RESEARCH STUDY ENTITLED, "MSFC SOLAR HEATING AND COOLING HIGH SPEED PERFORMANCE (HISPER) CODE VALIDATION

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FINAL REPORT
AND
REDUCTION IN SCOPE PROPOSAL

Prepared for George C. Marshall Space Flight Center
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INTRODUCTION

This final report and reduction in scope proposal is necessary in that the principal investigator (PI) conducting the validation study is leaving Western Kentucky University effective October 15, 1979, and will be unable to continue the work. Because there is no one at Western able to continue this project, a reduction in scope appears to be the most appropriate approach.

Contained within this document is a report of activities to this point, a description of results produced and an estimate of funds utilized in the reduced efforts.

STATUS OF WORK

The validation study of the MSFC Solar Heating and Cooling High Speed Performance, while presently in the first phase of the validation as outlined in the original contract document, is at a stage to permit validation of both phases with a minimum of additional effort. All program changes necessary to use Operational Test Site (OTS) data from solar space heating and/or domestic hot water (DHW) heating installations in simulating performance are complete and both types of systems have been successfully run with the modified HISPER (WKU-HISPER) program.

The work has resulted in many program modifications, and while most of the modifications were necessary to carry out the validation, they have served to "broaden" HISPER and make it easier for engineers and architects not familiar with the program to use.

One of the modifications, resulting from a comparison of simulated and actual system performance, is a major technical modification in a computational algorithm. HISPER simulations utilizing the Togus, ME site data yielded significant differences between simulated and actual performance. Analysis of these differences and subsequent discussions with the NASA COR led to the modification of the domestic hot water solar contribution as detailed in Appendix I.

Some of the modifications made to "broaden" the HISPER program and make it easier to conduct the validation study were the following:

1. The first and most significant change was the development of a HISPER version capable of running on IBM computational systems. This change while necessary to perform the validation study at Western Kentucky University is a significant step in making HISPER a universal program.
2. The format of the input was changed to a "NAMELIST" type of format permitting clear identification of every piece of input data.
3. A units option was added to the program. The units of input and output can be in either SI or English units at the discretion of the user. The output format has also been modified to print the units next to each output value.
4. An output option to permit the computation of daily performance figures has been added to the program. This feature while simplifying comparisons between simulated and actual performance is also useful for system designers.

5. The weather tape capability of HISPER has been broadened to utilize Operational Test Site (OTS) data, Typical Meterological Year (TMY) and SOLMET weather tapes. TMY and SOLMET weather tapes are the type of tapes commonly used by engineers and architects in running computer simulations since they are readily available from the National Climatic Center.
6. Extensive comments have been added to the program to assist the user in understanding the program, the input data and the options available.

The details of the HISPER modifications are discussed and illustrated in Appendix II.

The present state of the HISPER program (WKU-HISPER) modified by the principal investigator under this contract is such that the validation study can be continued at MSFC with a minimum of effort. The WKU-HISPER program has the capability of using OTS data from any solar space heating and/or domestic hot water systems of the National Solar Data Network. The user need only input NTAPE = 2 and the appropriate channel numbers (4 values) for weather data as explained in Appendix II to simulate the performance of the OTS installations. The principal investigator is furnishing the NASA COR along with this report the WKU-HISPER program in card form as well as a program listing. The changes have all been made in fortran and the program should run on the 1108 computer at Marshall with minor changes.

Should any difficulty be encountered in the use of this program either on IBM or 1108 computational systems, the principal investigator will provide assistance as mutually agreed upon by the PI and the NASA COR.

APPENDIX I

SOLAR HOT WATER CALCULATION

The solar energy delivered to the domestic hot water in the HISPER simulations QD was calculated as follows:

$$QD = UAHX\ (TO-TPH) \qquad (1)$$

where: QD = the solar energy delivered

UAHX = the heat exchanger overall coefficient of heat transfer multiplied by the area (UA)

TO = collector fluid outlet temperature

TPH = pre-heat tank inlet temperature

As pointed out in progress report, dated Sept. '79, there are several difficulties with this equation.

1. The UA value is a function of flow rate and temperature and a catalog value of UA may not be appropriate for an operating system.
2. The temperature difference (TO-TPH) is not a mean fluid temperature difference in the heat exchanger but the maximum temperature difference between the two fluids. An alternative to equation (1) would be to use the heat exchanger effectiveness, the minimum thermal capacitance and the maximum temperature difference (TO-TPH).

$$QD = E\ C_{min}\ (TO-TPH) \qquad (2)$$

where E is the heat exchanger effectiveness

$C_{Min} = M\ C_p$ minimum

This modification was discussed with Bob Elkin of MSFC and it was decided to modify the HISPER program to reflect the effectiveness. This change resulted in other adjustments, for example, the energy balance on the preheat tank, however, it was felt that the change should be made.

The change was put into both the liquid version by Bob Elkin (MSFC) and the air version by the principal investigator in a slightly different manner due to the differences between the two versions of HISPER (the time increment). Both of the changes resulted in significant improvements, however, the iterative solution (variable time increment) of the liquid version seemed to yield better results.

APPENDIX II

MODIFICATIONS TO HISPER
AT
WESTERN KENTUCKY UNIVERSITY
(WKU-HISPER)

Many modifications were made to the HISPER program (air system) as received from NASA-MSFC during the tenure of this project. The modifications made to the HISPER air system can be directly adapted to the HISPER liquid system. The major modifications mentioned in the body of this report are detailed below.

1. Development of an IBM Version of HISPER. The HISPER program was modified to make it compatible with IBM computational systems. This was necessary to conduct the work at Western Kentucky University and will make HISPER more usable to architects, engineers, and builders outside of NASA. The changes made in converting the 1108 program to an IBM program, while many in number, are insignificant in scope. Most of the changes served to clean up the fortran program and only one fortran change to the program should be required to run WKU-HISPER on the 1108, modification of the Alpha Numberic field length (from A4 on IBM to A6 on 1108).

2. The input data format on the original HISPER program is specified in array of F fields without any identification of values other than its position in the array. The principal investigator (PI) input incorrect data several times. It was felt that input

parameters clearly identified would minimize input errors and make the program much easier to use. The input format was changed to a NAMELIST type of input and grouped as to type of information. The names of the input parameters is consistent with the names in the original program only the method of input has been changed.

The data is grouped into five catagories: (1) analysis (ANLYS) (2) Solar System (SOLSYS) (3) Water System (Water) (4) Building (BLD) and (5) Storage (STRGE).

The analysis grouping identifies the type of analysis, and establishes starting time, ending time, time increment used in computation, type of weather tape and type of system being analyzed.

The solar system group gives the specifics of the solar system components. Variables such as slope, lattitude, operating power, etc. are grouped under this heading. There is, however, one change under this grouping that changes the input values. The collector efficiency curve is input directly as obtained from manufacturers information (intercept (FRTA) and slope (FRUC)). This change was necessary for conducting the validation study and will be a useful improvement to system designers.

The water system group gives the information concerning the domestic hot water system such as pre-heat tank size, tank loss coefficient, hot water system maximum temperature, etc.

The building group gives the building specifics - loss coefficients, infiltration rates, etc.

The storage group gives the specifics on the storage system, size density of rock, etc.

As stated previously, the change in input format did not effect anything other than the collector efficiency information. The change was made to simplify input and minimize input errors. A sample of the new input format is shown in Fig. AI-1.

3. A units option was added to the program. The units option permits the user to input data in either SI or English units and get the output in either units. The option is used by simply giving the UNITS variable a value between 1 and 4 as described in the comments at the beginning of the program.

   If units = 1 input in SI output in SI

   If units = 2 input in English output in English

   If units = 3 input in Sl output in English

   If units = 4 input in English output in SI

4. An output option that yields a daily summation of system performance has been added to WKU-HISPER. The option is activated by setting PDELT equal to 24 (for 24 hours). This option causes the usual summation to be replaced with a daily total. This option, while useful in the validation study, should be an improvement worth keeping in the final HISPER version.

5. The weather data format of the WKU-HISPER program has been changed completely. First of all to conduct the validation study, it was necessary to read and utilize OTS data tapes and secondly, the only weather data usable with the original HISPER program was a specially formated Huntsville data tape. This capability has been changed so that WKU-HISPER can use OTS data tapes (for validation), TMY and SOLMET tapes for simulation with data from other locations. The type of data tape to be used is identified by setting the input value NTAPE as specified in the comments at the beginning of the program.

   If NTAPE = 0, TMY tape

   If NTAPE = 1, SOLMET tape

   If NTAPE = 2, OTS data tape

   If the OTS data tape is used, the channels containing the weather information (which change @ each site) should be given as indicated by the comments.

Channel 1 (CHNL (1)) Solar Insolation

Channel 2 (CHNL (2)) DHW Flow

Channel 3 (CHNL (3)) Ambient Temperature

Channel 4 (CHNL (4)) Water Main Temperature

6. Extensive use of comment statements has been made to assist the infrequent user with the program. The comments relating to input data are shown in Fig. AI -2.

```
$ANLYS
ITIME   =            +78,        +5,        +1,        +0,
                      +5,       +20
NTIME   =            +78,        +5,        +7,       +24,
                      +0,        +0
DELT    =  .88800000E-01
UNITS   =             +2
PDELT   =  .10000000E+01
NTAPE   =             +2
SYSTYP  =             +2

$END
$SOLSYS
ALAT    =  .44300000E+02
AZMTH   =  .16420000E+03
SLOPE   =  .45000000E+02
XMDC    =  .29770000E+04
AC      =  .17500000E+03
RHO     =  .20000000E+00
FRTA    =  .55500000E+00
FRUL    =  .78960000E+00
MODE    =             +0
PPOWER  =  .40000000E+00
CPC     =  .38000000E+03
CVFR    =  .20000000E+00

$END
$WATER
CAPPH   =  .12000000E+03
UAHX    =  .92400000E+04
TM      =  .00000000E+00
TW      =  .15000000E+03
TENV    =  .65000000E+02
HWLOSS  =  .31600000E+01
TWMAX   =  .14000000E+03

$END

$BLD
TR      =  .00000000E+00
TLH     =  .00000000E+00
TSLAB   =  .00000000E+00
NSLAB   =             +0
OINF    =  .00000000E+00
AIR     =  .00000000E+00
OGEN    =  .00000000E+00
UL      =  .00000000E+00
AL      =  .00000000E+00
UANS    =  .00000000E+00
UAEW    =  .00000000E+00
UAHOR   =  .00000000E+00
UARF    =  .00000000E+00
UAWL    =  .00000000E+00
UABS    =  .00000000E+00
UABW    =  .00000000E+00

$END
$STRGE
RHOS    =  .00000000E+00
US      =  .00000000E+00
PERIM   =  .00000000E+00
HGT     =  .00000000E+00
AREA    =  .00000000E+00
XMOS    =  .00000000E+00
COND    =  .00000000E+00
CPS     =  .00000000E+00
SVFR    =  .00000000E+00

$END
```

FIG AI-1

SAMPLE OF INPUT

```
      C
      C  *****************************************************************
      C
      C  WESTERN KENTUCKY UNIVERSITY HISPER SHAC COMPUTER CODE WKHSPR
      C
      C  *****************************************************************
      C
      C
      C  INPUT DATA INFORMATION
      C  *****************************************************************
      C
      C  UNITS IN EITHER ENGLISH OR SI%METRIC<
      C       IF UNITS EQUALS 1, INPUT IN SI OUTPUT IN SI
      C       IF UNITS EQUALS 2 INPUT IN ENGLISH OUTPUT IN ENGLISH
      C       IF UNITS EQUALS 3 INPUT IN SI OUTPUT IN ENGLISH
      C       IF UNITS EQUALS 4 INPUT IN ENGLISH OUTFUT IN SI
      C  *****************************************************************
      C  ITIME IS STARTING TIME IN I FIELD %I2< OF YR,MO,DAY,HR,MIN,SEC
      C  NTIME IS ENDING TIME IN I FIELD%I2< OF YR,MO,DAY,HR,MIN,SEC
      C  CAPPH IS CAPACITY OF PREHEAT TANK IN GALLONS OR LITTERS
      C  INFILTRATION RATES IN CFH%E< OR CMH%SI< - HEAT LOSS BASED ON 32F
      C  FOR AIR SYSTEM FLOW RATE IN SCFM OR LPM%15 C<
      C  FRTA- COLLECTOR MAXIMUM EFFICIENCY FROM CURVE-DECIMAL
      C  FRUL-CLCTR SLOPEIN F-HR-FT2/BTU%E< OR C-HR-M2/KJ %SI<
      C  PUMPPOWER IS PUMP ENERGY REQUIREMENT IN HP%E< OR KJ/HR%SI<
      C  TWMAX # DHW HIGH TEMPERATURE CUT OFF SETTING
      C  SYSTYP  IS SYSTEM TYPE AS FOLLOWS
      C     IF SYSTYP # 1, COMBINED DHW AND SPACE HEATING, ROCK STORAGE
      C     IF SYSTYP # 2, DHW HEATING SYSTEM WITH PREHEAT TANK
      C     IF SYSTYP # 3, COMBINED DHW AND SPACE HEATING, NO STORAGE
      C
      C  *****************************************************************
      C  WEATHER TAPE INFORMATION (NTAPE)
      C      IF NTAPE= 0, TYPICAL METEROLOGICAL YEAR TAPE
      C      IF NTAPE= 1, SOLMET TAPE
      C      IF NTAPE= 2, IBM SITE DATA TAPE
      C
      C  IBMDTA TAPE, LOCATION OF DATA (CHANNEL)
      C  CHANNEL ONE (CHNL(1)) CONTAINS INSOLATION CHANNEL NUMBER
      C  CHANNEL TWO (CHNL(2)) CONTAINS DHW FLOW
      C  CHANNEL THREE (CHNL(3)) CONTAINS AMBIENT TEMPERATURE
      C  CHANNEL FOUR (CHNL(4)) CONTAINS WATER MAIN TEMPERATURE
      C
      C  **********************************************
      C
      C  COMMENTS ON UNITS OF OUTPUT
      C  PP-FAN POWER IN KW-HR%E< OR KJ%SI<
      C  EW-DHW AUX ENERGY REQUIRED IN KW-HR%E< OR KJ%SI<
      C  QA- TOTAL AUX ENERGY IN KW-HR%E< OR KJ%SI<
      C  EH-HOUSE AUX ENERGY IN KW-HR%E< OR KJ%SI<
      C  GD IS THE SOLAR ENERGY DELIVERED TO DHW AND/OR HOUSE
      C  *****************************************************************
      C
      C
0001     DIMENSION Y(12),YD1(8),MON(12),YSAVE(10),YP(10),NMON(36),ID(12),
        1ID2(10)
0002     DIMENSION YE(12),YPE(10),IDS1(12),IDS2(10),IDE1(12),IDE2(10)
0003     INTEGER  UNITS, SYSTYP, CHNL
```

FIG AI-2
COMMENT STATEMENTS

```
DAILY TOTALS    5/ 6/78
GU = 6.0100E 04BTU   QD = 4.7694E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 6.7313E 04BTU
EW = 6.4651E 00KWHR  QS = 0.0        BTU   HT = 1.7289E 03BTUF  QA = 6.4651E 00BTU   PP = 7.1578E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 67.2   PER CENT HEAT&DHW# 67.2

DAILY TOTALS    5/ 7/78
GU = 6.4754E 04BTU   QD = 4.4055E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 8.0495E 04BTU
EW = 7.4901E 00KWHR  QS = 0.0        BTU   HT = 2.0256E 03BTUF  QA = 7.4901E 00BTU   PP = 7.1578E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 68.2   PER CENT HEAT&DHW# 68.2

DAILY TOTALS    5/ 8/78
GU = 9.2026E 04BTU   QD = 8.1811E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 1.0926E 05BTU
EW = 1.4366E 01KWHR  QS = 0.0        BTU   HT = 2.2099E 03BTUF  QA = 1.4366E 01BTU   PP = 6.9192E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 55.1   PER CENT HEAT&DHW# 55.1

DAILY TOTALS    5/ 9/78
GU = 2.7873E 03BTU   QD = 0.0        BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 4.7387E 04BTU
EW = 6.7195E 00KWHR  QS = 0.0        BTU   HT = 1.6505E 02BTUF  QA = 6.7195E 00BTU   PP = 6.6011E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 51.6   PER CENT HEAT&DHW# 51.6

DAILY TOTALS    5/10/78
GU = 4.3602E 04BTU   QD = 3.5608E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 5.5576E 04BTU
EW = 8.4730E 00KWHR  QS = 0.0        BTU   HT = 1.2498E 03BTUF  QA = 8.4730E 00BTU   PP = 7.1578E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 48.9   PER CENT HEAT&DHW# 48.9

DAILY TOTALS    5/11/78
GU = 7.0152E 04BTU   QD = 5.1617E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 4.4991E 04BTU
EW = 4.0642E 00KWHR  QS = 0.0        BTU   HT = 2.2628E 03BTUF  QA = 4.0642E 00BTU   PP = 7.1578E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 69.2   PER CENT HEAT&DHW# 69.2

DAILY TOTALS    5/12/78
GU = 6.0617E 04BTU   QD = 4.0706E 04BTU   QH = 0.0          BTU   EH = 0.0          KWHR  QW = 5.7405E 04BTU
EW = 4.8451E 00KWHR  QS = 0.0        BTU   HT = 1.8363E 03BTUF  QA = 4.8451E 00BTU   PP = 7.1578E 00KWHR
SOLAR FRACTION
 PER CENT HEAT#******   PER CENT DHW# 71.2   PER CENT HEAT&DHW# 71.2

DAILY TOTALS    5/13/78
```

FIG AI-3
SAMPLE OF OUTPUT