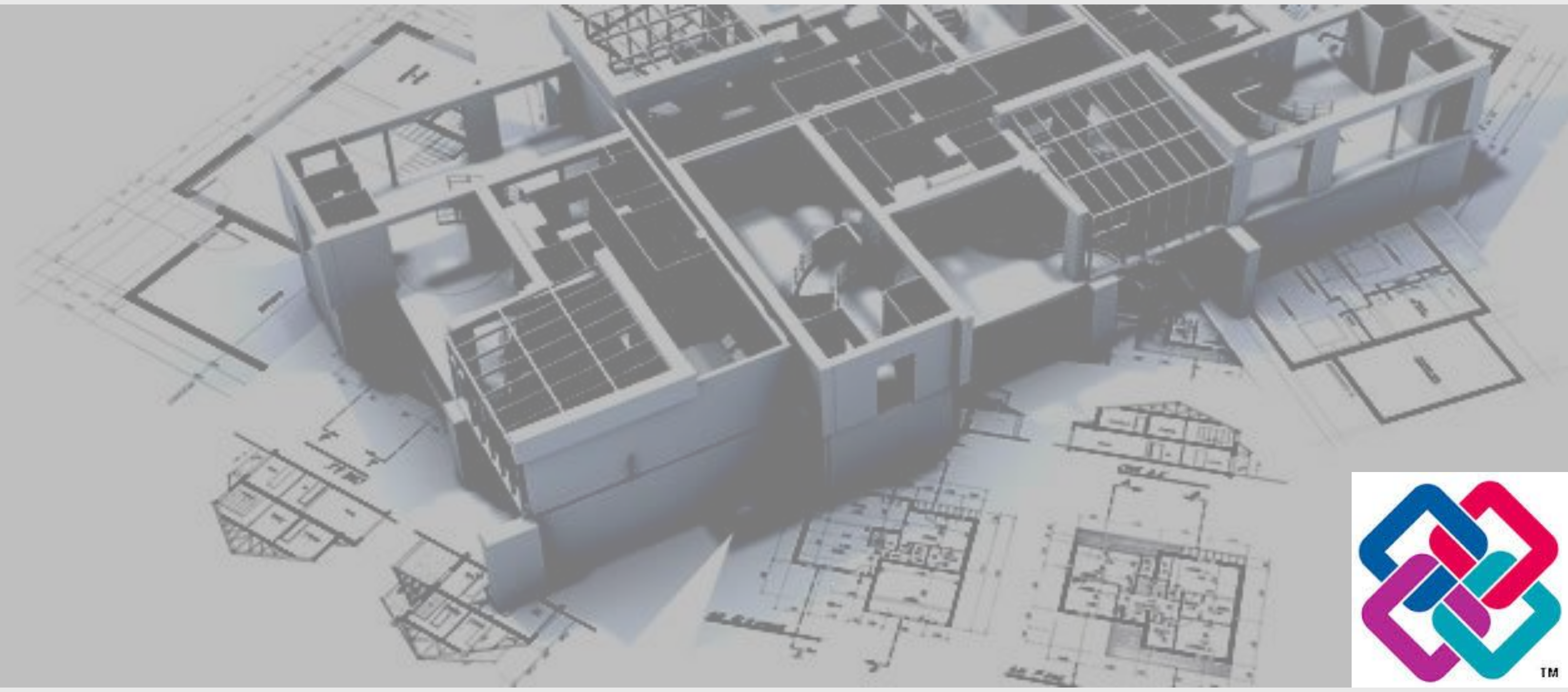
The possible integration of Facility Management in BIM: Development of a new IFC properties system



Student: Silvana Bruno

Supervisor: Joaquin Diaz

Moderator: Antonio Lecha Sangüesa

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Contents

Figure list

Table list

Abstract

Facility Management, as well as maintenance operations, suffers from the block in the operational level that avoid the leap to a strategic and integrated dimension expected to reduce risks and economic losses occurring after changing situations. Building Information Modelling seems to be an efficient system to introduce strategic FM, involve governments and their regulations inside public procurements and private construction processes. Is it possible the integration of Facility Management in BIM in Italy, Spain and Germany? If yes, how to ensure high levels of communication between AEC actors, manufacturers, users and Authorities?
The answers converge into the development of IFC (Industry Foundation Classes) Standard by buildingSMART International in compliance with European and national regulations in the three countries involved in this research.

Research statement

The research proposed in this final dissertation represents the personal response to the knowledge achieved during the Master in European Construction Engineering, an annual postgraduate course organized by the University of Cantabria in collaboration with other seven European universities.
This work has been developed at the THM (Technische Hochschule Mittelhessen) in Gieβen under the supervision of the professor Joaquin Diaz and in collaboration with the Construction and Informatics department staff.
It is evident Building Information Modelling is not so implemented in Italy, Spain and Germany at the same level of other European Nordic nations, despite its employment is more and more requested in public procurements (see European directive 24/2014/UE) to reduce errors, delays in time and extra costs.
The IFC Standard better supports the data exchanges through guidelines about inclusion of geometry, properties, quantities and other building components specifications.
Even though years of IFC releases, the contents of IFC have not yet been matching the regulations requirements to be followed in any private and public project in Italy, Spain and Germany.
The interest on these three countries is linked to their continuous collaboration and inspiration in regulation developments, the involvement of Italian, Spanish and German partner universities in the Master in European Construction, and the extreme need to contribute in Italian construction procurement evolution.

Thus, the idea is to develop a new IFC-HVAC system, linked to the buildingSMART International standard to have parameters compliant with regulations for maintenance purposes in order to ensure principles of economic, social (health and safety) and environmental sustainability gained during the design phase.

Keywords

BIM, Facility Management, maintenance, HVAC, air handler, AHU (air handling units), IFC, data exchange formats, buildingSMART International, European regulations, National regulations, Italy, Spain, Germany.

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1 Introduction

1.1 Background

The Facility Management is a strategic discipline introduced during the Korean War (1950-1953) by the US Army to organize space and resources of military construction. It has been developed to control of the working and teaching place with the objectives of quality life improvement, response to changes and technical innovation, increase of business value, diminution of risks, environmental sustainability and care of health and safety.

Maintenance of building components is an activity taking part of the Facility Management process, fundamental to succeed in the aims reported below. In fact, it consists in a system of activities, belonged to technical, governmental and managerial fields and executed during the working phase of an element, to safeguard or bring it back optimal conditions of operative reliability.

In this research the maintenance of a particular HVAC (Heating, Ventilation and Air Conditioning) equipment has been studied and developed: the air handler (or AHU). Its role is decisive to guarantee requirements of hygiene and ventilation now compulsory in every environment occupied by people. This is possible due to air exchange by treating the outside air ensuring the, according to European and national codes.

The application of this equipment is mainly suitable for cinemas, theaters, conference room, gyms, swimming pools, discotheques, large halls, exhibition centers, cafeterias, restaurants, industrial, shops and shopping centers, and open space, so public spaces.

Maintaining these devices represents respect for natural environment thanks to energy savings and reduction of CO_2 emissions and health and safety conditions.

The Building Information Modelling (BIM) probes to be an instrument to succeed in integrated Facility Management and programmed maintenance. Nevertheless, a reasonable and effective use of this Informatic System is suggested, because full interoperability and exhaustive and not redundant data collection could be performed. At this scope, the survey about data exchange formats discovered until now and their implementation in pioneer projects about Facility Management and Maintenance. The Industry Foundation Classes (IFC) Standard seems to be suitable, but totally efficient if further considerations and modifications will be executed.

1.2 Aims and Objectives

The intention of this research proposal is emerged from the necessity to improve the virtual collaboration between Facility Management and Building Information Modelling starting from the gaps of the two disciplines.

The core aim is the development of the standardized data exchange format IFC creating a new properties system to achieve complete compliance with European and national regulation requirements in view of the increasingly need of BIM in public procurements to ensure transparency, time and cost savings. The starting point is the working field in Italy, Spain and Germany.

The insertion of new object and performance properties related with maintenance purpose requested in governmental regulations must be included in the future edition of IFC2x if concrete reply and efficient results would be obtained. It involved only one HVAC equipment, the air handle, but the same procedure can be apply for each infrastructure and building component, if the objective is a greater involvement of the Authorities and Government.

The objectives pursued to reach the core aim are:

- Studying Building Information Modelling potentialities and weak points;
- Investigating progress and recent implementations of Building Information Modelling in Italy, Spain and Germany in comparison with further situations such as UK and European Nordic countries;
- Studying the definition, reason of concept creation, development and critics to eliminate about Facility Management;
- Focusing the research on the core area “maintenance”;
- Comparing the concept of maintenance in Italy, Spain and Germany;
- Selecting the sector with more common points about definitions and operations in the three European countries;
- Studying the issues and potentiality of BIM employment in FM;
- Investigating the available data exchange formats;
- Deepening the IFC (Industry Foundation Classes) architecture, contents and lacks;
- Comparing IFC object and performance properties and parameters and instructions required in European and national regulations;
- Writing new property sets and properties of air handler and its components object definitions in IFC, ifcXML and mvdXML files, according with the contents of regulations.

1.3 Research Methodology

The research starts from the review about Building Information Modelling meaning, progress pointing out Italy, Spain and Germany are still rearwards in the implementation of BIM in public procurements than UK where government imposed BIM use for 2016. The state of the art about Facility Management has been reconstructed focusing on HVAC maintenance and related regulations and standards. After the knowledge about basic concepts, a meticulous study of the possible integration between BIM and FM has been conducted to know about pioneer case studies, fixed points from which starting to think about an efficient solution to the aim predefined and gaps to be plugged. Some big European companies have been contacted to receive more information about their research and results in this new field. But, the responses have been negative or incomplete because they are still working on. This drove the research to find alternative solutions to the efficient integration BIM and FM and concrete implication of Authorities and governments.

The investigation of the data exchange formats (COBie, HVACie and IFC) used in Facility Management and imported in BIM models has provided the chance to develop IFC contents to accomplish the aim. The next step is analysis and understanding of the logic inside the IFC Documentation and the programming languages STEP (STEP physical exchange file), XML and EXPRESS used to write IFC specifications. So, all the web site of buildingSMART International tech-org has been browsed and each document and html file attached, the STEP tool and ifcDoc generator application have been used and analysed to produce the new properties of air handler and its components (coil, heat recovery, damper, filter, fan and humidifier).

A detailed study about AHU design and maintenance have been executed to define the parameters and instructions missing in IFC standard and give an exhaustive description and property template.

Initially, consulting technical brochure of MEP manufacturer companies and academic books or documents.

Then, European regulations by CEN (European Committee for Standardization) translated for Italy, Spain and Germany and national laws have been read and structured inside helpful tables to explain the research contents. Three groups of tables have been dine:

- First about IFC property sets and properties and added parameters, writing the correspondent descriptions. The ones about inserted requirements are resumed from standard contents. In the last three columns have been reported the reference standards;
- Second about property sets template with name, description and applicability type;

- Third collects property type (single, reference, bounded, table, list or complex value) and resource measures (about physical, descriptive and numerical magnitudes and their relative measurement units).

During this step, the employment of Revit MEP 2016 and ArchiCAD 2018 have been helpful to understand and probe the efficiency and reasonability of STEP files contents to be developed in ifcDoc.

Finally, some property sets and properties identified as missing have been exported as IFC, ifcXML and mvdXML files using ifcDoc provided by buildingSMART for IFC supporters and developers.

1.4 Limitations and Scope

The scope of this final dissertation is supporting the evolution of Building information Modelling in MEP (Mechanical, Electrical and Plumbing) maintenance, part of the strategic science Facility Management, excluding cost evaluations because different in any local contest. In order to face this topic, it has been necessary improving personal knowledge about building services, limited to the functionality of an air handler in air treatment (to modify temperature and humidity in airflow directed in indoor rooms) and its common components (coil, humidifier and heat exchanger), studied during the academic course "technical physics engineering". In addition, the absent practice in use BIM software products for MEP applications has been a weak point because a real project about HVAC system could be supporting the innovative IFC parameters system in finding errors or incongruences. Another limitation is represented by the low availability of CEN standards in English version to write the correct name of all the properties, not referring to secondary documentation and of UNI standards. Fortunately, full collection of UNE and DIN standard has been provided by the Spanish University of Cantabria and German Technische Hochschule Mittelhessen (THM).

Finally, the time and the number of persons involved in this study. The semester of practice is short to develop a very complete overview of HVAC parameters performed by only one person. And, a suggestion could be involved all experts in the subjects (academics, mechanical engineers and construction engineers) to support the development of the new HVAC-IFC properties system.

1.5 Dissertation Report Outline

The dissertation is divided in four chapters. The first consists on the explanation of the research intentions and process.

Every chapter is introduced by a brief description and ends with revealed issues and conclusions from which the following section starts.

The second chapter "State of the art" goes deeply in all the complex topics faced in the dissertation: Building Information Modelling, Facility Management, maintenance, attempts of integration of FM in BIM, air handler components and requirements and IFC data exchange format. Important is the focus on Italian, Spanish and German situation about HVAC maintenance and BIM implementation to define the direction of the research. The review literature consists also in the study of the web site by buildingSMART, IFC contents and architecture and programming language used for IFC specifications.

The core of the dissertation is the third chapter "Development of Property sets and Properties for an air handler" that presents all the steps followed to produce the explanation tables. They are reported in the Chapter 5 "Annex" and show, step by step, the development phase of the new HVAC-IFC properties system in compliance with Italian, Spanish and German codes for the air treatment equipment and its components.

The dissertation ends with conclusions and suggestions for a further theoretical work or practice and for BIM dissemination among professionals, manufacturers, academics, and students.

The annex contains all the analysis tables produced to develop the new IFC properties systems.

2 State of the art

The literature review has moved to discover advantages and disadvantages of the integration of Facility Management in BIM, fundamental to think about a solution for better compatibility and interoperability. In specific, Building Information Modelling characteristics and progress in UK and European Northern countries against Italian, Spanish and German situation have been first investigated from academic papers and governmental web sites. Then, the evolution of Facility Management concepts and focus on different definitions of maintenance types have been taken on. Finally, attempts of integration FM-BIM, data exchange format types, particularly IFC (Industry Foundation Classes) Standard, and real cases have been studied. A summary about the air handler and its components has been reported to understand the following phases of the research process.

2.1 Building Information Modelling

Before starting to develop the core of this research, a deep and meticulous study about the Building Information Modelling concept and the effects of its implementation in Italy, Spain and Germany will be executed. But, a comparison with the good results had in nations, as UK, where BIM has reached a high level of contents, consciousness and involvement in public and private construction, is essential to define the fixed points and issues for the elaboration of a resolution of gaps as the incomplete interoperability and the subdued implication of governments in BIM.

2.1.1 Introduction to BIM

If the terminology Building Information Modelling was devised the previous decade, the concept is traced back to thirty years ago. The BIM is an approach to the digital representation of components and operative features of a building. The method integrates 3D modelling, automatic drawing extraction, intelligent parametric objects, interactive databases, and temporal phasing of construction processes in a “central information model” (Eastman et al., 2011).

That scenario is possible because BIM system employs a particular type of platform software, called object-oriented, which permits to design a building not only as lines and dots but as parametric objects representing building components.

The object itself collects data and information, topologic related to position and location, semantic about relationship between the elements and functional such as time and costs operations (Volk et al., 2014).

BIM 3D visualization and spatial analysis are also considerable a facility information database which give several complete views of the building and its technical services, useful to plan the maintenance activities (Akcamete et al., 2010). It represents the wisdom about a facility, a reference for any decision of actions occurring through the building life cycle until the demolition (Malone, 2013a).

In the early stages of BIM system, the tools have been developed only to manage the design stage (in a narrow sense called "little BIM" or tool), recently it assesses construction, operation, maintenance and demolition of a facility (Malone, 2013b).

Regardless the ascertained benefits for the actors of a construction process (owners, users, the AEC personnel, contractors and suppliers), BIM is still mostly used for a unique scope, the design.

Switching from a "little BIM" to a real wisdom has been possible due to the introduction of BIM dimensions: 4D BIM adds construction scheduling to the 3D representation moderating the relations with the contractors, 5D introduces cost calculation producing a change into the figure of the quantity surveyor.

Beyond the last two, other two extra-dimensions are being investigated for facilities management (FM) and sustainability. The level order of the new-borns is still on a research step (Malone, 2013b).

Enthralling value proposition is the expansion in the use of BIM to handle huge quantities of data provided by different stakeholders employing several tools (Crumpton and Miller, 2008), effect of the interoperability.

This propriety denotes the possibility of communication and exchange data between systems or software programs. Exchange formats are classified in Open Standards, (for instance CIS/2 for steel applications and Industry Foundation Classes IFC), and proprietary exchange format (AISC, 2013). The paragraph 2.3.2 will contain more details about data exchange formats.

However, the data model specifications do not always present stout compatibility producing information loss, and this produces issues in the communication and collaboration inside a teamwork.

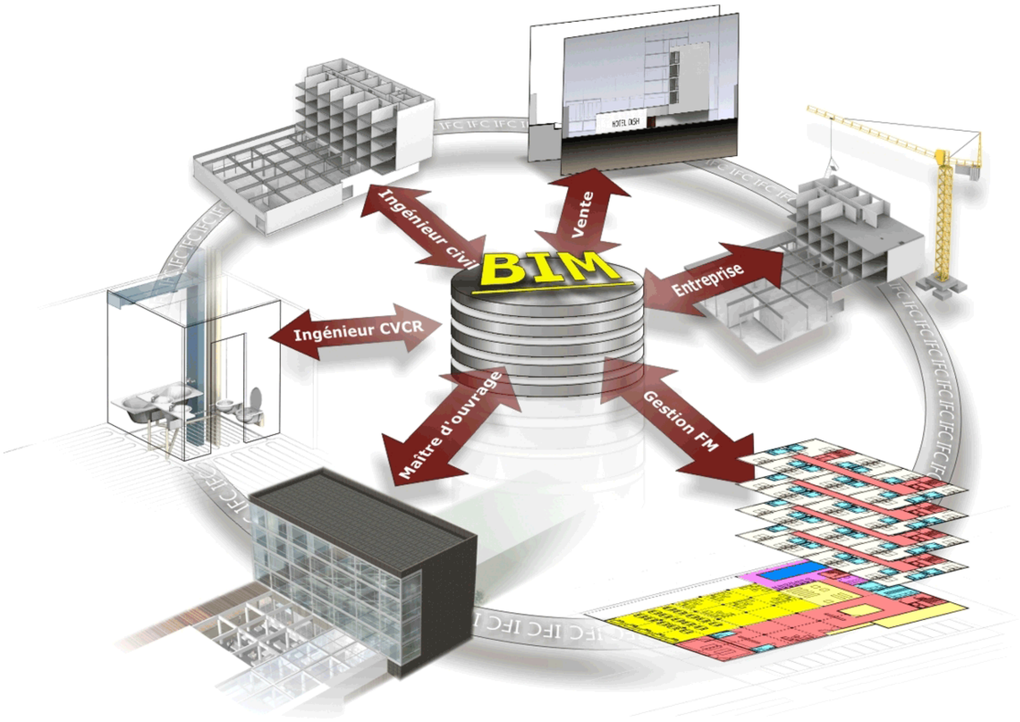


Fig. 1 Efficient planning with BIM technology (Probstel, 2013)

2.1.2 BIM progress in UK and European Nordic Countries

In United Kingdom, the BIM evolution ramp, or BIM levels, was studied to define the requirements to accomplish into every milestone or level. Inside the Construction Strategy, the UK government established to reach a minimum target in the public construction sector by 2016 respecting the criteria of BIM-2 level.

The scope is reducing waste in construction by 20%, caused by failed work, incongruities and errors, and repetitive and insufficient information (NBS, 2014).

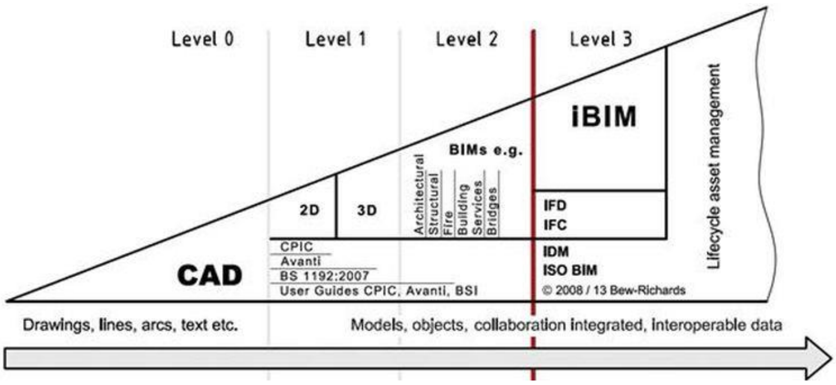


Fig. 2 BIM evolution ramp in UK (Richards and Bew, 2008)

In European northern countries, for instance Norway, the mandate is more forward than the UK BIM – 2 level, but without a precise definition of the criteria as in UK. The inclination to

BIM level 3 is due to the use of *open BIMs* working with Standard formats, conscious it is the only way to reduce the losses (Carr, 2015).

2.1.3 Recent developments of BIM in Italy, Spain and Germany

2.1.3.1 Italy

In Italy, the implementation of Building Information Modelling starts from a backward base and several steps should be accomplished to reach a painstaking utilization of it. The scope is ensuring transparency in public procurements and reorganizing the construction field. And, it is known how complex the BIM implementation is in an entire construction process. The proof of complex exploiting is given by UK government's efforts to respect the 2016 goal and the money has been invested for training, application and controls.

An Italian endeavour has been carried out proposing a draft for the decree law n. 133 in 12 September 2014, also called "Sblocca Italia" – "Unlock Italy" to set up a programmatic process in order to introduce BIM and promote the adoption of integrated project in public procurements.

The article about this topic has been cancelled because Italian construction shareholders are not ready to face this change. In addition, it has been considered that the mandatory employment of BIM will bring about a fake change.

The rejected proposal introduced:

- The institution of an expert committee in charge to determine modifications on the current regulations in compliance with the European Directive 2014/24/UE e to define the technical standards reference model;
- The setting up of a centralized informative platform has been proposed to collect informative parametric objects in a national library.

Fortunately, the Italian BIM experts are grouped into supporting groups such as INNOVance, BuildingSMART Italian chapter, ISO and UNI committee to work in voluntary processes developing normative about. However, these projects are still in an embryonic status ("il BIM fuori dallo SBLOCCA ITALIA," 2014).

The issues to be overcome are the partial software interoperability with restricted skills about information recording. Furthermore, the Italian AEC professionals do not employ the current software applications with their entire BIM functions. The professional studios occasionally collaborate, and they still perform several dated project methods such as for design (almost in 2D) and bill of quantity.

The start to lay firm foundations in concrete BIM implementation is the introduction of a specific training in academic study programs. BIM and its complete functionality is taught in very few universities, above all in Master courses. The knowledge background may be updated with informatics skills, in order to get ready a wide group of adequate BIM experts.

2.1.3.2 Spain

In Spain, BIM is not widly and efficiently implemented. In fact, project and construction phases record the same negative results and issues of the traditional approach. This because the attitude of the involved actors is not totally formed to succeed in BIM strategy. It is clear that Building Information Modelling represents a substantial instrument to reduce changes for brief project reviews by executors, insertion of new requirements with consequent cost overruns, difficulties for end users to quickly consult information model, skipping the proper workflow. And, above all, it can help the true and transparent handover of information (“¿España esta preparada para el bim? - TecniatTecniAT,” 2015).

Few pioneer BIM implementation occurrences have been gained by institutions and public authorities. The buildingSMART Spanish Chapter has been established in November 2014 to promote the standardization of openBIM and to purpose its use at national level, in private and public projects.

In 2012, the Normalization Commitee AEN/CTN 41/SC13 have been instituted by AENOR (Asociación Española de Normalización y Certificación) to organize BIM for building and civil works. On 28th April 2015, the Spanish Ministery of Development announced the creation of a public-private work group to introduce BIM implementation measures. A guideline is going to be written according to the Directive 2014/24/UE. The academic sector started to have interest when the publication of a academic BIM notice had been established during the third EUBIM Congress (2014) of the “Universidad Politécnica de Valencia”. The scope is to solicit an integrated and collaborative BIM education plan in any academic institution. The aim of this plan is to improve the training of students, lecturers and professionals of construction sector. Since 2014, the catalan public company “Infrastructures de la Generalitat de Catalunya” have performed pilot BIM projects about building construction. In February 2015, several catalan institutions signed and published an intention document under the European BIM Summit and a program of objectives addressed to all the catalan professionals for the next years until 2020.

However, a national implication is needed to reach efficient results in construction processes with BIM (“La implantación del BIM en España - ITeC,” 2015).

2.1.3.3 Germany

In 2013, a BIM guide for Germany has been elaborated to introduce BIM method and requirements because of the growing interest in the theme.

The BIM method finds its current utilization only in some private projects, while public administrations lack experience and do not assert their own point of view on the topic. The German trend is in contrast with the situation of other countries in which the authorities ask for BIM exploitation.

The reasons of the German block lay in knowledge break and perplexity in the combined use of BIM and software products (Egger et al., 2013).

In the beginning of 2015, German federal Minister of Transport and Digital Infrastructure introduced an industry-led "Digital Building Platform" during the BAU 2015 exhibition in Munich. Then, industry-led organisations created a group to collaborate to a BIM implementation plan. They are discussing about standardization, guidelines and trial contracts. In Germany, BIM system could be a solution to avoid further faulty public projects gone over budget and time (an example is the Berlin's Brandenburg Airport) ("BIM+ - France and Germany move forward on BIM adoption," 2015).

So, in May 2015, the "Verein Deutscher Ingenieure" has proposed the BIM-Standardization to create a consensual process inside architecture, civil engineering, building services and facility management. The German organization trusts in BIM as a Cross Discipline, for this it promoted conferences where discussing about the cultural change in progress. The scope is creating a Coordination Circle BIM between people involved, basic conditions, processes and technology. It will be composed by VDI committees, building owners, science, end-users, software developers, organisations and associations (Steinmann, 2015).

The role of German Universities is significant. In fact, the research about Building Information Modeling (BIM), conducted in 25 years, has been translated in BIM classes in universities since many years. The fundamental research has been conducted by the German Association of Computing in Civil Engineering (GACCE, or "Arbeitskreis Bauinformatik"), defining also BIM lessons program for universities in Architecture, Engineering, and Construction (AEC) (Smarsly, 2015).

2.2 Facility management

The development of Facility Management in BIM contest is going to be investigated in the next paragraph, but an overview about the complex discipline FM seems to be fundamental to trace the starting point of the research for a concrete improvement. After its definition, reason of its need, implementation and development in the field, critics have been analysed. In fact, some authors considered FM as the implementation of strategic measures of core business in changing situations (Alexander, 2013) but it is, overall, used as technic-based discipline although its flexible function (Ventovuori et al., 2007). Currently, facility management is even more applied by organizations using tools or services for the support of their core activities (Wagnon, 2015).

In addition, academic research and related publications are not numerous about the topic.

The following step is going deep in the maintenance core area, reporting differences about definitions of the concept and general contents of European and national codes in Italy, Spain and Germany. This permits to select the building components on which focus the efforts of the Master research.

2.2.1 Definition, beginning and development

Facility management is the corporate multidisciplinary science applied after the delivery of the building to the owner. In the specific, the European Facility Management Data Standard – EN 15221 furnishes this definition: *"Integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of its primary activities"*.

In the practice, it is supported by the integration of processes with people, place and technology to guarantee the functionality of the built environment (Wagnon, 2015), with the purpose to converge the resources on user demands and to ensure the economic value, the quality and the risk prevention (Alexander, 2013).

The birth of FM is traced during the Korean War (1950-1953) by the US Army when an applied science was needed to manage the secret operation of a huge army base, its logistics, storages and airport.

Nevertheless, the recognition of the emerging pressure in quality improving, the increasing complexity of buildings and high tech houses, the link between business success and cost and risk reduction, the protection of the environment and the health and safety of people produced the responsibility for companies to manage the workplace in an integrated solution. These are the reasons that pushed the growth of the Facility Management (Alexander, 2013).

In the 70s, the Facility Management Institute (FMI) born in Michigan. In 1980s facility management became an anchor for property and construction industry. In 1982, Northern American competent associations were united in a non-profit International Facilities Management Association (IFMA), born two years before with the name National Facility Management Association (NFMA) (GEFMA German Facility Management Association, 2014).

A formal reunion was organised by the Association of Facility Management (AFM) and held with the Second International Symposium on Facilities Management to define the reference skills of a facility manager.

In 1999, Nutt stated the lack of a proper knowledge base and a shared definition of FM and its structure (Ventovuori et al., 2007).

In the first experiences in FM, the operational and maintenance actions were executed in a technical and not strategic way, linked to the core business in an ambiguous way (Loosemore and Hsin, 2001).

Only recently, the discipline has been adopted by the most important societies in the world to strategically reorganize the business, improve profitability and competitiveness and minimize the loss in economic value due to the increase of customer interest and the achievement of business goals (Alexander, 2013).

The application fields are wide because the term of FM consists of processes, services, activities and equipment, so the service organization must declare principal and supporting activities to reach the objectives (*Fig. 3*).

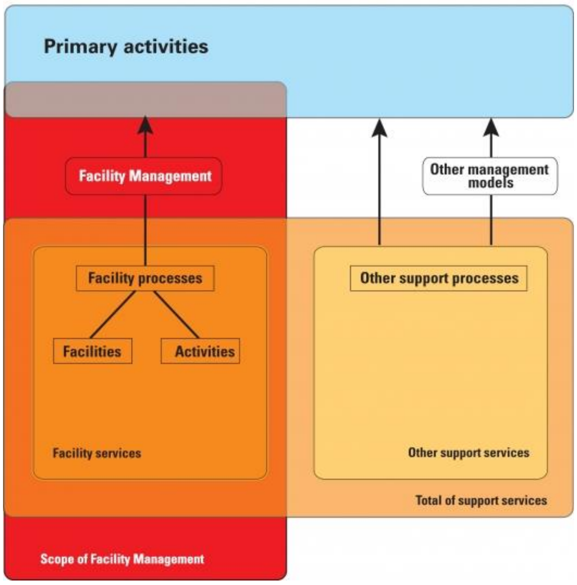


Fig. 3 Scope of the Facility Management (EN 15221, 2012)

In the EN 15221-1 is reported the informative Facility Management model represented in the following scheme (*Fig. 4*):

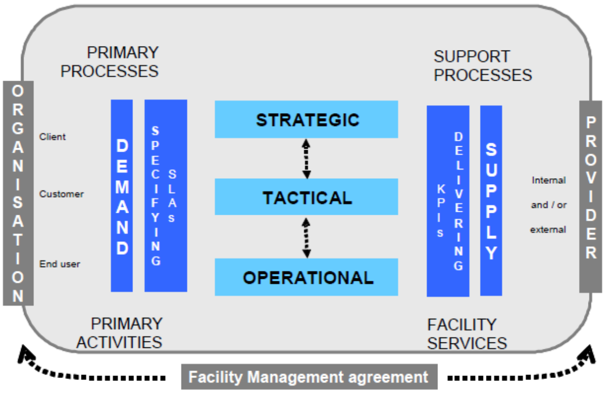


Fig. 4 Informative Facility Management model (EN 15221, 2012)

The model highlights the FM support to the main activities and tackles the relation between demand and supply. It presents also the different levels of interaction of FM: strategic, tactical and operational, to ensure and furnish the required needs.

The strategic results are reached in long term through many activities, for e.g., clear formulation of policy, directives for space, activities, processes and services, promotion of risk assessment and definition of relations with the authorities, user and owner, strategic associates, associations, etc. The creation of Service Level Agreements (SLA) and the definition of the Key Performance Indicators (KPI) are good supports to achieve these objectives.

The Service Level Agreement is a written or oral agreement between the client or the customer and the service provider about the performance, measures and conditions of the borrowed services.

The tactical level permits to implement the strategic objectives in middle term with the development of business plans and budgets activities, management of FM personnel, respect of current laws and regulations and other more specific decisions.

At last, the operational level makes the previous objectives in concrete terms through, for instance, the communication with the service providers and the performance evaluation asked to final users.

The choice of the Facility Management direction, also called operational sector, depends on the client demand and it could be "Space and Infrastructures" or "Persons and Organization". According to the UNE EN 15221-1 (the Spanish version of the CEN Standards), the maintenance of mechanical equipment is classified inside the "Space and Infrastructure" sector as technic_infrastructure. The services supplied contribute to create a comfortable climate, lighting/light graduation, electric energy, water and gas supplies also including operation and maintenance of the building systems. Other examples of pertinent activities are about room administration, renovation and refurbishment, the supply of equipment and furniture in the worksite, and facility cleaning.

The other sector, “Persons and Organization” (that is not focused in this Master thesis), is about health and safety measures, IT services and logistics.

A strong change has been including health, safety and environmental management approaches in the new standard (Alexander, 2013).

Another classification of the FM competences was operated during a global job task analysis (GJTA) in 2009. The core areas defined by the 62 questioned countries were (Wagnon, 2015):

- Communication
- Emergency Preparedness and Business Continuity
- Environmental Stewardship and Sustainability
- Finance and Business
- Human Factors
- Leadership and Strategy
- Operations and Maintenance
- Project Management
- Quality
- Real Estate and Property Management
- Technology

But this list could be extended adding, for example, renovations, organization of constructions, space planning and management, lease administration and asset management (Kensek, 2014).

The implementation of this discipline must be followed by the facility plan reporting organization description, organizational policies, standards and guidelines, corporate structure, procedures and responsibilities.

The management method must be proper to the application context, because the business effectiveness is different in every sector and in every country where FM is becoming relevant.

Another factor to consider is the change. The change is represented by business context, new legislation, politics, economic situation and innovation with effects on the structure of organizations and processes with direct consequences on facility management.

The solution is consider the facility management as a strategic measure, not only as technical procedures application, to have this changes under control and give a timely response. This

ensure continuity and solid aptitude towards risks occurring in the operational phase of a building functionality.
For instance, inside the building it is currently relevant the provision of a well-organized working background with innovative information technologies.
The Facility Management traced according to the guidelines drives to an efficient integration between the processes, a fluid articulation of the three levels, strategic, tactical and operational, a consistent communication overall between costumer/final user and providers. Also important is the role in the connection of historical situation, actuality and future needs.
In this way, an integrated and strategic facility management permits to reach high levels of economic value, efficiency, effectiveness, environmental respect and competitiveness, or in a word sustainability.
Standing to actual data, Italy, Spain and Germany are involved between the 105 countries worldwide of the IFMA organization.

2.2.2 Focus on maintenance core area

The maintenance is a core area highly involved in the integrated and strategic facility management to ensure sustainability in terms of economic value, social implication, health and safety, environmental respect and competitiveness, and risk prevention.
The European EN 13306 defines maintenance as *"a combination of all the technical, administrative and management actions realized during the life cycle of an element, in order to preserve or return it to an estate in which it could accomplish the required functionality"*.
This standard has been accepted with the same contents by the three European countries investigated in this dissertation: in Italy with the UNI EN 13306: 2003, in Spain with the UNE EN 13306:2011 and in Germany with the DIN EN 13306:2010-12.
Before starting with maintenance explanation, it is necessary the definition of "element" by the European Standard: the element is a part, component, device, subsystem, functional unit, equipment or system that could be individually described and considered.
The types of maintenance are classified by the aforementioned regulations in (*Fig.5*):

1. <u>Preventive maintenance:</u> it is realized to reduce the probability of breakdown or degradation of an element in predefined period or according to established criteria.
   1.1. <u>Scheduled maintenance:</u> it is a preventive maintenance realized according to established temporal periods or on a defined number of functional units, but without previous investigation about the condition.
   1.2. <u>Maintenance based on conditions:</u> it includes a combination of condition monitoring and/or inspection and/or essays, analysis, and consequent maintenance activities.

1.3. Predictive maintenance: it is based on the prediction of damages occurred after repeated analysis, knowledge of characteristics and evaluation of the significant parameters of degradation of the element.

2. Corrective maintenance: it starts after the recognition of a damage and it is useful to achieve the required functionality of the element.
   2.1. Deferred corrective maintenance: it is not immediately executed after the survey of a damage, and it is postponed according to other dispositions.
   2.2. Immediate corrective maintenance: it is realized without delay after the recognition of the damage, in order to avoid unacceptable consequences.

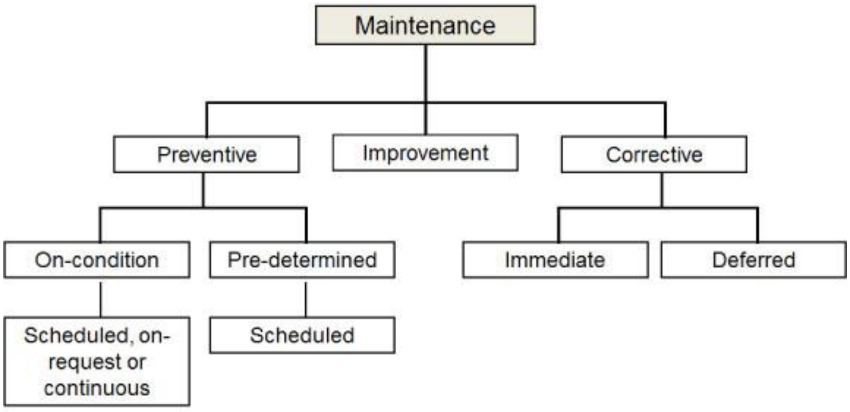


Fig. 5 Significant maintenance types or tactics (EN 13306)

Other classification is about the application mode:

1. Programmed maintenance: it is realized according an established calendar program or on an established number of units.
2. Remote maintenance: it is performed without the physical presence of the maintenance personnel.
3. In operation maintenance: it is carried out when the element is operating and without impact on the performances.
4. In situ maintenance: it is realized where the element is installed.
5. Autonomous maintenance: the maintenance operations are carried out by the user.

The maintenance activities are:

1. Inspection
2. Monitoring of conditions
3. Essay of conformity
4. Verification of the functionality
5. Routine maintenance
6. General revision
7. Diagnosis of breakdown
8. Localization of breakdown

9. Recovery
10. Temporary recovery
11. Improvement
12. Modification
13. Reconstruction
14. Maintenance tasks planning
15. Maintenance program

The EN 13460 defines the documents related to the maintenance management, divided in two categories:

- Documents of the preparatory phase: collection of technical documentation attached to an element, before it is put into service, to support the maintenance;
- Documents of the operational phase: collection of the documentation established during the operational phase, for example after an assessment, to support the maintenance requirements.

The defined objectives, strategies, responsibilities of the maintenance management are reported in a maintenance plan that must be controlled, implemented with activities and cost previsions.

The Chapter 5 and the Annex A of the UNE EN 13460 lists and defines the set of documents and information that should be connected with every installation, equipment, system or subsystem, with the objective to make possible the maintenance organization. The provider must emit the document and information related with the supplied service or element. It is not reported any suggestions about the quantity of information and if the contents must be written, tabled or schematic. This depends on the contract between the user and the provider.

The *Fig. 6* shows the sequence of activities necessary to perform an efficient maintenance management, including a continuous report of the conditions of the building components during the operation phase.

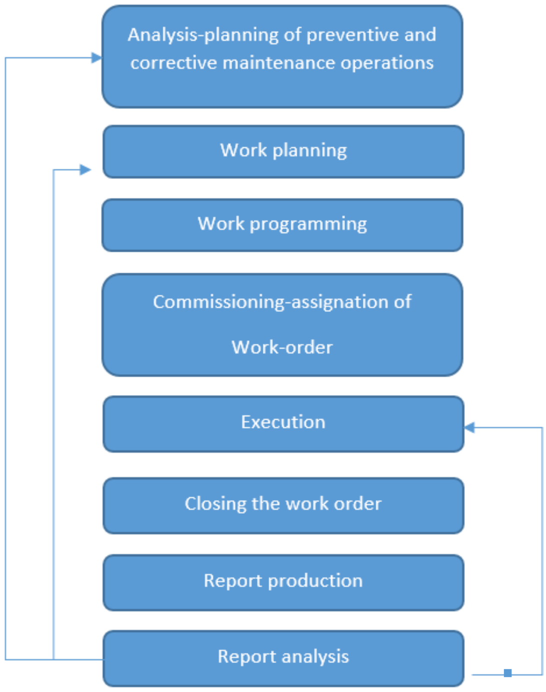


Fig. 6 Maintenance flow chart (Edited flow chart of the UNE EN 13460:2009)

2.2.3 Concept of maintenance in Italy, Spain and Germany

In the following paragraph, general concepts of maintenance will be explained to understand the differences and equalities about the theme in Italy, Spain and Germany. The discrepancies about the meaning of maintenance, renovation and refurbishment between the countries drive the research to investigate on building services, where the inspections and maintenance are similarly conceived. Thus, in the specific is going to deepen heating, ventilation and air conditioning (HVAC) systems.

2.2.3.1 Italy

In the Italian land, numerous are the Standards to define and coordinate the maintenance during the operational phase of the building and its components.
The UNI 11063 has been codified to introduce the concepts of ordinary and extraordinary maintenance. It integrates the terminology of UNI EN 13306, UNI 9910 e UNI 10147, and it is addressed to every sector where a maintenance activity is needed.

1. <u>Ordinary maintenance:</u> type of maintenance operations during the life cycle acts to:
   - Maintain the original integrity;
   - Maintain or restore the efficiency;
   - Contain the normal degradation for use;
   - Ensuring the life span;

    - Cope with accidental events.

This type follows the results of:

- detections of breakdown or failures (to failure or corrective maintenance, as defined in the UNI EN 13306 and UNI 9910);
- Implementation of maintenance plans (preventive, cyclical, predictive and condition-based maintenance) as defined by the Standards UNI9910, UNI 10147 and EN 13306;
- Need of optimizing the availability and improve efficiency (exploitation of interventions or small change that do not increase the asset value of the element).

Such actions do not alter the original characteristics (target data, dimension, building value, etc.) or the essential structure or the use. The costs should be precast (even if on statistical analysis in the budget of maintenance.

2. <u>Extraordinary maintenance:</u> type of non-recurring intervention and with higher cost than the replacement value of the asset and its annual ordinary maintenance. The purposes of the work are to:
    - Extend the life span and/or improve efficiency, reliability, productivity, maintainability and accessibility.
    - Not comport the variation of the asset use.

The Italian law "Testo unico dell'edilizia, D.P.R. n.380/2001" also considers maintenance as a building intervention defining the difference of ordinary maintenance and extraordinary maintenance in terms of building renovation. Preliminarily, it is worth noting that the definition of maintenance, as it appears in the UNI EN 13306, is not applicable outright to that of the "Testo Unico dell'Edilizia":

1. <u>Ordinary maintenance</u>: it is referred only to actions of repair, renewal and replacement of finishing of buildings and those necessary to integrate or maintain existing technological systems.
2. <u>Extraordinary maintenance</u>: it consists in works and changes necessary to renew and replace parts, including structural ones of the building, as well as to implement and integrate sanitation and technological systems. Nevertheless, it must not affect the volumes and surfaces of the individual units and not thereby modified destination of use.

Examples of ordinary and extraordinary maintenance are reported in *Table 1*.

Maintenance	**Element**	**Intervention**	**Examples**
Ordinary	Technological systems	Efficiency maintenance	- Remake of the old electric system ad substitution with a new one;

			- Remake of sanitary elements; - Substitution of the boiler.
		Improvement	- Adding of a further element; - Substitution of telephonic network.
	Finishing	Cleaning	- Painting of room walls; - Substitution tiles.
		Doors	- Substitution doors.
Extraordinary	Technological systems	Improvement	- Replacement of rundown wooden telephone poles
	Structure	Renovation	- Consolidation of the floors or staircase, the realization of ancillary works, but without increase the volume or surfaces; - Demolition and reconstruction of partition walls; - Consolidation of foundation or structure in elevation.
	Envelope	Windows	- Replacement of window and doors with shutters or blinds, with change of material and type of frame; - Energy efficiency retrofitting

Table 1 Examples of ordinary and extraordinary maintenance

The UNI 11257:2007 - Guidelines for building maintenance provides general criteria for a maintenance program, criteria for writing phases, suggestion for adequate strategies and an operative program. A programmed maintenance is promoted for each building component based on knowledge collection data and indications. The knowledge packet consists of duration of components and building elements, list of probable degrade & failure (effect & aspect), operation for inspection activities, preventive and corrective interventions and substitutions, frequency of the maintenance -derived from statistical studies- and a cost comparison in percentage respect a new construction.

In Italian procurements, maintenance documents must be attached to the design information at the delivery of the facility. The executive regulation of the Legislative Decree 163/2006

"Code for public contracts on works, services and supplies according to the ED 2004/17/CE and 2004/18/CE ("Regolamento di esecuzione e di attuazione del decreto legislativo 12 aprile 2006, n. 163, recante "Codice dei contratti pubblici relativi a lavori, servizi e forniture in attuazione alle direttive 2004/17/CE e 2004/18/CE") defines the maintenance plan on the construction and its parts.

The maintenance plan is made up of:

- Use manual: it furnishes instructions for a proper use of the building, its main parts and the mechanical, electrical and plumbing systems (MEP) by the users. In addition, conservation measures when specialist competences are not needed and methods to recognize deterioration issues to contact specialists are provided.
- Maintenance manual: it provides instructions for a proper maintenance, information about assistance services, and description of the needed resources to operate, minimum level of performances, possible issues, user-allowed maintenance operation and specialist maintenance.
- Maintenance program: about the programmed maintenance, it is redacted with a predefined frequency or after changing situations with a performance sub program, a control sub program and maintenance sub program.

The procurement manager (responsabile del procedimento) is in charge to decide if other operative documents are needed with the maintenance plan, written by the design team work made up of architects/engineers/geometricians of the tendering team. The information about the maintenance periods and operations are collected from manufacturers' manuals of HVAC devices, windows, and pre-cast elements, from national regulation and European Standards, and good practice data to adjust the suggestions to get them more cautionary. The construction manager should update the plan according to changes occurred during the execution phase.

The Italian Construction Technical regulations (NTC 14.10.2008) imposes for private and public building a structural maintenance plan, a document written during the third level of project (executive project) by the structural engineer that could be inside the tender team work or a consultancy company.

Nevertheless, the focus of the Master thesis is on the HVAC maintenance sector, and it is going to work on the air handler. The national and European standards will be deeply analysed in the chapter 3 *"Development of Property sets and Properties for an air handler".*

The new DPR n. 74/2013 redefines the methods of operation, control, maintenance and inspection confirming the relevancy of a periodical maintenance of heating systems for winter and summer air conditioning of buildings and for the domestic hot water executed according to the art rules. First, the requirements, given by the installer, must be followed and, in the absence thereof, the technical instructions of the manufacturer for the specific model. If there are no such indications, new maintenance frequencies, established in the table of "'Appendix A" of the decree, will be worth.

The checks are parts of ordinary maintenance with the frequency established in the plant manual - but usually yearly - and the “control of energy efficiency” with frequency to be determined according to the DPR n. 74/2013, which ranges from two to four years depending on the characteristics of the plant.

The maintenance operator drafts the document then sent to the competent authorities.

Nowadays, the Regions should institute a territorial cadastre of thermal systems and manage favouring an interconnection with the Energy Performance Certification (EPA).

The methods and frequencies of the ventilation plant are suggested by:

- UNI EN 15239:2008 - Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of ventilation systems;
- UNI EN 15240:2008 - Ventilation for buildings - Energy performance of buildings - Guidelines for inspection of air conditioning systems;
- UNI EN 15780:2011 - Ventilation for buildings - Ducts - cleaning of ventilation systems;
- UNI EN 12097:2007 - Ventilation for buildings - network of pipelines - Requirements for ductwork components to facilitate maintenance of networks of pipelines;
- Guidelines for defining technical protocols predictive maintenance on air conditioning: 2006.

Maintenance is essential for the proper management of ventilation systems to ensure energy saving and healthy air conditions. And, the air distribution can adversely affect indoor air quality through the air contamination with chemical or microbiological substances.

The checks should be conducted on payload, relative humidity, users comfort, fans, noise and dirt in the channels. A weekly operation is needed for the superficial cleaning, a maintenance every six months for the air ventilation outlets and an annual one for the air ventilation releasers. (Raisa, 2014).

2.2.3.2 Spain

The UNE EN 13306:2011 uses the same definition of “maintenance” (in Spanish *mantenimiento*) of the European EN 13306.

In Spain, the CTE (Codigo tecnico de los edificios) gives design, execution and maintenance indications of each part of the building.

- *Steel: Documento Basico SE-A, Seguridad estructural Acero* The maintenance of protective elements of a steel structure, with precise consideration on fire protection, is very important. The periodical actions will be applied according to the guarantee declared by producers. A maintenance plan is required only in cases of building under actions that induce overbearing. It occurs when the project is redacted according to the principle of safety life for the verification toward stress. When the principle of damage tolerance is employed for this verification, the maintenance plan should explain the interventions to avoid the spread of cracks.

- *Wood: Documento Basico SE-M, Seguridad estructural Madera* The satisfaction of requirements such as thermal insulation, acoustic, or fire resistance are aspects of manufacture, assembly, quality control, conservation and maintenance treated by the manufacturer of a product. This information must indicate on the packaging and in technical documentation the instructions for use and maintenance in accordance with the calculation bases. In fact, wood can be damaged by biotic and abiotic agents. The aim of preventive wood protection is to keep the probability of harm by this cause at an acceptable level.
- *Concrete: Documento Basico SE-F, Seguridad estructural Fabrica* The executor will provide a document about the work performed. It also contents maintenance suggestions according to the indications written in the Maintenance section of this *Documento Basico* including:
  a) a maintenance plan where the inspection is to discover cracks, moisture, differential movements, superficial changes in hardness, texture or color, and signs of corrosion of reinforcement bars and carbonation level of mortar;
  b) when a component demonstrates less durability than assumed for the remaining structural works, specific monitoring of aging will be established in the maintenance plan and constructive measures will be arranged to facilitate their replacement;
  c) when materials used require to be protected, a specific program will be established to review these protections are used.
- *Photovoltaic system: HE5 – Contribución fotovoltaica mínima de energía eléctrica* gives suggestions for a monitoring and preventive maintenance plan. It should be written by a competent technical personnel who knows the solar photovoltaic technology.
- *Lighting: HE 3 - Eficiencia energética de las instalaciones de iluminación*, about lighting systems, provides information on a maintenance plan for the lighting installations about frequency and suggestions for the substitution of the lamps, the cleaning of elements and lighted zone and the regulation for control systems. This

plan is important to ensure the conservation of the proper lighting parameters and the energy efficiency value. It is written by a competent technical personnel.

The Spanish laws about HVAC system maintenance are:

- *Heating: RITE – Reglamiento de installaciones termicas* reports that a documentation about the interventions of maintenance, reparation, inspection and substitution should be attached into the building book. The maintenance company and the facility maintenance manager must subscribe the maintenance certification. It could be sent, if needed, to the competent body of the “comunidad autonoma”. A copy is for the installer. The period of validity is a year.
- *Hot water: HE4 – Contribuciòn solar minima de agua caliente sanitaria* gives indications about the monitoring plan (plan de vigilancia) and a preventive maintenance plan (plan de mantenimiento preventivo). It is necessary controlling every day the installation to prevent any occasional damages due to the over-heating. The maintenance operations could be derived from other regulations. A competent technical personnel, who knows about the technology and electrical installations, is in charge to provide it. The maintenance manual reports the realized operations and the corrective maintenance technics.

The EN Standards about HVAC maintenance, as those investigated in the Italian contest, has been adopted in the Spanish version UNE.

2.2.3.3 Germany

In German regulations, the term maintenance is used only in reference to technological systems such as ventilation, heating, air conditioning systems. The intervention of building components such as envelope, substitution of windows, structural consolidation, are under the name of rehabilitation/restoration and modernization.

According to the DIN 31051, maintenance includes preventive and corrective measures of the original or current building state. For the implementation of these measures, a maintenance plan can be helpful to respect the fixed frequencies to ensure high performance and safety. The routine maintenance actions, often carried out by specialized personnel, may be required in the purchase contracts to ensure the acceptance of warranty claims when a damage occurs.

However, maintenance and repair of technical installations can be set in certain ranges. In particular, from the viewpoint of energy saving and environmental impact, a repair is not sufficient, and a partial or total modernization is the best solution. This concerns the implementation of the Energy Saving Ordinance *Energieeinsparverordnung* (EnEV) for new and existing buildings and the regulation about small combustion plants.

For sanitary engineering and gas installations, the measures and notes related to operation and maintenance of the equipment are described in the regulations and technical rules:

- Technical standards for drinking water systems (TRWI); Management systems; Worksheet DVGW - German Association for Gas and Water;
- Drainage systems for buildings and land - Specifications for service and maintenance (DIN 1986-3).

In order to maintain a safe operating condition, a maintenance contract is recommended to take out with an installation company. The functional tests are feasible by a technician. For each component there are suggestions for inspection and maintenance.

The maintenance of HVAC equipment is a task of a specialist technics; the different parts of the system have proper instructions. The release of a usage certification is needed.

Specific measures are described in the regulations and technical rules:

- operation of heating technology systems (VDI 3810);
- oil burners, oil burners in heating systems, safety requirements (DIN 4755-1);
- gas furnaces, gas furnaces in heating systems, safety requirements (DIN 4756);
- regulation about energy-saving thermal insulation and energy-saving systems engineering for buildings (Energy Saving Ordinance - EnEV);
- First Ordinance about the Implementation of the Federal Pollution Control Act (Ordinance of small combustion plants - 1. BImSchV).

In order to maintain a state of safe operation of the equipment, operators are advised to take out a maintenance contract with an installation company.

Instructions with information about the technology is helpful to ensure the correct use of the equipment by the users and to execute maintenance operation, guarantee comfort and energy and cost savings.

In Germany, there are no federal rules to monitor the operability of ventilation systems. The law about chimney sweeps (SchfG) provides that should be defined at the country level.

The DIN 1946-6 explains that the maintenance of HVAC systems and equipment for free ventilation of apartments should be done not more than every two-year and drawn up by qualified personnel according to a performing maintenance schedule.

The other EN Standards about HVAC maintenance, seen before, have been adopted in the German version DIN.

2.2.4 Issues about Facility Management

The most relevant problems found in the literature review are resumed in the next points:

- The facility management is a multidisciplinary and complex science, it should be flexible to respond to different needs and situations over the time. The flexibility brings to the definition of adequate policies and strategies in every sector and country (Alexander, 2013).
- The formation of FM as a new profession has been difficult because specialist competences are needed to develop a strategic process (Ventovuori et al., 2007).
- Inside the FM three paradoxes lie. First, it should be a strategic science but the competent persons in this sector are part of the operational level; second, FM should be inside the corporate development but the services are provided by external consultants or in-house teams set up as internal consultants; third, FM would be proactive when a managing change will occur but it always demonstrates to be reactive (Grimshaw, 1999).
- Academic research is insufficient to develop the complete science (Ventovuori et al., 2007).
- Fallacious dissemination of academic works among the companies (Ventovuori et al., 2007).
- Absence of objective research about the effect of facilities management on the corporate business (Ventovuori et al., 2007).
- Need of a research concerning FM strategies, different types of facilities organisations, generic FM systems and procedures (Alexander, 1992).

2.2.5 Conclusions

The concept of maintenance is differently used in the three European countries. On a hand, it is generally accepted that technical systems such as ventilation, air conditioning, heating and cooling systems, lighting, fire protections, and then also doors, windows, and structural elements need maintenance actions during the life span to keep their functionality and guarantee the quality of users life inside the building. But, the Italian legislation also introduces this term among the building interventions as a lighter renovation of existing building. In conclusion, a good theoretical and practical homogeneity has been found in the HVAC sector in terms of standardization, rules and good practices in design, installation and maintenance.

A solution to the executive problems synthetized in the previous paragraph could be the integration of Facility Management in Building Information Modelling. It can support flexibility and strategy thanks to data collected and easily upgraded during the life span to follow the change (reactivity) or foresee it (proactivity), to help the specialist individual to organize and respect the policies and the strategies without reading entire paperwork but only navigating a BIM model, to allow the passage from operational competent to strategic competent for the reason explained before, to handover information to external consultants that can work as in-house teams due to the use of BIM parametric models.

The proofs have been conducted most in American built contests, where BIM system and Facility Management is more developed then in Europe, with exception of UK and Northern Countries.

In base of this, the final dissertation will be focus on the integration of the HVAC maintenance management into BIM system in order to reach effective, reasonable and applicable results for the three European countries. It should be remembered that the objective is understanding the reaction of each investigated country toward facility management and BIM, starting on the facts they are not well employed together and related Standard Codes late in coming. A solution is defining a common maintenance management BIM format to collect and exchange structured and regulations compliant data. The attention on this aspect ensures the concrete application of corporate policies of quality, health and safety and environment respect, necessary in any design, construction and management organization.

2.3 Integration of Facility Management in BIM

The Facility Management discipline is linked with the previous construction phases so the handover of data is necessary from the design and execution teams to the service company to ensure the good success in the strategic and programmed activities. If BIM has been defined as a "wisdom about a facility, a reference for any decision of actions occurring through the building life cycle until the demolition" by Malone, which better tool can be employed to overcome the gaps and have concrete effects on the lifespan increase, building value rising, health and safe and sustainability.

But, Building Information Modelling has available several data exchange formats, some of these not highly performing in maintenance purpose or in interoperability.

Thus, an overview about the potential data exchange formats is done, before to elect the most suitable for the final dissertation objectives.

2.3.1 BIM as wisdom for Facility Management of existing and new buildings

The potential use of BIM in maintenance and management of facilities is in evidence and even more abreast of it for design and construction phases.

The facility maintenance is closely connected to the design and execution phases, for this an incomplete project, inadequate requirements and modest quality construction can arouse expensive identification of the fault and application of the resolved interventions. As consequence, necessary maintenance and reparations are needed incurring in unexpected costs. The entire construction lifecycle should be considered into the facility maintenance management in order to create a solid policy and to make good financial decisions, insuring resource and values assessment of the building. All the actors involved in the construction process should contribute to prepare the maintenance plans. The organisation's financial and taxation position must be taken into interest in the writing of a maintenance plan to stay in the provided budgets (Atkin, 2013).

The Facility Management is supported by cost estimation, scheduling features and quantification that could be executed in BIM software platforms.

BIM might be employed as a strategic mean for maintenance planning in an existing building and a new construction offering different start point of data collection. In the first case, if a previous BIM model has been redacted, it might be updated, or an as-build model can be realized.

In European countries is widespread the second option where about 80% of residential building have been constructed before 1990, when BIM formats were not so developed. A help to recollect the information is conducting by an opposite engineering process: *point-to-*

BIM or *scan-to-BIM*. In a new construction an as –planned BIM might be realized and updated to monitor all the LC stages (Volk, et al., 2014) (fig. 1).

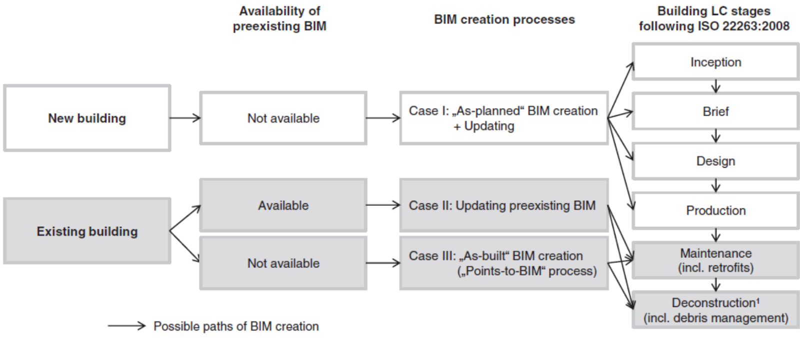


Fig. 7 BIM model creation processes in new or existing buildings (Volk, et al., 2014)

A study investigated the development in research and practice about the functionalities of the narrow BIM (tools) and emerges that a major effort should be done in the sector of maintenance and information updating for building and infrastructure (Volk, et al., 2014).

During the operation phases, the leveraging of BIM can produce high savings in energy, time and cost, as also verified in the early process stages by the AEC actors, using a digital model and analysis.

The 3D BIM, in the as-built edition (after the construction), can support the facility management working as a control system and a test bed of the real facility.

The HVAC maintenance could be validly sustained by an as-built BIM connected with sensors and actuators. The BIM model is the data control system to set the output. For instance, the sensors used for the measurement of indoor temperature can be useful to reveal failures in the heating system. The elaboration of the algorithm can be used as instructions for actuators in changing the configuration or notice a breakdown.

The building information modelling should be considered as an "actual physical and virtual database in communication with the neighbours".

The connection between BIM and the building supports:

- Recording of the building "health fitness" (real energy usage trend);
- Diagnosis of problems such as fan with fault is recognized in localization;
- Suggesting a solution by a message to a maintenance team (providing the technical specifications and manners of fixing);
- Giving periodic check-ups (for e.g., alarm check, fire sprinkler, age issues and localization of hazardous substances) (Kensek and Noble, 2014).

The focus on the application "maintenance and operation" in Facility Management, according to the table 2.2 reported at pages 78-81 in the book "Building Information modelling" of Karen M. Kensek, 2014 is reported below (*Table 2*):

Category	**Examples**	**Comments**
Operation and maintenance	Pursuit of durability an performance of the building during the life span Investigation on endurance of building component, fixtures, furnishings and equipment Preventative maintenance Equipment lists, element specifications, warranties Landscape design and irrigation automated system Infrastructure location (HVAC system, lighting, electric plant, gas) Decrease or elimination of the tie for research documents and use a the applicable information to an entire data	A BIM 3d map can localize the faulty elements and furnish a source for product data. Spatial edges can be defined around the simulated object and light clash detection with tolerance can be pretended to check if sufficient manoeuvre space for the maintenance. The engineer/architect should design the technical room for the installation of HVAC equipment in order to respect a buffer area between the elements and the wall of ceiling of the room, to operate maintenance. The virtual buffer zones in the 3D model help the software to recognize the clash.

Table 2 Examples and comments on BIM use for Maintenance Facility Management (Kensek, 2014)

In 2013, the National Facilities Management & Technology Convention of Baltimore presented a case study about the existing Eastern Service Area FAA Tower to explain the time and costs savings using BIM in every stages instead of traditional tools, recording 60% of saving hours and a projected cost saving of 65 million dollars in a period of 10 years for operation and maintenance (remotely diagnosable issue and on-site service).
In 2013, B. Haines wrote an article about the possibility to use the Integrated Workplace Management System (IWMS) for a BIM that includes the whole facility lifecycle. This represents a valid help for Facility Management, together with the 3D model, when the users might execute maintenance activities, but the design and construction teams scattered after

the delivery of the building. The passage of responsibilities from IWMS and BIM is performed by the Cloud (web-based technology) creating a link between the geometrical, functional and topological data that could be taken from an “easily maintainable digital operating and report manual for the building” for every subject matter expert.

Haines’ thought is also that to leave a 3D model with a right level of detail and data priorities to the building owner to help him in the updating it in an as-maintained, open to add data from facility professionals (Haines, 2013).

The integration of FM in BIM is an under development area and it is still accompanied by limited knowledge. In addition, the research are mainly interested on new buildings despite new works making up only 1-2 % of the total building stock in a typical year (Kincaid, 2003). Also, real world cases on BIM applications in FM are small in numbers and incomplete (Becerik-Gerber et al., 2012).

2.3.2 Potentiality of data exchange formats and open BIM

A big issue is that the AEC actors and contractors do not often use a unique single project BIM during the life cycle of a building project. It also has been revealed in United States. So, there are many BIMS to accomplish several commitments.

Software platforms as Computer-aided Facility Management (CAFM) and Computerized Maintenance and Management Systems (CMMS) consent automated data transfer with BIM (Akcamete, et al., 2010).

The automated transfer of data from BIM to CMMS could be executed using FM software, but the info are only about room areas, location, maintenance scheduling, attributes and asset information. The lacks of spatial and topological relations between building components avoid the detection of clash, breakdowns, repairs and, consequentially, causes and impacts that are important for the definition of a complete maintenance planning (Akcamete, et al., 2010).

During the integrated construction process, the BIM data are extracted from CAFM and/or CMMS platforms in a standard format, COBie (Construction Operations Building information exchange), which has the limitation of sharing no-graphic information. This BIM format was born in USA in December 2011 and approved by the US-based National Institute of Building Sciences to take part of the National Building Information Model standard (NBIMS-US) (East, 2012). In UK COBie became a British Standard in September 2014 (BS 1192-4:2014 - Collaborative production of information Part 4: Fulfilling employer’s information exchange requirements using COBie – Code of practice) (BSI Corporate, 2014). A positive purpose of COBie is expressed by the opportunity to create an open and complete database of information that can be used immediately and during the building life cycle from all the actors involved. In fact, a BIM integrated CAM system receives standard data, ready to be used by facility manager. The handover method could be of two types: using ad-hoc interfaces or giving manual input. Recently, these methods evolved into a web-based system allowing mobile access with bar codes or interactive masks. The relevant and no redundant data are handed over to the facility maintenance management, respecting the real estate condition of the facility. COBie is a platform which uses spreadsheets readable also with Microsoft Excel to insert data useful for next stages. COBie platform allows to collect information during the use of every BIM function; it also gives the possibility to extract maintenance plan and instructions and import this in a facility manager's CMMS (Akcamete, et al., 2010).

Nevertheless the continuous upgrade and the customable organization in categories according to the needs and the situation, this system made up of BIM, CoBie and CAFM/CMMS, is still not adequate to reduce critics and guarantee the national and local regulations. This is not easy if for the maintenance daily activities the CAFM use conventional tabular data and 2D plans (Caputi & Ferrari, 2013). It is important developing the adoption of BIM in its total capability, representing 3D parametric objects and highlighting reciprocal relations (Akcamete, et al., 2010).

In addition, FM is not completely inserted in CMMS in an effective way. This is the result of a "fragmented BIM", because information must be explicit, related and structured in only one "BIM box" and, overall, the responsibility of data included in the model is not always clear.

A gap, or a weak link, occurs between architect/engineer/consultant and Facility Manager & Owner. Better software and hardware, in terms of structure, interfaces, easiness, can represent a possible solution together to data transferred in an appropriate structure. A point in favour is the introduction of all the staff into the project since the design phase, because some should be not aware of this new methodology and not trust in data supplied. (Kensek and Noble, 2014).

Another data exchange format is the IFC (Industry Foundation Classes), as suggested in previous explanation, it is an open standard because it is vendor independent and introduced by the international Alliance for Interoperability (IAI). It supports the handover of data between 3D models and information sets, so from Building Information Modelling software to applications for cost estimation, CMMS and space management. For example, it is possible to export COBie file in IFC format thanks to BIM applications such as Revit (*Fig. 8*).

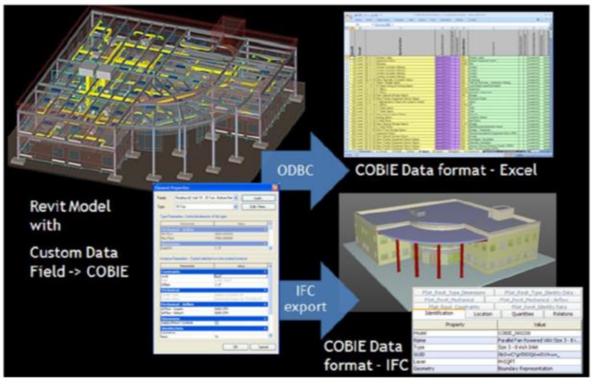


Fig. 8 COBIE exported in Excel and IFC with Revit model (Sabol, 2008)

About IFC data standard has been spent the entire paragraph 2.4 *"IFC Standard evolution and its last development: IFC4.*

HVACie exchange specification can be employed in the specific field of HVAC management.

HVACie is a technical extension of the IFC Coordination Model View Definition, to transfer the complete information system about properties and connections of mechanical equipment. But, it is not used for maintenance programming because only few software products implement HVACie and only during design and construction manufacturing (for e.g. Revit MEP and East Coast CAD/CAM).

2.3.3 Case studies

Three real cases will be shown about the implementation of BIM in Facility Management to understand the methods, practices, errors and useful reference. These are the Sidney Opera House in Australia, the Northumbria University's city in United Kingdom and the New Vélizy Campus in Yvelines in France, all public facilities. Unfortunately, the construction companies and the developers did not have intention to divulgate the detailed manner of working in the sector of FM with BIM, explaining it is still in a research status. But, at least this study about real projects supports the investigation of this final dissertation and gives the current arrival points.

2.3.3.1 Sidney Opera House - Australia

Since 2005, a pioneer integrated project about Facility Management and BIM has been performed on the Sydney Opera House. After years of investigation the need of a 3D model has been considered to improve effectiveness of management purposes in terms of time and costs. When the facility has been built (1958), BIM did not exist so the complex construction has been reported in paper and pencil drawings. In addition, it has been completed in 1973, with several modifications respect the original project and as-built plans and reports were not prepared. Thus, the data about the structure and equipment inside were missing and the CAD drawings, realized in 1980s, were useless and incomplete. For years, the management laid on different systems without coordination and collaboration. The operation and maintenance organizations felt the lack of an integrated and strategic facility management system to control the continuous changes. For this, recently a building information model has been executed with a meticulous geometry, the entire technical system (lighting, HVAC, fire system, lifts), maintenance and cost data, and topological relationships between them. There are the *"master model"* and the sub models about the specific disciplines (structure, architecture, mechanics, etc.). The structural model has been provide by Arup, the consulting company, and employed for the development of the others. The master model is about space organization (location, use). It uses GIS (Geographic Information System) transferred by IFC files to insert utilities, ground topography and other site characteristics. Objects contain information about identification, maintenance instructions and scheduling. In fact, a Building Condition Index has been created to define condition, tidiness and cleaning of rooms. The data exchange from a model to the other is supported by IFC format and to extract Facility Management tasks (*Fig. 9*).

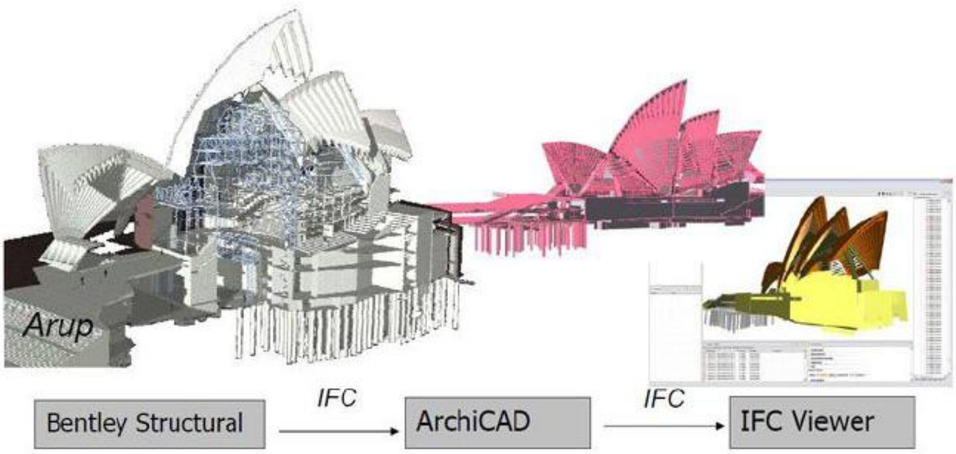


Fig. 9 Data exchange with IFCs in Facility Management applications (Sabol, 2008)

Because of the absence of solid bases under BIM and Facility Management, the project group provided guidelines and suggestions in form of specifications explaining the data population method and conventions to have a concrete and true BIM (Sabol, 2008).

2.3.3.2 A HVAC maintenance case and Northumbria University's city - UK

In UK case studies about facility maintenance management integrated in BIM solutions are available both as research topic and real application of construction companies.

In 2013, Ljiljana Marjanovic-Halburd completed a project about “the development of the HVAC Product Data Templates Suitable for 5D BIM software platforms” for the funding body/client “Amtech and TSB Technology Strategy Board”, software providers.

In this study 5D BIM software tools, generally linked with cost estimation, scheduling features and quantification, were employed to optimize spatial solutions of Heating, Ventilation and Air-Conditioning (HVAC) equipment about permission, mounting and arrangement but also to insert technical information such as efficiency, outputs, warranties, service and maintenance requirements. In this way, 5D BIM tools can become data-collection framework on HVAC design parameters, operation and maintenance requirements, and relevant legislation and standards.

Data templates have been formulated to collect information about the products to help the AEC personnel and contractors to select them according to the properties, operational performances, possible financial risks and specifications about installation, maintenance and decommissioning. The categories to organize the data attributes were: Legislation & Regulations; Performance; Environment & Sustainability; Financial Cost. The maintenance plans could be supported by this product-specific, process-driven database. This work has been accepted for the Lake Constance 5D-Conference 2015 in Konstanz, Germany (Marjanovic-Halburd, 2013).

In 2010, a real world case study was directed on 32 non-residential buildings in Northumbria University’s city campus, Newcastle, UK. It has a gross area of over 120,000 m^2. The University asked building information models to five developers to study the capability of BIM in space management, a particular FM function. The models have been produced from Estates Department’s floor plans in DWG format, scans of the original elevations, sections in JPEG format, and space information in Excel databases.

The use of BIM for FM permits to reduce the time employment of a CAD user generating automatically lots of information from a single integrated model. The BIM models collected further information involving integrated asbestos register, emergency equipment, escape routes, accessibility and maintenance. It is easily possible to extract and report the information on these components in schedules or documents. In *Fig. 10* is demonstrated the importance of BIM in managing the asbestos removal. It provides information about asbestos properties, location, date of removal and location of survey documentation.

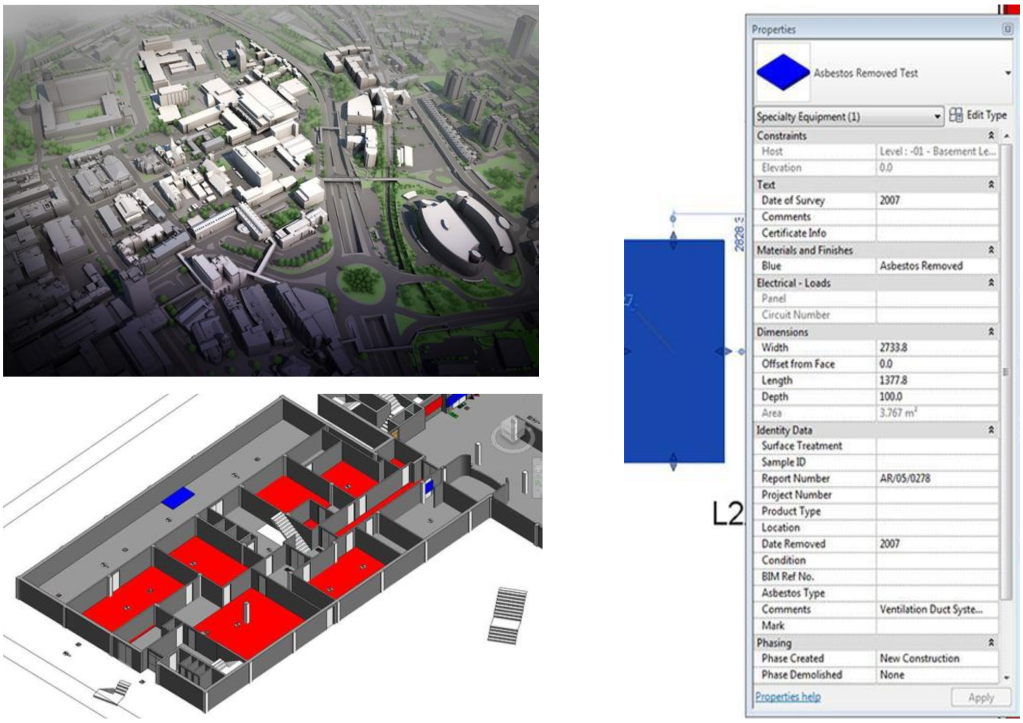


Fig. 10 Northumbria University's city campus: 3D view of space management and asbestos removal
(Marjanovic-Halburd, 2013)

BIM for FM models allowed to the estate department staff to implement actions of room finding, fault reporting, development and refurbishment option generation, and assessment of building performance. If there will be a request to replace a light bulb, the maintenance personnel could check in real time the bulb type and manufacturer using the FM model. Or, in case of wall finishing damages the model could provide the paint colour code for the room. BIM 3D visualization has been useful to provide alternatives for redevelopment and refurbishment compared through phased plans, sections, elevations and 3D renderings(Kelly et al., 2013) (*see Fig. 11*).

Fig. 11 Generation of design options for internal refurbishment (Kelly et al., 2013)

2.3.3.3 New Vélizy Campus in Yvelines - France

The New Vélizy Campus in Yvelines, France, counts in total 95,500 m² divided into 49,000 m² of offices and 46,500 m² of infrastructure with a construction time limit of 22 months.

It was designed in a digital model and the automated database will be used for operation and maintenance activities. It is just delivered to Thales by Foncière des Régions and the Insurance Credit Agricole offering administrative rooms for 2,400 workstations. The general contractor “Vinci Construction” performs its task on site, the “Vinci Facilities” subsidiary manages the buildings after the construction. Encrypting and dimensioning the contract and maintenance services with the BIM is a prime asset in the Facility Management, as explained David Ernest, director of the expertise centre at “Vinci Facilites”: *"Being able to see the BIM construction has already allowed us to have a complete state of the site. We were able to overcome the on-site visit of the building as of the audit, and establish reliable quantity surveys with identified facilities. Associated with project reviews, we have formalized the information we needed to optimize the daily management of the site and programming of maintenance and construction."*

During the last lifecycle phase, the tenants could change and BIM would be the "invariant" element for the maintenance activities. According to Jean-Eric Fournier of Foncière des Régions, BIM represents a new service provided to tenants, as the ability is to better manage its property assets. The precaution is the necessity of a specialist to ensure its good performance. BIM Manager leans at all stages of the life of the building (protocols, permits, update rules, organization) and the legal aspects of data identified as essential. *"There is what the books say and reality: we are now in position to check and formalize other than financial gains elsewhere, in terms of responsiveness and quality of intervention"* notes Thierry Berthomieu, Site Director of the headquarters of Thales. Therefore Vinci Facilities closely observes a control area "BIMée" with all materials used on the site (Nagy and Nicolas, 2014).

The result is to integrate into the BIM construction, CMMS and GTB (Green BIM template). Associated with project reviews, the need to formalize the information emerged for the daily site management and the maintenance and programming of works (“BIM de bout en bout,” 2014).

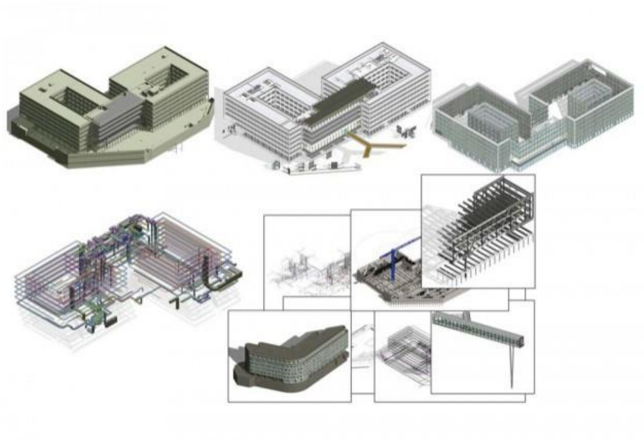


Fig. 12 Revit models (architecture, structure, MEP) for Facility Management (Di Giacomo, 2014)

2.3.4 Issues about the integration of FM in BIM

The review about the recent implementation of BIM method in Facility Management reveals the following problems.

- Theoretical and practical researches are mainly interested on new buildings (Kincaid, 2003), even if the Engineers and Architects are mostly called to restore or refurbish existing buildings.
- Real world cases on BIM applications in FM are limited and incomplete (Becerik-Gerber et al., 2012). The information about the method to include, organize and employ data inside the 3D model, such as maintenance and operation instructions, is not disseminated.
- A problem in the use and maintenance of BIM and COBie data lies in the transfer, in other words it is important the improvement of the BIM analytics (Kensek and Noble, 2014).
- It is clear the inconsistency of BIM, CoBie and CAFM/CMMS collaboration because topologic data and relationships between parametric objects are omitted.
- The real communication between BIM and building simulation software often suffers the negative effects of not applicable software, expensive structures, deficient feedback loops, and absence of a common language (Kensek and Noble, 2014).
- After the commissioning, the private owner or public administrations have to handle lots of information in different formats that are needed in different periods during the life span of the building, getting complicated the maintenance phase.

These critics reduces good practical results and avoids the total compliance with national and local regulations.

2.3.5 Conclusions

The solution lies in the complete employment of 3D BIM parametric objects and its open modifiability. A common language is necessary to populate data useful for all the members of the teamwork. So, the dissemination of the IFC Standard must be promoted because the interoperability and traceability of information can be possible also after several years. The guarantee about compliant data with regulation requirements can be achieved structuring the code contents in the IFC format language, so adding parameters and instructions useful for maintenance purposes in the current IFC Standard.

The efficient integration of FM in BIM crosses the formation of experts able to control and elaborate the results of the data provided by the software and others who create a model without errors and always in contact with the first to not have issues of misunderstandings. In other words BIM experts and BIM coordinators.

An important role is that of the user/owner of the building that uses it in many years. The owner should be instructed to use BIM information and execute effectively maintenance operation of his competence. Known that owners are not persons of the sector, the structured information should be well readable, understandable and easy to manage. Complex programs that provide numerous parameters and settings could be difficult and take lot of time to use. Thus, a good direction is creating platforms to help the user to understand intents, limitations and assumptions in few time and in an easy way.

The software vendors must do an effort in the evolution of their products to create a structured and univocal way to collect, elaborate and handoff data via IFC Standard.

2.4 IFC Standard evolution and its last development: IFC4

The investigation of advantages and issues reported in previous applications of integration BIM-FM to real case studies underlines the importance to develop the IFC Standard. IFC can support the compliance of an entire project (design, execution, maintenance, demolition) with national and local regulations and limit critics and errors, with the consequence of money savings. In addition, it can substitute the paper documents favouring maintenance and next conveyances of information about a construction project. The current BIM systems have been partially employed and IFC has not been adapted to local normative requirements until now. In fact, IFC libraries derive from European Northern countries standards based on American-typed requirements. The reason is the low participation and collaboration of European AEC industry and other construction shareholders in the writing and editing of the standard, although the birth of national buildingSMART chapters. But, also, the employment of private standards inside a teamwork. In this dissertation, the purpose of IFC improvement starts from a conscious knowledge of the IFC Standard structure and the evolution of contents, programming language, organization of the IFC documentation in the last twenty years.

2.4.1 Industry Foundation Classes (IFC) overview

The buildingSMART International is the organization working on the development and the maintenance of the open standard data specification IFC, better recognized as its own data standard. The reason of this declaration lies in the acceptation of IFC4 as ISO 16739 (http://www.buildingsmart-tech.org/specifications/ifc-overview). The IFC Standard encodes geometric and parametric data of an object:

- Semantics about identity of data;
- Relationships between data sets;
- Properties as attributes about physical and performance properties (e.g. materials and efficiency) and qualitative data (cost and manufacturer) grouped in property sets;
- And, quantities sets about the instances contained inside an IFC file.

A general building component, such as a HVAC or mechanical equipment in the current case study, is described inside an IFC data model file containing shape, costs, maintenance instructions, location, energy supply, connections (Kensek, 2014)

To write an IFC specification is employed the EXPRESS data definition language, or standard ISO10303-11 as declared by the ISO TC184/SC4 committee. For example, STEP and CIS/2 (CIMSteel Integration Standards) use this data definition language as programming syntax. The positive characteristics of this language is the compactness and the capability to take in data validation rules within the data specification. The STEP physical file format (or ISO10303-21 Standard for the ISO TC184/SC4 committee) structures the IFC data exchange file (*.ifc) and takes part of the ASCII (American Standard Code for Information Interchange) file formats used to ensure interoperability between different software products. Since the IFC2x release (in October 2000), an ifcXML specification is provided together with the IFC-EXPRESS specification. The ifcXML specification runs as an XML schema 1.0, according to the W3C (World Wide Web Consortium) definition, it is practically a XML translation of the STEP-based format.

The XML document has the ifcXML exchange file structure, IFC data file with suffix *.ifcXML. The advantage is that IFC-EXPRESS and ifcXML permit to manage the same data because the "XML representation of EXPRESS schemas and data" (ISO10303-28 ed. 2) automatically creates XML schema from IFC-EXPRESS source. Thus, *.ifc and *.ifcXML data files can be converted bi-directionally.

The*.ifczip is a compressed folder with all the IFC file formats and other files as PDFs and *.jpg. The *.ifcZIP files is able to compress an *.ifc down by 60-80% and an *.ifcXML file by 90-95%.

Each IFC standard release contains:

- the IFC Specification html documentation (including all definitions, schemas, libraries);
- the URL for the IFC EXPRESS long form schema;
- the URL for the ifcXML XSD schema.

Before going deep into the topic, main terms and definitions may be shown (Liebich and Chipman, 2013) :

- *"Attribute: unit of information within an entity, defined by a particular type or reference to a particular entity".*
- *"Entity: class of information defined by common attributes and constraints as defined in [ISO 10303-11]".*
- *"Type: basic information construct derived from a primitive, an enumeration, or a select of entities".*
- *"Property: unit of information that is dynamically defined as a particular entity instance".*
- *"Property template: metadata for a property including name, description, and data type".*
- *"Property set template: set of property templates serving a common purpose and having applicability to objects of a particular entity".*
- *"Instance: occurrence of an entity".*

2.4.2 IFC releases history

The previous IFC releases of the IFC2x Platform are:

- The oldest releases are IFC2.0, IFC1.5.1, IFC1.5 and IFC1.0 but just obsolete.
- IFC2x: October 2000, to provide a stable platform, and its IFC2x Add 1 (Addendum 1) released in October 2001, to fix issues emerged during implementation phase.
- IFC2x2: May 2003, second edition of the IFC2x Platform, published in several extensions of IFC in domain areas, and its IFC2x2-Add1, published in Jul 2004.
- IFC2x3: February 2006 and its IFC2x3-TC1 published in July 2007 as Technical Corrigendum1.
- IFC2x4: March 2013, or also declared IFC4. It can describe building, building service and structural elements. It has been integrated with ifcXML specification, and a new documentation format.
- The current release is the IFC4 Add1: 10 July 2015. It represents the buildingSMART Final Standard. It has been published after improvements and enhancements issues reported in pioneer implementations and to contain the official IFC4 Model View Definitions (MVD). The MVD (IFC View Definition) contains a subset of IFC schemas to convey data efficiently fixing specific Exchange Requirements defined by the AEC actors. These requirements must be inserted inside the Information Delivery Manual (IDM), ISO 29481.

  IFC4 Add 1 works as the baseline for IFC4 Reference View V1.0 and IFC4 Design Transfer View V1.0, the first two IFC4 Model View Definitions releases.
- IFC5: in a planning phase, it needs the support to create infrastructure domains to be developed in the IFC Alignment Project.

Focusing on the current IFC4 Add1 [Final Standard], it is more readable because entities and types are described with language independent sections, dividing EXPRESS to XSD coding. The MVD development and validation will be supported by the use of concept templates and concepts defined in mvdXML specification.

The concepts definition is important to explain the meaning of data types according to different situations, being applied to specific entities. Inside a template, these concepts are useful to understand how entities are related with their attributes and they are represented as graphs.

2.4.3 IFC data schema architecture

Four conceptual layers compose the "IFC data schema architecture" (*Fig. 13*) where individual schemas belong to only one conceptual layer.

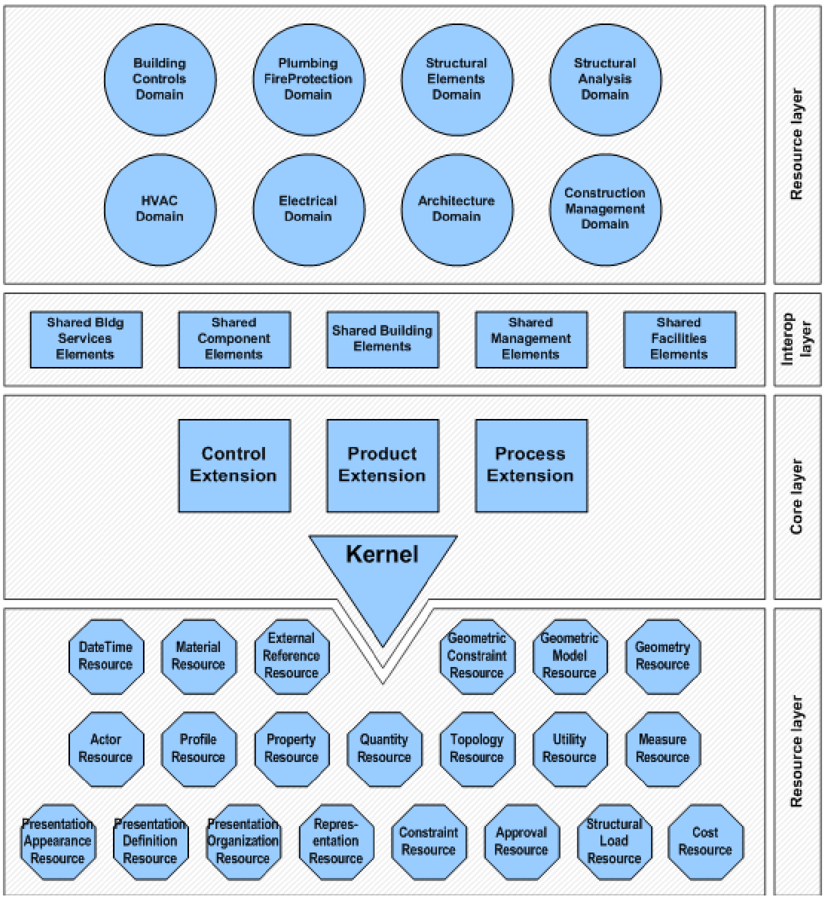


Fig. 13 IFC data schema architecture and conceptual layers (Liebich and Chipman, 2015)

- Core layer: the most general layer. It is possible to reference or specialize the included entities by all entities of the above layers. It defines the basic structure, the essential relationships and the common concepts for all eventual specializations in a model. All the entities of the core and the above layers come from *IfcRoot*, because they have only one identification, name, description, and change control information. It includes the kernel schema and the core extension schemas (Control Extension, Product Extension, and Process Extension).
- Interoperability layer: general entity definitions about a specific product, process and resource are defined in shared element data schemas. It provides also relationships inside multiple domains.

- Domain layer: entity definitions are provided as specializations of products, processes or resources inside a discipline. They contain all the useful information and cannot be referenced by any other layer.
- Resource layer: resource definitions are grouped in individual schemas but without a unique identifier. They cannot be used independently but must be referenced by entities inside *IfcRoot*.

The scope of this research is the development of IFC Standard with parameters required by national and European standards in the HVAC maintenance discipline. Thus, this will be concretized by the creation of properties organized in existing or new property sets of some entities inside the *IfcHVACDomain*.

The building service device is defined as concept template *Object Definition* that comprises the enumeration of *Property Set*s, explaining the association types between sets of properties and objects or object types.

A property set is defined by a name, the general applicability to instances and the properties grouped into.

The property sets are classified in three groups:

- Property Sets for Objects: definition of how object type and its property sets are related. The data type of an individual property can be defined as single value, enumerated value, bounded value, table value, reference value, list value, or combination of property occurrences.
- Property Sets for Types: the value of a property set is valid for all the occurrences if associated to an object type.
- Property Sets for Performance: properties about performance have values reported with a certain time frequency defined by *IfcTimeSeries*.

In *Fig. 14*, an example of instance diagram to understand how all the entities inside this concept templates are related with the attributes.

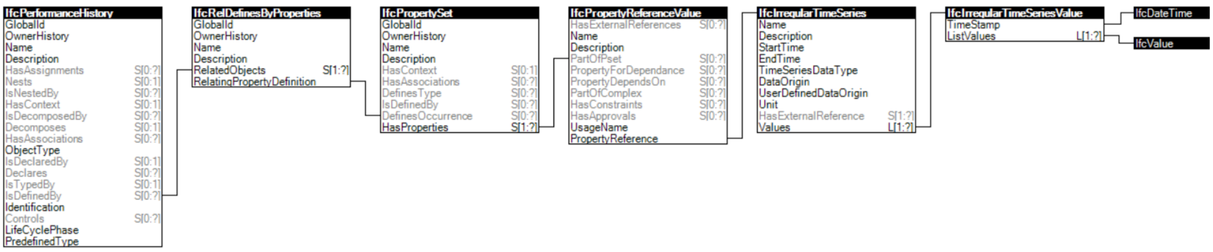


Fig. 14 Instance diagram of Property sets for Performance (Liebich and Chipman, 2015)

2.4.4 HVAC Domain organization

The development of the IFC Standard is going to involve some entities inside the *IfcHVACDomain schema*. It provides the basic object contents about the heating, ventilation and air conditioning field extending concepts of the *IfcSharedBldgServiceElements* schema.
It comprises building services equipment, individual components (chiller, fan, heat exchanger, vibration insulator, valves, etc.), and piping and ductwork.
IfcSharedBldgServiceElements schema provides basic types and occurrences about movement, distribution and control systems and property sets for common building services. *IfcDistributionElementType* specializes types, *IfcDistributionElement* gives occurrences. According to *IfcControlExtension*, *IfcPerformanceHistory* gathers performance parameters (*Fig. 15*).

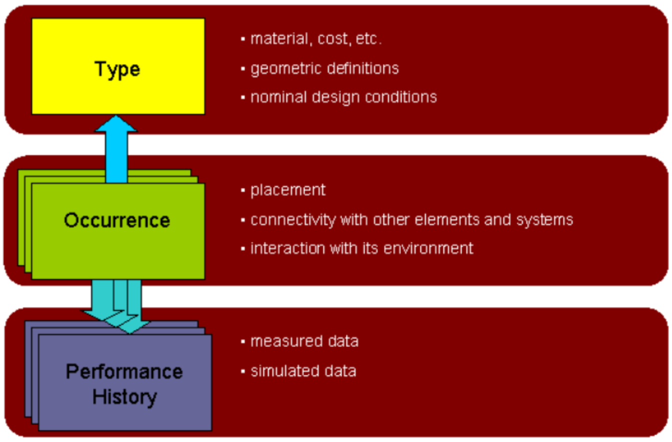


Fig. 15 Type, occurrence and Performance hystory (Liebich and Chipman, 2015)

In case of HVAC systems, the *IfcSharedBldgServiceElements* schema is developed in the following specific concepts:

- IfcEnergyConversionDevice: it tags a technical component able to convert energy or transfer heat inside a flow distribution system. In the specific occurrence of HVAC, it is used to heat or cool a secondary medium. A building service component is specified by its correspondent type *IfcEnergyConversionDeviceType*.
- IfcFlowController: it corresponds to a flow regulation element (for e.g. dampers). *IfcFlowControllerType* represents its type.
- IfcFlowFitting: it tags a joint or transition in a flow distribution system (e.g. elbow, tee). Its type is defined by *IfcFlowFittingType* or its subtypes.
- IfcFlowMovingDevice: it defines a flow driving device. It works performing a pressure differential to drive an airflow. An example is the fan. Its correspondent type is under *IfcFlowMovingDeviceType*.

- IfcFlowSegment: It tags the use of a segment for a flow distribution system. *IfcFlowSegmentType* contains all the characteristics of the segment type (e.g. material, shape, ports).
- IfcFlowStorageDevice: it corresponds to the devices used to gather energy, it is used with its type *IfcFlowStorageDeviceType*.
- IfcFlowTerminal: it corresponds to the inlet or outlet opening of a flow distribution system towards another environment. It has the type IfcFlowTerminalType.
- IfcFlowTreatmentDevice: It tags a component to improve fluid quality. Its type is defined by IfcFlowTreatmentDeviceType or its subtypes.

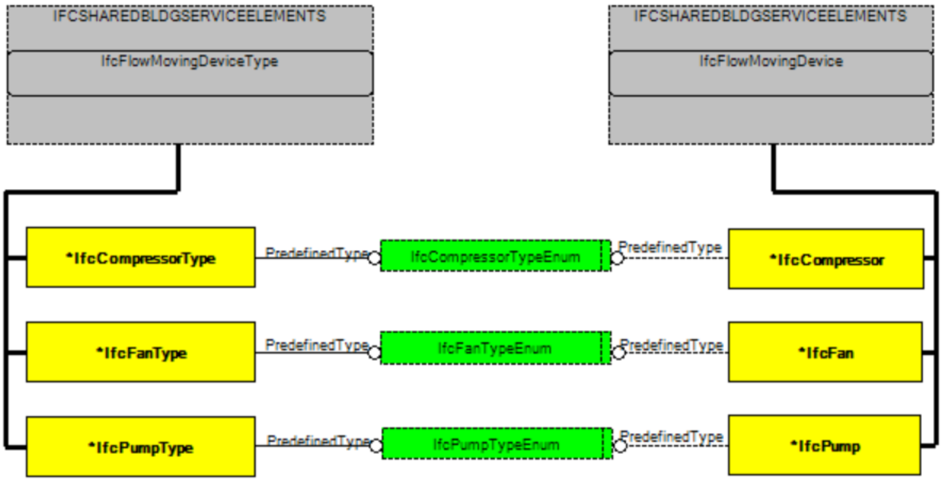


Fig. 16 A part of HVAC specific data schema in a EXPRESS-G diagram (Liebich and Chipman, 2015)

2.4.5 Focus on a HVAC equipment: Air handling unit in IFC4

The results of the analysis of current laws and regulations in the three European countries selected to arrange the efficient and compliant development of the next edition of IFC2x4 Standard drive to investigate building service elements with standardized and similar performance, geometrical parameters and maintenance instructions. Among the large building services set, the attention has been turned to the heating, cooling, ventilation and air conditioning systems (or HVAC).

Two motivations drive the choice about the research subject:

- the need to efficiently perform the experiences in MEP (Mechanical-Electrical-Plumbing) parametric representation in modelling software applications for maintenance purposes and allow a complete data exchange between all the operators involved since the design phase.
- the important role of HVAC equipment in sustainable design for energy savings and occupants comfort.

An advantage to eliminate a complexity grade of the research is the substantial equivalence of HVAC requirements independently of geographical location in European land. A difference is revealed in the requirements about ductwork and connections of HVAC for strategic buildings (hospital and military constructions) in Italy where seismic events are frequent. This topic will not be developed due to the limited time.

The huge structure of the IFC2x4 Standard imposes to focus the attention to the unitary equipment type air handler and its main components to succeed a logic, convincing and meticulous introduction of absent properties and organize a regulation compliant IFC Standard ready to be used in public procurements.

2.4.5.1 Air handler composition

The air handling unit (abbreviation in AHU) is part of HVAC (heating, ventilation, air conditioning) equipment to control and move air. An air handler contains large metal box containing fans, heating and cooling coils, filters, sound attenuators, dampers, and when needed also a humidifier and a heat recovery. But, it is a modular box where other components could be added according to the design requirements. The exchange of air between outside and inside environments can be executed directly by AHUs discharge (supply) and admit (return) air ports or it is needed a ductwork ventilation system to flow supply air to the building and returns the exhausted air to the AHU for the treatment. Instead of the big AHU, small air handler can be used in limited spaces and they are called terminal units (or blower coils and fan coils units). It is possible to classify the AHU according to the location: rooftop unit (RTU), outdoor and indoor units ("BS EN 13053:2006+A1:2011 -

Ventilation for buildings. Air handling units. Rating and performance for units, components and sections," 2011).

The general components of an AHU are (*Fig. 17*):

- Filter: its function is cleaning air from dust to ensure building occupants welfare. The filtration layer is installed in the first section inside the box to avoid dust reaches the following elements. The layer can be realized as single filter type (for e.g. HEPA or electrostatic), or a combination of these. If a high level of filtration is needed, several elements with a coarse-grade panel filter may be mounted after a fine-grade bag filter. In alternative, other filtration bank.
- Coil: the control of the supply air temperature and humidity percentage is handled by heating and cooling coils. They can be both installed or not, according to the use of the equipment. Some devices are provided also with heat exchanger coil that can work as direct or indirect in relation to the flowing medium. Among direct heat exchangers there are gas-fired fuel-burning heaters or a refrigeration evaporator. Buildings in dry climates have evaporative cooling. Alternative installations are electric heaters and heat pumps. Hot water or steam are fluid heat vectors in indirect coils for heating, and chilled water in cooling device. The condensate drainage in cooling coils is favorite by eliminator plates (or trays). The cooling coil has also the role to over-cool the air when dehumidification (reduction of relative humidity) is needed, producing the condensation when the temperature arrives to the dew point. In this arrangement another heating coil is installed after the dehumidification section to heat again the air. Other type of coil arrangement can be applied in relation with the climate conditions.
- Humidifier: when heated air becomes dry, the environmental comfort is damaged and static electricity rises. In this situation a humidifier is necessary to ensure human welfare. Commercial markets offer several technologies: evaporative, vaporizer, spray mist, ultrasonic and wetted medium.
- Fan: the airflow distribution is managed by fans or blowers thanks to the regulation of wheels speed with a driving equipment powered by an AC induction . In addition, inlet boxes or outlet dampers on the fan can controlled the airflow rate. Air handlers mounted inside public buildings are provided with more than one fan, certainly in the beginning and in the end of the supply ductwork (the so called supply fan), but they have also return fans to push air from the ducts to the AHU.
- Heat recovery: it is a heat exchanger mounted to save energy and improve the heating efficiency exchange from the extracted air to the supply airflow. They are

classified in relation of the operation method, among them there are fixed plate counter flow exchanger, rotary wheel, heat pipe and run around coil.

- Damper: this is a flow control device, it is extremely important to isolate the mixing chamber to manage the return, external, and exhaust airflow rate.

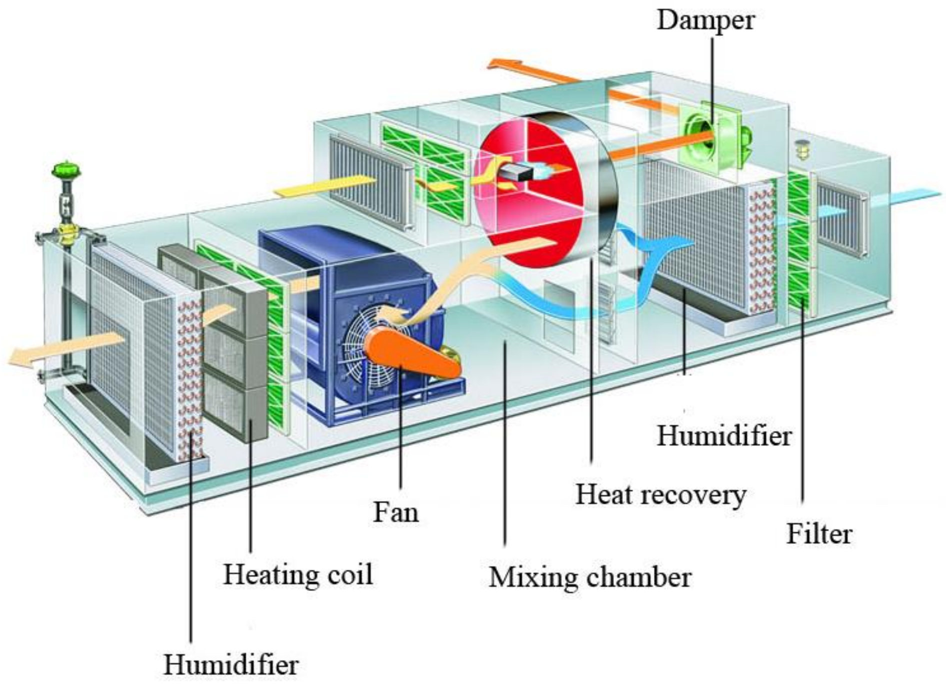


Fig. 18 Example of air handler ("Air Handling Systems for tablet coating applications," 2013)

2.4.5.2 Air handler in IFC2x4 Standard

The instance "air handler" is defined inside *IfcUnitaryEquipmentType*, subtype of *ifcEnergyConversionDevice.* The *Fig.* 18 explains graphically the inherited concepts at supertypes:

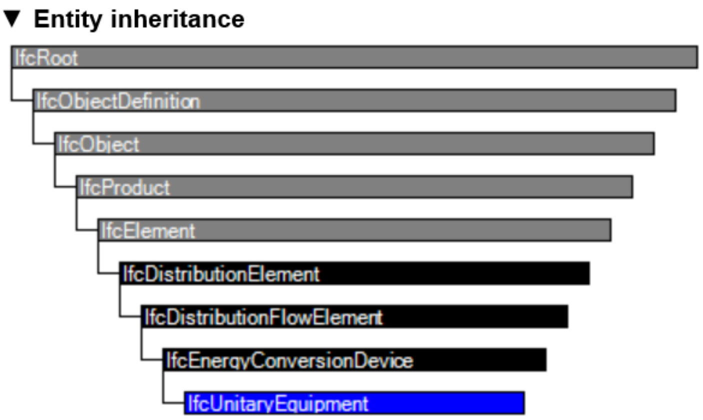


Fig. 19 Entity inheritance of ifcUnitaryEquipmentType in IFC2x4 Add 1 Final Standard (Liebich and Chipman, 2015)

Even if the AHU is not a compact system, it is important to gather information about every single component to better control design and maintenance phases. For this reason, the IFC2x platform codes all the possible discrete elements can be installed inside the unit.
The components revised to add the missing parameters are reported in the *Table 3* and their closest supertypes:

Subtype entity	**IfcSharedBldgServiceElement**
IfcAirToAirHeatRecovery	IfcEnergyConversionDevice
IfcAirToAirHeatRecoveryType	
IfcCoil	IfcEnergyConversionDevice
IfcCoilType	
IfcFan	IfcFlowMovingDevice
IfcFanType	
IfcHumidifier	IfcEnergyConversionDevice
IfcHumidifierType	
IfcDamper	IfcFlowController
IfcDamperType	
IfcFilter	IfcFlowTreatmentDevice
IfcFilterType	

Table 3 Air handler components in IFC2x4 Standard definition

The possibility to switch directly to the aggregated system is not foreclosed thanks to *IfcRelAggregates.* The *Fig. 19* shows a clear schema about the aggregation relationship between subtypes of *IfcObjectDefinition* and the connections with the entity *IfcRelConnects* when needed. The components selected for the development of the IFC Standard have been grouped inside the pointed out area.

Fig. 20 Aggregation relationship schema in an air handler

3 Development of Property sets and Properties for an air handler

After the comprehension of how IFC must be developed and implemented in visualization software applications (such as Revit MEP and ArchiCAD), it is possible to work on the improvement of the IFC International Standard inserting parameters required by European and national regulations in Italy, Spain and Germany. It is evident IFC Standard employs IFD Dictionary not compliant with all the European properties definitions, in the specific case about an air handler. The parameters, called *properties* in IFC Standard, are organized in property sets. The objective of this research is the introduction of new attributes will be compliant with local contexts. Found new properties, they must be analysed to understand if they can be introduced inside the existing property sets or it is necessary creating new ones. The regulations and laws investigated are the CEN (European Committee for Standardization) Standards, translated in the specific UNI (Ente Italiano di Normazione), UNE (Una Norma Española) and DIN (Deutsches Institut für Normung) regulations and laws launched by the local governments.

3.1 Compliance of IFC4 with Italian, Spanish and German regulations properties

In the IFC4 Documentation, the Object Definitions of the air handling unit's components show properties that are specific to the element itself and others that are common to all the objects presented in the Standard. In order to respect the deadline and to follow the main purpose of the thesis (support the integration between BIM and Facility Management in HVAC maintenance), only specific attributes will be compared with European and national requirements. They are all fundamental for the definition of the air handling and they can be implemented as they are in any MEP project edited inside a visualization software.

The tables reporting the comparison between IFC requirements and European and national regulations about air handler, fan, coil, air-to-air heat recovery, damper, humidifier and filter are collected in the Chapter 5 "Annex".

The structure of the table contains in columns:

- Property set name;
- Property set description (for the existing ones inside IFC4 Add 1);
- Presence or absence of property in IFC4;
- Italian, Spanish and German Standards.

Three situations can occur (*Table 4*):

Property to be inserted in IFC4 Standard	+
Property are both inside IFC4 Standard and European and National regulations when reported in the columns Standard. *It can occur that the properties are used in design or research works but they are not inside Standards.	✓
Property not found inside European and National regulations or common used	

Table 4 Legend to read the comparison tables

In the current paragraph, the most relevant additions are going to be presented and explained, pointing out on maintenance tasks and the most employed curves. For other details, it is suggested to consult European and national regulations have been listed in the Chapter 5 “Annex”, divided in Italian, Spanish and German standards in order to give more useful and detailed references.

The properties excluded from the research are reported in *Fig. 21*. Detailed explanations and contents about them are available in buildingSMART web site.

PredefinedType	Name
	Pset_AirToAirHeatRecoveryPHistory
	Pset_AirToAirHeatRecoveryTypeCommon
	Pset_SoundGeneration
	Pset_ElectricalDeviceCommon
	Pset_Condition
	Pset_EnvironmentalImpactIndicators
	Pset_EnvironmentalImpactValues
	Pset_ManufacturerOccurrence
	Pset_ManufacturerTypeInformation
	Pset_PackingInstructions
	Pset_ServiceLife
	Pset_Warranty

Fig. 21 The excluded properties evidenced with a red rectangular shape

Among these, the property sets tightly connected with maintenance purposes are:

- Pset_Condition;
- Pset_ServiceLife;
- Pset_Warranty.

However, the Pset_Condition is very general to really address maintenance operations in compliance with government regulations. It considers:

- AssessmentDate: it consists on the date on which the assessment about general status is performed;

- AssessmentCondition: it consists in the evaluation in points between 1 and 10 of the general status of the object considering several criteria defined in specific agreements.
- AssessmentDescription: it is the description of the general status.

Thus, new property sets proposals could substitute them:

- Pset_(AHUComponent)InspectionInstructions;
- Pset_(AHUComponent)MaintenanceInstructions;
- Pset_(AHUComponent)MaintenanceDocumentation.

Data and information about design, installation and operation must be attached, above all if different actors are going to handle them during the lifecycle of an air handler.

For this reason, the development of further properties considers also:

- Pset_(AHUComponent)DesignInstructions;
- Pset_(AHUComponent)InstallationInstructions;
- Pset_(AHUComponent)OperationInstructions.

Some selected devices have not all the property sets presented below because the contents of the regulations have been respected as much as possible (see Chapter 5 “Annex”).

A particular case is reported in the *IfcAirToAirHeatRecovery* and *IfcCoil.* In the regulations, inspection is called “general maintenance” and maintenance is defined “specific maintenance”.

Pset_(AHUComponent)GeneralInstructions and Pset_(AHUComponent)GeneralInstructions have been inserted for this two devices in order to not create doubts about the regulation contents.

A detailed explanation is provided inside the property set description in the Chapter 5 “Annex”.

In addition, the EN ISO 12499 about fan reports risk occurrences during maintenance activities and possible risk mitigation measures that have been considered inside the new IFC development as:

- Pset_FanMaintenanceRisk;
- Pset_FanMantRiskMitigation.

Another important change is the insertion of the PsychometricDiagram (*see Fig. 22*) used to design an air conditioner or an air handler as well, studying the physic transformations of humid air.

Psychometric charts can be represented in different manner according to the system moist air. Thermodynamic transformation lines must be drown about enthalpy, specific humidity, relative humidity, saturation pressure, and specific volume to have efficient relations between the parameters involved in air changing phases (Forgione and Di Marco, 2002).

In general, it is used to:

- determine the dew point of the humid air according to the values of temperature and specific humidity;
- define how heating or cooling a mixture without changing in weight of the moisture content;
- and, determine the final state of a mixture generated by two air currents (in the absence of condensation and evaporation).

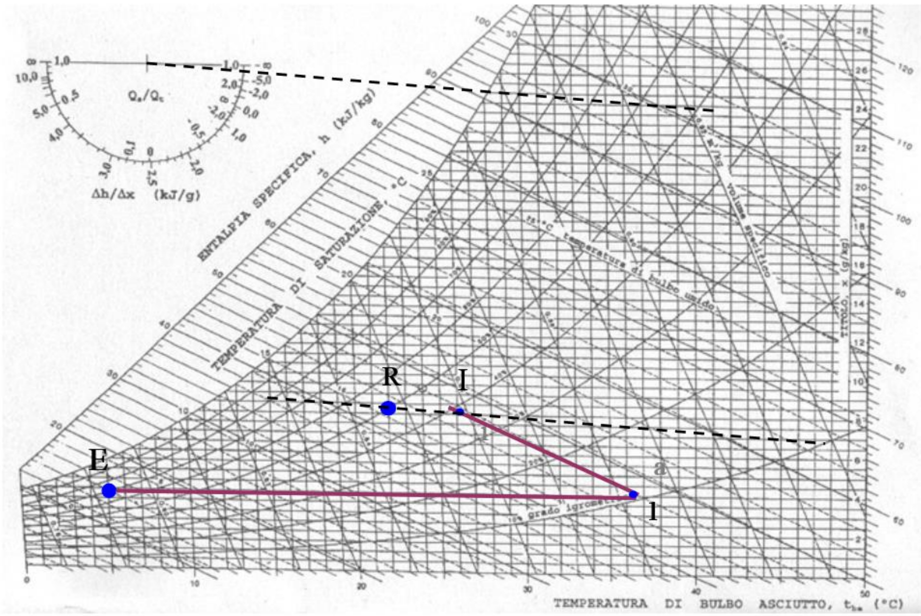


Fig. 22 Example of a psychometric chart for n air handler (Forgione and Di Marco, 2002).

Some incongruences have been figured out in the IFC Documentation after the comparison with regulations, such as the property *HasSoundAttenuation* inside the *IfcCoil* instead of in *IfcFan*. Other perplexities are personal and maybe derived from not detailed description of the property inside the IFC Documentation.

The Pset_SoundGeneration has been introduced in IFC Release 2x4 and it contains only the property SoundCurve, insufficient to describe the noise emitted by an air handler.

The noise issue is very preponderant in air handler units where the components are composed by hard metal representing source of noise (low or attenuate until very loud). The fan is the most involved in but its noise is amplified by the elimination of duct coatings and further causes that can disturb working and residential buildings.

Reading the standards and some technical brochures of AHU products in Italian, Spanish and German market, further parameters and graphs have been founded and added in the new IFC Standard about AHU systems: SoundPowerLevel, SoundPressureLevel (whose value is equal to the sound intensity level), TotalSoundPower, TotalPressurePower, SoundPressureCurve, NRCurve (Noise Rating Curve), NCCurve (Noise Criteria Curve), RCCurve (Room Criteria Curve), NCBCurve (Balanced noise criterion Curve) RCMarkIICurve (Room Criteria Mark II Curve), SoundType.

In fact, the sound properties of a unitary equipment (such as air handler or air conditioner) are reported in an octave frequency band spectrum or as sound levels (sound power level or sound pressure expressed in dB) provided per each single central frequency.

Two different curves about sound levels are usually employed:

- The sound powers spectrum (called in IFC4 SoundCurve): sound power per each octave frequency band;
- The sound pressure spectrum (added as SoundPressureCurve): sound pressure per each single octave frequency band.

But, important is the hearing sensation because humans are sensible to sounds between 1000Hz and 4000Hz, and they can perceive as lower intense sounds with the same sound pressure, the ones excluded by this frequency range. Thus, the calculation of the total sound level (as sum of each value corresponding to each frequency) is not sufficient to have an efficient hearing sensation index.

So, other criteria have been introduced to express the environmental noise perceived by humans with only one synthetized parameter:

- A-weighted scale total sound level (power and pressure);
- NR index (Noise Rating);
- NC index (Noise Criterion);
- RC (Room Criterion).

The widespread method is the A-weighted scale total sound level that corrects the sound level per each octave band as reporting in the *Table 5*. After the total sound level in pressure or power is calculated and expressed in dB(A).

Frequency [octave band centre]	Hz	63	125	250	500	1000	2000	4000	8000
Sound power levels spectrum	dB	70	75	72,5	67	71,1	69,4	64,5	62,1
Correction in weighted A scale	dB	-26,2	-16,1	-8,6	-3,2	0,0	+1,2	+1,0	-1,1
Sound power levels spectrum A weighted	dB(A)	43,8	58,9	63,9	63,8	71,1	70,6	65,5	61

Table 5 Example of sound power spectrum in weighted "A" scale

The other indexes are employed to evaluate the sound intensity because two difference sources characterized by different sound spectrum distribution and differently disturbing can be characterized by the same total sound level. In fact, the sound impact (related with its tolerability) depends on both the total weighted scale sound pressure level and sound level spectrum.

The evaluation criteria of personal sound intensity with the indexes is also limited because a complex phenomenon as the sound is not so easy to characterize only with a number.

In conclusion, the couple sound spectrum-index is more useful, for this the parameters must be inserted in the IFC4.

The most efficient method is the comparison between the sound pressure spectrum (not weighted) with reference curves for each index value (sound pressure level) at the threshold frequency of 1000Hz. The sound pressure level is used because the human ear can perceive only sound pressure.

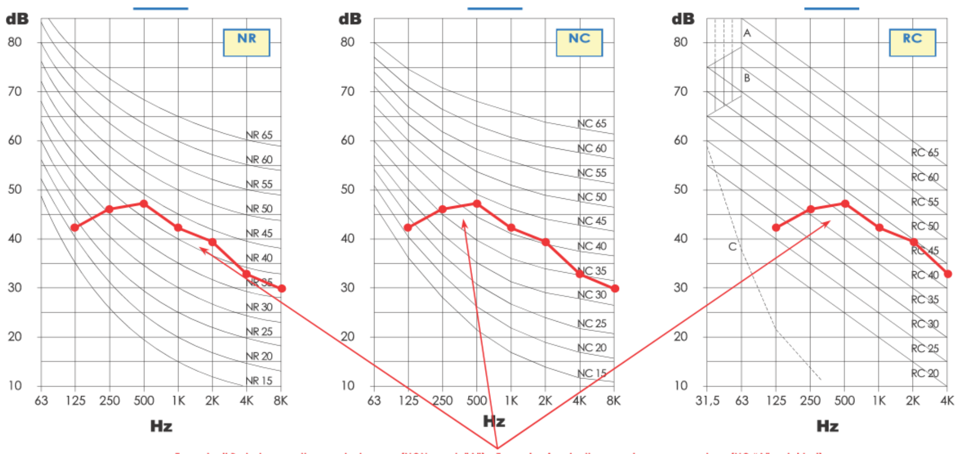
Among all the reference curves, the most used to design comfortable air handlers (or air conditioning units) is the noise criteria curve (NC curve). The others are based on the same concepts but with different references and corrections.

The NC curve is used to avoid the excess of sound power limits and ensure comfort users.

For design purposes, ASHRAE formulas are used to forecast sound power levels, and sound pressure levels depending of the distance between sound source and user, but sometimes the results are imprecise. Thus, the Standard 260 and NR Curve (Noise Rating Curve) have been introduced by AHRI (air conditioning and refrigeration institute) and developed by ISO for HVAC manufactures, engineers, installers, contractors and users. These are American requirements but employed in European products and cited in air handler technical sheets.

NC criteria is limited on the balance of the spectrum, for this reason ASHRAE created a new the Room Criteria or RC to fix this problem.

The RC curves are calculated as arithmetic average of the three sound pressure levels (not weighted) per the frequencies 500Hz, 1000Hz and 2000Hz. It supports the definition of noise type: rumbling, hissing or neutral sound.



Esempio di Proiezione spettro pressioni sonore (NON pesate"A") – Example of projection sound pressure spectrum (NO "A" weighted)

Frequenza - Frequency	Hz	125	250	500	1000	2000	4000	8000
Pressione sonora – Sound pressure level	dB	42,4	46,0	47,3	42,3	39,8	32,9	30,0

Fig. 23 Sound pressure spectrum reported in the three groups of reference curves (NR, NC and RC) (ACTIONclima, n.d.)

Balanced Noise Criterion (NCB) Curve is a new criteria added to improve analysis of sound levels at low frequency extending the NC graph down to 16 Hz. As the NC criteria, in NCB curve is also used the tangent method, so the NC or NCB line in correspondence of the sound spectrum defines the NC or NCB value.

The RC Mark II curves are based on RC curves and slighted down 16 Hz and use a Quality Assessment Index (QAI) to evaluate the acoustic occupant comfort, ranging from "acceptable" to "objectionable."

3.2 Writing IFC4 Documentation for new proposed properties

The following step is writing the added properties sets and properties in IFC format. A support to this elaboration has been the completion of property sets and property template tables reporting:

For the *property set template*:

- Property set name: the names are decided according to the contents of European Standards, as just explained below. In most of the cases they are the right translation of Italian, Spanish and German contents because taken from English Standard versions when they were referenced in conferences, books, and other sources. It is important to assert British Standards (BS) have not been available.
- IfcPropertySetTemplateTypeEnum: the enumeration defines the general applicability of instances of *IfcPropertySet* that can be (Liebich and Chipman, 2015):

  - PSET_TYPEDRIVENONLY: *"the property sets defined by this IfcPropertySetTemplate can only be attached to subtypes of IfcObjectType"*.
  - PSET_TYPEDRIVENOVERRIDE: *"the property sets defined by this IfcPropertySetTemplate can be related to subtypes of IfcObjectType and can be overridden by a property set with same name at subtypes of IfcObject"*.
  - PSET_OCCURRENCEDRIVEN: *"the property sets defined by this IfcPropertySetTemplate can only be assigned to subtypes of IfcObject"*.
  - PSET_PERFORMANCEDRIVEN: "*the property sets defined by this IfcPropertySetTemplate can only be assigned to IfcPerformanceHistory"*.
- Property set description: it contains detailed information about the meaning of the property group and the reference regulations. In addition, the method to fulfil the empty field is specified in some cases.

For the *property template*:

- IfcPropertyName: also in this case, the names are decided according to the contents of European Standards.
- IfcSimplePropertyTemplateTypeEnumpertyResource: it provides subtypes of *IfcSimpleProperty* and *IfcPhysicalSimpleQuantity* (not used in this work), attached to the *IfcSimplePropertyTemplate*. It defines the use of correspondent attributes (PrimaryUnit, SecondaryUnit, Enumerators, PrimaryDataType, SecondaryDataType). The Enumerated Item Definitions are:
  - P_SINGLEVALUE: it is employed when a property object has a single value (numeric or descriptive).
  - P_ENUMERATEDVALUE: it is defined if a property object has a value selected from an enumeration list.
  - P_BOUNDEDVALUE: a property object has values inside a range.
  - P_LISTVALUE: it is chosen if property is described by several (numeric or descriptive) values organized in an ordered list.
  - P_TABLEVALUE: when a property is defined with two lists of values that can be descriptive or numeric. The values are collected in a table with two columns. It is usually used to create representation of graphs.
  - P_REFERENCEVALUE: a property value belongs to a type of resource level entity that is a reference value.

  - IfcComplexProperty: it is not the paragraph 5.1.2.5 “IfcSimplePropertyTemplate TypeEnumpertyResource”, but in the IFC generator tool has been employed shows complex property as property type. This concept stands for a property that is referred to others inside a different property set.
- IfcObjectReferenceSelect: it provides a list of resource level entities that can be selected for property values referenced.
- IfcMeasureResource: it provides units and defined measure types for properties and quantities.
- IfcPropertyEnumeration: it is a collection of simple or measure values given to describe the property. It is important giving a name to the list of values or texts, according to the property.
- ListValues: it provides a list of values or text. Among these, one or more values must be selected to define the property.

The description about the individual properties is inserted in the table about the compliance IFC-Authorities regulations to help the understanding of existing parameters in IFC Standard and the ones to be inserted. In the period of execution of the current research work, the IFC2x4 has been substituted by the IFC2x4 Add 1 Final Standard. The substantial differences detected have been about the presentation of the properties of air handler components inside the object definition. In fact, all the properties with reference and table values have been excluded in the concept usage of the IfcObject, leaving only the *Property sets for objects*. Among these omitted properties, also the *Performance history* described with reference values assigned in a certain point in time as regular or irregular frequency (thanks to the *IfcTimeSeries*, *IfcIrregularTimeSeries* and *IfcRegularTimeSeries*) and the property curves.

All the changes figured out are evidenced in the tables of Chapter 5 “Annex”.

For more detailed explanations, it is strongly suggested to navigate the IFC Add 1[Final Standard] Documentation (Liebich and Chipman, 2015).

The type of value to be populated by the user (it can be a maintenance person, user or AEC actor) is a proposal, sprung from the study of the existing properties and their template, the analysis of standard content and the elaboration of a simple, unique, and structured method to provide regulation requirements and actors feedbacks. It is taken that parameters must be entered more times during the building element lifecycle for maintenance and inspections operations.

Although the IFC4 Final Standard separates the properties for performance from the object definition, these represent the most useful parameters to be fulfil to ensure an efficient

Facility Management in HVAC maintenance that is a continuous activity during operation phase of a building or construction. In addition, the instructions about inspection and maintenance given by regulations, sometimes directly delegated to manufacturer or maintenance operators, are referred to a time frequency that should be respected to ensure the sustainable and durable use of the mechanical devices.

Difficulties have been found to define values for complex charts obtained from the projection of a graph on another such as psychometric chart, NC, NR, RC, NCB curves about sound evaluations because a table value is not sufficient to describe the relations between the compared curves. Neither the complex property, because it is used when properties are related to others belonged to different property sets. For this reason, at moment they are given as P_SINGLEVALUE, waiting an extension of the Enumerated Item Definitions.

The other issue is the lack of important IfcObjectReferenceSelect to be used for referenced values. In fact, in the list report *ifcFrequency* as reference for SoundPressureLevel and SoundPowerLevel. So, for the moment the measurements are given with *ifcSoundPowerLevelMeasure* and *ifcSoundPressureLevelMeasure* as P_SINGLEVALUE or be omitted if sound spectrums are provided.

3.2.1 The use of ifcDoc as IFC documentation generator tool

Initially, two official certified buildingSMART software programs have been employed to write IFC files reporting the inserted property sets and properties: ArchiCAD (by Graphisoft) and Revit (by Autodesk) with not few problems. ArchiCAD is still not compliant with IFC4 Add 1, but it can export IFC2x3 files. It is thought to enter properties respecting the same schemas of IFC Documentation. Revit MEP can export IFC file in the current version IFC4 but it is not possible to introduce the parameters in an IFC Documentation appearance, collecting them in property sets. In addition, property values are partially brought from IFC Documentation, and some properties cannot be added.

Thus, the decision to develop the IFC Standard in a way as independent as possible from vendor’s software products using *ifcDoc* tool. This application has been developed by buildingSMART International, compatible with all the IFC editions. Its scope is to support the Model View Definitions (MVDs) generation thought a consistent and computer-interpretable subsets of IFC files. It provides also mvdXML specifications. It is used to generate IFC documentation for future releases and to write MVD's. The importation of adequate baselines inside the application is the start point in developing the Standard with MVDs specifications and IFC Documentations.

In general, the baseline comprises:

- full computer interpretable IFC schema specification and the complete documentation;
- some MVD concept definitions.

For the current aim, the IFC4 Addendum 1 Baseline has been imported. It also contains MVD definitions of IFC4 RV V1.0 and IFC4 DTV V1.0 contained in the IFC repository of the ifcDoc tool.

A generated ifcDoc file format comprises all IFC schema definitions, for e.g. the property set definitions and the quantity set definitions, and also MVD content such as:

- concept templates;
- MVD specific concept use definitions;
- MVD definitions with Exchange Requirements incorporated.

The scope of this work is introduce new property sets using the Common Use Definitions, among the available Model View Definitions. This because Common Use Definitions involves all the BIM exchange format definitions required in an entire project. In fact, Common Use Definitions gives definition along the entire life cycle of the building. But, the Facilities Management Handover [COBie] and Mechanical Design Information Exchange [HVACie] could also be employed as MVDs, narrowing the focus to the HVAC sector.

The detailed contents of the Common Use Definition is reported in the paragraph 1 "Scope" of the IFC2x4 Addendum 1 (Liebich and Chipman, 2015).

However, it is possible to use the recent release of MVDs, IFC4 Reference View V 1.0 or IFC4 Design Transfer View V1.0 in relation with the goals fixed by a teamwork, ensuring efficient communication and collaboration. In synthesis, IFC4 RV V1.0 only allows one-directional exchange of reference models to be upgraded by the original author. While, IFC4 DTV V1.0 permits the parametric change of the model during the work phases.

For more information, see the topic at http://www.buildingsmart-tech.org/specifications/ifc-view-definition.

The application interface has a menu tool to insert and edit the properties of each object entity. In this case, it has been working on the *IfcHVACDomain* components adding properties and property sets as described in the tables of Chapter 5 "Annex". The International English not related with any country has been selected as language, but it is possible to insert the properties in Italian, Spanish and German. The name, the description and the property set category have been fulfilled, the entity to which the property set is applicable has been selected among the AHU components studied (*Fig. 24*). Switching to the property template, the property type, the data type and the item have been inserted (*Fig. 25*).

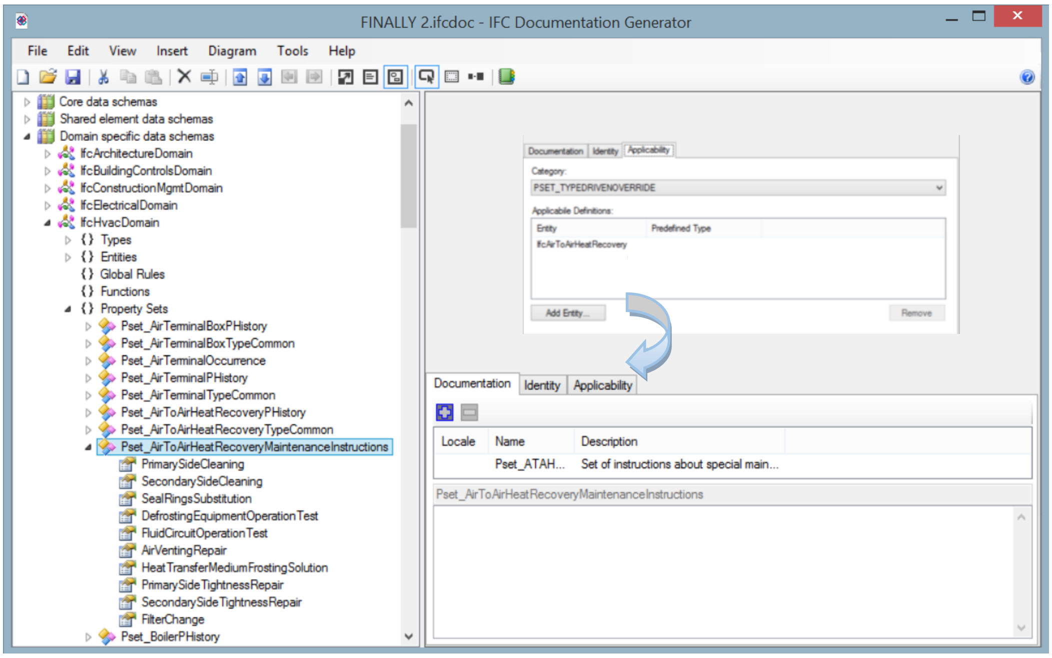


Fig. 24 Inserting and editing property sets contents

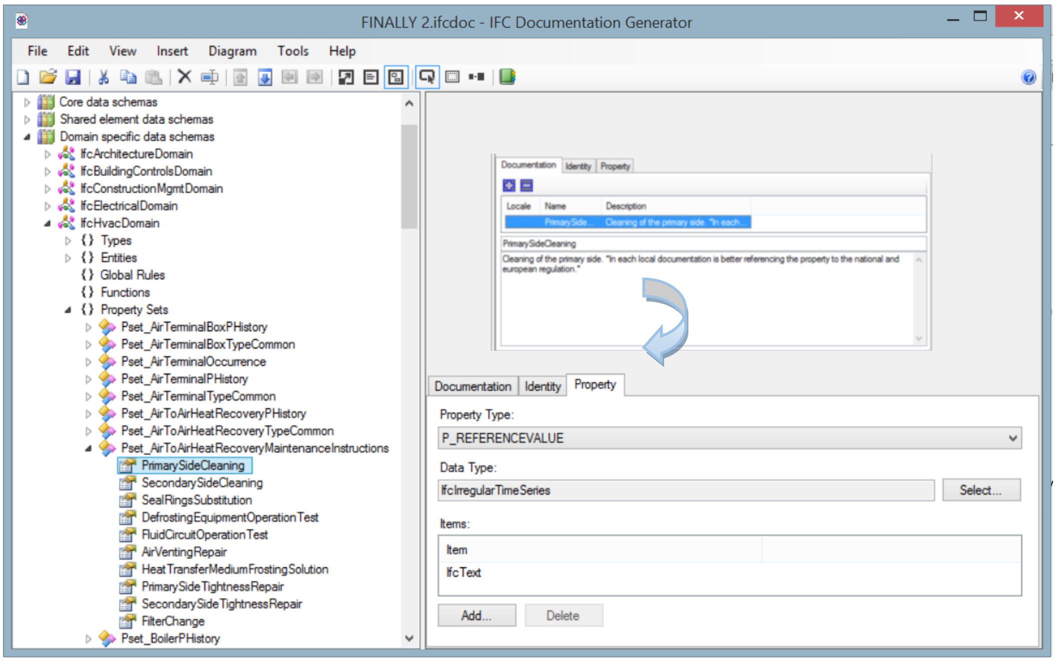


Fig. 25 Inserting and editing property contents

The files produced could be exported from ifcDoc as IFC format files, IFCXML and mvdXML specifications that are able to capture property sets and properties. In the tables attached parts of IFC-SPF and IFCXML are going to be reported.

4 Conclusions and recommendations

It is quite clear Building Information Modelling can represent a valid strategic system for maintenance planning in existing and new constructions offering itself as data wisdom.

In this way, stout foundation can be put to satisfy historical situation, actuality and future needs and to face changes giving appropriate solutions for Facility Management.

This science ensures sustainable results in term of economy, health, safety and energy savings through the interaction of information, disciplines and persons and exploitation of risk mitigation measures and innovative technologies.

The bigger gap in integration BIM-FM is represented by the data exchange specifications.

The data exchange format COBie, simple spreadsheets generally derived from CAFM and/or CMMS platforms, has proven to be incomplete in information handover, being not compatible with graphs and topological data. Thus, the solution is supporting parametric object development in data collection, based on standardized methods and languages to simplify and get compatible the sharing operations between construction shareholders, user/owner and Authorities.

The development and diffusion of IFC Standard content is the solution, reachable if an investment of experts, time and knowledge is going to be performed. Thus, a strategic FM, compliant with occurring changes and regulations can work properly in BIM environment.

In Italy, Spain and Germany, the BIM strategy must be disseminated in any construction phase, also in Facility Management (and consequently to manage programmed maintenance operations), but the buildingSMART International Standard is not perfectly compliant to European and national regulations requirements. The compliance of IFC with regulation requirements can be obtained structuring code contents with the IFC format language.

The employment of BIM in public and private projects is tidily linked with the extension of the IFC Documentation because the substantial omissions of building components properties may be overcame.

The immediate use of structured regulations can ensure code compliance and data collection to be maintained and transferred to the next actors involved during the entire building lifecycle, creating historical memory.

This has been the attempt of this research: the realization of a new IFC system BRUNO-SYS adding parameters and instructions recorded in current employed standards and useful for maintenance purposes to be proposed in the next edition of IFC Standard (*Fig. 26*).

The topic carried out in this final dissertation has been focus only on a HVAC equipment, the air handler, and its individual components but the same approach may be extended to the other building and infrastructure elements.

The current IFC Standard is based on American and English IFD dictionaries including parameters to define performances and general properties sometimes different from Italian, Spanish and German regulations requirements.

About maintenance purposes, the information about identification number, manufacturer and warranties are beneficial, less the ones about conditions, so general and unfitted with each mechanical component regulations instructions.

The MEP (Mechanical, Electrical and Plumbing plant) field has been partially investigated, visualization software products only recently can implement and model building services. And, lacks are still run into project and execution.

But, the correct design of mechanical equipment play a considerable role in the sustainability and human comfort of a private and public building.

The big lack of IFC standard is the inclusion of comparative curves such as psychometric charts and particular sound curves (Room Criterion graph, Noise Criteria graph etc.) obtained with the overlapping of two categories of curves, not possible to insert as tabled values.

But, the psychometric chart is fundamental for air handler and air conditioner design and checking, and the acoustic diagrams give an accurate measure of noise sensation and disturb in working, living and teaching rooms. They cannot be excluded, so the development of another IFC property type is proposed to include curves projections in future IFC releases.

Inside IFC Standard, some incongruences have been revealed for e.g. about sound attenuation presence inserted in the coil section instead of the fan object, the noisier element into an AHU. The properties definitions are sometimes quite poor and incomprehensible, they should present deeper explanations and precise formulas.

The efficient integration of FM in BIM crosses the formation of experts to control and elaborate the results of the data provided by the software and to create a model without errors.

In addition, the owner must be instructed to use BIM information and execute effectively maintenance operation of his competence. Known that owners are not persons of the sector, the structured information added in BRUNO-SYS are readable, understandable and easy to manage. Complex programs that provide numerous parameters and settings in a descriptive manner are difficult and take lot of time in use. Thus, a good direction is creating platforms to help the user to understand intents, limitations and assumptions in few time and in an easy way.

The software vendors must do an effort in the evolution of their products to create a structured and univocal way to collect, elaborate and handoff data via IFC Standard.

The IFC certified software products for MEP, such as ArchiCAD with the add-on MEP Modeller, and Revit MEP do not give still the chance to employ IFC4 Standard in its entire capability. As explained in the § 3.2.1, Revit does not follow the IFC architecture to edit and add new parameters and ArchiCAD (also in its last version 19) cannot read IFC4 files. In addition, Revit does not contain all the measure values in the chapter 8 “Resource schemas” enumerated in the IFC4 Documentation. The most important gap is the absence in Revit of the property types P_REFERENCEVALUE and P_TABLEVALUE. How it has been figured out, this types are fundamental to insert properties about efficiency, history performance, and inspection and maintenance information in form of graphs and/or according a certain regular or irregular time frequency.

The interoperability may be fully obtained when the standardized STEP data exchange format and the other openBIM specifications will be associated with sets of information valid in each country according to the European and local rules, because they can be correctly employed during the construction process. Thus, the Standardization organizations, government members, academics and professionals are invited to work on the Standards to reduce the percentage of missing requirements in IFC Standard and modelling software products.

Another important aspect is the attention to specific design requirements in some European countries. A particular case is represented by Italy. The construction regulations for structural works and particular guidelines for building services provide always instruction about design and maintenance to avoid risky consequences in case of seismic events. In this dissertation parameters and data about this topic have not been considered because are related with ductwork and pipe plant. And, the flow distribution elements have not been inserted in the research outline in order to respect the schedule and the deadline imposed for the final dissertation delivery.

But, this could be considered as a point to develop in a following research for the development of next IFC Standards in compliance with construction standards.

A BIM training and informatics knowledge basis are strongly recommended in the academic path of Architects, Engineers and Mechanical technicians to make really efficient the code structuring presented in this thesis in BIM implementation.

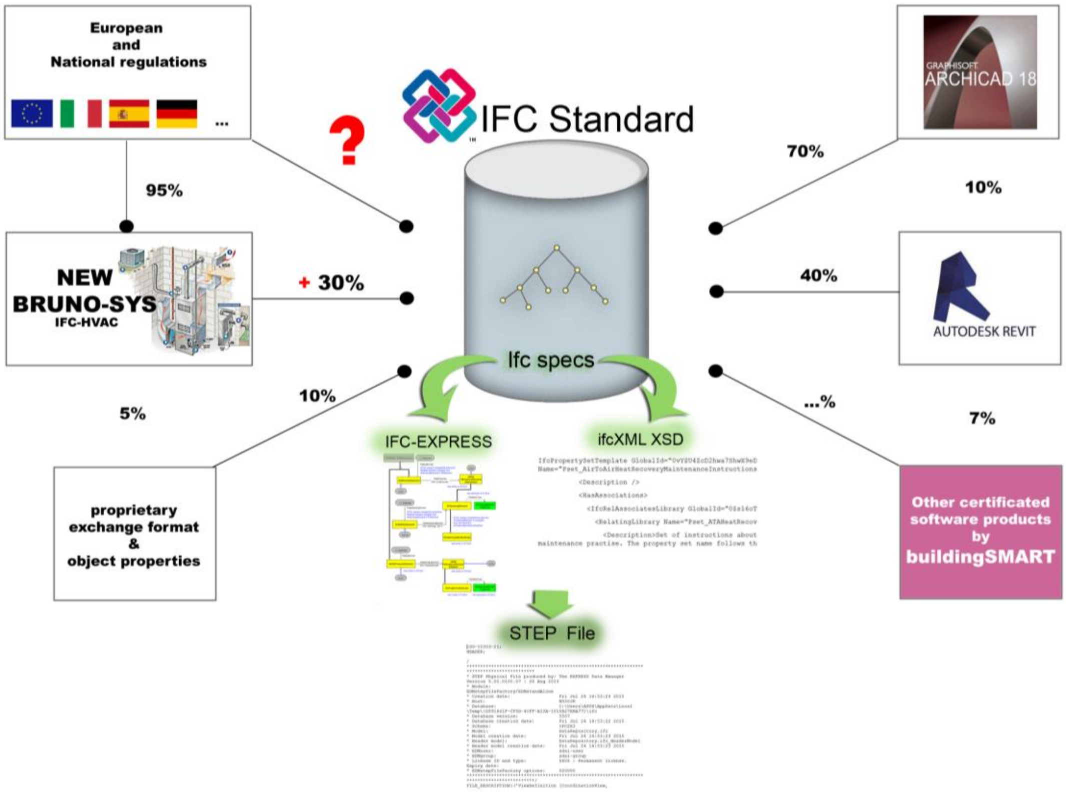


Fig. 26 Compliance of Objects Properties with IFC Standards and European and National regulations

5 Annex

The following tables are useful to understand how the aim of the research has been achieved, after the study of the IFC Standard structure.
As reported in § 3.1, *Table 4* explains the occurrences about comparison of IFC and regulations requirements.
The tables are not numerated because are grouped in different sections about the different mechanical equipment:

- Unitary equipment: air handler;
- Air to air heat recovery;
- Coil;
- Fan;
- Filter;
- Damper;
- Humidifier.

Property to be inserted in IFC4 Standard	+
Property are both inside IFC4 Standard and European and National regulations when reported in the columns Standard. *It can occur that the properties are used in design or research works but they are not inside Standards.	✓
Property not found inside European and National regulations or common used	

Table 6 Legend to read the comparison tables

IFCSHAREDBLDGSERVICEELEMENT
IfcEnergyConversionDevice
IfcUnitaryEquipment:AirHandler
Property set and property template

		Italy	Standard	Spain	Standard	Germany	Standard
Pset_UnitaryEquipment TypeAirHandler	Air handler unitary equipment type attributes. Note that these attributes were formerly Pset_AirHandler prior to IFC2x2.						
AirHandlerConstruction	Enumeration defining how the air handler might be fabricated.	✓		✓		✓	
AirHandlerFanCoil Arrangement	Enumeration defining the arrangement of the supply air fan and the cooling coil.	✓	UNI EN 13053:2011	✓	UNE EN 13053 :2007 +A1:2011	✓	DIN EN 13053 A1 :2012
DualDeck	Does the AirHandler have a dual deck? TRUE = Yes, FALSE = No.	✓	"	✓	"	✓	"
Pset_UnitaryEquipment TypeAirHandler PHistory	Air handler unitary equipment type attributes. Note that these attributes were formerly Pset_AirHandler prior to IFC2x2.						
AirFlowRate	Airflow rate.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007 +A1:2011	+	DIN EN 13053 A1 :2012
TotalExternalPressure	Difference of the total pressure of the air entrance and the air exit.	+	"	+	"	+	"
ElectricPower	Electric power supplied.	+	"	+	"	+	"
AirDensity	Density of the air.	+	"	+	"	+	"
AirTemperature	Air temperature.	+	"	+	"	+	"
FanRotationSpeed	Fan rotation speed.	+	"	+	"	+	"
FanPowerRate	Power consumption by the fan motor.	+	"	+	"	+	"
Pset_UnitaryEquipment TypeCommon	Unitary equipment type common attributes.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1').	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	

PsychometricDiagram	Psychometric diagram	+		+		+	
TotalExternalPressureCurve	Relation between the total external pressure and the airflow rate.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007 +A1:2011	+	DIN EN 13053 A1 :2012
FanPowerRateCurve	Relation between the fan power rate and the airflow rate. In case of installed air velocity modulators installed (or frequency modulators), the fan power rate must include the auxiliary device power.	+	"	+	"	+	"
Pset_SoundGeneration	Common definition to capture the properties of sound typically used within the context of building services and flow distribution systems. This property set is instantiated multiple times on an object for each frequency band. HISTORY: New property set in IFC Release 2x4.						
SoundCurve	Table of sound frequencies and sound power for the referenced octave band frequency (63-8000Hz). Sound Power level generated by the AHU into the ductwork.	✓	DPCM 5/12/97 Requisiti acustici passivi degli edifici ISO R226-1961 UNI 8199:1998	✓	REAL DECRETO 1367/2007 UNE ISO 1996:2005-1 UNE ISO 1996:2009-2 UNE EN ISO 16032	✓	ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
SoundPowerLevel	A sound power level (dB) is a logarithmic scale measure of total radiated noise energy per time unit (W) emitted by a source, at a reference power of 1 picowatt $(10^{-12}$ watt) (Wo). Lw=10log(W/Wo)	+	UNI EN ISO 3741 :2010 ISO 3742:1988 UNI EN ISO 3743 :2010-1 UNI EN ISO 3744 :2010 UNI EN ISO 3745 :2012 UNI EN ISO 3746 :2011 UNI EN ISO 3747 :2011 UNI 8199:1998	+	UNE EN ISO 3743 :2011-1 UNE EN ISO 3743 :2010-2 UNE EN ISO 3744 :2010 UNE EN ISO 3745 :2010 UNE EN ISO 3746 :2011 UNE EN ISO 3747 :2011	+	DIN EN ISO 9295:2013-07 DIN EN ISO 3741:2011-01 DIN EN ISO 3743-1:2011-01 DIN EN ISO 3744:2011-02 DIN EN ISO 3745:2012-07 DIN EN ISO 3746:2011-03 DIN EN ISO 3747:2011-03
SoundPressureLevel	A sound pressure level (dB) is a logarithmic scale measure of the variation of pressure produced by the noise (P in Pa) compared with pressure in quite conditions (P0=2x10^-5 Pa at 1000Hz). Lp=10log(P/Po)^2 The sound intensity level Li (dB) is almost equal to Lp, so Lp=Li=10log (I/Io), where I is the sound intensity studied (W/m^2) and Io the reference value of 10^-12 W/m^2.	+	UNI EN ISO 3744:2010 UNI EN ISO 3746:2011	+	UNE EN ISO 3744:2010 UNE EN ISO 3746:2011	+	DIN EN ISO 3744:2011-02 DIN EN ISO 3746:2011-03
SoundPressureCurve	Sound pressure spectrum [dB(A)] for the referenced octave band frequency (63-8000Hz).	+	EC 1-2010 UNI EN 12354-5:2009 UNI 8199:1998 L. 447 /1995 Legge quadro sull'inquinamento acustico UNI EN ISO 16032 :2005	+	REAL DECRETO 1367/2007 UNE ISO 1996:2005-1 UNE ISO 1996:2009-2 UNE EN 12354-5:2009/AC:2010 UNE EN ISO 16032:2005	+	DIN EN ISO 3746: 2011 DIN EN 12354-5:2009 DIN EN ISO 16032 :2004

TotalSoundPower	The total sound power [dB(A)], also called total sound level, is the sum of sound powers per each frequency.	+	“	+	“	+	“
TotalSoundPower	The total sound power level [dB(A)], is the sum of sound power levels per each frequency.	+	UNI EN ISO 3741 :2010 ISO 3742:1988 UNI EN ISO 3743 :2010-1 UNI EN ISO 3744 :2010 UNI EN ISO 3745 :2012 UNI EN ISO 3746 :2011 UNI EN ISO 3747 :2011 UNI 8199:1998	+	UNE EN ISO 3741 :2011 UNE EN ISO 3743 :2011-1 UNE EN ISO 3743 :2010-2 UNE EN ISO 3744 :2010 UNE EN ISO 3745 :2010 UNE-EN ISO 3746 :2011 UNE EN ISO 3747 :2011	+	DIN EN ISO 9295 :2013 DIN EN ISO 3741:2011 DIN EN ISO 3743-1 :2011 DIN EN ISO 3744:2011 DIN EN ISO 3745 :2012 DIN EN ISO 3746 :2011 DIN EN ISO 3747:2011
TotalSoundPressure	The total sound pressure level is the sum of sound pressure levels per each frequency.	+	UNI EN 12354:2002 UNI 8199:1998	+	REAL DECRETO 1367/2007 UNE-ISO 1996:2005-1 UNE-ISO 1996:2009-2 UNE-EN ISO 16032	+	DIN EN ISO 3746: 2011-03
NRCurve	Noise Rating.	+	AHRI Standard 260	+		+	ASHRAE Handbook—HVAC Systems and Equipment
NCCurve	NC curve (Noise Criteria ASHRAE).	+	DPCM 14-11-1997 Prescrizioni e limiti sul rumore ambientale	+		+	ASHRAE Handbook—HVAC Systems and Equipment ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
RCCurve	RC curve (Room Criteria).	+	ASHRAE Handbook—HVAC Systems and Equipment	+		+	
NCBCurve	NCB curve.	+	ref. ANSI/ASA S12.2-2008	+		+	
RCMarkIICurve	RC Mark II curve.	+	ref. ANSI/ASA S12.2-2008	+		+	
SoundType	Type of sound transfer.	+		+		+	

Pset_MaintenanceInstructions							
MaintenancePlan	All the documents about installation use and maintenance of each component will be inserted in this maintenance plan when the product is delivered and updated after a maintenance operation.	+		+		+	

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_UnitaryEquipmentTypeAirHandlerPHistory					
AirFlowRate	P_REFERENCEVALUE	IfcTimeSeries	IfcVolumetricFlowRateMeasure		
TotalExternalPressure	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
ElectricPower	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		
AirDensity	P_REFERENCEVALUE	IfcTimeSeries	IfcMassDensityMeasure		
AirTemperature	P_REFERENCEVALUE	IfcTimeSeries	IfcThermodynamicTemperature Measure		
FanRotationSpeed	P_REFERENCEVALUE	IfcTimeSeries	IfcRotationalFrequencyMeasure		
FanPowerRate	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		

Pset_UnitaryEquipmentTypeCommon					
TotalExternalPressureCurve	P_TABLEVALUE	IfcPressureMeasure /IfcVolumetricFlow RateMeasure			
FanPowerRateCurve	P_TABLEVALUE	IfcPowerMeasure/ IfcVolumetricFlow RateMeasure			
PsychometricDiagram	P_REFERENCEVALUE	IfcTimeSeries			

Pset_SoundGeneration					
SoundPowerLevel *it can be omitted if sound spectrum is used	P_SINGLEVALUE P_REFERENCEVALUE	IfcFrequency Measure	IfcSoundPowerLevelMeasure		
SoundPressureLevel *it can be omitted if sound spectrum is used	P_SINGLEVALUE P_REFERENCEVALUE	IfcFrequency Measure	IfcSoundPowerLevelMeasure		
SoundPressureCurve	P_TABLEVALUE		IfcFrequency Measure/IfcSoundPressureLevel Measure		
TotalPowerLevel	P_SINGLEVALUE		IfcSoundPowerLevelMeasure		
TotalPressureLevel	P_SINGLEVALUE		IfcSoundPressureLevelMeasure		
NRCurve	P_SINGLEVALUE				
NCDurve	P_SINGLEVALUE				
RCCurve	P_SINGLEVALUE				
NCBCurve	P_SINGLEVALUE				
RCMarkIICurve	P_SINGLEVALUE				
SoundType	P_ENUMERATEDVALUE		IfcLabel	PEnum_SoundType: Frontal, Lateral, Down, Up	

Pset_MaintenanceInstructions					
MaintenancePlan	P_SINGLEVALUE		IfcText		

Property set implementation as IFC Documentation in ifcDoc tool

The property *FanPowerRateCurve* has been inserted as example for the entity *IfcUnitaryEquipment:AirHandler*, it is in *Pset_UnitaryEquipment TypeCommon*.

IFC Specification

```
#10011=IFCSIMPLEPROPERTYTEMPLATE('2QTpKcABfFmQIM164yF08w',$,'FanPowerRateCurve',$,.P_TABLEVALUE.,'IfcPowerMeasure',$
,$,$,$,$,.READWRITE.);
```

```
#10012= IFCLIBRARYREFERENCE($,$,'FanPowerRateCurve','Relation between the fan power rate and the airflow rate. In case of installed air velocity modulators installed (or frequency modulators), the fan power rate must include the auxiliary device power.','',$);
```

IFCXML Specification

```
<IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2QTpKcABfFmQIM164yF08w" Name="FanPowerRateCurve" PrimaryMeasureType="IfcPowerMeasure" AccessState="READWRITE">

              <HasAssociations>

                <IfcRelAssociatesLibrary GlobalId="34hdDqIj10fhBMism34VaN">

                  <RelatingLibrary Name="FanPowerRateCurve" Language="">

                    <Description>Relation between the fan power rate and the airflow rate. In case of installed air velocity modulators installed (or frequency modulators), the fan power rate must include the auxiliary device power.</Description>
```

IFCSHAREDBLDGSERVICEELEMENT
IfcEnergyConversionDevice
IfcAIrToAirHeatRecovery
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_AirToAirHeat RecoveryPHistory	Air to Air Heat Recovery performance history common attributes.						
SensibleHeat TransferRate	Sensible heat transfer rate.						
AirPressureDropCurves	Air pressure drop as function of airflow rate.	✓	no standard, in some studies				
TotalEffectiveness	The ratio of heat transfer to the maximum possible heat transfer.						
TemperatureEffectiveness	The ratio of primary airflow temperature changes to maximum possible temperature changes in case of equilibrate mass airflow We =Wi (1:1), according the CEN standards). The calculation is in dry heat conditions.	✓	UNI EN 308:1998 (commercial and tertiary building)	✓	UNE EN 308:1997	✓	DIN EN 308:1997
HumidityEffectiveness	The ratio of primary airflow absolute humidity changes to maximum possible absolute humidity changes.	✓	UNI EN 308:1998 (commercial and tertiary building)	✓	UNE EN 308:1997	✓	DIN EN 308:1997
Defrost Temperature Effectiveness	Temperature heat transfer effectiveness when defrosting is active.						
SensibleEffectivenessTable	Sensible heat transfer effectiveness curve as a function of the primary and secondary airflow rate.						
LatentHeatTransferRate	Latent heat transfer rate.						
TotalHeatTransferRate	Total heat transfer rate.						
Sensible Effectiveness	Sensible heat transfer effectiveness, where effectiveness is defined as the ratio of heat transfer to maximum possible heat transfer.						
TotalEffectivenessTable	Total heat transfer effectiveness curve as a function of the primary and secondary airflow rate.						
HRSCapacity	Heat recovery system capacity corresponds to the recovered heat (QHRS).	+	UNI EN 13053:2011	+	UNE EN 13053:2007 +A1:2011	+	VDI 3803 (min H3) DIN EN 13053:2012
EfficiencyOfTemperature	The efficiency of temperature (ηt)=QHRS/Qp.	+	"	+	"	+	"
EnergyEfficiency	Energy efficiency ηe = ηt (1-1/COP).	+	"	+	"	+	"
PerformanceCoefficient	Performance coefficient is the ratio of the recovery system power to the electrical power consumed. COP (ε) = QHRS/Pel	+	"	+	"	+	"
AirPressureDrop	Air pressure drop.	+	UNI EN 308:1998 (commercial and tertiary building) UNI EN 13053: 2011	+	UNE EN 308:1997 UNE EN 13053:2007 +A1:2011	+	DIN EN 308:1997 DIN EN 13053:2012
ExternalDrop	The external leakage is the loss towards or from the air that passes through the heat recovery to the environment.	+	UNI EN 308:1997 (commercial and tertiary building)	+	UNE EN 308:1997	+	DIN EN 308:1997

InternalDrop	The internal loss is between the primary airflow and the secondary airflow in a heat recovery unit.	+	UNI EN 308:1997 (commercial and tertiary building)	+	UNE EN 308:1997	+	DIN EN 308:1997
InternalLeak	The internal leakage is the loss from the side of the exhausted air towards the side of the supplied air of a heat recovery.	+	UNI EN 308:1997 (commercial and tertiary building)	+	UNE EN 308:1997	+	DIN EN 308:1997
EntrainmentAirflowRate	The entrainment flow is the passage of exhausted air to the side of the supplied air, in a heat recovery unit of category III, with overpressure on the side of the supplied air.	+	UNI EN 308:1997 (commercial and tertiary building)	+	UNE EN 308:1997	+	DIN EN 308:1997
SpecificPowerInput	Specific power input (SPI).	+	UNI EN 13141-10:2008 UNI EN 13142: 2013	+	UNE EN 13141-10:2009 UNE EN 13142: 2014	+	DIN EN 13141-7:2011 DIN EN 13142:2013
NominalTemperature PerformanceFactor	Nominal Temperature Performance Factor (NTPF).	+	UNI EN 13141-10:2008 UNI EN 13142: 2013	+	UNE EN 13141-10:2009 UNE EN 13142: 2014	+	DIN EN 13141-7:2011 DIN EN 13142:2013-6
AnnualWorkingTime	Annual working time in hours.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2012	+	DIN EN 13053:2012

Pset_AirToAirHeatRecovery TypeCommon	Air to Air Heat Recovery type common attributes.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1'), provided, if there is no classification reference to a recognized classification system used.	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
HeatTransferTypeEnum	Type of heat transfer between the two air streams (conduction, convection, radiation).	✓		✓		✓	
HasDefrost	If the heat exchanger has defrost function or not. [TRUE or FALSE].	✓		✓		✓	
Operational Temperature Range	Allowable operation ambient air temperature range [K].	✓	UNI EN 307:2000	✓	UNE EN 307:1999	✓	DIN EN 307:1998
PrimaryAirflowRateRange	Possible range of primary airflow that can be delivered [m3/s].	✓	UNI EN 307:2000 UNI EN 13053: 2011	✓	UNE EN 13053:2007 +A1:2011 UNE EN 307:1999	✓	VDI 3803 DIN EN 13053 A1 :2011 DIN EN 307:1998-12
MaximumExternal AirflowRate	Maximum external airflow rate during the winter considering the annual working hours.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007 +A1:2011	+	DIN EN 13053:2012
SecondaryAirflowRateRange	Possible range of secondary airflow that can be delivered [Pa, N/m2].	✓	UNI EN 307:2000	✓	UNE EN 307:1999	✓	DIN EN 307:1998-12
HeatExchangerCategory	Category I - Recuperators Category II with a thermovector:	+	UNI EN 308:1997 UNI EN 13053: 2011	+	UNE EN 308:1997 UNE EN 13053:2007 +A1:2012	+	DIN EN 308:1997 DIN EN 13053:2012

	IIa without phase change; IIb with phase change (heat pipes). Category III regenerators (with mass accumulation): IIIa - no hygroscopic; IIIb - hygroscopic.						
SuppliedElectricPower	Supplied electric power (Pel).	+	UNI EN 13053:2011	+	UNE EN 13053:2007 +A1:2011	+	DIN EN 13053:2012
HRSMaximumCapacity	Heat recovery system capacity corresponds to heat recovery maximum potential (Qp).	+	"	+	"	+	"
EnergeticClass	Classification of the heat recoverers according to intervals of energy efficiency ηe (from H1 to H6).	+	"	+	"	+	"
Pset_SoundGeneration	Common definition to capture the properties of sound typically used within the context of building services and flow distribution systems. This property set is instantiated multiple times on an object for each frequency band. HISTORY: New property set in IFC Release 2x4.						
SoundCurve	Table of sound frequencies and sound power for the referenced octave band frequency (63-8000Hz).	✓	DPCM 5/12/97 Requisivi acustici passivi degli edifici I.S.O. R226-1961 UNI 8199:1998	✓	REAL DECRETO 1367/2007 UNE-ISO 1996:2005-1 UNE ISO 1996: 2009-2 UNE EN ISO 16032 :2005	✓	ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
SoundPowerLevel	A sound power level (dB) is a logarithmic scale measure of total radiated noise energy per time unit (W) emitted by a source, at a reference power of 1 picowatt (10^{-12} watt) (Wo). Lw=10log(W/Wo)	+	UNI EN ISO 3741 :2010 ISO 3742:1988 UNI EN ISO 3743 :2010-1 UNI EN ISO 3744 :2010 UNI EN ISO 3745 :2012 UNI EN ISO 3746 :2011 UNI EN ISO 3747 :2011 UNI 8199:1998	+	UNE EN ISO 3741 :2011 UNE EN ISO 3743 :2011-1 UNE EN ISO 3743 :2010-2 UNE EN ISO 3744 :2010 UNE EN ISO 3745 :2010 UNE EN ISO 3746 :2011 UNE EN ISO 3747 :2011	+	DIN EN ISO 9295 :2013 DIN EN ISO 3741 :2011 DIN EN ISO 3743-1:2011 DIN EN ISO 3744 :2011-02 DIN EN ISO 3745 :2012-07 DIN EN ISO 3746 :2011-03 DIN EN ISO 3747 :2011-03
SoundPressureLevel	A sound pressure level (dB) is a logarithmic scale measure of the variation of pressure produced by the noise (P in Pa) compared with pressure in quite conditions (P0=2x10^-5 Pa at 1000Hz). Lp=10log(P/Po)^2 The sound intensity level Li (dB) is almost equal to Lp, so Lp=Li=10log (I/Io), where I is the sound intensity studied (W/m^2) and Io the reference value of 10^-12 W/m^2.	+	UNI EN ISO 3744 :2010 UNI EN ISO 3746 :2011	+	UNE EN ISO 3744 :2010 UNE EN ISO 3746 :2011	+	DIN EN ISO 3744 :2011 DIN EN ISO 3746 :2011
SoundPressureCurve	Sound pressure spectrum [dB(A)] for the referenced octave band frequency (63-8000Hz).	+	UNI EN 12354:2002 UNI 8199:1998	+	REAL DECRETO 1367/2007 UNE ISO 1996 :2005-1 UNE ISO 1996 :2009-2 UNE EN ISO 16032 :2005	+	DIN EN ISO 3746: 2011
TotalSoundPower	The total sound power level [dB(A)] is the sum of sound power levels per each frequency.	+	UNI EN ISO 3741 :2010 ISO 3742:1988 UNI EN ISO 3743 :2010-1 UNI EN ISO 3744	+	UNE EN ISO 3741 :2011 UNE EN ISO 3743 :2011-1 UNE EN ISO 3743 :2010-2	+	DIN EN ISO 9295 :2013 DIN EN ISO 3741 :2011 DIN EN ISO 3743-

			:2010 UNI EN ISO 3745 :2012 UNI EN ISO 3746 :2011 UNI EN ISO 3747 :2011 UNI 8199:1998		UNE EN ISO 3744 :2010 UNE EN ISO 3745 :2010 UNE EN ISO 3746 :2011 UNE EN ISO 3747 :2011		1:2011 DIN EN ISO 3744 :2011-02 DIN EN ISO 3745 :2012-07 DIN EN ISO 3746 :2011-03 DIN EN ISO 3747 :2011-03
TotalSoundPressure	The total sound pressure level [dB(A)] is the sum of sound pressure levels per each frequency.	+	UNI EN 12354:2002 UNI 8199:1998	+	REAL DECRETO 1367/2007 UNE ISO 1996 :2005-1 UNE ISO 1996 :2009-2 UNE EN ISO 16032 :2005	+	DIN EN ISO 3746: 2011-03
NRCurve	Noise Rating.	+	L. 447 /1995 Legge quadro sull'inquinamento acustico	+		+	ASHRAE Handbook—HVAC Systems and Equipment ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
NCCurve	NC curve (Noise Criteria ASHRAE).	+	DPCM 14-11-1997 Prescrizioni e limiti sul rumore ambientale	+		+	ASHRAE Handbook—HVAC Systems and Equipment ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
RCCurve	RC curve (Room Criteria).	+	ASHRAE Handbook—HVAC Systems and Equipment	+		+	
NCBCurve	NCB curve.	+	ref. ANSI/ASA S12.2-2008	+		+	
RCMarkIICurve	RC Mark II curve.	+	ref. ANSI/ASA S12.2-2008	+		+	
SoundType	Type of sound transfer.	+		+		+	

Pset_ATAHeatRecovery InstallationInstructions							
AccessibilityForMaintenance	Presence of sufficient space for maintenance operations.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:2011	+	DIN EN 13053:2012-02
SpaceBoundaries	Sufficient distance between the fixed elements and the device.	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
CorrosionResistentTray	Presence of tray with corrosion resistance (e.g. min. AISI 316 (stainless steel 1.4301) or aluminium layer (min. AlMg), with a slope to allow drainage of condensation water.	+	"	+	"	+	"
SealedConnectionsStatus	The connections between parts must be sealed (supply, exhaustion, primary flux, secondary flux, condensed drain) to avoid heat losses.	+	UNI EN 307:2000 UNI EN 308:1997 UNI EN 13053: 2011	+	UNE EN 307:1999 UNE EN 308:1997 UNE EN 13053:2007 +A1:2011	+	DIN EN 307:1998-12 DIN EN 308:1997 DIN EN 13053:2012-02
ATAHeatRecoveryOrientation	Orientation (vertical, horizontal, inclined, height)	+	"	+	"	+	"
InternalVariableBypass	Presence of internal variable by pass.	+	"	+	"	+	"
ThermalInsulation	Presence of thermal insulation and its description.	+	"	+	"	+	"
ThermalInsulationInstallation	Installation method of the thermal insulation.	+	"	+	"	+	"
Tightness	Determination of the tightness.	+	"	+	"	+	"
IdentificationLabelContents	Presence of an identification label (reporting manufacturer or supplier name, identification number of the manufacturer, fluid type, maximum airflow pressure, service temperature). It is not necessary the	+	"	+	"	+	"

	identification of the devices produced.						

Pset_ATAHeatRecoveryOperationInstructions							
HasHeatRecoveryDescription	Document reporting heat recovery type, connections type and airflow direction. This specification must contain design, schemes, airflow diagram, function information, and working conditions. There must be specifications about the flow regulation and alarm systems.	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
SettingDocument	Report of the reference values in the moment of the product delivery in order to be applied during adjustments and settings according to the EN 305 test dispositions. It is mandatory.	+	"	+	"	+	"
FailureMeasures	Specification of corrective measures applied in case of alarm failure, functional interruptions or fire.	+	"	+	"	+	"
SafetyRegulations	List of safety regulations (pressured boxes, toxicity, leaks)	+	"	+	"	+	"

Pset_ATAHeatRecoveryGeneralMaintenanceInstructions (P Periodical N if necessary)								
PrimarySideControl	Fouling, corrosion and damages rate determination on the primary side.	P	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
SecondarySideControl	Fouling, corrosion and damages rate determination on the secondary side.	P	+	"	+	"	+	"
SealsOperationControl	Operation tests of the seals.	P	+	"	+	"	+	"
FluidFLowControl	Control of the fluid circuit operation.	P	+	"	+	"	+	"
DefrostingEquipmentControl	Control of the defrosting equipment operation.	P	+	"	+	"	+	"
AirVentControl	Air vent test.	P	+	"	+	"	+	"
HeatTranferMedium FreezingResistanceControl	Control of the heat transfer medium freezing resistance.	P	+	"	+	"	+	"
PrimarySidePressureControl	Measurement of airflow pressure on the primary side.	P	+	"	+	"	+	"
SecondarySidePressure Control	Measurement of airflow pressure on the secondary side.	P	+	"	+	"	+	"
FoulingOnFilterControl	Verification of fouling presence on the filter.	P	+	Linee guida manutenzione 2007			+	VDI 6022
FluidQualityControl	Quality control of the fluid.	P	+	"			+	"
AirContamination	Air contamination test.		+	"			+	"
Corrosion	Corrosion of the device.		+	"			+	"
Damages	Damages of the device.		+	"			+	"
Leakage	Leakage between the two heat transfer fluids.		+	"			+	"

InsufficientSuctionBlowing	Insufficient air suction and blowing.		+	"			+	"
CondensationWaterStagnation	Stagnation of condensed water in the drain pan or finned surfaces.		+	UNI EN 307:2000	+	UNE EN 307:1999	+	VDI 6022 Blatt 1:2011 DIN EN 307:1998

Pset_ATAHeatRecoverySpecialMaintenanceInstructions (P Periodical N if necessary)								
PrimarySideCleaning	Cleaning of the primary side.	N	+	UNI EN 307:2000	+	UNI EN 307:2000	+	UNI EN 307:2000
SecondarySideCleaning	Cleaning of the secondary side.	P	+	"	+	"	+	"
SealRingsSubstitution	Substitution of the seal rings.	P	+	"	+	"	+	"
DefrostingEquipment OperationTest	Operation test of the defrosting equipment.	P	+	"	+	"	+	"
FluidCircuitOperationTest	Operation test of the fluid circuit.	P	+	"	+	"	+	"
AirVentingRepair	Air venting repair.	P	+	"	+	"	+	"
HeatTransferMedium FrostingSolution	If a method against heat transfer medium frosting is used.	P	+	"	+	"	+	"
PrimarySideTightnessRepair	Repair of tightness issues on the primary side.	P	+	"	+	"	+	"
SecondarySideTightness Repair	Repair of tightness issues on the secondary side.	P	+	"	+	"	+	"
FilterChange	Filter change.	N	+	"	+	"	+	"

Pset_ATAHeatRecoveryMaintenanceDocumentation							
LogicConstructionDiagram	Logic construction diagram (detection of breakdown).	+	"	+	"	+	"
MaintenanceOccurrencesData	Maintenance occurrences data (Operation statistics).	+	"	+	"	+	"
BreakdownStatistics	Date about failures and breakdown occurred and maintenance (Breakdown statistics).	+	"	+	"	+	"
SubstitutedPiecesStatistics	List of substituted pieces and determination of the most employed.	+	"	+	"	+	"

Property set name	IfcPropertySetTemplateTypeEnum	Description
Pset_ATAHeatRecoveryInstallationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of installation instructions to be followed to ensure the good functionality and accessibility of the air-to-air heat recovery. These are furnished by national and European regulations.
Pset_ATAHeatRecoveryOperationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of operation instructions to be followed to ensure the good and sustainable operation of the air-to-air heat recovery. These are furnished by national and European regulations.
Pset_ATAHeatRecoveryGeneralMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about general maintenance that could be better defined inspections. The property set name follows the declaration of the CEN Standards. Inspections considered specific are: - Cleaning of the primary and secondary sides; - Substitution of the seal rings (rotary exchangers); - Repair of drive equipment (rotary exchangers); - Control of the defrosting equipment; - Control of the liquid circuit; - Air ventilation; - Security of the resistance to the frosting of the heat transfer medium; - Security of the tightness on the primary and secondary sides; - Filter change; - Substitution of the quality of fluids. It is important writing a comment when the maintenance has been executed reporting date, observations and material/tools used.
Pset_ATAHeatRecoverySpecialMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about special maintenance, corresponding to current maintenance practise. The property set name follows the declaration of the

		EN 307 standard. A periodic or irregular frequency is suggested for each maintenance operation, to be assigned by the installer. Maintenance actions considered general are: - Fouling, corrosion and damages rate determination on the primary and secondary sides; - Operation tests of the seals; - Control of the drive equipment (rotary heat exchangers); - Control of the liquid circuit operation; - Control of the defrosting equipment operation; - Air vent; - Control of the heat transfer medium freezing resistance; - Test system of pressure on the primary and secondary sides; - Determination of fouling on the filter; - Quality control of the fluid. It is important writing a comment when the inspection has been executed reporting date, observations and material/tools used.
Pset_ATAHeatRecoveryMaintenanceDocumentation	PSET_TYPEDRIVENOVERRIDE	Set of documents and information needed to report breakdown detection, operation statistics, breakdown statistics, list of substituted pieces and determination of the most employed. All these must be inserted inside the maintenance plan of the air-handling unit.

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_AirToAirHeatRecoveryPHistory					
HRSCapacity	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		
EfficiencyOfTemperature	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
EnergyEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
PerformanceCoefficient	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
AirPressureDrop	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
ExternalDrop	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
InternalDrop	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
InternalLeak	P_REFERENCEVALUE	IfcTimeSeries	IfcMassFlowRate Measure		
EntrainmentAirflowRate	P_REFERENCEVALUE	IfcTimeSeries	IfcMassFlowRate Measure		
SpecificPowerInput	P_REFERENCEVALUE	IfcTimeSeries	IfcMeasureWithUnit		
NominalTemperaturePerformanceFactor	P_REFERENCEVALUE	IfcTimeSeries	IfcReal		
AnnualWorkingTime	P_REFERENCEVALUE	IfcTimeSeries	IfcTimeMeasure		
Pset_AirToAirHeatRecoveryCommon					
MaximumExternalAirflowRate	P_SINGLEVALUE		IfcVolumetricFlowRate Measure		
HeatExchangerCategory	P_ENUMERATEDVALUE		IfcLabel	PEnum_HeatExchangerCategory: I, IIa, IIb, IIIa, IIIb	
SuppliedElectricPower	P_SINGLEVALUE		IfcPowerMeasure		
HRSMaximumCapacity	P_SINGLEVALUE		IfcPowerMeasure		
EnergeticClass	P_ENUMERATEDVALUE		IfcLabel	PEnum_Energetic Class:H1, H2, H3, H4, H5, H6	
Pset_SoundGeneration					
SoundPowerLevel *it can be omitted if sound spectrum is used	P_SINGLEVALUE P_REFERENCEVALUE	IfcFrequency Measure	IfcSoundPowerLevel		
SoundPressureLevel *it can be omitted if sound spectrum is used	P_SINGLEVALUE P_REFERENCEVALUE	IfcFrequency Measure	IfcSoundPowerLevel		
SoundPressureCurve	P_TABLEVALUE		IfcFrequency Measure/IfcSoundPressureLevelMeasure		
TotalPowerLevel	P_SINGLEVALUE		IfcSoundPowerLevel		
TotalPressureLevel	P_SINGLEVALUE		IfcSoundPressureLevel		
NRCurve	P_SINGLEVALUE				
NCDurve	P_COMPLEX				

RCCurve	P_COMPLEX				
NCBCurve	P_COMPLEX				
RCMarkIICurve	P_COMPLEX				
SoundType	P_ENUMERATEDVALUE		IfcLabel	PEnum_SoundType: Frontal, Lateral, Down, Up	

Pset_ATAHeatRecoveryInstallationInstructions					
AccessibilityForMaintenance	P_SINGLEVALUE		IfcText		
SpaceBoundaries	P_SINGLEVALUE		IfcText		
CorrosionResistentTray	P_SINGLEVALUE		IfcText		
SealedConnectionsStatus	P_REFERENCEVALUE	IfcTimeSeries	IfcLabel	PEnum_SealedConnectionsStatus: GOOD, BAD, ABSENT	
ATAHeatRecoveryOrientation	P_ENUMERATEDVALUE		IfcLabel	PEnum_DeviceOrientation: VERTICAL, HORIZONTAL, INCLINATED, HEIGHT	
InternalVariableBypass	P_SINGLEVALUE		IfcText		
ThermalInsulation	P_SINGLEVALUE		IfcText		
ThermalInsulationInstallation	P_SINGLEVALUE		IfcText		
Tightness	P_SINGLEVALUE		IfcBoolean		
IdentificationLabelContents	P_LISTVALUE		IfcLabel		Absent, Manufacturer name, Supplier name, Manufacturer, Identification number, Fluid type, Maximum airflow, Pressure, Service temperature.

Pset_ATAHeatRecoveryOperationInstructions					
HasHeatRecoveryDescription	P_LISTVALUE		IfcLabel		Heat recovery type, Technical designs, Connections type, Airflow direction, Airflow diagram, Schemes, Function, Working conditions, Flow regulation, and Alarm function.
SettingDocument	P_SINGLEVALUE		IfcText		
FailureMeasures	P_SINGLEVALUE		IfcText		
SafetyRegulations	P_SINGLEVALUE		IfcText		

Pset_ATAHeatRecoveryGeneralMaintenanceInstructions					
PrimarySideControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySideControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SealsOperationControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidFLowControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
DefrostingEquipmentControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
AirVentControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		

HeatTranferMediumFreezingResistanceControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
PrimarySidePressureControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySidePressureControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FoulingOnFilterControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidQualityControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
AirContamination	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Corrotion	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Damages	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Leakage	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
InsufficientSuctionBlowing	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
CondensationWaterStagnation	P_REFERENCEVALUE	IfcTimeSeries	IfcText		

Pset_ATAHeatRecoverySpecialMaintenanceInstructions					
PrimarySideCleaning	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		
SecondarySideCleaning	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		
SealRingsSubstitution	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
DefrostingEquipmentOperationTest	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidCircuitOperationTest	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
AirVentingRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
HeatTransferMediumFrostingSolution	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
PrimarySideTightnessRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySideTightnessRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FilterChange	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		

Pset_ATAHeatRecoveryMaintenanceDocumentation					
LogicConstructionDiagram	P_SINGLEVALUE		IfcText		
MaintenanceOccurrencesData	P_SINGLEVALUE		IfcText		
BreakdownStatistics	P_SINGLEVALUE		IfcText		
SubstitutedPiecesStatistic	P_SINGLEVALUE		IfcText		

Property set implementation as IFC Documentation in ifcDoc tool

The IFC documentation generator is the software tool used to generate the IFC documentation.
The property set *Pset_ATAHeatRecoverySpecialMaintenanceInstructions* has been only implemented among all the property sets and properties defined during the investigation of the entity ifcAirToAirHeatRecovery, as an example.

IFC Specification

The property set *Pset_ATAHeatRecoverySpecialMaintenanceInstructions* has been implemented inside the ifcDoc as an example of implementation of property sets.


```
($,$,'Pset_ATAHeatRecoverySpecialMaintenanceInstructions','Set of instructions about special maintenance,
corresponding to current maintenance practise. The property set name follows the declaration of the EN 307
standard. A periodic or irregular frequency is suggested for each maintenance operation, to be assigned by the
installer. \X\0D\X\0AMaintenance actions considered general are: \X\0D\X\0A- Fouling, corrosion and damages
rate determination on the primary and secondary sides; \X\0D\X\0A- Operation tests of the seals; \X\0D\X\0A-
Control of the drive equipment (rotary heat exchangers); \X\0D\X\0A- Control of the liquid circuit operation;
\X\0D\X\0A- Control of the defrosting equipment operation; \X\0D\X\0A- Air vent; \X\0D\X\0A- Control of the
heat transfer medium freezing resistance; \X\0D\X\0A- Test system of pressure on the primary and secondary
sides; \X\0D\X\0A- Determination of fouling on the filter; \X\0D\X\0A- Quality control of the fluid.
\X\0D\X\0AIt is important writing a comment when the inspection has been executed reporting date, observations
and material/tools used..','',$);
#8375= IFCRELASSOCIATESLIBRARY('2GY8UkvR56d8kA$$ZGsDsn',$,$,$,(#8373),#8374);
#8376= IFCSIMPLEPROPERTYTEMPLATE('11Ir_A1CzEwRtnaeZZ8gR4',$,'PrimarySideCleaning
','',.P_REFERENCEVALUE.,'IfcIrregularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8377= IFCLIBRARYREFERENCE($,$,'PrimarySideCleaning','Cleaning of the primary side. *In each local
documentation is better referencing the property to the national and european regulation.*','',$);
#8378= IFCRELASSOCIATESLIBRARY('0yD5E2IjrC6QPAkmDAJcP9',$,$,$,(#8376),#8377);
#8379=
IFCSIMPLEPROPERTYTEMPLATE('2nxOc9epHDOOKJCnT3M3jX',$,'SecondarySideCleaning',$,.P_REFERENCEVALUE.,'IfcIrregula
rTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8380= IFCLIBRARYREFERENCE($,$,'SecondarySideCleaning','Cleaning of the secondary side. *In each local
documentation is better referencing the property to the national and european regulation.*','',$);
#8381= IFCRELASSOCIATESLIBRARY('3nSshFvLnDSR8ae4dXcH$u',$,$,$,(#8379),#8380);
#8382= IFCSIMPLEPROPERTYTEMPLATE('0mo6lTrCT6T84JHk1Nj0Y$',$,'SealRingsSubstitution','Operation tests of the
seals. *In each local documentation is better referencing the property to the national and european
regulation.*',.P_REFERENCEVALUE.,'IfcRegularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8383= IFCLIBRARYREFERENCE($,$,'SealRingsSubstitution','Operation tests of the seals. ','',$);
#8384= IFCRELASSOCIATESLIBRARY('0egZlKgMn1Jwf3JHkDgFJ$',$,$,$,(#8382),#8383);
#8385=
IFCSIMPLEPROPERTYTEMPLATE('1tXtzmfXn4SeR4EE5IeOhp',$,'DefrostingEquipmentOperationTest',$,.P_REFERENCEVALUE.,'
IfcRegularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8386= IFCLIBRARYREFERENCE($,$,'DefrostingEquipmentOperationTest','Operation test of the defrosting. *In each
local documentation is better referencing the property to the national and european regulation.*','',$);
#8387= IFCRELASSOCIATESLIBRARY('3CRtReHs13I8PKTkp2JDse',$,$,$,(#8385),#8386);
#8388=
IFCSIMPLEPROPERTYTEMPLATE('0_sLQIegX6BeZ04jCJ1vTV',$,'FluidCircuitOperationTest',$,.P_SINGLEVALUE.,$,$,$,$,$,$
,.READWRITE.);
#8389= IFCLIBRARYREFERENCE($,$,'FluidCircuitOperationTest','Operation test of the fluid circuit. *In each
local documentation is better referencing the property to the national and european regulation.*','',$);
#8390= IFCRELASSOCIATESLIBRARY('25cXFCLor7QQc00wyIWuod',$,$,$,(#8388),#8389);
#8391=
IFCSIMPLEPROPERTYTEMPLATE('3x4i4kYRD8GPom96DIfS7h',$,'AirVentingRepair',$,.P_REFERENCEVALUE.,'IfcRegularTimeSe
ries','IfcText',$,$,$,$,.READWRITE.);
#8392= IFCLIBRARYREFERENCE($,$,'AirVentingRepair','Air venting repair. *In each local documentation is better
referencing the property to the national and european regulation.*','',$);
#8393= IFCRELASSOCIATESLIBRARY('0_Hbdl9jn6_vhmZ6G7MK23',$,$,$,(#8391),#8392);
#8394=
IFCSIMPLEPROPERTYTEMPLATE('0$rWDvd6n7WwFegFpsI8ug',$,'HeatTransferMediumFrostingSolution',$,.P_REFERENCEVALUE.
,'IfcRegularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8395= IFCLIBRARYREFERENCE($,$,'HeatTransferMediumFrostingSolution','If a method against heat transfer medium
frosting is used. *In each local documentation is better referencing the property to the national and european
regulation.*','',$);
#8396= IFCRELASSOCIATESLIBRARY('2zrblwNrz8CBNNJBO3X88z',$,$,$,(#8394),#8395);
#8397=
IFCSIMPLEPROPERTYTEMPLATE('3MjbVYnMn2rv5llwVsGeUQ',$,'PrimarySideTightnessRepair',$,.P_REFERENCEVALUE.,'IfcReg
ularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8398= IFCLIBRARYREFERENCE($,$,'PrimarySideTightnessRepair','Repair of tightness issues on the primary side.
*In each local documentation is better referencing the property to the national and european
regulation.*','',$);
#8399= IFCRELASSOCIATESLIBRARY('25LX8Qujr79BPWArpgdW3r',$,$,$,(#8397),#8398);
#8400=
IFCSIMPLEPROPERTYTEMPLATE('0$MkY_Ug5DnQZ2HzcQublF',$,'SecondarySideTightnessRepair',$,.P_REFERENCEVALUE.,'IfcR
egularTimeSeries','IfcText',$,$,$,$,.READWRITE.);
#8401= IFCLIBRARYREFERENCE($,$,'SecondarySideTightnessRepair','Repair of tightness issues on the secondary
side. *In each local documentation is better referencing the property to the national and european
regulation.*','',$);
#8402= IFCRELASSOCIATESLIBRARY('3qBo8_ybb2JRpqpFzajueb',$,$,$,(#8400),#8401);
#8403=
IFCSIMPLEPROPERTYTEMPLATE('2P$_1QHHH0Pv$J8F1XH2kI',$,'FilterChange',$,.P_REFERENCEVALUE.,'IfcIrregularTimeSeri
es','IfcText',$,$,$,$,.READWRITE.);
#8404= IFCLIBRARYREFERENCE($,$,$,$,'',$);
#8405= IFCRELASSOCIATESLIBRARY('0Svp0j2br1gvPvbhezquZs',$,$,$,(#8403),#8404);
#8406= IFCLIBRARYREFERENCE($,$,'FilterChange','Filter change. *In each local documentation is better
referencing the property to the national and european regulation.*','',$);
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IFCXML Specification

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IfcPropertySetTemplate GlobalId="0vY$U4ZcD2hwa7ShwX9eDp"
Name="Pset_AirToAirHeatRecoveryMaintenanceInstructions" ApplicableEntity="IfcAirToAirHeatRecovery">

          <Description />

          <HasAssociations>

            <IfcRelAssociatesLibrary GlobalId="0$s16oTiT9Vgtf3g6sd9$N">

              <RelatingLibrary Name="Pset_ATAHeatRecoverySpecialMaintenanceInstructions" Language="">

                <Description>Set of instructions about special maintenance, corresponding to current
maintenance practise. The property set name follows the declaration of the EN 307 standard. A periodic or
irregular frequency is suggested for each maintenance operation, to be assigned by the installer.

Maintenance actions considered general are:

- Fouling, corrosion and damages rate determination on the primary and secondary sides;

- Operation tests of the seals;

- Control of the drive equipment (rotary heat exchangers);

- Control of the liquid circuit operation;

- Control of the defrosting equipment operation;

- Air vent;

- Control of the heat transfer medium freezing resistance;

- Test system of pressure on the primary and secondary sides;

- Determination of fouling on the filter;

- Quality control of the fluid.

It is important writing a comment when the inspection has been executed reporting date, observations and
material/tools used..</Description>

              </RelatingLibrary>

            </IfcRelAssociatesLibrary>

          </HasAssociations>

          <PredefinedType>PSET_TYPEDRIVENOVERRIDE</PredefinedType>

          <HasPropertyTemplates>

            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="11Ir_A1CzEwRtnaeZZ8gR4"
Name="PrimarySideCleaning " PrimaryMeasureType="IfcIrregularTimeSeries" SecondaryMeasureType="IfcText"
AccessState="READWRITE">

              <Description />

              <HasAssociations>

                <IfcRelAssociatesLibrary GlobalId="3NyvRG2Y56QRmg4gB4cFE0">

                  <RelatingLibrary Name="PrimarySideCleaning" Language="">

                    <Description>Cleaning of the primary side. *In each local documentation is better
referencing the property to the national and european regulation.*</Description>

                  </RelatingLibrary>

                </IfcRelAssociatesLibrary>

              </HasAssociations>

              <TemplateType>P_REFERENCEVALUE</TemplateType>

            </IfcPropertyTemplate>

            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2nxOc9epHDOOKJCnT3M3jX"
Name="SecondarySideCleaning" PrimaryMeasureType="IfcIrregularTimeSeries" SecondaryMeasureType="IfcText"
AccessState="READWRITE">

              <HasAssociations>

                <IfcRelAssociatesLibrary GlobalId="2u2BHaXzbEK8ws3cWvuCIb">

                  <RelatingLibrary Name="SecondarySideCleaning" Language="">

                    <Description>Cleaning of the secondary side. *In each local documentation is better
referencing the property to the national and european regulation.*</Description>

                  </RelatingLibrary>

                </IfcRelAssociatesLibrary>

              </HasAssociations>

              <TemplateType>P_REFERENCEVALUE</TemplateType>
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            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="0mo6lTrCT6T84JHk1Nj0Y$" Name="SealRingsSubstitution" PrimaryMeasureType="IfcRegularTimeSeries" SecondaryMeasureType="IfcText" AccessState="READWRITE">
              <Description>Operation tests of the seals. *In each local documentation is better referencing the property to the national and european regulation.*</Description>
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1tVW$pYh52ovzQQXblJpKs">
                  <RelatingLibrary Name="SealRingsSubstitution" Language="">
                    <Description>Operation tests of the seals. </Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1tXtzmfXn4SeR4EE5IeOhp" Name="DefrostingEquipmentOperationTest" PrimaryMeasureType="IfcRegularTimeSeries" SecondaryMeasureType="IfcText" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="2056gUv8rEE8A6oyxVOQPl">
                  <RelatingLibrary Name="DefrostingEquipmentOperationTest" Language="">
                    <Description>Operation test of the defrosting. *In each local documentation is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="0_sLQIegX6BeZ04jCJ1vTV" Name="FluidCircuitOperationTest" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="39JXb1Vp9BfwoBrEztVV3V">
                  <RelatingLibrary Name="FluidCircuitOperationTest" Language="">
                    <Description>Operation test of the fluid circuit. *In each local documentation is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
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              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1VMm4WULL45w1AWTdJ4yKP">
                  <RelatingLibrary Name="AirVentingRepair" Language="">
                    <Description>Air venting repair. *In each local documentation is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
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Name="HeatTransferMediumFrostingSolution" PrimaryMeasureType="IfcRegularTimeSeries"
SecondaryMeasureType="IfcText" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="04JCafnN52wRBDEEOGhrI2">
                  <RelatingLibrary Name="HeatTransferMediumFrostingSolution" Language="">
                    <Description>If a method against heat transfer medium frosting is used. *In each local
documentation is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="3MjbVYnMn2rv5llwVsGeUQ"
Name="PrimarySideTightnessRepair" PrimaryMeasureType="IfcRegularTimeSeries" SecondaryMeasureType="IfcText"
AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="0F6lXykoXEgAyYnjXjPhz2">
                  <RelatingLibrary Name="PrimarySideTightnessRepair" Language="">
                    <Description>Repair of tightness issues on the primary side. *In each local documentation
is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="0$MkY_Ug5DnQZ2HzcQublF"
Name="SecondarySideTightnessRepair" PrimaryMeasureType="IfcRegularTimeSeries" SecondaryMeasureType="IfcText"
AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="299OJf_L1FsgfWbr8Z7M5z">
                  <RelatingLibrary Name="SecondarySideTightnessRepair" Language="">
                    <Description>Repair of tightness issues on the secondary side. *In each local
documentation is better referencing the property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2P$_1QHHH0Pv$J8F1XH2kI"
Name="FilterChange" PrimaryMeasureType="IfcIrregularTimeSeries" SecondaryMeasureType="IfcText"
AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="2Cm4Z18b5Ab9QuNcRjDU55">
                  <RelatingLibrary Language="" />
                </IfcRelAssociatesLibrary>
                <IfcRelAssociatesLibrary GlobalId="2qIBvmdQf1u8fHSA73KvA0">
                  <RelatingLibrary Name="FilterChange" Language="">
                    <Description>Filter change. *In each local documentation is better referencing the
property to the national and european regulation.*</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
```

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      <TemplateType>P_REFERENCEVALUE</TemplateType>
    </IfcPropertyTemplate>
  </HasPropertyTemplates>
</IfcPropertySetTemplate>
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IFCSHAREDBLDGSERVICEELEMENT
IfcEnergyConversionDevice
IfcCoil
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_CoilOccurrence	Coil occurrence attributes attached to an instance of IfcCoil.						
HasSoundAttenuation	TRUE if the coil has sound attenuation, FALSE if it does not. **ERROR: IT MUST BE IN FAN**	✓	DPCM 5/12/97 Requisivi acustici passivi degli edifici	✓	REAL DECRETO 1367/2007 UNE-ISO 1996:2005-1 UNE-ISO 1996:2009-2 UNE-EN ISO 16032	✓	ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987
Pset_CoilPHistory	Coil performance history common attributes. Sound attribute deleted in IFC2x2 Pset Addendum: Use IfcSoundProperties instead.						
AtmosphericPressure	Ambient atmospheric pressure.	✓		✓		✓	
TotalPressure	Total average absolute pressure. It must be measured in inlet airflow and outlet airflow.	+	UNI EN 305:1999 UNI EN 306:2001	+	UNE EN 305:1997 UNE EN 306:1997	+	DIN EN 305:1997 DIN EN 306:1997
StaticPressure	Static Pressure.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
DynamicPressure	Dynamic Pressure.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
AirPressureDrop	Air pressure drop calculated as the difference between the inlet air pressure and the outlet air pressure.	+	UNI EN 305:1999 UNI EN 306:2001	+	UNE EN 305:1997 UNE EN 306:1997	+	DIN EN 305:1997 DIN EN 306:1997
AirPressureDropCurve	Air pressure drop curve, pressure drop – flow rate curve, AirPressureDrop = f (AirflowRate).	✓		✓		✓	
Temperature	The average temperature must be measured in inlet airflow and outlet airflow.	+	UNI EN 305:1999 UNI EN 307:2000	+	UNE EN 305:1997 UNE EN 307:1999	+	DIN EN 307:1998-12
StaticPressureCurve	Static pressure curve, static pressure – airflow rate curve, StaticPressure = f (AirflowRate).	+		+		+	
SoundCurve	Regenerated sound versus airflow rate. **ERROR: IT MUST IN SOUND GENERATION**						
FaceVelocity	Air velocity through the coil.	✓	UNI EN 307:2000	✓	UNE EN 307:1999	✓	DIN EN 307:1998-12
ThermalEfficiency	Thermal efficiency is the relationship between the real thermal power exchanged and the maximum thermal power theoretically exchanged with an ideal equipment that uses the same media with the same airflow and the same inlet temperatures.	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
ThermalEfficiencyCurve	Thermal efficiency curve, thermal efficiency – NTU curve, Thermalefficiency = f(NTU).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997

Pset_CoilTypeCommon	Coil type common attributes.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1'), provided, if there is no classification reference to a recognized classification system used.	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
MaximumPressure	Maximum pressure.	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
LogaritmicMeanTemperature Difference	The logarithmic mean temperature difference (LMDT) must be calculated as the ratio between the difference of the temperature differences in input and output and logarithmic ratio of these two differences.	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
LMDTCorrectiveFactor	Corrective factor of the LMDT.	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
FinalDifferenceTemperature	The final temperature difference (limit) must be determined by diference of the primary circuit and the input or output of secondary circuit.	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
HeatExchangeGlobal Coefficient	Global coefficient of heat exchange (K or U) (W/Km2).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
OperationalTemperatureRange	Allowable operational air temperature range.	✓	UNI EN 307:2000	✓	UNE EN 307:1999	✓	DIN EN 307:1998-12
AirflowRateRange	Possible range of airflow that can be delivered. In cases where there is not airflow across the coil (e.g. electric coil in a floor slab), then the value is zero.	✓	UNI EN 13053: 2011 UNI EN 307:2000	✓	UNE EN 13053:2007+A1:2011 UNE EN 307:1999	✓	VDI 3803 (min H3) DIN EN 13053 A1 :2011 DIN EN 307:1998-12
MassiveAirFlowExpence/Rate	Massive airflow expense/rate (kg/s).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
VolumetricAirFlowExpence/ Rate	Volumetric airflow expense/rate (m3/s).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
NominalSensibleCapacity	Nominal sensible capacity.						
SensibleThermalPower	Sensible thermal power.	+		+		+	
NominalLatentCapacity	Nominal latent capacity.						
LatentThermalPower	Latent thermal power.	+		+		+	
ThermalPower	Thermal power as a quantity of exchanged heat for time unit (P).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
NominalUA	Nominal UA value (in CEN standards kA).	✓	UNI EN 305:1999	✓	UNE EN 305:1997	✓	DIN EN 305:1997

PlacementType	Indicates the placement of the coil. FLOOR indicates an under floor heater (if coil type is WATERHEATINGCOIL or ELECTRICHEATINGCOIL); CEILING indicates a cooling ceiling (if coil type is WATERCOOLINGCOIL); UNIT indicates that the coil is part of a cooling or heating unit, like cooled beam, etc.	✓		✓		✓	
FoulingResistance	The fouling resistance must be calculated in both the sides of the heat exchange surface. It is calculated with the average values obtained by the operational tests (m2k/W).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
HeatExchangeSurface Margins	Heat exchange surface margins factor (SM %).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
CleaningFactor	Cleaning factor (Cf).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997
NTU	Heat Exchange Number Unit (NTU).	+	UNI EN 305:1999	+	UNE EN 305:1997	+	DIN EN 305:1997

Pset_FluidTypeCommon	Fluid type common attributes.						
Density	Fluid density.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
SpecificHeatCapacity	Fluid specific heat capacity.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
SpecificEnthalpy	Specific enthalpy.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
SteamConcentration	Steam concentration.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
Viscosity	Viscosity.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997
MassProportion	Mass proportion.	+	UNI EN 306:2001	+	UNE EN 306:1997	+	DIN EN 306:1997

Pset_CoilTypeHydronic	Hydronic coil type attributes.						
FluidPressureRange	Allowable water pressure range inside the tube.	+		+		+	
CoilCoolant	The fluid used for heating or cooling used by the hydronic coil.	+		+		+	
CoilConnectionDirection	Coil connection direction (facing into the air stream).						
CoilFluidArrangement	Fluid flow arrangement of the coil. CrossCounterFlow: Air and water flow enter in different directions. CrossFlow: Air and water flow are perpendicular. CrossParallelFlow: Air and water flow enter in same directions.	+		+		+	
CoilFaceArea	Coil face area in the direction against airflow.	+		+		+	
HeatExchangeSurfaceArea	Heat exchange surface area associated with U-value.	+		+		+	
PrimarySurfaceArea	Primary heat transfer surface area of the tubes and headers.	+		+		+	

SecondarySurfaceArea	Secondary heat transfer surface area created by fins.	+		+		+	
Fluid	The properties of the hydronic fluid used for heat transfer within the coil tubes.	+		+		+	
TotalUACurves	Total UA curves, UA - air and water velocities, UA = [(C1 * AirFlowRate^0.8)^-1 + (C2 * WaterFlowRate^0.8)^-1]^-1. Note: as two variables are used, DefiningValues and DefinedValues are null, and values are stored in IfcTable in the following order: AirFlowRate,WaterFlowRate, UA. The IfcTable is related to IfcPropertyTableValue using IfcMetric and IfcPropertyConstraintRelationship.						
WaterPressureDropCurve	Water pressure drop curve, pressure drop – flow rate curve, WaterPressureDrop = f(WaterflowRate).						
WaterSidePressureDrop	Water pressure drop in correspondence of the water stream.	+		+		+	
BypassFactor	Fraction of air that is bypassed by the coil (0-1).	+		+		+	
SensibleHeatRatio	Air-side sensible heat ratio, or fraction of sensible heat transfer to the total heat transfer.						
WetCoilFraction	Fraction of coil surface area that is wet (0-1).						

The Pset_SoundGenration for ifcCoil is equal to the one shown for the air-to-air heat recovery.

Pset_CoilDesignInstructions	Design specifications to allow accessibility and easy cleaning of the component to ensure hygiene.						
InstallationDepth	For heat exchangers with a depth major of 300 mm (450 mm in aligned tube assembly), based on a fin spacing of 2 mm.					+	DIN 1946-4:2008-12
CondensateConnections	For larger fin spaces than 2 mm, the permissible installation depth may be proportional and be selected with linearly increases.					+	“
FinSpacing	For easier cleaning, all condensation connections must be made on the same page.					+	“
CoolingCoilDesignInstructions	In case of finned heat exchanger coil, fin spacing are exclusively permitted ≥ 2 mm.					+	“
CondensationDrain Components	Presence of systems to avoid the condensation water on components below the coil.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007 +A1:2011	+	DIN EN 13053:2012-02
CoolingCoilSeparatedFrom Filters CoolingCoilSeparatedFrom Silencer	Cooling and dehumidifying coil positioned not immediately before filters and silencers. The fans and the heating coil must be installed	+	"	+	"	+	"

	between them to reduce the relative humidity.						
InsulatedConnectionDucts	The connection ducts must be insulated when they cross the case, to avoid condensation in correspondence of these sections.	+	"	+	"	+	"
DriftSeparators	For hygiene, the drift separators must be used only when the air speed, trough the cooling coil, cannot avoid the drift pulling. They must be easily removable.	+	"	+	"	+	"
Pset_CoilInstallationInstructions							
AccessibilityForMaintenance	Presence of sufficient space for maintenance operations.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:2011	+	DIN EN 13053:2012-02
SpaceBoundaries	Sufficient distance between the fixed elements and the device.	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
RemovableCoil	Removable coil to allow an easy cleaning of the coil, if it is high more than 1,6 m.	+	UNI EN 13053: 2011	to insert in IFC4	+	+	DIN EN 13053:2012-02
CorrosionResistentTray	Presence of tray with corrosion resistance (e.g. min. AISI 316 (stainless steel 1.4301) or aluminium layer (min. AlMg), with a slope to allow drainage of condensation water.	+	"	+	"	+	"
SealedConnectionsStatus	The connections between parts must be sealed (supply, exhaustion, primary flux, secondary flux, condensed drain) to avoid heat losses.	+	UNI EN 307:2000 UNI EN 308:1997 UNI EN 13053: 2011	+	UNE EN 307:1999 UNE EN 308:1997 UNE EN 13053:2007 +A1:2011	+	DIN EN 307:1998-12 DIN EN 308:1997 DIN EN 13053:2012-02
CoilOrientation	Orientation (vertical, horizontal, inclined, height)	+	"	+	"	+	"
InternalVariableBypass	Presence of internal variable by pass.	+	"	+	"	+	"
ThermalInsulation	Presence of thermal insulation and its description.	+	"	+	"	+	"
ThermalInsulationInstallation	Installation method of the thermal insulation.	+	"	+	"	+	"
Tightness	Determination of the tightness.	+	"	+	"	+	"
IdentificationLabelContents	Presence of an identification label (reporting manufacturer or supplier name, identification number of the manufacturer, fluid type, maximum airflow pressure, service temperature). It is not necessary the identification of the devices produced.	+	"	+	"	+	"
Pset_CoilOperationInstructions							
SettingDocument	Report of the reference values in the moment of the product delivery in order to be applied during adjustments and settings according to the EN 305 test dispositions. It is mandatory.	+	"	+	"	+	"
FailureMeasures	Specification of corrective measures applied in case of alarm failure, functional interruptions or fire.	+	"	+	"	+	"

SafetyRegulations	List of safety regulations (pressured boxes, toxicity, leaks)		+	"	+	"	+	"

Pset_CoilGeneralMaintenanceInstructions (P Periodical N if necessary)								
PrimarySideControl	Fouling, corrosion and damages rate determination on the primary side.	P	+	UNI EN 307:2000	+	UNE EN 307:1999	+	DIN EN 307:1998-12
SecondarySideControl	Fouling, corrosion and damages rate determination on the secondary side.	P	+	"	+	"	+	"
SealsOperationControl	Operation tests of the seals.	P	+	"	+	"	+	"
FluidFLowControl	Control of the fluid circuit operation.	P	+	"	+	"	+	"
DefrostingEquipmentControl	Control of the defrosting equipment operation.	P	+	"	+	"	+	"
AirVentControl	Air vent test.	P	+	"	+	"	+	"
HeatTranferMedium FreezingResistanceControl	Control of the heat transfer medium freezing resistance.	P	+	"	+	"	+	"
PrimarySidePressureControl	Measurement of airflow pressure on the primary side.	P	+	"	+	"	+	"
SecondarySidePressure Control	Measurement of airflow pressure on the secondary side.	P	+	"	+	"	+	"
FoulingOnFilterControl	Verification of fouling presence on the filter.	P	+	Linee guida manutenzione 2007			+	VDI 6022
FluidQualityControl	Quality control of the fluid.	P	+	"			+	"
AirContamination	Air contamination test.		+	"			+	"
Corrosion	Corrosion of the device.		+	"			+	"
Damages	Damages of the device.		+	"			+	"
Leakage	Leakage between the two heat transfer fluids.		+	"			+	"
InsufficientSuctionBlowing	Insufficient air suction and blowing.		+	"			+	"
CondensationWaterStagnation	Stagnation of condensed water in the drain pan or finned surfaces.		+				+	VDI 6022 DIN EN 307:1998-12

Pset_CoilSpecialMaintenanceInstructions (P Periodical N if necessary)								
PrimarySideCleaning	Cleaning of the primary side.	N	+	UNI EN 307:2000	+	UNI EN 307:2000	+	UNI EN 307:2000
SecondarySideCleaning	Cleaning of the secondary side.	P	+	"	+	"	+	"
SealRingsSubstitution	Substitution of the seal rings.	P	+	"	+	"	+	"
DefrostingEquipment OperationTest	Operation test of the defrosting equipment.	P	+	"	+	"	+	"
FluidCircuitOperationTest	Operation test of the fluid circuit.	P	+	"	+	"	+	"
AirVentingRepair	Air venting repair.	P	+	"	+	"	+	"
HeatTransferMedium FrostingSolution	If a method against heat transfer medium frosting is used.	P	+	"	+	"	+	"
PrimarySideTightnessRepair	Repair of tightness issues on the primary side.	P	+	"	+	"	+	"

SecondarySideTightness Repair	Repair of tightness issues on the secondary side.	P	+	"	+	"	+	"
FilterChange	Filter change.	N	+	"	+	"	+	"
Pset_CoilMaintenanceDocumentation								
LogicConstructionDiagram	Logic construction diagram (detection of breakdown).		+	"	+	"	+	"
MaintenanceOccurrencesData	Maintenance occurrences data (Operation statistics).		+	"	+	"	+	"
BreakdownStatistics	Date about failures and breakdown occurred and maintenance (Breakdown statistics).		+	"	+	"	+	"
SubstitutedPiecesStatistics	List of substituted pieces and determination of the most employed.		+	"	+	"	+	"

Property set name	IfcPropertySetTemplateTypeEnum	Description
Pset_FluidTypeCommon	PSET_TYPEDRIVENOVERRIDE	Fluid type common attributes.
Pset_CoilDesignInstructions	PSET_TYPEDRIVENOVERRIDE	Design specifications to allow accessibility and easy cleaning of the component to ensure hygiene.
Pset_CoilOperationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of operation instructions to be followed to ensure the good and sustainable operation of the coil. These are furnished by national and European regulations.
Pset_CoilInstallationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of installation instructions to be followed to ensure the good functionality and accessibility of the coil. These are furnished by national and European regulations.
Pset_CoilGeneralMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about general maintenance that could be better defined inspections. The property set name follows the declaration of the CEN Standards. Inspections considered specific are: - Cleaning of the primary and secondary sides; - Substitution of the seal rings (rotary exchangers); - Repair of drive equipment (rotary exchangers); - Control of the defrosting equipment; - Control of the liquid circuit; - Air ventilation; - Security of the resistance to the frosting of the heat transfer medium; - Security of the tightness on the primary and secondary sides; - Filter change; - Substitution of the quality of fluids. It is important writing a comment when the maintenance has been executed reporting date, observations and material/tools used.
Pset_CoilSpecialMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about special maintenance, corresponding to current maintenance practise. The property set name follows the declaration of the EN 307 standard. A periodic or irregular frequency is suggested for each maintenance operation, to be assigned by the installer. Maintenance actions considered general are: - Fouling, corrosion and damages rate determination on the primary and secondary sides; - Operation tests of the seals; - Control of the drive equipment (rotary heat exchangers); - Control of the liquid circuit operation; - Control of the defrosting equipment operation; - Air vent; - Control of the heat transfer medium freezing resistance; - Test system of pressure on the primary and secondary sides; - Determination of fouling on the filter; - Quality control of the fluid. It is important writing a comment when the inspection has been executed reporting date, observations and material/tools used.
Pset_CoilMaintenanceDocumentation	PSET_TYPEDRIVENOVERRIDE	Set of documents and information needed to report breakdown detection, operation statistics, breakdown statistics, list of substituted pieces and determination of the most employed. All these must be inserted inside the maintenance plan of the air-handling unit.

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_CoilPHistory					
TotalPressure	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
StaticPressure	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
DynamicPressure	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
AirPressureDrop	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
Temperature	P_REFERENCEVALUE	IfcTimeSeries	IfcThermodynamic TemperatureMeasure		
StaticPressureCurve	P_REFERENCEVALUE	IfcTimeSeries			
ThermalEfficiency	P_ REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
ThermalEfficiencyCurve	P_REFERENCE	IfcTimeSeries			
Pset_CoilTypeCommon					
MaximumPressure	P_SINGLEVALUE		IfcPressureMeasure		
LogaritmicMeanTemperatureDifference	P_SINGLEVALUE		IfcPositiveRatioMeasure		
LMDTCorrectiveFactor	P_SINGLEVALUE		IfcReal		
FinalDifferenceTemperature	P_SINGLEVALUE		IfcThermodynamic TemperatureMeasure		
HeatExchangeGlobalCoefficient	P_SINGLEVALUE		IfcThermalTransmittance Measure		
MassiveAirFlowExpense/Rate	P_SINGLEVALUE		IfcMassFlowRateMeasure		
VolumetricAirFlowExpense/Rate	P_SINGLEVALUE		IfcVolumetricFlowRate Measure		
SensibleThermalPower	P_SINGLEVALUE		IfcPowerMeasure		
LatentThermalPower	P_SINGLEVALUE		IfcPowerMeasure		
ThermalPower	P_SINGLEVALUE		IfcPowerMeasure		
FoulingResistance	P_SINGLEVALUE		IfcThermalResistance Measure		
HeatExchangeSurfaceMargins	P_SINGLEVALUE		IfcRatioMeasure		
CleaningFactor	P_SINGLEVALUE		IfcReal		
NTU	P_SINGLEVALUE		IfcReal		
Pset_FluidTypeCommon					
Density	P_SINGLEVALUE		IfcMassDensityMeasure		
SpecificHeatCapacity	P_SINGLEVALUE		IfcSpecificHeatCapacity Measure		
SpecificEnthalpy	P_SINGLEVALUE		IfcEnergyMeasure		
SteamConcentration	P_SINGLEVALUE		IfcRatioMeasure		
Viscosity	P_SINGLEVALUE		IfcDynamicViscosity Measure		
MassProportion	P_SINGLEVALUE		IfcRatioMeasure		
Pset_CoilTypeHydronic					
WaterSidePressureDrop	P_REFERENCEVALUE	IfcTimeSeries	IfcPressureMeasure		
Pset_CoilDesignInstructions					
InstallationDepth	P_SINGLEVALUE		IfcLengthMeasure		
CondensateConnections	P_SINGLEVALUE		IfcText		
FinSpacing	P_SINGLEVALUE		IfcLengthMeasure		
CoolingCoilDesignInstructions	P_SINGLEVALUE		IfcText		
CondensationDrainComponents	P_SINGLEVALUE		IfcText		
CoolingCoilSeparatedFromFilters	P_SINGLEVALUE		IfcBoolean		
CoolingCoilSeparatedFromSilencer	P_SINGLEVALUE		IfcBoolean		
InsulatedConnectionDucts	P_SINGLEVALUE		IfcBoolean		
DriftSeparators	P_SINGLEVALUE		IfcBoolean		
CopperCollector	P_SINGLEVALUE		IfcBoolean		
Pset_CoilOperationInstructions					
SettingDocument	P_SINGLEVALUE		IfcText		

FailureMeasures	P_SINGLEVALUE		IfcText		
SafetyRegulations	P_SINGLEVALUE		IfcText		

Pset_CoilInstallationInstructions					
AccessibilityForMaintenance	P_SINGLEVALUE		IfcText		
SpaceBoundaries	P_SINGLEVALUE		IfcText		
RemovableCoil	P_SINGLEVALUE		IfcText		
CorrosionResistentTray	P_SINGLEVALUE		IfcText		
SealedConnectionsStatus	P_REFERENCEVALUE	IfcTimeSeries	IfcLabel	PEnum_Sealed ConnectionsStatus: GOOD, BAD, ABSENT	
CoilOrientation	P_ENUMERATEDVALUE		IfcLabel	PEnum_Device Orientation: VERTICAL, HORIZONTAL, INCLINATED, HEIGHT	
InternalVariableBypass	P_SINGLEVALUE		IfcText		
ThermalInsulation	P_SINGLEVALUE		IfcText		
ThermalInsulationInstallation	P_SINGLEVALUE		IfcText		
Tightness	P_SINGLEVALUE		IfcBoolean		
IdentificationLabelContents	P_LISTVALUE		IfcLabel		Absent, Manufacturer name, Supplier name, Manufacturer, Identification number, Fluid type, Maximum airflow, Pressure, Service temperature.

Pset_CoilOperation Instructions					
SettingDocument	P_SINGLEVALUE		IfcText		
FailureMeasures	P_SINGLEVALUE		IfcText		
SafetyRegulations	P_SINGLEVALUE		IfcText		

Pset_CoilGeneralMaintenanceInstructions					
PrimarySideControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySideControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SealsOperationControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidFLowControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
DefrostingEquipmentControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
AirVentControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
HeatTranferMediumFreezingResistanceControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
PrimarySidePressureControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySidePressureControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FoulingOnFilterControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidQualityControl	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		

AirContamination	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Corrotion	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Damages	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
Leakage	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
InsufficientSuctionBlowing	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
CondensationWaterStagnation	P_REFERENCEVALUE	IfcTimeSeries	IfcText		

Pset_CoilSpecialMaintenanceInstructions					
PrimarySideCleaning	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		
SecondarySideCleaning	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		
SealRingsSubstitution	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
DefrostingEquipmentOperationTest	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FluidCircuitOperationTest	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
AirVentingRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
HeatTransferMediumFrostingSolution	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
PrimarySideTightnessRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
SecondarySideTightnessRepair	P_REFERENCEVALUE	IfcTimeSeries IfcRegular TimeSeries	IfcText		
FilterChange	P_REFERENCEVALUE	IfcTimeSeries IfcIrregular TimeSeries	IfcText		

Pset_CoilMaintenanceDocumentation					
LogicConstructionDiagram	P_SINGLEVALUE		IfcText		
MaintenanceOccurrencesData	P_SINGLEVALUE		IfcText		
BreakdownStatistics	P_SINGLEVALUE		IfcText		
SubstitutedPiecesStatistic	P_SINGLEVALUE		IfcText		

Property set implementation as IFC Documentation in ifcDoc tool

The property set:

- Pset_CoilInstallationInstructions
- Pset_CoilGeneralMaintenanceInstructions
- Pset_CoilSpecialMaintenanceInstructions
- Pset_CoilMaintenanceDocumentation

Are almost equal to the property set generated for the air-to-air heat recovery. For this, they have not been implemented in ifcDoc tool.
Pset_FluidTypeCommon is shown below.

IFC Specification

```
#10161=
IFCPROPERTYSETTEMPLATE('1X_sXPhOX7XemcpeW8ElDg',$,'Pset_FluidTypeCommon',$,.PSET_TYPEDRIVENOVERRIDE.,'IfcCoil'
,(#10164,#10167,#10170,#10173,#10176,#10179));
#10162= IFCLIBRARYREFERENCE($,$,'Pset_FluidTypeCommon','Fluid type common attributes.','',$);
#10163= IFCRELASSOCIATESLIBRARY('2BnJYat$D76fkngqSbpg05',$,$,$,(#10161),#10162);
#10164= IFCSIMPLEPROPERTYTEMPLATE('2BdhQTbtvDeQv7xWLKNRil',$,'Density','Fluid
density.',.P_SINGLEVALUE.,'IfcMassDensityMeasure',$,$,$,$,$,.READWRITE.);
#10165= IFCLIBRARYREFERENCE($,$,'Density',$,'',$);
```

```
#10166= IFCRELASSOCIATESLIBRARY('1ZUURnyRD4CfLTesEzUUMp',$,$,$,(#10164),#10165);
#10167=
IFCSIMPLEPROPERTYTEMPLATE('1AoU19lyDAyuLlN$rdFg18',$,'SpecificHeatCapacity',$,.P_SINGLEVALUE.,'IfcSpecificHeat
CapacityMeasure',$,$,$,$,$,$,.READWRITE.);
#10168= IFCLIBRARYREFERENCE($,$,'SpecificHeatCapacity','Fluid specific heat.','',$);
#10169= IFCRELASSOCIATESLIBRARY('0uFXbi_h1FE9$YZjpku1CR',$,$,$,(#10167),#10168);
#10170=
IFCSIMPLEPROPERTYTEMPLATE('12LT2khCv1M8EuEsO3wSpb',$,'SpecificEnthalpy',$,.P_SINGLEVALUE.,'IfcEnergyMeasure',$
,$,$,$,$,.READWRITE.);
#10171= IFCLIBRARYREFERENCE($,$,'SpecificEnthalpy','Specific enthalpy.','',$);
#10172= IFCRELASSOCIATESLIBRARY('2LXMy95w1CqvLJulV0OgUI',$,$,$,(#10170),#10171);
#10173=
IFCSIMPLEPROPERTYTEMPLATE('3eKkELc25EZurwrnNZkkEB',$,'SteamConcentration',$,.P_SINGLEVALUE.,'IfcRatioMeasure',
$,$,$,$,$,.READWRITE.);
#10174= IFCLIBRARYREFERENCE($,$,'SteamConcentration','Steam concentration in fluid.','',$);
#10175= IFCRELASSOCIATESLIBRARY('2QnNFWAmL9j9Ma1TBbxOKA',$,$,$,(#10173),#10174);
#10176=
IFCSIMPLEPROPERTYTEMPLATE('00JSjPmx15jw$W2rf6BQp8',$,'Viscosity',$,.P_SINGLEVALUE.,'IfcDynamicViscosityMeasure
',$,$,$,$,$,.READWRITE.);
#10177= IFCLIBRARYREFERENCE($,$,'Viscosity','Fluid dynamic viscosity.','',$);
#10178= IFCRELASSOCIATESLIBRARY('2FpHH2jcnBVP1Yg7TkhUc7',$,$,$,(#10176),#10177);
#10179=
IFCSIMPLEPROPERTYTEMPLATE('3acf1NkfHC2u2ezgxTlPaK',$,'MassProportion',$,.P_SINGLEVALUE.,'IfcRatioMeasure',$,$,
$,$,$,.READWRITE.);
#10180= IFCLIBRARYREFERENCE($,$,'MassProportion','Mass proportion.','',$);
```

IFCXML Specification

```
  <IfcPropertySetTemplate GlobalId="1X_sXPhOX7XemcpeW8ElDg" Name="Pset_FluidTypeCommon"
ApplicableEntity="IfcCoil">
          <HasAssociations>
            <IfcRelAssociatesLibrary GlobalId="1ptzbOMz9EeAyEX0D1b9OH">
              <RelatingLibrary Name="Pset_FluidTypeCommon" Language="">
                <Description>Fluid type common attributes.</Description>
              </RelatingLibrary>
            </IfcRelAssociatesLibrary>
          </HasAssociations>
          <PredefinedType>PSET_TYPEDRIVENOVERRIDE</PredefinedType>
          <HasPropertyTemplates>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2BdhQTbtvDeQv7xWLKNRil"
Name="Density" PrimaryMeasureType="IfcMassDensityMeasure" AccessState="READWRITE">
              <Description>Fluid density.</Description>
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1CYUHcpXv03Plh09y7e3DE">
                  <RelatingLibrary Name="Density" Language="" />
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1AoU19lyDAyuLlN$rdFg18"
Name="SpecificHeatCapacity" PrimaryMeasureType="IfcSpecificHeatCapacityMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="16hnZDWOz5RROXTz1MzCrr">
                  <RelatingLibrary Name="SpecificHeatCapacity" Language="">
                    <Description>Fluid specific heat.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
```

```
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="12LT2khCv1M8EuEsO3wSpb"
Name="SpecificEnthalpy" PrimaryMeasureType="IfcEnergyMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="3lMTUO8_fCnBnqIaHZeDvT">
                  <RelatingLibrary Name="SpecificEnthalpy" Language="">
                    <Description>Specific enthalpy.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="3eKkELc25EZurwrnNZkkEB"
Name="SteamConcentration" PrimaryMeasureType="IfcRatioMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1khEHkGIb20PqH7jQggC4Z">
                  <RelatingLibrary Name="SteamConcentration" Language="">
                    <Description>Steam concentration in fluid.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="00JSjPmx15jw$W2rf6BQp8"
Name="Viscosity" PrimaryMeasureType="IfcDynamicViscosityMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1_ASvTiCLErQ9kDQL1gA9i">
                  <RelatingLibrary Name="Viscosity" Language="">
                    <Description>Fluid dynamic viscosity.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="3acf1NkfHC2u2ezgxTlPaK"
Name="MassProportion" PrimaryMeasureType="IfcRatioMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="22DJ4rBOX2b8rCwMBRJTcw">
                  <RelatingLibrary Name="MassProportion" Language="">
                    <Description>Mass proportion.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
          </HasPropertyTemplates>
        </IfcPropertySetTemplate>
```

IFCSHAREDBLDGSERVICEELEMENT
IfcFlowController
IfcDamper
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_DamperOccurrence	Damper occurrence attributes attached to an instance of IfcDamper						
SizingMethod	Identifies whether the damper is sized nominally or with exact measurements: NOMINAL: Nominal sizing method. EXACT: Exact sizing method						
Pset_DamperPHistory	Damper performance history attributes.						
AirFlowRate	Airflow rate.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
Leakage	Air leakage rate.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
PressureDrop	Pressure drop.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
BladePositionAngle	Blade position angle; angle between the blade and flow direction (0 - 90).	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
DamperPosition	Damper position (0-1); damper position (0=closed=90deg position angle, 1=open=0deg position angle.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
PressureLossCoefficient	Pressure loss coefficient.						
Pset_DamperPHistory	Damper performance history attributes.						
Pset_DamperTypeCommon	Damper type common attributes.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1'), provided, if there is no classification reference to a recognized classification system used.	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
Operation	The operational mechanism for the damper operation.	✓		✓		✓	
Orientation	The intended orientation for the damper as specified by the manufacturer.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014

BladeThickness	The thickness of the damper blade.	✓		✓		✓	
BladeAction	Blade action.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
BladeShape	Blade shape. Flat means triple V-groove.	✓		✓		✓	
BladeEdge	Blade edge.	✓		✓		✓	
NumberofBlades	Number of blades.	✓		✓		✓	
FaceArea	Face area open to the airstream.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
MaximumAirFlowRate	Maximum allowable airflow rate.	✓		✓		✓	
TemperatureRange	Temperature range.	✓		✓		✓	
MaximumWorkingPressure	Maximum working pressure.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
MaximumWorkingPressure	Maximum working pressure.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
TemperatureRating	Temperature rating.						
NominalAirFlowRate	Nominal airflow rate.						
OpenPressureDrop	Total pressure drop across damper.						
LeakageFullyClosed	Leakage when fully closed.	✓		✓		✓	
PressureAirFlowCurve	Static pressure – airflow rate, Static pressure = f (airflow rate).	+		+		+	
LossCoefficentCurve*	Loss coefficient – blade position angle curve; ratio of pressure drop to velocity pressure versus blade angle; C = f (blade angle position).						
LeakageCurve*	Leakage versus pressure drop; Leakage = f (pressure).						
RegeneratedSoundCurve*	Regenerated sound versus airflow rate.						
FrameType	The type of frame used by the damper (e.g., Standard, Single Flange, Single Reversed Flange, Double Flange, etc.).	✓		✓		✓	
FrameDepth	The length (or depth) of the damper frame.	✓		✓		✓	
FrameThickness	The thickness of the damper frame material.	✓		✓		✓	
CloseOffRating	Close off rating.						
FaceVelocity	The frontal velocity must be less than 8m/s (exception: gate sections and recirculation bypass).	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:2011	+	DIN EN 13053:2012
FlowEntranceAngle	The airflow must enter into the damper with an angle minimum of 25°.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:2011	+	DIN EN 13053:2012

FlowExitAngle	The airflow must enter into the damper with an angle minimum of 35°.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:20 11	+	DIN EN 13053:2012

In IFC4 Addendum 1 [Final Standard] the following properties have been moved from Pset_DamperTypeCommon to Material Constituents.

BladeMaterial	The material from which the damper blades are constructed.	✓		✓		✓	
SealMaterial	The material from which the damper seals are constructed.	✓		✓		✓	
FrameMaterial	The material from which the damper frame is constructed.	✓		✓		✓	

The three properties LossCoefficentCurve, LeakageCurve, and RegeneratedSoundCurve are not considered as properties for Object in IFC4 Addendum 1 [Final Standard], but they are inside the documentation.

The *Pset_SoundGenration* for ifcDamper is equal to the one shown for the air-to-air heat recovery.

Pset_DamperTypeControlDamper	Control damper type attributes. Pset renamed from Pset_DamperTypeControl to Pset_DamperTypeControlDamper in IFC2x2 Pset Addendum.						
TorqueRange	Torque range: minimum operational torque to maximum allowable torque.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014
ControlDamperOperation	The inherent characteristic of the control damper operation.	✓	UNI EN 1751:2014	✓	UNE EN 1751 :2014	✓	DIN EN 1751:2014

Pset_DamperInspectionInstructions							
InspectionOpening	Presence of openings for inspection.			+	UNE 100713 (hospitals)	+	DIN 1946-4:2008

Property set name	IfcPropertySetTemplateTypeEnum	Description
Pset_DamperInspectionInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about inspections. It is important writing a comment when the inspection has been executed reporting date, observations and material/tools used.

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpropertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
PressureAirFlowCurve	P_TABLEVALUE	IfcPressureMeasure	IfcVolumetricFlow RateMeasure		
FaceVelocity	P_SINGLEVALUE		IfcLinearVelocity Measure		
FlowEntranceAngle	P_SINGLEVALUE		IfcPlaneAngle Measure		
FlowExitAngle	P_SINGLEVALUE		IfcPlaneAngle Measure		
Pset_DamperInspectionInstructions					
InspectionOpening	P_SINGLEVALUE		IfcBoolean		

Property set implementation as IFC Documentation in ifcDoc tool

FaceVelocity is going to insert in ifcDoc, it is inside *Pset_DamperTypeCommon.*

IFC Specification

```
#8931=IFCSIMPLEPROPERTYTEMPLATE('1ZSH7KinvAAP0Uod_cU83V',$,'FaceVelocity',$,.P_SINGLEVALUE.,'IfcLinearVelocity
Measure',$,$,$,$,$,.READWRITE.);
#8932= IFCLIBRARYREFERENCE($,$,'FaceVelocity','The frontal velocity must be less than 8m/s (exception: gate
sections and recirculation bypass).','',$);
#8933= IFCRELASSOCIATESLIBRARY('3uImfSK4L1nx01OUyCEfj4',$,$,$,(#8931),#8932);
```

IFCXML Specification

```
<IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1ZSH7KinvAAP0Uod_cU83V"
Name="FaceVelocity" PrimaryMeasureType="IfcLinearVelocityMeasure" AccessState="READWRITE">

              <HasAssociations>

                <IfcRelAssociatesLibrary GlobalId="029YDqyu93MwtfuhN2tL$3">

                  <RelatingLibrary Name="FaceVelocity" Language="">

                    <Description>The frontal velocity must be less than 8m/s (exception: gate sections and
recirculation bypass).</Description>

                  </RelatingLibrary>

                </IfcRelAssociatesLibrary>

              </HasAssociations>

              <TemplateType>P_SINGLEVALUE</TemplateType>

            </IfcPropertyTemplate>

          </HasPropertyTemplates>

        </IfcPropertySetTemplate>
```

IFCSHAREDBLDGSERVICEELEMENT
IfcFlowMovingDevice
IfcFan
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_FanCentrifugal	Centrifugal fan occurrence attributes attached to an instance of IfcFan.						
DischargePosition	Centrifugal fan discharge position. TOPHORIZONTAL: Top horizontal discharge. TOPANGULARDOWN: Top angular down discharge. DOWNBLAST: Downblast discharge. BOTTOMANGULARDOWN: Bottom angular down discharge. BOTTOMHORIZONTAL: Bottom horizontal discharge. BOTTOMANGULARUP: Bottom angular up discharge. UPBLAST: Upblast discharge. TOPANGULARUP: Top angular up discharge. OTHER: Other type of fan arrangement.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010
DirectionOfRotation	The direction of the centrifugal fan wheel rotation when viewed from the drive side of the fan. CLOCKWISE: Clockwise. COUNTERCLOCKWISE: Counter-clockwise. OTHER: Other type of fan rotation.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010 DIN 1946-4:2008
Arrangement	Defines the fan and motor drive arrangement as defined by AMCA. ARRANGEMENT1: Arrangement 1. ARRANGEMENT2: Arrangement 2. ARRANGEMENT3: Arrangement 3. ARRANGEMENT4: Arrangement 4. ARRANGEMENT7: Arrangement 7. ARRANGEMENT8: Arrangement 8. ARRANGEMENT9: Arrangement 9. ARRANGEMENT10: Arrangement 10. OTHER: Other type of fan drive arrangement.	✓	AMCA Standards UNI EN ISO 13349 :2011	✓	AMCA Standards	✓	AMCA Standards DIN 1946-4:2008
FanNumber	Number of fans in the air-handling unit to produce air movement.	+	UNI EN 1886:2008	+	UNE EN 1886:2008	+	DIN EN 1886:2009

Pset_FanOccurrence	Fan occurrence attributes attached to an instance of IfcFan.						
DischargeType	Defines the type of connection at the fan discharge. Duct: Discharge into ductwork. Screen: Discharge into screen outlet. Louver: Discharge into a louver. Damper: Discharge into a damper.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010

ApplicationOfFan	The functional application of the fan. SupplyAir: Supply air fan. ReturnAir: Return air fan. ExhaustAir: Exhaust air fan. Other: Other type of application not defined above.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010
CoilPosition	Defines the relationship between a fan and a coil. DrawThrough: Fan located downstream of the coil. BlowThrough: Fan located upstream of the coil.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010
MotorPosition	Defines the location of the motor relative to the air stream. InAirStream: Fan motor is in the air stream. OutOfAirStream: Fan motor is out of the air stream.	✓	UNI EN 13053 :2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012
FanMountingType	Defines the method of mounting the fan in the building.						
FractionOfMotorHeatToAir Stream	Fraction of the motor heat released into the fluid flow.						
ImpellerDiameter	Diameter of fan wheel - used to scale performance of geometrically similar fans.	✓	UNI EN ISO 13349 :2011 EC 1-2012 UNI EN ISO 13351:2010	✓	UNE EN ISO 13349 :2011 UNE EN ISO 13351 :2010	✓	DIN EN ISO 13349 :2010 DIN EN ISO 13351 :2011

Pset_FanPHistory	Fan performance history attributes. Sound attribute deleted in IFC2x2 Pset Addendum: Use IfcSoundProperties instead.						
FanRotationSpeed	Fan rotation speed.	✓	UNI EN ISO 5801:2009	✓	UNE EN ISO 5801 :2010	✓	DIN EN ISO 5801:2014 DIN 1946-4:2008
WheelTipSpeed	Fan blade tip speed, typically defined as the linear speed of the tip of the fan blade furthest from the shaft.	✓	UNI EN ISO 5801:2009	✓	UNE EN ISO 5801 :2010	✓	DIN EN ISO 5801 :2014
FanEfficiency	Fan mechanical efficiency.	✓	UNI EN ISO 5801:2009 UNI EN ISO 5802:2009	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
FanStaticEfficiency	Ratio of the fan static power Pus to the propeller power Pr (ηSrA).	+	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	+	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	+	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
OverallEfficiency	Total efficiency of motor and fan.	✓	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
FanShaftEfficiency	Ratio of the fan power Pu to the fan shaft power Pa (ηa).	+	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	+	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	+	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
MotorEfficiency	Ratio of the fan power Pu to the supplied power Po by the motor (ηM).	+	UNI EN ISO 5802:2009	+	UNE EN ISO 5802 :2010	+	DIN EN ISO 5802:2011
FanPowerRate	Fan power consumption.	✓	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009 UNI EN 13053	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010 UNE EN 13053	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011 DIN EN 13053:2012 DIN EN 13779:2007 DIN 1946-4:2008

			:2011 UNI EN 13779 :2008		:2007+A1:2011 UNE EN 13779:2007		
ShaftPowerRate	Fan shaft power.	✓	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
FanPropellerPower	Fan propeller power.	+	UNI EN ISO 5802 :2009	+	UNE EN ISO 5802 :2010	+	DIN EN ISO 5802:2011
FanMotorSuppliedPower	Supplied power Po by the fan motor.	+	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	+	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	+	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011
FanMotorAbsorbedPower	Absorbed power PE by the fan motor.	+	UNI EN 13053 :2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
DischargeVelocity	The speed at which air discharges from the fan through the fan housing discharge opening.	✓	UNI EN 13053 :2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012
DischargePressureLoss	Fan discharge pressure loss associated with the discharge arrangement.	✓	UNI EN ISO 5801 :2009 UNI EN 13053 :2011	✓	UNE EN ISO 5801 :2010 UNE EN 13053 :2007+A1:2011	✓	DIN EN ISO 5801:2014 DIN EN 13053:2012
DrivePowerLoss	Fan drive power losses associated with the type of connection between the motor and the fan wheel.	✓	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011

Pset_FanTypeCommon	Fan type common attributes.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1').	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
MotorDriveType	Motor drive type: DIRECTDRIVE: Direct drive. BELTDRIVE: Belt drive. COUPLING: Coupling. OTHER: Other type of motor drive. UNKNOWN: Unknown motor drive type.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010
CapacityControlType	InletVane: Control by adjusting inlet vane. VariableSpeedDrive: Control by variable speed drive. BladePitchAngle: Control by adjusting blade pitch angle. TwoSpeed: Control by switch between high and low speed. DischargeDamper: Control by modulating discharge damper.	✓	UNI EN ISO 13349 :2011	✓	UNE EN ISO 13349 :2011	✓	DIN EN ISO 13349 :2010
	Inverter. Switched Reluctance actions. Eddy Current coupling.	+	No standard	+	No standard	+	

OperationTemperatureRange	Allowable operation ambient air temperature range.	✓	UNI EN ISO 13349 :2011 UNI EN ISO 5802 :2009	✓	UNE EN ISO 13349 :2011 UNE EN ISO 5802 :2010	✓	DIN EN ISO 13349 :2010 DIN EN ISO 5802:2011
AirVelocityClass	Class of airflow velocity trough the fan and the entire Air Handling Unit (V1 to V9).	+	UNI EN 13053 :2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
FanPowerClasses	Classes of fan supplied power (P1 to P7).	+	UNI EN 13053 :2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
SFPcategory	SFP categories (SFP1 to SFP 7).	+	UNI EN 13779 :2008	+	UNE EN 13779:2007 RITE n 238/2013	+	DIN EN 13779:2007
NominalTotalPressure	Nominal total pressure rise across the fan.	✓	UNI EN ISO 5801 :2009 UNI EN ISO 5802 :2009	✓	UNE EN ISO 5801 :2010 UNE EN ISO 5802 :2010	✓	DIN EN ISO 5801:2014 DIN EN ISO 5802:2011 DIN 1946-4:2008
NominalStaticPressure	The static pressure within the air stream that the fan must overcome to insure designed circulation of air.	✓	UNI EN ISO 5801 :2009	✓	UNE EN ISO 5801 :2010	✓	DIN EN ISO 5801:2014
NominalRotationSpeed	Nominal fan wheel speed.	✓	UNI EN 13053 :2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012 DIN 1946-4:2008
NominalPowerRate	Nominal fan power rate.	✓	“	✓	“	✓	“
OperationalCriteria	Time of operation at maximum operational ambient air temperature.	✓	No standard				
PressureCurve*	Pressure rise = f (flow rate).	✓	UNI EN ISO 5801 :2009	✓	UNE EN ISO 5801 :2010	✓	DIN EN ISO 5801:2014
EfficiencyCurve*	Fan efficiency =f (flow rate).	✓	UNI EN ISO 5801 :2009	✓	UNE EN ISO 5801 :2010	✓	DIN EN ISO 5801:2014

*The properties PressureCurve and EfficiencyCurve are not considered as properties for Object inside *Pset_FanTypeCommon* in the IFC4 Add 1 [Final Standard]. They are still mentioned inside the documentation. In the European regulations they are defined, so a suggestion is to consider again them inside the Final Standard.

The *Pset_SoundGenration* for ifcFan is equal to the one shown for the air-to-air heat recovery with a property more, to correct the IFC Documentation of the buildingSMART web site.

Pset_SoundGeneration	Common definition to capture the properties of sound typically used within the context of building services and flow distribution systems. This property set is instantiated multiple times on an object for each frequency band. HISTORY: New property set in IFC Release 2x4.						
HasSoundAttenuation	**FROM IFCCOIL ACCORDING TO EN 13053**	✓	DPCM 5/12/97 Requisivi acustici passivi degli edifici	✓	REAL DECRETO 1367/2007 UNE-ISO 1996:2005-1 UNE-ISO 1996:2009-2 UNE-EN ISO 16032	✓	ISO 1996-1:1982 ISO 1996-2:1987 ISO 1996-3:1987

Pset_FanDesignInstructions							
WaterDrainProtection	Supply air fans are installed 1 to 2 filter stage to arrange that a water precipitation must be excluded on the fan.					+	DIN 1946-4:2008-12
FreeWheelingFan	Freewheeling fans are without inserted volute for better cleaning.					+	DIN 1946-4:2008-12

Pset_FanDesignInstructions	

Sight Glasses& ViewingOpenings	Presence of advised openings in correspondence of the fans. These must be opened by a tool or key. In case of impossibility, protective devices must be mounted. If the doors are installed where the pressure is positive, retention mechanisms must be mounted. When the internal height is more than 1.6 m, an inspection opening with glass (internal diameter at least 150 mm or equivalent cross section) must be mounted. In centrifugal fans with a volute water drain and closure, characterized by a nominal size of 400 mm, an easy removable inspection cover is required for cleaning the fan housing.	+	UNI EN ISO 13349:2011 UNI EN 1886:2008	+	UNE EN ISO 13349:2011 UNE EN 1886:2008	+	DIN EN 1886:2009-07 DIN 1946-4:2008-12
Lighting	Presence of interior lighting with a smooth surface (ship fittings with metal mesh cover are not permitted) in correspondence of the fans.	+	UNI EN ISO 13349:2011	+	UNE EN ISO 13349:2011	+	DIN 1946-4:2008-12
Switch	Presence of a switch to block the fan for maintenance.	+	UNI EN ISO 13349:2011 UNI EN 1886:2008	+	UNE EN ISO 13349:2011 UNE EN 1886:2008	+	DIN EN 1886:2009-07
Pressure Drop Measurements	Installation of devices for pressure drop measurements.	+	UNI EN 13053: 2011	+	UNE EN 13053:2007+A1:2011	+	DIN EN 13053 A1 :2011

Pset_FanMaintenanceInstructions							
AccessibilityForMaintenance	Presence of sufficient space for maintenance operations.					+	VDI 6022-1:2014
WetCleaning	The liquid produced could be drained through the water drainage in the lower position of the fan location. The good operation must be controlled every year.	+	Linee guida manutenzione 2007			+	DIN EN 1886:2009-07
FanCleaning InspectionOccurrency	Once a season (year).			+	RITE n 238/2013		

Pset_FanMaintenanceRisk	A person could be damaged in case of the following causes.						
MobileFixedPartsGrab	Being caught between a mobile part and a fixed part (e.g. between the fan driving and the box).	+	UNI EN ISO 12499:2009	+	UNE EN ISO 12499:2010	+	DIN EN ISO 12499:2010-12
MobileMobilePartsGrab	Being caught between two mobile parts (e.g. between a strap and a pulley).	+	"	+	"	+	"
AspirationInFanEntry	Being absorbed in correspondence of the fan entry due to the air movement, causing contact with a rotary shaft or a driving.	+	"	+	"	+	"
MobilePartContact	Being in contact with a mobile part such as the driving.	+	"	+	"	+	"

ObjectCaughtAndExpulsed	Being caught of an object in correspondence of the fan entry and its high velocity expulsion.	+	"	+	"	+	"
FanStructureDamages	Structural damage of the fan components.	+	"	+	"	+	"
ExtremeTemperatureFan Contact	Contact with fan surfaces at extreme temperatures (<-20° or >+50°).	+	"	+	"	+	"
FanProtectionNoise	Noise produced by security protections.	+	"	+	"	+	"
InjuriesByTurning RotativeParts	In addition, when the fan is switched off, the rotary parts could turn due to the air movement and this effect could cause injuries.	+	"	+	"	+	"
NotAuthorizedOpeningAccess	Not authorized opening of the access doors in the ducts or fan section, above all when the fan is still turning.	+	"	+	"	+	"
Pset_FanMaintRiskMitigation							
DangersKnowledge	Identification or knowledge of the dangers.	+	UNI EN ISO 12499:2009	+	UNE EN ISO 12499:2010	+	DIN EN ISO 12499:2010-12
ProtectiveDevice	Employment of protective devices for the phisical security.	+	"	+	"	+	"
SecureWorkPractices	Employment of the "secure work practices".	+	"	+	"	+	"
EmploymentInstructions	Information for the employment.	+	"	+	"	+	"
SecurityDistances	Use of security distances.	+	"	+	"	+	"
MaintenanceSpecialized Personnel	Maintenance by specialized personnel.	+	"	+	UNE EN ISO 12499:2010 RITE n 238/2013	+	"
Pset_FanMaintenanceDocumentation							
HygienePlan	Presence of the hygiene plan, mandatory, in accordance with the Infection Protection Act (Infektionsschutzgesetz).					+	DIN 1946-4:2008-12 VDI 6022-1:2014 AMEV 2011-2014 VDMA 24176:2007 VDMA 24186-1:2002
MaintenanceReport	All maintenance works must be documented in a summary form.					+	DIN 1946-4:2008-12 AMEV 2011-2014 VDMA 24176:2007 VDMA 24186-1:2002
Operation&Maintenance Manual	AHU operation is performed in compliance with the operating documents (e.g. operating and maintenance instructions and hygiene plan). The maintenance of the supply and exhaust air systems must be regularly checked and maintained.	+	Linee guida manutenzione 2007	+	RITE n 238/2013		DIN 1946-4:2008-12 AMEV 2011-2014 VDMA 24176:2007 VDMA 24186-1:2002

Property set name	IfcPropertySetTemplateTypeEnum	Description
Pset_FanDesignInstructions	PSET_TYPEDRIVENOVERRIDE	Design specifications to allow accessibility and easy cleaning of the component to ensure hygiene.
Pset_FanInstallationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of installation instructions to be followed to ensure the good functionality and accessibility of the fan. These are furnished by national and European regulations.
Pset_FanMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about maintenance operations.

		It is important writing a comment when the maintenance has been executed reporting date, observations and material/tools used.
Pset_FanMaintenanceRisk	PSET_TYPEDRIVENOVERRIDE	A person could be damaged in case of the causes explained in detail in each property.
Pset_FanMaintRiskMitigation	PSET_TYPEDRIVENOVERRIDE	Set of risk mitigation measures to apply during a maintenance operation.
Pset_FanMaintenanceDocumentation	PSET_TYPEDRIVENOVERRIDE	Set of documents and information needed to report breakdown detection, operation statistics, breakdown statistics, list of substituted pieces and determination of the most employed. All these must be inserted inside the maintenance plan of the air-handling unit.

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_FanCentrifugal					
FanNumber	P_SINGLEVALUE	IfcInteger			
Pset_FanPHistory					
FanStaticEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
FanShaftEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
MotorEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcNormalisedRatio Measure		
FanPropellerPower	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		
FanMotorSuppliedPower	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		
FanMotorAbsorbedPower	P_REFERENCEVALUE	IfcTimeSeries	IfcPowerMeasure		
Pset_FanTypeCommon					
CapacityControlType	P_SINGLEVALUE		IfcLabel	PEnum_CapacityControlType: INLETVANE, VARIABLESPEEDDRIVE, BLADEPITCHANGLE, TWOSPEED, DISCHARGEDAMPER, UNSET, SWITCHEDRELUCTANCE, EDDYCURRENTCOUPLING OTHER, NOTKNOWN.	
AirVelocityClass	P_SINGLEVALUE		IfcLabel	PEnum_AirVelocityClass: V1, V2, V3, V4, V5, V6, V7, V8, V9.	
FanPowerClass	P_SINGLEVALUE		IfcLabel	PEnum_FanPowerClasses: P1, P2, P3, P4, P5, P6, P7.	
SFPCategory	P_SINGLEVALUE		IfcLabel	PEnum_SFPCategories: SFP1, SFP2, SFP3, SFP4, SFP5, SFP6, SFP7.	
Pset_FanDesignInstructions					
WaterDrainProtection	P_SINGLEVALUE		IfcBoolean		
FreeWheelingFan	P_SINGLEVALUE		IfcBoolean		
Pset_FanInstallationIstructions					
SightGlasses&ViewingOpenings	P_SINGLEVALUE		IfcText		
Lighting	P_SINGLEVALUE		IfcBoolean		
Switch	P_SINGLEVALUE		IfcBoolean		
PressureDropMeasurements	P_SINGLEVALUE		IfcText		
Pset_FanMaintenanceInstructions					
AccessibilityForMaintenance	P_SINGLEVALUE		IfcText		
WetCleaning	P_REFERENCEVALUE	IfcTimeSeries	IfcText		

FanCleaningInspectionOccurrency	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
Pset_FanMaintenanceRisk					
MobileFixedPartsGrab	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
MobileMobilePartsGrab	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
AspirationInFanEntry	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
MobilePartContact	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
ObjectCaughtAndExpulsed	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
FanStructureDamages	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
ExtremeTemperatureFanContact	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
FanProtectionNoise	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
InjuriesByTurningRotativeParts	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
NotAuthorizedOpeningAccess	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
Pset_FanMaintRiskMitigation					
DangersKnowledge	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
ProtectiveDevice	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
SecureWorkPractices	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
EmploymentInstructions	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
SecurityDistances	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
MaintenanceSpecializedPersonnel	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
Pset_FanMaintenanceDocumentation					
HygienePlan	P_SINGLEVALUE		IfcText		
MaintenanceReport	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
Operation&MaintenanceManual	P_REFERENCEVALUE	IfcTimeSeries	IfcText		

Property set implementation as IFC Documentation in ifcDoc tool

IFC Specification

```
#10194=
IFCPROPERTYSETTEMPLATE('1Ge_ZyafP9S8fCP$RXZAZy',$,'Pset_FanMaintenanceDocumentation',$,.PSET_TYPEDRIVENOVERRID
E.,'IfcFan',(#10197,#10200,#10203));
#10195= IFCLIBRARYREFERENCE($,$,'Pset_FanMaintenanceDocumentation','Set of documents and information needed to
report breakdown detection, operation statistics, breakdown statistics, list of substituted pieces and
determination of the most employed. All these must be inserted inside the maintenance plan of the air-handling
unit.','',$);
#10196= IFCRELASSOCIATESLIBRARY('02ms7uDl57_eONGC9fu4SO',$,$,$,(#10194),#10195);
#10197= IFCSIMPLEPROPERTYTEMPLATE('2FdlQ8k_1AT88uLFnwEyjf',$,'HygienePlan ','HygienePlan
',.P_SINGLEVALUE.,'IfcText',$,$,$,$,$,.READWRITE.);
#10198= IFCLIBRARYREFERENCE($,$,'HygienePlan ','Presence of the hygiene plan, mandatory, in accordance with
the Infection Protection Act (Infektionsschutzgesetz). ','',$);
#10199= IFCRELASSOCIATESLIBRARY('2k5uQK8Jf6UA3E8jzS$$Gu',$,$,$,(#10197),#10198);
#10200=
IFCSIMPLEPROPERTYTEMPLATE('2Xnghpeev2cQL4jFdQ$4nY',$,'MaintenanceReport',$,.P_REFERENCEVALUE.,$,'IfcText',$,$,
$,$,.READWRITE.);
#10201= IFCLIBRARYREFERENCE($,$,'MaintenanceReport','All maintenance works must be documented in a summary
form.','',$);
#10202= IFCRELASSOCIATESLIBRARY('0jsHtmAND0fRtNGJT13oxN',$,$,$,(#10200),#10201);
#10203=
IFCSIMPLEPROPERTYTEMPLATE('1lVUTZeX9CfRa_uGoReGeu',$,'Operation&MaintenanceManual',$,.P_REFERENCEVALUE.,$,'Ifc
Text',$,$,$,$,.READWRITE.);
#10204= IFCLIBRARYREFERENCE($,$,'Operation&MaintenanceManual','AHU operation is performed in compliance with
the operating documents (e.g. operating and maintenance instructions and hygiene plan). The maintenance of the
supply and exhaust air systems must be regularly checked and maintained. ','',$);
#10205= IFCRELASSOCIATESLIBRARY('18sfYU2cP4uukIYGXDPkRi',$,$,$,(#10203),#10204);
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IFCXML Specification

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<IfcPropertySetTemplate GlobalId="1Ge_ZyafP9S8fCP$RXZAZy" Name="Pset_FanMaintenanceDocumentation"
ApplicableEntity="IfcFan">
          <HasAssociations>
            <IfcRelAssociatesLibrary GlobalId="27KBYU6Ij3w8eQTTgq8uO9">
              <RelatingLibrary Name="Pset_FanMaintenanceDocumentation" Language="">
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```
                <Description>Set of documents and information needed to report breakdown detection, operation
statistics, breakdown statistics, list of substituted pieces and determination of the most employed. All these
must be inserted inside the maintenance plan of the air-handling unit.</Description>
              </RelatingLibrary>
            </IfcRelAssociatesLibrary>
          </HasAssociations>
          <PredefinedType>PSET_TYPEDRIVENOVERRIDE</PredefinedType>
          <HasPropertyTemplates>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2FdlQ8k_1AT88uLFnwEyjf"
Name="HygienePlan " PrimaryMeasureType="IfcText" AccessState="READWRITE">
              <Description>HygienePlan </Description>
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="2tPkE7AsPF49vVJAKxkt2W">
                  <RelatingLibrary Name="HygienePlan " Language="">
                    <Description>Presence of the hygiene plan, mandatory, in accordance with the Infection
Protection Act (Infektionsschutzgesetz). </Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="2Xnghpeev2cQL4jFdQ$4nY"
Name="MaintenanceReport" SecondaryMeasureType="IfcText" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="00vG40TpL998T0eODrUVMO">
                  <RelatingLibrary Name="MaintenanceReport" Language="">
                    <Description>All maintenance works must be documented in a summary form.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1lVUTZeX9CfRa_uGoReGeu"
Name="Operation&amp;MaintenanceManual" SecondaryMeasureType="IfcText" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="049gUTzuP25xpA5vJd3vKq">
                  <RelatingLibrary Name="Operation&amp;MaintenanceManual" Language="">
                    <Description>AHU operation is performed in compliance with the operating documents (e.g.
operating and maintenance instructions and hygiene plan). The maintenance of the supply and exhaust air
systems must be regularly checked and maintained. </Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_REFERENCEVALUE</TemplateType>
            </IfcPropertyTemplate>
          </HasPropertyTemplates>
        </IfcPropertySetTemplate>
```

IFCSHAREDBLDGSERVICEELEMENT
IfcFlowTreatmentDevice
IfcFilter
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_FilterPHistory							
CountedEfficiency	Filter efficiency based the particle counts concentration before and after filter against particles with certain size distribution.	different definitions					
InitialCountedEfficiency	Counted efficiency of the clean filter operating during the air test (expressed in% for each range of particle sizes considered).	+	UNI EN 779:2012	+	UNE EN 779:2013	+	DIN EN 779:2012
WeightedMeanEfficiency	Weighted mean of efficiencies (Em) for specified levels of dust clogging until the final pressure drop. Weighted mean counted efficiency is used for the classification of F-filters (expressed in %).	+	"	+	"	+	"
WeightedMeanCounted Efficiency	Weighted mean counted efficiency (Eij) for the range of dimensions "i" at different intervals "j" of dust clogging (expressed in %).	+	"	+	"	+	"
WeightedEfficiency	Filter efficiency calculates the particle weight concentration before and after filter for particles with certain size distribution.	better definitions					
InitialMassEfficiency	Mass efficiency of the first increment of dust for the clogging equal to 30 g (expressed in %).	+	"	+	"	+	"
MassEfficiency	Removal measured by weighing (by mass) of the dust causing clogging (expressed in %).	+	"	+	"	+	"
MeanArrestanceEfficiency	Ratio of the total amount of loading dust retained by the filter to total amount of dust fed up to final pressure drop. Average arrestance is used for classification of G-filters (expressed in %).	+	"	+	"	+	"
ParticleMassHolding	Mass of particle holding in the filter (expressed in g).	✓	"	✓	"	✓	"
Arrestance	Weighted (mass) removal of loading dust (expressed in %).	+	"	+	"	+	"
InitialArrestance	Arrestance of the first 30 g loading dust increment (expressed in %).	+	"	+	"	+	"
InitialEfficiency	Efficiency of the clean filter operating during the test airflow rate (expressed in % for each size range of selected particles).	+	"	+	"	+	"
Penetration	Ratio of the particle concentration downstream to	+	"	+	"	+	"

	upstream of the filter (expressed in %).						
Re-entrainment	Releasing particles previously collected on the filter due to the airflow.	+	"	+	"	+	"
Shedding	Releasing of particles due to particle bounce and re-entrainment effects, and to the release of fibres or particulate matter from the filter or filtering material.	+	"	+	"	+	"

Pset_FilterTypeAirParticleFilter	Air particle filter type attributes.						
AirParticleFilterType	A panel dry type extended surface filter is a dry-type air filter with random fiber mats or blankets in the forms of pockets, V-shaped or radial pleats, and includes the following:	✓	UNI EN 779:2012	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
	Coarse Filter: Filter with an efficiency lower than 30% for atmosphere dust-spot.						
	Coarse Metal Screen: Filter made of metal screen.						
	Coarse Cell Foams: Filter made of cell foams.						
	Coarse Spun Glass: Filter made of spun glass.						
	Medium Filter: Filter with an efficiency between 30-98% for atmosphere dust-spot.						
	Medium Electret Filter: Filter with fine electret synthetic fibers.						
	HEPA Filter: High efficiency particulate air filter.						
	ULPA Filter: Ultra low penetration air filter.						
	Membrane Filters: Filter made of membrane for certain pore diameters in flat sheet and pleated form. A renewable media with a moving curtain viscous filter are random-fiber media coated with viscous substance in roll form or curtain where fresh media is fed across the face of the filter and the dirty media is rewound onto a roll at the bottom or to into a reservoir.						
	Roll Form: Viscous filter used in roll form.						
	Adhesive Reservoir: Viscous filter used in moving curtain form. A renewable moving curtain dry media filter is a random-fiber dry media of relatively high porosity used in moving-curtain (roll) filters.						
	An electrical filter uses electrostatic precipitation to						

	remove and collect particulate contaminants.						
EfficientFilterClass1	Efficient filter class according to ranges of efficiency (G1-G4), (F5-F9), (H11, H14), (U15, U7). In an air handling unit it must be F5 to F9.	+	UNI EN 779:2012 UNI EN 1822-2:2010 UNI EN 13053: 2011	+	UNE EN 779:2013 UNE EN 1822-2 :2010 UNE 100180:2004 UNE EN 13053 :2007+A1:2011	+	DIN EN 779:2012 DIN EN 1822-2:2011 DIN 1946-6:2009 DIN EN 13053:2012
EfficientFilterClass2	Efficient filter class according to ranges of efficiency (Eu1-Eu9, Q, R, S, T, U)	+	UNI EN 1822-1 :2010	+	UNE EN 1822-1 :2010	+	DIN EN 1822-1 :2011 EUROVENT 4/5 EUROVENT 4/4
FilterMaterial	The material must be not nutrient for microbes.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012-02
FrameMaterial	Material of the filter frame.	✓	UNI EN 779:2012	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
SeparationType	Air particulate filter media separation type.	✓	"	✓	"	✓	"
DustHoldingCapacity	Maximum filter dust holding capacity.	✓	"	✓	"	✓	"
FaceSurfaceArea	Face area of filter frame.	✓	"	✓	"	✓	"
MediaExtendedArea	Total extended media area.	✓	"	✓	"	✓	"
NominalCountedEfficiency	Nominal filter efficiency based the particle count concentration before and after the filter against particles with a certain size distribution.	✓	"	✓	"	✓	"
NominalWeightedEfficiency	Nominal filter efficiency based the particle weight concentration before and after the filter against particles with a certain size distribution.	✓	"	✓	"	✓	"
PressureDropCurve	Under certain dust holding weight, DelPressure = f (fluidflowRate)	✓	"	✓	"	✓	"
CountedEfficiencyCurve	Counted efficiency curve as a function of dust holding weight, efficiency = f (dust holding weight).	✓	"	✓	"	✓	"
WeightedEfficiencyCurve	Weighted efficiency curve as a function of dust holding weight, efficiency = f (dust holding weight).	✓	"	✓	"	✓	"

Pset_FilterTypeCommon							
Reference	Reference ID for this specified type in this project (e.g. type 'A-1').	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
Weight	Weight of filter.	✓		✓		✓	

InitialResistance	Initial new filter fluid resistance (i.e., pressure drop at the maximum airflow rate across the filter when the filter is new per ASHRAE Standard 52.1).	✓	UNI EN 779:2012 UNI EN 1886:2008 UNI EN 13053:2011	✓	UNE EN 779 :2013 UNE EN 1886 :2008 UNE EN 13053 :2007+A1:2011	✓	DIN EN 779:2012 DIN EN 1886:2009 DIN EN 13053:2012
FinalResistance	Filter fluid resistance when replacement is required (i.e., Pressure drop at the maximum air flow rate across the filter when the filter needs replacement per ASHRAE Standard 52.1).	✓	UNI EN 779:2012 UNI EN 1886:2008 UNI EN 13053: 2011	✓	UNE EN 779:2013 UNE EN 13053 :2007+A1:2011	✓	DIN EN 779:2012 DIN EN 13053:2012
OperationTemperatureRange	Allowable operation ambient fluid temperature range.	✓	UNE EN 779 :2013	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
FlowRateRange	Possible range of fluid flow rate that can be delivered.	✓	UNI EN 13053: 2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012-02
NominalFilterFaceVelocity	Filter face velocity.	✓	UNI EN 779:2012	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
NominalMediaSurfaceVelocity	Average fluid velocity at the media surface.	✓	UNI EN 779:2012	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
NominalPressureDrop	Total pressure drop across the filter.	✓	UNI EN 1886:2008 UNI EN 13053: 2011	✓	UNE EN 1886 :2008 UNE EN 13053 :2007 +A1:2011	✓	DIN EN 1886:2009-07 DIN EN 13053 A1:2011
NominalFlowrate	Nominal fluid flow rate through the filter.	✓	UNI EN 779:2012	✓	UNE EN 779 :2013	✓	DIN EN 779:2012
NominalParticleGeometric MeanDiameter	Particle geometric mean diameter associated with nominal efficiency.						
NominalParticleGeometric StandardDeviation	Particle geometric standard deviation associated with nominal efficiency.						
Pset_FilterInstallation Instructions							
AccessibilityForMaintenance	Accessibility for maintenance operations.			+	UNE 100713 hospitals	+	DIN 1946-4:2008-12 VDI 6022-1:2014
InspectionOpening	Presence of an inspection opening in the lateral side of the filter service space. The dimensions must be bigger than the external size of the filter to be substituted. It must have a free space in correspondence of the opening and in the frontal access.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011 UNE 100713 (hospitals)	+	DIN 1946-4:2008-12 DIN EN 13053:2012-02
ManometerOpenings	Presence of openings where the manometer could be inserted to measure the pressure drops.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
InspectionGlassOpening& Lighting	When the internal height is more than 1.6 m, an inspection opening with glass (internal diameter at least 150 mm or equivalent cross section) must be mounted with internal lighting.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011 UNE 100713 (hospitals)	+	DIN EN 13053:2012 DIN 1946-4:2008 VDI 6022-1:2014
ClosureGates	Installation of closure gates before each third level of filtration or before each filter's group of third level, assembled in parallel.	+		+	UNE 100713:2005 (hospitals)	+	DIN 1946-4:2008 VDI 6022-1:2014
FirstFilterPosition	Installation of the first filter layer in correspondence of the	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012-02

	external air entrance. It is possible installing additional filters G1to G4.						
SecondFilterPosition	Installation of the second filter layer in correspondence of the air outlet thought the duct for supply.	+	"	+	"	+	"
SupplyFanPosition	Installation of the supply fan between the two filter layers.	+	"	+	"	+	"
OneFilterLayerArrangement	In case of only one filter layer, the efficient filter class must be almost F7.	+	"	+	"	+	"
CoolingDehumidifyingCoilHumidifierSeparation	Filters must be positioned not immediately after the cooling and dehumidifying coil and the humidifier (except humidifier for evaporation).	+	"	+	"	+	"
FiltrationZoneArea	If pocket filters are used, the filtration zone must be almost 10 m2 for 1 m2 of transversal section of the equipment.	+	"	+	"	+	"
JointsMaterials	Joints must be done of material in closed cells to avoid humidity absorption and microorganisms growth.	+	"	+	"	+	"
JointsMaterials	Permanent fixing with seals, especially in correspondence of the dirty air.	+	"	+	"	+	"
IdentificationLabelContents	Presence of clear and visible identification label (reporting manufacturer or supplier name, identification number of the manufacturer, efficient filter class, filtering fluid type, nominal airflow rate, initial pressure drop, and maximum final pressure drop) in correspondence of each filtering unit.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011 UNE 100713:2005 (hospitals)	+	DIN EN 13053:2012-02 VDI 6022-1:2014

The *Pset_SoundGenration* for ifcFilter is equal to the one shown for the air-to-air heat recovery.

ParticleSize	Equivalent optical diameter of a particle.	+	UNI EN 779:2012	+	UNE EN 779:2013		DIN EN 779:2012
DecompositionSignals	Absence of signals of decomposition, important deformations or defects of the filtering materials in the first and second filtration level caused by the moisture.	+	Linee guida manutenzione 2007	+	UNE 100713:2005 (hospitals)	+	DIN 1946-4:2008 VDI 6022-1:2014
FilteringMaterials DeformationsDefects	Absence of important deformations or defects of the filtering materials in the first and second filtration level caused by the moisture.	+	“	+	“	+	“
NewFiltersTightnessTest	Tightness in the bearing structure in the new filters fitted.	+	UNI EN 1886:2008 UNI EN 13053: 2011	+	UNE EN 1886 :2008 UNE EN 13053 :2007+A1:2011	+	DIN EN 1886:2009 DIN EN 13053:2012
PressureDropMeasurement	Pressure drop measurement (in site - manometer with liquid			+	UNE 100713 hospitals	+	DIN 1946-4:2008 VDI 6022-1:2014

	column or remote- pressure sensor).						
PressureDifference	Pressure difference upstream and downstream of the filter.	+	Linee guida manutenzione 2007	+	UNE 100713:2005 hospitals	+	DIN 1946-6:2009
AirTightness	Air tightness.	+	UNI EN 1886:2008 UNI EN 13053:2011	+	UNE EN 1886 :2008 UNE EN 13053 :2007+A1:2011	+	DIN EN 1886:2009 DIN EN 13053:2012
ExerciseTime	Exercise time.	+	"			+	"
CurrentEfficiencyProjected EfficiencyComparison	The value of efficiency compared with the expected projected value.	+	"			+	DIN EN 1822-5:2011
RelativeHumidity Measurement	Relative humidity measurement (especially for the second layer or more). It must be less than 90% to avoid the growth of microbes;	+	UNI EN 13053:2011	+	UNE EN 13053: 2007+A1:2011 UNE 100713:2005 (hospitals)	+	DIN EN 13053:2012
TemperatureMeasurement	Temperature measurement. It must be more than the dew temperature;	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
AirFlowRateVariation	Airflow rate variation for dust accumulation.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
AirflowVariationTolerances	When not specified, tolerances of +/-10% for airflow variation caused by pressure drop are accepted.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
InspectionFrequency	Frequency of inspection			+	UNE 100713 hospitals	+	DIN 1946-4:2008 VDI 6022-1:2014

Pset_FilterMaintenanceInstructions							
FilterCleaning	Cleaning (no filter washing).	+	Linee guida manutenzione 2007			+	DIN 1946-6:2009
SubstitutionCauses	Substitution when there are:						
	Air leaks;	+	Linee guida manutenzione 2007			+	DIN 1946-4:2008 VDI 6022-1:2014
	Air contaminations;	+	"			+	"
	Achievement of the final permissible pressure difference (measurement with a differential equipment with local display without sealing liquid and pressurized can, in filtering the 1st and 2nd filter stage);	+	"			+	"
	Modification or installation of the air conditioning;	+	"			+	DIN 1946-4:2008 DIN 1946-6:2009
	Every six months. For reasons of hygiene, the maximum service life should be limited to 12 months for the first filter stage and 24 months for the second filter stage. It is precisely established by the manufacturer;	+	"			+	DIN 1946-4:2008
	The pressure difference is equal to the maximum pressure drop recommended by the manufacturer.			+	UNE 100713:2005 (hospitals)		

FiltersPocketsBlockDamages	The pockets of the pocket filters must not be blocked or damaged	+	Linee guida manutenzione 2007	+	UNE 100713:2005 (hospitals)		
FiltersPocketsAllignment ToAirflow	The pockets of the filters must be able to align in the direction of airflow	+	"	+	"		
AirContamination	Avoiding the contamination downstream of the filter section and of the environments to be conditioned	+	"			+	DIN 1946-6:2009
NewFiltersContamination	Avoiding the contamination of the new filters with the dust of old ones	+	"				
FilterStorage	Storage of filters in rooms without dust and protected from any cause of damage	+	"				
LastFilterChange NotificationDate	The user must note the date of the last filter change.			+	UNE 100713:2005 (hospitals)	+	DIN 1946-4:2008 VDI 6022-1:2014

Property set name	**IfcPropertySetTemplateTypeEnum**	**Description**
Pset_FilterInstallationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of installation instructions to be followed to ensure the good functionality and accessibility of the filter. These are furnished by national and European regulations.
Pset_FilterInspectionInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about inspections. It is important writing a comment when the inspection has been executed reporting date, observations and material/tools used.
Pset_FanMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about maintenance operations. It is important writing a comment when the maintenance has been executed reporting date, observations and material/tools used

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_FilterPHistory					
InitialCountedEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
WeightedMeanEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
WeightedMeanCountedEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
InitialMassEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
MassEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
AverageArrestanceEfficiency	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
Arrestance	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
InitialArrestance	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
InitialEfficiency (*for each particles size range)	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
Penetration	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
Re-entrainment	P_REFERENCEVALUE	IfcTimeSeries	IfcBoolean		
Shedding	P_REFERENCEVALUE	IfcTimeSeries	IfcBoolean		
Pset_AirParticleFilterType					
EfficientFilterClass1	P_SINGLEVALUE		IfcLabel	PEnum_EfficientFilterClass1: F5, F6, F7, F8, F9	
EfficientFilterClass2	P_SINGLEVALUE		IfcLabel	PEnum_EfficientFilterClass2: Eu1,…, Eu9, Q, R, S, T, U	
FilterMaterial	P_SINGLEVALUE		IfcText		
Pset_FilterInstallationInstructions					

AccessibilityForMaintenance	P_SINGLEVALUE		IfcText		
InspectionOpening	P_SINGLEVALUE		IfcBoolean		
ManometerOpenings	P_SINGLEVALUE		IfcBoolean		
InspectionGlassOpening	P_SINGLEVALUE		IfcBoolean		
Lighting	P_SINGLEVALUE		IfcBoolean		
ClosureGates	P_SINGLEVALUE		IfcBoolean		
FirstFilterPosition	P_SINGLEVALUE		IfcText		
SecondFilterPosition	P_SINGLEVALUE		IfcText		
SupplyFanPosition	P_SINGLEVALUE		IfcText		
OneFilterLayerArrangement	P_SINGLEVALUE		IfcText		
CoolingDehumidifyingCoil HumidifierSeparation	P_SINGLEVALUE		IfcBoolean		
FiltrationZoneArea	P_SINGLEVALUE		IfcAreaMeasure		
JointsMaterials	P_SINGLEVALUE		IfcText		
PermanentFixing	P_SINGLEVALUE		IfcBoolean		
IdentificationLabelContents	P_LISTVALUE		IfcLabel		Absent, Manufacturer name, Supplier name, Manufacturer Identification, number, Filtering fluid type, Efficient filter class, Nominal airflow rate, Initial pressure drop, Maximum pressure drop.
Pset_FilterInspectionInstructions					
ParticleSize	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
DecompositionSignals	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
FilteringMaterialsDeformationsDefects	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
NewFiltersTightnessTest	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
PressureDropMeasurement	P_REFERENCEVALUE	IfcTimeSeries	IfcPressure Measure		
PressureDifference	P_REFERENCEVALUE	IfcTimeSeries	IfcPressure Measure		
ExerciseTime	P_REFERENCEVALUE	IfcTimeSeries	IfcTimeMeasure		
AirTightness	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
CurrentEfficiencyProjected EfficiencyComparison	P_REFERENCEVALUE	IfcTimeSeries	IfcBoolean		
RelativeHumidityMeasurement	P_REFERENCEVALUE	IfcTimeSeries	IfcPositiveRatio Measure		
TemperatureMeasurement	P_REFERENCEVALUE	IfcTimeSeries	IfcThermodynamic Temperature Measure		
AirFlowRateVariation	P_REFERENCEVALUE	IfcTimeSeries	IfcPressure Measure		
AirflowVariationTolerances	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
InspectionFrequency	P_REFERENCEVALUE	IfcTimeSeries	IfcTimeMeasure		
Pset_FilterMaintenanceInstructions					
FilterCleaning	P_REFERENCEVALUE	IfcTimeSeries	IfcBoolean		
SubstitutionCauses	P_LISTVALUE	IfcText			Air leaks, Air contamination, Final pressure difference, Modification or installation of the air conditioning,

					Every six months, Pressure difference equal to the maximum pressure drop.
FiltersPocketsBlockDamages	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
FiltersPocketsAllignmentToAirflow	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
AirContamination	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
NewFiltersContamination	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
FilterStorage	P_REFERENCEVALUE	IfcTimeSeries	IfcText		
LastFilterChangeNotificationDate	P_REFERENCEVALUE	IfcTimeSeries	IfcTimeMeasure		

Property set implementation as IFC Documentation in ifcDoc tool

Only three properties have been inserted about *Pset_FilterInstallationInstructions*: *AccessibilityForMaintenance, InspectionOpening and ManometerOpenings*.

IFC Specification

```
#10206= IFCPROPERTYSETTEMPLATE('2z3unYD3fAVfEW9p$qepo4',$,'Pset_FilterInstallation
Instructions',$,.PSET_TYPEDRIVENOVERRIDE.,'IfcFilter',(#10209,#10210,#10213));
#10207= IFCLIBRARYREFERENCE($,$,'Pset_FilterInstallation Instructions','Set of installation instructions to be
followed to ensure the good functionality and accessibility of the filter. These are furnished by national and
European regulations.','',$);
#10208= IFCRELASSOCIATESLIBRARY('0SLJ1s35XC$e2rLi1nUq_v',$,$,$,(#10206),#10207);
#10209= IFCSIMPLEPROPERTYTEMPLATE('1fkPgxCsH9quth3WgIXB9U',$,'AccessibilityForMaintenance','Accessibility for
maintenance operations.',.P_SINGLEVALUE.,'IfcText',$,$,$,$,$,.READWRITE.);
#10210=
IFCSIMPLEPROPERTYTEMPLATE('31tdKiWJzFjRKNp8w6N_iu',$,'InspectionOpening',$,.P_SINGLEVALUE.,'IfcBoolean',$,$,$,
$,$,.READWRITE.);
#10211= IFCLIBRARYREFERENCE($,$,'InspectionOpening','Presence of an inspection opening in the lateral side of
the filter service space. The dimensions must be bigger than the external size of the filter to be
substituted. It must have a free space in correspondence of the opening and in the frontal access. ','',$);
#10212= IFCRELASSOCIATESLIBRARY('3Pc1PPxEj9o8T8t3Cwzoon',$,$,$,(#10210),#10211);
#10213=
IFCSIMPLEPROPERTYTEMPLATE('05A$VlLab7Oxnx17biBKBZ',$,'ManometerOpenings',$,.P_SINGLEVALUE.,'IfcBoolean',$,$,$,
$,$,.READWRITE.);
#10214= IFCLIBRARYREFERENCE($,$,'ManometerOpenings','Presence of openings where the manometer could be
inserted to measure the pressure drops.','',$);
#10215= IFCRELASSOCIATESLIBRARY('2P00lHRf1AhRSuQfhy925u',$,$,$,(#10213),#10214);
```

IFCXML Specification

```
<IfcPropertySetTemplate GlobalId="2z3unYD3fAVfEW9p$qepo4" Name="Pset_FilterInstallation Instructions"
ApplicableEntity="IfcFilter">
          <HasAssociations>
            <IfcRelAssociatesLibrary GlobalId="2fD4rsnyPFvwoEQ4vWHDbs">
              <RelatingLibrary Name="Pset_FilterInstallation Instructions" Language="">
                <Description>Set of installation instructions to be followed to ensure the good functionality
and accessibility of the filter. These are furnished by national and European regulations.</Description>
              </RelatingLibrary>
            </IfcRelAssociatesLibrary>
          </HasAssociations>
          <PredefinedType>PSET_TYPEDRIVENOVERRIDE</PredefinedType>
          <HasPropertyTemplates>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1fkPgxCsH9quth3WgIXB9U"
Name="AccessibilityForMaintenance" PrimaryMeasureType="IfcText" AccessState="READWRITE">
              <Description>Accessibility for maintenance operations.</Description>
              <HasAssociations />
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="31tdKiWJzFjRKNp8w6N_iu"
Name="InspectionOpening" PrimaryMeasureType="IfcBoolean" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="3qK7rRgSH5qgp3jDz9RA3Z">
                  <RelatingLibrary Name="InspectionOpening" Language="">
                    <Description>Presence of an inspection opening in the lateral side of the filter service
space. The dimensions must be bigger than the external size of the filter to be substituted. It must have a
free space in correspondence of the opening and in the frontal access. </Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
```

```
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="05A$VlLab7Oxnx17biBKBZ"
Name="ManometerOpenings" PrimaryMeasureType="IfcBoolean" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="35PvO6IQz1Pev_XUgPK8Eh">
                  <RelatingLibrary Name="ManometerOpenings" Language="">
                    <Description>Presence of openings where the manometer could be inserted to measure the
pressure drops.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
          </HasPropertyTemplates>
        </IfcPropertySetTemplate>
```

IFCSHAREDBLDGSERVICEELEMENT
IfcEnergyConversionDevice
IfcHumidifier
Property set and property template

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_HumidifierPHistory	Humidifier performance history attributes. Sound attribute deleted in IFC2x2 Pset Addendum: Use IfcSoundProperties instead.						
AtmosphericPressure	Ambient atmospheric pressure.	✓	UNI EN 13053: 2011	✓	UNE EN 1305 3 :2007+A1:2011	✓	DIN EN 13053:2012
SaturationEfficiency	Saturation efficiency: Ratio of leaving air absolute humidity to the maximum absolute humidity.	✓	UNI EN 13053: 2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012
VolumetricAirflowRate	Volumetric airflow rate.	✓	UNI EN 13053: 2011	✓	UNE EN 13053 :2007+A1:2011	✓	DIN EN 13053:2012
InletWaterMeanTemperature	Mean temperature of water inlet.	+	"	+	"	+	"
OutletWaterMeanTemperature	Mean temperature of water outlet.	+	"	+	"	+	"
InletWaterMassRate	Water mass rate inlet.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
OutletWaterMassRate	Water mass rate of purge and overflow.	+	"	+	"	+	"
BacteriaConcentration	The non-pathogenic bacteria concentration in the water of humidification in cfu x ml-1. "cfu" stands for colony forming unit.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012

		Italy	Standards	Spain	Standards	Germany	Standards
Pset_HumidifierTypeCommon	Humidifier type common attributes. WaterProperties attribute renamed to WaterRequirement and unit type modified in IFC2x2 Pset Addendum.						
Reference	Reference ID for this specified type in this project (e.g. type 'A-1').	✓		✓		✓	
Status	Status of the element, predominately used in renovation or retrofitting projects. The status can be assigned to as "New" - element designed as new addition, "Existing" - element exists and remains, "Demolish" - element existed but is to be demolished, "Temporary" - element will exists only temporary (like a temporary support structure).	✓		✓		✓	
Application	Humidifier application. Fixed: Humidifier installed in a ducted flow distribution system. Portable: Humidifier is not installed in a ducted flow distribution system.	✓		✓		✓	
PositionInUnit	Between the first and the second filter layers. No immediately before filters and attenuators.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
Weight	The weight of the humidifier.	✓		✓		✓	
NominalMoistureGain	Nominal rate of water vapour added into the airstream.		better explained		better explained		better explained
NominalAirFlowRate	Nominal rate of airflow into which water vapour is added.		better explained		better explained		better explained

InternalControl	Internal modulation control.	✓		✓		✓	
WaterRequirement	Make-up water requirement.						
SaturationEfficiencyCurve*	Saturation efficiency as a function of the airflow rate.						
SaturationEfficiencyCurve	Saturation efficiency as a function of the temperature.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
AirPressureDropCurve*	Air pressure drop versus airflow rate.						
BacteriaConcentrationRange	The non-pathogenic bacteria concentration must be less than 10000 cfu x ml-1, however starting from a bacteria concentration of 1000 cfu x ml-1. "cfu" stands for colony forming unit.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
HumidifierCategory	According to the construction type, the humidifiers are classified in:	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
	Sprinklers (A air scrubbers; B ultrasonic humidifier; C High pressure atomizers)						
	Evaporative (D humidifier by contact)						
	Humidifier of vapour (E)						
DriftSeparation	Presence of drift eliminators or adequate section length	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012

The properties SaturationEfficiencyCurve and AirPressureDropCurve are not considered as properties for Object inside *Pset_HumidifierTypeCommon* in the IFC4 Add 1 [Final Standard]. They are still mentioned inside the documentation.

Pset_HumidifierMaterialConstituents							
CorrosionResistance	Corrosion resistant material.	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
Bactericidal/Bacteriostatic Surface	Bactericidal or bacteriostatic surfaces.	+	“	+	“	+	“
MicrobesMetabolism	Microbes metabolize material.	+	“	+	“	+	“
DisinfectionResistance	Material resistance to disinfection processes.	+	“	+	“	+	“
EasyCleaning	Material easy to cleaning.	+	“	+	“	+	“
SuperficialCaseMaterial	Material of the superficial termination of the humidifier case, according with the humidifier category.	+	“	+	“	+	“

Pset_HumidifierInstallation Instructions	Eleven requirements to apply during the design of the humidifier, according to the category.						
Sight Glasses &ViewingOpenings	Accessibility with inspection openings or panels for cleanings and maintenance operations (A to D).	+	UNI EN 13053: 2011	+	UNE EN 13053: 2007+A1:2011	+	DIN EN 13053:2012
IntegratedPieces	Integrated pieces such as drift eliminators, nozzles and removable pipes (A to E).	+	"	+	"	+	"
AnticorrosiveParts	Anticorrosive parts where water circulates (A to E).	+	"	+	"	+	"

AnticorrosiveTray	"Tray in anticorrosive materials (stainless steel or aluminium) (A to E).	+	"	+	"	+	"
CompletelyDrainable InclinatedTray	Tray with all the inclined sides completely drainable (A, C, D).	+	"	+	"	+	"
InspectionOpening&InteriorLighting	Inspection opening (minimum diameter of 150 mm) and interior lighting (B to E).	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012 DIN 1946-6:2009
DisplayInspectionOpening&InteriorLighting	Inspection opening (minimum diameter of 150 mm) with display and interior lighting (imum minimum IP65). Completely empty and dried (drying device). When an exterior lighting is there, if it is going to switch off, no lighting may enter in the case being connected (A).	+	UNI EN 13053: 2011	+	UNE EN 13053: 2007+A1:2011	+	DIN EN 13053:2012
PumpInVacuumProtection	Protection device against the function of the pump in vacuum (A, C, D).	+	UNI EN 13053: 2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012
DisinfectionTreatments	Use of disinfection treatments with proved efficacy and healty. The disinfectants must not enter in the case during the humidification (A to E).	+	"	+	"	+	"
AutomatedSedimentEliminationDevices	Automated purge/sediment elimination devices (A, D).	+	"	+	"	+	"
InteriorCaseWaterTightness	"Interior case water tightness in case of positive and negative pressure (A,C).	+	"	+	"	+	"

The *Pset_SoundGenration* for ifcHumidifier is equal to the one shown for the air-to-air heat recovery.

Pset_HumidifierInspectionInstructions							
PathogenicBacteriaControl	Control of pathogenic bacteria concentration in water.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012 DIN 1946-6:2009

Pset_HumidifierMaintenanceInstructions							
ContinuouslyContainer Emptying	Continuously emptying the container humidification water to reduce the concentration of solid particles and dirt.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012 DIN 1946-6:2009
DirtEliminating	Eliminating dirt products accumulated.	+	"	+	"	+	"
Disinfection	Disinfection.	+	"	+	"	+	"
UltravioletTreatment	Ultraviolet treatment.	+	"	+	"	+	"
Purge	Purge.	+	"	+	"	+	"

Pset_HumidifierMaintenanceDocumentation							
MaintenancePlan	Maintenance plan by the manufacturer.	+	UNI EN 13053:2011	+	UNE EN 13053 :2007+A1:2011	+	DIN EN 13053:2012 DIN 1946-6:2009

Property set name	**IfcPropertySetTemplateTypeEnum**	**Description**

Pset_HumidifierMaterialConstituents	PSET_TYPEDRIVENOVERRIDE	Description of the materials used to manufacture the product.
Pset_HumidifierInstallationInstructions	PSET_TYPEDRIVENOVERRIDE	Set of installation instructions to be followed to ensure the good functionality and accessibility of the humidifier. These are furnished by national and European regulations.
Pset_HumidifierInspectionInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about inspections. It is important writing a comment when the inspection has been executed reporting date, observations and material/tools used.
Pset_HumidifierMaintenanceInstructions	PSET_TYPEDRIVENOVERRIDE	Set of instructions about maintenance operations. It is important writing a comment when the maintenance has been executed reporting date, observations and material/tools used
Pset_HumidifierMaintenanceDocumentation	PSET_TYPEDRIVENOVERRIDE	Set of documents and information needed to report maintenance and operation instructions. All these must be inserted inside the maintenance plan of the air-handling unit.

IfcPropertyName	IfcSimplePropertyTemplate TypeEnumpertyResource (5.1.2.5)	IfcObjectReferenceSelect (8.16.2.2)	IfcMeasureResource (8.11)	IfcPropertyEnumeration (8.16.3.9)	ListValues
Pset_HumidifierPHistory					
VolumetricAirflowRate	P_SINGLEVALUE		IfcVolumetricFlowRateMeasure		
InletWaterMeanTemperature	P_REFERENCEVALUE	IfcTimeSeries	IfcThermodynamic TemperatureMeasure		
OutletWaterMeanTemperature	P_REFERENCEVALUE	IfcTimeSeries	IfcThermodynamic TemperatureMeasure		
InletWaterMassRate	P_SINGLEVALUE		IfcMassFlowRateMeasure		
OutletWaterMassRate	P_SINGLEVALUE		IfcMassFlowRateMeasure		
BacteriaConcentration	P_REFERENCEVALUE	IfcTimeSeries	IfcRatioMeasure		
Pset_HumidifierTypeCommon					
PositionInUnit	P_SINGLEVALUE		IfcText		
SaturationEfficiencyCurve	P_TABLEVALUE	IfcThermodynamicTemperature Measure	IfcNormalisedRatio Measure		
BacteriaConcentrationRange	P_BOUNDEDVALUE		IfcRatioMeasure		
HumidifierCategory	P_ENUMERATEDVALUE		IfcLabel	PEnum_HumidifierCategory: AIRSCRUBBER, ULTRASONIC HUMIDIFIER, HIGHPRESSURE ATOMIZER, EVAPORATIVE HUMIDIFIER, HUMIDIFIEROFVAPOR.	
DriftSeparation	P_SINGLEVALUE		IfcText		
Pset_HumidifierMaterialConstituents					
CorrosionResistance	P_SINGLEVALUE		IfcBoolean		
Bactericidal/BacteriostaticSurface	P_SINGLEVALUE		IfcAreaMeasure		
MicrobesMetabolism	P_SINGLEVALUE		IfcText		
DisinfectionResistance	P_SINGLEVALUE		IfcText		
EasyCleaning	P_SINGLEVALUE		IfcText		
SuperficialCaseMaterial	P_SINGLEVALUE		IfcText		

Pset_HumidifierInstallationInstructions					
Sight Glasses&ViewingOpenings	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
IntegratedPieces	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
AnticorrosiveParts	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
AnticorrosiveTray	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
CompletelyDrainableInclinatedTray	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
InspectionOpening&InteriorLighting	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
DisplayInspectionOpening&InteriorLighting	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
PumpInVacuumProtection	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
DisinfectionTreatments	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
AutomatedSedimentEliminationDevices	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		
InteriorCaseWaterTightness	P_SINGLEVALUE or P_REFERENCEVALUE	HumidifierCategory	IfcText		

Pset_HumidifierInspectionInstructions					
PathogenicBacteriaControl	P_REFERENCEVALUE	IfcTimeSeries IfcIrregularTimeSeries	IfcText		

Pset_HumidifierMaintenanceInstructions					
ContinuouslyContainerEmptying	P_REFERENCEVALUE	IfcTimeSeries IfcIrregularTimeSeries	IfcTimeMeasure		
DirtEliminating	P_REFERENCEVALUE	IfcTimeSeries IfcIrregularTimeSeries	IfcTimeMeasure		
Disinfection	P_REFERENCEVALUE	IfcTimeSeries IfcRegularTimeSeries	IfcTimeMeasure		
UltravioletTreatment	P_REFERENCEVALUE	IfcTimeSeries IfcRegularTimeSeries	IfcTimeMeasure		
Purge	P_REFERENCEVALUE	IfcTimeSeries IfcIrregularTimeSeries	IfcTimeMeasure		

Pset_HumidifierMaintenanceDocumentation					
MaintenancePlan	P_SINGLEVALUE		IfcText		

Property set implementation as IFC Documentation in ifcDoc tool

IFC Specification

```
#10183= IFCLIBRARYREFERENCE($,$,'Pset_HumidifierMaterialConstituents','Description of the materials used to
manufacture the product.','',$);
#10184= IFCRELASSOCIATESLIBRARY('0oCy6aadT95gmZbZoS$V2U',$,$,$,(#10182),#10183);
#10185=
IFCSIMPLEPROPERTYTEMPLATE('3pX624HYrARB4$nODIIFJZ',$,'Bactericidal/BacteriostaticSurface',$,.P_SINGLEVALUE.,'I
fcAreaMeasure',$,$,$,$,$,.READWRITE.);
#10186= IFCLIBRARYREFERENCE($,$,'Bactericidal/BacteriostaticSurface','Bactericidal or bacteriostatic
surfaces.','',$);
#10187= IFCRELASSOCIATESLIBRARY('05Zke1jo926QII947PTuoM',$,$,$,(#10185),#10186);
#10188=
IFCSIMPLEPROPERTYTEMPLATE('1KNxMDaurFfBQzukvB6WW3',$,'DisinfectionResistance',$,.P_SINGLEVALUE.,'IfcText',$,$,
$,$,$,.READWRITE.);
#10189= IFCLIBRARYREFERENCE($,$,'DisinfectionResistance','Material resistance to disinfection
processes.','',$);
```

IFCXML Specification

```
<IfcPropertySetTemplate GlobalId="0N5c$RNQb0Uwr2$0TAqRdP" Name="Pset_HumidifierMaterialConstituents"
ApplicableEntity="IfcHumidifier">
          <HasAssociations>
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              <RelatingLibrary Name="Pset_HumidifierMaterialConstituents" Language="">
                <Description>Description of the materials used to manufacture the product.</Description>
              </RelatingLibrary>
            </IfcRelAssociatesLibrary>
          </HasAssociations>
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          <HasPropertyTemplates>
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Name="Bactericidal/BacteriostaticSurface" PrimaryMeasureType="IfcAreaMeasure" AccessState="READWRITE">
              <HasAssociations>
                <IfcRelAssociatesLibrary GlobalId="1K4rMvDDf4PuVizhY3bq5L">
                  <RelatingLibrary Name="Bactericidal/BacteriostaticSurface" Language="">
                    <Description>Bactericidal or bacteriostatic surfaces.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
            <IfcPropertyTemplate xsi:type="IfcSimplePropertyTemplate" GlobalId="1KNxMDaurFfBQzukvB6WW3"
Name="DisinfectionResistance" PrimaryMeasureType="IfcText" AccessState="READWRITE">
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                  <RelatingLibrary Name="DisinfectionResistance" Language="">
                    <Description>Material resistance to disinfection processes.</Description>
                  </RelatingLibrary>
                </IfcRelAssociatesLibrary>
              </HasAssociations>
              <TemplateType>P_SINGLEVALUE</TemplateType>
            </IfcPropertyTemplate>
          </HasPropertyTemplates>
        </IfcPropertySetTemplate>
```

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7 Consulted Standards and regulations

7.1 European Standards about Facility Management

- ISO/TC 267: 2011 Facilities management
- ISO/CD 18480-1 Facility Management -Part 1: Terms and definitions
- ISO/CD 18480-2 Facility Management -Part 2: Guidance on strategic sourcing and the development of agreements
- ISO/AWI 41000 Facility Management- integrated Management System -- Requirements [with Guidance for Use]
- EN 15221 Facility Management – Terms and Definitions
- EN 15222 Guidance on Facility Management Agreements

7.2 European Standards and National regulations about HVAC system, air handler and components

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  - UNI EN 13053:2011
  - UNE EN 13053 :2007 +A1:2011
  - DIN EN 13053 A1:2012
- EN 13141 “Ventilation for buildings. Performance testing of components/products for residential ventilation. Externally and internally mounted air transfer devices.”
  - UNI EN 13141-10:2008
  - UNE EN 13141-10:2009
  - DIN EN 13141-7:2011
- EN 13142 “Ventilation for buildings. Components/products for residential ventilation. Required and optional performance characteristics.”
  - UNI EN 13142:2013
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- EN 305 “Heat exchangers. Definitions of performance of heat exchangers and the general test procedure for establishing performance of all heat exchangers.”
  - UNI EN 305:1999
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- EN 306 “Heat exchangers. Methods of measuring the parameters necessary for establishing the performance.”
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- EN 307 “Heat exchangers. Guidelines for preparing installation, operating and maintenance instructions required to maintain the performance of each type of heat exchanger.”
    - UNI EN 307:2000
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- EN 308 “Heat exchangers. Test procedures for establishing the performance of air to air and flue gases heat recovery devices.”
    - UNI EN 308:1997
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- EN 308 “Heat exchangers. Test procedures for establishing the performance of air to air and flue gases heat recovery devices.”
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- Linee guida per la definizione di protocolli tecnici di manutenzione predittiva sugli impianti di climatizzazione (G.U. N.256 DEL 03/11/2006)
- VDI 6022 Blatt 1:2011-07 „Ventilation and indoor-air quality - Hygiene requirements for ventilation and air-conditioning systems and units (VDI Ventilation Code of Practice).“
- EN 1751 “Ventilation for buildings. Air terminal devices. Aerodynamic testing of damper and valves.”
    - UNI EN 1751:2014
    - UNE EN 1751:2014
    - DIN EN 1751:2014
- ISO 13349 “Fans - Vocabulary and definitions of categories.”
    - UNI EN ISO 13349:2011
    - UNE EN ISO 13349 :2011
    - DIN EN ISO 13349 :2010
- ISO 13351 „Fans – Dimensions”
    - UNI EN ISO 13351:2010
    - UNE EN ISO 13351:2010
    - DIN EN ISO 13351:2011
- AMCA Standards about fan (Air Movement and Control Association International, Inc.)
- DIN 1946-4:2008 “Ventilation and air conditioning - Part 4: Ventilation in buildings and rooms of health care."

- DIN 1946-6:2009 “Ventilation and air conditioning - Part 6: Ventilation for residential buildings - General requirements, requirements for measuring, performance and labeling, delivery/acceptance (certification) and maintenance.”
- EN 1886 “Ventilation for buildings. Air handling units. Mechanical performance.”
  - UNI EN 1886:2008
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- ISO 5801 “Industrial fans - Performance testing using standardized airways.”
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  - DIN EN ISO 5801:2014
- ISO 5802 “Industrial fans - Performance testing in situ”
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  - UNI EN 13779:2008
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- EN 779 “Particulate air filters for general ventilation. Determination of the filtration performance”
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- EN 1822-2 “High efficiency air filters (EPA, HEPA and ULPA). Aerosol production, measuring equipment, particle counting statistics.”
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  - DIN EN 1822-2:2011
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- EN 1822-5 “High efficiency air filters (EPA, HEPA and ULPA) - Part 5: Determining the efficiency of filter elements.”
  - DIN EN 1822-5:2011
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- UNE 100713:2005 “Instalaciones de acondicionamiento de aire en hospitales.”

Acustic performances

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- REAL DECRETO 1367/2007
- UNE ISO 1996:2005-1 “Acústica. Descripción, medición y evaluación del ruido ambiental. Parte 1: Magnitudes básicas y métodos de evaluación.”
- UNE ISO 1996:2009-2 “Acústica. Descripción, medición y evaluación del ruido ambiental. Parte 2: Determinación de los niveles de ruido ambiental.”
- UNE EN ISO 16032:2005 “Acústica - Medición del nivel de presión sonora de los equipos técnicos en los edificios - Método de peritaje (ISO 16032:2004)”
- UNI 8199:1998 “Acustica - Collaudo acustico degli impianti di climatizzazione e ventilazione - Linee guida contrattuali e modalità di misurazione”
- ISO R226-1961 “Normal equal-loudness contours for pure tones and normal threshold of hearing under free field listening conditions”
- ISO 1996-1:1982 “Acoustics - Description and measurement of environmental noise - Part 1: Basic quantities and procedures”
- ISO 1996-2:1987 “Acoustics - Description and measurement of environmental noise - Part 2: Acquisition of data pertinent to land use”
- ISO 1996-3:1987 “Acoustics - Description and measurement of environmental noise - Part 3: Application to noise limits”
- ISO 3741 “Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Precision methods for reverberation test rooms.”
  - UNI EN ISO 3741:2010
  - UNE EN ISO 3741:2011
  - DIN EN ISO 3741:2011-01
- ISO 3742:1988 “Acoustics - Determination of sound power levels of noise sources - Precision methods for discrete-frequency and narrow-band sources in reverberation rooms.”
- ISO 3743 “Acoustics -- Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Engineering methods for small movable sources in reverberant fields -- Part 1: Comparison method for a hard-walled test room.”

  - UNI EN ISO 3743:2010-1
  - UNE EN ISO 3743:2011-1
  - DIN EN ISO 3743-1:2011-01
- ISO 3744 "Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering methods for an essentially free field over a reflecting plane."
  - UNI EN ISO 3744:2010
  - UNE EN ISO 3744:2010
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- ISO 3745 "Acoustics -- Determination of sound power levels and sound energy levels of noise sources using sound pressure -- Precision methods for anechoic rooms and hemi-anechoic rooms."
  - UNI EN ISO 3745:2012
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  - UNI EN ISO 3746:2011
  - UNE EN ISO 3746:2011
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- ISO 3747 "Acoustics - Determination of sound power levels and sound energy levels of noise sources using sound pressure - Engineering/survey methods for use in situ in a reverberant environment."
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  - EC 1-2010 UNI EN 12354-5:2009
  - UNE EN 12354-5:2009/AC:2010
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- ISO 16032 "Acoustics - Measurement of sound pressure level from service equipment in buildings - Engineering method."
  - UNI EN ISO 16032:2005
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- ISO 9295 "Acoustics - Determination of high-frequency sound power levels emitted by machinery and equipment."
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- ANSI/AHRI Standard 260 (I-P) 2012 “Sound Rating of Ducted Air Moving and Conditioning Equipment.”
- ASHRAE Handbook - HVAC Systems and Equipment
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Other regulations can be consulted

- UNI 10339:1995
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- Energieeinsparverordnung (EnEV) 2014

8 Abbreviations

AEC: Architecture Engineering Construction

AHRI: Air-Conditioning, Heating and Refrigeration Institute

ASCII: American Standard Code for Information Interchange

ASHRAE: American Society of Heating, Refrigeration, and Air-Conditioning Engineers

ATAHeatRecovery: Air-to-air heat recovery (invented)

BIM: Building Information Modelling

BSI: British Standards Institutions

COBie: Construction Operations Building Information Exchange

CAD: Computer Aided Design

CAFM: Computer Aided Facility Management

CAM: Computer-Aided Manufacturing

CEN: European Committee for Standardization

CIS/2: CIMSteel Integration Standards

CMMS: Computerized Maintenance Management System

DIN: Deutsches Institut für Normung

DTV: Design Transfer View

FM: Facility Management

GIS: Geographic Information System

HVAC: Heating, Ventilation and Air-Conditioning

HVACie: Heating, Ventilation and Air-Conditioning Information Exchange

IAI: International Alliance for Interoperability

IFC: Industry Foundation Classes

IFD: Industry Foundation Dictionary

ifcXML: Industry Foundation Classes eXtensible Markup Language

IWMS: Integrated Workplace Management Systems

LC: Lifecycle

MEP: Mechanical, Electrical and Plumbing

MVD: Model View Definitions

NBS: National BIM Standards (United Kingdom)

RV: Reference View

STEP: STEP physical file

TC: Technical Corrigendum

UNI: Ente Italiano di Normazione

UNE: Una Norma Española

UK: United Kingdom

XML: eXtensible Markup Language

W3C: World Wide Web Consortium

ISO: International Organization for Standardization

ISO/TC: ISO/Technical Committee