Saving Energy Through Heat Loss Survey of Residential Areas of Winnipeg

by Salah Hathout

1980

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Published 1980 by the Institute of Urban Studies, University of Winnipeg

Note: The cover page and this information page are new replacements, 2016.

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Institute of Urban Studies
Publication Number: 069

Fall 1980

1. INTRODUCTION

Changes in apparent roof temperature pattern can account for up to 30 percent of the total heat loss of a house. To detect and record such temperature changes, an air-borne IR line scanner survey of heat loss through the roofs of Winnipeg buildings was undertaken by using thermography. Analogue IR continuous black and white tone image thermographs were sliced into a master set of six even levels and each level was color enhanced to allow better discrimination between various classes of roof temperature. A reliable result was obtained by undertaking the survey under the right wind speed and air temperature conditions. The effect of roof slope and orientation was investigated as an external factor beside the roof insulation condition. The result of this study will allow home owners to pick out their building from normal aerial photographs, and to determine from thermographs whether heat loss warrants conservation measures.

2. HISTORICAL BACKGROUND

The method known as "thermography" utilizes a technique by which vision is extended beyond the normal confines of the visible spectrum into the infrared. This technique permits not only vision in the infrared but also the quantifications of actual temperature variations. "Heat pictures" are produced from the invisible thermal radiation emitted from moving or stationary objects at any distance (Holmsten, 1977).

2.1 Europe

For more than ten years "thermography" has been applied in Europe to reduce to a minimum energy wastage in residential and commercial buildings, and also in industrial plants. Thermographic building inspection methods are well established in Europe. For example, Sweden with a population of eight million people has ten building inspection firms and an Institute offering thermographic services. The Swedish authorities are considering making mandatory thermographic inspection of all new buildings. This would result in many benefits, especially greatly improved quality of building construction and building materials.

2.2 U.S.A.

More recently, infrared sensing has become an important tool in heat loss detections in North America. In the United States thermographic studies of buildings have been conducted by the National Bureau of Standards, the U.S. Army Cold Region Lab. in New Hampshire, and the Environmental Research Institute of Michigan (ERIM). ERIM has conducted two studies during the winter of 1975-1976 by which the use of modern infrared technology for buildings and facility inspection is defined and demonstrated. Thermographic consultants are largely used in the U.S. to inspect residential dwellings, helping the home owner to pinpoint areas that lose heat and appear relatively warm on the thermogram. In Minnesota, in 1977, State Energy Agency representatives estimate that nearly 99 percent of the homes were poorly insulated (Conservation News). Such heat losses can be severe as winter temperatures hover well below freezing during January and February. Aerial study of heat loss of 25 cities in U.S.A. between November and mid-March in 1977 from an altitude of 2,000 feet had shown that the scanning study was relatively inexpensive. The entire survey was done at a cost of between 10 and 25¢ per home. While a private contractor taking infrared pictures of individual homes with a simple hand-held camera might charge anywhere from between $50 to $75 per home.

2.3 Canada

Thermographic building inspection has now found its way into Canada. Much interest has been created by the infrared aerial coverage over residential areas conducted by the Ministry of Energy in Ontario and the Ontario Centre for Remote Sensing. Several cities have been scanned from the air using thermal imagery provided by the Canada Centre for Remote Sensing (CCRS) to distinguish between buildings with well-insulated and uninsulated roofs. In 1977 a meeting was held at the airborne operations section of the CCRS to assess the status of aerial thermography applications. The meeting was attended by individuals actively involved in data acquisition, data interpretations and operational utilization of the results. The group felt the value of aerial thermography for operational programs as follows.

2.3.1 Residential Programs

(i) Thermographs serve as an impetus for home owners to become interested in energy conservation. In many instances, home owners are not familiar with insulation, ventilation and other aspects of their homes prior to viewing the thermographs and thus are not in a position to implement energy conservation measures.

(ii) The interpretation of thermographs for home owners should indicate whether the house is relatively warm or relatively cold. For relatively warm houses, the interpreter would suggest that the house appears to be losing heat and would discuss the possible causes; inadequate insulation thickness, deteriorated insulation and poor ventilation. The most probable cause of the high roof temperature would be established during this discussion. In case of relatively cool houses, the interpreter would point to the lack of evidence for heat loss but stress that this does not necessarily imply a well insulated house (the house could have poor insulation but effective attic ventilation or vice versa).

(iii) Attempts to predict insulation thickness from gray scale levels will often be inaccurate at the present time due to the inadequate understanding of the relationships involved.

2.3.2 Industrial Programs

(i) Thermographs serve as an effective means of detecting energy loss at an establishment. Building managers are usually very interested in examining the thermograms and discussing the interpretation in light of their own experience. Correct interpretation increases credibility of the bus program as a whole. Since thermographs are retained by the building managers, they can be used at a later date when energy conservation issues arise within the company.

(ii) Careful interpretation of thermographs leads to a reliable identification of damaged roofs (waterproof membrane, deteriorated insulation, structural damages).

(iii) Detection of malfunctioning underground heating lines is reliable and simple.

3. ENERGY SAVING IN THE RESIDENTIAL AREA

Saving energy has become a prime concern to most institutions and individuals. The first step in saving energy is to help home owners realize the inadequate condition of their home insulation. Aerial thermography is ideally suited for this task. Initial success in the application of aerial thermography for detecting damaged and poorly insulated flat roof buildings was observed by Lawrence in 1976 and Philips in 1977. The objective of this study is to investigate the feasibility of the use of aerial thermography in detecting heat loss conditions of individual homes of two residential areas of Winnipeg: (Fig. 1)

(i) 1837 homes along Logan Avenue with a high percentage of older homes (50 years old).

(ii) 2606 homes along Jefferson Avenue, where both older and newer homes are found.

The Logan and Jefferson residential areas were selected because they contain older and newer homes. Thus, they can be used as models to check the technique of heat loss detection. In such cases, other factors affecting heat loss can be analyzed with higher degrees of accuracy such as home style and roof orientation.

The principle of using thermography to detect heat loss is based on the fact that all objects emit electromagnetic energy in variant quantities and within selected wave-bands which are a function of the temperature and the emissivity of that object. The higher the temperature of an object, the more radiation it will emit and the shorter will be the wavelength of peak emissions. The laws governing thermal infrared sensing are based on characteristics of black bodies, and bodies that absorb or emit all incident radiation. Since no surface is a true black body, all emissivities are less than unity and researchers must employ correction factors to estimate true temperatures (Brown and Cihlar, 1978).

Heat loss from a structure is subject to insulation conditions of the ceiling, walls, windows and basement. Since infrared line scanners (IRLS) measure the thermal radiation emitted from the roof of a structure, only ceiling losses are measured. However, these can account for approximately 30% of the total heat loss from a structure, depending upon its age and construction style (Mines and Resources Canada, 1975).

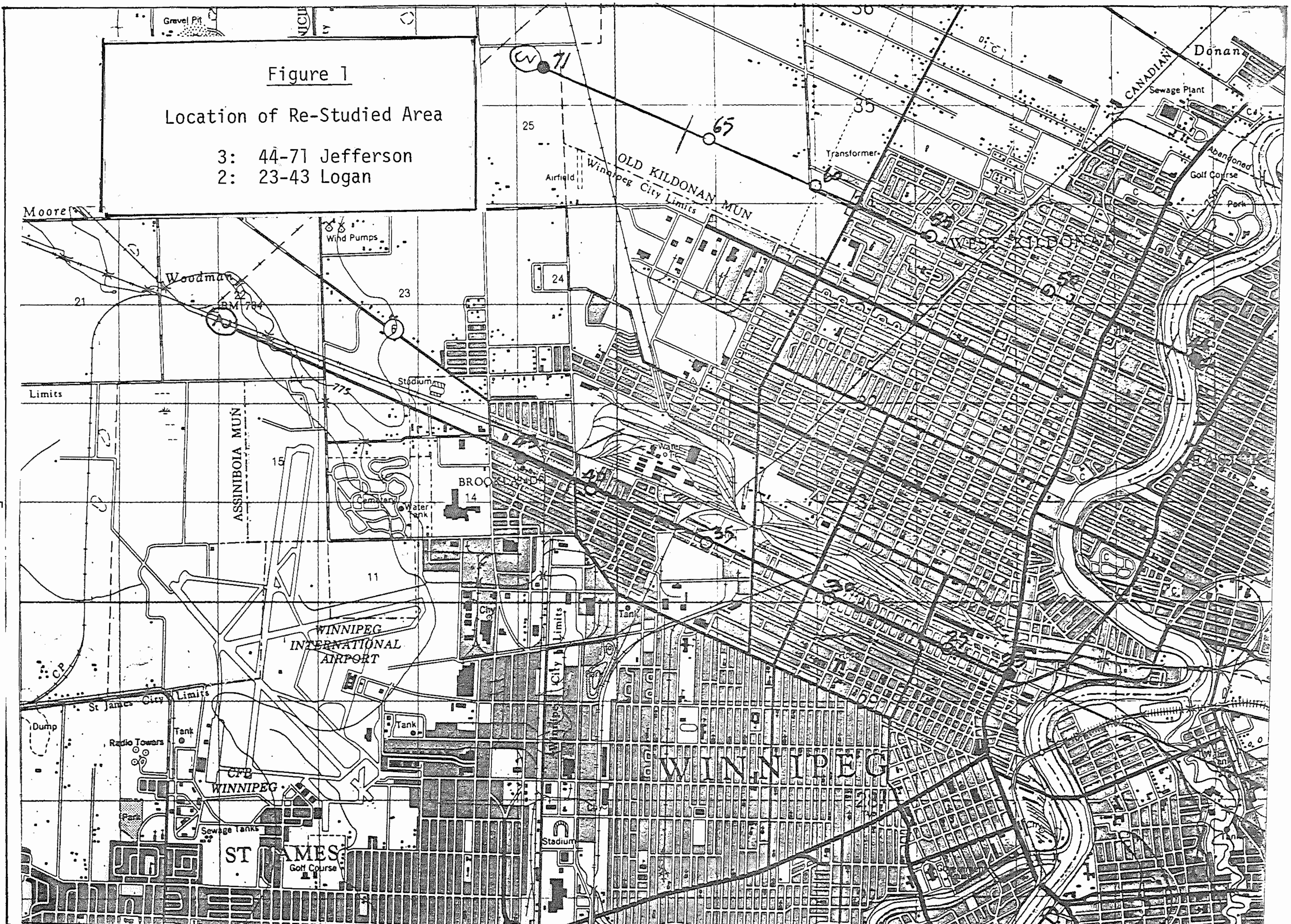


Figure 1

Location of Re-Studied Area

3: 44-71 Jefferson
2: 23-43 Logan

In order to estimate the amount of ceiling insulation in a structure, it is necessary to relate the measured radiation to the rate of heat transfer through the ceiling. Heat transferred through the ceiling of an individual home will depend on the following:

(i) Thickness of the insulation material of the roof.

(ii) Roof pitch variation.

(iii) Emissivity of radiation due to roof orientation.

In addition to the above mentioned parameters, the heat transfer will be strongly dependent upon the difference between indoor and outdoor temperature and the wind velocity. However, these factors are minimized when the thermographs are taken at air temperatures which do not exceed +3^{o}C and surface wind speeds which do not exceed 10 knots.

In the present study a relationship will be established between heat loss (depicted on sliced grey level thermographs) and enhanced four level color thermographs (using a density slicer); and roof shape variation and orientation of roof pitch as depicted on false color infrared air-photographs. The results of this research will illustrate the following:

(i) The rate of heat loss in two contrasting (old and new) residential areas by using thermographs.

(ii) The effect of roof shapes and pitch orientation on heat loss.

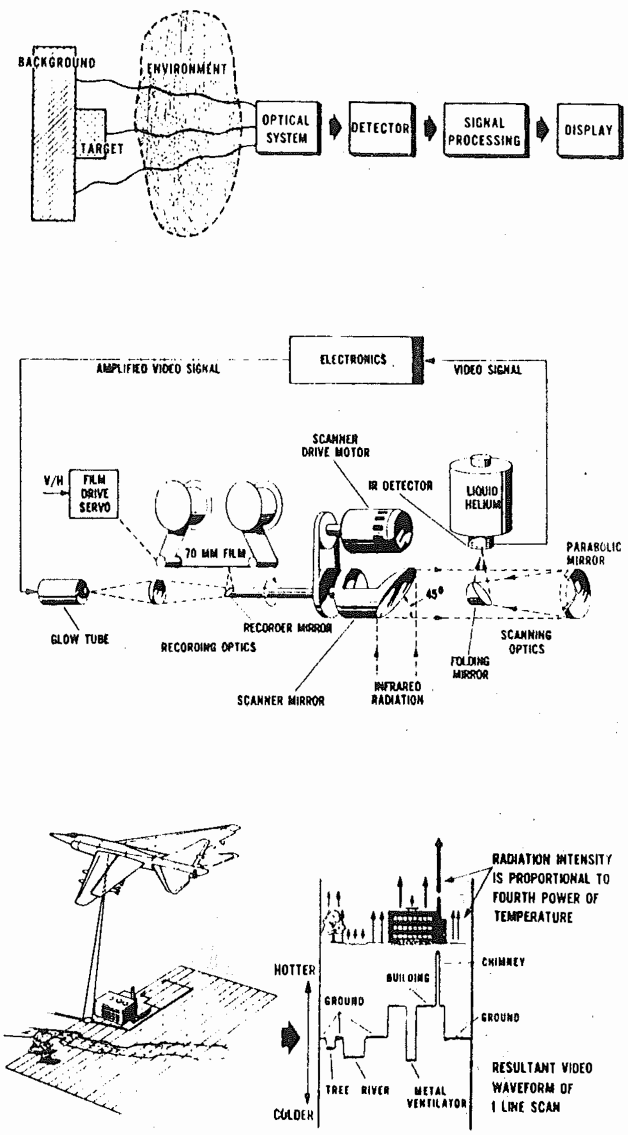
4. THERMOGRAPHY AND AERIAL PHOTOGRAPHY COVERAGE

4.1 Nighttime Thermographs

Nighttime thermographs were collected by Canada Centre for Remote Sensing (CCRS) on April 7, 1978 at 01:00 hours at the altitude of 1600 ft. Skies were clear, air temperature was 2.8^{O}C, winds were 11 km/hr., and roof tops were snow and ice free. Two heterogeneous residential areas with a wide selection of houses of different styles, ages, and insulation levels were chosen, namely Jefferson Avenue and Logan Avenue. The aerial infrared data was stored in analogue form on magnetic tape within the aircraft (Fig. 2). CCRS utilizes a field printer to produce negatives on film from this magnetic tape. The Deadline IR imagery on the film was processed into two basic modes (J. Cihlar, 1977): analogue tone image and sliced tone image, and colored enhanced image as follows.

Figure 2

Generalized and Detailed
Infrared System and
Radiation Illustration



4.1.1 Analogue Tone Image

Analogue Tone Image refers to the relative mode of processing producing a continuous tone image of the ground (the relative tones on the film represent relative temperatures on the ground, absolute temperatures cannot be determined by this method of processing),(Fig. 3).

4.1.2 Sliced Tone Image

The quantitative mode employing a set of voltage dividers which slice the tonal signal range into six even levels of information (Fig. 4).

The total level slicing of all six even levels is called a "Master Set" or "Range 1 to 7" (Fig. 5). The following ranges of 1 to 7 were selected from among the alternate ranges to represent the variation of roof temperatures on the ground of the night-time aerial thermographs: (Appendix C)

1. -5.00°C
2. -2.08°C
3. +0.83°C
4. +3.75°C
5. +6.67°C
6. +9.58°C
7. +12.50°C

On the sliced thermographs, an apparent roof temperature ranging from -5 to 6.67°C was classified into four categories and their corresponding grey shades were used to identify the various heat loss conditions as follows:

Level 1	No heat loss	-5.00 to -2.08°C	dark tone
Level 2	Slight heat loss	-2.08 to +0.83°C	dark grey
Level 3	Considerable heat loss	+0.83 to +3.72°C	light grey
Level 4	Extensive heat loss	+3.75 to +6.67°C	light tone

The above four levels of shades were color enhanced by using the density slicer and color scaled for the purpose of increasing the accuracy of interpretation as well as to investigate the difference between interpretation of heat loss from black and white via color signature.

4.1.3 Colored Enhanced Image

The Density Slicer or Datacolor 703-32 analyzes the grey scale of photographic transparencies and then displays the density values by means of a color television. The 32 level

Figure 3

Night Flight Analogue Tonal Images
(Jefferson)

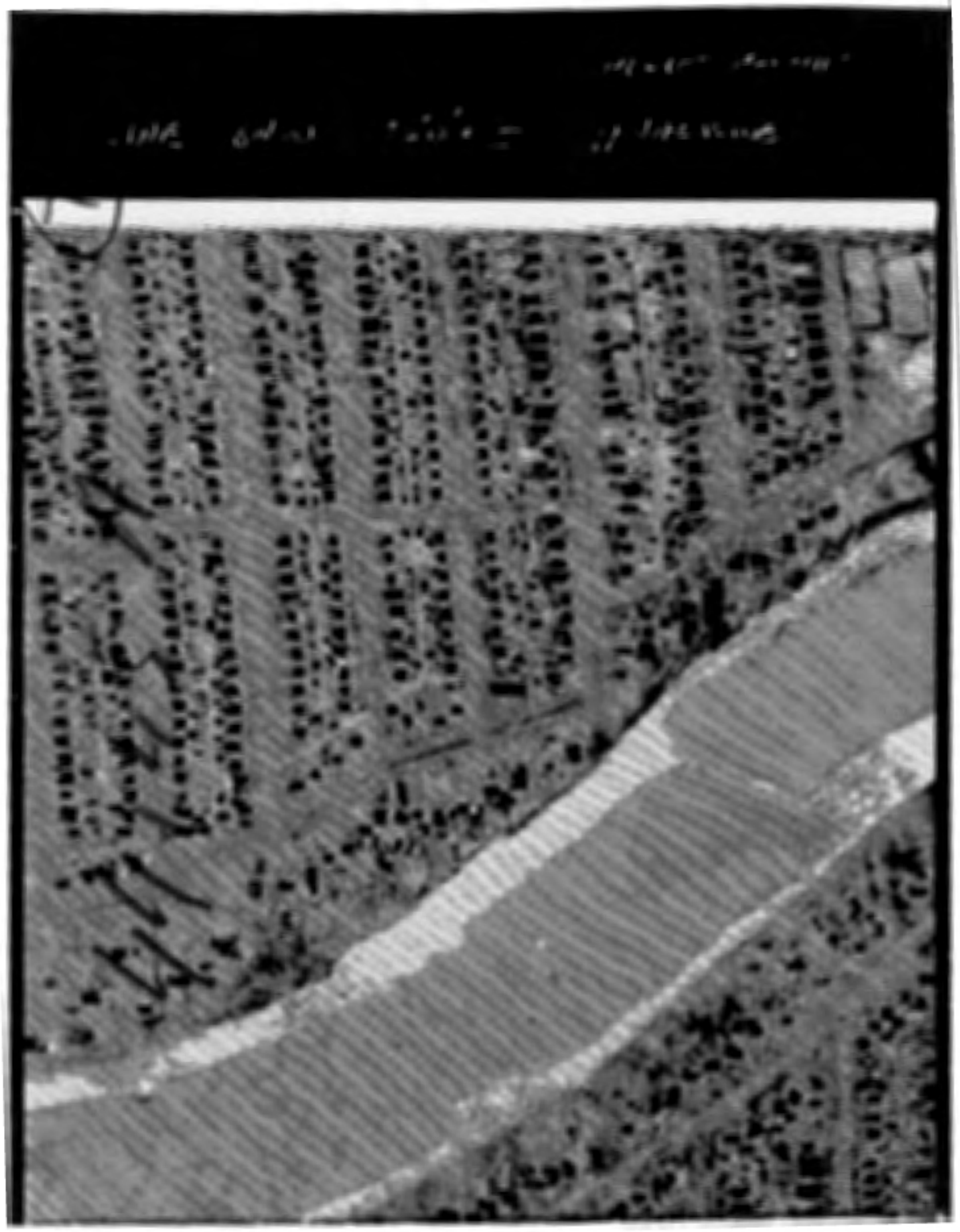
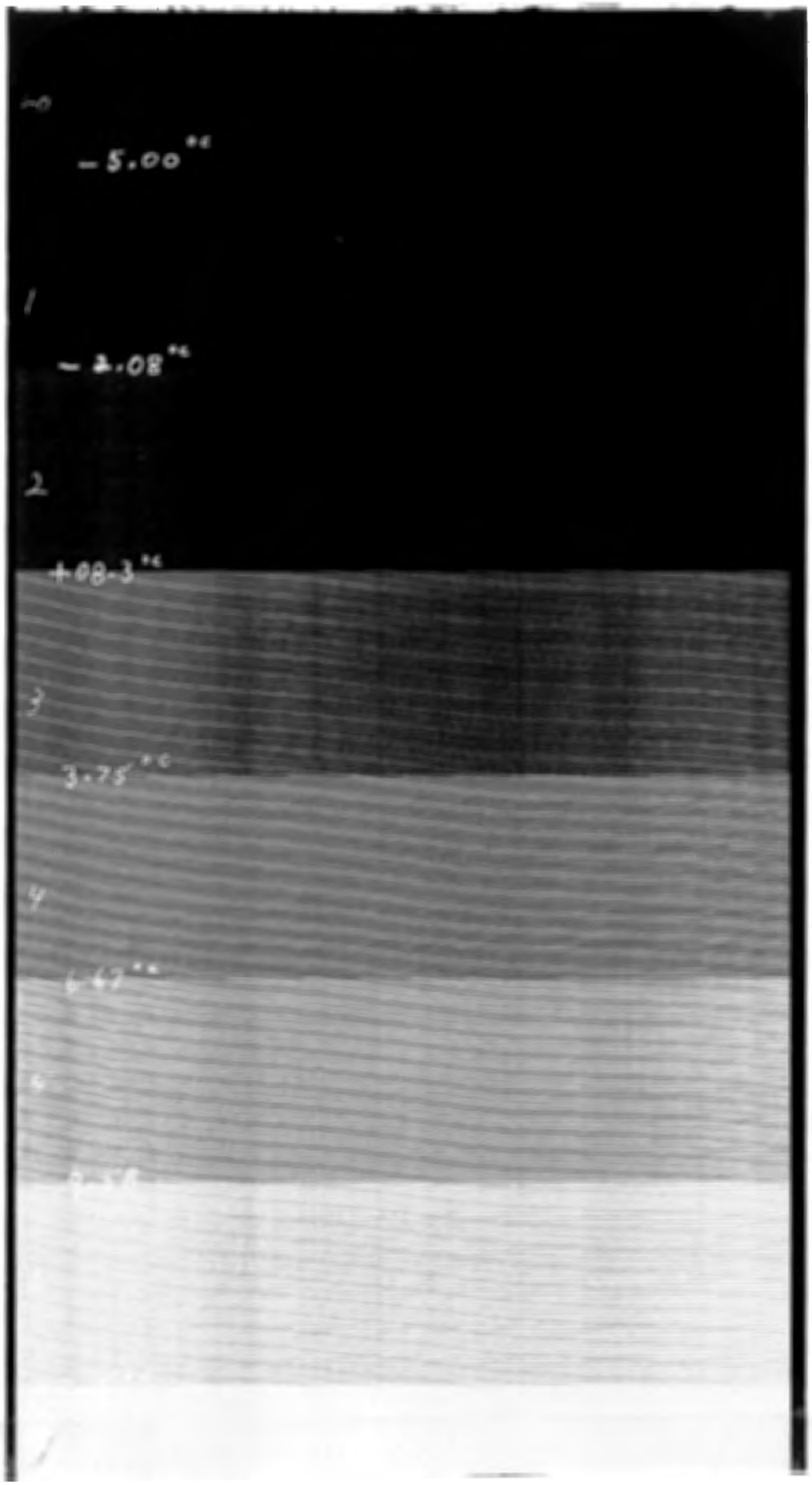


Figure 4

Night Flight Sliced Tonal Images
(Jefferson)

Figure 5

Master Set of Tonal Images



colors are in a fixed order starting with very light yellow representing the brightest or lowest density part of the picture and proceeding through light yellow, medium yellow, and then through 4 shades of cyan, green, orange, magenta, violet, red, and blue. Very dark blue, or black represents the darkest or highest density part of the picture.

Each color band represents an equal band of film densities. Density D is related to the transmittance (0 to 1) of the film by D = log 1/t. Thus a transmittance of 1/100 corresponds to density by means of a special logarithmic amplifier in the color analyzer.

The video signal from the camera is processed by the color analyzer. A logarithmic amplifier converts the camera signal that is proportional to the film density. A high speed analog-digital converter then digitizes the density signal into 32 levels. A color generator generates fixed proportions of red, green and blue signals for each of the 32 levels. The red, green, and blue signals drive the color television monitor to produce the color analysis. These colors are produced by trios of red, green, and blue phosper dots on the picture tube face. The dots are excited by the 3 electron beams from 3 electron guns. These are controlled by the red, green, and blue signals from the color analyzer. A gamma selector is provided, which produces contrast of the images, ERTS Experiments (1974).

4.2 Daytime Thermographs

In addition to the nighttime aerial thermograph coverage, daytime aerial thermographs were produced in an attempt to resolve ambiguities resulting from the presence of water, snow, and ice on the roof of the structure. However, in this study they do not appear essential for the individual homes, but they appear very essential for the industrial plants.

4.3 False Color Photographs

A total of 8 nautical miles of daytime false color infrared aerial photographs were produced for the study area. The photographs were taken at an altitude of 1600 feet a.s.l., with a cloud coverage of less than 15%, a sun angle of more than 25^{o}, and no precipitation between day and night. The photographic overlap was 60 percent.

5. RESULTS AND ANALYSIS

5.1 Industrial Plants

In the primary stage of interpretation of the trial image variations of black and white thermographs, most of the industrial plants with low roofs showed up with damaged waterproof membranes and consequently deteriorated insulation. Daytime thermographs were taken to check which of these roof tops had standing water or ice and would thus have appeared as suffering from heat loss on the nighttime thermographs. From ground truth it was found that the major heat loss from industrial plants was the result of: damaged waterproof membrane; deteriorated insulation; and structural damage.

5.2 Residential Areas

With regard to the residential areas, the relationship between grey levels and level-subset thermograms and level of insulation showed that well insulated homes tend to appear darker in tone while the poorly insulated homes tend to appear lighter in tone on the thermographs. Substantial overlap between well and poorly insulated homes were noticed on the thermographs. This overlap was somewhat reduced when various house styles were considered separately with regard to age, roof pitch variation and orientation.

However, a relationship was found between various roof shapes of one-storey homes (bungalows) and the apparent roof temperature or attic insulation (Tables 3 and 4). The results have also indicated that the temperature of flat roofed buildings were higher than those of sloping roofs, presumably due to a lack of attic ventilation of flat roofed buildings or to the fact that these latter roofs are wetter. Ground control was based on the age of the home, the thickness of roof insulation and the type of material used for insulation. The above results were checked through ground verification of 15 selected bungalows of various degrees of heat loss condition.

5.2.1 Grey Level and Enhanced Color Thermographs

A comparison between manual interpretation of heat loss condition from grey level and enhanced color thermographs is illustrated in Table 1 below. For the purpose of this comparison, heat loss levels were digitally grouped into four classes:

1) No heat loss,
2) Slight heat loss,
3) Considerable heat loss, and
4) Extensive heat loss.

Table 1
Class Difference In Heat Loss Reading
Between Grey Level and Enhanced Color Thermographs

Class Differences	LOGAN AVENUE No. Homes	LOGAN AVENUE % of Total Homes	JEFFERSON AVENUE No. Homes	JEFFERSON AVENUE % of Total Homes
One class	500	27.22	276	10.62
Two classes	41	2.23	3	-
Three classes	3	0.16	0	-

It is significant that the readings from the two types of thermographs, differ only by one class in most cases. In general, the density slicing results conform quite closely to the manual grey level interpretation. However, problems still exist in using only 4 levels of classification, using the density slices at a scale of 1:3,000, particularly as it relates to distinguishing and locating individual homes. Best results were most often obtained using the negative grey scale strip thermographs. The latter results were used in the following analysis.

5.2.2 The Nature and Intensity of Heat Loss Condition of Single Homes

When data was sorted according to the number of single homes (bungalows) under each of the four classes of heat loss condition, 2,117 or 84% of the units in the Jefferson areas were found to have moderate degrees of heat loss. The 1,026 units or 56% of the units in the Logan area were found to have a higher degree of heat loss (see Table 2).

Table 2
Heat Loss Conditions of the Two
Selected Residential Areas

Heat Loss Condition	LOGAN AVENUE No. Homes	LOGAN AVENUE % of Total Homes	JEFFERSON AVENUE No. Homes	JEFFERSON AVENUE % of Total Homes
No heat loss	84	4.68	310	12.00
Slight heat loss	601	32.72	2177	83.53
Considerable heat loss	1026	55.85	110	4.41
Excessive heat loss	122	6.75	9	0.42
TOTAL	1837	100.00	2606	100.36

These results correspond to the age of the homes; more than 50 years in the Logan area and less than 10 years in the Jefferson area. Other factors which may contribute to the higher degree of heat loss in the Logan area are a repetition of errors on homes built by the same contractors such as lack of proper insulation design, roof slope variation and orientation. These phenomena were not noticed in the Jefferson area, but ground verification indicated a general trend of higher heat loss with the increase in age of the house. No uniformity in heat loss was observed in the older area (Logan) but great variations over short distances were noticed while heat loss in the newer area (Jefferson) tends to fall within the same classes, which is most likely a design factor.

5.2.3 Roof Temperature in Relation to Roof Pitch Variations and Orientations

A relationship between roof temperature and roof pitch variations was found by Brown, et al., 1978, in a study on residential areas in Ottawa. Brown used model calculations of roof pitch and found that a change of temperature of 0.6^{o}C can result from a difference in roof pitch from 1/3 to 5/6. The present study combines the effect of roof shape and roof orientation on heat loss and the results are illustrated in Tables 3 and 4.

Analyzing these tables, one notices that in the Logan area the homes with slight or no heat loss are those having low-pitched roofs in which case the pitch orientation has very little effect on the heat transfer. The same results were found in the Jefferson area. In contrast, homes with considerable or excessive heat loss were those homes having high pitched roofs, in which case the roof pitch orientation affects much more the amount of heat transferred. For example, East-West oriented roofs tend to receive more solar energy in the daytime and hence have reduced roof ventilation or heat loss at night. These results are clearly illustrated in the case of the Logan area where only 192 high pitched East-West oriented roofs suffer considerable to excessive heat loss compared with 367 North-South orientation high pitched roofs.

These results thus indicate that the combined factor of roof pitch can have a substantial effect upon the apparent roof temperatures, this being the result of the change in ratio of radiation reflected from the sky to the radiation reflected from the surroundings. From the interpretation of the homes of the two residential areas, it is apparent that homes with a similar heat loss condition appear to be of a similar design, particularly in their roof pitch style and orientation.

Table 3
The Relationship Between Heat Loss and Roof Pitch Variation and Orientation of the Logan Residential Area

Heat Loss / Roof Pitch	No Loss No. Homes	No Loss % Total Homes	Slight No. Homes	Slight % Total Homes	Considerable No. Homes	Considerable % Total Homes	Excessive No. Homes	Excessive % Total Homes
High Pitch								
(1) N-S	18	27.7	99	15.1	327	32.8	40	33.6
(2) E-W	6	9.2	101	15.4	175	17.6	17	14.3
(3) Both Directions	4	6.2	26	4.0	75	7.5	10	8.4
Low Pitch								
(1) N-S	18	27.7	124	18.9	201	20.2	25	21.0
(2) E-W	6	9.2	158	23.7	81	8.1	0	0
(3) Both Directions	13	20.0	149	22.7	137	13.8	27	22.7
TOTAL 1837	65		657		996		119	

Table 4
The Relation Between Heat Loss and Roof Variation
and Orientation of the Jefferson Residential Area

Heat Loss / Roof Pitch		No Loss No. Homes	No Loss % Total Homes	Slight No. Homes	Slight % Total Homes	Considerable No. Homes	Considerable % Total Homes	Excessive No. Homes	Excessive % Total Homes
High Pitch									
(1)	N-S	8	2.6	62	2.9	39	34.5	1	-
(2)	E-W	0	0	205	9.4	15	13.3	0	-
(3)	Both Directions	1	0	38	1.7	12	10.6	0	-
Low Pitch									
(1)	N-S	67	21.5	354	16.3	14	12.4	0	-
(2)	E-W	100	32.1	500	23.0	10	8.9	1	-
(3)	Both Directions	136	43.6	1019	46.8	23	20.4	1	-
TOTAL	2606	312		2178		113		3	

6. CONCLUSION

Below are the main contributions of this study:

(i) A comparison has been made between heat loss interpretation from sliced black and white grey tone thermographs and from enhanced color thermographs.

(ii) The nature and intensity of heat loss conditions, from single homes of the two residential areas has been computed.

(iii) The relationship between roof temperature, as revealed on the thermographs and roof shape variation and orientation were established.

Nighttime grey tone level sliced and enhanced color density thermographs with a scale of 1:6,000 covering two residential areas of Winnipeg city; the Logan and Jefferson areas, were used to detect apparent roof temperatures or their heat loss conditions. In the primary investigation, the author obtained results similar to those of other researchers (Brown et al., 1978) in two aspects: first, flat roof buildings (apartment buildings) appear always warm due to excessive heat loss; and second, a lack of relation between roof temperature or heat loss and the style of the homes; i.e. bungalows, one-and-a-half storey homes and two-storey homes.

In the final analysis the conclusion of this study, based on the investigation of heat loss of 1837 home units in the Logan area and 2606 home units in the Jefferson area is illustrated as follows. First, the color density sliced results conform quite closely to the thermal grey level interpretation of heat loss condition. Differences in interpretation are no wider than one class in most cases either under the group of homes with good insulation or under the group with poor insulation. The ground verification has shown that best results were most often obtained using negative black and white strips. Second, the degree of heat loss was found critical in the Logan residential area where 62.7% or 1148 home units are suffering from considerable and excessive heat loss. This is in contrast to the investigated home units in Jefferson where only 5% of 119 units were suffering a high degree of heat loss. And third, roof pitch variation and orientation were found to have a substantial effect on the amount of heat transferred. High pitched roofs were found to be more affected by roof orientation than low pitched roofs.

Through thermograph imagery it is established that heat loss through the roof accounts for 30% of the home's total heat loss. The system thus seems to be of practical use for a minor part of the entire heat loss problem. However, it's major asset lies in the recognition that heat loss through roofs can be corrected easily by improved attic insulation, while heat loss through walls, doors and windows are much more difficult and costly to correct.

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APPENDIX A

Articles Published in Local Newspapers on Heat Loss Survey

Winnipeg Free Press, Saturday, November 17, 1979
C.B.C. 19/11/79 Channel Cable 6

Extensive heat loss shown

By Rick Blanchard

CITY

An aerial survey using remote sensing techniques has revealed extensive heat loss through rooftops of more than 1,000 Winnipeg homes in one study area alone.

Research showed that of 1,837 homes surveyed along Logan Avenue using a technique known as aerial thermography, 1,150 or 63 per cent were suffering considerable to excessive heat loss through their roofs.

Thermography uses infra-red cameras to detect and record changes in temperature patterns and can be done from both air and ground.

Professor is director

Dr. Salah Hathout, an Egyptian-born University of Winnipeg assistant professor of geography, is director of the heat-loss detection work.

His university-funded survey contrasted heat loss from homes along Logan Avenue with Jefferson Avenue homes. The former homes had mainly been constructed more than 50 years ago; those along Jefferson were built in the last 10 years.

Along Jefferson Avenue, of 2,606 homes surveyed, only 126 were experiencing considerable to excessive heat loss through their roofs. The vast majority of homes in this area had only "slight" heat loss.

Hathout said the infra-red aerial photography giving the researchers thermographs on which to base their findings was actually conducted April 7, 1978 at 1 a.m. from an altitude of 490 metres under clear skies. The temperature was 2.8°C and neither snow nor ice was on the rooftops.

Analysis since then has pinpointed how a home's roof angles and orientation as well as insulation levels contributed to possible heat loss.

Those homes with extensive heat loss had rooftops with temperatures up to 4C° warmer than the outside air; those showing no heat loss were recorded at temperatures as low as —5°C.

"We went first hand to some of the homeowners to ask the people if we could check their roof insulation," Hathout said.

He said they found extreme heat loss where insulation was practically non-existent or insulation material — usually wood chips — was wet because the roof had been leaking.

Hathout said they only went to some of the homeowners with their finding because they lacked the resources to approach all of the more than 4,400 homes surveyed.

30 per cent of total

Federal government information contained in his paper states heat loss through the roof could amount to almost 30 per cent of the total heat loss from the home.

Hathout also concluded:

☐ All apartment and flat-roof buildings in the two areas experience excessive heat loss.

☐ There was little or no relationship between roof heat loss and the general style of the homes whether they were bungalows, 1½- or two-storey buildings.

☐ High-pitched roofs of houses with north-south orientations in both residential areas were most susceptible to considerable heat loss, and those with moderate angles and east-west orientations were less prone.

Greater Winnipeg Gas last month turned down Hathout's proposal for an airborne heat loss detection scan of the entire city, at a projected cost of $44,000, and subsequent shopping centre displays and free advice to individual homeowners on the heat escaping through the roof.

Bill Salo, Greater Winnipeg Gas Company marketing manager, said the firm studied the proposal for several months and made separate investigations of the idea where it has been tried in Alberta and British Columbia.

Salo said aerial thermographic scans by the Canadian Western Natural Gas Company of the towns of High River (pop. 1,800) and Vulcan (pop. 900) south of Calgary cost $8,000 but drew little public response.

"We evaluated the over-all cost and benefits and concluded it would only be looking at part of the total heat loss," Salo said.

Surveys their specialty

About 85 per cent of Winnipeg homes are gas-heated, the balance either by oil, electricity or coal, he said. Homeowners interested in conserving energy may find individual surveys of their homes' total heat loss more practical, Salo said.

Robert LaChanse, president of Thermal Energy Consultants Incorporated, said his month-old firm has specialized in thermographic survey work and offers individual home, industrial and commercial analyses of heat loss from the ground up.

A2

12 Winnipeg Free Press, Thursday, December 13, 1979

Heat-loss survey results to be displayed next fall

Results of an aerial survey of heat lost through the roofs of Brandon buildings will be put on display next September, probably at a city shopping location, a Manitoba Hydro spokesman said yesterday.

Rudy Boivin of Hydro's consumer information group said the Brandon Chamber of Commerce "took the lead" in conducting the aerial thermographic survey of heat loss from city buildings after Hydro raised the idea.

The city was photographed from the air using special infra-red photography Nov. 17 at about 3 a.m. by Ottawa-based Intertech Remote Sensing Ltd.

Boivin said he hopes Hydro will be able to interest the Winnipeg Chamber of Commerce and Winnipeg Hydro to conduct a similar survey, provided the Brandon "test" proves popular with homeowners interested in saving on energy costs.

Thermography uses infra-red cameras to detect and record changes in temperature patterns. If the process is conducted from the air under the right conditions, only heat loss through ceilings can be determined — which could account for up to 30 per cent of a house's total heat loss.

Boivin said he has been told the thermographic photographs taken Nov. 17 have turned out and will form the basis of the display next fall.

Owners of houses and businesses will be able to pick out their buildings from normal aerial photographs, consult technical experts at the display and determine from the thermograms — infra-red photos — whether heat loss warrants conservation measures.

The Hydro spokesman said insulation companies will be asked to present their products at the display.

Standards sought to gauge heat loss

OTTAWA (CP) — Federal researchers hope to develop national standards for measuring heat loss in buildings, public works officials say.

And the department is training technical staff to measure energy loss from buildings, making use of a technique called themography, says Andrew Connidis of the architecture division.

Thermography uses infrared cameras to detect and record changes in temperature patterns.

Connidis said government structural and architectural inspectors will spend two weeks studying techniques used to survey heat loss from buildings.

While thermography is used by private industry, a department spokesman said such surveys are not always accurate. And the department hopes to train staff in precise measurement and proper interpretation of data.

For example, says Connidis, a thermogram might indicate heavy heat loss and possible poor construction in an area where the window was left open.

Comparison from records of images showing heat loss would also contrast poor and proper construction techniques.

A report released earlier this year by department thermography expert Peter Mill showed how several million dollars could have been saved if thermography had been used shortly after construction.

In one Arctic building, occupants complained of problems from water entering the building during thaws because of air leakage and condensation.

About $60,000 was spent on maintenance, manpower, consultation and changing the building's design, Mill said.

"If thermography had been used in the first year of occupancy, the severity of air leakage would have been identified and preventive maintenance procedures could have been carried out," said Mill. "That would have saved the government $50,000."

The National Institute for Materials Testing in Sweden has been using thermography to detect heat loss problems since 1968.

Heat loss measurement and interpretation is a requirement for new buildings there, said Mill. And a certain standard of heat loss measurement must be met after insulation is installed in new Swedish buildings.

Connidis said the department hopes to produce guides for thermogram use and eventually set a national standard for heat loss measurement in new buildings.

APPENDIX B

Estimated Flight
Expenditures

UNIVERSITY OF WINNIPEG	Requested: Acceptable: OCT 23 - 31	62-H/14	FALCON	77-98

LINE MILES	ALTITUDE	EXP. 9" x 9"	70 MM./CAM.	CLOUD	SUN	OVERLAP
8 nm per flight	1,600' ASL	67	NIL	< 15%	/ 25°	9" x 9" 60% 70 mm. ---

	CAMERA	LENS	FILM	FILTERS	ROLLS
1	9 x 9	6 inch	2443	525 2.0X	
2					
3					
4					
5					
6					
7					

	SENSOR	DETECTOR	RECORDING MEDIUM
8	IRLS	8-14	TAPE
9			
10			
11			
12			

NOTES

PRIMARY SENSOR 9 x 9 (day), IRLS (night)

1. TWO FLIGHTS ARE CALLED FOR
   i. DAY FLIGHT (ALL SENSORS)
   ii. NIGHT FLIGHT (IRLS ONLY)

2. NO PRECIPITATION BETWEEN DAY AND NIGHT FLIGHTS

3. CONTACT GROUND TRUTH FOR LOCAL AMBIENT TEMPERATURE AND WEATHER CONDITIONS.

PRIORITY: FOUR

Energy, Mines and Resources Canada / Énergie, Mines et Ressources Canada

B2

A37561 IR

CANADA CENTRE FOR REMOTE SENSING

9 INCH CAMERA REMOTE SENSING DATA SHEET

CAMERA TYPE & NO.	FILM TYPE		PROJECT NO.
WILD RC 10 #1771	AEROCHROME INFRARED		77-98/92
CALIBRATED F.L. 153.12 MM	LENS NO. UAG II 3005	EXPIRY DATE NOVEMBER 1974	OPERATOR McKAY
FILTER TYPE & NO. 525NM 2.0X AV	MAGAZINE NO. 2438-2439	EMULSION NO. 2443-202-3	FIELD ROLL NO(S) 892

DATE	LINE NO.	DIRECTION	FRAME NO. START	FRAME NO. END	GMT START	GMT END	ALTITUDE ASL	CAMERA EXPOSURE	REMARKS (POSITION OF START & END, AREA NO. OR LETTER, GEOGRAPHICAL NAMES, ETC.)
7	1	S	1	22	2024	2025	2300'	4/500	77-98
APRIL	2	NW	23	43	2031	2032	"	"	WINNIPEG MAN.
1978	3	NW	44	71	2037	2038	"	"	NTS: 62 H/14
									77-92
	4	E	72	93	2043	2045	"	"	DND WINNIPEG MAN.
	3	E	94	107	2048	2049	"	"	NTS: 62 H/14
	2	E	108	124	2051	2052	"	"	
	1	E	125	142	2057	2058	"	"	
	5	S	143	155	2102	2102	"	"	
	6	W	156	163	2106	2106	"	"	

REMARKS

Energy, Mines and Resources Canada — Énergie, Mines et Ressources Canada

CANADA CENTRE FOR REMOTE SENSING

DAEDALUS INFRARED LINESCANNER DATA SHEET

B3

FIELD ROLL NUMBER(S): 891.

OPERATOR: THOMPSON.

DATE	LINE NO.	DIRECTION	GMT START	GMT END	ALTITUDE ASL	GROUND SPEED	DET.	D.C. LEVEL	GAIN	NO. 1 REFERENCE	NO. 2 REFERENCE	TAPE SIDE	TAPE TRACK	FILTER
7-4-78.	4	E.	0510	0511	2300.	130	8-14	493	284	-6.8	+7.6	1	2/6.	
							3-5.	510	820.					
	3	E.	0514	0516	2300	140	8-14			~~[illegible]~~	~~[illegible]~~	1	2/6	
							3-5.			-9.1	+5.9			
	2	E	0519	0520	2300	140	8-14			-9.0	+5.9	1	2/6	
							3-5.							
	1	E	0523	0524	2300	140.	8-14			-9.0	+5.9	1	2/6	
							3-5.							
	6	S.	0528	0529	2300	140	8-14			-9.0	+6.0	1	2/6.	
							3-5							
	5	E.	0532.		2300		8-14			-9.0	+5.9	1	2/6.	
							3-5.							
	5	E.	0535	0536.	2300	140.	8-14			-9.0	+5.9	1	2/6.	
							3-5.							
	5.	S.	2102	2103.	2300.	145.	8-14	497	238	-2.5	+14.5.	1	2/6.	
							3-5.	510	820.					
	6.	W.	2106	2107.	2300.	155	8-14			-2.5	+14.5	1	2/6.	
							3-5.							

SEE ALSO SIMULTANEOUS DATA ON ROLLS:

9" X 9"	70MM	SCANNER

ED:	CFASU OPS	Air Express Collect	☐
ESTOR NOTIFIED PERIOD:	PRIORITY: 4	Normal Prepaid	X

ESTIMATED CHARGES PER FLIGHT

(Based on the parameters outlined on the reverse)

INITIAL PROCESSING			REPRODUCTION				TOTAL
141.00	75 Ft @	57.00	ROLL PRINTS ROLL TRANS	75 75	Ft/Ea @	114.00 152.00	464.00
6.00	52 Ft @	10.00	ROLL TRANS	52	Ft/Ea @	52.00	68.00
2.00	Ft @				Ft/Ea @		2.00
	Ft @		NAPL SERVICE CHARGE		Ft/Ea @		2.00
	Ft @				Ft/Ea @		
	Ft @				Ft/Ea @		
	Ft @				Ft/Ea @		
	Ft @				Ft/Ea @		
nm)@ 9.25							222.00
						GRAND TOTAL	758.00

ailer required on each roll or part roll expended.

document
ase insert
may be

The Project as outlined and estimated charges are acceptable. It is understood that charges for a partially completed Project may be pro-rated in accordance with results obtained from the primary sensor.

Principal Investigator

PLEASE RETURN SIGNED COPY TO
Canada Centre for Remote Sensing
2464 Sheffield Road
Ottawa, Ontario
K1A 0E4

Attn: Airborne Operations Section

Telephone No. (613) 995-3101
Telex CCRS: 053 3777

B4

APPENDIX C

Computer Analysis

Project 77-98
7 April 78

8-Level Quantitative Temperatures of Jefferson and Logan areas during night time.

BB1 = -89.00 BB2 = 60.00 DIFF = 149.00

RANGE	1-7	1-6	1-5	1-4	1-3	1-2
7	60.00	35.17	10.33	-14.50	-39.33	-64.17
6	35.17	14.47	-6.22	-26.92	-47.61	-68.31
5	10.33	-6.22	-22.78	-39.33	-55.89	-72.44
4	-14.50	-26.92	-39.33	-51.75	-64.17	-76.58
3	-39.33	-47.61	-55.89	-64.17	-72.44	-80.72
2	-64.17	-68.31	-72.44	-76.58	-80.72	-84.86
1	-89.00	-89.00	-89.00	-89.00	-89.00	-89.00

RANGE	2-7	2-6	2-5	2-4	2-3
7	60.00	35.17	10.33	-14.50	-39.33
6	39.31	18.61	-2.08	-22.78	-43.47
5	18.61	2.06	-14.50	-31.06	-47.61
4	-2.08	-14.50	-26.92	-39.33	-51.75
3	-22.78	-31.06	-39.33	-47.61	-55.89
2	-43.47	-47.61	-51.75	-55.89	-60.03
1	-64.17	-64.17	-64.17	-64.17	-64.17

RANGE	3-7	3-6	3-5	3-4
7	60.00	35.17	10.33	-14.50
6	43.44	22.75	2.06	-18.64
5	26.89	10.33	-6.22	-22.78
4	10.33	-2.08	-14.50	-26.92
3	-6.22	-14.50	-22.78	-31.06
2	-22.78	-26.92	-31.06	-35.19
1	-39.33	-39.33	-39.33	-39.33

RANGE	4-7	4-6	4-5
7	60.00	35.17	10.33
6	47.58	26.89	6.19
5	35.17	18.61	2.06
4	22.75	10.33	-2.08
3	10.33	2.06	-6.22
2	-2.08	-6.22	-10.36
1	-14.50	-14.58	-14.58

RANGE	5-7	5-6
7	60.00	35.17
6	51.72	31.03
5	43.44	26.89
4	35.17	22.75
3	26.89	18.61
2	18.61	14.47
1	10.33	10.33

RANGE	6-7
7	60.00
6	55.86
5	51.72
4	47.58
3	43.44
2	39.31
1	35.17

Project 77-98

7 April - 78

8-Level Quantitative Temperatures of Logan area during day time.

BB1 = -50.00 BB2 = 126.00 DIFF = 176.00

RANGE	1-7	1-6	1-5	1-4	1-3	1-2
7	126.00	96.67	67.33	38.00	8.67	-20.67
6	96.67	72.22	47.78	23.33	-1.11	-25.56
5	67.33	47.78	28.22	8.67	-10.89	-30.44
4	38.00	23.33	8.67	-6.00	-20.67	-35.33
3	8.67	-1.11	-10.89	-20.67	-30.44	-40.22
2	-20.67	-25.56	-30.44	-35.33	-40.22	-45.11
1	-50.00	-50.00	-50.00	-50.00	-50.00	-50.00

RANGE	2-7	2-6	2-5	2-4	2-3
7	126.00	96.67	67.33	38.00	8.67
6	101.56	77.11	52.67	28.22	3.78
5	77.11	57.56	38.00	18.44	-1.11
4	52.67	38.00	23.33	8.67	-6.00
3	28.22	18.44	8.67	-1.11	-10.89
2	3.78	-1.11	-6.00	-10.89	-15.78
1	-20.67	-20.67	-20.67	-20.67	-20.67

RANGE	3-7	3-6	3-5	3-4
7	126.00	96.67	67.33	38.00
6	106.44	82.00	57.56	33.11
5	86.89	67.33	47.78	28.22
4	67.33	52.67	38.00	23.33
3	47.78	38.00	28.22	18.44
2	28.22	23.33	18.44	13.56
1	8.67	8.67	8.67	8.67

RANGE	4-7	4-6	4-5
7	126.00	96.67	67.33
6	111.33	86.89	62.44
5	96.67	77.11	57.56
4	82.00	67.33	52.67
3	67.33	57.56	47.78
2	52.67	47.78	42.89
1	38.00	38.00	38.00

RANGE	5-7	5-6
7	126.00	96.67
6	116.22	91.78
5	106.44	86.89
4	96.67	82.00
3	86.89	77.11
2	77.11	72.22
1	67.33	67.33

RANGE	6-7
7	126.00
6	121.11
5	116.22
4	111.33
3	106.44
2	101.56
1	96.67

Project 77-98
7-April-78

8-Level Quantitative Temperatures of Jefferson area during day time.

BB1 = -5.00 BB2 = 12.00 DIFF = 17.00

RANGE	1-7	1-6	1-5	1-4	1-3	1-2
7	12.00	9.17	6.33	3.50	0.67	-2.17
6	9.17	6.81	4.44	2.08	-0.28	-2.64
5	6.33	4.44	2.56	0.67	-1.22	-3.11
4	3.50	2.08	0.67	-0.75	-2.17	-3.58
3	0.67	-0.28	-1.22	-2.17	-3.11	-4.06
2	-2.17	-2.64	-3.11	-3.58	-4.06	-4.53
1	-5.00	-5.00	-5.00	-5.00	-5.00	-5.00

RANGE	2-7	2-6	2-5	2-4	2-3
7	12.00	9.17	6.33	3.50	0.67
6	9.64	7.28	4.92	2.56	0.19
5	7.28	5.39	3.50	1.61	-0.28
4	4.92	3.50	2.08	0.67	-0.75
3	2.56	1.61	0.67	-0.28	-1.22
2	0.19	-0.28	-0.75	-1.22	-1.69
1	-2.17	-2.17	-2.17	-2.17	-2.17

RANGE	3-7	3-6	3-5	3-4
7	12.00	9.17	6.33	3.50
6	10.11	7.75	5.39	3.03
5	8.22	6.33	4.44	2.56
4	6.33	4.92	3.50	2.08
3	4.44	3.50	2.56	1.61
2	2.56	2.08	1.61	1.14
1	0.67	0.67	0.67	0.67

RANGE	5-7	5-6
7	12.00	9.17
6	11.06	8.69
5	10.11	8.22
4	9.17	7.75
3	8.22	7.28
2	7.28	6.81
1	6.33	6.33

RANGE	4-7	4-6	4-5
7	12.00	9.17	6.33
6	10.58	8.22	5.86
5	9.17	7.28	5.39
4	7.75	6.33	4.92
3	6.33	5.39	4.44
2	4.92	4.44	3.97
1	3.50	3.50	3.50

RANGE	6-7
7	12.00
6	11.53
5	11.06
4	10.58
3	10.11
2	9.64
1	9.17

APPENDIX D

Environmental Conditions for Heat Loss Data Acquisition

The conditions under which heat loss data acquisition is carried out may vary with special and specific users, but in general the following conditions should be followed as closely as possible:

1. Night flights should not begin until three hours after sunset and end before early morning dew or frost forms.

2. Not more than moderate cloud cover in order that night cooling can take place.

3. Ambient night air temperatures should not exceed $+3^{o}C$.

4. Surface winds should not exceed 10 knots.

5. Temperature-dew point spread should not be less than $4-5^{o}C$.

6. No precipitation in the previous 24 hours and roof tops essentially moisture free.

7. Black body settings is at operator's discretion. No constant temperature range is required.

8. Temperature inversions are not desirable but will be common, it will probably be necessary in that case to increase the scanner gain to offset the flattening effect of an inversion.

APPENDIX E

Land Use Classification
of Winnipeg Residential
Area

LEGEND

1 TRANSPORTATION

11 MAIN ROAD
12 SECONDARY ROAD
13 TERTIARY ROAD

2 INDUSTRIAL

21 EXTRACTION
211 GRAVEL PIT
22 FABRICATION
221 HEAVY (STEEL CONSTRUCTION)
222 LIGHT (HOME CONSTRUCTION)

3 COMMERCIAL

31 WHOLESALE (WAREHOUSES)
32 RETAIL (STORES)
33 OFFICES
34 HOTEL
35 GARAGE
36 BANK
37 LIBRARY

4 RECREATION

41 INDOOR
42 MUSEUM

5 INSTITUTIONAL

51 GOVERNMENT BUILDING
52 POLICE STATION
53 SCHOOL
54 MEDICAL CENTRE
55 CHURCH
56 CLUB
57 SALVATION ARMY
58 FIRE STATION

6 RESIDENTIAL

61 SINGLE FAMILY DWELLING
62 UNATTACHED GARAGE OR SHED
63 APARTMENT BUILDING
64 TOWNHOUSE

APPENDIX F

F1 Land Use of Jefferson

F2 Roof Shape Variation and Orientation

F3 Heat Loss Variation

F4 Land Use of Logan

F5 Roof Shape Variation and Orientation

F6 Heat Loss Variations