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Computer Spreadsheet Representation of the Groeneveld Et Al. 2006 Critical Heat Flux Look-Up Table

Nuclear Engineering Division

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The Groeneveld, et al. 2006 Critical Heat Flux Look-Up Table [1] provides values of Critical Heat Flux (CHF) in kW/m^2 for a vertical 8 mm water-cooled tube. The CHF values are a function of pressure, P (100 ≤ P ≤ 21000 kPa), mass flux, G (0≤ G ≤8000 kg/m^2-s), and quality, X (−0.50 ≤ X ≤ 1.00). Typically, obtaining a value of CHF for a particular triad of P, G, and X within the domain of the table requires looking up eight values of CHF in the table and performing linear interpolation. The purpose of this brief technical memo is to describe and formally transmit a Microsoft Excel® computer spreadsheet that has been developed to enable one to enter a triad of P, G, and X and obtain the corresponding value of CHF.

The spreadsheet has two worksheets. The "G2006CHF_table" worksheet contains the entire CHF look-up table, which was copied from Reference 1. The "chf(P,G,X) " worksheet, looks up the required values of CHF in the "G2006CHF_table" worksheet and does the linear interpolation to obtain the required value of CHF for a specified triad of P, G, and X within the domain of the table. In the "chf(P,G,X)" worksheet pressure is represented in bar rather than in kPa. (1 bar = 100 kPa) Figure 1 provides sample CHF calculations for four triads of P, G, and X. In the figure the 29 columns of the "chf(P,G,X)" worksheet are divided into two parts so that they will fit on a single page. One row of the worksheet is required to obtain the value of CHF for a triad of P, G, and X. By making multiple copies of a row and entering new values of P, G, and X in each copy, one can obtain and list CHF values for multiple triads. In the example, CHF values for the triads (1.7 bar, 8000 kg/m^2-s, 0), (5 bar, 5750 kg/m^2-s, −0.15) , (1 bar, 0 kg/m^2-s, −0.5), and (210 bar, 8000 kg/m^2-s, 1) are obtained. The last two triads represent the two extremes of the look-up table, i.e., lowest pressure, mass flux, and quality, and highest, pressure, mass flux, and quality. As indicated in the figure, all of these values are entered in columns D, E, and F. The required values of CHF appear in column C. If any of the values of a triad is beyond of the range of the CHF look-up table, an Excel error indicator appears in column C in place of a numerical value. The next three paragraphs provide more details about how the spreadsheet is organized and functions.

The "G2006CHF_table" worksheet is organized similar to the organization of the CHF table provided in the reference. In row 15, columns E through AA provide the 23 values of quality used in the look-up table. Cell C17 provides the lowest pressure of the 15 values of pressure used in the look-up table, 100 kPa. In column D, rows 17 through 37 provide the 21 values of mass flux used in the look-up table. The 21-row by 23-column array within Cells E17 through AA37 provide the values of CHF in kW/m^2 at 100 kPa. This pattern is repeated 22 rows further down the table for 300 kPa, and at 22 row intervals for successively higher values of pressure until the highest value of pressure, 21,000 kPa, is reached. Thus, the value 300 appears in Cell C39, the 21 values of mass flux are repeated in Cells D39 through D59, and the 21-row by 23-column array within cells E39 through AA59 provide the values of CHF at 300 kPa.

Columns G through AE of worksheet "chf(P,X,G)" are used for internal calculations. Column G identifies the first row in the "G2006CHF_table" worksheet that is closest to the required P, but not greater than it. In the second sample calculation of Figure 1, the required pressure is 5 bar (500 kPa). The nearest pressure that is not greater than 5 bar starts in row 61 of "G2006CHF_table". The pressure in row 61 is exactly 5 bar. Starting in this row and considering it to be the first row of a table of values of CHF for G vs. X at 5 bar, the closest value of G that is not greater than the required 5750 kg/m^2-s is 5500 kg/m^2-s. It is in the 16th row of this smaller table. Thus, 16 appears in column H of Figure 1. The sum of 61 and

16 reduced by 1, 76, appears in column I. This is the row in the "G2006CHF_table" worksheet that corresponds to both the lower of two values of P and the lower of two values of G needed for the interpolation. The 9 in column J of "chf(P,G,X)" identifies the column in row 15 of the "G2006CHF_table" for which the quality is closest to the required quality, −0.15, but not greater than it. This column is column I, which is the 9th column in the "G2006CHF_table" worksheet. Here 1 corresponds to column A, 2 to column B, etc. Thus, in the "chf(P,X,G)" worksheet, the 76 in column I and the 9 in column J, together identify the cell that contains the CHF value for the lower of each pair of values of P, G, and X in the "G2006CHF_table" worksheet that are used in the interpolation. Once this initial cell is found, all of the other seven cells containing needed CHF values can be found in relation to this cell. One row down is for the next higher value of G. One column to the right is for the next higher value of X. Twenty-two rows down from any of these values of CHF provides the corresponding value of CHF at the same G and X, but the next higher value of P. Special care is taken so that if the initial cell is at the table's maximum value of P, G, and/or X, the boundaries of the table are not exceeded. When the initial cell is precisely at the boundary value of P, G, or X, no interpolation with respect to the particular variable or variables is needed.

Columns K and L of "chf(P,G,X)" provided the two values of X in the "G2006CHF_table" worksheet that are used in the interpolation. Hence, when X is −0.15, X1 is −0.15 and X2 is −0.10. Similarly, columns M and N provide the two values of G in the "G2006CHF_table" worksheet that are used in the interpolation, and columns O and P provide the two values of P in the "G2006CHF_table" worksheet that are used in the interpolation. Columns Q through X provide the eight values of CHF in the "G2006CHF_table" worksheet that are used in the interpolation. Columns Y through AB interpolate in the P-direction thereby collapsing the four CHF values at P1 in columns Q through T and the four CHF value at P2 in columns U through X, into four CHF values at the required value of P. Similarly, columns AC and AD use columns Y through AB and interpolate in the G-direction. Column AE uses columns AC and AD and interpolates in the X-direction to find the required value of CHF at P, G, and X. For convenience, this value is simply copied back to column C.

For the first triad of P, G, and X in Figure 1, G is 8000. Because this is the maximum value of G in the Reference 1 CHF look-up table, in the spreadsheet calculation, G1 and G2 (columns M and N) are both 8000 and interpolation in the G-direction is not performed.

When copying the two worksheets to one's own Excel file, one should copy both worksheets together at the same time. This is accomplished by highlighting the tab of one worksheet and holding down the Ctrl key while highlighting the tab of the other worksheet so that the tabs of both worksheets are highlighted together. Then one can make a copy of both simultaneously. Otherwise, the two worksheets in the new Excel file may not be properly linked. Improper linkage, for example, could cause the "chf(P,G,X)" worksheet in a new file to be linked the to "G2006CHF_table" worksheet of the parent file.

Reference

1. D.C. Groeneveld, J.Q. Shan, A.Z. Vasić, L.K.H. Leung, A. Durmayaz, J. Yang, S.C. Cheng, and A. Tanase**,** **"**The 2006 CHF look-up table," *Nuclear Engineering and Design* 237 (2007) 1909-1922.

C	D	E	F	G	H	I	J	K	L	M	N	O	P
				row P1	row in G	row of G	column						
CHF,kW/m^2	P, bar	G kg/m2-s	X	starts	vector	with P1	of X1	X1	X2	G1	G2	P1	P2
5795.2	1.7	8000	0	17	21	37	12	0	0.05	8000	8000	1	3
10847.5	5	5750	-0.15	61	16	76	9	-0.15	-0.1	5500	6000	5	10
8111	1	0	-0.5	17	1	17	5	-0.5	-0.4	0	50	1	3
0	210	8000	1	325	21	345	27	1	1	8000	8000	210	210

Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE
CRITICAL HEAT FLUX VALUES, kW/m^2														
P1,G1, X1	P1,G1, X2	P1,G2, X1	P1,G2, X2	P2,G1, X1	P2,G1, X2	P2,G2, X1	P2,G2, X2	P,G1,X1	P,G1, X2	P,G2, X1	P,G2, X2	P,G,X1	P,G,X2	P,G,X
5392	4689	5392	4689	6544	4760	6544	4760	5795.2	4713.85	5795.2	4713.85	5795.2	4713.85	5795.2
10581	9306	11114	9598	10898	9280	11388	9491	10581	9306	11114	9598	10847.5	9452	10847.5
8111	7252	8317	7271	8027	7043	8153	7058	8111	7252	8317	7271	8111	7252	8111
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1 – Four Sample CHF Calculations

(The inputs, P, G, and X, are in columns D, E, and F. The output, CHF, is in column C. The other columns are for internal calculations.)

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