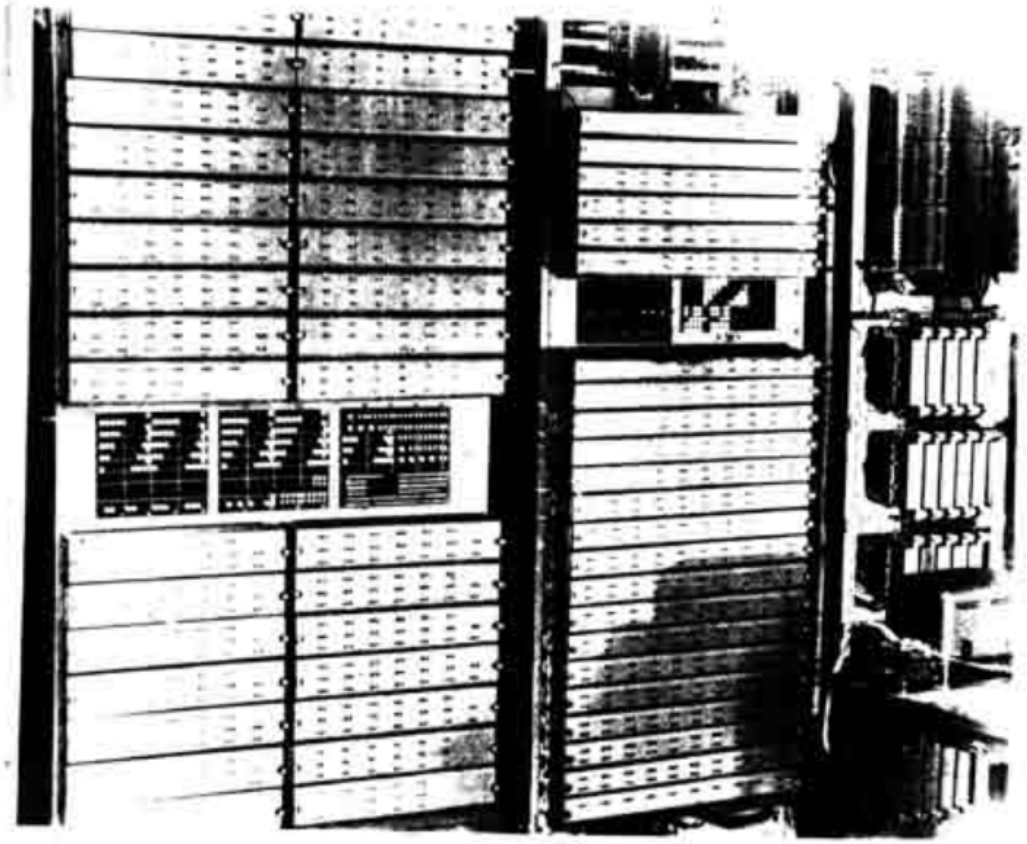


Fig XXVII
Dragon 2.

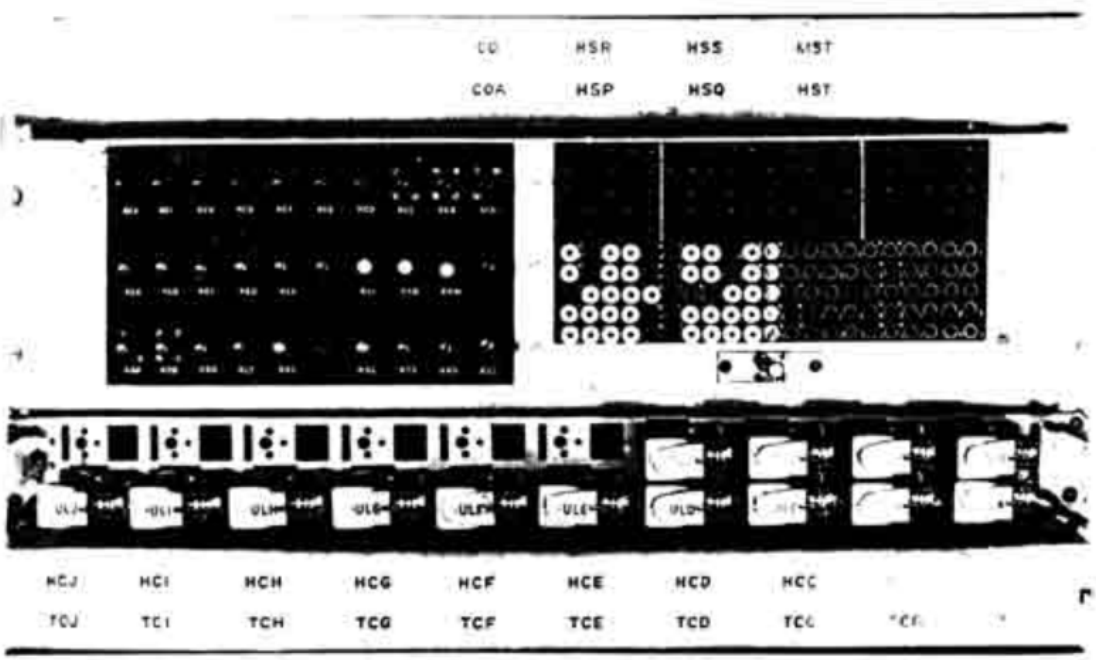


Fig XXVIII
Dragon 2:
switch panel

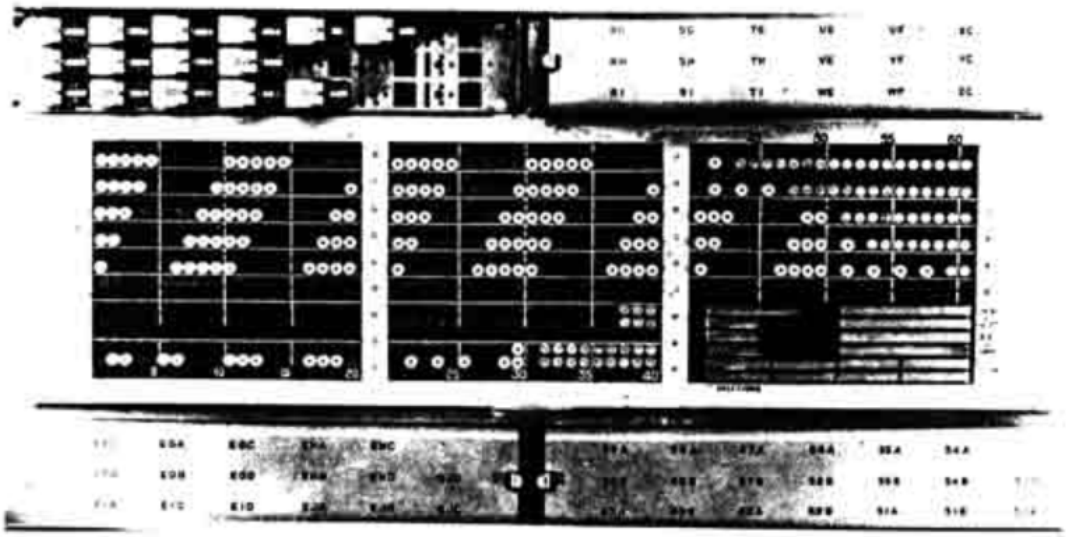


Fig XXIX

Dragon 2:
wheel patterns et

Fig XXX

Dragon 2

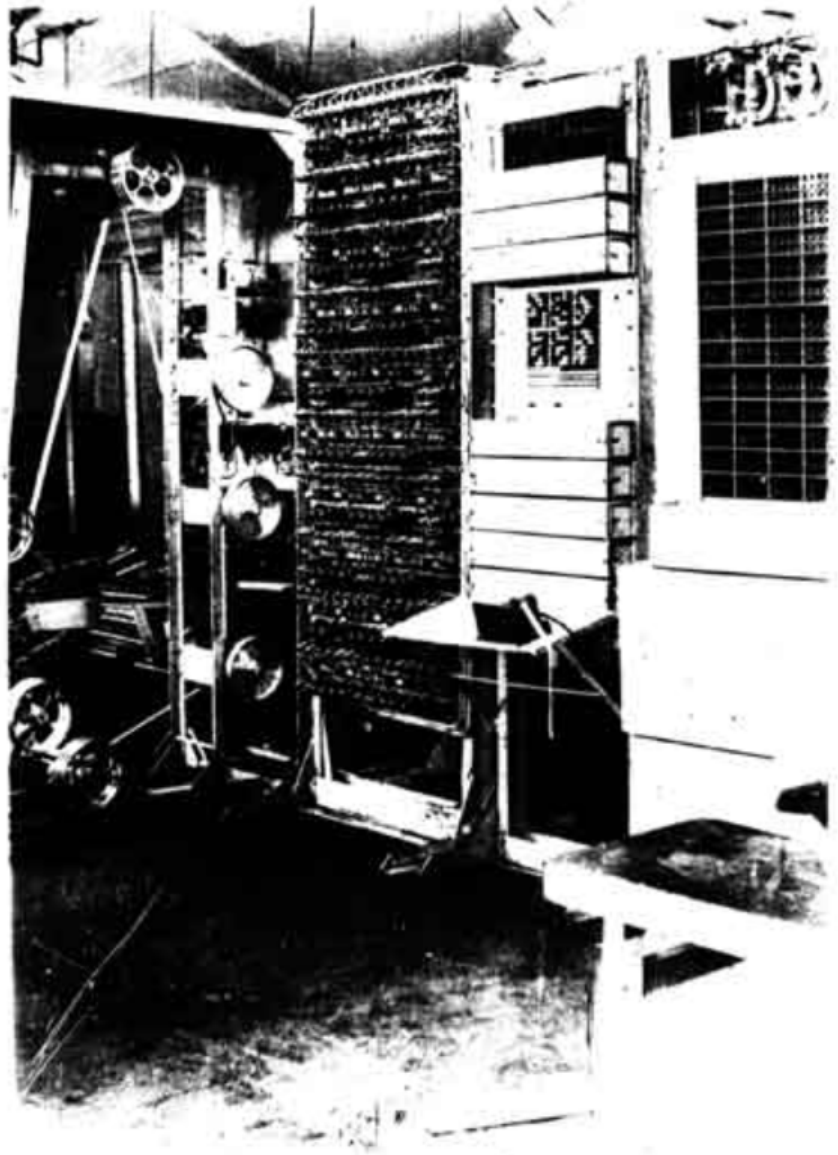
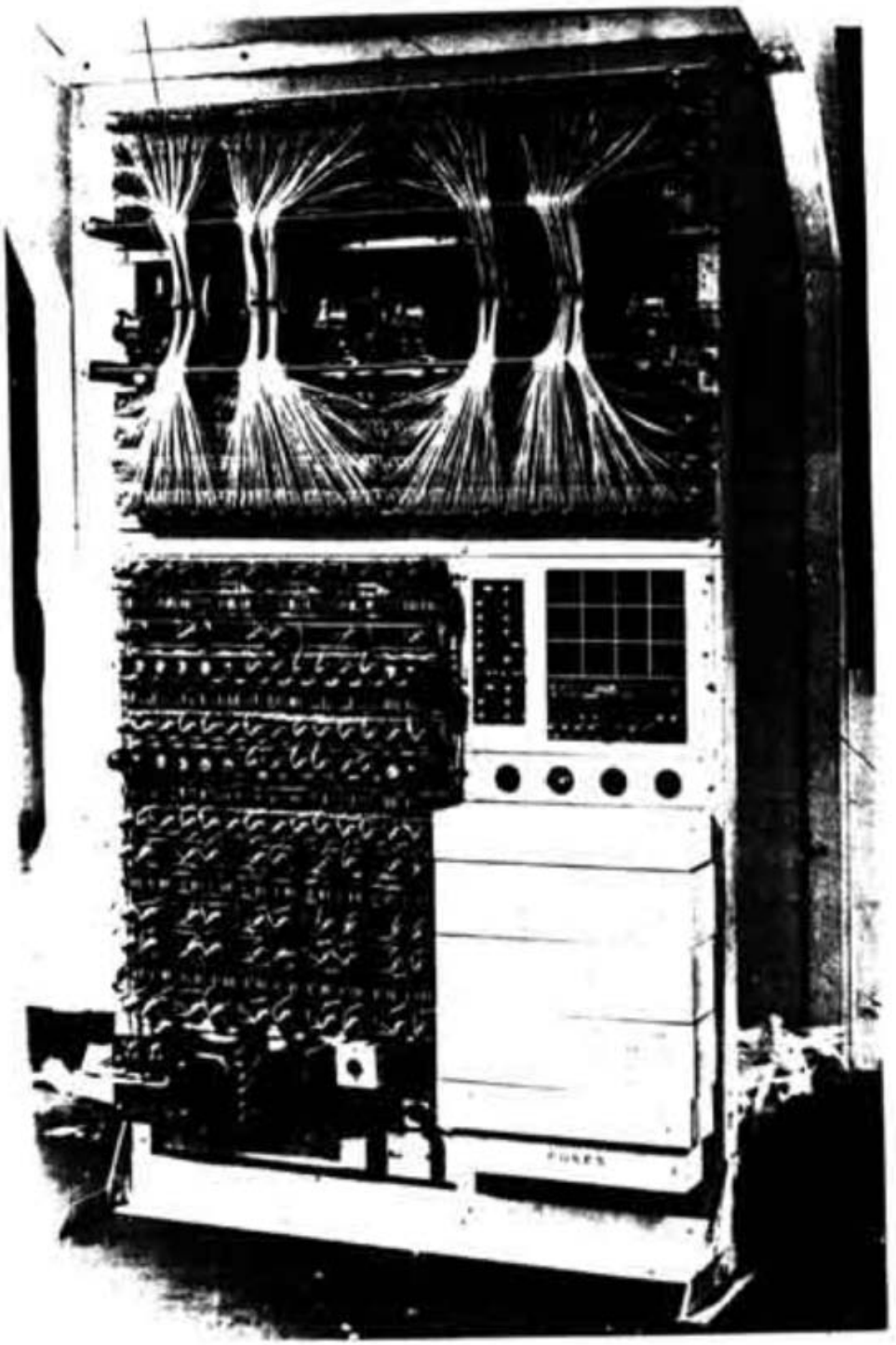
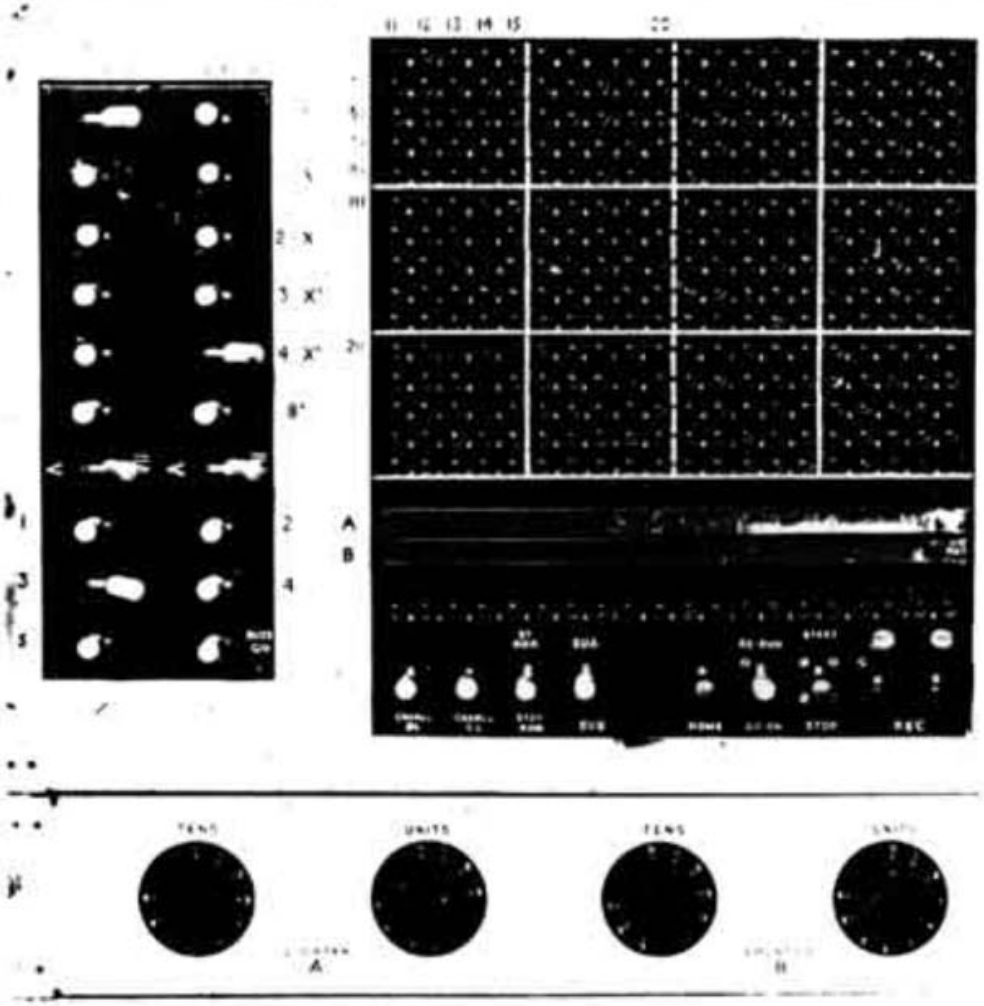


Fig XXXI

Proteus (panel on right belongs to a different machine).



F. XXII


TENS
UNITS
TENS
A
B

61 - RAW MATERIALS - PRODUCTION, WITH PLANS OF TUNNY LINKS.

The development of German Army links is shown in figs 61(I) to (V).

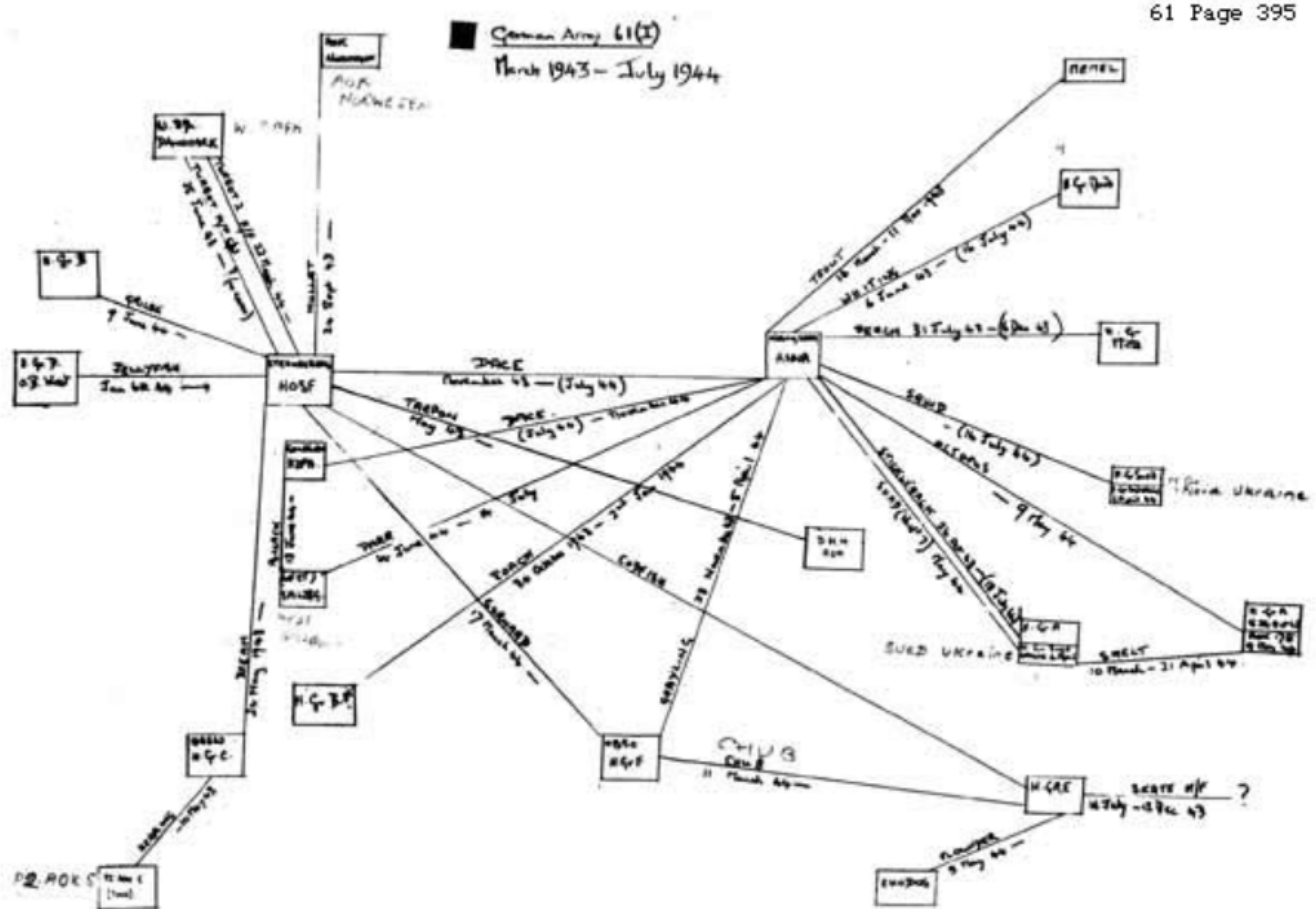
The table below shows the amount of material used and the results obtained. This table does not show the strong correlation between success and high μ_n dottage.

Period	Transmissions received at Knockholt	Tapes received	Tapes set on X's	Decodes	Decode in thousands of letters	Keys broken.
1942						
Nov.-Dec.	12,180	-	-	872	4,467	† 4
1943						
Jan-Mar	16,615	-	-	991	3,386	+ 10
Apr-June	23,970	73	2	965	3,063	+ 15
July-Sep	21,550	272	17	745	3,047	+ 19
Oct-Dec	34,740	955	199	733	3,145	+ 18
1944						
Jan-Mar	28,000	1,670	1,206	680	3,189	13
Apr-June	6,215	4,160	1,446	1,044	4,695	19
July-Sep	5,210	4,450	1,638	1,139	6,860	+ 80
Oct-Dec	6,922	5,496	2,182	1,861	9,607	+166
1945						
Jan-May 8th	12,325	10,555	*4,332	4,478	21,972	+374
TOTAL	167,727	27,631	11,021	13,508	63,431	+718

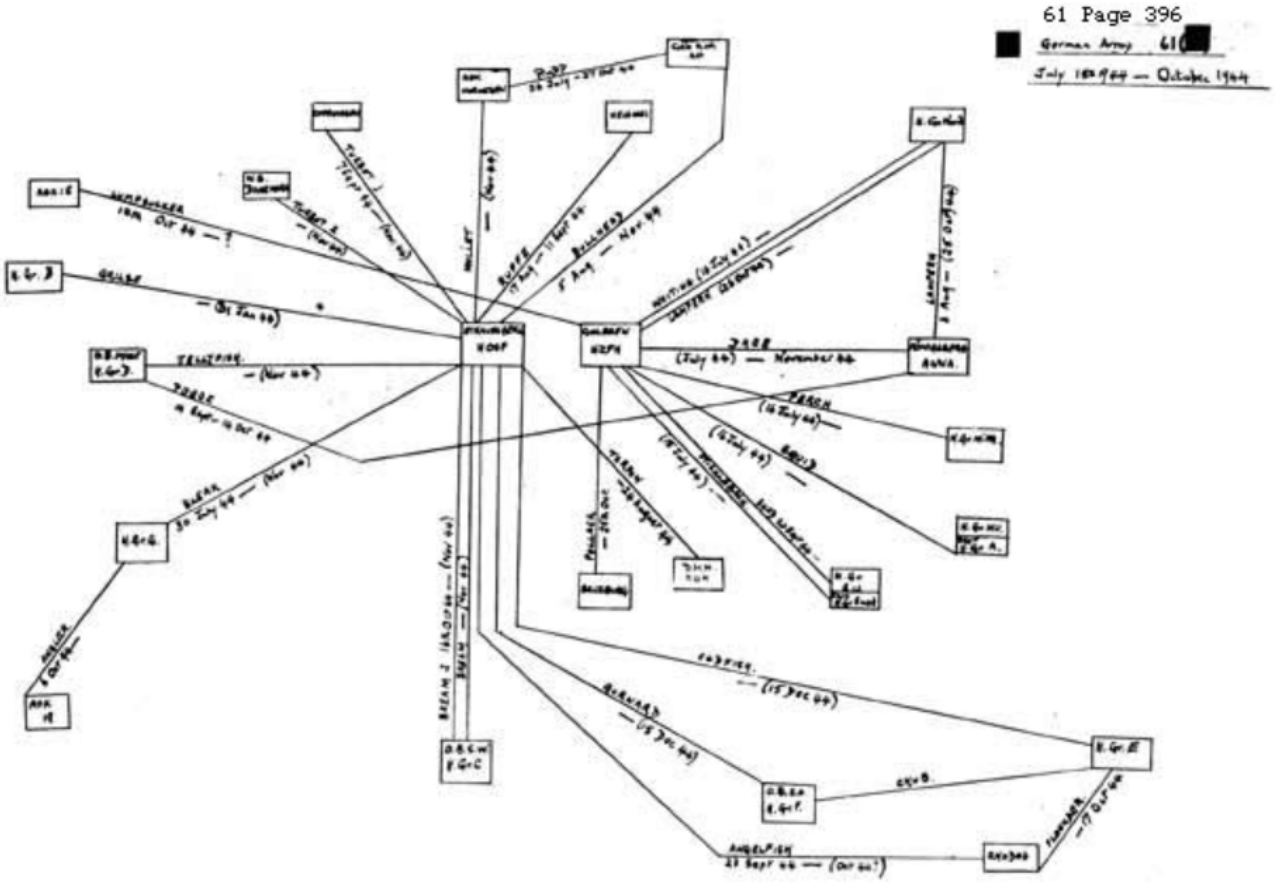
* Of these, 1040 were set mechanically on all 12 wheels.

† These were all broken by means of depths.

‡ Over half of these were broken by rectangles.

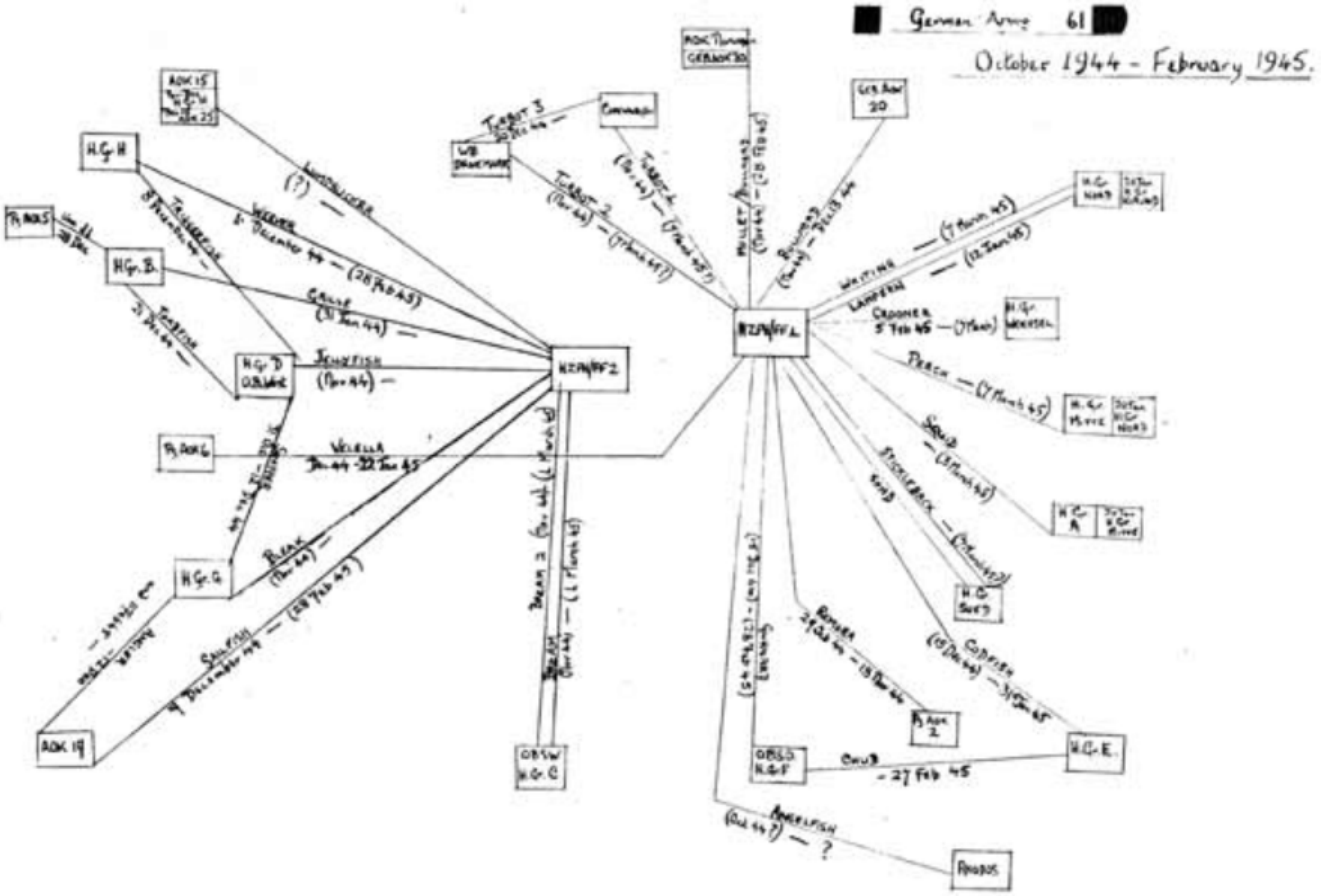


http://www.alanturing.net/turing_archive/archive/t/t20/TR20-003.html



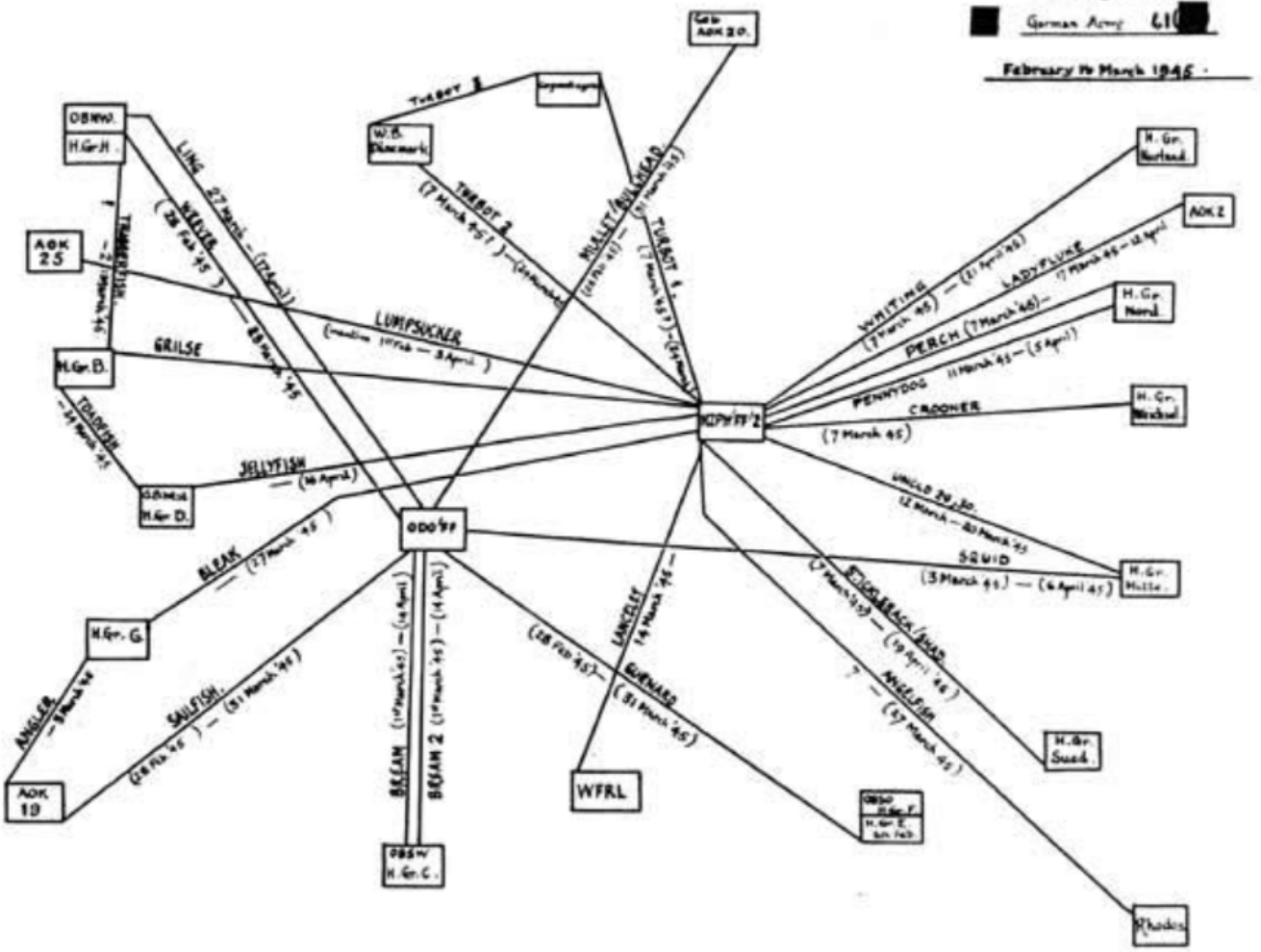
German Army 61

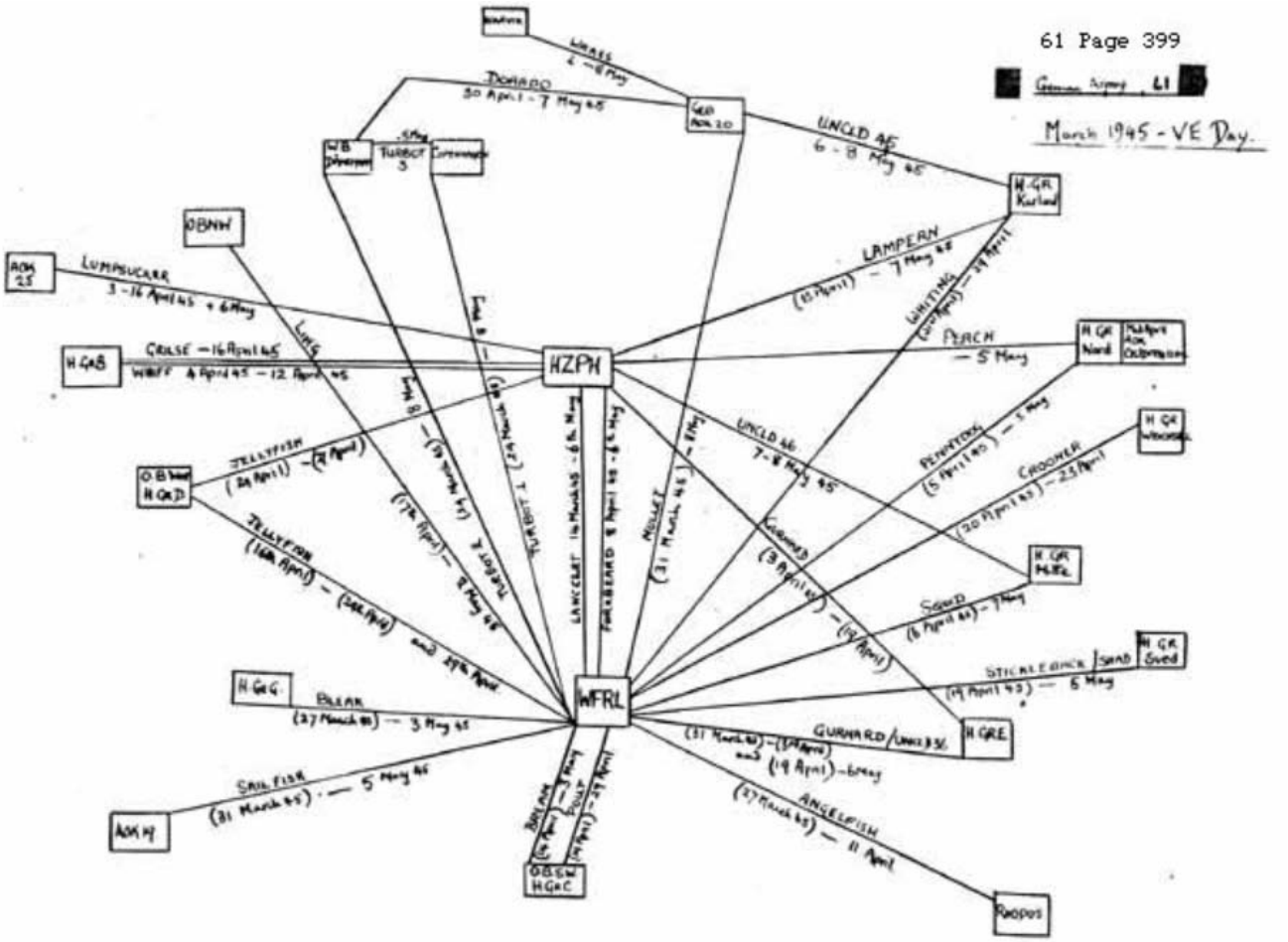
October 1944 - February 1945.



[redacted] German Army [redacted]

February to March 1945.





71 GLOSSARY AND INDEX

ALPHABETICAL COUNT — Letter count q.v.

AMBIGUITY — A short stretch of μ_{ψ} where the number but not the exact position of dots is known 28D(b); 28E(b)

ANAGRAM — To anagram a depth is to express it as the sum of two P's by language methods. To anagram a de-chi is to obtain P by hand, given the chi and psi settings but not the motor 28A(d),(f); 55B

ANALYSIS OF SETTINGS — See Settings, Analysis of

AND/OR MACHINE — A machine which will score one unit when some logical proposition involving the symbols 'and' and 'or' is satisified R0 p 43; 74 Sept'43

AND PLUS ($\&+$) — 54E(d)

ANGEL — A tape-copying machine 56B; 13C

ANTI-REPEAT — A letter in a differenced stream with any number of impulses from 2 to 5 all of which are crosses 23Z

ANTI-SLIDE — If a wheel (or differenced wheel) when differenced at distance n has a high proportion of crosses, the wheel (or differenced wheel) is said to have an anti-slide at distance n R5 p 6; 23G(d)

APPROXIMATE $\mu_{\overline{\psi}}$ AND μ_{ψ} — 92F

AQUARIUS — A machine for locating go-backs 55C; 13B(c), 28B(f), 58(XXXII),(XXXIII)

ARROW ($\longrightarrow$) — A symbol meaning "tends to" 22B(b)

ASTERISK — See Star

ATKIN COUNT — A combination count on P. The point was that the corresponding Ψ-setting combination runs all had the same R and σ.

AUTO — The part of a message which is sent (by the enemy) by running a tape through an auto-transmitter. 11A(b); 27C(a)

AUTOCLAVE — In our work, limitation involving $\overline{P_5}$. 44C; 11B(g)(iii),(iv)

AUTOMATIC RECORDING — 15A(e)

AUTO-PAUSE — A pause in auto-transmission while tape is reset or replaced by another tape. 28B(e), 11D(c); 27C(a),(d), 55D

AUTO-TRANSMITTER — A tape-reader from which the five impulses of each letter are sent successively along a single wire. Sometimes incorrectly used for transmitters (tape readers) in general. 51(h)

AUXILIARY TAPES	27F(f),(g)
AVERAGING GADGET	A gadget that was fitted on Heath Robinson, which would give the total for 50 consecutive readings.

$\flat$	Proportion of crosses in a $\Delta\Psi$. 11C(d); 22D
B	Bulge. Excess of score over random. See also Proportional Bulge
bb	See aa
BM	Basic Motor. 11B(f); 44C
BM C/O	Basic motor cut-out. 53C(d); 53L(k)
BM +/1+2	23L(i)
BI	Break-in. A setting run for a message which does not involve knowledge of the setting of any other wheel. 23B(c); 74 Nov'42, Aug'43
BI WITH SPANNING	23F(f)
BI FLOGGING	23H(b) 91C(c)
B PROCEDURE	A procedure for ordering individual priority tapes.
B TYPE	Strictly traffic with a high proportion of single punctuation. Commonly used to include C(language) type. 22G(e)(2)
BAN (10 db)	Logarithm of a factor to base 10.
BAN (NATURAL)	Logarithm of a factor to base e.
BAR ($\bar{U}$ or $\underline{U}$)	22A(b)
BAYE'S THEOREM	21(f); 21(c), 24W(a), 24X(d), (e)
BEDSTEAD	The part of Colossus or Robinson on which the tape runs, together with the photo-electric cells, etc (also used erroneously in RO for Heath Robinson). 13B(a); 52(f)
BEDSTEAD, COLOSSUS	53B(b); 52(h)
BEDSTEAD, ROBINSON	54C
BIBLE	A book in which wheel patterns are kept.
BIG RECTANGLE	See Rectangle, 150 x 150.
BIG BLACK SWITCHES	See Q selection switch.
BIGRAMS, ΔD	22H(h); 23H(g)
BIGRAMS, UN ΔP	22(IV); 22G(a),(g)
BITING TAPE	A tape with the end of the text running straight on to the beginning.
BLANKS (REQUIRED BY COLOSSUS)	53B(a)

BLATT — Sheet. 94(d)

BLOCK F — 14B(b)

BLOCK H — 14B(b); 15G(b)

BOOK OF SETTINGS — See Settings, Book of

BOOLEAN ADDITION — 1 + 1 = 0 + 1 = 1 + 0 = 1, 0 + 0 = 0 R1 p 14; 56G(1)

BOSTICK — A substance for sticking tapes for Robinson. Benzine is used as a solvent. 57(d); 54G(3)

BERAK	A stretch of P obtained by hand methods in depth or de-chi. 28A, B
BERAKING	Obtaining patterns of wheels (see wheel-breaking) Breaking a de-chi: setting or obtaining patterns of psis by hand from de-chi. 28B, C
BREAKERS	Testery language and key-breaking experts. 39B(a); Fig 31(I)
BRUSSELS	An intercept station set up rather late in the war.
BULGY	Showing bulges not easily ascribed to random variation.
BUZZER	55C(f)
C	Number of crosses in χ_{n+1}. 92B(a)
C PROCEDURE	The normal procedure for ordering tapes for setting.
C TYPE	Type of message likely to set on $3+4\chi$ (high proportion of German language). 22C(a)(1)
C1, C2, C3, C4	(i) Runs: C1 is 1 = 2 = 4, C2 is 1 = 2 = 5, C3 is 1 = 2 = 4 = 5, C4 is 1 = 2 = 3. R0 p 80; R5 p 60 (ii) Procedures for ordering tapes. C_n means over 500 (n+1) in length. (n = 1,2,3,4,5)
CAGE	26B(a); 43B
CAMERA	91B(d)
CAP	Cap as in chi 2 cap, or $\hat{\chi}_2$, means sum of the past, present and future characters. Thus $\hat{\chi}_2 = \overline{\chi}_2 + \chi_2 + \underline{\chi}_2 = \overline{\chi}_2 + \Delta\chi_2$ See also $\hat{\chi}_2$.
CARRIAGE RETURN	53M(b),(h)
CELL (OF A RECTANGLE)	A compartment, fixed by a definite row and column of a rectangle. 24B
CERTAIN	Used with different shades of meaning, (i) in a single setting run 50:1 on (ii) in setting a message 10:1 that all wheels are set correctly (iii) in chi-breaking, for one wheel, ostensibly 10,000:1 on. 23C; R3 p 134, R5 p 58, 25D(g)
CH	Checked (occasionally character).
CHAIN OF WITNESSES	See Witnesses, Chain of
CHARACTER	Dot or cross.
CHARACTERISTIC FUNCTION	21(n)
CHARACTERISTICS, WHEEL	See Wheel Characteristics.
CHARACTERISTICS, P	See Plain Language, Counts and Characteristics.

CONTRACTION OF Ψ — 55A(a),(b); 430(b)

CONTROL IMPULSE — Analogous to a control tape, q.v. but in a single impulse.

CONTROL OFFICER (CO) — Man in charge of liaison with Knockholt. 14B(a), 31(I)

CONTROL PANEL — 53M

CONTROL TAPE — (or Special Counter Tape) A tape used on Robinson for picking out letters on another tape. 54M

COUNTING MACHINES	Colossus, Robinson and the Hand Counter are all counting machines.
COPYING MACHINES	13C; 56D
CP	Letters written on crib jobs at first, to give them priority. The practice continued long after cribs were generally of top priority.
CRIB	A stretch of clear believed a priori to occur in a length of de-χ or cipher. Usually means a long retransmission of a routine message on another key. 12E(b), 27; 41C(a), 12B(c), 14B(b), 15C(f), 7&May'44 25D(g)8 31(I)

d	No. of dots in μ_{37} 22D(c)
d INFERRED FROM $\Delta\Psi$ PATTERNS	28C(b)
D	Proportion of dots in μ_{37} 23L(b),(c) 92B.
D PROCEDURE	Used for ordering crib priority tapes.
db	See deciban
DB	Occasionally used for double bulge.
DCL	56L(d)
DO	Duty Officer. Man in charge of all work on a given shift. 14B(b); 37(b)
DR	David Rees, Decoding Room, Dispatch Rider, Double Robinson.
DAILY CHANGE	The daily change of all 12 wheel patterns on a link. 43D(c)
DAILY FILM	A quaint term for "message film", used by the photographic section, but not in this report.
DECENTRALISATION	81A(c)
DE-CHI	See De-χ
DECIBAN(db)	The unit of decibanage. 21(g); 25B(b), (c),(d),(e)
DECIBANAGE	10 x logarithm to base 10 of a factor.
DECIBANAGE EXPECTED IN CRIB RUNS	27I(c); 27I(f),(g)
DECIBANAGE, NON LINEAR	24W(a)
DECIBANAGE OF ΔD LETTERS	92B
DECIBANNING	Calculating decibanages.
DECIBANNING "FROM A LETTER COUNT"	25W(f) 22Y
DECIBANNING, FUNDAMENTAL FORMULA	25W(b)
DECIBANNING A LETTER COUNT USING THE MESSAGE AS ITS OWN SAMPLE	22Y; 23J, 25B(c)
DECIBANNING MACHINE	A machine which would score different numbers for different conditions (Colossus only scores one or zero). 23Z; RO p 43
DECIBANNING RUNS	25W(d); 25W(e)
DECIPHER	Make intelligible (applied more often to bad handwriting than to cipher). 11B(i)

DIRECT PLUGGING (ROBINSON)	54D(a),(h)
DISAGREEMENT	Dot against cross. 43B
DISCRIMINANT	Control Tape
DISPLAY	Details of settings and scores are displayed by being lit up on a 'display panel'. The term is used in contrast to the printer.

EYE-START

A start for convergence of a rectangle by eye.
See also E_1 and E_2.

FLOGGING	Working exhaustively on a particular method or hypothesis. 23H; 25D(g), 91C(c)
FLOGGING THE EVIDENCE	23J
FOLLOW-ON	Messages sent consecutively without resetting the wheels. 11D(d); 23F(b)
FORMULAE, FOR KEY-BREAKING	See Key-breaking, Formulae
FOUR-LETTER COUNT	See Letter Count, Four-
FOUR-WHEEL RUN	Commonly used in the sense of doing a two-wheel run and using all scores above the set total for a further run on two other wheels. 23H(c)
FOURIER TRANSFORMS	22I(d); 22I(c)
FREAK ΔP COUNTS	See Plain Language Freak Counts.
FREEBORNERY	Any catalogue produced by Freeborn's section. See also Hollerith Section.
G CIRCUIT	91B(i)
g'	Special pattern (doubting) trigger for μ_{31}. 53C(b)
GPO	General Post Office. 51(g)
GADGET FOR RESETTING	See Resetting Gadget.
GAMMA TAPE (γ)	A tape punched /L/L/L, etc.
GARBAGE	Type-out done on Garbo (or Junior). 24(I); 26(XI)
GARBO	A machine for printing from a tape with (i) stockering (ii) differencing (iii) addition of differenced impulses. At one time it possessed a reperforator. 56E; 13C
GARBO RECTANGLE	See Rectangle, Garbo
GATE	The part of Colossus or Robinson through which a tape passes when being examined by the photo-electric cells.
GATE, ROBINSON	54C(c); 58(IV)
GAUSS (IAN DISTRIBUTION)	See Distribution, Gaussian.
GENERATING FUNCTION	See Characteristic Function.
GENERATING UNIT	91B(b)
GERMAN TUNNY	74 June'45
GERMAN WHEELS AND SETTINGS	94(b),(d)
GIFFORD	Inventor of the original Robinson printer.

GIFFORD PRINTER 52(c)

COAT Type of Colossus pin, as opposed to a "sheep". Used variously for good ones, bad ones, thin ones, thick ones.

HISTORY SECTION

74 May'45

HOLLERITH SECTION

Mr. Freeborn's Section for the application of ~~commercial~~ tabulatory machinery to cryptography.
94(b)

HUT 3	The main section for 'intelligencing' decodes. 14A(a); 39D
IBM	See Insert Machine.
IST	Intelligence Section Tester. An unofficial name for the Testery.
IMPORTANT (HUT 3 TERM)	Having high intelligence value.
IMPULSE	A character of a TP letter. 11A(a)
IMPULSE, GENERALISED	91A(d.c); 91B(a)
IMPULSE, SIXTH	See Sixth Impulse.
IMPURE COLUMN	Same as spoilt column, q.v.
IN and OUT JACKS, MILES A	56H(c)
IN and OUT JACKS, TUNNY	56K(c)
INDEPENDENCE	Two counts or runs are said to be independent if a knowledge of the score for one does not not affect the probability of any score for the other, if both are supposed to be random it follows that the evidence of the counts is independent.
INDICATOR	12A(d)
INDICATOR METHOD	42E
INDICATOR, 12-LETTER	41A(a)
"INSERT"	56C; 56D(c)
INSERT MACHINE (IBM)	13C, 56C
INSIDE OUT	Dots instead of crosses and vice versa. See also Sign of Key. 25D(f); 25G(c),(d),(e)
INSTRUCTION BOOKS	81A(f)(ii)
INTEGRATION	Recovery of the unΔ patterns from a Δ pattern, i.e. Δ^{-1}
INTEGRATION, MILES A	56H(c)
INTEGRATION OF χ_2	26B(b)
INTERVAL OR COLUMN DIFFERENCE	28D(b)
ISSUING	Routing decodes to appropriate intelligence authorities. 39D
JACK, JACKFIELD	See Plug Panel.
JACK, COMMON	See Common Jack

MODULUS OF A DOT — A notorious example of bad writing in which 1.1 was interpreted independently by several people as "modulus of a dot"! R3 p 50

MORNING MEETING — A meeting held at 1100 hours (of the administration, DO, CO, WM, representative of Hut 3 and Room 11) to discuss policy.

MOTOR — Usually means total motor, i.e. basic motor (μ_{BT}) modified by the limitation. 11B(f); 22C

NOT (SYMBOL FOR)	21(a). A somewhat different use of this symbol is in 22A(b).
NOT SWITCH	A switch which insists that the condition to which it is applied shall <u>not</u> be satisfied. 13B(a)
NOT SWITCH, COLOSSUS	53J(d)
NOT SWITCH, ROBINSON	54E(c)
NOT NOT	The importance of this is that NOT (NOT A, NOT B) is equivalent to EITHER A OR B. 53J(d); 54E(c)

ORDINARY ADDITION FIELD	See Addition Field, Ordinary.
OSCILLATING CONVERGENCE	24X(f)
OUT(MACHINES)	Not working properly.
OUT (WHEELS)	Broken and issued as certain.
OVER DECIBANNING	Decibanning for wheel-breaking assuming the letter-count on partial wheels to be a fair sample. 25B, 25W

OVERLAP	The end of one message (QEP) and the beginning of the next when they have the same plain language. 28B(g), 11D(c); 27A
P	Probability
P	Priority sign.
P	Symbol for Plain Language (Plain Text, Clear). Sometimes denoted by PL. See also Plain Language.
P^*	(i) A modification of P used in crib runs. 27G, 27W (ii) (a memo-use) $P_5^* = \bar{P}_5 + \Delta P_5$.
PQ	A tape used in making P^*. 27F
P_5 LIMITATION $(\chi_1 + \bar{\bar{P}}_5)$	11B(g)(iii), 14A(b), 43C(g), 44C; 27A, 11E(c), 74 Sept,Dec'44. See also Limitation.
P_5 LIMITATION, CRIBS	27G(n)
P_5 LIMITATION, CRIBS RUN	27G(n)
P_5 LIMITATION, ΔD COUNTS	22H(d)
P_5 LIMITATION, χ-BREAKING	25E(h)
$P_5\,Y_1$ LIMITATION	See Triple Limitation.
PARALLELEPIPEDS	See Rectangles.
PARTIAL DE-CHI	De-chi on fewer than 5 chis. 23H(h)
PARTIAL WHEELS	Wheels with some characters doubted. 25D(a)
PATTERN	The dots and crosses constituting a wheel: also the corresponding part of Colossus (see trigger, ptrigger, also wheels).
PATTERN FRAGMENTS	42E(d)
PAUSE	See Autopause.
PBA	Proportional Bulge Algebra (q.v.)
PB FUNCTION	Proportional Bulge Function (q.v.)
PBI	Partial break-in, i.e. setting on partial wheels (q.v.)
PCO	Printer cut-out. 53G(i), 54G(b); 53N

PECKERS

The pins in a tape-reader, which when a hole in the tape permits them to rise, produce the electrical impulse which represents a cross. A vulgar corruption is 'jigger'. In the absence of a tape the peckers can be seen through a rectangular aperture, known as the window, eye, or (a loose usage) the head. Thus all the phrases: on the peckers, on the jiggers, in th window, in the eye, in the head, have the same meaning, viz. that the letter referred to is the next to be copied.

PURGING

Method of starting a rectangle convergence by removing, from an eye start, characters which do not score well. 24D(g)

Whatever is switched into the Q panel of Colossus by means of the Ψ selection switches (big black switches). Q is necessarily of the form $\varepsilon_1 Z + \varepsilon_2 X + \varepsilon_3 \Psi'$ where $\varepsilon_1, \varepsilon_2, \varepsilon_3$ independently are 0, 1, or Δ

ROD	A strip of cardboard consisting of a column of the addition square arranged in a certain order. 28B(h)
ROLLE	93(a)
ROOM D	14B(b); 58(XX), 31(II)
ROOM 11	14B(a)
ROOM 12	14B(a); 34(b), 31(I)

SD See Standard Deviation.

SECCOTINE 57D

SHAUN COUNT	A count of the 32 numbers of occurences of $\Delta^0_{ij} \ldots\ldots\ldots k = .$ Sometimes loosely used for the corresponding thing for $P_{ij} \ldots\ldots\ldots\ldots k = .$ (Atkin Count)
SHEEP	Pins which are not 'goats' q.v.
SHIFT, LETTER and FIGURE	22Q(b), 11A(a)
SHORT, BEDSTEAD	A bedstead which can carry a tape not more than 11,000 long.
SHORT RUN	A setting run for one wheel.

SIX DIMENSIONAL CONVERGENCE — cf 5 dimensional convergence. $\Delta\chi_4$ is the limitation reversed and is treated in the same way as the other $\Delta\chi$'s, when six dimensional convergence is carried out. 26G(d)

SIXTA — Six Traffic Analysis. Log reading section. 27D(c); 39D, 27H, 31(I)

SIXTH IMPULSE	Limitation reversed. 22D(g), 26B(b), R41 p 67, 26(XXI), 26E
SKELETON FLAG	A rectangle in which the unit is replaced by a large unit and is entered in dots and crosses instead of numbers is called a skeleton (rectangle). It can be flagged and the result is called a skeleton flag. 24D(d); 24W(c)
SLAVE	See 'Chaser Settings.'
SLIDE, MESSAGE	If n cipher letters are omitted in a tape the tape is said to have a slide of n forwards since the key is n places further forward after the omission than it would have been without the omission (similarly for letters inserted). 23F; 23Z(21); 25D(c)
SLIDE OF COLUMNS	92D, 92E(a)
SLIDE OF THE MOTOR	23L(g)
SLIDE RUNS	Setting runs with all five chis, for determining a slide in a message with at least some of the chis already set on part of the message. 23F(d); 74July'44
SLIDE AND SIGNIFICANCE TEST	See 'Significance Test, Slide and.'
SLIDE (WHEEL SLIDE)	23G
SLIDE RULES	57A
SLIDE RULES FOR ACCURATE CONVERGENCE	Device for making the accurate scoring table, consisting of a slide-rule made of cardboard. 24W(a)
SLIDES, LOOKING FOR GOOD	92E(c)
SLIDING	28(VII)
SLIDING MACHINE	Hypothetical machine for sliding columns of a motor rectangle for motor breaking. RO p 68
SLIP READING	Examination of undulator tape (or 'slip') for production of cipher tape and red form.
SLIPS, RE and CRIBS	See 'Crib Re Slip' and 'Crib Slips.'
SMOOTH MOTOR	An artificial motor which gives (or is hoped to give) the correct number of motor dots up to the nth letter of a message for a large proportion of values of n. 92K; 92E(d)
SNAKE	28(VIII): 92F
SNAKING	56L(e)
SORTING OF SETTINGS	See 'Settings, analysis of'
SOURCE OF MACHINES	51(g)

STRETCHING OF TAPES	52(b), 54C(b), 54C(c), 23Z(1)
STRIPED SHEET	Chit used in wheel-breaking to record numbers and length of tapes for the specific day.
STURGEON	A TP cipher involving permutation of impulses. 11A(c)
SUBSETS	On plugboard of Robinson and Colossus. RC p 43
SUBSTANTIALLY RIGHT	24X(e)

TM	Total Motor. TM = dot, if and only if $\mu_{37}' = .$ and limitation = x. 11B(f); 11C(d). Tim Moilien.
TM SWITCH	53J(i)
TOILET ROLLS	Rolls of paper for printers on Robinson and Colossus
TONE TRANSMISSION	74 Mar'42
TOTAL MOTOR	See TM
TP	See Teleprinter and Tea-party.
TRAFFIC, CURRENT	74 July'42
TRANSLATING CIRCUIT	91B(e)
TRANSMISSION	11D(b)
TRANSMISSIONS RECEIVED	61
TRANSMITTER	A tape-reader.
TRE	Telecommunications Research Establishment. A source of some machines. 51G
TREE	A scheme of routine for setting messages in the form of a tree, i.e. giving instructions depending on what happens at each stage. Usually applies to fairly simple cases only. 23B(c); 26(VI)
TRIGGERS	Method of starting action in a circuit which then functions for a time under its own control. Hence used for the wheel-patterns panel on Colossus 1. The term was naturally extended to the wheel pattern panels on later Colossi, but as this was technically incorrect the word was modified to Ptrigger to appease the engineers. Later the p was dropped by everybody. 53C(a); 13B(a)
TRIPLE DOTS IN TM	26C; R41 p 92
TRIPLE LIMITATION	$\overline{\chi}_2, \overline{\psi}_1, \overline{P}_5$ lim. 11B(g)(iv), 74 June'44
TUNNY	Statistical determination whether cipher is Tunny cipher. 93.
TUNNY	The cipher dealt with in this work. 11, 11B(i), 14A, 12A(a),(b),(c), 41A
TUNNY (AND DECODING MACHINE)	31A, 74 June'43, 56K, 56J, 13C, 51(k), 15A(d)
TUNNY LINK (EXPERIMENTAL)	74 Oct'42
TUNNY MACHINE (GERMAN)	11(II), 11B(j)
TUNNY ROOM	14B(b), 31(I)
TUNNY, SZ40, ON FIRST LINK	74 June'41
TURING	21(f),(g)

TURINGERY	Method of key-breaking. The essential idea was differencing. 43B; 74 July'42. See Old-fashioned Turingery.
TURINGERY COUNT	43B
'TWO BACK' (ROBINSON)	54D(g)
TYPE A, B, C	23B(a), 22G(c)

TYPEWRITERS	See Printer.
U-SHAPED PIN	53C(a)
UN-Δ	See Integration.
UND	Undifferenced, i.e. not Δ'd.
UNDULATOR TAPE	A tape on which the electrical impulses of Tunny transmissions are graphically recorded (at Knockholt). 33B
UNEXTENDED	See Contraction.
UNISELECTOR SWITCHES	51(e); 56J
UNRINGED	43B
UNSTEADY	A count which is not exactly constant when checked (on Robinson or Colossus).
URGENCY (HUT 3)	A link is 'urgent' if its value decreases rapidly with time. R4 p 101
USABLE	Settings that are evens. R3 p 135
VARIANCE	Square of standard deviation. (q.v.)
VETTING	Rewriting. (q.v.)
VICTORY	74 May'45
WB	Wheel-breaking (usually χ-breaking).
WEIGHTED AVERAGE OF FACTORS	See Factors, weighted average of.
WHEEL-BOOK and WHEEL-BIBLE	Book containing record of wheel-patterns. A bible was an authoritive version.
WHEEL-BREAKER	Cryptographer whose job, for a week, is wheel-breaking.
WHEEL-BREAKING	See also χ-breaking, key-breaking and motor-breaking. 12B, 12A(b); 14C(c),(d), 15C(e), 74 Feb'44, 25, 26

WM	See Wheel-Man.
WORKED-ON (NOT)	A rectangle which is considered merely as 1271 different numbers (the entries in each cell) is said to be 'not worked on'.
WRONG CASE	21(j)
WYNN-WILLIAMS' COUNTER	A thyratron counter of electrical impulses usually based on a scale of two.

X	Cross, also typewriterese for χ
X (Mr)	See Mr. X
Y (Mr)	See Mr. Y
YES, NOT SWITCH, (ROBINSON)	54E(c)
Z	Cipher. 11B(b)
Z^*	27F, G, W, X, Y
Z ZZ ZZZ	Degrees of urgency.
z	Symbol used in 25W(a),(e) (q.v.)
ZIG-ZAG (ON GARBO)	Succession of . x . x . etc. in each of two impulses of a tape, at a stagger of one, so that the sum of the two impulses is a cross.
$\alpha, \beta, \gamma, \delta$	See Greek Orthodox.
β	22(d) See 72
γ TAPE	/L/L/L used in cribs. R2 p 107
δ	See Ch. 72
δ (RECT) MAXIMUM LIKELIHOOD VALUE OF	24X(d)
δ_0	24X(d); 24Y(a)
δ'	24X(d)

Δ (DELTA)	Difference in the sense of adding future to present (modulo 2). Used for whole or partial letters or for a single impulse. 11C(b), 22A(b) definitions. 43B, 22A(c) manipulation of Δ
Δ^2	The effect of applying the operation of Δ twice. Similarly for Δ^n. 22A(b); 43D(b)(ii)
Δ_n	Differenced at interval n, i.e. 1st + $(n+1)^{th}$, 2nd + $(n+2)^{th}$ ...etc.

ζ	A typical PB. 21(j); 22E(a)
$\psi = \frac{R\delta}{\omega\sigma}$	25W(e)
π	any ΔP PB. 25Y, 25E(e),(f),(g)
σ	Standard deviation . q.v.

72 NOTATION

Obsolete and rare notations are enclosed in brackets. The letters are arranged in the order large Latin, small Latin, large Greek, small Greek.

A	Average (expected random score)
A,B,C,D,	Ordering procedures; bedsteads of Super Robinson; Wren shifts
A,B,C,D,...	Versions of wheels in χ-breaking.
B	Bulge.
[B_1, B_2	Bulge of best and second best scores]
BM	Basic Motor.
C	Number of crosses in μ_{41}
[C	Total number of crosses in $\Delta\Psi'$ in key-breaking significance test II]
[C	A class of teleprinter letters.]
D	De-chi.
D	d/37
[D	Total number of dots in $\Delta\Psi'$ in key-breaking significance test II.]
[DB	Occasionally double bulge.]
E	Expected value of, as in EB, ES.
ET	Effective text (similarly ER)
E_1, E_2	Eye-starts for convergence.
H	Hypothesis.
K	Key.
K	Typewriterese for χ
[K	Symbol in significance test IV.]
L	Limitation.
$L_{n,m}$	Letter with n dots and m crosses.
[$L_{n,m,.}$, $L_{n,m,x}$ $L_{n,m,o}$	See 26Y(f)]
[Ⓛ	Generalized teleprinter letter.]
M	Typewriterese for μ : M1, μ_{ω} ; M2, μ_{37}

[M	Message tape (Old Robinson).]
N	Text length (especially for rectangles).
$N_1 N_2$	Text length against $\overline{\chi}_{2\times}$, $\overline{\chi}_2$.
$[N'_\alpha N''_\alpha$	Number of occurrences in ΔD of α against $\overline{\chi}_{2\times}$, $\overline{\chi}_2$.]
NM	Norm.
P	Probability, especially in $P(E\|H)$

P	Plain language.
P^*	Modified plain language (see 27G)
PB	Proportional bulge.
Q	Whatever is switched into the Q panel of Colossus.
[Q	Used, unhappily, in Robinson sign-writing.]
R	Number of places looked at.
R_i	Remembered impulse of Q.
S	Typewriterese for Ψ
S	Score.
S	Amount of column slide in a motor rectangle.
$[S_r$	$\sum \theta_{ij}^r$]
SD	Standard deviation.
ST	Set Total
T	Text length.
T	Theory.
TM	Total motor.
U, V	Typical teleprinter letter or stream.
[V	Depth.]
[W	Wheel tape on old Robinson.]
X	$\sum \lvert x_i \rvert$, more generally double bulge.
X	Typewriterese for χ
$[X_n^m . Y_n^m . Z_n^m$	Nonce-use in scoring go-backs.]
Z	Cipher.
Z^*	Modified cipher (see 27G).

a	$P(TM = x)$
a'	$P(BM = x\ (= 1 - D)$
$[a$	average.]
b	Ideal value for b_i, so that $ab = \frac{1}{2}$.
b_i	$P(\Delta\Psi_i = x)$
b	Bulge.
$[c$	Number of crosses in χ_2)

d	Number of dots in μ_{37}
[d	Decibanage.]
d_k	Number of $\Delta\Psi'$ letters with k dots and no crosses in key-breaking significance test II.
db	Deciban.
f	Factor.
i j	Suffixes most commonly denoting impulses, but also columns and rows of a rectangle.
[k,l	Number of dots, crosses, in the other impulses in Turingery.]
[k,l	Constants in 26Y(4)]
k	Depth (of rectangle $\hat{\chi}_\lambda$ etc.)
[k	Number of crosses in μ_ω]
[l	Tape length.]
m	Number of crosses in a letter.
[m	Number of impulses in a crib run.]
n	Text length.
$n_\chi n_\lambda$	Text length against $\bar{\chi}_i \chi$, $\bar{\chi}_\lambda$.
n'	Obsolete form of n_χ
n	Number of dots in a letter.
[n(θ)	Number of occurrences in a score θ]
n_Θ n_α	Number of occurrences of a letter Θ, α
o	Odds.
p	Probability.
[p	(Specialised uses) Probability that each $\Delta\chi$ character is correct.]
p_Θ	Probability of a letter Θ
p_x	Probability of a score x if the character is a cross. 24Y(c)
p	(originally $\wp$) Pip.
q	$= \frac{x^*}{x}$
[q	Probability that the right score has bulge $< B_2$.]
r	Number of places looked at.

$r_x, r_.$	(in motor run) Number of places looked against $\bar{\chi}_a \times \bar{\chi}_a$.
[r	Number of dots in a letter.]
[r	Number of dots in a cell of a rectangle.)
s	Sigma-age.
[s	Number of crosses in a letter.]
[s	Number of crosses in a cell of a rectangle.)
[s	Distance between settings (coalescence).]

t	s/43 (coalescence)
w	Wheel length.
x	$\sum\|x_i\|$, more generally double bulge.
x_i	Pippage of character (sometimes specifically $\Delta\chi_1$ character)
x^*	Double bulge on correct wheels.
[y	Number of doubled signs in key-breaking significance test I.]
$\left[\begin{matrix} y_i \\ y_i \end{matrix}\right.$	$\|x_i\|$. Inconsistent with the following use. $\left.\begin{matrix} \\ \end{matrix}\right]$
	Pippage of character of $\Delta\chi_2$ in converged rectangle.
[z	Double bulge against a typical character. 25W(a),(e).]
Δ	ΔU = U + (U one forward)
Δ^n	Δ applied n times.
Δ_n	$\Delta_n U$ = U + (U n places forward)
Δ^*	$\Delta^* U$ = U + (U one back)
$\left.\begin{matrix} \ominus \\ \Phi \\ \sum \end{matrix}\right\}$	Typical letter of the teleprinter alphabet (often written Ⓗ)
	Sum of
$\alpha, \beta, \gamma, \delta$	Editions of wheels, or special tapes.
β	Proportional bulge of $\Delta\Psi = x$
[β'	Proportional bulge of $\Delta\Psi' = x$, commonly written $\not\beta$]
For $\beta_\ominus \beta_{ij}$ &c.	see ξ
[γ	$\frac{\delta}{2}$, obsolete]
δ	Proportional bulge of ΔD_{ij} = .(most commonly $\Delta D_{12} = \cdot$)
δ_o	Observed bulge of ΔD_{ij} = .(most commonly $\Delta D_{12} = \cdot$)
$\overline{\delta}\ \underline{\delta}$	δ against $\overline{\chi}_2 \times, \overline{\chi}_2 \cdot$
$\delta_\ominus$ &c.	See ξ
ε_i	$\pm$ 1, or 0. (reprints ., x or ?)
ϑ	$\frac{1+\delta}{1-\delta}$
ϑ	ϑ term in significance test IV.
[θ	Proportional bulge of $\hat{\chi}_2$ = .]

[θ_i, θ_j'	Pippages in accurate scoring.]
θ_{ij}	Excess of dot over cross in a cell of a rectangle.
[$\theta(x)$	See 92D.]
[λ	$\pi/2$ (obsolete).]
[λ, μ	Co-efficients in series for banage that $f > f_0$.]
[λ	$b(1-p) + p(1-b)$]
[μ	$bp + (1-b)(1-p)$]
μ	Motor.
ν	Number of comparisons, generally in a composite flag, but also in crib scoring.
ν^*	ν when $\Delta\chi_i$ is included.
$\begin{bmatrix}\nu \\ \nu'\end{bmatrix}$	Number of different letters looked at in motor run. Number of different letters looked for in motor run (obsolete).]
ν_i	Number of clicks between A_i, B_i in general formula for standard deviation.
f	Typical proportional bulge: in full f^U_Θ is the proportional bulge of Θ in the stream U.
f_Θ	Proportional bulge of Θ
$f_x, f_{\cdot x}$ &c.	Proportional bulges of i = x; i = ., j = ., k = x, etc.
$f_i, f_{ij} = f_{i\cdot j}$ &c.	Proportional bulges of i = .; i ♦ j = ., etc.
[f	Proportional bulge of $\Delta^2\chi = x$]
[f	$\frac{R\delta}{\omega\sigma}$]
π	Proportional bulge in ΔP.
For π_Θ &c.	see f
[π	$\log_f$ odds.]
[ρ	31ρ is an interval used for differencing in $\overline{\chi}_2$ limitation crib tapes.]
[ρ	$\frac{1}{32} P\{\Delta D = /\}$, obsolete.]
σ	Standard deviation.
ϕ	A distribution function (χ^2 distribution)

[ϕ A distribution function for δ]

[ϕ PB($\Delta z_2 = .$)]

[ϕ in statistical motor-breaking : see ch 92.]

χ χ -stream.

$\Delta\chi_6$ $= \Delta\psi_6' = \widetilde{\lim}$. 22B(g), 26B(b), 26E

χ^2 In χ^2-distribution 21(1).

Ψ	Ψ-stream.
[$\Psi(r)$	$r(r-1) + s(s-1)$ in key-breaking significance test II]
⌀ ⌀ ⌀	Typewriterese for σ
$\tilde{U}$	U + x
$\bar{U}$	U one place back.
$\underline{U}$	U one place forward.
$\hat{U}$	$\bar{U} + U + \underline{U}$
U'	Extended U
U^*	U modified in various ways.
$\rightarrow$	$U \rightarrow .$ means $P(U = .) > \frac{1}{2}$
$\xrightarrow{p}$	$U \xrightarrow{p} .$ means $P(U = .) = p$
ⓩ z	To reduce errors, scores are usually entered thus + z as ⓩ; − z as z
⊙ , ⓧ	Symbols used in devil exorcism.
▭	Rectangle.

73 BIBLIOGRAPHY

This bibliography is by no means exhaustive, especially in the case of 73C and 73E, where the specimens included owe their preservation as much to chance as to deliberate selection.

73A RESEARCH LOGS

R0, R1, R2, R3, R4, R5, R41.

Index to Research Logs, R0 to R5.

Black File.

73B SCRKEDS

(a) General

An Introduction to Fish.

Elementary Screed on ΔD Counts and Colossus Runs.

Sigmas and Decibans.

From De-λ to Decode.

Elementary Theory of Wheel-breaking.

Motor and Ψ Runs.

Treatment of Key.

Checks and Tests.

Super-Robinson.

(b) For Coloperators

Setting on Colossus, Elementary Openings.

Ψ and Motor Runs.

Wheel Slides and Message Slides.

Colossus Testing for Wrens.

(c) Rectangles (largely obsolete).

I Theory of Rectangles.

II The Practice of Rectangle-making.

III What to do when a Significant Rectangle is Obtained.

73C STATISTICS.

Rectangle Statistics.

Significant Rectangles, Letter Counts.

Alphabetical Counts and Runs Statistics.

Δ D Counts on Set Messages, Volumes A, C and D.

Plain Language Alphabetical Counts.

Un Δ P Combination Counts.

$\Delta\chi_5$ Wheel Research.

73D ADMINISTRATION, STANDING ORDERS, ETC.

Grey File of Standing Orders.

Robinson Standing Orders.

Wheel Man's Compendium.

Specimen Ops Log, 05.

Tea Party Minutes.

73E CHARTS AND TABLES

(a) For Coloperators

A Colossus Bible, containing

Table for Estimating Odds of Runs,
Fifth Wheel Runs (χ_3 and χ_5) and (on back)
χ Runs for Colossus,
Decibanning of Single Wheel WB Runs,
Rectangling on Colossus (χ -length multiples),
Average 32 Letter Counts (Whiting and Lumpsucker),
Normalised Un Δ P Counts for Ψ-setting,
Runs Statistics.

Sigma Chart.

"Good Certain" Chart.

Elementary Setting.

Dottages for Colossus.

(b) For Wheel Man and Computers.

Significance Test IV, χ_s Flag Formulae, Wheel Characteristics, and General Formula for calculating ϑ Terms.

Value of X for Significance, for different Text Lengths.

Number of db up for given X, for Text Length 10168.

Table for Calculating ϑ Terms for N = 10168, and (on back)

Significance.Test IV and General Formula for ϑ Terms.

$10_n \log_{10} n$ Table.

Accurate Convergence Scoring Table.

Accurate Convergence Slide Wheel.

(c) Miscellaneous.

Decibanage of Erro Function.

Centiban Table.

Ratio of $\frac{EB}{\sigma}$ on /1+2 BM Run to the $\frac{\beta}{\sigma}$ of 1+2/.

Wheel-sliding Table.

Psi Test Tapes (for Tapes Registrar).

Tape Sub-section General Instructions (for Tunny and Angel Rooms).

74 CHRONOLOGY

	Changes in Turing	Organisation Changes	Machines	Theoretical Discoveries and Achievements
1	Szegoon first Turing link	Work in Research Section Starts		
y				
gust	The depth HQIBPEXEZMJG text ..... and read			
ember				
ober				
ember				
ember				

1942	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
January				Machine broken for Aug. 1941
February				
March	Broken traffic shows ab-à Tone transmission			
April			Decoding machine ordered	Machine broken for March 1942. First attempts at setting.
May				Wheels broken before the end of the month by indicator method.
June			First decoding machine arrives.	

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http://www.alanturing.net/turing_archive/archive/t/t23/TR23-003.html

1942	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
July		Testery founded to take over work on Tunny from Research Section.		Current traffic read for first time Turingery.
August	Introduction of Quatsch			
September				
October	Experimental Tunny link closed. Codfish and Octopus start with QEP system and monthly change of Ψ_5 patterns	Testery confined to depths. Research Section begin investigating Statistical Methods.		
November			Newman suggests electronic counters	1+2 break in invented by Tutte. Message set statistically using $\Delta z_1 + \Delta z_2$ rectangle
December		Newman given task of developing machines for setting Tunny		

1948	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
anuary			Early Robinson designed and ordered	
ebruary	DZ+2A (with χ_2 lim) makes first appearance on Codfish			Research section breaks chis statistically from Z by rectangles
larch	$\overline{\chi}_2 \overline{P}_5$ lim. tried experimentally on Herring		Plans for mechanical setting of Tunny and Sturgeon well under way	$\overline{\chi}_2$ lim broken
pril		First 16 Wrens arrived.		$\overline{\chi}_2 \overline{P}_5$ broken by Testery and Research Section
ay			Method of contracted de-χ successful.	
une		Newmanry work starts	Arrival of Heath Robinson + First Newmanry Tunny	

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1943	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
uly				
ugust		Ro started		Recognition that 1+6 in a break-in is not by any means certain. Discovery that Knockholt (or the [illegible]) were producing a lot of sides in tapes.
eptember			Suggestion of 'and/or' machine and repeated use of character on Colossus or Robinson	Discovery that best ΔP letter is not necessarily /. Expected score of motor run in terms of ΔD.
ctober		Change over from two to three shifts.		
ovember		Newmanry moved from Hut 11 to Block F.	First (production) Robinson arrived	Recognition that de-χ's can be broken by hand. Discovery of $\hat{\chi}_2$
ecember	Reappearance of $\bar{\chi}_2 + P_5^2$ limitation in Bream and Codfish traffic	Testery take on psi and motor setting and Newmanry concentrate on chi setting and breaking.	Second (production) Robinson arrived	Recognition that ΔD statistics (rather than ΔP) are the quickest way of finding new rubs.

http://www.alanturing.net/turing_archive/archive/t/t23/TR23-006.html

1944	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
January		General Registries of Newmanry and Testery amalgamated.	Direct TP line from Knockholt to Block F installed. Robinson 3 (First double bedstead Rob.) installed.	χ_3 now set in Newmanry, rather than sending deχ's on only 4 impulses to Testery.
February			Colossus I installed. Spanning suggested.	Colossus first used for wheel-breaking
March			Robinson IV installed.	
April		First motor runs successfully done on Colossus	New Tunny machine, new Garbos and one Mrs. Miles installed	Significance tests for rectangles.
May				Cribs, predicted by Sixta, successfully used for wheel-breaking for first time.
June	SZ 42 B first used on Codfish (with $\bar{\chi}_2$ $\bar{P}_1$ P_5 bm).	Daily meetings started	Colossus II installed.	

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1944	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
July	Invasion of Europe Daily wheel changes on Jelly Koenigsberg Exchange closes and moves to Colossus.	Slide-runs started, using test-tapes, to check machines	Colossus III installed More reliable Robinsons designed - suitable for work on Cribs First rectangles made on Colossus. Colossus IV finished.	New 'staircasing' method evolved for Cribs. Significance tests for wheel-breaking runs introduced.
August	Daily wheel changes on almost all Tunny links.	No. of computers increased very considerably		
September	Several links ceased using P_5 limitation	Work started in Block H	Colossus V installed	Thurlow rectangles first done. Combined χ_5 Flag for key introduced, with significance test
October	Further reorganisation of Tunny		Colossus VI and first super Robinson installed Colossus VI takes tapes up 25,000 long.	Copy correction write (for correction of tapes) introduced.
November		15th November. The Fire. New type of test runs for checking Colossus - test runs. Keadleston Hall started operating. Reorganisation at Knockholt.	Colossus VII installed	New adaptation of rectangling methods used to break short stretches of key. Complete pages of slips obs. with corresponding wheel settings recovered from Writing decode. Jacobs Flag started.
December	P_5 limitation largely abandoned by Germans.	Extensive motor and pc selling by machine.		Colossus decoding invented. Theory of coalescence.

1945	Changes in Tunny	Organisation Changes	Machines	Theoretical Discoveries and Achievements
nuary		$\Delta\Sigma$ test-runs first made De-χ checks first done Education committee formed	Colossus VIII installed. Second Super-Rob. Finished	
bruary		Δ_2 runs started	Device installed on Colossus XI enabling sum of squares of rectangle entries to be computed quickly. Rectangles now produced on tape - to mechanise computing on heyp. Colossus IX installed	Tests carried out on Thrasher (on new Robs) gave negative results, with regard to Tunny-type machines.
arch	Exchange set up at Salzburg	Raw tapes sent from Knockholt 4 wheel-runs instituted Setting of bars considered as responsibility of Testery rather than Testery Wrens taught wheel-breaking	Mechanical Flags instituted Machines tested regularly by Wrens	
pril		Rectangle making started on Super-Robs.	Colossus X installed 5202 arrived - to start work experimentally	
ay	Victory in Europe Last Tunny message sent	Change from 3 to 2 shifts Work on back traffic (1943-4) History and 5202 section formed		
ne			Two sets of German Tunny equipment arrive	Experimental operations using 5202.

CONCLUSIONS

A, ORGANISATION

(a) Checking
(b) Simplicity
(c) Division of labour
(d) Allocation of responsibility
(e) Decentralisation
(f) The written word: Colossus printing - notices and instruction books - log books - screeds - signing work - labelling - neatness - reading.
(g) Speed of work
(h) Teaching
(i) Research

B. THEORY

(a) Probability
(b) Notation
(c) Successive approximation
(d) Key and Cipher
(e) Cipher makers and cipher breakers

C. MACHINES

(a) Accuracy
(b) Adaptability
(c) Strength of paper
(d) Small machines
(e) Use of standard equipment
(f) Adequate supplies
(g) Tape-readers and electromatic typewriters

A. ORGANISATION

(a) Checking

The number of operations performed on a message from the time it is received at Knockholt to the time it is decoded is very large and therefore it is essential to have systematic checks at every stage. These checks are equally important for processes which are done by hand and by machine. Checking has become a mental habit with all the cryptographers who have been in the section for any length of time.

(b) Simplicity

Another method of avoiding mistakes is to choose simple processes if possible, even if some power is sacrificed. Mistakes are always made when a new routine is introduced. On the other hand the Wrens are quite capable of assimilating a complicated routine with practice, provided that they are specialists at a particular job (e.g. cribs). Sometimes there are alternative methods with not much to choose between them and then the choice can profitably be left to individual preference (e.g. methods of starting the convergence of a rectangle).

(c) Division of Labour

We have just referred to one advantage of specialising. The method of division of labour is a principle which applies to all grades. Cryptographers are given a definite job for at least a week at a time. Wrens have a definite job more or less permanently. An experiment was tried once of changing the jobs

of the Wrens round, but it was unsuccessful. The cryptographers, on the other hand, need to have a complete and detailed knowledge of the entire section if they are ever to act as duty officer. The principle of moving from one job to another after a week or two is particularly important as regards research. No important theoretical advance was made by anyone who did not have a good knowledge of the practical side.

(d) Allocation of responsibility

The method of division of labour is much the same as that of allocation of responsibility for particular jobs. The possibility of cribbing by long retransmissions would probably have been discovered much earlier if a definite individual had been made responsible for looking into the question (as a part time job).

(e) Decentralisation

Division of labour should not be confused with geographical decentralisation. This has nothing to be said for it except security from aerial attack. The spreading into three blocks of the people who broke Tunny, was due to historical causes and could not be remedied once it had happened. The Colossi were housed in four rooms. This necessitated a larger staff of cryptographers. A larger supply of PAX telephones would have helped in this connection.

(f) The Written Word

(i) Without a printer, runs on a Colossus would take about 50% more time to do and the results, written down from the display panel would be much less reliable.

(ii) Notices and Instruction books. When routines were first spread round the section in the form of notices there was an immediate decline in the number of mistakes. Previously the Wrens had been taught mainly by word of mouth. Later instruction books were introduced and each entry was signed by all who read it. This is the best method. Technical instructions prepared by the administration should be checked by someone with particular knowledge of the technique involved.

(iii) Log books. These have the following advantages:

(a) to show what work is done in each department and to help the administration.

(b) to help with the efficient handing over from shift to shift (though a short overlap of shifts is useful in addition). When a mistake is made that is so incredible that no single individual could have perpetrated it, the reason is always that there has been an inefficient hand-over from one shift to another.

(c) to encourage peaple to take a pride in their work.

(d) to provide a permanent record for research purposes.

(e) the research logs help new men to learn the work.

The only alternative to log books is a very great deal of talk. Verbal discussion should in any case be encouraged, as in the 'Tea Parties'. (The Tea Parties are meetings of the cryptographers held about once a week).

(iv) A form of log book appropriate for some purposes, e.g. Tea Party Agenda is a blackboard.

(v) Screeds. These are valuable if well written for teaching Wrens and new cryptographers. Men employed in operational work are usually too busy to teach new men by word of mouth though

lectures for Wrens were fairly frequent.

(vi) Signing work, Labelling, Neatness. The importance of these three things is often overlooked and thereby much time is wasted.

(vii) Reading. A failure to read the log books, instruction books, blackboard suggestions, etc. should be regarded as a 'howler'.

(g) Speed of work

In estimating in advance how long a particular job will take, it is useful to hold in mind that some time must be allowed for every transference of the job from one person to another. A rough estimate is about half an hour. This is a necessary evil of the shift system, and is most noticeable when cryptographers are being transferred from one job to another. It is accentuated by being housed in significantly separated buildings.

(h) Teaching

In addition to the value of screeds there is a general principle of learning that is only too easily overlooked. The principle is that of alternating theory and practice. The level of theory that can be assimilated without some experience is not very high with most people. Hence the best plan is to give theoretical lectures to all Wrens whether they are new arrivals or old hands.

(i) Research

An aspect of research not yet mentioned is the fact that it is useful to think from time to time about the theory even if no tangible result emerges. The effect is to make the practice easier, and in particular to make it easier to cope with unexpected practical situations. Incidentally the best ideas are often had outside working hours.

B. THEORY

(a) Probability

The most obvious conclusion, from the point of view of theory, is the value which the subject of probability has in certain types of cryptography. In particular the use of significance tests is noticeable and is a way of replacing the cryptographer's intuition by something more accurate, in certain cases. The 'deciban' has again proved its worth. On the whole the point of view of the theory of probability (including the so-called principle of inverse probability) is more powerful than that of the subject of statistics.

(b) Notation

If a mistaken notation is introduced it is sometimes difficult to change because everybody becomes accustomed to it. Improvements were made in the notation in 1943 in spite of a certain amount of ossification. The only outstanding flaw in notation now is the habit of using $\overline{x}_1$ crosses to permit motor dots. Though known to correspond to the German practice it would nevertheless have been better to reverse the convention.

(c) Successive approximation

Several of our processes are examples of the method of successive approximation. This is a well known part of ordinary scientific method.

(d) Key and Cipher

Key can be regarded as a special case of cipher with plain language all strokes. The statistical methods which apply to one, will also apply to the other. This idea should have application to other subtractor ciphers.

(e) Cipher makers and cipher breakers

With our experience of Tunny it would be easy to make suggestions for making Tunny unbreakable. Independent motorising of the Ψ's would achieve this, except that depths could be read if an autoclave were not introduced also (See R4, 116).

Anyone who designs a cryptographic machine should avoid the use of a gadget for returning the settings to the start of the message. Such gadgets are liable to encourage the production of depths.

C. MACHINES (Cf.ch.51,52)

(a) Accuracy

The most remarkable feature of our machines is the accuracy of Colossus, especially when doing Ψ runs.

(b) Adaptability

For Tunny wheel setting and breaking Colossus is a much more powerful machine than Robinson, but Robinson is more adaptable to other problems. The design of the Colossus switchboard and plugboard were also based on the principle of adaptability and this paid good dividends. The method of making a machine adaptable is first to think of a number of things required of it and then design the machine to cope with a general class of problem which includes all the special ones as particular cases.

(c) Strength of paper

We had several tape breakages, especially on the Robinsons, but on the whole the strength of the tapes, when run at speed, is very surprising to the layman.

(d) Small Machines

There is a danger of underestimating the importance of small machines and devices like hand counters, printers, adding machines, slide rules, charts and rubbers. Shortage of these things can cause bottle-necks. Our production increased considerably when we were able, in 1944, to present Knockholt with a few hand counters.

(e) Use of standard equipment

It is helpful in avoiding bottle-necks to use standard equipment as far as possible, even if not as efficient as some other device. For example the use of perforated tape rather than photographic apparatus was justified in this way.

(f) Adequate Supplies

As already implied, the supply of certain small machines was inadequate, while the supply of standard equipment was fairly plentiful. At times it looked as if the supply of electrical power would be definitely insufficient, but fortunately no very great trouble was caused on this account, partly owing to the economies effected in the Park as a whole.

(g) Tape-readers and electromatic typewriters

These are of great value for quickly typing out a length of cipher in given widths. They should be useful in other cryptographic work. The original discovery of the χ_1 wheel length, which led to the breaking of Tunny, was almost an accident. It would have been a routine if systematic use of a tape-reader and electromatic typewriter had been applied.