Final Report and Design Documentation

PASSIVE SOLAR ALASKAN SCHOOL

PROTOTYPE DESIGN

A JOINT PROJECT

OF

STATE OF ALASKA
DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES
DIVISION OF PLANNING AND PROGRAMMING
RESEARCH SECTION
2301 Peger Road
Fairbanks, Alaska 99701

AND

U.S. DEPARTMENT OF ENERGY
PASSIVE SOLAR COMMERCIAL BUILDINGS
DESIGN ASSISTANCE AND DEMONSTRATION
CHICAGO OPERATIONS AND REGIONAL OFFICE

January, 1981

PROJECT LOCATION: FAIRBANKS, ALASKA

OWNER: ALASKA DEPARTMENT OF TRANSPORTATION AND PUBLIC FACILITIES

ARCHITECT: JANET MATHESON, AIA

ENERGY CONSULTANT: RICHARD D. SEIFERT

The opinions, findings and conclusions expressed in this publication are those of the author and are not necessarily those held by the State of Alaska.
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Introduction 

Final Economic Analysis. 

Architectural Compatibility. 

Thermal Capacitance Test of Prompt Wall Idea 

Appendix
CHAPTER 1

OVERVIEW OF THE REQUIREMENTS
1. OVERVIEW OF THE WORK EXECUTED UNDER THE TASK

The State of Alaska is required by the Hootch Decision to build schools in rural Alaska in all villages where more than 8 students are present in order that they not be required to leave their villages to attend school. The Department of Transportation and Public Facilities is responsible for building these rural schools. Obviously, it is in the best interest of the state to build and maintain these buildings at the least cost and make them as self-sufficient as possible. This would contrast sharply with buildings presently in use, some of which cost $250/ft² to construct and use 800,000 BTU/ft²/year for heating and utilities. They are commonly supplied by fuel oil at some of the highest fuel prices in the nation. All functional and appropriate means were sought to limit these costs for schoolroom application.

Although the major problem of rural schools is electrical generation which is not load-following, and which is very expensively generated by a diesel generator often brought in for that purpose only, the problems addressed in the school design were those of heating and lighting that can displace some of the need for electrical generation, as well as the burning of fuel oil for heat. The electrical generation problem is being further addressed through another complimentary project in which the use of an organic Rankine cycle turbine generator, which is load-following, is investigated for electric generation. Our design approach then, should be regarded as attempting to solve one element of the operational problems of rural schools in Alaska: heating and lighting using passive solar gain.

Our design process was approached in a textbook manner. We assembled as much information and data as possible on present day rural schools, although very little data on fuel use is accurate or available. Interviews with DOTPF facilities planners and designers (Mr. Bob Venusti, Mr. Keith Gurkin, Mr. Charles Chaney) were conducted to give the design team further perspectives on school design. Models of school buildings were made and possible school configurations were investigated using the models. Configurations which optimized solar exposure of the classroom areas were, of course, preferred. It was found that a common design
pattern was emerging in rural schools. The pattern consists of a large central room (a combination gymnasium and multi-purpose room), surrounded by a cluster of classrooms that are typically 20 x 30 ft. We focussed upon this module to optimize our design process.

We determined that present school designs used 8-inch walls with 2 x 8 studs, and that optimization of the structure was not attempted by the state. Design tools open to us were the models, some state design experience, and some solar radiation data (hourly). We developed our own sun angle charts and utilized the TRNSYS computer program extensively for modeling the performance of our test module designs throughout the heating season.

The most important criteria for our decision-making processes regarding the rural school design were as follows:

1). What were the experiences of the DGTPF in past school buildings? I.e., we tried to avoid past errors.

2). What are the fundamental cost problems for schools in rural Alaska?

3). What are the available energy sources to tap? Solar energy is the best option, coupled with good structural and conservation design.

4). How is energy self-sufficiency best achieved for rural Alaska?

5). What onsite materials are available?

6). What systems are likely to fail in the environment of rural Alaska? "Keeping it simple," was a high priority.

2. DESCRIPTION OF DESIRED, BUT UNAVAILABLE INFORMATION

Much of our data and solar experience is limited and we as a team were relatively low on the solar learning curve, simply because this passive solar school project is the first experience that we were afforded. We used our own data, tabulated and developed for this work, drew our own sun charts, and used the Fairbanks climatic data. Our data for rural schools energy use included that of the design and planning division of the Alaska Department of Transportation and Public Facilities, and that obtained from Mr. Charles Chaney, director of Plant Facilities for the Yukon-Koyukuk School District.
TO: Rick Seifert  
Research Associate  
University of Alaska  
Fairbanks, Alaska 99701

FROM: Charley Chaney  
Director, Plant Facilities

SUBJECT: Energy Consumption

Got some numbers for a couple of sites—None of these run generators.

Bettles is a two classroom school with a one bedroom apartment attached. We have no way to separate the energy consumed in the separate parts of the building. Fuel is for heating. Only domestic water is pumped and heated electrically.

Manley Hot Springs is a modular hodgepodge, fuel heated with some auxiliary space heating by electricity roughly reflected as classroom lighting Meter No. One. Meter No. Two is mostly space heating, water pumping and heating. The monthly consumption patterns don't follow any logic—your guess is better than mine as to an explanation for the pattern.

Tanana has the most dependable numbers. The electrical load is lighting and air handling. Heat is fuel. The Tanana Voc. Ed. is added for interest. The fuel consumption can't be identified within the delivery tickets. The electrical consumption is lights, power tools, etc.

Anything else you need let me know.
ELECTRICITY AND FUEL CONSUMPTION  
(FY '79)

BETTLES - 2,120 sq. ft.

<table>
<thead>
<tr>
<th>Month</th>
<th>New Building</th>
<th>Old Building</th>
<th>Total KWH</th>
</tr>
</thead>
<tbody>
<tr>
<td>July '78</td>
<td>460</td>
<td>60 KWH</td>
<td>520 KWH</td>
</tr>
<tr>
<td>Aug. '78</td>
<td></td>
<td>870</td>
<td></td>
</tr>
<tr>
<td>Sep. '78</td>
<td></td>
<td>1630</td>
<td></td>
</tr>
<tr>
<td>Oct. '78</td>
<td></td>
<td>2090</td>
<td></td>
</tr>
<tr>
<td>Nov. '78</td>
<td></td>
<td>2250</td>
<td></td>
</tr>
<tr>
<td>Dec. '78</td>
<td></td>
<td>2190</td>
<td></td>
</tr>
<tr>
<td>Jan. '79</td>
<td></td>
<td>2590</td>
<td></td>
</tr>
<tr>
<td>Feb. '79</td>
<td></td>
<td>3750</td>
<td></td>
</tr>
<tr>
<td>Mar. '79</td>
<td></td>
<td>3290</td>
<td></td>
</tr>
<tr>
<td>Apr. '79</td>
<td></td>
<td>2800</td>
<td></td>
</tr>
<tr>
<td>May '79</td>
<td></td>
<td>1800</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>23780 KWH</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Fuel (gals.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/04/78</td>
<td>349.9</td>
</tr>
<tr>
<td>10/31/78</td>
<td>332.7</td>
</tr>
<tr>
<td>12/15/78</td>
<td>263.5</td>
</tr>
<tr>
<td>12/20/78</td>
<td>243.4</td>
</tr>
<tr>
<td>01/10/79</td>
<td>307</td>
</tr>
<tr>
<td>01/31/79</td>
<td>326</td>
</tr>
<tr>
<td>02/15/79</td>
<td>326</td>
</tr>
<tr>
<td>03/15/79</td>
<td>403.4</td>
</tr>
<tr>
<td>04/17/79</td>
<td>257.5</td>
</tr>
<tr>
<td>05/17/79</td>
<td>238</td>
</tr>
</tbody>
</table>

3047.4 gals. fuel
MANLEY HOT SPRINGS - Approximately 2,000 sq. ft.

**Manley Utility Co.**

<table>
<thead>
<tr>
<th>Month</th>
<th>Meter No. 1</th>
<th>Meter No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>May '79</td>
<td><em>510 KWH</em></td>
<td><strong>3470</strong></td>
</tr>
<tr>
<td>Apr. '79</td>
<td>630</td>
<td>3890</td>
</tr>
<tr>
<td>Mar. '79</td>
<td>670</td>
<td>7070</td>
</tr>
<tr>
<td>Feb. '79</td>
<td>800</td>
<td>6890</td>
</tr>
<tr>
<td>Jan. '79</td>
<td>520</td>
<td>4540</td>
</tr>
<tr>
<td>Dec. '78</td>
<td>680</td>
<td>3310</td>
</tr>
<tr>
<td>Nov. '78</td>
<td>590</td>
<td>2270</td>
</tr>
<tr>
<td>Oct. '78</td>
<td>490</td>
<td>1230</td>
</tr>
<tr>
<td>Sep. '78</td>
<td>100</td>
<td>210</td>
</tr>
<tr>
<td>Aug. '78</td>
<td>10</td>
<td>50</td>
</tr>
</tbody>
</table>

Fuel - 2,000 gallons

* Classroom Lights and Forced Air

** Water Heating; Some space heating (Not Classroom)
TANANA SCHOOL - 25,000 heated sq. ft.

**Tanana Power**

<table>
<thead>
<tr>
<th>Month</th>
<th>FY '79</th>
<th>FY '80</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>5200 KWH</td>
<td>6160 KWH</td>
</tr>
<tr>
<td>Aug.</td>
<td>5680</td>
<td>7840</td>
</tr>
<tr>
<td>Sep.</td>
<td>14640</td>
<td>13120</td>
</tr>
<tr>
<td>Oct.</td>
<td>21200</td>
<td>15760</td>
</tr>
<tr>
<td>Nov.</td>
<td>20880</td>
<td>15840</td>
</tr>
<tr>
<td>Dec.</td>
<td>20000</td>
<td></td>
</tr>
<tr>
<td>Jan.</td>
<td>22080</td>
<td></td>
</tr>
<tr>
<td>Feb.</td>
<td>19360</td>
<td></td>
</tr>
<tr>
<td>Mar.</td>
<td>19600</td>
<td></td>
</tr>
<tr>
<td>Apr.</td>
<td>19600</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>15280</td>
<td></td>
</tr>
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</table>

183520 KWH 58720 KWH
**Tanana Power**

<table>
<thead>
<tr>
<th>Month</th>
<th>FY'79</th>
<th>FY'80</th>
</tr>
</thead>
<tbody>
<tr>
<td>July</td>
<td>465 KWH</td>
<td>606 KWH</td>
</tr>
<tr>
<td>Aug.</td>
<td>379</td>
<td>768</td>
</tr>
<tr>
<td>Sep.</td>
<td>2472</td>
<td>2898</td>
</tr>
<tr>
<td>Oct.</td>
<td>4020</td>
<td>3599</td>
</tr>
<tr>
<td>Nov.</td>
<td>3373</td>
<td>13368</td>
</tr>
<tr>
<td>Dec.</td>
<td>2964</td>
<td></td>
</tr>
<tr>
<td>Jan.</td>
<td>4263</td>
<td></td>
</tr>
<tr>
<td>Feb.</td>
<td>4725</td>
<td></td>
</tr>
<tr>
<td>Mar.</td>
<td>4413</td>
<td></td>
</tr>
<tr>
<td>Apr.</td>
<td>4952</td>
<td></td>
</tr>
<tr>
<td>May</td>
<td>2309</td>
<td></td>
</tr>
</tbody>
</table>

34335 KWH  21239 KWH
FIGURE 1

HEATING DEGREE DAYS - FAIRBANKS, ALASKA

AVERAGE SOLAR RADIATION ON A VERTICAL SURFACE - SOUTH FACING
FAIRBANKS, ALASKA
October 20, 1980

Richard Seifert  
c/o Battelle-Northwest Laboratories  
HS-4 Building, 3000 Area  
Richland, Washington 99352

Re: Solar Alaskan School, Project No. 7988

Dear Rich,

Enclosed please find a copy of the solar school cost estimate, which I received last Thursday. At present, without a specific site, it works out at $162.50/square foot; this figure is deceptive, however, as it includes that huge ramp attached to one side of the building, which represents a sizeable framing and roofing cost.

<table>
<thead>
<tr>
<th>Item</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>$300</td>
</tr>
<tr>
<td>6100 Rough Carpentry</td>
<td>3,000</td>
</tr>
<tr>
<td>7210 Building Insulation</td>
<td>3,000</td>
</tr>
</tbody>
</table>

This figure is 9% of the total cost, which may prove a good comparison with the energy savings provided by the design.

Please let me know if you need more detailed information than the above.

Yours sincerely,

[Signature]

Janet M. Matheson AIA  
JANET MATHESON ARCHITECT

Enclosure (1)
October 10, 1980

Janet Matheson, Architect
P.O. Box 80567
Fairbanks, Alaska 99708

REF: Passive Solar Rural School Classroom Prototype

SUBJ: Preliminary Construction Cost Estimate

Dear Ms. Matheson:

The estimated cost of construction of the prototype classroom is $156,000. Enclosed is a recapitulation of the estimate together with the supporting data. This estimate is incomplete in that it does not include the costs generally associated with remote site construction. The cost does include an allowance for piling foundations as if it were to be constructed at a remote site. However, this amount could vary greatly depending on the site and other circumstances.

It is very difficult to offer a reliable cost guide for a completed structure until a site is selected. In this

When a site is selected, I will be glad to look at this estimate again and revise to meet actual conditions.

Very truly yours,

CLARK-GRAVES, INC.

Donald M. Graves

DG/jb
## Recapitulation

Passive Solar Rural Classroom Prototype  
Janet Matheson, Architect

<table>
<thead>
<tr>
<th>Code</th>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>General Requirements</td>
<td>n/a</td>
</tr>
<tr>
<td>2</td>
<td>Sitework</td>
<td>n/a</td>
</tr>
<tr>
<td>2350</td>
<td>Pile Foundations</td>
<td>$40,000</td>
</tr>
<tr>
<td>5</td>
<td>Metals</td>
<td>6,000</td>
</tr>
<tr>
<td>6100</td>
<td>Rough Carpentry</td>
<td>12,000</td>
</tr>
<tr>
<td>6170</td>
<td>Glulam Units</td>
<td>4,000</td>
</tr>
<tr>
<td>6190</td>
<td>Prefab Trusses</td>
<td>5,000</td>
</tr>
<tr>
<td>6192</td>
<td>Fabricated Joists</td>
<td>2,000</td>
</tr>
<tr>
<td>6200</td>
<td>Finish Carpentry</td>
<td>5,000</td>
</tr>
<tr>
<td>7190</td>
<td>Vapor Barrier</td>
<td>1,000</td>
</tr>
<tr>
<td>7210</td>
<td>Building Insulation</td>
<td>8,000</td>
</tr>
<tr>
<td>7600</td>
<td>Sheet Metal &amp; Metal Roofing</td>
<td>13,000</td>
</tr>
<tr>
<td>7900</td>
<td>Sealants</td>
<td>1,000</td>
</tr>
<tr>
<td>8110</td>
<td>Hollow Metal Work</td>
<td>1,000</td>
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<tr>
<td>8200</td>
<td>Wood Doors</td>
<td>2,000</td>
</tr>
<tr>
<td>8600</td>
<td>Wood Windows</td>
<td>3,000</td>
</tr>
<tr>
<td>8700</td>
<td>Finish Hardware</td>
<td>2,000</td>
</tr>
<tr>
<td>8850</td>
<td>Glass &amp; Glazing</td>
<td>-0-</td>
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<tr>
<td>9250</td>
<td>Gypsum Drywall</td>
<td>6,000</td>
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<tr>
<td>9500</td>
<td>Acoustical Treatment</td>
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<tr>
<td>9650</td>
<td>Resilient Flooring</td>
<td>1,000</td>
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<tr>
<td>9680</td>
<td>Carpeting</td>
<td>3,000</td>
</tr>
<tr>
<td>9900</td>
<td>Paint</td>
<td>4,000</td>
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<tr>
<td>10100</td>
<td>Chalkboard &amp; Tackboard</td>
<td>1,000</td>
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<tr>
<td>10800</td>
<td>Misc. Specialties</td>
<td>1,000</td>
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<tr>
<td>12670</td>
<td>Floor Mats</td>
<td>-0-</td>
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<tr>
<td>15</td>
<td>Mechanical</td>
<td>17,000</td>
</tr>
<tr>
<td>16</td>
<td>Electrical</td>
<td>9,000</td>
</tr>
</tbody>
</table>

**Total Estimated Cost**  
$156,000

CLARK-GRAVES, INC.  
October 10, 1980
We would have very much liked to have had actual experience and data correlating available solar radiation with building heating. Attached are data examples that we have developed or obtained.

3. INCREMENTAL SOLAR DESIGN COSTS

We have estimated the incremental solar costs of construction.

<table>
<thead>
<tr>
<th>Materials (see following pages.)</th>
<th>Solar</th>
<th>$ 7,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convection</td>
<td>6,300</td>
<td></td>
</tr>
<tr>
<td>Architectural work (follows)</td>
<td>15,000</td>
<td></td>
</tr>
<tr>
<td>Energy consultant</td>
<td>14,000</td>
<td></td>
</tr>
<tr>
<td>Computer time</td>
<td>1,400</td>
<td></td>
</tr>
<tr>
<td>Overhead and inhouse costs</td>
<td>14,000</td>
<td></td>
</tr>
<tr>
<td><strong>Total Passive Design Increment Costs</strong></td>
<td><strong>$57,700</strong></td>
<td></td>
</tr>
</tbody>
</table>

Note that $44,000 of this cost is atypical of future passive design efforts, since most of the learning from this experience is being incorporated into the Alaska Solar Design Manual and will be available as general professional knowledge henceforth. As stated earlier, a considerable amount of time was devoted to bringing our skills and experience levels up to the state of the art in passive solar design. We examined each possibility and tested it for its merits in this (sub-arctic) climate. The original test elements were derived from a staff brainstorming session.

4. PERFORMANCE ANALYSIS, RESULTS AND COMPARISONS

4a. Breakdown of Each End Use:

When passive solar design was chosen as a best approach to the rural school energy problem for heating, several standard passive design options were developed and tested using TRNSYS computer simulation. The base case school design is a module of the prototype design, 20 x 30 x 10 ft. Its performance is based on the specifications of an
actual school (the Manley School) built in 1978 at Manley Hot Springs, Alaska. It has 2 x 8-inch stud walls, an oil heating system. It is approximately twice the size of the module and has only south-facing glazing. A photo is included of this school. Lighting in the school is approximately 2.42 watts/ft$^2$, based on the design, or 8.29 BTU/ft$^2$/hr. This lighting energy provides a substantial amount of heat to the structure, and because of the requirements to load the generator 24 hours a day, the lighting is assumed to be on for 24 hours. This constitutes one of the major problems of rural schools—the problem of electrical utilities and diesel generation.

This project is attempting to solve the heating part of the rural school problem. We are aware that the electricity supply and efficiency problems are of greater magnitude, but they are being addressed in another project.

Below is a calculation of the base case heating and lighting loads for an Alaskan rural school classroom. Hereafter, it shall be referred to as Design 1.

---

**PRE-DESIGN ESTIMATE**
**STATE-OF-THE-ART SCHOOL**

<table>
<thead>
<tr>
<th>WALLS:</th>
<th>2x8 Stud with full batt fiberglass</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF:</td>
<td>12&quot; fiberglass, truss, metal surface</td>
</tr>
<tr>
<td>FLOOR:</td>
<td>6&quot; fiberglass, truss</td>
</tr>
<tr>
<td>FOUNDATION:</td>
<td>Pile, uninsulated crawl space</td>
</tr>
<tr>
<td>FLOOR AREA</td>
<td></td>
</tr>
<tr>
<td>WINDOWS:</td>
<td>96 ft$^2$ 60 ft$^2$ SOUTH FACING 36 ft$^2$ E-W FACING</td>
</tr>
<tr>
<td>VENTILATION REQUIREMENT:</td>
<td>~.5 Air change per hour</td>
</tr>
</tbody>
</table>

---

**HEAT LOSS CALCULATIONS**

24 hour day, 65°F base is used in the calculation. 24 hour lighting considered due to need to lead generator.
FOR INFILTRATION:
1. Code ventilation is 5 CFM per occupant.
2. Occupancy assumed: 12 hours, 10 adult-equivalent occupants, requiring 50 CFM × 60 MIN = 3,000 cf/hr
   \[= \frac{1}{2} \text{ air change/hr}\]
3. \[Q \text{ INF.} = 0.5 \text{ ACH (0.075 lb/ft}^3\text{)} (0.24 \text{ BTU/lb °F}) (24 \text{ hrs/day})\]
   \[= 1296 \text{ BTU}/^{\circ}\text{F-DAY}\]

FOR THE BUILDING SHELL:
A. CEILING:
   \[UA = \frac{1}{R} \text{(AREA)} = \frac{1}{\frac{1}{38.61}} (600) = 15.54 \text{ BTU}/\text{ft}^2\text{-hr}\]
B. FLOOR:
   \[UA = \frac{1}{R} \text{(AREA)} = \frac{1}{\frac{1}{18.99}} (600) = 31.59 \text{ BTU}/\text{ft}^2\text{-hr}\]
C. WALLS:
   \[UA = \frac{1}{R} \text{(AREA)} = \frac{1}{\frac{1}{22.23}} (904) = 40.67 \text{ BTU}/\text{ft}^2\text{-hr}\]
D. DOOR:
   \[UA = \frac{1}{10} \text{(20 ft)} = 2.\]
E. WINDOWS:
   \[UA = \frac{1}{5} \text{(96 ft)} = \frac{48.00}{137.80} \text{ BTU}/\text{ft}\text{-hr}\]

The total heat loss (UA Product) is, using 24 hour day:
\[3,307 \text{ BTU}/^{\circ}\text{F-day (Building Shell)}\]
\[1,296 \text{ BTU}/^{\circ}\text{F-day (Infiltration/ventilation)}\]
\[4,603 \text{ BTU}/^{\circ}\text{F-day}\]

Using the degree-days for Fairbanks, and without considering July and August, the total heating degree-days are:
14,344 (entire year)
- 148 (July)
- 304 (August)
13,892 Degree-days
CONSTRUCTIONS:

WALLS: 2x8 STUDS W/ FULL EXTERIOR FIBERGLASS.

ROOF: 12" FIBERGLASS METAL ROOFING.

FOUNDATION: PILES OF I-205 W/ INSULATED FLOOR.

FLOOR AREA: 600 SQ.

WINDOW: DOUBLE PANED, NON-SHUTTERED.

WINDOW AREA: SOUTH 60 SQ.

BUILDING UA: 8723 BTU/DEC.

VENT RATE: .54 ACH.

ADDED THERMAL MASS: NONE.

SHAPING MECHANISM: NONE.

FLOOR PLAN

SOUTH ELEVATION

SECTION
TRNSYS SIMULATION

COOLING FAN ENERGY

- Jan: 0
- Feb: 2.8 x 10^3 (4) KJ
- Mar: 4.2 x 10^3 (4) KJ
- Apr: 5.4 x 10^3 (4) KJ
- May: 8.5 x 10^4 (4) KJ
- June: 7.4 x 10^4 (4) KJ
- July: 
- Aug: 
- Sept: 3.85 x 10^4 (4) KJ
- Oct: 1.26 x 10^4 (4) KJ
- Nov: 3.88 x 10^3 (4) KJ
- Dec: 0

Based on 1976 Fairbanks data, one week of hourly simulation/mon. Includes 12 adult occupants, 8.29 Btu/ft^2 lighting load, building = 6000 ft^2, .06 ft^2 glass, U = 0.12, Btu/deg. Vent reqd: 0.54 ach.

ANNUAL HEATING PERCENTAGE

ANNUAL PERCENTAGE SOLAR: 42%

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE DESIGN TEST 1
total 63,947,654 btus

SOURCES

LOSSES

fuel oil auxiliary heat
34%

lighting
52%

human
4%
solar
10%

windows
25%
walls
21.2%

ventilation loss
28.2%

floor
16%

building shell
loss
71.8%
door
5%
Total Heating Requirements are:
(13,892 °F Days) x 4,603 BTU/°F-day
= 63,947,654 BTU
= 106,579 BTU/ft²yr
= 12.16 BTU/ft²/hr

LIGHTING ENERGY:
Assumed on 24 hours/day (generator loading):
24 hrs/day x 280 days/yr = 5720 hours
Avg. lighting ~ 2.42 watts/ft² x 3.414 BTU/hr/watt
8.26 BTU/hr/ft² x 600 ft² = 4955 BTU/hr
Lighting contributes 53,302,142 BTU
This is 52% of the annual BTU heating requirement!

All the performance analyses were done by the TRNSYS computer program. A printout of a TRNSYS run specification is attached. Each test was made using hourly data for the year 1976 at Fairbanks, Alaska, using one week of each month, the 15–21 days. This was done to limit simulation costs. Since it is only one year of data, the performance estimates probably don't predict the "real" annual performance well. What is provided is an internally consistent comparison between the passive solar design options presented. The pie charts and schematic designs of each option follow. The conditions for each design test are as follows: direct gain south-facing windows with shutters, labeled Design Test 2; a direct gain system with added thermal mass as a Trombe wall, labeled Design Test 3; an attached south-facing solar greenhouse backed by a Trombe wall, labeled Design Test 4; a direct gain application, superinsulated (BLC = 3,095 BTU/°F-day), shuttered, with some mass added, labeled Design Test 5.

Comparisons among these examples (see the pie charts) show that the direct gain systems are the best performing systems from both the standpoint of solar gain and annual heating requirements, especially if they are shuttered when solar energy is not available. The Trombe wall design (Design 3) in this case falls short of the performance of the
An exemplary listing of the control program for Trnsys as used in this study:

#LIST D71

NOLIST
WIDTH 72
SIMULATION 0.0 168.0 .50
TOLERANCES .1 .1
LIMITS 20 50
UNIT 1 TYPE 9 DATA READER
PARAMETERS 11
3.00 1.00 1.0 41.83 0.0 2.0 556 -17.78 3.0 .5150 0.0
UNIT 2 TYPE 16 SOLAR RADIATION PROCESSOR(MODE 1)
PARAMETERS 5
1.0 105.6 64.8 4871. 2.25
INPUTS 12
1,1 1,19 1,20 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0 0,0
0,0 0,0 0,0 .60 90. 0,0 90. 90. 90. 180. 90. -90.
UNIT 3 TYPE 17 WALLS
PARAMETERS 26
2.0 .50 .9 4 3 27.8 18.6 27.8 18.6 .84 2 .79 .05 .05
0.0 0.0 0.0 0.0 0.0 .0032 .0056 .0048 .00035
-.6021 .08720 .00031
INPUTS 7
1,2 2,6 2,15 2,13 2,11 1,3 7,2
2,044 0.0 0.0 0.0 0.0 0.0 20.0
UNIT 4 TYPE 34 OVERHANG
PARAMETERS 15
5.00 3.0 0.0 .20 0.0 0.0 0.0 .20 .20 .20 0.0 .20 .20 .20
.00 .00
INPUTS 6
2,2 2,3 2,4 2,5 2,7 0.0
0.0 0.0 0.0 0.0 0.0 .60
UNIT 5 TYPE 18 FLAT ROOF
PARAMETERS 13
-1 4 .80 .90 149. 0.0 0.0 0.0 149. 0.0 0.0 2.0 0.0
INPUTS 8
1,2 2,4 0.0 0.0 0.0 1,3 0,0 7,2
2,044 0.0 0.0 0.0 0.0 0.0 0.0 0.0 20.0
UNIT 6 TYPE 35 WINDOW
PARAMETERS 2
1.0 15.0
INPUTS 5
7,2 1,2 0.0 2,6 0,0
20.0 2,044 2.55 0.0 .81
UNIT 7 TYPE 19 ROOM AND BASEMENT
PARAMETERS 19
1 170. 1.0 55.7 2.0 772. 128 -1 0.0 30.3 2.0
4697. 10. 18.0 23.0 20.0 0.0 0.0 .004

25
INPUTS 10
1,2 10,2 0,0 1,2 0,0 0,0 12,1 6,2 0,0 0,0
2.044 0,0 .001 2.044 0.001 .001 0.0 0.0 0.0 0.0
UNIT B TYPE 36 THERMAL STORAGE WALL
PARAMETERS 14
2 1 1.00 9,14 .025 .128 418500 0.9 0.93 0.9 2 0.1 1.0 1.0
INPUTS 8
11,1 7,2 1,2 1,3 0,0 0,0 2,6 0,0
0.0 20,0 2.044 0.0 -1 70. 0.0 .34
UNIT 9 TYPE 2 FAN CONTROLLER
PARAMETERS 3
5.0 0.0 0.0
INPUTS 3
7,2 0,0 9,1
20.0 25.5 0.00
UNIT 10 TYPE 3 VENTILATION FAN
PARAMETERS 2
1000. 700.
INPUTS 3
1,2 0,0 9,1
2.044 1000. 0.000
UNIT 11 TYPE 2 ON-OFF CONTROLLER
PARAMETERS 3
4.0 1.0 1.0
INPUTS 3
7,2 8,9 11,1
20.0 2.044 0.0
UNIT 12 TYPE 15 ADD CONDUCTION
PARAMETERS 7
0.0 0.0 3.0 -3.0 0.0 3.0 -4.0
INPUTS 3
3.2 6,3 5,1
0.0 0.0 0.0
UNIT 14 TYPE 26 TEMPERATURE PLOT
PARAMETERS 4
1.00 0.0 168.0 1.00
INPUTS 2
1,2 7,2
TAMB: TRM
UNIT 16 TYPE 28 WEEKLY ENERGY SUMMARY
PARAMETERS 26
168.0 0.0 168.0 -1.0 0.0 -4.0 0.0 0.0 -4.0 0.0 -4.0
0.0 -4.0 0.0 -1.0 15.00 1.0 -4.0 0.0 -1.0 15.00 1.0
-4.0 0.0 -4.0 0.0 -4.0
INPUTS 8
7,1 7,6 12,1 6,2 2,6 4,1 6,3 10,3
LABELS 8
QHLD QS+L QCND QSHG HT HS Q QPAR
END
000. 036.2 08.0
000. 036.2 08.0
000. 036.2 08.0
000. 036.2 08.0
006. 036.2 08.0
030. 036.2 08.0
*BYE
CONSTRUCTION:
WALLS: 2x8 STUDS W/ FULL EXT PLEKANS.
ROOF: 12" PENCIL SHINGLE, METAL ROOFING.
FLOOR: 12" FIBER-GLASS.
FOUNDATION: PILES OF POTS W/ INSULATED FLOOR.
FLOOR AREA: 600 sq ft.
WINDOWS: SINGLE PANE, SHUTTERED.
WINDOW AREA: SOUTH 200 sq ft.
BUILDING IA: 2011 BUDD VENT REQUIREMENT: 54 ACH.
ADDED THERMAL MASS: NONE.
SHADING MECHANISM: COMMON EXTERIOR BLEN.

FLOOR PLAN

SOUTH ELEVATION

SECTION
fuel oil auxiliary heat 56.5%

passive solar heating 33%

lighting 8.7%

human 1.8%

ventilation loss 18.6%

door .2%

floor 5.1%

ceiling 5.1%
walls 7.9%

windows 62%

building shell heat loss 81.4%

units: $10^6$ btu

total = 129,744,000 btu/yr

216,240 btu/ft$^2$/yr

SOURCES

LOSSES

ELECTRO-MECHANICAL VENTILATION & FLUORESCENT LIGHTING

PASSIVE SOLAR RURAL SCHOOL CLASSROOM Prototype DESIGN TEST 2
### TRNSYS SIMULATION

#### ANNUAL HEATING PERCENTAGE

<table>
<thead>
<tr>
<th>Month</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>35</td>
</tr>
<tr>
<td>Mar</td>
<td>33</td>
</tr>
<tr>
<td>Apr</td>
<td>12</td>
</tr>
<tr>
<td>May</td>
<td>31</td>
</tr>
<tr>
<td>Jun</td>
<td>26</td>
</tr>
<tr>
<td>Jul</td>
<td>Not modeled</td>
</tr>
<tr>
<td>Aug</td>
<td>26</td>
</tr>
<tr>
<td>Sept</td>
<td>31</td>
</tr>
<tr>
<td>Oct</td>
<td>26</td>
</tr>
<tr>
<td>Nov</td>
<td>33</td>
</tr>
<tr>
<td>Dec</td>
<td>33</td>
</tr>
</tbody>
</table>

#### COOLING FAN ENERGY

<table>
<thead>
<tr>
<th>Month</th>
<th>Energy (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>0</td>
</tr>
<tr>
<td>Feb</td>
<td>1.1 x 10^4</td>
</tr>
<tr>
<td>Mar</td>
<td>7.7 x 10^3</td>
</tr>
<tr>
<td>Apr</td>
<td>4.4 x 10^4</td>
</tr>
<tr>
<td>May</td>
<td>7.0 x 10^4</td>
</tr>
<tr>
<td>Jun</td>
<td>8.3 x 10^4</td>
</tr>
<tr>
<td>Jul</td>
<td></td>
</tr>
<tr>
<td>Aug</td>
<td></td>
</tr>
<tr>
<td>Sept</td>
<td>5.6 x 10^4</td>
</tr>
<tr>
<td>Oct</td>
<td>1.2 x 10^5</td>
</tr>
<tr>
<td>Nov</td>
<td>8.2 x 10^3</td>
</tr>
<tr>
<td>Dec</td>
<td>0</td>
</tr>
</tbody>
</table>

*Based on 1976 Fairbanks Data. Includes 10 adult occupants, 829 BTU/Ft² lighting load. Building = 6000 Ft², 800 Ft² south glass, UA = 2011 BTU/°F (3518 KJ/°C). Vent retrofit 1.54 ACH.

### ANNUAL PERCENTAGE SOLAR: 33% (Based on 10 school months)
CONSTRUCTION

- HALL: DOUBLE WALL W/12" FIBERGLASS
- ROOF: 12" FIBERGLASS, METAL ROOFING
- FLOOR: 12" FIBERGLASS
- FOUNDATION: FILLS OF ROSES, W/ INSULATED FLOOR

FLOOR AREAS:
- CLASSROOM: 600 $
- TROMBIE WALL: 210 $
- WINDOWS: DOUBLE PANES

WINDOW AREA:
- SOUTH: 240 $ (TROMBE)
- EAST: 10 $
- WEST: 10 $

BUILDING U/L: 263 KJ/CAL
- VENT RATE: 50 ACH
- ADDITIONAL THERMAL STORAGE: 4,1800 KJ/CAL

GLAZING
- TROMBE WALL: INSULATED ROOM W/12" FIBERGLASS, YENTED W/TEMP CONTROLLED CIRCULATION

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

DESIGN TEST 3
TRNSYS SIMULATION

ANNUAL HEATING PERCENTAGE

COOLING FAN ENERGY
- Jan: 0
- Feb: 0
- Mar: 0
- Apr: 0
- May: 0
- June: 0
- July: 0
- Aug: 0
- Sept: 0
- Oct: 0
- Nov: 0
- Dec: 0

BUILT/AUGUST: NOT MODELED
- July: 32
- August: 19

ANNUAL PERCENTAGE SOLAR: 19%

BASED ON 1976 FAIRBANKS DATA, ONE WEEK OF HOURLY SIMULATION/MONTH. INCLUDES 10 ADULT OCCUPANTS, 8,292 BTU/Ft²/HR LIGHTING LOAD.
BUILDING: 600 Ft², 600 Ft²/CLASS
BUILD. Uₐ = 0.86 K/J²/F°C. THERMAL STORAGE CAPACITY: 4.04 K/J°C
CONSTRUCTION
Walls: 2x8 stud w/full batt
FIBERGLASS
Roof: 12" FIBERGLASS, METAL
Roofing
Floor: 12" FIBERGLASS
Foundation: Pile of rocks, in
Insulated Floor
Floor Area:
Classroom: 600 sf
Greenhouse: 240 sf
Windows: Double pane

Window Area:
South (Greenhouse) 240 sf
East 10 sf
West 10 sf

Building Layout
Ventilation:
-added thermal mass
4162.5 cu ft.
-shading mechanisms
Greenhouse blinds.

FLOOR PLAN

SOUTH ELEVATION

SECTION

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

DESIGN TEST 4
ANNUAL HEATING PERCENTAGE

ANNUAL PERCENTAGE SOLAR: 25%

JULY & AUGUST NOT MODELED

COOLING FAN ENERGY

Based on Hite fanbanks data; one week of hourly simulation.

*Based on 600 square feet building.

Btu's used: 280,000.
CONSTRUCTION:

WALLS: 2 X 6 STUDS WITH FULL BATT FIBERGLAS
CEILING: 12" FIBERGLAS, METAL ROOSTING
FLOOR: 12" FIBERGLAS
FOUNDATION: PILES OF POSTS W/ INSULATED PLATE.
FLOOR AREA: 600 Sq.
WINDOWS: DOUBLE PANE, SHUTTERED
WINDOW AREA: SOUTH 200 Sq.
BUILDING H: 24.4 KJ/°C
VENT REGIMENT: ½ A/C/HR.
ADDED THERMAL MASS: 200-2000 BTU/°C
NOTE: SOUTH WALL W/ MASS OF TRAPROPE WALL.

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE DESIGN TEST 5
TRNSYS SIMULATION

COOLING FAN ENERGY

<table>
<thead>
<tr>
<th>Month</th>
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</thead>
<tbody>
<tr>
<td>jan</td>
<td>90</td>
</tr>
<tr>
<td>feb</td>
<td>67.5</td>
</tr>
<tr>
<td>mar</td>
<td>75</td>
</tr>
<tr>
<td>apr</td>
<td>47</td>
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<tr>
<td>may</td>
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</tr>
<tr>
<td>june</td>
<td>0</td>
</tr>
<tr>
<td>july</td>
<td>0</td>
</tr>
<tr>
<td>aug</td>
<td>0</td>
</tr>
<tr>
<td>sept</td>
<td>0</td>
</tr>
<tr>
<td>oct</td>
<td>0</td>
</tr>
<tr>
<td>nov</td>
<td>0</td>
</tr>
<tr>
<td>dec</td>
<td>0</td>
</tr>
</tbody>
</table>

Based on 1976 Fairbanks data, one week of hourly simulation/month. Includes 12 adult/12 children; 4.24 Btu/ft² heating load. Building = 600 ft², 240 ft² glass, superinsulated (U < 0.2). Storage mass = 116.0 lb/ft².

ANNUAL HEATING PERCENTAGE

0 20 40 60 80 100

ANNUAL HEATING PERCENTAGE

0 20 40 60 80 100

ANNUAL PERCENTAGE SOLAR: 49.8%

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE
DESIGN TEST 5
direct gain system mainly because it is not possible to insulate the wall efficiently and still transfer heat to the space where it is needed. Because the Trombe wall is insulated, the total load is much less, however. This is achievable with shutters (they were not used in the Trombe wall test), but the system does not perform as well as a comparable direct gain system, and the Trombe wall severely limits the possibilities for daylighting at high latitudes. The greenhouse-Trombe wall combination (Design 4) also does not perform as well as the direct gain system, but it would have many direct and indirect advantages since the greenhouse space can be used for growing food and decorative plants. It is, however, more difficult to shutter and, very likely, the shuttering would be limited to the wall itself.

These design tests provide interesting case studies of the different standard passive solar design elements. This evidence indicates that the elements that perform best in combination for high latitude applications of passive solar design are shuttering, direct gain south-facing windows, and superinsulated construction.

4b. Estimated Yearly End-use BTUs:

The final design specifications and a performance prediction are included next. The design includes a three-element south facade: the upper-most third is Kalwall glazing to provide a diffusing direct gain to the interior and maximize daylighting capability. The middle area is standard transparent glass. The bottom is a "prompt" wall arrangement, the result of discussions and suggestions given at the schematic design review process in Chicago, April 30, 1980. It is simply a small low-mass Trombe wall with an allowance for convective heat exchange. The design provides 2.3% less annual heating from solar gain, but the compromise was justified by the resultant daylighting without glare, and the storage function of the prompt wall. In addition 2 x 8 ft end windows provide daylighting down the east and west wall, further adding to its usefulness and adequacy.
TRNSYS SIMULATION

ANNUAL HEATING PERCENTAGE

Jan 15.7
Feb 34.9
Mar 58
Apr 66.9
May 49.9
June 97.3
July 100
Aug 100
Sep 100
Oct 100
Nov 100
Dec 100

ANNUAL PERCENTAGE SOLAR: 46%

BUILDING:
- Area: 6,300 ft²
- Occupants: 110 Adults
- Fin. Thk.: 8" Thick
- Treated Wall: 85 ft
- Windows: 104 ft²
- Superinsulation
- 5 ft. Cont. BTU/Ft² ft³
- Double Gl. Shutter
  Det. by Phot. Period
- No Thermal Storage Added

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE DESIGN TEST 6
MANLEY SCHOOL LOAD PROFILE

AVG DD: 1068/MO 35.6/DAY

APRIL 21
4c. **Design Tools:**

The tools used to calculate the comparative performance of the different test designs were TRNSYS computer simulations and hand calculations of the other energy contributions.

4d. **Pre-Design Dynamic Energy Needs:**

Display plots showing the pre-design estimates of the dynamic energy needs of the school are shown on the following pages (54-58).

- **FEBRUARY 21**
- **MARCH 21** (AVERAGE SPRING DAY)
- **APRIL 21**
- **JUNE 21** (PEAK SUMMER DAY)
- **SEPTEMBER 21** (AVERAGE FALL DAY)
- **OCTOBER 21**
- **DECEMBER 21** (PEAK WINTER DAY)
- **DECEMBER 21** (WORST DAY)

An average summer day is not included because the building is not expected to be used regularly during the summer. The charts are based on the average heating degree days by month for Fairbanks. They also assume a requirement of 24 hour loading of the generator. The designers recognize that this requirement is a major part of the rural schools energy problem, and it is being addressed in another project. However, it is an accurate description of the present base case for school designs. We attempt to solve a portion of the heating problem in this project, and recognize that it is only a part of the problem.

4e. **Final Dynamic Energy Needs:**

Each of the following charts were calculated using the following method. The segments of heat loss were determined from the design calculations. For the final design, the values are again 1,296 BTU/°F-day for infiltration and ventilation and 1,799 BTU/°F-day for the
building losses. These values are then multiplied by the average number of degree-Fahrenheit days of heating in each case of interest.

Solar energy gain is calculated from the theoretical NBS values on a vertical south-facing surface (Kusuda and Ishii, 1979), and converted to BTU/ft$^2$/hr. This was an estimate of the actual solar radiation, as the TRNSYS simulation gives daily and weekly totals of radiation, but the data are for one year only and cannot be considered "average." Also, the summer extreme is not calculated, since the building use in summer is somewhat less important. No shading of the south facade was considered in the calculations.

The diagrams presented are not final in the sense that a complete investigation of the optimum use of daylighting has not been accomplished. A preliminary investigation of this option has been done and is included here. Indications from this study show that as early as February 21, 60% of the room is adequately lit at 8 a.m., even on a day of complete overcast. Previous to this date for a symmetrical period about the winter solstice (roughly from November 10 through February 20) electrical lighting will be required because of inadequate available daylighting. This is less lighting than was previously estimated to be required, and is generally due to the enhanced daylighting design of the south facade, and the conservative calculations. This problem should be addressed further by a study of the daylighting potential using a model during the winter (PHASE II) to prepare a better lighting load requirement.

The lighting contributions to the heating load for these charts were calculated using this schedule: 16 hours minus the average daylight hours plus 1 hour to cover twilight periods. The monthly contribution of heat from lighting is:

<table>
<thead>
<tr>
<th></th>
<th>JANUARY 1,828,275 BTU</th>
<th>FEBRUARY 943,626 &quot;</th>
<th>MARCH 761,781 &quot;</th>
<th>APRIL 294,883 &quot;</th>
<th>MAY 0 &quot;</th>
<th>JUNE 0 &quot;</th>
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<td>Hrs</td>
<td>12</td>
<td>8</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BTU/ft$^2$/hr</td>
<td>8.19 (2.4 watts/ft$^2$)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>Hrs</td>
<td>BTU/ft$^2$/hr</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>-----</td>
<td>---------------</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>September</td>
<td>457,068&quot;</td>
<td>3 &quot;</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>October</td>
<td>1,066,494&quot;</td>
<td>7 &quot;</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>November</td>
<td>1,326,974&quot;</td>
<td>9 &quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>December</td>
<td>2,132,988&quot;</td>
<td>14 &quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Sum</td>
<td>8,812,089 BTU</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This is based on an average electrical lighting heat loss of 8.19 BTU per ft$^2$ during lighting; a conservative (high) estimate considering the daylighting prospects. To compensate somewhat for this effect of daylighting, the March chart shows 80% of full lighting, an estimate of a "real day" case.

4f. Difficulties in Calculations:

As an example calculation, here is the case of the final design. Building dimensions are 20 feet wide x 30 feet long x 10 feet high with a volume of 6000 ft$^3$.

**Construction:**
1). 12 inch walls, R-38 insulation double stud construction.
2). 18 inch ceiling, R-56.6, truss.
3). 12 inch floor, R-38, truss.
4). "Trombed" wall, part of south facade, ~ 78 ft$^2$.
5). Windows 8 x 2 ft, 32 ft$^2$, corner orientation for east and west wall lighting.
6). Remainder of south facade in awning windows and double glazed/Kalwall, ~ 166 ft$^2$.
7). Remainder of south facade in framing and infrastructure (~ 24 ft$^2$).
8). Building on pile foundation.
9). Windows shuttered with R-9 at night.

**For Infiltration:**
1). Code ventilation is 5 CFM per occupant.
2). Occupancy assumed: 12 hours, 10 adult-equivalent occupants. Requiring 50 CFM x 60 min x 3,000 CF/hr = 1/2 ACH/hr.
AVG DO: 1739/MO  56/DAY

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

MAR 21

DESIGN TEST
BTU/SQ. FT./HR. heat gain

TIME OF DAY

m 4 8 noon 4 8 m

AVG DD: 222/MO 7.2/DAY

PASSIVE SOLAR RURAL SCHOOL CLASSROOM Prototype

DESIGN TEST
AVG DD: 642 / MO 21.2 / DAY
PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

SEPT 21
DESIGN TEST
PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

AVG DD: 2254/MO 70.7/DAY

DESIGN TEST

DEC 21
DAYLIGHTING - MARCH 21ST, NOON, OVERCAST SKY

1. AVAILABLE DAYLIGHT:

Solar altitude - 26°
Sky condition: overcast
Orientation: N/A

Ekw = 350
Ekg = 900 (old snow reflectance = 64%)
Egw = .900 x .64 x .5 = 288

2. ROOM CONDITIONS:

length = 30 ft  sill height = 3 ft
width = 20 ft  ceiling refl. = 80%  floor refl. = 30%
height = 10 ft  wall refl. = 70%

Transmittance: (avg. Kalwall x thermopane) 80%

3. WINDOW TRANSMITTANCE FACTORS:

Area = 198 ft²
Tg = 80%

4. COEFFICIENTS OF UTILIZATION:

From Sky:

\[ C_{og} \]
MAX: .0191  \[ K_{os} \]
MAX: .121
MID: .0101  MID: .107
MIN: .0063  MIN: .0951

From Ground:

\[ C_{ug} \]
MAX: .0102  \[ K_{ug} \]
MAX: .140
MID: .0094  MID: .122
MIN: .0082  MIN: .110

59
5. CALCULATIONS:

\[ E_{kwp} = E_k w \times A_g \times T_g \times C_{og} \times K_{og} \]

\[
\begin{align*}
\text{MAX:} & \quad 350 \times 198 \times 0.80 \times 0.0191 \times 0.121 = 128 \\
\text{MID:} & \quad 350 \times 198 \times 0.80 \times 0.0101 \times 0.107 = 60 \\
\text{MIN:} & \quad 350 \times 198 \times 0.80 \times 0.0063 \times 0.0951 = 33 
\end{align*}
\]

\[ E_{gwp} = E_g w \times A_g \times T_g \times C_{ug} \times K_{ug} \]

\[
\begin{align*}
\text{MAX:} & \quad 288 \times 193 \times 0.80 \times 0.0102 \times 0.140 = 65 \\
\text{MID:} & \quad 288 \times 193 \times 0.80 \times 0.0094 \times 0.122 = 52 \\
\text{MIN:} & \quad 288 \times 193 \times 0.80 \times 0.0082 \times 0.110 = 41 
\end{align*}
\]

6. TOTAL ILLUMINATION:

\[
\begin{align*}
\text{MAX:} & \quad 128 + 65 = 193 \\
\text{MID:} & \quad 60 + 52 = 112 \\
\text{MIN:} & \quad 33 + 41 = 74 
\end{align*}
\]

Daylight is adequate @ all points.
DAYLIGHTING - MARCH 21ST, CLEAR SKY @ 8 a.m.

1. AVAILABLE DAYLIGHT:

Solar altitude - 21°
Sky condition: clear sky, no sun on windows
Window orientation: 60° azimuth from sun

$E_{kw} = \text{(clear spring sky)} \times 300$
$E_{kg} = 800$
$E_{gw} = 800 \times 0.64 \times 0.5 = 256$

2. ROOM CONDITIONS:

length = 30 ft   sill height = 30 in
width = 20 ft   ceiling refl. = 80%   floor refl. = 30%
height = 10 ft   wall refl. = 70%

3. WINDOW TRANSMITTANCE:

Area = 198 ft$^2$
$T_g = 80\%$

4. COEFFICIENTS OF UTILIZATION (Clear sky)

From Sky:

$C_{os}$  MAX: 0.0143  $K_{os}$  MAX: 0.129
MID: 0.0100  MID: 0.116
MIN: 0.0079  MIN: 0.112

From Ground:

$C_{ug}$  MAX: 0.0102  $K_{ug}$  MAX: 0.140
MID: 0.0094  MID: 0.122
MIN: 0.0084  MIN: 0.110
5. CALCULATIONS:

\[ E_{kwp} = E_{kw} \times A_g \times T_g \times C_{CS} \times K_{CS} \]

MAX: \[ 800 \times 198 \times 0.80 \times 0.0143 \times 0.129 = 233 \]
MID: \[ 800 \times 198 \times 0.80 \times 0.0100 \times 0.116 = 147 \]
MIN: \[ 800 \times 198 \times 0.80 \times 0.0079 \times 0.112 = 112 \]

\[ E_{gwp} = \]

MAX: \[ 256 \times 198 \times 0.80 \times 0.0102 \times 0.140 = 58 \]
MID: \[ 256 \times 198 \times 0.80 \times 0.0094 \times 0.122 = 47 \]
MIN: \[ 256 \times 198 \times 0.80 \times 0.0084 \times 0.110 = 37 \]

6. TOTAL ILLUMINATION:

MAX: \[ 233 + 58 = 291 \]
MID: \[ 147 + 47 = 194 \]
MIN: \[ 112 + 37 = 149 \]

Adequate daylighting (including north wall).
DAYLIGHTING - MARCH 21ST, OVERCAST @ 8 a.m.

1. AVAILABLE DAYLIGHT:

Solar altitude = 20.7
Sky condition = overcast, no direct sun on window
Orientation = N/A

Ekw = 200
Ekg = 700
old snow = 64% reflectance
Egw = .700 x .64 x .5 = 224

2. ROOM CONDITIONS:

Same as previous example.

3. TRANSMITTANCE: 80%

4. COEFFICIENTS OF UTILIZATION:

Same as before.

5. CALCULATION:

\[ Ekwp = Ekw \times Ag \times Tg \times C_{OS} \times K_s \]
MAX: \[ 200 \times 198 \times .80 \times .0191 \times .122 = 73 \]
MID: \[ 200 \times 198 \times .80 \times .0101 \times .107 = 34 \]
MIN: \[ 200 \times 198 \times .80 \times .0063 \times .0951 = 19 \]

\[ Egwp = Egw \times Ag \times Tg \times Cug \times Kug \]
MAX: \[ 224 \times 198 \times .80 \times .0102 \times .140 = 50 \]
MID: \[ 224 \times 198 \times .80 \times .0094 \times .122 = 41 \]
MIN: \[ 224 \times 198 \times .80 \times .0082 \times .110 = 32 \]
6. TOTAL ILLUMINATION:

MAX: 73 + 50 = 123
MID: 34 + 41 = 75
MIN: 19 + 32 = 51

Illumination is adequate at all points: levels may be less on a clear day for the earlier hours of morning. This is a distinct possibility considering number of sunny days in March.
DAYLIGHTING - FEBRUARY 21ST @ NOON, OVERCAST SKY

1. AVAILABLE DAYLIGHT:

   Solar altitude: 16°
   Sky: overcast
   Orientation: N/A

   $E_{kw} = 200$
   $E_{kg} = 525$
   $E_{gw} = 0.525 \times 0.64 \times 0.5 = 168$

2. CALCULATIONS:

   $MAX: 200 \times 198 \times 0.80 \times 0.0191 \times 0.121 = 73$
   $MID: 200 \times 198 \times 0.80 \times 0.0101 \times 0.107 = 34$
   $MIN: 200 \times 198 \times 0.80 \times 0.0063 \times 0.0951 = 19$

   $MAX: 168 \times 198 \times 0.80 \times 0.0102 \times 0.140 = 38$
   $MID: 168 \times 198 \times 0.80 \times 0.0094 \times 0.122 = 30$
   $MIN: 168 \times 198 \times 0.80 \times 0.0082 \times 0.110 = 28$

3. TOTAL ILLUMINATION:

   $MAX = 111$
   $MID = 64$
   $MIN = 47$

Marginal availability of daylight @ back of room. Count on providing light artificially 100% December and January, 50% November and February.
1. AVAILABLE DAYLIGHT:

Solar altitude: 6°
Sky: overcast
Orientation: 0° (N/A)

\[ E_{kw} = 75 \]
\[ E_{kg} = 180 \]
\[ E_{gw} = 180 \times 0.64 \times 0.5 = 58 \]

2. ROOM CONDITIONS:

Same as March.

3. WINDOW TRANSMITTANCE:

Area = 198 ft²
Tg = 80%

4. Coefficients of Utilization:

Same as March, overcast.

5. CALCULATIONS:

\[ E_{kwp} = \]
\[ \text{MAX: } 75 \times 198 \times 0.80 \times 0.0191 \times 0.121 = 27 \]
\[ \text{MID: } 75 \times 198 \times 0.80 \times 0.0101 \times 0.107 = 13 \]
\[ \text{MIN: } 75 \times 198 \times 0.80 \times 0.0063 \times 0.0951 = 7 \]

\[ E_{gwp} = \]
\[ \text{MAX: } 58 \times 198 \times 0.80 \times 0.0102 \times 0.140 = 13 \]
\[ \text{MID: } 58 \times 198 \times 0.80 \times 0.0094 \times 0.122 = 10 \]
\[ \text{MIN: } 58 \times 198 \times 0.80 \times 0.0082 \times 0.110 = 8 \]
6. TOTAL ILLUMINATION:

MAX: 27 + 13 = 40
MID: 13 + 10 = 23
MIN: 7 + 8 = 15

These are inadequate levels of illumination.
3). \[ 1/2 \text{ACH/hr} = \text{BTU/°F-day}. \]

\[ Q_{\text{INF}} = 0.5 \text{ACH/hr} \left(0.075 \text{ lb/ft}^3\right)(0.24 \text{ BTU/lb°F})(\frac{12 \text{ hr}}{\text{day}}) \]

\[ (\text{vol}) = (0.108 \text{ BTU/°F-day}) 6000 \text{ ft}^3 \]

\[ Q_{\text{INF}} = 648 \text{ BTU/°F-day} \]

For the Building Shell:

1). Ceiling:

\[ UA = \frac{1}{R} \text{(area)} = \left(\frac{1}{56.6}\right)(600 \text{ ft}^2) = 10.60 \text{ BTU/°F-day} \]

2). Floor:

\[ UA = \frac{1}{R} \text{(area)} = \left(\frac{1}{38}\right)(600 \text{ ft}^2) = 15.78 \text{ BTU/°F-day} \]

3). Walls (except south-facade):

\[ UA = \left(\frac{1}{38}\right)(400 + 280 + 24 \text{ south facade}) = 18.52 \text{ BTU/°F-day} \]

4). Door:

\[ UA = \left(\frac{1}{10}\right)(20 \text{ ft}^2) \]

5) South Facade (Windows, Prompt Wall, Shuttered):

\[ \text{AREA} = 276 \text{ ft}^2 \text{ glazing double } \sim 1.5 = R \]

Heat loss on monthly basis because of varying time period of shuttering: 53.09 BTU/°F-day

Total \( \Sigma UA \) 99.90

\[ x \ 24 \text{ hr} = 2,398 \text{ BTU/°F-day} \]

The first question that arose is how to calculate the effect of the shuttering, since it varied by month. Since the TRNSYS program accommodates the effect of shutters by simply changing the heat loss coefficient (U-value) of the window, an "average" monthly U-value for the window for each month was calculated for use in the TRNSYS simulation. For the annual heat loss of the glazed south facade, the sum of the UA product of each month was determined and divided by 10 months to yield an average annual heat loss for the glazed south facade. The results are tabulated below.
R-VALUES BY MONTH FOR SHUTTERED WINDOW AREAS
(SOUTH FACADE): \( A = 270 \text{ ft}^2 \)

<table>
<thead>
<tr>
<th></th>
<th>( R )</th>
<th>( U )</th>
<th>UA</th>
</tr>
</thead>
<tbody>
<tr>
<td>JAN:</td>
<td>7.33</td>
<td>.1364</td>
<td>37.64</td>
</tr>
<tr>
<td>FEB:</td>
<td>6.66</td>
<td>.1501</td>
<td>41.43</td>
</tr>
<tr>
<td>MAR:</td>
<td>5.5</td>
<td>.1818</td>
<td>50.18</td>
</tr>
<tr>
<td>APR:</td>
<td>5.5</td>
<td>.1818</td>
<td>50.18</td>
</tr>
<tr>
<td>MAY:</td>
<td>5.5</td>
<td>.1818</td>
<td>50.18</td>
</tr>
<tr>
<td>JUN:</td>
<td>20</td>
<td>.5</td>
<td>138</td>
</tr>
<tr>
<td>SEP:</td>
<td>5.5</td>
<td>.1818</td>
<td>50.18</td>
</tr>
<tr>
<td>OCT:</td>
<td>6.6</td>
<td>.1501</td>
<td>41.43</td>
</tr>
<tr>
<td>NOV:</td>
<td>7.33</td>
<td>.1364</td>
<td>37.64</td>
</tr>
<tr>
<td>DEC:</td>
<td>8</td>
<td>.1250</td>
<td>34.50</td>
</tr>
</tbody>
</table>

Code ventilation and infiltration, at 648 BTU/°F-day is 26.4% of the heating requirements, for 10 adult equivalents. At 20 adult equivalents, it is 1,296 BTU/°F-day. For maximum ventilation loads, this latter number will be used. The total UA product is therefore:

\[
\begin{align*}
2,398 \text{ BTU/°F-day (building shell)} \\
1,296 \text{ BTU/°F-day (ventilation)} \\
3,694 \text{ BTU/°F-day}
\end{align*}
\]

Using the degree-days for Fairbanks and without considering July and August, the total heating degree-days are:

- 14,344 (entire year)
- 148 (July)
- 304 (August)

13,892 degree days

The total heating requirements are:

\[
(13,892 \text{ °F-days}) \times 3694 \text{ BTU/°F-day}
= 51,317,048 \text{ BTU/yr}
= 85,528 \text{ BTU/ft}^2/\text{yr} \text{ (total for 10 months)}
= 9.76 \text{ BTU/ft}^2/\text{hr}
\]
An additional difficulty has already been discussed—that of lighting options. The daylighting option will be used whenever possible, and should be better understood through this winter's research.

Difficulty was also encountered in designing a system to maximize solar heating, when in fact the electrical use kept the actual site energy use high because of the dependence of electricity on diesel generation. This problem was very distracting, and pointed toward dependence on day-lighting to minimize electrical requirements. However, that merely aggravates the problem of loading a generator. Ultimately the situation will require use of a load-following electrical generation system such as the ORMAT organic Rankine cycle turbine generator. This system will likely be tested in the passive solar school prototype.

4g. How Energy Savings Achieved:

The major energy saving design elements that substantially affect building performance are: the south glazing, prompt wall features; greater insulation, especially the shuttering of the glazed areas; the insulation was increased by 60% over the best existing school design. In addition, the daylighting potential (which has been previously discussed) provides for decreased electrical requirements.

The savings are achieved by utilizing the available solar energy to heat and light the school structure, by allowing some of the heat to be stored, and by using shutters to limit the rate of escape of this heat from the structure. The building structure itself also has 60% greater insulation and has a correspondingly decreased heat loss.

4h. Savings of Natural Resources:

The following measures were taken to save transportation energy, water and other natural resources through working with the client. The client, in our case, worked very closely with the design team and frequently participated in plenary brainstorming sessions.

A major consideration related to transportation energy is designing the building to be portable. The final design is made to be broken
down into three 10-foot wide sections for ease of movement or transport. Most villages in rural Alaska are accessible by barge or air, and some are accessible by road. Designing the prototype school so that it can be built in sections in the larger cities of Alaska and shipped easily by one of these three means is very cost effective. Constructing the building in some of the larger communities in the state also saves a larger portion of the skilled labor costs normally associated with bush construction. As an example, typical construction costs in bush Alaska can be $250 per square foot. Estimates of the cost of passive school prototype are then about $150,000. The same structure can be built in Fairbanks for less, with only the piling and local set-up on the final site, and transportation of the building sections as additional costs (estimated to be about $50,000). This represents a large probable savings for rural Alaska, although the actual savings have not been documented.

It is difficult to save transportation energy in the construction process, although maximum utilization of barging will be a fuel-saving option. The real fuel savings come in not having to transport fuel oil to the site in the same magnitude as is presently the case.

Although the prototype structure is not assumed to have the full plumbing system of a standard school (i.e. showers, kitchen and lavatories), the utilization of hot water heating systems is not ruled out because the prototype design is meant to be attached to the south side of a larger school building, the combination gymnasium and all-purpose room. For this reason, the prospect of incorporating an active solar hot water heating system into the prototype design was evaluated. The results of the evaluation follow. F-chart was used as a simulation model. The estimate of water use is based on the assumption of the hot water being used in the larger attached building. Use is estimated at 250 gallons/day for ephemeral handwashing and a shower a day for 20 students. Three conclusions can be drawn:

1). The system costs are a critical factor. The system's total cost, if expressed as a cost per square foot of collector area, must fall within the range of $15 to $25 per square foot to be competitive with fuel oil costs. It is unlikely that they can be incorporated for that cost.
<table>
<thead>
<tr>
<th>CODE</th>
<th>VARIABLE DESCRIPTION</th>
<th>VALUE UNITS</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AIR SH&amp;W=1, LIO SH&amp;W=2, AIR OR LIO WH ONLY=3.</td>
<td>2.00</td>
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</tr>
<tr>
<td>2</td>
<td>IF 1, WHAT IS (FLOW RATE/COL AREA)(SPEC. HEAT)?</td>
<td>2.15</td>
<td>BTU/H-F-F2</td>
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<td>3</td>
<td>IF 2, WHAT IS (EPSILON)(CMIN)/(UA)?</td>
<td>2.00</td>
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<td>4</td>
<td>COLLECTOR AREA</td>
<td>538.20</td>
<td>FT2</td>
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<td>5</td>
<td>FRRP=FLH-ALPHA PRODUCT(NORMAL INCIDENCE)</td>
<td>0.72</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>FRRP=FLH-UL PRODUCT</td>
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<td>BTU/H-F-F2</td>
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<tr>
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<td>INCIDENCE ANGLE MODIFIER (ZERO IF NOT AVAIL.)</td>
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<td></td>
</tr>
<tr>
<td>8</td>
<td>NUMBER OF TRANSPARENT COVERS</td>
<td>2.00</td>
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</tr>
<tr>
<td>9</td>
<td>COLLECTOR SLOPE</td>
<td>64.00</td>
<td>DEGREES</td>
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<tr>
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<td>BREAT ANGLE (E.g., SOUTH=0, WEST=90)</td>
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<td>DEGREES</td>
</tr>
<tr>
<td>11</td>
<td>STORAGE CAPACITY</td>
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<td>BTU/F-FT2</td>
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<td>12</td>
<td>EFFECTIVE BUILDING VA.</td>
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<td>BTU/F-DAY</td>
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<td>13</td>
<td>CONSTANT DAILY BLDG HEAT GENERATION</td>
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<td>BTU/DAY</td>
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<tr>
<td>14</td>
<td>HOT WATER USAGE</td>
<td>250.00</td>
<td>GAL/DAY</td>
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<td>15</td>
<td>WATER SET TEMP. (TO VARY BY MONTH, INPUT NEG.)</td>
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<td>F</td>
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<td>WATER MAIN TEMP. (TO VARY BY MONTH, INPUT NEG.)</td>
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<td>THERMAL PRINT OUT BY MONTH=1, BY YEAR=2</td>
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<td></td>
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<td>ECONOMIC ANALYSIS? YES=1, NO=2</td>
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<td>USE OPTIMO COLLECTOR AREA=1, SPECIFIED AREA=2</td>
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<td>/YR</td>
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<td>21</td>
<td>SOLAR SYSTEM THERMAL PERFORMANCE DEGRADATION</td>
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<td>YEARS</td>
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<td>22</td>
<td>PERIOD OF THE ECONOMIC ANALYSIS</td>
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<td>$/FT2 COLL</td>
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<td>COLLECTOR AREA DEPENDENT SYSTEM COSTS</td>
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<td>$</td>
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<td>24</td>
<td>CONSTANT SOLAR COSTS</td>
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<tr>
<td>25</td>
<td>DOWN PAYMENT (% OF ORIGINAL INVESTMENT)</td>
<td>10.00</td>
<td></td>
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<tr>
<td>26</td>
<td>ANNUAL INTEREST RATE ON MORTGAGE</td>
<td>20.00</td>
<td>YEARS</td>
</tr>
<tr>
<td>27</td>
<td>TERM OF MORTGAGE</td>
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<td>28</td>
<td>ANNUAL NOMINAL(MARKET) DISCOUNT RATE</td>
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<td></td>
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<tr>
<td>29</td>
<td>EXTRAS INSP. MAINT. IN YEAR 1% OF ORIG. INVE.</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>ANNUAL % INCREASE IN ABOVE EXPENSES</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>PRESENT COST OF SOLAR BACKUP FUEL (BF)</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>SF RISE: %/YR=1, SEQUENCE OF VALUES=2</td>
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<td></td>
</tr>
<tr>
<td>33</td>
<td>IF 1, WHAT IS THE ANNUAL RATE OF SF RISE</td>
<td>18.33</td>
<td>$/MMBTU</td>
</tr>
<tr>
<td>34</td>
<td>PRESENT COST OF CONVENTIONAL FUEL (CF)</td>
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<td></td>
</tr>
<tr>
<td>35</td>
<td>CF RISE: %/YR=1, SEQUENCE OF VALUES=2</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
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<td>IF 1, WHAT IS THE ANNUAL RATE OF CF RISE</td>
<td>2.00</td>
<td></td>
</tr>
<tr>
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<td>ECONOMIC PRINT OUT BY YEAR=1, CUMULATIVE=2</td>
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<td>EFFECTIVE FEDERAL STATE INCOME TAX RATE</td>
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<td>TRUE PROP. TAX RATE PER % OF ORIGINAL INVEST.</td>
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<td>ANNUAL % INCREASE IN PROPERTY TAX RATE</td>
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<td>RESALE VALUE (% OF ORIGINAL INVESTMENT)</td>
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<td>43</td>
<td>INCOME PRODUCING BUILDING? YES=1, NO=2</td>
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</table>

**TABLE 1:** This is a listing of the parameters of the F-Chart solar simulation program for analysis of the possible use of an active solar hot water system for incorporation into the Passive Solar Rural School Design Project.
### THERMAL ANALYSIS

<table>
<thead>
<tr>
<th>Time</th>
<th>Solar (W)</th>
<th>Incident Solar (W)</th>
<th>Heating Load (W)</th>
<th>Water Load (W)</th>
<th>Degree Days</th>
<th>Ambient Temp (°F)</th>
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</thead>
<tbody>
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<td>.80</td>
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</table>

### ECONOMIC ANALYSIS

- Optimized Collector Area: 86. FT²
- Initial Cost of Solar System: $2500
- Annual Mortgage Payment for 20 Years: $311
- Rate of Return on Solar Investment (%): 11.3
- Years Until Undiscounted Fuel Savings = Investment: 9
- Years Until Undiscounted Solar Savings = Mortgage Principal: 16
- Undiscounted Cumulative Solar Savings: $3442
- Present Worth of Yearly Total Costs with Solar: $32102
- Present Worth of Yearly Total Costs w/o Solar: $32525
- Present Worth of Cumulative Solar Savings: $423

**TABLE 2:** This table shows the thermal and economic analysis of an active solar hot water roof mounted system for the Passive Solar Rural School Design Project. The system is designed to heat 250 gallons of hot water per day to 140°F, using oil at $1.50 a gallon as a backup fuel. This is Run #1, with the collector cost estimate at $30/ft² and collector tilt of 60°.
## Thermal Analysis

<table>
<thead>
<tr>
<th>Time</th>
<th>Percent Incidence</th>
<th>Heating Water Degree</th>
<th>Ambient Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>Solar Load</td>
<td>Load Days</td>
<td>(F-Day)</td>
</tr>
<tr>
<td>(MMBTU)</td>
<td>(MMBTU x MMBTU)</td>
<td>(F)</td>
<td>(F)</td>
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## Economic Analysis

Optimized Collector Area = 106. FT2
Initial Cost of Solar System = $3180.
The Annual Mortgage Payment for 20 Years = $383.
The Rate of Return on the Solar Investment(%) = 12.5
Yrs Until Undisc. Fuel Savings = Investment
Yrs Until Undisc. Solar Savings = Mortgage Principal
Undiscounted Cumulative Solar Savings = $4771.
Present Worth of Yearly Total Costs with Solar = $31799.
Present Worth of Yearly Total Costs W/O Solar = $32525.
Present Worth of Cumulative Solar Savings = $726.

### Table 3:
This is a second run to evaluate the use of active solar hot water heating in the Passive Solar Rural School Design Project. This run differs from the specifications of Run #1 only in that the collector tilt has been changed from 64° to 44° from the horizontal. The effect is improved performance and an improved rate of return on the investment.
FAIRBANKS  AK  64.82

***THERMAL ANALYSIS***

<table>
<thead>
<tr>
<th>TIME</th>
<th>PERCENT</th>
<th>INCIDENT HEATING</th>
<th>WATER DEGREE</th>
<th>AMBIENT</th>
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<td>DAYS</td>
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<td>(MMBTU)</td>
<td>(MMBTU)</td>
<td>(F-DAY)</td>
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<td>(F)</td>
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<tr>
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</table>

***ECONOMIC ANALYSIS***

OPTIMIZED COLLECTOR AREA = 94. FT2
INITIAL COST OF SOLAR SYSTEM = $ 2820.
THE ANNUAL MORTGAGE PAYMENT FOR 20 YEARS = $ 340.
THE RATE OF RETURN ON THE SOLAR INVESTMENT(%) = 12.1.
YRS UNTIL UNDISC. FUEL SAVINGS = INVESTMENT = 8.
YRS UNTIL UNDISC. SOLAR SAVINGS = MORTGAGE PRINCIPAL = 16.
UNDISCOUNTED CUMULATIVE SOLAR SAVINGS = $ 4079.
PRESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR = $ 31940.
PRESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR = $ 32525.
PRESENT WORTH OF CUMULATIVE SOLAR SAVINGS = $ 565.

TABLE 4: Again a similar test of hot water heating changing the collector tilt to 30° from the horizontal. Performance decreases from the 44° tilt case, and the economic value and rate of return are less.
### Thermal Analysis

<table>
<thead>
<tr>
<th>Time</th>
<th>Percent Incident Heating</th>
<th>Water Degree Ambient Temp</th>
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</thead>
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<td>Jun</td>
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<td>Dec</td>
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</table>

### Economic Analysis

Optimized Collector Area = 567.2 ft²
Initial Cost of Solar System = $17010.
The annual mortgage payment for 20 years = $2850.
The discounted rate of return is greater than 100%.

Yrs until undiscounted fuel savings = Investment
Yrs until undiscounted solar savings = Mortgage principal

Undiscounted cumulative solar savings = $228613.
Present worth of yearly total costs with solar = $109961.
Present worth of yearly total costs w/o solar = $192223.
Present worth of cumulative solar savings = $82626.

---

**Table 5:** This is run #4 in the active solar hot water heating analysis for the Passive Solar Rural School. The collector tilt is set back to 44° from the horizontal, but the backup fuel is Alaska Village Electric Cooperative electricity at 37.2¢ per kWh ($108.23/10⁶ Btu). Even if collectors cost $30 per square foot, they are a very worthwhile investment in this case. All other system specifications are the same as those in Table 2.
### THERMAL ANALYSIS

<table>
<thead>
<tr>
<th>TIME</th>
<th>PERCENT INCIDENT</th>
<th>HEATING WATER DEGREE</th>
<th>AMBIENT TEMP</th>
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</thead>
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<td>SOLAR LOAD</td>
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<td>(MMBTU)</td>
<td>(F-DAY)</td>
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</table>

### ECONOMIC ANALYSIS

**OPTIMIZED COLLECTOR AREA = 361. FT2**

**INITIAL COST OF SOLAR SYSTEM = $ 5415.**

**THE ANNUAL MORTGAGE PAYMENT FOR 20 YEARS = $ 652.**

**THE RATE OF RETURN ON THE SOLAR INVESTMENT(%) = 32.6.**

**YRS UNTIL UNDISC. FUEL SAVINGS = INVESTMENT 6.**

**YRS UNTIL UNDISC. SOLAR SAVINGS = MORTGAGE PRINCIPAL 11.**

**UNDISCOUNTED CUMULATIVE SOLAR SAVINGS = $ 22057.**

**PRESENT WORTH OF YEARLY TOTAL COSTS WITH SOLAR = $ 25895.**

**PRESENT WORTH OF YEARLY TOTAL COSTS W/O SOLAR = $ 32525.**

**PRESENT WORTH OF CUMULATIVE SOLAR SAVINGS = $ 6630.**

---

**TABLE 6:** In this final analysis, the collector tilt is 44° from the horizontal, but collectors are assumed to cost $15 per ft². The backup fuel is oil at $18.33/mmBTU ($1.50 per gallon @ 60% efficiency). This case is instructive as it compares to table 2, where collectors are assumed to cost $30 per ft². Collector cost is a critical economic factor in this decision.
2). Collector tilt of $\sim 45^\circ$ from the horizontal is optimum. This probably will not match the roof slope.

3). If Alaska Village Electric Cooperative electricity is used to heat water (an unlikely prospect, but it is occurring), it is exceedingly economic to use active solar hot water heating. The additional expertise required was gained as a result of this project.

The performance of the revised final design is shown in the pie chart which follows. This is a conservative estimate of the energy flows in the building and is based on 1976 Fairbanks data, as is the case for all previous design analyses.

ECONOMIC ANALYSIS/RESULT

5a. Client's Budget:

See the architect's incremental cost estimate (section 4iii) of the final construction costs and compare to the estimated incremental costs of the schematic designs (section 6) which range from $3,500 to $9,000. The total incremental solar costs are $7,000, resulting in an annualized cost of $\sim 370/year for 45% heating.

The final design (direct gain shutters) is one of the least expensive designs, but the economic reasons for this were secondary to performance in the selection process. Performance was the primary factor in design selection and the design changes from schematic Design 5 to Design 6 were all performance-related design changes, especially as they affected daylighting.

5b. Pre-Design Energy Cost Estimates:

Pre-design estimates of the energy cost for each end use follow. Solar gain is not considered as having a cost in the pre-design cases.

1). Fuel oil for auxilliary heat:

\[
\frac{21,742,202 \text{ BTU}}{89,700 \text{ BTU/gal @ 65\% efficiency}} \times \$1.50/\text{gal} = \$364.
\]
PRE-DESIGN ENERGY COSTS

$2773/year

24 hour electrical loading of diesel generator
2). Fuel oil for diesel generation of electricity.

33,252,780 BTU lighting and mechanical x 6.67
(due to 15% electrical generating efficiency)

= 221,685,200 BTU
138,000 BTU/gal x $1.50/gal
= $2,409.

Total fuel oil costs for the pre-design case are $2,773/yr for energy assuming: 13% for heat and 87% for electricity (lighting) and mechanical.

5c. Final Energy Cost Estimates:

Estimates of the energy costs for the final design case (first year only) totals: 42,995,000 BTU.

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel oil</td>
<td>21.5%</td>
</tr>
<tr>
<td>Lighting</td>
<td>25%</td>
</tr>
<tr>
<td>Passive solar</td>
<td>45.7%</td>
</tr>
<tr>
<td>Human</td>
<td>7.8%</td>
</tr>
</tbody>
</table>

1). Fuel oil is required to provide:

9,243,925 BTU
89,700 BTU/gal @ 65% efficiency x $1.50/gal = $155.

2). Electricity provides, from fuel oil at 15% efficiency, 25% of the space heat from lighting and mechanical equipment.

10,748,750 BTU
138,000 BTU/gal x 6.67 (efficiency = \(\frac{1}{.75}\))
= 520 x $1.50 = $779.00

3). Solar energy provides 19,648,715 heating BTU/year at an average annualized cost of $937.00 based on a 20 year lifetime. This is the equivalent of $47.00/million BTU or $4.21/gal of fuel oil; this does not include the daylighting displaced electrical use. This appears uneconomic, but daylighting benefits are not considered. If the cost are based on $350 per year (capital costs only), then the energy costs $17.81/mmBTU.

If 50% of the lighting (from daylighting) is also given as a credit against oil use, the equivalent oil saved provided (approximately) 110 million BTU (see Vb (2)). With this credit, the savings by using solar daylighting can be said
OPERATIONAL FUEL COSTS - 1st YEAR

$155  Fuel oil    8.3%
779    Electricity 41.7%
937    Solar      50%

$1868   100%
to provide an additional fuel savings of 1,226 gallons. This represents $1,839 (if fuel is $1.50/gallon), which far exceeds the annualized cost of the solar elements in the first year.

A derivation of the annual solar costs follows. A first cost of $7,000 is amortized at 12% interest for 20 years. What is the annualized cost? The problem is solved by the annual cost method.

\[
\text{Annual cost} = \frac{7,000 \times (CR - .12 \times 20)}{(CR - .12 \times 20)}
\]

\[
= 7,000 \times (.1339)
\]

\[
= $937/yr
\]

If the purchase is made interest free and total, such as the state purchase of a school, the annualized cost is $350/yr plus maintenance.

If the costs of all passive solar and energy conservation cost additions are considered, then the annual cost is:

\[
\text{Annual cost} = \frac{13,300 \times (CR - .12 \times 20)}{(CR - .12 \times 20)}
\]

\[
= 13,300 \times (.1339)
\]

\[
= $1,780
\]

Again, if no interest is paid, the simple annual cost is $665.

5d. Difficulties in Calculations:

It is clear from the preceding two sections that the energy cost calculations are based on the pre-design building shell heat loss calculations and the solar annual fraction of heating calculated in a TRNSYS computer simulation for both cases. No problems were encountered. However, the calculations represent only estimates of the true thermal performance of the buildings. The mechanical energy for the ventilation fan is included in the electrical calculation.
CHAPTER 2

DESIGN PROCESS DOCUMENTATION REQUIREMENTS, PRE-DESIGN TASK
1. BUILDING ENERGY NEEDS

In order to evaluate and understand the requirements for energy in a rural Alaskan school, we investigated several basic elements of the problem. We first assessed all the locally available alternative energy sources that could conceivably be used in the rural school. These included hydroelectric, solar, wood, locally available coal, wind, and locally available geothermal energy. Of all these, solar energy was determined to be by far the most amenable to prototypical applications to rural schools. Solar energy was therefore incorporated as an energy source. Hydroelectric energy was determined to be unreliable because of the extreme variability of streamflow in interior Alaska. Wind is unreliable in most low-lying areas of the Interior. Coal and geothermal energy are both site specific, and may have application in some locations. Wood is generally available but requires daily attention and storage. Fuel oil is available commercially at all sites in interior Alaska, whether shipped by barge, truck, or air.

1(i). Task Overview:

The approach used to evaluate the building energy requirements was as follows. First, we had extensive consultations with the Yukon-Koyukuk School District maintenance manager, Mr. Charles Chaney, and Mr. Bob Venusti of the design section of Alaska DOTPF. Both these men gave us an overview of what a state-of-the-art building is and gave us information on pitfalls to avoid. Mr. Chaney also gave us access, along with Bill King, school district engineer, to the most recently designed and constructed school in the system, the Manley School. We were given the entire set of construction documents and design specifications. This allowed us to model the building energy requirements of a school classroom built to these specifications. Using the Manley School as a model for wall design, insulation, lighting and roof design, we used the standard method of R-values and building element surface area to calculate the building heat loss coefficient for a 600 ft$^2$ module school classroom, with 20 occupants maximum. Code ventilation requirements
FIGURE 1

HEATING DEGREE DAYS - FAIRBANKS, ALASKA

AVERAGE SOLAR RADIATION ON A VERTICAL SURFACE - SOUTH FACING
FAIRBANKS, ALASKA
were specified by the architect and lumped with the building infiltration heat loss. Code ventilation requirements are 5 CFM/occupant, which is about 0.5 air changes per hour.

Climate data were obtained from the Environmental Atlas of Alaska (Hartman and Johnson, 1979) for wind, snow load, and other climatic information. Solar radiation data are available for Fairbanks, and Solmet (NOAA) data are available for several other interior Alaska sites: Bettles, Big Delta, Summit, McGrath. In all cases, the Fairbanks data were used in our study. A copy of a chart showing the solar radiation available on a south-facing vertical surface versus heating degree days is attached here.

The building form was designed using wooden models of the school classroom modules and orienting them around a larger module presumed to be a gymnasium and multipurpose room. This design is becoming a standard for Alaska rural schools: a large central gymnasium and multipurpose room surrounded by smaller classrooms. Therefore, the prototype school is designed with the north wall common to a larger structure, and the roof slants upward toward the north, allowing drainage away from this larger building. The building form is an expression of this design option.

1(ii). Unavailable Information:

We had to construct our own sun path diagrams, and set up our own computer system using models of TRNSYS to simulate the performance of the solar rural school. Additional accurate information on the energy consumption rates and patterns of rural schools would have been instructive and helpful, but generally the information available was unreliable or simply missing. It was necessary in many instances that we start from "square 1," since this was the first work of its type in Alaska. We would have preferred solar radiation data in fortran-compatible tape format (we now have this), and an accurate daily accounting and correlation between available solar radiation and building heat loss.

1(iii). Incremental Passive Design Cost:

The design costs for passive solar includes the following items:

<table>
<thead>
<tr>
<th>Materials (after section 3v)</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>7,000</td>
</tr>
<tr>
<td>Conservation</td>
<td>6,300</td>
</tr>
</tbody>
</table>
October 20, 1980

Richard Seifert  
c/o Battelle-Northwest Laboratories  
HS-4 Building, 3000 Area  
Richland, Washington 99352

Re: Solar Alaskan School, Project No. 7988

Dear Rich,

Enclosed please find a copy of the solar school cost estimate, which I received last Thursday. At present, without a specific site, it works out at $162.50/square foot; this figure is deceptive, however, as it includes that huge ramp attached to one side of the building, which represents a sizeable framing and roofing cost.

I took extra time to separate out the costs attributable to the superinsulated structure and passive solar components, which are as follows:

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metals</td>
<td>$300</td>
</tr>
<tr>
<td>6100 Rough Carpentry</td>
<td>3,000</td>
</tr>
<tr>
<td>7210 Building Insulation</td>
<td>3,000</td>
</tr>
<tr>
<td>11100 Solar Energy Components (concrete trombe wall, shutters &amp; Kalwall glazing)</td>
<td>7,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$13,300</strong></td>
</tr>
</tbody>
</table>

This figure is 9% of the total cost, which may prove a good comparison with the energy savings provided by the design.

Please let me know if you need more detailed information than the above.

Yours sincerely,

Janet M. Matheson AIA  
JANET MATHESON ARCHITECT

Enclosure (1)
October 10, 1980

Janet Matheson, Architect
P.O. Box 80567
Fairbanks, Alaska 99708

REF: Passive Solar Rural School Classroom Prototype

SUBJ: Preliminary Construction Cost Estimate

Dear Ms. Matheson:

The estimated cost of construction of the prototype classroom is $156,000. Enclosed is a recapitulation of the estimate together with the supporting data. This estimate is incomplete in that it does not include the costs generally associated with remote site construction. The cost does include an allowance for piling foundations as if it were to be constructed at a remote site. However, this amount could vary greatly depending on the site and other circumstances.

It is very difficult to offer a reliable cost guide for a completed structure until a site is selected. If this structure were built in Fairbanks, on piling, it is likely that the cost would be less than the $156,000 estimate. The costs suggested assume the natural inefficiencies associated with bush construction. If this structure were built in any bush community the costs would be higher than this estimate. Site work and all direct overhead would have to be added in amounts dependent on the site selected.

When a site is selected, I will be glad to look at this estimate again and revise to meet actual conditions.

Very truly yours,

CLARK-GRAVES, INC.

Donald M. Graves

DG/ jb

CLARK-GRAVES, INC.
Recapitulation
Passive Solar Rural Classroom Prototype
Janet Matheson, Architect

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 General Requirements</td>
<td>n/a</td>
</tr>
<tr>
<td>2 Sitework</td>
<td>n/a</td>
</tr>
<tr>
<td>2350 Pile Foundations</td>
<td>$40,000</td>
</tr>
<tr>
<td>5 Metals</td>
<td>6,000</td>
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<tr>
<td>6100 Rough Carpentry</td>
<td>12,000</td>
</tr>
<tr>
<td>6170 Glulam Units</td>
<td>4,000</td>
</tr>
<tr>
<td>6190 Prefab Trusses</td>
<td>5,000</td>
</tr>
<tr>
<td>6192 Fabricated Joists</td>
<td>2,000</td>
</tr>
<tr>
<td>6200 Finish Carpentry</td>
<td>5,000</td>
</tr>
<tr>
<td>7190 Vapor Barrier</td>
<td>1,000</td>
</tr>
<tr>
<td>7210 Building Insulation</td>
<td>8,000</td>
</tr>
<tr>
<td>7600 Sheet Metal &amp; Metal Roofing</td>
<td>13,000</td>
</tr>
<tr>
<td>7900 Sealants</td>
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</tr>
<tr>
<td>8110 Hollow Metal Work</td>
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<tr>
<td>8200 Wood Doors</td>
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<tr>
<td>8600 Wood Windows</td>
<td>3,000</td>
</tr>
<tr>
<td>8700 Finish Hardware</td>
<td>2,000</td>
</tr>
<tr>
<td>8850 Glass &amp; Glazing</td>
<td>-0-</td>
</tr>
<tr>
<td>9250 Gypsum Drywall</td>
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</tr>
<tr>
<td>9500 Acoustical Treatment</td>
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<tr>
<td>9650 Resilient Flooring</td>
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<tr>
<td>9680 Carpeting</td>
<td>3,000</td>
</tr>
<tr>
<td>9900 Paint</td>
<td>4,000</td>
</tr>
<tr>
<td>10100 Chalkboard &amp; Tackboard</td>
<td>1,000</td>
</tr>
<tr>
<td>10800 Misc. Specialties</td>
<td>1,000</td>
</tr>
<tr>
<td>11100 Solar Energy Material</td>
<td>7,000</td>
</tr>
<tr>
<td>12670 Floor Mats</td>
<td>-0-</td>
</tr>
<tr>
<td>15 Mechanical</td>
<td>17,000</td>
</tr>
<tr>
<td>16 Electrical</td>
<td>9,000</td>
</tr>
</tbody>
</table>

Total Estimated Cost: $156,000

CLARK-GRAVES, INC.  
October 10, 1980
Architectural work $15,000
Energy consultant work $14,000
Computer time $1,400
Overhead and inhouse costs ~$14,000

Total Passive Design Increment Cost 57,700

Note that $44,000 of this cost is atypical of future passive design efforts, as most of the learning from this experience is being incorporated into the *Alaska Solar Design Manual* and will be available as general professional knowledge henceforth. As stated earlier, a considerable amount of time was devoted to bringing our staff up on the learning curve for passive solar applications.

1(iv). **Performance Analysis/Results:**

The following are pre-design performance estimates. The lighting and ventilation are assumed to run at full rating 24 hours per day because of the requirement to load the generator for efficient operation. We realize this is an inefficient and unacceptable mode of operation, but it nonetheless is a realistic example of present-day systems. In our prototype system, we use it to evaluate passive solar heating in a present-day context. Since this is a larger part of the energy problem, the electricity production is being investigated using ORMAT organic Rankine cycle turbines for rural applications. These are load-following and the waste heat can be used for heating the structure. Lighting levels may also appear high but in fact are based on the design of the Manley School, i.e., continuous fluorescents and 2.42 watts/ft² ceiling area.

Probable transportation modes building occupants will use to and from the building: This is a relatively simple matter. In almost all cases they will walk. In a very few cases (Fairbanks and Nome), they may use school buses. It is unlikely that any site changes will reduce transportation energy requirements.

Estimated total water volume required per year: For the module itself, only drinking water is required. At 1 quart/day per occupant, this is:
1 quart/day x 20 days x 20 occupants = 4,000 quarts
occupant

= 1,000 gal/school year

If the module is stand-alone, of course, more water will be required. For ephemeral handwashing and showers, much more water is required:

25 gal/day/occupant x 20 occupants x 20 days = 100,000 gal/year.

At least half of this would need to be hot water, perhaps more. Ideally, however, the main water use would be in another larger structure. Conservation of water may be a serious consideration in some villages, but most have a well near the school that is sufficient and causes few problems, since the river-determined water table is usually at a shallow depth in riverside villages. Water quality can be a large problem. Water conservation is also an important consideration from the point of view of sewage disposal, which can also be a severe problem in rural Alaskan villages. An organic waterless toilet system might be worth testing and developing.

l(v). Economic Analysis/Results:

Client's construction budget: The client is actually developing a prototype building and the construction budget is not constrained and, in fact, the operating and fuel costs are being considered on a life cycle costing basis. The Alaska DOTPF is attempting to incorporate life cycle costing in its budgeting process.

First-year energy costs: The following is a pie chart of operating energy costs for the first year of operation of the passive rural school design. No demand charges apply, and the building is state owned; therefore, the only taxes paid are those on fuels.

Economic implications: The economic implications for the passive rural school design are clear—the passive solar/energy conservation design option is highly desirable, but it must be coupled with a better electrical generating system to complete an efficient system for rural Alaska. Without changing the diesel electric generating systems, the
heating problem—even if solved by passive solar design—does not significantly alter the fossil fuel dependence of rural schools, so the costs would remain high without an improved electrical system.

1(vi). **Architectural Compatibility:**

The client's initial feelings toward saving nonrenewable energy resources are central to this project. Alaska's transportation problems and sparsely settled populations add inordinate burdens and expenses to energy transport. For the economic and social benefit of all Alaskans, substitution of fossil fuel use is a general policy that is gaining wider acceptance as satisfactory substitutions are made. This change is supported by the design team and the Alaska Department of Transportation and Public Facilities.

2. **SITE ENERGY POTENTIALS**

2(i). **Task Overview:**

The design team reviewed the resources available at schools in rural Alaska by reviewing several sources of information. The Alaska Regional Profiles (AEIDC, 1978) were used, as well as the inventory of rural schools being presently assembled by the planning department of the Alaska Department of Transportation and Public Facilities in Juneau.

Lastly, an energy resource assessment entitled Alaska Regional Energy Resources (1977) was reviewed to ascertain the available resources on site in interior Alaska. These resources were evaluated in terms of reliability, depth of knowledge about each, development costs, and the familiarity of Alaskans with the associated technologies of utilization.

2(ii). **Unavailable Information:**

Most of the information about the renewable energy resource options on site were difficult to obtain or unavailable (such as a technology
OPERATIONAL FUEL COSTS - 1st YEAR

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Cost</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>$145</td>
<td>Fuel oil</td>
<td></td>
<td>8.3%</td>
</tr>
<tr>
<td>779</td>
<td>Electricity</td>
<td></td>
<td>41.7%</td>
</tr>
<tr>
<td>937</td>
<td>Solar</td>
<td></td>
<td>50%</td>
</tr>
<tr>
<td>$1868</td>
<td></td>
<td></td>
<td>100%</td>
</tr>
</tbody>
</table>
FIGURE 1

HEATING DEGREE DAYS - FAIRBANKS, ALASKA

AVERAGE SOLAR RADIATION ON A VERTICAL SURFACE - SOUTH FACING
FAIRBANKS, ALASKA

104
<table>
<thead>
<tr>
<th>Station ID</th>
<th>Station Name</th>
<th>Latitude/Longitude</th>
<th>Elevation</th>
<th>Period of Record</th>
<th>Annual Average Wind Speed m/s</th>
<th>Annual Average Wind Power, watts/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrow</td>
<td>Wiley Post - Will Rogers Airport</td>
<td>71.3 156.8</td>
<td>9.4</td>
<td>04/05-12/64</td>
<td>7.4</td>
<td>370</td>
</tr>
<tr>
<td>Barter Island</td>
<td>Barter Island Airport</td>
<td>70.1 143.6</td>
<td>11.9</td>
<td>01/49-08/55</td>
<td>6.9</td>
<td>370</td>
</tr>
<tr>
<td>Bettles</td>
<td>Bettles CAA</td>
<td>66.9 133.5</td>
<td>203.0</td>
<td>05/51-12/64</td>
<td>8.2</td>
<td>37</td>
</tr>
<tr>
<td>Cape Lisburne</td>
<td>Cape Lisburne AFS</td>
<td>68.9 166.1</td>
<td>16.1</td>
<td>04/61-12/71</td>
<td>5.5</td>
<td>272</td>
</tr>
<tr>
<td>Fairbanks EIE</td>
<td>Fairbanks AFB</td>
<td>64.7 147.1</td>
<td>173.4</td>
<td>08/59-12/70</td>
<td>5.0</td>
<td>13</td>
</tr>
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<td>Fairbanks INT</td>
<td>Fairbanks International Airport</td>
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<td>134.1</td>
<td>09/57-12/64</td>
<td>4.1</td>
<td>26</td>
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<tr>
<td>Flaxman Island</td>
<td>Flaxman Island Air Field</td>
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<td>7.0</td>
<td>08/57-12/70</td>
<td>5.0</td>
<td>232</td>
</tr>
<tr>
<td>Fort Yukon</td>
<td>Fort Yukon CAA</td>
<td>66.6 145.3</td>
<td>129.5</td>
<td>01/52-09/63</td>
<td>5.6</td>
<td>69</td>
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<tr>
<td>Galena</td>
<td>Galena AFS</td>
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<td>45.4</td>
<td>04/62-11/68</td>
<td>5.2</td>
<td>35</td>
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<tr>
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<td>288.3</td>
<td>04/61-12/20</td>
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<tr>
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<td>Ralph Wein Memorial Airport</td>
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<td>6.1</td>
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<td>309</td>
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<tr>
<td>Lonely Point</td>
<td>Lonely Point Air Field</td>
<td>70.9 152.3</td>
<td>9.0</td>
<td>07/37-11/75</td>
<td>4.3</td>
<td>171</td>
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<tr>
<td>Moses Point</td>
<td>Moses Point AAF</td>
<td>64.7 162.1</td>
<td>6.4</td>
<td>06/52-07/64</td>
<td>5.6</td>
<td>241</td>
</tr>
<tr>
<td>Nenana</td>
<td>Nenana AAF</td>
<td>66.6 149.1</td>
<td>119.9</td>
<td>07/53-12/64</td>
<td>5.6</td>
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<td>Nome</td>
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<td>5.5</td>
<td>08/58-12/64</td>
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<td>247</td>
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<td>Oliktak Air Field</td>
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<td>5.0</td>
<td>08/57-11/75</td>
<td>5.2</td>
<td>254</td>
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<tr>
<td>Point Lay</td>
<td>Point Lay Air Field</td>
<td>69.7 163.0</td>
<td>6.0</td>
<td>08/57-11/75</td>
<td>5.4</td>
<td>281</td>
</tr>
<tr>
<td>Tanana</td>
<td>Tanana FSS</td>
<td>65.2 152.1</td>
<td>73.2</td>
<td>07/48-12/64</td>
<td>10.1</td>
<td>42</td>
</tr>
<tr>
<td>Tin City</td>
<td>Tin City AFS</td>
<td>61.6 167.9</td>
<td>78.6</td>
<td>06/60-12/11</td>
<td>7.4</td>
<td>519</td>
</tr>
<tr>
<td>Umiat</td>
<td>Umiat Airport</td>
<td>69.4 152.1</td>
<td>102.7</td>
<td>07/48-12/52</td>
<td>10.7</td>
<td>91</td>
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<tr>
<td>Wainwright</td>
<td>Wainwright Air Field</td>
<td>70.6 160.1</td>
<td>27.0</td>
<td>08/57-11/75</td>
<td>4.3</td>
<td>192</td>
</tr>
</tbody>
</table>
MONTHLY AVERAGE WIND POWER AND SPEED

--- WIND POWER --- LEFT ORIGINATE - WATTS/MI

--- WIND SPEED --- RIGHT ORIGINATE - MI/SEC

ABSCISSA - MONTH

V AND P ADJUSTED FROM Z TO 10 M BY 1/7 POWER LAW

Figure 4.11. Monthly Average Wind Power and Speed for Northern Alaska.
MONTHLY AVERAGE WIND POWER AND SPEED

WIND POWER
LEFT ORDINATE - WATTS/M²
WIND SPEED
RIGHT ORDINATE - M/SEC
ABSCissa - MONTH

V AND P ADJUSTED FROM Z TO 10 M BY 1/7 POWER LAW

Figure 4.11 (continued). Monthly Average Wind Power and Speed for Northern Alaska.
Figure 4.12. Diurnal Wind Speed by Season for Northern Alaska.
Figure 4.12 (continued). Diurnal Wind Speed by Season for Northern Alaska.
Figure 4.16. Wind Power Duration - Annual Average for Northern Alaska.
Figure 4.16 (continued). Wind Power Duration - Annual Average for Northern Alaska.
FIGURE 19, HYDROGRAPHS - Kuskokwim River / Yukon River
for geothermal applications, and flow data for small local streams for hydroelectric applications). It would only be necessary that streamflow records be available and annual acre-feet of runoff be tabulated.

2(iii). Incremental Passive Design Costs:

This is similar to the previous discussions of the same items in Section 1(iii).

2(iv). Performance Analysis of Site Energy Potentials:

Solar energy: available for all sites.
Wind: unreliable and generally average velocities in the sub-arctic/interior Alaska area are below 7 mph and are consequently not useful.
Fuel oil: generally available by barge, road or air.
Geothermal energy as hot springs: site specific and local, generally not available at required sites.
Hydroelectric, especially low head: site specific, requires impoundment of large storage volume and is not feasible at all prospective sites.

The following are data or plots showing the dynamic availabilities of the energy sources investigated during pre-design. Not all are included here. There is no point, for instance, in including a geothermal hot spring since its output is relatively constant. Included are plots of solar energy on a south-facing vertical surface by month, and a series of plots describing the availability of wind at 21 sites in interior and rural Alaska. Only the coastal sites in this region have wind speed that is high enough to provide an option: Barrow, Barter Island, Cape Lisburne, Kotzebue, Moses Point, and Tin City.

2(v). Economic Analysis/Results:

Attached is an article that describes very accurately and clearly the problems of rural electric rates and utilities in Alaska.
ELECTRIC RATES IN ALASKA:
An Opinion

Electricity rates in Alaska vary more from community to community than do those in any other state. Elsewhere it is rare to see a disparity of 2 to 1 from the highest to the lowest energy rates per kilowatt-hour; in Alaska, the disparity is in the range of 10 to 1 or higher. The state has not yet addressed this growing problem in a significant way; yet substantial construction money is flowing into remote areas, creating ever-increasing demands for energy.

The recently announced major price increase by the OPEC nations, with more increases to come, means that the state of Alaska and the Federal Government will receive substantially increased revenues, and the oil companies will receive major profit gains. All consumers suffer through the increased cost for various means of transportation and the universal inflationary problems touched off by these events. However, there is one class of consumer that receives a second major blow from these changing fortunes: everyone in areas where oil-fueled generation is the only practical established method of providing electric power in quantity. The majority of organized communities in Alaska are currently in that category.

The present tariff rate for the Alaska Village Electric Cooperative, Inc. (AVEC) approved by the Alaska Public Utilities Commission (APUC) for residential consumers is 37.2 cents per kWh. This rate was approved to be effective on March 1, 1978, and was justified as a minimum reasonable requirement after an extensive study of AVEC. The 1978 tariff rates were based on a delivered fuel cost of 68 cents per gallon. Current replacement fuel costs for AVEC only 18 months later are $1.10 per gallon and rising, an increase of 62%. (The price of delivered fuel in 1973 for AVEC was some 35 cents per gallon, so the cost of bulk-delivered fuel is up 314% in six years.)

Based only on the fuel price increase since the 1978 tariff went into effect, AVEC rates must soon be at 44 cents per kWh. With general inflation near 10%, further pushing up the kWh cost, rates will exceed 50 cents per kWh in village Alaska within two years, and this is more than the majority of consumers can stand.

There is a definite need for the government to consider seriously the problem of some reasonable equity in cost of electric energy to our citizens. This is an unusual situation affecting a commodity which has generally been accepted as a necessity in this country. Electric energy rates in many parts of Alaska are hitting a crisis level.

During the coming year, major new school projects are scheduled in many more villages as a result of the Hoistach Case settlement, which requires the state to provide secondary schools in rural Alaska so students are not forced to leave the region to finish their education. These follow major school construction activities during the past four years. Grant funds from one source or another continue to emerge at an increasing rate, and most of these lead to increased energy demands. Some 300 new houses are under construction in villages that AVEC serves. The Public Health Service has major plans for further activities and, of course, the communications network continues to expand. These facilities generally are required, but the long-range cost of operation may prove an overwhelming burden to local or regional resources.

More and more consumers and communities are not going to be able to pay for the energy to run these facilities. A review of AVEC problems to date demonstrates serious payment collection difficulties for electric power used to run these facilities. In addition, locally-established consumer rates for water or sewer services provide little or nothing for depreciation or maintenance, which may present major concerns when future modification, expansion, or replacement is required.
KEY PROPOSAL

Major investments have been made recently in many smaller communities to improve local education, communications, water and sewer, housing, transportation, and community facilities. Thousands of students will be graduating from outlying high schools with very inadequate opportunity to find jobs or start businesses in or near their hometowns. The greatest single problem in creating a balanced climate for economic activity is the high cost of electricity. The cost of most items in small communities (groceries, fuel oil, etc.) is generally in the range of 2 to 1 over Anchorage, and people tend to accept this, but electric rates at 10 to 1 are simply too high.

The state should normalize electric rates at more equitable levels to promote local small community business activity. Overall costs and service standards could be subject to APUC regulation, recognizing the increasing problems of serving very small isolated communities. The maximum retail electric energy rate across Alaska should not exceed 2.25 times the average retail rate per k\(\text{W}\) of the least expensive utility in Alaska during the previous calendar year. This would be simple and easy to administer. The state would reimburse the utility the difference between the actual cost of operations at a reasonable service level, as determined by APUC, plus minimum margin or return on equity to meet lender and regulatory requirements, less revenues from sales at the determined rate. This method would also automatically accommodate inflation factors working on the general economy. There would also be a strong incentive for the outlying areas and the state government to help provide the energy and other resources to hold down energy source costs for the lower cost producers in the major developed areas. A climate for real teamwork would be created to ensure dependable future access to energy resources at the lowest cost to Alaska utilities. This investment to provide an essential tool for economic activity will return itself to the state many-fold over the coming decades through more business, more employment, more state tax base, more self-sufficiency, and reduced social problems and costs.

The big difference between the smaller utilities in Alaska and national averages is the absence of substantial commercial and industrial load. For 1978, the breakdown of AVEC revenue by consumer categories was: schools, 42%; residences, 34%; other public facilities, 14%; and commercial, 10%. This breakdown clearly shows the dominant role of the school systems in providing economic feasibility for electric service in small communities.

These reduced electric rates, in addition to the primary task of stimulating economic activity would:

a) Help reduce the price of consumer goods in the stores through lowered operating costs.
   This is valuable for areas with the highest living costs in the world and limited incomes.

b) Reduce the very heavy burden on smaller local governments running local services such as water, sewer, and other health or community facilities.

c) Reduce direct cost to the Area School Systems, as the major electric user, and set the stage for using these funds for other required programs.

d) Reduce direct out-of-pocket expenses for residential consumers in these high-cost areas, thereby establishing a more equitable standard of family living. Even though the rate will be up to 2.5 times that in more developed areas, this will still establish a more favorable climate to attract and retain trained personnel required for new enterprises.

Expanded economic activity, plus the introduction of newer energy generating techniques, will produce a steady narrowing of the 10 to 1 cost ratio within 10 years, and it may well be within the 2.5 ratio by the year 2000 so that direct state investment would no longer be needed. The state should continue support for investigations into promising new energy sources for early use as soon as these are economically and technically sound. This policy would clearly establish a much-improved climate for increased economic activity throughout most of Alaska. People in the
Two other factors directly contribute to the economic difficulties in rural Alaska. The first is the cost of transporting and storing adequate amounts of fuel oil, which directly relates to the electrical generation cost problem, since electricity is generated by burning fuel oil. Fuel oil costs $1.50 to $3.50 per gallon, and is likely to increase at a rate in excess of inflation because of the increasing direct costs of transport associated with using fuel oil in rural Alaska.

The high cost of labor and maintenance requirements are also a definite disadvantage, because a breakdown requiring skilled maintenance could cost 3 days and $1,000 to $1,500 in costs. This is because the round trip air fare, three days pay, and food and lodging for the flown-in maintenance man costs that much. The important point is: try to keep any technological applications simple and within the scope of the village skills.

2(vi). Architectural Compatibility:

The architectural advantage of any prospective site with respect to energy utilization is that the building can be sited to take advantage of passive solar gain more easily that it can be used for any other renewable energy resource. The decision to optimize the use of passive solar energy clearly follows from this feature.

3. MATCHING ENERGY NEEDS AND SITE ENERGY POTENTIALS

3(1). Task Overview:

The energy needs of the building are determined by the use and the heating (degree-day) index of the site. In order to best match the potential energy sources with these needs, the annual variability and availability needed to be examined. Wind availability peaks in the winter. Wind is the only renewable resource to do so, but it is not generally available in interior Alaska. Conservation design, therefore, was a big consideration in determining the need and magnitude of heating for the structure, both from an economic and physical standpoint. It
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PROGRAM DEVELOPED BY: AXEL R. CARLSON, EXTENSION ENGINEER, COOPERATIVE EXTENSION SERVICE, UNIVERSITY OF ALASKA, FAIRBANKS, ALASKA 99701.

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TABLE: INSULATION ENERGY OPTIMIZATION, FAIRBANKS, AK

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<th>R-VALUE</th>
<th>BTU/H-F</th>
<th>FUEL OIL GALLON</th>
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<th>BUILDING COST($)</th>
<th>PAYBACK</th>
<th>NET SAVINGS($)</th>
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<td>FUTURE</td>
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<td>ANNUAL</td>
<td>YEARS</td>
<td>PRESENT</td>
<td>FUTURE</td>
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TOTAL PRINCIPAL $ 20374., TOTAL INTEREST $ -20374., AND TOTAL MORTGAGE PAYMENTS OF $ 0. OVER 0. YEARS.

TOTAL ENERGY COST OF $ 6210. OVER 5 YEARS.

AVERAGE INTERIOR TEMPERATURE (DEG. F) 65.0

THE BUILDING COSTS ONLY INCLUDE EXTERIOR SHELL.
was necessary to evaluate the incremental costs of conservation/insulation by construction type, in order to optimize the economic trade-off between conservation design and energy supply options. A copy of the chart of insulation optimization used for this decision is attached.

The task of matching solar energy to daylighting needs was also addressed using the Libbey-Owens-Ford Daylighting Guide and Handbook.

3(ii). **Unavailable Information:**

Matching end use to needs was not badly impaired by unavailable information, because the process is generally concerned with estimates. Performance data correlating passive solar structures with available solar radiation would have been helpful. Information on daylighting prospects and experience in the use of daylighting in Alaska would also have helped. Eventually, we will know how much waste heat we might capture from the use of an ORMAT generator for electrical production, but this information is also not available.

3(iii). **Incremental Passive Solar Design Cost:**

See Section 1(iii).

3(iv). **Performance Comparisons of Alternatives:**

1. **Passive Solar for Heating** - utilized in a direct gain system with Kalwall and standard glazings and a prompt wall. This represents approximately 29,000,000 heating end use BTU/year. It replaces fuel oil for heating and for producing electricity, lighting, and waste heat from lighting which also heats the building. Its contribution was determined by utilizing the TRNSYS computer simulation program to predict its annual performance.

2. **Solar Daylighting** - on an annual basis. Further study is required for this possibility, but it appears that solar daylighting could easily displace half the lighting (now considered to be 24 hours), and probably could displace more
because building use is coincident with the daylight hours. This could save perhaps 1/2 of all the fuel oil generation of electricity, and is an excellent opportunity to utilize waste for heating. The BTU savings of the electric substitution by daylighting could be as much as 58 million BTU/year because of the poor efficiency of the electrical generators (6.67 x 8 million BTU electrical equivalent).

An indicative pie chart follows. It shows which end use sectors can be displaced by solar energy and conservation and to what magnitudes.

Present goals for the building are:

1. **Code** ventilation with possible augmentation of heat loss requirements through air-to-air heat exchange. This technology remains imperfect for subarctic applications.

2. **Energy conservation** in building design, utilizing shutters, double wall construction with 11.5-12 inches of fiberglass, 16.5 inches of fiberglass in the ceiling, all of which contribute to halving the conductive building heat loss compared to the base case.

3. **Solar energy** provides approximately 45% of the space heating requirements saving 20 million BTU of fuel oil (at the minimum) for space heating per year.

In order that the solar energy is not negated by the discomfort of the school students, the direct gain system is modified to diffuse the gain for daylighting in the interior space (Kalwall glazing). Both ends of the south facade are glazed with 2 x 8 ft clear glazing to emphasize the daylighting of the interior east and west walls. At the bottom of the south facade is a "prompt wall" (an absorptive/radiative/convective low mass and storage wall) which mainly serves to help gain and convect solar heat throughout the classroom. Shutters are operated in response to available solar radiation and can save 20-30% of the heat loss of a system without shutters—a minimum of 8-12 million BTU. Forty-nine million BTU would be used if unshuttered, and 37 million if shuttered for 12 hours a day.
AT LEAST \(\frac{1}{2}\) OF THE LIGHTING REQUIREMENTS COULD BE REPLACED BY DAYLIGHTING.

65% OF WINDOW LOSSES SAVED BY SHUTTERING.

57% SAVINGS FROM INCREASED INSULATION.

**SOURCES**

- Human: 4%
- Fuel oil: 34%
- Auxiliary heat: 10%
- Solar: 25%
- Ventilation loss: 28.2%

**LOSSES**

- Walls: 21.2%
- Floor: 16%
- Door: 5%
- Building shell loss: 71.8%

**TOTAL**

- Units: \(10^6\) btus
- Total: 63,947,654 btus
- 106,579 btu/ft\(^2\)/yr

**ENERGY GOALS FOR THE BUILDING**

**BASE CASE**

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

**DESIGN TEST 1**
3(vi). Economic Analysis of Alternatives:

The analysis of alternatives was not discriminated by economic impact in the pre-design phase. The choice of a direct gain system was obtained by physical results from the TRNSYS simulations. The economic analysis was accomplished after the physical evaluations. A detailed economic evaluation of the options is included in Section 3(iii).

A point worth emphasizing in the discussion is that the total energy costs for a standard school (pre-design) case are estimated to be $2,773 per year, and for the final design passive solar school, they are $1,868/ year in the first year, of which $937 is the inflation-proof annualized cost of the solar elements of the building. See 5(c) 1, 2, and 3 of the section on pre-design.

3(vi). Architectural Compatibility:

Potential energy sources were disregarded for the following reasons:

3. Economic constraints - Trombe wall options: The costs of masonry delivery and construction in rural Alaska simply outweigh the benefits of the trombe wall.
4. Product availability - Wind products are available but wind is not, and technologies for storing and harnessing wind and hydroelectric power are not easily applied to the rural school heating problem.
5. Lack of suitable information or techniques - storage of solar energy suffers presently from this problem and was not considered because of it.
6. Liability or warranty problems - No energy options were dismissed on this basis.

The passive solar/conservation architectural option enhances the architectural program more than any other onsite energy option (such as wind electric or hydroelectric). Consequently, it was a simple choice to make it the energy option to include in the rural school for Alaskan situations.
4. DESIGN INDICATORS FOR BEST STRATEGIES/CONCEPTS.
PRE-DESIGN TASK.

4(i). Task Overview:

The tasks outlined for the energy designer were done in a team context. As one of its first activities, the team met and assembled a list of passive solar design options that consisted of the "classic" passive solar features (such as a trombe wall, attached solar greenhouse, direct gain systems, combinations of these, and conservation-oriented construction). A list of designs was drawn up to provide the examples for the series of design tests used in the TRNSYS computer simulations. Reference materials such as Mazria's Passive Solar Energy Book, the Solar Home Book by Bruce Anderson, and the ASHRAE Handbook of Fundamentals were all utilized for determining properties of systems and materials, and for exemplary design configurations for systems. The results are the 5 design test systems. They are included in the following pages.

4(ii). Unavailable Information:

Generally, we had no problem with unavailable information, since we were using standard passive designs and utilizing one year of solar radiation data for Fairbanks, from which we developed the designs and performance indicators.

4(iii). Incremental Passive Solar Design Cost:

The process of designing the best strategies and concepts required approximately 2 man-weeks of effort by the energy designer and a meeting by the entire team. In-house labor for this was approximately $1,800. The sketching of the schematic designs required approximately 2 man-weeks of an architectural assistant's time, at a cost of $3,040. Materials costs were approximately $50. Approximately 75% of these fees were required for this project only and would not have been required by a similar nonsolar building.
FLOOR PLAN

SOUTH ELEVATION

SECTION

CONSTRUCTION:

WALLS: 2x8 STUDS W/ FULL EXTERIOR FIREPLACE.
FLOOR: 12" PEEGLASS / METAL FOILING.
FLOOR: 12" PEEGLASS.
FLOOR AREA: 600 SF.
WINDOWS: DOUBLE PANED, SHUTTERED.
WINDOW AREA: SOUTH 200 SF.
BUILDING: 2011 BTU/PP.
VENT REQUIREMENT: 54 ACH.
ADDED THERMAL MASS: NONE.
SHADING MECHANISM: COMMON EXTERIOR BLIND.
CONSTRUCTION

Wall: Insulated W/12" Fiberglass.

Roof: 12" FiberGlass, Metal Roofing.

Floor: 12" FiberGlass.


Floor Areas:
Classroom: 600 sq.
Trombe Wall: 210 sq.
Windows: Double Pane.

Window Area:
South: 240 sq. ft. (Trombe)
East: 10 sq.
West: 10 sq.

Building UA: 280 K/°H.

Vent Regent: .50 ach.

Gazed Thermal Storage: 418,000 K/°.

Section

GLAZING

Trombe Wall: Insulated From Room W/6" FiberGlass, Vented W/Temperature Controlled Circulation.

South Elevation

FLOOR PLAN

CLASSROOM

Mass Wall
6" Insulation

ENTRY

SERVICE
FLOOR PLAN

CLASSEOROM

SERVICE

ENTRY

GREENHOUSE

SOUTH ELEVATION

SECTION

CONSTRUCTION

WALLS: 2 X 8 STUDS W/ FULL BATT
FIBERGLASS

ROOF: 1/2" FIBERGLASS, METAL
ROOFING

FLOOR: 1/2" FIBERGLASS

FOUNDATION: PILE OR FOOT, W
INSULATED FLOOR

FLOOR AREAS:

CLASSROOM: 600 sq.
GREENHOUSE: 240 sq.

WINDOWS: DOUBLE PANE

WINDOW AREA:
SOUTH (GREENHOUSE) 240 sq.
EAST 10 sq.
WEST 10 sq.

BUILDING LIA:

VENT RECOMMEND:
ADDED THERMAL Mass:
418,000 KJ/C.

SHADING: MECHANICAL
GREENHOUSE BLINDS.

PASSIVE SOLAR RURAL SCHOOL CLASSROOM prototype | Design Test 4
CONSTRUCTION:

WALLS: 2 x 6 STUDS W/ FULL BATT FIBERGLAS
ROOF: 12" FIBERGLAS, METAL ROOFING
FLOOR: 12" FIBERGLAS
FOUNDATION: PILES OR POLES W/ INSULATED FLOORS

FLOOR AREA: 600 sq. ft
WINDOWS: DOUBLE PANED, SHUTTERED
WINDOW AREA: SOUTH 200 sq. ft
BUILDING U/F: 245 kJ/C
VENT REGIME: 0.5 C.F.M./F.F.
ADDED THERMAL MASS: 20,000 kJ/C
NOTE: SOUTH WALL W/\frac{1}{2} MASS OF TROMBE WALL.

FLOOR PLAN

SOUTH ELEVATION

SECTION

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE DESIGN TEST 5
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<tr>
<td>Overhead</td>
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<tr>
<td><strong>INCREMENTAL TOTAL</strong></td>
<td><strong>$5,790</strong></td>
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</tbody>
</table>

About 25% of this $5,790 is likely to be typical for future passive design efforts. The remainder of the costs were the result of analyzing the "classic" passive systems for their appropriateness in Alaskan applications. Since this work determined the direct gain system to be the best option, that work doesn't need to be repeated. Typical costs for future design work should provide for analysis of best orientation, design and performance predictions.

4(iv). **Performance Design Indicators:**

The energy problems that the passive design concepts tried to solve were:

1. Building heating needs (supply).
2. Daylighting substitution for electrical lighting.

It is unlikely that passive solar heating can supply greater than about 40-45% of the annual heating needs. Seasonal variability and the lack of heat for efficient storage make this a natural reality. Daylighting values are likely to follow the solar availability but should provide 50% of the lighting requirements without many problems. The savings of energy possible through energy conservation are a matter of how much is used, and the ability to use air-to-air heat exchange. However, this analysis has shown that approximately 20-30 percent of the heat loss of a standard specification rural school can be saved by energy conservation measures.

The designer used base-case school specifications from the Manley School at Manley Hot Springs and evaluated each design test against this base, defining the improvements on the basis of annual BTU heating requirements, annual percentage of energy supplied by solar design and conservation improvements.

130
4(v). Economic Design Indicators:

Economic design indicators were not used or developed in any evaluative way during the pre-design.

4(vi). Architectural Compatibility:

Design Alternative 3, the trombe wall design, was discarded because its implementation would severely limit the potential for daylighting of the classroom. None of the design indicators were discarded due to conflicts with the architectural program. Adequate design indicators were developed utilizing the TRNSYS program so they were easily generated.

5. SCHEMATIC DESIGN ALTERNATIVES. DESIGN TASK.

5(i). Task Overview:

Schematic designs were generated to test the basic passive solar design options for an Alaskan rural school. The specifications for each design were developed by the energy designer and then given to the architect to have the schematic drawings made. The same specifications were then used as input for a TRNSYS computer run, and the results of the computer simulation were used to evaluate the expected energy performance of each design. The schematic designs are included in Section 4(i).

5(ii). Unavailable Information:

No problems were encountered at the schematic design stage that were due to unavailable information.

5(iii). Incremental Passive Design Costs:

The costs of the schematic design process break down as follows:
Energy designer/staff
1 man-month $2,800
Architect
1/2 man-month 4,000
Supplies 100
Overhead 1,400
TOTAL SCHEMATIC DESIGN PROCESS COSTS $8,300

Approximately 80% of this schematic design work was unique to this project and would not be required on a subsequent passive design processes.

5(iv). Performance Considerations:

Performance trade-offs in the passive design process were numerous. In the first four design tests shutters were not included in the simulations because they are not easily available commercially, even though they improve performance markedly, as the 5th and 6th (final) designs indicate.

Another trade-off was tested in Design Test 3. This is a trombe wall that is insulated from the interior space by 6 inches of fiberglass. Conceptually, this is an interior shutter. The trombe wall was designed this way to decrease its heat loss during the midwinter periods when little or no gain was available. A plenum type of passage was modeled behind the wall--but between it and the insulated wall--to increase heat transfer to the room. This arrangement was quite inefficient because of the decreased heat transfer from the wall and was not recommended as an option.

The final design is a trade-off itself, since on an annual basis, the final design performs worse than Design 5. The trade-offs are used to limit glare and direct intensive heating of the building interior, and the prompt wall is utilized as storage (short term) and as an inducement to convective air flow to distribute the heat. The prompt wall performs well, but in an annual sum it provides less of the heating requirement (in conjunction with the rest of the final design) than does a direct gain all-glazing system like Design 5. The performance differs by about 4% annually: 49% for direct gain, and 45% for the final design.
The energy systems for each design are as follows:

**Design 2** - features direct gain, no shutters, large glazed area. Heat enters daily, little storage is accomplished, poor performance in winter, overheating in summer.

**Design 3** - is a trombe wall insulated from living space. Heat transfer is by forced convection off the back of the trombe wall. The trombe wall is not a loser when sun is not available because of insulation. It also limits daylighting.

**Design 4** - is a trombe wall and attached greenhouse combination without shuttering and with no insulation behind the trombe wall. This provides better heat transfer into the room for heating, but also loses heat more rapidly because of the lack of the insulation. The advantage of this system is the use of the greenhouse for growing and heating, and also its use for education. Heat is force-convected from the greenhouse through the top and bottom (a convection loop) of the trombe wall. Heat is also conducted and radiated to the interior space from the trombe wall. The trombe wall additionally provides storage and helps extend the possible growing season in the greenhouse.

**Design 5** - is the same as Design 2, a direct gain system, but with shutters. No additional storage is provided. Superinsulation is included.

**Final Design 6** - is a direct gain system but also has a small area of prompt wall to provide a small amount of storage and induce convection. Two large (2 x 8 ft) windows are placed at each end of the south facade to enhance daylighting along the east and west walls. All but eye-level glazing is Kalwall translucent glazing instead of glass, which creates much less a glare problem. Superinsulation is included.

My professional estimate is that these designs provide a valid test of the performance of these systems in the North, and that solar heating may provide 40-50% of heating for systems in the subarctic that do not use seasonal storage. This level of performance requires shuttering.
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>R-VALUE (AVG)</th>
<th>BTU/H-F</th>
<th>FUEL OIL GALLON COST($)</th>
<th>QUANTITY SAVINGS PRESENT FUTURE</th>
<th>BUILDING COST($)</th>
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<td>STUD 2X6 16 OC 5.5 FG..................</td>
<td>17.00</td>
<td>43.1</td>
<td>144.</td>
<td>5</td>
<td>144</td>
<td>291.</td>
<td>4.760</td>
</tr>
<tr>
<td>STUD 2X6 20 OC 5.5 FG..................</td>
<td>18.17</td>
<td>42.2</td>
<td>141.</td>
<td>2</td>
<td>141</td>
<td>285.</td>
<td>4.594</td>
</tr>
<tr>
<td>STUD 2X6 24 OC 5.5 FG..................</td>
<td>18.43</td>
<td>41.6</td>
<td>139.</td>
<td>0</td>
<td>139</td>
<td>281.</td>
<td>4.477</td>
</tr>
<tr>
<td>STUD 2X6 16 OC 5.5 UF..................</td>
<td>21.96</td>
<td>34.9</td>
<td>117.</td>
<td>-22</td>
<td>117</td>
<td>236.</td>
<td>4.323</td>
</tr>
<tr>
<td>STUD 2X6 24 OC 5.5 UF..................</td>
<td>23.12</td>
<td>33.2</td>
<td>111.</td>
<td>-20</td>
<td>111</td>
<td>224.</td>
<td>4.619</td>
</tr>
<tr>
<td>STUD 2X6 16 OC 5.5 UF..................</td>
<td>18.43</td>
<td>41.6</td>
<td>139.</td>
<td>0</td>
<td>139</td>
<td>281.</td>
<td>4.477</td>
</tr>
<tr>
<td>STUD 2X6 24 OC 5.5 UF..................</td>
<td>21.96</td>
<td>34.9</td>
<td>117.</td>
<td>-22</td>
<td>117</td>
<td>236.</td>
<td>4.323</td>
</tr>
<tr>
<td>STUD 2X6 16 OC 3.5 UF..................</td>
<td>18.43</td>
<td>41.6</td>
<td>139.</td>
<td>0</td>
<td>139</td>
<td>281.</td>
<td>4.477</td>
</tr>
<tr>
<td>STUD 2X6 24 OC 3.5 UF..................</td>
<td>21.96</td>
<td>34.9</td>
<td>117.</td>
<td>-22</td>
<td>117</td>
<td>236.</td>
<td>4.323</td>
</tr>
<tr>
<td>STUD 2X6 16 OC 3.5 FG 2 URE...........</td>
<td>34.70</td>
<td>22.8</td>
<td>71.</td>
<td>-66</td>
<td>70</td>
<td>140.</td>
<td>5.384</td>
</tr>
<tr>
<td>STUD 2X4 BDR 1A OC 00.0 FG.............</td>
<td>2.99</td>
<td>256.5</td>
<td>859.</td>
<td>720</td>
<td>859</td>
<td>1731.</td>
<td>4.340</td>
</tr>
<tr>
<td>STUD 2X4 BDR 2A OC 18.0 FG.............</td>
<td>55.31</td>
<td>13.9</td>
<td>46.</td>
<td>-93</td>
<td>46</td>
<td>94.</td>
<td>6.274</td>
</tr>
<tr>
<td>STUD 2X4 BDR 2A OC 18.0 FG.............</td>
<td>56.26</td>
<td>13.6</td>
<td>46.</td>
<td>-94</td>
<td>46</td>
<td>92.</td>
<td>5.964</td>
</tr>
</tbody>
</table>

**TABLE: INSULATION ENERGY OPTIMIZATION, FAIRBANKS, AK**

**TYPE STRUCTURE: RURAL SCHOOL, 1-STORY, 20-OX10-0, POST & BEAM**

**SUM OF *BASE* SURFACES**

**TOTAL EXPOSED AREA (50 FT^2): 2200**

**INfiltration/Ventilation**

<table>
<thead>
<tr>
<th>Ceiling &amp; Wall Air Vision Sealed</th>
<th>0.2 CPH</th>
<th>20.</th>
<th>CFM</th>
<th>73.</th>
<th>BASE</th>
<th>146.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access Openings Thru Ceiling</td>
<td>0.4 CPH</td>
<td>40.</td>
<td>CFM</td>
<td>145.</td>
<td>73.</td>
<td>239.</td>
</tr>
<tr>
<td>Uninsulated Balloon Frame Walls</td>
<td>0.6 CPH</td>
<td>60.</td>
<td>CFM</td>
<td>218.</td>
<td>145.</td>
<td>439.</td>
</tr>
<tr>
<td>Two or More Broken Windows</td>
<td>0.8 CPH</td>
<td>80.</td>
<td>CFM</td>
<td>291.</td>
<td>218.</td>
<td>586.</td>
</tr>
<tr>
<td>Controlled Ventilation</td>
<td>3.2 CPH</td>
<td>320.</td>
<td>CFM</td>
<td>380.</td>
<td>315.</td>
<td>768.</td>
</tr>
</tbody>
</table>

**TOTAL OF *BASE* SURFACES**

| 824. | 824. | 1660. |
**TABLE INSULATION ENERGY OPTIMIZATION, FAIRBANKS, AK**

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>R-VALUE</th>
<th>BTU/H-F</th>
<th>FUEL OIL GALLON</th>
<th>COST(£) (AVG)</th>
<th>QUANTITY SAVINGS</th>
<th>PRESENT FUTURE</th>
<th>BUILDING COST(£)</th>
<th>PAYBACK</th>
<th>NET SAVINGS:</th>
</tr>
</thead>
</table>

Total principal £ 20374, total interest £ -20374, and total mortgage payments of £ 0, over 0 years.

Total energy cost of £ 6210, over 5 years.

Average interior temperature (deg-F): 65.0

The building costs only include exterior shell.
The trombe wall, and trombe wall-greenhouse strategies were both dropped because of their lower annual performance for solar heating, the difficulty in shuttering, and the decreased opportunity for daylighting. For any unshuttered system, the net gain is so diminished that passive solar design is less valuable as an option.

5(v). Economic Considerations:

Economic trade-offs were mainly made with regard to insulation and wall thickness, about which we obtained the most accurate information. It is attached here. Wall, truss, and other building elements were optimized utilizing the criteria of best payback over the base, and ease of construction. Economic information on the passive design elements was not used early on to eliminate options, although it is clear that masonry (trombe walls) are more expensive to build in rural Alaska because of shipping the masonry materials.

Energy options reinforced the architectural considerations in the building designs. A very good example is the architectural changes made between Designs 5 and 6, which is a result of how best to moderate the solar gain using architectural materials to diffuse the daylighting and convect the heat from the prompt wall. In no case did the energy considerations hamper the architectural program.

No energy options have been discarded due to architectural considerations.

Design indicators, most of which were of a physical performance nature or aesthetic judgement on the designs, lead clearly away from the use of trombe walls and storage mass as passive solar elements. Since the schematic designs were derived in order to test the classic passive solar design options, if one was out-performed by another, that was the reason for discarding or altering it. The schematics were a series of "cut-and-try" processes aimed at finding the "final" design, which hopefully was a best combination of conservation and passive solar features. The ineffectiveness of mass, and the virtues of simple direct gain systems were the two strategies that provided a clear decision: mass is not critical and direct gain systems perform best.

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6. PERFORMANCE TESTING THE SCHEMATIC DESIGN ALTERNATIVES.

   DESIGN TASK.

6(i). Task Overview:

Each schematic design was set up with its specifications to be computer simulated using TRNSYS, a fortran computer program. Using the available modules and hourly solar radiation data, each schematic design was simulated for one week's performance each month using 1976 real data. Additional input data beyond that available from the ASHRAE Handbook of Fundamentals was required for modeling the performance of walls with more than 3 inches of insulation. This was obtained using a program from the National Research Council of Canada for calculating heat transfer coefficients, given a wall specification. The tools fit our needs well, but are expensive to use. If a passive solar performance simulation program were developed to function as F-chart does in active applications, we could do more and faster analyses of passive systems.

6(ii). Unavailable Information:

No information was lacking.

6(iii). Incremental Passive Design Cost:

The testing of schematic designs required:

<table>
<thead>
<tr>
<th>Task</th>
<th>Cost (in USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/4 man-month</td>
<td>$1,100</td>
</tr>
<tr>
<td>Mech. engineer/comp. spec.</td>
<td></td>
</tr>
<tr>
<td>1 man-month</td>
<td>$2,800</td>
</tr>
<tr>
<td>Energy specialist</td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td>$1,200</td>
</tr>
<tr>
<td>Computer costs</td>
<td>$1,200</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$6,300</td>
</tr>
</tbody>
</table>

Again as in pre-design, about 80% of these costs are costs for climbing the learning curve. In a design problem in the future, it will be unnecessary to test all the design options, but rather use the final design as a model for future buildings.
6(iv). **Performance Analyses of the Designs:**

Pie charts follow for energy end-use of the four schematic designs tested prior to the April 30 schematic design review in Chicago. Plots of the dynamic energy needs of the pre-design are shown in section 5(iv). Plots of the dynamic energy needs of the final design are also included. Dynamic energy needs plots were not done for each design, because the computer analysis is done by month, and can give a clear indication of the dynamic energy sources and needs for each schematic.

The advantage of shutters is the most significant design indication to emerge from the schematic design process. Without shuttering the net heat transfer for passive systems is negative (Designs 2 and 4) or poorer than a design with shutters is not a must in all out energy conservation designs. The result clearly pointed to the best design strategies: direct gain, large south-wall glazed areas, small to negligible storage amounts, at least 11.5-12 inches of wall insulation and 16.5 inches in the ceiling.

6 (v). **Economic Analysis of the Schematic Designs:**

The alternative energy strategies for each schematic design are as follows:

**Design 2** - direct gain passive solar unshuttered. Estimated costs of construction $\sim$ $4,000 over conventional. (This is based on $7,000 estimated cost minus the cost of the standard south wall which was not built).

**Design 3** - trombe wall passive solar, insulated from the inside of the school. Estimated cost of construction:

- 5-1/2 yards concrete/wall $\sim$ $2,000
- Kalwall 500
- Insulated, framed, rear wall which backs plenum behind trombe wall 3,000
- Foundation for trombe 1,000

Total $6,500

Cost over standard costs $3,500
SOURCES

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

LOSSES

ELECTRO-MECHANICAL VENTILATION & FLUORESCENT LIGHTING

BUILDING FLOOR AREA = 600 FT²

Units: 10⁶ btu

Total = 129,744,000 btu/yr

216,240 btu/ft²/yr

fuel oil auxiliary heat 56.5%

passive solar heating 33%

lighting 8.7%

human 1.8%

ventilation loss 18.6%

door .2%

floor 5.1%

ceiling 5.1% walls 7.9%

windows 62%

building shell heat loss 81.4%
**SOURCES**

- Fuel oil auxiliary heat: 45.5%
- Solar heating: 19%
- Human: 4.9%
- Lighting: 30.6%

**LOSSES**

- Ventilation: 38.3%
- Walls: 35.9%
- Ceiling: 9.8%
- Floor: 9.8%
- Windows: 5%
- Door: 1.2%

Units: 10^6 btu

Total = 47,646,000 btu

79,410 btu/ft^2/yr

Building floor area = 600 ft^2 plus greenhouse
BUILDING
FLOOR AREA =
600 FT²

unit: 10⁶ btu

total = 117,317,000 btu

195,528 btu/ft²/yr

SOURCES
PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE
DESIGN TEST 4

LOSSES
ELECTRO-MECHANICAL VENTILATION & FLUORESCENT LIGHTING
BUILDING
FLOOR AREA =
600 FT$^2$

SOURCES

fuel oil
auxiliary heat 24.4%

lighting 21.9%

human 4.7%

passive solar heating 49%

LOSSES

ventilation loss 41.6%

floors 10.3%

doors 0.9%

windows (shuttered) 24.5%

walls 15.8%

ceiling 6.9%

building shell heat loss 58.4%

units: $10^6$ btu

total = 37,235,000 btu

62,058 btu/ft$^2$/yr

ELECTRICAL VENTILATION FAN & FLUORESCENT LIGHTING
Design 4 - attached greenhouse with trombe wall, passive solar heating without shuttering. Estimated costs:

- trombe wall $2,000
- greenhouse 5,000
- foundations 2,000

TOTAL $9,000

Cost over conventional $6,000

Design 5 - direct gain with shutters, passive solar. Estimated cost; similar to design 2, with the addition of shuttering:

- solar materials $7,000
- not building standard walls -3,000
- shutters +2,500

TOTAL $6,500

The percentage of the total load for each system, for each schematic design is listed in the section 6(iv) pie charts.

An analysis of the first year cost comparisons of the standard school costs as opposed to passive solar design is contained in the predesign tasks section 6(v).

The physical analysis combined with cursory economic judgements on the schematic designs were used to rate their advantages and disadvantages. Designs 3 and 4 both employed a trombe wall design, which (although not expensive) results in a less efficient use of solar energy because of the lower heat transfer rates, high losses in an unshuttered system, and possible foundation problems on permafrost.

Designs 2 and 5 are similar in design, except that Design 5 utilizes shutters, which markedly improves thermal performance. The economic advantage of Design 5 is the savings in back-up fuel afforded by passive heating and daylighting, and the savings from shuttering. Previous to the schematic review in Chicago, Design 5 was our selected design.
**Sources**

- Fuel oil: 21.5%
- Auxiliary heat: 7.8%
- Passive solar heating: 45.7%
- Lighting: 25%

**Losses**

- Ventilation loss: 58%
  - Walls: 7.7%
  - Floors: 6.6%
  - Ceiling: 4.4%
  - Door: 0.8%
  - Windows: 22.3%

Units: $10^6$ btu
Total: 42,995,000 btu
CONSTRUCTION:
WALLS: 2 X 6 STUDS 1 1/2 IN. FULL RTP, FULL FELT
FULL FELT, FULL FRP

ROOF: 18" PLYWOOD
METAL ROOFING

FLOOR: 12" PLYWOOD

FOUNDATION: PILES OF 6 X 6 SIPS W/ INSULATED CEMENT BLOCK

FLOOR AREA: 2000
2000 SQ. FT. SCHOOL
2000 SQ. FT. SCHOOL

WINDOW: 36" X 36"
SHUTTLELIGHT TO E. 36" X 36"

WINDOW AREA: 200 IN. SOUTH

"TROMPED WALL": 78 AT SOUTH
BUILDING USES SOLAR ROW/PUMP

VENT SYSTEM: 1/2 RIG H.

FINAL

PASSIVE SOLAR RURAL SCHOOL CLASSROOM PROTOTYPE

DESIGN TEST 6
7. DESIGN SELECTION. DESIGN TASK

7(i). Task Overview:

Several design features were used as criteria for the final design. The architectural requirement that the building can be attached to a larger building on the north side was stressed. It was necessary to utilize as much of the solar gain for heat and light in real time as possible without "roasting" the occupants or blinding them with glare. It is apparent that some heat had to be dumped at intervals to prevent overheating. And perhaps most important, the design should attempt to minimize the use of electricity (which is presently a huge problem in the bush) and be able to utilize the possible addition of an ORMAT organic Rankine cycle turbine for electrical generation. And, of course, it must function as a good school classroom.

The selected (final) design is indeed a revised scheme. Most of the revisions are the result of the advice of consultants and advisors to the schematic review process which was held in Chicago on April 30, 1980. The major revisions are centered on the south wall passive solar aperture. Large vertical windows were placed at the edge of both ends of the facade at the suggestion of Bill Lam, lighting consultant. Larry Bickle suggested the inclusion of a prompt wall, which is a low-mass trombe wall designed to respond more "promptly" than a trombe wall. And to help limit glare and direct sunlight on the occupants, an area of Kalwall translucent glazing was used on the major area of the south glazing.

7(ii). Unavailable Information:

We did not have available a computer program to easily weight the virtues of the prompt wall, and optimize the amount of mass for thermal storage. This was a major weakness of our final design review which has been remedied.
October 20, 1980

Richard Seifert
C/O Battelle-Northwest Laboratories
HS-4 Building, 3000 Area
Richland, Washington 99352

Re: Solar Alaskan School, Project No. 7988

Dear Rich,

Enclosed please find a copy of the solar school cost estimate, which I received last Thursday. At present, without a specific site, it works out at $162.50/square foot; this figure is deceptive, however, as it includes that huge ramp attached to one side of the building, which represents a sizeable framing and roofing cost.

I took extra time to separate out the costs attributable to the superinsulated structure and passive solar components, which are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Metals</td>
<td>$300</td>
</tr>
<tr>
<td>6100</td>
<td>Rough Carpentry</td>
<td>3,000</td>
</tr>
<tr>
<td>7210</td>
<td>Building Insulation</td>
<td>3,000</td>
</tr>
<tr>
<td>11100</td>
<td>Solar Energy Components (concrete trombe wall, shutters &amp; Kalwall glazing)</td>
<td>7,000</td>
</tr>
</tbody>
</table>

$13,300

This figure is 9% of the total cost, which may prove a good comparison with the energy savings provided by the design.

Please let me know if you need more detailed information than the above.

Yours sincerely,

Janet M. Matheson AIA
JANET MATHESON ARCHITECT

Enclosure (1)
October 10, 1980

Janet Matheson, Architect
P.O. Box 80567
Fairbanks, Alaska 99708

REF: Passive Solar Rural School Classroom Prototype

SUBJ: Preliminary Construction Cost Estimate

Dear Ms. Matheson:

The estimated cost of construction of the prototype classroom is $156,000. Enclosed is a recapitulation of the estimate together with the supporting data. This estimate is incomplete in that it does not include the costs generally associated with remote site construction. The cost does include an allowance for piling foundations as if it were to be constructed at a remote site. However, this amount could vary greatly depending on the site and other circumstances.

It is very difficult to offer a reliable cost guide for a completed structure until a site is selected. If this structure were built in Fairbanks, on piling, it is likely that the cost would be less than the $156,000 estimate. The costs suggested assume the natural inefficiencies associated with bush construction. If this structure were built in any bush community the costs would be higher than this estimate. Site work and all direct overhead would have to be added in amounts dependent on the site selected.

When a site is selected, I will be glad to look at this estimate again and revise to meet actual conditions.

Very truly yours,

CLARK-GRAVES, INC.

Donald M. Graves

DG/ jb
1 General Requirements
2 Sitework
2350 Pile Foundations
5 Metals
6100 Rough Carpentry
6170 Glulam Units
6190 Prefab Trusses
6192 Fabricated Joists
6200 Finish Carpentry
7190 Vapor Barrier
7210 Building Insulation
7600 Sheet Metal & Metal Roofing
7900 Sealants
8110 Hollow Metal Work
8200 Wood Doors
8600 Wood Windows
8700 Finish Hardware
8850 Glass & Glazing:
9250 Gypsum Drywall
9500 Acoustical Treatment
9650 Resilient Flooring
9680 Carpeting
9900 Paint
10100 Chalkboard & Tackboard
10800 Misc. Specialties
11100 Solar Energy Material
12670 Floor Mats
15 Mechanical
16 Electrical

Total Estimated Cost

$156,000

October 10, 1980
7(iii). Incremental Cost:

The design selection process did not of itself cost more than other design selections. The schematics and test of designs are the bulk of the incremental costs in this project, $2,773/year, all of which is subject to inflation. The estimated first year costs of the final design is $1,868/year, of which $937 (50%) is a fixed annualized cost not subject to inflation. This is a first year difference of $905.

7(vi). Architectural Compatibility:

Solar energy for heating and lighting are the only renewable, nonfossil-fuel alternatives included in the design. They provide for a very interesting facade on the south wall and are an enhancement of the design and fully meet the programmatic needs.

8. DESIGN DEVELOPMENT. DESIGN TASK.

Introduction:

This information has been generally covered, since the final design is a developed version of schematic Design 5. Much of the economic data are included here as a final analysis.

Final Economic Analysis:

A breakdown of the energy-related incremental costs is outlined in the attach letters.

The incremental solar/conservation cost (based on $10/ft² for a south wall not built) is:

$13,300 (superinsulated and solar components)
3,000 (wall replaced)
$10,300 total incremental costs
~ 4,000 total solar incremental ($10,300-6,300 for carpentry and insulation).
This is for a school built in the bush, not in Fairbanks. It is a worst case example for incremental and total costs.

If purchased by appropriation, the annualized cost of the solar increment is (based on 20-year lifetime) $200/year, and the annualized cost of the entire superinsulated and passive solar elements combined in $515/year (again: $10,300 / 20 yr = $515).

Since the estimated annual energy costs of a nonsolar school is $2,773 year, and this building requires $1,446 ($931 fuel, $515 solar annualized), the first year savings alone is $1,327. At this rate, assuming an inflation rate of 10%, the discounted payback period for the total incremental costs is less than 6 years (5.8 years). No problems are expected in financing the building, since it is a state building, and state policy is favorable to life cycle cost approaches.

Architectural Compatibility:

The attached drawings detail the building showing the energy elements and human effects. Shuttering design is not perfect, and requires user participation. The glazing options were specifically designed to minimize the negative effects on occupants from solar heat and glare. Additional maintenance requirements include the shutter, devices, and cleaning the windows.

The client is very pleased with the progress of the project.

Thermal Capacitance Test of Prompt Wall Idea:

Surface Area of rural school building of 600 ft$^2$
10 x 20 x 2 walls = 400 ft$^2$
10 x 30 x 2 walls = 600 ft$^2$
20 x 30 ceiling = \( \frac{600 \text{ ft}^2}{1600 \text{ ft}^2} \)

\( \times 5/8" \text{ sheetrock} = .0521 \text{ ft} \times 1600 \text{ ft}^2 = 83.33 \text{ cubic feet} \)
\( = 4166 \text{ lbs @ 50 lbs/ft}^3 \)
Increments of trombe wall @ 3 ft x 30 ft x each inch of thickness are

\[
\begin{align*}
1 \text{ inch} \times 90 \text{ ft}^2 &= 7.5 \text{ ft}^3 \\
2 \text{ inches} \times 90 \text{ ft}^2 &= 15 \text{ ft}^3 \\
3 \text{ inches} \times 90 \text{ ft}^2 &= 22.5 \text{ ft}^3 \\
4 \text{ inches} \times 90 \text{ ft}^2 &= 30 \text{ ft}^3 \\
5 \text{ inches} \times 90 \text{ ft}^2 &= 37.5 \text{ ft}^3
\end{align*}
\]

\[
\begin{align*}
7.5 \text{ ft}^3 &= 1080 \text{ lbs} = 138 \text{ KJ/°C} \\
15 \text{ ft}^3 &= 2160 \text{ lbs} = 276 \text{ KJ/°C} \\
22.5 \text{ ft}^3 &= 3240 \text{ lbs} = 414 \text{ KJ/°C} \\
30 \text{ ft}^3 &= 4320 \text{ lbs} = 553 \text{ KJ/°C} \\
37.5 \text{ ft}^3 &= 5400 \text{ lbs} = 691 \text{ KJ/°C}
\end{align*}
\]

(Concrete @ 144 lbs/ft$^3$ and 0.22 BTU/lb/°F or .128 KJ/°C)

Assumed – 90% Absorbtance:

<table>
<thead>
<tr>
<th>Case</th>
<th>Storage</th>
<th>Wall Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>I – Base case/no prompt wall</td>
<td>634 KJ/°C</td>
<td>0</td>
</tr>
<tr>
<td>II – 1” prompt wall</td>
<td>772 KJ/°C</td>
<td>.025 m</td>
</tr>
<tr>
<td>III – 2” prompt wall</td>
<td>910 KJ/°C</td>
<td>.058 m</td>
</tr>
<tr>
<td>IV – 3” prompt wall</td>
<td>1048 KJ/°C</td>
<td>.079 m</td>
</tr>
<tr>
<td>V  – 4” prompt wall</td>
<td>1187 KJ/°C</td>
<td>.120 m</td>
</tr>
<tr>
<td>VI – 5” prompt wall</td>
<td>1325 KJ/°C</td>
<td>.145 m</td>
</tr>
<tr>
<td>VII – 10” prompt wall</td>
<td>2116 KJ/°C</td>
<td>.290 m</td>
</tr>
</tbody>
</table>

From the above calculation, it is clear that the inclusion of a prompt wall 5-inches thick will increase the amount of thermal storage for the passive solar school to 2.08 times that of the base case (which is the storage mass of the passive solar school without a prompt wall).

Next a series of tests were made of a trombe (prompt) wall for the passive solar school design. The months of March and April were modeled. They are considered to be the best solar months, and were chosen as exemplary because they will be the months when the usefulness of storage
capacity to limit overheating will be greatest. (March and April are the two months of greatest solar radiation for Alaskan sites, especially interior Alaska).

Tests were run using the average daily solar radiation for March or April. The passive solar test module was modeled using TRNSYS, and its specifications are the same as for the final design, except that the internal storage mass was varied. The first design tested was without a storage wall (634 KJ/°C). The storage was then varied to simulate the increasing thickness of a prompt wall 3 feet high and 28 feet long. It was the intention of this brief study to attempt to determine the optimum storage mass and prompt wall thickness for the Alaskan passive solar school design.

The results are, in short, not conclusive. Varying the thickness of the prompt wall from 1 to 5 inches only delays the onset of required ventilation (overheating) by one hour. This delay in overheating (to 10 a.m.) occurs at 3 inches thickness (1048 KJ/°C). Increasing the prompt wall thickness to 5 inches does not alter the requirement for overheating ventilation in March. The ventilation requirement could not even be altered by going to a thickness of 10 inches for the storage wall.

From an economics standpoint, the cost differential between no wall and a wall of 5 inches is unlikely to be more than $400, since the materials costs are related primarily to the increasing cost of the masonry material in the wall. The following graph shows the relationship.

The true value of the prompt wall concept needs to be evaluated in practice. From the simulations utilizing the TRNSYS program, the value of the prompt wall system may not exist as previously perceived. Its value as a convector may have merit beyond its storage capacity. It is the intent of the designers and the Alaska Department of Transportation and Public Facilities to test the system further.
APPENDIX

Also included here is a listing of the estimated building costs in Fairbanks for the final design.
January 14, 1981

Richard Seifert
Institute of Water Resources
University of Alaska
Fairbanks, Alaska 99701

Re: Passive Solar Rural School
Project No. 798B
Design Development Cost Estimate

Dear Rich:

Enclosed is a revised version of the Solar School cost estimate, which I received yesterday. It was originally estimated by Clark-Graves at $181,000, but after discussions with them, I lowered their figures in the attached estimate in the areas of General Requirements (project administration), Sitework, and Piling, since a Fairbanks site would greatly simplify these items. I also reduced individual sections by about 10%-20% from our earlier estimate of last October, on the assumption that materials and sizes indicated on the design development drawings would not greatly change when translated into construction documents. The figure of $181,000 would certainly cover a bid by a large general contractor with high overhead costs; however, a conservative budget amount for the construction of the building, assuming that a smaller local general contractor would bid it, would be about $151,000. Our estimate of $140,500 (attached) assumes the most favorable bidding and supply conditions.

If the next phase is undertaken and the building put out to bid, I believe that the structure should be simplified for post & beam construction on site, eliminating the requirement for transport of 3 modules. The building is not completely designed now as modular nor can it be prefabricated for transport in complete sections, as exterior and interior finishes are field-applied. For research purposes, you would be better off building a simple box, with care given to its construction and details and with more time/money spent on adaptable solar or energy conserving features and their monitoring devices (rather like the Los Alamos test buildings).

In answer to your questions of November 4th, 1980, a standard 2 x 6 wall on the south side, with standard factory-manufactured windows would cost about $1,000 more than this design. Please let me know if this is what you requested.

Yours sincerely,

Janet M. Matheson AIA

Attachment(1)

P.O. BOX 80567, FAIRBANKS, ALASKA 99708 (907) 452-4640
### Passive Solar Rural School
#### Design Development Cost Estimate
January 14, 1981

<table>
<thead>
<tr>
<th>Division</th>
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<th>Amount</th>
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**Total Amount** $140,500
Passive Solar Rural School Classroom Prototype

GENERAL DESCRIPTION OF MATERIALS & CONSTRUCTION METHODS

September 24, 1980

DRAFT COPY
INDEX

TECHNICAL SPECIFICATIONS

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   1. Code Reference
   2. Occupancy
   3. Construction Type
   4. Allowable Area
   5. Separations
   6. Population Density (Egress)
   7. Required widths
   8. Stair Requirements
   9. Corridor Requirements
  10. Toilet Room Requirements

B. 1. Framing System
    2. Design Loads

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Division 3  Concrete  - Not Applicable

Division 4  Masonry  - Not Applicable

Division 5  Metals

Section 05500  Miscellaneous Metals

Division 6  Carpentry

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Section 06180  Glued Laminated Structural Units
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**Division 9 **  **Finishes**

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<td>Resilient Flooring</td>
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<td>Carpeting</td>
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**Division 10  **  **Specialties**

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**Division 11  **  **Equipment**

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**Division 12 - Furnishings**

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**Division 13 - Special Construction - Not Applicable**

**Division 14 - Conveying Systems - Not Applicable**

**Division 15 - Mechanical**

**Division 16 - Electrical**
Passive Solar Rural School Classroom Prototype

GENERAL DESCRIPTION OF MATERIALS & CONSTRUCTION METHODS

September 24, 1980

DIVISION 1 - GENERAL REQUIREMENTS

A. Code Requirements

   1976 Uniform Mechanical Code
   1976 Uniform Plumbing Code
   1978 National Electrical Code
   1980 ANSI Specifications for Making Buildings & Facilities Accessible to the Handicapped

2. Occupancy: E-2

3. Construction Type: V-N
   (Note: construction type of the attached version may be Type V- 1 Hour if a composite building over 9,100 sq.ft. is required.)

4. Allowable Area: 9,100 sq.ft.
   Area Designed: 960 sq.ft. (excluding ramp, stairs, & decks)

5. Separations: 1 Hour @ all interior walls.

6. Population Density for Egress:
   
<table>
<thead>
<tr>
<th>Use</th>
<th>Sq.Ft./Occupant</th>
<th>Required Exits</th>
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<tbody>
<tr>
<td>Classroom</td>
<td>20 sq.ft.</td>
<td>2 (per UBC 3318)</td>
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</tbody>
</table>

   (Note: Since the Mechanical Room door opens onto the Entry - for ease of maintenance while the building is in use- an emergency exit is provided via the west window, which is sized for egress per UBC 1204).

7. Required widths of exit doors, corridors, and stairs/ramps:
   
<table>
<thead>
<tr>
<th>Serving:</th>
<th>Door</th>
<th>Corridor</th>
<th>Stairs/Ramps</th>
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<tbody>
<tr>
<td>28 (=50/less)</td>
<td>Min.36&quot; wide</td>
<td>Min.44&quot; wide</td>
<td>Min. 36&quot; wide</td>
</tr>
<tr>
<td></td>
<td>(UBC 3303.a)</td>
<td>(UBC 3304.b)</td>
<td>(UBC 3305.b)</td>
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</tbody>
</table>

   Provided by design: 36"  60"  54"

8. Stair Requirements:
   a. Rise to run ratio = 7.5": 10"  (7 risers, 6 treads)
   b. Ramp: 1:12 slope.
   c. Railings: height and dimensions per Handicapped Code. details per drawings.

9. Corridor Requirements:
   a. Exit corridor (= Entry- Room #1) - 1 Hour wall and ceiling construction (UBC 3304.g)
   b. Doors (Doors #1, 2,3) - 20 Minute Rated (UBC 3304.h).

10. Toilet Room Requirements:
DIVISION 1 - GENERAL REQUIREMENTS

10. Toilet Room Requirements (continued):
   a. No. of water closets/sex = 1 each (1 each designed)
   b. No. of lavatories = 1 required (1 each designed)
   c. Urinal = 1 w.c. (omitted)
   d. Drinking fountain = 1 required (provide bubbler on each lavatory)

B. Structural Requirements:

1. Framing System

   The building's structural system is single storey, double wood stud wall framing, supported on glulam pile caps and wood floor joists. Roof framing is premanufactured wood trusses @ 2'0" o.c.

   Roof loads are carried through the north and south walls down to the floor beams, and on the south window headers down onto columns in the east and west walls.

2. Design Loads

   a. Live loads
      (1) Roof: Top chord of trusses = 40 psf
          Bottom chord of trusses = 5 psf
      (2) Floor = 10 psf

   b. Dead loads
      (1) Roof: Top chord of trusses = 15 psf
          Bottom chord of trusses = 10 psf
      (2) Floor = 40 psf

   c. Lateral loads
      (1) Wind: 90 mph w/gust factor; height less than 30' = 25 psf
      (2) Seismic: Zone 3.

      (Note: The only areas in Alaska which require Seismic Zone 4 design are: Anchorage, Kenai Peninsula, Kodiak Island, and the Aleutian Islands. Since most rural school locations therefore fall in Zones 1-3, (UBC 23.Fig. 2) Zone 3 was chosen for this design.)
DIVISION 2 - SITEWORK

(Clearing, Excavation, Compaction, Site Utilities and other items in this Division are site dependent, and would be included when construction documents for a specific site are prepared.)

SECTION 02350
PILE FOUNDATIONS

PART 2 PRODUCTS

2.01 PILES

A. Foundation piles shall meet the requirements of ASTM D25-73, with a minimum allowable compressive stress of 800 psi parallel to grain.

B. Wood piles shall conform to ASTM D25-73, Table 1 Friction Piles with minimum required circumference of 40” three feet from butt, and minimum tip circumference of 31”.

C. Wood piles shall be pressure treated in accord with requirements of AWPA C3-73, Modified 1975, for Foundation Piles. No oil base treatment vehicles detrimental to adfreeze bond will be permitted.

2.02 GENERAL

A. The top seven feet of pile below grade shall have four wraps of 6 mil visqueen stapled in place before placing the freezeback.

B. Heat pipes if required shall be as indicated on the drawings.

DIVISION 3 - CONCRETE - Not Applicable

(For a description of the trombe wall concrete component, see Division 13 - Special Construction).

DIVISION 4 - MASONRY - Not Applicable
DIVISION 5 - METALS

(This Division will be limited to Miscellaneous Metals only).

PART 1 GENERAL

1.01 DESCRIPTION

A. Furnish and install all miscellaneous metal fabrications as required, complete with all fittings, anchors and supports.

B. Items required include:
   1. Miscellaneous angles and clips.
   2. Nuts, bolts, screws, expansion shields, welding and all other required fasteners.
   3. Backing and supports as required.

PART 2 PRODUCTS

A. Steel: ASTM A-36, new and free from rust.


C. Screws manufactured from steel meeting ASTM A449.

D. Steel primer - rust inhibitive red lead type Federal Specification TT-P-86E, Type II.

E. Galvanized steel primer: Portland Cement, Alkyd resin type.

F. Stock commercial items, products, materials, patterns and fabrication methods, which meet with the requirements, are acceptable providing they conform to the design and details indicated.
### DIVISION 6 - CARPENTRY

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
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<tbody>
<tr>
<td>06100</td>
<td>Rough Carpentry</td>
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<tr>
<td>06180</td>
<td>Glued Laminated Structural Units</td>
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<tr>
<td>06190</td>
<td>Pre Fabricated Wood Trusses</td>
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<tr>
<td>06191</td>
<td>Wood Metal Joists</td>
</tr>
<tr>
<td>06200</td>
<td>Finish Carpentry</td>
</tr>
</tbody>
</table>
PART 2 PRODUCTS

2.01 MATERIALS

A. Lumber shall conform to the following grades for uses noted. For uses not specified or noted in detail, furnish at least "Standard" grade material.

1. "Light Framing" for material over 8' long; paragraph 122b, "Construction" for material less than 8'; paragraph 122c, "Standard". Douglas Fir No. 2.

2. Joist and plank: paragraph 123b, Structural Joist & Plank. Douglas Fir No. 2 or better.


4. Wood bucks, plates, nailers, etc. shall be nominal 2-inch material, Douglas Fir No. 2 and better, and kiln dried.

B. Plywood

1. Wall sheathing: APA Structural II CD INT. with exterior glue, thickness as indicated on drawings. Face grain parallel to studs.

2. Roof sheathing: APA Structural I CD EXT. 32/16 with exterior glue, thickness as indicated on drawings.
PART 2 PRODUCTS

2.01 MATERIALS

A. Structural Units
   1. Lumber for structural units shall conform to applicable portions of AITC Documents.
   2. Members shall be "Industrial Appearance" grade.
   3. Adhesive shall conform to dry use application requirements and meet Voluntary Product Standards P.S. 56-73, Structural Glued Laminated Timber.
   4. Use water resistant casein glue.
   5. All members strength combination 24f, Fb = 2400 psi, unless noted otherwise on drawings.
   6. Maximum moisture content of members to be 12%.

B. Connections
   1. Metal shall conform to the quality indicated in 1.02 QUALITY ASSURANCE.
   2. Details for connections shall conform to basic design type as detailed in AITC 104-72, unless otherwise indicated on plans.
   3. Remove burrs or rough edges, clean all welds sufficiently to allow a smooth prime coating.

2.02 FABRICATION

A. General
   1. All fabrication shall conform to applicable sections of AITC Documents AITC 115.
   2. Preform all connection, fabrication and machining of Structural Units in the shop where practical.
   3. Mark each piece for ready identification at the site.

B. Unless noted otherwise on the drawings, camber all members for dead load only.

C. Whenever possible, predrill members in the shop. Reaming of misfabricated holes will not be permitted.
2.01 MATERIALS

A. Trusses are to be by firm engaged in truss fabrication.

B. All trusses are to be manufactured using kiln dried lumber and pressed metal gusset plates. Plates shall be manufactured according to TPI standards.
PART 2 PRODUCTS

2.01 DESCRIPTION

A. Wood Members
   1. Lumber shall be graded according to the manufacturer's standards, to assure code required safety factors. Jointing following manufacturers standards. Use kiln dried material with average moisture content not exceeding 13%.

B. Provide all trusses and required accessories as shown on drawings and as required to complete the work.

C. Provide series, type, and load capacities as noted on structural drawings.

2.02 FABRICATION

A. Fabrication shall be only in a plant approved by ICBO for fabrication of trusses.

B. Products shall be equal to "Trus-Joist" as manufactured by Trus-Joist Corporation.

D. Metal members shall be cold rolled steel tubes, minimum 45,000 psi material, die stamped at connections. All metal parts shall be primed with a rust inhibitive primer meeting Federal Specification TT-P-86E or shall be electrogalvanized for rust protection. Size diameter and wall thickness as required to carry design load.
PART 1 GENERAL

1.01 DESCRIPTION

A. Items to be included:
   1. Exterior plywood siding
   2. Exterior wood trim, handrails, battens, fascias.

PART 2 PRODUCTS

2.01 MATERIALS

A. Exterior Plywood Siding: 5/8" thick T-1-11 EXT. APA, Group 3, rough
   sawn cedar, face grooves @ 4" o.c. Shiplapped edges.

B. Exterior Trim, Handrails, Battens, Fascias, & Trim:
   Shall be AWI Custom Grade rough sawn Red Cedar.

C. Fasteners: as required for each use.
DIVISION 7 - MOISTURE PROTECTION

<table>
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<tr>
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<td>07210</td>
<td>Building Insulation</td>
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<td>07600</td>
<td>Sheet Metal Work &amp; Metal Roofing</td>
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<tr>
<td>07900</td>
<td>Sealants</td>
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</table>
PART 1  GENERAL

1.01  DESCRIPTION

A. Work under this Section includes furnishing and installation of all vapor barriers in connection with blanket or rigid insulation at walls, soffits and ceilings as indicated on the drawings and as specified herein.

B. It is the intent of the documents that the vapor barrier will form a continuous envelope of all heated spaces on the warm side of the insulation.

PART 2  PRODUCTS

2.01  MATERIALS

A. Vapor barrier shall be clear 6 mil, polyethylene film and sheeting, per ASTM D2103.

B. Sprayed insulation shall be foamed-in-place insulation, as specified in Section 07210.

C. Adhesive shall be as recommended by vapor barrier manufacturer.

D. Joint tape for vapor barrier shall be clear 6 mil, polyethylene film with "stickyback" (pressure-sensitive coated one side).

E. Furnish vapor barrier in widest practical widths.

F. Sealant shall be as specified in Section 07900.
PART 1  GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installation of all insulation as shown on the drawings.

PART 2  PRODUCTS

2.01 PRODUCTS

A. Wall and soffit batt insulation shall be full thickness glass fiber blanket insulation, "Friction-Fit" as manufactured by Owens-Corning Fiberglas Corporation, or approved equal.

B. Sill joint sealer shall be "Sill-Sealer" as manufactured by Owens-Corning Fiberglas, or approved equal.

C. Foamed-in-place insulation: CPR Kode 25 spray isocyanurate foam by CPR Division, the Upjohn Company. Install per manufacturer's instructions.

D. Roof insulation shall be Styrofoam "TG" brand rigid insulation, as manufactured by Dow Chemical Company.
PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installing of Sheet Metal Work and Metal Roofing as shown on the drawings.

1.02 QUALITY CONTROL

A. Workmanship and construction not specifically detailed shall conform to Sheet Metal & Air Conditioning Contractors National Association Handbook detailing.

B. Coordinate metal roofing with rain drainage work, flashing, trim, and the construction of decks, parapets, walls and other adjoining work, to provide a permanently leakproof, secure and non-corrosive installation.

C. Roofing and associated work shall be guaranteed for a period of five years against any leakage, deteriorated work or other conditions resulting from failure of materials or workmanship.

PART 2 PRODUCTS

2.01 DESCRIPTION

A. Aluminum: Utility Grade, .050 inch thickness.

B. Solder shall be composed of 50% pig lead and 50% black tin. ASTM C-32-58T.

C. Building paper or felt shall be asphalt saturated felt conforming to ASTM D226.

D. Metal Roofing:
   1. Metal roofing sheets, flashing sheets and closures shall be "Zip-Rib" as manufactured by Kaiser Aluminum and shall be fabricated from 3004 Alclad aluminum alloy.
   2. Sheets shall be formed panels 12" wide, .032" thick, with 2-1/2" high interlocking standing seams. Standard width sheets, continuous for length of roof slope. Finish shall be stucco embossed aluminum; color to be selected by Architect. Panels shall have a continuous integral groove in one vertical leg to provide antisiphon protection in the interlocking joint.
   3. Provide the materials and types of fasteners, solder, welding rods, coatings, separators, sealants and accessory items as recommended by the sheet metal manufacturer for metal roofing work, except as otherwise indicated.
   6. Accessories: Kaiser Aluminum "Zip-Rib" Clips; "Zip-Rib" heavy duty clips #1920020 shall be used to attach the panels to the supporting structure.
   7. Closures: ridge and eave closures shall be low pitch closure with PVC foam insert #1920071.
2.01 DESCRIPTION (CONTINUED)

D. Metal Roofing: (continued)
8. Flashings: Flashings shall be fabricated from the same material and finish as the "Zip-Rib" panels.
9. Fasteners: All fasteners for flashings and accessories shall be fabricated from aluminum or stainless steel.

E. Protection of Contact Surfaces:
Where aluminum materials are placed in contact with or fastened to dissimilar metals, with the exception of stainless steel or zinc, the contact surface of the dissimilar metal shall be given a heavy brush coat of alkali resistant bituminous paint, or separated with a non-absorptive tape or gasket. Dissimilar metals shall be painted if drainage from them passes over aluminum work. Drainage passing over copper or any contact between copper and aluminum shall not be allowed.
PART 1 GENERAL

1.01 DESCRIPTION

A. Furnish and install all sealants for weather tightness.

1.02 LOCATIONS

A. One-part urethane non-sag sealant shall be applied to concrete work.
B. One-part silicone sealant (Dow Corning 780 & 781) for exterior work.
C. One-part silicone sealant (Dow Corning 784 & 785) for interior work.
D. Backup material for use with flexible sealant shall be non-asphaltic expanded closed cell polyethylene. Backup material shall not bond to sealant. Diameter of rod stock shall be at least 1/8" larger than the joint opening.
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<tr>
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<td>Wood Doors</td>
</tr>
<tr>
<td>08600</td>
<td>Wood Windows</td>
</tr>
<tr>
<td>08700</td>
<td>Finish Hardware</td>
</tr>
<tr>
<td>08850</td>
<td>Glass &amp; Glazing</td>
</tr>
</tbody>
</table>
SECTION 08110
HOLLOW METAL WORK

PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installing of all hollow metal frames and doors. Hollow metal doors shall be provided for all exterior doors shown on the drawings; hollow metal frames shall be provided for all interior and exterior door openings shown on the drawings.

1.02 QUALITY CONTROL

A. Where indicated, provide doors, frames and anchorage to meet U.L. label requirements. All units to have appropriate label affixed.

PART 2 PRODUCTS

A. All door frames, as detailed hollow metal (steel) on drawings shall be constructed of hot-rolled pickled and annealed steel. Interior openings shall be 16 gauge; sub-frames where required, 12 gauge.

B. Door material, in addition to frame requirements, shall be equal to stretcher level flatness.

C. Provide the following components:
   1. Hinge reinforcements: 3/16" x 1-1/2" x 9"
   2. Strike reinforcements: 3/16" x 1-1/2" x 3"
   3. Closer and holder reinforcements: 12 gauge
   4. Angle floor clips: 12 gauge
   5. Spreader: 16 gauge channel, arc welded
   6. Fully enclosed mortar boxes over all hardware mortises.
   7. Three (3) gum rubber bumpers for single frames, four(4) for each pair of doors, equal to Glynn Johnson 64.

D. Provide anchors with a minimum of three (3) anchors per standard height or 2'-6" on center. Anchors shall suit all wall conditions.

E. Doors shall be flush type, Style 2, as specified in SDI specifications, which allows exposed edge seam.
PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installation of all wood doors shown on the drawings. Wood doors shall be provided for all interior door openings.

PART 2 PRODUCTS

2.01 MATERIALS

A. Face Veneers: Shall be plain medium density overlay (MDO), stain grade.

B. Flush Solid Core Wood Doors: Shall be AWI Custom Grade PC particleboard solid core. Where fire doors are required, shall be 1/3 solid core FD type, rating as indicated.

C. Lites: Provide openings for lites as indicated on the drawings. Beads shall be same species as door face. Manufacturer's stock flush frame to be provided. Factory installation required.
PART 1    GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installation of clad windows as detailed on the drawings.

PART 2    PRODUCTS

2.01 MATERIALS

A. Wood windows shall be Pella, Andersen, or equal.

B. Sash and frames shall be water repellent preservative-treated Western Pine, with all exterior surfaces primed. Corners mortised and tenoned, glued and nailed.

C. Units shall be factory glazed with triple pane insulating glass in rigid vinyl glazing bead with flexible tip against glass.

D. Units shall be factory weatherstripped with spring tension rigid vinyl weatherstripping.

E. Furnish complete with Western Pine inside stops, jamb extensions, and trim.

F. Non-exit windows, Sash shall be hand operated without roto operator. Furnish in awning or casement position as shown on the drawings, with sliding hinges and special lock factory applied.

G. Exit windows: Sash shall open at least 90 degrees and comply with the 1976 Uniform Building Code requirements for egress windows. Provide jamb-mounted bar operator and special hardware as appropriate.

H. All units, plus: exit units, shall be furnished with factory standard aluminum insect screens in removable bronze-tone aluminum frames.

2.02 FABRICATION

A. Individual units shall be factory assembled with sash installed in frame.
SECTION 08700
FINISH HARDWARE

PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes complete finish hardware requirements for this project.

1.02 QUALITY CONTROL

A. Codes: All finish hardware shall comply with applicable local and/or state current building codes. Hardware for fire-rated openings shall also be in compliance with all fire building codes applicable to the district in which the building is located. Provide only hardware which has been tested and listed by UL for the types and sizes of doors required, and which complies with the requirements of the door and frame labels.

1.03 GUARANTEE

A. Finish hardware shall be guaranteed against defects in workmanship and operation for a period of one year, backed by a factory guarantee of the hardware manufacturer, except the door closers shall be so guaranteed for five years.

PART 2 PRODUCTS

2.01 MATERIALS

(Note: manufacturers specified herein will have to be verified with the specific client for congruence with their existing hardware systems.)

A. Finishes: US 32D - Satin Stainless Steel

B. Butts: Lawrence

C. Locksets: Schlage D series

D. Exit Devices: Von Duprin

E. Door Closers: LCN Closers

F. Push/Pulls: Cipco

G. Kick, Mop and Armor Plates: Cipco (note: required on all doors)

H. Stops & Holders: Glynn Johnson

I. Weatherstrip & Threshold: Pemko

J. Door Silencers: Glynn Johnson

K. Keying: All locksets shall be keyed and masterkeyed into the existing building system. Minimum: 6 Masterkeys, 4 keys/lock.
PART 1  GENERAL

1.01  DESCRIPTION

A. Work under this Section includes furnishing and installation of all glass and glazing materials in entry and classroom doors, as shown on the drawings.

1.02  QUALITY CONTROL

A. Labels showing glass manufacturer, type of glass, thickness and quality shall be on each piece of glass and shall remain until glass has been set and inspected.

B. All glass shall comply with Federal Specification DD-G-4516, as applicable to type specified, unless hereinafter specified differently.

C. A 3 year guarantee is required from the installer from date of approved installation against damage due to improper materials or workmanship.

PART 2  PRODUCTS

2.01  MATERIALS

A. Approved manufacturers: Libbey-Owens-Ford Glass Company (LOF), Mississippi Glass Company, Pittsburgh Plate Glass Company (PPG) and American St. Gobain Glass Company (ASG), or approved equal.

B. Wire Glass: Equal to ASG 1/4" polished Nuweld square shaped wire glass. Wire glass to bear UL seal of approval.

C. Glazing Materials:
   1. Sealant tape shall be a reinforced butyl-polyisobutylene tape equal to Tremco #440 tape, or approved equal.
   2. Sealant for glazing shall be a two-part polysulfide, meeting Federal Specification TT-S-00227E; or a one part acrylic or silicone base sealant meeting Federal Specification TT-S-230a, or approved equal.
   3. Setting blocks, neoprene 70-90 Shore "A" Durometer hardness, compatible with type of compounds and sealants used and shall not cause staining or discoloration of sealant or frame.
   4. Spacer blocks, neoprene 40-50 Shore "A" Durometer hardness, compatible with type of compounds and sealants used and shall not cause staining or discoloration of sealant or frame.
DIVISION 9 - FINISHES

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SECTION 09250
GYPSUM DRYWALL

PART 1   GENERAL

1.01   DESCRIPTION

A. Work under this Section includes furnishing and installing of all Gypsum Wallboard as shown on the drawings. This applies to all interior wall and ceiling surfaces.

1.02   QUALITY CONTROL

A. Fire rating of wallboard to be in conformance with applicable portions of ASTM C-36.

B. Moisture resistant wallboard shall conform to standards of ASTM C-630.

C. Finish of wallboard shall meet ANSI Standard Specifications for Gypsum Wallboard finishes A97.1. No texture surface finish required.

D. Two-hour wall construction shall comply with Tests T-194 OSU and OR 64-12.

PART 2   PRODUCTS

2.01   MATERIALS

A. Gypsum drywall construction materials shall be products of U.S. Gypsum or National Gypsum Company, Gold Bond, or equal. Do not mix materials.

B. Wallboard:
   1. Gypsum wallboard shall be Sheetrock SW Firecode as manufactured by U.S. Gypsum, or approved equal; tapered edge, 5/8" thick, except at double layered ceiling at wooden roof joist construction, at solid shaft walls and at structural columns, where it shall be 1/2" thick, number of layers as shown on the drawings.
   2. Gypsum wallboard labeled as moisture resistant shall be 5/8" Firecode Type X Sheetrock W/R Gypsum Panels as manufactured by U.S. Gypsum, or approved equal. Moisture resistant wallboard shall be installed in washroom and janitor walls and ceilings and as shown on the drawings.

C. Fasteners: Types and sizes as required and recommended by the manufacturer.

D. Sheetrock Brand W/R Sealant: Apply to all cut edges and nail heads of special moisture resistant wallboard used in high-moisture room areas. As manufactured by U.S. Gypsum Company, or approved equal.

E. Accessories:
   1. All metal accessories shall be galvanized.
   2. Exterior corner beads shall be standard metal type 1" x 1-1/4" by Gold Bond.
   3. Casing beads shall be USG No. 200-B.
   4. Interior corner reinforcement shall be USG Perf-A-Tape.
   5. Control joints shall be EZ strip expansion joints.
PART I  GENERAL

1.01  DESCRIPTION

A. Work under this Section includes providing all necessary labor, materials, equipment, and services required to install acoustical tile and sealant as shown on the drawings.

1.02  QUALITY CONTROL

A. Acoustical materials shall have noise reduction coefficient (NRC) in the range .60-.70 according to ASTM C423.

B. Ceiling sound transmission class (STC) shall be in range 35-39.

C. Acoustical materials shall have Class 25 Flame-Spread Rating according to Federal Specification SS-S-118A.

PART 2  PRODUCTS

2.01  MATERIALS

A. Materials shall be by Armstrong. Products manufactured by National Gypsum Company; U.S. Gypsum Company; Conwed Corporation; and Johns-Manville Corporation that are comparable may be accepted as equal.

B. Acoustical tile: Shall be equal to Armstrong Travertone Fire Guard tile. 24" x 24" x 3/4", square edge, for adhesive application to gypsum board. Flame spread rating to be 25 or less.
SECTION 09650
RESILIENT FLOORING

PART 1  GENERAL

1.01  DESCRIPTION

A. Work under this Section includes furnishing and installing all resilient flooring including base and related accessories as shown on the drawings.

1.02  QUALITY CONTROL

A. Vinyl sheet flooring shall meet Federal Specification FS-L-F-475, Type II, Grade A.

B. Resilient base shall meet Federal Specification FS-SS-W-40, Type I.

C. Vinyl sheet flooring shall have a flame spread of less than 75 when tested in accordance with ASTM-E-84.

PART 2  PRODUCTS

2.01  MATERIALS

A. Vinyl Sheet Flooring: Shall be .090" gauge resilient flooring by Armstrong, or approved equal. Furnish in 72" rolls.

B. Resilient base shall be 1/8" gauge rubber base, sizes as shown on the drawings, standard top set cove, as manufactured by Burke Industries or approved equal. Color to be selected by Architect. Include premoulded outside corners and matching end stops.

C. Reducer strips as required by job condition, or as detailed, shall be manufactured by Mercer Plastics Company, or approved equal.

D. Adhesive shall be approved by the tile and base manufacturer.
PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installing all carpeting including all related accessories as shown on the drawings.

1.02 QUALITY CONTROL

A. Carpet shall have a flame spread rating of Class B or less when tested according to ASTM #-84B and shall meet acceptance criterion of U.S. Department of Commerce DOC-FF-1-70 (Pill Test).

B. Static control fibers shall be sufficient to reduce static when tested by Walker method at 20% relative humidity at 70 degrees F. to not more than 3.5 KV.

PART 2 PRODUCTS

2.01 MATERIALS

A. Classroom Floor Carpet:
   1. Carpet shall meet the following specifications:
      a. Type Multi-level loop
      b. Face Yarn DuPont Antron III continuous filament nylon with static control
      c. Yarn Weight per SY 28- 40 oz.
      d. Primary Back Synthetic
      e. Second. Back Jute
      f. Width 144"

B. Accessories shall include all edge strips or reducers at changes of material. To be by Mercer Plastics or approved equal.

C. Adhesives shall be as recommended by the manufacturer.
PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes all painting and preparatory work required for proper execution of painting. The intent of this document is that all surfaces not finished by the manufacturer with a final finish, shall be finished, unless specifically excepted. Galvanizing is not a finished surfacing.

B. Painting will not be required in any vertical shafts, furred spaces or chases, or on metal roofing.

1.02 QUALITY CONTROL

A. Paint coatings shall be applied undiluted, except as specifically noted; each coat shall have the mil thickness specified by the manufacturer for the product in question, or as determined by the recommended spread rate.

B. Surfaces to receive finish shall be dry, free from dust, and warm enough to allow paint to dry properly following manufacturer's directions. Do not apply paint materials in any other environment.

PART 2 PRODUCTS

2.01 MATERIALS

A. Exterior Hollow Metal Doors & Frames: 1 coat alkyd metal primer
   2 coats alkyd gloss paint

B. Exterior Metal: 1 coat primer
   2 coats alkyd gloss paint

C. Exterior Wood Siding, Fascias & Trim: 2 coats semi-transparent stain

D. Interior Gypsum Wallboard: 1 coat primer
   1 coat primer sealer
   2 coats alkyd eggshell paint
   (flat enamel at moisture resistant gypsum wallboard)

E. Interior Metalwork: 1 coat sealer/primer
   1 coat enamel undercoat
   2 coats alkyd eggshell enamel paint

F. Interior Doors & Trim: 1 coat semi-transparent stain
   2 coats clear interior satin varnish

G. Wood Filler: paste filler, color to match adjacent wood.
SECTION 10100
CHALKBOARDS & TACKBOARDS

PART 1  GENERAL

1.01  DESCRIPTION

A. Work under this Section includes furnishing and installing of all chalkboards and tackboards with related accessories.

PART 2  PRODUCTS

2.01  MATERIALS

A. Chalkboards shall be "Duracite" on 1/4" hardboard by Claridge, or approved equal. Full-length map/display rails and chalkrails are required on all units. Lengths as shown on the drawings.

B. Tackboards shall be 1/2" "Fabricork" (Fire Rated) mounted on backer board. Lengths as shown on the drawings.
SECTION 10800
MISCELLANEOUS SPECIALTIES

PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installing all items specified herein.

B. Items to be included:
   1. grab bars
   2. wall mirrors
   3. toilet paper dispensers
   4. hand dryers
   5. fire extinguishers

PART 2 PRODUCTS

2.01 MATERIALS

A. Grab bars: Shall be equal to Bobrick, lengths as shown on the drawings. 1-1/2" diameter stainless steel, in non-slip finish; concealed mounting. Provide anchor plates for stud walls.

B. Wall mirrors: Equal to Bobrick, with type 304 stainless steel angle frame, satin finish. No seams or screws on frame. Corrosion resistant steel back, concealed and theft proof hangers.

C. Surface Mounted toilet paper dispenser: Shall be equal to Bobrick; duplex roll type. Provide stud anchors.

D. Surface Mounted hand dryers: equal to Bobrick #B-200; 115 volt, with high-speed, self lubricating 1/10 hp motor on resilient mounting; 60 second drying cycle. Nozzle to revolve 360 degrees. White porcelain enamel finish. Provide anchors for stud walls.

E. Fire Extinguishers: Shall be JL Industries, or approved equal. Wall bracket mounted; size and type as required for size and occupancy. Contractor to fill and service fire extinguishers prior to acceptance of project by Owner.
PART 1 GENERAL

1.01 DESCRIPTION

A. Items to be included:
   1. trombe wall, with casing, lightweight concrete, louvered vents.
   2. exterior window shutters, 4 types.
PART 1 GENERAL

1.01 DESCRIPTION

A. Work under this Section includes furnishing and installing floor mats for the Entry.

PART 2 PRODUCTS

2.01 MATERIALS

A. Floor Mats shall be 3/8" x 12" x 12" Fluff-Cord Tile by R.C. Musson Rubber Company or approved equal. Supply required adhesive and mat frames where required. Alternating perpendicular parquet pattern required for tiles.
DIVISIONS 13 & 14 - Not Applicable

Special Construction
Conveying Systems
DIVISION 15- MECHANICAL

A. PLUMBING
1. Water supply
   a. Well: Stainless steel screen, steel casing, Monitor pitless adapter, well cap, submersible pump, galvanized steel pipe riser, electric heat traced arctic pipe with copper water pipe (well to building), pressure tank, and water treatment (to suit water quality).
   b. City or PHS: Electric heat traced arctic pipe with copper water piping.
   c. Delivered: Steel tank with epoxy coating, pressure pump, and pressure tank.
   d. Adjacent building: Copper water piping.
2. Water piping: copper with 1 inch fiberglass insulation and vapor barrier jacket.
3. Plumbing fixtures:
   a. Water closet: vitreous china, wall hung, elongated bowl and flush tank or valve to suit water supply.
   b. Lavatory: vitreous china, wall hung with concealed arms, chrome plated faucet with lever wrist handles.
   c. Service sink: enameled cast iron, wall hung or moulded stone, floor mounted (to suit site) with chrome plated faucet, vacuum breaker, pail hook, hose end spout and wall bracket.
   d. Electric water heater: 20 gallon, 1000 watt lower and upper elements.
5. Waste disposal
   a. Septic tank and leach box/field with wood stave sewer piping and perforated sch. 40 PVC field piping. Tank and sewer piping insulated with 2 inch foamed urathane and field insulated with 4 inch closed cell polystyrene board insulation.
   b. City or PHS: Wood stave pipe with 2 inch urathane insulation or electric heat traced arctic pipe with DWV copper piping (to suit site).
   c. Trucked: steel holding tank with epoxy coating.
   d. Adjacent building: DWV copper piping.

B. HEATING
1. Fuel oil
   a. Tank farm: 500 gallon steel tank (UL).
   b. Delivered: 1000 gallon buried tank (UL).
   c. Piping: Farm-black steel, building service-type k soft copper with safety valve, OSV and check valve (2 pipe system).
2. Furnace: Residential upflow with flame retention burner and 2 stage oil pump.
3. Ductwork: Galvanized steel in accordance with SMACNA.
5. Exhaust and makeup air fans: Cabinet with FC wheel and internal spring isolation.
6. Heat recovery heat exchanger: heat pipe type or counter plated type (costs).
7. Controls: Electric.
DIVISION 16
ELECTRICAL

16010 GENERAL PROVISIONS

16011 SCOPE OF WORK

Defines the scope of electrical work.

16012 DRAWINGS

Requires the Electrical Contractor to verify all dimensions on the jobsite and not to lay out work from scaled plan dimensions. Directs the Contractor to review Architectural and Engineering drawings for detail work to be performed by other crafts.

16013 APPROVALS AND SHOP DRAWINGS

Advises the Contractor of the procedure for submitting descriptive information on items proposed for use in the work and lists the items which the Contractor must submit for approval.

16014 ACCESS PANELS

The Contractor is required to furnish proper access panels for installation by the General Contractor wherever access is required to electrical installations.

16015 ELECTRICAL REFERENCE SYMBOLS AND ABBREVIATIONS

The Contractor is directed to the Standard Symbols of the IEEE and to a listing of abbreviations used in the technical specifications and shown on the drawings.

16016 WORK NOT INCLUDED

This section defines work items, particularly serving utility company items, which are not included in the contract.

16017 WORK SPECIFIED UNDER OTHER SECTIONS

This section describes the electrically related and/or electrically operated work items provided under the division of the Specifications (except Mechanical) and defines the electrical subcontractors responsibilities for such work.

16018 WIRING OF MECHANICAL EQUIPMENT AND MOTORS

This section of the specifications defines the responsibility of the Electrical Contractor in regard to the provision of electrical work for mechanical equipment and devices. Electrical Contractor will provide and install all motor starters and heat tapes where required.
16019 FINAL CONNECTION TO ELECTRICAL UTILIZATION EQUIPMENT OTHER THAN MECHANICAL EQUIPMENT

Defines the electrical subcontractor's responsibilities in regard to final connection of miscellaneous equipment, etc.

16020 CODES

Lists the applicable codes which govern the electrical work.

16021 TESTS

This section of the specifications sets forth the Electrical Contractor's responsibilities for testing the electrical installations.

16022 DEMONSTRATIONS

Defines the Electrical Contractor's responsibilities for demonstrating the proper operation of the electrical installation and for instructing the Owner representative in operation and maintenance of the electrical systems and equipment.

16023 IDENTIFICATION

This section provides for the marking of terminals, the labeling of equipment and the identification of conductors and raceways.

16024 DEFINITIONS

Furnish - Shall mean bring to the jobsite.
Install - Shall mean build into the work.
Provide - Shall mean furnish and install.
Approval or Approved - Shall have reference to the Contracting Officer, in writing.
All and Typical - Is implied throughout the Specifications and drawings and is not repeated in every instance.
16100  BASIC MATERIALS AND METHODS

16110  RACEWAYS

All wiring to be run in concealed raceways except in mechanical rooms, on outside walls and roofs to preserve vapor barrier, where raceways are to be exposed or on the warm side of the vapor barrier. Raceways in accordance with the following:

Service and feeder raceways - rigid steel conduit.
Exposed branch circuits subject to damage - rigid steel conduit.
Underground raceways - rigid steel conduit.
Typical branch circuits - electrical metallic tubing or surface metal raceways.

16111  WIRES AND CABLES

All wires and cables sized and specified to be copper, minimum size No. 12 AWG. Insulation types as follows:

Service and feeder conductors - Type XHHW
Underground conductors - Type XHHW (USE)
Branch circuit conductors - Type THHN or THWN
Special applications - As required by the National Electrical Code and to suit the special conditions.

16112  WIRE CONNECTIONS AND DEVICES

Wire connections to be made with screw on, set screw, clamp on, split bolt, crimp and compression type lugs, taps and terminal fittings.

16113  OUTLET BOXES

Outlet boxes for general use to be stamped, one piece, galvanized steel, U.L. and NEC approved. Outlet boxes for exposed wiring to be of the threaded hub, cast metal type. All boxes to be of the deep type unless space limitations require shallow boxes.

16114  PULL AND JUNCTION BOXES

Pull and junction boxes to be completely accessible, concealed behind access panels in finished areas, exposed in utility areas, manufactured of code gauge steel, and with screw covers. Where special conditions require exposed boxes in finished areas, they are to be furnished with flush trim and hinged covers fitted with a latch and lock keyed to the panelboards.

16115  PANELBOARDS

Panelboards to be flush mounted in finished areas, surface mounted in service areas, with no visible fastenings, bolt on circuit breaker type, with hinged cover fitted with latch and lock - all locks keyed alike.
16116 SWITCHES AND RECEPTACLES

Switches - 20 amp, specification grade, silent type.
Receptacles - duplex grounding type, 15 amp, specification grade with nylon face.
Special purpose outlets - specification grade, rating and configuration to suit the use intended.
Cover plated - specification grade, stainless steel.

16117 MOTORS

Motors are specified with the driven equipment and furnished by the specialty contractor furnishing the equipment. Fractional H.P. motors 1/2 H.P. and smaller to operate on 120 volts, single phase. Motors 3/4 H.P. and larger to operate on 240 volts, single phase or 208 volts, 3 phase dependent upon the system voltage.

16118 MOTOR STARTERS

Motor starters specified in Division 16 and are furnished by the Electrical Contractor. Generally motors of 5 H.P. and less are to have across-the-line type magnetic starters and motors larger than 5 H.P. are to have reduced voltage magnetic starters. Magnetic starters to have 120 volt control circuits.

16119 DISCONNECTS

Disconnects are to be standard duty, side operated, quick-make, quick-break disconnect switches with enclosures to suit the installation conditions. Disconnect switches for motors to be H.P. rated and sized in accordance with the standard rating of the switch.

16120 OVERCURRENT PROTECTION DEVICES

Fuses - In general, if the load is:

- 600 amps or less - NEMA Class K-1, I.C. 200,000 amps RMS, current limiting.
- 30 amps or less and motor fuses - NEMA Class K-5.

Circuit Breakers - All circuit breakers to have minimum I.C. of 10,000 amps RMS, bolt in type, with thermal and magnetic trips. "E" frame is smallest size permitted. Breakers over 225 amps frame size to have interchangeable trip unit.

16121 MULTI-OUTLET ASSEMBLY

Multi-outlet assembly will be installed on the exterior walls between the cabinet work and the windows with duplex convenience outlets mounted 8'-0" on center. Multi-outlet assembly will be painted as directed by the Architect.
SERVICE AND DISTRIBUTION

GENERAL

Building service voltage to be 120/240 volts, 3 wire, single phase, or 208 volt, 4 wire, 3 phase with the neutral solidly grounded.

NORMAL POWER SERVICE

To be provided by A.V.E.C. in most cases, from an underground distribution system, at secondary voltage. Underground service conductors to be in rigid steel conduit from the service pole or pedestal to the school building service. The pilot project would take service from the local utility.

SERVICE DISCONNECT

Service disconnect switch to be located exterior to the building and would be fusible.

METERING

Metering will be secondary with a self contained meter exterior to the building beside the service disconnect switch.

GROUNDING

This is to be a completely grounded system. All electrical equipment, conduits, cabinets, switchgear, etc., to be solidly grounded in accordance with NEC requirements. A main grounding conductor will be provided from the service disconnect switch neutral to a ground field located outside the building and this grounding conductor will also be connected to the building water service piping system all to be bonded together and to the water service pipe.
16500 LIGHTING

16510 INTERIOR LIGHTING

Classroom lighting fixtures will be surface mounted 2' x 4' fluorescent fixtures. Diffusers will be prismatic virgin acrylic. The classroom lighting will have dimming ballasts controlled from a daylight sensor. This sensor automatically adjusts or dims the classroom lighting as the exterior ambient light increases. Catalog cuts of the system proposed are included in this submittal.

Lighting fixtures in utility spaces such as the mechanical room will be typically fluorescent strip lights with wire guards.

Lighting fixtures in the Lavatories will be surface mounted fluorescent with polycarbonate diffusers.

Entry and closet light fixtures will be incandescent with polycarbonate diffusers.

16530 EXTERIOR LIGHTING FIXTURES

Typical exterior lighting fixtures will be high pressure sodium, mounted on the building soffit at the ramp. Fixtures will be switched through an 'ON-OFF-AUTO' switch with photoelectric cell control in the auto position which is overridden by a thermostat set to override the photocell at minus 20°F and colder.

Light fixtures at the insulated accordion shutters installed for maintenance purposes will be incandescent with polycarbonate diffusers, locally switched with a pilot light switch in the mechanical room.

Fixtures chosen will have polycarbonate diffusers.

16551 LAMPS

Fluorescent lamps will be 35 watt rapid start, Watt-Miser II, Lite White in color.

Incandescent lamps will be inside frosted, either designed for 130 volt operation or extended service type for 120 volt operation.

High pressure sodium lamps will be clear.

16552 BALLASTS

Ballasts will be ETL-ETL labeled, premium very low heat type, Class P, sound rated "A", high power factor, 120 volt except where dimming ballasts are required.

High pressure sodium ballasts will be high power factor autotransformer type with minimum ambient starting temperature of -20°F.
EMERGENCY PATHWAY LIGHTING

Emergency pathway lighting will be accomplished with unit equipment consisting of a 12 watt tungsten halogen lamp, battery operation for 90 minutes with integral battery charger and test switch. Diffuser will be vandal resistant polycarbonate plastic.

Exit lights will also have battery packs with integral chargers for operation similar to the emergency pathway lighting.

Light fixture cuts of the fixtures proposed to be used in this project are enclosed as part of this submittal.

COMMUNICATIONS

FIRE ALARM AND DETECTION

A closed circuit, double supervised, non-coded, continuous ringing fire alarm system, with manual stations and automatic detectors will be provided which conforms to NFPA and the Handicapped Code. Ventilating fans and oil burners will be shut down by fire alarm operation.

Automatic thermal detectors will be installed as shown on the drawings. Fire alarm system will have a battery backup with integral charger which will provide power for the system for 24 hours in the standby mode and then ring for five minutes under the alarm condition.

CLOCK EQUIPMENT

A clock will be provided in the Classroom. Clock will be battery operated.

FREEZE ALARM SYSTEM

Freeze alarm system will consist of a rotating beacon on the exterior of the building which will be turned on by a thermostat set at +50°F when the temperature in the school drops below that point.
An exemplary listing of the control program for Trnsys as used in this study

*LIST DT1

WLIST
WIDTH 72
SIMULATION 0.0 168.0 .50
TOLERANCES .1 .1
LIMITS 20 50
UNIT 1 TYPE 9 DATA READER
PARAMETERS 11
3.00 1.00 1.0 41.83 0.0 2.0 .556 -17.78 3.0 .5150 0.0
UNIT 2 TYPE 16 SOLAR RADIATION PROCESSOR(MODE 1)
PARAMETERS 5
1.0 105 64.8 4871. 2.25
INPUTS 12
1,1 1,19 1,20 0,0 0,0 0,0 0,0 0,0 0,0 0,0
0.0 0.0 0.0 80 90. 0.0 90. 90. 90. 180. 90. -90.
UNIT 3 TYPE 17 WALLS
PARAMETERS 26
2.0 .50 .9 4 3 27.8 18.6 27.8 18.6 .84 2 .79 .05 .05
-6.2011 6.08720 .00031
INPUTS 7
1,2 2,6 2,15 2,13 2,11 1,3 7,2
2.044 0.0 0.0 0.0 0.0 0.0 20.0
UNIT 4 TYPE 34 OVERHANG
PARAMETERS 15
5.00 3.0 0.0 .20 0.0 0.0 0.0 .20 .20 .20 0.0 .20 .20
.20 0.0
INPUTS 6
2,2 2,3 2,4 2,5 2,7 0,0
0.0 0.0 0.0 0.0 0.0 .60
UNIT 5 TYPE 18 FLAT ROOF
PARAMETERS 13
-1 4 .90 .90 149. 0.0 0.0 0.0 149. 0.0 0.0 2.0 0.0
INPUTS 8
1,2 2,4 0.0 0.0 0.0 1,3 0,0 7,2
2.044 0.0 0.0 0.0 0.0 0.0 0.0 20.0
UNIT 6 TYPE 35 WINDOW
PARAMETERS 2
1.0 15.0
INPUTS 5
7,2 7,2 0,0 2,6 0,0
20.0 2.044 2.55 0.0 .81
UNIT 7 TYPE 19 ROOM AND BASEMENT
PARAMETERS 19
1 170. 1.0 55.7 2.0 772. 128 -1 0.0 30.3 2.0
457 10 10 27.0 20.0 0.0 0.0 0.0 0.0