Multi-Service Chilled Beams

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As written and presented by Guy Hutchins, Trox UK Ltd.

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TROX® TECHNIK

Multi-Service Chilled Beams

1.0 Summary

The purpose of this paper is to highlight an architectural alternative to conventional air conditioning system design in the form of Multi-Service Chilled Beams (MSCB's). Utilising off-site pre-fabrication, the system wholeheartedly embraces the recommendations of Egan. Where relevant comparisons have been made between MSCB's and the UK's other popular form of comfort cooling namely, fan coil units.

Every Multi-Service Chilled Beam incorporates a chilled beam at its heart, either as a passive or an active version.

The advent of Multi-Service Chilled Beams has brought the architect and services consultant closer together to create an architecturally designed services unit.

The system, which has already been installed into some landmark buildings, is set to change building services and architecture forever. The use of a suspended ceiling may well be a thing of the past once the benefits of exposed MSCB's are widely known.

Taking for granted the aesthetic benefits that Multi-Service Chilled Beams offer, other benefits include cost and program reductions. The challenge of providing building services to low height 1960's buildings is one that will be relished by designers of MSCB systems, particularly those that incorporate an active chilled beam.

2.0 Multi-Service Chilled Beams

Multi-Service Chilled Beam (MSCB) is the term used to describe the process of utilising proven chilled beam technology in the form of either a passive (illustration 1) or active chilled beam (illustration 2). It is the pre-fabrication of all services components normally associated with a fan coil unit system (illustration 8) into an architecturally designed module (illustration 9), which is simply connected to the main distribution ductwork, pipework and cables (illustration 10).

illustration 1 – passive chilled beam.

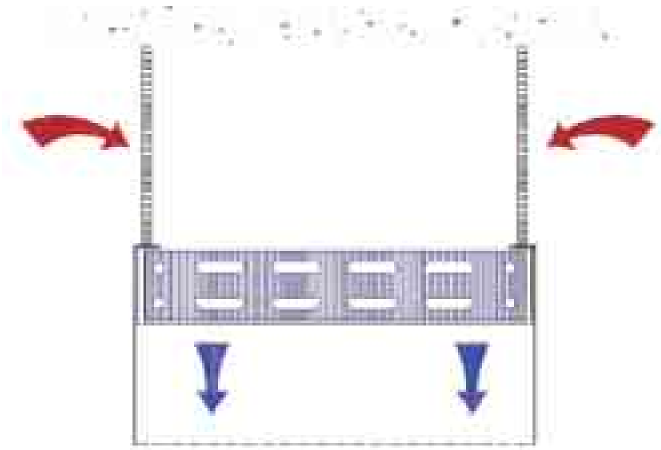
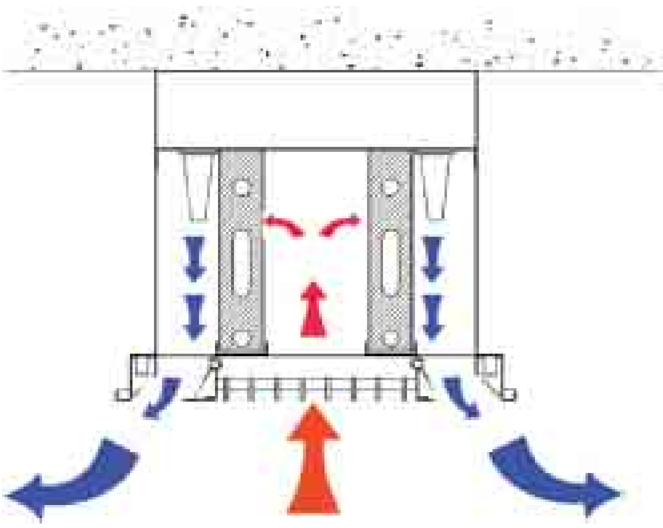


illustration 2 – active chilled beam.



2.1 Air Distribution Patterns – Chilled Beams and Fan Coil Units

The passive chilled beam (cooling only) uses a 'laminar' airflow pattern (illustration 3), while an active beam (cooling/heating) uses a 'mixed' air flow pattern (illustration 4) which is similar to the air distribution of a conventional fan coil unit (illustration 5). Exposed active MSCB's can project the discharge air stream up onto the soffit, improving comfort in the space (illustration 6). Mixed air flow relies on an induction process that achieves an even velocity and temperature in the occupied zone. Subject to the discharge velocity and temperature Δt it can be used for heating and cooling.

illustration 3 – passive chilled beam 'laminar' airflow distribution pattern.

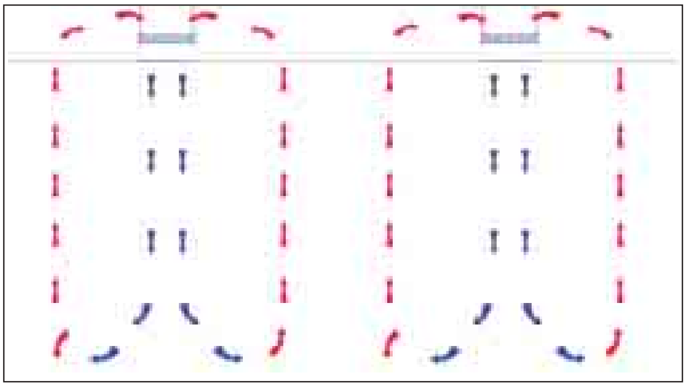


illustration 4 – active chilled beam 'mixed' airflow distribution pattern.

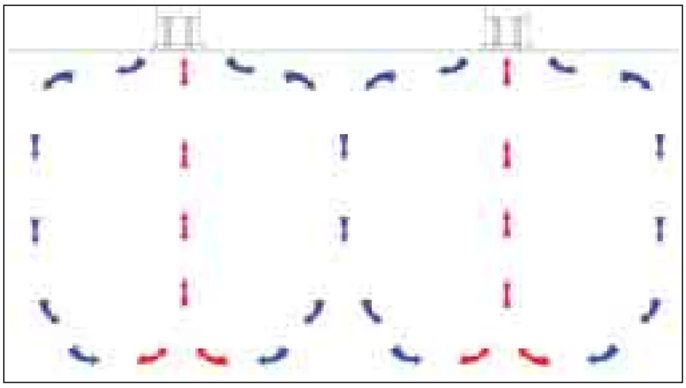


illustration 5 – fan coil unit 'mixed' airflow distribution pattern.

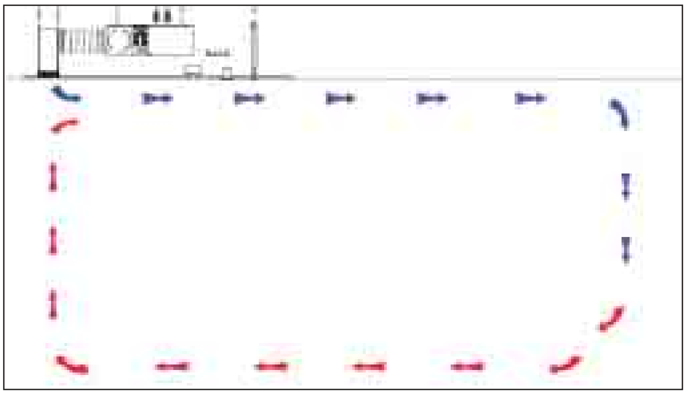
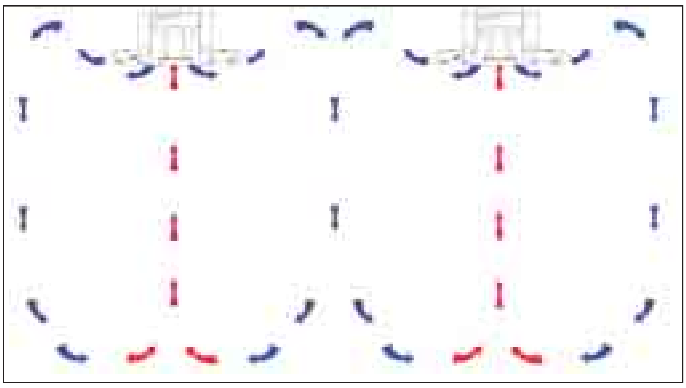


illustration 6 – active MSCB 'mixed' airflow distribution pattern.



2.2 Chilled Beam Performance Data

2.2.1 Chilled Beam design guidelines
Minimum water flow temperature 14°C.

Water supply temperature is minimum 1°C above theoretical room dew point.

Water return temperature between 2°C and 3°C above flow temperature.

Maximum terminal velocity 0.25m/s in occupied zone, (finished floor level up to a height of 1.8m).

2.2.2 Comparison of Passive and Active Chilled Beam Performance
Performance data based on Δt 8K, between mean water and room dry bulb temperature:

Passive Chilled Beam 450mm Wide

2 Row coil at 300 W/m at 3 metre beam centres = 100 W/m^2

Fresh air supply @ 15 l/s/person, 1 person/10m^2 = 14 W/m^2

Active Chilled Beam

Cooling duty 483* W/m at 3 metre beam centres = 161 W/m^2

*Selection based on an air generated S.W.L. of 39 dB(A) at 96 Pa static pressure with a primary air volume of 15.6 l/s/m. (illustration 7)

Multi-Service Chilled Beams

illustration 7 – Active chilled beam selection data.

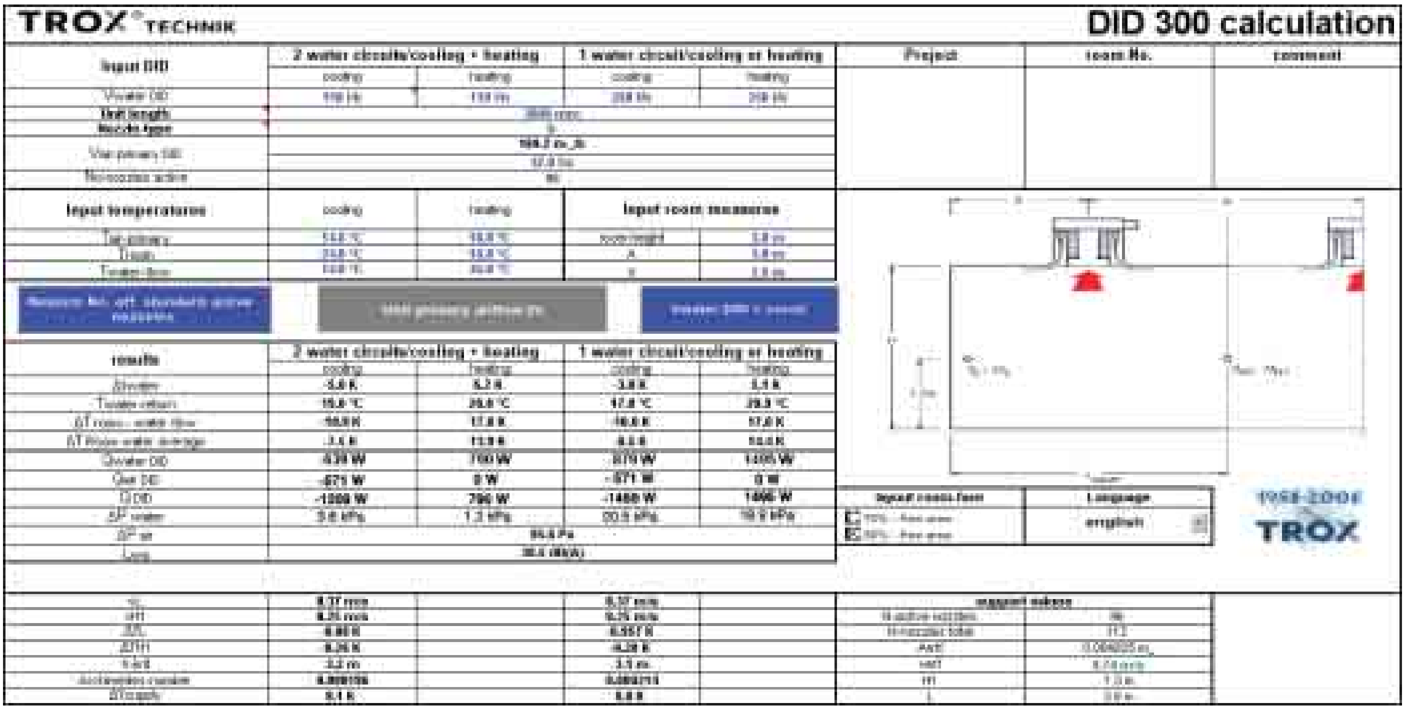


illustration 8 – conventional fan coil unit & services configuration, within a suspended ceiling.

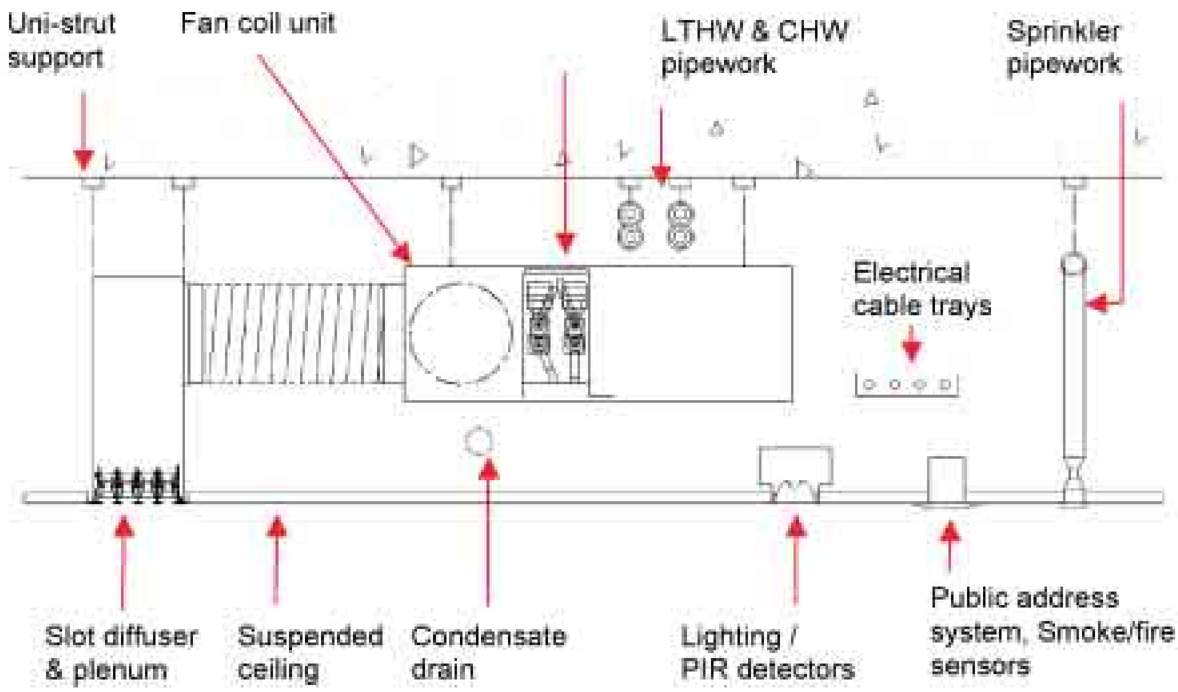
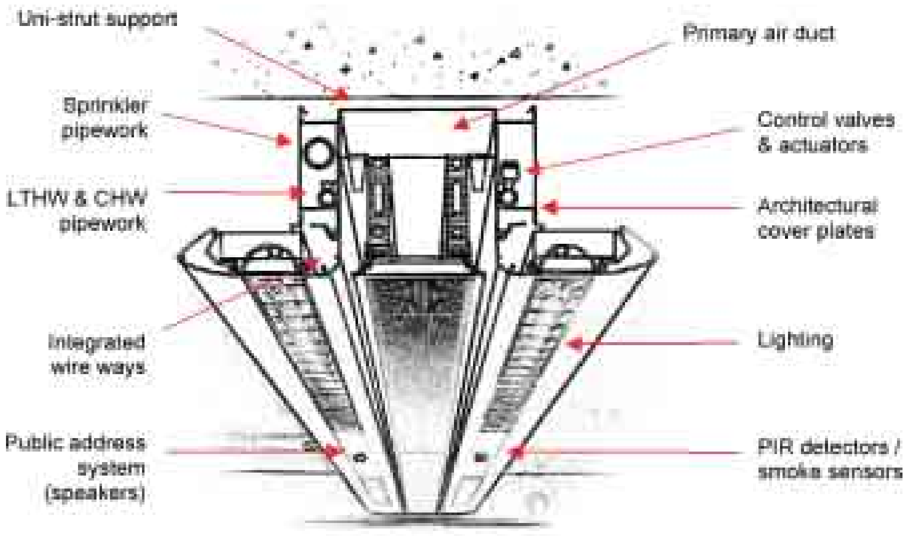


illustration 9 – Exposed Multi-Service Chilled Beam.



2.3 Integrated Services

An MSCB system allows the services engineer to involve the architect to design an aesthetic shroud around the co-ordinated building services, all in a controlled factory environment away from site.

The factory production and control processes encourage a consistent high quality to be manufactured, while meeting demanding fastrack programs. The highest safety standards can be administered in line with statutory health and safety regulations.

There are a wide variety of options when considering Multi-Service Chilled Beams, and it is possible to categorise them predominantly as either 'Exposed', with the MSCB fixed directly to the concrete soffit or 'Recessed' with the unit installed into a suspended ceiling.

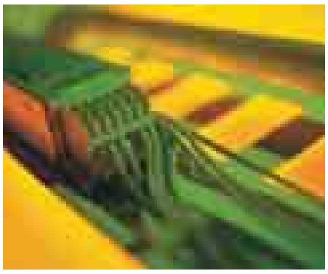
MSCB's accommodate a variety of building services, including:

- Lighting: lamps and control circuits
- Fire/smoke sensors and alarms
- Passive infra-red detectors
- Public address speakers
- Acoustic insulation
- Sprinklers
- Fresh air supply
- Cooling and Heating

Public Address Speaker

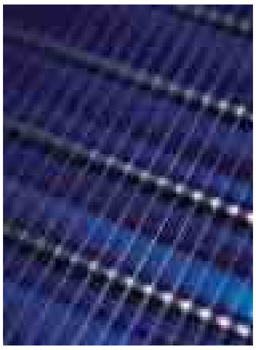
Electrical connections

Cabling

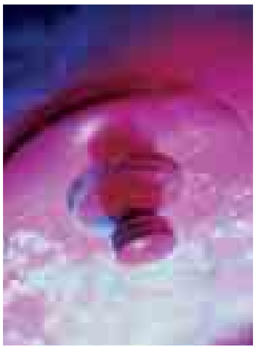


PIR Detector

Cooling/Heating Coil



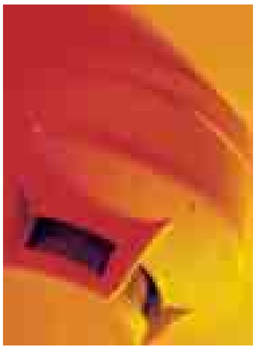
Sprinkler Head



Lighting

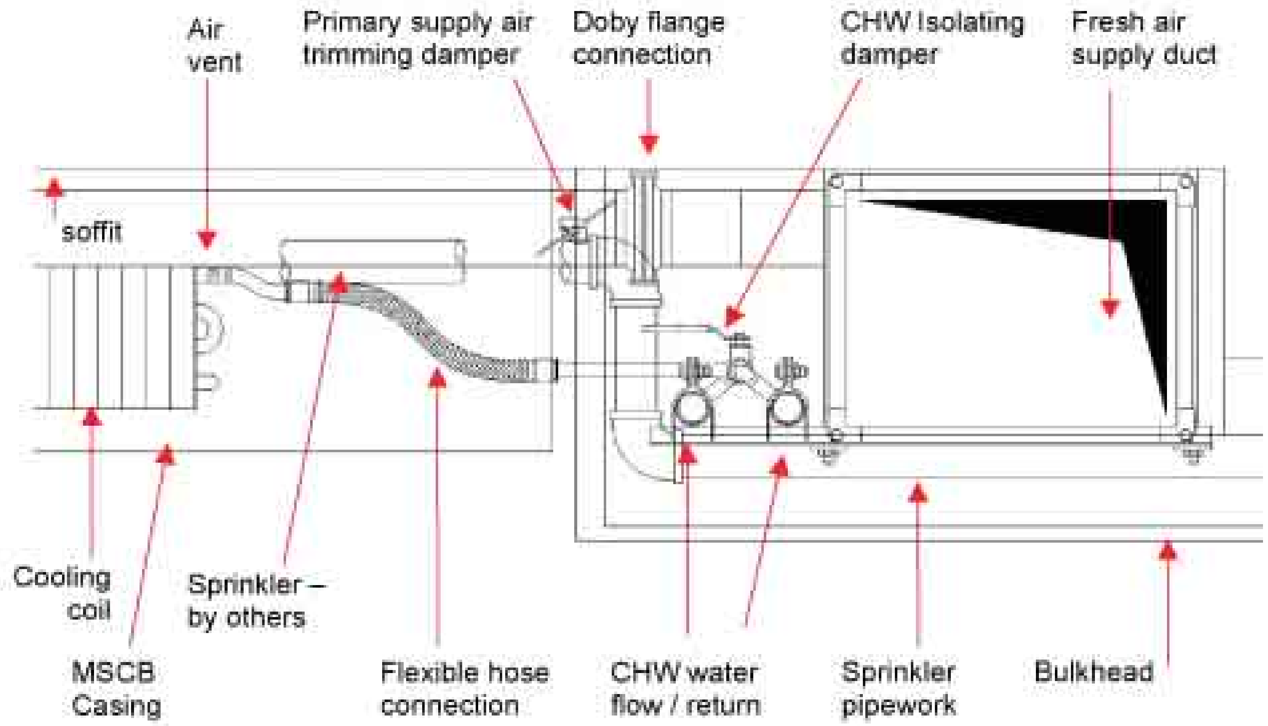
Fresh Air

Smoke sensor



Multi-Service Chilled Beams

illustration 10 – Exposed 'active' Multi-Service Chilled Beam services/bulkhead interface.



Push-fit flexible hose

Electrical connections

Pre-wired MSCB

3.0 Why Prefabricate

Much has been written about off-site pre-fabrication, particularly in the Egan report.

Some of the key issues that the report raises are:

- “Reduce construction costs and construction time by 10% annually”.
- “Reduce defects on projects by 20% per year.”
- “Integrate project processes around four key elements of product development, project implementation, partnering - the supply chain and production components.”
- “Early involvement of contractors (and suppliers) in the design stage.”
- “Teamwork between all parties and the elimination of confrontation.”

Nick Raynsford the former Secretary of State DETR is quoted, “improvements in construction performance and working conditions are only probably deliverable by switching a significant proportion of assembly away from site and into the controlled conditions of factories.”

Multi-Service chilled beams help each of these recommendations to be realised; there is also a good example of where these practices have been adopted to good effect, namely, the car industry.

3.1 The Car Industry
The construction industry is often compared to the motoring industry. In motoring you can see many examples of how prefabrication is encouraged to accelerate production and enhance efficiency and quality.

If you remove the dashboard of an old Ford Cortina you would find a menagerie of wiring, air vents and all manner of hidden equipment, similar to that which you would find behind most suspended ceilings. If however, the dashboard of a modern Ford Focus were to be removed then you would be faced with neatly positioned pre-fabricated wiring looms along with other fully co-ordinated services, ducts etc. which compares to the solution offered by MSCB’s.

4.0 Key Features of Multi-Service Chilled Beams

4.1 An Alternative to suspended ceilings
Containing all of the services within an MSCB allows the architect a very different choice from conventional suspended ceilings. Also, by exposing the soffit’s thermal mass will help offset part of the sensible cooling requirement. The engineer can explore various methods to maximise this to best effect.

Removing the suspended ceiling increases the perceived height within the space. 1960’s buildings with low slab to slab structures can be re-cycled more easily. A minimum of 2.8m slab to slab can be accommodated (illustration 11), providing 2.4m from F.F.L to underside of beam without experiencing the claustrophobia that would exist with a ceiling at the same height (illustration 12).

4.2 Production not Construction
The off-site advantages of pre-fabrication and co-ordination of fit-out services are realised. The services are fully co-ordinated, engineered and manufactured within the quality-controlled environment of the factory. There is now no need for various sub-contractors to jostle for position within the ceiling zone.

4.3 Reduced Structural Height
A nation-wide survey of construction professionals, conducted by Trox (UK), revealed that the most common new build structural clearance between concrete slab and concrete soffit is 3.5m (table 1).

The survey asked the participants “what is the most common structural clearance for a new build project 3.0m, 3.5m or 4.0m?” and included a copy of illustration 12, but without dimensions.

illustration 11 – section through low height exposed MSCB installation.

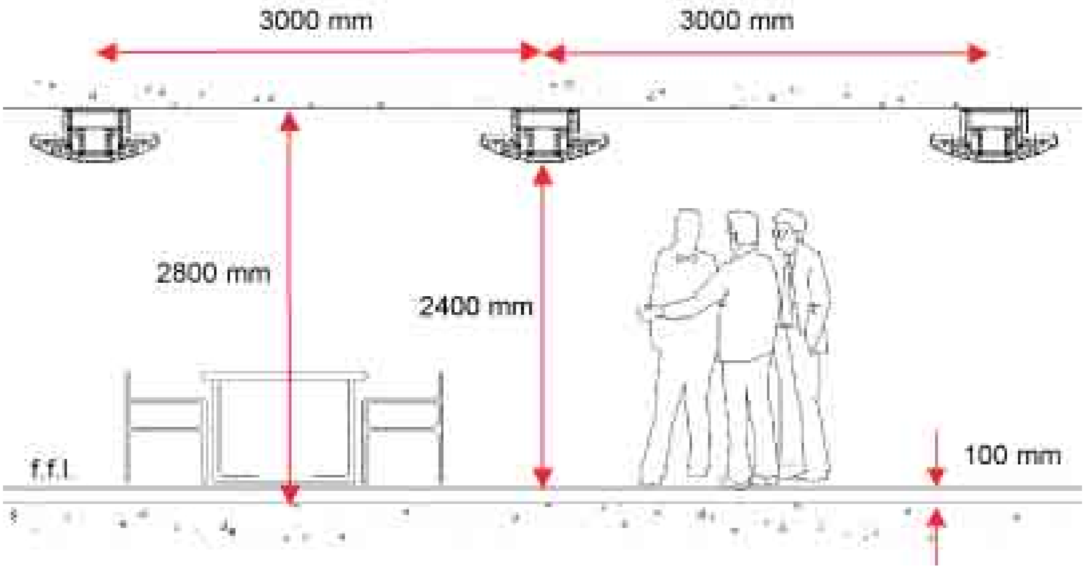
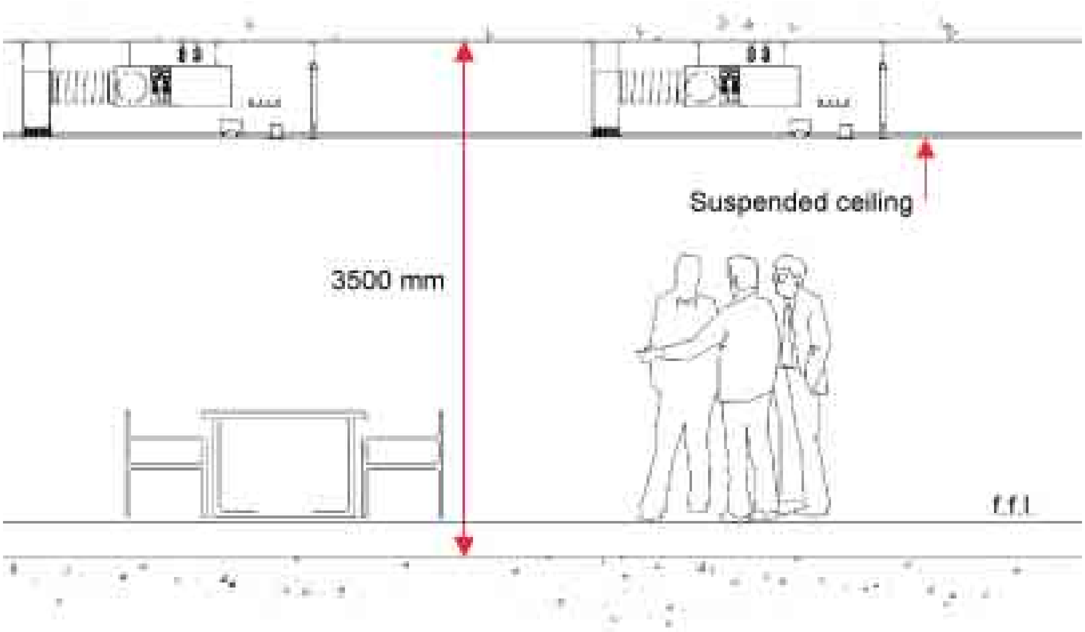


Table 1 – Structural Height Survey results:

Survey Location	Sample Size	Structural Clearance Of New Build Project					
		3.0m		3.5m		4.0m	
Birmingham	25	9	36%	12	48%	4	16%
Bristol	27	1	4%	26	96%	–	–
Edinburgh	27	4	14%	19	70%	4	16%
Glasgow	23	3	15%	15	65%	5	20%
London RIBA	68	8	12%	40	59%	20	29%
London HEVAR	92	20	21%	54	59%	18	20%
Manchester	27	4	10%	20	75%	3	15%
Newcastle	30	5	17%	18	60%	7	23%
Total	**319**	**54**	**17%**	**204**	**64%**	**61**	**19%**

This 3.5m height compares to the potential ‘slab to slab’ requirement of a Multi-Service Chilled Beam installation where 2.8m clear is required, providing a 700mm height reduction per floor (see illustrations 11 and 12). This enables a five-storey structure, rather than four, to be built within the same overall height, with the obvious requirement of one additional floor slab.

illustration 12 – Structural Clearance of a New Build Project with a Fan Coil Unit System.

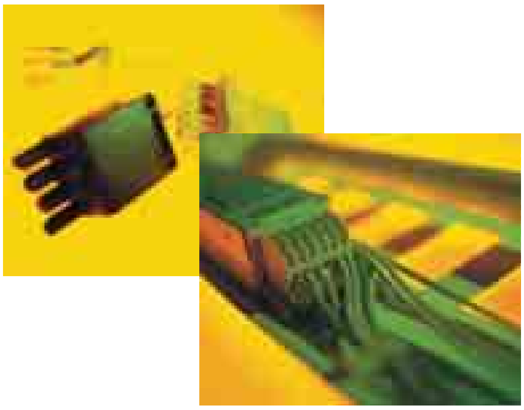


4.4 Plug and Play

Pre-fabrication and simple installation reduces time spent on site. MSCB's are designed to provide "plug and play" connectivity in each of the following areas:

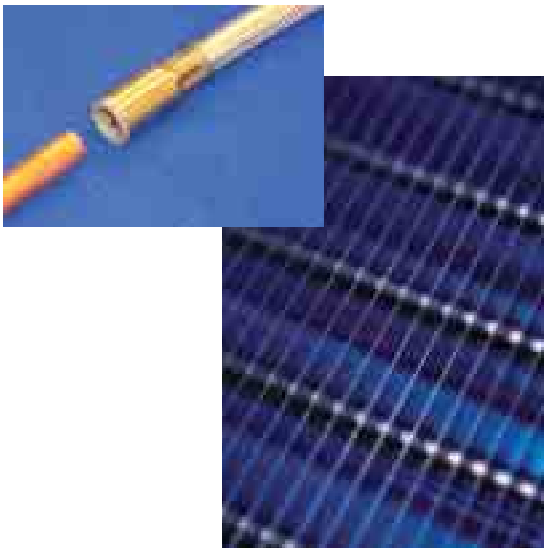
4.4.1 Cabling

The use of pre-wired 'plug and sockets' is commonplace for use with the lighting and lighting control. Wire ways are designed into the beam to accept these cables. Statutory requirements exist for continuous wiring to items such as smoke sensors, P.A. speakers for evacuation alarms, and emergency lighting. These items are also pre-wired with the cables coiled for delivery to site.



4.4.2 Flexible Hoses

High quality push fit flexible hoses are used to connect cooling coils to the distribution pipework.



4.4.3 Fixing

The design allows for separate support brackets, e.g. uni-strut, which are also used to set the beams out on the structural soffit. Sections of exposed units which remain on the base of their delivery crate platform, are placed onto 2 or 3 'Genie' type hoists (illustration 13). They are then lifted into position, located to the fixing brackets and levelled. Service connections are made at this time.

illustration 13 – MSCB positioned on 'Genie' hoist prior to fixing.

4.5 New Build and Refurbishment

The system has been adopted in major refurbishments such as Riverside House (section 9.2) and the Empress State Building (section 9.4) and also prestigious new builds such as the GLA Building (section 9.3).

Low height 1960's structures can be more easily re-cycled and refurbished rather than taking on expensive and timely demolition programs. New build projects can benefit from reduced structural heights too, see section 4.3.

5.0 The Design Process

5.1 The Designer

The 'designer' is a partnership that must include the architect, services consultant, contractor and the manufacturer. That team must deliver a solution that provides value for money in the form of an effective, engineered aesthetic installation into the building.

The architect will determine the product's aesthetics, including the beam's shape and finish. The services consultant's role of specifying components that satisfy the internal environment remains as critical as ever. The contractor brings knowledge of the structure and the installation process that will be most expedient. It is the manufacturer's role to ensure that the MSCB is an engineered solution while still providing value for money, he must also underwrite the product's performance.

5.2 Front End Design

The design parameters and responsibility for each of the building services components within an MSCB are the same as with a conventional design for the space. However, owing to the pre-fabrication of MSCB's the necessary co-ordination process necessitates that the design process is front-end loaded.

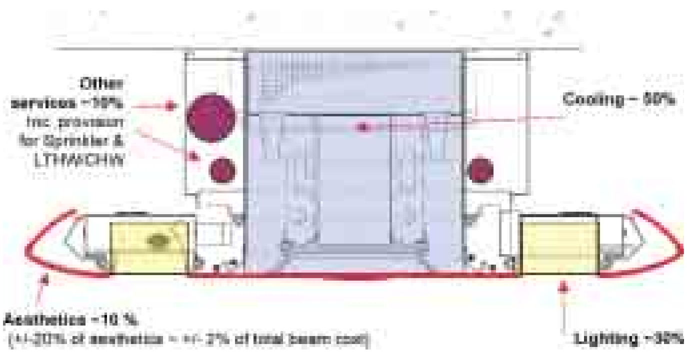
This design process encourages the professional team to tackle the issues of identifying space planning grids, building services to be included and aesthetic requirements early on to ensure that all MSCB design decisions maximise the products buildability and satisfy the occupant's requirements.

5.3 Bespoke Design Based on Standard Components

An important aspect of the design process is the use of known technology. The driving force of the beam's performance is the central chilled beam around which a shroud is created. It is possible to compare, yet again, the MSCB system with the motoring industry. Interestingly, 70% of the components are the same on the BMW 3-series, VW Golf, VW Bora, Skoda Octavia, Audi A3 and the Audi A4. It is predominantly the bodywork that is sculptured to give them their individuality. However the standardisation that is achieved delivers maximum cost advantage.

Bespoke MSCB's offer individual customisation of the aesthetics with little impact on cost. As the aesthetic components are typically 10% of the cost, a totally re-sculptured design can be crafted at a small increase to the beam's total cost (illustration 14).

illustration 14 – Indicative Multi-Service Chilled Beam component costs (supply only)



5.4 Exposed or Recessed

The services consultant will decide whether to use a passive or active chilled beam, taking account of the merits and suitability of each system. If an exposed route is to be taken it might be for green (exposed soffit), aesthetic, or probably height reasons that will jointly be decided in conjunction with the architect. The building's construction may necessitate a recessed Multi-Service Chilled Beam solution, eg. due to a hollow rib soffit which is not normally exposed to the space.

Examples of Multi–Service Chilled Beams recessed into suspended ceilings

Disneyland, Paris

GLA Building, London

5.5 Space Planning

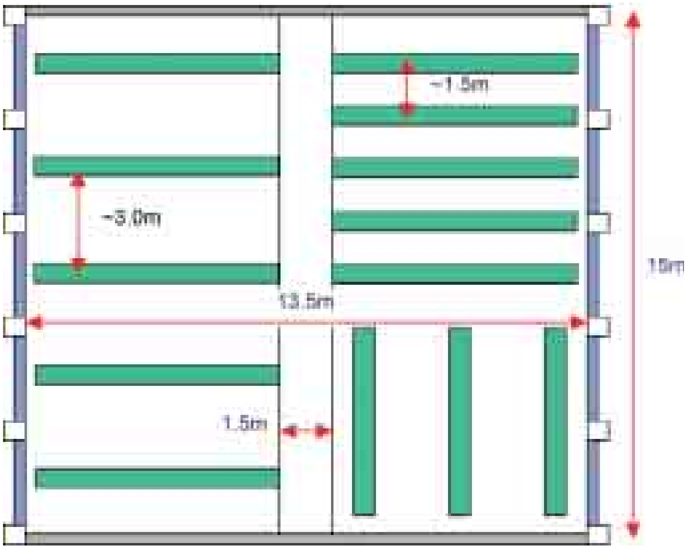
The design of the MSCB must be developed around the space planning grid. It is important that it has flexibility to suit future requirements. Typically the chilled beams are spaced at 3.0m centres providing good coverage of the space in terms of lighting and cooling. This nominal spacing satisfies a conventional 1.5m x 1.5m planning grid.

The MSCB must be able to accommodate partitions that 'slice' through the MSCB or butt up against the outer profile. The detailing will depend on the partition type, whether it is in the form of a glass screen (illustration 16) or a conventional demountable partition. Careful detailing at this point is key if cross talk between adjacent offices is to be prevented. MSCB's can be designed to incorporate partitions on 1.5m x 1.5m planning grid, even accepting the partition along the beam centre line (illustration 15).

illustration 15 – MSCB to suit partitions at 1500mm centres.

illustration 16 – glass partition intersecting MSCB.

Typical floor plate – plan view



5.6 Computer Configurator
The bespoke casing can be designed with the use of a 3D computer configurator (illustration 17) that can help determine whether the beam's shape should be flat or curved, along with the position of light fittings and other services while still achieving the expression that the architect requires.

5.7 3D Computer Modelling
3D modelling techniques (illustration 18) are used to translate AutoCAD to 3D images which are overlaid into architectural layouts enabling an on screen walk-through.

5.8 Full Scale Mock-ups
Polystyrene models can be used to expediently achieve the right 'feel' of the beam that works aesthetically as an interim step towards full-scale mock-ups. The laboratory testing process often facilitates an architectural mock-up and buildability, in addition to satisfying performance issues.

illustration 17 – 3D computer configurator.

illustration 18 – digital 3D mock-up courtesy of Hoare Lea Virtual Engineering.

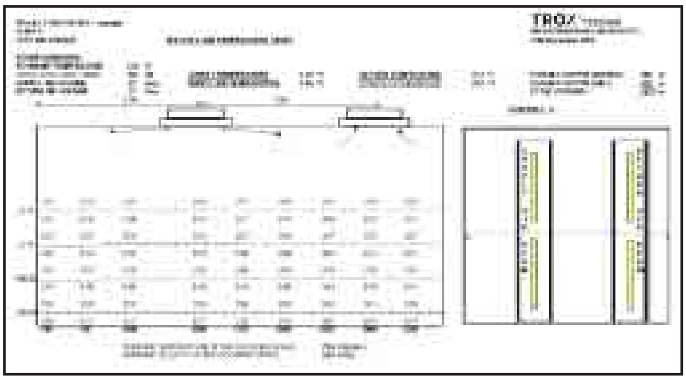
5.9 Laboratory Testing

Laboratory mock-up tests allow beam outputs to be assessed in simulations that replicate the installed environment including small power, occupant and solar loads. There is currently a draft European testing standard for chilled beams TC156 work item 156082.

Performance of the beams can be monitored (illustration 19) including space temperatures, air velocities and turbulence intensity. All of these factors enable the designer to assess the beam against recognised comfort standards; e.g. BS, DIN and Professor Fanger's comfort criteria.

Aerodynamics of the beams are also proven at this stage, particularly where coanda strips are used on exposed active beams to discharge the air up onto the concrete soffit. Indicative lighting levels can also be measured at the laboratory mock-up stage.

illustration 19 – laboratory test velocity and temperature photo and scan.



6.0 Lighting

The MSCB provides numerous lighting opportunities for the services engineer when selecting and specifying the light fittings. Recessed and exposed beams allow various solutions:

6.1 Recessed Beams

Recessed beams (illustration 20) usually incorporate a central downlight fitting.

6.2 Exposed MSCB's

Exposed MSCB's allow a wider choice for lighting the space, including:

6.2.1 Uplighting

The 2001 addendum to the LG3 lighting guide draws attention to the need for lighting the ceiling plane. It suggests various methods of achieving this including uplighting. They should prevent any perceived 'cave effect' which may result if the slab is not lit. Uplight options include all 'up' or a split of 'up and down', with the wash through the beam predominantly for effect (illustration 21).

illustration 20 – recessed MSCB with downlighting

illustration 21 – exposed MSCB with up/downlighting

illustration 22 – exposed MSCB with downlighting

6.2.2 Downlighting
Is achieved with fittings positioned either in the centre (illustration 20) or on the two outer edges (illustration 22). Outer fittings can be easily modified to provide feature up and downlighting (illustration 23).

Where outer fittings are used they will require asymmetric louvres due to their close proximity on the beam and the beam centres of say 3.0m (illustration 24).

Emergency lighting can be incorporated as necessary on the downlights.

MSCB's can be designed to incorporate fittings from a wide range, most commonly used now are T5 lamps.

illustration 23 – exposed MSCB with up/downlighting

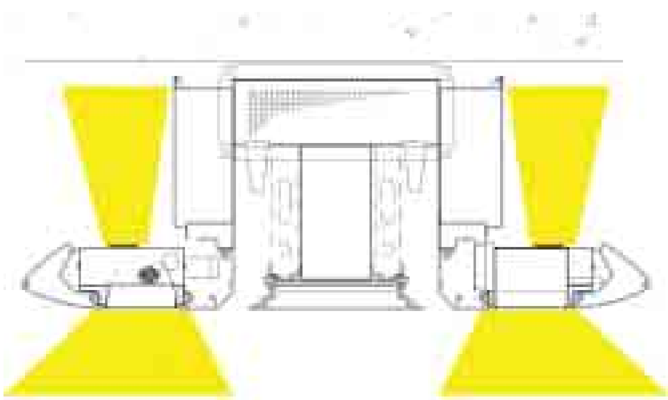
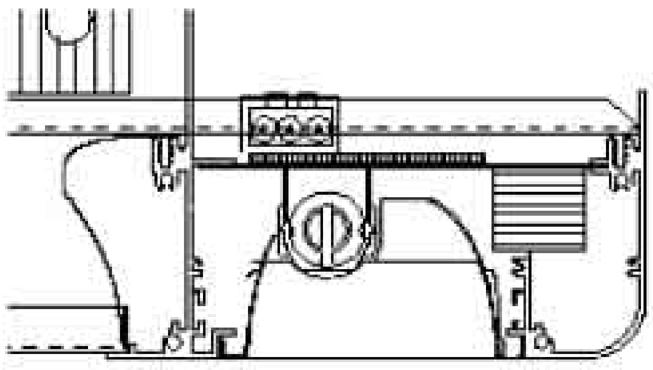


illustration 24 – asymmetric T5 louvre.



7.0 Cost

7.1 Capital Cost
A capital cost study, prepared by EC Harris, of an exposed architecturally designed Multi-Service Chilled Beam fixed directly to the concrete soffit, including a plaster skim and emulsion finish (illustration 9) is a cost of £225 per square metre. The beam is suitable for cooling and heating. This solution is 'cost neutral' when it is compared to a suspended ceiling and 2-pipe fan coil unit installation with low level perimeter heating, which is designed to suit a Category 'A' fit-out, with pre-engineered zones, partial cellularisation, and offers similar level of flexibility. Included are luminaires, primary air supply, valves and actuators, wire-ways, and free issued lighting controllers, public address speakers, sprinkler head and smoke detector.

7.2 Whole life Costs of Chilled Beams and Fan Coil Units
The following calculations (table 2) are based on an open plan office of gross floor area of 10,000 sq.m. with 1,000 sq.m. of cellularised offices. The running costs are based upon an occupation density of 1 person/10sq.m., with lighting and small power loads of 15 and 25 w/m^2 respectively. Operating times of the building have been taken to be between 8.00am to 6.00pm five days a week. Capital costs are as at 3rd quarter 2001. The cost includes for initial capital cost, replacement of plant and equipment as applicable, maintenance and energy consumption costs based upon a 25-year life cycle.

Table 2 – whole life costs provided by EC Harris.

A.C. System	Whole Life Cost (£/sq.m)
Two pipe fan coil	£625 to £685
Four pipe fan coil	£585 to £645
Active Chilled beam	£375 to £430

7.4 The Holistic Cost
Pre-fabrication of building services is acknowledged as a means of accelerating construction programs. It is impossible to accurately predict the program reduction that may be achieved on a given project, so below are example costs that may be realised by the 'client' for every program week that can be saved. The example is based on a new build office with a gross floor area of 10,000 sq.m, net floor area of 7,000 sq.m.

Description	Cost
Floor Area 10,000m^2 gross ~ 7,000m^2 net	
Construction Cost Total construction at £1700/m^2 x 10,000m^2 (excludes potential saving of reduced height structure)	= £17 million total
Prelims @ 13% = £2,210,000 (over 20 month construction period)	= £27,625 / week
Revenue Rent income @ £5/m^2 x 7,000m^2 = £3.5 million per annum	= £67,308 / week
Capital Repayment Interest @ 4.5% of £17 million = £765,000 per annum	= £14,712 / week
Total weekly potential savings Prelims + Revenue + Capital repayment	**= £109,645 / week**

8.0 The Implications of Part L

The changes to the Building Regulations in the form of Part L require designers to make the following changes:

- Improvements to the envelope standards with regard to solar overheating and air tightness.
- Achieve minimum efficiency standards for heating.
- Achieve minimum efficiency of A.C. systems based on input power.

The improvements required of the glazing will result in lower heating demands, possibly allowing perimeter heating to be omitted. Through good solar protection cooling loads will reduce dramatically, presenting more opportunities for the use of passive cooling at elevated water temperatures. This will present more opportunities for free cooling, along with the potential use of ground water sources.

Eliminating perimeter heating may be possible but pre-occupation pre-heating will still be necessary. In addition to 4-pipe systems mixed mode changeover systems can also be considered, in the form of a 2-pipe FCU or a 2-pipe active chilled beam system. The CIBSE and DTI HVAC ‘Strategies For Well-Insulated Buildings TM29:2002’ details cost savings of up to £30/sq.m that can be realised if the distribution pipework can be removed from each zone.

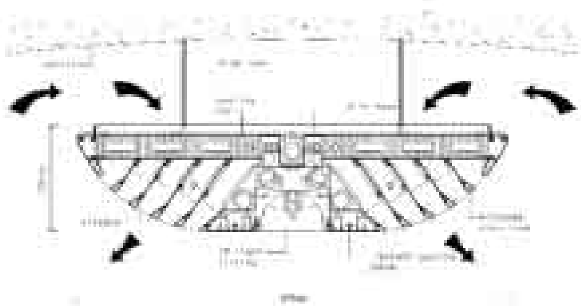
Active chilled beams used for heating operate efficiently and effectively at water flow temperatures of 35°C. , avoiding stratification in the space.

Designers are also encouraged to consider whole life costs and to invest in those elements which last the life of the building, and not those that are replaced before the end of their natural life, e.g. suspended ceilings during a re-fit. Organisations omitting a whole component may do so as part of their own ‘Eco policy’, rather than a Part L requirement, with consideration of the product’s inert energy of production all the way back to the power station.

9.0 Multi-Service Chilled Beam installations

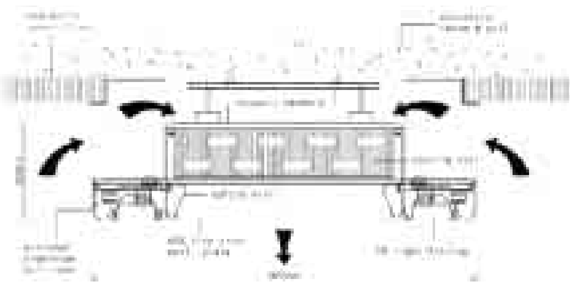
9.1 Lloyd’s Register of Shipping
Architect: Richard Rogers
Consultant: Ove Arup
Main Contractor: Sir Robert McAlpine

illustration 25 – section through exposed passive MSCB at Lloyd’s Register of Shipping.



9.2 Riverside House
Architect: RHWL
Consultant: GW Consultants
Main Contractor: Bovis Lend Lease
Installation: Trox (UK) Ltd

illustration 26 – section through exposed passive MSCB at Riverside House.



9.3 Greater London Authority Building
Architect: Foster and Partners
Services Consultant: Arup
Main Contractor: Mace
Services Contractor: Axima

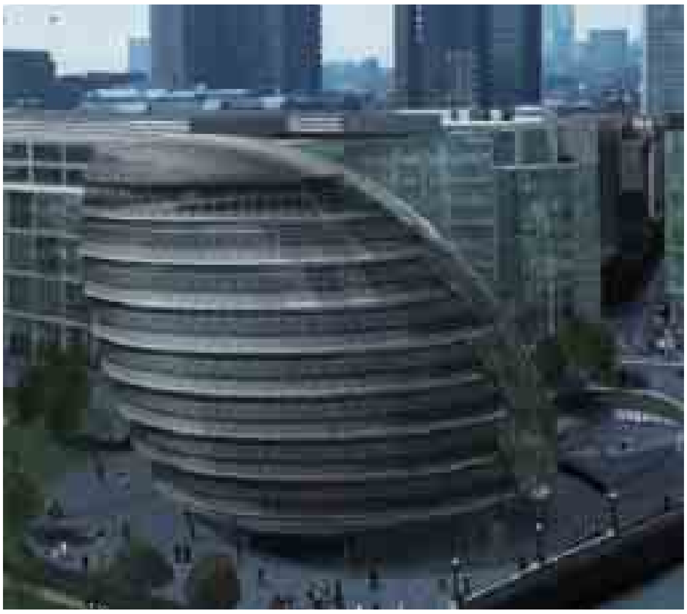
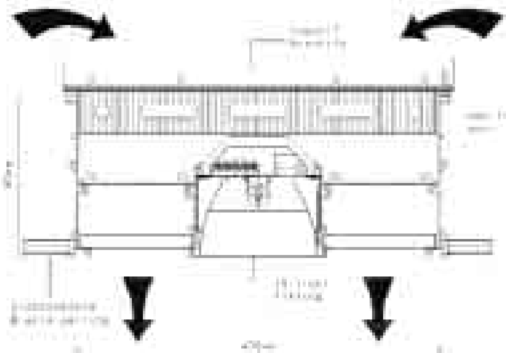
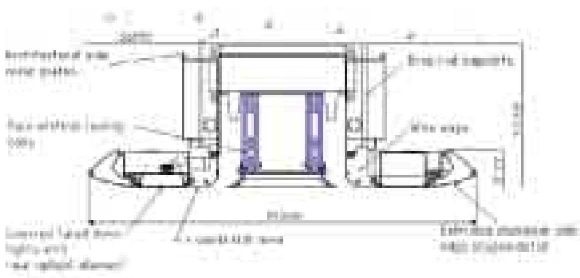


illustration 27 – section through recessed passive MSCB at GLA building.



9.4 Empress State Building
Developer: Land Securities
Architect: Wilkinson Eyre
Services consultant: MG Partnership and BWS
Main Contractor: Bovis Lend Lease

illustration 28 – section through exposed active MSCB at Empress State Building.



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As written and presented by Guy Hutchins, Trox UK Ltd.

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TROX® TECHNIK

Trox (UK) Ltd.
Caxton Way
Thetford
Norfolk IP24 3SQ

Tel: +44 (0)1842 754545
Fax: +44 (0)1842 763051
www.troxuk.co.uk
e-mail@troxuk.co.uk