

APPENDIX I
PREPARATION OF PIN AND
LUG SETTINGS

1. Pin Settings

a. Prepare a table of the key wheels by listing, in alphabetical order, the letters appearing on the face of each wheel: the first rotor, A to Z; the second wheel A to Z, omitting W; the third wheel A to X, omitting W; the fourth wheel A to U; the fifth wheel A to S; and the sixth wheel A to Q.

b. Prepare a set of 156 cards, 78 of which are marked R (right) and the remainder L (left). Shuffle the cards thoroughly and draw one at a time. Start with A on wheel number 1, and prepare the key list in accordance with the cards drawn: If a card bears an L, cross out the letter; if a card bears an R, do not cross the letter. Only letters with effective pins are then shown in the key list (table I page 13). More than six consecutive effective or noneffective pins on any wheel must be rearranged in order to prevent use of such a sequence. A random arrangement, in which from 40 to 60 percent of the pins are in the effective position, is assured by this method.

2. Lug Settings. To prepare a table of favorable lug settings, proceed with the following steps in the order given:

a. *Selection of Numbers.* Select a set of six numbers from either group A or group B in appendix II. Sets of numbers selected from group B must not exceed 10 percent of the

total sets selected. The sets are selected at random from the table, and a set is not used a second time as long as other unused sets are available. Sets of numbers from group B should be used at irregular intervals and should not succeed each other in key lists.

b. Rearrangement of Numbers. Rearrange the numbers so that they appear in random order.

c. Distribution of Overlaps. When the two lugs on lugs of a bar are both placed in effective positions, an *overlap* results. The total overlaps is found by subtracting 27 (the number of bars on the drum) from the total of the six numbers in a set. The overlaps required for each set of numbers has been calculated, and is given with the sets appearing in appendix II. Distribute the overlaps among the numbers according to the following four rules:

- (1) Most of the six numbers should be involved.
- (2) Overlaps should include numbers which are separated, and numbers which are side by side.
- (3) Several small overlaps should be used in preference to one large overlap.
- (4) There must not be more than four overlaps between any two numbers. It is permissible, however, for a number to have a combined overlap of more than four. (The number 12 in subpar. A below has a combined overlap of five).

Thu above rules offer a general guide for overlap distribution. But some deviation can be made from all but the rule appearing in subparagraph (4) above, which must always be followed.

d. Checking Placement of Overlaps. The overlaps must be so placed that a single number, or the sum of any two, three, four, five, or all six of the numbers, yields all the values from 1 to 27, inclusive. Remember that the result of two effective

lugs on the same drum bar is one. As an example, in table III there are three effective lugs in column 6, and one effective lugs in column 3, given a total of four. However, two of the effective lugs are on one bar which cancels the effect of one lug, yielding a result of only three. Hence, the proper total for columns 3 and 6 is three (two plus one) and not four.

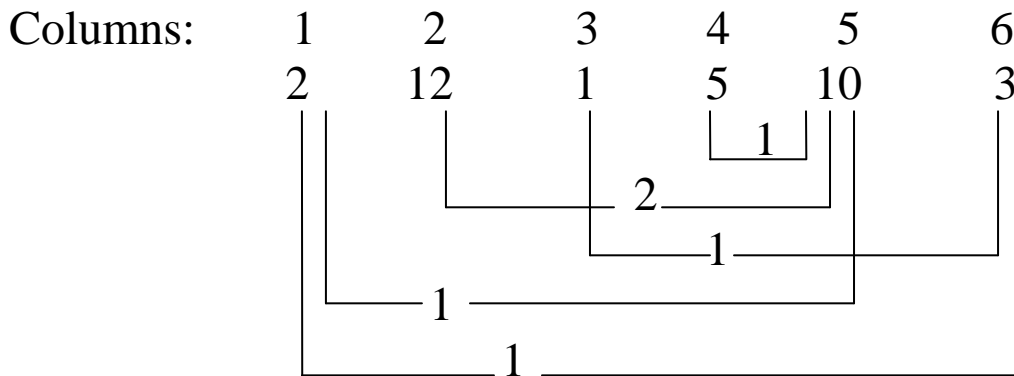
e. Preparing Lug Setting Work Sheet. The effective lugs (represented by X's) are now entered on a work sheet similar to that shown in table III; lugs in the same column are placed on successive drum bars in as many cases as the overlap condition permits. The completed work sheet should be checked carefully for accuracy with the results of the previous steps. The zero positions need not be shown on this chart.

f. Preparing Lug Setting Table. Convert the lug positions set up on the work sheet to a form illustrated in table II, page 15, by writing the numbered positions of the lugs opposite the number representing the drum bar. Determine the positions by referring to the number plate (29) at the rear of the drum-bar cage.

g. Complete Preparation of Lug Setting. The following example serves to illustrate the preparation of a lug setting. The steps are numbered to correspond to the steps described in subparagraphs 2a to 2d.

- (1) Select a set of numbers from group A.
1, 2, 3, 5, 10, 12 Overlaps = 6
- (2) Rearrange the numbers.
2, 12, 1, 5, 10, 3

(3) Distribute the overlaps.



(a) All of the six numbers are involved.

(b) Columns side by side: Columns separated:

4 and 5	1 and 5
	1 and 6
	2 and 5
	3 and 6

(c) Small overlaps are used in preference to one large one.

(d) Overlaps involving only two numbers do not exceed four.

(4) All values from 1 to 27, inclusive, are obtained. For example:

- 1 is given by column 3.
- 2 is given by column 1.
- 3 is given by column 6.
- 4 is given by columns 1 and 6.
- 5 is given by column 4.
- 6 is given by columns 3 and 4, and so on.

h. Alternate Overlap Distribution. Overlap distribution of the following produces a good key but does not follow strictly the rules for overlap distribution. Lug settings of this nature should be kept in a minimum in key lists.

1	2	3	4	5	6
1	5	12	10	3	2
	3	_2_		_1_	

3. PURPOSE. The foregoing limitations are imposed to provide the greatest amount of security possible in the shifting of the alphabets, and to add to the difficulties of enemy cryptanalysts engaged in making a mathematical analysis of the messages.

Table III. *Position of drum-bar lugs work sheet*

	1	2	3	4	5	6
1			X			X
2						X
3	X					X
4	X				X	
5				X	X	
6				X		
7				X		
8				X		
9				X		
10		X				
11		X				
12		X				
13		X				
14		X				
15		X				
16		X				
17		X				
18		X				
19		X				
20		X			X	
21		X			X	
22					X	
23					X	
24					X	
25					X	
26					X	
27					X	

APPENDI II
SETS OF NUMBERS AND OVERLAPS
FOR LUG SETTINGS

I Group A

Sets Overlaps							Sets Overlaps						
1 2 3 4 8 10	1	1 2 3 4 9 11	3										
1 2 3 4 7 11	1	1 2 3 4 8 12	3										
1 2 3 4 6 12	1	1 2 3 4 7 13	3										
1 2 3 4 5 13	1	1 2 3 5 9 10	3										
1 2 3 5 8 9	1	1 2 3 5 8 11	3										
1 2 3 5 7 10	1	1 2 3 5 7 12	3										
1 2 3 5 6 11	1	1 2 3 5 6 13	3										
1 2 3 6 7 9	1	1 2 3 6 8 10	3										
1 2 4 5 7 9	1	1 2 3 6 7 11	3										
1 2 3 4 9 10	2	1 2 3 7 8 9	3										
1 2 3 4 8 11	2	1 2 4 5 8 10	3										
1 2 3 4 7 12	2	1 2 4 5 7 11	3										
1 2 3 4 6 13	2	1 2 4 5 6 12	3										
1 2 3 5 8 10	2	1 2 4 6 8 9	3										
1 2 3 5 7 11	2	1 2 4 6 7 10	3										
1 2 3 5 6 12	2	1 2 3 4 10 11	4										
1 2 3 6 8 9	2	1 2 3 4 9 12	4										
1 2 3 6 7 10	2	1 2 3 4 8 13	4										
1 2 4 5 8 9	2	1 2 3 5 9 11	4										
1 2 4 5 7 10	2	1 2 3 5 8 12	4										
1 2 4 5 6 11	2	1 2 3 5 7 13	4										
1 2 4 6 7 9	2	1 2 3 6 9 10	4										

	Sets	Overlaps
1	2 3 6 8 11	4
1	2 3 6 7 12	4
1	2 3 7 8 10	4
1	2 4 5 9 10	4
1	2 4 5 8 11	4
1	2 4 5 7 12	4
1	2 4 5 6 13	4
1	2 4 6 7 11	4
1	2 4 6 8 10	4
1	2 4 7 8 9	4
1	2 3 4 10 12	5
1	2 3 4 9 13	5
1	2 3 5 10 11	5
1	2 3 5 9 12	5
1	2 3 5 8 13	5
1	2 3 6 9 11	5
1	2 3 6 8 12	5
1	2 3 6 7 13	5
1	2 3 7 9 10	5
1	2 3 7 8 11	5
1	2 4 5 9 11	5
1	2 4 5 8 12	5
1	2 4 5 7 13	5
1	2 4 6 9 10	5
1	2 4 6 8 11	5
1	2 4 6 7 12	5
1	2 4 7 8 10	5
1	2 3 4 11 12	6
1	2 3 4 10 13	6
1	2 3 5 10 12	6
1	2 3 5 9 13	6
1	2 3 6 10 11	6

	Sets	Overlaps
1	2 3 6 9 12	6
1	2 3 6 8 13	6
1	2 3 7 9 11	6
1	2 3 7 8 12	6
1	2 4 5 10 11	6
1	2 4 5 9 12	6
1	2 4 5 8 13	6
1	2 4 6 8 12	6
1	2 4 6 9 11	6
1	2 4 6 7 13	6
1	2 4 7 9 10	6
1	2 4 7 8 11	6
1	2 3 4 11 13	7
1	2 3 5 11 12	7
1	2 3 5 10 13	7
1	2 3 6 10 12	7
1	2 3 6 9 13	7
1	2 3 7 10 11	7
1	2 3 7 9 12	7
1	2 3 7 8 13	7
1	2 4 5 10 12	7
1	2 4 5 9 13	7
1	2 4 6 8 13	7
1	2 4 6 9 12	7
1	2 4 6 10 11	7
1	2 4 7 9 11	7
1	2 4 7 8 12	7
1	2 4 8 9 10	7
1	2 3 5 11 13	8
1	2 3 6 11 12	8
1	2 3 6 10 13	8
1	2 3 7 10 12	8
1	2 3 7 9 13	8

	Sets	Overlaps
1	2 4 5 11 12	8
1	2 4 5 10 13	8
1	2 4 6 9 13	8
1	2 4 6 10 12	8
1	2 4 7 10 11	8
1	2 4 7 9 12	8
1	2 4 7 8 13	8
1	2 4 8 9 11	8
1	2 4 8 10 11	9
1	2 4 8 9 12	9
1	2 4 7 9 13	9
1	2 3 5 12 13	9
1	2 3 6 11 13	9
1	2 3 7 11 12	9
1	2 3 7 10 13	9
1	2 4 5 11 13	9
1	2 4 6 10 13	9
1	2 4 6 11 12	9
1	2 4 7 10 12	9

1	2 4 5 12 13	10
1	2 3 6 12 13	10
1	2 3 7 11 13	10
1	2 4 8 9 13	10
1	2 4 8 10 12	10
1	2 4 6 11 13	10
1	2 4 7 11 12	10
1	2 4 7 10 13	10
1	2 3 7 12 13	11
1	2 4 6 12 13	11
1	2 4 7 11 13	11
1	2 4 8 11 12	11
1	2 4 7 9 13	9

2. Group B

	Sets	Overlaps
1	1 2 3 8 13	1
1	1 2 4 9 11	1
1	1 2 4 8 12	1
1	1 2 4 7 13	1
1	1 2 5 9 10	1
1	1 2 5 8 11	1
1	1 2 5 7 12	1
1	1 2 5 6 13	1
1	1 3 4 9 10	1
1	1 3 4 8 11	1

	Sets	Overlaps
1	1 3 4 7 12	1
1	1 3 4 6 13	1
1	1 3 5 8 10	1
1	1 3 5 7 11	1
1	1 3 5 6 12	1
1	1 3 6 8 9	1
1	1 3 6 7 10	1
1	2 2 3 9 11	1
1	2 2 3 8 12	1
1	2 2 3 7 13	1

		Sets	Overlaps
1	2	2 4 8 11	1
1	2	2 4 7 12	1
1	2	2 4 6 13	1
1	2	2 5 8 10	1
1	2	2 5 7 11	1
1	2	2 5 6 12	1
1	2	2 6 8 9	1
1	2	2 6 7 10	1
1	2	3 3 9 10	1
1	2	3 3 8 11	1
1	2	3 3 7 12	1
1	2	3 4 9 9	1
1	2	3 5 5 12	1
1	2	3 6 6 10	1
1	2	4 4 8 9	1
1	2	4 5 5 11	1
1	2	4 6 6 9	1
1	1	2 4 9 12	2
1	1	2 4 8 13	2
1	1	2 5 9 11	2
1	1	2 5 8 12	2
1	1	2 5 7 13	2
1	1	3 4 9 11	2
1	1	3 4 8 12	2
1	1	3 4 7 13	2
1	1	3 5 9 10	2
1	1	3 5 8 11	2
1	1	3 5 7 12	2
1	1	3 5 6 13	2
1	1	3 6 8 10	2
1	1	3 6 7 11	2
1	2	2 3 9 12	2
1	2	2 3 8 13	2

		Sets	Overlaps
1	2	2 4 9 11	2
1	2	2 4 7 13	2
1	2	2 5 9 10	2
1	2	2 5 8 11	2
1	2	2 5 7 12	2
1	2	2 5 6 13	2
1	2	2 6 10 11	2
1	2	2 6 7 11	2
1	2	3 3 9 11	2
1	2	3 3 8 12	2
1	2	3 3 7 13	2
1	2	3 5 5 13	2
1	2	3 5 9 9	2
1	2	3 6 6 11	2
1	2	3 7 7 9	2
1	2	4 4 7 11	2
1	2	4 4 5 13	2
1	2	4 5 5 12	2
1	1	2 4 9 13	3
1	1	2 5 10 11	3
1	1	2 5 9 12	3
1	1	2 5 8 13	3
1	1	3 4 10 11	3
1	1	3 4 9 12	3
1	1	3 4 8 13	3
1	1	3 5 9 11	3
1	1	3 5 8 12	3
1	1	3 5 7 13	3
1	1	3 6 9 10	3
1	1	3 6 8 11	3
1	1	3 6 7 12	3
1	2	2 3 9 13	3
1	2	2 4 10 11	3

	Sets	Overlaps
1	2 2 4 9 12	3
1	2 2 4 8 13	3
1	2 2 5 9 11	3
1	2 2 5 8 12	3
1	2 2 5 7 13	3
1	2 2 6 9 10	3
1	2 2 6 8 11	3
1	2 2 6 7 12	3
1	2 3 3 10 11	3
1	2 3 3 9 12	3
1	2 3 3 8 13	3
1	2 3 4 10 10	3
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1	2 3 6 9 9	3
1	2 3 7 7 10	3
1	2 4 4 9 10	3
1	2 4 4 8 11	3
1	2 4 4 7 12	3
1	2 4 4 6 13	3
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1	2 4 6 6 11	3
1	2 4 7 7 9	3
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1	1 3 5 10 11	4
1	1 3 5 9 12	4
1	1 3 5 8 13	4
1	1 3 6 9 11	4
1	1 3 6 8 12	4
1	1 3 6 7 13	4

	Sets	Overlaps
1	2 2 4 9 13	4
1	2 2 5 10 11	4
1	2 2 5 9 12	4
1	2 2 5 8 13	4
1	2 2 6 9 11	4
1	2 2 6 7 13	4
1	2 3 3 10 12	4
1	2 3 3 9 13	4
1	2 3 5 10 10	4
1	2 3 6 6 13	4
1	2 3 7 7 11	4
1	2 3 7 9 9	4
1	2 4 4 9 11	4
1	2 4 4 7 13	4
1	2 4 6 9 9	4
1	2 4 7 7 10	4
1	1 2 5 10 13	5
1	1 3 4 10 13	5
1	1 3 5 10 12	5
1	1 3 5 9 13	5
1	1 3 6 10 11	5
1	1 3 6 9 12	5
1	2 3 6 8 13	5
1	2 2 4 10 13	5
1	2 2 5 10 12	5
1	2 2 5 9 13	5
1	2 2 6 9 12	5
1	2 2 6 8 13	5
1	2 3 3 10 13	5
1	2 3 4 11 11	5
1	2 3 6 10 10	5
1	2 3 7 7 12	5
1	2 4 4 10 11	5

	Sets	Overlaps
1	2 4 4 9 12	5
1	2 4 4 8 13	5
1	2 4 6 6 13	5
1	2 4 7 7 11	5
1	2 4 7 9 9	5
1	2 4 8 8 9	5
1	1 3 5 11 12	6
1	1 3 5 10 13	6
1	1 3 6 10 12	6
1	1 3 6 9 13	6
1	2 2 4 11 13	6
1	2 2 5 11 12	6
1	2 2 5 10 13	6
1	2 2 6 9 13	6
1	2 3 3 11 13	6
1	2 3 5 11 11	6
1	2 3 7 7 13	6
1	2 3 7 10 10	6
1	2 4 7 7 12	6
1	2 4 8 9 9	6
1	1 3 5 11 13	7
1	1 3 6 11 12	7
1	1 3 6 10 13	7
1	2 2 4 12 13	7
1	2 2 5 11 13	7
1	2 2 6 11 12	7

	Sets	Overlaps
1	2 2 6 10 13	7
1	2 3 6 11 11	7
1	2 4 4 11 12	7
1	2 4 4 10 13	7
1	2 4 5 11 11	7
1	2 4 7 7 13	7
1	2 4 7 10 10	7
1	2 4 8 8 11	7
1	1 3 6 11 13	8
1	2 2 6 11 13	8
1	2 3 5 12 12	8
1	2 4 4 11 13	8
1	2 4 6 11 11	8
1	1 3 6 12 13	9
1	2 2 6 12 13	9
1	2 3 6 12 12	9
1	2 4 4 12 13	9
1	2 4 5 12 12	9
1	2 4 7 11 11	9
1	2 4 8 8 13	9
1	2 2 6 13 13	10
1	2 3 5 13 13	10
1	2 4 8 11 11	10
1	2 3 6 13 13	11
1	2 4 7 12 12	11
1	2 3 7 13 13	12