AN ANALYSIS OF TEMPERATURE INSULATION REQUIREMENTS FOR KLYSTRON GALLERY

REPORT TO STANFORD LINEAR ACCELERATOR CENTER - ABA No. 71

STANFORD UNIVERSITY SUBCONTRACT S-136

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INTRODUCTION

This report presents an analysis and ABA recommendations regarding insulation on the roof and walls of the Klystron Gallery. The study was requested in a memo, T. McClellan to R. Sharpe, dated 18 February 1963. Other references are listed at the end of this report.

Conclusions and recommendations are presented in the following paragraphs. The factors considered; criteria, capital costs, and operating costs are then reviewed. A general discussion of solar heat gain, temperature effects on wiring and temperature ranges follows. The report terminates with answers to seven questions posed in the McClellan memorandum noted above.

CONCLUSIONS AND RECOMMENDATIONS

Based on the criteria and an analysis of the conditions, the addition of insulation of the roof and walls is not considered economically justifiable or desirable. The net capital cost of insulating the building, including a credit for reduction in ventilation is estimated to be \$115,000. Insulating the building would also increase the operating cost by about \$11,000 a year. The critical temperature periods (those during which the outside ambient temperature is over 90°F) are estimated to occur for 36 hours each year. During these periods, roof insulation would reduce the internal temperature about 3°F (from 115 to 112°F maximum) assuming the presently proposed ventilation system is installed.

The recommended design is based on having a reflective, or at least a light colored roof. A dark roof would increase the surface temperature by about 25°F and would nearly double the solar load. The radiant heat factor would become particularly objectionable to workers. If a dark color is chosen for the roof, the need for insulation should be re-evaluated.

FACTORS CONSIDERED

Criteria

The Design Criteria Report, ABA-48, and the Title I Report, ABA-58, are the principal criteria for the design of the Klystron Gallery. In each of them it is established that the gallery is a housing for the klystrons and associated utility lines and equipment. In addition, Volume IV, Blume Report, states, "The housing will be occupied only briefly, and at isolated points by maintenance crews making replacements of klystron modulator cubicles". ABA-48 and ABA-58 state that there will be a maximum of ten of these temporary occupants per sector at a time. The ventilation design is based on providing an inside temperature not over 15°F above the outside temperature, as designated in each of the above reports. The gallery heat gain is based on that listed in Table II, Title I Report. Correction has been made for the increased modulator heat loads as listed in SLAC comments on the Title I report. The solar heat lead has been recalculated for an inside temperature of 115°F, instead of the 90°F base used in ABA-58, since this is the peak temperature expected in the Gallery. Other heat sources were not corrected although it is known that some of the heat losses to atmosphere will be less at the higher ambient temperature. Figure 1, attached, shows the heat gains and losses diagramatically.

Capital Costs

Insulation installed would cost about \$0.30 per square foot. This would provide the standard 2-inch-thick metal-building insulation such as a vinyl-faced blanket draped over the purlins before the roof and siding are installed.

A comparable alternate, at about the same cost, is a 1-inch-thick urethane-freon-foam board attached with spot welded pins after the roof and walls are in place. There are about 340,000 square feet of roof and about 150,000 square feet in each wall, including the alcoves. The estimated insulation cost is about \$100,000 for the roof and \$45,000 for each wall. Considering only the roof and south wall, the cost would then be \$145,000 for insulating the building. If insulation is installed, the ventilation can be reduced by the amount required to offset most of the solar heat load. This is less than 20% of the total heat gain. The reduction in cost of ventilation is about \$30,000. The net capital cost for adding insulation is then \$145,000 - \$30,000 = \$115,000.

Operating Costs

The accelerator is expected to operate around the clock. For about four to six hours of a bright summer day, the uninsulated roof could add to the internal heat. The rest of the time it would help to get rid of the internal heat. On a cloudy day, and at other times when the solar influence is small, a temperature differential inside to outside of 21°F to 25°F would get rid of all the heat from the equipment at full Stage I operation in the uninsulated building without ventilation. If a gallery temperature of 90°F is acceptable for normal operation, ventilating equipment could be partially cut off at temperatures below 75°F ambient, and all of the units could be turned off below 65°F ambient.

Under similar conditions, without ventilation, a temperature differential of 60°to 70°F would be required to get rid of the internal heat in a building with an insulated roof and south wall. Fans would have to operate continuously even during the winter, although fewer would be needed in winter. Fans also might be operated at reduced speed during cold weather.

Temperature data collected at the site in 1961 by the U. S. Geological Survey was plotted and is shown in Figure 2. The following information is presented graphically for ambient temperatures from 65°F to 105°F: (1) the total hours during the summer in which a temperature was exceeded; (2) the average number of hours per day in which a temperature was exceeded, and (3) the average number of days per month in which a temperature was exceeded.

The data indicates that a temperature of 65°F was exceeded an average of only nine hours per day during the summer. Based on a 90°F inside temperature for an uninsulated building, the fans would need to operate less than half of the time during the summer and an estimated 20% of the time (1760 hours per year) during the full year to handle the cooling load. However, in an insulated building, some ventilation would need to be provided at all times. The average fan would operate about 75% of the time (6600 hours per year). Fans would require about 3.0 Kw each for the uninsulated building against 2.5 Kw for the insulated building. For the insulated building, the fans would have to operate about four times as much, so fans and filters would require much more maintenance. Comparative power and maintenance costs are tabulated on the following page.

COMPARATIVE POWER & MAINTENANCE COSTS

Power Cost

Insulated Building

6600 hrs x 2.5 Kw x $0.005/Kw hr x 120 units	= $9900	

Uninsulated Building

1760 hrs x 3.0 Kw x $0.005/Kw hr x 120 units	= -3200	
ADDITIONAL YEARLY POWER COST (Insulated Building)	= $6700	

Filter Replacements Costs (Roll Filters)

120 rolls/yr @ $40.00 (insulated)	= $4800	
30 rolls/yr @ $46.00 (uninsulated)	= -1380	
ADDITIONAL YEARLY COST (Insulated Building)		$3420

Labor (Filter replacement @ 10 min/unit/trip)

12 service trips/yr @ 20 hrs @ $2.00 (insulated)	= $ 480	
3 service trips/yr @ 20 hrs @ $2.00 (uninsulated)	= -120	
ADDITIONAL YEARLY COST (Insulated Building)		$ 360

Fan Maintenance

20 overhauls/yr @ $50.00 (insulated)	= $1000	
5 overhauls/yr @ $50.00 (uninsulated)	= -250	
ADDITIONAL FAN COST/YEAR		$ 750
ADDITIONAL YEARLY MAINTENANCE COST (Insulated Building)		$4530
POWER COST		+6700
TOTAL ADDITIONAL YEARLY COST FOR INSULATED BUILDING		$11,230.

DISCUSSION

The Klystron Gallery has been compared to a warehouse. There is little similarity between conditions in the Klystron Gallery and in a warehouse. The Klystron Gallery with its high internal heat gain is more comparable to a boiler house. In a warehouse it is desired to keep the external heat out; whereas, in the Klystron Gallery it is desired to get the internal heat out. The most economical method for obtaining relief from excessive heat is to provide plenty of outside air during the high temperature periods with a capability for directing it to the working area, and then exhaust it near the roof after it has absorbed the heat.

Solar Heat Gain

The equivalent temperature differential for calculating solar heat gain for a dark colored, flat roof, of light construction is 62°F with an indoor temperature of 80°F and outdoor temperature of 95°F (ASHRAE GUIDE). Correcting for a light color brings it down to 35°F (125°F roof temperature at 90°F ambient). However, the fluted roof has 50% more surface area than a flat roof. If the solar heat absorbed is spread over the larger area, the inside surface temperature is lower and the percentage of radiant heat transfer is reduced. No credit was taken for the fluted roof. Because the conditions are quite different from those for which the air conditioning heat transfer constants were designed, the heat gains by radiation and convection were calculated independently and then added. A large proportion of the roof solar heat gain is by radiation. This heat is transferred to the floor, walls, people, and objects which are at a lower temperature than the roof and then released to the air by convection.

The temperature rise of floors, walls, etc., due to radiant transfer, will be small because the rapid air movement in the gallery is conducive to good heat transfer.

The south wall will not get as hot as the roof. The equivalent temperature differential based on 80°F inside is 20°F. When correction is made for the inside temperature and for the fluted wall, the solar effect is nullified. Insulation of the south wall will be of negligible benefit in reducing heat in the building when the equipment is operating.

Effect of Roof Temperature on Electric Wiring

Electric wiring should be kept a few inches away from the roof surface; and, if near the roof, should have free air circulation around it. Wiring should be designed for ambient temperatures up to 50°C or 122°F. (Standard NEC Type TW wire is rated for operation at 60°C.)

Temperature Ranges in Building

The design temperature for the gallery as given in the criteria is 15°F above ambient. The inside temperature in the uninsulated building can be expected to reach 105°F at occupant level when the outside temperature is 90°F. When outside temperatures go over 100°F, as they will occasionally, the inside temperature will rise almost proportionately and can be expected to reach 115°F in the uninsulated building at least once a year.

The winter temperature in an uninsulated metal building with no internal heat gain would approach within a degree or two of the outside temperature. Operation at full Stage I load without ventilation would give an inside temperature about 20 to 25°F above outside. When the accelerator is operating at reduced capacity on a cold night, the temperature in the gallery could drop to 40°F or even slightly below. The temperature in an insulated building would be several degrees higher at minimum heat load and would climb about three times as fast, as the load increases.

ANSWERS TO QUESTIONS

Seven specific questions were asked in the T. McClellan to R. Sharpe memorandum dated 18 February 1963. The questions and their answers are presented below:

1. Is insulation necessary?

   Ans: Insulation on the north wall would hold the heat in the building and defeat the purpose. Insulation on the south wall would provide little benefit. Insulation on the roof would decrease the heat in the building on a hot day. This would be beneficial at that time but is not considered economically justifiable or desirable for year around 24-hour a day operation.

2. If walls are insulated, would a wainscot be required?

   Ans: Probably not. A vinyl faced or foam insulation, although fragile, might be satisfactory as an inside surface for the building. This problem should be studied further if it is decided to install insulation.

3. What items other than wainscot might be affected?

   Ans: Hanging of pipes and equipment from walls and roof would be complicated. Relief openings for ventilation air would have to be provided instead of using "enlarged cracks" as presently planned.

4. Could the ventilation requirements be reduced if the building is insulated?

Ans: Yes, about 20% as ventilation air is proportional to the total heat load. Insulating the roof would practically eliminate the roof solar heat load which is now about 20% of the total.

5. How often will the maximum temperature be reached? What will this temperature be? For how long a period will it last?

Ans: During the four month period, 1 June through 30 September 1960, ambient temperatures over 90°F were recorded on the site on nine days, an average of four hours per day; 94°F was exceeded on three days for 7, 9 and 2 hours respectively, and on 2 June the temperature was at or above 102°F for five hours. The present ventilation design limits the temperature in the gallery to a 15°F rise above ambient. The maximum temperature expected in the gallery, allowing a little for thermal lag, would be 115°F and may last from about 2 p.m. until 7 p.m. one day a year.

6. If ventilation is designed for the building without insulation, and then insulation is added, what will be the effect?

Ans: The inside temperature at maximum conditions will be reduced in proportion to the decrease in heat gain. This is not over 20% (3°F), with latest calculations which include the higher (10 Kw) loss from modulators. However, the reduction in radiant heat from the roof would make the difference seem greater to a person. But bear in mind that there are other radiant surfaces in the gallery which will not be eliminated; for instance a 10 Kw loss from a modulator requires a surface temperature about 41°F above the surroundings or 146°F on a 90 degree day. The temperature gradient with the building should be quite small because of the air circulation. The air from the ventilating units would provide an air change approximately every three minutes and the discharge can be directed as required. Air relief openings would be near the roof so that the hottest air is discharged.

7. Will trees planted on the south side be effective?

Ans: Trees on the south side would be effective if they shade the building. However, the landscaping plans do not show the trees close enough to the gallery to be of any real benefit.

REFERENCES

(1) Memorandum, Conviser to Neal, dated 11 February 1963 "Insulation of Klystron Gallery".

(2) Memorandum, T. McClellan to R. Sharpe, dated 18 February 1963, "Thermal Insulation of the Klystron Gallery".

(3) Blume Report, Volume IV, December 1960.

(4) Design Criteria Report, ABA-48, Rev. 1, 13 August 1963.

(5) Title I Report, ABA-58, 28 January 1963.

(6) SLAC Comments on Title I Report, ABA-58, 15 February 1963.