LUCHTGORDIJNEN

air curtains for building entrances**

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Samenvatting

Om na te gaan of het aanbrengen van een luchtgordijn bij een gebouwingang een gunstige invloed heeft op het energieverbruik, werd aan de hand van een voorbeeld zowel het energieverbruik van het luchtgordijn als het energieverbruik in de situatie zonder luchtgordijn onderzocht.

Hiertoe zijn de energieverliezen berekend van diverse uitvoeringsvormen van ingangen. Om de invloed van de gebouwhoogte op het energieverlies te kunnen vaststellen is voor elke uitvoeringsvorm van gebouwingang het energieverlies berekend voor een gebouw bestaande uit één bouwlaag en voor een gebouw met vier bouwlagen.

Uit de berekeningen blijkt dat bij een gebouwingang met een tochtportaal met deuren en bij een ingang met draaideuren de laagste energieverliezen optreden ongeacht het aantal bouwlagen. Heeft men de keuze tussen glazen deuren bij een uitvoering zonder tochtportaal en een luchtgordijn, dan blijkt dat bij laagbouw de uitvoering met glazen deuren energetisch gezien het gunstigste is. Bij vier bouwlagen echter nemen de ventilatieverliezen zodanig toe dat een luchtgordijn de voorkeur verdient.

Een aantal systemen van luchtgordijnen worden in deze voordracht besproken. De keuze voor een bepaald systeem hangt onder andere af van de wijze waarop de ingang wordt gebruikt. Bij bestaande gebouwen zal men uit praktische overwegingen kiezen voor een eenvoudig aan te brengen systeem. By nieuwbouw kan bij de keuze van een systeem meer rekening worden gehouden met het energieverbruik.

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1. Introduction

In buildings like shops, department stores, railway stations and factory halls, doors necessarily remain open during a large part of the time that those buildings are used.
An open door in any building will locally cause a loss of energy. With reference to an example, we shall examine how large those losses are and, also, what is their cause.

There are various ways to restrict the losses. For example: draught halls, revolving doors and automatically closing doors. A considerable disadvantage of these measures is that free passage is hampered.
To overcome this disadvantage, an air curtain may be installed. The question is, however, whether installing an air curtain results in either a loss or a saving of energy. To solve this problem, we compared the calculated energy loss of an air curtain with that of other systems of building entrances.
Some applications of air curtains are indicated, as are the factors that can lead to the choice of a given system.

2. Energy consumption of a building

To evaluate the effect of an air curtain on the energy consumption of a building, we must properly know the factors determining the energy consumption of a building. When an airconditioning installation for a building is designed, use is generally made of the transmission calculation according to DIN 4701-1959 [12].
This indicates how the losses are to be calculated, starting from a comfortable climate within the building, and for minimum conditions of its outer climate. These losses consist of transmission losses and ventilation losses.
Transmission losses find their origin in heat flowing through wall, floors and roofs as soon as there is a temperature difference across the construction concerned. These losses are calculated for the maximum temperature differences to be expected. Extra losses, as a result of discontinued operation, are allowed for by a surchange. For the wind direction, too, a similar correction is applied.

Ventilation losses are caused by pressure differences across the building fronts. Ventilation is assumed to take place through slits in windows and doors. The size of the ventilation losses depends on the air pressure difference across the slits, the dimension and the air resistance of the slits. The air pressure difference depends on wind force and on the chances of the wind hitting the building.
This is expressed by a dwelling factor. The air pressure difference is also dependent on the internal air resistance of the building.
This, in turn, is allowed for by means of a room factor. The air resistance of window and door slits is known for the most common constructions. The ventilation losses can be calculated by means of the slit length, which is to be measured and calculated with the aforementioned factors.
Calculation of the total expected energy loss under minimum conditions is essential for the design of the heating installation. On the basis of the transmission calculation, an estimate can be made of the expected energy consumption over the period of a firing season or over a one-year period.
For buildings with entrances that are used very intensively (shops and department stores), the real energy consumption can differ considerably from the estimate for the following two reasons. First, the way in which the building entrance is used plays an important role. Secondly, the thermal draught in building entrances can cause a considerable energy loss. The following chapter will deal with these aspects in more detail.

3. Construction and use of building entrances

When designing a building entrance, the architect will consider the whishes of the owner or those of the future user. This applies both to the esthetics and to the proper functioning of the building entrance.
Wishes as regards its suitability can differ widely.
In shops, department stores and reception halls of airports, bus and railway stations, unhampered passage of persons is preferred.
The doors will remain open for the major part of the time that the building is being used.
The supply and discharge of goods also calls for an unobstructed passage available for vehicles. This applies to warehouses, factory halls and similar buildings.
In hotels, restaurants and banks, the advantages of good contacts with clients do not often outweigh the disadvantages of a less agreeable climate in the direct vicinity of the entrance. The clients themselves will take care of opening and closing the doors in these buildings.
In hospitals and swimming pools, high demands are set to their interior climate. This results in a building entrance in which special consideration has been given to the prevention of troublesome air currents.
A constuction much used for buildings entrances is a wall with hard-glass doors. In buildings of some size, draught portals are mostly installed; with or without automatically closing doors.
In factory halls and warehouses, self-closing rubber doors and strip curtains are often installed, so that transport with lift trucks and other vehicles is not too much hampered.
In a number of cases, air curtains are applied.
In contrast to the previous constructions, energy is clearly required for that of an air curtain.
This raises the question whether its energy consumption is outweighed by the energy losses of an entrance without air curtain.
To answer this question, we should have an idea of the volume of those losses and of the factors influencing them.

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4. Energy loss of a building entrance

4.1 *Factors constituting the energy loss*

In Chapter 2 it has been explained that the energy loss of a building is caused by transmission and ventilation. We shall now investigate what losses can occur when a building entrance is used and how the annual energy loss is constituted.

The following losses can occur:

— Transmission losses of the doors during the time they are closede, see Figure 1. These transmission losses depend on the difference between inside and outside temperature and on the material from which the doors are made.

— Ventilation losses through slits in closed doors caused by thermal draught in the building, see Figure 2. The heated air inside the building has a lower specific gravity than the colder air outside. Cold air will penetrate through the slits. The hot air rises and will leave the building through slits in window and door constructions, through non-tight roof constructions and through other openings like ventilations ducts.

— Ventilation losses through slits as a result of wind. When a building is attacked by the wind, an overpressure arises on the windward side and an underpressure on the leeward side. The pressure in the building is in between these pressures. The value this pressure ultimately takes depends on the air-resistance of the building. A building with many partitions and doors has a higher internal resistance than a building without partitions and with an open connection between ground floot and other floors.

— Ventilation losses caused by differences in specific gravity of the air, with opened doors. These differences generate from the difference in specific gravity between non-heated and heated air.
As will be seen from Figure 4, cold air flows in at the bottom and heated air leaves the building entrance at the top. This flow pattern only arises if the inside space, except for the entrance considered, is closed hermetically.
In practice this is not the case with buildings. It applies for instance to cold-storage cell doors.

— Ventilation losses as a result of thermal draught, with opened doors.
Thermal draught increases with increasing buiding height. The losses caused by draught are dependent on the height of the building, and on the air resistance.

— Ventilation losses caused by wind on the entrance. With wind on the entrance, the transport of air through the entrance also depends on the pressure difference between wind pressure and pressure inside the building.

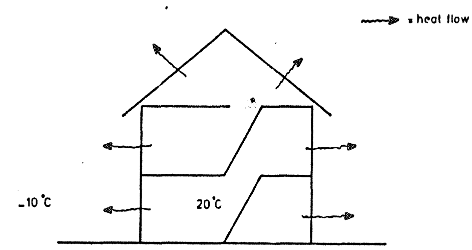

Fig. 1: Energy loss through transmission

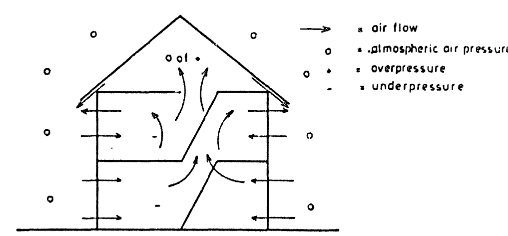

Fig. 2: Ventilation through thermal draught

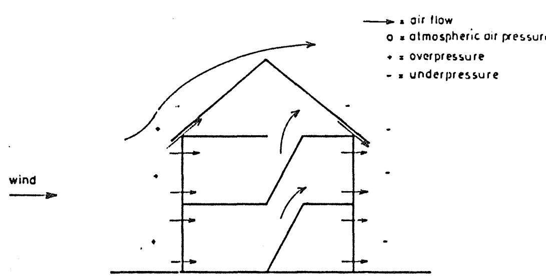

Fig. 3: Ventilation under the influence of wind

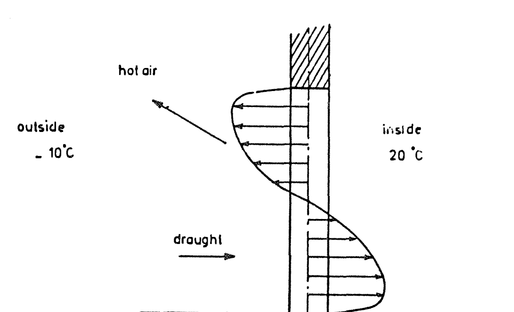

Fig. 4: Air velocity profile in a door opening

Figure 5 presents the velocity profile drawn for an entrance for which besides the difference in specific gravity, the influence of thermal draught and/or wind have been taken into account

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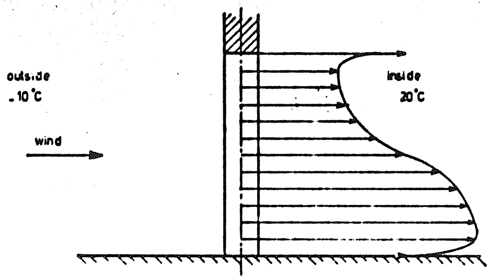


Fig. 5: Air velocity profile in a door opening under the influence of thermal draught and/or wind

4.2 *Extent to which the energy loss is influenced*

Not all losses occur during equal periods of time, nor to the same extent.
Transmission losses of doors, and ventilation losses through slits as a result of thermal draught, occur in the time that the doors are closed. Slit losses caused by the wind occur only when the wind is right on the closed entrance. With opened doors, ventilation by thermal draught takes place during the time the doors are open and ventilation by wind during the period the wind is on the opened entrance.

With wind coming from other directions it may generally be supposed that air enters the building through many smalle openings, rises under the influence of thermal draught and leaves the building at floors higher situated. For calculation purposes, we assume that there is no air transport by wind influence via the building entrance when the wind is not on the entrance. This applies only when all entrances are in one and the same front, so that no cross-ventilation can take place.

4.3 *Example*

With reference to an example, the energy losses will now be elucidated for a simulated department store where the entrance is either closed or opened.
Figure 6 shows that entrance; it consists of 6 hard-glass doors.

The dimensions of the doors are:

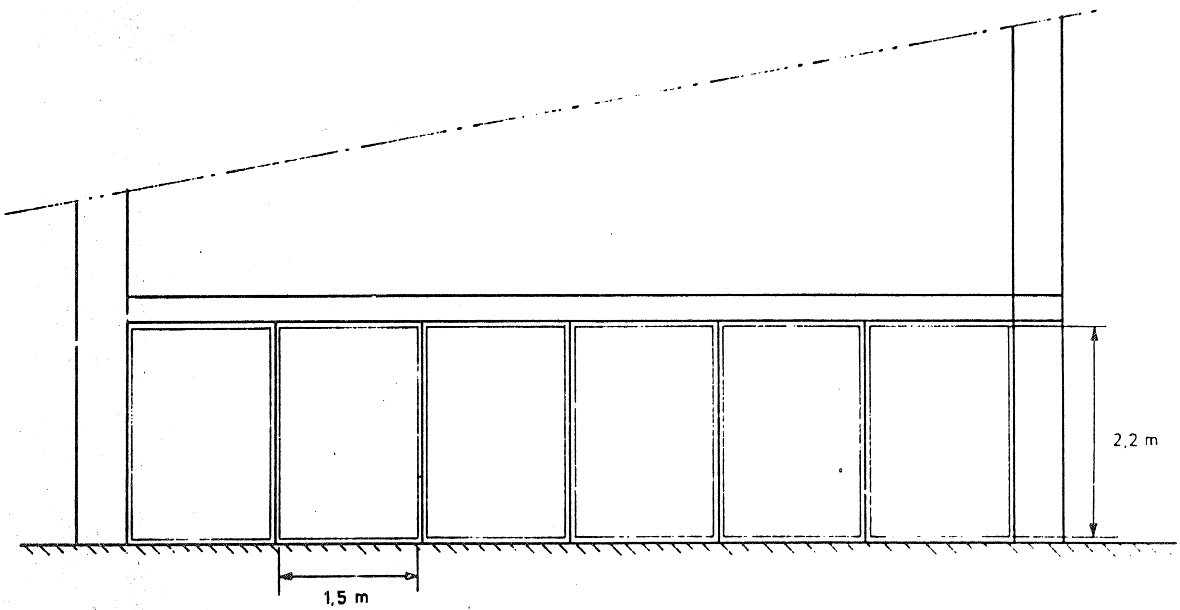
— width, B = 1.5 m
— height, H = 2.2 m
— slit length for each door, L = 7.5 m
— slit width, b_d, at top: 3 mm = 0.003 m;
  ditto, at sides: 2 mm = 0.002 m;
  ditto, at bottom: 7 mm = 0.007 m.

The calculations will be carried out for a building with only one floor (ground level) and for a building of 3 storeys, hence 4 floors.

— Hg_1, height of building = 3 m
— Hg_2, height of building = 12 m

It is supposed that in the 4 floor-building there are open connections between any two floors, like stairs and escalators.

Fig. 6: Entrance of department store



We also start from the assumption that no air curtain is present and that all doors are either closed or opened when the building is in use. For the simulated building, we suppose the entrance to be situated in a shopping street; it is hence somewhat protected. The entrance is situated in the building's north-east front.
The average temperature in the building is set at 20°C.

The values of average outside temperature, wind velocity and wind direction have been calculated from data of the Royal Dutch Meteorological Institute [refs. 1 and 2], as follows:

- the average outside temperature between 8 a.m. and 6 p.m. during the period from October to May is 7.8°C;
- the average wind velocity in quarters with low buildings, corrected at a height of 1.75 m above the ground, amounts to 2.4 m/s;
- during 21.8% of the time the wind comes from directions between north and east.

The entrance is used for 1,800 hours during the firing season; for 21.8% of this time (= 390 hours) there is wind on the front.

Summary of data used in the calculations:

- temperature difference between outside and inside air $\Delta T = 12.2°C$;
- average wind velocity, $v_w = 2.4$ m/s;
- time the entrance is in use, $t = 1{,}800$ h/year;
- time there is no wind on the entrance, $t_t = 1{,}410$ h/year;
- time there is wind on the entrance, $t_w = 390$ h/year.

The transmission losses have been calculated in accordance with DIN 4701. The ventilation losses for slits and for openings were calculated from the pressure differences across the entrance caused by thermal draught and/or wind pressure.
It has been assumed that, with large openings, the average air velocity is half the velocity calculated from the pressure difference.
For the cross-sectional area of the air flow, half of the total opening has been used in our calculation with large entrance openings; such because of edge disturbances, contraction and fluctuations in wind direction [refs. 3, 9, 10 and 13].
It would be beyond this publication's scope to consider all the calculations.
It may suffice to give a summary of the results. The following tables present the individual energy losses and the total energy loss during a firing season for each of the simulated building constructions. The losses are expressed as gas consumption in m³ natural gas/annum necessary to compensate the losses. It is also indicated what is the proportion that each of the losses contributes to the total loss, expressed as a percentage.

Table 1: Energy loss of the entrance of a department store with one floor (Hg = 3 m)

Loss by:	entrance closed m³ gas/annum	%	entrance opened m³ gas/annum	%
transmission	360	37	—	—
thermal draught through slits	460	47	—	—
wind through slits	150	16	—	—
thermal draught with open entrance	—	—	68300	75
wind with open entrance	—	—	22400	25
total loss	970	100	90700	100

Table 2: Energy loss of the entrance of a department store with four floors (Hg = 12 m)

Loss by:	entrance closed m³ gas/annum	%	entrance opened m³ gas/annum	%
transmission	360	25	—	—
thermal draught through slits	930	65	—	—
wind throught slits	150	10	—	—
thermal draught with open entrance	—	—	136600	86
wind with open entrance	—	—	22400	14
total loss	1440	100	159000	100

From Tables 1 and 2, the following conclusions may be drawn:

- The energy loss with closed doors, or with a draught hall, is only a fraction of the energy loss with opened doors. It has been assumed, in this text, that — in the event of a draught hall — the entrance is closed by either an outer or an inner door. With a fully open entrance, the calculated energy loss for the two buildings is approx. 100 times the loss with closed doors.
- With a one-floor building, the influence of thermal draught with an open entrance is predominant. In the example given this energy loss amounts to approx. 75% of the total loss. With an increasing number of floors, the influence of thermal draught increases considerably.

Figure 7 shows the air velocity in the building entrance resulting from thermal draught as a function of the height of the building for three differfent air resistances of the building. To take into account the influence of the air resistance of a building, when determining the air

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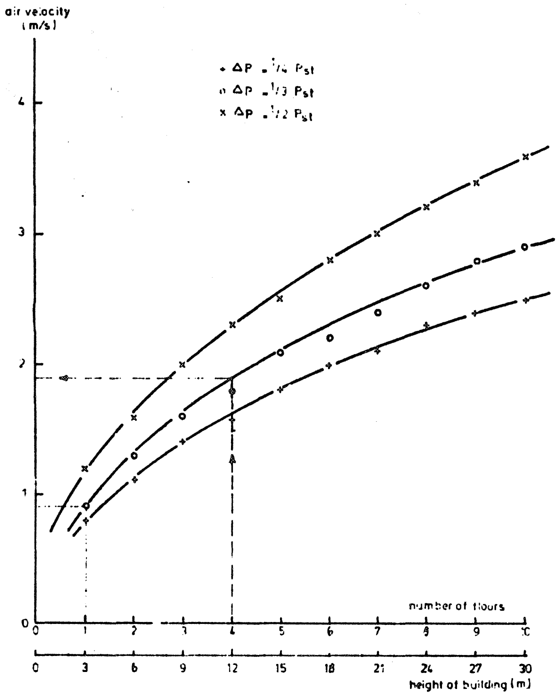

Fig. 7: Air velocity in an open building entrance as a function of the numbers of floors and the height of the building

velocity in the building entrance, the data of DIN 4701 [ref. 7] have been used. The air velocity depends on the pressure difference, $\Delta p = P_b - P_v$; where P_b = static pressure outside the building and P_v = static pressure inside the building.
When air hits a wall with a given velocity, a static pressure arises: $P = \frac{1}{2} \rho v^2$; where ρ = density of the air and v = air velocity. The pressure difference, Δp, is expressed as a function of P_{st}.

For calculation of the air resistances, the following situations have been taken:

- the inflowing air can move outwards only through inner doors and neighbouring rooms, $\Delta p = \frac{1}{4} P_{st}$;
- the inflowing air can move outwards directly (outer doors and windows), but in a restricted way as compared with the possibilities of inflow, $\Delta p = \frac{1}{3} P_{st}$;
- the inflowing air can move outwards through opposite openings of a size that is almost equal to that of the inflow openings, $\Delta P = \frac{1}{2} P_{st}$.

For the department stores in the examples, $\Delta p = \frac{1}{3} P_{st}$ has been used; these buildings generally have no partition walls with doors. There are open connections between two storeys, for instance in the form of stairs and escalators.

The graph shows that for the 4-floor building, an air velocity is caused in the open entrance of 1.9 m/s. The air velocity that has been taken into account is 2.4 m/s. The explanation for the appreciable influence of thermal draught on the annual energy consumption is that for only a small fraction of the total time the wind actually bears on the entrance.

5. Application of air curtains

5.1 *Working principle of an air curtain*

With the aid of an air curtain it is possible to screen off an opening in a building in such a way that there is hardly any air transport by wind or thermal draught.
In principle, an air curtain consists of a slit-like opening at the bottom, the top or at one or both sides of a building entrance. Through the slit, air is blown in a given direction. In this way, an air flow arises that is composed of the air jet from the slit and the air current on the building entrance. This resulting air flow should screen off the entrance, as is shown in Figure 8.
Demands are set to slit dimensions and air velocity, because of the impulse the air jet must have for screening off the opening effectively.
Eddies must be prevented.

5.2 *Kinds of air curtains*

Air curtains can be supplied in many designs. They vary from air heaters that can be installed in a simple way to large installations for which far-reaching technical arrangements have to be made.
A number of aspects that play an important part in choosing a system will now be elucidated below.
— Temperature of outflowing air.

A choice can be made from three situations. The fans can be installed at the outside of the building, so that cold outside air is drawn in and is blown along the entrance. Figure 9 gives an example of this. A second possibility is installing the equipment at the inside of the door opening so that heated inside-air is drawn in, see Figure 8.
When the installation is provided with heat exchangers, a third situations arises in that air or inner space

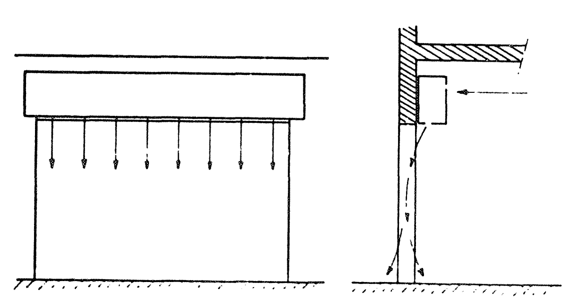

Fig. 8: Hot air curtain

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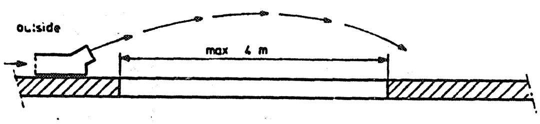

Fig. 9: Cold air curtain

temperature is heated to a higher temperature prior to being blown into the building entrance.

— Equipment with or without exhaust.

An installation without exhaust is shown in Figure 8. Under the influence of thermal draught and wind, the air current takes a more or less circular path. Part of the air finds its way into the building, part flows outwards. The screening effect of the air current is only dependent on the impulse of the air current leaving the fan.
With wind on the entrance there is a chance of the air current being broken up, both air from the installation and air from outside then being able to flow in. This situation is depicted in Figure 10.

Breaking up of the air current can be counteracted by making an arrangement under which the air ais drawn off. Figure 11 shows an entrance provided with an air curtain with exhaust. The effectiveness of the screening depends on a number of factors, such as: form and construction of the inflow openings, proper choice of the fans, influence of form, situation and orientation of the entrance, and air resistance of the building. For each case it should therefore be investigated what is the best construction.

— Place where the air is blown in.

When we again consider the situation of Figure 5, the air velocity caused by wind and thermal draught is found to be highest at a small distance above the floor. The screening effect of an air current is therefore highest when this is blown in from the floor; cf Figure 12.

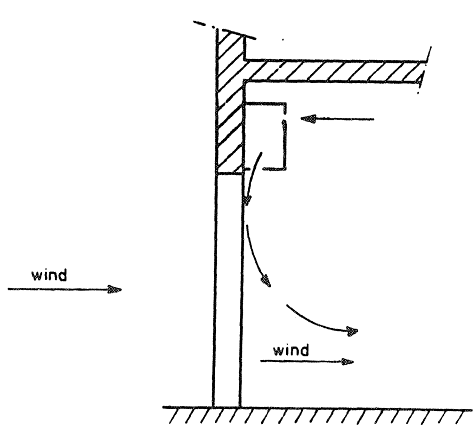

Fig. 10: Breaking up of air current by wind

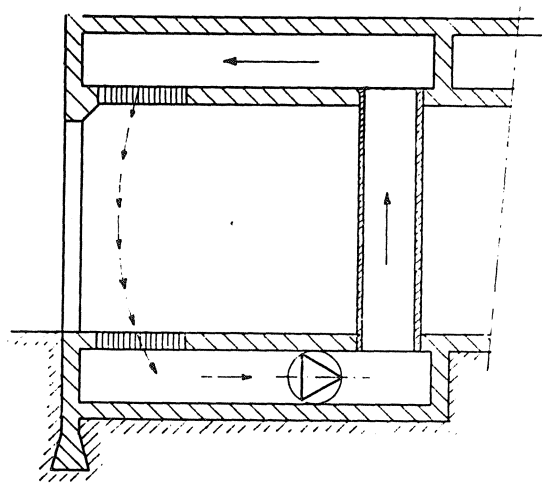

Fig. 11: Air curtain with exhaustion

For practical reasons, however, this is not possible in many cases. Cold-air curtains are often installed at the outside of a building entrance because of the nuisance from noise. The air current is then blown in from one or both sides, depending on the width of the entrance. From publications [ref. 6] it is apparent that entrances up to about 4 m width can be screened off with an air current on one side; see Figure 9. Openings up to 8 m width can be screened off with an installation blowing out on two sides; see Figure 13.
In view of the large inflow angle with respect to the front, it is recommended to install a lean-to roof over the entrance. In this way the penetration of air from above is avoided; see Figure 14.
According to a manufacturer, the lean-to roof should project from the front by approx. 0.9 x the width of the entrance.

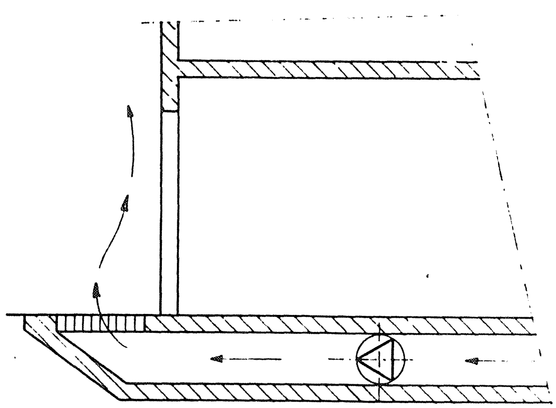

Fig. 12: Inblow openings in the floor

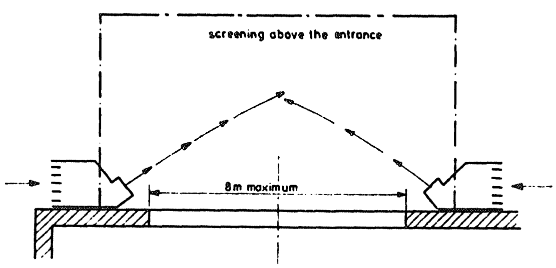

Fig. 13: Cold-air curtain for wide entrances

5.3 *Choice of an air curtain*

In Section 5.2, we have reviewed a number of designs. When the purchase of an air curtain is considered, a number of factors will have to be taken into account.

The most important are:

— what is the nature of the building?

— is the space heated?

— what are the dimensions of the entrance?

— is the entrance intended for persons or vehicles?

— how drastic may be the modification?

— what are capital outlay costs?

— what are energy costs?

— are energy costs equal to or lower than in the situation without air curtain?

— are there alternative solutions that involve less energy?

Prior to choosing a given type of air curtain, one should evaluate the building entrance as to the following points:

— T vo opposite entrances cause a horizontal ventilation ($\Delta p = \frac{1}{2} P_{st}$). This is to be avoided. It is much better to situate the entrances in the same front.

— When there is an airconditioning installation in the building, it is favourable to make the installation blow only air into the building, which gives rise to a slight overpressure. Thus the air transport to the inside by wind or thermal draught can be reduced.

— Orientation and location of the front in which the entrance is or is going to be situated should be sought such that the least trouble from wind nuisance is experienced.

From the points to be discussed hereafter it will be evident that it need not be difficult to select the proper system.

— Cold or hot air.

Experience has shown a cold air flow to be an unpleasant experience to most people. For entrances through which persons pass, either on foot or on an open vehicle, hot air curtains should be applied.
With hot air, due attention should be paid to the proper air velocity and temperature. When this combination is not the correct one, the air current is experienced as a draught. For entrances through which closed vehicles, like motor cars and lift trucks with a cabin, pass, a cold air curtain is to be preferred from the viewpoint of economic energy consumption.

— With or without exhaust.

It is a simple matter to install an air curtain without exhaust in existing buildings. This requires a relatively low investment.
By contrast, energy losses can be the result of the air screen being broken up. An installation with exhaust can not always be realized in an existing building without making extensive modifications. The investments will be much higher. The screening effect is better, however, as a result of which the chance of energy losses is much smaller than with an installation without exhaust.
When a hot-air curtain without exhaust is applied in combination with a draught hall, the screening effect of

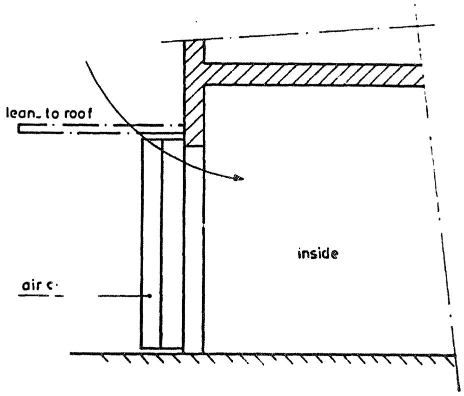

Fig. 14: Lean-to roof prevent penetration of air

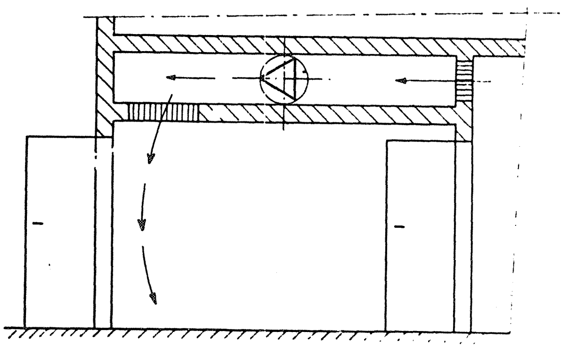

Fig. 15: Pressure build-up in a draught hall by draw.ng in air from a space other than the draught hall

The energy consumption of entrances with air curtains are inclusive of the energy consumption of the air curtain itself. The differences in energy consumption between a building of one floor and a building of 4 floors are caused by the differences in thermal draught. The result is that, to get the same screening effect, in a 4-floor building, a fan of higher power is required than in a building of one floor. This results in different power consumptions.

6. Conclusions

— The energy consumption of a building with an open entrance is many times higher than that of a building with a closed entrance.

— An air curtain can effect a saving in energy. Because an air curtain consumes energy, too, it should first be investigated if the energy loss of the entrance can be limited in other ways.

— The influence on the energy loss of the thermal draught in a building is larger. The leakage of a building should, therefore, be restricted to a minimum.

— The choice of an air curtain should be made after careful consideration. Much attention should be paid to screening effect, which depends on the type of equipment chosen.

— Table 5 clearly shows that closing the entrance by means of a draught hall, or revolving doors, is the most economic solution.

— With a one-floor building, the opening and closing of doors in an entrance without a draught hall is cheaper than applying an air curtain. When a building consists of more floors, an air curtain is found to require less energy than does the opening and closing of doors by clients. This, however, only applies, to this simulated example. For each particular situation, a calculation should be made in which the number of times the doors are opened and closed is taken into account.

— As regards the influence of the height of the building on the energy losses, this appears to be smaller with an air curtain than with an open entrance or an entrance with doors.

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Condensed Discussion

1) *Max:* I thought that, when using a closed entrance with a draught porch one ought to reckon with another item for an increase of the rate of air changes in this porch. Each time one of the doors opens, there will be an increase of the air flow through the slits compared with the situation with the two doors closed. This extra loss would have to be added.

Adam: That is correct. There are three cases:

a. both doors are closed;
b. one of the doors is open, the other is closed;
c. both doors are open at the same time.

The average actual situation lies somewhere between the extremes. We, therefore, started from the assumption that only one pair of doors is permanently closed and the other pair is open. So that the resistance of one pair of doors is considered, for which the slit losses are determined.

Knoll: It would be interesting to find out how often the doors opposite each other are open.
Adam: That differs for each building, and must be determined for each situation.

2) *Hageman:* Can such an air curtain stop moisture, e.g. in a swimming-pool or in foggy weather? Is it possible to keep the indoor relative humidity from rising to much when it is higher outdoors?
Would it be possible, e.g., in a swimming-pool, to control the relative humidity in an adjacent restaurant which is only screened with an air curtain, i.e. without a glass partition?

Adam: If one wants to say something about the penetration of relative humidity through an air curtain, one must first consider the absolute humidity in the air on both sides of the air curtains. Some mixing between indoor and outdoor air always occurs in the air curtain. Part of the curtain air goes outside again. The absolute humidity outdoors mostly is lower than that indoors; in winter, and in foggy weather too.
Then, the air exchange through the air curtain rather lowers than raises the relative humidity inside the building.

3) *Van Gunst:* In the Japanese journal "Transactions of the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan" there is an excellent article about how to screen the concentration on one side from that on the other side by air curtains.
And in Germany, there would be a swimming-pool where the spectators' room is screened from the swimming-hall by an air curtain proceeding from the ballustrade.
The Japanese article indicates how the concentrations can be controlled, how the concentration of the vapour or the poison mexes in the air flow, how it divides itself and what part of it gets through.

Crommelin: Besides how to screen heat and air pollution, the Japanese article also reports how to deal with wind.
Figure 5 shows that an underpressure will then occur, but I think this can be compensated by directing the air curtain not straight down but slanting against the wind. If this is done at the right angle, and at the right velocity, the air will arrive at the right place on the other side of the entrance. It seem to me that the change of pressure is compensated, too.

Adam: Yes, the air jet moves along about a circular path the radius of which depends among other things, on the angle of incidence.
If it concerns an air curtain without suction, a part of the air will re-enter the building.

4) *Crommelin:* If the direction of the air jet matches the wind velocity, the air jet wil arrive at the same place as otherwise with calm weather. Of course, the extract opening must be wider than the injection opening, for the jet widens.
But with the wind blowing on it, it will not go down in a vertical plane; the same process will take place in the form of a circular path, a parabola or something similar.

Adam: Data are known about the angle and the velocity at which the air must be injected with a given wind velocity. The path which the air jet then describes without the wind breaking the curtain.

Bremmer: When stating the energy consumption, did you make a distiction between a cold and a warm air curtain? I presume there will be a rather great difference in energy consumption.

Adam: We intentionally made two model calculations of warm air curtains because these are widely applied. We made no calculations for cold air curtains. This might be done for each case, though.
The outdoor air need not be heated to a higher temperature.

The amount of energy needed for heating the air to a given temperature depends on the amoundt of air to be heated and the temperature difference. At the moment I have no indication for this. The amount of air and the temperature difference can differ very much for each application. The amount of energy for heating the air must then be calculated in each case. Data are known from literature.

5) *Lam:* Using an air lock between two doors, entry of cold air can be prevented by introducing warm air into the lock. At what place would this be best to do: near the outer door, in the middle of the air lock, or near the inner door?
Has the wind still a certain influence there?

Adam: The best place for injecting the air is indeed in the air lock. There will then be overpressure in the lock which presents cold outdoor air from entering the lock, at least if both doors are closed.
The place where the warm air is introduced into the air lock is not so important then, thougt the best place will be near the outer door. The main effect, however, lies in providing some overpressure in the air lock.

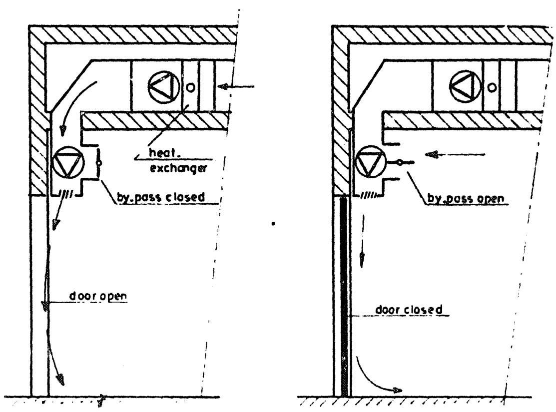

Fig. 16: Air curtain with by-pass

the air curtain can be improved by maintaining an excess-pressure in the draught hall. This can be done by drawing in air from a room other than the draught hall. The principle of such a system is given in Figure 15.
In the case of an entrance without a draught hall, unacceptable underpressure in the building can sometimes arise when inside air is drawn in. It is natural, then, to draw in outside air and raise it to the required temperature by means of an ar conditioning installation. This requires energy. If the entrance door is operated by passing people, however, an installation with by-pass can restrict the energy consumption.
During the time that the doors are closed, ambient air is drawn in via the by-pass. This air is not additionally heated. During this period, no outside air need be raised to the required temperature. Such a system is depicted in Figure 16.

— Direction in which the air is blown out.

The most effective operation is obtained by blowing air from the ground floor in upward direction.
With new buildings, the construction of such a system offers no problems. In existing buildings, this construction will call for a high investment.
Besides, with a system in which air is blown out from the floor, it should be remembered that to most people passing the air curtain on foot this is an unpleasant experience.
In practice it amounts to this arrangement: a hot-air curtain is fitted over an entrance with or without exhaust in the floor. Cold-air curtains are often placed on the outside in such a way that they blow out from the sides.

5.4 *Air curtain and energy consumption*

To make an air curtain function properly, energy is needed. The air current must be maintained, in many cases the air must be heated and to exhaust the air, energy is required. The amount of energy required for all this depends on the power of parts of the equipment, like fans and heat exchangers, and on their operating times.
It is useful to calculate the energy consumption prior to purchasing the equipment.
Mostly a reasonable approach can be made. The foregoing shows that the losses of a building entrance without an air curtain can likewise be roughly calculated. So long as the energy consumption of the air curtain equipment is lower than the "losses without air curtain", an air curtain will save energy.
Tables 3, 4 and 5 present results of calculations for some designs of building entrances as regards simulated department stores.
In the calculations concerned it has been assumed that one single opening and closing of a door takes 25 seconds.

Table 3: Energy loss of an entrance to a one-floor department store (Hg = 3 m)

Loss by:	doors opened and shut 500 times a day m³ gas/annum	%
transmission	280	0.7
thermal draught through slits	360	0.9
wind through slits	120	0.3
thermal draught with open doors	27,000	67.9
wind with open doors	12,000	30.2
total	39,760	100.0

Table 4: Energy loss of an entrance to a 4-floor department store (Hg = 12 m)

Loss by:	doors opened and shut 500 times a day m³ gas/annum	%
transmission	280	0.4
thermal draught through slits	720	1.0
wind through slits	120	0.2
thermal draught with open doors	57,000	81.3
wind with open doors	12,000	17.1
total	70,120	100.0

Table nergy consumption and energy costs for some designs of the building entrance of the simulated department store

Design	energy consumption in m³ natural gas/annum Hg=3m	Hg=12m	energy costs in guilders/annum at Nfls. 0.20/m³ gas Hg=3m	Hg=12m
entrance with draught hall	1,000	1,500	200.-	300.-
open entrance without air curtain	90,700	159,000	18,140.-	31,800.-
open entrance with air curtain	55,000	62.700	11.000.-	12,540.-
entrance opened and shut 500 times a day	39,700	70,000	7,940.-	14,000.-
3 revolving doors instead of 6 glass doors	1,000	1,200	240.-	240.-

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