TRUNKING AND GRADING

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Figs. 2, 3, 5, 11, 13, 14, 15, 16, 17, 18, 22 and 27 are appended to this pamphlet.

INTRODUCTION

This pamphlet explains in some detail the design and practical arrangements of the inter-connexions between two stages in an automatic telephone exchange system. The pamphlet is intended to be read after E.P. Draft Series TELEPHONES 6/2 and in conjunction with E.P. Draft Series TELEPHONES 6/3.

Before discussing the methods of inter-connexion between stages some of the terms commonly used will be defined.

Trunk The term 'trunk' refers to a connecting circuit between two switching stages, or ranks, in an automatic exchange network, or between one rank of selectors and a manual switchboard.

Selector The term 'selector' generally refers to a two-motion selector, uniselector, or any other mechanism which moves a set of wipers over a bank of contacts.

Availability In automatic telephony the number of trunks to which a selector has access on any route is known as the availability.
Thus, (a) if 8 trunks are connected to the contacts, or outlets, on a particular level of a two-motion selector bank, the selector is said to have an availability of 8 on that particular level, and (b) in general the maximum availability of any selector is the total number of working outlets possible in the bank, or level of the bank.

Full availability Under full availability conditions a selector has access to the whole of the trunks on a given route.
It should be understood, however, that full availability conditions can exist when a selector at one switching stage does not have access to the whole of the trunks to the next switching stage. Consider an exchange with, say, 600 1st selectors and the subscribers' lines connected to uniselectors having an availability of 24.

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No one uniselector can, therefore, be given access to all the 600 1st selectors. Full availability conditions from each uniselector will exist, however, if the uniselectors are divided into 25 groups and 24 1st selectors allocated to each group. With such an arrangement the given route from each uniselector contains only 24 trunks, hence full availability conditions exist.

Limited availability The condition under which a selector has access to a limited number only of the trunks on a given route is known as limited availability. The availability is usually limited by the number of outlets in the bank or level of the bank of the selector.

Multiple When a circuit is accessible at a number of points, to any of which connexion can be made, it is said to be multipled. Thus if the selector bank outlets are 'multipled', as shown in Fig. 1, a particular circuit can be made accessible at each selector. In practice selector contact banks are multipled in groups; the

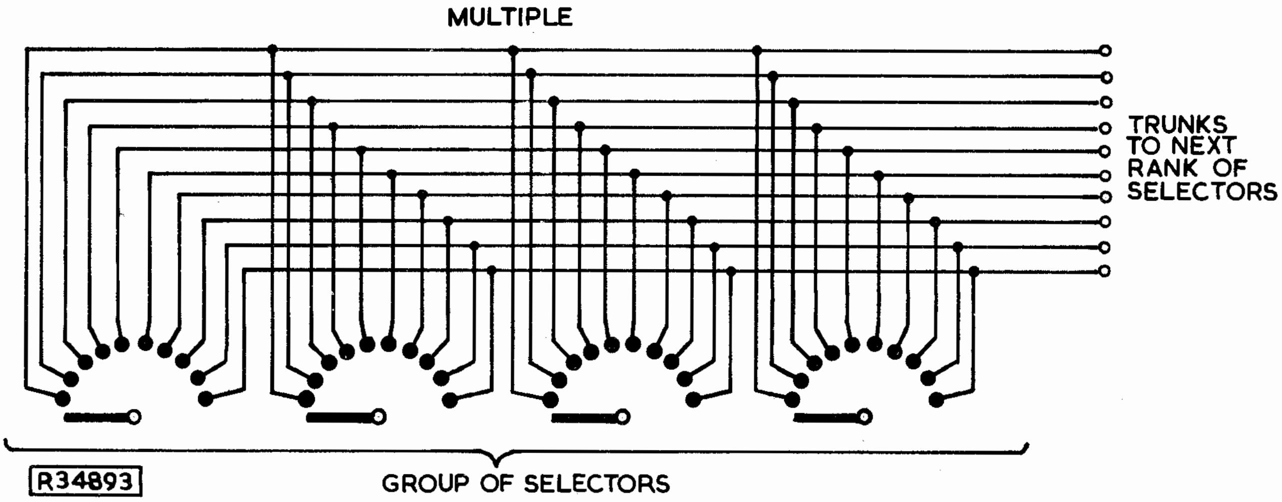

Fig. 1

number of banks in a group of two-motion selectors is usually 10, 15 or 20, and in groups of subscribers' uniselectors is 20 or 25. Contact banks multipled as shown in Fig. 1 are known as straight banks.

Interconnecting The method of connecting together multiples when the availability is limited, so that the sets of trunks available from different multiples are partially common to one another is known as interconnecting.

Grading Grading is a particular form of interconnecting whereby the multiples of several groups of selectors are connected together so that each selector is given access on the early outlets, or choices, of the bank, to circuits which are particular to its group, but on the later choices shares the circuits with the selectors in some or all of the other groups. Grading is also an arrangement of trunks connected to the banks of selectors by the method of grading.

The values for the traffic carried by particular trunks, or the traffic capacity of groups of trunks, quoted in this pamphlet have been obtained from tables and graphs which have been compiled with the aid of either Erlang's full availability formula or modifications of it. Graphs showing the traffic offered to each trunk in a full availability group for a given amount of traffic offered to the group, are shown in Figs. 2 and 3.

FULL AVAILABILITY GROUPS OF TRUNKS

The maximum number of trunks possible in a full availability group is determined in practice by the type of selector used, for instance, two-motion selectors provide availabilities of up to 20 per level, and uniselectors availabilities of up to 50. When the number of trunks necessary to carry the traffic between two stages in an automatic switching system does not exceed the number of outlets in the selector level or bank, the interconnexion arrangements are similar to those shown in Fig. 1. The diagrammatic representation of a full availability group of trunks connected to the multipled outlets of one level of a two-motion selector having an availability of 10 is shown in Fig. 4. The outlets of the group are always tested in the same order; in Fig. 4 and all the grading diagrams in this pamphlet the testing is carried out from left to right.

The labelling is similar to that found in practice and indicates, in this example, that the outlets are from level 2 of the contact bank multiple associated with the selectors on N 1st rack A, shelves A to F, and that the 10 trunks terminate on selectors on N 2nd rack A. The actual selector or relay-set on which a particular trunk terminates is usually indicated above the outlet to which the trunk is connected. In Fig. 4 the numbers above the outlets refer only to the trunks extended to the next stage, thus with a full availability group of 6 trunks, the numbers 7, 8, 9 and 10 would be omitted.

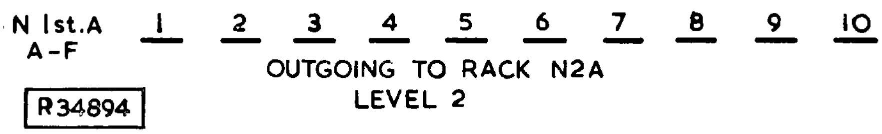

Fig. 4

TRAFFIC CARRYING CAPACITY

A table giving the traffic capacity of various sized groups of trunks at three different grades of service is given in Fig. 5 (appended). The term 'standard' in the table means a grade of service of .002.

Consider 2 full availability groups of trunks, one containing 10 trunks and the other 20 trunks, each carrying the traffic appropriate to a grade of service of .002. The distribution of the traffic over the trunks of the two groups is shown graphically in Fig. 6. Inspection of the curve 'a' shows that its gradient is virtually constant over the first 7 trunks, and it is steeper than either of the gradients formed by joining points W and X, and points X and Y on slope b. This indicates that the traffic carried by successive trunks in the 10 trunk group decreases more rapidly than it does in the 20 trunk group, hence the trunks in the larger group are more efficiently employed. The efficiency is measured in terms of the portion of the hour for which the trunk is occupied. It should be noted that the first 5 trunks of the 10 trunk group carry over 85 per cent of the total traffic, and that the first 10 trunks of the 20 trunk group carry only approximately 78 per cent of the total traffic.

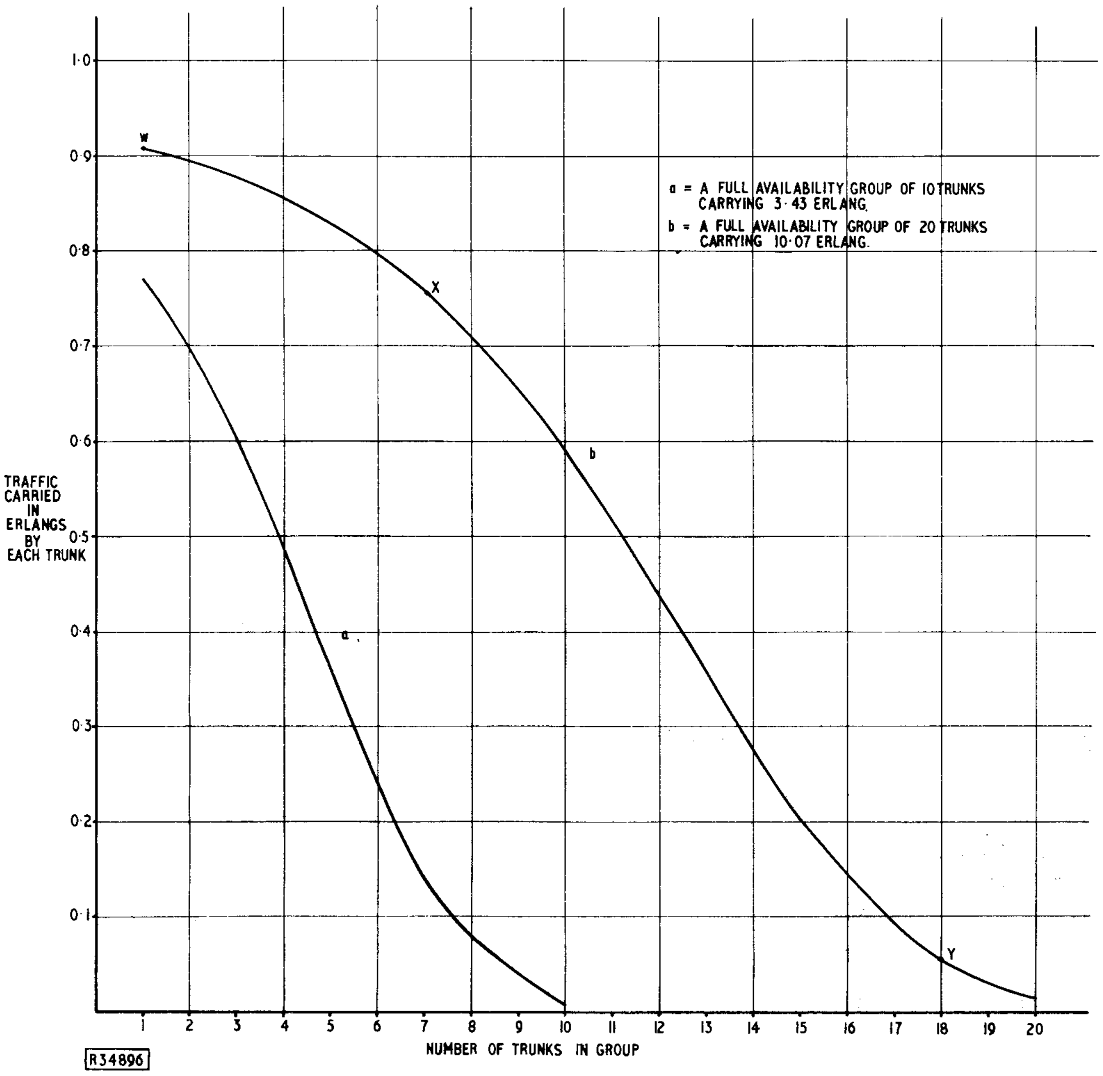

Fig. 6

The increase in the efficient of the larger group is accompanied by an increase in the deterioration of the grade of service when the group is subject to overloads of traffic; the reason for this may be illustrated as follows:-

When a full availability group of N trunks is offered A erlangs, and N is large, the grade of service, B, given by the group is given very nearly by the formula

$$B = \frac{A^N}{e^A \, N!}$$

Where e = 2.718 and N! = N x (N - 1) x (N - 2) .... x (N - (N - 1)). An increase in the value of A from a given figure results in the numerator of the expression increasing in value more than does the denominator, hence the value of B increases, i.e. the grade of service deteriorates. When the value of N is high the change in the value of B for a change in the value of A is also high; this is illustrated by the graphs shown in Fig. 7.

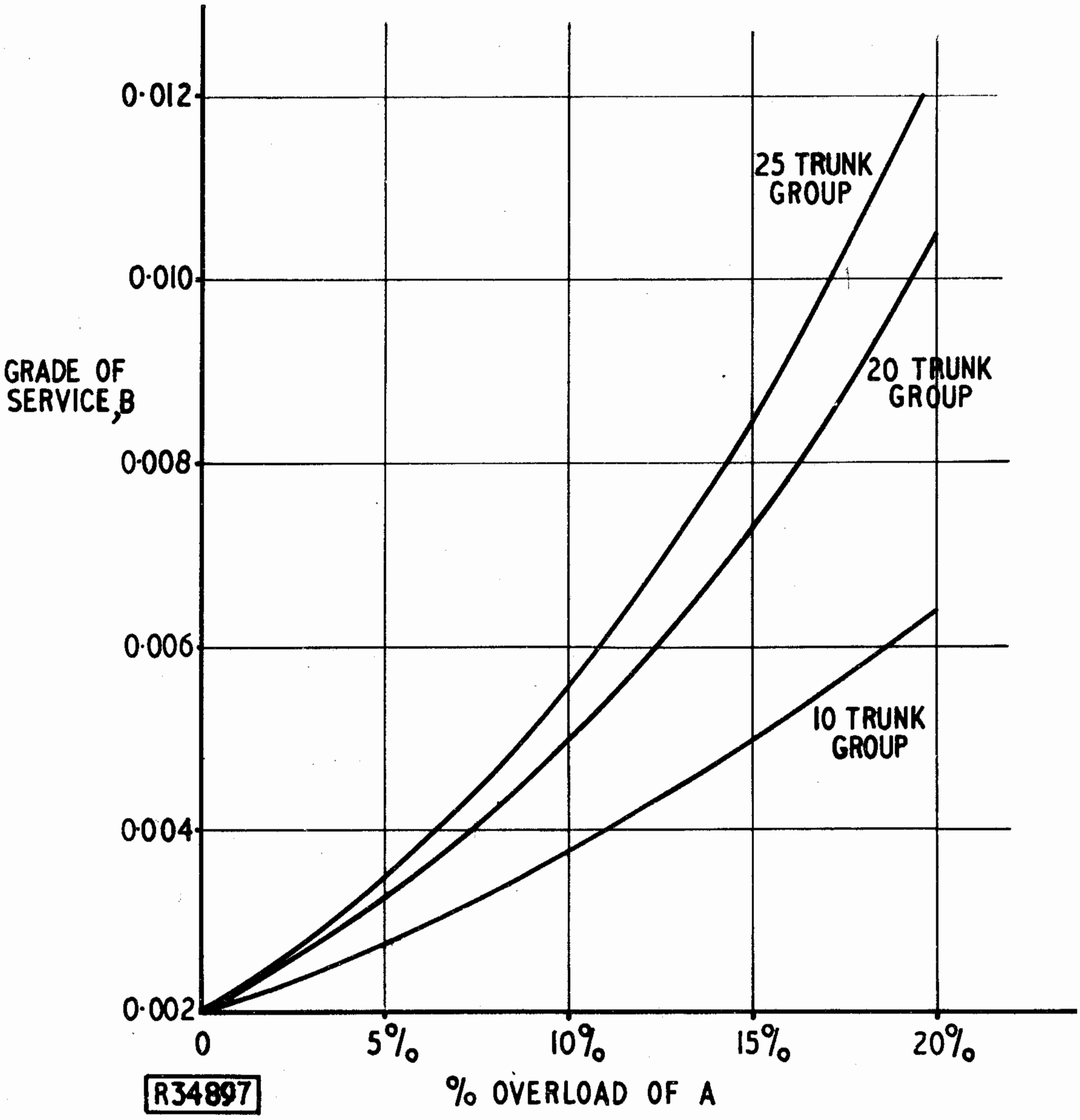

Fig. 7

Consideration of the modified formula shows also that the deterioration of the grade of service when a trunk is removed from the group increases as the value of A decreases. If A is constant, and the value of N is reduced to (N - 1), the numerator of the expression is decreased by the factor A, and the denominator by the factor N, thus the value of B increases because the value of N must always be greater than that of A. For a given grade of service however, the ratio of N to A increases as A decreases, hence at low values of A the increase in the value of the denominator with respect to the numerator is greater than it is at high values of A. The difference in the change in the grade of service when a trunk is removed from each of two groups, one having 10 trunks and the other 20 trunks, giving similar grades of service is shown in the following example.

Example

(a) The grade of service given by a group of 20 trunks carrying 10.07 erlangs is .002 i.e. 1 in 500, thus 10.07 erlangs is $^{499}/500$ of traffic offered. Therefore, traffic offered

$$= \frac{10.07}{499} \times 500 = \text{very nearly } 10.09 \text{ erlangs.}$$

The traffic carried by the last trunk in the group is 0.01982 erlang, hence if any trunk is removed from the group this amount of traffic will be lost. Thus the total traffic carried when the group is reduced to 19 trunks is

$$10.07 - 0.01982 \text{ erlangs.}$$

and the total traffic lost is

$$10.09 - (10.07 - 0.01982) = 0.03982 \text{ erlangs.}$$

$$\text{Grade of service} = \frac{\text{traffic lost}}{\text{traffic offered}},$$

hence the grade of service given by 19 trunks is

$$\frac{0.03982}{10.09} \simeq .0039464$$

Thus the grade of service is reduced to very nearly .004, i.e. 1 call lost in 250.

(b) For a grade of service of .002, 10 trunks carry 3.43 erlangs and the last trunk carries 0.01 erlangs.

Using the same reasoning as in (a)

$$\text{Traffic offered} = \frac{3.43}{499} \times 500 \simeq 3.4368 \text{ erlangs.}$$

The total traffic lost when 1 trunk is removed is

$$3.4368 - (3.43 - 0.01) = 0.0168 \text{ erlangs.}$$

Thus the grade of service when 1 trunk is removed is

$$\frac{0.0168}{3.4368} \simeq .0049 \text{ i.e. very nearly 1 call lost in 200.}$$

Summarizing the results of the two examples it is found that the grades of service deteriorate from .002 to very nearly .004 when 1 trunk is removed from a group of 20, and from .002 to very nearly .0049 when 1 trunk is removed from a group of 10 trunks.

From the foregoing considerations of full availability groups of trunks it is apparent that the later trunks in the group are not efficiently employed, but they cannot be dispensed with because of the effect on the grade of service. One method which may be used to overcome the inefficient use of the later choice trunks is to make them early choices at some of the other selectors; the first choice trunks at these selectors would likewise be late choice trunks at the former selectors. Such an arrangement, known as a 'slipped multiple', was used in practice and a typical allocation of the selector outlets to the trunks is shown in Fig. 8. A group of trunks connected by the slipped method has the same traffic carrying capacity as it has when connected normally, i.e. 'straight', and as it also has practical disadvantages it is no longer used by the B.P.O.

In practice, the traffic between switching stages is such that often the number of trunks required between stages is more than the number of outlets in the selector bank or level. One method of interconnexion used in such a case is to divide the selector contact bank multiple into a suitable number of groups, and then distribute the trunks over the outlets of the groups, so forming several full availability groups of trunks.

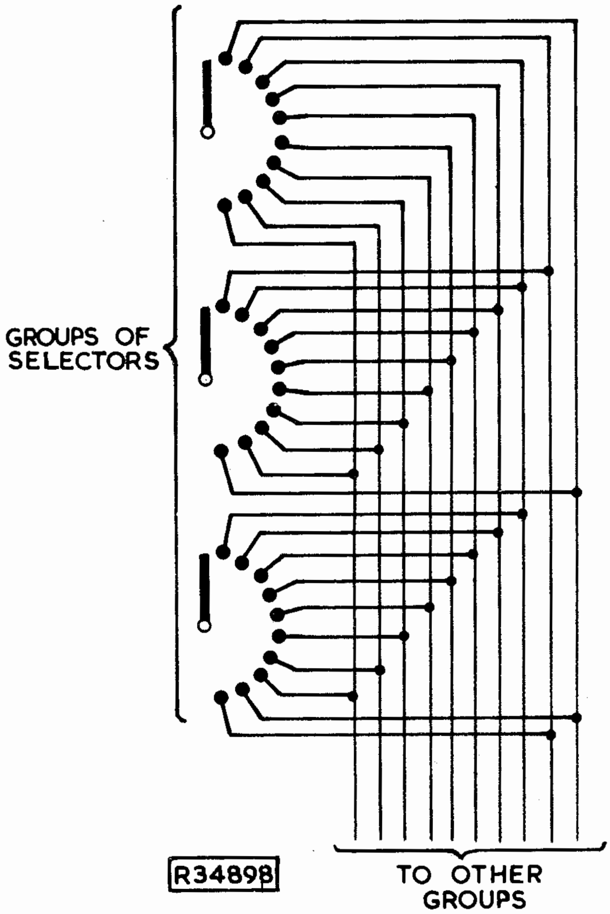

Fig. 8

Example

16 trunks are required on a route, access to which is obtained from a selector level having an availability of 10. The selector multiple can be arranged in 2 groups and 8 trunks allocated to each group. The diagrammatic representation of such a 2 group arrangement is shown in Fig. 9; it should be remembered that the two

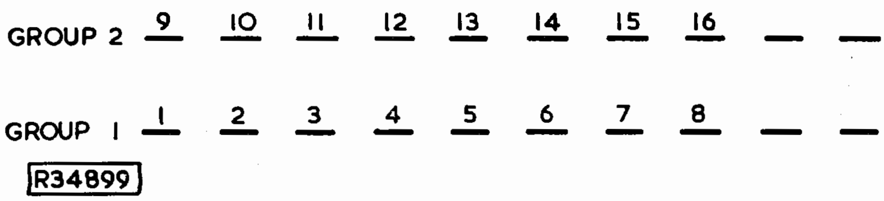

Fig. 9

rows of outlets represent the multipled contacts of a particular level in the contact bank multiple.

The method of forming a number of full availability groups is rarely used in practice because it increases the number of inefficiently used trunks.

GRADED GROUPS OF TRUNKS

The standard method of interconnexion between switching stages when the number of trunks exceeds the maximum availability of the hunting slectors is known as grading. Such a method improves the traffic carrying efficiency of the later choice trunks and thus requires less trunks for a given amount of traffic than the method previously described.

The term grading has been defined earlier in this pamphlet, and a simple example of 16 trunks graded over two groups of selectors having an availability of 10 is shown in Fig. 10a. The traffic distribution over the first 6 outlets of each group in Fig. 10a is the same as that for the full availability groups, Fig. 10b, but the traffic which would normally be passed from each 6th outlet to individual 7th outlets is passed to a commoned 7th outlet. Thus the trunk connected to the commoned 7th outlet is offered twice as much traffic as a corresponding trunk in a full availability group. The overall effect is that the trunks connected to the commoned outlets carry more traffic per trunk than the corresponding choice trunks in a full availability group. The increase in the traffic carried by the commoned trunks and the consequent reduction in the number of trunks required to carry a given amount of traffic is illustrated in the following example.

Example

It is estimated that the traffic between two switching stages, the selectors of which have an availability of 10, will be 6 erlangs. If the grade of service on the route must not be worse than .002, i.e. 1 in 500, what is the best arrangement for the necessary trunks?

For a grade of service of .002 a full availability group of 10 trunks will carry 3.43 erlangs, but a similar group of 9 trunks will carry only 2.85 erlangs. Thus the 6 erlangs could be carried by two equally loaded, i.e. 3 erlangs each, groups of 10 trunks, such an arrangement, Fig. 10b, however, suffers from the disadvantage of having several trunks in each group inefficiently used as shown in Table 2. Consider the effect on the average traffic carried by each trunk when the

TABLE 2

No. of Outlet	1	2	3	4	5	6	7	8	9	10
Traffic carried in erlangs.	.75	.66176	.54978	.42014	.28816	.17369	.09088	.04119	.01629	.00568

last four outlets of each group are commoned, so reducing the number of trunks from 20 to 16, as shown in Fig. 10a. The traffic carried by the first 6 outlets in each group of the grading is that shown for the corresponding outlets in Table 2. The

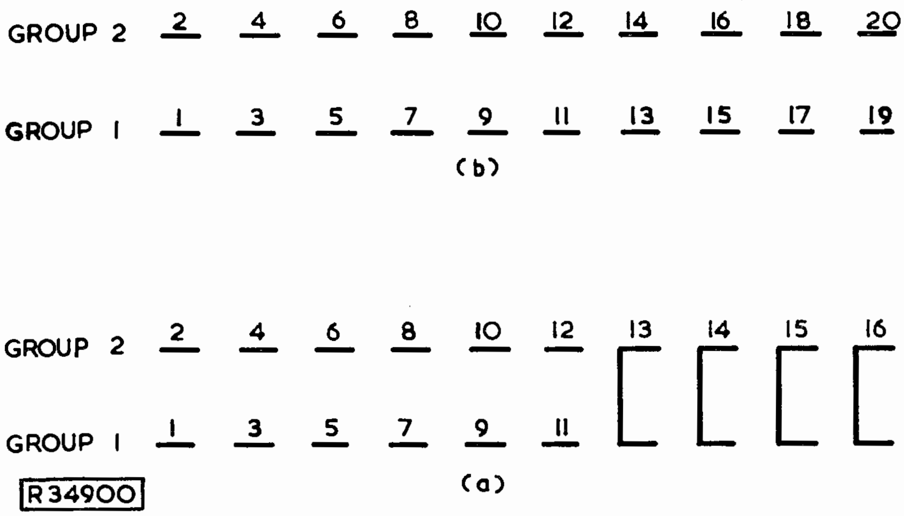

Fig. 10

traffic offered to the commoned seventh outlet, i.e. trunk number 13, is equal to that passed on from the sixth outlet of both groups 1 and 2, this is equal to .31294 erlangs. It can now be assumed that the traffic carried by the seventh and subsequent trunks will be the same as if .31294 erlangs were passed to the seventh trunk from the sixth trunk of a full availability group. The traffic carried by the remaining commoned outlets of the groups, i.e. trunks 13 to 16, is then as shown in Table 3. The traffic offered to the eleventh outlet is .0106 erlangs

TABLE 3

No. of Outlet	7	8	9	10
Traffic carried in erlangs.	.1549	.0905	.0409	.016

and represents the traffic lost to the group. The grade of service for the grading is better than .002 and is given by

$$\frac{\text{traffic lost}}{\text{traffic offered}} = \frac{.0106}{6} \simeq .0018$$

Thus, when using two separate full availability groups, 20 trunks must be provided to handle 6 erlangs for a grade of service not worse than .002, but by using grading the number of trunks can be reduced to 16 for the same grade of service specification. The traffic carried by each trunk in both arrangements is shown graphically in Fig. 11 (appended).

When access to the route in the foregoing example is from selectors having availabilities of 20 or more the 6 erlangs could be carried by 15 trunks arranged as a full availability group. For a grade of service of .002, 15 trunks will carry 6.58 erlangs, and 14 trunks will carry 5.92 erlangs, thus the grade of service offered by the 15 trunks is considerably better than .002. In terms of the average traffic per trunk, the 15 trunk full availability group gives 0.4 erlang against the 0.3 erlang and 0.37 erlang of the two separate groups, and the graded group respectively. The traffic carried by the eighth and subsequent trunks in the full availability group is, however, less than that carried by the subsequent trunks in the other arrangements as shown in Fig. 11.

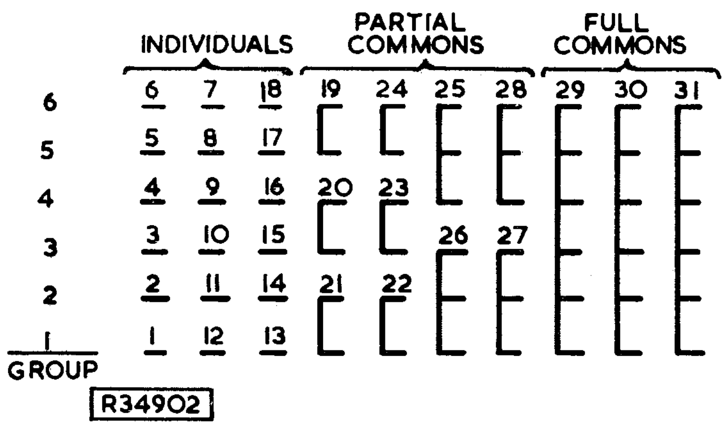

Fig. 12

The foregoing example shows that if selectors having an availability of 20 are used, the full availability group is the best arrangement, but if selectors having an availability of 10 are used the graded arrangement is to be preferred. For the sake of simplicity only a 2 group grading has so far been considered, but it should be appreciated that in practice gradings having as many as 12 groups and containing over 100 trunks are often used. A 6 group grading arranged for 31 trunks is shown in Fig. 12 which is also labelled with the terms usually applied to the individual and commoned outlets.

THE DESIGN OF GRADINGS

GENERAL

When designing a grading there are certain known factors, these are:-

(a) traffic flow,

(b) availability of selectors, and

(c) the number of trunks in the route.

The theoretical number of trunks required in the route can be obtained from tables similar to those shown in Figs. 5, 13, 14, 15 and 16 (appended), the figures show the traffic carrying capacity of groups of trunks when the availability is 10 and 20 and the traffic considered is of either a pure chance or smoothed nature. The tables given in Figs. 5, 13, 14, 15 and 16 are based on the theoretical considerations discussed in this pamphlet. In practice, however, it is found that circuits provided on theoretical basis results in an unduly generous provision of circuits particularly for smaller groups of circuits. Hence, a new set of tables to be used when considering the design of a grading, have been drawn up and an example is shown in Figs. 17 and 18. The traffic values quoted in this table are based on a grade of service equal to the nominal value (which is the theoretical value plus an increase of 50%) e.g. with a nominal grade of service of 0.015 the actual grade of service is 0.01.

There are many ways in which the outlets of the groups can be commoned, and it is therefore, necessary to introduce other factors for consideration when designing an efficient grading. The additional factors are;

(d) the number of graded groups,

(e) the formation of the grading,

(f) the allocation of selectors or relay-sets to the trunks, and

(g) the permissible size of the grading.

These factors will now be considered separately.

DETERMINATION OF THE NUMBER OF GRADED GROUPS

It has been found from practical and artificial traffic tests that the maximum efficiency of gradings with more than 6 groups is reached when the number of trunks is half the maximum possible number.

The maximum possible number of trunks is the product of the number of groups and the availability of the group, hence the number of trunks in the grading for maximum efficiency is

$$n = \frac{ga}{2} \qquad \text{where } g = \text{number of groups, and} \quad a = \text{availability.}$$

It has already been stated that the number of trunks and the availability are known factors, thus by rearranging the expression the minimum number of groups can be found as follows:-

$$g = \frac{2n}{a}$$

In practice the value obtained for 'g' is rounded up to at least the next even number in order to obtain a symmetrical formation of the grading; the reasons for this will be explained later in this pamphlet. A further increase in the number of groups may be necessary with certain arrangements of selector bank multiples in order to avoid excessive rack-to-rack cabling.

The maximum efficiency of 2-, 4- and 6- group gradings is not reached until slightly more than half the total possible trunks is reached; the maximum permissible number of trunks for these gradings has been found to be those given in Table 4.

TABLE 4

No. of Groups in Grading	Maximum No. of Trunks		
	Availability		
	10	20	24
2	16	32	38
4	25	50	60
6	32	64	76

SIZE OF THE GRADING

Theoretically, there is no limit to the size of a grading, but there are two main practical disadvantages associated with large gradings.

(a) Difficulty in tracing calls. If a large number of groups each containing many selectors, have access to a particular trunk, the job of finding a particular selector switched to the trunk takes a considerable time.

(b) Overhearing, or crosstalk, between circuits. The worst crosstalk conditions are obtained between two separate connexions which originate from adjacent outlets in adjacent levels, e.g. outlet 6 on level 4 and outlet 6 on levels 3 or 5, or from adjacent outlets in the same level, e.g. outlets 3 and 2, or 4 on level 7.

The amount of crosstalk is proportional to the number of outlets joined in multiple, hence the full commons in a large grading are liable to the most crosstalk. Therefore to minimize crosstalk between circuits the following precautions are taken;

(i) between outlets in the same level, the maximum permissible number of selector bank contacts which may be multipled on any one choice in a grading or full availability groups is 2400, and

(ii) between outlets in adjacent level, the number of contacts multipled on one choice in one level should not exceed 1250 when the number of contacts multipled on a choice which is adjacent in the other level is in the range 1250 to 2400.

The number of uniselector bank contacts multipled on any choice in a grading, or in a full availability group should not exceed 2000.

FORMATION OF THE GRADING

For a fixed number of grading groups and a given availability, there are several different grading arrangements possible for a given number of trunks. It is necessary, therefore, to determine which of the arrangements will provide the best grade of service for a given amount of traffic offered, that is to have the greatest traffic carrying capacity. The most efficient arrangement is provided when there is a smooth progression on the choices from individuals to partial commons, partial commons to larger partial commons, and the larger partial commons to full commons.

Thus the most efficient arrangement is when the number of choices of each type in a group is the same. It is not always possible for the number of choices of each type to be the same, but for a particular number of trunks and groups, and a given availability there is usually one grading arrangement which is more satisfactory than the others.

Generally the most satisfactory arrangement is the one which gives the minimum sum of the successive differences between the number of choices of one type and those of the type immediately following it, without respect to size, e.g.

Type of choice	a		b		c
Arrangement 1	4		3		3
Successive difference		1		0	
Arrangement 2	4		2		4
Successive difference		2		2	

The sum of the successive differences of arrangement 1 is 1 + 0 = 1, and that arrangement 2 is 2 + 2 = 4, thus the former arrangement is the best.

Consider the following example.

Example

Design the best 4 group grading for 22 trunks on an availability of 10.

The first step is to ascertain all the ways in which the choices of the groups can be interconnected, and this is determined by finding all the factors of the number of groups. The factors of 4 are 1, 2 and 4, thus the choices of each group can be arranged as individuals, paired with a choice of another group or commoned with choices of all the other groups. If individual choices = a, paired choices = b, full commoned choices = c, and the availability = 10 then

$$a + b + c = 10$$

Considering all 4 groups, 4 trunks are required for each individual choice, 2 for each paired choice, and 1 for each full common, thus

$$4a + 2b + c = 22$$

Values for a, b, and c can be obtained as follows.

$$4a + 2b + c = 22 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

$$a + b + c = 10 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Subtract (2) from (1)

$$3a + b = 12$$

Let a = 1, then b = 9 and from (2) c = 0,
a = 2 " b = 6 " " " c = 2,
a = 3 " b = 3 " " " c = 4, and
a = 4 " b = 0 " " " c = 6.

The four sets of results and the sum of the successive differences are shown in the following table, and the best arrangement is seen to be the third one, i.e.

Grading arrangement	1	2	3	4
Individual per group (a)	1	2	3	4
Pairs " " (b)	9	6	3	0
Full commons " (c)	0	2	4	6
Sum of successive differences	17	8	1	10

3 individuals, 3 pairs, and 4 commons, and the resultant grading is shown in Fig. 19.

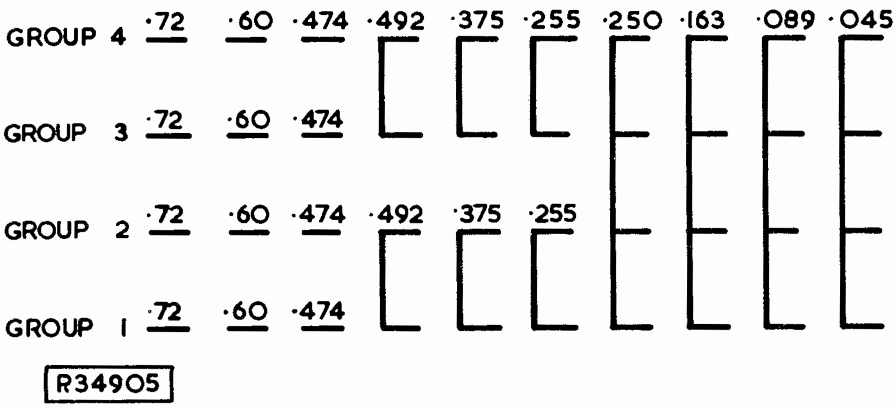

Fig. 19

By employing the Lubberger method, which is described later in this pamphlet, the traffic carried by each trunk can be found. Assuming 2.5 erlangs to be offered to each group the traffic carried by each trunk is as shown above the relevant choice in Fig. 19. The total traffic lost, i.e. that offered to a hypothetical twenty third trunk is 0.033 erlang consequently the grade of service for the whole grading is

$$B = \frac{.033}{4 \times 2.5} = \frac{.033}{10} = .0033$$

Grading arrangements 2 and 4 can be similarly analysed, and the traffic lost is .046 erlang and .036 erlang respectively; thus both of these arrangements give a grade of service worse than the one having the lowest sum of the successive differences.

The 'algebraic' method used in the foregoing example to determine all the possible grading arrangements becomes rather laborious when applied to a grading having a large number of groups and a large availability. Consequently a method known as 'transposition' is often used to determine the best arrangement for large gradings. The following is an example of the transposition method and algebraic method applied to the same problem.

Example

Design the best 6 group grading with 31 trunks on an availability of 10.

Algebraic method The availability is 10, hence the sum of the individual, partial commons, and full commons in each group equals 10. The factors of 6 are 1, 2, 3 and 6, therefore the grading will be made up of individuals, pairs, threes, and full commons.

Let a = number of individuals per group,

b = " " pairs " ",

c = " " threes " ", and

d = " " full commons " ".

Then $a + b + c + d = 10$ .... (1)

There are 6 groups, therefore the total number of individual trunks in the grading will be 6a; similarly there will be 3b pairs, 2c threes, and d full commons. The sum of these must equal the number of trunks in the grading.

$6a + 3b + 2c + d = 31$ .... (2)

It is now necessary to find all the values of a, b, c and d to satisfy equations (1) and (2) simultaneously.

Subtracting equation (1) and (2)

$5a + 2b + c = 21$ .... (3)

To satisfy this equation, 'a' cannot be greater than 4, and if a = 4, b = 0, and c = 1: Substituting these values in equation (1), d must equal 5. This gives one possible grading.
Substituting values of 3, 2 and 1 respectively for 'a' in equation (3) the arrangements given in the table are obtained. The least sum of the successive differences

No. of individuals	4	3	3	3	3	2	2	2	1	1
No. of pairs	0	3	2	1	0	5	4	3	8	7
No. of threes	1	0	2	4	6	1	3	5	0	2
No. of full commons	5	4	3	2	1	2	1	0	1	0
Sum of successive differences	9	7	2	7	14	8	5	8	16	13

is 2 and a grading using this formation is shown in Fig. 12.

Transposition method With the 6 group grading there are 4 possible types of outlet, individuals (a), pairs (b), threes (c), and full commons (d). With an availability of 10 the smoothest possible progression irrespective of the number of trunks to be connected, is

2a's, 2b's, 3c's, and 3d's .... (1)

which gives a sum of successive differences of 1.

There is, of course, another arrangement which is equally as smooth,

3a's, 3b's, 2c's, and 2d's

but for the purpose of this example only the first arrangement (1) will be considered.

With a 6 group grading there will be 6 trunks for each 'a', 3 for each 'b', 2 for each 'c' and 1 for each 'd'. Thus arrangement (1) provides for

$$(2 \times 6) + (2 \times 3) + (3 \times 2) + (3 \times 1) = 27 \text{ trunks},$$

that is 4 trunks short of the requirements, therefore changes must be made to (1) which give the minimum increase in the sum of successive differences but provide for 4 more trunks.

The following system of tabulation assists in deciding the necessary changes.

Types of Outlet			a	b	c	d	
Trunks per Outlet			6	3	2	1	
Change in Number of Trunks per Transposition				3	1	1	
Transposition	Change in No.	Total Trunks	a	b	c	d	Sum of Differences
		27	2	2	3	3	1
b to a	+3	30	3	1	3	3	4
c to b	+1	31	3	2	2	3	2

Thus the best grading is 3 individuals, 2 pairs, 2 threes, and three full commons, i.e. the same as that found by method 1.

As a further illustration of the use of the transposition method it will be used to find the best arrangement of a 12 group grading with 100 trunks on an availability of 20.

First find the factors of 12, i.e. 1, 2, 3, 4, 6 and 12. The grading can then consist of individuals 'a', pairs 'b', threes 'c', fours 'd', sixes 'e', and full commons 'f'. Thus there are six types of outlet, and with an availability of 20 a smooth progression can be

4a, 4b, 3c, 3d, 3e, and 3f .... (1)

and will provide for

$$(4 \times 12) + (4 \times 6) + (3 \times 4) + (3 \times 3) + (3 \times 2) + (3 \times 1) = 102 \text{ trunks.}$$

The arrangement must, therefore be transposed to reduce the trunks by 2.

If another smooth arrangement,

3a, 3b, 3c, 3d, 4e, and 4f .... (2)

is considered it will be found that only 87 trunks are provided for, and considerable transposition will be required to increase the provision to 100 trunks. Initially, therefore, choose the smooth progression which provides for the number of trunks nearest to that required.

Tabulate arrangement (1).

Types of Outlet			a	b	c	d	e	f	
Trunks per Outlet			12	6	4	3	2	1	
Change in Number of Trunks per Transposition.			6	2	1	1	1		
Transposition	Change in No.	Total Trunks	a	b	c	d	e	f	Sum of Differences
		102	4	4	3	3	3	3	1
b to c	-2	100	4	3	4	3	3	3	2

As an exercise in transpositioning, arrangement (2) will now be considered,

Transposition	Change in No.	Total Trunks	a	b	c	d	e	f	Sum of Differences
		87	3	3	3	3	4	4	1
e to a	+10	97	4	3	3	3	3	4	2
f to c	+3	100	4	3	4	3	3	3	2

thus two transpositions are necessary before the most efficient arrangement is found, this arrangement is illustrated in Fig. 20.

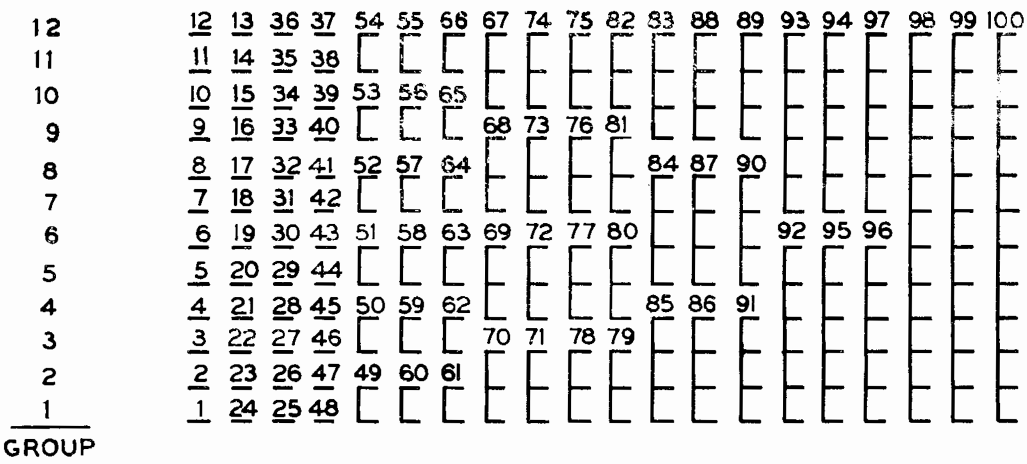

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Fig. 20

With both of the foregoing methods when a solution giving all the different types of partial and of full commons cannot be found, i.e. where an '0' always appears against one of the types, it is best that there should always be at least one full common. If there are no full commons the grading is, in reality, split into two or more limited availability groups, the combined traffic-carrying capacity of which is less than that of a suitable grading including full commons.

TRAFFIC CAPACITY OF GRADINGS

The calculation of the traffic capacity of a particular grading is a complex matter and the two main methods used are both empirical. The two methods are known as

(a) the Lubberger method, and

(b) the modified Erlang formula.

THE LUBBERGER METHOD

The Lubberger method of determining the traffic carried by individual trunks in a grading is based on the postulation that the traffic passed on by each graded trunk is the same as it would be if an equivalent amount of traffic were offered to the corresponding trunk in a full availability group. The traffic carried by each trunk in a 4 group grading as determined by the Lubberger method has already been given earlier in this pamphlet, Fig. 19; an explanation of how these results are obtained is as follows.

The traffic carried by each of the first three outlets in each group, Fig. 21, is found by Erlang's full availability formula. The traffic offered to each of the commoned 4th outlets, i.e. trunks 13 and 14, is the sum of that passed on from trunk 9 and 10, and the sum of that passed on from trunk 11 and 12 respectively. The traffic carried by trunks 13, 15, and 17 is then found by considering them as the 4th, 5th, and 6th, outlets of a full availability group and that the traffic

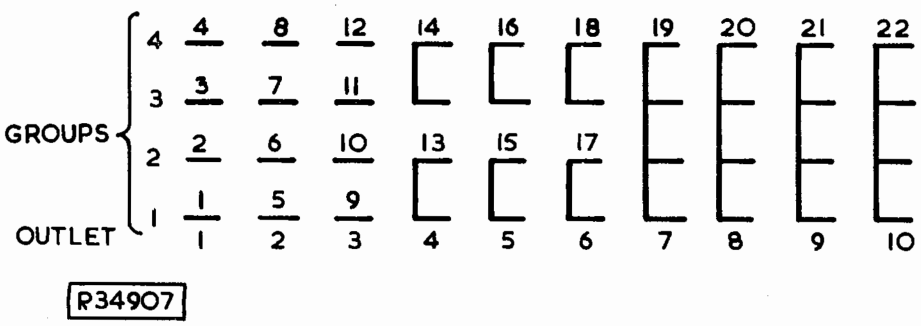

Fig. 21

offered to the 4th outlet is that which is passed to trunk 13. The traffic carried by trunks 14, 16 and 18 is determined in a similar fashion. The traffic offered to trunk 19 is the sum of that passed on from trunks 18 and 17, and the traffic carried by trunks 19, 20, 21 and 22 is determined by considering the trunks as the 7th, 8th, 9th and 10th outlets in a full availability group. The traffic passed on by the 22nd trunk is, of course, lost and, in conjunction with the traffic offered to the grading, is used to determine the grade of service.

Example

Consider that 10.0 erlangs are offered to the grading, Fig. 21, and that 2.5 erlangs are offered to each group. The traffic carried by each trunk is shown in Fig. 19, and is determined as follows:-

The traffic offered to the trunks connected to the 2nd, 3rd, and 4th outlets of each group is,

2nd outlet = 1.78 erlang,
3rd outlet = 1.18 erlang,
4th outlet = 0.706 erlang.

The traffic, therefore, carried by the trunk connected to the

1st outlet is 2.5 - 1.78 = 0.72 erlang, i.e. trunks 1, 2, 3 and 4.
2nd outlet is 1.78 - 1.18 = 0.6 erlang, i.e. trunks 5, 6, 7 and 8.
3rd outlet is 1.18 - 0.706 = 0.474 erlang, i.e. trunks 9, 10, 11 and 12.

The traffic offered to each commoned 4th outlet is twice that passed on from the 3rd outlet, that is

$$0.706 \times 2 = 1.412 \text{ erlangs.}$$

The traffic passed on by the 4th outlet is determined by Erlang's formula assuming that the 1.412 erlangs is passed from the 3rd to the 4th outlet of a full availability group; the traffic passed on from the 5th to subsequent outlets, in this example 6 and 7, can be found in a similar fashion. When 1.412 erlangs is passed from the 3rd to the 4th outlet, the traffic offered to the 4th, 5th, 6th and 7th outlets is

4th outlet	=	1.412 erlangs
5th outlet	=	0.920 erlangs
6th outlet	=	0.545 erlangs
7th outlet	=	0.290 erlangs.

The traffic, therefore, carried by the trunk connected to the

4th outlet is 1.412 - 0.920	=	0.492 erlang, i.e. trunks 13 and 14
5th outlet is 0.920 - 0.545	=	0.375 erlang, i.e. trunks 15 and 16
6th outlet is 0.545 - 0.290	=	0.255 erlang, i.e. trunks 17 and 18.

The traffic offered to the full commoned 7th outlet is twice that passed on from the pair commoned 6th outlets, that is

$$0.290 \times 2 = 0.580 \text{ erlang.}$$

Assuming that 0.580 erlangs are passed from the 6th to the 7th outlet of a full availability group, the traffic offered to the 7th, 8th, 9th, 10th and 11th outlets is

7th outlet	=	0.58 erlang
8th outlet	=	0.33 eerlang
9th outlet	=	0.167 erlang
10th outlet	=	0.078 erlang
11th outlet	=	0.033 erlang.

The traffic, therefore, carried by the trunk connected to the

7th outlet is 0.58 - 0.33	=	0.25 erlang, i.e. trunk 19
8th outlet is 0.33 - 0.167	=	0.163 erlang, i.e. trunk 20
9th outlet is 0.167 - 0.078	=	0.089 erlang, i.e. trunk 21
10th outlet is 0.078 - 0.033	=	0.045 erlang, i.e. trunk 22.

The traffic offered to the hypothetical 11th outlet is lost, therefore the grade of service for the grading is

$$\frac{0.033}{10} = 0.0033$$

The application of the Lubberger method becomes rather complicated as the number of groups and the availability increases, but it is facilitated by the family of curves shown in Figs. 2 and 3. The method is an approximation and has been found to underestimate the capacity of a large grading.

THE MODIFIED ERLANG FORMULA

The modified Erlang formula, although containing elements derived from Erlangs formula is, overall, an empirical statement.

Consider A erlangs of pure chance traffic offered to a group of N trunks with limited availability, a.

The average busy hour traffic per trunk $= \frac{A}{N}$ erlang. Therefore the proportion of the hour for which each trunk is engaged is $\frac{A}{N}$, and the probability of a call finding one trunk engaged is also $\frac{A}{N}$.

The probability of finding 2 trunks engaged is $\frac{A}{N} \times \frac{A}{N} = \left(\frac{A}{N}\right)^2$

and " " " " a " " " $\left(\frac{A}{N}\right)^a$

Selectors having access to the trunks can only test 'a' of them, hence the overall probability of loss, i.e. grade of service B, is

$$B = \left(\frac{A}{N}\right)^a$$

$$\text{or} \quad B^{1/a} = \frac{A}{N}$$

$$= \text{average traffic per trunk.}$$

This is an approximate expression which can only be applied theoretically when both A and N are large and the "a" outlets are selected at random. Such conditions are not found in practice but the formula is easily adapted so that the traffic carrying capacity of a grading can be determined.

When the traffic carrying capacity of a grading is being determined, it is assumed that Erlang's full availability formula applies to the outlets making up one group of the grading. The remaining outlets not considered in this manner are each considered to carry $B^{1/a}$ erlangs. Thus,

Traffic carrying capacity of a grading (T.C.C.) $= A + B^{1/a}$ (N-a) erlangs.

where A = traffic carrying capacity of a full availability group of "a" trunks at a grade of service of B,

a = availability of grading,

N = total number of trunks in the grading,

B = grade of service of the grading.

Capacity of grading with pure chance traffic

An empirical correction factor is applied to the foregoing formula when the grading is offered traffic of a pure chance nature. The factor corrects for the difference between the assumptions upon which Erlang's formula is based and the conditions met in practice. The corrected formula is

$$\text{T.C.C.} = A + (N-a)\left[C.B^{1/a} + \frac{A}{a}(1-C)\right]$$

C usually has the value 0.53, therefore for given values of a, and A, an expression can be derived which gives the traffic carrying capacity of the grading for any value of N. The expression is

$$\text{T.C.C.} = A + (N-a)\left[0.53B^{1/a} + \frac{A}{a}(0.47)\right]$$

Example

Derive a formula for the traffic capacity of gradings with an availability of 20 and a grade of service of 0.002 when offered pure chance traffic.

Substituting the given values in the formula

$$\begin{aligned}\text{T.C.C.} &= A + (N-a)\left[C.B^{1/a} + \frac{A}{a}(1-C)\right]\\ &= A + (N-20)\left[.53 \times .002^{1/20} + \frac{A}{20}(0.47)\right]\\ &= A + (N-20)\left[.3885 + \frac{A}{20}(0.47)\right]\end{aligned}$$

It is known that the traffic capacity of a full availability group of 20 trunks, with a grade of service of 0.002 is 10.07 erlangs, hence the traffic capacity, A , of the grading is

$$\begin{aligned}\text{T.C.C.} &= 10.07 + (N-20)\left[.3885 + \frac{10.07}{20}(0.47)\right]\\ &= 10.07 + (N-20)\left[.6252\right]\end{aligned}$$

By inspection of the formula it can be seen that each of the first 20 trunks in the grading is assumed to carry an average traffic of 0.5035 erlangs, and the trunks in excess of 20 each carry on average of 0.6252 erlangs. Thus the average traffic carried per trunk when considering the whole grading will approach 0.6252 erlang as N increases; this is illustrated as follows:-

$$\begin{aligned}\text{If } N &= 50 \text{ then}\\ \text{T.C.C.} &= 10.07 + (30)\left[.6252\right]\\ &= 28.826\end{aligned}$$

$\therefore$ Average tfc. per trunk = $\underline{.5765 \text{ erlang}}$

$$\text{If, however, } N = 200 \text{ then}$$

$$\text{T.C.C.} = 10.07 + 180 \left[.6252\right]$$

$$= 122.606$$

$$\therefore \quad \text{Average tfc. per trunk} = \underline{.613 \text{ erlang}}$$

Traffic capacity tables covering various values of availability and number of trunks have been compiled with the aid of the corrected Erlang formula.

Capacity with smooth traffic

When the traffic offered to a grading has already passed through a preceding grading, e.g. traffic offered to a grading from a level of selectors which themselves are offered traffic via a grading from subscribers' uniselectors, it is said to be smooth, and the constant C has the value 1. The formula then simplifies to

$$\underline{\text{T.C.C.} = A + B^{1/a}\ (N-a)}$$

Thus on inspection of the formula relating to pure chance traffic it can be seen that a grading offered smooth traffic will have a greater traffic carrying capacity than if it is offered pure chance traffic.

Example

Derive a formula for the traffic capacity of gradings with an availability of 20 and a grade of service of 0.002, when offered smooth traffic.

Substituting the given values in the formula.

$$\text{T.C.C.} = A + B^{1/a}\ (N-a)$$

$$= A + .002^{1/20}\ (N-20)$$

$$= A + 0.733\ (N-20)$$

and as the traffic carrying capacity of a full availability group of 20 trunks for a grade of service of .002 is 10.07 erlang.

$$\text{T.C.C.} = 10.07 + 0.733\ (N-20)$$

By inspection of the formula it can be seen that the trunks in excess of 20 are assumed to have an average traffic carrying capacity of 0.733 erlangs. Thus as the value of N increases the average traffic per trunk will approach 0.733 erlangs.

$$\text{If } N = 50, \text{ then}$$

$$\text{T.C.C.} = 10.07 + 0.733\ (50-20)$$

$$= 32.06 \text{ erlang.}$$

$$\therefore \quad \text{average tfc. per trunk} = \underline{.641 \text{ erlang.}}$$

$$\text{If, however, } N = 200 \text{ then}$$

$$\text{T.C.C.} = 10.07 + 0.733\ (200-20)$$

$$= 142 \text{ erlang.}$$

$$\therefore \quad \text{Average tfc. per trunk} = \underline{.71 \text{ erlang.}}$$

A section of the traffic carrying capacity table compiled for gradings having an availability of 20 is shown in Fig. 16 (appended).

EFFECT OF FAULTY TRUNK IN A GRADING

When a trunk in a grading is taken out of service the grade of service deteriorates, the degree of degradation depending on the position of the trunk in the grading. The Lubberger method of estimating the traffic carried by each trunk can, with a slight modification, be applied to ascertain the traffic lost when a trunk is taken out of service. The calculation is lengthy, but the following example will give a general outline of the principle of the method.

Assume that the 1st trunk in group 1 of the 4 group grading shown in Fig. 19 is taken out of service, then in this group the 2nd outlet acts as the 1st, the 3rd as the 2nd and so on. Thus the traffic passed to the paired common 4th outlet is increased because it is acting as the 3rd outlet in group 1. The traffic passed to the outlet is 1.18 + 0.706 = 1.886 erlangs, and as the outlet is acting as the 3rd in group 1 and the 4th in group 2 the following assumptions are made in order to determine the traffic carried by it and subsequent trunks.

(i) The paired common 4th outlet is an imaginary paired common outlet positioned between the 3rd and 4th outlet.

(ii) The position of the imaginary outlet is governed by the inverse ratio of the traffic offered to it by group 1 and group 2.

In this example the position of the outlet will be

$$3 + \frac{\text{tfc. offered by group 2}}{\text{tfc. offered by group 1 + tfc. offered by group 2}}$$

$$= 3 + \frac{0.706}{1.18 + 0.706}$$

$$= 3.374$$

The next outlet common to groups 1 and 2, i.e. 5, is then considered to be the 4.374th and so on until the full common is reached where a similar adjustment has to be made. The traffic carried by each choice can be determined from curves interposed between traffic curves for whole number choices.

The maximum degradation of service occurs when a full common is taken out of service because it is equivalent to reducing the availability of each group by one. The loss, however, is divided equally between all the groups whereas when an individual or partial common is taken the loss is shared only by some of the groups. Thus if an individual choice is taken out of service the degradation of service in the particular group is severe although the overall degradation may be slight.

TRUNK DISTRIBUTION

In practice the grading of the trunks between switching stages is carried out on

(a) centralized trunk distribution frames or,

(b) the selector racks.

TRUNK DISTRIBUTION FRAMES (T.D.F.)

A centralized trunk distribution frame is an iron framework which is fitted against, and lines up with, the selector racks. Connexion strips are fitted horizontally in the centre of the frame, on which the cables from the multiple terminal strips on the selector racks are terminated. Connexion strips are mounted at the left-hand side of the T.D.F., and cables are run from these to the incoming side of selectors or relay-sets in the next stage.

The trunk distribution frames are not usually grouped together, but are interspersed among the selector racks in order to reduce the amount of cabling. For example, the T.D.F. for connecting the subscribers' uniselectors to 1st selectors would be near the subscribers' uniselectors, and the T.D.F. for connecting the 1st selector banks to the second selectors would be near the first selector racks. At each stage provision is made to accommodate the number of connexion strips which will be required when the exchange is fully equipped. This provision reduces the rearrangements required when extensions to plant are made.

A part of a centralized T.D.F. situated between the 2nd Selectors and Final Selectors is shown in Fig. 22 (appended). The horizontal connexion strips serve the outlets on levels 6 and 7 of the 2nd Selectors; these selectors being reached from level 1 of the 1st Selectors. The designations at the right-hand side of each strip indicates the rack and shelves served; thus the bottom connexion strip shown in Fig. 20 serves the outlets from 2nd Selector rack 6A shelves A to F.

Each horizontal connexion strip has 22 sets of 3 tags arranged in echelon formation, so as to reduce the length of the strips to a minimum. This arrangement allows for any set of tags to be connected to the set of tags situated above or below it by means of vertical lengths of tinned copper wire soldered between the splayed ends of the tags. These wires, shown clearly in Fig. 22, effectively common the corresponding outlets of the shelves served by the strips.

The strips shown in Fig. 22 are arranged to serve 200 outlet selector banks. When serving 100 outlet selectors each strip can accommodate two groups of outlets. The two spare sets of tags on each strip can be used for overflow metering purposes. These meters record the number of calls which do not mature because all outlets to a particular rank of switches are engaged.

The connexion strips on the left-hand side of the T.D.F. are wired to the selectors on Final Selector racks number 5, 6 and 37. These selectors give access to the 16, 17 and 18 hundreds group of lines.

The necessary cross connexions between the horizontal connexion strips and the vertical connexion strips are made with three wire jumpers. These jumpers pass through holes above the groups of tags on the horizontal strips and then across the rear of the T.D.F. to the fanning holes in the vertical strip.

The centralized T.D.F. situated between the subscribers' uniselectors and the 1st Selectors is similar to that shown in Fig. 22. The horizontal connexion strips used on these frames have either 25 sets of 4 tags or 25 sets of 5 tags according to the type of subscriber's line circuit used. Usually two or more shelves of uniselectors are served by one connexion strip.

TRUNK DISTRIBUTION ON SELECTOR RACKS

Standard practice with modern equipment is to dispense with the centralized T.D.F. between,

(a) subscribers' uniselectors and 1st selectors,
(b) 2nd selectors and final selectors, and
(c) between ranks of group selectors.

Each equipment rack is provided with connexion strips which serve as part of a decentralized T.D.F. This method of distribution obviates the need for extensive recabling between individual shelves of equipment, and between the racks and T.D.F. in the event of large scale rearrangement of equipment. The floor space occupied by the centralized T.D.F.'s is also saved.

Uniselector Racks The type of rack employing decentralized trunk distribution has 12 shelves of 25 uniselectors per shelf.

The incoming cables from the I.D.F. are terminated on connexion strips mounted at the end of each shelf. The uniselector bank multiple tails are terminated on the trunk distribution connexion strips, to which are also connected the rack to rack tie cables and cables to the I.D.F. carrying the outlet connexions. Fig. 23 shows a view of the complete set of trunk distribution connexion strips and four shelves of uniselectors.

The connexion strips are shown in detail in Fig. 24. They provide a horizontal row of tags for the bank outlets of each shelf of 25 uniselectors. The uniselectors have two home positions, outlets 0 and 12, and these are not wired to the strips. The rows of tags labelled TIE provide terminations for tie-cables to and from adjacent racks. Standard practice is to connect the top row of tags to the bottom row on the next rack.

The arrangement of the tags on the connexion strips allows the bank outlets on any shelf to be connected to the corresponding outlets on other shelves by vertical lengths of tinned copper wire soldered to the tags. When this 'commoning' of outlets is required to be extended to the next rack, the tinned copper wire is extended to the top row of TIE tags. The commoning is then continued on the next rack, and if necessary to other racks in a similar fashion.

The block of tags in the centre of the strip provides for up to 80 circuits to the I.D.F. Sufficient of these circuits are cabled to the I.D.F. at the time of installation of the rack to provide for normal growth. The necessary number of bank outlets are connected to these circuits by means of 4-wire jumpers. The jumpers pass through fanning holes in the connexion strips and along a jumper field close behind the strips.

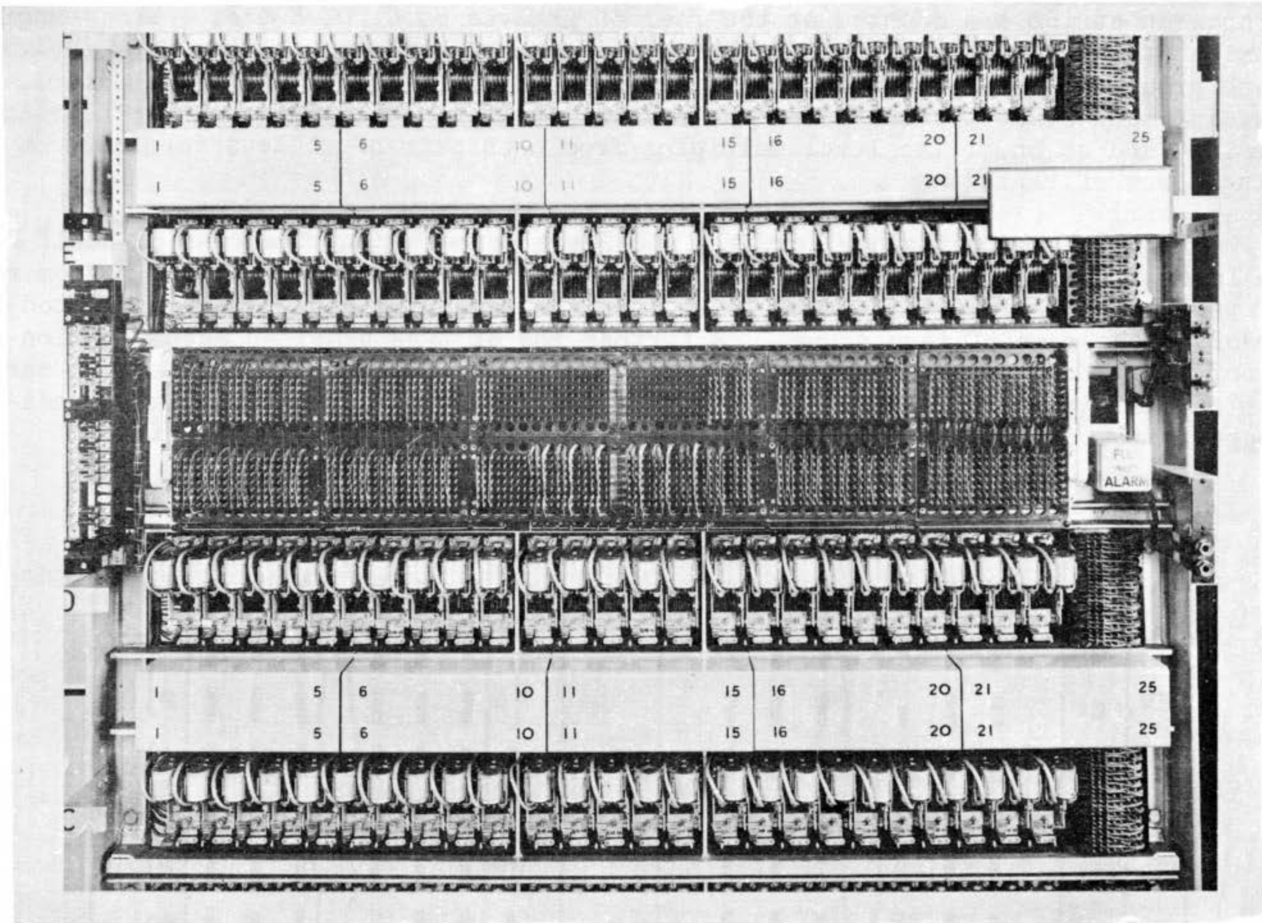

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Fig. 23

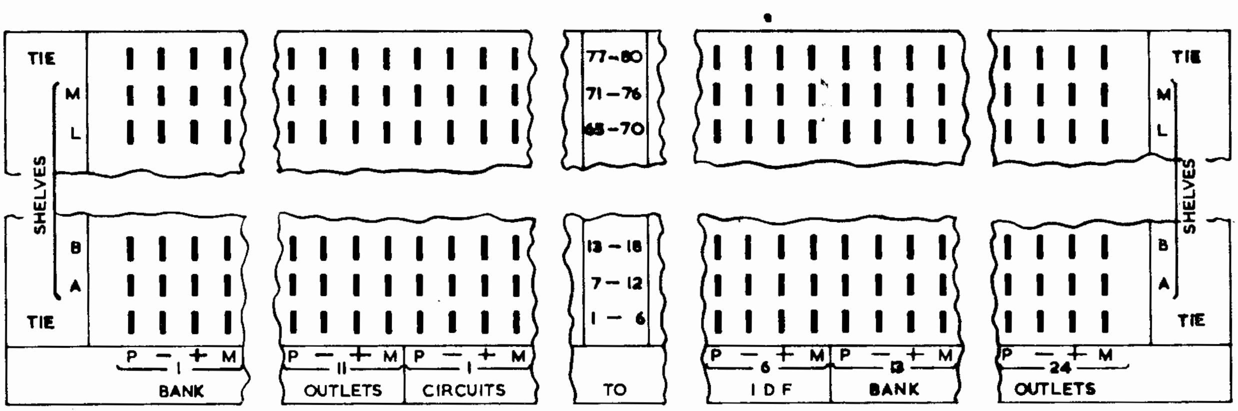

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Fig. 24

Two-motion selector racks On a selector rack of 8 shelves (lettered A to H) connexion strips are mounted at the rear of shelves B, C, D, E & F. The connexion strips are arranged in groups of three, one group behind each of the five shelves, each group accommodating the outlets from two adjacent levels of the selectors. Levels 1 and 2 are terminated at the rear of shelf B, levels 3 and 4 at the rear of shelf C and so on. The level multiples from each pair of shelves terminate on a single row of tags.

Fig. 25 illustrates how levels 1 and 2 are connected at the rear of shelf B. On level 1 the multiple tails from shelves A and B are connected to the bottom row of tags, the multiple tails from level 1 on the remaining shelves are connected in order on the rows of tags above. A further row of tags provides accommodation for twenty tie circuits per level to the next rack. The commoning of outlets is carried out on these connexion strips by strapping vertically adjacent tags with tinned-copper wire.

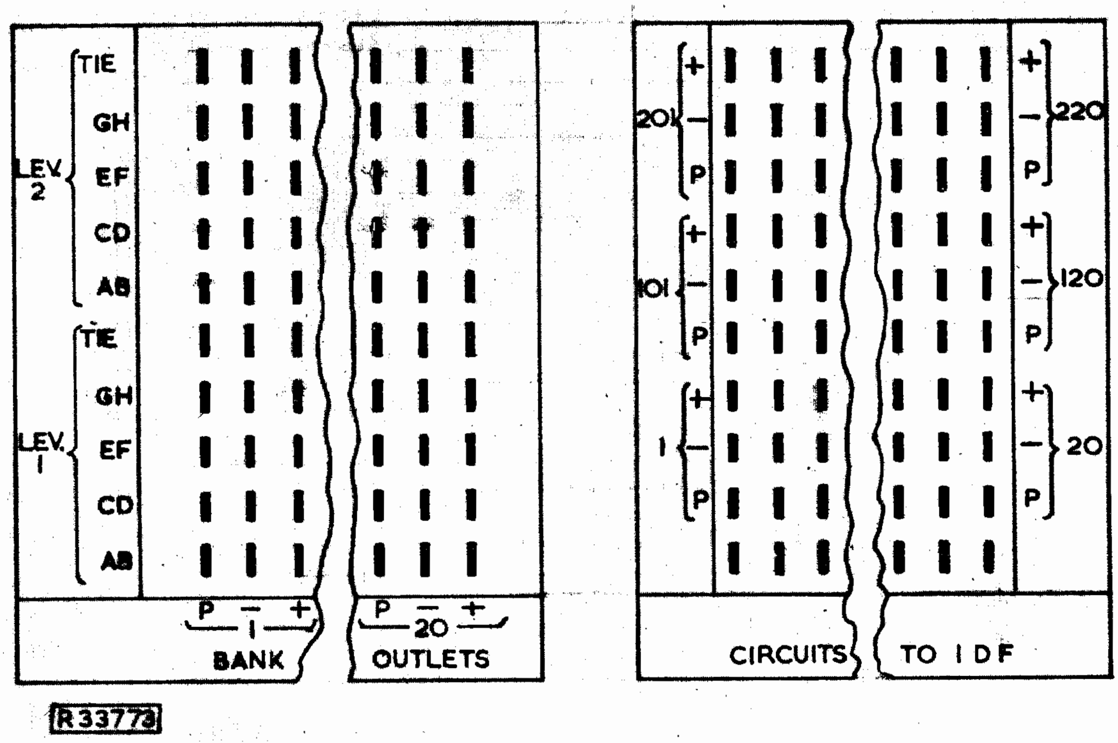

Fig. 25

At the rear of shelves B to F and in line with the bank-multiple connexion strips are further connexion strips which provide terminations for cables to the I.D.F. These strips are arranged on a basis of one per shelf and each one accommodates up to 60 circuits to the I.D.F. Fig. 25 shows the numbering and layout of the circuits on the connexion strip for shelf B.

The necessary cross connexions between the tags of the bank outlets and the tags of the circuits to the I.D.F. are made by means of 3-wire jumpers which are run in a similar fashion to those on the uniselector racks. Typical commoning on the first three outlets of level 2 on 1st selector racks A and B is shown in Fig. 26. The figures adjacent to the tags indicate the I.D.F. circuit on that particular rack to which those tags are jumpered.

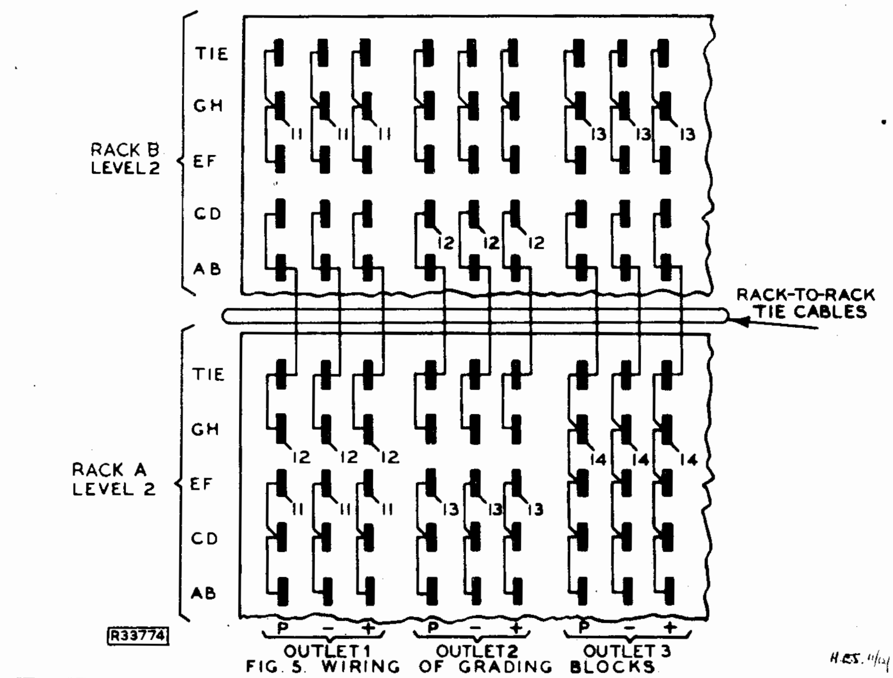

Fig. 26

On shelf F an additional terminal strip is provided for the connexion of the eleventh step contacts on each level for overflow metering purposes and for the connexion of N.U. tone to spare levels. Fig. 27 shows the rear view of a typical group selector rack using the decentralized method of trunk distribution. Covers have been removed to show the connexion strips.

ALLOCATION OF EQUIPMENT TO TRUNKS

The following points are considered when allocating selectors or relay sets to the choices of a grading in order to minimize the deterioration in the grade of service caused by a shelf fuse failure.

(a) Each group in the grading should have access to equipment on as many different shelves as possible.

(b) Consecutive items of equipment on any one shelf should not be so allocated that they appear as consecutive or nearby choices for any one grading group.

Also each shelf of equipment should be offered approximately the same amount of traffic.

A typical allocation of selectors to the choices of a grading is shown in Fig. 28. It should be noticed that the first selector in each shelf is allocated first, and the allocation commences with the first choice of the lowest group and then works up and down the choices of the grading until the partial commons are reached. Allocation then conforms to condition (b).

TOTAL TRUNKS = 55

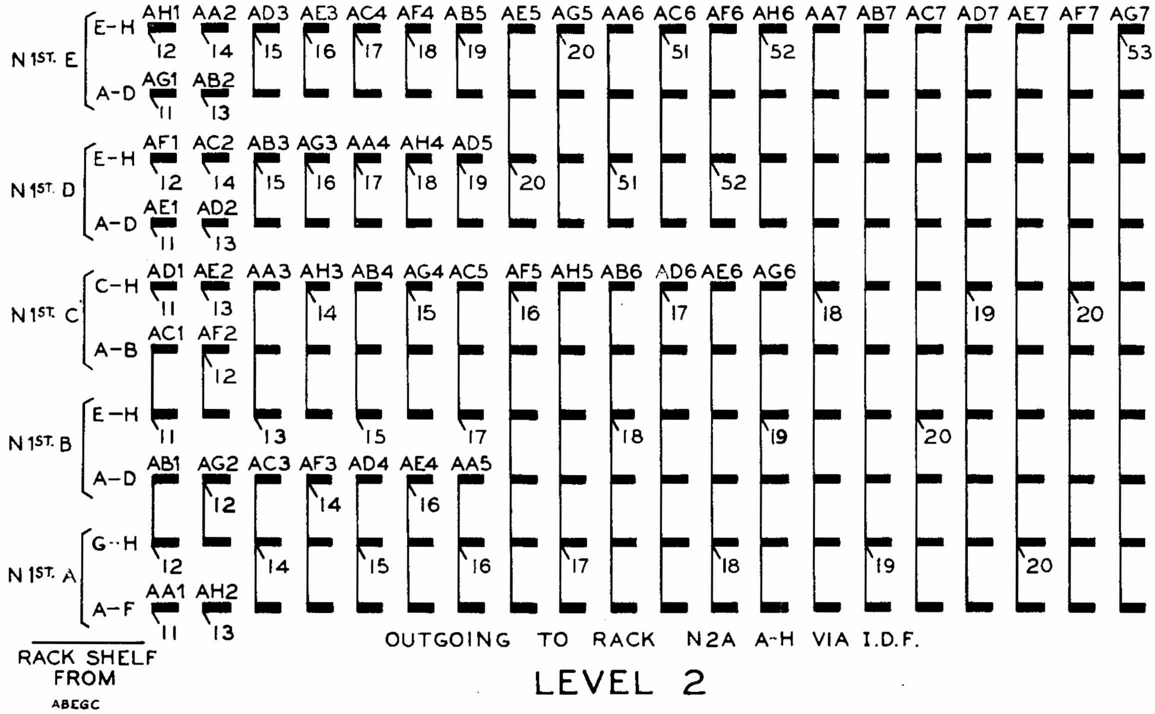

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Fig. 28

END

TRAFFIC OFFERED TO EACH TRUNK IN A FULL-AVAILABILITY GROUP
OF UP TO 10 CHOICES

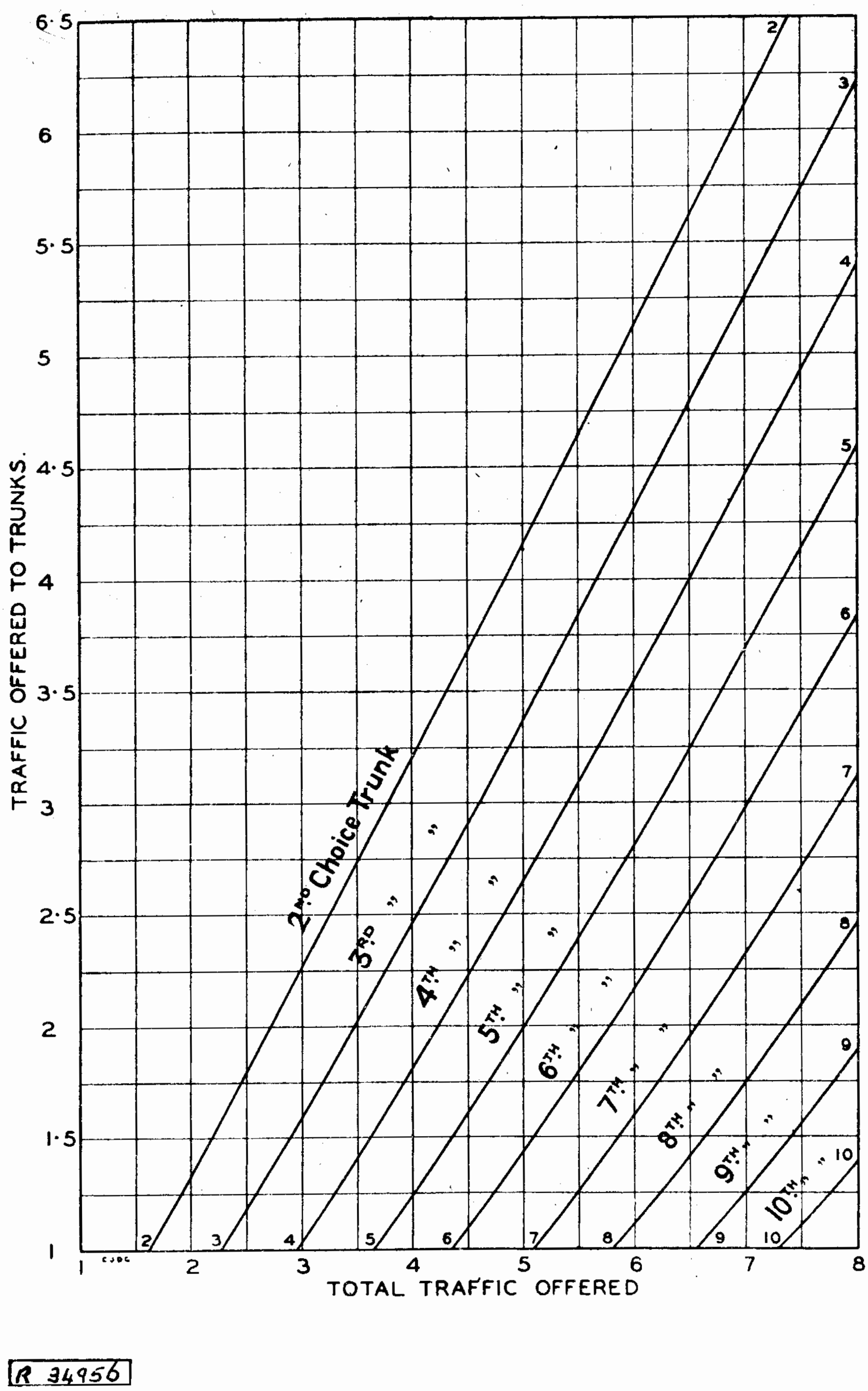

Fig. 2

TRAFFIC OFFERED TO EACH TRUNK IN A FULL-AVAILABILITY GROUP
(T.U. OFFERED 0-10)

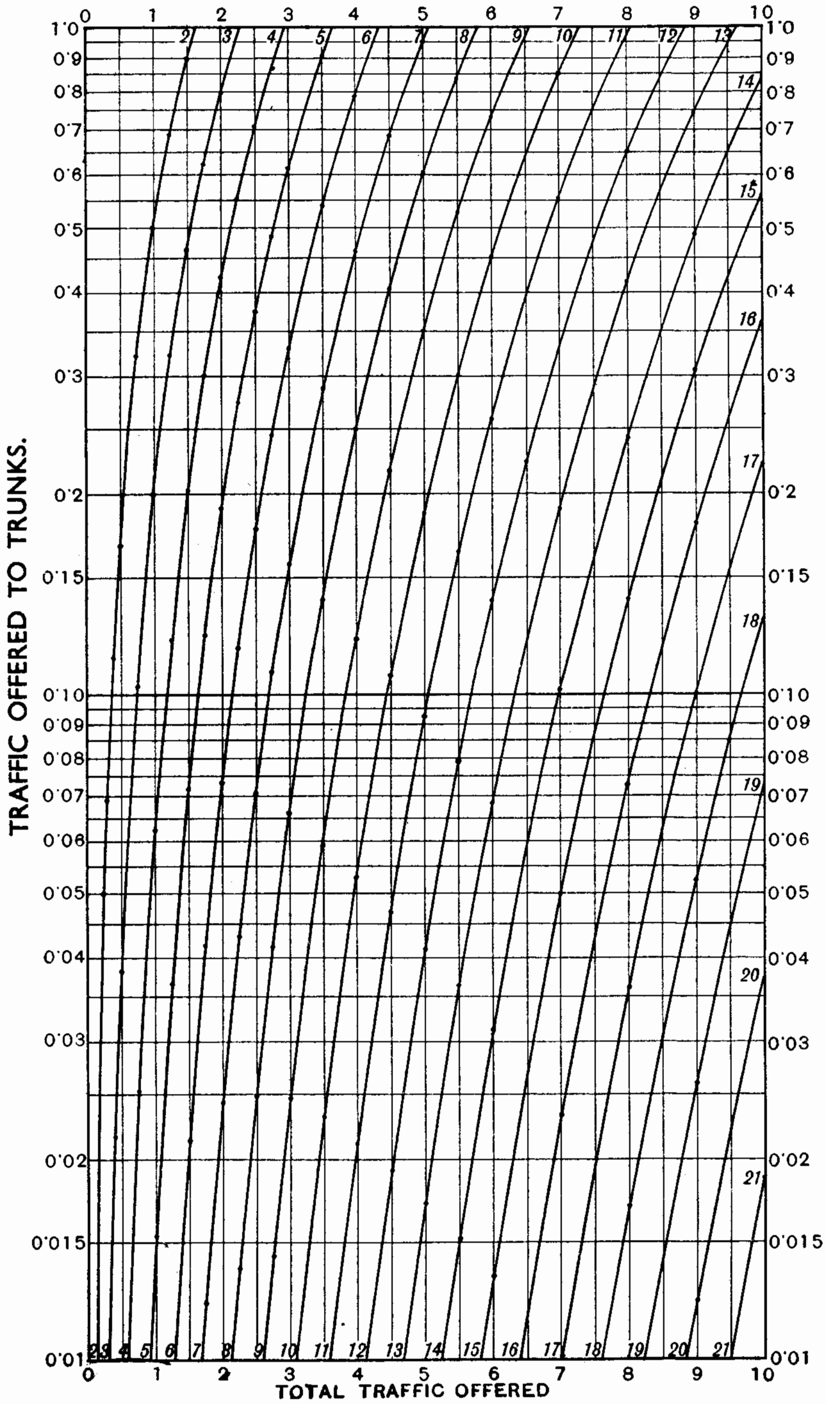

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Fig. 3

TRAFFIC CAPACITY TABLE A.

FULL AVAILABILITY.

No. of Trunks.	Capacity in T.U. for Grade of Service of :—			No. of Trunks.	Capacity in T.U. for Grade of Service of :—		
	·005.	Standard.	·001.		·005.	Standard.	·001.
1	0·005	0·002	0·001	51	36·8	34·7	33·4
2	0·105	0·065	0·046	52	37·6	35·6	34·2
3	0·35	0·25	0·19	53	38·5	36·4	35·0
4	0·70	0·53	0·43	54	39·4	37·2	35·8
5	1·13	0·90	0·76	55	40·3	38·1	36·7
6	1·62	1·32	1·14	56	41·2	38·9	37·5
7	2·16	1·80	1·58	57	42·1	39·8	38·3
8	2·73	2·31	2·05	58	43·0	40·7	39·1
9	3·33	2·85	2·56	59	43·9	41·5	40·0
10	3·96	3·43	3·09	60	44·7	42·4	40·8
11	4·61	4·02	3·65	61	45·6	43·3	41·6
12	5·28	4·63	4·23	62	46·5	44·1	42·5
13	5·97	5·27	4·83	63	47·4	45·0	43·3
14	6·63	5·92	5·44	64	48·3	45·8	44·1
15	7·38	6·58	6·08	65	49·2	46·7	45·0
16	8·10	7·26	6·72	66	50·1	47·6	45·8
17	8·84	7·95	7·38	67	51·0	48·4	46·6
18	9·58	8·64	8·04	68	51·9	49·3	47·5
19	10·34	9·35	8·72	69	52·8	50·1	48·3
20	11·10	10·07	9·41	70	53·7	51·0	49·2
21	11·87	10·80	10·11	71	54·6	51·9	50·1
22	12·64	11·53	10·81	72	55·5	52·7	50·9
23	13·42	12·27	11·52	73	56·4	53·6	51·8
24	14·21	13·01	12·24	74	57·3	54·4	52·6
25	15·0	13·76	13·0	75	58·2	55·2	53·5
26	15·8	14·5	13·7	76	59·1	56·1	54·3
27	16·6	15·3	14·4	77	60·0	56·9	55·2
28	17·4	16·1	15·2	78	60·9	57·8	56·1
29	18·2	16·9	15·9	79	61·8	58·6	56·9
30	19·0	17·7	16·7	80	62·7	59·4	57·8
31	19·8	18·4	17·4	81	63·6	60·3	58·6
32	20·6	19·2	18·2	82	64·5	61·1	59·5
33	21·4	20·0	18·9	83	65·4	62·0	60·4
34	22·3	20·8	19·7	84	66·3	62·8	61·3
35	23·1	21·6	20·5	85	67·2	63·7	62·1
36	23·9	22·4	21·3	86	68·1	64·5	63·0
37	24·8	23·2	22·1	87	69·0	65·4	63·9
38	25·6	24·0	22·9	88	69·9	66·2	64·8
39	26·5	24·9	23·7	89	70·8	67·0	65·6
40	27·3	25·7	24·5	90	71·8	67·9	66·5
41	28·2	26·5	25·3	91	72·7	68·7	67·4
42	29·0	27·3	26·1	92	73·6	69·6	68·3
43	29·9	28·1	26·9	93	74·5	70·4	69·1
44	30·8	28·9	27·7	94	75·4	71·3	70·0
45	31·6	29·7	28·5	95	76·3	72·1	70·9
46	32·5	30·5	29·3	96	77·2	73·0	71·8
47	33·3	31·4	30·1	97	78·2	73·8	72·6
48	34·2	32·2	30·9	98	79·1	74·7	73·5
49	35·1	33·0	31·7	99	80·0	75·6	74·4
50	35·9	33·9	32·5	100	80·9	76·4	75·3

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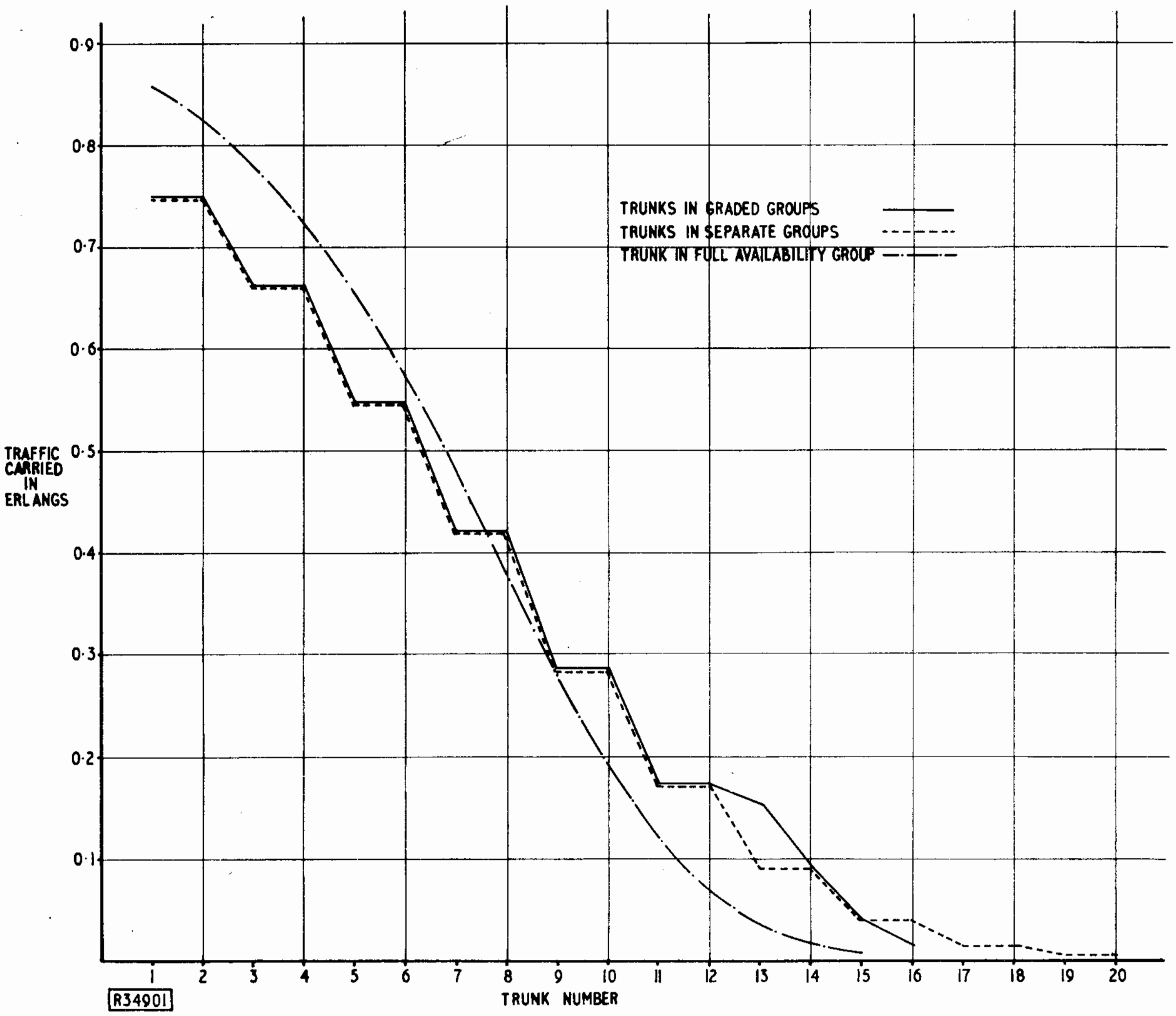
Fig. 5



TRUNKS IN GRADED GROUPS
TRUNKS IN SEPARATE GROUPS
TRUNK IN FULL AVAILABILITY GROUP
TRAFFIC CARRIED IN ERLANGS
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
TRUNK NUMBER
R34901

Fig. 11

TRAFFIC CAPACITY TABLE C/10

Table A

No. of Trunks	Capacity in T.U. for Grade of Service of :—			No. of Trunks	Capacity in T.U. for Grade of Service of :—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	51	24·38	21·72	19·94
2	0·105	0·065	0·046	52	24·88	22·16	20·35
3	0·35	0·25	0·19	53	25·37	22·61	20·76
4	0·70	0·53	0·43	54	25·87	23·05	21·17
5	1·13	0·90	0·76	55	26·37	23·50	21·59
6	1·62	1·32	1·14	56	26·87	23·95	22·00
7	2·16	1·80	1·58	57	27·37	24·39	22·41
8	2·73	2·31	2·05	58	27·86	24·84	22·82
9	3·33	2·85	2·56	59	28·36	25·28	23·23
10	3·96	3·43	3·09	60	28·86	25·73	23·64
11	4·46	3·88	3·50	61	29·36	26·18	24·05
12	4·96	4·32	3·91	62	29·86	26·62	24·46
13	5·45	4·77	4·32	63	30·35	27·07	24·87
14	5·95	5·21	4·73	64	30·85	27·51	25·28
15	6·45	5·66	5·15	65	31·35	27·96	25·70
16	6·95	6·11	5·56	66	31·85	28·41	26·11
17	7·45	6·55	5·97	67	32·35	28·85	26·52
18	7·94	7·00	6·38	68	32·84	29·30	26·93
19	8·44	7·44	6·79	69	33·34	29·74	27·34
20	8·94	7·89	7·20	70	33·84	30·19	27·75
21	9·44	8·34	7·61	71	34·34	30·64	28·16
22	9·94	8·78	8·02	72	34·84	31·08	28·57
23	10·43	9·23	8·43	73	35·33	31·53	28·98
24	10·93	9·67	8·84	74	35·83	31·97	29·39
25	11·43	10·12	9·26	75	36·33	32·42	29·81
26	11·93	10·57	9·67	76	36·83	32·87	30·22
27	12·43	11·01	10·08	77	37·33	33·31	30·63
28	12·92	11·46	10·49	78	37·82	33·76	31·04
29	13·42	11·90	10·90	79	38·32	34·20	31·45
30	13·92	12·35	11·31	80	38·82	34·65	31·86
31	14·42	12·80	11·72	81	39·32	35·10	32·27
32	14·92	13·24	12·13	82	39·82	35·54	32·68
33	15·41	13·69	12·54	83	40·31	35·99	33·09
34	15·91	14·13	12·95	84	40·81	36·43	33·50
35	16·41	14·58	13·37	85	41·31	36·88	33·92
36	16·91	15·03	13·78	86	41·81	37·33	34·33
37	17·41	15·47	14·19	87	42·31	37·77	34·74
38	17·90	15·92	14·60	88	42·80	38·22	35·15
39	18·40	16·36	15·01	89	43·30	38·66	35·56
40	18·90	16·81	15·42	90	43·80	39·11	35·97
41	19·40	17·26	15·83	91	44·30	39·56	36·38
42	19·90	17·70	16·24	92	44·80	40·00	36·79
43	20·39	18·15	16·65	93	45·29	40·45	37·20
44	20·89	18·59	17·06	94	45·79	40·89	37·61
45	21·39	19·04	17·48	95	46·29	41·34	38·03
46	21·89	19·49	17·89	96	46·79	41·79	38·44
47	22·39	19·93	18·30	97	47·29	42·23	38·85
48	22·88	20·38	18·71	98	47·78	42·68	39·26
49	23·38	20·82	19·12	99	48·28	43·12	39·67
50	23·88	21·27	19·53	100	48·78	43·57	40·08

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(PURE CHANCE TRAFFIC OFFERED)

Fig. 13

TRAFFIC CAPACITY TABLE C/20

Table A

No. of Trunks	Capacity in T.U. for Grade of Service of :—			No. of Trunks	Capacity in T.U. for Grade of Service of :—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	51	31·82	29·45	27·88
2	0·105	0·065	0·046	52	32·49	30·07	28·47
3	0·35	0·25	0·19	53	33·15	30·70	29·07
4	0·70	0·53	0·43	54	33·82	31·32	29·66
5	1·13	0·90	0·76	55	34·49	31·95	30·26
6	1·62	1·32	1·14	56	35·16	32·57	30·86
7	2·16	1·80	1·58	57	35·83	33·20	31·45
8	2·73	2·31	2·05	58	36·50	33·82	32·05
9	3·33	2·85	2·56	59	37·16	34·45	32·64
10	3·96	3·43	3·09	60	37·83	35·07	33·24
11	4·61	4·02	3·65	61	38·50	35·70	33·84
12	5·28	4·63	4·23	62	39·17	36·32	34·43
13	5·97	5·27	4·83	63	39·84	36·95	35·03
14	6·63	5·92	5·44	64	40·50	37·57	35·62
15	7·38	6·58	6·08	65	41·17	38·20	36·22
16	8·10	7·26	6·72	66	41·84	38·82	36·82
17	8·84	7·95	7·38	67	42·51	39·45	37·41
18	9·58	8·64	8·04	68	43·18	40·07	38·01
19	10·34	9·35	8·72	69	43·84	40·70	38·60
20	11·10	10·07	9·41	70	44·51	41·32	39·20
21	11·78	10·70	10·00	71	45·18	41·95	39·80
22	12·45	11·32	10·59	72	45·85	42·57	40·39
23	13·11	11·95	11·19	73	46·52	43·20	40·99
24	13·78	12·57	11·78	74	47·18	43·82	41·58
25	14·45	13·20	12·38	75	47·85	44·45	42·18
26	15·12	13·82	12·98	76	48·52	45·07	42·78
27	15·79	14·45	13·57	77	49·18	45·70	43·37
28	16·45	15·07	14·17	78	49·85	46·32	43·97
29	17·12	15·70	14·76	79	50·52	46·95	44·56
30	17·79	16·32	15·36	80	51·19.	47·57	45·16
31	18·46	16·95	15·96	81	51·85	48·20	45·76
32	19·13	17·57	16·55	82	52·52	48·82	46·35
33	19·79	18·20	17·15	83	53·19	49·45	46·95
34	20·46	18·82	17·74	84	53·86	50·07	47·54
35	21·13	19·45	18·34	85	54·53	50·70	48·14
36	21·80	20·07	18·94	86	55·19	51·32	48·74
37	22·47	20·70	19·53	87	55·86	51·95	49·33
38	23·13	21·32	20·13	88	56·53	52·57	49·93
39	23·80	21·95	20·72	89	57·20	53·20	50·52
40	24·47	22·57	21·32	90	57·87	53·82	51·12
41	25·14	23·20	21·92	91	58·53	54·45	51·72
42	25·81	23·82	22·51	92	59·20	55·07	52·31
43	26·47	24·45	23·11	93	59·87	55·70	52·91
44	27·14	25·07	23·70	94	60·54	56·32	53·50
45	27·81	25·70	24·30	95	61·21	56·95	54·10
46	28·48	26·32	24·90	96	61·87	57·57	54·70
47	29·15	26·95	25·49	97	62·54	58·20	55·29
48	29·81	27·57	26·09	98	63·21	58·82	55·89
49	30·48	28·20	26·68	99	63·88	59·45	56·48
50	31·15	28·82	27·28	100	64·55	60·07	57·08

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(PURE CHANCE TRAFFIC OFFERED)

Fig. 14

TRAFFIC CAPACITY TABLE B/10

	No. of Trunks	Capacity in T.U. for Grade of Service of :— 0·005	Standard	0·001	No. of Trunks	Capacity in T.U. for Grade of Service of :— 0·005	Standard	0·001
Table A	1	0·005	0·002	0·001	51	28·11	25·45	23·63
	2	0·105	0·065	0·046	52	28·70	25·98	24·13
	3	0·35	0·25	0·19	53	29·29	26·52	24·63
	4	0·70	0·53	0·43	54	29·88	27·06	25·13
	5	1·13	0·90	0·76	55	30·47	27·59	25·64
	6	1·62	1·32	1·14	56	31·05	28·13	26·14
	7	2·16	1·80	1·58	57	31·64	28·67	26·64
	8	2·73	2·31	2·05	58	32·23	29·21	27·14
	9	3·33	2·85	2·56	59	32·82	29·74	27·64
	10	3·96	3·43	3·09	60	33·41	30·28	28·14
	11	4·55	3·97	3·59	61	34·00	30·82	28·64
	12	5·14	4·50	4·09	62	34·59	31·35	29·14
	13	5·73	5·04	4·59	63	35·18	31·89	29·64
	14	6·32	5·58	5·09	64	35·77	32·43	30·14
	15	6·91	6·11	5·60	65	36·36	32·96	30·65
	16	7·49	6·65	6·10	66	36·94	33·50	31·15
	17	8·08	7·19	6·60	67	37·53	34·04	31·65
	18	8·67	7·73	7·10	68	38·12	34·58	32·15
	19	9·26	8·26	7·60	69	38·71	35·11	32·65
	20	9·85	8·80	8·10	70	39·30	35·65	33·15
	21	10·44	9·34	8·60	71	39·89	36·19	33·65
	22	11·03	9·87	9·10	72	40·48	36·72	34·15
	23	11·62	10·41	9·60	73	41·07	37·26	34·65
	24	12·21	10·95	10·10	74	41·66	37·80	35·15
	25	12·80	11·48	10·61	75	42·25	38·33	35·66
	26	13·38	12·02	11·11	76	42·83	38·87	36·16
	27	13·97	12·56	11·61	77	43·42	39·41	36·66
	28	14·56	13·10	12·11	78	44·01	39·95	37·16
	29	15·15	13·63	12·61	79	44·60	40·48	37·66
	30	15·74	14·17	13·11	80	45·19	41·02	38·16
	31	16·33	14·71	13·61	81	45·78	41·56	38·66
	32	16·92	15·24	14·11	82	46·37	42·09	39·16
	33	17·51	15·78	14·61	83	46·96	42·63	39·66
	34	18·10	16·32	15·11	84	47·55	43·17	40·16
	35	18·69	16·85	15·62	85	48·14	43·70	40·67
	36	19·27	17·39	16·12	86	48·72	44·24	41·17
	37	19·86	17·93	16·62	87	49·31	44·78	41·67
	38	20·45	18·47	17·12	88	49·90	45·32	42·17
	39	21·04	19·00	17·62	89	50·49	45·85	42·67
	40	21·63	19·54	18·12	90	51·08	46·39	43·17
	41	22·22	20·08	18·62	91	51·67	46·93	43·67
	42	22·81	20·61	19·12	92	52·26	47·46	44·17
	43	23·40	21·15	19·62	93	52·85	48·00	44·67
	44	23·99	21·69	20·12	94	53·44	48·54	45·17
	45	24·58	22·22	20·63	95	54·03	49·08	45·68
	46	25·16	22·76	21·13	96	54·61	49·61	46·18
	47	25·75	23·30	21·63	97	55·20	50·15	46·68
	48	26·34	23·84	22·13	98	55·79	50·69	47·18
	49	26·93	24·37	22·63	99	56·38	51·22	47·68
	50	27·52	24·91	23·13	100	56·97	51·76	48·18

R35905

(SMOOTHED TRAFFIC OFFERED)

Fig. 15

TRAFFIC CAPACITY TABLE B/20

Table A

No. of Trunks	Capacity in T.U. for Grade of Service of :— 0·005	Standard	0·001	No. of Trunks	Capacity in T.U. for Grade of Service of :— 0·005	Standard	0·001
1	0·005	0·002	0·001	51	34·87	32·79	31·36
2	0·105	0·065	0·046	52	35·63	33·53	32·07
3	0·35	0·25	0·19	53	36·40	34·26	32·77
4	0·70	0·53	0·43	54	37·17	34·99	33·48
5	1·13	0·90	0·76	55	37·94	35·73	34·19
6	1·62	1·32	1·14	56	38·70	36·46	34·90
7	2·16	1·80	1·58	57	39·47	37·19	35·61
8	2·73	2·31	2·05	58	40·24	37·92	36·31
9	3·33	2·85	2·56	59	41·00	38·66	37·02
10	3·96	3·43	3·09	60	41·77	39·39	37·73
11	4·61	4·02	3·65	61	52·54	40·12	38·44
12	5·28	4·63	4·23	62	43·30	40·86	39·15
13	5·97	5·27	4·83	63	44·07	41·59	39·85
14	6·63	5·92	5·44	64	44·84	42·32	40·56
15	7·38	6·58	6·08	65	45·61	43·06	41·27
16	8·10	7·26	6·72	66	46·37	43·79	41·98
17	8·84	7·95	7·38	67	47·14	44·52	42·69
18	9·58	8·64	8·04	68	47·91	45·25	43·39
19	10·34	9·35	8·72	69	48·67	45·99	44·10
20	11·10	10·07	9·41	70	49·44	46·72	44·81
21	11·86	10·80	10·12	71	50·21	47·45	45·52
22	12·62	11·54	10·83	72	50·97	48·19	46·23
23	13·39	12·27	11·53	73	51·74	48·92	46·93
24	14·16	13·00	12·24	74	52·51	49·65	47·64
25	14·93	13·74	12·95	75	53·28	50·39	48·35
26	15·69	14·47	13·66	76	54·04	51·12	49·06
27	16·46	15·20	14·37	77	54·81	51·85	49·77
28	17·23	15·93	15·07	78	55·58	52·58	50·47
29	17·99	16·67	15·78	79	56·34	53·32	51·18
30	18·76	17·40	16·49	80	57·11	54·05	51·89
31	19·53	18·13	17·20	81	57·88	54·78	52·60
32	20·29	18·87	17·91	82	58·64	55·52	53·31
33	21·06	19·60	18·61	83	59·41	56·25	54·01
34	21·83	20·33	19·32	84	60·18	56·98	54·72
35	22·60	21·07	20·03	85	60·95	57·72	55·43
36	23·36	21·80	20·74	86	61·71	58·45	56·14
37	24·13	22·53	21·45	87	62·48	59·18	56·85
38	24·90	23·26	22·15	88	63·25	59·91	57·55
39	25·66	24·00	22·86	89	64·01	60·65	58·26
40	26·43	24·73	23·57	90	64·78	61·38	58·97
41	27·20	25·46	24·28	91	65·55	62·11	59·68
42	27·96	26·20	24·99	92	66·31	62·85	60·39
43	28·73	26·93	25·69	93	67·08	63·58	61·09
44	29·50	27·66	26·40	94	67·85	64·31	61·80
45	30·27	28·40	27·11	95	68·62	65·05	62·51
46	31·03	29·13	27·82	96	69·38	65·78	63·22
47	31·80	29·86	28·53	97	70·15	66·51	63·93
48	32·57	30·59	29·23	98	70·92	67·24	64·63
49	33·33	31·33	29·94	99	71·68	67·97	65·34
50	34·10	32·06	30·65	100	72·45	68·69	66·05

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(SMOOTHED TRAFFIC OFFERED)

Fig. 16

LIMITING TRAFFIC VALUES

Table A. Full Availability

No. of trunks	Traffic offered at nominal Grade of Service						Traffic carried		
	0.1	0.03	0.02	0.01	0.005	0.002	0.1	0.03	0.02
1	0.15	0.047	0.031	0.015	0.008	0.003	0.14	0.045	0.03
2	0.8	0.35	0.29	0.2	0.14	0.07	0.68	0.34	0.28
3	1.6	0.85	0.71	0.55	0.4	0.3	1.35	0.72	0.69
4	2.5	1.46	1.26	1.0	0.8	0.6	2.23	1.22	1.23
5	3.35	2.15	1.9	1.57	1.27	1.00	3.00	1.84	1.86
6	4.75	2.98	2.6	2.17	1.89	1.56	3.8	2.9	2.55
7	5.15	3.71	3.28	2.79	2.44	2.05	4.6	3.6	3.21
8	6.05	4.47	3.99	3.44	3.03	2.53	5.4	4.3	3.91
9	7.0	5.26	4.71	4.11	3.64	3.14	6.3	5.07	4.62
10	8.0	6.06	5.46	4.78	4.28	3.72	7.3	5.86	5.35
11	9.0	6.88	6.22	5.5	4.94	4.3	8.2	6.65	6.1
12	10.0	7.7	7.00	6.25	5.62	4.9	9.0	7.4	6.8
13	11.0	8.5	7.8	6.9	6.30	5.5	9.9	8.2	7.6
14	12.0	9.4	8.6	7.7	7.0	6.2	10.8	9.1	8.4
15	13.0	10.3	9.4	8.5	7.7	6.9	11.7	9.9	9.2
16	14.1	11.1	10.2	9.3	8.4	7.6	12.6	10.7	10.0
17	15.1	12.0	11.0	10.1	9.2	8.2	13.5	11.6	10.8
18	16.1	12.9	11.9	10.9	9.9	8.9	14.5	12.5	11.6
19	17.1	13.8	12.7	11.7	10.7	9.7	15.4	13.3	12.4
20	18.2	14.7	13.6	12.5	11.4	10.4	16.3	14.2	13.3
21	19.2	15.6	14.5	13.3	12.2	11.1	17.2	15.1	14.1
22	20.3	16.5	15.3	14.1	13.0	11.9	18.2	15.9	15.0
23	21.3	17.4	16.2	14.9	13.8	12.6	19.1	16.8	15.8
24	22.3	18.3	17.1	15.7	14.6	13.3	20.1	17.7	16.7
25	23.4	19.2	18.0	16.5	15.4	14.1	21.0	18.6	17.5
26	24.4	20.2	18.8	17.4	16.2	14.9	22.0	19.5	18.4
27	25.5	21.1	19.7	18.2	17.0	15.7	22.9	20.4	19.3
28	26.5	22.0	20.6	19.1	17.8	16.5	23.9	21.3	20.1
29	27.6	23.0	21.5	19.9	18.6	17.3	24.9	22.2	21.2
30	28.7	23.9	22.4	20.7	19.4	18.0	25.9	23.1	21.9
31	29.8	24.8	23.3	21.6	20.2	18.8	26.8	24.0	22.8
32	30.8	25.7	24.2	22.4	21.0	19.6	27.8	24.9	23.6
33	31.9	26.7	25.1	23.3	21.8	20.4	28.8	25.8	24.5
34	32.9	27.7	26.0	24.2	22.7	21.2	29.7	26.7	25.4
35	34.0	28.7	26.9	25.0	23.5	22.0	30.6	27.6	26.3
36	35.1	29.6	27.8	25.9	24.3	22.8	31.6	28.5	27.2
37	36.1	30.4	28.7	26.8	25.2	23.6	32.5	29.4	28.1
38	37.2	31.4	29.6	27.7	26.0	24.4	33.4	30.3	29.0
39	38.2	32.3	30.5	28.5	26.9	25.3	34.4	31.3	29.9
40	39.3	33.3	31.5	29.4	27.7	26.1	35.3	32.2	30.8

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Fig. 17

LIMITING TRAFFIC VALUES

Table C/20

No. of Trunks	Traffic offered at nominal Grade of Service						Traffic carried		
	0.1	0.03	0.02	0.01	0.005	0.002	0.1	0.03	0.02
21	19.0	15.4	14.27	13.0	12.11	11.01	17.1	14.9	13.9
22	20.0	16.2	15.01	13.7	12.78	11.63	18.0	15.7	14.7
23	20.9	17.0	15.76	14.4	13.44	12.26	18.8	16.4	15.4
24	21.9	17.8	16.50	15.2	14.11	12.88	19.7	17.2	16.1
25	22.8	18.6	17.25	15.9	14.78	13.50	20.5	17.9	16.9
26	23.7	19.3	17.99	16.6	15.45	14.13	21.4	18.7	17.6
27	24.7	20.1	18.74	17.3	16.12	14.76	22.2	19.5	18.3
28	25.6	20.9	19.48	18.0	16.78	15.38	23.1	20.2	19.0
29	26.6	21.7	20.23	18.7	17.45	16.00	23.9	21.0	19.8
30	27.5	22.5	21.01	19.4	18.12	16.63	24.8	21.7	20.5
31	28.4	23.3	21.76	20.1	18.79	17.25	25.6	22.5	21.2
32	29.4	24.0	22.46	20.8	19.46	17.88	26.5	23.2	21.9
33	30.3	24.8	23.21	21.5	20.12	18.50	27.3	24.0	22.7
34	31.3	25.6	23.95	22.2	20.79	19.13	28.1	24.8	23.4
35	32.2	26.4	24.69	22.9	21.46	19.75	29.0	25.5	24.2
36	33.1	27.2	25.44	23.6	22.13	20.38	29.8	26.3	24.9
37	34.1	28.0	26.18	24.3	22.80	21.00	30.7	27.0	25.6
38	35.0	28.7	26.93	25.0	23.46	21.63	31.5	27.8	26.3
39	36.0	29.5	27.67	25.7	24.13	22.25	32.4	28.5	27.1
40	36.9	30.3	28.42	26.4	24.80	22.88	33.2	29.3	27.8
41	37.8	31.1	29.16	27.1	25.47	23.50	34.1	30.1	28.5
42	38.8	31.9	29.91	27.8	26.14	24.13	34.9	30.8	29.3
43	39.7	32.7	30.65	28.5	26.80	24.75	35.8	31.6	30.0
44	40.7	33.4	31.40	29.2	27.47	25.38	36.6	32.3	30.7
45	41.6	34.2	32.14	29.9	28.14	26.00	37.5	33.1	31.5
46	42.5	35.0	32.89	30.6	28.81	26.63	38.3	33.8	32.2
47	43.5	35.8	33.63	31.3	29.48	27.25	39.1	34.7	32.9
48	44.4	36.6	34.38	32.0	30.14	27.88	40.0	35.4	33.6
49	45.4	37.4	35.12	32.7	30.81	28.50	40.8	36.1	34.4
50	46.3	38.1	35.87	33.4	31.48	29.13	41.7	36.9	35.1
51	47.2	38.9	36.61	34.2	32.15	29.76	42.5	37.6	35.8
52	48.2	39.7	37.36	34.9	32.82	30.38	43.4	38.4	36.6
53	49.1	40.5	38.10	35.6	33.48	31.01	44.2	39.1	37.3
54	50.1	41.3	38.85	36.3	34.15	31.63	45.1	39.9	38.0
55	51.0	42.1	39.59	37.0	34.82	32.26	45.9	40.7	38.8
56	51.9	42.8	40.34	37.7	35.49	32.88	46.8	41.4	39.5
57	52.9	43.6	41.08	38.4	36.16	33.51	47.6	42.2	40.2
58	53.8	44.4	41.83	39.1	36.83	34.13	48.4	42.9	40.9
59	54.8	45.2	42.57	39.8	37.49	34.76	49.3	43.7	41.7
60	55.7	46.0	43.32	40.5	38.16	35.38	50.1	44.4	42.4

Fig. 18

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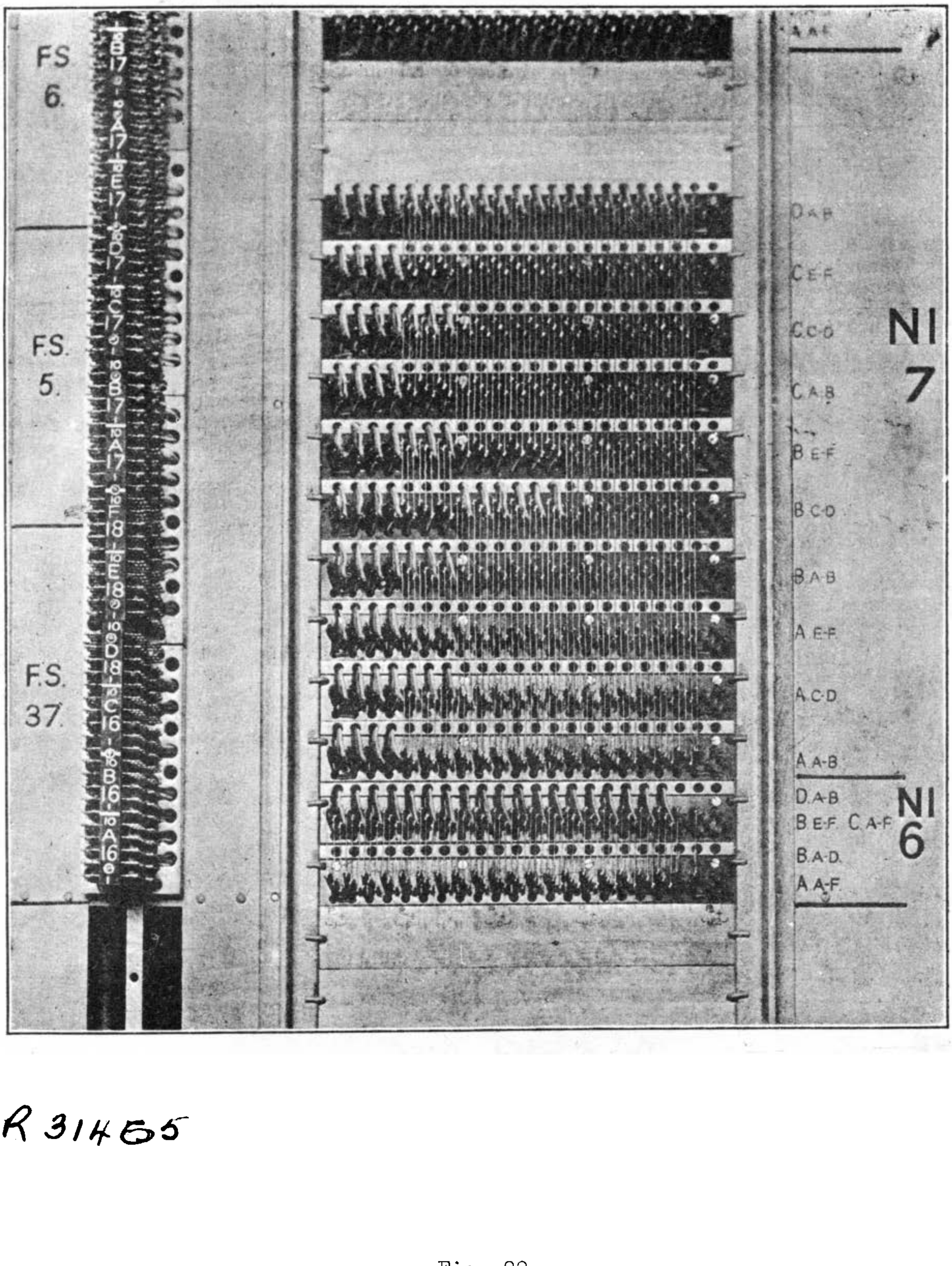
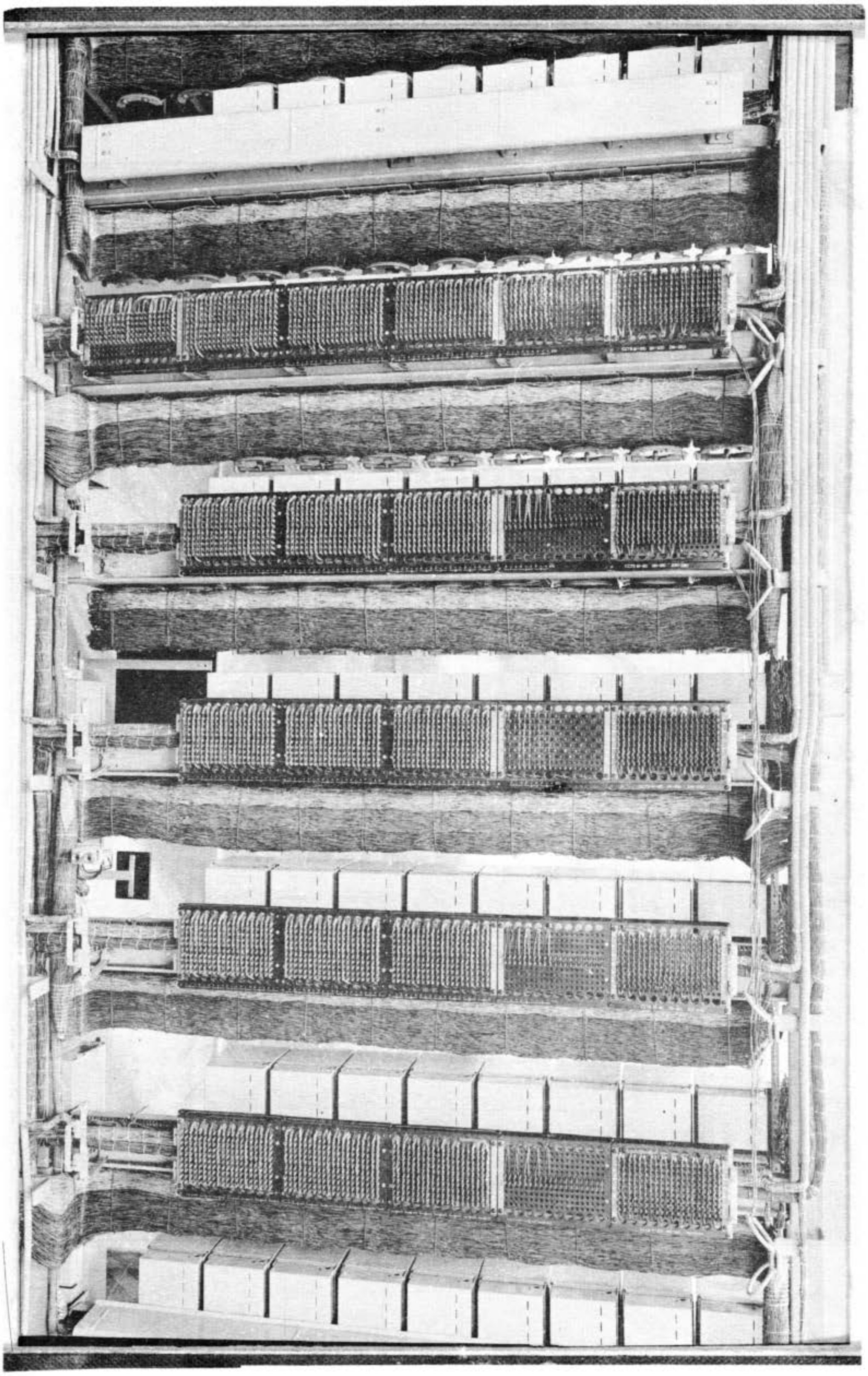


R 31465

Fig. 22



R 32872

Fig. 27