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Air Leakage Characteristics and New Standards For Swiss Construction

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Introduction

In the last few years energy regulations have been introduced in many Swiss Cantons. The main goal of these regulations, relative to the building envelope, is to improve the insulation value. Consequently, typical current construction for new buildings is characterized by exterior wall and roof insulation U-values under 0.5 $W/m^2{\cdot}K$ and windows with triple glazing or its thermal equivalent.

These energy regulations, however, address the airtightness of buildings merely by setting a maximum allowable a-value for windows and doors, for example 0.2 $m^3/h{\cdot}m{\cdot}Pa^{2/3}$. This set value is based on the customary way of calculating the heating capacity requirement of buildings by considering air leakage from joints of apparent building components. Swiss guidelines establish three classes of window air leakiness for these calculations (Table 1).[1]

In reality the a-values of contemporary building components are substantially better than indicated in Table 1. In calculating the heating plant capacity, however, values under 0.2 $m^3/h{\cdot}m{\cdot}Pa^{2/3}$ are not used. This recognizes the presence of other undefined but existent joints and cracks. Accordingly, calculations always start off with an air change rate per hour of at least 0.3.

Construction of windows and doors	a_F ($m^3/h{\cdot}m{\cdot}Pa^{2/3}$)
Wooden framed windows without weatherstripping and wooden doors without weatherstripping	0.6
Wooden or combined wooden/metal framed windows with weatherstripping (Performance requirement group A of SIA 180/l)[2] and doors with weatherstripping	0.3
Metal, plastic or wooden framed windows with special weatherstripping (Performance requirement groups B and C of SIA 180/1) and doors with special weatherstripping (special orders)	0.2

Table 1. Calculation values for the airtightness of joints at windows and doors

Inside this issue:

In Switzerland, residential buildings are primarily naturally ventilated (via windows). For interior rooms (e.g. toilets, bathrooms or kitchens) exhaust ventilation controlled by a timer or the light switch is common. In older apartment buildings ventilation shafts without fans can often be found. Warm air heating systems are practically unheard of in Swiss construction. The sharply reduced heat losses of modern buildings, however, afford greatly improved pre-conditions for including air heating systems.

In office buildings the installation of ventilation and cooling systems is common, although the tendency is to specify air conditioning only where it really is essential. It is considered obvious that ventilation and cooling systems should be equipped with means for heat recovery.

Recently, it has become acknowledged that maximum airtightness of the building envelope should not always be the goal. Rather, a degree of airtightness should be sought which is appropriate for the situation. To provide a sound basis for such decisions, typical buildings have been systematically studied to determine their actual air leakage characteristics and accordingly the natural air change rates. Until now the studies have concentrated primarily on residential structures. Above all, these studies have striven to define levels of airtightness appropriate for the cases dependent on natural ventilation. In other countries the path being taken is to equip all new buildings with mechanical ventilation including heat recovery from exhaust air. This allows, and actually requires, as tight construction of the building envelope as possible. In Switzerland the percentage of residential buildings with mechanical ventilation will surely increase in the future, but a greater percentage will continue to be naturally ventilated.

Measurement methods

Measurement methods to determine values for the airtightness of the building envelope and the air exchange are:

- Pressurization measurement

- Air change measurement with a tracer gas.

In addition infrared photography can serve well in analyzing thermally weak areas of the building envelope.

The application of measurement methods has been reported in detail in documentation of the AIC, but a short review (focusing on new techniques) is provided here.

A new apparatus for pressurization tests is shown in Figure 1. It consists of an axial fan with continuously variable speed. Volumetric measurement of air-flow is achieved with calibrated intake nozzles. In the illustrated apparatus three sizes of nozzles are available. These permit measurements in the range from 400–8000 m^3/h. To facilitate transporting the device to the measurement site, the three nozzles can be placed concentrically one inside the other.

In order to assure that pressure difference and air change measurement results are comparable, at least within Switzerland, detailed measurement guidelines have been set out.[3,4] Recent years of experience have proved the guidelines to be valuable tools.

Figure 1. Apparatus for pressurization test

Results of two measurement projects

Table 2 gives results from pressurization tests for 34 apartments in five typical, massive, Swiss buildings constructed between 1963–1973 (a NEFF* project[5]). The n_{L50} values were found to be between 1.6 and 6.5 h^{-1} for apartments having windows without weatherstripping, and between 1.6 and 2.4 h^{-1} for apartments having windows with weatherstripping.

Within the framework of another measurement project,[6] 19 units of primarily new single-family houses of frame (light) or mixed construction were studied. The n_{L50} values of these units ranged from 2 to 18 h^{-1}, which is a very large variation. The houses with the largest air leakage rates were typically untight where different components come together, such as where roof meets wall.

Another common problem area is the living space directly under the roof. The airtightness of the roof construction in such instances is too often ignored. This results not only in adverse energy consequences but can also cause discomfort due to the unnecessarily high air change rate from the outside (draught problems). Further, it can lead to building physics problems, such as for example damage resulting from water vapour condensation.

Measured Apartment Unit	Without weatherstripping			With weatherstripping		
	Average	Range	Standard deviation	Average	Range	Standard deviation
A	4.1	2.7–6.5	1.21 (30%)	–	–	–
B	2.3	1.6–2.9	0.60 (26%)	–	–	–
C	2.5	2.2–3.4	0.50 (20%)	–	–	–
D	3.4	2.2–5.2	1.27 (38%)	1.8	(only 1 apt)	(only 1 apt)
E	2.2	2.2–2.3	0.08 (4%)	1.9	1.6–2.4	0.43 (23%)

Table 2. Results from the NEFF project*

*National Energy Research Foundation

The results of both the above mentioned Swiss research projects are shown in Figure 2 in an international comparison.[7]

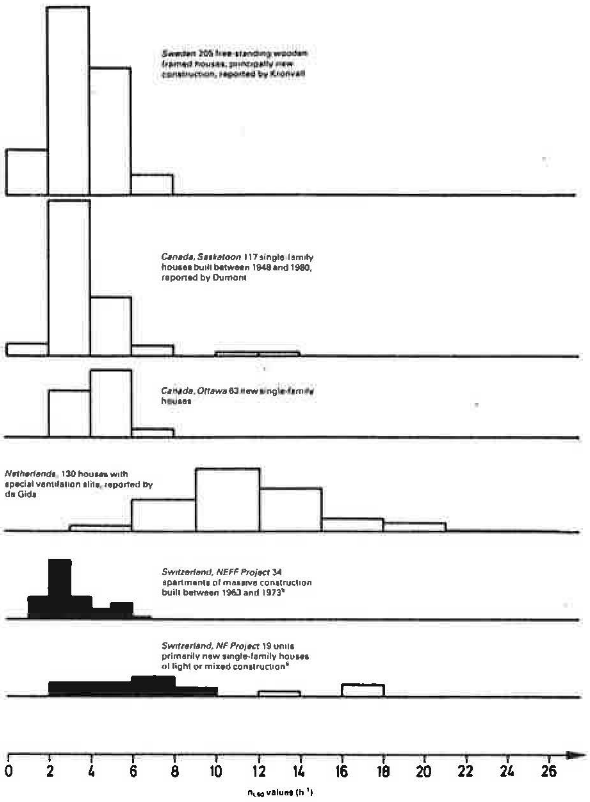

Figure 2. Results of the Swiss research projects compared internationally.

Recommendations for appropriate airtightness of buildings

Based upon the experience of these Swiss measurement campaigns, the author has made recommendations (shown in Figure 3) for appropriate levels of airtightness of the building envelope. These are valid for well insulated Swiss buildings. This year standard values in a similar form as presented here will be established by the Association of Swiss Engineers and Architects (SIA).[8] These standard values will be quickly put to use in the previously mentioned cantonal energy regulations.

Recommended airitghtness (n_{L50} values) can be read from the diagram in Figure 3 which shows three cases:

- without mechanical ventilation
- with mechanical exhaust air extraction without heat recovery
- with forced supply and exhaust air with heat recovery.

For **mechanical ventilation with forced supply and exhaust air**, the building envelope should be as tight as possible. This assures that most of the air exchange with outside air occurs via the ventilation system, where heat recovery can be efficiently put in operation. With current construction methods airtightness n_{L50} values under 2 h^{-1} can be achieved, as Figure 2 shows. Values greater than 3 h^{-1} in this case must be deemed unacceptable.

Ventilation systems should maintain the minimal outside air change rates and should be equipped with heat recovery.

Residential buildings **without mechanical ventilation** are still very common today. For these cases n_{L50} values between 2 and 4 h^{-1} are recommended. Residential structures with n_{L50} values above approximately 5 h^{-1} must certainly be classified as being too leaky. Conversely, cases

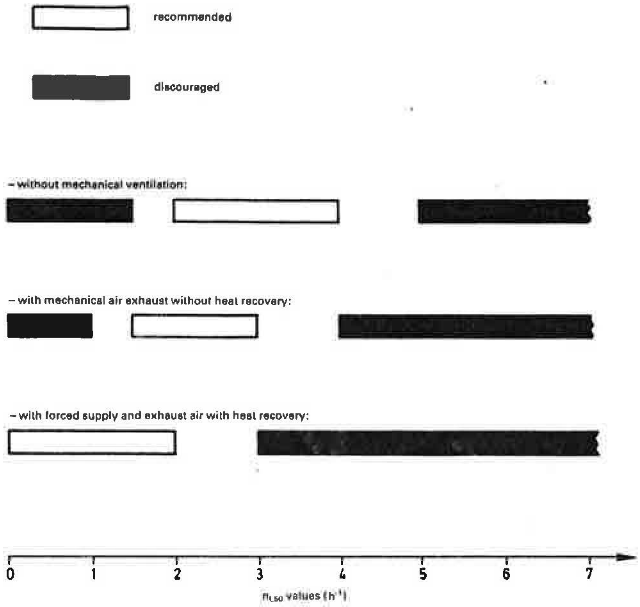

Figure 3. Provisional recommendations for the airtightness of the building envelope for residential construction

with n_{L50} values less than 1.5 h^{-1} have too little outside air exchange. Such instances cannot comply with the requirements for air hygiene or the avoidance of damage to the building construction.

Design solutions with **mechanical air exhaust** and make-up air via cracks and joints of the building construction should have n_{L50} values between 1.5 and 3 h^{-1}. These values are somewhat lower than those for design solutions without mechanical ventilation because the forced exhaust affords a certain level of fresh air intake.

Figure 3 reveals that, especially in the cases without mechanical ventilation or with forced exhaust air, values occur which are today neither recommended nor discouraged. It is to be hoped that these areas of uncertainty will occur less and less in the future.

It should also be noted that while complying with an appropriate global airtightness level for the building envelope, *local* occurrences of draughts from too large leakage sources can lead to discomfort. Such excessive leakage sources can be detected by smoke tubes, by pressurisation measurement or possibly by infrared photography.

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