

FIVE TENEMENT FLATS, EDINBURGH

WALL & WINDOW UPGRADES



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This case study was published by Historic Scotland, an executive agency of the Scottish Government.

This publication is a web publication and is available for free download from the Historic Scotland website: www.historic-scotland.gov.uk/refurbcasestudies

This publication should be quoted as:
Historic Scotland Refurbishment Case Study 1

ISBN 978 1 84917 097 0

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Historic Scotland Refurbishment Case Study 1

FIVE TENEMENT FLATS, EDINBURGH
WALL & WINDOW UPGRADES

MISIA JACK & ADAM DUDLEY

Context

by Historic Scotland

This case study is the first in a new Historic Scotland publication series: *Refurbishment Case Studies*. This series presents examples of refurbishment projects of pre-1919 buildings designed to improve their energy efficiency. The series will cover a range of building types including traditional cottages and tenements, and public buildings such as libraries or schools. Most, but not all, of the buildings are of traditional construction, and some are listed.

The case studies are not limited to energy-efficiency measures alone, but will contribute to a wider discussion about sustainability; together with indoor environmental quality, life cycle assessment and skills issues. Each case study will present one building, or a collection of buildings, which have been recently upgraded with support from Historic Scotland. The refurbishments typically incorporate experimental, adapted or non-standard materials, and novel upgrade measures. The impact of these interventions on the buildings' performance and occupants' comfort will be discussed. The aim is to showcase a variety of upgrade options which, although not always directly transferable to other projects, can provide inspiration for developing creative upgrade measures suitable for the refurbishment of the existing building stock. Sustainable measures will not only be physically compatible with the existing building fabric (e.g. by not adversely affecting the existing building physics), but should also allow the retention of the existing fabric (e.g. lime plaster on lath finishes) for reasons of both building conservation and waste reduction.

This first *Refurbishment Case Study* presents an energy-efficiency upgrade project carried out in tenement flats owned and managed by Castle Rock Edinvar Housing Association. The properties are Category 'B' listed buildings of traditional construction, which have received internal solid wall insulation and window upgrades. The latter is given a particular focus in this case study, not only because the ratio of external wall to window area means that upgrading windows is important for this building type, but also because improvement to the acoustic performance, one of many factors impacting on the indoor environmental quality, is of importance in these particular properties. With the trial complete, some techniques will be developed further, especially the use of blown materials behind existing linings, as well as other solutions in areas where less original internal fabric is extant. These reservations aside, the benefits to the tenants have been considerable and this refurbishment project was the winner in the refurbishment category for the fifth Carbon Trust Low Carbon Building Awards in March 2012.

Together, Historic Scotland's *Technical Papers* and *Refurbishment Case Study* series will provide practical and technical information and discussion points for all those working on the upgrade of existing buildings to make Scotland's built heritage more energy-efficient and sustainable.

Contents

1. Introduction.....	6
2. Summary of interventions	7
3. Costs	8
4. Property A – 16 Roxburgh Street.....	9
5. Property B – 22 Drummond Street, Flat 8	19
6. Property C – 33 Marshall Street, Flat 1F2	23
7. Property D – 2 Roxburgh Street, Flat 2F1	27
8. Property E – 2 Roxburgh Street, Flat 1F2	36
9. Thermographic testing	41
10. Acoustic performance	42
11. Feedback from tenants	43
12. Final cost and VAT calculation liability.....	44
13. Conclusion	46
Bibliography.....	48

Acknowledgements

Historic Scotland would like to thank all partners participating in this case study:



1. Introduction

This paper sets out five case studies demonstrating thermal improvement works to traditional tenement buildings in Edinburgh carried out by Castle Rock Edinvar Housing Association (CREHA) and partly funded by Historic Scotland. The aim of the project was to trial a series of site-specific interventions to establish the feasibility of undertaking thermal improvements to pre-1919 tenements without the tenants having to move out. Some of the interventions were experimental, some were conventional. Several similar properties were upgraded in order to obtain comparative results and to test replicability.

Objectives of the project

- Improve the thermal performance of the sash and case windows, including those with shutters, while maintaining the character, appearance and original operation
- Improve the thermal performance of the area surrounding the window, and where possible, the entire external wall fabric
- Improve acoustic performance
- Measure and record the improvement in thermal performance
- Assess whether the works meet the requirements of the Scottish Housing Quality Standard

Description of works

The pilot was undertaken in five Category 'B' listed, traditional Scottish tenement buildings in Edinburgh, presented below as properties A to E. Dating from the early 19th century, they are constructed from sandstone; ashlar to the front elevations, rubble to the rear, with timber sash and case windows and mainly lath and plaster internal linings. In three of the properties some of the original lath and plaster had been replaced with plasterboard as part of earlier renovation works, and there were some instances of lime plaster applied directly to the inside face of the stonework. The properties were selected to provide a range of window reveal configurations and variations in the construction of the external wall linings, so that each type of the improvement works could be fully tested under different conditions. As the works involved alterations to listed buildings, Listed Building Consent was applied for, and was subsequently granted for all of the treatment works to each of the properties.

The project brief allowed for thermal and acoustic improvement works to the external walls of a single room within three of the properties, and for improvement works to all of the external walls to the other two. The works included:

- Secondary glazing (timber and aluminium, with both double and single glazing)
- Replacement and upgrading works to external doors
- Fitting of rigid insulation to window reveals

- Blown insulation into the cavity behind existing wall linings
- Face fixed insulation to solid walls with plaster direct 'on the hard'
- Application of a variety of wall paint finishes

2. Summary of interventions

Timber secondary glazing

Bespoke casement units in softwood with the timber glazing beads to the opening sash run to match the mouldings on the window sashes. The single-glazed secondary glazed units were made up with 6.4 mm laminated glass. The double-glazed secondary glazed units were made up with 4 mm float glass, 16 mm argon-filled gap and 4 mm toughened low-e (internal pane). The units were made up in the workshop with fitted ironmongery and pre-painted with one coat of undercoat primer and one coat gloss, and delivered on site fully glazed, for final paint coat on completion of installation.

Aluminium secondary glazing

Bespoke casement units, manufactured in aluminium, with redwood timber outer frame. Plain chamfered glazing beads. Double glazed 6.4 mm laminated glass, 12 mm argon-filled air gap, 6.4 mm laminated low-e (internal pane). Satin powder coated finish to aluminium to match paintwork to timber sash and case window / reveals, and factory applied primer / undercoat to outer timber frame.

Rigid insulation

Pavaflex wood fibreboard. Wood fibreboard was specified; however, due to procurement issues, rigid phenolic insulation board was installed in some locations (Kooltherm K12).

Blown insulation

Two varieties of Warmfill insulation, an expanded polystyrene bead insulation with bonding agent, was installed: In properties A, B, C and D Warmfill White, which has a thermal conductivity of 0.040 W/(m·K), was installed; in property E Warmfill Silver, which has a thermal conductivity 0.033 W/(m·K), was installed.

Clay-based paint

Clay paint was used to buffer humidity in kitchens and bedrooms.

Site protection

In all instances furniture, loose floor coverings, curtains / rails etc. were removed from the working areas prior to commencement of operations. Any fitted floor coverings affected by the works were rolled back. All items remaining in the rooms were covered with dust sheets, and floor protection to both the working areas and the access routes was provided by means of polythene and hardboard taped in position. Services present within the working area, such as TV and telephone cables / sockets, power points etc. were also disconnected / isolated prior to any works commencing.

Downtakings

Care was required in the removal of original window linings, particularly in the case of the soffits, given the build up of dust. All joinery items were taken down piece by piece, to minimise any damage to the timber and paintwork. All removed components were brushed or vacuumed down, indexed, and set aside for reinstatement.

3. Costs

The outline costs are given for each property and are summarized for each window / wall configuration. These costs, given at the end of each description, relate to the individual elements of work, and do not take into account costs relating to protection, removal of curtain rails/soft furnishings and any repair works to the existing windows / shutters or the wall fabric, as these elements will inevitably vary from property to property. The summary of outline costs provided for each property includes the following elements of work:

Secondary glazing:	Removal of all joinery items (architraves, shutters, panelling, etc.), framing out and fitting of rigid insulation to the window opening, installation of secondary glazing, reinstatement of all joinery items and new joinery finishes, and paintwork
Blown insulation:	Installation of insulation, main contractor's attendance, patching blow holes as necessary
Rigid insulated wall framing:	Removal of defective wall lining, framing out and fitting rigid insulation, fitting plasterboard, and decoration
Insulated shutters:	Insulation works to existing shutters, new insulated shutter flaps, fitting weather seals, and paintwork

Professional fees for preparing and submitting applications for Listed Building Consent, and for providing full architectural services, from designing the works to administering the building contract to completion, are not included as these costs will not be common to all properties.

The costs are based on a main contractor carrying out the works under a single contract, sub-contracting the insulation works and the supply and fitting of the aluminium secondary glazed units. All contractors' prelims and attendance in relation to the sub-contracted works are included in the costs provided. The costs are also based on relatively small quantities, in terms of the number of properties and rooms treated, and it is anticipated that an increase in the scope of the works would result in a commensurate reduction in costs. The secondary glazed units were designed for this project, are non-standard units, and production of these by volume manufacturers would significantly reduce the unit cost.

VAT

VAT is applied at the standard rate for all repairs / upgrading works, but VAT is zero-rated where the works are alterations to a listed building, for which Listed Building Consent has been granted. Where the blown / rigid insulation is included in the Listed Building Consent, and has been accepted as part of the alteration works, then this too is zero-rated, as are all other associated works (making good, decoration etc.). Where the wall insulation (Spacetherm) was applied to the solid masonry walls, Listed Building Consent was not required, and this work is therefore classed as the installation of 'energy-saving materials' and VAT is thus charged at the reduced 5% rate.

4. Property A – 16 Roxburgh Street

This property is a main door, ground floor flat, within a three-storey and basement terrace, built around 1840. Upgrading works were carried out to the front and rear walls, windows, and external doors / fanlights.



Fig. 1. Views of 16 Roxburgh Street prior to works

4.1 Existing fabric

External wall to living room and entrance hall

- Wall to front, north east elevation of apartment built from polished ashlar, with chamfered rustication. Overall masonry thickness approx. 600 mm
- Wall linings to living room in lime plaster on timber lath, with a decorative cornice and box skirting
- 2 no. 6 over 6 pane sash and case windows to living room, with paint-bound shutters, panelled window reveal and soffit, and moulded architraves (without skirting blocks)
- Wall in hall plastered 'on the hard', in lime plaster, with plain run cornice and ogee skirting
- 6 panel entrance door and rectangular fanlight to hall, with integral inset mouldings, and ogee facings (flush with skirting)

External wall to bedroom and kitchen

- Wall to rear, south west elevation of apartment comprising random rubble stone with broached ashlar window surrounds. Overall masonry thickness approx. 650 mm
- Wall lining to bedroom in plasterboard on timber framing (with original lath & plaster previously removed, leaving exposed stonework behind), with plain run cornice and ogee skirting. Galvanised plasterer's bead to leading edge of window reveal / soffit
- 1 no. 6 over 6 pane sash and case window in bedroom, with plasterboard on timber framing to reveals, and no architraves
- Wall in kitchen plastered 'on the hard', in lime plaster, with ogee skirting, and no cornice
- 15 pane (single glazed) door to kitchen, with ply panel over rectangular fanlight, and plasterboard on timber framing to reveals, and no architraves

4.2 Improvements to living room

- The shutters in this property were found to be nailed shut, with the backs bonded to the pocket lining. As the shutters were opened up, the plaster to the pocket fell away, leaving the random rubble stonework to the reveals exposed
- Architraves and skirting blocks were carefully prised away from timber grounds, taking care not to disturb the decoration or plasterwork
- Soffit panels were prised away from timber packers / timber safe lintels, exposing the cavity at the head of the window opening

- Window elbows and backs were removed in one piece, exposing the cavities between the architrave / lath ground each side of opening, below cill level. (The cavities above cill level were also exposed as a result of the plaster linings to the shutter pockets coming away)



Fig. 2. Diagram and photograph showing dismantling of the window sets

- The open cavities around the perimeter of the window openings were packed with mineral wool insulation to form a continuous seal
- Expanded polystyrene bead insulation was blown into the wall lining cavity (approx. 30 – 40 mm deep) through the mineral wool packing, until a full fill was achieved



Fig. 3. Insulation being blown behind the existing linings

- The wallpaper was stripped from the external walls in the living room and re-papered in 800 gauge lining paper and painted with clay based paint, in three coats. The remaining walls were painted in standard emulsion, to match
- The shuttered windows were fitted with double glazed, aluminium, tilt and turn secondary glazing units with removable handles, to accommodate the shutters in the closed position
- The window reveals, elbows and back and shutter pockets were framed out with timber battens. All timbers were held clear from stonework, and sized to ensure adequate depth for pockets to accommodate shutters
- New timber packers were fitted to the window soffits
- Rigid insulation was cut and tightly fitted in between the timbers to the new framing and soffit packers as follows – 75 mm thick to window elbows, 100 mm thick to window back, 50 / 35 mm thick to shutter pockets, 35 / 25 mm thick to soffit



Fig. 4. Diagram and photographs showing reinstatement of window framing

- 6 mm ply shutter pocket linings were pinned to new framing
- 12 mm timber cover plates were fixed to the face of the secondary glazing case, and scribed to new shutter pocket lining, with all voids behind filled with rigid insulation
- Soffit panel screwed to new framing, and shutters re-fitted, with hinges screwed to face of secondary glazing case / cover plate

- Window elbows and back re-fitted, complete with cill pieces
- Continuous timber packers screwed to face of architrave / lath grounds, to sides and head of window openings, sized to neatly complete the shutter pockets (with the architraves fitted). Window architraves re-fitted, pinned through to new timber packers
- 12 mm timber cover plates to sides / top of architraves, scribed to the wall, and pinned through to the new timber packer
- All new woodwork to the window linings was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- Fitted carpets were trimmed and refitted, to suit the new line of the window linings and architraves / skirting blocks

4.3 Improvements to bedroom

Upgrade of window and external wall

- Existing skirting, window cill board, and apron, removed and set aside
- The plasterboard linings to the window reveals and back, fixed to timber framing, were removed, leaving the cavity around the opening exposed in places. The removal of the linings exposed large, structurally unsound voids in the inside face of the stonework to the base of the reveals and window back, which had to be made good

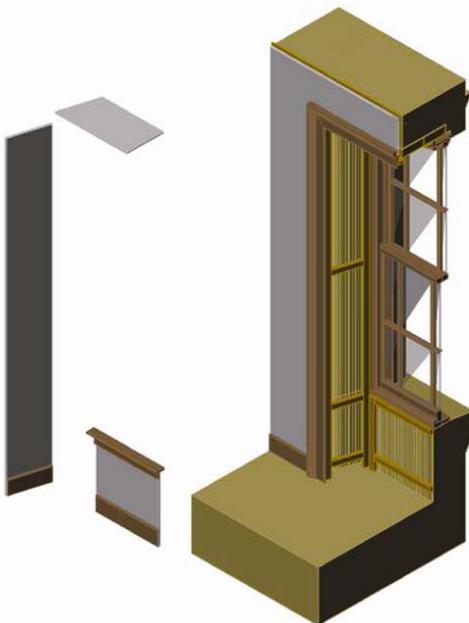


Fig. 5. Drawing and photograph showing soffit and panel insulation

- The leading edges of the window reveals / soffit were formed with a galvanized plasterers bead and plaster skim coat, and the plasterboard was cut short at the edge, so as not to disturb the bead
- The plasterboard soffit was removed from the timber framing, exposing the cavity at the head of the window opening. The original timber safe lintels had been replaced with concrete lintels
- The open cavities in the walls were packed with mineral wool, and bonded polystyrene bead was blown in behind the plasterboard to fully fill the cavity (approx. 70 – 80 mm deep)
- The window opening was fitted with an aluminium, double glazed, tilt and turn secondary glazed unit
- Rigid insulation was cut and tightly fitted between the new framing to the window back and the existing framing to the reveals and soffit: 100 mm thick to window back, 50 mm thick to reveals, 35 mm thick to soffit



Fig. 6. Drawing and photograph showing new secondary glazing in position

- Following fitting of insulation new plasterboard was fitted to the window back, elbows and soffit, fixed to new / existing framing
- 3 – 5 mm plaster skim coat to new plasterboard, including making good at the existing plasterers beads to the leading edge of the reveals / soffit
- New skirting to window back, and salvaged skirting to reveals fitted

- New window cill board and apron fitted
- All new woodwork was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- Fitted carpets were trimmed and refitted, to suit the new line of the window linings

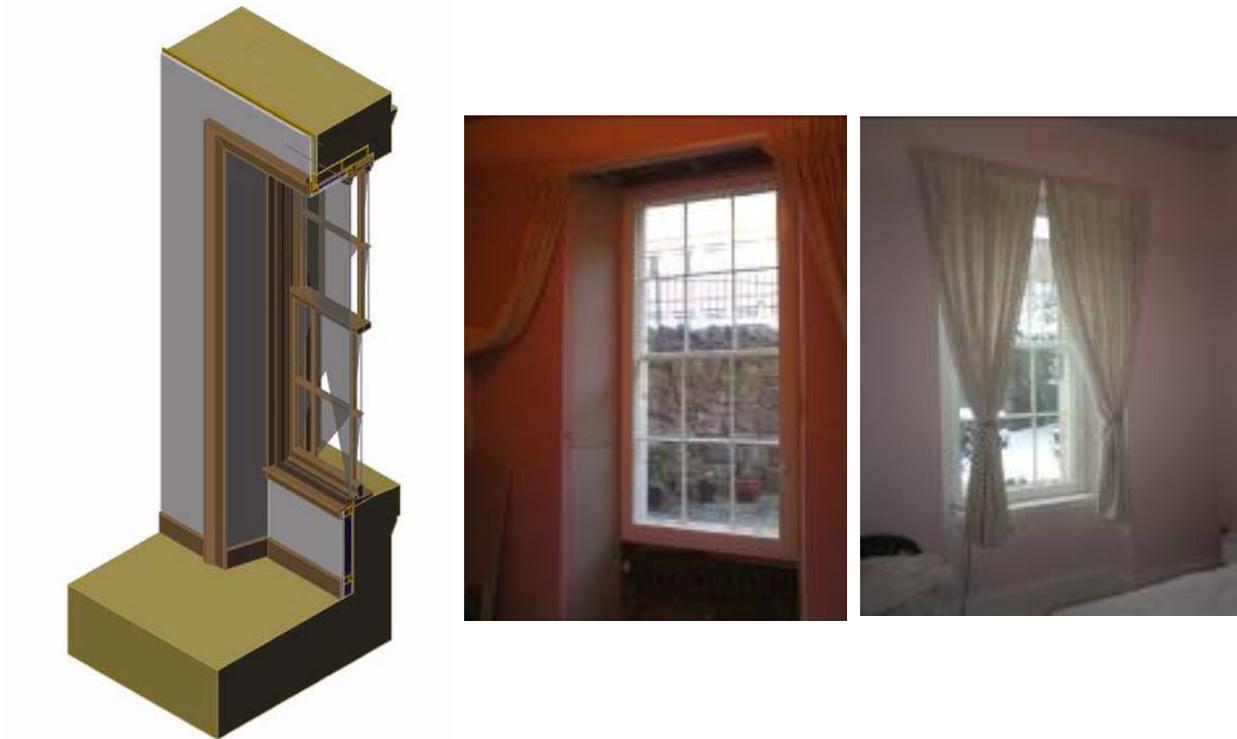


Fig. 7. Drawing and photographs showing completed works to wall sand window

4.4 Improvements to hall and kitchen

Face-fixed wall insulation and plasterwork to external

- Existing wallpaper removed
- Existing skirting removed and set aside
- Existing door facings in entrance removed and set aside
- 10 mm thick timber rail fixed to the head of the wall in the hall, below the cornice, with 15 mm stainless steel plasterers stop-end bead
- 25 mm thick dressed packing timbers fixed to the existing skirting grounds and door frame
- Light switches and sockets removed and made safe. Back boxes fitted with 25 mm extension pieces, and fittings replaced on completion of insulation/plaster works

- 10 mm thick Proctor Spacetherm insulation blanket fitted to external walls, and held in place with stainless steel expanded metal lath, fixed with proprietary 'mushroom headed' plugs drilled into masonry
- 12 mm bonding coat of Limelite plaster applied to the metal lath, and finished with a 3 mm Limelite skim coat
- Skirting and facings reinstated
- New plasterwork painted with clay based paint, in three coats
- All new joinery work painted one primer / undercoat and two coats gloss. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat



Fig. 8. Insulation of the front door



Fig. 9. Thin internal wall insulation

Upgrade work to front door

- 10 mm thick Proctor Spacetherm insulation blanket neatly fitted to inside face of plain, recessed door panels, and covered with 4 mm ply, flush with stiles and rails. Joints around panels covered with plant-on timber beads.

Replacement of external rear door and fanlight in kitchen

- Existing glazed door replaced with a purpose made eight pane glazed door, with opening fanlight above, manufactured in Douglas fir, complete with weather seals.

Moulding / astragals to match the existing profiles, and double glazed with 4 mm toughened glass, 4 mm argon-filled air gap with Edgtek seal, 4 mm low-e toughened glass, bedded in synthetic putty

- Existing, non-original glass to plain fanlight removed, and replaced with 4 mm toughened glass, 4 mm argon-filled air gap, 4 mm low-e toughened glass
- New woodwork pre-painted one coat undercoat / primer, and painted two coats gloss in situ. Site fitted ironmongery (salvaged) and new aluminium threshold weather strip
- Existing plant-on door stops removed and replaced with new stops with integrated neoprene weather seal
- Existing, non-original glass to plain fanlight removed, and replaced with 4 mm toughened glass, 4 mm argon-filled air gap with Edgtek seal, 4 mm low-e toughened glass
- All new joinery work painted one primer / undercoat and two coats gloss. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat



Fig. 10. Upgraded glazed door and fanlight

4.5 Results of thermal improvements

In order to quantify the above improvements, the thermal performance, or U-value, of all components was tested before and after improvement works. Heat flux sensors were used to measure heat flows through the selected walls and windows. The sensors were mounted on the inner face of the component for 14 days so that an average value could be measured. Sensor locations were chosen to avoid thermal bridging near windows and corners as well as probable stud locations of plasterboard linings.

Pre-intervention testing: 20th October to 5th November 2010; post-intervention testing: 28th January to 22nd February 2011 (first phase); 29th March to 12th of April 2011 (second phase). Location: living room and hall

16 Roxburgh St			U Values (W/m ² K) Living room & Hall	
			Pre-Intervention	Post-Intervention
Location of measurement	Thickness (mm)	Improvement type	Monitored	Monitored
Wall (living room)	590	40mm "warm Fill" poly- bead in cavity	1.4	0.8
Side wall inner window elbows	590	75mm "Kspan Kooltherm K12"	1.9	0.4
Plaster on hard (hall wall)	590	10mm Spacetherm w/ 'Limelite' plaster	-	0.8
Front Door (solid & Spacetherm)	40	10mm Spacetherm + 4mm Ply	3.0	0.7

4.6 Outline costs

Living room

Secondary glazing (and associated works)	Aluminium double glazed (approx. 2.2 m high x 1.0 m wide)	£ 1,400 per window
Blown insulation	Total area: 4.75 m ²	£ 50 per m ²

Bedroom

Secondary glazing (and associated works)	Aluminium double glazed (approx. 2.0 m high x 1.0 m wide)	£ 1,250 per window
Blown insulation	Total area: 6.00 m ²	£ 40 per m ²

Internal aerogel insulation

The total cost for Spacetherm insulation amounted to £3327.00 which equates to £250 per m² for the works carried out in the hall and kitchen. This excludes the associated joinery work (removing / replacing skirting boards, facings etc) and decoration works, but gives a "ball-park" rate per square metre. It should be noted that this is not typical cost; the material was new on the market at the time, and thus required extensive input from the contractor to work with the specification, which included mechanically fixing stainless steel lath finished with renovating plaster. The areas treated were also very small, and perhaps not ideally suited to such treatment.

5. Property B – 22 Drummond Street, Flat 8

Rear second floor flat, accessed from common stair, within five-storey, tenement block, c. 1790. Upgrading works were carried out to the rear wall and window to a single room (bedroom).

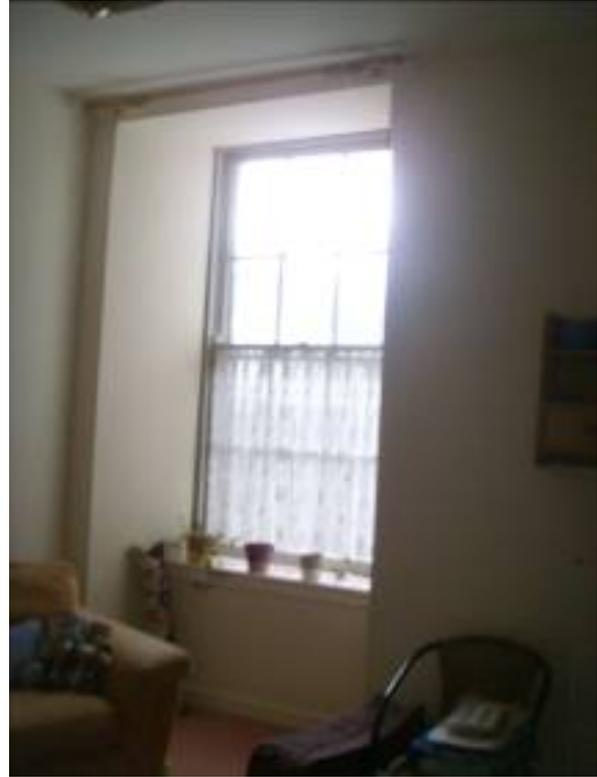


Fig. 11. The Drummond Street flat before the works

5.1 Existing fabric

- Wall to rear, south west elevation of apartment comprising random rubble stone with broached ashlar window surrounds. Overall masonry thickness approx. 750 mm
- Wall linings in plasterboard on metal studwork (with original plaster 'on the hard' behind) and pencil round skirting. No cornice
- 1 no. 6 over 6 pane sash and case window. Plasterboard on metal framing to window reveal. Taped corners to leading edge of window reveal / soffit

5.2 Upgrade works

Downtakings

- Existing skirting, window cill board, and apron, removed and set aside

- The plasterboard linings to the window reveals and back, fixed to metal framing, were removed, leaving the cavity around the opening fully exposed. The linings to the reveals were screwed to poorly fixed metal framing, which came away as the plasterboard was removed
- The leading edges of the window reveals / soffit were formed with taped corner strips, which were cut to allow the release of the plasterboard
- The plasterboard soffit was removed from the timber framing, exposing the cavity at the head of the window opening. The original timber safe lintels had been replaced with RSJ's, fixed tight to the head of the window



Fig. 12. Diagram and photograph showing downtakings

Window improvements

- Window fitted with aluminium, double glazed, tilt and turn secondary glazed unit
- New timber framing was fixed to the window reveals and the window back
- Rigid insulation was cut and tightly fitted between the new framing to the window back and reveals, and to the underside of the RSJ's at the window head, with timber grounds to take the new soffit lining as follows: 100 mm thick to window back, 50 mm to reveals, 25 mm thick to soffit



Fig. 13. Diagram and photograph showing insulation locations

Reinstatement of window linings

- New plasterboard to window back, elbows and soffit, fixed to new framing
- 3 – 5 mm plaster skim coat to new plasterboard, including new corner taping at the leading edge of the reveals / soffit
- New skirting to window back, and salvaged skirting to reveals fitted
- New window cill board and apron fitted
- All new woodwork was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- Fitted carpets were trimmed and refitted, to suit the new line of the window linings

Improvements to external walls

- The open cavities were packed with mineral wool, and bonded polystyrene bead was blown in behind the plasterboard to fully fill the cavity (approx. 100 mm deep).



Fig. 14. Open gaps (left) and gaps filled with mineral wool (right) prior to blown insulation

5.3 Monitoring and results of thermal improvements

Pre-intervention testing: 20th October to 5th November 2010; Post-intervention testing: 1st to 22nd February 2011. Location: bedroom.

22/8 Drummond St			U Values (W/m ² K) Bedroom	
			Pre-Intervention	Post-Intervention
Location of measurement	Thickness (mm)	Improvement type	Monitored	Monitored
Wall	750	100mm "warm Fill" poly- bead in cavity	0.5	0.4
Side wall inner window elbows	750	100mm "Kspan Kooltherm K12"	0.7	0.2
Sash & Case - SG Window	-	DG-Sec. glazing w/ Aluminium frame	5.4	0.8

The pre-intervention U-value results from this property were unusually low. This may be due to the large void behind the existing plasterboard, approx 100 mm deep, which acted as a thermal resistance barrier, lowering the overall U-value of the wall. With the insulation installed, the U-value of the wall was only marginally reduced, suggesting that the air space behind the linings was unventilated in this instance, and was therefore providing a degree of insulation. This is unusual as generally these cavities are slightly ventilated with lower thermal resistances influencing the passage of heat.

The monitoring of the window demonstrated a substantial improvement in U-value following the upgrade works. The double glazed secondary unit with aluminium frame gave a 4.4 W/m²K decrease. This is 0.2 W/m²K less than the window fitted in 2 (2F1) Roxburgh Street, although the reason is unexplained.

5.4 Outline costs

Bedroom

Secondary glazing (and associated works)	Aluminium double glazed (approx. 2.2 m high x 1.0 m wide)	£ 1,300 per window
Blown insulation	Total area: 8.00 m ²	£ 55 per m ²

6. Property C – 33 Marshall Street, Flat 1F2

End of terrace first floor apartment, accessed off common stair, within four-storey plus attic, mid-19th century tenement. Upgrading works were carried out to a single room (bedroom) with two external walls and two windows.



Fig. 15. The Marshall Street flat prior to the works

6.1 Existing fabric

- Walls to part north east and part south east elevation of apartment comprising of stugged ashlar with fair-faced window surrounds. Overall masonry thicknesses approx. 750 mm and 600 mm respectively
- Wall linings in lime plaster on timber lath, with a plain run cornice, and ogee skirting
- Lime plaster 'on the hard' to chimney breast, in south corner of room
- 2 no. 2 over 4 pane sash and case windows with timber tongue and groove boarding to window reveals and back, with ogee architraves, and flush timber lining to soffits

6.2 Upgrade works

Downtakings

- Cill board and timber tongue & groove linings were carefully prised away from the timber framing to the reveals and backs, with care taken not to disturb the facings / paintwork to the side of the openings, which remained in place. The tongue & groove boards were numbered and indexed, in order to be reinstated in the correct order / location
- Timber soffit boards were prised away from the timber packers / timber safe lintels, in two pieces, exposing the cavity at the head of the window opening
- Timber framing from the window reveals was removed, exposing the cavity at each side of the window opening. Where sound, the timber framing was indexed, and set aside for re-use
- Where the timber window wedges were loose, additional packers were to be fitted to keep the sash and case window in place until the new framing was installed
- Any obsolete / defective timber dooks set into the stonework were removed and disposed of



Fig. 16. Diagram and photograph showing downtakings

Wall insulation work

- The open cavities around the window openings were packed with mineral wool insulation. Expanded polystyrene bead insulation was blown into cavities through the mineral wool packing to fully fill the cavity (approx. 35 - 45 mm deep)

Windows / openings

- Windows (2 no.) fitted with double glazed, timber, tilt and turn secondary glazed units screwed to face of case lining
- New / salvaged timber framing to the window back and reveals
- New timber packers were fitted to the window soffits, and as necessary, screwed to underside of timber safe lintels / battens
- Rigid insulation was cut and tightly fitted in between the timbers to the new framing and soffit packers, as follows: 50 mm thick to the reveals, 100 mm thick to the window backs, 35 mm thick to the soffit



Fig. 17. Diagram and photograph showing reframing around window opening

Reinstatement of window linings

- Salvaged timber soffit linings re-fitted, pinned to the new packers. The opportunity was taken to form a recess in the soffit lining at the head of each window, directly in front of the secondary glazed units, to accommodate roller blinds
- Salvaged timber tongue and groove lining boards were reinstated, pinned to new / salvaged framing, complete with new cill board



Fig. 18. Photograph and diagram showing completed work with open sash

- Fitted carpets in the living rooms were trimmed and re-fitted, to suit the new line of the window linings and architraves / skirting blocks
- All new woodwork to the window linings was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units

6.3 Results of thermal improvements

Pre-intervention testing: 20th October to 5th November 2010. Post-intervention testing: 28th January to 22nd February 2011. Location: bedroom

33 Marshall St			U Values (W/m ² K) Bedroom	
Location of measurement	Thickness (mm)	Improvement type	Pre-Intervention Monitored	Post-Intervention Monitored
Wall (bedroom)	700	45mm "warm Fill" poly- bead in cavity	1.4	0.7
Wall under window - timber	200	100mm "Kspan Kooltherm K12"	1.6	0.4

A solid 700 mm wall with an internal lath and plaster finish gave a pre-intervention thermal transmission value of 1.4 W/m²K. Post-intervention improvement of polystyrene bead insulation pumped into the 45 mm slightly ventilated void behind the lath and plaster resulted in a final 0.7 W/m²K value. This represents a 50% reduction in thermal retention. The second wall tested was located below the window which is a thinner solid sandstone wall with a small void and a timber facing. It gave a pre-intervention U-value of 1.6 W/m²K while the addition of 100 mm of rigid Phenolic insulation behind the timber facing resulted in a drop of 1.2 to 0.4 W/m²K – a 75% reduction.

6.4 Outline costs

Bedroom

Secondary glazing (and associated works)	Aluminium double glazed (approx. 1.7 m high x 0.95 m wide)	£ 1,300 per window
Blown insulation	Total area: 12.20 m ²	£ 40 per m ²

7. Property D – 2 Roxburgh Street, Flat 2F1

North corner, second floor apartment accessed off common stair, within four-storey plus basement, tenement c. 1800. Upgrading works were carried out to the two external walls and five windows.



Fig. 19. The Roxburgh Street flat prior to the works

7.1 Existing fabric

- Wall to front, northwest and front, northeast elevations of apartment comprising broached ashlar, with droved margins to window surrounds. Overall masonry thickness approx. 650 mm

- Wall linings to living room and main bedroom in lime plaster on timber lath, with rich decorative cornices
- Wall linings to second bedroom and kitchen in plasterboard on timber framing, with plain run cornices
- Box skirting and timber dado rail in living room, and plain ogee skirting elsewhere
- Open shelved press in north corner of living room, and gas fire / back boiler to east side of room (with natural ventilation provided via an existing circular vent through an upper window pane)
- 2 no. 6 over 6 sash and case windows in the living room, and 1 no. in the main bedroom, each with working shutters with panelled elbows soffit and back. Moulded architraves with skirting blocks in living room and moulded architraves without skirting blocks in main bedroom
- 1 no. 6 over 6 pane sash and case window in the small bedroom and 1 no. in the kitchen, both with plywood lining on timber framing to reveals, and pencil round facings

7.2 Upgrade works to external walls and windows in living room and main bedroom

Downtakings



Fig. 20. Diagram and photograph showing downtakings

- Shutters / hinges were unscrewed from case lining, leaving the plaster 'on the hard' to the shutter pocket exposed
- Architraves and skirting blocks were carefully prised away from timber grounds, taking care not to disturb the decoration or plasterwork
- Soffit panels were prised away from timber packers / timber safe lintels, exposing the cavity at the head of the window opening
- Window elbows and backs were removed in one piece, exposing the cavities between the architrave / lath ground each side of opening, below cill level (the cavities above cill level being otherwise covered by the plaster to the shutter pockets)

Improvement works to walls

- The open cavities below cill level were packed with mineral wool insulation, and any gaps around the perimeter of the window opening were also filled to form a continuous seal
- 22 mm diameter holes were drilled through the sides of the plastered shutter pockets, either through the plaster fill and into the cavity where the cavities were more generous, or through the side of the architrave / lath grounds where the cavities were tighter. Holes were generally drilled at 1/3rd intervals up each side of the window opening
- Expanded polystyrene bonded bead insulation (Warmfill White) was blown into the wall lining cavity (approx. 40 – 50 mm deep to the NW wall, and 20 – 30 mm deep to the NE wall) through the holes in the plaster and timber grounds, until a full fill was achieved
- Where the length of the walls beyond the window openings were beyond 2.0 – 3.0 m or where there were obstructions in the cavities e.g. former fireplace surround in living room, additional holes were face-drilled, through the lath and plaster, in the top corners of the wall to complete the cavity fill



Fig. 21. Bonded bead being blown in behind plaster

- Walls / cupboards where the linings and architraves were not being opened up to give access to the cavity, holes were face-drilled through the adjacent lath and plaster, as necessary, to facilitate the cavity fill

Work to windows

- The windows were fitted with double glazed, timber, tilt and turn secondary glazing units with removable handles, to accommodate the shutters in the closed position
- The window reveals, elbows and back and shutter pockets were framed out with timber battens
- All timbers were held clear from the stonework / plaster 'on the hard', and the framing to the shutter pockets was sized to ensure adequate depth for pockets to accommodate shutters
- New timber packers were fitted to the window soffits
- Rigid insulation was cut and tightly fitted in between the timbers to the new framing and soffit packers as follows: 75 mm thick to window elbows, 100 mm thick to window back, 35 mm thick to shutter pockets, 35 / 25 mm thick to soffit



Fig. 22. Diagram and photographs showing insulation to shutter pockets

Reinstatement of window linings

- 6 mm ply shutter pocket linings pinned to new framing

- 12 mm timber cover plates fixed to face of secondary glazing case, and scribed to new shutter pocket lining, with all voids behind filled with rigid insulation
- Soffit panel screwed to new framing, and shutters re-fitted, with hinges screwed to face of secondary glazing case / cover plate
- Window elbows and back re-fitted, complete with cill pieces
- Continuous timber packers screwed to face of architrave / lath grounds, to sides and head of window openings, sized to neatly complete the shutter pockets (with the architraves fitted)
- Window architraves re-fitted, pinned through to new timber packers
- 12 mm timber cover plates to sides / top of architraves, scribed to the wall, and pinned through to the new timber packer
- All new woodwork to the window linings was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- All faced-drilled holes for the blown insulation were repaired with a bonding coat and finishing plaster
- The existing wallpaper was stripped from the external walls, and re-papered in 800 gauge lining paper and painted with clay based paint, in three coats. The remaining walls were painted in standard emulsion, to match, simply for continuity
- Fitted carpets were trimmed and refitted, to suit the new line of the window linings and architraves / skirting blocks



Fig. 23. Diagram and photographs showing reinstatement of window sets and facings

7.3 Kitchen and small bedroom

Downtakings

- Existing skirting, window cill board, and apron, to small bedroom removed and set aside. The deep cill to the kitchen window was removed and set aside, leaving the solid masonry below (in line with the wall) exposed
- Plywood linings to the reveals, back and soffit, in the small bedroom were removed and set aside, leaving the existing timber framing and window facings in place. Plasterboard linings to the reveals and soffit in the kitchen were removed, leaving the existing timber framing and facings in place



Fig. 24. Diagram showing removal of facings and soffit

Upgrade work to walls

- The open cavities were packed with mineral wool, and bonded polystyrene bead was blown in behind the plasterboard to fully fill the cavity (approx. 30 – 40mm deep). Elsewhere, exposed plaster lining to former shutter pockets were drilled and injected with bonded polystyrene bead



Fig. 25. Sealing of wall edges prior to insulation being blown in

Work to windows

- Window fitted with timber, double glazed, tilt and turn secondary glazed unit
- Rigid insulation was cut and tightly fitted between the existing framing to the reveals, soffits, and window back (small bedroom) and deep cill (kitchen) as follows: 75 mm thick to window back (small bedroom), 50 mm to reveals, 25 mm thick to soffits, 50 mm thick to deep cill (kitchen)



Fig. 26. Diagram showing removal of facings and soffit

Reinstatement of window linings

- Salvaged plywood to reveals, soffit, and window back, fixed to existing framing in small bedroom
- New plasterboard to reveals and soffit fixed to existing framing in kitchen, with 3 – 5 mm plaster skim coat
- Salvaged skirting, cill board and apron refitted to small bedroom. Salvaged deep cill re-fitted to kitchen
- All new woodwork was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- All faced-drilled holes for the blown insulation were repaired with a bonding coat and finishing plaster
- The existing wallpaper was stripped from the external walls, and re-papered in 800 gauge lining paper and painted with clay based paint, in three coats. The remaining walls were painted in standard emulsion, to match, simply for continuity

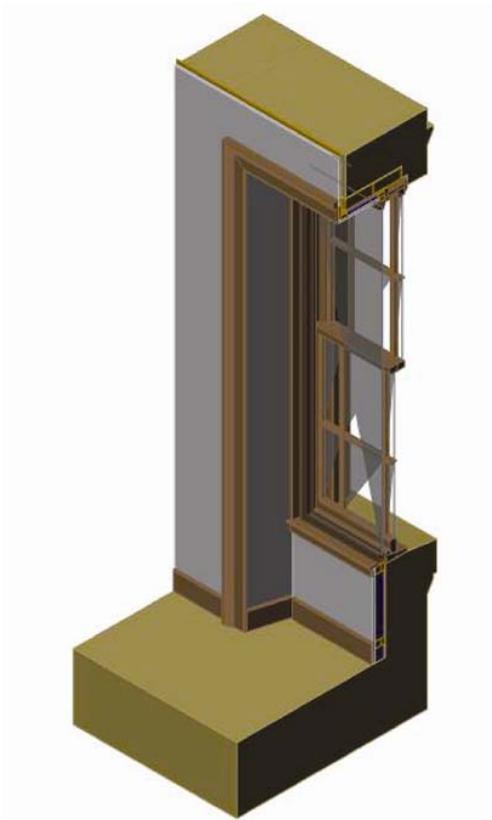


Fig. 27. Completed works to window opening showing tilting secondary glazing

7.4 Results of thermal improvements

Pre-intervention testing: 20th October to 5th November 2010; post-intervention testing: 28th January to 22nd February 2011 (first phase), 12th to 27th of April 2011 (second phase). Location: living room

2 (2F1) Roxburgh St			U Values (W/m ² K) Living Room	
			Pre-Intervention	Post-Intervention
Location of measurement	Thickness (mm)	Improvement type	Monitored	Monitored
Wall (living room)	630	40mm "warm Fill" poly- bead in cavity	1.3	0.7
Plaster on hard (behind shutters)	630	50mm "Kspan Kooltherm K12"	1.6	0.3
Wall under window - timber	200	100mm "Kspan Kooltherm K12"	-	0.4
Sash & Case - SG Window	-	DG-Sec. glazing w/ Timber frame	5.2	0.6

Similar components were tested as previous properties with comparable results and circumstances. Significantly, the tested single glazed window with a timber frame gave a high U-value of 5.2 W/m²K, whilst with the double-glazed secondary glazing unit installed internally it was reduced to 0.6 W/m²K. This is due to the additional glazed layer being installed and an adequate sealed space between the original glazing and the new layers. The better thermal performance of timber frames has also made a great contribution to this reduction

7.5 Outline costs

Living room and main bedroom

Secondary glazing (and associated works)	Timber double glazed (approx. 2.0 m high x 1.00 m wide)	£ 1,550 per window
Blown insulation	Total area: 25.00 m ²	£ 40 per m ²

Small bedroom and kitchen

Secondary glazing (and associated works)	Aluminium double glazed (approx. 1.7 m high x 0.95 m wide)	£ 1,300 per window
Blown insulation	Total area: 12.20 m ²	£ 40 per m ²

8. Property E – 2 Roxburgh Street, Flat 1F2

North east facing first floor apartment accessed off common stair, within four-storey plus basement tenement c. 1800. Upgrading works were carried out to the front wall and two windows to a single room (living room).



Fig. 28. The flat prior to the works

8.1 Existing fabric

- Wall to front, north east elevation of apartment comprising broached ashlar, with droved margins to window surrounds. Overall masonry thickness approx. 650 mm
- Wall lining in plasterboard, on inadequate timber framing, with the plasterboard largely nailed into the edges of the window shutters, which were, in turn, permanently fixed back into the pockets. Decorative cornice, with sections over the window heads missing, and ogee skirting.
- 2 no. 6 over 6 pane sash and case windows with fixed shutters with panelled elbows soffit and back. Moulded architraves with skirting blocks
- Living room – 2 no. windows to north east side
- Wall lining plasterboard, with 40 – 50 mm cavity

8.2 Upgrade works

Downtakings

- Architraves and skirting blocks were carefully prised away from timber grounds
- The wall linings had previously been replaced in plasterboard on timber battens. The shutters pockets had been framed out, and the shutters were nailed shut, with the plasterboard nailed to the leading edges. The entire wall lining was structurally unsound, and came away as the shutters were carefully opened up, leaving the original stonework fully exposed

- Soffit panels were prised away from timber packers / timber safe lintels, exposing the cavity at the head of the window opening
- Window elbows and backs were removed in one piece

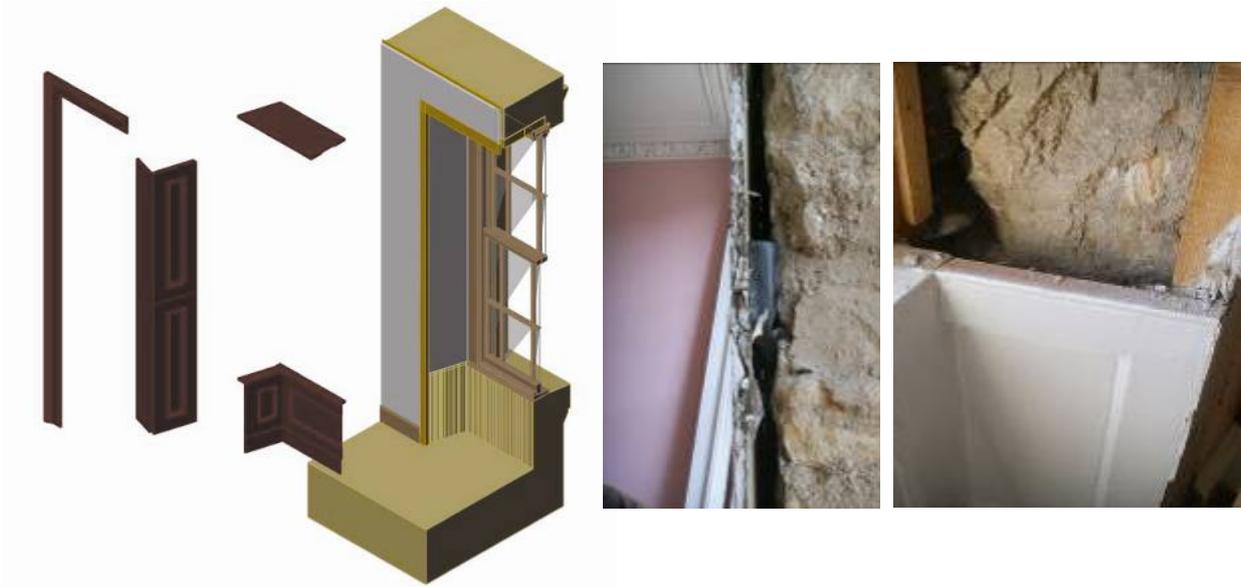


Fig. 29. Diagram and photographs showing dismantlings and exposed elements

Work to external walls

- The entire wall lining directly below the existing cornice was re-built in 50 x 25 mm timber framing, held clear from the masonry, with 25 mm rigid insulation, and 12.5 mm plasterboard, taped and filled



Fig. 30. Reframing and wall upgrade work

Upgrade work to windows

- The windows were fitted with single glazed, timber, side hung secondary glazed units with removable handles, to accommodate the shutters in the closed position
- The window reveals, elbows and back and shutter pockets were framed out with timber battens
- All timbers were held clear from the stonework, and the framing to the shutter pockets was sized to ensure adequate depth for pockets to accommodate shutters
- New timber packers were fitted to the window soffits
- Rigid insulation was cut and tightly fitted in between the timbers to the new framing and soffit packers as follows: 75 mm thick to window elbows, 100 mm thick to window back, 35 mm thick to shutter pockets, 35 mm thick to soffit



Fig. 31. Diagram and photograph showing insulation work to window opening

Reinstatement of window linings

- 6 mm ply shutter pocket linings pinned to new framing
- 12 mm timber cover plates fixed to face of secondary glazing case, and scribed to new shutter pocket lining, with all voids behind filled with rigid insulation
- Soffit panel screwed to new framing, and shutters re-fitted, with hinges screwed to face of secondary glazing case / cover plate

- Window elbows and back re-fitted, complete with cill pieces
- Continuous timber packers screwed to face of architrave / lath grounds, to sides and head of window openings, sized to neatly complete the shutter pockets (with the architraves fitted)
- Window architraves re-fitted, pinned through to new timber packers
- 12 mm timber cover plates to sides / top of architraves, scribed to the wall, and pinned through to the new timber packer
- All new woodwork to the window linings was painted with one primer / undercoat, and two coats gloss, and the final top coat applied to the timber secondary glazed units. All existing, reinstated woodwork was prepared, with any filling / making good painted with one undercoat / primer and one coat gloss, and a complete top coat
- New plasterboard wall lining re-papered in 800 gauge lining paper and painted with three coats emulsion
- Fitted carpets were trimmed and refitted, to suit the new line of the window linings and architraves / skirting blocks

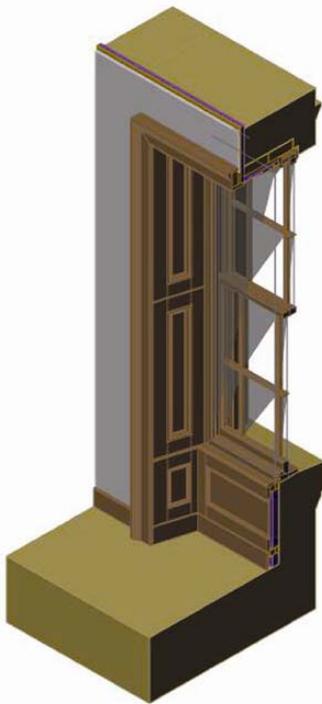


Fig. 32. Diagram and photographs showing completed works

Additional works

Insulation works were carried out to the shutters to one of the windows, involving upgrading works to the existing shutters and the manufacture of new shutter flaps, as these were missing, as follows:

- 10 mm Spacetherm blanket insulation packed into the existing shutter panels, with 3 mm ply cover plate pinned to shutter frame
- 10 mm Spacetherm blanket sandwiched between 3 mm ply panels pinned and glued to 16 x 18 / 40 mm re-bated frames, to form each new shutter flap
- Schlegel weather seal QWS 77 re-bated into leading edges of shutters, at hinged joint with flaps



Fig. 33. Completed works showing function of secondary glazing, simplex hinges and shutters

8.3 Results of thermal improvements

Pre-intervention testing: 17th to 25th February 2011; post-intervention testing; 28st March to 12th April 2011. Location: living room.

2 (1F2) Roxburgh St			U Values (W/m ² K) Living Room	
			Pre-Intervention	Post-Intervention
Location of measurement	Thickness (mm)	Improvement type	Monitored	Monitored
Sash & Case - SG Window	-	SG-Sec. glazing w/ Timber frame	5.2	1.5
Shutter	-	10mm Spacetherm blanket on to shutter	2.2	0.4

8.4 Outline costs

Living room and main bedroom

Secondary glazing (and associated works)	Timber single glazed (approx. 2.1 m high x 1.00 m wide)	£ 1,450 per window
Insulated wall framing	Total area: 3.90 m ²	£ 200 per m ²
Insulated shutters	Upgraded shutter and new flaps	£ 600 per window

9. Thermographic testing

Following completion of the thermal improvement works, one of the properties (Property E – 2 Roxburgh Street Flat 1F2) was surveyed using an infra-red camera. This can show up areas of heat loss by measuring surface temperatures. The higher the temperature on the surface, the more heat is escaping.

Prior to the works, this property had single glazed timber sash windows, which have a poor thermal performance. After being fitted with single-glazed secondary glazing, the U-value decreased from 5.2 to 1.5 W/m²K, an improvement of more than 70%. One set of window shutters were upgraded using a 10 mm aerogel quilt, which reduced the U-value down to 0.4 W/m²K with the shutters closed. This pre and post-intervention infra-red image was taken with the shutters shut. It demonstrates the reduction in heat loss from the improved windows and walls, indicated by the darker areas.



Fig. 34. Thermographic image of property E, showing the improved glazing
 © Scottish Energy Centre, Edinburgh Napier University



Fig. 35. Thermographic image of 16 Roxburgh Street, showing the thermal improvements to the ground floor windows on the left © Crown copyright (Historic Scotland)

10. Acoustic performance

The acoustic testing was performed in Property A, 16 Roxburgh Street, tested before and after the works. The table below shows the results:

Location	Condition	Acoustic performance* DIs,2m,nt,w(dB)
Front facade to living room	Closed sliding sash windows (pre-intervention)	28
Front facade to living room	Closed sliding sash windows and double-glazed secondary glazing.	41
Front facade to living room	Closed sliding sash windows and secondary double glazing, traditional wooden shutters closed.	42

* airborne sound insulation of facade wall construction

The results indicate an improvement from the original single glazed window to the secondary double glazed unit, and an additional improvement with the shutters closed. The testing was performed by taking into account street noise against internal conditions. A good benchmark for dwellings in this situation is above 35 dB. This figure indicates an acceptable level of sound insulation.

11. Feedback from tenants

Prior to improvements, tenants rated their windows as 'poor' with reference to security, ease of cleaning, thermal performance and acoustic performance. Tenants' annual energy costs in 2009/10 ranged from £569 to £1597 – all amounting to a little over or substantially more than 10% of the residents' predicted annual income. This put some of the tenants in 'fuel poverty'.

Post-completion feedback indicated that the outcome is seen as beneficial by the tenants, although there were a number of issues raised. As the specification was non-standard, and some elements were experimental, the level of site supervision required was beyond that of a normal window replacement contract. The duration of works was a major concern and all tenants would have preferred that the work could have been coordinated more tightly.



Fig. 36. Tenants pointed out that “you have to stretch both your arms wide and push hard to close the window from the tilt position. Not easy unless you are tall and strong”.

The work was conducted whilst the homes were still occupied. This presented challenges for all involved and was quite disruptive for residents. The fine dust exposed as areas previously undisturbed for over a century were opened up 'got

Historic Scotland Refurbishment Case Study 1

ADDRESS / WORKS	DESCRIPTION	TOTAL COSTS	ALTERATION COSTS	NET COST *	VAT RATE	VAT LIABILITY
	Less insulation works and repairs		10,053.69			
			6,692.64		0%	0.00
Flat 8, 22 Drummond Street						
INSULATION						
Rigid insulation	1 no. windows @ £88 per window			88.00		
Blown insulation	BCA insulation			278.31		
	attendance			176.00		
	patching blow holes			14.88		
				557.19	0%	0.00
ALTERATIONS						
Secondary Glazing Works	Joinery Downtakings / replacement secondary glazing units associated reinstatement works					
	Contract costs	1,651.31				
	variations	32.26				
			1,683.57			
	Less insulation works		557.19			
			1,126.38		0%	0.00
Flat 1, 33 Marshall Street						
INSULATION						
Rigid insulation	2 no. windows @ £88 per window			176.00		
Blown insulation	BCA insulation			276.31		
	attendance			176.00		
	patching blow holes			29.76		
				658.07	0%	0.00
ALTERATIONS						
Secondary Glazing Works	Joinery Downtakings / replacement secondary glazing units associated reinstatement works					
	Contract costs	3,202.31				
	variations	63.52				
			3,265.83			
	Less insulation works		658.07			
			2,607.76		0%	0.00
Flat 2F1, 2 Roxburgh Street						
INSULATION						
Rigid insulation	5 no. windows @ £88 per window			440.00		
Blown insulation	BCA insulation			743.20		
	attendance			176.00		
	patching blow holes			44.64		
				1,403.84	0%	0.00
REPAIRS						
Shelf over fireplace	Remove and re-fit			29.76	17.5%	5.21
				1,433.60		
ALTERATIONS						
Secondary Glazing Works	Joinery Downtakings / replacement					

Historic Scotland Refurbishment Case Study 1

ADDRESS / WORKS	DESCRIPTION	TOTAL COSTS	ALTERATION COSTS	NET COST *	VAT RATE	VAT LIABILITY
	secondary glazing units					
	associated reinstatement works					
	Contract costs	12,419.68				
	variations	158.80				
			12,578.48			
	Less insulation works and repairs		1,433.60			
			11,144.88		0%	0.00
Flat 1F2, 2 Roxburgh Street						
INSULATION						
Rigid insulation	2 no. windows @ £102.50 per window			205.00		
	1 no. pair shutters			520.00		
	Wall insulation/framing			1,092.80		
	Making good/re-decoration			860.00		
				2,677.80	0%	0.00
REPAIRS						
Window shutters	Repairs to split stiles			480.00	20%	96.00
				3,157.80		
ALTERATIONS						
Secondary Glazing Works	Joinery Downtakings / replacement					
	secondary glazing units					
	Alterations to shutter flaps					
	associated reinstatement works					
	Contract costs	6,321.96				
			6,321.96			
	Less insulation works and repairs		3,157.80			
			3,164.16		0%	0.00
TOTAL						
	TOTAL	40,596.17				867.50
	TOTAL VAT LIABILITY	867.50				

13. Conclusion

This case study contributes to Historic Scotland's wider programme of research into improving the thermal and acoustic performance of traditional buildings, and demonstrate how energy use and carbon emissions can be substantially reduced in pre-1919 buildings.

This project trialled a way of integrating secondary glazing with insulation behind the wall linings and around the window openings in tenement buildings, to improve the thermal performance of the entire external elevation. External doors were also upgraded. The secondary glazed units were designed so that the existing window features, such as the shutters and the easy-clean function of the sashes, remained fully operational. In addition, issues of how easily the measures could be replicated

and how occupants found the improvements in terms of usability were also considered. Communication with occupiers and how the disruption was managed and perceived were also important.

Due to the bespoke components used in this pilot study, and the small scale of works, the cost per property was substantial. Such an approach would not generally be affordable to social landlords unless the works attracted additional funding. However, it is believed that the tested approach is replicable, if unit costs can be substantially reduced. This could be achieved by modifying the specification of materials and by using factory-made secondary glazing units produced by volume manufacture. Cost savings might also be achieved by in-house maintenance departments being trained on how to coordinate the tested approach.

Carrying out the trial improvements without decanting the residents proved problematic, especially where all of the external wall/window elements were treated in a single operation. In these instances, it soon became clear that the treatment required to be phased if the properties were to remain occupied, possibly by treating each property in two halves to minimise the disruption. Also, by managing the tenants' expectations and carefully coordinating the works, further cost reductions should be possible.

The pilot demonstrated that the solution for installing secondary glazing where shutters are present can deliver a substantial thermal and acoustic improvement to the windows without impacting on the appearance or functionality of the existing window features. In addition, the thermal performance of walls and external doors was also improved considerably while retaining existing elements.

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Historic Scotland Refurbishment Case Studies

Available at www.historic-scotland.gov.uk/refurbcasestudies

- 1 Five Tenement Flats, Edinburgh
Wall and window upgrades
- 2 Wells o' Wearie, Edinburgh
Upgrades to walls, roof, floors and glazing
- 3 Wee Causeway, Culross
Insulation to walls and roof
- 4 Sword Street, Glasgow
Internal wall insulation to six tenement flats
- 5 The Pleasance, Edinburgh
Insulation of coom ceiling, attic space and lightwell
- 6 Kildonan, South Uist
Insulation to walls, roof and windows
- 7 Scotstarvit Tower Cottage, Cupar
Thermal upgrades and installation of radiant heating