Overall observations from HVAC Inspections – Report Summaries

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By

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Report #: AT1
Single split package air conditioning unit
Vienna, Austria.

Installed Capacity

Whilst the room heat load is only 250 W/m^2, an installed capacity of 438 W/m^2 is not unreasonable as it leaves room for future expansion, and as the motor/compressor is inverter driven there would be benefits from operating at a reduced capacity – the EER during the inspection was 4.45.

Condenser

The condenser coil was found to be completely blocked which was causing a severe fall in airflow and heat exchange, resulting in the compressor and condenser fan operating at increased speed to compensate. The airflow being so restricted the fan was creating a vacuum within the unit casing causing air to be pulled backwards through the inside half of the fan blades and only being rejected from the edge of the blades.

This, however, had no effect on the system's ability to maintain the correct room temperature as the cooling load was only 1.157kW at the time of the inspection. Cleaning the condenser had no influence on this but the reduction in input energy of 0.23kW from 0.26kW resulted in a saving of 11.5%.

Maintenance

No maintenance had been done for two years - on enquiring whether there was a maintenance contract in place our inspector was informed by the user, in no uncertain terms, that there was no law to say there has to be..

Evaporator

The high By-Pass factor of 44% would be in respect of the system operating at 33% of full load.

Report #: AT2

Twin split package air conditioning unit

Vienna, Austria

Installed capacity

The installed cooling capacity of 5.38kW is shared between an IT 'cupboard' (1.9kW 24 hour operations) and a meeting room (2.63kW – occasional use). The inverter drive motor/compressor would ensure good efficiency even when both were operation together as the total load is only 4.53kW – 84% of full capacity.

Condensing Unit

The condenser has only limited access to free air being located within the attic space which was 22.4°C, 2.8°C higher in temperature than the 19.4°C outdoor ambient air at the time of the inspection. The condenser coil was slightly dirty and in need of cleaning, the discharge air from the condenser was transferred to outside using flexible duct work. The manufacturers do not recommend that ductwork is used without changing the condenser fan to a high static model. However, as the main heat load for most of the time is relatively small, from the IT room, the condenser fan would be operating at a very low speed at which the air volume, very likely, would not be affected by the duct work, and as the occasional input from the Meeting room would only increase the load to 84%, then it would be prudent not to criticize the installation unduly as the adverse effect of the duct work may not be sufficient to warrant expensive modifications, even though maintaining the correct condensing air temperatures has shown to save an **average of 7.65%** in energy usage (HARMONAC) - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Report #: AT3
Single split package air conditioning unit
Vienna, Austria.

Installed capacity

The installed cooling capacity of 2kW compares favourably with the maximum room heat gain of 1.49kW with no option of downsizing from this lowest of the range unit.

Efficiency

We were unable to access the indoor unit to make cooling capacity measurements but the refrigeration system operating pressures and temperatures were as expected for satisfactory operation.

Maintenance

No maintenance has been carried out for two years on this system.

Operation

The condenser has only limited access to free air being located within the attic space which was 22.4°C, 2.8°C higher in temperature than the 19.4°C outdoor ambient air at the time of the inspection. The condenser coil was slightly dirty and in need of cleaning, the discharge air from the condenser was transferred to outside using flexible duct work. The manufacturers do not recommend ductwork is used without changing the condenser fan to a high static model. Maintaining the correct condensing air temperatures and preventing warm air recirculation has shown to save an **average of 7.65%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010). Keeping condensers clean has shown to save on average 7.65% in energy usage (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Report #: AT4
Monobloc through the wall air conditioning unit
Vienna, Austria

Installed capacity

The installed capacity compares favourably (95% of calculated maximum full heat load) with our calculated room heat load - the user accepting a higher than usual room temperature under high ambient conditions.

Maintenance

The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.

Operation

The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

Efficiency

The installed unit has a EER of 2.6 as found in the manufacturer's literature; using the manufacturers rated input of 1.4kW as there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW. The calculated EER was 1.86 before the filter was cleaned and 2.12 afterwards - an **improvement in efficiency of 13.98%**

Control

The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer in the room to avoid too low temperatures.

Report #: AT5
Monobloc through the wall air conditioning unit.
Vienna, Austria

Installed Capacity

The model number of the unit was not found and therefore the nominal cooling capacity is unknown although the measured cooling capacity after the filter clean was 2.85kW which is just 14% higher than the maximum heat load calculation of 2.48kW, and therefore appears to correctly sized for the room.

Maintenance

The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.

Operation

The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

Efficiency

As there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW we were unable to determine the energy input kW and therefore the EER, however the cooling output was measured at 2.02kW before the filter was cleaned and 2.83 afterwards - an **improvement in efficiency of 26.6%**

Control

The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer in the room to avoid too low temperatures.

Report #: AT6
Monobloc through the wall air conditioning unit
Vienna, Austria

Installed capacity
The installed capacity of 4.7kW compares favourably with the calculated maximum heat load of 4.06kW.
Maintenance
The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.
Operation
The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.
Efficiency
The installed unit has an EER of 2.19 as found in the manufacturer's literature, using the manufacturers rated input of 1.4kW as there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW. The cooling capacity was measured at 3.81kW before the filter was cleaned and 4.06kW afterwards - an improvement in efficiency of 6.56%
Control
The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer in the room to avoid too low temperatures.

Report #: AT7
Monobloc through the wall air conditioning unit
Vienna, Austria

Installed capacity

The installed capacity of 4.7kW far exceeds the calculated maximum heat load of 2.33kW.

Maintenance

The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.

Operation

The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

Efficiency

The installed unit has an EER of 2.19 as found in the manufacturer's literature, using the manufacturers rated input of 1.4kW as there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW. The cooling capacity was measured at 3.53kW before the filter was cleaned and 3.8kW afterwards - an **improvement in efficiency of 7.65%**

The calculated increased output of 270W after the filter clean reduced the calculated run time from 15:50 hours to 14:43 hours, a reduction of 1:08 hours or 7%

Control

The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer.

Report #: AT8
Monobloc through the wall air conditioning unit
Vienna, Austria

Installed capacity

The installed capacity compares favourably (95% of calculated maximum full heat load) with our calculated room heat load - the user accepting a higher than usual room temperature under high ambient conditions.

The installed capacity of 4.7kW compares favourably with the calculated maximum heat load of 4.06kW.

Maintenance

The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.

Operation

The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

Efficiency

The installed unit has an EER of 2.19 as found in the manufacturer's literature, using the manufacturers rated input of 1.4kW as there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW. The cooling capacity was measured at 2.93kW before the filter was cleaned and 3.32kW afterwards - an **improvement in efficiency of 13.3%.**
The measured cooling output of 3.32kW appears on the low side (70.6% of Nominal) although the unit was otherwise deemed to be working satisfactorily.

The calculated increased output of 390W after the filter clean reduced the calculated run time from 20:48 hours to 18:22 hours, a reduction of 1:08 hours or 11.7%

Control
The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer in the room to avoid too low temperatures.

Report #: AT9
Monobloc through the wall air conditioning unit
Vienna, Austria

Installed Capacity

The model number of the unit was not found and therefore the nominal cooling capacity is unknown although the measured cooling capacity after the filter clean was 2.85kW which is just 14% higher than the maximum heat load calculation of 2.48kW, and therefore appears to correctly sized for the room.

Maintenance

The unit has no maintenance contract and has not had a maintenance inspection for two years. The condenser has adequate access free air and is not affected by any hot air recirculation from the adjacent hot air discharge fans.

Operation

The unit has no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

Efficiency

As there was no access to the electrical components, whilst the unit was running, to gather data for calculating the actual input kW and as the installed unit is missing its data plate no manufacturer's information is known, we were unable to determine the energy input kW or the nominal cooling output and therefore the EER, however the cooling output was measured at 1.97kW, using the System performance calculator workbook which can be downloaded from www.harmonac.info, before the filter was cleaned and 2.2 afterwards - an **improvement in efficiency of 11.7%**

Control

The thermostat scale graded from 1 to 10 i.e. no specific temperature – the user selecting a comfortable setting. It would be advisable to locate a thermometer in the room to avoid too low temperatures.

The installed unit is missing its data plate so no manufacturer's information is known. Using the information from table 8 the actual cooling kW output from each unit can be calculated using the System performance calculator workbook which can be downloaded from www.harmonac.info.

This was calculated both before and after the return air filter was cleaned. An improvement of 11.7% in unit duty was calculated.

Report #: AT 10
Ceiling Underslung Single Split air conditioning unit,
Austria

Installed capacity

The heat gain of 332.6W/m^2 is not unusual for this type of existing combined IT and Telecommunications room and although it could be considerably higher, the installed capacity of 907.7W/m^2 is probably too high even when allowing for future expansion.

The installed units have a COP of 2.41 @ 35^{o}C as found in the manufacturer's literature; it is possible for modern systems of a similar type and design have a COP of 3.35 and over @ 35^{o}C as found on the Eurovent website. This would lead to a **38.4% improvement** over the existing installed unit. The use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load.

Maintenance, Operation and Efficiency

The units appear to be well maintained in general with no visual signs of refrigerant leakage. The condensers have adequate access free air but are affected by hot air recirculation from the adjacent condensing unit discharge fans discharging into the surrounding louvers. Using the information gathered in the verification inspection there would

Appear to be some issues with the refrigeration circuit indicated in the high discharge pressure, compressor compression ratio, and sub-cooling values recorded which would require further inspection by the incumbent maintenance company to identify the exact cause. These values would suggest a reduction in unit efficiency but without access to the indoor units it was not possible to be precise.

Control

The compressors in all units are fixed speed with no capacity control. The condenser fan is variable speed to maintain the correct condensing temperature. The evaporator fan motor located within the indoor unit is also fixed speed; the choice of speed is selectable on the remoter controller. The cooling set-point was 24^{o}C and the unit is permanently enabled.

Report #: AT11
Shopping Mall
Austria

Installed capacity

The installed cooling capacity of the AHU inspected was estimated at 132kW using the iSERVcmb Air conditioning Unit Capacity Spreadsheet which equates to 1452kW for the total of 11 AHUs on the chilled water circuit which is served, we believe, by 1 x 1700kW water chiller. Although the chiller is slightly oversized it would not present a problem due to the excellent part load efficiency of its 2 x screw compressors.

The area of the interest being 2597.1 m^2 would, therefore, have an installed AHU cooling capacity of 50.83 W/m^2 based on the estimated AHU capacity, although the total area of 29490.11m^2 would have a chilled water installed cooling capacity of 57.65W/m^2, assuming that 1 x chiller is dedicated to it whilst 11 x AHUs, @ 132kW, serving 29490.11 m^2 would be 49.23W/m^2, none of a which are not atypical for the retail sector.

The heat load in the area was found to be 73.64kW at the time of the inspection by dint of the difference between the return and supply air enthalpy which equates to 28.35W/m^2, which is reasonable considering the ambient conditions of 17°C and 68% RH.

We would conduce, therefore, that the installed capacity is reasonable.

Maintenance

The units appear to be exceptionally well maintained with motors, for instance being stripped down after recommended elapsed time periods, weekly check and the filters being replaced when required as indicated by the manometers.

The maintenance contract also has a remit to rectify problems as soon as found.

Control

Using the information gathered in the verification inspection there would appear to be some issues with the control of the AHU, especially with the use of fresh air, bypass and heat recovery – specifically at the time of the inspection when warm return air was being re-introduced in favour of the cooler fresh air.
With no opportunity at the time to determine from the BEMS whether or not this was an effect of the control strategy or a fault, we have assumed it to be a control issue as other AHUs were acting in the same manner.

Operation and Efficiency

During the inspection a mixed air condition of 22°C and 60.2%RH the AHU was producing 56.44kW of cooling to give an air off condition of 14.3°C 86.8%RH. To give the same air off condition but using 100% ambient fresh air, which was at 17.2°C and 67.5%RH, the AHU would only be required to produce 7.85kW of cooling. This is a reduction of 86.09% or 48.59kW in required cooling duty. Using the chiller manufacturers EER of 6.08 this would result in a reduction of 94.8kWh per day. If the same saving was

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possible on all 11 AHUs the reduction in required cooling kW would be 534.5kW, again using the chiller manufacturers EER of 6.08, a reduction of 1054.8kWh per day could be expected.
Otherwise, the calculated cooling coil By Pass Factor of 21.58% is an indication of efficient operation as is the Specific Fan Power of 1.06kW/m^3/s as measured.

Report #: AT12
Shopping Mall (LO8)
Austria

Installed capacity

The installed cooling capacity of the AHU inspected was estimated at 132kW using the iSERVcmb Air conditioning Unit Capacity Spreadsheet which equates to 1452kW for the total of 11 AHUs on the chilled water circuit which is served, we believe, by 1 x 1700kW water chiller. Although the chiller is slightly oversized it would not present a problem due to the excellent part load efficiency of its 2 x screw compressors.

The area of the interest being 2170 m^2 would, therefore, have an installed AHU cooling capacity of 60.83 W/m^2 based on the estimated AHU capacity, although the total area of 29490.11m^2 would have a chilled water installed cooling capacity of 57.65W/m^2, assuming that 1 x chiller is dedicated to it whilst 11 x AHUs, @ 132kW, serving 29490.11 m^2 would be 49.23W/m^2, none of a which are not atypical for the retail sector.

The heat load in the area was found to be 49.56kW at the time of the inspection by dint of the difference between the return and supply air enthalpy which equates to 22.84W/m^2, which is reasonable considering the ambient conditions of 17.6°C and 65% RH.

We would conduce, therefore, that the installed capacity is reasonable.

Maintenance

The units appear to be exceptionally well maintained with motors, for instance being stripped down after recommended elapsed time periods, weekly checks and the filters being replaced when required as indicated by the manometers.

The maintenance contractor also has a remit to rectify problems as soon as found.

Control

Using the information gathered in the verification inspection there would appear to be some issues with the control of the AHU, especially with the use of fresh air, bypass and heat recovery – specifically at the time of the inspection when warm return air was being re-introduced in favour of the cooler fresh air.
With no opportunity at the time to determine from the BEMS whether or not this was an effect of the control strategy or a fault, we have assumed it to be a control issue as other AHUs were acting in the same manner.
The zone temperature set point of 24 °C is typical for this type of application in the retail sector.

Operation and Efficiency

During the inspection a mixed air condition of 21°C and 64.3%RH the AHU was producing 42.95kW of cooling to give an air off condition of 15.3°C 85.8%RH. To give the same air off condition but using

100% ambient fresh air, which was at 17.6°C and 68.7%RH, the AHU would only be required to produce 3.41kW of cooling. This is a reduction of 86.09% or 48.59kW in required cooling duty. Using the chiller manufacturers EER of 6.08 this would result in a reduction of 78kWh per day. If the same saving was possible on all 11 AHUs the reduction in required cooling kW would be 434.9kW, again using the chiller manufacturers EER of 6.08, a reduction of 858.4kWh per day could be expected.

Report #: AT13
Liquid Chiller, Austria

Installed capacity

The installed chilled water cooling capacity of 101.84kW equates to 244.8Wm^2 which compares favourably with the ASHRAE guideline of 248 Wm^2 for this type of facility.

Maintenance

Maintenance is carried out just once per annum, which reflects the condition of the chillers. Only two of the four circuits are operational, albeit with refrigeration circuit issues and condenser fan control problems. The user should, therefore, consider revising the maintenance schedule and inspection tasks.

Operation, Control and Efficiency

The chillers deliver chilled water to hydronic FCUs within various laboratory areas by separate flow pipe-work but with a common chilled water return.

The chillers, each having two separate refrigeration circuits, have three control stages of 0, 50 or 100% set at 15.5° C return water temperature (minimum of 10°C Flow temperature by reason of a 5.5K TD) to the hydronic FCUs within various laboratory areas, where the room temperatures are controlled by wall mounted thermostats set to comfort conditions as required.

No observations were made internally, as owing to the sensitive nature of the user's operation access was limited although we were made aware that it was very warm in most areas and that it was thought to be caused by more laboratory equipment had been installed and therefore the chillers could no longer cope with the increased heat load.

However, we were able show that the probable cause was that only two inefficient circuits out of the four available were providing the cooling – one compressor on each enabled by the controller was not operating and there were refrigeration circuit problems on the two that were operating.

After adjusting the superheat value on Circuit 1 Chiller 1 and given the nominal TD of 5.5K and cooling capacity of 25.46kw for the circuit, the pro rata duty before and after intervention was calculated to be 7.87kW* (Compressor EER 0.95) and 23.61kW (Compressor EER 2.75), and by the same reasoning the cooling output of Circuit 1 Chiller 2 would be 4.63kW (Compressor EER 0.62).

On arrival, therefore, only 12.5kW of the total installed capacity of 101.84kW was available and afterwards 28.24kW.

Furthermore, the condenser fans associated with the compressors that are enabled by the controller but are not operating are running continuously because of pressure switch setting issues.

(*a capacity reduction of 66.66%)

Report #: AT14
Ceiling Suspended Single Split air conditioning unit
Austria

Installed capacity

The installed 12.5kW nominal cooling capacity (345 W/m^2) would be considered grossly oversized for this meeting room for which we have estimated a total maximum heat gain of 3.05kW (84.18 W/m^2) - a correctly sized unit would consume less input power by dint of smaller indoor fan and the reduction in motor/compressor starts per hour. Furthermore, the use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load, especially if the full capacity of 12.5kW was required for contingency plans regarding possible change of room use with high internal gains, for instance.

The installed units have a nominal COP of 2.41 @ 35^{o}C as found in the manufacturer's literature; it is possible for modern systems of a similar type and design have a COP of 3.35 and over @ 35^{o}C as found on the Eurovent website. This would lead to a 36.7% improvement over the existing installed unit. The use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load.

Maintenance

The units appear to be outwardly well maintained, considering their one visit per annum, although the filters weren't inspected owing to high level access problems. There were no visual signs of refrigerant leakage; and the condensers have adequate access free air but are affected by hot air recirculation from the adjacent condensing unit discharge fans discharging into the surrounding louvers.

Operation

Using the information gathered in the verification inspection there would appear to be some issues with the refrigeration circuit indicated in the suction pressure, discharge pressure, compressor compression ratio, superheat and sub-cooling values recorded which would require further inspection by the incumbent maintenance company to identify the exact cause, although because of the low suction pressure, high superheat, low sub cooling and low electrical input it's showing signs of a shortage of refrigerant, although the low discharge superheat of 17.65K is contradictory.

Efficiency

The operating pressure, temperature and energy input values suggest a reduction in unit efficiency but without access to the indoor units it was not possible to be precise.

Control

The unit operates within the time schedule regardless of occupation.

Report #: AT15
Ceiling Suspended Single Split air conditioning unit
Austria

The installed 10kW nominal cooling capacity (354.8 W/m^2) would be considered oversized for this room, for which we have estimated a total maximum heat gain of 4.37kW (155W/$m^{2.}$) Although, using the ASHRAE rule of thumb of 248W/m^2 as a typical normalisation value for a laboratory environment, 6.99kW would be required which, at 69.9% of the installed capacity, is way outside of a typical 20% margin of error.

A correctly sized unit would consume less input power by dint of smaller indoor fan and the reduction in motor/compressor starts per hour. Furthermore, the use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load, more so if the full capacity of 10kW was required for contingency plans regarding possible change of room use with high internal gains, for instance.

The installed units have a nominal EER of 2.56 @ 35°C as found in the manufacturer's literature; it is possible for modern systems of a similar type and design have a COP of 3.22 and over @ 35°C as found on the Eurovent website. This would lead to a 38.4% improvement over the existing installed unit. The use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load.

Maintenance

The units appear to be outwardly well maintained, considering their one visit per annum, although the filters weren't inspected owing to high level access problems. There were no visual signs of refrigerant leakage; and the condensers have adequate access free air but are affected by hot air recirculation from the adjacent condensing unit discharge fans discharging into the surrounding louvers.

From the information gathered in the verification inspection the system appears to be operating satisfactorily other than the high discharge temperature of 91.4°C causing a high superheat.

A further diagnostic inspection by incumbent service provider is recommended, as the discharge pressure, compressor compression ratio, superheat and sub-cooling values recorded which would require the incumbent maintenance company to identify the exact cause, although because of the low suction pressure, high superheat, low sub cooling and low electrical input it's showing signs of a shortage of refrigerant, although the low discharge superheat of 17.65K is contradictory.

Efficiency

The operating pressure, temperature and energy input values suggest a reduction in unit efficiency but without access to the indoor units it was not possible to be precise.

Using the manufacturer's EER for 35°C ambient we have determined from the recorded input a cooling capacity of 8.6kW which would have been nearer to the nominal cooling capacity of 10kW had we been able to use a more realistic EER relative to the lower operating conditions

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Control

The unit operates within the time schedule regardless of occupation.

Monitoring

The voltages and amperages of the unit are being monitored; however, the latter showing values of around three times that on the nameplate and as found during the inspection, could be wrongly interpreted as high energy use.

Report # : AT16
Ceiling Suspended Single Split air conditioning unit
Austria

Installed capacity

The installed 10kW nominal cooling capacity (163.55 W/m^2) would be considered reasonable for this room, for which we have estimated a total maximum heat gain of 5.06kW (83W/m$^{2.}$), which at 50.6% of the installed capacity.

Although, using the ASHRAE rule of thumb of 248W/m^2 as a typical normalisation value for a laboratory environment, 15.16kW would be required which, at 151.6% of the installed capacity would suggest that the room is not designed for 100% laboratory use.

Maintenance

Although receiving only one visit per annum the units appear to be well maintained in general with no visual signs of refrigerant leakage. The condensers have adequate access free air but are affected by hot air recirculation from the adjacent condensing unit discharge fans discharging into the surrounding louvers.

Operation and Control

The system is set to operate 24/7 at a reasonable 23^{o}C and operating satisfactorily to typical industry parameters.

Efficiency

A correctly sized unit would consume less input power by dint of smaller indoor fan and the reduction in motor/compressor starts per hour. Furthermore, the use of an inverter controlled compressor in the modern unit would also increase the system efficiency by matching the cooling output to the room load, more so if the full capacity of 10kW was required for contingency plans regarding possible change of room use with high internal gains, for instance.

Using the manufacturer's EER for 35^{o}C ambient we have determined from the recorded input a cooling capacity of 8.19kW which would have been nearer to the nominal cooling capacity of 10kW had we been able to use a more realistic EER relative to the lower operating conditions

Monitoring

The voltages and amperages of the unit are being monitored; however, the latter showing values of around three times that on the nameplate and as found during the inspection, could be wrongly interpreted as high energy use.

Report #: BE1
Liquid Chiller
Research Building
Arlon, Belgium

Installed capacity

There is total installed water cooled water chillers' nominal cooling capacity of 150kW (103.8W/m^2) although we have re-calculated this to 143.17kW (101.37W/m^2), in respect of the chillers having been modified, from the outset, with the inclusion of a dual circuit air cooled condenser and condenser pressure regulating valve with which to optimise the condensing pressure in order to maintain higher than normal condensing temperatures for a water cooled condenser - to enable heat recovery by the building hot water system.

Maintenance

Maintenance is carried out regularly and response to any alarms by in-house personnel and by a specialist contractor for the chillers

Operation, Control and Monitoring

The BEMS control system controls both heating and cooling functions - single liquid chiller being enabled on cooling demand between 08:00 and 18:00 Monday to Friday,

The second chiller is enabled when the ambient temperature is above 24°C, whilst the secondary pumps operate constantly at high speed during these normal operating hours.

Outside of these hours night time cooling operates on a single liquid chiller to maintain relaxed conditions between 23°C and 24°C, the secondary pumps are operated at low speed.

AHU CP1 supplies FCUs on the south side of the "A" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct.

AHU CP3 supplies laboratories on the north side of the "A" building and is a full fresh air system, working in conjunction with the GE extract fan to maintain a negative pressure and the required air changes within the laboratories.

AHU CP2 supplies FCUs in "B" building and balances the proportion of re-circulated and fresh air supplied, depending on CO_2 levels in the return air duct.

Air from the relevant AHUs is supplied the local terminal fan coil units at 23°C, mixing with the discharge air.

The FCUs have a pre-set room set-point of 23°C (return air temperature) which can be adjusted by +/- 3 degrees using an adjacent controller.

Fault conditions are detected by the BEMS system which alerts the building manager and the maintenance engineer by e-mail.

The liquid chillers are furnished with a single semi-hermetic, reciprocating motor/compressor, each of which have two offloading solenoid valves, giving three capacity stages, controlled by three stages of a four stage electro/mechanical thermostat, of 33%, 66%, and 100% and overall, six stages from the two chillers, of 17%, 34%, 51%, 68%, 84%, and 100%. Each compressor is also equipped with an unloaded start valve, greatly reducing the starting current.

The water cooled packaged liquid chillers are also connected to remote external air cooled condensers. The water shell and tube condenser (described as a 'Winter Condenser) has

interconnecting pipe-work with a hot water cylinder, within the plant room, where it apparently pre-heats the main LPHW water buffer tank, recovering heat from the high temperature refrigerant. Once the optimum cylinder temperature is reached, the refrigerant is diverted to the remote air cooled condenser. This function appears, although it's not certain, to have been withdrawn during the renewal of the control/BMS protocol.

Condenser pressure control is carried out using a condenser pressure regulator, to maintain a pre-set value, within the condenser with all of the fans operating, and at full speed.

Efficiency

There would be a 4.6% reduction in straight chiller efficiency operating in air cooled condenser mode rather than water cooled, but when making the comparison with the condenser fans operating, with the former, and the pump with the latter, there would be a 6.6% reduction.

This reduction in efficiency would have been off-set by the benefits of heat recovery feature of the system, which we understand is no longer used. Should this be the case the condensing pressures could be reset to 'normal' by adjustments to the regulating valve and by controlling the condenser fans appropriately.

The chillers are furnished with a single semi-hermetic, reciprocating motor/compressor, each of which have two offloading solenoid valves, giving three capacity stages, controlled by three stages of a four stage electro/mechanical thermostat, of 33%, 66%, and 100% and overall, six stages from the two chillers, of 17%, 34%, 51%, 68%, 84%, and 100%.

Each compressor is also equipped with an unloaded start valve, greatly reducing the starting current.

There are proposals for a single replacement air cooled packaged chiller which has a 15.84% superior energy efficiency rating at peak demand, but as, at part load, the input power of the reciprocating compressors of the existing chillers, would reduce proportionally, there would be an increased efficiency of the chillers in respect of the increased evaporating temperature and the lower condensing temperature; and therefore, by comparison with the 'loss' of four capacity stages, a single chiller with only two compressors operating at 100%, on or off, the benefit of its superior EER would be diminished – the likelihood of there being no net gain.

Report # BE2
Air cooled liquid chiller with re-circulated AHUs
Brussels, Belgium

Installed capacity

809.4kW (454.45W/m^2)

The systems of interest serve the studio area of the theatre with a calculated total room heat load of 392.1kW for Studios 2 & 3 combined, based on a 883 seating layout (small stage), and 128.61kW based on a 883 seating layout (large stage).

Studio 1 has a total room heat load of 46.49kW.

The combined floor area for Studios 2 & 3 is 1440m^2 and 341.04m^2 for Studio 1.

The areas are cooled by two air cooled liquid chillers each having a nominal cooling capacity of 404.7kW, via the three air handling units with chilled water coils.

AHU 6 supplying the control room is permanently disabled from the BMS, the room being independently cooled by a later installed split DX system to avoid treating the relatively small load with a relatively large AHU and chiller capacity when no other cooling is required in the case of the later.

It should also be noted that facilities, i.e. a plinth between the installed chillers and pipe work connections to the chilled water header etc, for a third chiller to be installed, or more likely, had intended to be installed, by reasoning of the current numbering i.e. Chiller 1 and Chiller 3, but deemed not required during installation.

Maintenance

A specialist contractor carries out one major and one minor maintenance visit annually when F-gas checks are also carried out, as well as every two weeks to checking the condition of the fan belts and filters, which are replaced as and when required.

Operation, Control and Monitoring

Chilled water is supplied to a low loss header, with secondary circulation pumps to distribute the chilled water to four AHUs, namely 1, 2, 3 and 6, although other units were installed to the original design but are now redundant.

Each AHU consists of a fan coil arrangement supplying full fresh air, re-circulated air or a combination of both. The air is passed through pre-coil panel filters before being conditioned if required. The conditioned air is then discharged back into the studio. If the internal set point is not being met the BEMS will automatically adjust the dampers to increase the amount of re-circulated air used until either set-point or until plenum mode with minimum fresh air is achieved. There are also three AHUs which have no chilled water cooling facility - AHU 11, a full fresh air with heat recovery unit, serving the offices which was operating, AHU 12, a full fresh air unit serving the indoor corridor and cafeteria, and AHU 13, a fresh air with heat recovery unit, serving the administration department, both of which were switched off.

There is no timing schedule - the AHUs being manually enabled when required. At the time of inspection the chillers were seasonally switched off.

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Efficiency

The installed Total fan input power for AHUs 1, 2 and 3 in High speed mode at 43.5kW or 24.42W/m^2 is extremely high when compared to CIBSEs UK typical benchmark of 8 to 12W/m^2 for air conditioned buildings, although the Specific Fan Power of AHUs 1, 2 and 3 at 1.37kW/m^3/s is well below the benchmark minimum of 1.8kW/m^3/s; whilst the value

In Low speed mode of 13.5kW or 7.58W/m^2 complies and is an indication that Low speed is the 'normal' mode. Although the Specific Fan Power of AHUs 1, 2 and 3 = 1.37kW/m^3/s

The Specific Fan Power of AHU 6 is high at 3.36kW/m^3/s, but it is not being used.

The total pump installed input power for Chillers 1 and 3 (Primary pumps), and AHUs 1, 2 and 3 (Secondary pumps) of 11.5kW or 6.46W/m^2, is extremely high when compared to CIBSEs UK typical benchmark of between 1.8 to 3.4W/m^2 for air conditioned buildings.

The chillers' EER of 2.93 would be typical for air cooled chillers but not as high as Eurovent's class 'A'.

There is good reason to believe if the control protocol was reassessed and the correct size cooling coils were found to be fitted then savings of **50% for the chillers and 69% for the fans** could be achieved**.**

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Report #: BE2
Air cooled liquid chiller with re-circulated AHUs
Brussels, Belgium

Installed capacity

809.4kW (454.45W/m^2)

The systems of interest serve the studio area of the theatre with a calculated total room heat load of 392.1kW for Studios 2 & 3 combined, based on a 883 seating layout (small stage), and 128.61kW based on a 883 seating layout (large stage).

Studio 1 has a total room heat load of 46.49kW.

The combined floor area for Studios 2 & 3 is 1440m^2 and 341.04m^2 for Studio 1.

The areas are cooled by two air cooled liquid chillers each having a nominal cooling capacity of 404.7kW, via the three air handling units with chilled water coils.

AHU 6 supplying the control room is permanently disabled from the BMS, the room being independently cooled by a later installed split DX system to avoid treating the relatively small load with a relatively large AHU and chiller capacity when no other cooling is required in the case of the later.

It should also be noted that facilities, i.e. a plinth between the installed chillers and pipe work connections to the chilled water header etc, for a third chiller to be installed, or more likely, had intended to be installed, by reasoning of the current numbering i.e. Chiller 1 and Chiller 3, but deemed not required during installation.

Maintenance

A specialist contractor carries out one major and one minor maintenance visit annually when F-gas checks are also carried out, as well as every two weeks to checking the condition of the fan belts and filters, which are replaced as and when required.

Operation, Control and Monitoring

Chilled water is supplied to a low loss header, with secondary circulation pumps to distribute the chilled water to four AHUs, namely 1, 2, 3 and 6, although other units were installed to the original design but are now redundant.

Each AHU consists of a fan coil arrangement supplying full fresh air, re-circulated air or a combination of both. The air is passed through pre-coil panel filters before being conditioned if required. The conditioned air is then discharged back into the studio. If the internal set point is not being met the BEMS will automatically adjust the dampers to increase the amount of re-circulated air used until either set-point or until plenum mode with minimum fresh air is achieved. There are also three AHUs which have no chilled water cooling facility - AHU 11, a full fresh air with heat recovery unit, serving the offices which was operating, AHU 12, a full fresh air unit serving the indoor corridor and cafeteria, and AHU 13, a fresh air with heat recovery unit, serving the administration department, both of which were switched off.

There is no timing schedule - the AHUs being manually enabled when required. At the time of inspection the chillers were seasonally switched off.

Efficiency

The installed Total fan input power for AHUs 1, 2 and 3 in High speed mode at 43.5kW or 24.42W/m^2 is extremely high when compared to CIBSEs UK typical benchmark of 8 to 12W/m^2 for air conditioned

buildings, although the Specific Fan Power of AHUs 1, 2 and 3 at 1.37kW/m^3/s is well below the benchmark minimum of 1.8kW/m^3/s; whilst the value in Low speed mode of 13.5kW or 7.58W/m^2 complies and is an indication that Low speed is the 'normal' mode. Although the Specific Fan Power of AHUs 1, 2 and 3 = 1.37kW/m^3/s the Specific Fan Power of AHU 6 is high at 3.36kW/m^3/s, but it is not being used.

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Report #: BE3
DX Split, IT Room
Research Building
Arlon, Belgium

Installed capacity

The installed cooling capacity of 13.4kW, 411W/m^2, is reasonable for this type of application even though the peak heat gain is only 113.8W/m^2 as the inverter compressor would ensure the system operated at the desired capacity.

Maintenance

Maintenance is carried out regularly and response to any alarms by in-house personnel and by a specialist contractor for the chillers

Operation, Control and Monitoring

The twin-split DX system in the IT server room is independent from the BEMS system and is set to operate continuously at 21^{o}C in cooling mode, using its own microprocessor controller and inbuilt return air sensors.

Efficiency

With an excellent EER of 3.31 the system has been given a Eurovent Class 'A' energy efficiency rating.

The Specific Fan Power of 0.14 is low compared to CIBSE's Guide 'F' general benchmark of 0.2 for local ventilation which also shows that the Total installed fan power of 1.41W/m^2 is also low compared to the Guide's 8 – 12W/m^2 for general buildings.

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Report #: BE4
Liquid chiller and Geothermal system
Belgium

Installed capacity

The air cooled liquid chiller has a nominal cooling capacity of 429.6kW (54.57W/m^2) with a total nominal input power of 152.3kW creating an EER of 2.79, delivers 7^{o}C chilled water to 240 fan assisted under-floor 'convector' units (147.7kW), wall mount fan coils units on the ground floor (estimated 26kW), three tempered fresh air handling units (252kW) and a 170kW plate heat exchanger maintaining the water temperature to a minimum of 17^{o}C to the embedded coils in the thermally active concrete ceilings when the 'free' cooling from the borehole is not available.

The total air side cooling capacity 425.7kW matches the capacity of 430kW for the chiller enabling the mechanical cooling to handle the peak heat gain of 394.86kW alone i.e. should the borehole water temperature be too high.

At peak heat gain conditions 252kW would be taken up by the AHUs providing tempered air at 20^{o}C which would leave 178kW of the 340kW air cooled chiller capacity available for the building cooling load, of 394.86kW leaving 216.86kW to be provided between the chiller and the field.
If the field is able to provide 170kW of cooling then the 34kW difference can easily be met by the chiller.
If the field is unable to provide cooling then there would be a short fall of 216.86 – 173.4 = 43.46kW that the fan coil units would be able to provide.
Time of day diversity would obviously be a factor but it does appear that because of the exactness of the installed capacity the likely-hood of a floating set point during high ambient conditions could not be ruled out.
It should be noted, however, that the domestic heat recovery chiller can potentially deliver 53.2kW of cooling to the geothermal field when producing its nominal capacity of around 70kW of hot water.
Also, during cooling mode the Heating water heat recovery chillers would not be operating and as such would not contribute to any temperature depression of the geothermal field.

Operation, control and monitoring

During the time of inspection the air liquid chiller was not operating as the system was in heating mode.

The thermally active concrete ceiling, the main source of heating and cooling, takes forty eight hours to fully change mode and neither can it be turned off or controlled zone-wise, so, during this time, localized cooling demand is satisfied by the underfloor units operating in a conflicting mode, although the user is aware of it and plans to address it during the summer of 2014.

Efficiency

The total installed fan power of 43.26kW at 5.5W/m^2 (Treated Floor Area) is considerably lower than CIBSE's Guide 'F' UK minimum energy performance guideline of 8 -8 W/m^2 therefore showing very good efficiency.

The total installed pump capacity of 9.39kW at 1.19W/m^2 (Treated Floor Area) is considerably lower than CIBSE's Guide 'F' UK minimum energy performance guideline of 1.8W/m^2 for new buildings and therefore showing very good efficiency.

The peak heat gain of 54.6W/m^2 is very moderate when compared to BSRIA's *Rules of Thumb 5th Edition* UK guideline for offices of 87W/m^2.

According to the UK's The Carbon Trust's *Heat recovery - A guide to key systems and applications*, *Technology guide*, Thermal wheel efficiency is typically 65%-75% so, as there were no underlying factors that could affect the performance of the installed Thermal wheel heat recovery systems the recorded values for AHU 1, AHU 2 and AHU3 of 58%, 55%, and 55% respectively must be considered less than satisfactory.

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Report #: BE5
Liquid chiller with heat recovery AHU
Luxembourg

Installed Capacity

The treated floor area is cooled by a water cooled liquid chiller having a nominal cooling capacity of 472kW at (132W/m^2) and a total nominal input capacity of 98kW.

There is also an essential services 75kW cooling capacity standby/backup water cooled chiller with a 15 kW input creating an EER of 5 which gives an energy efficiency classification of class B

Operation, control and monitoring

The ammonia chiller was enabled for the inspection but due to low cooling load conditions sufficiently steady conditions could not be achieved with which meaningful assessments as to it efficiency could be made and furthermore our inspectors did not have the appropriate competency qualification for working on ammonia equipment.

Maintenance

Maintenance is carried out by in-house personnel on a monthly basis - although the filters are cleaned every three months and replaced as and when required.

Efficiency

An EER of 4.81 for the water main chiller if verified would attract a very good efficiency classification, 'B', as does the back-up chiller.

The total installed chilled water pumps input power in normal cooling mode of 6.9kW would equate to around 8.0kW installed capacity or 2.23W/m^2 Treated Floor Area which shows good efficiency compared to CIBSE's UK Guide 'F' energy performance benchmark of 3.1 to 3.4W/m^2 for refurbishments, but not with their guidance of 1.8.to 2.0W/m^2 for new buildings.

The installed full load for Main Supply and Extract AHUs and fan input power of 19.5kW equates to 5.44W/m^2 is considerably lower than UK's CIBSE energy efficiency of 8 to 12W/m^2 and therefore showing very good efficiency as does the thermal wheel heat recovery at 64%.

The full fresh air AHU serving the offices which includes a water spray section used for humidification, and a thermal wheel for heat recovery would ensure good Indoor air quality without compromising efficiency – similarly, the exhaust air from the building being used to ventilate the car park does not adversely affect its efficiency.

Report #: UK1
Computer Server Room with Split DX Units
Cardiff, UK

Installed capacity

There is an installed cooling capacity of 2192W/m^2 (N+3) which suggests higher computer loads were expected – 1500W/m^2 would not be unusual in a high density IT room, and in which case a cooling capacity of 42.42kW (N+0.46) would be required.

With a total nominal electrical input of 24.72kW (877W/m^2) the EER would be 2.49.

The total install fan power of 4.56kW would at 162W/m^2, despite there being no guidelines or benchmarks for IT rooms, be considered high, as would the measured total fan power of 2.36kW (83.8W/m^2) which greatly exceeds, by comparison, CIBSE's UK general benchmark for air conditioned buildings of 8 to 12W/m^2 (TFA).

Maintenance

Maintenance checks are carried six monthly by specialist maintenance contractors.

Operation, Control and Monitoring

The LAN room is maintained at 22^{o}C by the four DX split terminal units, operating and controlled individually from each of their integral controllers' return air temperature sensors, and are independent of the BMS.

The evaporator fans and compressors are fixed speed, but the fan speed can be altered manually via a six position transformer control unit (variable voltage) which have been set to required airflow.

The outdoor air cooled condenser fans are variable speed and are automatically controlled to maintain the set refrigerant condensing temperature via proportional pressure controllers.

Some of the systems had operational indications of a shortage of refrigerant and although there were no visual signs of refrigerant leaks, PTFE tape on all eight liquid and discharge refrigerant pipes, of the four systems, would indicate a refrigerant leakage problem – although the use of PTFE tape in this manner is inappropriate as the threaded section of the plastic valve caps are not designed to effect a seal.

Plastic valve caps provide a secondary seal in the form of a 'O' gasket to the valve stem packing gland – they may not be even be designed to withstand any significant pressure and certain to be under stress thorough the packing of the tape; most now in fact have breather holes.

Efficiency

Although the nominal AHU EER is 2.49 we have shown a potential operational EER of 3.17, which should be classed as more than satisfactory for this type of activity.

However, the efficiency of this system as a whole is significantly compromised by refrigeration circuits being short of refrigerant and/or having poorly adjusted expansion valves, and by the poor room distribution within the room.

With Number 4 unit's compressor operating continuously to produce 7.17kW of cooling, a second unit compressor, operating at 100% efficiency of 15.4kW, would need to operate 53.24% of the time as well, to make up the 8.13kW shortfall. From this we can calculate the total power input at 6.0779kW, which compared to just one unit operating at 100% taking 4kW, for the same cooling load, represents an increase of 2.0779kW – **a 42.79% increase over total input. Annually there would be saving of 51667kWh.**

The total installed fan input power of 4.56kW would at 162W/m^2, despite there being no guidelines or benchmarks for IT rooms, be considered high, as would the measured total fan input power of 2.36kW (83.8W/m^2) which greatly exceeds, by comparison, CIBSE's UK general benchmark for air conditioned buildings of 8 to 12W/m2 (TFA), and therefore must be considered inefficient.

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Report #: UK2
Chilled water HVAC system
Cardiff, UK

Installed capacity

Combining the installed chiller nominal capacity of 950kW (165.39W/m^2) and the Archives DX system of 11.1kW (111W/m^2) there is a total installed cooling capacity of 961.1kW (164.46 W/m^2), which equates to N+2.5, although there is no stand by capacity. One of the single chiller's three compressors, with a nominal cooling capacity of 316.7kW (55,2W/m^2), would only need to operate at 87.5% full load to produce the 270kW required for the peak cooling demand.

However, in respect of the 25% by Volume (27% by weight) ethylene glycol in the chilled water, we have adjusted the chiller cooling capacity to 925.3kW (158.3W/m^2 Treated Floor Area) – the single compressor reducing to 308.43kW would need to operate at 89.9%, achieved by cylinder unloading, to achieve the peak cooling demand, and significantly less for most of the time.

Operation, control and monitoring.

The chillers are shut down outside the cooling season. The nominal flow and return temperatures are 7^{o}C and 9^{o}C respectively. The Primary Circuit and circuit serving the VAV AHUs are constant temperature, constant flow circuits. The pumps operate according to an optimised start and stop.
Controlled by the BMS the air handling fans operate continuously throughout the occupation hours whilst the chiller is enabled as necessary in occupation hours during the cooling season.

Maintenance

The chiller appear to be well maintained in general with no visual signs of refrigerant leakage – twice annual checks being carried out under a maintenance contractor with a specialist contractor the air handling and water loop systems being maintained regularly by in house personnel
The condensers have adequate access free air and are not affected by any hot air recirculation from the adjacent condenser discharge fans

Efficiency

Installed pump capacity: 29.4kW equates to 5W/m^2 Treated Floor Area which higher than CIBSE's benchmark of 3.1 to 3.4W/m^2 for old buildings, which for the latter would represent a **saving of 32%,** if implemented i.e. if the installed chiller was placed with a smaller chiller.

The CIBSE Benchmark would suggest suitable pump capacity of 17.8kW to 19.53kW.

Although the Specific Fan Power of 3.17 is only slightly above CIBSEs Energy Performance Benchmark of 3 the total installed fan power of 104kW equates to 18.1W/m^2 Treated Floor Area which is higher than the CIBSE's Guide 2004 'F' benchmark of 8 to 12W/m^2, which for the latter would represent a **saving of 33.7%,** if implemented.

The CIBSE Benchmark would suggest suitable fan power of 46.75kW to 70kW**.**

With one compressor operating to maintain peak load of 277.25kW there would be a total input, including fans and pumps of 180.73kW – producing a system EER of 1.53.

The chiller EER could be **improved by38.76%** if it was replaced with a modern one.

At 47Wm^2, the heat gain for the building would be regarded as very low, which can be attributed to the low density of occupancy (14.6m^2/person), the low internal heat gain from equipment and the significant effect the solar shading, hence the user is able to manually (via the BMS) switch the chiller and pumps off until they are genuinely needed.

In the absence of any energy efficiency benchmarks for systems providing the archive conditions it's suffice to say the installed system would be highly energy dependent, although no monitoring or spot checks were made at the time of the inspection, and that it would be prudent for the user to contemplate a re-assessment of its size/suitability.

The heat recovery run around coil loop is showing an efficiency of 46 %, which is commiserate with the UK's Carbon Trust's guidance of 45 – 55%.

Report: #UK3
VAV unit with Dual Duct system
Cardiff
UK

Installed capacity

The current installed chilled water cooling capacity of 157kW (114.5W/m^2) appears reasonable for this type of mixed use, very low window to wall ratio building where the Great Hall requires an estimated 96kW (245W/m^2), the lecture Theatre 16kW (157W/m^2) and Lecture room 8.16kW (84 W/m^2) of cooling capacity.

There is one primary and two secondary chilled water pumps with an installed input power of 1.41kW which would relate to an approximate output power of 1.12kW.

The fan serving the Great Hall has a measured/calculated output of 4.68kW and the Dual Duct fan 2.49kW.

Maintenance

Maintenance checks are carried six monthly by in-house maintenance staff and a specialist contractor for the cold generation equipment, who also carries out F–Gas Regulation checks.

Filters were all replaced October 2012.

Although it was found that the duct insulation is hanging off in places and needs attention, the Filter access doors are poorly fitted and leaking air.

Also, the Primary pump motor has been replaced to a different model which is causing a problem resulting in the duct insulation obstructing the motor cooling fan.

Operation, control and monitoring.

Cooling

The chiller is enabled via the BMS when the indoor temperature exceeds 24^{o}C and the ambient temperature exceeds 27^{o}C, although the chiller can also be manually enabled from the BMS if there is a specific demand for cooling on request. The chilled water circuits are constant temperature, constant flow circuits. The VAV heat exchanger pumps operate continuously, and the Dual Duct system pumps operate during the hours of operation of the dual duct system.

Great Hall

Operating periods for great hall are 24 hours with set points of 19^{o}C and 50%RH. RH sensors are located adjacent to the return air grilles in the hall with other BMS sensors located in the return air duct. As there is little load in the great hall during “normal” hours a proportion of the return air is then fed into the supply air of the lecture theatres along with ambient fresh air via dampers before the cooling (DX) or heating coils within the ductwork supplying the lecture theatres to take advantage of the already conditioned air.

The fans for the great hall normally run at a minimum of 70% during normal hours, this minimum is dropped to 50% out of hours but the fans can speed up if room conditions cannot be met.

The system generally operates at ‘relaxed conditions’ and reacts to the requirements for around 500 people during concerts.

The humidifier is currently out of use due to a “do not use” isolation from a gas inspection dated January 2013

System is full fresh air but does have the capacity for limited recirculation

Dual Duct

The dual duct system operates during opening hours only. The air in each duct is supplied at the design temperature for that duct. In each room there is a mixing box which blends the air arriving at two different temperatures to meet the room's individual set point.

System is full fresh air and supplied via a single fan and duct which splits just before the heating and cooling coils

Lecture theatres

The lecture rooms are supplied using a combination of fresh air and the exhaust air from the great hall, the bms system uses dampers to modulate the amount of great hall exhaust air and fresh air that is supplied into this system depending on both ambient and great hall conditions. The cooling is supplied from a chilled water coil recently installed into the ductwork which is supplied from the liquid chiller. The original Airedale units are no longer in use and in poor condition and have been turned off on the supply isolators, although they contain enough refrigerant to still require leak testing annually under the ODS regulations. The original DX coils are still located in the ductwork.

Efficiency

The installed chilled water pump input power of 1.03W/m^2 (Treated Floor Area), although the measured input was 1.33 W/m^2, would be considered low, and therefore very energy efficient, compared to the CIBSE benchmark for new 'Standard' buildings; as is the 6.96W/m^2 for the total fan power input, compared to CIBSE's Energy Efficiency Guide 19 of 8 to 12W/m^2 for 'Standard Buildings'.

The total fan input of 10.25kW or 6.96W/m^2 (Treated Floor Area), compared to CIBSE's Energy Efficiency Guide 19 of 8 to 12W/m^2 for 'Standard Buildings', shows good efficiency.

The current and voltage imbalance of the system components were within the recommended 10% although some were higher than others.

The operation of one of the chiller compressor circuits was analysed and shown to be satisfactory although some of the parameters were not as predicted owing to a suspected lack of water flow.

Report: #UK04
Packaged chillers and water cooled computer cabinets
Cardiff, UK

Installed Capacity

The original system consisted of three chillers with a total of 366.9kW (2409W/m^2) of cooling @30^{o}C ambient and 7^{o}C leaving water temperature; and because either an original estimate of installed IT electrical load was deemed to be 500kW (potentially 350kW to 500kW heat gain), or in respect of future expansion, one of the Airedale chillers was replaced with a Geoclima Turbocor chiller with a nominal cooling capacity of 300 kW.

The Airedale chillers are rated for use with 20% Ethylene Glycol but the Geoclima Chiller would be de-rated by a manufacture's correction factor of 0.963 to 288.9kW, giving a current total cooling capacity of 533.5kW (3503W/m^2).

However, from the annual kW/hrs IT equipment usage from a previous report, it can be calculated that the hourly use is 113kW which given typical input power to heat gain ratios of 70 to 100% from the equipment, would represent 79kW (519W/m) to 113kW (742W/m^2), which compares favourably with our present estimate of 123.72kW (812W/m^2) for total heat gain; and which effectively could be maintained by just one of the Airedale chillers.

It can be seen, therefore, that there appears to be more than sufficient capacity for future expansion and stand by purposes.

Maintenance

There was a significant amount of oil contamination on the motor/compressors of Chiller N^o 1 and adjacent pipe-work suggesting a significant loss of refrigerant, which was borne out by dint of the chiller being non-operational because of the operation of a safety circuit.

Maintaining the correct charge of refrigerant has **shown to save an average of 29.7%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

The problems found would indicate that the maintenance regime of two visits per annum is either insufficient (e.g. all of the condenser coils were dirty to some extent) or the maintenance undertaken needs to be reassessed. Certainly, it is usual for such critical use equipment to have a much more stringent regime – not only to maintain the integrity of the system but also to improve its reliability and hence the users confidence, sufficiently to enable load shedding of unnecessary units.

Needless to say, maintenance tasks employed should augment the possibilities of energy conservation opportunities.
Maintaining the correct condensing air temperatures and preventing warm air recirculation has shown to **save an average of 7.65%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Control

Both chillers N^{o}1 and N^{o}2 have a free cooling facility which is initiated wherever the outdoor ambient is 1K less than the return water temperature - mechanical DX cooling is enabled after a timed duration if the chilled water temperature cannot be maintained. When free cooling and DX mechanical cooling are operating simultaneously the condenser fan speed will operate at 100% maximising free cooling. In lower ambient conditions where the free cooling coil is capable of satisfying the full cooling demand, the condenser fans are modulated to provide the desired duty. The condenser fans are capable of

being modulated between 25-100% of airflow to maintain the supply water temperature. During periods where the condenser fan speed has been reduced to a minimum, the supply water temperature will then be controlled by the three way valve.

During low compressor loads, reduced optimum condensing pressure, refrigerant flow and superheat are maintained by an Electronic Expansion Valve.

All three chillers are always in circuit, configured in parallel, in the chilled water loop, so that when the Airedale chillers are not operating the unprocessed return water flowing through them is mixing with the water leaving the Geoclima chiller, thus increasing the common supply water temperature above the individual leaving water set points.

Efficiency

During the inspection the Turbocor chiller was monitored with the Refrigeration System Performance Analyser, under steady state conditions, whilst maintaining conditions when operating at:

- 40% – from controller display and calculated at 115.56kW cooling capacity.
- With an input of 16.3kW – a compressor EER of 7.1, this is testament to its excellent low load efficiency.

However, this would be offset to a certain extent by the new larger chilled water pump, which although is connected to an inverter drive is configured to 100% operation, and had a spot measured input of 12.44kW input compared to the 5.48kW input (calculated from a previous report monthly usage). In fact the energy input before and after the new chiller and pump were installed are almost the same, with no reason to believe that the heat load had increased.
The HVAC *Effectiveness Factor* (IT Input/Air conditioning input)[Ref note1] of 2.165 before and 2.17 after refurbishment.
would be deemed good; although, because of the far better efficiency of the Geoclima Turbocor chiller, the equally good performance by the Airedale chillers would have been in respect of their use of free cooling.

Evidently, in view of the excellent efficiency of the Turbocor chiller at low load it has been set to be the lead chiller – in fact on arrival it was holding the conditions at 40% loaded, with one of the Airedale chillers operating only when the Turbocor chiller was manually switched off – at 122.3kW is testament to the accuracy room heat gain estimate of 123.72kW.

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Report #: UK5
IT Server Room with close control down flow package DX systems,
Cardiff, UK

Using the information gathered in the inspection and using an estimated room load of 19.57kW and a combined nominal cooling output of 63.9 kW and a nominal kW input of 19.2 KW for the installed system as a whole then it would be expected for the cooling to operate for 7 hours 22 minutes per 24 hours using 138.62kWh. When the calculated combined values from the inspection of 32.99 kW cooling output and a 16.39 kW input for the installed system as a whole were used it would then result in the cooling operating for an expected 14 hours 14 minutes per 24 hours to maintain room conditions using 285 kWh per 24 hours. If the nominal input and output for the system was achieved **an estimated saving of 2482 hours (28.65%) or 16071 kWh annually**.

Condenser Coils

Although the condenser coils looked to be in good condition on the initial visual inspection many were found to be blocked during verification, this would result in increased fan speed and a higher refrigerant condensing temperature lowering the system performance and efficiency.

Maintaining the correct condensing air temperatures and preventing warm air recirculation has shown to **save an average of 7.65%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Installed Capacity

An installed capacity of 1080 W/m^2 would be considered oversized for an IT machine room such as this, **and gives a 226% redundancy**. It should be considered to disable unit CCO3E and configure it to run as a backup unit if one of the other units goes into fault.

Cold generators

All of the DX refrigeration circuit's efficiencies would be compromised by virtue of the dirty filters and condensers whilst two of the three have operational problems, which, more than likely is owing to a shortage of refrigerant, although no obvious signs of leaks were observed.

Maintaining the correct charge of refrigerant has **shown to save an average of 29.7%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Cleaning or replacing filters regularly has shown to **save an average of 24.94%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Floor Grilles

The discharges grilles are not entirely well placed with the majority, although clustered around the area of highest heat load and the AHU with the best performance; not best placed for good air distribution and therefore maintaining optimum conditions in the aisles– particularly after the rectification of the problems associated with the other units.

Reducing the airflow to actual needs has **shown to save an average of 10%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Energy input v output

At the time of the verification inspection adverse weather conditions i.e. heavy rain, made it prudent not to use the refrigeration performance analyser – so, data-loggers were used for monitoring the amperages and voltages of the compressors and condenser fans but no operating pressures were recorded.
An assessment of the system's performance was made by comparing the calculated energy and the actual cooling capacity output from AHU air side enthalpy calculations, and the manufacturer's specification for nominal cooling.

Maintenance

The problems found would indicate that the maintenance regime of two visits per annum is either insufficient or the maintenance undertaken needs to be reassessed. Certainly, it is usual for such critical use equipment to have a much more stringent regime – not only to maintain the integrity of the system but also to improve its reliability and hence the users confidence, sufficiently to enable load shedding of unnecessary units.
Needless to say, maintenance tasks employed should augment the possibilities of energy conservation opportunities.

Control

Originally the air conditioning units were installed to maintain stringent temperature and humidity conditions but the need for close humidity control appears to have been made redundant as more resilient IT equipment has been installed. This is born out by the fact, that while there are still existing humidifiers in the older units, they have been electrically isolated, with later models having only a de-humidification function.

The IT equipment manufacturer's recommended humidity range is 40 to 80% RH whilst the controllers are set to the original, and typical, 50% (+ or- 5%). An increase in the RH set point would prevent unnecessary compressor, and subsequent electric re-heat, operation for de-humidification.

Also, modern IT equipment usually does not have a need for close control at a specific temperature, as indeed it doesn't in this instance – the manufacturer's specification being 10°C to 40°C as long as the rate of change does not exceed 10 °C per hour, as opposed to the old typical close control conditions of 21°C (+ or - °C).

The current set points of 20°C could be raised to at least 22°C as besides the obvious reduction on energy consumed through the reduced condensing unit operating time the efficiency of the compressor will be increased by 2 to 3% for every 1°C increase.

Although ideally from energy conservation point of view the temperature should raised to a level close to the maximum allowed, with a reasonable 'buffer zone' in case of catastrophic failure of the A/C plant, it should afford a reasonable level of comfort for operators within the room, with CIBSE Guide A, 2007 suggesting upper temperatures ranges of 24 to 25°C would normally be suitable in many occupied air conditioned environments during the Summer. Indeed Cardiff University proposes similar figures itself for its air-conditioned occupied zones.

Maintaining the correct system control setpoint has shown to **save an average of 8.44%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Maintaining the correct evaporating temperature has shown to **save an average of 4.43%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

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Report: #UK6
IT Server Room with close control down flow package DX systems,
Cardiff, UK

The Inspection concluded that the installed system was operating in a manner when the calculated combined values of 32.81kW cooling output and a 16.38 kW input for the installed system as a whole were used it would result in the cooling operating continually to maintain room conditions using 393.4 kWh per 24 hours. If the nominal input and output for the system was achieved an estimated **saving of 4197 hours (49.03%) or 63831.2 kWh annually**.

Condenser Coils

Although the condenser coils looked to be in good condition on the initial visual inspection many were found to be blocked during verification, this would result in increased fan speed and a higher refrigerant condensing temperature lowering the system performance and efficiency.

Maintaining the correct condensing air temperatures and preventing warm air recirculation has shown to **save an average of 7.65%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Installed Capacity

An installed capacity of 509 W/m^2 is not unreasonable for an IT machine room such as this and in this instance affords a 96% redundancy for stand by purposes and future increases of the IT load - both of which also provides justification for operating all three of the AHUs for zoning purposes especially when each have two stages of cooling.

Cold generators

All of the DX refrigeration circuit's efficiencies would be compromised by virtue of the dirty filters and condensers whilst two of the three have operational problems, which, more than likely is owing to a shortage of refrigerant, although no obvious signs of leaks were observed.

Maintaining the correct charge of refrigerant has **shown to save an average of 29.7%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Cleaning or replacing filters regularly has shown to **save an average of 24.94%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Floor Grilles

The discharges grilles are not entirely well placed with the majority, although clustered around the area of highest heat load and the AHU with the best performance; not best placed for good air distribution and therefore maintaining optimum conditions in the aisles– particularly after the rectification of the problems associated with the other units.

Reducing the airflow to actual needs has **shown to save an average of 10%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Energy input v output

At the time of the verification inspection adverse weather conditions i.e. heavy rain, made it prudent not to use the refrigeration performance analyser – so, data-loggers were used for monitoring the

amperages and voltages of the compressors and condenser fans but no operating pressures were recorded.
An assessment of the system's performance was made by comparing the calculated energy and the actual cooling capacity output from AHU air side enthalpy calculations, and the manufacturer's specification for nominal cooling.

Maintenance

The problems found would indicate that the maintenance regime of two visits per annum is either insufficient or the maintenance undertaken needs to be reassessed. Certainly, it is usual for such critical use equipment to have a much more stringent regime – not only to maintain the integrity of the system but also to improve its reliability and hence the users confidence, sufficiently to enable load shedding of unnecessary units.
Needless to say, maintenance tasks employed should augment the possibilities of energy conservation opportunities.

Control

Originally the air conditioning units were installed to maintain stringent temperature and humidity conditions but the need for close humidity control appears to have been made redundant as more resilient IT equipment has been installed. This is born out by the fact, that while there are still existing humidifiers in the older units, they have been electrically isolated, with later models having only a de-humidification function.

The IT equipment manufacturer's recommended humidity range is 40 to 80% RH whilst the controllers are set to the original, and typical, 50% (+ or- 5%). An increase in the RH set point would prevent unnecessary compressor, and subsequent electric re-heat, operation for de-humidification.

Also, modern IT equipment usually does not have a need for close control at a specific temperature, as indeed it doesn't in this instance – the manufacturer's specification being 10°C to 40°C as long as the rate of change does not exceed 10 °C per hour, as opposed to the old typical close control conditions of 21°C (+ or - 1°C).

The current set points of 20°C could be raised to at least 22°C as besides the obvious reduction on energy consumed through the reduced condensing unit operating time the efficiency of the compressor will be increased by 2 to 3% for every 1°C increase.

Although ideally from energy conservation point of view the temperature should raised to a level close to the maximum allowed, with a reasonable 'buffer zone' in case of catastrophic failure of the A/C plant, it should afford a reasonable level of comfort for operators within the room, with CIBSE Guide A, 2007 suggesting upper temperatures ranges of 24 to 25°C would normally be suitable in many occupied air conditioned environments during the Summer. Indeed Cardiff University proposes similar figures itself for its air-conditioned occupied zone.

Maintaining the correct system control setpoint has shown to **save an average of 8.44%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Maintaining the correct evaporating temperature has shown to **save an average of 4.43%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Report #: UK7
Air cooled chillers and AHUs
Cardiff, UK

Installed capacity

The inspected system has a total chiller installed nominal cooling capacity of 600kW (198W/m^2) for a nominal capacity for the installed AHUs, of 959.9kW (316.8W/m^2).

The current two Geoclima Turbocor chiller replaced the original McQuay Screw chillers with a total cooling capacity of 2228kW – each capable of providing 367.66W/m^2 (Treated Floor Area) which proved to be excessive (HARMONAC Case Study UK7) and leading to inefficiencies, even though they had been sized with high air changes in mind.

However, in respect of the 15% by Volume (16.25% by weight) ethylene glycol in the chilled water, we have adjusted these values to 592.5kW (195.5W/m^2 Treated Floor Area) and 948kW (312.8W/m^2) respectfully, although we have also recalculated the AHUs' capacity, using the iSERV AC Estimator Spread sheet, to 573kW (189W/m^2) in respect of their inverter settings, to 566kW (186.7W/m^2) with glycol, which is compatible with the installed chiller cooling capacity.

The chiller EER is 3.25.

Maintenance

Maintenance checks are carried six monthly by in-house maintenance staff and a specialist contractor for the cold generation equipment, who also carries out F–Gas Regulation checks.

Operation, control and monitoring

The temperature and humidity room set points are set individually via the BMS. Humidity control is centralised but temperature can be adjusted separately, within set limits, in each room.

Although, mechanically disconnected, there is a steam humidifier dedicated to each AHU.

The building is occupied between 08:00 and 17:30.

Efficiency

Chiller EERs of 11.3 and 10.4 for 65.5% and 73% of full load operation, respectively, shows excellent part load efficiency.

The re-calculated fan input power using fan speeds from the inverter drive display of 29.85kW (9.85W/m^2 Treated Floor Area) is commiserate with CIBSE's typical energy efficiency benchmark of 8 to 12 W/m^2).

Unless AHU 2's 20 air changes an hour is necessary a **saving in fan power of 42%** could be achieved if was reduced to a more typical 12 for laboratories.

Report # UK8
Office Block
VAV system
Cardiff, UK

Installed capacity

There is a total chiller nominal cooling capacity of 740kW (2 x 370kW), which at 205W/m^2, equates to N + 1.34 when compared to the 87W/m^2 suggested by the *BSRIA Rules of Thumb 5th Edition*, or 314kW

Maintenance

Maintenance checks are carried six monthly by in-house maintenance staff and the equipment is in satisfactory condition with no issues that would compromise IAQ. The chillers are serviced, including F – gas leak checks, by a specialist contractor also every six months.

Operation, control and monitoring.

The building is predominantly open plan office space, arranged around a central core containing stairs and lift wells. There is also a restaurant with kitchen and dining area located on the 3rd Floor. Prior to occupation by the university, floors 4-11 housed a call centre, and the lower floors were let out as offices.

The HVAC systems operate 08:00 to 17:00, Monday to Friday and the chilled water systems are activated on an optimised stop and start basis, currently set to disable to chiller when the ambient temperature is under 18°C, although there is anecdotal evidence that it is 'manually' held off until there is an absolute need for cooling.

On the main system there are 10 sub-zones per floor (mostly within the same open plan space), each with its own temperature sensor and separately controlled reheat terminal unit. Air is supplied at the minimum temperature required in the building, the set points being controlled by maintenance staff using the BMS ie. the occupants have no direct control.

The HVAC system operates from 08:00 to 17:00, Monday to Friday and is controlled via a BMS.
Two air handling units supply cooled air to the terminal units with a controlled amount of fresh and exhaust air, providing an indoor environment for which there were no complaints of stuffiness.
The supply temperature in each AHU supply is controlled from a temperature to a zone set point of 23°C.

Efficiency

The total installed pump capacity of 34.71kW equates to 9.6W/m^2 which grossly exceeds CIBSE's UK Guide 'F' energy performance benchmarks of 3.1W/m^2 for an old standard building or 3.4W/m^2 for an old prestige building.

The total fan power of 69.48kW equates to 13.48 W/m^2 Treated Floor Area, which exceeds CIBSE's energy efficiency typical bench mark of 8 to 12W/m^2, although the estimated measured total fan output of 19kW equates to 5.26W/m^2, Treated Floor Area - good efficiency and with no complaints of stuffiness it may not have compromised the IAQ.
The Specific Fan Power for AHUs I and 2 of 2.83 and 3.79W/ litre•s^{-1} is significantly higher that CIBSEs guidance of 2.2 litre•s^{-1} and is represents poor energy performance.
There is a total supply AHU air volume of 10.5m^3/S, 10% of which would be fresh air at 1.05m^3/s. A typical amount would be 0.008m^3/S per person i.e. 400 x 0.008 = 3.2m^3/S.

Given and estimated ceiling height of 2.5m, at 10.5m^3/S there would be 4.2 air changes per hour of which fresh air would be the equivalent of only 0.42 air changes per hour.
Either way there appears to be low fresh air volumes, although we have no evidence of poor IAQ.

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Report #: UK9
Liquid chillers
Public library
Worcester, UK

Installed capacity

The installed main chillers' cooling capacity during normal opening/operational hours is 500kW (N+1) which at approximately 80W/m^2 would be considered prudent for this type of building's activities. However, owing to operational problems with the river water system, their use been substituted, for the short term, by a 256kW cooling capacity temporary air cooled packaged chiller, which has adequately maintained the required conditions.

Outside of normal operating hours and/or when the main plant is switched off, an air cooled chiller of 47.2kW nominal cooling capacity provides chilled water to the AHUs serving essential services such as the server rooms' and the basement archive's; although it is not exactly clear which areas are served.

There is a total of 193.28kW installed cooling capacity for the AHUs, FCUs and chilled beams, other than the six FCUs for Room 162 and the twenty six embedded coils, for which there was no data available.

Maintenance

The equipment is very well maintained by in house personnel carrying out checks continuously to the plant as whole, whilst the chillers are serviced regularly by a qualified chiller contractor in accordance with the F-gas regulations.

Filter condition monitoring is aided by pressure differential gauges.

Operation, Control and Monitoring

The building is open to the public from 08:30 until 22:00 hours seven days a week.

The inspected HVAC plant for the conditioned areas consist of a mixture of fan coil units, air handling units, chilled beams and embedded coils. These units are supplied with chilled water produced by two 250kW liquid chillers, operating as Run and Stand by, while the building is open and a 47.5kW overnight/backup air cooled chiller which serves the essential zones, including the 'concrete box' basement archive which is maintain to + or – 1^{o}C of its temperature set-point and + or – 5% of its RH set-point.

Heat rejection from the chiller's water cooled condensers is effected by the use of river water pumped through an intermediary heat exchanger

The whole system is controlled and monitored by the BEMS, although the Torbocor chillers have to be enabled locally because of a lack of synchronisation between three way valves' stroke times, pump motor inverter speed ramp up times and the chillers' anti-recycle time delays, which cause activation of the chillers' high refrigerant pressure (HP) safety circuits.

At present there is also a 256kW (20.48w/m^2) air cooled liquid chiller, which has been on long term hire due to problems with the river water abstraction system. If the river water is =≤10^{o}C then the system uses to water for free cooling, although according to on site data this function has never been implemented.

Efficiency

Pumps:

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The total installed Chilled water pump power input at 12.5kW equates to 1Wm^2 (TFA) which compares very favourably with CIBSE's GUIDE F 2004 Energy Performance benchmark of 1.8 to 2Wm^2 (TFA).

Fans:

The sampled AHUs had a Specific Fan Power at 100% inverter speed of between 1.07 and 1.69 and the sampled FCU 0.35 which also compares very favourably with CIBSE's GUIDE F 2004 Energy Performance benchmark of 2W/l.s^{-1}.

Cooling system:

Research (Ref Note 1) has shown that river water in the Midlands of England had an annual average of 168 days when the river water temperature was <10°C, and that they would be between the middle of October until the middle of April.

At the time of the inspection the Carrier 253.6kW hire chiller was cycling on and off to maintain what could only have been the internal gains from mainly the essential services' conditions, on two consecutive days, the 28th and 29th February 2014, when the ambient temperatures were 6°C and 9°C respectively, and the weather conditions were overcast and raining (second day).

Only one compressor was operating at any time which, at 25% full load, equates to 63.4kW cooling capacity (input 13.5kW), and therefore at <63.4kWh, by reason of the compressor cycling, substantiating the correct sizing of the back-up chiller's 47.2kW (input 18.73 kW), for the essential services.

Owing to the temporary nature of the hired chiller the condenser air heat rejection 'arrangement' is far from satisfactory, and although no verification checks were carried out during the inspection, its efficiency most probably is compromised.

To produce 47.2kW, one Rhoss Turbocor chiller would need to operate at 18.6%, which may be outside of the operational range of its steady state fine control (100 to ~20%) and why river water =≤10°C would become an option, especially when it is relative to low external heat gains.

At 20% capacity a Turbocor chiller would produce 50kW of cooling with an input of 5kW.

To make a comparison between free and electric cooling we have combined the total power inputs (using an arbitrary turn down inverter speed of 30% for the cooling water pumps i.e. operating at 70%) for the respective pump configurations whilst including the individual chillers' input for the latter.

On the premise that river water can only be effectively used for cooling in the months between September and April, and as the building has been designed to minimize unnecessary external gains and that our spot chiller capacity check of ≤63.4kW (Carrier Chiller), in January 2014, could only be in respect of internal gains from the essential services, we have concluded that only about 50kW of cooling would be required from the river water.

Report #: UK10
VAV unit with Dual Duct system
Cardiff, UK

Installed capacity

There is an installed potential cooling capacity of around 21kW should the cooling coil be connected to the existing chilled water system.

Maintenance

Maintenance checks are carried six monthly by in-house maintenance staff and the equipment is in excellent condition.

Filters were all replaced October 2012.

Operation, control and monitoring.

The chilled water cooling coil has never been connected to the chilled water supply, cooling is carried out using fresh air only, which is tempered by an LPHW heating coil and a cross flow heat recovery recuperation section.
Both supply and extract fan motors are inverter controlled - the operating speed being dependent on the demand.
The system operating hours are to suit the extended requirements of the casual use of IT VDU room.
The operating schedule and the temperature are controlled and/or monitored by a BEMS.

Efficiency

The total fan input power of 1.622kW or 7.17W/m^2 (Treated Floor Area), compared to CIBSE's Energy Efficiency Guide 19 of 8 to 12W/m^2 for 'Standard Buildings', shows good efficiency.

At 64% the measured heat recovery efficiency, although not the maximum that could be theoretically expected is at the high end of what is typically feasible (55 to 65%) and would be regarded as good and would attract a Class 'B' rating under Eurovent conditions.

The Specific Fan Power value of 0.72kW/m^3/s can be considered an excellent energy efficiency indicator when compared to the CIBSE's UK guidance values of 2 kW/m^3/s, for new buildings, and 3kW/m^3/s for refurbishments.

Anecdotal evidence shows that the system is working satisfactorily as there have been no complaints from the occupants, although this may be because of seasonal variation in usage i.e. minimal during the student's summer vacation period when peak heat gains would be at maximum.

REPORT #: GR1
Split DX Units
Pefki, Greece

Installed capacity

The cooling requirement of this supermarket is typical of others insomuch as there is a lot of internal gain due to refrigeration compressors, lights, and other equipment heat loads (46% of the Total Load of the reasonable 115W/m^2) on the ground floor, which includes the food hall, and has an installed cooling capacity of 134.2 W/m^2. Whilst the first floor, dedicated to non-electric household goods and products, has a modest heat load of 76.8 W/m^2 with an installed capacity of 139.7 W/m^2 we would expect the over capacity to be in respect of flexibility of use and therefore reasonable.

Maintenance

The systems appeared to be in good condition, and well maintained, not withstanding that we did not get access to the indoor ceiling concealed fan coil units, with a good prognosis of life expectancy; and there were no visual signs of refrigerant leakage. The condensers have adequate access free air and are not affected by any hot air recirculation from the adjacent condenser discharge fans. Using the information gathered in the verification inspection there would appear to be some issues with the refrigeration circuits indicated in the superheat and sub-cooling values recorded which would require further inspection by the incumbent maintenance company to identify the exact cause. These values would suggest a reduction in unit efficiency but without access to the indoor units it was not possible to be more precise.

Operation

At the time of the inspection the ambient and internal conditions, 35/36°C outdoor 26°C indoor, were virtually as per the manufacturer's design conditions of 35°C outdoor 25°C indoor, and even though there was some minor operating issues some of the condensing units were cycling on both floors – more so on the First, suggesting a reserve capacity to deal with the high ambient temperatures regularly experienced.

Another redeeming factor is that the motor/compressors were operating, on average, at 72.5% of full load amperage with the three phase supply being in balance satisfactorily by 1.25%.

Efficiency

The energy consumption, considering the type and age of the equipment, and other than some minor refrigeration system problems (see Table 16 - Recommended Energy Conservation Opportunities), would be deemed as satisfactory; and could be only radically improved by investing in the latest equipment, which might not be economically sensible.

The installed units have no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

The installed units have a COP of 2.41 @ 35°C as found in the manufacturer's literature; it is possible for modern systems of a similar type and design have a COP of 3.45 @ 35°C as found on the Eurovent website. This would lead to a reduction in energy used at the outdoor unit compared to the existing installed units.

Unit number 13 is also showing symptoms of being short of refrigerant but not to the same extent, but again without access to the indoor unit the exact reduction in efficiency cannot be calculated.

Maintaining a correct refrigerant charge has shown to result in an average **saving of 29.7%.** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

Report #: GR2
Split DX Air conditioning units
Pefki, Athens
Greece

Installed capacity

The cooling requirement of this supermarket is typical of others insomuch as there is a lot of internal gain due to refrigeration compressors, lights, and other equipment heat loads (46% of the Total Load of the reasonable 115W/m^2) on the ground floor, which includes the food hall, and has an installed cooling capacity of 134.2 W/m^2. Whilst the first floor, dedicated to non-electric household goods and products, has a modest heat load of 76.8 W/m^2 with an installed capacity of 139.7 W/m^2 we would expect the over capacity to be in respect of flexibility of use and therefore reasonable.

Maintenance

The systems appeared to be in good condition, and well maintained, not withstanding that we did not get access to the indoor ceiling concealed fan coil units, with a good prognosis of life expectancy; and there were no visual signs of refrigerant leakage. The condensers have adequate access free air and are not affected by any hot air recirculation from the adjacent condenser discharge fans. Using the information gathered in the verification inspection there would appear to be some issues with the refrigeration circuits indicated in the superheat and sub-cooling values recorded which would require further inspection by the incumbent maintenance company to identify the exact cause. These values would suggest a reduction in unit efficiency but without access to the indoor units it was not possible to be more precise.

Operation

At the time of the inspection the ambient and internal conditions, 35/36°C outdoor 26°C indoor, were virtually as per the manufacturer's design conditions of 35°C outdoor 25°C indoor, and even though there was some minor operating issues some of the condensing units were cycling on both floors – more so on the First, suggesting a reserve capacity to deal with the high ambient temperatures regularly experienced.

Another redeeming factor is that the motor/compressors were operating, on average, at 72.5% of full load amperage with the three phase supply being in balance satisfactorily by 1.25%.

Efficiency

The energy consumption, considering the type and age of the equipment, and other than some minor refrigeration system problems (see Table 16 - Recommended Energy Conservation Opportunities), would be deemed as satisfactory; and could be only radically improved by investing in the latest equipment, which might not be economically sensible.

The installed units have no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

The installed units have a COP of 2.41 @ 35°C as found in the manufacturer's literature; it is possible for modern systems of a similar type and design have a COP of 3.45 @ 35°C as found on the Eurovent

website. This would lead to a reduction in energy used at the outdoor unit compared to the existing installed units.

Unit number 13 is also showing symptoms of being short of refrigerant but not to the same extent, but again without access to the indoor unit the exact reduction in efficiency cannot be calculated.

Maintaining a correct refrigerant charge has shown to result in an average **saving of 29.7%.** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010)

Maintaining the correct condensing air temperatures and preventing warm air recirculation has shown to **save an average of 4.43%** (Ref. HARMONAC - Harmonizing Air Conditioning Inspection and Audit Procedures in the Tertiary Building Sector Final Report 2010).

The thermal insulation covering the refrigeration pipework is incomplete. Missing or incomplete insulation on the suction pipe-work can lead to the refrigerant absorbing heat, increasing the superheat and lowering the efficiency of the unit.

Units 10 and 13 have a current imbalance over the recommended 10%. Readings greater than 10% suggest voltage imbalance, partial phase loss or high resistance through the motor control circuit which could cause inefficiencies and possible premature failure of the motor

Control

The units operate individually reacting to their own control set-point but are under universal time clock control. The store also has a remote dial in facility so time clock, control set point can be altered and fault condition monitored.

Report #:GR3
Chilled water thermal storage system
Nea Kifissia, Greece

Installed capacity

The chiller name plate installed cooling capacity of 88.2kW (88.2Wm^2) and input of 31.2kW is that as stated, although not referenced, by Eurovent - contrary to the 90kW (90Wm^2) and 34.49kW (EER 2.61) respectively, quoted by the manufacturer in their literature. However, as one circuit of the chiller has been disabled the former is devalued to 50.27kW (50.27Wm^2).

There are four down flow AHUs which are rated between 14.08 and 17.6 kW or 56.32Wm^2 and 70.4 Wm^2, respectively, in total which is commiserate with the moderate peak load estimate of 63 Wm^2, which is testament to the external solar shading and heavy tinting of the glazing.

The installed pump capacity whether in night time storage mode or day discharge mode is 2.2kWm^2 Treated Floor Area, is slightly higher than the 2kWm^2 quoted in CIBSEs Guide 'F' for new 'Prestige' air conditioned buildings but significantly less than for the 3.4kWm^2 refurbishment value for old buildings.

Operation and Maintenance

Whilst the operation and maintenance was found to be good, the high suction superheat and low sub cooling values found may be an indication that the periodical diagnostics of the refrigeration circuits need reviewing.

The chiller consists of 2 circuits split 57% (51.3kW), with two compressors, and 43% (38.7kW) with one compressor. The 38.7kW circuit has been disabled to match the chiller's capacity closer to the historical typical demand (Peak demand 63kW) as understood by the user. The remaining circuit consists of 2 equal compressor stages each of 30% (27.44kW) when operating singularly.

Efficiency

The installed chiller has a full load EER of 2.83 (Eurovent), which is defined has having a Euorvent 'D' energy efficiency classification. If the chiller was replaced with a Class 'A', then a saving of 9.5% could be made.

Although the system has an uncommon feature of a below ground thermal storage tank there appears to little or no loss of efficiency. We have shown that below 30^{o}C ambient temperature the EER appears to drop off but this would be more than offset by the reduced operation of the condensers fans from 2 @ 2.1kW in high speed to 1 @ 0.77kW in low speed. However any night time savings would be negated by 0.75kW to 3kW through the daytime, as required, operation of the four chilled water circulating pumps to the AHUs.

Whilst we have calculated the cooling capacity of one compressor (30% of capacity @30^{o}C) as 27.44kW, the average Climacheck Analyser reading, at 30.1^{o}C air onto the condenser, was 17.6kW, **a 35.86% reduction**. Reducing the suction superheat from the default margin top end of 8K to 6K would go some way to rectifying this inefficiency and increase the low sub cooling value as a consequence. Ensuring the correct water flow may also improve the efficiency.

AHU, Unit reference #1, was found to operating efficiently having a measured cooling output of 15.13kW.

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Control

The thermal storage tank temperature is controlled at night by the offloading of the chiller stages to a water leaving temperature of 7°C. During the day the building temperatures are locally controlled by four individual chilled water pumps which are enabled on the cooling demand of each zone. Should the thermal storage be depleted during the day, the chiller circuit is diverted directly to the AHUs to supply water at 7°C.

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Report #: GR4
Fluid Chiller, Library of Science, Athens University
Athens, Greece

Installed capacity

The installed heat pump water chiller cooling capacity of 448.4kW equates to 216.68w/m^2, which by most standards would be considered too high, not just in a building of this type i.e. library and offices which few could argue would require 100w/m^2 at the most. This is borne out by the installed AHU capacity of 296.85kW (143.14w/m^2) and the fact that in an ambient temperature of around 35^{o}C and an average on coil temperature of 32.65^{o}C, only one compressor (74.73kW and 36.13 w/m^2) was operating and cycling.

The slight over sizing of the AHUs is of no consequence as, the cooling is proportionally controlled by three way chilled water diverting valves, and their Specific Fan Power of between 0.53 and 1.27 is more than satisfactory.

The chilled water pumps, having an Installed Cooling Pump Power of 2.13W/m^2, would be deemed to be good, based on the CIBSE Guide 'F' 2004 benchmarks of 1.8 to 2W/m^2 for new buildings and 3 to 3.4 W/m^2 for refurbishments.

Maintenance

The ad hoc maintenance provided by the in-house maintenance staff appears to be just sufficient at present but the user should consider a more structured schedule which might include specialist personnel with refrigeration/F-gas competency, for instance.

Operation & Control

The chiller has three refrigeration circuits – one per tandem hermetic scroll compressor i.e two compressors per circuit. There are six capacity steps controlling the six compressors to the required water outlet temperature in cooling mode. The condenser fans, two per circuit, are cycled, via a single stage per circuit, to maintain the correct condenser coil temperature and hence the operating compressor discharge pressures.

Whilst the chiller operating temperatures and pressures were found to be commiserate with the manufacture's recommended values and our calculated predicted values although the high 9.6K TD would be an indication of insufficient water flow – even if the high water temperature was allowed for in respect of the TD – and the high superheat of 14.1K would need further investigation as to the cause.

The AHUs positioned externally on the roof have no drain traps, resulting in the condensate water produced being held within the unit and overflowing into the adjacent sections, until the fan switched off on the daily time scheduled when the water would be able drain to the roof. The concern being, that water trapped within the unit would evaporate back into the conditioned air from which it was originally extracted from – indicated by the high By-pass factors recorded.

Despite the higher off coil RH values for AHUs 2, 3 & 4 we have concluded that, by anaylising the coil air on Absolute Humidity (moisture content) and Specific Enthalpy, there appears to be no increased load on the coil and therefore the water lying in the duct was not having an adverse effect on the system's efficiency, in this instance. The main concern, in this instance, would possibly be problems with air quality (although in this instance it was having little influence on the RH levels owing to the low ambient humidity conditions) and damage to the panels and ductwork in the long term.

Efficiency

Although the chiller is oversized it would be proportionally de-rated by dint of the off cycling of its six equal compressor stages in response to the reduced demand. Furthermore, it is usual in such arrangements that one compressor from each circuit is enabled before any of the second compressors are called; and in that condition the resulting higher evaporating pressure would be expected increase the efficiency of the compressor, with the expectation of maintaining, the excellent of Eurovent Class A rating of 3.38.

Condenser fan energy savings could be made, claim the manufacturer, if the user considered an 'optional extra' offered by them of 'continuous linear fan speed regulation'.

Monitoring

AHUs are BEMS controlled and enabled on internal room temperatures within the timed periods. Running status, temperature, filter Differential Pressure Switches and alarms are also monitored using the BEMS control.

However, the filter dirty Differential Pressure Switches have been rendered inoperable by dint of the air pressure tubes having been disconnected.

Report #: GR5
Fluid Chiller, Athens University
Athens
Greece

Installed capacity

With the installed chiller cooling capacity of 448.4kW equating to 312.91 W/m^2 and the total AHU cooling capacity of around 300kW it would appear that the system is significantly oversized, as even an over estimate of 150w/m^2 would only require 215kW of cooling. However, the slight over sizing of the AHUs is of no consequence as, the cooling is proportionally controlled by three way chilled water diverting valves, and their Specific Fan Power of between 1.33 and 1.58 is more than satisfactory.

The chilled water pumps, having an Installed Cooling Pump Power of 3.07W/m^2, would be deemed satisfactory based on the CIBSE Guide 'F' 2004 benchmarks of 1.8 to 2W/m^2 for new buildings and 3 to 3.4 W/m^2 for refurbishments.

Maintenance

The ad hoc maintenance provided by the in-house maintenance staff appears to be just sufficient at present but the user should consider a more structured schedule which might include specialist personnel with refrigeration/F-gas competency, for instance.

Operation & Control

The chiller has three refrigeration circuits – one per tandem hermetic scroll compressor i.e two compressors per circuit. There are six capacity steps controlling the six compressors to the required water outlet temperature in cooling mode. The condenser fans, two per circuit, are cycled, via a single stage per circuit, to maintain the correct condenser coil temperature and hence the operating compressor discharge pressures.

The chiller operating temperatures and pressures were found to be commiserate with the manufacture's recommended values and our calculated predictions and therefore would be considered to be working efficiently.

The AHUs positioned externally on the roof have no drain traps, resulting in the condensate water produced being held within the unit and overflowing into the adjacent sections, until the fan switched off on the daily time scheduled when the water would be able drain to the roof. The concern being, that water trapped within the unit would evaporate back into the conditioned air from which it was originally extracted from – indicated by the high By-pass factors recorded.

By dint of the low off coil Relative Humidity levels and satisfactory coil By-Pass factors, and by anaylising the coil air on Absolute Humidity (moisture content) and Specific Enthalpy, we have concluded that there appears to be no increased load on the coil and therefore the water lying in the duct was not having an adverse effect on the system's efficiency, in this instance. The main concern, in this instance, would possibly be problems with air quality (although in this instance it was having little influence on the RH levels owing to the low ambient humidity conditions) and damage to the panels and ductwork in the long term.

Efficiency

Although the chiller is oversized it would be proportionally de-rated by dint of the off cycling of its six equal compressor stages in response to the reduced demand. Furthermore, it is usual in such arrangements that one compressor from each circuit is enabled before any of the second compressors are called; and in that condition the resulting higher evaporating pressure would be expected to

increase the efficiency of the compressor, with the expectation of the excellent of Eurovent Class A rating of 3.3.

Condenser fan energy savings could be made, claim the manufacture, if the user considered an 'optional extra' offered by them of 'continuous linear fan speed regulation'.

Cooling coil By-pass factors of 28.3% and 30.1% show good efficiency.

Monitoring

AHUs are BEMS controlled and enabled on internal room temperatures within the timed periods. Running status, temperature, filter Differential Pressure Switches and alarms are also monitored using the BEMS control.

However, the filter dirty Differential Pressure Switches have been rendered inoperable by dint of the air pressure tubes having been disconnected.

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Report: #GR6
Roof top high air volume fresh air DX units with heat recovery
Athens
Greece

Installed capacity

The installed cooling capacity serving the Basement and Ground Floor sales areas of 517.4kW from one of the manufacturer's guide manual includes the heat recovery elements of the units -another gives it at 572.2kW. However, using data for the motor/compressors fitted, we have calculated the DX cooling capacity at 471.8kW; and from the measured amperages and voltages of the motor/compressors and fans we estimated 462.65kW.

We have also used the iSERV AC Estimator spreadsheet to determine the total installed DX cooling capacity of the four RTUs to be 495kW for a Treated Floor Area of 3700m^2; and by using the cooling capacity determined from the compressor data and the aforementioned area the normalization value for the cooling capacity would , therefore, be 134W/m^2.

Maintenance

The system is checked every two weeks by a specialist contractor.

Operation, Control and Monitoring

The inspected system is an air/air heat pump rooftop optimising application using a high volume of fresh air by recovering some of the energy from the exhaust air. Four motorised dampers and a supply and exhaust fans allows full modulation of the fresh air plus exhaust air mix, to maintain the correct pressure balance in the zones.
A constant supply air temperature is maintained by the use of two cooling circuits and multiple compressors controlled integrally.
Heat recovery is achieved with a Wheel Exchanger which is activated in cooling mode, if the zone temperature (return temperature) is less than the outside temperature.
Operators are able to interrogate the control system to monitor set-points, operating schedules and fault indications.

Efficiency

The 'excellent' EERs, stated in the manufacturer's literature, of between 3 and 3.73 are in respect of the heat recovery element of the units - without the heat recovery they would probably be reduced to typical.

The installed cooling capacity of 134W/m^2 would appear to be reasonable considering the high density of energized electrical goods e.g. television sets, on display in the sales areas.

At 18.33W/m^2 Treated Floor Area the installed fan power would seem high when compared to CIBSEs UK guidance of 8 to 12W/m^2 for office buildings, but perhaps is not for this type of application where air quality is important.

All of the units were operating in full DX mode i.e. no heat recovery, during the inspection when ambient temperatures reached the design temperature of 35^{o}C (possibly above), although maintaining conditions (26^{o}C return air temperature) at less than 100% fully loaded, i.e. compressor cycling on all units.

A gap between the condenser discharge air duct and the external wall aperture is causing hot air to enter the unit inlet grille. Once the gap was temporarily sealed the efficiency of cooling capacity **increased by 2.1%**

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Report #: HU1
Air cooled liquid chiller with underslung fan coil units
Supermarket
Budapest, Hungary

Installed capacity

The installed nominal cooling of the air cooled chiller is 37.6kW with a total nominal input of 13kW, serving six fan coil units with a total of 42kW cooling capacity for a peak cooling load of 48.11kW at 35°C outdoor and 24°C indoor.

Operation, control and monitoring

We were not able to bring the chiller into operation to carry out invasive monitoring during the inspection but its good condition and there being no visual evidence of refrigerant leaks etc. led us to believe that there is little wrong with it, although only by running and testing it would it be possible to tell; and the lack of high temperature discolouration on the compressor discharge pipe, no visual signs of the suction line or chilled water pipe work having been contaminated with condensation and the pristine condition of the condenser suggests the use of the chiller has been prudent, to say the least.

Maintenance

A specialist contractor carries out major maintenance inspections twice annually and the equipment is in excellent condition.

Efficiency

The total installed fan power is a modest 1.14kW or 1.57W/m^2 (Treated Floor Area) compared to CIBSE's UK Energy Performance Guide F, of 8 to 12Wm^2 Treated Floor Area, for offices when considering ventilation rates for the retail sector would be higher.
The total chilled water pump power of 1.26kW or 1.74m^2 (Treated Floor Area) shows very good efficiency when albeit compared to CIBSE's UK Energy Performance Guidance for office's minimum value of 1.8W/m^2.

The installed chiller nominal EER of 2.81, if verified, would be considered very good for this type of chiller but it is possible for modern chillers of a similar type and design to have a EER of up to 3.1 (Class A) @ 35°C ambient and 12/7°C leaving water temperature, as found on the Eurovent website, which would lead to a 10.3% improvement in efficiency.

Report #: HU2
Geothermal heat pump system
Budaörs, Hungary

Installed capacity

The installed nominal cooling capacity of the ground source heat recovery chiller is 23.57kW (42.85W/m^2 Treated Floor Area) for a modest 22.46kW (42.36W/m^2 TFA) total peak heat gain for the building.

There was no information available for the embedded ceiling cooling coils.

For the building volume of 1540m^3, the three installed ventilation units are capable of providing, for a combined air flow rate of 1050m^3/h, 0.68 air changes per hour.

Operation, Control and monitoring

The operating refrigerant pressures and temperatures were as expected, for the operating conditions, showing that it was operating efficiently – the acceptable current and voltage imbalances also showed that there were no faults or conditions of unit components that was compromising its efficiency.

An integral central controller manages all functions including, heating, cooling, 'free' cooling modes brine/water temperatures and zone temperatures.

The system operates to zone set points of 21^{o}C by limited adjustment thermostats, in cooling mode and operate 24 hours a day Monday to Friday by its integral controller.

The ventilation units' fresh air is supplied from the warehouse, where there are significant pollutants from fork lift truck activity, contrary to the design drawings which show the intake from outside of the building. This results in the ventilation units G3 class filters being changed monthly although they block up completely after two weeks prompting the user to switch the ventilation units off until the next filter change, which would compromise the heat recovery and night time cooling ventilation operation.

Maintenance

No specific maintenance checks have been carried out although it is assumed that, as implied by the manufacturer's instructions, that the heat pump unit has annual leak checks as per the EU F-gas Regulation.

Efficiency

With a modest total fan input power 0.69kW (1.25W/m^2 Treated Floor Area), compared to UK CIBSE's guidance of 8 – 12W/m^2 and their Specific Fan Power of 1.66, the three ventilation units are, given that 8l/S is a typical amount of fresh air per person, sufficient for 36 people - an occupancy level of 15m^2 per person, although at current occupancy levels it is providing 24l/s.

The installed cooling pump input 0.66kW at 1.2W/m^2 (Treated Floor Area) which compares very favourably with CIBSE's UK Guide 'F' benchmark of 1.8W/m^2 and therefore shows very good efficiency as does the installed 'free' cooling pump input of 0.66kW (1.2W/m^2 Treated Floor Area).

The heat recovery of the ventilation units, measured at 78% would regarded as excellent and does not adversely affect the ventilation rate and compromise the indoor air quality.

The nominal cooling capacity of 23.57kW, for the heat recovery chiller is, as quoted in the manufacturer's literature, for a brine entering temperature of 0^{o}C and a condenser leaving (heating) temperature of 35^{0}C, however, the monitoring was carried out with a steady state condition of 11.6^{o}C

entering brine temperature and a condenser leaving water temperature of 41°C with a cooling output of 35.6kW and an excellent EER of 4.98.

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Report #: HU3
Air cooled liquid chiller with heat recovery AHUs
Budapest, Hungary

Installed capacity

There is main chiller cooling capacity of 1824kW (105W/m^2 treated Floor Area) with a combined AHU and FCU cooling capacity of 2428.4kW (139.9W/m^2 TFA), with the FCUs operating at High Fan Speed, 2309.4kW (133W/m^2 TFA) at Medium Speed and 1476.4kW (85W/m^2 TFA) at Low Speed, compared to a calculated peak heat gain of 117.7W/m^2.

The 'out of hours' back up chiller has a cooling capacity of 55.3kWserving the IT room for which we have no heat gain details.

Operation, control and monitoring

Each fan coil unit operates to a set point of 24^{o}C controlled by a return air sensor above the ceiling, but can be altered by locally on room controllers by +/- 2^{o}C.

AHU 1 and 2, in the basement plant room, have a thermal wheel heat recovery sections and operate to a set point of 20^{o}C air leaving air temperature. AHU 3 is supply and extract only in respect of it being a catering area.

The BEMS controls all timing/operating schedules and shows temperatures and air pressures from all of the HVAC equipment for monitoring and analysing, including to discern when the filters need replacing. The average recorded super heat values of 10.2K and 7.7K for chillers 1 and 2 respectively would usually attract further investigation, especially in this case as the operation superheat is controlled at 2.8 to 5.5K.

Maintenance

A facilities management contractor provides permanent maintenance staff to carry out minor tasks and filter renewal every three to four months, or as necessary, on all AHUs and fan coil units, whilst a specialist contractor attends to all reactive HVAC visits and six monthly major maintenance checks – which is testament to the very good condition of the equipment.

Efficiency

The total installed fan power; including FCUs of 108.94kW (6.28W/m^2) shows good efficiency when compared to the UK's CIBSE energy performance typical benchmark of 8 – 12W/m^2 Treated Floor Area especially when the heat recovery is taken into consideration.

The installed pump input power of 40.6kW which at 2.34W/m^2 which when transposed into pump capacity is likely to be within or lower than the 1.8 to 2W/m^2 UK's CIBSE's energy performance typical benchmark for new buildings, and therefore showing good efficiency.

Should the Standard efficiency main chillers be replaced with the Premium efficiency model there would an **increase in efficiency of 24%.**

At the time of inspection the BMS was operating the heat recovery on AHUs 1 and 2 at 10% heat wheel sped and achieving 30% and 31% efficiency respectively, whilst AHU's 3 run around coil was achieving 29% compared to the UK's Carbon Trust's guidance of 45% to 55% for typical efficiency for this type of heat recovery.

The back-up chiller has an installed nominal EER of 2.3 - it is possible for an up to date Daikin McQuay chiller of a similar type and design to have a EER of 3.48 (Class A) @ 35oC ambient and 12/7oC leaving

water temperature, as found on the Eurovent website, which would lead to a **51.3% improvement in efficiency.**

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Physical Inspection Report

Report #: HU4
Liquid Chiller
Hungary

Installed capacity

The installed total cooling capacity of the two air cooled chillers is 2802kW or 139.4W/m^2 Treated Floor Area, for a peak heat gain of 116W/m^2.

No data was available from the AHUs or the FCUs regarding their cooling capacity or absorbed power in the case of the FCUs for which we have estimated 50W each.

The difference of 23.4W/m^2 (471kW) is therefore available for the fresh air AHUs which we have estimated could have a total cooling capacity of 802kW.

Given a certain element of leniency, there appears to be little or no spare capacity.

Operation, control and monitoring

The chillers supply chilled water at 7^{o}C in the primary circuit to a low loss header, situated in the roof plant room, from where the secondary circuit circulates chilled water to the six AHUs and seven hundred ceiling concealed ducted terminal fan coil units.

Each fan coil unit operates at a set point of 24^{o}C controlled by a return air sensor above the ceiling, but can be altered by locally on the room controller by +/- 2^{o}C.

AHUs 1 to 5 have thermal wheel heat recovery sections and operate at a set point of 24^{o}C leaving (off coil) air temperature and are located in the basement plant room.

AHU 6 supplies the kitchen and restaurant area.

The BEMS controls all timing/operating schedules and temperatures whilst all offices can be monitored and modified individually.

Although the we were only able to operate the chillers individually with only one unloaded compressor (out of three), because the lack of cooling load, the pressures and temperatures and pressures were as expected and therefore showing good operating efficiency, although we not able, at this time, to verify the excellent nominal chiller EER of 3.44, which is the equivalent of a Eurovent Class 'A' rating.

Maintenance

Permanent maintenance contractor's personnel carry out three monthly minor checks and filter changing – main filters every six months and others as necessary, whilst the AHUs manufacturer carries out six monthly major checks as does the chiller manufacture's agents for the chiller plant.

Efficiency

The total installed absorbed pump motor power of 57.2kW equates to 2.85W/m^2 (Treated Floor Area) or using a typical 87% efficiency, 49.76kW (2.48W/m Treated Floor Area), output power (capacity), which exceeds CIBSE's UK Guide 'F' energy performance benchmarks of 1.8W/m^2 for a new standard building or 2W/m^2 for a new prestige building.

The total installed AHU and FCU fan motor input power of 8.19W/m^2 is within CIBSE's UK Guide 'F' energy performance benchmark of 8 - 12W/m^2 and therefore indicates good efficiency, however, only one, the catering area AHU, with a Specific Fan Power of 1.37litre·s^{-1} conform to CIBSE's UK energy performance guideline benchmark of 2 litre·s^{-1}, for systems with heat recovery in new buildings – the others being between 2.3 and 2.9 litre·s^{-1}.

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Of the five heat recovery systems, other than one, low at 54% and another high at 84% they were within the typical 55 to 85% heat recovery rate.

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Report #: I1
Bank
Liquid chiller
Milan, Italy

Installed capacity

The installed chiller has an or original nominal cooling capacity of 68.4kW at 107W/m^2 (Total TFA) would be regarded as satisfactory for the combined activities of a banking hall AHU and FCUs, at low speed fan, of 64.93kW (133Wm^2) and the basement archives and vaults, where the AHU cooling capacity has been estimated at 8.57kW (56W/m^2), taking into consideration the negligible basement heat load.
The R22 chiller, however, has been retrofitted with R427A refrigerant which has the possible effect of reducing both the cooling output and input power by around 10%, thus de-rating the chiller capacity to 61.56kW; which, if 0.74kW is deducted for the basement, then the cooling available for the ground floor would be 125W/m^2.
The cooling tower has heat rejection capacity of 91.2kW.

Maintenance

The system has unspecified checks carried out monthly by a specialist air conditioning and refrigeration contractor which is testament to its reasonably healthy condition, considering its age.

Operation, Control and Monitoring

The water chiller and pumps are configured in parallel with the LPHW boiler and pumps isolated from each other whist sharing a common pipe-work loop to the AHUs and FCUs, which is re-configured manually on a seasonal basis.

The system is BEMS controlled; reacting to zone temperature set points, for the AHUs and time clock settings. The FCUs have local controllers which have ON/OFF, fan speed and temperature control functions.

The water chiller provides chilled water to the AHUs and FCUs whilst maintaining a return water temperature of 12^{o}C with two 50% cooling stages provided by two refrigeration circuits each containing one fixed speed scroll type compressor.
The condenser cooling water is provided by a fan assisted cooling tower - the fan operating to maintain the correct water temperature to the condenser.

Efficiency

The 15 year old chiller has a Eurovent Class 'E' energy rating of 3.82 – there are modern Class 'C' equivalent chillers currently available.

Although the chiller has been retrofitted with R427A refrigerant and possibly have up to a 10% reduction in capacity, its efficiency would not have been compromised as long as the compressor input reduction was of, at least, the same scale; there is no reason to believe that this not the case although we were unable to operate the chiller to verify it.

The current chiller cooling capacity of 61.56kW would adequately cope with the estimated the total peak heat gain of 45.21kW and at other times when the load is =<50% full load, then a higher part load efficiency would be expected in respect of its two compressor stages to one evaporator.
The installed fan full input of 5.53W/m^2 would be considered good efficiency when compared to CIBSE's Energy Efficiency Guide 19 benchmark of 8 to 12W/m^2 (Treated Floor Area) especially as the installed cooling capacity of the AHUs and FCUs is higher than needed.

Similarly, the total installed chilled water pump motor input of 2.125W/m^2 TFA is commiserate with CIBSE's benchmarks of 1.8 to 2.00W/m^2 and 3.1 and 3.8W/m^2 for new and old buildings respectively.

The cooling tower's heat rejection capacity of 91.2kW equates to a condenser to cooling capacity heat rejection ratio of 1.4, where 1.25 to 1.3 would be deemed typical and therefore attesting to it being more than adequately sized. Its efficiency, could not be assessed as it could not be enabled during the inspection.

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Report #: I2
Liquid chiller with AHUs
Milan, Italy

Installed capacity

There is an installed chiller cooling capacity of 82.1kW (181W/m^2) and AHU capacity of 67.26kW serving a peak cooling load of 36.26kW.

Maintenance

The system has unspecified checks carried out monthly by a specialist air conditioning and refrigeration contractor which is testament to its reasonably healthy condition, considering its age.

The chiller is currently undergoing retrofitting procedures to replace the R22 refrigerant with R407C, where Circuit 1 has been successfully completed.
A specialist contractor carries out unspecified maintenance checks on a monthly basis.

Operation, Control and Monitoring

The liquid chiller has two circuits which contain one fixed on/off scroll type compressor each connected to a single plate heat exchanger evaporator and a remote air cooled condenser.
The air cooled condenser fans are controlled by a variable fan speed controller.
The Chilled water circulation pumps, from the chiller, to four AHUs, two are full fresh air whilst the others are plenum systems with fresh air make up. Three way valves for each AHU react to their own individual set points and are controlled by the BEMS to maintain zone conditions. The BEMS also schedule the system to operate only when the building is occupied.

Efficiency

The Specific Fan Power for AHUs UTA1,2,3 and 4 of 0.61, 0.36, 0.69 and 0.69 , respectively, show good efficiency when compared to CIBSE's Guide 'F' benchmark of 1.8 to 2.0 for new and old buildings, respectively.

Using data from the manufacturer's current R407C model, as we were unable obtain details of the original R22 model, we have determined a Class 'C' energy efficiency performance i.e. an EER of 3.3; and as the chiller is over 100% oversized then only the single stage operating would give excellent part load efficiency.

The installed chilled water pump capacity of 3.125W/m^2 would be considered reasonable when compared to their benchmark of 3.1 W/m^2 for older 'Standard' buildings but high when compared to the 1.8W/m^2 for new buildings and is probably due to the chiller over sizing.

No cooling performance checks were carried out as after consultation with the facilities management it was deemed imprudent to enable the cooling during low ambient temperatures in order not compromise the comfort of the occupants.

Report #: IT3
Liquid chillers with AHU's
Milan, Italy

Installed capacity

The Treated Floor Area is adequately served by the York chiller, having a cooling capacity of 105kW (180.8W/m^2), at 35^{o}C Ambient and 12/7^{o}C Entering/Leaving chilled water temperature.

However, as it has had its Refrigerant R22 replaced with R427A, it could be de-rated by up to 10%, i.e. 94.5kW (162.7W/m^2) – still a reasonable installed cooling capacity at 15.7% above our estimated total building cooling load.

The secondary air cooled liquid chiller, a Blue Box, operates only on stand-by, should the main York chiller fail, has a nominal cooling capacity of 38.4kW (66W/m^2) - providing cooling to specific areas, in particularly the Public space.

Maintenance

A specialist contractor is employed to carry out unspecified maintenance to a good standard on a monthly basis.

There were no visual signs of refrigerant leakage and the condensers have adequate access free air and are not affected by any hot air recirculation from the adjacent condenser discharge fans.

Operation, Control and Monitoring

At time of inspection the water chillers had been seasonally electrically isolated with the system operating in heating mode and therefore no operational verification checks could be carried out.

The York chiller has undergone a retrofit of its refrigerant from R22 to R427A.

All of the units on site react to the same timing schedule set by the BEMS of 07:00am – 18:00pm, Monday to Friday, which reflects the building occupation times.

Efficiency

The York chiller, having a cooling capacity of 105kW (180.8W/m^2) with an electrical power input of 36kW would have an Energy Efficiency Classification 'B' with its EER of 2.92, which would not necessarily have been compromised by the lower cooling capacity because of the change of refrigerant as the power input may have reduced proportionally.

The secondary air cooled liquid chiller, a Blue Box, operates only on stand-by, should the main York chiller fail, and has a nominal cooling capacity of 38.4kW (66W/m^2) - providing cooling to specific areas, in particularly the Public space, has a nominal cooling capacity of 38.4kW with a nominal input capacity of 13.2kW creating an EER of 2.90.

The Specific Fan Power values of 1.15, 1.44, 0.29 and O.39W/l.s^{-1} for UTA125, UTA75, UTA35 and UTA125 Fresh Air supply fans, respectively, are significantly below CIBSE's benchmark of 2W/l.s^{-1} shows good efficiency.

The chilled water pump installed capacity of 1.73W/m^2 indicates good efficiency when compared to CIBSE's 1.8 to 2.0W/m^2 Good Practice benchmark.

Report #: IT4
Liquid chiller with close control downflow units
Rome, Italy

Installed capacity

The area is cooled by four chilled water close control down flow air handling terminal units, having a nominal total cooling capacity of 367.2kW, for an estimated 56.4kW room peak heat gain, which are supplied with chilled water from the 392kW air cooled water chiller.

Maintenance

There are in-house maintenance staff who carry out unspecified maintenance tasks on a monthly schedule. The equipment is in good condition although there is a question mark over the oil stains around the Pressure Relief valve suggesting a refrigerant leak having gone unnoticed as one would have expected expect the twice a year F-gas Regulation leak checks, for this 64kg, R134a refrigerant charge, would have been sufficient for detection.

Operation, Control and Monitoring

Outside of the operational hours for the building system of between 08:00 and 20:00 hours Monday to Friday, and
when there is no cooling demand on the same, the chiller can operate down to 50% capacity of one compressor, approximately 49kW (25% Full Load), with the condenser fans slowing down accordingly on its variable speed controller, down to 0°C ambient temperature.
The operation temperatures and pressures for refrigeration circuit N°1 were as expected but the high superheat and low sub-cooling values of for Circuit N°2 suggest the system is short of refrigerant, which is bourn out by the low measured EER of 3.05 and the presence of oil stains around the stem of the High Pressure Relief Valve.
Although the terminal units are not controlled by the BEMS it does monitor and signal any alarm condition

Efficiency

The chiller has a good nominal capacity EER of 2.96 (equivalent of Eurovent Class 'B'), whilst the part load EER measured during the inspection was better at 3.79 for Circuit N°1 and 3.05 for Circuit N°2.

The noticeable reduction in compressor COP and the EER of Circuit N°. 2, we believe is the result of the system being short of refrigerant. **The reduced COP reflects a 19.95% reduction in cooling capacity as does the reduced EER, 19.53%.**

The total fan input power for the four terminal units of 17.6kW represents a Fans' Full Load value of 87.6W/m^2 (TFA) which greatly exceeds, by comparison, CIBSE's UK general benchmark for air conditioned buildings of 8 to 12 W/m^2 (TFA) and also seemingly high for the current peak heat load gain of 281W/m^2, although the Specific Fan Power of 0.48W/ litre·s^{-1} shows good individual efficiency, by comparison, with CIBSE's UK general benchmark for air conditioned buildings of between 1.8 and 3 W/ litre·s^{-1}.

The total installed chilled water pump power of 10.5kW relates to 52.27W/m^2 (TFA) is seemingly extremely high when compared to CIBSE's UK general building benchmarks of between 1.8 and 3 .4 W/m^2 (TFA), even when allowing for the higher heat gain normalized values for IT rooms.

It can be assumed that the chiller efficiency is also being impaired by the excessive chilled water flow rate.

There are good grounds for replacing the chiller with a smaller, dedicated chiller employing a much smaller chilled water pump where energy savings could be made, and load shedding the terminal units to a minimum requirement would reduce the fan input power significantly.

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Report #: IT5
AHU's with supply, extract, & heat recovery
Rome, Italy

Installed capacity

The total Treated Floor Area of interest i.e. the building excluding the basement, is 2308.37m^2, and has total peak heat load of 257.01kW, at a design condition of 35^{o}C outdoor and 26^{o}C indoor temperatures. The area is cooled by an R134a, air cooled liquid chiller with a nominal cooling capacity of 414kW (179.5W/m^2) which has an overcapacity of 85% which, with a total building peak heat gain of 313.41kW (135.8W/m^2) - a 32% over-sizing of the chiller, would suggest the inclusion of any future increase in internal gains from the basement IT area, should the chiller be required in the case failure of the dedicated IT chiller.

The moderate peak heat gain for the building is testament to use of the solar shading methods used.

Three AHUs of capacity provide tempered fresh air, with two providing a combined 80kW of 'back ground' cooling, whilst one hundred and twelve 2.21kW (total 247.52kW) cooling capacity floor mounted terminal units are used to 'trim' local conditions, giving a total cooling capacity of 327.52kW (141.9W/m^2), which doesn't reflect the use of the heat recovery element, although is commiserate with the cooling load.

Maintenance

Unspecified maintenance checks are carried out by in house maintenance staff although the condition of the filters and drive belts would suggest that this needs reassessing.

Operation, Control and Monitoring

The chiller is furnished with two screw type compressors, each with step-less capacity control from 50 – 100%, which are accommodated in individual refrigeration circuits sharing a common shell and tube evaporator; whilst four axial type condenser fans per circuit, eight in total, operate in stages to maintain optimum condensing pressures.
The chilled water temperature is regulated by continuous modulation, based on a Dead Band on the evaporator leaving water temperature controlling it at 7^{o}C – or alternatively it can manage a step regulation based on an entering water temperature 12^{o}C, with proportional or proportional and integral logics.
The AHUs provide tempered fresh air and a limited amount of 'back ground' cooling to all floors, except the basement, to a set point of 26^{o}C from the BEMS, controlled by three way modulating chilled water valves - whilst the local chilled water free standing floor mounted terminal units being used to trim the conditions to the user preference, the temperature controlled locally, by an On/Off operation of individual chilled water solenoid valves, reacting to the user's controller set-point, and a choice of three fan speeds, although the units share the same timing schedule as the AHUs, linked to the BEMS.

Efficiency

The installed chiller has a nominal cooling capacity of 414kW with a total nominal input capacity of 147kW giving an EER of 2.81 – the equivalent of a Eurovent 'C' classification. With a total building peak heat gain of 313.41kW, the 32% over-sizing of the chiller would suggest the inclusion of any future increase in internal gains from the IT area should the chiller be required in the case of the IT dedicated chiller failure.

Although the chiller is oversized there would be good part load efficiency, but which would be offset to some extent by the power used by the chilled water pump.

No operational checks were carried out as the chiller was isolated for the duration of the heating season.

The total installed fan input power of 7.31W/m^2 (TFA) is satisfactory by comparison to CIBSE's UK Guidance of 8 to 12W/m^2, although the total installed pump power input of 5.42kW/m^2 (TFA) appears high, effectively 59% oversized, according to CIBSEs maximum benchmark of 3.4 W/m^2.

Whilst the Specific Fan Power for AHU1 at 2.34 falls within CIBSE's General 'Typical practice' UK benchmark of 1.5 to 3.0 it is above their 'Good practice' guidance of 1.0 to 2.0.

AHU2's, however, Specific Fan Power of 4.06 appears high compared to CIBSE's maximum of 3.0 for systems with heat recovery.

The heat recovery efficiency of 26% is below the EUROVENT minimum Classification 'E', and although the calculation was made in heating mode there would similar inefficiencies in cooling mode.

Report #: IT6
Liquid chillers with supply, extract, recovery
Rome, Italy

Installed capacity

There is an installed chiller cooling capacity of 732kW (210.5W/m^2) for a building peak heat load of 410.96kW (118.19W/m^2) although the two chillers are set up primarily on a run and standby basis, operating simultaneously should the cooling demand exceed the capacity of a single 366kW (105.26W/m^2) chiller.

The 112 fan coil terminal units have a maximum cooling capacity of 247.52kW (71.2W/m^2), whilst the AHUs have a combined total of 130kW, giving a total cooling capacity of 377.52kW (108W/m^2), which doesn't reflect the use of the heat recovery element, but does suggest that our peak heat gains of 410.96kW may be slightly overstated, which perhaps is testament to the efficiency of the solar shading.

Maintenance

Unspecified maintenance checks are carried out by in house maintenance staff although the condition of the filters and drive belts would suggest that this needs reassessing.

Operation, Control and Monitoring

The chiller is furnished with two screw type compressors, each with step-less capacity control from 50 – 100%, which are accommodated in individual refrigeration circuits sharing a common shell and tube evaporator; whilst four axial type condenser fans per circuit, eight in total, operate in stages to maintain optimum condensing pressures.

The chilled water temperature is regulated by continuous modulation, based on a Dead Band on the evaporator leaving water temperature controlling it at 7^{o}C – or alternatively it can manage a step regulation based on an entering water temperature 12^{o}C, with proportional or proportional and integral logics.

The AHUs provide tempered fresh air and a limited amount of 'back ground' cooling to all floors, except the basement, to a set point of 26^{o}C from the BEMS, controlled by three way modulating chilled water valves - whilst the local chilled water free standing floor mounted terminal units being used to trim the conditions to the user preference, the temperature controlled locally, by an On/Off operation of individual chilled water solenoid valves, reacting to the user's controller set-point, and a choice of three fan speeds, although the units share the same timing schedule as the AHUs, linked to the BEMS.

The heat recovery by-pass dampers were found to be fully open even though the heating coil was warming the supply air to 22.1^{o}C, with a return air temperature of 20.6oC and incoming fresh air at 14^{o}C

DPS have been disabled locally to prevent them functioning

Efficiency

The heat recovery efficiency of 18% is below the EUROVENT minimum Classification 'E', and although the calculation was made in heating mode there would similar inefficiencies in cooling mode.

The installed chillers have a nominal cooling capacity of 366kW with a total nominal input capacity of 176.8kW giving an EER of 2.07 – the equivalent of a Eurovent 'G' classification. Although the chiller is oversized there would be good part load efficiency, but which would be offset to some extent by the power used by the chilled water pump.

No operational checks were carried out as the chiller was isolated for the duration of the heating season.

The total installed fan input power of 10.39W/m2 (TFA) is satisfactory by comparison to CIBSE's UK Guidance of 8 to 12W/m^2, although the total installed pump power input of 5.14W/m^2 (TFA) appears high, effectively 51% oversized, according to CIBSEs maximum benchmark of 3.4 W/m2. The Specific Fan Power for AHU1 at 4.03kW/m^3/s, exceeds CIBSE's UK benchmark maximum of 3.0 kW/m^3/s for systems with heat recovery, which is good reason for ensuring that the heat recovery system is operating efficiently unlike at the current 18%, where efficiencies of 55 - 65% would be considered achievable.

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Report #: IT7
Supermarket sales area
Milan, Country

Installed capacity

There is total installed cooling capacity of 1150kW (N+0.37) which equates to 145.6W/m^2 Treated Floor Area, which is reasonable considering our estimated 106W/m^2 peak heat gain.

Maintenance

Maintenance is carried out by a specialist contractor, and was last performed on the day before the ISERVcmb inspection.

Filter cleaning and replacement is carried out monthly with a more in depth maintenance being carried out at three monthly intervals which includes checking drive belts, fans, refrigerant charge, controls and electrical connections.

The inspection of the heat recovery sections of the units needs reassessing.

Operation, Control and Monitoring

The compressors in all units are fixed speed hermetic scroll types with no capacity control - capacity control is achieved from starting and stopping compressors. The rooftop units are capable of operating in the following modes: Total recirculation, Partial fresh air with heat recovery, total fresh air with heat recovery, total fresh air with no heat recovery (free cooling). The units also contain the heat rejection air cooled condensers and the compressors. The units operate individually reacting to their own control set-point and adjust the operation mode function to suit, but are under universal time clock control.

Efficiency

Using information from the data plate we found an excellent EER of 3.32 and 3.13 for units numbers 5 to 12 and 13 respectively, which includes the heat recovery, and which would attract an Eurovent Class'A' rating. However, when using data from the manufacturer's literature the EERs are 2.46 and 2.68 respectively (Classes D and C), but when the heat recovery element is taken out of the equation, the DX only EERs are only 2.22 and 2.37 (Classes F and E). The benefit of the heat recovery facility would only be felt under suitable outdoor conditions.

With the loss of the recovery function, through blocked 'elements' there is a possible **11.6% reduction in efficiency** for unit number 13 and a **10.2% reduction in efficiency** on units 5 to 12, The loss of recovery at the design conditions of Cooling: Outdoor 35°C 50% RH. - Indoor 27°C 47% RH. - Fresh Air mixture 50% would result in **a loss of 459.5kW** of recovered cooling capacity throughout the zones, increasing the expected runtime of the mechanical cooling on each machine by 20 minutes over a 12 hour period absorbing an extra **173.5kWh**.

Whilst the Specific Fan Power values are satisfactory the total installed fan power of 5W/m^2(TFA) is more than satisfactory when compared to CIBSE's UK benchmark of 8 - 12W/m^2(TFA) for office buildings.

4 of the 12 motor/compressors' crank case heaters were found to have failed which can result in refrigerant migration to the compressors crankcases and cause the motor/compressor to draw higher starting currents, thus, increasing the consumed electrical power input - made all the more significant considering the lack of free cooling in suitably low ambient conditions by virtue of the blocked fresh air inlets, and necessitating electric cooling.

Report #: IT8
Roof top packaged air-conditioning units
Milan, Italy

Installed capacity

There is total installed cooling capacity of 437.8kW (N+1.425) which equates to 172.8W/m^2 Treated Floor Area, which, because none of the units operate as Run and Stand-by, appears to be oversized considering our estimated 79Wm^2 peak heat gains.

Maintenance

Maintenance is carried out by a specialist contractor, and was last performed on the day before the ISERVcmb inspection.

Filter cleaning and replacement is carried out monthly with a more in depth maintenance being carried out at three monthly intervals which includes checking drive belts, fans, refrigerant charge, controls and electrical connections.

The inspection of the heat recovery sections of the units needs reassessing.

Operation, Control and Monitoring

The compressors in all units are fixed speed hermetic scroll types with no capacity control - capacity control is achieved from starting and stopping compressors. The rooftop units are capable of operating in the following modes: Total recirculation, Partial fresh air with heat recovery, total fresh air with heat recovery, total fresh air with no heat recovery (free cooling). The units also contain the heat rejection air cooled condensers and the compressors. The units operate individually reacting to their own control set-point and adjust the operation mode function to suit, but are under universal time clock control.

Efficiency

Using information from the data plate we found an excellent EER of 3.32 and 3.13 for units 1&4 and 2&3 respectively, which includes the heat recovery, and which would attract an Eurovent Class'A' rating. However, when using data from the manufacturer's literature the EERs are 2.46 and 2.68 respectively (Classes D and C), but when the heat recovery element is taken out of the equation, the DX only EERs are only 2.22 and 2.37 (Classes F and E). The benefit of the heat recovery facility would only be felt under suitable outdoor conditions.

With the loss of the recovery function, through blocked 'elements' there is a possible **11.6% reduction in efficiency** for units numbers 2&3 and a **10.2% reduction in efficiency** on units 1&4, The loss of recovery at the design conditions of Cooling: Outdoor 35°C 50% RH. - Indoor 27°C 47% RH. - Fresh Air mixture 50% would result in **a loss of 54.2kW** of recovered cooling capacity throughout the zones, increasing the expected runtime of the mechanical cooling on each machine by 20 minutes over a 12 hour period absorbing an extra **64.5kWh**.

Whilst the Specific Fan Power values are satisfactory the total installed fan power of 11.99W/m^2(TFA) just makes it into CIBSE's UK benchmark of 8 - 12W/m^2(TFA) for office buildings.

4 of the 12 motor/compressors' crank case heaters were found to have failed which can result in refrigerant migration to the compressors crankcases and cause the motor/compressor to draw higher starting currents, thus, increasing the consumed electrical power input - made all the more significant considering the lack of free cooling in suitably low ambient conditions by virtue of the blocked fresh air inlets, and necessitating electric cooling.

Report #: PT1
Roof Top DX AHU
Porto, Portugal

Installed capacity

The installed nominal cooling capacity was found, from the manufacturer's literature, to be 80.6kW @ 35°C ambient, 27°C DB & 19°C WB internal in contrast with the 122kW stated on the nameplate. This matched our calculated maximum heat gain of 80.71kW almost exactly. However, it is clear from the marked difference in cleanliness of the condensers on this two circuit system that the conditions are being met, in the most part, with Circuit Number1. The two circuits are not identical and by extrapolating data from the manufacture's literature we determined the capacity split as follows:-

Circuit Number 1: 35.4kW

Circuit Number 2: 45.2kW.

Maintenance

The system is well maintained although at the time of inspection one of the condenser coils was due for a clean – understandable considering the unit is located in an enclosed entrance to the car park where it would be affected more than usually from exhaust fumes and dust disturbance.

Operation

The system was furnished with an integral electronic controller and set to maintain a temperature throughout the store of 23.5°C using a sensor in the unit return air stream. Satisfactory temperatures at the East and West end return air grilles of 23.3 °C and 24.4 °C, respectively were observed.

A time schedule limited the system operation to only daily working hours.

Efficiency

The system was showing good efficiency as determined from:-

- Our AC System Estimator spreadsheet we have determined reasonable nominal values for the number of air changes per hour (5.1), the Specific Fan Power (1.16) and the cooling coil face velocity (2.5m^2).
- And the operating compressor was showing a good COP of 4.35 whilst performing to typical industry pressure and temperature parameters. There could, however, be an improvement to the performance once the condenser is cleaned.

Although It was noticeable that the unit was being adversely affected by warm air recirculation on the condenser owing to the roller shutter door to the covered car park being closed for security reasons, at certain times and also because hot air removal from the condensers relied on draught from the prevailing wind when the door was open.

Report #: PT2
AHU
Portugal

Installed capacity

The installed nominal cooling capacity for the whole of the shopping mall is provided by six water chillers rated at 7176kW which at 186Wm^2 suggests a significant amount of redundancy.

For the most part the chilled water temperature is maintained by two Low Temperature Hot Water Carrier/Sanyo absorption chillers each rated at 525TR (1848kW) nominal cooling capacity supported by two McQuay centrifugal chillers rated at 886kW nominal cooling capacity in total. The two McQuay Screw chillers, rated in total at 2594kW nominal cooling capacity, it appears, would only be used if the absorption chillers were out of service; as at the time of the inspection, around mid day, with an ambient temperature of 29.9^{o}C the two absorption chillers were maintaining the conditions at 95.5Wm^2 whilst around two hours later with the ambient temperature >29.9^{o}C, one of the McQuay centrifugal chillers was also operating resulting in 107Wm^2 being used.

Available information was insufficient to establish the capacity of the AHU. The cooling coil performance, with an ambient temperature of 29.9^{o}C, however, was measured at 27kW; although the degree of opening of the chilled water control valve was not recorded.

Maintenance

The level of maintenance of the AHU is of a generally good standard and is carried out by on site staff.

The responsibility for the maintenance of the FCUs within the retail outlet units, however, lies with the tenant, and may not be so stringent which is causing in a conflict of the chilled water circulation configuration, which may not be the most efficient.

Operation

The system, which provides tempered fresh air, is operating with the exhaust fan isolated to reduce running costs and thus operating as a Total Loss system at all times, and not allowing conditioned air to be re-circulated even at times of high ambient temperature. Further investigation would be advised to re-think this strategy.

Efficiency

Both the 26% By-pass factor and the 1.86 Specific Fan Power show good efficiency of the AHU.

Potentially, good efficiency of the absorption chillers is achieved by dint of the Low Temperature Hot Water being supplied from the facility diesel generator cooling water, especially when there is a nett gain of power fed into the local electricity grid.

Control

The AHU operates at continuously during scheduled operating times with the chilled water cooling coil being controlled by a three way valve at 16/17 ^{o}C discharge air temperature when the public space temperature is above 25^{o}C.

Individual retail outlet units are served by individual chilled water FCUs controlled locally.

Report #: PT3
AHU
Portugal

Installed capacity

The installed nominal cooling capacity for the whole of the shopping mall is provided by six water chillers rated at 7176kW which at 186Wm^2 suggests a significant amount of redundancy.

For the most part the chilled water temperature is maintained by two Low Temperature Hot Water Carrier/Sanyo absorption chillers each rated at 525TR (1848kW) nominal cooling capacity supported by two McQuay centrifugal chillers rated at 886kW nominal cooling capacity in total. The two McQuay Screw chillers, rated in total at 2594kW nominal cooling capacity, it appears, would only be used if the absorption chillers were out of service; as at the time of the inspection, around mid day, with an ambient temperature of 29.9^{o}C the two absorption chillers were maintaining the conditions at 95.5Wm^2 whilst around two hours later with the ambient temperature >29.9^{o}C, one of the McQuay centrifugal chillers was also operating resulting in 107Wm^2 being used.

Available information was insufficient to establish the capacity of the AHU. The cooling coil performance, with an ambient temperature of 29.9^{o}C, however, was measured at 27kW; although the degree of opening of the chilled water control valve was not recorded.

Maintenance

The level of maintenance of the AHU is of a generally good standard and is carried out by on site staff although the AHU fan impeller blades were found to be dirty which could lead to a reduction the air volumes and the efficiency of the fan motor

The responsibility for the maintenance of the FCUs within the retail outlet units lies with the tenant, and may not be so stringent.

Operation

The system, which provides tempered fresh air, is operating with the exhaust fan isolated to reduce running costs and thus operating as a Total Loss system at all times, and not allowing conditioned air to be re-circulated even at times of high ambient temperature. Further investigation would be advised to re-think this strategy.

Efficiency

Both the 33% By-pass factor and the 2.01 Specific Fan Power show good efficiency of the AHU.

Potentially, good efficiency of the absorption chillers is achieved by dint of the Low Temperature Hot Water being supplied from the facility diesel generator cooling water, especially when there is a nett gain of power fed into the local electricity grid.

Control

The AHU operates at continuously during scheduled operating times with the chilled water cooling coil being controlled by a three way valve at 16/17 ^{o}C discharge air temperature when the public space temperature is above 25^{o}C.

Individual retail outlet units are served by individual chilled water FCUs controlled locally.

Report #: PT4
Fluid Chiller,
Portugal

Installed capacity

The installed chiller nameplate cooling capacity of 141.6kW has been adjusted using the manufacture's literature at 35°C ambient and a typical 21% Glycol reduction factor, to 126.58kW. Although the treated area of the building was not determined exactly we have shown a normalization of 50 to 60w/m^2 which, when compared to the CIBSE Guide 'F' Good Practice benchmark of between 90 and 100W/m^2.
The conditions were being met throughout the building with no complaints being recorded – this being achieved during an ambient temperature of 28.6°C with both of the chiller's two circuits efficiency being compromised by refrigeration faults, thus limiting the cooling capacity to around 85% or possibly less.

Each of the chiller circuit's capacity of 63.29kW (141.6/2), when adjusted to the ambient temperature of 28.6°C, would increase to 71.34kW by dint of 2% increase in efficiency for every 1K decrease in condensing temperature, which compares favourably with the ClimaCheck analyser's value of 72.7kW on circuit #1, after the suction superheat was corrected.

It could be said that the relatively small chiller sizing is a testament to the use of the Thermal Storage Ice Bank and external solar shading.

There are a total of 112 fan coil units installed, which if the size of the inspected sample are typical, their installed capacity is grossly oversized, as even if they were the lowest rated model their total nominal cooling would be 212.8kW (202.16kW Glycol de-rated) or 58% oversized. However, by dint of the high level of installed pump capacity being four times the CIBSE Good Practice at around 8W/m^2, it would suggest an even higher installed FCU capacity.

However, it would be difficult to imagine, by dint of our observations that all or even a large proportion of the FCUs would operate at any given time even under extreme conditions whether just fan only or with an element of cooling, thus negating a possibility of excessive fan power input; any 'extra' cooling would be negated by lowering the demand on the general area fresh air FCUs.

Maintenance

The equipment outwardly appeared generally to be in a good and clean condition, which was testament to the maintenance visits every three months but the level of maintenance may need to be enhanced, at least to conform with the F-Gas Regulations, to maintain the correct operation of the chiller refrigeration circuits.

Operation and Control

The building has full fresh air hydronic FCUs on each floor to maintain a temperature of 25°C, controlled centrally, with smaller local, floor mounted free air discharge terminal hydronic units to trim the temperature by +/- 2°C, as required, using inbuilt controllers, whilst operating on a daily time schedule.

The required zone temperature is met by controlling the fluid through the fan coil with individual electronic valves.

It was evident that the local units were rarely switched on – the cooling requirement being met by the fresh air units, although there was evidence that they are more likely to be switched on in the Heating season.

The fan coil units are fed with glycol/water mixture at 7^0C from initially, the Thermal storage Ice-bank and the fluid chiller when the ice is depleted.

Efficiency

The ice build is performed overnight, primarily to take advantage of low off peak electricity tariffs. However, the consequences of the lower operating fluid temperature would be to depress the efficiency, although this would be offset completely by a similar 11K reduction in night time ambient temperatures, with net savings in absorbed power of **2% to 4% per further 1K reduction in ambient temperature**.

The steadier state operation of the ice build period would also reduce the compressor cycling and its associated high electrical start up input.

Using the adjusted cooling capacity and absorbed power we have calculated the EER at 2.88 which compares favourably with that from the manufacture's literature of 2.91 and ASHRAEs recommended 2.8 minimum for packaged air cooled chillers – compared to the 3.28 suggested on the nameplate.

The FCUs inspected although oversized shown very good Specific fan Power values i.e. very much lower than CIBSE Good Practice values.

The chiller is shaded, through deliberate building design, with only the condenser air discharge section at the top exposed to the elements – the condenser coils therefore not being affected by solar gain, ensuring maximum efficiency.

Report #: PT5
Fluid Chiller,
Porto, Portugal

Installed capacity

At 7°C/35°C leaving chilled water/ ambient temperature the installed capacity of 241.2kW, which at between 82 and 104W/m^2, compares favourably with CIBCE's Guide 'F' UK's *Good Practice* of 90 to 100W/m^2, although the re-evaluated normalization of 83 and 93W/m^2 for 4°C/35°C is more commiserate with our zone heat load calculations of between 64 and 71.55 W/m^2.

Maintenance

The equipment outwardly appeared generally to be in a good and clean condition, which was testament to the maintenance visits every three months although there were visual signs of refrigerant leakage. Using the information gathered in the verification inspection there would appear to be some issues with the refrigeration circuits indicated in the superheat and sub cooling values which are associated with a shortage of refrigerant.

The level of maintenance, therefore, may need to be re-assessed; and enhanced to at least conform with the F-Gas Regulations, to maintain the correct and efficient operation of the chiller refrigeration circuits.

The condensers have adequate access free air and are not affected by any hot air recirculation.

Operation & Control

The building is served by three plenum systems consisting of three roof top AHUs to provide fresh air and maintain a general zone temperature of 25°C, controlled centrally, with smaller local, floor mounted free air discharge chilled water terminal units to trim the temperature by +/- 2°C, as required, using inbuilt controllers, whilst operating on a daily time schedule.

The required zone temperature is met by controlling the fluid through the fan coil with individual electronic valves.

Efficiency

Operating with a 4°C leaving chilled water temperature, instead of a typical/standard 7°C, the chiller's capacity is reduced by 8.58% from 2471.2kW to 193.5kW – a reduction of 2.86% per 1k, with the EER decreasing by 8.9%.

The specific Fan Power was calculated at 1.7kW/m^3/s, which would be considered reasonable for a modern building.

Report #: PT6
AHU with district cooling
Portugal

Installed capacity

The nominal cooling capacity of the AHU was determined to be 16.77W/m^2. However, our Heat Gain calculation, in this north elevation externally solar shaded building, was deemed to be only 30.36W/m^2 the shortfall would be taken up by chilled beams in the zones.

A common district chilled water system supplies water to the AHUs at 6^{o}C and although there were suggestion from the BEMS sensor readings that the water was 'losing' several degrees by the time it reached the AHUs we obtained our own reading of a satisfactory 6^{o}C (coil specification 7/13^{o}C @ 32^{o}C & 40%RH) which was comparable with the thermometers installed in the pipe-work.

No information was found or available for the chilled beams. However, as they would require a minimum cooling capacity to trim the zone temperatures by 1^{o}C, we can assume them to be of no more than a typical 1 to 1.5kW which at 1kW would amount to 80kW in total, or 22.55W/m^2, thus increasing the total installed cooling capacity to, potentially, 39.32W/m^2.

No information for the chilled water pumps were collated as they could not be identified from the many installed in the central pump plant room.

Maintenance

The AHU is in good condition with a maintenance visit every three months; but despite this the pre-filters were considered to be visually very dirty – unlike the main filters they are not monitored by the AHU controller and therefore require periodic visual inspection.

The chilled beams are outwardly in good condition.

Operation & Control

The zone temperature is maintained by a three way chilled water diverting valve at the AHU cooling coil, which is controlled from the BEMS.

With the cooling coil operating at 82.27% (51.39kW) of full load we would expect the coil TD to be 4.9K – given a 6K design, however the 4K value recorded suggests that the water flow is slightly lower than would be expected – which conflicts with the high chilled water pressure drop of 1.5bar recorded from the installed gauges, from which we would conclude that the gauges may be inaccurate – or there may be a blockage.

There were around six zoned chilled beams to one temperature controller which enabled trimming of the set point by +/- 1^{o}C.

It was apparent that there was a history of complaints, although not at the time of the inspection with the three way valve modulating down to 27.93% cooling capacity, that the room temperature was, at times, too high, which were dismissed because the cooling coil was delivering full cooling at the time. However during the inspection the valve controlling the LPHW flow was found to be passing causing the conditioned air to be reheated to 30.6^{o}C before entering the building.

This condition would have been disguised by dint of the chilled beams making up for it until high enough external loads could not be dealt with.

The zone conditions were being met during the inspection on a sunny day with an ambient temperature of 26.1^{o}C with a part load performance from the AHU coil of 34.9kW (18.9Wm^2) with the heating valve passing - the chilled beams compensating.

Cooling capacity measurements of the cooling coil were taken with the LPHW valve passing (15.04kW) and with it manually closed (51.39kW) a difference of 36.35kW – our estimate of the total chilled beam cooling capacity is 80kW.

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Report #: PT7
AHU with district cooling
Maia
Portugal

Installed capacity

The nominal cooling capacity of the Swegon AHU was determined to, what appeared to be, a reasonable 72.78Wm^2. However, our Heat Gain calculation, for this central core area in this externally solar shaded building, was deemed to be only 38.75Wm^2.

A common district chilled water system supplies water to the AHUs at 6°C and although there were suggestion from the BEMS sensor readings that the water was 'losing' several degrees by the time it reached the AHUs we obtained our own reading of a satisfactory 6.3°C (coil specification 7/13°C @ 32°C & 40%RH) which was comparable with the thermometers installed in the pipe-work.

No information was found or available for the chilled beams. However, as they would require a minimum cooling capacity to trim the zone temperatures by 1°C, we can assume them to be of no more than a typical 1 to 1.5kW which at 1kW would amount to 46kW in total, or 24.9Wm^2, thus increasing the total installed cooling capacity to, potentially, 97.76Wm^2 – which at present is oversized but would be required in the case of full occupancy in the future.

No information for the chilled water pumps was collated as they could not be identified from the many installed in the central pump plant room.

Maintenance

The AHU is in good condition with a maintenance visit every three months; but despite this the pre-filters were considered to be visually very dirty – unlike the main filters they are not monitored by the AHU controller and therefore require periodic visual inspection.

The chilled beams are outwardly in good condition.

Operation & Control

The zone temperature is maintained by a three way chilled water diverting valve at the AHU cooling coil, which is controlled from the BEMS.

With the cooling coil operating at 26.1% (34.93kW) of full load we would expect the coil TD to be 1.56K – given a 6K design, however the 2.3K value recorded suggests that the water flow is slightly lower than would be expected – which conflicts with the high chilled water pressure drop of 1.6bar recorded from the installed gauges, from which we would conclude that the gauges may be inaccurate – or there may be a blockage.

There were around six zoned chilled beams to one temperature controller which enabled trimming of the set point by +/- 1°C.

Efficiency

The Swegon AHU appears to have an excellent efficiency, with a Specific Fan Power of 1.44W/(litres·s^{-1}) compared to CIBSE's good practice minimum value of 2.0/(litres·s^{-1}) recommended for systems with

heat recovery, and a value of 7.1Wm^2 (Treated Floor Area) of full fan power compared to CIBSE's Guide 'F' good practice values of between 6.8 and 7.2Wm^2 for new buildings.

The zone conditions were being comfortably met on a sunny day with an ambient temperature of 24.9^{o}C with a part load performance from the AHU coil of 34.9kW (18.9Wm^2).

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Report #: PT8
Chilled water FCU
Maia
Portugal

Installed capacity

The nameplate installed cooling capacity value of 11.6kW (260W/m) relates to a motor reference R1, the highest of seven fan speeds potentially available although the unit comes prewired for three speeds (although they can be modified to suit on site), R6, R4 and R2 which relate to 6.59kW (147.6 W/m), 8.85kW (198.2W/m) and 10.9kW (244W/m) respectively according to the manufacturer's specification sheet and 5.08kW (113.75W/m), 6.72kW (15.5W/m) and 8.09kW (181.15W/m) respectively according to Eurovent.

When compared to our calculated room heat gain the FCU would appear to be oversized.

The difference between the manufacturer's lowest rating 5.33kW (Fan motor Reference 7) and our calculated room heat gain of 1.36kW is 3.97kW which would accommodate, for instance, an unlikely further 40 people more that the 5 that we allowed for considering the current occupancy.

Maintenance

The AHU is in good condition with a maintenance visit every three months which is relfected in the clean condition of the filters.

Operation and Control

Although the FCU is furnished with a 2 way chilled water regulating valve, the zone temperature of 24^{o}C appears to be met by the BEMS cycling the fan between a 'high' speed setting and a very low speed although it is not known which of the fan references have actually been selected.

The duct branch to each linear air discharge grille is furnished with a regulating damper, however one appears to be completely closed, as there is no air flow from the grille, unlike the other grille which has an access panel to the damper - the damper is likely to have remain closed from the installation date as there is no access to it.

Efficiency

Whilst our measured cooling output of 7.28kW compares favourably with the manufacturer's mid range capacity the air flow was relatively low, at 427m^3/h is 64% of the rated 670m^3/h, at the lowest fan speed, with the Specific Fan Power values of 1.58 m·s^{-1} and 0.71m·s^{-1} respectively - the former although considerably higher is within recommended limits.

The Coil By-pass Factor of 32.56%, however, would suggest a reasonable performance.

We had no reason to believe that the duct work pressure drop, on the relatively short run and simple configuration, was more than the specified 40kPa and so would conclude that the problem may lie with the closed damper.

We also had no reason to believe that there would be a reduction in efficiency because of the closed damper, from a control or air distribution point of view, owing to the small area involved.

Had the smaller FCU in the range been installed then the fan power input could have been reduced by around 40% from a range of 132W to 270W, for the installed unit to 76W and 175W for the smaller version.

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Report #: PT9
Screw and Centrifugal fluid chiller
Portugal

Installed capacity

There is installed N+2 chiller cooling capacity of 12692kW (328W/m^2). There are two absorption chillers which have a nominal cooling capacity of 1846kW each, two screw fluid chiller each have a nominal cooling capacity of 1303kW each and each have a nominal input of 2271kW, and the two centrifugal chillers each have a nominal nameplate cooling capacity of 2750kW with a nominal nameplate input of 915kW, although the manufacture's literature states that the minimum cooling capacity to be 2800kW and the input 436kW

Maintenance

Maintenance checks are carried out by in-house staff on a monthly basis, which is testament to central systems' good condition. AHUs and FCUs within the retail units are the responsibility of the tenants, which conflicts with the standard of maintenance carried out on the central plant by the centre management

Operation, Control and Monitoring

The Absorption chillers operate as the base load machines with the Centrifugal chillers enabled via BEMS when required. The Screw chillers primary use is as a standby system for the Absorption chillers. All chillers have a leaving water set-point of 6°C and operate on a time schedule of 08:00 until 00:00 Monday to Friday.

Efficiency

Absorption chillers have low efficiencies compared to mechanical chillers and therefore are only usually considered for use when there is adequate low grade waste steam or hot water available—especially during the cooling season. In this instance "waste" hot water from gas driven electricity generators is used, and, as such, is cost effective rather than energy efficient – the benefit coming from the income raised by the sale of the whole of the electricity generated to the national grid.

From an energy efficiency standpoint, it would make more sense to operate the Centrifugal chillers (EER 6.42) for the base load with the Screw chillers (EER 4.8) at first Stand-by with the Absorption chillers (EER 0.7) as second Stand-by.

The operating pressures and temperatures for one of each of the Centrifugal and Screw chillers were in the main as predicted and therefore testament to their efficient operation, although the there is a high condenser water TD of 6.4K on the Screw chiller, which should have been 1.34K (5 x 0.2675) given the cooling out-put at the time of the inspection of 468.1kW i.e. 26.75% of full load.

If the water flow to the retail units was corrected without the use of the flow and return bypass modification the chilled water setpoint could be increased to 9°C (as this is the water temperature currently being supplied after the mixing effect has taken place). For every 1°C the chilled water setpoint is raised a 2-4% increase in liquid chiller efficiency is possible.

Report number #: SLO1
Daikin Fluid chiller
Ljubljana
Slovenia

Installed capacity

The installed AHU cooling capacity of 104W/m^2 would be reasonable for this type of facility and the installed nominal chiller cooling capacity of 154.71W/m^2 is not significantly oversized considering the chiller's two circuits and the motor compressors' step-less control.

Maintenance

Maintenance checks are carried on a six monthly seasonal basis by in-house maintenance staff but it is uncertain whether specialist tasks with F-Gas Regulation competent personnel, for instance, are being carried out other than on an ad hoc basis. The units appear to be well maintained in general.

Operation, Control and Monitoring

The chilled water produced is circulated to six separate AHU cooling coils serving individual areas, which in turn directly cool the internal air. The areas are all controlled to a 23oC internal building set point, and the cooling system to a water temperature of 9.5oC returning to the chiller. There is no BEMS or time clock arrangement in place - the cooling system running in manual operation 24 hours a day during April to September – depending on ambient conditions. From September until March the Fluid chiller is shut down and used as required.

Efficiency

The installed chiller has a full load EER of 4.83 (Eurovent), which is defined has having a Euorvent 'B' energy efficiency classification in contrast to the manufacturer's specification and our own measured value, which both fall into Class 'D', and the iSERV spreadsheet which would have rendered it unclassified.

The average input of 32.2kW for one compressor, as determined by the Climacheck Performance Analyser, was lower than 37.25kW - the 50% share of the Eurovent value, and with an average output of 133kW in contrast to Eurovents value of 180kW - 50% share of full cooling duty. This reduction in cooling capacity is down to the compressor off loading with the chilled water return temperature below 12^{o}C at the end of the test.

With a return water temperature of 16.2^{o}C, the Climacheck Analyser recorded the cooling capacity at 181.9kW with an input of 37.7kW – an EER of 4.82.

We can conclude, therefore that the chiller is operating extremely efficiently.

The total installed pump capacity of 6.67kW equates to an acceptable 2.82W/m^2 which lies between CIBSE's Good Practice Guide 'F' recommend values for '*new building'* and '*refurbishments*' of 1.8W/m^2 and 3.1W/m^2 respectively.

The total Installed full load Fan rating for both Supply and Extract AHUs of 18.82W/m^2 (TFA) which is considerably higher than according to *The Energy Conservation Guide 19* values of 8 and 12W/m^2 for 'Good' and 'Typical' Practice respectfully.

Report #: SLO2
DX Air cooled system
Ljubljana
Slovenia

Installed capacity

The installed capacity of the condensing unit of 39.7kW (101W/m^2) of this full fresh air system, would appear be adequate for this restaurant area which has three internal walls and tinted windows in the fourth wall facing a shaded courtyard, and set to a zone temperature of 23^{o}C.

As we were unable to obtain any details, from any source, regarding the capacity of the air handling system we have determined, with the aid of our AC Estimator Spreadsheet (Table 5), its cooling capacity at 41.72kW (106W/m^2) commiserate with the condensing unit.

The system provides, for this type of application, a prudent 6.6 air changes per hour ensuring better efficiency, during high ambient temperatures, had there been typical values of between 8 and 12.

Maintenance

Unspecified maintenance checks are carried out six monthly, on seasonal basis, by in-house maintenance staff and it is uncertain whether scheduled specialist contractor checks, F-gas Regulation leak checking for instance, are being carried out other than on an ad hoc basis.

The units appear to be well maintained in general. The condensers have adequate access free air and are not affected by any hot air recirculation from the adjacent condenser discharge fans. Using the information gathered in the verification inspection there would appear to be some issues with the refrigeration circuit as the system was alarming out on low suction pressure immediately on being brought into operation.

Low pressure was also observed when the on coil temperature was maintained at >20^{o}C by manually deploying the LPHW coil, as was the superheat found to be high at 12.2K, thus indicating a probable shortage of refrigerant.

Further diagnostic checks would be needed to verify this, however, it would be prudent to do this during under summer conditions.

Operation, Control and Monitoring

The installed units have no variable fan speed to maintain condensing temperature or any compressor capacity control as both functions use on/off switching. The site could make savings by using variable speed fans which allow for closer control of the condensing temperature, and by using variable speed compressors which allow for closer control to the required cooling output demand to maintain room conditions. This would also reduce the electrical consumption compared to only switching them on and off when required.

The compressor is a fixed speed scroll type with no capacity control. The condenser fan motor also runs at a fixed speed and operates in conjunction with the compressor, when required, cycling to maintain condensing temperature. The evaporator coil is located within the AHU supply ductwork.

There is an electronic controller within the control panel situated in the plant-room which controls the LPHW three way valve as well as the condensing unit for cooling. Set point adjustment is effected at the controller although it is linked to the BMS for automatic time scheduling or ‘manual’ override, but it is uncertain whether monitoring is possible.

The AHU fan motor is inverter controlled – pre-set to the required air volume.

Efficiency

The Specific Fan Power at 0.34W/(litre.s-1) for a measured input of 0.69kW significantly lower than is at the low end of CIBSE'S Guide 'F' fan Good Practice values of 1.8 and 2W/(litre.s-1) for new buildings and old buildings respectively, and therefore showing excellent efficiency, and which is confirmed by the Installed Fan Motor Full Load value of 6.62W/m^2 (TFA), for which the Energy Efficiency Guide 19 suggest it should typically be between 8 and 12W/m^2.

Combining the measured AHU fan power input and the nominal cooling capacity, @ 36°C ambient temperature, as found in the manufacturer's literature we find a system EER of 2.67 which is in between the (CIBSE Guide F) EER of 2.77 and 2.33 values of High performance and Low performance guidelines respectively.

It is possible for modern systems of a similar type and design have a EER of 3.45 and over @ 35°C as found on the Eurovent website. This would lead to an increase of 22.6% efficiency over the existing system.

The efficiency is currently also being impaired by the system being short of refrigerant.

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Report number #: SLO3
Air cooled packaged liquid chiller
Ljubljana
Slovenia

Installed capacity

The installed nominal capacity of the Trane water chiller at 118.54W/m^2 is commiserate with CIBSE's General Office benchmark of 125W/m^2, and 75W/m^2 for Interior Zones for this open plan office.

Maintenance

Manufacturer's preventive maintenance procedures and other specific checks are carried six monthly by in-house maintenance staff but it is uncertain whether specialist tasks with F-Gas Regulation competent personnel, for instance, are being carried out, although intervention maintenance is also carried out in the event of a call out due to failure.

Condenser air filters dirty- although a maintenance was due.

Operation, Control & Monitoring

The chiller is controlled by The Chiller Management System SMM) Scroll Manager0 Module) with the following functions:-

- **Leaving chilled water temperature control:** The temperature of the water is measured at the evaporator outlet the SMM compares this value with the set point and starts or stops the compressors following a PID algorithm.
- **Condensing pressure control:** The SMM module controls the common centrifugal three scroll fan to maintain an optimum condensing pressure.
- **SMM Control Function:**
    a. Short cycle protection taking into account the frequency of compressor starts.
    b. Automatic re-start after a power cut.
    c. Equalization of the number of starts and the operating hours of the compressors.
- **Optimization:** In order to reduce electricity consumption the SMM module can automatically adjust the chilled water set-point in relation to the outdoor temperature.
- **Communication:** The SMM module caters for different types of communication systems, which simplifies considerably the maintenance and can supply information on the operating conditions of the chiller.
- **Remote control:** Dry contacts and analogue outputs allow for the remote control and surveillance of the chiller including adjustment of the chilled water temperature.

Efficiency

We have shown that the chiller is likely to have a Eurovent Energy Efficiency Classification 'C' rating, which is typical for those built in 1996.

The chilled water pump installed capacity at 4.35W/m^2 is higher than CIBSE's maximum typical value of 3.4W/m^2 and significantly higher than their Good Practice value of between 1.8 and 2W/m^2.

The shortage of refrigerant in Circuit 1 represents a loss of compressor efficiency by 6.4% to 12.8% (2% to 4% per further 1K reduction in evaporating temperature) by virtue of the 3.2K reduction in the evaporating pressure from our predicted value.

Report Number #: SLO4
Condensing unit with AHU
Ljubljana, Slovenia

Installed capacity

Using the installed nominal cooling capacity of 9kW is designed to complement the high air volume (18.5 air changes per hour) ventilation system, when comfortable conditions in the Hot Food Preparation cannot be maintained by fresh air alone.

At 101.7W/m^2 it would not necessarily be able to maintain a 'low' design temperature during high ambient temperatures, nor would it be expected to do, as besides requiring an unwanted (for power economy reasons) high cooling capacity, there could be problems with condensation forming in the area owing to the relatively cold air discharging into the hot area.

The installed condensing unit is designed for use on a 'multisplit' system for which the manufacturer supplies capacity data for various connection options with a range of selected FCUs. There is no data, therefore, available for the installed bespoke system.

At Eurovent conditions of 27°C Indoor and 35°C outdoor temperatures, the cooling capacity would be 8.55kW with a 2.97kW input (EER: 2.88), with a total fan coil air volume of 2332m^3/hr compared to the calculated operating value of 4136.4m^3/h and the unit maximum rating of 7250m^3/hr.

Maintenance

Maintenance checks are carried six monthly by in-house maintenance staff but it is uncertain whether specialist tasks with F-Gas Regulation competent personnel, for instance, are being carried out.

Operation, Control and Monitoring

The condensing unit which, houses a fixed on/off compressor and three speed condenser fan motor which is used to maintain the condensing temperature connected by refrigeration pipe-work to a DX cooling coil situated in the supply duct from the AHU situated in the kitchen plant room. The system which also includes an LPHW heating coil operates to a zone set point of 23°C.
There is no specific time schedule as the system would be employed only when require i.e. during hot food preparation.

The fan motor is not inverter driven as maximum air flow is required to provide 'free cooling' whenever possible.

Efficiency

The Installed Specific fan Power of 2.5 and the measured value of 1.7 is reasonable - a more efficient motor could be considered but it's difficult to envisage great savings for this intermittent ventilation, system.

The EER for the R22 condensing unit, when paired correctly with DAIKIN fan coil units, would have a Eurovent Class 'C' rating, in contrast a modern R410a, nominal 10kW cooling capacity be in the more efficient Class 'B' category, have a lower input power and the compressor would have inverter control.

However, with no load because of the low ambient temperature and no way of overriding the controls we were unable to carry out any cooling capacity and power input checks.

Report #: SLO5

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Liquid chiller with supply/extract and heat recovery AHU's
Ljubljana
Slovenia

Installed capacity

The chiller installed cooling load capacity of 64.56W/m^2 appears moderate but has been affected by the low requirement for the 202 guest bedrooms, whilst the installed cooling capacity normalization values for the AHUs are as would be expected for the various zone requirements for this type of building use and construction.

Operation, Control and Monitoring

The liquid chiller has two cooling circuits each furnished with three scroll compressors, which are staged for capacity control using a microprocessor with a PID algorithm.
There are also three condenser fans, per circuit, controlled by a progressive start-up, variable fan speed controller, operating with the compressors, whenever there is a cooling demand, in order to maintain the correct condensing temperature.
The two evaporators are contained in a common brazed plate heat exchanger equipped with an electronic expansion valve which offers optimized superheating under any conditions for maximum efficiency.
The AHU's, other than KN1 being a supply air only unit, use heat recovery/rejection through a cross flow box to help lower/increase (dependant on season) the ambient air before reaching the heating and cooling coils. They are controlled to a building set point of 22^0C by the BMS; and because of the needs of hotel, the system run twenty four hours a day seven days a week.
The guest bedrooms, however, are on local control.

Maintenance

The units appear to be well maintained in general with no visual signs of refrigerant leakage and the condensers have adequate access to free air flow.
There is a contract in place with a specialist air conditioning company to carry regular maintenance inspections.

Efficiency

The installed chiller has an EER of 2.7 (an Eurovent 'C' classification) based on the manufacturer's specification literature and Eurovent ambient conditions, which is historically fairly typical, however, the same manufacture can now offer a similar sized chiller with an EER of 3.11 - an Eurovent 'B' classification.

HVAC inspection comments relating to buildings where IAQ monitoring was also undertaken.

HVAC Inspection Report Reference	IAQ monitoring Report Reference	Comments from IAQ monitoring report	Comments from HVAC inspection.
GR6	IAQ15	No irritation or discomfort	Overall well maintained system - above minimum typical forced fresh air level.
GR4	IAQ12	No irritation or discomfort	Units are in a reasonable condition - above minimum typical forced fresh air level.
GR3	IAQ38	Possible irritation or discomfort depending on the interaction with the other factors	Overall well maintained system - does not have forced fresh air.
GR3	IAQ50	Possible irritation or discomfort depending on the interaction with the other factors	Overall well maintained system - does not have forced fresh air.
GR1	IAQ07	Possible irritation or discomfort depending on the interaction with the other factors	Overall well maintained system - does not have forced fresh air.
PT5	IAQ2	No irritation or discomfort	Two of the three AHUs are not operational due to faults and resulting in some zones not being supplied with forced fresh air.
PT4	IAQ1	No irritation or discomfort	Overall well maintained system although a filter was missing from one AHU - above minimum typical forced fresh air level.
BE4	IAQ23	No irritation or discomfort	Well maintained system. Humidistat wrongly positioned may cause poor RH control - above minimum typical forced fresh air level.
BE1	IAQ27	No irritation or discomfort	Overall well maintained system - above minimum typical forced fresh air level, but only if the terminal units are manually enabled.
HU3	IAQ39	No irritation or discomfort	Overall well maintained system - above minimum typical forced fresh air level.
HU4	IAQ42	No irritation or discomfort	Overall well maintained system - above minimum typical forced fresh air level.
UK8	IAQ45&46	No irritation or discomfort	Units are in a reasonable condition - lower than minimum typical forced fresh air level.
AT13-AT16	IAQ47	No irritation or discomfort	Units are in a reasonable condition - does not have forced fresh air.
AT1-AT9	IAQ48	No irritation or discomfort	No maintenance checks carried out - does not have forced fresh air.

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