Study on Energy Use by Air-Conditioning: Annex B - Analysis of Inspection Reports

BRE Client Report for the Department of Energy & Climate Change, HPR218-1001 - June 2016

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This report provides supporting information and explanation to the DECC Report “Study on Energy Use by Air-Conditioning: Final Report” (BRE Client Report HPR218-1001 The views expressed in this report are those of the authors, and not necessarily those of the Department of Energy and Climate Change (nor do they reflect Government policy).

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Annex B: Analysis of Inspection Reports

This Annex reports the results of the analysis of 500 air conditioning inspection reports.

1. (Formal) Objectives

1.1. To address the following questions:

1.1.1. Are air-conditioning systems sized for optimum performance?

1.1.2. Are they operated and maintained correctly?

1.1.3. Is there any information on refrigerant leakage rates?

1.1.4. What are the most common recommendations made by air-conditioning inspectors for improving efficiency?

2. Methodology and scope

2.1. The documents produced by an air conditioning inspection consist of an Air Conditioning Inspection Certificate (ACIC) and an Air Conditioning Inspection Report (ACIR). 500 air conditioning inspection files were submitted for review out of which a total of 457 ACICs and 486 ACIRs were actually reviewed[1].

2.2. This report presents the findings arising from the review of the ACICs and ACIRs.

3. Breakdown of sample

3.1. The data from the ACICs represents 457 buildings with an average installed cooling capacity of 154 kW, an average floor area of 1533 m^2, and utilising an average of 68 kg of refrigerant per building. The median values are 52 kW for cooling capacity, 305 m^2 floor area, and 19 kg of refrigerant.

3.2. 89 of these buildings (19.5%) had an F-gas inspection report. The F-gas inspection report is mandatory for systems with a refrigerant charge in excess of 3 kg, i.e. for over 90% of buildings inspected (see Table B2 for further details). The dates of the inspection reports ranged from 2008 to 2014. Analysis of the

[1] The discrepancy between the number of documents submitted for review and the number actually reviewed was due to sorting of the data.

ACIRs confirmed that documentation of F-gas inspection reports was the exception and not the rule. The comments in the ACIRs indicated that awareness of the F-gas regulations was generally low amongst building users. Analysis of the ACIRS indicated that over 25% of the systems inspected used R22 refrigerant, which has not been available for maintenance purposes since 1st January 2010 (for new refrigerant). R22 was phased out for new equipment in 2000.

3.3. 22 buildings (4.8%) had sub-metering of the HVAC systems installed, whilst another 16 buildings (3.5%) had partial sub-metering. Although the buildings with sub-metering were, on average, larger, the sub-metered building areas ranged from 26 m^2 to 28,000 m^2. Analysis of the ACIRs indicated that recommendations relating to metering and monitoring were very frequent.

3.4. The data from the ACIRs represent 486 buildings with an average installed cooling capacity of 200 kW, and an average floor area of 2060 m^2. The median values are a cooling capacity of 59.5 kW and a floor area of 302 m^2.

3.5. Although the format and content of ACIRs were changed when mandatory lodgement became a requirement from April 2012, the change to mandatory lodgement did not materially affect this analysis.

3.6. While the data sets for the ACIRs and ACICs represent the same buildings, there is a difference in the number of certificates since a number of the ACIRs submitted for review did not have corresponding ACICs. The ACICs specifically indicated the cooling capacity and floor area while this data had to be extracted from the ACIRs. Some discrepancies in area could be due to confusion between total floor area and conditioned floor area in the ACIRs. Differences in the cooling capacity could be due to the inclusion of some units for data rooms in the ACIRs.

3.7. The breakdown of the certificates by building use is shown in Figure B1. The majority of certificates relate to the retail sector. The other categories include a hospital, medical centres, bingo halls, laboratories and gyms. The analysis of certificates by system type in Figure B2 shows the predominance of split type units. There is a correlation between building use and system type in that retail outlets and bank branches are all air-conditioned by splits, multi-splits, or VRFs. The central systems (chillers) are mainly to be found in the office buildings with a very small number of examples (<5) of chiller installations in retail buildings and hotels.

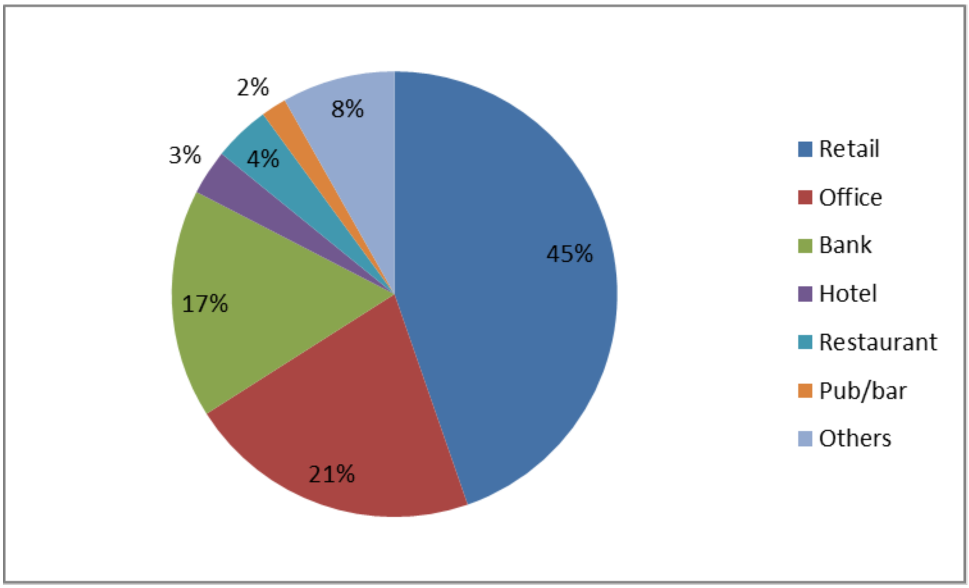

Figure B1 Breakdown of certificates by building use

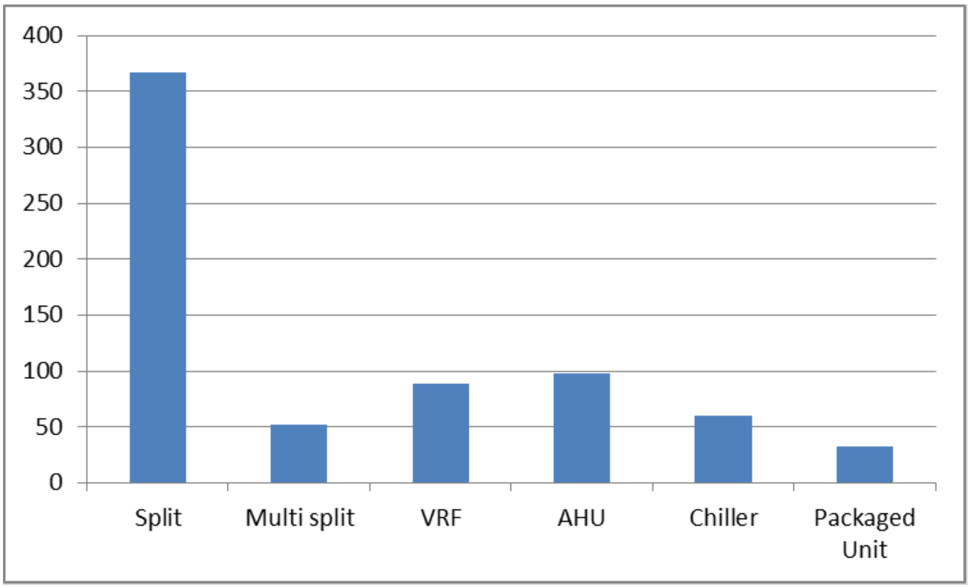

Figure B2 Analysis of system types

4. Sizing of systems

4.1. According to the ACIRs, approximately 56% of systems are incorrectly sized. The parameter for correct sizing is comparison against CIBSE benchmarks for the property type (Table 3.1 Inspection of air conditioning systems CIBSE TM44: 2012). The property types cover a wide range of different applications and discrepancies between the actual system capacity and the benchmark could be due to differences between the specific type of benchmark sub-category and the majority of properties included in the category. For example, a retail outlet could be a supermarket, a chemists, clothes store and so on. Systems which were highlighted as incorrectly sized were equally distributed between undersized and oversized. In the case of oversizing, a number of inspection reports highlighted the fact that the systems installed had capacity control (typically VRF systems as identified in Figure B2) which made oversizing less of an issue.

4.2. Table B1 shows that there is no specific correlation between building use and sizing in the sample selected.

4.3. The relationship between system sizing and energy use is one which requires further investigation. While it is generally considered that oversizing of equipment can result in inefficient performance, this does not apply to the same extent to all system types. Furthermore, the concept of oversizing is not one that is clearly defined.

4.4. 40 (9%) of the ACICs were for buildings with an installed capacity of 12 kW or less, which technically did not require certification under the Energy Performance of Buildings Regulations. Most ACICs (215 or 47%) were for buildings with installed capacities between 12 and 60 kW (see Figure B5). 158 (35%) of the buildings certified had a floor area between 100 and 300 m^2 (see Figure B6).

Building Use	% of air-conditioning systems incorrectly sized
Retail	53%
Office	45%
Bank	63%
Hotel	50%
Restaurant	65%
Pub/bar	78%
Others	63%

Table B1 Percentage of buildings in each category incorrectly sized

4.5. 67 buildings in the sample (14.7%) were located in London, followed by 12 buildings in Manchester (2.65%), and 9 in Bristol (1.99%). The majority of locations were represented by three or less buildings. Two hundred and fifty locations were represented by three or fewer certificates, with one hundred and forty locations having a single certificate.

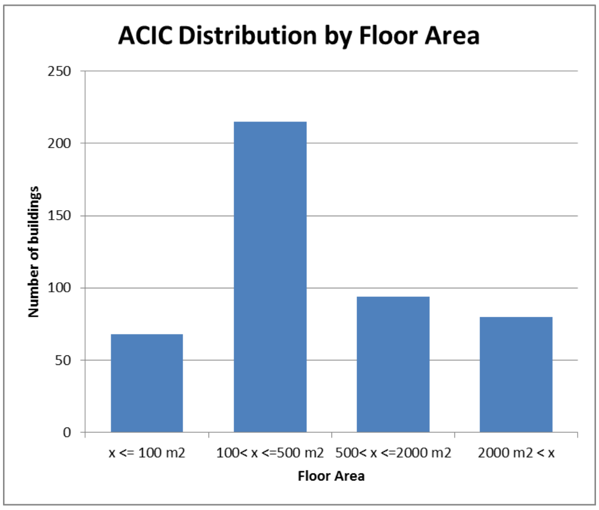

Figure 3 ACIC Distribution by Floor Area

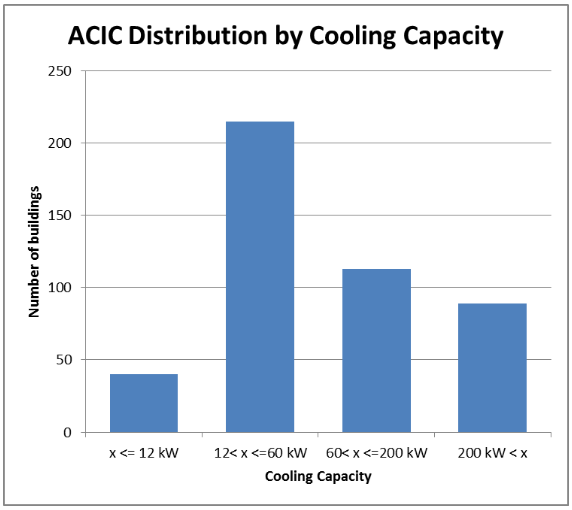

Figure 4 ACIC Distribution by Cooling Capacity

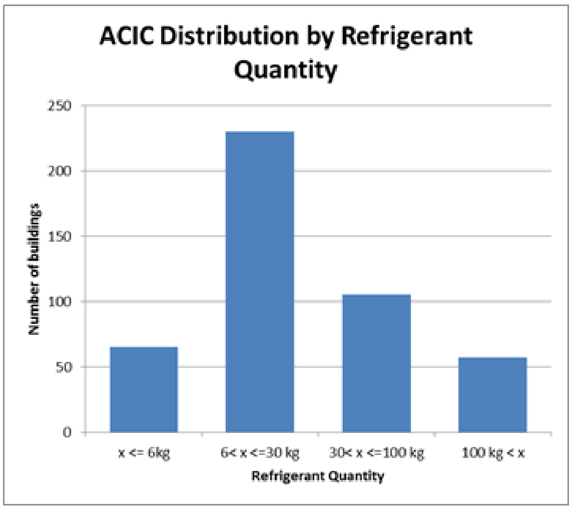

Figure B3 ACIC Distribution by Refrigerant Quantity

5. Operation and Maintenance

5.1. In the ACIRs, over 80% of installations are recorded as well-maintained. However, 25% of well-maintained systems include comments such as dirty or blocked filters, missing or damaged insulation, and units faulty or out of order. In some of these cases it appears that the decision to classify the systems as well-maintained is based on the presence of a maintenance agreement with a reputable firm.

6. Refrigerant leakage rates

6.1. There is no data available regarding leakage rates. However, F-gas inspections have been carried out for only 20% of the buildings in the sample, despite the fact that these inspections are mandatory[2]. The majority of buildings in the sample (280 or 61%) had between 3 and 30 kg of refrigerant installed (see Figure B4). The F-gas directive compliance requirements applicable at the time of inspection (Regulation EC 842/2006[3]) are summarised in Table B2 below for reference purposes.

Systems with below 3kg of refrigerant or 6kg if hermetically sealed	No requirement for leakage checking
Systems with between 3 and <30 kg	Leakage checking every twelve months
Systems with between 30 and <300 kg	Leakage checking every six months or every twelve months if leakage detection system installed
Systems with 300 kg or above	Must have leakage detection system and leakage checking every twelve months

Table B2 Requirements for compliance with F-gas directive.

6.2. 28% (138) of ACIRs reported systems which had R22 refrigerant installed. This refrigerant has been phased out, with a cut-off date for new equipment in 2001, a cut-off date for servicing with new refrigerant of 1st Jan 2010, and cut-off date for all servicing of 1st Jan 2015[4]. 30% (148) of systems were reported to contain R407C, whilst 60% (292) were reported to contain R410a. Several installations included more than a single refrigerant type. There were 13 instances of the use of R134a reported, 5 instance of R417, 3 instances of R404, and one report each for R434 and R422. This also indicates that the use of drop-in refrigerants for systems using R22 (e.g. R417, R404, R434 and R422) is very limited.

7. Most common recommendations

7.1. An analysis of the recommendations in the ACIRs was carried out on the basis of a classification of the main subject areas of the recommendations. Repeated recommendations in the same report were discarded. The data is presented in Table B3 below. The most frequent recommendations relate to the setting and operation of system controls, followed by maintenance, documentation, and staff

[2] The survey period (2008-14) falls before the new EU F-Gas Regulation came into effect in 2015. Part of the rationale for the new EU Regulation was the fact that the old Regulation had had limited impact on F-Gas emissions. The new Regulation has been accompanied by significant publicity and a new enforcement team was established in the Environment Agency in 2012.

[3] This regulation has been updated and replaced by EC 517/2014. The requirements for leakage checking are broadly similar although quantities are defined in terms of tonnes of CO_2 equivalent rather than kilogrammes of refrigerant.

[4] The ban is on the use of R22 for servicing. It does not prevent the continued use of the equipment, which can, however, only be done for as long as no intervention on the refrigeration circuit is necessary.

training. A list of the more popular recommendations in each category is found in Section 0. On average there were more than nine recommendations per ACIR, but the majority of the recommendations were quite generic and not linked to any specific measures, or indeed savings. The genericity of the recommendations meant that no trends could be identified to link recommendations to types of air-conditioning system types or to building use.

Description	Frequency
Controls	27%
Maintenance	16%
Documentation	10%
Staff training	10%
Metering and Monitoring	8%
Refrigerants	7%
Equipment	7%
Internal heat gains	4%
System sizing	4%
External heat gains	3%
Renewable energy	2%
Others	2%

Table B3 Categories for classification of ACIR recommendations

8. Cross-comparison with EPC data on system types, market sector

8.1. Although it was planned to compare the data from the ACIRs with the EPC data, the different sets of certificates appeared to relate to different properties and no reliable comparisons could be made.

9. Conclusions

9.1. The air conditioning certificates and inspection reports provide a valuable albeit limited source of data for commercial air conditioning systems in England and Wales. The sample set analysed represents less than 0.5% of the total number of air conditioned buildings in the UK as a whole (which is estimated to be in excess of 300,000 including Scotland and Northern Ireland). However, if it was representative of the stock as a whole[5], this data demonstrates that the majority of air conditioning installations are to be found in banks, offices, and retail outlets. Although retail outlets account for nearly half of the installations surveyed, after the figures are analysed in terms of cooling capacity, it can be seen in Figure B3 that offices actually account for over half of the installed

[5] A selection of 500 air conditioning inspection reports cannot be considered to be representative of the installed stock of air conditioned buildings in the U.K. without first establishing whether air conditioning inspection reports are representative of the installed stock.

cooling capacity. Clearly the majority of retail outlets surveyed consist of small units and this is reflected by the system type which, for retail buildings, consists almost exclusively of split and multi split type units.

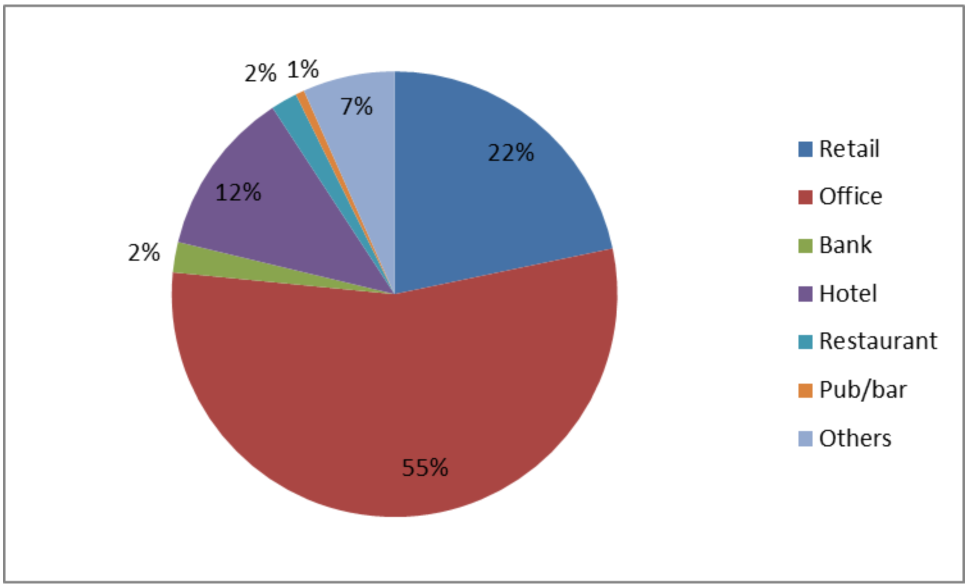

Figure B4 Breakdown of certificates by installed cooling capacity

9.2. The air conditioning certificates do not provide any specific information relating to refrigerant leakage rates. However, they do demonstrate low awareness and low compliance rates with the F-Gas directive requirements[6], and a significant proportion of installations are still using hydrofluorocarbon (HFC) refrigerants. Apart from the environmental implications, this indicates that the 28% of ACIRs reporting systems with R22 installed had equipment installed which is at least fifteen years old. The energy performance of older equipment is significantly lower than that of more modern units. Furthermore the effective maintenance of these units can be severely restricted if there are any problems with the refrigerant circuit requiring the removal and/or recharging of refrigerant. The very small number of systems (10) using R22 replacements indicates that this option is rarely taken up within the sample surveyed.

9.3. The fact that fewer than half of the systems surveyed have been recorded as correctly sized questions the validity of the guidelines that are utilised for benchmarking system sizing. While it is possible that system sizing might indeed be incorrect for the majority of installations, it is also possible that the guidelines used for comparison are too generic and cannot be rigorously applied to the wide range of properties that fall into the building use categories. The relationship

[6] The survey period (2008-14) falls before the new EU F-Gas Regulation came into effect in 2015. Part of the rationale for the new EU Regulation was the fact that the old Regulation had had limited impact on F-Gas emissions. The new Regulation has been accompanied by significant publicity and a new enforcement team was established in the Environment Agency in 2012.

between system sizing and energy efficiency can vary according to the system type and the mere fact of over or under sizing in comparison to a rule of thumb guideline is not necessarily an indication of low operating efficiency. This is an area where significantly more research and data are required before a meaningful conclusion can be reached. The recast Energy Performance of Buildings Directive has relaxed the requirement for ACIRs to include an assessment of the equipment sizing when there is an existing ACIR and when no changes have been made to the air-conditioning system or the cooling requirements of the building.

9.4. The inspection reports also recorded a significant amount of minor maintenance issues such as poor insulation and dirty or blocked filters. Whilst it is unlikely that these minor maintenance issues would have a significant impact on energy usage (our professional estimate would be below 10% for the majority of systems inspected), they are symptomatic of a lack of attention to the operation and energy performance of the systems installed. The Carbon Trust (Air conditioning technology overview, 2012) quite correctly draws attention to the fact that few maintenance contracts explicitly include energy efficient operation of systems as a requirement. The survey of ACIRs does imply that even the basic minimum procedures of filter cleaning and insulation repair are not necessarily carried out with sufficient frequency or to the expected level and this means that it is questionable how successful the move to a more energy efficient maintenance philosophy, as proposed by the Carbon Trust, could be.

9.5. The ‘key recommendations’ in the ACIRs were, in the main, a generic list of recommendations with limited tailoring to the specific requirements of the systems inspected. There was frequent repetition of similar recommendations across the ACIR sample with several references to standardised energy savings. It is considered that the majority of recommendations are unlikely to motivate building owners and operators to implement effective energy saving measures. A number of certificates appeared to exhort the building owner to investigate every single possible option to save energy, and this does not quite fall within the heading of ‘key’ recommendations. It should be kept in mind that the vast majority of buildings inspected were installed with split or multi split type air conditioning systems. These are smaller less complex air conditioning installations and it is questionable whether an air conditioning inspection of a split unit installation can produce any significant energy saving recommendations apart from the ‘common sense’ guidelines to operate the units sensibly and to maintain them effectively. It does appear practical to consider a simpler, more streamlined inspection procedure for smaller, simpler installations. Guidelines should consider the type of system, which can be more significant than the system capacity.

9.6. It should also be noted that the ACIRs clearly demonstrated that the inspectors generally had a suitable level of competence and professional knowledge of the systems inspected. There were occasional instances where knowledge of the requirements of the F-gas directive appeared to be limited, but the sample of ACIRS seems to have been generated by a competent body of inspectors with good general air conditioning knowledge. The limited usefulness of the air conditioning inspection procedure is more of a result of the structure and format of the inspection certificates and reports than any perceived lack of competency of the inspectors.

9.7. To conclude, there are several aspects of the air conditioning inspection procedure that might not be providing value for money to the building owner / user. Further investigation is required of the possibilities of a different implementation of the existing approach or indeed alternative approaches.

Sample of common recommendations from the ACIRs

Setting and use of controls (CT)

- All the system controls should be programmed to display the correct time and date.
- Consider the options of linking the split systems on-site to the BMS to provide an overall site control program.
- All system controllers should have timer schedules set to reflect the current staff occupancy hours.
- Consider the savings that could be made by implementing seasonal set points on the split systems at this site.
- Consider the saving that could be made by operating the terminal units at this site in low fan mode, this could always be readjusted in the future if the internal space temperature cannot be maintained.
- Consider upgrading the IRE remote controller at this site to a newer wall-mounted controller with full 7-day time facilities installed.
- Controllers for split systems do not have their timers set at present. This could lead to air conditioning systems being left on when the building is not in use. Ensure that the timers are set in line with building occupancy to avoid this.
- Consider installing a BEMS to control the AC systems and air handling units.
- The central controllers need to be reprogrammed to operate in a more energy efficient manner.
- It should be noted that for every degree of temperature above the default, operating costs increase by around 3%.
- Consider widening deadband to allow more tolerance on supply air temperature.
- Ensure that batteries are replaced on AC controllers to allow full control.
- Consider adopting a heating schedule to ensure optimum temperatures are maintained (22°C or higher in cooling mode and 22°C or below in heating mode). The CIBSE Guide A: Environmental Design suggests that the temperature range for comfort should be 21-23°C in winter and 22-24°C in summer. This will reduce energy consumption whilst the unit is operating and reduce operating periods.
- It is recommended that the heating and cooling set points are reviewed to enable a dead band of 4°C to be introduced to prevent simultaneous heating and cooling. It is recommended that during the winter and mid-

seasons the heating is set at 20°C and the cooling at 24°C, to provide a typical internal condition of 22°C ± 2°C. During the summer the cooling set point could be set to 22°C if required by the staff, provided that the heating set point is also reduced to 18°C.

Training of staff (ST)

- Consider placing notices adjacent to system controller so as to advise members of staff of the recommended method of operation of the air conditioning systems.
- There were no guidance notes located near indoor terminals at the time of inspection. If a manual control strategy is to be continued, consider mounting guidance notes in prominent positions near indoor terminals advising occupants to be wary of operating cooling systems when heating is on, windows open, or rooms unoccupied. Ensure that the instructions for controllers are present and accessible.
- Air flow rates from indoor terminals are modulated and controlled manually via system controllers. Ensure that guidance notes are supplied near controllers so that users understand how to modulate air flow rates.
- Ensure that the responsible person on site is adequately trained to efficiently operate the ventilation systems.
- Staff training would be useful to ensure that they can monitor and operate the controls.
- Explain how thermostats operate and give guidance on recommended operating temperatures.
- Consider installing guidance notices to inhibit staff from opening windows when AC plant is operational.

Refrigerants (RF)

- As a high ozone depleting refrigerant, the manufacture of R22 is banned as of 2004. As stocks diminish the costs will increase. Alternative drop-in replacement refrigerants are available. However in the light of the size and age of the R22 equipment on site, serious consideration should be given to ultimate replacement with new energy efficient equipment operating on zero ozone depleting refrigerants.
- Consider changing R410a to Honeywell Solstice L-41 or similar. This offers a 75% reduction in GWP compared to R-410a and is intended to replace R410a in residential and light commercial air conditioning and heat pump applications. In addition to a lower GWP, Solstice offers excellent energy efficiency, is cost effective, and can be used in existing equipment designs with minimal changes.

- As HFC refrigerants are used, the company must ensure that it meets the requirements in EC Regulation 842/2006 and the GB Fluorinated Greenhouse Gases Regulations 2009 (Statutory Instrument No 261). In summary the EC F Gas regulation requires 1) Regular checks for leakage 2) Refrigerant recovery during plant servicing and maintenance and at end of life 3) Good records kept for equipment containing 3kg or more of F gases, usually in the form of an F gas register 4) Appropriate certification for operatives and maintenance personnel 5) Certain other measures including labelling of new equipment.
- Some systems contain R22 refrigerant gas, an Ozone Depleting Substance (ODS). In addition to complying with the requirements of EC Regulation 842/2006 and the GB Fluorinated Greenhouse Gas Regulations 2009 (Statutory Instrument 261), if an organisation is using ODS refrigerants (such as R22) it must also comply with the requirements of EC Regulation 2037/2000 and GB Statutory Instruments 2002 No. 528, 2008 No. 91 and 2009 No. 216. In summary the EC Ozone Regulation requires 1) Phase out of HCFC usage between 2012 (virgin fluid) and 2016 (recycled fluid) 2) Annual leakage checks for equipment containing 3kg or more of refrigerant 3) Refrigerant recovery during plant servicing and maintenance and end of life 4) Use of personnel with prescribed qualifications.

Documentation (DC)

- Ensure that any records from air flow readings taken from the AHUs are recorded and kept on file during the next five years. This important information should be retained for the next AC inspection to fully assess the specific fan power.
- The basic level of information required by a TM44 assessment was not supplied. It is advised that a package of information be assembled that contains as a minimum 1) An itemised list of installed packaged cooling systems including a product make, date of installation, models and identification numbers together with cooling capacities (kW) and locations of both external equipment and all indoor terminals (including a plan of any concealed in the roof). 2) A description of the method of control of temperature for each system, including zoning arrangements. 3) A description of the method of control of periods of operation for each system.
- There were no recent copies of service sheets, nor confirmation of recent leak tests. It is a legal requirement under the F-Gas regulations for detailed records to be maintained and for a leak detection test to be carried out on each system every 12 months. Although this may be happening there were no records available to confirm this.
- A copy of the maintenance records should be kept on site to enable anyone to check that they have been undertaken in accordance with guidelines of 6 monthly visits by competent staff.

Replacement of Equipment (EQ)

- Install inverter drives for the AHU fan motor. This can allow fans to modulate their speed for actual conditions. It is recommended that this is installed as soon as possible due to the potential savings. A 20% reduction in speed can equate to a 50% reduction in energy consumption.
- Consider the replacement of the R407C non-inverter unit. Significant energy savings of between 20% and 50% can be achieved when replacing the R407C non-inverter systems with new R410a inverter units.
- When investigating replacements for the systems on-site consider the savings that could be made by ensuring that any new equipment is equipped with inverter technology.
- Consider the savings that could be made by linking the supply and extract motors within the AHU to VSDs.
- Consider installing VSDs (Variable Speed Drives) on fan motors.
- Replace old R22 units with newer R410a inverter units when funding allows (a 50% increase in COP is the potential).
- Investigate options of upgrading the AHU fan assemblies to utilise more efficient 'Plug' fans and 'EC Motors'.
- Consider installation of speed control so fan volume can be matched to occupancy needs

Renewable energy (RE)

- Consider the savings that could be made by utilising the AHUs on site to provide a free cooling regime.
- Consider review of installation and controls with a view to maximise energy conservation. Options could include heat reclaim coils, free cooling, night purge, etc.

Internal heat gain reduction (IH)

- Consider reducing unnecessary heat gains in areas requiring air conditioning. Before installing new cooling equipment, identify where excess heat is coming from. Sunlight, equipment, lighting and refrigeration are often the main causes. As a general rule, the more energy efficient equipment is, the less heat it produces. Therefore installing low energy lighting and keeping equipment operating at peak efficiency reduce cooling costs.

External heat gain reduction (EH)

- Brise soleils or other ways of limiting solar gains should be considered for east and west-facing glazed elevations.
- Consider fixed or moveable external shading for windows or solar control finishes on external glazing to reduce excessive solar gains.

- Consideration should be given to installing a reflective film on the windows to reduce the effects of solar gains, thus reducing demand on the building's cooling systems.
- Reduction of heat gains from lights and solar gains from the sun (where applicable) will also reduce the cooling load.

System sizing (SS)

- Using the very basic heat gain estimating method documented in CIBSE TM14, some systems appear to be oversized. This should be investigated further when any new cooling plant is introduced.
- The split systems appear to be oversized for cooling during peak loads. However, in practice the inverter controlled compressor will ensure that the cooling capacity matches the actual heat load. This will not affect running costs.
- The information to assess the specific fan power was unavailable for this inspection. This information should be retained for the next AC inspection to fully assess the specific fan power. Ensure that any records from air flow readings taken from the AHUs are recorded and kept on file during the next five years.

Metering and monitoring (MM)

- It should be a consideration to install metering and monitoring equipment to all the cooling plant to establish when the systems are in operation. This should be compared on a regular basis to the expected hours of operation which should be recorded on site.
- The installation of sub-metering to all the HVAC system is essential to identify where potential savings can be made with recorded results taken. The aim for buildings as a whole is to enable building occupiers to assign at least 90% of the estimated annual energy consumption of fuel to the various energy end-use categories (heating, cooling, lighting, etc.). Sub-metering should be implemented across all new HVAC installations in the future as standard policy.
- Consider sub-metering the individual items of HVAC plant on site and then record the energy consumption figure to enable areas of excessive consumption to be identified.
- No energy consumption metering on air conditioning plant has been installed. It is advised that the organisation reviews the scope to install appropriate metering at least to the more significant energy consuming air conditioning plant and subsequently to record the consumption on a regular basis. CIBSE TM39 Building Energy Metering provides guidance on developing a metering plan.
- Consider monitoring chiller usage to enable improving energy efficiency.

- Review the hours run against occupancy to ensure units aren't operating unnecessarily.
- Consider installing energy meters and/or hours run meters to monitor use and energy consumption. CIBSE TM 39 Building Energy Metering provides guidance on developing a metering plan and advice on best practice. The benefits of completing these works will be more compelling as energy monitoring will form an essential part of new carbon reducing legislation. Consider introducing a policy that all new electrical installations should be fitted with sub-meters as standard.

Maintenance (MT)

- It is recommended to clean away the stains on the packaged unit and test for a refrigerant leak. If no leak is present (the oil may be from a previous leak), the oil should be cleaned up to prevent this being highlighted as a new leak in the future. Details should be recorded in the F-gas register, even if the results are negative.
- Ensure all filters are clean and in place to maintain the efficiency of the systems.
- Consider installing a filter gauge to AHUs so as to aid with on-going maintenance and future inspections.
- Change filters to improve air flow and therefore efficiency. Check period of inspection/replacement.
- Carry out repairs to lagging to save energy. Fit protection to avoid further damage.
- The fluid-filled manometers linked to the AHUs should be inspected and repaired or replaced as necessary.
- The refrigerant pipework insulation should be inspected and any damaged areas of insulation repaired or replaced as necessary.
- Investigate the abnormal temperature readings provided by the temperature sensor linked to AHU.
- A number of the units were inspected and the filters were found to be fairly dirty, indicating that an interim clean is required. The service company were on site carrying out the PPM visit.
- Consider anti-corrosion coating for heat exchangers (fins, coils, etc.) to improve life expectancy and effectiveness. This reduces the chance of needing early replacement.
- Neither external condenser units nor indoor terminals were labelled correctly. Labelling indoor units, outdoor units, and controllers so that they can be identified as part of the same split system will assist with planned maintenance.

- Keep the area clean and free of debris.
- Ensure the area is regularly kept clear of obstacles.
- Maintain coil efficiency by regular brushing (combing) and cleaning of the coils.
- Inspect diffusers while servicing the fan coils.
- Inspect AHU and ductwork regularly to ensure supply air losses are minimised.

Others (OT)

- Schedule the next visit when the plant is able to run.