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"The airtightness of houses"

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J.T. Brunsell, S. Uvsløkk
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The airtightness of houses

Results of airtightness measurements in newer Norwegian dwellings

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The Norwegian Building Research Institute

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FOREWORD

This report presents the results from the first major airtightness investigation carried out on Norwegian dwellings. The investigation is part of a research project called " Energy Savings and the application of building technology".

The project is financed primarily by the Norwegian Natural Science Research Council. The Norwegian Building Research Institute, the Norwegian Institute of Wood Working and Wood Technology and Østlandskonsult have also provided a certain about of support.

Measurements have been carried out in conjunction with Østlandskonsult A/S.

Oslo, July 1980

Sven Erik Sundby

SUMMARY

Air leakages in a house can give rise to increased energy consumption, uncomfortable draughts and damaging moisture in the building structure. To achieve a better awareness of how tight Norwegian dwellings are built today, a field investigation of 61 detached houses and 34 flats selected at random from different parts of the country was carried out. They have been measured in accordance with the pressure method. In 14 of the detached houses and 6 of the flats, leakages were also traced with thermographic equipment. The occupants of the dwellings were interviewed, while the measurements were being carried out, with regard to draught problems etc. The most important results from the investigation are presented in this report.

The average leakage rate, at n_{50}, for detached houses was 4.7 air changes per hour and 1.3 for flats. The leakage rate for exposed dwellings was on average the same as for sheltered dwellings. Dwellings with more than one floor and skirting were significantly less tight than dwellings with only one floor and skirting. Dwellings with open fires were somewhat less tight than those with stoves. No clear connection was determined between the rate of leakage and dissatisfaction as a result of draughts.

Thermography indicated the same leakages, as a whole, from dwelling to dwelling, namely joints between individual building elements such as window/wall, roof/wall etc. As was expected, the greatest and most frequent leakages in blocks of flats were between the concrete structure and the lightweight infill walls.

The report concludes with comments on the results.

DEFINITIONS

The terms used in this report, and their definitions, are given below.

Envelope	- the structural elements of a dwelling which separate the indoor and outdoor climates.
Air change rate (changes/hour)	- the quantity of air supplied per unit of time to the room divided by the volume of the room.
Leakage rate n_{50}	- the mean number of air changes measured at 50Pa internal negative and positive pressure.
Air leakage	- adventitious airflow through the envelope or parts of the same.
Airtightness	- the ability a structure has to prevent air leakage.
Windtightness	- the ability a structure has to prevent air leakage into the structure though the effect of wind.
Draught	- airflow sensed as being cold or uncomfortable.
Pascal (Pa)	- measurement of pressure, 1 Pa = 1 $Nm/m^2 \simeq$ 0.1 mm wc.

1. INTRODUCTION

Traditionally energy consumption for heating has primarily been related to the thickness of insulation. As houses have become better insulated, the relative importance of air leakage to energy consumption has increased. Air leakages can also give rise to uncomfortable draughts and damaging moisture in the building structure. These problems, among others, have been considered in a research project at the Norwegian Building Research Institute on the application of building technology to energy savings.

To improve its knowledge of how tight normal buildings are constructed in Norway today, The Norwegian Building Research Institute carried out a series of measurements on dwellings selected at random throughout different parts of the country. Measurements were carried out according to the pressure method. In addition, some dwellings were subjected to thermographic testing to localise draughts. The prime purpose of the measurements was to collect basic data for calculating the extent of energy losses caused by air leakage and to evaluate the requirements for future technological measures concerning energy savings.

The calculations presented indicate that energy losses caused by air leakage depend to a considerable degree on local wind and temperature conditions. In a normal Norwegian detached house, a reduction in the leakage rate, at n_{50}, (see definition), from 6.0 to 3.0 will result in an annual reduction in energy consumption of between 1,500 and 10,000 kWh, irrespective of geographical location. The importance of airtightness in relation to energy consumption in dwellings will be discussed in detail in a later report.

Occupants of dwellings were interviewed in an attempt to find a possible connection between draught problems and leakage rates.

2. SELECTION OF THE DWELLINGS FOR THE INVESTIGATION

The number of dwellings measured was primarily limited by the measurement capacity and the funds available. In order to be able to measure a reasonable number of dwellings of roughly the same type, only detached houses and blocks of flats were selected as measurement objects. Measurements were concentrated to four districts, namely the districts of N. Kristiansund and Haugesund representing coastal areas with a considerable amount of wind and Oslo, Lørenskog and Fredrikstad districts, as less exposed areas of the country. The measurement objects cannot be considered a statistically representative selection of newer Norwegian dwellings. They are however considered representative of two of the commonest type of Norwegian dwellings with regard to design.

The detached houses were selected entirely at random in a number of communities in the districts in question. Selection was carried out by the communities themselves and in cooperation with the Norwegian Building Research Institute. Two of the conditions applied during selection were that the dwellings should be between 1 and 5 years old and of conventional design. As far as can be ascertained, only the selection carried out by one community cannot be considered completely random. In this particular case, the detached houses were selected so that the greatest number of builders were represented. It is thought that this method has not affected the average result for the district to any significant extent.

The detached houses were mostly standard mortgaged properties with a traditional timber framework. The detached houses were generally spread over the whole of the community. The blocks of flats had site-cast concrete party wall frames with timber framework infill walls. The flats measured are somewhat more concentrated to a few housing areas.

The purpose of measuring both in exposed areas and sheltered areas was mainly to register possible differences in the design of the buildings with regard to airtightness. This was s based on the assumption that exposed buildings affected by wind were given more attention to make them tight. On this basis, it would have been advantageous to carry out measurements in Northern Norway. This was not possible for practical reasons.

The quantity, type and geographical location of the dwellings measured can be seen in Table 2.1.

Table 2.1
Overview of types, quantity and location of dwellings investigated.

Community	Number of dwellings investigated	
	Detached houses	Blocks of flats
Haugesund	8	
Karmøy (Haugesund area)	3	
Tysvaer (" ")	6	
Kristiansund N.	14	19
Fredrikstad	2	
Borge (Fredrikstad area)	3	
Rolvsøy (" ")	3	
Kråkerøy (" ")	3	
Onsøy (" ")	4	
Oslo		15
Lørenskog (Oslo area)	15	

3. METHODS

Airtightness measurements were carried out according to the pressure method.

Using this method, the total air leakage through the dwelling´s floor, walls and roof, resulting from a forced pressure difference between inside and outside, was measured. The magnitude of this pressure difference was such that air leakages caused by temperature and wind, up to a certain velocity, did not have any effect on the final result. The method provided therefore a reproducible measurement of a dwelling´s airtightness resulting from leakages through the envelope.

The pressure test method should not be confused with the tracer gas method. The latter is used to measure the degree of ventilation in a dwelling from natural pressure differences resulting from prevalent wind and temperature conditions.

Apart from locating air leaks by feeling with our hands, we also used thermographic equipment and hot-wire anemometers. The method is described in more detail below.

The pressure method

Measurements were carried out as described in the proposal for Nordic test method "75-77 Method of test for air tightness of buildings", with one exception. See below.

By using an adjustable fan fitted to an external door, air was blown into or out of the dwelling such that a set pressure difference was maintained between indoors and outdoors.

Air leakages

Pressure difference measurement

Duct for measuring airflow

Airflow

Adjustable fan

Figure 3.1
Principle of tightness measurement using the pressure method. The fan is reversed to measure at an internal negative pressure.

The airflow past the fan, which was the same as the leakages through the dwelling, was measured at the following pressure differences: 10, 20, 30, 40, 45, 50 and 55 Pa. Measurements were taken at both positive and negative internal pressure. The leakage rate at n_{50} is a measurement of the dwelling´s tightness and is arrived at by dividing the average quantity of air supplied by the dwelling´s volume. n_{50} is therefore the number of air changes per hour measured at 50 Pa. A higher leakage rate indicates a pervious dwelling. Other methods to compare different dwellings are considered in Section 4.

The equipment used by the Norwegian Building Research Institute comprised a thyristor-controlled axial fan, a piezostatic tube, two micromanometers and an x-y plotter. see Figure 3.2.

Figure 3.2
Airtightness measuring equipment assembled for measuring a flat.

The speed of the fan was regulated automatically. The pressure difference across the piezostatic tube, which is an expression of the airflow, and the pressure difference between indoors and outdoors was measured with the aid of the micromanometers connected to the inputs of the x-y plotter.

The airflow was calculated from the equipment's calibration chart. The result was presented in the form of a curve showing the interdependent values between airflow and pressure difference. See figure 3.3.

$q(m^3/h)$ n (changes/h)

POSITIVE PRESSURE

n_{50} MEAN VALUE

NEGATIVE PRESSURE

50 Δp(Pa)

Figure 3.3
Relationship between air supplied and pressure difference

The dwellings were tightened as much as possible by the occupants prior to measurement. Windows, air supply devices, air valves etc. were closed. An exception was openings for mechanical exhaust and supply air which were sealed with tape. This also applied to kitchen extractor fans. According to the proposal for a Nordic test method, the valves for natural ventilation should also be sealed with tape. This however was omitted in the investigation. All rooms which were normally heated to 10^{o}C or more were included in the measurements.

The method is useful for charting the tightness characteristics of dwellings since the same measurement conditions can be applied from dwelling to dwelling. The results can therefore be compared directly. They do not however give an answer to how great the leakages are under normal non-test conditions. Furthermore, only the leakages which pass through the building envelope are included in the measurements.

The accuracy of the measurement results is dependent on the wind velocity. For wind velocities up to 6 m/s, the leakage rate at n_{50} can be stated with an accuracy of $\pm$ 8%.

Thermography

Measurements were carried out as described in "Nordtest Build 061".

Thermography equipment registers the intensity of part of the heat radiation (IR radiation) from a surface. For common surfaces, the radiation intensity is primarily determined by the surface´s temperature. Temperature variations of the surface investigated appear as variations in brightness on a screen. A cold surface appears as dark areas whereas warmer surfaces appear brighter. The screen can be photographed with a polaroid camera.

All faults or deficiencies which produce variations in surface temperatures can in principle be detected with the aid of thermography. Such faults or deficiencies may be inadequate insulation, cold bridges, air voids in a wall or air leakages.

To be able to localise air leakages using thermographic equipment, certain conditions must apply:

- There must be a temperature drop across the structure.
- There must be a pressure difference across the structure.
- The structure/leakage must be such that the airflow through the leakage either heats or cools the surface visible to the camera.

A negative pressure is normally established in the dwelling with the aid of a fan. Cold outdoor air then penetrates through the leakages and cools the internal covering. This is indicated by dark "jagged" areas on the screen. If the cold air penetrates the structure but does not emerge on the inside, the dark areas have rounded contours. See Figure 3.4.

Thus the results depend on the cold outdoor air cooling the visible surfaces and being registered by thermography. In cases where the air flows directly into the room without being in contact with inner surfaces, it is less simple to register such leaks with thermography.

Figure 3.4
Thermograms - air leakages.
a. Leakage through the structure.
b. Leakage inside the structure.

Thermography cannot be used to quantify leakages, only to locate them.

Measurements were carried out using AGA Thermovision 750 equipment. See Figure 3.5.

Figure 3.5
Thermography equipment.

Interviews

In interviews we attempted to assess energy consumption for heating, draught problems etc. Among the questions asked was, "Are you satisfied with the dwelling as far as tightness is concerned?". The replies were limited to the following three alternatives:

- Yes, quite satisfied.
- No, not completely satisfied.
- No, dissatisfied.

Because of the quantity of information related to other conditions, only this question is treated in this report.

4. MEASUREMENT RESULTS

Results from airtightness measurements

The results can be presented in several ways.

By stating the measured airflow in m^3/h at a fixed pressure difference the size of the dwelling has a significant effect on the result. The size needs to be considered when calculating energy consumption resulting from adventitious ventilation.

To be able to compare different dwellings, having different shapes and sizes, it is appropriate to convert the values measured.

By dividing the measured airflow by the dwelling's enveloping surface area, a direct expression of the envelope's average perviousness is obtained.

Another way of presenting the results is to divide the airflow measured by the volume heated. This method was selected for the following reasons:

- This is the commonest method used in the Nordic countries and the results can therefore be compared easily with other countries' results.
- The leakage rate is a comparatively easy and comprehensible expression of a building's perviousness.
- It is probable that future requirements will be stated in this form.

The results from tightness measurements are illustrated in Diagrams 1 - 15. The leakage rate, n_{50}, for each individual dwelling is indicated by a bar. The circles under the bars give answers by occupants to the question:

"Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied.

◐ No, not completely satisfied.

● No, dissatisfied.

Diagrams 1 and 2 illustrate the results from all the detached houses and flats together. To assess how the individual parameters affected airtightness, the dwellings were classified according to the following:

- geographical location
- number of floors
- whether they had stoves or open fires
- whether they were complete or incomplete with regard to tightness.

These parameters are illustrated in Diagrams 3 - 15. The letters above the bars indicate the communities in which the dwellings were situated.

B:	Borge	L:	Lørenskog
F:	Fredrikstad	On:	Onsøy
H:	Haugesund	O:	Oslo
K:	Kråkerøy	R:	Rolvsøy
Ka:	Karmøy	T:	Tysvaer
KN:	N. Kristiansund		

Diagram 1

TYPE OF DWELLING: Detached houses, all that were included in the investigation.
COMMUNITY: All the communities in the investigation.
QUANTITY: 61
MEAN LEAKAGE RATE $n_{50} = 4.7$
STANDARD DEVIATION $s = 1.5$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 2

TYPE OF DWELLING: Blocks of flats.
COMMUNITY: All the communities in the investigation.
QUANTITY: 34
MEAN LEAKAGE RATE $n_{50} = 1.3$
STANDARD DEVIATION $s = 0.4$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

LEGEND

The bar indicates the dwelling´s leakage rate n_{50}. See previous definition.

The circle under each bar gives the occupant´s answer to the question: "Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied
◐ No, not completely satisfied
● No, dissatisfied

Diagram 3

TYPE OF DWELLING: Detached houses

COMMUNITY: Fredrikstad, Borge, Kråkerøy, Onsøy

QUANTITY: 15

MEAN LEAKAGE RATE $n_{50} = 4.6$

STANDARD DEVIATION $s = 1.7$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 4

TYPE OF DWELLING: Detached houses

COMMUNITY: Lørenskog

QUANTITY: 15

MEAN LEAKAGE RATE $n_{50} = 4.8$

STANDARD DEVIATION $s = 1.6$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 5

TYPE OF DWELLING: Detached houses

COMMUNITY: Haugesund, Karmøy, Tysvaer

QUANTITY: 17

MEAN LEAKAGE RATE $n_{50} = 4.8$

STANDARD DEVIATION $s = 1.4$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 6

TYPE OF DWELLING: Detached houses

COMMUNITY: N. Kristiansund

QUANTITY: 14

MEAN LEAKAGE RATE $n_{50} = 4.7$

STANDARD DEVIATION $s = 1.3$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

LEGEND

The bar indicates the dwelling´s leakage rate n_{50}. See previous definition.

The circle under each bar gives the occupant´s answer to the question: "Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied

◐ No, not completely satisfied

● No, dissatisfied

Diagram 7

TYPE OF DWELLING: Detached houses, single storey
COMMUNITY: All that were included in the investigation
QUANTITY: 12
MEAN LEAKAGE RATE n_{50} = 4.6
STANDARD DEVIATION s = 1.1

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 8

TYPE OF DWELLING: Detached houses, single storey + basement
COMMUNITY: All that were included in the investigation
QUANTITY: 39
MEAN LEAKAGE RATE n_{50} = 4.4
STANDARD DEVIATION s = 1.4

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 9

TYPE OF DWELLING: Detached houses, more than one storey + basement
COMMUNITY: All that were included in the investigation
QUANTITY: 10
MEAN LEAKAGE RATE n_{50} = 6.1
STANDARD DEVIATION s = 1.6

LEAKAGE RATE, n_{50}

(Air change rate/hour)

LEGEND

The bar indicates the dwelling´s leakage rate n_{50}. See previous definition.

The circle under each bar gives the occupant´s answer to the question: "Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied

◑ No, not completely satisfied

● No, dissatisfied

Diagram 10

TYPE OF DWELLING: Detached houses with flue and stove

COMMUNITY: All that were included in the investigation

QUANTITY: 33

MEAN LEAKAGE RATE n_{50} = 4.6

STANDARD DEVIATION s = 1.5

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 11

TYPE OF DWELLING: Detached houses with flue and open fire

COMMUNITY: All that were included in the investigation

QUANTITY: 28

MEAN LEAKAGE RATE n_{50} = 4.9

STANDARD DEVIATION s = 1.5

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 12

TYPE OF DWELLING: Detached houses which are complete from a tightness point of view

COMMUNITY: All that were included in the investigation

QUANTITY: 37

MEAN LEAKAGE RATE n_{50} = 4.5

STANDARD DEVIATION s = 1.2

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 13

TYPE OF DWELLING: Detached houses which are incomplete from a tightness point of view

COMMUNITY: All that were included in the investigation

QUANTITY: 24

MEAN LEAKAGE RATE $n_{50} = 5.1$

STANDARD DEVIATION $s = 1.8$

LEAKAGE RATE, n_{50}

(Air change rate/hour)

LEGEND

The bar indicates the dwelling´s leakage rate n_{50}. See previous definition.

The circle under each bar gives the occupant´s answer to the question: "Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied

◐ No, not completely satisfied

● No, dissatisfied

Diagram 14

TYPE OF DWELLING: Blocks of flats

COMMUNITY: Oslo

QUANTITY: 15

MEAN LEAKAGE RATE n_{50} = 1.1

STANDARD DEVIATION s = 0.4

LEAKAGE RATE, n_{50}

(Air change rate/hour)

Diagram 15

TYPE OF DWELLING: Blocks of flats

COMMUNITY: N. Kristiansund

QUANTITY: 19

MEAN LEAKAGE RATE n_{50} = 1.4

STANDARD DEVIATION s = 0.2

LEAKAGE RATE, n_{50}

(Air change rate/hour)

LEGEND

The bar indicates the dwelling´s leakage rate n_{50}. See previous definition.

The circle under each bar gives the occupant´s answer to the question: "Are you satisfied with the dwelling as far as tightness is concerned?"

O Yes, quite satisfied

◐ No, not completely satisfied

● No, dissatisfied

Results from thermography

In total, 14 detached houses and 6 flats were thermophotographed. There are two reasons why so few dwellings were investigated. Firstly, earlier experience from damage investigation showed that the same leaks occurred from house to house. Secondly, thermography is so time-consuming that a higher frequency of thermography would have been at the cost of airtightness measurements.

Detached houses

Table 4.1 indicates the positions and extent of the commonest leakages in the 14 detached houses thermophotographed. The leakage rates in these dwellings varied between 3.2 and 7.7 with a mean value of 5.6 changes/h.

Flats

Table 4.2 indicates the positions and extent of the commonest leakages in the 6 flats thermophotographed. The leakage rates in these dwellings varied between 1.3 and 1.5 with a mean value of 1.4 changes/h.

Table 4.1

Leakages in detached houses

Structural part/ Leakage	No. of dwellings (of 14) which had leaks	No. of dwellings (of 14) where the leaks were significant
Window, between frame-jamb	7	2
Window, between jamb-wall	11	5
Window, slot valves	5	5
Outer door, between door-jamb	10	7
Outer door, between stile-wall	9	5
Between ceiling-outer wall	14	13
Between ceiling-inner wall	13	12
Between floor-outer wall	11	9
Between floor-inner wall	5	2
Between inner wall-outer wall	8	4
Adjacent to electrical installations	3	3
Around open fires	9 (of 12)	9 (of 12)
Around chimneys	5 (of 14)	5 (of 14)
Around skylights	12 (of 12)	11 (of 12)
Around glued timber sections	5 (of 6)	4 (of 6)

Table 4.2

Leakages in flats

Structural part/ Leakage	No. of flats (of 6) which had leaks	No. of flats (of 6) where the leaks were significant
Window, between frame-jamb	4	3
Window, between jamb-wall	5	3
Window, slot valves	5	4
Outer door, between door-jamb	3	2
Outer door, between jamb-wall	3	2
Between ceiling-outer wall	6	3
Between ceiling-inner wall	2	0
Between floor-outer wall	3	2
Between floor-inner wall	0	0
Between outer wall-inner wall	2	1
Adjacent to electrical installations	?	?

5. COMMENTS ON THE MEASUREMENT RESULTS

The classification of the dwellings in groups according to the number of floors etc. provided some interesting information.

Geographical location

The assumption that houses built in exposed areas of the country were more airtight than houses in sheltered areas proved to be incorrect.The average leakage rates bear this out:

Detached houses

Exposed areas (Kristiansund and Haugesund districts), 31 dwellings, $\bar{n}_{50}$ = 4.8 changes/h.

Sheltered areas (Lørenskog and Fredrikstad districts), 30 dwellings, $\bar{n}_{50}$ = 4.7 changes/h.

Flats

Exposed areas (N. Kristiansund), 19 dwellings, $\bar{n}_{50}$ = 1.4 changes/h.

Sheltered areas (Oslo), 15 dwellings, $\bar{n}_{50}$ = 1.1 changes/h.

Where detached houses are concerned, it is reasonable to assume that earlier variations in the state of the dwellings included airtightness measures which are now partly obsolete as a result of standardised design.

Number of floors (detached houses)

The mean leakage rates for the three groups were:

Single storey	12 dwellings, $\bar{n}_{50}$ = 4.6
Single storey + skirting	39 dwellings, $\bar{n}_{50}$ = 4.4
More than one storey + skirting	10 dwellings, $\bar{n}_{50}$ = 6.1

There is a clear indication that houses with more than one storey are less tight than others. Probably the main reason for this is the difficulty in making an airtight vapour barrier past the intermediate joist structure. The vapour barrier is often the most important component with regard to air resistance in a wall and any leakage in this, for example between storeys, can result in an increased leakage rate.

The results show that dwellings with open fires were less tight than those with only stoves. All the dwellings measured had flues.

Complete or incomplete tightness (detached houses)

In some of the dwellings, a certain amount of tightness work was lacking. This applied in particular to the basement.

Openings which did not have supply valves were however sealed with tape, plastic foil etc., and the doors into rooms were closed so as not to be included in the measurements. The average leakage rates for these groups were:

Tightness measures complete	37 dwellings, $\bar{n}_{50} = 4.5$
Tightness measures incomplete	24 dwellings, $\bar{n}_{50} = 5.1$

It is reasonable to assume that the mean leakage rate for the latter group will approach 4.5 changes/h when tightness measures are completed.

Localisation and extent of leakages

The dwellings thermographed were only investigated from the inside and with a forced negative pressure (50 Pa). The tests primarily showed leakages in the inner tightness layer. (See also under method description). The evaluation of the significance of leakages has been made bearing energy consumption in mind and primarily on the basis of thermography. Thus the evaluation is perhaps not conclusive.

The investigations showed however that leakages tend to occur around joints between different structural elements such as window/wall, ceiling/wall etc.

Sheet metal cladded surfaces were generally tight as were joints between metal sheets with the exception of some houses with panelled ceilings.

In some of the dwellings that had panelled walls or ceilings we found leakages in the middle of some panels.

This strengthened our previous assumption that a sheet metal clad surface is basically tight ....

.... irrespective of the type of vapour barrier and board, particularly when the panels have glued or taped joints. The vapour barrier is however important for the tightness of inner surfaces.

The flats investigated were all of the same design in principle. Floors dividing storeys and party walls were site-cast concrete with timber or steel framed infill walls. Dividing floors and party walls of site-cast concrete were almost completely tight as were the joints between them. Leakages in flats were therefore limited to infill walls and the joints to concrete, windows, doors and miscellaneous services holes in the concrete walls.

Correlation between leakage rate and dissatisfaction caused by draughts

The replies from occupants to the question of draughts does not indicate any clear correlation between dissatisfaction and leakage rate. A certain tendency can be seen in the case of detached houses that occupants of tight houses are less troubled by draughts than others. No connection was registered in flats for the same conditions. Even though the flats had a lower mean leakage rate than detached houses, 60% of flat occupants were not totally satisfied on the question of draughts whereas the figure was 30% in the case of detached houses.

There may be a number of reason for this:

- Most detached houses had natural ventilation whereas flats had mechanical exhaust air devices. Thus in flats there is usually a negative indoor air pressure. In a tight flat, the magnitude of this negative pressure is greatly dependent on whether the slot air valves are open or not. When it is cold outside, the valves are closed and the negative pressure increases. This leads to an increased air velocity through leakages and often subsequent draught problems.

- In flats, the air leakages were primarily concentrated to facade walls. These were often as bad as walls in detached dwellings.

- Many who lived in detached houses had often contributed in the building work and were therefore partly responsible for leakages in the houses. Thus they are less inclined to complain that the house they helped to build leaks than those who purchased a finished house or those who rent accomodation.

- Some people are more "energy-minded" than others.
- People tolerate draughts differently.
- The dwellings investigated were mostly new ones and thus the answers received depended on comparisons with previous dwellings.

Final comments

The results for all the groups, Diagrams 1 - 15, indicate a considerable spread. In detached houses, n_{50} varied from 2.0 to 8.0 changes/h. The variation was somewhat less in flats, n_{50} varied from 0.6 to 1.8 changes/h. The reasons for the variations, and why many houses are insufficiently tight, are many:

- insufficient motivation among those concerned, eg inferior inspection and ignorance of the importance of tightness,
- inadequate knowledge of how to build airtight houses.

Both these can lead to:

- inadequate or bad planning of tightness/jointing,
- the use of faulty or incorrect materials,
- incorrect working procedures on site,
- bad workmanship on site.

By rectifying these anomalies, it is fully possible to build reasonably airtight dwellings without changing techniques to any great extent. Already it is quite clear that houses are built with inferior airtightness. The degree of tightness to be aimed for is difficult to determine at present. This will however be treated in a later report.

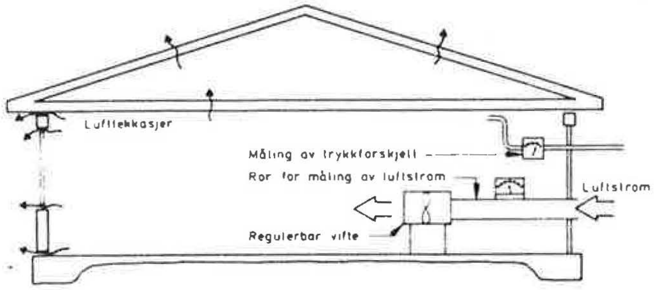


Fig. 3.1
Prinsipp for tetthetsmåling med trykkmetoden
Viften snus for måling med innvendig undertrykk.

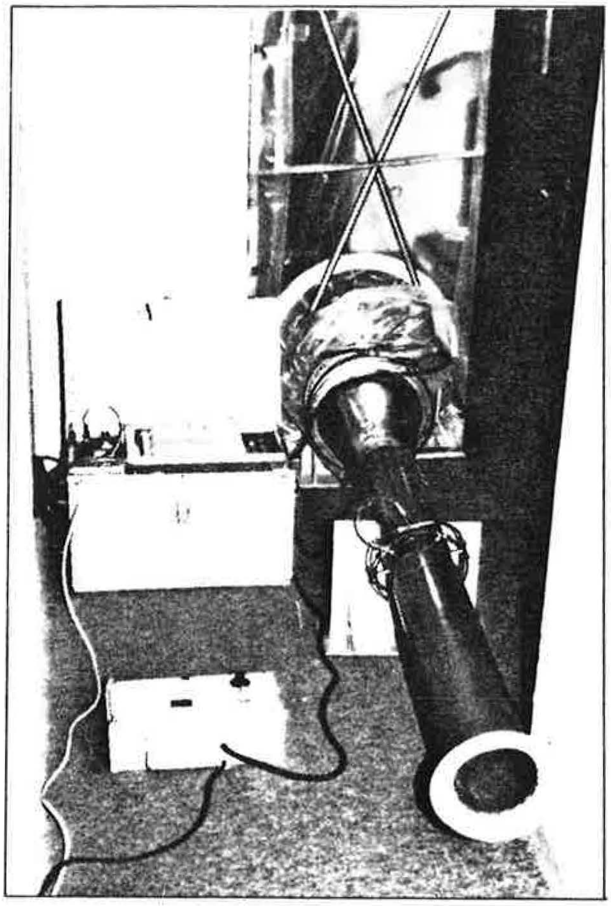


Fig. 3.2
Lufttetthetsmåleutstyret oppmontert for måling av en blokkleilighet

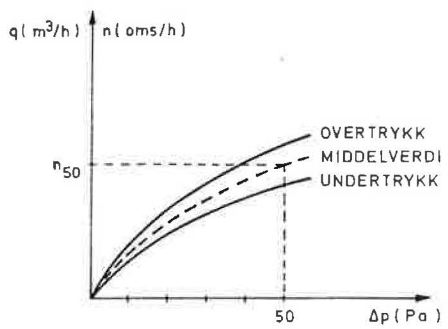
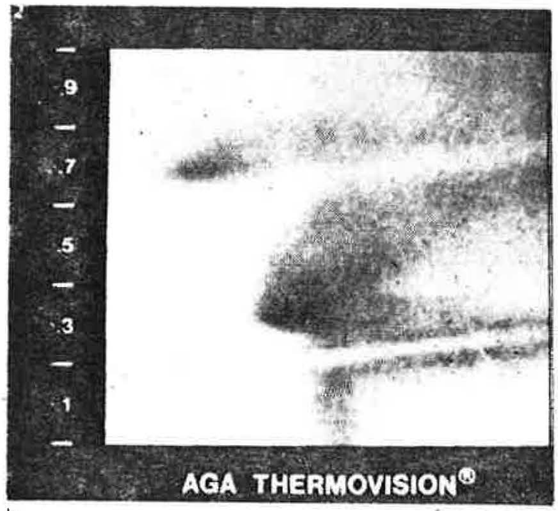


Fig. 3.3
Sammenheng mellom luftmengde og trykkforskjell

a



b

Fig. 3.4
Termogrammer - luftlekkasje
a. Lekkasje gjennom konstruksjonen
b. Lekkasje inne i konstruksjonen

Fig. 3.5
Termograferingsutstyr

Diagram 1

TYPE BOLIG : Eneboliger, alle som har vært med i undersøkelsen
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 61
MIDLERE LEKKASJETALL n_{50} = 4,7
STANDARDAVVIK s = 1,5

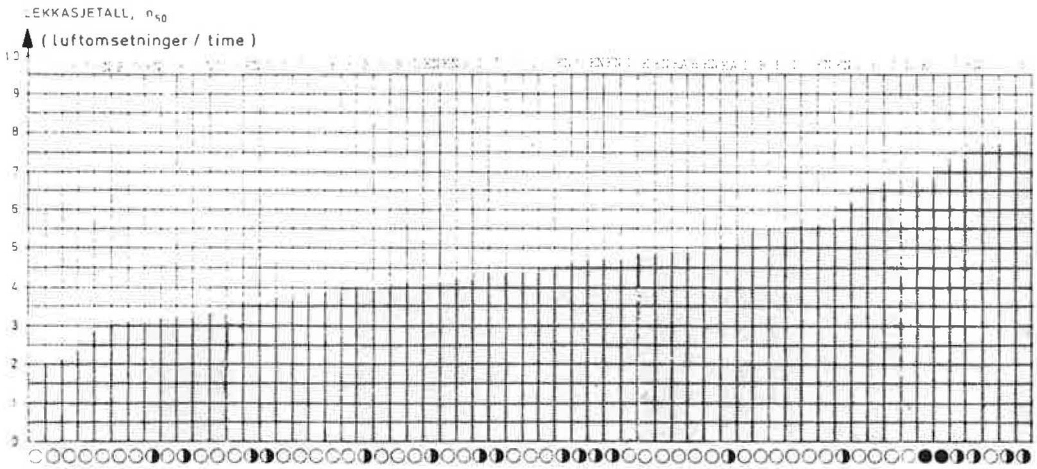
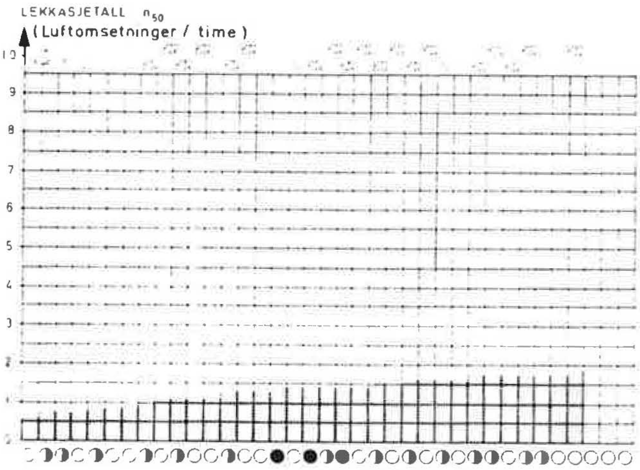


Diagram 2

TYPE BOLIG : Blokkleiligheter
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 34
MIDLERE LEKKASJETALL n_{50} = 1,3
STANDARDAVVIK s = 0,4



FIGURFORKLARING

 Stolpen angir boligens lekkasjetall, n_{50} (se difinisjon foran)

Sirklene under hver stolpe angir hvilket svar beboerne ga på spørsmålet: "Er dere fornøyde med boligen m.h.t. trekk?"

○ Ja, godt fornøyd

◗ Nei, ikke helt fornøyd

● Nei, misfornøyd

Diagram 3

TYPE BOLIG : Eneboliger
KOMMUNE : Fredrikstad, Borge, Kråkerøy, Rolvsøy, Onsøy
ANTALL : 15
MIDLERE LEKKASJETALL n_{50} = 4,6
STANDARDAVVIK s = 1,7

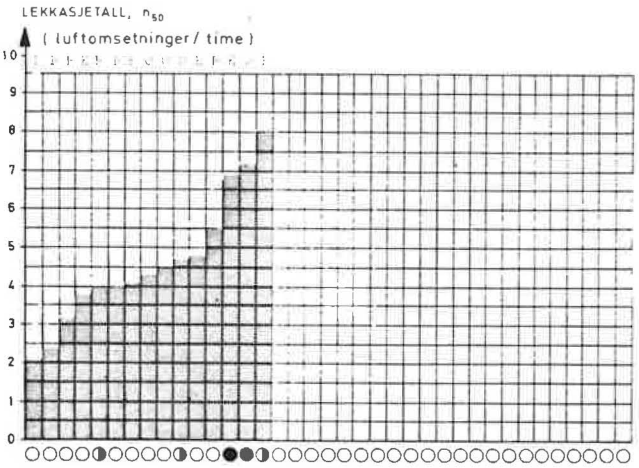


Diagram 4

TYPE BOLIG : Eneboliger
KOMMUNE : Lørenskog
ANTALL : 15
MIDLERE LEKKASJETALL n_{50} = 4,8
STANDARDAVVIK s = 1,6

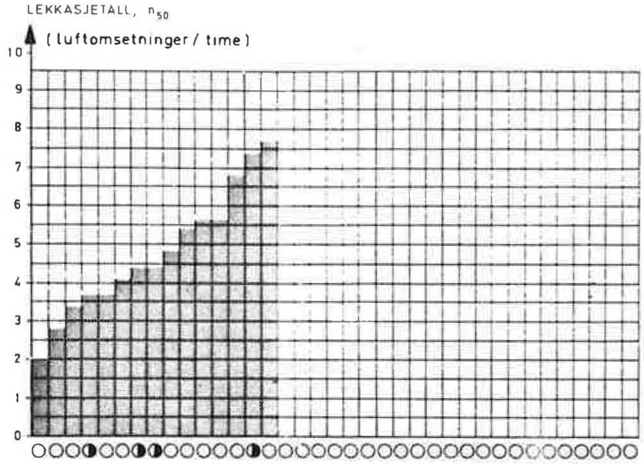


Diagram 5

TYPE BOLIG : Eneboliger
KOMMUNE : Haugesund, Karmøy, Tysvær
ANTALL : 17
MIDLERE LEKKASJETALL n_{50} = 4,8
STANDARDAVVIK s = 1,4

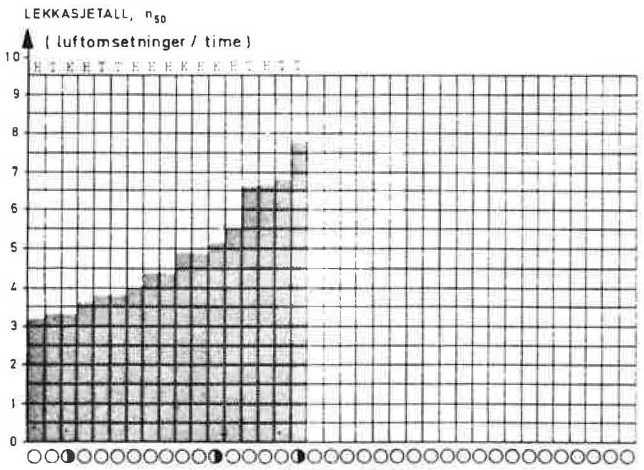
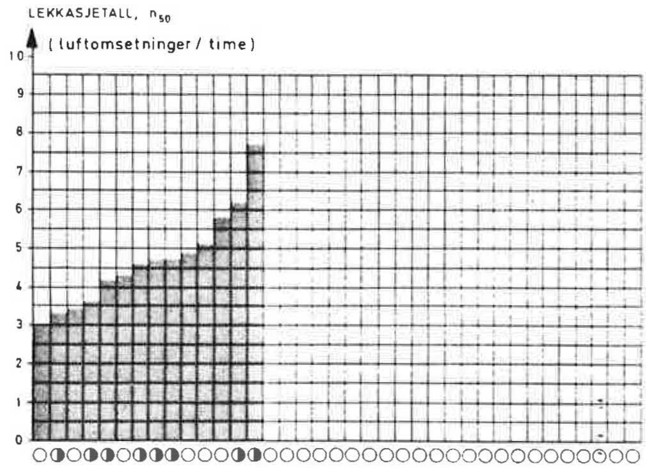


Diagram 6

TYPE BOLIG : Eneboliger
KOMMUNE : Kristiansund N
ANTALL : 14
MIDLERE LEKKASJETALL n_{50} = 4,7
STANDARDAVVIK s = 1,3



FIGURFORKLARING

▯ Stolpen angir boligens lekkasjetall, n_{50} (se difinisjon foran)

Sirklene under hver stolpe angir hvilket svar beboerne ga på spørsmålet: "Er dere fornøyde med boligen m.h.t. trekk?"

○ Ja, godt fornøyd

◑ Nei, ikke helt fornøyd

● Nei, misfornøyd

Diagram 7

TYPE BOLIG : Eneboliger, én etasje
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 12
MIDLERE LEKKASJETALL n_{50} = 4,6
STANDARDAVVIK s = 1,1

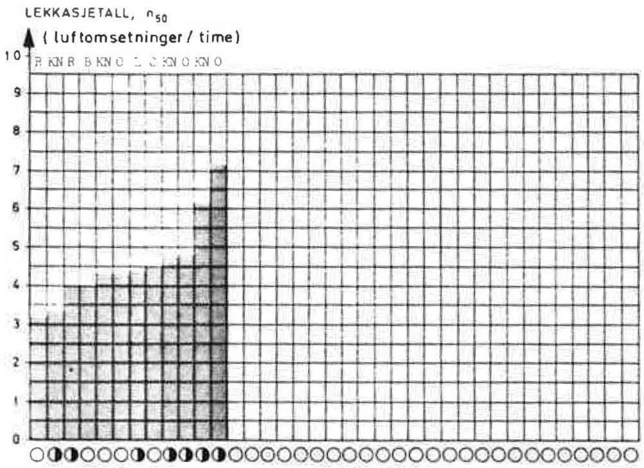


Diagram 8

TYPE BOLIG : Eneboliger, én etasje + sokkel
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 39
MIDLERE LEKKASJETALL n_{50} = 4,4
STANDARDAVVIK s = 1,4

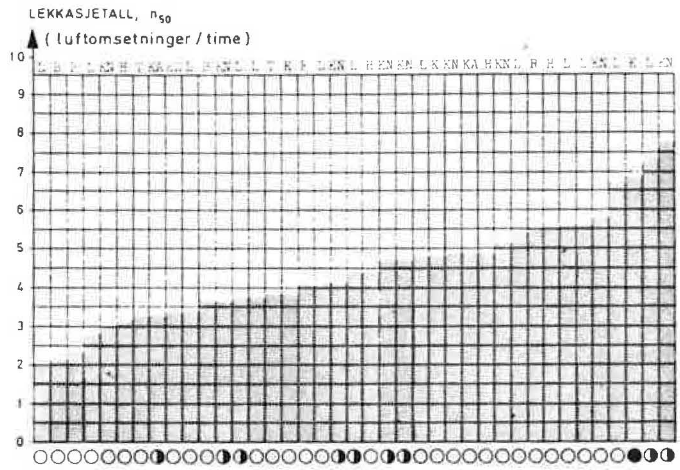


Diagram 9

TYPE BOLIG : Eneboliger, flere enn én etasje + sokkel
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 10
MIDLERE LEKKASJETALL n_{50} = 6,1
STANDARDAVVIK s = 1,6

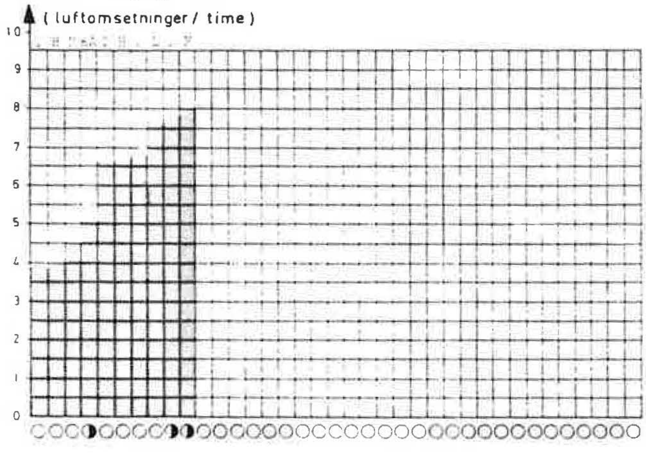


Diagram 10

TYPE BOLIG : Eneboliger med pipe og ovn
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 33
MIDLERE LEKKASJETALL n_{50} = 4,6
STANDARDAVVIK s = 1,5

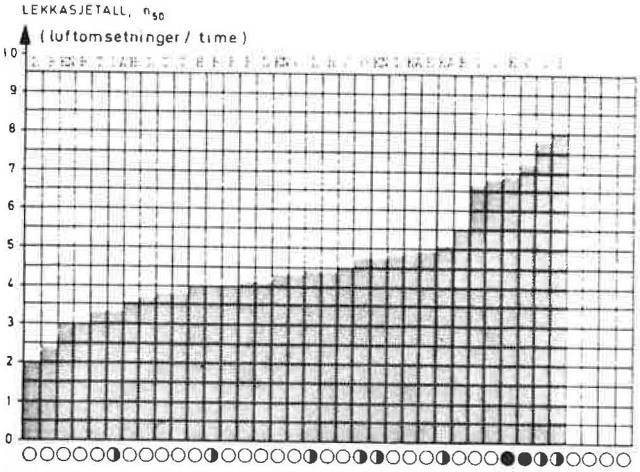


Diagram 11

TYPE BOLIG : Eneboliger med pipe og peis
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 28
MIDLERE LEKKASJETALL n_{50} = 4,9
STANDARDAVVIK s = 1,5

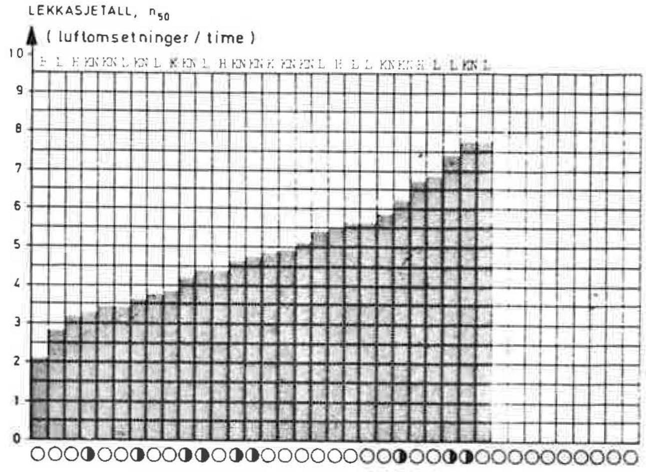


Diagram 12

TYPE BOLIG : Eneboliger som var helt ferdig m.h.t. tetting
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 37
MIDLERE LEKKASJETALL n_{50} = 4,5
STANDARDAVVIK s = 1,2

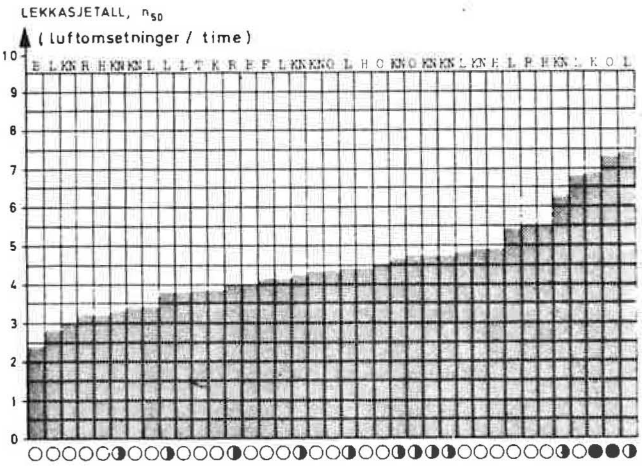


Diagram 13

TYPE BOLIG : Eneboliger som ikke var helt ferdige m.h.t. tettin
KOMMUNE : Alle som har vært med i undersøkelsen
ANTALL : 24
MIDLERE LEKKASJETALL n_{50} = 5,1
STANDARDAVVIK s = 1,8

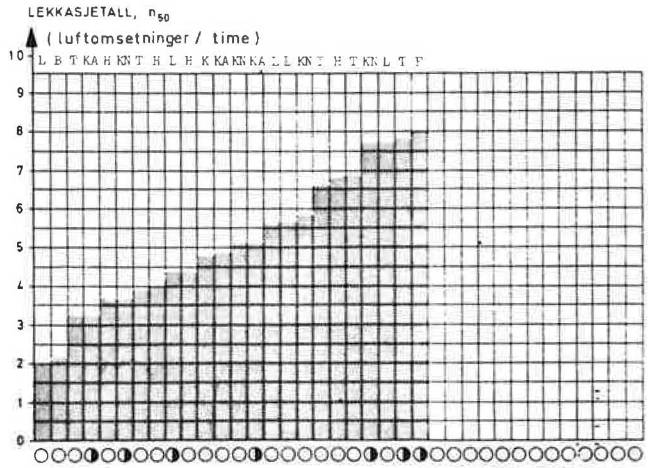


Diagram 14

TYPE BOLIG : Blokkleiligheter
KOMMUNE : Oslo
ANTALL : 15
MIDLERE LEKKASJETALL n_{50} = 1,1
STANDARDAVVIK s = 0,4

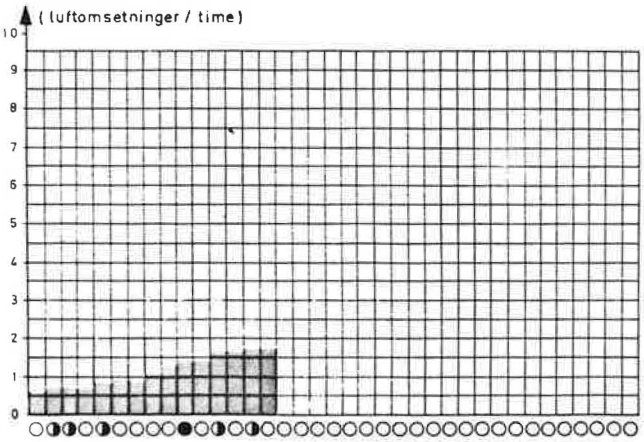


Diagram 15

TYPE BOLIG : Blokkleiligheter
KOMMUNE : Kristiansund N
ANTALL : 19
MIDLERE LEKKASJETALL n_{50} = 1,4
STANDARDAVVIK s = 0,2