Report Austria

In the framework of iSERV Intelligent Energy for Europe project a compact Indoor Air Quality system was developed and placed in buildings with HVAC systems larger than 12kW in different European metropolitan cities in order to investigate the relationship of IAQ and energy consumption. The sensor was capable of measuring temperature, relative humidity, CO2 and level of VOC'Ss while energy monitoring systems were also engaged to provide information on the building and HVAC system energy consumptions. The data was recorded locally and downloaded on a regular basis by NKUA.

SUMMARY

The measurements taken for the air quality in the buildings can be considered satisfactory. The air quality in all offices can be considered as good, as all of them had a majority of values below 600 ppm, but 4 offices only recorded a significant percentage of CO_2 values over 1000 ppm. CO_2 concentrations in buildings below do not exceed the limit of 1000 ppm, indicating that ventilation is adequate and occurs in higher concentrations during the operation of the office. Moreover, with refer to VOCs, in offices the air quality could not lead to any irritation or discomfort. VOCs concentrations in offices below could cause no irritation or discomfort, while Tair maintained at higher levels during the operation hours. Last but not least RH was at the same levels during the whole day or at higher levels during the non – operation hours. Finally, the frequency distributions showed that in this office the ventilation is adequate and the air quality leads to no irritation or discomfort.

1 DESCRIPTION OF THE BUILDINGS

The systems IAQ 47 and IAQ 48 are located in offices in Wien, Austria from August 2013 to September 2013 and from January 2014 to March 2014. Both buildings have been constructed on 14/3/1905. The first building has an air conditioned area of 1034,73 m^2, while the second one has an air conditioned area of 465,6 m^2.

2 RESULTS

2.1 Carbon dioxide measurements (CO_2)

CO_2 is produced by human expiration and is often observed in increased quantities in places with many people without adequate ventilation. It is not toxic, but it can cause suffocation in high concentrations. Initially there was an attempt to select limits of CO_2 and Volatile Organic Compounds (VOC'S). Guided by CO_2 limits by ASHRAE it was made an adaptation to the limits to the buildings and it was used as limits the values 800 ± 2 standard deviation and 1000 ± 2 standard deviation, 800 ± 1 standard deviation and 1000 ± 1 standard deviation which led to a large overlap between categories. For this reason a frequency distribution took place, based on classes by CIBSE guide and the classes of buildings relative to carbon dioxide resulted as follows:

Indoor Air Quality	CO_2 Concentration [ppm]
Good	< 600
Acceptable	600 – 1.000
Bad	>1.000

To reduce carbon dioxide indoors it would be necessary not only to eliminate the emission but also to ventilate often the room.

The need for selecting the most appropriate limits of carbon dioxide led to frequency distribution and found that the offices recorded the majority of values 0 - 600 ppm thus they can be classified in the category of good air quality, suggesting that the ventilation of the buildings is adequate Below are given the total chart of CO2 frequency distribution and an indicative diagram of one office:

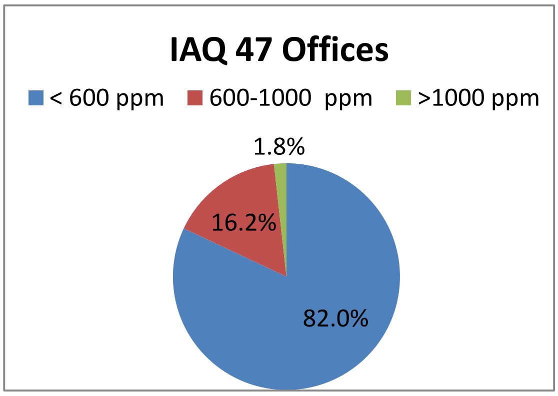

Diagram 1: Frequency distribution CO_2 (indicative)

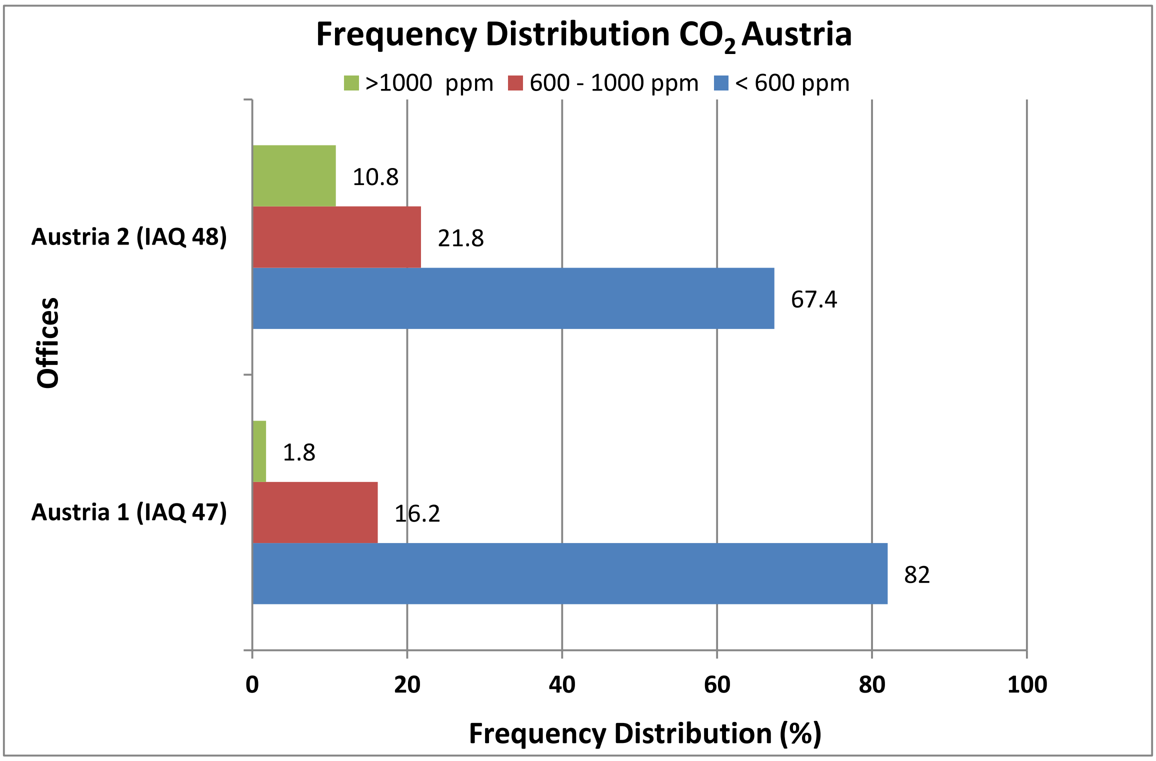

Diagram 2: CO_2 Frequency distribution

2.2 Volatile Organic Compounds measurements (TVOC's)

According to the European Directive 2004/42/CE as Volatile Organic Compounds, TVOC'S, defined as all organic compounds having an initial boiling point less than or equal to 250°C, measured at atmospheric pressure 101.3 kPa. According to EPA, the class of volatile organic compounds composed of all carbon compounds, which are involved in atmospheric photochemical reactions, except for carbon monoxide, carbon dioxide and carbonic acid.

The concentration of volatile organic compounds in the interior of buildings is derived from two species of sources (Wiglusz et al., 2002):

- The background emissions, such as chemical compounds derived mainly from construction materials and building equipment (furniture, etc). The background emission is continuous and has nearly constant transmission rate.
- Periodic emissions resulting from human activities such as smoking, cooking, cleaning etc.

The final concentration of volatile organic compounds in the interior of buildings depends on the transmission rate, the concentration in the external environment and the level of ventilation in the building.

Emissions of volatile organic compounds from the materials inside the building are an extremely complex phenomenon. These emissions are classified into two major categories (Wolkoff 1999, Zabiegala et al, 1999).

According to studies[1],, the concentrations of TVOC'S can be classified into four categories, depending on the effects that can cause in health. Furthermore, based on accredited institutions of the University of Athens the kits were calibrated, from which emerged the following correlation between price VOC'S output of the instrument and the scales by Molhave, as shown in the following table:

Total concentration	Sensor output (o/u)	Discomfort and Irritation Show	Exhibition scale
Less than 0.2 mg/m³ (Less than 0.05 ppm)	**Up to 10**	**No irritation or discomfort**	**Comfort Scale**
From 0.2 mg/m³ to 3.0 mg/m³ (from 0.05 to 0.80 ppm)	**From 10 to 20**	**Possible irritation or discomfort depending on the interaction with the other factors**	**Scale Exposure to multiple factors**
From 3.0 mg/m³ to 25 mg/m³ (From 0.80 to 6.64 ppm)	**From 20 to 30**	**Symptoms - Possible headaches depending on other factors**	**Discomfort Scale**
Over 25 mg/m³ (Over 6.64 ppm)	**Over 30**	**Additional neurotoxic effects may occur, apart from the headache**	**Toxic Exposure Scale**

Table 1: Scale of exposure to concentrations of volatile organic compounds (TVOC's)

[1] A. Molhave L., Human reactions to controlled exposures to VOC'S's and the "total VOC'S" concept. In: H, Knoppel and P. Wolkoff (eds.), Chemical, Microbiological, Health and Comfort Aspects of Indoor Air Quality - State of the art in SBS, Netherlands 1992, pp 247-261,

B. Molhave L., Volatile Organic Compounds, Indoor Air Quality and Health. In: Walkinshaw (ed.), Proceedings of Indoor Air 90, Toronto 1990, Vol.5, pp 15-33

C. Molhave L., Evaluations of VOC'S emissions from materials and products: solid flooring materials. In: Maroni M. (ed.), Proceedings of Healthy Buildings, '95, Milano 1995, Vol. 1, pp 145-162

Similar to carbon dioxide, it was made a frequency distribution for VOC's and found that the air quality could to lead to no irritation or discomfort, as the majority of hourly rates ranging from 0 – 10 o/u at both buildings Below are given the total chart of VOCs frequency distribution and an indicative diagram of one office:

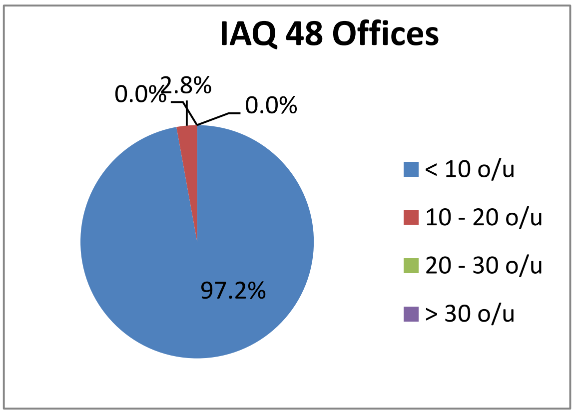

Diagram 3: Frequency distribution VOC'S (indicative)

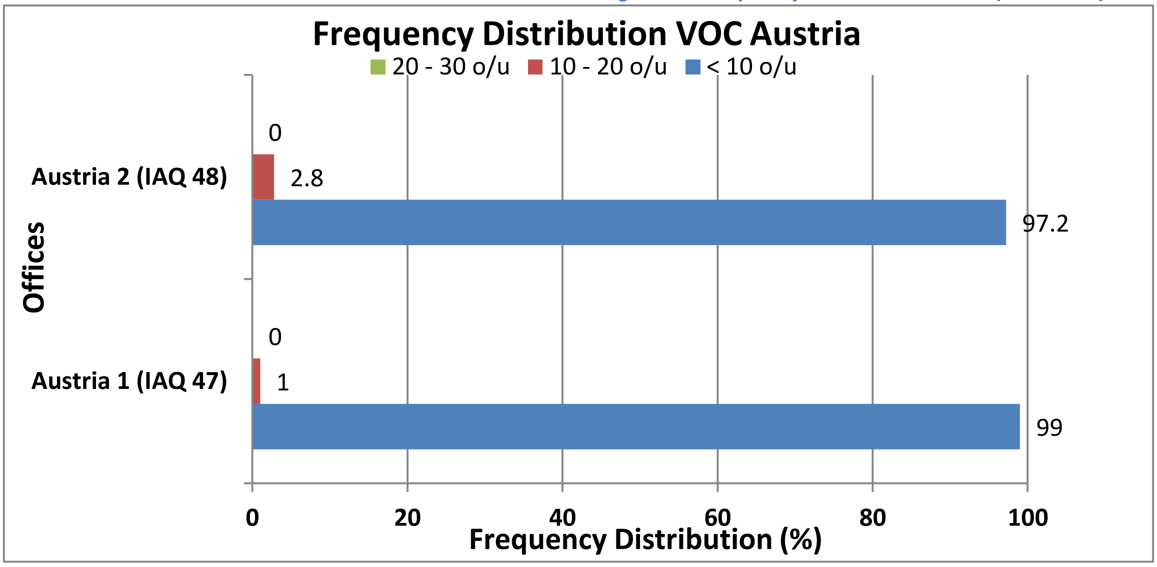

Diagram 4: VOCs Frequency distribution

3 MONTHLY VARIATIONS

At the following diagrams, the monthly morning and the daily values are illustrated. That means that the daily variation only in operation hours of each building for each month is depicted. The operation hours of office buildings are 8:00 – 18:00.

3.1 CO_2

There is a downward trend at the monthly CO_2 measurements for the systems IAQ 47 and IAQ 48 with the maximum of these exceeding the limit of 1000 ppm.

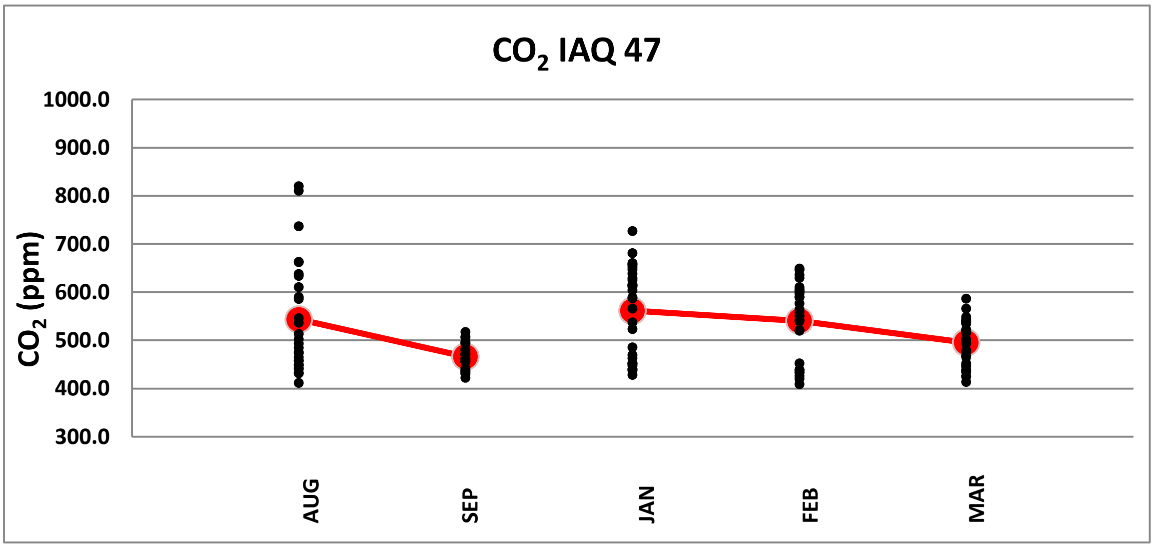

Diagram 5: Monthly CO2 measurements

3.2 VOC's

There is a downward trend at the monthly VOC'S rates for the systems IAQ 47 and IAQ 48 and the indoor air quality could lead to no irritation or discomfort, while some days the limit of 10 o/u was overcome.

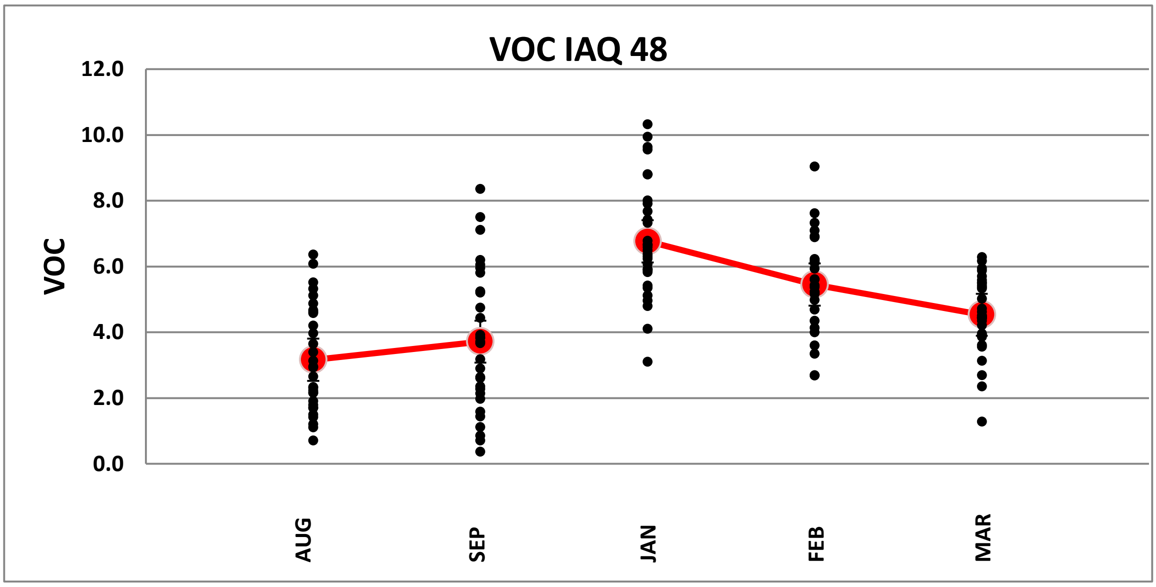

Diagram 6: Monthly VOC measurements

4 CONCLUSIONS

In conclusion, the building's air quality is considered to be good, since the recorded CO_2 values were 0 - 600 ppm. Moreover, both buildings recorded the majority of the hourly VOC's measurements between 0 – 10 o/u (0 - 0,05 of the Molhave scale), so they might be able to cause no irritation or discomfort. The percentages and the diagrams of values for CO_2 and VOC's from Frequency distributions for each building are given below:

CO_2 (%)					
IAQ No	Building Type	< 600 ppm	600 - 1000 ppm	>1000 ppm	Category
32	Office	82	16.2	1.8	Good
36	Office	67.4	21.8	10.8	Good
VOC's (%)					
IAQ No	Building Type	< 10 o/u	10 - 20 o/u	20 - 30 o/u	Category
32	Office	99	1	0	No irritation or discomfort
36	Office	97.2	2.8	0	No irritation or discomfort

Table 3: Percentages of values for CO_2 and VOC's from Frequency distributions for each building

CONCLUSIONS FROM THE HVAC INSPECTIONS

IAQ47

This building is conditioned using a combination of split package, VRV and hydronic fan coil units installed internally to the zones they are serving and only use recirculated air. No fresh air supply was noted in either the physical inspection or the iSERVcmb spreadsheet. Any fresh air would be from infiltration only. The units were in poor condition but there was nothing to indicate that there would be any adverse effect on air movement.

Report1

Installed capacity

The installed 10kW nominal cooling capacity (163.55 W/m2) would be considered reasonable for this room, for which we have estimated a total maximum heat gain of 5.06kW (83W/m2.), which at 50.6% of the installed capacity. Although, using the ASHRAE rule of thumb of 248W/m2 as a typical normalization 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 35oC 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.

Report2

Installed capacity

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 normalization 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^{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 3.22 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

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^{o}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^{o}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

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.

Report3

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.

Report4

Installed capacity

The installed chilled water cooling capacity of 101.84kW equates to 244.8Wm^2 which compares favorably 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^o C return water temperature (minimum of 10^{o}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%)

Report5

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.

IAQ building Energieeffizienz (IAQ 48)

This building is conditioned using a combination of split package and monobloc through the wall units installed internally to the zones they are serving and only use recirculated air. No fresh air supply was noted in either the physical inspection or the iSERVcmb spreadsheet. Any fresh air would be from infiltration only. No maintenance was carried out on the units; return air filters were dirty which may have an adverse effect on air movement.

Report1

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

Report2

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

Report3

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^{o}C, 2.8^{o}C higher in temperature than the 19.4^{o}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)