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Experimentation of the CEN standard on inspection of air-conditioning systems

Maxime Dupont, Center for Energy and Processes (CEP), Ecole des Mines de Paris
Jérôme Adnot, Center for Energy and Processes (CEP), Ecole des Mines de Paris
Patrice Drapier, Electricité de France (EDF)
Bruno Georges, Ingénierie tous Fluides (ITF)

Abstract

The paper presents the first results of few “simulations” of inspection on real air-conditioning installations. The aim of the on-site testing is to check the feasibility, the efficiency and to determine the blanks of procedures proposed by the CEN standard. It is however only a small part of a larger study aiming to define best practices for inspecting and auditing of air-conditioning systems. Especially, that paper discusses of several topics: how long is the procedure for a whole building? What can an inspector conclude about the performances of the installation by applying the standard in that state? Is the incentive strong enough to encourage building owners to improve or replace their equipments? Using conclusions of that first experiment, the paper will suggest some improvements of the original checklist by detailing possible measurements that should be made in order to conclude more precisely on both sizing and efficiency.

Introduction

The regular inspection of air-conditioning systems became compulsory with the energy performance of buildings directive (EPBD). Although most member-states agree with the helpfulness of such an inspection in order to evaluate performances and to advice building owners on how to make improvements, the consensus about the content of the procedure is difficult to reach. A CEN (European Committee for Standardization) standard, shortly presented by the paper, partially gave answers by proposing a common basis. First critics are that the framework is lacking of flexibility, the scope is far too large, the procedure is fuzzy and then potential savings are low. In order to check the feasibility of the inspection, the CEN standard has been on-site tested on several technical installations.

There is no doubt the CEN standard is a good common basis. Several difficulties however remain with its applicability in that state especially for the assessment of both sizing and efficiency. Starting from the test conclusions, several improvements will be brought. The problem is then to have quantitative measurements cohabited with qualitative observations in order that inspectors are able to assess sizing and performances as objectively as possible while minimizing the time spent.

The development of more exhaustive checklists seems not sufficient to reach both objectivity and homogeneity in assessments. In that state, the standard lets a wide range of interpretations especially about the necessary actions that building owners will have to take after an inspection. Therefore, further developments at the European level are crucial in order that the regular inspection becomes a real incentive for building owners to invest in improvements or replacements.

The EPBD Article 9 makes regular inspection compulsory

Definitions

The EPBD (EP 2003) defines an air-conditioning system as “a combination of all components required to provide a form of air treatment in which temperature is controlled or can be lowered, possibly in combination with the control of ventilation, humidity, and air cleanliness”. Moreover, “the effective rated output (kilowatt) is the maximum calorific output specified and guaranteed by the manufacturer as being deliverable during continuous operation while complying with the useful efficiency indicated by the manufacturer".

The EPBD Article 9, named "inspection of air-conditioning systems", stipulates that "with regard to reducing energy consumption and limiting carbon dioxide emissions, Member States shall lay down the necessary measures to establish a regular inspection of air-conditioning systems of an effective rated output of more than 12 kilowatts". Moreover, "this inspection shall include an assessment of the air-conditioning efficiency and the sizing compared to the cooling requirements of the building". Finally, "appropriate advice shall be provided to the users on possible improvement or replacement of the air conditioning system and on alternative solutions".

The CEN Standard for the transposition of the EPBD article 9

Concerning the article 9 issue, the European Commission requested CEN to develop a standard (CEN 2004) defining the guidelines for inspection of air-conditioning systems in order to accelerate the transposition and to homogenize national laws on that topic. The CEN philosophy was only to impose a minimal standard acceptable by every Member States. But it has been done to the detriment of the energy savings because almost only qualitative observations of operation and maintenance (O&M) were demanded. In order to compensate the lack of quantitative performance measurements and then to increase potential energy savings, the scope of article 9 was widened to its maximum. Thus, cooling equipments (reversible or not), water and air distribution, air-exhaust systems and the control system are included. Only, mechanical ventilation (without mechanical cooling) and heating only systems are excluded. Moreover, although several translations were possible for the 12-kilowatt limit of the article 9 (DUPONT 2005), the CEN chose the maximizing way: a building must be inspected when the sum of individual rated cooling capacities of each installed air-conditioners is higher than 12 kilowatts.

The inspected air-conditioning installations

What can an inspector conclude on the energy performances of an existing air-conditioning system by applying the CEN standard? That question was the basis of our study. We inspected (table 1) real systems in order to know about the feasibility and the efficiency of the CEN proposed solution. Our ambition was not to make a statistical study. The four inspected buildings are obviously not representative of the whole French and even European stock and then general observations we would make would not be the reflection of practices in force. Starting from our observations and taking into account the feasibility of some measurements and the time spent on site, we developed a simple procedure based on checklists that could be applicable by inspectors. Every method proposed is then deduced from both our experiment and inspection constraints (duration, feasibility, costs etc…).

The regular inspection of air-conditioning systems was developed in order to incite building owners to invest in improvements or even a whole replacement by proving them there are potential savings to achieve. But before any investment, buildings must be audited in order to determine which improvements are cost-effective. The objectives of the project, from which that paper is extracted, are to propose best practices for inspecting and auditing air-conditioning installations. The checklist-based structure of our method is then the same for these two levels of investigation. Only the time spent, metrology and tools used are different from inspection to audit.

Table 1: summary of the inspected buildings and systems

Owner	Location	Building	Zone	System	Control
Ecole des Mines de Paris	Paris, France	17th century Education Only few lecture rooms or offices are air-conditioned	415m^2 lecture room 310 occupants maximum Air-conditioned since 1985	64kW split-system 2-power levels Water-cooled Non-recycled water DX-AHU constant flow Heat-recovery	Thermostat Occupancy sensor for chiller Programmer for AHU
			150m^2 lecture room 130 occupants maximum Air-conditioned since 1997	29,7kW rooftop Constant flow Air-cooled Reversible (not used)	Timer Thermostat
			120m^2 lecture room 115 occupants maximum Air-conditioned since 1972	17,5kW packaged-unit Water-cooled Non-recycled water Constant flow Ducted Reversible (not used) Natural ventilation	Thermostat
Orpea	Agen, France	Built in 2001 Retirement home 3800m^2	3400m^2 treated areas 85 bedrooms Restaurant Living-room	8 VRF units (207kW) Air-cooled Reversible Mechanical ventilation Installation in 2001	BEMS
EDF	Moret-sur-Loing, France	Built in 1970 Restaurant	200 occupants maximum 400 meals/day Air-conditioned since 1970	80kW chiller 3-power levels Water-cooled Dry-cooler AHU constant flow 100% fresh air Extraction through kitchen hoods Storage	Supply temperature depends on outside temperature No time control
		Built in 1973 Offices	1140m^2 offices and meeting rooms 42 occupants Air-conditioned since 1993	197kW chiller 4-power levels Air-cooled AHU constant flow 34 FCU	One thermostat per FCU No time control

The development of our checklists

Necessary points to check

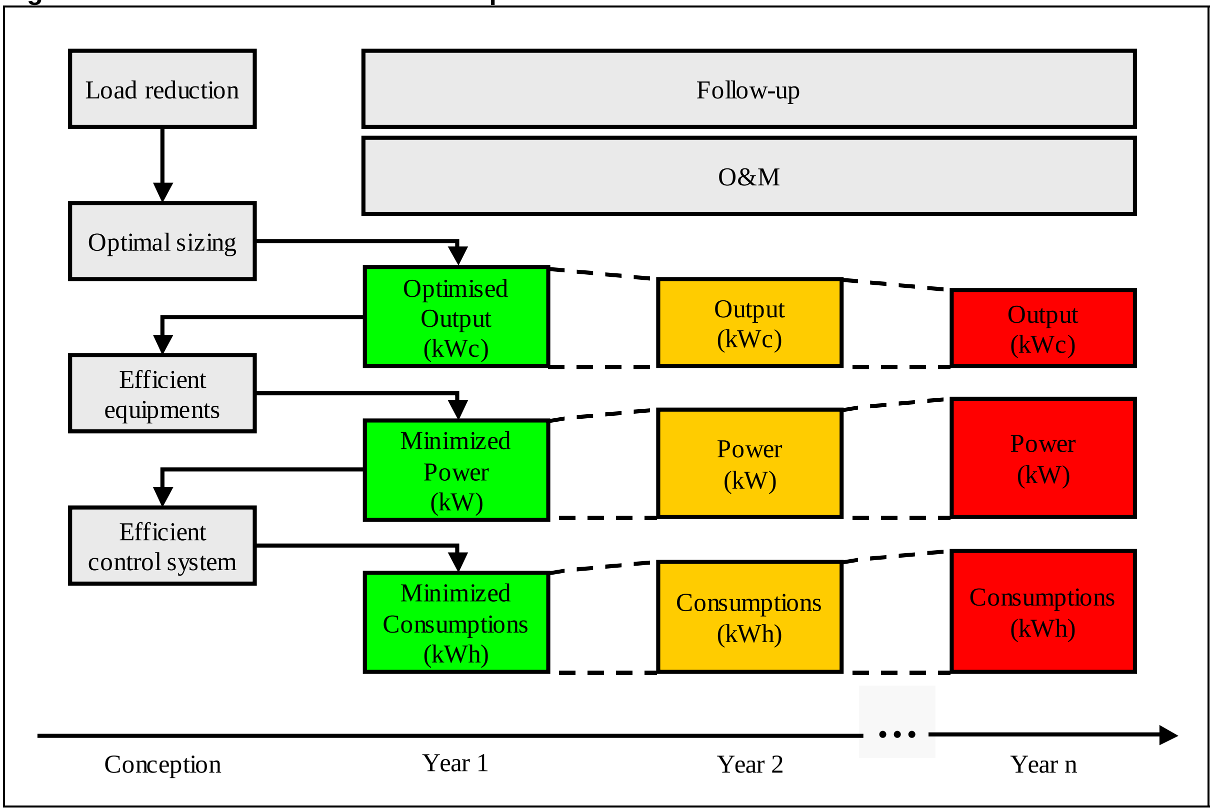
The EPBD article 9 only demands an assessment of both sizing and efficiency. However, that global performance assessment must not focus only on the air-conditioning system but also on everything that interacts with it. Like energy audits, it is better for the inspection to consider a whole system {building; equipments; occupants} because each component influences energy consumptions. Our idea was to develop checklists as exhaustive as possible so that an inspector can compare “bad” and “good” points in order to mark any air-conditioning installation. That is why our checklists were built to find any problem both in the design and during the every day operation. Necessary items to check are (figure 1):

Cooling needs
The system efficiency is not only due to the efficiency of each individual equipment. The whole system defined above would not be called "efficient" without an optimization of the cooling needs. Indeed, the building design (solar protections, thermal insulation and inertia, air infiltrations) and internal loads (occupancy, air renewal rate, artificial lighting, electrical appliances) have huge consequences on energy consumptions of air-conditioning systems. The way they are optimized must be a part of the inspection. Indeed, too many systems are simply improved or replaced without any previous load reduction that would have however led to much greater energy savings.

Individual efficiency of technical equipments
The second way to get the best efficiency is to correctly design and size networks and equipments. The effective rated output of cold generating systems and motors must fit to real needs. Indeed, part load operation is often (depending on the type of equipment and the load itself) less efficient than full load operation.

The choice of energy efficient equipments is not a sufficient condition but remains necessary to reach high levels of performance. Cold generating systems are only one part of the problem and energy efficiency must obviously be extended to auxiliaries. Indeed, in industry and tertiary sectors, the average motor load factor was estimated between 40% and 50% depending on the power (EC 2000). In addition, fans and pumps often operate for much longer periods than cooling systems so that auxiliaries can take part to 50% of annual energy consumptions (EECCAC 2003) for chiller based systems especially. That is why high attention must be paid on sizing methods and technology choices during the inspection procedure.

Figure 1: main examinations of the inspection



Power and time management
Correct sizing and rational choices ensure minimal cooling output to provide the required thermal comfort while minimizing the power absorbed. However, cooling needs are varying continuously because of occupancy (and other linked parameters) and solar gains. Despite the previous optimization, full load supply may remain too high at certain moments. Indeed, we noticed that the

sizing only on peak load is frequent. Flexibility strategies and power management devices allow to fit better or in real time the supply to the needs.

But, the “power” is only one part of energy consumptions. The operating time is the other term and its management is also an important way to achieve energy savings. Our experiments showed us that there was an important lack in that domain and some installations (cold generating systems, auxiliaries and ventilation) operate all night long and during weekends! That is why, any strategy or device allowing to better and quicker fit the system output close to the needs or to switch it on or off must be analyzed.

Operation, maintenance and follow-up
These only optimizations during the design phase cannot allow by themselves high efficiency during the whole lifespan. Indeed, O&M are crucial in order to avoid the inexorable decrease of performances, availability and reliability and the increase of operating costs. Therefore, the inspector must check O&M contracts and procedures but also their real application. O&M contracts are widespread for sites we inspected but the level of service is very variable according to building-owners.

The operation cannot be efficient without a good follow-up of energy parameters. A good metering is then essential so as to detect energy drifts or technical defaults much sooner before a breakdown occurs. However, during our inspections we noticed that relevant metering was almost exclusively implemented in largest buildings and installations. For low capacity systems, the only indicator is the annual operating time so that it is difficult for an inspector to judge performance changes. Therefore, any relevant metrology and indicator should be listed as good points by the inspector.

How to assess both sizing and efficiency?

If logbooks and annual reports including sufficient performance measurements are available, it is possible to limit the inspection only to the analysis of the documentation and few light qualitative observations. However, well-documented sites are often those that are correctly operated and maintained, in other words, buildings that would not need inspection. For other buildings, it is essential to inspect systems in operation to be able to assess quantitatively both sizing and efficiency as required by the EPBD article 9. Quantitative indicators are moreover essential in order to avoid or at least limit the subjectivity of inspectors.

Which measurements for the sizing assessment?

The CEN standard does not provide any typical method or measurement to do such assessment. The only considered way is to analyze commissioning results. However, during our on-site testing, we observed that the documentation often missed or was not sufficient. Moreover, the estimate of cooling needs is feasible room per room for lower capacity systems by using typical ratios (occupancy, lighting, air renewal rate etc…) but becomes too long and not accurate for larger systems. On the opposite, it is relevant to spend more time on an exhaustive calculation (manual, computer assisted or simulation methods) of cooling needs during an energy audit in order to increase the accuracy. If the two previous solutions are unfeasible, we observed that the only measurement of few indicators could confirm oversizing (table 2).

There are several oversizing indicators for cold generating systems. The first one is the average cycling duration for on/off-controlled air-conditioners. A too discontinuous operation of the compressor during a peak load period is synonym of oversizing. The annual operating time is also a good indicator if it is too low. On the opposite, a too high value can be due to undersizing or control defaults. However, the time counter does not take into account the different output levels that exist for most air-conditioners. The calculation of the full-load equivalent operating time for a certain time period from the division of energy consumption on the considered period by the certified full-load electrical power is thus better. The analysis remains the same. Finally, if the direct cooling load on-site measurement is impossible (split-systems, variable refrigerant flow systems), difficult (lack of metrology on the chilled water loop) or not accurate (measurements in air ducts), the electrical power can became a good indicator. The hourly recording and the yearly/seasonally averaging of that parameter can then be compared to the full load power. Too much cycling or too frequent operation at reduced output will reduce the average electrical load.

For the auxiliaries, the fan/pump efficiency calculation requires the air/water flow that can be difficult or costly to accurately measure, especially for air. If any flow-meter is installed, the flow can be extrapolated from fan/pump characteristics, speed and head measurements that remain easier but not necessarily more accurate. The extrapolated efficiency can thus be compared to the maximum value that could be reached in ideal operation condition (best efficiency point). For fixed speed drives, the magnitude of the difference between the two values is directly correlated to the oversizing. The efficiency loss for variable speed drives is less important because energy gains due to the fit of the regime remain largely predominant. A variable speed drive can however be oversized. If the speed (or flow) is much lower than the maximal value most of the time or during a peak load, the drive can be oversized or at least subject to control problems. Finally, a chiller-specific checking is the measurement of the chilled water return temperature from distribution networks. Indeed, if it is much lower than the theoretical value (9°C whereas typical 12°C) most of the time or during a peak-load period, it means that the water flow is too high in comparison to the cooling needs.

Table 2: some typical measurements to check the sizing of both cold generating systems and auxiliaries

	Measurement	Oversizing when…	Method - Comments
Cold Generating System	Mean cycling time (min)	Too low	1-hour recording
			During peak load On/Off controlled AC systems
	Electrical load (%)	Too low	Single point, 1-day recording, hourly (yearly average)
			During peak load if single point
	Load (W)	Too low	Single point, 1-day recording, hourly (yearly average)
			During peak load if single point Chillers & AHU only
	Cooling capacity per square-meter (W/m^2)	Much higher than reference values	Single point
			Benchmarking possible Need treated area
	Operating time (h/yr)	Too low	Seasonally, yearly
			Benchmarking possible
	Equivalent full-load operating time (h/yr)	Too low	Seasonally, yearly
			Benchmarking possible
Auxiliaries	Efficiency (%)	Much lower than maximum value	Single point
			Constant flow only Deduced from characteristics or calculated by head, flow, power
	Return water temperature (°C)	Much lower than maximum value	Single point, 1-day recording
			During peak load Chillers only
	Speed (rpm) or Flow (m^3/h)	Much lower than maximum value	Single point, 1-day recording, hourly (yearly average)
			During peak load (if single point) Variable flow only

Which measurements for the performance assessment?

The CEN standard provides only few solutions about efficiency assessment especially because it is much more difficult to estimate performances by single measurements. For example, the load varies continuously during a year - even a day - and has a great influence on the energy efficiency ratio. One single EER measurement would be largely different from a seasonally averaged EER (Seasonal Energy Efficiency Ratio, SEER) for example. It is then better to judge a system during a longer period that is more representative of the operation. That is why most of performance indicators are calculated from data aggregated on entire seasons or years.

Several measurements are possible on fans and pumps (table 3). The first one consists in an evaluation of the pressure loss in the whole network supplied by the fan/pump. Measuring the fan/pump differential pressure or electrical power (directly correlated to head by fan/pump laws) is then a good indicator. A regular follow-up of these values for the same regime even allows to detect drifts and then to anticipate actions. Fouling, especially on coils and filters, is among the network pressure drops. As for fans and pumps, a drift can be detected by a regular measurement of the differential pressure for similar flow conditions. Moreover, the coil fouling not only increases pressure losses but also decreases heat transfers and then the system efficiency.

Table 3: some typical performance indicators for auxiliaries

	Measurement	Indicator of…	Method - Comments
Losses	Fan & Pump Head (Pa)	Network pressure drop	Single point
			Constant flow only Regular follow-up
	Fan & Pump Power (W)	Network pressure drop	Single point
			Constant flow only Regular follow-up
	Filter & Coil pressure drop (Pa)	Fouling level	Single point
			Constant flow only Regular follow-up
Performance	Efficiency (%)	Pumping or ventilating performance	Single point, hourly (yearly average)
			Regular follow-up (if single point) Extrapolated (characteristics) or calculated (head, flow, power)
	Ventilating efficiency ratio (Wh/m^3) Pumping efficiency ratio ($Wh/m^3/Pa$)	Pumping or ventilating performance	Single point, hourly (yearly average)
			Benchmarking possible Extrapolated (characteristics) or calculated (head, flow, power)

These “loss” indicators do not mean anything without reference value measured when the installation was in a correct state of operation and maintenance. That is why these parameters must frequently be read as soon as the start-up of the installation. However, performance indicators exist and can be compared to current best practices or manufacturer maximum certified values. Once the flow is measured or extrapolated, it is possible to evaluate and compare the fan/pump efficiency to the maximum value that could be reached in ideal operation condition (best efficiency point). It is also possible to calculated pumping and ventilating efficiency ratios that can be compared between different installations. For example, the Swedish Indoor Climate Institute stipulates that if the ventilating efficiency ratio is lower than 0.4 Wh/m^3 the efficiency is good and if higher than 0.7 Wh/m^3 the efficiency is low.

All the previous measurements required portable metrology and take time. When available, it is essential to take advantage of the already installed metrology, especially energy meters that give access to typical ratios aggregated on a much longer period and for the whole system. Several typical ratios (table 4) require only regular readings of energy consumptions and any other parameter representing the building activity (KRARTI 2000) in order to get independency from the yearly activity level: number of rooms for hotels (Wh/room/year), beds for hospitals (Wh/bed/year), students for schools (Wh/student/year) or tickets for museums, concert-hall or any payable activity (Wh/ticket/year) etc… At least it is possible to use general area specific ratios as the annual energy consumption per square-meters (Wh/m^2/year). The comparison with statistics of buildings with similar characteristics could be a very quick way to check if evident efficiency improvements exist.

Table 4: some typical performance indicators for the whole air-conditioning system (auxiliaries included or not)

	Measurement	Indicator of…	Method - Comments
System	(Seasonal) Energy Efficiency Ratio	System performance of any building	Yearly/Seasonally follow-up (if energy meters) Hourly for summing on season or year Auxiliaries can be included or not
	Unitary energy consumption (Wh/m^2/yr)	System performance of any building	
	Yearly energy consumption per room (Wh/m^2/year)	System performance of hotels	
	Yearly energy consumption per bed (Wh/bed/yr)	System performance of hospitals	
	Yearly energy consumption per client (Wh/client/yr)	System performance of museums, concert-halls etc…	
	Yearly energy consumption per student (Wh/student/yr)	System performance of schools	

The necessity of qualitative observations

The inspection of air-conditioning systems is a very good initiative because it has professionals met with building owners during the operation of their installation. In reality, the contact is often lost just after the beginning of operation leaving the system without any follow-up. We observed that for a lot of systems, some obvious improvements with short payback times (especially on the management of operation times) can be easily found without long analyses.

The CEN standard understood well the necessity of qualitative observations to quicken the procedure, as it is unfortunately not possible to quantify every parameter during a one-day visit. For that part of the work, the inspector will have to use the documentation and to visit technical installations. To improve cost-efficiency of the procedure, it is important to valorize the work that had been already done especially in case of O&M subcontracts. For example, inspectors should use annual operation reports and logbooks if they are available and liable before doing any measurement. It is costly and time-consuming to measure what is regularly measured! Double-measurements can however be useful to check the correct calibration of the existing metrology and its liability.

Moreover, simple measurements at one moment do not give any information about the efficiency future trends, especially the improvement margin if actions were taken by the building-owner. For example, the efficiency of a “young” system that would have been optimally designed is likely to decrease with time because of its operation. The only advice of an earlier inspection would then to apply optimal operation and maintenance. On the opposite, poor performances may be the consequence of a malfunction, neglect or misuse So that the major advice is then to repair or change the considered equipment. Key O&M advice can be provided only after both qualitative visit of technical installations and analysis of the O&M documentation.

Cooling requirements
Seeking evident energy weaknesses in the building shell and internal loads is much more simple, quicker and less expensive than measurements, calculations or simulations. These methods should remain the monopoly of energy audits. Our document lists several quick qualitative observations in order to detect possible efficiency weaknesses in wall insulation, thermal inertia, air infiltration, glazing, lighting and its management, electrical devices and their management etc… These items must be accompanied by the relevant documentation (commissioning results, plans, type of materials

etc…). It is also essential to discuss with few occupants about the every-day use and thermal comfort to know about problems that might occur but unfortunately not during the inspection.

Efficiency
Systematic efficiency measurements are usually unnecessary. Once an inspector proved the sizing is optimized, to compare certified performances with best performances available on the market can be sufficient to assess the installation efficiency and find improvements. Several indicators like certified EER or IPLV (integrated part-load value) for cold generating systems, class (EC 1992) for room air conditioners, maximal efficiency or class for motors, AHU class (CEN 1998) can be used as they can normally be found in technical documentations or on equipment plates. If these indicators are not known because of a difficult access or an unavailable documentation, the EUROVENT database (EUROVENT) can be used for air-conditioners, air handling-units or fan coil units.

Power and time management
We observed in most buildings that there was a huge saving potential by the improvement of control and management of both supply power and time of operation. Some devices or practices specific to this kind of actions are essential to reduce energy consumptions. Check their existence and implementation can help in the assessment of the system performance. Our checklist summarizes what is essential in order to reach the highest efficiency level: the relevant zoning of the building, power reduction or variable speed on cold generating systems, modular structure (several smaller capacity generator in parallel ensure higher individual loads), thermostats, limited range for temperature set points (especially when controlled by occupants), timers or programmers or occupancy sensors, building energy management system (BEMS), flow control methods (some are more energy-efficient), free-cooling and/or free-chilling, heat-recovery on ventilation, cold storage etc… That analysis requires the highest expertise from the inspector so that documentation is essential such as characteristics (occupancy schedule, temperature set points, activity etc…) of each zone, technical manuals, description of control and management procedures.

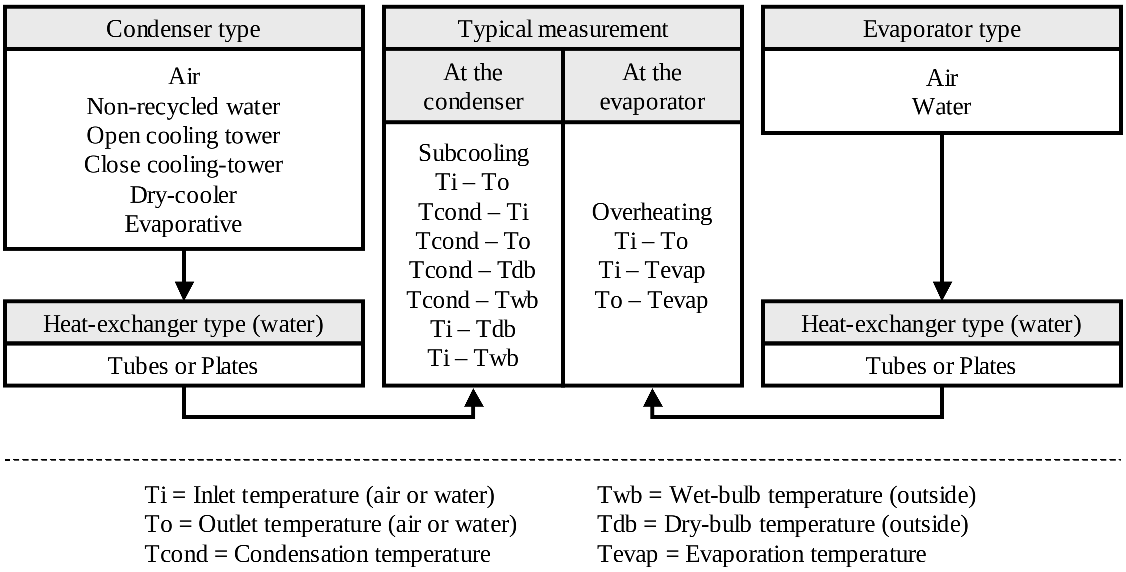
Operation, Maintenance and Follow-up
Almost every checking about O&M provided by CEN is feasible on-site because simple and quick. Our checklists are also largely focused on O&M and on follow-up in general. In order to create a hierarchy in our checklists, we used air-conditioning breakdown statistics on HVAC (HALE 2001) in general, on rooftops (BREUKER 1998) and on chillers (COMSTOCK 2002). Indeed, weaknesses are primarily at heat exchangers, compressors, fans and pumps and control devices. We observed that most of inspected installations were subject to O&M contracts. Indeed, thermodynamic cycles are really affected by bad adjustments and required a regular follow-up by a professional to limit the frequency of breakdowns or minimize their effects. For building owners who already signed O&M contracts, inspection is synonym of extra costs. It seems logical that if O&M contracts and the follow-up are efficient, the frequency of inspection should be reduced.

In practice, the content and the efficiency of O&M contracts are variable so that it is fundamental for an inspector to check what O&M procedures are and if they are really and correctly applied on-site. Again, that analysis requires a lot of documentation such as O&M contracts and procedures, O&M logbooks, refrigerant charge receipt, etc… The optimal operation of both the thermodynamic cycle and auxiliaries can be analyzed especially if there are doubts about the operator seriousness. In that case, several measurements (figure 2) can be done and compared to optimal values. These reference values are known but as they depend on the refrigerant, it is difficult to give them precisely.

Finally, building owners need indicators to decide to invest or not. For the follow-up assessment, the inspector will list every "good points" such as the dedicated metrology and metering, the inclusion of a guarantee of results in O&M contracts, the energy indicators measured and benchmarked, the existence of annual reports from O&M subcontractors etc… Pieces of advice can be provided about the relevant metrology and indicators to use.

The duration of such a procedure is very variable from one site to another and we observed it depends firstly on the installation background (documentation, complexity, metrology, follow-up). But whatever the content of the inspection, that duration could decrease thank to the necessary presence of a responsible person (building owner representative, operator etc…) that can facilitate access to equipments and ensure the procedure exhaustiveness by taking upon himself the responsibility of any problem that might occur during the inspection.

Figure 2: typical measurements on the thermodynamic cycle depending on the type of condensing and evaporating techniques (JACQUARD 2004)



What is the missing part?

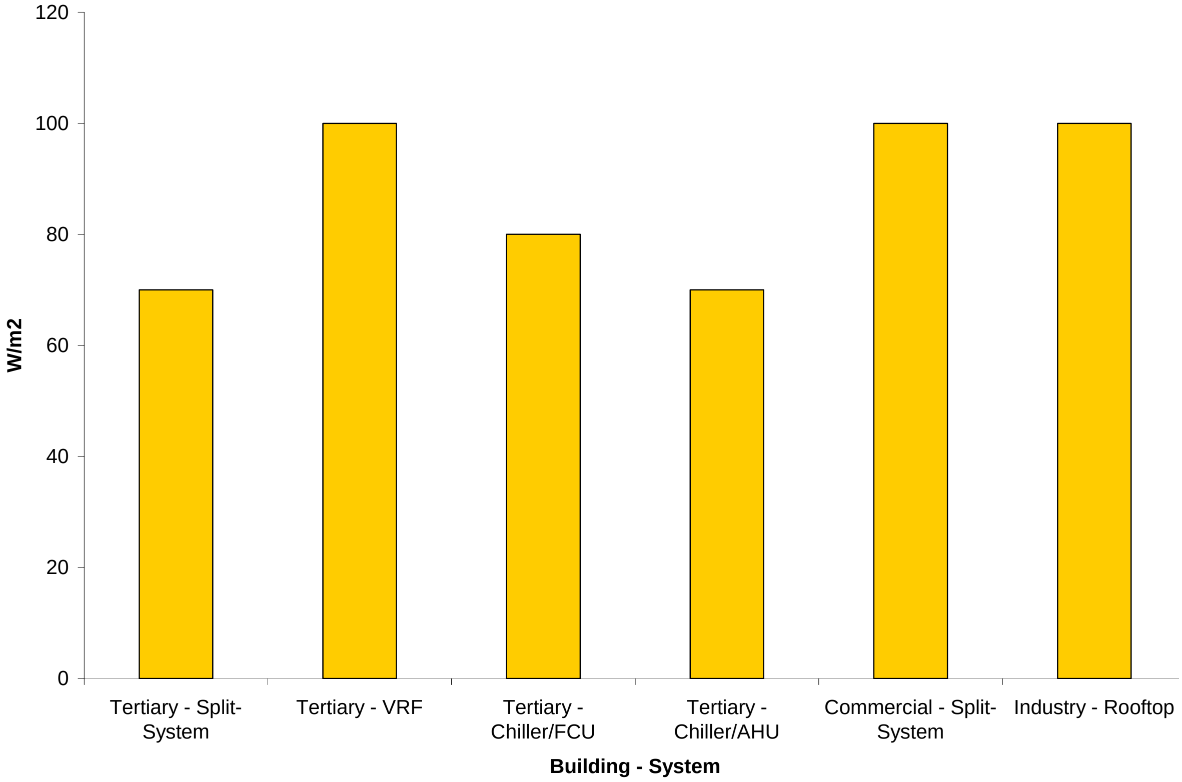
The need for benchmarking

The regular follow-up of previously introduced ratios is always profitable for building owners because it allows to detect performance drifts from one year to another. Independent from annual results (tickets sold, beds or rooms occupied etc…) and occupation, they can also become independent from local climate using a cooling degree-days (CDD) correction. These ratios can moreover be compared between several buildings, which is much more interesting in the framework of inspection.

Nevertheless, we observed that because of a general lack of relevant meters, benchmarking was rarely used or remained the privilege of big buildings. Indeed, electricity sub-meters remain unusual in most buildings and aggregated electricity consumptions at the main electricity meter are much more difficult to use because of the mix of electricity uses. The inclusion of sub-meters in an existing system is technically difficult when it had not been thought at the launch. The second reason, which is also a consequence, is the lack of statistics. In fact, statistics exist but they are not reliable enough to accurately reflect the characteristics (climate, occupancy, shell, system etc…) of various buildings. Therefore, only large ranges of reference values are available.

To develop and update a database listing the measured ratios as soon as the beginning of regular inspection in Europe would be profitable for benchmarking. Indeed, by having access to a large part of the air-conditioned building stock in various sectors and for different climate, European inspectors could ensure by their measurements the good statistical representativeness of these ratios. For example, the cooling capacity per square-meter is easy to calculate and can be compared to maximum, minimum and average values for the same type of building, system and climate. It is then possible to assess sizing with regard to common practices in force in the country. The figure 3 is an example of statistical study about the cooling capacity per square-meter. More detailed statistics and information about each sites are confidential and under EDF ownership. These statistics are not enough significant because on the one hand they represent only installations advised and followed by EDF and on the other hand, certain categories do not include enough installations to lead to a representative ratio. It is however a good basis that should be extended to a larger stock.

Figure 3: average installed cooling capacity per square-meters for several building and air-conditioning types in France (source: EDF[*])



Minimum requirements

The main difficulty we had to face was the problem of subjectivity. Indeed, unlike the “roadworthiness tests for motor vehicles” for which each measurement is associated to a strict limit value, the inspection of air-conditioning systems contains a lot of qualitative observations such as the existence of some devices, equipments or procedures. In that case, how can be defined the mandatory improvements, replacements or simple changes that must be implemented by the building owner after the inspection? It is then essential to stipulate by a law or a standard which documentation, control devices, O&M procedures or metrology are mandatory or at least necessary. To define minimum requirements is the only condition to reach objectivity and homogeneity in inspector judgments and advise.

The same comment could be done to quantitative measurements. Indeed, the development of both metering and benchmarking should lead to the definition of reference (indicative), legal or standard (mandatory) values for energy indicators of air conditioning installations. Minimal requirements reinforce the incentive on building owners to have their air-conditioning system audited before investing for its improvement or replacement.

Conclusion

Easily applicable on-site, the inspection is a good initiative because it introduces a regular follow-up of any air-conditioning installations that is not necessarily done by building owners. A previous paper (DUPONT 2005) dealt with the feasibility of the CEN inspection at the member-state level whereas that one underlines some of the blanks of the standard at the site level. Indeed, the assessment of both sizing and efficiency demanded by the EPBD is difficult to do with the standard in that state. By a

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[*] This diagram is only a small part of a larger study resulting of the follow-up of air-conditioning energy consumptions (100-building sample) in France carried out by EDF.

lack of minimal requirements from the CEN standard, the biggest part of the work remains for member-states so that the homogeneity of the measure is likely to be dissolved by national choices.

Therefore, we proposed some additional quantitative measurements that could be included in the standard or in national procedures that should follow. The aim of these additions is to give more objectivity in the assessment and to be able to stipulate correctly which installations are energy-efficient and which have poor performances. As the inspection duration is limited, a method based only on measurements is impossible because too long. The paper thus underlined the necessity to complete measurements by a brief description and qualitative observations about installed equipments and their functioning.

However, a lot of work remains after that. By having access to building-owners technical installations, it seems relevant to create a database and develop statistics on major ratios the paper proposes. The essential future step would be to define good practice as limit values for energy ratios and minimal requirements about the documentation and metrology in order to accelerate the set-up of the measure and to facilitate its application. The incentive would then be greater because building owners would know which level they would have to reach for the next deadline. Hence, they could take advantage of the inspector conclusions to take further actions and invest directly in some improvements or even replacements.

That paper is only a small part of a larger project, aiming to define best practices for the inspection and auditing of air-conditioning systems. More complete and detailed results will be provided in a future paper. For that project, we acknowledge funding and moral support by ADEME (the French energy agency) and active cooperation by ‘Electricité de France’ (EDF) and ‘Ingenierie Tous Fluides’ (ITF).

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