Determination 2008/35

Determination regarding the code compliance of a house in which injected foam wall insulation has been installed at 475 Soldiers Road, Tauranga,

1. The matter to be determined

1.1 This is a determination under Part 3 Subpart 1 of the Building Act 2004[1] ("the Act") made under due authorisation by me, John Gardiner, Manager Determinations, Department of Building and Housing ("the Department"), for and on behalf of the Chief Executive of that Department. The applicant is R L Boardman & Co Ltd, the owner of the building ("the applicant") and the other party is the Western Bay of Plenty District Council ("the territorial authority"). The controlling incorporated company, Airfoam Wall Insulations Limited ("Airfoam") has been included as a party with an interest in this determination.

1.2 The application for determination made in May 2007 initially arose from the decision of the territorial authority to refuse to issue a code compliance certificate for 1-year old alterations and additions to a house, and subsequently to issue a notice to fix,

[1] The Building Act 2004 is available from the Department's website at www.dbh.govt.nz.

because it was not satisfied that it complied with the Building Code[2] (Schedule 1, Building Regulations 1992).

1.3 The alterations included installation of urea-formaldehyde foam insulation ("foam insulation") in the cavities behind brick veneer cladding, as well as installation of fibre-cement cladding.

1.4 In December 2007 the territorial authority informed me that it had issued a code compliance certificate in June 2007 for all the consented work in the additions and alterations. As the consent did not include the installation of foam insulation the code compliance certificate did not include the installation of foam insulation. I have not been supplied with a copy of the certificate.

1.5 I note that the installation of the urea-formaldehyde foam insulation was not carried out under a building consent. Consequently, I believe, I must decide whether the installation is building work, and, if it is building work, whether it is exempt from the requirement to have a building consent. (See paragraph 13.3).

1.6 I also note that the territorial authority has issued a notice to fix (see paragraph 3.7) in which the sole matter of contravention is the unconsented installation of the injected foam insulation. However the notice to fix refers by number to the building consent that was issued for all the other building work, (ie excluding the installation of the foam insulation), for which a code compliance certificate has been issued.

1.7 As a consequence of the matters noted in paragraphs 1.5 and 1.6, and for the sake of clarity, I consider that the matters to be determined are whether:

- the unconsented building work, namely the installation of injected foam insulation, complies with the Building Code, in particular Clauses B2 "Durability", E2 "External Moisture", E3 "Internal Moisture", F2 "Hazardous Building Materials" and H1 "Energy Efficiency" (see sections 177 and 188 of the Act)
- the scope of the notice to fix as to matters of contravention is correct
- the consented building work complies with the Building Code, including Clauses B2 and E2.

1.8 In making my decision, I have considered:

- the submissions of the parties
- a study undertaken within the Department
- the reports of the two independent experts commissioned by the Department to advise on this matter ("the expert(s)")
- observations I made in the course of a visit to the house
- the other evidence in this matter.

[2] The Building Code is available from the Department's website at www.dbh.govt.nz.

I have evaluated this information using a framework that I describe more fully in paragraph 10.1.

1.9 In this determination, unless otherwise stated, references to sections are to sections of the Act and references to clauses are to clauses of the Building Code.

2. The building

2.1 The single-storey house is situated on a level section that is in a high wind zone in terms of NZS 3604[3]. The house is of standard light timber-framed construction on a concrete ground floor slab and the pitched roof generally has 600mm wide eaves projections. A close-boarded deck is constructed at ground level to three elevations of the building.

2.2 The exterior walls of the house are clad with a newly-plastered brick veneer. The main walls of the new extensions, apart from a small area of brick veneer below a bay window, are clad with fibre-cement sheets fixed over a cavity. Both the brickwork and the fibre-cement sheets are finished with mesh reinforced textured plaster, followed by a three-coat acrylic paint system. The high level gables of the house are clad with painted H3 treated radiata pine bevel-backed weatherboards.

2.3 The cavities behind the brick veneer have been in-filled with foam insulation. The applicant has informed me that the installation of this insulation was not included in the original building consent. Fibreglass insulation has been used in the new extension.

2.4 According to the second expert, the timber exterior wall framing is likely to be a mixture of both treated and untreated timber. I have not been provided with any more specific written information as to the treatment or otherwise of this framing.

3. Sequence of events

3.1 I have been supplied with an undated copy of a building consent (No 73702) issued by the territorial authority.

3.2 I have not received any information regarding inspections of the consented building work carried out by the territorial authority during the construction of the alterations. Although the notice to fix issued by the territorial authority (see paragraph 3.6) bears the consent number 73702, it refers only to the foam insulation inserted into the cavities behind the brick veneer, which is unconsented work. I accept that the installation of the foam insulation is the territorial authority's major concern.

3.3 On 1 March 2007 the textured plaster applicator faxed the builder, noting that due to the lack of building paper behind the brick veneer, the foam insulation had filled the cavity behind the brickwork as well as the cavities between the timber wall framing members. The applicator stated that, as the weep holes in the brickwork were now blocked with the insulation, they were no longer functioning as they should. This

[3] New Zealand Standard NZS 3604:1999 Timber Framed Buildings

problem had also been compounded by the installation of a deck constructed at floor level. The applicator expressed the hope that the lack of effective weep holes would not prevent a code compliance certificate being issued.

3.4 The textured plaster applicator provided a producer statement dated 7 May 2007 for mesh reinforced plaster applied to "Insulclad" and brick veneer. I note that while the statement refers to "Insulclad", the non-brick claddings as installed are fibre-cement sheets. The statement said that the applicator was satisfied that the substrate over which the plaster had been applied had been suitably prepared for that system and the required flashings had been properly installed.

3.5 The Airfoam franchisee that installed the foam insulation ("the installers") wrote to the applicant on 19 March 2007 guaranteeing the insulation for 50 years.

3.6 The territorial authority issued a notice to fix dated 23 March 2007. The notice listed the particulars of contravention or non-compliance as:

> Expanding foam insulation has been installed in the external walls thereby filling the cavity between the brick cladding and the wall framing and preventing drainage and ventilation of that cavity.

To remedy the contravention or non-compliance the applicant must:

> Remove the expanding foam and reinstate the cavity between the brick cladding and the wall framing.

3.7 I observe here that although the notice to fix referred to the building consent No 73702, the particulars of contravention or non-compliance refers only to the installation of the foam insulation which was unconsented building work.

3.8 In response to the notice to fix the installers stated that they were working towards getting their product tested as to its code-compliance by an independent testing authority. This was also confirmed in an email to the applicant sent on 29 March 2007.

3.9 On 28 March 2007 the applicant wrote to the territorial authority stating that a determination was being sought and that the installers were in the process of getting the foam insulation tested.

3.10 At the time of this determination the Department has received no results from the product testing described in paragraph 3.9.

3.11 The Department received an application for a determination on 16 May 2007.

4. The submissions

4.1 In a covering letter dated 28 April 2007, the applicant noted that the decision to use foam insulation was due to the lack of insulation in the existing walls of the house. The applicant was of the opinion that the foam insulation was a good product although there was disappointment that it may not be code-compliant. The applicant had been advised by the installers that Airfoam had been operating for some 26 years and had installed the foam insulation in over 9,000 houses. It was also noted that the

upper part of the house was generally protected by 700mm verge projections and there was additional protection provided by a high-level frieze board.

4.2 The applicant forwarded copies of:

- the plans
- the building consent
- the notice to fix
- the correspondence with the territorial authority, the installers, and the plaster applicator
- the textured plaster applicator's producer statement
- some of Airfoam's technical documentation.

4.3 The territorial authority did not provide a detailed submission.

4.4 Copies of the applicant's documentation were forwarded to the territorial authority at the time of application. The territorial authority made no submission in response.

4.5 On 11 December 2007 the territorial authority made a submission in response to the draft determination. The lengthy delay in making a submission left me ignorant of the fact that a code compliance certificate had been issued for all the consented building work. Had the territorial authority provided that information in good time I could have narrowed the scope of the determination and concentrated on the unconsented foam insulation work.

5 The effects of using foam insulation behind brick veneer

5.1 In order to form an opinion as to whether the house is currently compliant with the Building Code I need to consider to what extent the cladding and any other systems in the house have been affected by the use of foam insulation in this particular case. I also need to consider whether any of the other building work forming part of the alterations may have affected compliance.

5.2 The original cladding system consisted of a single-skin brick veneer separated by a cavity from the structural timber frame that supports the roof. While a barrier of water-proof but vapour permeable building paper is usually fixed to the cavity side of the timber frame in this instance such a barrier was not present. A single-skin brick veneer is designed to provide a rain screen that protects the timber frame from the weather. The cavity is designed to prevent moisture that may penetrate the brick veneer, through cracks in the mortar or through the interstices of the bricks, from coming into contact with the timber framing. The cavity is drained to the exterior by some open perpends (vertical gaps between some of the bricks in the lowest course of bricks) which also allow some ventilation of the cavity. Although it could not be observed in this house, it was common for the top of the cavity behind the brick veneer to be ventilated to the exterior or into the (ventilated) ceiling space. As originally built, the junction of the brick veneer with the concrete floor slab would

have occurred above ground but below floor level to facilitate drying of the bricks and the edge of the slab after rain.

5.3 A single-skin brick veneer takes advantage of the water absorbing properties of fired clay bricks. Those properties mean that although a skin of bricks is not completely water repellent or completely water-proof, moisture can be intercepted by absorption into the bricks and released later by evaporation into the interior cavity or to the exterior open air. In effect the bricks act as a reservoir for the temporary storage of external moisture.

5.4 The alterations to this house have significantly modified the original brick veneer cladding system. In particular I note that:

- an impervious three-coat paint system over a reinforced textured plaster has been applied to the exterior face of the brick veneer. The effect of the paint and plaster is that the brick skin has been made water-repellent to external moisture and can only absorb moisture from the cavity, if a cavity exists. Moisture from the bricks cannot escape to the exterior by evaporation through the surface of the bricks.
- a foam insulation material has been injected into the cavity between the brick skin and the interior wall lining. As a result there is no longer a drained and ventilated cavity between the brick skin and the timber frame. The perpends have become redundant. Another effect of the foam insulation is to alter (and improve) the thermal insulation properties of the wall system.
- a close-boarded deck has been constructed around some of the exterior walls of the house and fitted in contact with those walls. There is no provision for ventilation of moisture under large sections of these decks, as they are virtually resting on the ground. The effect of the deck installation is to trap accumulating moist air near the junction of the wall cladding with the concrete floor slab. The presence of the trapped moisture in that location may be expected to discourage the drying out of moisture from the bottom of the wall and the edge of the floor slab.

6. The Department's internal study

6.1 In order to assist me to form an opinion regarding the foam insulation an internal Departmental study was undertaken. I summarise the main findings of this study as set out in the following paragraphs.

6.2 Foam insulation has been used with a high degree of success in the United Kingdom ("the UK"), where there have been few failures reported, especially when installed by competent applicators.

6.3 The most commonly used UK technique is the injection of the foam insulation into the cavity formed by two skins of brick. The outer skin of brick is often not exposed to the combinations of wind and rain that affect New Zealand buildings. In New Zealand it is accepted (refer paragraph 5.2) that a brick veneer wall is a rain-screen that may admit moisture as a result of wind-driven rain, which can escape by

evaporation or draining to the exterior through the open perpends at the base of the wall.

6.4 Overseas evidence indicates that the formaldehyde gas ("formaldehyde") released as the foam insulation cures is an irritant to some people, the extent of which differs from person to person. The use of such insulation was banned in Canada in 1980 on account of reports of home-owners suffering ill effects from formaldehyde. No such ban appears to have been imposed in the UK or in Europe. Installers are recommended to advise owners about the need for an augmented ventilation regime for a few weeks after installation, and if discomfort occurs, the ventilation should be increased. Evidence indicates that short-term exposure to formaldehyde at the levels normally observed does not have any long-term effects.

6.5 As the foam insulation has a low thermal conductivity (and conversely a high thermal resistance (R) for a given thickness of material) when compared with other thermal insulating materials used in building work, it may be expected to make a useful contribution to the thermal resistance of a wall system and to enhance the whole-wall performance that the Building Code requires in this respect (refer paragraph 5.4).

6.6 As to timber-framed construction with a brick veneer, one reference paper[4] states that the 50mm wide cavity separating the timber frame from a brick veneer "must remain open to provide adequate ventilation for the timber frame and therefore should not be filled with [foam insulation] or any other insulation material." (The "adequate ventilation" is for the removal of moisture vapour). The majority of British houses in which foam insulation has been successfully used are of double-skin brick construction in which the barrier to infiltration of formaldehyde is the brick interior skin. The brick skin appears to be considered a better barrier than plasterboard lining, possibly because the interior brick skin is often plastered on the interior face, thus sealing off cracks or other defects in the skin.

6.7 Airfoam claim that foam insulation is permeable to water vapour but is otherwise impermeable to water. In that regard, it is similar to the "breather-type" building papers used behind claddings. Acceptable Solution E2/AS1 requires vapour resistance for wall wraps to be equal to or less than 7MN s/g in accordance with ASTM E96B. Airfoam states the Water Vapour Permeability of its product (u) is 1.7 to 3.4, in accordance with BS 4370. The relationship between ASTM E96 B and BS 4370 is not immediately clear to me.

6.8 A UK reference[5] notes that the total filling of the cavity of existing walls has been "very extensively and successfully used". The few reported failures due to rain penetration are attributed to pre-existing poor workmanship in the wall construction. Initially in the UK, the insulation was sometimes injected by ill-trained operatives, whose careless mixing and workmanship led to problems with irritant fumes being given off, both during the installation process and later into the building causing

[4] *Formaldehyde Vapour from Urea-formaldehyde Foam Insulation*, BRE Information Paper IP 25/82, Building Research Establishment, November 1982.

[5] *The Construction of Buildings*, Vol 1 sixth edition, R. Barry, published 1996 Blackwell Science.

considerable distress to the occupants. Research carried out in Australia[6] shows the importance of correct formulation, as some products with high acidity exhibited dimensional instability, with some exhibiting linear shrinkage of more than 30% after only short periods of exposure to high humidity.

6.9 A BRE Information Paper[7] says that discomfort and irritation caused by the produced formaldehyde occurs in a limited number of cases. In the UK most of the subject houses have an internal brick skin which generally works well to block off the formaldehyde. The suggested first stage remedy is to "slightly increase the ventilation of the property" followed by careful removal of foam insulation that has entered the loft or living space, and sealing of the points of entry. If necessary, the third stage is to remove the foam insulation from more inaccessible places and seal them off. The Australian study[8] reported a low incidence of people suffering discomfort and irritation.

6.10 In guidelines issued to homeowners Airfoam says "…we advise homeowners to retain the recommended ventilation regime for at least 4 weeks", indicating that Airfoam has considered the need for a period of extra ventilation to disperse the formaldehyde.

7 The first expert's report

7.1 The first independent expert whom I engaged is a registered Architect and has had significant experience in the New Zealand Institute of Building Surveyors. This expert carried out an assessment of the franchise arrangements, quality assurance procedures, and the processes involved in the supply and installation of foam insulation. The expert carried out his assessment and furnished a report that was dated 11 September 2007. The main areas of this report are summarised below.

7.2 The insulation system and its history

7.2.1 The insulation system is comprised of a urea-formaldehyde foam insulation that is injected into existing external wall cavities using specialised equipment. Airfoam claims to have carried out about 9,000 installations spanning a period of 26 years up to the present time. The installations have generally involved formerly un-insulated pre-1977 weatherboard or masonry veneer houses, although the system has also been installed in some Fibrolite and stucco clad houses.

7.3 Company and franchise structure

7.3.1 Airfoam is the controlling incorporated company and there are 12 active franchises operating throughout the country. The franchisees operate as independent contractors. Should a franchisee be unable or unwilling to proceed with a project within a set time scale, then Airfoam is entitled to take over that project.

[6] Field Performance, Hydrolysis and Durability of Urea Formaldehyde Foam Insulation in Australian Dwellings, Stephen K Brown in Insulation Materials: Testing and Applications. 2nd Volume, ASTM STP 1116,R S Graves and D C Wysocki, Eds, American Society for Testing and Materials, Philadelphia, 1991.
[7] *Urea-formaldehyde Foam Cavity Wall Insulation: Reducing Formaldehyde Vapour in Dwellings*, A. H Cockram and P J Arnold, BRE Information Paper IP 7/84, Building Research Establishment, March 1984.
[8] Ibid,12.

7.3.2 Airfoam says it leases the injection equipment and supplies all the raw materials and all the relevant support documentation to the franchisees. Airfoam says it also organises conferences, training programmes, and ongoing off-site training for all new franchisees and operatives on a compulsory basis. According to Airfoam a standardised tendering and monitoring procedure, including job record sheets that provide a record of the amounts of foam used and its properties, has been established. Each franchise is monitored twice each year and is required to submit job records and samples of foam to be tested by Airfoam on a monthly basis. I have also been informed that Airfoam have now introduced a random inspection procedure for all its franchises.

7.3.3 Information, including the quotation, the job record sheet and a copy of the certificate of completion for each project, is forwarded by the franchisee to Airfoam. Airfoam says it uses this information as a tool to assess quality control and to provide a post-installation check. The quality assurance plan used by Airfoam was established by Standards New Zealand in 1980. However, Standards New Zealand has not had any involvement in the plan over the last few years. While it does not have a specific ethical trading statement, Airfoam's "14 Points of Culture" includes references to ethical business behaviour.

7.4 Installation techniques

7.4.1 The expert observed and described both the existing and newly developed prototype mixing and injecting equipment used to install the foam insulation. The prototype automatically controls the delivery rates and material and air mixtures and incorporates data-capture features. A comprehensive operators' manual has been compiled and all installations have to be carried out under the direction of trained operatives. The expert also visited two properties to observe the foam injection processes.

7.4.2 The expert was not aware of any published data concerning the levels of formaldehyde produced during the foam insulation processes. The expert noted that a Department of Labour publication[9] had set a guideline for a safe exposure level of 1 part per million (1ppm) for formaldehyde. A UK publication, published in 2000[10], noted that the formaldehyde levels produced during the installation of foam insulation produced a work-face exposure of 0.5ppm. This amount is half the level quoted in the Department of Labour publication.

7.5 Building Code compliance

7.5.1 General

Airfoam informed the expert that it had not obtained building consents for the foam installation projects that have been completed to date. It considered that a consent was not required as the work was in the nature of an alteration. The expert noted that there are no Acceptable Solutions, NZ Standards or independent appraisals regarding the insulation applied by Airfoam.

[9] *Workplace Exposure Levels effective 2002.*
[10] "Local Authority Circular" published by the Health and Safety Executive/Local Authorities Enforcement Liaison Committee.

7.5.2 Clause B2 - Durability

The expert had not located any published material as to the durability of the foam insulation. However, he said the foam insulation would not be susceptible to those agents that commonly cause degradation of other building materials, nor is it exposed to the effects of UV light that can degrade some plastic products. The expert noted that in the UK, the Cavity Insulation Guarantee Association provide a 25 year warranty for foam insulation.

7.5.3 Clause E2 - Weathertightness

The expert referred to a UK paper[11], that identified combinations of potential factors for rain penetration that increase the risk to a dwelling with retro-fitted cavity insulation. These include walls that have defects in their outer faces and are exposed to prevailing driving rain. The expert was of the opinion that these associated risks would apply to conditions experienced in New Zealand. In addition, other risks include:

- absorption by the timber framing of water contained in the foam insulation
- the potential of the foam insulation to block drainage paths
- the incomplete or partial filling of wall cavities where building paper is present.

Table 4 of a UK Approved Document[12] attached to the expert's report sets out maximum recommended exposure to driving rain zones for masonry walls with foam insulation. Where there are unplastered walls with 50mm wide cavities, the foam insulation is restricted to walls that are in sheltered exposure zones. If such walls are plastered, the foam insulation can be considered where there is moderate to severe exposure. As Table 4 is particularly pertinent and informative I have chosen to reproduce the information from it below.

7.5.4 Clause E3 - Internal Moisture

The expert considered that the injection of the foam insulation would generally improve the thermal resistance of the walls. However, under some circumstances, there is also a risk of condensation forming within the wall cavity regardless of the type of insulation used.

7.5.5 Clause F2 - Hazardous Building Materials

The expert noted that F2/AS1 does not set limits for concentrations of formaldehyde and referred to the Labour Department publication described in paragraph 7.4.2[13]. Data provided by a test carried out by Airfoam in 1981[14] indicated levels in the range of 0.21 to 0.39ppm at a test site 30 days after installation. These levels are well within the limit (1ppm) set out in the Labour Department circular. Airfoam has

[11] *Rain Penetration Problems Associated with Retro-fitted Cavity Insulation,* Hillary Davies and Graham Wilmshurst, Structural Survey, Vol 12 No.2, 1993/4, pp5-9
[12] Approved Document C "Site preparation and resistance to contaminants and moisture", Office of the Deputy Prime Minister.
[13] Ibid, 5.
[14] *Preliminary Report on Formaldehyde Levels in Sandringham House*, J Spedding, Applied Research Office University of Auckland, April 1981.

informed the expert, but has not provided any supporting evidence, that the brand of foam insulation that they are now using releases less formaldehyde.

Table 4 Maximum recommended exposure zones for insulated masonry walls

Wall construction	Maximum recommended exposure zone for each construction (1 = low exposure, 4 = high exposure)							
Insulation method	Min. width of filled or clear cavity (mm)	Impervious cladding		Rendered finish		Facing masonry		
		Full height of wall	Above facing masonry	Full height of wall	Above facing masonry	Tooled flush joints	Recessed mortar joints	Flush sills and copings
Built-in full fill	50	4*	3	3	3	2	1	1
	75	4	3	4	3	3	1	1
	100	4	4	4	3	3	1	2
	125	4	4	4	3	3	1	2
	150	4	4	4	4	4	1	2
Injected fill <u>not</u> UF foam	50	4	2	3	2	2	1	1
	75	4	3	4	3	3	1	1
	100	4	3	4	3	3	1	1
	125	4	4	4	3	3	1	2
	150	4	4	4	4	4	1	2
Injected fill UF foam	50	4	2	3	2	1	1	1
	75	4	2	3	2	2	1	1
	100	4	2	3	2	2	1	1
Partial fill								
Residual 50mm cavity	50	4	4	4	4	3	1	1
Residual 75mm cavity	75	4	4	4	4	4	1	1
Residual 100mm cavity	100	4	4	4	4	4	2	1
Internal insulation								
Clear cavity 50mm	50	4	3	4	3	3	1	1
Clear cavity 100mm	100	4	4	4	4	4	2	2
Fully filled cavity 50mm	50	4	3	3	3	2	1	1
Fully filled cavity 100mm	100	4	4	4	3	3	1	2

*** The exposure zones are obtained from a map of UK exposure zones that accompany the Table.**

7.5.6 Clause H1 – Energy Efficiency

The Airfoam literature indicates that there is a thermal resistance of R2.9 for a 100mm thickness of foam, and the expert concluded that such resistance would meet the requirements of Clause H1.

7.6 Copies of the first expert's report were provided to each of the parties on 19 September 2007. The applicant responded in a letter dated 23 September noting the lack of research to provide evidence to show there may be a problem with the use of the foam insulation and that the installation of insulation is not new work (which would then require a building consent).

8. The second expert's reports

8.1 As mentioned in paragraph 1.8, I engaged a second independent expert, who is a member of the New Zealand Institute of Building Surveyors, to provide an assessment of the building work, with an emphasis on the installed foam insulation.

8.2 Testing

8.2.1 The expert inspected the house on 24 August 2007, 9 September 2007 and 11 September 2007, and furnished a report that was finalised in September 2007. The expert noted that the standard of building work and finish of elements is generally to a high standard.

8.2.2 The expert removed sections of internal linings to assess the details of the wall voids, and I am prepared to accept that the details exposed at these situations apply to other similar locations throughout the building.

8.2.3 The expert took three internal non-invasive moisture readings. One of these was at an exposed bottom plate in a foam insulated wall behind a bedroom wardrobe and an elevated reading was recorded in comparison with one taken in close proximity at a higher level. The third reading was at an exposed bottom plate in a fibreglass insulated wall where another elevated reading was recorded. There was also significant condensation on the fibreglass insulation and adjoining building wrap at this latter location. The expert did not find any evidence that the internal wall linings had become deformed.

8.2.4 Non-invasive readings taken at the external face of the brick veneer walls indicated that the lower sections contained higher moisture levels than the upper brick courses. The expert also removed a section of the deck and subsequent non-invasive testing at the base of the fibre-cement cladding also indicated elevated moisture levels.

8.2.5 On the final site visit the expert carried out 14 invasive moisture tests. Eleven of the tests were into the framing where the foam insulation has been installed. Four of the moisture readings were in an acceptable range and the remainder were at an elevated level, ranging from 20% to 48%. Three similar tests were undertaken where fibreglass insulation is present and two of these were at elevated levels of 22% and 28%. Elevated moisture levels recorded after cladding is in place generally indicate

that external moisture is entering the structure. The expert did not find any significant evidence that the foam insulation adversely affected adjoining pipework, metal fixings, and like elements.

8.2.6 The expert noted that every cubic metre of the prepared foam insulation contains approximately 40 litres of water. Given the height of the brick walls and the 150mm maximum thickness of the insulation, a large volume of water is present in the wall cavities. In this case the evaporation of the water as the foam cured was difficult because of the impervious nature of the total wall structure.

8.2.7 The expert also took samples of the foam insulation at four levels at one location. Tests of the residual moisture in the samples indicated that the samples from the two lower levels contained approximately 100% higher moisture contents than those from the upper levels. Permeability tests also indicated that water can easily percolate downwards through a "column" of the foam insulation.

8.2.8 The expert also noted that the two persons present at the site visits experienced eye and nasal irritations while the foam insulation cores were being removed and that there was some minor irritation on his hands while handling the lower two samples. Research by the expert indicated that the foam insulation contains high levels of urea-formaldehyde, acrylic acid, and possibly ammonia and acrylimide. However, the expert thought it likely that irritant levels could reach acceptable levels once the foam insulation dried out and internal air changes had flushed out any irritants in the insulation.

8.2.9 The expert carried out a series of air tests in five rooms using "Draeger Biocheck" urea formaldehyde test units either hung from the central ceiling areas, or positioned on wardrobe shelves or set in a wall cavity. It was noted that as three of the rooms were well ventilated, the formaldehyde levels obtained in these areas would be lower than if the rooms were fully sealed. The expert compared the results obtained with the Draeger technical information, and established that two locations in open rooms passed the test, two were marginal and two, which were within the wardrobes, failed. The expert observed that it was likely that the formaldehyde levels would increase in the winter months and noted that the free formaldehyde is present many months after the foam insulation was injected.

8.3 The brick veneer

8.3.1 The expert commented specifically on the brick veneer as follows:

- The ability for moisture introduced by the installation of the foam insulation to be removed from the veneer cavity is severely reduced because the exterior of the brickwork is now fully plastered and painted with the drainage holes (perpends) blocked, and the adjoining internal wall linings are wall papered. The expert also noted Airfoam's instructions state that the foam insulation should not be injected in situations where there are near impervious materials on both sides of a wall.
- Advice from one major brick manufacturer indicated that its veneer brickwork required at least one side being able to "breathe" or to be in contact with the air. This enables moisture to be carried away from the bricks and prevented

premature degradation of the materials. The expert noted that while the foam insulation had shrunk, this had occurred away from the framing or internal linings and it had adhered to the inner brickwork face, thus impeding ventilation of the bricks.

- The brick veneer on the south side of the garage, which has not been injected with foam, has vent holes at ground level and, although there is some drainage adjacent to them, any water ingress through the vent holes could prematurely damage the bricks.

8.3.2 As set out in paragraph 8.3.1, the expert obtained an opinion from a major brick manufacturer, which was attached to the expert's report. The opinion, which was dated 25 August 2007, stated that the 50-year warranty issued for the manufacturer's bricks when laid with a 40mm cavity would be invalidated if the cavity were to be infilled. Filling the cavity meant that any latent salts and moisture produced during the laying or plastering processes would be entrapped in the bricks. This could result in the structure and compressive strengths of the bricks being compromised.

8.3.3 The brick manufacturer also stated that a foam-filled cavity could be considered if the following actions were taken:

1. The bricks and plaster would need to be completely dry before foam could be added (how would this be measured?).
2. The coating system would need to be completely impervious to any form of moisture leakage or failure for the 50 year life of the brick. Zero leakage tolerance.
3. The top of the veneer would need to be completely closed off and sealed.
4. The brick would need to be a solid unit (no voids) simply because there is a real possibility of condensates forming on the inside walls of the brick voids causing moisture to be trapped in the veneer.

8.3.4 In the present case, I note that the brickwork has been in place for many years, which may affect the relevance of the brick manufacturer's opinion.

8.4 The fibre-cement cladding

8.4.1 With regard to the fibre-cement cladding, the expert noted:

- the taping and sealing at the junctions of the external joinery units and the cladding is poorly executed
- the close-boarded decking adjacent to the cladding is swollen, is hard up against the cladding and the top of the boards are above the base of the cladding. The decking is also flush with the adjoining ground levels at some locations, which prevents adequate drainage and ventilation of the space under the deck.

8.5 Copies of the second expert's report were provided to the parties on 12 September 2007.

8.6 The applicant responded to the report in a letter to the Department dated 17 September 2007. I summarise the applicant's comments as follows:

- No wallpaper had been applied to the interior of the external walls at the time that the foam insulation was installed.
- The ground levels adjoining the laundry have remained unchanged since the house was last purchased.
- The wettest area of the house, which is under the rear hall bay window seat, is of new brick veneer construction and has fibreglass insulation. There was evidence of moisture at this location that could be caused by condensation.
- The applicant noted that the high moisture readings could be due to the very wet winter weather that had been experienced this year. It was suggested that moisture readings be taken in the summer as a comparison with those already recorded.
- It was accepted that there could be a ventilation problem under the deck.
- The applicant had not experienced any problems when handling the foam insulation and was not conversant with the formaldehyde problems that had been raised. However, as the house was ventilated on an almost daily basis, the question of the presence of formaldehyde was not perceived to be a problem.
- The applicant also commented on his dealings with the territorial authority and the installation of the foam insulation in general.

8.7 On 19 October 2007 I visited the house at the invitation, and in the presence, of the owner. I was accompanied by the second expert and two officials from the Department. The territorial authority was invited but elected not to attend. The expert removed a section of interior wall in the laundry to show me the foam insulation, and showed me the window seat where fibreglass insulation had been used. He also lifted a section of the external decking to show me the ground conditions below.

8.8 In order to discover whether the moisture levels originally detected in the walls in August and September 2007 had altered with the passage of time I commissioned the second expert (see paragraph 8.1) to revisit the house and take a further set of moisture readings from the same locations he had tested during his first inspection. He visited the house in March 2008 and reported the following:

- Where Airfoam has been injected into the existing walls moisture levels had reduced to near acceptable levels of 16 to 19%. That is, the moisture associated with the Airfoam product at the time of injection appears to have dissipated. This dissipation may be expected to continue, albeit more slowly as the point of equilibrium moisture content (EMC) is neared.
- There is evidence of moisture transmission through the slab in the laundry where the garden is raised above the floor level. (Guidelines are for the interior floor level to be 225 mm above the external ground level.)
- The front deck which is exposed to the more direct sunlight appears to have sufficient ventilation. However along the rear wall ventilation is inadequate and moisture levels remain elevated in the bottom plate of the wall frame.

- The more that the ventilation can be improved the better.

9 The draft determination

9.1 On 13 November 2007, I issued a draft determination to the parties to give them the opportunity to check the accuracy of the facts, note any omissions, or any other errors they might identify. Insofar as the comments received related to the matters for determination in this case I have summarised the responses below.

9.2 On 11 December 2007, the territorial authority responded by letter. As noted in paragraph 4.5, this was the first occasion that the territorial authority made any submission on the matters in dispute. The territorial authority was of the opinion that the building consent should not be amended and that the contents of the notice to fix required additional elaboration. The territorial authority also stated that the removal of a cavity as detailed in E2/AS1 would make the building non-compliant.

9.3 I have considered the territorial authority's concerns but am not persuaded to amend the draft determination. I also observe that non-compliance with a Compliance Document does not necessarily make a building non-compliant.

9.4 On 6 December 2007, Airfoam made a detailed submission commenting on the draft determination. The submission agreed with some aspects of the draft and suggested certain amendments. I have taken the submission into account in preparing this determination. Airfoam also described additional processes that were being put in place to improve the quality of its product and to provide additional guidance as to its installation. Comment was also made regarding the past performance of the foam insulation, discussions held with various parties, and the content of the notice to fix. A "tutorial DVD" was enclosed as evidence that Airfoam is constantly improving and upgrading its systems.

9.5 In addition Airfoam made further comments that I summarise and discuss in the following paragraphs.

9.6 Airfoam referred to various tests that had been carried out on the foam insulation and to commentaries on foam insulation tests. However, not all this information was from independent sources, nor were any details provided to substantiate the described information.

9.7 The submission noted that moisture would dissipate to the "the low pressure side of the structure" but did not elaborate on how such moisture would be dissipated from the wall system itself.

9.8 Airfoam was concerned that most of the building defects related to the fibre-cement cladding and not to the infilled brick walls. I am of the opinion that the determination has clearly isolated the defects in the fibre-cement cladding from the concerns regarding the existing foam filled brick walls.

9.9 It was submitted that the brick veneer cladding was required to have a durability term of only 15 years and that this term should also apply to the foam infilled walls.

While I accept that the brick veneer cladding has only to be compliant for a minimum of 15 years, I note that the framing has to be durable for the "life of the building, being not less than 50 years".

9.10 Airfoam also questioned whether its foam insulation was required to comply with the requirements of the Building Code. Section 17 of the Building Act states that all building work must comply with the Building Code. As discussed in paragraph 13, it is my view that the installation of the insulating foam is building work under the Act and therefore must comply with the Building Code.

9.11 After careful consideration of the very general, but largely unsubstantiated (refer paragraph 9.6), Airfoam submission, I have not been persuaded that the draft determination requires to be changed, apart from minor amendments.

9.12 On 17 December 2007, the applicant wrote to the Department, noting with surprise that the territorial authority had issued a code compliance certificate for the work carried out but had treated the foam insulation as a separate matter. While the builder had received a copy of the code compliance certificate he had not informed the applicant of that fact.

10 Evaluation for code compliance

10.1 Evaluation framework

10.1.1 In evaluating the design of a building and its construction, it is useful to make some comparisons with a relevant Acceptable Solution[15], in this case E2/AS1in particular, which will assist in determining whether the elements of a house are code compliant. However, in making such comparisons, the following general observations are valid:

1. Some Acceptable Solutions are written conservatively to cover the worst case, so that they may be modified in less extreme cases and the resulting alternative solution will still comply with the Building Code.
2. Usually, when there is non-compliance with one provision of an Acceptable Solution, it will be necessary to add one or more other provisions to compensate for that in order to comply with the Building Code.

10.1.2 The approach in determining whether building work is code-compliant and is likely to remain so, is to apply certain principles. This involves the examination of the design of the building, the surrounding environment, the particular building elements and their installation, and the moisture tolerance of the external framing. The Department and its antecedent, the Building Industry Authority, have also described risk factors in previous determinations[16] (for example, Determination 2004/1) relating to cladding and these factors can also be used in the evaluation process for other elements.

10.1.3 The consequences of a building demonstrating a high risk is that building solutions that comply with the Building Code will need to be more robust. Conversely, where

[15] An Acceptable Solution is a prescriptive design solution approved by the Department that provides one way, but not the only way, of complying with the Building Code. The Acceptable Solutions are available from The Department's Website at www.dbh.govt.nz.
[16] Copies of all determinations issued by the Department can be obtained from the Department's website.

there is a low risk, the solutions may be less robust. In any event, there is a need for both the design of any building element and its installation to be carefully carried out.

10.2 Risk factors

10.2.1 In relation to these characteristics and in particular the foam insulation, I find that while the house is single storey and has 300mm to 600mm eaves projections, it is situated in a high wind zone that according to the first expert is subject to high dampness levels and frequent cold nights in a generally cloudy environment. Accordingly, I am of the opinion that the house is subject to adverse weather conditions that can detrimentally affect the performance of the foam insulation if the exterior cladding failed. In addition, by reason of its age, the house is likely to have at least some external wall framing that may not provide resistance to the onset of decay if the framing absorbs and retains moisture.

11 The legislation

11.1 I consider the Building Code applies to the building work involved in the installation of the injected foam insulation in the walls of the house (refer paragraph 13.3). The following is the clause of the Building code that is relevant to the main issue arising from this determination:

> **E2.3.6** Excess moisture present in the completion of *construction*, shall be capable of being dissipated without permanent damage to *building elements*.

12 Discussion

12.1 As previously described, I have commissioned a report within the Department itself and have obtained reports from two independent experts. The accumulated information has assisted me in determining this matter.

12.2 I have taken a two-stage approach in assessing the foam insulation. Initially, I have analysed the material and its installation in a general context, taking into account information obtained from overseas agencies. I have then applied this analysis to the work undertaken on the house that is subject to this determination.

12.3 The unconsented foam insulation to the brick veneer

A general analysis

12.3.1 The UK sources stress the importance of properly trained applicators and efficient mixing and delivery systems.

12.3.2 I accept the first expert's opinion that the foam insulation is not likely to be degraded by contact with moisture to the same extent as other adjoining building elements. I also agree that it will, in most instances, provide a useful contribution to thermal conductivity and therefore comply with Clause H1. However, this acceptance is

tempered by the fact that this contribution could be offset by the effects that the insulation may have on the code-compliance of the other elements.

The Airfoam organisation

12.3.3 The information obtained by the first expert has given me an insight into the practices and procedures established by Airfoam in the New Zealand context and this has assisted me in the determination process.

12.3.4 I would suggest that Airfoam carefully examine marketing information that describes aspects of its product particularly where it refers to brick veneer (refer paragraph 12.3.5) and make any revisions to this information that it considers to be appropriate.

12.3.5 As described in paragraph 8.3.1, the Airfoam documentation states that the foam insulation should not be injected where there are near-impervious materials on both sides of walls that are intended to be insulated. In addition, the technical manual also advises that the insulation should not be injected unless there is a good moisture path on at least one elevation.

12.3.6 Both overseas and New Zealand publications establish that, provided that correct application procedures are followed and adequate ventilation is provided during and after installation, foam insulation does not pose a formaldehyde emission risk.

12.3.7 I have also noted the brick manufacturer's concerns regarding the impact that foam insulation would have on the warranties provided by that manufacturer.

The house in question

12.3.8 Applying the above general analysis to the foam insulation present in the house in question, I have reached the following conclusions:

12.3.9 Despite some low risk features this house is subject at times to extreme wet and windy weather conditions (not uncommon in many parts of New Zealand) with consequent high humidity levels which may inhibit drying. This, as the UK experience shows, impacts on the performance of the foam insulation, and as described in paragraph 7.5.3, there are weather-based limitations placed on infilling of brickwork cavities. In addition, unlike the majority of the UK examples there is only one brick skin within the external wall structures. These factors, I believe, put this particular house, in the context of its insulation, outside the acceptable limits that might apply to other foam insulation installations in New Zealand.

12.3.10 The second expert's report established that the foam insulation and some of the adjoining framing and linings show evidence of containing moisture. The lower portion of the insulation contains elevated moisture levels despite having been in place for approximately one year.

12.3.11 However after revisiting the house in March 2008 and taking moisture tests at the same sites as in his first visits to the house in August and September 2007 the second expert has shown (refer paragraph 8.8) that where the lower walls are able to dry, the moisture associated with Airfoam appears to have dried out. Where external ground

levels and the deck are preventing drying, bottom plates continue to show elevated moisture levels.

12.3.12 Accordingly, I find that the exterior brick veneered walls of the house are currently showing evidence that, with the right conditions, they will eventually comply with Clauses B2 and E2 of the Building Code. It seems that if the deck is modified to provide sufficient ventilation the moisture is likely to dry out with the passing of another summer season, in which case the house would demonstrate compliance with those clauses and could be reviewed at that time.

12.3.13 I still have serious concerns regarding the concentrations of formaldehyde still present within the building as established by the first expert, taking into account the time that the insulation has been in place. Accordingly, I do not accept that the insulation complies with Clause F2 now, but at the same time acknowledge that, with adequate ventilation and the passing of time, this matter is also likely to be rectified.

12.3.14 The first expert was of the opinion that the house currently complies with Clauses E3 and H1 and, based on the evidence submitted, I agree with that opinion.

12.4 Conclusion

12.4.1 For the reasons set out in the preceding paragraphs, I find that the foam insulation installed in this house has resulted in the house complying with Clauses E3 and H1. However because of a combination of the moisture injected with the foam, and inadequate ventilation, the house does not currently comply with Clauses B2, E2, and F2.

12.4.2 I would like to emphasise that my decision relates only to:

- this particular house
- the design and construction features of the house.

and takes account of:

- the local topography and prevailing weather conditions
- the changes that have been made to the original brick veneer cladding system in the course of the alterations (see paragraph 5.4), because the performance of the cladding system will have been affected by those changes.

12.4.3 My decision is neither an endorsement nor a rejection of the foam insulation system as a whole. Nonetheless I draw the attention of the suppliers and installers of any building products to the importance of considering important elements of buildings, such as walls, roofs or floors, as systems. By that I mean that the effect of altering the performance properties of those elements (such as the brick veneer wall system in this case) needs to be carefully considered before work commences, in order to avoid situations in which compliance with the Building Code is compromised. In respect of these comments, I would urge Airfoam to ensure that its franchisees and operatives are aware of any limitations or prohibitions that should be taken into account when appraising whether use of the product is appropriate in a given circumstance. Where the use of the product is appropriate, the correct application techniques must be used. Any amended or new procedures required following

Airfoam's own investigation together with relevant issues that may arise from this determination should be fully documented and implemented.

12.5 The remaining consented work

12.5.1 The second expert raised some issues regarding the fibre-cement cladding. As I consider that these latter matters relate to the continuing code-compliance of the building, and may have some impact on the foam insulation, I have included them in this determination.

12.5.2 I consider the second expert's report establishes that the current performance of the fibre-cement cladding is not adequate because it is allowing some water penetration into the building in at least two locations at present. Consequently, I am satisfied that the cladding does not comply with Clause E2 of the Building Code.

12.5.3 In addition, the cladding is also required to comply with the durability requirements of Clause B2. Clause B2 requires that a building continues to satisfy all the objectives of the Building Code throughout its effective life, and that includes the requirement for the house to remain weathertight. Because the fibre-cement cladding faults on the building are likely to continue to allow the ingress of moisture in the future, the cladding does not comply with the durability requirements of Clause B2.

12.5.4 I note that the drainage cavity to the brick veneer walls has been lost as a result of the injection of the foam which is now drying out (refer paragraphs 8.8 and 12.3.11). The foam envelopes the timber framing which is unlikely to be treated. It is therefore important that the weathertightness, of what is now a monolithic cladding, is maintained to avoid the ingress of any water that might reach and effect the timber framing. Because of the presence of the foam, any water that does reach the timber framing cannot readily dry.

12.6 Conclusion

12.6.1 Because the faults identified with the fibre-cement cladding system occur in discrete areas, I am able to conclude that satisfactory rectification of the following items will result in it remaining weathertight and in compliance with Clauses B2 and E2:

- The inadequate taping and sealing at the junctions of the external joinery units.
- The swollen close-boarded decking adjacent to the cladding that is hard up against the cladding and has its top surface above the base of the cladding.
- The decking being flush with the adjoining ground levels at some locations.

12.6.2 In the light of the findings of the second expert outlined above, I consider the territorial authority should issue a notice to fix in respect of the faults in the consented building work.

13 Is the installation of the foam building work that needed to be consented?

13.1 The building work on the house, for which a building consent was issued, is described as alteration work. Section 112 of the Act requires that, after the alteration, the house must continue to comply, as nearly as is reasonably practicable with the provisions of the Building Code that relate to means of escape from fire, and continue to comply with the other provisions of the Building Code to at least the same extent as before the alteration.

13.2 In paragraph 5.4 I discuss in more detail the alteration arising out of installation of foam insulation and the application of a plaster and paint system to the existing brick cladding. I note that the building consent did not include the installation of the foam insulation.

13.3 I noted in paragraph 1.5 that in order to make the determination I must decide whether the installation of the injected foam insulation was building work, and if so, whether it was building work that was exempt from the requirement for a building consent by virtue of Schedule 1 of the Act.

13.4 Section 7 of the Act says 'building work'

> (a) means work
>
> > (i) for, or in connection with, the construction, alteration, demolition, or removal of a building; and ….

It is not contested that the purpose for injecting the foam insulation into the walls of the house was to improve the thermal resistance of the walls so that the house achieved an adequate degree of energy efficiency, a functional requirement of the Building Code. I conclude from that fact that the installation of the foam insulation is building work that alters the house and must be building work as defined in section 7 of the Act.

13.5 Turning now to considering whether the installation of the foam insulation is building work that is exempt from the requirement for a building consent, I refer to Schedule 1 of the Act, which sets out those items of building work that do not require a building consent. I do not believe that any of the specific elements described in that Schedule relate to foam insulation. Paragraph (k) of Schedule 1 provides that a territorial or regional authority may allow building work to proceed without the need for a building consent. That provision is subject to conditions concerning code-compliance or safety, and should only be invoked by the territorial authority after careful consideration of the nature and type of the building work concerned.

13.6 Taking into account the discussion set out in paragraphs 13.2 to 13.5, I am of the opinion that the installation of the foam insulation constituted one of the alterations to the house and should have been included in the building consent before the installation commenced. I note that Airfoam told the first expert (see paragraph 7.5.1) that it had not obtained consents for any of the projects it had completed to date.

13.7 In the present case, where the building work of installing injected foam insulation was not, but should have been, incorporated into the original building consent No 73702, or into a separate consent, the work is not eligible to receive a code compliance certificate. However, section 96 of the Act says a territorial authority may, on application, issue a certificate of acceptance for building work that is unconsented but which the territorial authority judges to be compliant with the Building Code.

14 What is to be done now?

14.1 The territorial authority should now issue a new notice to fix that distinguishes between the consented and un-consented work and requires the owners to bring the building up to compliance with the Building Code, identifying the defects listed in paragraphs, 12.3.12, 12.3.13 and 8.4.1, but not specifying how those defects are to be fixed. That is a matter for the applicants to propose and for the territorial authority to accept or reject. It is important to note that the Building Code allows for more than one method of achieving compliance.

14.2 Because there is evidence that the passage of time, including another spring and summer, and provision of additional ventilation at the base of the walls, whether external or internal, will allow the foam insulation and adjacent framing and linings to dry out to acceptable levels and allow any free formaldehyde present to dissipate, the new notice to fix in respect of the foam insulation should not be enforced until such a time lapse has occurred.

14.3 I suggest that the parties adopt the following process to meet the requirements of paragraph 14.2. Initially, the territorial authority should issue the notice to fix. The owner should then produce a response to this in the form of a technically robust proposal, produced in conjunction with a competent and suitably qualified person, as to the rectification or otherwise of the specified matters. I suggest that particular note be taken of paragraph 5.4 in developing an approach to permanently lowering the moisture content of both the fibre-cement and plastered brick walls.

14.4 Once the un-consented work has become compliant the territorial authority may, on application from the owner, issue a certificate of acceptance for that work. Any outstanding items of disagreement can then be referred to the Chief Executive for a further binding determination.

15 The Decision

15.1 In accordance with section 188 of the Building Act 2004, I determine that

- some of the building work carried out under building consent No 73702 for which a code compliance certificate was subsequently issued does not comply Clauses B2, and E2, of the Building Code. Accordingly the territorial authority's decision to issue a code compliance certificate is reversed
- the un-consented building work (the installation of the foam insulation) does not comply with Clauses B2, E2, and F2 of the Building Code

- for the avoidance of doubt the notice to fix No. 428 issued on 23 March 2007 is to be withdrawn.

Signed for and on behalf of the Chief Executive of the Department of Building and Housing on 19 May 2008.

John Gardiner
Manager Determinations