Please add this section to the DOE-2.1E Supplement, after p. 2.131.

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Calculation of Inside Surface Temperatures in DOE-2

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Introduction

The present version of *DOE-2.1E* does not calculate the inside surface temperatures because of the weighting factor approach [1]. But the wall and window inside surface temperatures are important to estimate the radiant temperature as one of the key elements in a thermal comfort evaluation. Therefore, in the frame of the Swiss national project NEFF 640, a model which calculates the surface temperatures has been developed and the required FORTRAN routines have been written. The work was partly performed at the Lawrence Berkeley National Laboratory in cooperation with the Simulation Research Group.

Model

The model is based on an energy balance on the wall surface. The different heat fluxes are shown in Fig. 1. The program *DOE-2.1E* does not take the radiative heat exchange between the room surfaces $\dot{q}_w$ separately into account, but as shown in Fig. 2, a combined convective and radiative film coefficient h is taken into consideration.

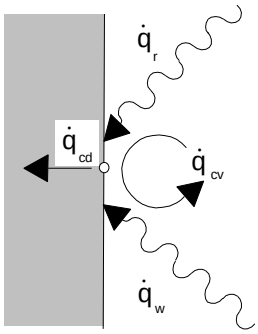


Fig. 1 *Heat fluxes at the wall surface*

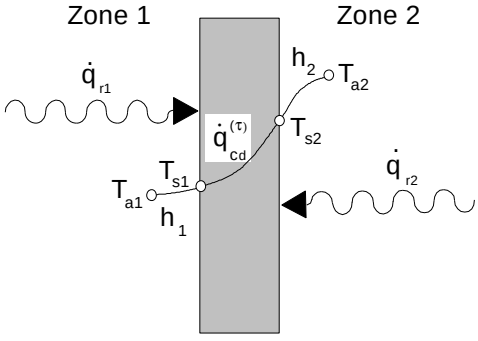


Fig. 2 *Temperature distribution and radiant heat flux for an interior wall (DOE-2.1E model).*

The flux of heat conduction at the wall surfaces is described by the response factors [1] as follows:

$$\dot{q}_{cd1}^{(t)} = \sum_{i=0}^{n} X_i^{'} \cdot T_{s1}^{(t-i\cdot\Delta t)} - \sum_{i=0}^{n} Y_i^{'} \cdot T_{s2}^{(t-i\cdot\Delta t)} + CR \cdot \dot{q}_{cd1}^{(t-\Delta t)} \qquad (1)$$

$$\dot{q}_{cd2}^{(t)} = \sum_{i=0}^{n} Y_i^{'} \cdot T_{s1}^{(t-i\cdot\Delta t)} - \sum_{i=0}^{n} Z_i^{'} \cdot T_{s2}^{(t-i\cdot\Delta t)} + CR \cdot \dot{q}_{cd2}^{(t-\Delta t)} \qquad (2).$$

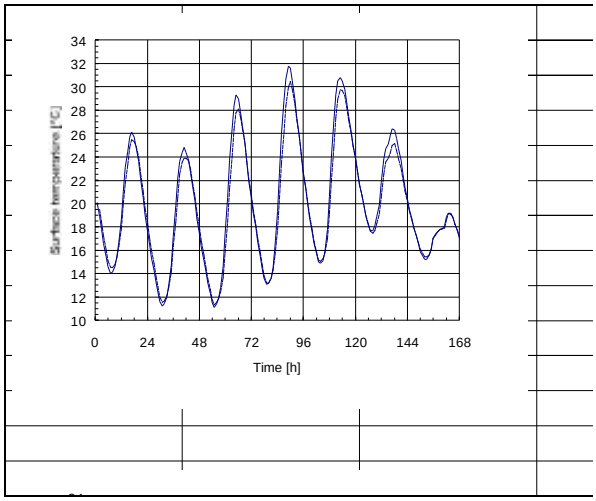
The surface temperatures can be calculated from an energy balance on both sides of the wall:

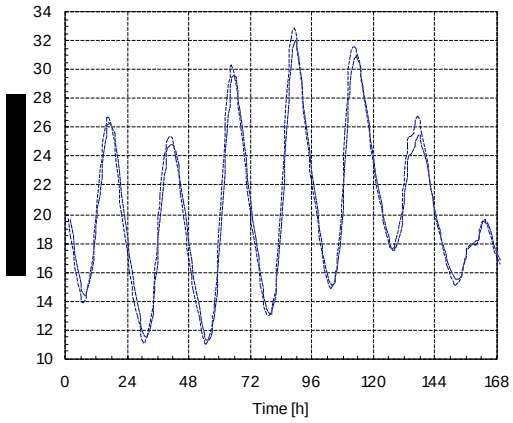
$$\begin{bmatrix} -X_0^{'}-h_1 & Y_0^{'} \\ Y_0^{'} & -Z_0^{'}-h_2 \end{bmatrix} \cdot \begin{pmatrix} T_{s1} \\ T_{s2} \end{pmatrix} = \begin{bmatrix} \sum_{i=1}^{n} X_i^{'} \cdot T_{s1}^{(t-i\cdot\Delta t)} - \sum_{i=1}^{n} Y_i^{'} \cdot T_{s2}^{(t-i\cdot\Delta t)} + CR \cdot \dot{q}_{cd1}^{(t-\Delta t)} - h_1 \cdot T_{a1} - \dot{q}_{r1} \\ -\sum_{i=1}^{n} Y_i^{'} \cdot T_{s1}^{(t-i\cdot\Delta t)} + \sum_{i=1}^{n} Z_i^{'} \cdot T_{s2}^{(t-i\cdot\Delta t)} - CR \cdot \dot{q}_{cd2}^{(t-\Delta t)} - h_2 \cdot T_{a2} - \dot{q}_{r2} \end{bmatrix} \quad (3).$$

The right side of the system of equations (3) only contains surface temperatures and conduction heat fluxes from previous time steps. The zone air temperature and the radiative heat flux to the wall for the current time step are output data of the present *DOE-2* program and therefore also known.

Comparison with measurements

The model has been compared with the measured data sets used in the validation efforts within IEA-ECB Annex 21 [2] and with measurements from the Pala test case [3].





___DOE-2.1E Simulation
- - -IEA Measurements

Fig. 3 *Inside surface temperature of the ceiling.*

Fig 4. *Inside surface temperature of the exterior wall.*

Fig. 3 and 4 show the good agreement between the measurements and the simulation.

Additional comparisons have been made with a window model developed for the building simulation program *TRNSYS* [4]. The calculated window surface temperature for a Window type 4651 has been compared with the result of the new surface temperature routine in *DOE-2.1E*. The comparison shows an excellent agreement (Fig. 5).

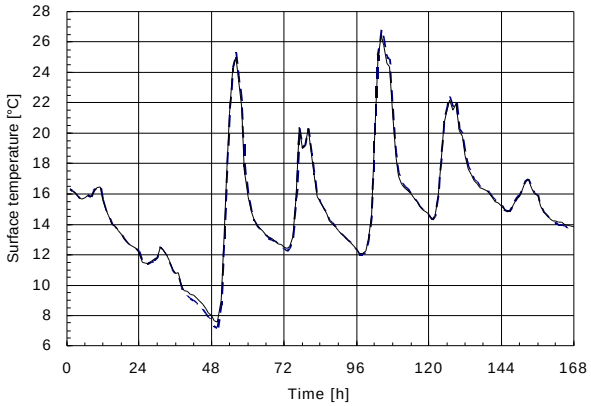


Fig. 5 *Window inside surface temperature.*

Additional Keywords

BUILDING-LOCATION

SURF-TEMP-CALC Defines whether the calculation of inside surface temperatures is performed or not. The allowable code-words are YES and NO (the default).

WALL-LEVEL KEYWORD

The surface temperature calculation is performed for EXTERIOR-WALLs, ROOFs, WINDOWs, DOORs, UNDERGROUND-WALLs, UNDERGROUND-FLOORs and INTERIOR-WALLs. However, for INTERIOR-WALLs it is not performed for type INTERNAL or AIR.

INSIDE-SURF-TEMP Defines whether the calculated inside surface temperature for the wall is written to a separate output file or not. The allowable code-words are YES and NO (the default).

The output data are written to the file fort.16 in UNIX and for016.dat in VAX/VMS with the following format:

```
ROOM  S-TR  S-TR        ROOM  WIN-  WIN-        ROOM  S-TR  S-TR  ROOM
       -1    -C45  -C45       -1     1     1          -1    -C02  -C02  -2
521 1  27.3  27.0  20.2  21.7  27.3  22.8 -17.8  21.7  27.3  27.0  21.4  21.0
521 2  26.7  26.4  20.2  21.7  26.7  22.6 -17.8  21.7  26.7  26.4  21.4  21.0
 (1)    (2)   (3)   (4)   (5)   (2)   (6)  (7)    (5)   (2)   (3)   (8)   (9)
```

1 Date and Time
2 Zone air temperature
3 Wall inside surface temperature
4 Wall outside surface temperature
5 Outside air temperature
6 Window inside surface temperature
7 Window outside surface temperature (not available in the current version; therefore 0°F or -17.8°C)
8 Wall surface temperature in NEXT-TO zone
9 Air temperature in NEXT-TO zone

The new routine calculates the mean radiative temperature for every zone as a sum of the area-weighted surface temperatures and makes it available as an additional zone hourly report variable in SYSTEMS. Also, the operative temperature, defined as the average of the zone air temperature and the mean radiative temperature, is calculated and available as an hourly report variable.

Hourly-Report Variable List SYSTEMS

VARIABLE-TYPE = u-name of ZONE

Variable-List Number	Variable in FORTRAN Code	Description
91	TMR	Mean radiative temperature
92	TEFF	Operative temperature

List of Symbols

CR	Common ratio	[–]
h	Combined film coefficient (convective and radiative)	$[W/(m^2)K]$
$\dot{q}_{cd}^{(t)}$	Wall conduction	$[W/m^2]$
$\dot{q}_{cv}$	Convective heat flux	$[W/m^2]$
$\dot{q}_r$	Radiative heat flux from people, equipment and solar radiation	$[W/m^2]$
$\dot{q}_w$	Radiative heat flux from other surfaces	$[W/m^2]$
T_a	Air temperature	$[K]$
T_s	Surface temperature	$[K]$
t	Time	$[h]$
Δt	Time step	$[h]$
X', Y', Z'	Surface-to-surface response factors	$[W/(m^2)K]$

References

[1] DOE-2 Engineers Manual, Version 2.1 A, LBNL University of California Berkeley, Nov 1982.

[2] Empirical Validation Data Sets 099 and 110 from EMC Test Room, BRE (Building Research Establishment), IEA Annex 21, March 1992

[3] R. Meldem and F. Winkelmann, Comparison of DOE-2 with Temperature Measurements in the Pala Test Houses, Energy and Buildings 27 (1998) 69-81

[4] R. Weber und M. Koschenz, Description of Type 97 for TRNSYS, Model for the Calculation of Multi-Layer Windows, EMPA Abteilung Haustechnik, Dez. 1995