ENERGY EFFICIENCY OF BUILDINGS: A SIMPLE BUT ACCURATE WAY TO PERFORM CALCULATIONS

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Overview

- In order to assess yearly energy demand of a building, Technical Specification 11300-1 requires a heat balance to be performed monthly during heating season.
- As a result, six or more heat balances are needed every year.

Overview

- Such a time-consuming calculation is justified by its alleged accuracy: the figure it provides is thought to be extremely precise.
- But…is it really the case?

Overview

- Based on “real life” calculations, this presentation shows that a single, seasonal calculation can replace numerous, monthly ones, with no significant loss of accuracy.

Overview

- According to TS 11300-1, main quantities to be included in the monthly balance are:
  - heat loss through building envelope;
  - heat loss because of air displacement;
  - heat gain from sun;
  - heat gain from occupants and appliances.

Overview

- Let us consider the first month of the heating season: November, for example.
- When the heating system is started, heat produced is first used to reach the desired inside temperature (20°C, for example), and then to keep this temperature.

Overview

- Let us now focus on December. At the beginning of the month, the building is already at 20°C, thanks to heat produced in November: this time, no heat will have to be produced to reach 20°C, which amounts to a December heat saving.

Overview

- The heating system then keeps the building at 20°C throughout December, and the temperature is still the same at the end of the month.
- Outcome: some of the heat produced in December will not be beneficial before January, when a new heat saving takes place.
- As far as December heat balance is concerned, this amounts to a heat loss.

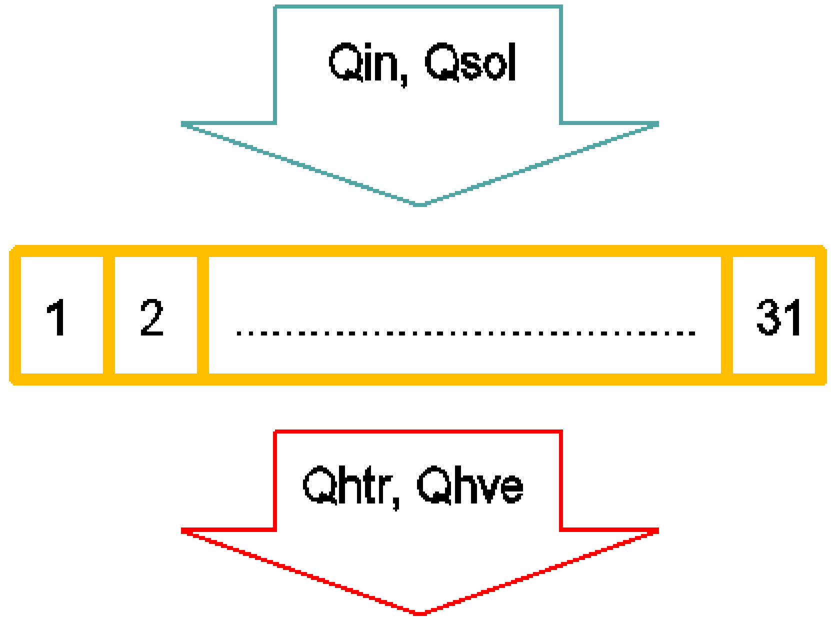
Overview

- In December (as well as in any other "in-between" month), two more quantities should be added to the heat balance:
  - residual heat from November (Qres; sign "+");
  - heat shifted to January (Qsh; sign "-").
- In November, only Qsh, and in April only Qres, should be added.

Overview

- Qres and Qsh are virtually impossible to assess with ordinary means; taking them into account would make monthly heat balances much more complicated.

Heat balance of an «in-between» month (according TS 11300-1)



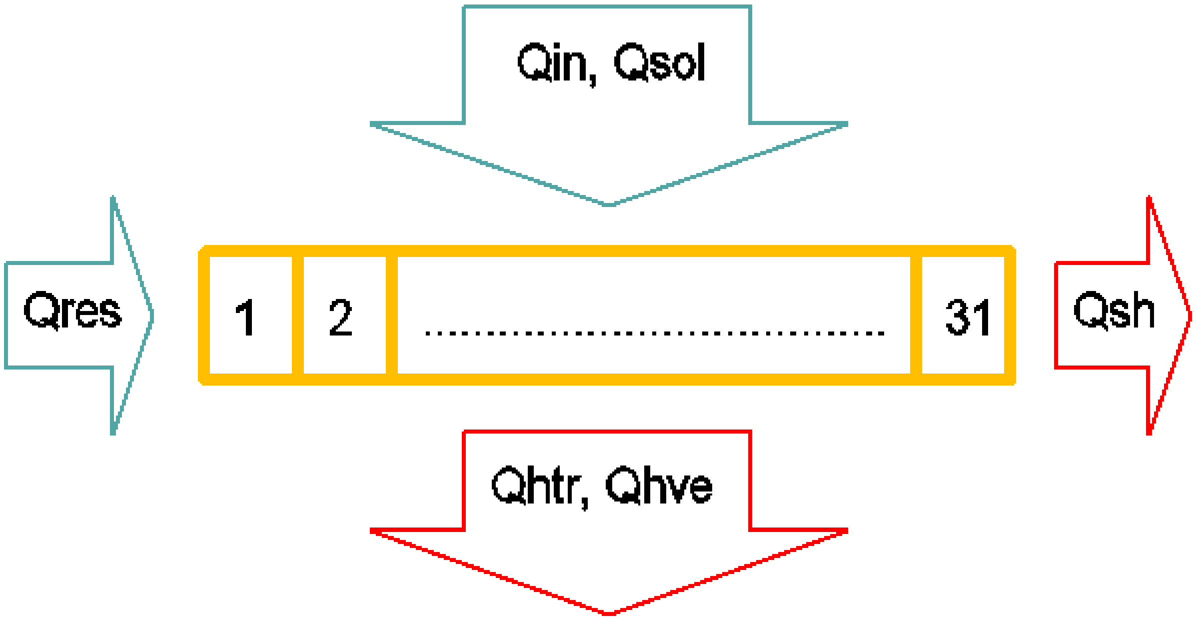
Qin: heat gain from occupants and from appliances

Qsol: heat gain from solar radiation

Qhtr: heat lost through building envelope

Qhve: heat lost due to air displacement

Heat balance of an «in-between» month (complete)



Qin: heat gain from occupants and from appliances

Qsol: heat gain from solar radiation

Qhtr: heat lost through building envelope

Qhve: heat lost due to air displacement

Qres: residual heat from previous month

Qsh: heat shifted to following month

Overview

- It might be argued that Qres and Qsh offset each other, and can therefore be both neglected.
- This is **not the case**.
- Qres and Qsh depend mainly on average air temperature during relevant months, which can be substantially different.

Overview

- in the case of March, for example:
  - Qres is determined by **February's** air temperature
  - Qsh is determined by **April's**.

- Qres is therefore much greater than Qsh
- No offset can be assumed.

Overview

- Qres and Qsh cause a loss of accuracy.

- Is there a way to perform a heat balance where they are sure to be **zero**, or at least neglectable?

Overview

- To do so, the one-month period currently used for heat balance should be replaced with another time duration, **before** and **after** which the **heating system** is turned **off**.

- The only such time period is the **heating season itself.**

- A calculation based on a seasonal heat balance would be more precise, as well as more rapid, than a monthly one.

Overview

- In the following we will describe in detail such a balance;

- The steps:
  - Find a way to calculate the individual heat balance terms on a **seasonal** basis.
  - Replace **monthly** quantities with **seasonal** quantities

Overview

<u>Heat dispersed through building envelope</u>

- Based on TS 11300-1, heat dispersed through building envelope is calculated monthly, by multiplying **transmission coefficient Htr** times a **temperature difference ΔT**, times the **number of hours t** in that specific month.

- ΔT is in turn calculated as average air temperature during that month, minus temperature desired inside the building.

- When monthly contributions are summed up in the seasonal calculation, the **sum of products ΔT times t** appears, each product being relative to an individual month.

Overview

Heat dispersed through building envelope

$$Qhtr=Htr\,[(Ti1-Te1)t1+(Ti2-Te2)t2+\ldots+(Tin-Ten)tn]$$

- This **sum of products** is **proportional**, and can therefore be replaced by, the annual **“degree days” (DD’s)** in that location.
- For all locations of importance, DD’s are in technical standards or in legislation.

Overview

- *<u>Heat dispersed by ventilation</u>*

- Virtually all we have described above also applies, with minor changes, to heat dispersed by ventilation. The only difference is in coefficient Hve, which replaces Ht. Apart from that, the month-by-month products are the same as above, and so is their annual sum. Once more, then, the **annual calculations** can be based on **degree-days**.

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Overview

- *Solar gains*
  - Based on TS 11300-1, monthly solar gains are calculated based on “solar irradiance”, or the energy that hits one square meter of envelope surface during that month, in that location. It is therefore straightforward to turn a month-by-month calculation into an annual one: it is sufficient to **sum monthly irradiance contributions**, which, like DD’s, are published for all major locations.

- *Internal gains*
  - Based on TS 11300-1, monthly internal gains are calculated based on the useful area of the building and the number of hours in that month. The seasonal value can be easily obtained by **replacing** the **monthly number of hours** with the **seasonal** one.

Overview

- *Utilization factor of internal and solar gains*
- Heat gained is not wholly available to meet building heat demand. A share of it does, in fact, contribute to establishing and maintaining the desired temperature within the building envelope. Thanks to this heat share, some fuel –or, in general, some primary energy- is saved: this share is therefore useful.
- However, another share of gained heat merely increases, at times, ambient temperature above the desired value. This is due, i.a., to alternation between day and night, and between hour during which people are and are not present. The latter heat share cannot, of course, be regarded as useful.

Overview

- *Utilization factor of internal and solar gains*

- Utilization factor: ratio of useful heat gain to total (useful plus non-useful) heat gain.
- Based on TS11300-1, the ratio should be calculated month by month. However, the useful-non useful distinction we have described is about daily, rather than monthly, processes.
- A monthly calculation is therefore a mere approximation, needed to perform monthly heat balances.
- Such an approximation can very well be replaced by a seasonal one.
- No accuracy would be lost: nothing suggests that a monthly calculation is more accurate than a seasonal one.
- On the other hand, the latter is needed for the annual heat balance we have previously envisaged.

Overview

- *Utilization factor of internal and solar gains*
- How exactly can the utilization factor be calculated **annually**? By suitably modifying the monthly calculation.
- The formula of utilization factor features:
  - thermal capacitance;
  - heat transfer coefficient;
  - ratio (gamma) of heat gained to heat dispersed during each month
  - parameters $a_{H,0\ (p.u)}$ and $\tau_{H,0}$ (hours).

- The first two are constant, as they characterize the building: they need no modification when turning to seasonal calculation.

Overview

- *Utilization factor of internal and solar gains*

- The only parameter that varies each month (and needs to be modified) is gamma.
- Calculating gamma for the whole season rather than for a single month is straightforward:
  - sum up heat gained during all individual months;
  - sum up heat dispersed during all individual months;
  - ratio the former to the latter.
- The seasonal gamma can now be used instead of the monthly one in the utilization factor formula (incidentally, this is envisaged in UNI EN ISO 13790).

Methods

- In order to assess the outcome difference between monthly and seasonal calculation, we have examined a real case:
  - a country house, recently built (around 2011) in central Italy, and fitted with a heating, but no cooling, installation.

Methods

- a) We first calculated the Energy Performance Index based on TS 11300-1 and TS 11300-2.
  - *Taking into account the legal duration of the heating season, we performed monthly heat balances from January to (first two weeks of) April and from November to December.*
  - *Average monthly temperatures were read into Standard UNI 10349:1994.*
- Parameters $a_{H,0}$ and $\tau_{H,0}$ were assigned the values prescribed by Standard ISO 13790:2008 for the monthly calculation: $a_{H,0}=1$ and $\tau_{H,0} = 15$ h.
  - *For the sake of simplicity, thermal radiation to the sky was neglected as much smaller than other heat quantities in the balance.*
- Summing the six monthly outcomes yielded an **Energy Performance Index** of **4,393.69 kWh per square meter and per year**.

Methods

- b) We then performed, on the same building, the **seasonal** calculation described in Standard **ISO 13790:2008**.
- We assumed parameters aH,0 and τH,0 to have the same respective values as in a).
  - *Albeit not completely correct (those values should only be used in a monthly calculation), this choice allowed an "all things being equal" comparison with a).*
- The calculation was now much simpler, as it only involved one heat balance instead of six.
- The outcome was an **Energy Performance Index** of **4,345.17 kWh per square meter and per year.**
- The **error** as compared to month by month calculation in a) is small: **-1.1%.**

Methods

- c) We repeated the same seasonal calculation as in b), but assumed parameters $a_{H,0}$ and $\tau_{H,0}$ to have the values prescribed by Standard **ISO 13790:2008** for the **seasonal** calculation: $\mathbf{a_{H,0}=0.8}$ and $\tau_{H,0}$ **=30 h**.
- The yield was an **Energy Performance Index** of **4,375.66 kWh per square meter and per year**. The **error** with respect to a) was even smaller than previously: **-0.4%.**

Results

Type of calculation	$a_{H,0}$	$t_{H,0}$	Epi	Error
		hours	kWh/m2 year	%
Monthly, based on 11300	1	15	4.393,69	0,00
Seasonal	1	15	4.345,17	-1,10
Seasonal	0,8	30	4.375,66	-0,41

Results

- The **monthly** calculation yielded an **Energy Performance Index** of **4,393.69 kWh per square meter and per year.**
- The **seasonal** calculation yielded an **Energy Performance Index** of **4,345.17 kWh** (or **4,375.66**, depending on values assumed for a few parameters in the balance equation) per square meter and per year.
- The **error** as compared to month-by-month calculation was as little as **-1.1%** (or **-0.4%**) .

Conclusions

- The seasonal calculation yields the same results as the monthly one.

- The **seasonal** calculation should be adopted **instead** of the **monthly** one, as much **simpler** and providing the **same accuracy**.

References

Assessments in the above text are based solely on the author's personal opinions.

[1] UNI/TS 11300-1: 2014, "Energy performance of buildings - Part 1: Evaluation of energy need for space heating and cooling"

[2] UNI/TS 11300-2: 2014, "Energy performance of buildings - Part 2: Evaluation of primary energy need and of system efficiencies for space heating, domestic hot water production, ventilation and lighting for non- residential buildings"

[3] ISO 13790: 2008, "Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008)"

Thank you for your attention

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