CHAPTER 4

Architectural Services Department

Installing building services systems in government buildings

Audit Commission
Hong Kong
25 October 2010

This audit review was carried out under a set of guidelines tabled in the Provisional Legislative Council by the Chairman of the Public Accounts Committee on 11 February 1998. The guidelines were agreed between the Public Accounts Committee and the Director of Audit and accepted by the Government of the Hong Kong Special Administrative Region.

Report No. 55 of the Director of Audit contains 11 Chapters which are available on our website at http://www.aud.gov.hk.

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INSTALLING BUILDING SERVICES SYSTEMS IN GOVERNMENT BUILDINGS

Contents

PART 1: INTRODUCTION

1.1 This PART describes the background to the audit and outlines its objectives and scope.

Building services systems

1.2 Building services systems are the electrical and mechanical installations inside a building that provide the internal infrastructure for the proper functioning of the building. Major building services systems include:

(a) electricity supply systems;

(b) air-conditioning systems;

(c) lighting systems;

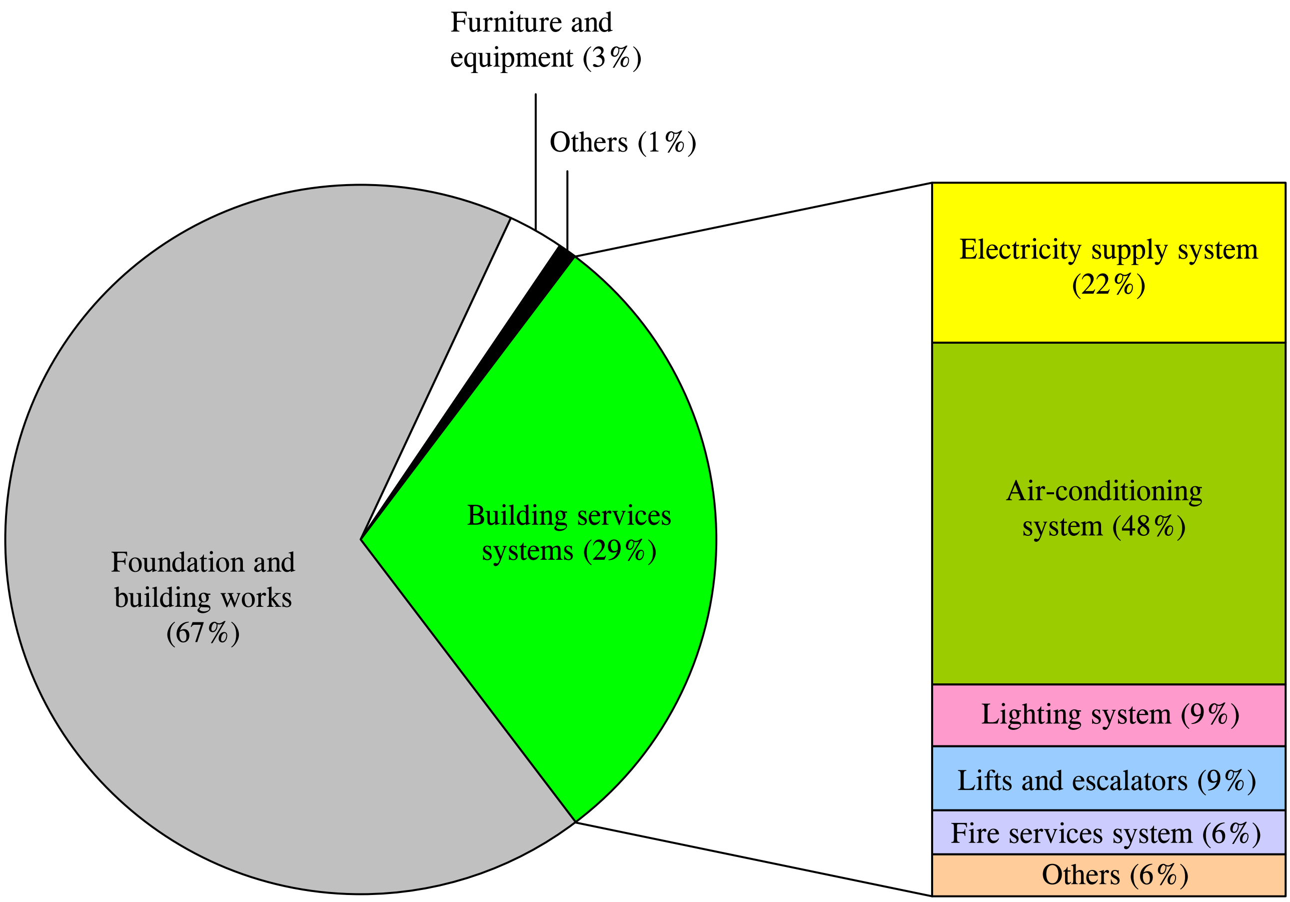
(d) lifts and escalators; and

(e) fire services systems.

1.3 Building services systems are essential provisions for a building, accounting for 20% to 40% of the total construction cost. Figure 1 shows the cost breakdown of a typical government office building.

Figure 1

Construction cost of a typical government office building



Source: Architectural Services Department records

Design, installation and maintenance of building services systems

1.4 The Architectural Services Department (ArchSD) is the works agent for the design and construction of government buildings, and is responsible for keeping up the prevailing standard in design, construction and maintenance of government building projects. In 2009, the ArchSD undertook 174 building works projects with a total expenditure of $6.7 billion.

1.5 The Building Services Branch (BSB) of the ArchSD provides professional services for the design, specifications, tendering, and installation of building services systems in government buildings and other projects under the ArchSD's management. The BSB compiles and regularly updates general specifications for building services systems to provide guidance on compliance with relevant standards and statutory requirements, including those relating to environmental, energy efficiency, health and safety aspects.

1.6 In 2002, the ArchSD rolled out a plan to progressively outsource the professional and technical services, including the design and supervision of works, for implementing new government building projects to the private sector. From then on, only a small number of building projects remained to be led by ArchSD in-house staff. Most of the building projects were designed and supervised by outside consultants or contractors, with the ArchSD assuming the role of project management. In these outsourced projects, the BSB provided functional support and technical advice on matters relating to building services systems, including checking of the design and installation of building services systems.

1.7 Upon completion of a building project, the building is handed over to the client department (for a departmental building) or the Government Property Agency (GPA — for a joint-user building) for occupation and operation. The client department or the GPA is responsible for day-to-day management of the building. The Electrical and Mechanical Services Department (EMSD) provides services to government departments and autonomous bodies on the operation and maintenance of building services systems through the Electrical and Mechanical Services Trading Fund (EMSTF). At present, most of the government buildings are under the services of the EMSTF for the daily operation and routine maintenance of building services systems. The Property Services Branch of the ArchSD carries out building maintenance and repair of government buildings and facilities, and undertakes refurbishment and minor building works to buildings maintained by the ArchSD, including their building services systems.

1.8 As most building services equipment items consume electricity in their operation, energy efficiency is a major concern in the design and operation of building services systems. The Energy Efficiency Office of the EMSD has issued guidelines on promoting energy efficiency of various building services systems. In November 2005, Environment, Transport and Works Bureau Technical Circular (Works) No. 16/2005 on "Adoption of Energy Efficient Features and Renewable Energy Technologies in Government Projects and Installations" was issued to bureaux and departments for guidance.

Audit review

1.9 The Audit Commission (Audit) has recently conducted a review to examine the design and installation of building services systems in government buildings. The review focused on the following areas:

(a) post occupancy evaluation of completed building projects (PART 2);

(b) design and installation of electricity supply systems (PART 3);

(c) design and installation of air-conditioning systems (PART 4);

(d) design and installation of lighting systems (PART 5); and

(e) rectification of defects in building services systems (PART 6).

Audit has found that there are areas where improvements can be made and has made a number of recommendations to address the issues.

Acknowledgement

1.10 Audit would like to acknowledge with gratitude the full cooperation of the staff of the ArchSD, the EMSD and the GPA during the course of the audit review.

PART 2: POST OCCUPANCY EVALUATION OF COMPLETED BUILDING PROJECTS

2.1 This PART examines the review conducted by the ArchSD on building services systems after completion of a building project.

Introduction of post occupancy evaluation

2.2 After completion of a building project, the ArchSD hands over the newly constructed building to the client department for occupation. The ArchSD also hands over the building services systems and the documents for operation and maintenance to the building operator (e.g. the GPA) and the maintenance agent (e.g. the EMSTF). The maintenance agent takes over the responsibilities for operation and maintenance of the building services systems.

2.3 Before 2005, there were no specific requirements for conducting a review of the building services systems after completing a building project. In July 2005, the ArchSD issued BSB Instruction No. 3 of 2005 on "Post Occupancy Evaluation", which promulgates a requirement for conducting a post occupancy evaluation (POE) of the building services systems. The Instruction mentions that, owing to the technical complexity and clients' concerns about the functional requirements and energy consumption of building services systems, there is a need to oversee the performance of these systems to ensure that they function satisfactorily, meet the clients' operational requirements, and achieve optimum energy efficiency during the post occupancy period.

2.4 The Instruction stipulates that, with effect from July 2005, POE exercises should be conducted on **complicated** projects and should cover three major areas:

(a) operational performance monitoring and handover;

(b) energy review; and

(c) new technology/specific system evaluation.

After completing a POE, a concluding report would be prepared for endorsement, and disseminated within the BSB for experience sharing.

2.5 In August 2006, the ArchSD decided to select a project to include architectural works in the scope of POE. After the trial run, the scope of POE was extended to cover both building services systems and architectural works.

2.6 In September 2006, the ArchSD issued BSB Circular No. 25 of 2006 on "Guidance Notes on Conducting Post Occupancy Evaluation Exercise", which provides detailed guidelines to further enhance the effectiveness and efficiency of conducting POE exercises.

Building projects selected for post occupancy evaluation

2.7 Between July 2005 (commencement of POE) and June 2010, the BSB selected 12 building projects, involving Buildings A to L, for conducting POE (see Table 1).

Table 1

Building projects selected for POE
(July 2005 to June 2010)

Building	Project cost (Note) ($ million)	Building completion (occupation)	Period covered by POE	POE completion
A	2,047.9	Apr. 2004 (Oct. 2004)	Jul. 2005 — Mar. 2006	Sep. 2006
B	658.8	May 2005 (Sep. 2005)	Sep. 2005 — Sep. 2006	Mar. 2007
C	759.2	Nov. 2004 (Apr. 2005)	Jun. 2005 — Jun. 2006	May 2007
D	445.0	Apr. 2005 (Dec. 2005)	Aug. 2005 — Dec. 2007	Mar. 2008
E	548.4	Jul. 2005 (Oct. 2005)	Oct. 2005 — Mar. 2008	Jan. 2009
F	486.5	Nov. 2006 (May 2007)	Jul. 2007 — Dec. 2008	Nov. 2009
G	934.2	Jun. 2007 (Jul. 2007)	Feb. 2008 — Mar. 2009	Dec. 2009
H	689.4	Apr. 2007 (Aug. 2007)	Jan. 2008 — Jul. 2009	Jun. 2010
I	212.7	Nov. 2006 (Jul. 2007)	Oct. 2007 — Sep. 2009	Report being drafted
J	99.9	Feb. 2007 (Jul. 2007)	Nov. 2007 — Jun. 2009	Report being drafted
K	257.6	Sep. 2009 (Nov. 2009)	(POE in progress)	
L	347.9	Oct. 2009 (Mar. 2010)	(POE in progress)	

Source: *ArchSD records*

Note: *This is the actual expenditure of the project up to 30 June 2010.*

As of June 2010, the POE exercises on 8 out of the 12 building projects had been completed. Four of the POE exercises were still in progress.

Consultancy study for development of post occupancy evaluation

2.8 In December 2008, the ArchSD commissioned a consultant to conduct a study on "Development of Post Occupancy Evaluation". The objective of the consultancy study was to develop a set of procedures and a POE framework by:

(a) advising on the approach and methodology to be adopted in the study;

(b) setting and developing a strategy for the POE framework;

(c) assisting POE teams to conduct a trial run of the proposed POE framework and evaluating its effectiveness and suitability; and

(d) conducting training for ArchSD staff on the finalised POE framework.

2.9 The consultancy study was conducted in three stages, as follows:

(a) ***Inception Stage.*** This stage was completed in January 2009;

(b) ***Research and Development Stage.*** This stage was completed in October 2009 with a report issued, which contained a proposed POE framework for trial run; and

(c) ***Implementation and Evaluation Stage.*** This stage commenced in October 2009 with two projects selected for trial runs of the proposed POE framework.

The consultancy study was scheduled for completion by October 2010. As of mid-October 2010, the study was still in progress.

2.10 In the report issued in October 2009 (see para. 2.9(b)), the consultant considered that the ArchSD had demonstrated management commitment by establishing the POE exercise as a way of making continuous improvement in implementing building projects. The report identified room for improvement in the following areas of the POE process:

(a) planning;

(b) scope of study;

(c) timing of conducting POE;

(d) study approach and methodology; and

(e) communication.

In each area, the consultant made recommendations for improvement. Based on the recommendations, the consultant also developed a proposed POE framework for trial run.

Audit observations and recommendations

Need to expedite action to implement improvement measures

2.11 Audit noted that the POE consultancy study was started in December 2008 and originally scheduled for completion in October 2009. As of mid-October 2010, the Implementation and Evaluation Stage of the study was still in progress. Meanwhile, the ArchSD was examining the recommendations proposed by the consultant on various aspects of the POE pending completion of trial run of the proposed framework.

2.12 Audit noted that the scheduled completion date of the study was extended to October 2010, one year behind the original schedule. In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) the trial run of the proposed POE framework required the availability of suitable projects. As suitable projects could only be available for POE exercises in early 2010, the consultancy study was thus extended to October 2010; and

(b) it would closely monitor the progress of this consultancy study and allow appropriate time for completing consultancy studies in future.

Audit considers that there is a need to closely monitor the progress of the consultancy study and promptly implement the consultant's recommendations where appropriate.

Need to set objective selection criteria

2.13 According to BSB Instruction No. 3 of 2005, POE exercises should be conducted on complicated projects (see para. 2.4). However, the Instruction did not provide guidelines on the selection of such projects. **In Audit's view, there is a need for setting out clear guidelines and objective criteria for selecting building projects for POE.**

Need for setting target on POE coverage

2.14 The ArchSD did not set a target number of building projects for conducting POE. Between July 2005 (commencement of POE) and June 2010, the ArchSD selected 12 building projects for conducting POE. On average, fewer than 3 completed projects were selected for POE each year. The 12 projects accounted for 7% of the 175 building projects completed during the period.

2.15 In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) the decision to carry out a POE was based primarily on the complexity of a project;

(b) setting a target number (or percentage coverage) of building projects might not be realistic as the number of suitable projects for conducting POE might vary from year to year;

(c) depending on workload demand, the availability of resources would affect the number of POE exercises to be conducted; and

(d) the current practice was to concurrently carry out about four to five POE exercises.

2.16 POE is a useful management tool for evaluating the effectiveness of the building services systems in completed buildings, and helps identify improvement measures for implementing building projects in future. **Audit considers that there are merits for the ArchSD in conducting more POE exercises.**

Need to cover different types of building projects

2.17 ArchSD building projects comprised in-house projects and outsourced projects. Since 2002, the ArchSD has progressively outsourced the design and supervision of works of building projects to the private sector (see para. 1.6). As a result, in-house projects had substantially decreased in number. Table 2 shows the number of completed building projects and that selected for POE between July 2005 and June 2010 by project type.

Table 2

Building projects selected for POE by project type
(July 2005 to June 2010)

Project type	**Projects completed (a) (No.)**	**Projects selected for POE (b) (No.)**	**Coverage** $(c) = \frac{(b)}{(a)} \times 100\%$ **(%)**
In-house projects	29 (17%)	6	21%
Outsourced projects	146 (83%)	6	4%
Overall	**175 (100%)**	**12**	**7%**

Source: ArchSD records

2.18 As shown in Table 2, despite the fact that 83% of the completed building projects were outsourced ones, only **4%** of such projects were selected for POE. On the other hand, **21%** of in-house projects were selected for POE. Apparently, by percentage coverage, more in-house projects were selected for POE than outsourced ones.

2.19 The building projects completed by the ArchSD comprised different types of building. Table 3 shows the number of completed building projects and that selected for POE between July 2005 and June 2010 by building type.

Table 3

Building projects selected for POE by building type (July 2005 to June 2010)

Building type (Note)	Projects completed (a) (No.)	Projects selected for POE (b) (No.)	Coverage $(c) = \frac{(b)}{(a)} \times 100\%$ (%)
Office	3	2	**67%**
Hospital	6	3	**50%**
Law and Order	7	3	**43%**
Recreation, Culture and Amenities	48	3	6%
Education	76	1	1%
Environmental Hygiene	19	0	0%
Quarters	4	0	0%
Social Welfare	4	0	0%
Public Safety	3	0	0%
Others	5	0	0%
Overall	**175**	**12**	**7%**

Source: ArchSD records

Note: This is in accordance with the classification of building type in the Public Works Programme shown in the Estimates.

2.20 Table 3 shows that, for three building types (i.e. Office, Hospital, and Law and Order), 43% to 67% of the completed projects were selected for POE. On the other hand, the coverage on the other seven building types was low. For five building types (i.e. Environmental Hygiene, Quarters, Social Welfare, Public Safety and Others), no POE had been conducted.

2.21 In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) the selection of projects for POE depended on the availability of suitable projects and was based primarily on the complexity of the projects. No POE had been conducted for the last five building types in Table 3 as the projects were comparatively simple and the cost for each project was under $200 million;

(b) during the initial implementation of POE, the scope, problems encountered and resources needed for conducting POE had yet to be ascertained. More in-house projects were thus selected so that the POE exercises could be put under close control and monitoring;

(c) based on the experience learnt from in-house projects, the POE exercises could be extended to cover more outsourced projects; and

(d) subject to availability of resources, projects of different building types with appropriate complexity would be considered in POE exercises in future to balance the building types in the POE portfolio in the longer term.

2.22 **Audit considers that the ArchSD needs to take into account different project and building types in selecting building projects for POE in future.**

Audit recommendations

2.23 **Audit has *recommended* that the Director of Architectural Services should:**

(a) **closely monitor the progress of the consultancy study on the development of POE and promptly implement the consultant's recommendations where appropriate (see para. 2.12);**

(b) **formulate guidelines and objective criteria for selecting building projects for POE (see para. 2.13);**

(c) **subject to availability of resources, consider selecting more building projects for POE (see para. 2.16); and**

(d) **in selecting building projects for POE in future, take into account different project and building types (see para. 2.22).**

Response from the Administration

2.24 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendations. She has said that the ArchSD will:

(a) closely monitor the progress of the consultancy study on the development of POE. Two suitable projects were identified and agreed with the consultant in early 2010 for inclusion in the trial runs of the proposed POE framework;

(b) document the criteria for selection of building projects for POE. A departmental instruction will be issued in the fourth quarter of 2010 and will cover the strategy, administrative procedures and criteria for selecting building projects for POE exercises;

(c) subject to availability of resources, select more building projects for POE to facilitate systematic collection of data and information; and

(d) focus on those buildings with complicated building services installations in selecting building projects for POE in future. Subject to availability of resources, buildings with relatively simple installations will also be selected for POE.

PART 3: DESIGN AND INSTALLATION OF ELECTRICITY SUPPLY SYSTEMS

3.1 This PART examines the design and installation of electricity supply systems in government buildings.

Functions and major components of an electricity supply system

3.2 In a building, the electricity supply system distributes electrical energy supplied by the electricity supply company through a network to individual building services equipment and other appliances that require electricity to function. The main components of an electricity supply system include:

(a) **distribution transformers** for stepping down electric voltage from a high voltage level (e.g. 11,000 volts) to a low voltage level (e.g. 380 volts) for distribution in a building;

(b) **main cubicle switchboards** for connecting electricity from the transformers to the distribution network. The main cubicle switchboard is the main equipment of the electricity supply system;

(c) **distribution network** for supplying electricity to various electrical circuits in the building;

(d) **switchboards and protection circuits** for the distribution network; and

(e) **emergency generators** for providing electricity during power failure.

3.3 For building projects in Hong Kong, the distribution transformers are normally supplied and installed by the electricity supply companies at no cost to the developers. The transformers remain assets of the electricity supply companies after installation. The developers provide transformer rooms for installing the transformers and facilities for connecting the transformers to the main cubicle switchboards.

3.4 The equipment and installation costs of an electricity supply system may make up a significant part of the total cost of the building services systems in a building. For example, the cost of the electricity supply system of Building N (see Table 5 in para. 3.15), a typical government office building, amounted to $47 million, representing 22% of the total cost of the building services systems.

Planning for the power capacity of an electricity supply system

3.5 The design and installation of an electricity supply system involve many technical considerations. One key consideration is the power capacity of the system, measured in kilovolt-amperes (kVA), which is set at a level to meet the **peak electrical load** on the system from all the building services systems and other electrical equipment and appliances in the building. The power capacity of an electricity supply system determines the number of distribution transformers (Note 1) and the number of main cubicle switchboards required.

3.6 According to the ArchSD Design Guide for Electrical Installation, the electrical load of an electricity supply system is estimated in two stages:

(a) ***Preliminary planning stage.*** A broad estimation of the electrical load is made based on the following factors:

   (i) the statistical electrical loading density per unit area of similar buildings;

   (ii) the gross floor area; and

   (iii) an expansion factor for future development; and

(b) ***Detailed design stage.*** During this stage, the schedule of accommodation and architectural sketch plans of the building are available showing the usage of each area within the building. A detailed estimation of the electrical load is made based on the following factors:

   (i) the summation of the electrical loads of individual building services systems, and electrical equipment and appliances in the building;

   (ii) a diversity factor (e.g. 80%) to discount the total load as the operation of all installed electrical equipment would not simultaneously occur in practice; and

   (iii) an expansion factor for future development.

Note 1: *Distribution transformers are usually available in a power rating of 1,500 kVA. For an electricity supply system with a power capacity of 9,000 kVA, 6 transformers are required. Each transformer is connected to a main cubicle switchboard.*

Guidelines for providing spare capacity in an electricity supply system

3.7 For an electricity supply system, it is essential to provide a reliable power supply and to ensure the proper functioning of all electrical equipment. The ArchSD has issued guidelines for enhancing the reliability of an electricity supply system, including the provision of spare capacity, in two documents.

3.8 ***BSB Circular No. 38 of 2003 on "Reliability Planning and Design of Electricity Supply System" issued in July 2003.*** According to the Circular, the measures adopted for enhancing the reliability of an electricity supply system should take into account factors such as building type, usage of space and operational requirements. The Circular also provides a checklist for reliability planning of the electricity supply system to minimise the disruption to normal operation of a building. The checklist includes the following provisions on spare capacity:

(a) **sufficient spare capacity, say 30%, should be allowed for each transformer;** and

(b) adequate space should be allowed in the transformer room(s) for installing additional transformers if required in future.

3.9 ***Design Guide for Electrical Installation issued in September 2004 (revised in December 2005).*** The Design Guide states that:

(a) in determining the capacity of an electricity supply system, sufficient spare capacity should be provided for both future expansion and operational reliability. The amount of spare capacity to be provided should take into account the nature of the building project. **A minimum of 30% spare capacity for each transformer is recommended**; and

(b) if future expansion is anticipated, adequate space should be allowed in the transformer room(s) for installing additional transformers.

3.10 Audit notes that the two documents have different wording on the provision of spare capacity. **In July 2010, the ArchSD informed Audit that:**

(a) **a 30% spare capacity of the estimated electrical load for future expansion and operational reliability could only be taken as a general rule for estimating the electrical load of an electricity supply system;** and

(b) there were other design considerations to take into account in determining the overall power capacity of an electricity supply system (see para. 3.18(b)).

3.11 The provision of spare capacity in the electricity supply system has implications in equipment and installation costs as it may require additional distribution transformer(s). While the ArchSD does not need to pay for the transformers (see para. 3.3), plant room space and connection facilities have to be provided. Moreover, the main cubicle switchboards are configured according to the number of transformers installed. By providing a higher level of spare capacity, the overall cost of the electricity supply system will be increased. At the same time, the level of operational reliability of the electricity supply system will be improved.

Audit observations and recommendations

3.12 Audit selected the eight government buildings with POE exercises completed (see para. 2.7) for detailed examination of their electricity supply systems, focusing on the following three key parameters:

(a) installed capacity;

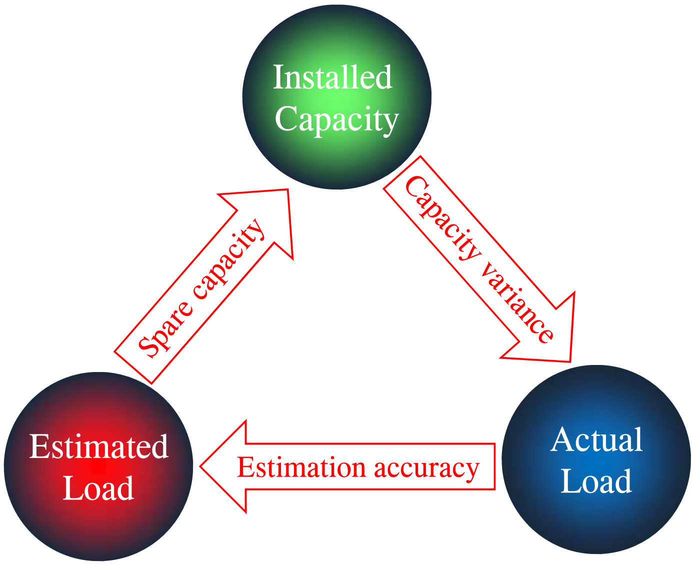
(b) actual electrical load during the period covered by POE (see Table 1 in para. 2.7) and in 2009; and

(c) estimated electrical load in the design report.

Figure 2 shows the relationship among these three parameters.

Figure 2

Key parameters of an electricity supply system



Source: Audit analysis

3.13 The audit analysis aimed to ascertain:

(a) the capacity variance (i.e. the difference between installed capacity and actual load — see Tables 4 and 5);

(b) the spare capacity provided (i.e. the difference between installed capacity and estimated load — see Table 6); and

(c) the estimation accuracy (i.e. the difference between actual load and estimated load — see Table 7).

Need to review capacity variances in electricity supply systems

3.14 For all the eight selected buildings, Audit found that the installed capacity of the electricity supply system was greater than the actual electrical load measured (Note 2) during the POE period, with a capacity variance (Note 3) ranging from 42% to 68% (see the 4th column in Table 4). For three buildings (Buildings B, H and A), the capacity variances were 60% or more. In September 2010, the ArchSD provided additional information about the peak electrical loads projected (Note 4) for these buildings during the POE period. According to the projected loads, the capacity variances ranged from 27% to 61% (see the last column in Table 4). Details are shown in Table 4.

Note 2: *The measured electrical load of each of the eight buildings was one measured by the ArchSD and recorded in the POE reports. According to the ArchSD, such load was a time-averaged one over an interval of 30 minutes and did not represent the instantaneous peak load of an electricity supply system (see para. 3.18(b)(ii)). However, Audit noted that the estimation and measurement of the instantaneous peak load were not mentioned in the design reports and the POE reports.*

Note 3: *The capacity variance is expressed as a percentage of the installed capacity.*

Note 4: *The projected peak electrical load of each building was estimated by the ArchSD based on the measured load and other relevant factors.*

Table 4

Capacity variance in electricity supply systems of eight government buildings during POE period

Building (Note 1)	Installed capacity (Note 2) (a) (kVA)	Measured time-averaged electrical load (Note 3) (b) (kVA)	Capacity variance based on (b) (Note 4) $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ (%)	Projected peak electrical load (Note 5) (d) (kVA)	Capacity variance based on (d) (Note 4) $(e) = \frac{(a) - (d)}{(a)} \times 100\%$ (%)
B	9,000	2,850	**68%**	3,476	**61%**
H	10,500	3,647	**65%**	5,882	**44%**
A	23,500	9,320	**60%**	13,507	**43%**
C	9,000	4,491	50%	5,614	38%
G	9,000	4,956	45%	6,195	31%
F	7,500	4,316	42%	5,395	28%
E	4,500	2,591	42%	3,239	28%
D	6,000	3,500	**42%**	4,375	**27%**

Source: *ArchSD records*

Note 1: *Table 1 in paragraph 2.7 shows the timing of completion and occupation of each building.*

Note 2: *The installed capacity of the electricity supply system in each building is made up of distribution transformers with a capacity of 1,500 kVA, except Building A which is made up of transformers with a capacity of 1,500 or 2,000 kVA.*

Note 3: *This is the electrical load measured and averaged over a 30-minute interval which is lower than the corresponding peak electrical load supplied by the distribution transformer.*

Note 4: *As a general rule, a spare capacity of about 30% of the estimated electrical load would be provided for future expansion and operational reliability.*

Note 5: *The projected peak electrical load was estimated by the ArchSD in September 2010 based on the measured electrical load and other relevant factors.*

3.15 **According to the ArchSD Design Guide, the spare capacity provided in an electricity supply system caters for future growth and operational reliability.** To ascertain the latest position, Audit examined the electrical loads in 2009 of the three buildings with the highest percentages of capacity variance in Table 4. Audit also selected two government buildings (Buildings M and N) completed in 1999 and 2001 for similar analysis.

Table 5

Capacity variance in electricity supply systems of five government buildings in 2009

Building	**Installed capacity (a) (kVA)**	**Measured time-averaged electrical load (b) (kVA)**	**Capacity variance based on (b) (Note 1)** $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ **(%)**	**Projected peak electrical load (Note 2) (d) (kVA)**	**Capacity variance based on (d) (Note 1)** $(e) = \frac{(a) - (d)}{(a)} \times 100\%$ **(%)**
B	9,000	2,460	73%	3,492	61%
H	10,500	3,886	63%	6,293	40%
A	23,500	9,589	59%	13,945	41%
M	13,500	7,604	44%	9,505	30%
N	9,000	3,726	59%	4,657	48%

Source: *Records of the ArchSD and the EMSD*

Note 1: *As a general rule, a spare capacity of about 30% of the estimated electrical load would be provided for future expansion and operational reliability.*

Note 2: *The projected peak electrical load was estimated by the ArchSD in September 2010 based on the measured electrical load and other relevant factors.*

3.16 The results of the audit analysis, as shown in Table 5, indicate that:

(a) for all the five buildings, the installed capacity was greater than the measured electrical load, with a capacity variance ranging from 44% to 73% (see the 4th column). Based on the projected peak electrical load, the capacity variance ranged from 30% to 61% (see the last column); and

(b) **the capacity variances existed not only in recently completed buildings but also in buildings completed earlier.**

Audit considers that there is a need to review the capacity variances in electricity supply systems of government buildings with a view to identifying measures for improvement in future.

Need to revise guidelines for provision of spare capacity

3.17 The ArchSD has laid down guidelines for the provision of spare capacity in the electricity supply system (see paras. 3.7 to 3.10). According to the ArchSD, a spare capacity of about 30% would be provided to allow for future load growth and operational reliability in addition to the estimated electrical load. For the three buildings with the highest percentages of capacity variance in Table 4 in paragraph 3.14 (Buildings B, H and A), Audit performed further analysis of the difference between the installed capacity and the estimated electrical load, i.e. the spare capacity provided. Table 6 shows the spare capacities provided to the electricity supply systems of these three buildings.

Table 6

Provision of spare capacity to electricity supply systems of three government buildings

Building	Installed capacity (a) (kVA)	Estimated electrical load (b) (kVA)	Spare capacity provided (Note) $(c) = \frac{(a) - (b)}{(b)} \times 100\%$ (%)
B	9,000	5,350	**68%**
H	10,500	8,148	29%
A	23,500	17,290	**36%**

Source: *ArchSD records*

Note: *As a general rule, a spare capacity of about 30% would be provided for future expansion and operational reliability.*

3.18 As shown in Table 6, the spare capacities provided for Buildings B and A were above the norm of 30% as stipulated in the ArchSD's guidelines (see para. 3.10). In response to Audit's enquiry, in July 2010, the ArchSD said that for the three buildings in Table 6, spare capacities of about 30% were initially provided on the basis of the **estimated electrical loads**. Additional spare capacities were provided to arrive at the **installed capacities** after taking into account the following considerations:

(a) in determining the capacity of an electricity supply system, an estimated electrical load would be calculated on the basis of the building services systems to be installed in the building. Based on the **estimated electrical load**, a spare capacity of about 30% would be added to arrive at the **estimated total electrical load**; and

(b) the total capacity of the system and the number of transformers required would depend on the **estimated total electrical load** and the following design considerations:

(i) the need for providing resilience and reliability in system design;

(ii) the need for meeting **instantaneous peak loads**. The electrical loads measured during the POE periods were the **time-averaged electrical loads of individual transformers**. The systems were designed to meet instantaneous peak loads of individual transformers occurring during the start-up of equipment with large motors (e.g. the chillers of an air-conditioning system). Though the instantaneous peak loads were not measured after building occupation, sufficient spare capacity had to be reserved for this purpose;

(iii) the need for providing reserve capacity for emergency transfer between two transformers to cater for transformer failure;

(iv) the need for providing separate transformers to cater for different operational requirements. Distribution transformers were usually available in a standard power rating of 1,500 kVA and separate transformers were needed for supplying electricity to electrical equipment with different load requirements (e.g. computer equipment, chillers, lifts and escalators). The surplus capacity in one transformer was not transferable to another transformer;

(v) power quality impurities (e.g. harmonic distortion caused by fluorescent lightings, computer equipment and office appliances) which might cause a reduction of the transformer capacity;

(vi) the need to locate transformers close to the major electrical equipment to reduce voltage drop and energy loss in electricity transmission; and

(vii) future growth in electrical load of the building.

According to the ArchSD, the number of distribution transformers required and thus the **installed capacity** so derived, after taking into account these design considerations, should be more than the **estimated total electrical load**. The extent of spare capacity varied from one building to another and was unique in accordance with the requirements and design of each building. A higher level of spare capacity would increase the overall cost of the electricity supply system by a small amount, but it would bring about an increase in operational reliability of the electrical supply system of the building.

3.19 Audit noted the ArchSD's explanations on the various design considerations to be taken into account in determining the total capacity and configuration of an electricity supply system. However, these considerations were not explicitly promulgated in the ArchSD's design guidelines. Moreover, such design considerations were not fully documented to demonstrate how the installed capacities were determined in the design reports of the eight buildings selected for audit examination.

3.20 **In Audit's view, there is a need to incorporate in the design guidelines relevant design considerations that would affect the determination of the capacity of an electricity supply system, with detailed instructions for application. There is also a need to fully document in the design report the calculations and justifications for providing spare capacity in an electricity supply system.**

Room for improvement in estimating electrical load

3.21 The ArchSD has laid down guidelines for estimating the capacity of an electricity supply system (see paras. 3.5 and 3.6). Audit examined the three buildings in Table 4 in paragraph 3.14 with the highest percentages of capacity variance and found that there were differences between the estimated and actual electrical loads. Table 7 shows the details.

Table 7

Estimation of electrical loads of three government buildings

Building	Estimated electrical load (a) (kVA)	Actual electrical load (Note) (b) (kVA)	Difference $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ (%)
B	5,350	3,492	**35%**
H	8,148	6,293	**23%**
A	17,290	13,945	**19%**

Source: ArchSD records

Note: This is the projected peak electrical load in 2009 — see the 5th column in Table 5 in paragraph 3.15.

3.22 In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) the estimated electrical load of a building was determined according to the best information available at the design stage. There might be subsequent changes during various stages of development of the building project;

(b) the electricity supply system was designed to cope with the ultimate electrical load of a building with a life span of 30 to 50 years or more. The occupancy rate and level of activities during the initial period of operation of a building might not have reached the planned levels;

(c) the load demand recorded in the initial years of occupation might not fully reflect the design condition of the building. As all the buildings with POE conducted were occupied for no more than 6 years, it might be too early to draw conclusions from the electrical load recorded in the initial years of building occupation; and

(d) the electrical load was dependent on the occupancy rate and level of activities which might vary from year to year. The electrical load measured during the POE period did not reflect the full load of some equipment which was usually operating in standby mode (e.g. the fire services equipment).

3.23 **In Audit's view, the difference between the estimated electrical load and the actual load is one reason giving rise to capacity variances in the electricity supply systems of government buildings. The ArchSD may need to review past cases where there were significant differences with a view to identifying measures for improving the accuracy in the estimation methodology.**

Audit recommendations

3.24 **Audit has *recommended* that the Director of Architectural Services should:**

(a) **review the capacity variances in electricity supply systems of government buildings with a view to identifying measures for improvement in future (see para. 3.16);**

(b) **incorporate in the design guidelines relevant design considerations that would affect the determination of the capacity of an electricity supply system, with detailed instructions for application (see para. 3.20);**

(c) **document in the design report the calculations and justifications for providing spare capacity in an electricity supply system (see para. 3.20); and**

(d) **review the methodology for estimating the electrical load of an electricity supply system with a view to identifying measures for improving the accuracy in estimation (see para. 3.23).**

Response from the Administration

3.25 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendations. She has said that the ArchSD will:

(a) further review the capacity variances in electricity supply systems to facilitate continuous improvement;

(b) review and refine, where possible, the design guidelines with further elaboration on the various design considerations stated in paragraph 3.18(b) so as to facilitate knowledge sharing and skills transfer. The design guidelines are intended to provide a common reference of the various criteria and principles involved in the design of electricity supply systems. The engineers of the ArchSD or the consultants will use their engineering knowledge and judgement throughout the course of design development;

(c) document in the design report the calculations and various design considerations in deriving the estimated total electrical loading and the number of transformers required to facilitate systematic collection of data and information for review; and

(d) review and refine, where possible, the methodology for estimating electrical load to facilitate continuous improvement.

PART 4: DESIGN AND INSTALLATION OF AIR-CONDITIONING SYSTEMS

4.1 This PART examines the design and installation of air-conditioning systems in government buildings.

Functions and major components of an air-conditioning system

4.2 The air-conditioning system in a building controls the environmental parameters, including air temperature, relative humidity, air movement and cleanliness, of the building space to provide the occupants with a comfortable indoor environment. In Hong Kong, air-conditioning systems are mainly used for space cooling and ventilation. They are also used for humidity control and space heating. In most government buildings, the air-conditioning systems are usually in the form of a centralised system comprising the following major components:

(a) a **chiller plant** consisting of one or more chillers for producing chilled water which is used as a cooling medium to cool air indirectly;

(b) a **water distribution system** for circulating the chilled water to each floor in the building for heat exchange;

(c) **air-handling equipment** on each floor for providing ventilation and cool air from chilled water, including:

   (i) primary air-handling units for treating fresh air;

   (ii) air-handling units for providing cool air to open plan areas; and

   (iii) fan coil units and air supply units for providing cool air to cellular offices; and

(d) an **air distribution system** consisting of a network of air ducts and fans.

4.3 The cost of an air-conditioning system is the highest among all building services systems. It may account for half of the total cost of the building services systems. For example, the cost of the air-conditioning system of Building N, a typical government office building, amounted to $101 million, representing 48% of the total cost of the building services systems.

Planning for the cooling capacity of an air-conditioning system

4.4 The design and installation of an air-conditioning system involve many technical considerations. One key consideration is the cooling capacity of the system, measured in kilowatts (kW), which is set at a level to meet the **estimated peak cooling load** of the air-conditioned floor area in the building. After determining the cooling load of an air-conditioning system, the chiller plant and air-handling equipment are configured accordingly to provide the required cooling capacity.

4.5 The ArchSD has laid down guidelines for estimating the cooling load of a building project. According to the guidelines, the cooling load of a building is made up of the following four components:

(a) **external cooling load** arising from:

  (i) solar heat gain through windows; and

  (ii) conduction heat gain through windows, roofs and external walls;

(b) **internal cooling load** arising from:

  (i) occupants;

  (ii) electric lights; and

  (iii) power equipment and appliances;

(c) **infiltration cooling load** arising from air flows through cracks and openings; and

(d) **ventilation cooling load** arising from the introduction of outdoor fresh air to maintain an acceptable ventilation level.

The ArchSD adopts methodologies developed by international professional bodies and employs computer software in estimating the cooling load of a building.

Guidelines for providing spare capacity in an air-conditioning system

4.6 The ArchSD provides spare capacity to an air-conditioning system to cater for future growth in the cooling load of a building. The spare capacity is expressed as a percentage of the estimated peak cooling load. The ArchSD has issued the following guidelines for determining the cooling capacity of an air-conditioning system:

(a) ***BSB Circular No. 38 of 1999 on "Quick Reference of Air-conditioning and Mechanical Ventilation Design Data" issued in November 1999.*** This Circular states that in determining the cooling capacity of an air-conditioning system, a spare capacity of 10% should be provided for equipment de-rating (Note 5) and another 10% for future expansion; and

(b) ***Design Guide for Air-conditioning, Refrigeration and Ventilation Installation issued in April 2005.*** The Design Guide states that in determining the capacity of the chiller plant, a spare capacity of 20% to 30% may be taken as a reference.

4.7 **In July 2010, the ArchSD informed Audit that, as a general rule, 20% to 30% of the estimated peak cooling load was allowed as spare capacity for future cooling load growth and standby purpose.** There were other design considerations to be taken into account in determining the cooling capacity (see para. 4.15).

4.8 The provision of spare capacity has implications on the equipment and installation costs of an air-conditioning system, particularly for the chiller plant. By providing a higher level of spare capacity, the overall cost of an air-conditioning system will be increased. At the same time, the capacity for meeting future growth in cooling load and standby/emergency purposes will be increased.

Note 5: *De-rating means the decline in the power rating of equipment over time.*

Audit observations and recommendations

4.9 Audit selected the eight building projects with POE exercises completed (see para. 2.7) for detailed examination of the capacity of their air-conditioning systems, focusing on the following three key parameters:

(a) installed capacity;

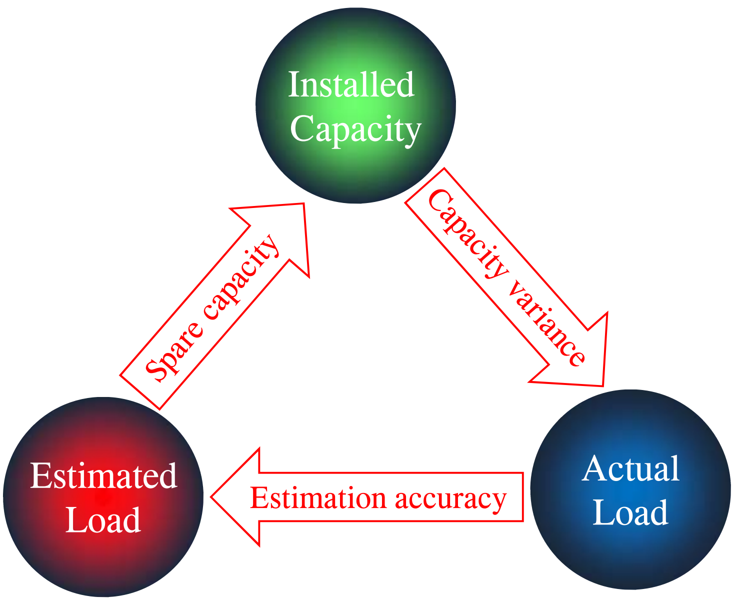
(b) actual cooling load during the POE period (see Table 1 in para. 2.7) and in recent years; and

(c) estimated cooling load in the design report.

Figure 3 shows the relationship among these three parameters.

Figure 3

Key parameters of an air-conditioning system



Source: Audit analysis

4.10 The audit analysis aimed to ascertain:

(a) the capacity variance (i.e. the difference between installed capacity and actual load — see Tables 8 and 9);

(b) the spare capacity provided (i.e. the difference between installed capacity and estimated load — see Table 10); and

(c) the estimation accuracy (i.e. the difference between actual load and estimated load — see Table 11).

Need to review cooling capacities in air-conditioning systems

4.11 For all of the eight selected buildings, Audit found that, during the POE period, the installed cooling capacity was greater than the actual peak cooling load, with a capacity variance (Note 6) ranging from 0.2% to 65% (see the 4th column in Table 8). Excluding the standby plant (Note 7), the capacity variances ranged from 0.2% to 47% (see the last column in Table 8). Details are shown in Table 8.

Note 6: *The capacity variance is expressed as a percentage of the installed capacity.*

Note 7: *According to the ArchSD, for some projects installed with both water-cooled chillers and air-cooled chillers, the air-cooled chillers are used for standby/emergency purpose. For some projects installed with water-cooled chillers, one chiller is assigned as the standby chiller to cater for resilience and reliability in system design. As the standby air-cooled chillers and the standby water-cooled chiller will not be operated during normal conditions, the ArchSD considered it more appropriate to compare the installed capacity excluding standby plant with the peak cooling load.*

Table 8

Capacity variance in air-conditioning systems of eight government buildings during POE period

Building (Note 1)	**Installed capacity (a) (kW)**	**Actual peak cooling load (b) (kW)**	**Capacity variance based on (a) (Note 2)** $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ **(%)**	**Installed capacity excluding standby plant (d) (kW)**	**Capacity variance based on (d) (Note 2)** $(e) = \frac{(d) - (b)}{(d)} \times 100\%$ **(%)**
A	22,035	7,766	**65%**	14,772	47%
B	8,128	3,428	**58%**	5,700	40%
G	9,100	5,047	**45%**	8,400	40%
F	7,200	4,700	35%	7,200	35%
E	3,600	2,358	35%	3,600	35%
H	7,438	5,111	31%	5,280	3%
D	4,300	3,800	12%	4,300	12%
C	4,920	4,908	0.2%	4,920	0.2%

Source: ArchSD records

Note 1: Table 1 in paragraph 2.7 shows the timing of completion and occupation of each building.

Note 2: As a general rule, a spare capacity of 20% to 30% of the estimated cooling load would be provided for future expansion and operational reliability.

4.12 As shown in Table 8, Buildings A, B and G had the highest percentages of capacity variance. Audit examined the peak cooling loads of these buildings during the period 2008 to 2010. Audit also selected two government buildings (Buildings M and N) completed in 1999 and 2001 for similar analysis. The results, as shown in Table 9, reveal that:

(a) Buildings A, B and G still had capacity variances ranging from 45% to 56% (see the 4th column). Excluding the standby plant, the capacity variances ranged from 28% to 40% (see the last column); and

(b) the two buildings completed earlier (i.e. Buildings M and N) had capacity variances of 37% and 53% (see the last column).

Table 9

Capacity variance in air-conditioning systems of five government buildings (2008 to 2010)

Building	Installed capacity (a) (kW)	Actual peak cooling load (Note 1) (b) (kW)	Capacity variance based on (a) (Note 2) $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ (%)	Installed capacity excluding standby plant (d) (kW)	Capacity variance based on (d) (Note 2) $(e) = \frac{(d) - (b)}{(d)} \times 100\%$ (%)
A	22,035	10,629	52%	14,772	28%
B	8,128	3,601	56%	5,700	37%
G	9,100	5,047	45%	8,400	40%
M	10,865	6,899	37%	10,865	37%
N	7,350	3,484	53%	7,350	53%

Source: *Records of the ArchSD and the EMSD*

Note 1: *The peak cooling loads of Buildings B and G were measured in 2008 to 2010. The peak cooling loads for Buildings A, M and N were measured in 2010 as the records for 2008 and 2009 were not available.*

Note 2: *As a general rule, a spare capacity of 20% to 30% of the estimated cooling load would be provided for future expansion and operational reliability.*

4.13 **Audit considers that there is a need for the EMSD (as the maintenance agent of building services systems) and the ArchSD to keep in view the cooling loads of government buildings and consider revising the capacities to be provided, where necessary, when the air-conditioning systems are due for replacement.**

Need to review the provision of spare capacity to air-conditioning system

4.14 For the three buildings with the highest percentages of capacity variance in Table 8, Audit performed further analysis of the difference between the installed capacity and the estimated peak cooling load. Audit noted that the spare capacities provided for Buildings A, B and G ranged from 43% to 137% (see the 4th column in Table 10), which were in excess of 30% as stipulated in ArchSD guidelines. Excluding the standby plant, the spare capacity ranged from -3% to 66% (see the last column in Table 10). The results are shown in Table 10.

Table 10

Provision of spare capacity to air-conditioning systems of three government buildings

Building	**Installed capacity** **(a)** **(kW)**	**Estimated peak cooling load** **(b)** **(kW)**	**Spare capacity provided based on (a) (Note)** $(c) = \frac{(a) - (b)}{(b)} \times 100\%$ **(%)**	**Installed capacity excluding standby plant** **(d)** **(kW)**	**Spare capacity provided based on (d) (Note)** $(e) = \frac{(d) - (b)}{(b)} \times 100\%$ **(%)**
A	22,035	15,151	**45%**	14,772	-3%
B	8,128	3,430	**137%**	5,700	66%
G	9,100	6,345	**43%**	8,400	32%

Source: ArchSD records

Note: As a general rule, a spare capacity of 20% to 30% of the estimated cooling load would be provided for future expansion and operational reliability.

4.15 In response to Audit's enquiry, in July 2010, the ArchSD said that the provision of a spare capacity of 30% in designing an air-conditioning system was only an initial reference. The determination of the cooling capacity of the chiller plant had to take into account the following design considerations:

(a) considerations for resilience and reliability in system design;

(b) energy performance of the chiller plant under various cooling load profiles;

(c) chiller equipment efficiency and de-rating factor (see Note 5 in para. 4.6(a));

(d) need to provide additional air-cooled chillers as emergency backup to meet disruption in water supply when using water-cooled chillers;

(e) need to match available equipment size in the market; and

(f) future growth in cooling load of the building.

According to the ArchSD, the resultant cooling capacity so derived should be higher than the estimated cooling load. The cost of additional chiller(s) and the associated pipework formed a small part of the cost of the air-conditioning system. The provision of additional chiller(s) would increase the capacity for future growth and standby/emergency purposes.

4.16 Audit noted the ArchSD's explanations on the various design considerations to be taken into account in providing spare capacity to an air-conditioning system. However, these design considerations were not explicitly promulgated in the ArchSD's design guidelines. Moreover, details of such design considerations were not fully documented in the design reports of the eight buildings selected for audit examination. **In Audit's view, there is a need to incorporate in the design guidelines relevant design considerations that would affect the determination of the cooling capacity of an air-conditioning system, with detailed instructions for application. There is also a need to document in design reports in future the workings for determining the installed capacity.**

Room for improvement in estimating cooling loads

4.17 The ArchSD has laid down guidelines for estimating the capacity of an air-conditioning system (see paras. 4.4 and 4.5). However, an audit examination of the three buildings in Table 8 in paragraph 4.11 with the highest percentages of capacity variance (i.e. Buildings A, B and G) indicated that there were differences between the estimated and peak cooling loads. Table 11 shows the examination results.

Table 11

Estimation of cooling loads of three government buildings

Building	Estimated cooling load (a) (kW)	Actual peak cooling load (Note) (b) (kW)	Difference $(c) = \frac{(a) - (b)}{(a)} \times 100\%$ (%)
A	15,151	10,629	**30%**
B	3,430	3,601	-5%
G	6,345	5,047	**20%**

Source: ArchSD records

Note: This is the actual peak cooling load in 2008 to 2010 — see the 3rd column in Table 9 in paragraph 4.12.

4.18 In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) the cooling load of an air-conditioning system was estimated on the basis of the best information available at the design stage, including:

(i) the building type and operational requirements of the client department;

(ii) the approximate size of the air-conditioned floor area; and

(iii) the schedule of accommodation indicating the number of occupants and the usage of different areas and rooms; and

(b) the peak cooling load recorded during the POE period might not represent the ultimate peak cooling load of the building which had a design life of 30 to 50 years or more.

4.19 **In Audit's view, the difference between the estimated cooling load and the actual load is one reason leading to capacity variances in the air-conditioning systems of government buildings. The ArchSD may need to make reference to past cases where there were significant differences between the estimated and actual loads and review the estimation methodology.**

Audit recommendations

4.20 **Audit has *recommended* that the Director of Architectural Services should:**

(a) **in conjunction with the Director of Electrical and Mechanical Services, keep in view the cooling loads of government buildings and consider revising the capacities to be provided, where necessary, when the air-conditioning systems are due for replacement (see para. 4.13);**

(b) **incorporate in the design guidelines relevant design considerations that would affect the determination of the cooling capacity of an air-conditioning system, with detailed instructions for application (see para. 4.16);**

(c) **document in the design reports the workings showing how the installed capacity in an air-conditioning system is determined (see para. 4.16); and**

(d) **review the methodology for estimating the cooling loads of government buildings. These may include further refining the existing guidelines by making reference to past cases (see para. 4.19).**

Response from the Administration

4.21 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendations. She has said that:

(a) funding for the replacement of air-conditioning systems will normally be allocated to the user departments. The ArchSD will provide the original design information on cooling load requirements to the party responsible for replacement of air-conditioning system;

(b) the ArchSD will review and refine, where possible, the design guidelines with further elaboration on the various design considerations stated in paragraph 4.15. The design guidelines are intended to provide a common reference of the various criteria and principles involved in the design of air-conditioning systems. The engineers of the ArchSD or the consultants will use their engineering knowledge and judgement throughout the course of design development;

(c) the ArchSD will document in the design reports the various design considerations in deriving the estimated peak cooling capacity and the chiller plant configuration so as to facilitate systematic collection of data and information for review; and

(d) the ArchSD will review and refine, where possible, the current methodology for estimating cooling load of government buildings to facilitate continuous improvement.

4.22 The **Director of Electrical and Mechanical Services** has said that for government buildings with the EMSD as the long-term, continuous maintenance agent of building services systems, the EMSD agrees to keep in view the cooling loads of the buildings and will recommend revising the capacities of the air-conditioning systems, as appropriate, when the air-conditioning systems are due for replacement.

Provision of facilities for space heating

4.23 Space heating is one of the functions of an air-conditioning system and is essential in countries with cold winters. In Hong Kong, space heating is not essential for office buildings because of the relatively warm winter. The ArchSD guidelines for design of air-conditioning systems mainly focus on space cooling and ventilation functions. The guidelines do not specifically mention whether and when space heating facilities should be provided in an air-conditioning system.

4.24 In April 2009, the Development Bureau and the Environment Bureau jointly issued a circular on “Green Government Buildings”. The circular stipulates that all new government buildings and all existing government buildings with a construction floor area of more than 10,000 square metres should aim to achieve the “Excellent Class” and “Good Class” respectively of the Indoor Air Quality (IAQ) Objectives stipulated by the Environmental Protection Department. In order to achieve the “Excellent Class”, the room temperature of a building should be maintained between 20°C and 25.5°C. For achieving the “Good Class”, the room temperature should be maintained below 25.5°C.

4.25 In response to Audit's enquiry, in August 2010, the ArchSD said that:

(a) **all building projects undertaken by the ArchSD with central air-conditioning systems were provided with space heating facilities;**

(b) design guidelines for air-conditioning systems did not specifically state whether space heating should be provided. Space heating facilities were provided to:

(i) achieve an indoor temperature of 20°C in winter;

(ii) meet client's requirements for a comfortable thermal environment in winter; and

(iii) meet operational needs of specialist buildings (e.g. hospitals, and recreational and amenity facilities); and

(c) if no space heating facilities were provided, the room temperature of a government building would unlikely be maintained at 20°C (i.e. one of the requirements for achieving the Excellent Class under the IAQ Objectives — see para. 4.24) during very cold days.

4.26 Space heating facilities in government buildings are provided in one or a combination of the following two forms:

(a) duct-heater systems (with electric heater elements embedded in air ducts); and

(b) centralised hot water systems (with circulation of hot water by a distribution system as a heating medium).

4.27 The provision of space heating facilities in a government building involves considerable capital cost. For example, the costs of space heating facilities installed in two government buildings amounted to $5 million (a centralised hot water system providing hot water for showers and space heating) and $2 million (a duct-heater system) respectively. Apart from the capital cost, the operation of space heating facilities also incurs considerable recurrent cost in terms of electricity charges.

4.28 For energy conservation, the following guidelines have been issued on the operation of space heating facilities in winter:

(a) ***Environmental Protection Department memorandum of May 2005 to bureaux and departments.*** For those premises where the air-conditioning systems are fitted with space heating facilities, operation of the facilities is not encouraged for the sake of conserving energy unless under very cold weather conditions; and

(b) ***Environment Bureau Circular Memorandum No. 1/2008 of June 2008.*** For premises where the air-conditioning systems are provided with heaters, operation of the heaters should be avoided as far as possible.

Audit observations and recommendations

Need to review provision of space heating facilities

4.29 Audit selected seven joint-user government office buildings managed by the GPA to examine the operation of the space heating facilities. Audit found that, from January 2005 to June 2010, such heating facilities had not been in operation for any one day.

4.30 According to the projections of the Hong Kong Observatory, the number of cold days (12°C or below) in Hong Kong will gradually decrease in the coming years. **In Audit's view, there is a need to review the provision of space heating facilities in government office buildings.**

Audit recommendation

4.31 **Audit has *recommended* that the Secretary for the Environment and the Director of Architectural Services should review the need for providing space heating facilities in government office buildings (see para. 4.30), taking into account:**

(a) **the views of bureaux and departments on the need to operate space heating facilities in winter;**

(b) **the need to conserve energy by avoiding the use of space heating facilities (see para. 4.28);**

(c) **the actual usage of the facilities (see para. 4.29); and**

(d) **the need to achieve Excellent Class under the IAQ Objectives (see para. 4.24).**

Response from the Administration

4.32 The **Secretary for the Environment** generally accepts the audit recommendation. He has said that:

(a) the Environment Bureau considers that the operation of space heating facilities should be avoided as far as possible for energy conservation. In the light of Audit's findings, the Environment Bureau will work with the ArchSD to review the need for providing such facilities in government office buildings; and

(b) the Environmental Protection Department is reviewing the IAQ Objectives under a separate study.

4.33 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendation. She has said that the ArchSD does not set policy nor standard on the provision of space heating facilities, but will provide technical support to the Environment Bureau to follow up the audit recommendation.

PART 5: DESIGN AND INSTALLATION OF LIGHTING SYSTEMS

5.1 This PART examines the design and installation of lighting systems in government buildings.

Functions and major components of a lighting system

5.2 The lighting system of a building provides artificial lighting for the occupants to carry out tasks and activities. Fluorescent lamps are widely used as the light source in office buildings.

5.3 The main components of a lighting system include:

(a) lamps (e.g. fluorescent lamps);

(b) lighting fittings that contain the lamps, reflectors and other components; and

(c) associated wiring, switching and protection circuits.

5.4 The equipment and installation costs of a lighting system may make up a notable part of the cost of the building services systems in a building. For example, for a typical government office building completed in 2001, the cost of the lighting system amounted to $19 million, representing 9% of the total cost of the building services systems.

Determination of lighting level in office areas

5.5 In the design of the lighting system in a building, the lighting level (measured in **lux**) is a key parameter. In December 2004, based on guidelines of overseas professional bodies and practical experience gained in previous projects, the ArchSD promulgated a "Design Standard of Lighting Levels for Offices" vide BSB Circular No. 36 of 2004. According to the Circular, the recommended lighting level for offices is determined according to the type of work and activity which would take place, as follows:

General office areas

(a) for **general offices** where visual tasks requiring perception of details are performed, the recommended level is **500 lux** on desk level;

Common areas

(b) for **circulation areas** without the need for visual tasks requiring perception of details, the recommended level is **200 to 500 lux**; and

(c) for **foyers and entrance lobbies**, the recommended level is **100 to 300 lux**.

5.6 The design standard stipulates that the lighting level of circulation areas including corridors should be related to that in the adjacent areas and should not differ too greatly (Note 8).

Audit observations and recommendations

Need to determine appropriate lighting levels for common areas

5.7 One of the core tasks of a POE is the conduct of an energy review to identify areas for energy saving in the operation and maintenance of building services systems. The energy review includes a walk-through inspection of the building premises conducted jointly by the ArchSD, the client department and the EMSD (maintenance agent of the building services systems). **Audit noted that, in six out of the eight buildings with POE completed, it was found during the walk-through inspections that there was room for reducing the lighting levels in common areas (see Table 12).** On requests of the client departments, the ArchSD and the EMSD carried out modification works on the lighting systems by de-lamping, i.e. detaching some of the fluorescent lamps from the lighting fittings. Photograph 1 shows an example of de-lamping.

Note 8: *The design standard stipulates that a difference of one step on the lighting level scale would be the rule of thumb to be adopted in the lighting design. The lighting level scale (in discrete steps of lux levels) is as follows:*

20 lux – 30 lux – 50 lux – 75 lux – 100 lux – 150 lux – 200 lux – 300 lux – 500 lux – 750 lux – 1000 lux – 1500 lux – 2000 lux – 3000 lux – 5000 lux.

Table 12

Walk-through inspections carried out at six government buildings

Building	Findings and actions taken on lighting levels in common areas
B	• High lighting level in common areas • Reduction of lighting level to 100 lux by de-lamping and switching arrangement in some of the circulation areas, including staircases and service lift lobbies
C	• Lighting level in public areas reduced by half • Lighting level in the internal common areas of open plan office reduced
D	• High lighting level in main entrance and car park areas • De-lamping conducted to reduce lighting level to 120 to 150 lux
F	• Approximately 50% of fluorescent tubes and lamps in circulation areas such as corridors and lift lobbies removed
G	• De-lamping exercises conducted for common areas on three floors
H	• Lighting fittings in common areas re-zoned or de-lamped to enhance energy efficiency

Source: ArchSD records

Photograph 1

An example of de-lamping
in the office corridors of Building H
(alternate lamps were detached from lighting fittings)

Source: ArchSD records

5.8 Audit could not ascertain from ArchSD records details about the lighting levels of locations before and after the de-lamping exercises, and the actual number of lamps involved in each case. Information on the additional costs incurred to modify the installed lighting systems was also not available. In this connection, Audit noted that some of the lighting equipment became redundant after de-lamping.

5.9 **Audit considers that the ArchSD needs to review the design lighting levels for common areas with reference to the current requirements for achieving energy efficiency. The ArchSD also needs to discuss with the client departments during the design stage of new building projects to determine the appropriate lighting levels for common areas so as to minimise the need for de-lamping after project completion.**

Lighting level at Building C

5.10 At Building C, after the de-lamping exercise conducted during the POE period (see para. 5.7), the client department concerned (i.e. the EMSD) subsequently conducted two other de-lamping exercises as a drive to reduce electricity consumption:

(a) ***August and September 2007.*** A total of 832 lamps were removed; and

(b) ***December 2008 to February 2009.*** A total of 349 lamps were removed.

5.11 In July 2010, in response to Audit's enquiry, the client department assisted Audit in conducting an exercise to measure the lighting levels in the common areas of two office floors at Building C, including some spots in the corridors and the lift lobbies. **The measurement exercise found that at many spots of the common areas, the lighting levels were under the recommended 100 lux (see para. 5.5(c)). At some spots, the lighting levels were under 50 lux.** Photograph 2 shows the lift lobby at one office floor of Building C where the average lighting level of the measured spots was about 30 lux.

Photograph 2

Lift lobby at one office floor of Building C

Source: *Photograph taken by Audit in July 2010 (around 3:00 p.m.)*

Remarks: *The lighting level (about 170 lux) of the office area adjacent to the lift lobby is shown for comparison.*

5.12 **Audit is concerned about the low lighting levels at some locations in Building C. There is a need for the client department concerned (see para. 5.10) to conduct a review of the lighting levels in the common areas of the building and take necessary follow-up actions.**

Audit recommendations

5.13 **Audit has *recommended* that the Director of Architectural Services should:**

(a) **review the design lighting levels for common areas with reference to the current requirements for achieving energy efficiency (see para. 5.9); and**

(b) **in new building projects, discuss with the client departments during the design stage to determine the appropriate lighting levels for common areas (see para. 5.9).**

5.14 **Audit has *recommended* that the Director of Electrical and Mechanical Services should conduct a review of the lighting levels in the common areas of Building C and take necessary follow-up actions (see para. 5.12).**

Response from the Administration

5.15 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendations in paragraph 5.13. She has said that:

(a) the ArchSD will review and refine the design guidelines on lighting levels for common areas to cover different types of common areas, including corridors and staircases;

(b) the ArchSD will continue to work closely with the client departments to establish their requirements and advise them on the appropriate lighting levels for common areas; and

(c) the lighting equipment that has been de-lamped may be re-used in future to suit changes in office layout.

5.16 The **Director of Electrical and Mechanical Services** agrees with the audit recommendation in paragraph 5.14. He has said that the EMSD has carried out de-lamping exercises in common areas of Building C to reduce energy consumption, taking into account the minimum average lighting levels stipulated in the Labour Department's Guidelines for Good Occupational Hygiene Practice in a Workplace.

Lighting design for office buildings

General lighting design

5.17 At present, government offices in Hong Kong usually adopt the **general lighting design** in the lighting systems. Under this design, the office space is illuminated uniformly at a lighting level of 500 lux to enable performance of visual tasks. The general lighting design has the advantage of permitting flexibility of task location over the entire office area. However, more electrical energy is consumed as the areas outside the task location or desk area will be illuminated at a lighting level higher than necessary.

Task lighting design

5.18 Alternatively, office lighting can adopt the **task lighting design** under which a lower ambient lighting level is provided, with only the task areas illuminated to the required level for visual tasks. For example, a lighting level of 300 lux can be provided in an open plan office and each desk is supplemented with a task light (e.g. a table lamp) to achieve a lighting level of 500 lux over the task area. According to the ArchSD, the task lighting design has been commonly adopted in Europe and the USA.

5.19 In November 2005, Environment, Transport and Works Bureau Technical Circular (Works) No. 16/2005 was issued to provide guidelines to bureaux and departments on the adoption of energy-efficient features and renewable energy technologies in government projects and installations. The Technical Circular also stipulates a list of energy-efficient features which should be incorporated into the building design as far as practicable. The adoption of task lighting design is one of the items included in the list.

Pilot projects for applying task lighting design in government buildings

5.20 The ArchSD has been examining the feasibility of adopting task lighting design in government buildings. **In 2008, the ArchSD completed two pilot projects and found that there was a 25% saving in electricity consumption from adopting the task lighting design over the general lighting design.** Moreover, there were also savings in the capital costs of the lighting systems.

5.21 Despite the success of the pilot projects, the ArchSD was mindful of the fact that Hong Kong people had already got used to a brighter and uniform office lighting environment. In December 2009, the ArchSD issued BSB Circular No. 25 of 2009 on "Energy Efficient Lighting Design for Offices — Task Lighting Approach" for internal reference. This document promulgates the task lighting design as an energy-efficient design for offices and encourages its adoption in new building and refurbishment projects. The document also mentions that there is a need to consult client departments before adopting such design in new projects.

Audit observations and recommendations

5.22 While the task lighting design is an energy-efficient and cost-effective lighting design, it would take some time for this design to gain acceptance in Hong Kong. In July 2010, the ArchSD informed Audit that, besides the two pilot projects, the task lighting design had been adopted in four new building projects. In addition, the ArchSD was consulting the client departments on the adoption of such design in two other building projects.

5.23 **Audit considers that the ArchSD has made good efforts in initiating and promoting the adoption of the task lighting design in government buildings. There is a need for continued efforts to facilitate the adoption of the task lighting design in new projects. The EMSD also needs to consider promoting to the public the task lighting design as an energy management measure.**

Audit recommendations

5.24 **Audit has** ***recommended*** **that the Director of Architectural Services should continue to take measures to facilitate the adoption of task lighting design in new government building and refurbishment projects (see para. 5.23).**

5.25 **Audit has** ***recommended*** **that the Director of Electrical and Mechanical Services should promote to the public the task lighting design as an energy management measure (see para. 5.23).**

Response from the Administration

5.26 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendation in paragraph 5.24. She has said that the ArchSD will continue to promote the use of task lighting design in appropriate new government building and refurbishment projects.

5.27 The **Director of Electrical and Mechanical Services** agrees with the audit recommendation in paragraph 5.25. He has said that:

(a) the task lighting design concept is applicable to specific types of offices such as those with open plan settings and the concept is relatively new to the trade in Hong Kong; and

(b) the EMSD will keep abreast of the performance outcome of the task lighting design recently adopted in some government building projects.

PART 6: RECTIFICATION OF DEFECTS IN BUILDING SERVICES SYSTEMS

6.1 This PART examines the rectification of defects found in building services systems upon completion of a new government building.

Rectification of defects upon completion of a building

6.2 Upon completion of a new building, there are usually a number of defects identified for rectification. During the defect liability period, which is usually one year counting from the date of completion, the project contractor is responsible for making good the defects at his own cost. The ArchSD has laid down guidelines and procedures for handling defect rectifications.

Rectification of defects in building services equipment

6.3 The POE exercises conducted by the BSB on completed government building projects (see para. 2.7) covered rectification of defects found in building services systems. In the POE reports, some significant defects in the building services equipment were highlighted for detailed examination with recommendations for improvement in future. After scrutinising the defect cases highlighted in the POE reports, Audit selected three cases for examination, as follows:

(a) smoke detectors of Building A (see paras. 6.4 to 6.14);

(b) compressor motors in the air-conditioning system of Building C (see paras. 6.15 to 6.19); and

(c) centralised hot water system of Building C (see paras. 6.20 to 6.24).

Smoke detectors of Building A

6.4 Building A was completed in April 2004. The fire services system was inspected and accepted by the Fire Services Department in December 2003 and January 2004 respectively. After occupation of the building in October 2004, there were a number of incidents of false fire alarm caused by false triggering and equipment faults of smoke detectors, and malfunctioning of the automatic fire alarm control modules. Improvement works were carried out to rectify the anomalies.

6.5 In July 2005, the ArchSD found that of the 1,137 smoke detectors installed in Building A, a few hundred of them were suspected counterfeit products with possible latent defects in their operation. The ArchSD investigated the case and all the installed smoke detectors were replaced with new ones supplied directly from the UK manufacturer. The replacement works were completed in August 2005 under the supervision of the ArchSD.

6.6 In March 2006, the ArchSD issued BSB Instruction No. 2 of 2006 on "Identification for Make and Origin for Building Services/Electrical & Mechanical Materials and Equipment". The Instruction mentions that:

(a) in view of the cases of suspected counterfeit building services materials and equipment found in some public building projects, the ArchSD had taken the initiative to collaborate with the stakeholders of the industry to study measures for ensuring the integrity of building services materials and equipment;

(b) in August 2003, a working group was formed in the ArchSD with representatives from local trade associations to review the approach and to develop the methodology for identification and verification of the make and origin of building services materials and equipment used in government building projects;

(c) on the recommendations of the working group, a sample check for identification of the make and origin of building services materials and equipment should be conducted with effect from 1 April 2006; and

(d) the sample check should be conducted on selected government building projects by sending enquiry letters to the original manufacturer for confirmation of the make and origin of the building services materials and equipment delivered.

6.7 In 2006, the ArchSD selected 18 building projects for sample checks. Based on the sample check results, the ArchSD decided that the checking mechanism should continue. In November 2007, the ArchSD issued BSB Circular No. 26 of 2007 to provide further guidelines with standard forms for conducting the sample check. In March 2008, the ArchSD issued Operational Instruction No. 3 of 2008 on "Guidelines on Conducting Identification of Make and Origin of Building Services/Electrical & Mechanical Materials and Equipment". The Operational Instruction stipulates that:

(a) as far as practicable, **all appropriate ArchSD's new works projects** are required to be checked so as to continuously uphold the integrity of the make and origin of building services materials and equipment used in government building projects; and

(b) for each building project selected for checking, at least two items should be selected from each of the five categories of building services systems (Note 9) with reference to the following selection criteria:

(i) the items are commonly found in building projects and in large quantities; and

(ii) the items are not subject to specific authentication requirements under the contract (e.g. factory tests and warranty from suppliers).

Audit observations and recommendations

Need to step up verification of building services equipment

6.8 Since the case of suspected counterfeit smoke detectors in Building A and other similar incidents, the ArchSD has issued instructions for conducting sample checks on the make and origin of building services materials and equipment used in government building projects. According to Operational Instruction No. 3 of 2008, the sample checks currently apply to "all appropriate ArchSD's new works projects" (see para. 6.7(a)). However, the Instruction does not define the meaning of "appropriate" and does not set a target number (or percentage coverage) of projects to be selected for checking in a year.

6.9 In response to Audit's enquiry, in August 2010, the ArchSD said that the current target of sample checks was intended to cover all new capital works projects except those involving no or a small quantity of building services works (such as demolition projects). The number of projects available for checking would vary from year to year. **Audit considers that there is a need for the ArchSD to state clearly the scope and intended coverage of sample checks.**

6.10 The sample checks only apply to new government building projects. In this regard, Audit noted that in some refurbishment projects and minor building works implemented by the Property Services Branch of the ArchSD, large quantities of building services materials and equipment might be involved. **In Audit's view, the ArchSD may need to consider extending the sample checks to refurbishment projects and minor building works.**

Note 9: *The five categories of building services systems are air-conditioning systems, electrical systems, fire services systems, plumbing systems, and lifts and escalators.*

6.11 To facilitate the selection of items for sample check, Operational Instruction No. 3 of 2008 includes a prime target list covering five categories of building services systems. Under the category of fire services system, the following items are listed:

(a) fire resistant cables;

(b) breakglass units;

(c) sprinkler heads;

(d) fire hydrant outlets; and

(e) hosereel sets.

6.12 **Audit notes that the prime target list does not include smoke detectors. As suspected counterfeit smoke detectors were found in Building A (see paras. 6.4 and 6.5), Audit considers that smoke detectors could be a high risk item that should be included in the list.**

Audit recommendations

6.13 **Audit has *recommended* that the Director of Architectural Services should, in conducting sample checks in future on the make and origin of building services materials and equipment used in government building projects:**

(a) **state clearly the scope and intended coverage of such checks (see para. 6.9);**

(b) **consider extending the sample checks to refurbishment projects and minor building works, especially those involving a substantial amount of building services works (see para. 6.10); and**

(c) **periodically review the prime target list of items for sample checks and consider including smoke detectors in the list (see para. 6.12).**

Response from the Administration

6.14 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendations. She has said that:

(a) the ArchSD will review Operational Instruction No. 3 of 2008 taking into consideration the audit recommendations so as to facilitate continuous improvement;

(b) it may not be practical to conduct the checking on all projects and works orders in view of the large number. As most refurbishment projects and minor building works are carried out by term contractors, the checking can be done for each term contract; and

(c) there is no objection to including smoke detectors in the prime target list. In fact, smoke detectors have been selected for checking in some projects.

Compressor motors in air-conditioning system of Building C

6.15 Building C was completed in November 2004. The central air-conditioning system of the building includes a chiller plant in which chilled water is generated by four chillers each driven by a compressor with a high-power motor. After the chiller plant was put into operation in April 2005, a number of breakdowns were reported. In December 2005, one of the four compressor motors suffered a serious breakdown. As it was still within the defect liability period, the contractor was instructed to replace the burnt motor with a new one at his own cost.

6.16 In February 2006, a similar breakdown occurred in another compressor motor. The ArchSD immediately carried out an investigation and found that:

(a) the motor enclosures did not meet the contract specifications on protection against solid objects and liquid; and

(b) the motors were not equipped with anti-condensation heaters.

It was suspected that there might be moisture accumulated in the motor winding which caused the breakdowns. The ArchSD instructed the contractor to replace all the motors with new ones that complied with the contract specifications. The work commenced in October 2006 to replace the four motors one by one. The work was completed in February 2007 and the chiller plant resumed normal operation afterwards.

Audit observations and recommendation

Need to ensure compliance with contract specifications

6.17 The ArchSD considered that the breakdown of the compressor motors was due to non-compliance with contract specifications (see para. 6.16). In Audit's view, this incident illustrates the importance of the need to comply with contract specifications for building services equipment. **The ArchSD needs to take measures to ensure building services equipment in government buildings comply with contract specifications.**

Audit recommendation

6.18 **Audit has *recommended* that the Director of Architectural Services should consider taking measures to provide additional assurance that building services equipment installed in government buildings comply with contract specifications (see para. 6.17). These may include requiring contractors to obtain and provide certificates of compliance for critical building services equipment.**

Response from the Administration

6.19 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendation. She has said that:

(a) the case mentioned in paragraphs 6.15 and 6.16 involved the installation of proprietary package equipment;

(b) in future, the ArchSD would strengthen the checking of major components of proprietary package equipment such as chillers; and

(c) the ArchSD will review and refine, where practicable, the requirements for contractors to provide certificates of compliance for critical building services equipment.

Centralised hot water system of Building C

6.20 For Building C, a centralised hot water system was installed for providing hot water to meet operational needs. The system generates hot water and distributes it through a network of thermally-insulated pipes.

6.21 Upon occupation of Building C in April 2005, the temperature of hot water supply was found not high enough. After thorough checking, the ArchSD found that many parts of thermal insulation materials on the water pipes were not properly installed by the contractor and some of the pipes were without adequate insulation materials. The ArchSD instructed the contractor to rectify the defects. After the rectification work, the performance of the hot water system was found satisfactory.

Audit observations and recommendation

Need to step up inspection of works

6.22 The ArchSD has developed a set of testing and commissioning procedures for inspection of works during construction and conducting functional performance tests on building services systems before acceptance of completed works. **This incident (see para. 6.21) indicates that the ArchSD needs to step up the inspection of works before acceptance of completed building services systems.**

Audit recommendation

6.23 **Audit has *recommended* that the Director of Architectural Services should step up the inspection of works before acceptance of completed building services systems (see para. 6.22).**

Response from the Administration

6.24 The **Director of Architectural Services** welcomes and generally agrees with the audit recommendation. She has said that the ArchSD:

(a) recognises the importance of the inspection of works before acceptance of completed building services systems; and

(b) will review and strengthen, where practicable, the testing and commissioning procedures concerning the acceptance of building services systems.

Appendix

Acronyms and abbreviations

ArchSD	Architectural Services Department
Audit	Audit Commission
BSB	Building Services Branch
EMSD	Electrical and Mechanical Services Department
EMSTF	Electrical and Mechanical Services Trading Fund
GPA	Government Property Agency
IAQ	Indoor Air Quality
kVA	Kilovolt-amperes
kW	Kilowatts
POE	Post occupancy evaluation