Infrared Imaging Radiometry on Bulk Tobacco Barns

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This article is reprinted from the TRANSACTIONS of the ASAE (Vol. 27, No. 4, pp. 1222–1226, 1984)
Published by the American Society of Agricultural Engineers, St. Joseph, Michigan

ABSTRACT

FLUE-CURED bulk-tobacco barns have been examined Thermographically with an infrared imaging radiometer. Regions of considerable heat loss were found to be the pad and the roof, in addition to any cracks or air leaks. Insulation reduced temperature range variations over a barn surface from a range of 50 °C to a range of 10 °C.

INTRODUCTION

Agricultural uses about three percent of the nation's energy supplies, much of which comes from petroleum sources. However, energy accounts for a considerable part of a farmer's annual expenses. For tobacco farmers in South Georgia, energy costs in curing may constitute as much as 20% of the cost of getting the tobacco to the warehouse floor. About 16% (fuel for heating) is required to elevate the temperature in the curing barn, while 4% (electrical) is required to drive the fan which forces air through the tobacco. In most instances petroleum fuels are burned as the source of heat. Conservation of heat is desirable, but at the same time correct humidity conditions in the barn must be maintained.

The conventional bulk tobacco barn has approximately one hundred square meters of surface area exposed to the atmosphere. Most tobacco barns built and installed before we became conscious of energy use were built with little or no thermal insulation in the structure. A survey of flue cured bulk tobacco barns in North Carolina indicated that 10 to 50% of energy expenses could be saved by properly insulating the barns (Hudson, 1981). In addition, hot air leaks such as those around doors and between structural joints need to be sealed.

Thermography is the science of applying optical imaging radiometry for the observation of infrared radiation emission (Allen, 1982). The purposes of this paper are to demonstrate the usefulness of thermography for agricultural purposes and to specifically analyze heat losses from a bulk tobacco curing barn by this technique, in order to illustrate the need for improved barn maintenance.*

Article was submitted for publication in September, 1983; reviewed and approved for publication by the Electric Power and Processing Div. of ASAE in February, 1984. Presented as ASAE Paper No. 82-3567.

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Acknowledgements: Our gratitude to Mr. Lee Allen of the Energy Savers for photographing the tobacco barns and to Mr. C. L. Talley and Mr. Michael Stephenson for the use of their tobacco barns.

*There is no intention here to be critical of any particular manufacturer's tobacco barn design.

VIEWING BULK TOBACCO BARNS

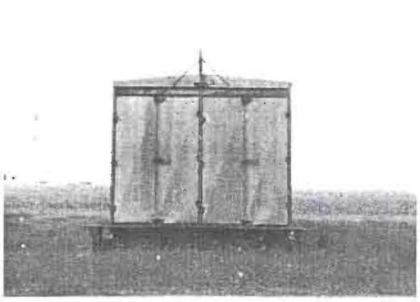
Loading Doors

An Inframetrics Imaging Radiometer, Model 525, with color capabilities was taken to several bulk-tobacco barn sites. This instrument has the ability of real time analysis. Results are presented for a partially insulated barn. The curing temperature in the barn was 71.1°, while the outside temperature was 23.1 °C. The barns were viewed during the night to minimize reflective radiation from other sources including the sun. The discussion which follows describes the observation of the barn in a logical sequence, beginning with the loading doors in Fig. 1.

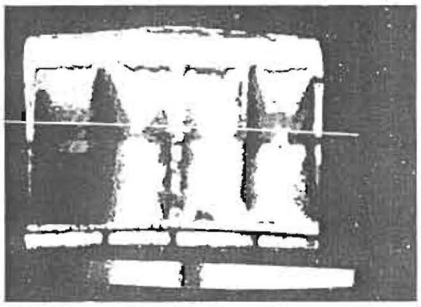
Fig. 1 exemplifies the format for subsequent figures. Fig 1(a) is a normal photograph of an uninsulated tobacco barn showing the loading doors closed. Fig. 1(b) is a thermogram from the same viewpoint of the tobacco barn with loading doors closed. There are various areas of white, different shades of grey and areas of black within the outline of the view. In fact, we are looking at a black and white photograph of a colorized thermogram. That is, colors have been assigned to different temperature regions on the surface of the barn and help to show more distinctly those different temperature regions. If this picture were in color, white would represent areas of highest heat loss, and black would represent temperatures indicating the lowest heat loss. Colors other than white and black would help us determine the temperature of a region relative to a reference surface temperature.

In Fig. 1(b) we can identify the areas of high heat loss from the surface of the barn by those white areas in the picture. Similarly, we can identify the cooler surface regions by black areas of the picture. A more detailed look at specific temperatures is to be found in Fig. 1(c). Fig 1(c) is a contour map drawn from the thermogram in Fig. 1(b) onto which have been added known contact surface temperatures, recorded with a separate thermometer at the time of the test. Knowing the instrument scale setting allows us to accurately specify contour intervals. Thus, it is possible to associate specific temperatures with visible regions on the thermogram.

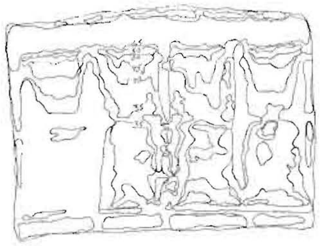
Also, on Fig. 1(b) there is a white line across the center of the picture running from left to right. This line marks the position of the line scan found in Fig. 1(d). A line scan is a graph of the temperature along a specified straight line and in this case passes from the left hand side of the loading doors, across the center post of the barn and over to the right hand side of the loading doors. There are two sets of double doors at the front of this particular barn in view. Observing the graph we see considerable heat loss occuring at the edges of the doors, especially at the center post, and towards the center of each door. The horizontal bars in the line scan, Fig. 1(d),



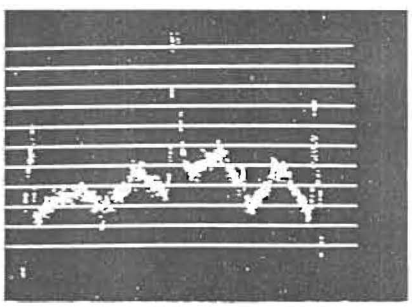
(a) Normal photograph



(b) Thermogram with line position of the line scan

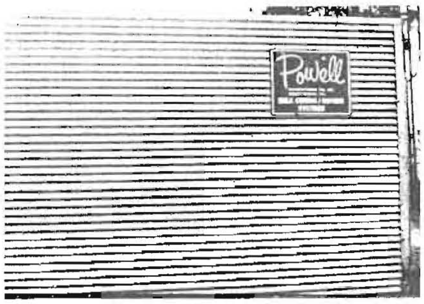


(c) Isotherm contour sketch

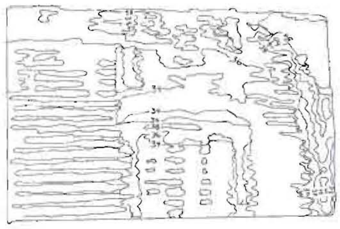


(d) Line scan

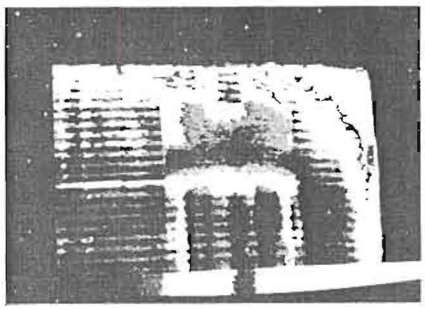
Fig. 1—Views of the closed uninsulated loading doors of a bulk tobacco barn.



(a) Normal photograph

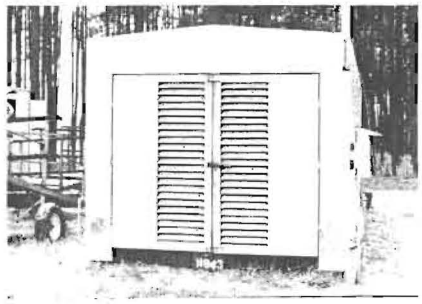


(b) Isotherm contour sketch

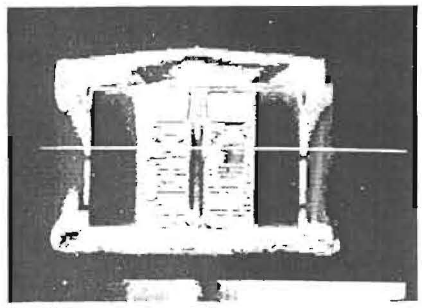


(c) Thermogram

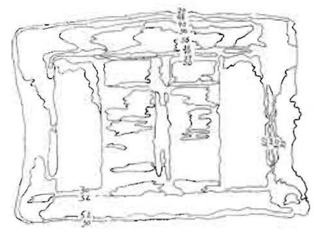
Fig. 2—Views of a bulk tobacco barn uninsulated side wall adjacent to the loading doors.



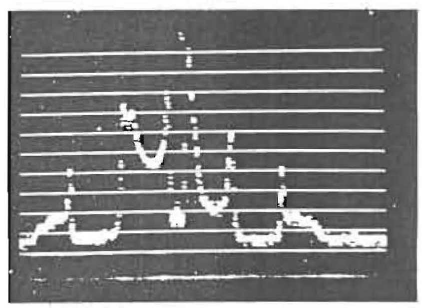
(a) Normal photograph



(b) Thermogram with line position of the line scan



(c) Isotherm contour sketch



(d) Line scan

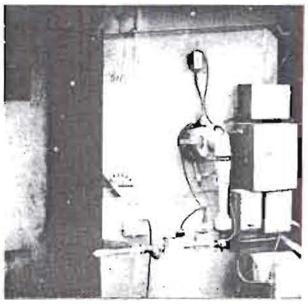
Fig. 3—Views of the furnace end of an uninsulated bulk tobacco barn.

correspond to the same temperature intervals as shown on the isotherm contour. Thus, in this case they are 5 °C apart. The size of interval between horizontal bars will vary from one line scan to the next, on subsequent figures. However, the interval can be determined by viewing the associated isotherm contour sketch.

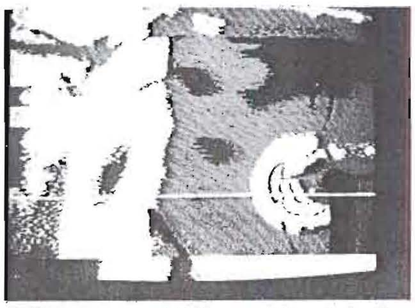
The results of Fig. 1 indicate to us that there is considerable heat loss at the sides, top and base of the tobacco barn loading doors. Poor door gaskets and incorrectly fitted doors are responsible for most of the heat loss at the edges of the doors. Above the doors there is a sheet metal vent cover which is freely radiating heat. Heat from this region is magnified when the vent is open and hot air is allowed to escape from the barns. At the base of the doors, there is a steel beam which forms part of the foundation of the barn and heat is being radiated from this surface. As a contrast to the uninsulated doors, there is one area of the left hand side door which is insulated and it is evident, on Fig. 1(b).

Walls

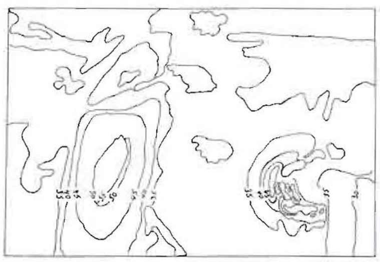
Fig. 2(a) is a regular photograph of the front corner of a tobacco barn and Fig. 2(c) shows that there is some wrap around conductive heat loss from the region in the top right hand corner of the barn on the walls. The specific temperature of this region is 48 °C. Corrugations in the side wall surface sheet metal are readily visible on the thermogram. Greater insulation occurs at the peak of



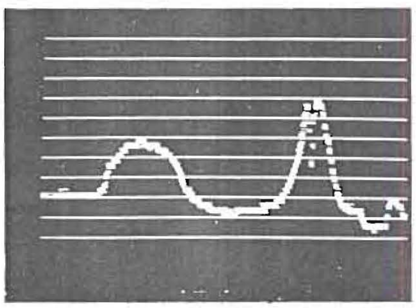
(a) Normal photograph



(b) Thermogram with line position of the line scan

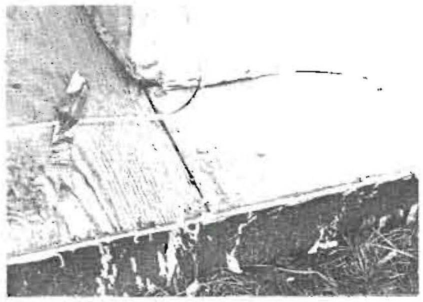


(c) Isotherm contour sketch



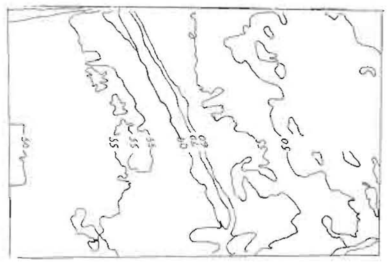
(d) Line scan

Fig. 4—Views of a bulk tobacco barn furnace.

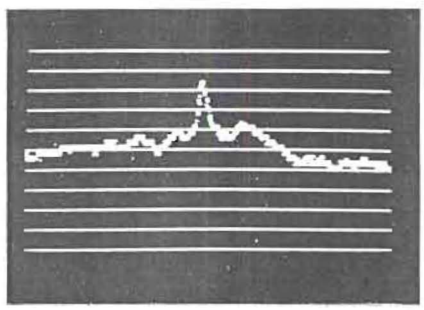


(a) Normal photograph

(b) Thermogram with line position of the line scan



(c) Isotherm contour sketch



(d) Line scan

Fig. 5—Views of a crack in the floor of a bulk tobacco barn furnace room.

the corrugations where the air space is deepest behind the sheet metal. Heat loss is also observed along the eave of the tobacco barn.

Furnace End

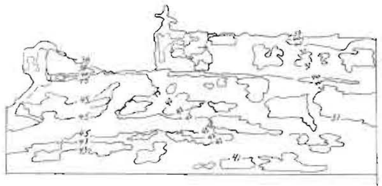
Fig. 3 shows the end of the barn that contains the furnace, which provides heated air for blowing through the tobacco being cured in the barn. As seen in the normal photograph, the doors of the furnace room are closed and yet the thermogram indicates that heat loss is in fact taking place through those doors. Other areas of loss are the ducting region above the doors and the back wall below the doors.

Fig. 3(c) indicates temperatures as high as 55 °C observed over certain areas of the barn. The line scan in Fig. 3(d) highlights the edges of the furnace room doors and also the burner of the furnace itself in the center of the picture. Of course, the burner is obscured from view in the normal photograph. Yet, we know that it is there from the thermogram. This is a good example of the flexibility of thermography as a detection tool. In this case, the temperature on the line scan at the location of the burner goes beyond the scale being used at this specific time on the scanner. Bringing the burner temperature back into view would also change the scale relationships of different regions in the rest of the picture.

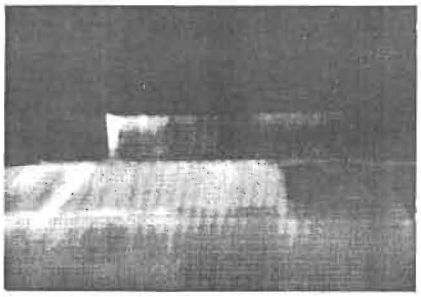
Furnace

Fig. 4 is of a close up of the furnace inside the furnace

(a) Normal photograph

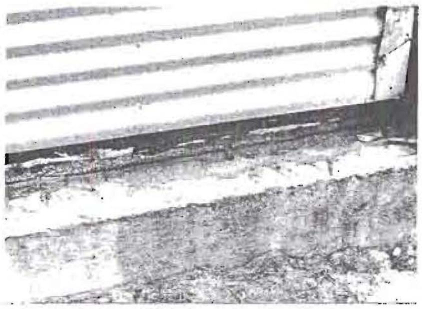


(b) Isotherm contour sketch

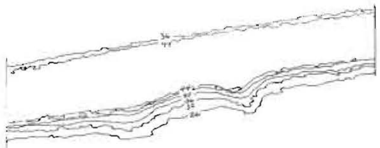


(c) Thermogram

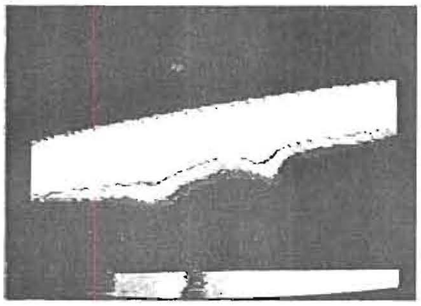
Fig. 6—Views of the roof of a bulk tobacco barn which is partically uninsulated.



(a) Normal photograph

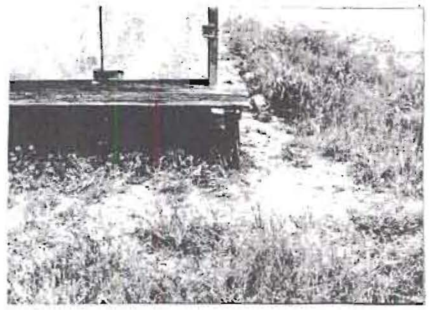


(b) Isotherm contour sketch

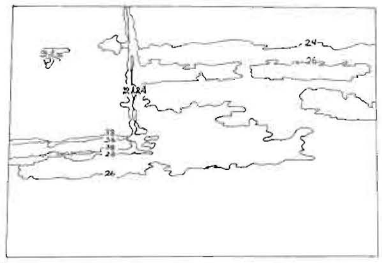


(c) Thermogram

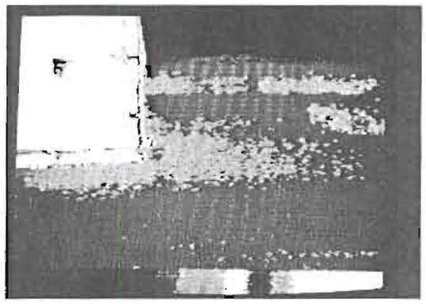
Fig. 7—Views of a crack at the base of a bulk tobacco barn.



(a) Normal photograph



(b) Isotherm contour sketch



(c) Thermogram

Fig. 8—Views of the concrete pad-soil contact region for a bulk tobacco barn.

room. At the center of the furnace is the burner which injects a flame into the airstream. The thermogram in Fig. 4(b) indicates that the side of the furnace is hotter than the front, apart from the burner itself. This is again highlighted on the line scan Fig. 4(d). These pictures then show us there is in fact some insulation on the front surface of the furnace which close examination revealed to be a layer of fiberglass.

Furnace Room Floor

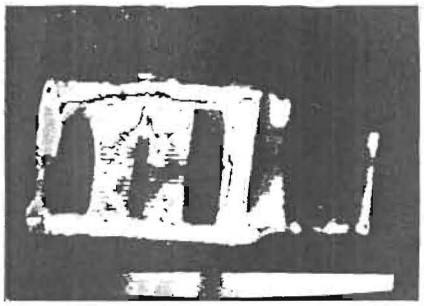
Fig. 5(a) is a photograph of a crack in the floor of a tobacco barn furnace room. Immediately beneath this floor is the plenum which transfers heated air from the furnace forward into the curing section of the barn. Any cracks, will allow heated air to escape. The furnace room is especially critical because the air is hottest at this point in the plenum. The isotherm contour sketch in Fig. 5(c) shows the temperature at the crack to be 70 °C.

Roof

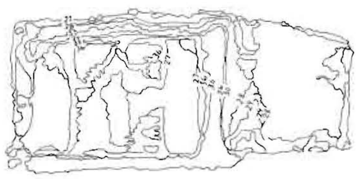
The normal photograph in Fig. 6(a) is taken looking down upon the roof of the specific barn being observed Focusing our attention on the first barn in the foreground of the photograph, the thermogram in Fig. 6(c) has lighter areas to the left hand side and darker areas to the right hand side of the barn roof. We are demonstrating here the importance of insulation in the roof of a barn. There is no insulation in left hand section of the barn roof. However, there is one inch of polystyrene foam material in the right hand side section of the roof. The surface temperatures of the roof according to Fig. 6(b) are 45 °C at the uninsulated area and only 37 °C at the insulated area. The heat loss from a tobacco barn can thus be reduced by roof insulation.

Base Cracks

The tobacco barn rests upon a concrete pad. Not only is insulation on the steel member of importance, but also the seal between the steel foundation member and the concrete. Fig. 7 is a good indication of the apparent heat loss from cracks along the base of a barn. The photograph in Fig. 7(a) would suggest that some type of sealant has been applied to the junction between the steel member and the concrete. However, this sealant appears to have cracked in places. The thermogram Fig. 7(c) shows this to be the case. Not only is there considerable heat loss from the steel member the full width of the picture, but there is also extended heat loss projection at two places along the base. The isotherm contour sketch Fig. 7(b) emphasizes the temperature variation at these two points. The use of a good seal around the base of the barn can be another plus in keeping down the overall

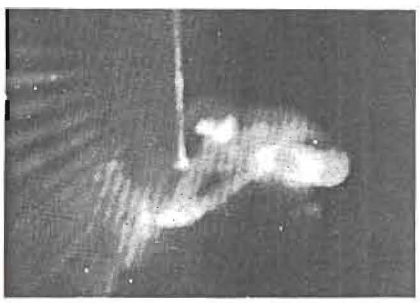


(a) Normal photograph



(b) Thermogram with line position of the line scan

(c) Isotherm contour sketch



(d) Line scan

Fig. 9—The effect of insulation upon the heat loss characteristics of a bulk tobacco barn.

heat loss from the structure. Hot air is being forced along the inside of the barn immediately on the other side of the steel member. The barn plenum has no floor other than the concrete pad itself.

Ground Spread

The concrete pad of a tobacco barn, if one is in existence at all, is pored immediately onto bare earth. Tests have shown that up to 5.6 percent of total fuel consumption can be attributed to loosing heat through the pad on which the barn is resting (Chang et al., 1979). To give some indication of this heat dissipation we refer to Fig. 8, where we are looking at a corner of the barn. Here the barn is visibly in direct contact with the ground. The thermogram displays a very clear dissipation of heat from the barn into the soil. Contact temperatures taken of the soil specific distances away from the barn indicate a temperature rise from 26 °C through 38 °C at the surface of the barn. Soil temperatures away from the barn were only 24 °C. This heat loss into the soil is a good justification for including some insulation materials in the concrete while it is being laid. Special attention should be given to the edges of the concrete, where it appears much of the heat loss takes place.

The Effect of Insulation

Fig. 9(a) is a thermogram of an insulated bulk tobacco barn as viewed from the furnace end of the barn. Special examination of the isotherm contour sketch discloses the small temperature variation of only 10 °C across the different surfaces of the barn, in the case of the insulated barn, Fig. 3(c). Insulating a barn includes sealing cracks to prevent air leaks. A more vivid demonstration of the effects of thermal insulation in the walls of a barn is shown in Fig. 9(c) and (d). In Fig. 9(c) we have the thermogram of a person along side of the wall of the uninsulated barn. It is quite evident that the surface temperature of the barn is almost equal to the body temperature of the person in certain places. Certainly more than the temperature of the person's clothed body. Yet the reverse is the case in Fig. 9(d). Here, the person's body temperature with clothing is higher than the temperature of the tobacco barn wall. Supposing that the body temperature was 32 °C, then our inclination is correct if we are to return to Fig. 2(b) and observe wall temperatures of 34°, 38° and even 48 °C on the surface of an uninsulated barn wall. However, in the case of an insulated barn we see from Fig. 9(b) that surface temperatures are not observed to be more than 36 °C, even at the furnace room doors.

SUMMARY

Thermography, the science of electro-optical imaging radiometry for observing emission of infrared radiation from the surface of a body, satisfies the need for a dynamic visual appraisal of surface temperatures. The usefulness of thermography for research, monitoring or trouble shooting is shown.

We have used thermography to examine the heat loss from bulk curing tobacco barns in order to identify those areas where recommendations could be made to the farmer on possible structural improvements. Regions of heat loss were found to be the pad, roof and cracks in surface material.

References

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3. Hudson, J. 1981. Energy audit saves flue cured curing dollars. Southest Farm Press, Oct. 14:8-9.