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Building Industry Authority
New Zealand

Recessed Downlights In Houses
A report on the effects of Heat Loss and Moisture Transfer

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SUMMARY

This document describes an investigation into heat losses, moisture transfer and fire hazards due to the installation of recessed downlights in dwellings.

Our conclusions are that if recessed downlights are selected in accordance with NZECP 54, heat losses through the light fittings will not be significant. The major path for heat (and moisture) losses appears to be through airflow across the fittings due to infiltration pressures caused by wind effects. There is scope for improving energy savings by restricting the maximum number of downlights in an installation and also improving the lamp efficiencies. Further improving the air tightness classification of fittings will also help.

Our tests indicate that moisture transfer from habitable spaces is not likely to be a problem, providing NZECP 54 is adhered to, and dwellings have ventilation in accordance with the New Zealand Building Code. However, moisture transfer from moist areas to inter-floor spaces and suspended ceilings are likely to cause problems and this is a concern. Also of concern are the effects of installing recessed fittings in moist areas which have skillion or pitched type roofs. We believe that the NZECP 54 needs to be more onerous in these areas.

With regards to electrical safety and fire risks, NZECP 54 requests manufacturers to provide important information with regards to minimum distances from flammable building elements, as part of the installation instructions. This will improve the present situation where we found the information supplied by some manufacturers to be inadequate.

1 INTRODUCTION

Ceiling recessed downlights are becoming a popular feature in New Zealand homes. The Building Industry Authority of New Zealand commissioned Energy Group to investigate the effects of this type of lighting on heat loss and moisture transfer to the roof, together with possible fire hazards due to heat emission from these light fittings to surrounding building elements.

This project was carried out in five main stages, which are briefly described below:

Stage 1. The first stage of this project was to carry out a search for any published data by others who had done similar research. The following organizations were contacted:

- Lighting Division of the Chartered Institution of Building Services Engineers (CIBSE)-UK.
- Building Research Establishment (BRE)-UK.
- Building Services Research and Information Association (BSRIA)-UK.
- Norwegian Building Research Institute.
- National Research Centre (NRC)-Canada
- BRANZ

Organizations, which had conducted similar research or published material relevant to this project, could not be found. BRANZ have published information regarding infiltration in New Zealand homes and some of this information proved to be useful.

A draft copy of NZECP 54:2001 New Zealand electrical code of practice for the installation of recessed luminaires and associated equipment was issued to Energy Group by the BIA.

Stage 2. The second stage of the project was to investigate the types of downlight commonly available in the market and to select generic types of fitting for testing. This included sending a reply paid questionnaire to organizations involved with selling, specifying and installing downlights.

Stage 3. Design and construction of the testing room, the test apparatus and the measuring and data logging equipment.

Stage 4. Testing and gathering data.

Stage 5. Analysis of results and production of the report.

2 THE TESTING APPARATUS

2.1 ENVIRONMENTAL CONTROL CHAMBER

The light fittings that were tested were installed on the ceiling of a test room, which was constructed within an environmental control chamber.

The environmental control chamber had internal dimensions measuring 5m (wide) 4.5m (deep) and 4m (high). The temperature and relative humidity within this room can be maintained within +/- 0.3°C and +/- 4% RH respectively.

2.2 TEST ROOM

The test room, which was constructed, had external dimensions 2.45m (wide) 3.6m (deep) and 2.45m (high).

The floor and the walls of the room were constructed using 90mm x 45mm timber studs with an outer skin of 6mm thick medium density fiberboard (MDF). Expanded polystyrene insulation of 40mm thickness was applied between the studs and all gaps were sealed using caulking compound. The inner surface of the polystyrene was painted with two coats of acrylic emulsion to minimize moisture transfer. To prevent the insulation on the floor getting compressed by feet and hence its insulation value changing throughout the testing period, an 18mm MDF board was laid above the polystyrene. As a further vapor barrier, a heavy-duty polythene sheet was then applied over the painted polystyrene sheet on the walls and the MDF board on the floor, with great care taken to maintain its integrity as a vapor barrier. This polythene sheet was stapled to the timber studs, with PVC tape applied over the staples and all joints.

The ceiling over the test room was constructed to represent a typical construction method using 140mm x 45mm joists at 600mm centres, 9.5mm Gib board with Gib stopping applied. 110mm of Pink Batt insulation was applied between the joists. Four 750mm x 600mm de-mountable Gib panels were installed to the ceiling to enable different light fittings to be installed.

At a later stage, when carrying out tests to evaluate the performance of an inter-floor space, a 570mm x 600mm area between the ceiling joists and above a light fitting was covered with 6mm thick MDF.

The test room had an insulated access hatch, which was screw fixed to the frame during testing, to minimise heat and moisture transfer.

2.3 HEATER AND HUMIDIFIER.

Within the test room a heater and a humidifier were installed, to maintain the required internal temperature and humidity conditions.

The heater was an electric panel type having a rated output of 630W, with lightweight elements to minimize hysteresis. The heater was controlled to maintain the average room temperature at 20 °C +/- 0.25°C using pulse length modulation, this control was provided by the data logger. This type of heater was considered most appropriate for the tests, a fan heater may have induced additional heat losses due to the movement of air. Throughout the testing it was found that stratification within the test room was minimal, especially when the humidifier was running.

The humidifier was a purpose built unit. It consisted of a plastic evaporative chamber with evaporative wicks suspended from the top lid, immersed in water at the bottom. When required, humidification was achieved by cycling an electric fan, which blew air into the evaporative chamber and across the wicks. The average humidity within the test room was controlled at 80% for the wet tests and uncontrolled for the dry testing. Average relative humidity within the test room was generally maintained within +/- 2% during testing.

2.4 MEASURING AND DATALOGGING.

Air temperatures were measured with precision negative temperature coefficient (NTC) thermistors and the relative humidity by Honeywell HIH-3605 IC humidity sensors. There were four sensor pairs both inside and outside the test room to average the conditions. Temperatures on the light fittings were measured using type J thermocouples.

The rate of moisture transfer from the humidifier was measured by mounting the humidifier on an electronic scale, which had an analogue output, and measuring the weight change. The power consumption of the heater and the humidifier fan was measured using a Carel & Carel LP Series Electrical Transducer with a pulse output. Lighting power consumption was measured by a Northern Design ND305 power meter.

Data was logged with a Campbell CR10X logger using a AM416 multiplexer with weight measurements carried out by a PC using the streamed weight data output by the scales.

2.5 PRESSURE FLOWRATE TESTING APPARATUS.

A separate test rig was used to establish the pressure/air flow-rate characteristics for each light fitting. This consisted of a centrifugal fan with speed controller, blowing into a chamber, which had the light fitting under test installed. A pressure transducer was used to record the pressure drop and the air flow-rate was measured using a rotating vane anemometer.

3 THE LIGHT FITTINGS.

3.1 FITTTING TYPES AVAILABLE

A wide range of recessed light fittings are available. Other than electrical safety, aesthetics, durability and cost, there are two other factors which are important in a light fitting. These are the ability of the light fitting to be an effective barrier to heat loss and moisture transfer from the occupied space, and the efficiency of the lamp (taking into consideration the light output in lumens/watt, light distribution and colour rendering ability). Our research indicated that in the domestic market, popular recessed light fittings are broadly of the open and restricted types (in accordance with (NZECP 54:2001) and they have a variety of lamps- mainly of the incandescent filament type. These lamps include the GLS type, reflector type and low voltage tungsten halogen, although 230V tungsten halogen lamps are now available and are becoming popular. More efficient compact fluorescent type lamps are popular in office and commercial applications but perhaps due to the relatively high initial cost of the lamp, they are not widely used in domestic applications.

For a light fitting to be an effective barrier to the passage of heat and moisture, there needs to be an effective seal between the occupied and unoccupied spaces. With incandescent type lamps, considerable heat is given out and most recessed light fittings at the cheaper end depend on airflow across the lamp and fitting to keep it cool, this inevitably increases the heat and moisture loss. Better fittings have heatcans, which restrict the passage of air from the occupied space and hence reduce losses.

As compact fluorescent lamps become more affordable and their cost effectiveness becomes more appreciated (they last 8 times as much as an incandescent lamp and they consume a fifth of the energy) these lamps are likely to become more popular in domestic applications. With this type of lamps, due to their lower heat output and longer lamp life, it will be feasible for manufacturers to seal the light fittings to a better standard, thereby reducing heat and moisture transfer. This will begin to happen with the application of higher standards to light fittings through the building code or other means.

Another recent development is the technological advancement of the white LED (light emitting diode) as a light source. These have a lamp life of 50-100,000 hours and it would be feasible to produce the entire light fitting as a sealed for life unit. Our research indicates that the rate of advancement of this technology is such that it would be another 5-8 years before it becomes feasible for spatial lighting applications.

3.2 SELECTION OF LIGHT FITTINGS FOR TESTING.

In order to establish the types of downlight popular in New Zealand, a reply paid questionnaire, with a prize draw was sent to 41 Lighting wholesalers, Architects and Contractors. 23 replies were received and the responses were taken into account when selecting the light fittings for evaluation. The prize draw was held and the winning entry picked by the Hon Clive Matthewson, on behalf of the BIA.

The light fittings tested were:

Fitting	**Lamps**
Superlux SD125	Sylvania 100W reflector, Phillips 100W GLS
Loretto Envirolamp	Par 38
Halcyon R670	12V dichroic

Table 1 Fittings and Lamps Selected for Testing

When selecting the fittings to be tested, the objective was to select popular fittings of the following generic types:

- A fitting which presented a high resistance to the passage of air between the occupied and unoccupied areas, i.e. a fitting with a heatcan.
- A fitting which presented a low resistance to the passage of air between the occupied and unoccupied areas, i.e a fitting without a heatcan.
- A fitting which would have a high heat density, hence a high surface temperature, ie a low voltage tungsten halogen type.

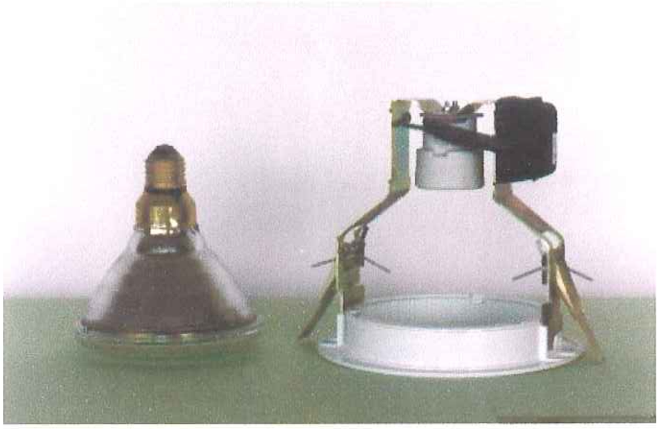
3.2.1 General Description Of Light Fittings

SuperLux SD 125. Cost: $35 with reflector type lamp.

The SD125 fitting is designed for E37 and R80 type incandescent lamps up to a maximum of 100 watts. The lamp is housed in a pressed metal enclosure (heat can) with an auto resetting thermal cut-out located on top of the housing. The housing has a number of small penetrations for mounting clips and the attachment of electrical fixtures. The ceiling opening for this fitting is 125mm diameter. This fitting can be classed as a “closed fitting” in accordance with NZECP 54

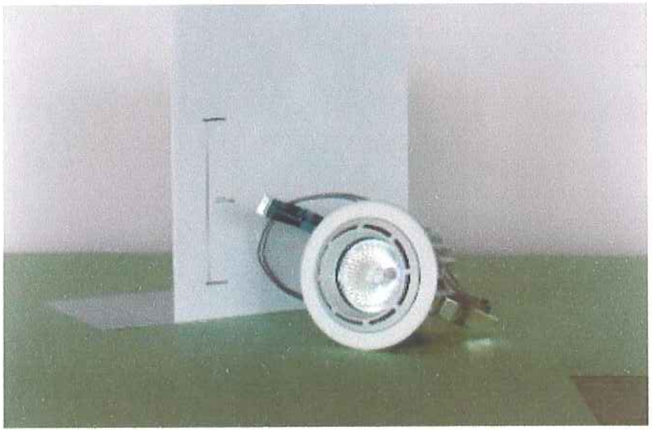
Loretto Envirolamp. Cost $27 with 150W PAR 38 type lamp

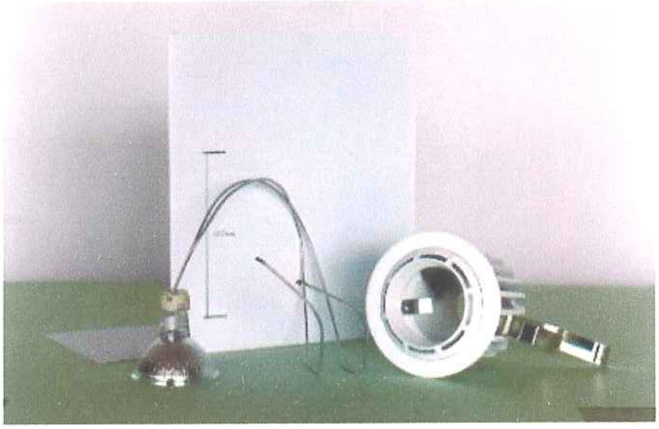
The Loretto Envirolamp is designed for PAR 38 lamps up to 150 watts. The fitting is of an open structure and uses a pressed metal frame for support of the lamp. In this fitting the lamp acts as the main restriction to air movement. The ceiling opening for this fitting is 145mm diameter. This fitting can be classed as a "restricted fitting" in accordance with NZECP 54



Halcyon R670. Cost $44 with transformer and 50W lamp.

The Halcyon R670 fitting is designed for12volt, 50 to 75 watt 38° Dichroic lamps. The fitting is of a cast alloy construction with cooling type fins on the upper part of the housing. There are a number of slots around the outside of the lamp, which are open to the ceiling space. The ceiling opening for this fitting is 72mm diameter. . This fitting can be classed as a "restricted fitting" in accordance with NZECP 54





3.2.2 Features Of Fitting Which Influence The Transfer of Air to Ceiling Space.

The three fittings tested all employed different methods for restricting air exchange between the room and the concealed space. In all cases any minor inaccuracy in the hole size cut in the ceiling does not appear to have a significant impact on the airflow between the spaces, provided the ceiling surface is flat. All systems for retaining the fixture appeared sufficient to maintain a good seal with a flat ceiling surface.

SuperLux SD125

Restriction of airflow is by the heat can, the area of penetrations in the enclosure being relatively small. The type of lamp fitted or the absence of a lamp does not change the equivalent area for airflow.

Loretto Envirolamp

The restriction of air flow is entirely dependent on the inclusion of a lamp in the fitting and how well the lamp closes the fitting opening.

Halcyon R670

Restriction of airflow is by the annulus surrounding the lamp in the metal housing and is dependent on the inclusion of a lamp in the fitting.

4 TESTING

4.1 GENERAL.

At the commencement of testing and at regular intervals afterwards, baseline tests were carried out on the test chamber (without light fittings being installed), to establish heat and moisture loss through its fabric. Although the test chamber was thermally insulated and great care had been taken to ensure its resistance to vapour transfer, it was inevitable for some losses to occur. The baseline value obtained was subtracted from test values measured with the light fittings installed, to establish the additional heat and moisture losses incurred after the installation of the fittings.

In general, three categories of tests were carried out to establish the following:

- The heat loss and moisture transfer characteristics under static (diffusion) conditions. For these tests, the only deliberate openings in the chamber were the apertures on the light fittings. In order to establish whether convective currents set up by light fittings in operation would cause a significant increase of heat and moisture transfer, some tests were carried out with two light fittings installed, with only one switched on.

- The maximum temperatures attained on the fitting surface. Readings of the surface temperatures on the fittings were taken concurrently whilst the fittings were being tested for heat loss and moisture transfer.

- The pressure drop/air flow-rate characteristics across the light fittings. In actual situations, in addition to losses due to conduction, convection and diffusion, infiltration due to pressure drops across the light fittings caused by wind effects and stack effects (due to the difference in density between indoor/outdoor air due to temperature differentials) contribute to losses. The aim of these tests was to establish the flow characteristics across the light fittings from which these losses could be estimated from assumed values for typical pressure drops across the fittings.

4.2 ADDITIONAL TESTS FOR CONVECTIVE LOSSES

Having carried out the tests described in 4.1 it was apparent that the results indicated a small static convective loss. Therefore, further testing was carried out in an attempt to induce a significant and measurable convective loss. These tests involved boring a 60mm diameter hole cut on the side of the test room 1.5m below the ceiling line. It was anticipated that due to the difference in density between the indoor and outdoor air, this test would produce a higher level of convection than that achieved with two fittings installed in the ceiling.

4.3 TESTS FOR INTERFLOOR SPACE.

These tests were carried out to establish the effects of moisture transfer to an interfloor space. A representative interfloor space was constructed by fixing a 570mm x 600mm x 6mm thick MDF board between the ceiling joists and above a light fitting. The SuperLux and Loretto types of fitting were tested.

4.4 SUMMARY OF TESTS

4.4.1 Tests for Heat Loss, Moisture Transfer and Surface Temperature

Test Ref.	No. of Light Fittings in Room	Fitting Type	Lamp Type	Insulation gap to lamp	Light 1	Light 2	Indoor Conditions	Outdoor Conditions
1a	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	N/A	20°C, 80% RH	8°C
1b	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	N/A	20°C	8°C
1c	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	N/A	20°C	12.5°C
1d	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	N/A	20°C, 80% RH	12.5°C
1e	1	Superlux SD125	Sylvania 100W Reflector	Abutted	ON	N/A	20°C, 80% RH	12.5°C
1f	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	N/A	20°C	12.5°C
1f2	1	Superlux SD125	Sylvania 100W Reflector	Abutted	ON	N/A	20°C	12.5°C
1h	1	Superlux SD125	Sylvania 100W Reflector	Abutted	ON	N/A	20°C, 80% RH	8°C
1i	1	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	N/A	20°C	8°C
1j	1	Superlux SD125	Philips 100W Frosted GLS	75 mm	ON	N/A	20°C	8°C
1k	1	Superlux SD125	Philips 100W Frosted GLS	75 mm	OFF	N/A	20°C	8°C
2a	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	OFF	20°C, 80% RH	8°C
2b	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	OFF	20°C	8°C
2c	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	OFF	20°C	12.5°C
2d	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	OFF	OFF	20°C, 80% RH	12.5°C
2e	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	OFF	20°C, 80% RH	12.5°C
2f	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	OFF	20°C	12.5°C
2g	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	OFF	20°C	8°C
2h	2	Superlux SD125	Philips 100W Frosted GLS	Abutted	ON	OFF	20°C, 80% RH	8°C
2i	2	Superlux SD125	Sylvania 100W Reflector	75 mm	ON	OFF	20°C, 80% RH	8°C
2j	2	Superlux SD125	Sylvania 100W Reflector	75 mm	ON	OFF	20°C	8°C
2k	2	Superlux SD125	Sylvania 100W Reflector	75 mm	OFF	OFF	20°C	8°C
3a	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	N/A	20°C, 80% RH	8°C
3b	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	N/A	20°C	8°C
3c	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	N/A	20°C	12.5°C
3d	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	N/A	20°C, 80% RH	12.5°C
3e	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	N/A	20°C, 80% RH	12.5°C
3f	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	N/A	20°C	12.5°C
3g	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	N/A	20°C	8°C
3h	1	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	N/A	20°C, 80% RH	8°C
3i	1	Loretto Envirolamp	Philips 150W PAR 38	75 mm	ON	N/A	20°C	8°C
3j	1	Loretto Envirolamp	Philips 150W PAR 38	75 mm	OFF	N/A	20°C	8°C
4a	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	OFF	20°C, 80% RH	8°C
4b	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	OFF	20°C	8°C
4c	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	OFF	20°C	12.5°C
4d	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	OFF	OFF	20°C, 80% RH	12.5°C

Test Ref.	No. of Light Fittings in Room	Fitting Type	Lamp Type	Insulation gap to lamp	Light 1	Light 2	Indoor Conditions	Outdoor Conditions
4e	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	OFF	20°C, 80% RH	12.5°C
4f	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	OFF	20°C	12.5°C
4g	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	OFF	20°C	8°C
4h	2	Loretto Envirolamp	Philips 150W PAR 38	Abutted	ON	OFF	20°C, 80% RH	8°C
4i	2	Loretto Envirolamp	Philips 150W PAR 38	75 mm	ON	OFF	20°C	8°C
4j	2	Loretto Envirolamp	Philips 150W PAR 38	75 mm	OFF	OFF	20°C	8°C
4k	2	Loretto Envirolamp	Philips 150W PAR 38	75 mm	ON	OFF	20°C, 80% RH	8°C

Table 2 Summary of Tests

4.4.2 Additional Tests for Convective Losses

Test Ref.	No. of Light Fittings in Room	Fitting Type	Lamp Type	Insulation gap to lamp	Light 1	Light 2	Indoor Conditions	Outdoor Conditions
4l	2	Loretto	PAR38	N/A	OFF	OFF	20°C, 80% RH	8°C
4m	2	Loretto	Philips 100W Frosted GLS	N/A	OFF	N/A	20°C, 80% RH	8°C
4n	2	Loretto	No Bulbs	N/A	N/A	N/A	20°C, 80% RH	8°C
4o	2	Loretto	No Bulbs	N/A	N/A	N/A	20°C	8°C
Hole in Wall Test	1	Loretto	PAR38	N/A	N/A	N/A	20°C, 80% RH	8°C

Table 3 Summary of Tests

4.4.3 Interfloor Space Test

Test Ref.	No. of Light Fittings in Room	Fitting Type	Lamp Type	Insulation gap to lamp	Light 1	Light 2	Indoor Conditions	Outdoor Conditions
Interfloor Test 1	1	Loretto	PAR38	N/A	OFF & ON	N/A	20°C, 80% RH	8°C
Interfloor Test 2	1	SuperLux	Philips 100W Frosted GLS	N/A	OFF	N/A	20°C, 80% RH	8°C

Table 4 Summary of Tests

5 ANALYSIS OF TEST RESULTS.

5.1 REDUCED INSULATION VALUE DUE TO THE INSTALLATION OF DOWNLIGHTS.

Installation of a downlight makes it necessary to cut a hole in the ceiling fabric and to remove a piece of insulation, thereby increasing the conductive heat loss from the ceiling.

Measurements of the heat loss before and after the down lights were installed showed little or no discernible change in the heating requirements for the test room. Manual calculations gave 0.215 W/°C of additional sensible heat loss per fitting, through the ceiling due to the removal of insulation and the introduction of an air gap. This small additional loss (2.58W at a 12°C temperature difference) was beyond the resolution of the test set up, in many cases the heat loss measured was less than the baseline value. Give the lower insulation value as a percentage of baseline heat loss.

The results of these tests are presented in the two tables below. Heat losses are expressed as Watts per °C temperature difference between occupied and concealed space.

	Loretto Envirolamp		SuperLux SD 125	
	8°C OD	12.5°C OD	8°C OD	12.5°C OD
BaseLine	26.05 W/°C	26.36 W/°C	26.05 W/°C	26.36 W/°C
1 fitting Installed	27.28 W/°C	25.73 W/°C	25.41 W/°C	27.15 W/°C
2 fittings Installed	25.66 W/°C	26.50 W/°C	25.70 W/°C	26.87 W/°C

Table 5 Heat loss with Insulation Abutted to Fitting Opening

	Loretto Envirolamp	SuperLux SD 125
	8°C OD	8°C OD
BaseLine	26.05 W/°C	26.05 W/°C
1 fitting Installed	25.33 W/°C	25.5 W/°C
2 fittings Installed	25.43 W/°C	25.8 W/°C

Table 6 Heat loss with Insulation 75mm from Fitting Opening

5.2 ADDITIONAL CONVECTION DUE TO HEAT GIVEN OFF BY LAMP

One of the concerns with the installation of multiple down lights in buildings is whether the hot fittings will set up significant convective currents which will have an effect to suck additional air from the occupied space. The air thus removed will be made up by infiltration into the room or through light fittings not turned on.

This test was conducted with two Loretto Envirolamp fittings installed with the PAR 38 bulb removed from one fitting and a 100w incandescent lamp installed in the other. Due to the smaller size of the 100w incandescent lamp there was little or no resistance to airflow from the fitting and the air was heated immediately above the hole in the ceiling.

The results for this test showed the heating load to be similar (within 5%) of the base line heat loss with the PAR 38 lamps installed and the moisture loss was similar to the test with no lamps installed. The conclusion drawn from this test is that there was no measurable convective loss from the room.

5.3 ADDITIONAL HEAT LOSS DUE TO LAMPS BEING REMOVED

An additional test was carried out to check on a worst case scenario. This test used two Loretto Envirolamp fittings without the PAR 38 lamps installed. As the installation of the lamps is the only means of restricting the effective area of the hole, this meant that there were two 0.12m diameter ($0.0123m^2$) holes in the ceiling.

The results from this test gave a heat loss of 27.98W/°C, which is 7.4% above the baseline loss.

5.4 INCREASED MOISTURE TRANSFER DUE TO INSTALLATION OF DOWNLIGHTS

The measurement of moisture loss showed some increase with the installation of down lights. Water vapour loss generally increased with the number of down lights installed and was higher with fittings having a larger effective orifice as measured during the air flow testing.

The results of these tests are presented in the table below. The moisture losses are expressed in grams per hour per 1Pascal vapour pressure difference between occupied and concealed space.

	Loretto Envirolamp		SuperLux SD 125	
	8°C OD	12.5°C OD	8°C OD	12.5°C OD
BaseLine	0.0276 g/h/Pa	0.0278 g/h/Pa	0.0276 g/h/Pa	0.0278 g/h/Pa
1 fitting Installed	0.0307 g/h/Pa	0.0309 g/h/Pa	0.0251 g/h/Pa	0.0206 g/h/Pa
2 fitting Installed	0.0365 g/h/Pa	0.0315 g/h/Pa	0.0290 g/h/Pa	0.0364 g/h/Pa

Table 7 Moisture loss from Room due to Down Light Installation

5.5 ADDITIONAL MOISTURE TRANSFER TESTS

Two extra tests were conducted to further establish what effect the hole size in the ceiling had on moisture loss. These tests were:

- Two Loretto Envirolamp fittings installed with the lamp removed from one fitting.
- Two Loretto Envirolamp fittings installed with lamps removed from both fittings.

Under the worst case test carried out with both lamps removed, moisture loss went from a baseline value of 24.55 g/hr to 54.56 g/hr. When this increase in moisture loss was calculated as additional ventilation it gave an increase of 0.1 air changes per hour or 0.6L/s.

The overall additional heat loss from the room due to an increased ventilation rate is 0.019kW (19Watts) or 2.15 watts/m².

	Loretto Envirolamp
	8°C OD
BaseLine	0.0408 g/h/Pa
1 Lamp Removed	0.0623 g/h/Pa
2 Lamps Removed	0.0643 g/h/Pa

Table 8 Moisture loss from Room with Lamps Removed

5.6 FITTING TEMPERATURES

Internal and external operating temperatures were measured for the three fittings tested under similar environmental conditions. The positioning of the insulation, either flush to the side of the fitting (abutted) or with a 75mm air gap, has a substantial effect on the operating temperatures. In general a 75mm air gap reduced the temperatures by up to 40°C.

Note: NZECP 54 refers to a 100mm air gap. The tests were carried out with a smaller 75mm air gap to allow for higher temperatures due to the possibility of the insulation being installed closer in actual circumstances, due to building errors.

5.6.1 SuperLux SD125 Temperatures

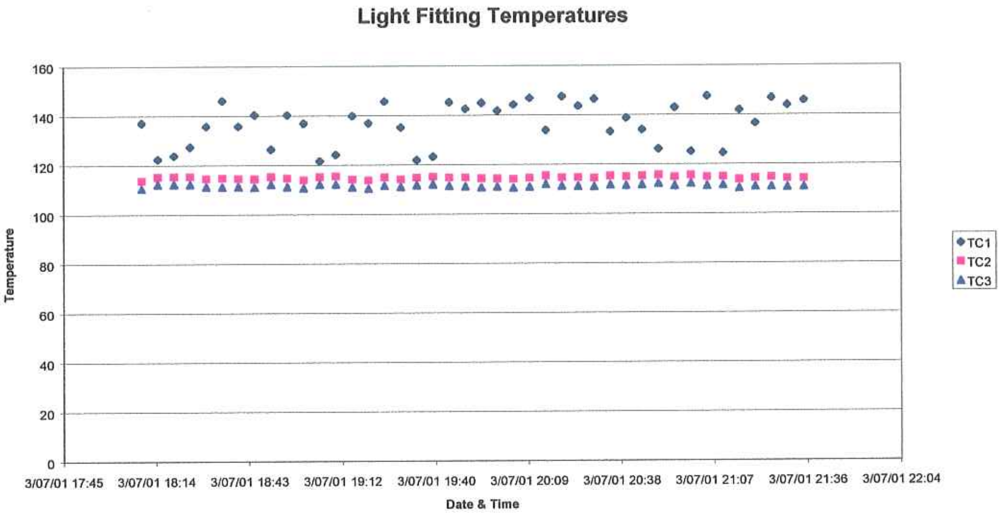


Figure 1 Fitting Temperatures with Insulation Abutted to the Housing

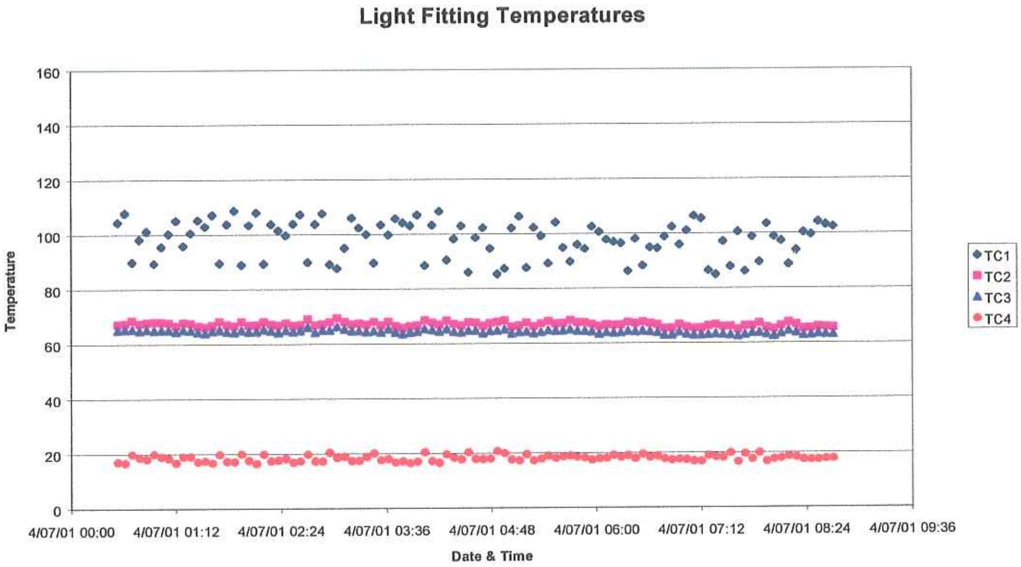


Figure 2 Fitting Temperature with Insulation 75mm from Housing

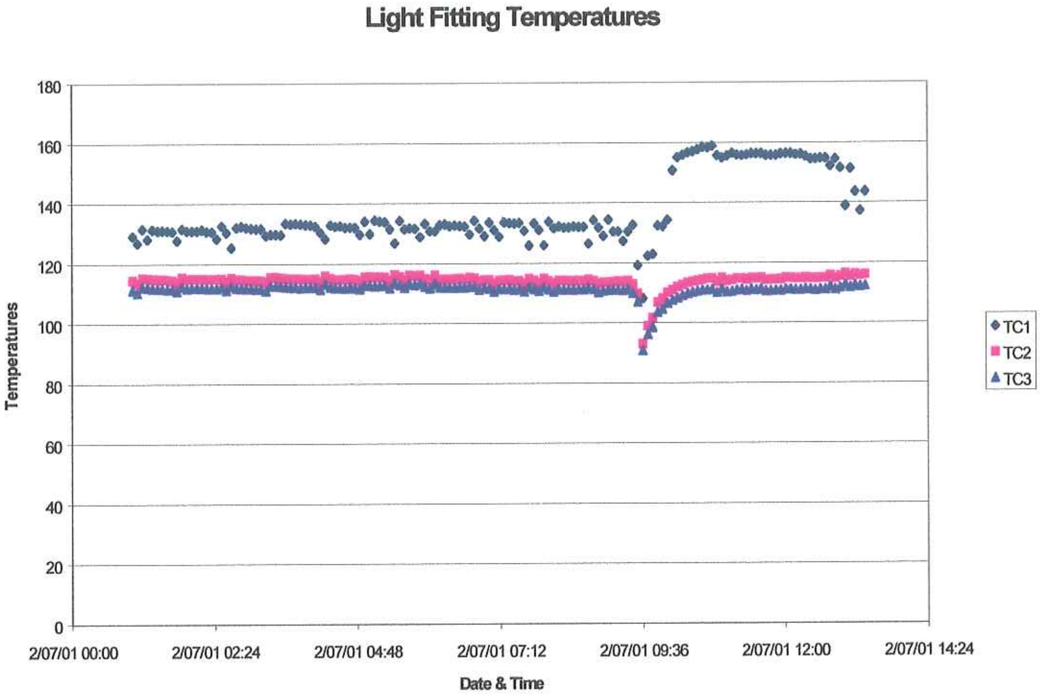


Figure 3 Difference in Fitting Temperature with Lampchanged from GLS to R80 Type

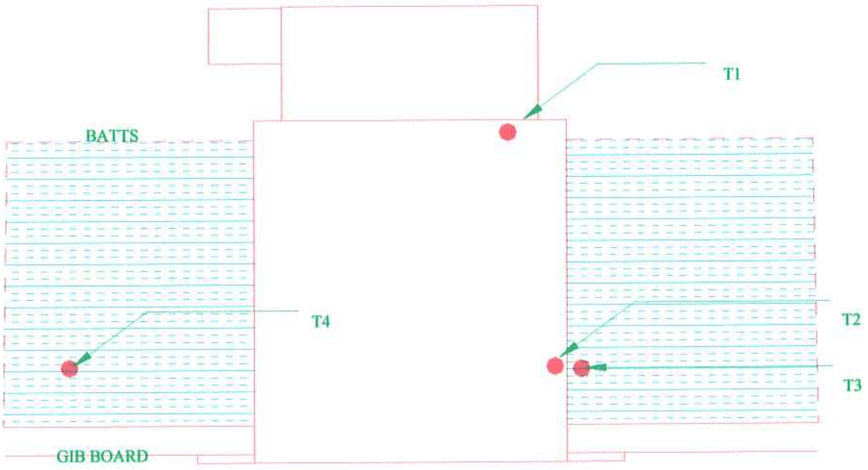


Figure 4 Diagram of SuperLux Fitting Installation and Thermocouple, TC1, 2, 3, and 4 Positions

5.6.2 Loretto Envirolamp Temperatures

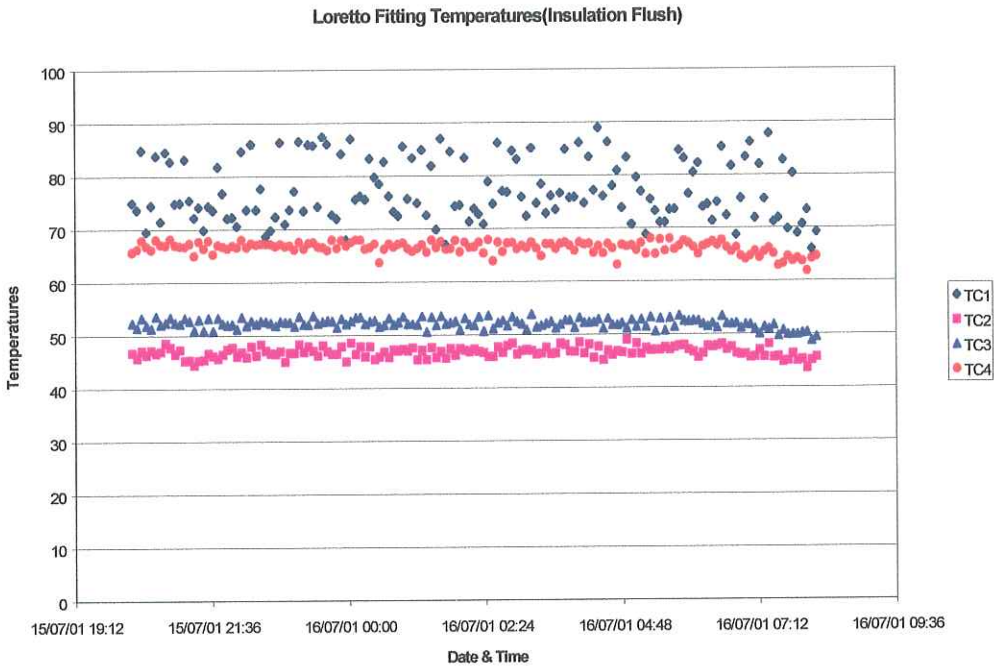


Figure 5 Fitting Temperatures with Insulation Flush with Ceiling Opening

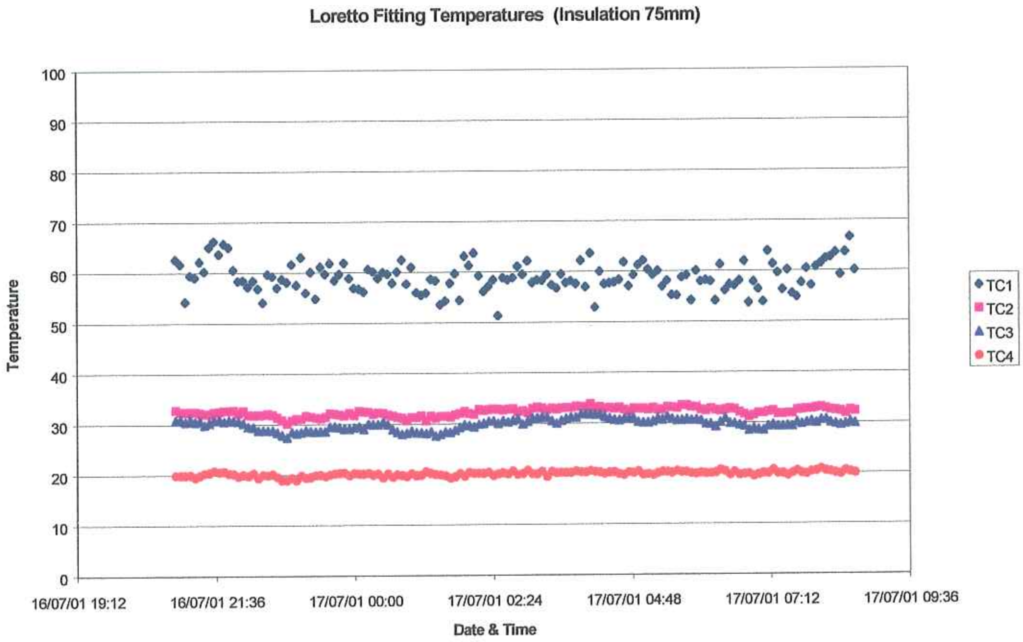


Figure 6 Fitting Temperatures with Insulation 75mm Back from Ceiling Opening

With this fitting the lamp is not protected by a housing but is open to the concealed space. Thermocouples TC2 and TC3 were taped to the frame, TC1 was not fixed to the lamp, but was placed in loose contact. Manual checks were made using a hand held contact thermometer to find the temperature profile of the exposed lamp parts. The maximum temperature for a surface accessible from the ceiling was 160 °C. The location of the temperature sensors for this test is shown below.

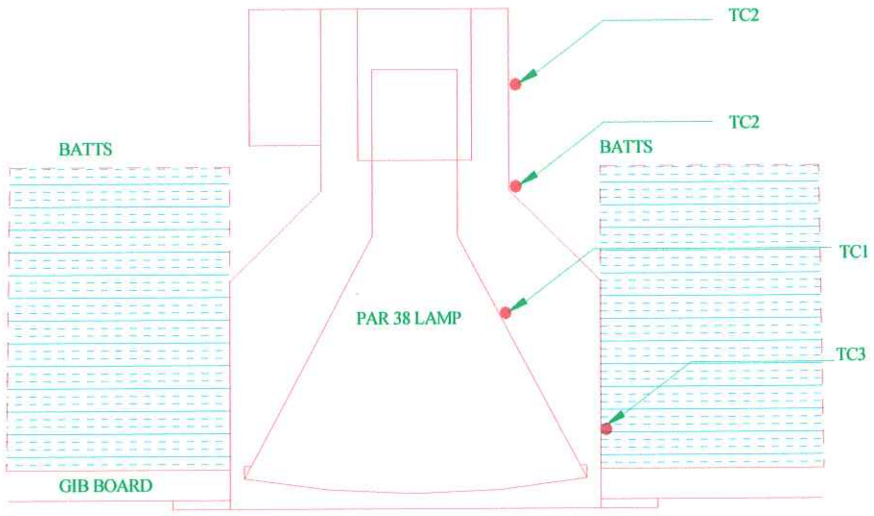


Figure 7 Diagram of Loretto Fitting Installation and Thermocouple, TC1, 2, 3, and 4 Positions

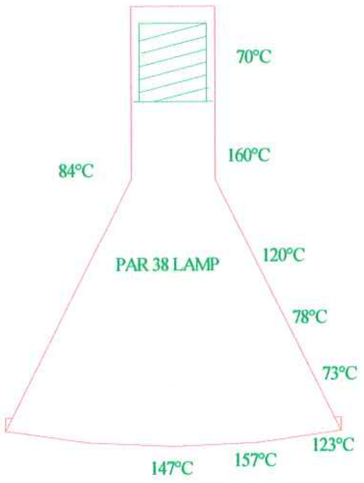


Figure 8 Diagram of PAR38 Lamp installed in the Loretto Fitting Showing Surface Temperatures Measured with Contact Probe.

5.6.3 Halcyon R670 Temperatures

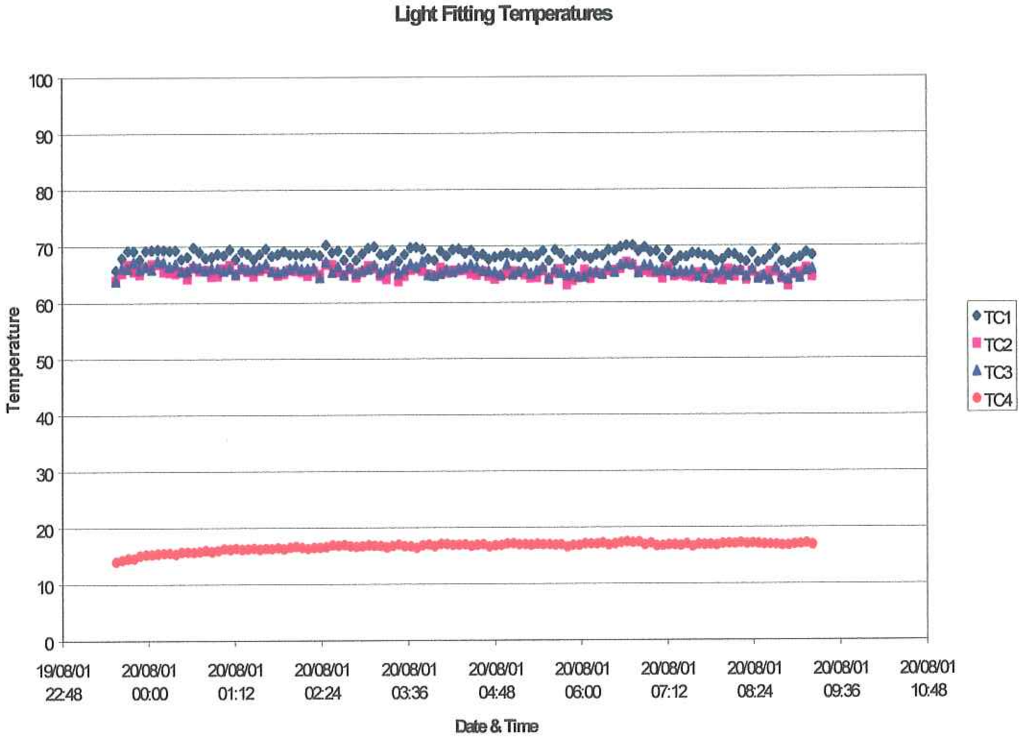


Figure 9 Fitting Temperatures with Insulation 75mm Back from Fitting

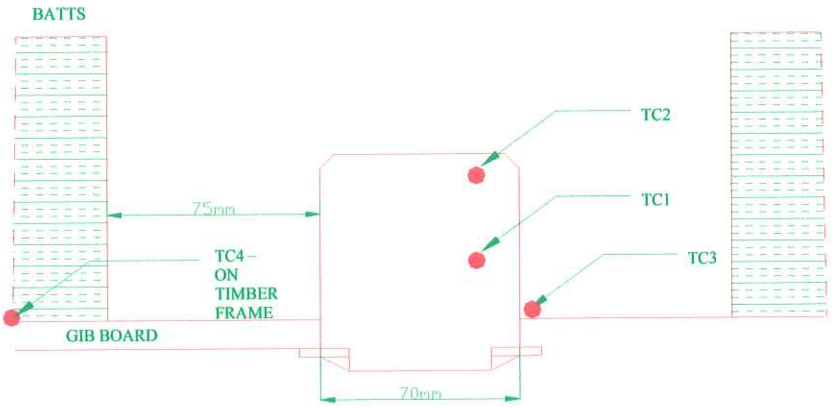


Figure 10 Diagram of Halcyon Fitting Installation and Thermocouple, TC1, 2, 3, and 4 Positions

5.7 MOISTURE TRANSFER TO INTERFLOOR SPACE.

5.7.1 Interfloor Space with Loretto Fitting

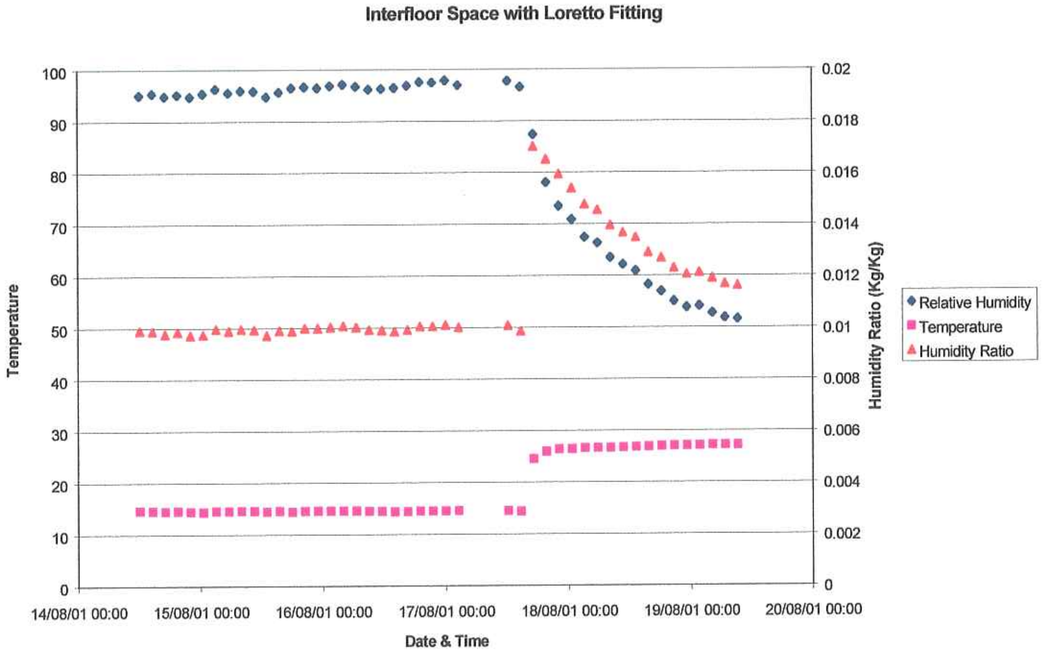


Figure 11 Interfloor Space Conditions with the Light Off and the Light On

The first half of Figure 11 above shows the temperature, relative humidity and humidity ratio of the interfloor space under steady state conditions when the room was at 20°C and 80% RH. The second half of the graph illustrates the change in conditions after the light was turned on.

One significant change was the sudden increase in humidity ratio after the light was turned on. This was probably caused by the evaporation of condensation, which had already formed within the cavity while the light was off. Gradually the humidity ratio reduces towards the equilibrium value of the room.

At the end of this test the under side of the floor above the cavity was inspected. This showed there was still some condensation at the corners of the interfloor space were the temperature could be expected to be lower. Also there was considerable water staining on the under side of the medium density fibreboard, used as the flooring, along with some changes to the surface texture probably caused by swelling due to condensation. This staining was especially obvious immediately above the light fitting.

5.7.2 Interfloor Space with SuperLux Fitting

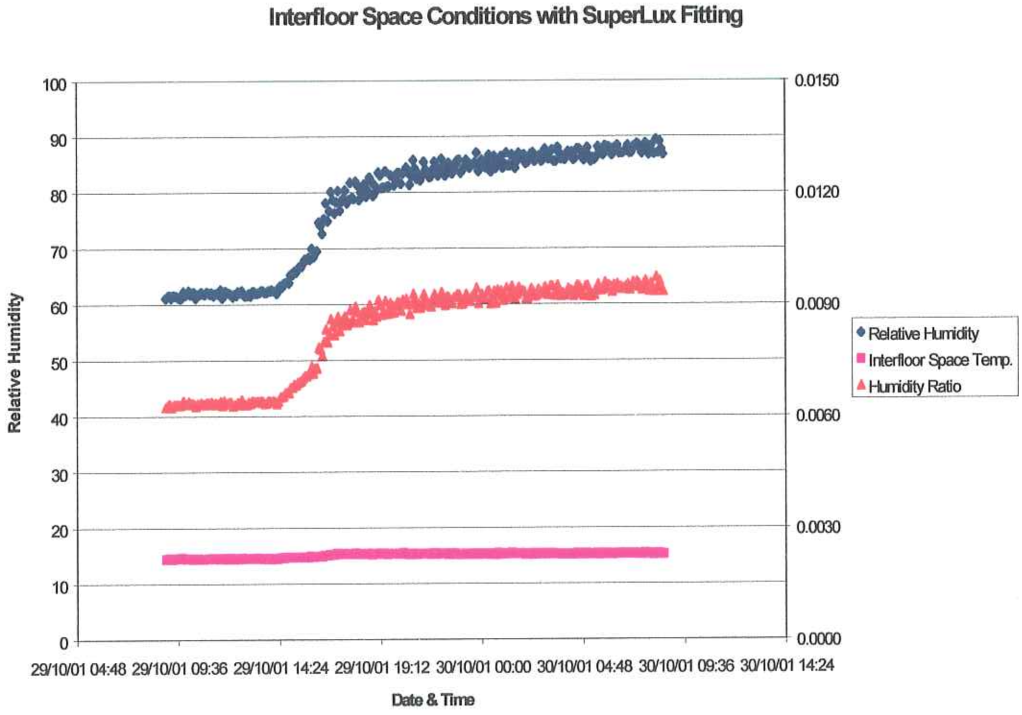


Figure 12 Interfloor Space Conditions

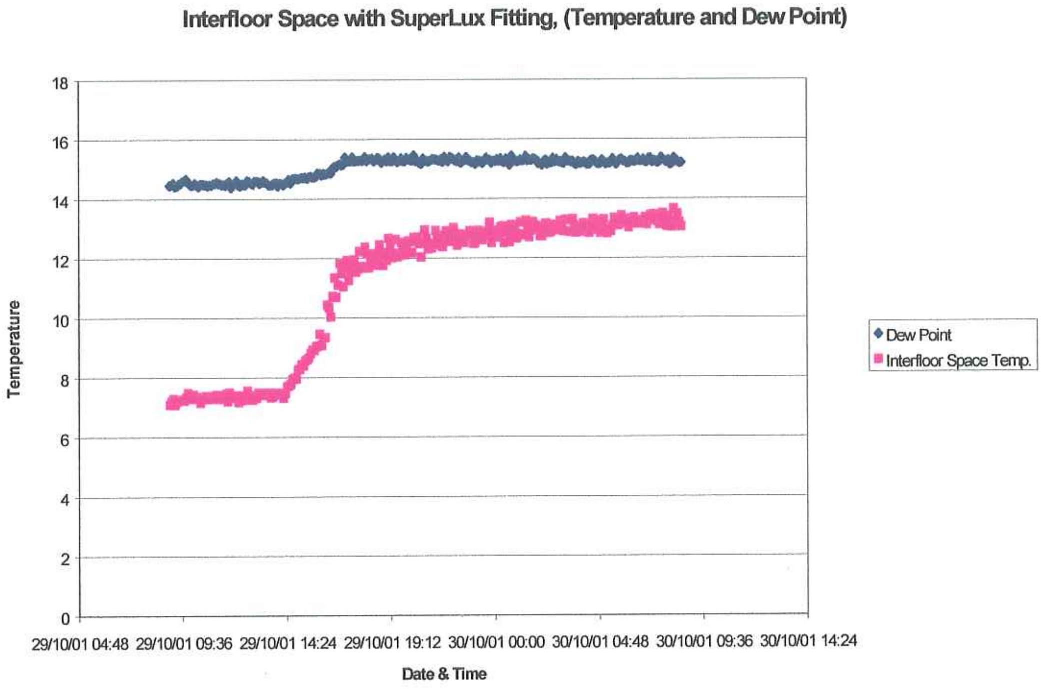


Figure 13 Interfloor Space Conditions

The graph in figure 12 shows the interfloor space conditions when a SuperLux fitting was installed. The first part of the graph until 29/10/01 14:21 was with the humidifier switched off and the light fitting sealed over with aluminium foil and tape. At 14:21 the humidifier was turned on with the light fitting still sealed. Some moisture still got into the interfloor space, this probably occurred around one of the sensor cable which went through the ceiling from the room.

At 16:11, after the room had reached the test conditions, the seal over the light fitting was removed.

At the end of this test the under side of the floor above the cavity was inspected. There was substantial condensation on the surface, the surface was stained and some swelling of the MDF was evident. Again the condensation was greatest immediately above the light fitting. Condensation also occurred on some metal components of the light fitting.

5.8 HEAT GAINS/LOSSES FROM LIGHT FITTINGS

Generally with a conventional light fitting any heat generated by the fitting ends up heating the room. From the table below it can be seen that with the downlight fitting there is less heat gain to the room, only 57% to 73% of the heat ends up inside the room.

Single Fitting Installed with Insulation Flush

	Loretto		SuperLux	
	8°C	12.5°C	8°C	12.5°C
Lamp OFF	0.2990 kW	0.1872 kW	0.2990 kW	0.1883 kW
Lamp ON	0.1934 kW	0.0956 kW	0.2260 kW	0.1313 kW
Lamp Wattage	0.15 kW	0.15 kW	0.10 kW	0.10 kW
Difference	0.1056 kW	0.0916 kW	0.0730 kW	0.0570 kW
Percentage	70%	61%	73%	57%

Table 9 Heat Gain to Room from Downlights

5.9 PRESSURE DROP AND AIR FLOW RATE RESULTS

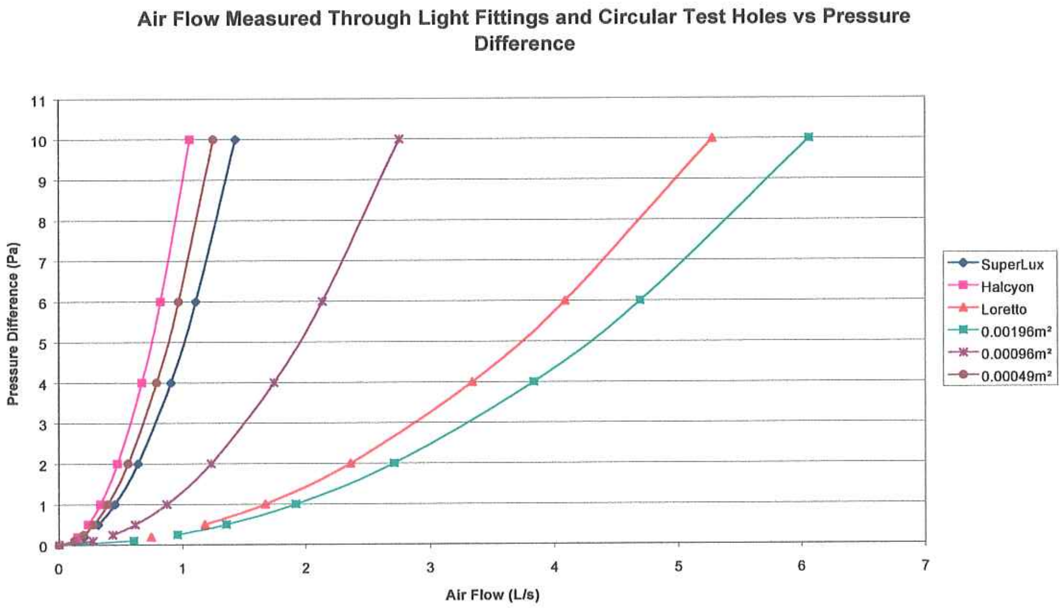


Figure 14 Comparison of Airflow Through Fittings and Circular Holes

	Equivalent Area (m^2)
Loretto	0.00173
SuperLux	0.00055
Halcyon	0.00044

Table 10 Equivalent Hole Size for Downlights

6 CONCLUSIONS

6.1 HEAT LOSSES

The conclusions from the tests are as follows:

- Heat losses from light fittings due to conduction (hole in the ceiling and removal of insulation) is negligible.
- In the absence of infiltration pressures (wind and stack effects) heat losses due to convective currents set up by light fittings in operation are minimal.
- Heat losses through fittings are most significant when there are pressure differences across the light fittings. This is covered in more detail below.

In actual circumstances there will be slight pressure differences across the light fittings which are caused by wind and stack effects. The latter are caused by the difference in density of air due to temperature differentials between the inside of the house and the outside. These pressure differences will cause air to flow through any gaps in the fittings.

The magnitude of the pressure differences will vary according to a number of factors including construction standards (the standard of air tightness of the building), inside/outside temperatures, wind speed and direction. The infiltration data we researched for New Zealand homes gave figures of an equivalent air leakage area but we could not source a representative pressure drop. The reference data is given for a pressure difference of 50Pa which, is far too high as an average value. The texts indicate that a figure of 4Pa will be more realistic and this is the figure we have used for our analysis.

	Outdoor Temperature		
	15°C	10°C	5°C
Loretto	0.020 kW	0.040 kW	0.060 kW
SuperLux	0.005 kW	0.011 kW	0.016 kW
Halcyon	0.004 kW	0.008 kW	0.012 kW

Table 11 Heat Loss Through Fitting due to Air Change Rate at 4 Pa Pressure Difference

The figures given above are an indication of the possible magnitude of heat losses from downlights due to infiltration. Although these losses are offset by heat gains into the room (refer table 9), they still represent a loss of potentially useful heat.

6.2 MOISTURE TRANSFER

The draft version of NZECP54 stipulates minimum standards (classes) of air-tightness for light fittings to be installed in different types of ceiling in various areas of dwellings.

Moisture transfer from the occupied space to the concealed space can be detrimental in two ways:

- Localised (direct) effects, where the moisture condenses directly on the upper parts of the light fitting and in the immediate vicinity of building elements, which are in the concealed space and below the dew point. Localised effects can lead to electrical faults (short circuits), premature failure of the light fitting due to corrosion and deterioration of the localised building elements.
- Widespread (indirect) effects, where the moisture gets diffused into the concealed space and due to inadequate ventilation, eventually affects large areas.

Out of the above two effects, direct effects are more likely to occur, because conditions which favour localised condensation are likely to be present even within concealed spaces which are well ventilated.

As with our previous conclusions for heat losses, where the dominant path was airflow through the fittings caused by pressure differences, most of the moisture transfer will also occur as a result of airflow through the fittings caused by infiltration pressure differences rather than diffusion effects.

The following table shows calculated roof space conditions for a pitched roof space using the following assumptions.

- A 135m² house with 2:1 aspect ratio and a 30° roof pitch.
- Pressure difference of 4 pascals.
- Open type fitting(s) giving 4.9 L/s air flow at 4 Pa.
- Habitable space conditions of 20°C and 50% RH.
- Outdoor conditions of 8°C and 80% RH.
- Roof space infiltration of 1 air change per hour at 4 Pa.
- Infiltration from downlight fittings displaces the roof space infiltration from outdoor air by an equivalent amount, eg constant roof space infiltration of 42.9 L/s.

	Temp	RH	HR (Kg/Kg)	Dew Point	Air Flow Through Fittings(L/s)
1 Fitting	9.4	76	0.00554	5.38	4.90
2 Fittings	10.7	72	0.00576	5.94	9.80
3 Fittings	12.1	68	0.00598	6.48	14.70
4 Fittings	13.5	65	0.00620	7.00	19.60
5 Fittings	14.9	61	0.00643	7.53	24.50
6 Fittings	16.2	58	0.00665	8.02	29.40
7 Fittings	17.6	55	0.00687	8.49	34.30
8 Fittings	19.0	52	0.00709	8.95	39.20

Table 12 Calculated Roof Space Conditions for a Pitched Roof

The following table shows calculated roof space conditions for a skillion roof space using the following assumptions.

- A 135m² house with 2:1 aspect ratio and a 30° roof pitch.
- Roof to ceiling gap of 0.1m.
- Pressure difference of 4 pascals.
- Open type fitting(s) giving 4.9 L/s air flow at 4 Pa.
- Habitable space conditions of 20°C and 50% RH.
- Outdoor conditions of 8°C and 80% RH.
- Roof space infiltration of 5 air change per hour at 4 Pa.
- Infiltration from downlight fittings displaces the roof space infiltration from outdoor air by an equivalent amount, eg constant roof space infiltration of 21.5 L/s.

	Temp	RH	HR (Kg/Kg)	Dew Point	Air Flow Through Fittings(L/s)
1 Fitting	10.7	72	0.00576	5.94	4.90
2 Fittings	13.5	65	0.00620	7.00	9.80
3 Fittings	16.2	58	0.00665	8.02	14.70
4 Fittings	18.9	52	0.00709	8.95	19.60
5 Fittings	21.7	47	0.00753	9.84	24.50
6 Fittings	24.4	42	0.00798	10.69	29.40
7 Fittings	27.1	38	0.00842	11.49	34.30
8 Fittings	29.9	34	0.00887	12.27	39.20

Table 13 Calculated Roof Space Conditions for a Skillion Roof

The possible effects of moisture transfer from a typical habitable space into a pitched and skillion roof are indicated above. Assumptions had to be made for the air change rates for the two different types of roof. As the number of fittings is increased, the dew point within the roof space increases and there is more likely to be condensation.

If the test results are analysed together with the requirements in NZECP 54, the following conclusions can be drawn.

- For habitable areas in dwellings having skillion or and pitched roofs, moisture transfer is not likely to cause problems providing means of ventilation is provided to the dwelling as stated in the building code. However further research into roof space ventilation is required before this can be confirmed.
- For moist areas, if ceiling recessed downlights are installed- even of the closed types, this will eventually lead to problems. Within interfloor voids there will be direct and indirect effects due to the void getting saturated, especially when upstairs is not heated. Similar effects are likely to occur in suspended ceilings. Within pitched and skillion roofs, there would definitely be localised condensation on the fitting and the building elements. Without further research, it is difficult to predict the extent of wider effects within the roof space.
- For open and restricted types of fitting the free area depends on the correct type of lamp being installed and this is a factor to consider when these types of light fitting are retrofitted with different lamps such as energy efficient compact fluorescents.

6.3 TEMPERATURE OF FITTINGS

The tests show that the surface temperature of the downlights tested can reach values of around 125-150°C. These temperatures will harm ordinary PVC electric cables, therefore it is important to ensure that the wiring to the fittings is done strictly in accordance with the manufacturers instructions and in accordance with electrical regulations. When retrofitting downlights, care must be taken to ensure that fittings do not affect existing electrical wiring.

Our tests indicate that if downlights are installed in accordance with NZECP 54, fire risks would be minimised. However, it is important that manufacturers specify the minimum required distance from building elements, such as insulation (especially flammable insulation) and timber. With certain types of fitting, eg the Loretto, there is little shielding of the lamp and the surface temperature reaches fairly high values (refer Figure 8).

Installation instructions for some fittings, which are sold currently, are vague on this important subject. Some specify a minimum distance from insulation but do not mention other building elements such as timber. With the introduction of NZECP 54, manufacturers will have to supply this information in the future.

6.4 GUIDELINES TO OPTIMISE DOWNLIGHT INSTALLATIONS.

NZECP 54 is a document, which will improve electrical and fire safety together with durability of the building elements. NZECP 54 will contribute to improving energy efficiency because it restricts the use of open type fittings. However it is limited in the sense it does not give guidelines to a maximum number of fittings for a particular area nor to lamp or fitting efficiencies. Current New Zealand building regulations H1-Energy Efficiency does not cover domestic installations either.

It was beyond the scope of this project to investigate the feasibility of including domestic lighting in the Building Code. However if this is to be developed, guidelines can be developed which would consider acceptable levels of illuminance for different areas together with lamp efficacies, luminaire efficiencies and their heat and moisture transfer characteristics.

7 REFERENCES

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3. BRANZ Technical Note 42: The infiltration component of ventilation in New Zealand Houses.

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