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Washington University ChE433 heat exchanger experiment        E0002 P  2
Young model F302DY4P                                             9/23/ 3
                                                                 CASE  1
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .100                 .200
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0      86.7*      70.0      96.6*
DENSITY            LB/FT3         61.2913   62.0604    62.2515   61.9363
VISCOSITY          CP               .4726     .8006      .9783     .7175
SPECIFIC HEAT      BTU/LB-F         .9973     .9997     1.0015     .9989
THERMAL COND.      BTU/HR-FT-F      .3723     .3599      .3554     .3624
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         113.4      99.8       83.3      99.3
VISCOSITY, AVG & SKIN  CP           .6035     .6933      .8329     .6969
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     188.19               133.27
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .005317
EFF TEMP DIF, DEGF  (LMTD= 28.0,F= .40,BYPASS= .92,BAFF=1.00)       10.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              71.96
CLEAN & FOULED COEFF     BTU/HR-FT2-F           72.90              71.77

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P  3
Young model F302DY4P                                             9/23/ 3
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                                                            CASE  1
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       5.6     4.0    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG        89.    261.    CROSSFLOW COEF   BTU/HR-FT2-F  134.2
RYNLD NO, IN BUN     76.    333.    WINDOW COEF      BTU/HR-FT2-F  132.8
RYNLD NO,OUT BUN    103.    197.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           80.08
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.57
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.27
 53.25  45.15    1.56     .05       BUNDLE TO SHELL BYPASS    C =  11.29
PCT OVER DESIGN             -.27    BAFFLE TO SHELL LEAKAGE   E =  17.87
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000037
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .997

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.8
HT OPP  NOZ  IN.       .25          END ZONE                    =    7.3
VELOCITY     FT/S      .16    .16   CROSS FLOW                  =    5.6
DENSITY    LB/FT3   62.252 61.936   INLET NOZZLE                =   39.4
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   37.9
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.060   WET                      =      165.
PRESS. DROP  %         2.3    1.5
Washington University ChE433 heat exchanger experiment        E0002 P  4
Young model F302DY4P                                            9/23/ 3
                                                               CASE  2
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                    Shell
                                      SENSIBLE LIQ            SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .100                    .300
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0      81.5*      70.0       89.4*
DENSITY            LB/FT3         61.2913   62.1221    62.2515   62.0270
VISCOSITY          CP               .4726     .8501      .9783     .7763
SPECIFIC HEAT      BTU/LB-F         .9973    1.0002     1.0015     .9995
THERMAL COND.      BTU/HR-FT-F      .3723     .3585      .3554     .3606
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------    ---------------
TEMP, AVG & SKIN       DEGF         110.8      95.4       79.7       94.8
VISCOSITY, AVG & SKIN  CP           .6192     .7270      .8686      .7314
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PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     189.35              161.30
                  --------------------------------------

TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .005834
EFF TEMP DIF, DEGF  (LMTD= 26.4,F= .42,BYPASS= .93,BAFF=1.00)       10.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               78.99
CLEAN & FOULED COEFF     BTU/HR-FT2-F           80.80               79.32

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P  5
Young model F302DY4P                                                9/23/ 3
                                                               CASE  2
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .000   NOMINAL VEL,X-FLOW  FT/S         .04
PRANDTL NUMBER       5.9     4.1   NOMINAL VEL,WINDOW  FT/S         .08
RYNLD NO, AVG       130.    254.   CROSSFLOW COEF   BTU/HR-FT2-F  161.9
RYNLD NO, IN BUN    115.    333.   WINDOW COEF      BTU/HR-FT2-F  162.9
RYNLD NO,OUT BUN    145.    185.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            81.17
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.75
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.74
 48.63  49.60    1.72     .06      BUNDLE TO SHELL BYPASS    C =  11.87
PCT OVER DESIGN              .42   BAFFLE TO SHELL LEAKAGE   E =  16.64
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000053
                                     SHELLSIDE HEAT TRANSFER FACTORS
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  DIAMETRAL CLEARANCES               TOTAL =(BETA)(GAMMA)(FIN)    =   .604
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .657
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN     OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    9.3
HT OPP  NOZ  IN.       .25          END ZONE                     =    5.7
VELOCITY     FT/S      .25    .25   CROSS FLOW                   =    4.6
DENSITY    LB/FT3   62.252 62.027   INLET NOZZLE                 =   40.7
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE                =   39.7
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA       IN     OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                       =      150.
DENSITY    LB/FT3   61.291 62.122   WET                       =      165.
PRESS. DROP  %         2.2    1.4
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Washington University ChE433 heat exchanger experiment        E0002 P  6
Young model F302DY4P                                            9/23/ 3
                                                                CASE  3
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .100                 .400
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0      78.7*      70.0      85.3*
DENSITY            LB/FT3         61.2913   62.1545    62.2515   62.0778
VISCOSITY          CP               .4726     .8788      .9783     .8140
SPECIFIC HEAT      BTU/LB-F         .9973    1.0005     1.0015     .9999
THERMAL COND.      BTU/HR-FT-F      .3723     .3578      .3554     .3595
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         109.4      92.4       77.6      91.8
VISCOSITY, AVG & SKIN  CP           .6279     .7512      .8905     .7563
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     190.50              191.02
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .006114
EFF TEMP DIF, DEGF  (LMTD= 25.1,F= .43,BYPASS= .93,BAFF=1.00)       9.9
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             86.27
CLEAN & FOULED COEFF     BTU/HR-FT2-F          87.91              86.09

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
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SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .000    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       6.0     4.1    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       169.    251.    CROSSFLOW COEF   BTU/HR-FT2-F  191.7
RYNLD NO, IN BUN    154.    333.    WINDOW COEF      BTU/HR-FT2-F  193.0
RYNLD NO,OUT BUN    185.    179.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.31
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.01
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  67.62
 44.57  53.50    1.87     .06       BUNDLE TO SHELL BYPASS    C =  13.08
PCT OVER DESIGN             -.21    BAFFLE TO SHELL LEAKAGE   E =  16.29
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000024
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .624
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .679
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    9.0
HT OPP  NOZ  IN.       .25          END ZONE                     =    5.0
VELOCITY     FT/S      .33    .33   CROSS FLOW                   =    4.2
DENSITY    LB/FT3   62.252 62.078   INLET NOZZLE                 =   41.3
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE                =   40.5
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                       =      150.
DENSITY    LB/FT3   61.291 62.154   WET                       =      165.
PRESS. DROP  %         2.2    1.4
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Young model F302DY4P                                            9/23/ 3
                                                                CASE  4
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .100                 .500
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0      77.0*      70.0      82.6*
DENSITY            LB/FT3         61.2913   62.1741    62.2515   62.1101
VISCOSITY          CP               .4726     .8971      .9783     .8400
SPECIFIC HEAT      BTU/LB-F         .9973    1.0007     1.0015    1.0001
THERMAL COND.      BTU/HR-FT-F      .3723     .3573      .3554     .3588
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         108.5      90.3       76.3      89.6
VISCOSITY, AVG & SKIN  CP           .6334     .7693      .9053     .7750
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     191.41               219.39
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .006285
EFF TEMP DIF, DEGF  (LMTD= 24.0,F= .43,BYPASS= .93,BAFF=1.00)       9.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             91.90
CLEAN & FOULED COEFF     BTU/HR-FT2-F           93.73             91.61

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000    NOMINAL VEL,X-FLOW  FT/S          .07
PRANDTL NUMBER       6.1     4.2    NOMINAL VEL,WINDOW  FT/S          .13
RYNLD NO, AVG       208.    249.    CROSSFLOW COEF   BTU/HR-FT2-F  220.2
RYNLD NO, IN BUN    192.    333.    WINDOW COEF      BTU/HR-FT2-F  221.8
RYNLD NO,OUT BUN    224.    176.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.22
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.67
 41.29  56.66    1.99     .07       BUNDLE TO SHELL BYPASS    C =  14.10
PCT OVER DESIGN             -.32    BAFFLE TO SHELL LEAKAGE   E =  16.00
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000034
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .645
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .701
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    4.5
VELOCITY     FT/S      .41    .41   CROSS FLOW                  =    3.9
DENSITY    LB/FT3   62.252 62.110   INLET NOZZLE                =   41.7
NOZZ RHO*VSQ LB/FT-S2   10     10   OUTLET NOZZLE               =   41.1
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.174   WET                      =      165.
PRESS. DROP  %         2.2    1.4
Washington University ChE433 heat exchanger experiment        E0002 P 10
Young model F302DY4P                                            9/23/ 3
                                                                CASE  5
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .100                 .600
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0     75.9*      70.0      80.7*
DENSITY            LB/FT3         61.2913   62.1872   62.2515   62.1324
VISCOSITY          CP               .4726     .9098     .9783     .8590
SPECIFIC HEAT      BTU/LB-F         .9973    1.0008    1.0015    1.0003
THERMAL COND.      BTU/HR-FT-F      .3723     .3570     .3554     .3583
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         107.9      88.6      75.3      87.9
VISCOSITY, AVG & SKIN  CP           .6371     .7837     .9158     .7900
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00
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PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      192.16              246.83
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .006402
EFF TEMP DIF, DEGF  (LMTD= 23.1,F= .43,BYPASS= .93,BAFF=1.00)       9.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              96.62
CLEAN & FOULED COEFF     BTU/HR-FT2-F            98.64             96.24

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 11
Young model F302DY4P                                                9/23/ 3
                                                                  CASE  5
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       6.2     4.2    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       247.    247.    CROSSFLOW COEF   BTU/HR-FT2-F  247.8
RYNLD NO, IN BUN    231.    333.    WINDOW COEF      BTU/HR-FT2-F  249.5
RYNLD NO,OUT BUN    263.    173.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.43
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.74
 38.55  59.29    2.09     .07       BUNDLE TO SHELL BYPASS    C =  15.01
PCT OVER DESIGN             -.40    BAFFLE TO SHELL LEAKAGE   E =  15.82
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000042
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .665
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BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .723
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    4.1
VELOCITY     FT/S      .49    .49   CROSS FLOW                  =    3.6
DENSITY    LB/FT3   62.252 62.132   INLET NOZZLE                =   42.0
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE               =   41.4
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.187   WET                      =      165.
PRESS. DROP  %         2.1    1.3
Washington University ChE433 heat exchanger experiment        E0002 P 12
Young model F302DY4P                                            9/23/ 3
                                                                CASE  6
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                  Shell
                                    SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .100                  .700
                                    IN       OUT         IN       OUT
TEMPERATURE        DEGF           140.0      75.0*      70.0      79.3*
DENSITY            LB/FT3       61.2913   62.1965    62.2515   62.1486
VISCOSITY          CP             .4726     .9191      .9783     .8735
SPECIFIC HEAT      BTU/LB-F       .9973    1.0009     1.0015    1.0005
THERMAL COND.      BTU/HR-FT-F    .3723     .3567      .3554     .3579
MOLAR MASS         LB/LBMOL                 18.02                18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       107.5      87.3       74.6      86.5
VISCOSITY, AVG & SKIN  CP         .6398     .7957      .9237     .8025
PRESSURE, IN & DESIGN  PSIA       50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI   .01     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S  .10     10.00        .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     192.79              274.10
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .006485
EFF TEMP DIF, DEGF  (LMTD= 22.4,F= .43,BYPASS= .93,BAFF=1.00)        9.0
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            100.44
CLEAN & FOULED COEFF     BTU/HR-FT2-F          102.93            100.28

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
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SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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Washington University ChE433 heat exchanger experiment        E0002 P 13
Young model F302DY4P                                            9/23/ 3
                                                                CASE  6
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S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S         .09
PRANDTL NUMBER       6.3     4.2    NOMINAL VEL,WINDOW  FT/S         .18
RYNLD NO, AVG       285.    246.    CROSSFLOW COEF   BTU/HR-FT2-F  275.2
RYNLD NO, IN BUN    269.    333.    WINDOW COEF      BTU/HR-FT2-F  276.9
RYNLD NO,OUT BUN    302.    171.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.61
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.12
 36.17  61.58    2.17     .07       BUNDLE TO SHELL BYPASS    C =  15.59
PCT OVER DESIGN             -.16    BAFFLE TO SHELL LEAKAGE   E =  15.67
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000016
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .686
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .746
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.8
VELOCITY     FT/S      .57    .57   CROSS FLOW                    =    3.4
DENSITY    LB/FT3   62.252 62.149   INLET NOZZLE                  =   42.2
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE                 =   41.7
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                        =      150.
DENSITY    LB/FT3   61.291 62.196   WET                        =      165.
PRESS. DROP  %         2.1    1.3
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Washington University ChE433 heat exchanger experiment        E0002 P 14
Young model F302DY4P                                            9/23/ 3
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                                                                CASE  7
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .100                 .800
                                     IN        OUT         IN        OUT
TEMPERATURE        DEGF            140.0       74.4*      70.0       78.2*
DENSITY            LB/FT3         61.2913   62.2035    62.2515   62.1610
VISCOSITY          CP               .4726     .9262      .9783     .8848
SPECIFIC HEAT      BTU/LB-F         .9973    1.0010     1.0015    1.0006
THERMAL COND.      BTU/HR-FT-F      .3723     .3566      .3554     .3576
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         107.2      86.1       74.1      85.4
VISCOSITY, AVG & SKIN  CP           .6419     .8061      .9298     .8132
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      193.33              301.66
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .006548
EFF TEMP DIF, DEGF  (LMTD= 21.7,F= .44,BYPASS= .93,BAFF=1.00)       8.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            104.05
CLEAN & FOULED COEFF     BTU/HR-FT2-F           106.78           103.89

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 15
Young model F302DY4P                                           9/23/ 3
                                                                CASE  7
S U P P L E M E N T A R Y    R E S U L T S
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  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       6.3     4.2    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       324.    245.    CROSSFLOW COEF   BTU/HR-FT2-F  302.9
RYNLD NO, IN BUN    308.    333.    WINDOW COEF      BTU/HR-FT2-F  304.8
RYNLD NO,OUT BUN    340.    170.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.78
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.81
 34.05  63.62    2.25     .07       BUNDLE TO SHELL BYPASS    C =  15.86
PCT OVER DESIGN             -.16    BAFFLE TO SHELL LEAKAGE   E =  15.56
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000015
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .708
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .770
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    3.6
VELOCITY     FT/S      .65    .66   CROSS FLOW                   =    3.2
DENSITY    LB/FT3   62.252 62.161   INLET NOZZLE                 =   42.3
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE                =   42.0
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15   DRY                       =      150.
DENSITY    LB/FT3   61.291 62.203   WET                       =      165.
PRESS. DROP  %         2.1    1.3
Washington University ChE433 heat exchanger experiment        E0002 P 16
Young model F302DY4P                                           9/23/ 3
                                                               CASE  8
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .100                 .900
                                      IN        OUT        IN        OUT
TEMPERATURE        DEGF             140.0      73.9*     70.0      77.3*
DENSITY            LB/FT3         61.2913   62.2089   62.2515   62.1707
VISCOSITY          CP               .4726     .9318     .9783     .8939
SPECIFIC HEAT      BTU/LB-F         .9973    1.0010    1.0015    1.0007
THERMAL COND.      BTU/HR-FT-F      .3723     .3564     .3554     .3574
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         107.0      85.2      73.7      84.4
VISCOSITY, AVG & SKIN  CP           .6435     .8151     .9347     .8227
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00
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PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .10     10.00        .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      193.81              329.52
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .006597
EFF TEMP DIF, DEGF  (LMTD= 21.2,F= .44,BYPASS= .93,BAFF=1.00)       8.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            107.11
CLEAN & FOULED COEFF     BTU/HR-FT2-F          110.26            107.14

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT   IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 17
Young model F302DY4P                                            9/23/ 3
                                                                CASE  8
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.018    .000    NOMINAL VEL,X-FLOW  FT/S          .12
PRANDTL NUMBER       6.4     4.3    NOMINAL VEL,WINDOW  FT/S          .23
RYNLD NO, AVG       362.    245.    CROSSFLOW COEF   BTU/HR-FT2-F  330.9
RYNLD NO, IN BUN    346.    333.    WINDOW COEF      BTU/HR-FT2-F  332.9
RYNLD NO,OUT BUN    379.    169.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.92
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.54
 32.15  65.45    2.32     .08       BUNDLE TO SHELL BYPASS    C =  16.09
PCT OVER DESIGN               .03   BAFFLE TO SHELL LEAKAGE   E =  15.45
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000003
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .731
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
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TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .795
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25            WINDOW                    =    8.9
HT OPP  NOZ  IN.       .25            END ZONE                  =    3.4
VELOCITY     FT/S      .74    .74    CROSS FLOW                 =    3.1
DENSITY    LB/FT3   62.252 62.171    INLET NOZZLE               =   42.5
NOZZ RHO*VSQ LB/FT-S2   33     33    OUTLET NOZZLE              =   42.1
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .15    .15    DRY                     =      150.
DENSITY    LB/FT3   61.291 62.209    WET                     =      165.
PRESS. DROP  %         2.1    1.3
Washington University ChE433 heat exchanger experiment        E0002 P 18
Young model F302DY4P                                            9/23/ 3
                                                                CASE  9
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .200                 .200
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0    100.0*      70.0     109.9*
DENSITY            LB/FT3         61.2913   61.8909   62.2515   61.7559
VISCOSITY          CP               .4726     .6915     .9783     .6247
SPECIFIC HEAT      BTU/LB-F         .9973     .9987    1.0015     .9981
THERMAL COND.      BTU/HR-FT-F      .3723     .3633     .3554     .3657
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         120.0     106.7      89.9     106.2
VISCOSITY, AVG & SKIN  CP           .5659     .6455     .7719     .6487
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00       .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .20     10.00       .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     195.02             134.15
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .007973
EFF TEMP DIF, DEGF  (LMTD= 30.1,F= .54,BYPASS= .93,BAFF=1.00)      15.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             73.45
CLEAN & FOULED COEFF     BTU/HR-FT2-F           74.34             73.18

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
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SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       5.2     3.7    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG        96.    557.    CROSSFLOW COEF   BTU/HR-FT2-F  134.6
RYNLD NO, IN BUN     76.    667.    WINDOW COEF      BTU/HR-FT2-F  134.8
RYNLD NO,OUT BUN    119.    456.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           80.36
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.60
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.50
 53.94  44.42    1.59     .05       BUNDLE TO SHELL BYPASS    C =  11.34
PCT OVER DESIGN             -.37    BAFFLE TO SHELL LEAKAGE   E =  17.56
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000051
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .996

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                      =    9.6
HT OPP  NOZ  IN.        .25         END ZONE                    =    6.9
VELOCITY     FT/S       .16    .16  CROSS FLOW                  =    5.4
DENSITY    LB/FT3   62.252 61.756   INLET NOZZLE                =   40.1
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   37.9
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S       .30    .29  DRY                      =      150.
DENSITY    LB/FT3   61.291 61.891   WET                      =      165.
PRESS. DROP  %          4.5    2.8
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SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                  Shell
                                     SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .200                  .300
                                     IN       OUT          IN       OUT
TEMPERATURE        DEGF            140.0      92.7*       70.0     101.4*
DENSITY            LB/FT3         61.2913   61.9857    62.2515   61.8722
VISCOSITY          CP               .4726     .7483      .9783     .6813
SPECIFIC HEAT      BTU/LB-F         .9973     .9992     1.0015     .9986
THERMAL COND.      BTU/HR-FT-F      .3723     .3614      .3554     .3636
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN       DEGF         116.4     101.3       85.7     100.7
VISCOSITY, AVG & SKIN  CP           .5860     .6826      .8098     .6866
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .01     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .19     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     195.63               164.73
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .009432
EFF TEMP DIF, DEGF  (LMTD= 30.0,F= .58,BYPASS= .93,BAFF=1.00)       16.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                81.43
CLEAN & FOULED COEFF     BTU/HR-FT2-F           82.99                81.45

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P 21
Young model F302DY4P                                           9/23/ 3
                                                               CASE 10
S U P P L E M E N T A R Y   R E S U L T S
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  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .000   NOMINAL VEL,X-FLOW  FT/S         .04
PRANDTL NUMBER       5.4     3.9   NOMINAL VEL,WINDOW  FT/S         .08
RYNLD NO, AVG       139.    538.   CROSSFLOW COEF   BTU/HR-FT2-F  165.4
RYNLD NO, IN BUN    115.    667.   WINDOW COEF      BTU/HR-FT2-F  166.4
RYNLD NO,OUT BUN    165.    421.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW          81.20
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.81
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.43
 48.89  49.29    1.77     .06      BUNDLE TO SHELL BYPASS    C =  12.19
PCT OVER DESIGN              .02   BAFFLE TO SHELL LEAKAGE   E =  16.56
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000003
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .609
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .662
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    9.2
HT OPP  NOZ  IN.       .25         END ZONE                     =    5.5
VELOCITY     FT/S      .25    .25  CROSS FLOW                   =    4.5
DENSITY    LB/FT3   62.252 61.872  INLET NOZZLE                 =   41.2
NOZZ RHO*VSQ LB/FT-S2    3      3  OUTLET NOZZLE                =   39.6
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.986  WET                       =      165.
PRESS. DROP  %         4.3    2.7
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Washington University ChE433 heat exchanger experiment E0002 P 22
Young model F302DY4P 9/23/ 3
CASE 11

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SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE        COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .200                  .400
                                      IN        OUT        IN        OUT
TEMPERATURE        DEGF             140.0      88.2*      70.0      95.8*
DENSITY            LB/FT3         61.2913   62.0422   62.2515   61.9460
VISCOSITY          CP               .4726     .7872     .9783     .7233
SPECIFIC HEAT      BTU/LB-F         .9973     .9996    1.0015     .9990
THERMAL COND.      BTU/HR-FT-F      .3723     .3603     .3554     .3622
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         114.1      97.5      82.9      96.9
VISCOSITY, AVG & SKIN  CP           .5991     .7105     .8365     .7152
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .02     10.00       .00     10.00
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VELOCITY, CALC & MAX ALLOWED  FT/S    .19     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     196.31               195.02
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .010337
EFF TEMP DIF, DEGF  (LMTD= 29.3,F= .60,BYPASS= .93,BAFF=1.00)      16.4
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             88.16
CLEAN & FOULED COEFF     BTU/HR-FT2-F           90.20             88.30

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 23
Young model F302DY4P                                           9/23/ 3
                                                               CASE 11
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.6     3.9    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       180.    526.    CROSSFLOW COEF   BTU/HR-FT2-F  195.7
RYNLD NO, IN BUN    154.    667.    WINDOW COEF      BTU/HR-FT2-F  197.1
RYNLD NO,OUT BUN    208.    400.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.34
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.07
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  67.32
 44.77  53.25    1.91     .06       BUNDLE TO SHELL BYPASS    C =  13.39
PCT OVER DESIGN              .16    BAFFLE TO SHELL LEAKAGE   E =  16.21
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000018
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .630
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .685
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BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25            WINDOW                      =    9.0
HT OPP  NOZ  IN.       .25            END ZONE                    =    4.9
VELOCITY     FT/S      .33    .33    CROSS FLOW                  =    4.1
DENSITY    LB/FT3   62.252 61.946   INLET NOZZLE                =   41.7
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE               =   40.4
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.042   WET                      =      165.
PRESS. DROP  %         4.2    2.6
Washington University ChE433 heat exchanger experiment        E0002 P 24
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 12
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                  HOT TUBE SIDE       COLD SHELL SIDE
                                   Tube                 Shell
                                   SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR               .200                 .500
                                   IN        OUT         IN        OUT
TEMPERATURE        DEGF          140.0      85.1*      70.0      91.9*
DENSITY            LB/FT3       61.2913   62.0794    62.2515   61.9963
VISCOSITY          CP             .4726     .8152      .9783     .7553
SPECIFIC HEAT      BTU/LB-F       .9973     .9999     1.0015     .9993
THERMAL COND.      BTU/HR-FT-F    .3723     .3595      .3554     .3612
MOLAR MASS         LB/LBMOL                 18.02                18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       112.6      94.7       80.9      94.1
VISCOSITY, AVG & SKIN  CP         .6082     .7322      .8561     .7375
PRESSURE, IN & DESIGN  PSIA       50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .19     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU     .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     196.87              223.83
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .010949
EFF TEMP DIF, DEGF  (LMTD= 28.5,F= .61,BYPASS= .93,BAFF=1.00)      16.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             93.84
CLEAN & FOULED COEFF     BTU/HR-FT2-F          96.07              93.85

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
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BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 25
Young model F302DY4P                                            9/23/ 3
                                                                CASE 12
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S         .07
PRANDTL NUMBER       5.8     4.0    NOMINAL VEL,WINDOW  FT/S         .13
RYNLD NO, AVG       220.    518.    CROSSFLOW COEF   BTU/HR-FT2-F  224.7
RYNLD NO, IN BUN    192.    667.    WINDOW COEF      BTU/HR-FT2-F  226.3
RYNLD NO,OUT BUN    249.    387.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.29
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.38
 41.46  56.44    2.03     .07       BUNDLE TO SHELL BYPASS    C =  14.40
PCT OVER DESIGN               .01   BAFFLE TO SHELL LEAKAGE   E =  15.94
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000001
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .651
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .708
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    4.4
VELOCITY     FT/S      .41    .41   CROSS FLOW                  =    3.8
DENSITY    LB/FT3   62.252 61.996   INLET NOZZLE                =   42.0
NOZZ RHO*VSQ LB/FT-S2   10     10   OUTLET NOZZLE               =   41.0
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.079   WET                      =      165.
PRESS. DROP  %         4.1    2.6
Washington University ChE433 heat exchanger experiment        E0002 P 26
Young model F302DY4P                                            9/23/ 3
                                                                CASE 13
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
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                                  che433b(70).OUT
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                  Shell
                                     SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .200                  .600
                                     IN        OUT         IN        OUT
TEMPERATURE        DEGF            140.0      82.9*      70.0      89.0*
DENSITY            LB/FT3        61.2913   62.1055    62.2515   62.0328
VISCOSITY          CP              .4726     .8362      .9783     .7804
SPECIFIC HEAT      BTU/LB-F        .9973    1.0001     1.0015     .9995
THERMAL COND.      BTU/HR-FT-F     .3723     .3589      .3554     .3605
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN       DEGF        111.5      92.6       79.5      91.9
VISCOSITY, AVG & SKIN  CP          .6149     .7497      .8711     .7556
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .19     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     197.36               251.64
                 --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .011387
EFF TEMP DIF, DEGF  (LMTD= 27.8,F= .62,BYPASS= .93,BAFF=1.00)       16.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              98.52
CLEAN & FOULED COEFF     BTU/HR-FT2-F          101.01              98.50

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.     .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.      .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.      .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 27
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 13
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
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WALL CORRECTION    1.020    .000   NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.9     4.1   NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       259.    513.   CROSSFLOW COEF   BTU/HR-FT2-F  252.6
RYNLD NO, IN BUN    231.    667.   WINDOW COEF      BTU/HR-FT2-F  254.3
RYNLD NO,OUT BUN    289.    377.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.45
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.49
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  65.47
 38.71  59.09    2.14     .07      BUNDLE TO SHELL BYPASS    C =  15.28
PCT OVER DESIGN             -.02   BAFFLE TO SHELL LEAKAGE   E =  15.77
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000002
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .672
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .730
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25         END ZONE                     =    4.0
VELOCITY     FT/S      .49    .49  CROSS FLOW                   =    3.5
DENSITY    LB/FT3   62.252 62.033  INLET NOZZLE                 =   42.2
NOZZ RHO*VSQ LB/FT-S2   14     15  OUTLET NOZZLE                =   41.4
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29  DRY                       =      150.
DENSITY    LB/FT3   61.291 62.106  WET                       =      165.
PRESS. DROP  %         4.1    2.5
Washington University ChE433 heat exchanger experiment        E0002 P 28
Young model F302DY4P                                            9/23/ 3
                                                                CASE 14
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE      COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .200                 .700
                                     IN       OUT         IN       OUT
TEMPERATURE        DEGF            140.0      81.3*      70.0      86.7*
DENSITY            LB/FT3        61.2913   62.1250    62.2515   62.0602
VISCOSITY          CP               .4726     .8526      .9783     .8005
SPECIFIC HEAT      BTU/LB-F         .9973    1.0003     1.0015     .9997
THERMAL COND.      BTU/HR-FT-F      .3723     .3584      .3554     .3599
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                   ---------------    ---------------
TEMP, AVG & SKIN       DEGF        110.6      90.8       78.4      90.1
VISCOSITY, AVG & SKIN  CP           .6200     .7644      .8828     .7708
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .19     10.00        .11     10.00
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FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      197.78               279.43
                 --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .011718
EFF TEMP DIF, DEGF  (LMTD= 27.1,F= .63,BYPASS= .93,BAFF=1.00)       15.9
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              102.85
CLEAN & FOULED COEFF     BTU/HR-FT2-F          105.35              102.58

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 29
Young model F302DY4P                                            9/23/ 3
                                                                CASE 14
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000   NOMINAL VEL,X-FLOW  FT/S          .09
PRANDTL NUMBER       6.0     4.1   NOMINAL VEL,WINDOW  FT/S          .18
RYNLD NO, AVG       298.    508.   CROSSFLOW COEF   BTU/HR-FT2-F  280.5
RYNLD NO, IN BUN    269.    667.   WINDOW COEF      BTU/HR-FT2-F  282.3
RYNLD NO,OUT BUN    329.    370.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            81.44
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.67
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  65.00
 36.30  61.40    2.22     .07      BUNDLE TO SHELL BYPASS    C =  15.70
PCT OVER DESIGN             -.26   BAFFLE TO SHELL LEAKAGE   E =  15.63
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000025
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .694
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .754
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994
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  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    3.8
VELOCITY     FT/S      .57    .57   CROSS FLOW                   =    3.3
DENSITY    LB/FT3   62.252 62.060   INLET NOZZLE                 =   42.4
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE                =   41.7
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29   DRY                       =      150.
DENSITY    LB/FT3   61.291 62.125   WET                       =      165.
PRESS. DROP  %         4.0    2.5
□□Washington University ChE433 heat exchanger experiment        E0002 P 30
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 15
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .200                 .800
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0      80.0*      70.0      85.0*
DENSITY            LB/FT3         61.2913   62.1397    62.2515   62.0816
VISCOSITY          CP               .4726     .8655      .9783     .8170
SPECIFIC HEAT      BTU/LB-F         .9973    1.0004     1.0015     .9999
THERMAL COND.      BTU/HR-FT-F      .3723     .3581      .3554     .3594
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         110.0      89.4       77.5      88.6
VISCOSITY, AVG & SKIN  CP           .6239     .7770      .8923     .7838
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .19     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F      198.18             307.41
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .011971
EFF TEMP DIF, DEGF  (LMTD= 26.4,F= .64,BYPASS= .93,BAFF=1.00)       15.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                          106.14
CLEAN & FOULED COEFF     BTU/HR-FT2-F          109.23          106.22

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
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PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 31
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 15
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.018    .000    NOMINAL VEL,X-FLOW  FT/S         .10
PRANDTL NUMBER       6.0     4.1    NOMINAL VEL,WINDOW  FT/S         .20
RYNLD NO, AVG       337.    505.    CROSSFLOW COEF   BTU/HR-FT2-F  308.6
RYNLD NO, IN BUN    308.    667.    WINDOW COEF      BTU/HR-FT2-F  310.6
RYNLD NO,OUT BUN    368.    364.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.83
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.70
 34.17  63.45    2.30     .08       BUNDLE TO SHELL BYPASS    C =  15.95
PCT OVER DESIGN               .08   BAFFLE TO SHELL LEAKAGE   E =  15.52
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000007
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .716
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .779
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.5
VELOCITY     FT/S      .65    .66   CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 62.082   INLET NOZZLE                =   42.5
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE               =   41.9
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.140   WET                      =      165.
PRESS. DROP  %         4.0    2.5
□□Washington University ChE433 heat exchanger experiment        E0002 P 32
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 16
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
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                                   Tube                 Shell
                                   SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR               .200                 .900
                                   IN       OUT         IN       OUT
TEMPERATURE        DEGF          140.0     79.0*      70.0     83.5*
DENSITY            LB/FT3       61.2913  62.1515   62.2515  62.0988
VISCOSITY          CP             .4726    .8760     .9783    .8307
SPECIFIC HEAT      BTU/LB-F       .9973   1.0005    1.0015   1.0000
THERMAL COND.      BTU/HR-FT-F    .3723    .3578     .3554    .3590
MOLAR MASS         LB/LBMOL                18.02               18.02
                                 ---------------    ---------------
TEMP, AVG & SKIN       DEGF      109.5      88.1      76.8      87.3
VISCOSITY, AVG & SKIN  CP         .6271    .7880     .9000    .7952
PRESSURE, IN & DESIGN  PSIA      50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .02     10.00       .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .19     10.00       .14     10.00

FOUILNG RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     198.52              335.71
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .012175
EFF TEMP DIF, DEGF  (LMTD= 25.9,F= .64,BYPASS= .93,BAFF=1.00)      15.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            109.36
CLEAN & FOULED COEFF     BTU/HR-FT2-F          112.73            109.49

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.017    .000    NOMINAL VEL,X-FLOW  FT/S          .12
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PRANDTL NUMBER       6.1     4.1    NOMINAL VEL,WINDOW  FT/S         .23
RYNLD NO, AVG       376.    503.    CROSSFLOW COEF   BTU/HR-FT2-F  337.1
RYNLD NO, IN BUN    346.    667.    WINDOW COEF      BTU/HR-FT2-F  339.1
RYNLD NO,OUT BUN    408.    360.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.97
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.45
 32.25  65.30    2.37     .08       BUNDLE TO SHELL BYPASS    C =  16.17
PCT OVER DESIGN               .12   BAFFLE TO SHELL LEAKAGE   E =  15.41
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000011
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .740
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .804
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.4
VELOCITY     FT/S      .74    .74   CROSS FLOW                    =    3.1
DENSITY    LB/FT3   62.252 62.099   INLET NOZZLE                  =   42.6
NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE                 =   42.1
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .30    .29   DRY                        =      150.
DENSITY    LB/FT3   61.291 62.151   WET                        =      165.
PRESS. DROP  %         3.9    2.5
Washington University ChE433 heat exchanger experiment        E0002 P 34
Young model F302DY4P                                            9/23/ 3
                                                                CASE 17
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE     KLB/HR                 .300                 .200
                                      IN       OUT         IN       OUT
TEMPERATURE         DEGF            140.0     108.9*      70.0     116.6*
DENSITY             LB/FT3        61.2913   61.7703    62.2515   61.6588
VISCOSITY           CP              .4726     .6312      .9783     .5846
SPECIFIC HEAT       BTU/LB-F        .9973     .9981     1.0015     .9977
THERMAL COND.       BTU/HR-FT-F     .3723     .3654      .3554     .3672
MOLAR MASS          LB/LBMOL                  18.02                18.02
                                    ---------------    ---------------
TEMP, AVG & SKIN        DEGF        124.4     110.8       93.3     110.3
VISCOSITY, AVG & SKIN  CP           .5429     .6190      .7436     .6222
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .02     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29     10.00        .03     10.00
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FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      201.10               134.76
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .009316
EFF TEMP DIF, DEGF  (LMTD= 30.5,F= .62,BYPASS= .92,BAFF=1.00)       17.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              74.64
CLEAN & FOULED COEFF     BTU/HR-FT2-F            75.55             74.36

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH           IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM    IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM     IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 35
Young model F302DY4P                                            9/23/ 3
                                                                CASE 17
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       5.0     3.6    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG       100.    871.    CROSSFLOW COEF   BTU/HR-FT2-F  135.1
RYNLD NO, IN BUN     76.   1000.    WINDOW COEF      BTU/HR-FT2-F  136.0
RYNLD NO,OUT BUN    127.    749.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             80.51
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.61
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.64
 54.56  43.78    1.61     .05       BUNDLE TO SHELL BYPASS    C =  11.35
PCT OVER DESIGN             -.38    BAFFLE TO SHELL LEAKAGE   E =  17.40
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000051
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .995
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  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    9.6
HT OPP  NOZ  IN.       .25          END ZONE                      =    6.7
VELOCITY     FT/S      .16    .17   CROSS FLOW                    =    5.3
DENSITY    LB/FT3   62.252 61.659   INLET NOZZLE                  =   40.5
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE                 =   38.0
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.770   WET                        =      165.
PRESS. DROP  %         6.3    4.0
Washington University ChE433 heat exchanger experiment        E0002 P 36
Young model F302DY4P                                            9/23/ 3
                                                                CASE 18
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .300                 .300
                                     IN       OUT         IN       OUT
TEMPERATURE        DEGF            140.0     101.4*      70.0     108.5*
DENSITY            LB/FT3        61.2913   61.8722    62.2515   61.7756
VISCOSITY          CP              .4726     .6813      .9783     .6336
SPECIFIC HEAT      BTU/LB-F        .9973     .9986     1.0015     .9981
THERMAL COND.      BTU/HR-FT-F     .3723     .3636      .3554     .3653
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN       DEGF        120.7     105.3       89.2     104.8
VISCOSITY, AVG & SKIN  CP          .5621     .6542      .7780     .6582
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .02     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .29     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     201.64             166.93
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .011540
EFF TEMP DIF, DEGF  (LMTD= 31.5,F= .66,BYPASS= .93,BAFF=1.00)     19.4
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             83.38
CLEAN & FOULED COEFF     BTU/HR-FT2-F          84.81              83.20

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0
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TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT   IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 37
Young model F302DY4P                                           9/23/ 3
                                                               CASE 18
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .000    NOMINAL VEL,X-FLOW  FT/S          .04
PRANDTL NUMBER       5.2     3.7    NOMINAL VEL,WINDOW  FT/S          .08
RYNLD NO, AVG       145.    841.    CROSSFLOW COEF   BTU/HR-FT2-F  167.6
RYNLD NO, IN BUN    115.   1000.    WINDOW COEF      BTU/HR-FT2-F  168.7
RYNLD NO,OUT BUN    178.    694.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.22
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.85
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.28
 49.29  48.85    1.80     .06       BUNDLE TO SHELL BYPASS    C =  12.37
PCT OVER DESIGN             -.21    BAFFLE TO SHELL LEAKAGE   E =  16.50
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              -.000025
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .612
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .665
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.1
HT OPP  NOZ  IN.       .25          END ZONE                    =    5.4
VELOCITY     FT/S      .25    .25   CROSS FLOW                  =    4.4
DENSITY    LB/FT3   62.252 61.776   INLET NOZZLE                =   41.5
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE               =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.872   WET                      =      165.
PRESS. DROP  %         6.1    3.8
Washington University ChE433 heat exchanger experiment        E0002 P 38
Young model F302DY4P                                           9/23/ 3
                                                               CASE 19
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
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                                          SENSIBLE LIQ        SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                     .300                .400
                                           IN       OUT        IN       OUT
TEMPERATURE        DEGF                  140.0     96.4*      70.0    102.6*
DENSITY            LB/FT3              61.2913  61.9383   62.2515  61.8565
VISCOSITY          CP                    .4726    .7187     .9783    .6730
SPECIFIC HEAT      BTU/LB-F              .9973    .9989    1.0015    .9985
THERMAL COND.      BTU/HR-FT-F           .3723    .3624     .3554    .3639
MOLAR MASS         LB/LBMOL                       18.02              18.02
                                         ---------------    ---------------
TEMP, AVG & SKIN       DEGF              118.2    101.3      86.3    100.7
VISCOSITY, AVG & SKIN  CP                .5757    .6820     .8044    .6867
PRESSURE, IN & DESIGN  PSIA              50.00   165.00     50.00   165.00

PRESSURE DROP, TOT & ALLOWED  PSI          .02    10.00       .00    10.00
VELOCITY, CALC & MAX ALLOWED  FT/S         .29    10.00       .06    10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     202.15              197.80
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                  .013040
EFF TEMP DIF, DEGF  (LMTD= 31.6,F= .68,BYPASS= .94,BAFF=1.00)        20.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                 90.72
CLEAN & FOULED COEFF     BTU/HR-FT2-F           92.24                 90.26

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH           IN.          .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM    IN.           .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM     IN.           .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 39
Young model F302DY4P                                           9/23/ 3
                                                               CASE 19
S U P P L E M E N T A R Y    R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.4     3.8    NOMINAL VEL,WINDOW  FT/S          .10
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RYNLD NO, AVG       187.    821.    CROSSFLOW COEF   BTU/HR-FT2-F  198.5
RYNLD NO, IN BUN    154.   1000.    WINDOW COEF      BTU/HR-FT2-F  199.9
RYNLD NO,OUT BUN    223.    658.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.36
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.11
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  67.16
 45.12  52.86    1.96     .06       BUNDLE TO SHELL BYPASS    C =  13.58
PCT OVER DESIGN             -.51    BAFFLE TO SHELL LEAKAGE   E =  16.15
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000056
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .634
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .689
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                       =    9.0
HT OPP  NOZ  IN.        .25         END ZONE                     =    4.8
VELOCITY     FT/S       .33    .33  CROSS FLOW                   =    4.0
DENSITY    LB/FT3   62.252 61.857   INLET NOZZLE                 =   41.9
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE                =   40.4
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S       .44    .44  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.938   WET                       =      165.
PRESS. DROP  %          5.9    3.7
Washington University ChE433 heat exchanger experiment       E0002 P 40
Young model F302DY4P                                            9/23/ 3
                                                                CASE 20
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .300                 .500
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0      92.9*      70.0       98.2*
DENSITY            LB/FT3          61.2913   61.9836    62.2515   61.9152
VISCOSITY          CP               .4726     .7470      .9783     .7052
SPECIFIC HEAT      BTU/LB-F         .9973     .9992     1.0015     .9988
THERMAL COND.      BTU/HR-FT-F      .3723     .3615      .3554     .3628
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         116.4      98.3       84.1      97.6
VISCOSITY, AVG & SKIN  CP           .5856     .7043      .8251     .7096
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
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FILM COEFFICIENT       BTU/HR-FT2-F      202.59              227.06
                  ------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .014099
EFF TEMP DIF, DEGF  (LMTD= 31.4,F= .70,BYPASS= .94,BAFF=1.00)       20.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               95.98
CLEAN & FOULED COEFF     BTU/HR-FT2-F            98.25              95.95

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 41
Young model F302DY4P                                            9/23/ 3
                                                                CASE 20
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S          .07
PRANDTL NUMBER       5.6     3.9    NOMINAL VEL,WINDOW  FT/S          .13
RYNLD NO, AVG       228.    807.    CROSSFLOW COEF   BTU/HR-FT2-F  227.9
RYNLD NO, IN BUN    192.   1000.    WINDOW COEF      BTU/HR-FT2-F  229.5
RYNLD NO,OUT BUN    267.    633.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.33
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.19
 41.78  56.07    2.08     .07       BUNDLE TO SHELL BYPASS    C =  14.58
PCT OVER DESIGN             -.03    BAFFLE TO SHELL LEAKAGE   E =  15.90
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000003
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .655
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .712
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
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HT UNDR NOZ  IN.       .25         WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25         END ZONE                    =    4.3
VELOCITY     FT/S      .41    .41  CROSS FLOW                  =    3.7
DENSITY    LB/FT3   62.252 61.915  INLET NOZZLE                =   42.2
NOZZ RHO*VSQ LB/FT-S2   10     10  OUTLET NOZZLE               =   40.9
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA      IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44  DRY                      =      150.
DENSITY    LB/FT3   61.291 61.984  WET                      =      165.
PRESS. DROP  %         5.8    3.7
Washington University ChE433 heat exchanger experiment        E0002 P 42
Young model F302DY4P                                              9/23/ 3
                                                                  CASE 21
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .300                 .600
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0      90.3*      70.0      94.8*
DENSITY            LB/FT3         61.2913   62.0168    62.2515   61.9592
VISCOSITY          CP               .4726     .7692      .9783     .7314
SPECIFIC HEAT      BTU/LB-F         .9973     .9994     1.0015     .9990
THERMAL COND.      BTU/HR-FT-F      .3723     .3608      .3554     .3620
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------      ---------------
TEMP, AVG & SKIN       DEGF         115.1      95.9       82.4      95.2
VISCOSITY, AVG & SKIN  CP           .5931     .7228      .8415     .7287
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .02     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      202.96              255.30
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .014891
EFF TEMP DIF, DEGF  (LMTD= 31.1,F= .71,BYPASS= .94,BAFF=1.00)      20.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                           100.31
CLEAN & FOULED COEFF     BTU/HR-FT2-F          103.31           100.70

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0
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TUBE TYPE                  PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL            76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT     1.500   TUBE PITCH             IN.      .3125
TUBE LGTH, EFF      FT     1.436   TUBE OUTSIDE DIAM      IN.       .250
TUBE LAYOUT         DEG       60   TUBE INSIDE DIAM       IN.       .214
PITCH RATIO                1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0    1.0   TUBE NOZZ ID, IN&OUT   IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.7     3.9    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       268.    797.    CROSSFLOW COEF   BTU/HR-FT2-F  256.3
RYNLD NO, IN BUN    231.   1000.    WINDOW COEF      BTU/HR-FT2-F  258.0
RYNLD NO,OUT BUN    309.    615.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.46
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.53
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.28
 39.00  58.74    2.18     .07       BUNDLE TO SHELL BYPASS    C =  15.46
PCT OVER DESIGN               .40   BAFFLE TO SHELL LEAKAGE   E =  15.72
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000039
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .677
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .736
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                         =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                       =    3.9
VELOCITY     FT/S      .49    .49   CROSS FLOW                     =    3.4
DENSITY    LB/FT3   62.252 61.959   INLET NOZZLE                   =   42.4
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE                  =   41.3
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44   DRY                         =      150.
DENSITY    LB/FT3   61.291 62.017   WET                         =      165.
PRESS. DROP  %         5.8    3.6
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SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
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TOTAL FLOW RATE    KLB/HR                .300                .700
                                   IN       OUT        IN       OUT
TEMPERATURE        DEGF          140.0     88.1*      70.0      92.2*
DENSITY            LB/FT3       61.2913  62.0433   62.2515   61.9927
VISCOSITY          CP             .4726    .7880     .9783     .7529
SPECIFIC HEAT      BTU/LB-F       .9973    .9996    1.0015     .9993
THERMAL COND.      BTU/HR-FT-F    .3723    .3602     .3554     .3613
MOLAR MASS         LB/LBMOL                18.02               18.02
                                ---------------   ---------------
TEMP, AVG & SKIN       DEGF      114.1      93.9      81.1      93.1
VISCOSITY, AVG & SKIN  CP         .5994    .7387     .8546     .7450
PRESSURE, IN & DESIGN  PSIA       50.00   165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03    10.00       .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29    10.00       .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F      203.25             283.64
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .015532
EFF TEMP DIF, DEGF  (LMTD= 30.6,F= .72,BYPASS= .94,BAFF=1.00)       20.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                         104.93
CLEAN & FOULED COEFF     BTU/HR-FT2-F          107.75         104.88

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 45
Young model F302DY4P                                            9/23/ 3
                                                                CASE 22
S U P P L E M E N T A R Y    R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .09
PRANDTL NUMBER       5.8     3.9    NOMINAL VEL,WINDOW  FT/S          .18
RYNLD NO, AVG       308.    789.    CROSSFLOW COEF   BTU/HR-FT2-F  284.8
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RYNLD NO, IN BUN    269.   1000.    WINDOW COEF      BTU/HR-FT2-F  286.6
RYNLD NO,OUT BUN    350.    600.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.71
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.93
 36.56  61.09    2.27     .08       BUNDLE TO SHELL BYPASS    C =  15.76
PCT OVER DESIGN             -.05    BAFFLE TO SHELL LEAKAGE   E =  15.60
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000005
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .699
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .760
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.7
VELOCITY     FT/S      .57    .58   CROSS FLOW                  =    3.3
DENSITY    LB/FT3   62.252 61.993   INLET NOZZLE                =   42.6
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE               =   41.6
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.043   WET                      =      165.
PRESS. DROP  %         5.7    3.6
Washington University ChE433 heat exchanger experiment        E0002 P 46
Young model F302DY4P                                            9/23/ 3
                                                                CASE 23
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .300                 .800
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0     86.5*      70.0      90.0*
DENSITY            LB/FT3         61.2913   62.0635   62.2515   62.0196
VISCOSITY          CP               .4726     .8030     .9783     .7712
SPECIFIC HEAT      BTU/LB-F         .9973     .9998    1.0015     .9994
THERMAL COND.      BTU/HR-FT-F      .3723     .3598     .3554     .3607
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         113.2      92.2      80.0      91.4
VISCOSITY, AVG & SKIN  CP           .6043     .7524     .8656     .7592
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03     10.00       .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29     10.00       .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      203.53               312.06
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                    .016030
EFF TEMP DIF, DEGF  (LMTD= 30.2,F= .73,BYPASS= .94,BAFF=1.00)          20.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                 108.35
CLEAN & FOULED COEFF     BTU/HR-FT2-F           111.71                108.59

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2               7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL         7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS             4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.          30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.        .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED            NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %                .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                     36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN          1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8     .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 47
Young model F302DY4P                                            9/23/ 3
                                                                CASE 23
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.9     4.0    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       348.    782.    CROSSFLOW COEF   BTU/HR-FT2-F  313.3
RYNLD NO, IN BUN    308.   1000.    WINDOW COEF      BTU/HR-FT2-F  315.3
RYNLD NO,OUT BUN    390.    589.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.87
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.64
 34.41  63.16    2.35     .08       BUNDLE TO SHELL BYPASS    C =  16.01
PCT OVER DESIGN              .22    BAFFLE TO SHELL LEAKAGE   E =  15.49
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000020
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .723
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .785
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
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HT OPP  NOZ  IN.        .25          END ZONE                      =    3.5
VELOCITY     FT/S       .65    .66   CROSS FLOW                    =    3.1
DENSITY    LB/FT3   62.252 62.020   INLET NOZZLE                  =   42.7
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE                 =   41.8
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S       .44    .44   DRY                        =      150.
DENSITY    LB/FT3   61.291 62.064   WET                        =      165.
PRESS. DROP  %          5.6    3.5
Washington University ChE433 heat exchanger experiment        E0002 P 48
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 24
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                 Shell
                                    SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .300                 .900
                                    IN        OUT        IN        OUT
TEMPERATURE        DEGF            140.0      85.0*      70.0      88.3*
DENSITY            LB/FT3        61.2913   62.0811    62.2515   62.0412
VISCOSITY          CP              .4726     .8165      .9783     .7865
SPECIFIC HEAT      BTU/LB-F        .9973     .9999     1.0015     .9996
THERMAL COND.      BTU/HR-FT-F     .3723     .3594      .3554     .3603
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN       DEGF        112.5      90.8       79.1      90.0
VISCOSITY, AVG & SKIN  CP          .6086     .7646      .8746     .7718
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03     10.00        .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .29     10.00        .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     203.74               340.82
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .016465
EFF TEMP DIF, DEGF  (LMTD= 29.7,F= .74,BYPASS= .94,BAFF=1.00)      20.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            112.18
CLEAN & FOULED COEFF     BTU/HR-FT2-F          115.27            111.91

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
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NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 49
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 24
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.018    .000    NOMINAL VEL,X-FLOW  FT/S         .12
PRANDTL NUMBER       5.9     4.0    NOMINAL VEL,WINDOW  FT/S         .23
RYNLD NO, AVG       387.    777.    CROSSFLOW COEF   BTU/HR-FT2-F  342.2
RYNLD NO, IN BUN    346.   1000.    WINDOW COEF      BTU/HR-FT2-F  344.3
RYNLD NO,OUT BUN    431.    579.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.00
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.41
 32.47  65.03    2.43     .08       BUNDLE TO SHELL BYPASS    C =  16.22
PCT OVER DESIGN             -.24    BAFFLE TO SHELL LEAKAGE   E =  15.38
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000022
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .747
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .811
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    3.3
VELOCITY     FT/S      .74    .74   CROSS FLOW                   =    3.0
DENSITY    LB/FT3   62.252 62.041   INLET NOZZLE                 =   42.8
NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE                =   42.0
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .44    .44   DRY                       =      150.
DENSITY    LB/FT3   61.291 62.081   WET                       =      165.
PRESS. DROP  %         5.6    3.5
□□Washington University ChE433 heat exchanger experiment        E0002 P 50
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 25
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .400                 .200
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                                            IN        OUT          IN        OUT
TEMPERATURE        DEGF                   140.0     114.7*       70.0     120.5*
DENSITY            LB/FT3               61.2913   61.6869    62.2515   61.6008
VISCOSITY          CP                     .4726     .5956      .9783     .5632
SPECIFIC HEAT      BTU/LB-F               .9973     .9978     1.0015     .9976
THERMAL COND.      BTU/HR-FT-F            .3723     .3668      .3554     .3681
MOLAR MASS         LB/LBMOL                         18.02                18.02
                                          ---------------     ---------------
TEMP, AVG & SKIN        DEGF              127.4     113.5       95.3     112.9
VISCOSITY, AVG & SKIN   CP                .5285     .6028      .7279     .6061
PRESSURE, IN & DESIGN   PSIA              50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI           .03     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S          .39     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      206.23               135.28
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                   .010094
EFF TEMP DIF, DEGF  (LMTD= 30.4,F= .68,BYPASS= .91,BAFF=1.00)          18.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                 75.42
CLEAN & FOULED COEFF     BTU/HR-FT2-F           76.55                 75.34

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2               7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL         7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS             4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.          30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.        .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED            NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %                .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                     36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN          1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8     .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 51
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 25
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.026    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       4.9     3.5    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG       102.   1193.    CROSSFLOW COEF   BTU/HR-FT2-F  135.8
RYNLD NO, IN BUN     76.   1334.    WINDOW COEF      BTU/HR-FT2-F  136.7
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RYNLD NO,OUT BUN    132.   1058.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW          80.60
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.62
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.73
 55.06  43.25    1.63     .05       BUNDLE TO SHELL BYPASS    C =  11.34
PCT OVER DESIGN              -.11   BAFFLE TO SHELL LEAKAGE   E =  17.31
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              -.000015
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.5
HT OPP  NOZ  IN.       .25          END ZONE                    =    6.6
VELOCITY     FT/S      .16    .17   CROSS FLOW                  =    5.2
DENSITY    LB/FT3   62.252 61.601   INLET NOZZLE                =   40.6
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   38.0
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .59    .59   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.687   WET                      =      165.
PRESS. DROP  %         7.9    5.0
Washington University ChE433 heat exchanger experiment        E0002 P 52
Young model F302DY4P                                            9/23/ 3
                                                                CASE 26
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .400                  .300
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0     107.8*       70.0     112.9*
DENSITY            LB/FT3         61.2913   61.7853    62.2515   61.7135
VISCOSITY          CP               .4726     .6380      .9783     .6065
SPECIFIC HEAT      BTU/LB-F         .9973     .9982     1.0015     .9979
THERMAL COND.      BTU/HR-FT-F      .3723     .3652      .3554     .3664
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         123.9     108.2       91.4     107.6
VISCOSITY, AVG & SKIN  CP           .5456     .6356      .7592     .6395
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .39     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010                .00010
FILM COEFFICIENT       BTU/HR-FT2-F     206.91                168.37
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .012850
EFF TEMP DIF, DEGF  (LMTD= 32.2,F= .71,BYPASS= .93,BAFF=1.00)       21.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               84.77
CLEAN & FOULED COEFF     BTU/HR-FT2-F           86.26               84.61

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P 53
Young model F302DY4P                                           9/23/ 3
                                                               CASE 26
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .000   NOMINAL VEL,X-FLOW  FT/S          .04
PRANDTL NUMBER       5.1     3.6   NOMINAL VEL,WINDOW  FT/S          .08
RYNLD NO, AVG       148.   1155.   CROSSFLOW COEF   BTU/HR-FT2-F  169.0
RYNLD NO, IN BUN    115.   1334.   WINDOW COEF      BTU/HR-FT2-F  170.1
RYNLD NO,OUT BUN    186.    988.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            81.24
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.88
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.19
 49.69  48.41    1.83     .06      BUNDLE TO SHELL BYPASS    C =  12.47
PCT OVER DESIGN             -.19   BAFFLE TO SHELL LEAKAGE   E =  16.46
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000022
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .614
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .667
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                      =    9.1
HT OPP  NOZ  IN.       .25         END ZONE                    =    5.3
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VELOCITY     FT/S       .25    .25   CROSS FLOW                =    4.4
DENSITY    LB/FT3   62.252 61.714   INLET NOZZLE              =   41.6
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE             =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S       .59    .59   DRY                    =      150.
DENSITY    LB/FT3   61.291 61.785   WET                    =      165.
PRESS. DROP  %          7.6    4.8
Washington University ChE433 heat exchanger experiment        E0002 P 54
Young model F302DY4P                                            9/23/ 3
                                                                CASE 27
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .400                 .400
                                      IN        OUT          IN       OUT
TEMPERATURE        DEGF             140.0     102.9*       70.0     107.1*
DENSITY            LB/FT3         61.2913   61.8529    62.2515   61.7956
VISCOSITY          CP               .4726     .6712      .9783     .6429
SPECIFIC HEAT      BTU/LB-F         .9973     .9985     1.0015     .9982
THERMAL COND.      BTU/HR-FT-F      .3723     .3640      .3554     .3650
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         121.4     104.2       88.5     103.5
VISCOSITY, AVG & SKIN  CP           .5583     .6622      .7843     .6668
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .39     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     207.42              199.74
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .014814
EFF TEMP DIF, DEGF  (LMTD= 32.9,F= .73,BYPASS= .94,BAFF=1.00)      22.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             91.87
CLEAN & FOULED COEFF     BTU/HR-FT2-F            93.93            91.89

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
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TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 55
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 27
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .000    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.3     3.7    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       192.   1129.    CROSSFLOW COEF   BTU/HR-FT2-F  200.5
RYNLD NO, IN BUN    154.   1334.    WINDOW COEF      BTU/HR-FT2-F  201.9
RYNLD NO,OUT BUN    234.    939.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.38
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.14
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  67.06
 45.49  52.45    1.99     .07       BUNDLE TO SHELL BYPASS    C =  13.69
PCT OVER DESIGN              .02    BAFFLE TO SHELL LEAKAGE   E =  16.11
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000002
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .636
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .692
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                        =    8.9
HT OPP  NOZ  IN.        .25         END ZONE                      =    4.7
VELOCITY     FT/S       .33    .33  CROSS FLOW                    =    4.0
DENSITY    LB/FT3   62.252 61.796   INLET NOZZLE                  =   42.1
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE                 =   40.3
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S       .59    .59  DRY                        =      150.
DENSITY    LB/FT3   61.291 61.853   WET                        =      165.
PRESS. DROP  %          7.5    4.7
□□Washington University ChE433 heat exchanger experiment        E0002 P 56
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 28
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .400                  .500
                                      IN       OUT          IN       OUT
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TEMPERATURE        DEGF             140.0      99.2*      70.0     102.5*
DENSITY            LB/FT3          61.2913   61.9015    62.2515   61.8574
VISCOSITY          CP                .4726     .6974      .9783     .6735
SPECIFIC HEAT      BTU/LB-F          .9973     .9987     1.0015     .9985
THERMAL COND.      BTU/HR-FT-F       .3723     .3631      .3554     .3639
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         119.6     101.1       86.3     100.3
VISCOSITY, AVG & SKIN  CP           .5680     .6842      .8047     .6894
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .03     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .39     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      207.82              229.37
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .016266
EFF TEMP DIF, DEGF  (LMTD= 33.2,F= .75,BYPASS= .94,BAFF=1.00)       23.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               97.65
CLEAN & FOULED COEFF     BTU/HR-FT2-F          100.12               97.74

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8     .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 57
Young model F302DY4P                                            9/23/ 3
                                                                CASE 28
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000    NOMINAL VEL,X-FLOW  FT/S          .07
PRANDTL NUMBER       5.4     3.7    NOMINAL VEL,WINDOW  FT/S          .13
RYNLD NO, AVG       234.   1110.    CROSSFLOW COEF   BTU/HR-FT2-F  230.2
RYNLD NO, IN BUN    192.   1334.    WINDOW COEF      BTU/HR-FT2-F  231.8
RYNLD NO,OUT BUN    279.    904.
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FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW          81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.37
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.04
 42.13  55.68    2.12     .07       BUNDLE TO SHELL BYPASS    C =  14.73
PCT OVER DESIGN             .08     BAFFLE TO SHELL LEAKAGE   E =  15.87
TOT FOUL RESIST         .000217     TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             .000009
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .658
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .716
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                       =    8.9
HT OPP  NOZ  IN.        .25         END ZONE                     =    4.2
VELOCITY     FT/S       .41    .41  CROSS FLOW                   =    3.7
DENSITY    LB/FT3   62.252 61.857   INLET NOZZLE                 =   42.4
NOZZ RHO*VSQ LB/FT-S2   10      10  OUTLET NOZZLE                =   40.9
BUND RHO*VSQ LB/FT-S2    7       7

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S       .59    .59  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.902   WET                       =      165.
PRESS. DROP  %          7.4    4.6
Washington University ChE433 heat exchanger experiment        E0002 P 58
Young model F302DY4P                                            9/23/ 3
                                                                CASE 29
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE      COLD SHELL SIDE
                                      Tube                Shell
                                      SENSIBLE LIQ        SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .400                .600
                                      IN        OUT       IN        OUT
TEMPERATURE        DEGF            140.0      96.4*     70.0      99.0*
DENSITY            LB/FT3        61.2913   61.9384   62.2515   61.9049
VISCOSITY          CP              .4726     .7188     .9783     .6993
SPECIFIC HEAT      BTU/LB-F        .9973     .9989    1.0015     .9987
THERMAL COND.      BTU/HR-FT-F     .3723     .3624     .3554     .3630
MOLAR MASS         LB/LBMOL                  18.02               18.02
                                   ---------------    ---------------
TEMP, AVG & SKIN       DEGF        118.2      98.5      84.5      97.8
VISCOSITY, AVG & SKIN  CP          .5757     .7027     .8214     .7086
PRESSURE, IN & DESIGN  PSIA        50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .04     10.00       .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .39     10.00       .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      208.14              258.10
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                          .017390
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EFF TEMP DIF, DEGF  (LMTD= 33.2,F= .76,BYPASS= .94,BAFF=1.00)       23.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               102.45
CLEAN & FOULED COEFF     BTU/HR-FT2-F           105.33              102.64

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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Washington University ChE433 heat exchanger experiment E0002 P 59
Young model F302DY4P 9/23/ 3
CASE 29

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S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.5     3.8    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       275.   1095.    CROSSFLOW COEF   BTU/HR-FT2-F  259.1
RYNLD NO, IN BUN    231.   1334.    WINDOW COEF      BTU/HR-FT2-F  260.8
RYNLD NO,OUT BUN    323.    877.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.46
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.57
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.24
 39.32  58.38    2.23     .07       BUNDLE TO SHELL BYPASS    C =  15.50
PCT OVER DESIGN              .19    BAFFLE TO SHELL LEAKAGE   E =  15.70
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000018
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .680
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .740
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                      =    8.9
HT OPP  NOZ  IN.        .25         END ZONE                    =    3.9
VELOCITY     FT/S       .49    .49  CROSS FLOW                  =    3.4
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DENSITY    LB/FT3   62.252 61.905   INLET NOZZLE                =   42.5
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE               =   41.3
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .59    .58   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.938   WET                      =      165.
PRESS. DROP  %         7.3    4.6
Washington University ChE433 heat exchanger experiment        E0002 P 60
Young model F302DY4P                                            9/23/ 3
                                                                CASE 30
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                  Shell
                                    SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .400                 .700
                                    IN       OUT         IN       OUT
TEMPERATURE        DEGF           140.0      94.1*      70.0      96.2*
DENSITY            LB/FT3       61.2913   61.9687   62.2515   61.9415
VISCOSITY          CP             .4726     .7374     .9783     .7206
SPECIFIC HEAT      BTU/LB-F       .9973     .9991    1.0015     .9989
THERMAL COND.      BTU/HR-FT-F    .3723     .3618     .3554     .3623
MOLAR MASS         LB/LBMOL                 18.02               18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       117.0      96.4      83.1      95.6
VISCOSITY, AVG & SKIN  CP         .5823     .7189     .8348     .7253
PRESSURE, IN & DESIGN  PSIA       50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .04     10.00       .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .39     10.00       .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     208.36             286.88
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .018329
EFF TEMP DIF, DEGF  (LMTD= 33.0,F= .77,BYPASS= .94,BAFF=1.00)       23.9
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             107.51
CLEAN & FOULED COEFF     BTU/HR-FT2-F          109.89             106.92

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
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TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 61
Young model F302DY4P                                           9/23/ 3
                                                               CASE 30
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S         .09
PRANDTL NUMBER       5.6     3.8    NOMINAL VEL,WINDOW  FT/S         .18
RYNLD NO, AVG       315.   1083.    CROSSFLOW COEF   BTU/HR-FT2-F  288.0
RYNLD NO, IN BUN    269.   1334.    WINDOW COEF      BTU/HR-FT2-F  289.8
RYNLD NO,OUT BUN    365.    855.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.74
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.89
 36.85  60.75    2.32     .08       BUNDLE TO SHELL BYPASS    C =  15.79
PCT OVER DESIGN             -.55    BAFFLE TO SHELL LEAKAGE   E =  15.57
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000052
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .704
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .765
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.7
VELOCITY     FT/S      .57    .58   CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 61.942   INLET NOZZLE                =   42.7
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE               =   41.6
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .59    .58   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.969   WET                      =      165.
PRESS. DROP  %         7.2    4.5
Washington University ChE433 heat exchanger experiment        E0002 P 62
Young model F302DY4P                                           9/23/ 3
                                                               CASE 31
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .400                .800
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0      92.3*      70.0      93.8*
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DENSITY            LB/FT3          61.2913   61.9911    62.2515   61.9723
VISCOSITY          CP                .4726     .7519      .9783     .7397
SPECIFIC HEAT      BTU/LB-F          .9973     .9993     1.0015     .9991
THERMAL COND.      BTU/HR-FT-F       .3723     .3613      .3554     .3617
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF          116.2      94.6       81.9      93.8
VISCOSITY, AVG & SKIN  CP            .5873     .7330      .8466     .7399
PRESSURE, IN & DESIGN  PSIA          50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .04     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .39     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     208.64               315.69
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .019035
EFF TEMP DIF, DEGF  (LMTD= 32.8,F= .78,BYPASS= .94,BAFF=1.00)      24.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            110.45
CLEAN & FOULED COEFF     BTU/HR-FT2-F           113.97           110.73

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P 63
Young model F302DY4P                                          9/23/ 3
                                                              CASE 31
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.7     3.9    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       356.   1073.    CROSSFLOW COEF   BTU/HR-FT2-F  317.0
RYNLD NO, IN BUN    308.   1334.    WINDOW COEF      BTU/HR-FT2-F  318.9
RYNLD NO,OUT BUN    407.    838.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
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                                          HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL            TUBE TO BAFFLE LEAKAGE    A =   3.90
 SHELL   TUBE  FOULING  METAL             MAIN CROSSFLOW            B =  64.61
 34.68  62.84    2.40     .08             BUNDLE TO SHELL BYPASS    C =  16.04
PCT OVER DESIGN              .26          BAFFLE TO SHELL LEAKAGE   E =  15.46
TOT FOUL RESIST          .000217          TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000023
                                            SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES                    TOTAL =(BETA)(GAMMA)(FIN)    =   .727
BUNDLE TO SHELL       IN.    .5000        BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE   IN.    .0284        GAMMA (TUBE ROW ENTRY EFCT)  =   .791
BAFFLE TO SHELL       IN.    .1000        END   (HT LOSS IN END ZONE)  =   .994

  SHELL NOZZLE DATA      IN    OUT          SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25               WINDOW                       =    8.9
HT OPP  NOZ  IN.        .25               END ZONE                     =    3.5
VELOCITY     FT/S       .65    .66        CROSS FLOW                   =    3.1
DENSITY    LB/FT3   62.252 61.972         INLET NOZZLE                 =   42.8
NOZZ RHO*VSQ LB/FT-S2   26     26         OUTLET NOZZLE                =   41.8
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA       IN    OUT          WEIGHT PER SHELL, LB
VELOCITY     FT/S       .59    .58        DRY                       =      150.
DENSITY    LB/FT3   61.291 61.991         WET                       =      165.
PRESS. DROP  %          7.1    4.5
Washington University ChE433 heat exchanger experiment        E0002 P 64
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 32
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                           HOT TUBE SIDE       COLD SHELL SIDE
                                            Tube                 Shell
                                            SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                       .400                 .900
                                            IN       OUT         IN       OUT
TEMPERATURE        DEGF                   140.0      90.7*      70.0      91.9*
DENSITY            LB/FT3               61.2913   62.0118    62.2515   61.9966
VISCOSITY          CP                     .4726     .7658      .9783     .7555
SPECIFIC HEAT      BTU/LB-F               .9973     .9994     1.0015     .9993
THERMAL COND.      BTU/HR-FT-F            .3723     .3609      .3554     .3612
MOLAR MASS         LB/LBMOL                         18.02                18.02
                                          ---------------    ---------------
TEMP, AVG & SKIN       DEGF               115.3      93.1       80.9      92.2
VISCOSITY, AVG & SKIN  CP                 .5920     .7456      .8562     .7529
PRESSURE, IN & DESIGN  PSIA               50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI           .04     10.00        .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S          .39     10.00        .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      208.78               344.92
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .019693
EFF TEMP DIF, DEGF  (LMTD= 32.5,F= .79,BYPASS= .95,BAFF=1.00)       24.2
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OVERALL COEFF REQUIRED   BTU/HR-FT2-F                           114.02
CLEAN & FOULED COEFF     BTU/HR-FT2-F          117.62           114.14

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2          7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL    7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS        4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.     30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.   .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED       NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN     1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment       E0002 P 65
Young model F302DY4P                                            9/23/ 3
                                                                CASE 32
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.018    .000   NOMINAL VEL,X-FLOW  FT/S        .12
PRANDTL NUMBER       5.8     3.9   NOMINAL VEL,WINDOW  FT/S        .23
RYNLD NO, AVG       395.   1065.   CROSSFLOW COEF   BTU/HR-FT2-F  346.3
RYNLD NO, IN BUN    346.   1334.   WINDOW COEF      BTU/HR-FT2-F  348.4
RYNLD NO,OUT BUN    448.    823.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW          81.43
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   4.03
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  64.41
 32.72  64.72    2.47     .08      BUNDLE TO SHELL BYPASS    C =  16.21
PCT OVER DESIGN              .10   BAFFLE TO SHELL LEAKAGE   E =  15.35
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000009
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .752
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .817
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25         END ZONE                    =    3.3
VELOCITY     FT/S      .74    .74  CROSS FLOW                  =    3.0
DENSITY    LB/FT3   62.252 61.997  INLET NOZZLE                =   42.9
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NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE              =   42.0
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .59    .58   DRY                      =      150.
DENSITY    LB/FT3   61.291 62.012   WET                      =      165.
PRESS. DROP  %         7.0    4.4
Washington University ChE433 heat exchanger experiment        E0002 P 66
Young model F302DY4P                                            9/23/ 3
                                                                CASE 33
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                  .200
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0     118.7*       70.0     123.0*
DENSITY            LB/FT3         61.2913   61.6273    62.2515   61.5625
VISCOSITY          CP               .4726     .5728      .9783     .5500
SPECIFIC HEAT      BTU/LB-F         .9973     .9977     1.0015     .9975
THERMAL COND.      BTU/HR-FT-F      .3723     .3677      .3554     .3687
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         129.4     115.3       96.5     114.7
VISCOSITY, AVG & SKIN  CP           .5189     .5921      .7180     .5953
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010                .00010
FILM COEFFICIENT       BTU/HR-FT2-F      210.68                135.78
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .010598
EFF TEMP DIF, DEGF  (LMTD= 30.1,F= .71,BYPASS= .91,BAFF=1.00)       19.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              76.25
CLEAN & FOULED COEFF     BTU/HR-FT2-F           77.42              76.19

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
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TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 67
Young model F302DY4P                                           9/23/ 3
                                                              CASE 33
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.027    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       4.8     3.4    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG       104.   1518.    CROSSFLOW COEF   BTU/HR-FT2-F  136.3
RYNLD NO, IN BUN     76.   1667.    WINDOW COEF      BTU/HR-FT2-F  137.2
RYNLD NO,OUT BUN    136.   1376.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           80.66
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.62
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.79
 55.48  42.81    1.65     .05       BUNDLE TO SHELL BYPASS    C =  11.34
PCT OVER DESIGN             -.08    BAFFLE TO SHELL LEAKAGE   E =  17.25
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000011
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.5
HT OPP  NOZ  IN.       .25          END ZONE                    =    6.6
VELOCITY     FT/S      .16    .17   CROSS FLOW                  =    5.1
DENSITY    LB/FT3   62.252 61.562   INLET NOZZLE                =   40.8
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   38.0
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.627   WET                      =      165.
PRESS. DROP  %         8.6    5.4
Washington University ChE433 heat exchanger experiment        E0002 P 68
Young model F302DY4P                                           9/23/ 3
                                                              CASE 34
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                 .300
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0     112.5*      70.0     115.8*
DENSITY            LB/FT3         61.2913   61.7191    62.2515   61.6708
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VISCOSITY          CP                    .4726     .6088      .9783     .5893
SPECIFIC HEAT      BTU/LB-F              .9973     .9979     1.0015     .9978
THERMAL COND.      BTU/HR-FT-F           .3723     .3663      .3554     .3670
MOLAR MASS         LB/LBMOL                        18.02                18.02
                                        ---------------     ---------------
TEMP, AVG & SKIN       DEGF             126.2     110.2       92.9     109.6
VISCOSITY, AVG & SKIN  CP               .5339     .6226      .7469     .6266
PRESSURE, IN & DESIGN  PSIA             50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI        .05     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S       .49     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     211.51               169.39
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .013729
EFF TEMP DIF, DEGF  (LMTD= 32.5,F= .75,BYPASS= .93,BAFF=1.00)       22.4
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              85.72
CLEAN & FOULED COEFF     BTU/HR-FT2-F           87.46              85.77

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 69
Young model F302DY4P                                            9/23/ 3
                                                                CASE 34
S U P P L E M E N T A R Y    R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .000    NOMINAL VEL,X-FLOW  FT/S          .04
PRANDTL NUMBER       5.0     3.5    NOMINAL VEL,WINDOW  FT/S          .08
RYNLD NO, AVG       151.   1476.    CROSSFLOW COEF   BTU/HR-FT2-F  170.0
RYNLD NO, IN BUN    115.   1667.    WINDOW COEF      BTU/HR-FT2-F  171.1
RYNLD NO,OUT BUN    191.   1294.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.26
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THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE     A =   2.90
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW             B =  68.14
 50.07  48.01    1.86     .06       BUNDLE TO SHELL BYPASS     C =  12.53
PCT OVER DESIGN              .06    BAFFLE TO SHELL LEAKAGE    E =  16.43
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS       F =    .00
DIFF RESIST              .000007
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .615
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .669
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    9.1
HT OPP  NOZ  IN.       .25          END ZONE                     =    5.3
VELOCITY     FT/S      .25    .25   CROSS FLOW                   =    4.4
DENSITY    LB/FT3   62.252 61.671   INLET NOZZLE                 =   41.8
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE                =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.719   WET                        =      165.
PRESS. DROP  %         8.5    5.4
Washington University ChE433 heat exchanger experiment        E0002 P 70
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 35
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                 .400
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0    107.8*       70.0     110.2*
DENSITY            LB/FT3         61.2913  61.7855    62.2515   61.7515
VISCOSITY          CP               .4726    .6381      .9783     .6228
SPECIFIC HEAT      BTU/LB-F         .9973    .9982     1.0015     .9980
THERMAL COND.      BTU/HR-FT-F      .3723    .3652      .3554     .3657
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         123.9    106.3       90.1     105.6
VISCOSITY, AVG & SKIN  CP           .5456    .6479      .7706     .6526
PRESSURE, IN & DESIGN  PSIA         50.00   165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05    10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49    10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      212.05              201.16
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .016069
EFF TEMP DIF, DEGF  (LMTD= 33.6,F= .76,BYPASS= .93,BAFF=1.00)     24.0
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            93.59
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CLEAN & FOULED COEFF     BTU/HR-FT2-F            95.35            93.26

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT   IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 71
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 35
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .000   NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.2     3.6   NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       195.   1444.   CROSSFLOW COEF   BTU/HR-FT2-F  201.9
RYNLD NO, IN BUN    154.   1667.   WINDOW COEF      BTU/HR-FT2-F  203.3
RYNLD NO,OUT BUN    242.   1235.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            81.40
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.16
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  67.00
 45.84  52.07    2.02     .07      BUNDLE TO SHELL BYPASS    C =  13.76
PCT OVER DESIGN             -.35   BAFFLE TO SHELL LEAKAGE   E =  16.08
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000038
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .638
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .694
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25        WINDOW                      =    8.9
HT OPP  NOZ  IN.        .25        END ZONE                    =    4.6
VELOCITY     FT/S       .33    .33  CROSS FLOW                  =    3.9
DENSITY    LB/FT3   62.252 61.752  INLET NOZZLE                =   42.2
NOZZ RHO*VSQ LB/FT-S2    6      6  OUTLET NOZZLE               =   40.3
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BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                         =      150.
DENSITY    LB/FT3   61.291 61.785   WET                         =      165.
PRESS. DROP  %         8.4    5.3
Washington University ChE433 heat exchanger experiment        E0002 P 72
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 36
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                 Shell
                                    SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR               .500                 .500
                                    IN       OUT         IN       OUT
TEMPERATURE        DEGF           140.0    104.2*      70.0     105.7*
DENSITY            LB/FT3        61.2913   61.8343    62.2515   61.8146
VISCOSITY          CP              .4726    .6617      .9783     .6519
SPECIFIC HEAT      BTU/LB-F        .9973    .9984     1.0015     .9983
THERMAL COND.      BTU/HR-FT-F     .3723    .3643      .3554     .3646
MOLAR MASS         LB/LBMOL                 18.02                18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       122.1    103.2       87.8     102.4
VISCOSITY, AVG & SKIN  CP         .5547    .6692      .7904     .6745
PRESSURE, IN & DESIGN  PSIA       50.00   165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05    10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49    10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     212.48               231.13
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .017835
EFF TEMP DIF, DEGF  (LMTD= 34.3,F= .78,BYPASS= .94,BAFF=1.00)      25.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             99.16
CLEAN & FOULED COEFF     BTU/HR-FT2-F          101.71             99.27

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
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PITCH RATIO              1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 73
Young model F302DY4P                                            9/23/ 3
                                                                CASE 36
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000    NOMINAL VEL,X-FLOW  FT/S          .07
PRANDTL NUMBER       5.3     3.6    NOMINAL VEL,WINDOW  FT/S          .13
RYNLD NO, AVG       238.   1420.    CROSSFLOW COEF   BTU/HR-FT2-F  232.0
RYNLD NO, IN BUN    192.   1667.    WINDOW COEF      BTU/HR-FT2-F  233.6
RYNLD NO,OUT BUN    289.   1191.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.39
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.97
 42.47  55.31    2.15     .07       BUNDLE TO SHELL BYPASS    C =  14.80
PCT OVER DESIGN               .10    BAFFLE TO SHELL LEAKAGE   E =  15.84
TOT FOUL RESIST           .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000011
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .661
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .718
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25           WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25           END ZONE                    =    4.2
VELOCITY     FT/S      .41    .41    CROSS FLOW                  =    3.6
DENSITY    LB/FT3   62.252 61.815    INLET NOZZLE                =   42.5
NOZZ RHO*VSQ LB/FT-S2   10     10    OUTLET NOZZLE               =   40.9
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73    DRY                      =      150.
DENSITY    LB/FT3   61.291 61.834    WET                      =      165.
PRESS. DROP  %         8.4    5.3
Washington University ChE433 heat exchanger experiment        E0002 P 74
Young model F302DY4P                                            9/23/ 3
                                                                CASE 37
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                 .600
                                      IN        OUT        IN        OUT
TEMPERATURE        DEGF             140.0     101.4*      70.0     102.1*
DENSITY            LB/FT3         61.2913   61.8722   62.2515   61.8639
VISCOSITY          CP               .4726     .6813     .9783     .6769
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SPECIFIC HEAT      BTU/LB-F         .9973     .9986     1.0015     .9985
THERMAL COND.      BTU/HR-FT-F      .3723     .3636      .3554     .3638
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         120.7     100.6       86.0      99.8
VISCOSITY, AVG & SKIN  CP           .5621     .6875      .8069     .6934
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     212.81              260.25
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .019233
EFF TEMP DIF, DEGF  (LMTD= 34.6,F= .79,BYPASS= .94,BAFF=1.00)       25.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             104.17
CLEAN & FOULED COEFF     BTU/HR-FT2-F           107.08            104.31

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment       E0002 P 75
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 37
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S         .08
PRANDTL NUMBER       5.4     3.7    NOMINAL VEL,WINDOW  FT/S         .15
RYNLD NO, AVG       280.   1402.    CROSSFLOW COEF   BTU/HR-FT2-F  261.3
RYNLD NO, IN BUN    231.   1667.    WINDOW COEF      BTU/HR-FT2-F  262.9
RYNLD NO,OUT BUN    334.   1156.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.46
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.59
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                                    che433b(70).OUT
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW             B =  65.21
 39.63  58.03    2.26     .07       BUNDLE TO SHELL BYPASS     C =  15.53
PCT OVER DESIGN             .14     BAFFLE TO SHELL LEAKAGE    E =  15.68
TOT FOUL RESIST         .000217     TUBE PASSLANE BYPASS       F =    .00
DIFF RESIST             .000013
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .683
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .743
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    3.9
VELOCITY     FT/S      .49    .49   CROSS FLOW                   =    3.4
DENSITY    LB/FT3   62.252 61.864   INLET NOZZLE                 =   42.6
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE                =   41.3
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.872   WET                       =      165.
PRESS. DROP  %         8.3    5.3
Washington University ChE433 heat exchanger experiment        E0002 P 76
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 38
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .500                 .700
                                      IN        OUT          IN       OUT
TEMPERATURE        DEGF             140.0      99.1*       70.0      99.1*
DENSITY            LB/FT3         61.2913   61.9029    62.2515   61.9031
VISCOSITY          CP               .4726     .6981      .9783     .6983
SPECIFIC HEAT      BTU/LB-F         .9973     .9987     1.0015     .9987
THERMAL COND.      BTU/HR-FT-F      .3723     .3630      .3554     .3630
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------      ---------------
TEMP, AVG & SKIN       DEGF         119.6      98.4       84.6      97.6
VISCOSITY, AVG & SKIN  CP           .5683     .7036      .8207     .7100
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49     10.00        .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      213.06              289.37
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .020384
EFF TEMP DIF, DEGF  (LMTD= 34.7,F= .80,BYPASS= .94,BAFF=1.00)       26.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              108.71
CLEAN & FOULED COEFF     BTU/HR-FT2-F          111.78              108.72
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SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment        E0002 P 77
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 38
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S          .09
PRANDTL NUMBER       5.5     3.7    NOMINAL VEL,WINDOW  FT/S          .18
RYNLD NO, AVG       321.   1386.    CROSSFLOW COEF   BTU/HR-FT2-F  290.5
RYNLD NO, IN BUN    269.   1667.    WINDOW COEF      BTU/HR-FT2-F  292.3
RYNLD NO,OUT BUN    377.   1129.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.77
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.87
 37.15  60.41    2.36     .08       BUNDLE TO SHELL BYPASS    C =  15.82
PCT OVER DESIGN                .01    BAFFLE TO SHELL LEAKAGE   E =  15.55
TOT FOUL RESIST            .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST                .000001
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES                TOTAL =(BETA)(GAMMA)(FIN)   =   .707
BUNDLE TO SHELL       IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .768
BAFFLE TO SHELL       IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25           WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25           END ZONE                    =    3.6
VELOCITY     FT/S      .57    .58    CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 61.903    INLET NOZZLE                =   42.8
NOZZ RHO*VSQ LB/FT-S2   20     20    OUTLET NOZZLE               =   41.5
BUND RHO*VSQ LB/FT-S2   13     13
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  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                          =      150.
DENSITY    LB/FT3   61.291 61.903   WET                          =      165.
PRESS. DROP  %         8.3    5.2
Washington University ChE433 heat exchanger experiment        E0002 P 78
Young model F302DY4P                                            9/23/ 3
                                                                CASE 39
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                  .800
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0      97.2*       70.0       96.7*
DENSITY            LB/FT3         61.2913   61.9278    62.2515   61.9353
VISCOSITY          CP               .4726     .7124      .9783     .7169
SPECIFIC HEAT      BTU/LB-F         .9973     .9989     1.0015     .9989
THERMAL COND.      BTU/HR-FT-F      .3723     .3626      .3554     .3624
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         118.6      96.6       83.3      95.7
VISCOSITY, AVG & SKIN  CP           .5735     .7178      .8325     .7247
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     213.28              318.55
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .021329
EFF TEMP DIF, DEGF  (LMTD= 34.7,F= .81,BYPASS= .94,BAFF=1.00)       26.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              112.47
CLEAN & FOULED COEFF     BTU/HR-FT2-F           115.96             112.63

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH           IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM    IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM     IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
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SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 79
Young model F302DY4P                                            9/23/ 3
                                                                CASE 39
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S         .10
PRANDTL NUMBER       5.6     3.8    NOMINAL VEL,WINDOW  FT/S         .20
RYNLD NO, AVG       362.   1374.    CROSSFLOW COEF   BTU/HR-FT2-F  319.8
RYNLD NO, IN BUN    308.   1667.    WINDOW COEF      BTU/HR-FT2-F  321.8
RYNLD NO,OUT BUN    420.   1106.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.92
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.59
 34.96  62.52    2.44     .08       BUNDLE TO SHELL BYPASS    C =  16.06
PCT OVER DESIGN              .14    BAFFLE TO SHELL LEAKAGE   E =  15.44
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000012
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .731
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .795
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =   8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =   3.4
VELOCITY     FT/S      .65    .66   CROSS FLOW                    =   3.1
DENSITY    LB/FT3   62.252 61.935   INLET NOZZLE                  =  42.8
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE                 =  41.8
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.928   WET                        =      165.
PRESS. DROP  %         8.3    5.2
Washington University ChE433 heat exchanger experiment        E0002 P 80
Young model F302DY4P                                            9/23/ 3
                                                                CASE 40
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .500                 .900
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0      95.5*     70.0      94.7*
DENSITY            LB/FT3         61.2913   61.9507   62.2515   61.9609
VISCOSITY          CP               .4726     .7262     .9783     .7325
SPECIFIC HEAT      BTU/LB-F         .9973     .9990    1.0015     .9991
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THERMAL COND.      BTU/HR-FT-F      .3723     .3621      .3554     .3619
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------      ---------------
TEMP, AVG & SKIN        DEGF        117.7      94.9       82.3      94.0
VISCOSITY, AVG & SKIN  CP           .5784     .7306      .8422     .7380
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .05     10.00        .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .49     10.00        .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     213.38               348.23
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .022213
EFF TEMP DIF, DEGF  (LMTD= 34.4,F= .82,BYPASS= .95,BAFF=1.00)       26.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              116.30
CLEAN & FOULED COEFF     BTU/HR-FT2-F           119.71             116.12

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.          .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8     .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment       E0002 P 81
Young model F302DY4P                                              9/23/ 3
                                                                  CASE 40
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .12
PRANDTL NUMBER       5.7     3.8    NOMINAL VEL,WINDOW  FT/S          .23
RYNLD NO, AVG       402.   1362.    CROSSFLOW COEF   BTU/HR-FT2-F  349.7
RYNLD NO, IN BUN    346.   1667.    WINDOW COEF      BTU/HR-FT2-F  351.7
RYNLD NO,OUT BUN    462.   1085.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.05
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.42
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 32.97  64.43    2.52     .08       BUNDLE TO SHELL BYPASS    C =  16.20
PCT OVER DESIGN             -.15    BAFFLE TO SHELL LEAKAGE   E =  15.33
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000013
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .756
BUNDLE TO SHELL       IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE   IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .822
BAFFLE TO SHELL       IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    3.3
VELOCITY     FT/S      .74    .74   CROSS FLOW                   =    3.0
DENSITY    LB/FT3   62.252 61.961   INLET NOZZLE                 =   42.9
NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE                =   42.0
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .74    .73   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.951   WET                       =      165.
PRESS. DROP  %         8.3    5.2
Washington University ChE433 heat exchanger experiment        E0002 P 82
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 41
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .600                 .200
                                      IN        OUT        IN        OUT
TEMPERATURE        DEGF             140.0     121.7*      70.0     124.8*
DENSITY            LB/FT3         61.2913   61.5830    62.2515   61.5352
VISCOSITY          CP               .4726     .5570      .9783     .5409
SPECIFIC HEAT      BTU/LB-F         .9973     .9976     1.0015     .9975
THERMAL COND.      BTU/HR-FT-F      .3723     .3684      .3554     .3691
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         130.8     116.7       97.4     116.1
VISCOSITY, AVG & SKIN  CP           .5121     .5843      .7111     .5876
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .07     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .59     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     214.66               136.13
                          --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .010952
EFF TEMP DIF, DEGF  (LMTD= 29.8,F= .74,BYPASS= .90,BAFF=1.00)     19.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            77.24
CLEAN & FOULED COEFF     BTU/HR-FT2-F           78.15            76.91
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SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT    IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 83
Young model F302DY4P                                            9/23/ 3
                                                                CASE 41
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.027    .000    NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       4.7     3.3    NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG       105.   1846.    CROSSFLOW COEF   BTU/HR-FT2-F  136.7
RYNLD NO, IN BUN     76.   2000.    WINDOW COEF      BTU/HR-FT2-F  137.5
RYNLD NO,OUT BUN    138.   1698.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           80.70
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.63
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.84
 55.86  42.42    1.67     .06       BUNDLE TO SHELL BYPASS    C =  11.34
PCT OVER DESIGN             -.44    BAFFLE TO SHELL LEAKAGE   E =  17.20
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000057
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.5
HT OPP  NOZ  IN.       .25          END ZONE                    =    6.5
VELOCITY     FT/S      .16    .17   CROSS FLOW                  =    5.1
DENSITY    LB/FT3   62.252 61.535   INLET NOZZLE                =   40.9
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   38.0
BUND RHO*VSQ LB/FT-S2    1      1
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  TUBE NOZZLE DATA       IN     OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S       .89     .88   DRY                         =      150.
DENSITY    LB/FT3   61.291 61.583   WET                         =      165.
PRESS. DROP  %          8.7     5.5
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE. CONSIDER RERUNNING WITH ITEM 132 IN EFFECT.

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Washington University ChE433 heat exchanger experiment        E0002 P 84
Young model F302DY4P                                            9/23/ 3
                                                                CASE 42
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                  HOT TUBE SIDE       COLD SHELL SIDE
                                   Tube                 Shell
                                   SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR               .600                 .300
                                   IN       OUT          IN       OUT
TEMPERATURE        DEGF          140.0    116.0*       70.0     118.0*
DENSITY            LB/FT3       61.2913   61.6684    62.2515   61.6386
VISCOSITY          CP             .4726     .5883      .9783     .5770
SPECIFIC HEAT      BTU/LB-F       .9973     .9978     1.0015     .9977
THERMAL COND.      BTU/HR-FT-F    .3723     .3671      .3554     .3675
MOLAR MASS         LB/LBMOL                 18.02                18.02
                                ---------------     ---------------
TEMP, AVG & SKIN       DEGF      128.0     111.8       94.0     111.1
VISCOSITY, AVG & SKIN  CP        .5255     .6129      .7380     .6170
PRESSURE, IN & DESIGN  PSIA      50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .07     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .59     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     215.59               170.15
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .014384
EFF TEMP DIF, DEGF  (LMTD= 32.5,F= .77,BYPASS= .92,BAFF=1.00)       23.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              87.08
CLEAN & FOULED COEFF     BTU/HR-FT2-F           88.47              86.76

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0
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TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 85
Young model F302DY4P                                           9/23/ 3
                                                               CASE 42
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .000   NOMINAL VEL,X-FLOW  FT/S         .04
PRANDTL NUMBER       4.9     3.4   NOMINAL VEL,WINDOW  FT/S         .08
RYNLD NO, AVG       153.   1799.   CROSSFLOW COEF   BTU/HR-FT2-F  170.8
RYNLD NO, IN BUN    115.   2000.   WINDOW COEF      BTU/HR-FT2-F  171.9
RYNLD NO,OUT BUN    195.   1607.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.27
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.91
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.11
 50.42  47.64    1.88     .06      BUNDLE TO SHELL BYPASS    C =  12.57
PCT OVER DESIGN             -.38   BAFFLE TO SHELL LEAKAGE   E =  16.41
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000043
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .616
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .670
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    9.1
HT OPP  NOZ  IN.       .25         END ZONE                     =    5.2
VELOCITY     FT/S      .25    .25  CROSS FLOW                   =    4.3
DENSITY    LB/FT3   62.252 61.639  INLET NOZZLE                 =   41.8
NOZZ RHO*VSQ LB/FT-S2    3      3  OUTLET NOZZLE                =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.668  WET                       =      165.
PRESS. DROP  %         8.6    5.5


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
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Washington University ChE433 heat exchanger experiment        E0002 P 86
Young model F302DY4P                                           9/23/ 3
                                                               CASE 43
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .600                  .400
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0     111.6*       70.0     112.5*
DENSITY            LB/FT3         61.2913   61.7309    62.2515   61.7194
VISCOSITY          CP                .4726     .6138      .9783     .6089
SPECIFIC HEAT      BTU/LB-F          .9973     .9980     1.0015     .9979
THERMAL COND.      BTU/HR-FT-F       .3723     .3661      .3554     .3663
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         125.8     107.9       91.2     107.2
VISCOSITY, AVG & SKIN  CP           .5360     .6371      .7609     .6419
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .07     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .59     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     216.24               202.21
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .016969
EFF TEMP DIF, DEGF  (LMTD= 34.1,F= .79,BYPASS= .93,BAFF=1.00)     25.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             94.45
CLEAN & FOULED COEFF     BTU/HR-FT2-F           96.57             94.44

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH           IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM    IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM     IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 87
Young model F302DY4P                                           9/23/ 3
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CASE 43

S U P P L E M E N T A R Y   R E S U L T S

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  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .000    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.1     3.5    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       198.   1764.    CROSSFLOW COEF   BTU/HR-FT2-F  203.0
RYNLD NO, IN BUN    154.   2000.    WINDOW COEF      BTU/HR-FT2-F  204.4
RYNLD NO,OUT BUN    247.   1540.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.41
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.17
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.96
 46.18  51.70    2.05     .07       BUNDLE TO SHELL BYPASS    C =  13.82
PCT OVER DESIGN               -.01    BAFFLE TO SHELL LEAKAGE   E =  16.06
TOT FOUL RESIST             .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST                -.000001
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .639
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .695
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    4.6
VELOCITY     FT/S      .33    .33   CROSS FLOW                    =    3.9
DENSITY    LB/FT3   62.252 61.719   INLET NOZZLE                  =   42.3
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE                 =   40.3
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.731   WET                       =      165.
PRESS. DROP  %         8.6    5.4
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE. CONSIDER
RERUNNING WITH ITEM 132 IN EFFECT.

Washington University ChE433 heat exchanger experiment   E0002 P 88
Young model F302DY4P   9/23/ 3
CASE 44

SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING

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                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .600                 .500
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0     108.3*       70.0     108.0*
DENSITY            LB/FT3         61.2913   61.7788    62.2515   61.7823
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VISCOSITY          CP                  .4726     .6350      .9783     .6367
SPECIFIC HEAT      BTU/LB-F            .9973     .9981     1.0015     .9982
THERMAL COND.      BTU/HR-FT-F         .3723     .3653      .3554     .3652
MOLAR MASS         LB/LBMOL                      18.02                18.02
                                       ---------------    ---------------
TEMP, AVG & SKIN       DEGF            124.1     104.8       89.0     104.0
VISCOSITY, AVG & SKIN  CP              .5444     .6577      .7801     .6632
PRESSURE, IN & DESIGN  PSIA            50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI        .07     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S       .59     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010                .00010
FILM COEFFICIENT       BTU/HR-FT2-F      216.70                232.47
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                  .018995
EFF TEMP DIF, DEGF  (LMTD= 35.0,F= .81,BYPASS= .94,BAFF=1.00)         26.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                100.39
CLEAN & FOULED COEFF     BTU/HR-FT2-F           103.09               100.60

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2               7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL         7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS             4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.          30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.        .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED            NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %                .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                     36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.          .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.           .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.           .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN          1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 89
Young model F302DY4P                                            9/23/ 3
                                                                CASE 44
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .000    NOMINAL VEL,X-FLOW  FT/S          .07
PRANDTL NUMBER       5.2     3.6    NOMINAL VEL,WINDOW  FT/S          .13
RYNLD NO, AVG       241.   1737.    CROSSFLOW COEF   BTU/HR-FT2-F  233.4
RYNLD NO, IN BUN    192.   2000.    WINDOW COEF      BTU/HR-FT2-F  234.9
RYNLD NO,OUT BUN    296.   1489.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.46
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THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.40
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.91
 42.79  54.96    2.18     .07       BUNDLE TO SHELL BYPASS    C =  14.86
PCT OVER DESIGN              .21    BAFFLE TO SHELL LEAKAGE   E =  15.82
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000021
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .662
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .720
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                       =    8.9
HT OPP  NOZ  IN.        .25         END ZONE                     =    4.2
VELOCITY     FT/S       .41    .41  CROSS FLOW                   =    3.6
DENSITY    LB/FT3   62.252 61.782   INLET NOZZLE                 =   42.5
NOZZ RHO*VSQ LB/FT-S2   10     10   OUTLET NOZZLE                =   40.8
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S       .89    .88  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.779   WET                       =      165.
PRESS. DROP  %          8.5    5.4



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
Washington University ChE433 heat exchanger experiment        E0002 P 90
Young model F302DY4P                                            9/23/ 3
                                                               CASE 45
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .600                 .600
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0     105.5*      70.0     104.5*
DENSITY            LB/FT3         61.2913   61.8175    62.2515   61.8314
VISCOSITY          CP                .4726     .6534      .9783     .6603
SPECIFIC HEAT      BTU/LB-F          .9973     .9983     1.0015     .9984
THERMAL COND.      BTU/HR-FT-F       .3723     .3646      .3554     .3643
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         122.7     102.2       87.2     101.4
VISCOSITY, AVG & SKIN  CP           .5516     .6756      .7960     .6816
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .07     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .59     10.00        .09     10.00
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FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      217.00              261.95
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .020665
EFF TEMP DIF, DEGF  (LMTD= 35.5,F= .82,BYPASS= .94,BAFF=1.00)      27.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            105.95
CLEAN & FOULED COEFF     BTU/HR-FT2-F          108.60            105.77

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P 91
Young model F302DY4P                                          9/23/ 3
                                                              CASE 45
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .000   NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.3     3.6   NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       284.   1714.   CROSSFLOW COEF   BTU/HR-FT2-F  263.0
RYNLD NO, IN BUN    231.   2000.   WINDOW COEF      BTU/HR-FT2-F  264.7
RYNLD NO,OUT BUN    342.   1447.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.46
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.61
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  65.19
 39.93  57.70    2.29     .08      BUNDLE TO SHELL BYPASS    C =  15.55
PCT OVER DESIGN             -.17   BAFFLE TO SHELL LEAKAGE   E =  15.66
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000016
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .685
BUNDLE TO SHELL       IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE   IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .745
BAFFLE TO SHELL       IN.    .1000   END   (HT LOSS IN END ZONE) =   .994
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  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25            WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25            END ZONE                     =    3.8
VELOCITY     FT/S      .49    .49     CROSS FLOW                   =    3.4
DENSITY    LB/FT3   62.252 61.831     INLET NOZZLE                 =   42.7
NOZZ RHO*VSQ LB/FT-S2   14     15     OUTLET NOZZLE                =   41.2
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88     DRY                       =      150.
DENSITY    LB/FT3   61.291 61.817     WET                       =      165.
PRESS. DROP  %         8.5    5.3



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
Washington University ChE433 heat exchanger experiment        E0002 P 92
Young model F302DY4P                                           9/23/ 3
                                                               CASE 46
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .600                 .700
                                     IN        OUT          IN        OUT
TEMPERATURE        DEGF            140.0     103.2*       70.0     101.4*
DENSITY            LB/FT3        61.2913   61.8481    62.2515   61.8722
VISCOSITY          CP              .4726     .6687      .9783     .6813
SPECIFIC HEAT      BTU/LB-F        .9973     .9984     1.0015     .9986
THERMAL COND.      BTU/HR-FT-F     .3723     .3640      .3554     .3636
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN       DEGF        121.6     100.0       85.7      99.2
VISCOSITY, AVG & SKIN  CP          .5574     .6915      .8098     .6980
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .07     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .59     10.00        .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      217.28               291.36
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .022008
EFF TEMP DIF, DEGF  (LMTD= 35.8,F= .83,BYPASS= .94,BAFF=1.00)      27.9
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                           110.42
CLEAN & FOULED COEFF     BTU/HR-FT2-F           113.43          110.30

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
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SHELL DIAMETER IN.         3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.      4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.      4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.      4.309
BAFFLE THICKNESS  IN.       .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES       1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                  PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL            76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.         .214
PITCH RATIO                1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 93
Young model F302DY4P                                          9/23/ 3
                                                              CASE 46
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S          .09
PRANDTL NUMBER       5.4     3.7    NOMINAL VEL,WINDOW  FT/S          .18
RYNLD NO, AVG       325.   1696.    CROSSFLOW COEF   BTU/HR-FT2-F  292.5
RYNLD NO, IN BUN    269.   2000.    WINDOW COEF      BTU/HR-FT2-F  294.4
RYNLD NO,OUT BUN    387.   1414.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.78
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.85
 37.43  60.10    2.39     .08       BUNDLE TO SHELL BYPASS    C =  15.83
PCT OVER DESIGN             -.11    BAFFLE TO SHELL LEAKAGE   E =  15.53
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000010
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .710
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .771
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.6
VELOCITY     FT/S      .57    .58   CROSS FLOW                    =    3.2
DENSITY    LB/FT3   62.252 61.872   INLET NOZZLE                  =   42.8
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE                 =   41.5
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88   DRY                        =      150.
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DENSITY    LB/FT3   61.291 61.848   WET                    =      165.
PRESS. DROP  %         8.4    5.3
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE. CONSIDER
RERUNNING WITH ITEM 132 IN EFFECT.

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Washington University ChE433 heat exchanger experiment        E0002 P 94
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 47
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                  Shell
                                    SENSIBLE LIQ        SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .600                .800
                                    IN       OUT          IN       OUT
TEMPERATURE        DEGF           140.0    101.4*       70.0      98.9*
DENSITY            LB/FT3       61.2913   61.8734    62.2515   61.9058
VISCOSITY          CP              .4726     .6819      .9783     .6998
SPECIFIC HEAT      BTU/LB-F        .9973     .9986     1.0015     .9987
THERMAL COND.      BTU/HR-FT-F     .3723     .3636      .3554     .3630
MOLAR MASS         LB/LBMOL                  18.02               18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF        120.7      98.1       84.5      97.2
VISCOSITY, AVG & SKIN  CP          .5624     .7057      .8217     .7127
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .07     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .59     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      217.50              320.86
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .023132
EFF TEMP DIF, DEGF  (LMTD= 36.0,F= .83,BYPASS= .94,BAFF=1.00)     28.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                           114.25
CLEAN & FOULED COEFF     BTU/HR-FT2-F          117.72           114.30

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2          7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL    7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS        4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.     30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.   .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED       NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                36
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TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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                                                                 CASE 47
S U P P L E M E N T A R Y    R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.5     3.7    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       366.   1681.    CROSSFLOW COEF   BTU/HR-FT2-F  322.2
RYNLD NO, IN BUN    308.   2000.    WINDOW COEF      BTU/HR-FT2-F  324.1
RYNLD NO,OUT BUN    430.   1386.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.93
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.57
 35.22  62.21    2.48     .08       BUNDLE TO SHELL BYPASS    C =  16.07
PCT OVER DESIGN              .05    BAFFLE TO SHELL LEAKAGE   E =  15.42
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000004
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .734
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .798
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.4
VELOCITY     FT/S      .65    .66   CROSS FLOW                    =    3.1
DENSITY    LB/FT3   62.252 61.906   INLET NOZZLE                  =   42.9
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE                 =   41.8
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.873   WET                        =      165.
PRESS. DROP  %         8.4    5.3


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
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                                                                    CASE 48
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                 Shell
                                    SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .600                 .900
                                    IN        OUT         IN        OUT
TEMPERATURE        DEGF           140.0       99.5*      70.0       96.9*
DENSITY            LB/FT3        61.2913   61.8981    62.2515   61.9318
VISCOSITY          CP              .4726     .6954      .9783     .7148
SPECIFIC HEAT      BTU/LB-F        .9973     .9987     1.0015     .9989
THERMAL COND.      BTU/HR-FT-F     .3723     .3631      .3554     .3625
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       119.8       96.5       83.5      95.5
VISCOSITY, AVG & SKIN  CP          .5673     .7184      .8312     .7259
PRESSURE, IN & DESIGN  PSIA       50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .07     10.00        .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .59     10.00        .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     217.57              350.94
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .024241
EFF TEMP DIF, DEGF  (LMTD= 35.9,F= .84,BYPASS= .95,BAFF=1.00)       28.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              118.57
CLEAN & FOULED COEFF     BTU/HR-FT2-F          121.56              117.88

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P 97
Young model F302DY4P                                           9/23/ 3
                                                                CASE 48
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S
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  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.019    .000    NOMINAL VEL,X-FLOW  FT/S          .12
PRANDTL NUMBER       5.6     3.7    NOMINAL VEL,WINDOW  FT/S          .23
RYNLD NO, AVG       407.   1667.    CROSSFLOW COEF   BTU/HR-FT2-F  352.4
RYNLD NO, IN BUN    346.   2000.    WINDOW COEF      BTU/HR-FT2-F  354.4
RYNLD NO,OUT BUN    474.   1360.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.07
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.43
 33.21  64.15    2.56     .08       BUNDLE TO SHELL BYPASS    C =  16.18
PCT OVER DESIGN             -.58    BAFFLE TO SHELL LEAKAGE   E =  15.32
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000049
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .760
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .826
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.3
VELOCITY     FT/S      .74    .74   CROSS FLOW                    =    3.0
DENSITY    LB/FT3   62.252 61.932   INLET NOZZLE                  =   43.0
NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE                 =   41.9
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S      .89    .88   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.898   WET                        =      165.
PRESS. DROP  %         8.4    5.3



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
Washington University ChE433 heat exchanger experiment        E0002 P 98
Young model F302DY4P                                           9/23/ 3
                                                               CASE 49
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .700                 .200
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0     123.9*       70.0     126.3*
DENSITY            LB/FT3         61.2913   61.5497    62.2515   61.5119
VISCOSITY          CP               .4726     .5457      .9783     .5335
SPECIFIC HEAT      BTU/LB-F         .9973     .9975     1.0015     .9974
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THERMAL COND.      BTU/HR-FT-F      .3723     .3689      .3554     .3694
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------      ---------------
TEMP, AVG & SKIN       DEGF         131.9     118.4       98.2     117.8
VISCOSITY, AVG & SKIN  CP           .5071     .5745      .7054     .5778
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .09     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .69     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     237.96             136.54
                  ---------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .011252
EFF TEMP DIF, DEGF  (LMTD= 29.3,F= .76,BYPASS= .89,BAFF=1.00)     19.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            79.95
CLEAN & FOULED COEFF     BTU/HR-FT2-F           81.70            80.38

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2          7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL    7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS        4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED       NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
□□Washington University ChE433 heat exchanger experiment       E0002 P 99
Young model F302DY4P                                            9/23/ 3
                                                               CASE 49
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.028    .979    NOMINAL VEL,X-FLOW  FT/S         .03
PRANDTL NUMBER       4.7     3.3    NOMINAL VEL,WINDOW  FT/S         .05
RYNLD NO, AVG       106.   2175.    CROSSFLOW COEF   BTU/HR-FT2-F  137.1
RYNLD NO, IN BUN     76.   2334.    WINDOW COEF      BTU/HR-FT2-F  137.9
RYNLD NO,OUT BUN    140.   2021.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            80.75
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.63
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.90
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 58.21  39.99    1.74     .06       BUNDLE TO SHELL BYPASS    C =  11.32
PCT OVER DESIGN              .54    BAFFLE TO SHELL LEAKAGE   E =  17.15
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000067
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .598
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.5
HT OPP  NOZ  IN.       .25          END ZONE                    =    6.5
VELOCITY     FT/S      .16    .17   CROSS FLOW                  =    5.1
DENSITY    LB/FT3   62.252 61.512   INLET NOZZLE                =   40.9
NOZZ RHO*VSQ LB/FT-S2    1      1   OUTLET NOZZLE               =   38.0
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.550   WET                      =      165.
PRESS. DROP  %         8.8    5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  215.71 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1231.08 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P100
Young model F302DY4P                                           9/23/ 3
                                                               CASE 50
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .700                 .300
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0     118.6*      70.0     119.9*
DENSITY            LB/FT3         61.2913   61.6298    62.2515   61.6101
VISCOSITY          CP               .4726     .5737      .9783     .5665
SPECIFIC HEAT      BTU/LB-F         .9973     .9977     1.0015     .9976
THERMAL COND.      BTU/HR-FT-F      .3723     .3677      .3554     .3680
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         129.3     113.6       95.0     112.9
VISCOSITY, AVG & SKIN  CP           .5193     .6023      .7303     .6064
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .09     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .68     10.00        .05     10.00
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FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      233.31              170.93
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .014956
EFF TEMP DIF, DEGF  (LMTD= 32.3,F= .78,BYPASS= .92,BAFF=1.00)       23.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             90.07
CLEAN & FOULED COEFF     BTU/HR-FT2-F           92.04             90.23

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P101
Young model F302DY4P                                            9/23/ 3
                                                                CASE 50
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.026    .976   NOMINAL VEL,X-FLOW  FT/S          .04
PRANDTL NUMBER       4.9     3.4   NOMINAL VEL,WINDOW  FT/S          .08
RYNLD NO, AVG       154.   2124.   CROSSFLOW COEF   BTU/HR-FT2-F  171.6
RYNLD NO, IN BUN    115.   2334.   WINDOW COEF      BTU/HR-FT2-F  172.7
RYNLD NO,OUT BUN    199.   1923.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.28
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.92
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.09
 52.19  45.78    1.96     .06      BUNDLE TO SHELL BYPASS    C =  12.60
PCT OVER DESIGN              .17   BAFFLE TO SHELL LEAKAGE   E =  16.39
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000019
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .617
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .671
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994
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  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.1
HT OPP  NOZ  IN.       .25          END ZONE                    =    5.2
VELOCITY     FT/S      .25    .25   CROSS FLOW                  =    4.3
DENSITY    LB/FT3   62.252 61.610   INLET NOZZLE                =   41.9
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE               =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.630   WET                      =      165.
PRESS. DROP  %         8.8    5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  217.48 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1237.51 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P102
Young model F302DY4P                                            9/23/ 3
                                                                CASE 51
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .700                 .400
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0     114.5*      70.0     114.5*
DENSITY            LB/FT3         61.2913   61.6895    62.2515   61.6898
VISCOSITY          CP               .4726     .5967      .9783     .5968
SPECIFIC HEAT      BTU/LB-F         .9973     .9978     1.0015     .9978
THERMAL COND.      BTU/HR-FT-F      .3723     .3667      .3554     .3667
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         127.3     109.6       92.3     108.9
VISCOSITY, AVG & SKIN  CP           .5290     .6262      .7523     .6311
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .09     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .68     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      229.67               203.24
                 --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .017788
EFF TEMP DIF, DEGF  (LMTD= 34.1,F= .80,BYPASS= .93,BAFF=1.00)      25.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             97.60
CLEAN & FOULED COEFF     BTU/HR-FT2-F            99.86            97.62
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SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P103
Young model F302DY4P                                            9/23/ 3
                                                                CASE 51
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .972    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.0     3.5    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       200.   2085.    CROSSFLOW COEF   BTU/HR-FT2-F  204.0
RYNLD NO, IN BUN    154.   2334.    WINDOW COEF      BTU/HR-FT2-F  205.4
RYNLD NO,OUT BUN    252.   1849.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.43
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.19
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.93
 47.49  50.32    2.12     .07       BUNDLE TO SHELL BYPASS    C =  13.86
PCT OVER DESIGN              .02    BAFFLE TO SHELL LEAKAGE   E =  16.03
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000002
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .641
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .696
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                     =    4.6
VELOCITY     FT/S      .33    .33   CROSS FLOW                   =    3.9
DENSITY    LB/FT3   62.252 61.690   INLET NOZZLE                 =   42.3
NOZZ RHO*VSQ LB/FT-S2    6      6   OUTLET NOZZLE                =   40.3
BUND RHO*VSQ LB/FT-S2    4      4
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  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.689   WET                       =      165.
PRESS. DROP  %         8.7    5.5



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  218.76 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1241.99 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment       E0002 P104
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 52
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .700                  .500
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0     111.3*       70.0     110.1*
DENSITY            LB/FT3         61.2913   61.7354    62.2515   61.7535
VISCOSITY          CP               .4726     .6158      .9783     .6236
SPECIFIC HEAT      BTU/LB-F         .9973     .9980     1.0015     .9980
THERMAL COND.      BTU/HR-FT-F      .3723     .3660      .3554     .3657
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         125.7     106.4       90.0     105.6
VISCOSITY, AVG & SKIN  CP           .5368     .6470      .7712     .6525
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .09     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .68     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      226.74               233.71
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .020018
EFF TEMP DIF, DEGF  (LMTD= 35.3,F= .82,BYPASS= .94,BAFF=1.00)       27.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             103.37
CLEAN & FOULED COEFF     BTU/HR-FT2-F          105.95             103.35

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
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PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P105
Young model F302DY4P                                            9/23/ 3
                                                                CASE 52
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .969    NOMINAL VEL,X-FLOW  FT/S         .07
PRANDTL NUMBER       5.2     3.5    NOMINAL VEL,WINDOW  FT/S         .13
RYNLD NO, AVG       244.   2055.    CROSSFLOW COEF   BTU/HR-FT2-F  234.6
RYNLD NO, IN BUN    192.   2334.    WINDOW COEF      BTU/HR-FT2-F  236.2
RYNLD NO,OUT BUN    302.   1791.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.47
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.42
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.87
 43.72  53.96    2.24     .07       BUNDLE TO SHELL BYPASS    C =  14.90
PCT OVER DESIGN              -.03   BAFFLE TO SHELL LEAKAGE   E =  15.80
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              -.000003
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .664
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .722
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    4.1
VELOCITY     FT/S      .41    .41   CROSS FLOW                  =    3.6
DENSITY    LB/FT3   62.252 61.753   INLET NOZZLE                =   42.6
NOZZ RHO*VSQ LB/FT-S2   10     10   OUTLET NOZZLE               =   40.8
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.735   WET                      =      165.
PRESS. DROP  %         8.7    5.5


*** SPECIAL MESSAGES AND WARNINGS ***
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WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  219.69 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1245.26 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P106
Young model F302DY4P                                            9/23/ 3
                                                                CASE 53
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .700                  .600
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0     108.8*       70.0     106.4*
DENSITY            LB/FT3         61.2913   61.7718    62.2515   61.8051
VISCOSITY          CP               .4726     .6318      .9783     .6474
SPECIFIC HEAT      BTU/LB-F         .9973     .9981     1.0015     .9983
THERMAL COND.      BTU/HR-FT-F      .3723     .3654      .3554     .3648
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         124.4     103.7       88.2     102.9
VISCOSITY, AVG & SKIN  CP           .5432     .6652      .7874     .6713
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .09     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .68     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     224.37               263.39
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .021812
EFF TEMP DIF, DEGF  (LMTD= 36.1,F= .83,BYPASS= .94,BAFF=1.00)      28.3
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            107.90
CLEAN & FOULED COEFF     BTU/HR-FT2-F          110.98            108.05

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8
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  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P107
Young model F302DY4P                                            9/23/ 3
                                                                CASE 53
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .967    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.3     3.6    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       287.   2031.    CROSSFLOW COEF   BTU/HR-FT2-F  264.4
RYNLD NO, IN BUN    231.   2334.    WINDOW COEF      BTU/HR-FT2-F  266.1
RYNLD NO,OUT BUN    349.   1746.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.47
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.62
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.18
 40.56  57.01    2.34     .08       BUNDLE TO SHELL BYPASS    C =  15.56
PCT OVER DESIGN              .14    BAFFLE TO SHELL LEAKAGE   E =  15.64
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000013
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .687
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .747
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.8
VELOCITY     FT/S      .49    .49   CROSS FLOW                  =    3.4
DENSITY    LB/FT3   62.252 61.805   INLET NOZZLE                =   42.7
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE               =   41.2
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.772   WET                      =      165.
PRESS. DROP  %         8.6    5.4



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  220.42 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1247.62 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P108
Young model F302DY4P                                            9/23/ 3
                                                                CASE 54
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
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                                         Tube                 Shell
                                         SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                     .700                 .700
                                         IN       OUT         IN       OUT
TEMPERATURE        DEGF                140.0    106.6*       70.0    103.4*
DENSITY            LB/FT3            61.2913   61.8024    62.2515   61.8463
VISCOSITY          CP                  .4726     .6461      .9783     .6678
SPECIFIC HEAT      BTU/LB-F            .9973     .9982     1.0015     .9984
THERMAL COND.      BTU/HR-FT-F         .3723     .3649      .3554     .3641
MOLAR MASS         LB/LBMOL                      18.02                18.02
                                       ---------------    ---------------
TEMP, AVG & SKIN       DEGF            123.3     101.4       86.7     100.5
VISCOSITY, AVG & SKIN  CP              .5487     .6814      .8010     .6880
PRESSURE, IN & DESIGN  PSIA            50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI        .09     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S       .68     10.00        .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010                .00010
FILM COEFFICIENT       BTU/HR-FT2-F      222.27                293.05
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .023346
EFF TEMP DIF, DEGF  (LMTD= 36.6,F= .84,BYPASS= .94,BAFF=1.00)        29.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              112.42
CLEAN & FOULED COEFF     BTU/HR-FT2-F          115.27              112.05

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P109
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 54
S U P P L E M E N T A R Y    R E S U L T S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .964    NOMINAL VEL,X-FLOW  FT/S          .09
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PRANDTL NUMBER       5.4     3.6    NOMINAL VEL,WINDOW  FT/S         .18
RYNLD NO, AVG       329.   2010.    CROSSFLOW COEF   BTU/HR-FT2-F  294.2
RYNLD NO, IN BUN    269.   2334.    WINDOW COEF      BTU/HR-FT2-F  296.0
RYNLD NO,OUT BUN    394.   1707.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.80
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.84
 37.81  59.68    2.43     .08       BUNDLE TO SHELL BYPASS    C =  15.84
PCT OVER DESIGN              -.33    BAFFLE TO SHELL LEAKAGE   E =  15.52
TOT FOUL RESIST           .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              -.000029
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .712
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .774
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.6
VELOCITY     FT/S      .57    .58   CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 61.846   INLET NOZZLE                =   42.9
NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE               =   41.5
BUND RHO*VSQ LB/FT-S2   13     13

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.802   WET                      =      165.
PRESS. DROP  %         8.6    5.4
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  220.97 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1249.62 BTU/HR-FT2-F
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Washington University ChE433 heat exchanger experiment        E0002 P110
Young model F302DY4P                                           9/23/ 3
                                                               CASE 55
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .700                  .800
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0     104.8*       70.0     100.8*
DENSITY            LB/FT3         61.2913   61.8272    62.2515   61.8813
VISCOSITY          CP               .4726     .6582      .9783     .6862
SPECIFIC HEAT      BTU/LB-F         .9973     .9984     1.0015     .9986
THERMAL COND.      BTU/HR-FT-F      .3723     .3644      .3554     .3634
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MOLAR MASS          LB/LBMOL                   18.02                 18.02
                                     ---------------     ---------------
TEMP, AVG & SKIN        DEGF         122.4      99.5       85.4      98.5
VISCOSITY, AVG & SKIN   CP           .5534     .6958      .8130     .7029
PRESSURE, IN & DESIGN   PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .09     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .68     10.00        .12     10.00

FOULING RESISTANCE      HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT        BTU/HR-FT2-F      221.35              322.77
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .024606
EFF TEMP DIF, DEGF  (LMTD= 37.0,F= .85,BYPASS= .94,BAFF=1.00)        29.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              116.08
CLEAN & FOULED COEFF     BTU/HR-FT2-F           119.29             115.80

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.        .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM        IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P111
Young model F302DY4P                                              9/23/ 3
                                                                  CASE 55
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .000    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.5     3.6    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       370.   1993.    CROSSFLOW COEF   BTU/HR-FT2-F  324.1
RYNLD NO, IN BUN    308.   2334.    WINDOW COEF      BTU/HR-FT2-F  326.0
RYNLD NO,OUT BUN    439.   1676.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.95
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.56
 35.47  61.93    2.51     .08       BUNDLE TO SHELL BYPASS    C =  16.08
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PCT OVER DESIGN             -.24    BAFFLE TO SHELL LEAKAGE   E =  15.40
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000021
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .736
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .800
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.4
VELOCITY     FT/S      .65    .66   CROSS FLOW                  =    3.1
DENSITY    LB/FT3   62.252 61.881   INLET NOZZLE                =   43.0
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE               =   41.7
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.03   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.827   WET                      =      165.
PRESS. DROP  %         8.6    5.4



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
Washington University ChE433 heat exchanger experiment        E0002 P112
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 56
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .700                 .900
                                      IN        OUT        IN        OUT
TEMPERATURE        DEGF             140.0     103.0*      70.0       98.7*
DENSITY            LB/FT3         61.2913   61.8512    62.2515   61.9085
VISCOSITY          CP                .4726     .6703     .9783     .7013
SPECIFIC HEAT      BTU/LB-F          .9973     .9985    1.0015     .9988
THERMAL COND.      BTU/HR-FT-F       .3723     .3640     .3554     .3629
MOLAR MASS         LB/LBMOL                    18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF          121.5      97.8      84.4      96.8
VISCOSITY, AVG & SKIN  CP            .5580     .7085     .8227     .7161
PRESSURE, IN & DESIGN  PSIA          50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .09     10.00       .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .68     10.00       .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      221.45               353.15
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TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                  .025839
EFF TEMP DIF, DEGF  (LMTD= 37.0,F= .85,BYPASS= .96,BAFF=1.00)          30.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                                119.79
CLEAN & FOULED COEFF     BTU/HR-FT2-F           123.24               119.47

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2               7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL         7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS             4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.          30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.        .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED            NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %                .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                     36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.          .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM        IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN          1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.      .8     .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P113
Young model F302DY4P                                            9/23/ 3
                                                                CASE 56
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.020    .000    NOMINAL VEL,X-FLOW  FT/S            .12
PRANDTL NUMBER       5.5     3.7    NOMINAL VEL,WINDOW  FT/S            .23
RYNLD NO, AVG       412.   1977.    CROSSFLOW COEF   BTU/HR-FT2-F  354.6
RYNLD NO, IN BUN    346.   2334.    WINDOW COEF      BTU/HR-FT2-F  356.7
RYNLD NO,OUT BUN    483.   1646.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.44
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.08
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.45
 33.45  63.87    2.59     .09       BUNDLE TO SHELL BYPASS    C =  16.17
PCT OVER DESIGN             -.26    BAFFLE TO SHELL LEAKAGE   E =  15.30
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000022
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .762
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .829
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    8.9
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HT OPP  NOZ  IN.        .25          END ZONE                    =    3.2
VELOCITY     FT/S       .74    .74   CROSS FLOW                  =    3.0
DENSITY    LB/FT3   62.252 61.908   INLET NOZZLE                 =   43.0
NOZZ RHO*VSQ LB/FT-S2   33     33   OUTLET NOZZLE                =   41.9
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.03   1.02   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.851   WET                       =      165.
PRESS. DROP  %          8.5    5.4



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
Washington University ChE433 heat exchanger experiment        E0002 P114
Young model F302DY4P                                            9/23/ 3
                                                                CASE 57
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .800                .200
                                     IN       OUT          IN       OUT
TEMPERATURE        DEGF            140.0     125.5*       70.0     127.8*
DENSITY            LB/FT3        61.2913   61.5244    62.2515   61.4884
VISCOSITY          CP              .4726     .5375      .9783     .5262
SPECIFIC HEAT      BTU/LB-F        .9973     .9974     1.0015     .9974
THERMAL COND.      BTU/HR-FT-F     .3723     .3692      .3554     .3698
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------      ---------------
TEMP, AVG & SKIN       DEGF        132.8     120.5       98.9     119.8
VISCOSITY, AVG & SKIN  CP          .5034     .5635      .6998     .5670
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .11     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .78     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     278.47              137.00
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                             .011552
EFF TEMP DIF, DEGF  (LMTD= 28.6,F= .76,BYPASS= .87,BAFF=1.00)      18.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            85.83
CLEAN & FOULED COEFF     BTU/HR-FT2-F            86.94           85.52

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
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SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P115
Young model F302DY4P                                           9/23/ 3
                                                               CASE 57
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.030    .981   NOMINAL VEL,X-FLOW  FT/S          .03
PRANDTL NUMBER       4.7     3.3   NOMINAL VEL,WINDOW  FT/S          .05
RYNLD NO, AVG       107.   2504.   CROSSFLOW COEF   BTU/HR-FT2-F  137.5
RYNLD NO, IN BUN     76.   2667.   WINDOW COEF      BTU/HR-FT2-F  138.4
RYNLD NO,OUT BUN    142.   2345.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            80.80
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   2.63
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  68.97
 61.73  36.36    1.85     .06      BUNDLE TO SHELL BYPASS    C =  11.30
PCT OVER DESIGN             -.36   BAFFLE TO SHELL LEAKAGE   E =  17.10
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000042
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .598
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .650
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    9.5
HT OPP  NOZ  IN.       .25         END ZONE                     =    6.4
VELOCITY     FT/S      .16    .17  CROSS FLOW                   =    5.1
DENSITY    LB/FT3   62.252 61.488  INLET NOZZLE                 =   41.0
NOZZ RHO*VSQ LB/FT-S2    1      1  OUTLET NOZZLE                =   38.1
BUND RHO*VSQ LB/FT-S2    1      1

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.18  DRY                        =      150.
DENSITY    LB/FT3   61.291 61.524  WET                        =      165.
PRESS. DROP  %         9.0    5.7
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  214.46 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1230.11 BTU/HR-FT2-F
□□Washington University ChE433 heat exchanger experiment        E0002 P116
Young model F302DY4P                                              9/23/ 3
                                                                  CASE 58
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                    Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .800                 .300
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF             140.0     120.5*       70.0     122.0*
DENSITY            LB/FT3         61.2913   61.6013    62.2515   61.5791
VISCOSITY          CP                .4726     .5634      .9783     .5556
SPECIFIC HEAT      BTU/LB-F          .9973     .9976     1.0015     .9975
THERMAL COND.      BTU/HR-FT-F       .3723     .3681      .3554     .3685
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         130.2     115.9       96.0     115.1
VISCOSITY, AVG & SKIN  CP            .5149     .5890      .7222     .5932
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .11     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .78     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     273.53              171.85
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .015570
EFF TEMP DIF, DEGF  (LMTD= 31.5,F= .78,BYPASS= .91,BAFF=1.00)       22.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              96.69
CLEAN & FOULED COEFF     BTU/HR-FT2-F            99.04             97.03

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
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TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.028    .978    NOMINAL VEL,X-FLOW  FT/S         .04
PRANDTL NUMBER       4.8     3.4    NOMINAL VEL,WINDOW  FT/S         .08
RYNLD NO, AVG       156.   2449.    CROSSFLOW COEF   BTU/HR-FT2-F  172.5
RYNLD NO, IN BUN    115.   2667.    WINDOW COEF      BTU/HR-FT2-F  173.6
RYNLD NO,OUT BUN    203.   2238.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.30
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.93
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.08
 55.83  42.00    2.10     .07       BUNDLE TO SHELL BYPASS    C =  12.63
PCT OVER DESIGN             .35     BAFFLE TO SHELL LEAKAGE   E =  16.35
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000036
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .618
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .672
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                       =    9.1
HT OPP  NOZ  IN.       .25          END ZONE                     =    5.2
VELOCITY     FT/S      .25    .25   CROSS FLOW                   =    4.3
DENSITY    LB/FT3   62.252 61.579   INLET NOZZLE                 =   42.0
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE                =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.18   DRY                       =      150.
DENSITY    LB/FT3   61.291 61.601   WET                       =      165.
PRESS. DROP  %         8.9    5.6


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  216.35 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1236.27 BTU/HR-FT2-F
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SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                             HOT TUBE SIDE       COLD SHELL SIDE
                                              Tube                 Shell
                                              SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                          .800                 .400
                                             IN        OUT        IN        OUT
TEMPERATURE        DEGF                    140.0     116.5*      70.0     116.9*
DENSITY            LB/FT3                61.2913   61.6604    62.2515   61.6548
VISCOSITY          CP                      .4726     .5852      .9783     .5831
SPECIFIC HEAT      BTU/LB-F                .9973     .9977     1.0015     .9977
THERMAL COND.      BTU/HR-FT-F             .3723     .3672      .3554     .3673
MOLAR MASS         LB/LBMOL                          18.02                18.02
                                           ---------------     ---------------
TEMP, AVG & SKIN       DEGF                128.3     112.1       93.4     111.2
VISCOSITY, AVG & SKIN  CP                  .5242     .6112      .7425     .6162
PRESSURE, IN & DESIGN  PSIA                50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI            .11     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S           .78     10.00        .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      269.49              204.57
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                  .018742
EFF TEMP DIF, DEGF  (LMTD= 33.5,F= .80,BYPASS= .93,BAFF=1.00)         24.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               105.99
CLEAN & FOULED COEFF     BTU/HR-FT2-F          108.34               105.81

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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Young model F302DY4P 9/23/ 3
CASE 59

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S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.026    .975    NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       5.0     3.4    NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       203.   2405.    CROSSFLOW COEF   BTU/HR-FT2-F  205.3
RYNLD NO, IN BUN    154.   2667.    WINDOW COEF      BTU/HR-FT2-F  206.8
RYNLD NO,OUT BUN    258.   2154.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.20
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  66.91
 51.15  46.48    2.29     .08       BUNDLE TO SHELL BYPASS    C =  13.89
PCT OVER DESIGN             -.16    BAFFLE TO SHELL LEAKAGE   E =  16.00
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000015
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .642
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .698
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                    =    4.6
VELOCITY     FT/S      .33     .33  CROSS FLOW                  =    3.9
DENSITY    LB/FT3   62.252 61.655   INLET NOZZLE                =   42.4
NOZZ RHO*VSQ LB/FT-S2    6       6  OUTLET NOZZLE               =   40.3
BUND RHO*VSQ LB/FT-S2    4       4

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18    1.17  DRY                      =      150.
DENSITY    LB/FT3   61.291 61.660   WET                      =      165.
PRESS. DROP  %         8.9     5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  217.71 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1240.84 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P120
Young model F302DY4P                                           9/23/ 3
                                                               CASE 60
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .800                  .500
                                      IN       OUT          IN       OUT
TEMPERATURE        DEGF              140.0     113.4*      70.0     112.5*
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DENSITY             LB/FT3          61.2913   61.7061    62.2515   61.7184
VISCOSITY           CP                .4726     .6034      .9783     .6085
SPECIFIC HEAT       BTU/LB-F          .9973     .9979     1.0015     .9979
THERMAL COND.       BTU/HR-FT-F       .3723     .3665      .3554     .3663
MOLAR MASS          LB/LBMOL                    18.02                18.02
                                      ---------------     ---------------
TEMP, AVG & SKIN        DEGF          126.7     108.9       91.3     108.0
VISCOSITY, AVG & SKIN   CP            .5317     .6308      .7606     .6365
PRESSURE, IN & DESIGN   PSIA          50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .12     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .78     10.00        .08     10.00

FOULING RESISTANCE      HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT        BTU/HR-FT2-F     266.27              235.40
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .021246
EFF TEMP DIF, DEGF  (LMTD= 34.8,F= .82,BYPASS= .93,BAFF=1.00)       26.5
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              112.27
CLEAN & FOULED COEFF     BTU/HR-FT2-F           115.71             112.73

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.        .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM        IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P121
Young model F302DY4P                                              9/23/ 3
                                                                  CASE 60
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .972    NOMINAL VEL,X-FLOW  FT/S           .07
PRANDTL NUMBER       5.1     3.5    NOMINAL VEL,WINDOW  FT/S           .13
RYNLD NO, AVG       247.   2371.    CROSSFLOW COEF   BTU/HR-FT2-F  236.3
RYNLD NO, IN BUN    192.   2667.    WINDOW COEF      BTU/HR-FT2-F  237.9
RYNLD NO,OUT BUN    309.   2089.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
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                                     HEAT TRANSFER X-FLOW          81.48
THERMAL RESISTANCE, % OF TOTAL       TUBE TO BAFFLE LEAKAGE    A =   3.44
 SHELL   TUBE  FOULING  METAL        MAIN CROSSFLOW            B =  65.85
 47.35  50.12    2.44     .08        BUNDLE TO SHELL BYPASS    C =  14.94
PCT OVER DESIGN               .42    BAFFLE TO SHELL LEAKAGE   E =  15.78
TOT FOUL RESIST           .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000037
                                       SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES               TOTAL =(BETA)(GAMMA)(FIN)   =   .666
BUNDLE TO SHELL      IN.    .5000    BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284    GAMMA (TUBE ROW ENTRY EFCT) =   .724
BAFFLE TO SHELL      IN.    .1000    END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT      SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25           WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25           END ZONE                      =    4.1
VELOCITY     FT/S      .41    .41    CROSS FLOW                    =    3.6
DENSITY    LB/FT3   62.252 61.718    INLET NOZZLE                  =   42.7
NOZZ RHO*VSQ LB/FT-S2   10     10    OUTLET NOZZLE                 =   40.8
BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA      IN    OUT      WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.17    DRY                        =      150.
DENSITY    LB/FT3   61.291 61.706    WET                        =      165.
PRESS. DROP  %         8.8    5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  218.75 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1244.09 BTU/HR-FT2-F
□□Washington University ChE433 heat exchanger experiment       E0002 P122
Young model F302DY4P                                            9/23/ 3
                                                                CASE 61
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                      HOT TUBE SIDE       COLD SHELL SIDE
                                       Tube                 Shell
                                       SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .800                 .600
                                       IN        OUT        IN        OUT
TEMPERATURE        DEGF              140.0     110.7*      70.0     109.0*
DENSITY            LB/FT3          61.2913   61.7442   62.2515   61.7689
VISCOSITY          CP                .4726     .6195     .9783     .6305
SPECIFIC HEAT      BTU/LB-F          .9973     .9980    1.0015     .9981
THERMAL COND.      BTU/HR-FT-F       .3723     .3659     .3554     .3654
MOLAR MASS         LB/LBMOL                    18.02               18.02
                                     ---------------    ---------------
TEMP, AVG & SKIN       DEGF          125.4     106.3      89.5     105.3
VISCOSITY, AVG & SKIN  CP            .5383     .6481     .7759     .6545
PRESSURE, IN & DESIGN  PSIA          50.00    165.00     50.00    165.00
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PRESSURE DROP, TOT & ALLOWED  PSI      .12     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .78     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      263.44              265.55
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .023367
EFF TEMP DIF, DEGF  (LMTD= 35.7,F= .83,BYPASS= .94,BAFF=1.00)       27.6
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              118.48
CLEAN & FOULED COEFF     BTU/HR-FT2-F           121.84             118.46

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P123
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 61
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .969    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.2     3.5    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       291.   2342.    CROSSFLOW COEF   BTU/HR-FT2-F  266.6
RYNLD NO, IN BUN    231.   2667.    WINDOW COEF      BTU/HR-FT2-F  268.3
RYNLD NO,OUT BUN    358.   2035.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.48
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.64
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.18
 44.11  53.24    2.57     .09       BUNDLE TO SHELL BYPASS    C =  15.56
PCT OVER DESIGN             -.02    BAFFLE TO SHELL LEAKAGE   E =  15.61
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000002
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)    =   .690
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BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .750
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25            WINDOW                    =    8.9
HT OPP  NOZ  IN.       .25            END ZONE                  =    3.8
VELOCITY     FT/S      .49    .49     CROSS FLOW                =    3.3
DENSITY    LB/FT3   62.252 61.769     INLET NOZZLE              =   42.8
NOZZ RHO*VSQ LB/FT-S2   14     15     OUTLET NOZZLE             =   41.2
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.17     DRY                    =      150.
DENSITY    LB/FT3   61.291 61.744     WET                    =      165.
PRESS. DROP  %         8.8    5.5



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  219.53 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1246.83 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P124
Young model F302DY4P                                            9/23/ 3
                                                                CASE 62
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .800                 .700
                                     IN       OUT         IN       OUT
TEMPERATURE        DEGF            140.0     108.5*      70.0     106.0*
DENSITY            LB/FT3        61.2913   61.7759    62.2515   61.8108
VISCOSITY          CP              .4726     .6337      .9783     .6501
SPECIFIC HEAT      BTU/LB-F        .9973     .9981     1.0015     .9983
THERMAL COND.      BTU/HR-FT-F     .3723     .3653      .3554     .3647
MOLAR MASS         LB/LBMOL                  18.02               18.02
                                   ---------------     ---------------
TEMP, AVG & SKIN        DEGF       124.2     103.9       88.0     102.9
VISCOSITY, AVG & SKIN   CP         .5439     .6638      .7892     .6707
PRESSURE, IN & DESIGN   PSIA       50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .12     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .78     10.00        .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F      261.01             295.63
                  ------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .025160
EFF TEMP DIF, DEGF  (LMTD= 36.2,F= .83,BYPASS= .94,BAFF=1.00)       28.4
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OVERALL COEFF REQUIRED   BTU/HR-FT2-F                           123.89
CLEAN & FOULED COEFF     BTU/HR-FT2-F           127.14          123.39

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2          7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL    7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS        4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.     30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.   .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED       NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %           .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH           IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM    IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM     IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN     1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P125
Young model F302DY4P                                          9/23/ 3
                                                              CASE 62
S U P P L E M E N T A R Y   R E S U L T S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .967   NOMINAL VEL,X-FLOW  FT/S         .09
PRANDTL NUMBER       5.3     3.6   NOMINAL VEL,WINDOW  FT/S         .18
RYNLD NO, AVG       334.   2318.   CROSSFLOW COEF   BTU/HR-FT2-F  296.8
RYNLD NO, IN BUN    269.   2667.   WINDOW COEF      BTU/HR-FT2-F  298.6
RYNLD NO,OUT BUN    405.   1989.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.46
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.82
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  64.84
 41.27  55.97    2.68     .09      BUNDLE TO SHELL BYPASS    C =  15.85
PCT OVER DESIGN             -.40   BAFFLE TO SHELL LEAKAGE   E =  15.49
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000033
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .715
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .777
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                      =    8.9
HT OPP  NOZ  IN.       .25         END ZONE                    =    3.6
VELOCITY     FT/S      .57    .58  CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 61.811  INLET NOZZLE                =   42.9
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NOZZ RHO*VSQ LB/FT-S2   20     20   OUTLET NOZZLE               =   41.5
BUND RHO*VSQ LB/FT-S2   13     14

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.17   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.776   WET                      =      165.
PRESS. DROP  %         8.7    5.5



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  220.15 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1248.99 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P126
Young model F302DY4P                                            9/23/ 3
                                                                CASE 63
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .800                 .800
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0     106.6*      70.0     103.3*
DENSITY            LB/FT3          61.2913   61.8014    62.2515   61.8473
VISCOSITY          CP                .4726     .6456      .9783     .6683
SPECIFIC HEAT      BTU/LB-F          .9973     .9982     1.0015     .9984
THERMAL COND.      BTU/HR-FT-F       .3723     .3649      .3554     .3641
MOLAR MASS         LB/LBMOL                    18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         123.3     101.9       86.6     100.9
VISCOSITY, AVG & SKIN  CP           .5486     .6780      .8013     .6855
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .12     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .78     10.00        .12     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     259.05               325.73
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                               .026626
EFF TEMP DIF, DEGF  (LMTD= 36.7,F= .84,BYPASS= .94,BAFF=1.00)       29.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              127.67
CLEAN & FOULED COEFF     BTU/HR-FT2-F          131.81              127.72

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
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SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH              IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM       IN.       .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM        IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT    IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P127
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 63
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .965    NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.4     3.6    NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       376.   2298.    CROSSFLOW COEF   BTU/HR-FT2-F  327.1
RYNLD NO, IN BUN    308.   2667.    WINDOW COEF      BTU/HR-FT2-F  329.0
RYNLD NO,OUT BUN    451.   1953.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.46
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.97
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.57
 38.77  58.37    2.77     .09       BUNDLE TO SHELL BYPASS    C =  16.08
PCT OVER DESIGN              .03    BAFFLE TO SHELL LEAKAGE   E =  15.38
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000003
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .740
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .804
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                        =    8.9
HT OPP  NOZ  IN.       .25          END ZONE                      =    3.4
VELOCITY     FT/S      .65    .66   CROSS FLOW                    =    3.0
DENSITY    LB/FT3   62.252 61.847   INLET NOZZLE                  =   43.0
NOZZ RHO*VSQ LB/FT-S2   26     26   OUTLET NOZZLE                 =   41.7
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.17   DRY                        =      150.
DENSITY    LB/FT3   61.291 61.801   WET                        =      165.
PRESS. DROP  %         8.7    5.5
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  220.70 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1250.44 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P128
Young model F302DY4P                                            9/23/ 3
                                                                CASE 64
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .800                .900
                                     IN        OUT        IN        OUT
TEMPERATURE        DEGF            140.0     104.9*      70.0     101.2*
DENSITY            LB/FT3        61.2913   61.8260   62.2515   61.8758
VISCOSITY          CP              .4726     .6576     .9783     .6833
SPECIFIC HEAT      BTU/LB-F        .9973     .9983    1.0015     .9986
THERMAL COND.      BTU/HR-FT-F     .3723     .3644     .3554     .3635
MOLAR MASS         LB/LBMOL                  18.02               18.02
                                   ---------------    ---------------
TEMP, AVG & SKIN       DEGF        122.4     100.1      85.6      99.0
VISCOSITY, AVG & SKIN  CP          .5532     .6910     .8111     .6991
PRESSURE, IN & DESIGN  PSIA        50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI    .12     10.00       .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S   .78     10.00       .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     257.02              356.53
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .028050
EFF TEMP DIF, DEGF  (LMTD= 36.8,F= .85,BYPASS= .96,BAFF=1.00)      29.9
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            131.49
CLEAN & FOULED COEFF     BTU/HR-FT2-F          135.92            131.52

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
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TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
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S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.021    .964    NOMINAL VEL,X-FLOW  FT/S          .12
PRANDTL NUMBER       5.5     3.6    NOMINAL VEL,WINDOW  FT/S          .23
RYNLD NO, AVG       418.   2279.    CROSSFLOW COEF   BTU/HR-FT2-F  358.0
RYNLD NO, IN BUN    346.   2667.    WINDOW COEF      BTU/HR-FT2-F  360.1
RYNLD NO,OUT BUN    496.   1917.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW             81.45
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.10
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  64.48
 36.47  60.58    2.85     .09       BUNDLE TO SHELL BYPASS    C =  16.14
PCT OVER DESIGN              .02    BAFFLE TO SHELL LEAKAGE   E =  15.28
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000001
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .766
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .833
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN     OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                      =    8.9
HT OPP  NOZ  IN.        .25         END ZONE                    =    3.2
VELOCITY     FT/S       .74     .74   CROSS FLOW                =    2.9
DENSITY    LB/FT3   62.252 61.876   INLET NOZZLE                =   43.1
NOZZ RHO*VSQ LB/FT-S2   33      33    OUTLET NOZZLE             =   41.9
BUND RHO*VSQ LB/FT-S2   22      23

  TUBE NOZZLE DATA       IN     OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.18   1.17   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.826   WET                      =      165.
PRESS. DROP  %          8.7    5.5


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  221.07 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1252.21 BTU/HR-FT2-F
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                                                                  CASE 65
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE        COLD SHELL SIDE
                                    Tube                  Shell
                                    SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .900                  .200
                                    IN       OUT          IN       OUT
TEMPERATURE        DEGF           140.0     126.9*       70.0     128.9*
DENSITY            LB/FT3        61.2913   61.5030    62.2515   61.4723
VISCOSITY          CP              .4726     .5307      .9783     .5213
SPECIFIC HEAT      BTU/LB-F        .9973     .9974     1.0015     .9974
THERMAL COND.      BTU/HR-FT-F     .3723     .3696      .3554     .3700
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                  ---------------     ---------------
TEMP, AVG & SKIN       DEGF       133.5     122.1       99.4     121.4
VISCOSITY, AVG & SKIN  CP          .5003     .5548      .6960     .5584
PRESSURE, IN & DESIGN  PSIA        50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .14     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .88     10.00        .03     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     319.31              137.36
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .011756
EFF TEMP DIF, DEGF  (LMTD= 28.1,F= .77,BYPASS= .85,BAFF=1.00)        18.4
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                               89.65
CLEAN & FOULED COEFF     BTU/HR-FT2-F           91.36               89.85

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P131
Young model F302DY4P                                             9/23/ 3
                                                                  CASE 65
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S
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HT PARAMETERS	SHELL	TUBE
WALL CORRECTION	1.031	.983
PRANDTL NUMBER	4.6	3.3
RYNLD NO, AVG	107.	2835.
RYNLD NO, IN BUN	76.	3001.
RYNLD NO,OUT BUN	143.	2672.
FOULNG LAYER IN.	.0014	.0014

THERMAL RESISTANCE, % OF TOTAL

SHELL	TUBE	FOULING	METAL
64.68	33.31	1.95	.06

PCT OVER DESIGN	.22
TOT FOUL RESIST	.000217
DIFF RESIST	.000025

DIAMETRAL CLEARANCES		
BUNDLE TO SHELL	IN.	.5000
TUBE TO BAFFLE HOLE	IN.	.0284
BAFFLE TO SHELL	IN.	.1000

SHELL NOZZLE DATA		IN	OUT
HT UNDR NOZ	IN.	.25	
HT OPP NOZ	IN.	.25	
VELOCITY	FT/S	.16	.17
DENSITY	LB/FT3	62.252	61.472
NOZZ RHO*VSQ	LB/FT-S2	1	1
BUND RHO*VSQ	LB/FT-S2	1	1

TUBE NOZZLE DATA		IN	OUT
VELOCITY	FT/S	1.33	1.32
DENSITY	LB/FT3	61.291	61.503
PRESS. DROP	%	9.0	5.7

SHELLSIDE PERFORMANCE		
NOMINAL VEL,X-FLOW	FT/S	.03
NOMINAL VEL,WINDOW	FT/S	.05
CROSSFLOW COEF	BTU/HR-FT2-F	137.9
WINDOW COEF	BTU/HR-FT2-F	138.7

SHELLSIDE FLOW, % OF TOTAL		
HEAT TRANSFER X-FLOW		80.84
TUBE TO BAFFLE LEAKAGE	A =	2.64
MAIN CROSSFLOW	B =	69.03
BUNDLE TO SHELL BYPASS	C =	11.27
BAFFLE TO SHELL LEAKAGE	E =	17.06
TUBE PASSLANE BYPASS	F =	.00

SHELLSIDE HEAT TRANSFER FACTORS		
TOTAL =(BETA)(GAMMA)(FIN)	=	.598
BETA (BAFF CUT FACTOR)	=	.920
GAMMA (TUBE ROW ENTRY EFCT)	=	.650
END (HT LOSS IN END ZONE)	=	.994

SHELL PRESSURE DROP, % OF TOTAL		
WINDOW	=	9.4
END ZONE	=	6.4
CROSS FLOW	=	5.0
INLET NOZZLE	=	41.0
OUTLET NOZZLE	=	38.1

WEIGHT PER SHELL, LB		
DRY	=	150.
WET	=	165.

*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE. CONSIDER
RERUNNING WITH ITEM 132 IN EFFECT.
HEAT TRANSFER COEFF. AT RE = 2000 IS 213.35 BTU/HR-FT2-F
HEAT TRANSFER COEFF. AT RE = 10000 IS 1229.18 BTU/HR-FT2-F

Washington University ChE433 heat exchanger experiment E0002 P132
Young model F302DY4P 9/23/ 3
CASE 66

SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING

		HOT TUBE SIDE		COLD SHELL SIDE	
		Tube		Shell	
		SENSIBLE LIQ		SENSIBLE LIQ	
TOTAL FLOW RATE	KLB/HR	.900		.300	
		IN	OUT	IN	OUT
TEMPERATURE	DEGF	140.0	122.1*	70.0	123.6*
DENSITY	LB/FT3	61.2913	61.5768	62.2515	61.5541

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VISCOSITY          CP                 .4726     .5548      .9783     .5472
SPECIFIC HEAT      BTU/LB-F           .9973     .9975     1.0015     .9975
THERMAL COND.      BTU/HR-FT-F        .3723     .3685      .3554     .3688
MOLAR MASS         LB/LBMOL                     18.02                18.02
                                      ---------------      ---------------
TEMP, AVG & SKIN       DEGF           131.1     117.8       96.8     117.0
VISCOSITY, AVG & SKIN  CP             .5111     .5782      .7159     .5826
PRESSURE, IN & DESIGN  PSIA           50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI       .14     10.00        .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S      .88     10.00        .05     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F      314.06               172.61
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                .016060
EFF TEMP DIF, DEGF  (LMTD= 30.9,F= .78,BYPASS= .91,BAFF=1.00)        22.0
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              102.33
CLEAN & FOULED COEFF     BTU/HR-FT2-F          105.04              102.86

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED          NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %              .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                   36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.         .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.          .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.          .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN        1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P133
Young model F302DY4P                                           9/23/ 3
                                                               CASE 66
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.029    .980    NOMINAL VEL,X-FLOW  FT/S          .04
PRANDTL NUMBER       4.8     3.3    NOMINAL VEL,WINDOW  FT/S          .08
RYNLD NO, AVG       157.   2775.    CROSSFLOW COEF   BTU/HR-FT2-F  173.3
RYNLD NO, IN BUN    115.   3001.    WINDOW COEF      BTU/HR-FT2-F  174.4
RYNLD NO,OUT BUN    206.   2556.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.32
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THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   2.94
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  68.08
 58.92  38.77    2.23     .07       BUNDLE TO SHELL BYPASS    C =  12.64
PCT OVER DESIGN              .52    BAFFLE TO SHELL LEAKAGE   E =  16.33
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000050
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .619
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .672
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    9.0
HT OPP  NOZ  IN.       .25          END ZONE                    =    5.2
VELOCITY     FT/S      .25    .25   CROSS FLOW                  =    4.3
DENSITY    LB/FT3   62.252 61.554   INLET NOZZLE                =   42.0
NOZZ RHO*VSQ LB/FT-S2    3      3   OUTLET NOZZLE               =   39.5
BUND RHO*VSQ LB/FT-S2    2      2

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.577   WET                      =      165.
PRESS. DROP  %         9.0    5.7



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  215.30 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1235.14 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P134
Young model F302DY4P                                           9/23/ 3
                                                               CASE 67
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .900                  .400
                                      IN        OUT         IN        OUT
TEMPERATURE        DEGF             140.0     118.3*      70.0     118.8*
DENSITY            LB/FT3         61.2913   61.6344    62.2515   61.6264
VISCOSITY          CP               .4726     .5754      .9783     .5724
SPECIFIC HEAT      BTU/LB-F         .9973     .9977     1.0015     .9977
THERMAL COND.      BTU/HR-FT-F      .3723     .3676      .3554     .3677
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         129.1     114.1       94.4     113.3
VISCOSITY, AVG & SKIN  CP           .5200     .5989      .7347     .6041
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00
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PRESSURE DROP, TOT & ALLOWED  PSI      .14     10.00         .00     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .88     10.00         .06     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      309.73              205.68
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .019505
EFF TEMP DIF, DEGF  (LMTD= 32.9,F= .80,BYPASS= .92,BAFF=1.00)      24.2
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            112.78
CLEAN & FOULED COEFF     BTU/HR-FT2-F          115.73            112.95

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment       E0002 P135
Young model F302DY4P                                            9/23/ 3
                                                                CASE 67
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.028    .977   NOMINAL VEL,X-FLOW  FT/S          .05
PRANDTL NUMBER       4.9     3.4   NOMINAL VEL,WINDOW  FT/S          .10
RYNLD NO, AVG       205.   2727.   CROSSFLOW COEF   BTU/HR-FT2-F  206.5
RYNLD NO, IN BUN    154.   3001.   WINDOW COEF      BTU/HR-FT2-F  207.9
RYNLD NO,OUT BUN    263.   2465.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW            81.47
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.22
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  66.90
 54.30  43.17    2.45     .08      BUNDLE TO SHELL BYPASS    C =  13.92
PCT OVER DESIGN              .15   BAFFLE TO SHELL LEAKAGE   E =  15.97
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000013
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .643
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)      =   .920
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TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .699
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT     SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25            WINDOW                    =    8.9
HT OPP  NOZ  IN.       .25            END ZONE                  =    4.5
VELOCITY     FT/S      .33    .33     CROSS FLOW                =    3.9
DENSITY    LB/FT3   62.252 61.626     INLET NOZZLE              =   42.5
NOZZ RHO*VSQ LB/FT-S2    6      6     OUTLET NOZZLE             =   40.3
BUND RHO*VSQ LB/FT-S2    4      4

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32     DRY                    =      150.
DENSITY    LB/FT3   61.291 61.634     WET                    =      165.
PRESS. DROP  %         9.0    5.7


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  216.75 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1239.62 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P136
Young model F302DY4P                                            9/23/ 3
                                                                CASE 68
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .900                 .500
                                     IN       OUT         IN       OUT
TEMPERATURE        DEGF            140.0     115.1*      70.0     114.7*
DENSITY            LB/FT3        61.2913   61.6808    62.2515   61.6868
VISCOSITY          CP               .4726     .5932      .9783     .5956
SPECIFIC HEAT      BTU/LB-F         .9973     .9978     1.0015     .9978
THERMAL COND.      BTU/HR-FT-F      .3723     .3669      .3554     .3668
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                   ---------------    ---------------
TEMP, AVG & SKIN       DEGF         127.6     111.1       92.4     110.1
VISCOSITY, AVG & SKIN  CP           .5275     .6173      .7515     .6232
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .14     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .88     10.00        .08     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F      306.06              236.89
                   --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .022337
EFF TEMP DIF, DEGF  (LMTD= 34.3,F= .81,BYPASS= .93,BAFF=1.00)      25.8
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             121.13
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CLEAN & FOULED COEFF     BTU/HR-FT2-F          124.29          120.97

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.        .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.         .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM      IN.         .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P137
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 68
S  U  P  P  L  E  M  E  N  T  A  R  Y     R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.027    .974    NOMINAL VEL,X-FLOW  FT/S         .07
PRANDTL NUMBER       5.0     3.4    NOMINAL VEL,WINDOW  FT/S         .13
RYNLD NO, AVG       251.   2688.    CROSSFLOW COEF   BTU/HR-FT2-F  237.8
RYNLD NO, IN BUN    192.   3001.    WINDOW COEF      BTU/HR-FT2-F  239.4
RYNLD NO,OUT BUN    316.   2391.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.49
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.45
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.82
 50.50  46.79    2.62     .09       BUNDLE TO SHELL BYPASS    C =  14.97
PCT OVER DESIGN             -.13    BAFFLE TO SHELL LEAKAGE   E =  15.75
TOT FOUL RESIST          .000217    TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST             -.000010
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .667
BUNDLE TO SHELL      IN.    .5000   BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284   GAMMA (TUBE ROW ENTRY EFCT) =   .726
BAFFLE TO SHELL      IN.    .1000   END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.        .25         WINDOW                      =    8.8
HT OPP  NOZ  IN.        .25         END ZONE                    =    4.1
VELOCITY     FT/S       .41    .41  CROSS FLOW                  =    3.5
DENSITY    LB/FT3   62.252 61.687   INLET NOZZLE                =   42.7
NOZZ RHO*VSQ LB/FT-S2   10      10  OUTLET NOZZLE               =   40.8
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BUND RHO*VSQ LB/FT-S2    7      7

  TUBE NOZZLE DATA       IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32   DRY                          =      150.
DENSITY    LB/FT3   61.291 61.681   WET                          =      165.
PRESS. DROP  %         8.9    5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  217.84 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1243.13 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P138
Young model F302DY4P                                            9/23/ 3
                                                                CASE 69
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                  Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .900                 .600
                                      IN        OUT          IN        OUT
TEMPERATURE        DEGF             140.0     112.5*       70.0     111.2*
DENSITY            LB/FT3         61.2913   61.7185    62.2515   61.7380
VISCOSITY          CP               .4726     .6086      .9783     .6169
SPECIFIC HEAT      BTU/LB-F         .9973     .9979     1.0015     .9980
THERMAL COND.      BTU/HR-FT-F      .3723     .3663      .3554     .3660
MOLAR MASS         LB/LBMOL                   18.02                18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         126.3     108.4       90.6     107.4
VISCOSITY, AVG & SKIN  CP           .5339     .6338      .7665     .6404
PRESSURE, IN & DESIGN  PSIA         50.00    165.00      50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .14     10.00        .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .88     10.00        .09     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     303.00              267.40
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                                 .024676
EFF TEMP DIF, DEGF  (LMTD= 35.2,F= .82,BYPASS= .94,BAFF=1.00)        27.1
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                              127.58
CLEAN & FOULED COEFF     BTU/HR-FT2-F           131.54             127.73

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2             7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL       7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS           4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.        30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.      .764
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SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P139
Young model F302DY4P                                            9/23/ 3
                                                                CASE 69
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.025    .972    NOMINAL VEL,X-FLOW  FT/S          .08
PRANDTL NUMBER       5.1     3.5    NOMINAL VEL,WINDOW  FT/S          .15
RYNLD NO, AVG       295.   2657.    CROSSFLOW COEF   BTU/HR-FT2-F  268.5
RYNLD NO, IN BUN    231.   3001.    WINDOW COEF      BTU/HR-FT2-F  270.1
RYNLD NO,OUT BUN    366.   2330.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW           81.49
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   3.66
 SHELL   TUBE  FOULING  METAL       MAIN CROSSFLOW            B =  65.19
 47.23  49.91    2.77     .09       BUNDLE TO SHELL BYPASS    C =  15.56
PCT OVER DESIGN               .12   BAFFLE TO SHELL LEAKAGE   E =  15.59
TOT FOUL RESIST           .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST               .000009
                                      SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES              TOTAL =(BETA)(GAMMA)(FIN)   =   .692
BUNDLE TO SHELL       IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE   IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .752
BAFFLE TO SHELL       IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25          WINDOW                      =    8.8
HT OPP  NOZ  IN.       .25          END ZONE                    =    3.8
VELOCITY     FT/S      .49    .49   CROSS FLOW                  =    3.3
DENSITY    LB/FT3   62.252 61.738   INLET NOZZLE                =   42.9
NOZZ RHO*VSQ LB/FT-S2   14     15   OUTLET NOZZLE               =   41.2
BUND RHO*VSQ LB/FT-S2   10     10

  TUBE NOZZLE DATA      IN    OUT     WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32   DRY                      =      150.
DENSITY    LB/FT3   61.291 61.719   WET                      =      165.
PRESS. DROP  %         8.9    5.6
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*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  218.71 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1245.80 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P140
Young model F302DY4P                                            9/23/ 3
                                                                CASE 70
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                     HOT TUBE SIDE       COLD SHELL SIDE
                                      Tube                 Shell
                                      SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                  .900                 .700
                                      IN       OUT         IN       OUT
TEMPERATURE        DEGF             140.0    110.3*      70.0     108.1*
DENSITY            LB/FT3         61.2913  61.7505   62.2515   61.7804
VISCOSITY          CP                .4726    .6223     .9783     .6358
SPECIFIC HEAT      BTU/LB-F          .9973    .9980    1.0015     .9982
THERMAL COND.      BTU/HR-FT-F       .3723    .3657     .3554     .3652
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         125.1    106.1      89.1     105.1
VISCOSITY, AVG & SKIN  CP            .5394    .6489     .7795     .6561
PRESSURE, IN & DESIGN  PSIA         50.00   165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI      .15    10.00       .01     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S     .88    10.00       .11     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010              .00010
FILM COEFFICIENT       BTU/HR-FT2-F     300.31              297.86
                    --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .026689
EFF TEMP DIF, DEGF  (LMTD= 35.9,F= .83,BYPASS= .94,BAFF=1.00)      28.0
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            133.51
CLEAN & FOULED COEFF     BTU/HR-FT2-F          137.84            133.58

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL         ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH            IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM     IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM      IN.        .214
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PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P141
Young model F302DY4P                                           9/23/ 3
                                                               CASE 70
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.024    .970   NOMINAL VEL,X-FLOW  FT/S         .09
PRANDTL NUMBER       5.2     3.5   NOMINAL VEL,WINDOW  FT/S         .18
RYNLD NO, AVG       338.   2629.   CROSSFLOW COEF   BTU/HR-FT2-F  299.1
RYNLD NO, IN BUN    269.   3001.   WINDOW COEF      BTU/HR-FT2-F  300.9
RYNLD NO,OUT BUN    414.   2279.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.47
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.84
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  64.85
 44.35  52.66    2.90     .10      BUNDLE TO SHELL BYPASS    C =  15.85
PCT OVER DESIGN              .05   BAFFLE TO SHELL LEAKAGE   E =  15.47
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000004
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)   =   .717
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)     =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .780
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA     IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                      =    8.8
HT OPP  NOZ  IN.       .25         END ZONE                    =    3.5
VELOCITY     FT/S      .57    .58  CROSS FLOW                  =    3.2
DENSITY    LB/FT3   62.252 61.780  INLET NOZZLE                =   43.0
NOZZ RHO*VSQ LB/FT-S2   20     20  OUTLET NOZZLE               =   41.5
BUND RHO*VSQ LB/FT-S2   13     14

  TUBE NOZZLE DATA      IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32  DRY                      =      150.
DENSITY    LB/FT3   61.291 61.750  WET                      =      165.
PRESS. DROP  %         8.9    5.6


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  219.40 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1247.99 BTU/HR-FT2-F
Washington University ChE433 heat exchanger experiment        E0002 P142
Young model F302DY4P                                           9/23/ 3
                                                               CASE 71
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SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                   HOT TUBE SIDE       COLD SHELL SIDE
                                    Tube                  Shell
                                    SENSIBLE LIQ          SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                .900                .800
                                    IN       OUT          IN       OUT
TEMPERATURE        DEGF            140.0    108.3*       70.0     105.5*
DENSITY            LB/FT3         61.2913  61.7778    62.2515  61.8164
VISCOSITY          CP               .4726    .6346      .9783    .6529
SPECIFIC HEAT      BTU/LB-F         .9973    .9981     1.0015    .9983
THERMAL COND.      BTU/HR-FT-F      .3723    .3653      .3554    .3646
MOLAR MASS         LB/LBMOL                  18.02                18.02
                                   ---------------    ---------------
TEMP, AVG & SKIN       DEGF        124.2    104.1       87.8     103.0
VISCOSITY, AVG & SKIN  CP           .5442    .6627      .7910    .6705
PRESSURE, IN & DESIGN  PSIA        50.00   165.00      50.00   165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .15    10.00        .01    10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .88    10.00        .12    10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010             .00010
FILM COEFFICIENT       BTU/HR-FT2-F     297.95             328.41
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .028427
EFF TEMP DIF, DEGF  (LMTD= 36.4,F= .84,BYPASS= .94,BAFF=1.00)      28.7
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                             138.74
CLEAN & FOULED COEFF     BTU/HR-FT2-F          143.41             138.73

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2            7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL      7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS          4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.       30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.     .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED         NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %             .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                  36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.       .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.        .250
TUBE LAYOUT         DEG      60   TUBE INSIDE DIAM       IN.        .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN       1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P143
Young model F302DY4P                                            9/23/ 3
                                                                CASE 71
S U P P L E M E N T A R Y   R E S U L T S
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  HT PARAMETERS    SHELL    TUBE     SHELLSIDE PERFORMANCE
WALL CORRECTION    1.023    .968   NOMINAL VEL,X-FLOW  FT/S          .10
PRANDTL NUMBER       5.3     3.6   NOMINAL VEL,WINDOW  FT/S          .20
RYNLD NO, AVG       381.   2606.   CROSSFLOW COEF   BTU/HR-FT2-F  329.8
RYNLD NO, IN BUN    308.   3001.   WINDOW COEF      BTU/HR-FT2-F  331.7
RYNLD NO,OUT BUN    461.   2235.
FOULNG LAYER IN.   .0014   .0014     SHELLSIDE FLOW, % OF TOTAL
                                   HEAT TRANSFER X-FLOW           81.47
THERMAL RESISTANCE, % OF TOTAL     TUBE TO BAFFLE LEAKAGE    A =   3.99
 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW            B =  64.58
 41.77  55.12    3.01     .10      BUNDLE TO SHELL BYPASS    C =  16.08
PCT OVER DESIGN              .00   BAFFLE TO SHELL LEAKAGE   E =  15.35
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS      F =    .00
DIFF RESIST              .000000
                                     SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .743
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .808
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    8.8
HT OPP  NOZ  IN.       .25         END ZONE                     =    3.3
VELOCITY     FT/S      .65    .66  CROSS FLOW                   =    3.0
DENSITY    LB/FT3   62.252 61.816  INLET NOZZLE                 =   43.1
NOZZ RHO*VSQ LB/FT-S2   26     26  OUTLET NOZZLE                =   41.7
BUND RHO*VSQ LB/FT-S2   18     18

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32  DRY                       =      150.
DENSITY    LB/FT3   61.291 61.778  WET                       =      165.
PRESS. DROP  %         8.8    5.6



*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  219.97 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1249.78 BTU/HR-FT2-F
□□Washington University ChE433 heat exchanger experiment       E0002 P144
Young model F302DY4P                                             9/23/ 3
                                                                 CASE 72
SIZE 4- 18 TYPE BEM, MULTI-PASS FLOW, SEGMENTAL BAFFLES, RATING
                                    HOT TUBE SIDE       COLD SHELL SIDE
                                     Tube                 Shell
                                     SENSIBLE LIQ         SENSIBLE LIQ
TOTAL FLOW RATE    KLB/HR                 .900                 .900
                                     IN        OUT        IN        OUT
TEMPERATURE        DEGF            140.0     106.4*      70.0     103.5*
DENSITY            LB/FT3        61.2913   61.8043    62.2515   61.8445
VISCOSITY          CP              .4726     .6470      .9783     .6668
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SPECIFIC HEAT      BTU/LB-F         .9973     .9982    1.0015     .9984
THERMAL COND.      BTU/HR-FT-F      .3723     .3648     .3554     .3641
MOLAR MASS         LB/LBMOL                   18.02               18.02
                                    ---------------     ---------------
TEMP, AVG & SKIN       DEGF         123.2     102.3      86.7     101.1
VISCOSITY, AVG & SKIN  CP           .5491     .6754     .8003     .6837
PRESSURE, IN & DESIGN  PSIA         50.00    165.00     50.00    165.00

PRESSURE DROP, TOT & ALLOWED  PSI     .15     10.00       .02     10.00
VELOCITY, CALC & MAX ALLOWED  FT/S    .88     10.00       .14     10.00

FOULING RESISTANCE     HR-FT2-F/BTU      .00010               .00010
FILM COEFFICIENT       BTU/HR-FT2-F     295.51               359.74
                  --------------------------------------
TOTAL HEAT DUTY REQUIRED MEGBTU/HR                              .030139
EFF TEMP DIF, DEGF  (LMTD= 36.5,F= .84,BYPASS= .96,BAFF=1.00)      29.4
OVERALL COEFF REQUIRED   BTU/HR-FT2-F                            143.71
CLEAN & FOULED COEFF     BTU/HR-FT2-F          148.36            143.29

SHELLS IN SERIES  1 PARALLEL  1   TOTAL EFF AREA      FT2           7.1
PASSES, SHELL     1 TUBE      4   EFFECTIVE AREA      FT2/SHELL     7.1
SHELL DIAMETER IN.        3.820   TEMA SHELL TYPE  E   ; REAR HEAD  FXTS

BAFFLE TYPE      HORZ  SEGMENTL   CROSS PASSES PER SHELL PASS         4
SPACING, CENTRAL  IN.     4.309   BAFFLE CUT, PCT SHELL I.D.      30.00
SPACING, INLET    IN.     4.309   CUT DISTANCE FROM CENTER, IN.    .764
SPACING, OUTLET   IN.     4.309
BAFFLE THICKNESS  IN.      .125   IMPINGEMENT BAFFLE INCLUDED        NO
PAIRS OF SEALING DEVICES      1   TUBESHEET BLANK AREA, %            .0

TUBE TYPE                 PLAIN   MATERIAL          ELECTROLYTIC COPPER
NO. OF TUBES/SHELL           76   EST MAX TUBE COUNT                 36
TUBE LGTH, OVERALL  FT    1.500   TUBE PITCH             IN.      .3125
TUBE LGTH, EFF      FT    1.436   TUBE OUTSIDE DIAM      IN.       .250
TUBE LAYOUT        DEG       60   TUBE INSIDE DIAM       IN.       .214
PITCH RATIO               1.250   TUBE SURFACE RATIO, OUT/IN      1.184
SHL NOZZ ID, IN&OUT   1.0   1.0   TUBE NOZZ ID, IN&OUT  IN.     .8    .8

  * CALCULATED ITEM--HEAT BALANCE CODE = 8
Washington University ChE433 heat exchanger experiment        E0002 P145
Young model F302DY4P                                            9/23/ 3
                                                                CASE 72
S  U  P  P  L  E  M  E  N  T  A  R  Y    R  E  S  U  L  T  S

  HT PARAMETERS    SHELL    TUBE      SHELLSIDE PERFORMANCE
WALL CORRECTION    1.022    .966    NOMINAL VEL,X-FLOW  FT/S          .12
PRANDTL NUMBER       5.4     3.6    NOMINAL VEL,WINDOW  FT/S          .23
RYNLD NO, AVG       423.   2583.    CROSSFLOW COEF   BTU/HR-FT2-F  361.3
RYNLD NO, IN BUN    346.   3001.    WINDOW COEF      BTU/HR-FT2-F  363.3
RYNLD NO,OUT BUN    508.   2192.
FOULNG LAYER IN.   .0014   .0014      SHELLSIDE FLOW, % OF TOTAL
                                    HEAT TRANSFER X-FLOW            81.46
THERMAL RESISTANCE, % OF TOTAL      TUBE TO BAFFLE LEAKAGE    A =   4.12
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 SHELL   TUBE  FOULING  METAL      MAIN CROSSFLOW             B =  64.51
 39.39  57.41    3.11     .10      BUNDLE TO SHELL BYPASS     C =  16.11
PCT OVER DESIGN             -.30   BAFFLE TO SHELL LEAKAGE    E =  15.25
TOT FOUL RESIST          .000217   TUBE PASSLANE BYPASS       F =    .00
DIFF RESIST             -.000021
                                    SHELLSIDE HEAT TRANSFER FACTORS
  DIAMETRAL CLEARANCES             TOTAL =(BETA)(GAMMA)(FIN)    =   .770
BUNDLE TO SHELL      IN.    .5000  BETA  (BAFF CUT FACTOR)      =   .920
TUBE TO BAFFLE HOLE  IN.    .0284  GAMMA (TUBE ROW ENTRY EFCT) =   .837
BAFFLE TO SHELL      IN.    .1000  END   (HT LOSS IN END ZONE) =   .994

  SHELL NOZZLE DATA      IN    OUT    SHELL PRESSURE DROP, % OF TOTAL
HT UNDR NOZ  IN.       .25         WINDOW                       =    8.8
HT OPP  NOZ  IN.       .25         END ZONE                     =    3.2
VELOCITY     FT/S      .74    .74  CROSS FLOW                   =    2.9
DENSITY    LB/FT3   62.252 61.844  INLET NOZZLE                 =   43.1
NOZZ RHO*VSQ LB/FT-S2   33     33  OUTLET NOZZLE                =   41.9
BUND RHO*VSQ LB/FT-S2   22     23

  TUBE NOZZLE DATA       IN    OUT    WEIGHT PER SHELL, LB
VELOCITY     FT/S     1.33   1.32  DRY                        =      150.
DENSITY    LB/FT3   61.291 61.804  WET                        =      165.
PRESS. DROP  %          8.8    5.6


*** SPECIAL MESSAGES AND WARNINGS ***

WARNING--TUBESIDE FLUID HAS PASSED THROUGH TRANSITION ZONE.  CONSIDER
         RERUNNING WITH ITEM 132 IN EFFECT.
         HEAT TRANSFER COEFF. AT RE =  2000 IS  220.36 BTU/HR-FT2-F
         HEAT TRANSFER COEFF. AT RE = 10000 IS 1251.91 BTU/HR-FT2-F
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