# INTERNAL HEAT GAINS IN RELATION TO THE DYNAMICS OF BUILDINGS HEAT REQUIREMENTS

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Abstract

**The paper presents time functions of internal heat gains in apartment and office buildings. Assumed hourly functions have been used as input data for development of a simulation program concerning dynamics of heat requirements and the operation of central heating systems with thermostatic valves. Concluding remarks may be applied to influence analysis of internal heat gains in the tested buildings.**

Streszczenie

**Przedstawiono czasowe przebiegi zmienności występowania wewnętrznych zysków ciepła w budynkach mieszkalnych i biurowych. Przyjęte godzinowe przebiegi tych zysków posłużyły następnie, jako dane wejściowe do opracowanego programu symulującego dynamikę potrzeb cieplnych i pracę instalacji centralnego ogrzewania z zaworami termostatycznymi. W konkluzji podano wnioski mogące znaleźć zastosowanie przy analizach wpływu wewnętrznych zysków ciepła w badanych budynkach.**

Keywords: **Internal heat gains; Occupation profiles; Heat balance of the rooms; Simulation; Efficiency of the heat gains use; Apartment and office buildings.**

## 1. INTRODUCTION

For a correct estimation of the internal load, the most important thing is a correct and as accurate as possible determination of the sources of heat present in the studies of building. The main sources of internal load are occupants, lights and electric appliances. The paper presents two principal problems – identification and analyses of internal heat gain profiles in apartment and office buildings as well as the impact of these gains on heat demand in these buildings. The aim of the work was the elaboration of time functions of inner heat gains in analysed buildings and the qualification of the influence of the above-mentioned gains on heat balance of these buildings. To elaborate profiles [1,2] hourly time-courses of the sojourn of persons in rooms were used as well as activities undertaken by them, and also own research in this range. Assumed hourly functions have been used as input data for development of a simulation program concerning dynamics of heat requirements and the operation of central heating systems with thermostatic valves. The results are occupation patterns, use of electric appliances, and occupants activities influencing the generation of heat in dwellings and office buildings. The impact of internal heat gains on heat demand in the tested buildings are presented too. The results can be used for the calculation of heating and cooling loads in analysed buildings or for the estimation of heat gains in a building energy model.

## 2. SOURCES OF INTERNAL HEAT GAINS IN BUILDINGS

Main sources of heat gains from internal sources in buildings are:

- occupants,
- lighting,
- equipment in rooms (household equipment, TV sets, radios, computers),

and in apartment buildings additionally:

- use of hot water,
- preparation of meals.

Occurrence of internal heat gains and their value depends on the kind of room (or building). The literature study [3] shows that the only unknown in determining heat gains from internal sources in buildings is a time profile of those gains. Most frequently it depends on the presence of people (lighting, use of equipment, preparation of meals, etc.). Data concerning the average value of heat flux emitted by sources mentioned above and their nominal quantity can be found both in standards or handbooks and in literature [4, 5, 6, 7, 8, 9, 10, 11].

## 3. TIME-COURSES OF INTERNAL HEAT GAINS

Considering different purposes of particular types of buildings and, in the result, time profile of the variability of occurrence of gains mentioned above, the analysis should be done separately for apartment and office buildings.

In case of apartment buildings the evaluation of power of heat gains sources in particular hours has been based on the analysis of statistics, based on the schedule of presence of residents (men, women in paid employment and not in paid employment, children, elderly people, etc.) and activities undertaken by them, connected with the use of household equipment or lighting in presented works [2, 1]. Hourly profiles of people's presence and other heat gains, connected with the use of rooms developed in this way, has been adjusted to Polish conditions (on the basis of Statistical yearbook): an average number, age and position of people, occupying an "average" apartment and it's equipment (Fig. 1 and Fig. 2).

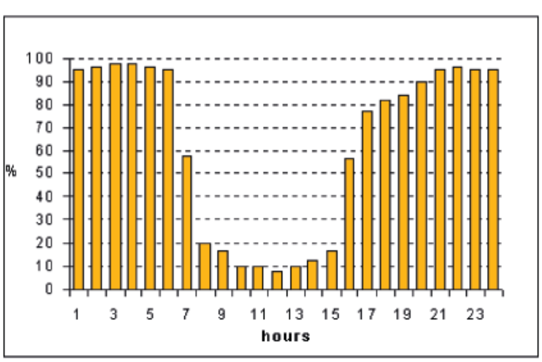


**Figure 1.**
**Example of hourly profiles of people's presence – men in working days**

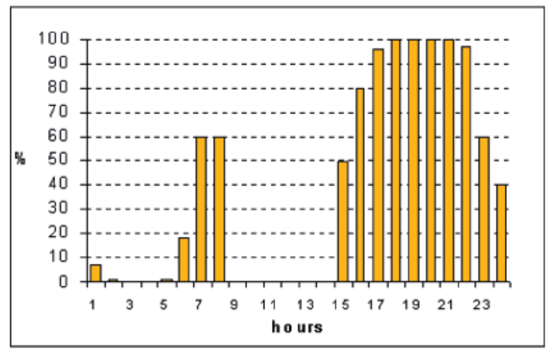


**Figure 2.**
**Hourly profile of the use of lighting in flats**

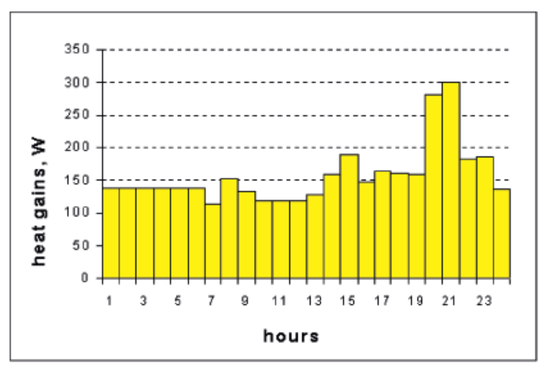


**Figure 3.**
**24 hour profile of total heat gains from people in apartment building**

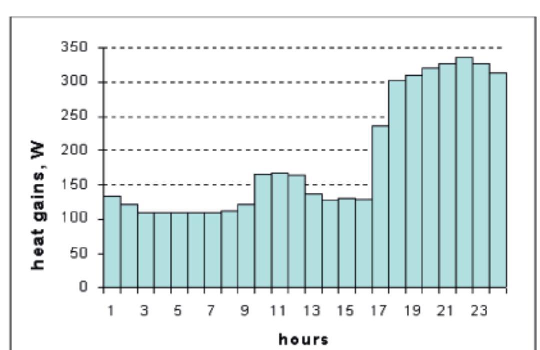


**Figure 4.**
**24 hour profile of total heat gains from others sources**

Since available standards and guidelines [5, 6, 12, 13] provide only average daily values of heat gains per apartment to check the correctness of representation of the achieved time profiles, an average daily flux of heat gains per apartment for analyzed and acknowledged typical families was determined and compared with the available data (Fig. 3 and 4).

For office buildings the identification of time profiles of internal sources heat gains occurrence was done on the basis of the study of electric energy consumption, connected with the use of lighting and other office equipment in the building daily (with the time step equal 2 minutes) in particular days of week. Histograms of electric power demand achieved this way (Fig. 5) and research in situ of people's presence, use of lighting and computers, allowed to create hourly runs of variability of internal heat gains in analysed rooms (Fig. 6). Those observations also show that profiles of the use of lighting and computers may be considered constant during the day (also during lunch break) [14].

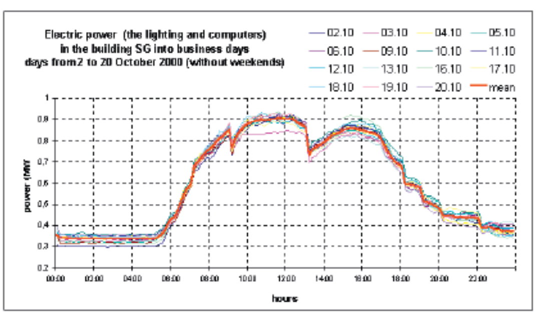


**Figure 5.**
**Profile of electric power demand in building *Justus Lipsius* in working days in October 2000**

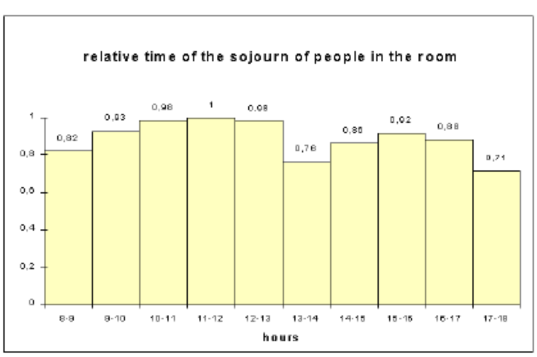


**Figure 6.**
**Average profile of the people's sojourn in building *Justus Lipsius* – October 2000**

## 4. EXEMPLARY RESULTS OF SIMULATION – MONTHLY BALANCES

Considering time profiles of the occurrence of heat gains from internal sources in apartment and office buildings, simulations of heat balances of chosen flats in apartment buildings and offices for each month of heating season were carried out with the use of programs **DYNINST** [15] and **ESP-r** [16]. For the analysis 3 flats on repeatable stories (II floor) in a small multiple dwelling (4 stories, 3 flats on each) and a part of office building, consisting of 2 rooms (first for 2 persons, second for 1) and a piece of hall were chosen.

In calculations average monthly runs of external climate with a time step of 1 hour for Sulejow (chosen from years 1966-1995) were used.

Furthermore:

- a constant number of air changes rates in buildings was analysed (0.75 $h^{-1}$ for flats, 1.0 $h^{-1}$ for offices), as well as variable in time number of air changes, coming from a real amount of air, flowing into building,
- monthly heat balances of the flats and offices were analysed for the averaged daily runs of rooms exploitation, and variable in time profiles of rooms exploitation,
- different orientation of rooms and flats was analysed,
- the heat accumulation in internal partitions in office buildings was not included in analysis.

Analysing the results of simulation for each month of heating season (October-April) for chosen rooms, one can notice that heat gains in the rooms, both from the sun and internal sources, start to have important influence on heat balances of analysed rooms and working conditions of internal installations [17].

Relative, referred to heat losses, share of internal heat gains for different flats, oscillates from 10% (January) to 32% (October) in cases of west-oriented rooms. Heat gains from the sun in balances of particular rooms oscillate from 12% (December) to as much as 72% for west-oriented rooms in April. In general, for apartment buildings, heat gains from internal sources make from 13% to 24% of heat losses balance in analysed flats (with a low insulation of building envelop), and were compared with the amount of heat gains from sun radiation (especially in winter months). Gains from the sun have dominant influence on heat burdens only in the edge months of heating season (Fig. 7).

In cases of office rooms an average share of internal heat gains was even bigger (22-36%). For winter months their influence was decisive for heat burdens (Fig. 8).

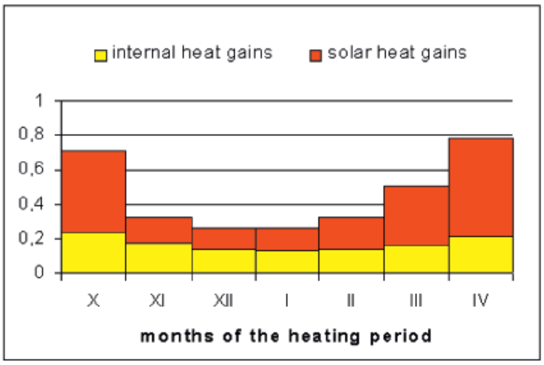


**Figure 7.**
**Relative (referred to heat losses) share of internal heat gains for analysed flats in the apartment building**

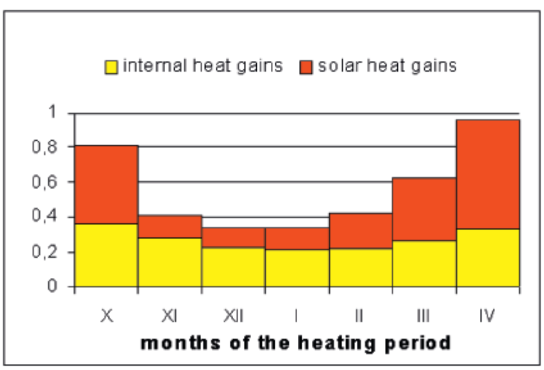


**Figure 8.**
**Relative (referred to heat losses) share of internal heat gains in analysed office rooms**

Heat gains from sun radiation predominate in autumn and spring (although not in north-oriented rooms, nor in some east-oriented rooms). No matter what the orientation of the room is, relative, referred to heat losses, share of internal heat gains oscillates from 20% (January) to 39% (October) in cases of office rooms for two persons. Orientation of the room has a great influence on the amount of heat gains from the sun.

An average efficiency of the use of heat gains in analysed buildings, specified according to PN-B-02025, oscillates from 0.65 to 0.97 (Fig. 9), depending on the month of heating season and function of the room type, although predominating here is the share of gains from sun radiation, which corresponds with coefficient *GLR* (relation between gains and losses) at the level from 0.9 to 0.25.

The range of fluctuation of efficiency value of heat gains use for analysed apartment buildings is 0.63 (west-oriented flats in April) to 0.99 (for winter months). In cases of office rooms this range is similar (from 0.59 for west-oriented offices in April to 0.96 for northern or eastern rooms in December and January), but it's level is lower. Above results prove that, in edge months of the heating season, only the small part of gains can be used for reducing heat efficiency of heaters. In those periods rise of internal air temperature was noticed of more than a planned value of 20%, especially in offices.

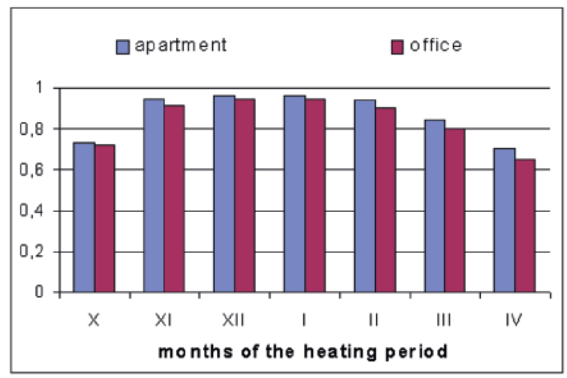


**Figure 9.**
**Average efficiency of the utilization of heat gains in analysed buildings**

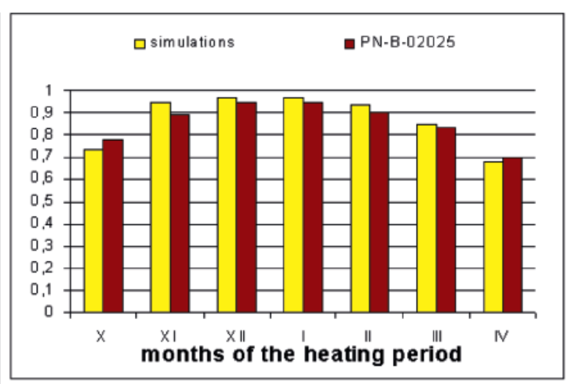


**Figure 10.**
**Comparison of the efficiency of heat gains utilization in individual months during heating season – the dynamic simulations and the algorithms according to PN-B-02025**

The results of dynamic simulations for analysed flats (lack of the proper input data for public utility buildings, concerning ventilation and internal heat gains) were compared with results of calculations performed according to algorithms, consistent with PN-B-02025. The comparison is illustrated in Fig. 10.

The achieved results for analysed flats show high convergence, what indirectly confirms the correctness of the use of the worked out time profiles of people's presence in rooms, and the use of flats, and may suggest the possibility of formulating requirements of proper input data, concerning internal heat gains in public utility buildings.

## 5. INFLUENCE OF ROOMS USE ON HEAT BURDENS OF BUILDINGS

As all the standards and guidelines for design give rough and averaged values of internal heat gains, it was decided to check, whether using the average daily runs of rooms use and variable in time profiles of rooms use, may affect monthly heat burdens of analysed cases. The problem concerns especially rooms used in particular time ranges, which means mainly office buildings.

The results confirmed the difference in total heat balance of analysed rooms, depending on whether constant or variable profile of internal heat gains occurrence was considered. For apartment buildings the differences were small (lack of heat gains from people during the day was compensated with sun radiation). For office buildings, however, especially in edge months of the heating season, the differences were more visible (Fig. 11). Average monthly heat demand in those months, considering time profile of gains occurrence was, even for south- and west-oriented rooms, 50% bigger than in case when constant value of heat flux from internal sources was considered (Fig. 12).

In the analysed case room orientation does not affect the result of calculations in winter months (November-February), but it is visible in the remaining months of heating season, especially in the edge ones. The use of constant occurrence profiles (which means: those, fixed in standards) results in the reduction of heat demand for heating purposes of the building in autumn-spring period (Fig. 11).

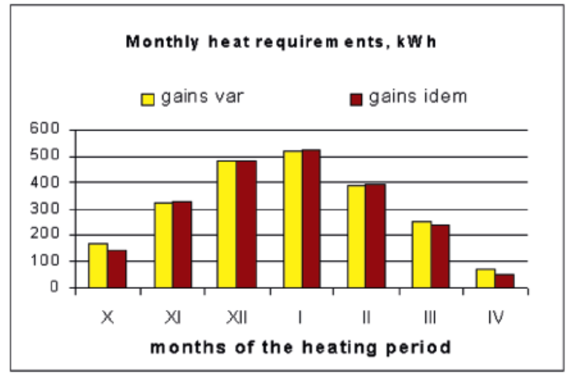


**Figure 11.**
**Comparison of the thermal balances for analysed office rooms – constant and variable profiles of the internal heat gains occurrence**

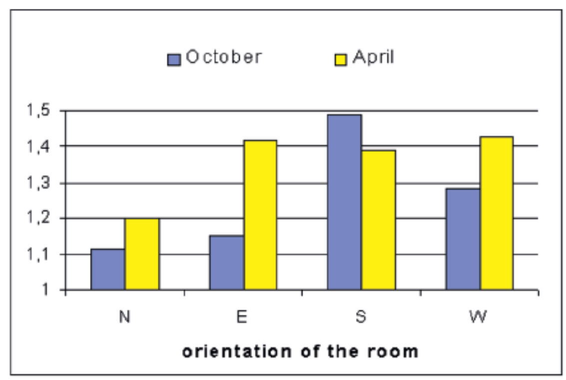


**Figure 12.**
**Relative growth of heat demand (in relation to calculations with obtained constant profile of room occupation) for office rooms of different orientation in extreme months of heating season**

## 6. CONCLUSIONS

Carried out tests and analysis of time profiles of internal heat gains variability allow to formulate the following conclusions:

- Results of the in-situ observation, research and the statistical analysis of time-courses of internal heat gains (people, lightning and equipment of rooms) confirmed the dynamic character of changes of these components of the heat balance [3, 17],
- Heat fluxes, emitted by people and the office equipment for the analysed cases, achieve values from 300 to 650 W; similar amounts of heat gains can be found in analysed flats,
- The presented profiles of people's presence in the rooms, and the use of those rooms, correspond well the real occurrence of internal heat gains, and may become a basis for the calculations of the living heat gains variability for dynamic simulations of living heat gains variability for dynamic simulations of apartment buildings, as well as office buildings.

General conclusions from the analysis of influence of internal heat gains on heat balance of rooms can be presented in a few points:

- Internal heat gains make from 13% to 24% of heat losses balance of the analysed apartment buildings (with a low insulation of the building envelop), and for office buildings from 22 to 36%,
- An average efficiency of the heat gains use oscillates from 0.70 to 0.97, depending on the month of

the heating season and the function of the room (but here the predominating factor is the presence of gains from sun radiation),

- There are differences, especially in edge months of the heating season, in a total heat balance of the analysed rooms or flats, depending on whether the constant or variable profile of the internal heat gains occurrence was assumed (this concerns, first of all, office buildings),
- Assuming constant (average in the period of a day) values of heat gains from living sources, results in the reduction of heat demand for heating purposes of the office building,
- In case of apartment buildings the knowledge of time profiles of people's presence in rooms and the use of those rooms is not of so great importance in the simulation of heat burdens in longer time periods. The knowledge of the people's presence profile is growing in cases of dynamic simulations of particular rooms or in shorter time periods (e.g. 24 hours).

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