Commissioning, a way to get better HVAC Systems

*Ir. J.L.C.L. Boot**

"Why is it we never have enough time or money to do it right the first time, but we always find enough time and money to fix it when it goes wrong?"

1. History

In the 1980s it was found that many vague complaints as well as a high absentee rate occur among personnel employed in modern, air-conditioned office buildings, while work performances fall short of what may be expected.
Initially the complaints seem inexplicable. Trivializing the problems turns out to be no longer tenable, as publications on the pattern of complaints bring about a snowball effect and make the national press. A label is quickly found and attached: Sick Building Syndrome or SBS for short.
Several investigations at home and abroad show that the bulk of the complaints, over 90%, can actually be explained on the basis of concrete and measurable quantities such as air temperature, radiation temperature, relative humidity, light, sound and chemical or biological pollutions. It also becomes clear that the "explicable" complaints are often caused by poorly performing HVAC systems.

Investigations carried out in England show that poor performances, including poor energy efficiency, predominantly result from:
- operating errors and improper maintenance;
- purely technical defects, of which
- 50% develops during the design stage,
- 40% develops during the realization stage and
- 10% can be attributed to the quality of the components used.

Investigations in the Netherlands yield similar results.

Based on these understandings more and more initiatives are taken to improve the quality of HVAC systems. In that respect the quality of the HVAC system is regarded as an important parameter in the strive for healthy, energy efficient buildings.

2. The investigation

As you may have gathered from the above, the Netherlands is not the only country having to cope with inadequately performing HVAC systems. Some time ago in England this already led to a form of quality assurance referred to as "commissioning". A so-called commissioner, appointed by the principal, is made responsible for the ultimate quality of the HVAC system.
By order of SBR, the NOVEM and the VNI, Cauberg-Huygen Raadgevende Ingenieurs have analysed, on the basis of national and international literature, the (different) interpretations given to the concept of commissioning in the various countries. Following on from that it was investigated whether commissioning offers prospects for the Netherlands as well, what kind

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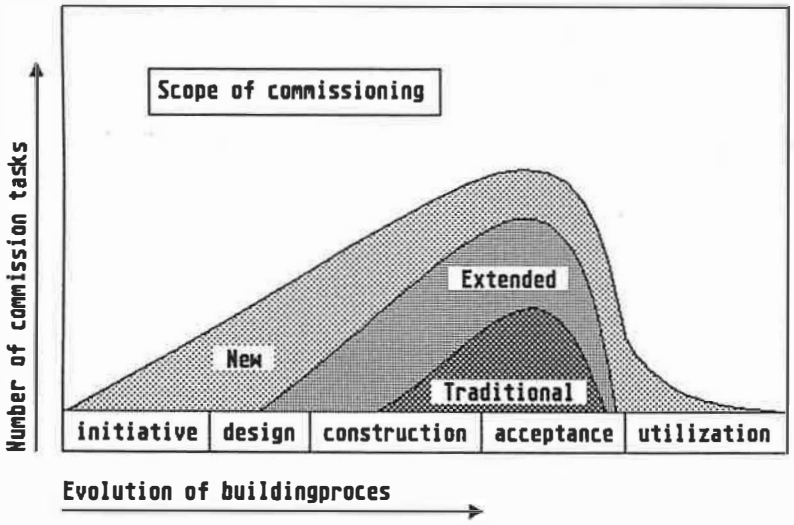
of interpretation should be given to commissioning in order to achieve better HVAC system performance control, taking into account other developments in the field of quality assurance in the Dutch construction practice.

3. The origins of commissioning

The concept of commissioning has its origins in the (petro)chemical industry, where new plants are inspected, set to work and subsequently completely tuned by internationally operating teams of specialists in accordance with very strict, standard safety procedures, until the plant is producing the way the design technicians have calculated.
In the 1960s the pressure from cooperating principals led to the commissioning of HVAC systems in England. These principals were increasingly dissatisfied with the performances of supplied HVAC systems. These poor performances were caused by new techniques and materials becoming available and thus being used, which made the systems ever bigger and more complex.
Principals found that well commissioned systems performed better and therefore they were willing to pay for this additional work. Specialized commissioning agencies developed as a spin-off of this willingness, as well as new measuring techniques and equipment and, last but not least, a strong need for standardization and normalization.
Today commissioning is a well known concept, particularly in England, the United States and Canada. The interpretation the concept of commissioning is given varies from one country to another, yet there are some distinct similarities.

4. Traditional commissioning

In the world of HVAC systems commissioning is traditionally understood to mean all activities forming part of the setting to work of the HVAC system. In the Netherlands this traditional form of commissioning is often, yet wrongly, regarded as an upgraded acceptance check. Figure 1 shows a schematic representation of the scope of traditional commissioning.



Figuur 1

Concrete tasks in traditional commissioning include:
- checking the installing work;
- actually turning on the system;
- tuning and adjusting;
- measuring volume flows, temperatures, noise levels;
- reporting the results, indicating whether the system meets the requirements specified by the principal.

This rough overview of tasks clearly shows that the practical execution of the commissioning work commences in the acceptance stage, although its preparations start much earlier.
It should be noted that serious defects in the system are indeed pointed out by the commissioner, yet this does not prevent them. Often a flaw in the design cannot be corrected, unless disproportionally high expenses will (may) be incurred.
This is the main reason why the traditional form of commissioning has not always produced satisfactory results.

5. Commissioning according to BSRIA

The definition of (extended) commissioning according to BSRIA is "the advancement of an installation from static completion to full working order, including setting to work and balancing".

5.1. Tasks

The BSRIA has drawn up several diagrams, based on the construction practice in England, indicating which party is essentially responsible for which tasks, to be carried out within the scope of commissioning.

The following five parties are mentioned in the diagrams.
- The principal, this may also be the future user;
- The design team, viz. the architect and the various advisers involved in the design;
- The construction management, the managing company, or e.g. the main contractor;
- The contractor responsible for the installation of the HVAC system (the installer);
- The company or individual carrying out the commissioning work.

The tasks have been categorized in four essential stages within the commissioning process, viz.:
- the design stage,
- the construction stage,
- the commissioning stage, and
- the documentation stage.

A non-exhaustive overview of the work to be carried out, the procedures to be followed and the applicable regulations is given below, in order to provide a proper understanding of the commissioning work.

The design stage
- The design team notifies the construction management whether and when a commissioner is called for.
- The design team has to record the information required for commissioning in the form of drawings, diagrams and specifications, e.g.:
  - what should be commissioned;

- who is responsible for what;
- a technical specification of the commissioning work:
  - standards to be followed (CIBSE Codes, BSRIA Manuals);
  - tolerances with respect to measuring results;
  - reporting and documentation procedures;
  - inspection procedures;
  - design drawing with lay-out of the system;
  - schematic drawings, clearly indicating the intent of the design, including volume flows, system pressures, pressure losses, duct dimensions, fan locations, measuring points, etc.;
  - other information required to carry out the commissioning work, e.g. drawings of the electrical installation.

- In the design stage the design team has to follow a number of regulations with respect to the choice and the course of the duct system, the selection of fans, the positioning of valves.
- The design must allow for assembly work, inspection, measurements and maintenance; fixed measuring points must be included at specified locations; the commissioner will see to this.
- The method to be used for measuring volume flows should be specified, stating the acceptable tolerances.

The construction stage

- The installer must have a complete picture of the commissioning work and who will carry out the job (he himself or an independent commissioner).
- Installer and commissioner should draw up a complete plan for the execution of the commissioning work, including:
  - drawings indicating the (temporary) provisions for the execution of the commissioning work;
  - planning of the commissioning work in relation to the construction activities;
  - planning of on-site inspection work;
  - collecting all documentation concerning the equipment installed.
- When installing duct work standard procedures must be followed, in order to:
  - minimize transport and assembly damage;
  - ensure that the duct work is clean and will remain clean;
  - ensure that the duct work is air tight, which will be verified by normalized measurements (CIBSE "Air Leakage Code") during the assembly stage.
- Regular on-site inspections will be carried out, in order to correct mistakes, if any, immediately.
- The preparations for the (traditional) commissioning work should be made:
  - the leakage tests have been performed with favourable results;
  - the system has been delivered sufficiently clean;
  - all components of the HVAC have been made well accessible for inspection and measurement purposes;
  - the system is safe and ready to be put into operation.

  In England installations which have reached this stage of the completion process are referred to as "static(ally) complete".

The commissioning stage

- The commissioner should have been allowed to properly prepare his work for this stage. This is not quite possible if the commissioner is not involved in the project until the time the installer is ready to deliver the system as "static complete".
  The preparations include:
  - setting up communication lines with all parties involved, such as architect, adviser and installer;

- collecting and studying the final drawings of the system, verifying whether the measuring points have been included, etc.;
- studying drawings of the electrical installation, as regards the provisions for the HVAC system;
- collecting and studying manuals provided by suppliers, for putting into operation parts of the HVAC system;
- drawing up forms and checklists to be completed;
- carrying out a pre-commissioning check, consisting of a number of tests and inspections to determine whether the system is ready for (traditional) commissioning.
- The commissioner should have at his disposal a comprehensive set of instruments to carry out the required measurements (air speeds, pressures, number of axle revolutions, current intensity etc.); the required equipment will be specified, stating the accuracy requirements and the calibration requirements.
- The method to be used for the determination of air speeds over grids and in ducts (which instrument, location to be measured, how many measuring points, division of measuring points etc.) will be specified.
- If the results of the pre-commissioning check are in order, then the commissioner, in cooperation with suppliers' experts, will set the system to work.
- Thereupon the commissioner will tune the system. To that end he will:
- check whether all windows and doors are open or closed as arranged, whether the duct system is clean and whether all grids, valves and filters are functioning;
- tune the entire system using the specified balancing techniques, in accordance with BSRIA regulations TM 2/88 "A Procedure for Commissioning Variable Air Volume Systems";
- subsequently record the final measuring results and control readings, and seal the controls.

The documentation stage

This stage cannot be placed chronologically after the commissioning stage, as it is interwoven with the other stages.
The duties of the commissioner are:

- Providing a number of reports on the so-called key control points during the construction stage;
- Completing the forms and checklists mentioned before, indicating the quality of the construction and the performances measured; this information is essential for the commissioner as well as the design team, the installer and future users;
- Drawing up an evaluation report, stating to what extent the system meets the requirements set beforehand (by the principal).

5.2. Who are commissioners?

On the basis of BS-5750 the PSA (Property Services Agency, similar to our RGD) has formulated several requirements for companies carrying out commissioning work. Upon request companies are tested against these requirements, whereupon they may be admitted to the "List of Approved Commissioning Specialists".
This certification has various levels, e.g.:

- PSA W2031 for mechanical ventilation;
- PSA W2179 for HVAC systems;
- PSA W2200 for heating, hot/cold water systems, gas pipings.

Particularly with larger buildings only PSA certified commissioners are used.

6. Commissioning according to ASHRAE

The definition of (extended) commissioning according to ASHRAE is "Bringing the building HVAC system from a state of static completion to a state of dynamic operation to meet the design intent, in accordance with the Contract Specifications".
Although this definition is similar to that of the BSRIA, the following will show that the interpretations given to the definition differ in a number of main points.

6.1. Tasks

ASHRAE too uses a division into parties when dividing the commissioning tasks. This division is roughly identical to the BSRIA division.
ASHRAE specifies a number of procedures, in order to secure the quality of the HVAC systems.
The procedures relate to:
- documenting the points of departure for the design;
- documenting the intent of the design, to be used by the contractors, the principal and the managing personnel;
- testing and documenting the performances of a HVAC system, as a condition for acceptance;
- tuning the system.

To that end ASHRAE divides the commissioning process into five stages:
- the pre-design stage;
- the design stage;
- the construction stage;
- the acceptance stage and
- the post-acceptance stage.

A non-exhaustive overview of the work to be carried out, the procedures to be followed and the applicable regulations is given below, in order to provide a proper understanding of the commissioning work.

The pre-design stage
- Defining the role and responsibilities of the design team and the construction team;
- Evaluating the construction plan; this should contain information regarding:
  - the occupation of the building;
  - physical conditions (temperature, relative humidity, atmospheric pressure);
  - available budgets;
- determining the requirements with respect to temperature, ventilation and air conditions for all activities and rooms on the basis of standards;
- developing a HVAC design concept;
- determining the space requirements for equipment, air inlets and air outlets;
- establishing the responsibilities of the various parties within the commissioning process;
- establishing the points of departure for the design and the performance requirements of the HVAC system.

The design stage
- Establishing the design criteria for all rooms, including:
  - the temperature;
  - relative humidity;
  - outside temperature;
  - number of air changes per hour;
  - internal heating load;
  - glazed area and type of glazing;

  - sound pressure level etc.
- Describing the HVAC system by recording:
  - design intent;
  - description of main components;
  - criteria for capacity and dimensions;
  - performance in various seasons;
  - energy saving procedures;
  - emergency procedures, etc.
- Formulating the commissioning specifications, laying down the duties and requirements for all parties, including the required level of knowledge of the commissioning team and the managing personnel;
- Formulating the requirements to be set for all participants with respect to the documentation to be composed:
  - checklists to be used in the performance tests;
  - forms for the documentation of measuring data etc.;
- Establishing the procedures to be followed in the test/acceptance stage, for:
  - the testing, balancing and adjusting (TAB) of the entire system;
  - checking the performances of coolers, pumps, pipe work etc.
- Describing the documentation to be composed by the commissioner, upon completion of the commissioning process, including:
  - indication of the performances achieved by all components;
  - data concerning the functioning of the system, as required for the managing personnel;
  - data required for keeping the system in operation, etc.
- Drawing up schedules for the participation of future managing personnel in the various stages of the commissioning process.

The construction stage
- The HVAC system is assembled, tested and put into operation, whereupon it is ready for the performance tests.
- The commissioner witnesses all leakage and pressure tests, the putting into operation of all equipment as well as the TAB (Testing, Adjusting, Balancing) work; the latter should result in pressures and volume flows which meet the design requirements.
- The commissioner is in charge of managing personnel training. To that end they should be present at the building site frequently during construction work and TAB work.
- The commissioner will compose a complete documentation regarding the HVAC system, which will include, among other things:
  - a description of the system with the modifications made during the construction stage;
  - manuals of equipment used;
  - technical data concerning all components, such as:
    - rates of flow;
    - pressure losses;
    - power consumptions;
  - control and valve settings;
  - required special tools etc.
- The commissioner will draw up a commissioning work plan including:
  - the duties of the members of the commissioning team;
  - a list and planning of the work to be carried out;
  - forms to be used during the commissioning;
  - The commissioner will specify the activities contained in the TAB work, on the basis of standards such as:
  - NEBB "HVAC, Testing, Adjusting and Balancing";
  - AABC "National Standards";
  - ASHRAE "Standards III".

The acceptance stage
In the USA this stage is also referred to as the commissioning stage.
- The commissioner should make sure that the system has been installed in accordance with the contract documents, viz. that the tests have been performed, the TAB work has been carried out and the control equipment has been calibrated.
- The performance tests should be carried out as laid down in the design stage, using the forms that were made.
  Function tests of all components are performed under all operating conditions, such as accelerated firing, full load operation, partial load operation, calamities and intentional malfunctions.
  - The performance tests will be carried out starting with the separate components, then the sub-systems and finally the system as a whole.
  - The commissioner will check the (reported) results of the TAB work.
  - The commissioner will report his findings, including the results of the performance tests, to the designer.
  - The training of managing personnel is continued in the acceptance stage.

The acceptance stage is completed by a final report of the commissioner, recommending the acceptance of the HVAC system.

The post-acceptance stage
- Modifications of the system or its use should be documented.
- Tests should be carried out on a regular basis, using the results of the performance tests carried out in the acceptance stage as a reference.
- Maintenance should be carried out in accordance with the guidelines laid down in the documentation composed by the commissioner.
- Evaluating the performances of the system under various seasonal loads.
- Maintaining an acceptable indoor air quality. The standards set for this quality may be incorporated in the contract documents, based on relevant standards such as ASHRAE Standards 52-76 "Filtration" and 62-1989 "Indoor Air Quality".

6.2. Differences as compared to the BSRIA interpretation

In several respects the ASHRAE interpretation of commissioning is distinctly different from the BSRIA interpretation.
- Training and instruction of managing personnel is a vital part of the commissioning work.
- Tuning of the system, the so-called TAB work at the end of the construction stage, is done by specialized companies, obviously in cooperation with installer and commissioner.
  The technical execution of the TAB work is specified by the NEBB (National Environmental Balancing Bureau), which was established by the MCA (Mechanical Contractors of America) and the SMACNA (Sheet Metal and Air Conditioning Contractors National Association).
  The reasons why the TAB work is "contracted out" are:
  - the TAB work is specialist work;
  - the installer has already put his personnel on another project: the jobs still to be performed often pass off rather chaotically, as it is "last minute" assembly and repair work;
  - under financial pressure the installer may be inclined to complete the project as quickly as possible.
- The intent of the design, to be formulated by the designer in the design stage, forms an integral part of the documents describing the system (Design Brief, System Description). This way the other parties (commissioner, installer) are also made aware of the designer's intent with the design.

7. Towards "new style" commissioning

Nowadays commissioning is given a much broader interpretation, as you may have gathered from the above.
The purpose of commissioning, however, is being able to guarantee the principal that the HVAC system will eventually come up to expectations.
Yet in the BSRIA and ASHRAE interpretations several vital tasks are lacking, which emerge when the philosophy behind commissioning is formulated, viz. guaranteeing the quality of the HVAC system by starting from the end product, the HVAC system, and reworking to all contributions made by the various parties to that HVAC system end product, which together determine the ultimate quality.
Reasoning on the basis of this philosophy, commissioning according to BSRIA and ASHRAE lacks the following tasks:

BSRIA:
- Training and instruction of building managers.
- Verifying whether the system can realize the requirements set for the indoor climate under various loads. The reason BSRIA gives for this is that the commissioning work only covers a limited time span, within which it is simply impossible, on account of seasonal influences, to assess all performances, e.g. the cooling capacity in February.
- Determining whether the principal's requirements are in line with the intended use of the building.
- Assessing/checking the design of the system, except for those points directly relating to the work of the commissioner, such as e.g. reading orifice plates.

ASHRAE:
- Checking the design, other than from the commissioner's perspective (reading orifice plates etc.), in order to prevent design errors.
- Assessing to what extent the design principles, viz. the requirements specified by the principal, are realistic and in accordance with the practical use of the building.

Once again, the tasks performed within the scope of commissioning are all intended to control the quality of the various contributions, and thereby the final product. These contributions originate from various fields, such as system design and installation technology, but also electrotechnical engineering, building physics and interior construction.
The scope of commissioning should therefore extend from the initiative stage of the construction process to well into the managing stage of the building, covering almost all fields of activity.

8. Commissioning of buildings

In the above attention was paid only to commissioning of HVAC systems.
In view of the philosophy behind commissioning, however, other parts of the final product, the building, may be commissioned in an absolutely analogue way; this goes e.g. for the lift units or the data transmission systems.
Once all components of a building are commissioned, all contributions determining the quality of those components are controlled as well, thereby securing the quality of the building as a whole.
Here an important consideration is that the component-wise approach offers the possibility of gradually introducing quality assurance within the construction process.

Example: The construction specifications of an office building stipulate that the building should be provided with an automatic window shading system.

The fact that a window shading system will be fitted directly affects the heating load resulting from solar access within the building, and thereby the cooling capacity to be installed. This makes it an influence factor to be controlled when commissioning the air conditioning system.
However, the technical design of the window shading has no direct influence on the ultimate quality of the air conditioning system, and therefore it will not be controlled. The latter aspect could nevertheless be covered by one of the other commissioning tasks.

9. Commissioning and quality assurance systems

In the above a picture was painted of the way in which the concept of commissioning has been interpreted by BSRIA and ASHRAE, and of the supplementations in extent and content (see figure 1) required for commissioning in the Netherlands.
This gives rise to the question how commissioning relates to other developments in the field of quality assurance, e.g. TNO's "MKS-Bouw"

9.1. The point of departure

Typical of the present initiatives regarding quality assurance in construction is generally that they are set up by the parties contributing to the construction process, e.g. the installation consultants or the electrician.
By providing the parties with a quality assurance system based on e.g. ISO 9000-9004 the quality of the contributions to the construction process made by these parties is optimized.
If all parties had a well-functioning quality assurance system, then the quality of the joint end product, viz. the building, would be secured. Obviously this also applies to all components of the building, such as the air conditioning system.
If the commissioning approach is used, the quality philosophy is developed on the basis of one component of end product building, in this case the air conditioning system.
Therefore it is not necessary that all contributing parties have quality assurance systems.

Example: The window shading system of an office building is controlled automatically. Commissioning of the window shading systems implies that the contribution made by the electrician, e.g. fitting the light sensor, is controlled. Under MKS-construction the electrician needs to have a quality assurance system, controlling all contributions.

9.2. Initiative and responsibility

In the quality philosophy the initiative and the responsibility for quality assurance are initially in the hands of the parties contributing to the construction process.
It is they who with a quality assurance system control the quality of the contribution to be made, with possibly an independent certifying authority assessing whether the quality assurance system used is indeed functioning.
With commissioning the initiative proceeds from the construction process.
For each separate construction project the principal determines which tasks have to be performed (and by whom) as part of the commissioning work, in other words, how much care has to be devoted to quality.
Whether the parties involved have a quality assurance system has basically nothing to do with this, yet obviously it could play a part.

9.3. Phasing and dosing

In the quality assurance system for the construction process as a whole the quality of all components of a building will be controlled if all parties contributing to the construction process have well-functioning quality assurance systems.
Failure of one of the parties on this point could directly affect the quality of one or more components of the building, to which the company in question is contributing.
From this perspective a gradual introduction of such a quality assurance system is undesirable.
Dosing quality assurance per construction process (adapting extent and content) is difficult to realize as well, since quality assurance systems just happen to be based on fixed patterns and procedures within a company.
Commissioning, on the other hand, does offer prospects for gradual introduction.
- For a specific building a principal could decide to only commission the window shading systems, while in a next building the air conditioning system is involved in the commissioning process as well.
- Furthermore, a principal can determine the amount of attention to be paid to quality assurance for each specific building; the quality assurance level can be differentiated on the basis of the complexity of the building component.
- The placement of the commissioning tasks offers a third possibility for differentiation. Basically the tasks can be placed with any party (designer, installer, principal, independent third parties) possessing the required capabilities.

These three aspects of commissioning make it possible to introduce quality assurance into the construction process very gradually, step by step.

9.4. Technical expertise

Quality systems are primarily aimed at procedural matters. By laying down, following and controlling standard procedures a company can supply high quality products.
Commissioning, however, adds some purely technical expertise, which is used for all contributions to the construction process.

Example: A designer makes a computational error in the dimensioning of the air ducts, a miscalculation that slips through the design agency's quality assurance system. Commissioning of the design (= the designer's contribution) leads to timely detection of the miscalculation, because of the additional expertise that has been brought in.

9.5. Checking

In quality assurance checking of the contributions made is primarily the responsibility of the contributing company.
Commissioning provides an extra check, as proceeding from the construction process all contributions to that construction process are controlled, insofar as they affect the quality of the building component under consideration.

9.6. Joint ultimate object

Commissioning and quality assurance in general are aimed at a joint object: to secure the quality of (all components of) buildings, by controlling the quality of all contributions.
Both approaches use similar means to achieve that ultimate object, means which can be derived from generally applicable quality standards such as ISO 9000-9004.
In the final situation, however, two fundamental differences remain, viz.:

- with commissioning the initiative and the responsibility proceed from the construction process, whereas in general quality assurance they are in the hands of the various parties;
- with commissioning it is possible to dose the care taken over quality, i.e. extent and content of quality assurance can be adapted to the construction process, a possibility which general quality assurance systems do not offer.

10. Summary

It is obvious that commissioning offers prospects for the Dutch construction world.
In England and in the USA/Canada it has been demonstrated in actual practice that the commissioning of HVAC systems leads to better performances, resulting in fewer complaints and a higher energy efficiency.
If, however, commissioning is to be used in the Netherlands too as a means to obtain better HVAC systems, then the philosophy behind commissioning will have to be followed more consistently.
In actual practice this means that the tasks to be performed within the scope of commissioning will run throughout the construction process, i.e. starting from the initiative to realize a building up to and including building management.
Consistently following the philosophy means that all contributions to the HVAC system are controlled too, including the design of the system.
In order to be able to go from theory to practice a framework for commissioning in the Netherlands will have to be developed, on the basis of the available international standards and guidelines.
In this framework the commissioning tasks should be subdivided by construction stages and parties, as existing in the Dutch construction practice.
Furthermore a criterion will have to be developed, as a basis on which to determine the required extent and content of commissioning for each construction project. Relevant parameters are e.g. the complexity of the design, the reliability of the design, the consequences of malfunctions and whether or not the parties involved have quality assurance systems.
Commissioning: a field-tested and proven solution for quality problems with HVAC systems.

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GEMS Specifications

Ir. P.D. van Dam *

In general

The General Energy Management System (GEMS) has been developed in order to manage the consumption of energy and, thus, to be able to establish price control. By using the GEMS package, one will be able to convert the readings that have been gathered by a Building Automation System (BAS) or Building Energy Management System (BEMS) in a simple manner into useful information. By the introduction of the management of energy and by passing on consumption-costs to the consumer (department, building, etc.), a more efficient consumption will prevent the squandering of energy .

The information made available by software can be used on different levels in the organization. Separate ways of reporting will be made available to managers, controllers and operators.

Management will be interested primarily in the flows of money connected to the consumption of energy. Controllers, however, want an analysis of consumption in order to bring the consumption of energy under control. Finally, on the level of operators, people will seek an optimal control of processes.
There are several ways in which these various demands can be met:
- attributing costs to financial units (sections, departments, companies);
- analyzing the consumption of energy by means of multiple linear regression (M.L.R.). This tool can generate a model of this process, with which the process can be monitored.

Computer configuration for GEMS-package

This program can be used on micro-computers with the MS-DOS operating system. The configuration of the computer has to meet the following demands:

- PC-AT 80286, preferably 80386
- 40 Megabyte hard disk (minimally)
- 2 Megabytes of extended memory

Input of data on the consumption of energy

Input of meter readings in the GEMS-package can be realized in the following ways:

1. Automatically from a Building Automation System (BAS)
2. Manual
3. With a floppy disk
4. Manually through a Comesta-package

* Organization VABI, Delft

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Healthy buildings in relation to building services

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