MODELLING THE DYNAMIC THERMAL CHARACTERISTICS OF CONFINEMENT LIVESTOCK HOUSING

J.J.R. Feddes  
Department of Agricultural Engineering  
University of Alberta  
Edmonton, Alberta

J.B. McQuitty  
Department of Agricultural Engineering  
University of Alberta  
Edmonton, Alberta

G.W. Sadler  
Department of Mechanical Engineering  
University of Alberta  
Edmonton, Alberta

INTRODUCTION

Present-day, large-scale, total-confinement livestock production units with their high density stocking and high level of automation are far removed from the production systems of less than a generation ago. By their very nature, these modern units are complex. The factors that affect the animals' total environment within them have become more difficult to define and evaluate. Not only do these factors produce direct effects, but also, interactions between these factors often produce effects that are less apparent yet equally important.

To maximize financial returns from these production units, all inputs must be carefully analyzed. Such an analysis should include consideration of parameters related to the environment. Problems of doing so, however, arise from incomplete data on the tolerances of livestock to their immediate environment and on the interrelationships between structural, social, and thermal environmental parameters. A further complication results from the dynamic nature of the animals' environment, in which many parameters are fluctuating and interacting. The lack of techniques to assist in this analysis is another problem.

The dynamic nature of the external environment has long been appreciated but its contribution to the overall variations in the animals' thermal environment within a specific confinement unit is not well defined. This has particular relevance in extreme climate regions such as the Canadian prairies, where the yearly temperature range is in excess of 120 Fahrenheit degrees (67 Celsius degrees). Daily temperature fluctuations often 30 Fahrenheit degrees (11 Celsius degrees) or more and where the frequency of days with clear skies is high.

A digital model has been developed that should help to evaluate the effects of environmental factors on pig production under Alberta conditions. The model was designed, however, to be adapted to any environmental situation. This paper is a report on the model and its capabilities, with examples of how it may be used. The thermal characteristics of a confinement unit may be determined for any given time period on an hourly basis.

MODELING PROCEDURE

Variables considered in the model included the following parameters:

1. Location of the unit with respect to latitude and longitude;
2. Day of the year with regard to the intensity of solar radiation;
3. Orientation of the building;
4. Indoor and outdoor dry- and wet-bulb temperatures;
5. Maximum recommended relative humidity;
6. Type and area of structural components;
7. Building color;
8. Location of windows and doors;
9. Roof slope;
10. Number and liveweight of animals confined; and
11. Heat and moisture output of the animals.

For illustrative purposes, an insulated and noninsulated unit were considered. Each unit was assumed to be located in the Edmonton area and subject to climatic conditions typical of the months of January, April, and June and representative of winter, spring, and summer seasons. The temperature range considered was from -20 to 80°F (-29 to 26.7°C). For each month, a day was chosen in which daily fluctuations in temperature varied as follows: January, -20 to 20°F (-29 to -6.7°C); April, 20 to 50°F (-6.7 to 10°C); June, 50 to 80°F (10 to 26.7°C). These daily temperatures were fitted on a representative temperature distribution curve for their respective season.

The model as represented in the flow diagram (Figure 1) was divided into five basic parts to provide the following functions, each of which is discussed subsequently.

1. Determination of solar position and intensity of solar radiation on outer surfaces of the confinement unit at hourly intervals.
2. Calculation of the response factors and heat fluxes for the individual structural components of the unit.
3. Calculation of the thermal resistance of the attic space in the pitched roof.
4. Calculation of the resultant heat load for the unit.

Figure 1. Simplified flow diagram of the confinement housing model.
Solar Radiation

The solar heat load on a wall or roof is calculated by dividing the solar radiation incident on the surface into a series of components. Each component represents a time interval. By adding the heat flux resulting from each component, the heat flow from each driving temperature can be calculated. The surface temperature history becomes a time series in which the response factors characterize the heat flow in and out of a structural slab and equations (3) and (4) consider only the outside surface of the slab.

\[
\begin{align*}
q_i, t & = q_{i+1}, t - j = \frac{Q_o, t - j}{t} \\
q_i, t & = q_{i+1}, t - j = \frac{Q_o, t - j}{t} 
\end{align*}
\]

where

\[
q_o, t = \frac{Q_o, t}{t} \quad \text{and} \quad q_i, t = \frac{Q_i, t}{t} \quad \text{he heat fluxes at a given time} \quad t \quad \text{for the outside and inside surfaces, respectively.}
\]

\[
T_o, t-j \quad \text{and} \quad T_i, t-j = \text{the outside and inside surface temperatures at time} \quad t-j \quad \text{hour.}
\]

Convection and radiation at each surface at time \( t \) were calculated as follows:

\[
S_T = \alpha T_o, t \quad \text{and} \quad S_r = \pi T_i, t \quad \text{where}
\]

\[
S = \text{radiation absorbed by surface} \quad \text{BTU} \quad \text{(h)} \quad \text{(ft}^2) \quad \text{;}
\]

\[
\alpha = \text{absorptivity of surface for short wave radiation;}
\]

\[
I = \text{shortwave radiation incident on surface, BTU} \quad \text{(h)} \quad \text{(ft}^2) \quad \text{;}
\]

\[
e = \text{gray body emissivity or absorptivity;}
\]

\[
\sigma = \text{Stefan-Boltzmann constant} \quad (0.1712 \times 10^{-8})
\]

\[
r = \text{radiation (longwave), BTU} \quad \text{(h)} \quad \text{(ft}^2) \quad \text{;}
\]

\[
\theta = \text{slab surface temperature, } ^{\circ} \text{F;}
\]

\[
C = \text{convection, BTU} \quad \text{(h)} \quad \text{(ft}^2) \quad \text{; and}
\]

\[
h = \text{film conductance, BTU} \quad \text{(h)} \quad \text{(ft}^2) \quad \text{(} ^{\circ} \text{F).}
\]

Equation (5) applied to both sides of the slab and equations (3) and (4) considered only the outside surface of the slab. The heat balance equations used in the model for each surface were as follows:

\[
S_0, t \quad - \quad T_0, t \quad + \quad C_0, t \quad - \quad q_0, t \quad = \quad 0 \quad \quad \text{(6)}
\]

\[
C_i, t \quad - \quad q_i, t \quad = \quad 0 \quad \quad \text{(7)}
\]

To solve for the outside and inside surface temperatures, the two heat balance equations were solved simultaneously in the model using the iterative procedure (6). The number of response factors for a certain slab indicated the time interval in which each surface temperature would have an effect on the heat transfer of the slab and also the time interval required to start the computation in advance such that the results are independent of the surface temperatures that were estimated prior to the computation.

Attic Space Resistance

The thermal resistance of the attic space in the pitched roof was calculated by means of an algorithm (2) that was included in the model. The degree of ventilation in the attic space, together with the convection occurring due to temperature differential, presented a problem in accurately calculating this parameter. Because the model was primarily set up to deal with maximum summer ventilation rates, the air space was assumed to be sealed. The algorithm considered the following variables: temperature differential across the air space; average temperature of the air space; thickness of the air space; direction index of the heat flow; and the emittance of the surfaces facing the air cavity. The temperature of each roof slope was assumed to be equal to its respective sol-air temperature whereas the ceiling temperature was assumed to be the indoor ambient temperature. The thickness of the air cavity was assumed to be one-half of the gable height.

Heating Load and Ventilation Rate

The heat transfer through the building and the heat production of the animals were then calculated. The resultant heat load was available for warming the exchange air and vaporizing the water excreted by the animals. The incoming air was heated and humidified as it moved through the building (Figure 2). The locations of A, B, and C (Figure 2) were obtained by the following equations (1, 4), incorporated in the model, from which the ventilation rates required to remove the moisture and heat were obtained.

\[
W_1 = 0.622 \times PW/(B - PW) \quad \text{(8)}
\]

\[
H_1 = 0.24T_o + (W_1 X HG1) \quad \text{(9)}
\]

\[
H_2 = 0.24T_i + (W_1 X HG2) \quad \text{(10)}
\]

\[
V = (0.754(T_o + 459.7)/BG1 + W_1/(4360)) \quad \text{(11)}
\]

\[
C_i = Q \times V/(60(H_2 - H_1)) \quad \text{(12)}
\]

\[
W_{th} = W_1 + (M X V)/(60 X C_h) \quad \text{(13)}
\]

\[
U_h = W_{th}/WS \quad \text{(14)}
\]

\[
WS = 6.622 \times PW/2(B - PW) \quad \text{(15)}
\]

\[
RH = 100 U_i X W_1/(1 - ((1 - U_i)/(PW/2))) \quad \text{(16)}
\]

\[
U_m = (RH1 X B) - (RH1 X PW2)/(100B) \quad \text{(17)}
\]

\[
W_m = U_m X WS \quad \text{(18)}
\]

\[
C_m = M X V/(60(W_m - W_1)) \quad \text{(19)}
\]

where

\[
W_1 = \text{absolute humidity of incoming air, lb moisture/lb dry air (d.a.);}
\]

\[
PW = \text{vapor pressure of outside air, inches Hg;}
\]

\[
H_1 = \text{enthalpy of outside air at outdoor temperature, BTU/lb d.a.;}
\]

\[
H_2 = \text{enthalpy of outside air at indoor temperature, BTU/lb d.a.;}
\]

\[
T_o = \text{outside temperature, } ^{\circ} \text{F;}
\]

\[
T_i = \text{inside temperature, } ^{\circ} \text{F;}
\]

\[
HG1 = \text{enthalpy of saturated air at outside temperature, BTU/lb d.a.;}
\]

\[
HG2 = \text{enthalpy of saturated air at inside temperature, BTU/lb d.a.;}
\]

\[
V = \text{specific volume of incoming air, ft}^3 \text{lb d.a.;}
\]

\[
C_h = \text{ventilation rate required to re-}
\]
move resultant heat load, ft²/min;

\[ Q = \frac{W^*}{H_2 - H_1} \]

\[ W = \] absolute humidity of exhaust air at \( H_2 \), lb moisture/lb d.a.;

\[ \text{PW2} = \] vapor pressure at saturation (inside temperature), inches Hg;

\[ \text{RH} = \] relative humidity for \( C_m \), %;

\[ U_h = \] degree of saturation for \( C_h \); \( \%
\]

\[ U_m = \] degree of saturation for \( C_m \); \( \%
\]

\[ \text{RH1} = \] relative humidity at \( C_m \), 70 %;

\[ W_m = \] absolute humidity of exhaust air at \( C_m \), lb moisture/lb d.a.; and

\[ C_m = \] ventilation rate required to remove moisture, ft²/min.

The ventilation rate, \( C_m \), was the quantity of air required to remove the moisture produced at 70% relative humidity. For 125-lb (56.7-kg) pigs, 70% relative humidity is the maximum recommended relative humidity for optimum conditions (4). The ventilation rate, \( C_h \), was the rate of air exchange required to remove the heat as it was being produced. During colder periods, the ventilation rate, \( C_h \), would not be sufficient to remove all the moisture produced. This was indicated by the relative humidity exceeding 70%. Under these conditions, supplemental heat would be required to ensure a ventilation rate of \( C_m \). The supplemental heat requirement was based on the following equations:

\[ Q = 60(H_2 - H_1) \times C_m/V \]  

\[ \text{SUP} = Q - Q \]  

where

\[ Q = \] heat required to remove the moisture at 70% relative humidity, BTU/h, and

\[ \text{SUP} = \] supplemental heat requirement, BTU/h.

### Pig Unit Detail

The pig confinement unit used in this model was assumed to be 32 ft wide by 180 ft long by 8 ft to the eaves (9.75 X 50.48 X 2.44 m) and oriented with its long axis running east-west. The capacity of the unit was taken to be 320 pigs at an average liveweight of 125 lb (56.7 kg).

The model included an insulated and an uninsulated version of the unit. The frame walls of the former unit were assumed to consist of two 3/8-inch (9.53-mm) plywood skins with 3-1/2-inch (88.9-mm) batt insulation. The roof, with a 1:3 slope, consisted of 3/8-inch (9.53-mm) plywood lining with 4-inch (101.6-mm) batt insulation in the false ceiling, the attic space and 1-inch (25.4-mm) wood decking with asphalt roll roofing. Double-glazed windows were located in both the north and south walls, including 80 ft² (7.43 m²) in each case. Forty-two ft² (3.90 m²) of door, insulated with 1-1/2-inch (38.1-mm) batt insulation, was provided in each gable end of the unit.

The uninsulated unit, the batt insulation was omitted from the walls to give an air space between the plywood skins. The insulation was also omitted in the ceiling and doors but the double-glazed windows were unchanged. The areas of the various components remained the same as in the insulated unit.

In the noninsulated unit, the batt insulation was omitted from the walls to give an air space between the plywood skins. The insulation was also omitted in the ceiling and doors but the double-glazed windows were unchanged. The areas of the various components remained the same as in the insulated unit.

The psychrometric data used in the model were obtained from a standard reference (5). The heat and moisture outputs for the 125-lb (56.7-kg) pigs were varied, with ambient temperatures in accordance with the data given in the Code for Farm Buildings (3). The minimum ambient temperature considered was 65°F (18.3°C) but, if the outside temperature exceeded this value, then the inside-outside temperature differential was limited to 5 Fahrenheit degrees (3.8 Celsius degrees). The external wall surface, assumed to be white, had an absorptivity factor of 0.40 and an emissivity factor of 0.92. The respective values for the roof were 0.82 and 0.93 (9).

### DISCUSSION

The program was run on an IBM System 360 Model 67 computer using Virtual Memory facilities and the Michigan Terminal System. The run cost for a 48-h period in each of the three seasons considered and for the two pig confinement units was $8.49. This included $6.76 (CPU time 48.95 s) for compiling and storage of the Fortran program and $1.73 (CPU time 8.25 s) for processing of the sample data.

Sample outputs from the model are presented in Tables I, II, and III. Although the model was programmed to obtain output values on an hourly basis, the data in these tables are given at 2-h intervals. Their purpose is to indicate the nature of the information provided and to illustrate the trends that may occur for various variables.

A major advantage of this model is its flexibility. New or additional algorithms may be added at any time provided that the data for these are available. The effects of wind or snow on the heat load, for example, may be readily incorporated in the model. This flexibility thus allows many variables to be considered.

Because the dynamic thermal characteristics of a confinement unit may be studied over a several day period, the model would appear to be a potentially valuable tool for the designer. Various combinations of materials for structural components may be evaluated for any building orientation and the results used as an aid in decision making with respect to such considerations as a cost analysis of supplemental heating requirements for different levels of insulation. A study, for instance, of peak heat loads and their duration may be valuable in deciding whether additional ventilation is required or whether the animals can tolerate the stress conditions without suffering adverse effects on their production.

The model appears to have value in assisting in defining areas in which data
## TABLE I

**WEST WALL THERMAL CHARACTERISTICS FOR BOTH INSULATED AND NONINSULATED CONFINEMENT PIG UNITS**

- **Date:** Jung 21; **Latitude:** 53.34°; **Longitude:** 90.00°; **Surface azimuth:** 90.00°11.31;
- **Location:** Edmonton; **Equation of time:** -1.633; **Declination:** 23.521°

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td></td>
</tr>
</tbody>
</table>

## TABLE II

**RESULTANT HEAT FLOW (BTU/h) THROUGH STRUCTURAL COMPONENTS OF THE INSULATED AND NONINSULATED CONFINEMENT UNITS ON JUNE 21**

<table>
<thead>
<tr>
<th>Hour</th>
<th>Walls</th>
<th>Doors</th>
<th>Floor</th>
<th>Roof</th>
<th>Windows</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0:00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>1:00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>2:00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
<td>2.00</td>
</tr>
<tr>
<td>3:00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
<td>3.00</td>
</tr>
<tr>
<td>4:00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

The model has not yet been verified in the field. Experience with and modifications to the model are required before it can be fully evaluated and its limitations are understood. The model is not yet proven in the field, and its performance is not yet adequate and may be insufficient for the conditions in which it is used, especially in conjunction with existing models. It may assist in relieving thermal stress on the animals under extreme temperatures or, conversely, in reducing supplemental heating requirements under winter conditions.
TABLE III  VENTILATION RATES AND THERMAL ENVIRONMENT CHARACTERISTICS OF THE INSULATED AND NONINSULATED CONFINEMENT PIG UNITS ON JUNE 21

<table>
<thead>
<tr>
<th>Environment</th>
<th>0400</th>
<th>0600</th>
<th>0800</th>
<th>1000</th>
<th>1200</th>
<th>1400</th>
<th>1600</th>
<th>1800</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent rate ($C_m$), moisture control, ft³/min</td>
<td>4824</td>
<td>3724</td>
<td>4953</td>
<td>3542</td>
<td>3908</td>
<td>3810</td>
<td>2745</td>
<td>2966</td>
<td>3200</td>
</tr>
<tr>
<td>Relative humidity at $C_m$, %</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
<td>70</td>
</tr>
<tr>
<td>Animal sensible heat, BTU/h</td>
<td>88000</td>
<td>80000</td>
<td>80000</td>
<td>67200</td>
<td>48000</td>
<td>41600</td>
<td>32000</td>
<td>32000</td>
<td>32000</td>
</tr>
<tr>
<td>Animal moisture, lb/h</td>
<td>67</td>
<td>67</td>
<td>74</td>
<td>80</td>
<td>90</td>
<td>96</td>
<td>106</td>
<td>106</td>
<td>106</td>
</tr>
<tr>
<td>Outside dry bulb, °F</td>
<td>50</td>
<td>58</td>
<td>65</td>
<td>69</td>
<td>75</td>
<td>77</td>
<td>80</td>
<td>78</td>
<td>78</td>
</tr>
<tr>
<td>Outside wet bulb, °F</td>
<td>47</td>
<td>55</td>
<td>56</td>
<td>57</td>
<td>63</td>
<td>62</td>
<td>64</td>
<td>64</td>
<td>63</td>
</tr>
<tr>
<td>Outside relative humidity, %</td>
<td>81</td>
<td>84</td>
<td>58</td>
<td>49</td>
<td>53</td>
<td>44</td>
<td>43</td>
<td>43</td>
<td>45</td>
</tr>
<tr>
<td>Inside dry bulb, °F</td>
<td>65</td>
<td>65</td>
<td>70</td>
<td>74</td>
<td>80</td>
<td>82</td>
<td>85</td>
<td>85</td>
<td>83</td>
</tr>
</tbody>
</table>

### Insulated

<table>
<thead>
<tr>
<th>Environment</th>
<th>0400</th>
<th>0600</th>
<th>0800</th>
<th>1000</th>
<th>1200</th>
<th>1400</th>
<th>1600</th>
<th>1800</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent rate ($C_h$), heat control, ft³/min</td>
<td>5436</td>
<td>12466</td>
<td>14632</td>
<td>14306</td>
<td>11562</td>
<td>11019</td>
<td>7133</td>
<td>7635</td>
<td>7635</td>
</tr>
<tr>
<td>Relative humidity at $C_h$, %</td>
<td>67</td>
<td>74</td>
<td>36</td>
<td>48</td>
<td>53</td>
<td>46</td>
<td>48</td>
<td>49</td>
<td>49</td>
</tr>
<tr>
<td>Resultant heat load, BTU/h</td>
<td>84142</td>
<td>85700</td>
<td>72004</td>
<td>71175</td>
<td>56903</td>
<td>34011</td>
<td>39651</td>
<td>37222</td>
<td>42665</td>
</tr>
<tr>
<td>Heating or cooling load at $C_m$, BTU/h</td>
<td>-9471</td>
<td>80102</td>
<td>-47173</td>
<td>-53999</td>
<td>-39147</td>
<td>-40235</td>
<td>-26269</td>
<td>-23839</td>
<td>-28642</td>
</tr>
</tbody>
</table>

### Noninsulated

<table>
<thead>
<tr>
<th>Environment</th>
<th>0400</th>
<th>0600</th>
<th>0800</th>
<th>1000</th>
<th>1200</th>
<th>1400</th>
<th>1600</th>
<th>1800</th>
<th>2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vent rate ($C_h$), heat control, ft³/min</td>
<td>4377</td>
<td>11013</td>
<td>14858</td>
<td>16972</td>
<td>15531</td>
<td>15430</td>
<td>11547</td>
<td>9802</td>
<td>8891</td>
</tr>
<tr>
<td>Relative humidity at $C_h$, %</td>
<td>72</td>
<td>75</td>
<td>56</td>
<td>47</td>
<td>51</td>
<td>43</td>
<td>44</td>
<td>46</td>
<td>45</td>
</tr>
<tr>
<td>Resultant heat load, BTU/h</td>
<td>67743</td>
<td>78367</td>
<td>74623</td>
<td>84438</td>
<td>76438</td>
<td>75635</td>
<td>57754</td>
<td>47784</td>
<td>43508</td>
</tr>
<tr>
<td>Heating or cooling load at $C_m$, BTU/h</td>
<td>6929</td>
<td>90439</td>
<td>-49792</td>
<td>-67262</td>
<td>-58683</td>
<td>-61859</td>
<td>-44372</td>
<td>-3402</td>
<td>-24845</td>
</tr>
</tbody>
</table>

The flexibility and adaptability of the model are discussed. Several advantages are outlined and its potential value in both practical and research considerations stressed.

**ACKNOWLEDGEMENTS**

The authors acknowledge the financial support of the Alberta Agricultural Research Trust.

**REFERENCES**

<table>
<thead>
<tr>
<th>Number</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>American Society of Heating, Refrigerating and Air-Conditioning Engineers.</td>
</tr>
<tr>
<td>2</td>
<td>American Society of Heating, Refrigerating and Air-Conditioning Engineers.</td>
</tr>
</tbody>
</table>