USFOS
Reality Engineering

USFOS AS

Phone: +47 905 05 717

www.USFOS.com

Enterprise No.: NO 986 827 374 MVA

MEMO

MEMO CONCERNS	FOR YOUR ATTENTION	COMMENTS ARE INVITED	FOR YOUR INFORMATION	AS AGREED
Efficient Heat Transfer Coefficient The "U-Value"				
DISTRIBUTION Members of USFOS user group				X

FILE CODE	CLASSIFICATION
	Confidential
REFERENCE NO.	

PROJECT NO.	DATE	PERSON RESPONSIBLE / AUTHOR	NUMBER OF PAGES
	2006-01-20	Tore Holmas	4

Effective Heat Transfer Coefficient: "U-Value"

1 INTRODUCTION 2

2 BASIC HEAT TRANSFER EQUATIONS AND DEFINITIONS 2

3 U-VALUE ESTIMATION. SIMPLIFIED FORMULA. 3

4 U-VALUE ESTIMATION. ACCURATELY 4

5 EXAMPLES. 4

1 Introduction

The performance of passive fire protection is most general expressed through one number, the "*effective heat transfer coefficient*". The coefficient has the unit [W/m^2 K], (Watt per square meter and degree Kelvin). The coefficient is named the "U-Value".

Different insulation products behave differently during the fire exposure, but the "bottom line" interesting thing is the insulation performance of the actual layer, (how effective is the pfp to slow down the heating of the steel).

2 Basic Heat transfer equations and definitions

For solid materials, the effective heat transfer coefficient, U_{eff} (U-Value) is expressed as follows:

$$U_{eff} = \frac{\lambda}{d}$$

Where:

λ: specific heat conductivity of the actual material [W/mK]
d: thickness of the material [m]

For more complex insulation materials (like the one used in "Chartek", "Pitt Char", Termolag" Jotachar, etc) both thickness and conductivity change continuously when exposed to fire. In addition, several chemical reactions in the material, which absorb energy, will further complicate the picture.

The U_{eff} value therefore has to be derived from laboratory tests, where the fire temperature and the steel temperatures of the specimen is recorded continuously during the test, (for example every minute). Since the specific heat capacity of the specimen material (steel) is well known, the energy transfer through the thermal insulation is easily computed. Heat Energy transfer divided by the actual time gives the heat flow, and heat flow divided by temperature gradient gives the U_{eff} value.

$$Energy = c\,\rho\,V\,dT$$
$$Q = Energy / dTime$$
$$U_{eff} = Q / \Delta T$$

c : Specific heat capacity [Joule/kgK]
ρ : Density [kg/m^3]
V : Volume [m^3]
dT : Temperature increase of the material [º K]
dTime : Time increment (the temperature has increased during the time dTime).
Q : Heat Flow [Joule/Time= Effect = Watt, W]
ΔT : Temperature Gradient over the insulation (typically Fire temperature – Steel Temp)

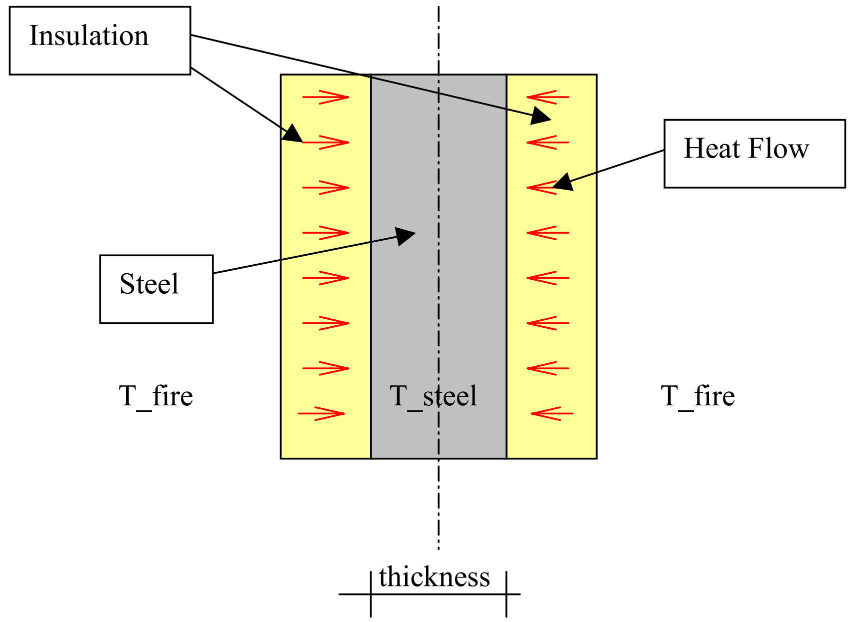

Figure 1 Open Steel Exposed from both sides

Figure 1 defines the parameters for an open cross section. It is assumed symmetric heating (same fire temperature on both sides of the steel section part). Since the steel part is heated from two sides, the actual thickness to be used is T_Steel / 2. For closed profiles, (like Pipes and Box sections), the actual steel thickness is exposed from only one side, and the full thickness should be used in the formulas.

3 U-Value estimation. Simplified formula.

If a product is tested in a standard HC fire, a simplified formula could be developed. It is assumed that the fire temperature is 1100ºC and an average temperature gradient ΔT = 1100-T_avg, where T_avg = (T_end-T_0) / 2.0, T_End is final steel temperature and T_0 is start temperature of the steel. The time to reach the T_End temperature is denoted dTime in the equations below.

The equations becomes:

$$U_{eff} = \frac{c \cdot thick \cdot \rho (T_{End} - T_0) \cdot}{dTime \cdot (T_{Fire} - T_{Avg})}$$

$$T_{Avg} = \frac{(T_{End} - T_0)}{2}$$

NOTE! Pure SI units have to be used, (kg, m, ºK and s).

4 U-value estimation. Accurately.

If the entire temperature development of both the steel specimen and the flame temperature is known, the accurate, time dependent heat transfer coefficient could be computed. The simple formula described in the previous section is used for every time increment.

5 Examples.

Figure 2 describes the Ueff (U-Value) as function of time of one specific test of a 4.5mm insulation applied on a 13 mm steel plate, two-sided exposure. The degradation of the performance during the fire time is easily seen, (The higher U-Value, the less insulation).

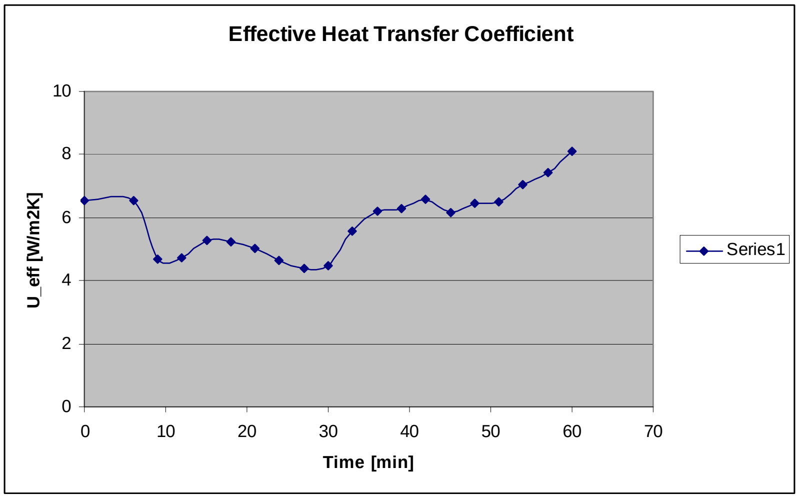

Figure 2 Effective heat transfer coefficient (U-Value) as function of time

The simplified, average Ueff (or U-Value) could also been derived from the same data sheet since some key data are printed.

T_0 : 30 ºC
T_End : 620º C (after 60 minutes)
Fire Temp : ~1100º C

Two sides exposure => actual thickness is divided by 2 : 0.013/2 = 0.0065m

Ueff = 510 * 0.0065 * 7850 (620-30) / 3600(1100-330) = 5.6 [W/m^2 ºK].

The simplified value is relative close to the real average, and the difference is caused by the assumption of the constant flame temperature, (in reality it takes approx 5 minutes before 1000ºC is reached).