HISTORIC SCOTLAND
ALBA AOSMHOR

11 Annat Road, Perthshire

Thermal improvements to an interwar period cottage.

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Foreword

This case study describes work undertaken by the Gannochy Trust on a traditional cottage from the interwar period. The measures installed were part of the suite of thermal interventions for traditional and historic buildings developed by Historic Scotland as part of the Energy Efficiency Research Programme that has been running since 2009 and whose main outcomes are summarised in Historic Scotland Short Guide 1. While most of the property was built in a traditional way, some aspects of the build were different, notably the use of cement in the external walls. This allowed the opportunity to assess how the measures performed with building fabric with a lower level of vapour movement in the walls. What is also of note in this project was the change in refurbishment practice that the Trust, at Board level, wished to adopt to take on the wider concept of sustainability, beyond factors of energy efficiency alone. This included considerations of amenity, welfare and indoor air quality, in addition to reducing heating costs for tenants. This had been driven by a concern over waste, the overall cost of the works and high levels of condensation as a result of previous refurbishments.

The planning, costing, procurement and delivery of a simple suite of thermal upgrade measures in this project have been successful. It used largely existing local trades, and with a conscious effort to up-skill the workforce, achieved buy-in from operatives and resulted in a durable and sustainable retrofit. Careful planning by the project team, with oversight and costing by the Quantity Surveyors, has allowed the validation of rates of refurbishment works and more accurate cost planning by the Trust in the future. The success of this project was recognised by The Green Organisation with a Green Apple Award in summer 2015.

Acknowledgements:

To the project partners The Gannochy Trust and Glasgow Caledonian University.

CONTENTS

1. Introduction

The Gannochy Trust owns and operates a portfolio of property in the Perth area, which is managed as affordable housing and let to tenants. Most properties are located on the north east side of Perth and comprise an estate of detached cottages built between 1923 and 1931 by AK Bell. In this development of housing, largely for his employees, there was an emphasis on vernacular detailing, higher than average internal volumes, and a focus on natural light and ventilation. The detailed focus given by AK Bell to internal air quality is best summarised by the embossed plaques fastened to the walls of each house giving what could be called an early ventilation strategy for the tenants (Fig. 1).

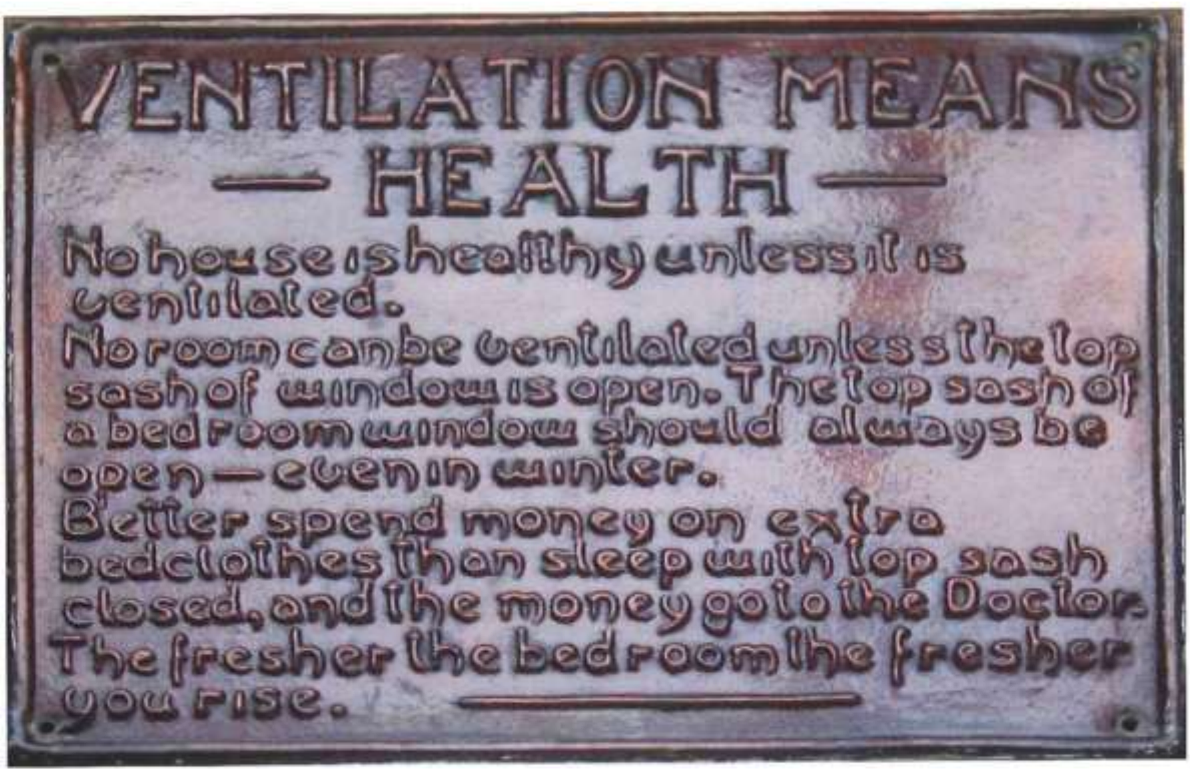

Figure 1: *Embossed tinplate notice with ventilation instructions for tenants*

The layout of the dwellings might be described as being inspired by the 'Garden City movement' of the early 20th century; the properties have remained popular with residents and there is a waiting list. These benefits aside, modern expectations on thermal comfort, and the requirements of Scottish Government legislation meant that for some time refurbishment and insulation work has been undertaken. From 2001 to 2014 over half the cottages had been improved to varying specifications, with some using standard thermal upgrade techniques and materials. However, there were concerns regarding the disruption caused and some technical issues involving condensation in some refurbished properties. Following a review of the refurbishment activities a new approach was sought, which would improve the environmental performance of the houses whilst retaining the original character.

The Trust therefore approached Historic Scotland to assist them with a review of the work for the remainder of the properties. A refurbishment strategy was subsequently drawn up to allow retention of AK Bell's vision for high quality housing, whilst allowing for sustainable thermal improvement to be progressed in the longer term. The approach of this strategy is best described as 'retainability', that is the retention of site material and infrastructure. Whilst more commonly applied to the recycling of waste concrete, this concept seeks to change construction industry culture from one of disposal to one of retention and upgrade where required. The refurbishment strategy developed for the Trust is at Annex A. Following discussion of this strategy Historic Scotland and the Trust developed an outline plan for a trial refurbishment of an individual property. Various properties were inspected, and due to an upcoming vacancy, Number 11 Annat Road was selected for the trial. Experience gained by the Trust suggested that refurbishment works require a vacancy or at the least a decant of the tenant; this agreed with Historic Scotland experience when working with Castle Rock Edinvar Housing Association on thermal upgrades in a tenement (Refurbishment Case Study 1).

2. The site

Number 11 Annat Road is a detached single storey three-bedroom cottage (Fig. 2) consisting of a hall, bathroom, kitchen, lounge and three bedrooms, giving living space of 77m^2. The property was built in 1927, with mass walls of cement-bonded red sandstone approximately 500mm thick. Colliery brick is used for some internal partitions, and they are finished with lime plaster directly onto the brick. In Scotland this is referred to as being 'plastered on the hard'. As originally designed there were two chimney stacks of two flues each. These had all been closed off in the past. The ceilings are of generous height and the slated pitched roof is set from the wall head at ceiling level with storage space in a partially floored attic. The property has been well designed and finished with good internal circulation (Fig. 3). Overhanging eaves give good protection to much of the external envelope from wind driven rain. The existing timber windows were double glazed and dated from the 1990s; apart from one unit that needed replacement all the timber was in good condition.

Figure 2: *The Gannochy Trust property at Annat Road, Perth*

The walls and ceilings are lined internally with lath and plaster; there is a small cavity of approximately 40mm between the inner face of the wall and the lining. The kitchen and the bathroom have solid concrete floors; other spaces have suspended timber floors over a generous void over the solum. This solum was packed earth with legacy building debris and all base/plinth areas were dry. The orientation of the rear of the building is to the south west and could be described as reasonably exposed to driving rain. There had been some modest thermal upgrade work carried out in the past. This consisted of mineral wool between the ceiling joists in the attic and insulation in the lowered ceilings in the kitchen and bathroom.

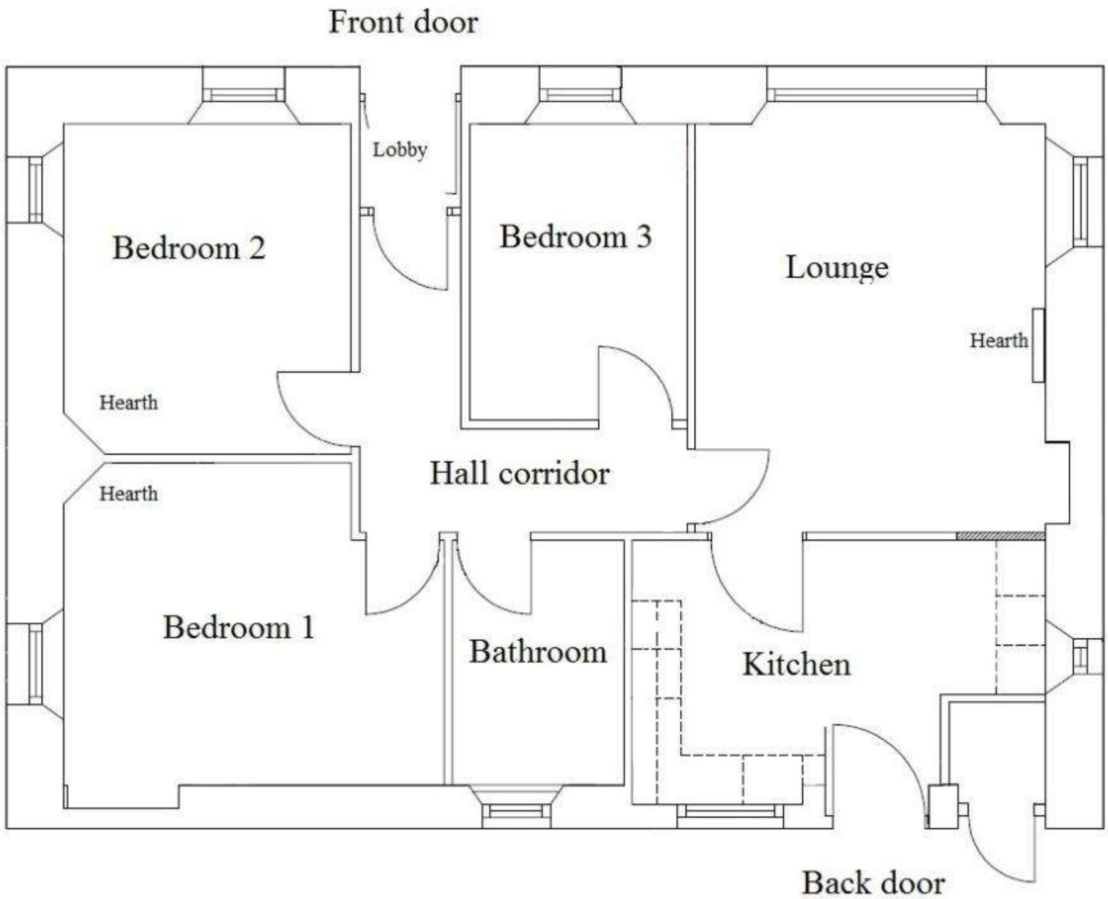

Figure 3: *Floor plan of the Annat Road property*

3. Project Objectives

The partners in the project, The Gannochy Trust, and Historic Scotland, wished to demonstrate the following:

a). Install a series of technically appropriate thermal upgrades to the building fabric consisting of walls, floors and roof space.

b). Maintain the design, texture and amenity of the original cottage and minimise waste.

c). Manage costs and specification to allow replication of the project at scale.

d). Conduct pre and post hygrothermal monitoring to quantify fabric improvements.

e). Achieve an improvement in the SAP rating for the Energy Performance Certificate.

f). Write up the project as a Historic Scotland Refurbishment Case Study to disseminate the techniques to a wider audience.

4. Pre-intervention monitoring and assessment

Part of the objective of the works was to demonstrate the thermal improvements to the building fabric, and that through monitoring of conditions in the wall core they did not result in any adverse consequences. Glasgow Caledonian University conducted pre-intervention monitoring in Spring 2014 on a similar property, and post-intervention work was assessed in February/March 2015. The full results of this monitoring will be published in 2016, but a summary table is at Table 2 in Section 8 of this report.

5. Procuring and delivering the work

The Trust, in conjunction with Historic Scotland, drew up a schedule of works. This was priced by Quantity Surveyors and issued as a tender document to a range of local contractors. As the Trust was keen to maintain the relationship with their existing contractors, they were given the opportunity to tender for the work. Most of the Trades selected were familiar with the properties and had worked on them for some years. However, as the contractors were not familiar with some of the materials and techniques in the schedule, pre-tender briefings were delivered to the potential contractors on what was expected. For example, there were reservations over the lifting and re-laying of the suspended timber floor, so guidance and instruction were given by Historic Scotland. The daily oversight of the works was carried out by The Trust, with a weekly visit from Historic Scotland technical staff.

6. The upgrade works

General joinery and facings

The refurbishment included additional aspects such as updating the kitchen and bathroom, and new wiring obliged extensive downtakings; the lead trade for most of this work was the joinery contractor. The new refurbishment strategy called for the retention of doors, fittings, facings and detailing; previously these items had been disposed of. The existing facings and doors were therefore removed for storage during the works. Many skirting boards turned out to be damaged through the cutting of plug sockets and other damage, so they were not all retained. The doors were original to the cottage, and wear and tear, as well as paint removal treatment, had caused distortion of the relatively thin rails and styles. The repair of the doors was carried out most competently by the joiner; the twisting of the door was addressed by an established traditional technique: thorough wetting with water, clamping tight with sash cramps in a flat plane, and controlled drying over a two week period. The handles and hinges were worn and damaged so were replaced. The doors were also repainted in a modern white water-based eggshell. Facings from doors and other features were re-fixed in their original locations. Lowered ceilings in the kitchen and the bathroom were removed. It was of note that on the external wall of the bathroom, exposed by the removal of the modern ceiling, there was an extensive area of mould (Fig. 4). While lowered ceilings are a common feature of some recent work they are not normally an appropriate intervention in traditional buildings, and especially in areas of high vapour loading they can mask changes in building fabric, as well as limiting cleaning.

Figure 4: *Mould uncovered in the bathroom following the removal of the lowered ceiling*

Kitchen upgrades

While not part of the energy efficiency works, the Trust wished to re-configure the kitchen to modern expectations. A fitted larder and a cupboard accessed from the living room were removed to create space for a dining table. The new kitchen required routes for new wiring; these were to be chased into the brickwork partitions and plastered smooth. Under the previous scheme such routes were boxed in. To maximise the volume of the kitchen and improve amenity the lowered ceiling was removed.

Plaster ceilings

Due to concerns over cracks in the plaster and a need for new cable runs, the convention for previous refurbishments had been to lower the ceilings and use the new void for insulation and services. This approach was changed following an assessment of the ceiling condition; cables and other services would be circulated through existing routes. The textured wall coverings were removed and all small cracks filled. Where the ceiling appeared to be loose in one small area, it was fastened to the joists with plasterboard screws.

Cable and services routes

As planned, there was an emphasis on retention and re-use of existing cable and service routes as opposed to boxing or 'framing in'. In the kitchen new wiring was chased into existing brickwork and plastered flush, and in all rooms the steel conduits were used where possible. While there was some reluctance on behalf of the contractors, the results allowed retention of original room dimensions and prevented the creation of hidden voids.

Wall insulation

Due to the disruption and loss of space from previous measures it was decided to retain the existing linings and apply blown materials behind the existing finishes. Initially blown cellulose was to be used, but contractor availability prevented this, and another contractor had to be found. The alternative contractor proposed a relatively new product; a water-based expanding foam called Icynene that was injected into the cavity behind the lath and plaster. While this approach is considered unusual, tests by Glasgow Caledonian University had shown it was very vapour open and therefore would allow the dissipation of any wall humidity through evaporation and diffusion. The property of being vapour open is described as 'permeance'; Table 1 shows the permeance of the material against other common product types.

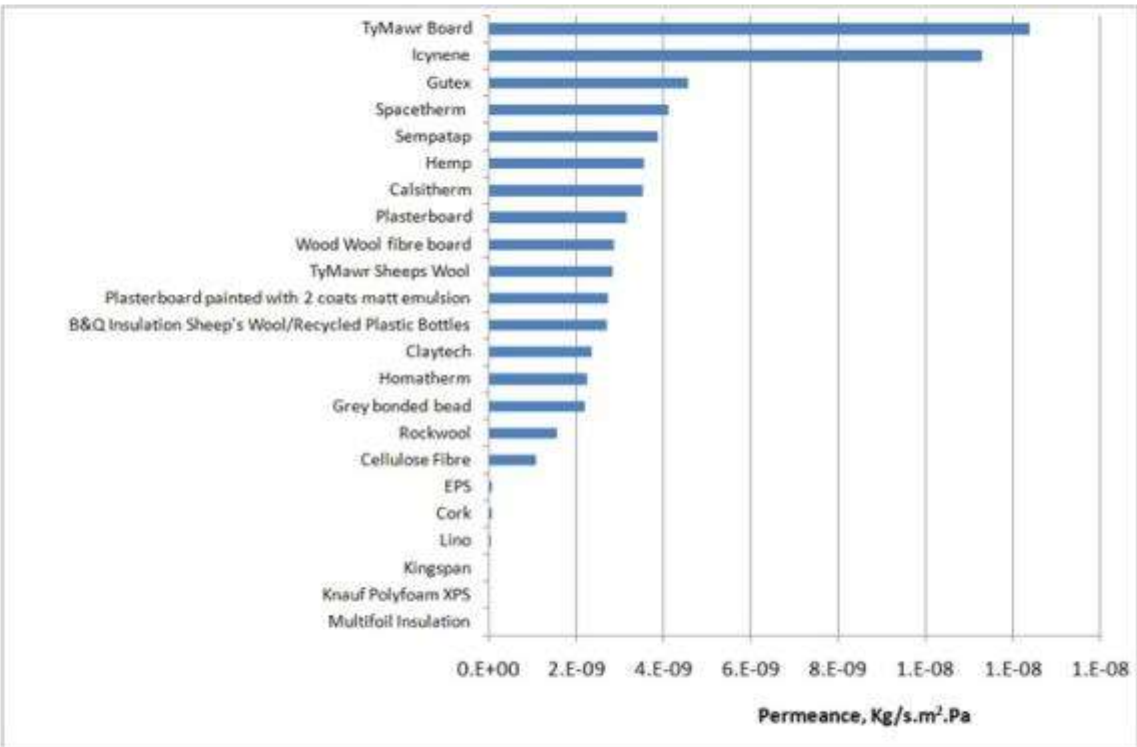

Table 1: *Relative permeance of common building materials and finishes*

To inject the material required the drilling of many holes, approximately 25mm in diameter normally at 1 metre centres. Preparation for the installation of this product was extensive: it involved the removal of existing wall coverings and skirting boards, plugging of the junction between the timber ground for the plaster and the masonry (to keep the material from entering the solum) and sleeving of the mains electrical cable from plug boxes on the wall. However, with these preparations complete, the actual installation was relatively straightforward (Fig. 5). As with many types of blown or injected material, it is often the handling of the equipment and the parking of the required vehicle that can be problematic. An infra-red camera was used to check that the foam had spread evenly into the void. Once the material had set, the holes were patched over and skirting boards refitted.

A condensation risk assessment was carried out following the process outlined in BS EN 13788, sometimes referred to as 'The Glaser method'. This methodology, while common in planning solid wall insulation retrofit in all types of buildings in Scotland, does not account for all the factors concerning mass masonry walls; however, this procedure was followed to see what it showed. It indicated low risk within normal conditions, although at low external temperatures there was a risk of condensation within the wall fabric. However, extended periods of such low temperatures are rare and the risk was deemed acceptable as traditional walls, even bonded with cement mortar, are able to disperse water vapour.

Figure 5: *Installing the foam insulation*

Timber floor insulation

The suspended timber floor, in direct contact with the solum void, was an obvious area for improvement. In order to minimise waste the existing floor was lifted, the insulation, also wood fibre board, fitted between the floor joists, and the floor put back. Initially there was concern as to whether the floor could be lifted, upgraded, and replaced. However, a short trial lifting quickly showed that this was entirely possible, with most boards taken up easily once the laying sequence and the nailing pattern had been established. Careful use of a claw hammer and a pry bar resulted in minimal damage. Due to the availability of access to much of the generous solum void below, only two areas of floor needed to be lifted, and most of the floor remained in situ. To secure the insulation batts between the joists, light timber runners were fastened to the bottom of each floor joist, and a nail gun was used due to the joist spacing restricting the swing of a hammer. The insulation material was 100mm of wood fibre material. This was cut outside to the joist separation width, giving a snug, but not overly tight fit in order to allow modest air movement between the solum and the room above (Fig. 6).

Figure 6: W*ood fibre board insulation installed between the floor joists*

The floorboards set aside were de-nailed and refastened. About 15% new floorboards were required to make good breakages and account for legacy interventions and cuts in the floor from previous works. An access panel was formed in each room for subsequent inspection of the solum void and access to services. As ventilation was being considerably reduced, especially from the solum void up the back of the wall, the proper functioning of the air bricks at the base of the external walls was checked, and any blockages removed. In some places the ground levels were lowered. Previous works included a plastic sheet, laid against the wall and covered in gravel to restrict weed growth. This was preventing the earth adjacent to the wall footing to dry out and it was removed.

Works to the attic space

As the Gannochy Trust cottages have no cooms, and the roof pitch is approx 45 degrees, there is ample space in the roof void. In order to provide a warm storage area for tenants' spare possessions, wood fibre insulation was fitted between the vertical hangars on the sides, and to the underside of the rafters. As with the floor work, this used 100mm thick boards, mounted with timber runners fastened to the cheeks of the rafters and between the hangars (Fig. 7). This geometry of insulation follows that used for many rooms in the roof upgrades, and has the benefit of this layout being recognised by RdSAP.

Figure 7: *The wood fibre board insulation installed in the roof space*

The space behind the hangars was already insulated with mineral wool; this was left in place but checked and any gaps filled. Due to the fibrous and dusty nature of the wood fibre boards they were painted with a coat of vapour permeable paint to bind the fibres and thus consolidate the surface of the material. Roof ventilation has always been an issue in many of the Trust’s cottages, and the roof vent disposition was modified to allow four of the existing fittings to ventilate the cold roof space behind the insulation, and two others at the upper level to give modest ventilation to the ‘warm roof’ space. The success of this approach will be monitored.

In traditional Scottish roofs of sarking boards and slate, excessive roof space humidity is often indicated by condensation forming on the nail heads. In some circumstances this results in drips and even wet sarking itself. Beyond certain levels mould will form (see Refurbishment Case Study 5). All of these indicate a need to improve ventilation, and possibly reduce the amount of insulation at ceiling joist level to increase the attic temperature and reduce the ambient relative humidity.

Concrete floor improvements
The un-insulated concrete floors in the kitchen and bathroom were clearly in need of attention, but any insulation had to be low enough so as not to give a change in level between the corridor and the room; this limited the options available to a few high performance materials. However, even their modest thickness gave a distinct step up from the timber floored areas that was considered too high. A standard water resistant sub-floor underlay material of thin plywood and wood composite was therefore used. While not an insulation material as such, as this was wood-based it was felt it would give a reasonable degree of thermal break from the concrete substrate.

Ventilation
The original design intent at build in 1927 was for a well-ventilated home; this was provided by sash windows, the four chimney flues and a ventilator in the second bedroom and the bathroom. As the flues had been blocked off, and the windows were generally kept shut, additional ventilation would be required. This was to be provided by a passive system re-using the existing flues in bedrooms 1 and 2, and by uncovering the blocked vent in bedroom 3.

However, the plan to install a passive flue system in bedrooms 1 and 2 was not possible; as is sometimes found out, site conditions can sometimes vary from that envisaged at the planning stage. The unusual geometry of the bedroom hearths (set at 45 degrees to the wall line) meant that this was not possible with the passive flue equipment as it was delivered to site. Instead, to retain the passive ventilation at a simpler level, two locally made large vent grilles were installed to each closed off hearth instead. This allowed a modest degree of flue and room ventilation. The planned ventilation for bedroom 3 also foundered on an equipment issue; the supplier of the humidity controlled vent considered that the stack would not work due to its height, and the joiners, keen to press ahead, covered in the opening. The correct solution would have been to re-instate the vertical duct through the roofline, and fit a hand operated grille in the ceiling and operate as intended in 1927. This could then be refitted with the passive vent should the technology improve. Both these situations were slightly frustrating, as it shows that while equipment in catalogues and brochures can work in test conditions, all such items need a degree of physical and system flexibility to allow for the variety of site conditions found in all existing buildings, regardless of age.

The new front door, fitted under a previous upgrade programme, was to be left in place, and provided a very air tight barrier; however this gave problems with damp in the lobby when the glazed lobby door was closed. When originally designed, it was customary for occupants of the Trust’s houses to keep the outside front door open, and the lobby door closed. This indicated that there was someone at home, and allowed light and some air through into the house. The damp in the lobby was largely due to this route being no longer used and there being no heating in the lobby, probably compounded by the drying of wet coats etc. In this pilot a new approach would be trialled. Instead of removing the glazed draught lobby door, as was done previously, a ventilation grille was fitted above the door. This would allow better ventilation and higher temperatures in the unheated lobby.

Investigation of the bathroom ceiling had shown considerable areas of mould growth; improved ventilation would be required and the lowered ceiling would be removed. As with many properties, occasional condensation in the bathroom is common, but on occasion there had been excessive amounts in this and other properties. While poor ventilation will contribute to high internal relative humidity, the surface temperature of building elements is also important. To assist in managing condensation in this space a radiant panel heater was fitted above the wash hand basin (Fig. 8). In this small room the arc of radiated heat easily covered the window reveals, the end wall and the wall on which part of the shower is located. By keeping these surfaces at a higher temperature water vapour is not able to condense.

Figure 8: *The mirrored radiant panel in the bathroom*

A heated towel rail, run from the central heating loop, was also fitted. This will allow tenants to dry out items quickly and in direct contact, instead of relying on ambient air temperature or ambient conditions. In addition, the extractor fan was upgraded, and clear guidance was given to the tenant on its use, and on the changing of the filters so crucial to its effective operation.

Decoration

With work completed on the walls and floors, redecoration was required. The walls were in a cleaned state, with all coatings removed down to bare plaster. Small holes were covered with filler. Lining paper was then applied to all walls below the picture rail to improve the wall surface and give a vapour open base for the new paint. While the exact nature of the decoration was considered a matter for the new tenants, they were consulted on colours. The cracks in some of the plaster ceilings that had caused concern were stopped with fine filler. Clay paint was used for all ceilings (Fig. 9).

Figure 9: *Areas of completed clay paint*

This type of paint is able to absorb and release the water vapour produced by occupants and other domestic activity; sometimes referred to as ‘humidity buffering’. While the use of such clay paint cannot replace adequate ventilation, it can assist in managing times of peak loading such as the use of showers or cooking. The picture rails were left in place, and formed a natural junction between the off white clay paint and the standard emulsion on the lower part of the walls. Clay paint was also used in the bathroom above the dado rail adjacent to the lower lining to assist with buffering the high levels of humidity during daily use.

7. The Energy Performance Certificate

Prior to the works an Energy Performance Certificate (EPC) was prepared for Annat Road based on the existing conditions. This gave a SAP rating of 45, putting the pre-intervention property into EPC band F. Following the works a second EPC was produced, and the property achieved an EPC rating of E, having gained five SAP points. This certificate is at Annex B. Given the extent of the works, this is a modest improvement, and is likely to be caused by the limited number of upgrade measures available for use, as well as many assumptions of traditional building fabric performance. Work is ongoing by Historic Scotland to seek a review of SAP methodology, and product assessment to allow SAP assessors to enter more accurate information on the building.

8. Assessment of the upgrades and monitoring

With the work complete in February 2015, there was time to conduct limited heat flux measurements in the finished building. To obtain an average value, four heat flux plates were mounted on the wall in bedroom 1 (Fig. 10). The measurements were then compared with those taken in the Autumn, and also from a similar property close by. The U-values showed good improvement in all areas. This monitoring will have to be conducted over a three year period to fully assess the effects of the wall insulation. Table 2 shows these initial results.

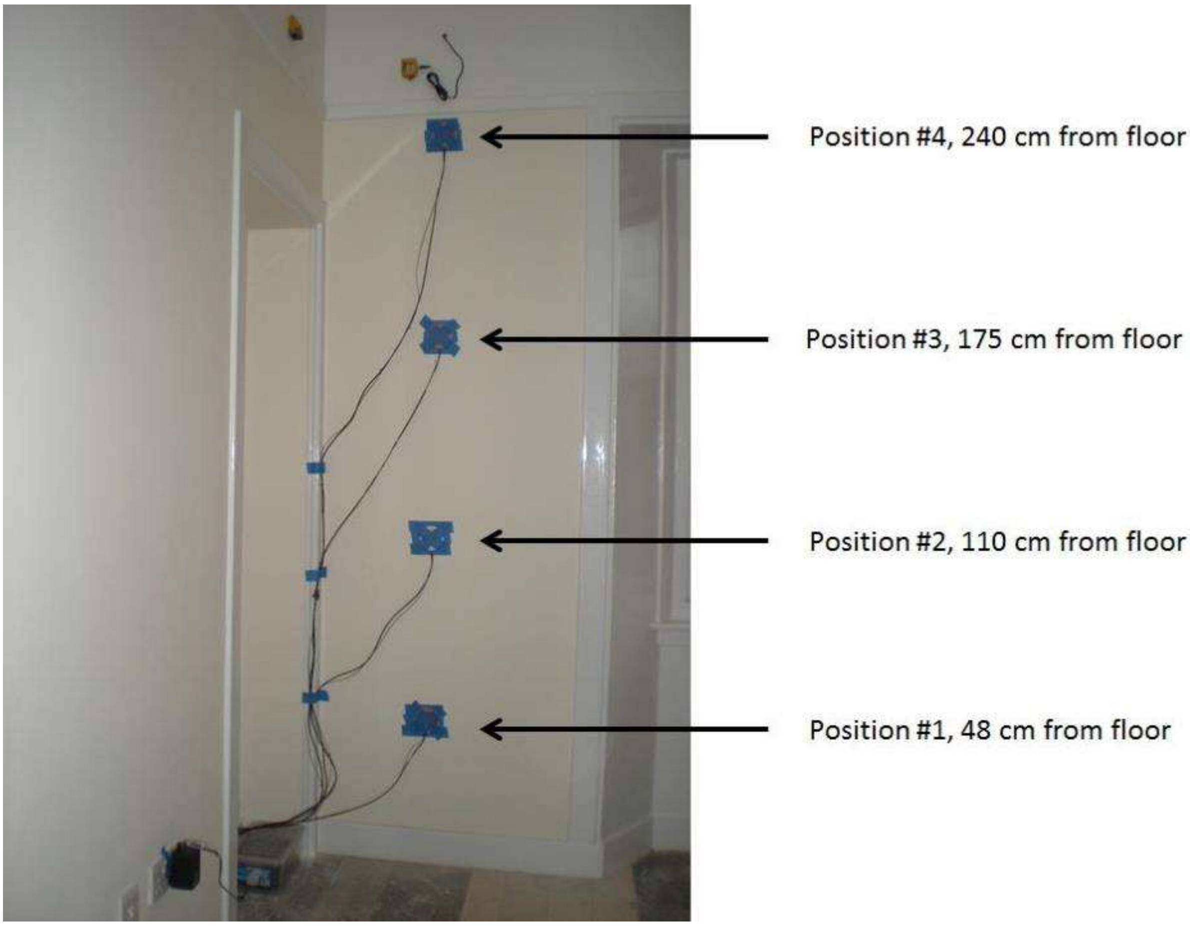

Figure 10: *The heat flux plates used to assess u-values in position*

Location	Pre-intervention U-Value (W/m^{2}K)	Post-intervention U-Value (W/m^{2}K)	% Improvement
External wall	1.1W/m^{2}K	0.41W/m^{2}K	63%
Attic coomb	1.0W/m^{2}K	0.13W/m^{2}K	87%
Attic wall	1.0W/m^{2}K	0.15W/m^{2}K	85%

Table 2: *Summary table showing pre- and post-intervention U-values*

The humidity in the filled cavity behind the lath and plaster was also monitored by the use of temperature and relative humidity probes behind the existing plaster lining. This would allow assessment of how quickly the foam insulation was drying out, and that the wall, once dry, remained so during future weather and calendar cycles. Whilst the measuring period was quite short the trend was downwards in the living room (Fig. 11) and bedroom 1. This will be confirmed by longer term monitoring in this and other properties on the same estate.

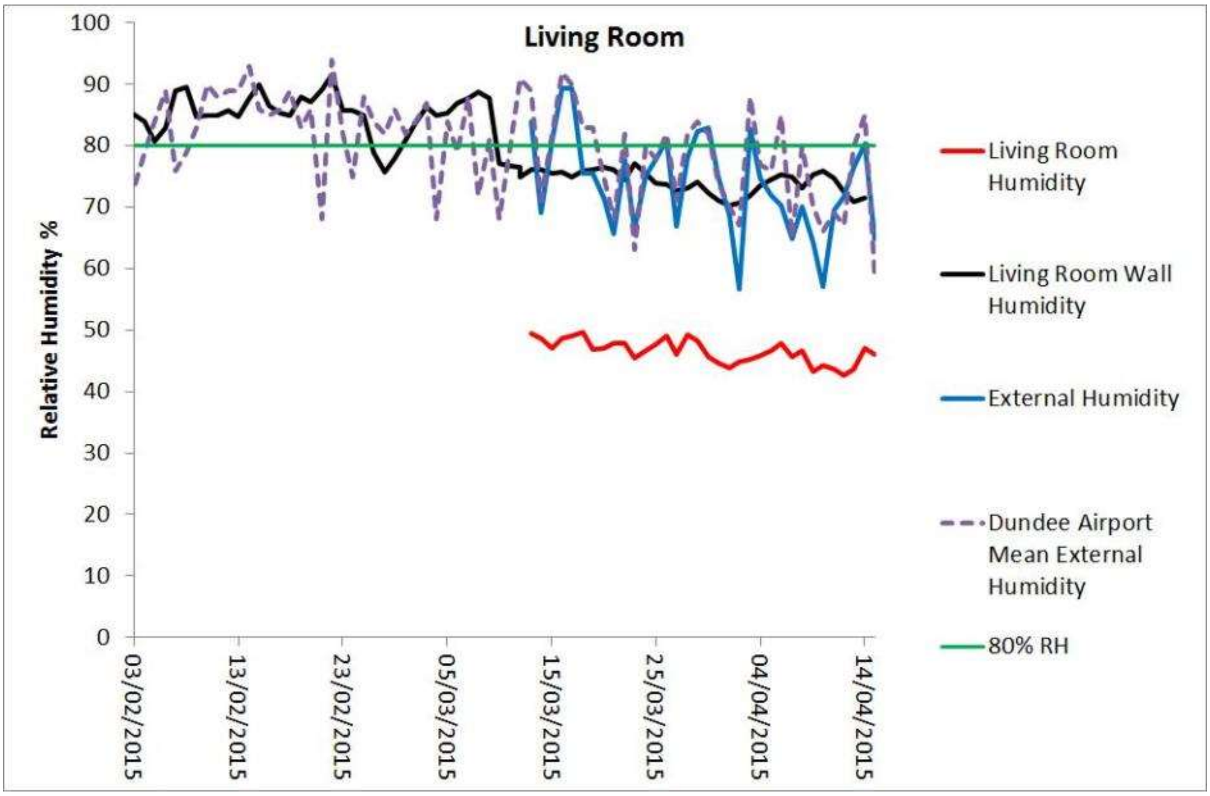

Figure 11: *The relative humidity within the living room wall after the works*

The roof space insulation was also monitored; across the wood fibre board, the air gap and through the sarking and the roof material gave a total U-value of 0.13 W/m^2K. In contrast to the walls, relative humidity remained high in the roof space in the winter months, and only reduced later in the Spring of 2015 (Fig. 12). This increase in relative humidity is consistent with the lower roof temperatures resulting from the insulation works. The situation improved as roof temperatures rose in the Spring. Regardless of the recent refurbishment work, these high relative humidity levels echo conditions experienced in other similar properties with partial refurbishments carried out by the Trust in recent years, and issues of defective slates cannot be entirely dismissed. A review of roof space air management will be progressed by the Trust over the next year.

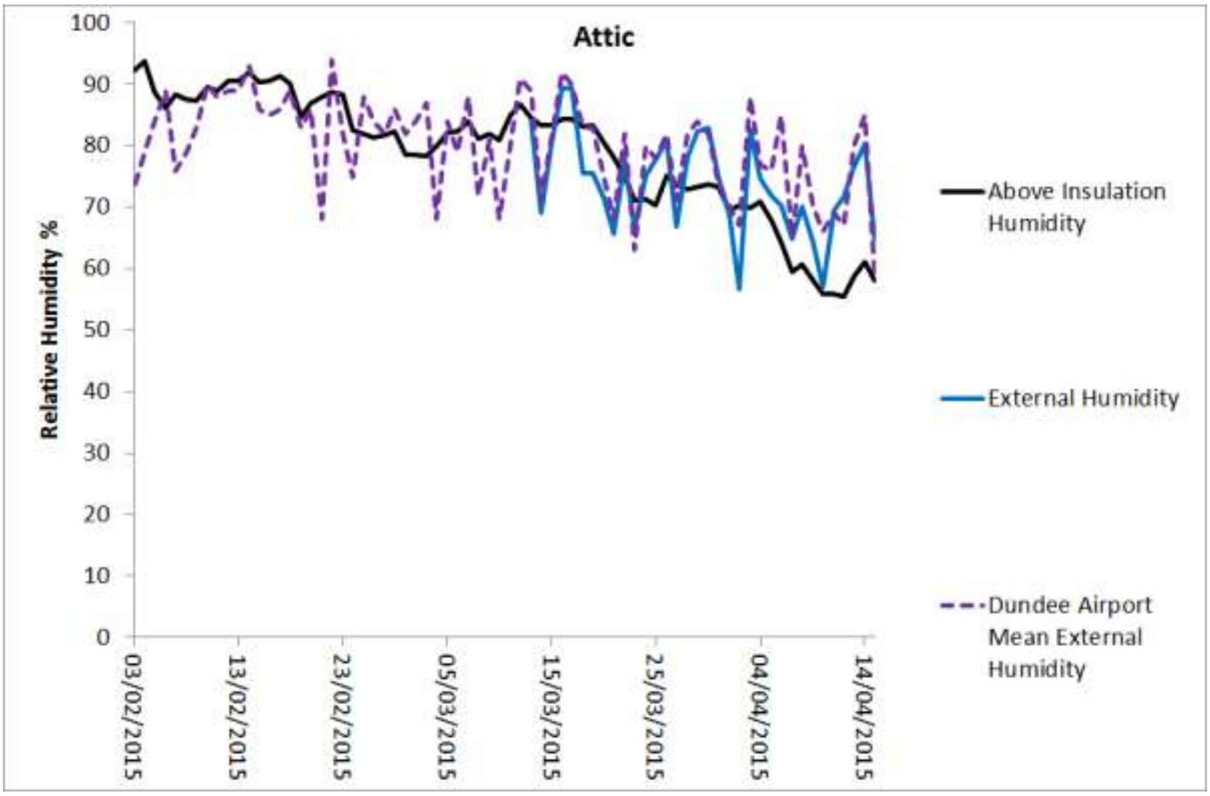

Figure 12: *The relative humidity within the roof space following insulation work*

9. Costs of the work

One of the objectives of the project was to validate or establish costs for the various measures in terms of a finished price per square metre. Careful planning and monitoring of the tendered rates from the contractors during the site phase, including any adjustments, allowed the preparation of a detailed cost plan. This information will allow confident planning by the Trust for future works, as well as a degree of security for the contractors when responding to new tenders. The final rates for the works are shown at Table 3. These results compare reasonably with the figures worked out following the refurbishment work at Kirkton of Coull Farmhouse (Refurbishment Case Study 16). It should be noted that these figures only cover the energy efficiency works; electrical, plumbing and other general refurbishment work has not been included.

Measure	Area/ no.	Rate	Total	VAT	Total Cost inc. VAT
Wall insulation	97m^2	£38.66	£3750	£187.50	£3937.50
Removing skirting and lifting timber floor	74m^2	£18.63	£1378.40	£68.92	£1447.32
Installation of timber floor insulation and relaying the timber floor	74m^2	£69.22	£5121.94	£256.10	£5378.04
Insulation works to attic space	42m^2	£63.98	£2687.18	£134.36	£2821.54
Bathroom vapour management – installation of radiant panel heater	1	£602.35	£602.35	£120.47	£722.82
Supply and fit Passivent A161 humidity controlled extract grille	1	£108.22	£108.22	£21.64	£129.86
Duct work for bathroom kitchen vent	1	£200	£200	£40	£240
Ventilation grilles to hearths	2	£1000	£2000	£400	£2400
Total			**£15,848.09**	**£11,58.99**	**£17,007.08**

Table 3: *Final rates for the thermal upgrade works at Annat Road*

10. Future work

The Trust will plan to refurbish further properties of this type with a combination of measures trialled in this pilot. The extent of intervention in each property will vary based on what thermal upgrade work has been done already, the condition of other services such as heating and hot water systems, and general fabric condition. For future works it is likely that a single contractor will be procured to deliver a set number of refurbishments per year. A programme of monitoring has also been established to run until 2017; this will include other in situ U-value measurements, hygrothermal monitoring in the walls and assessment of conditions in the roof spaces.

11. Conclusion

Although detailed long term analysis is still on-going the project was considered a success, with most objectives achieved. Through the review of the Trust’s estate refurbishment strategy, the drawing up of a new refurbishment specification and its trial, appropriate thermal upgrades can be delivered that improve the energy efficiency of traditional fabric, yet retain the technical and aesthetic features that are popular with tenants and an important part of the Trust’s wider objectives. Lessons were learnt in the use of wood fibre board and new wall insulation techniques; monitoring is proving that these measures are effective both in thermal terms and in maintaining the important characteristic of vapour open construction in traditional buildings. Local contractors are now familiar with a wider range of refurbishment materials and techniques, as well as the new refurbishment principles of the Trust. Following the success of this project the Trust is confident in procuring further refurbishment work on their estate with similar materials and techniques.

Technical Papers

Our Technical Papers series disseminate the results of research carried out or commissioned by Historic Scotland, mostly related to improving energy efficiency in traditional buildings. At the time of publication the series has 20 titles covering topics such as thermal performance of traditional windows, U-values and traditional buildings, keeping warm in a cool house, and slim-profile double-glazing.
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