

RESEARCH REPORT



Attic Moisture Control North of 60: Investigation and Comparison of Two Potential Solutions



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ATTIC MOISTURE CONTROL
NORTH OF 60

INVESTIGATION AND COMPARISON
OF TWO POTENTIAL SOLUTIONS

PREPARED FOR:

CANADA MORTGAGE AND HOUSING CORPORATION
OTTAWA

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YELLOWKNIFE, N.W.T.

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STACK VENT COSTS CHART

EXECUTIVE SUMMARY

HOUSING THROUGHOUT THE ARCTIC HAS EXPERIENCED SEVERE PROBLEMS WITH WINTER FROST BUILD-UP AND ITS SUBSEQUENT DAMAGE TO CEILINGS AND ROOF INSULATION. IN MANY COMMUNITIES IT HAS BECOME "NORMAL" TO REPLACE THE INSULATION EVERY YEAR, AND TO LIVE WITH BADLY STAINED AND DAMAGED CEILINGS.

THIS STUDY LOOKS AT TWO PROPOSED RETRO-FIT SYSTEMS, TO ELIMINATE OR MINIMIZE ATTIC MOISTURE ACCUMULATION AND THE ASSOCIATED DAMAGE. TEST HOUSES IN THE COMMUNITIES OF YELLOWKNIFE, CAMBRIDGE BAY, ESKIMO POINT AND BAKER LAKE, N.W.T. WERE TYPICAL TEN YEAR OLD, FOUR BEDROOM STICK-BUILT BUNGALOWS, WITH ASPHALT SHINGLE SLOPED ROOFS, WOOD TRUSS ROOF FRAMING AND AN UNINSULATED ATTIC SPACE.

1) VAPOUR BARRIER RETRO-FIT - YELLOWKNIFE, N.W.T.

EXISTING CEILING INSULATION WAS REMOVED AND A NEW VAPOUR BARRIER WAS FITTED BETWEEN THE EXISTING ROOF TRUSSES, THE INSULATION WAS REPLACED, AND THE GABLE VENTS WERE BLOCKED OFF.

A HUMIDISTAT CONTROLLED STACK VENT WAS INSTALLED TO CONTROL HUMIDITY IN THE HOUSE AND MODIFY THE POSITION OF THE NEUTRAL PRESSURE PLANE.

2) METAL ROOF RETRO-FIT - CAMBRIDGE BAY, ESKIMO POINT, N.W.T.

75 MM OF RIGID INSULATION WAS ADDED OVER THE EXISTING ROOF AND GABLES AND WAS COVERED WITH A NEW METAL ROOF.

ALTHOUGH NOT PART OF THE ORIGINAL DESIGN INTENTIONS, THE ORIGINAL VAPOUR BARRIER AND CEILING INSULATION WERE LEFT IN PLACE.

3) MODIFIED METAL ROOF RETRO-FIT - BAKER LAKE, N.W.T.

BASED ON PRELIMINARY FINDINGS OF THIS STUDY, THE METAL ROOF SUPPORT SYSTEM WAS MODIFIED TO 150 DEEP SHEET METAL GIRTS WITH BATT INSULATION BETWEEN.

TO DETERMINE THE RELATIVE PERFORMANCE OF THE TWO SYSTEMS, VISUAL INSPECTIONS WERE MADE IN THE WINTER AND SUMMER AND AIR PRESSURE, RELATIVE HUMIDITY, TEMPERATURE, AND TIMBER MOISTURE CONTENT READINGS WERE TAKEN PERIODICALLY.

VAPOUR BARRIER RETRO-FITS

- 1) EXCESS HUMIDITY IS NOT A PROBLEM IN TYPICAL ARCTIC HOUSING. THE STACK VENTS WERE COMPLICATED AND EXPENSIVE, PRODUCED NO BENEFICIAL CHANGE TO THE UNITS, AND DETRACTED FROM THE OCCUPANTS COMFORT. STACK VENTS ARE NOT RECOMMENDED.
- 2) IMPROVEMENT OF THE CEILING VAPOUR BARRIER DID NOT SIGNIFICANTLY CHANGE THE AIR TIGHTNESS OF THE UNITS.

- 3) VAPOUR BARRIER RETRO-FIT SYSTEM DEMANDED METICULOUS ATTENTION TO DETAIL, AND ABOVE AVERAGE SUPERVISION.

QUALITY OF WORKMANSHIP AND SUPERVISION SUPPLIED FOR THIS TEST WAS BETTER THAN COULD BE EXPECTED IN A LARGE SCALE PROGRAMME, ESPECIALLY IN REMOTE COMMUNITIES.

- 4) TEST HOUSES DID NOT HAVE MOISTURE DAMAGE AFTER ONE WINTER SEASON. HOWEVER, LARGE AREAS OF SLIGHTLY MOIST INSULATION WERE NOTED, AND MOISTURE WAS ENTERING THE ATTICS.

THE VAPOUR BARRIER TEST HOUSES WERE LOCATED IN YELLOWKNIFE, WHERE THE CLIMATE IS LESS SEVERE THAN IN OTHER TEST LOCATIONS.

BASED ON OBSERVED PERFORMANCE, IT IS DOUBTFUL THAT THE VAPOUR BARRIER RETRO-FIT SYSTEM COULD BE USED SUCCESSFULLY IN A LARGE SCALE PROGRAMME TO PREVENT MOISTURE ACCUMULATION AND DAMAGE IN ARCTIC HOUSING.

A

METAL ROOF RETRO-FITS

- 1) THE METAL ROOF RETRO-FITS WERE RELATIVELY SUCCESSFUL IN MINIMIZING ATTIC FROST ACCUMULATION WITH THE EXCEPTION OF SOME OBVIOUS THERMAL BRIDGES.
- 2) THE METAL ROOF SYSTEM IS AIR TIGHT. THIS PREVENTS MOISTURE TRANSFER THROUGH EXFILTRATING MOIST AIR.
- 3) WITH THE MODIFIED METAL ROOF SYSTEM, THE COSTS OF THE TWO APPROACHES WERE ESSENTIALLY SIMILAR (BASED ON YELLOWKNIFE COSTS). THE METAL ROOF SYSTEM COSTS INCLUDE FOR A NEW LONG-LIFE ROOF COVERING.
- 4) THERE ARE SOME RESERVATIONS ABOUT DETAILED CONSTRUCTION PRACTICES WITH THE METAL ROOF SYSTEM. WE RECOMMEND THAT THERMAL BRIDGES BE MINIMIZED, THAT THE EAVES BE MORE AIR TIGHT AND THAT THE ROOF FASTENING SYSTEM BE UPGRADED TO PREVENT POSSIBLE FASTENER WITHDRAWAL AND SUBSEQUENT STRUCTURAL FAILURE.

BASED ON THE (LIMITED) OBSERVATIONS IN THIS STUDY, WE RECOMMEND THAT, WITH RESERVATIONS, THE METALROOF RETRO-FIT AS THE BETTER OF THE TWO APPROACHES TO MINIMIZING MOISTURE ACCUMULATION AND DAMAGE IN ARCTIC HOUSING.



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C.M.H.C. MONITORING AND EVALUATION
OF ATTIC MOISTURE CONTROL IN ARCTIC HOUSING

MAY 1983

1. OVERVIEW

PROBLEMS WITH MOISTURE CONTROL IN ATTIC SPACES OF ARCTIC HOUSING HAVE BEEN WELL KNOWN SINCE THE BEGINNING OF CONVENTIONAL CONSTRUCTION NORTH OF 60. OVER THE YEARS, THERE HAVE BEEN NUMEROUS ATTEMPTS AT RESOLVING THE PROBLEM, ATTEMPTS WHICH HAVE MET WITH VARYING DEGREES OF SUCCESS ON AN INDIVIDUAL UNIT BASIS, BUT HAVE RESULTED IN SHORTCOMINGS IN A GLOBAL APPLICATION.

THIS STUDY WAS INITIATED BY C.M.H.C. TO TAKE AN OBJECTIVE, SCIENTIFIC LOOK AT TWO POSSIBLE RETRO-FIT SOLUTIONS TO ATTIC MOISTURE CONTROL.

MONITORING AND EVALUATION WERE CONDUCTED BY FERGUSON, SIMEK, CLARK, AN ARCHITECTURAL AND ENGINEERING FIRM SPECIALIZING IN ARCTIC CONSTRUCTION AND INFRASTRUCTURE, INCLUDING HOUSING AND HOUSING RETRO-FIT PROGRAMS.

SEE APPENDIX 'A' FOR TERMS OF REFERENCE.

2. STUDY OUTLINE

TWO POTENTIAL MOISTURE CONTROL SOLUTIONS WERE INVESTIGATED: A NEW VAPOUR BARRIER RETRO-FIT, AND THE ADDITION OF AN INSULATED METAL ROOF OVER THE EXISTING ROOF. IDENTICAL HOUSES WERE USED FOR BOTH SOLUTIONS, WITH 5 VAPOUR BARRIER RETRO-FITS IN CAMBRIDGE BAY, N.W.T., 4 METAL ROOF RETRO-FITS IN ESKIMO POINT, N.W.T., 3 MODIFIED METAL ROOF RETRO-FITS WERE EXAMINED IN BAKER LAKE, N.W.T.

TEST HOUSES WERE; APPROXIMATELY 6 YEAR OLD, FOUR BEDROOM, STICK-BUILT HOUSES WITH WOOD TRUSS ROOF FRAMING, CEILING INSULATION, AND AN ATTIC SPACE VENTED TO THE OUTDOORS.

2.1 VAPOUR BARRIER RETRO-FIT

THE FIVE YELLOWKNIFE UNITS WERE MODIFIED IN ACCORDANCE WITH PLANS PROVIDED BY SOLARARCTIC ENERGY CONSCIOUS HOUSING INC., OF OTTAWA, ONTARIO. WORK INCLUDED THE REMOVAL OF THE EXISTING CEILING INSULATION, FITTING A NEW VAPOUR BARRIER ABOVE THE CEILING, BETWEEN THE EXISTING TRUSSES, CAULKING THE VAPOUR BARRIER ALONG THE TRUSSES, AND BLOCKING OFF THE GABLE VENTS. A HUMIDISTAT CONTROLLED STACK VENT WAS INSTALLED TO CONTROL HUMIDITY AND MODIFY THE NEUTRAL PRESSURE PLANE.

2.2 METAL ROOF RETRO-FIT

THE CAMBRIDGE BAY AND ESKIMO POINT UNITS WERE MODIFIED BY THE NORTHWEST TERRITORIES HOUSING CORPORATION (N.W.T.H.C.O, THE OWNERS OF UNITS, TO THEIR OWN PLANS. WORK INCLUDED THE ADDITION OF 75 MM (3 INCHES) OF FOIL FACED RIGID URETHANE INSULATION AND A GALVANIZED METAL ROOF ABOVE THE EXISTING ROOF. CEILING INSULATION WAS TO BE REMOVED, AND CEILING VENTS WERE TO BE INSTALLED.

THE MODIFIED METAL ROOF SYSTEMS IN BAKER LAKE CONSISTED OF A METAL ROOF ON METAL Z-GIRTS, WITH BATT INSULATION BETWEEN THE GIRTS.

THIS APPROACH PROVIDES A WARM ATTIC SPACE AND ATTEMPTS TO ELIMINATE MOISTURE BUILD-UP BY MOVING THE DEW POINT OUTSIDE THE OLD ROOF SHINGLES.

2.3 PROJECT METHODOLOGY

AS ORIGINALLY CONCEIVED, TESTS TO BE CONDUCTED WERE:

1. AIR FLOW CONTINUOUSLY IN ONE STACK VENT IN YELLOWKNIFE.
2. RELATIVE HUMIDITY AND TEMPERATURE CONTINUOUSLY.
3. NEUTRAL PRESSURE PLANE PERIODICALLY.
4. WATER USAGE IN THE YELLOWKNIFE UNITS.
5. VISUAL INSPECTIONS OF THE ATTIC SPACES IN ALL UNITS.
6. RECORD OF OIL DELIVERIES OVER THE HEATING SEASON.

2.4 TEST EQUIPMENT

THE FOLLOWING TEST EQUIPMENT WAS USED TO EVALUATE AND MONITOR MOISTURE CONTROL PERFORMANCE OF THE LATERATE SOLUTIONS. (COMPLETE TEST EQUIPMENT DATA IS INCLUDED IN APPENDIX 'B').

DIGITAL PSYCHROMETER - MEASURES WET AND DRY BULB TEMPERATURES IN HOUSE AND IN WALLS VIA PRESSURE TUBES.

PRESSURE SENSOR/ELECTRICAL MANOMETER

- MEASURE AIR PRESSURE IN WALLS AND CEILING RELATIVE TO ROOM AIR PRESSURE ALLOWING CALCULATION OF NEUTRAL PRESSURE PLANE AND QUANTIFICATION OF STACK VENT EFFECTS.

TEMPERATURE/HUMIDITY RECORDER

- CONTINUOUS RECORDING OF TEMPERATURE AND RELATIVE HUMIDITY IN HOUSE.

- THERMOMETER - MEASURE EXTERIOR TEMPERATURE AND TEMPERATURE VARIATION ACROSS BOTTOM CHORD OF TRUSS.
- WIND METER - MEASURE EXTERIOR WIND SPEED.
- LIMBER MOISTURE METER - TO MEASURE EQUILIBRIUM MOISTURE CONTENT IN WOOD FRAMING, FROM WHICH AVERAGE RELATIVE HUMIDITY IN AIR CAN BE DETERMINED.

3. STATEMENT OF LIMITATIONS

THE ORIGINAL TERMS OF REFERENCE FOR THIS STUDY OUTLINED AN EXTENSIVE TESTING PROGRAM INCLUDING CONTINUOUS TESTING THROUGHOUT AN ENTIRE HEATING SEASON, WITH TEN MONITORING TRIPS TO BOTH CAMBRIDGE BAY AND ESKIMO POINT, THE MONITORING PROGRAM STARTED MUCH LATER IN THE SEASON THAN HAD ORIGINALLY BEEN ANTICIPATED, AND FOR THIS REASON, THE MONITORING ASPECTS OF THIS STUDY WERE OF A LIMITED NATURE.

THE CONCLUSIONS OF THIS REPORT ARE BASED ON LIMITED OBSERVATIONS.

4. TESTING PROGRAM

THE FOLLOWING TESTING PROGRAM WAS CARRIED OUT ON THE UNITS AS LISTED. APPENDIX 'C' TO THIS REPORT CONTAINS STANDARD SITE MONITORING PROCEDURES AND FIELD WORK SHEETS FOR THE COLLECTION OF RAW DATA.

4.1 VAPOUR BARRIER RETRO-FIT - YELLOWKNIFE

1. AIR INFILTRATION TESTS WERE CONDUCTED BEFORE AND AFTER THE VAPOUR BARRIER RETRO-FIT.
2. PRESSURE TUBES WERE INSERTED IN FOUR WALLS OF FOUR HOUSES, AT THE BASEBOARD, ONE METRE ABOVE FINISHED FLOOR, AND CEILING LEVELS.
3. CHART RECORDERS WERE INSTALLED TO CONTINUOUSLY MONITOR TEMPERATURE AND RELATIVE HUMIDITY.

4. VISUAL INSPECTIONS WERE PERIODICALLY MADE OF THE ATTIC SPACES. MOISTURE CONTENT READINGS WERE TAKEN OF THE WOOD TRUSS MEMBERS.
5. PERIODIC TEMPERATURE, RELATIVE HUMIDITY, AND PRESSURE READINGS IN THE WALLS WERE OBTAINED THROUGH THE PRESSURE TUBES.
6. FUEL CONSUMPTION STATISTICS AVAILABLE, BASED ON OIL DELIVERY RECORDS, WERE NOT ACCURATE OR WERE UNAVAILABLE, AND HAVE THEREFORE NOT BEEN INCLUDED.
7. THE PIECES OF TEST EQUIPMENT FOR THE AIR FLOW TESTING IN THE STACK VENT ARRIVED LATE AND PROVED TO BE INCOMPATIBLE. SINCE PRELIMINARY OBSERVATIONS HAD SHOWN THE INEFFECTIVENESS OF THE STACK VENT, THIS TESTING WAS NOT CARRIED OUT.

4.2 METAL ROOF RETRO-FIT - CAMBRIDGE BAY

1. NO AIR INFILTRATION TESTS WERE CONDUCTED.
2. PRESSURE TUBES WERE INSTALLED IN FOUR HOUSES, IN SIMILAR LOCATIONS TO YELLOWKNIFE UNITS, AND ONE SET OF TEMPERATURE, RELATIVE HUMIDITY, AND PRESSURE READINGS WAS OBTAINED.
3. ONE CHART RECORDER WAS INSTALLED TO RECORD TEMPERATURE AND RELATIVE HUMIDITY.
4. VISUAL INSPECTIONS WERE CONDUCTED IN FOUR ATTICS. COMPLETE MOISTURE READINGS WERE OBTAINED IN TWO ATTICS.

4.3 METAL ROOF RETRO-FIT - ESKIMO POINT

1. NO AIR INFILTRATION TESTS WERE CONDUCTED.
2. NO PRESSURE TUBES WERE INSTALLED.
3. NO CHART RECORDERS WERE INSTALLED.
4. A VISUAL INSPECTION WAS CARRIED OUT IN FOUR ATTICS, AND MOISTURE CONTENT READINGS WERE OBTAINED.
5. FUEL USE STATISTICS WERE UNAVAILABLE.

4.4 MODIFIED ROOF RETRO-FIT - BAKER LAKE

1. VISUAL INSPECTION OF THREE ATTICS WAS CARRIED OUT.
2. MOISTURE CONTENT READINGS WERE TAKEN OF THE TRUSS MEMBERS.
3. TEMPERATURE READINGS WERE TAKEN IN THE ATTICS.

5. OBSERVATIONS ON VAPOUR BARRIER RETRO-FIT UNITS

5.1 CONSTRUCTION CONTRACT

THE PHYSICAL CONSTRUCTION CONTRACT WAS SET UP WITH THE NORTHWEST TERRITORIES HOUSING CORPORATION OVERSEEING THE CONSTRUCTION PORTION. AS PROJECT MANAGERS, THE WRITER'S ROLE WAS LIMITED TO OBSERVING THE CONSTRUCTION PROCESS. WE REFRAINED FROM INFLUENCING THE CONTRACTOR IN ORDER TO MORE ACCURATELY REFLECT THE LEVEL OF INSTALLATION AND SUPERVISION WHICH WOULD ACTUALLY BE FOUND IN THE FIELD IN A FULL SCALE PROGRAM.

5.2 VARIANCES FROM PLANS

THE YELLOWKNIFE RETROFITTED HOUSES HAD THE FOLLOWING VARIANCES FROM THE DRAWINGS PREPARED BY SOLARCTIC:

1. DRAWING NO. 43: SOFFIT SECTION E: 6 MIL. VAPOUR BARRIER WAS ELIMINATED AT THE SOFFIT AND ACOUSTICAL SEALANT WAS NOT USED ON THE STYROFOAM RIGID INSULATION.
2. GABLE SECTION E1: INSULATION AND 6 MIL. POLYETHYLENE. AIR BARRIERS WERE NOT INSTALLED ON THE GABLE ENDS.

5.3 INFILTRATION TESTS

INFILTRATION TESTS WERE CARRIED OUT ON THE YELLOWKNIFE UNITS BEFORE AND AFTER CONSTRUCTION. THESE TESTS WERE CARRIED OUT BY NOR-SASK-AIR LEAKAGE CONTROL OF SASKATOON, SASKATCHEWAN. THE RESULTS ARE INCLUDED AS APPENDIX "D". NOTE THAT THE INFILTRATION INTO THE HOUSES DID NOT DECREASE SIGNIFICANTLY AFTER THE INSTALLATION OF THE NEW CEILING VAPOUR BARRIER. IN FACT, ONE UNIT SHOWED A 50% INCREASE IN INFILTRATION AFTER THE WORK WAS CARRIED OUT.

OUR OWN EXPERIENCE INDICATES THAT THIS RESULT IS TO BE EXPECTED. IN UNITS WE HAVE ASSESSED THROUGH THERMOGRAPHY, THE MAJORITY OF INFILTRATION AND EXFILTRATION OCCURS AT THE FLOOR/WALL/ AND WALL/CEILING INTERFACES. THE INCREASED INFILTRATION IN ONE UNIT WAS PROBABLY CAUSED BY RACKING OF THE HOUSE AS IT SHIFTED ON ITS PADS, A 'NORMAL' PHENOMENON ASSOCIATED WITH SEASONAL GROUND FLUCTUATIONS.

5.4 TESTING PROGRAM

PRESSURE, TEMPERATURE AND RELATIVE HUMIDITY READINGS WERE OBTAINED PERIODICALLY IN YELLOWKNIFE FROM 1 MARCH 1983 TO 12 APRIL 1983. FIELD DATA COLLECTED IS CONTAINED IN APPENDIX "F". SEE 4.1 TESTING PROGRAM.

5.5 NEUTRAL PLANE OBSERVATIONS

PRESSURE READING TAKEN THROUGH WALL TUBES WAS USED TO CALCULATE HEIGHT OF THE NEUTRAL PRESSURE PLANE (THE HEIGHT AT WHICH INFILTRATION CHANGES TO EXFILTRATION). PRESSURE READINGS WERE TAKEN WITH THE STACK VENT BOTH OPEN AND CLOSED.

THE NEUTRAL PRESSURE PLANE WAS APPROXIMATELY 2,000 MM ABOVE THE FLOOR WITH THE STACK VENT CLOSED, AND 2,400 MM ABOVE THE FLOOR WITH IT OPEN.

SEE 5.9 FOR DISCUSSION ON OPERATION AND EFFECTIVENESS OF STACK VENTS.

5.6 RELATIVE HUMIDITY OBSERVATIONS

VERY LITTLE CHANGE HAS BEEN NOTED IN THE RELATIVE HUMIDITY CHARTS, WITH MINOR EXCEPTIONS AT BATH TIME, LAUNDRY TIME, ETC.

RELATIVE HUMIDITIES CHARTED REMAINED AT APPROXIMATELY 28%.

R.H. MEASUREMENTS TAKEN THROUGH TUBES INDICATE THERE IS A POTENTIAL FOR ROTTING OF STUDS OR JOISTS IN SOME LOCATIONS (I.E., 40% R.H. AT 20 C). THESE ARE WINTER MEASUREMENTS. SPRING AND SUMMER CONDITIONS MAY BE WORSE.

5.7 OBSERVATIONS WITHIN THE ATTIC SPACE

OBSERVATIONS REVEALED THAT SOME LEAKAGE IS OCCURRING INTO THE ATTIC SPACE IN SPITE OF THE NEW VAPOUR BARRIER INSTALLATION. VAPOUR LEAKAGE OCCURRED WHERE THE VAPOUR BARRIER IS DISCONTINUOUS, ESPECIALLY WHERE THE TRUSS CHORDS JOINED.

HEAVISET FROST BUILD-UP WAS ON THE GABLE ENDS, WITH A UNIFORM HOAR FROST ON THE SHADED SIDE OF THE HOUSE.

AT THE TIME OF INSPECTION THERE WAS APPROXIMATELY 300 MM OF SNOW COVER ON THE ROOFS. THE SNOW'S INSULATING VALUE RAISES THE TEMPERATURE OF THE UNDERSIDE OF THE ROOF SHEATHING A SMALL AMOUNT ABOVE THAT EXPERIENCED ON THE GABLE ENDS. MOISTURE ENTERING THE ATTIC CONDENSES ON THE COLDEST SURFACE AVAILABLE. THE END GABLES ACT AS COLLECTOR PLATES FOR THIS MOISTURE, AND ARE, IN A SENSE, SACRIFICIAL ANODES. (THIS IS SIMILAR TO THE FAMILY AUTOMOBILE WHERE FROST SHIELDS, WHICH ARE SLIGHTLY WARMER THAN THE WINDOWS, STAY FROST FREE WHILOE THE WINDOWS FROST UP).

TIMBER MOISTURE READINGS WERE IN THE 18 TO 25% MOISTURE CONTENT RANGE, INDICATING A RELATIVE HUMIDITY IN THE ATTICS OF 80 TO 95%.

A SIGNIFICANT MOISTURE DIFFERENCE WAS NOTED BETWEEN THE SHADED AND SUNNY SIDES OF THE HOUSES. AS WELL, DAMPNESS WAS DETECTED IN THE INSULATION ON THE SHADED SIDE, INDICATIVE OF MELTED FROST.

5.8 OPERATION AND EFFECTIVENESS OF STACK VENTS

THE TEMPERATURE AND HUMIDITY CHART RECORDERS INDICATED VARY LITTLE CHANGE IN RELATIVE HUMIDITY REMAINED AT APPROXIMATELY 28% IN ALL UNITS. IN TESTS WHERE THE STACK VENTS WERE DELIBERATELY OPENED, THERE WAS NO NOTICEABLE CHANGE IN RELATIVE HUMIDITY READING OVER THE CLOSED STACK CASE.

STACK VENTS GENERALLY RAISED THE NEUTRAL PRESSURE PLANE APPROXIMATELY 0.4 METRE. COMMENTS BY THE TENANTS GENERALLY INDICATE THAT THE UNITS APPEAR TO BE COLDER THAN THEY WERE BEFORE RETRO-FIT. THIS IS CONSISTENT WITH THE FACT THAT THE HOUSES ARE VIRTUALLY AS 'LEAKY' AS BEFORE, AGGRAVATED BY OUTSIDE AIR DRAWN INTO THE BUILDING AT THE FLOOR/WALL JUNCTION. (THE LOWEST POINT IN THE STACK PRESSURE PLANE).

IT IS OUR OPINION THAT THE STACK VENT APPROACH TO DE-HUMIDIFICATION AND PRESSURE PLANE MOVEMENT IS CONTRARY TO THE DESIGN OBJECTIVES FOR ARCTIC HOUSING. IN THE PAST, THE ARCHITECTURAL COMMUNITY HAS TAKEN GREAT PAINS TO DELIVER A WARM FLOOR SYSTEM WITH AN EVOLUTION AS FOLLOWS:

1. INCREASING THE FLOOR INSULATION VALUES IN AN ATTEMPT TO ELIMINATE THE COLD FLOOR SYNDROME NOTICED BY OCCUPANTS WITH COLD FEET AND ROASTING HANDS.
2. MODIFICATION TO INCREASED INSULATION WITH A FALSE SUB-FLOOR WARMED BY FORCED AIR. THIS APPROACH PROVED VERY COSTLY TO CONSTRUCT, AND IN SOME CASES PROVED DISASTROUS WHEN INFILTRATION OCCURRED AT THE WALL PLATE LEVEL, ABOVE THE INSULATION BUT BELOW THE FLOORING.
3. REFLECTIVE FOIL WAS INCLUDED ON THE BOTTOM OF THE FALSE SUB-FLOOR, TO REFLECT HEAT FROM LOWER LEVEL BACK INTO THE SPACE, ELIMINATING THE COLD FLOOR. THIS SYSTEM DID NOT PERFORM ANY BETTER THAN THE ORIGINAL FALSE FLOOR SYSTEM AND ADDED EVEN FURTHER COST.
4. PLACEMENT OF AN AIR BARRIER ON THE COLD SIDE OF THE FLOOR INSULATION. THIS APPROACH PROVED TO WORK VERY WELL. HOWEVER, THE USE OF 6 MIL. POLYETHYLENE, THE BEST MATERIAL AVAILABLE AT THE TIME, VIOLATED THE BUILDING CODE. TESTS ON THE SYSTEM REVEALED THAT NONE OF THE PROBLEMS OF WET INSULATION OR CONDENSATION OCCURRED IN THIS BOTTOM PLANE, SINCE AIR MOVEMENT IS STRICTLY INFILTRATING AT THIS LEVEL. COLD OUTSIDE AIR BEING DRAWN INTO THE HOUSE DE-HUMIDIFIES AS IT WARMS UP.

THE LATEST VARIATION ON THIS APPROACH USES A 'TYVEK' AIR BARRIER AS AN ALTERNATE TO POLYETHYLENE FILM.

5. STACK DAMPERS WERE INSTALLED ON HEATING APPLIANCES TO LOWER THE NEUTRAL PRESSURE PLANE AND REDUCE FLOOR LEVEL INFILTRATION PRESSURES. STACK DAMPERS SHUT OFF EXHAUSTING OF AIR WHICH NORMALLY OCCURS AT THE DRAFT REGULATOR.

AS CAN BE SEEN, THE STACK VENT APPROACH TAKEN IN THIS PROJECT IS 180 DEGREES TO PREVIOUS EFFORTS, WHICH EVOLVED OUT OF NECESSITY FOR COMFORT AND IN THE INTERESTS OF REDUCING BUILDING FUEL CONSUMPTION.

ALONG WITH THE ABOVE APPROACHES, BETTER DETAILING IN CEILING AIR/VAPOUR BARRIERS HAS RESULTED IN ROOF SYSTEMS WHICH TO DATE DO NOT APPEAR TO GIVE SIGNIFICANT PROBLEMS. HOWEVER, THESE HOUSES HAVE NOT REACHED THE END OF THEIR USEFUL LIFE AND MANY MORE YEARS OF OBSERVATION WILL BE REQUIRED TO ENSURE THAT THE CEILING BARRIERS ARE IN EFFECT EFFECTIVE.

5.9 SUMMER OBSERVATIONS - YELLOWKNIFE

THE YELLOWKNIFE VAPOUR BARRIER UNITS WERE VISITED ON 14 & 15 JULY 1983 TO DETERMINE ATTIC MOISTURE LEVELS IN THE SUMMER TIME, AND THE POTENTIAL FOR ROT IN THE STRUCTURAL MEMBERS.

ON 14 JULY, THE EXTERIOR WAS 23 C, SUNNY, WITH A RELATIVE HUMIDITY OF 38%, THE TEMPERATURE IN THE INSULATED AND NON-VENTED ATTICS WERE APPROXIMATELY 50 C, AT THE PEAK AND 36 C IN THE CEILING INSULATION. TRUSS MOISTURE CONTENT WAS LESS THAN 9% IN THE UPPER CHORDS (EXPOSED TO THE AIR) AND 12 - 14% IN THE LOWER CHORDS (BURIED IN THE CEILING INSULATION).

ON 15 JULY THE WEATHER HAD CHANGED TO 16.3 C, 82% RELATIVE HUMIDITY, OVERCAST TO RAIN. TEMPERATURES IN THE INSULATED, NON-VENTED ATTICS WERE 19-22 C AT THE PEAK AND 21-23 C IN THE INSULATION. TRUSS MOISTURE CONTENT IN THE EXPOSED UPPER CHORDS (EXPOSED TO ATTIC AIR) WAS LESS THAN 9% AND 11-12% IN THE LOWER CHORD (BURIED IN THE CEILING INSULATION).

THE RECORDED TIMBER MOISTURE CONTENTS INDICATE A LONG TERM RELATIVE HUMIDITY IN THE ATTIC AIR OF APPROXIMATELY 55 TO 70% R.H. AT THE INSULATION LEVEL, AND LESS THAN 50% R.H. IN THE AIR.

5.10 ESKIMO POINT 'E.O.M.' UNIT #222

A) INSTALLATION - ESKIMO POINT E.O.M. #222

ESKIMO POINT UNIT #222, WHICH HAD BEEN UPGRADED UNDER THE LOCAL HOUSING AUTHORITIE'S 'EXTRAORDINARY MAINTENANCE' (E.O.M.) PROGRAMME WAS EXAMINED.

THIS UNIT DID NOT HAVE A NEW METAL ROOF. THERE HAD, HOWEVER, BEEN A RADICAL UPGRADING: THE ENTIRE CEILING, VAPOUR BARRIER, AND CEILING INSULATION WERE REMOVED AND REPLACED. ALTHOUGH THE ROOF VENTILATION PIPES WERE STILL IN PLACE, THE INLET PIPES FROM BELOW THE HOUSE WERE BLOCKED BY THE INSULATION. (THIS UNIT IS TEN ESSENTIALLY A "YELLOWKNIFE SOLUTION")

FROM ALL VISIBLE INDICATIONS, AND IN DISCUSSIONS WITH WORKMEN INVOLVED, THE WORKMANSHIP ON THIS UNIT APPEARS VERY GOOD. THE VAPOUR BARRIER APPEARED TO BE LAPPED AND WAS REPORTEDLY CAULKED AT THE JOINTS. HOWEVER, THE VAPOUR BARRIER WAS NOT SEALED AT THE ELECTRICAL FIXTURES, AND IT WAS NOT DETERMINED HOW THE VAPOUR BARRIER HAD BEEN INSTALLED AT THE TOP OF EXISTING PARTITIONS.

B) OBSERVATIONS - UNIT #222 - ESKIMO POINT

EVERYWHERE IN THIS ATTIC WE FOIUND EXTREME FAILURE TO CONTROL FROST AND MOSITURE BUILD-UP. ALL SHEATHING AND TRUSS MEMBERS WERE COVERED WITH HOAR FROST. THE INSULATION WAS WET, WITH THE TOP THIRD FROZEN. FROST WAS ESPECIALLY HEAVY NEAR THE HATCH OPENING.

TEMPERATURE GRADIENT RECORDED IN THIS ATTIC WAS FROM -4 C TO 0 C, SLIGHTLY COLDER THAN THE OTHER AVERAGE TEMPERATURES.

TIMBER MOISTURE CONTENT READINGS INDICATE AN ATTIC RELATIVE HUMIDITY OF APPROXIMATELY 80-90%. IN AREAS, HOWEVER THE WOOD WAS SATURATED.

CEILING PIPE VENTS IN THIS HOUSE WERE COVERED BY THE INSULATION.

6. METAL ROOF RETRO-FITS

6.1 METAL ROOF INSTALLATION - CAMBRIDGE BAY - SITE VISIT

- A) FOUR HOUSES (No. 118, 121, 122, 124) WITH THE METAL ROOF RETRO-FIT PACKAGE INSTALLED WERE INSPECTED IN CAMBRIDGE BAY FROM 17 TO 19 MARCH, 1983.
- B) THE MATERIAL PACKAGES FOR THE CAMBRIDGE BAY ROOF RETRO-FITS WERE SUPPLIED BY THE NORTHWEST TERRITORIES HOUSING CORPORATION, VIA A MATERIALS ONLY TENDER. INSTALLATION OF THE MATERIALS WAS SUPERVISED BY A LOCAL ARCHITECT, ACTING ON BEHALF OF THE N.W.T.H.C. THEREFORE, THE AMOUNT OF SUPERVISION, AND POSSIBLY LABOUR, WHICH WENT INTO THE CAMVBRIDGE BAY RETRO-FITS IS SOMEWHAT HIGHER THAN THAT WHICH WOULD BE EXPERIENCED WITH A GENERAL CONTRACTOR.

THE COMPLETE RETRO-FITTING OF THE CAMBRIDGE BAY UNITS IS BEING STAGED OVER TWO OR MORE YEARS. THE MONITORING DONE TO DATE HAS BEEN ON PARTIALLY COMPLETED UNITS. CONTRARY TO THE DRAWINGS, THE CEILING INSULATION HAS NOT BEEN REMOVED, AND NO CEILING VENTS WERE INSTALLED. THE ATTIC SPACES ARE THEREFORE FLOATING AT AN INTERMEDIATE TEMPERATURE BETWEEN THAT OF THE HOUSE AND THE EXTERIOR. (OBSERVED ATTIC TEMPERATURES WERE BETWEEN - 0.5 AND 10 C).

REMEDIAL WORK TO THE PAD BEARING STRUCTURE OF THE HOUSE, UPGRADING OF THE INTERIOR FINISHES, AND "TIGHTENING" OF THE HOUSE ARE TO BE DONE AS PHASE TWO OF THE RETRO-FIT PROGRAM, IN THE SUMMER OF 1983.

C) TESTING PROCEDURES - CAMBRIDGE BAY

WALL AND CEILING VENT TUBES WERE INSTALLED IN THE FOUR UNITS IN CAMBRIDGE BAY, WITH ONE AT THE BASEBOARD LEVEL, ONE AT WAIST LEVEL, AND ONE IN THE CEILING ON EACH OF THE FOUR WALLS OF THREE UNITS. (BASEBOARD AND HIGH LEVEL WALL UNITS ONLY IN UNIT 122). DRY AND WET BULB TEMPERATURE READINGS WERE TAKEN WITH THE DIGITAL PSYCHROMETER, AND PRESSURE READINGS WERE OBTAINED WITH THE PRESSURE SENSOR AND THE ELECTRONIC MANOMETER. A VISUAL INSPECTION FOR FROST BUILD-UP WAS CARRIED OUT IN ALL FOUR ATTICS. THE TIMBER MOISTURE METER WAS USED TO MEASURE THE MOISTURE CONTENT IN THE TRUSSES IN TWO OF THE UNITS.

D) GENERAL OBSERVATIONS - CAMBRIDGE BAY

THE CAMBRIDGE BAY UNITS, WITH ONE EXCEPTION, WERE IN WORSE SHAPE THAN THEIR YELLOWKNIFE COUNTERPARTS. HIGHER INFILTRATION LEVELS WERE NOTED, ESPECIALLY IN HIGH WINDS. ALL CEILINGS SHOWED EXTENSIVE WATER DAMAGE FROM FROST MELTING IN PREVIOUS YEARS. WOOD WINDOWS WERE DETERIORATING FROM CONDENSATION.

THE AIR IN THE ATTIC SPACE WAS AT THE SAME TEMPERATURE AS THE HOUSE AIR.

THE WALL TEMPERATURE READINGS SHOWED A CONSISTENT TEMPERATURE GRADIENT, DROPPING FROM THE CEILING TOWARDS THE FLOOR.

E) ATTIC OBSERVATIONS - CAMBRIDGE BAY

THE READER IS REMINDED THAT THE CEILING INSULATION IN THESE ATTICS WAS NOT REMOVED, AND THAT THE ATTIC TEMPERATURE WAS APPROXIMATELY 4 TO 6 CELSIUS WITH A MEASURED RANGE OF -0.5 TO 10 RANGE.

CEILING INSULATION WAS REPORTEDLY WET FROM PREVIOUS YEARS. THIS MAY ACCOUNT FOR SOME OF THE MOISTURE FOUND IN THE ATTIC SPACES.

FROST ACCUMULATION WAS NOTED IN THE DEAD AIR SPACE AT THE EAVES, ALONG THE UPPER TRUSS CHORD AT THE GABLE END, ON THE SCREW HEADS WHICH PENETRATED THE ROOF SHEATHING AND AT THE ELECTRICAL SERVICE ENTRANCE. FROST AT THE EAVES WAS CONTINUOUS, APPROXIMATELY 300 TO 400 WIDE, AND 10 TO 15 MM THICK. (VISUAL ESTIMATE ONLY).

NOTED FROST DOES NOT APPEAR TO BE HEAVY ENOUGH TO CAUSE DAMAGE, WITH THE POSSIBLE EXCEPTION OF ALONG THE EAVES.

A TEMPERATURE DIFFERENTIAL BETWEEN THE UNDERSIDE OF THE ROOF DECK AND THE TOP OF THE INSULATION OF APPROXIMATELY 2 TO 4 DEGREES WAS NOTED. A TEMPERATURE DIFFERENTIAL OF APPROXIMATELY 13 DEGREES WAS NOTED ACROSS THE CEILING INSULATION.

F) TRUSS MOISTURE CONTENT - CAMBRIDGE BAY

MOISTURE CONTENT READINGS WERE TAKEN IN THE WOOD TRUSSES AT THREE POINTS: THE UPPER CHORD, THE TOP OF THE LOWER CHORD AND THE BOTTOM OF THE LOWER CHORD. MOISTURE CONTENT IN THE TOP CHORD WAS APPROXIMATELY 18% TO 20%. THE TOP OF THE LOWER CHORD WAS APPROXIMATELY 8% TO 17%, AND THE BOTTOM OF THE LOWER CHORD WAS LESS THAN 9%, THE LOWEST READING ON THE METER. THIS IS A SIGNIFICANT MOISTURE GRADIENT ACROSS THE BOTTOM CHORD OF THE TRUSS, A SUSPECTED CAUSE OF TRUSS UPLIFT.

READINGS OBTAINED ON THE TOP OF THE LOWER CHORD WERE VARIABLE, AND SEEMED DEPENDENT ON THE LEVEL OF THE INSULATION ADJACENT TO THE CHORD. IN CASES WHERE THE INSULATION COVERED THE LOWER CHORD, THERE WAS NO MOISTURE GRADIENT, WITH A READING OF LESS THAN 9% OBTAINED BOTH AT THE TOP AND THE BOTTOM OF THE CHORD, INDICATING A POTENTIAL SOLUTION TO TRUSS UPLIFT PROBLEMS.

G) PRESSURE TESTS - CAMBRIDGE BAY

IT IS SIGNIFICANT THAT THERE WAS NO PRESSURE GRADIENT ACROSS THE ORIGINAL CEILING AND VAPOUR BARRIER. THIS COULD ONLY BE ACCOMPLISHED BY THE METAL ROOF RETRO-FIT BEING ESSENTIALLY AIR TIGHT, STOPPING INFILTRATION.

CONVERSION OF TEMPERATURES AND RELATIVE HUMIDITIES ACROSS THE CEILING INDICATE THAT THE ATTIC AND HOUSE ARE IN A MOISTURE EQUILLIBRIUM.

WITH NO PRESSURE GRADIENT TO MOVE AIR THROUGH THE CEILING, MOISTURE IS ONLY TRANSMITTED BY THERMALLY INDUCED MOISTURE TRANSFUSION, WHICH WOULD ACCOUNT FOR THE LOW MOISTURE LEVEL IN THE ATTICS.

MOISTURE CONTENT IN THE ATTIC WOULD REMAIN IN BALANCE WITH THE HOUSE AIR, WITH SOME TIME LAG BETWEEN EQUILIBRIUM POINTS.

6.2 ESKIMO POINT

6.8 METAL ROOF INSTALLATION - ESKIMO POINT

- A) THE MATERIAL PACKAGES SUPPLIED BY N.W.T. HOUSING CORPORATION FOR THE METAL ROOF INSTALLATIONS IN ESKIMO POINT WERE SIMILAR TO THOSE IN CAMBRIDGE BAY. HOWEVER, THE INSTALLATION WAS CARRIED OUT BY A LOCAL CONTRACTOR, UNDER "NORMAL" INSPECTION PROCEDURES BY N.W.T. HOUSING CORPORATION.

6.9 TESTING PROCEDURES - ESKIMO POINT

- A) NO WALL MONITORS WERE INSTALLED IN ESKIMO POINT. A VISUAL INSPECTION FOR EVIDENCE OF FROST OR MOISTURE WAS CARRIED OUT IN EACH ATTIC. TEMPERATURE READINGS WERE TAKEN AT THE TOP AND BOTTOM OF THE ATTIC SPACE WITH THE DIGITAL PSYCHROMETER. THE TIMBER MOISTURE METER WAS USED TO MEASURE THE MOISTURE CONTENT IN VARIOUS PARTS OF THE WOOD ROOF TRUSSES.

6.10 SITE VISIT - ESKIMO POINT

- A) THE COMMUNITY OF ESKIMO POINT WAS VISITED ON 7 & 8 APRIL 1983. THE ATTICS OF FOUR METAL ROOF RETRO-FITS WERE EXAMINED (UNITS NO. 230, 239, 243, AND 214). THESE UNITS WERE ESSENTIALLY SIMILAR TO THE CAMBRIDGE BAY UNITS.
- B) TWO UNITS WHICH HAD BEEN UPGRADED UNDER THE LOCAL HOUSING AUTHORITY'S "EXTRAORDINARY MAINTENANCE" (E.O.M.) PROGRAM WERE ALSO EXAMINED. THESE HOUSES DID NOT HAVE A NEW METAL ROOF. HOWEVER, UNIT 222 HAD BEEN RETROFITTED WITH A COMPLETELY NEW CEILING, VAPOUR BARRIER, AND INSULATION, (A VARIATION ON THE YELLOWKNIFE VAPOUR BARRIER RETRO-FITS). THE OTHER UNIT (NO. 208) HAD BATT INSULATION INSTALLED ON THE UNDERSIDE OF THE ROOF SHEATHING.

6.11 GENERAL CONDITIONS - ESKIMO POINT

- A) THE WORKMANSHIP ON THE ESKIMO POINT METAL ROOF INSTALLATION APPEARED VERY GOOD, EQUAL TO THAT FOUND IN CAMBRIDGE BAY. THE ESKIMO POINT UNITS WERE GENERALLY IN BETTER SHAPE THAN THEIR CAMBRIDGE BAY COUNTERPARTS.

6.12 ATTIC OBSERVATIONS - ESKIMO POINT

- A) AS IN CAMBRIDGE BAY, THERE WAS A VAPOUR BARRIER AND INSULATION AT THE CEILING LINE, AN UNVENTED ATTIC SPACE AND RIGID INSULATION ON TOP OF THE ORIGINAL ROOF DECK, (A NEW METAL ROOF). IT APPEARED THAT THE CEILING INSULATION HAD BEEN REPLACED AT THE TIME OF THE METAL ROOF RETRO-FIT.

A TEMPERATURE DIFFERENTIAL OF APPROXIMATELY 5 C WAS RECORDED BETWEEN THE UNDERSIDE OF THE ROOF DECK AND THE TOP OF THE INSULATION. RECORDED ATTIC TEMPERATURES WERE SOMEWHAT LOWER IN ESKIMO POINT THAN IN CAMBRIDGE BAY (-4 C TO +5 C), PROBABLY A FUNCTION OF THICKER AND DRIER CEILING INSULATION.

OF THE FOUR UNITS, TWO HAD NO VISIBLE FROST BUILD-UP, ONE HAD VERY SLIGHT BUILD-UP, AND ONE UNIT (#239) HAD EVIDENCE OF GABLE AND EAVE FROSTING SIMILAR TO THAT FOUND IN CAMBRIDGE BAY. THE ESKIMO POINT VISIT WAS THREE WEEKS LATER THAN THE CAMBRIDGE BAY VISIT AND THE ATTIC FROST SHOWED NOTICEABLE DEGRADATION, POSSIBLY DUE TO THE HIGHER SOLAR LOADING ON THE ROOFS.

MOISTURE CONTENT READINGS WERE TAKEN IN THE WOOD TRUSSES AT THREE POINTS: THE UPPER CHORD, THE TOP OF THE LOWER CHORD, AND THE BOTTOM OF THE LOWER CHORD. THREE OF THE UNITS RECORDED LESS THAN 9% MOISTURE CONTENT AT ALL LOCATIONS INDICATING LESS THAN 40% RELATIVE HUMIDITY IN THE ATTIC AIR. THE FOURTH UNIT (#239) HAD MOISTURE CONTENT READINGS OF 20 TO 23%, A RESULT OF RELATIVE HUMIDITY OF APPROXIMATELY 90% IN THE ATTIC AIR. ENCLOSED PHOTOGRAPHS SHOW SATURATED PLYWOOD AND POSSIBLE PLYWOOD DELAMINATION. THE RELATIVE HUMIDITY IN THIS HOUSE (#239) WAS 19%, SIGNIFICANTLY LOWER THAN OTHER THREE HOUSES AT 31 TO 37% R.H.

OBSERVED SOMEWHAT PERFORMANCE OF THE ESKIMO POINT METAL ROOF RETRO-FIT WAS BETTER THAN IN CAMBRIDGE BAY, WITH THREE OUT OF THE FOUR HOUSES SHOWING NO FROST, AND DRY ATTICS.

VARIATIONS BETWEEN THE TWO LOCATIONS INCLUDE:

- 1) CLIMATIC DIFFERENCES, AND INCREASED SOLAR LOAD AT TIME OF INSPECTION
- 2) AMOUNT OF CEILING INSULATION - (200 MM IN ESKIMO POINT V.S. 100 MM IN CAMBRIDGE BAY). CEILING INSULATION MAY HAVE BEEN DRIER IN ESKIMO POINT.
- 3) THE ESKIMO POINT HOUSES WERE IN BETTER CONDITION THAN THE CAMBRIDGE BAY HOUSES.
- 4) CAMBRIDGE BAY HOUSES HAD WOOD FIBRE TILE (300 x 300) WHILE ESKIMO POINT HOUSES HAD 600 x 1200 HARDBOARD TILE SHEETS.
- 5) POSSIBLE DIFFERENCES IN USE PATTERNS BETWEEN THE TWO COMMUNITIES.

6.3 BAKER LAKE

A) SITE VISIT - BAKER LAKE

THE COMMUNITY OF BAKER LAKE WAS VISITED ON 19 JANUARY 1984. DUE TO WEATHER CONSTRAINTS, ONLY THREE UNITS (#148, 149 AND 150) WERE COMPLETED AND AVAILABLE FOR TESTING AT THE TIME OF THIS REPORT.

B) METAL ROOF INSTALLATION - BAKER LAKE

SUBSEQUENT TO THE OBSERVATIONS IN A PRELIMINARY VERSION OF THIS REPORT, REVISIONS WERE MADE TO THE METAL ROOF CONSTRUCTION SYSTEM.

DEEP METAL Z-BAR GIRTS AT 1500 ON CENTRE WERE SCREWED (TO THE PLYWOOD SHEATHING) ON TOP OF THE EXISTING SHINGLES, THE VOID WAS FILLED WITH BATT INSULATION, AND THE METAL ROOF WAS INSTALLED ON THE Z-BARS.

THESE REVISIONS WERE MADE TO DECREASE THE COST OF THE INSTALLATION AND INCREASE THE THERMAL RESISTANCE OF THE ROOF ASSEMBLY.

C) TESTING PROCEDURES - BAKER LAKE

VISUAL INSPECTIONS FOR FROST BUILD-UP AND TRUSS MOISTURE READINGS WERE TAKEN IN THE ATTICS OF THREE UNITS. ATTIC TEMPERATURE READINGS WERE TAKEN AT THE BOTTOM OF THE ATTIC SPACE WITH THE THERMOMETER.

D) GENERAL OBSERVATIONS - BAKER LAKE

THE THREE UNITS IN BAKER LAKE WERE IN SIMILAR SHAPE TO THE CAMBRIDGE BAY AND ESKIMO POINT UNITS. THERE WAS EVIDENCE OF EXTENSIVE MOISTURE DAMAGE TO THE 300 x 300 WOOD FIBRE CEILING TILES.

OF THE THREE UNITS INSPECTED, ONLY ONE UNIT HAD THE ORIGINAL CEILING INSULATION PARTIALLY REMOVED, AND THE OTHER UNIT HAD IT COMPLETELY REMOVED.

E) ATTIC OBSERVATIONS - BAKER LAKE

.1 UNIT 148 (CEILING INSULATION INTACT)

ATTIC TEMPERATURE WAS 0 C. FROST BUILD-UP NOTED WAS CONSISTENT WITH UNITS IN CAMBRIDGE BAY AND ESKIMO POINT, E.G. ALONG THE EAVES, AND AT COACH SCREWS.

THERE WAS AN OBVIOUS THERMAL BRIDGE AT THE METAL Z-GIRTS, WITH A CONTINUOUS FROST LINE BENEATH EACH GIRT, BOTH ON THE ROOF SHEATHING AND THE GABLE ENDS.

THE KITCHEN AND WASHROOM VENTS WERE AN OBVIOUS THERMAL BRIDGE, WITH FROST ACCUMULATING ON THEIR EXTERIOR. A SERIOUS LOCALIZED PROBLEM WAS NOTED WHERE CONDENSATION FROM THE KITCHEN EXHAUST HAD MELTED, SATURATED THE INSULATION, AND FORMED AN ICICLE BENEATH THE VENT.

.2 UNITS 148 & 149 - (CEILING INSULATION REMOVED)

AS EXPECTED, THE TEMPERATURES IN THESE ATTICS WITH CEILING INSULATION REMOVED WERE MUCH HIGHER (14 TO 10 C).

A SLIGHT FROST BUILD-UP WAS NOTED ALONG THE EAVES. EXPOSED SCREWS WERE WET.

IN UNIT #149, FROST WAS NOTED ON THE GABLE METAL GIRT, BETWEEN THE GIRT AND THE POLYETHYLENE HATCH COVER.

6.4 HALL BEACH

HALL BEACH METAL ROOF RETRO-FITS

INCLUDED IN THIS REPORT ARE PHOTOGRAPHS TAKEN BY N.W.T. HOUSING CORPORATION OF ATTICS IN UNITS 118, 121, AND 122 IN HALL BEACH, N.W.T. THESE UNITS HAD METAL ROOF RETRO-FITS SIMILAR TO CAMBRIDGE BAY AND ESKIMO POINT, BUT CEILING VENTS WERE REPORTEDLY INSTALLED. THUS, THE ATTIC SPACE SHOULD BE AT THE SAME HUMIDITY AND NEARLY THE SAME TEMPERATURE AS THE HOUSE BELOW.

NO TEMPERATURE, MOISTURE CONTENT, OR RELATIVE HUMIDITY DATA IS AVAILABLE FOR THESE HOUSES.

FROM THE PHOTOGRAPHS, IT APPEARS THAT UNIT 118 IS FREE OF ANY FROST BUILD-UP, WHILE UNITS 121 AND 122 HAVE FROST ON THE EXPOSED SCREWS, ON THE GABLE AND TRUSSES, AND ALONG THE EAVES. THIS IS CONSISTENT WITH OBSERVATIONS IN CAMBRIDGE BAY, ESKIMO POINT AND BAKER LAKE.

FURTHER STUDY ON TEMPERATURE, MOISTURE CONTENT, EXISTENCE OF CEILING ACCESS HATCHES, SIZE AND LOCATION OF CEILING VENTS, ETC., WOULD BE NEEDED TO EXPLAIN DIFFERENCES BETWEEN THE TWO SLIGHTLY FROSTED ATTICS AND THE DRY ONE.

6.5 ESKIMO POINT "E.O.M." UNIT #208

A) INSTALLATION: THE LOCAL ESKIMO POINT HOUSING AUTHORITY UPGRADED TWO HOUSES, WHICH ARE ESSENTIALLY VARIATIONS OF THE METAL ROOF AND YELLOWKNIFE SOLUTIONS.

UNIT #208 HAD 100 MM BATT INSULATION ADDED TO THE UNDERSIDE OF THE ROOF INSULATION, HELD IN PLACE WITH WOOD STRAPPING, IN ADDITION TO THE EXISTING 150 MM OF CEILING INSULATION. NO ADDITIONAL VAPOUR BARRIER WAS ADDED. THE ATTIC SPACE WAS STILL VENTILATED VIA TWO 150 DIAMETER PIPE VENTS, WITH AIR SUPPLIED FROM BENEATH THE HOUSE VIA TWO 150 DIAMETER PIPES. (SEE PHOTOGRAPHS). THE INSULATION USED BENEATH THE SHEATHING REPORTEDLY HAD BEEN REMOVED FROM ANOTHER HOUSE WHICH HAD MOISTURE PROBLEMS, AND HAD BEEN DRIED OUT OVER THE SUMMER.

B) OBSERVATIONS - UNIT #208 - ESKIMO POINT

RECORDED ATTIC TEMPERATURE GRADIENT WAS FROM 3 TO 7 C APPROXIMATELY 3 DEGREES WARMER THAN IN THE METAL ROOF INSTALLATIONS.

THERE WAS NO FROST VISIBLE IN THE ATTIC SPACE, BUT THE SHINGLE NAIL HEADS IN THE SHEATHING INSULATION HAD A FROST COVERING.

MOISTURE CONTENT READINGS OF THE TRUSS INDICATE A RELATIVE HUMIDITY OF 60% IN THE ATTIC AIR. A MOISTURE GRADIENT OF APPROXIMATELY 10% MOISTURE CONTENT WAS FOUND ACROSS THE UPPER CHORD, WITH THE TOP OF THE CHORD NEAR THE FIBRE SATURATION POINT. THE BOTTOM CHORD, WHICH WAS COVERED WITH INSULATION WAS DRY (LESS THAN 9% MOISTURE CONTENT).

AIR FLOW WAS DETECTED THROUGH THE CEILING LEVEL PIPE VENT, INDICATING THAT THE VENTILATION SYSTEM IS WORKING, AND THAT THE ATTIC SPACE IS VENTILATED.

6.6 SUMMER OBSERVATIONS.....CAMBRIDGE BAY

FOUR CAMBRIDGE BAY UNITS WERE RE-EXAMINED ON 7 AND 8 JULY 1983, TO MEASURE MOISTURE CONTENT OF THE TRUSSES AND DETERMINE THE POTENTIAL FOR WOOD ROT AND STRUCTURAL DAMAGE.

A) OBSERVATIONS

EXTERIOR WAS 16 C, MEDIUM OVERCAST, 10% R.H., WITH A 10 TO 14 K.P.H. BREEZE. THE TEMPERATURE IN THE ATTIC SPACE WAS APPROXIMATELY 19 C, WITH TEMPERATURES ON THE UNDERSIDE OF THE CEILING INSULATION WAS 20-21 C APPROXIMATELY THE SAME AS THE HOUSE INTERIOR.

TIMBER MOISTURE CONTENTS IN THE EXPOSED UPPER CHORDS WERE APPROXIMATELY LESS THAN 13 % MOISTURE CONTENT, AND LESS THAN 9% IN THE CHORDS BURIED IN THE CEILING INSULATION.

B) AIR INFILTRATION

IN THE FOUR HOUSES INSPECTED IN THE SUMMER, LIGHT LEAKS WERE VISIBLE ABOVE THE RIGID INSULATION ALONG THE EAVES. IN ONE HOUSE, LIGHT WAS ALSO VISIBLE AT THE GABLE EAVE AND AROUND THE BLOCKED OFF VENTS.

THE PRESENCE OF LIGHT LEAKS IS AN INDICATION OF WHERE AIR INFILTRATION IS TAKING PLACE. AS NOTED IN THE WINTER OBSERVATIONS, THE EAVES WERE WHERE THE HEAVIEST FROST BUILD-UP OCCURED.

IT HAS BEEN NOTED THROUGHOUT THE ARCTIC, ESPECIALLY IN MOBILE HOMES, THAT SMALL CRACKS IN AREAS OF EXFILTRATION WILL EVENTUALLY SEAL THEMSELVES WITH FROST. MOBILE HOMES BECOME NOTICEABLY WARMER AS THE INFILTRATION/EXFILTRATION IS CUT DOWN BY THE FROST.

THE METAL ROOF SYSTEM APPEARS TO BE WORKING WELL, PARTIALLY BECAUSE THE SYSTEM BECOMES AIR TIGHT THROUGH SELF-SEALING.

7.1 COMPARISON OF VAPOUR BARRIER AND METAL ROOF SOLUTIONS

A) COSTING LIMITATIONS

ALL COST DATA BELOW WAS OBTAINED FROM THE N.W.T. HOUSING CORPORATION, BASED ON THEIR ACTUAL CONTRACT PRICES FOR THE WORK CARRIED OUT.

THE CONTRACTS LET WERE RELATIVELY SMALL, AND INCURRED SOMEWHAT HIGHER COSTS DUE TO THE CONTRACTOR'S LACK OF FAMILIARIZATION (LEARNING CURVE) AND THE RELATIVELY HIGH PERCENTAGE OF SUPERVISION REQUIRED. WITH A LARGER NUMBER OF UNITS, SAVINGS SHOULD BE REALIZED DUE TO ECONOMICS OF SCALE AND MORE COMPETITIVE BIDDING.

CAMBRIDGE BAY AND ESKIMO POINT PRICES ARE FROM 1982 CONSTRUCTION SEASON. BAKER LAKE PRICES ARE FROM 1983 SEASON. DUE TO STAGNATION IN THE ECONOMY AND THE RESULTANT COMPETITIVE BIDDING, THESE COSTS CAN BE CONSIDERED AS COMPARABLE, WITH NO INFLATION FACTOR REQUIRED BETWEEN THE TWO YEARS.

VENT STACK COSTS ARE FROM THE CONTRACTOR INVOLVED WITH THE WORK. YELLOWKNIFE LABOUR COSTS ESTIMATED AT 25% LESS THAN IN BAKER LAKE OR ESKIMO POINT.

NOTE THAT COSTING IN THE ARCTIC IS HIGHLY VARIABLE, SINCE FREIGHT, AIR TRAVEL, ACCOMMODATION, AND LOCAL LABOUR COSTS AND AVAILABILITY VARY SIGNIFICANTLY FROM COMMUNITY TO COMMUNITY.

B) COSTS OF VAPOUR BARRIER RETRO-FIT

THE COST TO UPGRADE THE CEILING VAPOUR BARRIER, AND TO INSTALL NEW CEILING INSULATION, GABLE ACCESS HATCHES, AND VENT STACKS WAS \$9,060 PER UNIT, BASED ON 5 UNITS.

APPROXIMATELY \$1,127 OF THIS COST IS ATTRIBUTED TO THE VENT STACK, WHICH WE FEEL IS UNNECESSARY.

THEREFORE, THE COST FOR THE VAPOUR BARRIER AND INSULATION RETRO-FIT WAS \$7,933 PER UNIT (1982 - YK).

C) COSTS FOR METAL ROOF RETRO-FIT

MATERIAL SUPPLY PACKAGES FOR THE ESKIMO POINT ROOFS, (METAL ROOF, AND RIGID INSULATION) WERE APPROXIMATELY \$8,000. AIR FREIGHT FROM CHURCHILL, MANITOBA AND MARSHALLING AND OFFLOADING ADDED AN ADDITIONAL \$2,500.

CAMBRIDGE BAY MATERIAL PACKAGES WERE \$9,100 F.O.B. YELLOWKNIFE, WITH AN AVERAGE FREIGHT COST TO CAMBRIDGE BAY OF \$2,700, (A MIXTURE OF AIR AND BARGE). THE DIFFERENCE BETWEEN MATERIAL PRICES IN CHURCHILL AND YELLOWKNIFE SHOULD BE NOTED, AN INDICATION OF THE SHIPPING COSTS TO YELLOWKNIFE.

MATERIAL SUPPLY PACKAGES FOR THE (MODIFIED) BAKER LAKE METAL ROOF PACKAGES WERE \$5,315 PER UNIT (A SAVING OF APPROXIMATELY \$2,700 OVER THE ESKIMO POINT ROOFS). BARGE FREIGHT COSTS TO BAKER LAKE WERE \$1,700 PER UNIT.

LABOUR COSTS FOR THE METAL ROOF INSTALLATIONS WERE \$3,300 PER UNIT IN ESKIMO POINT, \$3,200 PER UNIT IN CAMBRIDGE BAY, AND \$3,200 PER UNIT IN BAKER LAKE. SINCE LOCAL CONTRACTORS WERE USED, THERE WERE NO TRANSPORTATION OR ACCOMMODATION COSTS IN THESE PRICES.

THE THEORETICAL PRICE FOR SUPPLY AND INSTALLATION OF THE MODIFIED METAL ROOF RETRO-FIT SYSTEM IN YELLOWKNIFE, FOR COMPARISON PURPOSES WOULD BE \$5,315 FOR MATERIALS, \$1,000 FREIGHT, \$2,400 FOR LABOUR, FOR A TOTAL PRICE OF \$8,715.

D) COST COMPARISON

THE VAPOUR BARRIER RETRO-FIT COST LESS MONEY THAN THE INITIAL METAL ROOF SYSTEM.

1. MATERIALS REPRESENT 70% OF THE METAL ROOF COST (EXCLUSIVE OF SHIPPING). SINCE THIS IS A CAPITAL INVESTMENT RESULTING IN EXTENDED LIFE TO THE BUILDING, THE ENTIRE COST SHOULD NOT BE ASSESSED AGAINST THE MOISTURE CONTROL PROGRAM, ESPECIALLY IN THOSE INSTANCES WHERE THE HOUSE REQUIRES RE-SHINGLING ANYWAY.
2. THE LABOUR CONTENT IN THE VAPOUR BARRIER SOLUTION IS APPROXIMATELY 67% HIGHER THAN IN THE METAL ROOF SOLUTION. THE VAPOUR BARRIER SOLUTION WILL THUS INCUR GREATER COSTS IN THOSE COMMUNITIES WHERE LABOUR MUST BE FLOWN IN ACCOMMODATED. (RETURN AIR FLIGHTS OF \$400 TO \$1200 PER PERSON AND HOTEL BILLS OF \$110 TO \$130 PER DAY ARE COMMON IN THE ARCTIC).

THEREFORE, IN MORE REMOTE COMMUNITIES, THE METAL ROOF SYSTEM WOULD BECOME RELATIVELY CHEAPER. CONVERSELY, WHERE LOCAL LABOUR IS AVAILABLE, THE VAPOUR BARRIER APPROACH SUPPLIES MORE LOCAL EMPLOYMENT.

3. THE GREATER MATERIAL WEIGHT IN THE METAL ROOF RETRO-FITS RESULT IN SOMEWHAT HIGHER SHIPPING COSTS TO THE REMOTE COMMUNITIES.
4. THE RELATIVE COSTS MUST BE EXAMINED IN LIGHT OF THEIR RELATIVE PERFORMANCES, TO DETERMINE LOWEST COST/BENEFIT RATIO.

THE MODIFIED METAL ROOF SYSTEM IS SIGNIFICANTLY LESS EXPENSIVE (33%) THAN THE ORIGINAL SYSTEM, AND BASED ON YELLOWKNIFE PRICES, IS ESSENTIALLY THE SAME PRICE AS THE VAPOUR BARRIER RETRO-FIT.

THE FOLLOWING FACTORS MUST BE CONSIDERED IN COMPARING THE TWO

COST COMPARISON CHART

LOCATION/CONSTRUCTION TYPE	MATERIALS	LABOUR	FREIGHT	TOTAL	TOTAL (EXCLUDING FREIGHT)
<u>VAPOUR BARRIER RETRO-FIT</u>					
YELLOWKNIFE	+ -2433	+ - 5500	INCL. IN MATERIALS	7933	7933
<u>METAL ROOF</u>					
CAMBRIDGE BAY	9100-1100 = 8000	\$3200	1100+2700 = 3800	15000	11200
ESKIMO POINT	8000	\$3300	2500(AIR)	13800	11300
YELLOWKNIFE(ESTIMATED)	8000	\$2475	1100	11575	10475
<u>MODIFIED METAL ROOF</u>					
BAKER LAKE	5315	\$3200	1700(BARGE)	10215	8515
YELLOWKNIFE(ESTIMATED)	5315	\$2400	- 1000	8716	7715

7.2 LABOUR SKILLS REQUIRED

PERFORMANCE OBSERVATIONS ABOVE HAVE SHOWN THAT MOISTURE ENTERS THE ATTICS WHERE METICULOUS ATTENTION HAS NOT BEEN PAID TO THE DETAILED EXECUTION OF THE WORK.

IN THIS RESPECT, THE VAPOUR BARRIER SOLUTION IS MORE SUSCEPTIBLE TO FAILURE: THE VAPOUR BARRIER MUST BE FIT BETWEEN EXISTING TRUSSES, IT MUST BE CONTINUOUSLY SEALED, ALL CEILING LEVEL JOINTS IN THE TRUSSES MUST BE SEALED, AND THERE IS LIMITED ACCESS AND LIGHT FOR THE WORKMEN. IN SPITE OF THE SUPERVISION AND SCRUTINY GIVEN TO THE INSTALLATIONS IN YELLOWKNIFE, THERE WERE STILL GAPS IN THE VAPOUR BARRIER. WE SUSPECT THAT OVER A LARGER NUMBER OF UNITS, WITH LESS SUPERVISION, AND ESPECIALLY IN THE COMMUNITIES WHERE WORKMEN ARE USUALLY RACING AGAINST WEATHER OR PLANNED FLIGHTS OUT, THAT THE LEVEL OF WORKMANSHIP WOULD BE SIGNIFICANTLY POORER THAN IN THE YELLOWKNIFE TEST HOUSES.

SINCE THE REQUIRED INSTALLATION PERFECTION IS UNLIKELY TO BE ACHIEVED IN A LARGE SCALE FIELD APPLICATION, ESPECIALLY SINCE IT WAS NOT ACHIEVED IN A RELATIVELY SMALL SCALE AND HIGHLY MONITORED TRIAL, WE WOULD RECOMMEND SYSTEM REDUNDANCIES WHEREVER POSSIBLE, NOTABLY IN THE CRITICAL VAPOUR BARRIER.

THE METAL ROOF SOLUTION HAS LESS STRINGENT LABOUR REQUIREMENTS: THE INSULATION IS LAID ON TOP OF THE EXISITNG ROOF, FREE FROM OBSTRUCTION, THE WORKMEN HAVE EASY ACCESS TO THE WORK, AND THERE IS NO REQUIREMENT FOR THE METICULOUS VAPOUR SEALING REQUIRED IN THE VAPOUR BARRIER SOLUTION.

7.3 COMPARISON OF MOISTURE CONTROL PERFORMANCE

.1 LIMITATION

MOISTURE CONTROL COMPARISONS ARE BASED ON A VERY LIMITED NUMBER OF OBSERVATIONS AND UNITS.

.2 VAPOUR BARRIER RETRO-FIT

FROST NOTED IN THE VAPOUR BARRIER RETRO-FIT HOUSES WAS LOCATED ALONG THE NON-SOLAR LOADED SIDES OF THE HOUSE OR AT THE GABLES.

FROST ACCUMULATION DID NOT APPEAR SUFFICIENT TO CAUSE DAMAGE UPON MELTING. HOWEVER, LARGE AREAS OF MOIST INSULATION WERE NOTED (NON-SOLAR SIDE).

.3 METAL ROOF RETRO-FIT

FROST OBSERVED IN THE METAL ROOF INSTALLATIONS WAS CONCENTRATED IN SPECIFIC, THERMALLY BRIDGED AREAS (GABLE ENDS AND NAIL HEADS) AND IN THE DEAD AIR SPACES ALONG THE EAVES.

FROST ACCUMULATIONS DID NOT APPEAR SUFFICIENT TO CAUSE MELT DAMAGE, WITH THE POSSIBLE EXCEPTION OF HEAVY CONCENTRATIONS ALONG THE EAVE LINES.

NO AREAS OF MOIST INSULATION WERE DETECTED. ALL METAL ROOFS OBSERVED STILL HAD THE CEILING INSULATION IN PLACE.

.4 MODIFIED METAL ROOF RETRO-FIT

FROST OBSERVED WAS ALONG THE EAVES AND WHERE SPECIFIC THERMAL BRIDGES OCCURED, E.G. BENEATH THE METAL GIRTS.

AS ABOVE, FROST ACCUMULATION DID NOT APPEAR SUFFICIENT TO CAUSE MELT DAMAGE WITH THE POSSIBLE EXCEPTION OF ALONG THE EAVES.

7.4 COMPARISON OF POTENTIAL PROBLEMS

ANY POTENTIAL SOLUTION FOR CONTROL OF MOISTURE ACCUMULATION IN ATTICS MUST NOT BE THE CAUSE OF FURTHER PROBLEMS.

.1 VAPOUR BARRIER RETRO-FIT

A) MOISTURE ACCUMULATION

LARGE AREAS OF MOIST INSULATION WERE NOTED (NON-SOLAR SIDE). AT A MINIMUM, THIS REPRESENTS A LOSS IN THERMAL EFFICIENCY. IN OTHER YEARS, WHERE MORE SEVERE CONDITIONS COULD EXIST, OR IN A LARGE SCALE PROGRAM WHERE VARIATIONS IN VAPOUR BARRIER INTEGRITY WOULD OCCUR, THIS OBSERVATION INDICATES A POTENTIAL FOR SERIOUS WATER ACCUMULATION.

IN FACT, THIS IS WHAT WAS OBSERVED IN THE ONE ESKIMO POINT 'E.O.M.' HOUSE. THERE IS NOT SUFFICIENT DATA TO CONCLUSIVELY PROVE THE REASON FOR THIS FAILURE, BUT THE FOLLOWING MUST BE CONSIDERED:

1. INSTALLATION QUALITY OF THE VAPOUR BARRIER.
2. CLIMATIC DIFFERENCES BETWEEN YELLOWKNIFE AND ESKIMO POINT.
3. MOISTURE LEAKAGE AROUND CEILING ACCESS HATCH.
4. ROUTING OF KITCHEN AND WASHROOM EXHAUSTS.
5. USE PATTERNS OF HOUSE'S INHABITANTS.
6. AIR TIGHTNESS IN THE ROOF AND GABLE CONSTRUCTION.

B) SUMMER VENTING

THE GABLE ACCESS HATCHES INSTALLED WOULD ALLOW THE VAPOUR BARRIER RETRO-FIT ATTICS TO BE "DRIED OUT" IN THE SUMMER AND FALL, PRIOR TO NEXT HEATING SEASON. (SINCE 20% RELATIVE HUMIDITY AIR AT 24 C WILL GIVE 100% RELATIVE HUMIDITY AT 0 C, CARE MUST BE TAKEN NOT TO SEAL IN EXCESSIVE MOISTURE FROM SUMMER AIR WHICH HAS A HIGH ABSOLUTE MOISTURE CONTENT). HOWEVER, EVEN IN THE YELLOWKNIFE TEST HOUSES, THE ATTIC HATCHES WERE NOT OPENED DURING THE SUMMER, SO A NON-VENTED SUMMER CONDITION COULD BE EXPECTED AS NORMAL.

2. METAL ROOF RETRO-FITS

A) ORIGINAL VAPOUR BARRIER

AT PRESENT, THE METAL ROOF UNITS ARE RELYING ON THEIR ORIGINAL VAPOUR BARRIER, AND ARE RELYING ON THE AIR TIGHTNESS OF THE METAL ROOF TO PREVENT AIR/MOISTURE INFILTRATION.

B) LACK OF THERMAL RESISTANCE

IF THE CEILING INSULATION IS REMOVED AS PART OF THE PHASE TWO RETRO-FIT, THE ROOF WILL ONLY HAVE A THERMAL RESISTANCE OF APPROXIMATELY RS1 4.3 (R-24). IF ADDITIONAL INSULATION IS REQUIRED, ONE SOLUTION PROPOSED BY N.W.T.H.C. IS TO ADD INSULATION TO THE UNDERSIDE OF THE ROOF DECK BETWEEN THE TRUSSES. WE CAUTION THAT ANALYSIS OF THE EXPECTED DEW POINT LOCATION IS NECESSARY TO DETERMINE IF AN ADDITIONAL VAPOUR BARRIER WILL BE REQUIRED. IF IT IS A SIMILAR PROBLEM TO THE VAPOUR BARRIER RETRO-FIT WILL BE CREATED, WHERE THE VAPOUR BARRIER MUST BE FIT BETWEEN THE EXISTING TRUSSES WITH THE INHERENT DIFFICULTY OF ACHIEVING A PERFECT VAPOUR SEAL.

C) MOISTURE CONTENT

THE HIGH MOISTURE CONTENT READINGS IN THE ROOF TRUSSES INDICATE THAT THE ATTIC AIR IS AT OR NEAR THE SATURATION POINT. A SLIGHT LOWERING OF TEMPERATURE DUE TO CLIMATIC VARIATIONS COULD RESULT IN GREATER FROST ACCUMULATION THAN OBSERVED, GIVING A LESS FAVOURABLE OPINION OF THE METAL ROOF SOLUTION.

D) POTENTIAL FOR STRUCTURAL DAMAGE

SOME OF THE TIMBERS AND PLYWOOD SHEATHING WERE BEYOND THE FIBRE SATURATION POINT ("WET"). PHOTOGRAPHS OF UNIT #239, ESKIMO POINT, INDICATE THAT SOME DELAMINATION OF THE PLYWOOD MAY HAVE ALREADY TAKEN PLACE. (THIS WAS NOT NOTED DURING THE VISUAL INSPECTION, AND THUS CANNOT BE CONSIDERED AS CONFIRMED).

THE POSSIBILITY OF DRY ROT DAMAGE TO THE STRUCTURE MUST BE CONSIDERED. FOR ROT TO OCCUR, ALL THREE OF THE FOLLOWING MUST BE PRESENT:

1. A TEMPERATURE OF 20 C.
2. OXYGEN.
3. TIMBER ABOVE 20% EQUILIBRIUM MOISTURE CONTENT (REACHED AT APPROXIMATELY 85% RELATIVE HUMIDITY IN THE AIR).

E) THERMAL BRIDGING

THE COACH SCREWS USED TO HOLD DOWN THE METAL ROOF AND THE METAL GIRTS IN THE MODIFIED SYSTEM ARE OBVIOUS THERMAL BRIDGES, EVIDENCED BY EXTENSIVE FROST ON THEM. THE ENTIRE UPLIFT FORCES ON THE ROOF ARE BORNE BY THESE SCREWS AND THE WITHDRAWAL RESISTANCE OF THE PLYWOOD DECK. SINCE THE PLYWOOD AROUND THE SCREW IS SATURATED BY THE FROST MELT, WE HAVE RESERVATIONS ABOUT THE LONG TERM STRUCTURAL ADEQUACY IN THIS AREA.

7.5 COMPARISON OF SUMMER TIME PERFORMANCE

A) METAL ROOF SYSTEM

THE INSULATION ABOVE THE NON-VENTED ATTIC SPACE WILL MODERATE TEMPERATURE SWINGS IN THE ATTIC, RESULTING IN A COOLER ATTIC AND THEREFORE A COOLER HOUSE.

THE WHITE COLOUR OF THE METAL ROOF SURFACE WILL REFLECT SOLAR RADIATION, FURTHER DECREASING THE ATTIC AND HOUSE TEMPERATURES.

B) VAPOUR BARRIER RETRO-FIT

EXTREMELY HIGH TEMPERATURES WERE RECORDED IN THE NON-VENTED ATTICS OF THE VAPOUR BARRIER RETRO-FIT HOUSES (50 C ON A SUNNY 23 C DAY). TO MINIMIZE THE HOUSE TEMPERATURES, WE RECOMMEND VENTING THE ATTIC SPACES IN THE SUMMER.

THE VAPOUR BARRIER RETRO-FIT HOUSES HAD BLACK ASPHALT SHINGLES, WHICH ABSORB SOLAR RADIATION INCREASING THE ATTIC TEMPERATURE.

8. CONCLUSIONS & RECOMMENDATIONS

8.1 VAPOUR BARRIER RETRO-FITS

1. THE STACK VENTS CONTRIBUTE TO THE COLD FLOOR PHENOMENON AND PRODUCE A LOWER LEVEL OF COMFORT FOR THE OCCUPANTS.

AS THE STACK VENTS ARE CUMBERSOME, COMPLICATED AND EXPENSIVE, AND PRODUCE NO BENEFICIAL CHANGE ON THE UNITS, WE RECOMMEND THAT THE STACK VENTS BE ELIMINATED FROM THE PROGRAM.

2. HUMIDIFICATION LEVELS ARE NOT A PROBLEM IN ANY OF THE UNITS STUDIED. (THIS INCLUDES A UNIT WHICH HAD A 30 GALLON FISH TANK MOUNTED WITHIN 5 FEET OF THE SENSOR PROBE. NO NOTICEABLE DIFFERENCE WAS RECORDED BETWEEN THIS UNIT AND ANY OTHER UNIT STUDIED).

3. IMPROVEMENT OF THE CEILING VAPOUR BARRIER DOES NOT SIGNIFICANTLY AFFECT THE AIR TIGHTNESS OF THE UNIT.
4. THE WORST MOISTURE CONTROL, PERFORMANCE ENCOUNTERED IN THIS STUDY WAS "E.O.M." UNIT #222 IN Eskimo Point. THE RADICAL FAILURE OF THIS UNIT INHIBITS LARGE SCALE RECOMMENDATION OF THIS RETRO-FIT SYSTEM WITHOUT CLARIFICATION OF REASONS FOR FAILURE.
5. VENTING OF THESE ROOFS IN THE SUMMER WOULD MINIMIZE ATTIC TEMPERATURES, RESULTING IN A COOLER HOUSE.

8.2 METAL ROOF RETRO-FIT

1. VERY HIGH INFILTRATION WAS NOTED IN THREE OF THE FOUR CAMBRIDGE BAY UNITS. THIS WAS ESPECIALLY TRUE OF THE UNIT BEING MONITORED DURING A 75 K.P.H. WIND. AS FOUND IN THE YELLOWKNIFE VAPOUR BARRIER RETRO-FIT, TIGHTENING THE ROOF STRUCTURE ON THE HOUSE APPEARS TO ONLY AFFECT THE TOTAL HOUSE INFILTRATION IN A MINOR WAY.
2. FROM THE DATA COLLECTED IT CAN BE DETERMINED THAT THE METAL ROOF STRUCTURE IS EXTREMELY AIR TIGHT. (THE ATTIC SPACE IS AT THE SAME PRESSURE AS THE HOUSE, UNLIKE THE YELLOWKNIFE UNITS, WITH INFILTRATION/EXFILTRATION DYNAMICS TAKING PLACE BELOW THE CEILING LINE.

THE METAL ROOF SYSTEM SEALS ITSELF, NOTICEABLY ALONG THE EAVES, BY FROST BUILD-UP.

THIS RESULTS IN VAPOUR MOVEMENT ACROSS THE ORIGINAL CEILING VAPOUR BARRIER BY TRANSFUSION ONLY, AND NOT BY MOVEMENT OF WARM, MOIST AIR.

3. BASED ON EXISTING MOISTURE DAMAGE TO CEILING TILE, IT APPEARS THERE WAS LESS FROST ACCUMULATION THAN IN PREVIOUS YEARS. FROST BUILD-UP HAS BEEN MINIMIZED BY THE TEMPERATURE IN THE ATTIC, AND THE LACK OF AIR INFILTRATION INTO THE ATTIC. WE CAUTION THAT THE TWO INSULATION LEVELS ARE IN A DYNAMIC BALANCE, AND THAT OBSERVATIONS ARE THE RESULT OF ONLY ONE WINTER SEASON.
4. SIGNIFICANT VARIATIONS WERE FOUND IN THE MOISTURE CONTENT OF THE VARIOUS TRUSS CHORDS, WITH LARGE MOISTURE GRADIENT ACROSS THE BOTTOM CHORD, A SUSPECTED CAUSE OF TRUSS UPLIFT.

READINGS OBTAINED ON THE TOP OF THE LOWER CHORD WERE VARIABLE, AND SEEMED DEPENDENT ON THE LEVEL OF THE INSULATION ADJACENT TO THE CHORD. IN CASES WHERE THE INSULATION COVERED THE LOWER CHORD, THERE WAS NO MOISTURE GRADIENT, WITH A READING OF LESS THAN 9% OBTAINED BOTH AT THE TOP AND THE BOTTOM OF THE CHORD, INDICATING A POTENTIAL SOLUTION TO TRUSS UPLIFT PROBLEMS.

5. GIVEN AN AIRTIGHT METAL ROOF/INSULATION SYSTEM, RETAINING THE ORIGINAL VAPOUR BARRIER AND CEILING INSULATION IN CONJUNCTION WITH THE NEW ROOF INSULATION APPEARS TO PREVENT A REASONABLE APPROACH TO MINIMIZING ATTIC VAPOUR BUILD-UP, GIVING AN ACCEPTABLE LEVEL OF THERMAL RESISTANCE.

8.3 REVISIONS TO CONSTRUCTION SYSTEMS

WE RECOMMEND THE FOLLOWING DETAILS OF THE TESTED CONSTRUCTION SYSTEMS BE REVIEWED AND/OR MODIFIED:

1. VAPOUR BARRIER RETRO-FIT

- A) STRAPPING THE VAPOUR BARRIER TO THE SIDE OF THE BOTTOM TRUSS CHORD IS EXPENSIVE AND OF QUESTIONABLE VALUE.
- B) UPGRADE THE VAPOUR BARRIER RETRO-FIT SYSTEM BY MAKING THE ATTIC AIR TIGHT, THUS MINIMIZING AIR/VAPOUR MOVEMENT INTO THE ATTIC.
- C) IMPLEMENT A MANAGEMENT SYSTEM TO VENT ATTICS IN THE SUMMER TO KEEP HOUSE COOL.

2. METAL ROOF RETRO-FIT

- A) IF EXISTING COACH SCREW FASTENING THROUGH PLYWOOD IS TO BE RETAINED, INCREASE WITHDRAWAL RESISTANCE OF THE FASTENERS, ESPECIALLY IN LIGHT OF THE LOCALIZED MOISTURE ACCUMULATION.

WE RECOMMEND A WASHER ON THE UNDERSIDE, WITH LOCALIZED INSULATION ON THE EXPOSED FASTENER TO MINIMIZE FROST ACCUMULATION.

- B) UPGRADE THERMAL RESISTANCE AT THE GABLES.
- C) ELIMINATE THERMAL BRIDGING OF EXHAUST THROUGH THE GABLES, OR INSULATE VENTS.
- D) REVISE EAVE DETAIL TO INCREASE AIR TIGHTNESS.

3. MODIFIED METAL ROOF RETRO-FIT

- A) INCREASE THERMAL PERFORMANCE THROUGH ROOF GIRTS, TO MINIMIZE FROSTING.
- B) AS ABOVE, INCREASE WITHDRAWAL RESISTANCE OF ROOF FASTENERS AND ELIMINATE LOCALIZED MOISTURE BUILD-UP ON FASTENERS.
- C) MONITOR THESE ATTICS TO DETERMINE IF THEY ARE AS AIR TIGHT AS ORIGINAL DESIGN, SINCE FIBREGLASS INSULATION IS MORE SUSCEPTIBLE TO MOISTURE DAMAGE THAN ORIGINAL RIGID FOAM INSULATION.

8.4 RECOMMENDATIONS

BASED ON THE (LIMITED) OBSERVATIONS IN THIS STUDY, WE RECOMMEND THE METAL ROOF RETRO-FIT AS THE BETTER OF THE TWO APPROACHES TO MINIMIZING MOISTURE BUILD-UP AND DAMAGE IN THESE ATTICS:

- A) THE METAL ROOF RETRO-FITS HAD BETTER (OBSERVED) MOISTURE CONTROL PERFORMANCE THAN THE VAPOUR BARRIER RETRO-FITS.
- B) THE METAL ROOF SYSTEM COSTS INCLUDES A NEW, LONG-LASTING ROOF SYSTEM, MINIMIZING FUTURE MAINTENANCE AND REPLACEMENT COSTS.
- C) WITH THE MODIFIED METAL ROOF SYSTEM, COSTS OF THE TWO APPROACHES WAS ESSENTIALLY SIMILAR. IN REMOTE COMMUNITIES, THE VAPOUR BARRIER SYSTEM WILL HAVE HIGHER LABOUR, TRAVEL AND ACCOMMODATION CHARGES, WHILE THE METAL ROOF SYSTEM WILL HAVE SOMEWHAT HIGHER FREIGHT COSTS.
- D) THE VAPOUR BARRIER SOLUTION IS MORE DEPENDENT ON SUPERIOR WORKMANSHIP FOR SUCCESSFUL PERFORMANCE. THIS REQUIRES INCREASED SUPERVISION AND PRESENTS A GREATER RISK OF FAILURE.

BASED ON THE INSTALLATION AND PERFORMANCE OBTAINED IN THE YELLOWKNIFE UNITS, WHICH HAD ABOVE NORMAL SUPERVISION AND WORKING CONDITIONS, WE ARE SKEPTICAL THAT AN ACCEPTABLE LEVEL OF SUPERVISION/WORKMANSHIP WOULD BE OBTAINED IN THE REMOTE COMMUNITIES.

OBSERVATIONS AND TEST EQUIPMENT OPERATIONS

.1 PRESSURE SENSOR AND ELECTRONIC MANOMETER

THE PLASTIC TUBE USED BETWEEN THE WALL PROBES AND THE PRESSURE SENSOR PROVED TO BE TOO INFLEXIBLE. MOVEMENT IN THE TUBE CAUSED SHOCK PRESSURES, RESULTING IN A LONG STABILIZATION TIME WHILE THE TUBE SETTLED DOWN ON THE FLOOR.

READINGS TAKEN DURING PERIODS OF HIGH OUTSIDE WIND SPEEDS WERE HIGHLY VARIABLE, INDICATING THE GUSTING NATURE OF THE WIND AND THE RESULTING INFILTRATION.

THE MANOMETER AND PRESSURE SENSOR TAKE A RELATIVELY LONG TIME TO STABILIZE, ESPECIALLY THERMALLY. TO MINIMIZE ADVERSE AFFECTS ON THE READINGS, THE PRESSURE EQUIPMENT WAS SET UP AS EARLY AS POSSIBLE DURING THE TESTING PROCEDURE, AND CONTROL READINGS WERE TAKEN BEFORE AND AFTER EACH SET OF READINGS, TO ALLOW FOR THE DRIFT IN THE MACHINE.

.2 DIGITAL PSYCHROMETER

THE THERMAL MASS OF THE INSTRUMENT RESULTS IN A LONG STABILIZATION PERIOD, AND WE SUSPECT SOME INACCURATE READINGS DUE TO OPERATOR IMPATIENCE. THIS WAS ESPECIALLY NOTED WHEN GOING FROM THE HOUSE TO THE ATTIC, WHERE THERE WAS A SIGNIFICANT TEMPERATURE DIFFERENCE, OR WHERE WALL READINGS WERE NEAR ZERO, WHILE THE INSTRUMENT WAS AT ROOM TEMPERATURE.

THE WALL PROBES WERE INSERTED 90 MM INTO THE WALL, WITH 60 MM PROTRUDING. WE SUSPECT THAT THIS PROTRUSION, WHICH WAS AT ROOM TEMPERATURE, TENDED TO MODULATE THE TEMPERATURE OF THE INCOMING AIR, RESULTING IN A SOMEWHAT HIGHER THAN ACCURATE READING.

DISTILLED WATER IN THE PSYCHROMETER DOES NOT SHIP VERY WELL IN THE ARCTIC, WHERE FREEZING TEMPERATURES ARE NOT UNCOMMON.

WET BULB READINGS COULD NOT BE OBTAINED IN THE ATTIC SPACES WITH THE PSYCHROMETER, SINCE THEY WERE LESS THAN 0 C.

.3 THERMOMETER

THE THERMOMETER CARRIED WAS VERY SLOW ACTING, TO THE POINT WHERE IT WAS ALMOST USELESS EXCEPT AS A CHECK ON PSYCHROMETER READINGS, OR FOR EXTERIOR READINGS WHERE IT COULD BE LEFT TO STABILIZE. A MORE USEFUL INSTRUMENT, (ESPECIALLY FOR MEASUREMENTS OF THE THERMAL GRADIENT ACROSS THE CEILING INSULATION) WOULD BE A FAST ACTING, END SENSING THERMOMETER.

.4 TIMBER MOISTURE METER

THE MOISTURE METER DID NOT REGISTER MOISTURE CONTENTS LESS THAN 9%, THE EQUILIBRIUM MOISTURE CONTENT AT LESS THAN 40% RELATIVE HUMIDITY, A COMMON CONDITION IN ARCTIC HOUSING.

STACK VENT COSTS

(FROM NORTARM CONSTRUCTION, 1982 AND YELLOWKNIFE)

ITEM	MATERIAL	LABOUR
FLARE STACK	230	225
3 CHIMNEY SECTIONS 750 LONG @ \$40 EACH	120	INCL.
BOX	50	250
200 'T' SECTIONS	INCL.	---
ROOF FLASHING	INCL.	---
CHIMNEY CAP	50	---
DE-HUMIDISTAT	40	---
WIRING	---	150
GRILLE	12	---

SUB-TOTAL	\$502	\$625

TOTAL STACK VENT COST (1982 \$ YELLOWKNIFE) \$ 1,127.00 EACH.

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