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NIK - CHARTS

for the Design of Link Systems
operating in the
Point - to - Point Selection Mode
or
Point - to - Group Selection Mode

by

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PREFACE

The present volume is devoted to field engineers and designers of link systems. It enables the quick manual design of symmetrical link systems for traffic distribution (group selection units) with 3 up to 6 stages by means of diagrams (Nik-charts).

These Nik-charts base on extensive investigations lasting for many years. As a result mathematical models were developed for a reliable calculation of loss in link systems operating in the point-to-point selection mode or in the point-to-group selection mode.

This booklet consequently continues the series of dimensioning tables for practical application edited by the teletraffic research team of the University of Stuttgart:

- Table of the Modified Palm-Jacobaeus Loss Formula (MPJ) 1963 (LOTZE,A.,WAGNER,W.)
- Tables for Variance Coefficient D and Overflow Traffic R of One-Stage Gradings with Limited Access. Calculation of Secondary Routes in Case of Offered Overflow Traffic 1965
- Tables for Overflow Variance Coefficient and Loss of Gradings and Full Available Groups, (2nd Edition) 1966
- Alternate Routing Tables for the Economic Dimensioning of Telephone Networks 1973 (HERZOG,U., LÖRCHER,W., LOTZE,A., SCHEHRER,R.)
- Tables on Delay Systems 1976 (KÜHN, P.)

The authors hope that also the present volume of Nik-charts will be a useful tool to many telephone engineers.

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1. INTRODUCTION

1.1 Object of the Nik-Charts

The present volume of precalculated diagrams allows a simple and quick manual design of symmetrical link systems (group selection units) for traffic distribution having 3 up to 6 stages

a) operating in the point-to-point selection mode (PPS)
   (charts 1 .. 44 on the chamois pages for PCT1,
   charts 45 .. 88 on the yellow pages for PCT2)

b) operating in the point-to-group selection mode (PGS)
   (charts 89 .. 92 on the blue pages).

In /2/ it has been shown that one-sided (folded and reversed) link systems can be mapped into two-sided link systems and vice versa. Hence, the following design methods are also fully applicable for one-sided systems.

The abbreviation Nik-charts is derived from 3 significant structural parameters in a link system:

N - the total number of inlets (or outlets, resp.) of the link system
i_1 - the number of inlets of each multiple in the first stage
k_1 - the number of outlets of each multiple in the first stage.

Nik-charts for the point-to-point selection mode were calculated for a structural design with prescribed carried traffic per inlet Y/N=0.4 ... 0.9 Erl. and for point-to-point losses B_{pp} of 0.1%, 1%, 5% and 10% (single attempt losses). Hereby, the size of a considered outgoing trunk group does not have any significant influence /1/.

Nik-charts for systems operating in the point-to-group selection mode guarantee practically full accessibility for all outgoing trunk groups.

1.2 Theoretical Background

On the 8th International Teletraffic Congress (ITC) in Melbourne a new method for the calculation of the point-to-point loss (PPL) has been published /1,2,3/.
As to the point-to-point loss occuring if multiple marking attempts are permitted, this method PPL has been extended to a method PPLM /7/.

On the 7th ITC in Stockholm 1973 the method CLIGS (Calculation of Loss in Link Systems with Group Selection) has been presented /4,5/. In /6/, formulae for optimum link systems using point-to-group selection and having a most crosspoint saving structure are derived and discussed.

The calculation methods (PPL and CLIGS) are relatively easy to program on a computer. Nevertheless, for practical application, it may be very useful to design link systems directly by means of pre-calculated diagrams. The Nik-charts in this volume enable this for a very wide range of link system sizes.

2. DEFINITIONS

2.1 Selection Modes

If an incoming call is to be switched through a link system to a trunk of a certain outgoing group, two strategies have to be distinguished regarding the selection procedure from the calling inlet to an idle outlet.

- Point-to-Group Selection (PGS-Mode)
  Each call offered to an idle inlet in the first stage can hunt all accessible idle trunks of the desired group behind the last stage.
- Point-to-Point Selection (PPS-Mode)
  If a call is offered to an idle inlet in the first stage, an idle outlet of the desired outgoing group is determined.
  As a second step, the marker has to find a chain of idle links leading from the calling inlet to the a priori determined outlet

of the desired trunk group. For economic reasons, many existing PPS-systems allow also second or more attempts, respectively.

The calculation method PPL considers the first attempt loss only.

2.2 Types of Traffic

PCT1 (Pure Chance Traffic of Type 1)

An infinite number of sources produces the offered traffic with the mean value A. The total call rate is constant and independent of the number of busy sources.

PCT2 (Pure Chance Traffic of Type 2)

A finite number of sources (e. g. equal to the number of inlets per first stage multiple) produces the offered traffic. Each idle source has the same constant call rate α. The idle times per source are negative exponentially distributed.

In both cases (PCT1, PCT2), the distribution of holding times is assumed to be negative exponential with the mean value of h_m.

2.3 Point-to-Group Loss (PGS-Mode)

The point-to-group loss is defined as follows:
Upon arrival at an idle inlet, a call suffers a point-to-group loss

- if no connection can be established to any idle trunk of the desired outgoing group no. r, having n_r trunks, or
- if all trunks of the outgoing group are busy.

Only those calls contribute to the arrival rate that find one inlet idle. According to this definition, the point-to-group loss is defined as

$$B_{PG} = \text{lost calls / offered calls.}$$

2.4 Point-to-Point Loss (PPS-Mode)

The point-to-point loss is defined as follows:
Upon arrival at an idle inlet, a call suffers a point-to-point loss, if no chain of idle links through the link system can be found,

provided at least one outlet to the desired outgoing group is still idle. Only those calls contribute to the arrival rate that find one inlet idle as well as at least one outlet of the desired outgoing trunk group idle. According to this definition, the point-to-point loss is defined as

$$B_{PP} = \text{lost calls/offered calls.}$$

2.5 The Total Loss of an Outgoing Trunk Group (PPS-Mode)

The probability of loss B_{tot} of a certain outgoing trunk group no. r of a link system for traffic distribution can - as it is known - be composed of two parts being defined as follows:

- The probability of loss $B(n_r)$ referred to the state where all n_r trunks of the considered outgoing group are occupied (being approximated by Erlang's Loss Formula for PCT1 and Erlang's Bernoulli Formula in case of PCT2),
- the point-to-point loss B_{pp} as defined in Section 2.4.

Hence, one gets the total loss B_{tot} for link systems operating in the PPS-mode

$$B_{tot} = B(n_r)+(1-B(n_r))\cdot B_{PP}$$

This probability B_{tot} corresponds to B_{PG} in case of systems operating in the PGS-mode (cf. 2.3).

3. ABBREVIATIONS AND CONSIDERED STRUCTURES

For the time being, all Nik-charts in this volume consider only symmetrical structures having the same number of inlets and outlets and the same average traffic load per multiple of the first and the last stage. Expansion between the inlets and outlets in the first stage multiples, and, analogously, concentration between inlets and outlets of the last stage multiple are permitted.

S	number of stages
N	total number of inlets (or outlets,resp.)
Y	total carried traffic of the link system
Y_j	carried traffic per multiple in stage j (j=1..S)
Y_r	carried traffic of a considered outgoing trunk group
LB	number of link blocks
i_j	inlets per multiple in stage j } (j=1..S)
k_j	outlets per multiple in stage j } (j=1..S)
g_{lj}	number of multiples belonging to a link block in stage j } (j=1..S)
g_{bj}	number of multiples belonging to a group of link blocks in stage j } (j=1..S)
$l_{j,j+1}$	average number of links from each multiple in stage j to each multiple within the link block or to each link block or to each group of link blocks in stage j+1, (j=1..S-1).

3.1 Structures with Three Stages

Figure 1 shows the notations applied to the considered type of 3-stage link systems with single linkage (SL-systems).
Single linkage implies $l_{j,j+1}=1$ (j=1,2).

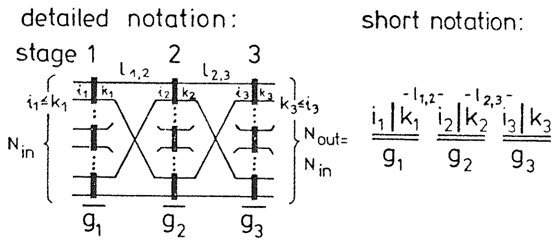

Fig. 1: Notations for 3-stage one-block link systems

This type of a one-block structure is used for the calculation of the Nik-charts for point-to-point selection (PPS).
Here, the following equations hold:

$$k_1=g_2=i_3$$

For point-to-group selection, a multi-block structure according to Fig.2 was used for the calculation of the Nik-charts. That type of structure makes use of link blocks between stage 1 and 2. Additionally, for handy wiring between stage 2 and 3, the expression $k_1 \cdot k_2/g_3$ should be an integer number.

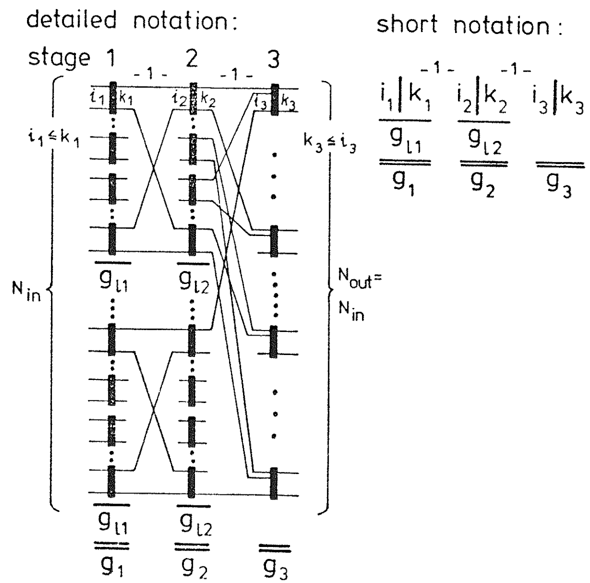

Fig. 2: Notations for 3-stage multi-block link systems

From Fig.2, one can determine the number N of inlets (or outlets, resp.):

$$N_{in} = N_{out} = i_1 \cdot i_2 \cdot LB = i_1 \cdot g_1$$

A structure as shown in Fig.2 should not be used in the point-to-point selection mode because of its rather small point-to-point accessibility which causes too high losses compared to a structure as shown in Fig.1.
As it can be easily verified, the structure according to Fig.1 is a special case of a structure according to Fig.2, if there is only one link block.

3.2 Structures with Four Stages

Figure 3 shows the notations applied to 4-stage link systems with single linkage (SL-systems with $l_{1,2}=l_{2,3}=l_{3,4}=1$).
All 4-stage link systems are wired with link blocks between stages 1-2 and 3-4.

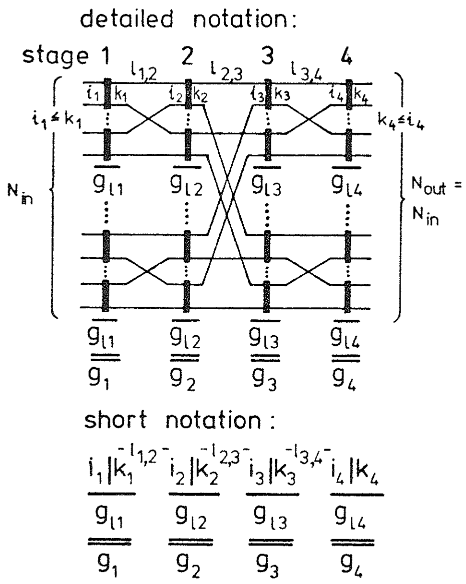

Fig. 3: Notations for 4-stage link systems

From Fig.3, one can determine the number N of inlets (or outlets, resp.). It holds in the case of SL-systems:

$$N_{in} = N_{out} = i_1 \cdot i_2 \cdot i_3$$

3.3 Structures with Five Stages

Figure 4 shows the notations applied to 5-stage link systems with single linkage (SL-systems with $l_{1,2}=l_{2,3}=l_{3,4}=l_{4,5}=1$).

All 5-stage link systems are wired with link blocks between stage 1-2 and 4-5.

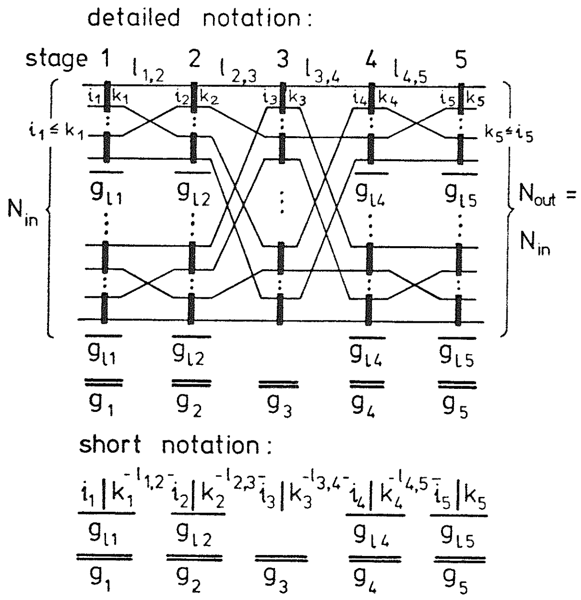

Fig. 4: Notations for 5-stage link systems

3.4 Structures with Six Stages

Figure 5 shows the notations applied to 6-stage link systems with single linkage (SL-systems with $l_{1,2}=l_{2,3}=l_{3,4}=l_{4,5}=l_{5,6}=1$).
These systems consist of link blocks and of groups of link blocks.

As to the wiring, one link from stage 1 to stage 2 must have access - via the connection graph - to as many multiples as possible in stage 5 which belong to the link block of the destination multiple in stage 6.

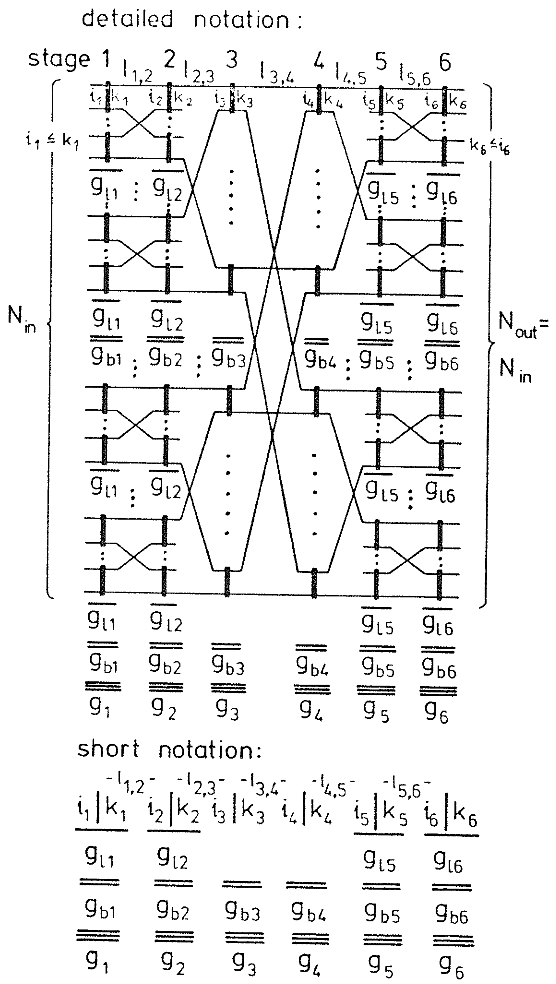

Fig. 5: *Notations for 6-stage link systems*

3.5 System-to-Outgoing-Group Wiring

The outlets behind the last stage of a link system can be wired to the outgoing trunk groups in two different manners (cf. Fig.6):

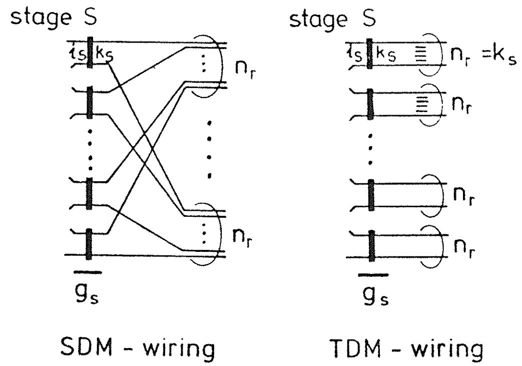

Fig. 6: *System-to-outgoing-group wiring*

a) SDM wiring (Space Division Multiplex)
In a SDM system, the trunks of a certain outgoing group are usually wired to the multiples of the last stage such that as many multiples as possible have access to a certain group.

b) TDM wiring (Time Division Multiplex)
One multiple of the last stage represents one trunk group, as it is mostly the case in PCM systems, namely, one multiple of the last stage corresponds to one PCM-highway.

4. NIK-CHARTS FOR THE DESIGN OF LINK SYSTEMS WITH POINT-TO-POINT SELECTION (PPS)

4.1 General Remarks

As to the point-to-point selection mode, two main sets of Nik-charts have to be distinguished depending on the type of offered traffic:

Charts for pure chance traffic of type 1 (PCT1) with a constant call rate, "infinite number of sources", are presented on the chamois pages.

Charts for pure chance traffic of type 2 (PCT2) with a state dependent call rate,"finite number of sources", can be found on the yellow pages.

Furthermore, each of those two sets is subdivided according to the number of stages.

Finally, another distinction has to be regarded.

First, space division multiplex link systems (SDM) are dealt with in charts 1..87 except for 11, 22, 33, 44, 55, 66 and 77. Here, the trunks of a certain outgoing group are wired to the multiples of the last stage such that as many multiples as possible have access to the considered group (cf. Chapter 3.5).

Second, time division multiplex link systems (TDM) can be mapped into fully corresponding SDM link system structures. However, here all outlets of a multiple in the last stage form one outgoing trunk group, i.e. one PCM highway. The distribution function of simultaneously occupied outlets of such a multiple is different from that one occuring in the case of SDM systems. Hence, extra Nik-charts have been calculated for usual sizes of 24 or 30 time channels. These are the Nik-charts 11,22,33,44,55,66, 77 and 88.

4.2 Application of the Nik-Charts for PPS-Link Systems

Besides the above mentioned types of traffic offered and the system-to-outgoing-group wiring, the following parameters must be known, when designing a link system in the PPS mode:

- N - the approximate total number of inlets (or outlets, resp.) of the system
- Y/N - the carried traffic per inlet
- B_{PP} - the prescribed first-attempt loss.

The design is performed in 4 steps as follows:

Step 1 The number S of stages is chosen (cf. remarks on the number of stages at the end of Ex.2).

Step 2 One calculates the number of inlets i_1 of a multiple in the first stage. For a given number of stages S a most crosspoint saving SL-structure can be achieved only if $i_1, i_2, \ldots, i_{s-1}; k_2, k_3, \ldots, k_s$ all have the same value. Thus one gets the well known equation

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N}$$

The term $\left[\frac{S}{2}+1\right]$ denotes the integer part of $\left(\frac{S}{2}+1\right)$.

Structures with the above parameters shall be named link systems having a "master size", e.g. for S=4,N=4096 see Ex.1, e.g. for S=6,N=4096 see Ex. 2.

Step 3 Use Nik-chart (PPS) with chart parameter S, i_1, PCT1 (PCT2), SDM-(TDM)-wiring.
For the prescribed carried traffic per inlet Y/N,
for the prescribed loss B_{PP} (first marking attempt) and
for the number of inlets N read off the expansion ratio k_1/i_1.

Step 4 The 3 parameters N, i_1, k_1 define the structure of the desired SL-link system for point-to-point selection.

The following examples illustrate this way of design.

4.2.1 Link Systems with "Master-Sizes"

In this section, the design of link systems having a socalled "master size" is shown.

Example 1 for PPS:

Be prescribed PCT1 and SDM wiring. Furthermore, the number of inlets (or outlets, respectively) be N=4096. For a traffic carried of 0.7 Erlang per inlet, i.e. a total of 2867.2 Erl., a loss of B_{PP}=5% is prescribed.

Step 1 Be chosen the number of stages S=4

Step 2 $i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[3]{4096} = 16$

Step 3 With N=4096 and i_1=16 use Nik-chart for PCT1 and SDM wiring with parameter i_1=16 (cf. Nik-chart 17 on the right hand side). For 0.70 Erl per inlet and B_{PP}=5% one reads off an expansion $k_1/i_1 \approx 1.35$ from the bold line curve drawn for 4096 inlets. Hence, one gets $k_1 = 1.35 \cdot 16 = 21.6$, be chosen $k_1 = 22$.

Step 4 With these 3 parameters N, i_1 and k_1, the following 4-stage SL-link system is obtained.

$$N_{in} = 4096 \left\{ \begin{array}{cccc} 16|22 \;{}^{-1-}\; & 16|16 \;{}^{-1-}\; & 16|16 \;{}^{-1-}\; & 22|16 \\ \underline{16} & \underline{22} & \underline{22} & \underline{16} \\ 256 & 352 & 352 & 256 \end{array} \right\} N_{out} = N_{in} = 4096$$

The total number of crosspoints required amounts to 360,448 which is CPL=88 crosspoints per trunk (inlet, line) and CPE=88/0.7=125.71 crosspoints per Erl.

Example 2 for PPS:

Be given again PCT1, SDM wiring, N=4096, B_{PP}=5% and Y/N=0.70 Erl (as in Example 1).

Step 1 This time be chosen the number of stages S=6

Step 2 $i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[4]{4096} = 8$

Step 3 With N=4096 and i_1=8 use Nik-chart with parameter i_1=8 (cf. Nik-chart 35 on the right hand side).
For Y/N=0.70 Erl. per inlet and B_{PP}=5% one reads off an expansion $k_1/i_1 \approx 1.31$ from the bold line curve drawn for 4096 inlets. Hence, one gets $k_1 = 1.31 \cdot 8 = 10.48$, be chosen k_1=11.

Step 4 With these parameters N, i_1, and k_1 the following 6-stage link system is obtained:

$$N_{in} = 4096 \left\{ \begin{array}{cccccc} 8|11 \;{}^{-1-}\; & 8|8 \;{}^{-1-}\; & 8|8 \;{}^{-1-}\; & 8|8 \;{}^{-1-}\; & 8|8 \;{}^{-1-}\; & 11|8 \\ \underline{8} & \underline{11} & \underline{\quad} & \underline{\quad} & \underline{11} & \underline{8} \\ \underline{64} & \underline{88} & \underline{88} & \underline{88} & \underline{88} & \underline{64} \\ 512 & 704 & 704 & 704 & 704 & 512 \end{array} \right\} N_{out} = N_{in} = 4096$$

The total number of crosspoints required amounts to 270,336 which is CPL=66 crosspoints per trunk (inlet, line) and CPE=94.3 crosspoints per Erlang.

Comment on Example 1 and 2 for PPS

For an equal number of inlets (N) and an equal amount of traffic carried (Y/N), two systems were designed for S=4 and S=6 stages. The system with 6 stages requires remarkably less crosspoints (CPL=66 vs. 88). However, the 6-stage system is clearly more sensitive to overload. In order to compare the overload behavior, one has to regard the expansion values as they were read off the Nik-charts. (Otherwise, with the rounded values of k_1 one would not have an exact comparison.) With the planning value k_1/i_1=1.31 (6-stage system), the loss increases from 5% to 10% as the load carried increases from 0.70 to 0.735 Erlang per inlet. This corresponds to an overload of 5% only.
Similarly, for the solution with 4 stages, on obtains B_{PP} = 10% as the traffic carried per inlet is increased from 0.70 to 0.76 Erl. (cf. Nik-chart 17 on the right hand side). This, however, corresponds to an overload of about 8.6%. The decision, whether S=4 or S=6 should be realized, therefore depends, in practice, on the crosspoint requirements mentioned above, and on the overload sensitivity admitted. Furthermore, the software and/or hardware costs of the common control as well as available switch sizes and wishes regarding the modular expansion of the system will have an influence on the decision.

4.2.2 Link Systems with "Non-Master-Sizes"

Sometimes a number N of inlets (or outlets, resp.) is desired which cannot be realized by a master structure, e.g. S=6 and $N \approx 5200$. Here, one gets $i_1 = \sqrt[4]{5200} = 8.49$. Rounding off to i_1=8, one obtains $N=8^4=4096$ which is too small, and with i_1=9, N becomes 9^4=6561 which is too large.

In these cases, the values i_m and k_m of the middle stages have to be chosen not equal to i_1. For S=3 and S=5, this applies to the multiples (switch matrices) in the one middle stage.
For S=4 and 6, this applies to the multiples in the two middle stages.

In the above example, for S=6 one achieves N=5184 with $i_1=i_2=k_2=i_5=k_5=k_6=8$ and $i_3=k_3=i_4=k_4 = \sqrt{\frac{N}{i_1^2}} = 9$.

For S=5 stages, the size of the switches in the one middle stage (No.3) is obtained by $i_3=k_3=\frac{N}{i_1^2}$.

For S=4 stages, the size of the switches in stage 2 and 3 is obtained by $i_2=k_2=i_3=k_3=\sqrt{\frac{N}{i_1}}$.

Finally, for S=3 stages, the size of the switches in the middle stage is obtained by $i_2=k_2=\frac{N}{i_1}$.

The Nik-charts show not only the curves for master sizes (bold lines), but also curves for non-master sizes. In each diagram, the dashed-dotted lines belong to a larger system, whereas the dashed lines belong to a smaller system. The difference between the largest and smallest size has been chosen such that a wide range is covered, thus giving additional information on non-optimal link systems.

For a number N of inlets (or outlets, resp.) which cannot be realized by a master size (as N=5200 above), one easily finds the necessary expansion ratio k_1/i_1 by interpolation in the concerning Nik-chart.

4.2.3 Extension Strategies for PPS

Example 1 and Example 2 describe a socalled "master size" where exactly holds $N=i_1^3$ or $N=i_1^4$, respectively. Also, master size systems guarantee the minimum number of crosspoints per inlet for a given traffic carried and for a prescribed loss B_{PP}.
In practice, link systems have to be designed which grow stepwise from an initial size to a final extension.
There are 2 different strategies that can be applied for this purpose:

- SYG-the concept of symmetrical growth (see Ex.3 and 4 for PPS)
  This method allows the use of a fixed switch size only in the first and in the last stage. The switches in the intermediate stages have to be enlarged whenever the system has to be extended. This concept saves crosspoints in the initial sizes of the considered link system. But whenever the link system has to be altered in size, one has to replace the middle stage switches and to form new link blocks, too. This, however, can outweigh the initial crosspoint savings.

- CBS-the concept of constant block size (see Ex.5 for PPS)
  The concept of constant block size is applied to S≥4 stages. It leaves the switch sizes and link block sizes unchanged. It requires a constant number of crosspoints per inlet from the smallest up to the largest planned extension size of the link system. This means, that one tolerates a certain pre-investment of crosspoints. The structure of the link blocks is determined by the planned maximum size.

Example 3 for PPS: (Extension strategy SYG)

Smallest size	N ≈ 300
Main size	N ≈ 500
Largest size	N ≈ 2000

Furthermore, be prescribed PCT1, SDM wiring, a loss B_{PP}=1%, and a carried traffic per inlet Y/N=0.8.

Main size: (N ≈ 500)

Step 1 Be chosen S=4 stages

Step 2 Starting with the economically most interesting main size N ≈ 500, one obtains

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[3]{500} = 7.94\text{, hence, } i_1=8 \text{ is chosen.}$$

Step 3 With N≈500 and i_1=8 use Nik-chart with parameter i_1=8 (cf. Nik-chart 13 on the right hand side).
For Y/N=0.8 Erl per inlet and B_{PP}=1% one reads off an expansion k_1/i_1≈1.83 from the bold line curve drawn for 512 inlets.Therefrom, k_1=1.83 · 8 = 14.64, and k_1 = 15 is chosen.

Step 4 With these 3 parameters, N, i_1, and k_1, the structure of the main size is as follows:

$$\begin{array}{c} N_{in} \\ 512 \end{array} = \left\{ \begin{array}{cccc} 8|15 \overset{-1-}{} & 8|8 \overset{-1-}{} & 8|8 \overset{-1-}{} & 15|8 \\ \hline 8 & 15 & 15 & 8 \\ \hline\hline 64 & 120 & 120 & 64 \end{array} \right\} \begin{array}{l} N_{out} = \\ N_{in} = 512 \end{array}$$

The total number of crosspoints required amounts to 30.720, which is CPL=60 crosspoints per trunk (inlet,line) and CPE=75 crosspoints per Erlang.

Smallest size: ($N \approx 300$)

In a 4-stage SL-link system the following equation holds (see Fig.3):

$$N = i_1 \cdot i_2 \cdot i_3$$

With $i_2=i_3$ for symmetrical reasons, one obtains

$$i_2 = \sqrt{N/i_1}, \text{ hence, } i_2 = \sqrt{300/8} = 6.12$$

which is rounded off to $i_2=6$. Thus, the smallest size becomes N=288.

$$\begin{array}{c} N_{in} = \\ 288 \end{array} \left\{ \begin{array}{ccccccc} 8|15 & -1- & 6|6 & -1- & 6|6 & -1- & 15|8 \\ 6 & & 15 & & 15 & & 6 \\ \hline 36 & & 90 & & 90 & & 36 \end{array} \right\} \begin{array}{c} N_{out} = \\ N_{in} = 288 \end{array}$$

As one can see from Nik-chart 13 on the right hand side, the chosen expansion for the main size guarantees the prescribed $B_{PP}=1\%$ also for the smallest size.

The total number of crosspoints is 15,120 which is CPL=52.5 crosspoints per trunk (inlet, line) and CPE=65.625 crosspoints per Erl.

Largest size: ($N \approx 2000$)

Analogously, using the above equation, one gets for the largest size:

$$i_2 = \sqrt{N/i_1}, \text{ hence, } i_2 = \sqrt{2000/8} = 15.81$$

which is rounded up to $i_2 = 16$.

For the main size, $k_1=15$ was chosen which corresponds to an expansion of 1.875. This expansion ensures the prescribed B_{PP}-loss of 1% also for the largest size of $N \approx 2000$ (cf. Nik-chart 13 on the right hand side).

$$\begin{array}{c} N_{in} = \\ 2048 \end{array} \left\{ \begin{array}{ccccccc} 8|15 & -1- & 16|16 & -1- & 16|16 & -1- & 15|8 \\ 16 & & 15 & & 15 & & 16 \\ \hline 256 & & 240 & & 240 & & 256 \end{array} \right\} \begin{array}{c} N_{out} = \\ N_{in} = \\ 2048 \end{array}$$

The total number of crosspoints required amounts to 184,320 which is CPL=90 crosspoints per trunk (inlet,line) and CPE=112.5 crosspoints per Erlang.

Remarks on link systems having 3 or 5 stages

The concept of symmetrical growth (SYG) is also applicable to link systems with 3 or 5 stages. In this case, only the switches in the one middle stage must be extended, whereas in systems with 4 or 6 stages the switches of the two middle stages must be altered.

Example 4 for PPS: (Extension Strategy SYG)

Smallest size	$N \approx 400$
Main size	$N \approx 700$
Largest size	$N \approx 1600$

Furthermore, be prescribed PCT1, SDM wiring, a loss $B_{PP}=1\%$, and a carried traffic per inlet Y/N=0.8.

Main size ($N \approx 700$)

Step 1 Be chosen S=5 stages

Step 2 Again, starting with the main size $N \approx 700$, one obtains

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{700} = 8.88, \text{ hence, } i_1=9 \text{ is chosen.}$$

Step 3 With $i_1=9$ and $N=i_1^3=729$ one reads off Nik-chart 25 on the left hand side an expansion of $k_1/i_1 \approx 1.32$ for a traffic carried per inlet Y/N=0.8 and for $B_{PP}=1\%$. Therefore, $k_1=1.32 \cdot 9 = 11.88$, and $k_1=12$ is chosen.

Step 4 With these 3 parameters, N, i_1, and k_1 the structure of the main size is as follows

$$\begin{array}{c} N_{in} = \\ 729 \end{array} \left\{ \begin{array}{ccccccccc} 9|12 & -1- & 9|9 & -1- & 9|9 & -1- & 9|9 & -1- & 12|9 \\ 9 & & 12 & & & & 12 & & 9 \\ \hline 81 & & 108 & & 108 & & 108 & & 81 \end{array} \right\} \begin{array}{c} N_{out} = \\ N_{in} = 729 \end{array}$$

The total number of crosspoints required amounts to 43.740 which is CPL=60 crosspoints per trunk (inlet, line) and CPE=75 crosspoints per Erlang.

Smallest size: ($N \approx 400$)

In a 5-stage, single linkage link system, the following equation holds (see Fig.4):

$$N = i_1 \cdot i_2 \cdot i_3$$

with $i_1 = i_2$, since only i_3 is to be altered, one gets

$$i_3 = \frac{N}{i_1 \cdot i_1} = \frac{400}{81} = 4.94$$

which is rounded up to $i_3=5$. Thus the smallest size becomes N=405.

$$\begin{array}{c} N_{in} = \\ 405 \end{array} \left\{ \begin{array}{ccccccccc} 9|12 & \text{-1-} & 9|9 & \text{-1-} & 5|5 & \text{-1-} & 9|9 & \text{-1-} & 12|9 \\ 9 & & 12 & & & & 12 & & 9 \\ \hline 45 & & 60 & & 108 & & 60 & & 45 \end{array} \right\} \begin{array}{l} N_{out} = \\ N_{in} = 405 \end{array}$$

Largest size: ($N \approx 1600$)

Analogously, using the above equation, one gets for the largest size

$$i_3 = \frac{N}{i_1 \cdot i_1} = \frac{1600}{81} = 19.75$$

which is rounded up to $i_3=20$. Thus the largest size becomes N=1620.

$$\begin{array}{c} N_{in} = \\ 1620 \end{array} \left\{ \begin{array}{ccccccccc} 9|12 & \text{-1-} & 9|9 & \text{-1-} & 20|20 & \text{-1-} & 9|9 & \text{-1-} & 12|9 \\ 9 & & 12 & & & & 12 & & 9 \\ \hline 180 & & 240 & & 108 & & 240 & & 180 \end{array} \right\} \begin{array}{l} N_{out} = \\ N_{in} = 1620 \end{array}$$

The prescribed $B_{PP}=1\%$ is fulfilled also for this size (cf. Nik-chart 25).

Example 5 for PPS: (Extension strategy CBS)

Smallest size (initial size) $N_{in}=N_{out} = 512$
Largest size (final size) $N_{in}=N_{out} = 4096$

Furthermore, be prescribed PCT1, SDM wiring, a loss $B_{PP}=10\%$, and a carried traffic per inlet Y/N=0.7.

Step 1 Be chosen S=6 stages

Step 2 Dimensioning always starts with the final size $N_{max}=4096$. One gets

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{4096} = \sqrt[4]{4096} = 8$$

Step 3 With N=4096 and $i_1=8$ use Nik-chart 35 on the right hand side. For Y/N=0.7 Erl. per inlet and $B_{PP}=10\%$ one reads off an expansion $k_1/i_1 \approx 1.25$. Therefrom, $k_1 = 1.25 \cdot 8 = 10.00$ and $k_1=10$ is chosen.

Step 4 Thus, one gets the following structure:

$$\begin{array}{c} N_{in} = \\ 4096 \end{array} \left\{ 512 \left\{ \begin{array}{ccccccccccc} 8|10 & \text{-1-} & 8|8 & \text{-1-} & 8|8 & \text{-1-} & 8|8 & \text{-1-} & 8|8 & \text{-1-} & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ \hline 64 & & 80 & & 80 & & 80 & & 80 & & 64 \\ \hline 512 & & 640 & & 640 & & 640 & & 640 & & 512 \end{array} \right. \right\} \begin{array}{l} N_{out} = \\ N_{in} = \\ 4096 \end{array}$$

This above structure is of type SL, i.e. single linkage. Stages 1,2, and 3 form 8 groups of link blocks with 512 lines each. The same holds true for stages 4, 5 and 6.

Now, intermediate sizes are considered starting with N=512 as the smallest size.
The one left hand side group of 8 link blocks has to be wired to the one right hand side group of 8 link blocks.

$$\begin{array}{c} N_{in} = \\ 512 \end{array} \left\{ \begin{array}{ccccccccccc} 8|10 & \text{-1-} & 8|8 & \text{-1-} & 8|8 & \text{-8-} & 8|8 & \text{-1-} & 8|8 & \text{-1-} & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ \hline 64 & & 80 & & 80 & & 80 & & 80 & & 64 \end{array} \right\} \begin{array}{l} N_{out} = \\ N_{in} = \\ 512 \end{array}$$

The $80 \cdot 8 = 640$ links from stage 3 to 4 can be wired either in the parallel or in the meshed mode (cf. /1/). In both wiring modes, the loss for a not yet fully extended system will be significantly below the B_{PP} planned for the largest size. It could also be calculated by the PPL-method described in /1/.

Next, N=1024 is considered. Here in this case, one has two groups of link blocks in each half of the link system.

$$\begin{array}{c} N_{in} = \\ 1024 \end{array} \left\{ \begin{array}{ccccccccccc} 8|10 & \text{-1-} & 8|8 & \text{-1-} & 8|8 & \text{-4-} & 8|8 & \text{-1-} & 8|8 & \text{-1-} & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ \hline 64 & & 80 & & 80 & & 80 & & 80 & & 64 \\ \hline 128 & & 160 & & 160 & & 160 & & 160 & & 128 \end{array} \right\} \begin{array}{l} N_{out} = \\ N_{in} = \\ 1024 \end{array}$$

Analogously, one gets an extension size of 2048, if using 4 groups of link blocks on the left hand side and also 4 groups of link blocks on the right hand side. Again, the loss B_{PP} will be significantly lower than in the planned maximum size for N_{max}=4096 lines.

As to the other intermediate sizes, i.e. for $N_{in}=N_{out}$=1536,2560, 3072 and 3584, the outlets of the multiples in stage 3 cannot be partitioned evenly among the groups of link blocks on the right hand side. In other words, $l_{3,4}$ is not an integer number. Nevertheless, in most cases, the wiring can be performed in such a manner, that the number of links leading into a certain group of link blocks does not differ significantly.

A further extension beyond the planned final size (4096 trunks) is also possible. In that case, the sizes of the switches in the 2 middle stages should be increased, as it was suggested in Example 3 (concept of symmetrical growth).

5. NIK-CHARTS FOR THE DESIGN OF LINK SYSTEMS WITH POINT-TO-GROUP SELECTION (PGS)

5.1 General Remarks

As to the point-to-group selection mode, all considered link systems having 4,5 or 6 (or more) stages are symmetrical in any case, and they have one uniform type of Nik-charts, i.e. one chart per number of stages only (see charts 89,90).

For the case of S=3 stages, unsymmetrical multiblock-structures have to be considered (cf. Fig.2). This type is designed with a special kind of Nik-charts (see Section 5.3,and Nik-chart 91/92).

The design of all link systems operating in the point-to-group selection mode, having an arbitrary number of stages and with a minimum crosspoint requirement has been derived in /6/.
This derivation prescribes the carried traffic per inlet a_1=Y/N, and furthermore the relative transparency T_{rel} of the link system.

It holds

$$T_{rel}=\frac{T}{N_{in}} = \prod_{j=1}^{S-1} (k_j-y_j)\cdot k_s \cdot \frac{1}{N_{in}} \qquad (1)$$

Note that in /6/ this T_{rel} is also denoted as "Meshing Coefficient M".

The loss calculation of PGS-systems with a limited effective accessibility can be performed reliably with the method CLIGS published in /4/ and /5/.

The difference in crosspoints per inlet between systems with limited accessibility and those with practically full accessibility is, however, rather small (cf. /6/). Therefore, the following PGS-Nik-charts consider only systems with practically full access. This means that all systems being designed according to these charts have outgoing trunk groups which can be dimensioned simply by means of Erlang's Loss Formula E_{1,n_r} for PCT1 or Erlang's Bernoulli Formula ("lost calls cleared") for PCT2, resp. (Note that for historical reasons Erlang's Bernoulli Formula is also known as Engset Formula.)

The design of link systems with practically full access implies a relative transparency $T_{rel} \geq 1.0$ (=100%). Hence, the internal blocking is extremely small and the measured losses can in practice not be distinguished from that of a theoretically fully accessible group /4,5,6/. For safety reasons, e.g. regarding an occasional overload, the following Nik-charts imply a relative transparency T_{rel}=120% for S=4 stages and 130% for S=5 and S=6 stages. The reason for these different prescriptions lies in the fact that the transparency decreases in case of overload according to equation 1 in higher orders the more,the more stages the system has /4,5/.

For S=3 stages, the Nik-charts consider, for practical reasons, the two cases T_{rel}=100% and 125% (cf. 5.3).

Note that the crosspoint requirement of a link system with a given number of inlets and outlets increases only with the Sth root of T_{rel}!

The strict application of the Optimum Link Method /6/ leads to structures having generally not single linkage ($l_{j,j+1}$=1),

but sometimes less than one link between multiples (or link blocks, resp.) of subsequent stages ($l_{j,j+1} < 1$). This latter case, $l_{j,j+1} < 1$, may often be unsuitable from the viewpoint of wiring, manufacturing, control, maintenance etc. Hence, in /3/ a modified concept of crosspoint-saving design has been developed. It always leads to SL-systems having a number of crosspoints per line sometimes slightly higher than its theoretical minimum or T_{rel} will be sometimes slightly smaller. Therewith, the concept of constant block size (CBS) (cf. Example 5 in Chapter 4) is also applicable for link systems operating in the point-to-group selection mode.
An example will make this clear.

Be chosen S=4 and a maximum of N≈1000 (final extension) inlets (or outlets, resp.) of a link system. The prescribed carried traffic per inlet be Y/N=0.8 Erl. The relative transparency be $T_{rel} \approx 120\%$, thus guaranteeing full access, i.e. negligibly small internal blocking.

From /6/, Equation (10) follows for S=4

$$i_1 = 2\cdot\sqrt[4]{\frac{N\cdot T_{rel}}{4\cdot a_1}} = 2\cdot\sqrt[4]{\frac{1000\cdot 1.2}{3.2}} = 8.8$$

Furthermore, from Equations (11) and (12) in /6/ one gets

$$k_1 = \frac{Y/N}{0.5}\cdot i_1 = 8.8 \cdot 1.6 = 14.08$$

Be chosen $i_1=9$, $k_1=14$. Therewith the structure shown in Fig.7a is obtained. This structure requires CPL=56 crosspoints per outgoing line (trunk).

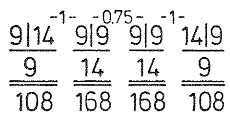

Fig. 7a

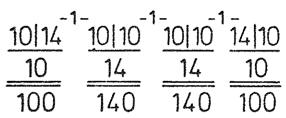

Fig. 7b

As one can see from Fig. 7a, this structure has 12 link blocks. An average of only 0.75 links leads from a multiple in stage 2 to a link block on the right hand side. For wiring, marking purposes etc. this is often undesirable as mentioned before.

Therefore, one chooses a similar single linkage structure (SL) having exactly one link from a multiple in stage 2 to a link block on the right hand side and about the same value T_{rel}. This is done according to the following procedure:

One calculates the number of inlets in a first-stage multiple in the same way as for PPS-systems, namely:

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N}$$

where $i_1, i_2, \ldots, i_{s-1}$ and $k_2, k_3, \ldots, k_s$ all have the same value.

The term $\left[\frac{S}{2}+1\right]$ denotes the integer part of $\left(\frac{S}{2}+1\right)$.

Now, one determines the not yet known parameters $k_1 = i_s$ for prescribed carried traffic per inlet Y/N and for a prescribed relative transparency T_{rel}. This must be performed iteratively, provided no Nik-charts exist. The resulting value of k_1 has to be rounded, thus changing slightly the value of the allowed carried traffic per inlet to hold the prescribed T_{rel}.
In this example, the number of crosspoints per line (trunk) is equal in both cases, Fig. 7a and 7b, namely CPL=56.

5.2 Application of the Nik-Charts for PGS-Link Systems (S≥4)

This section deals with the design of link systems with Point-to Group Selection (PGS) having S≥4 stages. Those systems having 3 stages will be discussed separately in Section 5.3.

The following parameters must be known when designing a link system operating in the PGS mode.

N - approximate total number of inlets/outlets, resp. of the system
Y/N - carried traffic per inlet.

5.2.1 Link Systems with "Master Sizes"

The design is performed in 4 steps as follows:

Step 1 The number S of stages is chosen.

Note that the most crosspoint saving number S is, according to the Optimum Link Theory /6/

$$S_{opt} = \ln \frac{N \cdot T_{rel}}{4 \cdot a_1}$$

However, often a number $S < S_{opt}$ is chosen with regard to the costs for control, maintenance etc., as well as to the smaller sensitivity against overload for $S < S_{opt}$ /4,5,6/.

Step 2 One calculates the number of inlets i_1 of a multiple in the first stage. For a given number of stages S a most crosspoint saving SL-structure can be achieved only if $i_1, i_2, \ldots, i_{s-1}$; $k_2, k_3, \ldots, k_s$ all have the same value. Thus one gets the well known equation for $S \geq 4$ stages

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} \quad \text{(eventually to be rounded).}$$

Step 3 Use the Nik-chart for PGS (blue pages) with chart parameter S. For the prescribed carried traffic per inlet Y/N and the pair i_1, N read off the expansion ratio k_1/i_1. Therewith k_1 is known which eventually must be rounded up.

Step 4 With the 3 parameters N, i_1, k_1 the structural design is defined for a SL-link system for Point-to-Group selection having practically full access to all outgoing trunk groups.

The following examples illustrate this way of design.

Example 1 for PGS:

As mentioned earlier, the type of traffic (PCT1 or PCT2) need not be regarded in the Nik-charts for point-to-group selection, since here, only the fact of practically full access is relevant. Be prescribed the number of inlets (or outlets, resp.) $N \approx 4000$ and a traffic carried of 0.7 Erl. per inlet.

Step 1 Be chosen S=4 stages.

Step 2 $i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[3]{4000} \approx 16$, $N_{actual} = 16^3 = 4096$

Step 3 Use Nik-chart 89 for PGS and chart parameter S=4. For Y/N=0.7 Erl per inlet one reads off an expansion $k_1/i_1 \approx 1.17$. Hence, one gets $k_1 = 1.17 \cdot 16 = 18.72$, be chosen (at least) $k_1 = 19$.

Step 4 With these 3 parameters N, i_1, k_1 the following 4-stage SL-link system is obtained

$$\begin{array}{c} N_{in} = \\ 4096 \end{array} \left\{ \begin{array}{cccc} 16|19 & \overset{-1-}{} 16|16 & \overset{-1-}{} 16|16 & \overset{-1-}{} 19|16 \\ 16 & 19 & 19 & 16 \\ \hline 256 & 304 & 304 & 256 \end{array} \right\} \begin{array}{c} N_{out} = \\ N_{in} = 4096 \end{array}$$

The total number of crosspoints required amounts to 31.296, which is 76 crosspoints per trunk (inlet, line) (CPL=76) and 108.57 crosspoints per Erlang (CPE=108.57).

If, e.g. for reasons of available switch modules, $k_1 = 20$ is chosen, one obtains $T_{rel} > 1.2$, or vice versa $Y/N > 0.7$ Erlang is allowed for $T_{rel} = 1.2$.

Example 2 for PGS:

Be given the total number of inlets (or outlets, resp.) N=4096. The carried traffic per inlet be 0.7 Erlang.

Step 1 This time be chosen the number of stages S=6.

Step 2 $i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[4]{4096} = 8$

Step 3 Use Nik-chart 90 for PGS and chart parameter S=6. For Y/N=0.7 Erlang per inlet one reads off an expansion $k_1/i_1 \approx 1.25$. Hence, one gets $k_1 = 1.25 \cdot 8 = 10$.

Step 4 With these 3 parameters, N, i_1, k_1 the following 6-stage SL-link system is obtained.

$$\begin{array}{c} N_{in} = \\ 4096 \end{array} \left\{ \begin{array}{cccccc} 8|10 & \overset{-1-}{} 8|8 & \overset{-1-}{} 8|8 & \overset{-1-}{} 8|8 & \overset{-1-}{} 8|8 & \overset{-1-}{} 10|8 \\ 8 & 10 & & & 10 & 8 \\ \hline 64 & 80 & 80 & 80 & 80 & 64 \\ \hline 512 & 640 & 640 & 640 & 640 & 512 \end{array} \right\} \begin{array}{c} N_{out} = \\ N_{in} = 4096 \end{array}$$

The total number of crosspoints required amounts to $CP = 4096 \cdot 6 \cdot 10 = 245.760$ which is CPL=60 crosspoints per trunk (inlet, line) and CPE=85.71 crosspoints per Erlang.

5.2.2 Extension Strategies for PGS

Example 1 and Example 2 describe a so-called "master size" where exactly holds $N=i_1^{\,3}$ or $N=i_1^{\,4}$, respectively (cf. Chapter 4.21). Also, "master size" systems guarantee the minimum number of crosspoints per inlet for a given traffic carried and for full accessibility. In practice, link systems have to be designed which grow stepwise from an initial size to a final extension. There are two different stategies that can be applied for this purpose:

- SYG - the concept of symmetrical growth.

  This method allows the use of a fixed switch size only in the first and in the last stage. The switches in the intermediate stages have to be enlarged whenever the system has to be extended. This concept saves crosspoints in the initial sizes of the considered link system.
  But whenever the link system has to be altered in size, one has to replace the middle stage switches and to form new link blocks, too. This however, can outweigh the initial crosspoint saving.

- CBS - the concept of constant block size.

  The concept of constant block size leaves the switch sizes and link block sizes unchanged. It requires a constant number of crosspoints per inlet from the smallest up to the largest planned extension size of the link system. This means, that one tolerates a certain pre-investment of crosspoints. The structure of the link blocks is determined by the planned maximum size.

The following examples outline the design according to SYG or CBS, resp. Once again, Nik-charts are used for the design.

Example 3 for PGS: (Extension Strategy SYG)

Smallest size	$N\approx 300$	
Main size	$N\approx 500$	(most manufactured size)
Largest size	$N\approx 2000$	

Furthermore, a traffic carried per inlet of $Y/N=0.8$ Erlang is prescribed.

Main Size: $(N\approx 500)$

Step 1 Be chosen $S=4$ stages

Step 2 Starting with the economically most interesting main size, one obtains

$$i_1 = \sqrt[\left[\frac{S}{2}+1\right]]{N} = \sqrt[3]{500} = 7.94, \text{ hence, } i_1=8 \text{ is chosen.}$$

Step 3 Use Nik-chart 89 for PGS and chart parameter $S=4$. For 0.8 Erlang per inlet one reads off an expansion $k_1/i_1\approx 1.49$, hence, one gets $k_1=1.49\cdot 8 = 11.92$, so $k_1=12$ is chosen.

Step 4 With these 3 parameters N, i_1, k_1, the structure of the main size is as follows

$$\begin{matrix} N_{in} = \\ 512 \end{matrix} \left\{ \begin{matrix} 8|12^{-1} & 8|8^{-1} & 8|8^{-1} & 12|8 \\ \hline 8 & 12 & 12 & 8 \\ \hline\hline 64 & 96 & 96 & 64 \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 512 \end{matrix}$$

The total number of crosspoints required amounts to 24,576 which is CPL=48 crosspoints per trunk (inlet, line) and CPE=60 crosspoints per Erlang.

Smallest size: $(N\approx 300)$

In a 4-stage SL-link system the following equation holds:

$$N=i_1\cdot i_2\cdot i_3$$

with $i_2=i_3$ for symmetrical reasons, one obtains

$$i_2 = \sqrt{N/i_1}, \text{ hence, } i_2 = \sqrt{300/8} = 6.12$$

which is rounded off to $i_2=6$. Thus, the minimum size becomes $N=288$. The structure of the smallest size is

$$\begin{matrix} N_{in} = \\ 288 \end{matrix} \left\{ \begin{matrix} 8|12^{-1} & 6|6^{-1} & 6|6^{-1} & 12|8 \\ \hline 6 & 12 & 12 & 6 \\ \hline\hline 36 & 72 & 72 & 36 \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 288 \end{matrix}$$

The total number of crosspoints is CP=12,096 which is CPL=42 crosspoints per trunk (inlet, line) and CPE=52.5 crosspoints per Erlang.

As one can easily prove, the relative transparency T_{rel} remains unchanged compared to that one of the main size (see Equation (1)).

Largest size: (N≈2000)

Analogously, using the above equation, one gets for the largest size being envisaged:

$$i_2 = \sqrt{N/i_1}, \quad \text{hence, } i_2 = \sqrt{2000/8} = 15.81$$

which is rounded up to $i_2=16$.
Thus, the largest size becomes N=2048. Again the relative transparency T_{rel} (cf. Equation (1)) remains unchanged.

$$\begin{matrix} N_{in} = \\ 2048 \end{matrix} \left\{ \begin{array}{ccccccc} & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -1- & \\ 8|12 & & 16|16 & & 16|16 & & 12|8 \\ 16 & & 12 & & 12 & & 16 \\ 256 & & 192 & & 192 & & 256 \end{array} \right\} \begin{matrix} N_{out} = \\ N_{in} = 2048 \end{matrix}$$

The total number of crosspoints is CP=147,456 which is CPL=72 crosspoints per trunk (inlet, line) and CPE=90 crosspoints per Erlang.

Example 4 for PGS: (Extension Strategy CBS)

The smallest size (initial size) be $N_{in}=N_{out}$ = 512

The largest size (here final size) be $N_{in}=N_{out}$ = 4096.

Furthermore, a traffic carried per inlet of Y/N=0.7 Erl be prescribed. Dimensioning always starts with the largest size when using the CBS strategy.

Step 1 Be chosen S=6 stages.

Steps 2,3,4 lead to the same SL-system as obtained in Example 2 for PGS (according to Nik-chart 90) namely

$$\begin{matrix} N_{in} = \\ 4096 \end{matrix} \left\{ 512 \left\{ \begin{array}{ccccccccccc} & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -1- & \\ 8|10 & & 8|8 & & 8|8 & & 8|8 & & 8|8 & & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ 64 & & 80 & & 80 & & 80 & & 80 & & 64 \end{array} \right. \right. \atop \begin{array}{cccccc} 512 & 640 & 640 & 640 & 640 & 512 \end{array} \left. \right\} \begin{matrix} N_{out} = \\ N_{in} = 4096 \end{matrix}$$

This above largest size is of type SL, according to the designing rules.
Stages 1,2, and 3 form 8 groups of link blocks with 512 lines each. The same holds true for stages 4,5, and 6 on the right hand side of the system.

Now, intermediate sizes are considered, starting with N = 512 as the smallest size.

Only one left hand side group of 8 link blocks has to be installed and wired to the one right hand side group of 8 link blocks.

$$\begin{matrix} N_{in} = \\ 512 \end{matrix} \left\{ \begin{array}{ccccccccccc} & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -8- & & \scriptstyle -1- & & \scriptstyle -1- & \\ 8|10 & & 8|8 & & 8|8 & & 8|8 & & 8|8 & & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ 64 & & 80 & & 80 & & 80 & & 80 & & 64 \end{array} \right\} \begin{matrix} N_{out} = \\ N_{in} = 512 \end{matrix}$$

The 80·8=640 links from stage 3 to 4 can be wired either in the parallel or in the meshed mode (cf. /1/). In both wiring modes, the relative transparency T_{rel} will be significantly higher than the one for the largest size.

Next, N=1024 is considered. Here in this case, one has two groups of link blocks in each half of the link system.

$$\begin{matrix} N_{in} = \\ 1024 \end{matrix} \left\{ \begin{array}{ccccccccccc} & \scriptstyle -1- & & \scriptstyle -1- & & \scriptstyle -4- & & \scriptstyle -1- & & \scriptstyle -1- & \\ 8|10 & & 8|8 & & 8|8 & & 8|8 & & 8|8 & & 10|8 \\ 8 & & 10 & & & & & & 10 & & 8 \\ 64 & & 80 & & 80 & & 80 & & 80 & & 64 \\ 128 & & 160 & & 160 & & 160 & & 160 & & 128 \end{array} \right\} \begin{matrix} N_{out} = \\ N_{in} = 1024 \end{matrix}$$

Analogously, one gets an extension size of 2048, if using 4 groups of link blocks on the left hand side and also 4 groups of link blocks on the right hand side. Again, the value of T_{rel} will be significantly higher than in the planned maximum size for N_{max}=4096 lines.

As to the other intermediate sizes, i.e. for $N_{in}=N_{out}$=1536, 2560, 3072 and 3584, the outlets of the multiples in stage 3 cannot be partitioned evenly among the groups of link blocks. In other words, $l_{3,4}$ is not an integer number. As a rule, the wiring can be performed in such a manner, that the number of links leading into a certain group of link blocks does not differ significantly.

A further extension beyond the planned final size (4096 trunks) is also possible. In that case, however, the sizes of the switches in the 2 middle stages must be increased, as it was suggested in Example 3 (concept of symmetrical growth).

The design engineer will not always be able to realize the structures obtained according to SYG or CBS. This is the case, if manufactured switch modules have to be used whose size is not compatible with the i, k values obtained by steps 1 to 4. In any case, the relative transparency should reach $T_{rel} \approx 1.2$ or 1.3 which guarantees practically full accessibility for all outgoing trunk groups without respect to their size.

5.3 Application of the Special Nik-Charts for PGS Link Systems with 3 Stages

5.3.1 Link Systems with "Master Sizes"

3-stage systems for point-to-group selection are multi-block systems, as a rule. The transparency of one-block systems as dealt with in Chapter 4 for PPS is too much abundant here. In the Nik-charts for PGS and S≥4, the expansion k_1/i_1 is drawn versus the carried traffic per inlet Y/N (as those charts for PPS).

On the contrary, in the Nik-charts for PGS in 3-stage systems, the absolute value k_1 (number of outlets in a first stage multiple) is drawn versus the carried traffic per inlet Y/N.

Again, for the design of a link system, the following parameters must be prescribed:

N - the approximate total number of inlets (or outlets, resp.) of the system

Y/N - the carried traffic per inlet

T_{rel} - relative transparency.

Note, that for practical reasons, a 3-stage PGS-link system should preferably have the following properties (cf. Fig.2):

a) Constant and equal number $g_1=g_3$ of multiples in the first and third stage in all extension sizes.

Thus, switching matrices of the same size can be used in stage 1 and 3 (main size).

b) Integer number LB of link blocks (first and second stage)

c) Uniform and integer number of link wires from each link block to each multiple of the third stage.

The properties a), b) and c) can be achieved if the value of $4 \cdot T_{rel}$ is an integer number. The Nik-charts for S=3 and PGS take this into account (T_{rel}=1.0 or 1.25).

Furthermore, the value k_1 which is to be read off the concerning Nik-chart must not be rounded to the next integer value, but in such a manner that k_1 is an integer multiple of $4 \cdot T_{rel}$.

By observing these rules the design is performed in 4 steps:

Step 1 Use Nik-chart for S=3 with the desired relative transparency T_{rel}. For the given values Y/N and N, read off the value k_1=number of outlets per multiple in the first stage. Round up as explained before.

Step 2 The number of link blocks LB (stage 1 and 2) is determined by

$$LB = \frac{k_1}{4 \cdot T_{rel}}$$

Step 3 The number of inlets i_1 of a multiple in the first stage is obtained by

$$i_1 = \frac{k_1}{2 \cdot Y/N}$$

This formula implies 0.5 Erl. per link within the link system. This is the most crosspoint saving case (cf. /6/). The obtained value i_1 has to be rounded off in order to be on the safe side with regard to the desired relative transparency T_{rel}.

Step 4 The actual number N of inlets (or outlets, resp.) of the link system must be an integer multiple of i_1^2, which is the number of inlets per link block. Hereby, $i_2=k_2=i_1$ is implied according to the optimum link rules /6/.

Thus it holds

$$N_{actual} = i_1^2 \cdot LB = \frac{i_1^2 \cdot k_1}{4 \cdot T_{rel}} \quad \text{and} \quad g_1 = g_3 = \frac{N}{i_1}$$

(As to the notations, see Chapter 3).

Example 5 for PGS:

Be desired $S=3$ stages, $N \approx 200$ inlets (or outlets, resp.) and a carried traffic per inlet $Y/N=0.7$ Erl, and further, a relative transparency $T_{rel} = 1.0$.

Step 1 Use Nik-chart for $S=3$ and $T_{rel}=1.0$ (chart 91). For a carried traffic of 0.7 Erl per inlet and $N=200$ read off $k_1=11.6$ to be rounded up to $k_1=12$, thus fulfilling the rule "k_1 an integer multiple of $4 \cdot T_{rel}$".

Step 2 The number of link blocks becomes $LB = \frac{k_1}{4T_{rel}} = \frac{12}{4} = 3$.

Step 3 The number of inlets i_1 in a first stage multiple is obtained

$$i_1 = \frac{k_1}{2 \cdot Y/N} \quad . \quad \text{Here, } i_1 = \frac{12}{2 \cdot 0.7} = 8.57$$

so $i_1=8$ is chosen.

Step 4 Thus, the number of inlets per link block becomes $i_1^2=64$ and the actual total number of inlets (or outlets, resp.) $N=3 \cdot 64=192$.

The following system is obtained:

$$\begin{matrix} N_{in} = \\ 192 \end{matrix} \left\{ \begin{matrix} 8|12 & \text{-1-} & 8|8 & \text{-1-} & 12|8 \\ 8 & & 12 & & \\ \overline{24} & & \overline{36} & & \overline{24} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 192 \end{matrix}$$

Due to rounding off i_1, the actual relative transparency is $T_{rel}=1.14=114\%$ for a carried traffic of $Y/N=0.7$ Erlang per inlet. By increasing Y/N to 0.75, T_{rel} becomes 1.0 or 100%.

The above structure requires a total of 6912 crosspoints, which is CPL=36 crosspoints per trunk (inlet, line) and CPE=51.4 crosspoints per Erlang.

Example 6 for PGS:

Be given $S=3$ stages, $N \approx 600$ inlets (or outlets, resp.), a carried traffic per inlet $Y/N=0.8$ Erlang and a relative transparency $T_{rel}=1.25$.

Step 1 Use Nik-chart for $S=3$ and $T_{rel}=1.25$ (chart 92). For a carried traffic of 0.8 Erlang per inlet and $N=600$ read off $k_1=19.7$. As suggested before, k_1 should be rounded up to the next higher integer of $4 \cdot T_{rel}$, here $k_1=20$.

Step 2 The number of link blocks becomes $LB = \frac{20}{4 \cdot 1.25} = 4$.

Step 3 One obtains $i_1 = \frac{20}{2 \cdot 0.8} = 12.5$, so $i_1=12$ is chosen.

Step 4 Thus, the total number of inlets per link block $i_1^2=144$ and the actual total number of inlets (or outlets, resp.)

$$N = 4 \cdot 144 = 576$$

The following system is obtained:

$$\begin{matrix} N_{in} = \\ 576 \end{matrix} \left\{ \begin{matrix} 12|20 & \text{-1-} & 12|12 & \text{-1-} & 20|12 \\ 12 & & 20 & & \\ \overline{48} & & \overline{80} & & \overline{48} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 576 \end{matrix}$$

A total of 34,560 crosspoints is required, which means CPL=60 and CPE=75.
With the prescribed $Y/N=0.8$ the actual transparency is $T_{rel}=1.35$ (due to rounding).

Example 7 for PGS:

Be given $S=3$ stages, $N \approx 3000$ inlets (or outlets, resp.), a carried traffic per inlet $Y/N=0.75$ Erlang and a relative transparency $T_{rel}=1.0$.

Step 1 Use Nik-chart for $S=3$ and $T_{rel}=1.0$ (Nik-chart 91). For a carried traffic of 0.75 Erlang and $N=3000$ read off $k_1=30$. As suggested before, k_1 should be rounded up to the next integer multiple of $4 \cdot T_{rel}$, here $k_1=32$.

Step 2 The number of link blocks becomes $LB = \frac{32}{4 \cdot 1.0} = 8$

Step 3 One obtains $i_1 = \frac{32}{2\cdot 0.75} = 21.33$. Be chosen $i_1=20$.

Step 4 Thus, the number of inlets per link block $i_1^2=400$ and the actual total number of inlets (or outlets, resp.)

$$N = 8\cdot 400 = 3200$$

Thus the following system is obtained:

$$\begin{matrix} N_{in} = \\ 3200 \end{matrix} \left\{ \begin{matrix} 20|32 & \text{-1-} & 20|20 & \text{-1-} & 32|20 \\ 20 & & 32 & & \\ \overline{\overline{160}} & & \overline{\overline{256}} & & \overline{\overline{160}} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 3200 \end{matrix}$$

With the prescribed $Y/N=0.75$, the actual transparency is $T_{rel}=1.13$ (due to rounding). For a prescribed $T_{rel}=1.0$, Y/N can be increased to 0.8 Erlang. A total of 307,200 crosspoints is required, thus CPL=96 and CPE=128 Erlang.

Example 8 for PGS:

As in Example 7, again be given S=3 stages, $N\approx 3000$ inlets (or outlets, resp.), a carried traffic per inlet $Y/N=0.75$ Erlang and a relative transparency $T_{rel}=1.0$.

Step 1 As in Example 7, one reads off the value $k_1=30$. Now, because of available switches having $k_1=30$, k_1 will not be rounded up to 32.

Step 2 The number of link blocks would be $LB = \frac{30}{4\cdot 1.0} = 7.5$.

Step 3 One obtains $i_1 = \frac{30}{2\cdot 0.75} = 20$

Step 4 Solution 1: LB is chosen as 7, thus one gets the following structure:

$$\begin{matrix} N_{in} = \\ 2800 \end{matrix} \left\{ \begin{matrix} 20|30 & \text{-1-} & 20|20 & \text{-1-} & 30|20 \\ 20 & & 30 & & \\ \overline{\overline{140}} & & \overline{\overline{210}} & & \overline{\overline{140}} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 2800 \end{matrix}$$

This structure implies an average of $\frac{600}{140} = 4.286$ links leading from each link block to each multiple in the third stage. From the viewpoint of wiring and marking, this is not desirable.

The relative transparency of this system is $T_{rel}=1.07$ for a carried traffic $Y/N=0.75$ Erlang per inlet.

Solution 2: By chosing LB=8 link blocks, one gets the following structure:

$$\begin{matrix} N_{in} = \\ 3200 \end{matrix} \left\{ \begin{matrix} 20|30 & \text{-1-} & 20|20 & \text{-1-} & 30|20 \\ 20 & & 30 & & \\ \overline{\overline{160}} & & \overline{\overline{240}} & & \overline{\overline{160}} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 3200 \end{matrix}$$

Again, as in solution 1, one gets a non-integer number of links $= \frac{600}{160} = 3.75$ leading from each link block to each multiple in the third stage. Furthermore, with $Y/N=0.75$ Erlang per inlet, the relative transparency becomes $T_{rel}=0.94<1.0$ which often can be tolerated regarding the fact that the effective accessibility k_{eff} per outgoing group is greater than $N\cdot T_{rel}$, as long as $T_{rel}<1$. As to k_{eff}, details can be found in /4,5/.

Example 9 for PGS:

As mentioned earlier, a design engineer will not always be able to use the optimal switch sizes obtained by the previously described steps. This example shows that in certain cases one will have still satisfactory results also with a comparatively small transparency:

Be given S=3 stages, $N\approx 3300$, $Y/N=0.75$ and $T_{rel}=1.0$. One obtains the same structure as in Example 7, namely

$$\begin{matrix} N_{in} = \\ 3200 \end{matrix} \left\{ \begin{matrix} 20|32 & \text{-1-} & 20|20 & \text{-1-} & 32|20 \\ 20 & & 32 & & \\ \overline{\overline{160}} & & \overline{\overline{256}} & & \overline{\overline{160}} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 3200 \end{matrix}$$

which requires CPL=96 crosspoints per trunk (inlet,line).

Now, it is assumed that only the switch sizes 12|24 and 24|24 are available. So a system using only switches of that size must be designed. One gets the following structure

$$\begin{matrix} N_{in} = \\ 3456 \end{matrix} \left\{ \begin{matrix} 12|24 & \text{-1-} & 24|24 & \text{-1-} & 24|12 \\ 24 & & 24 & & \\ \overline{\overline{288}} & & \overline{\overline{288}} & & \overline{\overline{288}} \end{matrix} \right\} \begin{matrix} N_{out} = \\ N_{in} = 3456 \end{matrix}$$

This structure has the same crosspoint requirement of 331,776 or CPL=96 as before. However, the relative transparency $T_{rel}=(24-9)\cdot(24-9)/288 = 0.78125$ or 78.125% is less than desired. Now, one calculates the probability of loss for the smallest outgoing trunk group with the method CLIGS /4,5/. This reliable method bases on an effective accessibility, especially developed for point-to-group selection. One has to decide whether the additional loss caused by internal blocking is still tolerable. The calculation yielded the following results:

The traffic carried in an outgoing group of 10 trunks is assumed to be 4.417 Erl. This value is obtained for a fully accessible trunk group which has a loss of 1% according to Erlang's loss formula $E_{1,n_r}(A)$. The calculation of loss in a link system with group selection (CLIGS) yields a corresponding loss $B(n_r)$=1.229%, for a group of n_r=10 trunks, provided an average traffic carried per inlet of 0.75 Erl. If this additional loss (1.229-1.0)%=0.229% due to internal blocking of the link system is considered to be sufficiently small, the discussed structure can be accepted. It should be pointed out that only trunk groups of such small sizes are critical with respect to internal blocking in a link system having a comparatively small relative transparency $T_{rel}<1.0$. For an outgoing group of n_r=50 trunks, the CLIGS-calculation for the same link system yields a loss of 1.053%, provided the same average carried traffic of 0.75 Erl. per inlet and a carried traffic of 37.522 Erlangs in that group of 50 trunks (which is the value of the traffic carried in a fully accessible group with 1% loss).

This example shows that also a "suboptimal" link system whose relative transparency is somewhat small because of structural restrictions can be operated as "practically full accessible" provided the loss $B(n_r)$ has been precalculated as above and provided one finds $\{B_{actual}(n_r)-E_{1,n_r}(A)\}$ to be sufficiently small.

5.3.2 Stepwise Extension for PGS

Dimensioning link systems for stepwise extension always starts with the structural design of the mostly used size which is named "main size". Be considered Example 7 as main size:

$$\begin{matrix}N_{in}=\\3200\end{matrix}\left\{\frac{\frac{20|32}{20}}{160}\;{}^{-1-}\;\frac{\frac{20|20}{32}}{256}\;{}^{-1-}\;\frac{32|20}{160}\right\}\begin{matrix}N_{out}=\\N_{in}=3200\end{matrix}$$

The multiples (switches) are assumed to be composed of modules 8|5. One gets the smallest size of a stepwise extension, if only one link block is used. In that case, one has the following structure:

$$\begin{matrix}N_{in}=\\400\end{matrix}\left\{\frac{20|32}{20}\;{}^{-1-}\;\frac{20|20}{32}\;{}^{-1-}\;\frac{4|2}{160}\text{(or 3)}\right\}\begin{matrix}N_{out}\\\approx 400\end{matrix}$$

In the above initial extension size, the switches of the third stage, of course, must be 8|5 also in the first extension size, where only 4 inlets and 2 (or 3) outlets are used.

Extending the system link block by link block, one reaches the main size in the case of 8 link blocks (as shown in Example 7). Accordingly, the multiples in the third stage are increased from 8|5, to 16|10, to 24|15, and finally to 32|20. An extension beyond the main size (which is closest to a minimum number of crosspoints per Erlang) is done analogously.

Advantages of PGS with S=3 stages:

- Because the number of multiples in stage 3 remains constant throughout all extension stages, the relative transparency remains also constant.
- The wiring between each link block and the third stage need not be altered when further link blocks are added.
- The outgoing trunk groups are uniformly distributed over all multiples in stage 3, in the initial extension size of the link system already. With growing extension the wiring of the outgoing groups need not be rearranged.
- As already mentioned, the sensitivity of a 3-stage link system in the case of overload is less than in those having 4 or more stages.

These 4 quoted advantages must be paid for a somewhat higher minimum crosspoint requirement per Erlang compared to PGS-link systems having $S\geq 4$ stages /6/.

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/2/ LOTZE,A., RÖDER,A., THIERER,G.: Investigations on Folded and Reversed Link Systems.
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/3/ LOTZE,A., RÖDER,A., THIERER,G.: Point-to-Point Selection versus Point-to-Group Selection in Link Systems.
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/5/ BAZLEN,D., KAMPE,G., LOTZE,A.: Design Parameters and Loss Calculation of Link Systems.
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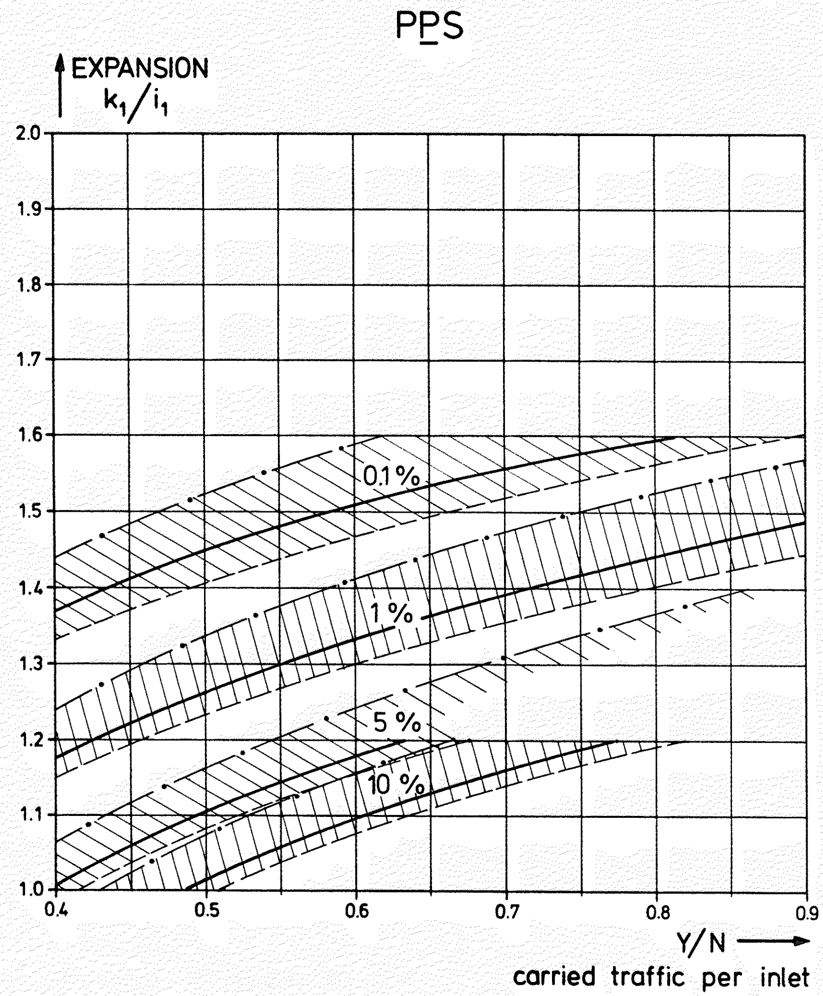
/7/ LOTZE,A., RÖDER,A., THIERER,G.: Point-to-Point Loss in Case of Multiple Marking Attempts.
Supplement to the Congress Papers No. 541, 544, 547 distributed at the 8th ITC, Melbourne 1976.

NIK-CHARTS FOR POINT-TO-POINT SELECTION AND PCT 1

chart 1 .. 44

Number of stages	S = 3, 4, 5, 6
Number of inlets per first stage multiple	i_1 = 5 .. 30
Point-to-point loss (first attempt)	B_{PP}=0.1, 1, 5, 10%
System-to-outgoing group wiring for	SDM: chart 1..10,12..21,23..32,34..43 TDM: chart 11, 22, 33, 44



S = 3

i_1 = 5

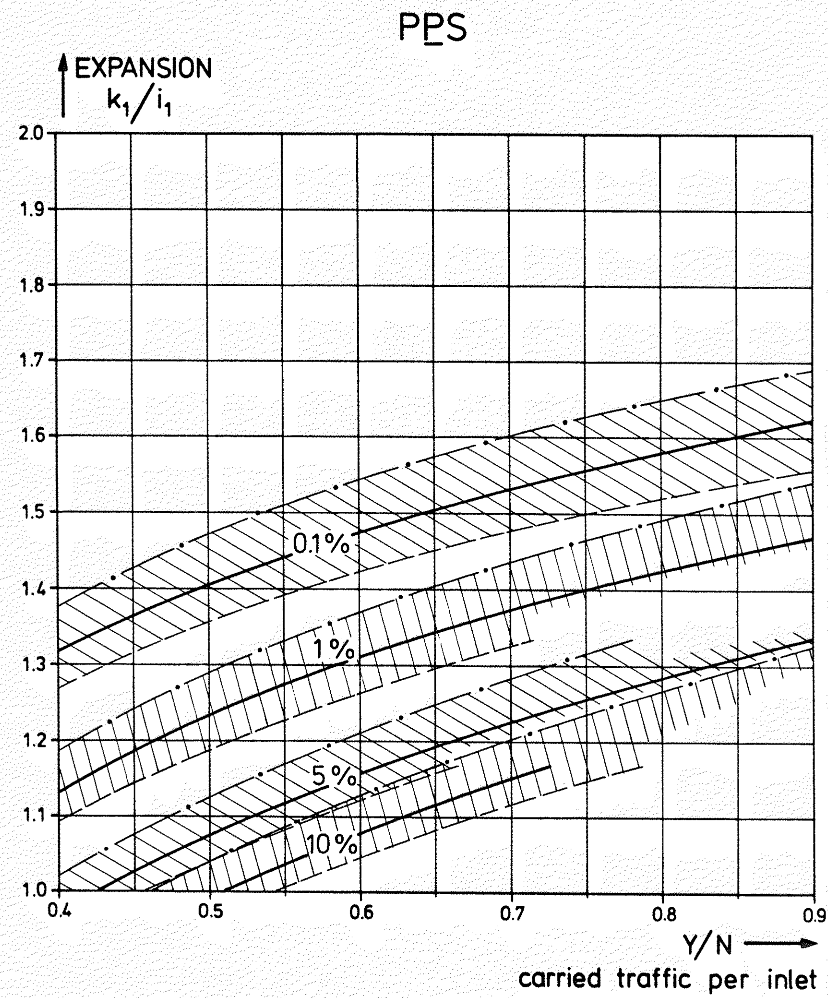
PCT 1

SDM

N = 100 —— · ——

N = 25 ————

N = 20 — — —



S = 3

i_1 = 6

PCT 1

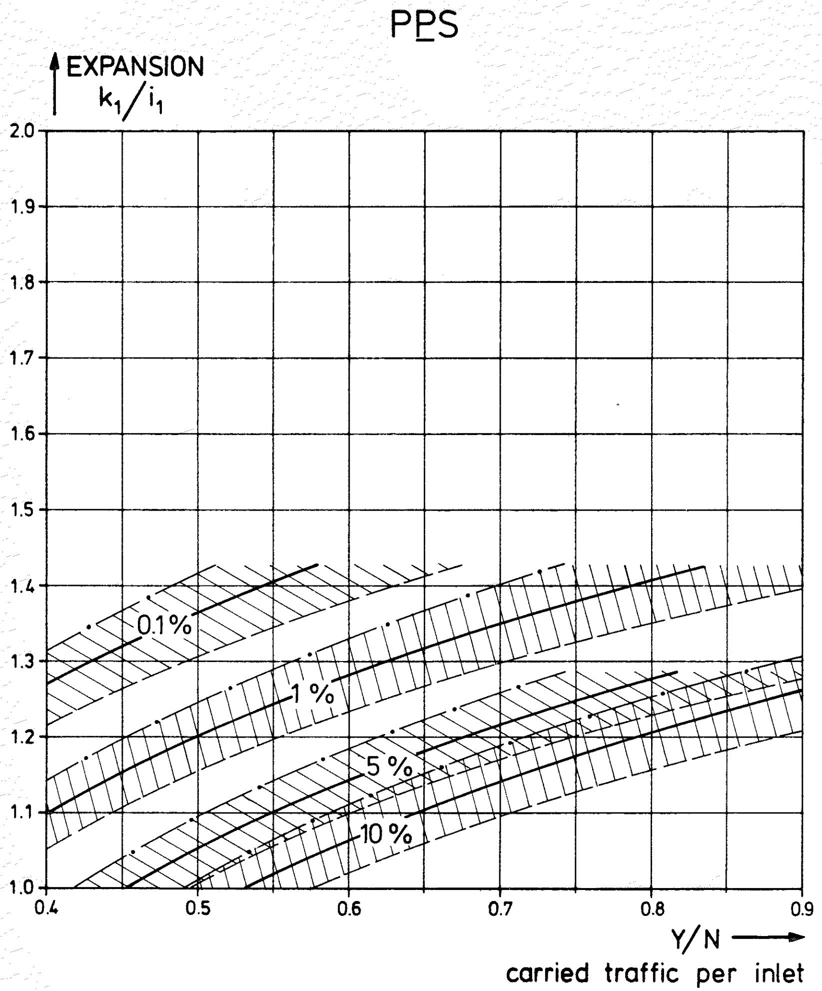
SDM

N = 120 —— · ——

N = 36 ————

N = 24 — — —

THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.



S = 3

i_1 = 7

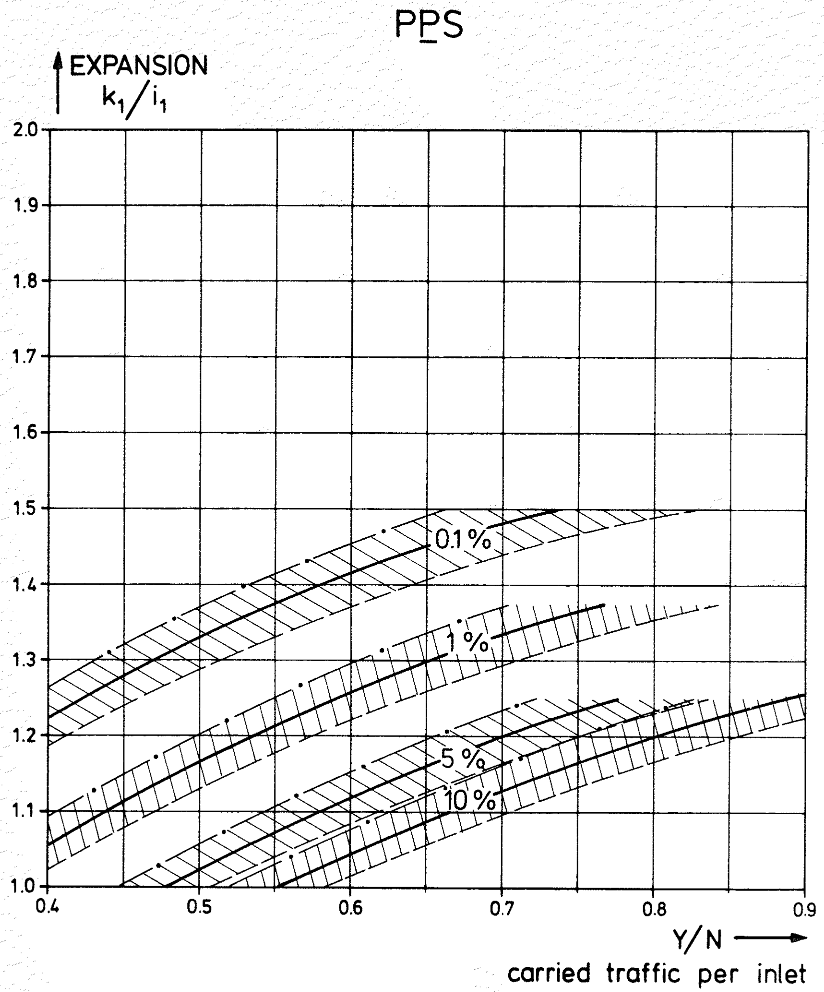
PCT 1

SDM

N = 140 —— · ——

N = 49 ————

N = 28 — — —



S = 3

i_1 = 8

PCT 1

SDM

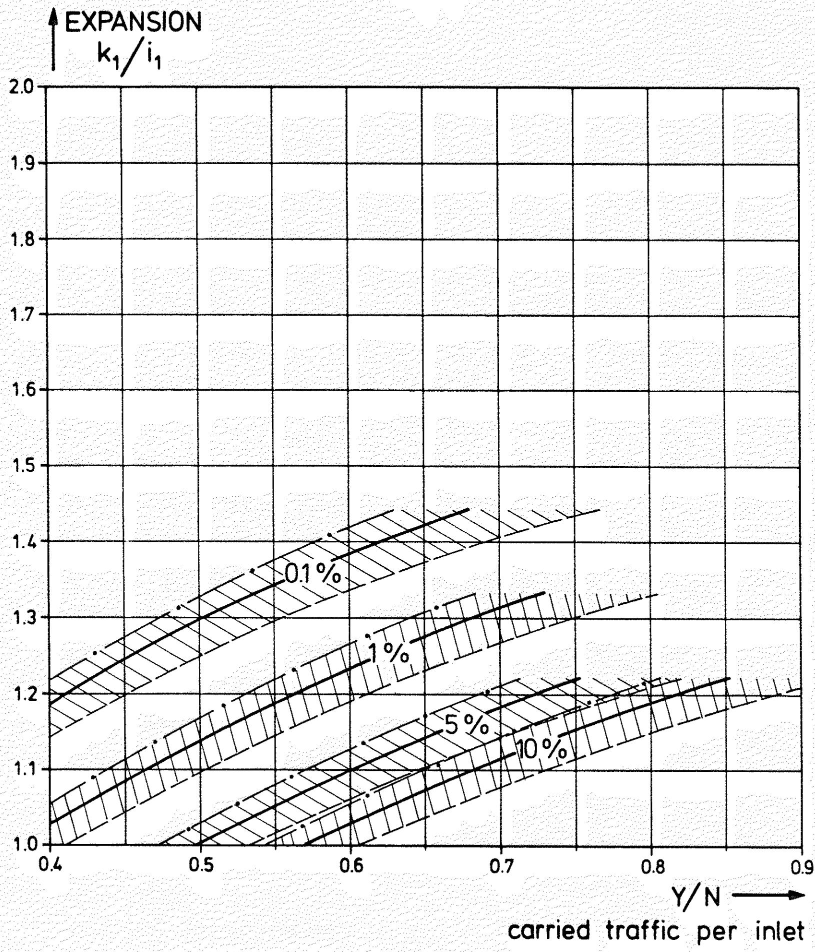
N = 160 —— · ——

N = 64 ————

N = 40 — — —

THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.

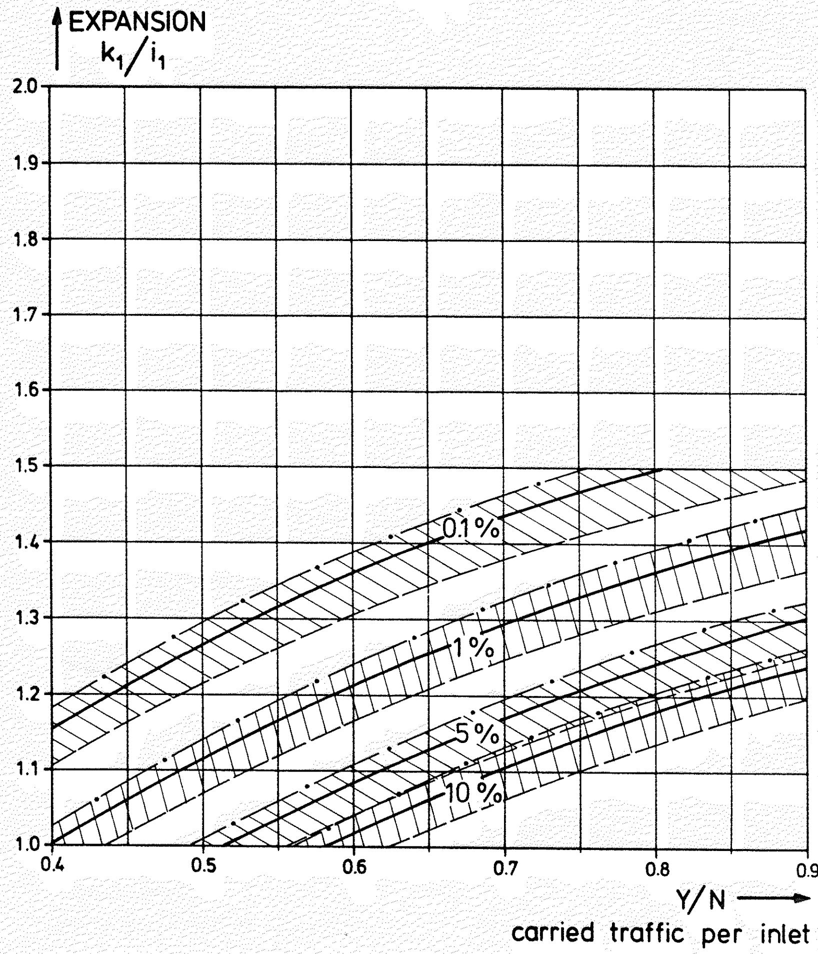
PPS



S = 3
i_1 = 9
PCT 1
SDM

N = 180 ——·——
N = 81 ————
N = 45 — — —

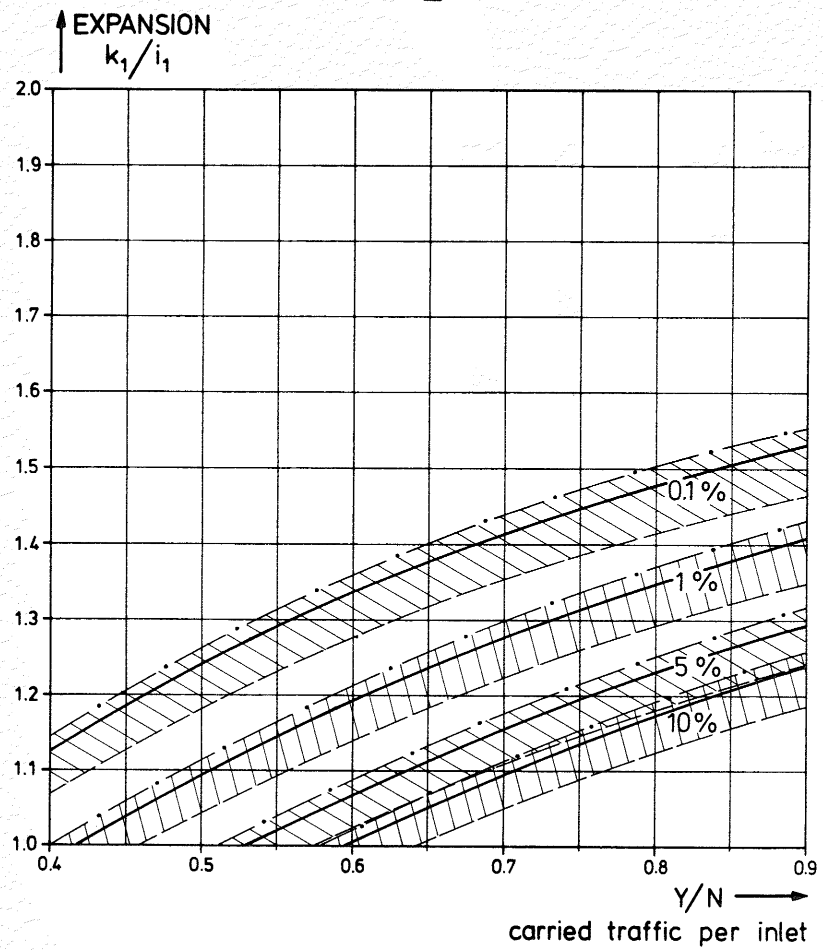
PPS



S = 3
i_1 = 10
PCT 1
SDM

N = 200 ——·——
N = 100 ————
N = 50 — — —

THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.



S = 3

i_1 = 11

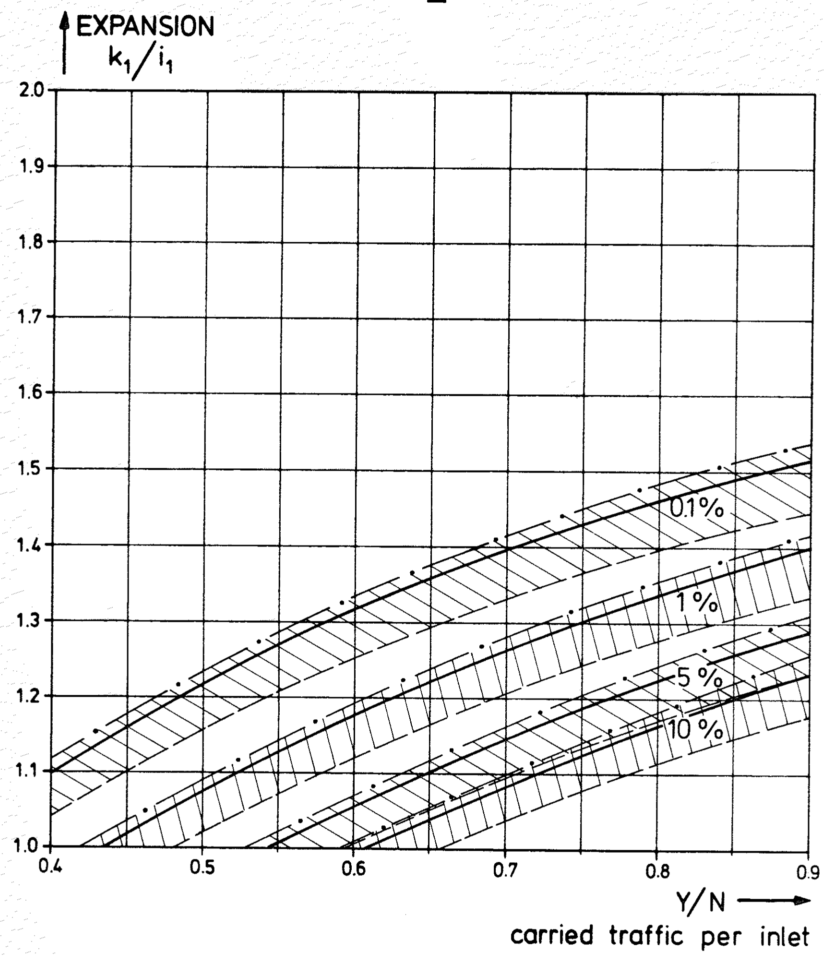
PCT 1

SDM

N = 220 —·—

N = 121 ——

N = 55 – – –



S = 3

i_1 = 12

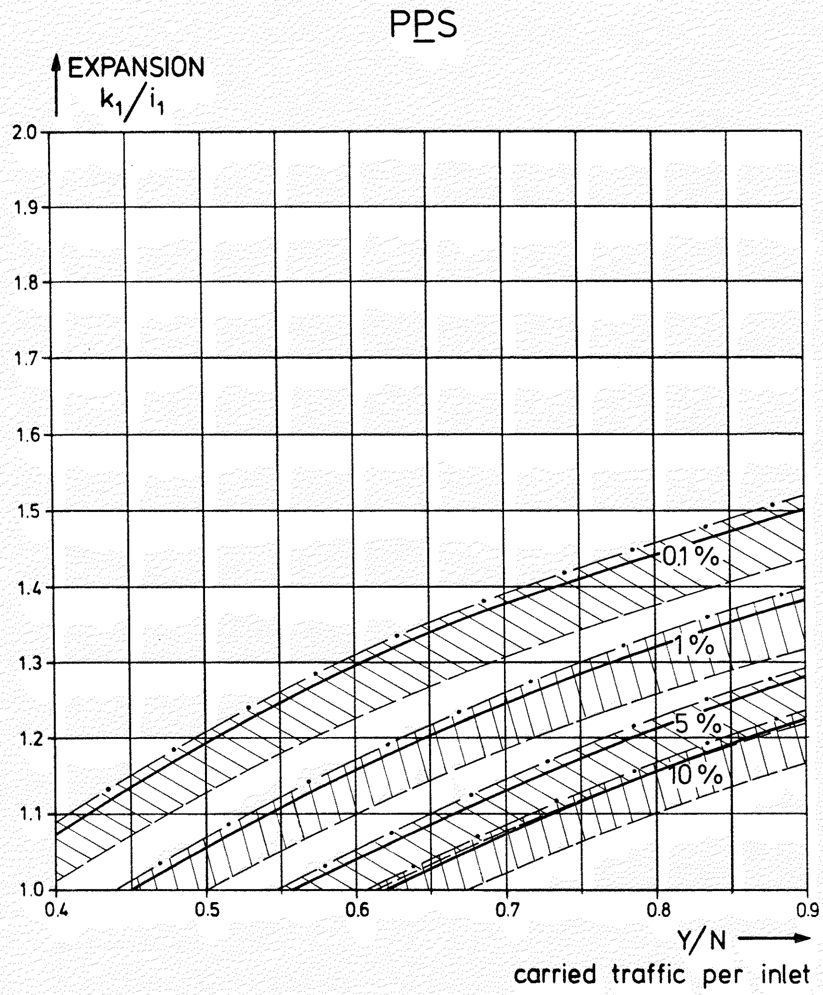
PCT 1

SDM

N = 240 —·—

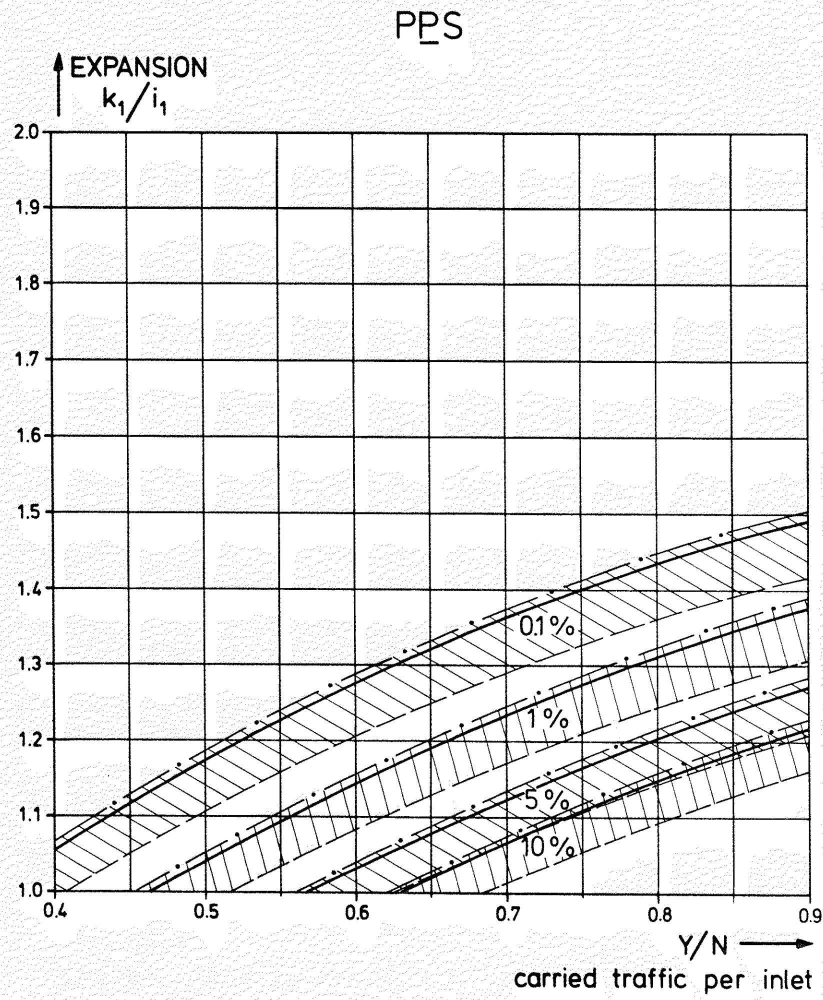
N = 144 ——

N = 60 – – –



S = 3
i_1 = 13
PCT 1
SDM

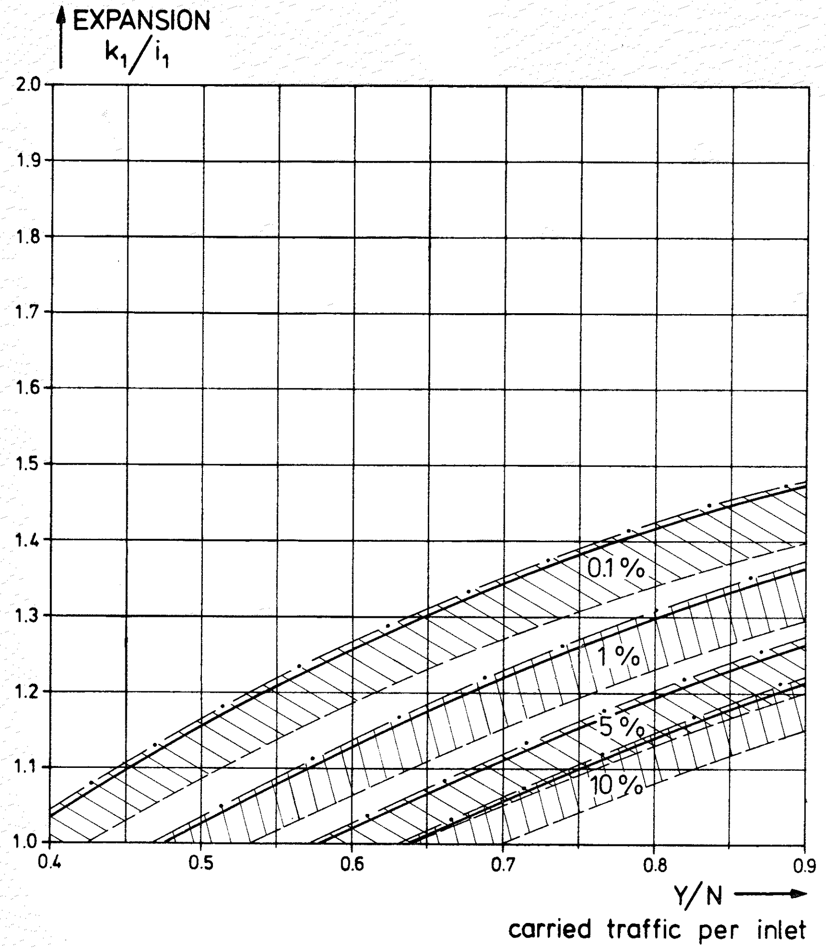
N = 260 —·—
N = 169 ——
N = 65 — — —



S = 3
i_1 = 14
PCT 1
SDM

N = 280 —·—
N = 196 ——
N = 70 — — —

PPS



S = 3

i_1 = 15

PCT 1

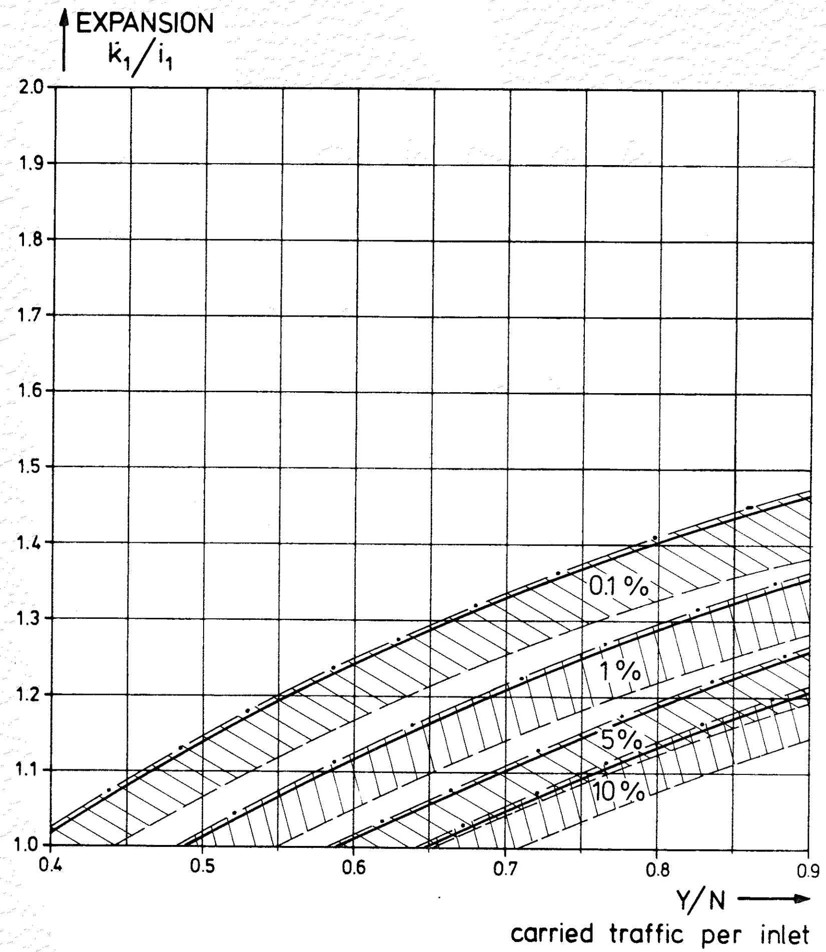
SDM

N = 300 —·—

N = 225 ——

N = 75 — — —

PPS



S = 3

i_1 = 16

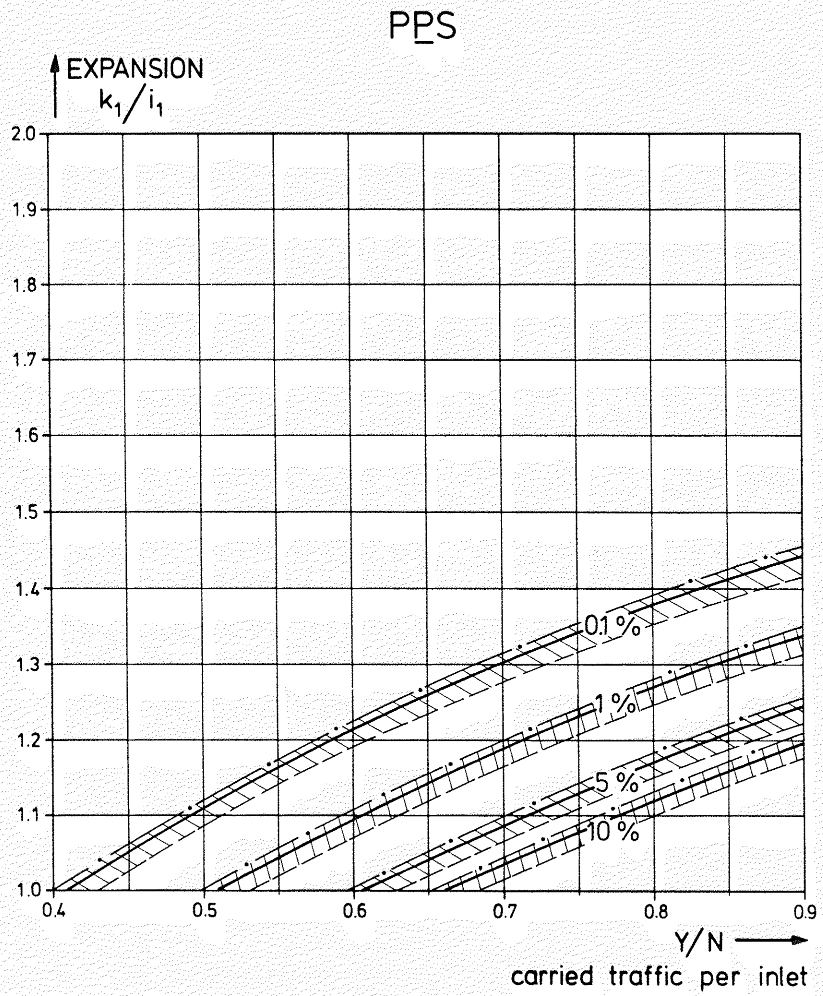
PCT 1

SDM

N = 320 —·—

N = 256 ——

N = 80 — — —



S = 3

i_1 = 18

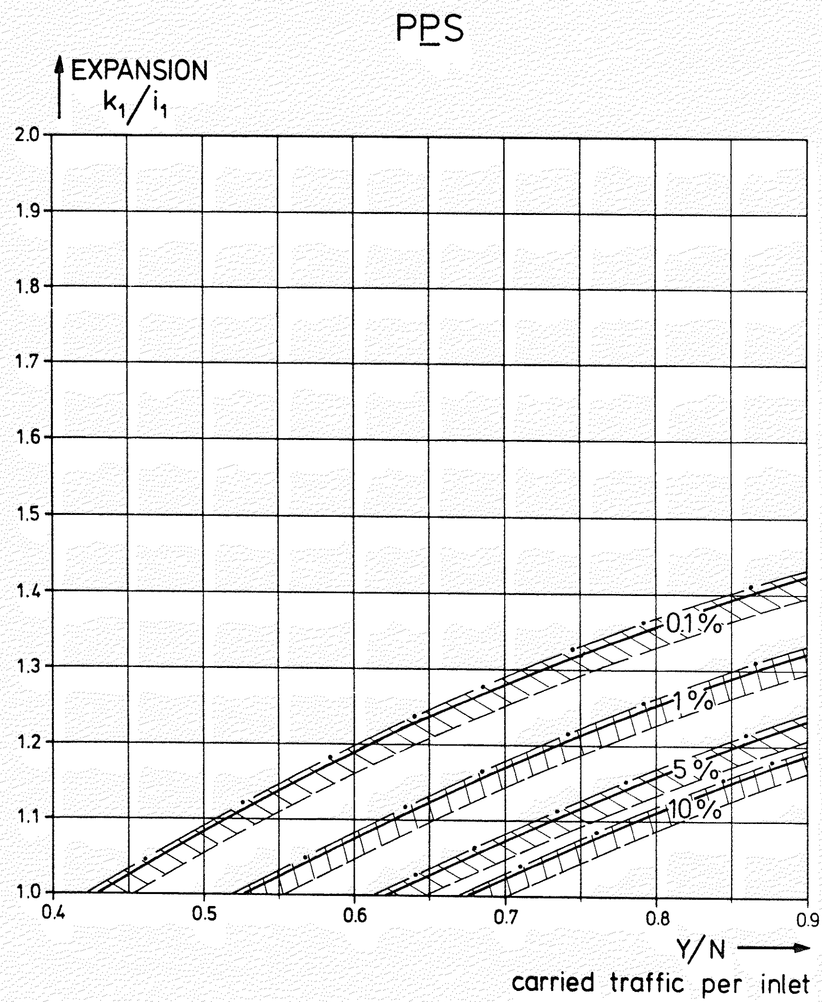
PCT 1

SDM

N = 540 —·—

N = 324 ——

N = 180 — — —



S = 3

i_1 = 20

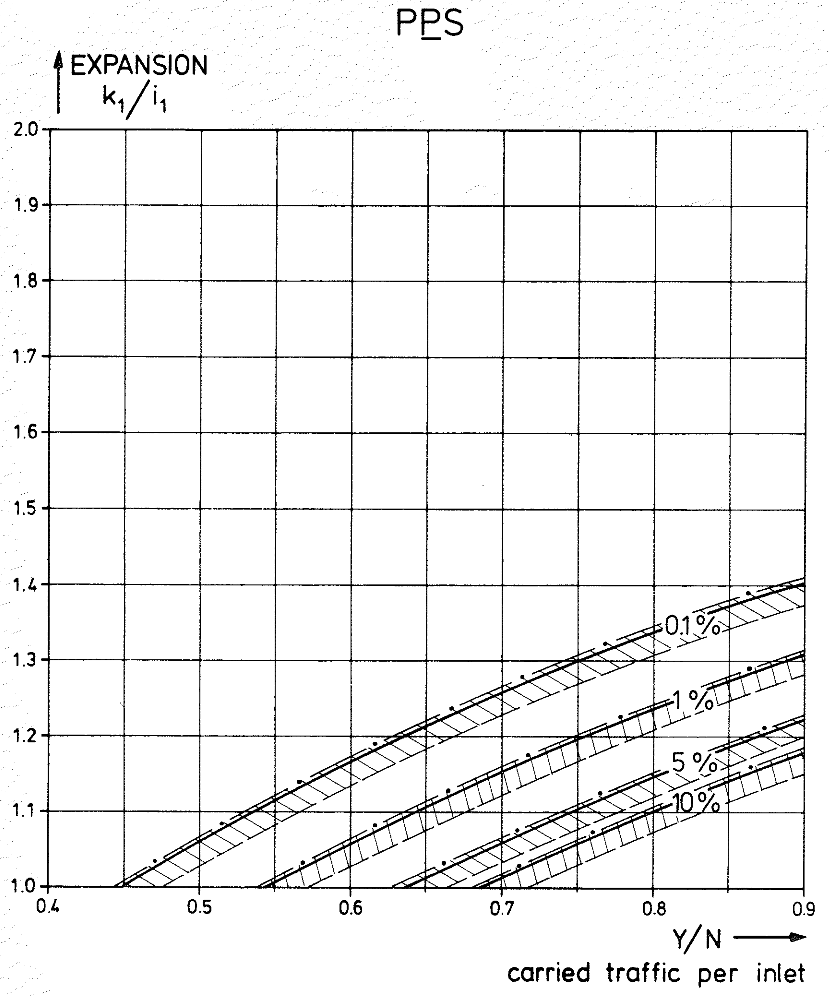
PCT 1

SDM

N = 600 —·—

N = 400 ——

N = 200 — — —



S = 3

i_1 = 22

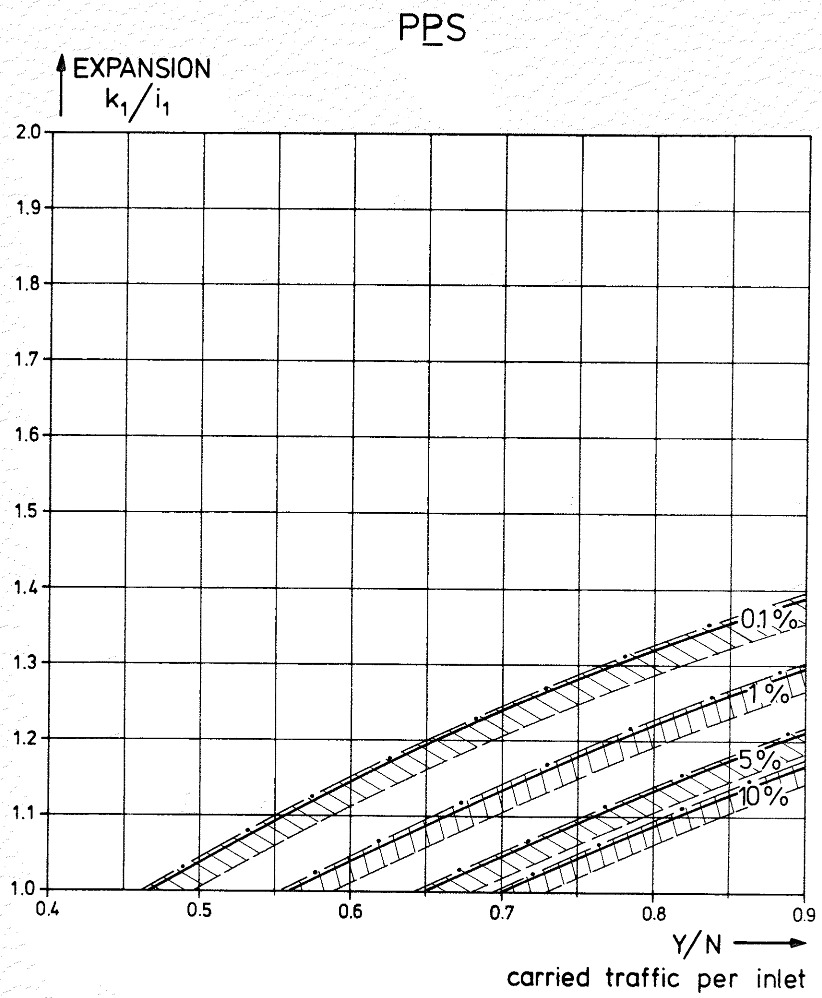
PCT 1

SDM

N = 660 ——·——

N = 484 ————

N = 220 — — —



S = 3

i_1 = 24

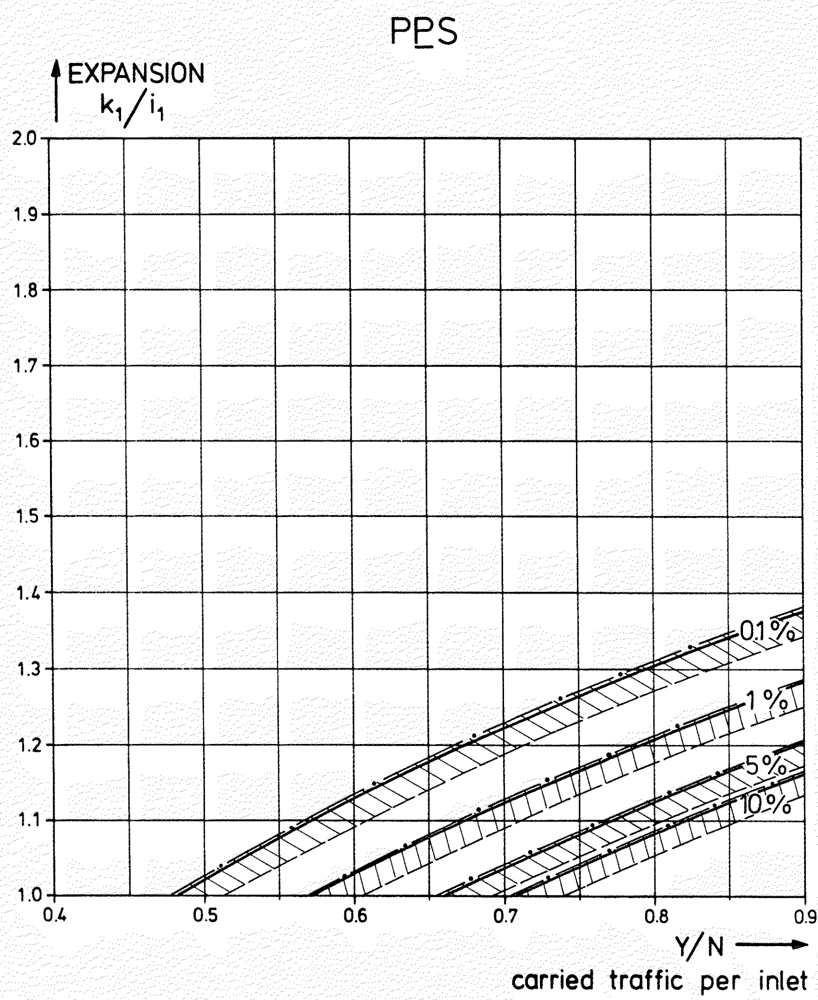
PCT 1

SDM

N = 720 ——·——

N = 576 ————

N = 240 — — —



S = 3

i_1 = 26

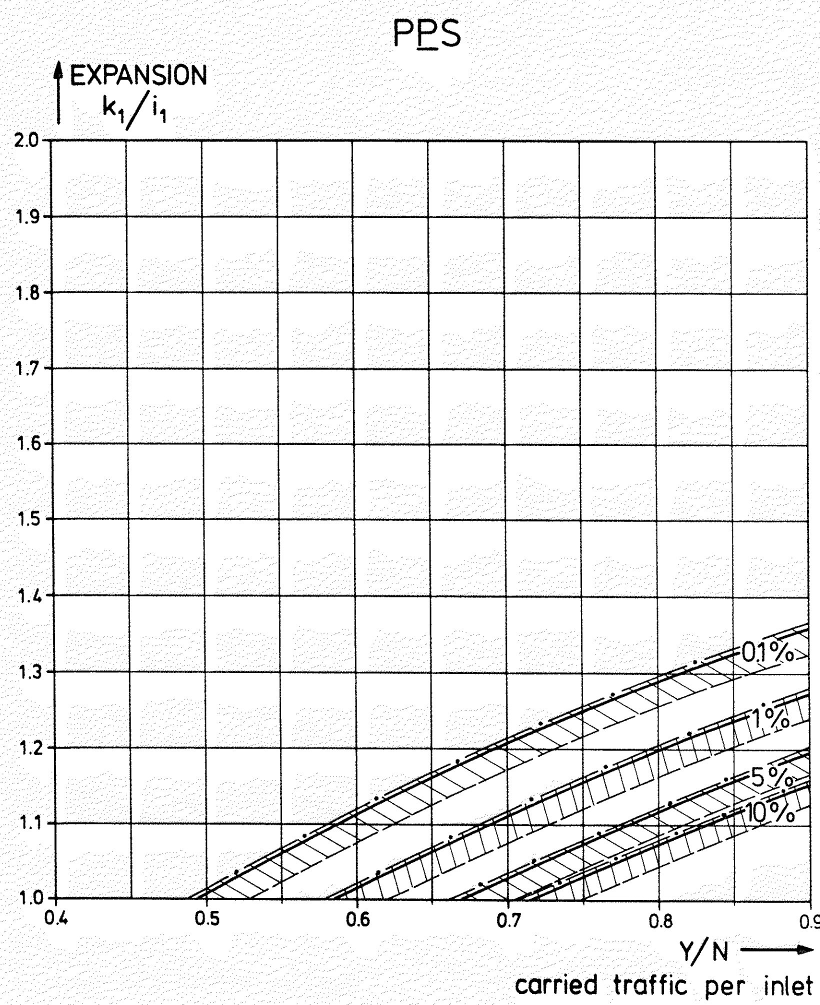
PCT 1

SDM

N = 780 —·—

N = 676 ——

N = 260 — — —



S = 3

i_1 = 28

PCT 1

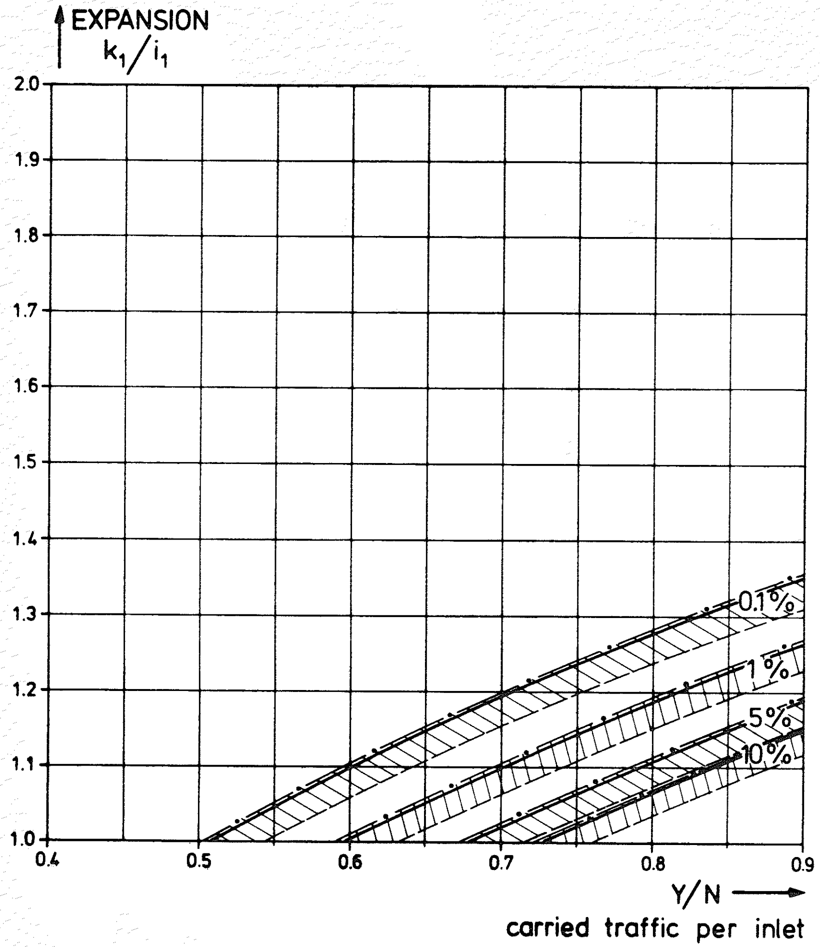
SDM

N = 1120 —·—

N = 784 ——

N = 280 — — —

PPS



S = 3

i_1 = 30

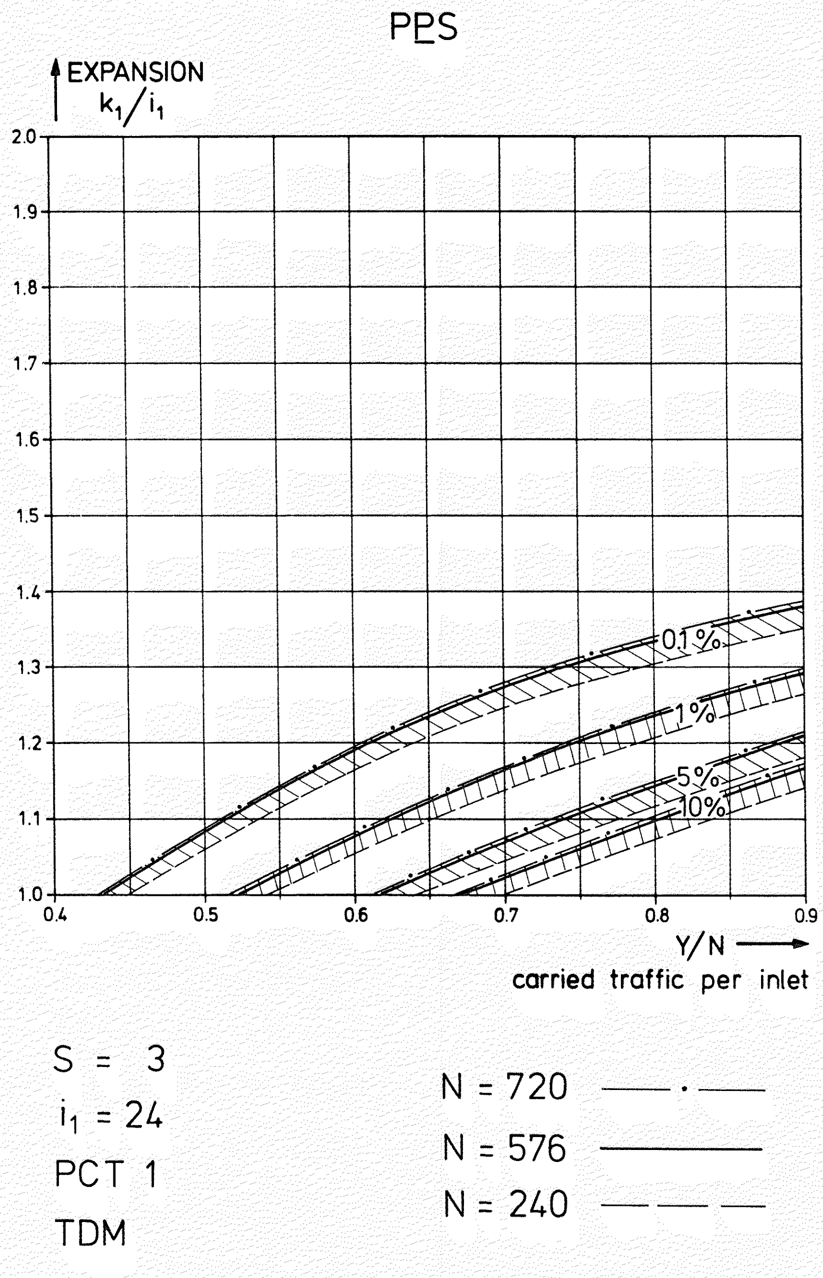
PCT 1

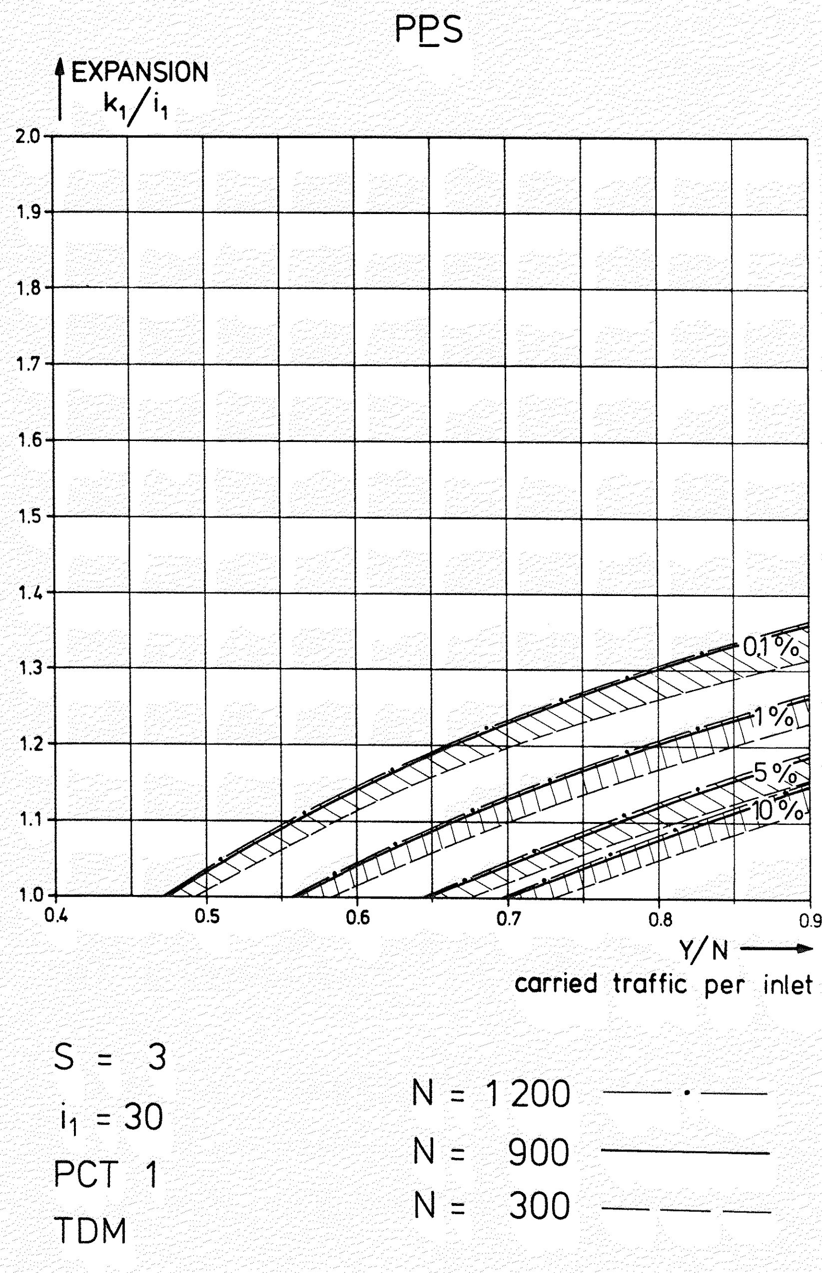
SDM

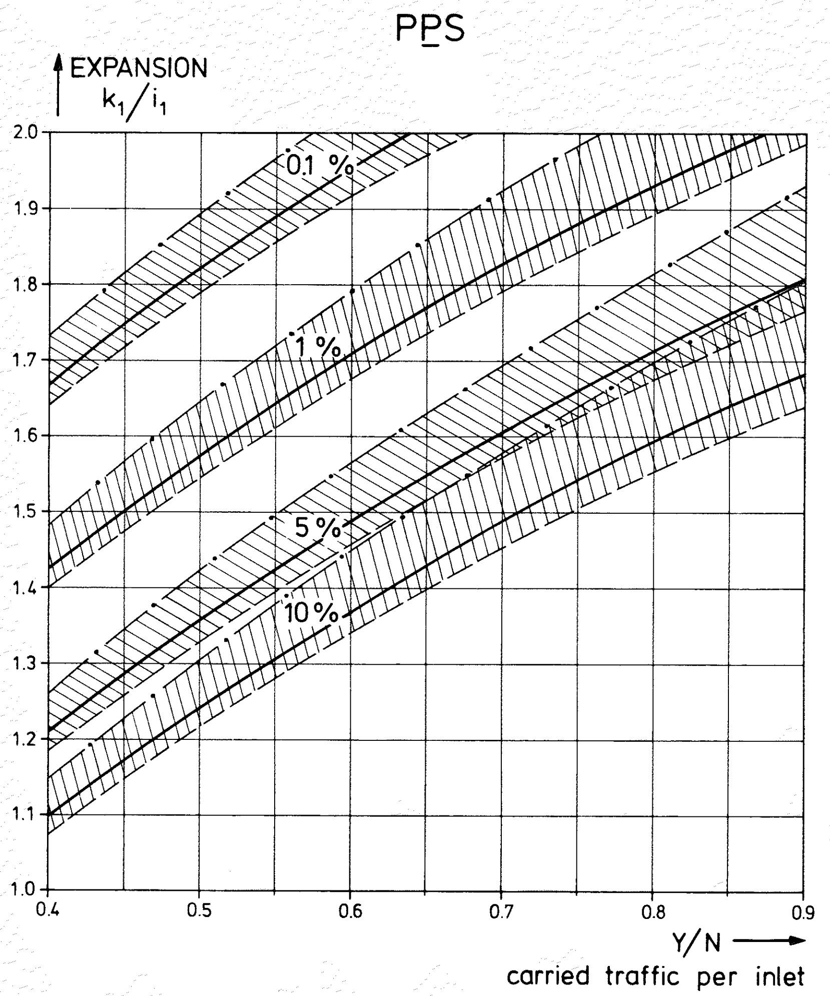
N = 1200 —— · ——

N = 900 ————

N = 300 — — —

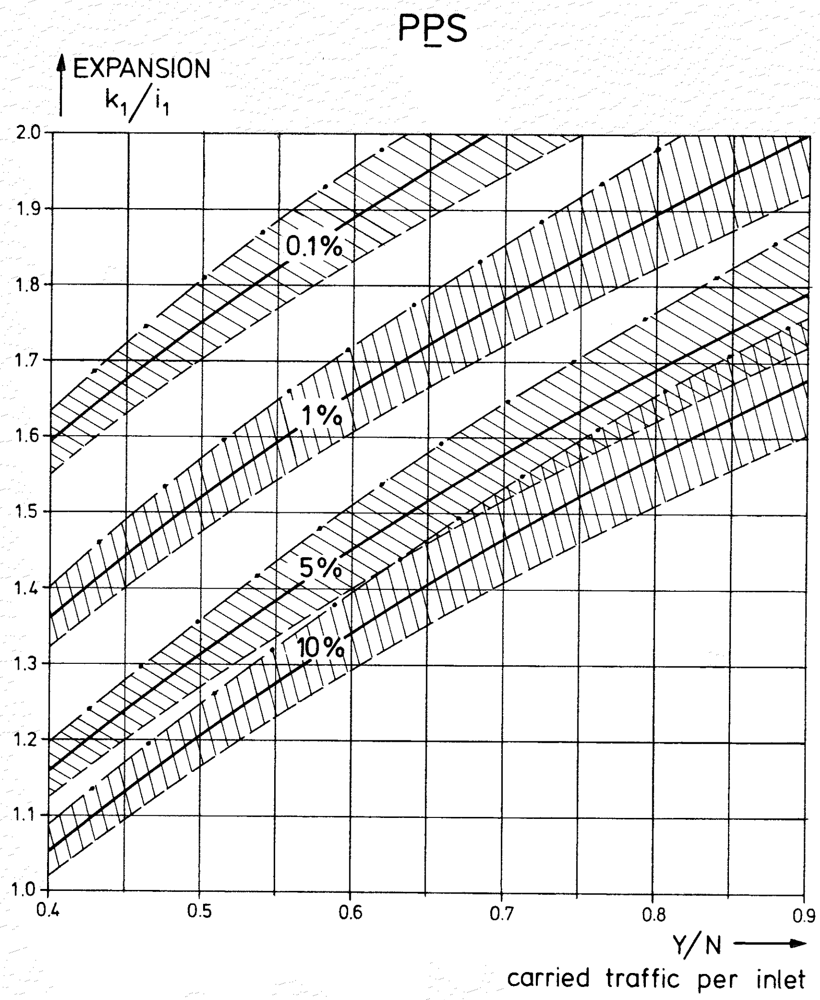

PPS
EXPANSION
k1/i1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.4
0.5
0.6
0.7
0.8
0.9
0.1%
1%
5%
10%
Y/N
carried traffic per inlet
S = 3
i1 = 24
PCT 1
TDM
N = 720
N = 576
N = 240


PPS
EXPANSION
k1/i1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.4
0.5
0.6
0.7
0.8
0.9
0.1%
1%
5%
10%
Y/N
carried traffic per inlet
S = 3
i1 = 30
PCT 1
TDM
N = 1 200
N = 900
N = 300



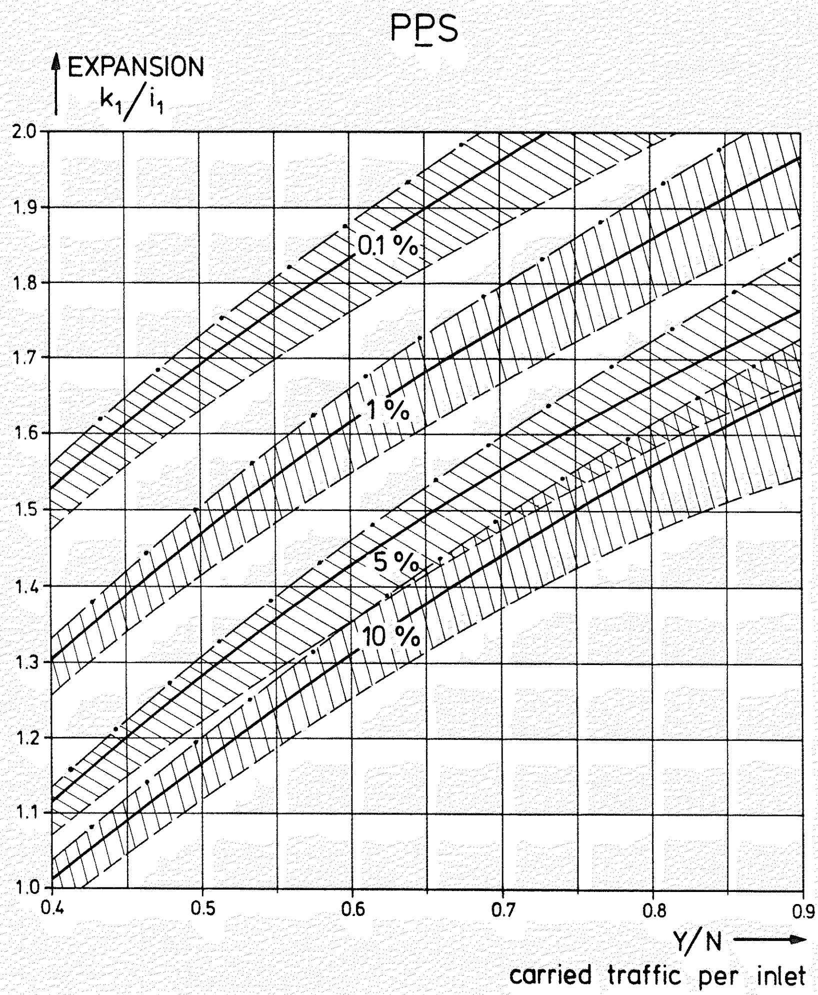
S = 4
i_1 = 5
PCT 1
SDM

N = 2000 —·—
N = 125 ———
N = 80 — — —



S = 4
i_1 = 6
PCT 1
SDM

N = 2400 —·—
N = 216 ———
N = 96 — — —



S = 4

i_1 = 7

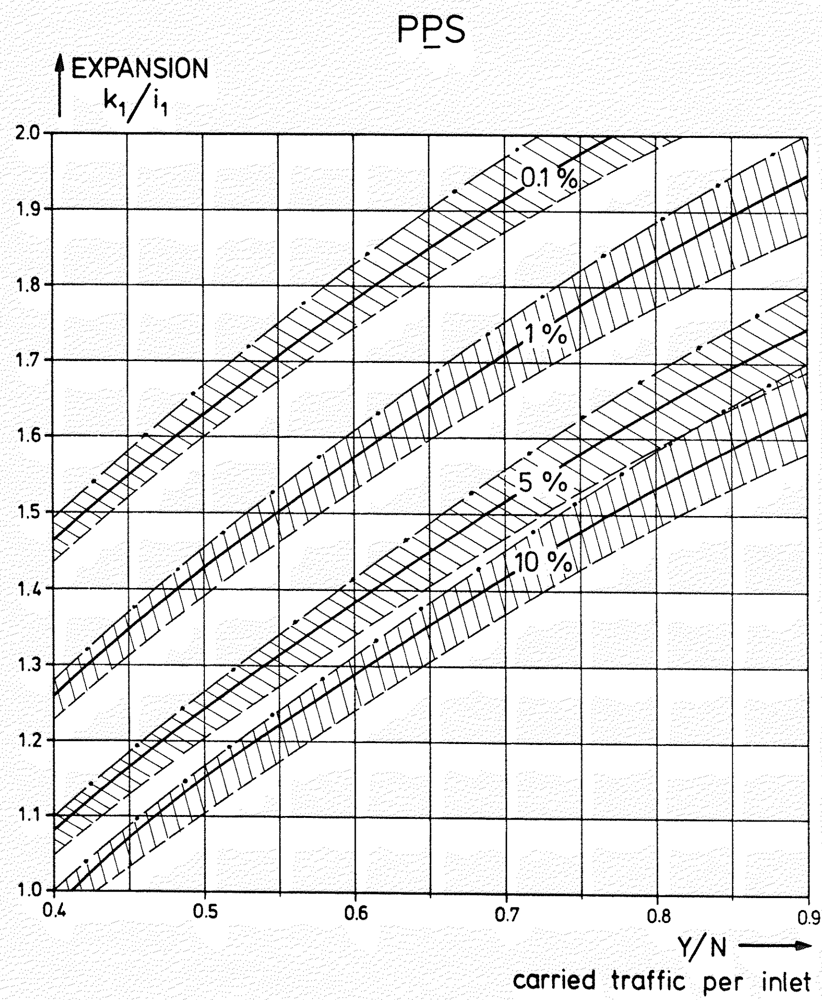
PCT 1

SDM

N = 2800 —·—

N = 343 ——

N = 112 — — —



S = 4

i_1 = 8

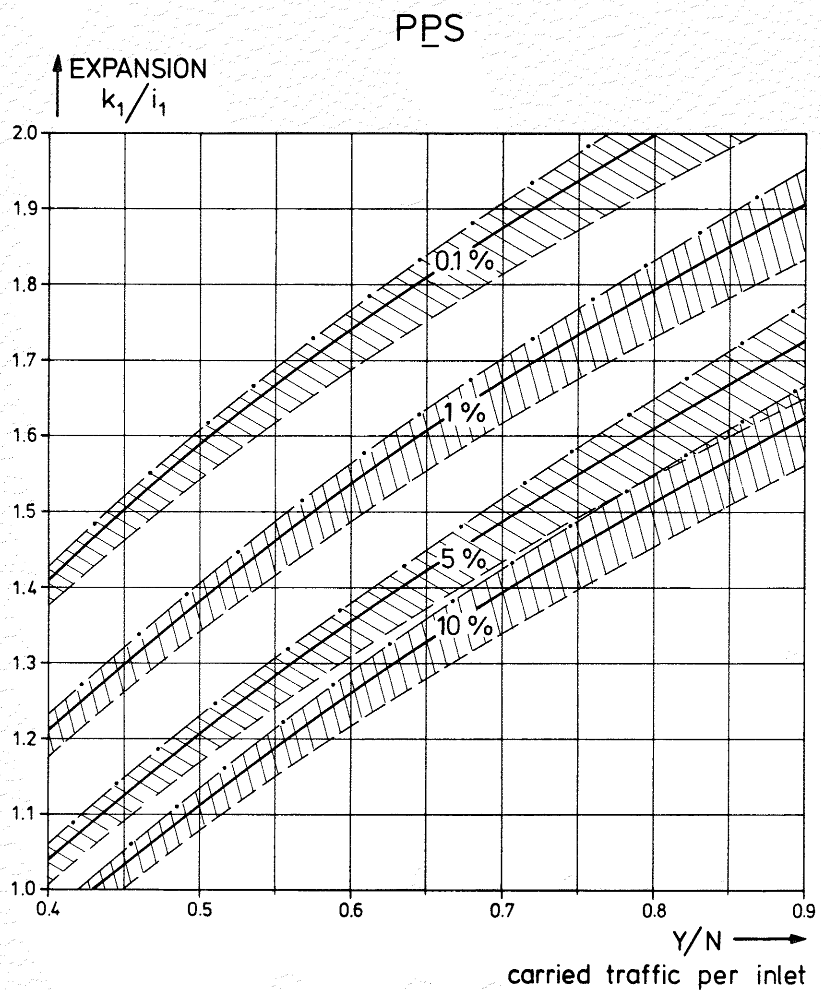
PCT 1

SDM

N = 3200 —·—

N = 512 ——

N = 200 — — —



S = 4

i_1 = 9

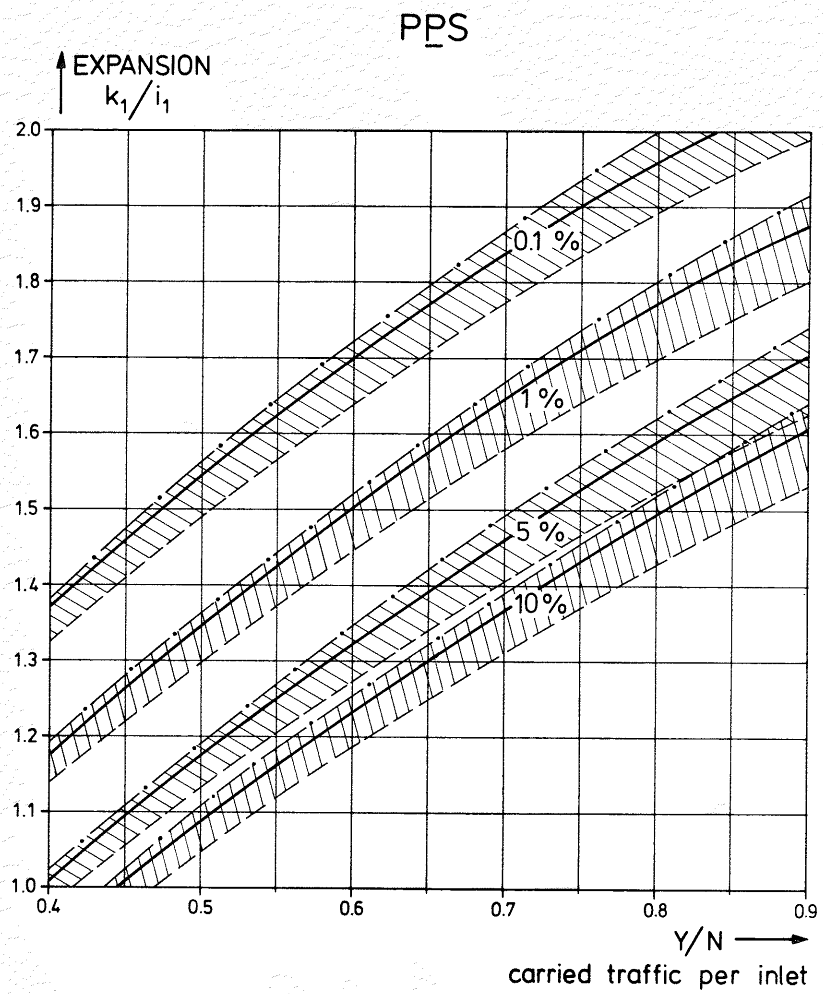
PCT 1

SDM

N = 3600 ——·——

N = 729 ————

N = 225 — — —



S = 4

i_1 = 10

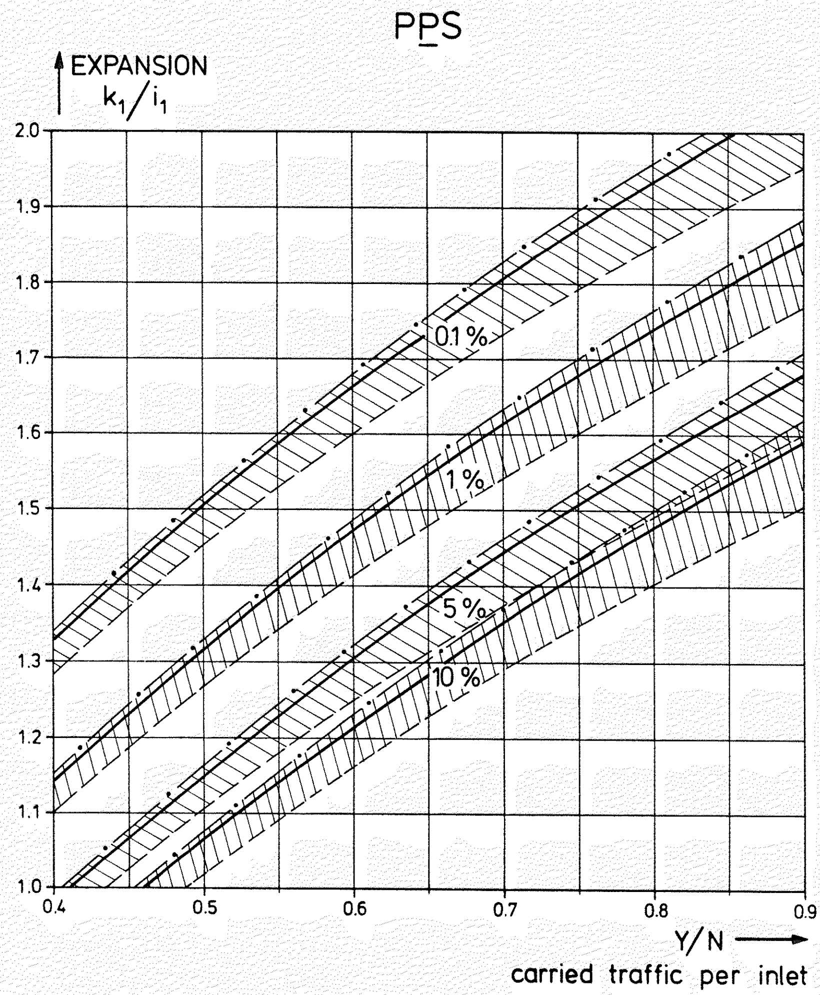
PCT 1

SDM

N = 4000 ——·——

N = 1000 ————

N = 250 — — —



S = 4

i_1 = 11

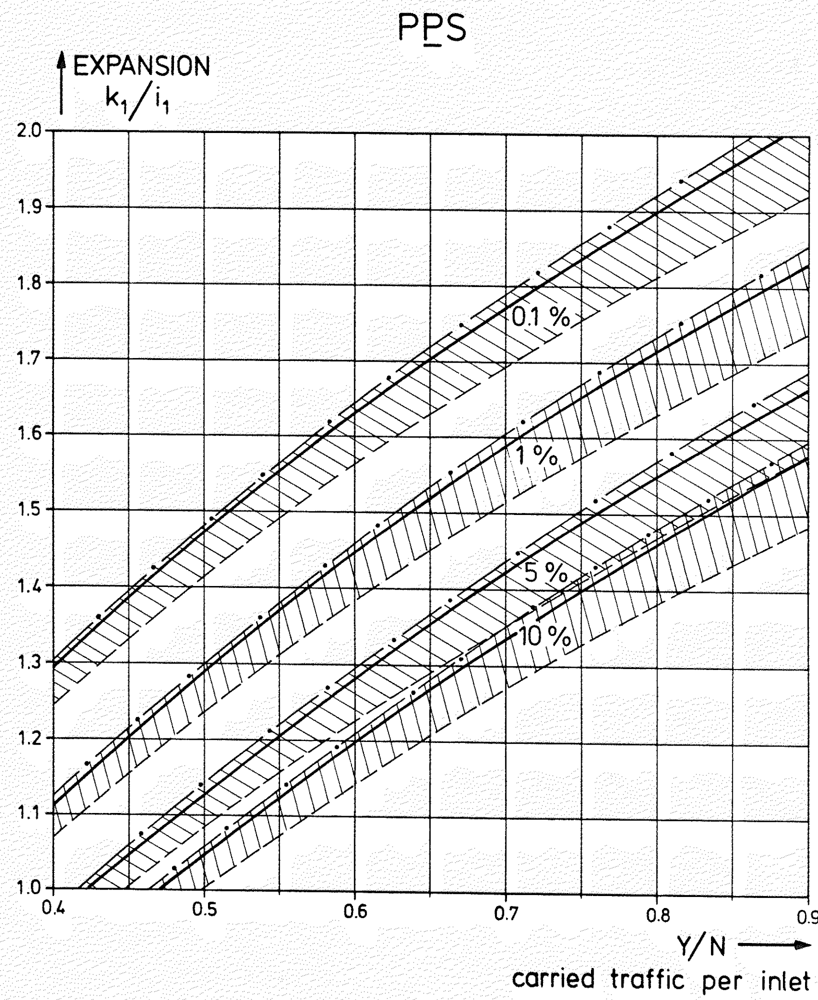
PCT 1

SDM

N = 4400 —·—

N = 1331 ——

N = 275 — — —



S = 4

i_1 = 12

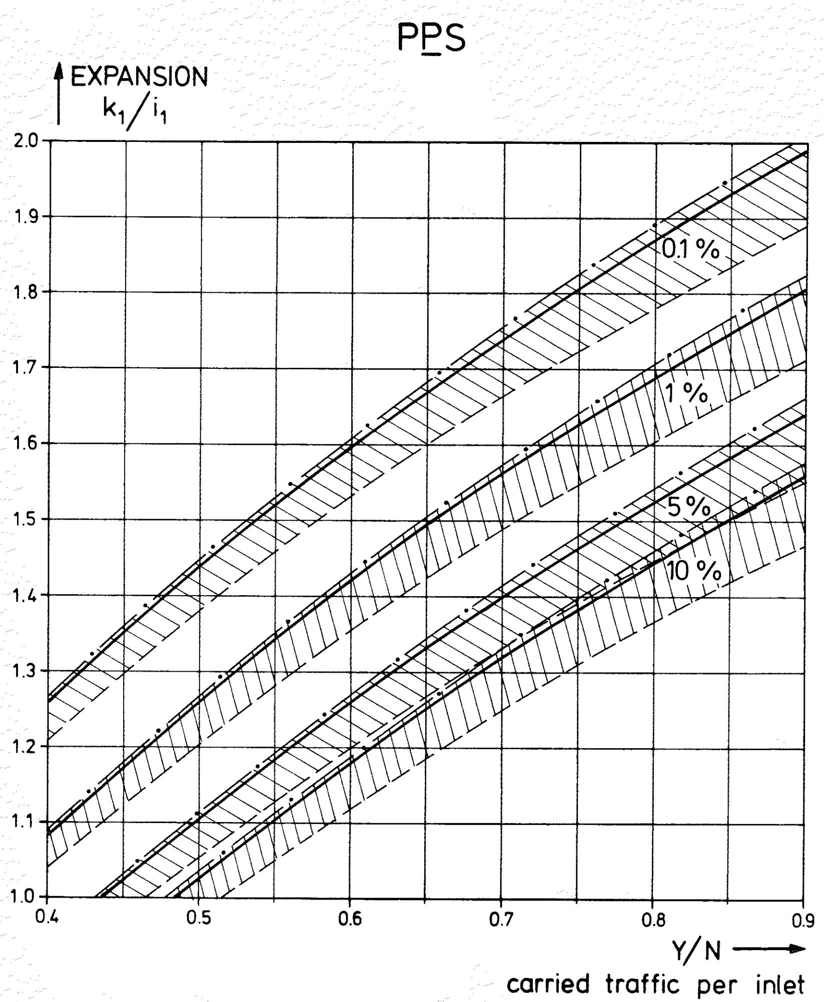
PCT 1

SDM

N = 4800 —·—

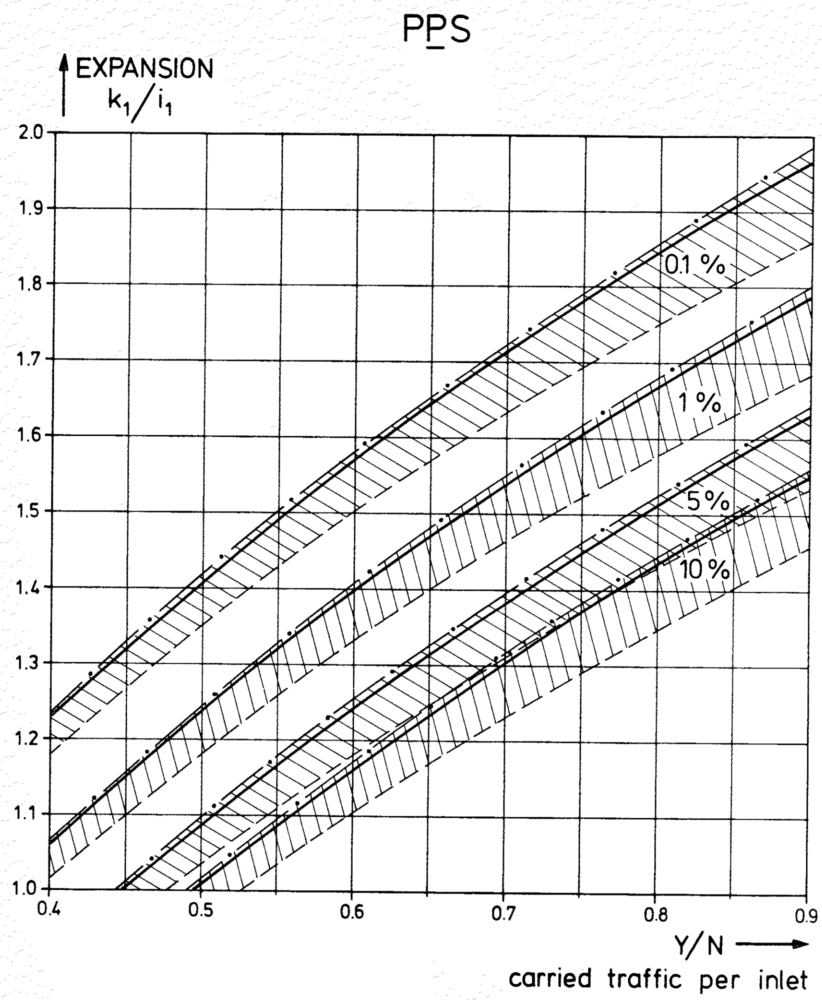
N = 1728 ——

N = 300 — — —



S = 4
i_1 = 13
PCT 1
SDM

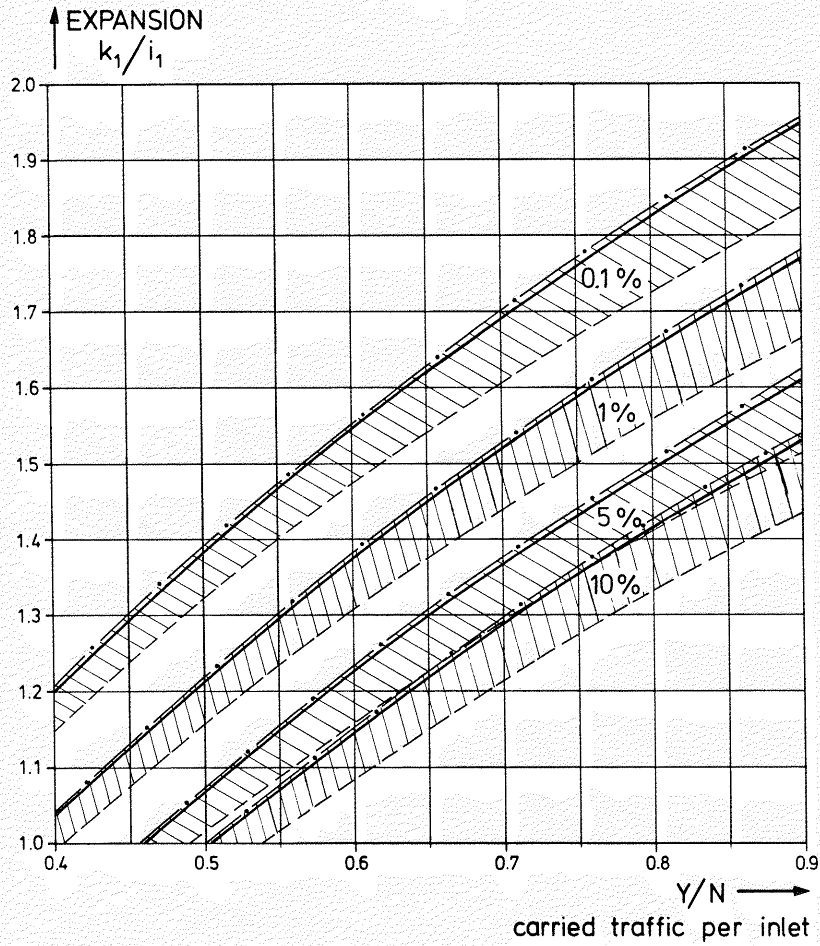
N = 5 200 —— · ——
N = 2 197 ————
N = 325 — — —



S = 4
i_1 = 14
PCT 1
SDM

N = 5 600 —— · ——
N = 2 744 ————
N = 350 — — —

PPS



S = 4

i_1 = 15

PCT 1

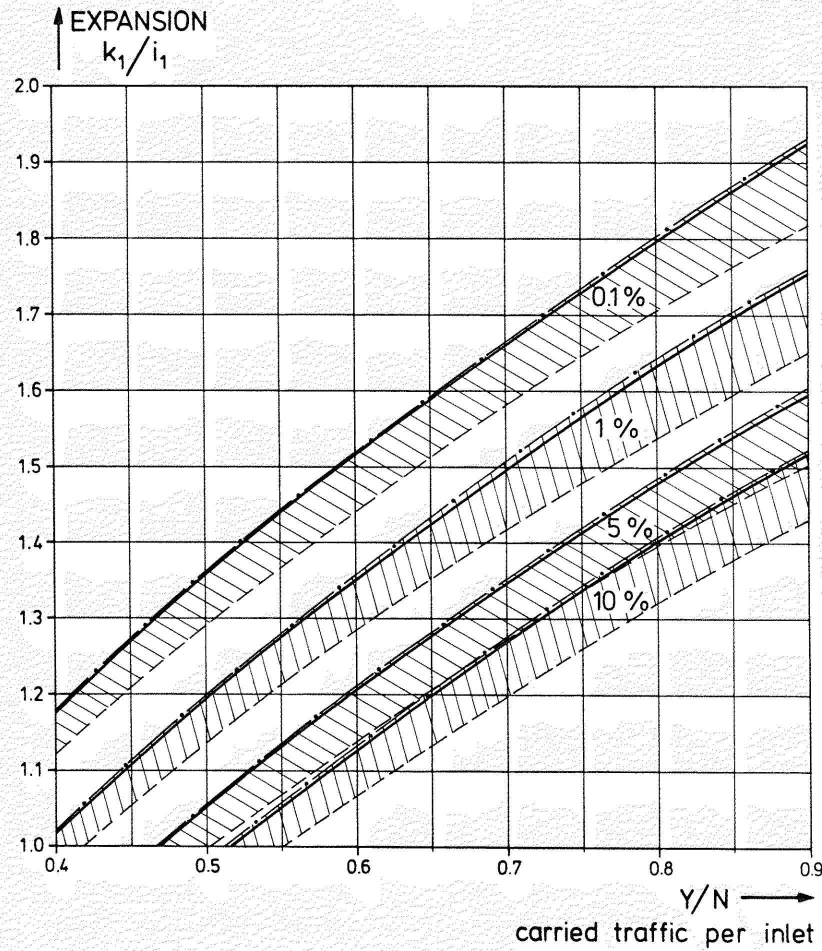
SDM

N = 6 000 —·—

N = 3 375 ———

N = 375 — — —

PPS



S = 4

i_1 = 16

PCT 1

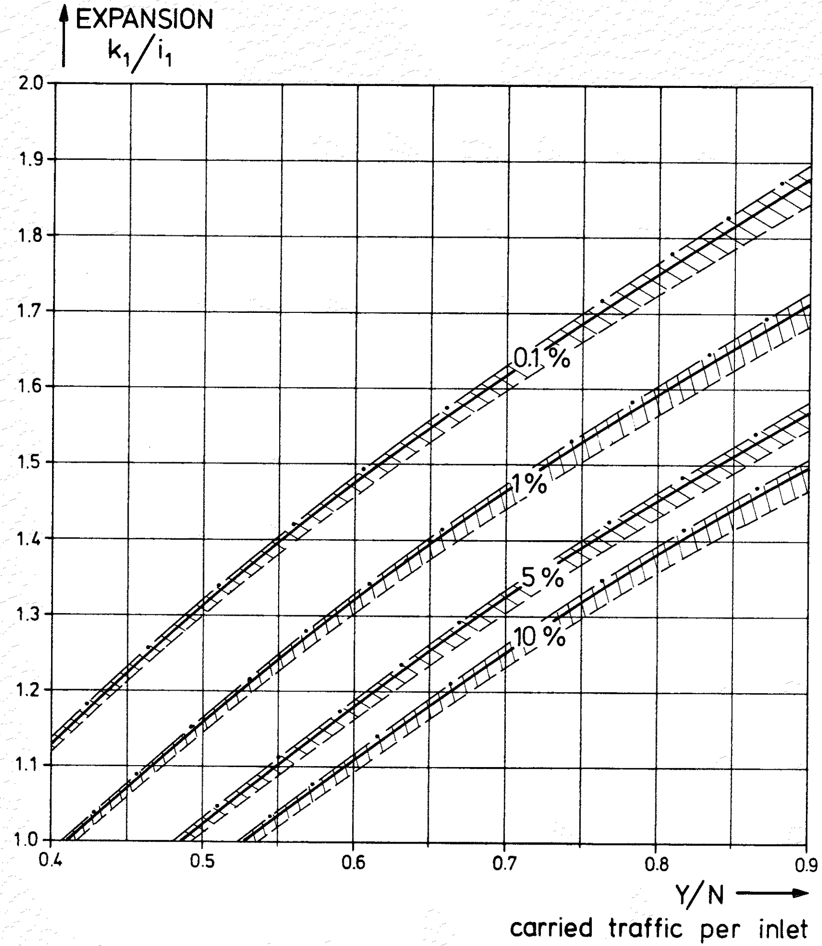
SDM

N = 6 400 —·—

N = 4 096 ———

N = 400 — — —

PPS



S = 4

i_1 = 18

PCT 1

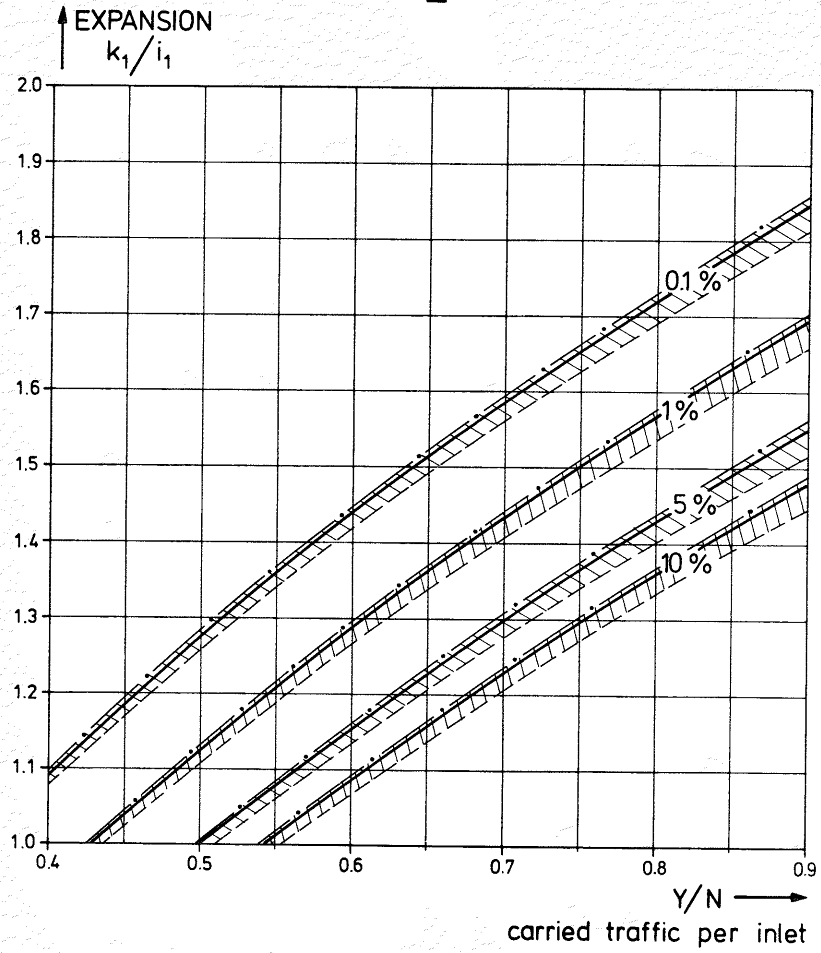
SDM

N = 16200 —·—

N = 5832 ——

N = 1800 — — —

PPS



S = 4

i_1 = 20

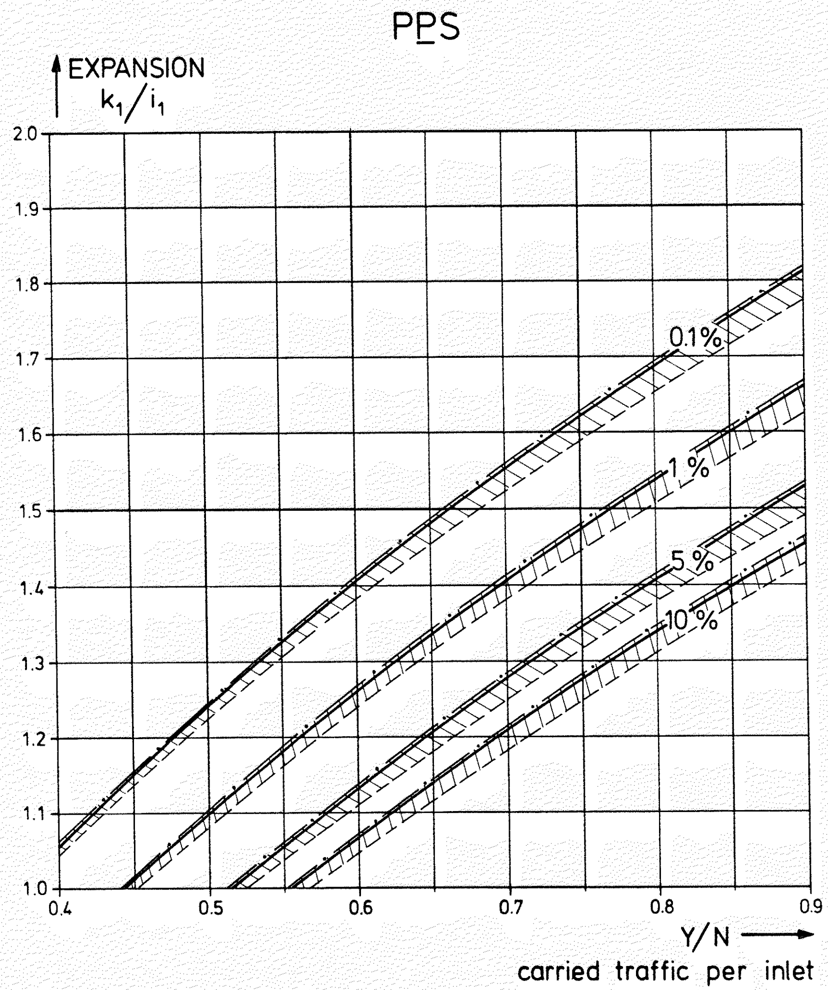
PCT 1

SDM

N = 18000 —·—

N = 8000 ——

N = 2000 — — —



S = 4

i_1 = 22

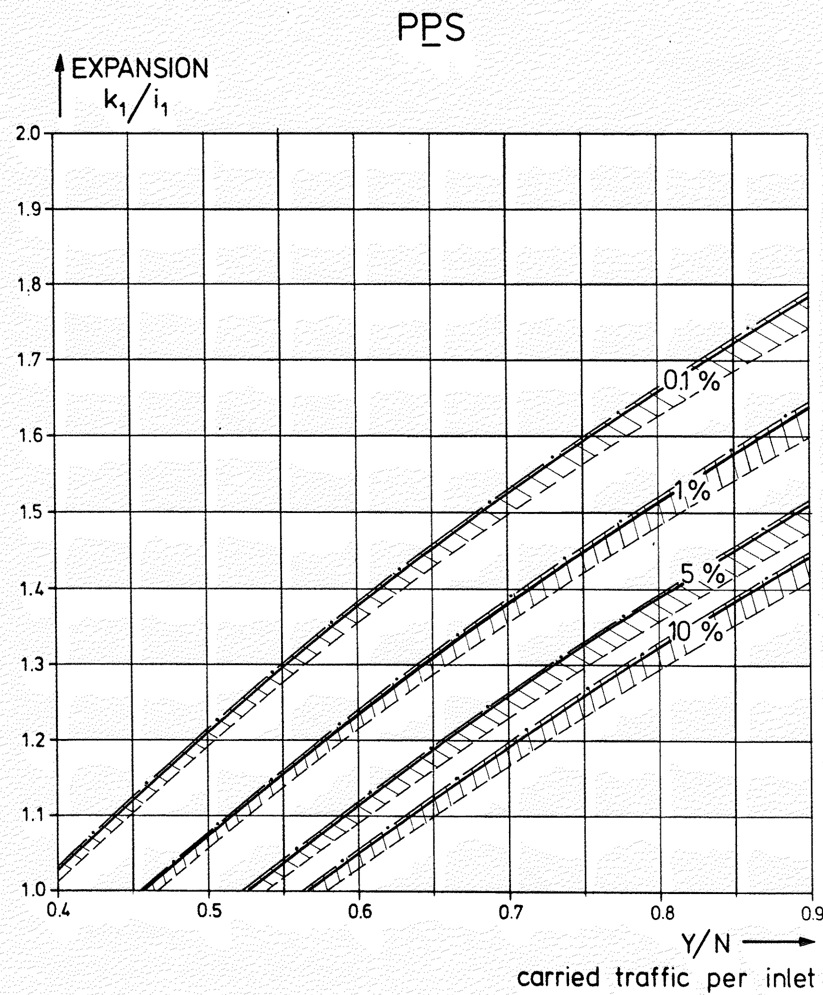
PCT 1

SDM

N = 19 800 —·—

N = 10 648 ——

N = 2 200 — — —



S = 4

i_1 = 24

PCT 1

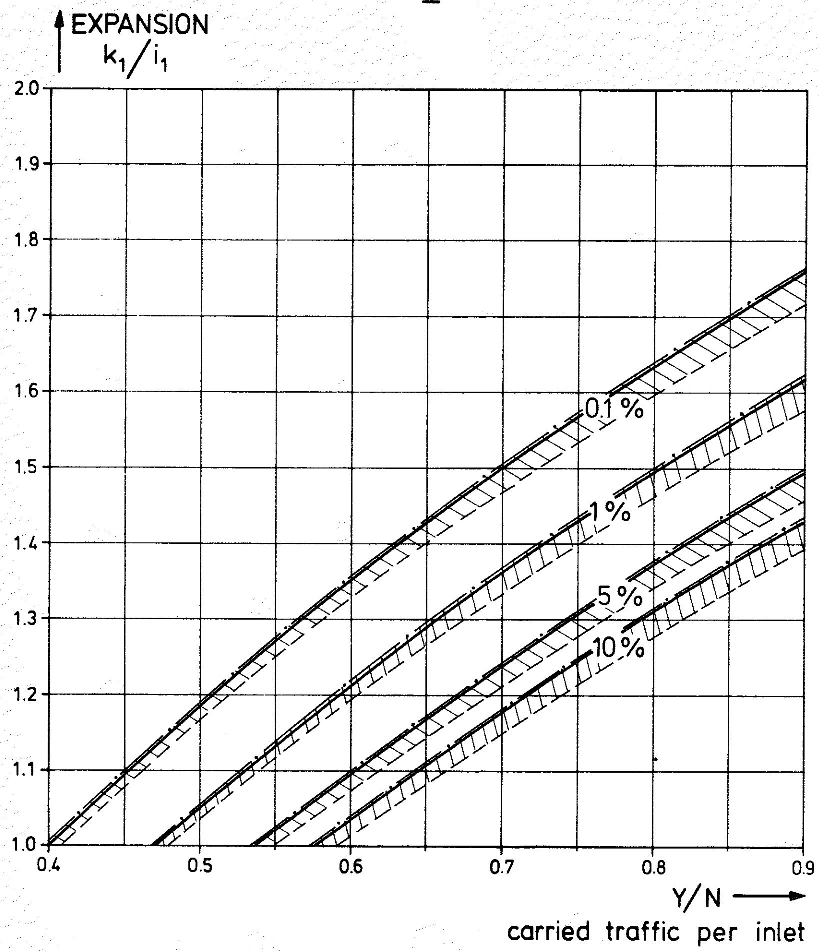
SDM

N = 21 600 —·—

N = 13 824 ——

N = 2 400 — — —

PPS



S = 4

i_1 = 26

PCT 1

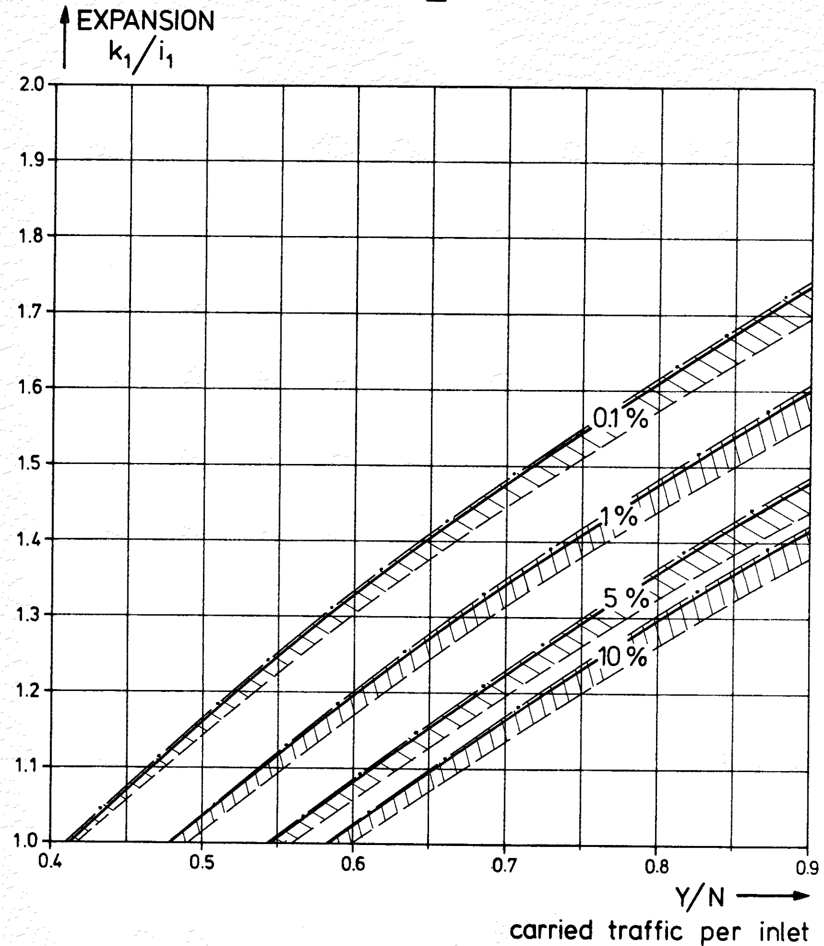
SDM

N = 23400 —— · ——

N = 17 576 ————

N = 2600 — — —

PPS



S = 4

i_1 = 28

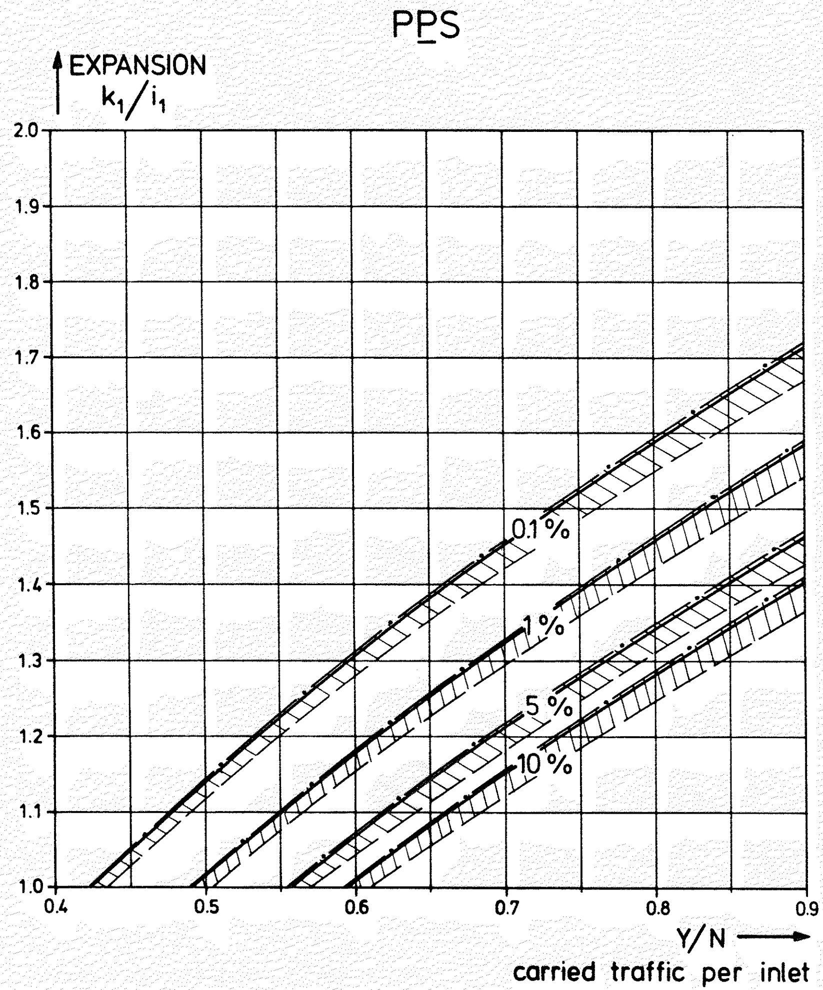
PCT 1

SDM

N = 44 800 —— · ——

N = 21952 ————

N = 2800 — — —



S = 4

$i_1 = 30$

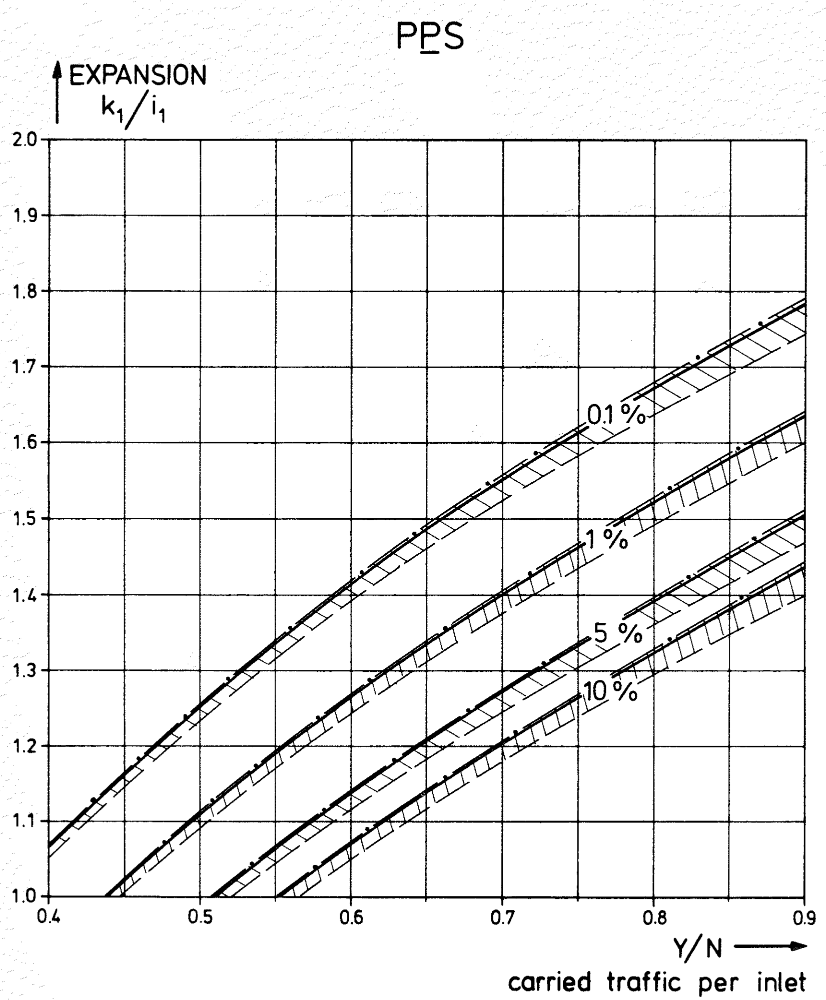
PCT 1

SDM

N = 48 000 —·—

N = 27000 ——

N = 3000 — — —



S = 4

i_1 = 24

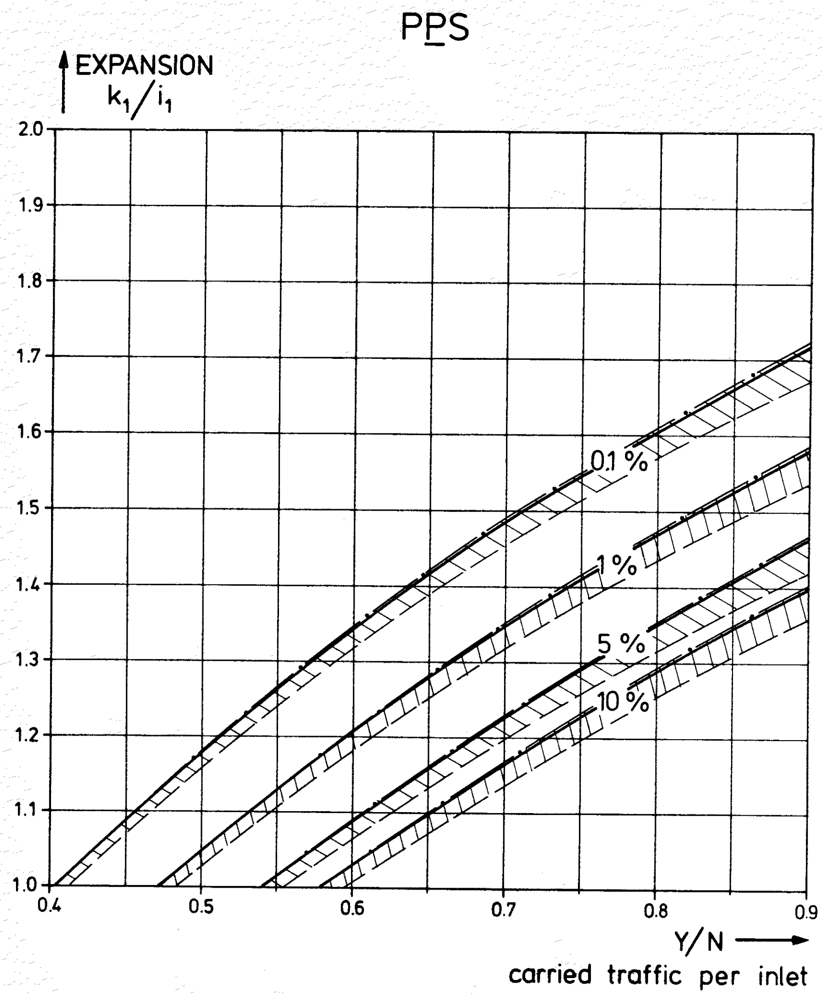
PCT 1

TDM

N = 21 600 —·—

N = 13 824 ———

N = 2400 — — —



S = 4

i_1 = 30

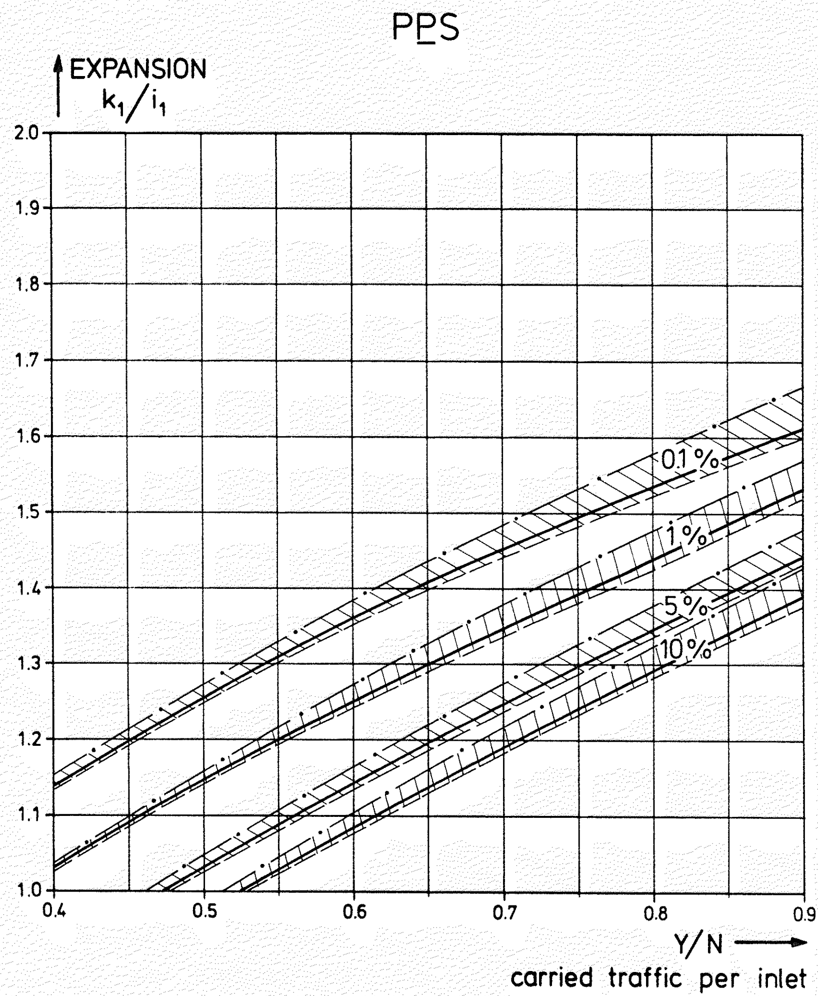
PCT 1

TDM

N = 48 000 —·—

N = 27000 ———

N = 3000 — — —



S = 5

i_1 = 5

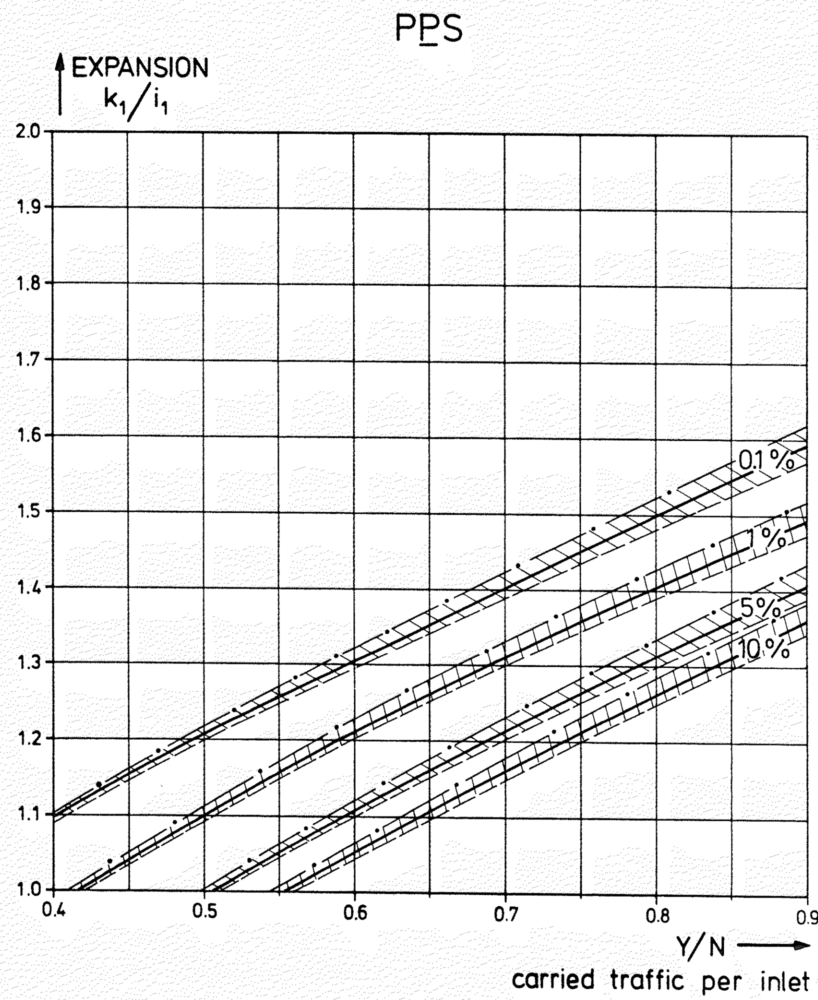
PCT 1

SDM

N = 500 —·—

N = 125 ——

N = 100 — — —



S = 5

i_1 = 6

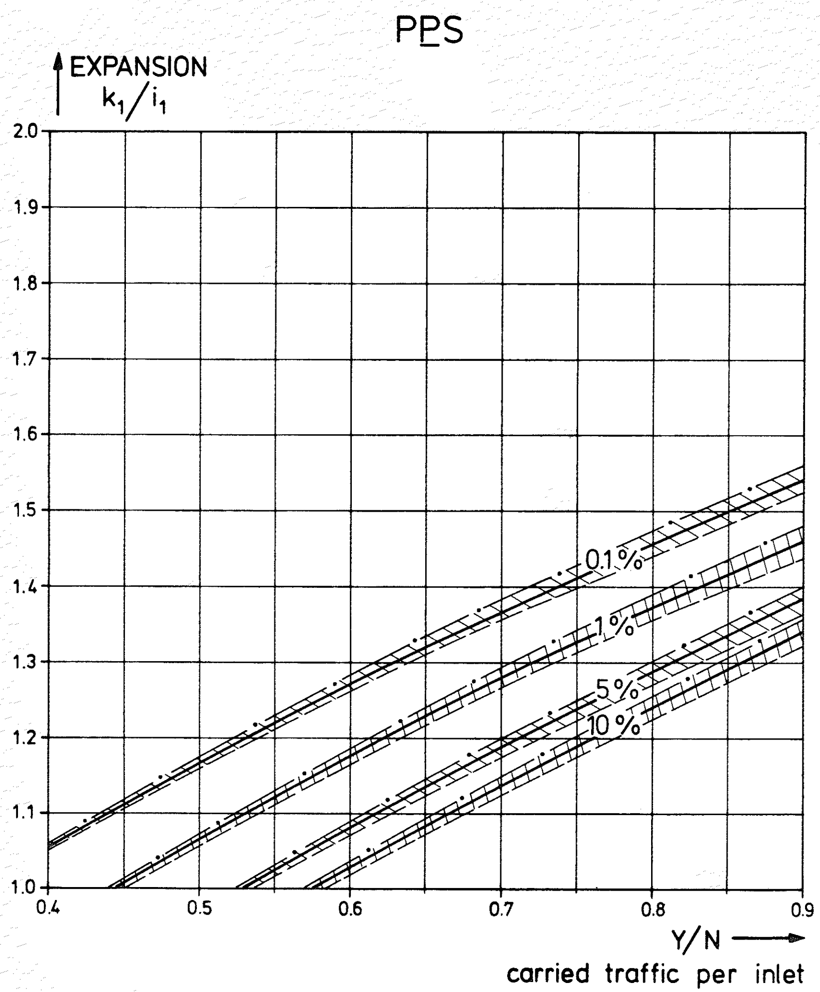
PCT 1

SDM

N = 720 —·—

N = 216 ——

N = 144 — — —



S = 5

i_1 = 7

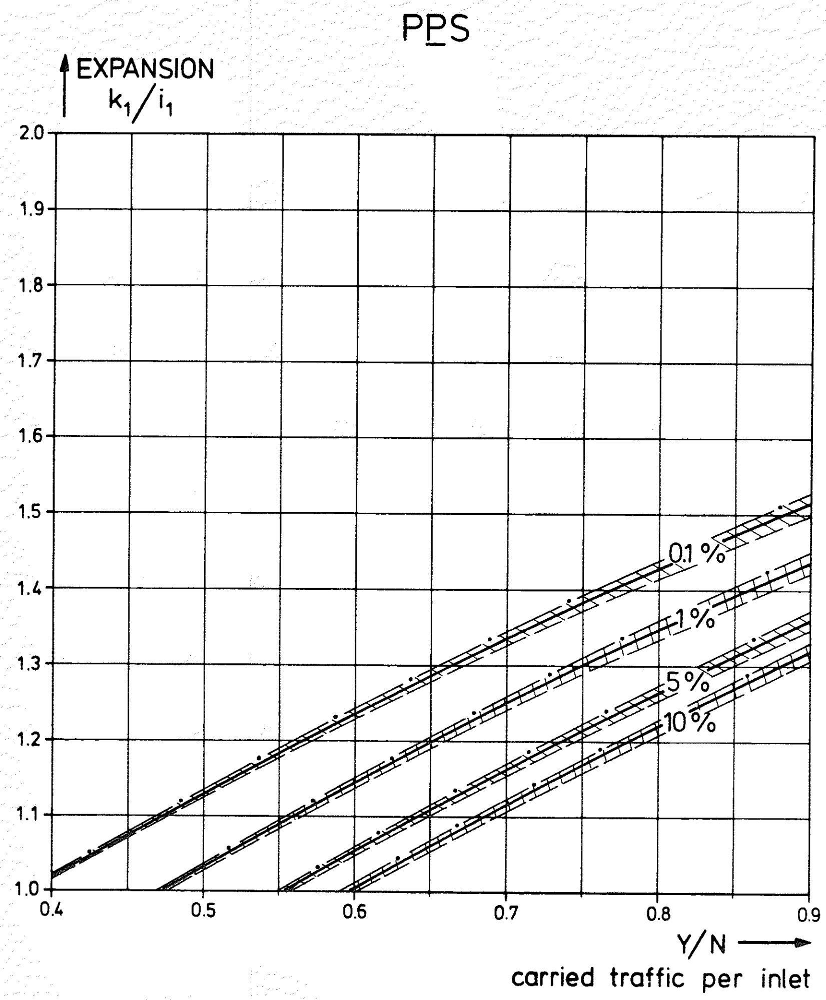
PCT 1

SDM

N = 980 —·—

N = 343 ——

N = 196 – – –



S = 5

i_1 = 8

PCT 1

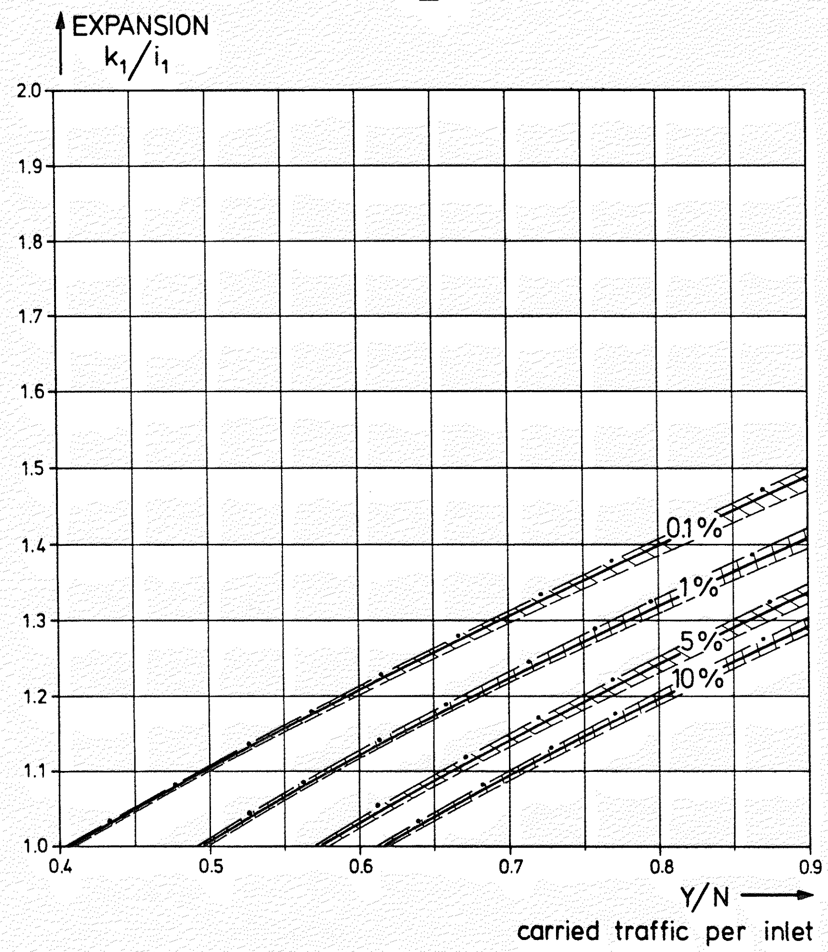
SDM

N = 1 280 —·—

N = 512 ——

N = 320 – – –

PPS



S = 5

i_1 = 9

PCT 1

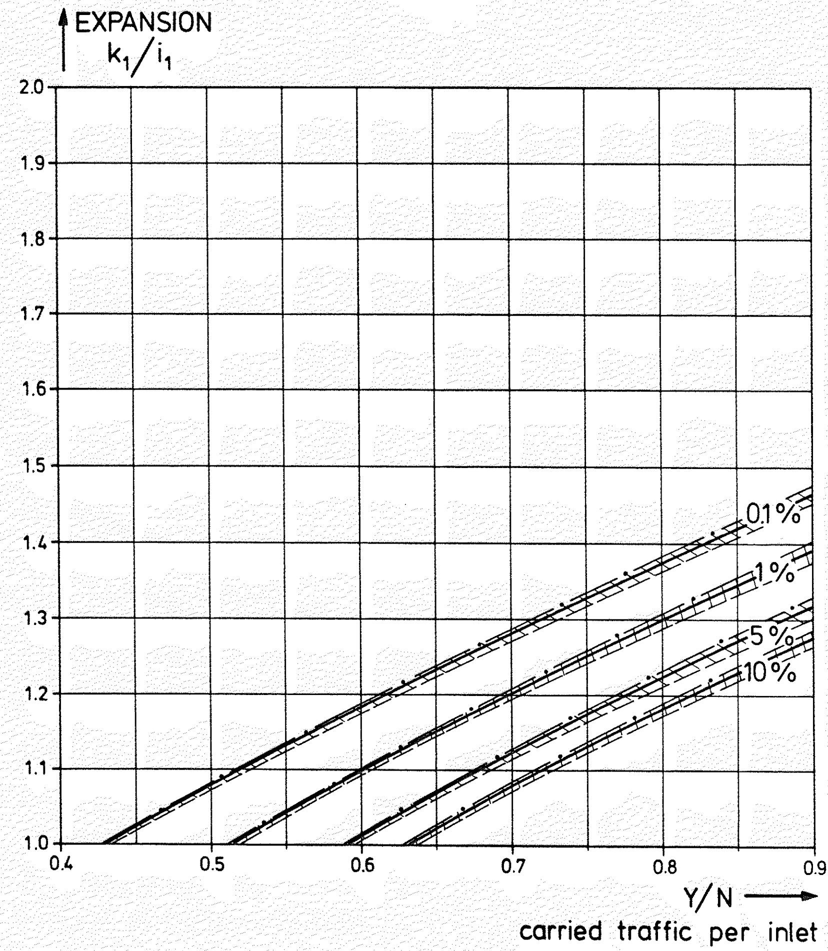
SDM

N = 1620 —·—

N = 729 ——

N = 405 — — —

PPS



S = 5

i_1 =10

PCT 1

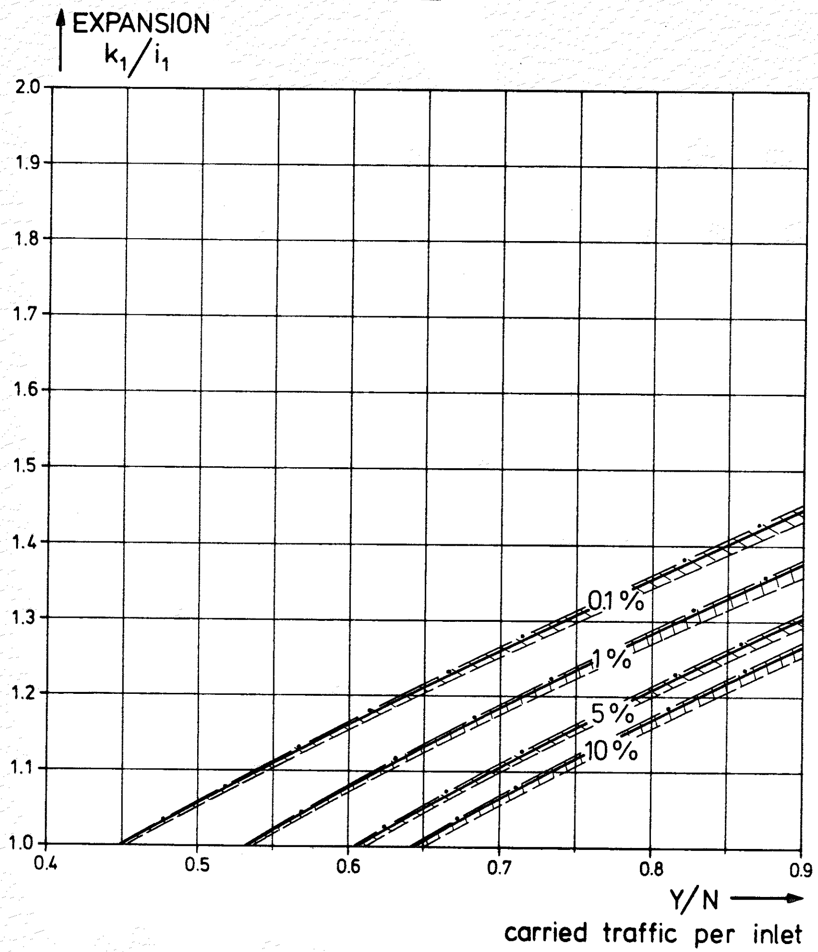
SDM

N = 2 000 —·—

N = 1 000 ——

N = 500 — — —

PPS



S = 5

i_1 = 11

PCT 1

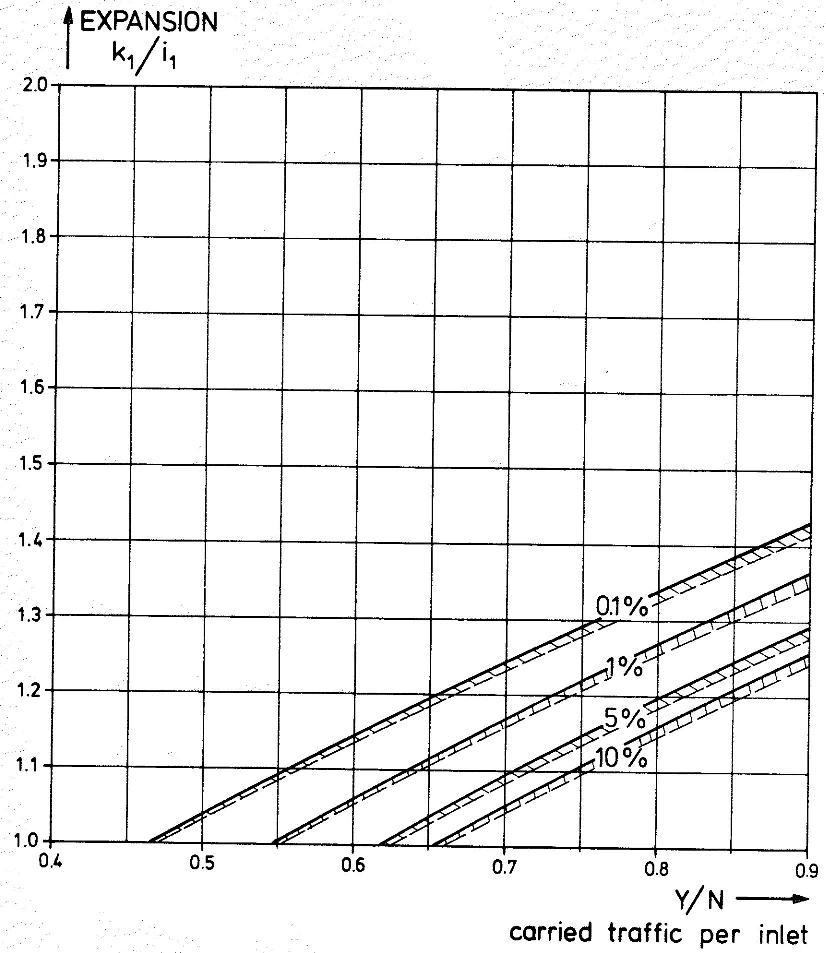
SDM

N = 2 420 —— · ——

N = 1 331 ————

N = 605 — — —

PPS



S = 5

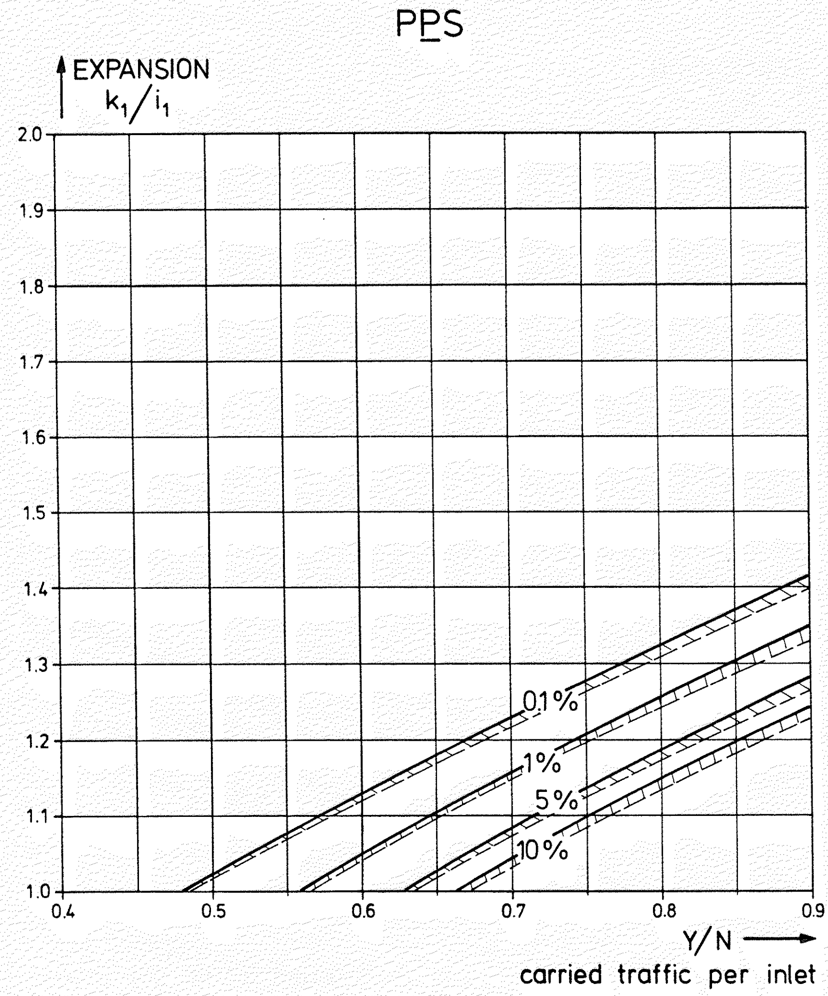
i_1 = 12

PCT 1

SDM

N = 2880 }
N = 1728 } ————

N = 720 — — —



S = 5

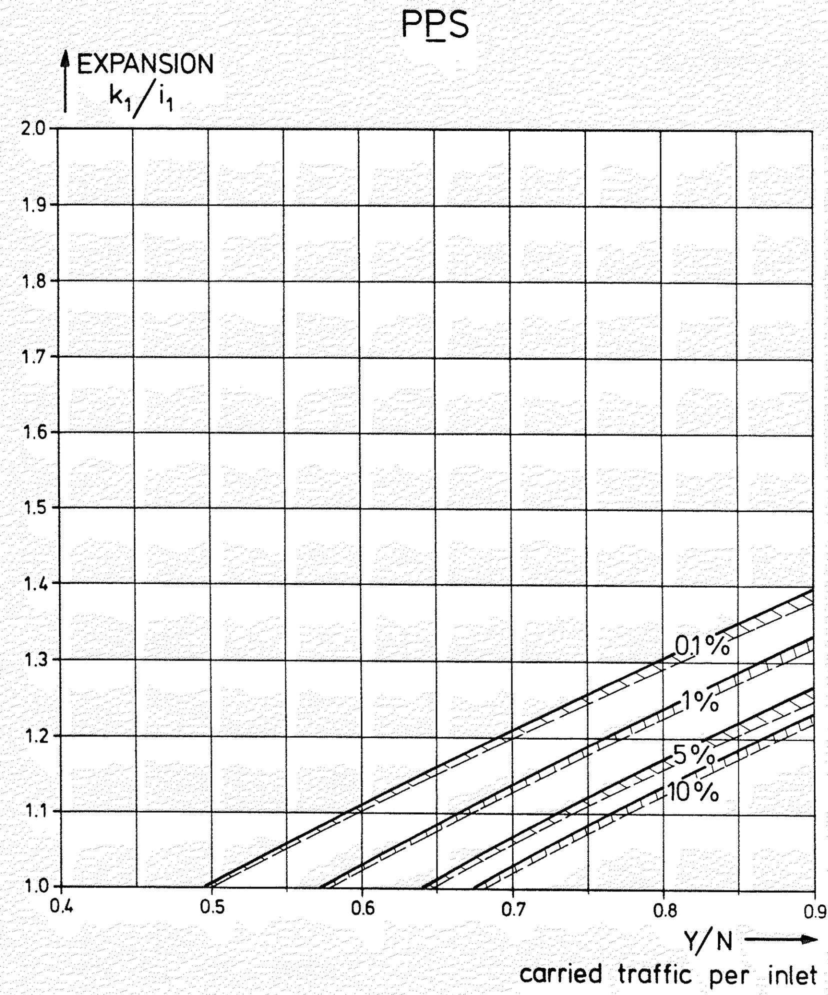
i_1 = 13

PCT 1

SDM

N = 3 380 }
N = 2197 } ————

N = 845 — — —



S = 5

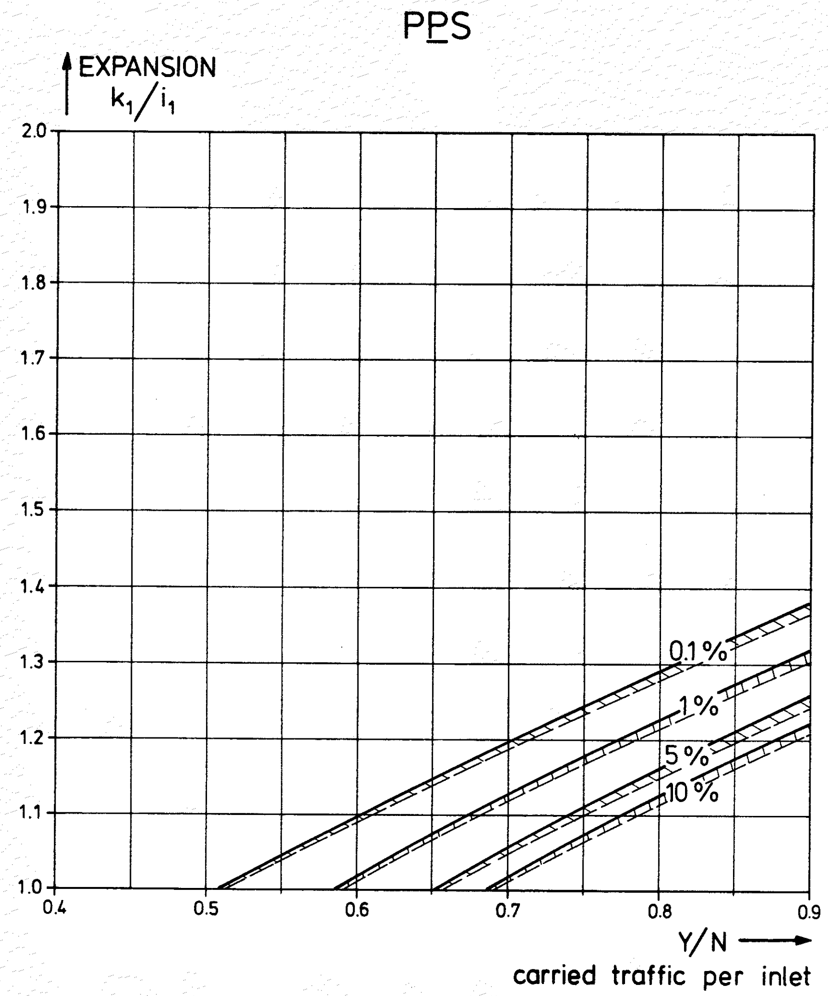
i_1 = 14

PCT 1

SDM

N = 3920 }
N = 2744 } ————

N = 980 — — —



S = 5

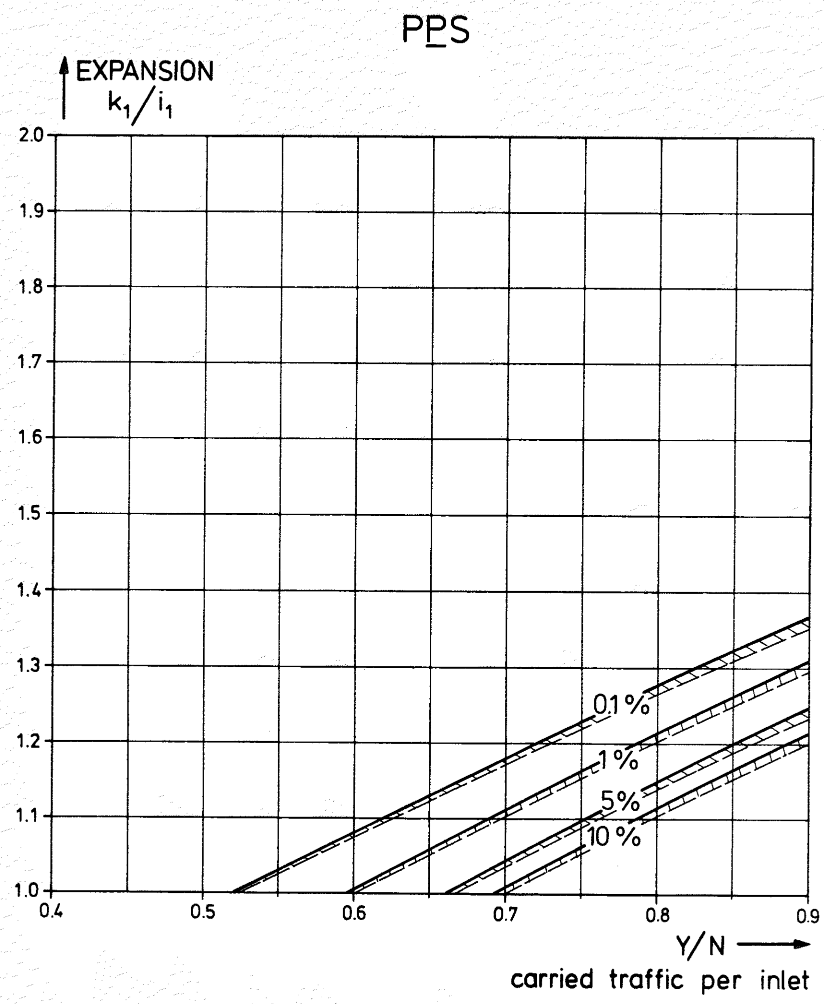
i_1 = 15

PCT 1

SDM

N = 4 500 }
N = 3 375 } ————

N = 1125 — — —



S = 5

i_1 = 16

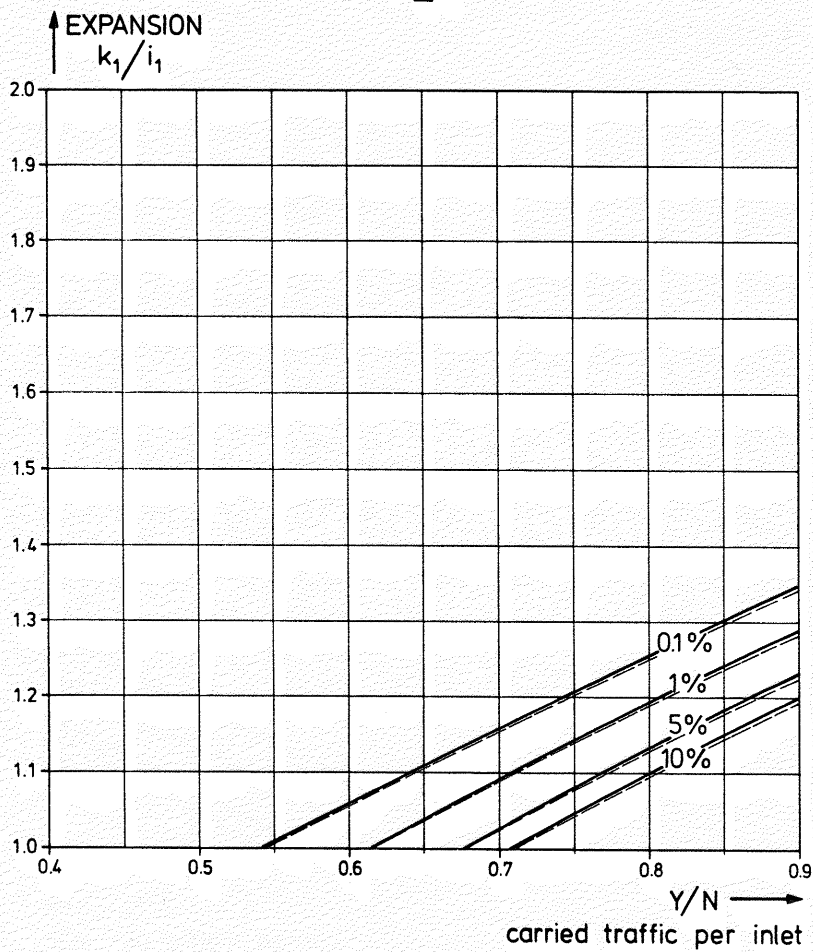
PCT 1

SDM

N = 5 120 }
N = 4 096 } ————

N = 1 280 — — —

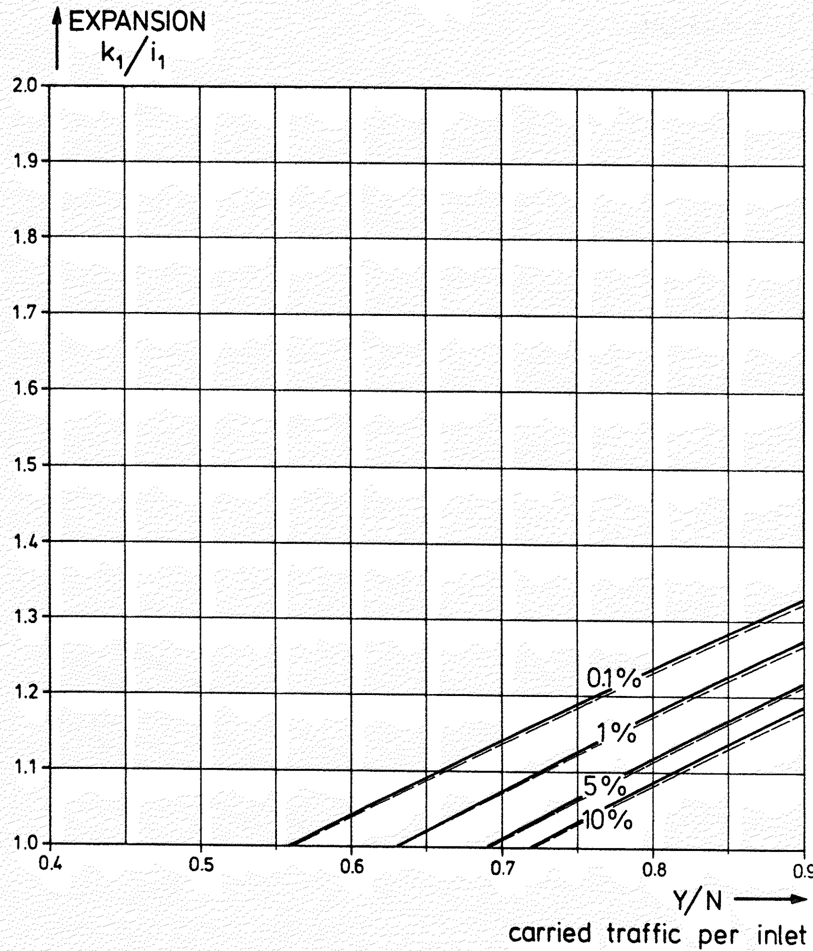
PPS



S = 5
i_1 = 18
PCT 1
SDM

N = 9 720 } ———
N = 5 832 }
N = 3 240 — — —

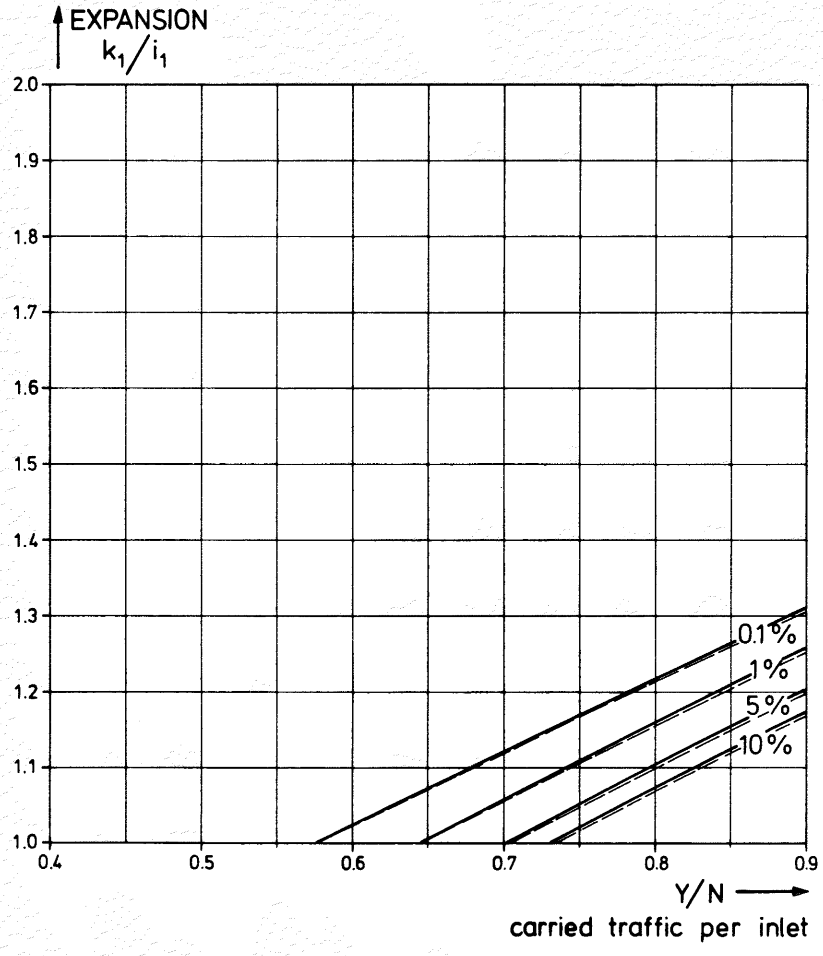
PPS



S = 5
i_1 = 20
PCT 1
SDM

N = 12 000 } ———
N = 8 000 }
N = 4 000 — — —

PPS



S = 5

i_1 = 22

PCT 1

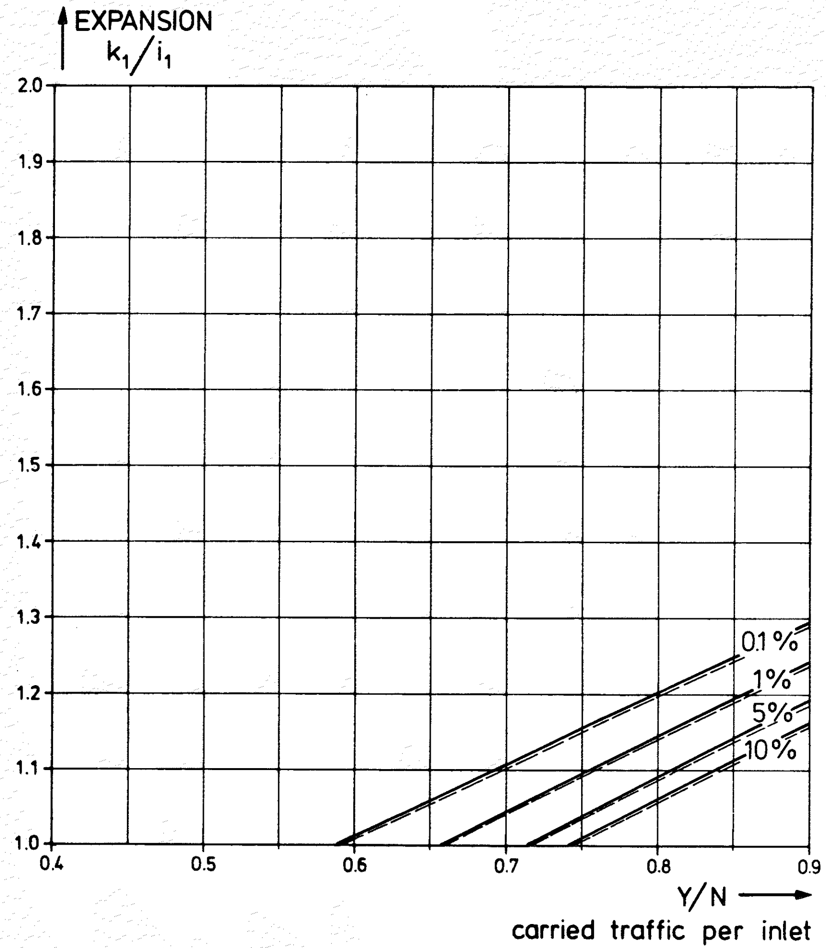
SDM

N = 14 520 } ———

N = 10 648 }

N = 4 840 — — —

PPS



S = 5

i_1 = 24

PCT 1

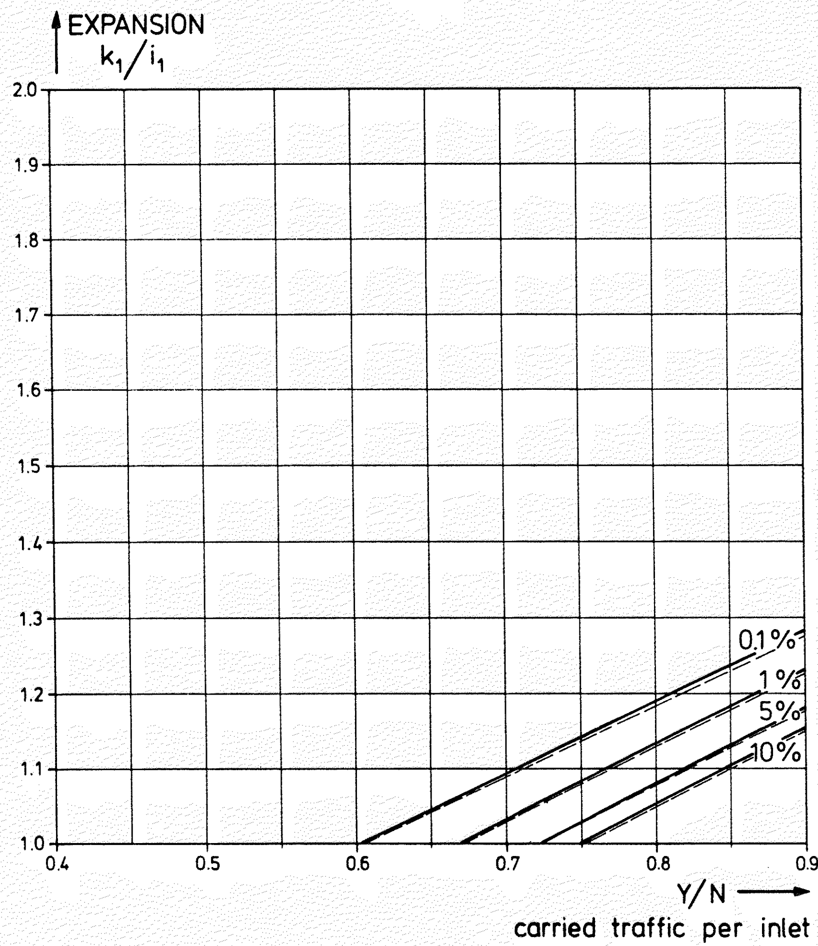
SDM

N = 17 280 } ———

N = 13 824 }

N = 5 760 — — —

PPS



S = 5

i_1 = 26

PCT 1

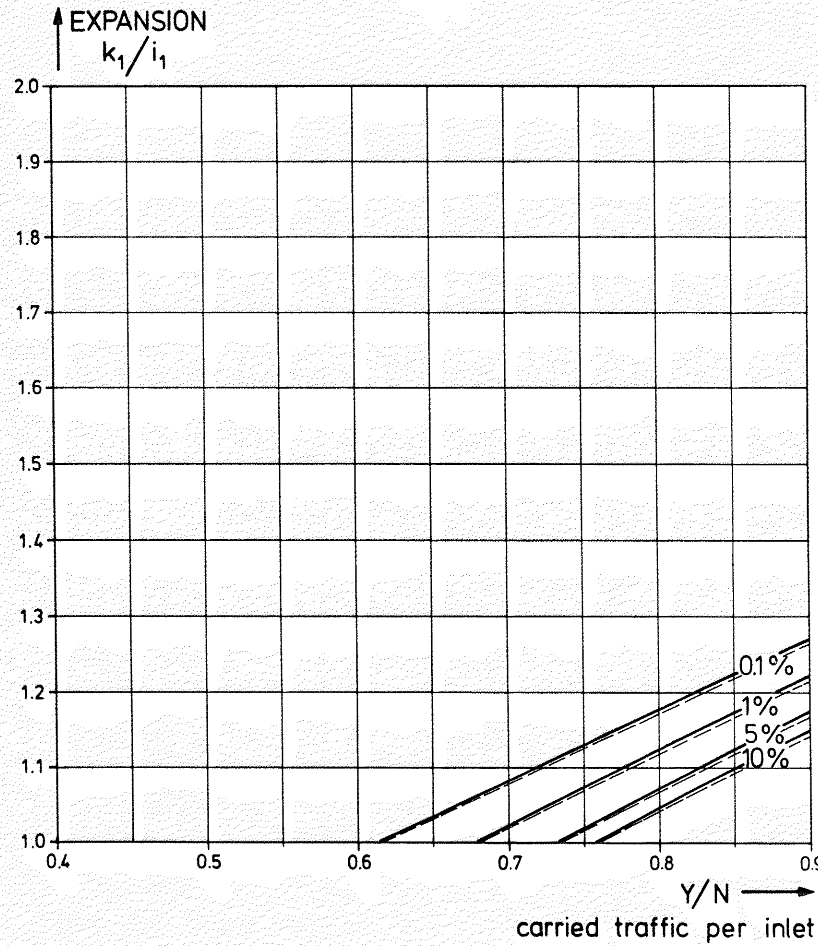
SDM

N = 20 280 } ———

N = 17 576 }

N = 6 760 — — —

PPS



S = 5

i_1 = 28

PCT 1

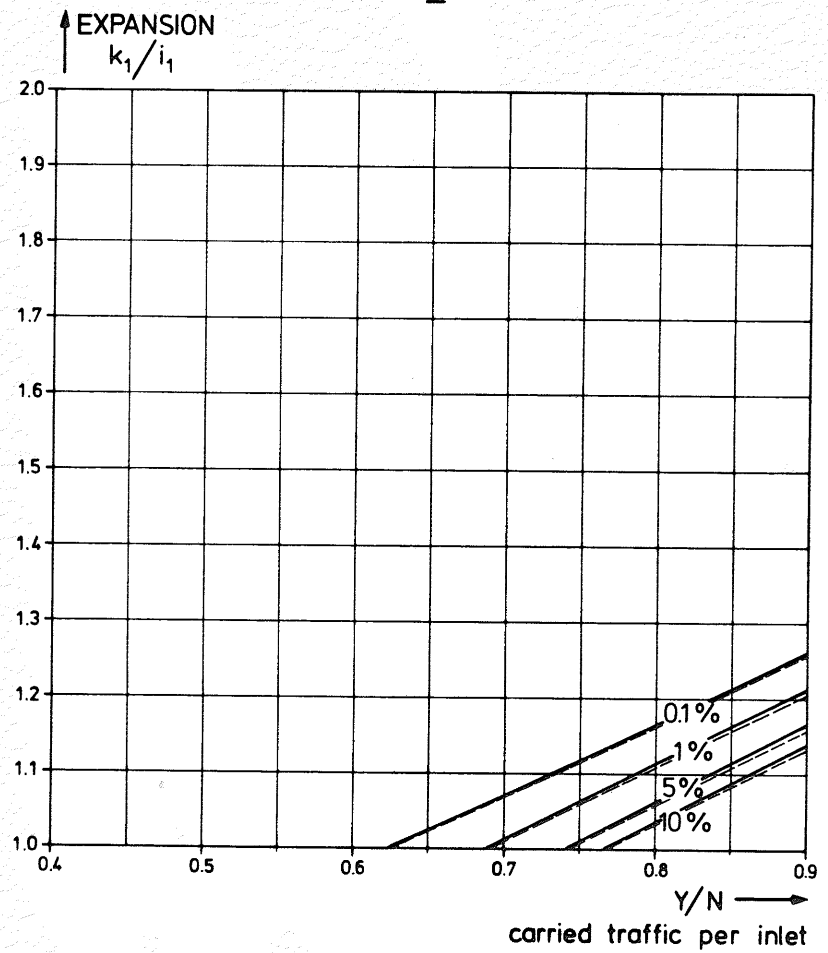
SDM

N = 31360 } ———

N = 21952 }

N = 7840 — — —

PPS



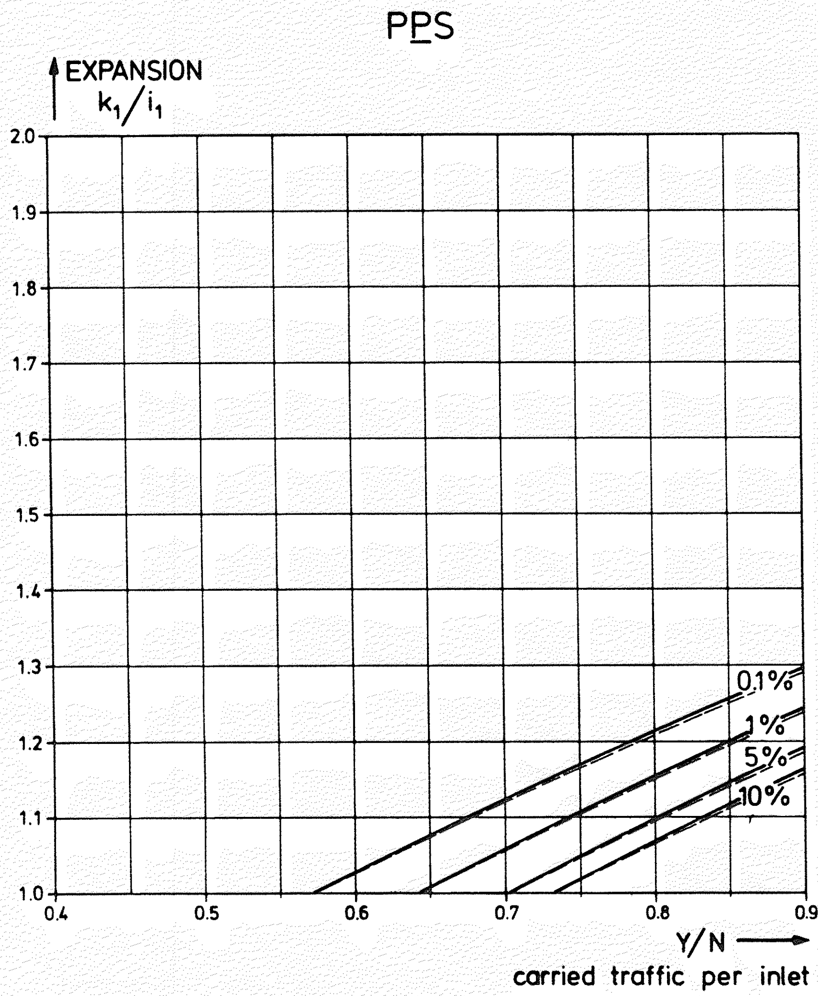
S = 5

i_1 = 30

PCT 1

SDM

N = 36 000 } ———
N = 27 000 }
N = 9 000 – – –



S = 5

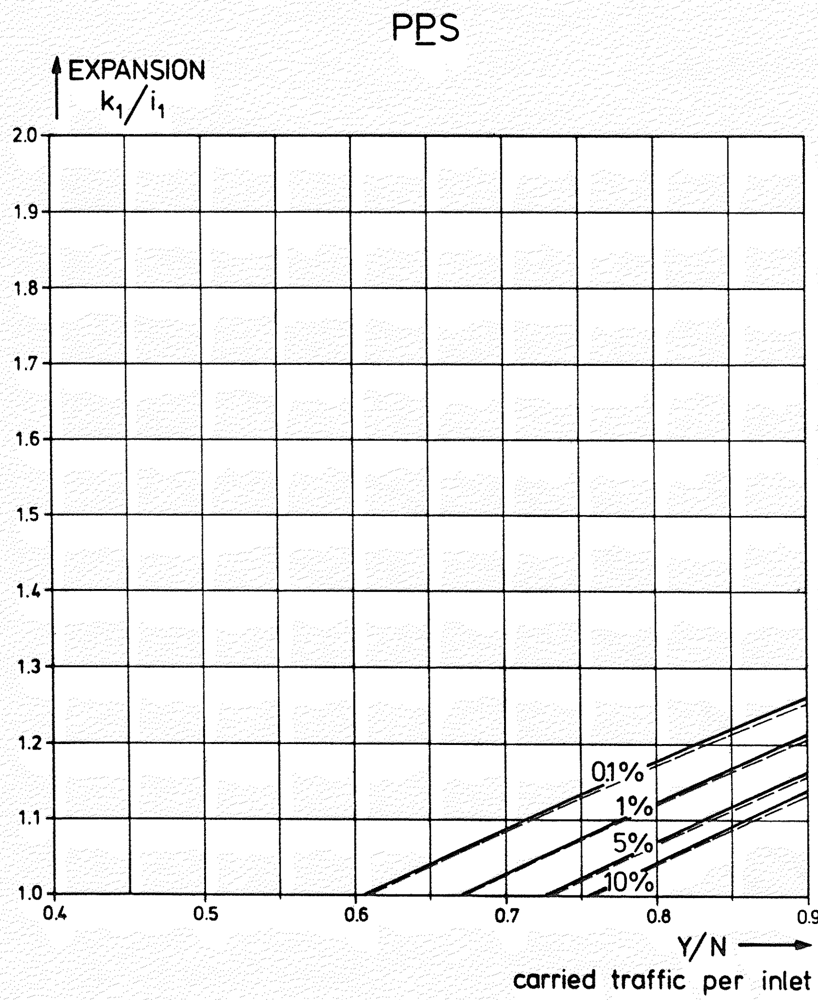
i_1 = 24

PCT 1

TDM

N = 17 280 }
N = 13 824 } ————

N = 5 760 — — —



S = 5

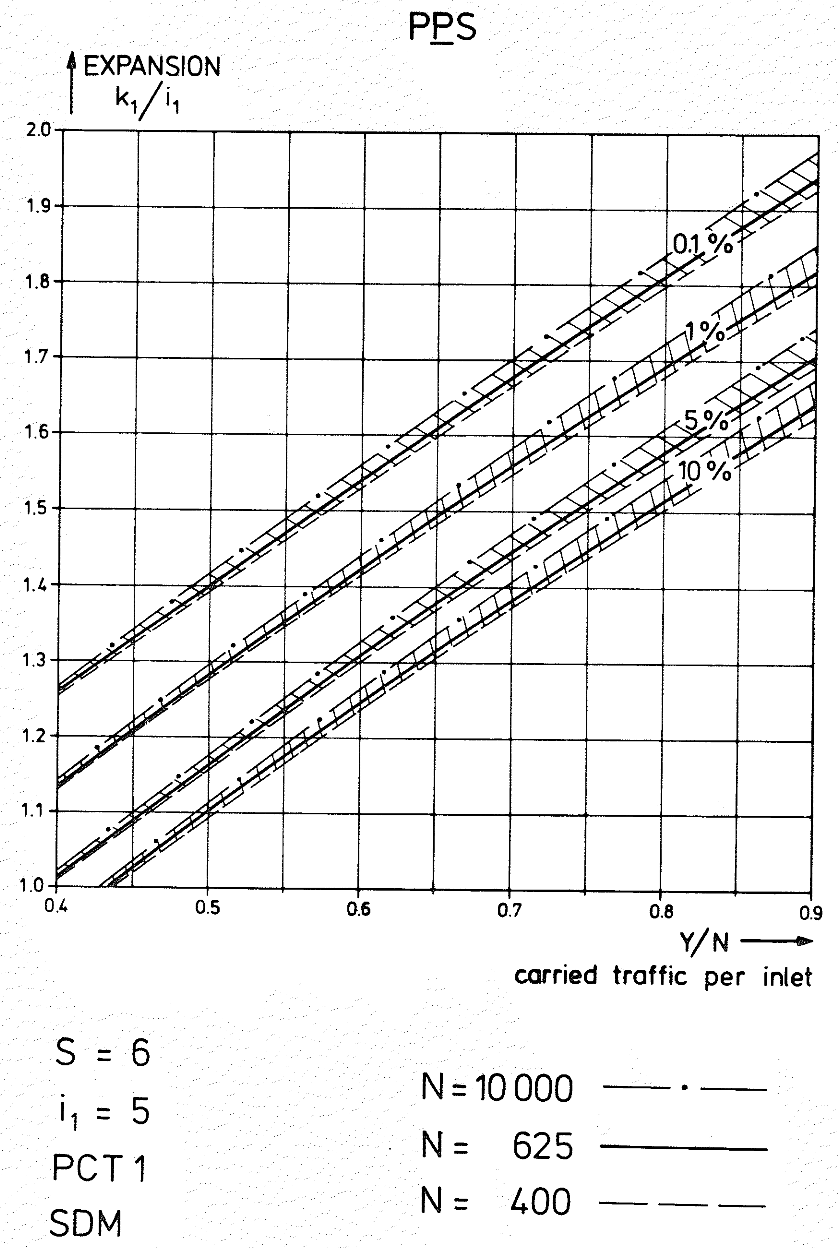
i_1 = 30

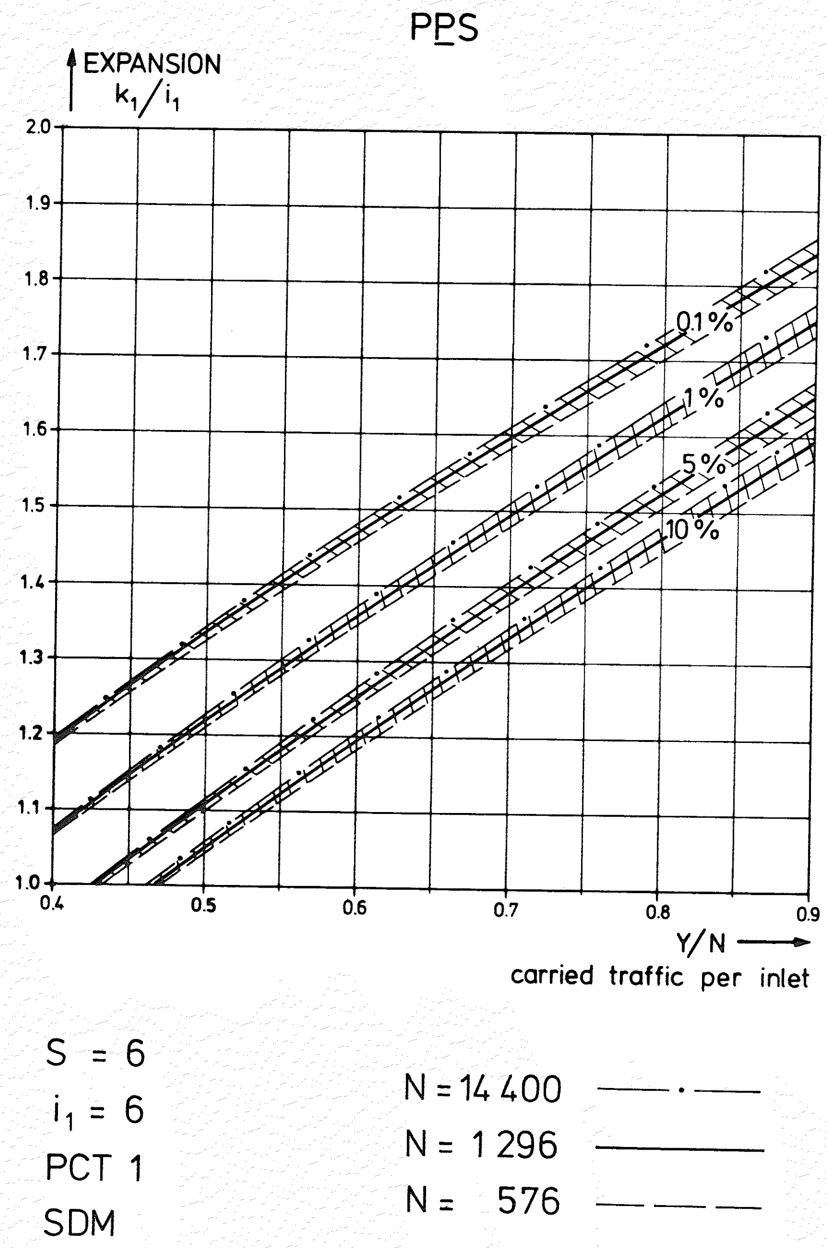
PCT 1

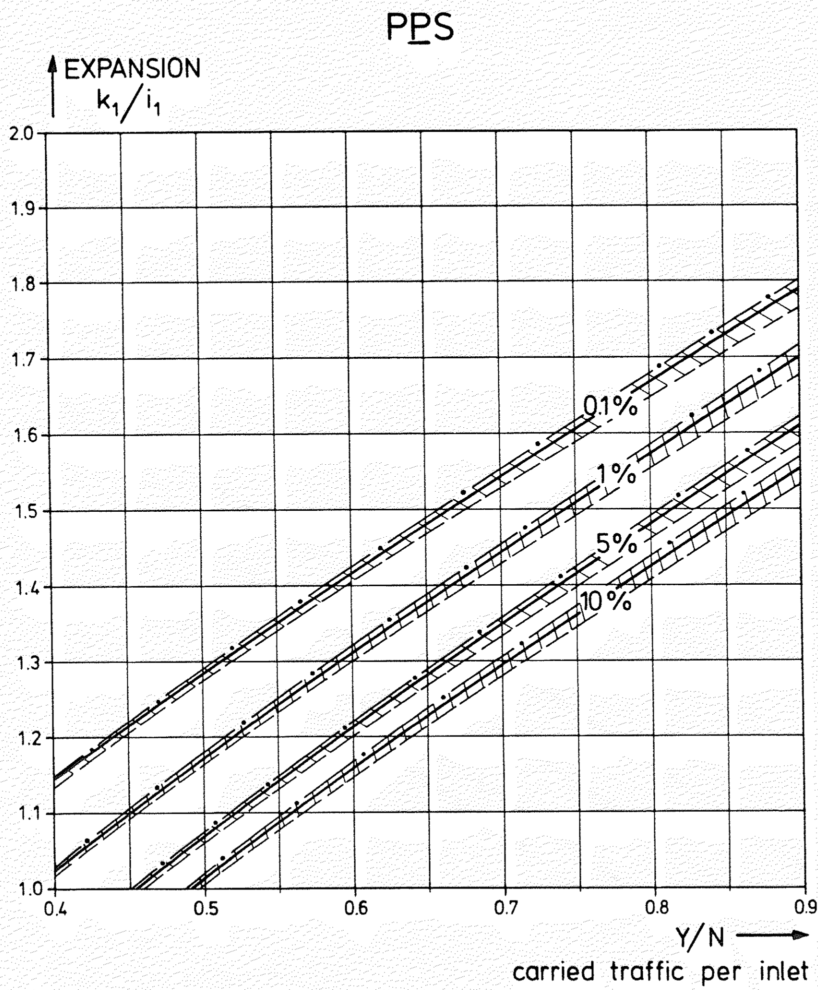
TDM

N = 36 000 }
N = 27000 } ————

N = 9000 — — —

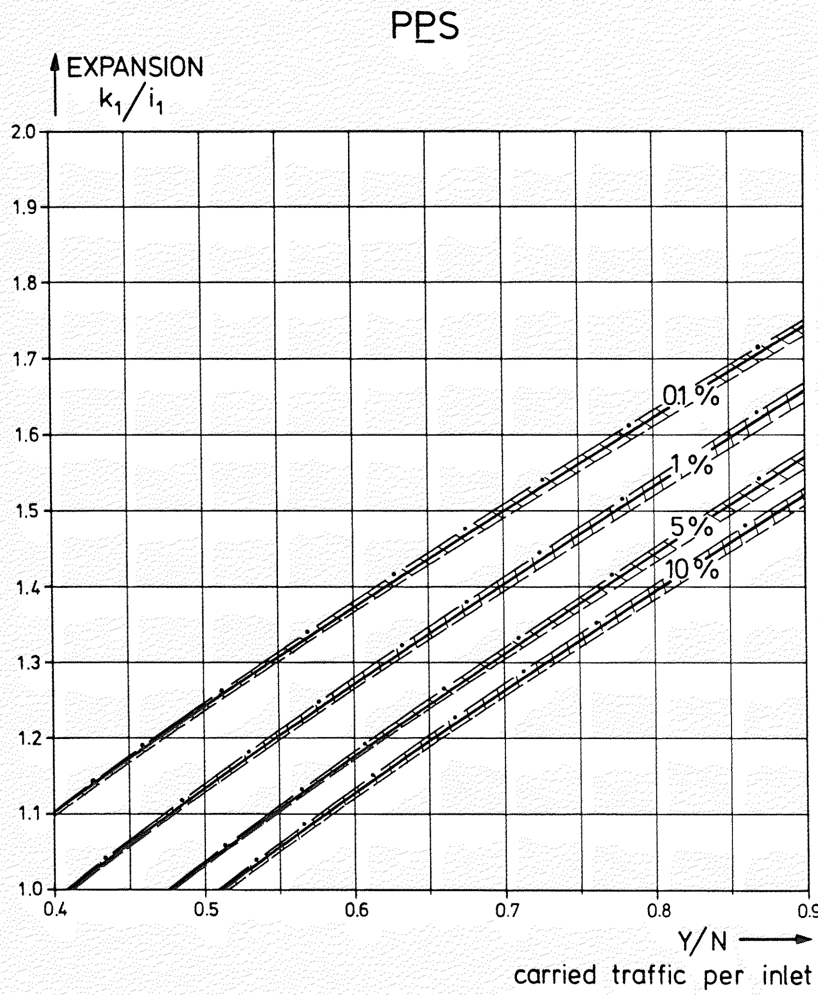

PPS
EXPANSION
k1/i1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.4
0.5
0.6
0.7
0.8
0.9
0.1 %
1 %
5 %
10 %
Y/N
carried traffic per inlet
S = 6
i1 = 5
PCT 1
SDM
N = 10 000
N = 625
N = 400


PPS
EXPANSION
k1/i1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.4
0.5
0.6
0.7
0.8
0.9
0.1 %
1 %
5 %
10 %
Y/N
carried traffic per inlet
S = 6
i1 = 6
PCT 1
SDM
N = 14 400
N = 1 296
N = 576



S = 6
i_1 = 7
PCT 1
SDM

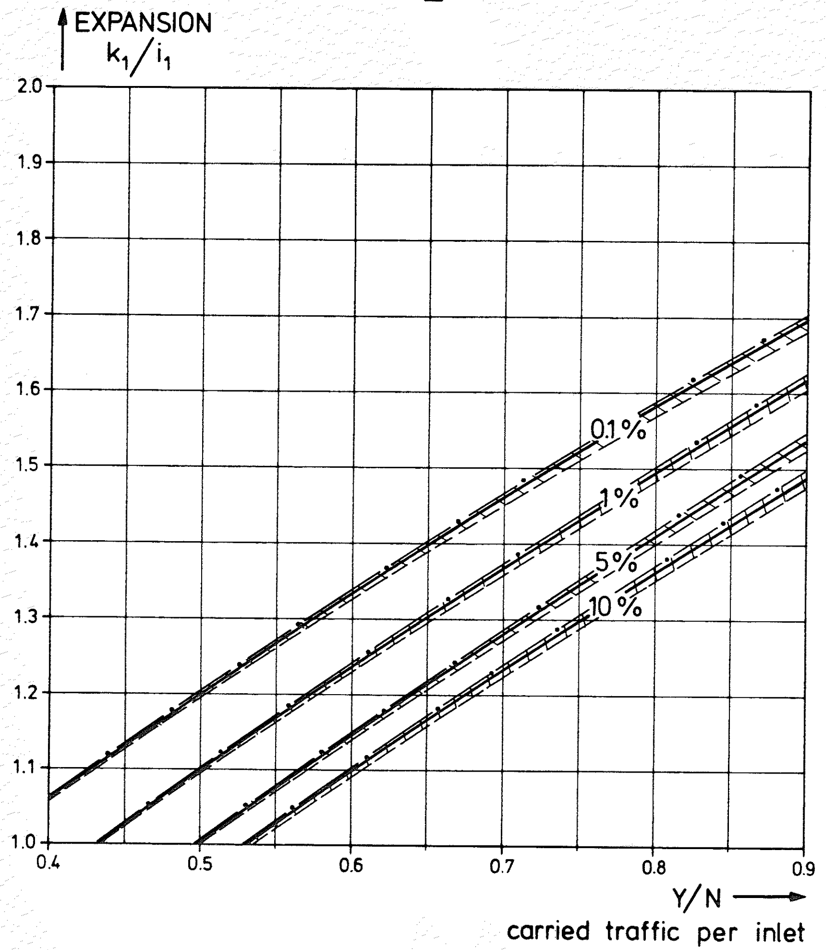
N = 19 600 —·—
N = 2401 ——
N = 784 — — —



S = 6
i_1 = 8
PCT 1
SDM

N = 25600 —·—
N = 4096 ——
N = 1600 — — —

PPS



S = 6

i_1 9

PCT 1

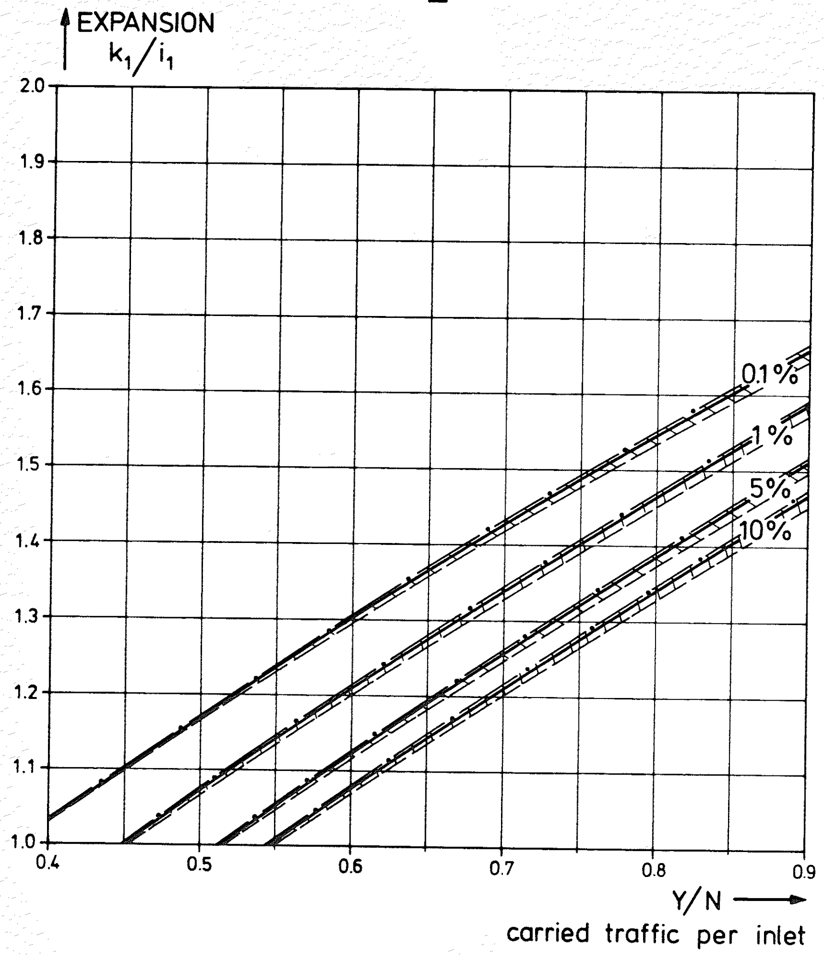
SDM

N = 32400 —— · ——

N = 6561 ————

N = 2025 — — —

PPS



S = 6

i_1 =10

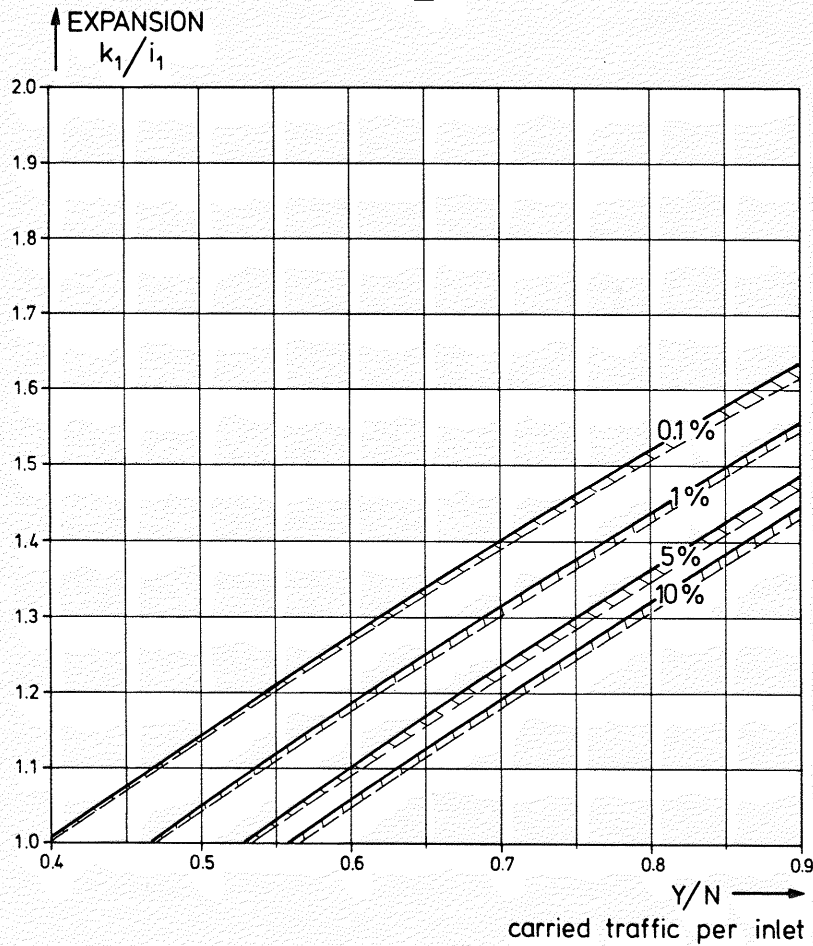
PCT 1

SDM

N = 40 000 —— · ——

N = 10 000 ————

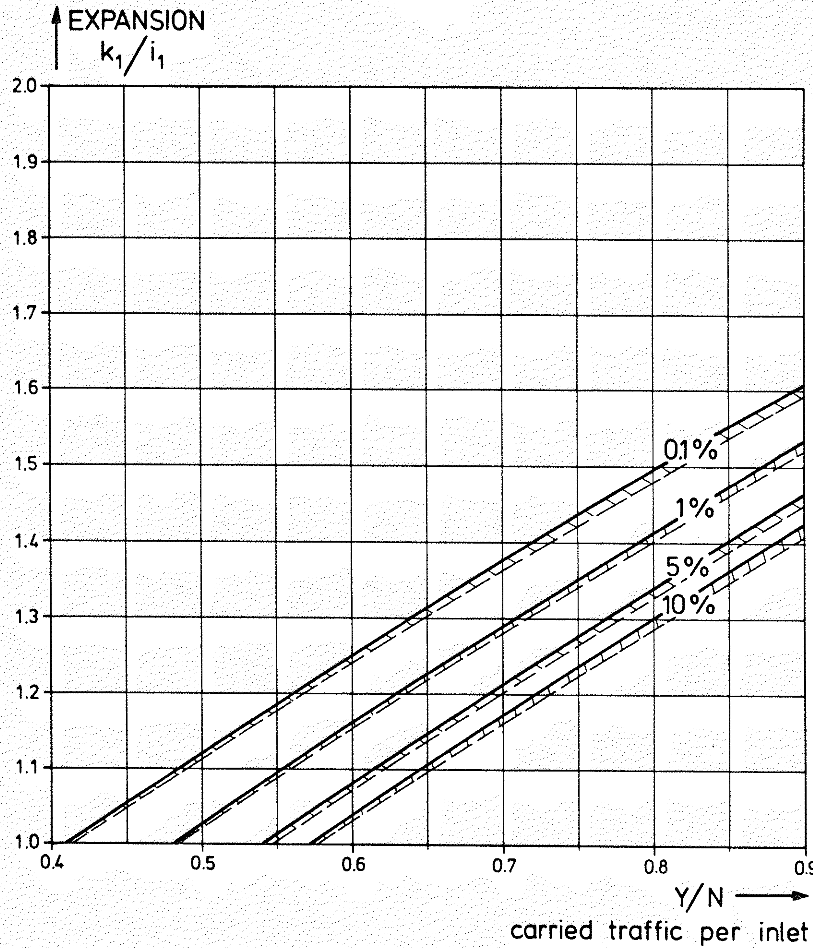
N = 2500 — — —



S = 6
i_1 = 11
PCT 1
SDM

N = 48 400, N = 14 641 ——————

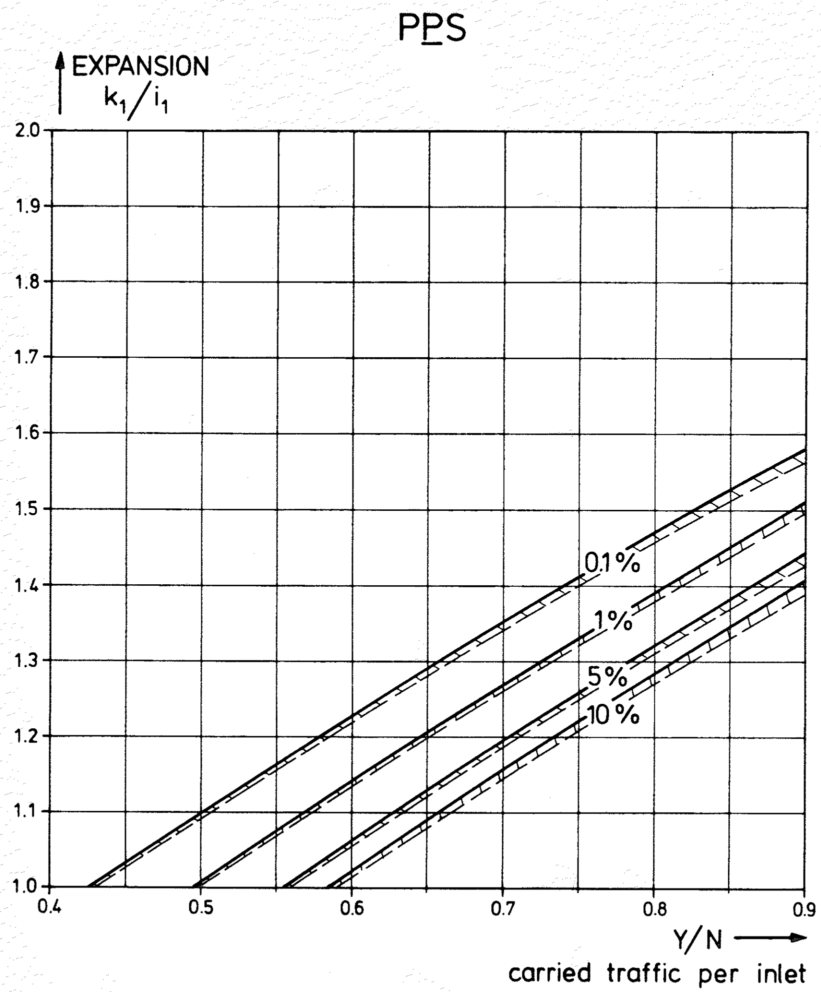
N = 3025 — — — —



S = 6
i_1 = 12
PCT 1
SDM

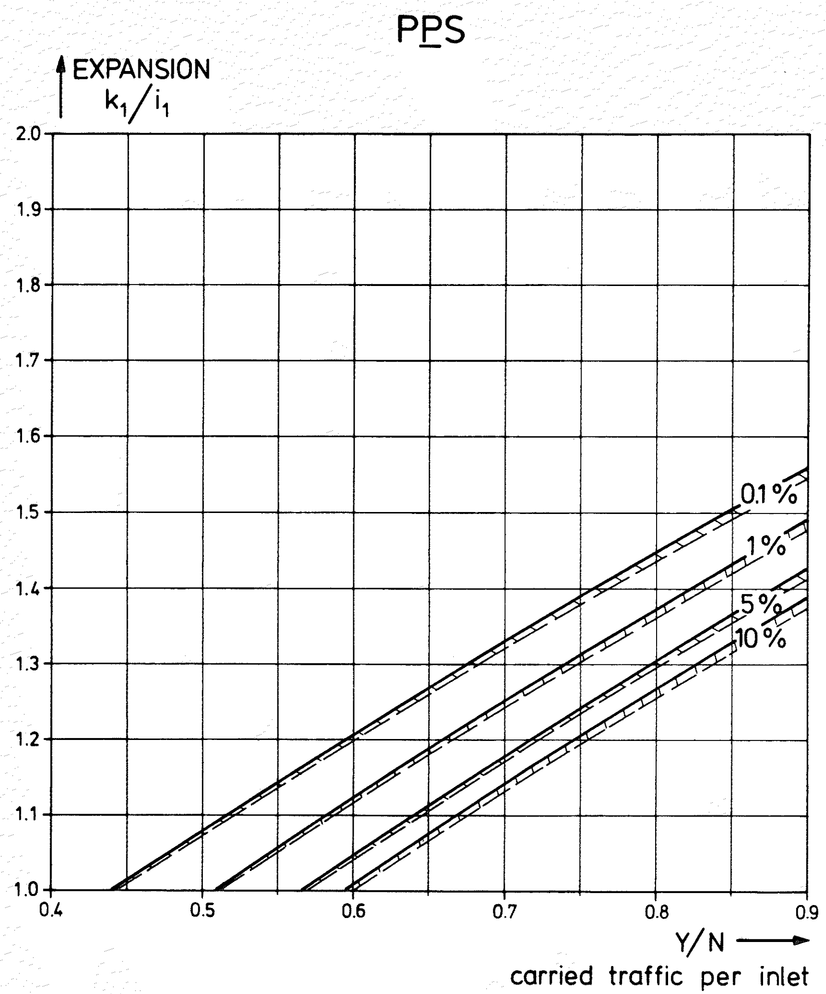
N = 57 600, N = 20 736 ——————

N = 3600 — — — —



S = 6
i_1 = 13
PCT 1
SDM

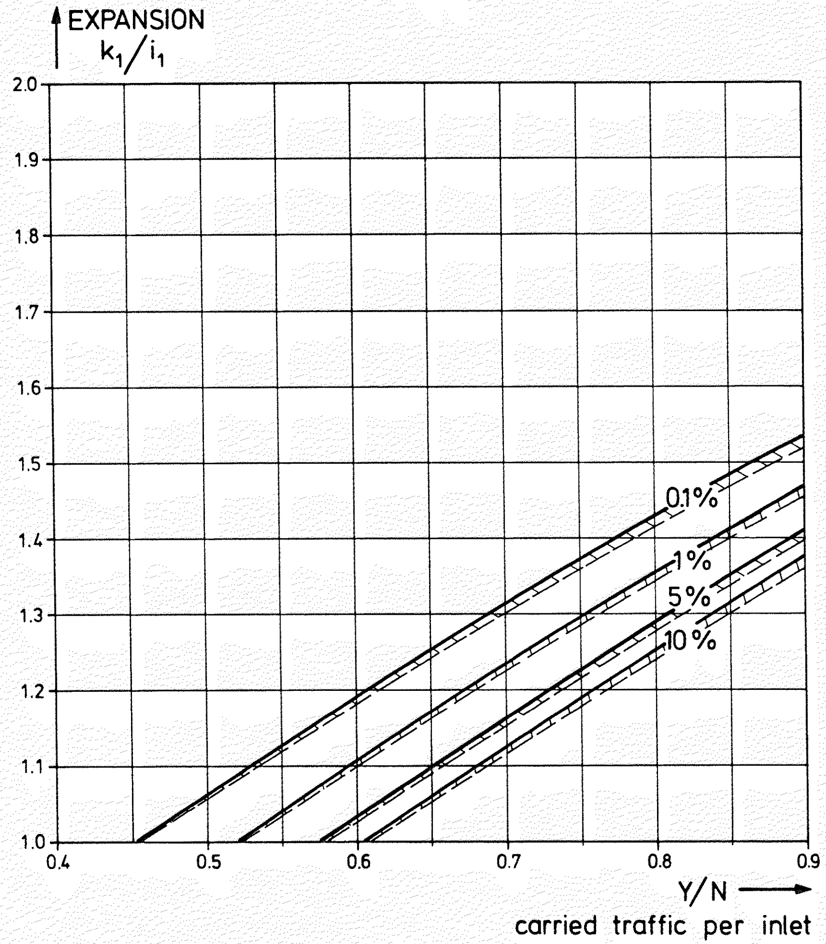
N = 67 600, N = 28 561 ———
N = 4225 — — —



S = 6
i_1 = 14
PCT 1
SDM

N = 78 400, N = 38 416 ———
N = 4900 — — —

PPS



S = 6

i_1 = 15

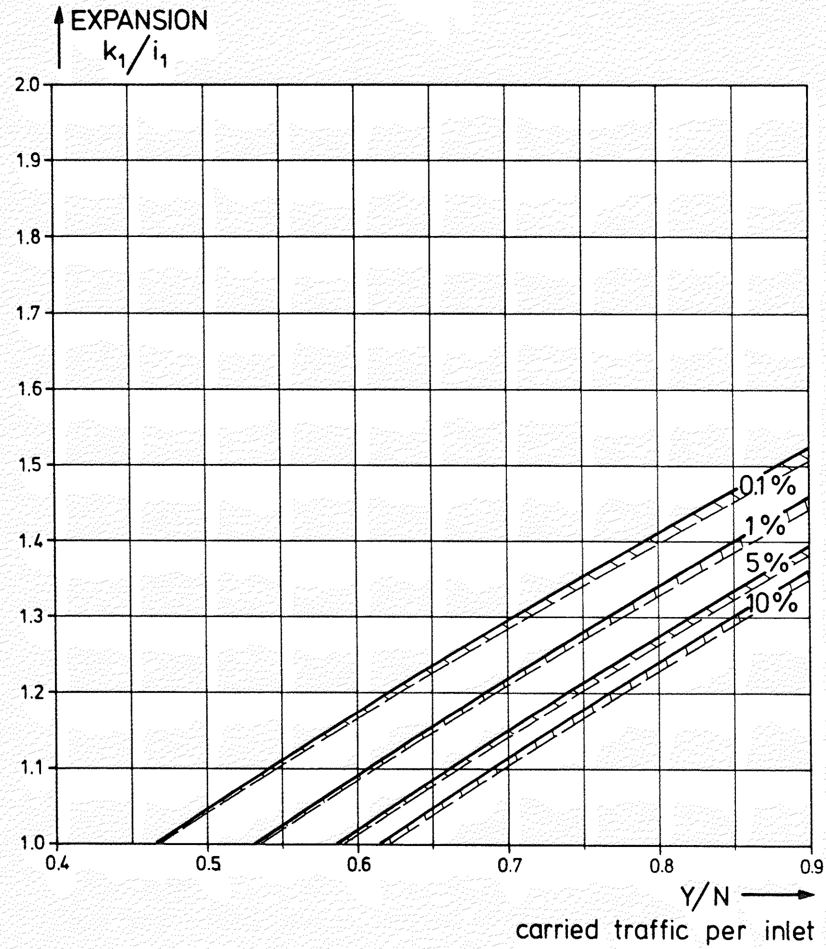
PCT 1

SDM

N = 90 000 } ———
N = 50 625 }

N = 5 625 — — —

PPS



S = 6

i_1 = 16

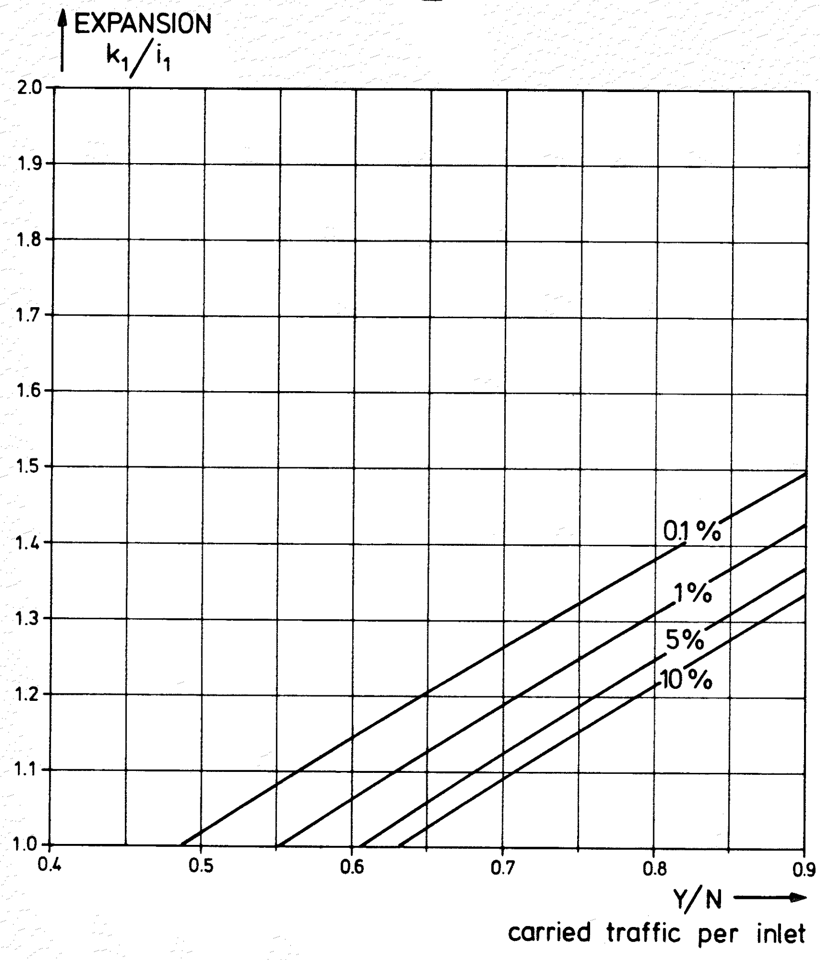
PCT 1

SDM

N = 102 400 } ———
N = 65 536 }

N = 6 400 — — —

PPS



S = 6

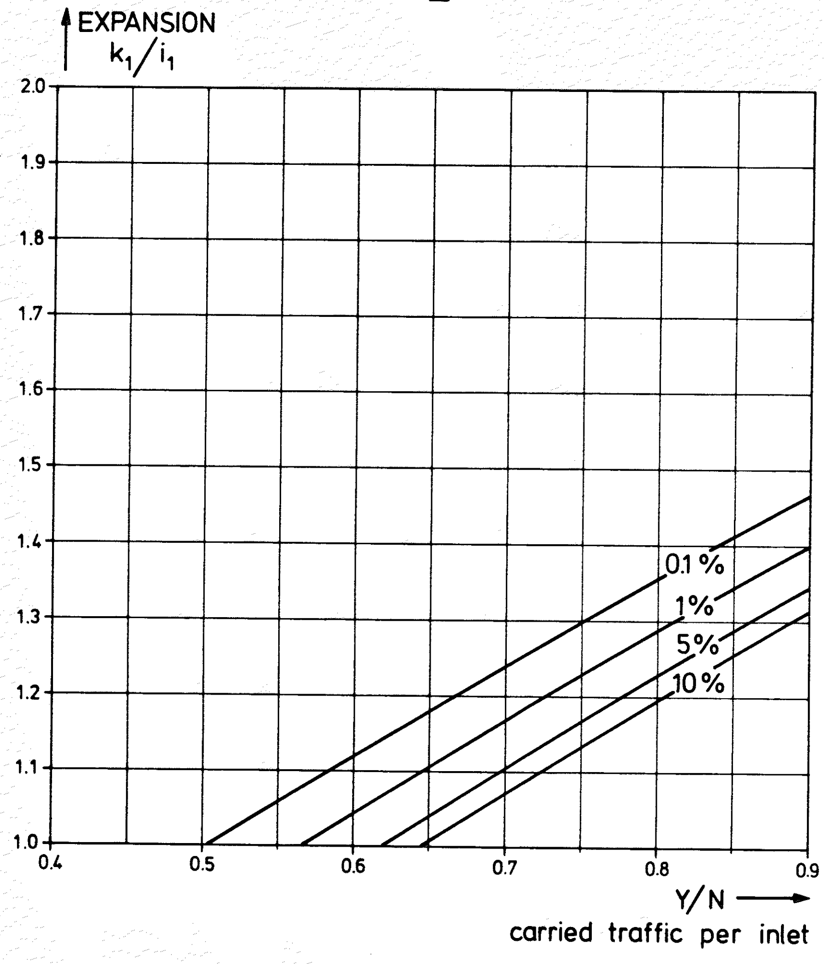
i_1 = 18

PCT 1

SDM

N = 291 600
N = 104 976
N = 32 400

PPS



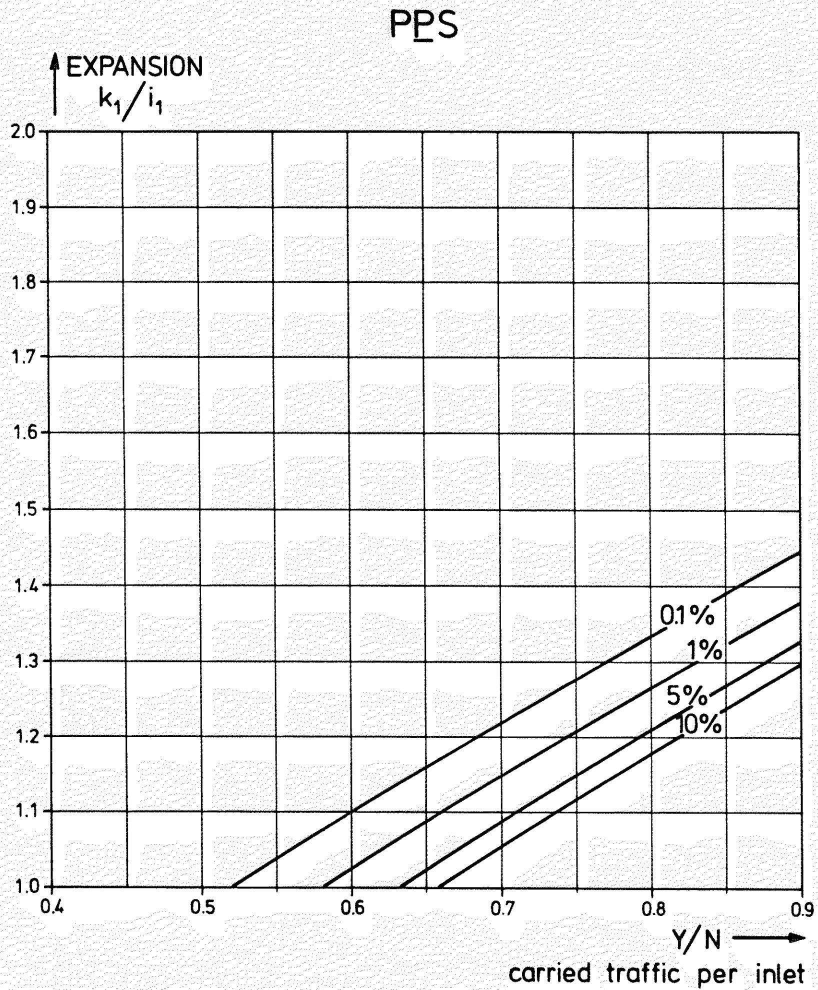
S = 6

i_1 = 20

PCT 1

SDM

N = 360 000
N = 160 000
N = 40 000



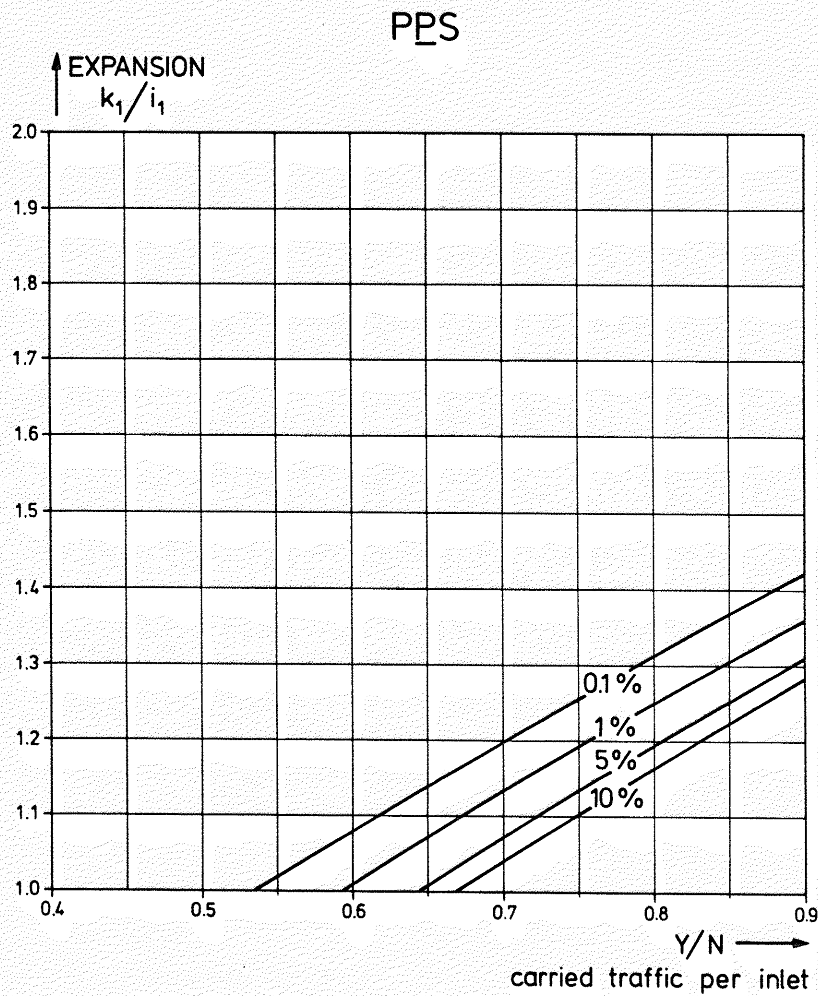
S = 6

i_1 = 22

PCT 1

SDM

N = 435 600
N = 234 256
N = 48 400



S = 6

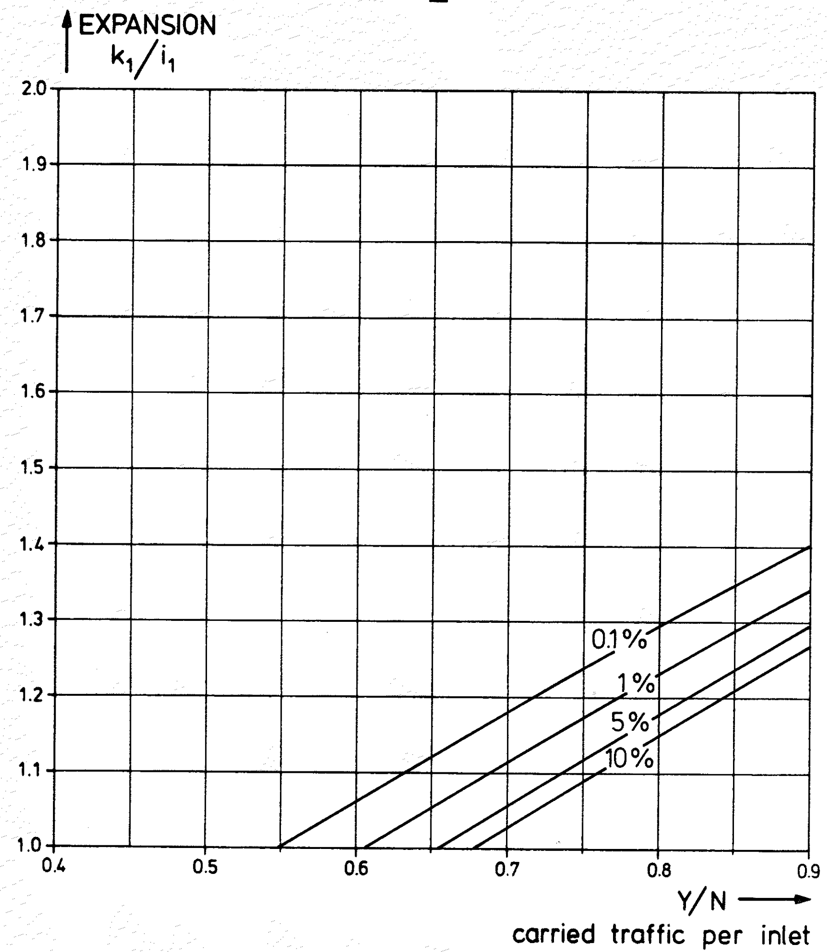
i_1 = 24

PCT 1

SDM

N = 518 400
N = 331 776
N = 57 600

PPS



S = 6

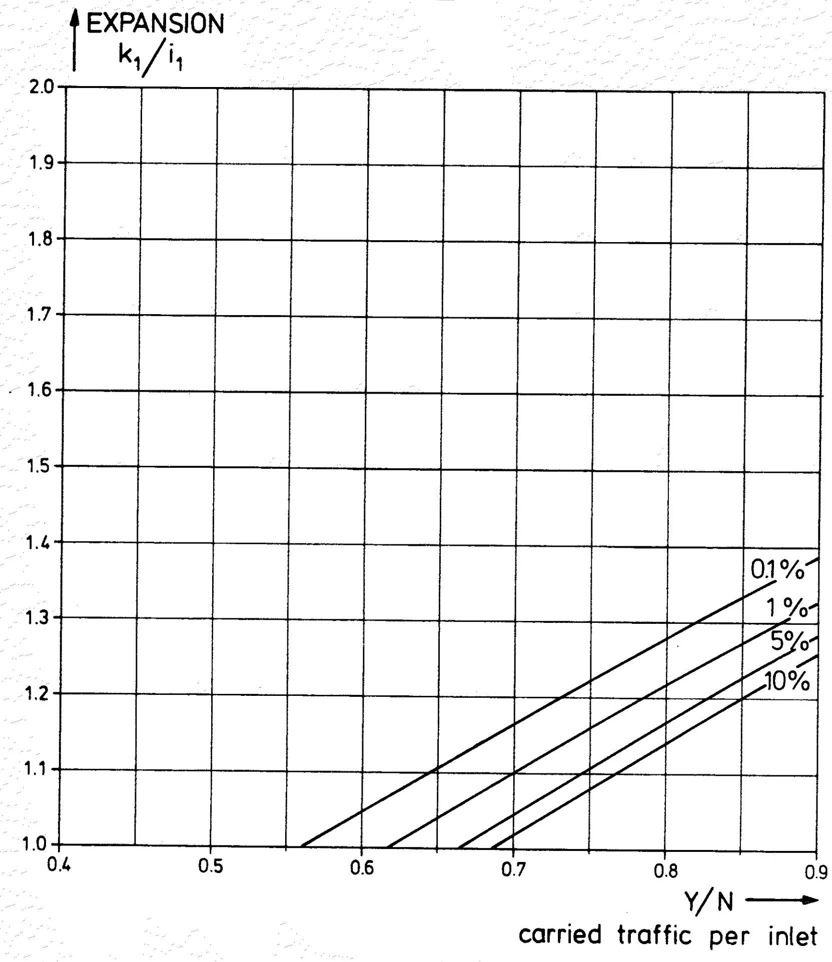
i_1 = 26

PCT 1

SDM

N = 608 400
N = 456 976
N = 67 600

PPS



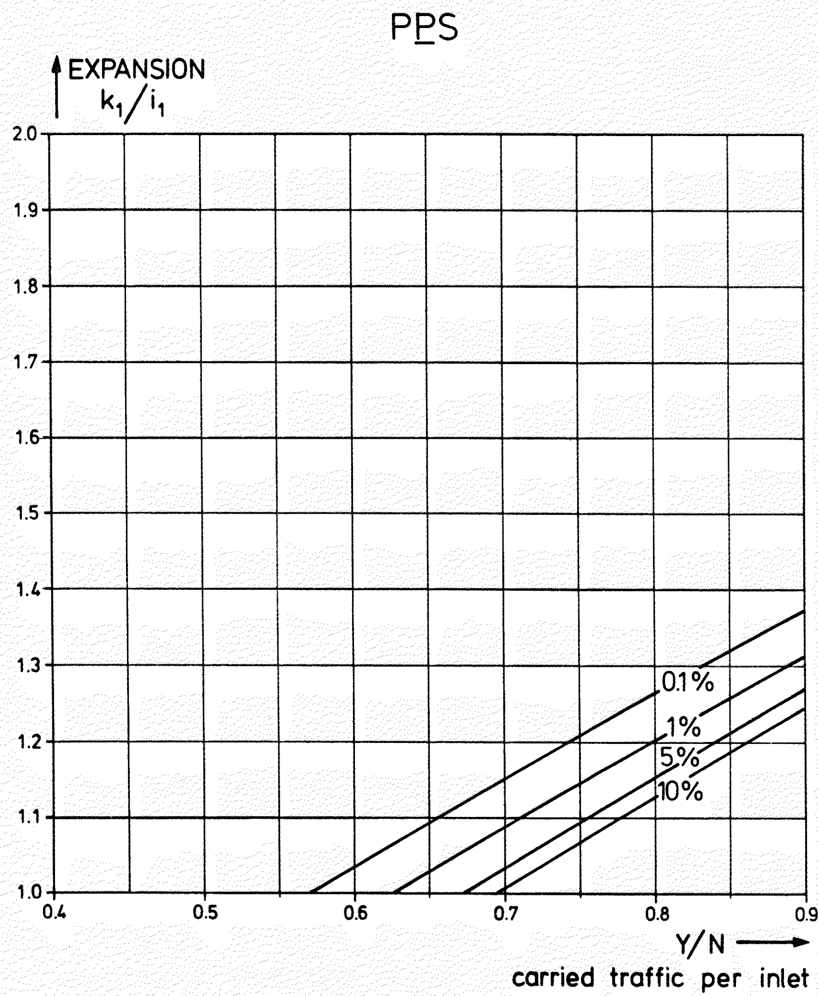
S = 6

i_1 = 28

PCT 1

SDM

N = 1254 400
N = 614 656
N = 78 400



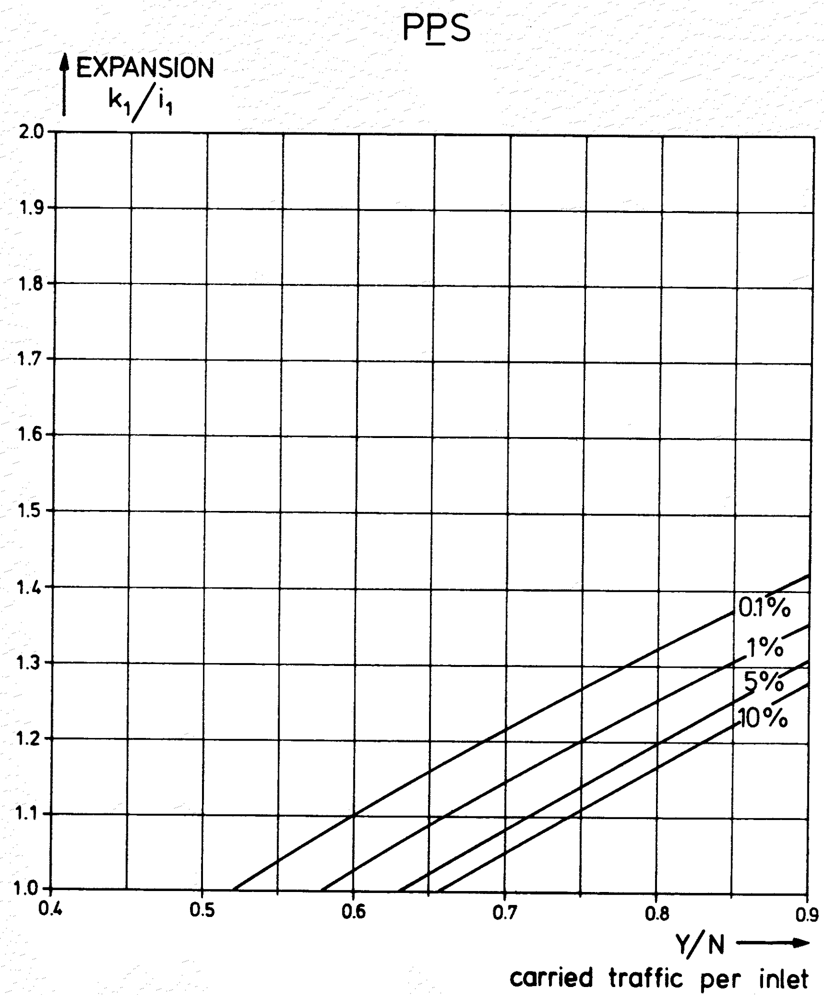
$S = 6$

$i_1 = 30$

PCT 1

SDM

N = 1 440 000
N = 810 000
N = 90 000



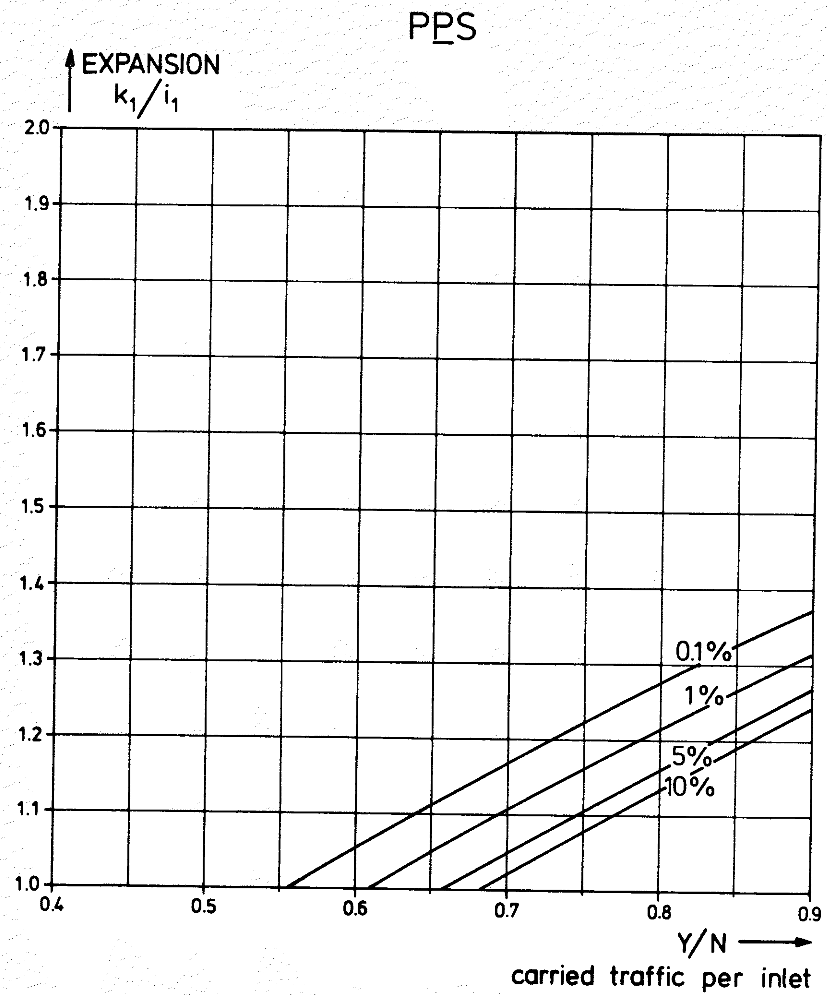
S = 6

i_1 = 24

PCT 1

TDM

N = 518 400
N = 331 776
N = 57600



S = 6

i_1 = 30

PCT 1

TDM

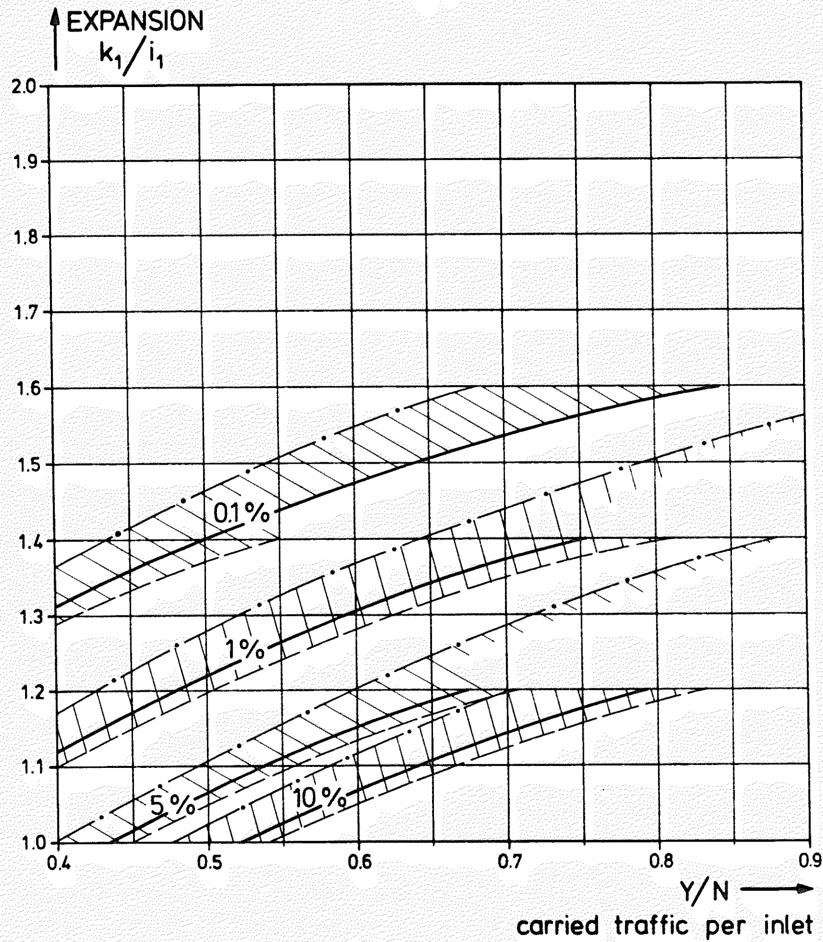
N = 1440 000
N = 810 000
N = 90 000

NIK-CHARTS FOR POINT-TO-POINT SELECTION AND PCT 2

chart 45 .. 88

Number of stages	S = 3, 4, 5, 6
Number of inlets per first stage multiple	i_1 = 5 .. 30
Point-to-point loss (first attempt)	B_{PP}=0.1, 1, 5, 10%
System-to-outgoing group wiring for	SDM: chart 45..54,56..65,67..76,78..87 TDM: chart 55, 66, 77, 88

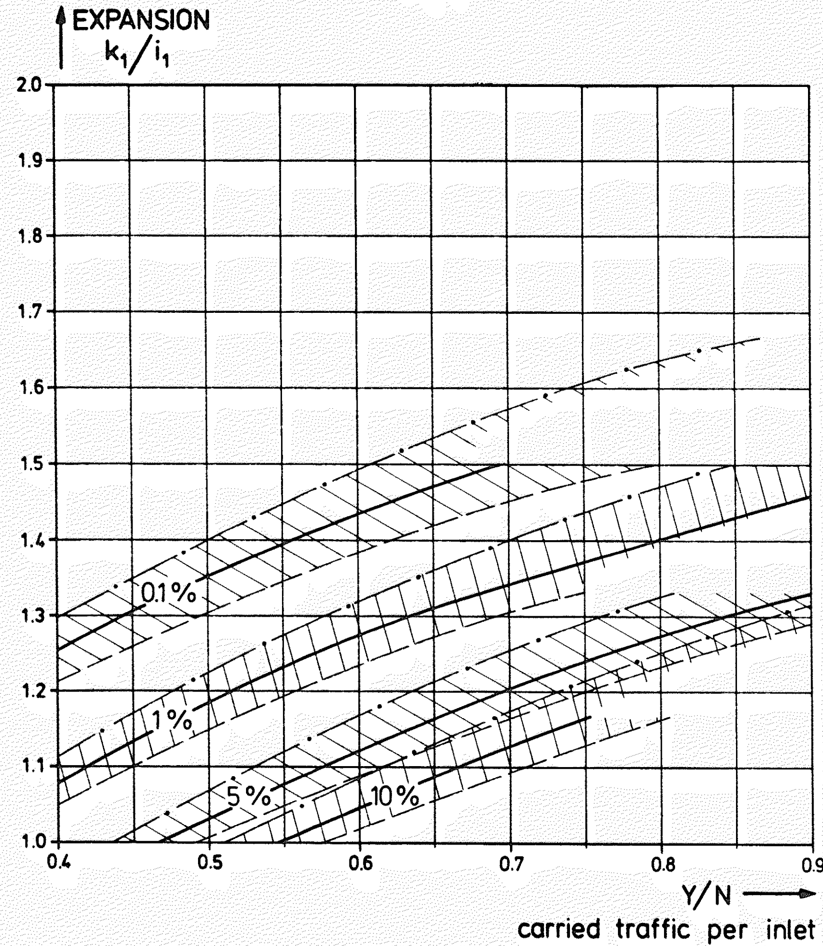
PPS



S = 3
i_1 = 5
PCT 2
SDM

N = 100 —·—
N = 25 ——
N = 20 — — —

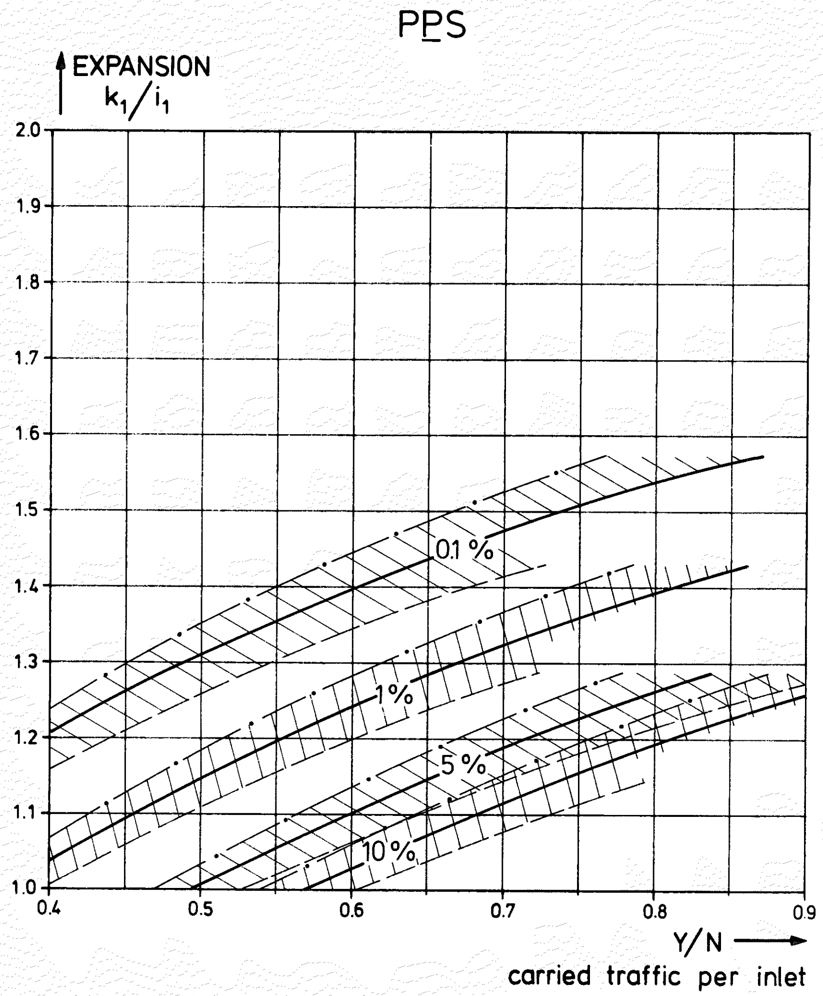
PPS



S = 3
i_1 = 6
PCT 2
SDM

N = 120 —·—
N = 36 ——
N = 24 — — —

THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.



S = 3

i_1 = 7

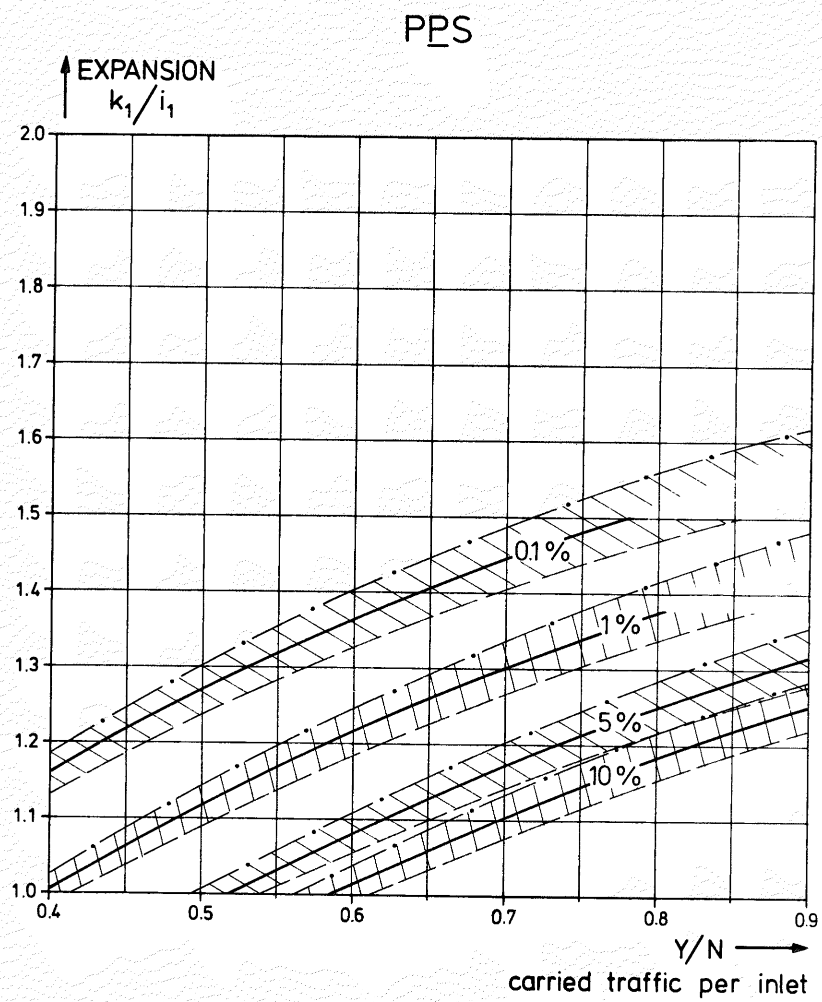
PCT 2

SDM

N = 140 —— · ——

N = 49 ————

N = 28 — — —



S = 3

i_1 = 8

PCT 2

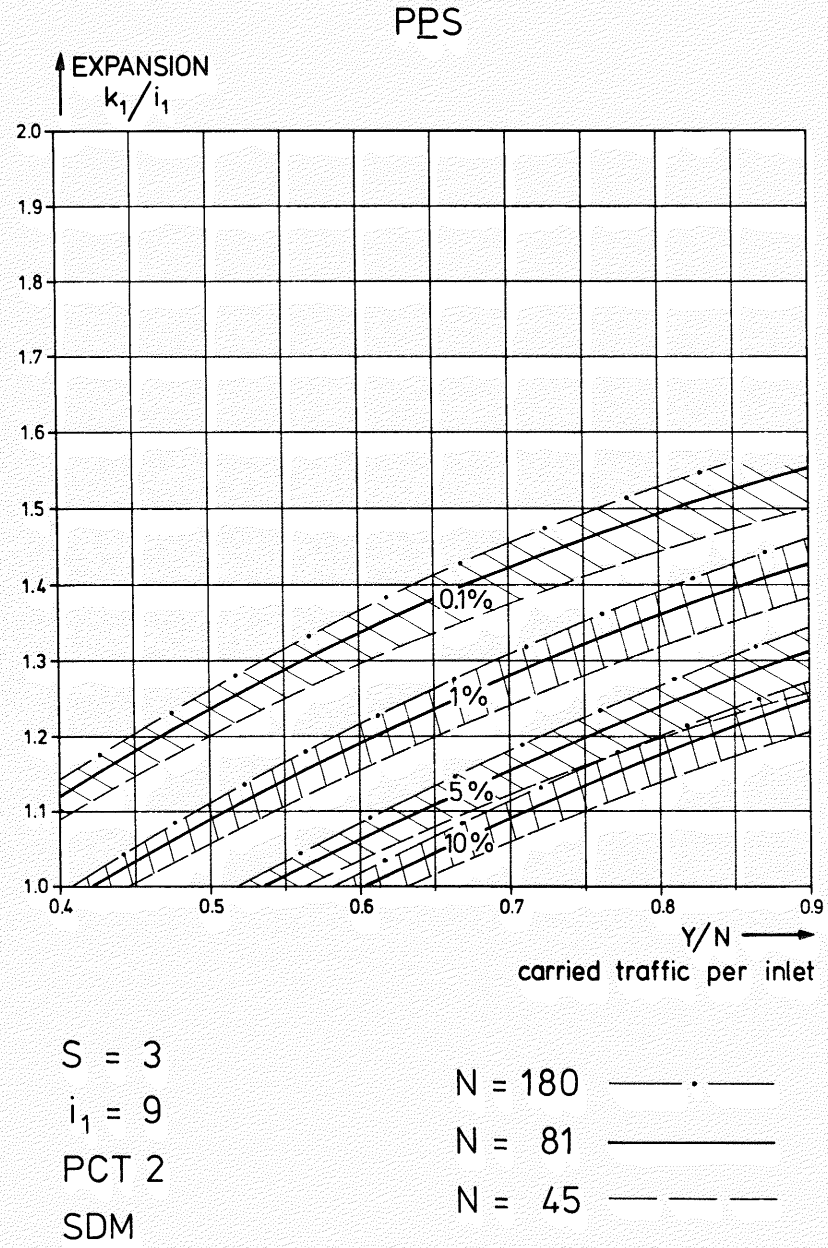
SDM

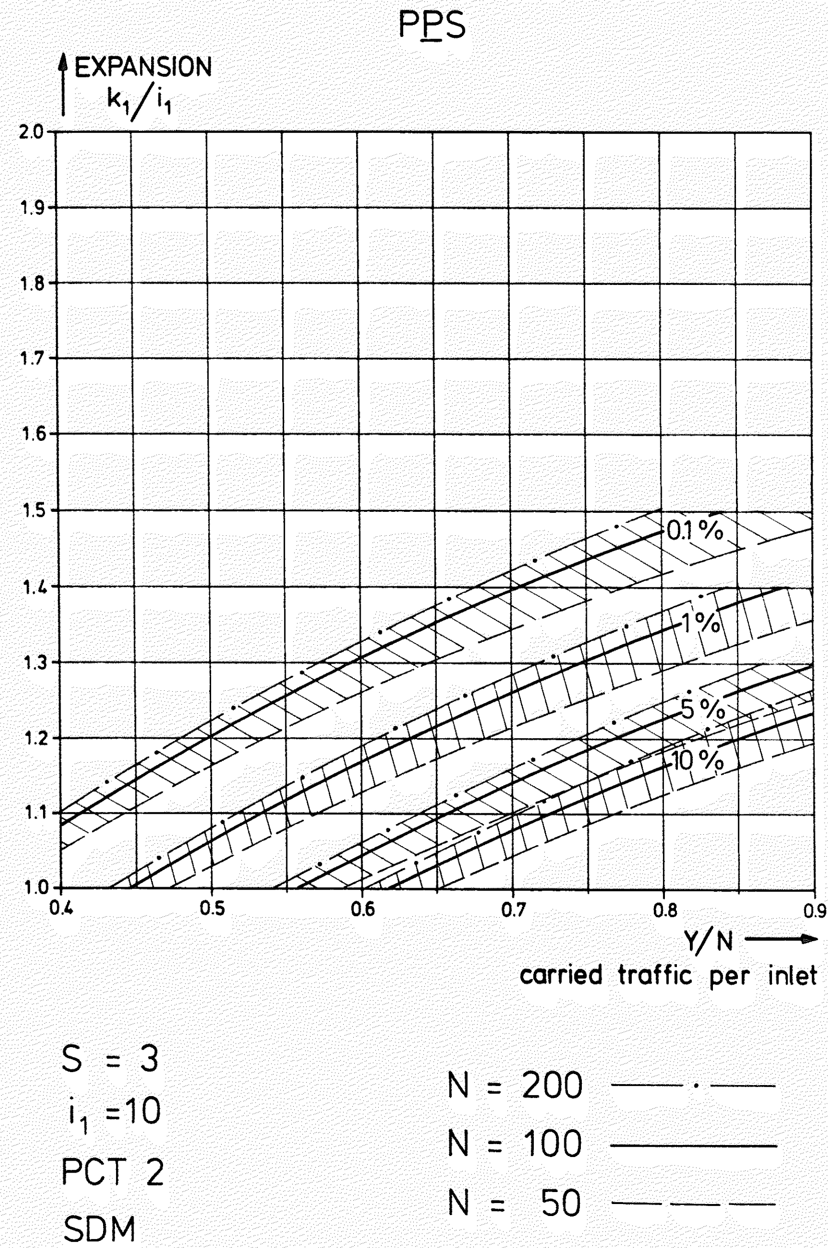
N = 160 —— · ——

N = 64 ————

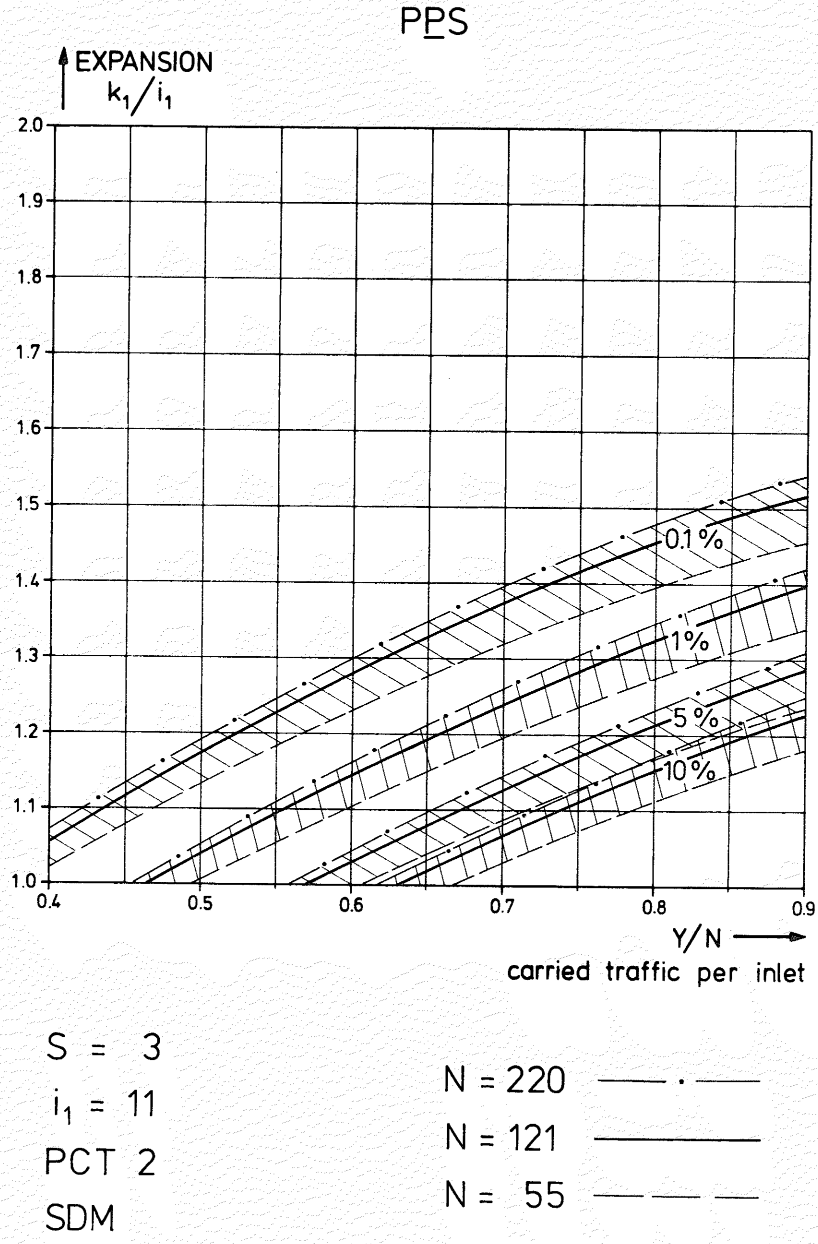
N = 40 — — —

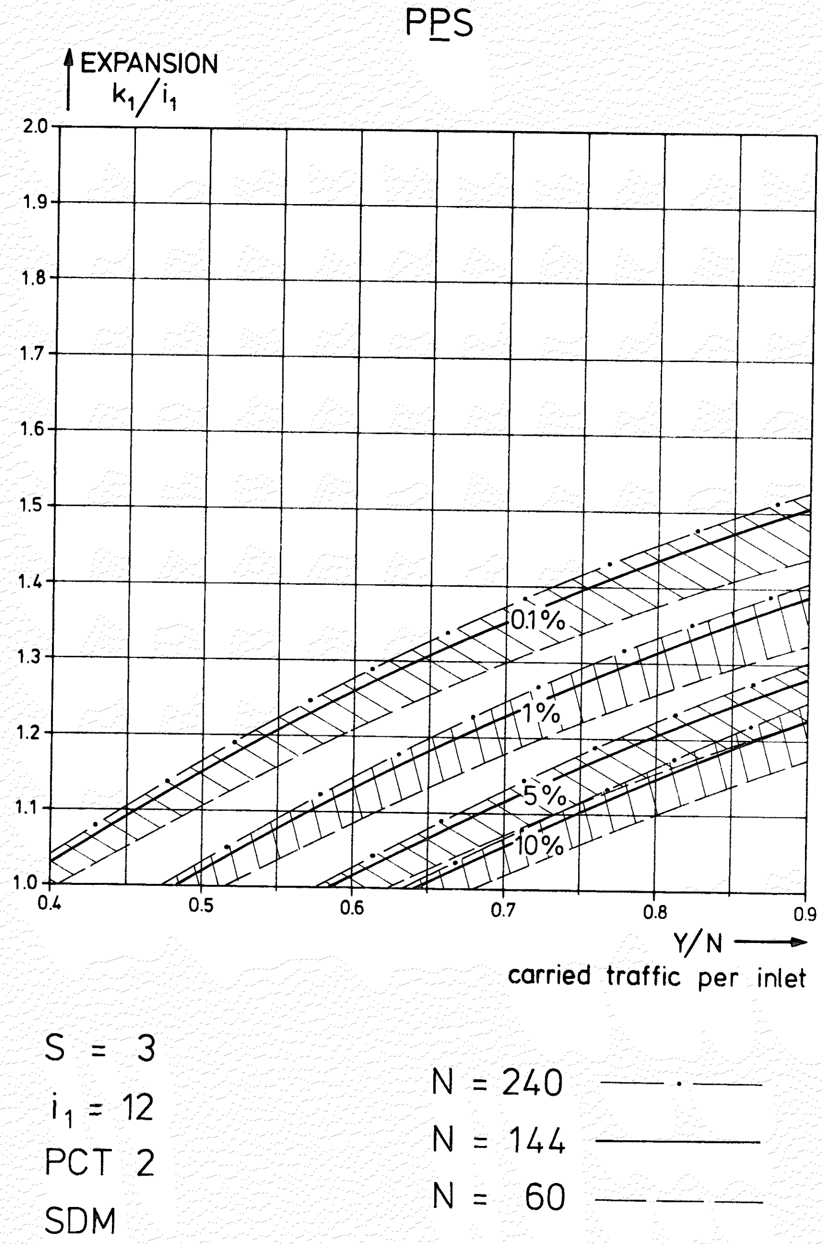
THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.



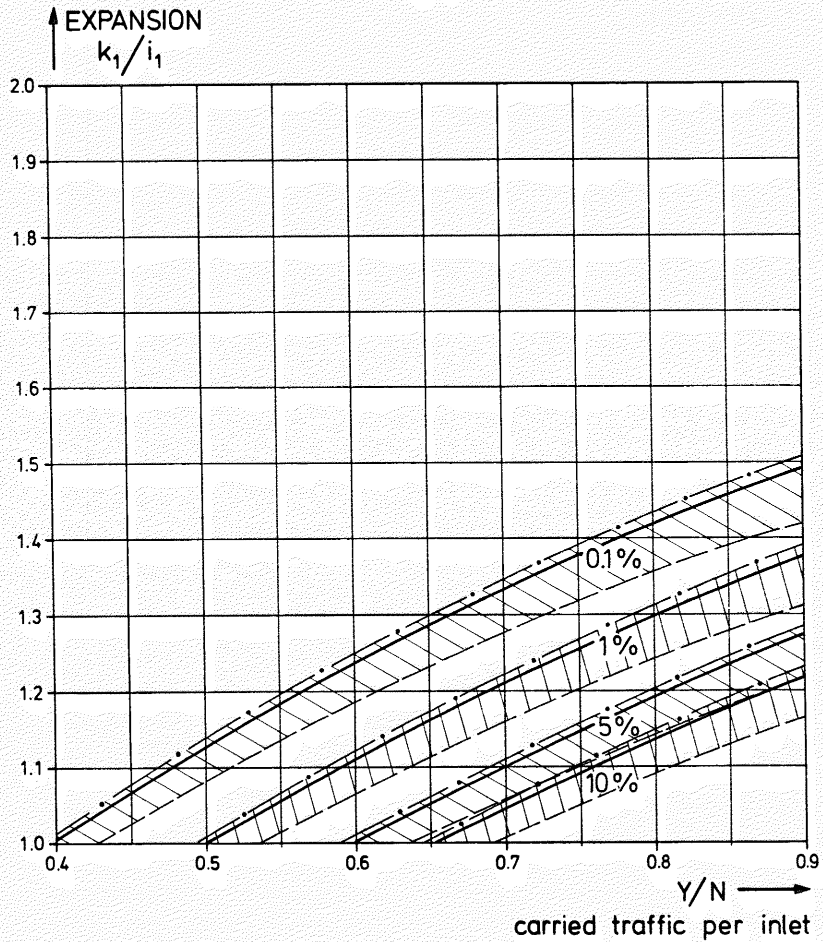


THE CURVES IN THE DIAGRAMS ARE CUT OFF AT THAT POINT WHERE THE NEXT HIGHER INTEGER VALUE OF K_1 WOULD ALLOW THE CARRIED TRAFFIC Y/N TO APPROACH 1.0 ERLANGS PER LINE.


PPS
EXPANSION
k_1/i_1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.1 %
1 %
5 %
10 %
0.4
0.5
0.6
0.7
0.8
0.9
Y/N
carried traffic per inlet
S = 3
i_1 = 11
PCT 2
SDM
N = 220
N = 121
N = 55


PPS
EXPANSION
k_1/i_1
2.0
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.1 %
1 %
5 %
10 %
0.4
0.5
0.6
0.7
0.8
0.9
Y/N
carried traffic per inlet
S = 3
i_1 = 12
PCT 2
SDM
N = 240
N = 144
N = 60

PPS



S = 3

i_1 = 13

PCT 2

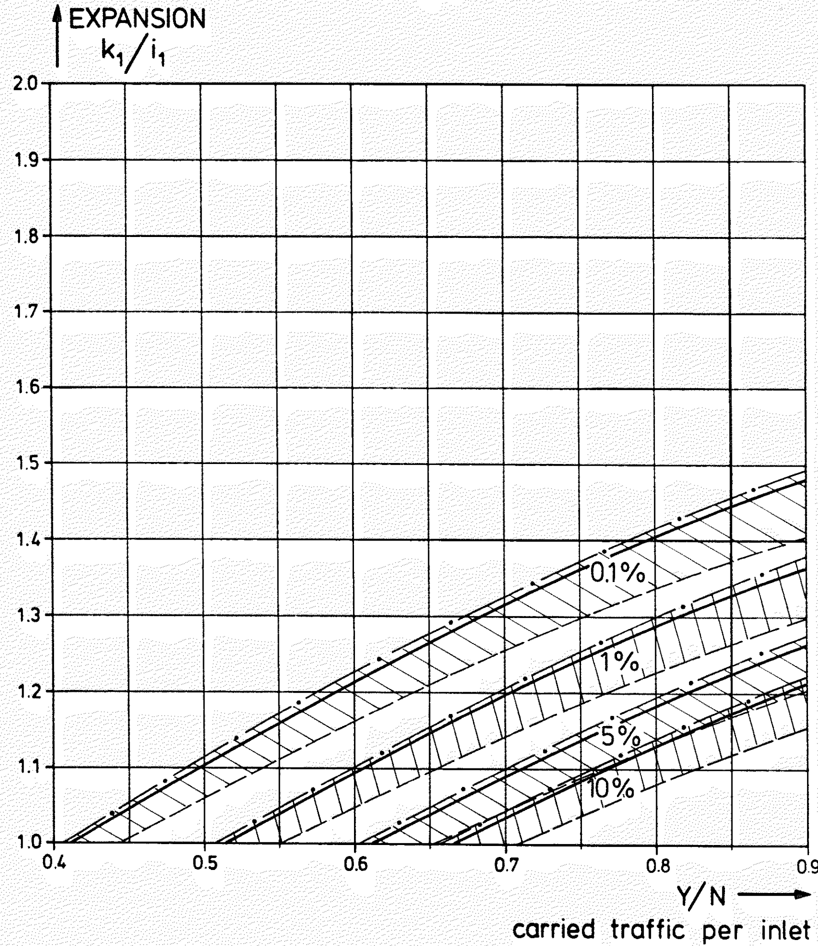
SDM

N = 260 —— · ——

N = 169 ————

N = 65 — — —

PPS



S = 3

i_1 = 14

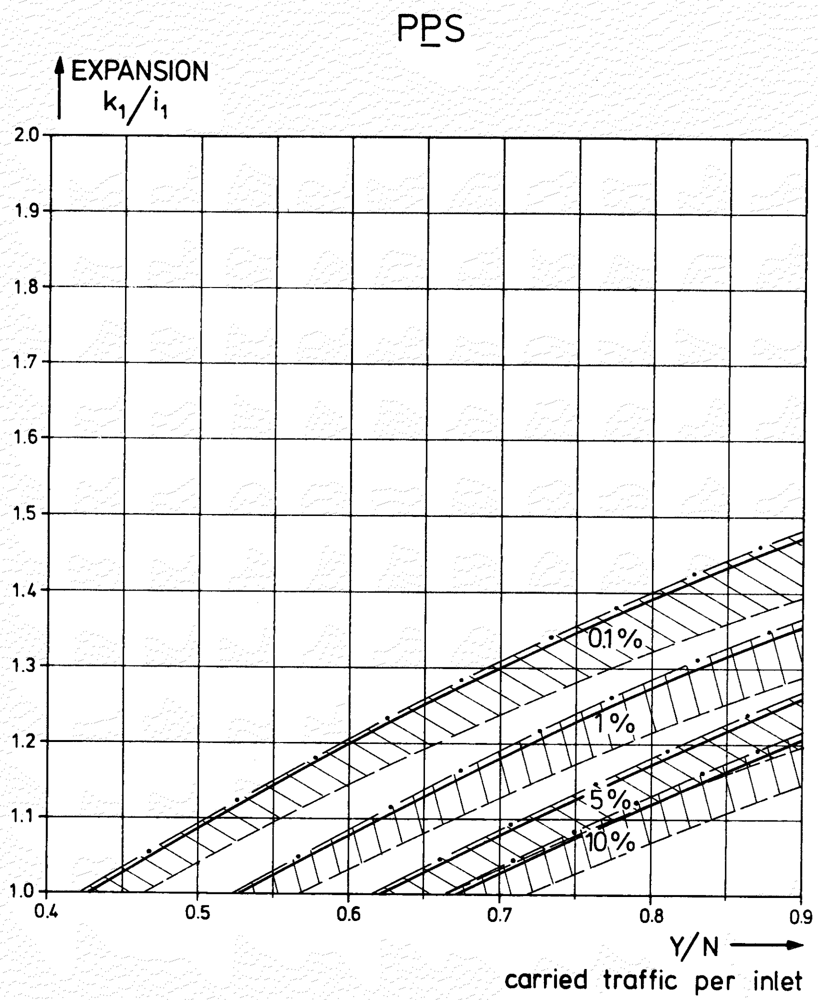
PCT 2

SDM

N = 280 —— · ——

N = 196 ————

N = 70 — — —



S = 3

i_1 = 15

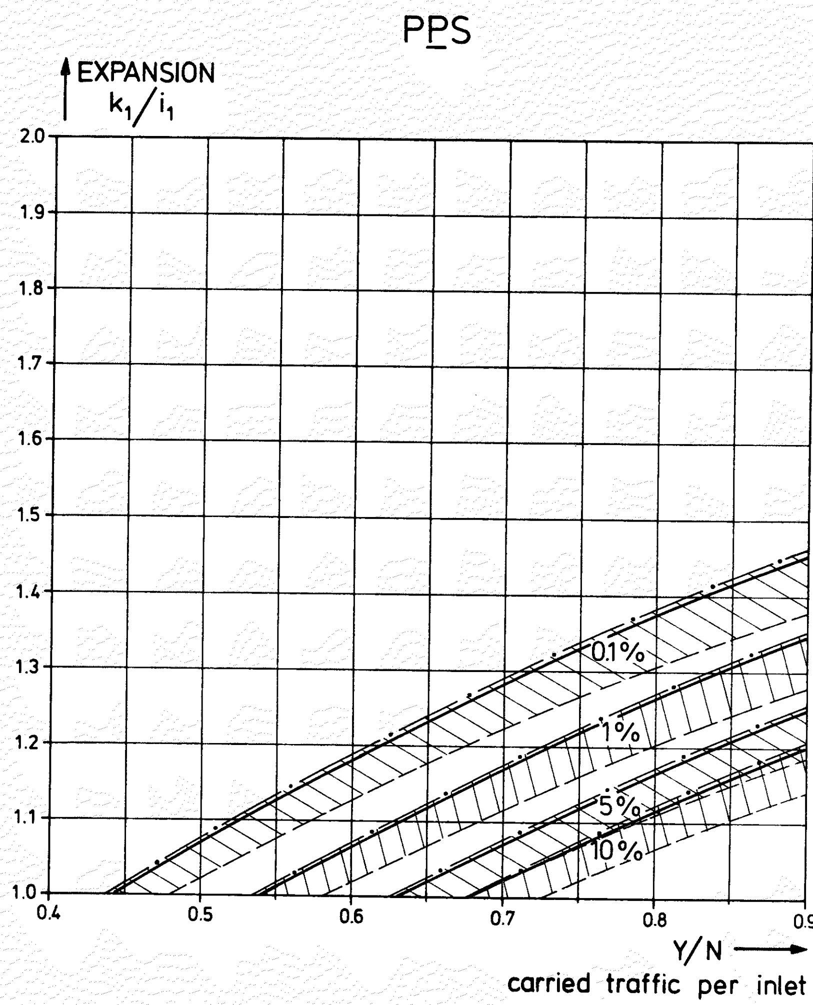
PCT 2

SDM

N = 300 —·—

N = 225 ——

N = 75 — — —



S = 3

i_1 = 16

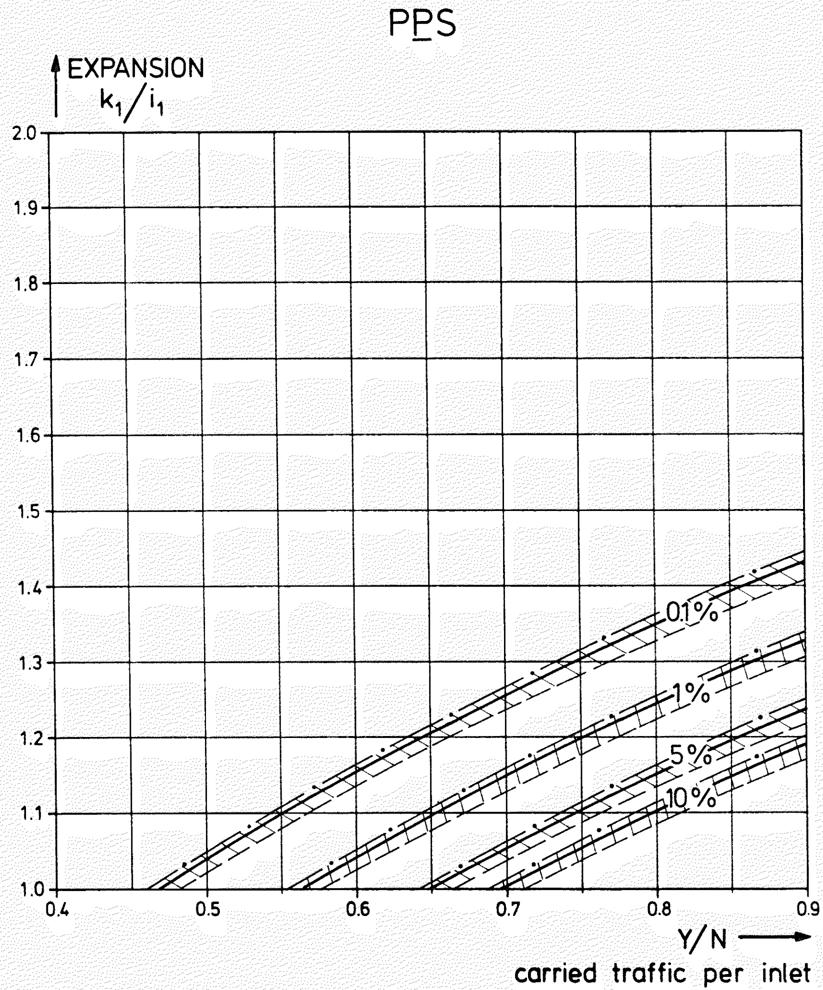
PCT 2

SDM

N = 320 —·—

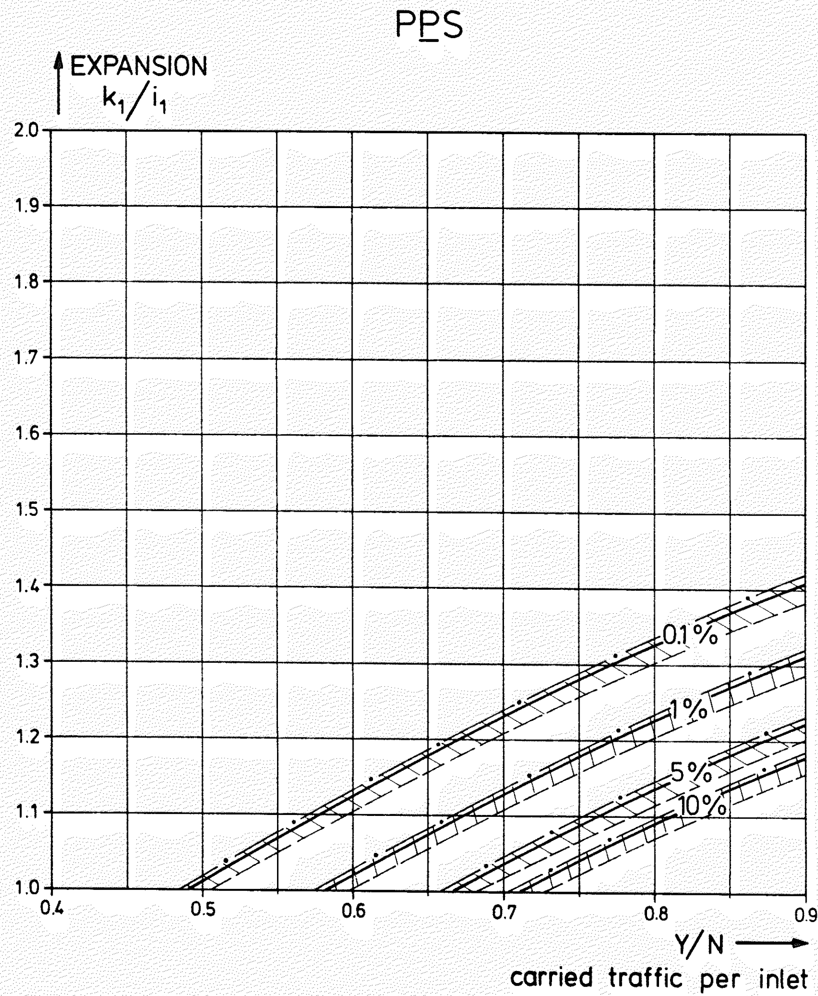
N = 256 ——

N = 80 — — —



S = 3
i_1 = 18
PCT 2
SDM

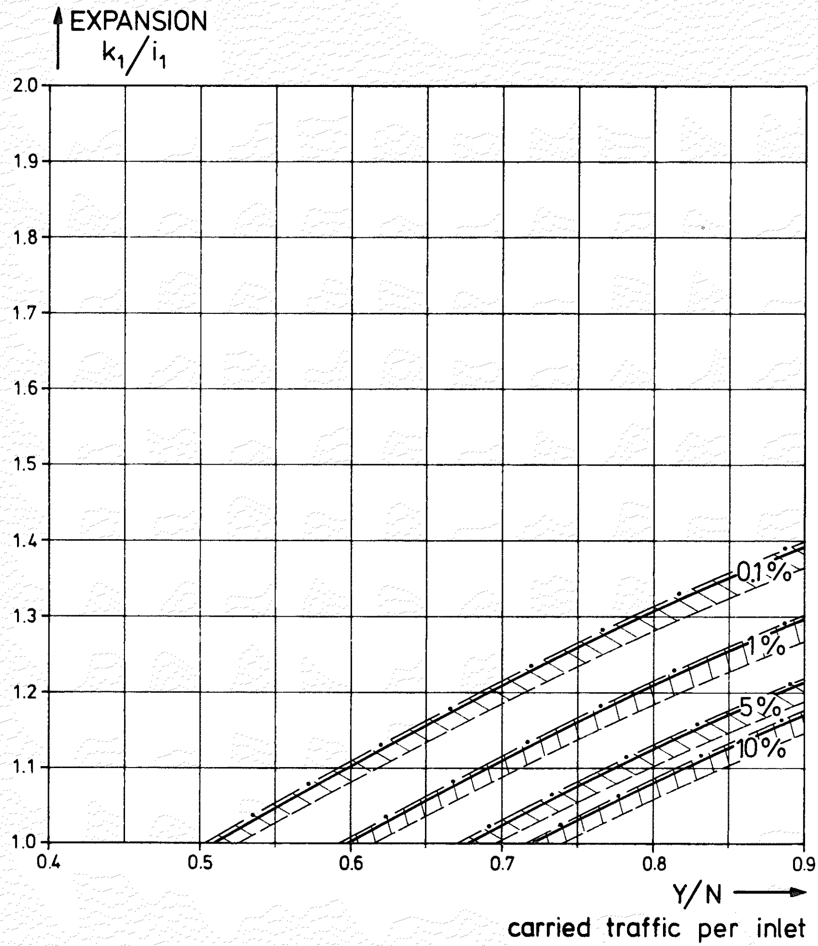
N = 540 —·—
N = 324 ——
N = 180 — — —



S = 3
i_1 = 20
PCT 2
SDM

N = 600 —·—
N = 400 ——
N = 200 — — —

PPS



S = 3

i_1 = 22

PCT 2

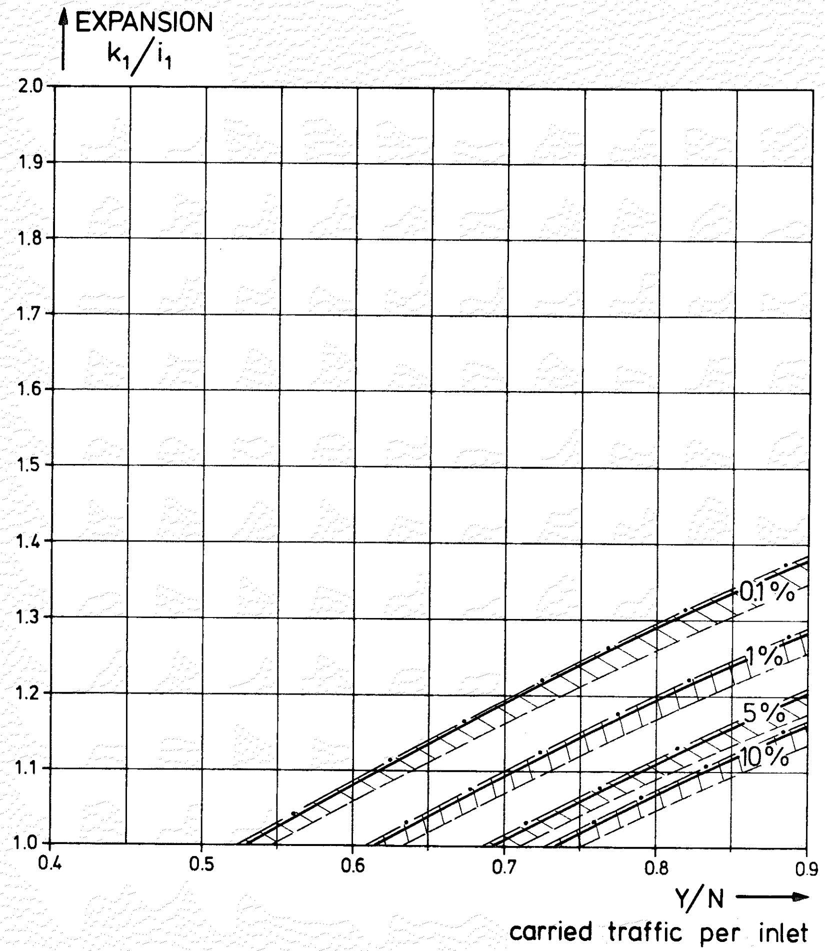
SDM

N = 660 —— · ——

N = 484 ————

N = 220 — — —

PPS



S = 3

i_1 = 24

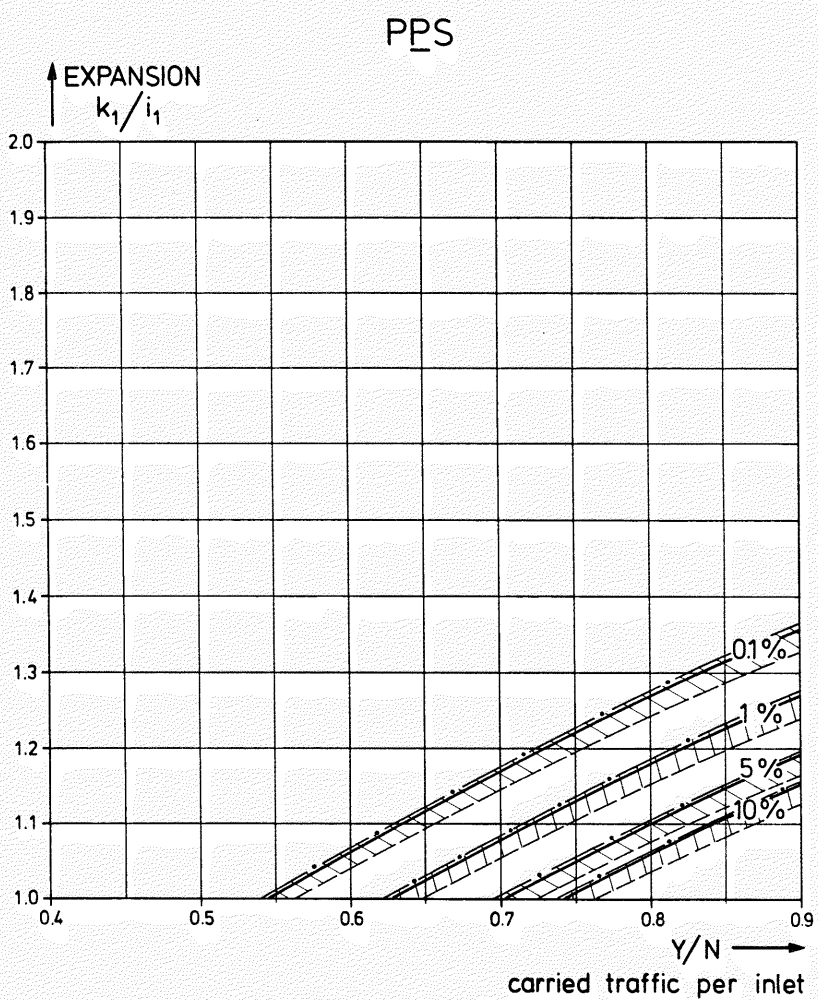
PCT 2

SDM

N = 720 —— · ——

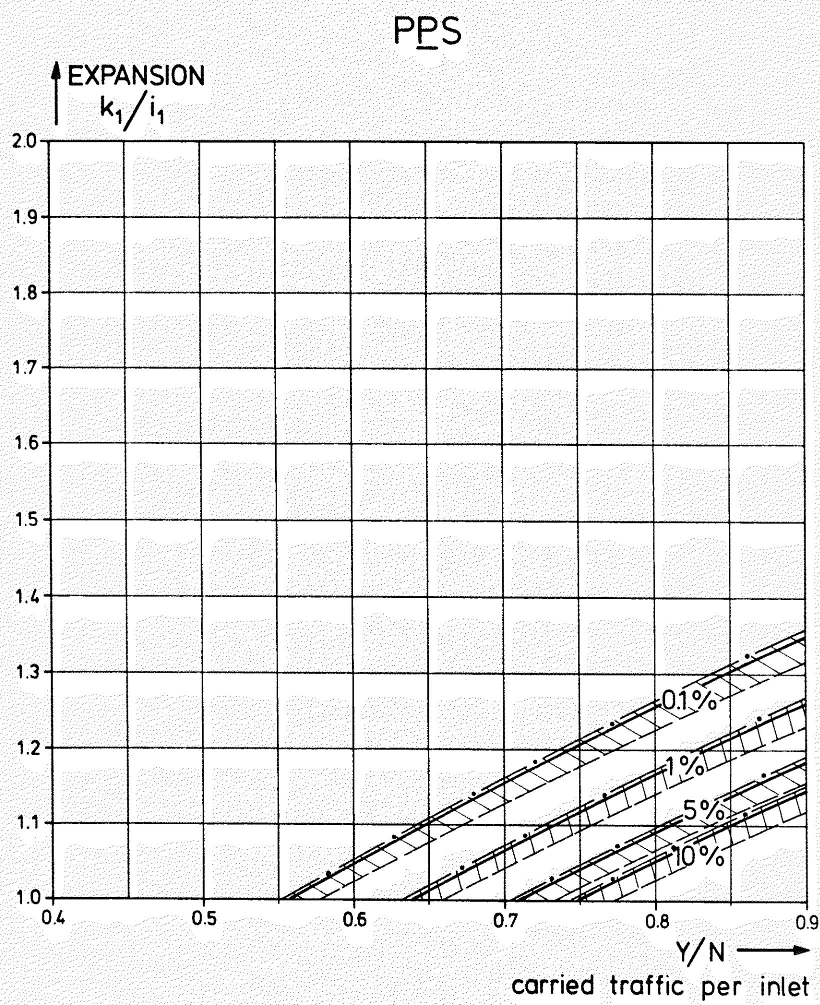
N = 576 ————

N = 240 — — —



S = 3
i_1 = 26
PCT 2
SDM

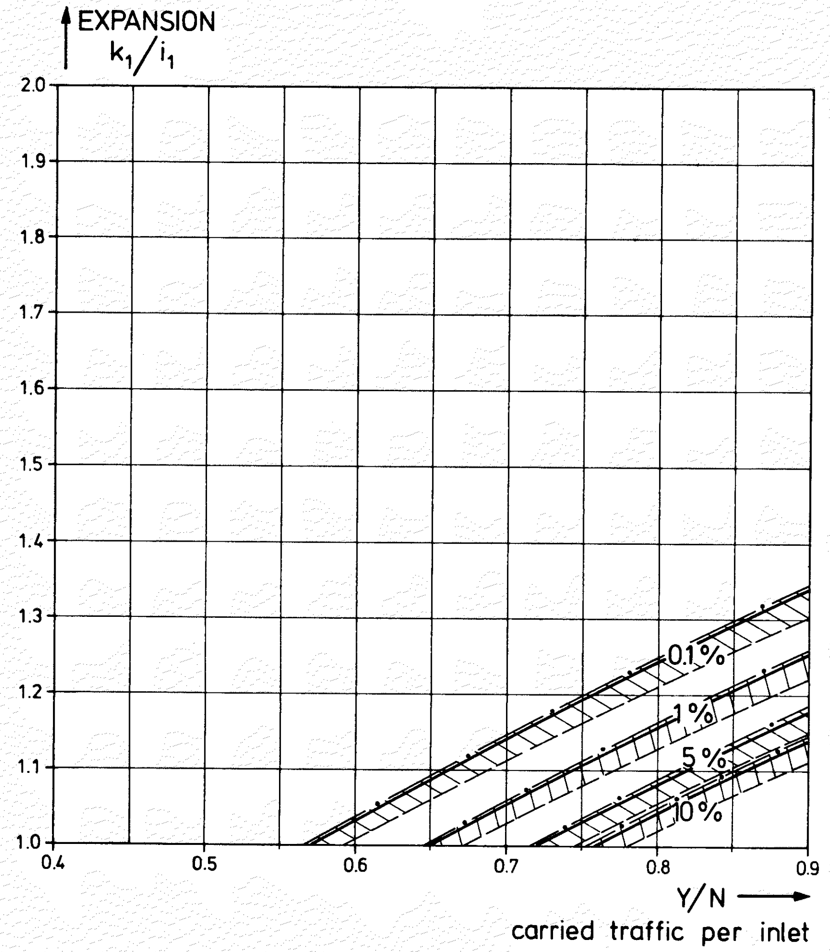
N = 780 —·—
N = 676 ——
N = 260 — — —



S = 3
i_1 = 28
PCT 2
SDM

N = 1120 —·—
N = 784 ——
N = 280 — — —

PPS



S = 3

i_1 = 30

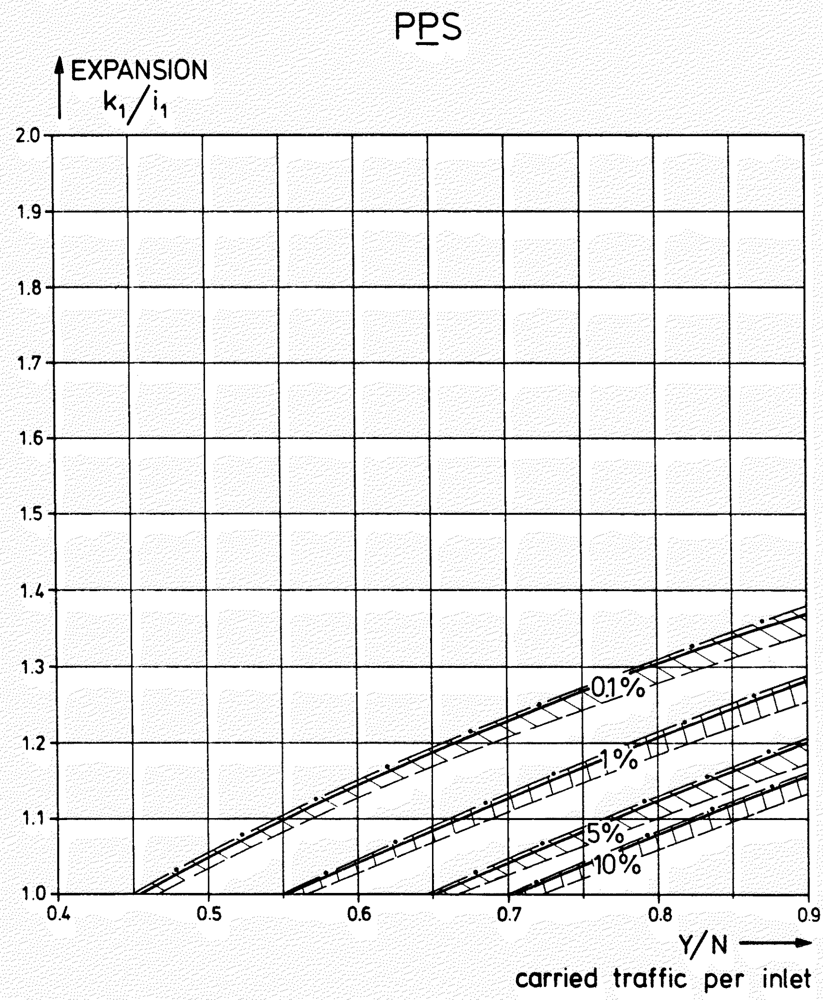
PCT 2

SDM

N = 1200 —·—

N = 900 ——

N = 300 — — —



S = 3

i_1 = 24

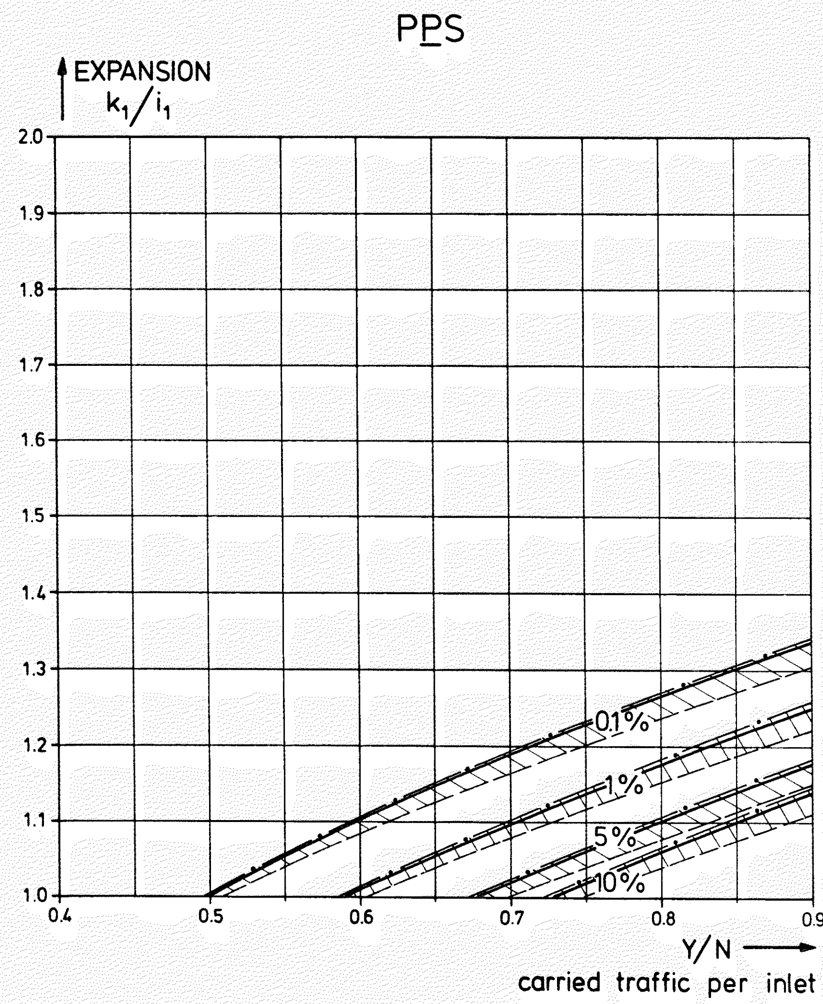
PCT 2

TDM

N = 720 ——·——

N = 576 ————

N = 240 — — —



S = 3

i_1 = 30

PCT 2

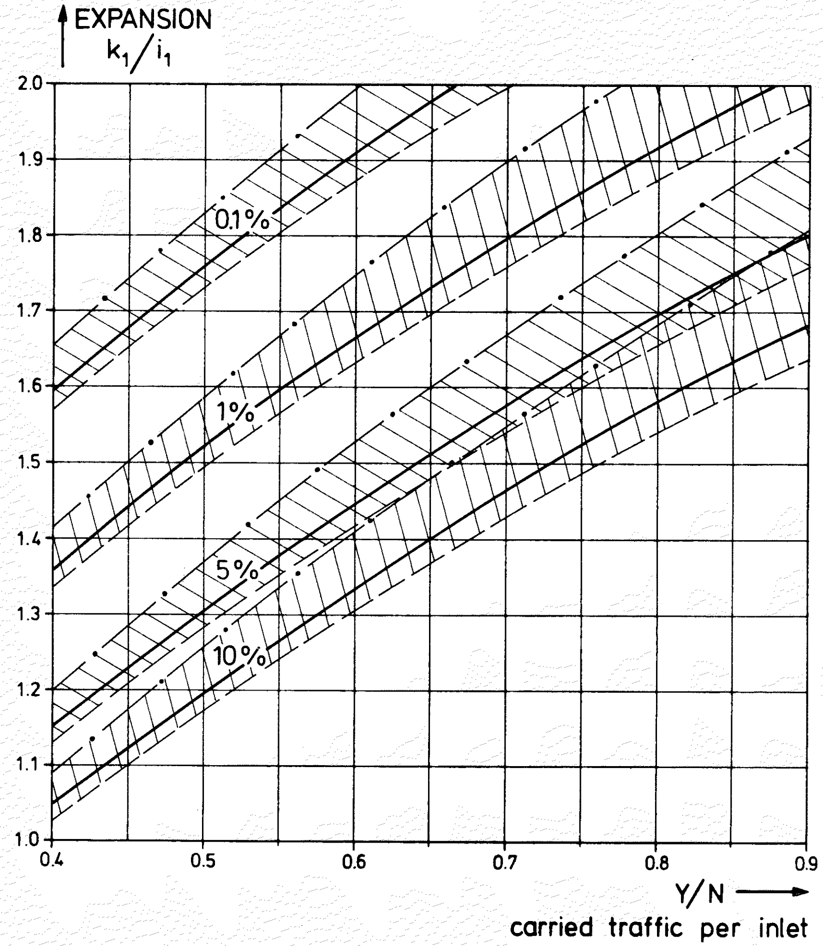
TDM

N = 1 200 ——·——

N = 900 ————

N = 300 — — —

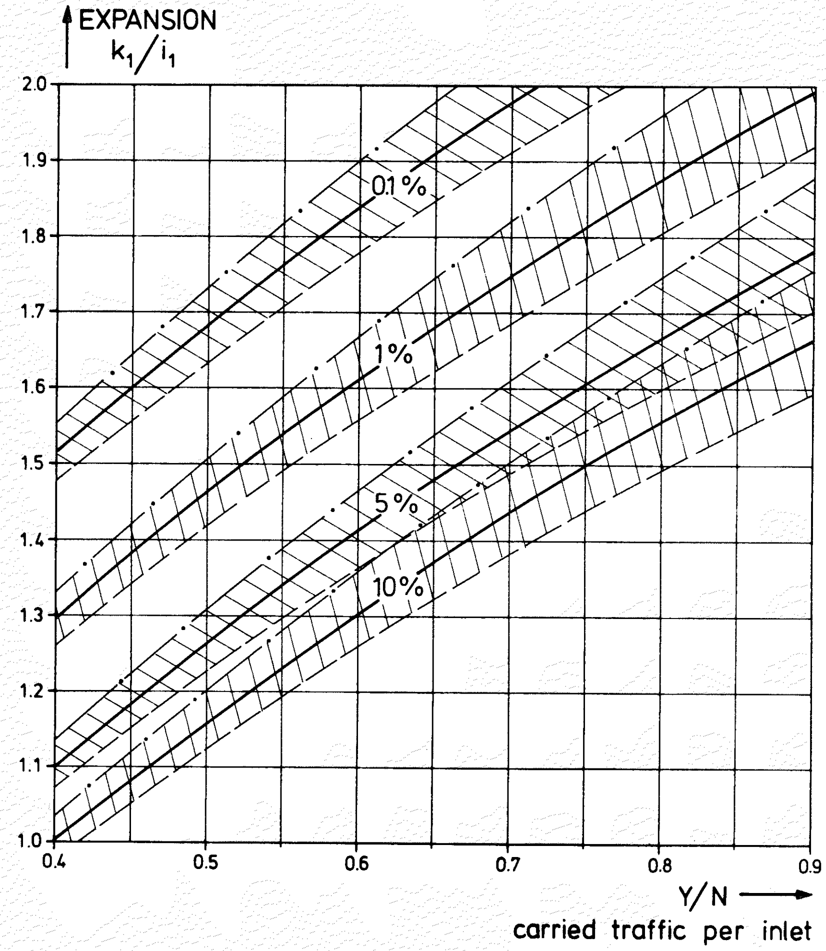
PPS



S = 4
i_1 = 5
PCT 2
SDM

N = 2000 —·—
N = 125 ——
N = 80 — — —

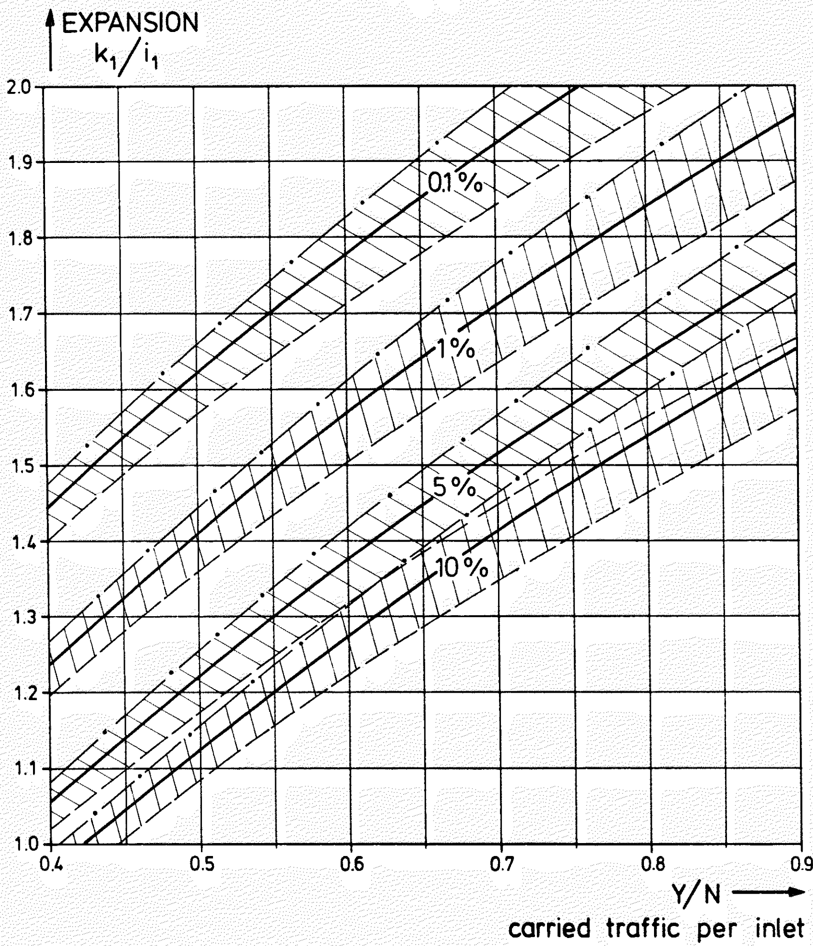
PPS



S = 4
i_1 = 6
PCT 2
SDM

N = 2400 —·—
N = 216 ——
N = 96 — — —

PPS



S = 4

i_1 = 7

PCT 2

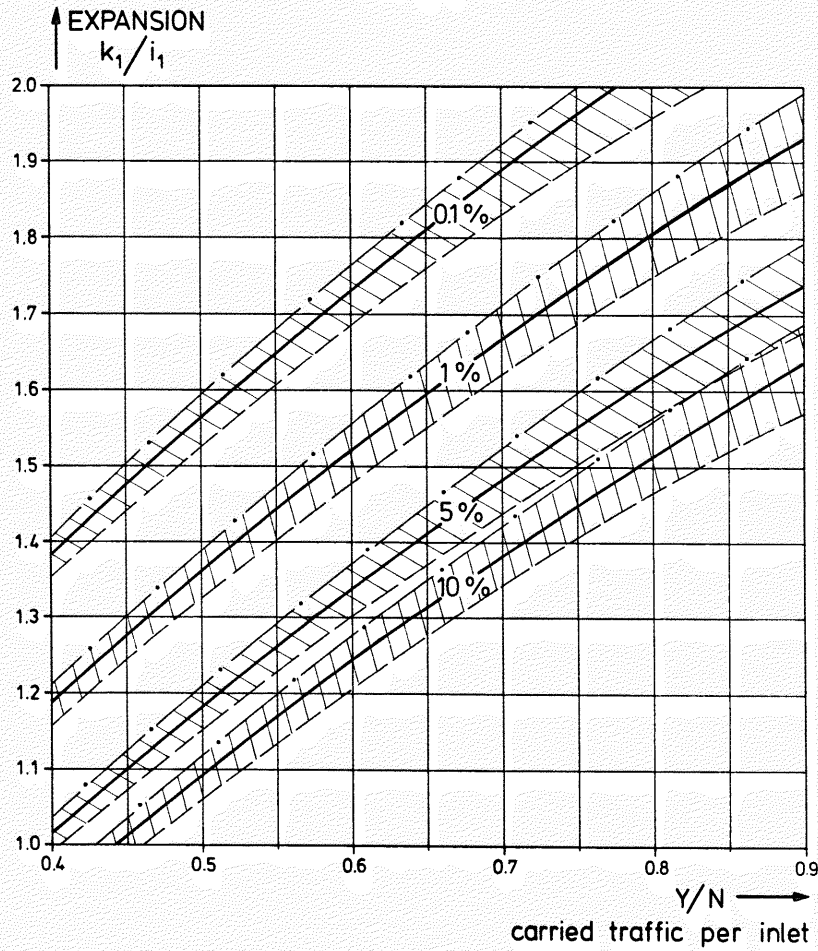
SDM

N = 2 800 —·—

N = 343 ———

N = 112 — — —

PPS



S = 4

i_1 = 8

PCT 2

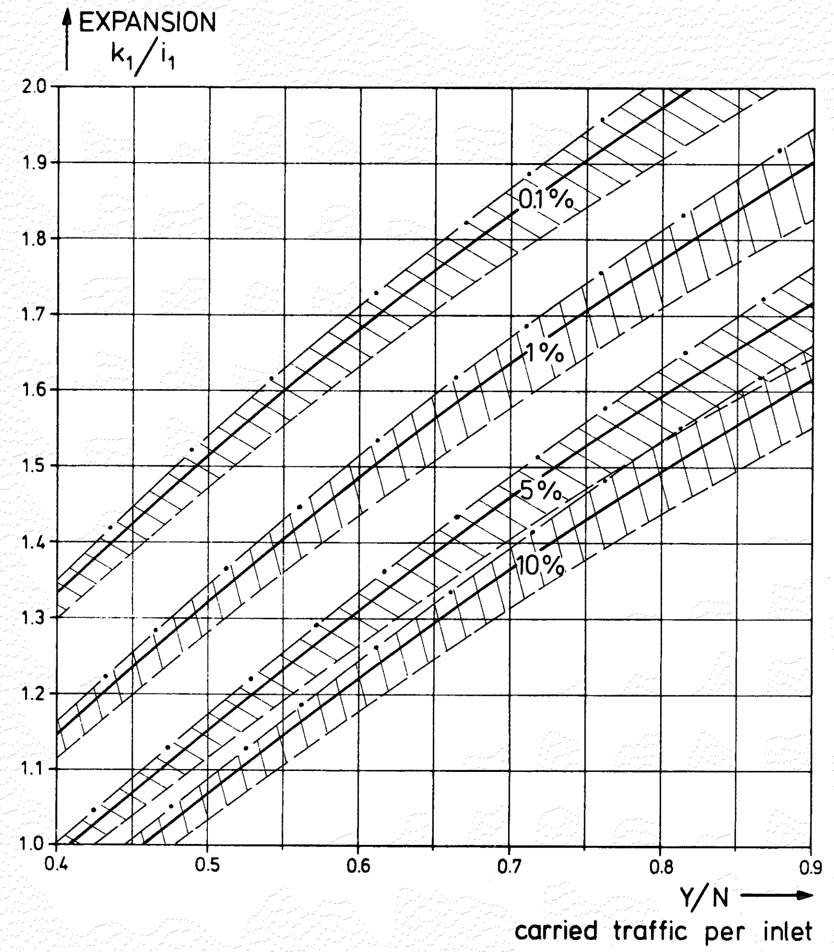
SDM

N = 3 200 —·—

N = 512 ———

N = 200 — — —

PPS



$S = 4$

$i_1 = 9$

PCT 2

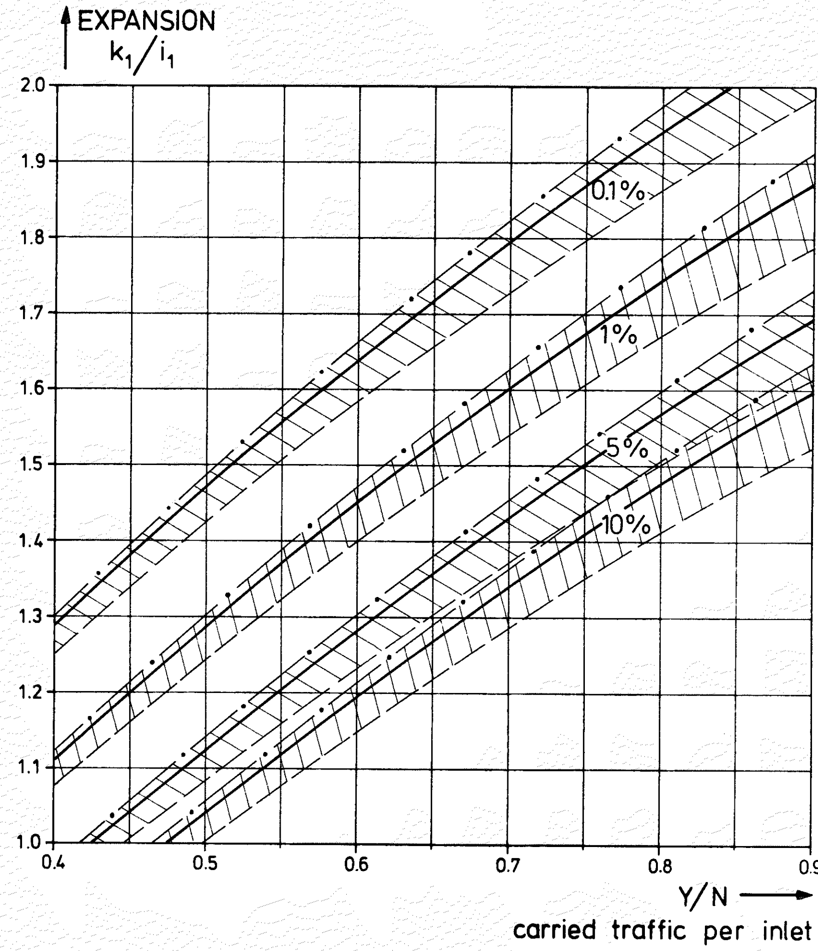
SDM

N = 3 600 —·—

N = 729 ——

N = 225 — — —

PPS



$S = 4$

$i_1 = 10$

PCT 2

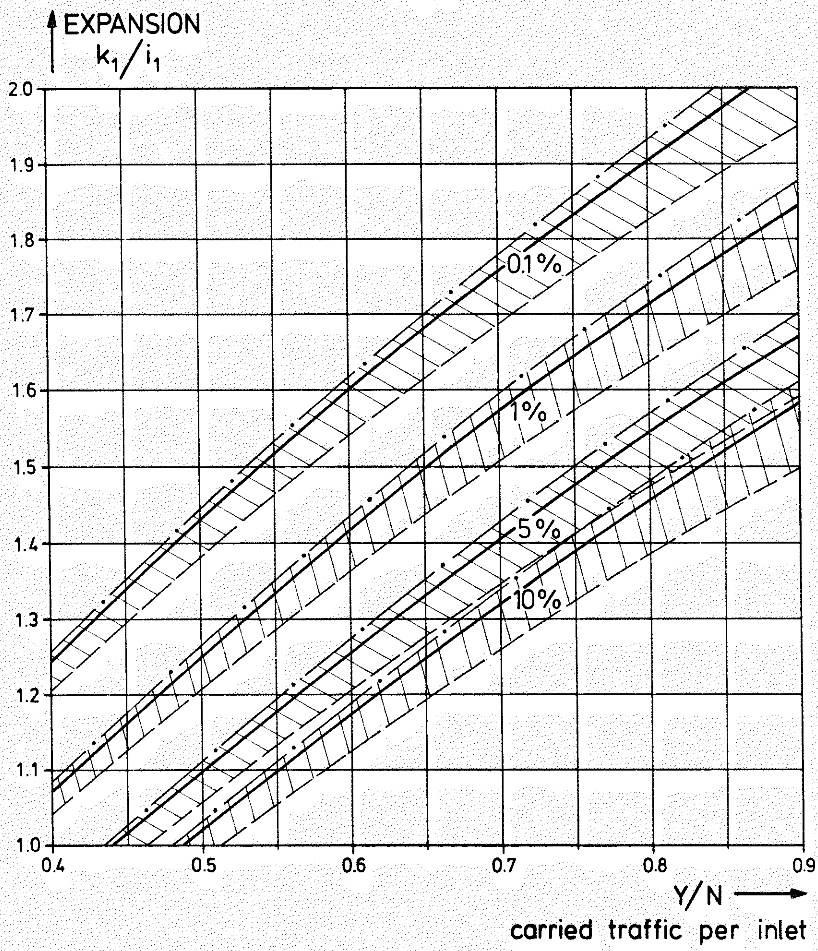
SDM

N = 4 000 —·—

N = 1 000 ——

N = 250 — — —

PPS



S = 4

i_1 = 11

PCT 2

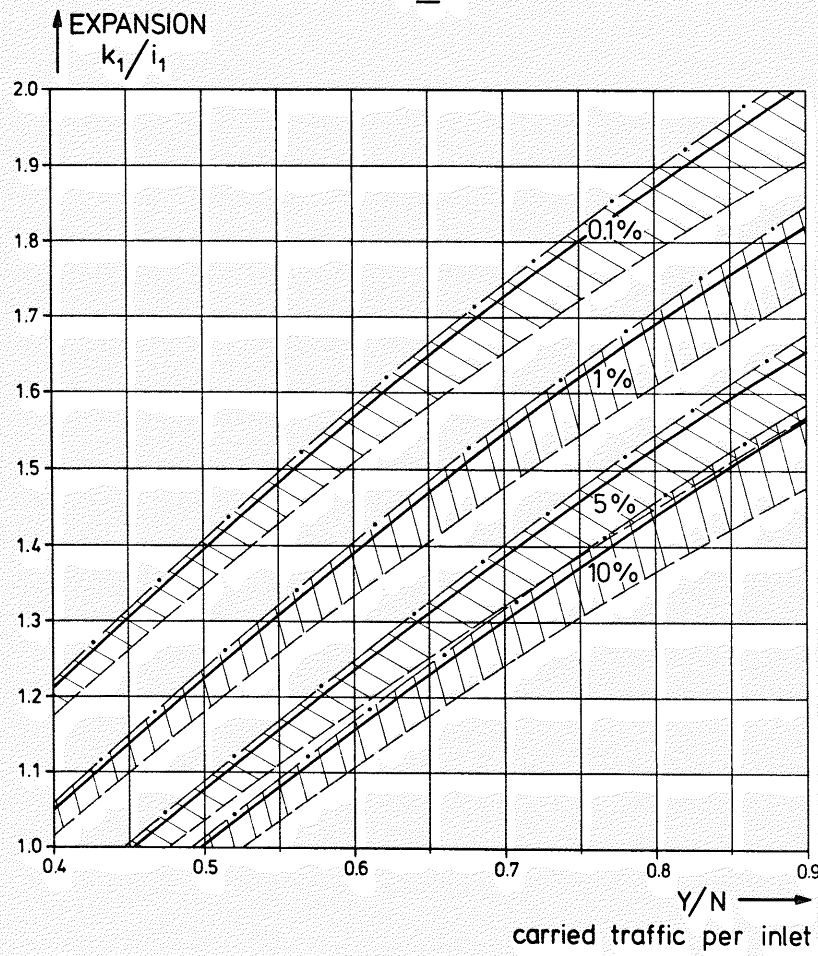
SDM

N = 4 400 —·—

N = 1331 ——

N = 275 — — —

PPS



S = 4

i_1 = 12

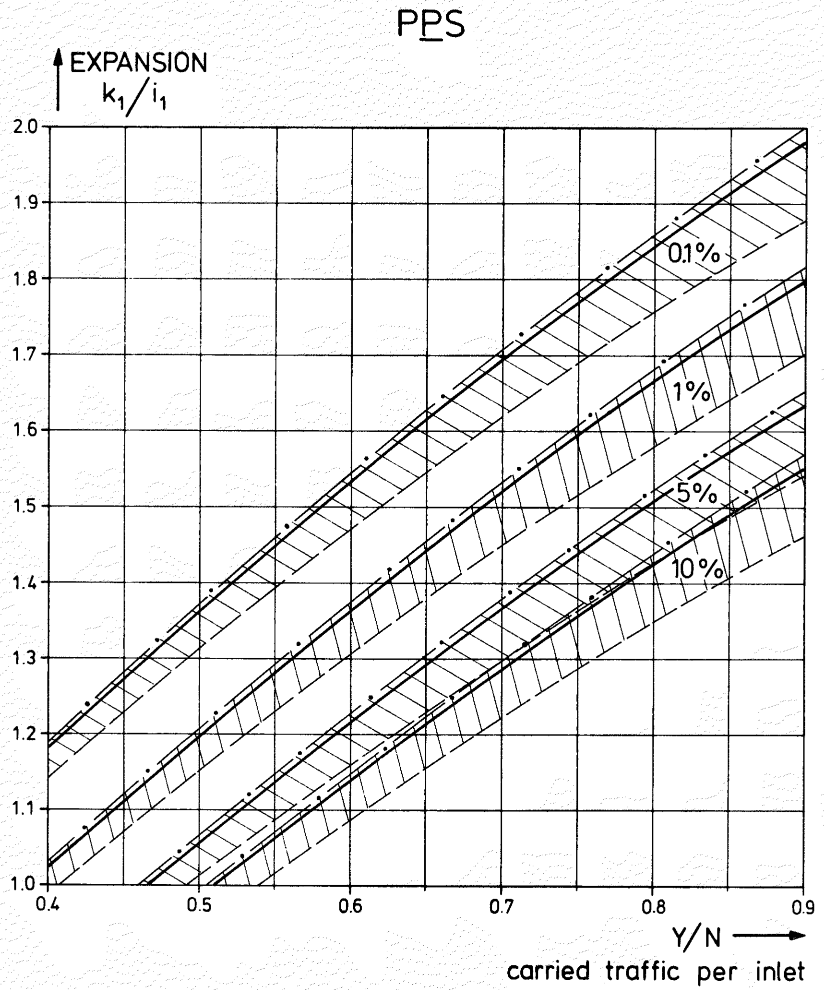
PCT 2

SDM

N = 4 800 —·—

N = 1 728 ——

N = 300 — — —



S = 4

i_1 = 13

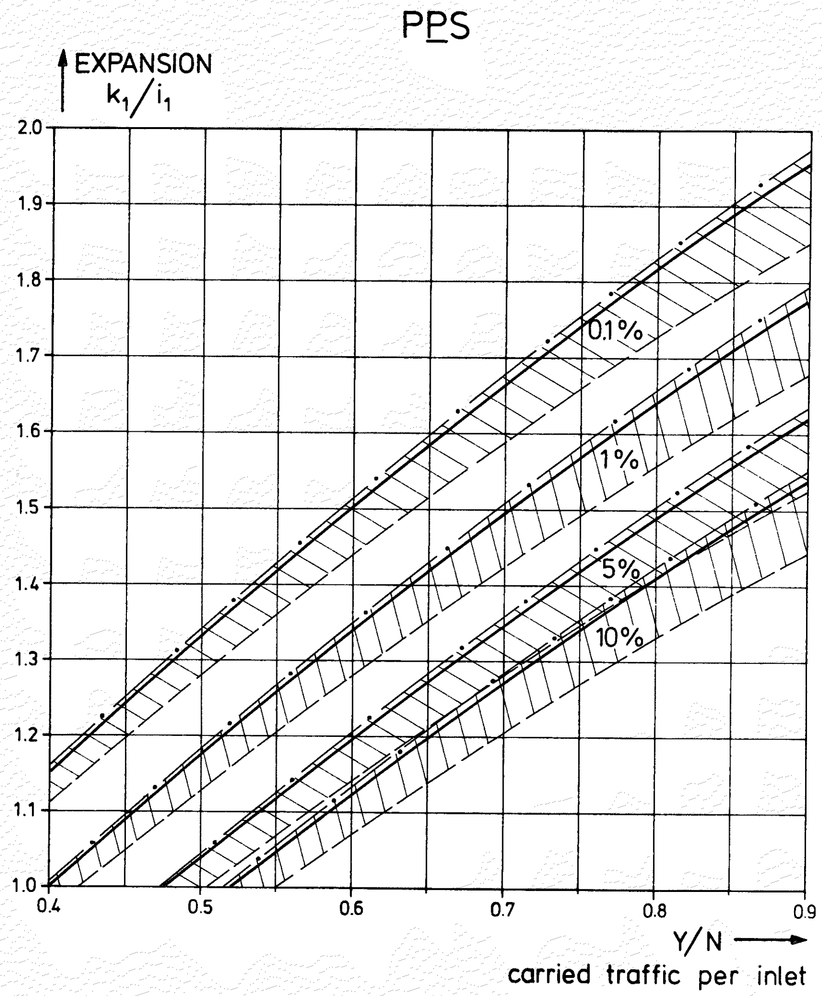
PCT 2

SDM

N = 5 200 —·—

N = 2 197 ——

N = 325 — — —



S = 4

i_1 = 14

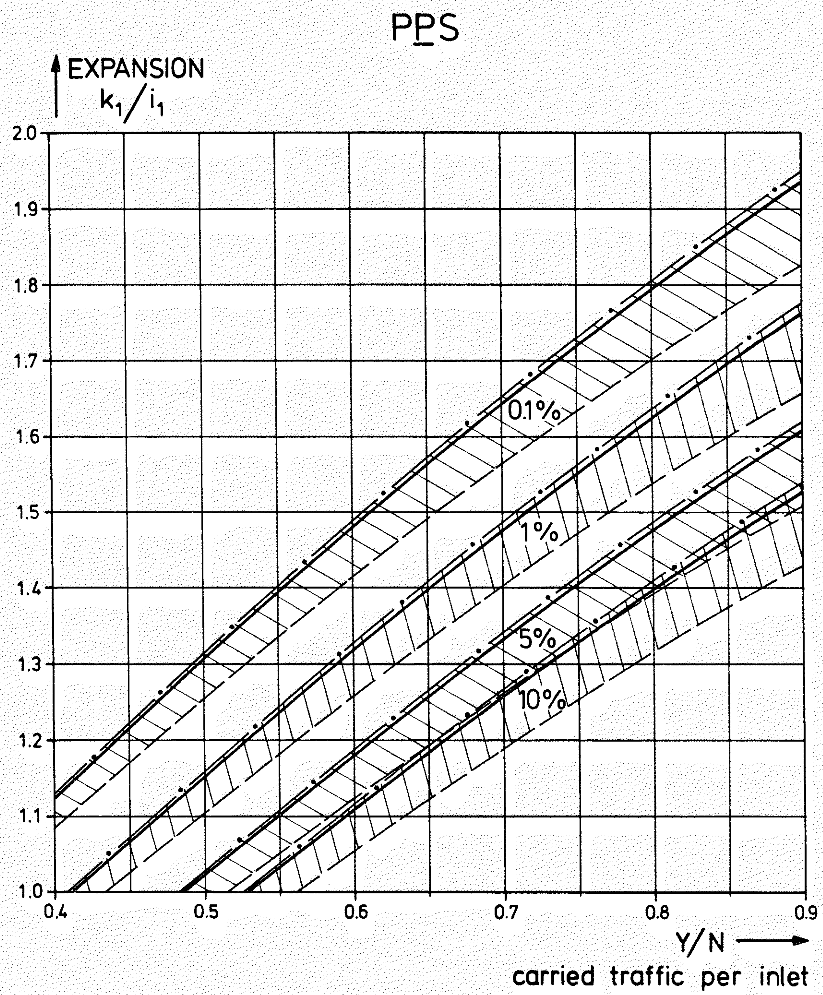
PCT 2

SDM

N = 5 600 —·—

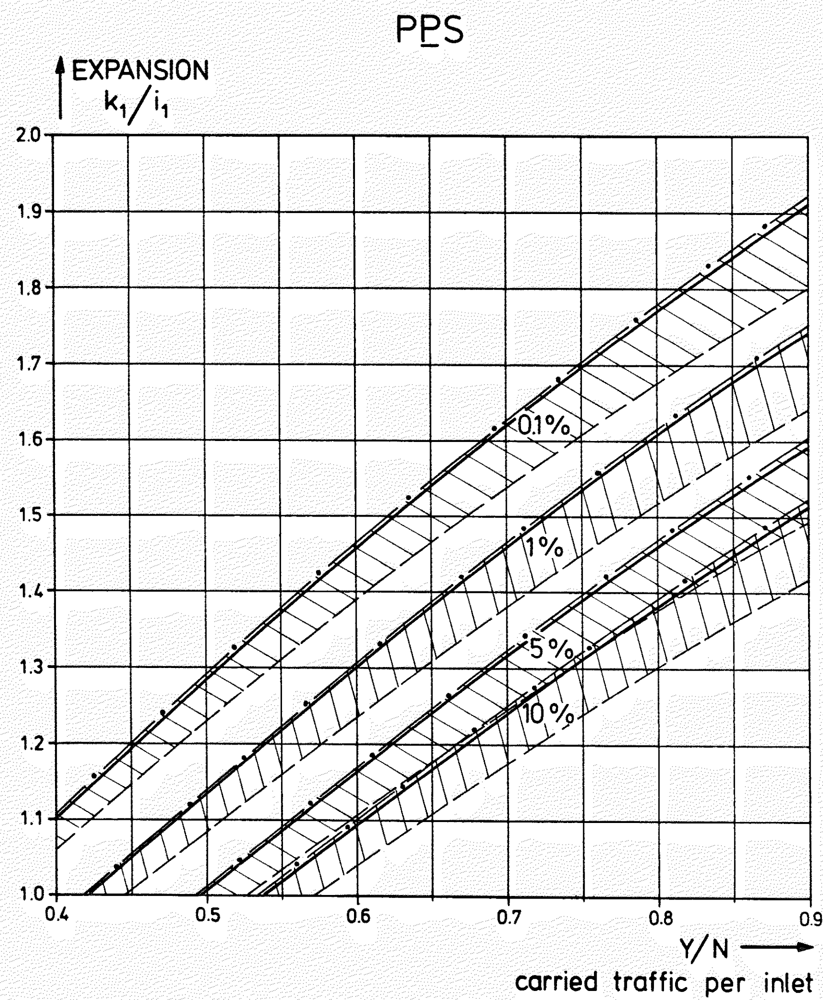
N = 2 744 ——

N = 350 — — —



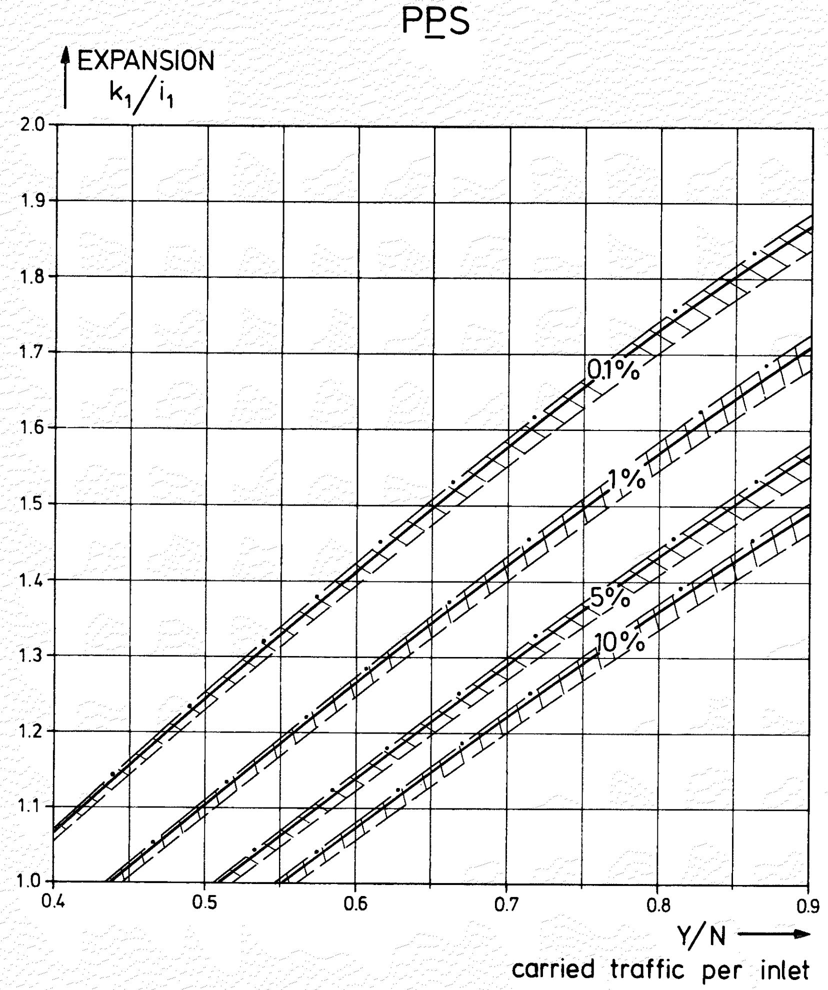
S = 4
i_1 = 15
PCT 2
SDM

N = 6000 —·—
N = 3375 ——
N = 375 — — —



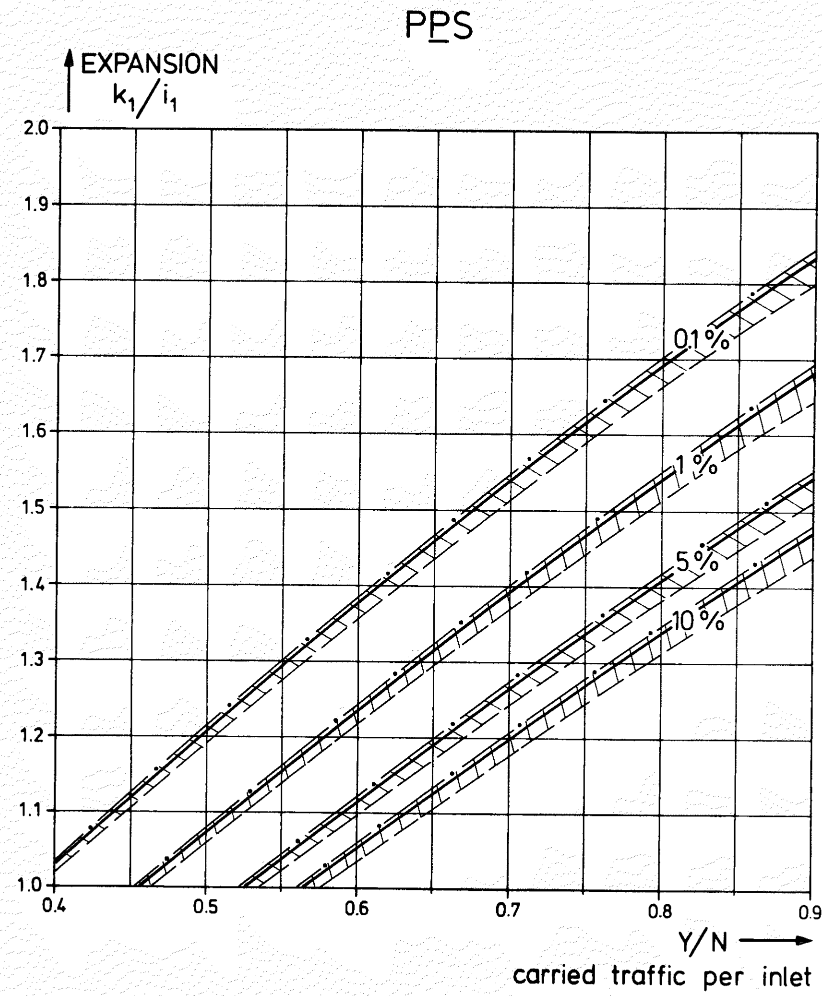
S = 4
i_1 = 16
PCT 2
SDM

N = 6400 —·—
N = 4096 ——
N = 400 — — —



S = 4
i_1 = 18
PCT 2
SDM

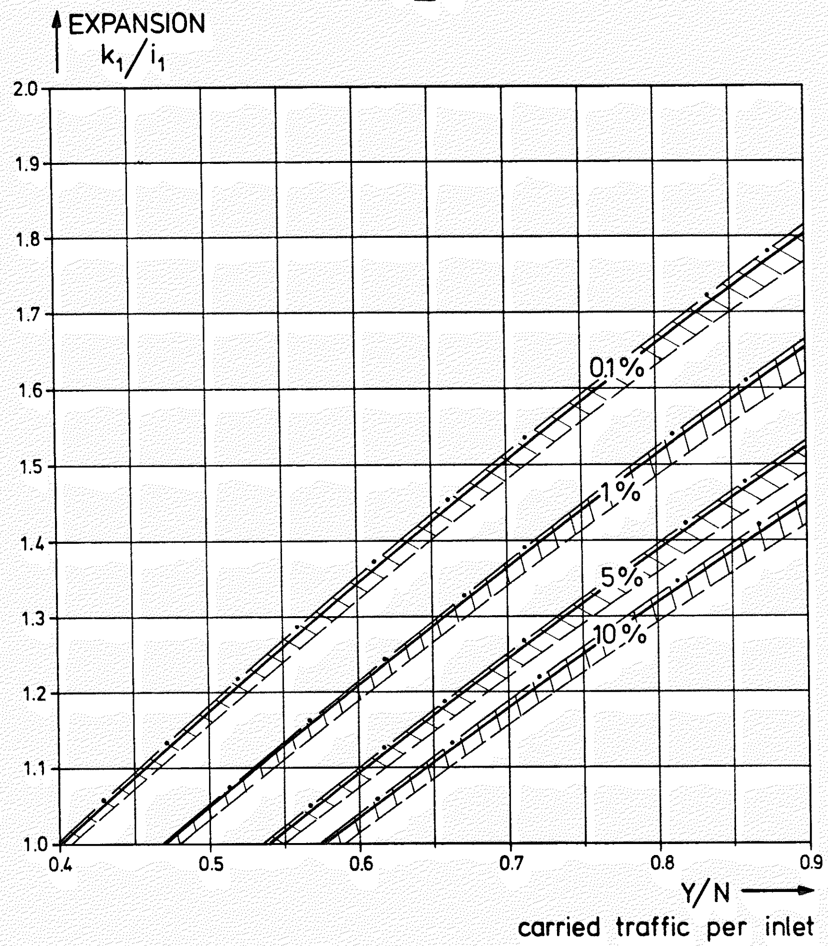
N = 16 200 ——·——
N = 5 832 ————
N = 1 800 — — —



S = 4
i_1 = 20
PCT 2
SDM

N = 18 000 ——·——
N = 8 000 ————
N = 2 000 — — —

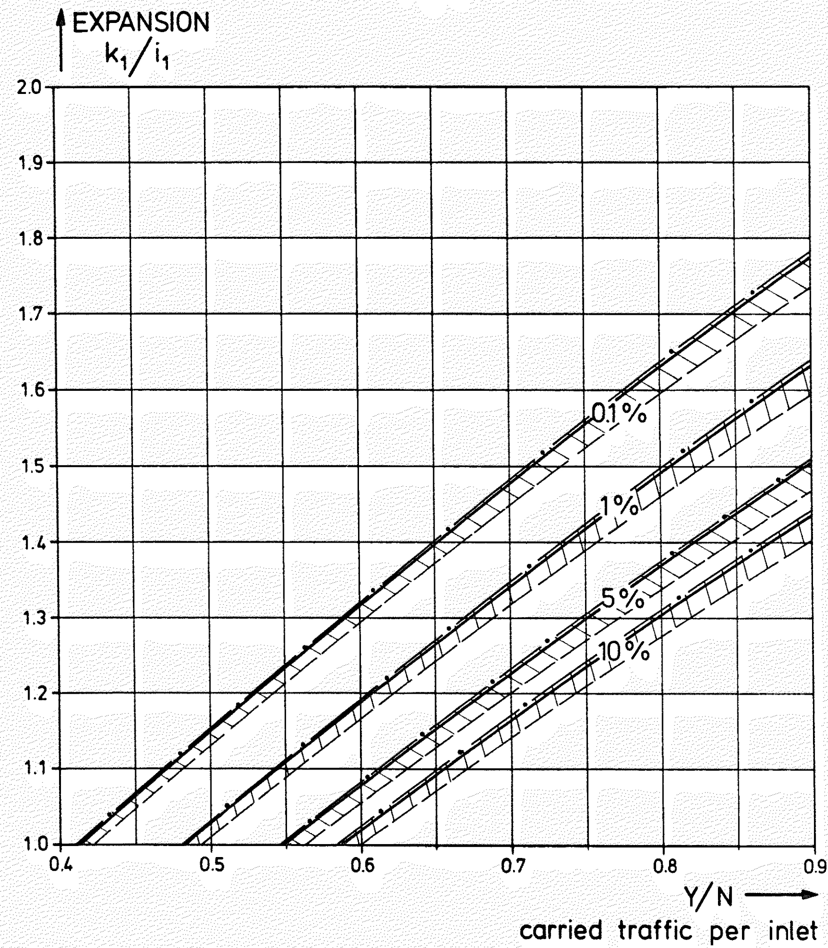
PPS



S = 4
i_1 = 22
PCT 2
SDM

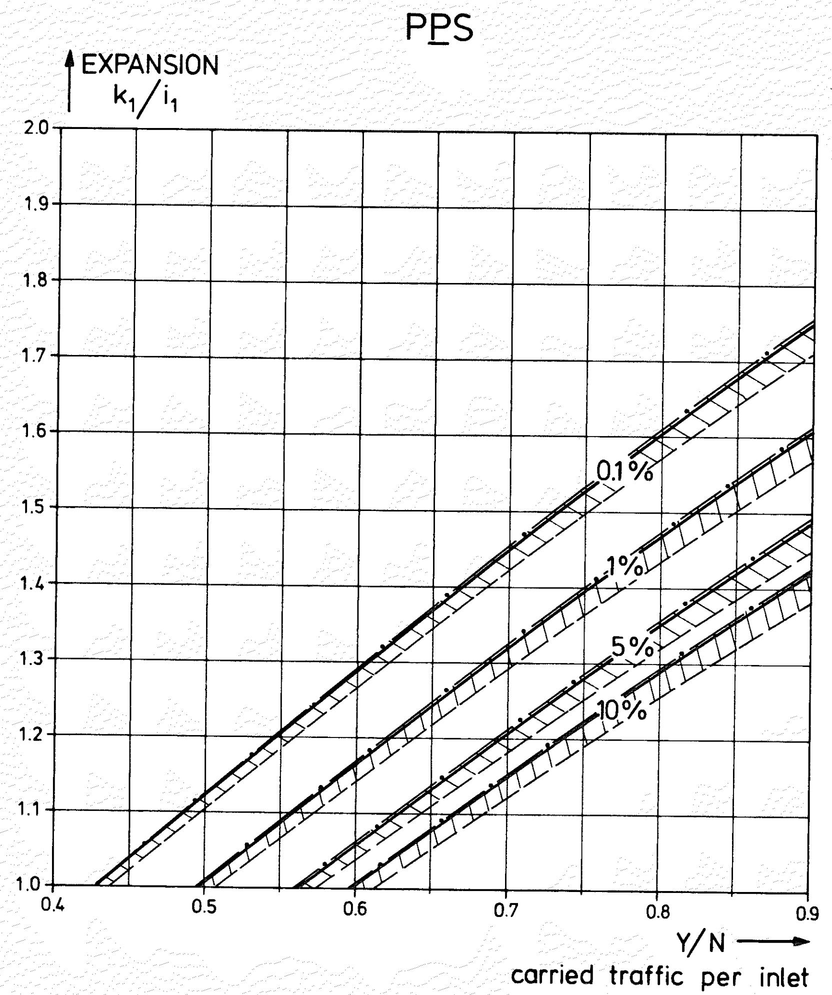
N = 19 800 —·—
N = 10 648 ——
N = 2 200 — — —

PPS



S = 4
i_1 = 24
PCT 2
SDM

N = 21 600 —·—
N = 13 824 ——
N = 2 400 — — —



S = 4

i_1 = 26

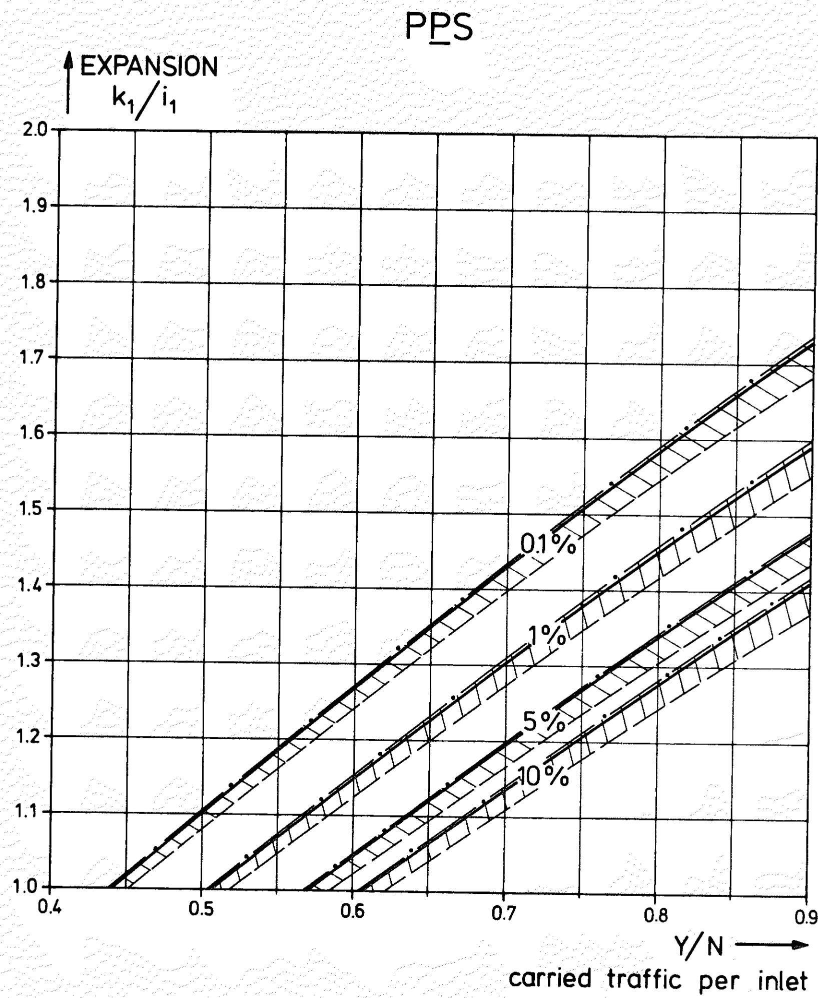
PCT 2

SDM

N = 23 400 —·—

N = 17 576 ——

N = 2 600 — — —



S = 4

i_1 = 28

PCT 2

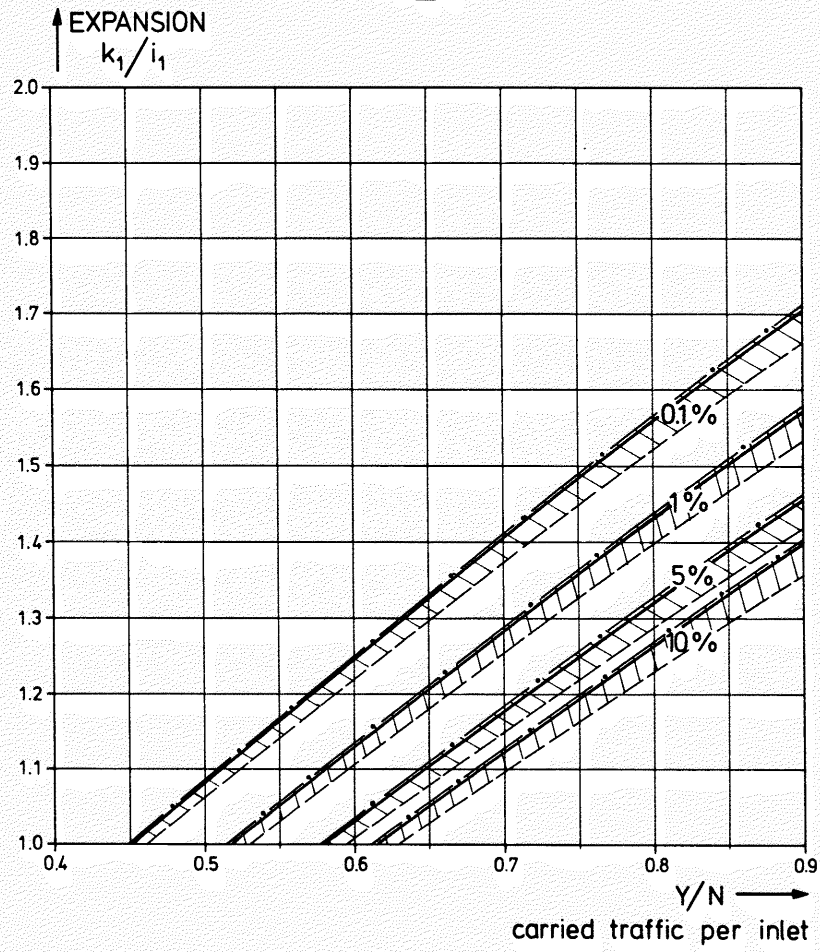
SDM

N = 44 800 —·—

N = 21 952 ——

N = 2 800 — — —

PPS



$S = 4$

$i_1 = 30$

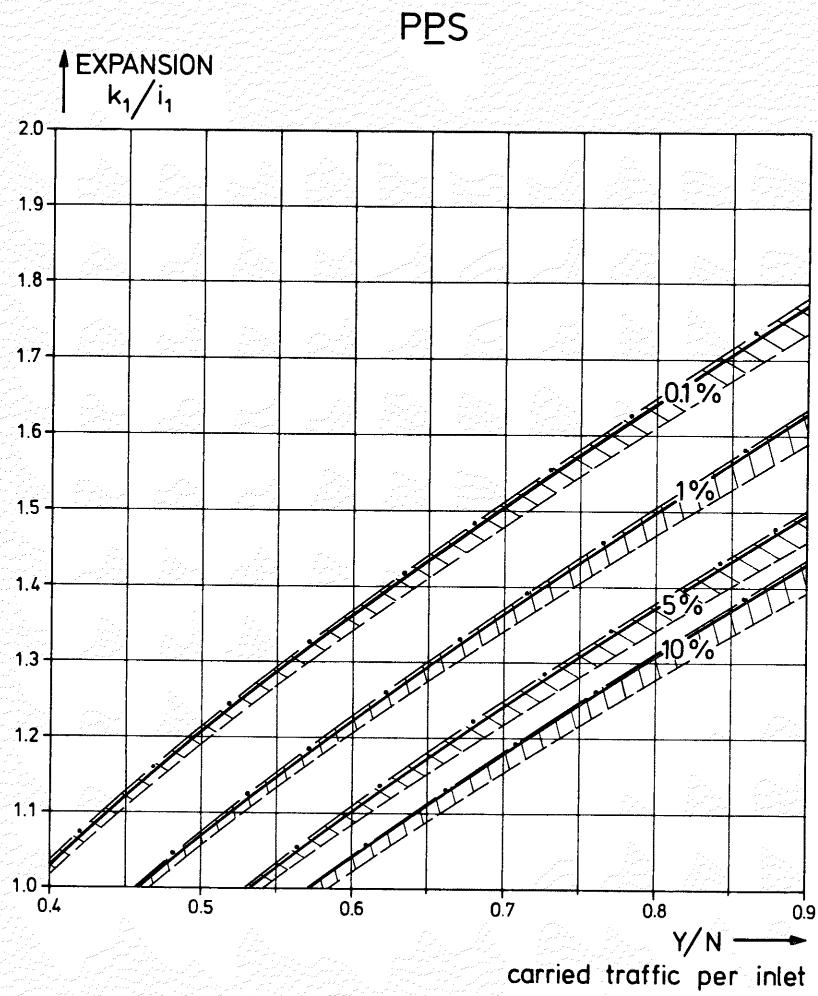
PCT 2

SDM

$N = 48000$

$N = 27000$

$N = 3000$



S = 4

i_1 = 24

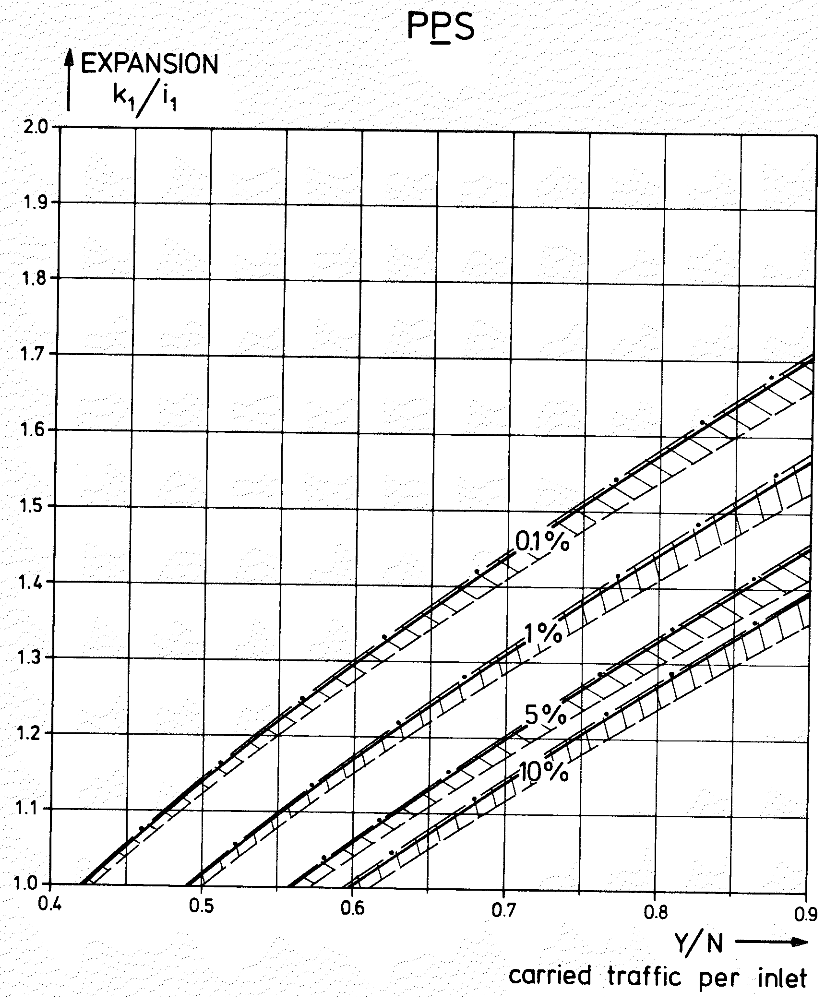
PCT 2

TDM

N = 21600 ——·——

N = 13824 ————

N = 2400 — — —



S = 4

i_1 = 30

PCT 2

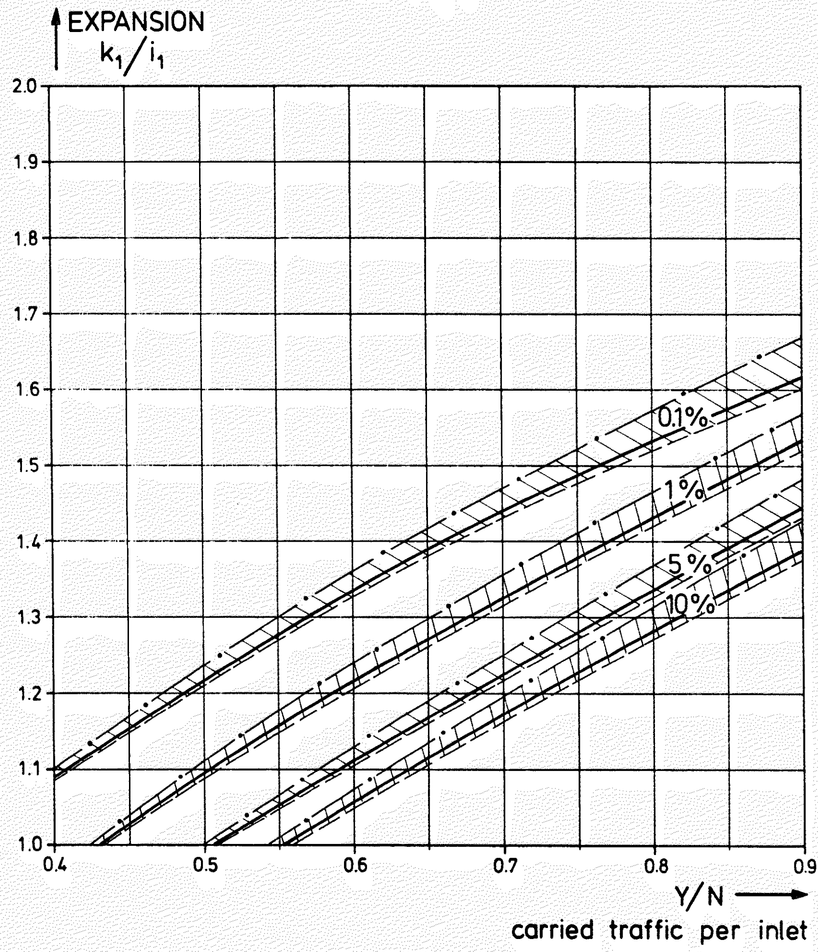
TDM

N = 48000 ——·——

N = 27000 ————

N = 3000 — — —

PPS



S = 5

i_1 = 5

PCT 2

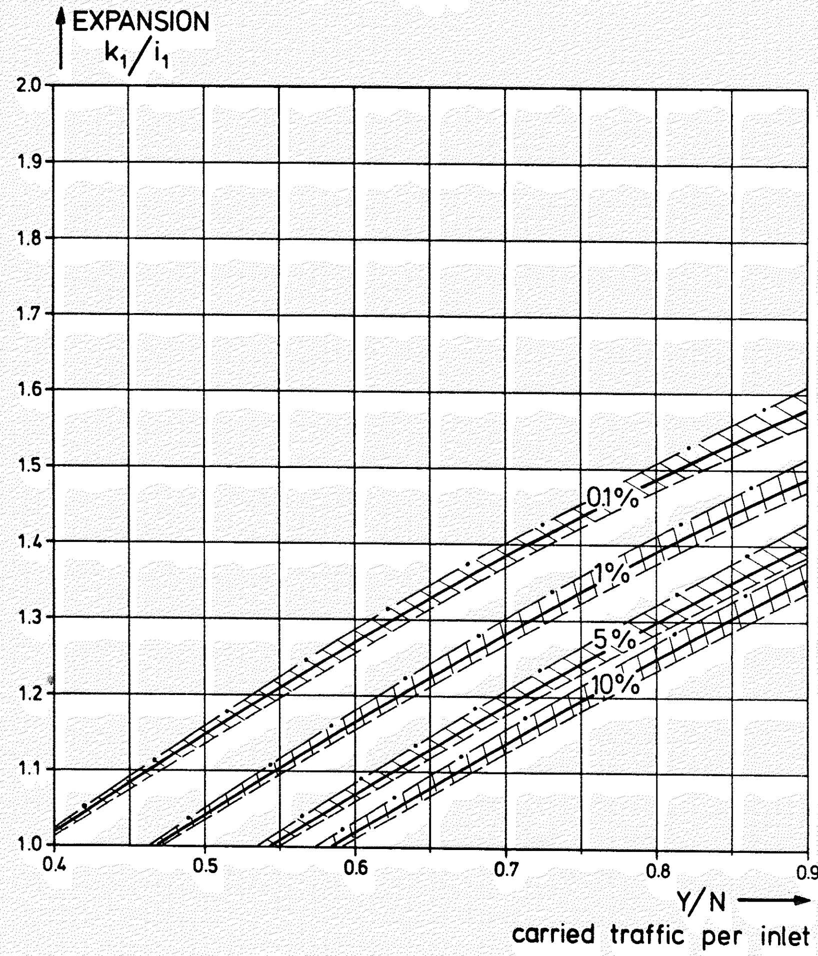
SDM

N = 500 —·—

N = 125 ———

N = 100 — — —

PPS



S = 5

i_1 = 6

PCT 2

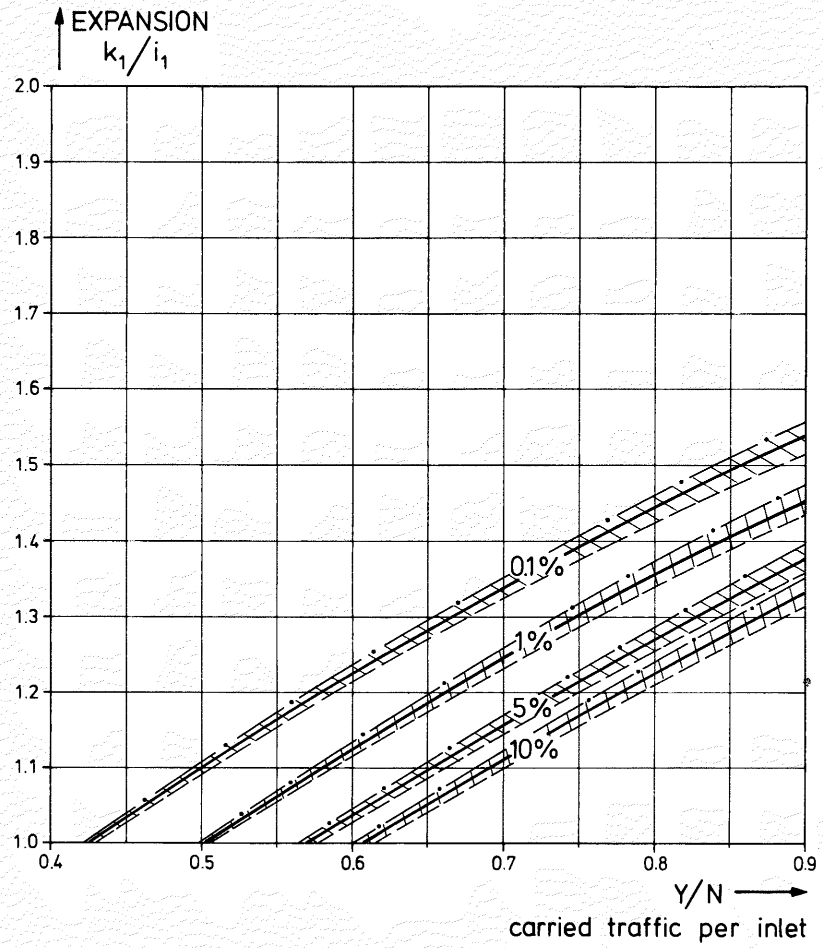
SDM

N = 720 —·—

N = 216 ———

N = 144 — — —

PPS



S = 5

i_1 = 7

PCT 2

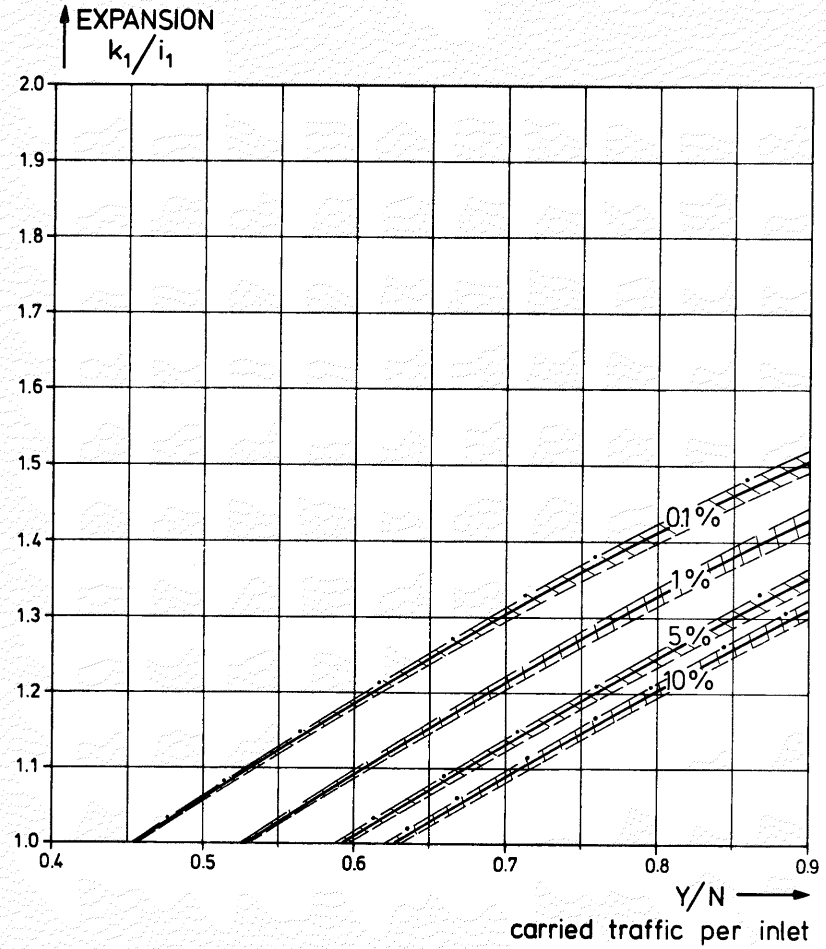
SDM

N = 980 —— · ——

N = 343 ————

N = 196 — — —

PPS



S = 5

i_1 = 8

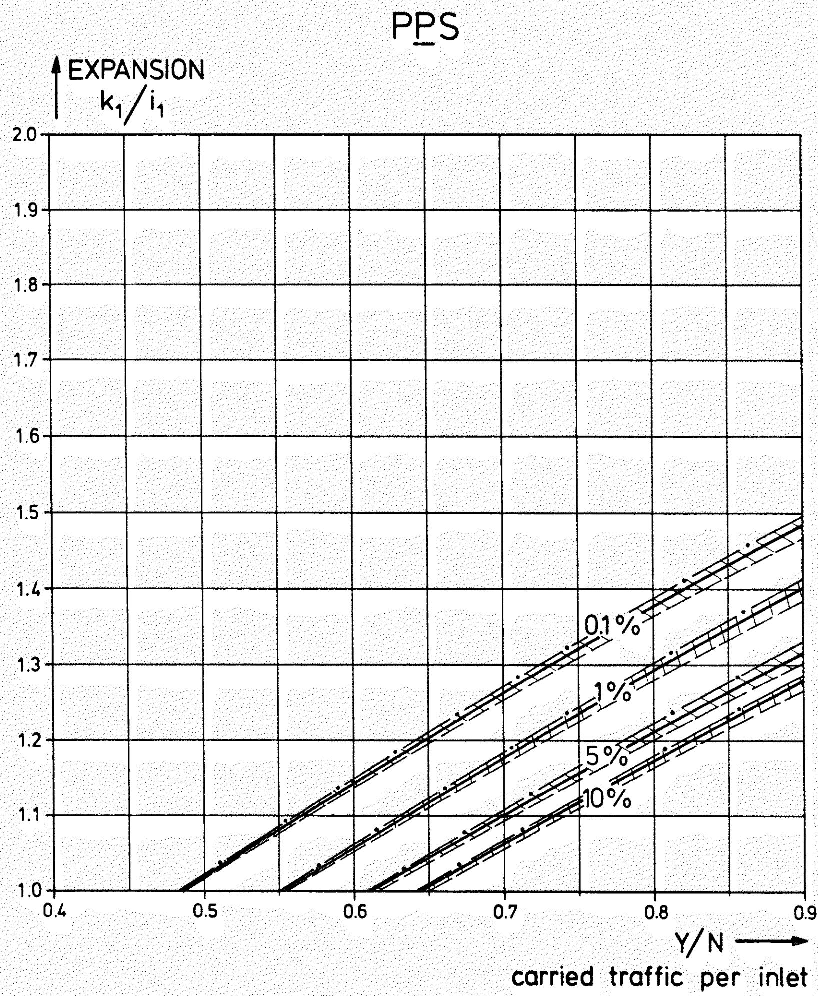
PCT 2

SDM

N = 1 280 —— · ——

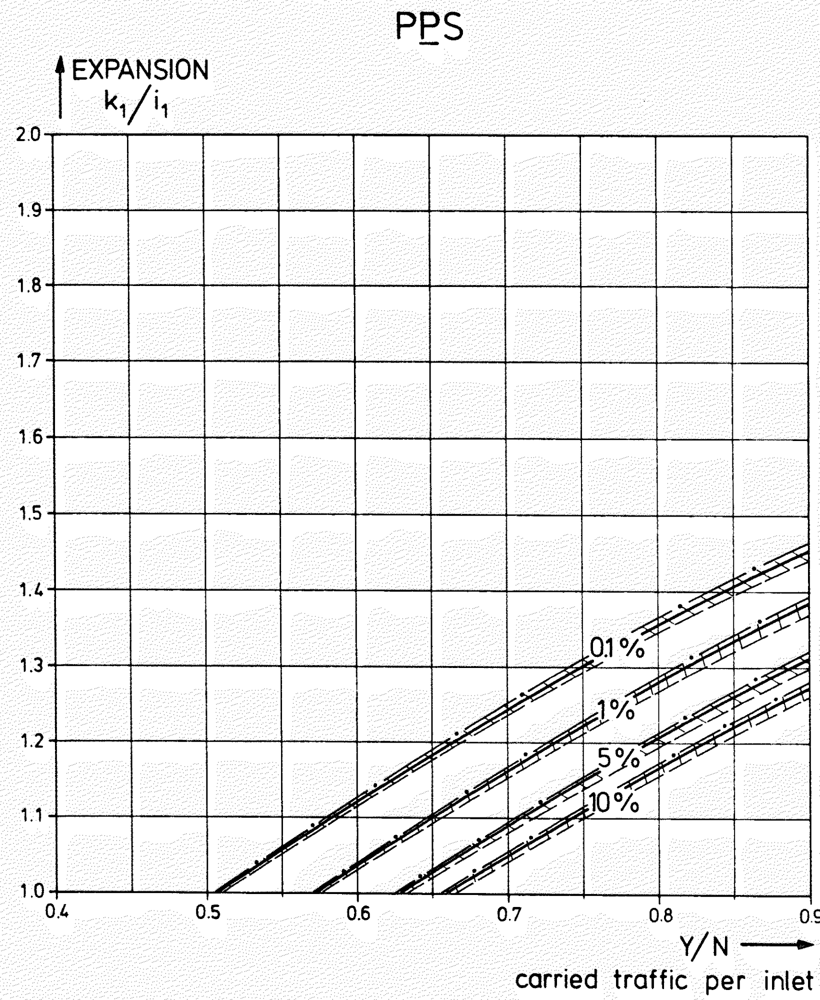
N = 512 ————

N = 320 — — —



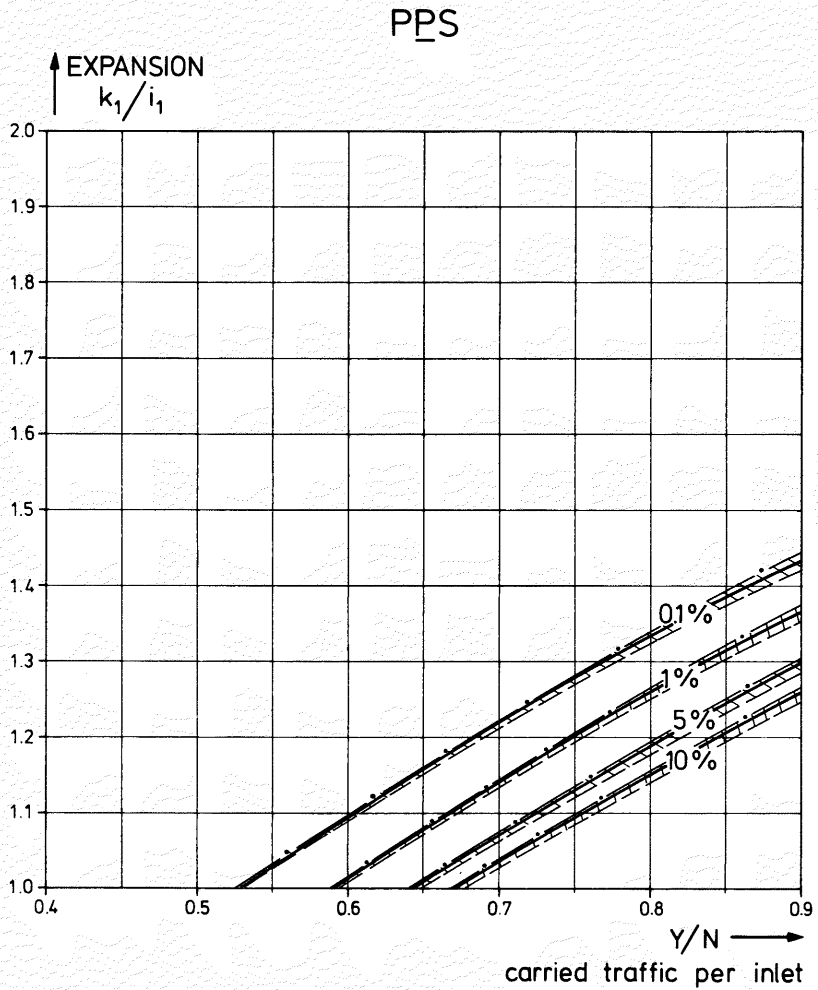
S = 5
i_1 = 9
PCT 2
SDM

N = 1620 ——·——
N = 729 ————
N = 405 — — —



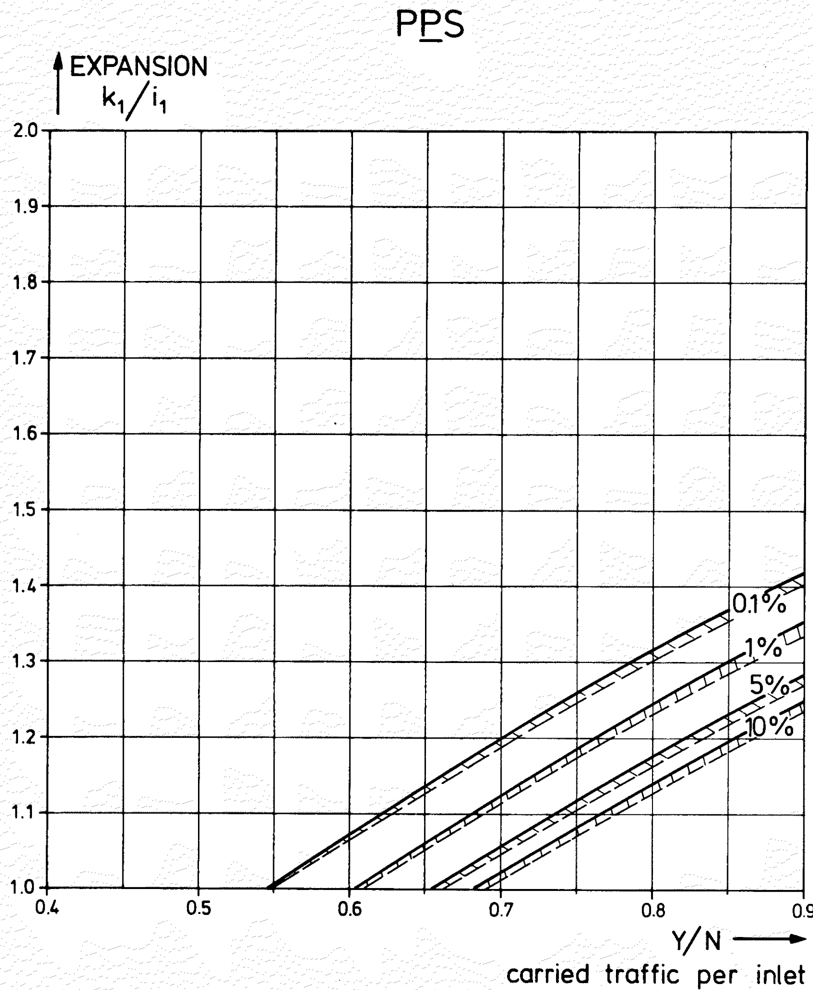
S = 5
i_1 = 10
PCT 2
SDM

N = 2000 ——·——
N = 1000 ————
N = 500 — — —



S = 5
i_1 = 11
PCT 2
SDM

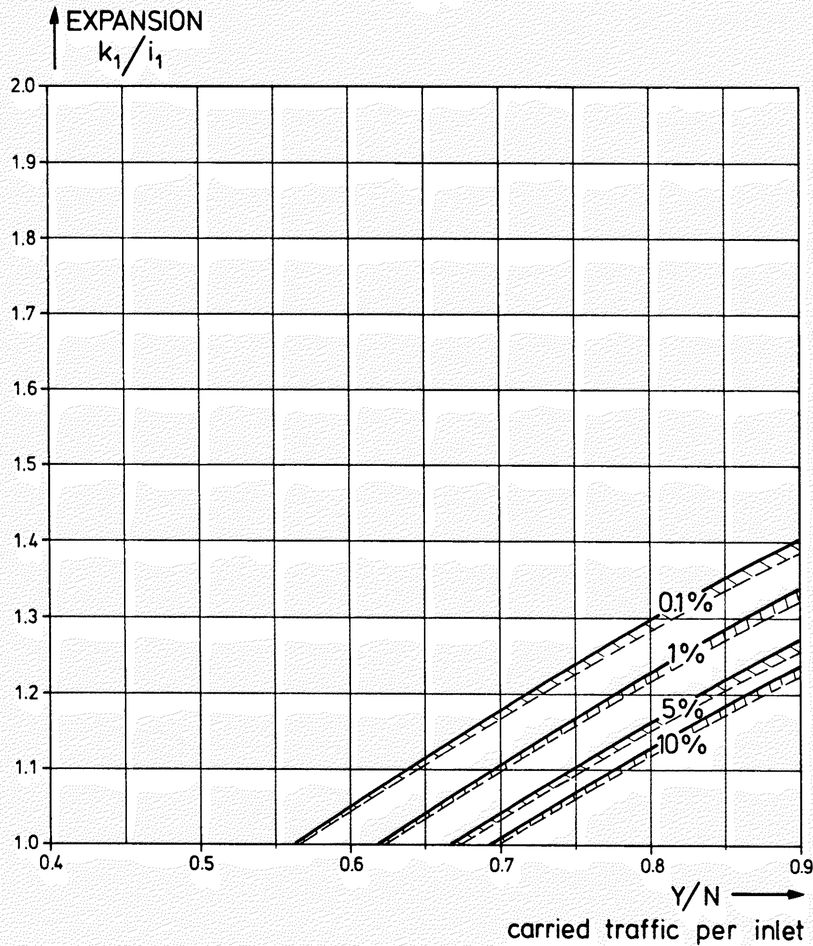
N = 2 420 —— · ——
N = 1 331 ————
N = 605 — — —



S = 5
i_1 = 12
PCT 2
SDM

N = 2 880 } ————
N = 1 728 }
N = 720 — — —

PPS



$S = 5$

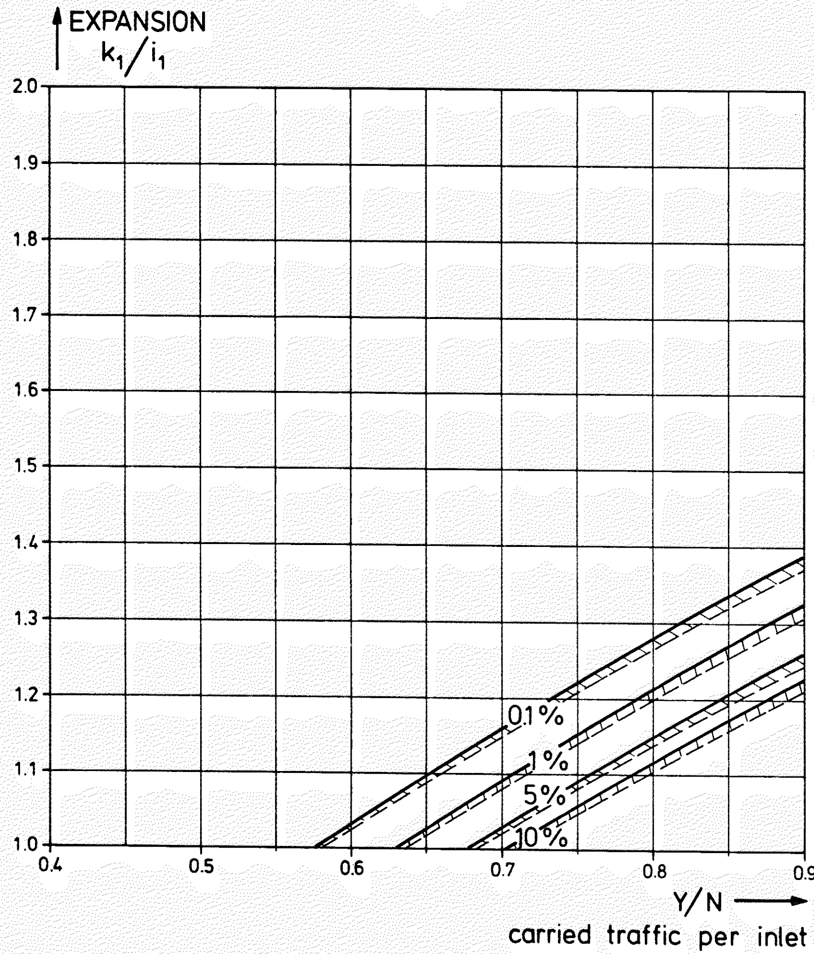
$i_1 = 13$

PCT 2

SDM

N = 3 380 } ———
N = 2 197 }
N = 845 — — —

PPS



$S = 5$

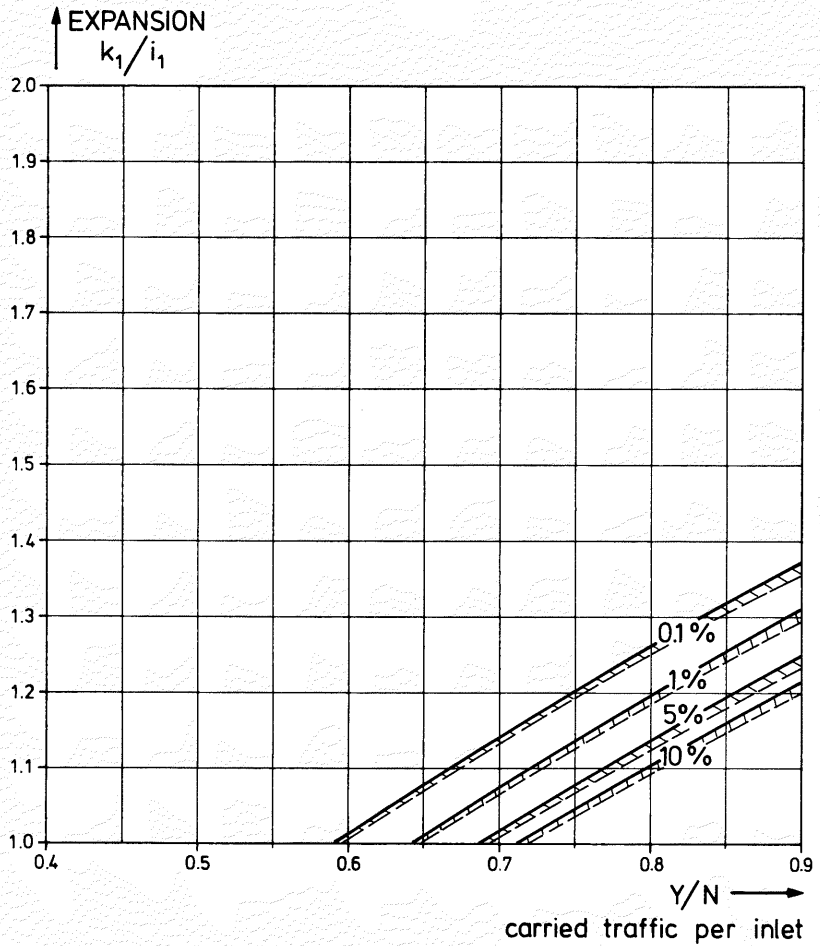
$i_1 = 14$

PCT 2

SDM

N = 3 920 } ———
N = 2 744 }
N = 980 — — —

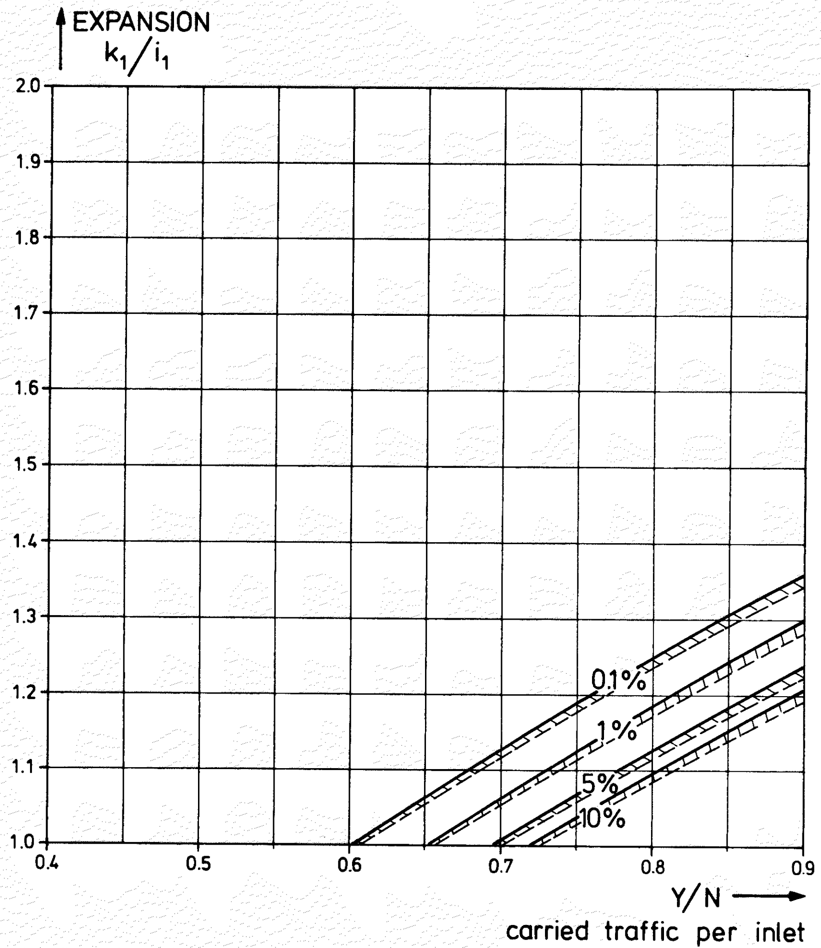
PPS



S = 5
i_1 = 15
PCT 2
SDM

N = 4 500, N = 3 375 ———
N = 1125 — — —

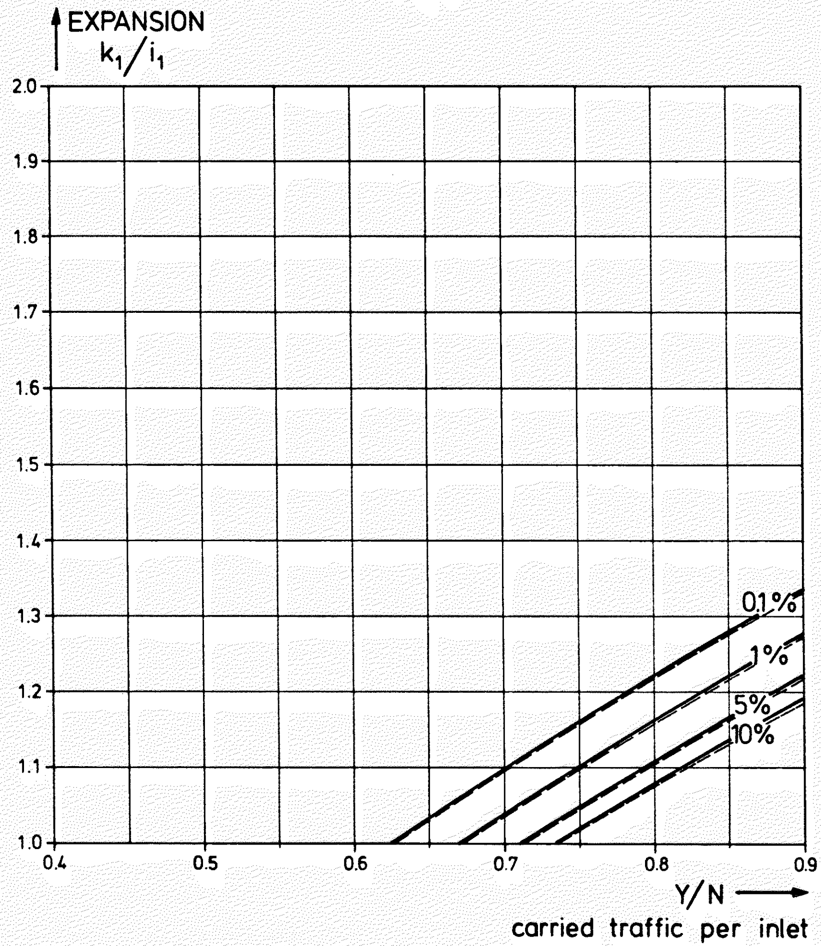
PPS



S = 5
i_1 = 16
PCT 2
SDM

N = 5 120, N = 4 096 ———
N = 1280 — — —

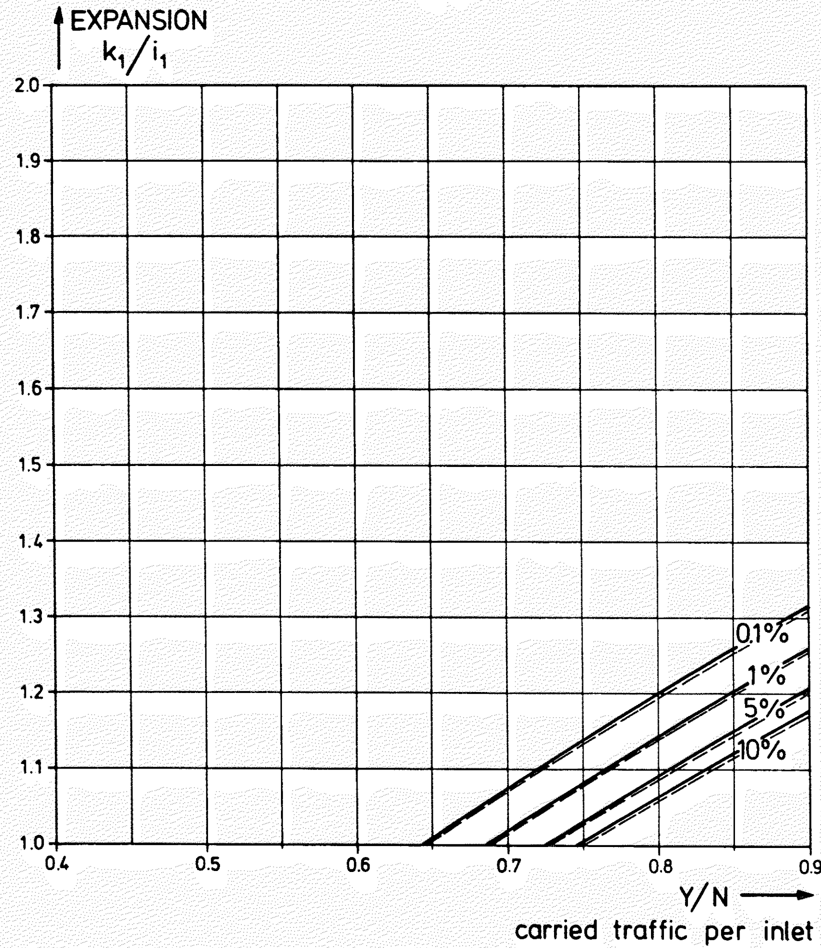
PPS



S = 5
i_1 = 18
PCT 2
SDM

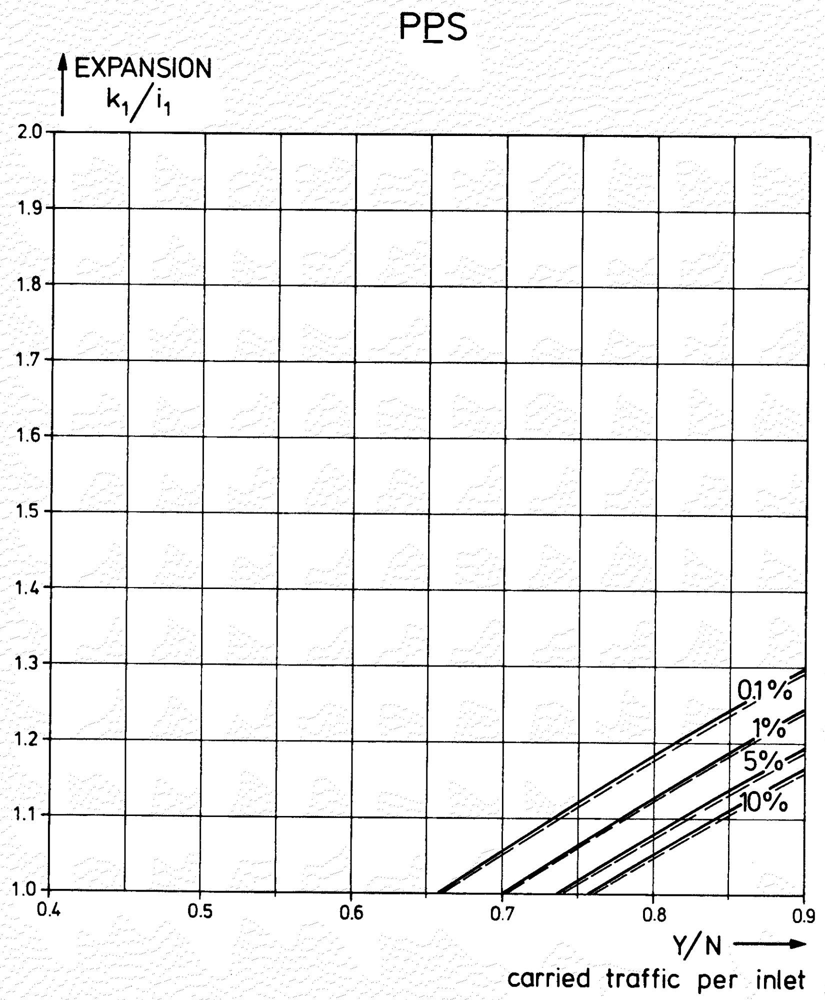
N = 9720
N = 5832 } ————
N = 3240 — — —

PPS



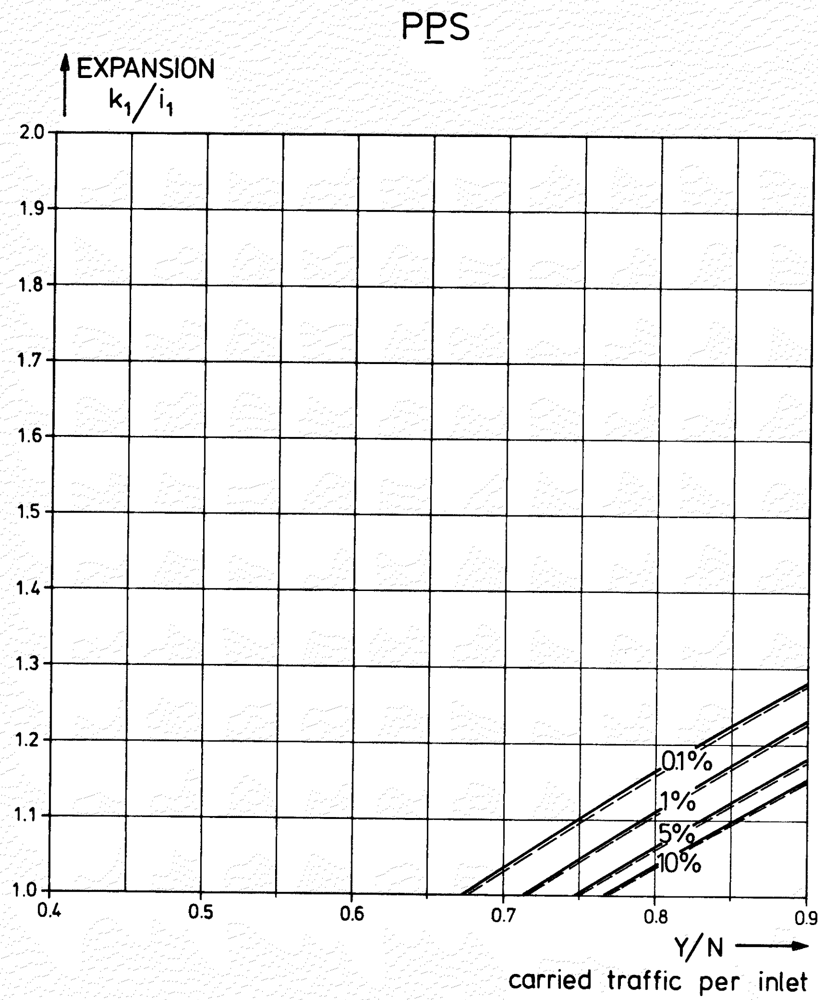
S = 5
i_1 = 20
PCT 2
SDM

N = 12000
N = 8000 } ————
N = 4000 — — —



S = 5
i_1 = 22
PCT 2
SDM

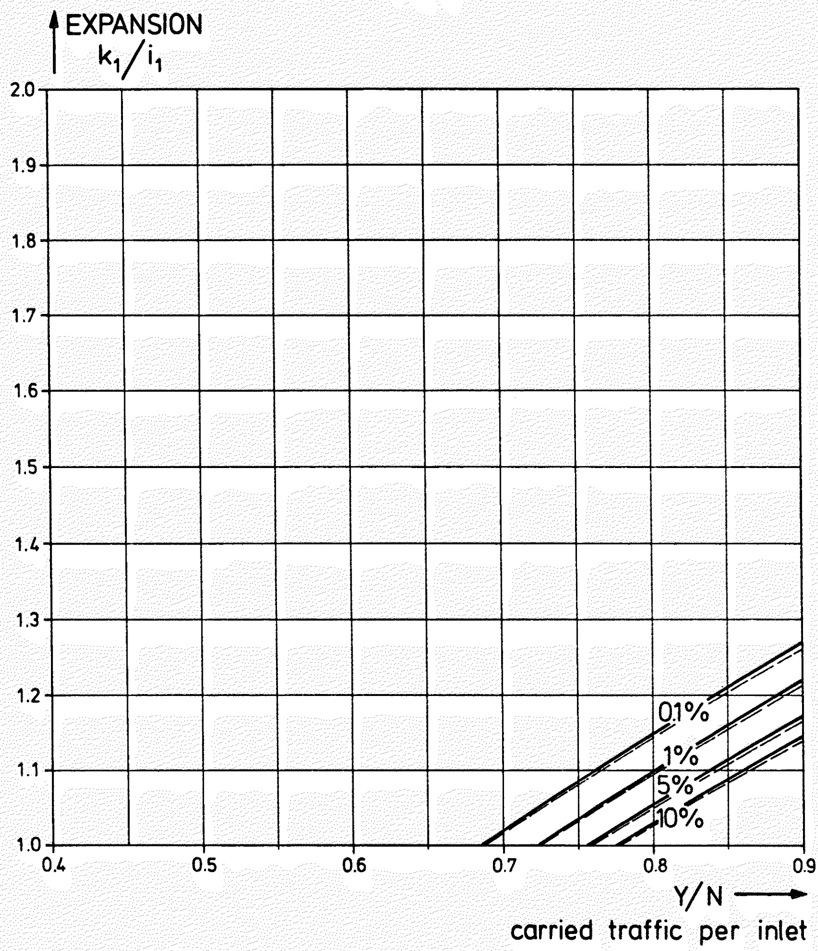
N = 14 520 } ————
N = 10 648 }
N = 4 840 — — —



S = 5
i_1 = 24
PCT 2
SDM

N = 17 280 } ————
N = 13 824 }
N = 5 760 — — —

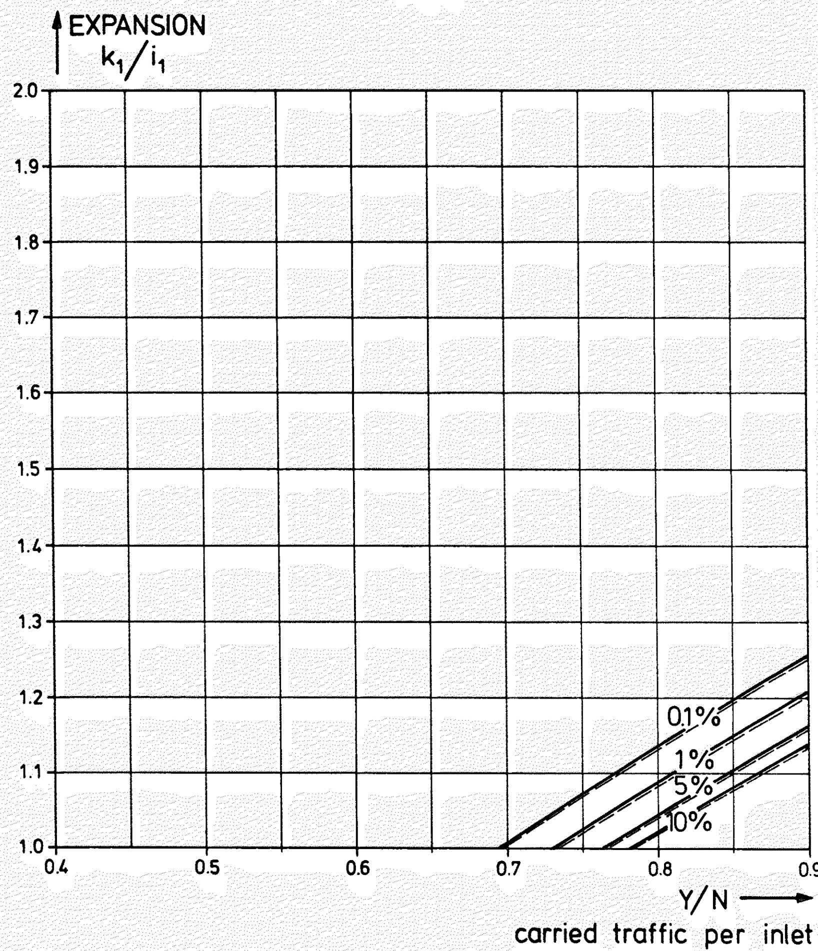
PPS



S = 5
i_1 = 26
PCT 2
SDM

N = 20 280 } ————
N = 17 576 }
N = 6 760 — — —

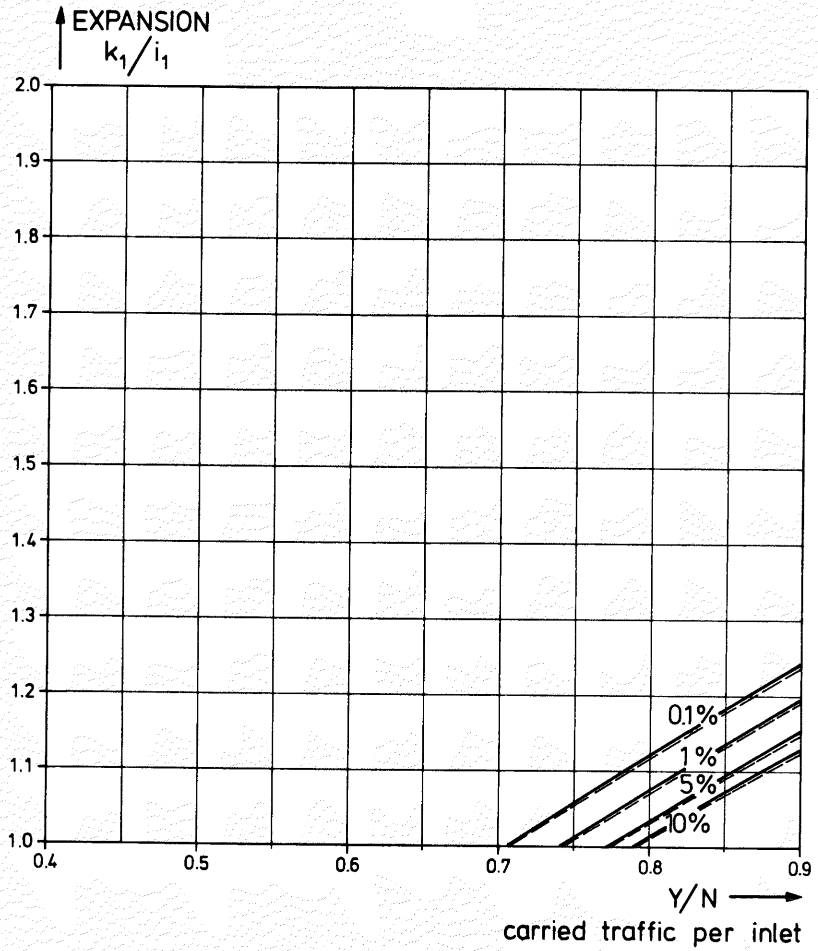
PPS



S = 5
i_1 = 28
PCT 2
SDM

N = 31 360 } ————
N = 21 952 }
N = 7 840 — — —

PPS



S = 5

i_1 = 30

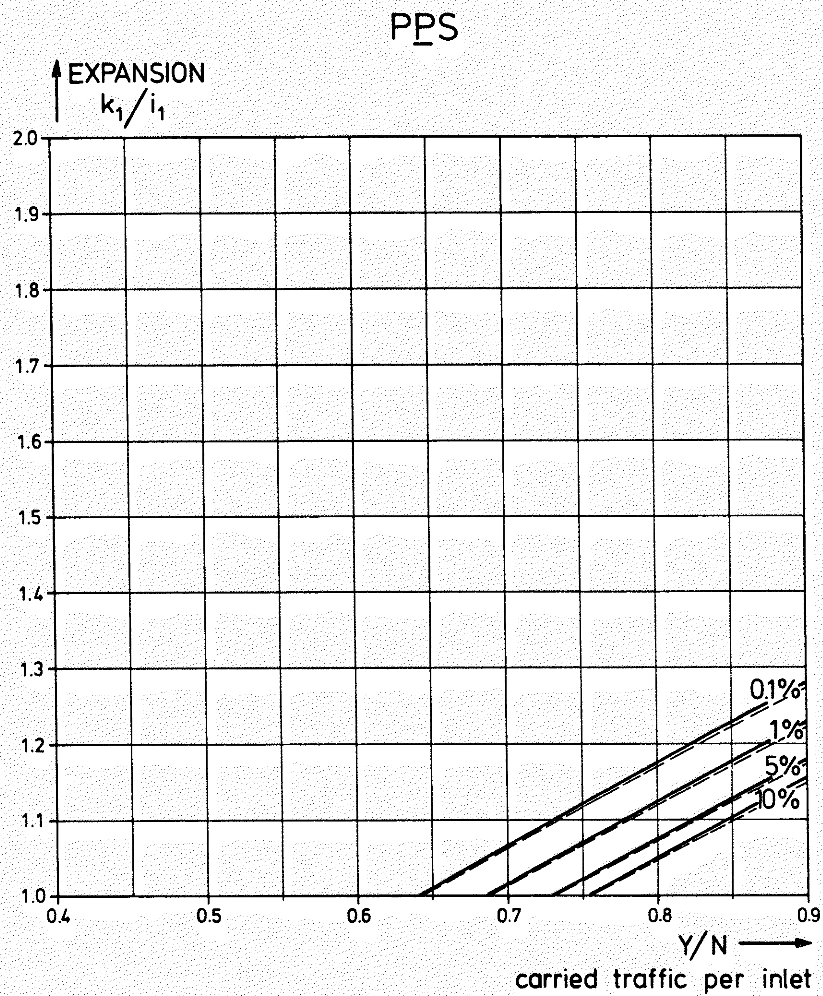
PCT 2

SDM

N = 36 000 } ————

N = 27 000 }

N = 9 000 — — —



S = 5

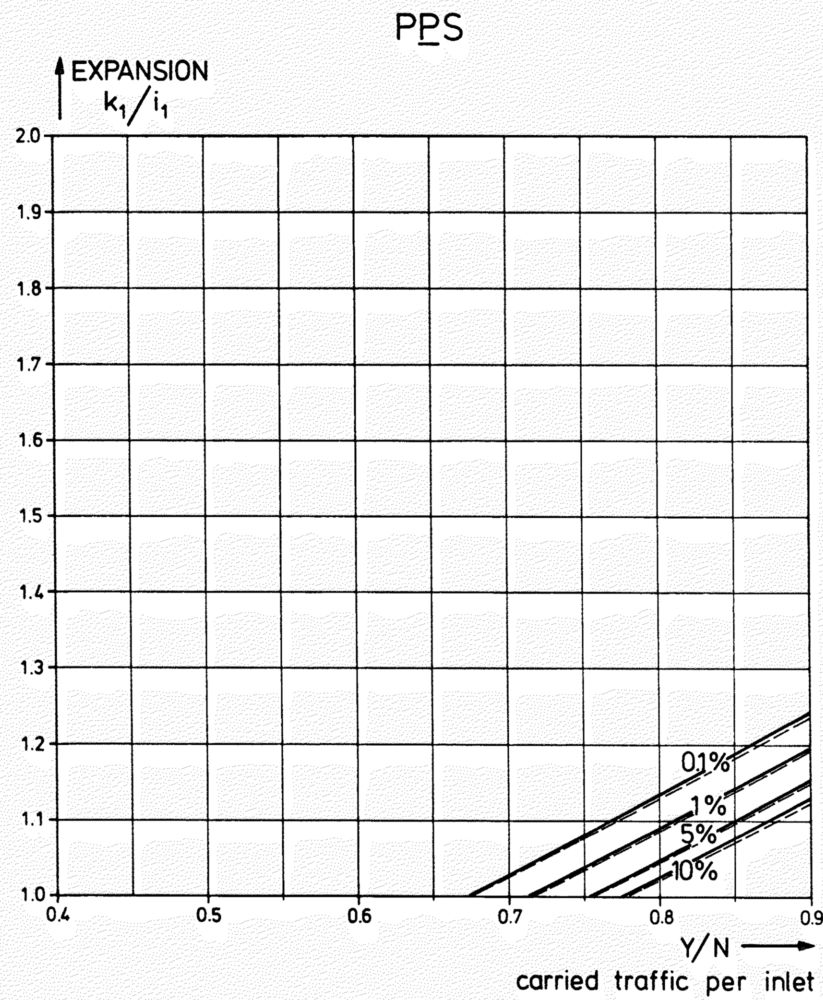
i_1 = 24

PCT 2

TDM

N = 17 280, N = 13 824 ————

N = 5 760 — — —



S = 5

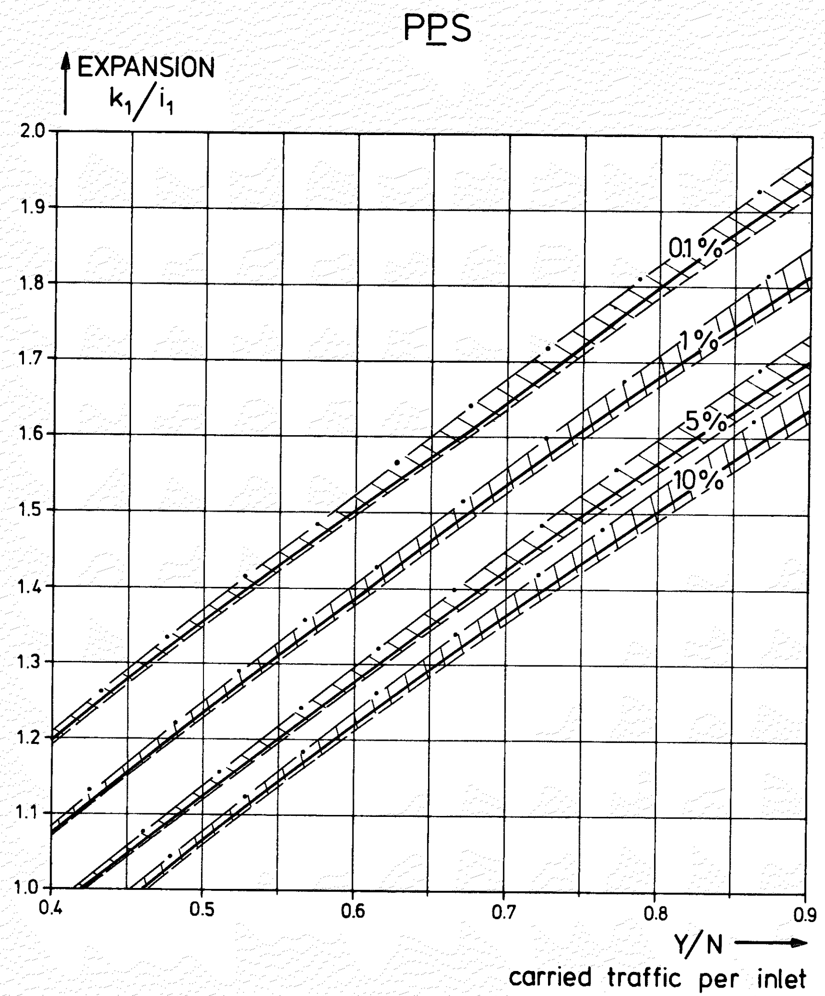
i_1 = 30

PCT 2

TDM

N = 36 000, N = 27 000 ————

N = 9 000 — — —



S = 6

i_1 = 5

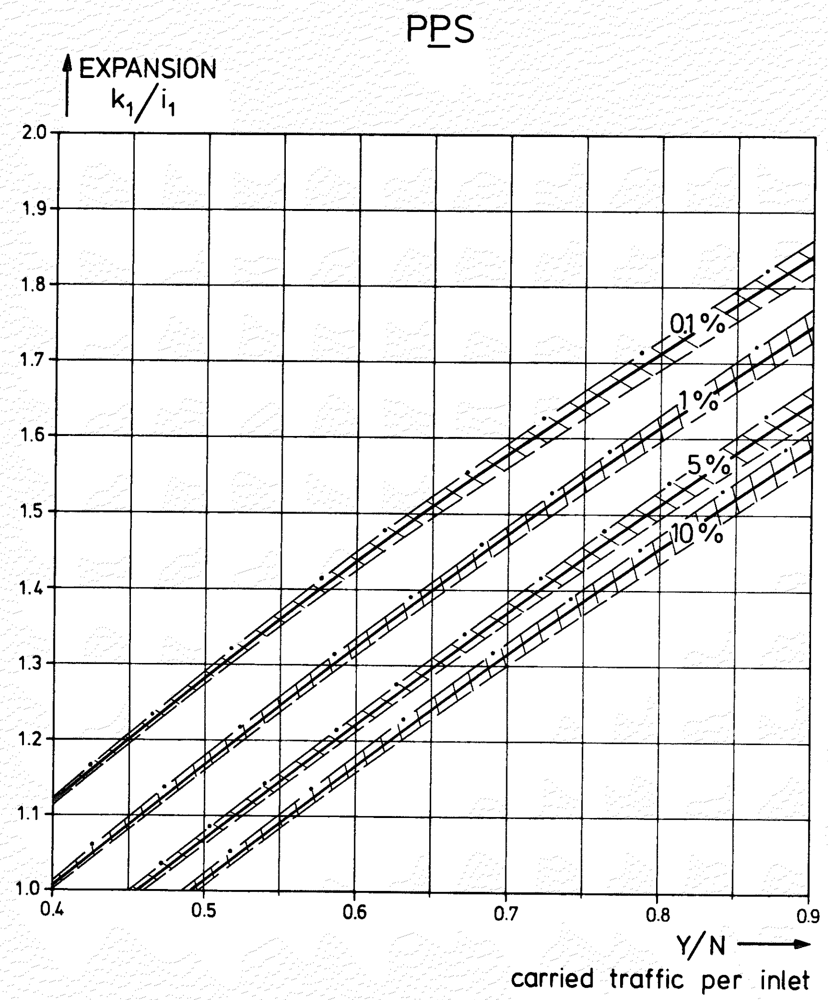
PCT 2

SDM

N = 10 000 —·—

N = 625 ———

N = 400 — — —



S = 6

i_1 = 6

PCT 2

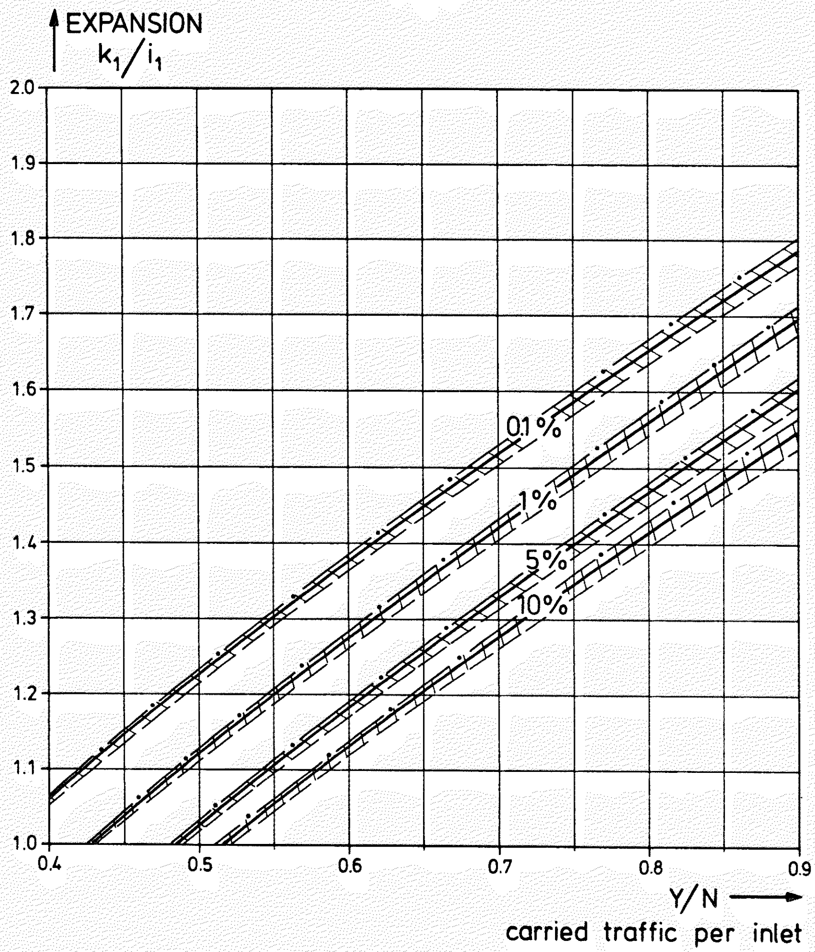
SDM

N = 14 400 —·—

N = 1 296 ———

N = 576 — — —

PPS



S = 6

i_1 = 7

PCT 2

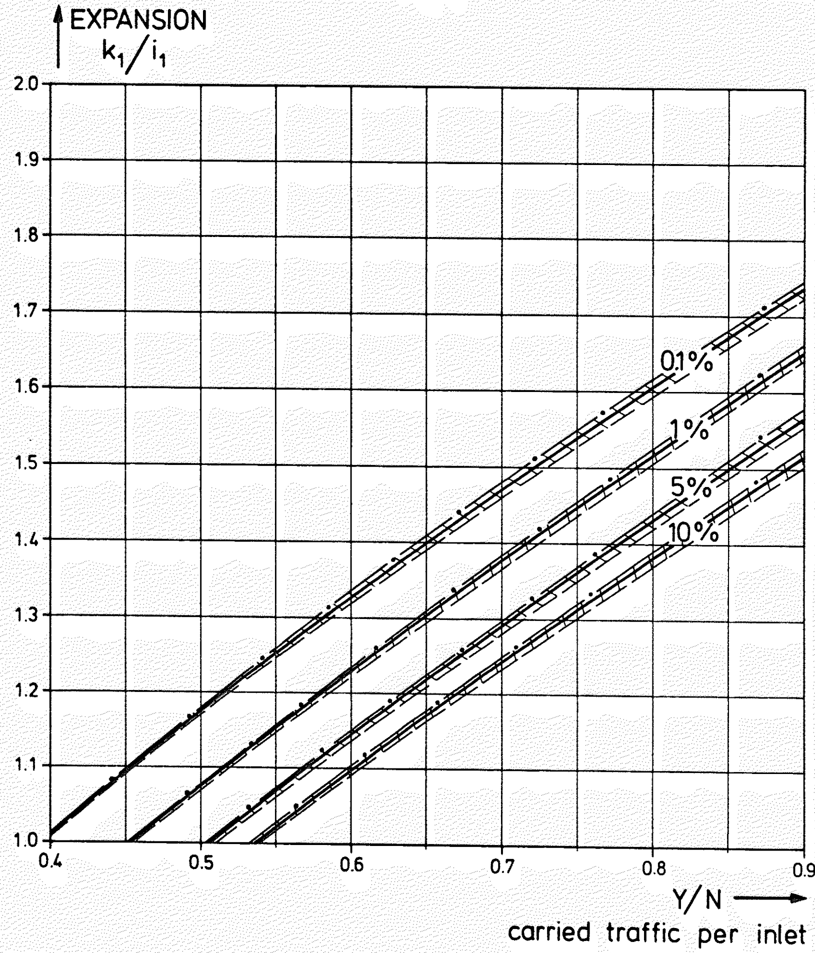
SDM

N = 19 600 —— · ——

N = 2 401 ————

N = 784 — — —

PPS



S = 6

i_1 = 8

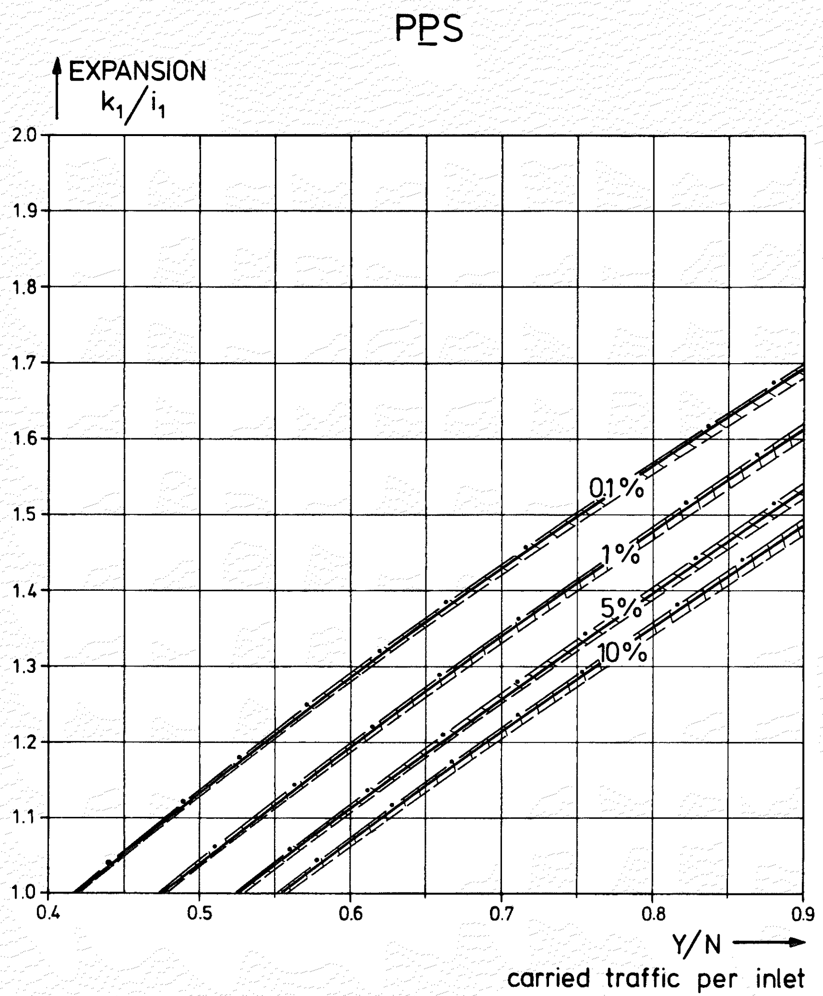
PCT 2

SDM

N = 25 600 —— · ——

N = 4 096 ————

N = 1 600 — — —



S = 6

i_1 = 9

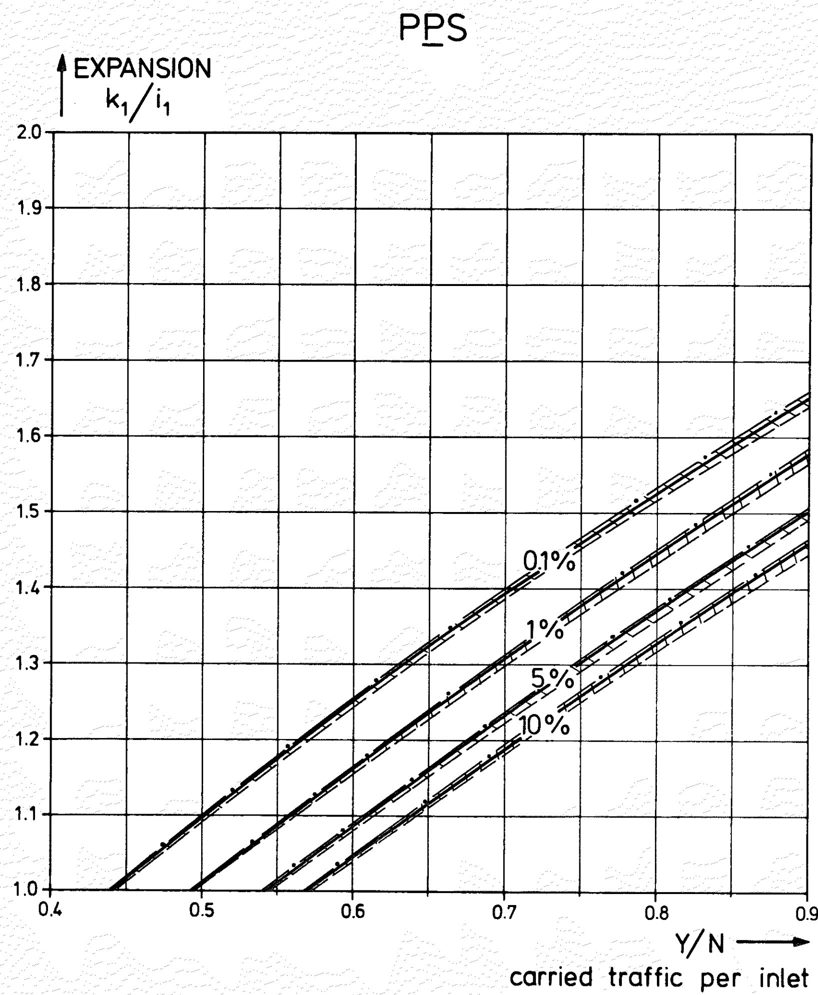
PCT 2

SDM

N = 32400 ——·——

N = 6561 ————

N = 2025 — — —



S = 6

i_1 = 10

PCT 2

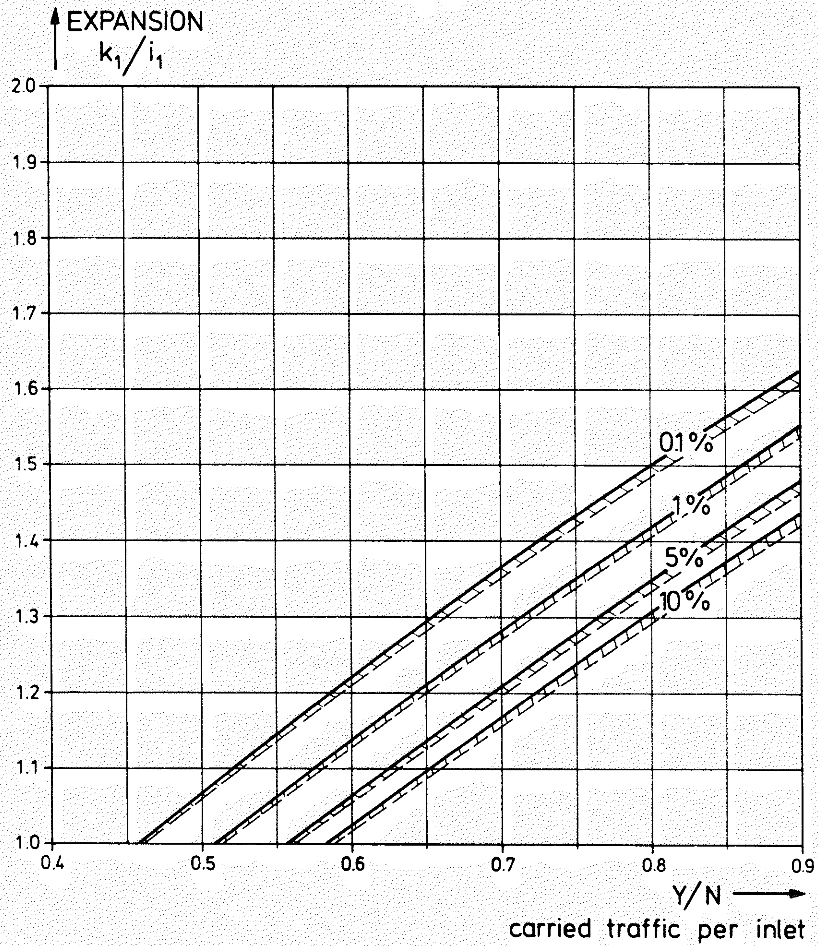
SDM

N = 40000 ——·——

N = 10000 ————

N = 2500 — — —

PPS



S = 6

i_1 = 11

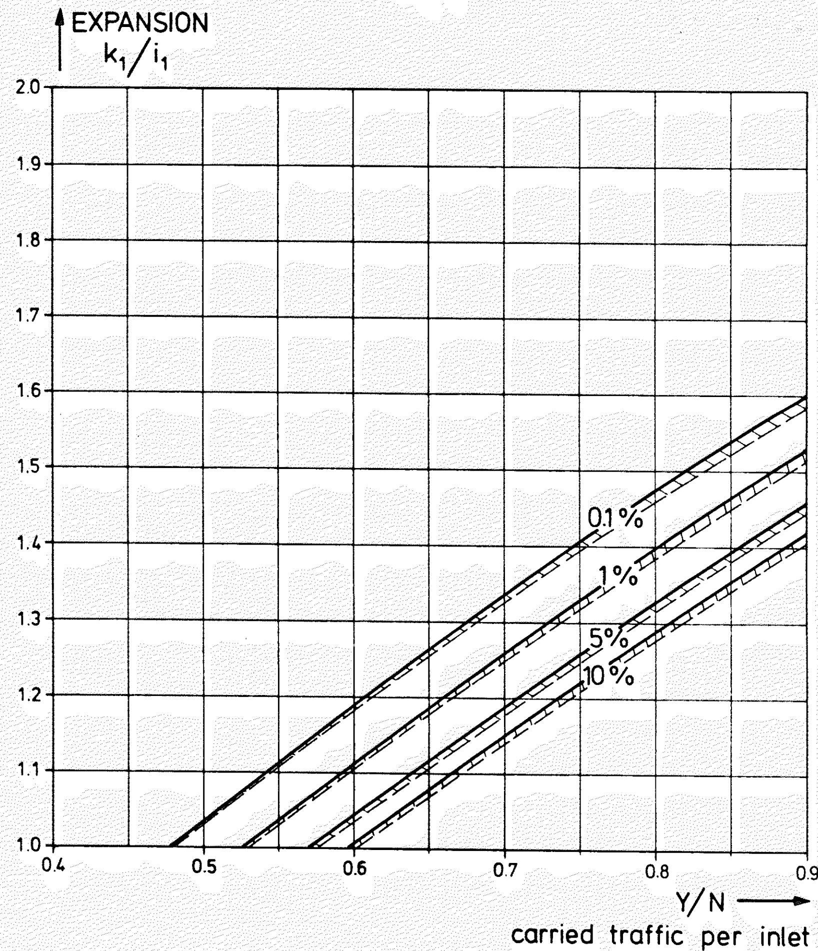
PCT 2

SDM

N = 48 400 }
N = 14 641 } ————

N = 3025 — — —

PPS



S = 6

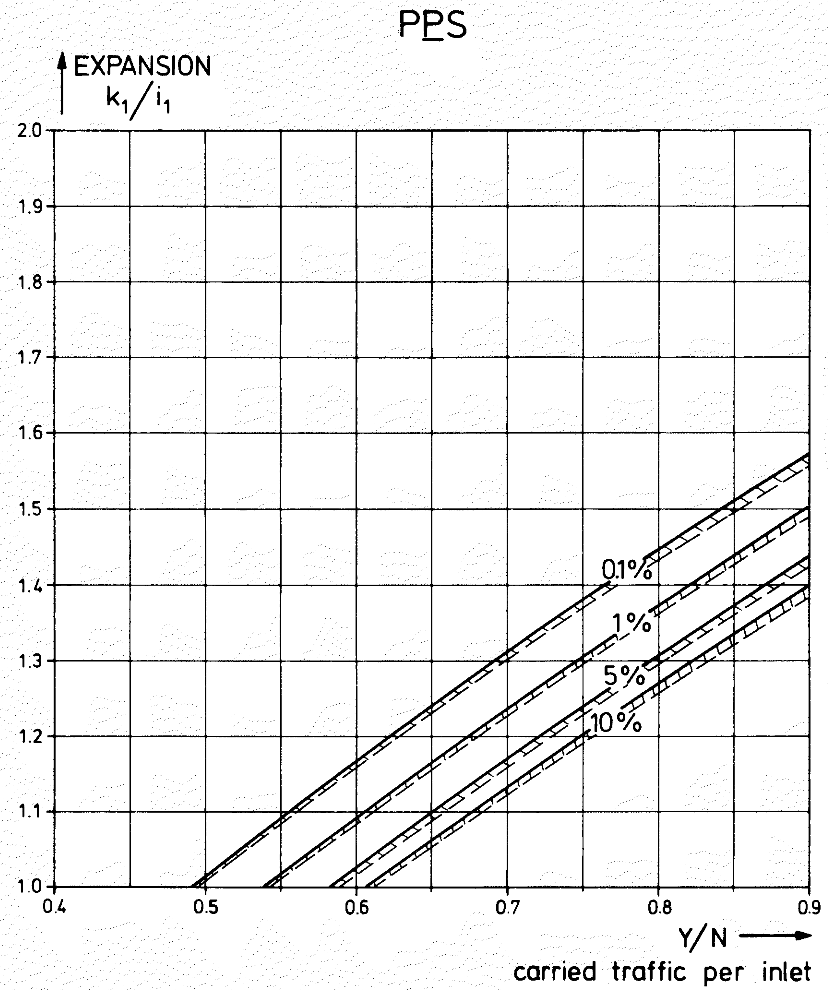
i_1 = 12

PCT 2

SDM

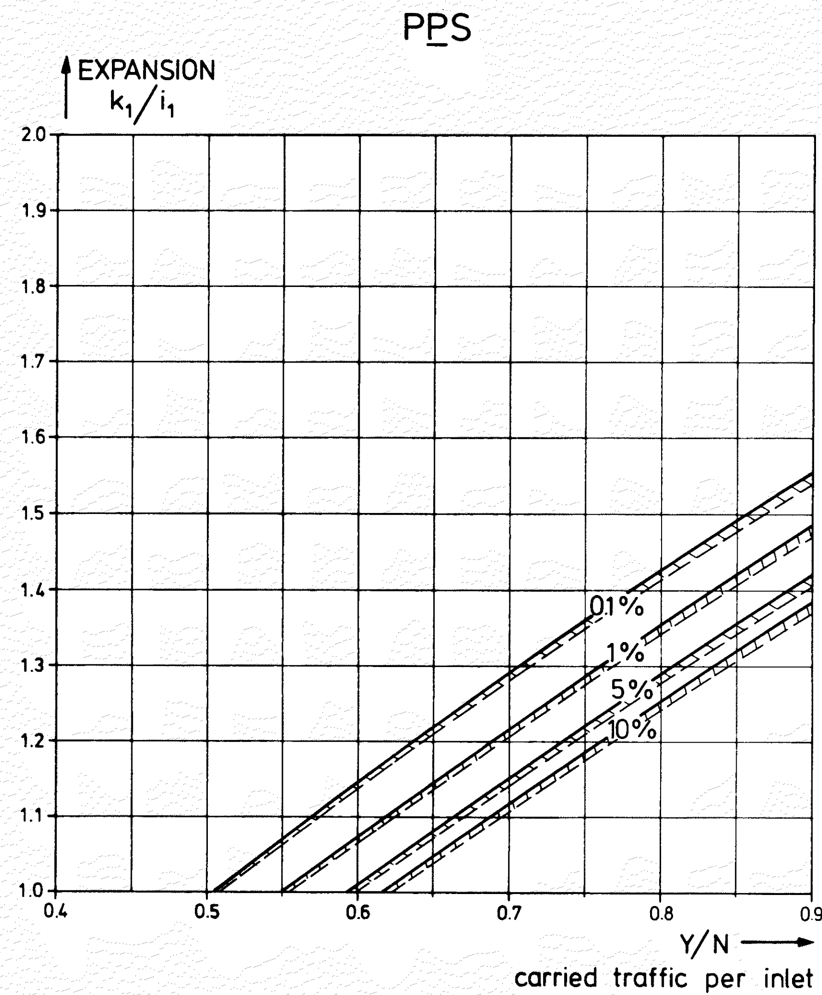
N = 57 600 }
N = 20 736 } ————

N = 3600 — — —



S = 6
i_1 = 13
PCT 2
SDM

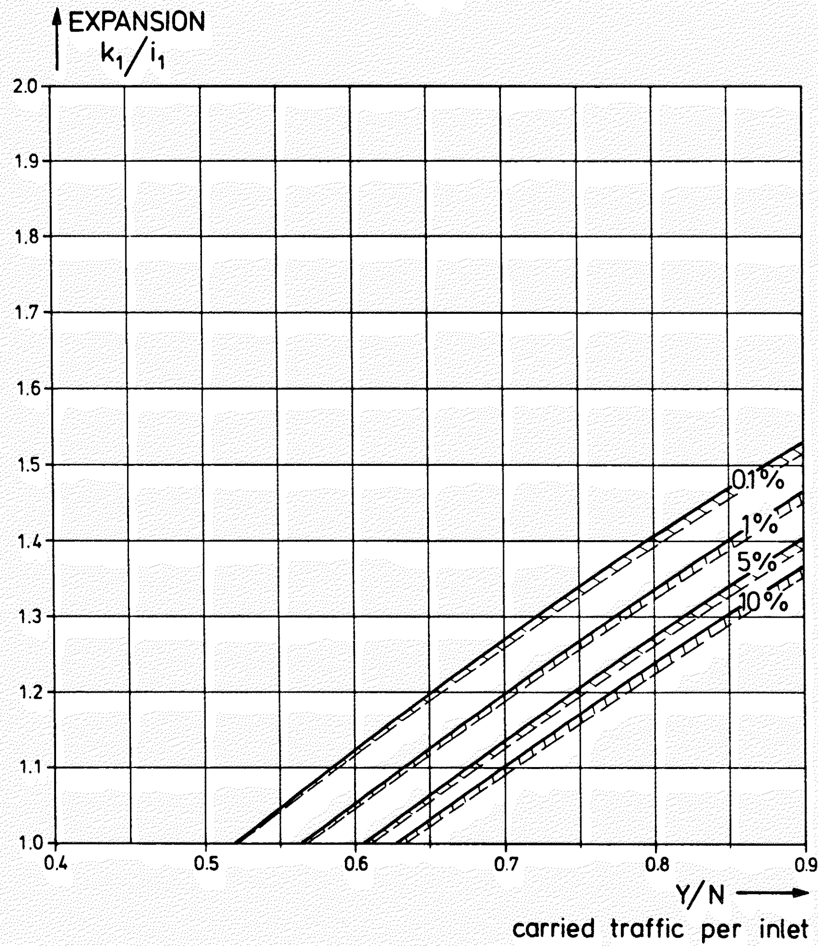
N = 67 600 } ———
N = 28 561 }
N = 4 225 — — —



S = 6
i_1 = 14
PCT 2
SDM

N = 78 400 } ———
N = 38 416 }
N = 4 900 — — —

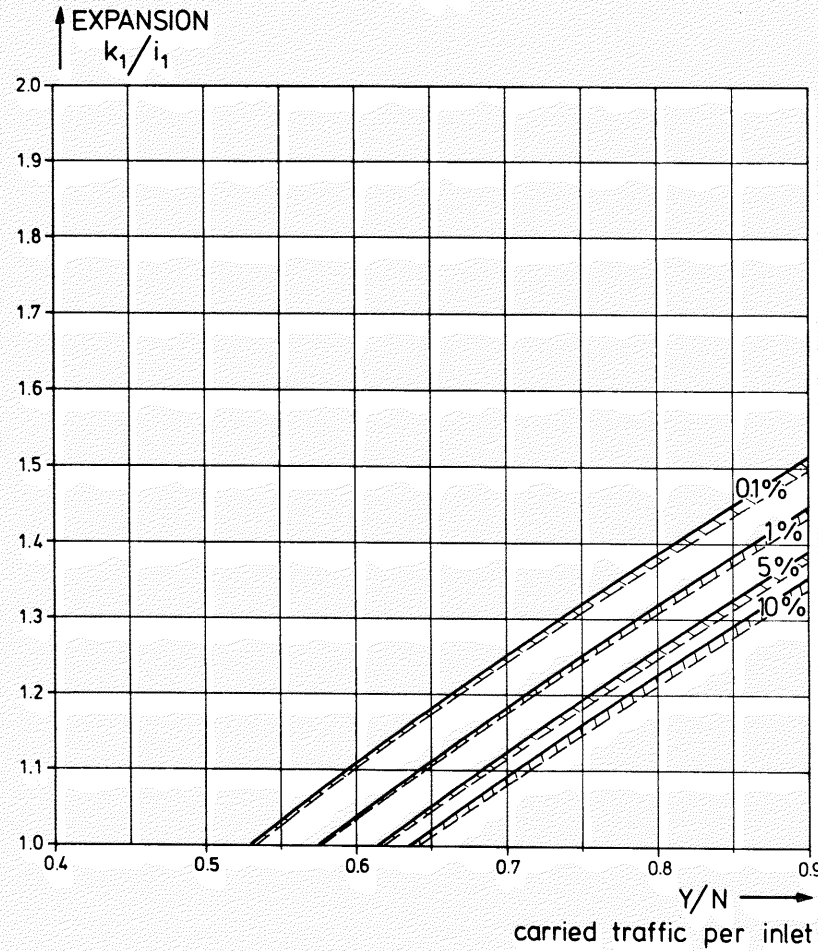
PPS



S = 6
i_1 = 15
PCT 2
SDM

N = 90000 } ———
N = 50625
N = 5625 — — —

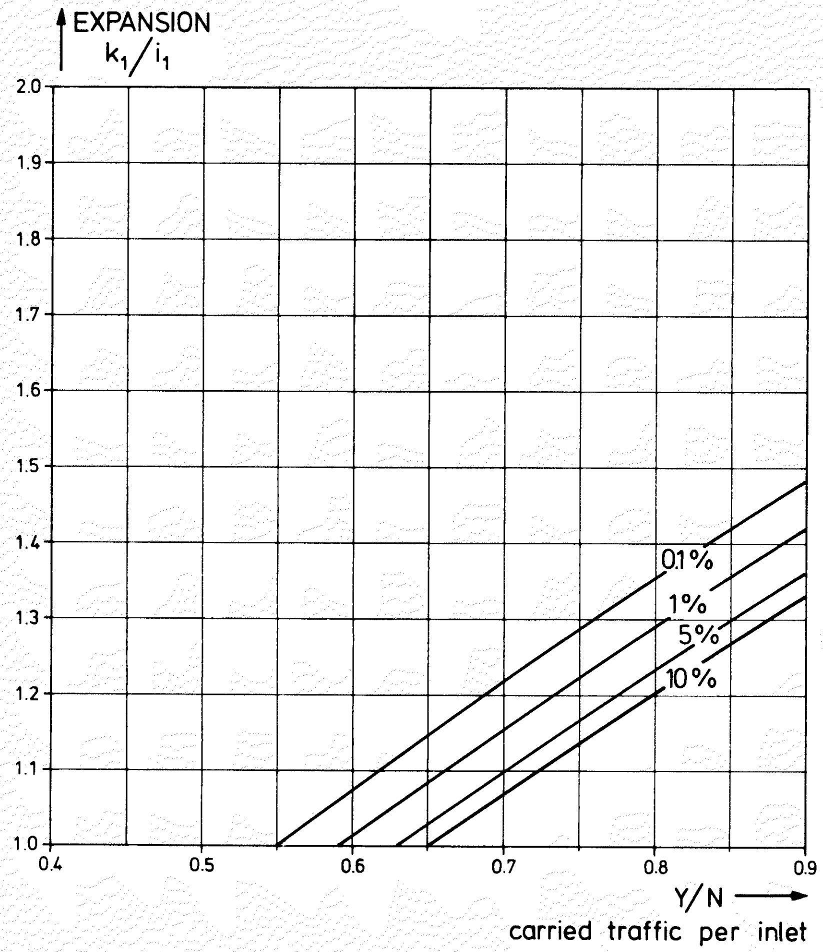
PPS



S = 6
i_1 = 16
PCT 2
SDM

N = 102 400 } ———
N = 65 536
N = 6 400 — — —

PPS



S = 6

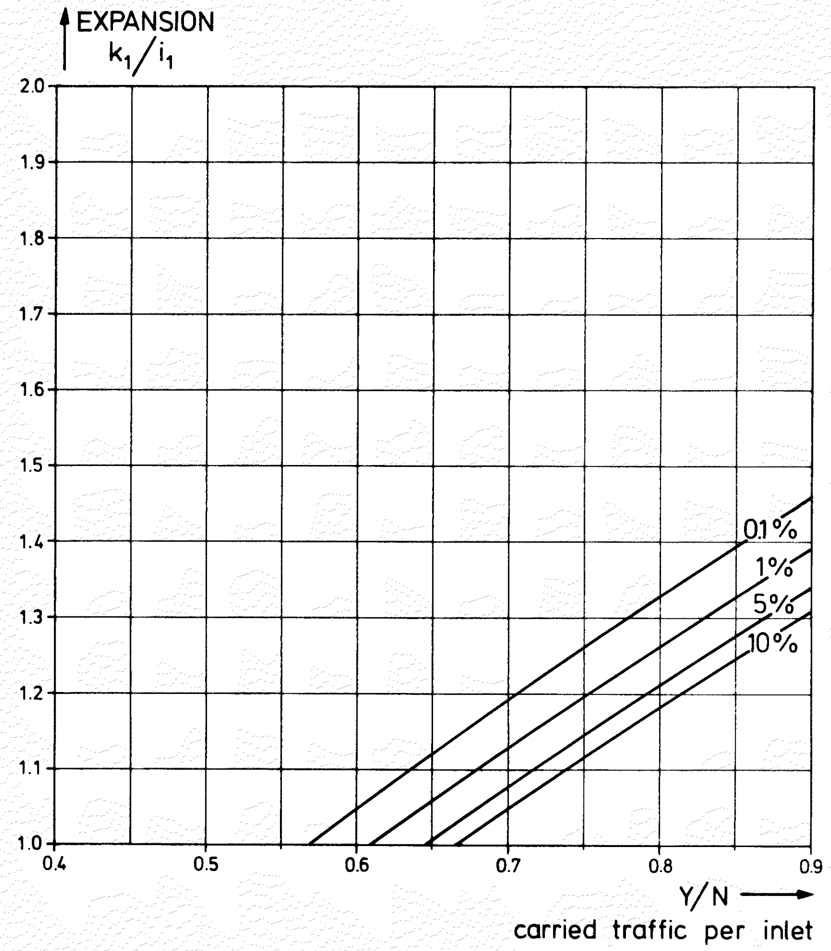
i_1 = 18

PCT 2

SDM

N = 291 600
N = 104 976
N = 32 400

PPS



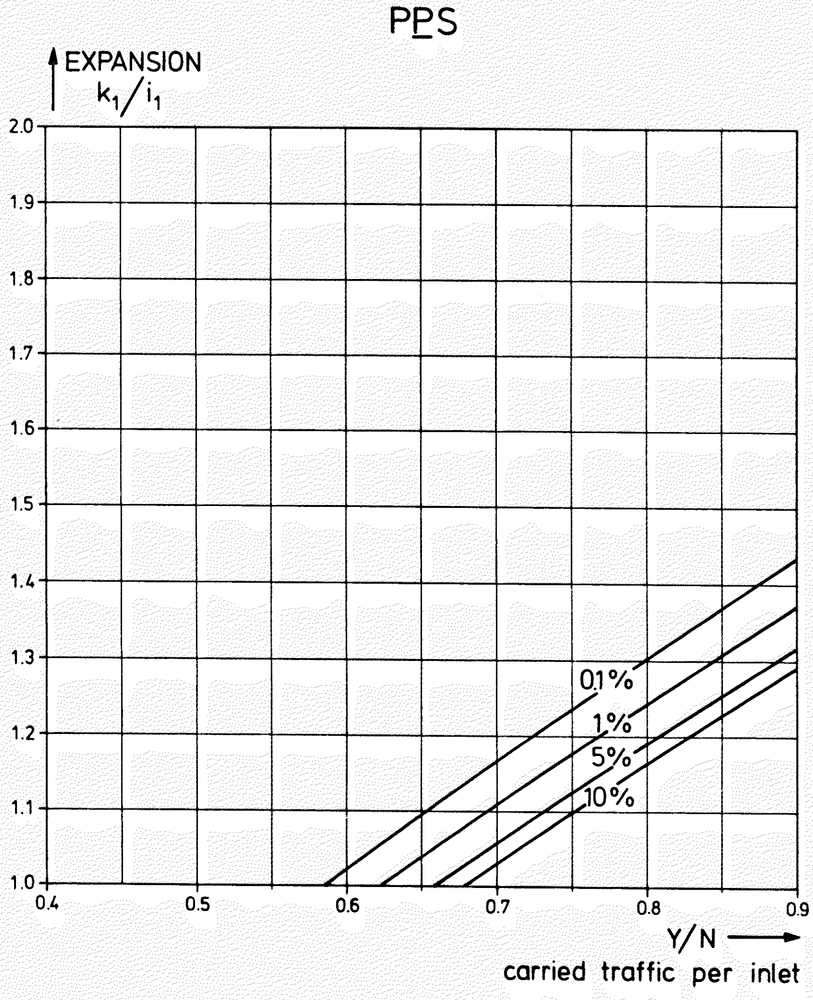
S = 6

i_1 = 20

PCT 2

SDM

N = 360 000
N = 160 000
N = 40 000



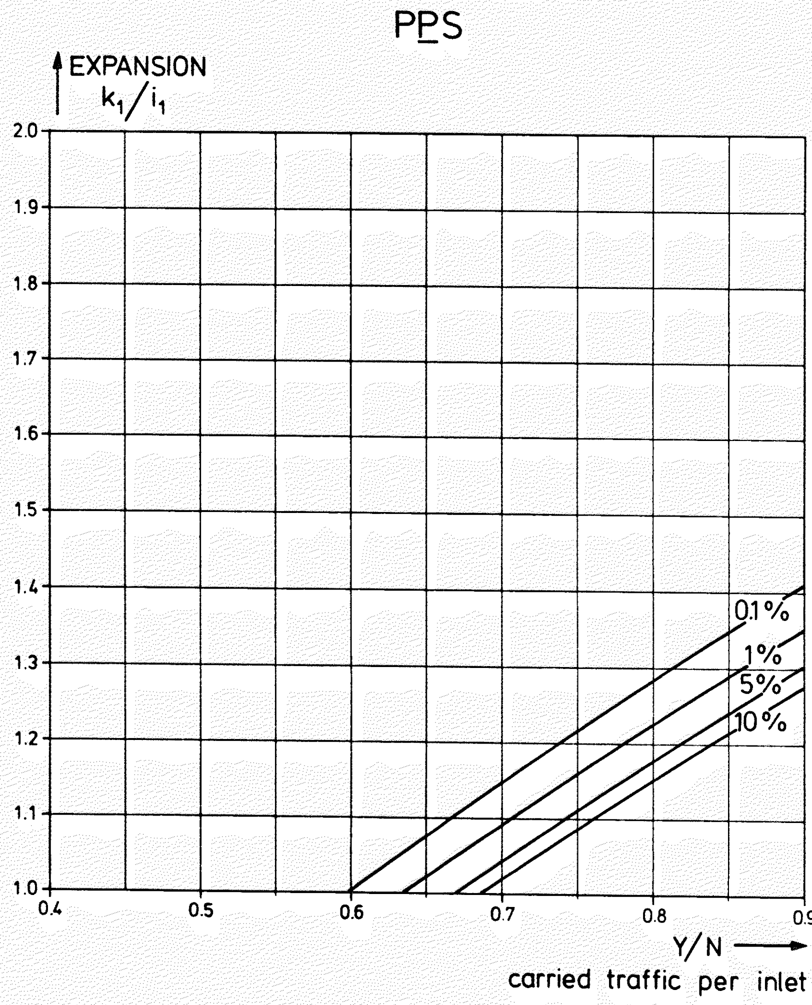
S = 6

i_1 = 22

PCT 2

SDM

N = 435 600
N = 234 256
N = 48 400



S = 6

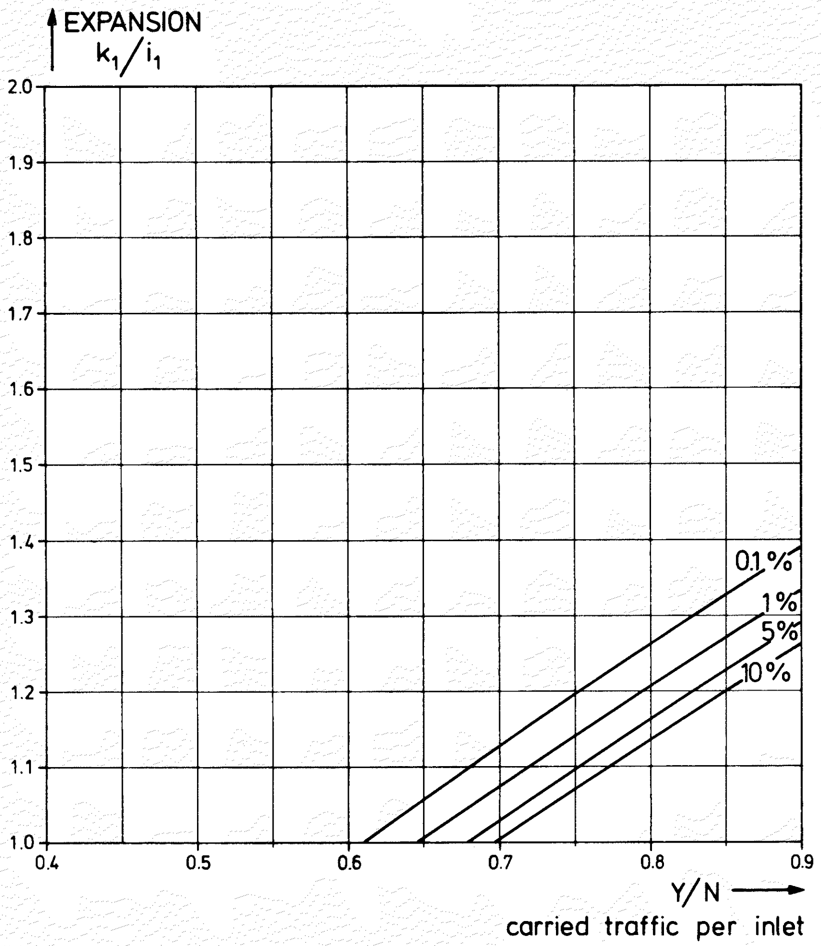
i_1 = 24

PCT 2

SDM

N = 518 400
N = 331 776
N = 57 600

PPS



S = 6

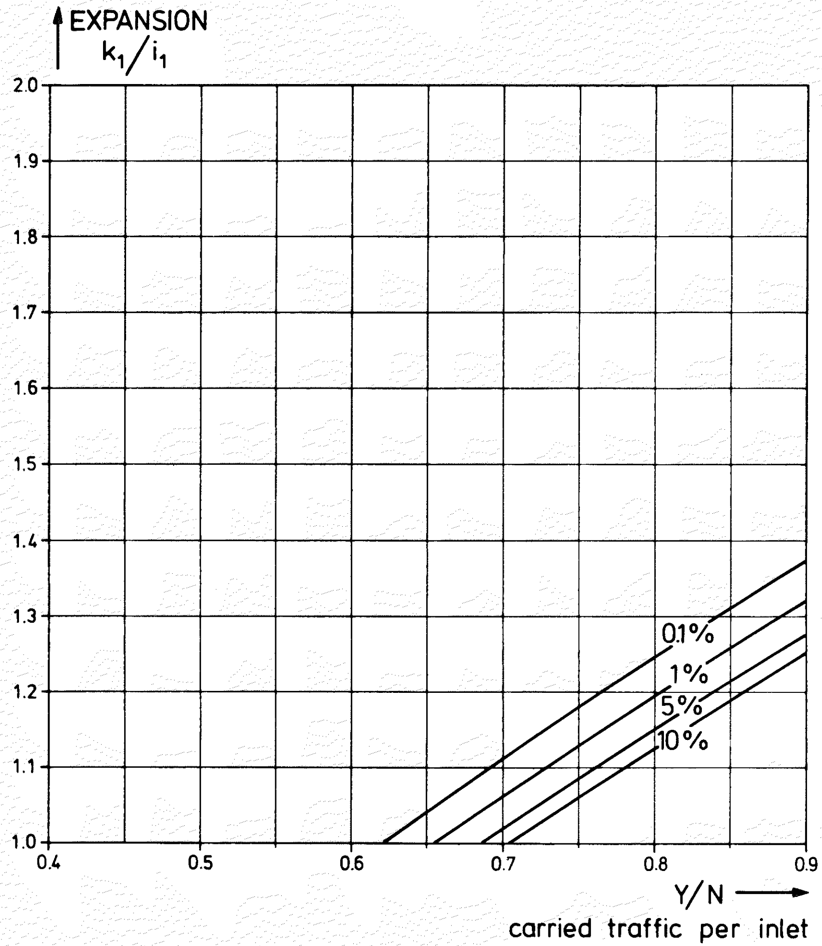
i_1 = 26

PCT 2

SDM

N = 608 400
N = 456 976
N = 67 600

PPS



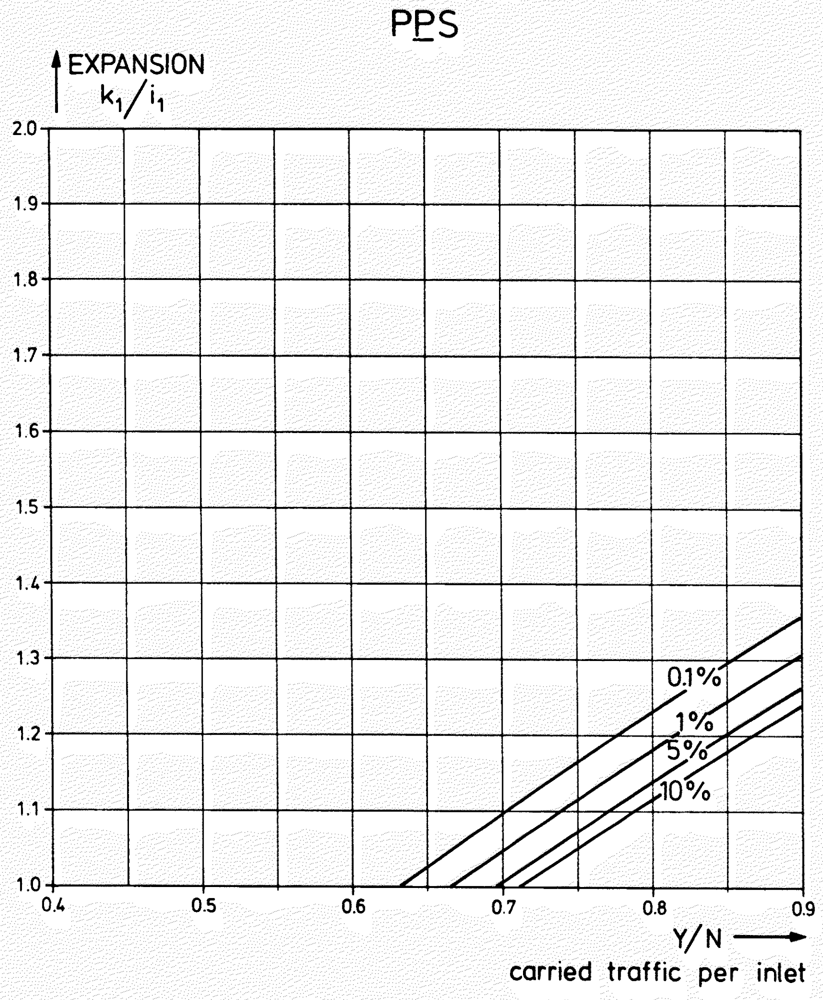
S = 6

i_1 = 28

PCT 2

SDM

N = 1 254 400
N = 614 656
N = 78 400



S = 6

i_1 = 30

PCT 2

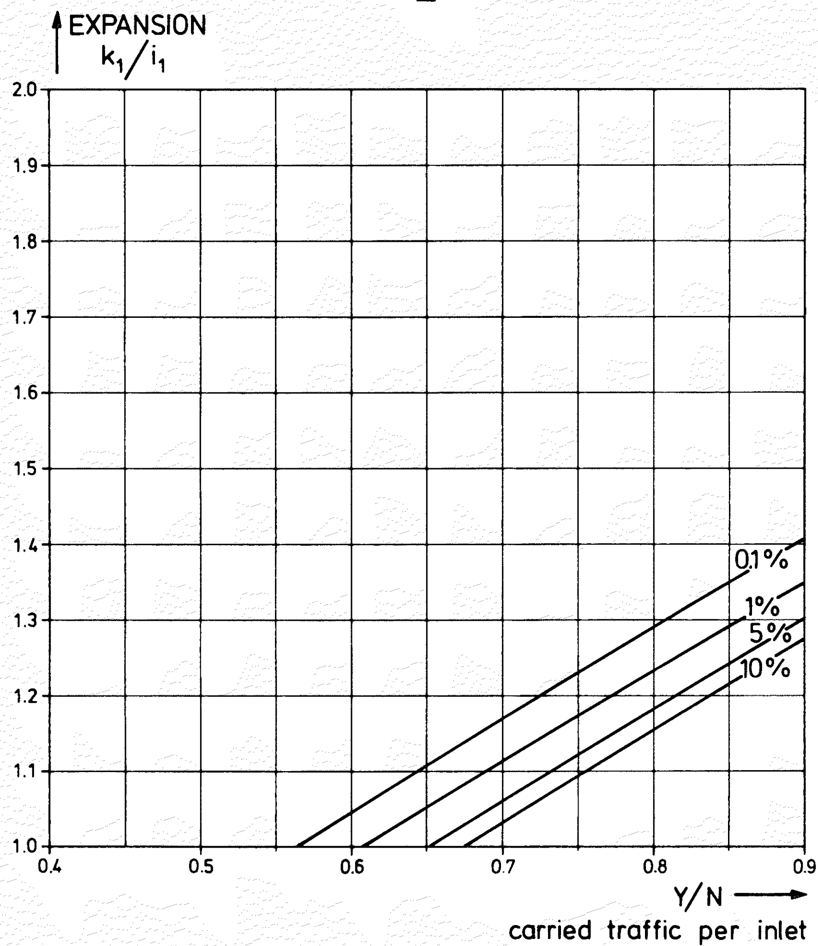
SDM

N = 1 440 000

N = 810 000

N = 90 000

PPS



S = 6

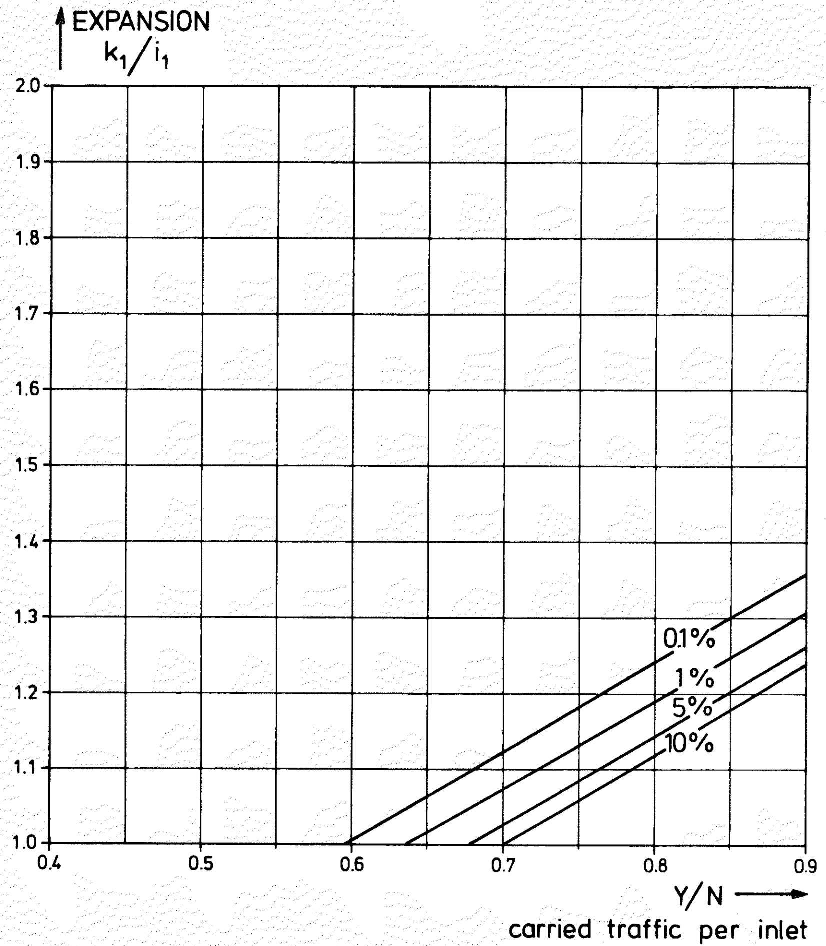
i_1 = 24

PCT 2

TDM

N = 518400
N = 331776
N = 57600

PPS



S = 6

i_1 = 30

PCT 2

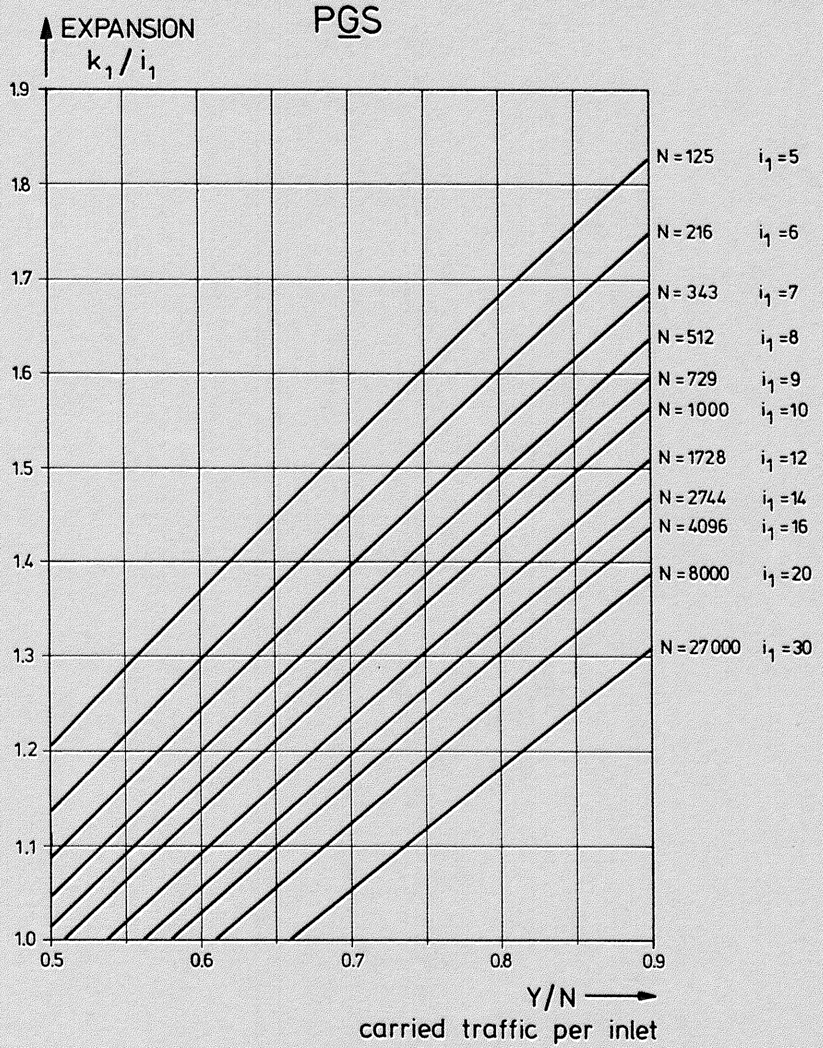
TDM

N = 1 440 000
N = 810 000
N = 90 000

NIK-CHARTS FOR POINT-TO-GROUP SELECTION

Number of stages	$S = 4, 5, 6$	chart 89, 90
Number of inlets per first stage multiple	$i_1 = 5 .. 30$	
Relative transparency	T_{rel}=120% for S=4	
	T_{rel}=130% for S=5,6	

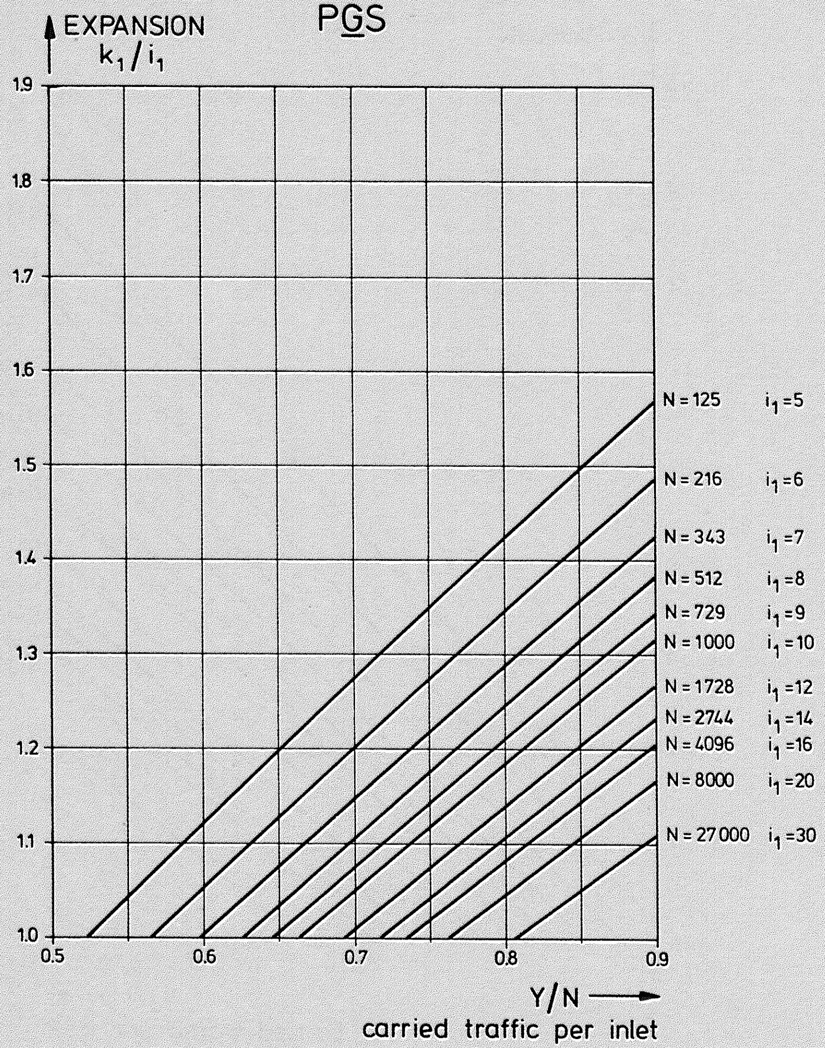
Number of stages	$S = 3$	chart 91, 92
Number of outlets per first stage multiple	$k_1 = 4 ..38$	
Relative transparency	T_{rel}=100%, 125%	



S = 4

i_1 = 5 ... 30 N = 125 ... 27000

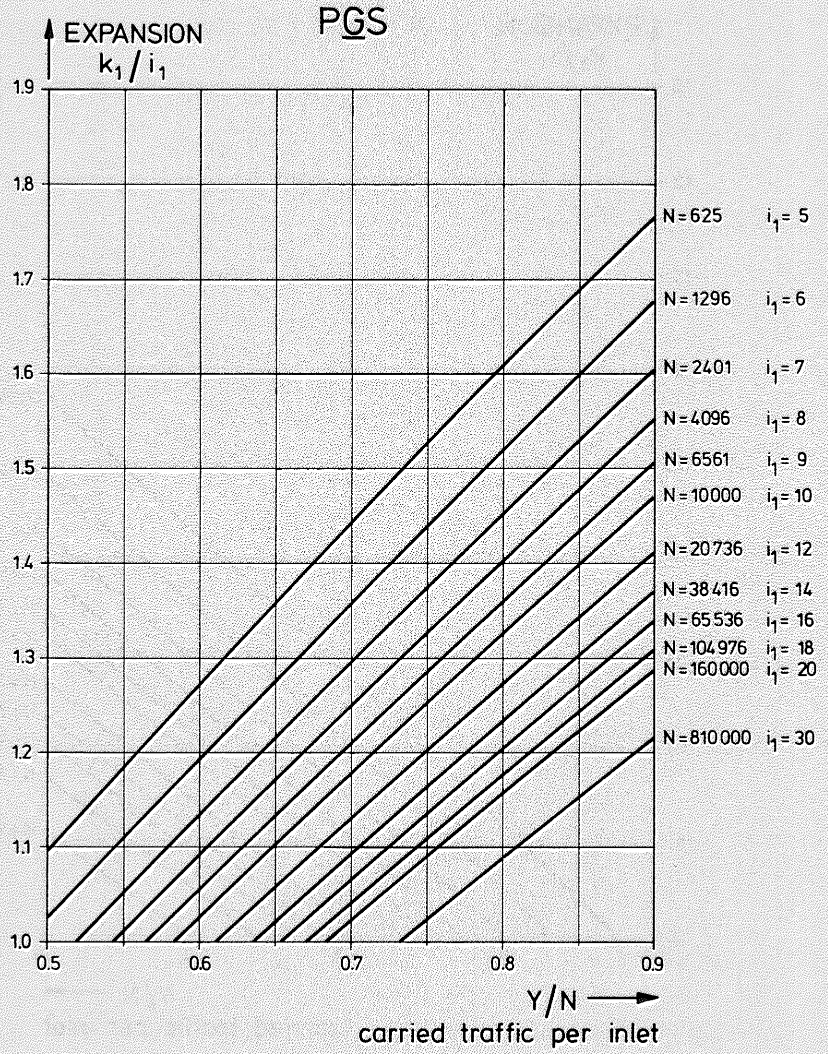
T_{rel} = 120%



S = 5

i_1 = 5 ... 30 N = 125 ... 27000

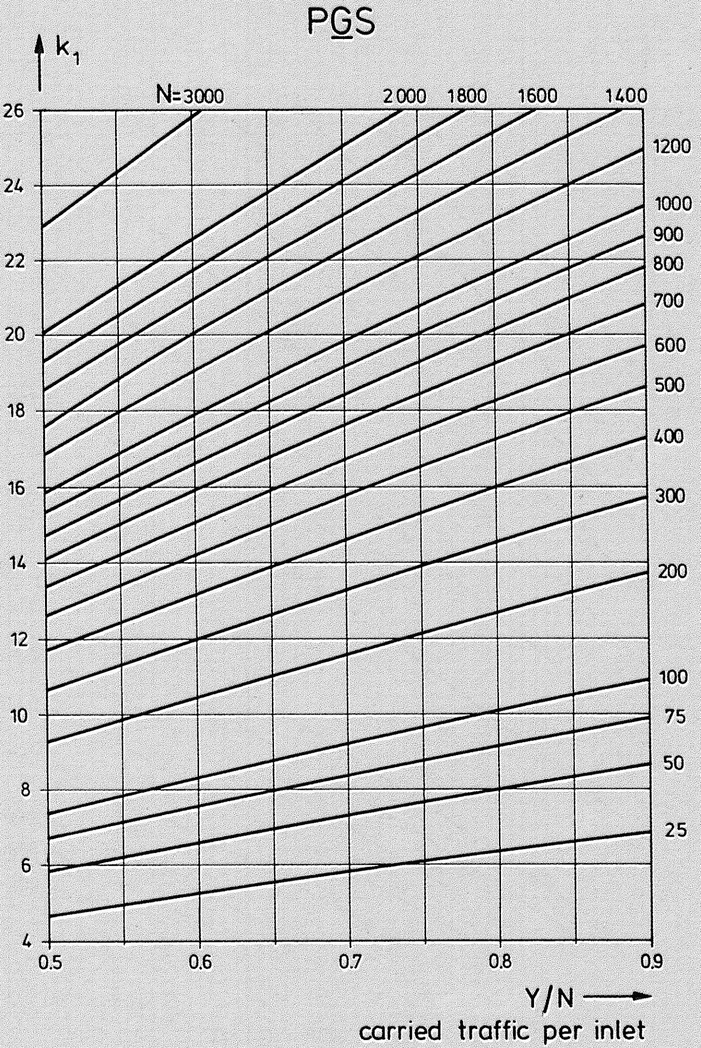
T_{rel} = 130%



S = 6

i_1 = 5...30 N = 625...810000

T_{rel} = 130 %

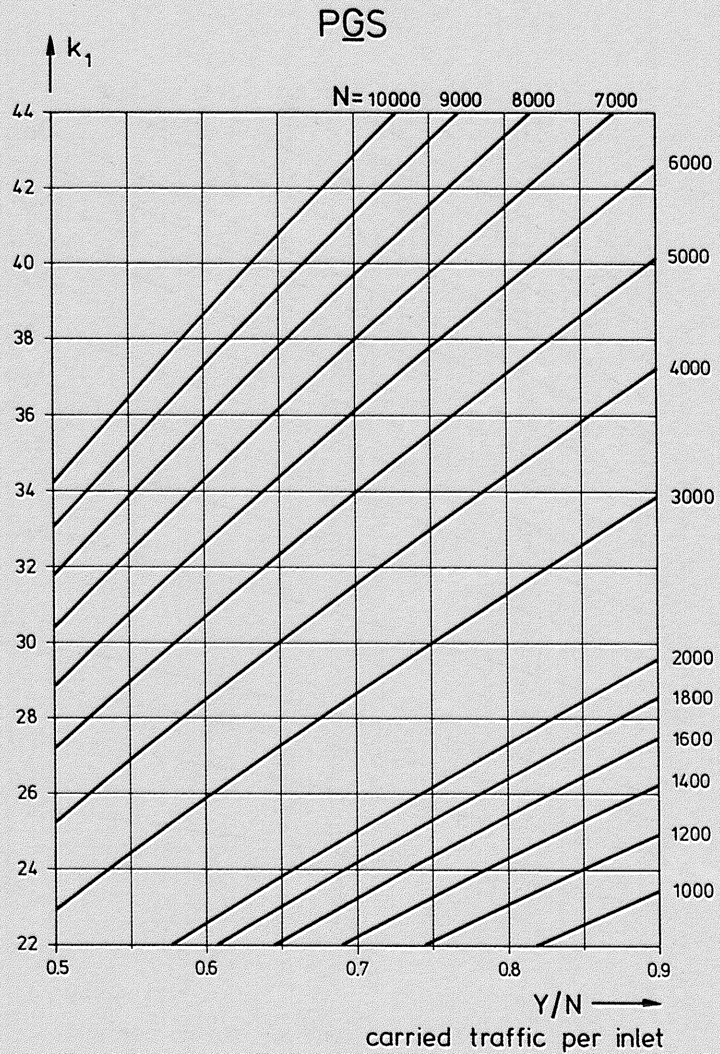


S = 3

k_1 = 4 ... 26

N = 25 ... 3 000

T_{rel} = 100 %

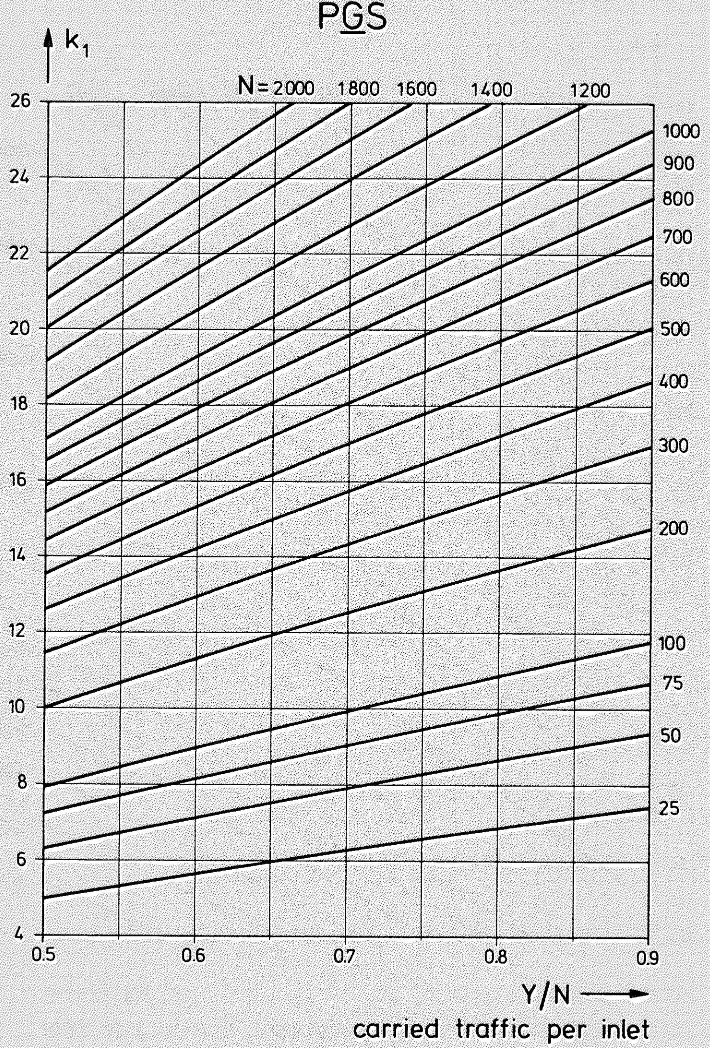


S = 3

k_1 = 22 ... 44

N = 1000 ... 10000

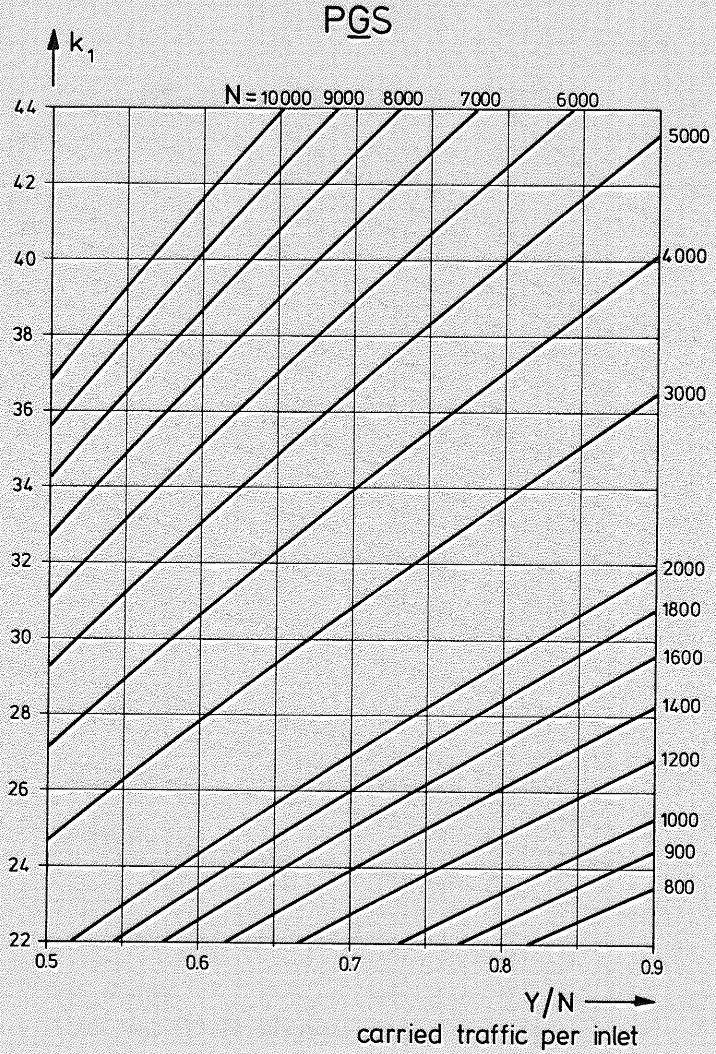
T_{rel} = 100 %



S = 3

$k_1 = 4 \dots 26$ N = 25 ... 2000

T_{rel} = 125%



S = 3

$k_1 = 22 \dots 44$ N = 800 ... 10000

T_{rel} = 125%